Low Temperature Cure Study of Latex Modified Concrete

Wagman Heavy Civil, Inc. and Trinseo LLC.
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February 15, 2018

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Agenda

- Project Details
  - Project Overview and Scope of Work
  - Schedule & LMC Specifications
- Low Temperature Cure Study
- LMC Technology
  - Characteristics, Durability, etc.
- Project Success / Closing

Project Details

- Location: Baltimore, MD - I-95, South of the Fort McHenry Tunnel to Canton Ave.
- Cost: $54.9 Million
- Project length extends about 4.4 miles on Mainline I-95 and ramp bridges serving I-95
- The project site was on one of the most heavily traveled interstates in the nation
- This was the largest Latex Modified Concrete project awarded as a single contract in the US

Featured Project: I-95 Deck Rehabilitation & Joint Modification

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Why LMC?

- Decks in good condition. High chloride levels extend to 2” depths
- Phased construction to maintain traffic on I-95 and ramps
- Successfully resurfaced 34 bridges with LMC North of Fort McHenry Tunnel in early 2000
  - 205,818 SY
  - 11,935 CY
- South end already had LMC when originally constructed

AVERAGE DAILY TRAFFIC (ADT)	
North of I-395:	**South of I-395**
68,600 SB	96,900 SB
64,600 NB	96,400 NB
6,900 SB-AM Peak	6,700 SB-AM Peak
2,800 NB-AM Peak	6,600 NB-AM Peak
3,600 SB-PM Peak	7,100 SB-PM Peak
6,000 NB-PM Peak	6,500 NB-PM Peak

Project Overview

- Rehabilitation to 28 bridges
- LMC Overlay on 18 bridge decks
- Replacement of 67 joints and drainage troughs
  - Finger joints
  - Strip seals
  - Compression seals
  - Poured seals

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Project Scope

- 236,735 SY of deck area
  - Scarify
  - Hydro-demolition
  - LMC overlay
- 15,695 CY of LMC
- 16 separate work zone
- Up to 5 stages in each work zone

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Project Scope

- 1.25 Million LF of temporary markings
- 275,000 LF of temporary barrier
- 2,725 LF of joint replacements
- 10,900 Tons of HMA on roadway approaches

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Construction Aspects

- Required to complete 18,210 SY of deck area or 3 lane miles of LMC/month
  - Multiple work zones → Multiple traffic switches per month
  - Mill & Hydro demo
  - Joint replacement
  - LMC overlay and cure
  - Groove
  - Pavement markings and switch traffic

Project Schedule

- 2 Seasons to complete the LMC
- Work began March each year (weather dependent)
- April 1 – “Up and Running” with work areas
- LMC Season over October 2014 and September 2015
  - Total LMC Duration = 13 Months
- 47 total work area (traffic shifts occurring as frequently as every few weeks – 14 in 2014 and 33 in 2015)
- Project included incentive/penalties

LMC Curing Project Specifications

- Cover with wet burlap and polyethylene film for 48 hours
- Air cure for 72 hours
- Do not place below 45°F
- Place at 45°F and rising temperature for at least 8 hours
- Below 55°F, required longer curing and conformance with cold weather protection specs
  - Protect and maintain at 50°F
  - Any day below 50°F will not count toward curing

Other LMC Curing Specifications

- ACI
  - Protect LMC from temperature below 45°F for first 72 hours; follow cold weather specs
- Pennsylvania DOT
  - Maintain temperature of 45°F degree through wet and dry
  - Do not count cure day below 45°F
  - Cold weather specs, for lower temperature
- Virginia DOT
  - 50°F and rising for placement

Critical Issues

- Schedule demands
  - Work 6 - 7 days per week during the season (13 month window)
  - Need every day possible for pouring & curing LMC
- Project specifications & schedule create issues in Fall & Spring
  - Using blankets to maintain temperature added curing days to schedule
  - Trinseo completes Low Temperature Cure Study

