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This report presents the results of a study undertaken to evaluate the installation and performance of two high molecular weight methacrylate monomers used to treat the cracks and seal the surfaces on two bridges on I-81 over the New River. The evaluation is based on data collected during the treatments, skid tests, permeability tests on cores removed from the deck, petrographic examination of the cracks in the cores, and inspections of the underside of the deck for leaks.

The evaluation indicates that no significant application problems occurred and the treatments partially filled the top 1/2 in of the cracks. However, because of traffic and temperature induced strains across the cracks, the polymer in many of the cracks was cracked after 1 year in service. Even so, the treatments significantly reduced the permeability to chloride ion of the top 2 in of both cracked and uncracked sections of the deck. Cores taken through treated cracked and uncracked areas after 1 year had permeabilities that were 59 and 43 percent, respectively of the untreated bases.

The study concludes that the application of high molecular weight methacrylate monomers is a practical way to reduce the infiltration of chloride ions into cracked concrete surfaces because of the low cost and ease with which the treatment can be applied as compared to pressure injection of epoxy. The report also indicates that high molecular weight methacrylate monomers can be applied as a prime coat to improve the bond strength of polyester styrene concrete overlays.

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FINAL REPORT

# EVALUATION OF THE USE OF HIGH MOLECULAR WEIGHT METHACRYLATE MONOMERS TO SEAL CRACKS IN DECKS ON I-81 OVER THE NEW RIVER


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Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Transportation and the University of Virginia)

In Cooperation with the U.S. Department of Transportation
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This report presents the results of a study undertaken to evaluate the installation and performance of two high molecular weight methacrylate monomers used to treat the cracks and seal the surfaces on two bridges on I-81 over the New River. The evaluation is based on data collected during the treatments, skid tests, permeability tests on cores removed from the deck, petrographic examination of the cracks in the cores, and inspections of the underside of the deck for leaks.

The evaluation indicates that no significant application problems occurred and the treatments partially filled the top 1/2 in. of the cracks. However, because of traffic-induced and temperature-induced strains across the cracks, the polymer in many of the cracks was cracked after 1 year in service. Even so, the treatments significantly reduced the permeability to chloride ion of the top 2 in. of both cracked and uncracked sections of the deck. Cores taken of treated cracked and uncracked areas after 1 year had a permeability that was 59 and 43 percent, respectively, of the permeability of the untreated bases.

The study concludes that applying high molecular weight methacrylate monomers is a practical way to reduce the infiltration of chloride ions into cracked concrete surfaces because of the low cost and ease with which the treatment can be applied as compared to pressure injection of epoxy. The report also indicates that high molecular weight methacrylate monomers can be applied as a prime coat to improve the bond strength of polyester styrene concrete overlays.

# FINAL REPORT

# EVALUATION OF THE USE OF HIGH MOLECULAR WEIGHT METHACRYLATE MONOMERS TO SEAL CRACKS IN DECKS ON I-81 OVER THE NEW RIVER

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## INTRODUCTION

Cracks in concrete can provide water and salt with easy access to reinforcement, and this can cause premature corrosion. The use of an injection of epoxy to seal cracks is costly and time-consuming; therefore, a more economical method of sealing cracks is needed. High molecular weight methacrylate (HMWM) monomers can be applied to the surface of a bridge deck to seal the concrete and fill and seal the cracks.[1-5] The application is a simple process that does not require specialized pressure injection equipment. Typically, a promotor and an initiator are mixed with the monomer, and the monomer is applied to the cracked surface with a broom or a squeegee. Aggregate is usually broadcast onto the monomer to provide for adequate skid resistance. When cracks are not closely spaced, the monomer can be applied to the cracks without covering the entire deck surface.

## BACKGROUND

The California Department of Transportation (Caltrans) has applied HMWM monomers to concrete surfaces to seal cracked and deteriorated concrete in bridge decks, retard alkali-aggregate reactivity, and prime the surface prior to placing a premixed polyester overlay.[1] The HMWM monomer has been used to seal cracks in a bridge in Texas,[1] a bridge in Iowa,[2] and a bridge in Florida[3] and to extend the life of a continuously reinforced concrete pavement in South Dakota that is spalling because of an alkali silica fine aggregate reaction.[4] Tests for recracking strength and filling, conducted on specimens prepared in the laboratory, indicate that HMWM monomers can be successfully used to seal cracks of variable widths (0.2 to 2.0 mm) and moisture content.[5]

A demonstration conducted in Virginia on May 6, 1987, showed that a simple application of an HMWM monomer was as effective in sealing some cracks in the deck on I-81 over the New River as a vacuum injection of methacrylate and more effective than a pressure injection of epoxy.[6] Although none of the three techniques successfully filled the cracks, which were typically 0.1 to 0.2 mm in width on the average, an HMWM low modulus monomer (Rohm & Haas PCM 1680) filled approximately 50 percent of the volume of the cracks in the top 4 in. of the deck. It is believed that a factor in the relative success of the HMWM monomer was the time of application. The HMWM was applied in the early morning when the cracks were open. Because of the time required to prepare cracks for injection, the injections were not done until in the afternoon when the cracks were closed. An HMWM monomer was selected to treat the cracks in the decks because of the anticipated low cost: approximately $1/ft as compared to approximately $6/ft for routing and sealing with a low modulus epoxy, $20/ft for an epoxy injection, and $40/ft for a vacuum injection.[6]

A meeting was held on December 8, 1987, at the Salem District Office to obtain the input from FHWA and industry representatives necessary to draft a special provision for the treatment of the cracks in the bridges on I-81 over the New River (see Appendix A).[7] Since it had been noted during the demonstration that a small amount of the HMWM monomer had leaked through the cracks into the New River, the special provision required that the contractor protect traffic, waterways, and bridge components from the monomer. It is believed that the unit price for the HMWM treatment was high because of this requirement, which makes it necessary for the contractor to work on the underside of the deck to seal the cracks or collect the drips.

At least five companies market an HMWM monomer for use in treating cracks. Four are noted by Sprinkel,[6] and the fifth, Transpo Industries, Inc. (20 Jones Street, New Rochelle, New York), supplied the T70M and T70X monomers that were applied to the bridges on I-81 over the New River. Unfortunately, data on the physical properties of HMWM monomers and concrete are limited and recommendations for applications differ as a result of the recent development of the monomers. Therefore, it was necessary to collect the data needed to revise the special provision to prescribe the physical properties of the monomers and the application requirements for future installations. It was noted from the literature from five manufacturers that each could provide an HMWM monomer with a viscosity of 8 to 25 cps (Brookfield Model LVT Viscometer, Spindle 1 at 60 rpm), a specific gravity of 1.02 to 1.08 at 77°F, a low odor, a bulk cure in less than 3 hr at 73°F, a surface cure in less than 8 hr at 73°F, and a gel time of 20 to 50 min.

## PURPOSE AND SCOPE

The objective of this project was to describe the installation of two HMWM monomers on two bridges on I-81 over the New River, evaluate the condition of the cracks following the treatments and 1 year after installation, and collect data on the physical properties of the monomers so that the special provision could be refined for future installations (see Appendix B). The evaluations are based on skid tests (ASTM E524), permeability tests on cores (AASHTO T277), petrographic examination of cores taken from cracks, and periodic on-site inspections of the underside of the cracks for leaks. Cracks in at least two spans treated with a high modulus monomer (T70M) and two spans treated with a low modulus monomer (T70X) were evaluated.

# RESULTS

## Description of Installation

The two bridges treated with the HMWM monomers were the continuous span, steel plate girder type constructed with prestressed concrete subdeck panels and a composite site cast concrete deck (see Appendix A). Each bridge has five plate girders and 10 spans. The southbound travel lane (SBTL) was opened to traffic in September 1985, and the northbound travel lane (NBTL) in September 1986. Transverse cracks were observed in both decks in 1986 directly above the joints between the subdeck panels. Longitudinal cracks were observed above the girders.

The installation was performed in accordance with the special provision (see Appendix A). The special provision required that the contractor protect traffic, waterways, and bridge components from the monomer. To satisfy this requirement, the contractor suspended polypropylene tarps under the decks from the parapets on each side of the bridges. By using the tarps to catch HMWM drippings, it was not necessary to caulk or seal the cracks on the underside of the decks. According to the contractor, no HMWM dropped onto the tarps.

Also, the special provision required that prior to application of the HMWM monomer, the concrete surface and the cracks should be blasted with oil-free compressed air to remove dirt, dust, and other loose material. Finally, the special provision required that the monomer be applied between 1 a.m. and 11 a.m. and at a deck surface temperature between 55°F and 70°F. According to the inspector, the monomer was applied between sunrise and 11 a.m. and at a deck surface temperature between 51°F and 70°F. On many days, the application was stopped prior to 11 a.m. because the temperature had reached 70°F. Data recorded by the inspector are shown in Table 1.

Monomer used to fill the cracks was mixed in 1- or 2-gal batches and poured into 2-gal spray cans that were used to apply the monomer to the cracks (see Figure 1). The HMWM monomer gels rapidly when contained in large quantities, and therefore only 1 gal or less of mixed monomer was placed in a spray can. The monomer was applied to the cracks at the rate of 200 ft per gal. According to the inspector, many spray cans were lost because the monomer gelled in the nozzle or in the line between the nozzle and the container. The special provision required three applications to each crack. However, because of the narrow width of many of the cracks and because the first application tended to seal the top of the cracks, only the wider cracks received more than one application. As can be seen in Figure 2, the deck surface within ±3 in. of a crack was usually treated with the resin. When too

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Table 1

INSTALLATION DATA

| Crack Applications | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Temperature Data (°F) | | | | | | Gel Time (min) | |
| | | | | Air | | Monomer | | Surface | | | |
| Lane | Spans | Application Date | Monomer | Avg | Range | Avg | Range | Avg | Range | Avg | Range |
| NBPL | 8 & 9 | 5/11/88 | T70M | 50 | 46–59 | 54 | 51–60 | 56 | 52–61 | 49 | 45–55 |
| NBPL | 1 & 2 | 5/11/88 | T70M | 64 | 61–68 | 69 | 69–70 | 69 | 68–70 | 38 | 37–40 |
| NBPL | 3, 4, & 5 | 5/13/88 | T70X | 49 | 49–49 | 51 | 51–51 | 51 | 51–51 | 50 | 50–50 |
| NBPL | 3–6 & 10 | 5/14/88 | T70X | 50 | 50–50 | 53 | 53–53 | 52 | 52–52 | 55 | 55–55 |
| NBPL | 1, 2, 8, & 9 | 5/18/88 | T70M | 61 | 61–61 | 64 | 64–64 | 63 | 63–63 | 40 | 40–40 |
| SBPL | 1, 2, & 3 | 5/25/88 | T70X | 60 | 60–60 | 60 | 60–60 | 66 | 66–66 | 50 | 50–50 |
| SBPL | 8 & 9 | 5/25/88 | T70M | 63 | 63–63 | 66 | 66–66 | 69 | 69–69 | 40 | 40–40 |
| SBPL | 4–7 & 10 | 5/26/88 | T70X | 51 | 51–51 | 49 | 49–49 | 55 | 55–55 | 65 | 65–65 |
| SBTL | 4–7 | 5/27/88 | T70X | 57 | 57–57 | 59 | 59–59 | 61 | 61–61 | 62 | 60–65 |
| SBTL | 8 & 9 | 5/27/88 | T70M | 61 | 61–61 | 63 | 63–63 | 66 | 66–66 | 45 | 45–45 |
| NBTL AVG | | | T70M | 61 | 61–61 | 64 | 64–64 | 63 | 63–63 | 40 | 40–40 |
| NBPL AVG | | | Both | 53 | 46–68 | 56 | 51–70 | 57 | 51–70 | 48 | 37–55 |
| NB AVG | | | Both | 54 | 46–68 | 58 | 51–70 | 58 | 51–70 | 46 | 37–55 |
| SBTL AVG | | | Both | 59 | 57–61 | 61 | 59–63 | 63 | 61–66 | 53 | 45–65 |
| SBPL AVG | | | Both | 58 | 51–63 | 58 | 49–66 | 63 | 55–69 | 51 | 40–65 |
| SB AVG | | | Both | 58 | 51–63 | 59 | 49–66 | 63 | 55–69 | 52 | 40–65 |
| NB & SB AVG | | | Both | 56 | 46–68 | 58 | 49–70 | 60 | 51–70 | 49 | 37–65 |
| NBTL 8 & 9 AVG | | | Both | 61 | 61–61 | 64 | 64–64 | 63 | 63–63 | 40 | 40–40 |

*continues*

Table 1 (Continued)

| Surface Applications | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Temperature Data (°F) | | | | | | Gel Time (min) | | Surface Cure |
| | | Applica-tion Date | | Air | | Monomer | | Surface | | | | |
| Lane | Spans | | Monomer | Avg | Range | Avg | Range | Avg | Range | Avg | Range | (hr) |
| NBPL | 1 & 2 | 5/12/88 | T70M | 49 | 49–49 | 51 | 51–51 | 55 | 55–55 | 50 | 50–50 | 7.5 |
| NBPL | 3 & 4 | 5/16/88 | T70X | 54 | 54–54 | 60 | 60–60 | 58 | 58–58 | 35 | 35–35 | 5.5 |
| NBTL | 1 & 2 | 5/19/88 | T70M | 60 | 60–60 | 61 | 61–61 | 63 | 63–63 | 45 | 45–45 | 4.5 |
| NBTL | 4, 5, & 6 | 5/23/88 | T70X | 61 | 61–61 | 64 | 64–64 | 65 | 65–65 | 40 | 40–40 | 5.0 |
| NBTL | 8 & 9 | 5/23/88 | T70M | 68 | 68–68 | 73 | 73–73 | 70 | 70–70 | 35 | 35–35 | 3.5 |
| SBPL | 5–7 & 10 | 5/26/88 | T70X | 56 | 56–56 | 58 | 58–58 | 63 | 63–63 | 60 | 60–60 | 6.3 |
| SBPL | 8 & 9 | 5/26/88 | T70M | 60 | 60–60 | 63 | 63–63 | 66 | 66–66 | 40 | 40–40 | 5.5 |
| SBTL | 1 – 5 | 6/1/88 | T70X | 55 | 55–55 | 56 | 56–56 | 63 | 63–63 | 65 | 65–65 | 7.0 |
| SBTL | 8 & 9 | 6/1/88 | T70M | 61 | 61–61 | 64 | 64–64 | 66 | 66–66 | 45 | 45–45 | 5.5 |
| NBTL AVG | | | Both | 63 | 60–61 | 66 | 61–73 | 66 | 63–70 | 40 | 35–45 | 4.3 |
| NBPL AVG | | | Both | 51 | 49–54 | 55 | 51–60 | 56 | 55–58 | 42 | 35–50 | 6.5 |
| NB AVG | | | Both | 58 | 49–61 | 61 | 51–73 | 62 | 55–70 | 41 | 35–50 | 5.2 |
| SBTL AVG | | | Both | 58 | 55–61 | 60 | 56–64 | 64 | 63–66 | 55 | 45–65 | 6.3 |
| SBPL AVG | | | Both | 58 | 56–60 | 60 | 58–63 | 64 | 63–66 | 50 | 40–60 | 5.9 |
| SB AVG | | | Both | 58 | 55–61 | 60 | 56–64 | 64 | 63–66 | 52 | 40–65 | 6.1 |
| NB & SB AVG | | | Both | 58 | 49–61 | 61 | 51–73 | 63 | 55–70 | 46 | 35–65 | 5.6 |
| NBTL 6 & 7 AVG | | | T70X | 61 | 61–61 | 64 | 64–64 | 65 | 65–65 | 40 | 40–40 | 5.0 |
| NBTL 8 & 9 AVG | | | T70M | 68 | 68–68 | 73 | 73–73 | 70 | 70–70 | 35 | 35–35 | 3.5 |
| NBTL 6–9 AVG | | | Both | 64 | 61–68 | 68 | 64–73 | 67 | 65–70 | 37 | 35–40 | 4.3 |

Figure 1. HMWM monomer is applied to cracks in deck on I-81 over the New River in May 1988.

