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<th>Date of Publication or Revision</th>
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METHODS OF SAMPLING AND TESTING

CONTRACTOR SUBMITTED CONCRETE MIX DESIGN

1 Scope:

1.1 This document describes required mix design procedures for independent concrete mix designs and establishes the information required for a mix design submittal.

1.2 This procedure applies to the Montana Department of Transportation (MDT) projects requiring an approved concrete mix design. It is to be used for preparation of a mix design by the contractor for submission to MDT’s Materials Bureau for final approval.

1.3 It is the responsibility of the contractor to provide mix designs meeting the required specifications of Section 551, plans, supplemental requirements, and any special provisions included in the contract. The development and testing of the contractor’s proposed mix design must be performed by a certified laboratory. A certified laboratory is any laboratory meeting the requirements of ASTM C 1077. Perform concrete mix designs in conformance with Montana, AASHTO, ACI and ASTM procedures.

2 Referenced Documents:

2.1 ASTM C 1077 Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

3 Procedure:

3.1 A mix design must be submitted for each class of concrete to be used on an MDT project to the Project Manager. Mix designs, including all required information, must be submitted 15 working days prior to concrete placement. Mix designs are to be submitted as either a new mix design or a mix design transfer.

3.2 Materials: All materials proposed are subject to approval. Refer to MT 601 for sampling and testing requirements.

3.3 New Mix Design (Trial Batches): When submitting a new mix design, trial batches must be performed. Batches must be based on the same materials and proportions proposed for the project. Trial batches must be completed 15 working days before concrete placement. The Materials Bureau will review all documentation and accept or reject the mix design.

Create at least one trial batch for each concrete mix design. Simulate haul time and mixing conditions to ensure proper workability at the jobsite. It is also recommended that a larger, more representative trial batch be made in the same manner as intended for project placement. For each trial batch, test in accordance with Annex A.1. All mix designs must include aggregate properties testing information for each aggregate size in accordance with Annex A.2. For alternative mix designs, per contract specifications, test in accordance with Annex A.3. Include data sheets for cementitious materials and admixtures with the design submittal. The trial batch will be subject to rejection if any test results fail to meet specified ranges and a new trial batch will be requested. For each trial batch, cast a minimum of three sets of three test cylinders in 4” x 8” molds. Test and average one set at 3 days, one set at 7 days, and one set at 28 days. If earlier strength information is needed for de-tensioning prestressed applications, post tensioning, form removal, etc., submit strength data for the anticipated work. The average of the cylinders at 28 days must meet the minimum strength requirements of the contract. Cast one additional set of cylinders when permeability testing is required. Based on the anticipated application of the mix design, cast and test as many specimens as needed to supply sufficient information.
3 Procedure: (continued)

3.4 Mix Design Transfer: Concrete mix designs used on MDT projects are valid for three years, provided they are transferred within 12 months of their previous use. Any request for transfer after three years will require new trial batches and resubmittal of the mix design. The contractor may request, in writing, the transfer of a concrete mix design to another project. There will be no substitutions of any materials or changes in mix proportions under this method. The Department may deny the transfer for any reason including, but not limited to, past performance, failing materials test results, raw material property changes, etc.

4 Acceptance

4.1 Approval: A representative of the MDT’s Materials Bureau will verify and sign off approval of the new or transferred concrete mix design provided required information, test results, and proper forms are submitted, and all required MDT specifications are met. When a signed copy of approval is issued to the contractor, concrete placement may begin. Any time before or after approval of the design, the Material’s Bureau may request additional materials for testing. Throughout the project, MDT may request additional tests be performed by the contractor to ensure proper placement and satisfactory test results.

4.2 Rejection: If a mix design produces failing results, a new mix design must be submitted for approval. The Materials Bureau may reject any design on the basis of any one failing test result.

4.3 In no case will the approval of a concrete mix design relieve the contractor of producing material meeting the contract requirements. Any changes or modifications to a mix design needed in the field must be approved by the Project Manager. A halt in production may be required for additional testing. Review and approval of the concrete mix design by a representative of the MDT’s Materials Bureau does not constitute acceptance of the concrete. Acceptance of concrete will be based solely on the test results of concrete placed on the project.

ANNEX:

A.1 The following tests are required for all concrete mix design submittals:
- AASHTO T 152 Air Content of Freshly Mixed Concrete by the Pressure Method
- AASHTO T 119 Slump of Hydraulic Cement Concrete
- AASHTO R 60 Sampling Fresh Concrete
- AASHTO T 121 Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- AASHTO R 39 Making and Curing Concrete Test Specimens in the Laboratory
- AASHTO T 23 Making and Curing Concrete Test Specimens in the Field
- AASHTO T 22 Compressive Strength of Cylindrical Concrete Specimens
- ASTM C 1064 Temperature of Freshly Mixed Hydraulic Cement Concrete
- MT -116 Method of Test for Slump Flow of Self-Consolidating Concrete (if applicable)
- AASHTO TP 74 J-Ring Test of Self-Consolidating Concrete (if applicable)
- AASHTO TP 80 Test for Visual Stability Index of Self-Consolidating Concrete (if applicable)

A.2 The following tests are required for aggregates for all concrete mix design submittals:
- AASHTO T 2, Sampling of Aggregates
- AASHTO T 11, Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
- AASHTO T 21, Organic Impurities in Fine Aggregates for Concrete
- AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregates (Including Fineness Modulus)
- AASHTO T 84, Specific Gravity and Absorption of Fine Aggregate
- AASHTO T 85, Specific Gravity and Absorption of Coarse Aggregate
- AASHTO T 104, Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
- AASHTO T 96, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- AASHTO T 112, Clay Lumps and Friable Particles in Aggregate
ANNEX: (continued)

A.3 The following tests are required for alternative mix designs for specific classes of concrete:

- AASHTO T 277, Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration
- AASHTO TP 95, Surface Resistivity Indication of Concrete’s Ability to Resist Chloride Ion Penetration
- ASTM C 512, Standard Test Method for Creep of Concrete in Compression
- ASTM C 469, Standard Test Method for Static Modulus of Elasticity and Poisson’s Ratio of Concrete in Compression
- ASTM C 457, Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete
1 Scope:

1.1 This method covers procedures for making and curing cylindrical and beam specimens from representative samples of fresh concrete for a construction project.

1.2 The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:

2.1 AASHTO:
M 195 Lightweight Aggregates for Structural Concrete
M 205 Molds for Forming Concrete Test Cylinders Vertically
T 23 Making and Curing Concrete Test Specimens in the Field
T 141 Sampling Freshly Mixed Concrete
T 231 Capping Cylindrical Concrete Specimens
T 309 Temperature of Freshly Mixed Cement Concrete

MT Materials Manual:
MT 102 Air Content of Freshly Mixed Concrete by the Pressure Method
MT 104 Slump of Portland Cement Concrete
MT 105 Sampling Fresh Concrete
MT 107 Air Content of Freshly Mixed Concrete by the Volumetric Method
MT 609 Field Numbering Concrete Cylinders

3 Significance and Use:

3.1 This method provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.

3.2 If the specimens are made and standard cured, as stipulated herein, the resulting strength test data where the specimens are tested may be used for the following purposes:

3.2.1 Acceptance testing for specified strength.

3.2.2 Checking the adequacy of mixture proportions for strength.

3.2.3 Quality control.

3.3 If the specimens are made and field cured, as stipulated herein, the resulting strength test data where the specimens are tested may be used for the following purposes:

3.3.1 Determination of whether a structure is capable of being put into service (Note 5).
3 Significance and Use: (continued)

3.3.2 Comparison with test results of standard cured specimens or with test results from various in-place test methods.

3.3.3 Adequacy of curing and protection of concrete in the structure, or,

3.3.4 Form or shoring removal time requirements (Note 5).

4 Apparatus:

4.1 Molds, General--Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, non-reactive with concrete containing Portland or other hydraulic cements. Molds shall hold their dimensions and shape under conditions of severe use. Molds shall be watertight during use as judged by their ability to hold water poured into them. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax, shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Reusable molds shall be lightly coated with mineral oil or a suitable reactive form release material before use.

4.2 Cylinder--Reusable molds shall be provided with a closure or base on the lower end at right angles to the axis of the cylinder. Molds may be single piece molds or made from castings with a separate detachable base plate or a base that is an integral part of the sidewall. The mold shall be either coated or made of a material that will prevent adherence to the concrete. At the time of use, molds shall not leak water. An inside fillet, if any, at the bottom of the side wall shall have an indentation around the circumference no more than 1/8 in. (3 mm) in the vertical direction or no more than 3/16 in. (5 mm) in the horizontal direction.

4.3 Beam Molds--Beam molds shall be rectangular in shape or the dimensions required producing the specimens stipulated in Section 5.2. The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed 1/8 in. (3.2 mm) for molds with depth or breadth of 6 in. (152 mm) or more. Molds shall produce specimens not more than 1/16 in. (1.6 mm) shorter than the required length in accordance with Section 4.2, but may exceed it by more than that amount.

4.4 Tamping Rods--Two sizes are specified in Table 1. Each shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod. Both ends may be rounded if preferred.

<table>
<thead>
<tr>
<th>Diameter of Cylinder or Width of Beam, In. (mm)</th>
<th>Rod Dimensions*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter, in. (mm)</td>
<td>Length of Rod, in. (mm)</td>
</tr>
<tr>
<td>&lt;6 (150)</td>
<td>3/8 (10)</td>
</tr>
<tr>
<td>6 (150)</td>
<td>5/8 (16)</td>
</tr>
<tr>
<td>9 (225)</td>
<td>5/8 (16)</td>
</tr>
</tbody>
</table>

*Rod tolerances length ± 4 in. (100 mm) and diameter ± 1/16 in. (2 mm).

4.4.1 Large Rod--5/8 in. (16 mm) in diameter and approximately 24 in. (610 mm) long.

4.4.2 Small Rod--3/8 in. (10 mm) in diameter and approximately 12 in. (305 mm) long.
4 Apparatus: (continued)

4.5 Vibrators—Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7,000 vibrations per minute or greater while in use. The diameter of a round vibrator shall be no more than one-forth the diameter of the cylinder mold or one-forth the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in. (76 mm).

4.6 Mallet—A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb (0.57 ± 0.23 kg) shall be used.

4.7 Small Tools—Tools and items which may be required are shovels, pails, trowels, wood float, metal float, blunted trowels, straightedge, feeler gage, scoops, and rules.

4.8 Slump Apparatus—The apparatus for measurement of slump shall conform to the requirements of Method MT 104.

4.9 Sampling and Mixing Receptacle—The receptacle shall be a suitable heavy gage metal pan, wheelbarrow, or flat, clean, nonabsorbent mixing board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

4.10 Air Content Apparatus—The apparatus for measuring air content shall conform to the requirements of Methods MT 107 or MT 102.

4.11 Temperature Measuring Devices—The temperature measuring devices shall conform to the applicable requirements of T309/T309M.

5 Test Specimens:

5.1 Compressive Strength Specimens—Compressive strength specimens shall be cylinders of concrete cast and hardened in an upright position, with a length equal to twice the diameter. The standard specimen shall be the 6 by 12 in. (150 by 300 mm) cylinder when the maximum size of the coarse aggregate does not exceed 2 in. (50 mm). Either the concrete sample shall be treated by wet sieving as described in AASHTO T 141 or the diameter of the cylinder shall be at least three times the nominal maximum size of the coarse aggregate in the mixture. The specimens may be 4 by 8 in. (100 by 200 mm) cylinders when the nominal maximum size of the coarse aggregate does not exceed 1 in. (25 mm).

5.2 Flexural Strength Specimens—Flexural strength specimens shall be rectangular beams of concrete cast and hardened with long axes horizontal. The length shall be at least 2 in. (50 mm) greater than three times the depth as tested. The ratio of width to depth as molded shall not exceed 1.5. The standard beam shall be 6 by 6 in. (152 by 152 mm) in cross section, and shall be used for concrete with a nominal maximum size coarse aggregate up to 2 in. (50 mm). When the nominal maximum size of the coarse aggregate exceeds 2 in. (50 mm), the smaller cross-sectional dimension of the beam shall be at least three times the nominal maximum size of the coarse aggregate. Unless required by the project specifications, beams made in the field shall not have a width or depth of less than 6 in.

6 Sampling Concrete:

6.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with Method MT 105 unless an alternative procedure has been approved.

6.2 Record the identity of the sample with respect to the location of the concrete represented and the time of casting.
7 Slump, Air Content:

7.1 Slump—Measure the slump of each batch of concrete, from which specimens are made, immediately after remixing in the receptacle as required in Method MT 104.

7.2 Air Content—Determine the air content in accordance with either Method MT 102 or Method MT 107. The concrete used in performing the air content test shall not be used in fabricating test specimens.

8 Molding Specimens:

8.1 Place of Molding—Mold specimens promptly on a level, rigid, horizontal surface, free from vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

8.2 Placing the Concrete—Place the concrete in the molds using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of concrete from the mixing pan to ensure that it is representative of the batch. Remix the concrete in the mixing pan with a shovel or trowel to prevent segregation during the molding of specimens. Move the scoop, trowel, or shovel around the perimeter of the mold opening when adding concrete to ensure an even distribution of the concrete and to minimize segregation. Further distribute the concrete by use of a tamping rod prior to the start of consolidation. In placing the final layer, the operator shall attempt to add an amount of concrete that will exactly fill the mold after compaction. Do not add non-representative concrete to an under filled mold.

8.2.1 Number of Layers—Make specimens in layers as indicated in Tables 2 or 3.

<table>
<thead>
<tr>
<th>Specimen Type and Size</th>
<th>Number of Layers of Approximately Equal Depth</th>
<th>Number of Roddings per Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cylinders:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter in. (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (100)</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>6 (150)</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>9 (225)</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td><strong>Beams:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width in. (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 (150) to 8 (200)</td>
<td>2</td>
<td>Sec 8.3.2</td>
</tr>
<tr>
<td>&gt;8 (over 200)</td>
<td>3 or more equal depths, each not to exceed 6 in. (150 mm)</td>
<td>Sec 8.3.2</td>
</tr>
</tbody>
</table>
Table 3 – Molding Requirements by Vibration

<table>
<thead>
<tr>
<th>Specimen Type and Size</th>
<th>Number of Layers</th>
<th>Number of Vibrator Insertions per Layer</th>
<th>Approximate Depth of Layer, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter, in. (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (100)</td>
<td>2</td>
<td>1</td>
<td>one-half depth of specimen</td>
</tr>
<tr>
<td>6 (150)</td>
<td>2</td>
<td>2</td>
<td>one-half depth of specimen</td>
</tr>
<tr>
<td>9 (225)</td>
<td>2</td>
<td>4</td>
<td>one-half depth of specimen</td>
</tr>
<tr>
<td>Beams:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width in. (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 (150) to 8 (200)</td>
<td>1</td>
<td>Sec 8.3.3.2</td>
<td>depth of specimen 8 (200)</td>
</tr>
<tr>
<td>over 8 (200)</td>
<td>2 or more</td>
<td>Sec 8.3.3.2</td>
<td>depth of specimen 8 (200) as near as practicable</td>
</tr>
</tbody>
</table>

8.2.2 Select the proper tamping rod from section 4.4 and Table 1 or the proper vibrator from Section 4.5. If the method of consolidation is rodding, determine the molding requirements from Table 2. Determine the molding requirements from Table 3, if the method of consolidation is vibration.

8.3 Consolidation:

8.3.1 Methods of Consolidation--Preparation of satisfactory specimens require different methods of consolidation. The methods of consolidation are rodding, and internal or external vibration. 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. Rod concrete with a slump greater than 3 in. (75 mm). Rod or vibrate concretes with slump of 1 to 3 in. (25 to 75 mm). Vibrate concretes with slump of less than 1 in. (25 mm).

8.3.2 Rodding--Place the concrete in the mold, in the required number of layers of approximately equal volume. For cylinders, rod each layer with the rounded end of the rod using the number of strokes specified in Table 2. The number of roddings per layer required for beams is one for each 2 in.² (13 cm²) top surface area of the specimen. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold and for each upper layer allow the rod to penetrate about 1/2 in. (12 mm) into the underlying layer when the depth of the layer is less than 4 in. (100 mm), and about 1 in. (25 mm) when the depth is 4 in. (100 mm) or more. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by rodding and to release any large air bubbles that may have been trapped. Tap light-gage single-use molds, susceptible to damage if tapped with the mallet, using an open hand. After tapping, spade the concrete along the sides and ends of beam molds with a trowel or other suitable tool.

8.3.3 Vibration--Maintain a uniform time period for duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete (See Note 1). Over-vibration may cause segregation. Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. When vibrating the specimen, insert the vibrator slowly and do not allow it to rest on the bottom or sides of the mold. Slowly withdraw the vibrator so that no large air pockets are left in the specimen. When placing the final layer, avoid overfilling by more than 1/4 in. (6 mm).
8.3 **Consolidation**: (continued)

Note 1 – Generally no more than 5 seconds of vibration should be required for each insertion to adequately consolidate concrete with a slump greater than 3 in. (75 mm). Longer times may be required for lower slump concrete, but the vibration time should rarely have to exceed 10 seconds per insertion.

8.3.3.1 **Cylinders**—The number of insertions of a vibrator per layer is given in Table 3. When more than one insertion per layer is required, distribute the insertion uniformly within each layer. Allow the vibration to penetrate through the layer being vibrated, and into the layer below, approximately 1 in. (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gage single use molds that are susceptible to damage if tapped with a mallet.

8.3.3.2 **Beam**—Insert the vibrator at intervals not exceeding 6 in. (150 mm) along the centerline of the long dimension of the specimen. For specimens wider than 6 in. (150 mm), use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer approximately 1 in. (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped.

8.4 **Finishing**—After consolidation, strike off excess concrete from the surface and float or trowel it as required. Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and that has no depressions or projections larger than 1/8 inch (3.2 mm).

8.4.1 **Cylinders**—After consolidation, finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits or with a wood float or trowel.

8.4.2 **Beams**—After consolidation of the concrete, strike off the top surface to the required tolerance to produce a flat even surface. A wood float may be used.

8.5 **Initial Storage**—Immediately after being struck off, the specimens shall be moved to the storage place where they will remain undisturbed for the initial curing period. If specimens made in single use mold are moved, lift and support the cylinders from the bottom of the molds with a large trowel or similar device.

9 **Curing:**

9.1 **Standard Curing**—Standard curing is the curing method used when the specimens are made and cured for purposes stated in Section 3.2.

9.1.1 **Storage**—If specimens cannot be molded at the place where they will receive initial curing, immediately after finishing, move the specimens to an initial curing place for storage. The supporting surface on which specimens are stored shall be level within 1/4 in./ft. (20 mm/m). If cylinders in the single-use molds are moved, lift and support the cylinders from the bottom of the molds with a large trowel or similar device. If the top surface is marred during movement to the place of initial storage, immediately refinish.

9.1.2 **Initial Curing**—For initial curing of cylinders, there are two methods. In both methods, the curing place must be firm, within 1/4 in. (6 mm) of a level surface, and free from vibrations or other disturbances. Immediately after molding and finishing, the specimens shall be stored for a period up to 48 hours in a temperature range between 60º to 80ºF (16º to 27ºC), and in a moist environment preventing any loss of moisture from the specimens. For concrete mixtures with a specified strength of 6000 psi (40 Mpa) or greater, the initial curing temperature shall be between 68º and 78º F (20º to 26º C). Various procedures are capable of being used during the initial
curing period to maintain the specified moisture and temperature conditions. An appropriate procedure or combination of procedures shall be used (See Note 3). Shield all specimens from direct rays of the sun and if used radiant heating devices. If cardboard molds are used, protect the outside surface of the molds from contact with wet burlap or other sources of water.

9.1.2.1 Method 1 – Initial cure in a temperature controlled chest-type curing box: Finish the cylinder using the tamping rod, straightedge, float or trowel. Use a sawing motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 1/8 in. (6.3 mm). Place the mold in the curing box. When lifting light-gauge molds be careful to avoid distortion (support the bottom, avoid squeezing the sides). Place the lid on the mold to prevent moisture loss. Mark the necessary identification data on the cylinder mold and lid.

9.1.2.2 Method 2 – Initial cure by burying in earth or by using a curing box over the cylinder (See Note 2).

Note 2 – This procedure may not be the preferred method of initial curing due to the problems in maintaining the required range of temperature.

Move the cylinder with excess concrete to the initial curing location. Place the cylinder on level sand or earth, or on a board, and pile sand or earth around the cylinder to within 2 in. (50 mm) of the top. Finish the cylinder using the tamping rod, straightedge, float or trowel. Use a sawing motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 1/8 in. (6.3 mm). If required by the agency, place a cover plate on top of the cylinder and leave it in place for the duration of the curing period or place the lid on the mold to prevent moisture loss. Mark the necessary identification data on the cylinder mold and lid.

Note 3 – A satisfactory moisture environment can be created during the initial curing of the specimens by one or more of the following procedures: (1) immediately immerse molded specimens with plastic lids in water saturated with calcium hydroxide, (2) store in properly constructed wood boxes or structures, (3) place in damp sand pits, (4) cover with removable plastic lids, (5) place inside plastic bags, or (6) cover with plastic sheets or nonabsorbent plates if provisions are made to avoid drying and damp burlap is used inside the enclosure, but the burlap is prevented from contacting the concrete surfaces. A satisfactory temperature environment can be controlled during the initial curing of the specimens by one or more of the following procedures: (1) use of ventilation, (2) use of ice, (3) use of thermostatically controlled heating or cooling devices, or (4) use of heating methods such as stoves or light bulbs. Other suitable methods may be used if the requirements limiting specimen storage temperature and moisture loss are met. For concrete mixtures with a specified strength of 6000 psi (40 Mpa) or greater, heat generated during the early stages may raise the temperature above the required storage temperature. When specimens are to be immersed in water saturated with calcium hydroxide, specimens in cardboard molds or other molds that expand when immersed in water should not be used. Early age strength test results may be lower when stored near 60ºF (16ºC) and higher when stored near 80ºF (27ºC). On the other hand, at later stages, test results may be lower for higher initial storage temperatures.

