1. SCOPE

1.1. The following method covers the procedure for developing a maturity curve Time-Temperature-Factor (TTF) for concrete applications.

2. SUMMARY OF DETERMINATION OF CONCRETE MATURITY

2.1. Estimating the in-place concrete strength is a two step procedure:
   - The first step is establishing a relationship between the maturity TTF and the concrete strength.
   - The second step is the temperature monitoring of the placed concrete.

3. SIGNIFICANCE AND USE

3.1. The maturity TTF approach provides a simple and useful means of estimating the strength gain of concrete at early ages (generally less than 7 days). Its greatest benefit is that it allows engineers, inspectors and contractors to assess the in-place strength of concrete pavement or structure. This valuable information can then be used to help determine the appropriate time for opening pavement to traffic, sawing joints and stripping forms. It currently is used by NDOR for acceptance testing for pavement repairs and high early concrete.

4. EQUIPMENT NEEDED TO DEVELOP A MATURITY CURVE

4.1. Equipment needed to develop a curve.
   - 4x8 cylinder molds with lids (10 min. - 14 max.)
   - Scoop, rod and strike off
   - Cure box, insulated blanket
   - Type T thermocouple wire (24 gauge), mini connectors (blue), screwdriver, wire snips
   - Maturity meter & plastic bag
   - Concrete compression machine

5. PROCEDURE FOR DEVELOPING MATURITY CURVE

5.1. A maturity curve can be developed at the ready mix plant or on the project. The fresh concrete test will be performed by the project inspector. The air and slump shall meet the required specifications for the concrete mix. Since there is a relationship between the w/c ratio and strength, the concrete used to develop the maturity-strength relationship should be at or near the maximum w/c ratio expected during production.

5.2. Cast a minimum of ten (4 in. x 8 in.) concrete cylinders as per ASTM C 31.

5.3. Embed a thermocouple wire in two separate cylinders to monitor the temperature, in case one wire fails. Embed each wire at approximately mid-depth of the cylinder. These cylinders will not be tested for compressive strength.

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5.4. Cure the cylinders accordingly at the test site to best represent the concrete placement. Cylinders cast for paving or structures may be cured in an insulated box, curing blankets, on grade, near the structure or in a trailer (Figure 1.). Cylinders cast for Pavement Repair (PR) and High Early (HE) concrete shall be cured in an insulated box until the time of compressive strength testing (Figure 2.).

![Figure 1. Cylinders cast from paving](image1)

![Figure 2. Cylinders cast from Patching](image2)

5.5. Immediately after the cylinders have been moved to their final location for curing there are two methods that can be used to calculate the TTF.

5.5.1. Maturity Meter

This is the preferred method for monitoring the concrete temperature. After the cylinders have been moved to their final location, connect the mini-connectors to Channel 1 (CH 1) and to Channel 2 (CH 2) on the maturity meter and start recording (Maturity Meter datum temperature setting shall be set to -10 C). The age to test the first set of cylinders is determined from when the maturity meter was started and the initial temperature taken. Temperature reading will be in Celsius and rounded up to the next whole number. For your own documentation, record the initial temperature and the time it was taken. Cylinders for PR concrete may be moved 2.5 hours after casting. Cylinders for HE and Paving concrete may be moved 8 hours after the concrete has reached final set. For reference, the following are approximate ages when to perform compressive strength testing on your first set of cylinders;

- PR concrete may begin at three or four hours depending on the time of year and the type of cement used.
- HE concrete may begin at twelve to twenty-four hours.
- Paving concrete may begin at twenty-four hours.

The TTF is computed by the maturity meter. The TTF is read from the maturity meter at the same age the cylinders are tested for compressive strength. There is a correlation between the TTF and cylinder strength. The age of tests shall be spaced, so the cylinders tested are performed at somewhat consistent intervals. This data is then entered into the NDOR Maturity Method Form. (Appendix A-1)
5.5.2. Hand Calculated Method

An alternative method for monitoring the temperature of the concrete is by the digital hand held thermometer. Connect the mini connectors one at a time to a digital hand held thermometer and designate them as Channel 1 (CH 1) and Channel 2 (CH 2) then take the initial temperature. Record the time the initial temperature was taken for each designated channel. The temperature reading will be in Celsius and rounded up to the next whole number. This method of calculating the TTF by hand shall be performed at each age that a set of cylinders are tested. The Nurse-Saul Equation (Equation 1) is used by NDOR for calculating the TTF by hand calculation (Example 1) or by Field Data Spreadsheet (Figure 3). Both the TTF and cylinder strength will be reported in the NDOR Maturity Method Form (Appendix A-1).

\[
M(t) = \sum (T_a - T_o) \Delta t \\
M(t) = \text{Time Temperature Factor (Maturity) at age } \Delta t \\
T_a = \text{Average temperature of the concrete during time interval } \Delta t \\
T_o = \text{Datum temperature (-10° C)} \\
\Delta t = \text{A time interval (Hours)}
\]

Equation 1. Nurse –Saul Equation

Example 1: The initial temperature of concrete is 20° C when placed, and 3 hours later it was 50° C.