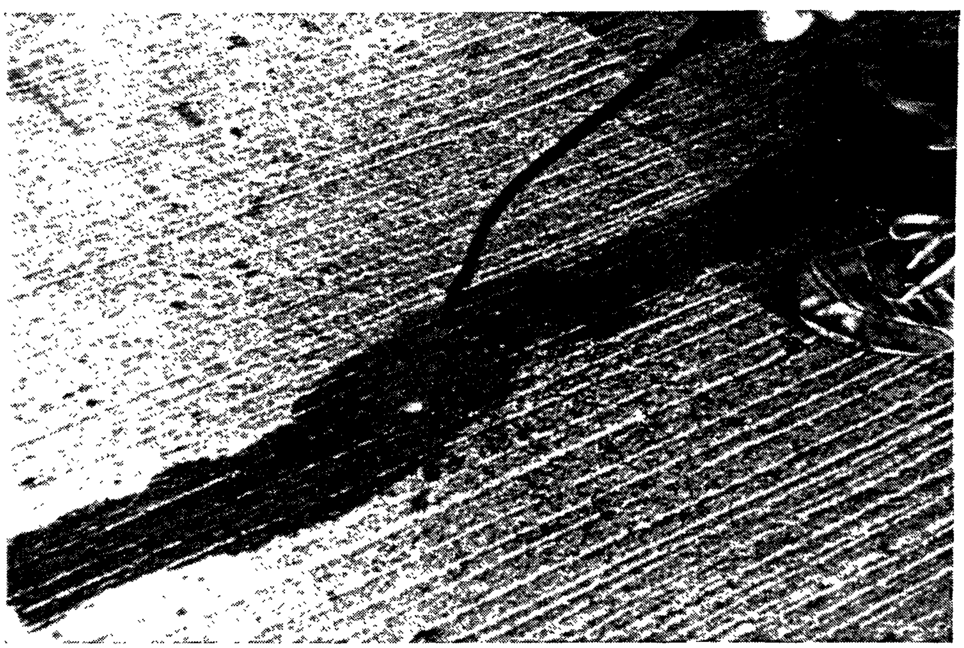

Figure 2. HMWM monomer is applied to cracks in deck on I-81 over the New River. To maintain a good skid number, excess resin in valleys must be broomed over the deck surface before it gels.

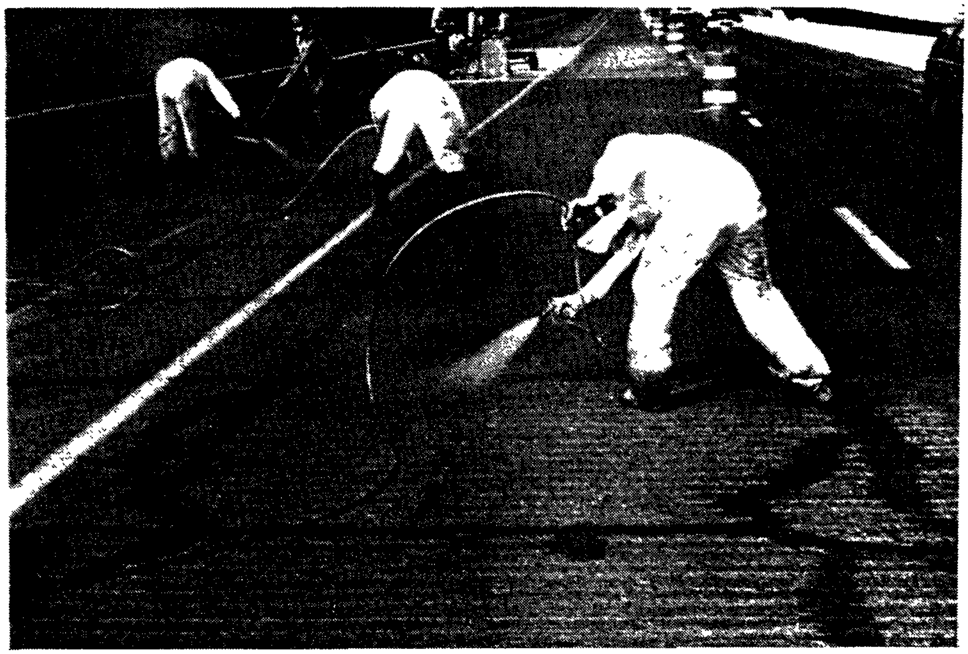

Figure 3. Airless spray guns are used to apply HMWM resin to the surface of the deck on I-81 over the New River in May 1988. Note that the work crew is wearing rubber boots and gloves, impermeable coveralls, and canister breathing masks.

much resin was applied to a crack, the excess resin was brushed over the deck surface before it gelled so that the grooves were not filled.

Once the cracks were filled, the HMWM monomer was applied to the deck surface to seal the concrete and bring the color of the deck surface between the cracks close to the color of the surface in the vicinity of the cracks. The HMWM monomer used to seal the deck surface was mixed in 5-gal batches and applied with an airless sprayer (see Figure 3).

The project was initiated on May 10 and completed on June 2, 1988, with no significant application problems. Only 13 workdays and 17 days of lane closure were required for the $271,496 contract. The cost was as follows:

- Traffic control = $39,538 (14.6%)
- Crack sealing [15,000 ft @ $2.97/ft + 226 gal HMWM @ $85.20/gal] = $63,805 (23.5%)
- Deck treatment [125,656 ft$^2$ @ $0.77/ft$^2$ + 838 gal @ $85.20/gal] = $168,153 (61.9%).

## Mechanical Properties of HMWM Polymer Specimens

The mechanical properties of the HMWM polymer specimens are shown in Table 2. The 2-in. cube specimens of T70X and T70M were molded at the job site using an ASTM C33 concrete sand. The sand/monomer ratio was approximately 4.5 to 1 by weight. Some of the neat tensile specimens were molded at the job site, and some were molded in the laboratory of VDOT's Materials Division. Subsequent to the treatment of the decks on I-81, other HMWM monomers were evaluated. Data for specimens of RPM1100V polymer that were molded at the Materials Laboratory and at a job site (I-64 in New Kent County) are shown in Table 2.

The data for compressive strength and modulus of elasticity (ASTM C109) shown in Table 2 are typical for cubes of HMWM polymer and sand. The data for tensile strength, elongation at break, and modulus of elasticity (ASTM D638) are typical for very brittle polymers, such as T70M, and flexible polymers, such as RPM1100V. On-site inspections on June 2, 1988, revealed many cracks in the T70M polymer in the deck cracks and few cracks in the T70X polymer in the deck cracks. However, it can be seen from the data that the T70X polymer lost most of its flexibility within 15 months, which tends to explain the large increase in the number of cracks in the polymer in the deck cracks after 1 year in service. The T70M specimens were too brittle to test after 15 months. Also, neat cubes of T70M made during an installation on I-64 in New Kent County shattered at compressive strengths less than 3,000 psi when tested at 30 hr and 28 days of age. On the other hand,

Table 2

MECHANICAL PROPERTIES OF SPECIMENS OF HMWM POLYMER

| Specimen Type | Age | Strength (psi) | | Elongation at Break (%) | | Young's Modulus of Elasticity[a] ($lb/in^2 \times 10^4$) | |
|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | $s$ | $\bar{X}$ | $s$ | $\bar{X}$ | $s$ |
| T70M mortar cubes | 2 mo | 6,420 | 660 | — | — | 24.0 | 5.5 |
| T70M mortar cubes | 15 mo | 6,500 | 330 | — | — | 25.5 | 2.4 |
| T70X mortar cubes | 2 mo | 8,000 | 160 | — | — | 20.3 | 2.7 |
| T70X mortar cubes | 15 mo | 8,540 | 590 | — | — | 25.5 | 6.3 |
| T70M neat tensile | 7 day | 215 | 106 | 0.5 | 0.3 | 4.40 | 0.37 |
| T70M neat tensile | 15 mo | — | — | — | — | — | — |
| T70X neat tensile | 7 day | 3,036 | 402 | 5.4 | 0.8 | 5.80 | 0.47 |
| T70X neat tensile | 15 mo | 881 | 397 | 1.3 | 0.4 | 6.77 | 1.05 |
| RPM1100V neat cubes[b] | 28 day | 4,250 | 350 | — | — | — | — |
| RPM1100V mortar cubes | 28 day | 7,390 | 14 | — | — | — | — |
| RPM1100V neat tensile | 7 day | 2,900 | 230 | 20.2 | 5.0 | — | — |

[a]Measured at $\leq$0.004 in./in. for cubes and $\leq$0.05 in./in. for tensile specimens.
[b]At 1-in. deflection.

neat cubes of RPM1100V were compressed 1 in. without failure when tested at 28 days of age. More flexible polymers such as RPM1100V should perform much better.

## Tests on Cores Removed From the Deck

Cores 4 in. in diameter and approximately 5.5 in. long were removed from the NBTL of spans 6 and 7 (treated with T70X) and spans 8 and 9 (treated with T70M). Twenty-eight cores were removed on June 2, 1988, and 14 were removed on July 11, 1989. The cores were taken through transverse cracks, longitudinal cracks, and concrete that did not appear to be cracked (see Table 3).

Two slices 2 in. thick were cut from each core. A top slice was cut from the top 2 in. of each core (*Top* in Figure 4), and a second slice was cut at a depth of 2 1/8 in. to 4 1/8 in. from the top surface (*Base* in Figure 4). In 1988, the cores were taken in pairs approximately 2 ft apart along cracks selected for evaluation. Two slices from one core in each pair were subjected to rapid permeability tests, and two slices from the other core were subjected to a tensile splitting test.

After the rapid permeability tests were run, a slice 3/4 in. thick, 2 in. wide, and approximately 4 in. long was cut from each permeability specimen. The slice was cut in the vertical plane and perpendicular to the crack in the specimens with the cracks (see Figure 4). Both surfaces were polished and examined under the microscope so that the width of the crack could be measured as a function of depth and so that the percentage of the crack width that was filled with HMWM monomer could be recorded as a function of depth. Forty-eight cracked surfaces were examined in 1988, and none was examined in 1989.

The two segments that were left after the center slice was cut from each permeability specimen were subjected to a flexural test. A total of 56 specimens were tested in flexure in 1988, and none was tested in 1989.

Following the permeability tests on cores taken in 1989, the specimens were subjected to a splitting tensile test, and, therefore, 14 cores did not have to be taken

Table 3

NUMBER OF CORES TAKEN AND TESTS CONDUCTED ON CORES

| Type Crack in Core | Number of Cores Taken | | Permeability Tests | | Petrographic Examinations | | Flexural Tests | | Tensile Splitting Tests | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | 1989 | 1988 | 1989 | 1988 | 1989 | 1988 | 1989 | 1988 | 1989 |
| Transverse | 16 | 8 | 16 | 16 | 32 | 0 | 32 | 0 | 16 | 16 |
| Longitudinal | 8 | 4 | 8 | 8 | 16 | 0 | 16 | 0 | 8 | 8 |
| None | 4 | 2 | 4 | 4 | 0 | 0 | 8 | 0 | 4 | 4 |
| Total | 28 | 14 | 28 | 28 | 48 | 0 | 56 | 0 | 28 | 28 |

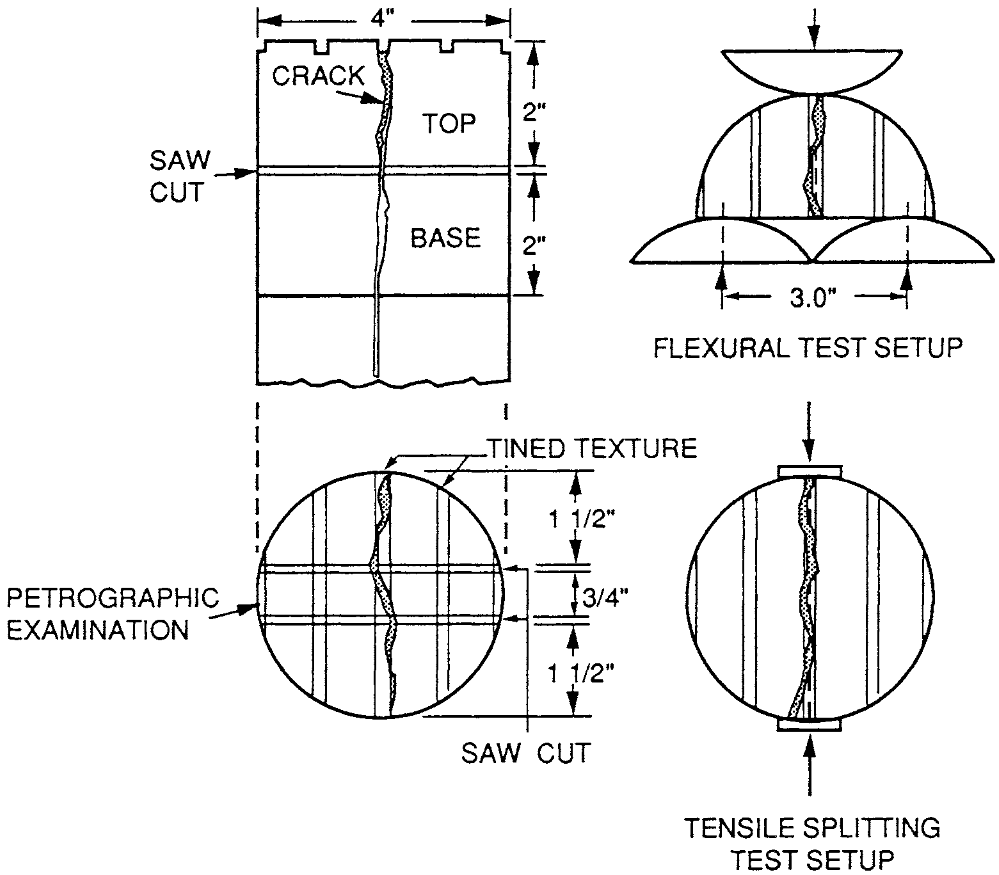


Figure 4. Sketch of test specimens obtained from cores.

for splitting tensile tests in 1989. The objective of the tests on the cores was to obtain as much information as possible from as few cores as possible.

