A Concrete Bridge Deck Survey by the SUR/FAX Photographic Method

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As part of a study of the deterioration of concrete bridge decks, a condition survey of 18 structures was made with SUR/FAX photographic equipment, developed as a tool for conducting surveys of pavements. The purpose of the study was to determine the ability of the photographic equipment to detect typical defects in concrete bridge decks. The structures surveyed, 15 of which were less than five years old, were selected to include crazing, disintegration, hair checking, map cracking, pitting, popouts, surface scaling, and transverse structural cracks.

The results of the photographic survey were compared with those of a detailed visual survey. The general conclusion drawn was that additional development was needed in the SUR/FAX method to make it practical for general use in surveys of bridge decks.

• IN RECENT YEARS, the problems associated with deterioration of portland cement concrete bridge floors have received increased attention. Particular emphasis has been placed on the effects of de-icing chemicals on this deterioration. Determination of the contribution of these agents to the deterioration has been given a high priority in the recently initiated National Cooperative Highway Research Program. Extensive studies and condition surveys have been conducted and reported (1).

Condition surveys such as those required for field observations of structures are time consuming and expensive; in many cases, the results are of a subjective nature difficult to express quantitatively. The need exists for a method of survey that will be rapid and will make data available in a form more practical for office or laboratory evaluation.

A method has recently been developed for making pavement condition surveys by photographing the pavement on a continuous film similar to that used in aerial photography. This method, designated SUR/FAX, offers the advantages of speed, permanent recording, and, if used extensively, relatively low cost (2).

The method has been studied experimentally and found to have certain promise, particularly in the surveying of portland cement concrete pavements, in which photographic contrast is high (3, 4). The possibility of applying the method to portland cement concrete bridge decks formed the basis of the study reported in this paper. It was recognized that a number of practical problems would limit the use of the method for surveying bridge decks exclusively. The relatively great distances between structures, for example, would result in an inefficient operation and thus increased cost. On the other hand, if the method did prove practical for the routine surveying of pavements, a number of structures would be covered in the process, and the extent to which the method as generally applied would be successful in determining bridge defects would

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be important. The fact that the method would successfully detect defects in portland cement concrete pavements does not assure that it would be of value for bridge deck surveys because, in the latter case, small and less apparent defects would be of structural significance. It should be emphasized then that the SUR/FAX method as studied in this investigation was employed in a situation requiring resolution and magnification greater than was necessarily anticipated by the manufacturer in developing it for pavement surveys, but the normal procedures were employed because they would be the ones most likely to be extensively used.

CRITERIA

Most of the defects encountered in the study were typical of those found in portland cement concrete pavements but in many cases the degree of distress was less than that normally associated with pavements. This would be particularly true of the defects listed later as crazing, transverse cracking, and map cracking. A considerable effort was expended in trying to determine the ability of the equipment to detect very fine map cracking because of its applicability to another study under way (5). It was recognized that this phase of the testing was severe; therefore, it was given minimal significance in the over-all evaluation.

In this study, all defects were classified in accordance with the terminology used in HRB Special Report 30. From this report, under the heading of Defects and Manifestations, the following terms and definitions are presented to describe the types of distress:

> Crazing—Pattern cracking extending through only the surface layer; a result of more drying shrinkage in the surface than in the interior of the plastic concrete.
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> Disintegration—Deterioration into small fragments or particles due to any cause.
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> Hair checking—Small cracks not conforming to a regular pattern which extend to an appreciable depth but not to the full depth of the pavement; occurring before the concrete takes its final set.
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> Map Cracking— A form of disintegration in which cracking of the slab surface develops in random pattern resembling the political subdivisions on a map.
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> Pitting—The displacement of individual particles of aggregates from the pavement surface, without major displacement of the cementing material or mortar.
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> Popouts— Craterlike depressions caused by the breaking away or forcing off a portion of the pavement surface by the expansion of a piece of underlying coarse aggregate.
>
> Scaling (Surface)--The peeling away of the surface mortar of portland cement concrete exposing sound concrete even though the scale extends into the mortar surrounding the coarse aggregate.
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> Transverse Cracking— Approximately vertical cleavage due to natural causes or traffic action which follows a course approximately at right angles to the centerline.

To provide a means by which the effectiveness of the photographic method could be determined, all bridge decks in the study were visually surveyed and all defects identified and plotted to scale. For this study, pitting and surface scaling were considered sufficiently similar to be grouped as one defect type.

