Maturity for Opening PCC Pavements: Iowa Experience

NCC - Kalispell, MT, September 10, 2019

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Introduction

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

History

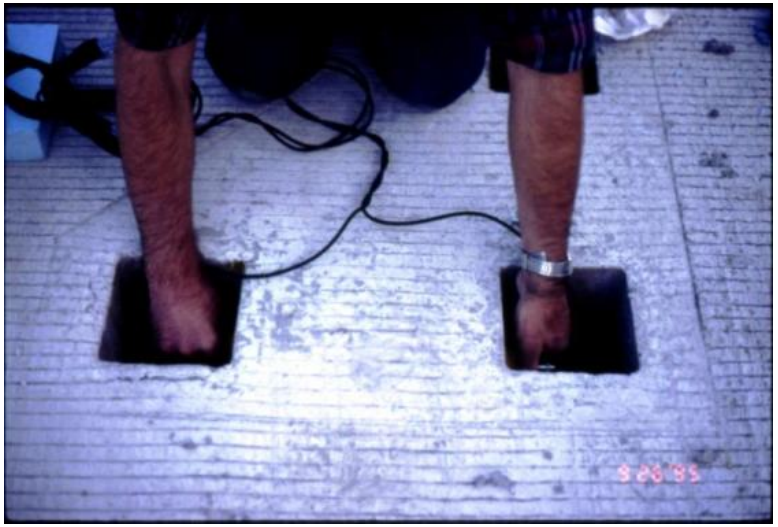
- 1988 – Fast Track II trial
  - First demonstration of maturity
  - FHWA trailer assisted with project
- 1989 – Fast Track IA 100 in Cedar Rapids
  - Maturity & Pulse velocity used

History

- 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

- 1995 – Lee County River Rd.
- Limited access for local traffic
  - 7 miles between bluffs & river/RR
- Maturity & Pulse velocity used to open pavement to traffic
  - Pulse velocity cumbersome
  - Maturity better in the field
- Standard Class C mix
  - 350 psi MOR-CPL 12-24 hrs
  - Allowed cars on pavement



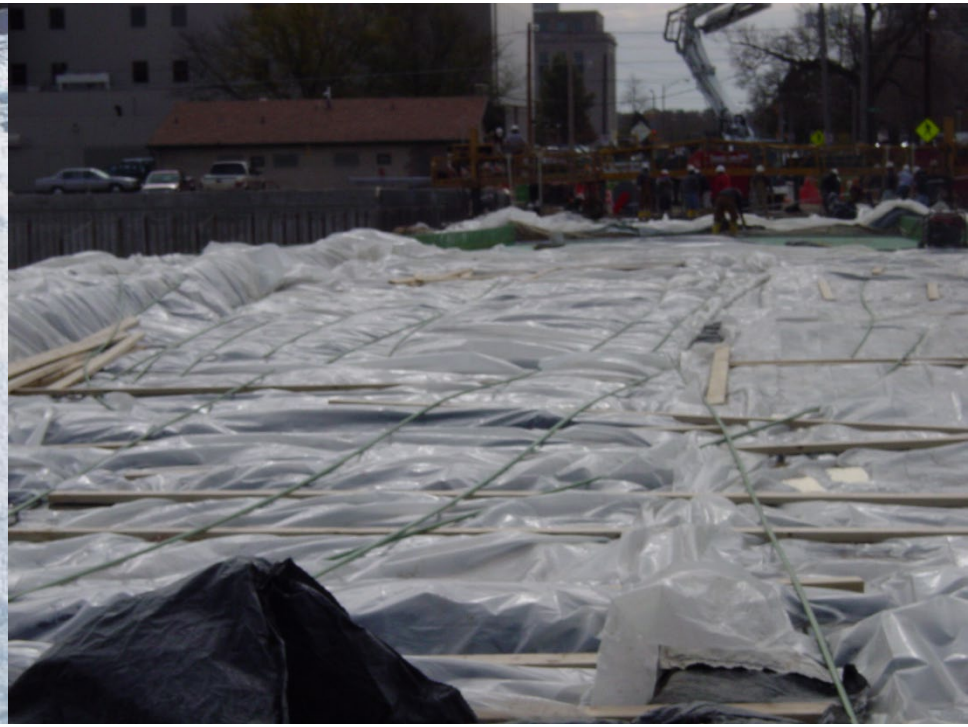
Maturity Method to Determine Opening Strength

- Since 1997 - Contractor option added to Standard Specifications
- Now standard practice for opening pavements to traffic
- Opening conventional mixes 18-36 hours during summer conditions
  - No Fast Track practices

Concrete Maturity or When Is It Okay to Drive On?

- What strength is needed?
- How do we measure?

How representative are these cylinders of the in-place concrete ?



