Application of Styrene-Butadiene Latex Modified Portland Cement Concrete Overlays in Parking Structure Repair and Rehabilitation

by B.D. Irvin

Synopsis: The Styrene-Butadiene latex modified concrete system is an effective technique for repair and rehabilitation of parking garage decks. The system appears to retard corrosion of the reinforcing steel, and has many benefits including ease of placement and workability, superior flexural and bonding strength and deicer scaling resistance. Styrene-Butadiene latex modified concrete can be applied in parking structures during the winter months with few problems.

Keywords: concrete slabs; latex (plastic); parking structures; reinforced concrete; renovating; repairs; resurfacing; styrene-butadiene resins

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INTRODUCTION

Deterioration of parking structures has become a costly concern. The typical method of concrete construction does little to resist the primary cause of deterioration. Consequently, maintenance and repair costs are substantial.

Understanding the reason for this deterioration is the first step in making a decision concerning selection of the repair process.

Parking structure deterioration can be related to some or all of the following causes:

(A) Poor concrete quality assurance during the construction phase.
(B) Lack of proper concrete cover for the reinforcing steel.
(C) Expansion joint leakage
(D) Freeze-thaw cycle
(E) Cracking
(F) Deicing salts

The main cause for deterioration is the use of deicing salts on roadways. Vehicles carry the salts onto the parking structure. Melted ice transfers oxygen and dissolved salts through voids in the concrete to the surface of the reinforcing steel, initiating the corrosion process. The physical presence of corrosion products creates pressure, causing the concrete to crack. The salt laden water can then freely penetrate the reinforcing steel and hasten the destructive corrosion process. Spalling and delamination ensue resulting in total deterioration of the parking structure deck .

In recent years, several repair techniques have been used to attempt to repair parking structure decks. Some of these include the use of superplasticized concrete, silica fume concrete, low water-cement ratio, high air concrete, deck coatings and deck sealers. Each has inherent advantages and disadvantages that are not within the scope of this paper, but one should consider every technique when selecting a repair process.

This paper will address the use of BASF Styrofan 1186, Styrene-Butadiene latex modified concrete overlay as the method of rehabilitation for parking structure decks, specifically the Gateway Center Parking Garage in Pittsburgh, Pennsylvania. Specifications for the repair area and the production, placement, finishing and curing of the latex modified concrete will be presented.

BACKGROUND

Latex modified concrete has been used primarily in the rehabilitation of bridge decks. Over 10,000 bridges have been rehabilitated using a Styrene-Butadiene latex modified concrete overlay. It has proved to be a long lasting and cost effective repair method for this application.

Parking structure and bridge decks are both subject to high concentration of deicing salts. It is expected that the excellent performance record established for latex modified concrete in bridge decks will be duplicated in parking structure repairs.

COST FACTORS

The final decision of a repair technique is usually based solely on economic considerations. In the rehabilitation of a parking structure, the tendency in the past has been to consider only the initial cost of the repair. In such instances, latex modified concrete overlays are precluded.

Styrene-Butadiene latex modified concrete overlays cost somewhat more initially than other repair systems. However, when consideration is given to the extended life of the system and the low maintenance cost, overall costs are lower than those for alternative systems. (bridge deck repair data projects a twenty year life).

A life cycle cost analysis has been prepared by Wiss, Janney, Elstner & Associates to demonstrate this point.

PROPERTIES OF STYRENE-BUTADIENE LATEX

Styrene-Butadiene latex is a dispersion of organic polymer particles in water. It looks very much like milk, and is often referred to as "milk" on the job site. A quantitative indication of the magnitude of these particles is given in figure 1.

Typical properties for latex used in latex modified concrete are listed in figure 2.

PROPERTIES OF LATEX MODIFIED CONCRETE IN THE PLASTIC STATE

In the plastic state, latex modified concrete has a high slump (4 to 7 inches) at a very low water/cement ratio i.e. .30 to .40. This combination of properties is attributable to the effect of the several different components of the latex on the rheology of the concrete mix. The latex modified concrete system provides a concrete that can be easily placed and worked. This system has the added benefit of a long slump life.

PROPERTIES OF LATEX MODIFIED CONCRETE IN THE CURED STATE

Latex modified concrete exhibits many desirable properties in the cured state. Among them are resistance to chloride permeability, resistance to deice scaling and increased bond and flexural strength.

