International Standard ISO 4848

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Concrete — Determination of air content of freshly mixed concrete — Pressure method

Béton — Détermination de la teneur en air du béton frais — Méthode de la compressibilité

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4848 was developed by Technical Committee ISO/TC 71, *Concrete, reinforced concrete and pre-stressed concrete*, and was circulated to the member bodies in March 1978.

It has been approved by the member bodies of the following countries :

Australia	Germany, F.R.	Portugal
Austria	India	Romania
Belgium	Ireland	South Africa, Rep. of
Brazil	Israel	Spain
Bulgaria	Italy	Switzerland
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Czechoslovakia	Mexico	United Kingdom
Denmark	Netherlands	USA
Egypt, Arab Rep. of	New Zealand	USSR
France	Norway	Yugoslavia

No member body expressed disapproval of the document.

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Concrete — Determination of air content of freshly mixed concrete — Pressure method

1 Scope and field of application

This International Standard specifies a method for the determination of the air content of freshly mixed concrete from observation of the change in volume of concrete with a change in pressure.

This method is intended for use with concretes and mortars made with relatively dense aggregates for which the aggregate correction factor can be satisfactorily determined by the technique described in clause 5. It is not applicable to concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity.

2 References

ISO 2736, *Concrete — Sampling, making and curing of test pieces.* [1]

ISO 4109, *Fresh concrete — Determination of the consistency — Slump test.* [1]

ISO 6276, *Concrete, compacted fresh — Determination of density.* [1]

3 Apparatus

3.1 Air meters

There are available satisfactory apparatus of two basic operational designs employing the principle of Boyle-Mariottes law. For purposes of reference herein these are designated meter type A and meter type B.

3.1.1 Meter type A, consisting of a measuring bowl and cover assembly (see figure 1) conforming to the requirements of 3.2 and 3.3. The operational principle of this meter consists of introducing water to a predetermined height above a sample of concrete of known volume, and the application of a predetermined air pressure over the water. The determination consists of the reduction in volume of the air in the concrete sample by observing the amount the water level is lowered under the applied pressure, the latter amount being calibrated in terms of percentage of air in the concrete sample.

3.1.2 Meter type B, consisting of a measuring bowl and cover assembly (see figure 2) conforming to the requirements of 3.2 and 3.3. The operational principle of this meter consists of equalizing a known volume of air at a known pressure in a sealed air chamber with the unknown volume of air in the concrete sample, the dial on the pressure gauge being calibrated in terms of percentage of air for the observed pressure at which equalization takes place. Working pressures of 50 to 200 kPa have been used satisfactorily.

3.2 Measuring bowl, essentially cylindrical in shape, made of steel or other hard metal not readily attacked by the cement paste, having a minimum diameter equal to 0,75 to 1,25 times the height, and a capacity of at least 5 l. It shall be flanged or otherwise constructed to provide for a pressure-tight fit between bowl and cover assembly. The interior surfaces of the bowl and surfaces of rims, flanges and other component fitted parts shall be machined smooth. The measuring bowl and cover assembly shall be sufficiently rigid to limit the expansion factor, D, of the apparatus assembly (see annex) to not more than 0,1 % of air content on the indicator scale when under normal operating pressure.

3.3 Cover assembly

3.3.1 The cover assembly shall be made of steel or other hard metal not readily attacked by the cement paste. It shall be flanged or otherwise constructed to provide for a pressure-tight fit between bowl and cover assembly and shall have machined smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover shall be sufficiently rigid to limit the expansion factor of the apparatus assembly as prescribed in 3.2.

3.3.2 The cover assembly shall be fitted with a means of direct reading of the air content. The cover for the type A meter shall be fitted with a standpipe, which may be a graduated precision-bore glass tube or may be metal of uniform bore with a glass water gauge attached. In the type B meter, the dial of the pressure gauge shall be calibrated to indicate the percentage of air. Graduations shall be provided for a range in air content of at least 8 % as determined by the proper air pressure calibration test.

