

Performance-Based Multi-Property Concrete Mixtures

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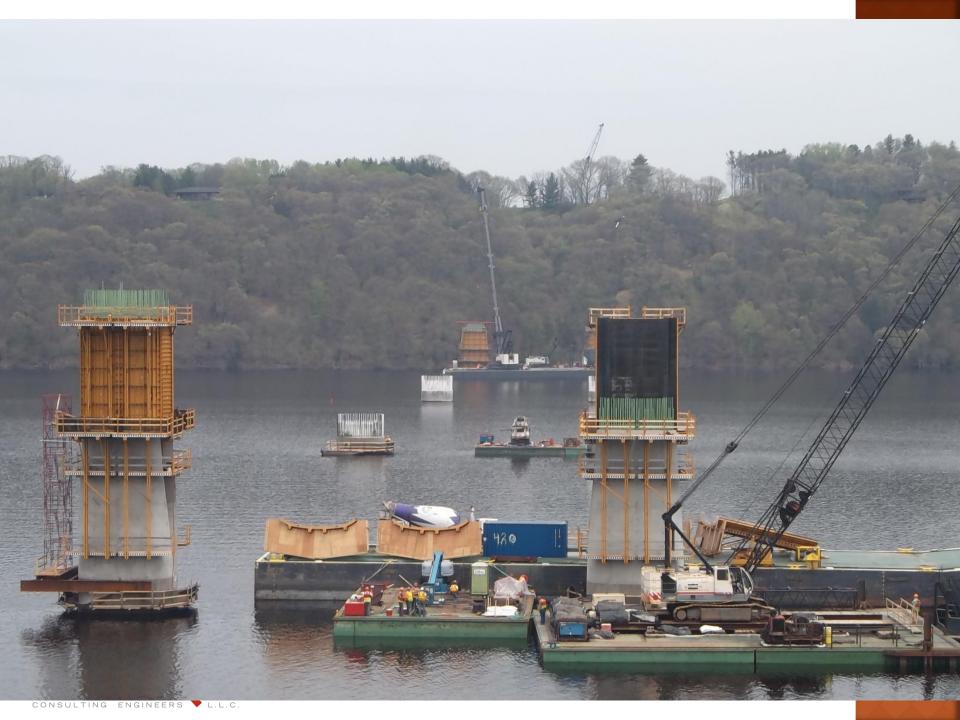


St. Croix Crossing project

This photo simulation is trained on designs available in June 2011 it does not necessarily represent the final appearance.

View from the river looking upstream toward Stillwater









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)	3ЈМ	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)	3ЈМ	6000	28 days
Substructure – Extradosed piers (as shown in Plan) and overlook	ЗЈМ	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 minutes. All mixes must be tested for standard delivery up to 90 minutes and for extended delivery times to 180 minutes.









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.	$1.93 \mathrm{ft}^3$
FLYASH	(ASTM C618)	120 lbs.	0.79 ft³
SILICA FUME		20 lbs.	0.14 ft³
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 ${ m ft}^3$
WATER,		231 lbs. = 27.7 gal.	3.70 ${\rm ft}^3$
AIR CONTENT,		6 % +/- 1.5 %	$1.62 \mathrm{ft}^3$
			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