CORROSION REDUCTION WITH LATEX MODIFIED CONCRETE

The role of Styrene-Butadiene latex in improving the resistance of reinforced concrete to chloride ion attack is not completely understood, but it is believed that the low water-cement ratio permitted by the use of latex results in a higher density concrete. Fewer voids are formed during curing and those that do form are smaller than those produced in conventional water-cement ratio concretes.

In addition, the latex is thought to form an elastic film through the matrix of the concrete that helps to reduce formation of hairline cracks during the curing process.

The end result is a concrete that is much more impervious to penetration by chloride laden water to the reinforcing steel, compared with unmodified concrete.

RESISTANCE TO DEICE SCALING

There is dramatically increased resistance to deice scaling of a horizontal concrete surface exposed to freeze-thaw cycles in the presence of deicing chemicals.

ADHESION OF CONCRETES AND SHEAR BOND STRENGTH

Styrene-Butadiene latex modified concrete increases bond strength (adhesion of the overlay to base concrete). A good bond between the repair material used in the overlay and the base concrete allows the deck to function as one in flexure.

FLEXURAL STRENGTHS

The importance of this flexibility is to avoid stresses between the overlay and base concrete.

BRIEF DESCRIPTION OF THE GATEWAY CENTER PARKING FACILITY

The Gateway Center Parking facility is an enclosed three level underground structure with parking spaces for 750 vehicles. It is open on two sides with ramps to street level with each ramp providing ingress and egress. The structure had been in service 25 years prior to the time when repairs and rehabilitation were undertaken.

The owners of the Gateway Center parking garage chose to use Styrene-Butadiene latex modified concrete because of the ease of placement and workability, superior flexural and bonding strength, deicer scaling resistance, absorbed chloride permeability resistance and long-term savings.

TECHNICAL SPECIFICATION FOR THE REPAIR

The work involved the in-place repair of all existing slabs, walls, columns, ramps and beams and the installation of expansion joints and trench drains. This paper will be concerned only with the deck slab repair.

Workers tested the slabs using the "chain drag" method. A map was made targeting suspect areas. A mechanical scarifier removed a minimum of one quarter inch of concrete from the deck surfaces. The decks were sounded again with hammer and chain drag. In hollow sounding areas, a 30 lb. jackhammer was used to remove the deteriorated concrete. All areas were then resounded and additional concrete was removed where necessary. The slab was removed to full depth in areas where concrete had deteriorated to two-thirds of the original slab depth.

FULL DEPTH CONCRETE REPAIR

Workers sandblasted the reinforcing steel after all unsound concrete was removed. Reinforcing steel was replaced in areas where more than 10% of the section had been lost. The actual usage replacement of reinforcing steel exceeded the original estimate by about five times.

Bottom steel was replaced using thirty-six diameters of lap. Top steel used forty-eight diameters of lap, extending beyond the last point of the lost section. The decks were shored using post shores.

A low water-cement ratio, patching concrete was used for full depth repair to the top of the scarified surface of the existing slab.

Specification for the low water-cement ratio concrete was as follows:

1 Cubic Yard	
Cement Factor	= 658 lbs.
Water Cement Ratio	= 0.38 to 0.42
Air Content	= 4% to 8%
Slump	= 1 1/2" to 2 1/2"
Compressive Strength at 28 days	= 4,000 psi

The low water-cement ratio concrete received a light rake finish after placement. The patch was wet cured for seven days, then air dried for seven days. Forms were stripped when the concrete reached 85% of the specified 28 day compressive strength.

STYRENE-BUTADIENE LATEX MODIFIED CONCRETE BONDED TOPPING

The approved mix design for the Styrene-Butadiene Latex Modified Concrete is illustrated in figure 8.

All surfaces were sandblasted and any remaining contaminated areas were re-scarified before placing the latex modified concrete topping.

The prepared surface was sprayed with water until thoroughly wet. Workers used compressed air to remove all standing water immediately prior to placement.

A Styrene-Butadiene latex modified grout was broomed onto all horizontal and vertical surfaces. The grout was prepared by brooming out the coarse aggregate from the latex modified concrete used in the placement.

PRODUCTION AND TRANSPORTATION OF THE LATEX MODIFIED CONCRETE

The latex modified concrete was produced by a concrete mobile unit. The concrete was calibrated prior to each pour. Workers tested the yield, temperature, slump and percentage of air at the onset of each production batch, approximately every 13 cubic yards.

