# AN ELECTRICAL METHOD FOR EVALUATING BRIDGE DECK COATINGS

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An electrical method for evaluating bridge deck coatings is being experimentally used on California highway bridges. Field and laboratory tests have indicated that the electrical resistance of a bridge deck coating can be related to the voids and, thus, sealing ability of the coating. This nondestructive method for evaluating bridge deck coatings may be an additional tool for evaluating the performance of membranes used to prevent the ingress of de-icing salts that cause corrosion of the steel.

•IN RECENT years, an increasing amount of attention is being devoted to the problem of bridge deck deterioration (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11). Most recently, the Highway Research Board has published a finding that indicates that one of the most significant causes of bridge deck deterioration is spalling of the concrete resulting from the use of de-icing chemicals (12). In general, the spalling of the concrete has been found to be the result of corrosion of reinforcing steel (10, 11, 12). One method to prevent the corrosion of the steel caused by de-icing salt is to apply a waterproof membrane to the bridge deck (12) before any salt is used. However, the authors have not found any literature that describes a technique for the field evaluation of the waterproofing ability of bridge deck seals. It has been reported that a measure of the performance of a membrane is its ability to remain in place on the deck surface (3, 12, 13). In this study, one additional criteria for performance of a bridge deck coating is that it be a waterproof membrane. In the case of a dielectric material being used in the seal, it is assumed that the electrical resistance of the coating should be a measure of the waterproofing ability of the coating. For example, it is assumed that, if a coating is porous and water can pass through these pores, then the coating should have a low electrical resistance because of the multiple paths that are available for current flow. Conversely, if the coating is not porous and is of a dielectric nature, then the electrical resistance of the coating should be high. Although the authors are not aware of any specific reports concerning measuring of the electrical resistance of bridge deck coatings, they are aware that such techniques have been previously utilized on buried pipelines (14). Therefore, the concept of the measurement of electrical resistance of a coating is not considered to be new, but the use of this technique as applied to the measurement of the electrical resistance of bridge deck coatings may be unique.

## INSTRUMENTATION

The basic concept for the instrumentation is to connect one lead of the ohmmeter to a plate or contact that could be placed on the surface of the bridge deck and thus measure gross electrical resistance. This arrangement would permit the measurement of the electrical resistance from the reinforcing steel through the concrete, through the membrane or surface coatings or both, and then to the contact placed on top of the deck surface. The measurement of the electrical resistance on the surface of the bridge was facilitated by the use of a moist sponge as a conducting medium that will electrically complete the current (Fig. 1). In the construction of the contact, a piece of copper

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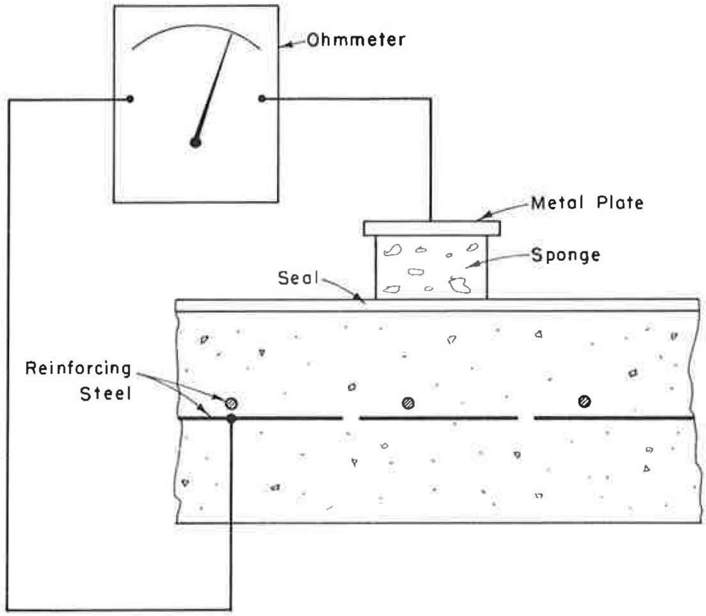


Figure 1. Method for measuring resistance.

plate, 7 by 9 by ⅛ in. thick, was used and an electrical connection was made to the plate. A nonmetallic handle was attached to the plate for convenience in moving and placing the plate at various points on the bridge surface. Two sponges totaling about 63 in.$^2$ of area on the bottom of the plate facilitate contact with the surface. These sponges are attached by means of wooden dowels that are inserted into the sponges and secured to the plate. Because many bridge deck surfaces contain an asphaltic concrete wearing surface, water containing a wetting agent was utilized to increase the rapidity of the penetration through the asphaltic concrete. The wetting agent used is a nontoxic, nonvolatile, practically odorless ester of a sulphonated dicarboxylic acid. The wetting agent is mixed with water at the ratio of about 95 ml of wetting agent to 5 gal of water and has a specific resistance of 2,350 ohm/cm.

