State Aid
Concrete Office Updates

Gordy Bruhn

651-366-5523

Winter 2019-2020

We all have a stake in A to B

Concrete Office Personnel

Maria Masten – Concrete Engineer
651-366-5572
-Specifications and Special Provisions
-Standard Plans and Plates
-Materials Failure Recommendations

Vacant – Structural Concrete Engineer
651-366-5575
-Structural Concrete
-High Performance and Mass Concrete
-Specialty Concrete, Self Consolidating Concrete

Matt Herbst – Ready-Mix Engineering Specialist
651-366-5423
-Concrete Mix Designs
-Concrete Aggregates
-Certified Ready-Mix Program – Metro District

Concrete Office Personnel

Rob Golish – Assistant Concrete Engineer
651-366-5576
-Concrete Paving and Joint Layout Reviews
-Materials Design Recommendations
-Pervious Concrete

Gordy Bruhn – Concrete Field Engineering Specialist
651-366-5523
-General Concrete Field Issues
-Concrete Pavement Rehabilitation (CPR)
-CPR and Paving Plan Review
-Materials Certification

Brad Swenson – Greater MN Plant Coordinator
218-232-1012
-Certified Ready-Mix and Bituminous Plants Support – Outstate
-Materials Certification

Changes in the Concrete Unit

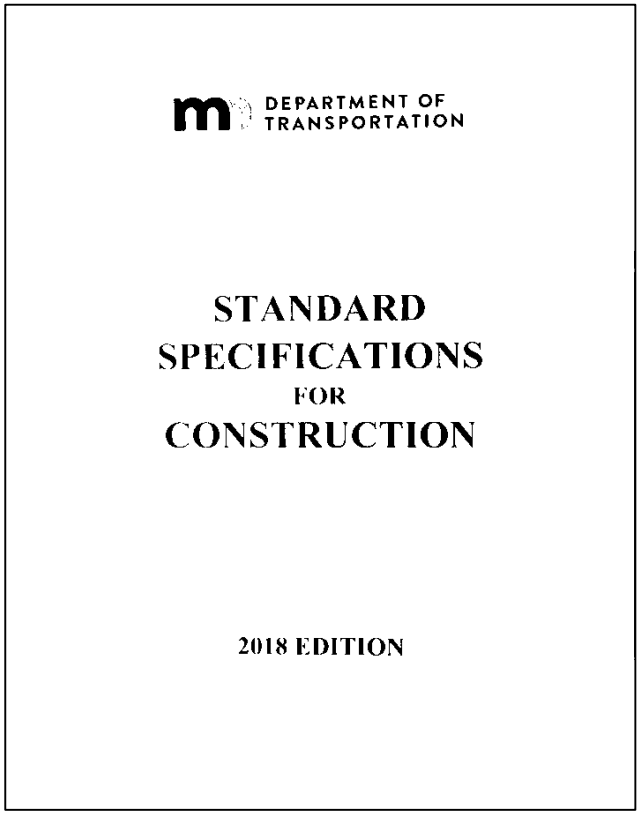
- Matt Herbst, Concrete Mix Design and Aggregate Specialist
  - General Concrete Mix Designs
  - HPC, Mass, and SCC Mix Designs
  - Concrete Aggregate
  - Provide support to Metro District and Producers to ensure compliance
  - Liaison to Lab Supervisors and Independent Assurance

Changes in the Concrete Unit

- Brad Swenson, Greater Minnesota Plant Coordinator
  - Concrete and Bituminous to provide support to Districts and Producers to ensure compliance
  - Assist with Material Certification
  - Review Documentation
  - Instructor
    - Concrete Plant Tech Cert Classes with Wendy Garr
    - Instructor for Plant Monitor Training

2020 MnDOT Spec Book

- Contracts let in November 2020 will use new 2020 Spec Book
- Monetary Adjustments moved to Basis of Payment Section
- Majority of Additions were Previous Special Provisions to 2018 Spec Book
- All Tables Renumbered
- Industry Review Due February 28, 2020



Recurring Ready-Mix Plant Issues

- Certificate of Compliance
  - Incorrect Mix Design Weights
  - Incorrect Sources for JMF Mix Designs
  - Unapproved Mix Design
  - Not using current moisture results
  - Batching in SSD (Saturated Surface Dry)
  - Incorrect / Missing absorption
  - Unsigned first load
  - Signed first load with incorrect information
  - Over design water

Recurring Field Issues

- Certificate of Compliance
  - Dosage Rates of Air Entraining Agent Increased or Decrease without an Air Test Being Performed

Ingredient	Source	MCFac	AbsFac	OD		ABS
67ROS	19128	0.013	0.015	1653	lb	25
SANDROS	19128	0.033	0.005	683	lb	3
SANDROS2	19128	0.033	0.005	683	lb	3
GRCEMENT	DACRC6D			385	lb	
FLYASH	PSG9MAIN			175	lb	
AEA	MAIR90			4.00	oz	
CCWATER	COLDCITY			20.2	gal	
CLWATER	CLARIFIED			.0	%	
HCWATER	HOTCITY			.0	%	

Recurring Field Issues

- Certificate of Compliance
  - Ingredients Sources for Job Mix Formulas Can Not be substituted

Ingredient	Source	MCFac	AbsFac	OD		ABS
67ROS	19128	0.013	0.015	1653	lb	25
SANDROS	19128	0.033	0.005	683	lb	3
SANDROS2	19128	0.033	0.005	683	lb	3
GRCEMENT	DACRCSD			385	lb	
FLYASH	PSGS/MAIL			175	lb	
AEA	MAR90			4.00	oz	
CCWATER	COLDCITY			20.2	gal	
CLWATER	CLARIFIED			.0	%	
HCWATER	HOTCITY			.0	%	

Signing the Certificate of Compliance

- Review the first Certificate of Compliance for each mix type, each day, for accuracy; and
- Legibly hand sign the Certificate of Compliance at a location designated for Producer signature signifying agreement to the terms of this program and to certify that the materials comply with the requirements of the Contract; and
- Print their name and write their MnDOT Technical Certification Number next to their signature.

DEPARTMENT OF TRANSPORTATION

Things that are coming…

Certificate of Compliance

- Assemble Committee – Meet Winter/Spring 2020
- Capture MnDOT and Industry Changes
- Discuss use of Oven Dry (OD) vs. Saturated Surface Dry (SSD)
- **Implementation Timeline: January 1, 2022**

E-Ticketing Technology

- MnDOT Currently Evaluating E-Ticketing Technology with Bituminous Trucks
- Look for concrete ready-mix pilot projects in 2020 & 2021
- Implementation Timeline: TBD

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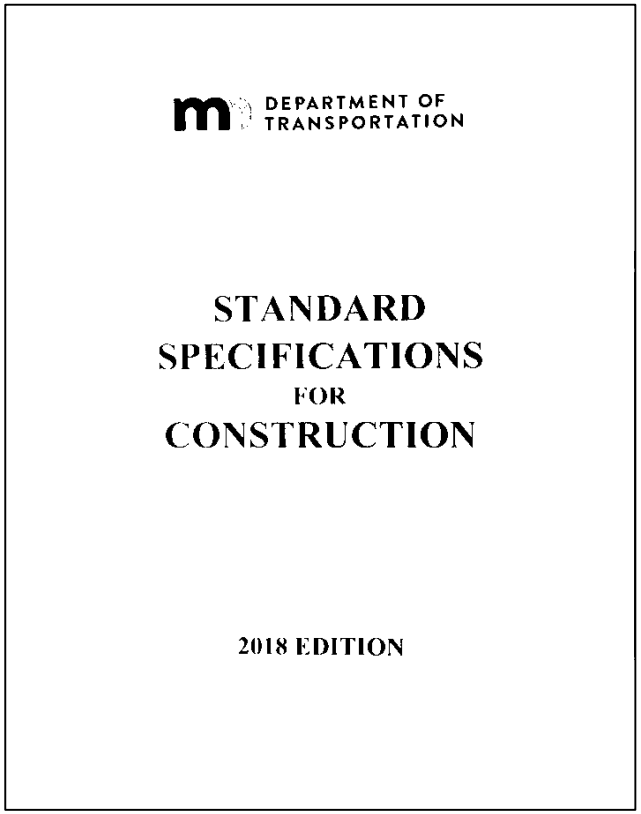


DEPARTMENT OF TRANSPORTATION

What’s New?

Concrete Maturity for Estimating Concrete Strength

DEPARTMENT OF TRANSPORTATION

More info on Maturity Method

Concrete Maturity

Materials Home | Concrete Home | Contacts

Maturity

Introduction

- The maturity method is an non-destructive procedure used to estimate the strength of in-place concrete based on temperature history of the concrete.

Did you know

Maturity is an allowable method to determine development of concrete strength. See Standard Specifications for Construction 2018, Specification 2461.3.G.6, "Estimating Concrete Strength by the Maturity Method."

Uses

- Predicting opening times to traffic, striping forms, terminating cold weather protection are several uses for the maturity method.

