



COMMONWEALTH OF KENTUCKY  
DEPARTMENT OF HIGHWAYS  
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COMMISSIONER OF HIGHWAYS

ADDRESS REPLY TO  
DEPARTMENT OF HIGHWAYS  
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MEMO TO: D. V. Terrell  
Director of Research

The attached report, "The Use of Epoxy Resin for Sealing Cracks in a Reinforced Concrete Bridge", resulted from an inquiry from the Bridge Construction Engineer's office. Structural cracks developed soon after the removal of false work on two bridges. The structures were inspected by Research Division Engineers and the Bridge Construction Engineer.

Earlier reports on the use of epoxy resin as a cement to fix anti-skid aggregate on bridge floors were available and also information on the tensile strength of the material. After a brief laboratory study of the cementing properties it was decided to try the resin as a crack sealing and cementing agent. Indications to date are that the material has merit for such purposes. We have been advised quite recently that the price for some of the epoxy resin formulations has been reduced to near \$8.00 per gallon. I expect further decreases.

We are investigating the use of epoxy resin for protecting structures against acid water damage and for structural concrete patching.

Mr. T. J. Hopgood, Bridge Maintenance Engineer, requested that we investigate damage to concrete deck and walks apparently resulting from salt action (snow removal chemicals). It now appears that one or more structures will be treated with epoxy resin and possibly other materials in such a manner as to provide information on the relative effectiveness of the materials.

We plan to continue our observations on the Levisa Fork Bridge and to evaluate the other proposed uses of this material.

Respectfully submitted,

  
W. B. Drake

Associate Director of Research

WBD:d1  
Enc.  
cc: Research Committee Members  
Bureau of Public Roads (3)

Commonwealth of Kentucky  
Department of Highways

THE USE OF EPOXY RESIN FOR SEALING  
CRACKS IN A REINFORCED CONCRETE BRIDGE

by

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July, 1959

## INTRODUCTION

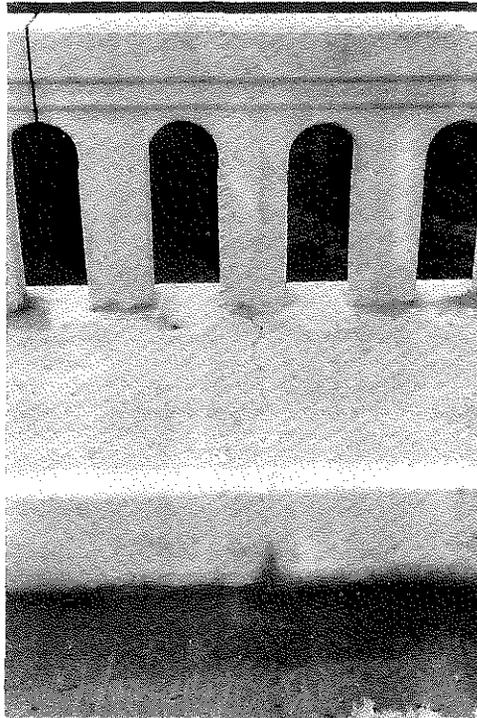
In the summer of 1958, a special formulation of epoxy resin(1) was used to seal hairline cracks in the safety walks of the Levisa-Fork bridge at Paintsville, Kentucky. This bridge, a reinforced concrete box girder-type, Fig. 1, developed fine cracks soon after the falsework was removed. The cracks which were typically like those in Figs. 2 and 3, occurred in two areas, each extending about 30 ft. on either side of the center piers. They were through the full depth of the slab and ranged from about .005 in. to .031 in. in width. In all, there were 55 cracks averaging 3 ft. in length, making a total of 165 lineal ft. of cracks to be sealed.

After conducting laboratory investigations to test the flexural and bonding strengths and penetrating ability of the epoxy formulation, "Reliance Relcote 6.0", Figs. 4 and 5, it was concluded that this material would be suitable for sealing cracks in structural concrete (2). The resin's strength and resistance to water, weather, and corrosion were considered sufficient to protect the concrete and steel exposed by the cracks.