1) At present at the stage of draft.

3.3.3 The cover assembly shall be fitted with air valves, air bleeder valves, and petcocks for bleeding off or through which water may be introduced as necessary for the particular meter design. Suitable means for clamping the cover to the bowl shall be provided to make a pressure-tight seal without entrapping air at the joint between the flanges of the cover and bowl. A suitable hand pump shall be provided with the cover either as an attachment or as an accessory.

3.4 Calibration vessel, having an internal volume equal to a percentage of the volume of the measuring bowl corresponding to the approximate percentage of air in the concrete to be tested, or, if smaller, it shall be possible to check calibration of the meter indicator at the approximate percentage of air in the concrete to be tested by repeated filling of the measure. When the design of the meter requires placing the calibration vessel within the measuring bowl to check calibration, the measure shall be cylindrical in shape and of an inside depth approximately 10 mm less than that of the bowl. A satisfactory measure of this type may be machined from brass tubing of more than 1,5 mm wall thickness, and of a diameter to provide the volume desired, to which a brass disk of about 10 mm thickness is soldered to form an end. When design of the meter requires withdrawing of water from the waterfilled bowl and cover assembly to check calibration, the measure may be an integral part of the cover assembly or may be a separate cylindrical measure similar to the above described cylinder.

3.5 Coil spring, or other device for holding the calibration cylinder in place (see note after 3.14).

3.6 Spray tube, comprising a brass tube of appropriate diameter, which may be an integral part of the cover assembly or which may be provided separately. It shall be so constructed that when water is added to the container, it is sprayed to the walls of the cover in such a manner as to flow down the sides causing a minimum of disturbance to the concrete.

3.7 Trowel : a standard brick mason's trowel.

3.8 Tamping rod, as described in ISO 4109.

3.9 Mallet, having a rubber or rawhide head weighing approximately 0,25 kg.

3.10 Strike-off bar, of steel or other suitable metal.

3.11 Funnel, the spout of which shall fit into the spray tube.

3.12 Measure for water, having the necessary capacity to fill the indicator with water from the top of the concrete to the zero mark.

3.13 Vibrator, as described in ISO 2736.

3.14 Sieves, of 45 mm mesh with not less than 180 000 mm^2 of sieving area.

NOTE — The designs of various available types of airmeters are such that they differ in operating techniques and therefore, all of the items described in 3.5 to 3.13 may not be required. The items required shall be those necessary for use with the particular design of apparatus used to satisfactorily determine air content in accordance with the procedures prescribed herein.

4 Calibration of apparatus

Make calibration tests in accordance with procedures prescribed in the annex. Rough handling will affect the calibration of both types A and B meters. Changes in barometric pressure will affect the calibration of type A meter but not type B meter. The steps described in A.1 to A.5 of the annex, as applicable to the meter type under consideration, are prerequisites for the final calibration test to determine the operating pressure, p, on the pressure gauge of the type A meter as described in A.6, or to determine the accuracy of the graduations indicating air content on the dial face of the pressure gauge of the type B meter. Normally the steps in A.1 to A.5 need be made only once (at the time of initial calibration), or only occasionally to check volume constancy of the calibration cylinder and measuring bowl. On the other hand, the calibration test described in A.6 and A.8 of the annex, as applicable to the meter type being checked, must be made as frequently as necessary to ensure that the proper gauge pressure, p, is being used for the type A meter or that the correct air contents are being indicated on the pressure gauge air content scale for the type B meter. A change in elevation of more than 200 m from the location at which a type A meter was last calibrated will require recalibration in accordance with A.6.

5 Determination of aggregate correction factor

5.1 Procedure

Determine the aggregate correction factor on a combined sample of fine and coarse aggregate as directed in 5.2 to 5.4. It is determined independently by applying the calibrated pressure to a sample of inundated fine and coarse aggregate in approximately the same moisture condition, amount, and proportions occurring in the concrete sample under test.