Specification

- Specification 2461.3.G.6, "Development of Maturity-Strength Relationship"
- The updated special provisions will be posted in the near future

Procedures

- Maturity method procedures

Forms

Concrete maturity workbook - beams (revised 7/22/2019)

Concrete maturity workbook - cylinders (revised 9/2018)

Benefits of Using Maturity

- Reduce field control cylinders/beams
- Real-time and Continuous
- Effectiveness of Cold Weather Protection Plan
- Monitoring Temperature of Concrete
- Form Removal
- Sawing
- Opening to Traffic

Maturity Method

Developing the maturity-strength relationship requires three steps:

Step 1 - Develop the maturity-strength curve

Step 2 - Estimating the in-place strength

Step 3 - Verifying the strength-maturity relationship

Development of Maturity Curve Required Equipment

- Provide maturity meter or temperature sensor wires and data logger with a secure means of collecting, measuring, recording and storing temperature data that is unalterable

- Provide beam or cylinder molds for casting strength specimens, and other ancillary equipment for casting and curing strength specimens

Development of Maturity Curve
No. of Strength Specimens Required

Table 2461-20
Chronological Testing Ages of Strength Specimens

Type of Concrete	Testing Ages *
Concrete Pavement as defined in2301, "Concrete Pavement" ***(Cast 12 beams + 2 beams w/ imbedded sensors)***	Test at least two (2) sets of strength specimens before and two (2) sets after the anticipated opening strength.
Normal Strength Concrete as defined in 2461, "Structural Concrete"	1, 3, 7, 14 and 28 days ***(Cast 15 cyl. plus 2 with imbedded sensors)***
High-Early (HE) Concrete as defined in 2461, "Structural Concrete"	12 hours, 1, 2, 7 and 28 days
Ultra High-Early (UHE) Concrete per Contract	3, 4 and 8 hours, 1 and 14 days

*** The Contractor may adjust the testing ages if approved by the Concrete Engineer in conjunction with the Project Engineer.**

Development of Maturity Curve Cast Strength Specimens

Development of Maturity Curve Cast 2 Strength Specimens W/ Sensors

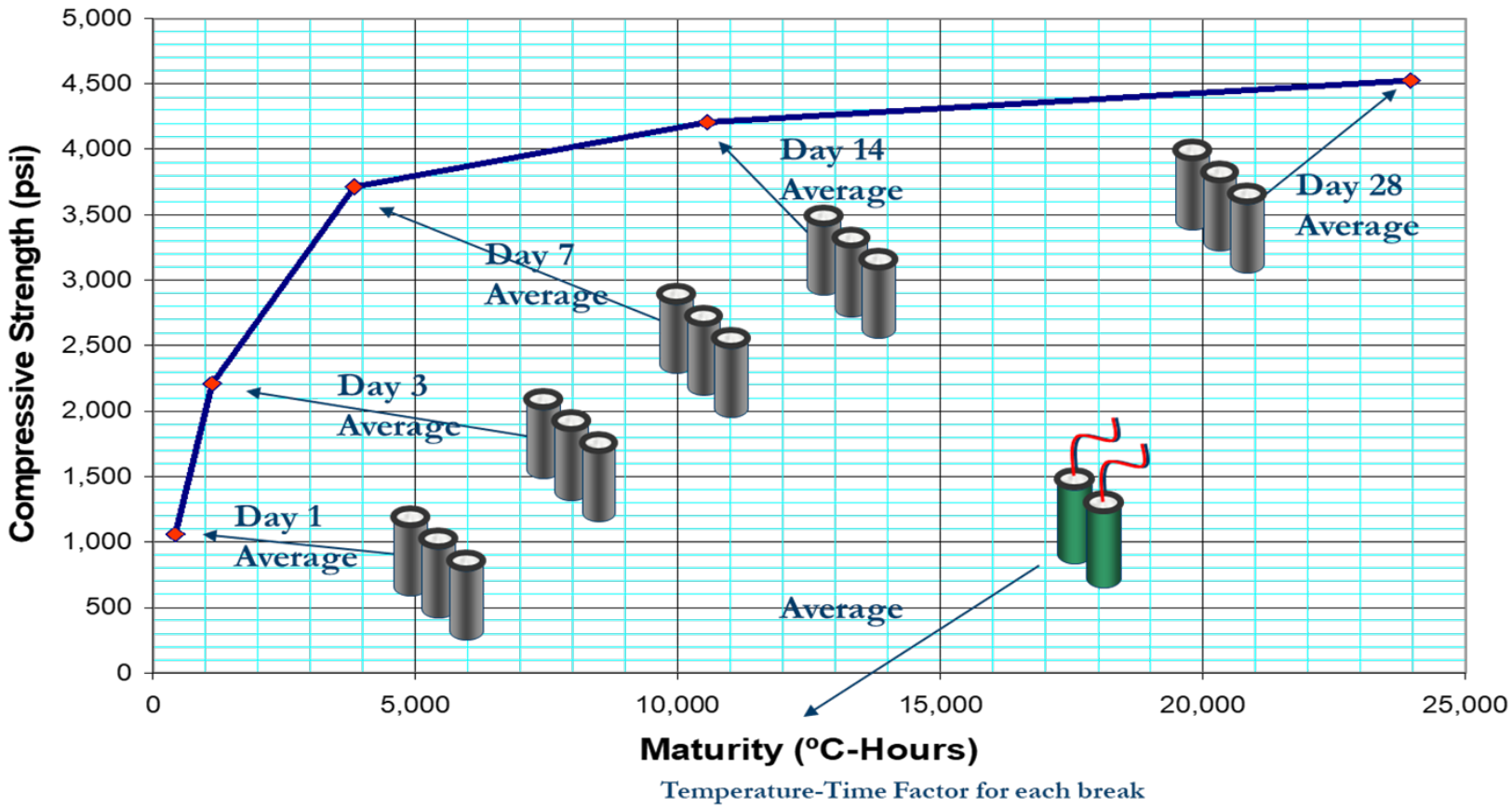
- Embed the sensors in the center of the 2 additional beams or cylinders specimens

Development of Maturity Curve Cure Strength Specimens

- Cure specimens in a moist condition at a temp of range 50° – 80° F

Development of Maturity Curve

- Strength Test specimens at time specified in 2461



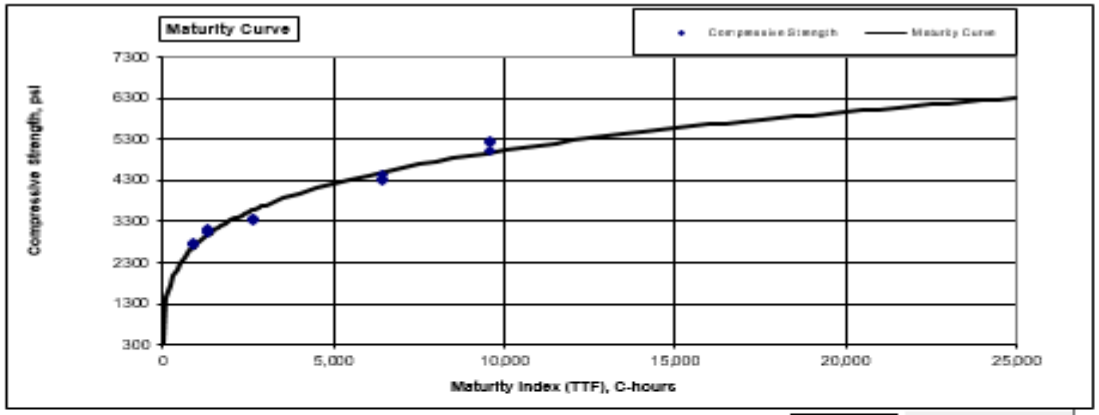
Minnesota Department of Transportation

10/22/2019

Concrete Maturity - Compressive Strength Development

Project No.:	8901-23	Tester:	C.Calloway	Report Date:	11/27/19
Location:	I-425	Contractor:	TUV	Casting Date:	11/20/19
Curve #:	1	Engineer:	T.Sander	Casting Time:	7:45am
				Opening Strength, psi	3000

Beam No.	Age at Break (hours)	Ave. Diameter "D" (in)	Ave. Length "L" (in)	Total Test Load (lbs)	Failure Type	Compressive Strength (psi)	TTF Sensor 1 (C-Hours)	TTF Sensor 2 (C-Hours)	Ave. TTF (C-Hours)
1	16.5	6.01	12.02	79060	Cone	2785	881	887	885
2		6.00	12.00	77090	Cone/Split	2725			
3		5.96	11.99	76720	Cone	2750			
4	28.5	6.01	12.02	85625	Cone	3020	1235	1321	1280
5		6.00	12.01	87290	Cone	3085			
6		5.97	12.00	87830	Cone/Split	3140			
7	39.5	6.00	12.00	95400	Cone	3375	2547	2654	2600
8		6.02	12.00	95900	Cone	3370			
9		6.00	11.99	94230	Cone	3335			
10	53.5	6.00	11.99	121740	Cone/Split	4305	6521	6352	6435
11		5.98	12.00	124110	Cone	4420			
12		5.99	12.01	121800	Cone/Split	4320			
13	64.5	6.01	12.00	149940	Cone	5285	9542	9654	9600
14		6.00	12.00	147070	Cone/Split	5200			
15		6.01	12.01	142340	Cone/Split	5020			



Required TTF for Opening **1349** C-hours

Su=	2638056.59
t=	1.1826E+24
a=	0.03968784

Solve Maturity Curve

Comments:

Mix Information	
Mix No.	3F52
Truck No.	52654
Air, %	6.8
Temperature	67
W/C Ratio	0.45

Certified Contractor Rep:

Maturity Curve Reviewed by:

Maturity Method

Developing the maturity-strength relationship requires three steps:

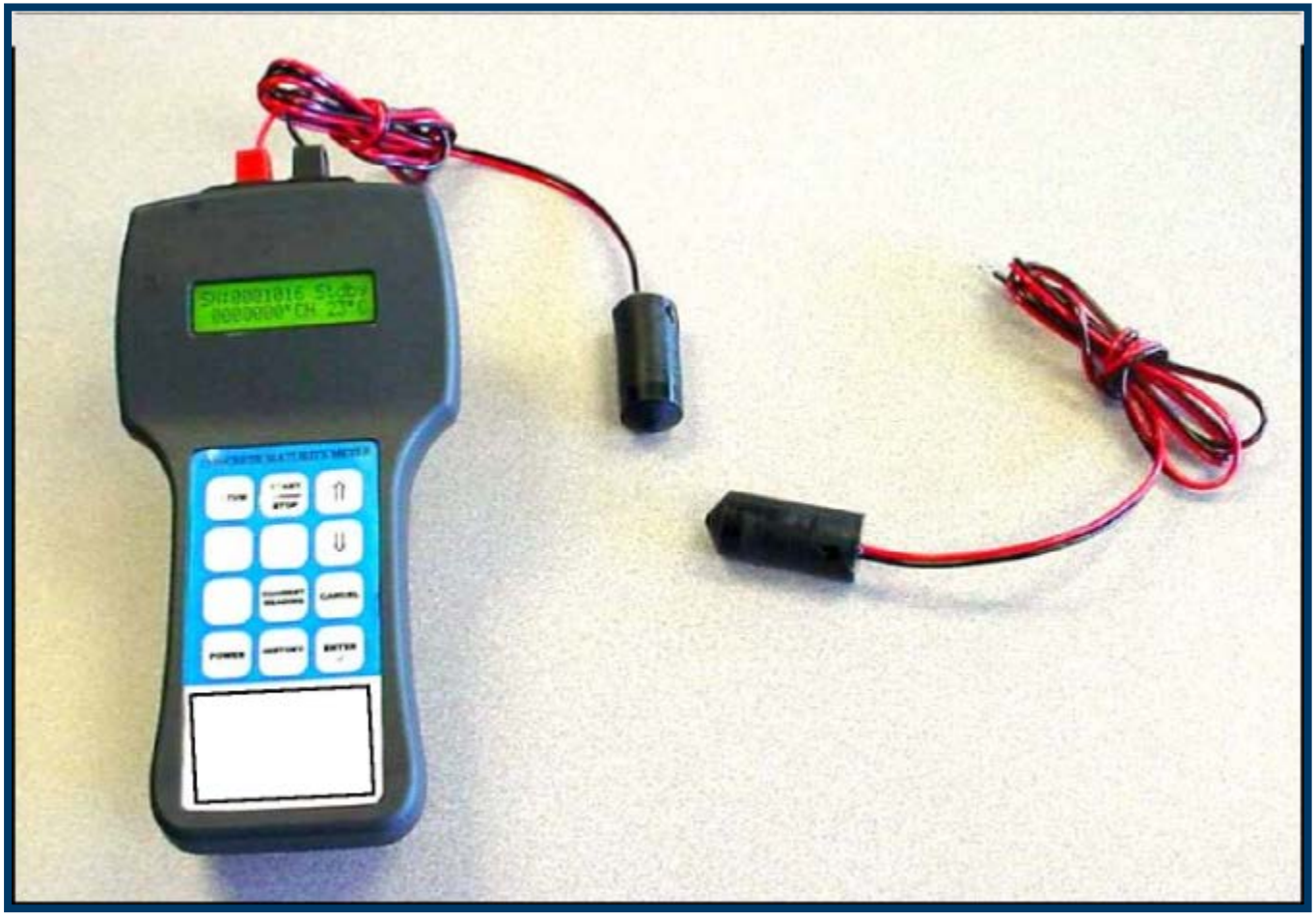
Step 1 - Develop the maturity-strength curve

Step 2 - Estimating the in-place strength

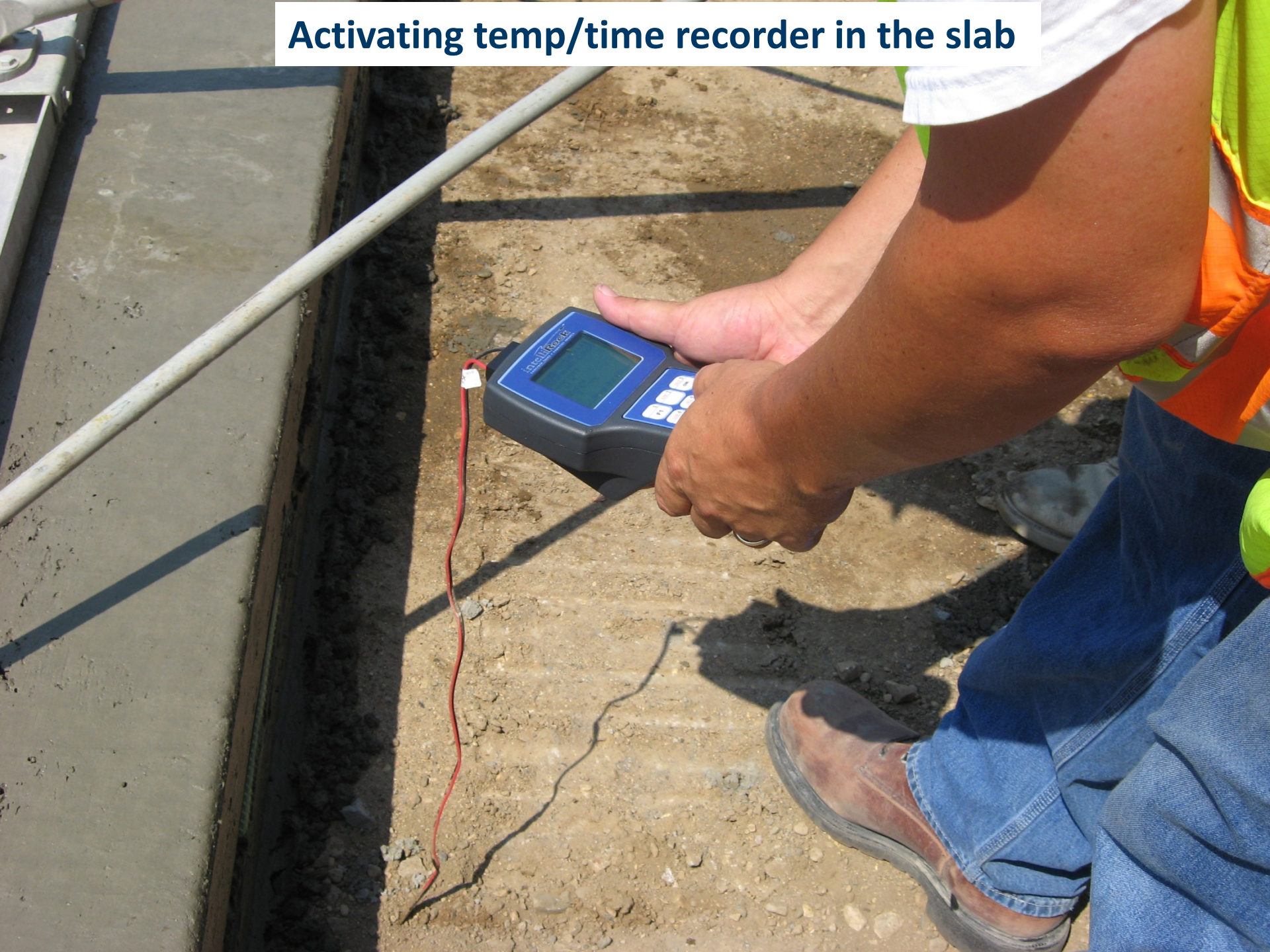
Step 3 - Verifying the strength-maturity relationship

Maturity Reader

Maturity Reader



Activating temp/time recorder in the slab



Data Loggers

Data Loggers Down Loading

Maturity Method

Developing the maturity-strength relationship requires three steps:

Step 1 - Develop the maturity-strength curve

Step 2 - Estimating the in-place strength

Step 3 - Verify the maturity-curve

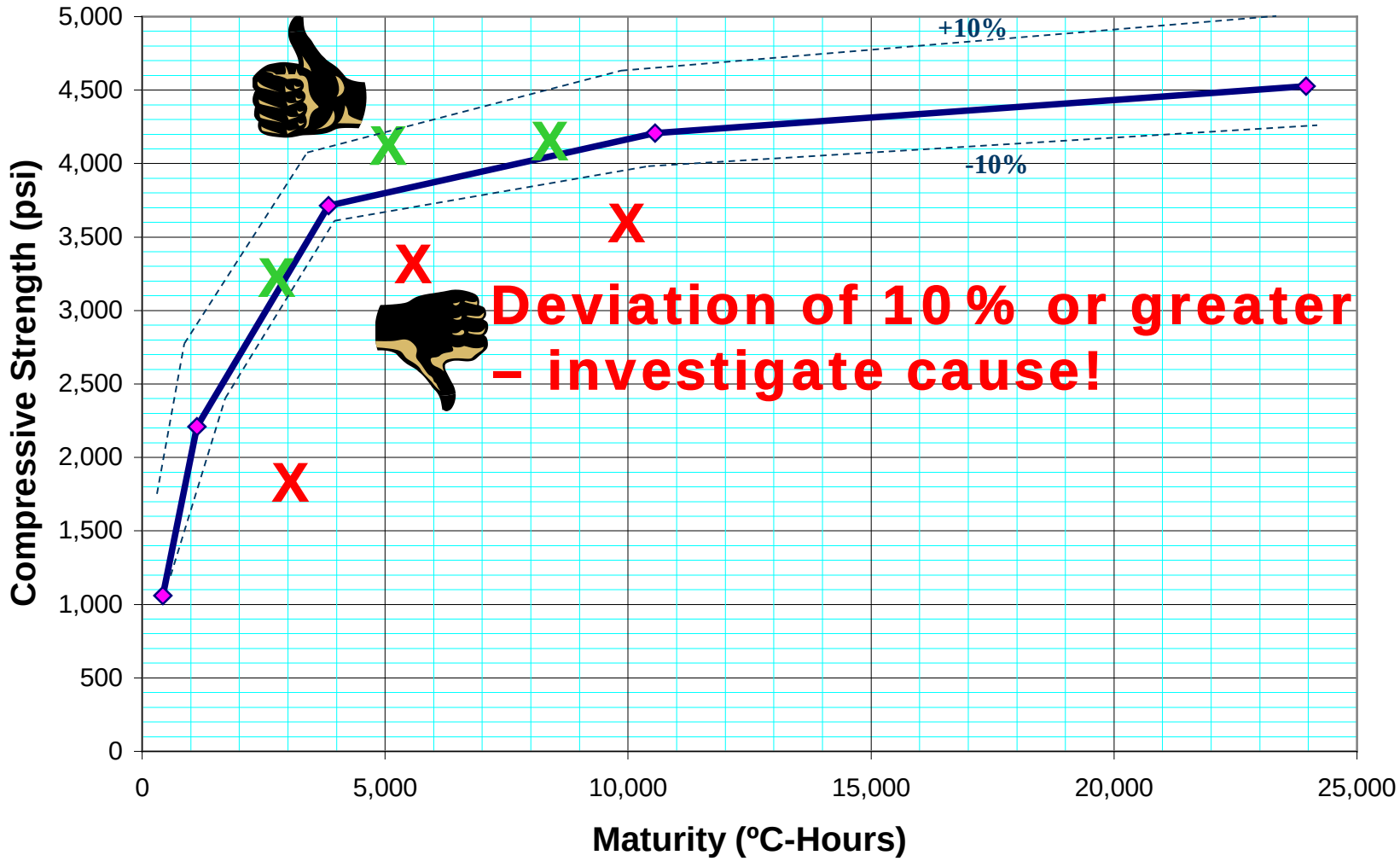
Do not compare the strength test results with the sensor placed in the concrete structure

Validation the Maturity Curve

- Cast 4 Cylinders or Beams, embed a sensor in 1 of the 4 specimens
- Strength test the three remaining cylinders/beams when the data shows 3000 psi compressive strength, or 350 to 500 psi flexural strength.