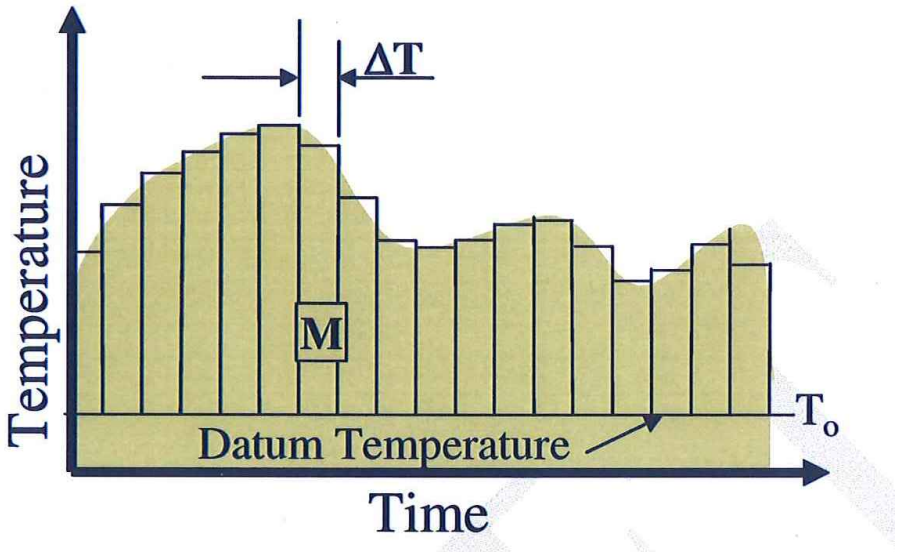
- Use maturity concept – a non-destructive test to estimate in-place concrete strength

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
- ASTM C 1074
  - Nurse•Saul Equation
  - $M\ (°C•hrs) = \Sigma[(T - T_0)\Delta t]$
    - *where* T_0 *= (0 , -10°C, or determined)*



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

Strength- Maturity Curve Pavements Flexural

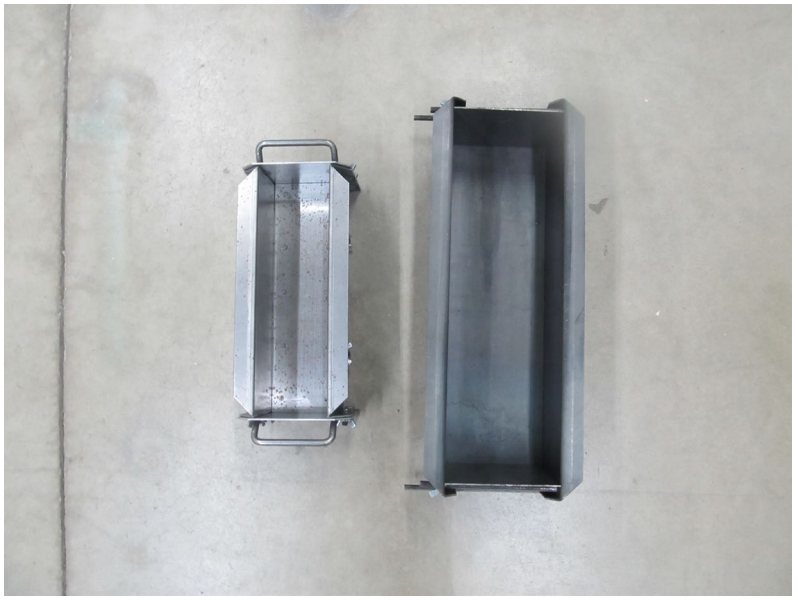
- Cast 12 beams (15)
- Thermocouple both ends of one beam
- Test 3 beams at 4 different ages
- Develop Strength vs. Maturity curve

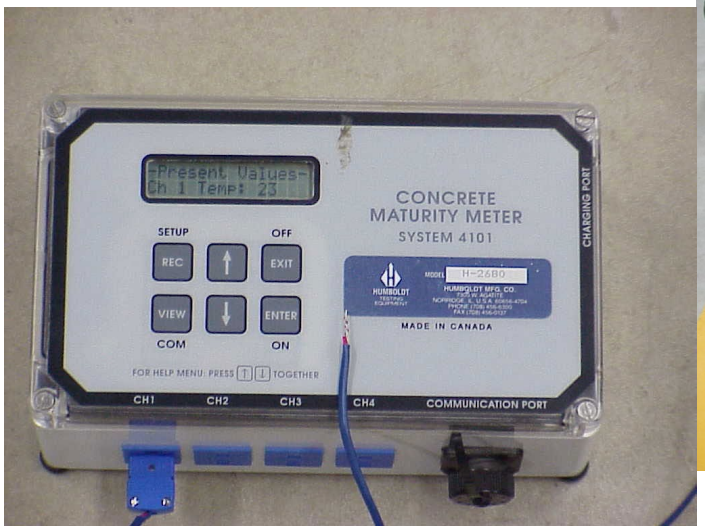
Strength-Maturity Curve Structures Compressive

- Cast 15 cylinders
- Thermocouple in two cylinders
- Test 3 cylinders at 1, 3, 7, 14, and 28 days
- Develop Strength vs. Maturity curve

Equipment for Maturity Curve

- Beam Molds
- Maturity Meter
- Thermocouple Wire
- Testing Machine
- Computer





Iowa DOT Spreadsheet

MATURITY - STRENGTH DEVELOPMENT

COUNTY: Polk
CURVE #: 1
PROJ. #: Im-35-5(109)