Mix Numbers: scB83 -18

JMF_____

AGGREGATE SIZE
PROPORTION, %
2"
1 1/2
1"
3/4"
1/2"
3/8"
#4
#8
#16
#30
#50
#100

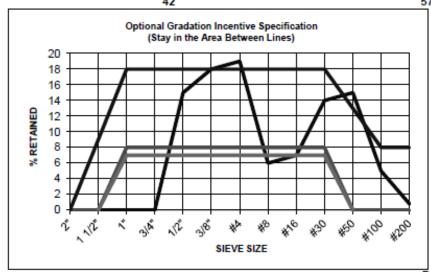
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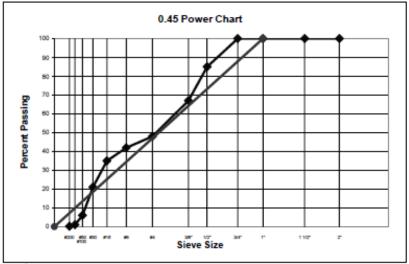
	CA #1	CA #2	CA #3	CA #4	FA #1	FA #2	TOTAL %	WORKING	JI	MF	TOTAL %
	3/4-				Sand		PASSING	PASSING RANGE		KING	RETAINED
	55%				45%		100%	6 LIMITS	RA	NGE	
	100.0				100.0		100	± 5	95	100	0
'	100.0				100.0		100	± 5	95	100	0
	100.0				100.0		100	± 5	95	100	0
	100.0				100.0		100	± 5	95	100	0
	72.0				100.0		85	± 5	80	90	15
	41.0				100.0		67	± 5	62	72	18
	5.0				100.0		48	± 5	43	53	19
	0.0				93.0		42	± 4	38	46	6
	0.0				79.0		35	± 4	31	39	7
	0.0				46.0		21	± 4	17	25	14
	0.0				13.0		6	± 3	3	9	15
	0.0				2.0		1	± 2	0	3	5
	0.0				0.4		0.2	± 1.6% max	0.0	1.6	1

Workability Factor (% passing #8) Coarseness

Factor

(% retained above 3/8" / % retained above #8)