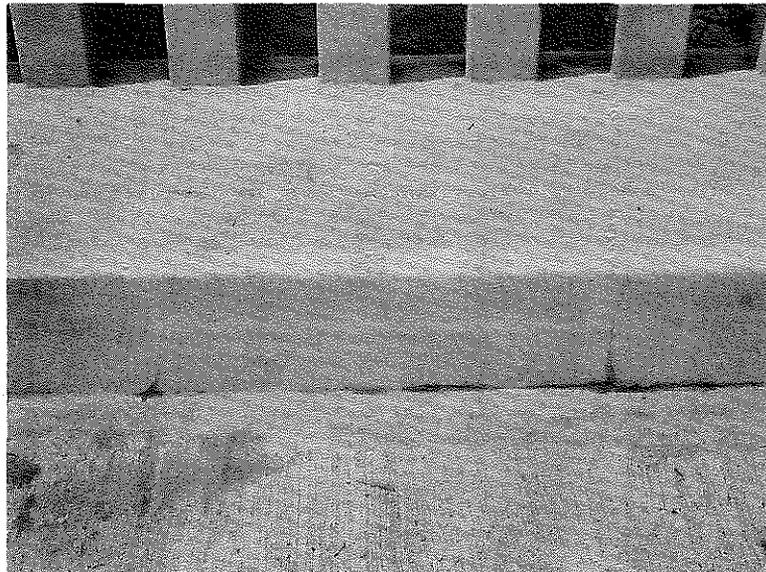
## METHOD

Dry weather and temperatures above 50°F were necessary for proper application of the epoxy resin formulation. The applications were made during dry weather on two different days at average

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- (1) A brief description of this material is given in Appendix A
  - (2) A special proposed specification is available covering this application - Appendix B



**Fig. 2.** A Crack Typical of the Wider Cracks in the Safety Walk, Before Treatment. The crack was filled with moisture from a light rain. The presence of any moisture such as this in a crack to be treated with epoxy would be unacceptable.



**Fig. 3.** Typical Hairline Cracks in the Safety Walk before Treatment. These cracks had moisture in them from a light rain and it was necessary to wait for a period of dry weather before treatment.

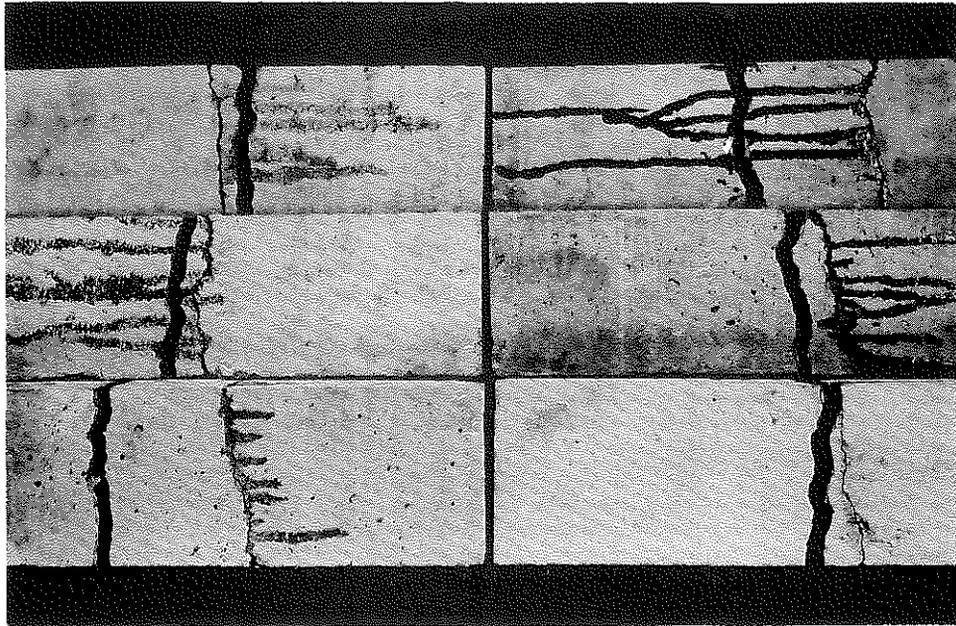


Fig. 4. These Six 3" x 5" x 30" Flexural Strength Test Beams were Broken and then Welded Back Together with the Epoxy Resin Used on the Bridge. Twenty-four hours later they were subjected to flexure test again, and the breaks occurred at a different place. The cementing material thus withstood an average of 850 psi in flexure.

