

Performance-Based Multi-Property Concrete Mixtures

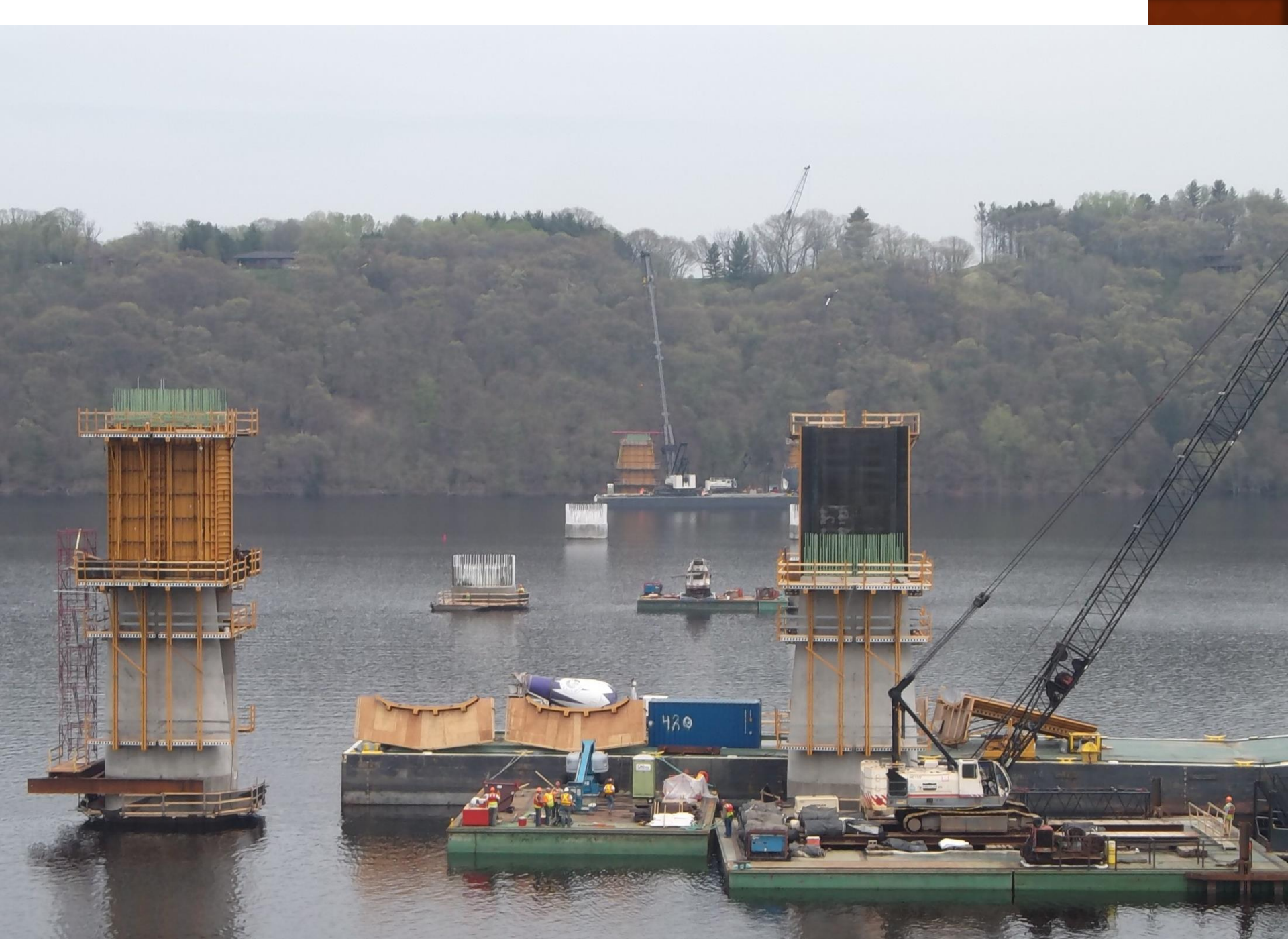
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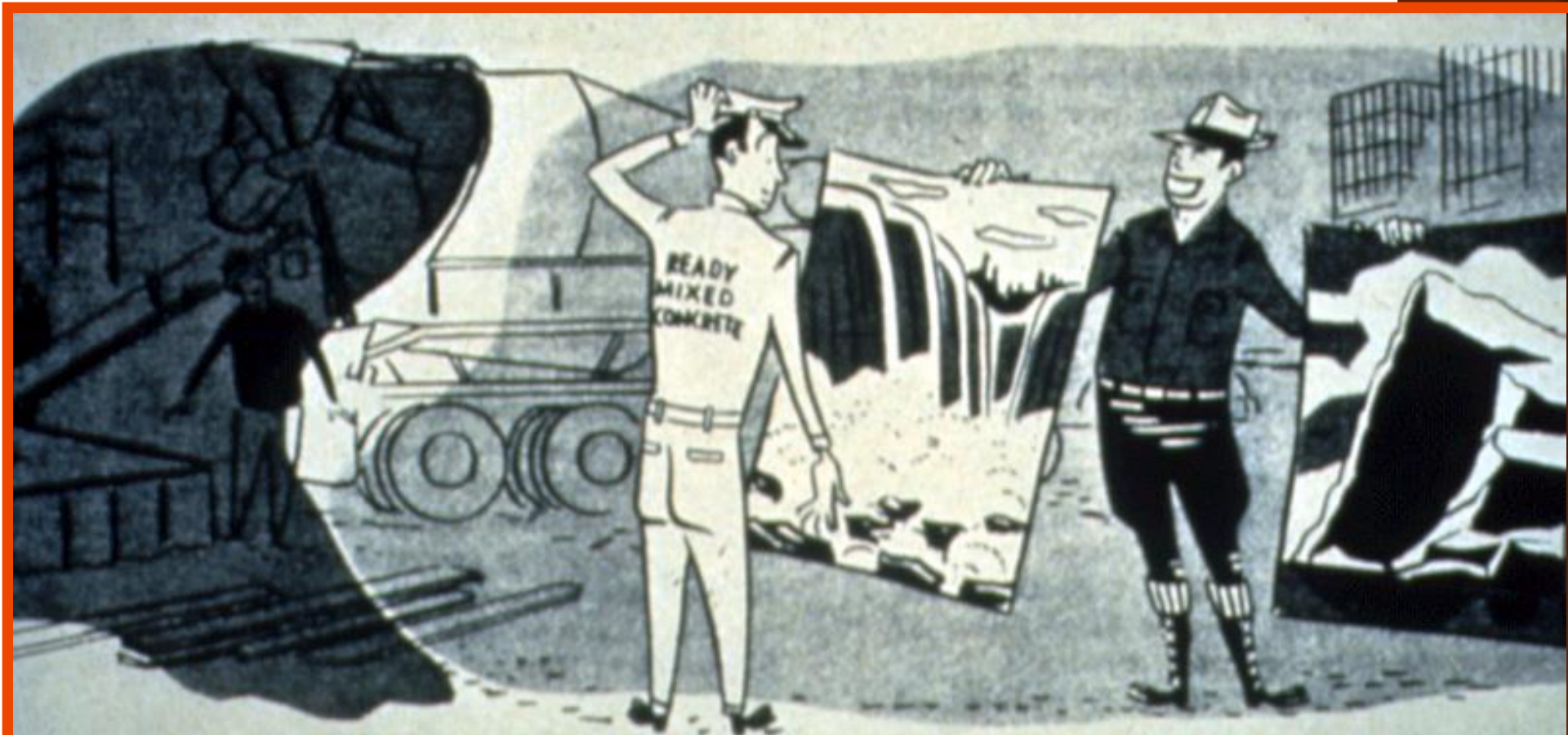