- \( T_a = (20 + 50) / 2 = 35 \)
- \( T_o = \text{always add 10 to the average. When subtracting a negative number add it.} \)
- \( \Delta t = \text{elapsed time is 3 hours since the initial temperature was taken} \)

\[
M \text{ (TTF)} = \sum (35 + 10) \times 3 \\
M \text{ (TTF)} = 135
\]

The Field Data Spreadsheet (Figure 3) is a tool that can be used to generate the TTF. Enter the project information at the top of the spreadsheet then proceed to enter the date, time, age in hours and temperature. The spreadsheet will generate the Sum TTF by using the Nurse-Saul Equation. The sum TTF shall correspond with a set of cylinders at an age tested. This data will be reported in the NDOR Maturity Method Form (Appendix A-1).
6.0 STEPS FOR PLOTTING THE MATURITY CURVE

The following steps are for entering the data into the NDOR Maturity Method Form (Appendix A-1).

6.1 NDOR Maturity Method Form information.

6.1.1 Required Project information:

- Project number and description
- Control Number
- Contract Number
- Contractor performing the work
- Date maturity curve developed
- Curve number *(The curve number is identified for project use):
  - PR Concrete - Curve No.:
    - 1 – Open *(This will represent 3000 psi)* Refer to Appendix A-2
    - 1 – Acceptance *(This will represent 3500 psi)* Refer to Appendix A-3
  - Paving/HE - Curve No.:
    - 1 – Acceptance *(This will represent 3500 psi)*
  - Structures - Curve No.:
    - 1 – *(This will represent the required strength)*

* For each additional curve developed for a project, number the curves in ascending order. For example; 2-Open, 3-Open, etc.
6.1.2 Required cylinders & TTF data entry
- Load at break (Total machine load in lbs)
- Length (in)
- Diameter (in)
- Age at break (Hrs)
- TTF CH 1 & TTF CH 2 (Values from maturity meter or hand calculated method)
- Cylinder Temperature Average (Not necessary to enter at every age)

6.1.3 Required Mix Information *
- Mix (Class of Concrete)
- Air (Percent)
- Method of Development (Curing method)
- DESIRED COMPRESSIVE STRENGTH (psi)**

(*) Additional mix information may be entered if available
(**) REQUIRED MINIMUM TTF (This corresponds with the desired compressive strength)

6.1.4 Required Comments
- Weather conditions
- Any pertinent information (Additional admixtures, water, etc)
- Enter site manager sample identification information

6.1.5 Signatures
- Certified Representative & Company Name - Required

6.2 Distribution of the developed Maturity Curve
After NDOR or Consultant have developed the maturity curve it is then submitted by email to the Project Engineer (PE), Field Inspectors and NDOR PCC Manager.
- PE and NDOR PCC Manager will place a copy of Maturity Curve in project file.

7.0 STEPS FOR VALIDATING MATURITY CURVE

7.1 Curve Validation
The validation tests shall be conducted to determine if the concrete strength is being represented by the current maturity curve. The following criteria and steps are for validating the maturity curve:
- Curve validation shall be performed approximately every 4 to 6 weeks during normal plant production. Validation is also needed when the original mix design changes and any time.

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NDOR PCC Manager or Consultant will schedule the validation date with the PE and Field Inspectors.

- The Field Inspectors will be requested to make five cylinders on the validation scheduled date.
- The Field Inspector will need to embed two thermocouple wires into two concrete cylinders.
- The certified personnel will request that the Field Inspector document the time the cylinders were cast and the initial temperature of the cylinders. This will be used to generate the TTF as stated in (5.5.1) or (5.5.2) in this document at the age requested.
- Cure the cylinders as stated in (5.4) of this document.
- Test three cylinders as close as possible to the Required Minimum TTF that is from the most current maturity curve being used.