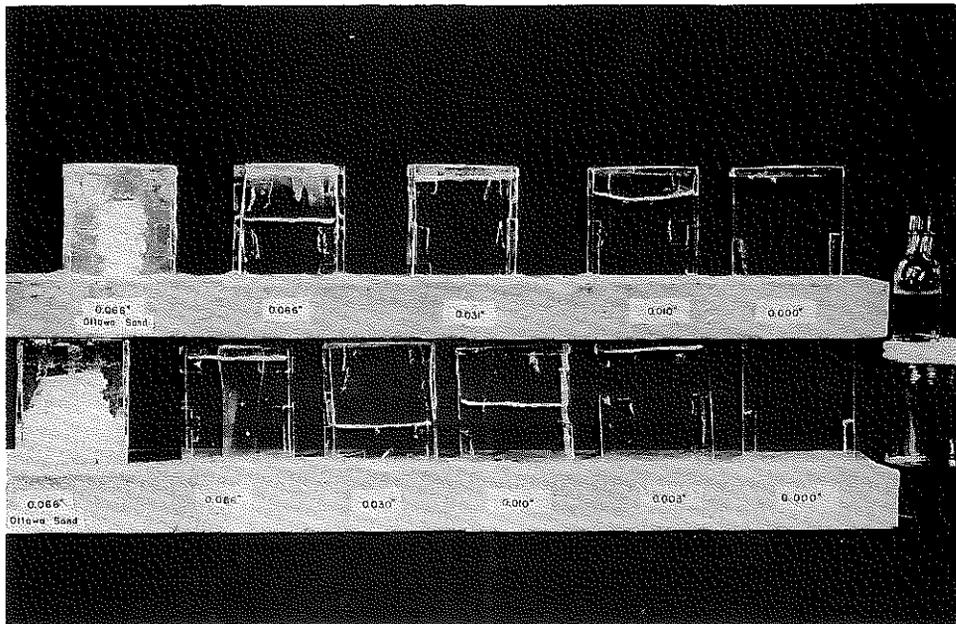


Fig. 5. Glass Plates were Spaced as Labels Indicate. Epoxy resin was poured into the cracks thus formed to test its penetrating ability. The resin penetrated to the bottoms of the cracks and filled them up to the lines marked on the plates. The cracks formed by the plates on the left were filled with graded Ottawa sand before epoxy was applied. Penetration into the sand-filled cracks was also good.

temperatures of 75°F and 95°F. The higher temperature proved to be undesirable because the reaction between the resin and hardener was accelerated so much that working time (pot-life) before the resin hardened was very short. On the other hand, a temperature of 75°F did not cause any adverse effects.

Unfortunately, before the cracks were treated, the bridge was opened to traffic. Traffic passing over the bridge filled the open cracks with dust and dirt, making rigorous cleaning necessary. Thorough cleaning was accomplished with chisels, brushes and compressed air, so that no foreign particles, greases, or moisture would interfere with the bond between the epoxy resin and the concrete and steel. When the cracks were clean and dry, the two components of the formulation were mixed, starting the chemical reaction which would result in rapid hardening of the material. The resinous mixture was then carefully poured from a cup, with a spout, onto a crack so that a fine bead slightly larger than the crack opening was formed over the crack, Figs. 6 & 7. Resin from this bead immediately began to penetrate into the cracks. Additional material was applied within a short period of time until no further penetration occurred - indicating that the cracks were filled. Small bristle brushes and putty knives were used to work the material into the cracks where necessary.

Even though the cracks extended through the full depth of the slab, no material was wasted at the bottom. These cracks were all found to be smaller at the bottom than at the top so that material poured into a relatively wide opening at the top of the crack did not pass completely through and waste. If the cracks had been the same width

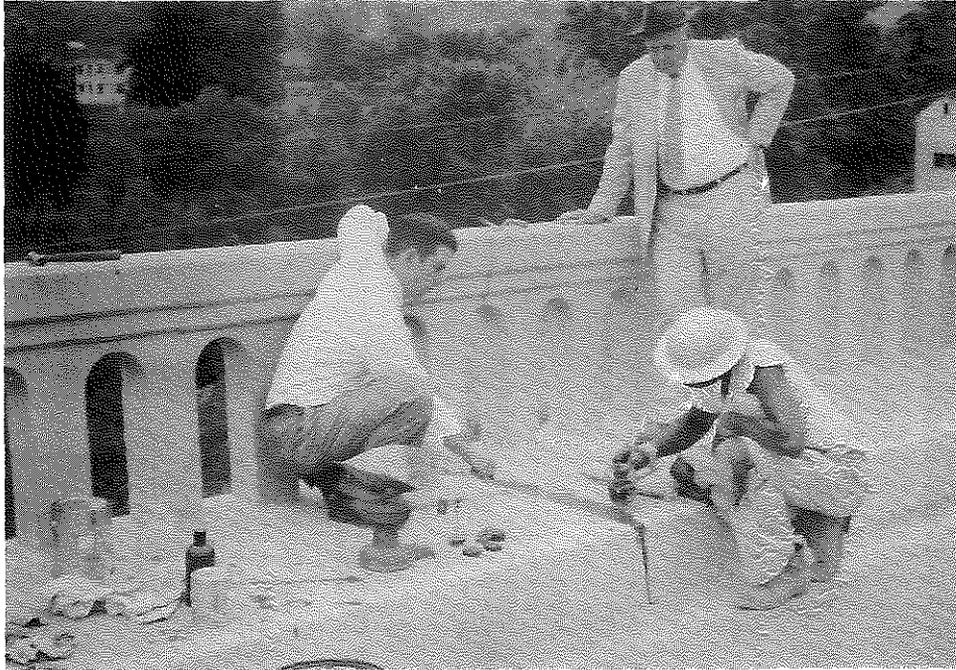


Fig. 6. The Mixed Epoxy Resin is Being Poured into a Clean Dry Crack.