St. Croix Crossing project

View from the river looking upstream toward Stillwater

This photo simulation is based on designs available in June 2013.
It does not necessarily represent the final appearance.





"Here's what I want: Your concrete should pour like Niagara and have the strength of Gibraltar."

Specifications

- Air, Slump, and Compressive strength ASTM C31 / ASTM C39
- Hardened Air Void Analysis ASTM C457
- Freeze/Thaw Resistance ASTM C666
- Surface Scaling ASTM C672
- 28-Dry Shrinkage ASTM C157
- Chloride Permeability ACI 1202
- Modulus of Elasticity at 3, 7, 28, 56, 90, 1 year, and 2 year.
- ASR at 14 and 28-Days ASTM C1260 / C1567
- Creep
- Chloride Ion Diffusion ASTM C1556

Specifications

- St. Croix Bridge specification SB-27.1 on page 306-SB, “The Contractor shall provide designs for all concrete mixes used in construction of Bridges No. 82045, 82047, and 82048. Design the mixes to produce a 100-year bridge service life.”

Acceptance for Strength

Bridge 82045			
Location	Mix Designation	Min. Comp. Strength (psi)	Comp. Strength Measured At
Superstructure – CIP (Units 2E & 2W)	3JM	6000	28 days
Superstructure – Precast, CIP (Units 1E & 1W), Architectural Skirt	3JM	6000	28 days
Superstructure – Precast, CIP (Unit 3 as shown in Plan), External Struts (Unit 3)	3JM	8000	56 days
Superstructure – Precast (Unit 3)	3JM	9000	90 days
Superstructure – Barriers and Parapets	3YJM *	4000	28 days
Substructure – Abutment stems and backwalls	3YJM	4000	28 days
Substructure – Footings (Except Pier 13)	1AJM	4000	28 days
Substructure – Footings (Pier 13)	1YJM	5000	28 days
Substructure – Pier Columns	3YJM	4000	28 days
Substructure – Pier Columns (Extradosed piers and Piers 5E, 5W, 6E & 6W where noted)	3JM	6000	28 days
Substructure – Extradosed piers (as shown in Plan) and overlook	3JM	8000	56 days
Substructure – Bearing pedestals	3YJM	4000	28 days
Pile Infill	1Y62	5000	28 days

Acceptance for Strength

The specified 28-day concrete strength above shall be obtained in no more than 56-days for concretes utilizing cement replacement with fly ash, slag, or other cementitious materials or pozzolans. However, concrete shall have sufficient early strength to permit the application of construction loads, falsework/formwork removal, and all other construction operations at the required times and in accordance with the approved construction methods, shop drawings, Contract Plans, and Project Specifications. The specific mixes designated above as meeting a specified strength at either a 56-day strength or 90-day strength shall obtain the specified strength in no more than the number of days noted.

