Tex-417-A, Unit Weight, Yield, and Air Content (Gravimetric) of Concrete

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Section 1
Overview


This test method covers determining the weight per cubic meter (cubic yard) of freshly mixed concrete and gives formulas for calculating yield, cement content, and air content of the concrete. Except for editorial differences, this procedure is the same as ASTM C 138 and AASHTO T 121.

Symbols

The following information provides detailed descriptions of various symbols contained in this test method:

- A = air content (percentage of voids) in the concrete
- N = actual cement content, kg/m³ (lb/yd³)
- N₁ = weight of cement in the batch, kg (lb.)
- Rᵧ = relative yield
- T = theoretical weight of the concrete computed on an air-free basis, kg/m³(lb/ft³) (See NOTE 1)
- V = total absolute volume of the component ingredients in the batch, m³ (ft³)
- W = unit weight of concrete, kg/m³ (lb/ft³)
- W₁ = total weight of all materials batched, kg (lb.) (See NOTE 2)
- Y = volume of concrete produced per batch, m³(yd³)
- Yₒ = volume of concrete which the batch was designed to produce, m³(yd³)
- Yᵣ = volume of concrete produced per batch, m³ (ft³).

**NOTE 1:** The theoretical weight per cubic foot or cubic meter is, customarily, a laboratory determination, the value for which is assumed to remain constant for all batches made using identical component ingredients and proportions. It is calculated from the equation:

\[ T = \frac{W₁}{V} \]
The absolute volume of each ingredient in cubic meters is equal to the weight of the ingredient in kilograms divided by 1000 times its specific gravity. (The absolute volume of each ingredient in cubic feet is equal to the quotient of the weight of that ingredient divided by the product of its specific gravity times 62.4). For the aggregate components, the bulk specific gravity and weight should be based on the saturated, surface-dry condition. For cement, the actual specific gravity should be determined by ASTM C 188. A value of 3.15 may be used for cements manufactured to meet the requirements of Specification ASTM C 150 and AASHTO M 85.

NOTE 2: The total weight of all materials batched is the sum of the weights of the cement, the fine aggregate in the condition used, the coarse aggregate in the condition used, the mixing water added to the batch, and any other solid or liquid materials used.

Units of Measurement

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.
Section 2

Apparatus

The following apparatus is required:

♦ Balance, accurate to within 0.3% of the test load at any point within the range of use, which extends from the weight of the measure empty to the weight of the measure plus its contents at 2600 kg/m³ (160 lb/ft³).

♦ Tamping rod, round, straight steel rod, 16 mm (5/8 in.) in diameter and approximately 600 mm (24 in.) in length, having the tamping end rounded to a hemispherical tip with a diameter of 16 mm (5/8 in.).

♦ Internal vibrator, with rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration should be 7000 per minute or greater. The outside diameter or the side dimension of the vibrating element shall be at least 19 mm (3/4 in.) and not greater than 38 mm (1-1/2 in.). The shaft length shall be at least 600 mm (24 in.).

♦ Measure, cylindrical container, steel or other suitable metal (See NOTE 3), with a minimum capacity which conforms to the requirements of Table 1, based on the nominal size of aggregate in the concrete to be tested. All measures, including measuring bowls of air meters, which may also be used, shall be calibrated for volume. The top rim of air meter bowls shall be smooth and plane within 0.25 mm (0.01 in.) (See NOTE 4).

♦ Strike-off plate, flat rectangular metal, at least 6 mm (0.25 in.) thick, or glass or acrylic, at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used, with straight, smooth edges within a tolerance of 1.5 mm (1/16 in.)

♦ Mallet, with rubber or rawhide head, one weighing approximately 0.57 ± 0.23 kg (1-1/4 ± 1/2 lb.) for use with measures of 14 L (1/2 ft³) or smaller, and a second, weighing approximately 1.02 ± 0.23 kg (2-1/4 ± 1/2 lb.) for measures larger than 14 L (1/2 ft³).

NOTE 3: The metal should not be readily subject to attack by cement paste. However, reactive materials such as aluminum alloys may be used in instances where as a consequence of an initial reaction, a surface film, is rapidly formed which protects the metal against further corrosion.

NOTE 4: The top rim is satisfactorily plane if a 0.25 mm (0.01 in.) feeler gage cannot be inserted between the rim and a piece of 6 mm (1/4 in.) or thicker plate glass laid over the top of the measure.
Section 3

Sampling Requirements

Perform sampling of freshly-mixed concrete according to Test Method "Tex-407-A, Sampling Freshly Mixed Concrete."
Section 4

Procedure

Obtaining Unit Weight of Concrete

The following describes the steps used in obtaining the unit weight of concrete.

