Revisiting (Early Opening) Strengths for Pavement. What Do You Need, and How Do You Measure It?

Matt Zeller (CPAM)
Maria Masten (MnDOT)
Todd Hanson (IowaDOT)

ACPA
AMERICAN CONCRETE PAVEMENT ASSOCIATION

National Concrete Pavement Technology Center

CP Tech Center

Contractor Perspective on Early Opening

Technology Tuesday: Revisiting (early opening) strengths for pavement. What do you need, and how do you measure it?

June 16, 2026

Matt Zeller, PE
Concrete Paving Association of MN

Very Early Loading

Count on Concrete PAVEMENT


STATE TROOPER
MINNESOTA

Drawbacks of Conservative Specs

- We can't build concrete because it takes too long to get traffic on the pavement
  - Roadways
  - Intersections
  - Driveways
  - Sidewalks

Goodhue Co Hwy 6 (2016)

Goodhue Co Hwy 6 (2016)

- MnDOT Initial recommendation R&R
- County agreed to core and review
  - Core and run petrographic analysis. If no excessive cracking; allow to remain in place
  - Diamond grind to remove excessive ruts and patches
  - Warranty for 2 years

MnDOT TH 12 (Paved 1994, photos taken 2016, 20+ years after the fact, no ill effects)

Count on Concrete PAVEMENT

MnDOT TH 12 (Paved 1994, photos taken 2025, 30+ years after the fact, no ill effects)

When Can We Allow Traffic on New Concrete?

- 1/3/7 Days?
- 2000/3000/4000 psi Compressive?
- 150/300/500 psi Flex?

Concrete Pavement Opening Strength

- Why 3000 psi?
  - Where did that come from?
- Vehicle Tire Pressure
  - Car 35 psi +/-
  - Pickup truck 35 psi – 80 psi
  - Semi truck/trailer 75 psi – 135 psi+
- Quote from MnDOT rep regarding MnROAD
  - “… where Matt gets to try out his crazy ideas”

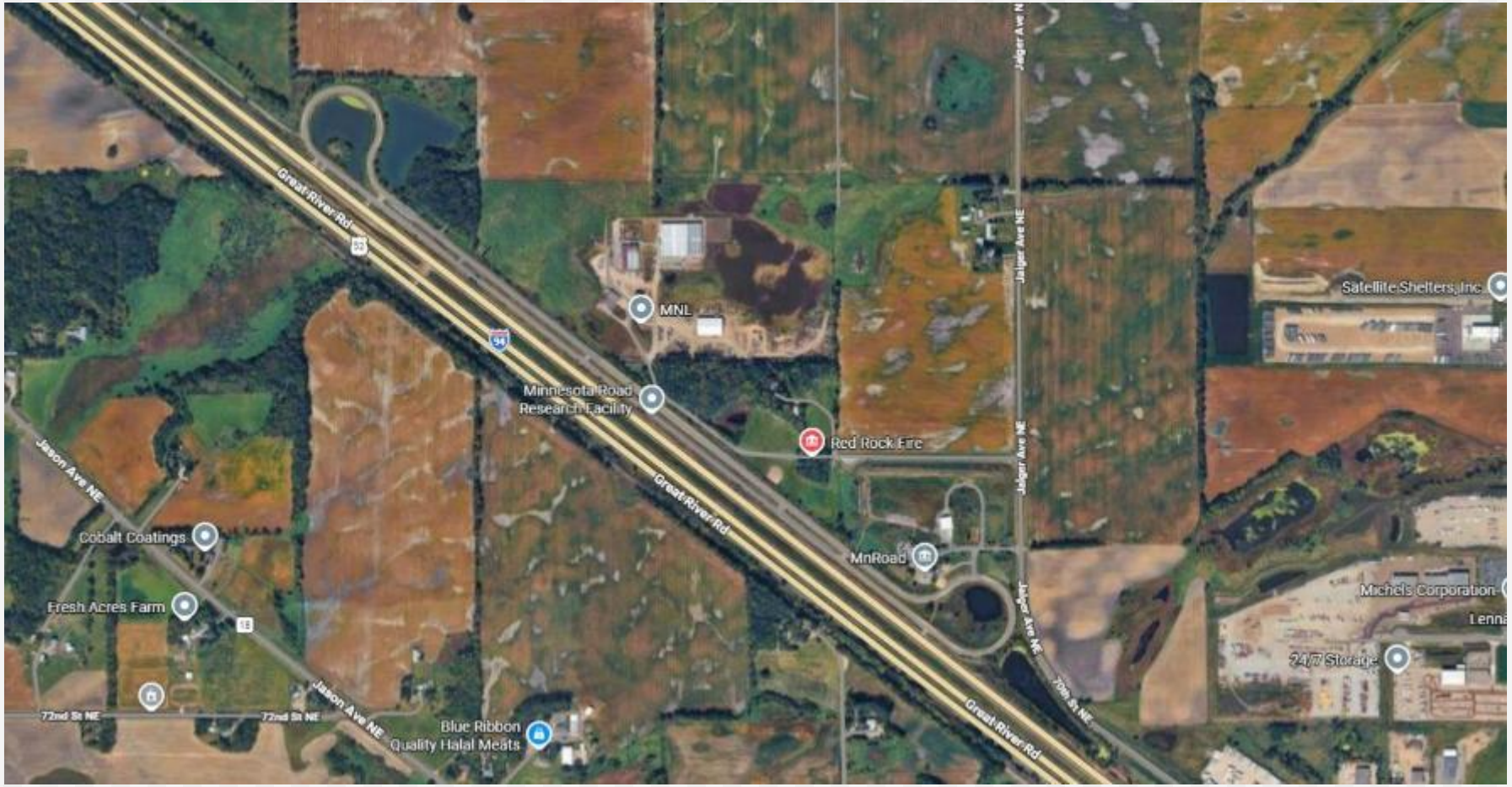
Opening Strength Research Background and Motivation

- Concerns
  - Durability
    - How is the durability of an early loaded pavement affected?
    - How damaging is a rut from an errant vehicle?
    - How damaging is an early load without visible ruts?
  - Related
    - Damage vs strength gain
    - Load repetitions vs damage

MnROAD

Count on Concrete PAVEMENT

MnROAD



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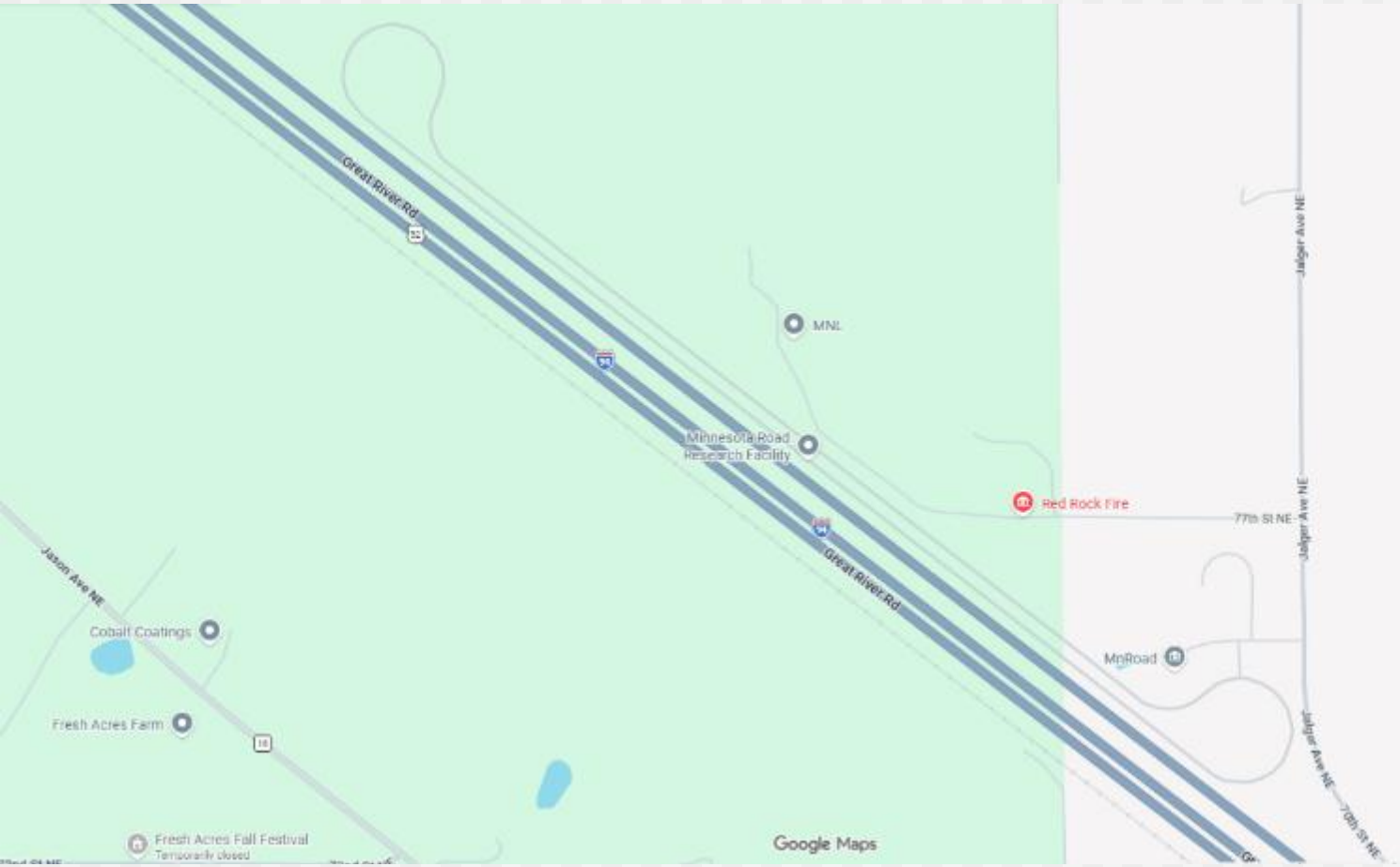
MnROAD


Great River Rd
MNL
Minnesota Road Research Facility
Red Rock Fire
77th St NE
Jäger Ave NE
Great River Rd
Jason Ave NE
Cobalt Coatings
MnRoad
Fresh Acres Farm
Fresh Acres Fall Festival
Temporarily closed
Google Maps

Opening Strength Test

Early loading of Cells 124-424

4,000 lb axle vs 14,000 lb axle loads (1st Cell @ 3hrs)

- https://www.youtube.com/watch?v=ZyNy2UA9mSs&ab_channel=NationalRoadResearchAllianceNationalRoadResearchAlliance

Count on Concrete PAVEMENT

MnROAD – Early Opening (rut)

The Experiment

Concrete Age:

3 hrs.	5-3/4 hrs.	8-1/3 hrs.	10-1/2 hrs.	No Load
124	**224**	**324**	**424**	**524**

Cell x24 Early Loading Sequence		
Maturity (Deg-Hr)	**Flexural (psi)**	**Loads applied to lanes**
100	73	1st Load on Cell 124 (forward and back)
200	196	1st Load on Cell 224, 2nd load on Cell 124
300	267	1st Load on Cell 324, 2nd load on Cell 224, 3rd load on Cell 124
400	318	1st Load on Cell 424, 2nd load on Cell 324, 3rd load on Cell 224, 4th load on Cell 124