Strength Requirements

- Stressing and stripping strength of mass concrete was performed with Flir Match Cure Boxes.
- All segment concrete was 8,000 psi or 9,000 psi with a 4,000 psi requirement in 18-hours for stripping strength.

Specification - Concrete Placement

Due to the extended haul times to the point of placement, all mixes must be designed to remain plastic for a minimum of ~~240~~¹⁸⁰ minutes. All mixes must be tested for standard delivery up to 90 minutes and for extended delivery times to 180 minutes.





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8000 psi girders

MIX TYPE: 8000 psi
APPLICATION: Superstructure
PLACEMENT: Pump or Truck Discharge

Cement	(ASTM C C595)	170 lbs.	0.86 ft ³
SLAG	(ASTM C 989/Grade 100)	350 lbs.	1.93 ft ³
FLYASH	(ASTM C618)	120 lbs.	0.79 ft ³
SILICA FUME		20 lbs.	0.14 ft ³
SAND,	(ASTM C 33)	1,150 lbs. SSD	6.90 ft ³
3/4" AGGREGATE,	(MN/DOT Class A)	1,850 lbs. SSD	11.06 ft ³
WATER,		231 lbs. = 27.7 gal.	3.70 ft ³
AIR CONTENT,		6 % +/- 1.5 %	1.62 ft ³
			<hr/> 27.00 ft ³

Specification

(6) Develop a Job Mix Formula (JMF) and gradation working range by using procedures such as, but not limited to, 8-18, 8-20 gradation control, Shilstone process, FHWA 0.45 power chart or any other performance related gradation control to produce a workable and pumpable concrete mixture meeting all the requirements of this Contract.

Sieve Size	Working Range
4.75 mm [# 4] sieve or greater	±5 %
2.36 mm [# 8] to 600 µm [# 30] sieve	± 4 %
300 µm [# 50] sieve	± 3 %
150 µm [# 100] sieve	± 2 %

(8) The concrete shall obtain a **rapid chloride permeability** of not more than 2,500 Coulombs at 28 days and not more than 1,500 Coulombs at 56 days. The 28-day results are for preliminary approval only. Final acceptance will be based on the 56-day results.

Minnesota Department of Transportation

Job Mix Formula

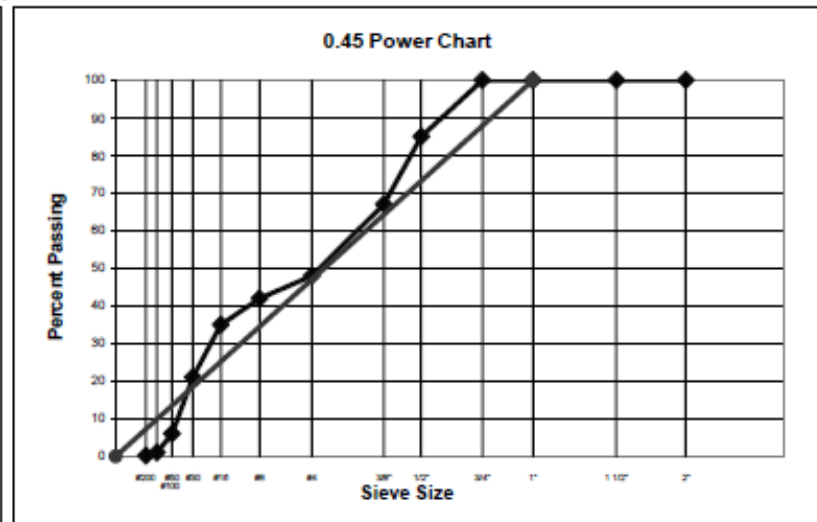
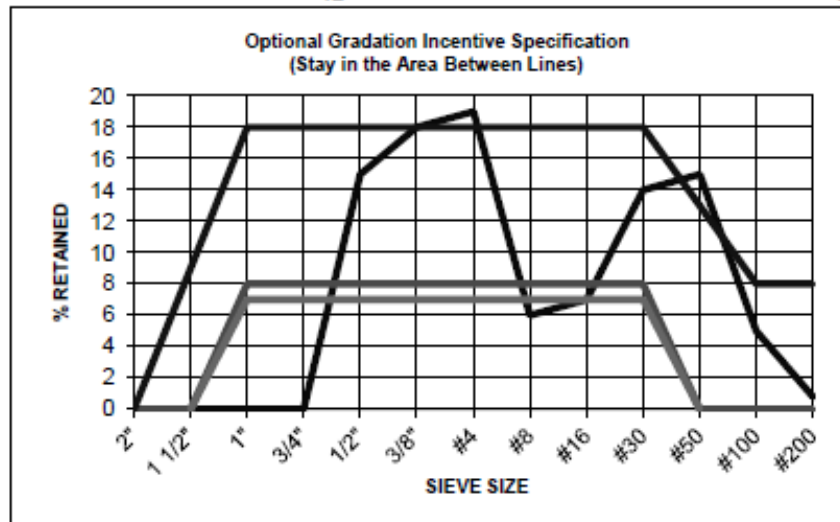
JMF
SP 8221-01