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Mixture Development

Saint Croix Bridge (SP: 8221-01) - Test Result Due Dates & Results

Revised: Feb-23-15

				C231			ASTM	IC 39			ASTM	C 457	C1556	C666	C 672	CI	567	AASHTO	C157	ASTM	C 1202				ASTM C 469			
Mix					Comp. Strength	Comp. Strength	Comp. Strength	Comp. Strength	Comp. Strength	Comp. Strength	Air Void Specific	Air Void Spacing	Cement Diffusion	Freeze Thaw	Surface Scaling	Alkali Slica	Alkali Slika		28-Day Drying	Chloride Permeab.	Chloride Permeab.	Modulus Elasticty	Modulus Elasticty	Modulus Elasticty	Modulus Elasticty	Modulus Elasticty	Modulus Elasticty	Modulus Elasticty
Designation	Application	Description	Test Date	Air (%)	1-Day (psl)	3-Day (psl)	7-Day (psl)	28-Day (psi)	56-Day (psl)	90-Day (psl)	Surface (ln²/ln²)	Factor (inches)	Coef. (10 ⁻¹³ m ² /s)	RDME (%)	50 Cycles (%)	14-Days (%)	28-Days (%)	Сгеер	Shrinkage (%)	28-Day (Coul.)	56-Day (Coul.)	3-Days (10 ⁶ psl)	7-Days (10 ⁵ psl)	28-Days (10 ⁵ psl)	56-Days (10 ⁵ psl)	90-Days (10 ⁶ psl)	1-Year (10 ⁶ psl)	2-Years (10 ⁶ psl)
SCB46-1	Footing for Piers 1-7	1AJM - Mass	12/9/13	3.4	220	665	1,550	5,950	7,170	8,070																		
SCB46-2	Footings for Abutments & Retaining Walls	1AJM	12/11/13	3.6	1,150	3,480	5,180	6,950	7,880	7,980																		
SCB56-3	Footing for Pier 13	1YJM - Mass	12/9/13	3.4	205	625	1,670	6,160	7,540	8,000																		
SCB56-4	Pile Fill for Pier 13	1Y3M	12/13/13	2.3	1,720	3,940	5,390	7,180	7,780	8,790																		
SCB43-5	Bridge Rail Form	3Y46A	1/6/14	6.2	605	2,060	2,870	4,550	6,530	7,510	833	0.003		95	0	0.006 & 0.002	0.020 & 0.026		-0.026	3,125	1,236							
SCB43-6	Bridge Rall Slip & Barrier	3Y16A & 3Y12	1/6/14	7.0	620	1,210	2,780	4,940	6,080	7,120	982	0.004		96	0	0.006 & 0.002	0.020 & 0.026		-0.023	2,440	959							
SCB46-7	Plers 1-7, 13	3YJM - Mass	11/27/13	7.2	265	670	1,700	6,310	7,270	7,920	688	0.005	5.14	99	0	-0.035 & -0.035	-0.033 & -0.024		-0.023	923	215	n/a	3.56	5.27	5.54	5.65	Jan-2015	Jan-2016
SCB46-8	Abutments, Stem Walls, & Back Walls	ЗУЭМ	12/13/13	5.7	810	1,930	2,860	4,240	5,190	6,170																		
SC866-9	Plers 5-6, 8-12	33M - Mass	11/27/13	6.2	290	850	2,400	6,300	6,990	7,580	767	0.005		96	0	-0.035 & -0.035	-0.033 & -0.024		-0.010	1,065	234	n/a	3.29	5.22	5.20	5.49	Jan-2015	Jan-2016
SCB63-10	Extradosed Plers	33M - Mass	12/2/13	6.8	290	1,060	2,830	6,960	8,090	8,550	775	0.005		95	0	-0.035 & -0.016	-0.033 & -0.022		-0.011	793	194	n/a	3.45	5.46	5.66	5.79	Jan-2015	Jan-2016
