# A STRUCTURAL RESTORATION SYSTEM FOR CONCRETE SURFACES

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## Abridgment

We like to think of something cast in concrete as being indestructible, a thing that will last into some distant future. Yet, we know that for various reasons concrete surfaces do deteriorate, and some of them do it pretty quickly. Then, either for aesthetic or serviceability reasons, it becomes necessary to repair them, not necessarily in the cheapest manner but with the most expedient and permanent method available. Because of coefficient of thermal expansion compatibility, it is also generally desirable to repair a portland cement concrete surface with portland cement material. Lasting application of thin sections of portland cement materials to old concrete surfaces has long been sought in the construction industry.

In the chemical industry, we are well aware of the un-permanent nature of concrete surfaces in the presence of some chemicals. Floors, foundations for heavy machinery, and drains in production areas are very vulnerable and require constant attention. Some years back our research people began looking at ways to make these repairs more quickly and more permanent, still using portland cement for its strength properties. It was discovered that, when certain polymers or plastics could be made stable in the alkaline environment of a portland cement composition, their presence in the mix made some significant contributions. Nearly all of the properties of the cured compositions were greatly improved, flexural and tensile strengths in particular. However, abrasion resistance, impermeability, and durability were also greatly enhanced. Perhaps most important, the mixes containing the polymers showed great tenacity of bond when laminated to clean, sound concrete.

These polymeric emulsions, called latexes, are nontoxic and when properly stabilized are readily dispersed in a portland cement mix. A film-forming latex is a water dispersion of plastic particles. When the water evaporates, the plastic particles coalesce to form a clear, plastic film. Portland cement mortar or concrete containing such polymeric emulsions are referred to as latex-modified compositions and are simply mixtures of portland cement, aggregate, latex, and water.

Results of our research program and subsequent field test installations convinced us that we could successfully apply highly durable modified compositions in sections as thin as ½ in. In 1957, a field testing program was initiated that eventually involved some 200,000 sq ft of bridge decks throughout the United States. The early installations were experimental and involved some failures as well as successes. Typical of these was the first done in cooperation with the Michigan Department of State Highways (1). The deck of the structure was badly scaled and spalled. In the fall of 1957 it was overlaid with a minimum ½-in. section of latex-modified mortar. In order to establish the

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optimum surface condition to achieve maximum bond, 4 treatments were evaluated: surface wet, surface dry, surface primed with latex, and surface primed with latex-cement slurry.

Inspection of the deck in the spring of 1958 revealed extensive bond failure in all areas except those where the modified mortar was placed on wet substrate. These were in excellent condition and are so today even though sustaining heavy applications of deicing salts for the past 12 years. In the fall of 1958 the overlay in the failed areas was removed and replaced according to the techniques that proved successful in 1957. There are similar long-term (10 years) installations showing good performance records in Maine, Vermont, Kentucky, and Massachusetts.

Evaluation of results of the field testing program provided the following information to establish a sound technology for the operation:

1. The substrate must be clean and sound. This requires that at least ¼ in. be removed from the surface to be overlaid. Mechanical scarification has been found to be the fastest and most thorough means. In addition, any unsound concrete below that depth must be removed.
2. The substrate must be wet without standing water at time of placement.
3. The modified material must be vigorously brushed into the surface to ensure maximum contact.
4. The utmost in quality control must be exercised in proportioning and mixing modified materials.
5. Only non-air-entraining cements may be used.
6. Because of the film-forming nature of latex, the rate of production of mixed material must be geared to the limitations of placement and finishing.
7. Finishing consists mainly of a floating operation and must be accomplished prior to surface film formation.
8. Wet cure, by prewetted burlap, must be applied promptly upon formation of the plastic film on the finished surface to avoid drying cracking.
9. The curing schedule when using Type III cement is 24 hours wet and 2 days dry under favorable curing conditions. One extra day dry cure is required for Type I cement. During cool weather, the curing schedule is appropriately longer.

Nearly all of the various types of mixing equipment were tried during our early work with modified materials. Transit mixers and 1- or 2-bag stationary mixers were most commonly used. Although it is possible to produce satisfactory material with these machines, the operation requires considerable technical supervision because of the sensitivity of modified compositions to air entrapment. Because the plastic tends to fluidize the mixture, water-to-cement ratio is also a critical factor not easily controlled in these mixers. It will be appreciated that the application of thin sections does not require high volume production of mixed materials. However, a steady flow having uniform consistency is required to facilitate the finishing operation within the time limitations set by climatic conditions during placement.

In 1966 after evaluating the 6- to 8-year performance of field installations, we concluded that we had a superior concrete surface restoration material. At the same time we recognized that it was highly technical in nature and required a considerable degree of quality control in the substrate preparation as well as in production and placement. It was also during this period that the magnitude of the problem of structural slab deterioration began to be widely recognized.

In an effort to meet the challenge presented by these conclusions, we set out during the 1968 and 1969 construction seasons to refine and mechanize the operation of installing our structural restoration system. The system consists of 3 steps.

1. To prepare the substrate, a Tennant G-12 concrete scarifier removes the required ¼-in. from the surface at the rate of 150 to 200 sq yd/hour. This type of scarification will generally remove surface concrete weakened by subsurface fractures that may not otherwise be detected but that provides poor anchorage for overlays. A vacuum type of street cleaner picks up the debris during the cutting operation. Sawing, pneumatic hammer chipping in deeper areas, sandblasting if necessary, clean-up and pressure water flushing complete the preparation; and screed rails are set in place.

2. This is the keystone to quality control in the production of latex-modified portland cement materials. A truck-mounted, automatic, continuous concrete mixer is positioned to discharge directly in front of the screeding device. We use 8-cu yd mobile machines that, when properly calibrated, automatically proportion and mix the cement, aggregate, latex, and water either continuously or intermittently as required. Mixing water is controlled by a flowmeter and can be quickly adjusted for variable moisture in the sand. A metering device with ticket printout measures and records the production of the machine.

3. As with any portland cement composition, the strength of latex-modified materials is influenced by the water-cement ratio. In order to place and consolidate low-slump, modified mortar to concrete in thin sections, a self-propelled, vibrating-beam, strike-off machine follows closely behind the mixer. We ordinarily place latex-modified compositions at a water-cement ratio on the order of 0.35. When the struck-off surface has been floated as needed for smoothness and texturized for traction, it is generally ready for the curing cover. One layer of wet burlap with a layer of polyethylene over it has been found to provide adequate curing conditions during warm weather.

It will be recognized that the operation is a specialty, in view of the highly technical nature of the material as well as the degree of quality control necessary for its successful application. We have organized several of these specialty application groups and during 1969 performed deck restoration work on 29 bridges in 8 states. It is not our plan to go into the bridge construction business. We do expect to offer a sound restoration system that will include not only the material but the technology and organization to make the best use of it.

## REFERENCE

1. Cardone, S. M., Brown, M. G., and Hill, A. A. Latex-Modified Mortar in the Restoration of Bridge Structures. HRB Bull. 260, 1960, pp. 1-13.