ASTM C138

Standard Test Method for Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete

Understanding ASTM International Test Procedures for Cement and Concrete - Staying Up to Standard

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April 27-28, 2015

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Acknowledgments

Slides Adapted from ASTM International

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Outline

- Scope
- Define Key Terminology
- Identify Necessary Equipment
- Procedure
- Understand Limitations of Procedure
- Calculations
- Report

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Related Procedures

- ASTM C29 – Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
- ASTM C31 – Practice for Making and Curing Concrete Test Specimens in the Field
- ASTM C143 – Test Method for Slump of Hydraulic-Cement Concrete
- ASTM C150 – Specification for Portland Cement
- ASTM C172 – Practice for Sampling Freshly Mixed Concrete
- ASTM C173 – Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
- ASTM C188 – Test Method for Density of Hydraulic Cement
- ASTM C231 - Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

Scope

- This test method addresses the procedures for determining the density and calculating the yield, cement content, and air content of fresh concrete.

Terminology

- ***Density:*** mass per unit volume of concrete, kg/m^3
- ***Yield:*** volume of concrete produced for a batch, m^3
- ***Gravimetric Air Content:*** air content computed as a percentage of the volume of concrete and determined on the basis of a theoretical and measured density, %

Terminology

- ***Theoretical Density:*** density of the concrete computed on an air free basis, kg/m^3.
  - density computed based on the mass and volume of the liquids and solids only
  - volume occupied by air (both entrapped and entrained) is taken as zero
  - T = M / V
  - M = Σ M = Σ [all masses]
  - V = Σ V = Σ [Mass / (1000*Specific Gravity)]

Apparatus

- Balance (scale)
- Tamping rod
- Internal Vibrator
- Measure
- Strike-off Plate
- Mallet
- Scoop

Apparatus: Balance

- Accurate, at any point in the range of use, to the greater of,
  - 45 g or
  - 0.3% of the load in the range of use
- "Range of use" extends from the mass of the measure when empty to the mass of the measure filled with material having a density of 2600 kg/m^3.

Apparatus: Tamping Rod

- Round, smooth, straight, steel.
- 16 mm diameter.
- Tamping end, or both ends, shall be rounded to a hemispherical tip.
- The length shall be at least 100 mm greater than the depth of the measure, but not greater than 600 mm.
  - a length of 400 to 600 mm meets these requirements

Apparatus: Internal Vibrator

- Rigid or flexible shaft.
- Preferably powered by an electric motor.
- Frequency ≥ 7000 vibrations/min.
- 19 mm ≤ diameter, or side dimension ≥ 38 mm

Apparatus: Measure

- Cylindrical container.
- Minimum capacity based on the Nominal Maximum Size (NMS) of the coarse aggregate per Table 1.
- Shall conform to the requirements of ASTM C29.

Apparatus: Table 1

NMS of Coarse Aggregate (mm)	Capacity of Measure (L)
25.0	6
37.5	11
50	14
75	28
112	70
150	100

Apparatus: Measure

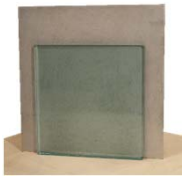
- When an air meter bowl is used as the measure,
  - the bowl shall conform to the requirements of ASTM C231
  - the bowl shall be calibrated for volume per ASTM C29
  - the top rim shall be smooth and plane within 0.3 mm.

Apparatus: Strike-off Plate

- Flat, rectangular plate.
- Can be made of,
  - metal, 6 mm thick
  - glass or acrylic, 12 mm thick

Apparatus: Strike-off Plate

- Length and width should be at least 50 mm greater than the diameter of the measure.
- Edges shall be straight and smooth within 2 mm.



Apparatus: Mallet

- Shall have a rubber or rawhide head.
- Required mass of head depends on the capacity of the measure.
  - 600 ± 200 g, for measures ≤ 14 L
  - 1000 ± 200 g, for measures > 14 L

Apparatus: Scoop

- Shall have a size,
  - large enough so the material taken from the sampling receptacle is representative
  - small enough so concrete is not spilled during placement of material in the mold

Procedure: Note

To compute density, it is necessary to determine the mass and volume of the empty measure.

follow the procedures in Section 8 of ASTM C 29 to determine the volume of any measure

Procedure: Sample

- Obtain a representative sample of concrete according to ASTM Practice C172.

Procedure

- Unless otherwise specified, determine the method of consolidation based on the measured slump.

Measured Slump	Method of Consolidation
Slump < 25 mm	Vibrate
25 mm < Slump < 75 mm	Rod or Vibrate
Slump ≥ 75 mm	Rod

Procedure

- Dampen the interior of the measure. Place measure on a flat, level, and firm surface.
- Use a scoop to place concrete in the measure.
- Move the scoop around the measure opening so material is evenly distributed and segregation is minimized.