Mix Numbers: SCB83 -18

AGGREGATE SIZE PROPORTION, %	CA #1	CA #2	CA #3	CA #4	FA #1	FA #2	TOTAL % PASSING	WORKING RANGE LIMITS	JMF WORKING RANGE	TOTAL % RETAINED
	3/4-				Sand		100%			
	55%				45%					
2"	100.0				100.0		100	± 5	95 100	0
1 1/2"	100.0				100.0		100	± 5	95 100	0
1"	100.0				100.0		100	± 5	95 100	0
3/4"	100.0				100.0		100	± 5	95 100	0
1/2"	72.0				100.0		85	± 5	80 90	15
3/8"	41.0				100.0		67	± 5	62 72	18
#4	5.0				100.0		48	± 5	43 53	19
#8	0.0				93.0		42	± 4	38 46	6
#16	0.0				79.0		35	± 4	31 39	7
#30	0.0				46.0		21	± 4	17 25	14
#50	0.0				13.0		6	± 3	3 9	15
#100	0.0				2.0		1	± 2	0 3	5
#200	0.0				0.4		0.2	± 1.6% max	0.0 1.6	1

Workability
Factor
(% passing #8)
42

Coarseness
Factor
(% retained above 3/8" / % retained above #8)
57



Conflicts:

- Aggregate Gradation Requirements / slump / constructability
- High Early Strength / Thermal Requirements / Diffusivity / Shrinkage
- Multiple Failure Modes:
 - C457 / C666
 - C1202 / C1556
 - ASR Interpretation

○ Focus on 3 mixtures:

- Footing
- Crossbeams
- Crossbeams on extra-dosed piers



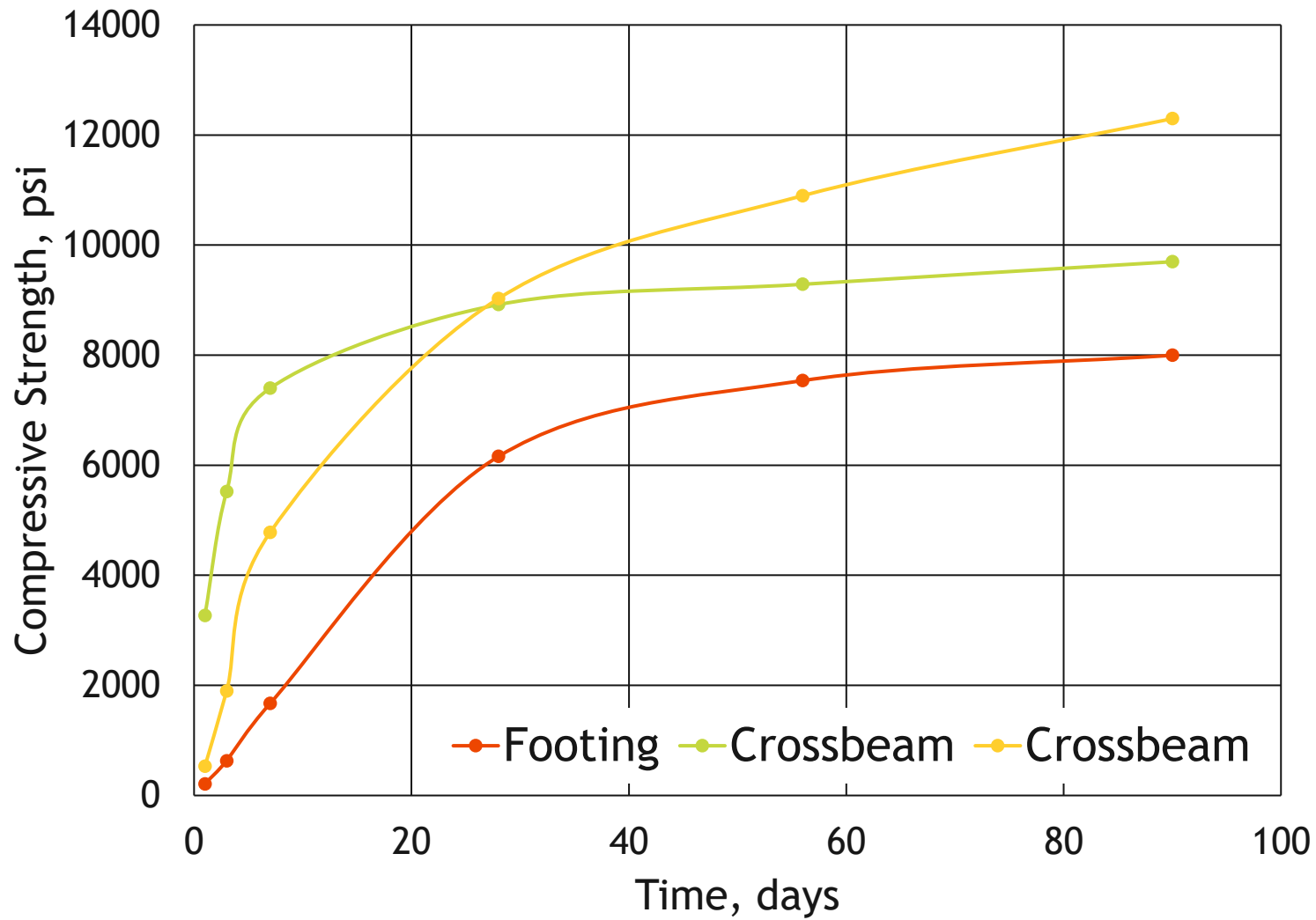




Mixture Proportions

Mixture	Portland Cement	GGBFS	Class C/F Fly Ash	Silica Fume	Total CM	RCP, C	D, x10 ⁻¹² m ² /sec
Footing	17	66	17	0	540	617	2.5
Crossbeam	18	48	29	4	660	358	0.87
Crossbeam	26	18	53	3	660	349	0.511

All mixes are Thermal Control Mixtures. The Footing is not air entrained.