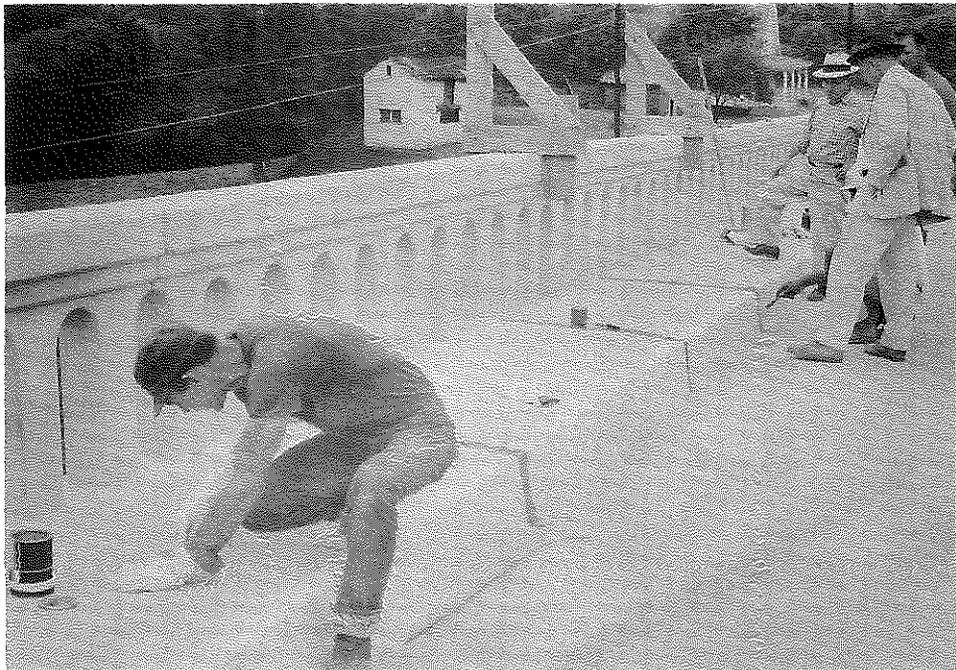


Fig. 7. The Resin is Being Worked into the Cracks with Brushes and Putty Knives.

through the slab, it would have been necessary to tape or otherwise seal them temporarily at the bottom in order to contain the resin until it hardened.

It was considered desirable to give the sealing material a color and texture as much like that of the adjacent concrete as possible. Since the resin was an amber color, a fine white silica sand was sprinkled on the crack surfaces to obtain a concrete color and a durable non-skid finish. Then the mixture of sand and resin covering the crack was smoothed out with a putty knife and brush to conform with the finish of the concrete, Figs. 8 and 9. This completed the application phase of the crack sealing and the material was allowed to harden and cure for several weeks. After hardening, the swath of resin and sand covering the cracks was rubbed vigorously with a carborundum block to obtain a non-glossy concrete-like surface, Figs. 10, 11 and 12.

It is important to note that traffic was maintained on the bridge during the application and curing. The vibrations caused by passing traffic did not appear to be harmful or to prevent proper setting of the sealer. Actually the resin hardened and had attained sufficiently high strength for the repair in less than 8 hours. The setting time varied with prevailing temperatures as mentioned before.



Fig. 8. This is a Typical Crack After the Resin and Sand has been Applied and the Mixture Flattened out to Fit the Contour of the Existing Concrete.

