DEPARTMENT OF MAINTENANCE

Corrective Measures Employing Epoxy Resins on Concrete Bridge Decks

HAROLD W. GOLDBERGER, *Engineer of Maintenance, Garden State Parkway, New Jersey Highway Authority, Red Bank, N. J.*

This paper describes the application of an epoxy polysulfide sealer to the concrete bridge decks of the Bass and Mullica River Bridges on the Garden State Parkway operated by the New Jersey Highway Authority. The main problem on these bridges is deterioration of the concrete decks and curbs from the action of salt penetrating cracks and causing scaled and spalled areas to develop. Corrective measures to date, such as crack sealing and filling spalled areas with asphaltic compounds, have been unsuccessful. Past experience with epoxy compounds let to seeking improved compounds and methods of application to repair and seal the bridge decks from further crack penetration and deterioration in one complete operation. Use of bulk materials in experimentation with various application methods gave a fully automated operation using a troweling compound mixer and a two-component epoxy spray unit plus accessories. Application of non-skid emery aggregate to the freshly applied sealer was accomplished using a sandblaster and an open-end hose. The general result of this automated operation was a skid-resistant road surface. The concrete decks were sealed from the damaging effects of salt and the life of these bridges was extended by this preventive maintenance program.

Other benefits include low cost of application through the training of Parkway maintenance personnel and purchase of material in bulk from the raw material suppliers.

• SEVERAL INFORMAL papers describing the uses of epoxy resins in the highway field were presented at the 39th Annual Meeting of the Highway Research Board. One by the author, entitled "The Use of Epoxy Resins on the New Jersey Turnpike," mentioned varied uses of epoxies in buildings or on structures of the Turnpike. The contents of the paper were published in the March 1960 issue of *Public Works* and in other construction magazines. The applications included patching of spalled areas in concrete bridge decks, filling of cracks in concrete slabs, and surface treatment of various concrete deck areas.

NEW JERSEY TURNPIKE

The epoxy resins employed in these projects on the Turnpike were purchased by the Authority Maintenance

Division in small containers and were blended by makeshift electric mixers. Maintenance personnel were able to patch approximately 15 areas per day at a cost of $150, including labor, traffic protection, and materials, but not including equipment rental cost of Turnpike-owned equipment, tools, etc. A contractor using the same material patched a large number of spalled areas of a concrete viaduct deck. The areas, totaling 3,300 sq ft, were patched at a cost of $26,000, or about $8 per sq ft, including labor, insurance, welfare and pension funds, materials, flagmen, tools, performance bond, overhead, and profit. Because the material was purchased in small containers, the cost for this particular operation was high.

GARDEN STATE PARKWAY

During October 1959, approximately 2,000 sq yd of scaled concrete bridge deck of the Raritan River Bridge on the Garden State Parkway were treated by hand methods with an epoxy sealing compound by an outside contractor at a cost of about $6 per square yard. During a recent inspection of this area of the bridge, it was found that the condition of the sealer is excellent; however, in spite of this proven performance, the high cost per square yard made the use of epoxies prohibitive for applications other than small critical areas.

During the summer and fall of 1960, compounded epoxy polysulfide resins were purchased by the Maintenance Division for use on Parkway concrete bridge decks to seal cracks, patch spalled areas, and as a surface sealant. The epoxy resins were mixed and applied to the decks by means of mechanical equipment. Due to this improvement in application methods, larger areas were completed, application time was reduced, and the resulting cost was considerably lower than for previous applications.

The Garden State Parkway is 173 miles long and extends south from the New York State line to Cape May at the southern tip of New Jersey. The 407 bridges and culverts on the Parkway vary in length from 50 ft to approximately 6,200 ft. The 83 miles of the Parkway north of Toms River carry passenger cars and buses; the southern 90 miles carry a combination of trucks, buses, and passenger cars. The longest bridge north of Toms River is the Raritan River Bridge, which is 4,385 ft long and has a deck width of 60 ft. The three longest bridges south of Toms River are Great Egg Harbor Bay, 6,200 ft long and 27 ft wide; Bass River, 1,023 ft long and 54 ft wide; and Mullica River, 979 ft long and 54 ft wide. Most of the bridges carrying Parkway traffic have been in use since 1954. The average daily number of toll transactions during the peak summer months in 1960 was 320,000.

