G.6 Estimating Concrete Strength by the Maturity Method

The Engineer will allow the maturity method to determine development of concrete strength to open to traffic loading or form removal. Use of this method requires the establishment of a relationship between concrete strength and the computed maturity index (using the Nurse-Saul method) for a specific concrete mixture. Use this method, in accordance with this Specification and the "Estimating Concrete Strength by the Maturity Method" procedure available from the MnDOT Concrete Engineering website to estimate the in-place strength of the concrete.

G.6.a Development of Strength-Maturity Relationship

The Engineer will allow development of the maturity curve in a laboratory, at the concrete plant or at the project site.

Determine the strength development criteria based on the type of concrete in accordance with the following:

(1) For concrete pavement: 2301.3.O, "Opening Pavement to Traffic"
(2) For concrete pavement repairs: 2302.3.B.4, "Opening to Construction Equipment and Traffic"
(3) For concrete structures: 2401.3.G, "Concrete Curing and Protection"
(4) For sidewalks, driveway entrances and curb and gutter, a minimum of 3000 psi is required

Until an acceptable strength-maturity relationship (maturity curve) is established and approved by the Engineer, use concrete beams or cylinders to open to traffic loading or form removal.

G.6.a(1) Procedure

Develop the strength-maturity relationship (maturity curve) to estimate concrete strength in accordance the "Estimating Concrete Strength by the Maturity Method" procedure available from the MnDOT Concrete Engineering Website and the following:

(1) Cast and cure 12 beams or 15 cylinders, plus 2 additional beams or cylinders to embed temperature sensors
(2) Establish the maturity curve using the Concrete Maturity-Strength Development form.
(3) Test three (3) strength specimens at testing ages specified in Table 2461.3-3 for the type of concrete Work.

Table 2461.3-3
Chronological Testing Ages of Strength Specimens

Type of Concrete	Testing Ages *
Concrete Pavement as defined in 2301, "Concrete Pavement"	Test at least 2 sets of strength specimens before and the remaining sets after the anticipated opening strength
Normal Strength Concrete as defined in 2461, "Structural Concrete"	1, 2, 3, 7 and 28 Calendar Days
High-Early (HE) Concrete as defined in 2461, "Structural Concrete"	12 hours, 1, 2, 7 and 28 Calendar Days
Ultra High-Early (UHE) Concrete per Contract	3, 4 and 8 hours, 1 and 14 Calendar Days
* The Contractor may adjust the testing ages if approved by the Engineer, in conjunction with the Concrete Engineer.	

G.6.a(2) Equipment

Provide the following equipment for determining the maturity:

(1) Maturity meter or temperature sensor and data logger with a secure means of collecting, measuring, recording and storing temperature data that is unalterable
(2) Beam or cylinder molds for development of the maturity curve and other concrete making and testing equipment

G.6.a(3) Estimating In-Place Strength Using Maturity

Place concrete maturity meters or temperature sensors within the concrete in accordance with Table 2461.3-4.

Table 2461.3-4
Maturity Meter or Temperature Sensor Placement and Frequency

Maturity Application	Placement	Frequency
Concrete Paving	Embed at approximately mid-depth and approximately 18 (but no less than 12) inches from the edge of the pavement.	Place one for each day within the last hour of placement. Place additional sensors as necessary.
Full Depth Concrete Pavement Repairs	Embed at approximately mid-depth and approximately 18 (but no less than 12) inches from the edge of the pavement.	Place one for each day within the last hour of placement. Place additional sensors as necessary.
Partial Depth Concrete Repairs	Embed at least 2 inches from the surface.	Place one for each day within the last hour of placement. Place additional sensors as necessary.
Sidewalk, Driveway Entrances, Curb and Gutter	Embed at approximately mid-depth and approximately 18 (but no less than 12) inches from the edge of the pavement.	Place one for each day within the last hour of placement. Place additional sensors as necessary.
Concrete Structures	Attach to the reinforcing steel near the edge of the exposed surface using a non-metallic fastener.	Place at least two for each concrete element.