## Permeability to Chloride Ion

The results of the tests for the permeability to chloride ion (AASHTO T277) of slices of cores 2 in. thick taken in 1988 and 1989 are shown in Table 4. A value of 1,000 to 2,000 C is considered to represent low permeability; 2,000 to 4,000, moderate; and more than 4,000, high. The data in Table 4 show that the average permeability of the top 2 in. of the cores taken in 1988 was 44 percent of that of the base concrete, and for cores taken in 1989, it was 52 percent of that of the base concrete. The permeability has increased after 1 year in service, probably because of traffic wearing away the HMWM coating and cracking the HMWM in the cracks.

Table 4

PERMEABILITY TO CHLORIDE ION OF CORES (COULOMBS)

| Type Crack | HMWM Monomer | 1988 | | | 1989 | | |
|---|---|---|---|---|---|---|---|
| | | Top 2 in. | Base | Top/Base | Top 2 in. | Base | Top/Base |
| Transverse | Both | 1,669 | 3,528 | .47 | 1,980 | 2,444 | .81 |
| Longitudinal | Both | 1,373 | 3,570 | .38 | 1,391 | 3,612 | .39 |
| Both | Both | 1,570 | 3,539 | .44 | 1,784 | 3,028 | .59 |
| None | Both | 1,297 | 3,850 | .34 | 1,908 | 4,404 | .43 |
| All specimens | T70X | 1,427 | 3,416 | .42 | 1,496 | 3,013 | .50 |
| All specimens | T70M | 1,635 | 3,571 | .46 | 2,107 | 3,960 | .53 |
| All specimens | Both | 1,531 | 3,497 | .44 | 1,801 | 3,487 | .52 |

The data in Table 4 also suggest that after 1 year the permeability of the cracks treated with T70M had increased more than the permeability of the cracks treated with T70X, which is as would be expected since the T70X is more flexible than the T70M. Also, after 1 year, the permeability of the transverse cracks had increased more than that of the longitudinal cracks, as would be expected since the transverse cracks moved more than the longitudinal cracks. It is not known why for the base concrete the average permeability without cracks was higher than the average with cracks. The lower permeability of the cracked specimens of base concrete cannot be attributed to the HMWM monomer since very little monomer penetrated the cracks to a depth of 2 to 4 in.

## Petrographic Examinations

Figures 5 through 8 show the results of petrographic examinations of vertical, polished cracked surfaces obtained by cutting a slice 3/4 in. wide from the top 2 in. and next 2 in. of each of 12 cores (see Figure 4). Both cut surfaces were polished and examined under the microscope, and, therefore, 48 surfaces were obtained from 12 cores taken through cracks in 1988. No petrographic examinations were done in 1989.

Figures 5 through 8 show the average width of the cracks as a function of depth and the average width that is filled with HMWM monomer. The following can be seen from Figures 5 through 8:

- Many of the cracks are much wider at the surface than throughout the top 4-in. depth of the deck.
- The cracks are very narrow (<0.2 mm) except on the surface.
- The transverse cracks are typically wider than the longitudinal cracks.
- The HMWM monomer did not fill the cracks very well at depths >0.5 in. from the surface.
- There is no difference in the performance of the monomers (T70X vs. T70M) from the standpoint of percentage of crack width filled as a function of depth.

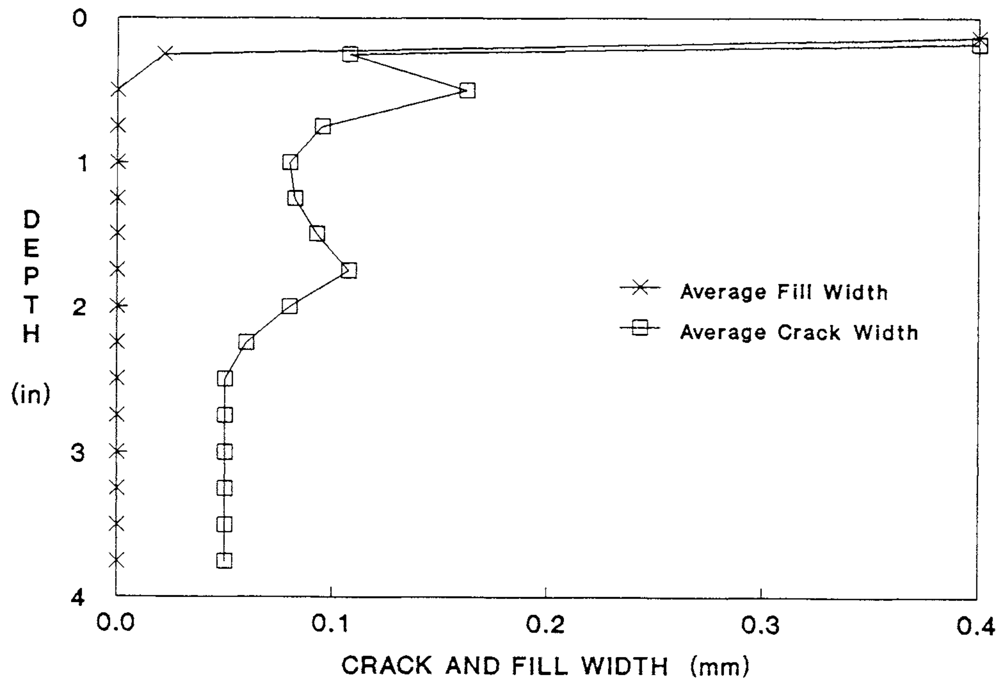


Figure 5. Average crack width and crack width filled vs. depth. Longitudinal cracks, spans 6 and 7 (T70X). At the surface, the average fill width = 0.86 mm and the average crack width = 1.15 mm.

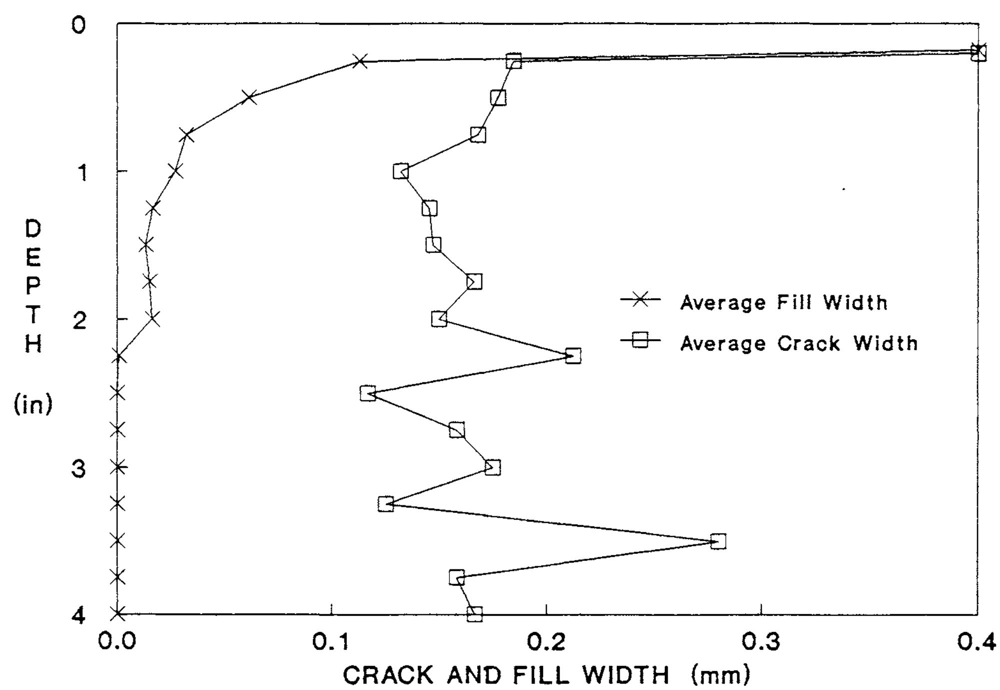


Figure 6. Average crack width and crack width filled vs. depth. All cracks, spans 6 and 7 (T70X). At the surface, the average fill width = 1.09 mm and the average crack width = 1.26 mm.

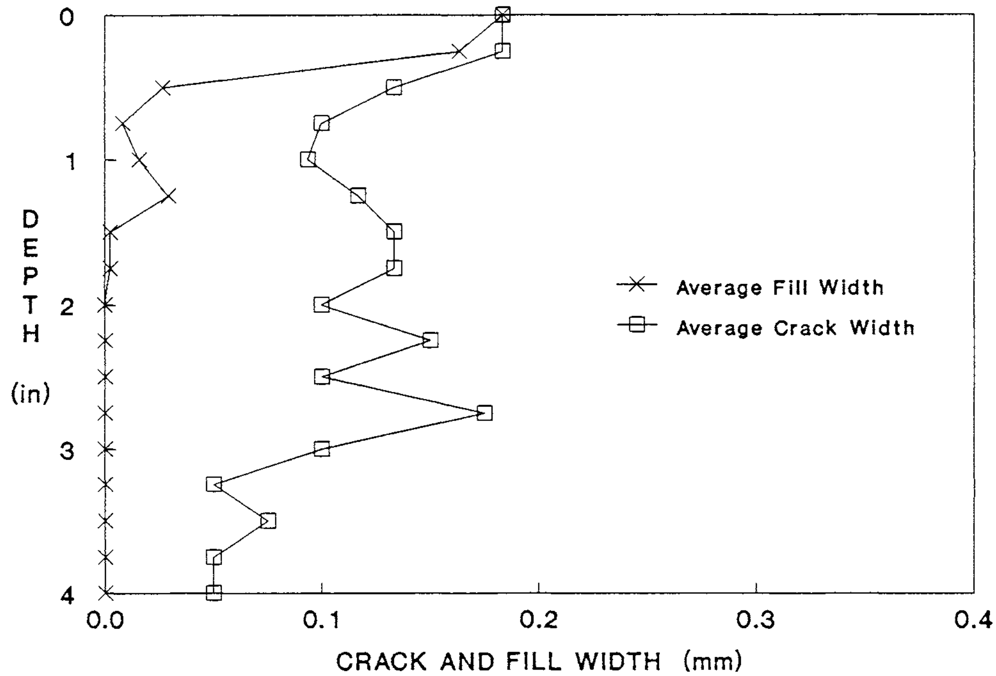


Figure 7. Average crack width and crack width filled vs. depth. Transverse cracks, span 8 (T70M). At the surface, the average fill width = 0.18 mm and the average crack width = 0.18 mm.

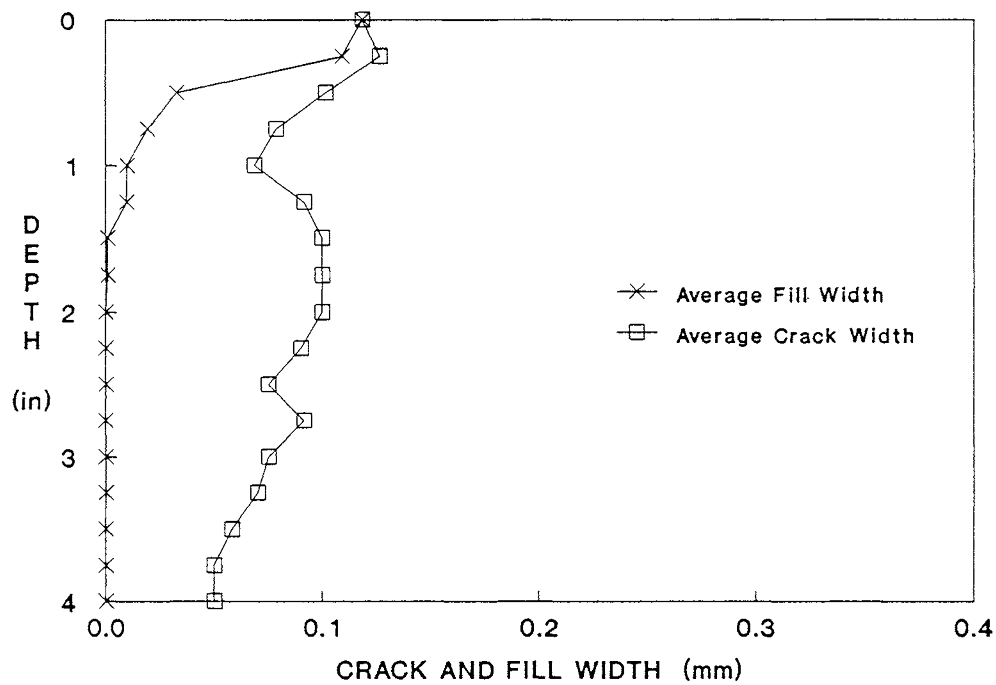


Figure 8. Average crack width and crack width filled vs. depth. All cracks, spans 8 and 9 (T70M). At the surface, the average fill width = 0.12 mm and the average crack width = 0.12 mm.

Laboratory work[5] indicated that the HMWM monomer worked well for cracks with a width of 0.2 to 2.0 mm. It is unlikely that any currently available crack filling technique would have led to the cracks being filled more than with the HMWM monomer because of the narrow width of most of the cracks in the bridge decks on I-81 over the New River. Because of their low viscosity, penetrating sealers (such as silanes or siloxanes) may have done a better job of sealing the walls of the cracks.

