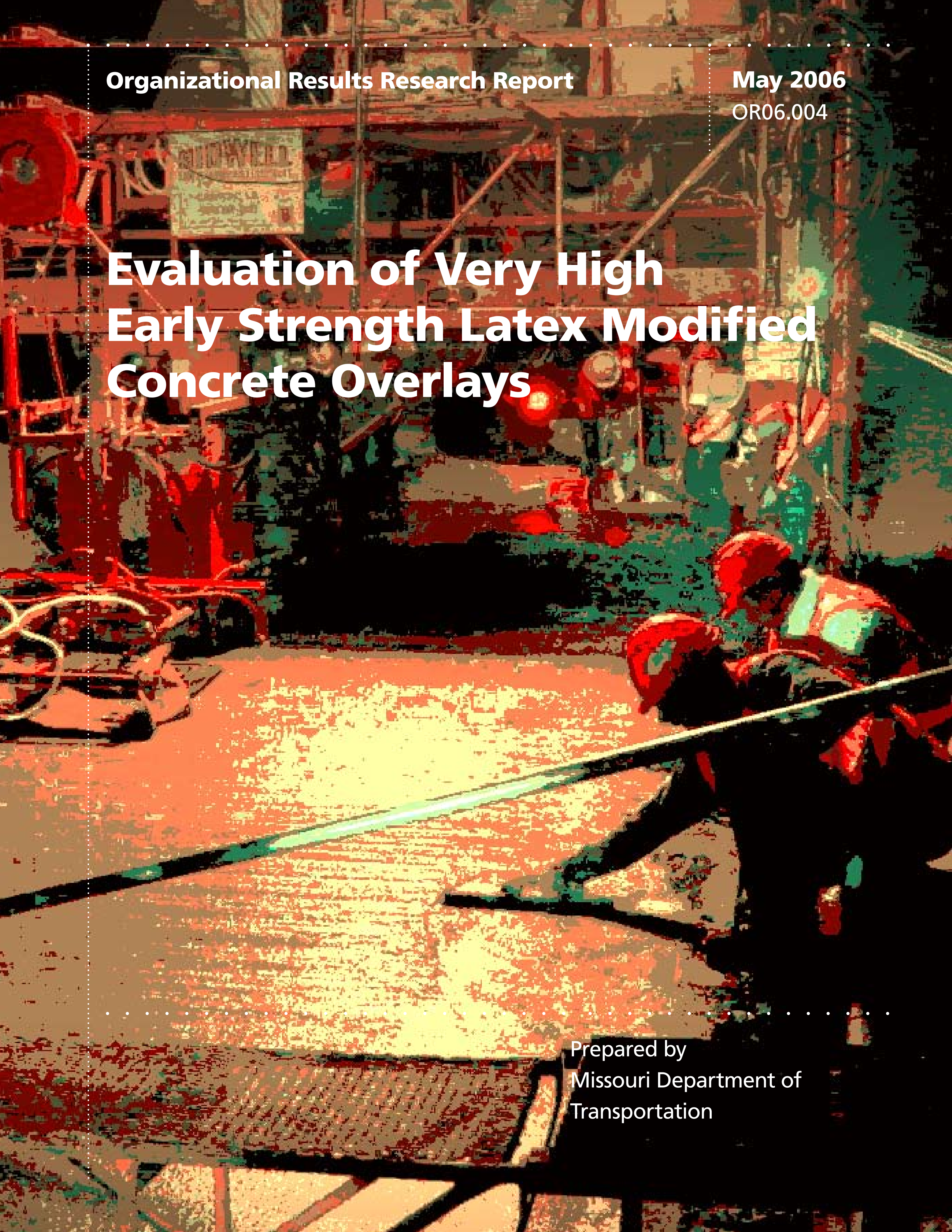

Organizational Results Research Report

May 2006
OR06.004

Evaluation of Very High Early Strength Latex Modified Concrete Overlays

Prepared by
Missouri Department of Transportation

FINAL REPORT

RI04-005

Evaluation of Very High Early Strength Latex Modified Concrete Overlays

Prepared for the
Missouri Department of Transportation
Organizational Results

By
John D. Wenzlick, P.E.

May 2006

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. OR06-004	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of Very High Early Strength Latex Modified Concrete Overlays		5. Report Date May 2006 6. Performing Organization Code
7. Author(s) John "JD" Wenzlick, P.E.		8. Performing Organization Report No. RI04-005
9. Performing Organization Name and Address Missouri Department of Transportation Organizational Results P. O. Box 270 Jefferson City, MO 65102		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Missouri Department of Transportation Organizational Results P. O. Box 270 Jefferson City, MO 65102		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes
The investigation was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.

16. Abstract

These projects were the first time that Latex Modified Concrete Very High Early (LMC-VE) strength concrete was used in Missouri. On one of the bridge decks the LMC-VE was placed, the deck was hydroblasted and repaired and overlaid all in one night, and reopened to traffic the next morning. A second deck with a concrete superstructure was milled and received conventional deck repair. It was overlaid and opened to traffic several days later to allow faster changing of traffic control on a multi-lane interstate. Finally the third bridge and its approach slabs were hydroblasted and overlaid and open several days later to expedite traffic control. This report was to document procedures and any materials or constructability problems on these projects.