9.1.3 Final Curing:

9.1.3.1 Cylinders – Upon receipt in the Materials Bureau, store specimens in a moist condition with free water maintained on their surfaces at all times at a temperature of 73 ± 3ºF (23 ± 2ºC) using water storage tanks or moist rooms complying with the requirements of AASHTO M 201, except when capping with sulfur mortar compound and immediately before testing. When capping with sulfur mortar compounds, the ends of the cylinder shall be dry enough to preclude the formation of steam or foam pockets under or in the cap larger than 1/4 in. (6 mm) as described in AASHTO T 231. Temperatures between 68º and 86ºF (20º and 30ºC) are permitted for a period not to exceed 3 hours immediately prior to test if free moisture is maintained on the surfaces of the specimen at all times.
9.1.3 Final Curing: (continued)

9.1.3.2 Beams – Beams are to be cured the same as cylinders (Section 9.1.3.1) except that they shall be stored in water saturated with calcium hydroxide at 73º ± 3ºF (23 ± 2ºC) for at least 20 hours prior to testing. Drying of the surfaces of the beam shall be prevented between removal from the water and storage completion of testing (Note 4).

Note 4 - Relatively small amounts of drying of the surface of flexural specimens induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9.2 Field Curing – Field curing is the curing method used for the specimens made for the purpose stated in Section 3.3.

Note 5 – The Project Manager may elect to use the departments “7 day” break strength result for opening to traffic or form removal.

9.2.1 Cylinders – Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified moisture treatment. To meet these conditions, specimens made for the purpose of determining when a structure may be put in service shall be removed from the molds at the time of removal of formwork.

9.2.2 Beams – As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of 48 ± 4 hours after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements or slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the side and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structural concrete as near to the point in the structure they represent as possible and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in water saturated with calcium hydroxide at 73 ± 3ºF (23 ± 2ºC) for 24 ± 4 hours immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Observe the precautions given in Section 9.1.3.2 to guard against drying between the times of removal from curing to testing.

9.3 Structural Lightweight Concrete Curing – Cure structural lightweight concrete cylinders in accordance with AASHTO M 195.

10 Transportation to Laboratory:

10.1 Prior to transporting, cure and protect specimens as required in Section 9. Specimens shall not be transported until at least three days after molding (Note 6). Before transporting cylinders and beams from the field to the laboratory for testing, place specimens in sturdy boxes surrounded by a suitable cushioning material to prevent damage from jarring. During cold weather, protect the specimens from freezing with suitable insulation material. Prevent moisture loss during transportation by wrapping the specimens in plastic, wet burlap, by surrounding them with wet sand or sawdust or tight-fitting plastic caps on plastic molds.
10 Transportation to Laboratory: (continued)

Note 6 - Retaining the cylinders on the project for three days will permit sufficient strength to develop to greatly reduce the possibility of latent damage from rough handling or exposure to low temperatures during shipping. Past cylinder failure investigations have produced considerable evidence that such latent damage may be a major factor in low-test cylinder strengths. This is particularly evident where cylinders have been removed from the molds and shipped the day after casting during periods of below freezing weather. It is realized that, in some cases, retaining the cylinders on the project for three days may result in the first cylinder being tested later than the specified seven days. However, a late seven-day test is preferable to the possibility of damaging the entire set by shipping before adequate strength is developed. Every effort should be made, however, to comply with Section 9.1.3.1 above in order that the specimen will receive the 24 hour curing in the moist room in the Materials Bureau.
METHODS OF SAMPLING AND TESTING
MT 102-07

METHOD OF DETERMINING AIR CONTENT OF
FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD
(Modified AASHTO T152)

1 Scope:

1.1 This method covers determination of the air content of freshly mixed concrete from observation of the change in volume of concrete with a change in pressure.

1.2 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 Section 5. It is not applicable to concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity. In these cases, AASHTO T 196M/T 196 should be used. This test method is not applicable to nonplastic concrete such as is commonly used in the manufacture of pipe and concrete masonry units.

1.3 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables and figures shall not be considered as requirements for this standard.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2 Reference Document:

2.1 AASHTO:
T 121 Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
T 141, Sampling Freshly Mixed Concrete
T 152 Air Content of Freshly Mixed Concrete by the Pressure Method
R 39 – making and Curing Concrete Test Specimens in the Laboratory

MT Materials Manual:
MT-105 Sampling Freshly Mixed Concrete

3 Significance and Use:

3.1 This test method covers the determination of the air content of freshly mixed concrete. The test determines the air content of freshly mixed concrete exclusive of any air that exists inside the voids within aggregate particles. For this reason, it is applicable to concrete made with relatively dense aggregate particles and requires determination of the aggregate correction factor. (See Sections 6.1 and 91.).

3.2 Thus test method and T 121M/T 121 and T 196M/T 196 provide pressure, gravimetric, and volumetric procedures, respectively, for determining the air content of freshly mixed concrete. The pressure method of this test method gives substantially the same air content as the other two test methods for concrete made with dense aggregates.

3.3 The air content of hardened concrete may be either higher or lower than that determined by this test method. This depends upon the methods and amount of consolidation effort applied to the concrete from which the hardened concrete specimen is taken; uniformity and stability of the air bubbles in the fresh and hardened concrete; accuracy of the microscopic examination, if used, time of comparison; environmental exposure; stage in the delivery, placement, and consolidation processes at which the air determined, that is, before or after the concrete goes through a pump; and other factors.
4 Apparatus:

4.1 Air Meter - There are two basic operational designs available employing the principle of Boyle's law. For purposes of reference, these will be designated Type A Meter and Type B Meter.

4.1.1 Type A Meter - An air meter consisting of a measuring bowl and cover assembly (Figure 1) conforming to the requirements of Sections 4.2 and 4.3. 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 percent of air in the concrete sample.

4.1.2 Type B Meter - An air meter consisting of a measuring bowl and cover assembly (Figure 2) conforming to the requirements of Section 4.2 and 4.3. 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 gage being calibrated in terms of percent air for the observed pressure at which equalization takes place. Working pressures of 7.5 to 30.0 psi (51 to 207 kPa) having been used satisfactorily.

4.2 Measuring Bowl - The measuring bowl must be essentially cylindrical in shape, made of steel, hard metal, or other hard material 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 0.20 ft³ (0.006 m³). It must 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 must be machined smooth. The measuring bowl and cover assembly must be sufficiently rigid to limit the expansion factor, \( D \), of the apparatus assembly (Annex A1.5) to not more than 0.1 percent of air content on the indicator scale when under normal operating pressure.

4.3 Cover Assembly:

4.3.1 The cover assembly shall be made of steel or other hard metal not readily attacked by the cement paste. It must be flanged or otherwise constructed to provide for a pressure-tight fit between bowl and cover assembly and must have machined smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover must be sufficiently rigid to limit the expansion factor of the apparatus assembly as prescribed in 4.2.

4.3.2 The cover assembly must be fitted with a means for direct reading of the air content. The cover for the Type A meter must be fitted with a standpipe, which may be a transparent graduated tube or may be a metal tube of uniform bore with a glass water gage attached. In the Type B meter, the dial of the pressure gage must be calibrated to indicate the percent of air. Graduations shall be provided for a range in air content of at least 8 percent easily readable to 0.1 percent as determined by the proper air pressure calibration test.

4.3.3 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.

4.4 Calibration Vessel - A measure having an internal volume equal to a percent of the volume of the measuring bowl corresponding to the approximate percent 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 percent 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 1/2 in. (13 mm) less than that of the bowl.
Note 1: A satisfactory measure of this type may be machined from No. 16 gage brass tubing, of a diameter to provide the volume desired, to which a brass disk 1/2 in. in thickness is soldered to form an end. When design of the meter requires withdrawing of water from the water-filled bowl.
4 Apparatus: (continued)

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.

4.5 The designs of various available types of airmeters are such that they differ in operating techniques and therefore, all of the items described in 4.6 through 4.16 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.

4.6 **Coil Spring or Other Device for Holding Calibration Cylinder in Place:**

4.7 **Spray Tube** - A brass tube of appropriate diameter, which may be an integral part of the cover assembly or which may be provided separately. It must 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.

4.8 **Trowel** - A standard brick mason's trowel.

4.9 **Tamping Rod** - The tamping rod shall be a round, straight steel rod 5/8 in. (16 mm) in diameter and not less than 16 (400 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is 5/8 in. (16 mm).

4.10 **Mallet** - A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb. (0.57 ± 0.23 kg) for use with measures of 0.5 ft³ (14 L) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb. (1.02 ± 0.23 kg) for use with measures larger than 0.5 ft³ (14 L).

4.11 **Strike-Off Bar** - A flat straight bar of steel or other suitable metal at least 1/8 in. (3 mm) thick and 3/4 in. (20 mm) wide by 12 in. (300 mm) long.

4.12 **Strike-Off Plate** – A flat rectangular metal plate at least ¼ inch (6 mm) or a glass or acrylic plate at least ½ inch (12 mm) thick with a length and width at least 2 inches (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1/16 inch (1.5 mm).

4.13 **Funnel** - with the spout fitting into spray tube.

4.14 **Measure of Water** - having the necessary capacity to fill the indicator with water from the top of the concrete to the zero mark.

4.15 **Vibrator** – as described in AASHTO R 39.1

4.16 **Sieves** – 1½ inch (37.5 mm) with not less than 2 ft² (0.19 m²) of sieving area.

5 Calibration of Apparatus:

5.1 Make calibration tests in accordance with procedures described in the annex. Rough handling will affect calibration of both Type 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 section A1.2 to A1.6, 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 Section A1.7, 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 Sections A1.2 to A1.6 need be made only once (at 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 Section A1.7 to A1.9, 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.
Calibration of Apparatus: (continued)

content scale for the Type B meter. A change in elevation of more than 600 ft (183 m) from the
location at which a Type A meter was last calibrated will require recalibration in accordance with
Section A1.7.

Determination of Aggregate Correction Factor:

6.1 Procedure – Determine the aggregate correction factor on a combined sample of fine and coarse
aggregate as directed in sections 6.2 to 6.4. 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.

6.2 Aggregate Sample Size – Calculate the weights of fine and coarse aggregate present in the
sample of fresh concrete whose air content is to be determined, as follows:

\[
\begin{align*}
F_s &= (S/B) \times F_b \\
C_s &= (S/B) \times C_b 
\end{align*}
\]

where:

- \(F_s\) = weight of fine aggregate in concrete sample under test, lb (kg);
- \(S\) = volume of concrete sample (same as volume of measuring bowl), ft\(^3\) (m\(^3\));
- \(B\) = volume of concrete produced per batch (Note 2), ft\(^3\) (m\(^3\));
- \(F_b\) = total weight of fine aggregate in the moisture condition used in batch, lb (kg);
- \(C_s\) = weight of coarse aggregate in concrete sample under test, lb (kg), and
- \(C_b\) = total weight of coarse aggregate in the moisture condition used in batch, lb (kg).

Note 2 – The volume of concrete produced per batch can be determined in accordance with applicable
provisions of T 121M/T 121.

Note 3 – The term “weight” is temporarily used in this standard because of established trade usage. The
word is used to mean both “force” and “mass” and care must be taken to determine which is
meant in each case (SI unit for force = Newton and for mass = kilogram).

6.3 Placement of Aggregate in Measuring Bowl – Mix representative samples of fine aggregate \(F_s\),
and coarse aggregate \(C_s\), 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 1 in. (25 mm) of the aggregate about 8 – 12 times. Stir after each
addition of aggregate to eliminate entrapped air.

6.4 Aggregate Correction Factor Determination:

6.4.1 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 section
6.4.2 and 6.4.3.
6 Determination of Aggregate Correction Factor: (continued)

6.4.2 Type A Meter – Complete the test as described in Sections 8.2.1 and 8.2.2. The aggregate correction factor, $G$, is equal to $h_1 - h_2$. (Figure 1) (Note 4)

6.4.3 Type B Meter – Perform the procedures as described in section 8.3.1. 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 Section A1.9 of the Annex for the calibration tests. Complete the test as described in Section 8.3.2. 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 percent of the volume of the bowl. (Figure 2)

Note 4 – 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.

7 Preparation of Concrete Test Sample:

7.1 Obtain the sample of freshly mixed concrete in accordance with applicable procedures of Method MT-105/T 141. If the concrete contains coarse aggregate particles that would be retained on a 2 inch (50 mm) sieve, wet-sieve a sufficient amount of the representative sample over a 1½ inch (37.5 mm) sieve, as described in Mt-105/T 141 to yield more than enough material to fill the measuring bowl of the size selected for use. Carry out the wet-sieving operation with the minimum practical disturbance of the mortar. Make no attempt to wipe adhering mortar from coarse aggregate particles retained on the sieve.

8.1 Placement and Consolidation of Sample:

8.1.1 Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Place a representative sample of the concrete, prepared as described in Section 7, in the measuring bowl in equal layers. Consolidate each layer by the rodding procedure (Section 8.1.2) or by vibration (Section 8.1.3). Strike off the final consolidated layer (8.1.4). Rod concretes with a slump greater than 3 inches (75 mm). Rod or vibrate concrete with a slump of 1 to 3 inches (25 to 75 mm). Consolidate concretes with a slump of less than 1 inch (25 mm) by vibration.

8.1.2 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. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. 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 1 in. (25 mm). Add the final layer of concrete in a manner to avoid excessive overfilling (8.1.4).

8.1.3 Vibration – Place the concrete in the measuring bowl in two layers of approximately equal volume. Place all 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 (Section 8.1.4). In consolidating each layer, do not allow the vibrator to rest on or touch the measuring bowl. Take care in withdrawing the vibrator to ensure that no air pockets are left in the specimen. 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.
8.1 Placement and Consolidation of Sample: (continued)

Continue vibration only long enough to achieve proper consolidation of the concrete. Never continue vibration long enough to cause escape of froth from the sample.

Note 5 – Over vibration 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.

8.1.4 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 1/8 in. (3 mm) during strike off is optimum. When a strike-off plate is used, strike off concrete as prescribed in T121M/T 121.

Note 6 - 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 7 – The use of the strike-off plate on cast aluminum or other relatively soft metal air meter bases may cause rapid wear of the rim

8.1 Placement and Consolidation of Sample: (continued)

8.1.5 Application of Test Method – Any portion of the test method not specifically designated as pertaining to Type A or Type B meters shall apply to both types.

8.2 Procedure - Type A Meter:

8.2.1 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 about the halfway mark in the standpipe. Incline the apparatus assembly about 30 degrees 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. Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column. (Figure 1A)

Note 8 – Some Type A meters have a calibrated starting fill mark above the zero mark. Generally, this starting mark should not be used since, as noted in Section 8.2.3, the apparent air content is the difference between the water level $h_1$ at pressure $P$ and the water level $h_2$ at zero pressure after release of pressure $P$.

8.2.2 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.

8.2.3 Test Procedure - Apply slightly more than the desired test pressure, $P$, (about 0.2 psi (1,380 kPa 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 gage indicates the exact test pressure, $P$, as determined in accordance with Section A1.7, read the water level, $h_1$, and record to the nearest division or half-division on the graduated precision-bore tube or gage glass of the standpipe. (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 one
minute. Record the water level, \( h_2 \), to the nearest division or half division. (Figure 1C) Calculate the apparent air content as follows:

\[
A_1 = h_1 - h_2
\]

where:

- \( A_1 \) = apparent air content;
- \( h_1 \) = water level reading at pressure, \( P \); and
- \( h_2 \) = water level reading at zero pressure after release of Pressure, \( P \).

8.2.4 **Check Test** - Repeat the steps described in 8.2.3 without adding water to reestablish the water level at the zero mark. The two consecutive determinations of apparent air content should check within 0.2 percent of air and shall be averaged to give the value \( A_1 \) to be used in calculating the air content, \( A_s \), in accordance with Section 9.

8.2.5 In the event the air content exceeds 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 Sections 8.2.2 and 8.2.3.

**Note 9** – See Section A1.7 for exact calibration procedures. An approximate value of the alternative pressure, \( P_1 \), such that the apparent air content will equal twice the meter reading can be computed from the following relationship:

\[
P_1 = \frac{P_aP}{2P_a+P}
\]

Where:

- \( P_1 \) = alternative test pressure, psi (kPa);
- \( P_a \) = atmospheric pressure, psi (kPa) (approximately 14.7 psi (101kPa) but will vary with altitude and weather conditions); and
- \( P \) = normal test or operating pressure, psi (kPa).

8.3 **Procedure - Type B Meter:**

8.3.1 **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 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 the same petcock.

8.3.2 **Test Procedure** - Close the air bleeder valve on the chamber and pump air into the air chamber until the gage hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gage hand at the initial pressure line by pumping or bleeding-off air as necessary, tapping the gage lightly by hand. Close both petcocks on the holes through the cover. Open the air valve between the air chamber and the measuring bowl. Tap the side of the measuring bowl smartly with the mallet to relieve local restraints. Lightly tap the pressure gage by hand to stabilize the gage hand and read the percentage of air on the dial of the pressure gage. Failure to close the main valve before releasing the pressure from either the container or the air chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber, it must be bled
from the air chamber through the bleeder valve followed by strokes of the pump to blow out the last traces of water. Release the pressure by opening both petcocks (Figure 2) before removing the cover.

9 Calculation:

9.1 Air Content of Sample Tested – Calculate the air content of the concrete in the measuring bowl as follows:

\[ A_s = A_t - G \]

where:

\( A_s \) = air content of sample tested, percent;

\( A_t \) = apparent air content of the sample tested, percent (Section 8.2.3 and 8.3.2); and

\( G \) = aggregate correction factor, percent (Section 6).

9.2 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 a 1 ½ inch (37.5 mm) sieve, the air content may be calculated as follows:

\[ A_t = 100A_sV_c/(100V_t - A_sV_c) \]

where (Note 10):

\( A_t \) = air content of the full mixture, percent;

\( V_c \) = absolute volume of the ingredients of the mixture passing 1 ½ inch (37.5 mm) sieve, airfree, as determined from the original batch weights, ft³ (m³);

\( V_t \) = absolute volume of all the ingredients of the mixture, airfree, ft³ (m³); and

\( V_c \) = absolute volume of the aggregate in the mixture coarser than a 1 ½ inch (37.5 mm) sieve, as determined from the original batch weights, ft³ (m³).

9.3 Air content of the Mortar Fraction - When it is desired to know the air content of the mortar fraction of the mixture, calculate it as follows;

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

where (Note 10):

\( A_m \) = air content of the mortar fraction, percent; and

\( V_m \) = absolute volume of the ingredients of the mortar fraction of the mixture, airfree, ft³ (m³).

Note 10 – The values for use in Equations in Sections 9.2 and 9.3 are most conveniently obtained from data on the concrete mixture tabulated as follows for a batch of any size:

<table>
<thead>
<tr>
<th>Absolute Volume, ft³ (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
</tr>
</tbody>
</table>

9 Calculation: (continued)
ANNEX:

A1 Calibration of the Apparatus:

A1.1 The calibration tests shall be performed in accordance with the following procedures as applicable to the meter type being employed.

A1.2 Calibration of the Calibration Vessel – Determine accurately the weight of water required to fill the calibration vessel \( w \), using a scale accurate to 0.1 percent of the weight of the vessel filled with water. This step shall be performed for Types A and B meters.

A1.3 Calibration of the Measuring Bowl – Determine the weight of water required to fill the measuring bowl, \( W \), using a scale accurate to 0.1 percent of the weight of the bowl filled with water. Slide a glass plate carefully over the flange of the bowl in a manner to ensure that the bowl is completely filled with water. A thin film of grease smeared on the flange of the bowl will make a watertight joint between the glass plate and the top of the bowl. This step shall be performed for Types A and B meters.

A1.4 Effective Volume of the Calibration Vessel, \( R \) – The constant \( R \), represents the effective volume of the calibration vessel expressed as a percentage of the volume of the measuring bowl.

A1.4.1 For Type A meters, calculate the \( R \) as follows (Note A1):

\[
R = 0.98 \frac{w}{W} \quad (A1.1)
\]

where:

\( w \) = weight of water required to fill the calibration vessel, and

\( W \) = weight of water required to fill the measuring bowl.

Note A1 – The factor 0.98 is used to correct for the reduction in the volume of air in the calibration vessel when it is compressed by a depth of water equal to the depth of the measuring bowl. This factor is approximately 0.98 for an 8-in. (203 mm) deep measuring bowl at sea level. Its value decreases to approximately 0.975 at 5000 ft (1524 m) above sea level and 0.970 at 13000 ft (3962 m) above sea level. The value of this constant will decrease by about 0.01 for each 4-in. (102 mm) increase in bowl depth. The depth of the measuring bowl and atmospheric pressure do not affect the effective volume of the measuring vessel for Type B meters.

A1.4.2 For Type B meters, Calculate \( R \) as follows (Note A1):

\[
R = \frac{w}{W} \quad (A1.2)
\]

A1.5 Determination of, or Check of, Allowance for Expansion Factor, \( D \):

A1 Calibration of the Apparatus: (continued)
A1.5.1 For meter assemblies of Type A, determine the expansion factor, \( D \) (Note A2) by filling the apparatus with water only (making certain that all entrapped air has been removed and the water level is exactly on the zero mark (Note A3) and applying air pressure approximately equal to the operating pressure, \( P \), determined by the calibration test described in Section A1.7. The amount the water column lowers will be the equivalent expansion factor, \( D \), for that particular apparatus and pressure (Note A5).

Note A2 – Although the bowl, cover, and clamping mechanism of the apparatus must of necessity be sturdy constructed so that it will be pressure-tight, the application of internal pressure will result in a small increase in the volume. This expansion will not affect the test results because, with the procedure described in Sections 6 and 8, the amount of expansion is the same for the test for air in concrete as for the test for aggregate correction factor on combined fine and coarse aggregates, and is thereby automatically cancelled. However, it does enter into the calibration test to determine the air pressure to be used in testing fresh concrete.

Note A3 – The water columns on some meters of Type A design are marked with an initial water level and a zero mark, the difference between the two marks being the allowance for the expansion factor. This allowance should be checked in the same manner as for meters not so marked and in such a case, the expansion factor should be omitted in computing the calibration readings in Section A1.7.

Note A4 – It will be sufficiently accurate for this purpose to use an approximate value for \( P \) determined by making a preliminary calibration test as described in Section A1.7 except that an approximate value for the calibration factor, \( K \), should be used. For this test \( K = 0.98R \) which is the same as Equation A1.2 except that the expansion reading, \( D \), as yet unknown, is assumed to be zero.