To see the effect of crack width on the percentage of crack width filled, cracks were grouped according to width for each of the depths from the surface that measurements were made. The exercise revealed that at the surface most cracks were 95 percent filled regardless of width. At a depth of 1/4 in. from the surface, cracks > 0.15 mm were 92 percent filled but cracks ≤ 0.15 mm were 44 percent filled. At a depth of 1/2 in. from the surface, cracks > 0.15 mm were 57 percent filled but cracks ≤ 0.15 mm were 35 percent filled. At depths ≥ 1/2 in. from the surface, the data were too variable to draw conclusions but most cracks were filled less than 20 percent and no HMWM polymer was found at depths > 2 1/4 in. However, one crack as narrow as 0.05 mm was 100 percent filled at a depth of 1 in.

## Flexural Tests

As shown in Figure 4, the portions of the cores that were left after a slice was cut for petrographic examination were subjected to a three-point flexural test to determine the degree to which the HMWM monomer treatment had bonded the sides of the cracks together and restored the flexural strength of the concrete. A modulus of rupture was computed for each specimen using the formula in ASTM C293 as follows:

$$R = 3\,Pl/2\,bd^2$$

where

$R$ = modulus of rupture
$P$ = maximum applied load
$l$ = 3 in.
$b$ = 2 in.
$d$ = depth of specimen at point of fracture.

As can be seen in Table 5, the treatment did not restore the flexural strength of the concrete. The average modulus of rupture was 110 psi for the cracked specimens as compared to 990 psi for the uncracked specimens taken from the top 2 in. of the cores in 1988. The results are as would be expected considering that the HMWM monomer did not completely fill the cracks.

The surfaces of the failed specimens were examined to determine the location of the failure. For the cracked specimens, no failures occurred in the concrete and all failures occurred through the cracks. As can be seen from Table 5, on the average, 40 percent of the failed surfaces from the top 2 in. of the cores were coated with polymer and 60 percent were coated with dust, road dirt, and carbonation. Of the

Table 5

FLEXURAL TESTS ON SEGMENTS OF SLICES OF CORES

| | | | | Failure Surface (%) | | | |
|---|---|---|---|---|---|---|---|
| | HMWM | Modulus of Rupture (psi) | | Top 2 in. | | Base | |
| Type Crack | Monomer | Top 2 in. | Base | Polymer | Bond | Polymer | Bond |
| Transverse | Both | 70 | 110 | 50 | 50 | 0 | 100 |
| Longitudinal | Both | 160 | 300 | 30 | 70 | 0 | 100 |
| Both | Both | 110 | 180 | 40 | 60 | 0 | 100 |
| None | Both | 990 | 950 | 0 | 0 | 0 | 0 |
| All cracks | T70X | 100 | 130 | 40 | 60 | 0 | 100 |
| All cracks | T70M | 120 | 230 | 50 | 50 | 0 | 100 |

failed surfaces from the base slices, 100 percent were coated with dust, road dirt, and carbonation and no polymer was observed. Because of the foreign material in a crack in a structure that is in service, it is unlikely that any crack filling technique can bond the crack surfaces together unless a technique is developed to clean the surfaces of the crack prior to the filling operation. The restoration of flexural strength in laboratory specimens[5] can be attributed to the fact that the surfaces of the cracks were clean prior to the treatment since the specimens were fabricated, broken in flexure, put back in molds, treated with HMWM monomer, and broken in flexure a second time. No flexural tests were done on cores taken from the bridge deck in 1989.

## Tensile Splitting Tests

In 1988, slices 2 in. thick were cut from one core for each pair of cores taken along a crack and from one half of the cores taken through uncracked concrete. The slices were subjected to a tensile splitting test as described by ASTM C496 and as shown in Figure 4. The specimens were loaded at the rate of 2,000 lb/min, and the tensile splitting strength was computed as $2P/ld$ where $P$ is the applied load, $l$ is 2 in. and $d$ is 4 in. In 1989, tensile splitting tests were conducted on the specimens that had been subjected to the rapid permeability test since the specimens were not needed for petrographic examinations and flexural tests.

As can be seen from the data in Table 6, similar values were found for the cracked and uncracked specimens in 1988 and 1989, which suggests that the HMWM treatment restored the tensile strength of the concrete across the crack. However, this result is not supported by the petrographic examinations or the flexural test results. Evidently, the test subjected the cracked surfaces to shear rather than tension and there were enough irregularities between the surfaces that shear stresses were transferred as well as in the uncracked concrete. Approximately 30 percent of the failures in the cracked specimens occurred in the concrete in 1988 and 1989. The failures that occurred through the cracks provided surfaces that were coated with polymer, dust, road dirt, and carbonation.

Table 6

TENSILE SPLITTING TESTS ON SLICES OF CORES

| Type Crack | HMWM Monomer | 1988 Splitting Tensile Strength (psi) | | 1989 Splitting Tensile Strength (psi) | |
|---|---|---|---|---|---|
| | | Top 2 in. | Base | Top 2 in. | Base |
| Transverse | Both | 470 | 490 | 530 | 630 |
| Longitudinal | Both | 580 | 470 | 580 | 450 |
| Both | Both | 520 | 480 | 550 | 540 |
| None | Both | 550 | 420 | 670 | 670 |
| All cracks | T70X | 570 | 510 | 570 | 560 |
| All cracks | T70M | 470 | 440 | 520 | 520 |

## Skid Resistance

Skid tests were conducted at 40 mph using the bald tire (ASTM E524) and the treaded tire (ASTM E501). As required by the work plan, tests were done with the bald tire in the summer of 1988 following the treatments. Tests were done with both tires in 1989. As can be seen from the data in Table 7, the treated surfaces have an acceptable skid resistance. The acceptable skid resistance (bald tire numbers > 20) can be attributed to the tined texture on the deck surface and the fact that the HMWM monomer did not fill the valleys in the texture. The application of sand (1 lb/$yd^2$) may have had a minor effect on the number.

Table 7

SKID NUMBERS AT 40 MPH IN TRAVEL LANE

| Structure | Spans | HMWM Treatment | Sand Application (lb/$yd^2$) | Skid Numbers: Treaded Tire 1987 | Treaded Tire 1989 | Bald Tire 1987 | Bald Tire 1988 | Bald Tire 1989 |
|---|---|---|---|---|---|---|---|---|
| I-81/New River | 6 & 7 | T70X[a] | 1 | — | 48 | — | 36 | 36 |
| I-81/New River | 8 & 9 | T70M[a] | 1 | — | 45 | — | 37 | 35 |
| I-64 Pavement | — | R & H 1540[b] | 0 | 7 | — | 7 | — | — |
| I-64 Pavement | — | R & H 1540[b] | 0.3 | 39 | — | 39 | — | — |
| I-64 Pavement | — | R & H 1540[b] | 1.0 | 55 | — | 47 | — | — |
| I-64 Pavement | — | R & H 1540[c] | Excess | 62 | — | 59 | — | — |
| I-64 Pavement | — | R & H 1540[d] | Excess | 61 | — | 59 | — | — |
| I-64 Pavement | — | None | 0 | 46 | — | 24 | — | — |

[a] 150 $ft^2$/gal.
[b] 126 $ft^2$/gal.
[c] 58 $ft^2$/gal.
[d] 38 $ft^2$/gal.

The relationship between the skid number and the sand application rate for HMWM monomer applications applied to a screeded concrete surface can also be-seen in Table 7. The data show the results of tests on 50-ft sections of pavement on I-64 that were treated in 1987 with sand at various application rates. The pavement had a screeded texture, and, as can be seen, the treated section with no sand had an unacceptable skid resistance.

### Visual Inspections

The inspector made visual inspections of the underside of the bridges during periods of rain for 1 year following the treatments. According to the inspector, some leaks were noted on spans 6 through 9 of the NBL but he attributed the leaks to the holes caused by taking cores from the deck. An inspection by the author in the spring of 1989 revealed carbonation stains next to the joints between the subdeck panels for approximately 50 percent of the joints on the NBL. Very few stains were noted on the underside of the deck on the SBL. The stains were more prevalent in the negative movement areas, as would be expected. There was not a clear difference between the number of stains under spans 6 and 7 as compared to spans 8 and 9. The design of the continuous span structure and the large amount of deflection under traffic likely accelerated the cracking of the polymer in the cracks.

## OTHER APPLICATIONS OF HMWM MONOMER IN VIRGINIA

### Untined Deck Treatment

The bridge crew in the Fredericksburg District applied Rohm & Haas PCM 1100 and 1500 monomers to the eastbound lane of two spans of a bridge (structure No. 6005 in Caroline County) on Rte. 601 over Polecat Creek on June 18, 1986 (see Figure 9). Approximately 20 to 30 min after the deck was flooded with the HMWM monomers and prior to the gellation of the monomers, the deck was covered with an excess of grade A sand (see Appendix C, Table II-19, VDOT *Road and Bridge Specifications*, July 1982) to provide a good skid number. Class I waterproofing (VDOT *Road and Bridge Specifications*, July 1982) was applied to all other areas of the deck. The sections with the HMWM monomers and the Class I waterproofing were opened to traffic at the end of each workday. The results of tests conducted on the overlays on July 14, 1987, and November 1, 1989, are shown in Table 8. The results are based on the average of three tests on each overlay. It can be seen from the data in Table 8 that the HMWM monomer treatment is performing as well as the Class I waterproofing (EP5-LV epoxy sand overlay).

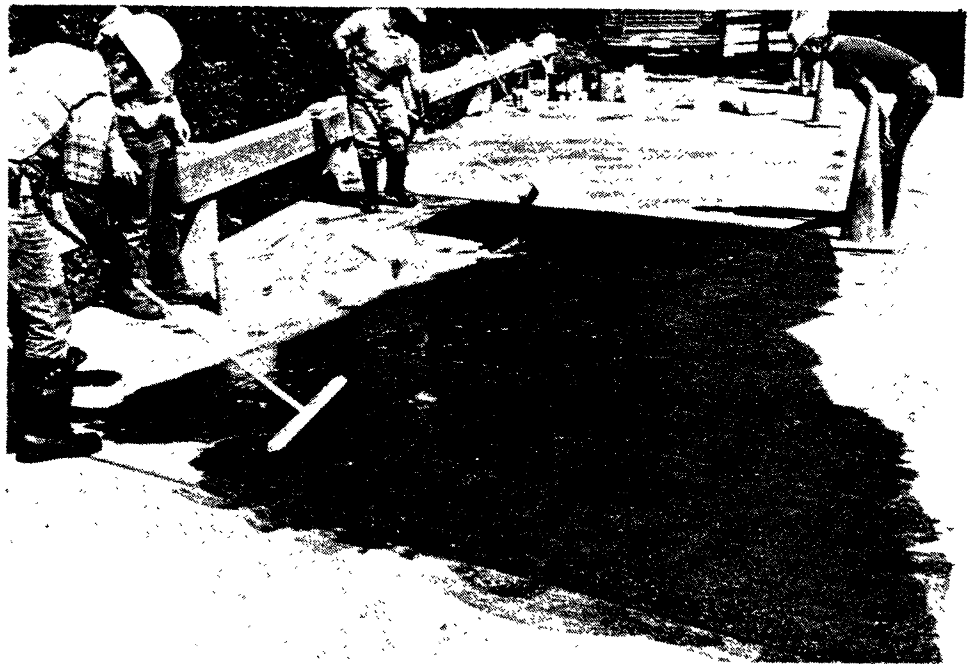

Figure 9. HMWM monomer is applied to the deck surface (no tined texture) to fill cracks. Sand is broadcast into the monomer to provide adequate skid resistance (Rte. 601 over Polecat Creek, Caroline County, June 1986).

Table 8

TEST RESULTS FOR RTE. 601 OVER POLECAT CREEK

| Overlay | Average Tensile Rupture Strength (psi) | | Failure at Bond Interface (%) | | Permeability of Top 2 in. (C) | | Permeability of Base Concrete (C) | |
|---|---|---|---|---|---|---|---|---|
| | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 |
| HMWM | 294 | 453 | 20 | 83 | 1,301 | 1,529 | 7,189 | 5,640 |
| EP5-LV | 175 | 342 | 63 | 47 | 1,087 | 1,187 | — | 6,447 |

## Surface Sealer and Crack Filler to Retard Alkali Silica Aggregate Reaction

Test sections were placed on June 17, 1986, and August 5, 1987, on the westbound travel lane of I-64 in Louisa County near Rte. 616 and on October 23, 24, and 25, 1989, on the eastbound and westbound travel lanes of I-64 in New Kent County (Mile Posts No. 207.87 through 208.07, 212.39 through 212.54, and 208.67 through 208.86). Monomer was also applied to individual cracks on June 17, 1986 (see Figure 10).

The applications placed on June 17, 1986, were removed the following year when the concrete was replaced. Cores taken through the cracks following the treatments indicated that the monomer partially filled the top 1 in. of the cracks.

Figure 10. A squeeze bottle is used to apply HMWM monomer to a crack on I-64 in Louisa County in June 1986.

Figure 11. HMWM monomer is applied to pavement on I-64 in New Kent County in October 1989 to reduce spalling caused by alkali-silica reaction.

The sections placed on August 5, 1987, were tested for skid resistance on September 15, 1987. The results of the tests are shown in Table 7. Sections placed with 0 and 0.3 lb/yd$^2$ of sand were removed prior to the opening of the pavement to traffic. Most of the sand placed on the other sections was in place in 1990.

The twenty 100-ft test sections that were placed in October 1989 (see Figure 11) are currently under evaluation. Monomers applied included Revolan RPM 1100 V, Transpo T70M, and Sika Pronto 19.

### Primer for Polyester Styrene Overlay

A multiple-layer polyester concrete overlay was placed on a 33-span bridge on Rte. 33 over the Mattaponi River east of West Point, Virginia, in September and October 1988. Approximately 1 hr prior to the placement of the first layer of the overlay on the westbound lane, a primer was placed on each of 6 spans. One polyurethane primer and five HMWM primers were placed. Twenty-seven days later, three ACI 503R tensile adhesion tests were conducted on each of 9 spans of the bridge: 3 spans with no primer and 6 spans with primer. The tests showed that the average tensile rupture strength at 27 days was significantly greater for the spans that received the primer. Based on the test results, it is recommended that a primer be used for all multiple-layer polyester concrete overlays. A special provision for a multiple-layer polyester/methacrylate overlay system that consists of a first course of HMWM monomer and two courses of polyester is provided in Appendix C.