5.2 Aggregate sample size

Calculate the masses of fine and coarse aggregate present in the sample of fresh concrete, m_f and m_c respectively, in kilograms, whose air content is to be determined, from the following formulae :

$$m_f = (V_S / V_B)\, m'_f$$

$$m_c = (V_S / V_B)\, m'_c$$

where

V_S is the volume of concrete sample (same as the volume of the measuring bowl), in cubic metres;

V_B is the volume of concrete produced per batch, in cubic metres;

m'_f is the total mass of fine aggregate in the moisture condition used in the batch, in kilograms;

m'_c is the total mass of coarse aggregate in the moisture condition used in the batch, in kilograms.

5.3 Placement of aggregate in measuring bowl

Mix representative samples of fine aggregate and coarse aggregate and place in the measuring bowl filled one-third full with water. Place the mixed aggregate, a small amount at a time, into the measuring bowl; if necessary, add additional water so as to inundate all of the aggregate. Add each scoopful in a manner that will entrap as little air as possible and remove accumulations of foam promptly. Tap the sides of the bowl and lightly rod the upper 25 mm of the aggregate about ten times. Stir after each addition of aggregate to eliminate entrapped air.

5.4 Aggregate correction factor determination

5.4.1 Initial procedure for types A and B meters

When all of the aggregate has been placed in the measuring bowl, remove excess foam and keep the aggregate inundated for a period of time approximately equal to the time between introduction of the water into the mixer and the time of performing the test for air content before proceeding with the determination as directed in 5.4.2 or 5.4.3.

5.4.2 Type A meter

Complete the test as described in 7.2.1 and 7.2.2. The aggregate correction factor, G, is equal to $h_1 - h_2$ (see figure 1 and note in 5.4.3).

5.4.3 Type B meter

Perform the procedures as described in 7.3.1. Remove a volume of water from the assembled and filled apparatus approximately equivalent to the volume of air that would be contained in a typical concrete sample of a size equal to the volume of the bowl. Remove the water in the manner described in A.8 of the annex for the calibration tests. Complete the test as described in 7.3.2. The aggregate correction factor, G, is equal to the reading on the air-content scale minus the volume of water removed from the bowl expressed as a percentage of the volume of the bowl (see figure).

NOTE — The aggregate correction factor will vary with different aggregates. It can be determined only by test, since apparently it is not directly related to absorption of the particles. The test can be easily made and must not be ignored. Ordinarily the factor will remain reasonably constant for given aggregates, but an occasional check test is recommended.

6 Preparation of test sample

Obtain the sample of freshly mixed concrete in accordance with ISO 2736. If the concrete contains coarse aggregate particles that would be retained on a 45 mm[1)] sieve, sieve a sufficient amount of the representative sample over a 45 mm sieve, to yield somewhat more than enough material to fill the measuring bowl of the size selected for use. Carry out the sieving operation with the minimum practicable disturbance of the mortar. Make no attempt to wipe adhering mortar from the coarse aggregate particles retained on the sieve.

7 Procedure

7.1 Placement and consolidation of sample

7.1.1 Introduction

Place a representative sample of the concrete, prepared as described in clause 6, in the measuring bowl in equal layers. Consolidate each layer by the rodding procedure (see 7.1.2) or by vibration (see 7.1.3). Vibration shall not be employed to consolidate concrete having a slump greater than 76 mm.

7.1.2 Rodding

Place the concrete in the measuring bowl in three layers of approximately equal volume. Consolidate each layer of concrete by 25 strokes of the tamping rod evenly distributed over the cross-section.

Follow the rodding of each layer by tapping the sides of the bowl sharply 10 to 15 times with the mallet until any voids left by the rodding are consolidated and no large bubbles of air appear on the surface of the rodded layer. Rod the bottom layer throughout its depth but the rod shall not forcibly strike the bottom of the measure. In rodding the second and final layers, use only enough force to cause the rod to penetrate the surface of the previous layer about 25 mm. Add the final layer of concrete in a manner to avoid excessive overfilling (see 7.1.4).