In the detailed sketches, crack widths were recorded as: <0.005 in., 0.005 to 0.010 in., 0.010 to 0.025 in., 0.025 to 0.050 in., 0.050 to 0.100 in., 0.100 to 0.125 in., 0.125 to 0.250 in., and >0.250 in. Areas of distress, such as disintegration, and pitting and surface scaling, were approximated to the nearest square foot.

EQUIPMENT

The photographic apparatus used in this study consists principally of a 35-mm camera mounted atop a retractable hydraulic mast. A panel body truck is used to transport the camera-mast assembly (Fig. 1).

During the photographing operation, the camera assembly is raised approximately 14 ft, and when traveling between sites it is lowered to about 10 ft. To lessen the possibility of any relative movement between the camera and the surface being photographed, the camera is tilted upward to a rectangular mirror which reflects the pavement image through the shutterless slit of the camera onto a continuously moving film. Shock absorbers and stabilizer arms are attached to the mast to protect the camera assembly against shock and to prevent it from moving while in the photographing position. Banks of lights directed downward at an angle of approximately 30^0 from the

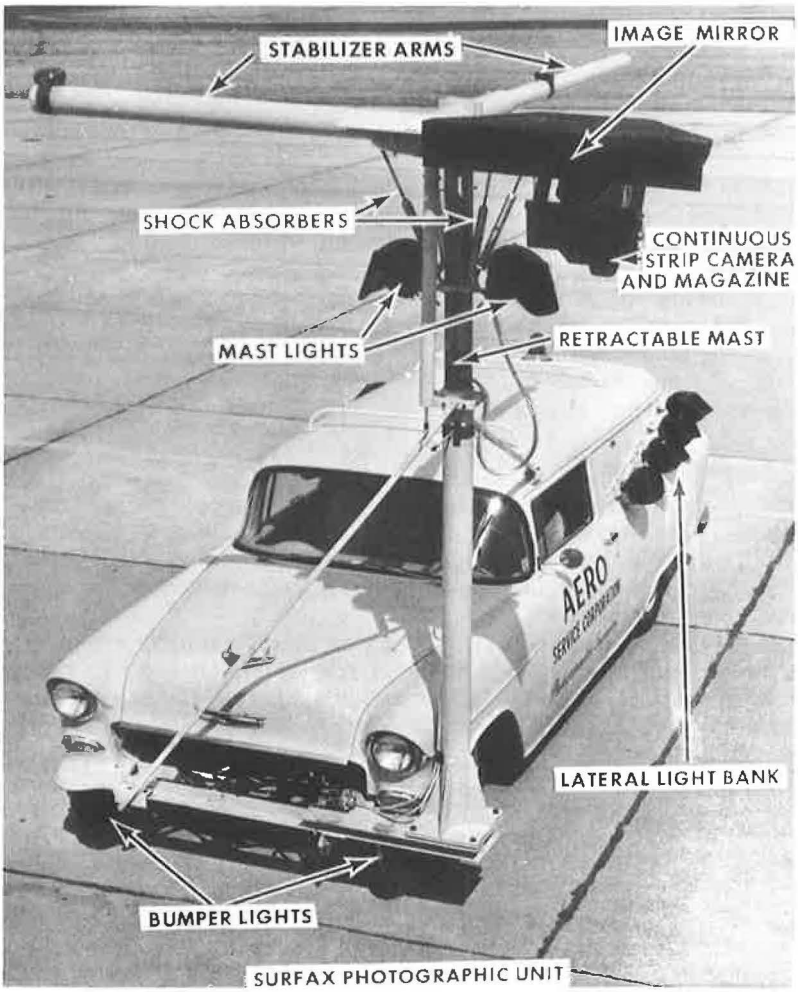

Figure 1. SUR/FAX photographic road unit.

horizontal are mounted on the truck sides, below the front bumper, and on the mast to permit photographing to be done at night. The use of artificial lighting serves a threefold purpose by permitting greater control over the light intensity, reducing the effects of shadows, and allowing the photographing to be accomplished during the hours of minimum traffic. A generator carried in the rear of the vehicle furnishes current for the lighting system.

In the photographic operation, as used in normal pavement surveys, the truck travels at 25 to 30 mph in the right-hand lane photographing both the right- and left-hand lanes simultaneously. Between sites, with the camera-mast assembly in the lowered position, speeds of 45 to 50 mph are commonplace. In this study, the photographic operation was generally conducted by two-men teams provided by the Aero Service Corporation.

