We create chemistry

Placement of Latex Modified Concrete

Foreword

This manual compiles information from experienced contractors, Department of Transportation personnel, engineers and consultants. It is provided as a convenient reference material for the industry. This information is not intended to replace or supersede specifications or instructions from any official specifying body.

Many of the situations referred to in the manual can be resolved in several ways. We have presented what we feel is the best approach to each situation.

Information herein is furnished in good faith, without warranty, representation, inducement or a license of any kind. BASF does not assume any legal responsibility for use of or reliance upon same. No representation is given as to freedom from patent infringement.

Contents

Tables and Figures

Introduction

Bridge deck deterioration is a major problem wherever de-icing salts are used. De-icing salts are a major contributor to corrosion of the rebar within the bridge deck. The breakdown begins when salts attack the deck surface. Water carries oxygen and chloride ions through the pores in the concrete to the surface of the steel. An oxidation process creates pressure, causing the concrete to crack. The cycle of cold winter freezes followed by mild temperatures opens the concrete even further. Eventually, the bridge deck crumbles.

Section I
Utility of Latex as an Additive in Bridge Decks

A. Conventional Concrete Systems on Bridge Decks

When Portland Cement is mixed with water to form a paste, the components of the cement react and combine with the water over time to form a cementitious crystalline structure which adheres to the intermixed sand and coarse aggregate. When the excess water evaporates from this mass, voids and microscopic cracks develop. Moisture, weather cycling and heavy traffic loads, encourage voids and cracks, allowing de-icing salts to penetrate the structure and corrode the rebars. The voids and cracks become enlarged over time, due to the physical and chemical punishment.

Iron has a natural tendency to oxidize. Normally, in an alkaline concrete environment, a passivating oxide layer forms over the steel reinforcement and prevents corrosion from taking place. However, when salt, such as sodium chloride or calcium chloride penetrates through the concrete structure to the reinforcing steel, the chloride ions break down the oxide layer and the reinforcement is unprotected against corrosion. The electrical potential of steel in concrete varies with the concentration of salt. The steel that is more positive (anodic) corrodes while the steel that is more negative (cathodic) does not corrode.

The top rebar within a bridge deck usually is anodic, while the bottom mat is cathodic. The rust that forms around the anodic bars tends to increase the effective volume of the steel by approximately 2.2 times, increasing the pressure around the reinforcement. Because concrete is weak in tension, it cracks under these pressures and eventually begins spalling away from the steel.

B. Role of Latex in Concrete

Addition of latex to conventional unmodified concrete reduces the amount of water required to achieve the appropriate viscosity for placement of the mix. This lower water requirement results in a cured concrete with higher compressive strength. The latex forms elastic membranes throughout the matrix of concrete, reducing the formation of voids and hairline cracks during the curing stage. The Latex Modified Concrete (LMC) resists penetration of oil, water, salts and aids in the adhesion of new concrete to old. The flexural strength is improved, and there is increased abrasion resistance.

1. Laboratory Evaluation of Latex Modified Concrete

The Federal Highway Administration (FHWA) conducted extensive laboratory testing on Dylex 1186 (now known as Styrofan 1186). The physical and chemical properties of the LMC were compared with those of unmodified concrete. Testing included controlled mix designs, mix procedures and curing procedures.

The FHWA report, RD-78-35, demonstrated that LMC has superior compressive and flexural bonding strengths, freeze-thaw resistance, de-icer scaling resistance and absorbed chloride permeability resistance compared to conventional concrete.

Styrofan 1186 is manufactured to conform to the acceptance criteria for styrene-butadiene latex emulsions listed in Chapter VII, section 11-2, page 110 of the FHWA-RD-78-35 report, April 1978.

2. Laboratory Mix Procedure

All concrete mixes were prepared in the laboratory using a Lancaster pan type mixer. Total mixing time was 3.5 minutes and the ingredients were combined as follows:

(a) the coarse aggregate and latex were combined and mixed for $^1/_2$ minute.

(b) The sand and cement were added and mixed for 1 additional minute.

(c) The water was added and mixed for 2 minutes.

3. Specifications of the Mix Components

Coarse aggregate	Angular dolomitic limestone, 1/2 inch maximum size and graded, specific gravity 2.77
Fine aggregate	Natural sand with a fineness modules of 2.71
Cement	Type 1 Portland Cement – rate of 7 bags/cu. yd.
Latex	Adjusted to 46% solids, rate of 24.5 gal./cu. yd.

4. Formulations Used in the Mixes

	Styrofan 1186	Conventional Concrete
Water/Cement (wt.)	0.36	0.50
Fine/coarse aggregate (wt.)	59/41	59/41
Fine/coarse aggregate (vol.)	60/40	60/40
Latex/cement (wt.)	0.15	–
Slump	5.5 – 6.0	4 – 6
Air content, %	< 7%	5 – 7

Results of the various physical tests are shown in the following tables and figures.

5. Results of Evaluations

Table 1: Resistance to Rapid Freezing and Thawing (Test Procedure in accordance with ASTM C666)

Cure Prior to Testing and Concrete Type	Results after 3D0 Freeze-Thaw Cycles Average %	
	Original Dynamic Modulus	Flexural Strength, psi
1. Conventional Concrete W/C = 0.50 Air Content = 6 % Cured 1 day wet burlap 13 days fog room 14 days limewater	90	619
2. Styrofan 1186 Concrete Modified with W/C = 0.36 Air Content = 7 % Cured 1 day wet burlap 13 days lab air 14 days limewater	87	625

Table 2: Air Void Systems (Test Procedure in accordance with ASTM C457)

Concrete	Air Content		Specific Surface Inches	Void Spacing Factor Inches
	Fresh Concrete	Hardened Concrete		
Conventional Concrete No AEA	2.1	1.65	272	0.0293
Conventional Concrete With AEA	7.0	6.70	513	0.0078
Concrete Modified with Styrofan 1186	7.0	7.16	415	0.0106

1. AEA – air entraining agent

2. General accepted limit of air void spacing factor for conventional concrete is 0.008 inches.

Table 3: Resistance to De-Icer Scaling (Test procedure in accordance with ASTM C672				
Concrete	Scaling Rating at Cycles Indicated			
	25 Cycles	50 Cycles	75 Cycles	90 Cycles
Concrete Modified with Styrofan 1186	0	0	0	0
Conventional Concrete W/C = 0.5, Air = 7 %	1	1	2	2
Conventional Concrete W/C = 0.5, Air = 2 %	5	5	5	5

1. ASTM C672 rating scale of 0 (no scaling) to 5 (severe scaling).
2. Solution – 3 % NaCl.
3. Cure for Concrete Modified with Styrofan 1186
   1 day wet burlap
   13 days laboratory air
   14 days limewater
4. Conventional Concrete Cure
   1 day wet burlap
   13 days moist room
   14 days limewater