Low Temperature Cure Study of Latex Modified Concrete

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Introduction and Background

Typical LMC curing/drying conditions

- 2 days wet cure
  - cement hydration
  - compression strength development
- 2-3 days air dry
  - coalescence of latex
- Minimum temperature 50 ℉

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Limitations

Spring and fall seasons

- Ambient temperatures can fall below 50℉
- Blankets are used to maintain temperature >50℉
  - Concern: blankets hinder air drying and performance property development

Low Temperature Cure Project

Questions

- What is the impact of using blankets?
  (simulated by extended wet cure)
- What is the impact of low temperatures on compression strength development and chloride permeation resistance?
  - Short term (Spring conditions)
  - Long term (Fall conditions)

Cure Conditions

	Control	Control + Freezing	5d Wet Cure	5d Wet Cure + Freezing	50°F Total	Fall Profile	Spring Profile
Cure Condition	**Days @ Each Cure Condition**						
Wet cure @ 50°F	2	2	5	5	2	2	2
Air dry/cure @ 50°F	3	3			26		10
Air dry/cure @ 20°F (freezing)		2		2			
Air dry/cure 72°F	23	21	23	21		10	8 @ 60°F
Air dry/cure @ 60°F						8	8 @ 72°F
Air dry/cure @ 50°F						8	
Total days	28	28	28	28	28	28	28
	Additional Curing						
Air dry/cure @ 72°F	90 (total)	90 (total)	90 (total)	90 (total)	90 (total) @ 50°F	90 (total) @ 50°F	90 (total)
Air dry/cure @ 72°F	6-mo (total)	6-mo (total)	6-mo (total)	6-mo (total)	6-mo (total) @ 50°F	6-mo (total) @ 50°F	6-mo (total)

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LMC Mix Design

Type I-II cement

7 sack cement/yd^3

3.5 gal Mod A latex per sack

Cement : Sand : Stone – 1.0 : 2.5 : 1.77

Water : Cement target - 0.35

Air: 3-7% (target 4-5%)

Slump: 4-6 in

LMC Mix Design

LMC Mix Design Requirements	Supplier	Cubic feet	lb/yd^3
Type I-II Cement	Lehigh	3.35	658
Water	Local	2.00	230.3
Fine Aggregate	Lambart	10.16	1667
Coarse Aggregate	#7 Granite Vulcan	6.90	1160
Modifier A/NA Latex	Trinseo	3.25	207
Designed Air Content		1.35	5%
Theoretical Yield & Unit Weight (pcf)		27.01	141.3
Average Measured Slump	5.7 in		
Average Measured Air	4.0%		