Procedure: Rodding

- Fill the measure in three layers of approximately equal volume.
- Consolidate the concrete using the rounded end of the tamping rod.
  - uniformly distribute the rodding strokes over the cross section of the measure
  - rod the bottom layer through its depth
  - rod each upper layer through its depth and into the layer below approximately 25 mm.

Procedure: Rodding

- Number of rodding strokes per layer is a function of the size of the measure.

Volume of Measure	Number of Strokes per Layer
Volume ≤ 14 L	25
Volume = 28 L	50
Volume > 28 L	1 per each 20 cm^2 of surface area

Procedure: Rodding

- After rodding a layer, tap the outside of the measure 10 to 15 times with a mallet.
  - This closes voids left by the rod and releases large air bubbles
- Avoid overfilling the measure when adding the final layer of concrete.

Procedure: Vibration

- Fill the measure in two approximately equal layers.
- Add all material for a layer before vibrating the layer.
- With each layer, insert the vibrator at three different points.
- For the final layer, the vibrator shall penetrate the layer below approximately 25 mm.

Procedure: Vibration

- Do not allow the vibrator to touch the measure.
- Withdraw the vibrator so that no air pockets are left in the concrete.
- Continue vibrating until proper consolidation is achieved.
  - duration will depend on the characteristics of the concrete and vibrator
  - duration should be consistent for all insertions

Procedure: Notes 8 and 9

- Sufficient vibration has occurred when the top surface of the concrete is relatively smooth.
- Over-vibration may cause segregation and loss of intentionally entrained air.

Procedure: Vibration

Procedure

- Following the consolidation process,
  - there should not be a substantial excess or deficiency of concrete in the measure
  - the optimum is approximately 3 mm of material above the rim of the measure
- If necessary,
  - a small amount of material may be added to correct a deficiency
  - representative material can be removed with a trowel or scoop

Procedure: Strike off

- Strike off the top surface using a flat strike-off plate.
  - produce a smooth finish to the top surface
- Strike off should result in a measure that is just level full.

Procedure: Strike off

- While pressing down,
  - cover 2/3 of the concrete surface
  - push down and pull back with a sawing motion
  - keep plate level and in contact with the measure at all times

Procedure: Strike off

- While pressing down,
  - cover the same 2/3 of the concrete surface
  - push down and advance the plate forward with a sawing motion
  - move the plate across the entire surface until its back edge slides completely off the measure
  - keep the plate level and in contact with the measure at all times

Procedure: Strike off

- Incline the plate and use an edge to produce a smooth finished surface.

Procedure: Strike off

Procedure: Clean and Weigh

- Clean the exterior of the measure and determine its mass (weight) when full.

Procedure: Rodding

1. Dampen Interior of Mold Remove Excess Water and Fill Measure Approximately 1/3 Full.

2. Rod Layer 25 Strokes.

3. Tap the Sides of the Mold 10-15 Times.

Procedure: Rodding and Strike-Off

4. Place Two More Layers and Repeat Rodding and Tapping Procedures.

5. Measure must not Contain Substantial Excess or Deficiency of Concrete

6. Strike-Off by Covering 2/3 and Sawing off the Surface. Then 2/3 Pushing Away.

Procedure: Rodding and Strike-Off

7. Incline Plate and Perform Final Strokes to Smooth Surface.

8. Clean all excess Concrete.

9. Measure and Determine the Mass of Concrete.

Calculation

- Density (unit weight), kg/m^3

- Yield, m^3

Calculation

- Relative Yield

$$= \frac{\text{Actual Yield}}{\text{Design (Intended) Yield}}$$

- Ratio of Actual Concrete Obtained to Volume as Designed
  - Value greater than 1.00 indicates excessive concrete being produced.
  - Value less than 1.00 indicates short designed volume

Calculation

- Air Content, %

$$= \left(\frac{\text{Theoretical Density - Measured Density}}{\text{Theoretical Density}} \right) \text{x100 \%}$$

Terminology

- ***Theoretical Density:*** density of the concrete computed on an air free basis, kg/m^3.
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Report

- Identification of concrete and date of test.
- Report the test results as follows.
  - volume of measure to the nearest 0.01 L
  - density to the nearest 1.0 kg/m^3
- When requested, report
  - yield to the nearest 0.1 m^3
  - relative yield to the nearest 0.01
  - cement content to the nearest 0.5 kg
  - air content to the nearest 0.1 %

Limitations and Errors

- Determine the volume of the measure at least once a year.
- Tap the sides of the measure with a rubber mallet to close any voids. Voids cause the unit weight to be lower than the true value.
- In the filing of the container, add concrete and not mortar to ensure proportions remain the same.
- Use a flat plate to strike off the concrete. Tamping rod, trowel, float, or straight-edge will leave high spots.
- Wipe off the outside of the measure after filling.

Questions & Answers