BRIDGE DECK FAILURES

The main problem on the bridges, as was the case on the New Jersey Turnpike, is a deterioration of the concrete decks and curbs from the action of deicing salt penetrating cracks that form directly over reinforcing steel, causing scaled and spalled areas to develop. The following is quoted from the 39th Annual Meeting paper: "Investigation of deck failures revealed that reinforcing steel was too close to the surface of the concrete. In some cases the steel was within ½ in. of the surface. Where that condition existed, hairline cracks appeared in the concrete deck surface. In time, these cracks became wider due to the use of rock salt or calcium chloride for snow and ice control. Brine formed by melting snow and the rock salt found its way into the cracks and onto the reinforcing steel. The steel rusted under these conditions, expanded, weakened the

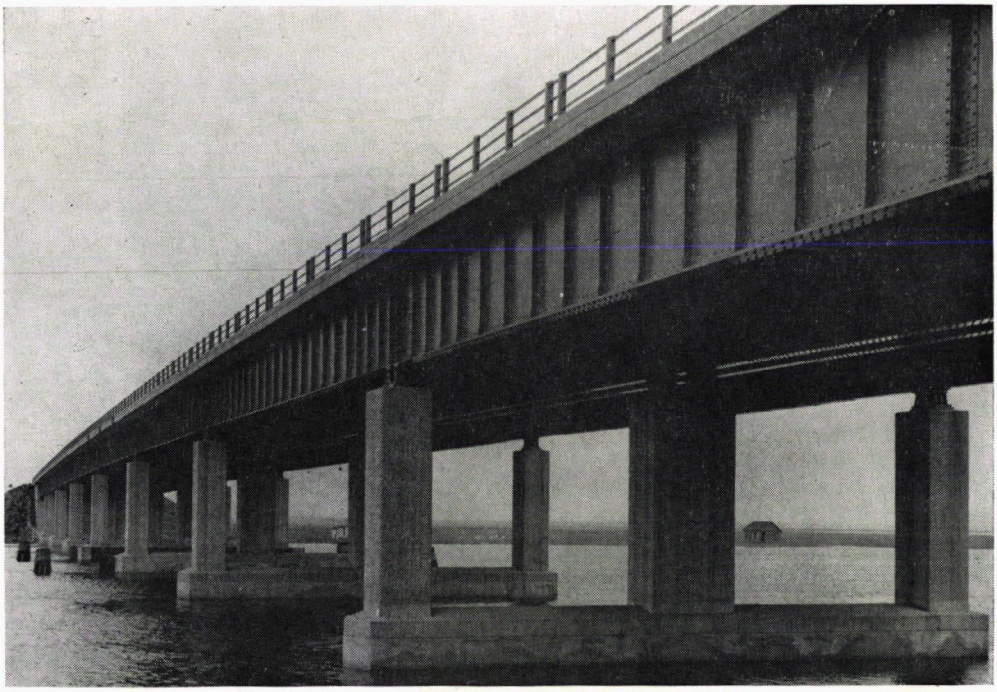

Figure 1. Substructure of Mullica River Bridge.

Figure 2. Typical pattern of surface cracks on roadway.

