Tex-426-A, Estimating Concrete Strength by the Maturity Method

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Section 1

Overview


This test method provides a procedure for estimating concrete strength by means of the maturity method. The maturity method is based on strength gain as a function of temperature and time.

The maturity method consists of three steps:
◆ develop strength-maturity relationship
◆ estimate in-place strength
◆ verify strength-maturity relationship.

The Nurse-Saul “temperature-time factor (TTF)” maturity index shall be used in this test method, with a datum temperature of -10 °C (14 °F).

Units of Measurement

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

Apparatus

The following apparatus is required:

- If the maturity meter has input capability for datum temperature, verify that the proper value of the datum temperature has been selected prior to each use.

- Commercial battery-powered maturity meters that automatically compute and display the maturity index in terms of a temperature-time factor, or both a temperature-time factor and equivalent age, are acceptable.
  - Batteries in maturity meters are to be adequately charged prior to use. The same brand and type of maturity meters shall be used in the field as those used to develop and verify the strength-maturity relationship.
  - A minimum of one maturity meter shall be provided for each thermocouple location. The Engineer may allow the use of a multi-channel meter when several thermocouples are in close proximity.
  - Meters shall be protected from excessive moisture and theft, and the LCD display shall be protected from direct sunlight.

NOTE 1: Commercial maturity meters use specific values of datum temperature or activation energy in evaluating the maturity; thus the displayed maturity index may not be the same for different brands and types of maturity meters.

- Thermocouple wire grade greater than or equal to 20 awg.
Section 3 — Procedures

Calibration

Verify calibration prior to use on a project and, as a minimum, on an annual basis by placing a thermocouple in a controlled-temperature water bath and recording whether the indicated result agrees with the known temperature of the water bath. At least 3 different temperatures, for example, 5 °C, 25 °C, and 45 °C (41 °F, 77 °F, 113 °F), are recommended. The temperature recording device shall be accurate to within ± 1 °C (2 °F).

Developing Strength-Maturity Relationship

The following table outlines the procedure for developing strength-maturity relationship.

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>For every concrete design that will be evaluated by the maturity method, prepare a minimum of 20 cylinders or beams according to Test Method “Tex-447-A, Making and Curing Concrete Test Specimens.” Additional specimens should be cast to avoid having to repeat the procedure. The mixture proportions and constituents of the concrete shall be the same as those of the job concrete whose strength will be estimated using this practice. The minimum size of each batch shall be approximately 3 m³ (4 yd³).</td>
</tr>
<tr>
<td>2</td>
<td>Fresh concrete testing for each batch shall include concrete placement temperature, slump, and air content according to test methods “Tex-415-A, Slump of Portland Cement Concrete” and “Tex-414-A, Air Content of Freshly Mixed Concrete by the Volumetric Method” or “Tex-416-A, Air Content of Freshly Mixed Concrete by the Pressure Method.”</td>
</tr>
<tr>
<td>3</td>
<td>Embed thermocouples in at least two specimens using two maturity meters. Place thermocouples 50 to 100 mm (2 to 4 in.) from any surface. Connect the thermocouples to maturity meters. Do not disconnect meters. Data collection must be uninterrupted.</td>
</tr>
<tr>
<td>4</td>
<td>Moist-cure the specimens in a water bath or in a moist room according to Test Method “Tex-447-A, Making and Curing Concrete Test Specimens.”</td>
</tr>
<tr>
<td>5</td>
<td>Perform compression or flexural tests at ages of 1, 3, 5, 7, 14, and 28 days according to Test Method(s) “Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens” or “Tex-448-A, Flexural Strength of Concrete Using Simple Beam Third-Point Loading” as appropriate. Additional specimens and test ages may be evaluated at the discretion of the Engineer. Test three specimens at each age and compute the average strength. <strong>NOTE:</strong> The specimens with thermocouples are to be tested last. If a specimen is obviously defective (for example, out of round, not square, damaged due to handling), discard the specimen. If an individual cylinder strength is greater than 10 percent (15 percent for beams) outside the average of three specimens, the specimen can be considered defective and be discarded. When two of the three specimens are defective, a new batch must be evaluated unless additional acceptable specimens are available.</td>
</tr>
</tbody>
</table>
### Developing Strength-Maturity Relationship

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<tr>
<td>6</td>
<td>At each test age, record the individual and average values of maturity and strength for each batch on a permanent data sheet. (Contact CST/M&amp;P for sample record log.)</td>
</tr>
</tbody>
</table>
| 7    | Plot the average strengths as a function of the average maturity values, with data points shown. Using a computer spreadsheet program such as Microsoft Excel, calculate a logarithmic best-fit curve through the data. Record the equation of the curve as well as the R2 value. The resulting curve is the strength-maturity relationship to be used for estimating the strength of the concrete mixture placed in the field.  
**NOTE:** When developing the strength-maturity relationship, the spreadsheet software allows the Engineer to develop the corresponding maturity equation that defines the strength-maturity relationship and an R2 value to fit the strength-maturity relationship. The R2 value indicates the reliability of the strength-maturity relationship. Expected results should produce an R2 value of no less than 0.90. When the reliability is less than 0.90, the Engineer should carefully examine the data for “outliers,” faulty beam breaks, or faulty maturity readings. The Engineer should use judgment to determine if certain points should be discarded, retested, or whether the entire strength-maturity relationship should be regenerated. |
| 8    | The plot, with data points, of the strength-maturity relationship for each concrete mixture shall be circulated and signed by the Contractor or his representative and reviewed by the District Materials Engineer or the Construction Division, Materials & Pavements Section. Provide copies to the Engineer, the District Materials Laboratory, and the Contractor. |

