Latex-Modified Concrete Use in Low Temperatures and Extended Wet-Cure Conditions

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Many roads and bridges across the United States were constructed in the 1960s and 1970s. Because traffic and truck loads have increased since then, more than one-third of U.S. bridges now need repairs or replacement.[1] Bridge maintenance is critical because a sound infrastructure improves our daily quality of life and offers a global competitive advantage.

Latex-modified concrete (LMC) plays an integral role in the story of our nation's infrastructure maintenance and repair. The use of latex as a performance-enhancing additive in modified concrete systems for bridge deck overlays is a proven technology. With a combination of excellent compressive, flexural, and bond strengths, an LMC overlay is one of the best choices for many bridge and roadway repair projects.

An Introduction to LMC

LMC is a modified concrete designed to meet latex specifications and concrete performance criteria suggested in the Federal Highway Administration (FHWA) report *Styrene-Butadiene Latex Modifiers for Bridge Deck Overlay Concrete* (FHWA RD-78-35).[2] Latex materials can be tested to determine whether the properties meet the FHWA report's criteria.[3] LMC has been recognized for its longevity, superior performance, and overall economic advantage when used for bridge deck overlay repair.[4]

LMC was designed for thin, bonded overlays and can provide a service life of more than 30 years when placed properly. Studies performed by the Virginia Transportation Research Council[5] and the Strategic Highway Research Program[6] conservatively estimate that LMC can last between 22 and 26 years. Because of this longevity, LMC is often used on bridge decks, highway overlays, parking decks, and other roadways where surface rehabilitation is required.

LMC's appeal comes from three main properties:

- Bond strength typically exceeds the strength of the base concrete.
- Low modulus of elasticity makes the overlay more flexible and less brittle.
- Low permeability reduces moisture and chloride-ion penetration, which helps protect reinforcing steel from corrosion.

Thanks to these properties, LMC overlays require less maintenance and have lower overall costs over the life of the bridge compared with other repair alternatives.

One drawback of LMC, as with many concrete systems used for bridge deck overlays, is that the installation season is limited in the spring and fall when temperatures are cooler. However, a low-temperature cure study conducted by Trinseo showed that LMC cured under longer wet-cure conditions and lower temperatures can still obtain the required compressive strength, thus demonstrating its efficacy under these conditions.

Curing Study Results

State departments of transportation (DOTs) have varying requirements for LMC curing conditions; however, typical specifications require two days of wet curing followed by two to three days of air drying. The air drying enables the polymer in the concrete matrix to coalesce, thereby developing the water and chloride-ion penetration resistance for which LMC is known. Freshly placed LMC must also be protected from cold temperatures. Curing blankets are recommended to help maintain heat when the air temperature drops below the specified minimum, typically 45°F to 50°F depending on the DOT. In isolated cases, there is concern that curing blankets, although useful for temperature maintenance, can hinder air drying and the development of chloride-ion penetration resistance.

A study of the impact of using curing blankets was conducted to evaluate the effects of low curing temperatures on the development of compressive strength and chloride-ion penetration resistance. The study simulated extended wet-cure conditions. It followed FHWA criteria[2] for LMC mixture proportions, which help ensure that a mixture can be placed and handled in a similar fashion as conventional concrete. **Table 1** shows the cure conditions to which the test cylinders were subjected. The cylinders were then tested for compressive strength and chloride-ion penetration at various time intervals. Testing was performed in accordance with methods specified by ASTM International[7] and the American Association of State Highway and Transportation Officials.[8]

The study concluded that the extended wet cure using curing blankets is not detrimental to compressive strength development or chloride-ion penetration resistance (**Fig. 1** and **Table 2**).

The results for the compressive strength tests were excellent under all cure conditions. The extended wet cure was used to simulate the use of blankets, and results showed excellent strength development; therefore, the use of blankets is not expected to negatively affect compressive strength development. The compressive strength of LMC specimens cured under longer wet-cure conditions and/or lower temperatures continued to increase at 28 days, and

Table 1. Curing profile description and details for latex-modified concrete samples

	Control*	Control* and freezing	5-day wet cure	5-day wet cure and freezing	Constant 50°F	Fall profile	Spring profile
Cure condition	Days at each cure condition						
Wet cure at 50°F	2	2	5	5	2	2	2
Air dry/cure at 50°F	3	3	n/a	n/a	26	n/a	10
Air dry/cure at 20°F (freezing)	n/a	2	n/a	2	n/a	n/a	n/a
Air dry/cure at 72°F	23	21	23	21	n/a	10	8 at 60°F
Air dry/cure at 60°F	n/a	n/a	n/a	n/a	n/a	8	8 at 72°F
Air dry/cure at 50°F	n/a	n/a	n/a	n/a	n/a	8	n/a
Total days	28	28	28	28	28	28	28
Additional curing							
Air dry/cure, days	90 (total) at 72°F	90 (total) at 72°F	90 (total) at 72°F	90 (total) at 72°F	90 (total) at 50°F	90 (total) at 50°F	90 (total) at 72°F
Air dry/cure	6 months (total) at 72°F	6 months (total) at 72°F	6 months (total) at 72°F	6 months (total) at 72°F	6 months (total) at 50°F	6 months (total) at 50°F	6 months (total) at 72°F

n/a = not applicable.
*Control represents standard curing conditions.
Table: Trinseo.