A1.5 For meters of Type B design, the allowance for the expansion factor, \( D \), is included in the difference between the initial pressure indicated on the pressure gauge and the zero percent mark on the air-content scale on the pressure gauge. This allowance shall be checked by filling the apparatus with water (making certain that all entrapped air has been removed), pumping air into the air chamber until the gauge hand is stabilized at the indicated initial pressure line, and then releasing the air to the measuring bowl (Note A5). If the initial pressure line is correctly positioned, the gauge should read zero percent. The initial pressure line shall be adjusted if two or more determinations show the same variation from zero percent and the test repeated to check the adjusted initial pressure line.

Note A5 – This procedure may be accomplished in connection with the calibration test described in Section A1.9.

A1.6 Calibration Reading, \( K \) – The calibration reading, \( K \), is the final meter reading to be obtained when the meter is operated at the correct calibration pressure.

A1.6.1 For Type A meters, the calibration reading, \( K \), is as follows:

\[
K = R + D \quad (A1.3)
\]

where:

\( R \) = effective volume of the calibration vessel (Section A1.4.1), and

\( D \) = expansion factor (Section A1.5.1, Note A6).

A1.6.2 For Type B meters, the calibration reading, \( K \), equals the effective volume of the calibration vessel (Section A1.4.2) as follows:

\[
K = R \quad (A1.4)
\]

A1 Calibration of the Apparatus: (continued)
Note A6 – If the water column indicator is graduated to include an initial water level and zero mark, the difference between the two marks being equivalent to the expansion factor, the term D shall be omitted from Equation A1.4.

A1.7 Calibration Test to Determine Operating Pressure, $P$, on Pressure Gauge, Type A Meter – If the rim of the calibration cylinder contains no recesses or projection, fit it with three or more spacers equally spaced around the circumference. Invert the cylinder and place it at the center of the dry bottom of the measuring bowl. The spacers will provide an opening for flow of water into the calibration cylinder when pressure is applied. Secure the inverted cylinder against displacement and carefully lower the cover assembly. After the cover is clamped in place, carefully adjust the apparatus assembly to a vertical position and add water at air temperature, by means of the tube and funnel, until it rises above the zero mark on the standpipe. Close the vent and pump air into the apparatus to the approximate operating pressure. Incline the assembly about 30 degrees from vertical and, using the bottom of the bowl as a pivot, describe several circles with the upper end of the stabpipe, simultaneously tapping the cover and sides of the bowl lightly to remove any entrapped air adhering to the inner surfaces of the apparatus. Return the apparatus to a vertical position, gradually release the pressure (to avoid loss of air from the calibration vessel) and open the vent. Bring the water level exactly to the zero mark by bleeding water through the petcock in the top of the conical cover. After closing the vent, apply pressure until the water level has dropped an amount equivalent to about 0.1 to 0.2 percent of air more than the value of the calibration reading, $K$, determined as described in Section A1.6. To relieve local restraints, lightly tap the sides of the bowl and when the water level is exactly at the value of the calibration reading, $K$, read the pressure, $P$, indicated by the gauge and record to the nearest 0.1 psi (690 kPa).

Gradually release the pressure and open the vent to determine whether the water level returns to the zero mark when the sides of the bowl are tapped lightly (failure to do so indicates loss of air from the calibration vessel or loss of water due to a leak in the assembly). If the water level fails to return to within 0.05 percent of air of the zero mark and no leakage beyond a few drops of water is found, some air probably was lost from the calibration cylinder. In this case, repeat the calibration procedure step-by-step from the beginning of this paragraph. If the leakage is more than a few drops of water, tighten the leaking joint before repeating the calibration procedure. Check the indicated pressure reading promptly by bringing the water level exactly to the zero mark, closing the vent, and applying pressure, $P$, just determined. Tap the gauge lightly with a finger. When the gauge indicates the exact pressure, $P$, the water column should read the value of the calibration factor, $K$, used in the pressure application within about 0.05 percent of air.

Note A7 – Caution: The apparatus assembly must not be moved from the vertical position until pressure has been applied which will force water about one-third of the way up into the calibration cylinder. Any loss of air from this cylinder will nullify the calibration.

A1.8 Calibration Test to Determine Alternative Operating Pressure $P_1$ – Type A Meter – The range of air contents which can be measured with a given meter can be doubled by determining an alternative operating pressure $P_1$ such that the meter reads half of the calibration reading, $K$ (Equation A1.3). Exact calibration will require determination of the expression factor at the reduced pressure in Section A1.5. For most purposes the change in expression factor can be disregarded and the alternative operating pressure determined during the determination of the regular operating pressure in Section A1.7.

A1.9 Calibration Test to Check the Air Content Gradations on the Pressure Gauge, Type B Meter – Fill the measuring bowl with water as described in Section A1.3. Screw the short piece of tubing or pipe furnished with the apparatus into the threaded petcock hole on the underside of the cover assembly. Assemble the apparatus. Close the air valve between the air chamber and the measuring bowl and open the two petcocks on holes through the cover assembly. Add water through the petcock on the cover assembly having the extension below until all air is expelled from the second petcock. Pump air into the air chamber until the pressure reaches the indicated 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

A1 Calibration of the Apparatus: (continued)
gauge lightly. Close the petcock not provided with the tube or extension on the underside of the cover. Remove water from the assembly to the calibrating vessel controlling the flow, depending on the particular meter design, by opening the petcock provided with the tube or extension and cracking the air valve between the air chamber and the measuring bowl, or by opening the air valve and using the petcock to control the flow. Perform the calibration at an air content that is within the normal range of use. If the calibration vessel (Section A1.2) has a capacity within the normal range of use, remove exactly that amount of water. With some meters the calibrating vessel is quite small and it will be necessary to remove several times that volume to obtain an air content within the normal range of use. In this instance, carefully collect the water in an auxiliary container and determine the amount removed by weighing to the nearest 0.1 percent. Calculate the correct air content, $R$, by using Equation A1.2. Release the air from the apparatus at the petcock not used for filling the calibration vessel and if the apparatus employs an auxiliary tube for filling the calibration container, open the petcock to which the tube is connected to drain the tube back into the measuring bowl (Note A7). At this point of the procedure the measuring bowl contains the percentage of air determined by the calibration test of the calibrating vessel. Pump air into the air chamber until the pressure reaches the initial pressure line marked on the pressure gauge, close both petcocks in the cover assembly, and then open the valve between the air chamber and the measuring bowl. The indicated air content on the pressure gauge dial should correspond to the percentage of air determined to be in the measuring bowl. If two or more determinations show the same variation from the correct air content, the dial hand shall be reset to the correct air content within 0.1 percent. If the dial hand was reset to obtain the correct air content, recheck the initial pressure mark as in Section A1.5.2. If a new initial pressure reading is required, repeat the calibration to check the accuracy of the graduation on the pressure gauge described earlier in this section. If difficulty is encountered in obtaining consistent readings, check for leaks, for the presence of water inside the air chamber (Figure 2), or the presence of air bubbles clinging to the inside surfaces of the meter from the use of cool, aerated water. In this latter instance, use de-aerated water, obtained by cooling hot water to room temperature.

*Note A8 – If the calibrating vessel is an integral part of the cover assembly, the petcock used in filling the vessel should be closed immediately after filling the calibration vessel and not opened until the test is complete.*
METHODS OF SAMPLING AND TESTING
MT 103-07
METHOD FOR MEASURING THE THICKNESS OF IN-PLACE CONCRETE
BY USE OF CONCRETE THICKNESS GAUGE
(Montana Method)

1  Scope:

1.1 This method covers the procedure for measuring the thickness of concrete pavements. Thickness is determined by using a concrete thickness gauge to measure the time required for an echo to bounce off the backside of the concrete member being tested. The thickness is a product of the velocity of sound in the material and one half the transit time (round trip) through the material.

2  Referenced Documents:

2.1 Materials Manual:
MT 106  Measuring Length of Drilled Concrete Cores
MT 606  Selecting Sampling Locations by Random Sampling Technique

3  Apparatus:

3.1 Standard Surveying Equipment – EDM, mirrors, level, rod, etc.
3.2 Concrete Thickness Gauge
3.3 Core Drill – for obtaining cylindrical core specimens
3.4 Measuring Tape

4  Vertical Control:

4.1 When possible, it is recommended that at least one vertical control point be established for each day’s placement of concrete, using survey methods prior to placement. After the concrete has hardened sufficiently, re-measure the same control point to determine the depth of the finished concrete. Use this point as a calibration point for the concrete thickness gauge. (Pre-established reference points and grade control points may also be used to determine concrete thickness).

5  Gauge Calibration Methods:

5.1 Gauge Calibration:

Place the concrete thickness gauge on the concrete, at the pre-established vertical control point, and calibrate according to the manufacturers instructions. The gauge will now establish the velocity for the particular concrete being tested.

5.2 Direct Input Method:

Following the manufacturer’s instructions, a direct input method may be used to calibrate the concrete thickness gauge. For the purpose of this method, a core will be taken to determine the actual thickness of the placed concrete. The concrete thickness gauge will then be calibrated using the core thickness.

6  Procedure:

6.1 Calibrate the gauge according to one of the procedures described above. The gauge must be calibrated on the concrete to be tested or the correct velocity entered into the gauge. The calibration should be done on a smooth, clean surface to obtain the best data possible. (See Note 1) This data will be used for all subsequent tests and all tests must be completed on the
same day as the gauge calibration.

6.2 Randomly select test locations (see Note 1) according to MT 416, Random Sampling Technique or as directed by the Engineering Project manager.

6.3 At the test location, take four measurements by rotating the gauge around a center point and at 90 degrees from the previous reading and average the results. (See Note 1)

Note 1: *Make certain that the test head of the concrete thickness gauge is in good contact with the concrete surface, should be done on a smooth clean surface to obtain the best data possible.*

7 Calculation:

7.1 Record gauge readings to the hundredth of a foot or (mm) on lab form

7.2 Record the average of the four (4) readings from each test location to a hundredth of a foot or (mm).

7.3 Determine and record the concrete thickness variation by subtracting the average of the four readings from the design thickness and record to the nearest hundredth of a foot (mm).

8 Report:

8.1 Project Number
Project Name
Name of tester
Title
Address
Date Measurements made
Test Location/Station
Test results
Montana Department of Transportation  
Materials Division  

REPORT ON DEPTH OF PCCP CONCRETE

<table>
<thead>
<tr>
<th>Lab No.</th>
<th>Project No.</th>
<th>Project Name</th>
<th>Gauge No.</th>
<th>Tested by</th>
<th>Title</th>
<th>District</th>
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Submitted By: ____________________  Date tested: ____________________

Sta. of section: ____________________  Date placed: ____________________

**Depth measurement at four points**

<table>
<thead>
<tr>
<th>Sta. Cal or Tested</th>
<th>Avg. Depth</th>
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</tbody>
</table>

Remarks: ____________________

**Distr.**

1-Materials Bureau  
1-Constr Bureau  
1-Pavement  
   Analysis Sec.  
1-EPM,  
1-Dist/Area Lab

Design thickness of PCCP: __________ (in / mm)

Avg. variation from design: __________ (in / mm)
METHODS OF SAMPLING AND TESTING
MT 104-09
METHOD OF TEST FOR
SLUMP OF PORTLAND CEMENT CONCRETE
(Modified AASHTO T 119)

1 Scope:

1.1 This test method covers determination of slump of concrete, both in the laboratory and in the field (Note 1).

Note 1 - This test is not considered applicable to non-plastic and non-cohesive concrete, nor when there is a considerable amount of coarse aggregate over two inches (50 mm) in size in concrete.

1.2 This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems 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. (Warning – Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure).

2 Referenced Documents:

2.1 AASHTO:
T 119 Slump of Portland Cement Concrete
T 141 Sampling Freshly Mixed Concrete

MT Materials Manual:
MT105 Sampling Fresh Concrete

3 Summary of Test Method:

3.1 A sample of freshly mixed concrete is placed and compacted by rodding in a mold shaped as the frustum of a cone. The mold is raised, and the concrete allowed to subside. The vertical distance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete.

4 Apparatus:

4.1 Mold - The test specimen shall be formed in a mold made of metal not readily attacked by the cement paste. The metal shall not be thinner than 0.060 in. (1.5 mm) and if formed by the spinning process, there shall be no point on the mold at which the thickness is less than 0.045 in. (1.15 mm). The mold shall be in the form of the lateral surface of the frustum of a cone with the base 8 in. (203 mm) in diameter, the top 4 in. (102 mm) in diameter, and the height 12 in. (305 mm). Individual diameters and heights shall be within ± 1/8 in. (3.2 mm) of the prescribed dimensions. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles similar to those shown in Figure 1. The mold shall be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections. The mold shall be free from projections. A mold which clamps to a nonabsorbent base plate is acceptable instead of the one illustrated provided the clamping arrangement is such that it can be fully released without movement of the
4 **Apparatus**: (continued)

mold and the base is large enough to contain all of the slumped concrete in an acceptable test..

4.1.1 Check and record conformance to the mold’s specified dimensions when it is purchased or first placed into service and at least annually thereafter.

4.2 *Mold with Alternative Materials* - Molds other than metal are permitted if the following requirements are met: The mold shall meet the shape, height, and internal dimensional requirements of Section 4.1. The mold shall be sufficiently rigid to maintain the specified dimensions and tolerances during use, resistant to impact forces, and shall be nonabsorbent. The mold shall be demonstrated to provide test results comparable to those obtained when using a metal mold meeting the requirements of Section 4.1. Comparability shall be demonstrated on behalf of the manufacturer by an independent testing laboratory. Test for comparability shall consist of not less than 10 consecutive pairs of comparisons performed at each of three different slumps ranging from 2 to 8 inches (50 to 200 mm). No individual test results shall vary by more than 0.50 in. (15 mm) from that obtained using the metal mold. The average test results of each slump range obtained using the mold constructed of alternative material shall vary by more than 0.25 in. (6 mm) from the average test results obtained using the metal mold. Manufacturer comparability test data shall be available to users and laboratory inspection authorities (see Note 4). If any changes in material or method of manufacturer are made, tests for comparability shall be repeated.

*Note 1 – Because the slump of concrete decreases with time and higher temperatures, it will be advantageous to perform comparability tests by alternating the use of metal cones and alternative material cones, to utilize several technicians, and to minimize the time between test procedures.*

4.3 If the condition of any individual mold is suspected of being out of tolerance from the as manufactured condition, a single comparative test shall be performed. If the test results differ by more than 0.50 in. (15 mm) from that obtained using the metal mold, the mold shall be removed from service.

4.4 *Tamping Rod* - The tamping rod shall be a round, straight steel rod 5/8 in. (16 mm) in diameter and approximately 24 in. (600 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is 5/8 in. (16 mm).

4.5 *Measuring Device* – A ruler, metal roll-up measuring tape, or similar rigid or semi-rigid length measuring instrument marked in increments of 1/4 in. (5 mm) or smaller. The instrument length shall be at least 12 in. (300 mm).

5 **Sampling:**

5.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with MT 105.

6 **Procedure:**

6.1 Dampen the mold and place it on a flat, moist, nonabsorbent (rigid) surface such as a pre-moistened concrete floor or a base plate. It shall be held firmly in place during filling by the operator standing on the two foot pieces, or by clamping to a base plate as described in Section 4.1. From the sample of concrete obtained in accordance with
6 Procedure: (continued)

Section 5, immediately fill the mold in three layers, each approximately one third the volume of the mold (Note 2).

Note 2 - One third of the volume of the slump mold fills it to a depth of 2 5/8 in. (67 mm); two thirds of the volume fills it to a depth of 6 1/8 in. (155 mm).

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<table>
<thead>
<tr>
<th>Dimensional Units</th>
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</thead>
<tbody>
<tr>
<td>mm</td>
</tr>
<tr>
<td>in.</td>
</tr>
</tbody>
</table>

Note: All dimensions shown in millimeters unless otherwise noted.
6 Procedure: (continued)

6.2 Rod each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross section of each layer. For the bottom layer this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spirally toward the center. Rod the bottom layer throughout its depth. Rod the second layer and the top layer each throughout its depth, so that the strokes just penetrate into the underlying layer.

6.3 In filling and rodding the top layer, heap the concrete above the mold before the rodding is started. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the concrete by means of a screeding and rolling motion of the tamping rod. Continue to hold the mold down firmly and remove concrete from the area surrounding the base of the mold to preclude interface with the movement of the slumping concrete. Remove the mold immediately from the concrete by raising it carefully in a vertical direction. Raise the mold a distance of 12 in. (300 mm) in 5 ± 2 seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of the filling through the removal of the mold without interruption and complete it within an elapsed time of 2 ½ min.

6.4 Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs (Note 3), disregard the test and make a new test on another portion of the sample.

Note 3 - If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.

7 Report:

7.1 Report the slump in terms of inches (millimeters) to the nearest 1/4 in. (6 mm) of subsidence of the specimen during the test as follows:

\[ \text{Slump} = 12 \text{ inches} - \text{inches of height after subsidence} \]

\[ = 12" - 10 \frac{1}{4} " = 1 \frac{1}{4}" \]
METHODS OF SAMPLING AND TESTING
MT 105-04
METHOD OF SAMPLING FRESH CONCRETE
(Modified AASHTO T 141)

1 Scope:

1.1 This method describes the procedures for obtaining representative samples of fresh concrete as delivered to the project site and on which tests are to be performed to determine compliance with quality requirements of the specifications under which the concrete is furnished (Note 1). The method includes sampling from stationary, paving and truck mixers, and from agitating and non-agitating equipment used to transport central mixed concrete.

Note 1 - Composite samples are required by this method, unless specifically excepted by procedures governing the tests to be performed such as tests to determine uniformity of consistency and mixer efficiency. Procedures used to select the specific test batches are not described in this method, but it is recommended that random sampling be used to determine overall specification compliance.

1.2 This method also covers the procedures to be used for preparing a sample of concrete for further testing where it is desirable or necessary to remove the aggregate larger than a designated size. This removal of larger aggregate particles is preferably accomplished by wet-sieving. (See paragraph 5.4.)

2 Referenced Documents:

2.1 AASHTO Standards:
T 119 Slump of Portland Cement Concrete
T 121 Weight Per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete

MT Manual:
MT-405 Wire Cloth Sieves for Testing Purposes

3 Sampling:

3.1 The elapsed time between obtaining the first and final portions of the composite samples shall be as short as possible, but in no instance shall it exceed 15 min.

3.1.1 Transport the individual samples to the place where fresh concrete tests are to be performed or where test specimens are to be molded. They shall then be combined and remixed with a shovel the minimum amount necessary to ensure uniformity and compliance with the minimum time limits specified in Section 3.1.2.

3.1.2 Start tests for slump or air content, or both, within 5 min. after obtaining the final portion of the composite sample. Complete these tests as expeditiously as possible. Start molding specimens for strength tests within 15 min. after fabricating the composite sample. Keep the elapsed time between obtaining and using the sample as short as possible and protect the sample from the sun, wind, and other sources of rapid evaporation, and from contamination.

4 Procedure:

4.1 Size of Sample--Make the samples to be used for strength tests a minimum of 1 ft³ (28 liters). Smaller samples may be permitted for routine air content and slump tests and the size shall be dictated by the maximum aggregate size.
4 Procedure: (continued)

4.2 The procedures used in sampling shall include the use of every precaution that will assist in obtaining samples that are truly representative of the nature and condition of concrete sampled as follows:

Note 2 - Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms; however, specifications may require other points of sampling, such as at the discharge of a concrete pump.

Note 3 - As routine air content and slump tests are not readily adaptable to sampling the concrete at two or more regularly spaced intervals during discharge of the middle portion of the batch as specified in this method, the sample for air content, slump, and temperature may be taken after at least one-quarter cubic yard of concrete has been discharged.

4.2.1 Sampling from Stationary Mixers, Except Paving Mixers--Sample the concrete at two or more regularly spaced intervals during discharge of middle portion of the batch. Take the samples within the time limit specified in Section 3, and composite them into one sample for test purposes. Do not obtain samples from the very first or last portions of the batch discharge. Perform sampling by passing a receptacle completely through the discharge stream, or by completely diverting the discharge into a sample container. If discharge of the concrete is too rapid to divert the complete discharge stream, discharge the concrete into a container or transportation unit sufficiently large to accommodate the entire batch and then accomplish the sampling in the same manner as given above. Take care not to restrict the flow of concrete from the mixer, container, or transportation unit so as to cause segregation. These requirements apply to both tilting and non-tilting mixers.

4.2.2 Sampling from Paving Mixers--Sample the concrete after the contents or the paving mixer have been discharged. Obtain samples from at least five different portions of the pile and then composite into one sample for test purposes. Avoid contamination with subgrade material or prolonged contact with an absorptive subgrade. To preclude contamination or absorption by the subgrade, sample the concrete by placing three shallow containers on the subgrade and discharging the concrete across the containers. Composite the samples so obtained into one sample for tests purposes. the containers shall be of a size sufficient to provide a composite sample size that is in agreement with the maximum aggregate size.

Note 4 - In some instances, the containers may have to be supported above the subgrade to prevent displacement during discharge.

4.2.3 Sampling from Revolving Drum Truck Mixers or Agitators--Sample the concrete at two or more regularly spaced intervals during discharge of the middle portion of the batch. Take the samples within the time limit specified in Section 3 and composite them into one sample for test purposes. In any case do not obtain samples until after all of the water has been added to the mixer; also do not obtain samples from the very first or last portions of the batch discharge. Sample by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.

4.2.4 Sampling from Open-Top Truck Mixers, Agitators, Non-agitating equipment, or Other Types of Open-Top Containers--Take samples by whichever of the procedures described in 4.2.1, 4.2.2, or 4.2.3 is most applicable under the given conditions

5 Additional Procedure for Large Maximum Size Aggregate Concrete:

5.1 When the concrete contains aggregate larger than that appropriate for the size of the molds or equipment to be used, wet-sieve the sample as described below except make unit-weight tests for use in yield computations on the full mix.
5 Additional Procedure for Large Maximum Size Aggregate Concrete: (continued)

Note 5 - The effect of wet-sieving the test results should be considered. For example, wet-sieving concrete causes the loss of a small amount of air due to additional handling. The air content of the wet-sieved fraction of concrete is greater than that of the total concrete because the larger size aggregate, which is removed, does not contain air. The apparent strength of wet-sieved concrete in smaller specimens is usually greater than that of the total concrete in larger appropriate size specimens. The effect of these differences may need to be considered or determined by supplementary testing for quality control or test result evaluation purposes.

