

MnDOT Guidance for Concrete Cylinders

Strength tests are required for one or both of the following purposes:

Standard Strength Cylinders

The Engineer will use “**Standard strength**” test specimens (cylinder or beams) to verify if a concrete mixture meets minimum compressive strength or flexural strength requirements.

- Because this is a concrete materials test, the strength test specimens are cured under ideal conditions.
- The strength specimens are most often cured and tested 28-days from the date made.
- However, some mix designs require curing/testing out to 56-days after the date of casting.
- MnDOT requires averaging three (3) standard strength cylinders to determine compressive strength tests results. This applies to both 4 in x 8 in and 6 in x 12 in cylinders.

Control Strength Cylinders

The Engineer will use “**Control strength**” test specimens (cylinder or beams) to determine the strength of concrete within the poured concrete structure.

- Because control strength cylinders or beams are used to determine in-place concrete strengths, the control cylinder or beams are cured with and in the same manner as the poured concrete structure. Thus, ensuring the concrete strength test results are relatively representative of the poured concrete structure.
- Control cylinders are tested at varying ages depending upon the concrete operations.
- **NOTE:** ASTM C31 refers to “control” cylinder or beams as “field cured” cylinder or beams.

Responsibilities for Cylinders

MnDOT Spec 2461.3.G.5 outlines Agency and Contractor responsibilities for standard (28-day) strength cylinders for acceptance.

Agency and Contractor Responsibilities					
Cylinder Type	Supply of Cylinder Molds	Fabrication of Cylinders per Structure/Unit	Supply of Initial and Intermediate Curing Environment	Monitoring Temperature during Initial and Intermediate Curing	Transport of Cylinders
Standard (28-day)	Agency	Agency	Contractor	Contractor *	Agency
Control	Agency	Agency (First 3) Contractor (Any Additional)	N/A	N/A	Agency
* Recommend Agency Record Temperature at Least Once Daily					

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Casting Cylinders

Follow ASTM C31, Section 9. Molded Specimens, for casting concrete cylinders for uniform and comparable results.

When making the test specimens:

- Place molds on a level, firm foundation in a sheltered place where they can remain undisturbed and protected from direct sunlight and maintained at temperatures of 60 - 80°F [16 - 27°C] for the initial 16-48 hours.
- The supporting surface on which specimens are stored shall be level to within ¼ in. per ft.
- 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.
- If temperatures are outside the range of 60 - 80°F, or a casting site is not available in the immediate proximity of the work, transport the sampled concrete to a casting location where the specimens will remain at 60 - 80°F undisturbed for the initial 16-48-hour period. Re-mix by hand shoveling prior to casting the test cylinder.

Cylinder Mold Requirements

- White is MnDOT's standard color for concrete cylinder molds & cylinder mold covers.
- MnDOT Concrete Engineer requires use of flat cylinder mold covers.
- All three 4" by 8" standard strength test cylinders are all made from the same concrete sample. The same applies to sets of 6 in x 12 in cylinders.

Cylinder Size	Maximum Aggregate Size	 Standard Strength Cylinders	Control Cylinders
4 in x 8 in	≤ 1.25 inch	Sets of 3	1
* 6 in x 12 in	>1.25' inch	Sets of 3	1
* 6" by 12" cylinder molds required when nominal aggregate size exceeds 1 ¼". Refer to Schedule of Materials Control for Number of Sets Required			

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Numbering Sets of Cylinders

- ID sets of cylinders sequentially, 1.1 – 1.2 – 1.3, 2.1 – 2.2 – 2.3 etc.
- Prefixes and suffixes are allowed, i.e. BR 1.1 – 1.2 – 1.3
- Keep the same whole numbers for control cylinders and continue increasing numbers after the decimal.
- For example, an additional two control cylinders were made when casting the standard strength cylinders (2.1-2.2-2.3), the control cylinders would then continue the numbered as 2.4 and 2.5.
- Control Cylinders require separate ID cards for each cylinder.
- Control strength cylinders are not averaged.

Curing and Handling Standard (28-day) Strength Cylinders

For concrete to develop its full strength potential, ensure the standard strength test specimens are stored in a moist condition within specified temperature range and transported with care.