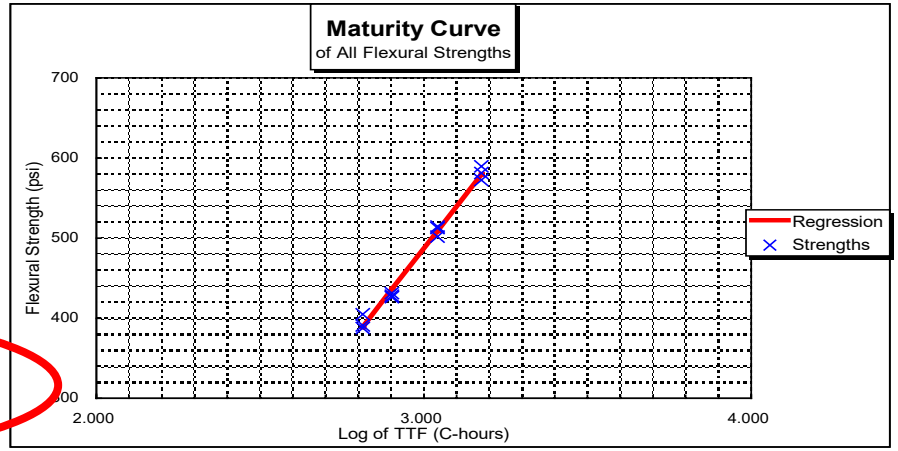
MONITOR:
REP/CONTRACTOR: CedarValley

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:

Pavement Temperature Measurement

- Insert thermocouple in pavement
  - 12-18” 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 : _____
County : _____
Contractor: _____