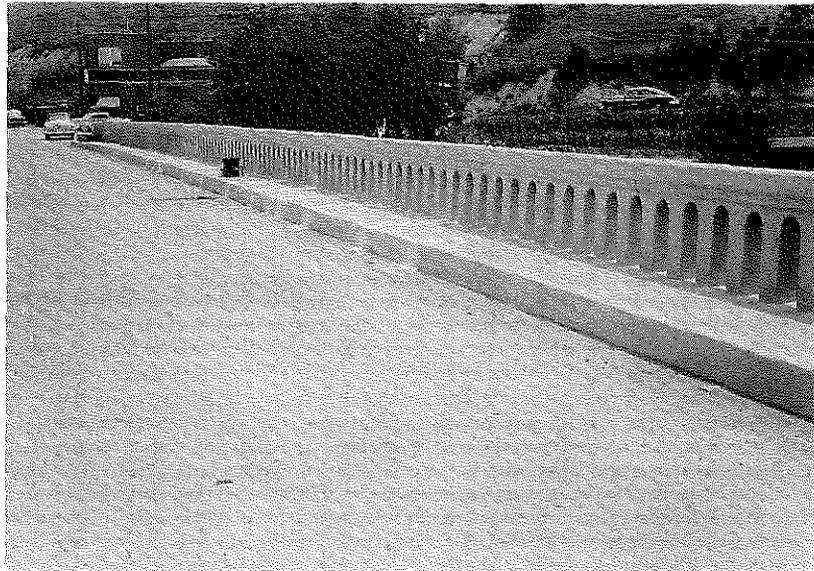


Fig. 9. This is a View of the Cracks in the Safety Walk on One Side of the Bridge Over One Center Pier. The cracks have been filled and the sand applied and the material was curing.

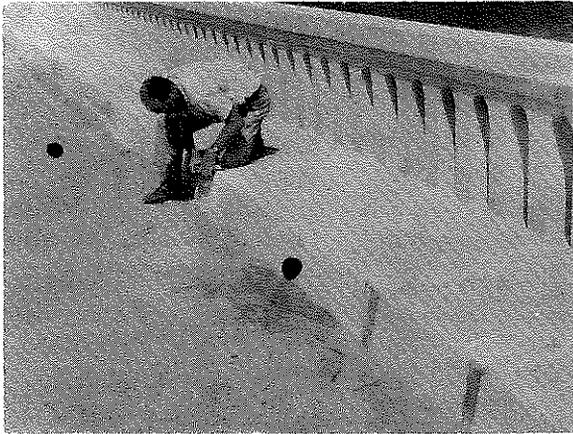


Fig. 10. The Material Used in Repairing the Cracks in this Figure has Cured and a Carborundum Finishing Stone is being Used to Obtain a Non-Glossy Concrete-Like Finish.

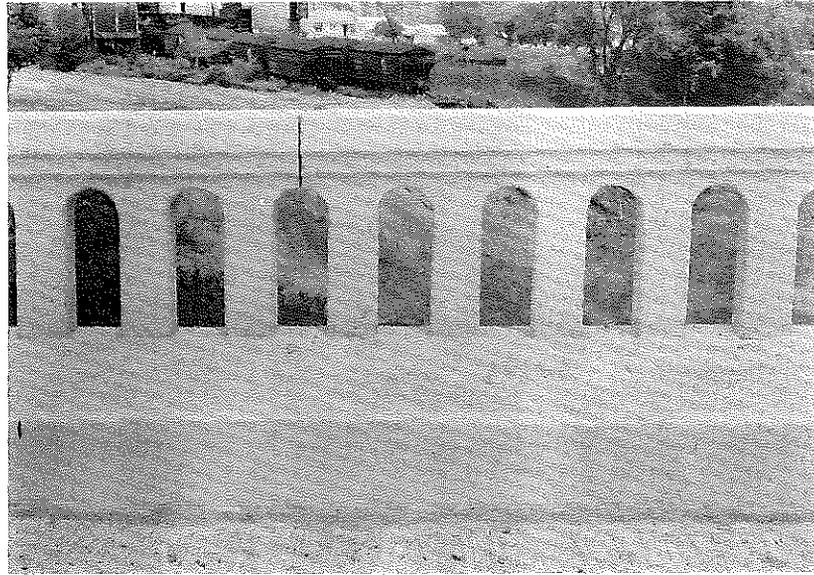
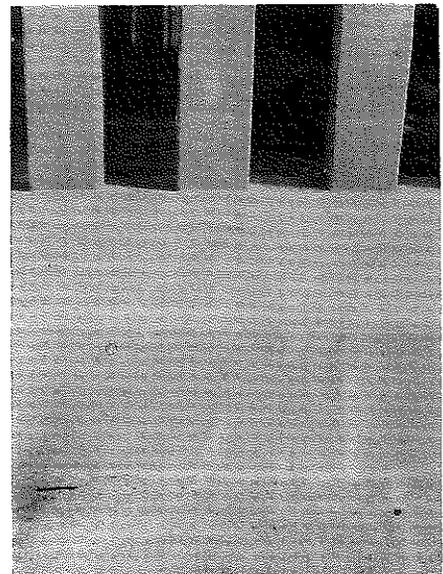


Fig. 11. These are 2 Typical Cracks Just After Rubbing With a Carborundum Block.

