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Standard Test Method for Determination of Relative Density and Absorption of Fine, Coarse and Blended Aggregate Using Combined Vacuum Saturation and Rapid Submersion[1]

This standard is issued under the fixed designation D7370/D7370M; 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 covers the determination of relative density and absorption of fine aggregates by Method A and coarse and blended aggregates by Method B.

1.2 A multi-laboratory precision and bias statement for coarse and combined aggregate tests in this standard has not been developed at this time. Therefore, this standard should not be used for acceptance or rejection of coarse and combined aggregate materials for purchasing purposes.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Some values have only SI units because inch-pound equivalents are not used in practice.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Summary of Test Method

3.1 Sufficient aggregate sample is dried to constant mass. For each test two representative dry aggregate samples of the same material are selected for testing. One sample is evacuated in a vacuum chamber inside a plastic bag and opened under water for rapid saturation of the aggregate. The dry mass and submerged mass of the sample is used for calculation of apparent relative density. The second sample of the same aggregate is tested in a known volume metal pycnometer. The known mass of the pycnometer with water, mass of the dry aggregate and mass of the aggregate and pycnometer filled with water is used for calculation of unsaturated density. The results from the two samples tested are then used to calculate absorption, and relative density (OD).

3.2 This test can be completed in less than 30 min and can be used for rapid determination of aggregate properties in construction testing laboratories.

3.3 This test can be performed on fine, coarse and blended (combined) aggregates by using appropriate plastic bag and pycnometer sizes.

4. Significance and Use

4.1 Relative density (specific gravity) is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate, including Portland cement concrete, bituminous concrete, and other

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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.

mixtures that are proportioned or analyzed on an absolute volume basis. Relative density (specific gravity) is also used in the computation of voids in aggregate in Test Method C29/C29M. Relative density (specific gravity) saturated surface dry (SSD) is used if the aggregate is at SSD, that is, if its absorption has been satisfied. Conversely, the relative density (specific gravity) oven-dry (OD) is used for computations when the aggregate is dry or assumed to be dry.

4.2 Apparent density and apparent relative density (apparent specific gravity) pertain to the solid material making up the constituent particles not including the pore space within the particles which is accessible to water.

4.3 Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, when it is deemed that the aggregate has been in contact with water long enough to satisfy the absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for a prescribed period of time.

NOTE 1—There are other test methods that have been used and continue to be used to determine these aggregate properties: C127 and C128. This test method may result in values for these properties that are close to or divergent from values from other test methods.

NOTE 2—The quality of the results produced by this standard are dependent upon the competence of the personnel performing the procedure and the capability, calibration, and the maintenance of the equipment used. Agencies that meet the criteria of Practice D3666 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3666 alone does not completely assure reliable results. Reliable results depend on many factors: following the suggestions of Practice D3666 or similar acceptable guideline provides a means of evaluating and controlling some of those factors.

5. Apparatus

5.1 *Balance,* a balance that conforms to Guide D4753. The balance shall be sensitive, readable and accurate to 0.1 g. The balance shall be equipped with suitable apparatus for suspending the sample in water.

5.2 *Water Bath,* with minimum dimensions (length by width by depth) of 610 by 460 by 460 mm [24 by 18 by 18 in.] or a large cylindrical container with a minimum diameter of 460 mm and depth of 460 mm [18 by 18 in.], for completely submerging the sample in water while suspended, equipped with an overflow outlet for maintaining a constant water level and means to maintain the water temperature at 25 ± 1°C [77 ± 2°F].

NOTE 3—It is preferable to keep the water temperature constant by using a temperature controlled heater. Also, to reduce the chance for the bag to touch the sides of the water tank, it is preferable to elevate the water tank to a level at which the sample can be placed on the weighing mechanism while the operator is standing up (waist height), and the placement of the sample and the bag in the water tank can easily be inspected.

5.3 *Sample Holder,* for water displacement of the sample, having no sharp edges.