17. Key Words Very High Early Strength, Concrete bridge deck overlay, Latex Modified Concrete, Blended Cement		18. Distribution Statement No restrictions. This document is available to the public through National Technical Information Center, Springfield, Virginia 22161	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 23	22. Price

Form DOT F 1700.7 (06/98)

Executive Summary

This project was the first time that Latex Modified Concrete Very High Early strength (LMC-VE) concrete was used in Missouri. MoDOT chose LMC-VE overlays because bridge repairs on heavily traveled urban interstate highways would require expensive and complicated traffic control. It was important to disturb the driving public the least amount possible by getting the work done at night or on weekends. One deck was hydroblasted, repaired and overlaid all in one night and opened to traffic the next morning. A second deck with a concrete superstructure was milled and received conventional deck repair. It was overlaid and opened to traffic several days later to allow faster changing of traffic control on a multi-lane interstate. Finally the third bridge and its approach slabs were hydroblasted and overlaid and open several days later to expedite traffic control. This report was to document procedures and any materials or constructability problems on these projects.

The only problem encountered was inadequate bonding when the surface texture to which the LMC-VE overlay was placed did not have a rough enough surface texture. One lane of the first bridge was milled and did not give as rough a surface as the others, which were hydroblasted. Also the thickness of the overlay was planned to be 2 ¼” and in order to meet the grade of the existing approach slabs had to be placed up to 5 ¾” thick. This caused debonding problems and some of the LMC-VE had to be removed and replaced in some areas. It is suggested that MoDOT only use this type of overlay on high volume roads where traffic control is very costly or complicated or for overnight or over weekend closures when needed to expedite the repair of a bridge deck. LMC-VE can be a good tool to reaching MoDOT’s goals of smoother safer roads and also keeping uninterrupted traffic flows. As more LMC-VE overlays are built MoDOT should move toward incorporating it into the Standard Specifications. It is also recommended that the substrate surface be hydroblasted to get a rough bonding surface any time a LMC-VE overlay is used. Finally, the LMC-VE overlay should be limited to 3 inches maximum thickness.

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Background and Preliminary Work

This concept of quick bridge repair was borrowed from the Virginia DOT who repaired and overlaid two bridge decks with Latex Modified Concrete Very High Early strength (LMC-VE) in 1997 and opened the new decks to traffic within three hours.[1] The St. Louis District of MoDOT was looking for a way to replace the riding surface on four ramp bridges leading to the busiest Mississippi River crossing in downtown St. Louis. The Poplar Street Bridge caries eight lanes and three Interstate routes between Missouri and Illinois. As a trial placement, Pat Martens - District Bridge Maintenance Engineer picked a closed ramp bridge on Interstate 70 near downtown St. Louis to verify how the process of quick repair might work. The process consisted of hydroblasting the bridge to remove bad concrete and then applying a monolithic repair and overlay that could be opened as quickly as possible to traffic. Three different concrete overlays placed on the experimental bridge were compared; the LMC-VE, plus a Latex Modified Concrete High Early strength (LMC-HE, using Type III cement that would gain strength in 24-48 hours) and MoDOT's normal Type B2 bridge deck concrete

The objective of the trial repair, which was on a concrete box girder bridge identical to the Poplar Street approach bridges, was to see first how well hydro-demolition could be used as a removal method on a box girder superstructure bridge and, second, the effectiveness of placing very high early strength latex modified concrete, LMC-VE.

Objective 1: Currently repairs of these structures must be accomplished using repair zones that allow only very small areas of the deck concrete to be removed over the large reinforcing bars located over the substructure column bents to insure a minimum loss of bond in the negative moment areas. It would be allowable to open up an area 6 ft. wide the entire length of the bridge for concrete removal by using hydro-demolition, if less than 25% of the reinforcing steel cage was exposed after removal in this strip. Then further excavation could be done, however, it would be necessary to leave a 6 ft. wide strip of the concrete deck in place between the hydro-demolition areas so that the reinforcing steel cage with concrete around it could carry the negative moment stresses. This would allow hydro-demolition in alternating 6 ft. wide sections across the width of the deck and possibly as little as two concrete placements to repair and overlay the deck at the same time. This is much faster than conventional zone concrete removal and repairs and then a separate placement of the overlay. Quick removal of the deteriorated concrete was only partially accomplished on this test bridge because there was almost 75% of the reinforcing steel uncovered in the first pass of the hydroblasting machine. This meant that the first area needed to be repaired and the new concrete cured before more hydro-demolition could be done.

Objective 2: On November 11, 1999 the first 1/3 of the first 6 ft. wide by 330 ft. strip hydro-blasted was placed using normal B2 concrete, and went smoothly. It was planned to place the next 1/3 with LMC-VE on November 18, 1999 but the placement was called off due to delays caused by equipment problems. The evaporation rate, which was being monitored by Dow Latex representative Cliff Heckman, was also going up because of high winds late that afternoon. Values to determine the evaporation rate taken at 1:00 PM (Air Temp. = 75^0 F, Air Speed = 9 mph, Relative Humidity = 31%, Mix. Temp. = 70^0 F(est.)) showed an evaporation rate = 0.12 lbs./s.f./hr. By MoDOT specifications for placement of silica fume concrete, the recommended limit is 0.1 lbs./s.f./hr., as determined by ACI 308-81, to limit shrinkage cracking. When the winds picked up about an hour later, the evaporation rate was near the 0.15 lbs./s.f./hr., and the placement was re-scheduled for Friday morning. On November 19, 1999 the placement started at 8:50 AM, and continued very smoothly until completed at 9:40 AM. The evaporation rate was determined to be 0.1 lbs./s.f./hr. The final amount placed was 9 1/2 c.y. and covered about 110 linear foot of the bridge. MoDOT supplied the sand and coarse aggregate and the contractor, Henry Frerk Sons, Inc. from Chicago, IL, provided the mobile mixer, Rapid Set cement, and latex additive. **The cost was $ 500/c.y. of concrete.** The price for hydro-demolition worked out to be $ 29.09 /sq.yd.of surface.