Maturity Curve #: 1
Date Placed: 9/11/99
Mix: C3W RC20

Probe # : 1

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	

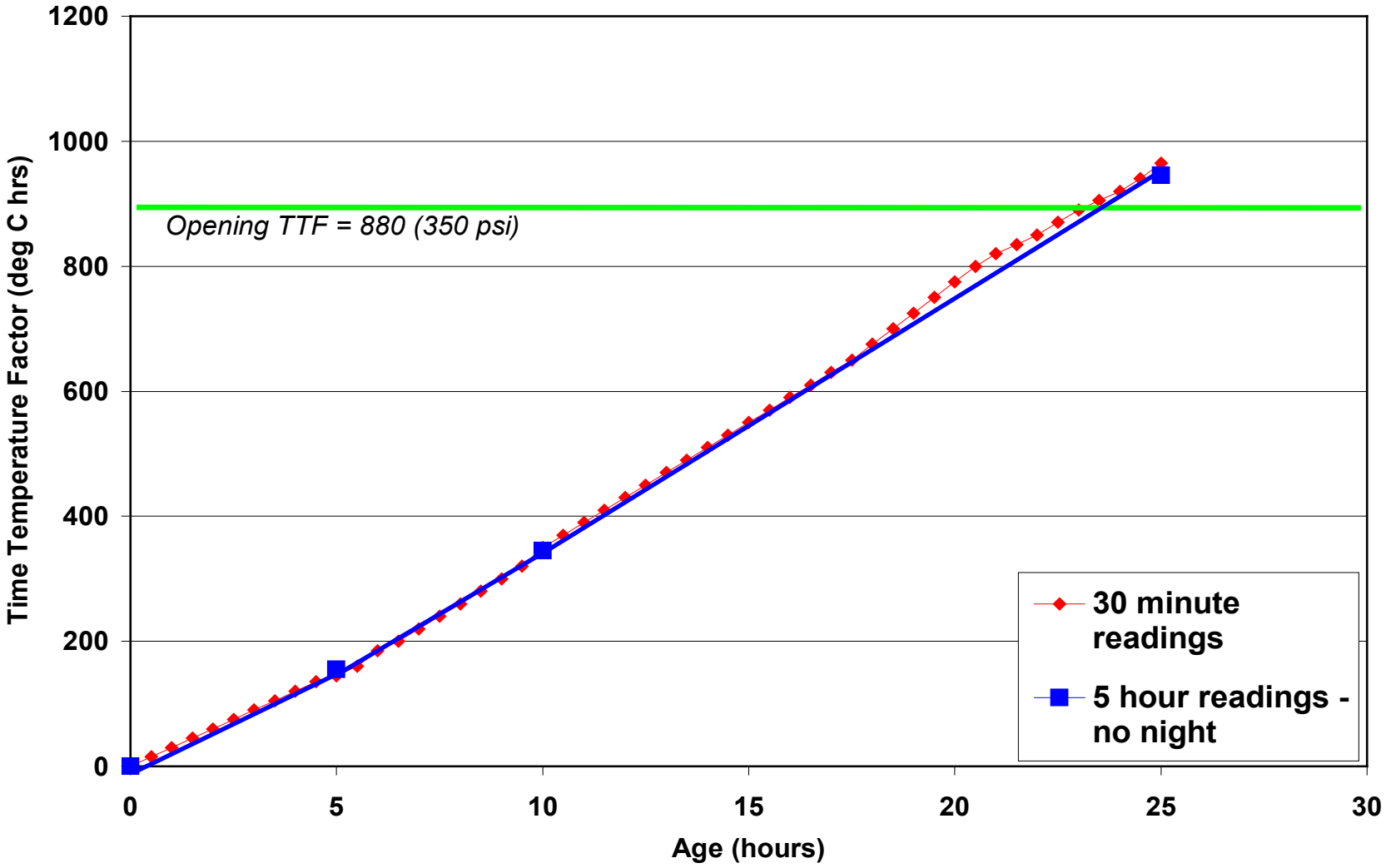
TTF: 1108.5

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

_____
Contractor Representative

cc: RCE, Central Materials, Contractor

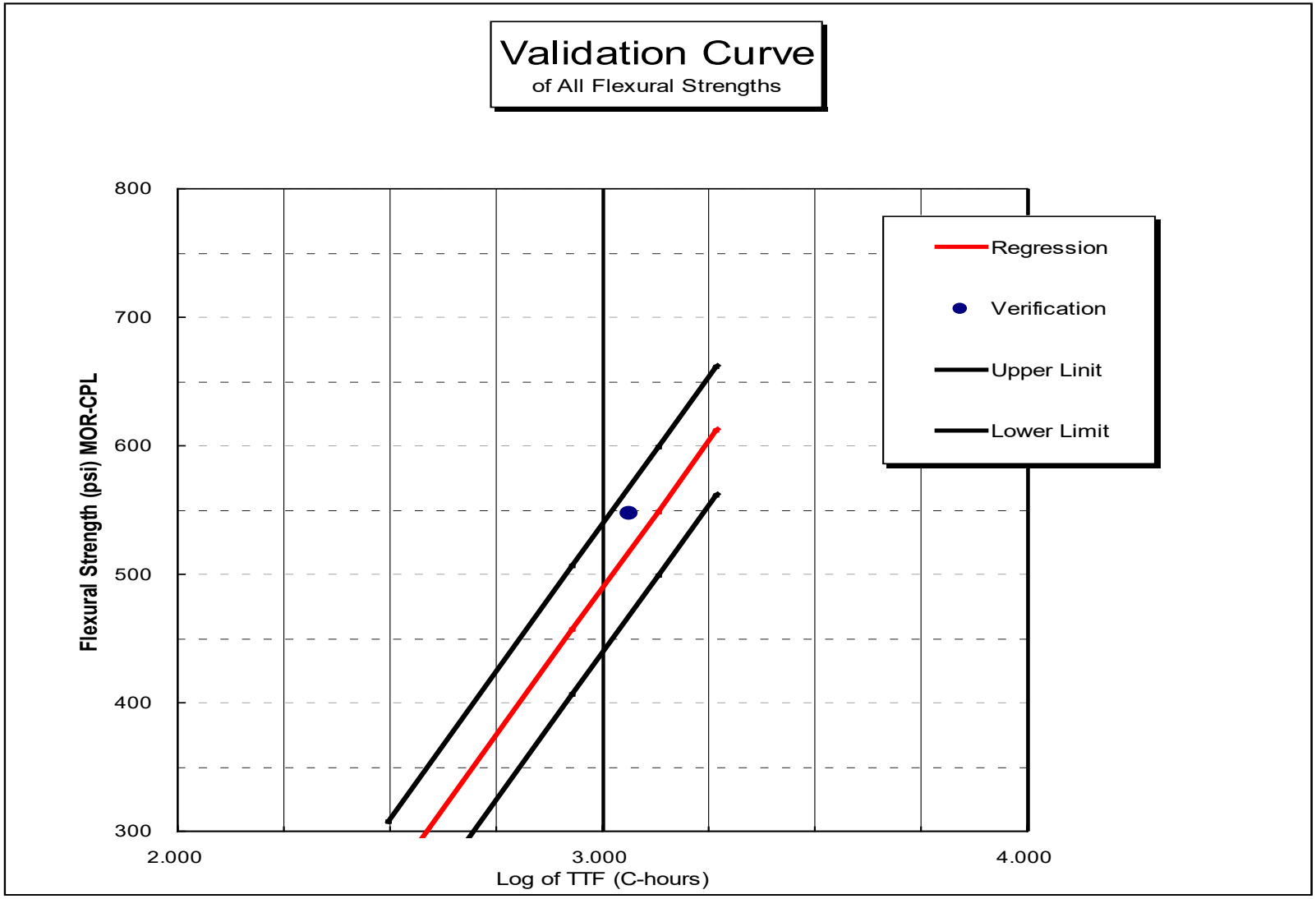
Effect on Opening
Continuous vs. 5 hour Readings