Moisture loss is detrimental to the concrete strength. Prevent/control moisture loss by:

- Placing the specimen in an insulated box/coolers containing moisture
- Covering with polyethylene sheeting or bags
- Covering with a minimum of 4 thicknesses of wet burlap
- Covering with waterproof paper
- **Placing caps on plastic cylinder molds**
- **NOTE: Do not allow standard strength cylinder or beams to dry to a whitened state.**

Transport strength test specimens with tightly affixed cylinder mold covers to prevent moisture loss to the tops of the cylinders.

MnDOT Defined Curing Periods for Standard Strength Cylinders

The Concrete Engineer has broken down the curing requirements into three curing/time periods:

1. Initial Curing
2. Intermediate Curing
3. Final Curing

Further explanation of acceptable curing practices for each of the curing periods is explained below:

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Initial Curing Period Standard (28-day) Strength Cylinders				
Curing Period (MnDOT Spec 2461.3.G.5.b)	Curing Duration 	Acceptable Curing Temperature Range	Storage Condition	Storage Location
Initial Curing	After final finishing to 48 hours	60 °F to 80 °F † [16 °C and 27 °C]	Moist environment in molds with caps in place	In a shaded area
<p>* Delivered to the laboratory after initial curing is allowed</p> <p> Standard Strength Cylinders can be moved/transported 16 hours after casting. High Early Strength Cylinders can be moved/transported 12 hours after casting.</p> <p>† For concrete with a specified strength of 6000 psi [40 MPa] or greater, the initial curing temperature is 68 °F to 78 °F [20 °C and 26 °C].</p>				

Initial Curing Period

Follows ASTM C31, paragraph 10.1.2 for initial curing of standard strength concrete cylinders.

- Initial curing period begins after final finishing of the standard strength cylinders
- After final finishing, the initial cure lasts up to a maximum of 48 hours.
- Initially cured at ambient temps from 60° to 80° F, in a shaded area.
- Initially cured in a moist environment.
 - Cylinder covers affixed creates a suitable moist cure environment.

Ambient temperatures < 60°F or > 80°F requires a manufactured curing environment maintained between 60°F and 80°F.

- Transport sampled concrete to a temp controlled field office or field warming shack and cast cylinders.
- Place concrete cylinders in an insulated cooler with warm water, cool water or ice when ambient temperatures are moderately outside the 60°F to 80°F requirements.
- Place newly cast cylinders in an insulated box with a source of moisture (coffee can or cake pan filled w/water) and heat source capable of maintaining 60 °to 80° F (small electric heater).

Additional considerations regarding concrete mixtures with a specified strength of 6000 psi (40 MPa) or greater:

- Heat generated during the early ages may raise the temperature above the required storage temperature.
- The initial curing temperature is 68°F to 78°F
- Immersion in water may be the easiest method to maintain the required storage temperature.

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- Early-age strength test results may be lower when stored at 60°F (16°C) and higher when stored at 80°F (27°C).
- On the other hand, at later ages, test results may be lower for higher initial storage temperatures.

Collect and transport concrete cylinders from the Initial Cure site.

- For concrete mixtures listed in Table 2461-6, Concrete Engineer recommends transporting concrete cylinders to the “Intermediate” or “Final” curing site 16-24 hours after final finishing.
- High Early (HE) concrete mixtures listed in Table 2461-7, Concrete Engineer recommends transporting concrete cylinders to the “Intermediate” or “Final” curing site in 12-24 hours after final finishing.

Intermediate Curing Period Standard (28-day) Strength Cylinders				
Curing Period (MnDOT Spec 2461.3.G.5.b)	Curing Duration 	Acceptable Curing Temperature Range	Storage Condition	Storage Location
Intermediate Curing *	16 hours to 7 days	60 °F to 80 °F † [16 °C and 27 °C]	In molds with caps in place	Curing tanks with water
* Skip intermediate curing if the cylinders are delivered to the laboratory after initial curing.				
Standard Strength Cylinders can be moved/transported 16 hours after casting. High Early Strength Cylinders can be moved/transported 12 hours after casting.				

Intermediate Curing Period

MnDOT Concrete Engineer has established the intermediate curing requirements to alleviate the need to make daily cylinder deliveries to the laboratory.