## CONCLUSIONS

1. Based on inspections of cores, it is estimated that, on the average, the HMWM monomer filled 95 percent of the crack width at the surface. Cracks > 0.15 mm were 92 percent filled at a depth of 1/4 in., 57 percent filled at a depth of 1/2 in., and less at greater depths. Cracks ≤ 0.15 mm in width were 44 percent filled at 1/4 in., 35 percent filled at 1/2 in., and less at greater depths. HMWM monomer was observed at depths up to 2 1/4 in. and in cracks as narrow as 0.05 mm.

2. The HMWM monomer probably did not penetrate and fill the cracks more completely because of the narrow width of the cracks, <0.2 mm on average. Cracks that are wider than 0.2 mm are better candidates for the HMWM monomer treatment.

3. The HMWM monomer treatment did not restore load transfer across the cracks because the monomer only partially filled the cracks and because of the dust, road dirt, and carbonation on the cracked surfaces. Because of contaminants on the walls of cracks in structures in service, it is unlikely that crack treatments of any type can bond the sides of cracks together.

4. The HMWM monomer treatment reduced the permeability of the cracked and uncracked concrete to chloride ion. The reductions were greater for the longitudinal cracks than for the transverse cracks, particularly after 1 year in service.

5. Acceptable skid numbers were obtained when the HMWM monomer was applied to a tined texture and when an excess of sand was applied to the HMWM monomer applied on screeded surfaces.
6. HMWM monomer can be applied as a prime coat to improve the bond strength of polyester styrene concrete overlays.

## RECOMMENDATIONS

1. The application of HMWM monomers should be considered when it is necessary to reduce the infiltration of chloride ions into cracked concrete surfaces.
2. HMWM monomers should be used as a prime coat to improve the bond strength of polyester styrene overlays.

## ACKNOWLEDGMENTS

The author acknowledges Jim Obrian, Academe Paving, Inc., for treating the decks and William Lee, Transpo Industries, Inc., for supplying the HMWM monomer and providing technical advice.

The author is grateful to Dallas V. Cranford, Salem District Bridge and Structures Engineer, for specifying the HMWM monomer treatment of the decks and for providing staff to assist with taking the cores. The author is grateful to E. C. Cutright, Physical Laboratory Engineer, for conducting the tests on the HMWM monomers. The author thanks Jay Walker, Inspector, for recording the installation data shown in Table 1 and inspecting the underside of the decks for leaks during periods of heavy rain. The author acknowledges Hollis N. Walker, petrographer, for the petrographic examinations of the cores. Bobby F. Marshall is acknowledged for cutting and polishing the cores, Michael W. Burton and Kevin K. McGee for testing the cores, Andy J. Mills, Jr., for assisting with taking the cores, and Angela Sellars for preparing the computer-generated figures..

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The study was sponsored by the Virginia Transportation Research Council (VTRC) and the Federal Highway Administration (FHWA).

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# APPENDIX A

## Special Provision for HMWM Treatment of Bridges on I-81 Over the New River

# VIRGINIA DEPARTMENT OF TRANSPORTATION
# SPECIAL PROVISION FOR
# HIGH MOLECULAR WEIGHT METHACRYLATE BRIDGE DECK CRACK SEALING AND DECK TREATMENT

January 19, 1988

## I. DESCRIPTION

This work shall consist of preparing concrete deck cracks and deck surfaces and furnishing and applying High Molecular Weight Methacrylate (HMWM) treatment materials.

## II. MATERIALS

The material used for sealing concrete deck cracks and surfaces shall be a low viscosity, non-fuming, HMWM resin conforming to the following:

Resin Specification:

Physical Properties of Resin

Viscosity: 8-25 cps (Brookfield Model LVT Viscometer, Spindel 1 at 60 RPM)

Specific Gravity: 1.02 to 1.08 @ 77°F

Odor: Low

Performance Properties of Resin

Cure Speed:

| | |
|---|---|
| Bulk Cure | < 3 hours @ 73°F |
| Surface Cure | < 8 hours @ 73°F |
| | < 24 hours @ application temperature |

Gel Time:

20-50 min. at application
Temperature (50 ml sample)

The Contractor shall have a qualified technical representative on-site to provide expert expert advice to the Contractor on storage, mixing, application, clean-up and disposal of materials.

The promoter and initiator, if supplied separatly shall not contact each other directly. Containers of promoters and initiators shall not be stored together in a manner that will allow leakage or spillage from one to contact the containers or material of the other.

A Material Safety Data Sheet (MSDS) shall be furnished for the HMWM resin (promoter, and initiator) to be used on this project. A certification showing conformance to these specifications shall be provided with each batch of resin.

The HMWM material supplied shall be one of or equal to one of the following proprietary brands.

| COMPANY | ADDRESS | BRAND | MODULUS |
|---|---|---|---|
| Rohm and Haas Co. | 727 Norristown Road<br>Spring House, PA<br>19477 | PCM 1680 | Low |
| Rohm and Haas Co. | 727 Norristown Road<br>Spring House, PA<br>19477 | PCM 1540 | High |

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| | | | |
|---|---|---|---|
| Revolan | P. O. Box 18922<br>San Jose, CA<br>95158 | RPM 1100 | Low |
| Revolan | P. O. Box 18922<br>San Jose, CA<br>95158 | RPM 2000 | High |
| Adhesive Engr. Co. | 1411 Industrial Road<br>San Carlos, CA<br>94070 | AEX 2075 | High |
| Sika Corporation | 201 Polito Avenue<br>Lyndhurst, N. J.<br>07071 | Pronto 19 | High |

Spans 8 and 9 in each bridge will be treated with a HMWM material that has a modulus of elasticity that is significantly different (high vs. low) from that of the material used on the other spans.

Sand shall conform to Grade D, Table II-19 of Section 254 of Specifications.

## III. SURFACE PREPARATION

Concrete surfaces shall be prepared by air cleaning the entire deck surface using sufficient air pressure to remove all loose material from visible cracks. All accumulations of dirt and debris shall be removed from the surface. The surface and cracks to be treated shall be dry (visual inspection). The concrete deck temperature shall be not less than 55°F and not more than 70°F at the time of resin application.

## IV. APPLICATION OF HMWM

Resin shall be applied to cracks three times; one application per curing period. The application shall be at a rate of 200 linear feet per gallon. The curing period will be determined by the manufacturer's technical representative. Additional applications will be made by work order at 1/3 times the unit bid price for crack sealing. Equipment to apply resin shall be a container with a nozzle or an approved roller not more than three inches in width. Resin shall be applied within 10 minutes after mixing. Excess resin shall be swept to untreated areas not less than 10 minutes and not than 20 minutes after resin application.

Excess resin for the purpose of this specification is that which does not fill the cracks and is not absorbed by the concrete surface but fills or partially fills the grooves in the deck surface.

After completion of crack sealing, resin shall be applied to entire deck at a rate of 150 square feet per gallon. Excess resin shall be swept to untreated areas not less than 10 minutes and not more than 20 minutes after resin application.

## V. APPLICATION OF SAND

The entire treated area of the bridge deck shall have dry silica sand broadcast to effect a visually uniform coverage of 1 lb. per square yard. Sand shall be placed before any gelling of the resin occurs. Excess sand shall be removed after the curing period as determined by the technical representative.

## VI. LIMITATIONS OF OPERATIONS

The Contractor shall plan and prosecute his operations in such a manner as to protect persons and vehicles from injury or damage.

Armored joints shall be covered, scuppers plugged and cracks sealed underneath or other protective measures shall be used in such a manner as to protect traffic, waterways and bridge components. In the event material or solvent harms the appearance of bridge components, removal will be required as determined by the Engineer.

No work will be permitted on Saturdays, Sundays and Holiday. Further resin shall be applied between 1:00 a.m. and 11:00 a.m. Monday through Thursday.

Traffic will not be permitted on the treated surface until sand cover adheres sufficiently such that no tracking will occur as determined by the Engineer.

## VII. METHOD OF MEASUREMENT

Cracks sealing will be measured in linear feet. Bridge Deck Treatment will be measured in square yards of surface area. Furnish HMWM Bridge Deck Treatment will be measured in gallons.

## VIII. BASIS OF PAYMENT

Crack sealing will be paid for at the contract unit price bid per linear foot which price shall be full compensation for preparing cracks, providing manufacturer's technical representative, protection of waterways and traffic, cleaning up and for all labor, tools, equipment and incidentals necessary to complete the work.

Bridge Deck Treatment will be paid for at the contract unit price bid per square yard which price shall be full compensation for preparing concrete surfaces, providing manufacturer's technical representative, protection of waterways and traffic, cleaning up and for all labor, tools, equipment and incidentals necessary to complete the work.

Furnish HMWM Bridge Deck Treatment will be paid for at the contract unit price bid per gallon of material, which price shall be full compensation for furnishing all resin treatment materials to the site of work, ready for application.

No payment will be made for material wasted or not used in the work.

Payment will be made under:

| Pay Item | Pay Unit |
|---|---|
| Crack Sealing | Linear Foot |
| HMWM Bridge Deck Treatment | Square yard |
| Furnish HMWM Deck Treatment Material | Gallon |

# SUMMARY OF ESTIMATED QUANTITIES

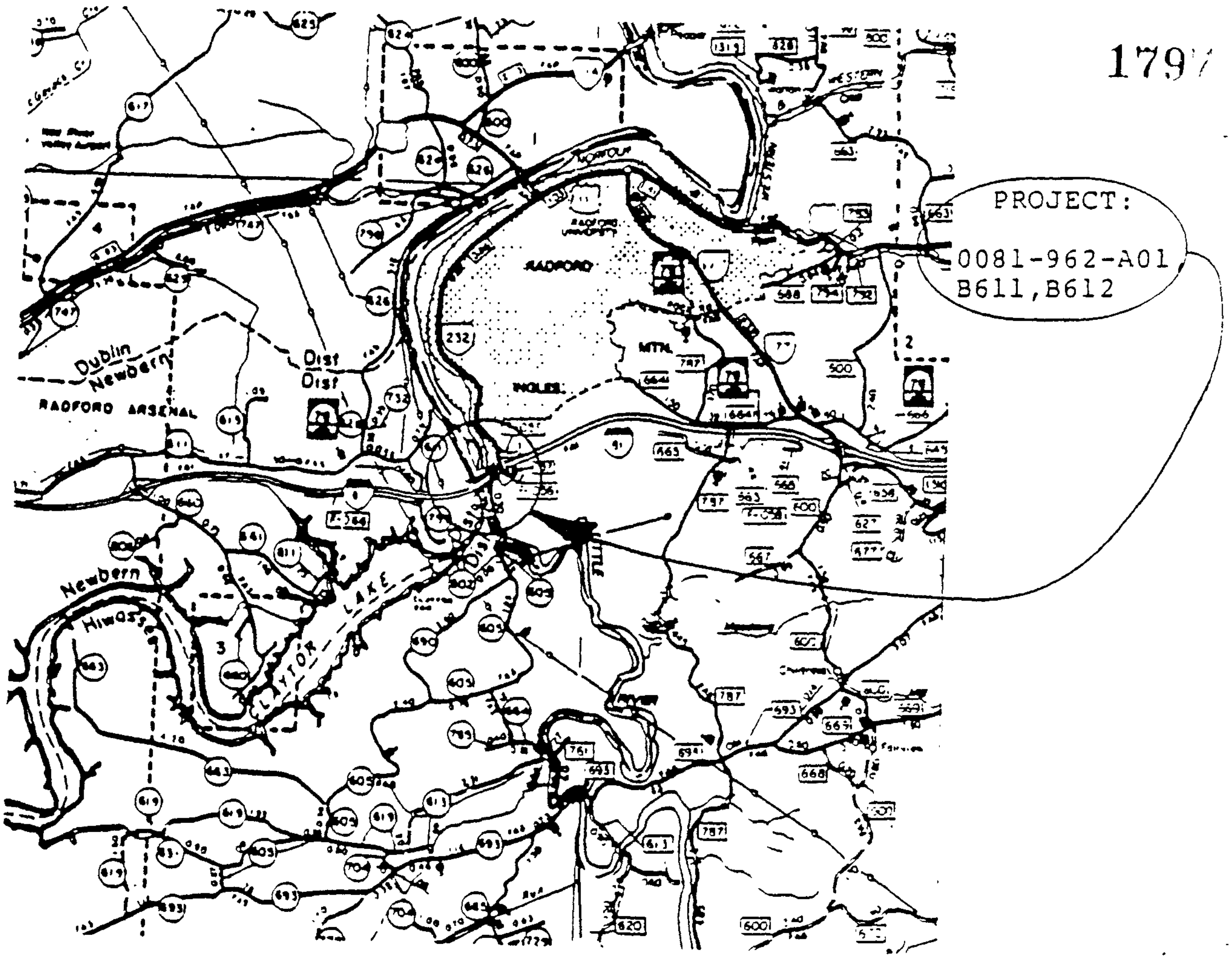
| ITEM DESCRIPTION | QUANTITIES | UNIT |
|---|---|---|
| MOBILIZATION | | L.S. |
| FURNISH HMWM* DECK TREATMENT MATERIAL | 1063 | GAL. |
| CRACK SEALING | 15,000 | L.F. |
| HMWM* DECK TREATMENT | 125,655 | S.F. |
| ELECTRONIC ARROW | 1200 | HR. |
| WARNING LIGHTS | 1800 | DAY |
| GROUP 2 CHANNELIZING DEVICES | 4500 | DAY |
| **CONSTRUCTION PAVEMENT MARKING - 4" | 3500 | L.F. |

* HIGH MOLECULAR WT. METHACRYLATE

** TYPE III - REMOVABLE

STATE FORCES WORK NON - PARTICIPATING

CONSTRUCTION SIGNS - T E C

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PROJECT LOCATION

MONTGOMERY AND PULASKI COUNTIES

GENERAL NOTE:

| | | | |
|---|---|---|---|
| Roadway Width: | 38'-7" | Length: | 1657'-6" SBL |
| | 38'-7" | | 1599'-6" NBL |

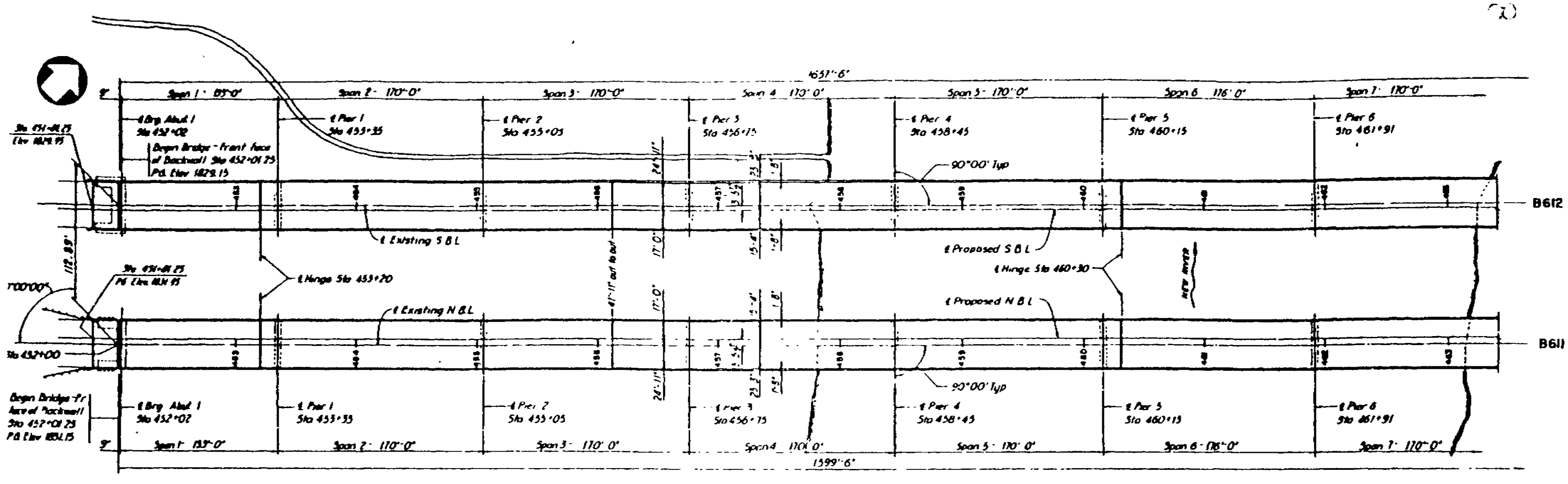
Specifications: Virginia Department of Transportation Road and Bridge Specifications, 1987

These plans are incomplete unless accompanied by the Supplemental Specifications and Special Provisions included in the contract documents.