PROCEDURES

Two photographic surveys were made for this study. In the original survey, 18 structures were photographed with the same equipment and procedures as are used in the normal pavement surveys. On the basis of the results of this original survey, it was mutually agreed that rephotographing with modified procedures and equipment should be attempted. In the modified survey, the five structures exhibiting the most severe cases of distress as shown by the original survey were rephotographed with the same equipment, except that improved lens and lighting systems were used.

The camera used in the original survey was equipped with a wide angle lens which enabled pavement widths up to 36 ft to be photographed in a single traverse. In the modified survey, after the sensitivity of the camera's lens system was improved, the width of pavement encompassed was reduced to approximately 20 ft. The degree of resolution obtained in the modified survey was increased considerably over that of the original survey by these modifications; however, most bridge decks in Virginia are 24 ft or greater in width, so two traverses of the structure were required to photograph the entire deck surface. As an aid in checking the degree of resolution obtained in the photographs, 2-ft square resolution charts similar to those used in eye examinations were placed on the decks prior to photographing.

From the exposed film, the Aero Service Corporation prepared and furnished enlarged glossy and matte prints, and 35-mm film positives for study purposes. The enlargement of the glossy and matte prints resulted in an average scale of 1 in. equals 6 ft. However, the results and conclusions of the study are based solely on the data obtained from the enlarged glossy prints.

RESULTS

In selecting the structures for photographing, considerable attention was given to both the extent and the severity of the distressed area so as to include as large a range of conditions as possible. Of the 18 bridges photographed in the original survey, 5 were selected as being most representative of the group, and these were rephotographed in the modified survey.

The glossy and matte prints and film positives furnished for each bridge were compared, the film positives being projected on a screen and viewed with the aid of a variable speed projector. On the basis of the comparisons it was concluded that greater detail could be detected from the glossy prints than from the other two means. Hence, the data and conclusions of this study were obtained entirely from the information provided by the enlarged glossy prints.

In the original survey there were occasions when the prints of the wider decks contained both unusually dark and unusually light areas, resulting in a decrease in the degree of resolution. This was believed to be caused by variations in light intensity. In the modified survey, additional lights were mounted beneath the front bumper, and a narrower width of roadway was photographed. As a result, a decrease in the number of dark and light areas was noted.

In both photographic surveys there were instances in which the longitudinal scale of the prints was not constant for a given bridge deck. The distortion in these cases was as great as 3 ft in a 50-ft slab. In the modified survey the number of instances of dis-

tortion in the longitudinal direction was reduced, but not eliminated, through the addition of a fifth wheel arrangement to synchronize the camera and vehicle speeds. Further, within each photographic survey the quality of the prints was different in that the clarity and detail were better in some cases than in others. The prints from both photographic surveys were compared with the sketches from the visual survey, and, because the photographs from the first survey were of poorer quality than those of the second, it was believed desirable to base the conclusions of this study on the results of the modified survey only. To point out the increase in percent of defects detected in the modified survey over that of the original survey, data from both surveys are shown in Figure 2. These data were obtained by comparing the photographs with the detailed sketches of the bridge decks. In the detailed sketches unusual effort and precision were employed in the attempt to obtain a true description of the deck condition so that a fair and complete evaluation of the photographs could be obtained. In these sketches the extent of the distressed area and each visible crack were sketched to scale and classified according to the HRB system. In most cases an average was taken of two or more persons' work in determining the number of defects found from the photographs.

The results of the visual and modified surveys are given in Table 1.

Column 2 gives the number of that particular defect detected from sketches of the visual survey; column 3 gives the number of these same defects detected from the glossy prints; and column 4 gives the percent of defects present which were detected from the prints. Column 4 shows that the data fall into two broad classes. The defects in Class A (crazing, hair checking, and map cracking) are the more difficult to detect. Class B includes the defects that were more easily detected; such as disintegration, pitting and surface scaling, popouts, and transverse cracks.

The defects in Class A were more difficult to detect because of the relatively small width of cracks occurring in these types of distress. Of the bridge decks observed in this study it was found that the crack openings of the defects in Class

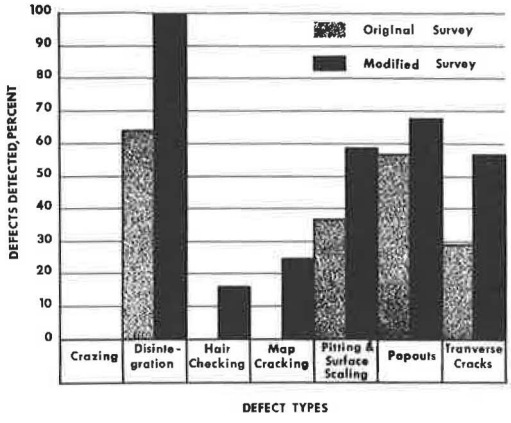

Figure 2. Percent defects detected in surveys.