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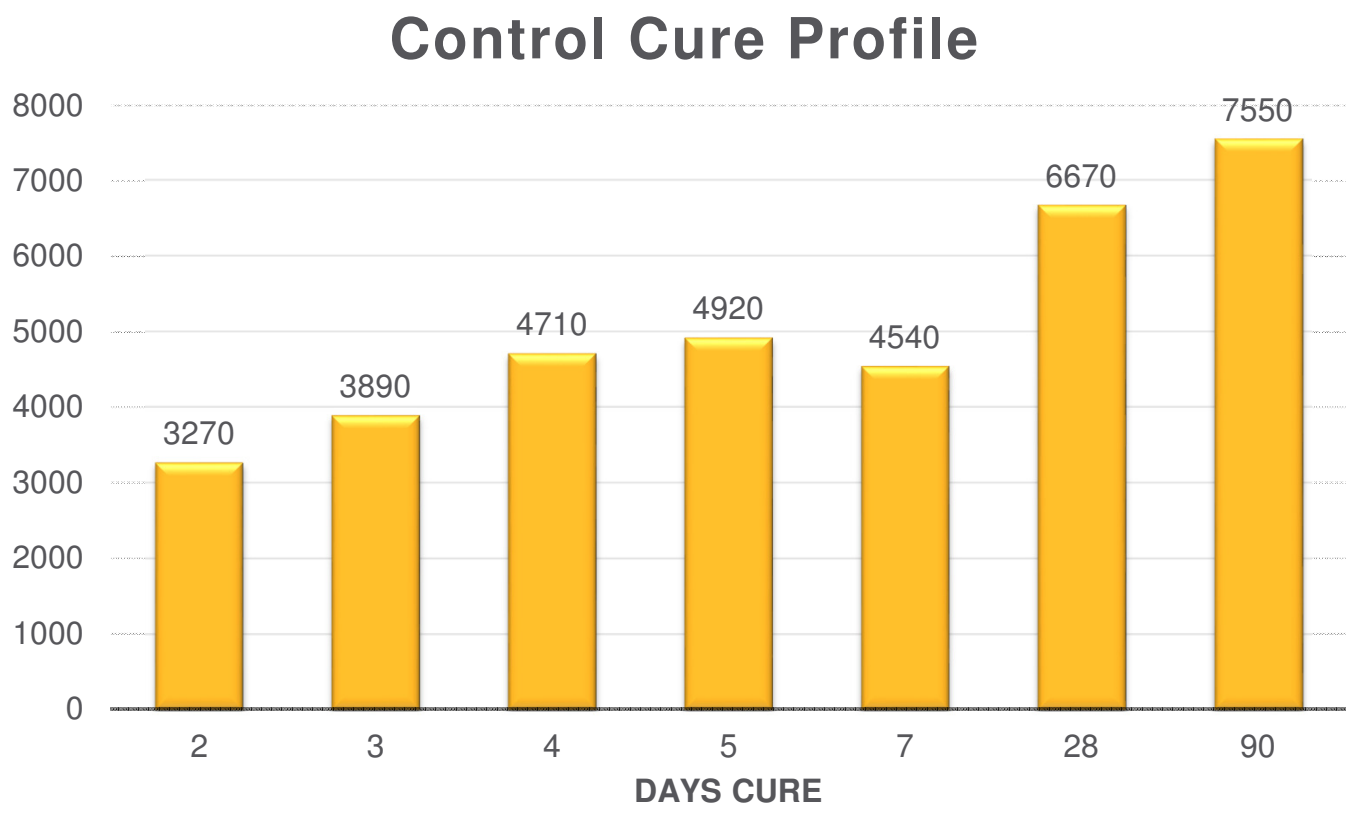
ASTM C39 Compressive Strength, psi



