

METHODS OF SAMPLING AND TESTING
MT 101-13
MAKING AND CURING CONCRETE COMPRESSIVE AND
FLEXURAL STRENGTH TEST SPECIMENS
IN THE FIELD
(Modified AASHTO T 23 and M 205)

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 1 – Tamping Rod Requirements

Diameter of Cylinder or Width of Beam, In. (mm)	Rod Dimensions*	
	Diameter, in. (mm)	Length of Rod, in. (mm)
<6 (150)	3/8 (10)	12 (300)
6 (150)	5/8 (16)	20 (500)
9 (225)	5/8 (16)	26 (650)

*Rod tolerances length \pm 4 in. (100 mm) and diameter \pm 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-fourth the diameter of the cylinder mold or one-fourth 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 2 – Molding Requirements by Rodding

Specimen Type and Size	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
<i>Cylinders:</i>		
Diameter in. (mm)		
4 (100)	2	25
6 (150)	3	25
9 (225)	4	50
<i>Beams:</i>		
Width in. (mm)		
6 (150) to 8 (200)	2	Sec 8.3.2
>8 (over 200)	3 or more equal depths, each not to exceed 6 in. (150 mm)	Sec 8.3.2

Table 3 – Molding Requirements by Vibration

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

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. (150mm), 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 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.

9.1.1 *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 60° to 80°F (16° to 27°C), 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 68° and 78° F (20° to 26° C). Various procedures are capable of being used during the initial

9 Curing: (continued)

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 60°F (16°C) and higher when stored near 80°F (27°C). 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 ± 3°F (23 ± 2°C) 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 68° and 86°F (20° and 30°C) 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 $73^{\circ} \pm 3^{\circ}\text{F}$ ($23 \pm 2^{\circ}\text{C}$) 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 $73 \pm 3^{\circ}\text{F}$ ($23 \pm 2^{\circ}\text{C}$) 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.

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