5.2 Definition:

5.2.1 Wet-Sieving Concrete - The process of removing aggregate larger than a designated size from the fresh concrete by sieving it on a sieve of the designated size.

5.3 Apparatus:

5.3.1 Sieves - as designated, conforming to MT-405, Wire-Cloth Sieves for Testing Purposes.

5.3.2 Wet-Sieving Equipment - Equipment for wet-sieving concrete shall be a sieve as noted in 5.3.1 of suitable size and conveniently arranged and supported so that one can shake it rapidly by either hand or mechanical means. Generally, a horizontal back and forth motion is preferred. The equipment shall be capable of rapidly and effectively removing the designated size of aggregate.

5.3.3 Hand Tools - Shovels, hand scoops, plastering trowels, and rubber gloves as required.

5.4 Procedure:

5.4.1 Wet-Sieving - After sampling the concrete, pass the concrete over the designated sieve and remove and discard the aggregate retained. This shall be done before remixing. Shake or vibrate the sieve by hand or mechanical means until no undersize material remains on the sieve. Mortar adhering to the aggregate retained on the sieve shall not be wiped from it before it is discarded. Place only enough concrete on the sieve at any one time so that after sieving, the thickness of the layer of retained aggregate is not more than one particle thick. The concrete which passes the sieve shall fall into a batch pan of suitable size which has been dampened before use or onto a clean, moist, nonabsorbent surface. Scrape any mortar adhering to the sides of the wet-sieving equipment into the batch. After removing the larger aggregate particles by wet-sieving, remix the batch with a shovel the minimum amount necessary to ensure uniformity and proceed testing immediately.
METHODS OF SAMPLING AND TESTING
MT 106-05
METHOD OF MEASURING LENGTH OF
DRILLED CONCRETE CORES
(Modified AASHTO T 148)

1 Scope:

1.1 This method covers the procedure for determining the length of a core drilled from a concrete pavement or structure.

2 Referenced Documents:

2.1 AASHTO:
T 148 Measuring Length of Drilled Concrete Cores

MT Materials Manual:
MT 112 Obtaining and Testing Drilled Concrete Cores
MT 609 Field Numbering Concrete Cylinders

3 Apparatus:

3.1 The apparatus shall consist of a caliper that will measure the length of axial elements of the core. While the details of the mechanical design are not prescribed, the apparatus shall conform to the requirements of paragraphs 2.2 through 2.6, inclusive.

3.2 The apparatus shall be so designed that the specimen will be held with its axis in a vertical position by three symmetrically placed supports bearing against the lower end. These supports shall be short posts or studs of hardened steel, and the ends that bear against the surface of the specimen shall be rounded to a radius of not less than 6.4 mm (¼ inch) and not more than 12.7 mm (½ inch).

3.3 The apparatus shall provide for the accommodation of specimens of different nominal lengths over a range of at least 100 to 250 mm (4 to 10 inches).

3.4 The caliper shall be so designed that it will be possible to make a length measurement at the center of the upper end of the specimen and at eight additional points. The additional points should be spaced at equal intervals along the circumference of a circle whose center point coincides with that of the end area of the specimen and whose radius is not less than one-half, or more than three-fourths of the radius of the specimen.

3.5 The measuring rod or other device that makes contact with the end surface of the specimen for measurement shall be rounded to a radius of 3.2 mm (1/8 inch). The scale on which the length readings are made shall be marked with clear, definite, and accurately spaced graduations. The spacing of the graduations shall be 2.54 mm (0.10 inch) or a decimal part thereof.

3.6 The apparatus shall be stable and sufficiently rigid to maintain its shape and alignment without a distortion or deflection of more than 0.25 mm (0.01 inch) during all normal measuring operations. (Note 1)

Note 1 - For further information relating to the development of this method and apparatus, reference should be made to the "Project Report on a Study of Methods of Measurement of the Length of Cores Drilled from Concrete Structures," prepared by L.W. Teller for Subcommittee VII on Methods and Apparatus for Testing Concrete, of Committee C-9, see Proceedings, Am. Soc. for Testing Materials, Vol. 41 (1942).
4 Test Specimen:

4.1 Cores used as specimens for length measurement shall be in every way representative of the concrete in the structure from which they are removed. The specimen shall be drilled with the axis normal to the surface of the structure, and the ends shall be free from all conditions not typical of the surfaces of the structure. Cores that show abnormal defects or that have been damaged appreciably in the drilling operation shall not be used.

5 Procedure:

5.1 Before any measurements of the core length are made, the apparatus shall be calibrated with suitable gages so that errors caused by mechanical imperfections in the apparatus are known. When these errors exceed 0.25 mm (0.01 inch), suitable corrections shall be applied to the core length measurements.

5.2 The specimen shall be placed in the measuring apparatus with the smooth end of the core (that is, the end that represents the upper surface of a pavement slab or a formed surface in the case of other structures) placed down so as to bear against the three hardened-steel supports. The specimen shall be so placed on the supports that the central measuring position of the measuring apparatus is directly over the mid-point of the upper end of the specimen.

5.3 Nine measurements of the length shall be made on each specimen, one at the central position and one each at eight additional positions spaced at equal intervals along the circumference of the circle of measurement described in paragraph 2.4. Each of these nine measurements shall be read directly to 2.5 mm (0.10 inch) and to 1.27 mm (0.05 inch) either directly or by estimation. (Note 2)

Note 2 - If, in the course of the measuring operation it is discovered that at one or more of the measuring points the surface of the specimen is not representative of the general plane of the core end because of a small projection or depression, the specimen shall be rotated slightly about its axis and a complete set of nine measurements made with the specimen in the new position.

6 Report:

6.1 The individual observation shall be recorded to the nearest 1.27 mm (0.05 inch) and the average of the nine measurements expressed to the nearest 2.5 mm (0.10 inch) shall be reported as the length of the concrete core.
METHODS OF SAMPLING AND TESTING
MT 107-04

METHOD OF DETERMINING AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE VOLUMETRIC METHOD
(Modified AASHTO T 196)

1 Scope:

1.1 This method covers determination of the air content of freshly mixed concrete containing any type of aggregate, whether it is dense, cellular, or light-weight.

2 Reference Documents:

2.1 AASHTO:
T 196 Air Content of Freshly Mixed Concrete by the Volumetric Method

MT Materials Manual:
MT-102 Air Content of Freshly Mixed Concrete by the Pressure Method
MT-105 Sampling Fresh Concrete
MT-115 Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
MT-203 Unit Weight of Aggregate

3 Apparatus:

3.1 Airmeter - An airmeter consisting of a bowl and a top section (Figure 1) conforming to the following requirements:

3.1.1 Bowl - The bowl shall be constructed of machined metal of such thickness as to be sufficiently rigid to withstand normal field use and of such composition as not to be readily attacked by cement paste. The bowl shall have a diameter equal to 1 to 1.25 times the height and be constructed with a flange at or near the top surface. Bowls shall not have a capacity of less than 0.075 ft.³ (0.002m³).

3.1.2 Top Section - The top section shall be constructed of machined metal of thickness sufficiently rigid to withstand normal field use and of composition not readily attacked by cement paste. The top section shall have a capacity at least 20 percent larger than the bowl and shall be equipped with a flexible gasket and with hooks or lugs to attach to the flange on the bowl to make a watertight connection. The top section shall be equipped with a glass-lined transparent plastic neck, graduated in increments not greater than 0.5 percent from 0 at the top to 9 percent, or more, of the volume of the bowl. Graduations shall be accurate to ± 0.1 percent by volume of the bowl. The upper end of the neck shall be threaded and equipped with a screw cap having a gasket to make a water-tight fit.

3.2 Funnel - A metal funnel with a spout of a size permitting it to be inserted through the neck of the top section and long enough to extend to a point just above the bottom of the top section. The discharge end of the spout shall be so constructed that when water is added to the container there will be a minimum disturbance of the concrete.

3.3 Tamping Rod - A round, straight steel rod, 0.625 in. or 16 mm in diameter at least 12 in. or 300 mm long with both ends rounded to a hemispherical tip of the same diameter.

3.4 Strike-off Bar - A flat, straight steel bar at least 1/4 by 3/4 by 12 in. or 3 by 20 by 300 mm long.

3.5 Measuring Cup - A metal cup having a capacity equal to 1.03 ± 0.04 percent of the volume of the bowl of the air meter.
3    **Apparatus:** (continued)

*Note 1 - The volume of the measuring cup is slightly larger than 1.0 percent of the volume of the bowl to compensate for the volume contraction that takes place when 70 percent isopropyl alcohol is mixed with water. Other alcohols or defoaming agents may be used if calculations show that their use will result in an error indicated air content less than 0.1 percent.*

3.6 **Syringe** - A small rubber bulb syringe having a capacity at least that of the measuring cup.

3.7 **Pouring Vessel** - A metal or glass container of approximately 1 qt. or 1 litre capacity.

3.8 **Trowel** - A blunt-nosed brick mason's trowel.

3.9 **Scoop** - A small metal scoop.

3.10 **Isopropyl Alcohol** - Use 70 percent by volume isopropyl alcohol (approximately 65 percent by weight) (Notes 1 and 2).

*Note 2 - Seventy percent isopropyl alcohol is commonly available as rubbing alcohol. More concentrated grades can be diluted with water to the required concentration.*

3.11 **Mallet** - A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb. (0.57 ± 0.23 kg) for use with measures of 0.5 ft³ (0.014 m³) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb. (1.02 ± 0.23 kg) for use with measures larger than 0.5 ft³ (0.014 m³).

4 **Calibration of Apparatus:**

4.1 The volume of the bowl of the air-meter in cubic feet or cubic metres shall be determined by accurately weighing the amount of water required to fill it at room temperature, and dividing this weight by the unit weight of water at the same temperature. Follow the calibration procedure outlined in Section 6 of Method MT-203.

4.2 Determine the accuracy of the graduations on the neck of the top section of the air meter by filling the assembled measuring bowl and top section with water to a preselected air content graduation and then determining the quantity of 70º F (21.1ºC) water required to fill the meter to the zero mark. The quantity of water added shall equal the preselected air content graduation within ± 0.1 volume percent of the measuring bowl. Repeat the procedure to check a minimum of 3 graduations within the expected range of use.

4.3 Determine the volume of the measuring cup using water at 70º F (21.1º C) by the method outlined in Section 6.1. A quick check can be made by adding one or more cups of water to the assembled apparatus and observing the increase in the height of the water column after filling to a given level as described in Section 6.2.

5 **Sample:**

5.1 Obtain the sample of freshly mixed concrete in accordance with applicable provisions of Method MT-105. If the concrete contains coarse aggregate particles that would be retained on a ½ in. (37.5 mm) sieve, wet sieve a representative sample over a 1 in. (25 mm) sieve to yield somewhat more than enough material to fill the measuring bowl. The wet sieving procedure is described in Method MT-105. Carry out the wet sieving operation with the minimum practicable disturbances of the mortar. Make no attempt to wipe adhering mortar from coarse aggregate particles retained on the sieve.
6 Procedure:

6.1 *Rodding and Tapping* - Using the scoop, aided by the trowel if necessary, fill the bowl with freshly mixed concrete in three layers of equal depth. Rod each layer 25 times with the tamping rod. After each layer is rodded, tap the sides of the measure 10 to 15 times smartly with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.

6.2 *Striking Off* - After placement of the third layer of concrete in accordance with Section 6.1, strike off the excess concrete with the strike-off bar until the surface is flush with the top of the bowl. Wipe the flange of the bowl clean.

6.3 *Adding Water* - Clamp the top section into position on the bowl, insert the funnel, and add water until it appears in the neck. Remove the funnel and adjust the water level, using the rubber syringe until the bottom of the meniscus is level with the zero mark. Attach and tighten the screw cap.

6.4 *Agitating and Rolling* - Invert and agitate the unit until the concrete settles free from the base; and then, with the neck elevated, roll and rock the unit until the air appears to have been removed from the concrete. Set the apparatus upright, jar it lightly and allow it to stand until the air rises to the top. Repeat the operation until no further drop in the water column is observed.

6.5 *Dispelling Bubbles* - When all the air has been removed from the concrete and allowed to rise to the top of the apparatus, remove the screw cap. Add, in one cup increments, using the syringe, sufficient isopropyl alcohol to dispel the foamy mass on the surface of the water.

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**Figure 1**—Apparatus for Measuring Air Content of Fresh Concrete by Volumetric Method
6 Procedure: (continued)

6.6 Reading - Make a direct reading of the liquid in the neck, reading to the bottom of the meniscus, and estimating to the nearest 0.1 percent.

7 Calculation:

7.1 Calculate the air content percent of the concrete in the measuring bowl in percent by adding to the reading from Section 6.6 the amount of alcohol used in accordance with Section 6.5.

7.2 When the sample tested represents that portion of the mixture obtained by wet sieving over a 1 in. (25 mm) sieve, calculate the air content of the mortar or of the full mixture using the formulas given in Method MT-102. Use appropriate quantities coarser or finer than the 1 in. (25 mm) sieve instead of the 1½ in. (37.5 mm) sieve specified in Method MT-102.
METHODS OF SAMPLING AND TESTING
MT 108-04
SAMPLING AND CERTIFICATION OF PORTLAND CEMENT

1 Scope:

1.1 This method covers the requirements for sampling and certification of portland cement.

2 General:

2.1 Cement samples shall weigh a minimum of 6.8 Kg (15 pounds). Such samples shall be placed in air-tight plastic bags which shall in turn be placed in canvas bags to protect against breakage during shipment. The bin or silo number and the grind number shall be shown on the Lab. Form No. 55 to accompany the sample.

3 Procedure:

3.1 A sample of cement shall be submitted to the Materials Bureau, prior to construction, for all projects which involve bridge construction or projects which involve 114.3 cubic meters (125 cubic yards) of concrete. The sample may be taken from existing stock at the ready mix plant. On many projects this will be the only sample required unless the provisions of paragraph 4 make additional sampling necessary.

4 Sampling Frequency:

4.1 Bridge Projects:

4.1.1 Minimum of one sample taken prior to the start of concrete production.

4.1.2 One sample for each additional 458.6 cubic meters (600 cubic yards) of concrete used.

4.1.3 This procedure shall be used regardless of the number of structures involved in the project.

4.2 Paving Projects:

4.2.1 One sample taken prior to the start of concrete production.

4.2.2 Additional samples taken for each 4572.0 cubic meters (5,000 cubic yards) of concrete produced.

4.3 Cement Treated Base Projects:

4.3.1 One sample taken at the start of the project.

4.4 Miscellaneous Projects (cattle guards, sign bases, etc.):

4.4.1 One sample taken prior to the start of concrete production on jobs involving 114.3 cubic meters (125 cubic yards) of concrete or more.

4.4.2 Samples need not be submitted for projects involving less than 114.3 cubic meters (125 cubic yards) of concrete.
4.5 Random Sampling:

4.5.1 Each district shall, in addition to samples taken in accordance with paragraph 4.1 above, submit a random sample of each brand of cement used in that district during the year. These samples may be taken at any time during the year.

5 Cement Certification:

5.1 The cement plants shall furnish the Materials Bureau with certified test results for each new grind or bin of cement produced for use within the state.

5.2 Each shipment of cement from the manufacturing plant to a highway project shall be accompanied by a certificate of compliance. This certificate shall state that the cement complies with all the requirements of AASHTO M-85 or ASTM C-150, low alkali cement, and shall be signed by a responsible representative of the cement plant. Two copies of this certification shall accompany the shipment, one for the consignee and one for the Engineering Project Manager.
METHODS OF SAMPLING AND TESTING
MT 109-04
METHOD OF SAMPLING WATER

1 Scope:

1.1 This method covers the sampling of water for determination of its suitability for use in concrete, for determination of corrosivity, and for chemical testing for potability. It does not include sampling for biological testing.

2 Application:

2.1 This method is applicable to sampling industrial and domestic water supplies from sources such as wells, rivers, streams, lakes, ponds, reservoirs, pipelines and conduits for chemical or physical tests.

3 Point of Sampling:

3.1 Where the water in a stream is mixed so as to approach uniformity, a sample taken at any point in the cross section is satisfactory.

3.2 For bodies of water such as ponds or reservoirs, avoid surface and/or bottom sampling and attempt to obtain an integrated sample containing water from all points in a vertical section. Depending upon the nature of the source being sampled, it may be desirable to sample at several points and to combine the samples to obtain a representative sample of the source.

3.3 In sampling from pipelines, conduits, pump discharge, etc., make certain that all conduits have been flushed. In the case of water wells, initial pumping for well cleaning purposes shall have been completed so the sample represents the sustained output of the source.

4 Frequency of Sampling:

4.1 A sample of the water proposed for use shall be submitted in accordance with the frequency specified in MT-601.

5 Volume of Sample and Type of Container:

5.1 Furnish a one liter (quart) sample in a clean glass or plastic bottle or jar with a screw cap lid with liner. Fill almost to the top, but allow a small space to allow for possible expansion due to temperature change.

6 Labeling:

6.1 Label with identifying source data and state the purpose for which the sample is taken.
METHODS OF SAMPLING AND TESTING
MT 110-12
METHOD OF ACCEPTANCE FOR
REINFORCED CONCRETE PIPE AND OTHER PRECAST ITEMS
(Montana Test Method)

1 Scope:

1.1 This procedure defines inspection responsibilities and verification processes applicable to all suppliers of pre-cast concrete pipe and associated items.

2 Referenced Documents:

2.1 AASHTO:

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<thead>
<tr>
<th>Reference</th>
<th>Description</th>
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<tbody>
<tr>
<td>M 55</td>
<td>Steel, Welded Wire Reinforcement, Plain, for Concrete</td>
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<tr>
<td>M 85</td>
<td>Portland Cement</td>
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<tr>
<td>M 170</td>
<td>Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe</td>
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<td>Precast Reinforced Concrete Box Sections for Culvert, Storm Drains, and Sewers</td>
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ASTM:

C361 Standard Specification for Reinforced Concrete Low-Head Pressure Pipe

MT Manual:

MT-108 Sampling and Certification of Portland Cement
MT-101 Making and Curing Compressive and Flexural Strength Test Specimens in the Field
MT-102 Air Content of Freshly Mixed Concrete by the Pressure Method
MT-104 Slump of Portland Cement Concrete
MT-112 Obtaining and Testing Drilled Concrete Cores
MT-116 Method of Test for Slump Flow of Self-Consolidating Concrete
MT-117 Making and Curing Concrete Compressive and Flexural Strength Specimens in the Field for Self Consolidating Concrete (SCC)
MT-118 Method of Determining Air Content of Freshly Mixed Self Consolidating Concrete by the Pressure Method

Construction Bureau:

Manual for Uniform Installation and Inspection of Culverts and Pipes

3 Definitions:

3.1 ACPA – American Concrete Pipe Association
NPCA – National Precast Concrete Association

4 Inspection Process for ACPA and NPCA Certified Plants

4.1 Each participating manufacturer must maintain sufficient procedures and documentation to assure that their products are manufactured and tested in accordance with the guidelines of ACPA and/or NPCA certification programs. An MDT Inspector will conduct a thorough inspection of each Certified Plant to verify compliance with these requirements. Plants meeting these requirements will be listed on the Qualified Products List.
4.1.1 Yearly:

**Inspection Checklist**

- Verify ACPA and/or NCPA certification.
- Verify that certified manufacturing plants have a Quality Control Manual, applicable AASHTO, ASTM standards, organizational chart, and personnel training and qualification records.
- Verify that production and testing equipment has been properly calibrated according to the calibration requirements as stated in the Quality Control manual.
- Verify mix designs are approved.
- Verify that the manufacturers detailed design information meets MDT requirements.
- Verify that documents are maintained for all suppliers of materials for the months the plant is producing.
  - Admixture Certifications
  - Gasket and Joint Sealant Material Certifications and Test Reports
    - Verify 12” to 33” have been sampled/tested at 1/300 frequency
    - Verify 36” and larger have been sampled/tested at 1/100 frequency
- Verify that test reports are maintained per ACPA and/or NCPA testing frequencies for the following:
  - Absorption Test Results
  - Three Edge Bearing Test
- Conduct Monthly or Frequency Based Inspection outlined in Sec. 4.2
- Sample concrete cylinders and reinforcing steel for Department testing.
- Verify that any deficiencies recorded from the previous inspection have been addressed.

4.2 Monthly or Frequency Based:

4.2.1 Approximately once a month, unless another frequency is defined, inspect the fabricating plant’s certification reports, test results, and other records from the previous inspection date to present. Ensure that the plant is ‘Buy America’ compliant for all steel products. Witness concrete cylinder testing is being performed correctly on certified equipment and meets MDT requirements.

**Inspection Checklist**

- Verify that any deficiencies recorded from the previous inspection have been addressed.
- Verify the following documentation has been maintained:
  - Buy America Certification
  - Cement Mill Reports
  - Sieve Analysis of Fine and Coarse Aggregates (once every 3 months)
  - Fly Ash Certifications
  - Other Cementitious Material Certifications and Test Reports
  - Cylinder Break Strength Results and Frequencies
- Verify fabricated cages and reinforcement conforms to MDT specifications.
- Verify a dimensional test report on one pipe size to ensure that they match the dimensions shown on the detailed drawings or AASHTO Standard Specifications.
4 Inspection Checklist (continues)

- Observe or perform the following concrete tests:
  - Slump
  - Air Content
  - Temperature of the mix
  - Making of cylinders
  - Cylinder compression testing
  - Slump Flow (when applicable)
  - J Ring (when applicable)
  - Three Edge Bearing Test including Destructive Testing outlined in Section 4.3 (once every 3 months)

4.3 Observe destructive testing in the form of crushing precast pipe and other precast items in conjunction with the three edge bearing tests. Inspector will randomly select precast pipe sample to be tested. Verify the size, amount, and origin of the reinforcing steel. Coring and random inspections will be performed on Concrete Box culverts and miscellaneous precast items such as cutoff walls, cattle guard bases, FETS, and sound walls as directed by MDT.