The ohmmeter used was an ordinary general purpose voltmeter having an input impedance of 100,000 ohms/volt in the dc voltage ranges and a maximum readable resistance value of 200 million ohms. Figure 2 shows the metal plate contact assembly that is touched to the surface of the concrete to measure the gross electrical resistance. Figure 3 shows the general setup and operations for measuring the electrical resistance of the coating.

In the use of direct current ohmmeters, a problem of nonreproducible values has developed when low electrical resistance values are measured. The cause of this problem is the generation of an external voltage that results from the galvanic coupling of the copper plate to the reinforcing steel. Normally, when external galvanic voltages are present, they cannot be balanced out by shorting of the instrument leads as is normally done. Therefore, depending on the magnitude of the external galvanic voltages that exist, gross errors can occur in the low resistance ranges. For example, with the leads connected with one polarity, the apparently measured values can be in the order of 1,000 ohms. By reversing the leads or polarity, the resistance values can be in the order of 3,000 or 4,000 ohms.

Two techniques for measuring coating resistance have been utilized. One is by obtaining at least 20 resistance measurements at random across the deck. The values are then plotted on probability paper as shown in Figure 4. The other method is to systematically measure the resistance values on approximately 5-ft interval grid across the bridge

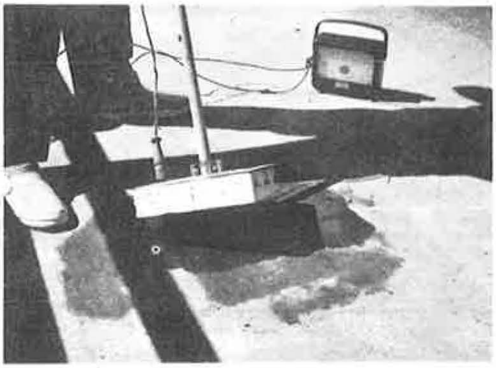

Figure 2. Volt-ohmmeter and apparatus to measure bridge deck coating.

Figure 3. Measuring electrical resistance of bridge deck coating.

deck. Then by making a contour map of equal resistance values, areas of low resistance contours could indicate the location of significant larger perforations of the coating as shown in Figure 5.

Greater precision can be obtained by reversing polarity and averaging the resistance values. Using impressed voltages (15) could result in even more accurate measurements. However, at this time, it is not considered necessary to go to more sophisticated instrumentation because these errors are significant only in the low resistance

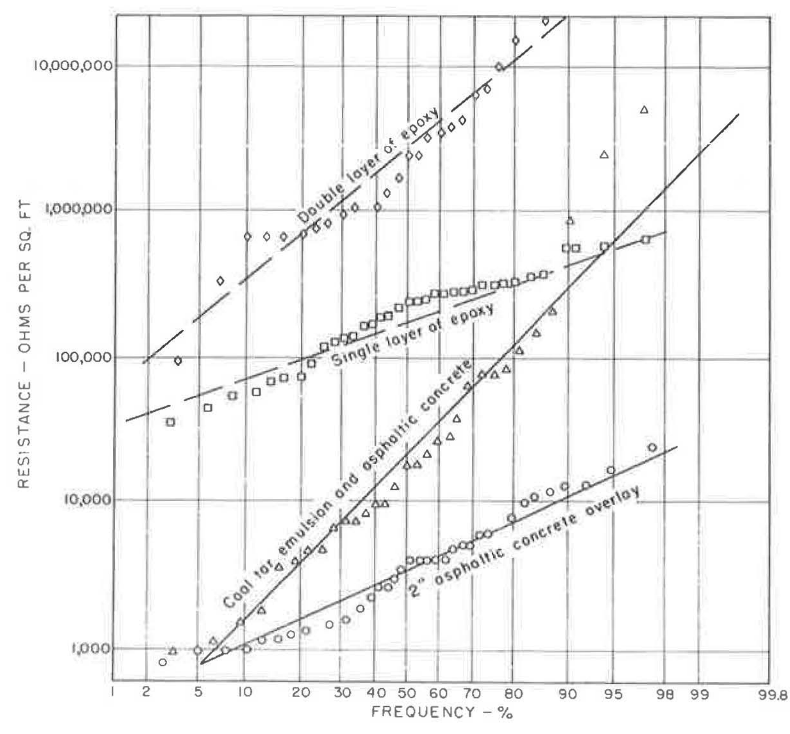


Figure 4. Gross resistance of deck coatings.