Mass Concrete

The maximum peak curing temperature of all mass concrete elements shall not exceed 160° F.

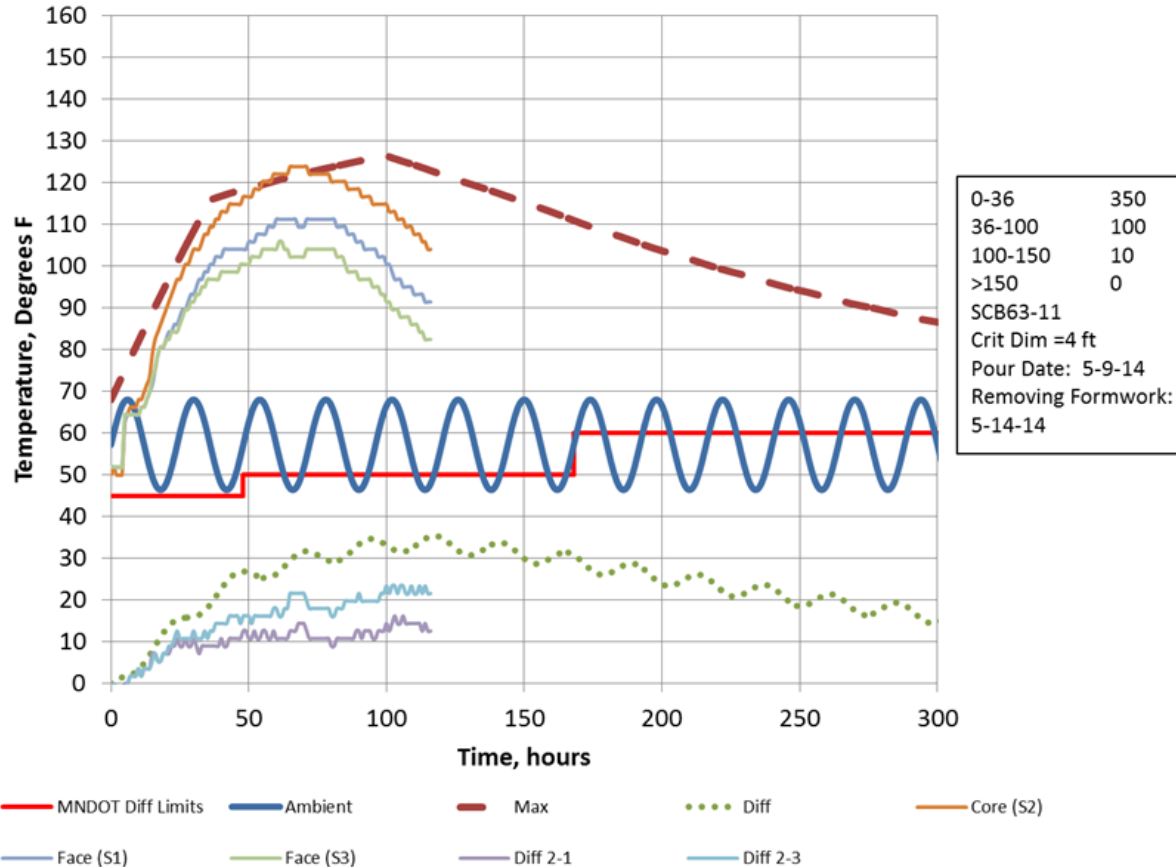
During the curing period, the temperature differential between the center of the placement and a point 2 inches from the surface along the shortest line from the center to the

nearest surface of the element shall not exceed the following limits:

First 48 hours	35° F (Superstructure)
	45° F (Substructure)
Next 2 to 7 days	50° F
Next 8 to 14 days	60° F

Thermal Requirements

Saint Croix Bridge No. 82045 Pier 9S Base



Wisconsin

All crossbeams are complete

What makes up a crossbeam?

- 478,000 lbs. of rebar
- 18.2 ft. tall by 15.2 ft. wide by 116.4 ft. long
- 5,273,000 lbs. of concrete (that's 130 truckloads!)

Pier 13 column construction has started

3 of 5 river piers are complete
- Towers rise 65 ft. from the bridge deck

28 of 160 stay cables are installed

- One stay cable consists of 76 steel strands bunched together
- Each strand's threshold is more than 32,900 lbs.