Store Cylinders in water-filled temperature controlled storage tanks.

- Provide a curing tank with adequate capacity for concrete test cylinder curing, As per Specification, 2031.3.C “Special Requirements,”
- Maintain the water in the curing tanks between the temperature of $\geq 60^\circ\text{F}$ and $\leq 80^\circ\text{F}$, As per, 2461.3.G.5.b “Curing and Transporting Standard Strength (28-day) Strength Specimens,”
- The inspection staff should record water-tank temperatures daily.
- **Store cylinder in water tanks with cylinder covers affixed.**

NOTE: Do not extend intermediate storage time beyond 7-days after final finishing.

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MnDOT Concrete Cylinder Identification Card (Standard)

- Completely fill out the MnDOT's Concrete Cylinder Identification Card.
- One ID card per set of (3) cylinders is required.
- Include the following test results:
 - Air content
 - Slump (if required)
 - Concrete temperature
 - Air temperature
 - Batch ticket number that corresponds with the load of concrete tested.
- **Transport the standard strength test specimens to the laboratory.**

Cylinder ID Card for Standard (28-day) Strength Cylinders

MnDOT TP-02409-02 (8-15) LAB I.D. NUMBER		Minnesota Department of Transportation Concrete Cylinder Identification Card		
Date Made: <u>9/29/2015</u>		Field I.D.: <u>119</u>		
Spec No.: <u>2461</u>		Spec Yr: <u>2016</u>		
Email reports to: <u>clay.pitts@state.mn.us</u>				
<input checked="" type="checkbox"/> S.P.	Proj. No. <u>1020-30</u>	Br. / TH No. <u>394</u>		
<input type="checkbox"/> S.A.P.	Submitted By <u>Tom Sands</u>	Tel. No. <u>(612) 345-6789</u>		
<input type="checkbox"/> Co./City	Proj. Eng. <u>Clay Pitts</u>	Res. Eng. <u>Bob Loams</u>		
<input type="checkbox"/> Maint.	County/City <u>Hennepin</u>	District No.: <u>Metro</u>		
Mix No. (3F52, etc.) <u>3G52</u>		Part of Structure <u>Light Pole Foundation</u>		
Source of Ready Mix <u>QuickMix – Mill City</u>		<input type="checkbox"/> Mobile Mixer	<input type="checkbox"/> Job Mix	
Required Strength <u>4500</u>		Testing Age: <input checked="" type="checkbox"/> 28 days <input type="checkbox"/> 56 days <input type="checkbox"/> other _____ hrs/days		
Remarks _____				
Field Test Results:				
Ticket No. <u>67394304</u>	Concrete Temp (°F) <u>73</u>	Air Temp (°F) <u>59</u>	% Air Content <u>6.2</u>	Slump (In.) <u>4</u>

Transporting Test Cylinders to the Laboratory

- Transport standard strength test specimens **with** the cylinder mold covers affixed.
- Ensure both the project number and cylinder ID number are clearly written on the side of the cylinder mold.
- During transportation of cylinders, protect with a suitable cushioning material to prevent damage from jarring. During cold weather, protect the cylinders from freezing with suitable insulation material.
- Transport the cylinders to the laboratory with securely placed tight fitting plastic caps on plastic molds, wrapping the specimens in plastic, wet burlap, or by surrounding them with sand to prevent moisture loss. **In no case shall the transportation time exceed 4 hours.**

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Table 562.1 Final Curing Period for Standard (28-day) Strength Cylinders				
Curing Period (MnDOT Spec 2461.3.G.5.b)	Curing Duration 	Acceptable Curing Temperature Range	Storage Condition	Storage Location
Final Curing	≥ 16 hours to 28 days	73.5 °F ± 3.5 °F [23.0 °C ± 2.0 °C]	Stripped from molds and cured in moist condition	Laboratory Moist Curing Room or Storage Tank

Final Curing Period

Follows ASTM C31, paragraph 10.1.3 for final curing of standard strength concrete cylinders.