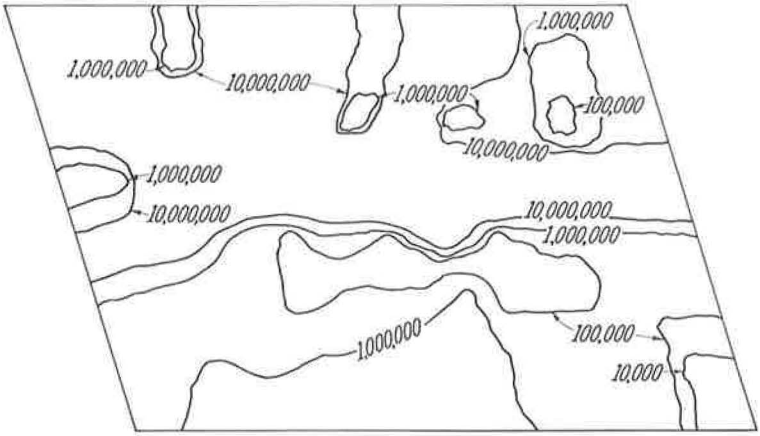


Figure 5. Equiresistance contours of bridge deck membrane in ohms/sq ft.

range where readings would indicate a conducting or highly permeable membrane. In the areas of high dielectric strength of, say, greater than 1 million ohms, an error of 2,000 or 3,000 ohms in most cases is not significant or even readable on the instrument scale.

## SEALANT VOIDS AND ELECTRICAL RESISTANCE

In order to determine what effect perforations in a coating would have on the electrical resistance, studies were made on 2 bridge decks that were coated with epoxy (California state specification 35). Initially, locations on the sealant were selected where the gross electrical resistance was in excess of 8 million ohms. Then, by means of drill bits of various sizes, holes were drilled into the coating, and the electrical resistance was remeasured by repeatedly placing the copper over the hole. By the method of least squares, an equation was derived that related the area of the drilled holes to the measured resistance. In one case, the resulting equation was

$$A = 79.6R^{-0.76}$$

where

$A$ = area of the holes in coating in in.$^2$, and
$R$ = ohms resistance.

The coefficient of correlation for this equation was -0.989, the number of observations was 31, and the standard error of estimate was 0.091 $\log_{10}$.

For the second bridge, the same procedure of drilling holes and measuring resistance of the coating was repeated. The resulting equation and correlation are shown in Figure 6a. When the area of the hole is reduced by about one-half, the electrical resistance approximately triples. A further graphic representation of the influence of the perforations made in the coating to the gross electrical resistance is shown in Figure 6b. In what might be considered a large area of holes or openings in the coating (approximately 0.1 in.$^2$), the measured electrical resistance would be about 30,000 ohms. In what might be considered as a small area of perforation (0.02 in.$^2$), the measured resistance would be approximately 250,000 ohms. Fortunately, in the area of holes we are interested in, the sensitivity to electrical resistance is greatest.

From the preceding relationships, it is apparent that there is a significant value to measuring the electrical resistance of bridge deck sealants, and this gross figure, although not precise, can be an indicator of the porosity of the coating of de-icing salts. To further demonstrate the influence of the gross electrical influence on bridge deck coatings, Figure 6a shows some of the values that were measured on various types of