The work was done in winter months and concrete was produced only when a minimum temperature specification of 40°F could be met. Data showing the strength development at 40°F and 72°F is shown in figure 9.

"Georgia buggies" were used to transport the latex modified concrete to the placement site.

PLACING, FINISHING AND CURING

Prior to each placement, wind barricades were erected. No external heat source was used. The ambient temperature in the parking structure was approximately 45°F and slab temperature was maintained at approximately 45 F under these conditions.

The Styrene-Butadiene latex modified concrete overlay was placed and struck off slightly above grade, then consolidated with hand-held vibrators. It was then bull-floated and a rough broom finish was applied.

Wet burlap was used to cure the overlay for the first 24 hours. The burlap was covered with polyethylene sheets to prevent evaporation of water . After this period, the wet burlap was removed and the overlay was permitted to air cure for an additional 72 hours. After placement, work was restricted within one bay in any direction for 48 hours.

No major problems were encountered in the placement or curing phase of the rehabilitation. The original estimate for the latex modified concrete topping was 2,000 cubic yards. Actual usage was over 3,000 cubic yards.

CONCLUSIONS AND RECOMMENDATIONS

A. The scope of the Gateway Center rehabilitation project was seriously underestimated. This appears to be a common problem which points to the fact that many parking structures are in far worse condition than anticipated at the outset of the repair projects.

It would be deplorable if the structural failure of a parking garage is necessary to call needed attention to this fact.

B. The Styrene-Butadiene latex modified concrete system is cost effective for the repair and rehabilitation of parking structures, as well as bridge decks and marine structures.

C. Styrene-Butadiene latex modified concrete provides a means of protecting reinforcing steel from corrosion brought on by chloride ion penetration.

D. Styrene-Butadiene latex modified concrete can be produced and placed in parking structures during the winter months with few problems.

E. As a recommendation, the old adage, " an ounce of prevention is worth a pound of cure," should be given special consideration when constructing new parking facilities. A coordinated approach involving an overlay of Styrene-Butadiene latex modified concrete in the original construction phase should be thoroughly investigated.

Works Cited

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Life Cycle Cost Analysis
Wiss, Janney, Elstner & Associates

Comparative Life Cycle Cost Analysis for Different Surface Protection Methods

The following economic analysis was originally prepared in 1984 by R.G. Tracy of Tracy Material Consultants, Kalamazoo, Michigan. The prices have been updated to 1988 values by Wiss, Janney, Elstner & Associates, Inc., Northbrook, Illinois.

Problem Assumptions:

- 100,000 square foot, 10-year old, two-way flat plate structure
- Slab repairs are required on 20% of the surface
- Latex modified concrete (LMC) is to be used for patching in all cases as follows:

Type 1 repairs (shallow) to 10,000 sq ft @ $8.50/sq ft	$85,000
Type 2 repairs (deep) to 8,000 sq ft @ $12.00/ sq ft	$96,000
Type 3 repairs (full depth) to 2,000 sq ft @ $20.00/ sq ft	$40,000
Total Slab Repair Costs	$221,000

LMC OVERLAYS 20-year expected life		DECK COATINGS 8-year expected life		SURFACE SEALERS 4-year expected life	
Slab repairs to 20,000 sq ft	$221,000	Slab repairs to 20,000 sq ft	$221,000	Slab repairs to 20,000 sq ft	$221,000
Plus overlay cost 100,000 sq ft @ $4.00/ sq ft	$400,000	Plus coating cost 100,000 sq ft @ $3.00/ sq ft	$300,000	Plus sealer cost 100,000 sq ft @ $.75/ sq ft	$75,000
TOTAL INITIAL COST	$621,000	TOTAL INITIAL COST	$521,000	TOTAL INITIAL COST	$296,000
		Plus replacement of coating after 8 and 16 years, assume 4% annual inflation	$972,480	Plus repeat sealer application after 4, 8, 12 and 16 years, assume 4% annual inflation	$450,938
Plus maintenance costs, assume 1/2% (500 sq ft) additional repair annually @ $10.50/ sq ft first year, ($5,000) 4% inflation for future years, 20 years total	$162,588	Plus maintenance costs, assume 1% additional concrete and coating re-pair(1,000 sq ft) @ $13.00/ sq ft first year, ($12,500) 4% inflation for future years, 20 years total	$360,459	Plus maintenance costs, assume 2% additional concrete patching (2,000 sq ft) @ $10.50/ sq ft first year, ($21,000) 4% inflation for future years, 20 years total	$524,091
TOTAL INVEST-MENT FOR 20 YEARS SERVICE	$783,588	TOTAL INVEST-MENT FOR 20 YEARS SERVICE	$1,853,939	TOTAL INVEST-MENT FOR 20 YEARS SERVICE	$1,270,091
Net present value of investment assuming 10% discount rate	$682,381	Net present value of investment assuming 10% discount rate	$973,003	Net present value of investment assuming 10% discount rate	$668,671

