

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**

Anthony F. Bentivegna, Ph.D.

April 27-28, 2015



Acknowledgments

Slides Adapted from ASTM International



Outline

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

www.CTLGroup.com



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

www.CTLGroup.com



Scope

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

www.CTLGroup.com



Terminology

- ▶ **Density:** mass per unit volume of concrete, kg/m³
- ▶ **Yield:** volume of concrete produced for a batch, m³
- ▶ **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, %

www.CTLGroup.com



Terminology

- ▶ **Theoretical Density:** density of the concrete computed on an air free basis, kg/m³.
 - 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
 - $T = M / V$
 - $M = \Sigma M = \Sigma$ [all masses]
 - $V = \Sigma V = \Sigma$ [Mass / (1000*Specific Gravity)]

www.CTLGroup.com



Apparatus

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

www.CTLGroup.com



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/m³.

www.CTLGroup.com



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

www.CTLGroup.com



Apparatus: Internal Vibrator

- ▶ Rigid or flexible shaft.
- ▶ Preferably powered by an electric motor.
- ▶ Frequency \geq 7000 vibrations/min.
- ▶ $19 \text{ mm} \leq \text{diameter, or side dimension} \geq 38 \text{ mm}$



www.CTLGroup.com

 CTL GROUP

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.



www.CTLGroup.com

 CTL GROUP

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

www.CTLGroup.com



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.



www.CTLGroup.com



Apparatus: Strike-off Plate

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



www.CTLGroup.com

 CTL GROUP

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.



www.CTLGroup.com

 CTL GROUP

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



www.CTLGroup.com

 CTL GROUP

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



www.CTLGroup.com

 CTL GROUP

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



www.CTLGroup.com



Procedure: Sample

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



www.CTLGroup.com



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

www.CTLGroup.com



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.

www.CTLGroup.com



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.

www.CTLGroup.com



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 \leq 14 L	25
Volume = 28 L	50
Volume $>$ 28 L	1 per each 20 cm ² of surface area

www.CTLGroup.com



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.

www.CTLGroup.com



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.

www.CTLGroup.com



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

www.CTLGroup.com



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.

www.CTLGroup.com



Procedure: Vibration



www.CTLGroup.com



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

www.CTLGroup.com



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.

www.CTLGroup.com



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



www.CTLGroup.com



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

www.CTLGroup.com



Procedure: Strike off

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



www.CTLGroup.com



Procedure: Strike off



◀ ◀ ◀ ■ ▶ ▶ ▶

www.CTLGroup.com



Procedure: Clean and Weigh

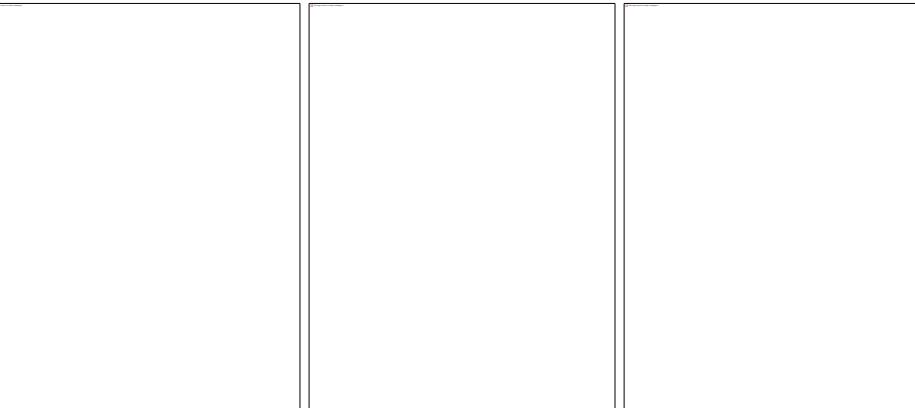
- ▶ Clean the exterior of the measure and determine its mass (weight) when full.



www.CTLGroup.com



Procedure: Rodding



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

www.CTLGroup.com

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.

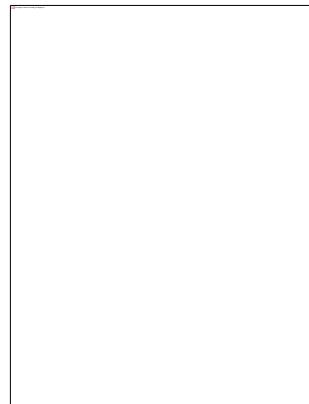
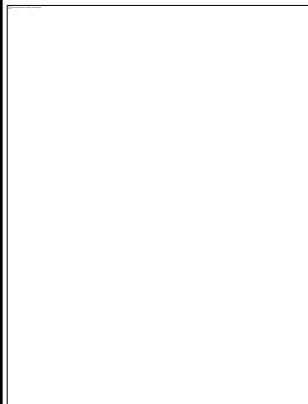


5. Measure must not Contain Substantial Excess or Deficiency of Concrete



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.

www.CTLGroup.com



Calculation

- ▶ Density (unit weight), kg/m³

- ▶ Yield, m³

www.CTLGroup.com



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

www.CTLGroup.com



Calculation

- ▶ Air Content, %

$$= \left(\frac{\text{Theoretical Density} - \text{Measured Density}}{\text{Theoretical Density}} \right) \times 100 \text{ \%}$$

www.CTLGroup.com



Terminology

- ▶ **Theoretical Density:** density of the concrete computed on an air free basis, kg/m³.
 - 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
 - $T = M / V$
 - $M = \Sigma M = \Sigma$ [all masses]
 - $V = \Sigma V = \Sigma$ [Mass / (1000*Specific Gravity)]

www.CTLGroup.com



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/m³
- ▶ When requested, report
 - yield to the nearest 0.1 m³
 - relative yield to the nearest 0.01
 - cement content to the nearest 0.5 kg
 - air content to the nearest 0.1 %

www.CTLGroup.com



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 filling 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.

www.CTLGroup.com



Questions & Answers