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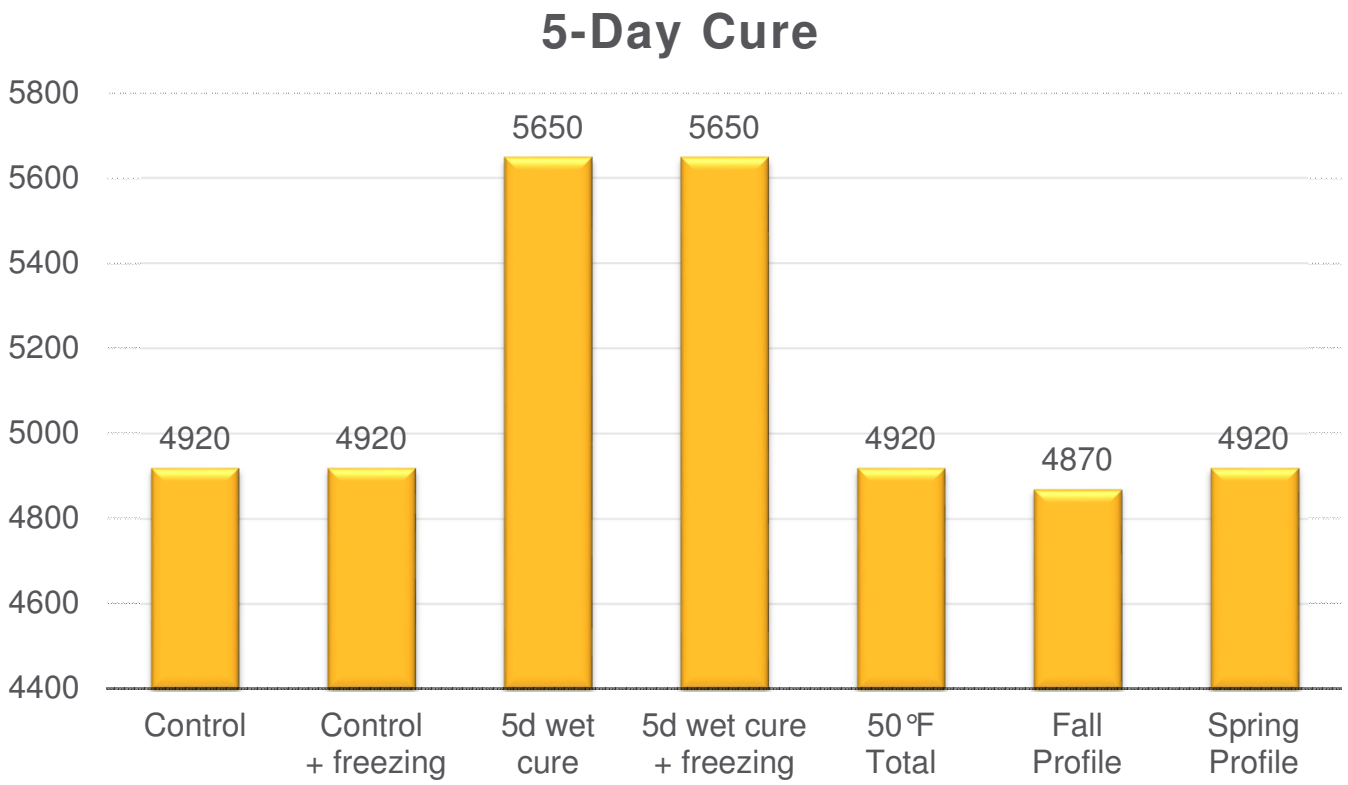