SC863-11 SC863-118	CIP Units 1-2; Architectural Skirt (-11 = 6"-9") (-118 = 5"-8") (-11E = 3"-6") (-11F = 7"-10")	33M	12/16/13	6.8	755	2,950	3,930	6,550	8,380	9,790	651	0.006		92	0	0.006 & 0.002	0.020 & 0.026	Feb-2016	-0.029	755	797	n/a	3.70	4.76	5.17	5.44	Jan-2015	Jan-2016
SCB83-12 SCB83-12A SCB83-12B	Cross Beams 8-12 (SCB83-12 = 6"-9") (SCB83-12A = 5"-8") (SCB83-12B = 7"-10")	3JM - Mass	12/17/13	5.5	180	810	1,890	6,140	8,190	9,230	722	0.006		93	0	0.007 & -0.003	0.012 & -0.003	Feb-2016	-0.024	918	358	n/a	2.78	5.22	5.62	5.86	Jan-2015	Jan-2016
SCB83-13	Closure Pour, External Struts, CIP Unit 3, Non-Mass Crossbeam	33M	12/17/13	6.6	830	3,510	5,060	8,600	10,010	10,190	617	0.005		94	0	0.006 & 0.002	0.020 & 0.026	Feb-2016	-0.029	1,299	553	n/a	3.98	5.25	5.66	5.74	Jan-2015	Jan-2016
SC883-14 SC883-16	6,000 psi and 8,000 psi Segments (SCB83-16 has MRWRA added)	33M - 3,000 psi in 18 Hours with 60 NCA	2/25/14	6.0	3,040	5,040	6,870	8,880	9,080	9,160	463	0.007		95	0	0.008 & 0.0012	0.008 & 0.011	Feb-2016	-0.036	2,020	1,309	3.60	5.05	5.85	5.95	5.85	Feb-2015	Feb-2016
SCB83-15	6,000 psi and 8,000 psi Segments	33M - 3,000 psi in 18 Hours with 32 NCA	2/26/14	6.3	3,270	5,520	7,400	8,920	9,290	9,700	401	0.008		96	0	0.008 & 0.0012	0.008 & 0.011	Feb-2016	-0.034	1,284	848	4.70	5.15	5.90	6.25	5.95	Feb-2015	Feb-2016
SCB83-18	Cross Beams 8-12	33M - Mass	12/16/14	6.0	530	1,900	4,780	9,030	Feb-10	Mar-16	349	0.006	Apr-15	May-15	Apr-15	-0.02 & -0.01	Feb-10	Jan-2017	Mar-10	Feb-10	45	3.20	4.90	6.85	Feb-10	Mar-16	Dec-2015	Dec-2016
SC883-19	Cross Beams 8-12	33M - Mass	12/16/14	6.6	890	1,760	5,830	9,390	Feb-10	Mar-16	486	0.005	Apr-15	May-15	Apr-15	-0.03 & -0.03	Feb-10	Jan-2017	Mar-10	Feb-10	44	3.55	4.95	6.70	Feb-10	Mar-16	Dec-2015	Dec-2016
3Y3M-7	This mix was used on the Foundation Phase and is now being used on this phase.	6,000 psi at 90 Days - Mass	11/11/13	7.2	160	1,080	3,290	4,720	5,050		625	0.005		92	0				0.002	241	182							
SCB4230	This is Hasting Bridge mix HAS1230 and is substantially the same as mix 3YJM-7.	4,000 psi at 28 Days - Mass	8/25/10	7.9	200	1,410	2,400	5,030	5,450		662	0.006	6.00E-13	90	1	-0.014	-0.019	See Doc	-0.024	291	177							
SCB6236	This is Hasting Bridge mix HAS6236.	6,000 psi at 28 Days - Mass	8/25/10	7.4	1,140	3,940	5,010	7,150	7,790		794	0.006	5.00E-13	100	1	-0.031	-0.032	See Doc	-0.025	442	300	5.29		6.76		6.88		