Starting Day 2, 5 passes per day for first week

Burnham - NCC 2017

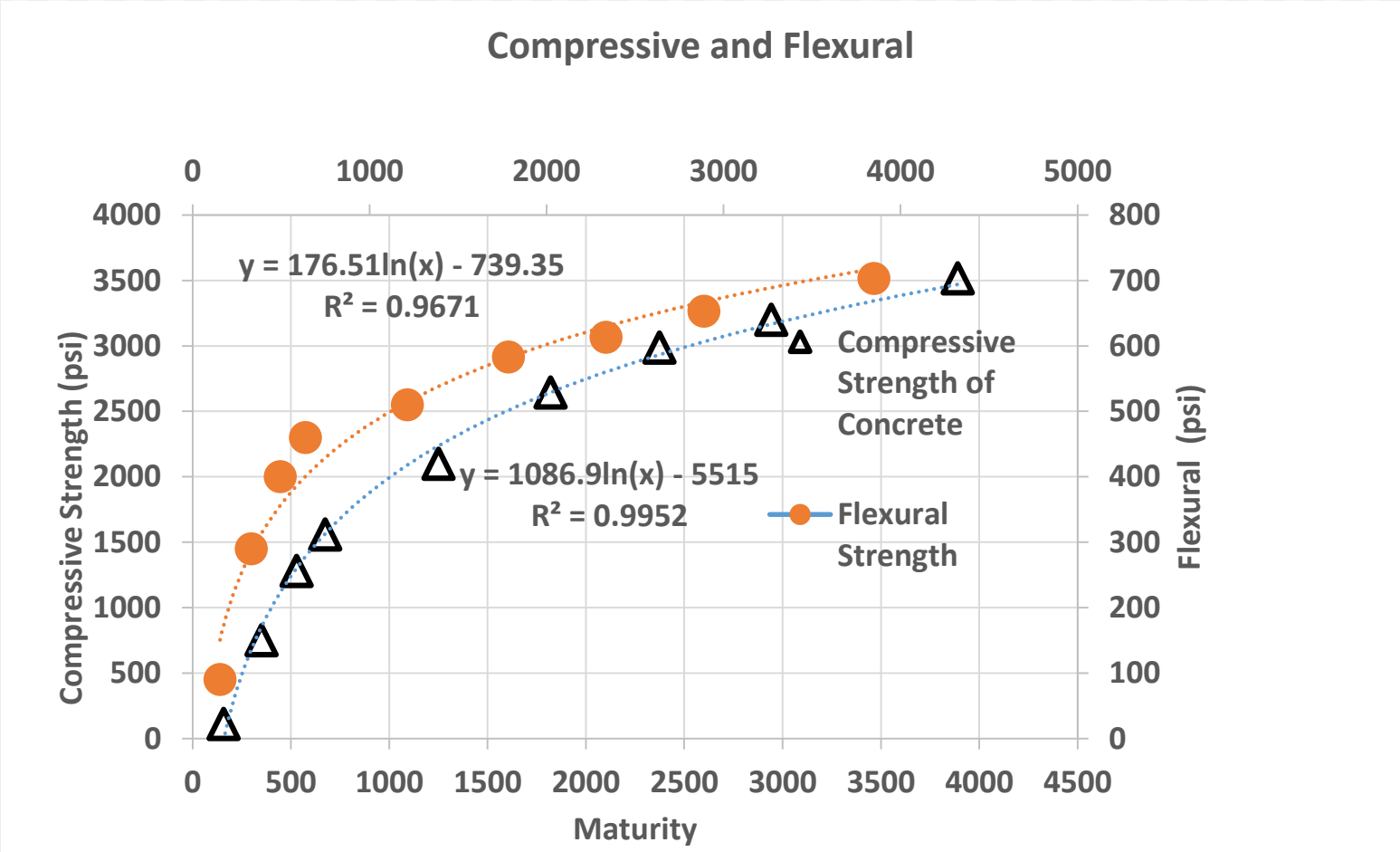
- 6" PCC
- 6" Agg Base
- 1" Dowels
- 15'L x 12'W joints
- 2017 Const.

- https://www.youtube.com/watch?v=A7n-CaONIwU&ab_channel=NRRA

Count on Concrete PAVEMENT

MnROAD Maturity Curve

Hours	TTF
3.0	= 100
5.75	= 200
8.33	= 300
10.5	= 400



Count on Concrete PAVEMENT

Evaluation of Long-Term Impacts of Early Opening of Concrete Pavements

NRRA RIGID TEAM

Authors: Lev Khazanovich, Katelyn Kosar, Haoran Li

A pooled fund project administered by the Minnesota Department of Transportation

Report No. NRRA202111

Count on Concrete PAVEMENT

Conclusions

- Strain gauges picked up first pass only of the snowplow
- No visible damage
- No damage seen in cores
- 80,000 lb. truck, 80 times per day since day 6
- Ruts not fixed; no additional damage visible (until 2023 or so)

MnROAD – Early Opening (Repair)

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Activating Joints on TH 63

TH 63 Joint Activation

Count on Concrete PAVEMENT

TH 63 Joint Activation

ADVANCING CONCRETE PAVEMENT TECHNOLOGY SOLUTIONS

Optimizing Concrete Pavement Opening to Traffic

National Concrete Pavement Technology Center

IOWA STATE UNIVERSITY
Institute for Transportation

Technical Summary
September 2023

Count on Concrete PAVEMENT

Real World Example

- I-94 East of St Paul
- Missed a phase when developing schedule
- Updated schedule based on 300 psi opening
- Gained 15 working days to get back on overall schedule

So, When Are YOU Comfortable Allowing Traffic on New Concrete?

- 1/3/7 Days?
- 2000/3000/4000 psi Compressive?
- 150/300/500 psi Flex?

Count on Concrete PAVEMENT

Thank You – Maria…

Count on Concrete PAVEMENT

Opening Strengths for Pavements – State of Practice and Minnesota DOT

Maria Masten, PE, MnDOT Concrete Engineer

Technology Tuesday Webinar

June 16, 2026

Summary

- State of practice varies widely
- Evidence from research and case studies suggests current opening strengths are overlay conservative
- 300psi flex or 2000psi compressive appear to be appropriate, maybe lower…?
- Excessive strength requirements lead to concrete mixtures that may achieve the required strength quickly but may not be durable in the long term.
- Use conventional mixtures whenever possible, prioritizing low heat, low shrinkage and durability over strength.
- Consider other technology such as maturity to determine opening strength

Concrete Pavement Opening Strength Requirements

Has this been researched in the past?

Opening Strength Requirements

- Accelerated Rigid Pavement Techniques State-of-the-Art Report, Special Project 201 (FHWA, 1994)
  - Construction Traffic – 300 -460 psi flexural depending on k-value and thickness
  - Public Traffic (6-8 inches) – 300-630 psi flexural depending on k-value, thickness and ESALS
  - Public Traffic (8-10.5 inches) – 300-470 psi flexural depending on k-value, thickness and ESALS
- Agency Opening Strength Requirements – 2020 (From a survey by Tara Cavalline)
  - Construction traffic
    - 500 – 650 flexural (2,200 – 3,500 psi compressive)
  - Regular traffic
    - 500 – 650 psi flexural (3,000 – 4,500 psi compressive)
  - Minnesota 350 – 500 psi flexural based on pavement thickness (3,000 psi compressive)

NATIONAL CONCRETE CONSORTIUM

"Moving Advancements into Practice"

MAP Brief Winter 2021-2022

Best practices and promising technologies that can be used now to enhance concrete paving

Optimizing Concrete Pavement Opening to Traffic

www.cptechcenter.org/national-concrete-consortium

Winter 2021

PROJECT TITLE
Optimizing Concrete Pavement Opening to Traffic

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Introduction

For concrete pavements, early opening may be desirable to provide access for local traffic, for construction traffic, or to put the pavement into service. For heavily trafficked pavements, particularly in urban areas, it may be necessary to limit closures to weekends or even overnight. Early opening to traffic needs to be balanced with potential negative impacts, such as early fatigue damage and poor curing.

While conventional paving concretes have been used for short closures, agencies often use special early-opening-to-traffic (EOT) mixtures. The EOT mixtures are subdivided into two categories—mixtures designed to be opened in 6–8 hours and mixtures designed to be opened in 20–24 hours (Van Dam et al. 2005).

In some cases, EOT mixtures may not be necessary. If, for example, the desired time of opening is two or three days, it is possible that conventional paving concrete may achieve sufficient strength in that time. For larger projects, it might also be desirable to consider more than one mixture, such as conventional paving concrete for the bulk of the project and EOT concrete for the final closure placements.

There are current specifications for opening concrete pavements to traffic that are very conservative and lead to unnecessary delays and user costs. Data often do not support such extended time to opening and required opening strengths (Antico et al. 2015a; Freeseman et al. 2016a, 2016b).

Furthermore, while increasing concrete strength may appear at first to be a conservative approach to early opening to traffic, some EOT mixtures have been found to crack early or show poor durability. Therefore, there appears to be considerable risk, as well as higher cost, to using mixtures with high cement contents (Antico et al. 2015b). When developing EOT mixtures for overnight closures, low heat, low shrinkage, and durability are more important than excessively high strength.

Agency Opening Strength Requirements

Many agencies have developed specific EOT concrete paving mixtures or opening specifications. Often, agencies have specified a minimum time to open to traffic (e.g., seven days). Depending on temperatures and mixture constituents, the concrete may attain sufficient strength much earlier.

"On the basis of results obtained from fatigue analyses, it appears that the strengths typically required for early opening to traffic—a flexural strength (MOR) of 300 psi (2.1 MPa) or a compressive strength of 2,000 psi (13.8 MPa)—are reasonable criteria under most conditions for repairs up to 12 feet (3.7 m) in length. The compressive strength is a more accurate indicator of early opening for very short sections 6 feet (1.8 m) or less—because dowel bearing stress is the critical factor in these cases" (Whiting et al. 1997, 181).

A survey of 16 st
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Strength requir
mixtures were ge
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strength and 300
flexural strength

NC² MAP Brief Winter 2021

Published 2021 11 pages

Published 2023 42 pages

NC2 MAP Brief Winter 2021 Recommendations

- For concrete construction, it is often thought that higher strength is more conservative. However, given the experience of early cracking and durability problems with some EOT concrete, particularly mixtures designed for very short closures, that approach may not be conservative for paving. Instead, it is probably better to reduce opening strength requirements and use more durable mixtures.
- Agencies should reduce opening strength requirements. Experience suggests that the opening strengths provided in the tables in the Appendix are reasonable.
- When possible, agencies should use conventional paving mixtures for early opening to traffic, particularly for weekend closures.
- Agencies should consider maturity, UPV/impact-echo, and other NDT technologies rather than curing time for opening pavements to traffic.

Optimizing Concrete Pavement Opening to Traffic Technical Summary 2023 Recommendations

- The current strength requirements set by some state transportation agencies for opening concrete pavements to traffic may be overly conservative.
- Excessive strength requirements lead to concrete mixtures that may achieve the required strength quickly but may not be durable in the long term.
- Instances of significant pavement fatigue damage due to early opening were not reported in the case studies or the literature.
- For opening to traffic, the Strategic Highway Research Program (SHRP C-206) recommends a minimum flexural strength of 300 psi with third-point bending and/or a minimum compressive strength of 2,000 psi.
- Alternatively, a damage-based online tool has been published that uses early opening damage analysis to determine cracking risks for a given pavement system loaded at a given strength (Khazanovich 2021).

Evaluation of Long-Term Impacts of Early Opening of Concrete Pavements

NRRA RIGID TEAM

Authors: Lev Khazanovich, Katelyn Kosar, Haoran Li

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Report No. NRRA202111

Published
October 2021
190 pages

Conclusions

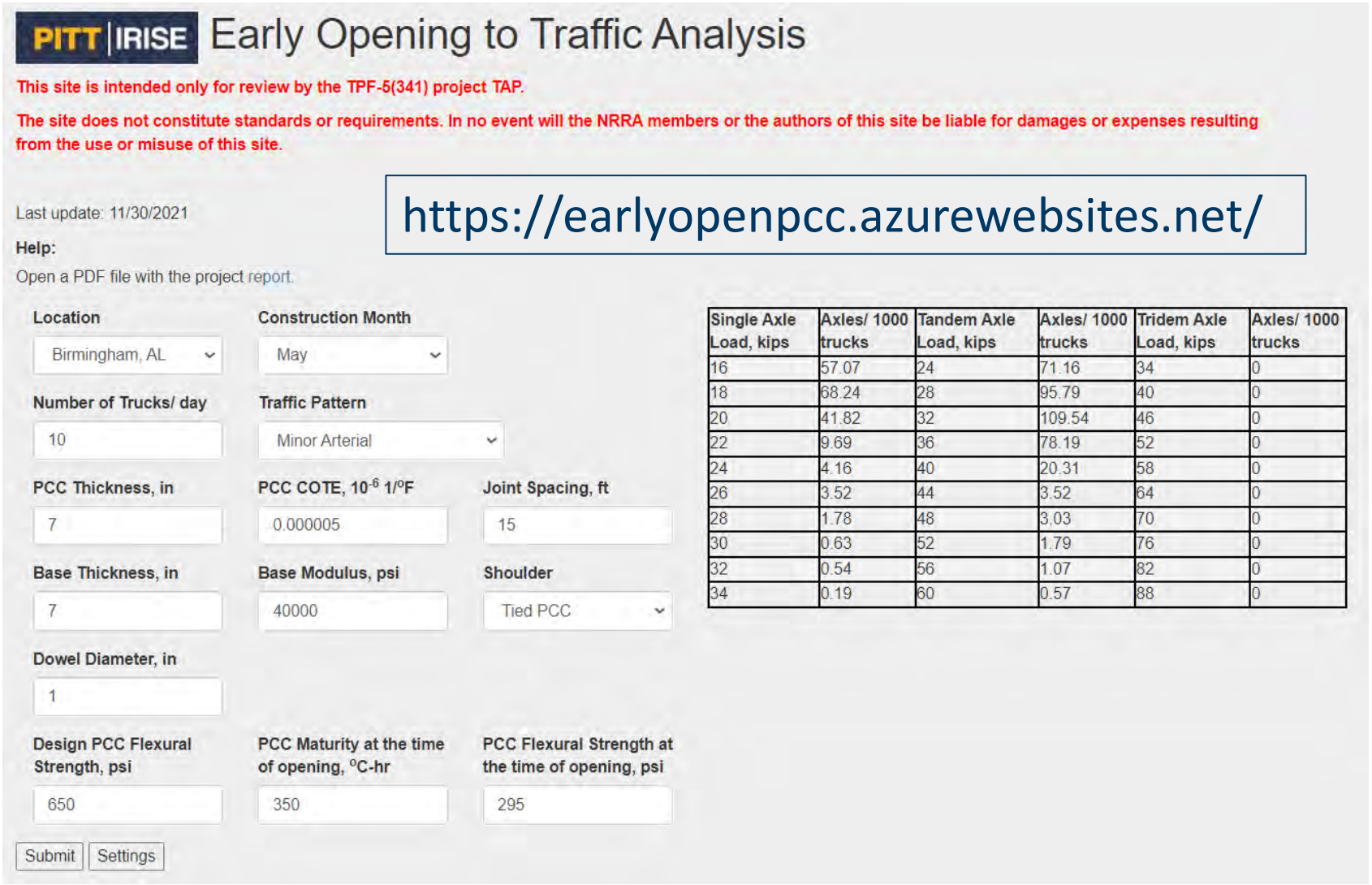
MnDOT/NRRA research supports allowing traffic on concrete pavements earlier:

- Microcracking, carbonation, dowel bar looseness, pavement smoothness were not impacted by early loading
- Extensive analysis of pavement performance, non-destructive testing, and embedded sensors could not identify any long-term damage associated with those early loadings
- Finite Element Analysis and Mechanistic-Based Early Opening Damage Analysis performed
- This experiment showed no damage occurring at an estimated 73 psi flexural strength

- ***Current criteria for traffic opening is overly conservative and that modern concrete pavements can safely open to traffic earlier than currently allowed.***

If you still aren't sure – Web-Based Tool

- Better assess the risk of early opening by accounting for the rate of concrete strength gain, traffic volume, load characteristics, and pavement structure properties.
- Simulations performed with this tool compared well to data gathered at MnROAD.



Single Axle Load, kips	Axles/ 1000 trucks	Tandem Axle Load, kips	Axles/ 1000 trucks	Tridem Axle Load, kips	Axles/ 1000 trucks
16	57.07	24	71.16	34	0
18	68.24	28	95.79	40	0
20	41.82	32	109.54	46	0
22	9.69	36	78.19	52	0
24	4.16	40	20.31	58	0
26	3.52	44	3.52	64	0
28	1.78	48	3.03	70	0
30	0.63	52	1.79	76	0
32	0.54	56	1.07	82	0
34	0.19	60	0.57	88	0

Concrete Pavement Opening Strength Requirements

When is it acceptable to open your concrete pavement to traffic of any type?

Is there one answer?

Flexural or Compressive Strength?

Is there a difference between construction traffic and public traffic?

Is the answer it depends?

MnDOT Requirements for Opening Pavement to Traffic

Strength and Opening to Traffic

- MnDOT does not have a required strength for acceptance for concrete pavement
- MnDOT does have an opening to traffic strength requirement
- One 28-day beam or cylinder is cast per week for information only – historical data used for pavement design

MnDOT Acceptable Methods to Determine Opening Strength

Concrete Strength Specimens

- *Contractor casts 6”x6”x20” beams or 6”X12” cylinders - Quantity determined by Contractor*
- *Cast strength specimens within last hour of paving each day*
- *Fabricated and cured in field by Contractor*
- *Tested by Agency*

Maturity Method - AASHTO T413

- Contractor develops and validates
- Develop the maturity-strength curve – *Test at least 2 sets before and 2 sets after anticipated opening strength will be achieved*
- Estimating the in-place strength – *Place one maturity sensor for each day within the last hour of placement*
- Validating the strength-maturity curve once every 15 calendar days during production – *Cast 4 beams or cylinders*

MnDOT Spec in 2005
Closed Period for New Pavement

- Newly constructed pavement may be opened to use by light vehicles (axle loads of 2700 kg (6000 pounds) or less) 72 hours after the concrete has been placed.
- New pavement shall be closed to use by construction and general public traffic for 7 days or according to the values listed in the Table 2301-A whichever is the shorter.

Table 2301-A
Minimum Strength Requirements for Opening Pavements to Construction and General Public Traffic

Slab Thickness mm (**in.**)	Flexural Strength Mpa (**psi**)
150 (**6.0**)	3.4 (**500**)
165 (**6.5**)	3.4 (**500**)
175 (**7.0**)	3.4 (**500**)
190 (**7.5**)	3.3 (**480**)
200 (**8.0**)	3.2 (**460**)
215 (**8.5**)	3.0 (**440**)
225 (**9.0**)	2.7 (**390**)
240 (**9.5**)	2.4 (**350**)
255 (**10.0**)	2.4 (**350**)
≥265 (≥**10.5**)	2.4 (**350**)

MnDOT Spec Implementation in 2023
Opening to Traffic (2301) Concrete Pavement

- Do not open a new pavement slab to general public traffic or operate paving or other heavy Equipment on it for 7 Calendar Days, or until the concrete has reached a minimum flexural strength of **300** pounds per square inch, or minimum compressive strength of **2,000** pounds per square inch; whichever occurs first.

- *Result: only taking 1-day vs. 2-3 days to get strength, seemed to save a day or more for construction this summer on most projects*

MnDOT Spec by Request – Local Traffic Access

O.2 Local Passenger Traffic Pavement Access

The Contractor may at their own risk allow local passenger traffic (total gross vehicle weight not to exceed 10,000 lbs or equivalent to a ¾ ton pickup truck) to drive across the new pavement slab to access their residence or business after satisfactory completion of all initial joint sawing, excluding early entry sawing, in accordance with 2301.3N.2, "Joint Establishment."

Prior to placement of any concrete pavement, provide a Quality Control Plan to the Engineer for acceptance which provides the Contractor's plan for management of local traffic during concrete pavement placement including a procedure for identification of vehicles allowed to drive across the new pavement.

If any damage occurs, the Engineer will evaluate the concrete pavement in accordance with 2301.3.Q, "*Workmanship and Quality*."

DEPARTMENT OF TRANSPORTATION

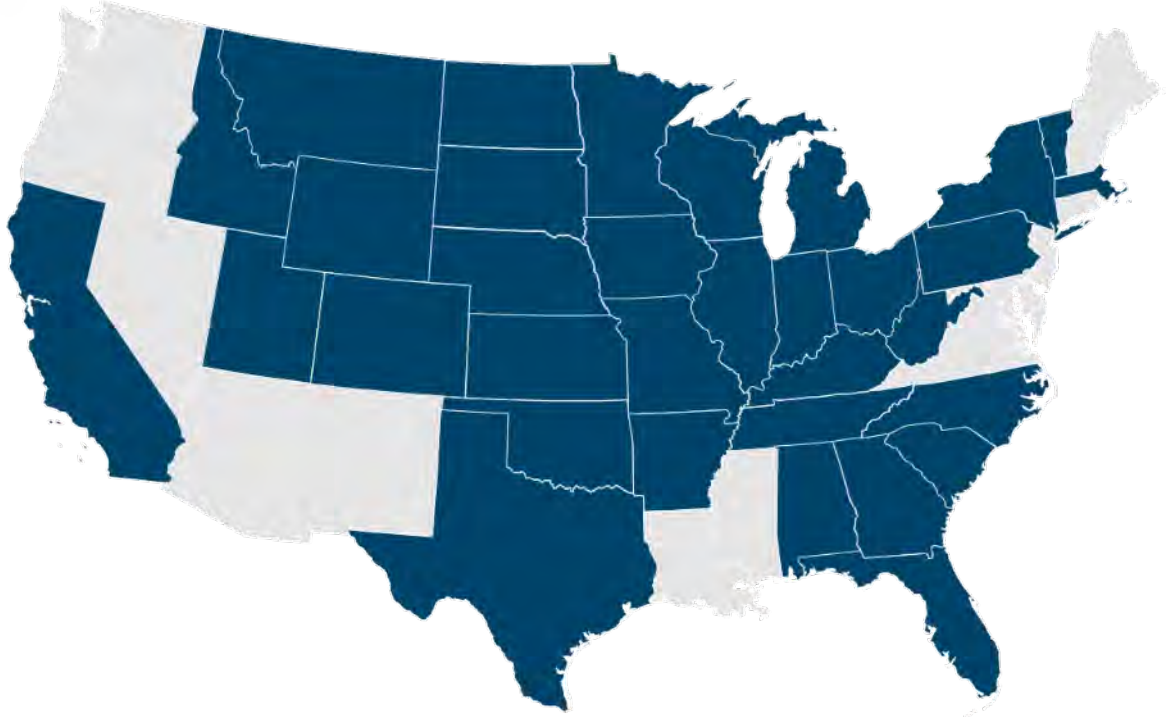
State of Practice - Opening Pavement to Traffic