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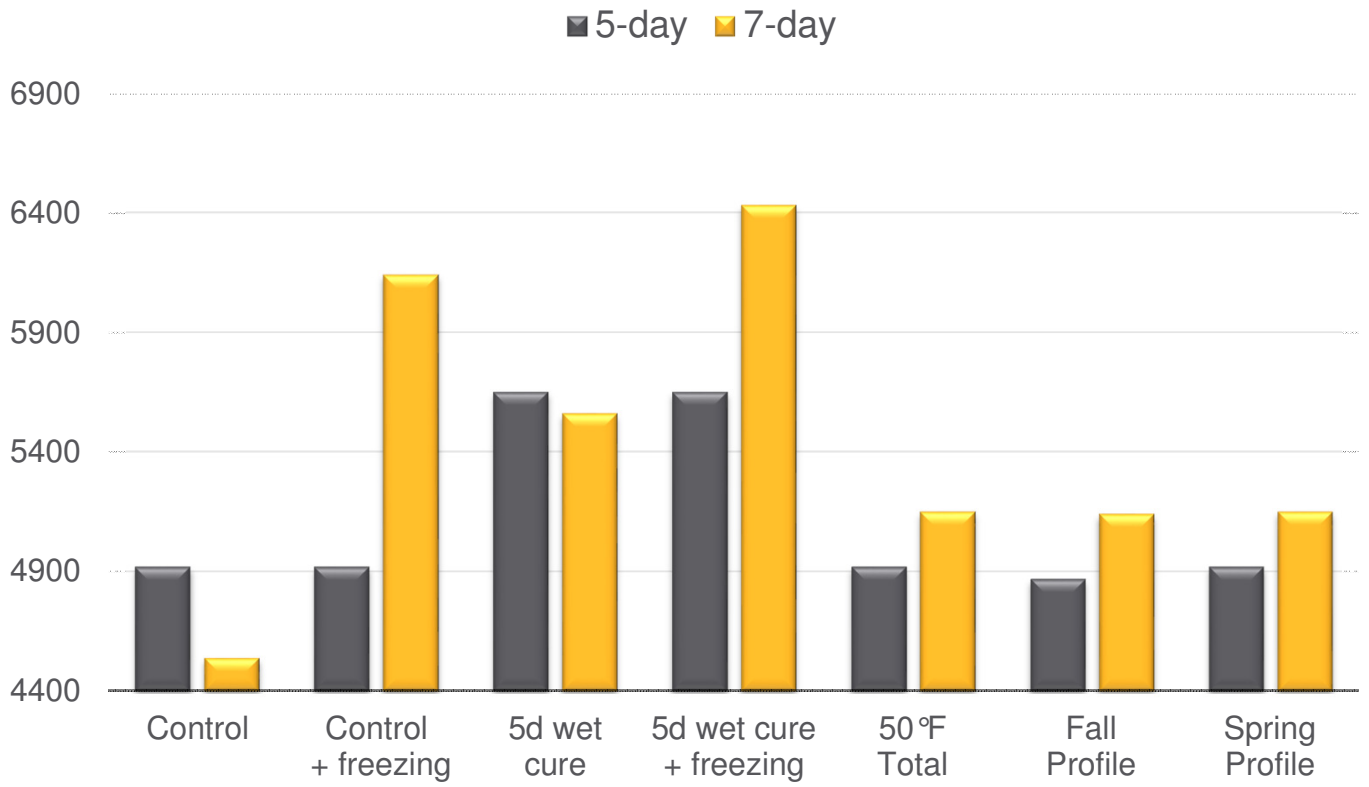

