Fig. 5—Concrete pile cap showing severe sulfate attack causing overlay cracking

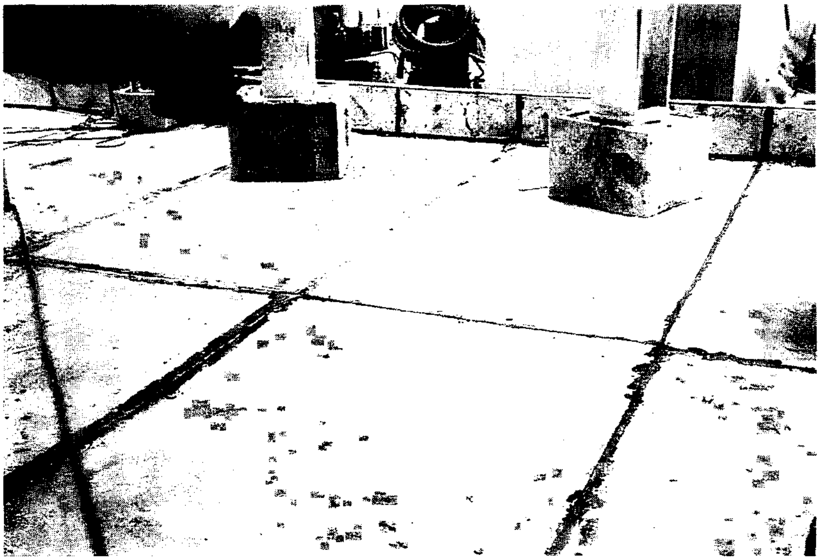

Fig. 6—Current view of overlaid floor and pile caps in good condition after 10 years

SP 169-6

Thin-Bonded Polymer Concrete Overlays for Exposed Concrete Bridge Deck Protection and Maintenance

by David White and Richard Montani

Synopsis: The use of concrete-polymer materials for bridge deck rehabilitation has been increasing in the United States since the 1970's[1,2]. As demands on worldwide transportation increase, the need for improved methods of rehabilitation and maintenance of bridges continues to grow. At the same time, more than 40% of the 500,000 highway bridges in the United States are now classified as structurally or functionally deficient[3]. This crumbling of the nation's infrastructure has allowed cost-effective, alternative methods to be utilized, extending the life span on many of these bridges.

Various polymer concretes have been used as overlay materials since the 1950's. Project requirements, as well as product limitations have changed considerably over this time as improvements are continually made to the process. Recommendations are made to improve project specifications in the following areas: tensile elongation, abrasion resistance, water absorption, chloride ion permeability, and quality standards.

Keywords: Abrasion resistance; absorption; bridge decks; chlorides; epoxy resins; permeability; polymers; resurfacing

David White is Product Manager, Reactive Resins and Floorings for Sika Corporation in Lyndhurst, New Jersey. He holds a B.S. degree in Civil Engineering from Columbia University in New York City and an M.S. degree in Civil Engineering from Polytechnic University in Brooklyn, New York. He is a licensed Professional Engineer in the State of New York and is active on several ACI Committees, including 548 (Polymers), and 503.

Richard Montani is Director of Marketing for Sika Corporation in Lyndhurst, New Jersey. He holds a B.S. degree in Chemical Engineering from the University of Dayton in Ohio. He is active on several ACI Committees, including 503 (Adhesives), 546 (Repair), and 548 (Polymers). He is also active in the International Concrete Repair Institute (ICRI) and the Transportation Research Board (TRB).

INTRODUCTION

A successful overlay is dependent upon many factors. The resin binder and graded aggregate must be formulated to meet the demands of high traffic patterns, large temperature cycles, de-icing salts, moisture and many other variables. In addition, the overlay must be capable of being applied in many different working environments and temperatures by contractors of varying skills. The overlay and its material components must also be economically feasible to the owner, especially when compared to other alternate methods.