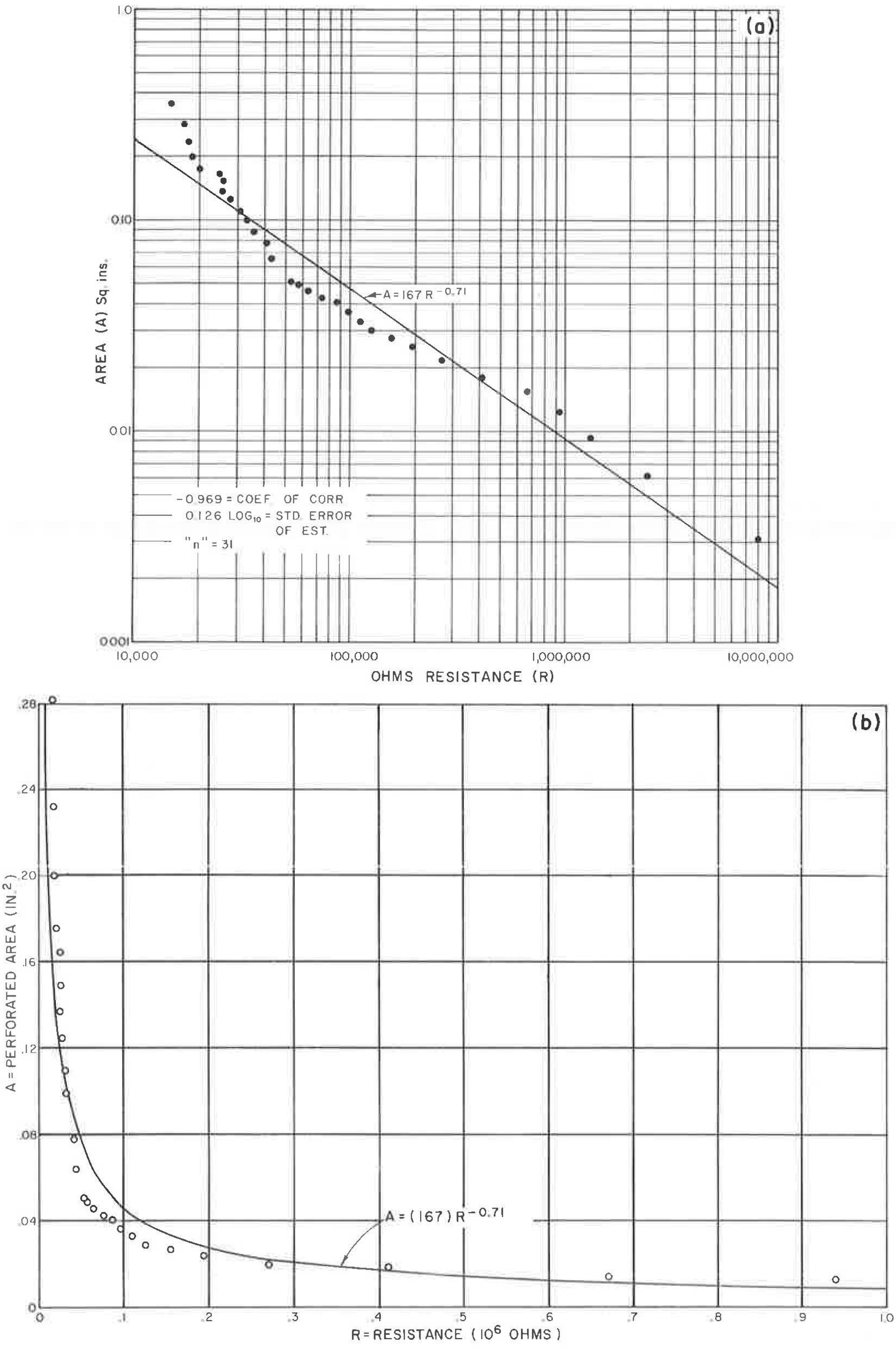


Figure 6. Area of perforations versus ohms resistance with epoxy coating.