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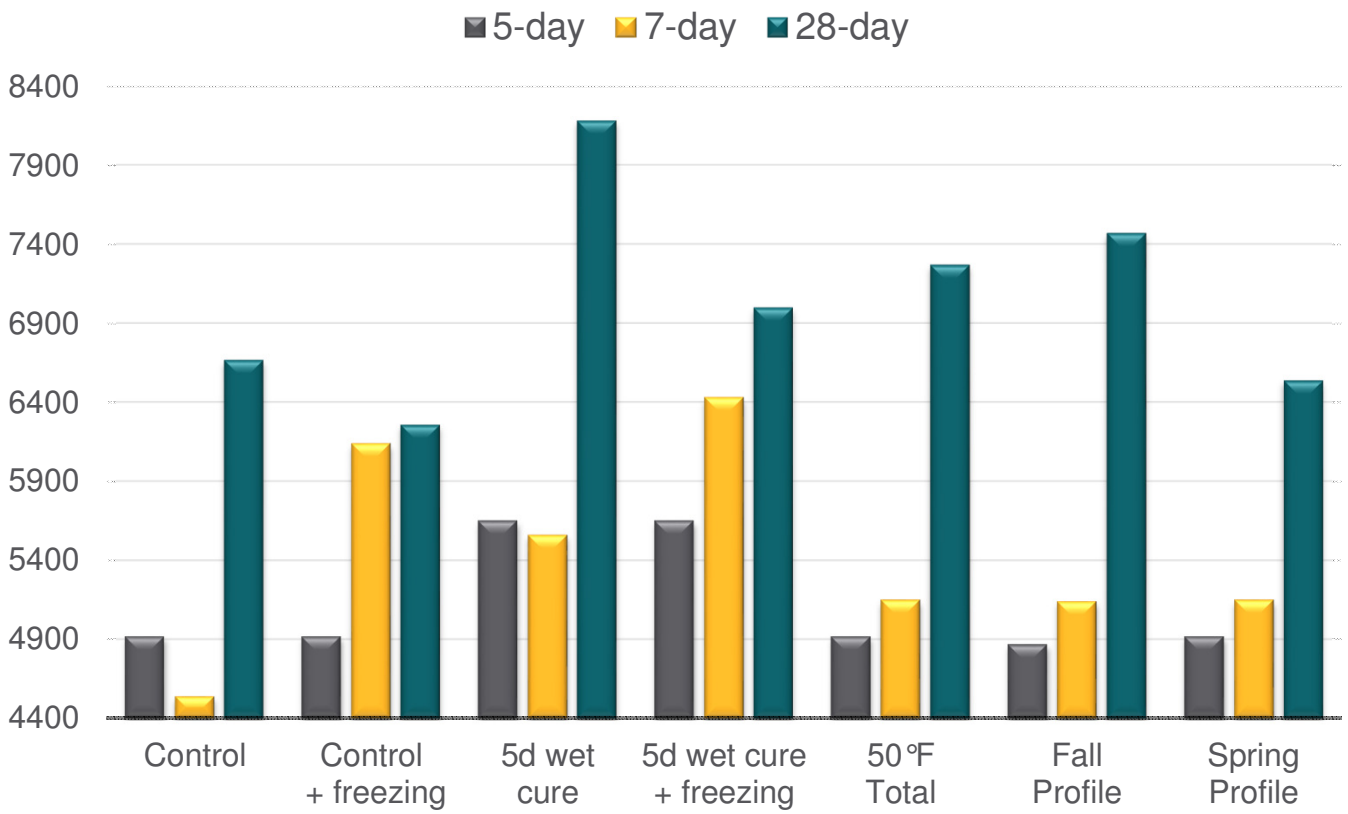