National Concrete Consortium (NC^2) State of Practice

NCC Fall 2024 State Reports on Strength and Maturity

Monday, August 19, 2024

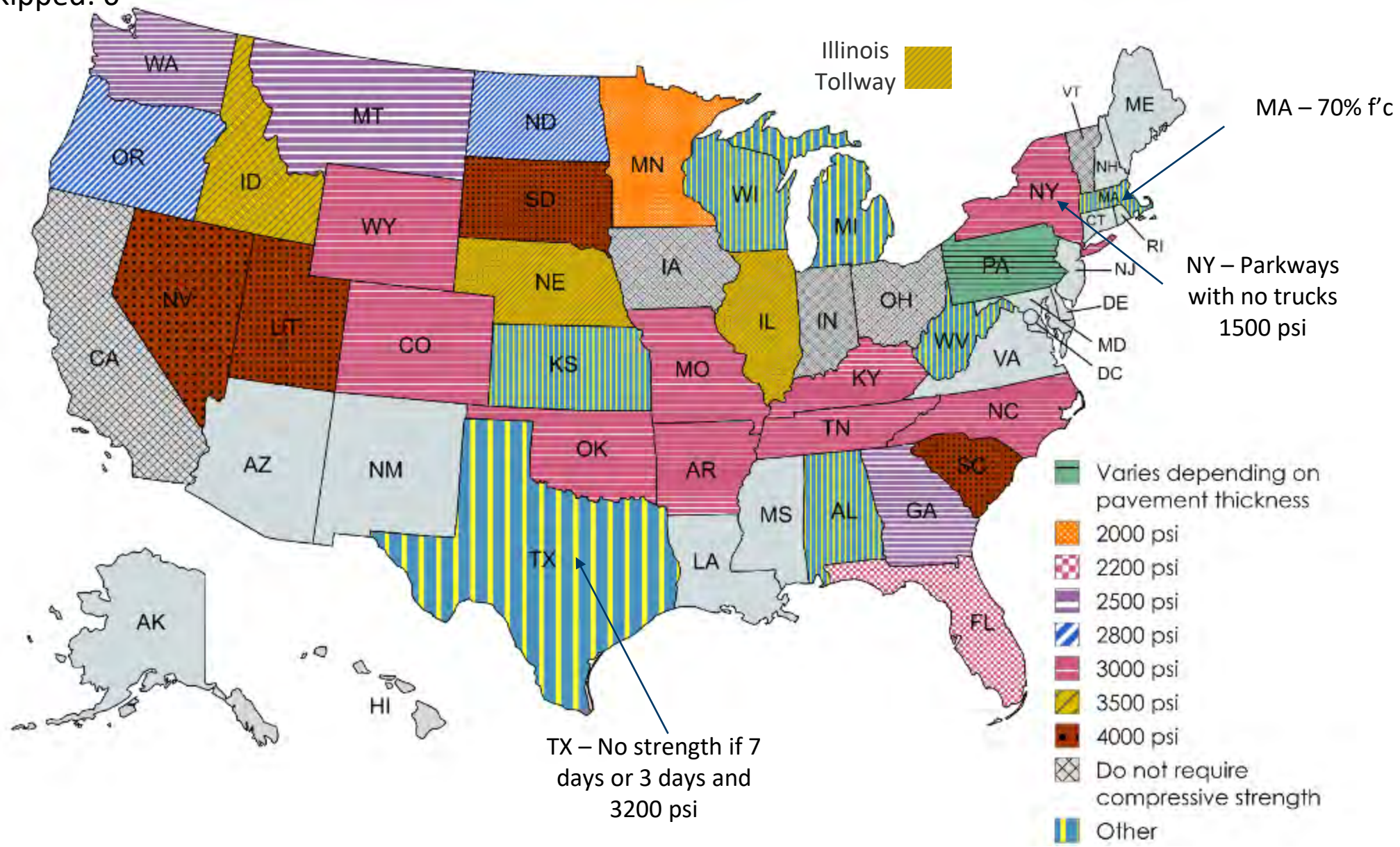
NATIONAL CONCRETE CONSORTIUM



https://www.cptechcenter.org/national-concrete-consortium/

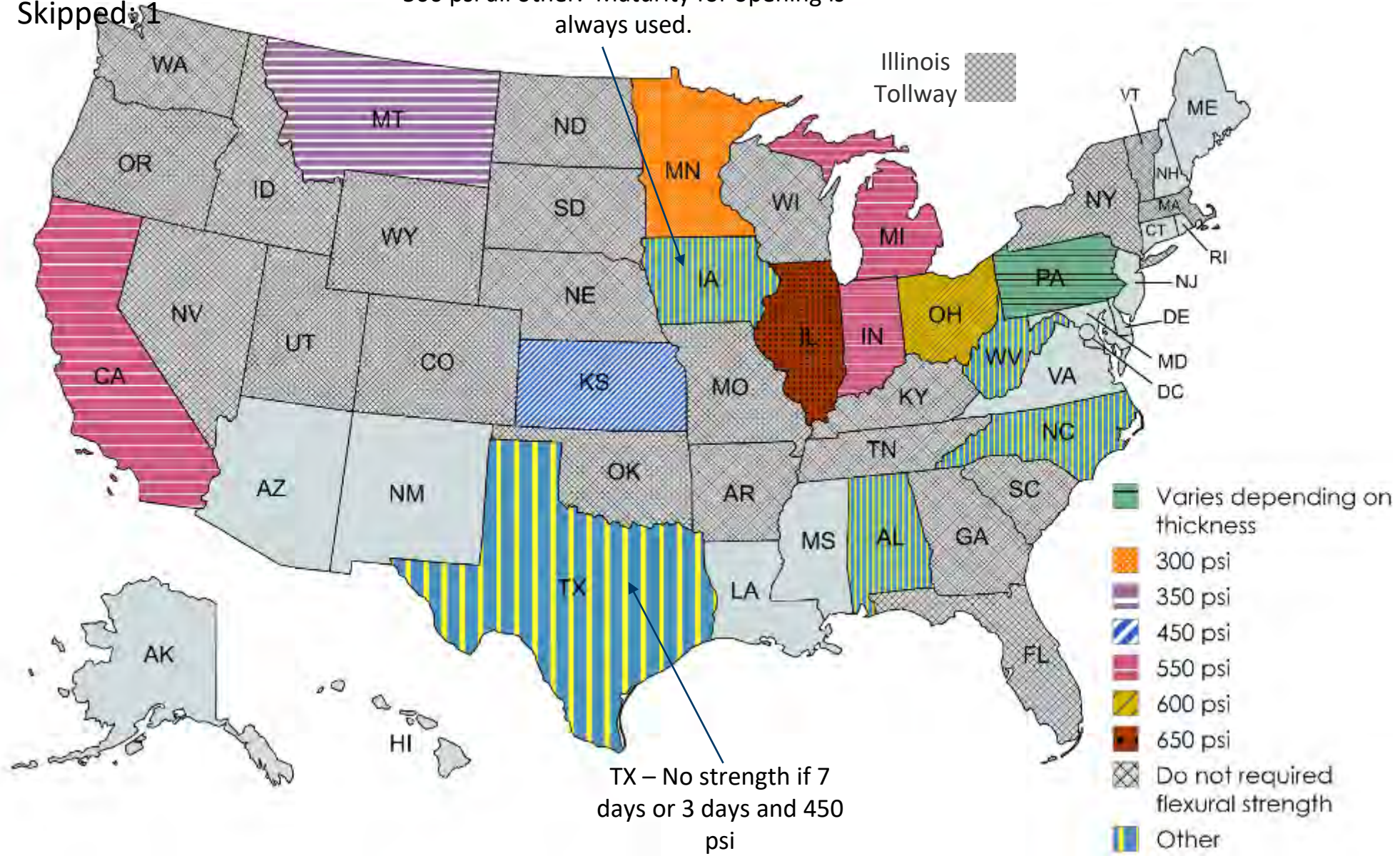
Q2: What compressive strength does your State require for opening concrete pavement to public traffic?

- Answered: 35 Skipped: 0



Q4: What flexural strength does your State require for opening concrete pavement to public traffic?

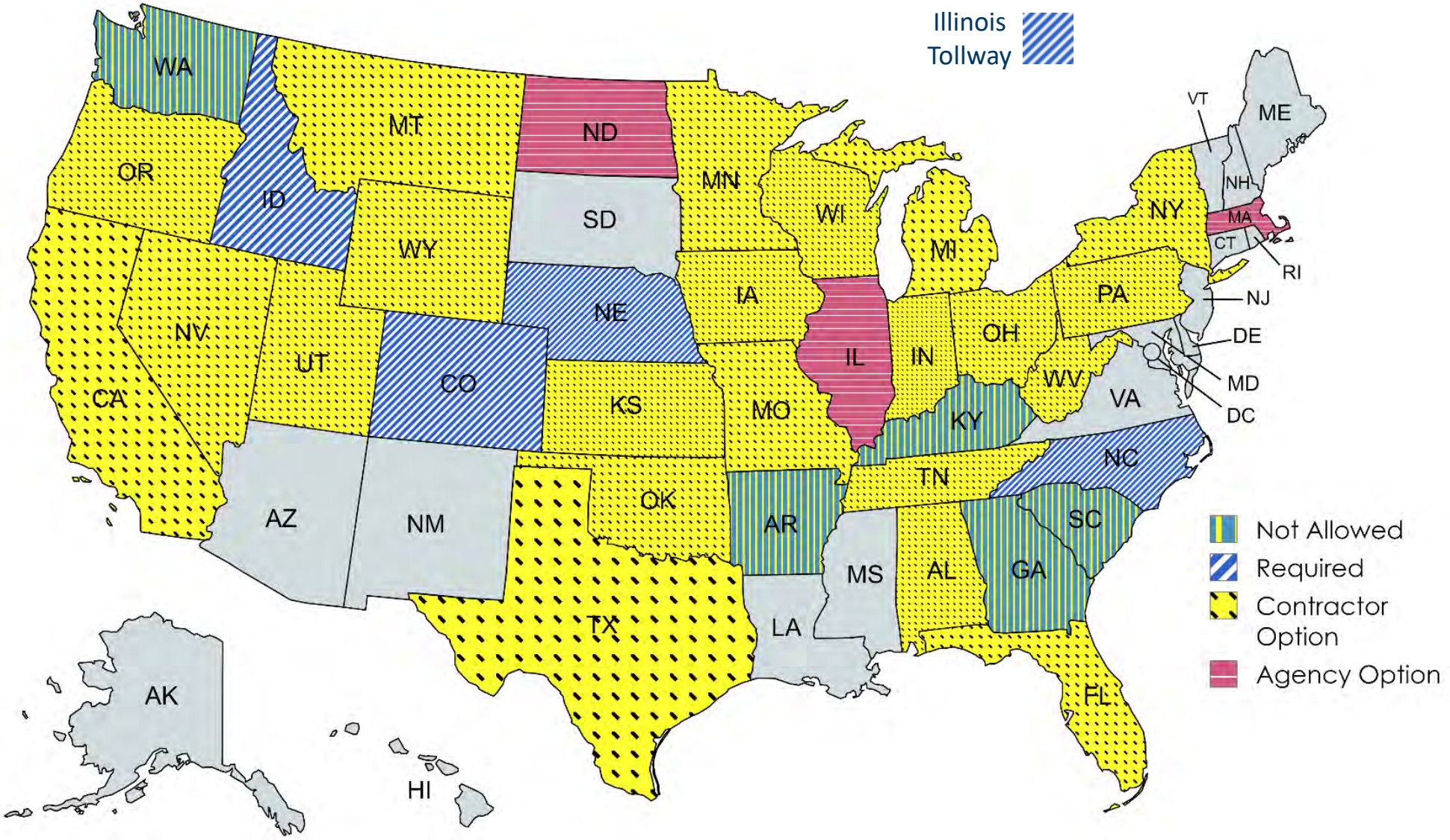
- Answered: 34 Skipped: 1



Q9: What applications does your State currently use maturity for now?

Opening Pavement to Construction Traffic

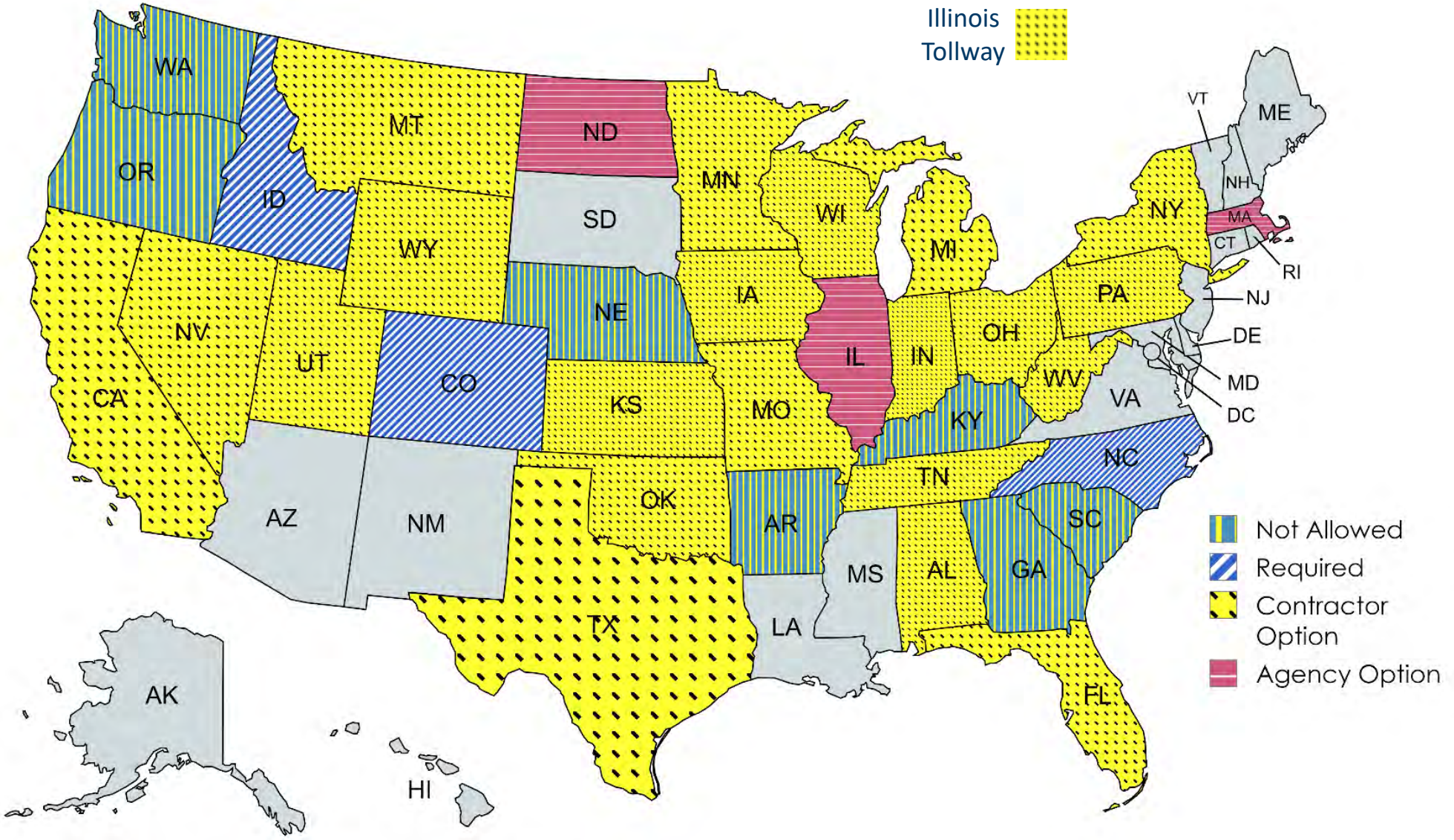
- Answered: 33 Skipped: 2



Q9: What applications does your State currently use maturity for now?

