



# MATES

## MATERIALS AND TECHNOLOGY ENGINEERING AND SCIENCE

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### UNDERSTANDING AND PREVENTING BRIDGE DECK DETERIORATION - PART I

#### The Problem

Let's begin by noting why concrete bridge decks in general are deteriorating. A major factor in bridge deck deterioration is the cracking and spalling (breaking away) of the concrete due to corrosion of the reinforcing steel. Corrosion is the process by which iron, and iron-based products such as steel, are returned to their natural states which are iron oxides. The common name for the end product of the corrosion process in steel is rust. The products generated as a result of corrosion occupy many times the volume of the steel they replace. These corrosion products consequently exert an outward pressure that has been reported to range as high as 1,200 to 4,000 lb/sq in. When this pressure exceeds the forces holding the concrete together, the concrete cracks. Cracking generally extends either to the surface (Fig. 1), or along a plane-of-weakness created by excess water in

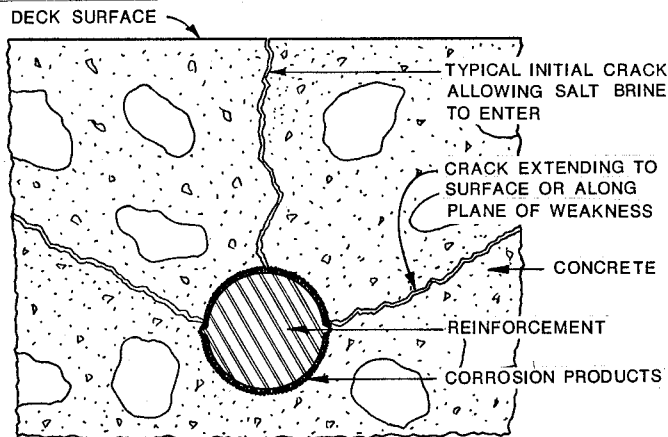


Figure 1. The result of corrosion.

the concrete mix and structural vibration during deck construction (as explained in MATES No. 9). When the cracks extend along the plane-of-weakness a delamination occurs. To help visualize this, consider a piece of plywood made of thin layers or 'laminations.' When one of these comes loose, it is said to have 'delaminated.' In concrete, a thin layer stretching along the plane-of-weakness from one reinforcing bar to another can delaminate from the rest of the deck. When this crack eventually reaches the surface, traffic will remove the pieces creating a spall, more typically called a pot hole (Fig. 2).

When steel is encased in new concrete it is surrounded by a protective environment. The concrete not only provides protection from the elements, but its highly alkaline (non-acidic) nature causes a passive layer to form around the reinforcing steel. This passive layer helps to prevent corrosion of the reinforcing steel.

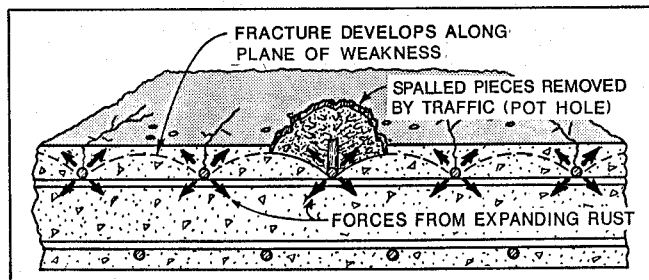


Figure 2. Failure caused by expanding rust.

If these conditions remained unchanged, an almost ideal environment would exist and most bridge decks would last well beyond their designed life spans. Now the major culprits are added. During winter, Michigan, like most northern states, spreads rock salt on the roads to melt ice and snow. In urban areas, particularly, other corrosive materials from traffic exhaust and industrial emissions reach the pavement surface. For simplicity, we will refer to this combination of chemicals as 'salt,' since deicing salt is the primary chemical that is present. This salt combines with water, creating a brine that penetrates into the cracks and pores of the concrete and eventually reaches the reinforcing steel. As increasing amounts of salt reach the reinforcing steel, the passive alkaline layer surrounding the steel gradually becomes acidic. The difference in salt concentration between the upper and lower mats of reinforcing steel then acts as a 'battery' of sorts, and sets up very low level electrical currents in the deck (Fig. 3). These currents drive the corrosion reaction causing the upper mat of reinforcing steel to rust and the deterioration of the bridge deck to begin.

What can be done to slow, prevent, or stop this corrosion process? Several measures have been tried, and used, since the problem was discovered. Michigan first began the battle against deterioration of bridge decks many years ago, and it continues today. Only measures that have been tried and at this time appear to be working successfully will be discussed.

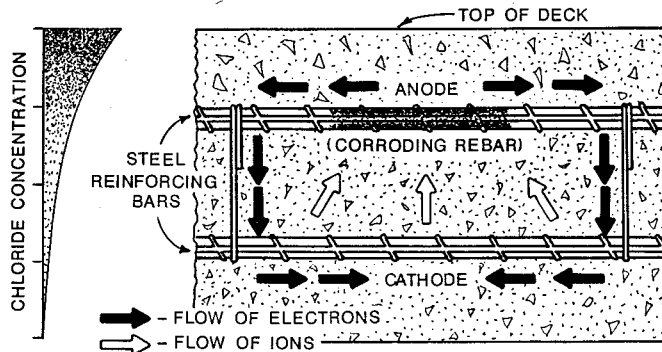


Figure 3.