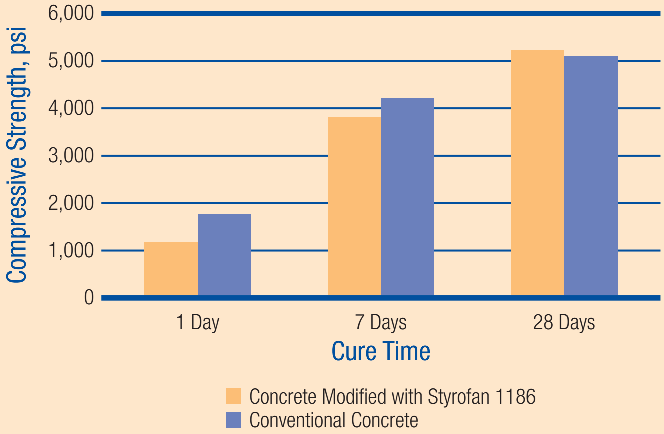
Table 4

An electrical test has been developed by the FHWA for rapid testing of chloride permeability of hardened concrete. The test requires only six hours, rather than the 90 days required by the presently accepted ponding test. It is an electrical resistance test which has shown that increasing permeability is proportional to an increase in measured current flow. Concretes of different water-cement ratios (0.50 and 0.40), as well as the Iowa Low Slump and latex concretes have been tested by the FHWA. The data from this study, highlighted in the following table, correlate well with the AASHTO 90 day ponding test.

Chloride Permeability (Six Hour Test)**	
Concrete	Charge passed (coulombs)
Latex modified	876
Low slump	1170
Conventional, W/C = 0.40	1210
Conventional, W/C = 0.50	2560

**FHWA Report RD-81/119

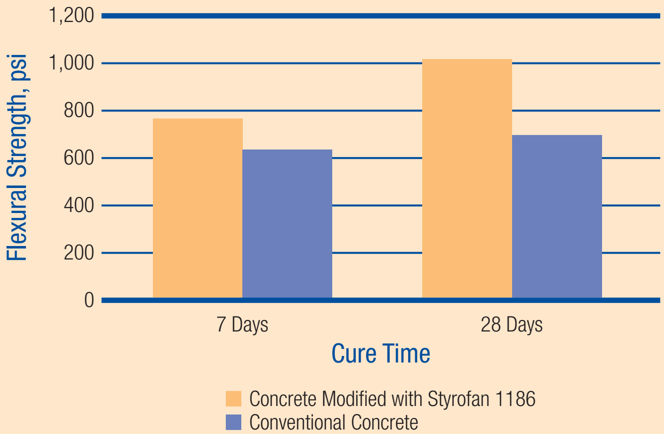
Figure 1: Average Compressive Strengths



Curing Procedures		
	Styrofan 1186 Modified Concrete	Conventional Concrete
1 Day	Mould under wet burlap	Wet burlap
27 Days	Laboratory air	Moist Room

Test Procedure in accordance with ASTM C-39

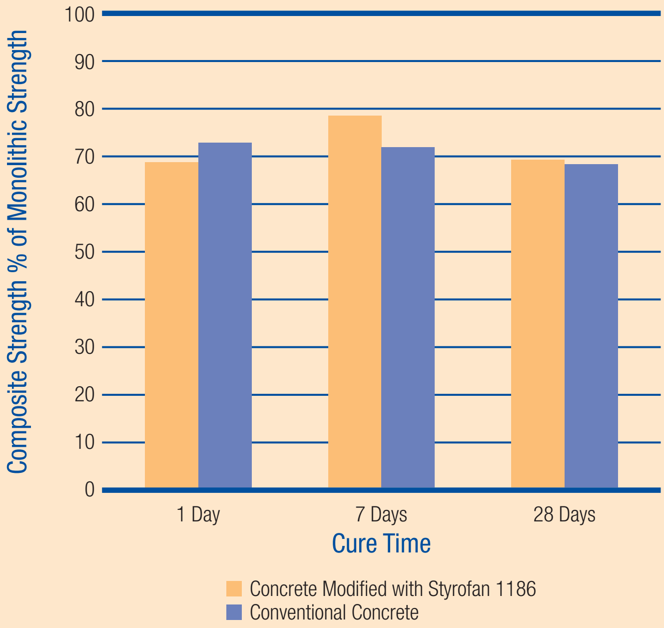
Figure 2: Flexural Strengths



Curing Procedures		
	Styrofan 1186 Modified Concrete	Conventional Concrete
1 Day	Wet burlap	Wet burlap
27 Days	Laboratory air	Moist Room

Test Procedure in accordance with ASTM C-78

Figure 3: Bond to Underlying Concrete

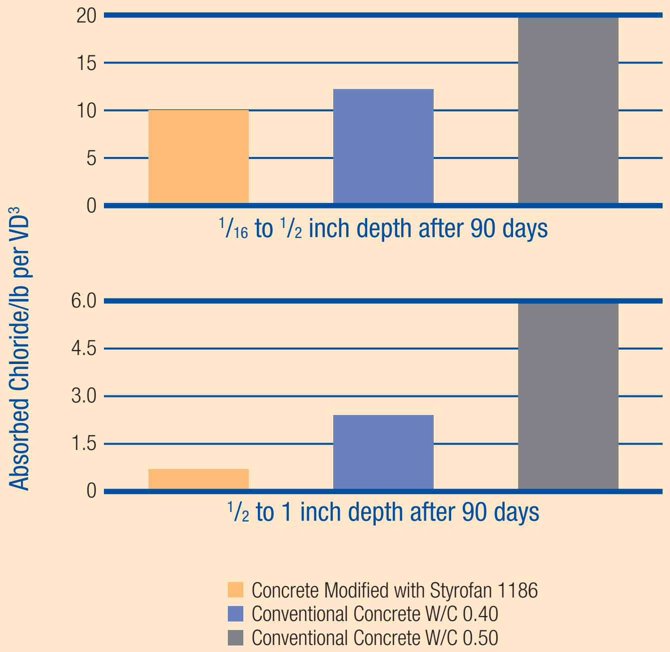


1. Composite psi is the compressive force to fail the composite cylinder
2. Monolithic psi is the compressive force to fail the full cylinders fabricated entirely of the overlay material

Curing Procedures		
	Styrofan 1186 Modified Concrete	Conventional Concrete
1 Day	Wet burlap	Wet burlap
27 Days	Laboratory air	Moist Room

Test Procedure in accordance with Arizona Slant Shear Bond Test

Figure 4: Chloride Permeability



Cure Procedures		
Concrete Modified with Styrofan 1186		
1 Day	–	Wet burlap
20 Days	–	Laboratory air, Sandblast Surface
7 Days	–	Laboratory air, Start Ponding
Conventional Concrete		
1 Day	–	Wet burlap
13 Days	–	Moist room
6 Days	–	Laboratory air
7 Days	–	Laboratory air, Start Ponding

C. Components of Latex Modified Concrete

1. Portland Cement

Several types of Portland Cement are manufactured to meet different physical and chemical requirements.

Type I. (ASTM C150) is a general purpose cement. It is used where special properties of the other types are not required.

Type II. is lower in heat of hydration and is somewhat resistant to sulfate attack from soil and water. Type II. may be used where the temperature rise from heat of hydration is excessive.