Table 1 - 1999 LMC-VE Trial Placement Mix Proportions

Rapid Set Cement:	658 Lbs
DOW Modifier A:	208 Lbs
Fine Aggregate:	1700 Lbs
Coarse Aggregate:	1300 Lbs
Water:	160 Lbs
Air Content:	6.5 % +/- 1 %
Slump:	4 – 6 inches

Also, Citric Acid would have been used as retarder, but because of the low temperatures, none was used.

Due to the rough surface provided by the hydro-demolition, no bonding grout was brushed into the existing deck. The existing concrete deck surface was in a surface saturated condition; it had been wetted and covered with plastic for 24 hrs. prior to placement of the concrete. There was also plenty of rebar exposed to help in the bonding of the overlay. A rotating drum screed on 2"x 4" lumber guides on both sides of the placement and a hand vibrator was used to place the LMC-VE. A quick pass with a bull float and then tining application was all that was needed to finish the surface. The placement was covered with pre-wetted burlap and plastic quickly after finishing.

Eight 6"x12" cylinders were made for compressive strength, results were as follows:

Table 2 – 1999 LMC-VE Trial Placement Compressive Strength Results

Cylinders	Break	Age	Average
1	2760	3 Hours	2937 psi
2	3115	3 Hours	
3	4370	6 Hours	4255 psi
4	4140	6 Hours	
5	6190	3 Days	6075 psi
6	5960	3 Days	
7	6530	5 Days	6580 psi
8	6630	5 Days	

Three 4" diameter by 2" high cylinders were made to test for chloride permeability, these test were made when the LMC-VE was 28 days old. Results indicated that these were the best numbers of any concrete ever tested by MoDOT. Of the four samples tested, the total current passed for each was 97, 107, 108, and 93 coulombs for an average of 101 coulombs. The test, AASHTO T 277**,** designates 100 coulombs as “Negligible – typical of Polymer Impregnated Concrete or Polymer Concrete”. It designates 100 – 1,000 coulombs as “Very Low – Latex Modified Concrete or Internally Sealed Concrete”.

The last placement made used Latex Modified Concrete - High Early (LMC-HE) strength using Type II cement instead of the more expensive Rapid Set cement used in the LMC-VE. The chloride permeability tests were good at 542 coulombs but there was trouble finishing the mix and it experienced quite a bit of plastic shrinkage cracking.

Conclusions from trial placements:

Objective 1 showed that because of the poor condition of the existing deck, the hydroblasting did not work as well as hoped, but it still cut in third the time for preparation of the deck. It would be hoped that the concrete condition on the Poplar Street Bridge ramps would be better than A-135 Ramp. This would allow two 6 ft. wide strips at a time to be hydro-blasted on these box girder bridges. However, even if that weren't the case, the reduced preparation time by specifying hydro-demolition would still justify a somewhat higher bid price for bridge deck repair.

Objective 2 was met on all counts. The LMC-VE mix went down and finished well at the 70^{o}F fall temperatures even under a moderate wind. If used, however, it is believed that night operations will probably be necessary or that a strict evaporation rate specification be included in the mix special provisions to ease finishing of the concrete surface and avoid shrinkage cracking. The Rapid Set cement seems to have performed well in compressive tests. It's also expected the LMC-VE, using the Rapid Set cement, to have very low chloride permeability based on the 101 coulombs average on tests from this project, the lowest ever tested by MoDOT. Because of the high initial slump of the mix, no problems are anticipated with placing patches monolithically with the surface course as long as adequate vibration of the mix is made during placement.

Recommendations from trial placement:

At this time it's believed both objectives have been partially met and would recommend this operation on the Poplar Street Bridge approach ramps, namely, hydro-demolition and monolithic repair and overlay with Latex Modified Concrete - High Early (LMC-HE) Strength concrete which would save some materials costs. If very quick opening of the lanes to traffic is needed, it is recommended to use the Latex Modified – Very High Early (LMC-VE) Strength concrete.

Postscript:

Two different projects were let to repair and overlay with LMC-VE the Poplar Street Bridge approach ramp bridges. Both times the bids were too high above the engineer's estimate and all had to be rejected. Ultimately a project was let to replace the pavement portion for these ramps and at that time the bridge deck surfaces were patched. Since no permanent repair could be done on the four bridges it is hoped the patching will last for 7-10 years. The bridges are programmed to be replaced when some of the traffic will be diverted to a planned new Mississippi River crossing about a mile north of the Poplar Street Bridge complex. The LMC-VE never was used on the Poplar Street bridges.

Present Conditions

At present MoDOT specifications require a curing time for Bridge Deck Concrete Wearing Surface mixes of 3 days to 7 days, depending upon the type of concrete overlay used: Low Slump, Latex Modified or Silica Fume Concrete. On major freeways in urban areas this requires closing lanes for extended times with various stages to work on multiple lane bridges. This causes intolerable congestion when near major interchanges or segments that are already at capacity during heavy traffic hours. The situation can become even more congested when there are sports or other special events scheduled during the construction timeline. Latex Modified Concrete - Very High Early (LMC-VE) strength applied to these bridge deck repair projects would be a way to keep from long lane closures in these very high trafficked areas.