5 Inspection Process for Non-Certified Plants

5.1 Inspect non-certified plants to confirm the products meet MDT specifications. Sample components i.e. concrete, reinforcing steel and other items. Check fabrication drawings and inspect the final product for quality. The plant’s quality control program must be sufficient that MDT can confirm quality of materials and processes used. MDT level of inspection will vary according to Department needs.

- Verify personnel training and qualification records.
- Verify production and testing equipment has been properly calibrated.
- Verify mix designs are approved.
- Verify that the manufacturers detailed design information meets MDT requirements.
- Verify fabricated cages and reinforcement conforms to MDT specifications.
- Verify a dimensional test report on product to ensure that they match the dimensions shown on the detailed drawings or AASHTO Standard Specifications.
- Verify rate and frequency of testing is adequate and Quality Control records are maintained.
- Verify the following documentation has been maintained and required samples have been acquired:
  - Buy America Certifications and reinforcing steel samples
  - Cement Mill Reports
  - Aggregate samples for Sieve Analysis of Fine and Coarse Aggregates
  - Fly Ash Certifications
  - Other Cementitious Material Certifications and Test Reports
  - Cylinder Break Strength Results and Frequencies
  - Admixture Certifications
  - Gasket and Joint Sealant Material Certifications and Test Reports
5  **Inspection Process for Non-Certified Plants** (continued)

- Observe or perform the following concrete tests:
  - Slump
  - Air Content
  - Temperature of the mix
  - Making of cylinders
  - Cylinder compression testing
  - Slump Flow (when applicable)
  - J Ring (when applicable)
  - Concrete Absorption
  - Three Edge Bearing Test or verification of test results

- Verify concrete cylinders are made and tested periodically to represent the concrete placed in all items.

- Concrete items other than concrete pipe will be entered on Form 19A. These items, together with pipe too large to test, are represented by cylinder tests as outlined above.

6  **Mark of Inspection:**

6.1 Products manufactured at a certified plant will not carry the mark of inspection. Non-certified manufacturers of concrete pipe and other concrete items must notify MDT when producing products for a project so that inspection arrangements can be made. All concrete products produced by a non-certified plant must carry a mark of inspection. (see Figure 1) This will be stamped on each section of product, by the inspector, where it will be clearly visible. The circle M indicates the product was inspected. Final acceptance will be made in the field.

6.2 If a product is to be rejected in the field, place an X next to the product identification stamp. This mark indicates that the product is rejected for all MDT projects. If the product requires repairs, but is not necessarily rejected; mark areas requiring repair to clearly designate and track what needs correction prior to acceptance.
METHODS OF SAMPLING AND TESTING
MT 111-12
SAMPLING, INSPECTION AND REPORTING
ON PRESTRESSED STRUCTURAL MEMBERS

1 Scope:
1.1 This method is written to the individuals completing inspection and establishes a uniform procedure for the sampling, inspecting, and reporting of pre-stressed structural members.

1.2 Inspection Process Overview:
1.2.1 Provide data to the field as it becomes available. Send original test results and reports to MDT Helena Materials Lab (to be placed in the job file), keep one copy in the Inspectors personal file, and send one copy to the Project Manager for the project file.

1.2.2 Send an inspection report with each beam to the project. Provide copies to the EPM, District Materials Lab, the Construction Bureau, and the Materials Bureau. This report must state that all of the materials used in the completed beams have been sampled, tested, and documented within reports that are in the possession of the Plant Inspector. Identify the beams by number and place in the report file as an indication that the beams are complete and acceptable subject to final field inspection.

1.2.3 The following links provide access to the Department’s most current forms to be used during Pre-stress Inspection:

- Strand Tensioning & Cylinder Breaks
- Form 45 – Rebar or Strand Sample
- Form 48 – Shipping & Final Approval
- Form 48A – Final Plant Inspection
- Ready Mix Pour Record
- Fabrication Inspection Report
- Miscellaneous Inspection Report

2 Referenced Documents:

2.1 MT Manual:

MT-108 Sampling and Certification of Portland Cement
MT-201 Sampling Roadway Materials
MT-101 Making and Curing Compressive and Flexural Strength Test Specimens
MT-102 Air Content of Freshly Mixed Concrete by the Pressure Method
MT-104 Slump of Portland Cement Concrete
MT-112 Obtaining and Testing Drilled Concrete Cores
MT-116 Method of Test for Slump Flow of Self-Consolidating Concrete
MT-117 Making and Curing Concrete Compressive and Flexural Strength Specimens in the Field for Self Consolidating Concrete (SCC)
MT-118 Method of Determining Air Content of Freshly Mixed Self Consolidating Concrete by the Pressure Method
3 Materials:

3.1 Materials used in the manufacture of pre-stressed beams are covered individually to avoid any misunderstanding on the part of the Plant Inspectors.

3.2 Sample and test aggregates will be sampled and tested quarterly in accordance with MT-201. If new sources or deviations in material properties are apparent, resample aggregates as necessary for quality assurance.

3.3 Cementitious materials and admixtures are listed on the Department’s Qualified Products. Verify that the mix design has been approved by the Helena Materials Bureau and appropriate material types and quantities are used.

3.4 Wire strand is tested in the Materials Bureau. Submit samples with a Form 45, a copy of the mill test results of the load elongation curve, and associated documentation to meet Buy America requirements. The pre-stress plant is responsible for notifying the Plant Inspector when shipments of strand are received at the pre-stress plant. Sample strand by obtaining two 5 foot (1.5 m) long sections from a reel in the shipment. Submit these samples together with reel numbers, heat numbers, and all available information such as size, strength, etc., to the Materials Bureau for testing. Strand or any other item or ingredient used in the manufacture of a structural member prior to test results being received by the Plant Inspector are at the plant’s risk. Reject members constructed with strand that does not meet Department requirements.

3.5 Sample reinforcing steel as each new shipment arrives at the plant. The pre-stress plant is responsible for notifying the Plant Inspector when shipments of rebar are received at the pre-stress plant. Submit two 3 foot (1.0 m) long samples of each bar size to the Materials Bureau with a Form 45 and associated documentation required to meet Buy America requirements. Verify that all of the pertinent information is shown on the accompanying reports.

3.6 Witness the casting of cylinders representing release breaks by the pre-stress plant personnel. Witness or cast the cylinders for acceptance of twenty-eight day strength testing in accordance with MT-101. Ensure that a set of at least 3 cylinders are fabricated for each pour in addition to release cylinders of a sufficient number to perform the required tests prior to release of the strand per Specification Subsection 553.03.11 Transfer of Pre-stress (minimum of 3 cylinders).

4 Plant Inspection and Acceptance:

4.1 Review all documentation to verify conformity with contract requirements. For typical documentation requirements, see Specification Subsections 553.02 and 553.03.

4.2 Verify that the bed layout measurements have been checked by plant personnel and are in agreement with the approved shop drawings.

4.3 Verify strand patterns are in agreement with the approved shop drawings prior to tensioning. Check strands for strength and elongation (temperature correction) as provided on the approved shop drawings. Document and notify pre-stress plant personnel of any materials used in the beam that have not been sampled and tested in accordance with Section 3.1.3.

4.4 Verify that the rebar cage layout has been checked by pre-stress plant personnel and is in accordance with contract requirements. Document and notify pre-stress plant personnel of any materials used in beam that have not been sampled and tested in accordance with Section 3.1.4.

4.5 Verify that a final pre-pour inspection occurs prior to forms being set. Obtain a copy of the plant’s pre-pour inspection form which must include details on the placement of inserts, bulkheads, bearing plate locations, and all other applicable details.

4.6 Visually check forms for proper placement. Verify that remaining steel and lift hooks have been included in accordance with approved shop drawings prior to concrete placement.
4  Plant Inspection and Acceptance: (continued)

4.7  Witness concrete tests and cylinder breaks to verify requirements of Section 3.1.5 and Specification Sections 553.03.10 and 553.03.11 are met. After forms are removed, visually inspect before allowing the strand release (cutting of strands). If repairs are necessary, do not allow strand release until repairs are completed and are cured for a minimum of 24 hours.

4.7.1  Record pour placement times and field verification information using the “Ready Mix Pour Record” when pre-stress items are constructed using ready mix concrete.

4.8  Perform Final Inspection to ensure the finished member meets plan dimensions. Document the Final Inspection on Form 48-A.

4.8.1  Mark each pre-stress member that conforms to specification requirements in all respects with a Circle M stamp (see Fig.1) before shipment from the plant. This identifying mark indicates that fabrication procedures, quality of materials and workmanship are satisfactory and the member is complete at the plant.

4.8.2  If deficiencies are identified, notify the Physical Testing Engineer, Bridge Bureau and Project Manager of the concerns and determine the corrective actions that are required. Do not mark these members with a Circle M stamp unless corrective actions have been completed and no additional concerns exist. Absence of a Circle M stamp indicates that the member is not complete or deficiencies have been observed by the Plant Inspector and additional corrective actions may be required. Note any deficiencies on the Pre-stress Beam - Final Plant Inspection Check List (Form 48-A). Noted deficiencies not corrected before shipment will be transmitted to the field with the Pre-stressed Beam Report Lab Form 48.

5  Field Inspection and Acceptance:

5.1  When the product arrives at the job site, inspect members for shipping and handling damage or other defects. Notify the Project Manager of any damage or defects observed in the field.

5.2  Final acceptance of the member is made in the field in accordance with the contract. Ensure any deficiencies identified on the Pre-stressed Beam Report (Form 48) are addressed before final acceptance. Project Manager may reject any product that does not serve the necessary function or fails to meet contract requirements.
METHODS OF SAMPLING AND TESTING
MT 112-05
OBTAINING AND TESTING DRILLED CONCRETE CORES
(Modified AASHTO T24)

1 Scope:

1.1 This method covers obtaining, preparing, and testing cores drilled from concrete for length or compressive strength determination.

2 Referenced Documents:

2.1 AASHTO:
T 22 Compressive strength of Cylindrical Concrete Specimens
T 148 Measuring Length of Drilled Concrete Cores

MT Materials Manual:
MT 106 Measuring Length of Drilled Concrete Cores
MT 609 Field Numbering Concrete Cylinders

3 Significance and Use:

3.1 This test method provides standardized procedures to determine the length of drilled cores and the compressive strength of in-place concrete. Sampling and sample preparation requirements are given to ensure that the dimensional requirements are met and that the cores are made of intact, sound concrete, and are as free of flaws as the particular structure will allow.

3.2 Generally, test cores are obtained when doubt exists about the in-place concrete quality due to either too low strength test results during construction or signs of distress in the structure. Additionally, this method may be used to provide strength information on older structures.

3.3 Concrete strength is affected by the location of the concrete in the structural element, with the concrete at the bottom tending to be stronger than the concrete at the top. Core strength is also affected by core orientation relative to the horizontal plane of the concrete as placed, with strength tending to be lower when measured parallel to the horizontal plane. These factors shall be considered in planning the locations for obtaining concrete samples and in comparing strength test results.

3.4 The strength of concrete measured by tests of cores is affected by the amount and distribution of moisture in the cores at the time of test. There is no standard procedure to condition a core that will ensure that, at the time of test, it will be in the identical moisture condition as concrete in the structure. The moisture conditioning procedures in this test method are intended to provide reproducible moisture conditions that minimize within-laboratory and between-laboratory variations and to reduce the effects of moisture introduced during core preparation.

3.5 There is no universal relationship between the compressive strength of a core and the corresponding compressive strength of standard-cured molded cylinders. The relationship is affected by many factors, such as the strength level of the concrete, the in-place temperature and moisture history, and the strength gain characteristics of the concrete. Historically, it has been assumed that core strengths are generally 85 percent of the corresponding standard-cured cylinder strengths, but this is not applicable to all situations. The acceptance criteria for core strength is to be established by the specifying authority.
4 Apparatus:

4.1 Core Drill – For obtaining cylindrical core specimens, a diamond drill will be used.

5 Sampling:

5.1 General:

5.1.1 Samples of hardened concrete shall not be taken until the concrete has become hard enough to permit sample removal without disturbing the bond between the mortar and the coarse aggregate. In general, the concrete shall be 14 days old before the cores are removed. When preparing strength test specimens from samples of hardened concrete, samples that show abnormal defects or samples that have been damaged in the process of removal shall not be tested.

5.1.2 Cores containing embedded reinforcement shall not be used for determining compressive strength.

5.2 Core Drilling – A core taken perpendicular to a horizontal surface shall be located, when possible, so that it's axis is perpendicular to the bed of the concrete as originally placed and not near formed joints or obvious edges of a unit of deposit. A core taken perpendicular to a vertical surface, or perpendicular to a surface with a batter, shall be taken from near the middle of a unit of deposit when possible and not near formed joints or obvious edges of a unit of deposit.

6 Length of Drilled Cores:

6.1 Minimum Diameter – Cores shall have a diameter of at least 3.75 inches (95 mm) or as specified by the specifying authority.

6.2 Procedure for Length Determination – Measure the length of the cores according to MT-106.

7 Cores for Compressive Strength:

7.1 Test Cores – The nominal diameter of cores for compressive strength determination shall be at least 3.75 inches (95 mm). Core diameters less than 3.75 inches (95 mm) are permitted when it is possible to obtain cores with length to diameter (L/D) ratio >1 for compressive strength evaluations in cases other than load bearing situations. For concrete with nominal maximum aggregate size greater than 1½ inches (37.5 mm), the nominal diameter should preferably be at least three times the nominal maximum size of the coarse aggregate and must be at least twice the nominal maximum size of the coarse aggregate. The preferred length of the capped core is between 1.9 and 2.1 times the diameter. If the ratio of the length to the diameter of the core exceeds 2.1, reduce the length of the core so that the ratio is between 2.1 and 1.9. Cores with length-to-diameter ratios less than 1.75 require corrections to the measured compressive strength (see Section 7.7.2). A core having a maximum length of less than 95 percent of its diameter before capping or a length less than its diameter after capping shall not be tested.

Note 1 – The compressive strengths of nominal 2 inch (50 mm) diameter cores are known to be somewhat lower and more variable than those of nominal 4 inch (100 mm) diameter cores. In addition, small diameter cores appear to be more sensitive to the effect of length to diameter ratio.

7.2 End Preparation – The ends of the cores for compression testing, shall be essentially smooth, perpendicular to the longitudinal axis, and of the same diameter as the body of the core. If necessary, saw or tool the ends of the cores until the following requirements are met:

7.2.1 Projections, if any, shall not extend more than 0.2 inches (5 mm) above the end surfaces,

7.2.2 The end surfaces shall not depart from perpendicularity to the longitudinal axis by more than five degrees, and
7 Cores for Compressive Strength: (continued)

7.2.3 The diameter of the ends shall not depart more than 0.1 inch (2.5 mm) from the mean diameter of the core.

7.3 Moisture Conditioning – Test cores after moisture conditioning as specified in this test method or as directed by the specifying authority. The moisture conditioning procedures specified in this test method are intended to preserve the moisture of the drilled core and to provide a reproducible moisture condition that minimizes the effects of moisture gradients introduced by wetting during drilling and core preparation.

7.3.1 After cores have been drilled, wipe off the surface drill water and allow remaining surface moisture to evaporate. When surfaces appear dry, but not later than 1 hour after drilling, place cores in separate plastic bags or nonabsorbent containers and seal to prevent moisture loss. Maintain cores at ambient temperature, and protect cores from exposure to direct sunlight. Transport the cores to the testing laboratory as soon as practicable. Keep cores in the sealed plastic bags or nonabsorbent containers at all times, except when the cores may be unsealed for a maximum of 2 hours, for end preparation and capping, before testing.

7.3.2 If water is used during sawing or grinding of core ends, complete these operations as soon as practicable, but no later than two days after drilling of cores unless stipulated. After completing end preparation, wipe off surface moisture, allow the surfaces to dry, and place the cores in sealed plastic bags or nonabsorbent containers. Minimize the duration of exposure to water during end preparation.

7.3.3 Allow the cores to remain in the sealed plastic bags or nonabsorbent containers for at least five days after last being wetted before testing, unless otherwise stipulated.

Note 2 – The waiting period of at least five days is intended to reduce moisture gradients introduced when the core is drilled or wetted during sawing or grinding.

7.3.4 When direction is given to test cores in a moisture condition other than achieved by conditioning according to Sections 7.3.1, 7.3.1, and 7.3.3, report the alternative procedure.

7.4 Capping – Before making the compression test, cap the ends of the cores in conformance with the procedure prescribed in the applicable section of T 231. The capped surfaces of the cores shall conform to the planeness requirements of T 231.

Note 3 – Prior to capping, the density of a core may be determined by weighing it and dividing it by the volume calculated from the average diameter and length, or by any other standard method for determining density.

7.5 Measurement – Prior to testing, measure the length of the capped core to the nearest 0.1 inch (2.5 mm) and use this length to compute the length-diameter ratio. Determine the average diameter by averaging two measurements taken at right angles to each other about mid-height of the core. Measure core diameters to the nearest 0.01 inch (0.25 mm) whenever possible, but at least to the nearest 0.1 inch (2.5 mm). Do not test cores if the differences between the largest and smallest diameter exceeds 5 percent of their average.

7.6 Testing – Test the cores within seven days after coring, unless otherwise specified.

8 Calculations:

8.1 Calculate the compressive strength of each core using the computed cross sectional area based on the average diameter of the core.
8.2 **Length** – The preferred length of the ground or capped core is between 1.9 and 2.1 times the diameter. If the ratio of the length to the diameter (L/D) of the core exceeds 2.1, reduce the length of the core so that the ratio is between 2.1 and 1.9. Cores with length-to-diameter ratios equal to or less than 1.75 require corrections to the measured compressive strength (see Section 7.7.2). A strength correction factor is not required for (L/D) greater than 1.75. A core having a maximum length of less than 95 percent of its diameter before capping or end grinding shall not be tested.

8.3 If the ratio of the length to the diameter of the core is less than 1.75, apply correction factors shown in the table below:

<table>
<thead>
<tr>
<th>Ratio of Length of Cylinder to Diameter</th>
<th>Strength Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75</td>
<td>0.98</td>
</tr>
<tr>
<td>1.50</td>
<td>0.96</td>
</tr>
<tr>
<td>1.25</td>
<td>0.93</td>
</tr>
<tr>
<td>1.00</td>
<td>0.87</td>
</tr>
</tbody>
</table>

*Use interpolation to determine the correction factors for L/D values not given in the table.*

Note 4 – Correction factors depend on various conditions, such as moisture condition, strength level, and elastic modulus. Average values are given in Table 1. These correction factors apply to lightweight concrete weighing between 100 and 120 lb/ft³ (1600 and 1920 kg/m³) and normal weight concrete. They are applicable to both dry and wet concrete for strengths between 2000 and 6000 PSI (13.8 and 41.4 MPa). For strengths above 10,000 PSI (70 MPa), test data on cores show that the correction factors may be higher than the values listed above. Thus, these factors should be applied to high-strength concrete with caution.

9 **Report:**

9.1 Report the results as follows:

9.2 Length of core as drilled to the nearest 0.2 in. (5 mm),

9.3 Length of core before and after capping or end grinding to the nearest 0.1 in. (2.5 mm), and the average diameter of the core to the nearest 0.01 in. (0.25 mm) or 0.1 in. (2.5 mm),

9.4 Compressive strength to the nearest 10 PSI (69 kPa) when the diameter is measured to the nearest 0.01 in. (0.25 mm), and to the nearest 50 PSI (345 kPa) when the diameter is measured to the nearest 0.1 in. (2.5 mm), after correction for length-diameter ratio when required,

9.5 Direction of application of the load on the core with respect to the horizontal plane of the concrete as placed,

9.6 The moisture condition history:

9.6.1 The date and time the core was obtained and first placed in sealed bag or no-absorbent container,

9.6.2 If water was used during end preparation, the date and time end preparation was completed and the core placed in the bag or no-absorbent container,
9.7 The date and time when tested,

9.8 The density, if determined,

9.9 The description of any defects in the core that could not be tested, and

9.10 If any deviation from this test was required, describe the deviation and explain why it was necessary.
1 Scope:

1.1 This method describes the procedure for measuring texture depth of fresh or hardened concrete by using a tire tread depth gauge.

1.2 The values stated in SI units are to be regarded as the standard.

2 Referenced Documents:

2.1 AASHTO: T 261 Measuring Texture Depth of Portland Cement Concrete Using a Tire Tread Depth Gauge

3 Apparatus:

3.1 Tire Tread Depth Gauge – A tire tread depth gauge with 1 mm (1/32 in.) graduations similar to the one shown in Figure 1. The gauge end may be modified to a shape suitable for the measurement.

3.2 Wire or stiff bristle brush, carborundum stone.

3.3 Steel straightedge approximately 6 by 25 by 300 mm (1/4 by 1 by 12 in.)

3.4 30 m (100 ft.) tape.

4 Selection of Test Locations:

4.1 The lot size represented by the testing shall be as required by the specifying agency.

4.2 The lot shall be subdivided into five approximately equal sublots and one test area location shall be selected for each sublot at random. The random location shall be identified transversely and longitudinally.

5 Procedure:

5.1 Document the nature and purpose of the measurement (inspection of new construction, condition survey, safety review, etc.); include the date of measurement, test area location, the position within the lane (wheelpath or outside wheelpath), whether the concrete is fresh (plastic), hardened without traffic, or approximate time that the pavement has been opened to traffic. Note whether the texture was constructed by grinding or tining.

5.2 At each test area measure the texture depth of 10 consecutive grooves. The test location of each groove shall be in line perpendicular to the grooves, starting at the point randomly located in accordance with Section 4.2.

5.3 The texture depth shall be measured from the original concrete surface. Any projections above the original surface shall be removed by brushing with a wire brush or carborundum stone as necessary to remove ridges adjacent to grooving, or with the steel straightedge prior to taking a measurement on hardened concrete. If measurements are being made on fresh concrete, the depth gauge guide shall be pressed down to the level of the original concrete surface.
5 Procedure: (continued)

5.4 With the depth gauge guides in contact with the original concrete surface, the plunger is
depressed until contact is made with the bottom of the groove in the concrete. The gauge is then
removed without disturbing the plunger. The texture depth is read to the nearest 1 mm (1/32 in.)
on the calibrated plunger. The plunger is then zeroed and the procedure is repeated until all
measurements are completed.