G.6.c Verify Strength-Maturity Relationship

- **Verification Through Strength tests**



Intervals for Validating Strength-Maturity Relationship

1. When the maturity curve is developed before the start of construction or in a laboratory, perform a **validation** strength test on the first day of concrete placement.
2. For slipform concrete paving, perform a **validation** strength test at least once every fifteen (15) calendar days during normal plant production.
3. For all other concrete, perform a **validation** strength test at least once every thirty (30) calendar days during normal plant production.
4. If the plant has not supplied concrete utilizing the maturity curve for a period of greater than ninety (90) calendar days and begins producing with intent to use the existing maturity curve, perform a **validation** strength test.

Changes in Concrete Mixture

Perform a **validation** strength test if any of the following changes occur:

(1) Change in mixture proportions greater than 5% by weight
(2) Increase in the water-cementitious materials ratio by more than 0.02
(3) Change in the cementitious source
(4) Change in the class of coarse aggregate material

Validation of Maturity Curve Cure Strength Specimens

- Cure specimens in a moist condition at a temp of range 50° – 80° F

“Match Curing” Field Control Cylinders

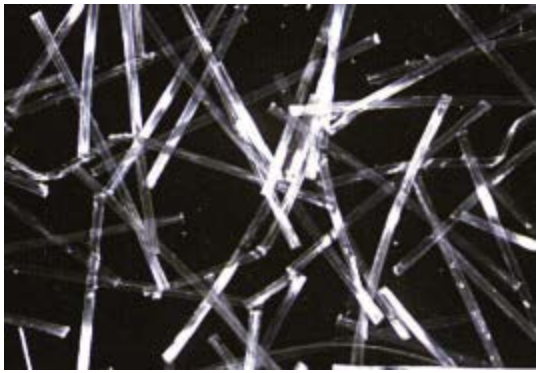
The Engineer will allow “Match Curing of Concrete Test Specimens” method in accordance with AASHTO R72 modified as follows:

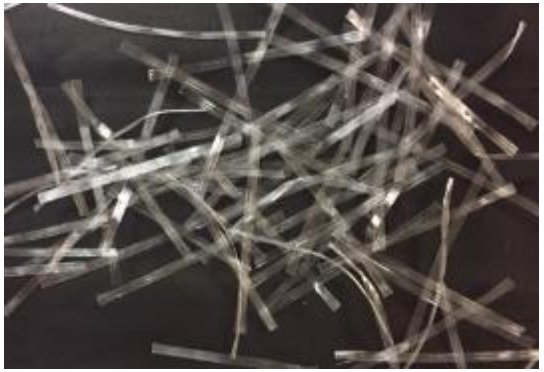
(1) Provide an apparatus that consist of a monitoring and heating system capable of maintaining concrete cylinders at a temperature no greater than 5°F above the temperature of the concrete at a specific location in the member. A satisfactory system to continually monitor the concrete temperatures may include a temperature sensor in the concrete structure or unit involved, **a controller, special insulated cylinder molds with built-in heating systems, and a temperature sensor in the molds.**

(2) When the temperature exceeds 5°F or the temperature monitoring system fails, the Engineer will not accept field control cylinder results.

Fibers (Non Metallic)

- Required in <u>ALL</u> Decks
- Approved products list
- Method of Incorporating Fibers
  1. Open bag and distribute fibers on aggregate belt at ready-mix concrete plant;
  2. Open bag, break apart any fiber clumps, and introduce fibers into ready-mix concrete truck in a well-distributed manner (i.e., "chicken feed")

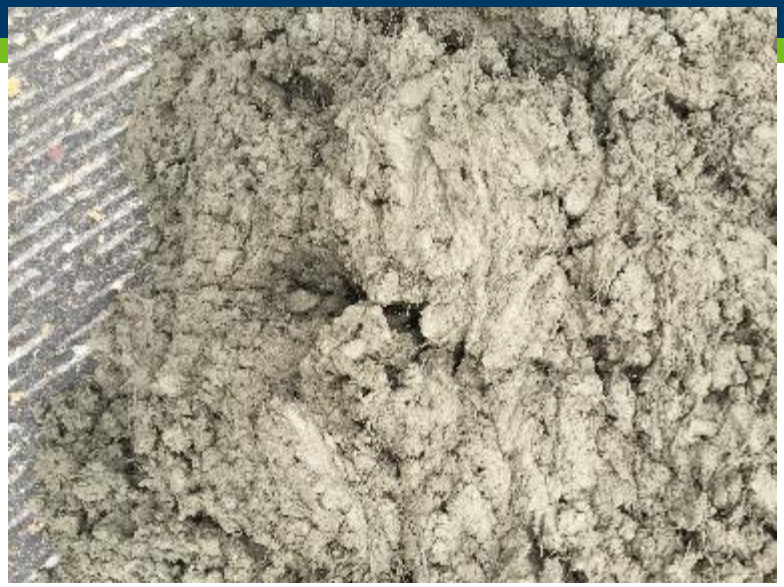




Proper Mixing of Fibers

- Concerns with fiber balling – Discuss at Pre-con!!
  - Ready-Mix
    - Spec Requires breaking open the bags of fiber prior to mixing
    - **Any fibers from balling in test pour?**
    - The pumping grate will stop a most of fiber balls,
    - What about fiber balls when belting concrete
    - Fibers may impact mix times
    - Have heard of instances where air entrainment test seemed to be erratic,
    - Didn't seem to impact finishing or closure of the surface

Placing the fiber reinforced concrete



Review of Old Business

Structural Concrete 2461
Type C & E Accelerating Admixtures

- Requires Concrete Engineers approval when temps are greater than 35º F.

- Becomes Contractor option when **all** of following conditions exist:

(3.1) The ambient temps are less than 36º F,

(3.2) Project has an Engineer approved cold weather protection plan,

(3.3) The cold weather protection materials are on-site and prepared for use.

Structural Concrete Specification 2461

Water Adjustments

- For **all** grades of concrete, no water additions 1 hour after batching,
- For **grades of concrete NOT used for Slip-Forming**, do not make water adjustments after discharging approximately 1 cubic yard.
- **2461.3.G.7.a "Concrete Placed by the Slip-Form Method"**, The Engineer will allow water adjustments as necessary to facilitate slip-form placement.

(Again, NO water additions 1 hour after batch time!)

Structural Concrete Specification 2461

Admixture Adjustments

- **Approved admixture additions are allowed within 90 min from the initial batch time stated on the Certificate of Compliance.**
- **If the load of concrete has no available water to add, or the load is greater than 60 minutes old, the Engineer will allow one admixture adjustment diluted with up to 2 gallons of water.**
- **Admixture adjustments as needed up to the 6o minute mark.**

Concrete Sampling
ASTM C172

- **Changing Concrete Manual to ASTM C172 Sampling Requirements**
- **Minimum Sample Size for Strength Testing is 1 Cubic Foot.**

  In Other words, Around 145 Pounds of Concrete
- **Concrete Field Testers Need Wheelbarrows**
- **Mix sample in wheelbarrow prior to performing tests**

Vibratory and Backfilling Concrete Restrictions

- Protect newly placed concrete from damage by adjacent vibratory or backfilling operations for a minimum of 24 hours.

- Wait at least 72 hours after placing the concrete or after the concrete reaches a compressive strength of at least 3,000 psi (Changing to 2000psi by special provision in March 2020)

  (2000 psi for Concrete Paving)