Type III. is a high early strength cement.

Only non-air extraining cement is suitable in LMC.

Portland Cement is a moisture sensitive material. If it is kept dry, it will retain its quality indefinitely. Bagged cement should be stored in a warehouse or shed where all cracks and openings are closed. It should be stacked on pallets, close together to reduce air circulation (never against outside walls). Where no shed is available, bags should be placed on a raised wooden platform and water proof coverings should be fitted over the pile and allowed to extend over the edges.

Bulk cement should be stored in weathertight bins or silos made of either concrete or steel. These containers should be subjected to low-pressure aeration with dry air or to vibration to avoid bridging of the contents which, if allowed to occur, will impair flow rate during discharge.

2. Water

It is not necessary to use high quality water when mixing LMC. However, excessive levels of impurities may cause efflorescence, staining or rebar corrosion. The following specification is recommended.

Specification for Mixing Water	
Chemicals	**Maximum Concentration – ppm**
Chloride as Cl	1,000 ppm
Sulfate as SO4	3,000 ppm
Alkalies	600 ppm
pH (minimum)	5

Water should be free from sewage, oil, vegetable matter or clay.

3. Aggregates

Aggregates generally occupy 60 – 80 % of concrete volume and strongly influence its properties and mix proportions. The most commonly used aggregates are natural sand, gravel or crushed stone. These produce normal weight LMC used on bridge overlays.

Aggregates conform certain standards for optimum engineering use:

(a) They must be clean, hard, strong particles free of absorbed chemicals, coatings of clay and other fine materials in amounts that could affect hydration and bond of the cement paste.

(b) Avoid particles that are easily crushed or capable of being split.

(c) Aggregates containing appreciable amounts of shale, soft and porous materials and certain types of chert should be avoided since they have a low resistance to weathering and can cause surface defects such as pop outs.

Grading of the aggregates is determined by the distribution of particles of various sizes, usually expressed in terms of cumulative percentages larger or smaller than each of a series of sieve openings. The following are the recommended gradings of the find and coarse aggregates for an LMC mix:

3.1. Fine Aggregate

Material Natural Sand	
Sieve Size	Percentage Passing (by Weight)
3/3 inch	100
No. 4	95 – 100
No. 8	80 – 100
No. 16	45 – 80
No. 30	25 – 60
No. 50	5 – 30
No. 100	1 – 10

(I) The fineness modulus shall not be less than 2.3 nor more than 3.1.
(II) There shall not be more than 45 % retained between any two consecutive sieve sizes.
(III) Sodium sulfate soundness test – loss – 12 % maximum.
(IV) Harmful aggregate substances shall not exceed:

Substance	% by Weight
Soft particles	3.0
Coal and lignite	1.0
Clay lumps	0.5
Shale or shaly materials	1.0
Alkalies, metals, chert	1.0

3.2 Coarse Aggregate

Material-Crushed Stone or Rock	
Sieve Size	**Percentage Passing (by Weight)**
1/2 inch	100
3/4 inch	85 – 100
No. 4	10 – 30
No. 8	0 – 10
No. 16	0 – 5

(I) Los Angeles Abrasion, maximum loss – 35 %
(II) Absorption, maximum – 2 %
(III) Sodium sulfate soundness test - loss – 12 % maximum
(IV) Flat and elongated particles, maximum – 15 %
(V) Harmful aggregate substances shall not exceed:

Substance	% by Weight
Soft particles	3.0
Coal and lignite	1.0
Clay lumps	0.5
Shale or shaly material	1.0
Alkalies, metals, chert	1.0

The important characteristics and tests of aggregates for LMC are as shown in Table 5. Harmful aggregate materials and their effects are shown in Table 6.

Table 5: Characteristics and Tests of Aggregates			
Characteristic	**Significance**	**Requirement of Test Designation**	**Item reported**
Resistance to abrasion	Index of aggregate quality; wear resistance	ASTM C131 ASTM C295 ASTM C535	Maximum percentage age of weight loss
Resistance to freezing and thawing	Surface scaling, and roughness	ASTM C295 ASTM C666 ASTM C682	Maximum number of cycles; durability factor
Resistance to disintegration by sulfates	Soundness against weathering action	ASTM C88	Weight loss, particles exhibiting distress
Particle shape and surface textured	Workability of fresh concrete	ASTM C295	Maximum percentage of flat and elongate pieces
Grading	Workability of fresh concrete	ASTM C117 ASTM C136	Minimum and maximum percentage passing standard sieves
Bulk unit weight or density	Mix design calculations	ASTM C29	Compact weight and loose weight
Specific gravity	Mix design calculation	ASTM C127 – fine aggregate ASTM C128 – coarse aggregate	———
Absorption and surface moisture	Control of concrete quality	ASTM C70 ASTM C127 ASTM C128 ASTM C566	———
Compressive and Flexural strength	Acceptability of fine aggregate failing other tests	ASTM C39 ASTM C78	———
Definitions of Constituents	Clear understanding and communication	ASTM C125 ASTM C294	———

Table 6: Harmful Aggregate Materials

Substances	Effect on concrete	Test Designation
Organic impurities	Affect setting and hardening, may cause deterioration	ASTM C40 ASTM C87
Materials finer than No. 200 sieve	Affect bond, increases water requirement	ASTM C117
Coal, lignite or other lightweight materials	Affect durability, may cause stains and pop outs	ASTM C123
Soft particles	Affect durability	ASTM C851
Clay lumps and friable particles	Affect durability and workability – may cause pop outs	ASTM C142
Chert of less 2.40 specific gravity	Affect durability – may cause pop outs	ASTM C123 ASTM C295
Alkali-reactive aggregates	Abnormal expansion, map cracking, pop outs	ASTM C227 ASTM C289 ASTM C295 ASTM C342 ASTM C586

Aggregates should be handled and stored to minimize segregation and prevent contamination by harmful substances. Stockpiles should be build up in layers of uniform thickness. The front end loader or reclaimer should remove slices from the edges of the pile from top to bottom so that every slice will contain a portion of each horizontal layer. Washed aggregates should be stockpiled well in advance so that they are drained to a uniform moisture content. Damp fine material has less tendency to segregate.

4. Styrofan 1186

Styrofan 1186 is a styrene-butadiene emulsion suitable for bridge deck overlay concrete. Each shipment is similar in composition to the latex pre-qualified by the FHWA in accordance with Report No. FHWA-RD-78-35.

Typical Properties of Styrofan 1186	
Total solids (wt. %)	47
Bound styrene (%)	66
Residual monomer (%)	0.03 max.
pH (25º C)	10
Brookfield viscosity LVT spindle #2, 20 rpm (mPas)	37
Surface tension (mN/M)	38
Coagulum (100 mesh) %	0.1 max.
Specific gravity	1.02
Weight/Volume (lb./U.S. gal.) (lb./imp. gal.) (kg/l)	8.55 10.2 1.02

D. Typical Mix Design

The LMC must be accurately proportioned. The mix must contain no less than 7 bags of cement and no less than 24 U.S. gallons of latex per cubic yard.