Bolded Mix ID's = Approved

= No Testing Needed

= Results Have Been Obtained

 Result has not been obtained yet and it does not have to meet a required range.



Conflicts:

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



- Focus on 3 mixtures:
 - Footing
 - Crossbeams
 - Crossbeams on extra-dosed piers







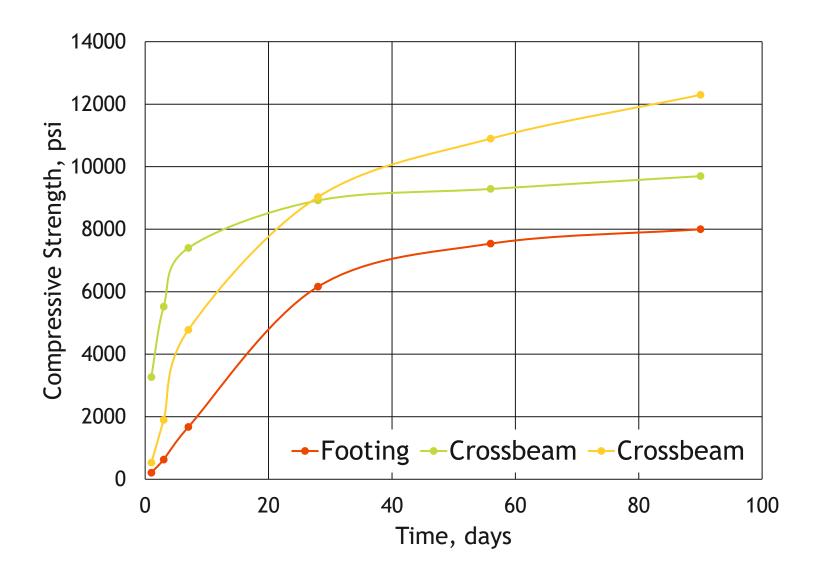


Mixture Proportions

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	Portland	GGBFS	Class C/F	Silica			D, x10 ⁻¹²
Mixture			Fly Ash		Total CM	RCP, C	m²/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.

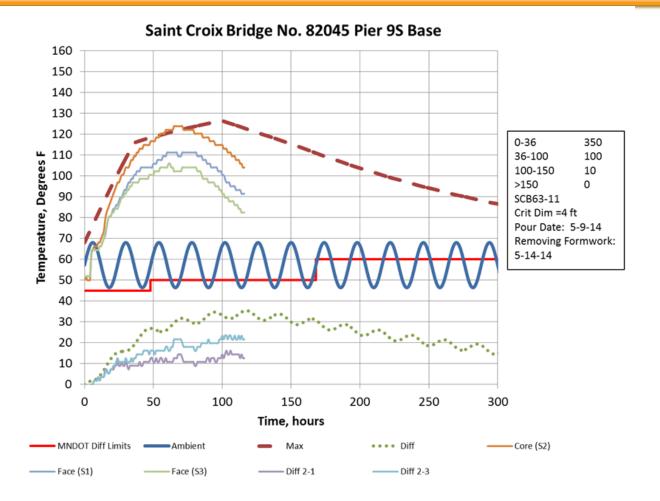
During the curing period, the temperature differential between the center of the placement and a point 2 inches from the surface along the shortest line from the center to the