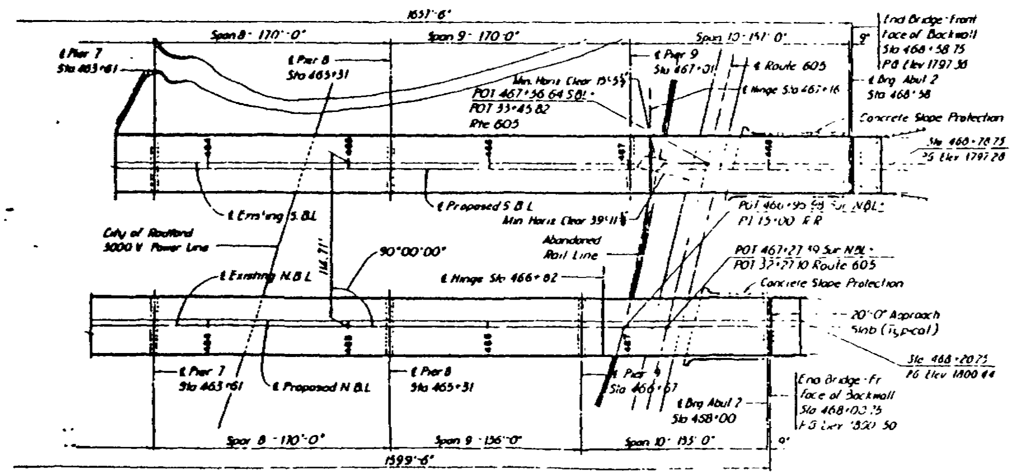
This project is to be constructed in accordance with the Virginia Department of Transportation Work Area Protection Manual, January 1987.

This plan is for (1) sealing bridge deck cracks with High Molecular Weight Methacrylate (HMWM) (2) furnishing and applying High Molecular Weight Methacrylate (HMWM) to bridge Decks. (3) Traffic control necessary to complete the work.

Traffic shall be controlled with electronic arrow, pavement marking, warning lights, group 2 channelizing devices and signing.



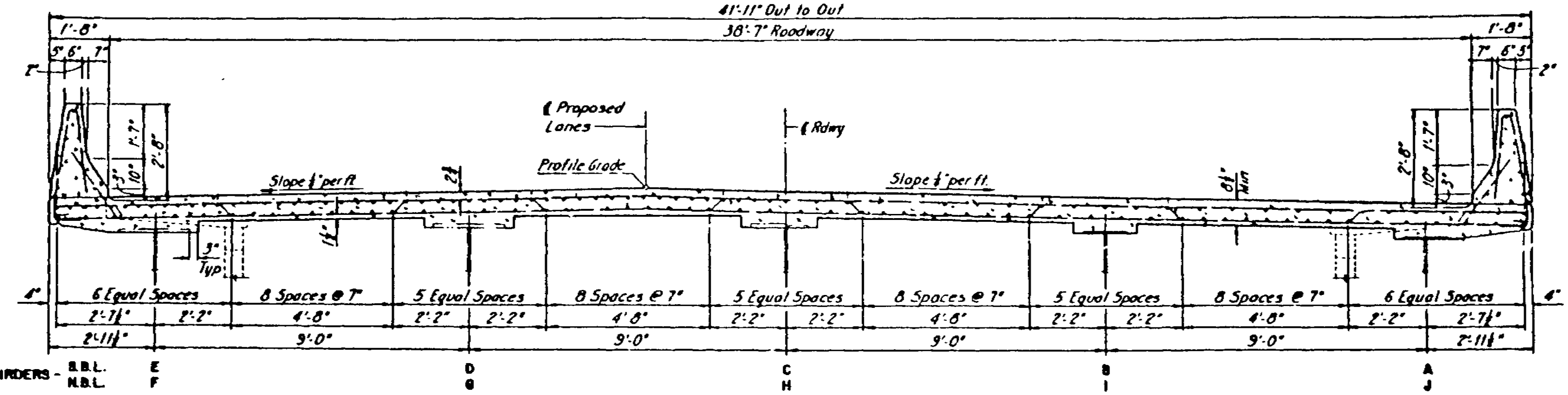

**PLAN**
Scale 1"=40'




**PLAN**
Scale 1"=40'

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF
HIGHWAYS & TRANSPORTATION

# RTE 81 OVER NEW RIVER
# NBL - STRUCTURE 2901
# SBL - STRUCTURE 2900




Looking north on Northbound Lanes. Looking south on Southbound Lanes similar

AT PIERS

AT MID-SPAN

**Note:**
Dimensions are to centers of bars.

**TYPICAL CROSS SECTION**
Scale ¼" = 1'-0"

Girder depth at Piers = 9'-6" plus flange thicknesses.
Intermediate Girder depth = 6'-0" " " "

**RTE 81 OVER NEW RIVER**
**NBL - STRUCTURE 2901**
**SBL - STRUCTURE 2900**

# APPENDIX B

## Special Provision for HMWM for Crack Sealing and Treatment of Concrete Surfaces

VIRGINIA DEPARATMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
**HIGH MOLECULAR WEIGHT METHACRYLATE
FOR CRACK SEALING AND TREATMENT
OF CONCRETE SURFACES**

April 9, 1990
Rev. May 1, 1990

## I. DESCRIPTION

This work shall consist of preparing concrete cracks and concrete surfaces and furnishing and applying High Molecular Weight Methacrylate (HMWM) treatment materials.

## II. MATERIALS

The materials used for sealing cracks and concrete surfaces shall be a low viscosity, non-fuming, HMWM resin from the Department's preapproved products list and conforming to the following:

Resin Specifications:

Physical Properties of Resin

Viscosity: 8-25 cps (Brookfield Model LVT Viscometer, Spindel 1 at 60 RPM)

Specific Gravity: 1.02 to 1.08 @ 77°F

Tensile Elongation $>$ 5% (ASTM D638)

Odor: Low

Performance Properties of Resin

Cure Speed:

| | | |
|---|---|---|
| Bulk Cure | $<$ | 3 hours @ 73°F |
| Surface Cure | $<$ | 8 hours @ 73°F |
| | $<$ | 24 hours @ application temperature |

Gel Time:

20-50 min. at application
Temperature (50 ml sample)

The Contractor shall have a qualified technical representative on-site to provide expert advice to the Contractor on storage, mixing, application, clean-up and disposal of materials.

The promoter and initiator, if supplied separately shall not contact each other directly. Containers of promoters and initiators shall not be stored together in a manner that will allow leakage or spillage from one to contact the containers or material of the other.

A Material Safety Data Sheet (MSDS) shall be furnished for the HMWM resin (promoter, and initiator) to be used on this project. A certification showing conformance to these specifications shall be provided with each batch of resin.

Aggregate Materials shall consist of clean, dry with less than 0.2% moisture, angular grained silica sand and shall be free from dirt, clay, asphalt and other organic materials, Except as otherwise approved by the Engineer, silica sand shall conform to the following gradation for the grading specified:

(Continued)

Percent Passing

| Grading | No. 12 Sieve | No. 16 Sieve | No. 20 Sieve | No. 30 Sieve | No. 100 Sieve |
|---|---|---|---|---|---|
| D | 95-100 | 30-70 | Max. 10 | Max. 3 | Max. 1 |

## III. SURFACE PREPARATION

All concrete surface patches shall cure at least 7 days before High Molecular Weight Methacrylate may be applied.

Tined Surfaces:

Tined Concrete surfaces shall be prepared by air blasting, with oil free compressed air, the surface area designated on the plans using sufficient air pressure to remove all loose material from visible cracks. All accumulations of dirt and debris shall be removed from the surface. The surface and cracks to be treated shall be dry (visual inspection).

Surfaces Without a Tined Texture:

Surfaces with a broom, screeded, worn, or otherwise untined texture shall be prepared by shotblasting the entire surface area designated on the plans to significantly change the color of the concrete surface and to remove all asphaltic material, oils, dirt, rubber, curing compounds, paint, carbonation, laitance, weak surface mortar and other potentially detrimental materials, that may interfere with the bonding and curing of the surface treatment.

## IV. APPLICATION OF HMWM

The concrete surface temperature shall not be less than 55°F and not more than 75°F at the time of resin application for crack sealing. The concrete surface temperature shall not be less than 55°F and not more than 90°F at the time of resin application for deck surface treatment.

Resin shall be applied to cracks at a rate of 1 gallon per 200 linear feet. A broom shall be used to work the resin into the cracks. The curing period will be determined by the manufacturer's technical representative. Additional applications may be required by the Engineer in which the quantities will be adjusted in accordance with Section 104.02 of the specifications. Equipment to apply resin shall consist of a container with a nozzle or an approved roller not more than three inches in width. Resin shall be applied within 10 minutes after addition of the initiator to the resin. Excess resin shall be swept to untreated areas not less than 10 minutes and not more than 20 minutes after resin application. Dry silica sand shall be applied at the rate of 8lbs ± 1lb per square yard to surfaces treated with excess resin.

Excess resin for the purpose of this specification is that which does not fill the cracks and is not absorbed by the concrete surface but fills or partially fills the grooves in a tined deck surface.

Tined Surfaces:

After completion of crack sealing, resin shall be applied to the concrete surface area as detailed on the plans at a rate of 1 gallon per 150 square feet. Excess resin shall be swept to untreated areas not less than 10 minutes and not more than 20 minutes after resin application.

Surfaces Without a Tined Texture.

After completion of crack sealing, resin shall be applied to the designated surface area at a rate of 1 gallon per 60 square feet.

(Continued)

V. APPLICATION OF SAND

The entire treated area of the concrete surface shall have dry silica sand broadcast to effect a visually uniform coverage for tined surfaces a rate of no less than 1 $lb/yd^2$ and surfaces without a tined texture a rate of 8 $lb/yd^2 \pm 1 lb/yd^2$. Sand shall be placed before any gelling of the resin occurs. Excess sand shall be removed after the curing period as determined by the technical representative.

VI. LIMITATIONS OF OPERATIONS

The Contractor shall plan and prosecute his operations in such a manner as to protect persons and vehicles from injury or damage.

Armored joints shall be covered, scuppers plugged and cracks sealed underneath or other protective measures shall be used in such a manner as to protect traffic, waterways and bridge components. In the event material or solvent harms the appearance of bridge components, removal will be required as determined by the Engineer.

Resin for crack sealing shall be applied between 1:00 a.m. and 10:00 a.m.

Traffic will not be permitted on the treated surface until sand cover adheres sufficiently such that no tracking will occur as determined by the Engineer.

VII. METHOD OF MEASUREMENT

Crack sealing will be measured in linear feet.

High Molecular Weight Methacrylate Concrete Surface Treatment will be measured in square yards of surface area.

VIII. BASIS OF PAYMENT

Crack sealing will be paid for at the contract unit price bid per linear foot which price shall be full compensation for preparing cracks, furnishing and applying the resin, providing manufacturer's technical representative, protection of waterways and traffic, cleaning up and for all labor, tools, equipment and incidentals necessary to complete the work.

High Molecular Weight Methacrylate Concrete Surface Treatment will be paid for at the contract unit bid per square yard which price shall be full compensation for preparing concrete surfaces, furnishing and applying the resin, manufacturer's technical representative, protection of waterways and traffic, cleaning up and for all labor, tools, equipment and incidentals necessary to complete the work.

Payment will be made under:

| Pay Item | Pay Unit |
|---|---|
| Crack Sealing | Linear Foot |
| HMWM Concrete Surface Treatment | Square Yard |

# APPENDIX C

## Use of Primers To Improve the Bond Strength of Multiple-Layer Polyester Concrete Overlays

1808

## PURPOSE AND SCOPE

The purpose of this research was to determine the effectiveness of selected primers for improving the bond strength of polyester overlays that are placed under less than ideal conditions.

## TEST INSTALLATION

An ideal opportunity arose on the night of September 28, 1988, during the placement of the overlay on the westbound lane of a bridge on Rte. 33 over the Mattaponi River east of West Point, Virginia. That night, six primers were placed on each of 6 spans approximately 1 hr prior to the placement of the first layer of the three-layer polyester concrete overlay. The deck temperature dropped from 66°F as the primers were applied to 59°F as the first layer of polyester was applied. The primers were applied to spans 7 through 12 between 11:45 p.m. and 12:33 a.m., and the first layer of polyester was applied to spans 7 through 28 between 1:05 a.m. and 3:20 a.m. The primers were mixed in a 5-gal pail, a watering can was used to pour the primers over the deck surface, and stiff bristle brooms were used to brush the primers into the deck surface. A Venus pump and chopper gun were used to apply the polyester resin, and the sand was blown into the air under pressure and allowed to drop onto the resin. The overlay was constructed in accordance with the special provision for multiple-layer polyester concrete overlays. The first layer of polyester resin was opened to traffic at 6:30 a.m. Test patches had been placed and tested on the westbound lane of spans 1 through 33 the previous week. The patches were placed on September 20 when the temperature was 85°F and tested on September 21. Also, the first layer of the overlay had been placed on spans 1 through 6 on September 27 between 12:30 and 1:15 p.m. The deck temperature was 68°F. The second layer of polyester was placed on spans 1 through 33 on October 4 between 9:40 p.m. and 12:45 a.m. (deck temperatures = 62 to 57°F). The third layer was placed on spans 1 through 18 on October 12 between 9:40 a.m. and 1:00 p.m. (deck temperature = 56°F). The contractor was allowed to work between 8:00 a.m. and 4:30 p.m. and 6:00 p.m. to 6:30 a.m., Monday through Thursday. A general summary of the installation of the overlay on the westbound lane is shown in Table C1.