5.4 *Vacuum Chamber,* with a pump capable of evacuating a sealed and enclosed chamber to a pressure of 6 mm Hg [6 Torr], when at sea level. The device shall automatically seal the plastic bag and exhaust air back into the chamber in a controlled manner to ensure proper conformance of the plastic to the specimen. The air exhaust and vacuum operation time shall be set at the factory so that the chamber is brought to atmospheric pressure in 80 to 125 s, after the completion of the vacuum operations.

5.5 *Vacuum Measurement Gauge,* independent of the vacuum sealing device that could be placed directly inside the chamber to verify vacuum performance and the chamber door sealing condition of the unit. The gauge shall be capable of reading down to 3 mm Hg [3 Torr] and readable to ±1 mm Hg [±1 Torr].

5.6 *Plastic Bags,* used with the vacuum device shall be one of the two following sizes. The smaller bags shall have a minimum opening of 235 mm [9.25 in.] and maximum opening of 260 mm [10.25 in.] and the larger bags shall have a minimum opening of 375 mm [14.75 in.] and a maximum opening of 394 mm [15.5 in.]. The bags shall be of plastic material, shall be puncture resistant, and shall be impermeable to water. The bags shall have a minimum thickness of 0.127 mm [0.005 in.]. The apparent specific gravity for the bags shall be provided by the manufacturer.

5.7 *Small Metal Pycnometer,* with 137 ± 0.2 mm [5.375 ± 0.01 in.] ID and 89 ± 0.40 mm [3.5 ± 0.02 in.] height, for testing fine aggregates. The pycnometer shall be machined to be smooth on all surfaces. The inside of the lid shall be machined at a 5° angle to create an inverted conical surface. The pycnometer shall be equipped with a graduated temperature strip to allow the user to visually monitor temperature during testing.

5.8 *Large Metal Pycnometer,* with 198 ± 0.2 mm [7.776 ± 0.01 in.] ID and 114 ± 0.8 mm [4.5 ± 0.03 in.] height, for testing coarse and blended aggregate. The pycnometer shall be machined to be smooth on all surfaces. The inside of the lid shall be machined at a 5° angle to create an inverted conical surface. The pycnometer shall be equipped with a graduated temperature strip to allow the user to visually monitor temperature during testing.

5.9 *Fine Aggregate Fixture,* for holding and securing the lid on the small metal pycnometer from lifting during fine aggregate tests. The fixture shall be provided with a level indicator.

5.10 *Accessories*—Bag cutting knife or scissors, spray bottle filled with isopropyl alcohol, a bucket large enough to allow the pycnometer to be fully submerged in water, water containers to dispense water into pycnometer during testing, syringe with a needle no larger in diameter than 3 mm [0.125 in.], small paint brush and 25 ± 5 mm [1 ± 0.2 in.] wide metal spatula.

5.11 *Rubber Sheets,* for protecting the plastic bags against punctures caused by sharp edges on coarse and blended aggregate samples. The apparent specific gravity for the rubber sheets shall be provided by the manufacturer.

5.12 Thermometric device for monitoring the temperature to within ±1°C [±2°F].

6. Verification

6.1 *System Verification:*

6.1.1 The vacuum settings of the vacuum chamber shall be verified once every 12 months and after major repairs and after each shipment or relocation.

6.1.2 Place the gauge inside the vacuum chamber and record the setting, while the vacuum unit is operating. The gauge should indicate a pressure of 6 mm Hg [6 TORR] or less. The unit shall not be used if the gauge reading is above 6 mm Hg [6 TORR].

6.1.3 Vacuum gauge used for verification shall be standardized for accuracy on annual basis.

NOTE 4—In line vacuum gauges, while capable of indicating vacuum performance of the pump, are not suitable for use in enclosed vacuum chambers and cannot accurately measure vacuum levels.

NOTE 5—The worksheet in the appendix is provided as an optional tool to the user for recording of masses obtained during this test method. Users may develop their own worksheet or a computer program for this purpose.

6.2 *Calibration of the Small Pycnometer:*

6.2.1 Prior to testing, condition the pycnometer at 25 ± 1°C [77 ± 2°F] by placing it inside a bucket of water that is maintained at 25 ± 1°C [77 ± 2°F]. Use a level indicator or the provided level to level the fixture.