Material	Quantity
Type I, II, or III Portland Cement	658 lbs.
Latex	24.5 U.S. gallons
Fine Aggregate	1,575 – 1,855 lbs.
Coarse Aggregate	1,106 – 1,386 lbs.
Water (including free moisture) on the fine and coarse aggregates	154 lbs. maximum
Latex	3.5 gal/bag

The properties of the LMC shall be as follows:

Property	Value
Slump	9 inches max.
Air Content	7 % max.
Water - Cement ratio (2)	0.3 – 0.4
Compressive strength (Type 1 cement) at: 3 calendar days 7 calendar days	 2,500 psi min. 3,000 psi min.

1. Slump test shall be performed 5 minutes after discharge from the mixer when continuous type mixers are used.

2. All of the non-solids in the latex are included in the total water content.

E. Storage, Handling and Sampling of Styrofan 1186

1. Storage of Styrofan 1186

Storage requirements for Styrofan 1186 vary according to the method of shipment. Since indoor storage at a construction site usually is not feasible, a temporary covering must be provided for the storage container. Use of a white polyethylene film, a minimum of 4 mil thickness, is suggested for protection of the storage container from the elements. In hot weather, at temperatures over 85º F, the storage container should be covered with wet burlap, which will help to maintain the ideal temperature of the latex.

The ideal storage temperature range for Styrofan 1186 is between 50º F to 85º F. However, slightly higher or lower temperatures will not affect the quality of the latex. At higher temperatures, surface skin formation may occur. This phenomenon is usually caused by the evaporation of water at the latex surface. To minimize this effect the latex temperature should not be allowed to exceed 105º F. While Styrofan 1186 has been tested by the FHWA and shown to be freeze-thaw stable, it is recommended that the latex not be subjected to freezing conditions and to circulate the latex prior to use.

2. Handling of Stryofan 1186

Styrofan 1186 is shipped in rail tank cars, tank trucks or drums. For bulk shipments, full loads are necessary to minimize the exposed surface area of the latex and reduce movement of the latex within the tank. Bulk shipments must be recirculated every five days to insure that the latex is homogeneous. It is recommended that the latex be circulated prior to use.

Bulk shipments may be unloaded using pumps, pressure, or gravity, separately, or in combination for maximum efficiency. When using a pump or gravity system, the manhole must be open to safeguard against implosion of the tank. Although Styrofan 1186 is filtered during production and loading, filtration is recommended during unloading using a 40 – 60 mesh fabric filter sock tied to the end of the discharge hose or line. Centrifugal or air driven double membrane type pumps are recommended for unloading or transferring. A small quantity of drinking quality water can be used for priming, but excessive use must be avoided to prevent dilution of the latex. In the selection of a pump, the following should be considered:

(a) An open impeller with wide clearances to avoid coagulation of the latex.

(b) A pump construction that permits easy dismantling and cleaning.

(c) A water connection installed on the suction side of the pump for flushing after use.

3. Sampling

To obtain a representative sample from rail tank cars or tank trucks, samples should be taken from the top, middle, and bottom levels according to the following procedure:

(a) Top level – Use a clean, dry ladle with a one quart capacity and sample latex 4 below the surface. Remove any dry surface skins which may have formed.

(b) Middle level – Use a one quart cup with stopper attached to a handle and sample latex from the middle of the tank car or tank truck.

(c) Bottom level – Drain approximately 3 gallons of latex from the unloading pipe into a clean, dry container. Collect a one quart sample and return the remaining latex to the tank.

(d) The three samples should be mixed together and the tests conducted on the final mix.

Section II
Quality Assurance

Successful application of an LMC overlay on bridge structures depends upon early detection of deterioration sites. Appropriate control procedures must be used throughout the repair project. Items that require strict attention are as noted:

A. Pre-application inspection and testing.

B. Personnel training and equipment.

C. Testing of approved raw materials and mix.

D. Proper surface preparation.

E. Proper placement, finishing and curing procedures.

F. Control testing during placement.

G. Post application inspection and testing.

A. Pre-Application Inspection and Testing
A number of test methods have been developed to determine the condition of a bridge deck and the extent of repair required. However, these tests provide limited guidance. Testing must be continued during preparation of the deck's surface to ensure that the extent of the repair is adequate.

1. Detecting Delaminated Areas

(a) Visual Technique
The first visible sign of reinforcing steel problems is the appearance of rust-staining on the surface. At a later stage, cracks appear on the surface and eventually the concrete begins spalling away from the reinforcing.

(b) Sonic Technique
The two pieces of equipment most often used for detecting delaminated areas on bridge decks are the chain drag and the sounding hammer. A dull sound indicates an area of delamination. The chain drag has the advantage that the operator works in an upright position and a bridge deck can be covered relatively quickly. Frequently a sounding hammer is used to confirm problem areas indicated by the chain drag. In some instances, however, delaminations exist in locations where the hammer method cannot be used.

A portable electronic instrument has been developed to map delaminated areas on a bridge deck. These machines are commercially available.

2. Determining Depth of Reinforcing Steel
The position and depth of the reinforcing steel can be determined by the use of a pachometer. A complete survey of all the reinforcing bars in a bridge deck is both tedious and time consuming. A random survey, indicating the average depth of

cover, can be completed in a relatively short time. Pachometers can only be used on exposed concrete decks.

3. Determination of Chloride in Concrete

The chloride content can be determined by means of standard chemical techniques or by use of a copper/copper sulfate half cell.

(a) Chemical Technique

The concrete sample is usually obtained by coring the deck. The cure is sliced, split and pulverized and then analyzed for chloride content. Since the chloride content of a bridge deck diminishes rapidly as the distance from the surface increases, it is advisable to make more measurements of the chloride content near the surface when determining chloride profiles. If any small number of measurements are to be made, the chloride content of the concrete at the average level of the top reinforcing steel is the concern. Experience has shown that under favorable environmental conditions, notably in the presence of moisture and oxygen, corrosion will occur on the rebar when 1.4 lb. of chloride per cubic yard of concrete is concentrated in this area.

(b) Copper/Copper Sulfate Half Cell Technique

The copper sulfate half cell gives a valid indication of the corrosion activity of the reinforcing steel. It has been found that if the potential of a reinforcing bar is greater than -0.35 volt CSE, there is a 95 % chance that the steel is corroding. The potential associated with spalling is typically -0.50 volt CSE or greater.

B. Personnel Training and Equipment

It is imperative that the personnel should have adequate training in the application procedures for LMC. They must be made aware of all the "pitfalls," and know what actions to take to overcome there difficulties.

In addition, the mechanical equipment must be cleaned regularly and kept in first class condition. Miscellaneous equipment, such as brooms, shovels and vibrators, must be readily available to permit continuous placement of the concrete.

C. Testing of Approved Raw Materials and Mix

A critical factor in assuring a satisfactory project is the quality of the basic materials used for LMC overlay. Testing must be done to assure that the basic specification of the cement, coarse aggregate, fine aggregate, water and latex are met. These material specifications and the precautions to be taken are discussed in more detail in Section I of the manual. In addition, a careful review is required of the products available and their compatibility. This compatibility can be ensured by pre-production laboratory testing, and in the case of large projects, small scale field testing is advisable.