Fig. 12. The Treatment of this Crack had been Completed and it was Ready for Service.



## COST

The cost of this treatment was as follows:

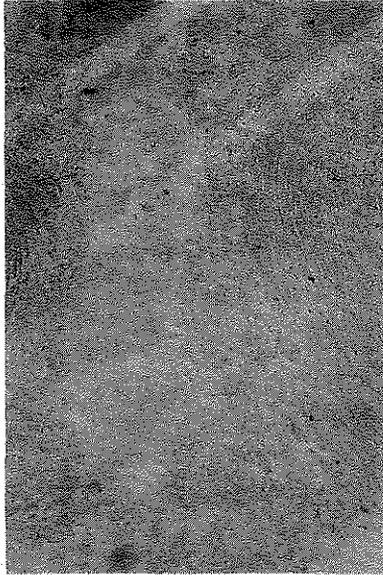
2 gallons epoxy resin	\$ 34.66
Labor, 62 man hours	248.00
White sand	10.00
Cleaning equipment	30.00
Miscellaneous	<u>10.00</u>
Total Cost	\$332.66

This amounted to approximately \$2.02 per lineal ft. of crack.

## PERFORMANCE

Inspections have been made subsequent to filling these cracks, and no changes have been observed. The most significant inspection was made in January of 1959, about 6 months after completion of the work. At that time, the temperature was approximately 30°F, some 45° to 65° below the temperatures at which the cracks were filled, and it was estimated that this reduction in temperature would cause sizeable stresses in the slabs because of thermal contraction. Even under these conditions no failures in the treated cracks were observed, Figs. 13, 14 and 15.

In order to test the cracks for water tightness, they were flooded with water, Figs. 16 and 17, and watched closely to detect any water seepage. None was apparent. The wetted cracks were also observed when nearly dry, and it was apparent that water had not entered the cracks because there was no water remaining in the cracks after adjacent surfaces had dried, Fig. 18.



**Fig. 13. This Close-up of a Typical Treated Crack after 6 Months Exposure Showed no Change.**



**Fig. 14. This Crack Appeared to be in Good Condition after 6 Months Exposure.**

**Fig. 15. The Appearance of These Cracks Hadn't Changed after 6 Months Service.**

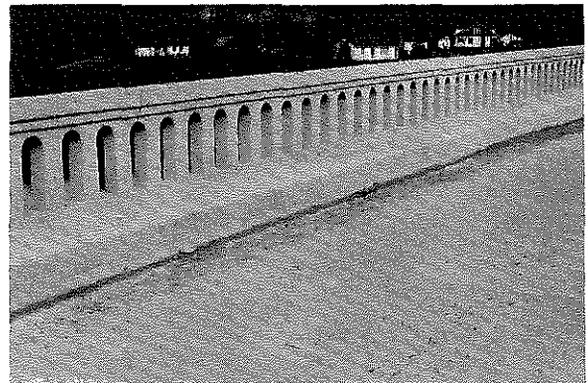




Fig. 16. This is a Typical Crack After 6 Months Service which was Flooded to Detect any Seepage. No water entered the crack and its water tightness was verified. The outline of the crack can be seen here through the thin covering of transparent resin. If it had been possible to apply more sand before the swath of resin hardened the sealed crack would not have been visible. However, the crack was sealed and the concrete and steel protected.



Fig. 17. This Close-up of a Flooded Crack Showed the Effect Obtained with a Thicker Coating of epoxy and sand. The crack was well sealed as evidenced by its refusal to allow ingress of water.