6.2.2 Remove the pycnometer from the water bucket and dry it with a towel. Place the pycnometer in the fixture and push it back until it makes contact with the stops.

6.2.3 Fill the pycnometer with 25 ± 1°C [77 ± 2°F] water to approximately 10 mm [0.375 in.] from the top. Using the alcohol spray bottle, spray the surface of the water to remove bubbles.

6.2.4 Gently place the lid on the pycnometer and close the clamps on the fixture.

6.2.5 Using a syringe filled with 25 ± 1°C [77 ± 2°F] water, slowly fill the pycnometer through the large fill hole on the lid post. Make sure the syringe tip is far enough in the pycnometer to be below the water level. Gentle application in this step prevents formation of air bubbles inside the pycnometer. Fill the pycnometer until water comes out the 3 mm [0.125 in.] hole on the surface of the lid.

6.2.6 Wipe any remaining water from the top of the lid with a towel.

6.2.7 Place the entire fixture with the pycnometer on the scale and record the mass to the nearest 0.1 g.

6.2.8 Clean the pycnometer and repeat steps 6.2.1 to 6.2.7 two more times and average the calibration masses obtained in 6.2.7.

6.2.9 If the range for the 3 calibration masses is larger than 0.5 g, then the test is not being run correctly. Check to see if the fixture is level. Make certain the water injection with the syringe is done below the pycnometer water surface and is applied gently. Check the water temperature. Check the pycnometer temperature. Repeat the above procedure until you have three masses that are within 0.5 g range.

6.2.10 Re-calibrate the pycnometer for each day of use.

6.3 *Calibration of the Large Pycnometer:*

6.3.1 Prior to testing, condition the pycnometer at 25 ± 1°C [77 ± 2°F] by placing it inside a bucket of water that is maintained at 25 ± 1°C [77 ± 2°F].

6.3.2 Remove the pycnometer from the water bucket and dry it with a towel. Set the pycnometer on a level surface.

6.3.3 Fill the pycnometer with 25 ± 1°C [77 ± 2°F] water to approximately 10 mm [0.375 in.] from the top. Using the alcohol spray bottle, spray the surface of the water to remove any air bubbles.

6.3.4 Gently place the lid on the pycnometer. Using a syringe filled with 25 ± 1°C [77 ± 2°F] water, slowly fill the pycnometer through the large fill hole on the lid post. Make sure the syringe tip is far enough in the pycnometer to be below the water level. Gentle application in this step prevents formation of air bubbles inside the pycnometer. Fill the pycnometer until water comes out the 3 mm [0.125 in.] hole on the surface of the lid.

6.3.5 Wipe any remaining water from the top of the lid and sides with a towel. Place the pycnometer on the scale and record the mass to the nearest 0.1 g.

6.3.6 Clean the pycnometer and repeat steps 6.3.2 to 6.3.5 two more times and average the calibration masses obtained in 6.3.5.

6.3.7 If the range for the 3 calibration masses is larger than 1 g, then the test is not being run correctly. Check to see if the fixture is level. Make certain the water injection with the syringe is done below the pycnometer water surface and is applied gently. Check the water temperature. Check the pycnometer temperature. Repeat the above procedure until you have three masses that are within 1 g range.

6.3.8 Re-calibrate the pycnometer for each day of use.

7. Sampling

7.1 *Fine Aggregate Samples (Method A):*

7.1.1 Sampling shall be done in accordance with Practice D75. For fine aggregate testing thoroughly mix the sample and reduce it to obtain one 1000 ± 5 g [2.0 ± 0.01 lb] sample for apparent density and two 500 ± 3 g [1.1 ± 0.01 lb] samples for determination of apparent bulk density. For aggregate reduction use the appropriate procedures described in Practice C702.