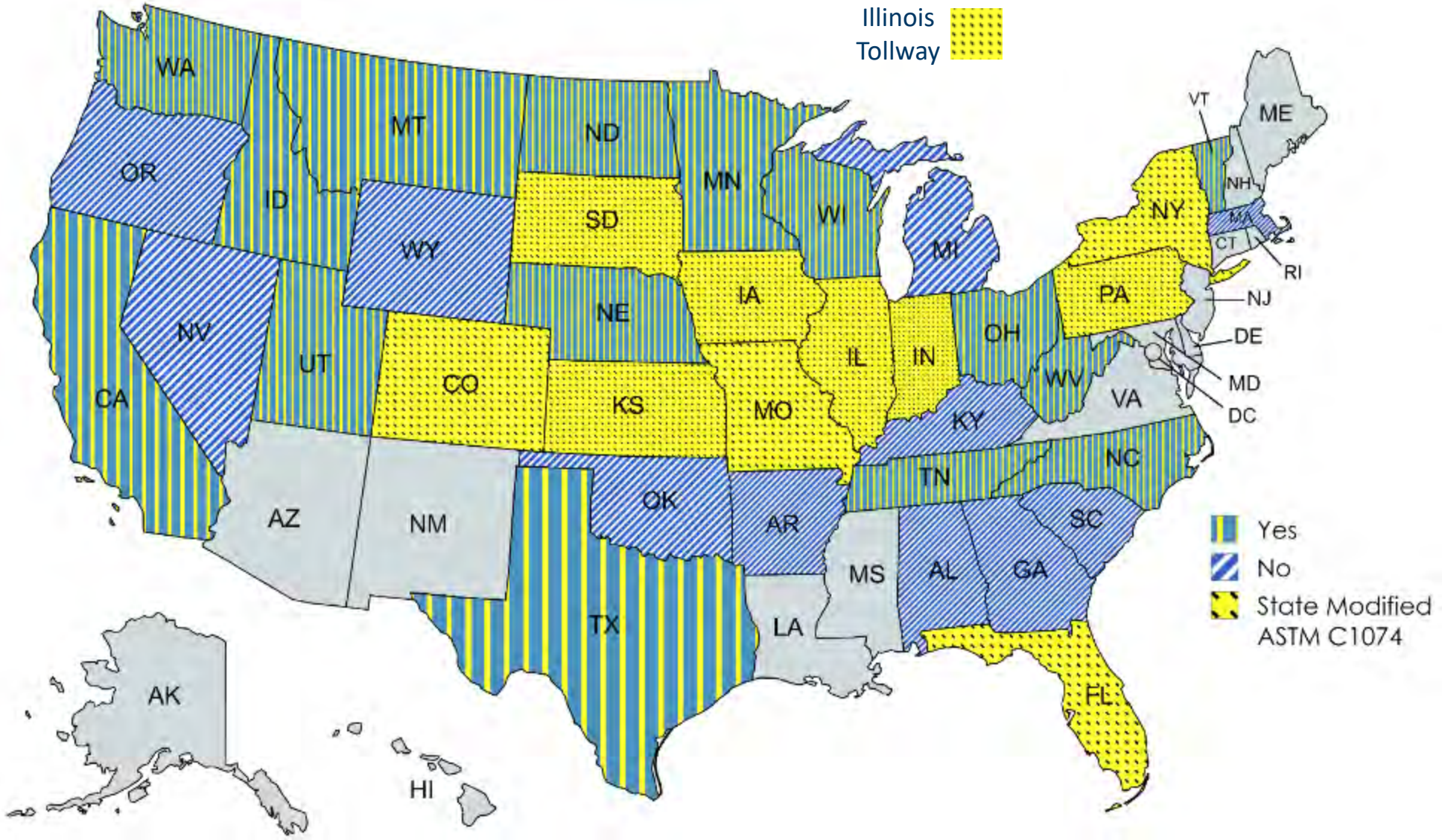
Opening Pavement to Public Traffic

- Answered: 33 Skipped: 2



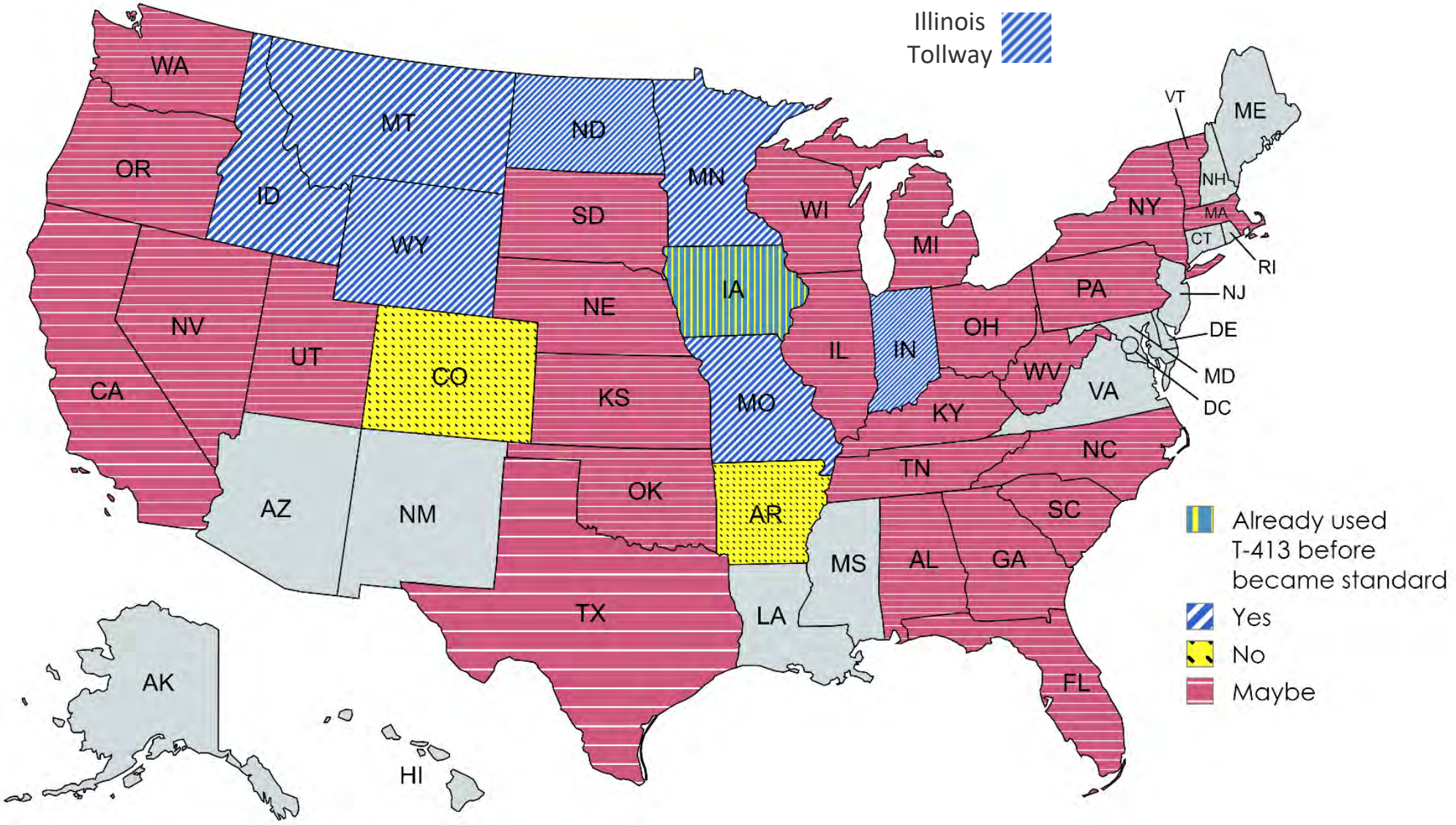
Q10: Does your State currently require ASTM C1074 for maturity?

- Answered: 35 Skipped: 0



Q11: Will your State consider adopting the new AASHTO T-413 Simpler Method for Early Opening of Concrete Pavements by Maturity Test Method?

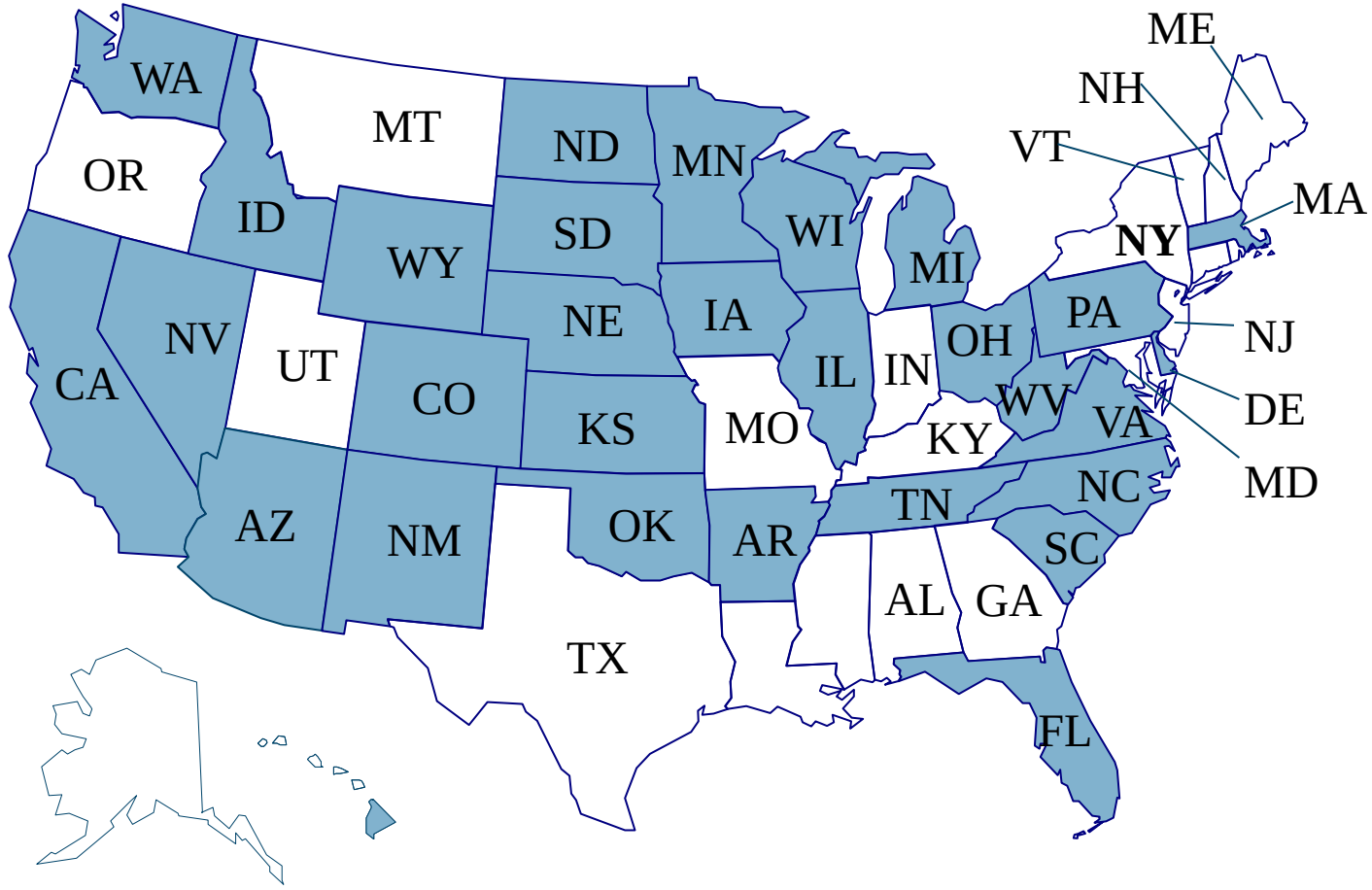
Answered: 35 Skipped: 0



MCTC's Maturity Data from Projects

U.S. Department of Transportation
Federal Highway Administration

- Maturity data from 29 states
  - 32 mixtures
- 2012-2023
- Only mainline paving projects
  - Except for the Massachusetts project
- Variety of mixtures
  - Geography
  - Cementitious content
  - SCM types and contents
  - Water to cementitious ratio
  - Maximum size of aggregates
  - Interstates to rural roads



