Maturity for Opening PCC Pavements: Iowa Experience

John Smythe, Construction Engineer
Introduction

- Maturity Concept
- Opening Specification
- Procedures
- Challenges
- Conclusions
When Is It Okay to Drive On?

- What strength is needed?
- How do we measure?
Beams/Cylinders vs. Maturity

- Specimen – not actual structure
- Different curing than pavement

- Direct measurement of pavement concrete
- Actual temperature in pavement
Maturity Concept

- Non-destructive test
- Measures strength of in-place concrete
- Early age test
- Not a 28-day strength test
Maturity Concept

- **Time Temperature Factor: TTF**
  - Relationship between thermal history and strength of a concrete

- **ASTM C 1074**
  - Nurse•Saul Equation
    - \[ M \ (°C \cdot hrs) = \Sigma [(T - T_0) \Delta t] \]
      - where \( T_0 = (-10 \ °C) \)
  - Time × Temperature = Maturity (TTF)
### Time for Opening
#### Standard Class C Concrete

<table>
<thead>
<tr>
<th>Pavement Thickness (in.)</th>
<th>Min. Flexural Strength, (psi MOR-CPL)</th>
<th>Min. Time (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;9</td>
<td>500</td>
<td>5</td>
</tr>
<tr>
<td>&lt;9</td>
<td>500</td>
<td>7</td>
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</table>

*Both strength and time conditions must be met.*

*At contractor’s option, maturity method to determine time for opening based on strength requirement only.*
Typical Opening Times Utilizing Maturity

- Summer (>80 °F) 24-48 hours
- Fall/Spring (>55 °F) 36-72 hours
- Late Fall (<50 °F) 48-144 hours
Seasonal Changes

Temperature Effect on Opening Time
NHSX-218-2(57--3H-44)

Date
5/1/01 5/8/01 5/22/01 5/29/01 6/4/01 6/12/01 6/19/01 6/25/01 6/27/01 7/10/01 7/16/01 7/23/01 8/1/01 8/6/01 8/14/01

Temperature (deg F)
30 35 40 45 50 55 60 65 70 75

Time to Open (hours)
30 40 50 60 70 80 90 100

High
Low
Hours
3 days
2 days
Advantages - Contractor

- Use as haul road
- Expedite sub-drain & shouldering
- Accelerate staged construction
- Reduced construction time & Costs
Advantages – Public

- Provide local access early
  - Homeowners
  - Businesses
- Reduced Construction Time & Costs
Maturity Procedure

- Contractor develops strength-maturity curve for mix used
  - Determine required opening TTF
- Contractor takes pavement temperature readings and calculates TTF
  - Submit data to Engineer
  - Engineer responsible for opening section
- Contractor performs monthly curve validation

Agency monitors testing at all steps
Step 1- Develop Strength-Maturity Curve

- Cast 12 beams
- Thermocouple both ends of one beam
- Test 3 beams at 4 different ages
- Develop Strength vs. Maturity curve
Equipment for Opening TTF

- Beam Molds
- Maturity Meter
- Thermocouple Wire
- Testing Machine
- Computer
Maturity Meters
## Iowa DOT Spreadsheet

<table>
<thead>
<tr>
<th>BEAM #</th>
<th>LOAD AT BREAK (lbs)</th>
<th>TABLE VALUE (lbs)</th>
<th>BREAK LOCATION (in)</th>
<th>WIDTH (in)</th>
<th>DEPTH (in)</th>
<th>FLEXURAL COEFFICIENT</th>
<th>FLEXURAL STRENGTH (psi)</th>
<th>AGE AT BREAK (days)</th>
<th>TTF CH 1</th>
<th>TTF CH 2</th>
<th>AVERAGE TTF</th>
<th>BEAM TEMP (AVG)</th>
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### Mix Information
- AIR: 7.8%
- SLUMP: 2 in.
- w/c: 0.42
- MIX: C3WRC20
- FLY ASH SOURCE: Port Neal #4
- CEMENT SOURCE: Ash Grove
- COARSE AGGREGATE SOURCE: Durham Mine
- FINE AGGREGATE SOURCE: Vandalia
- WATER REDUCER BRAND: Daralard 17
- Add. Rate: 2 oz.
- AIR ADMIXTURE BRAND: Daravair 1400
- Add. Rate: 6 oz.
- METHOD OF DEVELOPMENT: Maturity Meter
- Desired Flexural Strength (MOR): 300

### Required TTF: 1058
Step 2- Pavement Temperature Measurement

- Insert thermocouple in pavement
  - □ 18” from edge
  - □ Mid depth
- Minimum of 2 locations per day’s paving
- Read morning and evening minimum
- Calculate pavement TTF
- When pavement TTF > required opening TTF OK to open
Equipment for Measuring Pavement TTF

- Thermal Meter or datalogger
- Thermocouple wire
# Field Data

## Maturity - Field Data

**Project:**

**County:**

**Contractor:**

**Maturity Curve #:**

**Probe #:**

**Date Placed:** 9/11/99

**Mix:** C3W RC20

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**Section of Pavement for Opening by Maturity**

<table>
<thead>
<tr>
<th>From Location:</th>
<th>To Probe Location:</th>
</tr>
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<tbody>
<tr>
<td>104+00</td>
<td>121+50</td>
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<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Age (hours)</th>
<th>Temp (deg C)</th>
<th>TTF at age (deg C-hr)</th>
<th>Sum TTF (deg C-hr)</th>
<th>Air Temp (deg C)</th>
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**TTF:**

Value in box should be equal to or greater than required TTF.

**Contractor Representative**

cc: RCE, Central Materials, Contractor
Step 3- Monthly Curve Validation

- Cast & Cure 3 Beams
- Monitor Maturity until approximate required opening TTF is reached
- Test all 3 beams and average
- Average Strength should be within ±50 psi of opening strength at TTF
  - □ >50 psi okay, more conservative
  - □ <50 psi must develop new curve
Monthly Curve Validation

Assured same basic mix being placed

Weather conditions did not affect TTF, only time of opening
Factors Affecting TTF

- Cement
- Fly Ash
- Admixtures
- w/c ratio
- Mix Type
- Aggregates

A curve validation can be used to allow some changes without establishing a new curve
Challenges to Implementation

- Contractor casting test specimens for acceptance based on strength
- Require new curve for minor mix changes
- Require more expensive field maturity devices
  - Some cost $10 – 25 each
Keys to Implementation

- Contractor flexibility
  - Allow minor mix changes – fly ash, etc.
  - Allow curve validation instead of requiring new curve to be developed
- Utilize thermocouple wire and thermometer or datalogger
  - Minor cost for few inches of thermocouple wire
- Build in Factors of Safety
Factors of Safety

- Iowa uses 500 psi opening
  - Only 300 psi needed (Table previous slide)
- Curve established on concrete with higher air content
- Require curve development at highest w/c ratio expected
  - Iowa allows w/c to change 0.02 higher
- Field maturity tested near edge
  - Temperature lower than at mid slab
Conclusions

- Reliable method of opening PCC pavements
- Many factors affect strength maturity relationship
- May use validations to allow mix changes
- Monthly curve validations give a measure of reliability
- Contractor’s option since 1997 – zero instances of cracking from opening early
Any Questions

About Maturity?