7.2 *Coarse Aggregate Samples (Method B):*

7.2.1 Sample the aggregate in accordance with Practice D75.

7.2.2 Dry the fine, coarse and combined aggregate to constant mass at 110 ± 5ºC [230 ± 9ºF] and thoroughly mix the sample of aggregate and reduce it to one 2000 ± 10 g [4.4 ± 0.02 lb] sample for determination of apparent density and two 1000 ± 10 g [2.0 ± 0.02 lb] samples for determination of apparent bulk density. For reduction of the aggregate samples, use the appropriate procedures in Practice C702.

7.2.3 If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with Test Method C136, including the sieves used for separating the size fractions for the determinations in this method.

NOTE 6—When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more sub samples, and the values obtained combined for the computations.

8. Procedures

8.1 *Method A, Fine Aggregate Test:*

8.1.1 Make certain water temperature used for this test remains at 25 ± 1°C [77 ± 2°F].

8.1.2 Prior to testing, condition the pycnometer at 25 ± 1°C [77 ± 2°F] by placing it inside a bucket of water that is maintained at 25 ± 1°C [77 ± 2°F].

8.1.3 *Determine Apparent Bulk Density:*

8.1.3.1 Make certain the samples are dried to constant mass.

8.1.3.2 For a single test select and separate two 500 ± 3 g samples (samples A and B) for the test in the pycnometer and one 1000 ± 5 g sample for vacuum saturation test.

8.1.3.3 Allow the sample to cool to room temperature.

8.1.3.4 Place the empty pycnometer in the fixture and push it back until it makes contact with the stops.

8.1.3.5 Weigh a 500 ± 3 g [1.1 ± 0.01 lb] dry sample that is at 25 ± 1°C [77 ± 2°F] and record its mass to the nearest 0.1 g (column A in appendix).

8.1.3.6 Steps 8.1.3.7 to 8.1.3.14 shall be completed in less than 2 min.

8.1.3.7 Place approximately 500 mL [17.0 oz] (halfway full) of 25 ± 1°C [77 ± 2°F] water in the pycnometer.

8.1.3.8 Slowly and evenly pour the sample into the pycnometer. Make certain aggregate is not lost in the process of filling the pycnometer. Use a brush if necessary to sweep any remaining fines into the pycnometer. If any aggregate is lost during the process of filling the pycnometer, start the test over.

8.1.3.9 Use a metal spatula and push it to the bottom of the pycnometer against the inside circumference. Slowly and gently drag the spatula to the center of the pycnometer, removing the spatula after reaching the center. Repeat this procedure 7 more times so that the entire circumference is covered in 8 equal angles, that is, every 45 degrees until the starting point is reached. If necessary, use a squeeze water bottle to rinse any sample residue off the spatula into the pycnometer.

8.1.3.10 Fill the pycnometer with 25 ± 1°C [77 ± 2°F] water to approximately 10 mm [0.375 in.] of the pycnometer rim. It is important that the water level is kept at or below the 10 mm [0.375 in.] line to avoid spills during lid placement.

8.1.3.11 Use the spray bottle filled with isopropyl alcohol and spray the top of the water to remove air bubbles.

8.1.3.12 Gently place the lid on the pycnometer and lock the clamps. Using the syringe, slowly fill the pycnometer through the center hole on top of the lid post. Make sure the syringe tip is far enough in the pycnometer to be below the water level. Gentle application in this step will prevent formation of air bubbles inside the pycnometer.

8.1.3.13 Fill the pycnometer until water just comes out the 3 mm [0.125 in.] hole on the surface of the lid.

8.1.3.14 Wipe any remaining water from around the 3 mm [0.125 in.] hole with a towel.

8.1.3.15 Weigh the pycnometer and the fixture. Record the mass to the nearest 0.1 g (column B in appendix).

8.1.3.16 Repeat steps 8.1.3.1 to 8.1.3.15 for the second 500 ± 3 g [1.1 ± 0.01 lb] sample, Sample B.

8.1.3.17 Record the mass of the sample B to the nearest 0.1 g (column B of the appendix).

8.1.3.18 Average the mass for sample A and sample B.

8.1.4 *Determine Apparent Density:*

8.1.4.1 Set the pressure level on the vacuum device according to manufacturer's recommendation.

8.1.4.2 Use a small plastic bag and inspect the bag to make sure there are no holes, stress points or side seal discontinuities in the bag. If any of the above conditions are noticed, use another bag.