Curve Validation

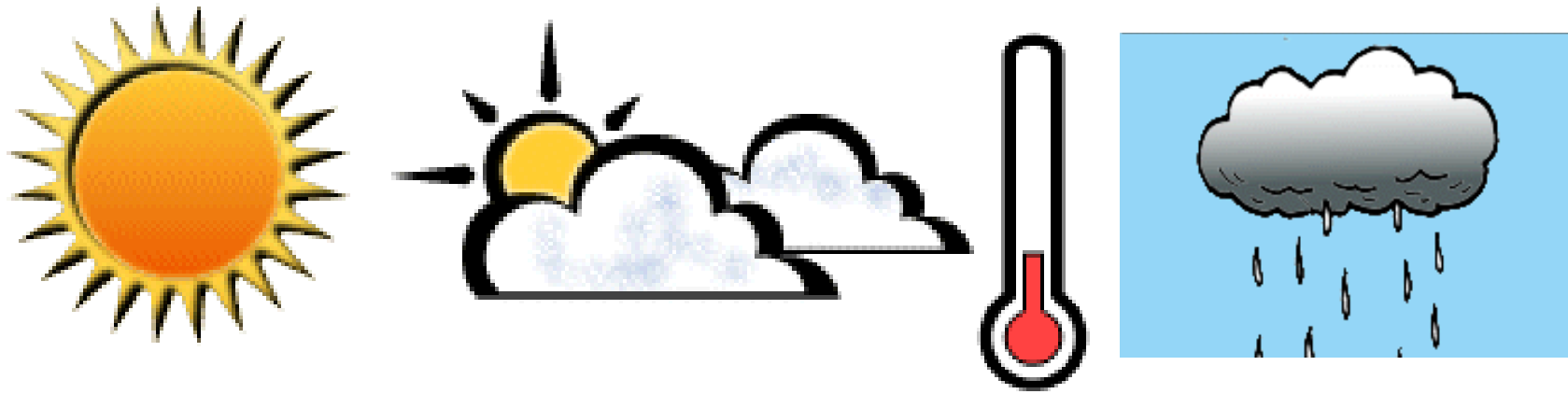
- Cast & Cure 3 Beams/Cylinders
- Monitor Maturity until approximate required opening TTF is reached
- Test all 3 beams and average
- Average Flexural Strength should be within ±50 psi of opening strength at TTF
  - >50 psi okay, more conservative
  - <50 psi must develop new curve
- Average compressive strength greater than original curve calculated compressive strength