Subsequent to the trial placement on the closed I-70 ramp bridge of the Latex Modified Concrete – Very High Early strength (LMC-VE) overlay and the two attempted projects on the Poplar Street Bridge approaches the need came up on Interstate 270 in St. Louis County and I-70 in St. Charles County to repair several bridge decks and get them open to traffic as quickly as possible. Both of these projects took place in the summer of 2004 and were observed by the Research, Development and Technology Division at MoDOT since they were the first construction projects contracted using the LMC-VE overlays. The objective of this effort was to document the effectiveness and feasibility of placing LMC-VE overlays on Missouri bridges and make recommendations for future applications.

Project J6I1515, Rt. I-270, St. Louis County

This is a summary of the LMC-VE placement observed on May 21, 2004. The bridge, No. A1056 is a twin structure with 5-lanes in each direction, northbound and southbound, with an average daily traffic (ADT) of 187,000. The bridges have a voided slab superstructure and had an existing 1 ¾" Low Slump concrete overlay. This bridge was planned to have a new Low Slump concrete overlay but the contractor, Millstone Bangert, Inc., substituted LMC-VE. Using the LMC-VE allowed the contractor quicker change of traffic control staging on this multilane interstate highway.

The old low slump overlay on the inside SB lane was removed by milling, patching of the deck done and the first placement of LMC-VE made on May 7, 2004. After this lane was cured and had reached the compressive strength required of 3200 psi it was sounded to check for any unbonded areas according to the specifications. An area 10' wide by the length of the bridge was found to be unbonded. It had already been milled off when RDT division personnel arrived on May 21,2004. In order to determine the "pull off" or direct tensile strength, 5-2" diameter holes were cored in the new LMC-VE overlay that was left in place, and considered to be well bonded to the original deck. It was necessary to drill 5 holes in order to get the 3 cores required for the test, which didn't break loose of the original deck surface. The depth of the cores averaged 5 ¾", the plan thickness of the overlay was supposed to be 1 ¾" planned depth of the low slump overlay removed. However, to match the existing grade of the approach slabs, it had to be increased to 5 ¾" thick. The debonding problem is believed to be due to the thickness of the overlay and the stresses caused between it and the original substrate as a result of differential expansion and contraction, and also due to the relatively smooth surface texture left by the milling operations.

Table 3 – Pull Off Test Results

215 psi	
135 psi	
135 psi	Average = 162 psi.

While there is no pull off strength requirements in MoDOT's specifications, no individual core test under 150 psi is desired per ACI (American Concrete Institute) recommendations..

This area, all but a 2' wide strip near the median of the southbound inside lane, was re-placed on the night of May 21, 2004. Two 4"x 8"cylinders were made of the LMC-VE mix to do chloride permeability tests in the lab at 28 days and 56 days. After the overlay had reached strength and been sounded by the construction inspector with no delaminations noted, about 7:00 AM the next morning, three cores were drilled and the pull off strengths were as noted in Table 4.

Table 4 - Pull Off Tests From 2nd Overlay Placement (approximately 6 hours old)

150 psi	
26 psi	
170 psi	Average = 115 psi.

Two cores broke aggregate within the original deck, so the 150 psi and 170 psi were considered good tests. The 26 psi test broke at the bond interface and is conjectured either due to some kind of surface contamination or lack of texture. If the 26 psi test is thrown out the average pull off strength would be 160 psi and considered acceptable. The overlay thickness from these cores averaged 5 ½".

The roughness of the surface on the original deck from being milled a second time to remove the 10 ft. wide unbonded section of first LMC-VE overlay and possibly better cleaning of the surface of the original concrete deck than the first time are attributed with the higher pull off strengths attained in the above tests. This allowed the new LMC –VE overlay to pass the sounding test and be finally accepted.

The chloride permeability tests taken from samples of the LMC-VE from the second placement of the overlay are presented below in Table 5.

Table 5 - Chloride Permeability Tests Results

	28 Days		**56 Days**	
	684		917	Very Low 100-1,000 Latex Mod. Concrete
	793		1082	Internally sealed
	833		1038	
Avg.	770 coulombs	Avg.	1013 coulombs	

It can't be explained why the permeability went up after 56 days curing. The contractor was using two mobile mixers and one was having trouble-adding retarder (citric acid), the cylinders might have been taken out of two different loads. However, in talks with Michael Sprinkle in

Virginia the chloride permeability test using AASHTO T252 on their samples went to almost zero at 1 year old.[1]

The other bridge, No. A1051R, on this project was a conventional deck on steel girders. It was hydroblasted just before the LMC-VE was placed. The surface texture was much rougher and there were no problems on any of the 6 separate deck placements. The one overlay placement that RDT observed started on Saturday night, May 22 and was over by 1:00 AM. The LMC-VE exceeded the required 3200 psi minimum compressive strength and when it had reached the required 6 hours old was opened to traffic at 7:00 AM on Sunday morning, May 23. Only concrete placement was observed on this bridge, no pull-off tests or chloride permeability samples were taken.