HISTORY OF POLYMER CONCRETE OVERLAYS

Polymer concrete overlay systems have been used in the United States since the 1950's. The first systems used were coal tar epoxies heavily broadcast with fine aggregates. These overlays had poor abrasion resistance to traffic and were relatively porous[4]. Polyester resins, epoxy resins, and methyl methacrylates were first used in the 1960's. While these systems had improved abrasion resistance, the early formulations proved very brittle, especially at low temperatures, and therefore were susceptible to cracking. Moisture tolerant epoxies were introduced in the 1970's, offering much needed, long-term performance.

Abrasion resistance to traffic was the primary performance requirement for the early epoxy resins. Lower modulus, higher elongation, and "flexibilized" epoxy resins were later developed for improved overall performance on in-place bridge decks. These materials were verified for use by testing at high and low temperature extremes while checking the thermal compatibility with the concrete substrate. With a greater understanding of the corrosion process today, and the damaging effects chlorides have on the reinforcing steel in concrete, these low modulus systems have proven to be very useful and forgiving in both application and performance, considering the harsh and extreme conditions they are subjected to.

There are already high performance specifications in place in many state D.O.T.'s. However, additional key performance criteria should be considered to enhance these specifications to ensure that quality products and application techniques are being utilized. Performance criteria should include at least the following:

1. **Tensile Elongation**

Tensile elongation is an important criteria in polymer concrete overlays for two reasons:

a. Flexibility to withstand repeated freeze/thaw cycles.
b. Provide stress relief within itself to bridge cracks, especially at low temperatures.

All bridge decks will experience a substantial degree of temperature changes both at the surface and within the structure. In some areas, freeze/thaw cycles are fairly common. In addition, cracks have a propensity for forming in bridge deck surfaces due to heavy live and dead load conditions. An overlay material which is tested at room temperature for tensile elongation is serving little purpose. Some epoxies have excellent elongation properties at 60F, but poor performance at 40F (Figure 1). Overlay materials should always be tested at both low and high temperatures since polymer materials tend to become brittle in cool weather and soft in hot weather. Tests show that the elongation should be a recommended 20% minimum when cured and tested at 40F and 30% minimum at 73F, per ASTM D638.

2. **Abrasion Resistance**

As in the 1950's, the long-term performance of most overlay materials is still directly related to its abrasion resistance. Traffic loads create extremely high shearing forces on the road surface and are very abrasive. However, most current state specification only test for abrasion at room temperature. It is suggested that an abrasion test (ASTM D4060) be conducted at elevated temperatures since polymer materials tend to soften and then lose their abrasion resistance when heated. Overlay materials should maintain a wear index of less than 2.0 (1,000 g load, 1,000 cycles) when tested at 120F.

3. **Water Absorption**

There are still specifications in place today that have no provisions for testing the material's water absorption. This aspect is crucial since bridges are always exposed to rain, snow, ice, humidity, etc. The maximum weight gain by a material, when tested in accordance with ASTM D570, should be 1% (Figure 2). In the past, many conventional systems have delaminated from bridge decks as a direct result of their high water absorption and subsequent loss of adhesion to the deck (Figure 3).

4. **Chloride Ion Permeability**

The ingress of chlorides into concrete will accelerate corrosion of the reinforcing steel. A flexible overlay material that is waterproof and bridges thermal cracks will provide an effective barrier against chlorides and other deleterious substances.

While most polymers will pass the AASHTO T277 test for chloride ion permeability, it is recommended that this still be a requirement in all project specifications. In fact, the polymer and the system in place should be required to register zero coulombs in this test to ensure chloride resistance.

5. **Quality Standards**

The materials used on polymer concrete overlay projects must both be manufactured and applied in a consistent and repeatable manner to ensure quality. In manufacturing materials, ISO 9000 is a minimum quality standard now fully recognized in the United States and Europe. To become ISO 9000 certified, a company must pass a rigorous, independent, on-site audit to verify quality standards. The company must have well designed, well documented, and well implemented quality systems demonstrated throughout the entire organization. This standard should be a requirement by all manufacturing locations which supply materials on these projects. In Europe, ISO 9000 is now also becoming a prerequisite qualification for contractors, as well as manufacturers, on all public projects.