The following materials were used in the installation:

- *Primer, span 7*: a general purpose, one-component polyurethane primer called Deco-Rez Type I supplied by General Polymers
- *Primer, span 8*: a three-component HMWM high modulus primer called T70-P supplied by Transpo Industries
- *Primer, span 9*: a three-component HMWM low modulus primer called T70-X supplied by Transpo Industries
- *Primer, span 10*: a three-component HMWM low modulus primer called RPM-1100-V supplied by Revolan Systems

Table C1

SUMMARY OF OVERLAY INSTALLATION ON WESTBOUND LANE

| Date | Course | Span | Installation Time | Deck Temp. (°F) | Gel Time (min) |
|---|---|---|---|---|---|
| 9/20[a] | 1, 2 | 1–33 | 10:00 a.m.—1:30 p.m. | 85 | 10 |
| 9/27 | 1 | 1–6 | 12:30 p.m.—1:15 p.m. | 68 | 12 |
| 9/28 | 1 | 7–28 | 11:45 p.m.—3:20 a.m. | 66/59 | 34/17 |
| 9/29 | 1 | 29–33 | 8:00 p.m.—9:30 p.m. | 65 | 14 |
| 10/4 | 2 | 1–33 | 9:00 p.m.—12:45 a.m. | 62/57 | 14/18 |
| 10/10 | 3 | 19–33 | 10:00 a.m.—1:30 p.m. | 62 | 13 |
| 10/12 | 3 | 1–18 | 9:40 a.m —1:00 p.m. | 56 | 22 |

[a]Test patches.

- *Primer, span 11*: a three-component HMWM high modulus primer called RPM-2000 supplied by Revolan Systems (routinely used as a primer for polyester overlays in California)
- *Primer, span 12*: a three-component HMWM medium modulus primer called RPM-2000 XT supplied by Revolan Systems
- *Polyester resin*: a one-component, general purpose, unsaturated polyester resin called 32-044 supplied by Reichhold Chemical
- *Aggregate*: a dry angular grained silica sand having the gradation (shown in Table C2).

Table C2

AGGREGATE GRADATION

| Course | No. 8 Sieve | No. 12 Sieve | No. 16 Sieve | No. 20 Sieve | No. 30 Sieve | No. 100 Sieve |
|---|---|---|---|---|---|---|
| 2 & 3 | 95–100 | — | Max. 15 | Max. 5 | Max. 2 | Max. 1 |
| 1 | — | 95–100 | 30–70 | Max. 10 | Max. 3 | Max. 1 |

Note: Numbers indicate percentage passing U.S. Standard Sieve Series.

Table C3 provides a summary of the polyester/primer installations.

# Table C3

## SUMMARY OF POLYESTER/PRIMER INSTALLATION: RTE. 33, WBL, MATTAPONI RIVER, WEST POINT, VIRGINIA

Lane closure: 6:00 p.m. 9/28/88 to 6:30 a.m. 9/29/88
Shotblasted spans 6 through 28 WBL 4th time: 6:00 p.m. to 11:30 p.m.
Blew dust off spans 6 through 25 WBL with compressed air: 11:30 p.m. to 12:28 a.m.
Blew dust off spans 26 through 28 WBL: 2:45 a.m.
Mixed primers in 5-gal bucket and placed with brooms spans 6 through 11 WBL: 11:45 p.m. to 12:33 a.m.
Placed first layer polyester with spray gun, spans 6 through 28 WBL: 1:05 a.m. to 3:20 a.m.
Opened WBL to traffic: 6:30 a.m.
Deck temperature = 66°F @ 11:30 p.m. and 59°F @ 2:15 a.m.

| Span | Primer | Promoter | Initiator | Mix Time | Gel Time | Area Primed | Start Time Polyester[a] | Delay Time Primer—Polyester |
|---|---|---|---|---|---|---|---|---|
| 7 | Gen. Polymers Deco-Rez Type I Polyurethane 5 gal @ 104 ft²/gal | None | None | 11:45 | None | 13 x 40 ft 520 ft² | 1:05 a.m. | 1 hr 20 min |
| 8 | Transpo HMWM T70P 5 gal @ 100 ft²/gal | 200 ml 12% CoN provided by Transpo | 600 ml 78% CuHP VTRC | 12:00 | 1:10 (70 min) | 13 x 40 ft 500 ft² [b] | 1:13 a.m. | 1 hr 13 min |
| 9 | Transpo HMWM T70X 5 gal @ 104 ft²/gal | 200 ml CRC Cobalt provided by Transpo | 400 ml 78% CuHP VTRC | 12:07 | <12:40 (<33 min) | 13 x 40 ft 520 ft² | 1:18 a.m. | 1 hr 11 min |
| 10 | Revolan RPM-1100-V 5 gal @ 104 ft²/gal | 400 ml[c] 6% CoN provided by VTRC | 600 ml[c] 78% CuHP VTRC | 12:15 | <12:40 (<25 min) | 13 x 40 ft 520 ft² | 1:22 a.m. (delay) 1:32 a.m. | 1 hr 7 min 1 hr 17 min |
| 11 | Revolan RPM-2000 5 gal @ 104 ft²/gal | 400 ml[c] 6% CoN provided by VTRC | 600 ml[c] 78% CuHP VTRC | 12:22 | 12:50 (28 min) | 13 x 40 ft 520 ft² | 1:42 a.m. | 1 hr 20 min |
| 12 | Revolan RPM-2000XT 5 gal @ 104 ft²/gal | 400 ml[c] 6% CoN provided by VTRC | 600 ml[c] 78% CuHP VTRC | 12:28 | <12:40 (<12 min) | 13 x 40 ft 520 ft² | 1:47 a.m. | 1 hr 19 min |
| 13 | None | — | — | — | — | — | 1:52 a.m. | — |

[a]Gel time polyester = 33-min sample @ 1:08 and 17-min sample @ 1:55 a.m. (increased MEKP% @ 1:52 a.m.).
[b]Triangle area approximately 5 ft along the center line and 6 ft along the west end of the span was not primed.
[c]Recommended dosages = 300 ml 6% CoN and 300 ml CuHP. Used more because temperature was 66°F @ 11:30 p.m.

## RESULTS OF BOND STRENGTH TESTS

Three tensile adhesion tests were conducted on each of spans 6 through 14 between 10:30 a.m. and 4:15 p.m. on October 25, 1988. The first layer of the overlay and the primers were 27 days old when the tests were conducted with the exception that the first layer on span 6 was 28 days old. Three tensile adhesion tests were conducted on each of spans 6 through 13 on October 12, 1989, after the overlay was in service for 1 year. The results of the tests are shown in Table C4 and summarized in Table C5.

It is obvious from the data in Tables C4 and C5 that each of the six primers provided for an improvement in bond strength. The average bond strength for spans 7 through 12 was 341 psi, which is 43 percent higher than the 238 psi found for the test patches on spans 7 through 12. Unfortunately, the data in Tables C4 and C5 also show that the average bond strength of spans 6, 13, and 14, which represent spans without the primers, was 35 percent less than that of the test patches on spans 6, 13, and 14. It is believed that the bond strength of the overlay without the primers is less than that of the test patches because the first layer of the overlay was not cured as well as the first layer of the test patches. For example, the first layer of the test patches were placed on September 20 during daylight hours when the deck temperature was 85°F (gel time = 10 min). The second layer was placed several hours later and prior to opening the test patches to traffic. On the other hand, the first layer of the overlay was placed at night when it was 59 to 66°F (gel time = 17 min) and later opened to traffic. The second layer was not placed until October 4, 1988. It is believed that the bond strength of the overlay without the primers is also less than that of the test patches because the stress of traffic on the first course damaged the bond before course 2 was placed. The results also show the importance of using a primer to improve bond strength when polyester is placed under less than ideal conditions. In addition, the results show the importance of constructing the test patches under the conditions and with the personnel, equipment, timing, and sequence of events that are anticipated to be encountered during the installation of the overlay. Finally, the test results show that the application of traffic to course 1 prior to placing course 2 causes a reduction in bond strength. The special provision for the multiple layer polyester overlay has been revised to incorporate the findings of this study without significantly changing the first cost of the overlays. A copy of the revised special provision follows on page C-11.

Table C4

ACI 503R TENSILE RUPTURE STRENGTHS (PSI)

| 1988 Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Strength (psi) | | | Failure Mode (%) | | | | |
| | | | | | Base | Base | | | |
| Span | Primer | Avg | S | COV | >1/4 in. | <1/4 in. | Bond | Overlay | Epoxy |
| 6 | None | 212 | 66 | 31 | 0 | 73 | 27 | 0 | 0 |
| 7 | Polyurethane | 361 | 112 | 31 | 33 | 28 | 32 | 7 | 0 |
| 8 | T70P | 351 | 25 | 7 | 100 | 0 | 0 | 0 | 0 |
| 9 | T70X | 268 | 96 | 36 | 100 | 0 | 0 | 0 | 0 |
| 10 | RPM-1100-V | 363 | 83 | 23 | 67 | 13 | 20 | 0 | 0 |
| 11 | RPM-2000 | 338 | 6 | 2 | 33 | 7 | 50 | 10 | 0 |
| 12 | RPM-2000XT | 365 | 85 | 23 | 100 | 0 | 0 | 0 | 0 |
| 13 | None | 163 | 38 | 23 | 0 | 20 | 80 | 0 | 0 |
| 14 | None | 184 | 53 | 29 | 0 | 47 | 53 | 0 | 0 |
| 6[a] | None | 260 | 26 | 10 | 0 | 100 | 0 | 0 | 0 |
| 13[a] | None | 320 | 35 | 11 | 0 | 100 | 0 | 0 | 0 |
| 14[a] | None | 282 | 33 | 12 | 0 | 100 | 0 | 0 | 0 |
| 5–33[a] | None | 269 | 35 | 13 | 17 | 59 | 0 | 12 | 12 |
| 6,13,14[a] | None | 287 | 30 | 11 | 0 | 100 | 0 | 0 | 0 |
| 6,13,14 | None | 186 | 25 | 13 | 0 | 47 | 53 | 0 | 0 |
| 7–12[a] | None | 238 | 53 | 22 | 39 | 61 | 0 | 0 | 0 |
| 7–12 | All | 341 | 37 | 11 | 72 | 8 | 17 | 3 | 0 |

| 1989 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Strength (psi) | | | Failure Mode (%) | | | |
| Span | Primer | Avg | S | COV | Base | Bond | Overlay | Epoxy |
| 6 | None | 198 | 26 | 13 | 57 | 43 | 0 | 0 |
| 7 | Polyurethane | 355 | 96 | 27 | 20 | 17 | 30 | 33 |
| 8 | T70P | 360 | 95 | 26 | 54 | 3 | 43 | 0 |
| 9 | T70X | 284 | 51 | 18 | 17 | 10 | 40 | 33 |
| 10 | RPM-1100-V | 181 | 125 | 69 | 20 | 47 | 33 | 0 |
| 11 | RPM-2000 | 298 | 37 | 13 | 13 | 37 | 50 | 0 |
| 12 | RPM-2000XT | 307 | 58 | 19 | 47 | 6 | 47 | 0 |
| 13 | None | 260 | 35 | 14 | 30 | 20 | 50 | 0 |
| 6 & 13 | None | 229 | 97 | 43 | 43 | 32 | 25 | 0 |
| 7–12 | All | 298 | 90 | 30 | 28 | 20 | 41 | 11 |

[a]Bond tests conducted on test patches 9/21/88.

Table C5

SUMMARY OF ACI 503R TENSILE RUPTURE STRENGTHS (PSI)

| Span | System | Deck Temp. at Installation (°F) | Rupture Strength (psi) | |
|---|---|---|---|---|
| | | | 1988 | 1989 |
| 6, 13, 14 | Polyester test patches | 85 (day) | 287 | — |
| 6, 13, 14 | Polyester overlay | 62 (night) | 186 | 229 |
| 7–12 | Polyester test patches | 85 (day) | 238 | — |
| 8–12 | HMWM primer/polyester overlay | 62 (night) | 337 | 286 |
| 7 | Polyurethane primer/polyester overlay | 62 (night) | 361 | 355 |

## CONCLUSIONS

1. Primers equal to those used in this study can be used to improve the initial bond strength of polyester overlays placed under less than ideal conditions.
2. Test patches must be placed under the conditions and with the personnel and equipment and timing and sequence of events that will be used in the installation of the overlay to ensure that the bond strengths measured for the test patches will be obtained in the overlay.
3. The application of traffic to course 1 prior to placing course 2 causes a significant reduction in bond strength.

## RECOMMENDATIONS

The special provision for multiple-layer polyester concrete overlays should be and has been revised

1. to require the use of primers equal to those used in this study
2. to require that test patches be constructed in a manner that will simulate the construction of the overlay
3. to require that course 2 applications be placed prior to opening the overlay to traffic.

## ACKNOWLEDGMENTS

The author acknowledges the assistance of Cameron Jewell and his crew of Jewell Paining, Inc., who helped with the application of the primers prior to placing the overlay, and Crowder Construction Company for allowing us to place the primers and conduct the bond tests using their traffic control. The author thanks Bob Morecock, District Bridge Engineer, for allowing the experimental installation on his bridge and David Estes, Inspector, for maintaining records and making the necessary contacts to allow for a smooth experimental installation and evaluation. The author appreciates the assistance of Andy Mills, Jr., who made the necessary arrangements and assisted with the installation of the primers and the conducting of the bond tests.

1816

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR MULTIPLE LAYER
POLYESTER/METHACRYLATE CONCRETE OVERLAY

September 20, 1988
Revised November 3, 1988

## I. DESCRIPTION

This work shall consist of preparing deck surfaces and furnishing and applying thin polymer concrete overlays on designated bridge structures in accordance with this specification and in reasonably close conformity with the lines, grades and details shown on the plans or established by the Engineer.