8.1.4.3 Weigh the bag and record in column C of the worksheet.

NOTE 7—Handle the bag with care to avoid creating weak points and punctures.

8.1.4.4 Weigh 1000 ± 5 g [2.2 ± 0.01 lb] of oven dry aggregate and record the mass to the nearest 0.1 g in column E.

8.1.4.5 Place the sample in the bag. Support the bottom of the bag on a smooth tabletop when pouring the aggregate to protect against punctures and impact points.

8.1.4.6 Place the bag containing the sample inside the vacuum chamber.

8.1.4.7 Grab the two sides of the bag and spread the sample flat by gently shaking the bag side to side. Do not press down or spread the sample from outside the bag. Pressing down on the sample from outside the bag will cause the bag to puncture and will negatively impact the results. Lightly mist aggregates with high minus 75-µm (no. 200) sieve material to hold down dust prior to sealing.

8.1.4.8 Place the open end of the bag over the seal bar and close the chamber door. The unit will draw a vacuum and seal the bag, before the chamber door opens.

8.1.4.9 Gently remove the sample from the chamber and immediately submerge the sample in a large water tank equipped with a balance for water displacement analysis. It is extremely important that the bag be removed from the vacuum chamber and immediately placed in the water bath. Leaving the bag in the vacuum chamber or on a bench top after sealing can cause air to slowly enter the bag and can result in low apparent density results.

8.1.4.10 Cut one corner of the bag, approximately 25 to 50 mm [1 to 2 in.] from the side while the top of the bag is at least 2 in. below the surface of the water. Make sure the bag is completely submerged before cutting. Introducing air into the bag will produce inaccurate results.

8.1.4.11 Open the cut portion of the bag and hold open for 45 s. Allow the water to freely flow into the bag. Allow any small residual air bubbles to escape. Do not shake or squeeze the sample, as these actions will cause the fines to escape from the bag.

8.1.4.12 After water has filled in, cut the other corner of the bag approximately 25 to 50 mm [1 to 2 in.]. Squeeze any residual air bubbles on top portion of the bag through the cut corners by running your fingers across the top of the bag.

8.1.4.13 Place the bag containing the aggregate on the weighing basket in the water to obtain the under water mass to the nearest 0.1 g. The bag may be folded before placing it on the basket. However, once on the basket under water, unfold the bag and allow water to freely flow into the bag. Keep the sample and bag under water at all times. Make certain the bag or the sample are not touching the bottom, the sides, or floating out of the water tank. If the bag contacts the tank it will negatively impact the results of this test.

8.1.4.14 Allow the sample to stay in the water bath for a minimum of 15 min.

8.1.4.15 Record the submerged mass to the nearest 0.1 g (column F of appendix).

8.1.4.16 Optional PC software provided by the manufacturer can be used to enter the masses and obtain the results. Alternatively, users can program their own software for calculation of the results with equations given in Section 9 and develop correlations.

8.2 *Method B, Coarse and Combined Aggregate Test:*

8.2.1 Make certain water temperature used for this test remains at 25 ± 1°C [77 ± 2°F].

8.2.2 Prior to testing, condition the pycnometer at 25 ± 1°C [77 ± 2°F] by placing it inside a bucket of water that is maintained at 25 ± 1°C [77 ± 2°F].

8.2.3 *Determine Apparent Bulk Density:*

8.2.3.1 Make certain the samples are dried to constant mass.

8.2.3.2 Allow the sample to cool to room temperature.

8.2.3.3 For a single test select and separate two 1000 ± 10 g [2.2 ± 0.02 lb] samples (samples A and B) for the test in the pycnometer and one 2000 ± 10 g [4.4 ± 0.02 lb] sample for vacuum saturation test.

8.2.3.4 Make certain the pycnometer is set on a level surface.

8.2.3.5 Weigh a 1000 ± 10 g [2.2 ± 0.02 lb] dry sample (sample A) that is at 25 ± 1°C [77 ± 2°F] and record in column A of the worksheet.