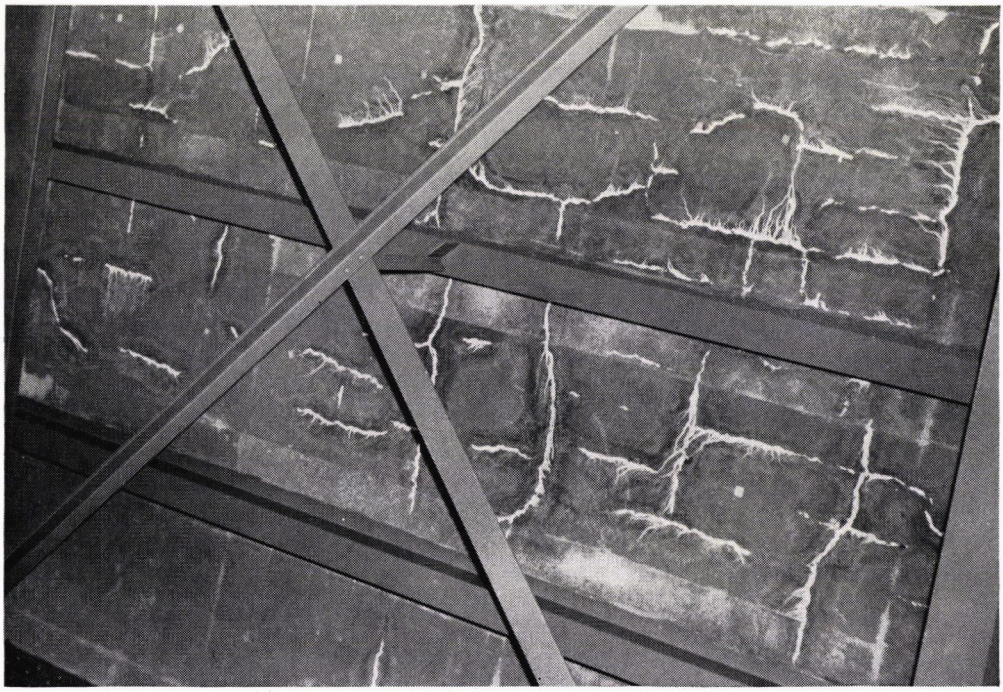

Figure 3. Penetrating cracks as seen from beneath bridge. Patterns follow positions of reinforcing rods.

concrete, and finally a spalled area was formed."

In addition to the spalled areas, numerous hairline cracks were found in most Parkway bridge decks. A careful inspection of the underside of the bridge decks revealed that the crack patterns on the top of the decks were extended completely through the concrete to the underside of the concrete slab. Although these cracks may not seem to be dangerous, they are potential forerunners of spalled or scaled areas. A crack between the curb and the bridge deck permitted the deicing salts to flow down onto the structural steel, causing extensive corrosion damage. In addition, spalled areas appeared along the joint. The repair of each type of damage not only is expensive, but it also inconveniences the traveling public, especially those who pay a toll for the privilege of making a trip on a highway free from stop signs, traffic lights, cross traffic, etc. It was determined from test sections on the New Jersey Turnpike that patched

Figure 4. Spalled area resulting from untreated hairline cracks.

spalled areas did not fail under traffic, but the areas around the patches did fail. The conclusion reached from this behavior is that after a deck is patched, the entire area must be sealed to prevent pavement deterioration.

SEALING OF MULLICA AND BASS RIVER BRIDGE DECKS

Experience with epoxies on the New Jersey Turnpike led to seeking improved compounds and methods of application to repair and seal the bridge decks from further crack penetration and deterioration in one complete operation at a more realistic price. This was accomplished on two structures of the Garden State Parkway by the purchase of 1,100 gal of compound at a delivered price of $9 per gallon. A cooperative effort was initiated by the Union Carbide Plastics Company to train Parkway employees on the job in the proper application of the epoxies. The company made available to the Maintenance Division the latest epoxy handling devices, such as a mechanical troweling compound mixer and two-component spray equipment. The Maintenance Division supplied trucks, small tools, traffic protection, and necessary labor. The bridges sealed by this method were those at the Mullica River and the Bass River, located some 50 and 52 miles north of Cape May. Epoxy polysulfide compound was furnished in 55-gal drums. Manufactured stone sand was used as the aggregate in patching spalled areas; emery grit was used in the seal coating operation to provide a non-skid surface.

SURFACE PREPARATION

Prior to installation of the sealer, it was necessary to remove from the concrete decks an asphalt residue remaining from an unsuccessful sealer application and other foreign road materials, such as motor oils and grease. After experimenting with detergents, the concrete decks were finally cleaned by sand blasting. The entire operation was satisfactory and economical, as 12,000 sq yd of deck were cleaned at a cost of about $300 for materials and rental of equipment.