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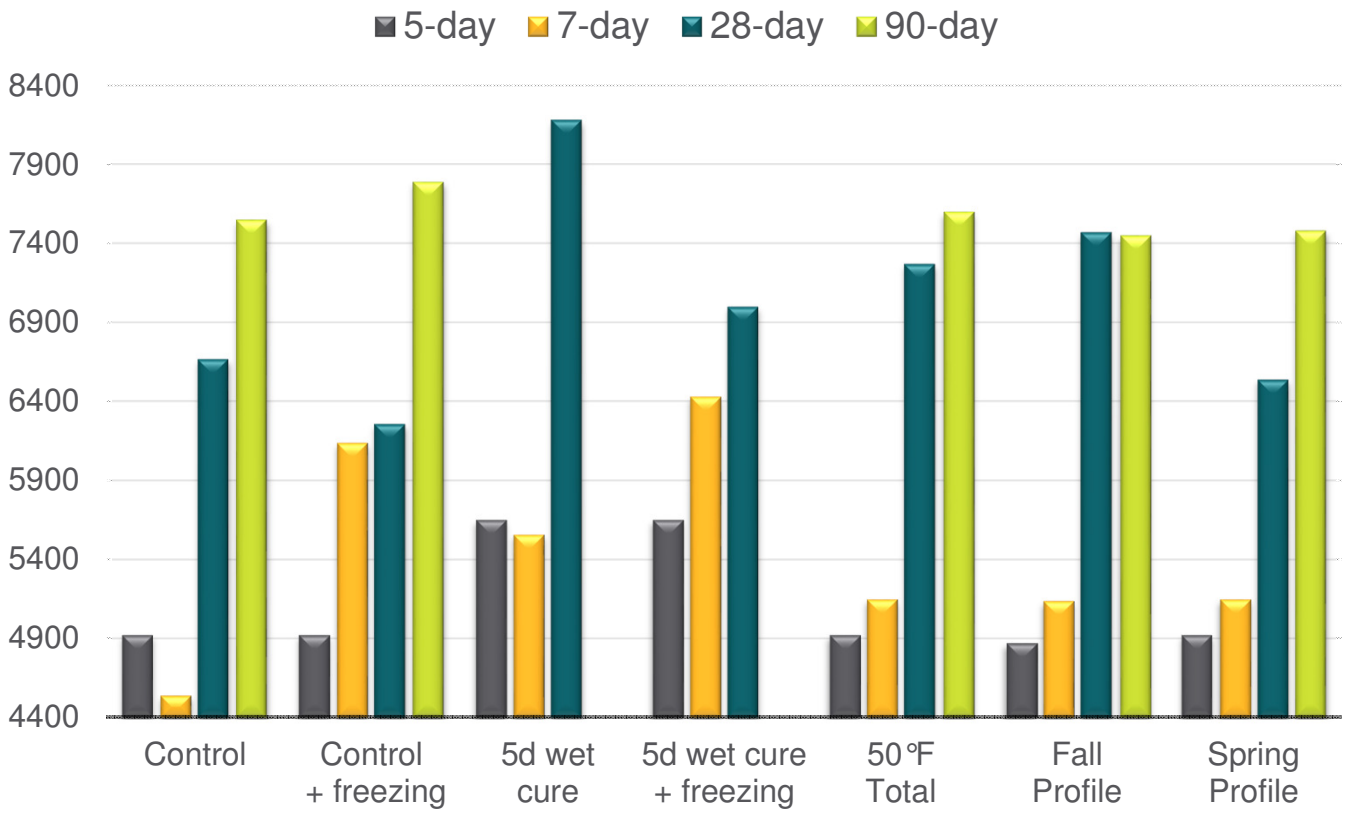