at 90 days where data were available. At 90 days, the compressive strengths were essentially equivalent for all cure conditions for which data were available. For the two conditions where 90-day test data were unavailable, the 28-day test values were roughly equal to or well above the other 28-day test results, so the 90-day values could be expected to be at least equal to test results for the other conditions.

The study also showed that chloride-ion penetration resistance improved over time (that is, test results were lower) under all curing conditions, demonstrating that extended wet-curing periods and/or lower temperatures are not detrimental. Table 2 shows that resistance to chloride-ion penetration after six months was better for all specimens with longer wet-cure conditions and/or lower temperatures than for specimens with standard curing. The specimens with 5 days of wet curing exhibited the best chloride-ion penetration resistance at each test interval, whereas the specimens with extended low temperatures during curing developed chloride-ion resistance more slowly than other systems but still achieved values lower than specimens subjected to the control curing conditions.

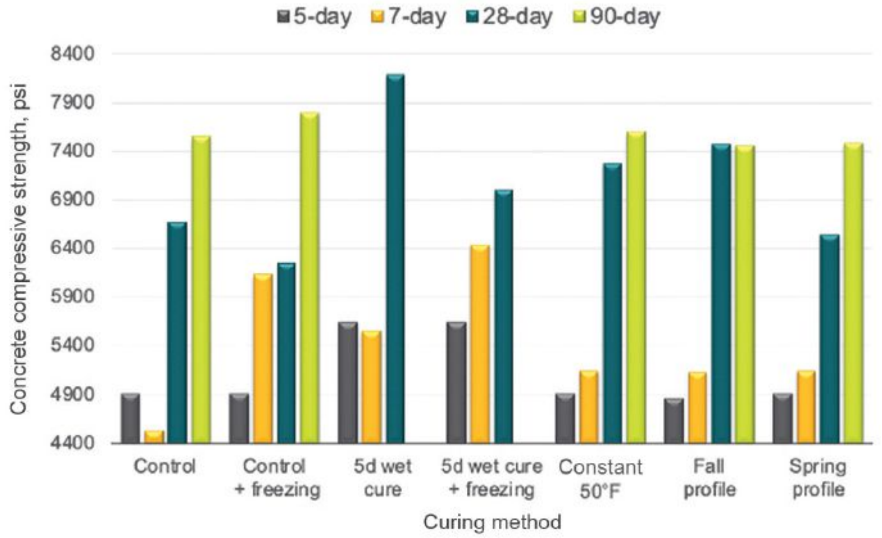

Figure 1. Compressive strength of latex-modified concrete samples under different curing conditions from the average of three cylinders tested according to ASTM C39.[7] Figure: Trinseo.

Concrete Repair Implications

The results of the study are good news for concrete professionals looking to repair concrete bridge decks by placing LMC overlays quickly, effectively, and cost efficiently, while navigating state regulations for minimum temperatures and cure times. The results confirm the efficacy of curing blankets to maintain temperature without affecting LMC performance, thus contributing to an extended installation season and allowing overlays to be reopened to traffic in an expedited fashion.

Table 2. Electrical charge passed (coulomb) as an indication of ability of latex-modified concrete to resist chloride-ion penetration (average of three tests according to AASHTO T277)[8]

Age tested (average of 2 cylinders)	Control*	Control* and freezing	5-day wet cure	5-day wet cure and freezing	Constant 50°F	Fall profile	Spring profile
	Adjusted readings, coulomb						
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

Definitions for chloride-ion penetrability ratings	High	Moderate	Low	Very low	Negligible
Charge passed, coulomb	>4000	2000–4000	1000–2000	100–1000	<100

*Control represents standard curing conditions.
Table: Trinseo.

A crew places a latex-modified concrete overlay with good flow and consistency. All Photos: Pat Martens, Bridge Preservation & Inspection Services.

For those considering LMC for their next bridge deck overlay repair project, look for products that meet the criteria suggested in FHWA RD-78-35.[2] Using a product that meets these criteria will ensure that your project benefits from similar performance properties exhibited in this study.

Future studies should evaluate whether LMC will cure properly under even lower ambient temperatures. A better understanding of performance under different environmental conditions will help better define seasonal placement limitations and preferred curing conditions for LMC.

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A crew places wet burlap on a latex-modified concrete overlay for optimal curing to ensure superior results.