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16. Abstract

The objective of this study was to develop a technique for surveying heavily trafficked highways that is compatible with a visual condition survey but does not restrict the flow of traffic. Because of the need to be able to conduct a survey at a speed of at least 30 miles per hour (48 km/h), the possibility of utilizing photographic techniques was investigated. Accuracy, speed, and reasonable cost are important criteria for a successful condition survey on urban highways. Previous studies showed that only a few important distress types need to be surveyed and that sections can be selected from a construction project for a condition survey without a sacrifice in the quality of the results. It was found that by mounting a camera with a shutter speed of up to 1/2000 second and capable of taking 4 to 5 frames per second on a boom hanging in front of a vehicle so that the line through the camera lens is perpendicular to the road surface, a birdseye view of the distress can be seen on film. By adjusting the vehicle speed and equipment, a survey of condition of a CRCP pavement is possible. The difference in quality between a visual and a photographic survey is minimal with proper sampling. If a 300-ft (91.44-m) section of every mile is surveyed, the quality of the survey is still high and slight cost savings materialize. A cost study indicates that a photographic survey is more economical than a visual condition survey. Although the photographic survey is based on only a six percent coverage, there are the additional advantages that the mean crack spacing can be easily determined from the photographs and that visual records of the pavement condition can be obtained for future reference. The use of color film was also found to be beneficial.

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DEVELOPMENT OF PHOTOGRAPHIC TECHNIQUES FOR PERFORMING CONDITION SURVEYS

by

Pieter Strauss
James Long
B. Frank McCullough

Research Report Number 177-10

Development and Implementation of the Design, Construction,
and Rehabilitation of Rigid Pavements

Research Project 3-8-75-177

conducted for

Texas
State Department of Highways and Public Transportation

in cooperation with the
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Federal Highway Administration

by the

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

May 1977

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

This report deals with the development of a technique for surveying heavily trafficked highways without interrupting the flow of traffic.

The implementation of the Rigid Pavement Management System (Ref 1) in Texas generates the need for monitoring the pavement network. It was found that the visual condition survey method used under Project 21, "A Performance Survey of Continuously Reinforced Concrete Pavements in Texas" (Ref 2), would not be suitable for use in urban areas or on heavily trafficked highways, and therefore other means of conducting a survey of this kind were investigated. This report describes the development of a method utilizing photographic techniques.

The research for this report was conducted under Project 177, "The Development and Implementation of the Design, Construction and Rehabilitation of Rigid Pavements," for the State Department of Highways and Public Transportation and the Federal Highway Administration.

Appreciation is extended to Messrs. Gerald Peck, James L. Brown, Larry Buttler, Curtis Goss, and Kenneth Hankins of the State Department of Highways and Public Transportation for the valuable suggestions and assistance in conducting this study, as well as the Center for Highway Research staff, who assisted with the manuscript.

Pieter Strauss
James Long
B. Frank McCullough

LIST OF REPORTS

Report No. 177-1, "Drying Shrinkage and Temperature Drop Stresses in Jointed Reinforced Concrete Pavement," by Felipe R. Vallejo, B. Frank McCullough, and W. Ronald Hudson, describes the development of a computerized system capable of analysis and design of a concrete pavement slab for drying shrinkage and temperature drop. August 1975

Report No. 177-2, "A Sensitivity Analysis of Continuously Reinforced Concrete Pavement Model CRCP-1 for Highways," by Chypin Chiang, B. Frank McCullough, and W. Ronald Hudson, describes the overall importance of this model, the relative importance of the input variables of the model and recommendations for efficient use of the computer program. August 1975

Report No. 177-3, "A Study of the Performance of the Mays Ride Meter," by Yi Chin Hu, Hugh J. Williamson, B. Frank McCullough, and W. Ronald Hudson, discusses the accuracy of measurements made by the Mays Ride Meter and their relationaship to roughness measurements made with the Surface Dynamics Profilometer. January 1977

Report No. 177-4, "Laboratory Study of the Effect of Non-Uniform Foundation Support on CRC Pavements," by Enrique Jimenez, W. Ronald Hudson, and B. Frank McCullough, describes the laboratory tests of CRC slab models with voids beneath them. Deflection, crack width, load transfer, spalling, and cracking are considered. Also used is the SLAB 49 computer program that models the CRC laboratory slab as a theoretical approach. The physical laboratory results and the theoretical solutions are compared and analyzed and the accuracy is determined. (being prepared for submission)