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

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



Thermal Requirements









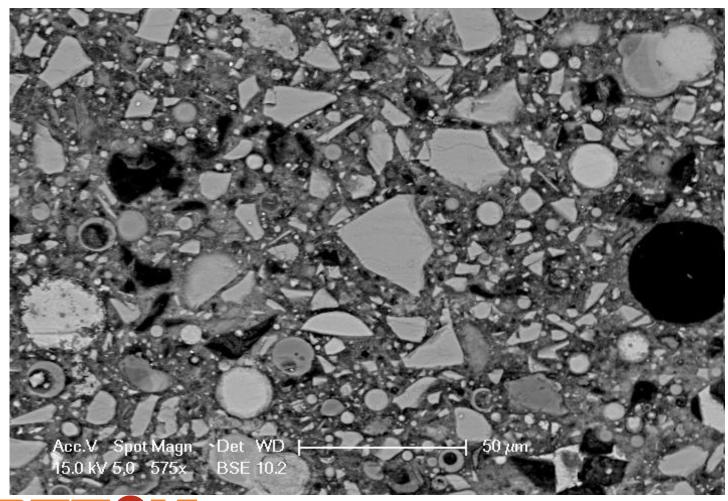
2015 St. Croix Crossing Construction





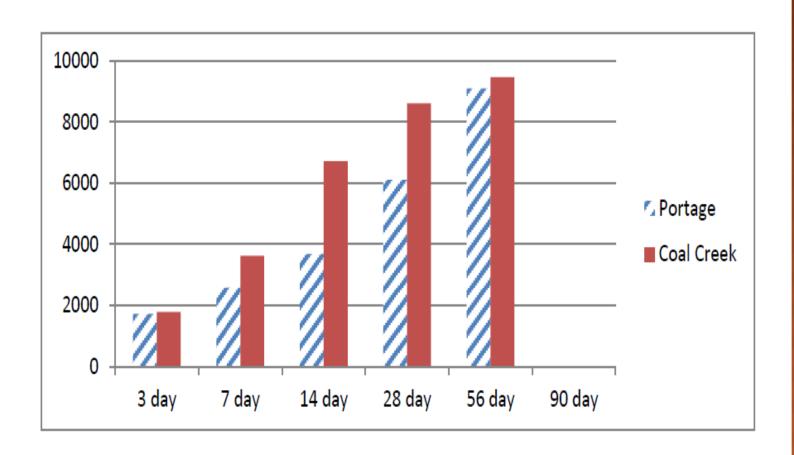


Cold Weather - Hydration

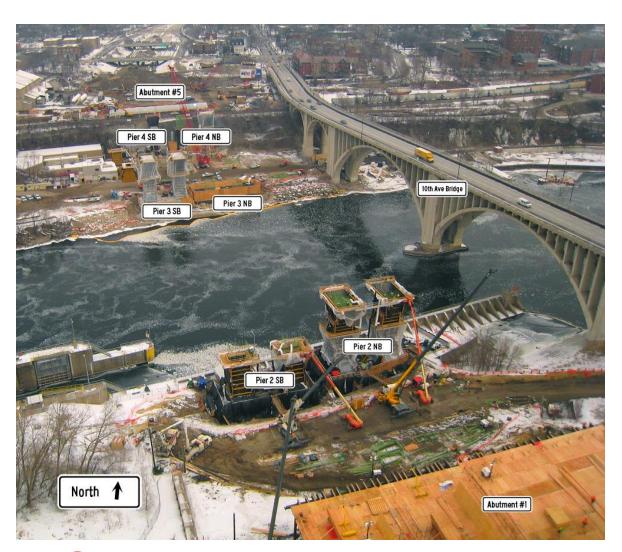




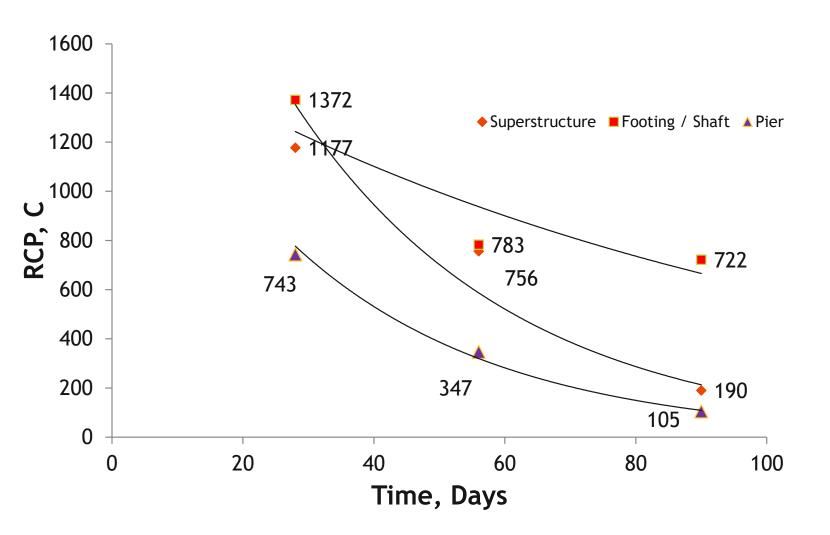
Materials Issue



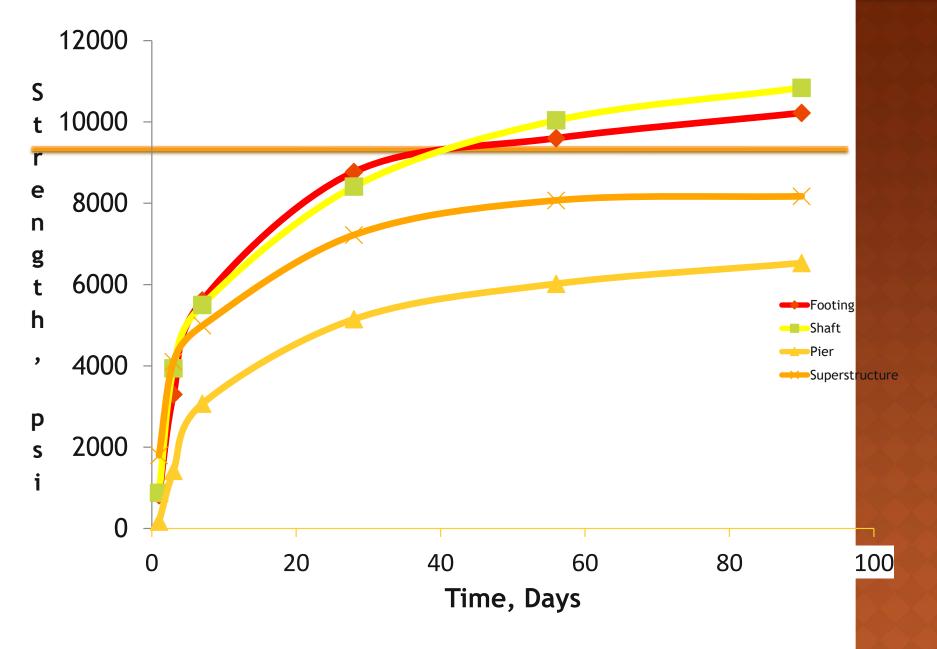














Shaft Concrete

- 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

















Questions?

Thank you for the time and attention.