Project J6I1444, Rt. I-70, St. Charles County

This project was to repair and overlay a 5-lane bridge on eastbound I-70, bridge no. A3582 that has an ADT of 83,000. The special provisions for the LMC-VE had been revised from those in the previous project (see Appendix B), mostly since the approach pavements were going to be overlaid with the LMC-VE as well as the bridge. The curing specifications were tightened requiring a misting system to be attached to the finishing machine. The contractor Fred Weber, Inc, a different contractor than on the I-270 project, purchased a system from Bidwell that fit right on their Bidwell finishing machine, this was the first time this system was used on a MoDOT project and it worked very well. See Figure 1 below. Placement and finishing of the overlay was routine and similar to any other overlay concrete (Figure 2). The mix does set up more quickly and allowed early placement of the curing mats of wet burlap. In fact the Rapid Set Cement manufacturers representative on the job directed when the curing mats be placed and was able to stand on the tined surface within 30 – 45 minutes without marring it at all.

Figure 1: Close-up of fogging nozzles on pan screed, burlap drag and arm behind Bidwell finishing machine.

Figure 2: Last placement on Bridge No. A3582 - minimum finishing required.

Before curing was complete a 2” wide expansion joint was sawed through the overlay at each end of the bridge between the deck ends and the approach slabs. This worked well and only some minor raveling on the edges occurred later when the overlay concrete was removed in this area and the silicone expansion material was poured in the 2” opening. Before the bridge was opened to traffic, however, during asphalt paving on the roadway matching into the ends of the approach slabs, a worker operating an asphalt roller backed over the expansion joint and turned his roller over the edges several times causing some large areas of the sawed edges to break off. (See Figure 3) Observation of how these edges hold up over time will be made, but leaving an open saw cut edge on the LMC-VE might not be advisable in the future.

Overall the finished deck, which took three separate placements of the LMC-VE overlay, turned out very well (Figure 4). There were no areas of debonding identified when the inspectors sounded the overlay and no patching was needed before the deck was accepted and opened to traffic. A smooth transition on and off the bridge was obtained and a good surface texture provided. MoDOT now has a smooth riding bridge it expects to get a 20 year service life from even with it being on the busiest section of roadway in Missouri.

Figure 3: Edges broken off overlay on Bridge No. A3582 and approach pavement at sawed expansion joint.

Figure 4: Finished LMC-VE overlay on Bridge No. A3582, the placement observed (inside shoulder and 1 ½ lanes) is in the foreground.

Results and Discussion (Evaluation)

Table 6 – Bid Prices Project J6I1515

Br.No. A10562	Low Slump Concrete Wearing Surface	2613 Sq.Yd.	$93.00	$243009.00
Br.No. A10512	LMC-VE Concrete Wearing surface	1182 Sq.Yd.	$115.00	$135930.00
Br.No. A10513	LMC-VE Concrete Wearing surface	1182 Sq.Yd.	$115.00	$135930.00

Millstone Bangert, Inc., took a $22.00 Sq.Yd. price difference to substitute the LMC-VE concrete wearing surface on Br. No. A10562. With 2613 Sq.Yd. this ended up being a potential loss for him of $57,486 but he believed with the traffic control and the time savings for each of three stages of construction he figured he more than made up the difference.

Table 7 – Bid Prices Project J6I1444

Br.No. A3582	LMC-VE Concrete Wearing surface	1800 Sq.Yd.	$76.00	$136800.00
Br.No. A3582	Additional LMC-VE Concrete	10 Cu.Yd.	$143.00	$1430.00

Fred Weber, Inc. got paid per square yard for 2 ¼" depth for the bridge deck overlay and 1 ¼" depth for the approach slabs. Any overlay deeper than this and any patches were paid for at the bid price per cubic yard.

The bid per square yard for these two projects compared to the trial placement costs found in Appendix A was 46% - 79% above of $52.05 Sq.Yd. However, on the cubic yard bid prices the trial placement cost of $375 Cu.Yd. was 162% - 226% higher than these two projects. For comparison of prices to our normal bridge deck overlay concrete, the average unit bid price in 2004 in Missouri for plain Latex Modified Wearing Surface was $78.18 per Sq. Yd., and compared to MoDOT's other alternate wearing surfaces Low Slump Concrete Wearing Surface at $ 60.67 Sq.Yd. and Silica Fume Concrete Wearing Surface at $60.67 Sq.Yd. (Compared to the cost of the two projects observed the LMC-VE was 25% - 53% higher.) No current costs could be found for a regular LMC overlay by the cubic yard. Despite the increased construction costs LMC-VE overlays provide a reliable driving surface and are placed in minimal time causing significantly less user delay.

As more LMC-VE overlays are built MoDOT needs to move away from using a Bridge Special Provision in each contract and incorporate LMC-VE into the Missouri Standard Specifications for Highway Construction as a fourth alternate in Section 505, Bridge Deck Concrete Wearing Surface. This would give contractors another choice to build a better and faster project. The only foreseeable problem doing this may be to find more suppliers with comparable rapid setting cements. Bridge Special Provision from this project, included in Appendix B, specified only one supplier with blended hydraulic cement that had the qualities needed for fast setting and low shrinkage cracking. The current Bridge Special Provision calls for a Type HE high-early-strength cement, in accordance with ASTM C 1157, may be used. Hopefully this will allow more cements with the right qualities to qualify for use in the LMC_VE mix.

As stated earlier from the 1999 trial placements using Type III fast setting cement to get what Virginia called a Latex Modified Concrete High Early strength (LMC-HE) mix, the concrete doesn't set up fast enough to reach strength in 6 hours needed for overnight work, and on top of this showed much more shrinkage cracking.[2] For these reasons the use of Type III cement is not recommended.