Report No. 177-5, "A Comparison of Two Inertial Reference Profilometers Used to Evaluate Airfield and Highway Pavements," by Chris Edward Doepke, B. Frank McCullough, and W. Ronald Hudson, describes a United States Air Force owned profilometer developed for measuring airfield runway roughness and compares it with the Surface Dynamics Profilometer using plotted profiles and mean roughness amplitude data from each profilometer. Preliminary March 1976

Report No. 177-6, "Sixteenth Year Progress Report on Experimental Continuously Reinforced Concrete Pavement in Walker County," by Thomas P. Chesney, and B. Frank McCullough, presents a summary of data collection and analysis over a 16 year period. During that period, numerous findings resulted in changes in specifications and design standards. These data will be valuable for shaping guidelines for future construction. April 1976

Report No. 177-7, "Continuously Reinforced Concrete Pavement: Structural Performance and Design/Construction Variables," by Pieter J. Strauss, B. Frank McCullough, and W. Ronald Hudson, describes a detailed analysis of design, construction, and environmental variables that may have an effect on the structural performance of a CRCP is presented. May 1977.

Report No. 177-8, "Continuously Reinforced Concrete Pavement: Prediction of Distress Quantities," by John P. Machado, B. Frank McCullough, and Hugh J. Williamson, presents a general analysis of environmental, design, construction and historic pavement behavior conditions and their effects on future performance. (being prepared for submission)

Report No. 177-9, "CRCP-2, An Improved Computer Program for the Analysis of Continuously Reinforced Concrete Pavements," by James Ma and B. Frank McCullough, describes the modification of a computerized system capable of analysis of a continuously reinforced concrete pavement based on drying shrinkage and temperature drop. Preliminary August 1977.

Report No. 177-10, "Development of Photographic Techniques for Performance Condition Surveys," by Pieter Strauss, James Long, and B. Frank McCullough, discusses the development of a technique for surveying heavily trafficked highways without interrupting the flow of traffic. Preliminary May 1977.

ABSTRACT

The objective of this study was to develop a technique for surveying heavily trafficked highways that is compatible with a visual condition survey but does not restrict the flow of traffic. Because of the need to be able to conduct a survey at a speed of at least 30 miles per hour (48 km/h), the possibility of utilizing photographic techniques was investigated. Accuracy, speed, and reasonable cost are important criteria for a successful condition survey on urban highways.

Previous studies on Project 21 (Ref 4) showed that only a few important distress types need to be surveyed and that sections can be selected from a construction project for a condition survey without a sacrifice in the quality of the results.

It was found that by mounting a camera with a shutter speed of up to 1/2000 second and capable of taking 4 to 5 frames per second on a boom hanging in front of a vehicle so that the line through the camera lens is perpendicular to the road surface, a birdseye view of the distress can be obtained on film. By adjusting the vehicle speed and equipment, a survey of condition of a CRCP pavement is possible. The difference in quality between a visual and a photographic survey is minimal with proper sampling. If a 300-ft (91.44-m) section of every mile is surveyed, the quality of the survey is still high and slight cost savings materialize.

A cost study indicates that a photographic survey is more economical than a visual condition survey. Although the photographic survey is based on only a six percent coverage, there are the additional advantages that the mean crack spacing can be easily determined from the photographs and that visual records of the pavement condition are obtained for future reference. The use of color film was also found to be beneficial.

KEY WORDS: photographic techniques, condition survey, pavement monitoring, structural performance of pavements

IMPLEMENTATION STATEMENT

The method of using photographic techniques for performing condition surveys that is described in this report is a feasible way of assessing the structural performance of pavements in urban areas where traffic density discourages a visual condition survey such as was made in a rural part of Texas under Project 21. The experimental work described in this report is not intended to serve as a specification but is used merely in an attempt to illustrate the possibility of a condition survey in the form of a photographic study.

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CHAPTER 1. INTRODUCTION

Background

The implementation of the Rigid Pavement Management System (Ref 1) in Texas has generated a need to implement a pavement performance evaluation. One of the basic requirements of an evaluation scheme, the pavement network monitoring, was done under Project 21, "A Performance Survey of Continuously Reinforced Concrete Pavements in Texas," (Ref 2) and consisted of a condition survey together with a determination of riding comfort. The follow-up study, Project 177, has engaged in the evaluation of the information gather under Project 21. Since these data did not involve the continuously reinforced concrete pavements (CRCP) in the Dallas, Fort Worth, Houston, and San Antonio Districts, a need to survey highways in the urban areas still had to be fulfilled. This report investigates the possibility of utilizing photographic techniques to accomplish this task. The requirements as well as the background and history that led to the technique will be discussed briefly.