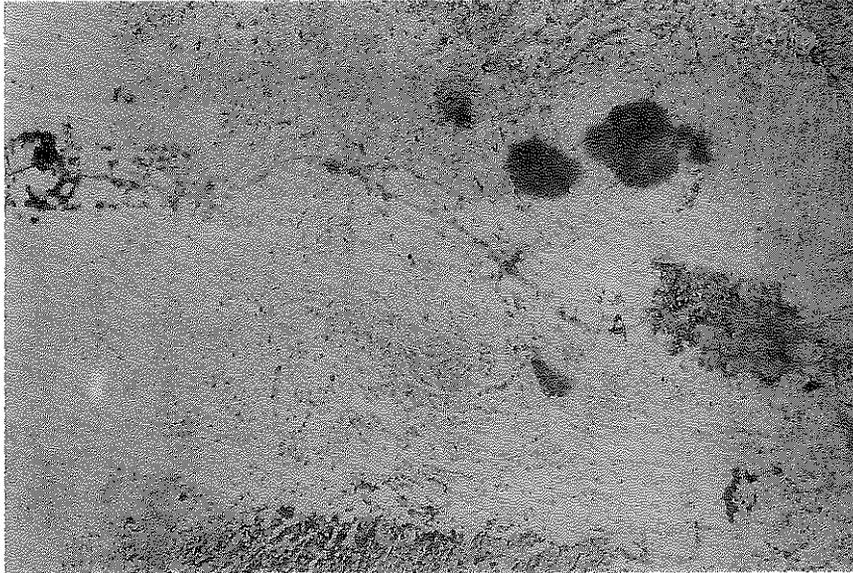


Fig. 18. This was the Appearance of One of the Flooded Cracks when it was just Barely Surface Dry. Apparently, no moisture was trapped in the crack where it would have evaporated more slowly and would have been detected.

### CONCLUSIONS

To date, the cracks in the safety walk of the Levisa-Fork R. C. B. G. bridge have been effectively sealed. In addition, the slabs appear to have been repaired structurally. Also, the repairs have been accomplished in such a manner that the appearance of the bridge has not been altered.

The cost of the repair of these cracks does not seem to be excessive, and it can be assumed that similar work could be done more economically in the future as methods are improved.

This project will be kept under observation to determine the permanency of the repairs, and any further developments will be recorded and reported.

## APPENDIX A

Epoxy resin is a transparent amber-colored thermo-setting liquid plastic which is supplied in two parts, i. e., a basic resin component and a hardener.

Epoxies are produced by the reaction between epichlorohydrin and bisphenol, or by the condensation of epichlorohydrin, phenol, and acetone. Two broad classes are available: solid resins, which are modified by blending with other resins and/or fatty acid drying oils (esterfication); and liquid resins which are hardened by a catalyst. The hard resins are usually modified and dissolved in liquid hydrocarbons and are used in coatings such as paints and varnishes. There is, of course, a volume change attending the evaporation of the solvent. The liquid resins are catalyzed with liquid amines or acid anhydrides. Some of the amines "trigger" the reaction at temperatures as low as 50 °F. The reaction is exothermic and is accelerated by its own heat. This setting involves very little volume change, probably less than 1%. The unmodified epoxies cure to hard, inflexible resins, whereas those blended with liquid polyamides (versamids) or polysulfides (Thiokol) have increased toughness and flexibility. The liquid resins are suitable for precise potting, casting, and encapsulating, and even for making tools and dies, jigs and prototype models. The tensile strength of the unmodified resin is in the order of 10,000 psi.

Many formulations of epoxy resins are available with various modifications of the resins basic properties. However, the characteristics of the epoxies which are most important in applications with concrete are:

1. High tensile and compressive strengths much higher than those of concrete.
2. High strength bond to concrete and steel and many other materials.
3. Toughness - hard, but not brittle.
4. Imperviousness to water.
5. High resistance to weather.
6. High resistance to corrosive chemicals.
7. High wearing ability.
8. Light weight.
9. Approximately the same coefficient of thermal expansion as portland cement concrete with proper fillers.
10. Color variability.
11. Controllable viscosity - low to high.
12. Room temperature curing.
13. Controllable setting time - rapid to slow.
14. Chemical hardening with almost no shrinkage.
15. Miscibility with sand and grit to make mortars and non-skid surfaces.

These resins are fairly expensive, averaging \$17.50 per gallon, and careful consideration must be given to the costs of specific jobs on this basis. Notwithstanding, many applications can be fore-seen where expenditures at this level can be justified, and significant reductions in price are anticipated as these materials are more fully developed.

## APPENDIX B

PROPOSED SPECIAL SPECIFICATION NO. \_\_\_\_\_

### SEALING CRACKS IN CONCRETE WITH EPOXY RESIN

This Special Specification, No. \_\_\_\_\_, covers the requirements, materials, and methods of application for a special crack-sealing compound for use on concrete structures and decks. It shall be applicable when indicated on plans, proposals, or in special contract provisions.

#### 1. DESCRIPTION

This work shall consist of, and shall include, the furnishing of crack-sealing materials as herein specified and the application thereof, all in accordance with these specifications.

#### 2. MATERIALS

The crack-sealing material shall consist of a modified liquid epoxy resin and a catalyst which shall be provided in the proper proportions for blending at the work site. A fine silica sand shall be provided for filling and covering the resin.

A. Epoxy Resin-Catalyst. The resin shall be a liquid epoxy composed of 100 percent reactive constituents. The epoxide equivalent shall be between 140 and 210. The catalyst shall be a 100 percent reactive agent which will function at ambient temperatures between 40° and 100°F.