8.2.3.6 Steps 8.2.3.7 to 8.2.3.17 shall be completed in less than 2 min.

8.2.3.7 Place approximately 1000 mL [34 oz] (halfway full) of 25 ± 1°C [77 ± 2°F] water in the pycnometer.

8.2.3.8 Slowly and evenly pour the sample into the pycnometer. Make certain aggregate is not lost in the process of filling the pycnometer. Use appropriate pouring techniques to help in transferring the aggregate into the pycnometer. If any aggregate is lost during the process of filling the pycnometer, start the test over.

8.2.3.9 Use a metal spatula and push it to the bottom of the pycnometer against the inside circumference. Slowly and gently drag the spatula to the center of the pycnometer, removing the spatula after reaching the center. Repeat this procedure 7 more times so that the entire circumference is covered in 8 equal angles, that is, every 45 degrees until the starting point is reached. If necessary, use a squeeze water bottle to rinse any sample residue off the spatula into the pycnometer.

8.2.3.10 Fill the pycnometer with 25 ± 1°C [77 ± 2°F] water to approximately 10 mm [0.375 in.] of the pycnometer rim. It is important that the water level is kept at or below the 10 mm [0.375 in.] line in order to avoid spills during lid placement.

8.2.3.11 Use the spray bottle filled with isopropyl alcohol and spray the top of the water to remove air bubbles.

8.2.3.12 Gently place the lid on the pycnometer. Using the syringe, slowly fill the pycnometer through the center hole on top of the lid post. Make sure the syringe tip is far enough in the pycnometer to be below the water level. Gentle application in this step will prevent formation of air bubbles inside the pycnometer.

8.2.3.13 Fill the pycnometer until you see water coming out the 3 mm [0.125 in.] hole on the surface of the lid.

8.2.3.14 Wipe any remaining water from around the 3 mm [0.125 in.] hole with a towel.

8.2.3.15 Weigh the pycnometer and the fixture. Record this mass to the nearest 0.1 g (column B of the appendix).

8.2.3.16 Repeat steps 8.2.4.6 to 8.2.4.16 for the second 1000 ± 10 g [2.2 ± 0.02 lb] sample, Sample B.

8.2.3.17 Record the mass of the sample B to the nearest 0.1 g (column B of the appendix).

8.2.3.18 Average the mass for sample A and Sample B.

8.2.4 *Determine Apparent Density:*

8.2.4.1 Set the vacuum device according to manufacturer's recommendation.

8.2.4.2 Use one small and one large plastic bag. Inspect both bags to make sure there are no holes, stress points or side seal discontinuities in the bag. If any of the above conditions are noticed, use another bag.

8.2.4.3 Weigh both bags and record the mass, to the nearest 0.1 g (column C of the appendix).

NOTE 8—Handle the bag with care to avoid creating weak points and punctures.

8.2.4.4 Weigh the two rubber sheets and record the mass to the nearest 0.1 g (column D of the appendix).

8.2.4.5 Weigh 2000 ± 10 g [4.4 ± 0.02 lb] of aggregate and record the mass to the nearest 0.1 g (column E of the appendix).

8.2.4.6 Place the sample in the small bag. When filling, support the bottom of the bag on a smooth tabletop to protect against puncture and impact points.

8.2.4.7 Place the large bag into the vacuum chamber, then place one of the rubber sheets inside the large bag. The rubber sheet should be flat, centered, and pushed all the way to the back of the large bag.

8.2.4.8 Place the small bag containing the sample into the large bag centered on top of the rubber sheet. Manually spread the sample inside the small bag. Be sure the area taken up by the sample inside the small bag remains completely contained within the area of the rubber sheets. Lightly mist aggregates with high minus 75-µm (no. 200) sieve material to hold down dust prior to sealing.

8.2.4.9 Place the other rubber sheet on top of the small bag, inside the large bag. The small bag should be between the two rubber sheets.