The conditon survey performed during Project 21 (Ref 2) concentrated on six different types of distress manifestation. Since the survey only involved rural highways with relatively low traffic volumes, visual surveying from a vehicle travelling at about seven miles per hour on the shoulder of the highway was possible. Two people were able to handle all aspects of the survey by inspection of the outside lane of each highway in 0.2-mile (0.32-km) segments.

Considering the fact that all the urban highways in the state carry high volumes of traffic, along with the hazard of travelling on the shoulder at about seven miles per hour (11 km/h), reduces the feasibility of a survey on the same basis as the rural survey mentioned above. In addition, the outside lane is utilized as a ramp weaving facility in urban areas on the interior traffic lane and may be carrying the heaviest loads, thus precluding a visual conditon survey at seven miles per hour (11 km/h).

Study Concepts

The requirement to survey a highway at least 30 miles per hour (48 km/h) precipitates the need for an investigation into the possibility of photographic techniques. Several options, such as aerial photography, pictures taken from side lanes, and night time surveying, could be considered.

The basic requirement to identify transverse cracks as well as spalling and pumping prohibits the use of aerial photography even from a helicopter, without extensive enlarging and other equipment. Several unreported studies by the Houston Urban Office revealed the details required could not be obtained from a low-level flights even with extensive enlarging. The second option, namely, the photographing of heavily trafficked lanes from other less congested side lanes, leads back to the visual survey, without promise of improving existing techniques. The third option, nighttime photography, combined with a modified aerial photographic technique will be investigated in this report.

Objective and Scope of the Study

The objective of the report, therefore, is to develop a technique for surveying heavily trafficked highways that is compatible with a visual condition survey that does not restrict the flow of traffic. The process of a visual condition survey is discussed briefly as a background to the requirements of the pavement minitoring. Experimental studies are discussed in which different lenses and other equipment are investigated, and finally the results are analyzed on the basis of employment in the rigid pavement management system.

CHAPTER 2. CONDITION SURVEYS

The determination of the condition of CRCP highways in rural Texas was done visually under Project 21. This chapter will discuss the different distress types surveyed as well as the method employed in doing the survey as efficiently as possible. Subsequent analysis of the results will be discussed in order to lead the discussion to the requirements of a proper condition survey with respect to the important types of distress. Photographic studies and their relation to condition surveys will be discussed.

Project 21 Survey

This survey was performed with two men riding in travelling at a maximum speed of seven miles per hour (11 km/h) on the shoulder of the road. The outside lane was the only lane that was surveyed, although special note was made of outstanding failures that appeared in the inside lane. Responsibilities were subdivided between the driver of the vehicle and the passenger, who sat right behind the driver. The driver would note the condition of the shoulder and estimate the quantity and quality of punchouts and the size and number of patches and repairs. The passenger, on the other hand, took responsibility for transverse and localized cracking and spalling as well as the recording of all data on the appropriate form.

Pumping. This was broken down into severe pumping, which is an indication of severe loss of fines from the sublayers and is also associated with vertical movement of the pavement where pumping occurs, and minor pumping, which is defined as water being pumped out and leaving streaks of fines on the surface of the shoulder of the pavement. Both are recorded as the percent of the section that showed pumping. If a section had both minor and severe pumping in the same area, the worse condition was reported.

Punchouts. A punchout is defined as closely spaced transverse cracks linked by longitudinal cracks. A minor punchout is defined as a condition where longitudinal cracks start to form between transverse cracks; they need not be connected to the transverse cracks. A severe punchout is defined as a condtion where longitudinal cracks connect with transverse cracks and form blocks which move under traffic.

This condition was recorded by the length of punchouts and their severity in four categories, 1 through 3, 4 through 9, 10 through 19, and 20 feet above, and shown on the survey sheet as number of punchouts by size in the section.

Repair Patches. Repairs can be made with either portland cement concrete or asphaltic cement concrete. Asphalt cement concrete patches were defined as minor repair patches in the survey, although the patches may be extensive in size. Care was taken to make sure short asphaltic cement concrete overlays were not counted as patches; these were noted in the general comments. Repairs made with portland cement concrete were reported as severe patches. There were no notes made in regard to the condition of either repair unless it warranted a reference under general comments.