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Results

Compression strength development is excellent under all cure conditions.

- LMC cured under longer wet cure conditions and/or lower temperatures exhibit increased compression strength at 28 days.
- At 90 days compression strength is essentially equivalent for all cure conditions.
- Use of blankets (extended wet cure) is not detrimental to compression strength development.

AASHTO T-277 Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

Age Tested Avg of 2 cylinders	Control	Control + Freezing	5d Wet Cure	5d Wet Cure + Freezing	50° F Total	Fall Profile	Spring Profile
	Adjusted Readings, Coulombs						
28 days	2507	2639	1921	2437	3677	2803	2700
90 days	1229	1124	1002	1247	1401	1433	1137
6 months	821	831	692	793	801	795	788

Charge Passed (Coulombs)	Chloride Ion Penetrability
>4,000	High
2,000–4,000	Moderate
1,000–2,000	Low
100–1,000	Very Low
<100	Negligible

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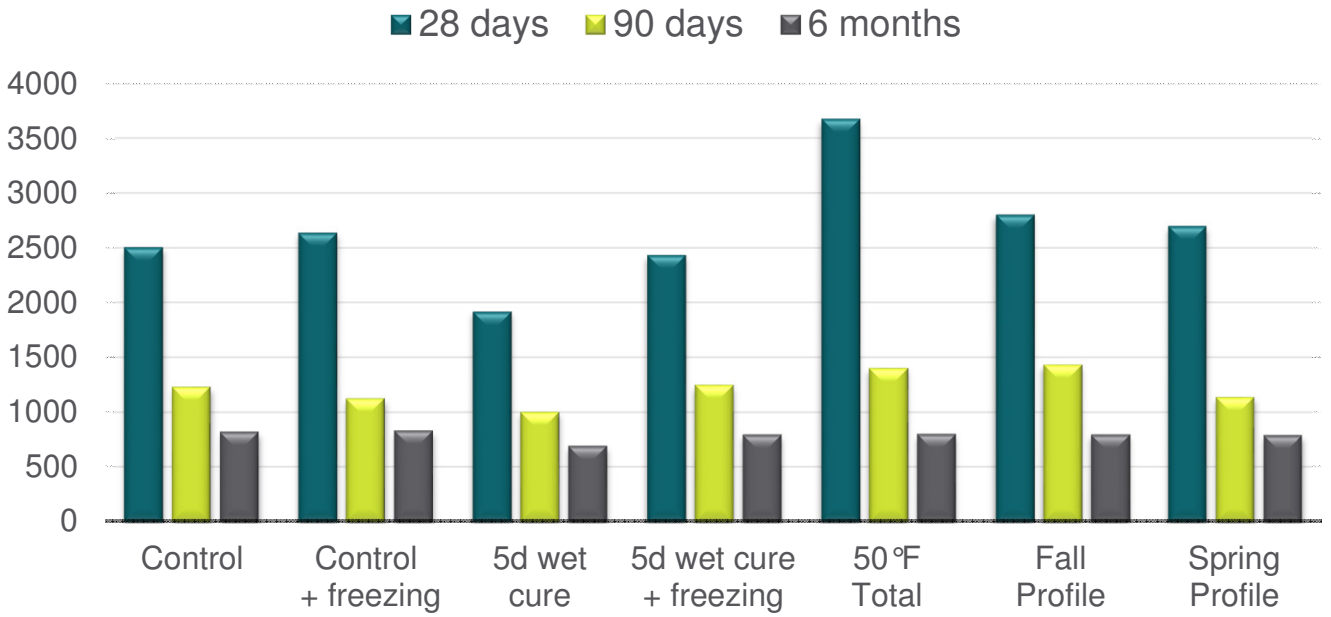

Charge Passed (Coulombs)	Chloride Ion Penetrability
>4,000	High
2,000–4,000	Moderate
1,000–2,000	Low
100–1,000	Very Low
<100	Negligible

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Results

Chloride ion penetration resistance improves over time under all cure conditions.

- For all systems chloride ion penetrability improves from moderate → low → very low over 6 months
- Extended wet cure exhibits lower chloride ion penetrability at each test interval
- Use of blankets (extended wet cure) is not detrimental to chloride ion penetration resistance

LMC Performance

- Proven technology since the 1970's specifically designed for thin bonded overlays
- LMC can provide a 30+ year service life when placed properly
- LMC bond strength exceeds the strength of the base concrete
- Low Permeability reduces penetration of moisture, chloride ions and protects reinforcing steel from corrosion
- Low modulus of elasticity makes the concrete less brittle and more flexible

Meets FHWA RD-75-35 Requirements

Styrene-Butadiene Latex Modifiers for Bridge Deck Overlay Concrete

Standard	Standard Test Method
ASTM C39-12	Compressive Strength of Cylindrical Concrete Specimens
ASTM C78-10	Flexural Strength of Concrete (Single Simple Beam with Third-Point Loading)
ASTM C882-12	Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear
ASTM C1543-10	Determining the Penetration of Chloride Ion into Concrete by Ponding
ASTM C672-12	Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

Project was Success

- Partnering
  - Streamlined communication and decision making
  - Team effort and solution oriented
  - Cost effective project decisions

- Owner Perspective
  - New LMC overlay with 30 Year life expectancy
  - Finished project on time and under budget

Project was Success

- Contractor Perspective
  - Received completion incentive
  - Project received 7 awards including:
    - 2016 – Best Specialty Contracting Project, Mid-Atlantic Region – Engineering News Record (ENR)
    - 2017 – MdQI Project of the Year Over $5 Million
    - 2017 – MdQI Modal Award Over $5 Million

LMC has Proven to be Successful

- In the last 15 years
  - Maryland spent more than $114 Million on 10 LMC overlays projects that Wagman has been the General Contractor
  - Over 515,000 SY of deck area
  - Over 34,000 CY of Latex Modified Concrete

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Summary

- Mid-Atlantic Region finds LMC as proven success for more than 45 years for both new and rehabilitated bridge decks
- Study confirms LMC is robust under low temperature and extended wet cure conditions
- Use of blankets (extended wet cure) is not detrimental to compression strength development or chloride ion penetration resistance