Monthly Curve Validation



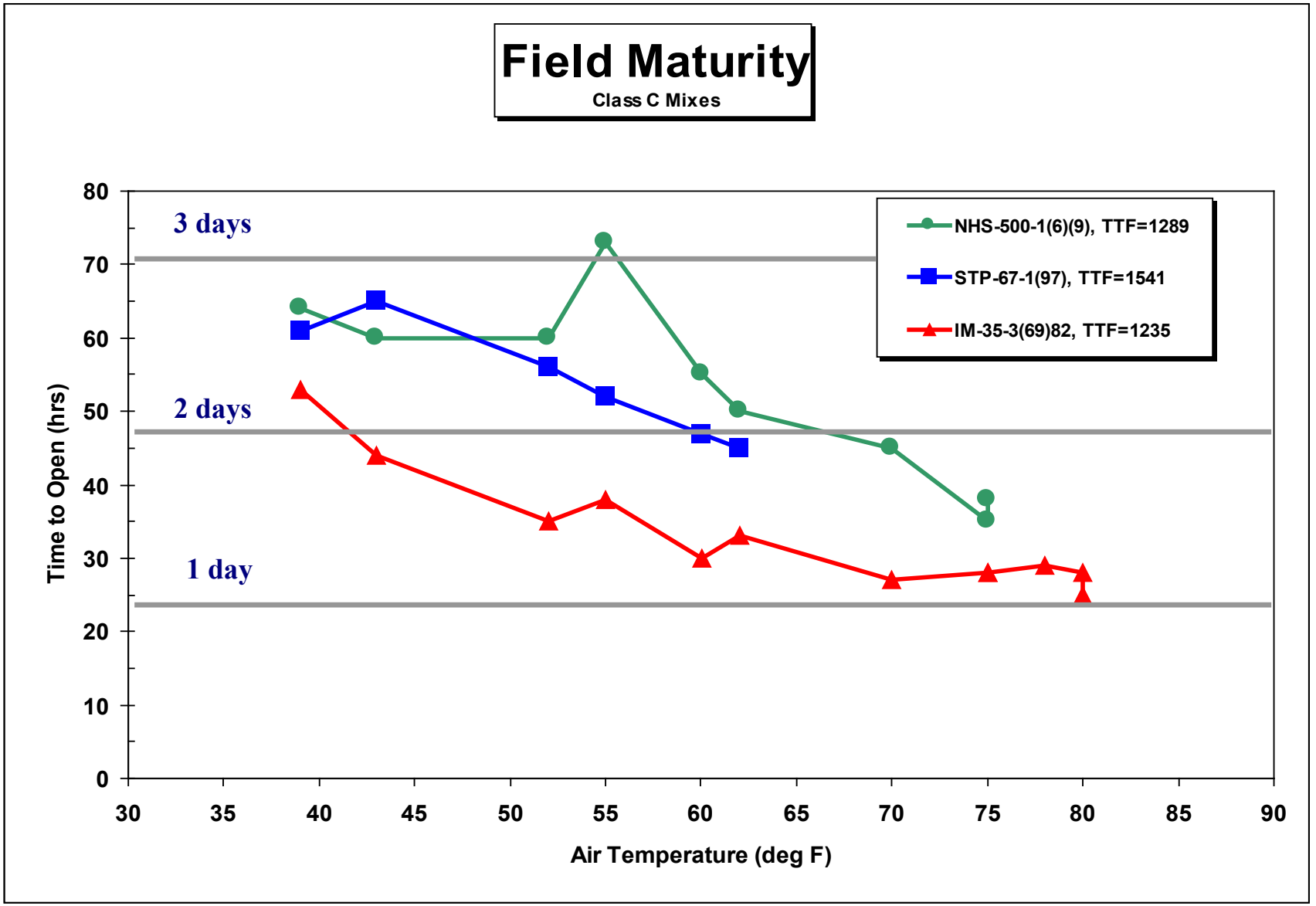
Monthly Curve Validation

Assured same basic mix being placed

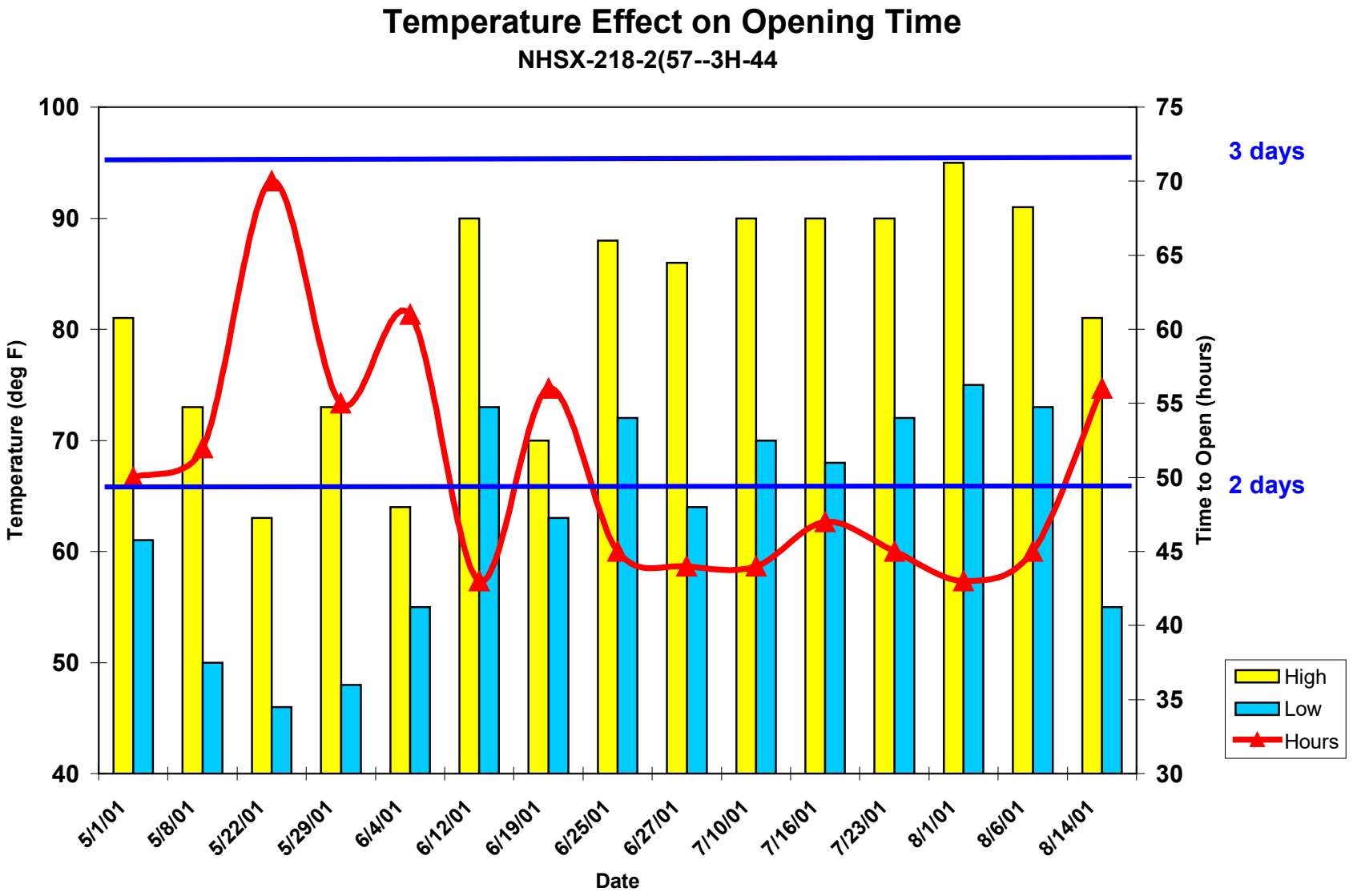


Weather conditions did not affect TTF, only time of opening

Time of Opening vs Temperature



Seasonal Changes



Factors Affecting TTF

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

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

Mix Change Effect on Maturity

Project	w/c	Fly Ash	Cement	Coarse	Fine	W. Reducer	TTF	TTF Change
FM-10(17)--55-10	0.447	P. Neal 4	**Holnam IS**(35)	Mishler	Miller	Sika 161	2498	
FM-10(17)--55-10	0.447	P. Neal 4	**Holnam I**	Mishler	Miller	Sika 161	1527	**-971**
NHS-61-8(96)--19-31	0.380	**Louisa**	Lafarge	Andrew	McCabe	Conchem 25DP	2396	
NHS-61-8(96)--19-31	0.380	**P. Prarie**	Lafarge	Andrew	McCabe	Conchem 25DP	1069	**-1327**
NHS-61-8(96)--19-31	0.380	**N/A**	Lafarge	Andrew	McCabe	Conchem 25DP	963	**-106**
NHS-18-6(42)--19-34	**0.389**	Ottumwa	Lehigh	Lacosta	Rockford	Sika 161	1030	
NHS-18-6(42)--19-34	**0.431**	Ottumwa	Lehigh	Lacosta	Rockford	Sika 161	1843	**813**