D. Proper Surface Preparation

To restore the structural integrity of the brick deck, all unsound concrete must be removed, including concrete suspected of being chloride contaminated. The proper removal of unsound concrete has the greatest effect on the ultimate quality of the overlay. Detailed procedures on the equipment and methods are elaborated in Section III of this manual.

E. Proper Placement, Finishing and Curing Procedures

Production and application of the overlay must be a continuous operation from the start of the placement to the final cure of the overlay. Finishing equipment must maintain a forward pace to be as close to placement as possible.

Immediately behind the finishing machine, personnel must be prepared to complete the finishing operation along the edges and obstructions, such as drains, and to touch up any areas which may not have received the proper finish. Timing of sequential texturing and application of wet burlap and polyethylene film for curing must be strictly adhered. Detailed procedures are elaborated in Section III of this manual.

F. Control Testing During Placement

Mixing equipment for the overlay material should be calibrated and tested prior to production. Typically, volumetric proportioning mixing machines are used. A complete calibration is also required when a major change in materials is made or the design of the mixture is changed.

After the calibration procedure, pre-production tests shall be made to confirm the laboratory mix design and at the same time provide a reference for production testing. At this time, the following minimum tests shall be made:

Air content (ASTM C231)

Slump (ASTM C143)

Unit Weight (ASTM C138)

Preparation of Compressive strength test cylinders (ASTM C39)

Tests should be performed three to five minutes after mixer discharge to allow for aggregate absorption.

During the production period, yield tests by 1/4 yard box method shall be run on the first load from each mobile mixer and every third load thereafter. Additional tests may be required after making any adjustment. Slump, air and compressive strength tests shall be performed after each acceptable yield test.

G. Post Application and Testing

Immediately after the wet cure, the complete overlay shall be visually inspected for imperfections and, if necessary, corrective action should be taken.

A final inspection prior to the opening of traffic (by means of the sonic technique as described in Section II-A) Should be made to establish that the overlay is completely adhered to the original concrete. If any problems are noted, connective action should be taken immediately.

Section III
Placement of Latex Modified Concrete

A. Equipment

Surface Preparation

1. The scarifying machine shall be self-propelled and shall have a floating head with the capability of locking out the head float. The machine shall be able to remove one quarter (1/4) inch across the cutting pass and shall have the capability of preparing 1,000 square yards per day.

2. Approved sandblasting or hydro demolition equipment capable of removing partially loosened chips of concrete and removing rust and or corrosion products from reinforcing bars.

3. Sawing equipment capable of sawing concrete to the specified depth.

4. Power driven hand tools for removal of unsound concrete are subject to the following restrictions:

    (a) Jack hammers heavier than the nominal 30 pound class shall not be used.

    (b) Triple-headed tampers with star drills shall not be less than two (2) inches in the temper sockets.

    (c) Chipping hammers heavier than the nominal 15 pound class shall not be used to remove concrete from beneath any reinforcing bar.

Proportioning and Mixing

The proportioning and mixing equipment shall be a self-contained, mobile, continuous mixer capable of meeting following requirements:

1. The mixer shall be self-propelled and have the capability to carry sufficient unmixed dry bulk cement, fine aggregate, coarse aggregate, latex emulsion and water in separate compartments, and to produce no less than 6 cubic yards of concrete on site.

2. The mixer shall be capable of measuring cement introduced into the mix. A recording meter, visible at all times and equipped with a ticket printout, shall indicate this quantity.

3. The mixer shall provide control of the flow of water and latex emulsion into the mixer chamber. Water flow shall be indicated by a flow meter and be readily adjustable to provide for minor variations in aggregate moisture. The mixer shall be capable of continuously circulating or mechanically agitating the latex emulsion and shall have a flow through screen between the storage tank and discharge. The screen shall be a type that can be cleaned.

4. The mixer shall have a scalping screen over the fine aggregate bin to screen out mud balls, cemented or conglomerated lumps, or any other oversize materials which could interrupt the flow of fine aggregate during proportioning.

5. The mixer shall be capable of being calibrated to automatically proportion and blend all components on a continuous or intermittent basis as required by the finishing operation, and shall discharge mixed material through a conventional chute directly in front of the finishing machine.

6. The following steps should be followed for a typical calibration of the mobile unit according to the mix design for the proposed LMC overlay:

(a) All calibrations must be conducted at the power requirements for the design of the machine, and proper rpm for the mechanical drive design.

(b) Load the cement hopper with sufficient cement to completely cover the dispensing mechanism. Using a stopwatch, determine the exact time and meter count required to discharge one unit or 94 pounds of cement. Frequent aeration of cement in the hopper contributes to uniformity of density of the cement being discharged. At least 5 such determinations should be made in quick succession and the variations averaged to establish the time cycle and meter count for the particular cement. Tolerance on weight percent should be between 0 and plus 4. Only scales known to be accurate should be used. Aggregate bins must be empty during cement calibration to avoid sand and/or small stone particles being conveyed into the cement. All remaining ingredients are calibrated to the time cycle and meter count established in this step.

(c) To calibrate the delivery of Styrofan 1186, the cement discharge mechanism must be disconnected so that the only latex is discharged into a container for weighting. Since this disconnects the counter meter also, use the time cycle determined by stopwatch (see section b). The latex tank must be vented before pumping and the pump allowed to run for 2 – 3 minutes to eliminate air from the system before calibration. The throttle valve setting for control of latex flow is then determined to dispense 3.5 U.S. gallons of latex in the same time cycle. It is very important that the filter screen in the transfer line between the latex tank and pump be maintained clear at all times, so that an unobstructed flow is maintained through the throttle valve. A pressure gauge may be installed in the line between the pump and throttle valve to monitor this flow at calibration pressure.

(d) Gale settings for sand and coarse aggregate are established in the same manner for the designed proportion of the mix. In the time cycle established in section (b), to discharge 94 pounds of cement, the designed proportions are based on dry weight. Moisture content determinations will need to be made on the aggregates at time of calibration.

(e) The theoretical water setting on the flow meter can be determined by calculating the total water required according to the mix design and then deducting for aggregate moisture and water in the latex emulsion.

(f) After theoretical quantities of all ingredients of the mix have been calibrated to the cement discharge meter count, the yield of the integrated mixing system must be checked to insure that the seven bag mix is indeed producing a cubic yard of LMC. To confirm this, the cement meter is set on zero and activated to discharge mixed material into a one quarter yard container. When the container is level struck full and provision has been made for setting the material into all corners, the cement meter must show discharge of 1.75 bags of cement for LMC (7 bags/cu. yd. mix). During the yield checks, slump and air tests should be made.

7. The mixer shall be capable of spraying water over the entire placement width as it moves ahead to insure that the surface to be overlaid is wet when the LMC is placed.

Placement and Finishing

1. Shovels and brooms shall be used to place and brush-in freshly mixed concrete and to distribute the material the correct level for striking-off.