TABLE 1

GROSS RESISTANCE OF BRIDGE DECKS

| Bridge | Coating | Average Resistance (ohm/sq ft) | Standard Deviation Factor | Number of Observations |
|---|---|---|---|---|
| Grizzly Creek | None | 300 | 2.251 | 24 |
| | Coal tar emulsion + 2 in. of asphalt concrete | 22,000 | 7.799 | 31 |
| Sacramento River No. 2-02 | None | 2,600 | 1.174 | 42 |
| | Epoxy 35 | 21,000 | 2.458 | 42 |
| Sims Road No. 6-111 | None | 1,700 | 1.689 | 19 |
| | Coal tar emulsion | 2,638,000 | 7.722 | 19 |
| | Coal tar emulsion + 1 in. of asphalt concrete | 18,000 | 2.020 | 14 |
| Yuba Pass No. 17-23 R | None | 1,300 | 2.963 | 23 |
| | Epoxy 35 | 114,000 | 3.141 | 20 |
| Yolo Bypass No. 22-124R | None | 2,000 | 1.304 | 22 |
| | Epoxy 91 (8 by 16) | 73,000 | 1.660 | 14 |
| | Epoxy 91 (4 by 8) | 82,000 | 1.776 | 18 |
| | Epoxy 45 (4 by 8) | 178,000 | 2.138 | 35 |
| | Epoxy 45 (8 by 16) | 679,000 | 3.933 | 42 |
| | Epoxy, 2 layers, 35 (4 by 8) under 45 (8 by 16) | 2,505,000 | 5.097 | 29 |
| | Epoxy 35 (4 by 8) | 195,000 | 2.990 | 47 |
| | Epoxy 35 (8 by 16) | 541,000 | 5.881 | 61 |
| | Asphalt emulsion shoulder | 12,000 | 1.677 | 25 |
| Yolo Causeway | None | 1,700 | 1.463 | 43 |
| | 2-in. asphalt concrete overlay | 3,500 | 2.512 | 38 |
| Towle OH No. 19-40 | None | 1,000 | 1.380 | 33 |
| | Thermoplastic | 97,180 | 2.485 | 22 |

bridge deck sealants. As will be noted, the average gross resistance of a 2-in. asphalt concrete overlay was in the order of 3,500 ohms/sq ft.

In one case, the average electrical resistance of a reinforced coal tar emulsion coating having an asphalt concrete overlay was about 22,000 ohms/sq ft. A single layer of epoxy was approximately 110,000 ohms/sq ft, while a double layer of epoxy was in excess of 2,500,000 ohms/sq ft. In calculating the resistance on a square foot basis, we assumed that the holes in the membranes that were tested were randomly and normally distributed. Therefore, because our apparatus had approximately 63 in.$^2$ of contact surface, the reported gross ohms/sq ft was directly calculated as an inverse proportion of a square foot to the 63 in.$^2$ on contacting electrode. Table 1 gives the results of a number of tests on bridges on which electrical resistance measurements were made. These gross resistance values were further checked insofar as a tool that may be applicable to laboratory work by constructing coatings on 3- by 18- by 24-in. concrete blocks (Fig. 7). In order to measure the electrical resistance of the coating, a metal plate was first placed on the bench, on top of that was placed a sponge wetted with water containing a wetting agent, and above that but in contact with the sponge the block was placed. The metal plate and sponge assembly as shown in Figure 2 was placed on the sealed

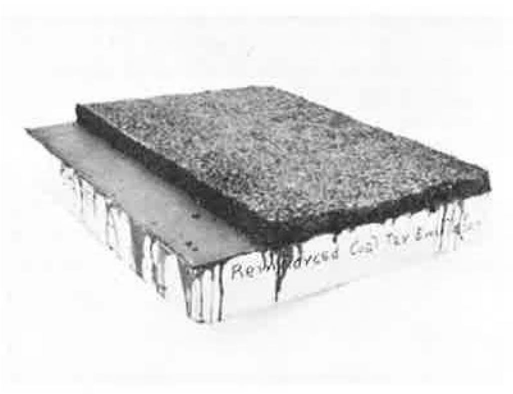

Figure 7. Laboratory test of bridge deck coating on 3- by 18- by 24-in. concrete block.

concrete block surface. In constructing these membranes in the laboratory, we attempted to create, as far as possible, conditions similar to those that would be encountered in the field. The sealants were placed on the concrete and, if required, hot asphalt concrete was compacted in the laboratory by means of a roller. In general, in the laboratory, the asphalt concrete was compacted to a density of approximately 90 percent or more.

TABLE 2
GROSS RESISTANCE TESTS OF COATINGS

| Coating | Laboratory Tests (ohm/sq ft) | Field Tests (ohm/sq ft) |
|---|---|---|
| Bare concrete | 1,100 | 1,300 |
| Reinforced coal tar emulsion, no asphalt concrete | 43,800,000 | 2,600,000 |
| Reinforced coal tar emulsion + $1\frac{1}{2}$ in. of asphalt concrete | 15,000 | 18,000 to 43,800 |
| Thermoplastic + $1\frac{1}{2}$ in. | 660,000 | 350,000 |

Table 2 gives the gross resistance tests of laboratory specimens and also some field test results. As will be noted, the values are not exactly the same; however, if reference is made to the magnitude of the resistance values shown in Figure 6b, then we would consider that there is a close approximation between the laboratory and the field tests of the gross electrical resistance of the coatings.