Recommendations

From observing these two projects and previous experience with Latex Modified Concrete – Very Early strength bridge deck wearing surface these recommendations are made:

- With the moderate cost differential, 25% - 53%, of the LMC-VE compared to regular LMC wearing surface the use LMC-VE should be accelerated. This will help take care of our many deteriorating and rough riding bridge decks and provide safer, smoother and unrestricted roads. In areas of extreme traffic congestion it will allow:
    1. Uninterrupted traffic flow during peak hours if the site conditions allow by doing nighttime or weekend closures, because the concrete overlay can be driven on in 3-6 hours after its placed.
    2. On projects with complicated staging of construction because of multi lanes of heavy traffic it can accelerate the time between stages because of the fast setting concrete overlay. Additionally, if the decks don't need extensive repair and can use hydroblasting, it can accelerate the time savings even more.

- MoDOT has had debonding problems with several new deck overlays both with the first LMC-VE on one of these projects and also with new silica fume concrete overlays because they were so much thicker than planned (up to 6" thick) and because of no surface texture for the overlay to bond. The following changes to the specifications are needed:
    1. All concrete bridge deck overlays need to be kept to a maximum of 3" thickness.
    2. On all new LMC-VE overlays we need to specify surface hydro blasting after milling to get a more irregular and better bonding surface on the concrete substrate.
    3. As more LMC-VE overlays are built MoDOT needs to move away from using a Bridge Special Provision in each contract and incorporate LMC-VE into the Standard Specifications as a fourth alternate in Section 505, Bridge Deck Concrete Wearing surface.

Footnotes

[1] pg. 8, “Technical Assistance Report, Very-Early-Strength Latex-Modified Concrete Overlay”, Michael M. Sprinkel – Research Manager, Virginia Transportation Research Council, Charlottesville, Virginia, December 1998, TAR 99-TAR3

[2] “Final Report, High Early Strength Latex Modified Concrete Overlay”, Michael M. Sprinkel – Research Manager, Virginia Transportation Research Council, Charlottesville, Virginia, January 1988, VTRC 88-R12

Bibliography

“Final Report, Evaluation of High Performance Concrete Overlays Placed on Route 60 Over Lynnhaven Inlet in Virginia”, Michael M. Sprinkel – Research Manager, Celik Ozylidirim, Ph.D., Principal Research Scientist, Virginia Transportation Research Council, Charlottesville, Virginia, August 2000, VTRC 01-R1

“Final Report, Evaluation of Latex Modified and Silica Fume Concrete Overlays Placed on Six Bridges in Virginia”, Michael M. Sprinkel – Research Manager, Virginia Transportation Research Council, Charlottesville, Virginia, August 2000, VTRC 01-R3

Appendix A

1999 Trial Mix Costs

The bids for the high early strength Latex Modified concrete were:

Frerk	$ 450 / cu yd	+	$995 Mob
Modified	$ 375 / cu yd	+	$1000 Mob

We are anticipating putting down 10 Cu yds.

Modified Concrete Suppliers, L.P. of Indianapolis, IN was awarded the contract.
10.7 yards were placed on 7/19/00 on Br. A-185 Ramp, which had been previously hydroblasted.

Total contract cost was $ 1000.00 mobilization +
10.7 cy x $ 375/cy = 4012.50
$ 5012.50

(Assuming 4 in. thick placement this would translate to 9 SY per cy placed, so
$ 5012.50/(9 x 10.7) = $ 52.05 SY)

Appendix B

Bridge Special Provisions –

LATEX MODIFIED CONCRETE - VERY HIGH EARLY STRENGTH (LMC-VE)

1.0 Description. This work shall consist of a wearing surface of LMC-VE constructed on a prepared surface in accordance with this specification and in accordance with lines, grades, thickness and typical cross sections shown on the plans or as directed by the engineer.

2.0 Material. All material shall be in accordance with Sec 505.10, Division 1000, Materials Details and specifically as follows:

Item	Section
Latex Emulsion Admixture	1054
Polyethylene-Burlap Sheeting	1055
Polyethylene Sheeting	1058
Water	1070

2.1 The use of rapid set Portland cement will be required as provided by:
CTS Cement Manufacturing Company
11065 Knott Ave., Suite A
Cypress, CA 90630
800-929-3030

2.2 Coarse aggregate shall be an approved crushed limestone, crushed quartzite, flint chat from the Joplin area, or porphyry in accordance with Sec 1005, Gradation E, except the percentage of deleterious substances shall not exceed the following values, and the sum of percentages of all deleterious substances shall not exceed one percent.

Item	Percent by Weight (Mass)
Deleterious Rock	1.0
Shale and Pyrite	0.2
Chert in Limestone	0.5
Other Foreign Material	0.1

2.3 Fine aggregate shall be in accordance with Sec 1005 and shall be Class A sand in accordance with Sec 501.

2.4 Pozzoloanic material or Portland pozzolan cements shall not be used.

2.5 Latex admixture shall be kept in suitable enclosures which will protect it from freezing and from exposure to temperatures in excess of 85°F (30°C). Drums of latex admixture to be stored at the work site in direct sunlight shall be covered both top and sides with suitable insulating blanket material in order to maintain an enclosed temperature below 85°F (30°C).