7.1.3 Vibration

Place the concrete in the measuring bowl in two layers of approximately equal volume. Place all of the concrete for each layer before starting vibration of that layer. Consolidate each layer by three insertions of the vibrator evenly distributed over the cross-section. Add the final layer in a manner to avoid excessive overfilling (see 7.1.4). In consolidating the bottom layer, do not allow the vibrator to rest on or touch the bottom or sides of the measuring bowl. Take care in withdrawing the vibrator to ensure that no air pockets are left in the specimen.

1) Samples of concrete containing coarse aggregate particles larger than 45 mm may exceptionally be tested without further preparation if the diameter of the measuring bowl is larger than 4 times the maximum size of the aggregate.

Observe a standard duration of vibration for the particular kind of concrete, vibrator and measuring bowl involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Continue vibration only long enough to achieve proper consolidation of the concrete. Overvibration may cause segregation and loss of intentionally entrained air. Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth and has a glazed appearance. Never continue vibration long enough to cause escape of froth from the sample.[1)]

7.1.4 Strike off

After consolidation of the concrete, strike off the top surface by sliding the strike-off bar across the top flange or rim of the measuring bowl with a sawing motion until the bowl is just level full.

On completion of consolidation, the bowl must not contain a great excess or deficiency of concrete. Removal of approximately 3 mm during strike off is optimum. A small quantity of representative concrete may be added to correct a deficiency. If the measure contains a great excess, remove a representative portion of concrete with a trowel or scoop before the measure is struck off.

NOTE — Any portion of the test method not specifically designated as pertaining to type A or type B meter shall apply to both types.

7.1.5 Determination of density

Determine the density of the sample in accordance with ISO 6276.

7.2 Procedure — Type A meter

7.2.1 Preparation for test

Thoroughly clean the flanges or rims of the bowl and of the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus and add water over the concrete by means of the tube until it rises to about the halfway mark in the standpipe. Incline the apparatus assembly about 30° from vertical and, using the bottom of the bowl as a pivot, describe several complete circles with the upper end of the column, simultaneously tapping the cover lightly to remove any entrapped air bubbles above the concrete sample. Return the apparatus assembly to a vertical position and fill the water column slightly above the zero mark, while lightly tapping the sides of the bowl. Remove foam on the surface of the water column with a syringe or with a spray of alcohol to provide a clear meniscus. Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column [see figure 1a)].

NOTE — The internal surface of the cover assembly should be kept clean and free from oil or grease; the surface should be wet to prevent adherence of air bubbles that might be difficult to dislodge after assembly of the apparatus.

7.2.2 Test procedure

Apply slightly more than the desired test pressure, p, (about 1 500 Pa more) to the concrete by means of the small hand pump. To relieve local restraints, tap the sides of the measure sharply and, when the pressure gauge indicates the exact test pressure, p, (as determined in accordance with A.6), read the water level, h_1, and record to the nearest division or half-division on the graduated precision-bore tube or gauge glass of the standpipe [see figure 1b)]. For extremely harsh mixes it may be necessary to tap the bowl vigorously until further tapping produces no change in the indicated air content. Gradually release the air pressure through the vent at the top of the water column and tap the sides of the bowl lightly for about 1 min. Record the water level, h_2, to the nearest division or half-division [see figure 1c)]. The apparent air content, A_1, is equal to $h_1 - h_2$.

7.2.3 Check test

Repeat the steps described in 7.2.2 without adding water to re-establish the water level at the zero mark. The two consecutive determinations of apparent air content should check within 0,2 % of air and shall be averaged to the nearest 0,1 % to give the value A_1 to be used in calculating the air content, A, in accordance with clause 8.

7.2.4 Test pressure

In the event of the air content exceeding the range of the meter when it is operated at the normal test pressure, p, reduce the test pressure to the alternative test pressure, p_1, and repeat the steps outlined in 7.2.2 and 7.2.3.