## DISCUSSION OF FINDINGS

A technique for comparing the electrical resistance of bridge deck sealing coatings has been presented. Although no correlation between measured resistance and sealant performance in the field has been possible because of the short time these sealants have been in place, it is hoped that with time such data may become available. However, if these measurements are made on new sealants and on a periodic basis, it is considered that this technique may enable researchers to have a common tool whereby they can report on the apparent porosity of bridge deck coatings as related to the penetration of deicing chemicals.

Because of seasonal and climatic variations, it is obvious that there may be variable moisture conditions on the surface of a coating and within the matrix of an asphaltic mix overlay that can affect electrical measurements. For this reason, the specific values for gross resistance will not be closely reproducible except in broad terms. For example, it is speculated that an excellent waterproof coating for bridges would always have an average electrical resistance greater than 500,000 ohms/sq ft, while a poor or perforated coating would never have an average resistance greater than about 100,000 ohms/sq ft. Uniformity of measurements can be improved in some cases by thoroughly and repeatedly wetting the overlay (asphaltic concrete) at the locations to be measured and allowing time for the water to permeate the layer before making measurements. This may require different waiting periods depending on the permeability of the asphaltic concrete layer. For example, on dry asphaltic concrete overlays about 4 in. thick, it has taken as long as $1\frac{1}{2}$ hours for the applied water to penetrate the asphalt to the concrete deck surface. In addition, seal coats are also applied to the surface of asphaltic concrete that greatly impede the rate of permeation of the wetting fluid. As a result, the electrical measurements could be misleading in that high values on a dry asphalt concrete overlay would be recorded that would imply the presence of a "waterproof" membrane seal.

Because of the observed and measurable time element for water to penetrate a "dry" asphalt concrete, further work is being considered in evaluating the applicability of resistance measurements as an empirical permeability type of test for asphalt concrete and soils.

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## REFERENCES


1. States Escalate Bridge Deck Battle. Eng. News-Record, May 4, 1967.
2. Maun, V. P., and Britton, H. Examples of Repairs to Concrete in Bridges. HRB Bull. 353, 1962, pp. 66-71.
3. Hughes, R. D., and Scott, J. W. Concrete Bridge Decks—Deterioration and Repair, Protective Coatings, and Admixtures. Kentucky Dept. of Highways, Res. Rept., June 1966, 283 pp.
4. Larson, T. D., Cady, P. D., and Price, J. T. Review of a Three-Year Bridge Deck Study in Pennsylvania. Highway Research Record 226, 1968, pp. 11-25.
5. Durability of Concrete Bridge Decks—A Cooperative Study of Ten States. Federal Highway Administration and Portland Cement Association, Repts. 1, 2, 3, 4, 5, and 6, 1965, 1966, 1967, 1968, 1969, and 1970.
6. A Study of Deterioration in Concrete Bridge Decks. Division of Materials and Research, Missouri State Highway Commission, Oct. 1965.
7. Crumpton, C. F., Pattengill, N. G., and Badgley, W. A. Bridge Deck Deterioration Study: Part 8. Special Study of Blue Rapids Bridge Deck. Planning and Development Department, State Highway Commission of Kansas, 1969.
8. Axon, E. O., Murray, L. T., and Rucker, R. M. A Study of Deterioration in Concrete Bridge Decks. Highway Research Record 268, 1969, pp. 80-88.
9. Hilton, M. H., Newlon, H. H., Jr., and Shelburne, T. E. Research Relating to Bridge Decks in Virginia. Virginia Department of Highways, 1965.
10. Spellman, D. L., and Stratfull, R. F. Chlorides and Bridge Deck Deterioration. Highway Research Record 328, 1970, pp. 38-49.
11. Riley, O. Bridge Deck Repair Techniques on the New Jersey Turnpike. Highway Research Record 11, 1963, pp. 50-61.
12. Concrete Bridge Deck Durability. NCHRP Synthesis of Highway Practice 4, 1970.
13. Riley, O. Development of a Bridge Deck Protective System. Highway Research Record 173, 1967, pp. 13-24.
14. Kemp, W. E. Coal Tar Enamel Coatings for Underground Pipelines. Materials Protection, Vol. 9, No. 6, June 1970, p. 14.
15. Parker, M. E. Pipeline Coating Conductance Materials Protection, Vol. 6, No. 8, Aug. 1967, p. 25.