8.2.4.10 Place the open end of the large external bag over the seal bar and close the chamber door. Make certain the rubber sheets are not over the seal bar.

8.2.4.11 After the chamber door opens, gently remove the sample from the chamber. Immediately place the sample in the water, for water displacement analysis.

8.2.4.12 Cut one corner of the bag, approximately 70 to 100 mm [3 to 4 in.] from the side. Make sure the bag is completely submerged before cutting. Introducing air into the bag will produce inaccurate results.

8.2.4.13 Open the cut portion of the large bag and the small bag with your fingers and hold open for 25 s. Allow water to freely flow into the bags. Allow any small residual air bubbles to escape from the bags.

8.2.4.14 After water has filled in, cut the other corner of the bag approximately 70 to 100 mm [3 to 4 in.]. Squeeze any residual air bubbles out of the cut corners by running your fingers across the top of the bag.

8.2.4.15 Place the bags containing the rubber sheets and the aggregate on the weighing basket under water. The bag maybe folded for placement on the basket. However, once on the basket under water, unfold the bag and allow water to freely flow into the bag.

8.2.4.16 Make certain the bag or the sample are not touching the bottom, the sides, or floating out of the water tank. If the bag contacts the tank during mass measurement, it will negatively impact the results of this test.

8.2.4.17 Allow the sample to stay in the water bath for a minimum of 20 min.

8.2.4.18 Record the submerged mass to the nearest 0.1 g (column F of the appendix).

8.2.4.19 Optional PC software provided by the manufacturer can be used to enter the masses and obtain the results. Alternatively, users can program their own software and correlations for calculation of the results with equations given in Section 9 and develop correlations.

9. Calculations

9.1 In this method two densities are measured, one fully saturated (apparent density), ρ_v, and the other "unsaturated" using a calibrated pycnometer (apparent bulk density), ρ_u. With these two densities measured, one can derive the following relations:

$$\rho_u = \frac{Ma}{Va} \tag{1}$$

$$\rho_v = \frac{Ma}{Va - V_{abs}} \tag{2}$$

$$V_{abs} = \frac{a\ Ma}{\rho w} \tag{3}$$

where:

a = fractional absorption,
ρ_v = apparent density,
ρ_u = apparent bulk density,
Va = volume of sample, including the pores,
V_{abs} = volume of pores,
Ma = mass of sample, and
ρ_w = density of water.

9.1.1 Substituting Eq 3 in Eq 2 and rearranging:

$$\rho_v = \frac{1}{\frac{Va}{Ma} - \frac{a}{\rho_w}} = \frac{1}{\frac{1}{\rho_u} - \frac{a}{\rho_w}} \tag{4}$$

9.1.2 Rearranging Eq 4 and solving for absorption:

$$a = \left[\left(\frac{\rho_v - \rho_u}{\rho_v\,\rho_u}\right)\rho_w\right] 100 \tag{5}$$

NOTE 9—The apparent bulk density (the unsaturated density), ρ_u, is determined using a calibrated pycnometer. This measurement has to be completed in less than 2 min. The reason for the 2 min test time is to make certain that aggregate absorption is kept at a minimum level. However, the amount of water absorbed by the aggregate varies during the 2 min, depending on the specific aggregate type. For this reason a calibration is performed at the factory at different vacuum levels. Alternatively, corrections can be established by users based on known aggregates within an area. The correction parameters obtained during calibration are automatically used by the software program provided by the manufacturer. Corrections obtained by the users can be used with the equations in this section to calculate the results. Results can be obtained by using a PC software application or hand calculation.

9.1.3 Once percent absorption (Eq 5) and apparent density are known, equations based on sample mass can be written:

$$\%\,\text{absorption} = \frac{100(B - A)}{A} \tag{6}$$

$$\text{Apparent Density} = Pv = \frac{A}{A - C} \tag{7}$$

where:

A = mass of oven-dry sample in air, g,
B = mass of saturated surface-dry sample in air, g, and
C = mass of saturated sample in water, g.