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Compact the concrete in measures smaller than 11 L (0.4 ft³) by rodding because of the danger of excessive loss of entrained air.</td>
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<tr>
<td></td>
<td>For measures 11 L (0.4 ft³) or larger, base the selection of the method of consolidation on the slump, unless the method is stated in the specifications under which the work is being performed.</td>
</tr>
<tr>
<td></td>
<td>The methods of consolidation are rodding and internal vibration.</td>
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<tr>
<td></td>
<td>Rod concrete with a slump greater than 75 mm (3 in.).</td>
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<tr>
<td></td>
<td>Rod or vibrate concrete with a slump of 25 to 75 mm (1 to 3 in.).</td>
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<tr>
<td></td>
<td>Vibrate concrete with a slump less than 25 mm (1 in.).</td>
</tr>
<tr>
<td>2</td>
<td>Rodding:</td>
</tr>
<tr>
<td></td>
<td>Place concrete in the measure in three layers of approximately equal volume.</td>
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<tr>
<td></td>
<td>Rod each layer with 25 strokes of the tamping rod when nominal 14 L (1/2 ft³) or small measures are used, 50 strokes when nominal 28 L (1 ft³) measures are used, and one stroke per 2000 mm² (3 in.²) of surface for larger measures.</td>
</tr>
<tr>
<td></td>
<td>Rod the bottom layer throughout its depth but the rod shall not forcibly strike the bottom of the measure.</td>
</tr>
<tr>
<td></td>
<td>Distribute the strokes uniformly over the cross section of the measure and for the top two layers, penetrate about 25 mm (1 in.) into the underlying layer.</td>
</tr>
<tr>
<td></td>
<td>After each layer is rodded, tap the side of the measure smartly 10 to 15 times with the appropriate mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.</td>
</tr>
<tr>
<td></td>
<td>Add the final layer to avoid overfilling.</td>
</tr>
<tr>
<td>3</td>
<td>Vibration:</td>
</tr>
<tr>
<td></td>
<td>Fill and vibrate the measure in two approximately equal layers.</td>
</tr>
<tr>
<td></td>
<td>Place all concrete for each layer in the measure before starting vibration of that layer.</td>
</tr>
<tr>
<td></td>
<td>Insert the vibrator at three different points for each layer.</td>
</tr>
<tr>
<td></td>
<td>In compacting the bottom layer, do not allow the vibrator to rest on or touch the bottom or sides of the measure.</td>
</tr>
<tr>
<td></td>
<td>In compacting the final layer, the vibrator shall penetrate into the underlying layer approximately 25 mm (1 in.)</td>
</tr>
<tr>
<td></td>
<td>Take care that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen.</td>
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<tr>
<td></td>
<td>The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator (NOTE 5).</td>
</tr>
<tr>
<td></td>
<td>Continue vibration only long enough to achieve proper consolidation of the concrete (NOTE 6).</td>
</tr>
<tr>
<td></td>
<td>Observe a constant duration of vibration for the particular kind of concrete, vibrator, and measure involved.</td>
</tr>
<tr>
<td>4</td>
<td>On completion of consolidation the measure must not contain a substantial excess or deficiency.</td>
</tr>
</tbody>
</table>
of concrete.

- An excess of concrete protruding approximately 3 mm (1/8 in) above the top of the mold is optimum.
- A small quantity of concrete may be added to correct a deficiency.
- If the measure contains a great excess of concrete at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately following completion of consolidation and before the measure is struck off.

### 5 Strike off:

- After consolidation, strike-off the top surface of the concrete and finish it smoothly with the strike-off plate, using care to leave the measure just level full.
- The strike-off is best accomplished by pressing the strike-off plate on the top surface of the measure to cover about two thirds of the surface and withdrawing the plate with a sawing motion to finish only the area originally covered.
- Then place the plate on top of the measure to cover the original two thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure.
- Several final strokes with the inclined edge of the plate will produce a smooth finished surface.

### 6 Cleaning and Weighing:

- After strike-off, clean all excess concrete from the exterior of the measure and determine the net weight of the concrete in the measure to an accuracy consistent with the requirements of balance.

**NOTE 5:** Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth.

**NOTE 6:** Over-vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
Section 5

Calculations

Use the following calculations to determine the unit weight, yield, relative yield, cement content, and air content:

♦ Unit Weight
  • Calculate the net weight of the concrete in kilograms (pounds) by subtracting the weight of the measure from the gross weight.
  • Calculate the unit weight, \( W \), by dividing the net weight by the volume of the measure used.

♦ Yield

\[
Y(m^3) = \frac{W_i}{W}, \quad \text{or} \\
Y(yd^3) = \frac{W_i}{(27W)}, \quad \text{or} \\
Y_f(ft^3) = \frac{W_i}{W}
\]

♦ Relative Yield
  • Relative yield is the ratio of the actual volume of concrete obtained to the volume as designed for the batch calculated:

\[
R_y = \frac{Y}{Y_d}
\]

NOTE 8: A value of \( R_y \) greater than 1.00 indicates an excess of concrete being produced whereas a value less than this indicates the batch to be "short" of its designed volume.

♦ Cement Content
  • Calculate the actual cement content:

\[
N = \frac{N_f}{Y}
\]

♦ Air Content
  • Calculate the air content:

\[
A = \frac{(Y-V)}{Y} \times 100 (SI \ units), \quad \text{or} \\
A = \frac{(T-W)}{T} \times 100, \quad \text{or} \\
A = \frac{(Y_f-V)}{Y_f} \times 100 (in.-lb. units)
\]
The following table specifies capacities of measure that correspond to coarse aggregate sizes:

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Coarse Aggregate</th>
<th>Capacity of Measure$^\text{a}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>in.</td>
</tr>
<tr>
<td>25.0</td>
<td>1</td>
</tr>
<tr>
<td>37.5</td>
<td>1-1/2</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>75</td>
<td>3</td>
</tr>
<tr>
<td>112.5</td>
<td>4-1/2</td>
</tr>
<tr>
<td>150</td>
<td>6</td>
</tr>
</tbody>
</table>

$^\text{a}$ The indicated size of measure shall be used to test concrete containing aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95% if the nominal volume listed.