3.0 Concrete Mixture.

3.1 The proportions of cement, fine aggregate, coarse aggregate and latex emulsion admixture will be approved by the engineer and shall meet the following requirements:

Property	**Specific Value**
Air Content percent	0 to 6.5
Slump, inches (mm)	3 to 6 (75 to 150)
Percent Fine Aggregate as percent of total aggregate by weight	50 to 55
Weight Ratio, Cement: Sand: Coarse Aggregate (dry basis)	1.0: 2.5: 2.0
Cement Content, lb/cu yd (kg/m^3)	658 (390)
Latex Emulsion Admixture, gal/cu yd (L/m^3)	24.5 (121.3)
Water, maximum, gal/cu yd (L/m^3)	18.9 (93.6)
Net Water-Cement Ratio, max.	0.40

3.1.1 Mixing water added shall be adjusted to control the slump within the prescribed limits. Net water shall be considered the quantity of mixing water added plus the non-solid portion of the latex emulsion.

3.2 Any change in mix design or proportions shall be approved by the engineer.

3.3 Anti-foam additives as recommended by the latex emulsion manufacturer may be required if the concrete mixture entrains air is above the specified amount.

3.4 Air-entraining admixtures shall not be added.

3.5 A set control in accordance with the cement manufacturer's recommendation may be considered.

4.0 Testing. Testing will be done in accordance with Sec 505.10, except that the slump test will be conducted 4 to 5 minutes after discharge from the mixer. During this waiting period, the concrete shall be deposited on the deck and shall not be disturbed.

5.0 Mixing.

5.1 The concrete shall be volumetrically mixed at the bridge site by a continuous mixer in accordance with Sec 501. In addition to other requirements, the mixer shall provide positive control of the latex emulsion into the mixing chamber, and the latex emulsion shall calibrate to within ±2 percent of that required. The mixer shall be capable of continuously circulating the latex emulsion and have a flow-through screen between the storage tank and the discharge.

5.2 The concrete discharged from the mixer shall be uniform in composition and consistency. Mixing capability shall be such that initial and final finishing operations can proceed at a steady pace. Final finishing shall be completed before the formation of a plastic surface film on the surface.

5.3 The moisture content of aggregates at time of proportioning shall be such that water will not drain or drip from a sample. Coarse and fine aggregate shall be furnished and handled such that variations in the moisture content affecting the uniform consistency of the concrete will be avoided. Any aggregate fractions used which vary more than ±1 percentage point from the mean moisture content established near the start of the day's operations will be subject to rejection. The engineer may permit a change in the mean moisture content and the moisture content of the aggregate shall then vary not more than ±1 percentage point from the newly established mean. These provisions shall in no way alter the slump and mixing water requirements of these specifications.

5.4 Each drum of latex admixture shall be mechanically agitated or hand rolled until thoroughly mixed prior to being introduced into the mixer storage compartment. Latex admixture that is stored overnight in the mixer storage compartment or during delays in mixing of four hours or more shall be agitated by at least two complete cycles in a continuous circulating pump or by mechanical means in the storage compartment. The flow through screen shall be cleaned immediately prior to beginning proportioning and as often as necessary thereafter. Latex admixtures of different brands shall not be combined together in any manner.

6.0 Surface Preparation. Surface preparation shall be in accordance with Sec 505.10 except as noted.

6.1 Prior to scarifying or chipping on concrete adjacent to LMC-VE, 96 hours of curing shall have elapsed. If practical, or unless otherwise shown on the plans, all scarifying by mechanical units shall be completed prior to placing any latex modified concrete. Areas from which unsound concrete and patches have been removed shall be kept free of slurry produced by wet sawing or wet scarifying by planning the work so that this slurry will drain away from the completed areas of preparation.

6.2 On both old and new decks within 24 hours before LMC-VE placement begins, the entire surface shall be thoroughly cleaned by sandblasting followed by an air blast in accordance with Sec 505.10.

7.0 Finishing Equipment. Placing and finishing equipment shall include hand tools for placement and brushing in freshly mixed LMC-VE and for distributing it to approximately the correct level for striking-off with the screed.

7.1 Finish Machine. The finishing machine shall be self-propelled and capable of forward and reverse movement under positive control, with a provision for raising all screeds to clear the screeded surface for traveling in reverse. A Gomaco C450 or equivalent self-propelled finishing machine with one or more rollers, augers and 1500 to 2500 vpm vibratory pans shall be used. A drag float may be necessary. Any modifications shall be subject to approval from the engineer.

7.2 Support Rails. Support rails shall meet Sec 505.10.

8.0 Placing and Finishing Concrete. Placing and finishing shall be in accordance with Sec 505.10 except as noted herein.

8.1 Prior to placement of LMC-VE, the cleaned surface shall be thoroughly wetted for a period of not less than one hour, then covered with polyethylene sheeting until time of placement. The surface shall be damp at the time the overlay is placed. Any standing water in depressions, holes or areas of concrete removal shall be blown out with compressed air. No free water or puddles of standing water will be permitted at time of placement.

8.2 Expansion joints and dams shall be formed in the concrete overlay. Formation of the joint by sawing through the overlay will not be allowed.

8.3 Some of the LMC-VE mixture shall be thoroughly brushed onto the wetted, prepared surface immediately ahead of the overlay. Care shall be exercised to ensure that all vertical as well as horizontal surfaces receive a thorough, even coating of mortar from the concrete. The rate of progress shall be controlled so that the mortar from the brushed concrete does not become dry before it is covered with additional concrete as required for the final grade. Concrete that has been used for brushing shall be disposed of when the mortar is gone.

8.4 Texturing shall occur immediately after finishing and before the plastic film forms on the surface. Texturing shall proceed toward the centerline to prevent pulling the concrete away from the curb face. The wire comb should be held at approximately a 20 degree angle to the surface and carefully pressed into the concrete. Care shall be taken not to texture too deep and not to tear the surface. Frequent cleaning of the comb is necessary.