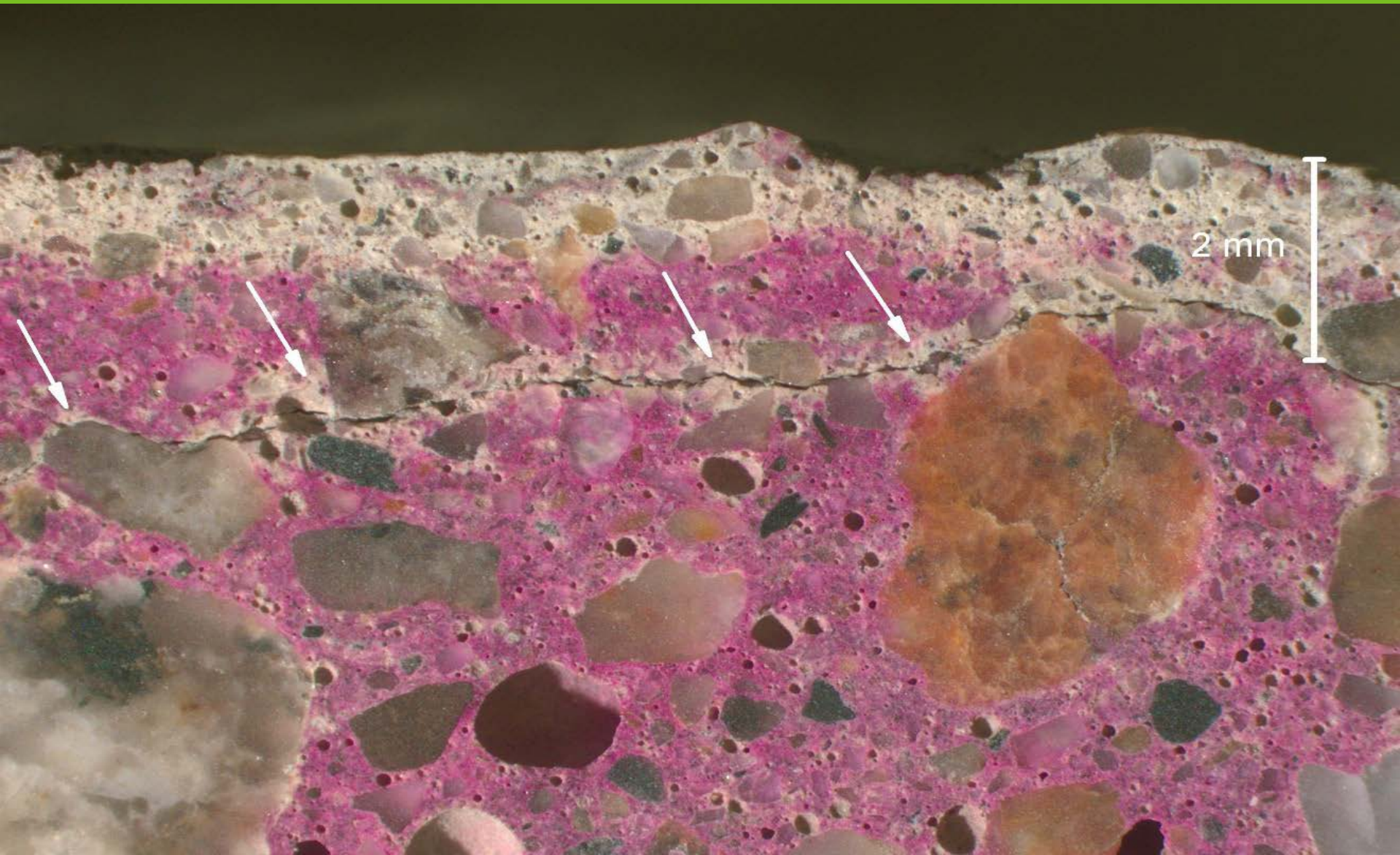
- Hand operated concrete consolidation equipment and walk behind vibratory plate compactors are allowed 24 hours after placing the concrete, and other equipment as approved by the Engineer, in conjunction with the Concrete Engineer.

What Happened Here?

Cored Raised Bridge Walk for a Petrographic Analysis

Poor Curing?

“Scaling of the concrete surface was caused by a combination of inadequate/untimely curing and late season placement of the concrete.”



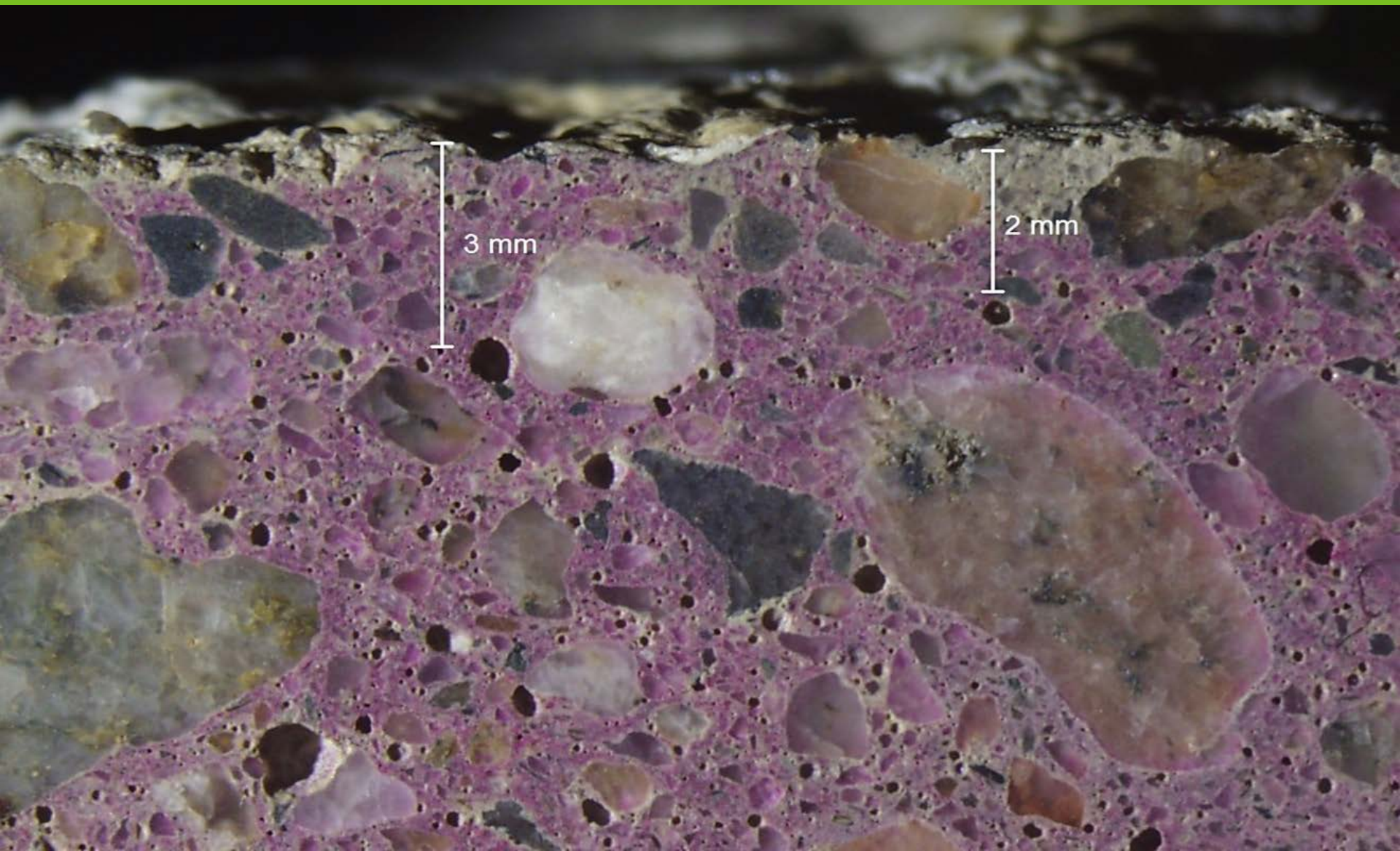
Flatwork Mortar Flaking

Conclusion

Scaling of the top surface of each of the samples was caused by exposure to cyclic freezing and thawing of a saturated, poorly durable surface paste compromised by a combination of factors:

1) “Late season placement of the concrete,”
2) “Over-finishing and reduced air void content within the top few millimeters of each sample,” and
3) Inadequate curing of the concrete surfaces.

Over Finishing Compromised the Entrained Air



Cool/Cold Weather Concreting

Evaporation rates of Lake Ontario (concrete).
Warm lake (concrete) & cold air, equals higher evaporation rates.

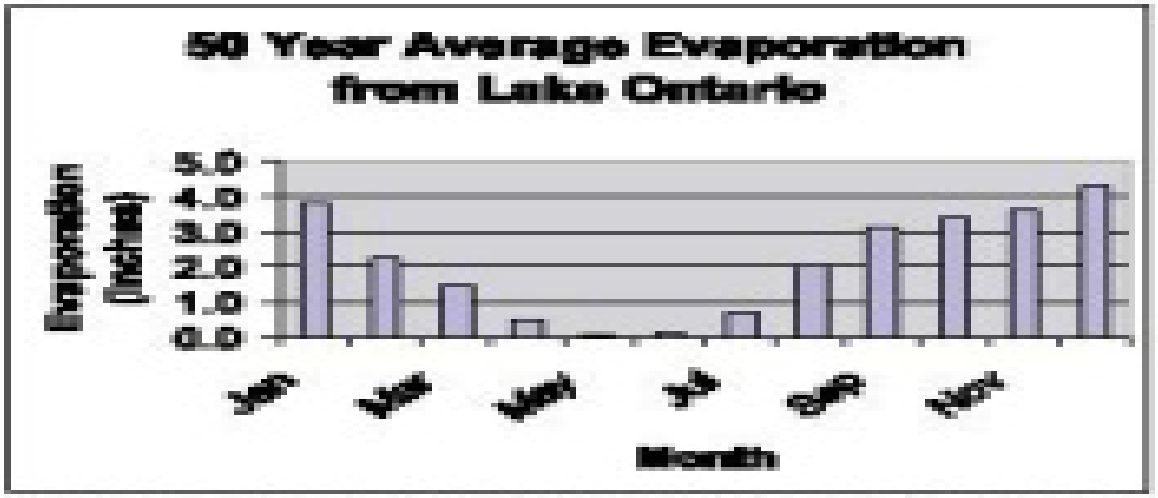


Fig. 1: Rate of evaporation from Lake Ontario peaks in December - January when the water is still relatively warm but the air is rapidly cooling. Minimum evaporation is in the months of May and June when the air is warmer than the cold water.

Moisture loss in cool/cold weather

Fig. 2(b): Fog over warm concrete during cold-weather concreting

Concrete Curing

Verify Curing Compound

Refer to the approved products list of curing compounds for pre-tested lots or call (651) 366-5556 before applying

Concrete Curing Material

- Use Spec 3754 AMS or Spec 3755 Linseed Cure anytime year round
- New Curing Spec Number
  - Spec 3753 - Colored and Architectural Concrete

Standard Specification Curing Requirements 2301, 2406, 2521, 2531, 2533

Use one of the following curing methods:

(1)Place/install curing medium within 30 minutes of concrete placement **or once the bleed water has dissipated.**

(2) place the membrane curing compound on the edges within 30 minutes after permanent removal of the forms or (poly or insulated) curing blankets.