### 7.1.1 Steps for Plotting Validation of Maturity Curve

The following steps are for entering the data into the NDOR Validation of the Maturity Curve – Compressive Strength Development Form. (Appendix A-4)

#### 7.1.2 Required Project information:
- Project number and description
- Control Number
- Contract Number
- Contractor performing the work
- Date maturity curve developed
- Curve number *(The curve number is identified for project use):
  - 1–Validate

  (*) For each additional validation curve developed for a project, number the curves in ascending order. For example; 2-Validate, 3-Validate, etc.

#### 7.1.3 Required Cylinders & TTF data entry
- Load at break (Total Machine load in lbs)
- Length (in)
- Diameter (in)
- Age at break (Hrs)
- TTF CH 1 & TTF CH 2 (Values from maturity meter (5.5.1) or hand calculated method (5.5.2))

#### 7.1.4 Required Mix Information
- Mix (Class of Concrete)
- Air (Percent)
- Slump - *Not Required*
- METHOD OF DEVELOPMENT (Curing method)
- Maximum Difference Allowed (psi)
- PR and Paving Concrete: If the average calculated strength value at the TTF is within the range of ± 350 psi of the original curve, the original curve shall be validated. As shown in the Validation Curve graph and represented by the validation dot displayed between upper and lower limit. However:

  o If the average of the calculated strength value at the TTF falls below the Lower Limit represented by the Validation Curve graph a new curve shall be developed.
  o If the average of the calculated strength value at the TTF falls above the Upper Limit represented by the Validation Curve graph a new curve may be developed.

- Concrete Structures: The range will depend on the mix design strength. This may vary depending on the work performed. If the average calculated strength value at the TTF is within the range of ± 10% of the original curve, the original curve shall be validated, as shown in the Validation Curve graph and represented by the validation dot displayed between upper and lower limit. However:

  o If the average of the calculated strength value at the TTF falls below the Lower Limit represented by the Validation Curve graph a new curve shall be developed.
  o If the average of the calculated strength value at the TTF falls above the Upper Limit represented by the Validation Curve graph a new curve may be developed.

7.1.5 Required Comments
- Weather conditions
- Any pertinent information (Additional admixtures, water, etc)
- Enter sitemanager sample identification information

7.1.6 Signatures
- Certified Representative & Company Name - Required

7.1.7 Distribution of the developed Validation of Maturity Curve
After NDOR or Consultant have developed the maturity curve it is then submitted by email to the Project Engineer (PE), Field Inspectors and NDOR PCC Manager.
- PE and NDOR PCC Manager will place a copy of Maturity Curve in project file.
APPENDIX

Documents for Maturity Method can be found at the following Location: *FCAC\Forms\M&R Forms

*Consultants must have a LAN Account

Document Titles:

- NDOR Maturity Method – Compressive Strength Development
- NDOR Validation of Maturity Curve – Compressive Strength Development
- Maturity Method - Field Data Spreadsheet

Presentation for the Maturity Curve Method of Development can be found at the following location:
NDOR Website \ Materials & Research \ Training Videos & Tutorials \ M&R Division Presentations
http://www.transportation.nebraska.gov/mat-n-tests/divisionPresentations.htm

Document Title:

- Presentation – Maturity Curve Method of Development
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<th>DIAMETER (in)</th>
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**Maturity Curve of Compressive Strength Development**

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**Comments:**

---

**NDOR Maturity Method - Compressive Strength Development**

- Mix Information:
  - Air: __________
  - Aggregate: __________
  - Fines Aggregate: __________
  - Water Reducing Agent: __________
  - Air Admixture: __________

- Method of Development:
  - Desired Comp. Strength (psi):

**Certified Rep. & Company Name:**

**C: PIA, Project Inspector, NDOR District OAM, NDOR PCC Mgr.**

---

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### Maturity Curve Method of Development - Certification

**NDOR Maturity Method - Compressive Strength Development**

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**Curve No. 1**

- **Average TFP:**
- **Nils:**
- **Avg:**
- **Nils:**
- **Avg:**

**Comments:**
- Added Sodium 3050 A, UltraLine.
- See Alamogordo, NM for all information.

**Certified Rep. & Company Name:**
- Tim A. Kress, NDOR
- Nebraska Department of Roads

**Certified Rep. & Company Name:**
- NDOR District QAM, NDOR PCC Mgr.

---

**PROJECT:** 090-2012-129, South 21st Street

**CONTRACT No.: 307**

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MATERIALS & RESEARCH DIVISION
MATURITY CURVE METHOD OF DEVELOPMENT-CERTIFICATION

Created January 2012 ----------- Revised July 2013

A-4