8.5 Screed rails and headers shall be separated from the newly placed material by passing a pointing trowel along their inside face. Metal expansion dams shall not be separated from the new overlay. Care shall be exercised to ensure that this trowel cut is made for the entire depth and length of rails or headers after the mixture has stiffened sufficiently to prevent the concrete from flowing back into the cut.

8.6 During placement of the overlay, all joints with adjacent concrete shall be sealed with a mortar paste of equal parts cement and fine aggregate, using latex emulsion in lieu of mixing water.

8.7 The overlay concrete shall be moist cured from the time placed until opened to traffic.

8.8 The finished surface shall be promptly covered with a single layer of clean, wet burlap as soon as the surface will support it without deformation. Extreme care shall be taken not to deform the finished surface.

8.9 Within one hour of covering with wet burlap, a layer of white polyethylene sheeting shall be placed on the wet burlap.

8.10 White polyethylene-burlap sheeting thoroughly wetted may be substituted for the white polyethylene sheeting with the approval from the engineer but shall not replace the initial wet burlap.

8.11 No surface sealing shall be applied to the LMC-VE wearing surface.

9.0 Limitations of Operations.

9.1 LMC-VE concrete shall be placed after sundown and prior to sunrise.

9.2 No LMC-VE concrete shall be placed when the ambient or deck surface temperature is above 85°F (30°C). Deck temperature shall be determined in accordance with MoDOT Test Method T20.

9.3 Since LMC-VE concrete may not exhibit bleed water, the probability of plastic shrinkage cracking is increased. At surface evaporation rates above 0.1 pounds per square foot per hour (0.05 kg/m^2/hr) plastic shrinkage cracking is probable and the contractor should take precautions such as erecting windbreaks, lowering the mix temperature or delaying operations until ambient temperatures are lower. Fogging the concrete surface will only be allowed, as provided for in this specification. Surface evaporation rates can be predicted from mix temperature, air temperature, relative humidity and wind velocity using Figure 1 of ACI 308-81 (revised 1986) "Standard Practice for Curing Concrete".

9.4 A fogging system shall be in-place prior to concrete placement. The fogging system shall consist of pressurized equipment that distributes water at minimum rate of 0.10 gallon per hour per square foot (40.7 L/hr/m^2). The fogging system shall apply the fog uniformly over the entire surface of the bridge deck. The fogging system shall produce atomized water that has a droplet with a maximum diameter of 0.003 inches (80 µm) and which keeps the finished deck surface saturated without producing standing water. The contractor shall submit a letter certifying that their fogging system is in accordance with this special provision.

9.5 The fogging system shall be started progressively along the length of the deck, during or immediately after floating.

9.6 No LMC-VE shall be placed at ambient or deck surface temperatures below 45°F (7°C). Concrete placement may begin when the ambient and deck surface temperatures are 45°F (7°C) and rising. The new overlay shall not be exposed to temperatures below 45°F (7°C). LMC-VE placed in cold weather or when the temperature is forecast to be less than 45°F (7°C) shall be protected by the use of a heated weatherproof enclosure, to maintain the minimum specified curing temperature of 45°F (7°C). Any concrete damaged by freezing or which is exposed to a temperature of less than 45°F (7°C) during the first 8 hours after placement shall be removed and replaced at the contractor's expense.

9.7 The temperature of the LMC-VE at time of placement shall be between 45°F (7°C) and 90°F (32°C). If either the aggregate or water is heated, the maximum temperature for each shall be 100°F (38°C) at the time of addition to the mix. Any method of heating during the mixing of concrete may be used provided the heating apparatus will heat the mass uniformly and avoid hot spots which will burn the material. Cement or aggregate containing lumps or crusts of hardened material or frost shall not be used.

9.8 No vehicle traffic shall be permitted on the LMC-VE surface until the LMC-VE is at least 6 hours old or has attained a minimum compressive strength of 3200 psi (22 MPa). At temperatures below 55°F (13°C), a longer curing period may be necessary to attain this strength.

9.9 Concrete shall not be placed adjacent to a parallel surface course less than 48 hours old; however, this restriction does not apply to a continuation of placement in a lane or strip beyond a joint in the same lane or strip.

9.10 Preparation of the area, except scarifying, may be started in a lane or strip adjacent to newly placed surface the day following its placement. If this work is started before the end of the curing period, the work will be restricted so that any interference with the curing process is held to the minimum practical time only.

9.11 In order to avoid locating the longitudinal construction joints in a wheel path, longitudinal joints shall be placed outside the wheel path. The location of the longitudinal joints shall be subject to the approval from the engineer.

9.12 Transverse joints in the overlay will be permitted with approval from the engineer. Transverse joints shall be located a minimum of 10 feet (3 m) from the centerline of bent.

9.13 A header shall be installed in case of delay in the placement operations exceeding one-half hour in duration. During minor delays of one-half hour or less, the end of the placement shall be protected from drying with several layers of wet burlap.

9.14 Adequate precautions shall be taken to protect freshly placed concrete from sudden or unexpected rain. All placing operations shall stop when it starts to rain. The engineer may order removal of any material damaged by rainfall. Damaged material shall be replaced in accordance with this specification at the contractor's expense.

10.0 Removal. Material removal and disposal shall be in accordance with Sec 505.10.

11.0 Repair. Repair shall be in accordance with Sec 505.10.

12.0 Method of Measurement. Measurement will be in accordance with Sec 505.10.

13.0 Basis of Payment. The basis for payment will be in accordance with Sec 505.10.