(3)Place plastic (white opaque poly / insulated) curing blankets or completely saturated burlap curing blankets as soon as practical without marring the surface.

Concrete Curing-Bridge Decks

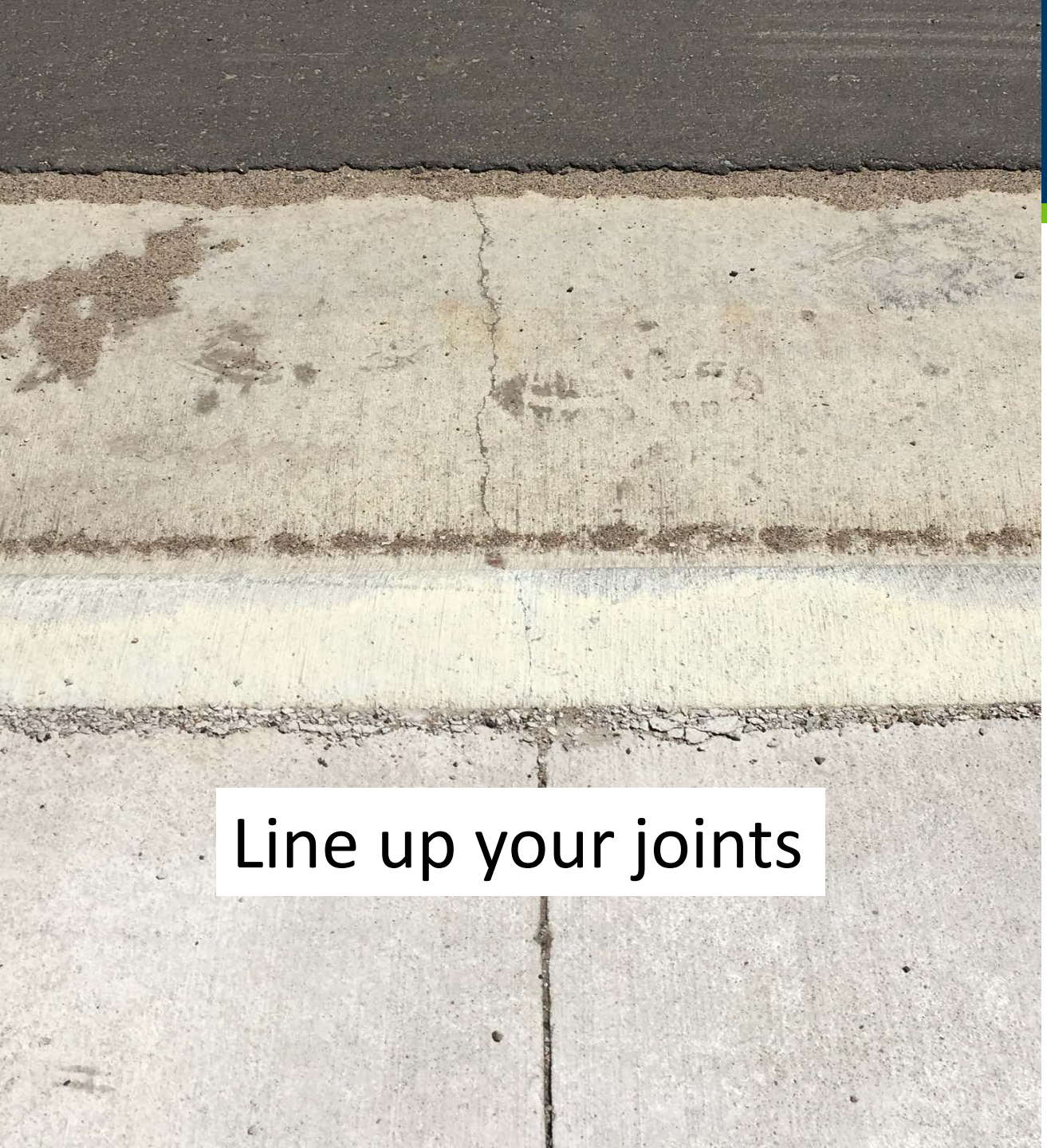
- Specification – Bridge Concrete
  - Structural Slab (overlay)
    - Wet burlap within 30 minutes
    - $500.00 deduct For every 5 minutes
  - Bridge Deck Slab
    - Membrane curing within 30 minutes.
    - Wet burlap for minimum of 7 days
    - $500.00 deduct For every 5 minutes
    - If diamond grinding can use wet cure

Bleed Water!!!

Machine placed C&G.
Not a curing issue, over consolidated.

Slip formed machine had a single vibrator that was over vibrating the entrained air out of concrete.

Jointing Issues



Preplan Jointing

Preformed Joint Filler

Preformed Joint Filler is now on the APL

In tangent, Place joint filler between C&G and sidewalk

http://www.dot.state.mn.us/products/concrete/preformedjointfillers.html

Standard Specification Rain Protection Requirements 2301, 2302, 2406, 2521, 2531, & 2533

- Protect the concrete from damage due to rain. Have available, near the site of the work, materials for protection of the edges and surface of concrete.

- After removing the rain protection, apply membrane curing compound to all concrete surfaces.

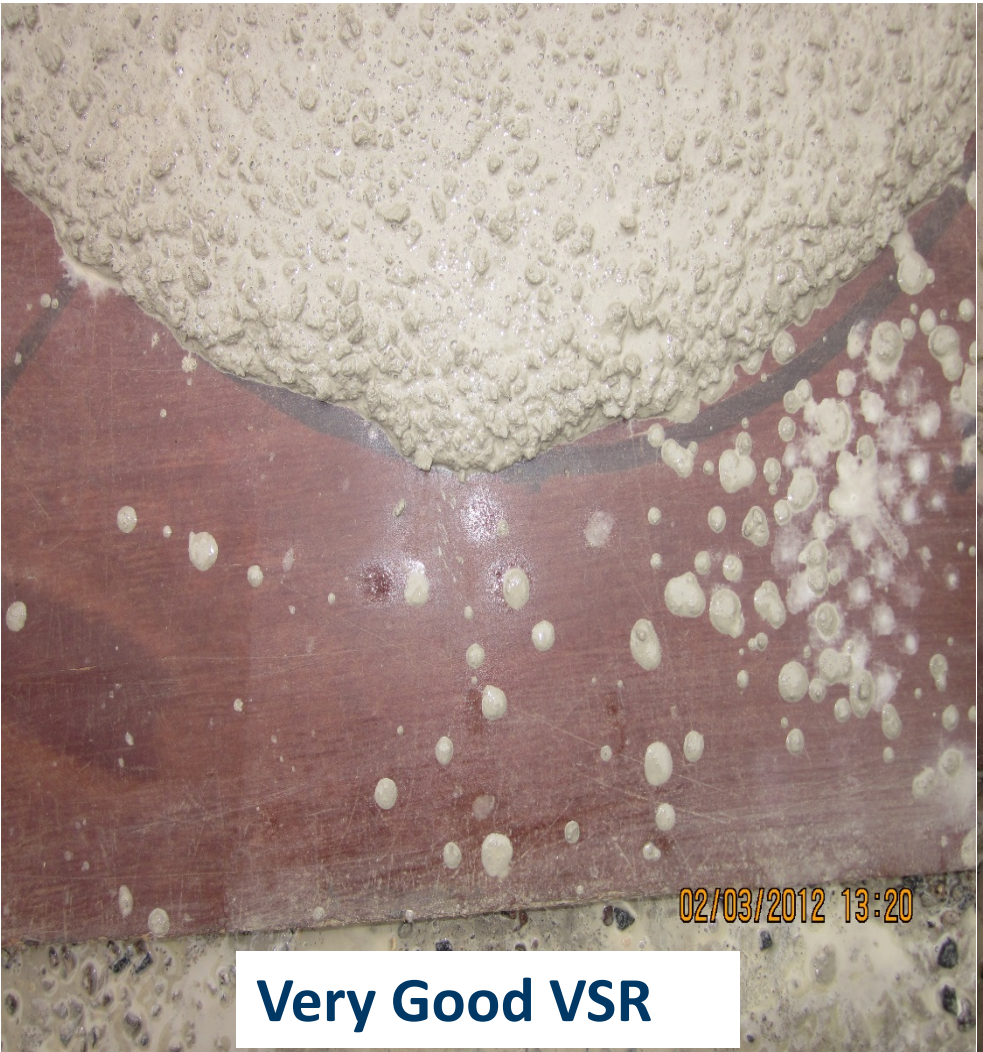
Self Compacting Concrete (SCC)

SCC Spread Test

SCC Spread Test

Spread = Measured at 90º and Average 2 Measurements

SCC Visual Stability Rating (VSR)



Very Good VSR

Marginal VSR (at best)

Test Pour
Self Compacting Concrete

SCC uses an admixtures that keep the aggregate from segregating.

Cored Multiple Locations

When a SCC Test Pour goes Wrong

Wall Infills using SCC

Do the Required Test Pours

Structural Concrete Specification 2461 Definitions…

- **Strength Test,** is an average of 3 cylinder **all** cast from the same sample of concrete.
- **F'c** is a specified compressive strength (psi.)
- Concrete may have multiple minimum f'c requirements. For example: f'c requirement to opening to traffic, f'c requirement to ship precast structures, f'c requirement for cutting pre-stressed strands, f'c requirement for 28-day strengths, etc.