2. Hand-held vibrators and trowels should be used in areas where the finishing machine is not effective (scuppers, gutters and joints).

3. A self-propelled finishing machine shall be used for finishing all large areas of work. It should have the capability of forward and reverse movement under positive control and comply with the following requirements:

(a) It should be a rotating cylinder type finishing machine, equipped with one or more steel cylinders, augers and vibratory pans and capable of spanning the width of the placement.

(b) It should also be vibrating screed type finishing machine with positive control of vibration frequency between 3,000 and 11,000 rpm. The bottom face of the screeds shall not be less than 4 inches wide, be metal covered and be provided with positive control of vertical movement.

4. Travel racks for the finishing machine shall be capable of providing rigid support – 2 inch schedule 80 steel pipe or equivalent is recommended. Support chairs should be 2 feet on center.

5. A suitable portable lightweight or wheeled work bridge should be used behind the finishing operation.

6. Texturing grooves may be formed by mechanized equipment using a vibrating beam roller or a series of discs. Manual tools such as fluted floats or rakes with spring steel tines may also be used.

7. Burlap – 7 1/2 oz. minimum – new burlap shall be soaked in water for a minimum of 24 hours before the first use.

8. Polyethylene film, 4 mil thickness minimum and preferable white.

B. Surface Preparation

1. Scarifying: The entire surface of the bridge floor shall be scarified a minimum of 1/4 inch. In areas which cannot be machine scarified, hand tools should be used.

2. Hand-chipping: Remove any dust from the scarifying operation and inspect the bridge floor. Mark any loose and unsound floor concrete that will require hand removal. Where the bond between existing concrete and reinforcing steel has been destroyed hand-chip the concrete adjacent to the bar creating a minimum of 1 inch clearance around the bar. This procedure should also be followed if the chipping operation caused 1/2 inch of the periphery of a bar to be exposed for a distance of 12 inches or more.

3. Blasting and Cleaning: After the scarifying and hand-chipping has been completed, the main bridge deck and depth patching areas shall be thoroughly cleaned by sandblasting followed by an air blast to remove all dust and chips. Sandblast reinforcing steel and the concrete under and around the steel.

The sandblast shall be of sufficient duration to remove all dirt, oil, concrete loosened by the scarifier and hand-chipper, and other foreign material, as well as any unsound concrete or laitance from the surface. The compressor shall be equipped with a filter to prevent oil from entering the air supply. Sandblast that portion of the curb and previously placed overlays against which new concrete is to be placed. Remove trowel cut surfaces. In the event of rain after the sandblasting is completed, the deck and patching areas must be kept wet until the overlay is placed. If it is not feasible the sandblasting and cleaning procedure must be repeated.

4. Wetting – Bridge Deck: Prior to placement of LMC, the cleaned surface shall be thoroughly wetted for a period 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. Remove any standing water in depressions or holes prior to the application of the overlay.

C. Placement and Finishing Procedure

1. Expansion joints and dams shall be maintained throughout placement of the overlay. A bulkhead (equal in thickness to the width of the joint) shall be installed to the required grade and profile, prior to placing the overlay.

2. Screed rails for the finishing machine shall be placed and fastened into position to insure finishing the new surface to specifications. Do not treat screed rails with parting compound to facilitate their removal.

3. Placement of the supporting rails of the finishing machine shall provide horizontal and vertical stablity.

4. After the screed rails have been set to the proper profile, the finishing machine shall be given a dry run to assure that the specified nominal thickness of overlay will be attained over the entire deck.

5. Thoroughly wet the surface one hour before placing the overlay.

6. The LMC should be broomed onto the wet prepared surface. All vertical as well as horizontal surfaces should receive a thorough, even coating. It is important that this step be controlled so that brushed material does not dry prior to covering with additional material as required for the final grade. Aggregate remaining after the grout paste has been used up should be removed from the deck and disposed.

7. The LMC shall be mixed at the site in a mobile mixer in accordance with the specified requirements. Mixing capacity should be such that finishing operations can proceed at a steady pace and the final finishing is completed before the plastic surface film finish. Under normal operating conditions the elapsed time between depositing the concrete on the deck and final creeding shall not exceed 10 minutes.

8. The LMC mixture should be placed and struck-off to at least one quarter (1/4) inch above grade, it should be then consolidated and finished to final grade with vibrating devices.

9. Spud vibration shall be used in deep pockets, along edges and adjacent to joint bulkhead. Hand finishing with a float may be required along the edge of the placement or on small areas of repair.

10. Where the surface preparation has left alternate deep and shallow areas that don’t require patching, the deep sections may be partially filled (approximately 3/4 of depth) sufficiently in advance that the material stiffens enough that it will not roll back under the paving screeds. In lieu of filling the deep areas in advance of paving, the entire depth may be placed at one time, if care is taken to insure that the latex concrete is thoroughly worked into these areas and provided the concrete dies not roll back under the paver screed.

11. If it becomes necessary to add concrete to an area behind the finishing machine or if the overlay tears at any time, use the finishing machine to vibrate that area again.

12. To obtain the best grooved texture, use mechanical grooving machines after the dry cure process. The following is applicable when pre-cure texturing is desires:

When a tight, uniform surface has been achieved, it shall be textured immediately after finishing and before the plastic film forms. The transverse grooves shall be formed by specified texturing equipment and shall be terminated a specified distance from the faces of the curbs, concrete barrier walls or other vertical walls. The depth and width of the grooves shall be specified to suit the particular application. Regardless of forming method used, the grooves shall be relatively uniform and smooth, and shall be formed without tearing the surface and without exposing pieces of the coarse aggregate.

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

14. 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 the latex in lieu of mixing water.

D. Curing Procedure

1. Cover the overlay promptly with a single layer of clean, wet burlap. New burlap, even when presoaked, can dry out quickly and should be avoided. Sprinkle occasionally, if necessary, to keep burlap moist. Be sure to pre-saturate the burlap with water, overlapped a minimum of 6 inches, and place as soon as the surface will support it without significant deformation. LMC forms a plastic film at the surface upon drying, usually within 25 minutes in hot dry weather. It is imperative that a pre-saturated burlap cover be applied promptly to prevent dry cracking.

2. Place a second layer of wet burlap on the first layer as soon as possible. The entire covering should be maintained in a wet condition for 24 hours.

3. In lieu of step 3, a layer of white polyethylene film of 4 mils minimum thickness may be placed on the first wet layer of burlap for the required minimum 24 hour period. The burlap must be wet when the polyethylene is placed and remain wet for the entire 24 hour period.

4. The burlap or burlap-polyethylene film combination shall be removed after 24 hours wet cure and the overlay allowed to dry cure for 72 hours. After this period the structure is ready to accept traffic.

5. If during either the wet or dry curing period the ambient temperature falls below 45º F, the number of hours the temperature is below 45º F will not be considered as part of the 96 hour curing period. Also, if during the dry curing period, there is sufficient rainfall to wet the surface of the overlay one our or more, this number of hours will not be considered as part of the 72 hour dry curing period.