CONCLUSIONS

The future of polymer concrete overlays in the United States is dependent upon the success of the projects being installed today (Figure 4). By requiring additional key performance criteria, and not just ease of application or lowest cost per square foot, specifications can only be enhanced. Improved products and controlled application techniques will help to improve the infrastructure. Quality standards are therefore necessary, as a minimum requirement, to ensure success and cost effective performance.

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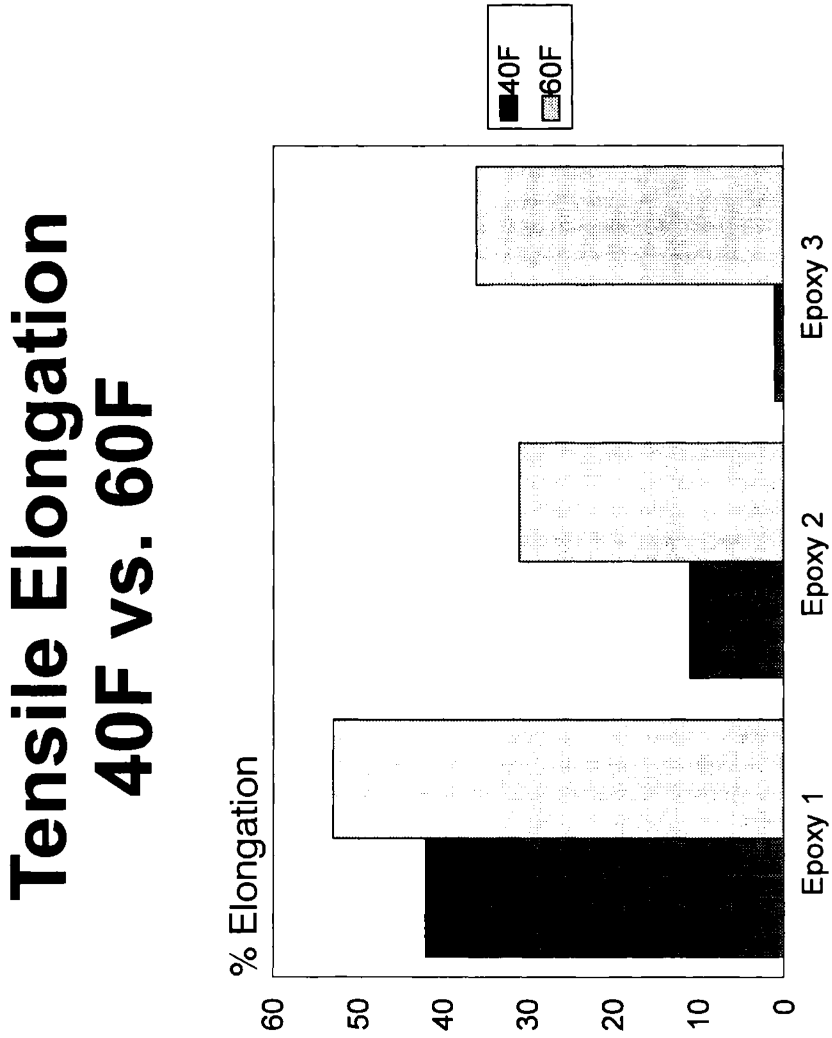