PATCHING

Several spalled areas and cracks more than ⅛-in. wide in the decks were patched and sealed with epoxy troweling compound mixes. Cracks smaller than this were taken care of in the over-all sealing operation. However, before this patching could be accomplished it was necessary to remove all deteriorated concrete so

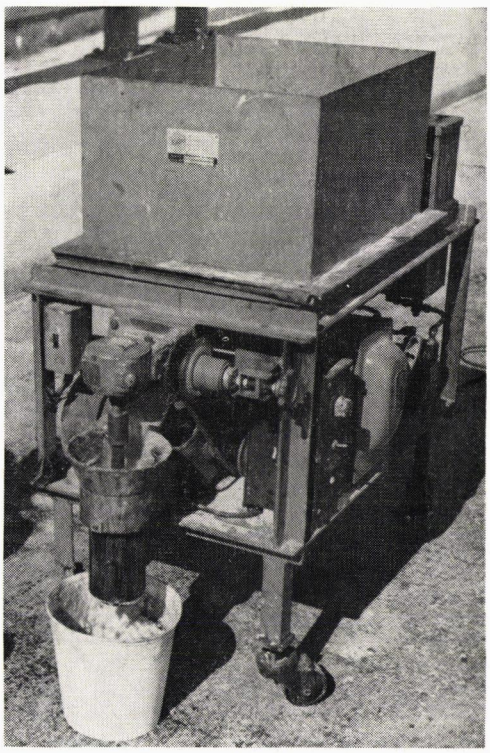

Figure 5. Three-component portable epoxy troweling compound mixer.

that a firm bond between concrete and epoxy could be made. Previous work with epoxies indicated that this was a necessary and important step. Failure to get a good bond would result in the patch lifting at the first freeze. An air compressor and a small chipping hammer easily cleaned out loose material, and all holes and cracks were blown clean with compressed air. The holes were primed with an unfilled epoxy mix and then patched with a sand-filled compound using the epoxy troweling compound mixer, which meters and mixes the epoxy components and sand in a continuous operation. This mixer enables one man to do the work of the three required in earlier patching operations.

SEALING OPERATION

The seal coat was applied to the concrete deck by means of two-component spray guns. The emery grit was broadcast on the tacky epoxy with a conventional sand blaster. Both pieces of equipment, as well as the troweling compound mixer, are described later herein.

EPOXY

The sealer used was epoxy polysulfide compound as formulated by the Thiokol Chemical Company, Hunter-Bristol Division. This sealer compound consists of two parts—an epoxy resin component and a polysulfide hardener component—color coded for identification. These components are mixed together in a volume ratio of 1:1 during the application. When the two components are mixed, a chemical reaction occurs causing the sealer to cure and harden. This formulation is designed to seal and penetrate concrete, give excellent adhesion to concrete, and provide the necessary flexibility to resist freeze-thaw cycles.

The sealer compound was sprayed on the concrete bridge deck at a thickness of 10 to 15 mils, giving a coverage of 100 sq ft per gallon. Under normal conditions, a lane coated with this sealer can be opened to traffic 5 hr after it is applied.

GRIT

Crushed emery No. 20 grit (passing No. 8 screen, retained on No. 30 screen) was broadcast on the surface of the freshly applied sealer coat at a rate of 2 lb per square yard to provide a non-skid surface.

Actually there are many types of aggregate that could be used for this purpose. The crushed emery was chosen because of its ability to retain its original form under extreme traffic and weight conditions.

EQUIPMENT

The two-component spray equipment chosen for applying the epoxy polysulfide was the Pyles Industries Duo-Mix spray gun and Duo-Flo Metering Pump. This spray unit was made available to the Parkway Maintenance Division by the Union Carbide Plastics Company, selected as a result of their experience in evaluating a number of two-component spray units. The spray unit was found to be reliable, rugged, simple and, most important, capable of a high spray rate; that is, 50 gal per hour with the sealer furnished for spray application.

