**MATES**

**MICHIGAN DEPARTMENT OF TRANSPORTATION**

Issue No. 46 August 1990

## BRIDGE DECKS PART II

Last month, Part I of this article stated that the evaluation and analysis of existing bridge deck conditions are far from being exact sciences, with rehabilitation recommendations based on general guidelines, engineering judgement, and years of experience. This article will summarize our experiences with various overlay alternatives, discuss recent trends in evaluation and rehabilitation techniques, and present the outlook for future bridge deck rehabilitation.

### Latex-Modified Concrete Overlay

When a concrete mix is modified by adding styrene butadiene latex, it is referred to as a latex-modified concrete (LMC). This type of overlay has been the Department's preferred choice for all bridge decks for the past 20 years. This overlay has been found to be the best choice considering its superior bonding characteristics, its impermeability to deicing salts and water, and its ability to be placed in relatively thin layers without excessive shrinkage cracking, when placed and cured properly.

Current MDOT standards specify a 1-1/2-in. minimum LMC overlay thickness on deck surfacing projects. Based upon our observations to date, we expect LMC overlays to give an average 15-year service life, which may include some patching of the overlay itself. At one time, LMC overlays were specified for new deck construction on heavily traveled routes, but this is no longer true. The current Departmental philosophy is that the use of epoxy coating on all bridge deck reinforcing steel, plus specifying a 3-in. minimum concrete cover over the top transverse reinforcement provide comparable protection against corrosion and chloride intrusion into the deck to the level of the reinforcing steel.

### Low-Slump High-Density Concrete Overlay

The use of a low-slump high-density (LSHD) concrete is based on the premise that the ability of water to penetrate the concrete is related to the water content of the original mix. That is, a mix with a very low initial water content will have a low slump (be very dry and not easily placed) and when properly consolidated, will have a high density and will be more impervious to water and chloride ion penetration than a conventional mix. This concept has been applied quite extensively throughout the country. It requires special equipment and procedures for placing, consolidating, and curing the overlay.

In 1975 the Department placed three experimental LSHD concrete overlays for the purpose of comparing their performances with those of LMC overlays. The initial conclusions of this experiment were that LSHD concrete overlays were more difficult to construct than LMC overlays due to the low slump which presented difficulties in placing, compacting, and finishing. Susceptibility to weather conditions, extensive hand manipulation and finishing, and wet curing time, were cited as major disadvantages. Since the laboratory tests did show good bond strength and low shrinkage characteristics, and the overlay was successful in other states, it was anticipated that the construction disadvantages would be overcome as the contractors gained experience. Hence, the LSHD overlay was approved as an alternate to the LMC overlay.

In 1977-78 fourteen LSHD overlays of existing bridges were placed, and eight new decks were constructed using LSHD concrete overlays. Placement and finishing problems persisted, however, so the LSHD overlay has not been permitted for use in Michigan since 1978. Other states have had more success, and continue to use LSHD concrete overlays.

### Microsilica-Modified Concrete Overlay

In its continuing search for a less expensive overlay concrete, the Research Laboratory began field evaluation and laboratory testing of microsilica-modified concrete in 1986. A microsilica-modified concrete (MSMC), as the name implies, is a concrete mix that is modified by the addition of an admixture of microscopic silica particles (also called condensed silica fume). Microsilica is a by-product of the silicon carbide abrasive industry and the metallic silicon industry, and its particle size is about like that of tobacco smoke, or roughly 1/100 of the size of portland cement particles. The major economic advantage of MSMC is that, unlike LMC which requires the use of high-cost mobile mixers, MSMC can be batch-mixed at any concrete plant with facilities for handling the microsilica admixture. This advantage allows the purchase of economical bulk quantities of microsilica, and allows the MSMC to be produced anywhere in the State at the closest approved concrete plant. Thus, the MSMC overlay is potentially a very economical alternative to LMC, particularly in the outstate areas.