More than half of segments for the bridge deck are placed at Piers 8 & 9

Minnesota



- 17 total public boat tours of the bridge construction site
- Average 350 passengers per tour



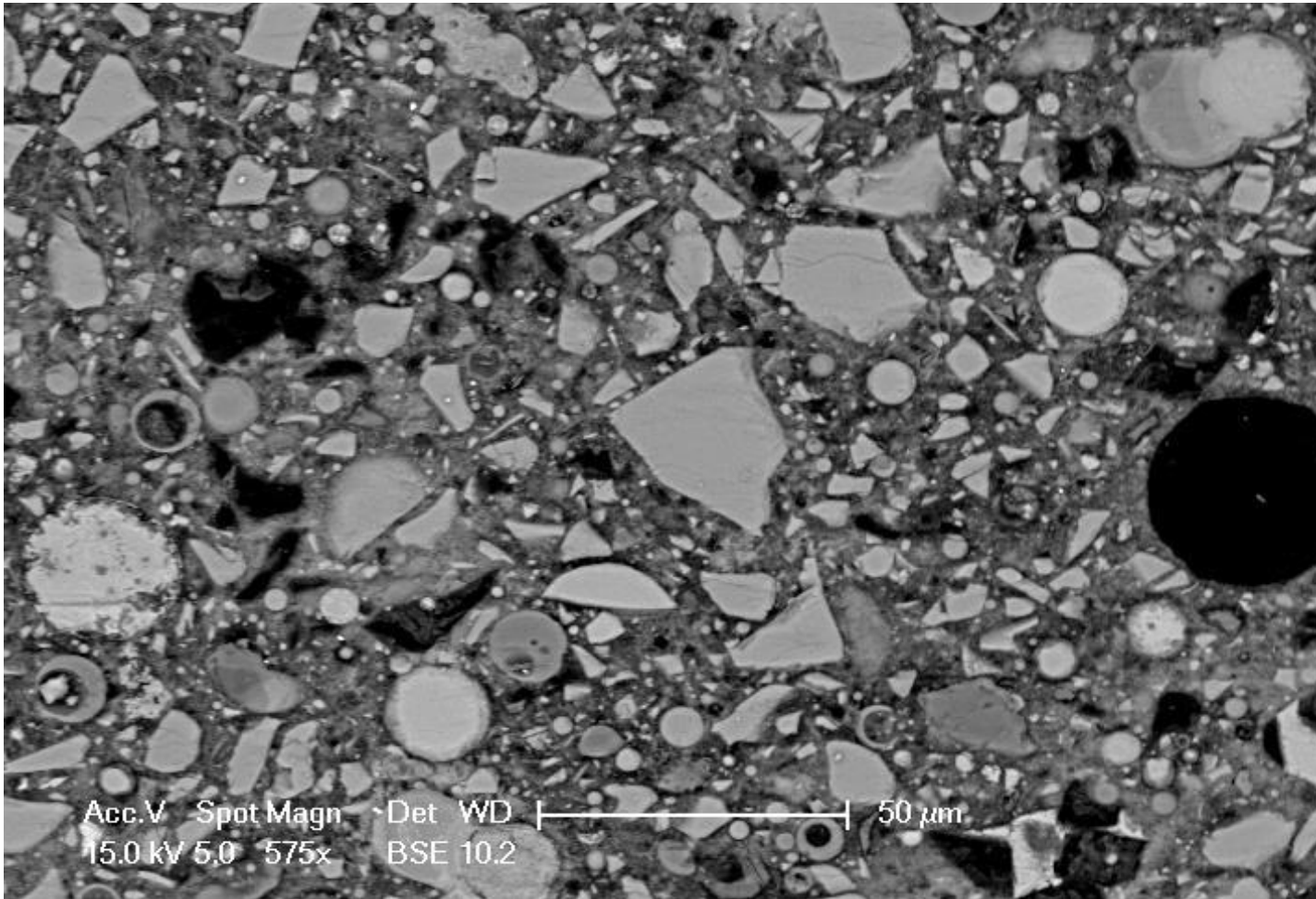
St. Croix
CROSSING