The metering pump consisted of two vertically-mounted piston pumps mechanically linked together and driven by a single reciprocating air cylinder. The pump is set up to draw directly from 55-gal drums, and the lower ends of the two piston pumps actually dip into the resin and hardener drums, respectively. The metering pump was run at a 1:1 ratio of resin to hardener by volume.

The spray gun was of the mechanical mixing, air atomizing type.

The metered streams of resin and hardener are fed into the mixing chamber under low pressure where an agitator driven by a small air motor completely mixes the two components. The mixed stream is then fed to an air atomizing spray head where a fan-shaped spray is formed. A sealer coating of from 10 to 15 mils in thickness was applied at the rate of about 5,000 sq ft per hour. Overspray was at a minimum.

A portable troweling compound mixer, developed at Union Carbide Plastics, simply mixes resin and hardener in proper proportions and blends in sand filler. This model was powered by a small portable generator. The mixer has a maximum output of 1,000 lb per hour.

The emery grit necessary to provide the skid-resistant surface was applied to the sealer with a conventional sand blaster with the blasting nozzle removed, thereby permitting the grit to be sprayed or broadcast across the surface of the freshly applied coating. The 20-grit emery was applied at a rate of approximately 1,100 lb per hour.

The power source required for operation of the spray units and the sand blaster was a diesel-powered air compressor. This machine is capable of producing 315 cfm of air at a pressure of 100 psi. The spray units required 60 cfm at 100 psi and the sand blaster required at least 75 to 80 cfm. As three spray units were used, the total requirements were 260 cfm at 100 psi. The fresh-air respirators worn by the spray operators consumed another 5 or 10 cfm.

To expedite the spraying and emery broadcasting operations, dump trucks owned by the Highway Authority and operated by Maintenance Division personnel were used to haul equipment and materials. Truck No. 1 was used to pull the air compressor and to carry approximately three tons of emery grit, solvent, tools, etc. Truck No. 2 carried, in addition to the spray equipment, hoses, three

Figure 6. Equipment employed in spraying the epoxy sealer.

drums of hardener, a sand blaster, and about 800 lb of emery.

MAINTENANCE EQUIPMENT

The two trucks traveled as a unit with the air compressor between them. When in spraying and broadcasting position, the trucks moved 8 ft at a time to keep ahead of the operations. With this setup the sealer and the emery grit were applied and carried simultaneously. This permitted maintenance personnel to seal a lane 13½ ft wide by 1,000 ft long in about 2 hr. The entire sealing operation involved two drivers, two sand blaster operators, two sprayers, two broom men, one flagman, and one foreman, or ten men in all. As specialized equipment is further developed, the manpower complement will be reduced considerably.

COST OF SEALING OPERATION

The cost of the entire operation on the two bridges for 12,000 sq yd was $12,517, or $1.05 per sq yd, of which the material cost was $0.95 per sq yd. The balance represents Parkway labor costs but does not include rental cost of Authority-owned equipment or Authority overhead.

The same operation performed by a contractor would have cost much more.

SAFETY PRECAUTIONS

In addition to complying with the traffic safety regulations prescribed by the Executive Director of the Authority, safety precautions required when handling and spraying epoxies were carefully followed. Cover-alls, boots, safety glasses, gloves, and hood-type fresh-air respirators were supplied to the men operating the spray equipment. Protective cream was used liberally on the hands and face. Although overspray of sealer and rebounding of grit were slight, normal precautions were observed to protect passing traffic.

CONCLUSION

Based on the work completed on the two bridges the Authority, with the concurrence of its consultants, anticipates within the next five years the patching and sealing of all other bridge decks carrying Parkway traffic. This preventative maintenance program will be accomplished by Parkway maintenance personnel, who will operate Authority-owned equipment using epoxy polysulfide compounds purchased from Parkway-approved suppliers.

The scenic Garden State Parkway needs a sound maintenance program to continue its reputation as an important part of the New Jersey system of good roads and bridges. Epoxies are expected to play a significant role in this program.

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