These components shall be formulated to produce a penetrating, low-viscosity liquid with a pot-life of not less than 60 minutes at 75°F

ambient temperature . Their conversion or "set" shall be complete to the extent that the repairs will be serviceable within 18 hours at 75°F . No volatile substances will be incorporated into the sealing material and no more than 2 percent shrinkage will be tolerated.

B. Silica Sand. The silica sand shall be a white, angular quartz sand, free of iron oxides, organic matter or other objectionable impurities. The sand shall conform to the following gradation:

<u>Sieve</u>	<u>Percent Passing</u>
No. 30	95-100
No. 40	90-100
No. 100	5-50
No. 200	0-15

### 3. EQUIPMENT

Equipment shall include an air compressor fully equipped with hose and cleaning nozzles, hand tools such as putty knives, paint brushes, wire brushes, brooms, cans or glass jars with pouring spouts, and carborundum rubbing bricks, and other incidentals necessary for cleaning the repair area, mixing and applying the materials, and finishing the sealed cracks.

Note: The catalyst used with the resin may be strongly basic and direct contact with the skin should be avoided. In case of accidental contact, the skin should be flushed immediately with white vinegar and thoroughly washed with soap and water. Prolonged or repeated breathing of the vapors of these materials should also be avoided. Tools and clothing may be cleaned with toluene or acetone if used before the resin has hardened. After the resin has set, it can not be cleaned off of tools or clothing.

#### 4. METHOD OF APPLICATION

A. Preparation of Cracks for Sealing. Cracks should be thoroughly cleaned to remove oil, grease, bitumen or other materials likely to interfere with the bonding action between the resin and concrete. If the crack extends through the slab or concrete member such that the resin might drain through and be wasted, the crack shall be sealed at the bottom with tape, putty, or paint prior to pouring. Sufficient length of crack should be prepared ahead of the sealing operation to use each batch of prepared resin in less than 30 minutes, at an ambient temperature of 75°F.

B. Preparation of Resin. Resin and catalyst shall be combined in the directed proportions and thoroughly mixed immediately before application. Usually batches of less than one quart will prove most advantageous, since larger quantities generate considerable heat, which decreases the setting time.

C. Application and Sealing. The sealing material shall be poured onto the crack from a small container with a pouring spout. A bead approximately 1/2" wide shall be formed on the crack. As the material penetrates into the crack, more shall be added until the crack is full. At this point a slightly different treatment will be necessary if (1) the surface of the concrete has a broomed finish, or (2) if the surface of the concrete has a trowled finish. In case (1) above, the excess material on the surface of the crack shall be smoothed out with a stiff bristle paint brush, brushing in the direction of the brooming, thereby leaving a thin swath of material covering an area approximately 1" on either side of the crack. If the crack is

still full, the silica sand, previously provided, shall be sprinkled sparingly on the swath of material covering the crack. The sand shall then be smoothed into the swath of epoxy resin covering the crack with a stiff bristle paint brush (brushing in the direction of the brooming). There shall be sufficient sand in and on the coating of resin so that it appears like mortar, but there shall not be excess material filling the broomed grooves or making the swath thicker than 1-1/2 times the diameter of the largest particles in the silica sand. In case (2) above, the excess material on the surface of the crack shall be smoothed out with a wide putty knife and/or a brush, thereby leaving a thin swath of material covering an area approximately 1" on either side of the crack. If the crack is still full, the silica sand, previously provided, shall be sprinkled generously on the swath of material covering the crack. The sand shall then be smoothed into the swath of epoxy resin covering the crack with a putty knife. There shall be sufficient sand in and on the coating of resin so that it appears like mortar, but the coating shall not be thicker than 1-1/2 times the diameter of the largest particles in the silica sand.

The resin shall be allowed to cure a minimum of 24 hours at an ambient temperature of 75°F or above to insure complete initial setting before finishing procedures are begun. However, at lower temperatures the necessary curing time may be greatly extended, and the work shall be observed closely to determine when the material has cured.

D. Finishing. After the material has reached its initial set the excess silica sand shall be broomed off the covered cracks and

(1) for broomed surfaces, a stiff wire brush shall be used (brushing in the direction of the brooming) to smooth the coating of epoxy resin and fine silica sand, (2) for smooth surfaces, a carborundum rubbing block shall be used to smooth the coating of epoxy resin and fine silica sand. This procedure shall give the repair work a concrete-like texture.

#### 5. METHOD OF MEASUREMENT

The unit of measurement shall be a lineal foot of sealed crack.

#### 6. BASIS OF PAYMENT

The quantity of work thus determined shall be paid for at the contract unit price per lineal foot of sealed crack, and this price shall be full compensation for all materials and work herein prescribed including all equipment, tools, labor and incidentals necessary to complete the work.