6. Ponding or total saturation should not be allowed to occur during the dry curing step.

E. Placement limitations

1. Replace reinforcing steel if damaged or if the section loss from corrosion is greater than 1/4 of the original diameter.

2. Newly placed reinforcing bars shall be lapped sufficiently to develop the original full strength of the reinforcement.

3. Jack hammers or mechanical chipping tools shall not be operated at an angle in excess of 45 degrees measured from the surface of the stab.

4. Preparation of an area, except scarifying, may be started in a lane or strip adjacent to a newly placed surface after the 24 hour wet cure period. Scarification may begin after 72 hours of cure time.

5. Concrete shall not be placed adjacent to a parallel surface course less than 72 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.

6. Longitudinal construction joints shall be placed between designated traffic lanes, if necessary.

7. Transverse joints in the overlay are permitted but shall be located a minimum of 10 feet from the centerline of a bent.

8. The minimum thickness of a latex concrete overlay shall be 1 1/2 inches.

9. The latex concrete mixture shall not be placed at temperatures lower than 40º F. It may be placed at 40º F when rising temperatures are predicted, and then only if the prediction indicates 8 hours over 45º F for the curing period.

10. Placement of the overlay shall be completed under favorable atmospheric conditions. Placement (meeting #9 requirements above) during the late evening, night and early morning hours is permissible.

11. Daytime placement of overlays may be made if the overlay surface evaporation rate is 0.10 pounds per square foot per hour or less. The evaporation rate is affected by ambient air temperature, concrete temperature, deck temperature,

relative humidity and wind velocity. Use Figure 5 to determine the loss of surface moisture from the overlay.

12. A construction dam or bulkhead shall be installed in case of an expected one hour delay in the placement operation. During delays of less than one hour, the end of the placement may be protected from drying with several layers of wet burlap.

13. Do not place material when rain is expected. Take adequate precautions to protect freshly placed concrete from sudden or unexpected rain. The application of wet burlap and polyethylene film is an acceptable precaution.

14. LMC will not cure properly if film forming surface sealers are applied.

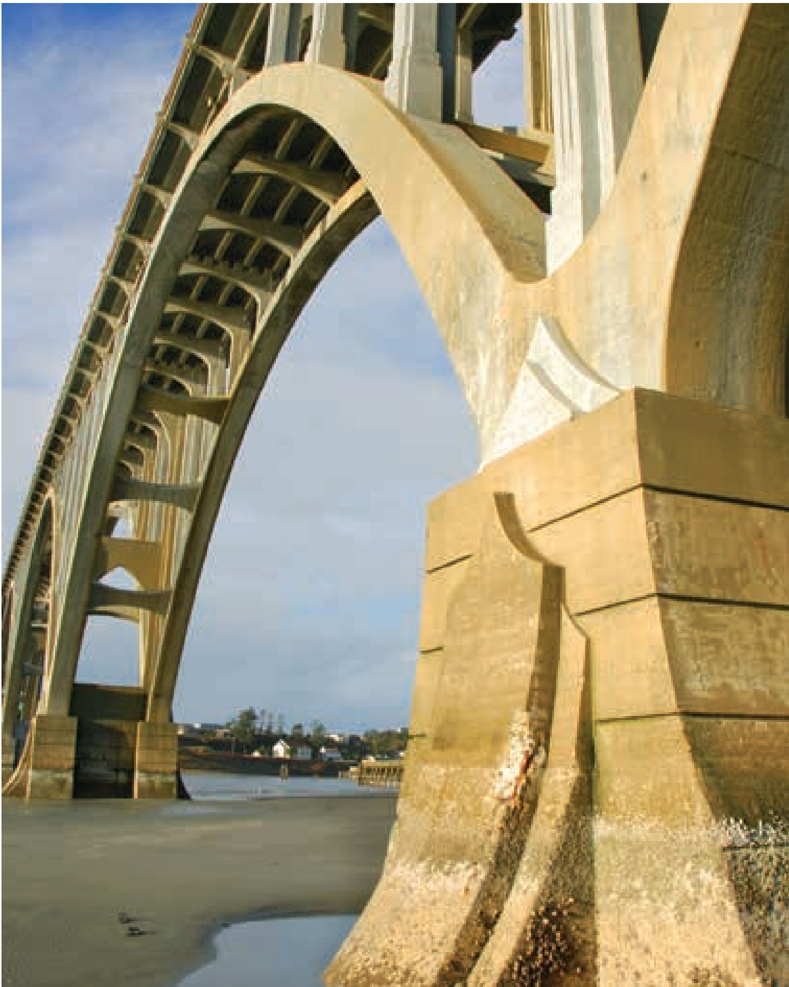
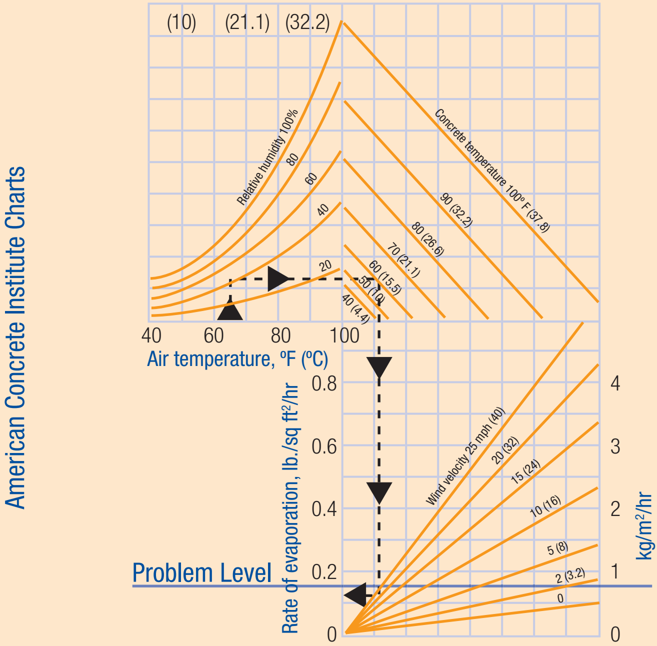


Figure 5: Effect of Concrete and Air Temperatures, Relative Humidity, and Wind Velocity on Rate of Evaporation of Surface Moisture from Concrete



This chart provides a method of estimating the loss of surface moisture for various weather conditions. To use this chart:

1. Enter with air temperature, move up to relative humidity.

2. Move right to concrete temperature.

3. Move down to wind velocity.

4. Move left; read approximate rate of evaporation.

If the rate of evaporation approaches 0.10 lb/ft.^{2}/hr. (0.75 kg/m^2/hr.), precautions against plastic shrinkage cracking are necessary.

Reference: ACI 308

Section IV
Miscellaneous Situations – Questions and Answers

1. What are "Plastic Shrinkage" cracks?
"Plastic Shrinkage" cracks appear as short, irregular cracks.

2. Why do plastic shrinkage cracks form in concrete?
The cracks are formed by rapid drying. When water evaporates from the surface of the concrete faster than it can bleed to the surface of the concrete, plastic shrinkage cracks result. High concrete temperature, low humidity, high winds and high ambient temperature promote the cracks.