Laboratory tests have shown that MSMC, like LMC, possesses excellent properties. MSMC exhibits improved high-early strength and its very low permeability characteristics make it difficult for water and chemicals to penetrate. MSMC overlays bond adequately, though not as well as LMC overlays, and they also fall short of LMC performance in the critical properties of post-set shrinkage and resilience. The post-set shrinkage problems became evident in the field when extensive shrinkage and craze cracking developed on two 1986 experimental bridge decks just two weeks after the MSMC overlays were placed. The cause of this shrinkage cracking was found to be a result of the necessity of using superplasticizers in the microsilica slurry used as the admixture.

Evaluation of MSMC continues, including additional laboratory work and another experimental MSMC overlay placed in early June of this year. Combined with a reduction in the amount of superplasticizers used and the addition of polypropylene fibers, a full seven-day moist cure procedure was used on this overlay in contrast with the four-day moist cure and no fibers specified in 1986. Initial observations appear to be favorable. The shrinkage and craze cracking observed in 1986 have not been observed on this deck to date. It is felt that the success of this MSMC overlay will lead to further experimentation and its eventual general use on bridge decks in the future. The cost of a cubic yard of MSMC should be about half the cost of LMC resulting in considerably lower costs for deck overlays.

### Bituminous Overlay

Although not recommended as a long-term remedy, bituminous overlays have occasionally been placed as temporary repairs on decks scheduled for replacement within a few years. The disadvantage of a bituminous overlay is that it traps salt and moisture which accelerate the deterioration of the underlying deck. When a bituminous overlay is selected current specifications require the use of a waterproofing membrane to control the penetration of water. Like the LSHD overlays, bituminous overlays with membranes have not been successfully used in Michigan. Some other states use them and appear to be satisfied with their performance.

## Cathodic Protection System

The use of cathodic protection (CP) systems as an economic rehabilitation alternative for salt-contaminated bridge decks is gaining national support. An 'impressed current' CP system is the type generally specified for use in protecting concrete bridge decks (See MATES, March 1988, Issue No. 17, for a detailed explanation of this type of system). An external direct-current power source forces a low voltage current to flow to the reinforcing steel, and this has been found to prevent rusting of the steel. In theory, as long as the impressed current is present the steel reinforcement should not corrode.

The FHWA fully supports and endorses the use of CP systems. (Currently, a CP system is the only viable deck rehabilitation alternative for our concrete T-beam bridges where the deck slab is an integral part of the structural support system and cannot be removed without temporarily supporting the span, and thus interfering with traffic beneath the bridge.) The Department installed its first CP system on a concrete T-beam bridge deck in November 1988. Final contract plans are currently being prepared for the rehabilitation of four additional T-beam structures using CP technology. The use of this system has yet to demonstrate its cost-effectiveness, since we still do not know how long the CP systems themselves will last.

## Hydrodemolition

The use of hydrodemolition as a method of scarifying or removing concrete during bridge deck rehabilitation has been gaining support throughout the Department. Hydrodemolition uses high-pressure water jets (typically at 17,000 lb/sq in.) to break concrete apart, rather than using a conventional jack-hammer. Generally, the hydrodemolishing machine is applied over the entire surface of the deck. It is set to remove about 1/2 in. of sound concrete from the surface. When it encounters unsound or delaminated areas, they will be penetrated and removed.

The key advantages hydrodemolition offers over conventional jack-hammer methods are: it creates a highly superior bonding surface; it minimizes or eliminates microcracking of the remaining concrete; it does not damage existing reinforcing steel; and, it minimizes existing steel reinforcement debonding from the concrete left in place. It is hoped that the use of hydrodemolition will help minimize the large quantity overruns we have been experiencing on the 'hand-chipping' contract bid items. The use of hydrodemolition will help to put more control of the removal process back in the hands of MDOT inspectors during the equipment calibration, and out of the hands of an inexperienced operator on the end of a 30-lb jack-hammer.