MnDOT Specification requires starting the “Final” curing period no later than 7-days after making/casting standard strength cylinders

- Delivery to the laboratory after the 16 to 48 hours “Initial” curing period is an acceptable practice
- The Laboratory will maintain the Standard Strength test specimens at a temperature of 73.5°F ± 3.5°F and at 100% humidity or in water tanks

Curing and Handling Control Cylinders

Often the specifications require minimum time requirements and/or strengths prior to loading the concrete structures. In order to determine the real time concrete strengths MnDOT uses concrete control cylinders to dictate or “control” when the cast in place concrete has achieved strength to progress work.

NOTE: It is critical to store control cylinders in a condition that most represents the newly placed concrete structure. MnDOT recommends storing cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. It is critical to protect all surfaces of the cylinders, cylinder covers should also be used on control cylinders.

Curing High Early Strength Control Test Cylinders

Cure high early strength control cylinders in the same manner as other control cylinders.

- MnDOT will allow storage of high early (HE) control cylinders in an insulated storage compartment, provided the Contractor monitors both the temperature inside the insulated storage compartment and internal temperature of the cast in-place concrete structure.
- The temperature inside the storage compartment needs to be the same or less than the corresponding concrete structure.

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- Insulated storage compartment temperatures that rise **5° F** greater than in-place concrete temperatures, invalidates the control cylinders compression test results.
- Initially, extra control cylinders should be cast and cured with the cast in place structure. Use these extra control cylinders if/when the insulated storage compartment temperature exceeds the **5° F** differential requirements.

MnDOT Concrete Cylinder Identification Card (Control)

- Completely fill out the MnDOT's Concrete Cylinder Identification Card.
- One ID card per control cylinder is required.
- Include the following test results:
 - Air content
 - Slump (if required)
 - Concrete temperature
 - Air temperature
 - Batch ticket number that corresponds with the load of concrete tested.
- **Transport the standard strength test specimens to the laboratory.**

Cylinder ID Card for Control Cylinders

MnDOT TP-02409-02 (8-15) LAB I.D. NUMBER	Minnesota Department of Transportation Concrete Cylinder Identification Card Date Made: <u>10/6/2015</u> Field I.D.: <u>122</u> Spec No.: <u>2461</u> Spec Yr: <u>2016</u> Email reports to: <u>clay.pitts@state.mn.us</u>										
<input checked="" type="checkbox"/> S.P. Proj. No. <u>1020-30</u> Br. / TH No. <u>98765</u> <input type="checkbox"/> S.A.P. Submitted By <u>Tom Sands</u> Tel. No. <u>(612) 345-6789</u> <input type="checkbox"/> Co./City Proj. Eng. <u>Clay Pitts</u> Res. Eng. <u>Bob Loams</u> <input type="checkbox"/> Maint. County/City <u>Hennepin</u> District No.: <u>Metro</u> Mix No. (3F52, etc.) <u>3GHE52</u> Part of Structure <u>Full Depth Repair</u> Source of Ready Mix <u>QuickMix – Mill City</u> <input type="checkbox"/> Mobile Mixer <input type="checkbox"/> Job Mix Required Strength <u>3000</u> Testing Age: <input type="checkbox"/> 28 days <input type="checkbox"/> 56 days <input checked="" type="checkbox"/> other <u>4</u> hrs (<u>days</u>) Remarks _____											
Field Test Results:											
<table border="1" style="width: 100%; text-align: center;"> <tr> <th style="width: 20%;">Ticket No.</th> <th style="width: 20%;">Concrete Temp (°F)</th> <th style="width: 20%;">Air Temp (°F)</th> <th style="width: 20%;">% Air Content</th> <th style="width: 20%;">Slump (In.)</th> </tr> <tr> <td>82996</td> <td>72</td> <td>64</td> <td>6.8</td> <td>3</td> </tr> </table>	Ticket No.	Concrete Temp (°F)	Air Temp (°F)	% Air Content	Slump (In.)	82996	72	64	6.8	3	
Ticket No.	Concrete Temp (°F)	Air Temp (°F)	% Air Content	Slump (In.)							
82996	72	64	6.8	3							

NOTE: Check the box provided on the back of the Concrete Cylinder Identification Card when the field personnel would like to have the lab compression test results phone to them. "Please Phone Cylinder Results" check box **should only be used for control strength cylinders**, not for reporting routine cylinder test results.