Fig. 1—Tensile elongation of epoxy resins 40F vs. 60F

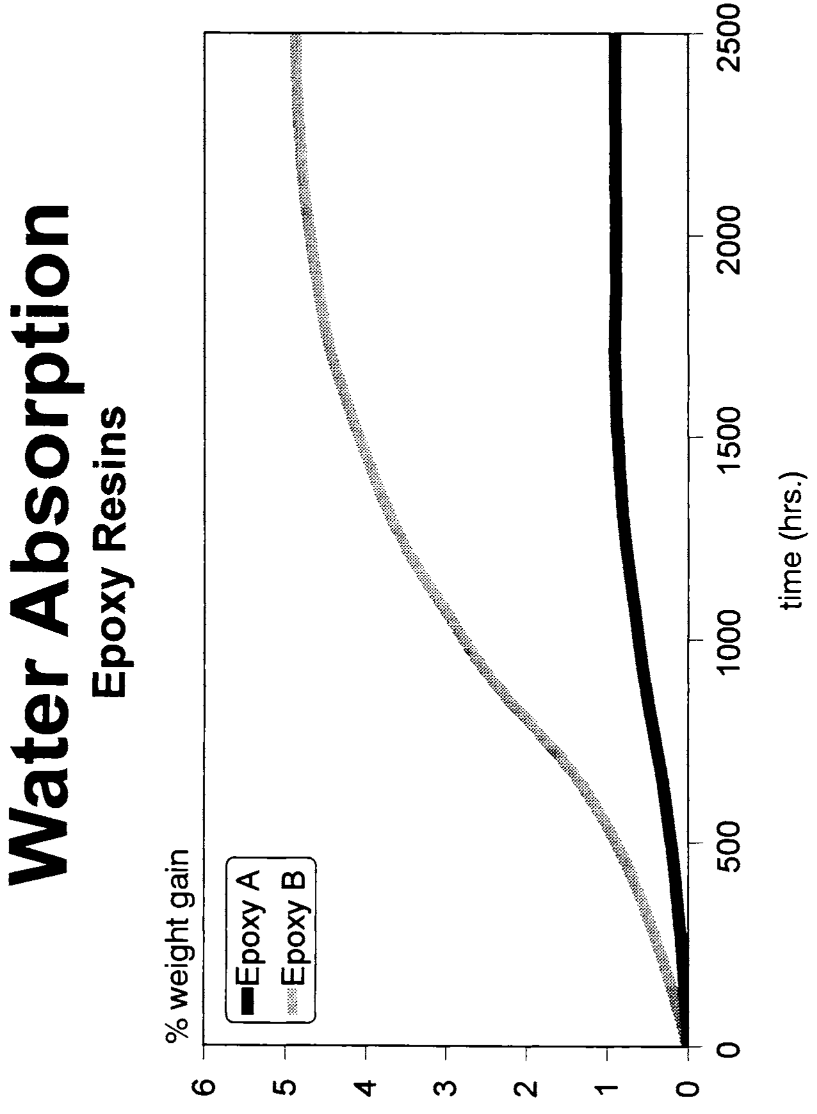

Fig. 2— Water absorption of epoxy resins

Fig. 3—Delamination of a bridge deck

Fig. 4—Project installation

A Procedure for Determining Performance of Thin Polymer Overlays on Alberta Bridge Decks

by P. D. Carter

Synopsis : This paper reports on the overall field performance and some of the lessons learned from more than 100 thin polymer overlays in the province of Alberta, Canada. These overlays were applied between 1985 and 1995 as maintenance work to existing concrete decks, where it was thought that protection against moisture and chloride absorption was needed to reduce the rate of bridge deck deterioration. The paper is intended to answer the basic question "what has been learned from ten years of thin overlay experience?"

Two measures of field performance are presented on overlays in service for up to ten years with special attention to overlays aged from eight to ten years. Various types of polymer overlay failures are discussed. The reported field performance suggests that different proprietary polymer overlay materials have varying degrees of resistance to degradation by ultraviolet radiation. The physical properties of the proprietary overlay materials change with time and exposure conditions. The materials appear to lose flexibility and compatibility with concrete at differing rates. Field performance indicates that the type of aggregate used in the thin overlay systems also affects the overlay performance and compatibility with concrete. The aggregates contribute significantly to the durability of the overlays. Workmanship, as reflected by contractor experience, is shown to be a significant service life factor. Field experience shows that polymer overlays have been effective in increasing the durability of non-air-entrained concrete exposed to aggressive environments, but the effectiveness was reduced when reflective cracks propagate from the deck through the polymer overlay. Most bridge deck cracks have not reflected through the overlays after eight to ten years in service and remain sealed by the polymer overlays. Reflective cracks are different from most bridge deck cracks in that they require special repairs to prevent propagation through the overlay within a period of several years.

Keywords: Bridge decks; chlorides; corrosion; cracking (fracturing); durability; freeze-thaw durability; polymer concrete