TABLE 1

COMPARISON OF DEFECTS DETECTED FROM SKETCHES AND PRINTS

Type of Defect	Number of Defects Detected		Percent Defects Visible from Prints
	Sketches	Prints	
(1)	(2)	(3)	(4)
Crazing	4	0	0
Disintegration	11	11	100
Hair checking	497	78	16
Map cracking	20	5	25
Pitting and surface scaling	242	142	59
Popouts	44	30	68
Transverse cracks	7	4	57

A ranged from 0.01 to 0.25 in. Table 1 shows that the SUR/FAX equipment was generally unsuccessful in detecting cracks in this width range. Only in instances where the area of distress and crack openings were comparatively large could the defects be noted from the prints. Occasionally the larger areas of these defects were recognized from the photographs as an inconsistency in the general appearance of the surface. However, if a distressed area was noted, it was generally impossible to identify the particular type of distress. Furthermore, many times the distressed area could not be noted because it was not sufficiently large to offer adequate contrast to the surrounding unaffected area. Under the conditions of this study it was concluded that distressed areas containing cracks of widths less than 0.25 in. could not be consistently detected nor could they be classified on detection from the photographs.

A greater percentage of the defects in Class B were noted from the photographs for the following reasons:

1. In the case of disintegration and of pitting and surface scaling a very noticeable contrast exists on the prints between these areas of distress and the unaffected areas. In addition to the aid in detection offered by the contrasting surface appearance, the detection of these types of defects was also increased by their depth, which caused pronounced shadows to appear on the surface of the deck. Because the system of lights was directed on the deck surface from an angle, the small vertical face of the defect farthest from the camera would reflect a relatively large amount of light to the camera system. Consequently, the nearer face of the defect was hidden to the camera and hence no light was reflected. This resulted in light and dark areas appearing on the prints and served to outline the extent of the distressed area.
2. In a similar manner, the shadow effects resulting from popouts and transverse crack openings larger than 0.25 in. appeared on the prints as black dots and dark lines, respectively. In the case of crack detection, it was found that the length of cracks is an important factor in that for cracks of equal width the crack with the greater length was more easily noted.

In a supplemental experiment in which the deck surface of a bridge containing map cracking was sprayed with water, it was observed that the detection of the cracks was considerably easier if the surface was photographed at various stages of the drying-out process. When a concrete surface containing cracks is wetted sufficiently and then allowed to undergo drying, moisture remains in the cracks for a longer period than it does on the surface. This condition, in which the dampened cracks were of darker color than that of the dry surface, accentuated the contrast between the unaffected and distressed surfaces as they appeared on the photographs. (Possibly, this contrast could be enhanced through the use of a wetting agent.) As a result, it was found that the detection of cracks in a distressed surface is increased substantially when the surface is photographed in a state of differential drying.

In a further effort to increase the detection of cracks by the SUR/FAX method, infrared film was used to photograph the bridge deck sprayed with water. As before, the photographing was conducted when the surface was in a drying-out process; however, the results of this experiment proved to be of less value than those received from the conventional method.

CONCLUSIONS

As a result of this work the following conclusions appear justified:

1. The SUR/FAX methods and equipment used in the original survey, and representative of the techniques normally employed in pavement surveys, are not suitable for detection of many of the types of distress common to bridge decks.
2. The particular procedures used in the modified survey were better adapted to the envisioned concepts of this study; however, additional development is needed in the SUR/FAX method to make it practical for general use in surveys of bridge decks.
3. The results obtained from the procedures used in the modified survey indicate the following:

(a) The detection of defects was greater from the enlarged glossy prints than from the matte prints or the projections of the film positives.
(b) Crack openings less than 0.25 in. cannot be consistently detected. Neither can crazing, hair checking, or map cracking be distinguished from each other at crack openings less than 0.25 in.
(c) Types of distress exhibiting a depth dimension that reflects light are more easily noted.
(d) Longer cracks are more easily detected than shorter cracks of the same width.

4. The detection of map cracking and similar types of distress is greatly enhanced from photographs of the distressed surface undergoing differential drying.

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