To determine the amount of patches that were involved, a scale was provided in square feet of patching. The scale was divided into four categories, namely, 1 through 15, 16 through 120, 121 through 240, and greater than 241 square feet. The size and number of all patches are determined and the category which it fell in is recorded on the survey sheets.

Transverse Cracking. Transverse cracking for this survey was defined as cracking that changed from the normal crack pattern and occurred at a spacing closer than 18 inches. The different lengths of road within the section surveyed that experienced transverse cracking were added up, and the accumulated length of road as a percentage of the section length, 0.2 mile or 1000 feet (.30 Km), in this case, was entered on the survey sheet as minor or severe transverse cracking.

Minor transverse cracking is defined as cracks which are newly formed, narrow, or not easy to see. Severe transverse cracking is defined as a condition where the crack width appears wide.

Localized Cracking. Localized cracking is defined as transverse cracks starting to deteriorate because of the formation of cracking that links the transverse cracks.

Minor localized cracking is defined as occurring when the cracking is not joined to the transverse cracks or the edge of the pavement. Severe localized cracking is defined as occurring when Y cracking is connecting to transverse cracks and a radical pattern of cracking is developing.

To determine the amount of localized cracking in a section, the different lengths of road that experienced localized cracking are added up and expressed as a percentage of the section length, 0.2 mile (0.32 km) or 1000 feet (0.30 km) and then recorded on the survey sheet in the appropriate block.

Spalling. Spalling is defined as the widening of the crack through secondary cracking or breaking of the crack edges. The depth of a spall is generally less than one inch but a spall can be up to 6 inches (150 mm) wide.

Minor spalling is defined as a condition of cracking where the loss of material has formed a spall one-half inch wide. Severe spalling is defined as occurring when the cracks have been widened to such an extent that the smoothness of ride is affected. Spalling was measured by the percent of cracks have spalled areas in them. If a crack had both minor and severe spalling visible, it was counted as severe. An estimate of the percentage of cracks that showed minor and severe spalling was made and then recorded on the survey form.

Results of Project 21 Data Analysis

The data accumulated from the condition survey were analyzed by means of regression techniques. The main purpose of the analysis was the establishment of problem areas and the development of models by which future distress could be predicted.

A gross study (Ref 3) covered all sections of highways that were surveyed, and distress was related to certain "gross" variables, which included type of clay in subgrade, number of equivalent 18-kip (80 kN) load applications, type of concrete aggregate, type of base and subbase, and climatic as well as environmental conditions. No theoretical models are involved in the anlaysis and basically the model is used to predict future distress for administrative purposes.

The other study, a detailed analysis (Ref 4), involves the employment of theoretical models and attempts to take into account all possible variables. Since the gross analysis researched the influence of climatic and regional factors, no effort was made to incorporate these factors in into the detailed study. Therefore, the study was done on two sections of interstate highways in two Texas counties which involved 54 1200-foot (366 m) subsections.

Both the gross and the detailed analysis involved investigations into all types of distress. The most important distress types turned out to be the crack spacing, minor spalling, pumping, punchouts, and repair patches. It was also evident from the above mentioned two studies that the variation within a construction project was small compared to inter-project variations. This variation was small enough to collapse the 0.2-mile sections into mile sections(0.32-km sections into 1.61-km sections) for analysis purposes in the gross analysis. It can, therefore, be conceded that sample surveys are entirely possible with a concentration on important types of distress. The mean crack spacing, although concluded to be of importance in the detailed analysis, was not quantified in the Project 21 condition survey. Since determination of crack spacing involves their actual measurement, photographic techniques can be considered beneficial in this respect.

The question of repeatability can be considered as being of some concern. Since district personnel were employed in the conditon survey, schooling by a central team was done to insure consistency of evaluation. Two control teams, one from D-10 Research of the State Department of Highways and Public Transportation and one from the Center for Highway Research, made a simple survey of 10 percent of the CRCP pavement in each district as a means of determining the variaton among the teams and to be used as a factor of adjustment to bring all ratings to the same standard.

In summary, it can be said that analysis of Project 21 survey data brought to light that only a few important distress types need to be surveyed. Furthermore, certain sections can be selected from a construction project for condition surveying without a sacrifice in quality. Finally, it can be said that surveying by a single team will be beneficial from the viewpoint of having obtaining uniformity.