6 Calculations:

6.1 Calculate the average groove depth for each of the five sublots.

6.2 Calculate the average groove depth for each lot to the nearest 1 mm (1/32 in.).

7 Report:

7.1 The report shall indicate the lot identification and the average groove depth to the nearest 1 mm
(1/32 in.).
METHODS OF SAMPLING AND TESTING
MT 114-10
METHOD OF SAMPLING FOR CHLORIDE CONTENT OF BRIDGE DECK CONCRETE

1 Scope:

This is a method of sampling bridge deck concrete for chloride content.

2 Apparatus:

2.1 Coring Machine

2.2 Pachometer - A pachometer is available upon request from the Materials Bureau.

2.3 Gas powered (110-115 Volt A.C.) generator with transport cart for operating drill.

2.4 Rotary - impact drill of heavy duty construction.

2.5 Bit - 3/4 inch (19mm) diameter carbide steel bit.

2.6 Vacuum cleaner.

2.7 Pliable sampling spoon - Copper or flexible spoon 3 inches (7.5mm) in length and less than 3/4 inch (19mm) in width.

2.8 Plastic bottles - Approximately 2 inches (50mm) tall and 1 inch diameter with sealable caps.

2.9 Ruler with .10" increments and millimeters

2.10 Paper labels

2.11 "Set 45", "Rockite" or other fast setting grout.

2.12 Plastic goggles, hearing protection, gloves

2.13 Plastic bottle containing one of the following: distilled water, deionized water, ethanol (denatured) or methanol (technical grade).


3 Sampling:

3.1 Chloride samples shall be taken before coring and in an area as close as possible and with the same types of distress (i.e. delaminations or cracking) as that intended for coring.

3.2 When coring or sampling for chlorides extreme caution will be required due to traffic hazards and use of power equipment. For standard safety practices refer to the MDT Safety Policies and Procedures Manual.

4 Procedure:

4.1 The Bridge Plans are used to find approximate rebar location, cover over rebar, and thickness of concrete.
4 Procedure: (continued)

4.2 The pachometer is used to locate top layer of reinforcing steel and its depth.

4.3 Drill a hole 1/4 inch (6mm) deep and discard this portion of the sample by using the Vacuum cleaner. (See Note 1)

4.4 Drill the hole to a depth corresponding to the top of the rebar (see Note 1 and 2) and use copper or plastic spoon to collect minimum 10 g sample in plastic bottle labeled "A".

4.5 Clean the hole out with the Vacuum cleaner.

4.6 Drill hole to a depth of one inch below the top layer of reinforcing steel. Secure minimum 10 g sample of pulverized concrete with copper or plastic spoon and place into plastic bottle labeled as "B". (See Note 1 and 2)

4.7 Clean holes and fill with high strength epoxy grout patching compound such as "Set 45" or "Rockite".

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**Note 1** - The sketch as shown below defines the drilling depth for sampling:

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**CROSS SECTION THROUGH SLAB**

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**Note 2** - During sample collection and pulverizing, personnel shall use caution to prevent contact of the sample with hands or other sources of body perspiration or contamination. Further, all sampling tools (drill bits, spoons, bottles, sieves, etc.) shall be washed with alcohol or distilled water and shall be dry prior to use on each separate sample. Alcohol is normally preferred for washing because of the rapid drying which naturally occurs.
5 Labeling:

5.1 The following data will be written on each label and attached to each sample bottle:

5.1.1 Project number and termini
5.1.2 E.B. or W.B. lane
5.1.3 Position in lane measured from curb
5.1.4 Depth range of sample measured from top of deck and labeled as "A" or "B"; (See Note 1)
5.1.5 Depth of reinforcing steel
5.1.6 Core number cross reference
5.1.7 Brief description of condition of area (i.e., delaminations, cracks).

6 Submittal:

6.1 Cores with chloride samples will be submitted to the Materials Bureau.
METHODS OF SAMPLING AND TESTING
MT 115-04

WEIGHT PER CUBIC FOOT, YIELD, AND AIR CONTENT
(GRAVIMETRIC) OF CONCRETE
(Modified AASHTO T121)

1 Scope:

1.1 This method covers determination of the weight per cubic foot (or cubic meter) of freshly mixed concrete and gives formulas for calculating the yield, cement content, and the air content of the concrete. Yield is defined as the volume of concrete produced from a mixture of known quantities of the component materials.

1.2 The values stated in in-pound units are to be regarded as the standard.

2 Referenced Documents:

2.1 AASHTO:
M 85 Portland Cement
T 121 Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
T 133 Specific Gravity of Hydraulic Cement

MT Manual:
MT-102 Air Content of Freshly Mixed Concrete by Pressure Method
MT-105 Sampling Fresh Concrete
MT-203 Unit Weight of Aggregate

3 Symbols:

\( A \) = air content (percentage of voids) in the concrete
\( N \) = actual cement content, lb/yd\(^3\) or kg/m\(^3\)
\( N_t \) = mass of cement in the batch, lb or kg
\( R_y \) = relative yield
\( T \) = theoretical weight of the concrete computed on an airfree basis, lb/ft\(^3\) or kg/m\(^3\) (Note 1)
\( V \) = total absolute volume of the component ingredients in the batch, ft\(^3\) or M\(^3\)
\( W \) = unit of mass of concrete, lb/ft\(^3\) or kg/m\(^3\)
\( W_t \) = total mass of all materials batched, lb or kg (Note 2)
\( Y \) = volume of concrete produced per batch, yd\(^3\) or m\(^3\)
\( Y_d \) = volume of concrete which the batch was designed to produce, yd\(^3\) (m\(^3\))
\( Y_f \) = volume of concrete produced per batch, ft\(^3\)

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:

\[ T = \frac{W_t}{V} \]

The absolute volume of each ingredient in cubic feet is equal to the quotient of the mass of that ingredient divided by the product of its specific gravity times 62.4. The absolute volume of each ingredient in cubic meters is equal to the mass of the ingredient in kilograms divided by 1,000 times its specific gravity. For the aggregate components, the bulk specific gravity and mass should be based on the saturated, surface-dry condition. For cement, the actual specific gravity should be determined by Test Method T 133. A value of 3.15 may be used for cements manufactured to meet the requirements of Specification 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.

4 Apparatus:

4.1 Balance - A balance or scale accurate to within 0.3% of the test load at any point within the range of use. The range of use shall be considered to extend from the weight of the measure empty to the weight of the measure plus its contents at 160 lb/ft³ (2,600 kg/m³).

4.2 Tamping Rod - A round straight steel rod, _ in. (16 mm) in diameter and approximately 24 in. (60 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is _ in.

4.3 Internal Vibrator - Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7,000 vibrations per minute or greater while in use. The outside diameter or the side dimension of the vibrating element shall be at least 0.75 in. (19 mm) and not greater than 1.50 in. (38 mm). The length of the shaft shall be at least 24 in. (600 mm).

4.4 Measure - A cylindrical container made of steel or other suitable metal (Note 3). It shall be watertight and sufficiently rigid to retain its form and calibrated volume under rough usage. Measures that are machined to accurate dimensions on the inside and provided with handles are preferred. The minimum capacity of the measure shall conform to the requirements of Table 1. All measures, except for measuring bowls of air meters that are used for Method T 121 tests, shall conform to the requirements of Test Method MT-203. When measuring bowls of air meters are used, they shall conform to the requirements of Test MT-102. The top rim of the air meter bowls shall be smooth and plane within 0.01 in. (0.25 mm).

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 0.01 in. (0.25 mm) feeler gage cannot be inserted between the rim and a piece of ¼ in. (6 mm) or thicker plate glass laid over the top of the measure.

4.5 Strike-Off Plate - A flat rectangular metal plate at least ¼ in. (6 mm) thick or a glass or acrylic plate at least ½ in. (12 mm) thick with a length and width at least 2 in. (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1/16 in. (1.5 mm).

4.6 Calibration Equipment - A piece of plate glass, preferably at least ¼ in.(6 mm) thick and at least 1 in. (25 mm) larger than the diameter of the measure to be calibrated. A supply of water pump or chassis grease that can be placed on the rim of the container to prevent leakage.

4.7 Mallet - A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb (0.57 ± 0.23 kg) for use with measures of 0.5 ft³ (14 dm³) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb (1.02 ± 0.23 kg) for use with measures larger than 0.5 ft³.
Apparatus: (continued)

### TABLE 1 - Capacity of Measures

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Coarse Aggregate</th>
<th>Capacity of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>in. mm</td>
<td>ft³</td>
</tr>
<tr>
<td>1 25.0</td>
<td>0.2</td>
</tr>
<tr>
<td>1½ 37.5</td>
<td>0.4</td>
</tr>
<tr>
<td>2 50</td>
<td>0.5</td>
</tr>
<tr>
<td>3 75</td>
<td>1.0</td>
</tr>
<tr>
<td>4½ 112</td>
<td>2.5</td>
</tr>
<tr>
<td>6 150</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*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 percent of the nominal volume listed.

### Calibration of Measure:

5.1 Calibrate the measure and determine the factor used to convert the mass in pounds (or kilograms) contained in the measure to mass in pounds per cubic foot (or kilograms per cubic meter). Follow the procedure outlined in MT-203. Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

### Sample:

6.1 Obtain the sample of freshly mixed concrete in accordance with MT-105.

### Procedure:

7.1 The methods of consolidation are rodding and internal vibration. Rod concretes retain with a slump greater than 3 in. (75 mm). Rod or vibrate concrete with a slump of 1 to 3 in. (25 to 75 mm). Consolidate concretes with a slump less than 1 in. (25 mm) by vibration.

Note 5 - The non-plastic concrete, such as is commonly used in the manufacture of pipe and unit masonry, is not covered by this method.

7.2 **Rodding** - Place the concrete in the measure in three layers of approximately equal volume. Rod each layer with 25 strokes of the tampering rod when the 0.5 ft³ (14 dm³) or smaller measures are used and 50 strokes when the 1 ft³ (28 dm³) measure is used. Rod the bottom layer throughout its depth but the rod shall not forcibly strike the bottom of the measure. Distribute the strokes uniformly over the cross section of the measure and for the top two layers, penetrate about 1 in. (25 mm) into the underlying layer. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the appropriate mallet (see 3.7) to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Add the final layer so as to avoid overfilling.

7.3 **Internal Vibration** - Fill and vibrate the measure in two approximately equal layers. Place all of the concrete for each layer in the measure before starting vibration of that layer. Insert the vibrator at three different points of each layer. In compacting the bottom layer, do not allow the vibrator to rest on or touch the bottom or sides of the measure. In compacting the final layer, the vibrator shall penetrate into the underlying layer approximately 1 in. (25 mm). Take care that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator (Note 6). Continue vibration only long enough to achieve proper consolidation of the
concrete

7 Procedure: (continued)

(Note 7). Observe a constant duration of vibration for the particular kind of concrete, vibrator, and measure involved.

Note 6 - Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth.

Note 7 – Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

7.4 On completion of consolidation the measure must not contain a substantial excess or deficiency of concrete. An excess of concrete protruding approximately 1/8 in. (3 mm) 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.

7.5 Strike-Off - After consolidation, strike-off the top surface of the concrete and finish it smoothly with the flat strike-off plate using great 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 the 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.

7.6 Cleaning and Weighing - After strike-off, clean all excess concrete from the exterior of the measure and determine the net mass of the concrete in the measure to an accuracy consistent with the requirements of 4.1.

Note 8 - A value for $R_y$ 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.

8 Calculations:

8.1 Unit Weight - Calculate the net mass of the concrete in pounds or kilograms by subtracting the mass of the measure from the gross mass. Calculate the unit mass, $W$, by multiplying the net mass by the calibration factor for the measure used, determined according to Test Method MT-203.

8.2 Yield - Calculate the yield as follows:

$Y_{(ft^3)} = W_i/W$

or,

$Y_{(yd^3)} = W_i/27 W$

or,

$Y_{(m^3)} = W_i/W$

8.3 Relative Yield - Relative yield is the ratio of the actual volume of concrete obtained to the volume as designed for the batch calculated as follows:
\[ R_y = Y / Y_d \]

8 Calculations: (continued)

8.4 Cement Content - Calculate the actual cement content as follows:

\[ N = N_t / Y \]

8.5 Air Content - Calculate the air content as follows:

\[ A = [(T - W)T] \times 100 \]

or,

\[ A = [(Y_f - V)Y_f] \times 100 \text{ (Inch-pound units)} \]

or,

\[ A = [(Y - V)/Y] \times 100 \text{ (SI units)} \]
METHODS OF SAMPLING AND TESTING

METHOD OF TEST FOR SLUMP FLOW OF
SELF-CONSOLIDATING CONCRETE
(Montana Modified Method)

1 Scope:
1.1 This test method covers the determination of slump flow of self-consolidating concrete.
1.2 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. (WARNING – Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure).

2 Referenced Documents:
2.1 ASTM Standards:
C 143/C 143M  Test method for Slump of Hydraulic Cement Concrete

MT Materials Manual:
MT 105  Sampling Fresh Concrete
MT 104  Slump of Portland Cement Concrete

3 Terminology:
3.1 halo – an observed cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of concrete after flowing from the slump cone.
3.2 spread – the distance of lateral flow of concrete during the slump-flow test.
3.3 stability – the ability of a concrete mixture to resist segregation of the paste from the aggregates.
3.4 viscosity – resistance of material to flow under an applied shearing stress.

4 Summary of Test Method:
4.1 A sample of freshly mixed concrete is placed in a mold shaped as the frustum of a cone. The concrete is placed in one lift without tamping or vibration. The mold is raised, and the concrete is allowed to spread. After spreading ceases, two diameters of the concrete mass are measured in approximately orthogonal directions, and slump flow is the average of the two diameters.

5 Significance and Use:
5.1 This test method provides a procedure to determine the slump flow of self-consolidating concrete in the laboratory or the field.
5.2 This test method is used to monitor the consistency of fresh, unhardened self-consolidating concrete and its unconfined flow potential.
5 **Significance and Use:** (continued)

5.3 It is difficult to produce self-consolidating concrete that is both flowable and non-segregating using coarse aggregates larger than 1 in. (25 mm). Therefore, this test method is considered applicable to self-consolidating concrete having coarse aggregate up to 1 in. (25 mm) in size.

5.4 The rate at which the concrete spreads is related to its viscosity.

6 **Apparatus:**

6.1 *Mold* – The mold used in this test method shall conform to that described in MT 104.

6.2 *Base Plate* – The base plate on which the mold rests shall be nonabsorbent, smooth, rigid, and have a minimum diameter of 36 in. (915 mm).

Note 1 – *Field experience and results from a round robin test program have shown that base plates made from sealed/laminated plywood, acrylic plastic, or steel are suitable for performing this test.*

6.3 *Strike-Off Bar* – A flat, straight steel bar at least 1/8 in. by 3/4 in. by 12 in. (3 by 20 by 300 mm) or a flat, straight high-density polyethylene bar, or other plastic of equal or greater abrasion resistance, at least 1/4 in. by 3/4 in. by 12 in. (6 by 20 by 300 mm).

7 **Sample:**

7.1 The sample of concrete from which test specimens are made shall be of the entire batch. It shall be obtained in accordance with MT 105.

8 **Procedure:**

8.1 The slump-flow test shall be performed on a flat, level, nonabsorbent surface such as a pre-moistened concrete floor or a base plate. The base plate shall be used in conditions where a flat, level surface is not available, such as on a construction job site. When the base plate is used, position and shim the base plate so that it is fully supported, flat, and level. When performing the slump flow test for a given study or project, do not change the base plate surface type for the duration of the study or project.

8.2 *Filling the mold* – The user has the option of filling the mold by following either Procedure A or Procedure B.

8.3 *Procedure A (Upright Mold)* – Dampen and place the mold, with the larger opening of the mold facing down, in the center of a flat, moistened base plate or concrete surface. Firmly hold the mold in place during filling by the operator standing on the two foot pieces. From the sample of concrete obtained in accordance with Section 7, immediately fill the mold in one lift. Slightly overfill the concrete above the top of the mold.

8.4 *Procedure B (Inverted Mold)* - Dampen and place the mold, with the smaller opening of the mold facing down, in the center of a flat, moistened base plate or concrete surface. From the sample of concrete obtained in accordance with Section 7, immediately fill the mold in one lift. Slightly overfill the concrete above the top of the mold.

Note 2 – *During the development of this test method, it was found that some of the users preferred to perform the test with the large opening of the mold facing down. The provision of a collar to the top of the mold is useful to reduce the probability of concrete
8 Procedure: (continued)

spilling over the mold and on to the base plate. Other user preferred to place the mold with the smaller opening face down, which facilitates the ease of filling. Both procedures have been found to be suitable for performing this test.

8.3 Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike-off bar. Remove concrete from the area surrounding the base of the mold to preclude interference with the movement of the flowing concrete. Remove the mold from the concrete by raising it vertically. Raise the mold a distance of 9 ± 3 in. (225 ± 75 mm) in 3 ± 1 seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of the filling through removal of the mold without interruption within the elapsed time of 2 ½ minutes.

8.4 Wait for the concrete to stop flowing and then measure the largest diameter of the resulting circular spread of concrete to the nearest ¼ in. (5 mm). When a halo is observed in the resulting circular spread of the concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter of the circular spread at an angle approximately perpendicular to the original measured diameter.

8.5 If the measurement of the two diameters differs by more than 2 in. (50 mm), the test is invalid and shall be repeated.

9 Calculation:

9.1 Calculate the slump-flow using the following equation:

\[
\text{Slump-flow} = \frac{(d_1 + d_2)}{2}
\]

Where:

\[d_1 = \text{the largest diameter of the circular spread of the concrete, and}\]

\[d_2 = \text{the circular spread of the concrete at an angle approximately perpendicular to } d_1.\]

9.2 Record the average of the two diameters to the nearest ½ in. (10 mm).

10 Report:

10.1 Report which procedure was used to fill the mold.

10.2 Report the slump-flow to the nearest ¼ in. (10 mm).
1 Scope:

1.1 This method covers procedures for making and curing cylindrical and beam specimens from representative samples of fresh self-consolidating concrete (SCC) for a construction project.

1.2 The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2 Referenced Documents:

2.1 **AASHTO:**

M 205 Molds for Forming Concrete Test Cylinders Vertically
T 23 Making and Curing Concrete Test Specimens in the Field
T 141 Sampling Freshly Mixed Concrete
T 309 Temperature of Freshly Mixed Cement Concrete

**MT Materials Manual:**

MT 105 Sampling Fresh Concrete
MT 116 Slump Flow of Self Consolidaing Concrete
MT 118 Air Content of Freshly Mixed Concrete by the Pressure Method
MT 609 Field Numbering Concrete Cylinders

3 Significance and Use:

3.1 This method provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.

3.2 If the specimens are made and *standard cured*, as stipulated herein, the resulting strength test data where the specimens are tested may be used for the following purposes:

3.2.1 Acceptance testing for specified strength.

3.2.1 Checking the adequacy of mixture proportions for strength.

3.2.3 Quality control.

3.3 If the specimens are made and *field cured*, as stipulated herein, the resulting strength test data where the specimens are tested may be used for the following purposes:

3.3.1 Determination of whether a structure is capable of being put into service (Note 5).

3.3.2 Comparison with test results of standard cured specimens or with test results from various in-place test methods.

3.3.3 Adequacy of curing and protection of concrete in the structure, or,
3 Significance and Use: (continued)

3.3.4 Form or shoring removal time requirements (Note 5).

4 Apparatus:

4.1 Molds, General—Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, non-reactive with concrete containing Portland or other hydraulic cements. Molds shall hold their dimensions and shape under conditions of severe use. Molds shall be watertight during use as judged by their ability to hold water poured into them. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax, shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Reusable molds shall be lightly coated with mineral oil or a suitable reactive form release material before use.

Note 1 - Single use molds (plastic, cardboard, tin) are not acceptable for use to cast concrete cylinders for acceptance samples. Single use molds are permitted for field cured cylinders used to determine false work removal, opening to traffic, etc.

4.2 Cylinder --Molds shall be constructed in the form of right circular cylinders which stand with the cylindrical axis vertical and the top open to receive the concrete. They shall have a nominal inside height equal to twice the nominal inside diameter. The average diameter of a mold shall not differ from the nominal diameter by more than 1 percent and no individual diameter shall differ from any other diameter by more than 2 percent. The plane of the rim of the mold and the bottom shall be perpendicular to the axis of the mold within 0.5 degrees (approximately equivalent to 1/8 in. in 12 in. or 3 mm, in 305 mm.). The molds must be provided with a closure or base on the lower end at right angles to the axis of the cylinder. The base will consist of a separate base plate and a means of attaching it to the cylindrical side walls. In preparation for use, the assembled mold and base plate shall be coated with a material that will prevent adherence to the concrete.

4.3 Beam Molds--Beam molds shall be rectangular in shape and or the dimensions required to produce the specimens stipulated in Section 4.2. The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed 1/8 in. (3.2 mm) for molds with depth or breadth of 6 in. (152 mm) or more. Molds shall produce specimens not more than 1/16 in. (1.6 mm) shorter than the required length in accordance with Section 4.2, but may exceed it by more than that amount.

4.4 Mallet--A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb (0.57 ± 0.23 kg) shall be used.

4.5 Small Tools--Tools and items which may be required are shovels, pails, trowels, wood float, metal float, blunted trowels, straightedge, feeler gage, scoops, and rules.

4.6 Slump Flow Apparatus--The apparatus for measurement of slump flow shall conform to the requirements of Method MT-116.

4.7 Sampling and Mixing Receptacle--The receptacle shall be a suitable heavy gage metal pan, wheelbarrow, or flat, clean, nonabsorbent mixing board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

4.8 Air Content Apparatus--The apparatus for measuring air content shall conform to the requirements of Method MT-102.

4.9 Temperature Measuring Devices -- The temperature measuring devices shall conform to the applicable requirements of T309/T309M.
Test Specimens:

5.1 Compressive Strength Specimens--Compressive strength specimens shall be cylinders of concrete cast and hardened in an upright position, with a length equal to twice the diameter. The standard specimen shall be the 6 by 12 in. (150 by 300 mm) cylinder when the maximum size of the coarse aggregate does not exceed 2 in. (50 mm), either the concrete sample shall be treated by wet sieving as described in AASHTO T 141 or the diameter of the cylinder shall be at least three times the nominal maximum size of the coarse aggregate in the mixture. The specimens may be 4 by 8 in. (100 by 200 mm) cylinders when the nominal maximum size of the coarse aggregate does not exceed 1 in. (25 mm).