Table 2461-6
Concrete Mix Design Requirements (Not applicable to High Performance Concrete or Mass Concrete)

Concrete Grade	Mix Number	Intended Use *	Maximum w/c ratio †	Maximum Cementitious Content (lbs/yd³)	Maximum %SCM (Fly Ash/ Slag/Ternary)	Slump Range	Minimum 28-day Compressive Strength, f'c	3137 Spec.
B Bridge Substructure	3B52 ‡	Abutment, stems, wingwalls, paving brackets, pier columns and caps, pier struts	0.45	750	30/35/40	2 - 5"	4000 psi	2.D.1
F Flatwork	3F32 ‡	Slipform curb and gutter	0.42	750	30/35/0	½ - 3" #	4500 psi	2.D.1
	3F52 ‡ 3F52EX 3F53EX 3F52CO ‖	Walks, curb and gutter, slope paving, median walks, driveway entrances, ADA pedestrian walks	0.45	750	25/30/0	2 - 5"	4500 psi	2.D.1
G General Concrete	1G52 ‡	Footings and pilecap	0.55	750	30/35/40	2 - 5"	4500 psi	2.D.1
	3G52 ‡	Footings, pilecap, walls, cast-in-place manholes and catch basins, fence posts, signal bases, light pole foundations, erosion control structures, cast-in-place box culverts, culvert headwalls, open flumes, cast-in-place wall stems	0.45	750	30/35/40	2 - 5"	4500 psi	2.D.1
M Median Barrier	3M12	Slipform barrier, median barrier, non-bridge	0.42	750	30/35/40	½ - 1" #	4500 psi	2.D.1
	3M52	Barrier, median barrier, non-bridge	0.45	750	30/35/40	2 - 5"	4500 psi	2.D.1
P Piling	1P62 ‡	Piling, spread footing leveling pad	0.68	750	30/35/40	3 - 6"	3000 psi	2.D.1
R Pavement Rehabilitation	3R52 ‡	CPR - Full depth concrete repairs, concrete base	0.45	750	30/35/40	2 - 5"	4000 psi	2.D.3
S Bridge Superstructure	3S12	Slipform bridge barrier, parapets, end post	0.42	750	30/35/40	½ - 1" #	4000 psi	2.D.2
	3S52	Bridge median barrier, raised median, pilaster, curb, sidewalk, approach panel, formed bridge barrier, parapet, end post, collar	0.45	750	30/35/40	2 - 5"	4000 psi	2.D.2
X Miscellaneous Bridge	1X62	Cofferdam seals, rock sockets, drilled shafts	0.45	750	30/35/40	3 - 6"	5000 psi	2.D.1
	3X62	Drilled shafts above frost line	0.45	750	30/35/40	3 - 6"	5000 psi	2.D.1
Y Bridge Deck §	3Y42-M 3Y42-S	Bridge decks, integral abutment diaphragms, pier continuity diaphragms, expansion joint replacement mix	0.45	750	30/35/40	2 - 4"	4000 psi	2.D.2
	3Y47 **	Deck patching mix	0.45	750	30/35/40	2 - 4"	4000 psi	2.D.2

If the intended use is not included elsewhere in the Specification or Special Provisions, use mix 3G52, unless otherwise directed by the Engineer.
Identify specific color used on the certificate of compliance. Colored concrete is only allowed when specified in the plans or the Contract.
The minimum water/cement (w/c) ratio is 0.30.
The Contractor may choose to use the Coarse Aggregate Designation "1" for the 4th digit in accordance with Table 2461-3.
Adjust slump in accordance with 2461.3.G.7.a for slipform concrete placement.
The "-S" indicates a bridge deck with a structural slab and "-M" indicates a monolithic bridge deck.
* Mix 3Y47 requires the use of Coarse Aggregate Designation "7" or "3" for the 4th digit in accordance with Table 2461-3.

Structural Concrete Specification 2461 Definitions…

Low Concrete Strength Test

- A strength test is considered **low** when the result are **no** greater than 500psi deficient. (F'c minus ≤ 500psi)
- Example: A 3F32 concrete mix requires a minimum 28-Day strength of 4500psi, a low strength for a 3F32 mix is then 4000psi to 4499psi
- **Low strengths have achieved adequate strength to remain in place.**
- Other than applying the low strength(s) to the moving average of 3 strength test, further action is not required… Unless the moving average of 3 strength tests falls below the 28-day f'c requirements.

Structural Concrete Specification 2461 Definitions…

Failing Concrete Strength Test

- A strength test is considered a **failing** , when the test results shows **greater** than 500psi deficiency in strength (F'c minus > 500psi)

- A determination must be made as to whether or not the compressive strength is adequate to perform as intended.

Strength Test Result Evaluation

- **Single Strength Test > 500 psi Below f'c**
  - The Engineer, in conjunction with the Concrete Engineer, <u>will investigate</u> to determine if the concrete has attained the critical load-carrying capacity.
  - Document all failing strength as a Material Exception
  - **In 2016 Removed a 3' by 12' signal pole foundation due to low strength… 14% hardened air content contributed to low strength**
  - **May need to removing hand placed barrier constructed in 2018.**

Structural Concrete Specification 2461 Definitions…

Moving average of 3 Consecutive Strength Tests

- A moving average is **NOT** the average of 3 cylinder all cast from the same representative sample of concrete!
- Moving average is the average of 3 strength tests.
- A failing strength test is included in the moving average calculation if the concrete structure was allowed to remain in place

Moving Average of 3 Cylinder Test Results
NOTE: Passing Cylinder has the Deduct

Minnesota Department of Transportation

Cylinder Strength Failures

Project #:	8888-888	Mix Design:	3M52
Plant Name:	Gordy's Not So Ready Mix LLC	Minimum 28-day Compressive Strength (psi):	4500
		Concrete Price per Cubic Yd:	$100.00
Total Cubic Yards being Adjusted:	125.0	Total Monetary Adjustment:	$1,562.50

* Contact Concrete Engineering Unit, per Specification 2461.3.G.5.e(1)

** Contact Concrete Engineering Unit, per Specification 2461.3.G.5.e(4)

‖ Remove and replace concrete in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work," as directed by the Engineer. If the Engineer, in conjuction with the Concrete Engineer, determines the concrete can remain in place, the Engineer will not pay for the concrete.

Cylinder Field ID:	Date Made	Cubic Yards Placed	Strength Test (psi)	Strength Deficiency > 500 psi	Concrete Grades B,S,X,Y Strength Failures	Moving Average (psi)	Moving Average % of Req'd	Adjusted Contract Unit Price per Cubic Yard	Cubic Yards being Adjusted	Monetary Adjustment	Action Required per 2461.G.5.e(4)
.608240724DI	8/24/16		5340								
.608250940DI	8/25/16		4360								
.608260700DI	8/26/16		4250			4650	103.33				
1609011330	9/1/16	125	4690			4433	98.52	$12.50	125.0	$1,562.50	Pay 87.5% of contract unit price for materials placed
.609071200DI	9/7/16		4860			4600	102.22				
.609080800DI	9/8/16		4860			4803	106.74				
.609090713DI	9/9/16		5080			4933	109.63				
.609100830DI	9/10/16		4480			4807	106.81				
.609120830DI	9/12/16		4400			4653	103.41				

ONLY MOVING AVERAGE FAILURES HAVE MONETARY DEDUCTIONS!

Moving average of 3 Consecutive Strength Tests

The Agency will remove any cylinders kept in the field longer than 7 days that negatively impacts the moving average calculation.

- Example 1: (4450, ***4700***, 4427)/3 = 4525psi

  (4450 + 4427)/2 = 4438psi – *WOULDN'T REMOVE*

- Example 2: (4550, ***4300***, 4627)/3 = 4493psi

  (4550 + 4627)/2 = 4589psi – *WOULD REMOVE*

RED = Cylinders left in the field Greater than 7-days

Documenting Material Exceptions
Materials Certification Exception Summary (MCES)

Document All:

- Failing Tests (All strength Tests > 500psi deficient)
- Low Strength Test (strengths ≤ 500 psi deficient), If the cylinders remained in the field greater than 7 days
- Strength Test Moving Average that have fallen Below the 28-Day F'c re requirements
- Missing Tests
- *Test Tolerance Between Lab/field or Between QC/QA
- Non-Certified Testers

Moving Average Monetary Adjustment for Compressive Strength

Table 2461-19 All Concrete Grades	
Moving average of 3 consecutive strength tests	**Monetary Reduction for Moving Average Failure ***
> 98.0% of f'c	No deductions for the materials placed as approved by the Engineer.
93.0% to 98.0% of f'c	$20.00 per cubic yard or 10% of the Contractor-provided invoice for quantity represented by test that brought moving average into non-conformance
87.5% to < 93.0% of f'c	$50.00 per cubic yard or 25% of the Contractor-provided invoice for quantity represented by test that brought moving average into non-conformance
< 87.5% of f'c	Remove and replace concrete in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work," as directed by the Engineer. If the Engineer, in conjunction with the Concrete Engineer, determines the concrete can remain in place, the Engineer will adjust the concrete at a reduction of $100.00 per cubic yard or 50% of the Contractor-provided invoice for quantity represented by test that brought moving average into non-conformance.

Moving Average of 3 Cylinder Test Results
NOTE: Passing Cylinder has the Deduct

Minnesota Department of Transportation

Cylinder Strength Failures

Project #:	8888-888	Mix Design:	3M52
Plant Name:	Gordy's Not So Ready Mix LLC	Minimum 28-day Compressive Strength (psi):	4500
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Total Cubic Yards being Adjusted:	125.0	Total Monetary Adjustment:	$1,562.50

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Cylinder Field ID:	Date Made	Cubic Yards Placed	Strength Test (psi)	Strength Deficiency > 500 psi	Concrete Grades B,S,X,Y Strength Failures	Moving Average (psi)	Moving Average % of Req'd	Adjusted Contract Unit Price per Cubic Yard	Cubic Yards being Adjusted	Monetary Adjustment	Action Required per 2461.G.5.e(4)
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.609100830DI	9/10/16		4480			4807	106.81				
.609120830DI	9/12/16		4400			4653	103.41				

ONLY MOVING AVERAGE FAILURES HAVE MONETARY DEDUCTIONS!