The current disadvantage of hydrodemolition is that it is a relatively new technology, only having been used in the United States for about five years. Contractors have been reluctant to invest in hydrodemolition equipment until a commitment has been made by MDOT specifying hydrodemolition on contract bridge deck work. The Indiana Department of Highways now specifies hydrodemolition as the method of concrete removal on all bridge deck rehabilitation projects. Early results in Michigan indicate that this method will see increasing use here as well.

## Delamination Survey Techniques

The search for an automated delamination survey technique continues at many research facilities across the country. Current research and development efforts appear to be focusing on infrared thermography, ground penetrating radar, and acoustic 'impact-echo' technology.

A project was initiated in 1985 at the Department's Materials and Technology Division, to evaluate infrared thermographic methods for identifying areas of delamination on exposed concrete bridge decks. An infrared scanner was used to record temperature differences (between delaminated areas and sound concrete) that exist when the bridge deck is warmed by the sun. Cracks beneath a delaminated area act as insulators, permitting the delamination to become warmer than the surrounding sound concrete. The infrared scanner passing over the deck at a speed of about 2 mph is capable of detecting temperature differences of about 0.4 F. Plotting the temperature variations reveals the existing delamination patterns.

It was concluded from this research that thermographic survey methods are about as accurate in detecting the location and size of delaminated areas as conventional methods currently used. Thermographic methods, however, require the use of sophisticated equipment, operation by trained personnel, and very restrictive climatic conditions when the survey is conducted, as well as taking some cores from the deck for calibration purposes.

Based on the results of this research, and the large backlog of deck survey requests, the M&T and Design Divisions currently are contemplating the use of thermographic surveys on a contract basis. Infrared thermography and ground-penetrating radar are being evaluated and developed by the National Strategic Highway Research Program (SHRP, See MATES, May 1990, Issue No. 43). It is anticipated that more practical versions of these devices will be available before long, to assist in more rapid, accurate, nondestructive evaluation of bridge decks.

## Chloride Analysis

Many questions exist as to the value of current bridge deck chloride criteria. Bridge decks in snow-belt states generally contain significant amounts of chloride. Much uncertainty exists on how to interpret and apply the data. Current FHWA guidelines specify 2 lb of chloride/cu yd of concrete as the threshold for causing active corrosion of the reinforcing steel. MDOT currently uses 4 lb of chloride/cu yd of concrete as its threshold, but routinely overlays decks with much higher values. The relevance and significance of this threshold is often debated since its correlation to a bridge deck's actual physical condition or ability to perform in the future has not been determined in detail. M&T continues to monitor the performance of approximately 200 deck overlays where the chloride content of the deck concrete ranged from 1 to 14 lb/cu yd, to determine how long the overlays may serve.

## Outlook

The objective of developing an economical, high performance, concrete overlay appears to be closer at hand due to recent favorable experience with microsilica-modified concrete. Reductions in the amounts of the prescribed superplasticizer, the addition of the polypropylene fibers, and an improved curing procedure appear to be capable of solving the shrinkage cracking problem. The anticipated economic advantage of MSMC is clearly becoming evident. On the recent experimental project, completed in June of this year, MSMC was bid at approximately one-half the current cost of LMC. This major economic advantage, combined with its high performance characteristics, make MSMC a good competitor with LMC.

Environmental and air quality concerns favor the use of hydrodemolition for deck chipping and cleaning. It is a virtually dust-free operation with its residue commonly removed by large vacuum trucks. Specifying hydrodemolition as the method of concrete removal will avoid air quality violations caused by the discharge of cement dust into the air.

Combining the advantages of both hydrodemolition and a LMC or MSMC overlay should provide MDOT with cost effective, environmentally acceptable, longterm, high-performance bridge deck rehabilitation alternatives.

-Glenn Bukoski

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