## II. DEFINITION OF TERMS

A. Monomer as used herein is a low viscosity, liquid organic material from which a polymer is made.

B. Polymers are hard glassy solids commonly called plastics.

C. Polymerization is a chemical process by which a monomer is converted to a polymer.

D. Inhibitors are materials that are added to monomers to prevent polymerization from occurring during shipping and storage.

E. Initiators are chemical materials that are required to start the polymerization process.

F. Promoters are chemicals used to accelerate the polymerization process.

## III. MATERIALS

The polymer binder materials for this work shall be from the Department's preapproved products list.

The Contractor shall have a qualified technical representative on-site to provide expert advice to the Contractor on storage, mixing, application, clean-up and disposal of materials.

The promoter and initiator, if supplied separately shall not contact each other directly. Containers of promoters and initiators shall not be stored together in a manner that will allow leakage or spillage from one to contact the containers or material of the other.

A Material Safety Data Sheet (MSDS) shall be furnished for the resins (promoter, and initiator) to be used on this project. A certification showing conformance to these specifications shall be provided with each batch of resin.

### A. High Molecular Weight Methacrylate (HMWM):

#### 1. HMWM Resin

The material used for sealing concrete deck cracks and surfaces shall be a low viscosity, non-fuming, HMWM resin conforming to the following:

Viscosity: 8-25 cps (Brookfield Model LVT Viscometer, Spindel 1 at 60 RPM)

Specific Gravity: 1.02 to 1.08 @ 77°F

Tensile Elongation $>$ 5% (ASTM D638)

Odor: Low

Bulk Cure $<$ 3 hours @ 73°F

(Continued)

Polyester/Methacrylate Concrete Overlay

Gel Time:

10-40 min. at application
Temperature (50 ml sample)

2. Initiators -

Cumene Hydroperoxide unless otherwise recommended by the manufacturer of the resin and approved by the Engineer.

3. Promoters -

Cobalt Naphthenate with approximately 12 % active cobalt in naphtha unless otherwise recommended by the manufacturer of the resin and approved by the Engineer.

4. Initiator - Promoter Quantities -

The quantity of initiator and promotor is affected by mixing efficiency and temperature, and may vary from day to day. The quantity of initiator and promoter shall be determined at the beginning of each day. Unless otherwise recommended by the manufacturer and approved by the Engineer the Gel time should be between 10 and 40 minutes when tested using a container which will produce a depth of approximately 1 to 1 1/2 inches when filled with 50 ml of resin.

Ungelled portion of overlay course represented by a Gel test which has not gelled within 50 minutes shall be removed immediately and replaced at no additional cost to the Department.

B. Polyester Overlay Materials:

1. Monomers Polyester Resin -

A clear, low viscosity, highly resilient, general purpose, unsaturated polyester resin designed for applications requiring toughness and high impact and shall have a viscosity of 100 to 200 cP at 77°F (25°C) using Spindle 2 at 60 RPM on a Brookfield Model LVT viscometer, a tensile elongation of 20-40% (ASTM D638) and, equal to Reichhold Chemicals, Inc. blend Polylite 90-570. All courses shall contain 1% of Union Carbide A-174 coupling agent and 1% of Surfynol S440 wetting agent to enhance bond strength and to reduce surface tension.

2. Initiators -

a. Methyl Ethyl Ketone Peroxide (MEKP) $C_4H_8O_2$ and BPO-40 shall consist of a 60% MEKP in dimethyl phthalate with approximately 9% active oxygen and with a Specific Gravity of 1.15 at 64°F (18°C), shall be in a liquid state with a water white color, with a flash point (Cleveland Open Cup) of above 180°F (82°C) and with a thermal decomposition point (rapid rise) at 302°F (150°C).

b. 40% Benzoyl Peroxide Dispersion (BPO-40) shall be either Reichhold Chemicals, Inc. formulation 46-742, or Witco Chemical's formulation BZQ-40.

3. Promoters -

(a) N,N, Dimethyl Aniline (DMA) $C_6H_4N(CH_3)_2$ shall be technical

(Continued)

grade with a freezing point of 35.8°F (2.1°C), a percentage purity of 98.9 mole, a maximum monomethyl aniline content of 0.5%, a density of 8 lb./gal. (0.96 g/cc), a refractive index of 1.5581.

(b) Cobalt Naphthenate (CoN) shall contain approximately 6% active cobalt in naphtha, shall be in a liquid state with a bluish red color, with a flash point at or above 121°F (49°C), and with a density of 7.5 lb./gal. (0.90 g/cc).

4. Initiator - Promoter Quantities -

The quantity of initiator and promoter is affected by mixing efficiency and temperature, and may vary from day to day. The quantity of initiator and promoter shall be determined at the beginning of each day. Unless otherwise recommended by the manufacture and approved by the Engineer the Gel time should be between 10 and 20 minutes when tested using a container which will produce a depth of approximately 1 to 1 ½ inches when filled with 50 ml of resin.

Ungelled portion of overlay course represented by a Gel test which has not gelled within 30 minutes shall be removed immediately and replaced at no additional cost to the Department.

C. Aggregate Materials shall consist of clean, dry with less than 0.2% moisture, angular grained silica sand and shall be free from dirt, clay, asphalt and other organic materials. Except as otherwise approved by the Engineer, silica sand shall conform to the following gradation for the grading specified:

| No. 4 Sieve | No.8 Sieve | No.16 Sieve |
|---|---|---|
| 100 | 30-75 | Max. 1 |

Note: Numbers indicate percent passing U. S. Standard Sieve Series.

## IV. CONSTRUCTION METHODS

A. Safety Provisions:

Personnel shall be thoroughly trained in the safe handling of materials in accordance with the Manufacturer's recommendations.

B. Storage of Materials:

Information pertaining to the safe practices for the storage, handling and disposal of the materials and to their explosive and flammability characteristics, health hazards and the recommended fire fighting equipment shall be obtained from the manufactures and posted at storage areas. All required fire fighting equipment shall be kept readily accessible at storage areas. A copy of such information shall be provided to the Engineer.

In addition:

1. Monomers - shall be stored in an area separate from the areas in which the initiator is stored. Sufficient ventilation shall be maintained in the storage area to prevent the hazardous buildup of monomer vapor concentration in the storage air space.

2. Initiators - shall be stored in a cool place away from the monomer and promoter storage area.

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3. Promotors - shall be stored in a cool place away from the initiator storage area.

C. Surface Preparation:

Prior to placing the first course, the contractor shall use the test method prescribed in ACI 503R - Appendix A of the ACI Manual of Concrete Practice to determine the cleaning practice (size of shot, flow of shot, forward speed of shotblast machine, and number of passes) necessary to provide a tensile bond strength greater than or equal to 250 psi or a failure area, at a depth of ¼ in. or more into the base concrete, greater than 50% of the test area. A test result shall be the average of three tests on a test patch of approximately 1 ft x 3 ft, consisting of courses one and two. One test result must be obtained for each span or 200 yd which ever is the smaller area. The engineer will designate the location of the test patches. To provide assurance that the cleaning procedure, materials, installation procedure, and curing period will provide the desired overlay, test patches shall be installed with the same materials, equipment, personel, timing, sequence of operations, and curing period prior to opening to traffic, that will be used for the installation of the overlay. The cleaning practice, materials and installation procedure will be approved if one passing test result is obtained from each test area.

If the cleaning practice, materials, and installation procedure are not acceptable, the contractor must remove failed test patches and make the necessary adjustments and test all test areas at no additional cost to the Department until satisfactory test results are obtained.

Before placement of the polyester concrete overlay, the entire deck surface shall be cleaned by shotblasting and other means using the approved cleaning practice to remove asphaltic material, oils, dirt, rubber, curing compounds, paint, carbonation, laitance, weak surface mortar and other potentially detrimental materials, which may interfere with the bonding or curing of the overlay. Acceptable cleaning is usually achieved by significantly changing the color of the concrete and mortar and beginning to expose coarse aggregate particles. Mortar which is sound and soundly bonded to the coarse aggregate must have open pores due to cleaning to be considered adequate for bond. Areas of asphalt larger than one inch in diameter, or smaller areas spaced less than six inches apart, shall be removed. Traffic paint lines shall be considered clean when the concrete has exposed aggregate showing through the paint stripe. A vacuum cleaner shall be used to remove all dust and other loose material.

If the Engineer determines that an approved cleaning practice has changed prior to the completion of the job, the contractor must return to the approved cleaning methods and reclean the suspect areas or verify through tests at no additional cost to the Department that the practice is acceptable.

All patching and cleaning operations shall be inspected and approved prior to placing each layer of the overlay. Any contamination of the deck or to intermediate courses, after initial cleaning, shall be removed. The first two courses shall be applied following the cleaning and prior to opening the area to traffic. The third course shall be placed as soon as practicable, but within seven days.

There shall be no visible moisture present on the surface of the concrete at the time of application of the polymer concrete overlay. Compressed air may be used to dry the deck surface.

D. Equipment:.

The Contractor's equipment shall consist of no less than a polymer distribution system, fine aggregate spreader, broom and sweeper broom or vacuum truck, and a source of lighting if work will be performed at night. The distribution system or distributor shall accurately blend the monomer and initiator/promoter, and shall uniformly and accurately apply the polymer materials at the specified rate

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to the bridge deck in such a manner as to cover approximately 100% of the work area. The fine aggregate spreader shall be propelled in such a manner as to uniformly and accurately apply the dry silica sand at the specified rate over 100% of the work area. The sweeper broom or vacuum truck shall be self-propelled.

With the approval of the Engineer, the Contractor's equipment may consist of calibrated containers, a paddle type mixer, squeegees, rollers and brooms, which are suitable for mixing the resin and applying the resin and aggregate in accordance with the manufacturer's recommendations.

E. Application of Polymer Concrete Overlays:

The handling, mixing and addition of promoters, initiators and monomers shall be performed in a safe manner to achieve the desired results in accordance with the manufacturer's recommendations as approved or directed by the Engineer. Polymer concrete overlay materials shall not be placed when weather or surface conditions are such that the material cannot be properly handled, placed and cured within the specified requirements of traffic control.

The Contractor shall plan and prosecute his operations in such a manner as to protect persons and vehicles from injury or damage and to protect traffic, waterways and bridge components. In the event material or solvent harms the appearance of bridge components, removal will be required as determined by the Engineer.

1. Application of HMWM for Crack Sealing

HMWM Resin shall be applied to cracks which are to be sealed at a rate of 200 linear feet per gallon. The curing period will be determined by the manufacturer's technical representative. Additional applications will be made by increase quantities at the unit bid price for crack sealing. Equipment to apply resin shall be a container with a nozzle or an approved roller not more than three inches in width. Resin shall be applied within 10 minutes after mixing. Excess resin shall be swept to untreated areas not less than 10 minutes and not more than 20 minutes after resin application.

Excess resin for the purpose of this specification is that which does not fill the cracks and is not absorbed by the concrete surface.

2. Polymer Overlay -

The polymer concrete overlay shall be applied in 3 separate courses in accordance with the following rate of application; the total of the 3 applications shall not be less than 5.75 lbs. per square yard.

| Course | Polymer | Polymer Rate (lb./S.Y.) | Silica Sand Rate (lb./S.Y.) |
|---|---|---|---|
| 1 | HMWM | 0.75+0.25-0.0 | 2± |
| 2 | Polymer | 2.00±0.25 | 14±* |
| 3 | Polymer | 3.00±0.25 | 14±* |

* Applicaton of sand shall be of sufficient quantity to completely cover the polymer.

After the polymer mixture has been prepared for the polymer concrete overlay, it shall be immediately and uniformly applied to the surface of the

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bridge deck with spray equipment, a broom, a squeegee or a paint roller. The temperature of the bridge deck surface shall be above 55°F. The dry silica sand shall be applied in such a manner as to cover the polymer mixture completely within 5 minutes. Applications which do not receive enough sand prior to gel shall be removed and replaced before opening to traffic. The second course shall be applied approximately 1 hour after the first course was applied and before the first course is completely cured. The second and third courses shall be cured at least one hour, or until brooming or vacuuming can be performed without tearing or otherwise damaging the surface and no traffic or equipment shall be permitted on the overlay surface during the curing period. After the curing period, all loose silica sand shall be removed from courses 2 and 3 by brooming or vacuuming. All loose sand shall be removed from course 2 prior to placing course 3 and from course 2 and 3 prior to opening to traffic.

Unless otherwise specified the polymer concrete overlay courses shall be applied over the expansion joints of the bridge deck. The expansion joints shall be provided with a bond breaker. Prior to opening any application to traffic, the overlay shall be removed over each joint by removal of tape, bond breakers, or by scoring the overlay prior to gelling, or by saw cutting after cure.

The Contractor shall plan and prosecute the work so as to provide a minimum of 3 hours cure on courses 2 and 3 prior to opening that section to public or construction traffic,unless otherwise permitted. Night operations, or other times of slow curing, the minimum time shall be increased to 4 hours cure or as recommended by the manufacturer so that the compressive strength of 2 In. cubes of the polyester overlay mixture is 1000 PSI prior to opening to traffic. Course 1 applications shall not be opened to traffic.

In the event the Contractor's method of operation or polymer mixture is outside the limitations provided herein, the overlay as placed will be removed and replaced to the satisfaction of the Engineer at no additional cost to the Department.

## V. METHOD OF MEASUREMENT

Crack sealing will be measured in linear feet.

Polymer concrete overlay will be measured in square yards of bridge deck surface for the type specified, complete-in-place.

Repairing of the deck and removing bituminous overlay will be measured and paid for in accordance with Section 416 of the Specifications.

## VI. BASIS OF PAYMENT

Crack sealing will be paid for at the contract unit price bid per linear foot which price shall be full compensation for preparing cracks, furnishing all HMWM resin (initiator and promoter) materials, mixing and applying all HMWM materials, providing manufacturer's technical representative, protection of waterways and traffic, cleaning up and for all labor, tools, equipment and incidentals necessary to complete the work.

Polymer concrete overlay will be paid for at the contract unit price per square yard, which price shall be full compensation for deck preparation and testing, for furnishing and applying polymer concrete overlay courses, for all safety precautions, for any necessary repairs, for saw-cutting expansion joints, and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

Payment will be made under:

| Pay Item | Pay Unit |
|---|---|
| Crack Sealing | Linear Foot |
| Polymer Concrete Overlay | Square Yard |