5.2 Flexural Strength Specimens--Flexural strength specimens shall be rectangular beams of concrete cast and hardened with long axes horizontal. The length shall be at least 2 in. (50 mm) greater than three times the depth as tested. The ratio of width to depth as molded shall not exceed 1.5. The standard beam shall be 6 by 6 in. (152 by 152 mm) in cross section, and shall be used for concrete with a nominal maximum size coarse aggregate up to 2 in. (50 mm). When the nominal maximum size of the coarse aggregate exceeds 2 in. (50 mm), the smaller cross-sectional dimension of the beam shall be at least three times the nominal maximum size of the coarse aggregate. Unless required by the project specifications, beams made in the field shall not have a width or depth of less than 6 in.

Sampling Concrete:

6.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with Method MT-105 unless an alternative procedure has been approved.

6.2 Record the identity of the sample with respect to the location of the concrete represented and the time of casting.

Slump Flow, Air Content:

7.1 Slump Flow--Measure the slump flow of each batch of concrete, from which specimens are made, immediately after remixing in the receptacle as required in Method MT-104.

7.2 Air Content--Determine the air content in accordance with Method MT-118. The concrete used in performing the air content test shall not be used in fabricating test specimens.

Molding Specimens:

8.1 Place of Molding--Mold specimens promptly on a level, rigid, horizontal surface, free from vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

8.2 Placing the Concrete--Place the concrete in the molds using a container large enough to fill each mold in one lift.

8.2.1 Number of Layers--Make specimens by filling the mold in one lift. Do not rod or vibrate.

8.3 Finishing:

8.4 Finishing—After filling, strike off excess concrete from the surface and float or trowel it as required. Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and that has no depressions or projections larger than 1/8 inch (3.2mm).

8.4.1 Cylinders--After filling, finish the top surfaces by striking them off with the strike-off bar where the consistency of the concrete permits or with a wood float or trowel.
8.3 Finishing: (continued)

8.4.2 Beams—After filling, strike off the top surface to the required tolerance to produce a flat even surface. A wood float may be used.

8.5 Initial Storage—Immediately after being struck off, the specimens shall be moved to the storage place where they will remain undisturbed for the initial curing period. If specimens made in single use mold are moved, lift and support the specimens from the bottom of the molds with a large trowel or similar device.

9 Curing:

9.1 Standard Curing – Standard curing is the curing method used when the specimens are made and cured for purposes stated in Section 3.2.

9.2 Storage – If specimens cannot be molded at the place where they will receive initial curing, immediately after finishing, move the specimens to an initial curing place for storage. The supporting surface on which specimens are stored shall be level within ¼ in./ft. (20 mm/m). If cylinders in the single-use molds are moved, lift and support the cylinders from the bottom of the molds with a large trowel or similar device. If the top surface is marred during movement to the place of initial storage, immediately refinish.

9.3 Initial Curing – For initial curing of cylinders, there are two methods. In both methods, the curing place must be firm, within ¼ in. of a level surface, and free from vibrations or other disturbances. Immediately after molding and finishing, the specimens shall be stored for a period up to 48 hours in a temperature range between 60º to 80ºF (16º to 27ºC), and in a moist environment preventing any loss of moisture from the specimens. For concrete mixtures with a specified strength of 6000 psi (40 Mpa) or greater, the initial curing temperature shall be between 68º and 78º F (20º to 26º C). Various procedures are capable of being used during the initial curing period to maintain the specified moisture and temperature conditions. An appropriate procedure or combination of procedures shall be used (See Note 4). Shield all specimens from direct rays of the sun and if used radiant heating devices. If cardboard molds are used, protect the outside surface of the molds from contact with wet burlap or other sources of water.

9.3.1 Method 1 – Initial cure in a temperature controlled chest-type curing box: Finish the cylinder using the tamping rod, straightedge, float or trowel. Use a sawing motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 1/8 in. (6.3 mm). Place the mold in the curing box. When lifting light-gauge molds be careful to avoid distortion (support the bottom, avoid squeezing the sides). Place the lid on the mold to prevent moisture loss. Mark the necessary identification data on the cylinder mold and lid.

9.3.2 Method 2 – Initial cure by burying in earth or by using a curing box over the cylinder:

Note 3 – This procedure may not be the preferred method of initial curing due to the problems in maintaining the required range of temperature.

Move the cylinder with excess concrete to the initial curing location. Place the cylinder on level sand or earth, or on a board, and pile sand or earth around the cylinder to within 2 in. (50 mm) of the top. Finish the cylinder using the tamping rod, straightedge, float or trowel. Use a sawing motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 1/8 in. (6.3 mm). If required by the agency, place a cover plate on top of the cylinder and leave it in place for the duration of the curing period or place the lid on the mold to prevent moisture loss. Mark the necessary identification data on the cylinder mold and lid.

Note 4 – A satisfactory moisture environment can be created during the initial curing of the specimens by one or more of the following procedures: (1) immediately immerse molded specimens with plastic lids in water saturated with calcium hydroxide, (2) store in properly constructed wood boxes or structures, (3) place in damp sand pits, (4) cover with removable plastic lids, (5) place inside plastic bags, or (6) cover with plastic sheets or nonabsorbent plates if provisions are made to
9 Curing: (continued)

avoid drying and damp burlap is used inside the enclosure, but the burlap is prevented from contacting the concrete surfaces. A satisfactory temperature environment can be controlled during the initial curing of the specimens by one or more of the following procedures: (1) use of ventilation, (2) use of ice, (3) use of thermostatically controlled heating or cooling devices, or (4) use of heating methods such as stoves or light bulbs. Other suitable methods may be used if the requirements limiting specimen storage temperature and moisture loss are met. For concrete mixtures with a specified strength of 6000 psi (40 Mpa) or greater, heat generated during the early stages may raise the temperature above the required storage temperature. When specimens are to be immersed in water saturated with calcium hydroxide, specimens in cardboard molds or other molds that expand when immersed in water should not be used. Early age strength test results may be lower when stored near 60ºF (16ºC) and higher when stored near 80ºF (27ºC). On the other hand, at later stages, test results may be lower for higher initial storage temperatures.

9.4 Final Curing:

9.4.1 Cylinders – Upon receipt in the Materials Bureau, store specimens in a moist condition with free water maintained on their surfaces at all times at a temperature of 73 ± 3ºF (23 ± 2ºC) using water storage tanks or moist rooms complying with the requirements of AASHTO M 201, except when capping with sulfur mortar compound and immediately before testing. When capping with sulfur mortar compounds, the ends of the cylinder shall be dry enough to preclude the formation of steam or foam pockets under or in the cap larger than ¼ inch (6 mm) as described in AASHTO T 231. Temperatures between 68º and 86ºF (20º and 30ºC) are permitted for a period not to exceed 3 hours immediately prior to test if free moisture is maintained on the surfaces of the specimen at all times.

9.4.2 Beams – Beams are to be cured the same as cylinders (Section 9.1.3.1) except that they shall be stored in water saturated with calcium hydroxide at 73º ± 3ºF (23 ± 2ºC) for at least 20 hours prior to testing. Drying of the surfaces of the beam shall be prevented between removal from the water and storage completion of testing (Note 5).

Note 5 - Relatively small amounts of drying of the surface of flexural specimens induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9.5 Field Curing – Field curing is the curing method used for the specimens made for the purpose stated in Section 3.3.

Note 6 – The Project Manager may elect to use the departments “7 day” break strength result for opening to traffic or form removal.

9.5.1 Cylinders – Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified moisture treatment. To meet these conditions, specimens made for the purpose of determining when a structure may be put in service shall be removed from the molds at the time of removal of formwork.

9.5.2 Beams – As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of 48 ± 4 hours after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements or slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the side and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structural concrete as near to the point in the structure they represent as possible and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in water saturated with calcium hydroxide at 73 ± 3ºF (23 ± 2ºC) for
9  **Curing: (continued)**

24 ± 4 hours immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Observe the precautions given in Section 9.1.3.2 to guard against drying between the time of removal from curing to testing.

9.6  *Structural Lightweight Concrete Curing* – Cure structural lightweight concrete cylinders in accordance with AASHTO M 195.

10  **Transportation to Laboratory:**

10.1 Cylinders and beams shipped from the field to the laboratory for testing shall be packed in sturdy wooden boxes supplied by the Materials Bureau, surrounded by wet sawdust and protected from freezing during shipment. Upon receipt by the laboratory, cylinders shall be capped and immediately placed in the moist room. The shipper shall fill out Laboratory Form No. 93 and place one copy in the plastic envelope supplied, to accompany the cylinder, mail one copy to the Materials Bureau, and retain one copy for the shipper's file.

10.2 Test specimens shall not be shipped from the field until at least three days after casting.

10.3 Retaining the cylinders on the project for three days will permit sufficient strength to develop to greatly reduce the possibility of latent damage from rough handling or exposure to low temperatures during shipping. Past cylinder failure investigations have produced considerable evidence that such latent damage may be a major factor in low-test cylinder strengths. This is particularly evident where cylinders have been removed from the molds and shipped the day after casting during periods of below freezing weather.

10.4 It is realized that, in some cases, retaining the cylinders on the project for three days may result in the first cylinder being tested later than the specified seven days. However, a late seven-day test is preferable to the possibility of damaging the entire set by shipping before adequate strength is developed. Every effort should be made, however, to comply with paragraph 9.1.3.1 above in order that the specimen will receive the 24-hour curing in the moist room in the Materials Bureau.

11  **Preparation of Laboratory Form No. 93:**

11.1 Form No. 93, which accompanies each cylinder, should be completed with extreme care, paying particular attention to the date when the cylinders were made. The mix design, water and air content, cement certification and the laboratory numbers of the aggregates being used should be checked to make certain they are correct and they should be changed whenever new project mixes, laboratory numbers or other information is available. Project numbers should be accurate and complete including unit numbers and the correct termini should be shown. Special attention is directed to MT-510, Field Numbering Concrete Cylinders.
1 Scope:

1.1 This method covers determination of the air content of freshly mixed self consolidating concrete from observation of the change in volume of concrete with a change in pressure.

1.2 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 Section 5. It is not applicable to concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity. In these cases, AASHTO T 196M/T 196, should be used. This test method is not applicable to non-plastic concrete such as is commonly used in the manufacture of pipe and concrete masonry units.

1.3 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables and figures shall not be considered as requirements for this standard.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2 Reference Document:

2.1 AASHTO:
- T 121  Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
- T 141, Sampling Freshly Mixed Concrete
- T 152  Air Content of Freshly Mixed Concrete by the Pressure Method
- R 39 – Making and Curing Concrete Test Specimens in the Laboratory

MT. Materials Manual:
- MT-105 Sampling Freshly Mixed Concrete

3 Significance and Use:

3.1 This test method covers the determination of the air content of freshly mixed self-consolidating concrete. The test determines the air content of freshly mixed concrete exclusive of any air that exists inside the voids within aggregate particles. For this reason, it is applicable to concrete made with relatively dense aggregate particles and requires determination of the aggregate correction factor. (See Sections 6.1 and 9.1).

3.2 The air content of hardened concrete may be either higher or lower than that determined by this test method. This depends upon the methods and amount of consolidation effort applied to the concrete from which the hardened concrete specimen is taken; uniformity and stability of the air bubbles in the fresh and hardened concrete; accuracy of the microscopic examination, if used, time of comparison; environmental exposure; stage in the delivery, placement, and consolidation processes at which the air determined, that is, before or after the concrete goes through a pump; and other factors.

4 Apparatus:

4.1 Air Meter - There are two basic operational designs available employing the principle of Boyle's law. For purposes of reference, these will be designated Type A Meter and Type B Meter.
4 Apparatus: (continued)

4.1.1 *Type A Meter* - An air meter consisting of a measuring bowl and cover assembly (Figure 1) conforming to the requirements of Sections 4.2 and 4.3. 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 percent of air in the concrete sample.

4.1.2 *Type B Meter* - An air meter consisting of a measuring bowl and cover assembly (Figure 2) conforming to the requirements of Section 4.2 and 4.3. 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 gage being calibrated in terms of percent air for the observed pressure at which equalization takes place. Working pressures of 7.5 to 30.0 psi (51 to 207 kPa) having been used satisfactorily.

4.2 *Measuring Bowl* - The measuring bowl must be essentially cylindrical in shape, made of steel, hard metal, or other hard material 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 0.20 ft³ (0.006 m³). It must be flanged or otherwise constructed to provide for a pressure tight fit between the bowl and cover assembly. The interior surfaces of the bowl and surfaces of rims, flanges and other component fitted parts must be machined smooth. The measuring bowl and cover assembly must be sufficiently rigid to limit the expansion factor, $D$, of the apparatus assembly (Annex A1.5) to not more than 0.1 percent of air content on the indicator scale when under normal operating pressure.

4.3 *Cover Assembly:

4.3.1 The cover assembly shall be made of steel or other hard metal not readily attacked by the cement paste. It must be flanged or otherwise constructed to provide for a pressure-tight fit between bowl and cover assembly and must have machined smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover must be sufficiently rigid to limit the expansion factor of the apparatus assembly as prescribed in 4.2.

4.3.2 The cover assembly must be fitted with a means for direct reading of the air content. The cover for the Type A meter must be fitted with a standpipe, which may be a transparent graduated tube or may be a metal tube of uniform bore with a glass water gage attached. In the Type B meter, the dial of the pressure gage must be calibrated to indicate the percent of air. Graduations shall be provided for a range in air content of at least 8 percent easily readable to 0.1 percent as determined by the proper air pressure calibration test.

4.3.3 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.

4.4 * Calibration Vessel* - A measure having an internal volume equal to a percent of the volume of the measuring bowl corresponding to the approximate percent 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 percent 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 1/2 in. (13 mm) less than that of the bowl.
Note 1: A satisfactory measure of this type may be machined from No. 16 gage brass tubing, of a diameter to provide the volume desired, to which a brass disk 1/2 in. in thickness is soldered to form an end.

When design of the meter requires withdrawing of water from the water-filled bowl

Figure 1—Illustration of the Pressure Method for Air Content—Type A Meter

Figure 2—Schematic Diagram—Type B Meter
4 Apparatus: (continued)

Note 1 - A satisfactory measure of this type may be machined from No. 16 gage brass tubing, of a diameter to provide the volume desired, to which a brass disk 1/2 in. in thickness is soldered to form an end. When design of the meter requires withdrawing of water from the water-filled 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.

4.5 The designs of various available types of air meters are such that they differ in operating techniques and therefore, all of the items described in 4.6 through 4.16 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.

4.6 Coil Spring or Other Device for Holding Calibration Cylinder in Place:

4.7 Spray Tube - A brass tube of appropriate diameter, which may be an integral part of the cover assembly or which may be provided separately. It must 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.

4.8 Trowel - A standard brick mason's trowel.

4.9 Container - A container large enough to fill the measuring bowl in one lift is required. Example: A 5 gallon bucket.

4.10 Mallet - A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb. (0.57 ± 0.23 kg) for use with measures of 0.5 ft.³ (14 L) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb. (1.02 ± 0.23 kg) for use with measures larger than 0.5 ft.³ (14 L).

4.11 Strike-Off Bar - A flat straight bar of steel or other suitable metal at least 1/8 in. (3 mm) thick and 3/4 in. (20 mm) wide by 12 in. (300 mm) long.

4.12 Strike-Off Plate – A flat rectangular metal plate at least ¼ inch (6 mm) or a glass or acrylic plate at least ½ inch (12 mm) thick with a length and width at least 2 inches (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1/16 inch (1.5 mm).

4.13 Funnel - with the spout fitting into spray tube.

4.14 Measure of Water - having the necessary capacity to fill the indicator with water from the top of the concrete to the zero mark.

4.15 Sieves – 1 ½ inch (37.5 mm) with not less than 2 ft² (0.19 m²) of sieving area.

5 Calibration of Apparatus:

5.1 Make calibration tests in accordance with procedures described in the annex. Rough handling will affect calibration of both Type 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 section A1.2 to A1.6, 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 Section A1.7, 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 Sections A1.2 to A1.6 need be made only once (at 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 Section A1.7 to A1.9, as applicable to the meter type being checked, must be made
5 Calibration of Apparatus: (continued)

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 600 ft (183 m) from the location at which a Type A meter was last calibrated will require recalibration in accordance with Section A1.7.

6 Determination of Aggregate Correction Factor:

6.1 Procedure – Determine the aggregate correction factor on a combined sample of fine and coarse aggregate as directed in sections 6.2 to 6.4. 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.

6.2 Aggregate Sample Size – Calculate the weights of fine and coarse aggregate present in the sample of fresh concrete whose air content is to be determined, as follows:

$$F_s = \frac{S}{B} \times F_b$$

$$C_s = \frac{S}{B} \times C_b$$

where:

- $F_s = \text{weight of fine aggregate in concrete sample under test, lb (kg)}$;
- $S = \text{volume of concrete sample (same as volume of measuring bowl), ft}^3 (m^3)$;
- $B = \text{volume of concrete produced per batch (Note 2), ft}^3 (m^3)$;
- $F_b = \text{total weight of fine aggregate in the moisture condition used in batch, lb (kg)}$;
- $C_s = \text{weight of coarse aggregate in concrete sample under test, lb (kg)}$,
- $C_b = \text{total weight of coarse aggregate in the moisture condition used in batch, lb (kg)}$.

Note 2 – The volume of concrete produced per batch can be determined in accordance with applicable provisions of T 121M/T 121.

Note 3 – The term “weight” is temporarily used in this standard because of established trade usage. The word is used to mean both “force” and “mass” and care must be taken to determine which is meant in each case (SI unit for force = Newton and for mass = kilogram).

6.3 Placement of Aggregate in Measuring Bowl – Mix representative samples of fine aggregate $F_s$ and coarse aggregate $C_s$, 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 1 in. (25 mm) of the aggregate about 8 – 12 times. Stir after each addition of aggregate to eliminate entrapped air.

6.4 Aggregate Correction Factor Determination:

6.4.1 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 section 6.4.2 and 6.4.3.
6 Determination of Aggregate Correction Factor: (continued)

6.4.2 Type A Meter – Complete the test as described in Sections 8.2.1 and 8.2.2. The aggregate correction factor, \( G \), is equal to \( h_1 - h_2 \). (Figure 1) (Note 4)

6.4.3 Type B Meter – Perform the procedures as described in section 8.3.1. 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 Section A1.9 of the Annex for the calibration tests. Complete the test as described in Section 8.3.2. 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 percent of the volume of the bowl. (Figure 2)

Note 4 – 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.

7 Preparation of Concrete Test Sample:

7.1 Obtain the sample of freshly mixed self consolidating concrete in accordance with applicable procedures of Method MT-105/T 141. If the concrete contains coarse aggregate particles that would be retained on a 2 inch (50 mm) sieve, wet-sieve a sufficient amount of the representative sample over a 1 1/2 inch (37.5 mm) sieve, as described in Mt-105/T 141 to yield more than enough material to fill the measuring bowl of the size selected for use. Carry out the wet-sieving operation with the minimum practical disturbance of the mortar. Make no attempt to wipe adhering mortar from coarse aggregate particles retained on the sieve.

8 Placement and Consolidation of Sample:

8.1 Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Place a representative sample of the concrete into the measuring bowl in one lift. Do not rod or vibrate the concrete.

8.2 Strike-Off - After filling the measuring bowl, 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 filling, the bowl must not contain a great excess or deficiency of concrete. Removal of approximately 1/8 in. (3 mm) during strike off is optimum. When a strike-off plate is used, strike off concrete as prescribed in T121M/T 121.

Note 5 - 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 6 – The use of the strike-off plate on cast aluminum or other relatively soft metal air meter bases may cause rapid wear of the rim

8.3 Application of Test Method – Any portion of the test method not specifically designated as pertaining to Type A or Type B meters shall apply to both types.

9 Procedure - Type A Meter:

9.1 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 about the halfway mark in the standpipe. Incline the apparatus assembly about 30 degrees from vertical and, using
9.2 **Procedure - Type A Meter: (continued)**

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. Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column. (Figure 1A)

*Note 7 – Some Type A meters have a calibrated starting fill mark above the zero mark. Generally, this starting mark should not be used since, as noted in Section 8.2.3, the apparent air content is the difference between the water level $H$, at pressure $P$, and the water level $h_2$ at zero pressure after release of pressure $P$."

9.2.1 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.

9.2.2 **Test Procedure** - Apply slightly more than the desired test pressure, $P$, (about 0.2 psi (1,380 kPa 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 gage indicates the exact test pressure, $P$, as determined in accordance with Section A1.7., read the water level, $h_1$, and record to the nearest division or half-division on the graduated precision-bore tube or gage glass of the standpipe. (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 one minute. Record the water level, $h_2$, to the nearest division or half division. (Figure 1C) Calculate the apparent air content as follows:

$$ A_1 = h_1 - h_2 $$

where:

$A_1$ = apparent air content;

$h_1$ = water level reading at pressure, $P$; and

$h_2$ = water level reading at zero pressure after release of Pressure, $P$.

9.2.3 **Check Test** - Repeat the steps described in 8.2.3 without adding water to reestablish the water level at the zero mark. The two consecutive determinations of apparent air content should check within 0.2 percent of air and shall be averaged to give the value $A_1$ to be used in calculating the air content, $A_a$, in accordance with Section 9.

9.2.4 In the event the air content exceeds 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 Sections 8.2.2 and 8.2.3.

*Note 9 – See Section A1.7 for exact calibration procedures. An approximate value of the alternative pressure, $P_1$, such that the apparent air content will equal twice the meter reading can be computed from the following relationship:

$$ P_1 = P_0 P / (2P_0 + P) $$

where:

$P_1$ = alternative test pressure, psi (kPa);
9.2 Procedure - Type A Meter: (continued)

\[ P_a = \text{atmospheric pressure, psi (kPa)} \text{ (approximately 14.7 psi (101kPa) but will vary with altitude and weather conditions); and} \]

\[ P = \text{normal test or operating pressure, psi (kPa).} \]

9.3 Procedure - Type B Meter:

9.3.1 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 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 the same petcock.