SOURCE: Jagan Gudimettla, FHWA

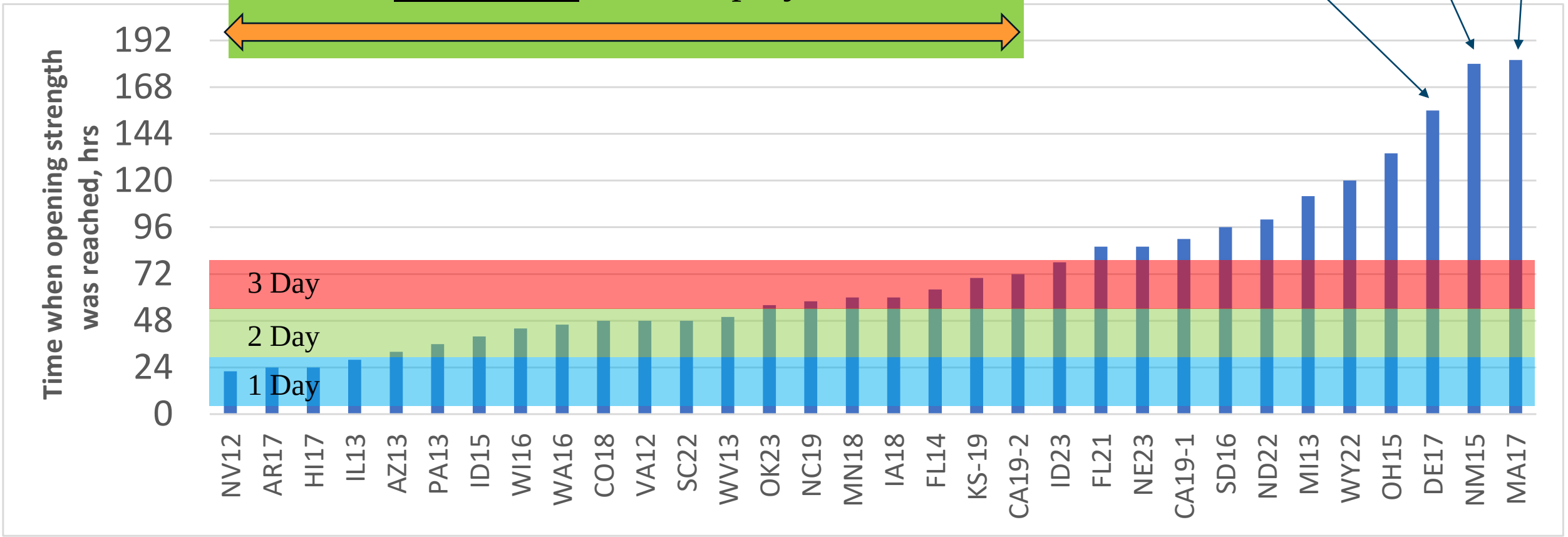
When Opening Strength was met

March

November

September

Opening strength reached within **three days** in **two thirds** of 32 the projects



SOURCE: Jagan Gudimettla, FHWA

Early Opening for PCC Pavements – Iowa DOT

Technology Tuesday
June 16, 2026

Todd Hanson PE, Concrete Materials Engineer
Iowa Department of Transportation

Introduction

- History
- Maturity Concept
- Opening Specification
- Procedures
- Challenges
- Advantages
- Conclusions

History - Iowa Pavement Opening

- 1937 – Opening based on 500 psi flexural & 7 days
- 1972 – 500 psi flexural & 5 days - ≥9 inches

History – Iowa Early Opening

- 1988 – Fast Track II trial
  - First demonstration of maturity
  - FHWA trailer assisted with project
  - High cement, blankets to open within 12 hrs.
- 1989 – Fast Track IA 100 in Cedar Rapids
  - Maturity & Pulse velocity used

History-Early Opening

- 1994 – IA 3 Franklin County
- Half width bonded overlay with pilot car
- Fast Track - 822 lbs cement
- Maturity & Pulse velocity used to open pavement to traffic each night
  - Opening in 8-10 hrs

History-Early Opening

- 1995 – Lee County River Road Project
- Limited access for locals – 7 mi. project
  - Houses between bluffs & RR & Mississippi River
- Maturity & Pulse velocity used to open pavement to traffic
  - Pulse velocity cumbersome
  - Maturity better suited for the field
- Standard IDOT Class C mix
  - Cars allowed at 350 psi MOR-CPL 12-24 hrs
- Developed Materials IM 383 for Maturity

Maturity Method to Estimate Opening Strength

- Since 1997 - Contractor option added to Standard Specifications
- Standard practice for opening pavements to traffic in Iowa
- Opening conventional mixes 18-36 hours during summer conditions at 500 psi estimated by maturity
  - No Fast Track practices

Concrete Maturity - When Is It Okay to Drive On?

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

Concrete Maturity - When Is It Okay to Drive On?

- Story Co R-38 paved 1980
- Plastic concrete drove on
  Patch in place since then
- This is too early, but No Pavement Failure after 46 years

Concrete Maturity - When Is It Okay to Drive On?

- MNDOT research showed as low as 73 psi

https://mdl.mndot.gov/items/NRRA202111

- PCC Overlay opening strength can be lower
  - Underlying pavement support

Thickness		k -value		Required Flexural Strength (MOR-TPL) in Mpa (psi)									
mm	in	Mpa/m	psi	Estimated ESAL's from Time of Opening to Design Strength									
				100		500		1000		2000		5000	
200	8	27	100	2.55	370	2.82	410	2.96	430	3.10	450	3.24	470
		54	200	2.14	310	2.34	340	2.41	350	2.55	370	2.69	390
		136	500	2.07	300	2.07	300	2.07	300	2.07	300	2.14	310
215	8.5	27	100	2.34	300	2.55	370	2.62	380	2.78	400	2.96	430
		54	200	2.07	300	2.07	300	2.20	320	2.07	330	2.41	350
		136	500	2.07	300	2.07	300	2.07	300	2.48	300	2.07	300
230	9	27	100	2.07	300	2.27	330	2.41	350	2.07	360	2.69	390
		54	200	2.07	300	2.07	300	2.07	300	2.07	300	2.20	320
		136	500	2.07	300	2.07	300	2.07	300	2.27	300	2.07	300
240	9.5	27	100	2.07	300	2.07	300	2.20	320	2.07	330	2.41	350
		54	200	2.07	300	2.07	300	2.07	300	2.07	300	2.07	300
		136	500	2.07	300	2.07	300	2.07	300	2.07	300	2.07	300
250	10	27	100	2.07	300	2.07	300	2.07	300	2.07	300	2.20	320
		54	200	2.07	300	2.07	300	2.07	300	2.07	300	2.07	300
		136	500	2.07	300	2.07	300	2.07	300	2.07	300	2.07	300
265	>10.5	27	100	2.07	300	2.07	300	2.07	300	2.07	300	2.07	300
		54	200	2.07	300	2.07	300	2.07	300	2.07	300	2.07	300
		136	500	2.07	300	2.07	300	2.07	300	2.07	300	2.07	300

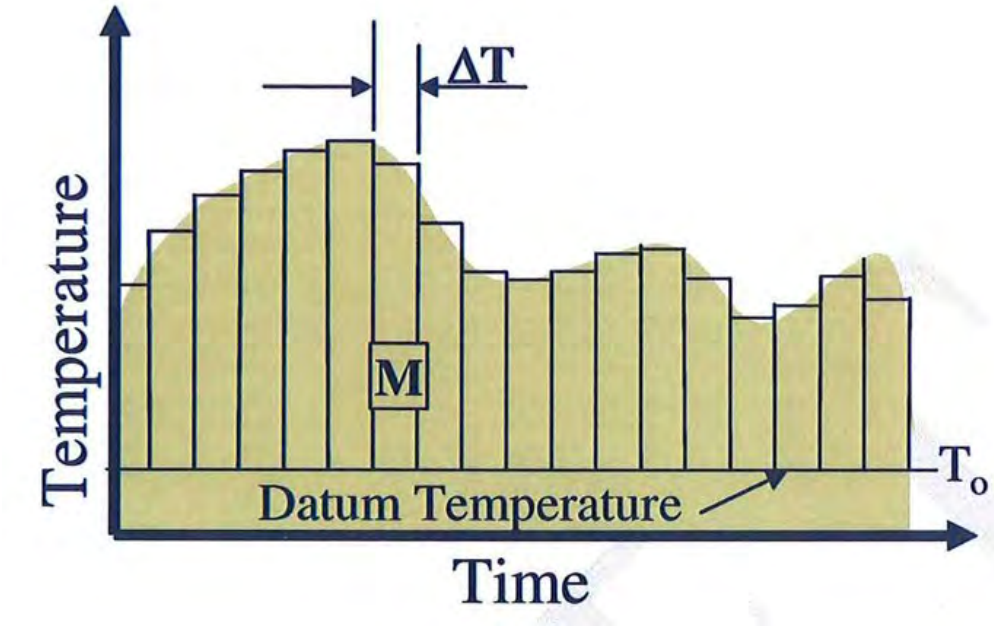
Cole, Lawrence & Okamoto, Paul, Flexural Strength Criteria for Opening Concrete Roadways to Traffic, TRB paper 950222

Do these cylinders represent in-place concrete?

- Use maturity concept – a non-destructive test to estimate in-place concrete strength

Maturity Concept

- Non-destructive test
- Gives estimate of in-place concrete strength
- Early age opening – Time Savings
- Not a 28-day strength acceptance test
- Iowa does not accept on strength



Nurse•Saul Equation

$M\ (°C \bullet hrs) = \Sigma[(T - T_0)\Delta t]$

where T_0 = (-10°C, 0°C)

Iowa Maturity Procedure

1. Contractor develops strength-maturity curve for mix to determine opening TTF
2. Contractor takes pavement temperature readings and calculates TTF
   a) Submit data to Engineer
   b) Engineer responsible for opening section
3. Contractor performs curve validation every 90 days

<u>Agency monitors testing at all steps</u>

1. Strength- Maturity Curve -Flexural

- Used for pavement opening or form removal for structures
- Concrete within 0.02 of max w/c
- Concrete temperature >50 °F
- Cast 12 beams (15)
- Thermocouple/sensor in beam
- Test 3 beams at 4 different ages
- Develop Strength vs. Maturity curve

1. Strength- Maturity Curve Pavements (Flexural)

- Immediately cover with wet burlap and plastic
- At 16 to 24 hours store specimens in wet sand pit
- Maintain above 40 °F
  - Place foam board or plywood on bottom and cover with insulating blankets

Equipment for Maturity Curve

- Beam or cylinder molds
- Maturity Meter
- Thermocouple Wire or probe
- Testing Machine
- Computer

Iowa DOT Spreadsheet

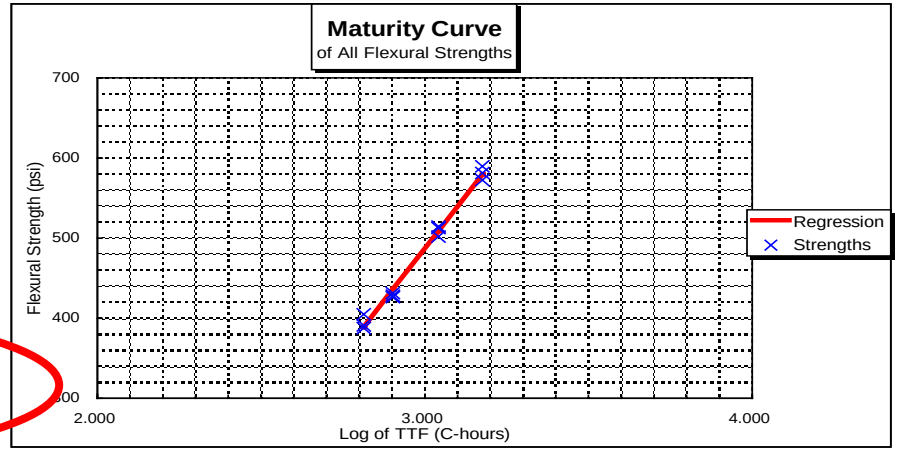
MATURITY - STRENGTH DEVELOPMENT

COUNTY: Polk
CURVE #: 1
PROJ. #: Im-35-5(109)
MONITOR:
REP/CONTRACTOR: CedarValley
INSPECTOR:
DATE: 06/21/98

BEAM #	LOAD AT BREAK (lbs)	TABLE VALUE (lbs)	BREAK LOCATION (in)	WIDTH (in)	DEPTH (in)	FLEXURAL COEFFICIENT	FLEXURAL STRENGTH (psi)	AGE AT BREAK (days)	TTF CH 1	TTF CH 2	AVERAGE TTF	BEAM TEMP (AVG)
	Enter	Enter	Enter	Enter	Enter			Enter	Enter	Enter		Enter
1	3000	3100	0.5	5.96	6.02	0.125004	388	1	650	650	650	24
2	3100	3250	0.5	6.00	6.01	0.124584	405	1	650	650	650	24
3	3050	3150	0.5	6.00	6.02	0.124171	391	1	650	650	650	24
4	3450	3400	0.5	5.98	6.00	0.125418	426	2	800	800	800	22
5	3550	3450	0.5	6.00	6.00	0.125000	431	2	800	800	800	22
6	3500	3425	0.5	6.00	6.00	0.125000	428	2	800	800	800	22
7	4000	4100	0.5	5.98	6.00	0.125418	514	3	1100	1100	1100	21
8	3990	4000	0.5	5.98	6.00	0.125418	502	3	1100	1100	1100	21
9	4000	4100	0.5	6.00	6.00	0.125000	513	3	1100	1100	1100	21
10	4600	4650	0.5	6.00	6.00	0.125000	581	4	1500	1500	1500	21
11	4700	4580	0.5	6.00	6.00	0.125000	573	4	1500	1500	1500	21
12	4750	4700	0.5	5.98	6.00	0.125418	589	4	1500	1500	1500	21