### Estimating In-Place Strength

#### The following table outlines the steps for estimating in-place strength.

<table>
<thead>
<tr>
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</table>
| 1    | A TxDOT inspector should be present at the concrete plant when placing concrete that will be evaluated by the maturity method.  
For Structural and Pavement Concrete, the inspector shall be at the plant on a daily basis, and shall verify batching operations using a checklist.  
For Miscellaneous Concrete, the inspector shall be at the plant a minimum of once per week on a random basis, and shall verify batching operations using a checklist.  
**NOTE:** Any alteration in mix proportions or source or type of any material, in excess of those tolerable by batching variability, requires the development of a new strength-maturity relationship prior to its use. This includes a change in type, source, or proportion of cement, fly ash, coarse aggregate, fine aggregate, or admixtures. A change in water-to-cementitious material ratio greater than 0.05 requires the development of a new strength-maturity relationship. (See “Inspector’s Batch Plant Checklist” for example checklist.) |
| 2    | Prior to or at the time of concrete placement, install thermocouples at the frequency specified in the pertinent item of work.  
Install a minimum of two thermocouples, using two maturity meters, at locations in the structure that are critical in terms of structural considerations or exposure conditions as directed by the Engineer.  
Place thermocouples 50 to 100 mm (2 to 4 in.) from any formed surface or at mid-depth of the section for sections less than 50 mm (4 in.).  
**NOTE:** Thermocouples may be tied to reinforcing steel, but should not be in direct contact with the reinforcing steel or formwork. |
3 When verification tests are required or when maturity will be used to estimate strength for
removal of structurally critical formwork or falsework, or for steel stressing or other safety-
related operations, specimen strength tests shall be done according to
‘Verifying Strength-Maturity Relationship.’

4 As soon as practical after concrete placement, connect and activate the maturity meter(s).
*NOTE:* Do not disconnect meters until the required maturity values are achieved. Data collection
must be uninterrupted.

5 Record maturity data on a permanent data sheet. The permanent data sheet shall show the
Required Strength and the Required TTF for the specified Operation. (Contact CST/M&P for
sample record log.)

6 When the maturity is at a value that is equal to or greater than the required strength for that
concrete mixture, as determined by the strength-maturity relationship, record the maturity value
and when appropriate as per Step 3, verify the specimen strength according to ‘Verifying
Strength-Maturity Relationships.’

Then remove the meter and clip the thermocouple wires at the concrete surface.
Verifying Strength-Maturity Relationship

*NOTE:* When maturity is used to estimate strength for removal of structurally-critical formwork or falsework, or for steel stressing or other safety-critical operations, the specimen strength tests may be included as Verification Tests.

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<tr>
<td>1</td>
<td>Make a minimum of either three cylinders or three beams according to Test Method(s) “Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens” or “Tex-448-A, Flexural Strength of Using Simple Beam Third-Beam Loading” respectively, at the frequency specified in the pertinent item of work.</td>
</tr>
<tr>
<td>2</td>
<td>Fresh concrete testing shall include concrete placement temperature, slump, and air content according to test methods “Tex-415-A, Slump of Portland Cement Concrete” and “Tex-414-A, Air Content of Freshly Mixed Concrete by the Volumetric Method” or “Tex-416-A, Air Content of Freshly Mixed Concrete by the Pressure Method.”</td>
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<td>3</td>
<td>Embed thermocouples in two specimens. Place thermocouples 50 to 100 mm (2 to 4 in.) from any surface. Connect the thermocouples to maturity meters. Do not disconnect meters. Data collection must be uninterrupted.</td>
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<td>4</td>
<td>Moist-cure the specimens in a water bath or in a moist room in accordance with Test Method “Tex-447-A, Making and Curing Concrete Test Specimens.”</td>
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<td>5</td>
<td>Perform compression or flexural strength tests, as appropriate, when the specimen achieves the TTF (within 10%) corresponding to the design strength, or when the required TTF of the member is achieved in the field if estimating strength for removal of structurally critical formwork or falsework or for steel stressing or other safety-related operations. Test the three specimens according to Test Method(s) “Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens” or “Tex-448-A, Flexural Strength of Concrete Using Simple Beam Third-Point Loading” and compute the average strength of the specimens. If a specimen is obviously defective (for example, out of round, not square, damaged due to handling), discard the specimen. If an individual cylinder strength is greater than 10 percent (15 percent for beams) outside the average of three specimens, the specimen can be considered defective and be discarded. When two of the three specimens are defective, a new batch must be evaluated unless additional acceptable specimens are available.</td>
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<td>6</td>
<td>Compare the average strength determined from the specimen breaks to the strength predicted by the strength-maturity relationship. The average strength of the specimens shall be within the verification tolerance specified for the item of work. When three (3) consecutive verification test results fall between 5% and 10% above or below the predicted strength based on the S-M Relationship, the condition does not warrant a redo of the S-M Relationship; the condition, however, requires a mathematical adjustment to the S-M Relationship. Adjust the curve using the adjustment feature of the Excel spread sheet program. When a single verification test exceeds the 10%, a new S-M Relationship curve must be developed according to specification requirements.</td>
</tr>
</tbody>
</table>
Section 4

Forms

The following forms may be used:

♦ Record Log to Develop Strength-Maturity Relationship
♦ Record Log for Field Maturity Data with Sample Data
♦ Record Log to Verify Strength-Maturity Relationship
♦ Inspector’s Batch Plant Checklist.