1. COMMON PIN → | 1 MM | ←

AREA = 7.8×10^{13} Å^2 (Å = ANGSTROM)

AREA OF 2000 Å DIAMETER LATEX PARTICLE = 3.1×10^6 Å^2

NUMBER OF LATEX PARTICLES REQUIRED TO COVER THE PIN HEAD = 25,000,000

2. ONE POUND LATEX OF 2000 Å DIAMETER PARTICLES SURFACE AREA = 18,000 YARD

3.

ITEM	PARTICLE DIAMETER A
LATEX	2,000
CEMENT	20,000 +
SAND	50,000 +
AGGREGATE	50,000,000 +

Fig. 1--Latex particle size

POLYMER TYPE:	STYRENE-BUTADIENE COPOLYMER
TOTAL SOLIDS, % BY WT.	47.0
pH	10.5
VISCOSITY, cps	85
SURFACE TENSION, Dynes/cm	40
PARTICLE SIZE (ANGSTROMS)	2000
FREEZE THAW STABILITY	PASS 2-CYCLE
WEIGHT (Lb./GALLON)	8.4

Fig. 2--Typical latex properties

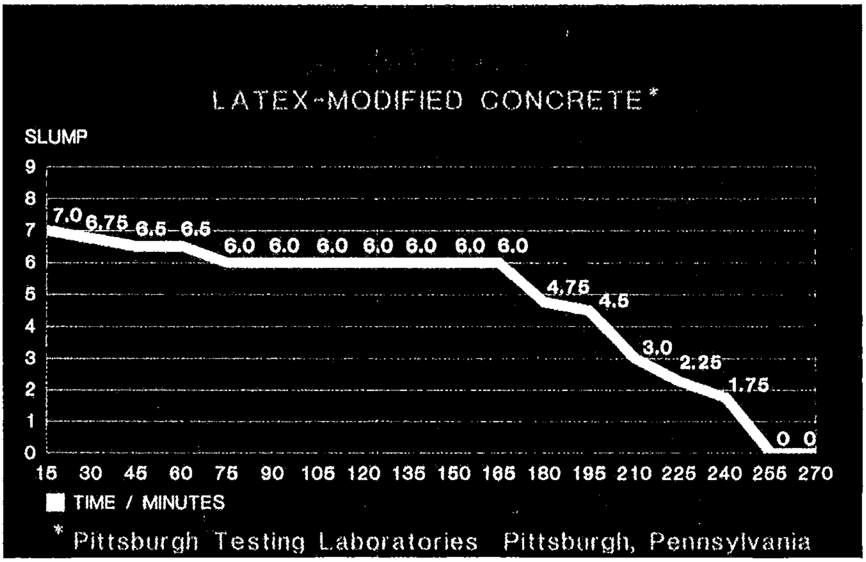

Fig. 3--Slump loss

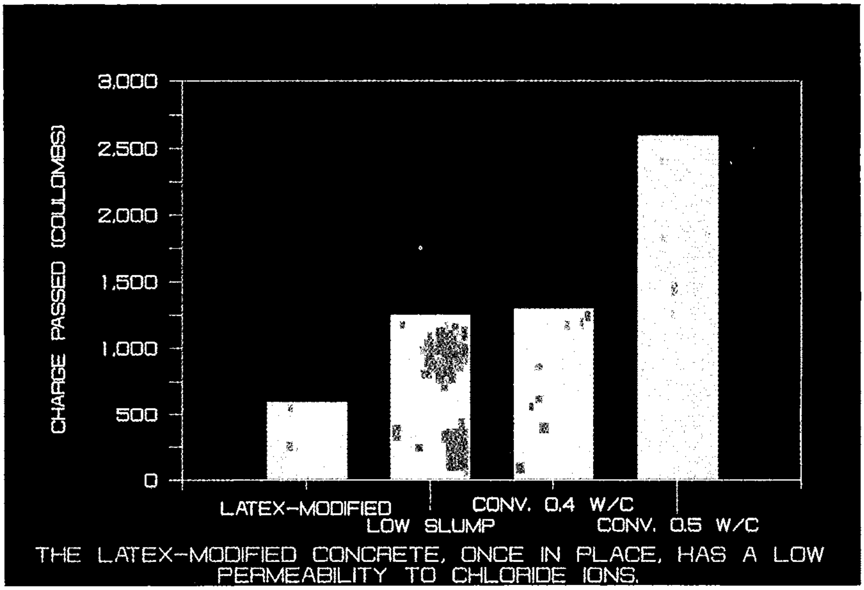

Fig. 4--Chloride permeability

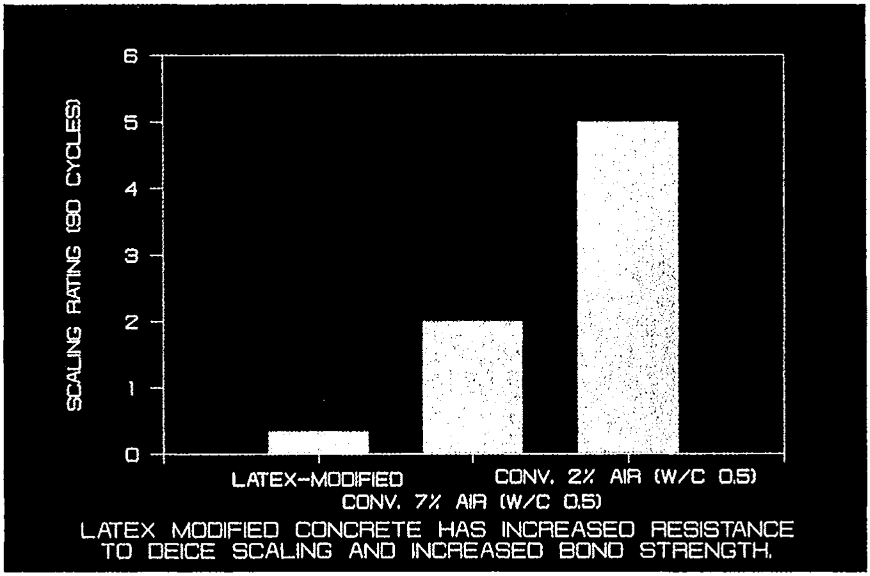

Fig. 5--Resistance to deice scaling

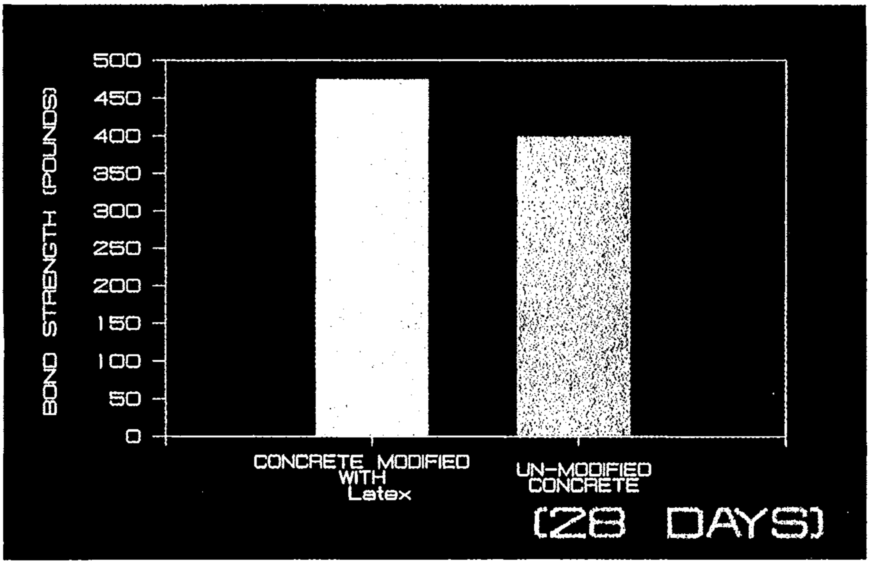

Fig. 6--Adhesion of concretes