The computed maturity results from each sensor will only apply to concrete placed under the following conditions:

(1) The same mix designation and the same Project as the test location
(2) Placed on the same day and on, before, or within 50 feet after placement of the sensor
(3) Cured under conditions similar to those of the test location

Record the maturity index (or temperature readings and calculate the maturity index) on the Maturity-Field Data form or as approved by the Concrete Engineer.

G.6.b Opening to Traffic Loading or Form Removal

Prior to opening the concrete to traffic loading or removal of the forms, submit the maturity index results to the Engineer. The Engineer will review and verify the maturity index has reached the required TTF of the maturity curve developed for that concrete mix.

G.6.c Validation of Strength-Maturity Relationship for Continued Use

When utilizing the maturity method on the project, perform a strength-maturity test for each mix used to ensure the concrete strength correlates with the current maturity-strength relationship (maturity curve) as follows:

(1) Notify the Engineer at least 24 hours in advance of the specimen casting for the validation testing.

(2) The Contractor or their Representative is responsible for casting, curing and testing three (3) beams or cylinders plus one additional beam or cylinder to embed the sensor. Cast the validation specimens at the concrete plant or at the Project Site.
   (a) If the maturity curve was initially developed in a laboratory, perform a validation strength-maturity test on the first day of concrete placement.
   (b) For slipform concrete paving utilizing a dedicated portable batching plant, perform a validation strength-maturity test once every 15 Calendar Days during plant production.
   (c) For all other concrete, if the maturity curve was developed greater than 30 Calendar Days before the start of construction or has not been validated for 30 Calendar Days, perform a validation strength-maturity test on the first day of concrete placement. The Concrete Engineer will allow a single validation strength-maturity test fabricated at the concrete plant to validate a maturity curve used on multiple projects. Validation strength-maturity tests fabricated at the project site only validate the maturity curve for that Project.

(3) The Contractor or representative is responsible for providing the curing environment for the specimens in accordance with the "Estimating Concrete Strength by the Maturity Method" procedure available from the MnDOT Concrete Engineering website.

(4) Perform the validation testing as close as practically possible to the maturity value determined to represent the opening, loading or form removal strength criteria. Record the results of the tests on the Concrete Maturity-Strength Validation form and provide to the Engineer within 24 hours of the test completion.

(5) If a specimen is obviously defective (i.e., out of round, not square, damaged due to handling), discard the specimen. If an individual specimen is greater than 10 percent for cylinders or 15 percent for beams outside the average of three specimens, consider the specimen defective and discard. When two of the specimens are defective, evaluate a new batch, unless additional acceptable specimens are available.

The Engineer may direct additional validation testing as necessary.

The Engineer will review the validation strength-maturity test results and determine if the validation testing confirms the maturity curve in accordance with Table 2461.3-5.

Table 2461.3-5
Evaluation of Validation Strength-Maturity Test Results

If the actual strength-maturity test falls:	Result	Action
Within the 10% limits of the maturity curve	Maturity curve verified	Continue using the current maturity curve
> 10% higher than the maturity curve	The Department will not consider the maturity curve verified, but will continue to allow use of the maturity curve.	Develop a new maturity curve at the discretion of the Contractor.
> 10% lower than the maturity curve	The maturity curve will no longer be acceptable.	1. Develop a new maturity curve. 2. The Engineer will not allow the maturity method for that concrete mix until a new maturity curve is developed.

G.6.d Changes in Concrete Mixture

Perform a validation strength-maturity test in accordance with 2461.3.G.6.c, "Validation of Strength-Maturity Relationship," if any of the following changes occur:

(1) Change in mixture proportions greater than 5 percent by weight
(2) Increase in the water-cementitious materials ratio by more than 0.02
(3) Change in the cementitious source

(4) Change in the class of coarse Aggregate Material

Evaluate validation strength-maturity test results in accordance with Table 2461.3-5.

G.6.e Maturity Meter Calibration

Calibrate maturity meters yearly to ensure proper operation and temperature sensing in accordance with the "Estimating Concrete Strength by the Maturity Method" procedure available from the MnDOT Concrete Engineering website.