Maximum Allowable Range Between Set of 3 Cylinders in a Single Strength Test

- MnDOT will remove all individual cylinder strengths that are more than 350 psi below the highest individual strength
  - Example #1: ~~3500psi~~ + 4000psi + 4200psi = 3900psi
    - New average: 4000psi + 4200psi = 4100psi
  - Example #2: ~~3200psi~~ + ~~4000psi~~ + 4500psi = 3900psi
    - New average: 4500 psi

Low Cylinder Strengths

Low 28-Day Cylinder Strengths

- Poorly consolidated cylinders
  - When concrete is on the lower end of the slump ranges, Use the rod to tap the outside of the cylinder mold after rodding the lifts.
  - Rule of Thumb: Use the rod to tap the outside of the cylinder mold when the rod is extracted from the concrete and the rod hole remains, or the concrete is used for slip-form operations.

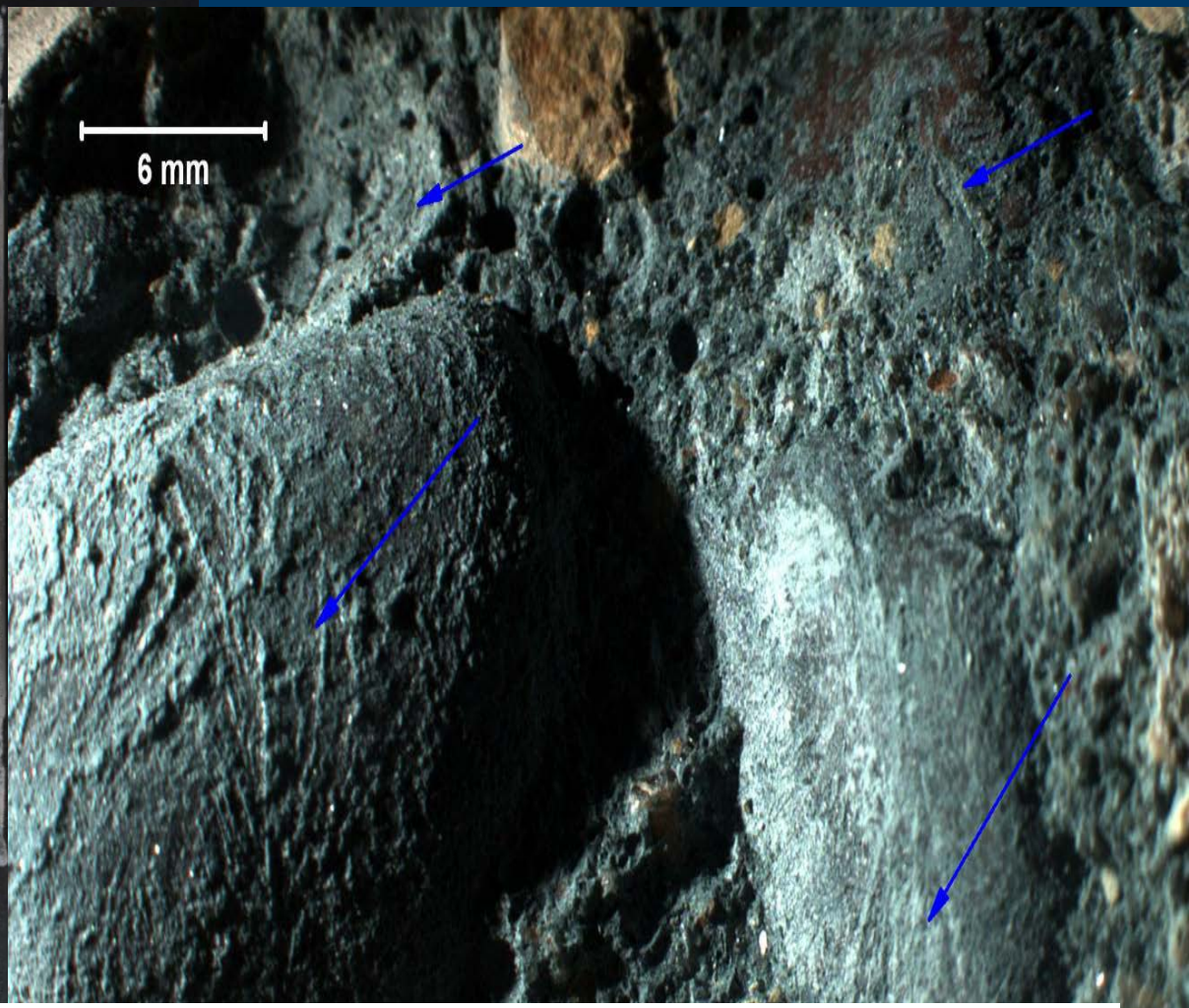
Low Cylinder Strengths

- Cylinder tops not perpendicular to sides
- Plan ahead! Cure cylinders on a level surface

Saw Slice

Concrete Strength (Cylinders) Testing

Frozen Cylinder



DESCRIPTION: Bladed frost crystal impressions (blue arrows) were observed on the fractured outer surface of the received cylinder.

Low Strengths Related to Curing Issues

7-days in Field warm Temps
26% Strength Reduction

7-days in field at 73ºF
w/o moist cure environment
18% Strength Reduction

Table 1-Measured strength reduction by nonstandard conditions

Variable	Strength loss, %	Lab or field
Convex ends	Up to 75	Lab
Insufficient consolidation	Up to 61	Field
Immediate freezing for 24 h	Up to 56	Field
Rubber cap, no restraint	Up to 53	Lab
Weak, soft capping compound	Up to 43	Lab
Flat particle, vertical orientation	Up to +0	Field
Concave ends	Up to 30	Lab
Rough end before capping	Up to 27	Field
Seven days in field, warm temperature	Up to 26	Field
Reuse of plastic molds	Up to 22	Lab
Cardboard mold	Up to 21	Field
Seven days in field at 73 F no added moisture	Up to 18	Field
Plastic mold	Up to 14	Field
Rough end, air gaps under cap	Up to 12	Field
Convex end capped	Up to 12	Field
Eccentric loading	Up to 12	Lab
Out-of-round diameter	Up to 10	Field
Ends not perpendicular to axis	Up to 8	Field
Rough handling	Up to 7	Field
Three days at 37 F, mixed at 73 F	Up to 7	Field
One day at 37 F, mixed at 46 F	Up to 7	Field
Excessive tapping	Up to 6	Field
Thick cap	Up to 6	Lab
Sloped end, leveled by cap	Up to 5	Field
Wet mixture subjected to vibrations	Up to 5	Field
Chipped cap	Up to 4	Lab
Reinforcing bar rodding	Up to 2	Field
Insufficient cap cure	Up to 2	Lab
Slick end cap	Up to 2	Lab
Slow loading rate	Up to 2	Lab

NRMCA Pub. 179 – David Richardson

Low 28-Day Strength Cylinders

- **Initial curing (Final finish up to 48 hours)**
  - An increase in compressive strength failures historically parallels increases in ambient and concrete temperature
  - The Contractor is required to supply **whatever** it takes to maintain the temperature between 60°F and 80°F.
  - Contractors not providing or Inspectors not asking for Initial curing environments that will maintain the cylinders between 60°F & 80°F
  - Document requests for initial curing supplies

Low 28-Day Strength Cylinders

- **Initial curing in the field (continued)**
  - **When outside ambient temps are between 60°F and 80°F, store cylinders in shaded area with mold covers affixed**

Temp Monitoring

Item# 13TAY-1441E

$28.95

Add to cart

Product Description

Digital Thermometer, Waterproof, 7 Day Max/Min, Multi-mode

Structural Concrete (2461)
(2017) Special Provision & 2018 Spec Book

- The Contractor will,
  - For each separate (initial & Intermediate) curing environment, provide a calibrated waterproof digital temperature recording device that records the daily maximum and minimum ambient temperatures for the previous 7 days.
- The Engineer will,
  - Monitor the daily temperatures of the curing environments. Agency monitoring does not relieve the Contractor of the responsibility to maintain the water temperature as specified herein.

Low 28-Day Strength Cylinders
(An Email from the MnDOT Concrete Engineer)

Lessons learned (that can be prevented)

- **Initial curing in the field (continued)**
  - Options for cooling the cylinders include:
    - Have the Contractor supply insulated cooler(s),
    - Add chilled water, and
    - Add ice if needed during hot weatl

28-Day Cylinders

- **Initial Curing in the Field in Cold/Hot Weather**
  - If field office is nearby, transport sampled concrete to temperature controlled (60º to 80º F) field office and cast cylinders**.**
  - **(Begin casting within 15 minutes of obtaining concrete sample.)**
  - Place caps on molds after final finishing
  - Use insulated coolers with heated water

Intermediate Curing Period (Not Required)

Store cylinders in field water tanks maintained 60º-80ºF for up to 7-days after casting

Transporting from Initial Curing Site

- For all grades of concrete (except Mass & HE concrete.) Cure minimum 16 hours after casting
- Mass Concrete, cure minimum of 24 hours after casting.
- High Early Concrete, cure minimum of 12 hours after casting.

Transporting Cylinders

- Standard (28-day) strength cylinders for intermediate or final curing as follows:
  - With securely placed tight fitting plastic caps on plastic molds, or by other methods to prevent moisture loss.
  - Properly protected during transportation to prevent damage from jarring, bouncing, freezing, and drying.
  - Transportation time not to exceed 4 hours, unless cylinders are maintained in the moistened condition at ambient temperature of 60 °F to 80 °F.

Low 28-Day Strength Cylinders

Erroneous Cylinder Compression Test Results

- Cylinders remain in field greater than 7-days. **(Bring cylinders into lab at least once per week!)**
- Cylinders delivered to the lab without lids and have dried to a whitened state
- Improper handling/field curing of cylinders
- Improper testing of the cylinders (not taken to complete failure)
- Cores taken from deficient structure have shown adequate strength… If cores pass Agency pays coring and third party testing.