MIX INFORMATION	Enter
AIR:	7.8
SLUMP:	2
w/c:	0.42
MIX:	C3WRC20
FLY ASH SOURCE:	Port Neal #4
CEMENT SOURCE:	Ash Grove
COARSE AGGREGATE SOURCE:	Duraham Mine
FINE AGGREGATE SOURCE:	Vandalia
WATER REDUCER BRAND:	Daratard 17
Add. Rate:	2 oz.
AIR ADMIXTURE BRAND:	Daravair 1400
Add. Rate:	6 oz.
METHOD OF DEVELOPMENT:	Maturity Meter
Desired Flexural Strength (MOR):	500 psi

REQUIRED TTF:	1058



Certified Maturity Contractor Representative - _____
Signature

Maturity Curve Reviewed - _____
Testing Engineer

Comments:

2. Pavement Temperature Measurement

- Insert thermocouple in pavement
  - 12” from edge at mid depth
- Min. of 2 locations per day paving
- Read morning and evening minimum
- Calculate pavement TTF
- When pavement TTF > required opening TTF can open to traffic
- Engineer responsible for opening

Equipment for Field Maturity

- Thermal Meter or datalogger
- Thermocouple wire

Field Data

Maturity - Field Data

Project : _____ **Maturity Curve #:** 1 **Probe # :** 1

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

Contractor: _____ **Mix:** C3W RC20

TTF Required to Open : 1058

Section of Pavement for Opening by Maturity

From Location:	104+00	To Probe Location:	121+50

Date	Time	Age (hours)	Temp (deg C)	TTF at age (deg C-hr)	Sum TTF (deg C-hr)	Air Temp (deg C)
09/11/99	10:00 AM	0.00	28		0	
	03:00 PM	5.00	30	195	195	
	07:00 PM	9.00	29	158	353	
09/12/99	07:00 AM	21.00	21	420	773	
	06:00 PM	32.00	20	335.5	1108.5	
				0	0	
				0	0	
				0	0	
				0	0	

TTF: **1108.5**

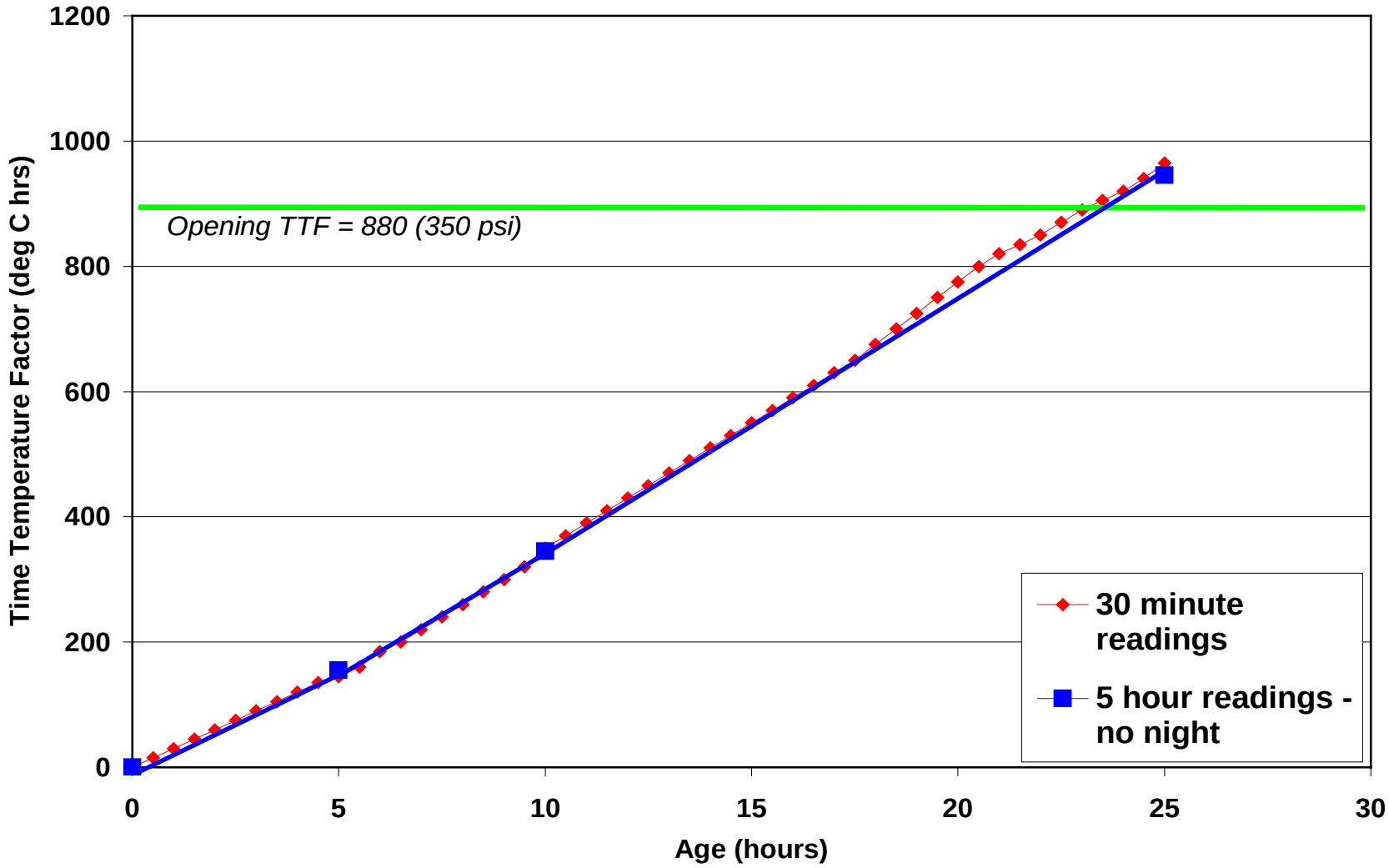
Value in box should be equal to or greater than required TTF.

_____

Contractor Representative

cc: RCE, Central Materials, Contractor

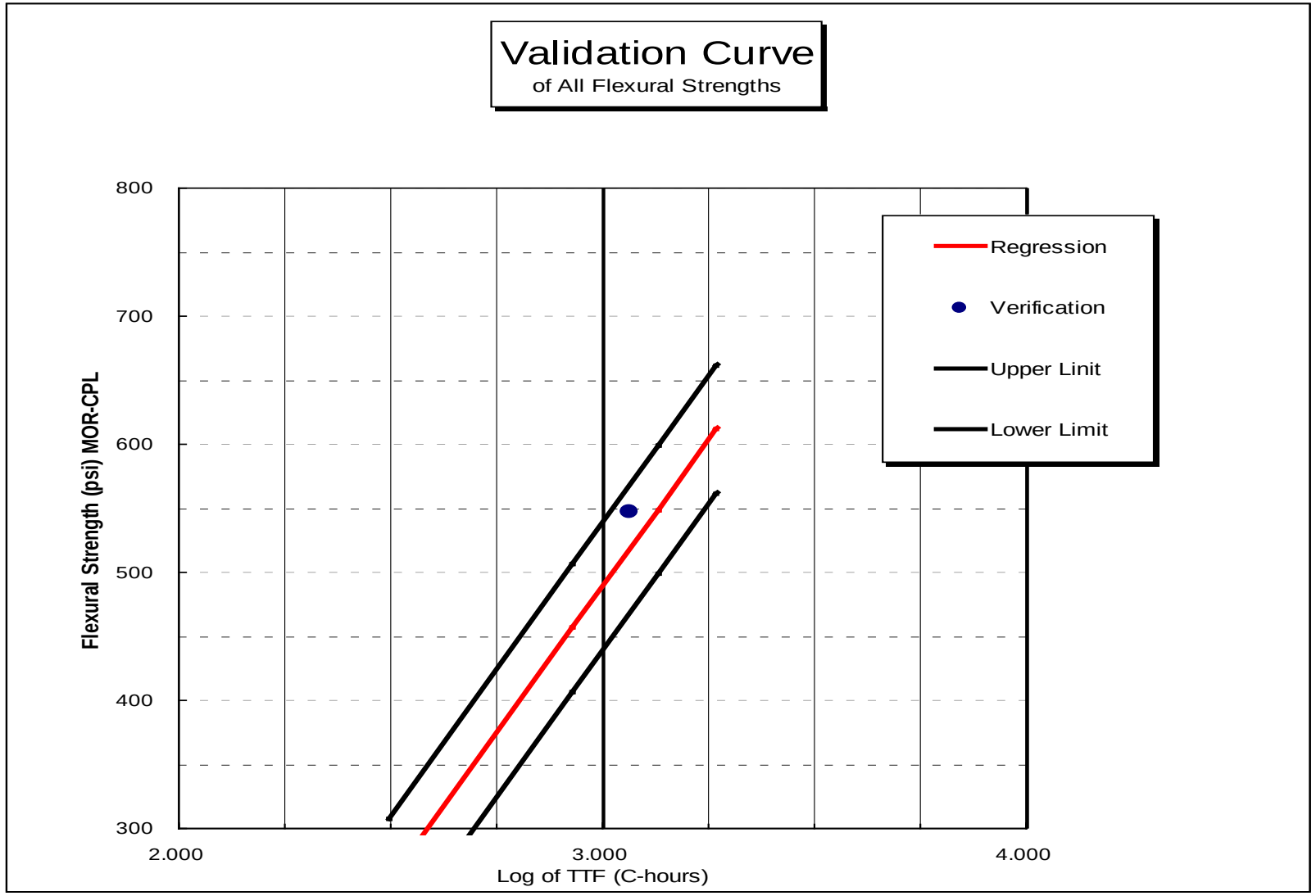
Effect on Opening Continuous vs. 5 hour



3. Curve Validation

- Cast 3 Beams from production concrete – 90 day interval
- Cure specimens same as curve development
- Monitor Maturity until approximate required opening TTF is reached
- Test all 3 specimens and average
- Average Flexural Strength should be within ±50 psi of opening strength at TTF
  - >50 psi okay, it is more conservative!
  - <50 psi must develop new curve

Curve Validation

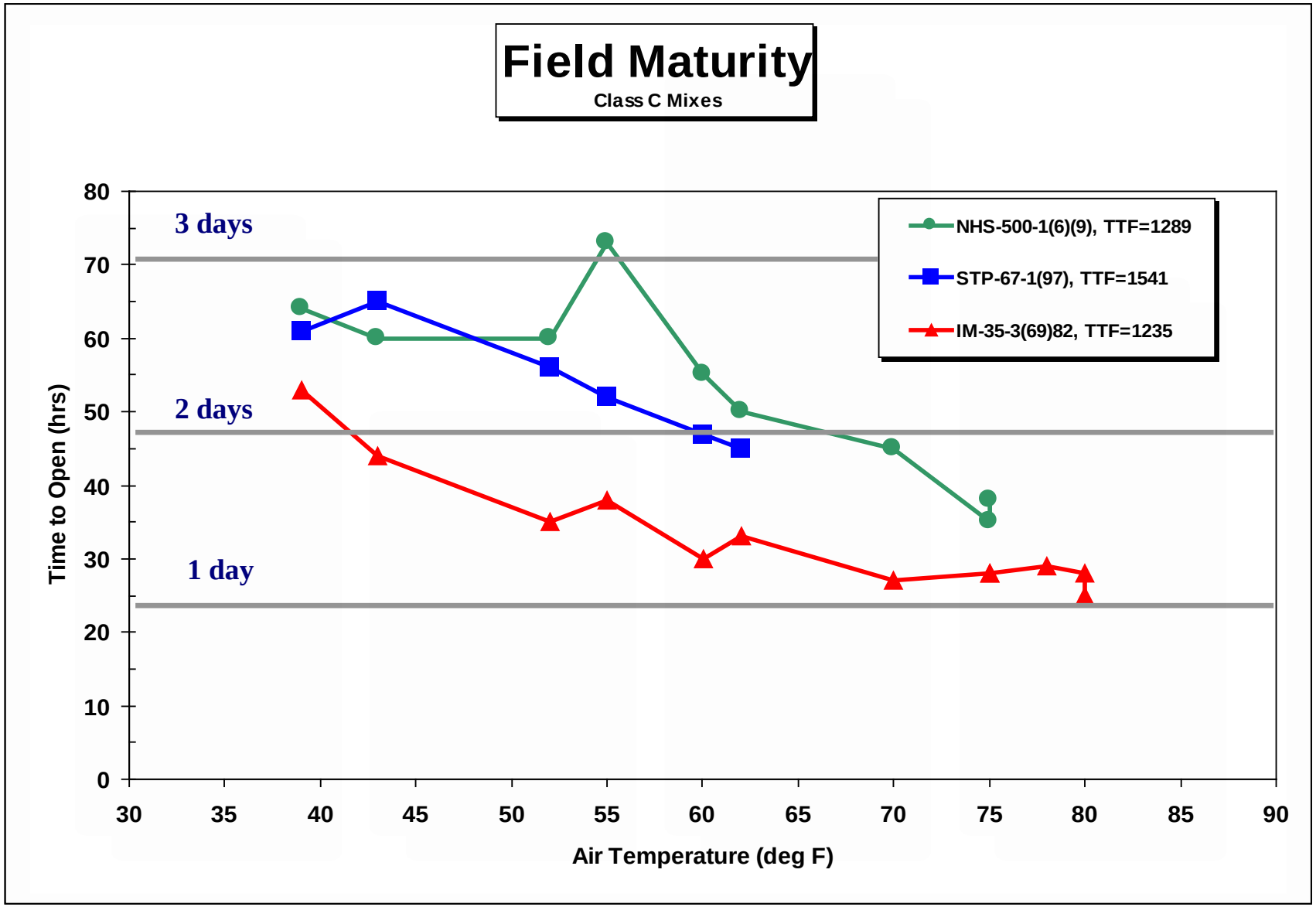


Curve Validation

Assured same basic mix being placed

Weather conditions did not affect TTF, only time of opening

Time of Opening vs Temperature



Factors Affecting TTF

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

The curve validation can be used to allow changes without establishing a new curve