9.3.2 Test Procedure - Close the air bleeder valve on the chamber and pump air into the air chamber until the gage hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gage hand at the initial pressure line by pumping or bleeding-off air as necessary, tapping the gage lightly by hand. Close both petcocks on the holes through the cover. Open the air valve between the air chamber and the measuring bowl. Tap the side of the measuring bowl smartly with the mallet to relieve local restraints. Lightly tap the pressure gage by hand to stabilize the gage hand and read the percentage of air on the dial of the pressure gage. Failure to close the main valve before releasing the pressure from either the container or the air chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber, it must be bled from the air chamber through the bleeder valve followed by strokes of the pump to blow out the last traces of water. Release the pressure by opening both petcocks (Figure 2) before removing the cover.

10 Calculation:

10.1 Air Content of Sample Tested – Calculate the air content of the concrete in the measuring bowl as follows:

\[ A_s = A_t - G \]

where:

\[ A_s = \text{air content of sample tested, percent;} \]
\[ A_t = \text{apparent air content of the sample tested, percent (Section 8.2.3 and 8.3.2); and} \]
\[ G = \text{aggregate correction factor, percent (Section 6).} \]

10.2 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 a 1 ½ inch (37.5 mm) sieve, the air content may be calculated as follows:

\[ A_t = \frac{100A_sV_c}{100V_t - A_sV_c} \]

where (Note 10):

\[ A_t = \text{air content of the full mixture, percent;} \]
\[ V_c = \text{absolute volume of the ingredients of the mixture passing 1 ½ inch (37.5 mm) sieve, air-free, as determined from the original batch weights, ft}^3 \text{ (m}^3)\);
10 Calculation: (continued)

\[ V_i = \text{absolute volume of all the ingredients of the mixture, air-free, ft}^3 (\text{m}^3); \text{ and} \]

\[ V_c = \text{absolute volume of the aggregate in the mixture coarser than a } 1\frac{1}{2} \text{ inch (37.5 mm) sieve, as determined from the original batch weights, ft}^3 (\text{m}^3). \]

10.3 Air content of the Mortar Fraction - When it is desired to know the air content of the mortar fraction of the mixture, calculate it as follows;

\[ A_m = \frac{100A_sV_c}{100V_m + A_s(V_c - V_m)} \]

where (Note 10):

\[ A_m = \text{air content of the mortar fraction, percent; and} \]

\[ V_m = \text{absolute volume of the ingredients of the mortar fraction of the mixture, air-free, ft}^3 (\text{m}^3). \]

Note 10 – The values for use in Equations in Sections 9.2 and 9.3 are most conveniently obtained from data on the concrete mixture tabulated as follows for a batch of any size:

<table>
<thead>
<tr>
<th>Absolute Volume, ft³ (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
</tr>
<tr>
<td>Water</td>
</tr>
<tr>
<td>Fine Aggregate</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
</tr>
<tr>
<td>No. 4 (4.75 mm) to 1 ½ in.</td>
</tr>
<tr>
<td>(37.5 mm)</td>
</tr>
<tr>
<td>Coarse aggregate 1 ½ in.</td>
</tr>
<tr>
<td>(37.5 mm)</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>( V_i )</td>
</tr>
<tr>
<td>( V_m )</td>
</tr>
<tr>
<td>( V_c )</td>
</tr>
<tr>
<td>( V_a )</td>
</tr>
</tbody>
</table>

ANNEX:

A1 Calibration of the Apparatus:

A1.1 The calibration tests shall be performed in accordance with the following procedures as applicable to the meter type being employed.

A1.2 Calibration of the Calibration Vessel – Determine accurately the weight of water required to fill the calibration vessel \( w \), using a scale accurate to 0.1 percent of the weight of the vessel filled with water. This step shall be performed for Types A and B meters.

A1.3 Calibration of the Measuring Bowl – Determine the weight of water required to fill the measuring bowl, \( W \), using a scale accurate to 0.1 percent of the weight of the bowl filled with water. Slide a glass plate carefully over the flange of the bowl in a manner to ensure that the bowl is completely filled with water. A thin film of grease smeared on the flange of the bowl will make a watertight joint between the glass plate and the top of the bowl. This step shall be performed for Types A and B meters.

A1.4 Effective Volume of the Calibration Vessel, \( R \) – The constant \( R \), represents the effective volume of the calibration vessel expressed as a percentage of the volume of the measuring bowl.
A1 Calibration of the Apparatus: (continued)

A1.4.1 For Type A meters, calculate the \( R \) as follows (Note A1):

\[
R = 0.98 \frac{w}{W} \quad (A1.1)
\]

where:

\( w \) = weight of water required to fill the calibration vessel, and

\( W \) = weight of water required to fill the measuring bowl.

Note A1 – The factor 0.98 is used to correct for the reduction in the volume of air in the calibration vessel when it is compressed by a depth of water equal to the depth of the measuring bowl. This factor is approximately 0.98 for a 8-in. (203 mm) deep measuring bowl at sea level. Its value decreases to approximately 0.975 at 5000 ft (1524 m) above sea level and 0.970 at 13000 ft (3962 m) above sea level. The value of this constant will decrease by about 0.01 for each 4-in. (102 mm) increase in bowl depth. The depth of the measuring bowl and atmospheric pressure do not affect the effective volume of the measuring vessel for Type B meters.

A1.4.2 For Type B meters, Calculate \( R \) as follows (Note A1):

\[
R = \frac{w}{W} \quad (A1.2)
\]

A1.5 Determination of, or Check of, Allowance for Expansion Factor, \( D \):

A1.5.1 For meter assemblies of Type A, determine the expansion factor, \( D \) (Note A2) by filling the apparatus with water only (making certain that all entrapped air has been removed and the water level is exactly on the zero mark (Note A3) and applying air pressure approximately equal to the operating pressure, \( P \), determined by the calibration test described in Section A1.7. The amount the water column lowers will be the equivalent expansion factor, \( D \), for that particular apparatus and pressure (Note A5).

Note A2 – Although the bowl, cover, and clamping mechanism of the apparatus must of necessity be sturdily constructed so that it will be pressure-tight, the application of internal pressure will result in a small increase in the volume. This expansion will not affect the test results because, with the procedure described in Sections 6 and 8, the amount of expansion is the same for the test for air in concrete as for the test for aggregate correction factor on combined fine and coarse aggregates, and is thereby automatically cancelled. However, it does enter into the calibration test to determine the air pressure to be used in testing fresh concrete.

Note A3 – The water columns on some meters of Type A design are marked with an initial water level and a zero mark, the difference between the two marks being the allowance for the expansion factor. This allowance should be checked in the same manner as for meters not so marked and in such a case, the expansion factor should be omitted in computing the calibration readings in Section A1.7.

Note A4 – It will be sufficiently accurate for this purpose to use an approximate value for \( P \) determined by making a preliminary calibration test as described in Section A1.7 except that an approximate value for the calibration factor, \( K \), should be used. For this test \( K = 0.98R \) which is the same as Equation A1.2 except that the expansion reading, \( D \), as yet unknown, is assumed to be zero.

A1.5.2 For meters of Type B design, the allowance for the expansion factor, \( D \), is included in the difference between the initial pressure indicated on the pressure gauge and the zero percent mark on the air-content scale on the pressure gauge. This allowance shall be checked by filling the apparatus with water (making certain that all entrapped air has been removed), pumping air into the air chamber until the gauge hand is stabilized at the indicated initial pressure line, and then
Calibration of the Apparatus: (continued)

releasing the air to the measuring bowl (Note A5). If the initial pressure line is correctly positioned, the gauge should read zero percent. The initial pressure line shall be adjusted if two or more determinations show the same variation from zero percent and the test repeated to check the adjusted initial pressure line.

Note A5 – This procedure may be accomplished in connection with the calibration test described in Section A1.9.

A1.6 Calibration Reading, K – The calibration reading, K, is the final meter reading to be obtained when the meter is operated at the correct calibration pressure.

A1.6.1 For Type A meters, the calibration reading, K, is as follows:

\[ K = R + D \quad (A1.3) \]

where:

\( R \) = effective volume of the calibration vessel (Section A1.4.1), and

\( D \) = expansion factor (Section A1.5.1, Note A6).

A1.6.2 For Type B meters, the calibration reading, K, equals the effective volume of the calibration vessel (Section A1.4.2) as follows:

\[ K = R \quad (A1.4) \]

Note A6 – If the water column indicator is graduated to include an initial water level and zero mark, the difference between the two marks being equivalent to the expansion factor, the term D shall be omitted from Equation A1.4.

A1.7 Calibration Test to Determine Operating Pressure, P, on Pressure Gauge, Type A Meter – If the rim of the calibration cylinder contains no recesses or projection, fit it with three or more spacers equally spaced around the circumference. Invert the cylinder and place it at the center of the dry bottom of the measuring bowl. The spacers will provide an opening for flow of water into the calibration cylinder when pressure is applied. Secure the inverted cylinder against displacement and carefully lower the cover assembly. After the cover is clamped in place, carefully adjust the apparatus assembly to a vertical position and add water at air temperature, by means of the tube and funnel, until it rises above the zero mark on the standpipe. Close the vent and pump air into the apparatus to the approximate operating pressure. Incline the assembly about 30 degrees from vertical and, using the bottom of the bowl as a pivot, describe several circles with the upper end of the stabpipe, simultaneously tapping the cover and sides of the bowl lightly to remove any entrapped air adhering to the inner surfaces of the apparatus. Return the apparatus to a vertical position, gradually release the pressure (to avoid loss of air from the calibration vessel) and open the vent. Bring the water level exactly to the zero mark by bleeding water through the petcock in the top of the conical cover. After closing the vent, apply pressure until the water level has dropped an amount equivalent to about 0.1 to 0.2 percent of air more than the value of the calibration reading, K, determined as described in Section A1.6. To relieve local restraints, lightly tap the sides of the bowl and when the water level is exactly at the value of the calibration reading, K, read the pressure, P, indicated by the gauge and record to the nearest 0.1 psi (.690 kPa). Gradually release the pressure and open the vent to determine whether the water level returns to the zero mark when the sides of the bowl are tapped lightly (failure to do so indicates loss of air from the calibration vessel or loss of water due to a leak in the assembly). If the water level fails to return to within 0.05 percent air of the zero mark and no leakage beyond a few drops of water is found, some air probably was lost from the calibration cylinder. In this case, repeat the calibration procedure step-by-step from the beginning of this paragraph. If the leakage is more than a few drops of water, tighten the leaking joint before repeating the calibration procedure. Check the
indicated pressure reading promptly by bringing the water level exactly to the zero mark, closing the vent, and applying pressure, \( P \), just determined. Tap the gauge lightly with a finger. When the gauge indicates the exact pressure, \( P \), the water column should read the value of the calibration factor, \( K \), used in the pressure application within about 0.05 percent of air.

Note A7 – Caution: The apparatus assembly must not be moved from the vertical position until pressure has been applied which will force water about one-third of the way up into the calibration cylinder. Any loss of air from this cylinder will nullify the calibration.

A1.8 Calibration Test to Determine Alternative Operating Pressure \( P_1 \) – Type A Meter – The range of air contents which can be measured with a given meter can be doubled by determining an alternative operating pressure \( P_1 \) such that the meter reads half of the calibration reading, \( K \), (Equation A1.3). Exact calibration will require determination of the expression factor at the reduced pressure in Section A1.5. For most purposes the change in expression factor can be disregarded and the alternative operating pressure determined during the determination of the regular operating pressure in Section A1.7.

A1.9 Calibration Test to Check the Air Content Gradations on the Pressure Gauge, Type B Meter – Fill the measuring bowl with water as described in Section A1.3. Screw the short piece of tubing or pipe furnished with the apparatus into the threaded petcock hole on the underside of the cover assembly. Assemble the apparatus. Close the air valve between the air chamber and the measuring bowl and open the two petcocks on holes through the cover assembly. Add water through the petcock on the cover assembly having the extension below until all air is expelled from the second petcock. Pump air into the air chamber until the pressure reaches the indicated 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 the petcock not provided with the tube or extension on the underside of the cover. Remove water from the assembly to the calibrating vessel controlling the flow, depending on the particular meter design, by opening the petcock provided with the tube or extension and cranking the air valve between the air chamber and the measuring bowl, or by opening the air valve and using the petcock to control the flow. Perform the calibration at an air content that is within the normal range of use. If the calibration vessel (Section A1.2) has a capacity within the normal range of use, remove exactly that amount of water. With some meters the calibrating vessel is quite small and it will be necessary to remove several times that volume to obtain an air content within the normal range of use. In this instance, carefully collect the water in an auxiliary container and determine the amount removed by weighing to the nearest 0.1 percent. Calculate the correct air content, \( R \), by using Equation A1.2. Release the air from the apparatus at the petcock not used for filling the calibration vessel and if the apparatus employs an auxiliary tube for filling the calibration container, open the petcock to which the tube is connected to drain the tube back into the measuring bowl (Note A7). At this point of the procedure the measuring bowl contains the percentage of air determined by the calibration test of the calibrating vessel. Pump air into the air chamber until the pressure reaches the initial pressure line marked on the pressure gauge, close both petcocks in the cover assembly, and then open the valve between the air chamber and the measuring bowl. The indicated air content on the pressure gauge dial should correspond to the percentage of air determined to be in the measuring bowl. If two or more determinations show the same variation from the correct air content, the dial hand shall be reset to the correct air content within 0.1 percent. If the dial hand was reset to obtain the correct air content, recheck the initial pressure mark as in Section A1.5.2. If a new initial pressure reading is required, repeat the calibration to check the accuracy of the graduation on the pressure gauge described earlier in this section. If difficulty is encountered in obtaining consistent readings, check for leaks, for the presence of water inside the air chamber (Figure 2), or the presence of air bubbles clinging to the inside surfaces of the meter from the use of cool, aerated water. In this latter instance, use de-aerated water, which can be obtained by cooling hot water to room temperature.
Note A8 – If the calibrating vessel is an integral part of the cover assembly, the petcock used in filling the vessel should be closed immediately after filling the calibration vessel and not opened until the test is complete.
METHODS OF SAMPLING AND TESTING

MOISTURE CORRECTION FOR CONCRETE MIX DESIGNS
(Montana Method)

1 Scope:

1.1 This method describes the procedure for making a correction in the moisture requirement of a concrete mix, due to absorbed moisture. Concrete mix designs furnished by the Materials Bureau are based on saturated surface dry aggregate and the moisture correction must be made when concrete is produced. Moisture may be figured on a one sack basis or on a one cubic meter (one cubic yard) basis. A typical Class “A” mix for one sack of cement would be shown as: 94 - 213 - 190 - 190.

2 Moisture Requirement:

2.1 The example mix makes no mention of water as it is controlled by slump requirements, but for the purpose of mix designs it is assumed to be 22.7 liters (6 gallons) per sack of cement. This 22.7 liters (6 gallons) is not a specified amount to be used, and in fact, a lesser amount will most generally obtain the required slump. 22.7 liters (6 gallons) per sack is the maximum net amount of water which may be used under Montana Specifications, and includes free water in excess of water absorbed by the aggregates, additives, air entraining agents, etc.

2.2 It is impossible for the Materials Bureau to know in advance what the moisture condition of the aggregate stockpiles will be when concrete is ultimately produced, so the following procedure is to be observed.

3 Absorption of Fine Aggregate:

3.1 Fine aggregate will always require an adjustment for the moisture content. A moisture content will seldom be less than 3% or more than 7%. The moisture correction is made by multiplying the aggregate weight shown by 100 plus the percentage of moisture in the material. If a moisture determination shows that the sand has 5% total moisture, multiply the sand weight shown by 105%. This would make the new sand weight about 102 Kg (224 pounds), which would total about 5 Kg (11 pounds) of water (free and absorbed) or approximately 5.0 liters (1-1/3 gallons) per sack.

3.2 If the fine aggregate has an absorption of 1.0%, the amount of water that can be counted as free water (mix water) would be computed as follows:

3.2.1 5.0% (total moisture) minus 1.0% (absorption) equals 4.0% free water.

3.2.2 96.6 Kg (213 lbs.) x .04 (4% free water) equals approximately 3.9 Kg (8.5 lbs.) free water.

3.2.3 Therefore, only 3.9 Kg (8.5 lbs.) of water would be counted as mix water.

4 Absorption of Coarse Aggregate:

4.1 Medium and coarse aggregate are open-graded and free draining and will not usually require a correction for moisture unless they are being used directly from a washing plant or are being heated with live steam.

4.2 If a correction is deemed necessary, the procedure shown for fine aggregate will be followed.

5 Corrected Mix:

5.1 The corrected mix would be: 94 - 224 - 190 - 190.
METHOD OF SAMPLING AND TESTING
MT 120-04
METHOD FOR FIGURING YIELD OF CONCRETE
(Montana Method)

1 Scope:

1.1 This method is intended to be used to figure the yield of a mix design for Portland cement concrete, either by a one sack mix or a one cubic foot mix, when critical values of the various ingredients are known.

1.2 An example of a basic mix design, as furnished by the Materials Bureau might be:

Class “A” = 94 – 213-190-190

1.3 Cubic yard quantities are obtained by multiplying the individual weights, as shown, by the number of sacks of cement required for the class of concrete being used.

2 Requested Number of Sacks of Cement

2.1 The number of sacks of cement required for various classes of concrete are as follows:

Plain

<table>
<thead>
<tr>
<th>Class</th>
<th>Sacks of Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A &amp; D</td>
<td>5.5</td>
</tr>
<tr>
<td>AD &amp; DD</td>
<td>6.5</td>
</tr>
<tr>
<td>AP &amp; DP</td>
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<td>7.0</td>
</tr>
<tr>
<td>AC &amp; DC</td>
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</table>

With Additive

<table>
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<tr>
<td>ADA &amp; DDA</td>
<td>5.9</td>
</tr>
<tr>
<td>APA &amp; DPA</td>
<td>5.5</td>
</tr>
<tr>
<td>Pre. Min</td>
<td>6.5</td>
</tr>
</tbody>
</table>

3 Water:

3.1 Water content is not stated as it is controlled by slump requirements but for mix design purpose it is always figured as 6 gallons per sack, total water, in the mix. This figure includes free water added, moisture in material, additives, air entraining agents, etc.

4 Total Paste:

4.1 Total paste for a one sack mix need not be figured as it is always the same, 1.28 cubic feet, arrived at as follows: 6 gals. Water divided by 7.5 (gallons of water per cubic foot) equals .80 cubic foot. One bag of cement, 94 pounds, divided by 196.6 pounds (solid weight of cement) = .48 cubic foot. Then .80 + .48 =1.28 cubic feet. This figure multiplied by sacks of cement used gives the total paste in a cubic yard of concrete.

5 Fine Aggregate:

5.1 Volume of fine aggregate is determined by dividing the weight of sand used in the mix by the solid weight of that sand which is the specific gravity of the sand multiplied by the weight of water per cubic foot (62.4). Example:

Specific gravity of sand 2.61 x 62.4 =162.9 solid weight of sand. 213 pounds sand divided by 162.9 = 1.3075 cubic feet of sand per sack of cement.

1.3075 times the total number of sacks of cement used will give the volume of sand in one cubic yard of concrete.
Medium and Coarse Aggregate:

The volume of the medium and coarse aggregates are figured in the same manner as the sand or they may be combined and figured as total coarse aggregate which is usually done. The total coarse aggregate in the mix above is 380 pounds. The specific gravity of the medium aggregate is 2.61 and the specific gravity of the coarse aggregate. 380 pounds of aggregate divided by 163.5 = 2.324 cubic feet of rock per sack of cement.

Yield:

Yield may be figured on a one sack basis or on a one cubic yard basis, whichever is most convenient. Yield is the sum of the solid volumes of all of the ingredients, which go to make a yard of concrete, including air.

One sack mix:

Paste - 6 gallons water, 1 sack cement = 1.28 cubic feet
Sand - 213 pounds divided by 162.9 = 1.3075 cubic feet
Rock - 380 pounds divided by 163.5 = 2.3240 cubic feet
Total volume for each sack of cement = 4.9115 cubic feet

Total Volume per cubic yard = 4.9115 x 5.5 = 27.0132 cubic feet.

One Cubic Yard Mix:

Paste - 5.5 x 1.28 = 7.04 cu. ft
Sand - 5.5 x 213 = 1172 lbs. Sand divided by 162.9 = 7.1945 cu ft.
Rock - 5.5 x 380 = 2090 lbs. Coarse divided by 163.5 = 12.7828 cu. Ft.
Total volume per cubic yard = 27.0173 cu. Ft.

Data for Figuring Concrete Yield:

The following data is recorded as a convenient reference:

Cement:

8.1.1 Weight per sack = 94 lbs
8.1.2 Absolute volume per sack = .48 cu ft
8.1.3 Specific gravity = 3.15

Water:

8.2.1 Weight per gallon = 8.33 lbs.
8.2.2 Weight per cu. Ft. = 62.4 lbs
8.2.3 Gal. Per cu ft. = 7.5

Volume of varying Amounts of Water in Cubic Feet:

8.4.1 1 gal = .1334 5 gals = .667 5.5 gals = .734 6.0 gals = .80
Volume of Varying Amounts of Water Plus 1 Sack of Cement in Cubic Feet:

9.1 5.0 gal. + 94 cement = 1.15
9.2 5.5 gal. + 94 cement = 1.21
9.3 6.0 gal. = 94 cement = 1.28

Weight of Materials Divided by Specific Gravity x Weight of Water = Volume of Materials:

\[
\frac{150}{2.65 \times 62.4} = \frac{150}{165.4} = 0.90711 \text{ cu. ft.}
\]

Specific Gravity x Weight of Water x Volume of Material = Weight of Material:

\[
2.65 \times 62.4 = 165.4 \times 0.90711 = 150 \text{ pounds.}
\]

Percent Voids:

\[
\frac{\text{S. G.} \times 62.355 - \text{Wt.} \times 100}{\text{S. G.} \times 62.355}
\]

\[
2.65 \times 62.355 = 165.24 - 105 = 60.24 \text{ divided by } 165.24 = 36.46 \%
\]

Solid Weights of Material for Various Specific Gravities:

<table>
<thead>
<tr>
<th>S. G.</th>
<th>Solid WT</th>
<th>S. G.</th>
<th>Solid WT</th>
<th>S. G.</th>
<th>Solid WT</th>
<th>S. G.</th>
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