IM-80-6(175)220--48	0.402	Louisa	Lafarge	Conklin	Disterhoff	**Conchem 25DP**	1368	
IM-80-6(175)220--48	0.383	Louisa	Lafarge	Conklin	Disterhoff	**Prokrete N3**	720	**-648**
IM-80-6(175)220--48	0.386	Louisa	Lafarge	Conklin	Disterhoff	**Daratard 17**	984	**264**

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 for paving
  - Iowa requires continual meters for structures

Keys to Implementation

- Contractor flexibility
  - Allow minor mix changes – fly ash, etc.
  - Allow curve validation instead of requiring new curve to be developed
- Built in Factors of Safety
  - Higher air & w/c ratio

Required Opening Strength

Thickness		k -value		Required Flexural Strength (MOR-TPL) in Mpa (psi) Estimated ESAL's from Time of Opening to Design Strength									
mm	in	Mpa/m	pci	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 or greater	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

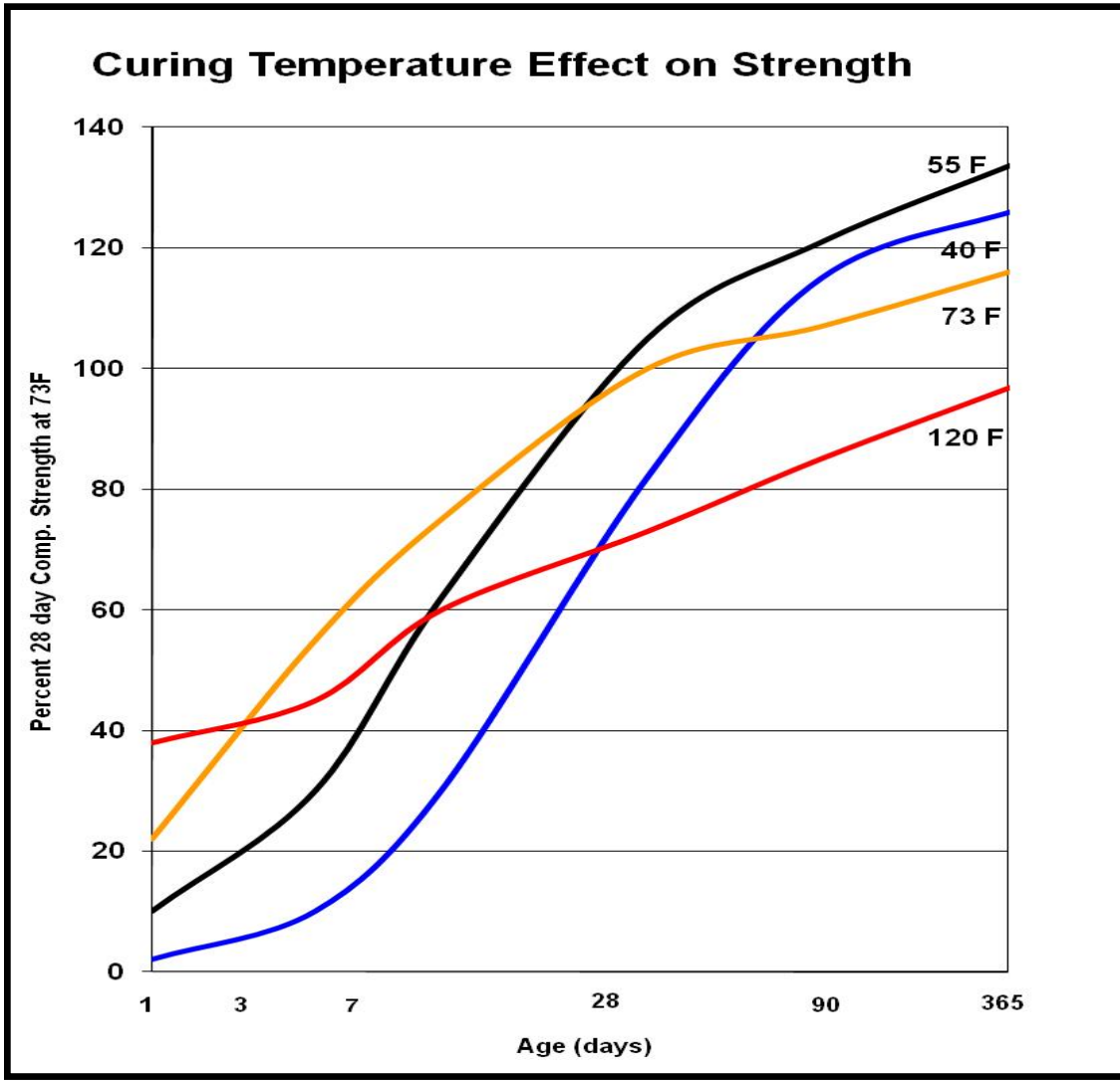
Cole, Lawrence & Okamoto, Paul, Flexural Strength Criteria for Opening Concrete Roadways to Traffic, TRB paper 950222