Challenges to Implementation

- Excess maturity curve requirements
- Require a new curve for minor mix changes
- Simplicity is the key

Keys to Implementation

- Contractor flexibility
  - Allow mix changes – admixture, fly ash, etc.
  - Use curve validation as opposed to developing a new curve
  - Built in factors of safety

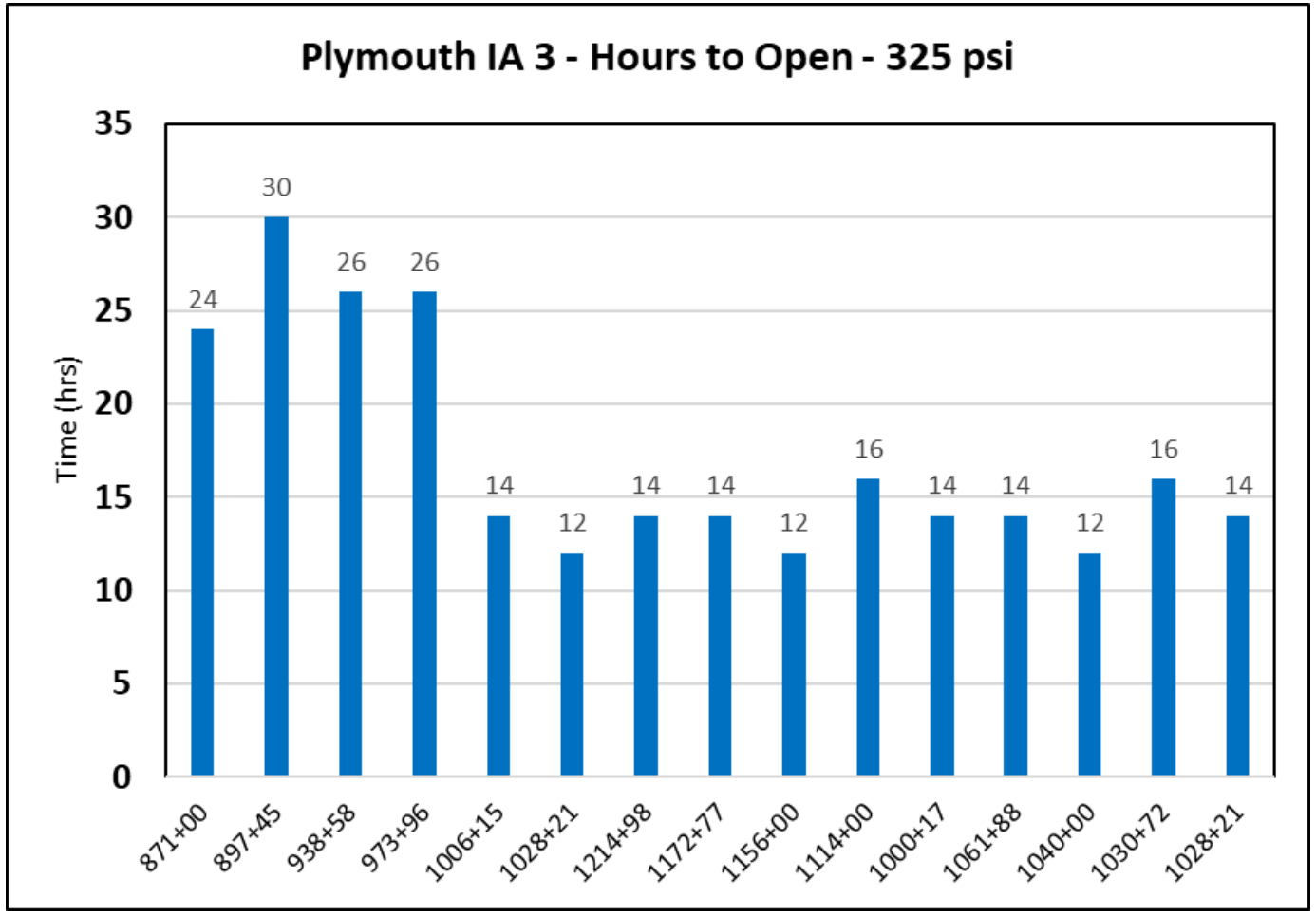
Keys to Implementation

- Built in Factors of Safety
  - Curves developed at plant with higher air content and w/c ratio within 0.02 of max
  - Validations performed on production concrete
  - Field maturity tested near edge – temperature is lower than mid slab

Accelerated Project Opening using Maturity

- 2022 Plymouth Co. IA 3
  - 9 mile 6-inch PCC overlay
- Placed full width – 36 ft.
  - 24 ft. ML w 6 ft. shoulders
- Open with 325 psi maturity
- Rock shoulder and open within 3 days.
- Entire project open 25 days
  - Even with supply issues, rain, + intersection

Accelerated Project – Opening Times



- Initially using a retarder
  - Opening TTF =1102 °C-hr
  - 24-30 hours to open
- Switched to hydration stabilizer
  - Opening TTF =575 °C-hr
  - 13-16 hours to open
- 150 psi for joint filling equipment

Time for Opening to Traffic

- October 2024

Pavement Thickness	PCC Overlay Thickness	Opening Strength MOR-CPL	Minimum Time (Days) Beams only
≥9”	≥6”	350 psi*	5
<9”	<6”	500 psi	7

** When maturity is used.*

Flexural Beams - Both strength and time must be met.

Maturity method - time for opening based on strength requirement only (TTF).

Typical Opening Times Utilizing Maturity

- Summer (>80 °F) 18-36 hrs
- Fall/Spring (>55 °F) 36-72 hrs
- Late Fall (<50 °F) 48-96 hrs

Advantages - Contractor

- Use as haul road
- Expedite sub-drain & shouldering
- Accelerate staged construction
- Reduced construction Time & Costs
- Worker Safety

Advantages - Contractor

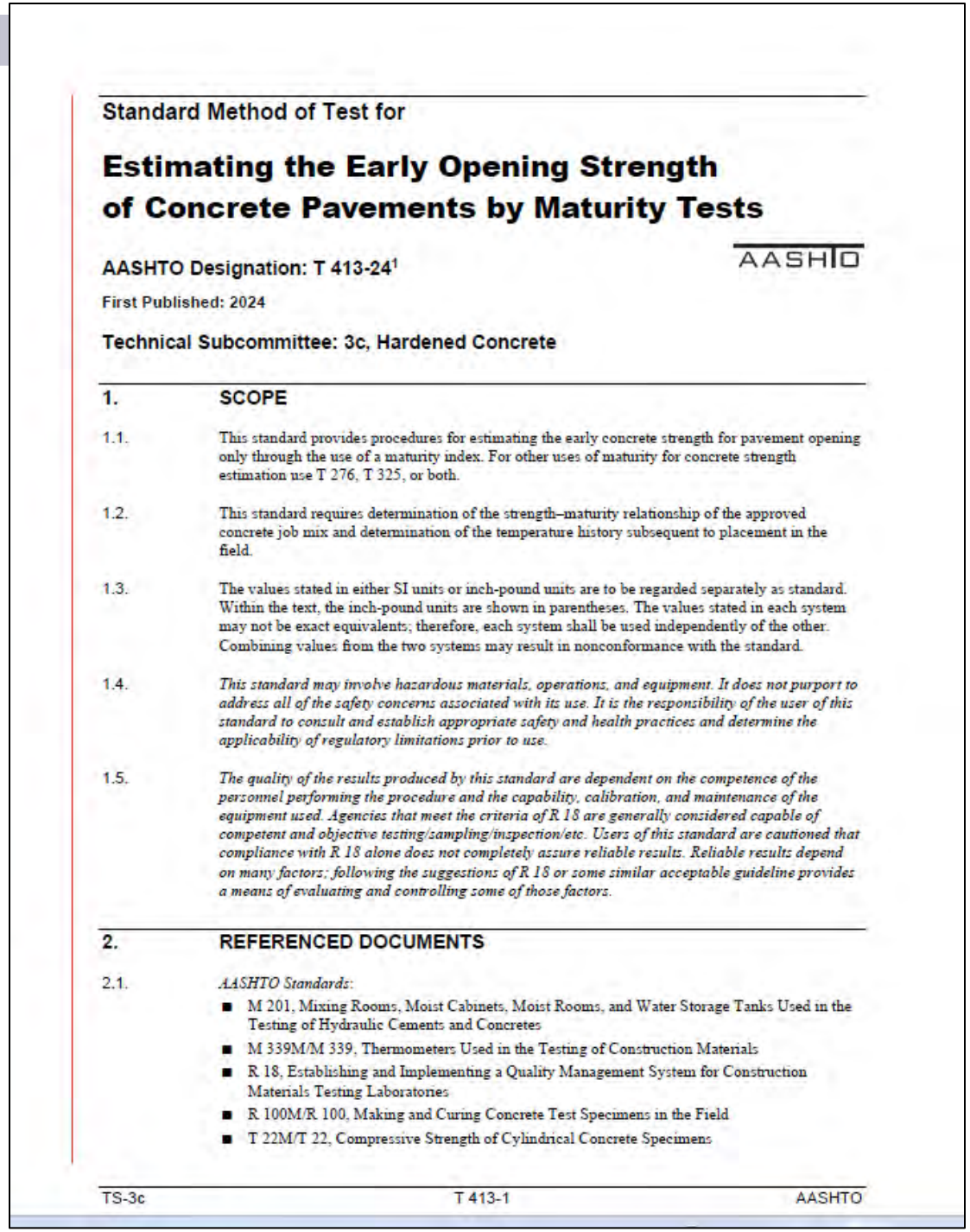
- Allow joint cleaning & filling equipment on slab
  - 150 psi with maturity
  - 150 psi & 24 hrs with flexural beams

Advantages – Public & Agency

- Provide local access early
  - Homeowners
  - Businesses
- Safety – work zone time reduced
- Reduced Construction Time & Costs

New AASHTO Test Method for Maturity

- T-413 24
- Simpler method for early opening of concrete pavements than ASTM C1074
- Based on Iowa DOT IM 383



Standard Method of Test for

Estimating the Early Opening Strength of Concrete Pavements by Maturity Tests

AASHTO

AASHTO Designation: T 413-24[1]

First Published: 2024

Technical Subcommittee: 3c, Hardened Concrete

1. SCOPE

1.1. This standard provides procedures for estimating the early concrete strength for pavement opening only through the use of a maturity index. For other uses of maturity for concrete strength estimation use T 276, T 325, or both.

1.2. This standard requires determination of the strength–maturity relationship of the approved concrete job mix and determination of the temperature history subsequent to placement in the field.

1.3. The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in parentheses. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4. *This standard may involve hazardous materials, operations, and equipment. It does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards:*

- M 201, Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
- M 339M/M 339, Thermometers Used in the Testing of Construction Materials
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- R 100M/R 100, Making and Curing Concrete Test Specimens in the Field
- T 22M/T 22, Compressive Strength of Cylindrical Concrete Specimens

Conclusions

- Reliable method of opening PCC pavements
  - Contractor's option since 1997 and used 100% of the time
  - Zero instances of cracking from opening early
- Time savings = safety, reduced cost, faster local access
- Develop curve with highest replacement and within 0.02 of max w/c ratio
- Use curve validations to allow mix changes
- Perform curve validation with production concrete
- Win-win for contractor and travelling public

Thank You!


NLY
WET CONCRETE
It's like fly paper for bad drivers
auto-fail.com