Testing Laboratory  
U of M 1913

Research Laboratory  
MSU 1939

Investigation and Research Division  
1924

Testing and Research Division  
1933

Materials and Technology Division  
1985

## Newly Constructed Bridges

On new construction, several processes are being used singly and in combination to solve the problem. These are:

- a) Deeper Cover - The top layer of reinforcement has been placed farther from the surface of the deck. This extra depth of concrete increases the time it takes for salt to reach the reinforcing steel and increases the amount of stress required to crack the concrete.
- b) Better Quality Concrete - The concrete being used in bridge decks is of a better quality than it used to be. Less water and more cement are being used in the mix which decreases the porosity of the concrete and makes it more difficult for the salt to reach the reinforcing steel.
- c) Latex Modified Concrete Overlay - An overlay of 1-1/2 in. of latex modified concrete is laid over the original deck. The latex additive is a rubber-like liquid that fills some of the pores in the concrete. This concrete is even less porous than regular concrete making it even more difficult for the salt to reach the steel.
- d) Epoxy Coating of the Reinforcing Steel - This process coats the reinforcing steel with a protective layer of epoxy. The salt may reach the level of the reinforcing steel but it can't reach the steel itself. The epoxy also acts as an insulator, restricting the electrical flow between the top and bottom mats of reinforcing steel, thereby preventing or severely reducing corrosion.

Today, all new concrete bridge decks use a), b), and d); and in areas of heavy traffic where larger amounts of salt are used, all four of these treatments may be used together.

## Existing Bridges

The processes just discussed seem to be working well for new construction and, if proper specifications and methods are followed, the structure should enjoy a long life. But, what about all the bridge decks that were put into service

before the implementation of these treatments? In older bridges the reinforcement was uncoated, and placed nearer the surface, and in many cases the deck concrete was easier for salts to penetrate.

Before the reason for the deterioration of bridge decks was understood, the repair method normally used was to remove the loose concrete and patch the holes. This method proved ineffective as patches sometimes popped out again in as little as two or three years and adjacent areas deteriorated rapidly. A later method called for removal of more of the contaminated concrete and overlay of entire decks with latex modified concrete. This process provides a totally new riding surface for the deck and extends deck life up to 15 years or more. Ultimately though, continuing corrosion in the remaining salt-contaminated deck will generate additional problems. If patching is done without first removing all the salt-contaminated concrete in the area, the corrosion process continues, although perhaps at a lower effective rate. Where new salt-free concrete is placed around the reinforcement next to existing salt-contaminated concrete, the local corrosion process may actually accelerate, because the difference in salt content between the old and new concrete drives the corrosion process. Removing all the salt-contaminated concrete is a time consuming, labor intensive, and very expensive process, and may not be practical. When a structure has exceptionally high levels of salt in the concrete it may even be more reasonable to replace the entire deck than to remove all of the salt contaminated concrete.

Under any of the above described methods of patching and deck overlays, the basic causes of corrosion remain within the deck and in the long-run the deterioration process recurs.

## Arresting Corrosion in Existing Bridges

In the next issue of MATES, we will discuss what is currently the only known practical way to prevent the continued corrosion of reinforcing steel in salt-contaminated bridge decks.

-Bard Lower

## **TECHADVISORIES**

The brief information items that follow here are intended to aid MDOT technologists by advising or clarifying, for them, current technical developments, changes or other activities that may affect their technical duties or responsibilities.

### NEW MATERIALS ACTION

The New Materials Committee recently:

Approved the following products for trial installations:

TP-250 Waterproofing Membrane  
CON/SPAN Culverts

Approved the following products:

Plexco Polyethylene Pipe  
Poly Sheath 1019  
Hit and Run Safety Systems  
Concrete Sealants:  
Chem-Trete  
Hydrozo 650  
Stifel  
Consolideck Saltguard  
Pen 2000  
Pentane  
Maccaferri Gabions  
Maccaferri Reno Mattresses  
OS Splice Clip  
Evercrete-Crib Retaining Wall

It should be noted that some of the products may have restrictions regarding use. For details contact Don Malott at (517) 322-5687.

### MDOT RESEARCH PUBLICATIONS

**Experimental Resurfacing of Concrete Bridge Decks with Microsilica Modified Concrete - Initial Report**, Research Report No. R-1282, by H. L. Patterson. Two Detroit area bridges were selected to receive a resurfacing treatment using a microsilica modified mix to investigate its ability to resist the entry of chloride-laden moisture into the deck. A nearby bridge with a conventional latex-modified overlay was selected for comparison. The work described in this report involves the development of the microsilica (also called 'silica fume') modified concrete mix design, the field application, and the initial evaluation of the material as an overlay concrete. With respect to permeability, the mix proved superior to a latex-modified control mix; however, it did develop early map cracking which may prove to be a problem later. Shrinkage is considerably higher than that of the latex-modified concrete. A final report will be issued in the future describing longer term performance of these bridges.

### SPECIFICATION UPDATE

**Filler Walls for Bridge Piers, 5.03(11b)**, dated 12-16-87. This revision adds requirements for filler wall extensions and geotextile covering for drain holes because of related changes in the revised Special Detail 5, "Filler Walls Between Existing Bridge Pier Columns."

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