2015 St. Croix Crossing Construction

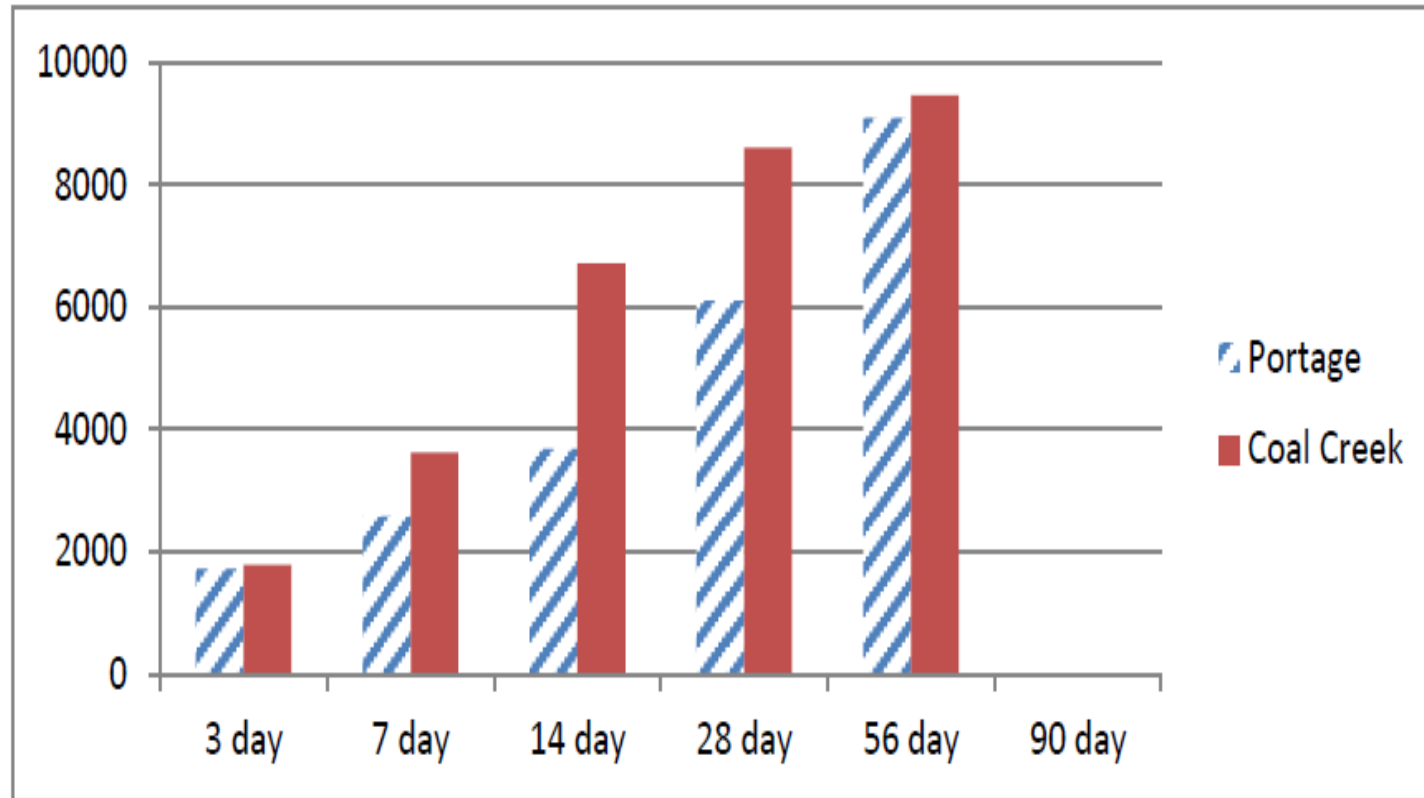




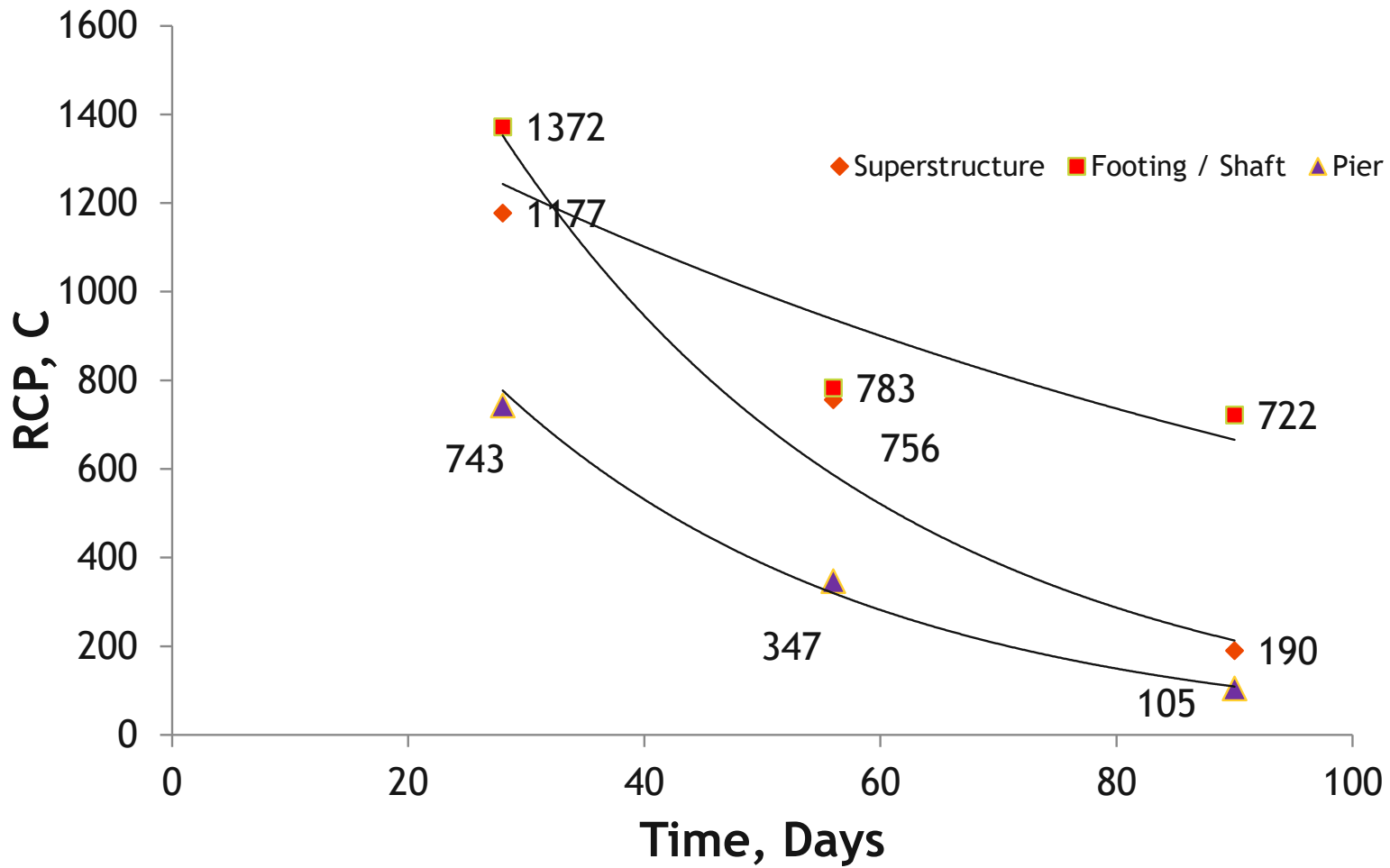
Cold Weather - Hydration

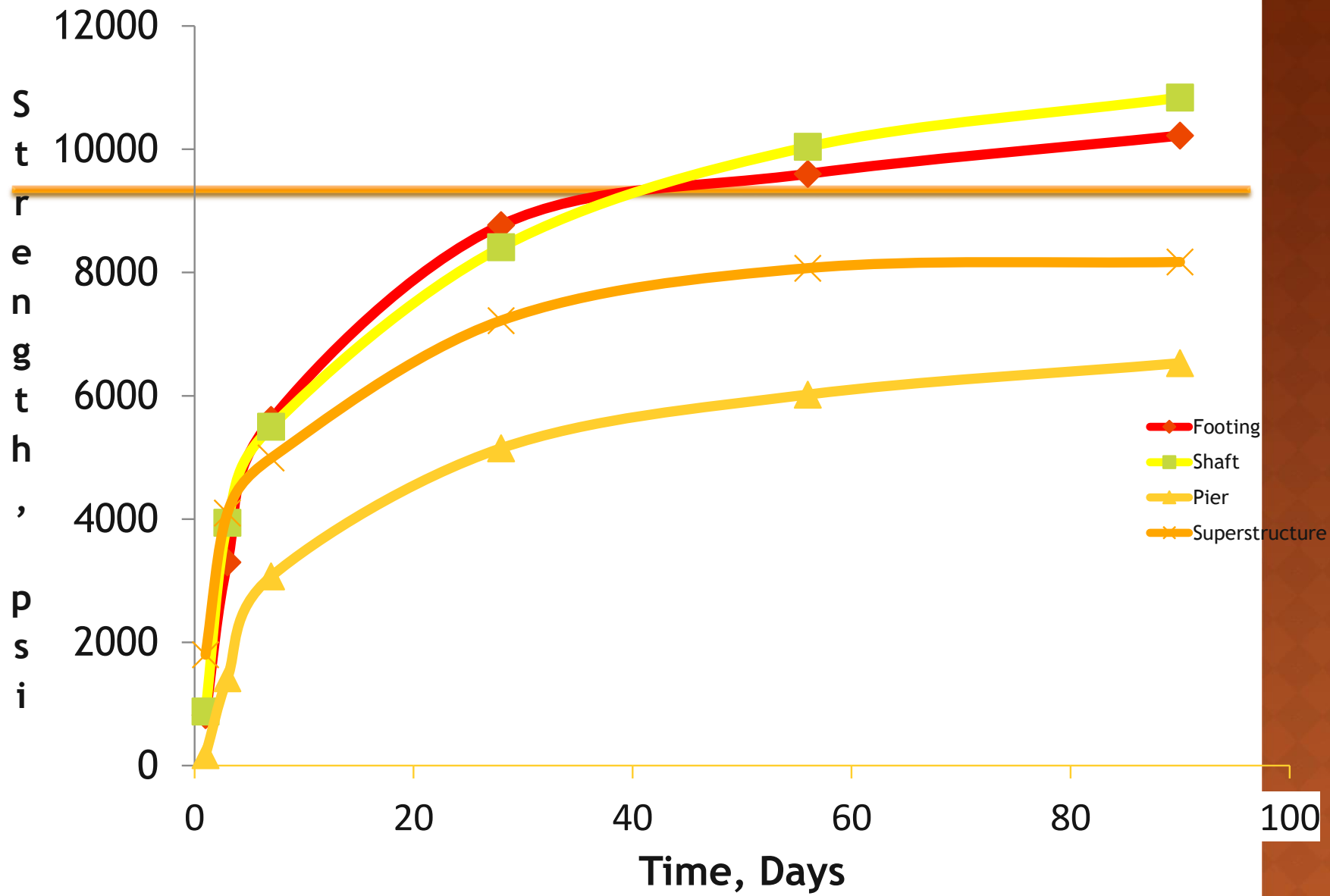


Materials Issue









Shaft Concrete

- ◉ 60 Percent Pozzolan Replacement
- ◉ 24 inch spread
- ◉ Air entrained
- ◉ RCP
- ◉ Shrinkage
- ◉ Strength at 28 days (lab cure) 5500 psi
- ◉ Cores from 21 day old Shaft 10,250 psi









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Questions?

- Thank you for the time and attention.