Factors of Safety

- Iowa uses 500 psi opening
  - Only 300 psi needed (Table previous slide)
- Curve established on concrete with higher air content at plant
- 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

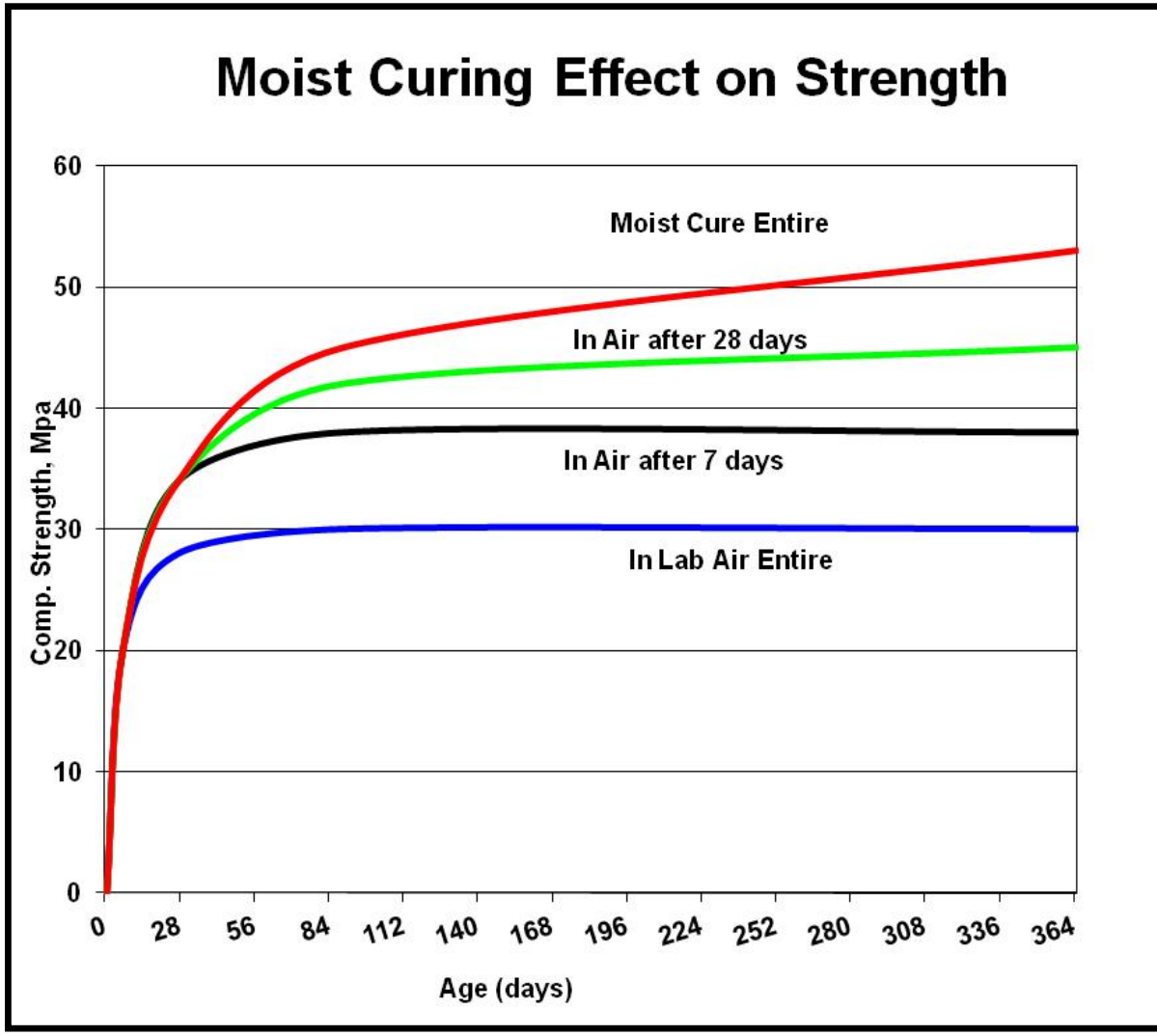
Limitations – Crossover Effect

- Early age curing temperature influence on later strength
- Early strength for opening pavements



Limitations - Curing

- Assume that adequate moisture for hydration is available



Limitations –Materials

- Each maturity curve is unique to a given set of materials

Time for Opening Standard Class C Concrete

Pavement Thickness (in.)	Min. Flexural Strength, (psi MOR-CPL)	Min. Time (Days)
>9	500	5
<9	500	7

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) 18-36 hours
- Fall/Spring (>55 °F) 36-72 hours
- Late Fall (<50 °F) 48-144 hours

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

Other Applications

- Emergency Bridge Replacement
  - Form Removal
- Post Tension
- Saw Time
  - Probe near surface

Conclusions

- Reliable method of opening PCC pavements
- Many factors affect strength maturity relationship
- Use validations to allow mix changes
- Curve validations give a check on reliability
- Contractor's option since 1997 – zero instances of cracking from opening early

Any Questions ?

About Maturity ?