3. How can a plastic shrinkage crack problem be anticipated?
This problem can be anticipated prior to the placement of the overlay through study of weather forecasts and the factors (air temperature, relative humidity, concrete temperature and wind velocity). Refer to the ACI chart (figure 5) for determination of evaporation rate.

4. At what evaporation rate is plastic shrinkage cracking likely to occur?
A rate above 0.15 lbs. per square foot per hour.

5. What simple precautions can be used to minimize the possibility of plastic cracking?

(a) Delay the application until the weather conditions are favorable.

(b) Moisten the subgrade to reduce concrete surface temperatures.

(c) Erect temporary windbreaks to reduce wind velocity.

(d) Keep the fresh concrete temperature low by cooling the aggregates, mixing water and latex.

(e) Avoid delays during construction. Reduce time between placement and start of curing.

(f) Protect the concrete immediately after finishing.

(g) Pour at night.

(h) Use the highest slump feasible.

6. How do you repair "plastic shrinkage" cracks?
Narrow hairline cracks should be filled with a modified methyl methacrylate.

7. What causes settlement cracking?
Settlement cracking is caused by continued consolidation after placement, vibration and finishing. It is usually prevented by adequate vibration, lower slump mix and an increase in concrete cover.

8. What causes drying shrinkage?
This problem usually occurs in hardened concrete when the surface layer has a higher water content than the interior. It is usually prevented by using the maximum practical amount of aggregate and lowest usable water content in the mix.

9. How can you lower the chloride permeability of LMC?
The chloride permeability of LMC is lowered by reducing the water cement ratio and thickness of overlay.

10. What is the purpose of wetting the deck prior to overlaying with LMC?

(a) Reduces chances of substrate robbing water from the fresh LMC.

(b) Improves the contact between the overlay and substrate.

(c) Reduces the last setting of the molar paste.

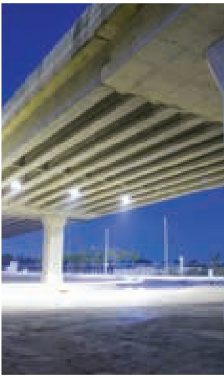
(d) Cools the substrate.

11. Should the longitudinal joints of an LMC overlay be formed when the overlay is poured or should they be saw-cut later?
Longitudinal joints should be performed. Saw cutting has been used but problems may arise from missing the joint and debonding inside the joint line.

12. Does LMC set faster than conventional concrete?
Both have the same setting time, but LMC crusts faster.

13. What is the recommended minimum moisture content of sand?
Approximately 1 – 2%.

14. Why is some moisture required in the fine aggregate?
Moisture is required to prevent the sand from flowing off the belt of the mobile and to prevent segregation of the different grades in the sand pile.



15. What types of Portland Cement can be used with latex?
Type I, Ii and III, non-air entraining.

16. Why is scarification required on a newly placed concrete deck prior to placing on overlay?
To remove laitances so that the aggregate is exposed.

17. Does an LMC overlay stop the penetration of the chloride ion?
No, it dramatically reduces the degree of penetration.

18. Why is the deck re-sandblasted if it has dried after wetting?
To remove a film of fine talc-like material.

19. Is there an alternative method available to sandblasting?
High pressure water at approximately 7,000 psi can be used as long as appropriate safety precautions are taken.

20. How long can an LMC overlay of 1 1/2 inches be expected to last?
Life expectancy will vary depending on conditions such as weather, traffic problems, etc.

Some experts believe that a 15 – 20 year life can be anticipated for property placed overlays produced in accord with recommended specifications.

Section V
Glossary

Aging
Time period after initial mixing of ingredients to gain strength.

Air Content
Total air present in a concrete mix.

Air-Entrained
Additives that generate small air cells evenly distributed throughout concrete that accommodate expansion of infiltrating water when it freezes.

Air-Entrapped
Air entrapped in concrete, resulting from shears generated during mixing, errors in placement and incomplete consolidation.

Bleeding
The movement of water to the top surface of freshly placed concrete brought about by setting of the cement, sand and stone. Excessive bleeding increases the water-cement ratio near the top surface resulting in a weak top layer.

Cement Factor
The number of bags (94 lb.) of cement in a cubic yard of concrete.

Cement Paste
A mixture of Portland Cement and water. The components of the cement react and combine with the water to form a slowly developing crystalline structure which adheres to intermixed sand and stone particles.

Cold Joint
The concrete that sets at the end of the concrete pour prior to placement of the adjoining concrete.

Consolidation
Compacting and vibrating procedures to maximize density of concrete for greater strength and durability.

Curing
The maintenance of an environment (temperature and humidity) in the concrete that will promote the necessary chemical reactions between water and cement components that lead to the desired physical properties.

Elastic Modulus (youngs modulus)
The stress required to produce unit strain and the measure of elasticity or flexibility of concrete. The lower the value, the more flexible the concrete.

Latexes have the unusual ability to increase the flexural strength of concrete and at the same time make them more flexible.

FHWA
Federal Highway Administration.

Fineness Modulus
A number obtained by adding the cumulative percentages (by weight) of aggregates retained on each of the specified series of sieves and dividing the sum by 100.

Laitance
Mixture of cement and fine aggregate (caused by poor consolidation) that bleeds to the surface, resulting in a low strength, talc-like material.

LMC
Latex Modified Concrete.

Plastic Mix
The condition of the mix in which all grains of sand and coarse aggregate are coated and held in place relative to one another – such a mix lends to result in a homogeneous final concrete.

Setting of Cement
A general term relating to the character of the mix with respect to its state of fluidity.

Slump
A test that is useful as an indication of consistency of concrete.

Strength-Bond
Capacity of the overlay to bond the strata of concrete – the resistance to shear action on the bond plane interface.

Strength-Compressive
Ability to withstand compressive loads of stresses without failing.

Strength-Flexural
The strength concrete possesses under bending conditions.

Strength-Tensile
The strength concrete possesses under tensile or stretching forces or stress.

Substrate
The deck surface over which an overlay is placed and bonded.

Workability
The ease of placing and consolidating fresh mixed concrete.

Contact

For additional information please contact:

BASF Corporation
11501 Steele Creek Road
Charlotte, NC 28273
Email: dpsolutions@basf.com
Web: www.basf.us/bridge

For Customer Service, please call:
1-800-251-0612 (U.S.)
1-800-821-8689 (Canada)

For chemical emergencies,
please call Chemtrec:
1-800-424-9300

Important: Although all statements and information in this publication are believed to be accurate and reliable, they are presented gratis and for guidance only, and risks and liability for results obtained by use of the products or application of the suggestions described are assumed by the user. THERE ARE NO WARRANTIES OF ANY KIND. ALL EXPRESS AND IMPLIED WARRANTIES ARE DISCLAIMED. Statements or suggestions concerning possible use of the products are made without representation or warranty that any such use is free of patent infringement and are not recommendations to infringe any patent. The user should not assume that toxicity data and safety measures are indicated or that other measures may not be required.

BF-9636 r01/2018