9.1.4 Using Eq 6 and Eq 7, the mass B and C can be calculated:

$$B = \left(\frac{\%\,\text{absorption} \times A}{100}\right) + A \tag{8}$$

$$C = A - \left(\frac{A}{\text{Apparent Density}}\right) \tag{9}$$

9.1.5 With A and C known, the bulk gravities can be calculated from the following:

$$\text{Relative Density (Specific gravity), SSD Basis} = \frac{B}{B - C} \tag{10}$$

$$\text{Relative Density (Specific gravity), OD Basis} = \frac{A}{B - C} \tag{11}$$

9.2 These calculations are automatically performed by the PC software provided by the manufacturer.

10. Report

10.1 Report the following information:

10.1.1 Relative density and relative apparent density to four significant figures.

10.1.2 Water absorption to the nearest 0.01 %.

11. Precision

11.1 The criteria for judging the acceptability of test results obtained by this method are given in the following tables. Although this standard is written generically, the precision values shown in the following tables are based on InstroTek CoreLok vacuum device and may not be applicable to other units until similar study is performed.

Fine Aggregate	Within-Lab Standard Deviation (1S)	Between-Lab Standard Deviation (1S)	Within-Lab Acceptable Range of Two Results (D2S)	Between-Lab Acceptable Range of Two Results (D2S)
Percent water absorption	0.18	0.26	0.51	0.74
Apparent relative density (apparent specific gravity)	0.0043	0.005	0.012	0.014
Relative density (specific gravity)	0.0154	0.0205	0.044	0.058

11.1.1 The above estimate for fine aggregate is based on six different aggregate types. The materials included limestone, medium and high dust diabase, slag, rounded natural sand and angular natural sand. Ten different laboratories participated in this round robin. This study was conducted by National Center for Asphalt Technology (NCAT). The precision of this standard were derived from the results of this study which was published by Brian Prowell and Nolan Baker under NCAT Report Number 05-07.

Coarse Aggregate	Within-Lab Standard Deviation (1S)	Within-Lab Acceptable Range of Two Results (D2S)
Percent water absorption	0.0875	0.2475
Apparent relative density (apparent specific gravity)	0.00970	0.0274
Relative density (specific gravity)	0.00524	0.0148

11.1.2 The above estimate for coarse aggregate was based on thirteen different aggregate samples, seven limestone, four dolomite, 1 granite and 1 steel slag. Tests were performed by a single operator at Missouri DOT materials laboratory, Jefferson City, MO. Each aggregate type was tested four times by the same operator for all thirteen aggregate samples. The report with all the details is on file at ASTM.

11.2 The figures given in the above two tables represent (1S) and (D2S) limits described in Practice C670. When more than two tests are being evaluated, the (D2S) range must be increased. Additional guidance and background is given in Practice E691.

11.3 No information can be presented on the bias of this procedure because no material having an accepted reference value is available.

12. Keywords

12.1 absorption; aggregate; apparent density; apparent relative density; blended aggregate; coarse aggregate; combined aggregate; density; fine aggregate; relative density; specific gravity

APPENDIX

(Nonmandatory Information)

X1. WORKSHEET

X1.1 This Worksheet is provided for reference and may be used if the users of this standard have not developed other methods for recording of data.

Fine Aggregate Only
Mass of pycnometer and fixture filled with water.

1. _____ 2. _____ 3. _____ Avg _____

Coarse Aggregates Only
Mass of pycnometer filled with water.

1. _____ 2. _____ 3. _____ Avg _____

Sample Number or Label	Trial Number	Aggregate Grade (Coarse or Fine)	A. Dry Sample Mass (g)	B. Sample Mass in Pycnometer Filled with Water (g)	C. Bag Mass (g)	D. Mass of Two (2) Rubber Sheets	E. Dry Sample Mass (g)	F. Mass of Sealed Sample Opened Under Water
	Sample A							
	Sample B							
	Re-test							
	Avg							
	Sample A							
	Sample B							
	Re-test							
	Avg							
	Sample A							
	Sample B							
	Re-test							
	Avg							

	Sample A							
	Sample B							
	Re-test							
	Avg							