NOTE — See A.6 for exact calibration procedures. An approximate value of the alternative pressure, p_1, in kilopascals, such that the apparent air content will equal twice the meter reading, can be computed from the following formula

$$p_1 = p_n\, p / (2\, p_n + p)$$

where

p_n is the atmospheric pressure (approximately 100 kPa, but will vary with altitude and weather conditions);

p is the normal test or operating gauge pressure, in kilopascals.

1) If, exceptionally, a vibrating table is used for consolidation, vibration of the two layers shall continue to, and stop at, the point where large air bubbles are no longer released, and a thin layer of mortar covering all large aggregate particles appears on top of the concrete. However, overvibration shall be avoided.

7.3 Procedure — Type B meter

7.3.1 Preparation for test

Thoroughly clean the flanges or rims of the bowl and the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus. Close the air valve between the air chamber and the measuring bowl and open both petcocks on the holes through the cover. Using a rubber syringe, inject water through one petcock until water emerges from the opposite petcock. Jar the meter gently until all air is expelled from this same petcock.

7.3.2 Test procedure

Close the airbleeder valve on the air chamber and pump air into the air chamber until the gauge hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gauge hand at the initial pressure line by pumping or bleeding-off air as necessary, tapping the gauge lightly. Close both petcocks on the holes through the cover. Open the air valve between the air chamber and the measuring bowl. Tap the sides of the measuring bowl sharply to relieve local restraints. Lightly tap the pressure gauge to stabilize the gauge hand and read the percentage of air on the dial of the pressure gauge. Release the pressure by opening both petcocks [see figure 2] before removing the cover.

NOTE — The main air valve should be closed before releasing pressure from either the container or the air chamber. Failure to do so will result in water being drawn into the air chamber, thus introducing an error in subsequent measurements. In the event that water enters the air chamber, it must be bled from the air chamber through the bleeder valve followed by several strokes of the pump to blow out the last traces of water.

8 Test results

8.1 Air content of sample tested

Calculate the air content of the concrete in the measuring bowl, A_s, as a percentage, from the formula

$$A_s = A_1 - G$$

where

A_1 is the apparent air content of the sample tested, as a percentage to the nearest 0,1 % (see 7.2.2 and 7.3.2);

G is the aggregate correction factor, as a percentage to the nearest 0,1 %.

Express the result to the nearest 0,1 %.

8.2 Air content of full mixture

When the sample tested represents that portion of the mixture that is obtained by wet sieving to remove aggregate particles larger than 45 mm, the air content of the full mixture, A_t, as a percentage, may be calculated from the formula

$$A_t = 100\, A_s\, V_c / (100\, V_t - A_s\, V_a)$$

where

V_c is the absolute volume of the ingredients of the mixture passing a 45 mm sieve, air-free, as determined from the original batch masses, in cubic metres;

V_t is the absolute volume of all ingredients of the mixture, air-free, in cubic metres.

V_a is the absolute volume of the aggregate in the mixture coarser than a 45 mm sieve, as determined from original batch masses, in cubic metres.

Express the result to the nearest 0,1 %.

8.3 Air content of the mortar fraction

The air content of the mortar fraction of the mixture, A_m, as a percentage, is calculated from the formula

$$A_m = 100\, A_s\, V_c / [100\, V_m + A_s (V_c - V_m)]$$

where V_m is the absolute volume of the ingredients of the mortar fraction of the mixture, air-free, in cubic metres.

Express the result to the nearest 0,1 %.

9 Test report

The test report shall refer to this International Standard and shall include the following particulars :

a) **Mandatory data :**

1) identification of the test sample;

2) date and time of test;

3) type of meter used (A or B);

4) method of compaction used;

5) measured air content of the sample tested and, if applicable, calculated air content of the full mixture containing aggregate larger than 45 mm;

6) density of the sample tested.

b) **Optional data :**

7) cement content, water/cement-ratio, consistency, maximum size of aggregate and type of admixture used (if any);

8) temperature of the fresh concrete.