Photo Survey

It follows from the above discussion that a photographic survey may have several advantages apart from the facto that a distress history will be in permanent record for future reference. Several photographic techniques have been used in the condition surveying of concrete pavement at the Center for Highway Research (Ref 5). Movies have been used in a survey of CRCP in different states and have been proven to be a way of recording thecondition of a section in the field and that then allows a review of its condition later in the office. Because of the slow speed, 0 to 5 miles per hour, this method is not considered to be practical in urban area, as mentioned before.

Color slides and black and white photographs have also been used to record the condition of CRCP. This method was used in the Project 21 survey. The pictures were taken from the shoulder of the road in the ten percent that was surveyed by the CFHR personnel and were very helpful in analyzing the condition of these sections, although only about 5 to 9 pictures were taken per construction project.

No photographic survey has been done on a large scale at the Center for Highway Research. Experience of CFHR personnel as well as that of the SDHPT had to be employed in developing a useful method of survey. Some of the techniques that were put to use on a trail basis will be discussed in the next chapter.

CHAPTER 3. EXPERIMENTAL PHOTOGRAPHIC RUNS

The requirements for a successful condition survey on urban highways as discussed in the previous chapter can be summarized as follows:

(1) Survey accuracy has to be sufficient to detect distress manifestations, such as transverse cracking, pumping, spalling, punchouts, and repair patches.

(2) The speed of the surveying vehicle must be high enough not to impede the regular flow of traffic.

(3) The cost of a photographic survey has to match a regular condition survey as performed under Project 21, which includes control surveys by outside teams as well as the schooling of regular teams.

The different possibilities in camera equipment will be discussed in this chapter together with alternative photographic techniques. Subsequent trial runs and the test results will also be analyzed.

Photographic Equipment

Photographic surveys are possible during daylight hours and at night, with the assistance of a strobe. The latter method however poses two important restrictions. The first problem is that photocoverage only of one traffic lane is possible, which requires "manual" surveying of the other lanes unless the extra cost of photosurveying the other lanes is warranted. Manual surveying implies the counting of structural failures in the form of punchouts and repairs which are easily detected at 30 miles per hour (48 km/h). Thus, daylight surveying is required.

The second restriction is that in order to photograph a continuous strip of pavement at 30 miles per hour (48 km/h) for determination of crack spacing, a camera speed of at least 4 frames per second is required. Thus, a strobe with an output of 4 or more flashes per second for about 8 seconds is required, which will require an extensive layout.

A third consideration is safety of operation; flashes from a strobe may interfere with the vision of fellow drivers on the highway. Night driving may also be hazardous as regards positioning and orientation of the surveying crew on the highway.

Since several restrictions on strobe photography exist, the decision was made to pursue daytime photography and it will be discussed in the following paragraphs.

Equipment Characteristics. The speed of the vehicle as well as the restriction on clarity of pictures from which to survey transverse cracking and minor spalling immediately precipitated an important requirement, namely, that therebe no or very little blur. This requires high speed equipment which has a shutter speed of 1/2000 second. Shutter speeds as high as 1/2000 second require relatively large lens openings, which is not a disadvantage if the range in field length is not critical. Thus, by mounting the camera on a boom hanging in front of the vehicle, so that a line through the camera lens is perpendicular to the road surface, a birds-eye view of the distress can be obtained on film. Figure 3.1 illustrates this concept.

The positioning of the camera as shown in Fig 3.1 has an additional advantage: it is possible to scale distances on the resulting picture, which facilitates the determination of sizes of structural failures as well as crack spacing. A further advantage is that depth of focus is not important since the plane of focus is the plane of the road surface.

The positioning of the camera as shown in Fig 3.1 implies that pictures can be taken at a frequency equal to the time it takes the camera, or vehicle, to travel a distance L . The different combinations of the height of the camera H , the length of L , and the width of the pavement B being photographed are summarized in Table 3.1 for different lenses. The values are approximations since lenses with the same focal may have different angles of acceptance.

In order to tie speed of the vehicle camera with the speed that a camera can take pictures, the data in Table 3.2 were developed. Also shown on the table are borderlines which indicate the approximate area within which different shutterspeeds, as shown in the table, may render pictures with blur which is acceptable from a condition survey point of view. These

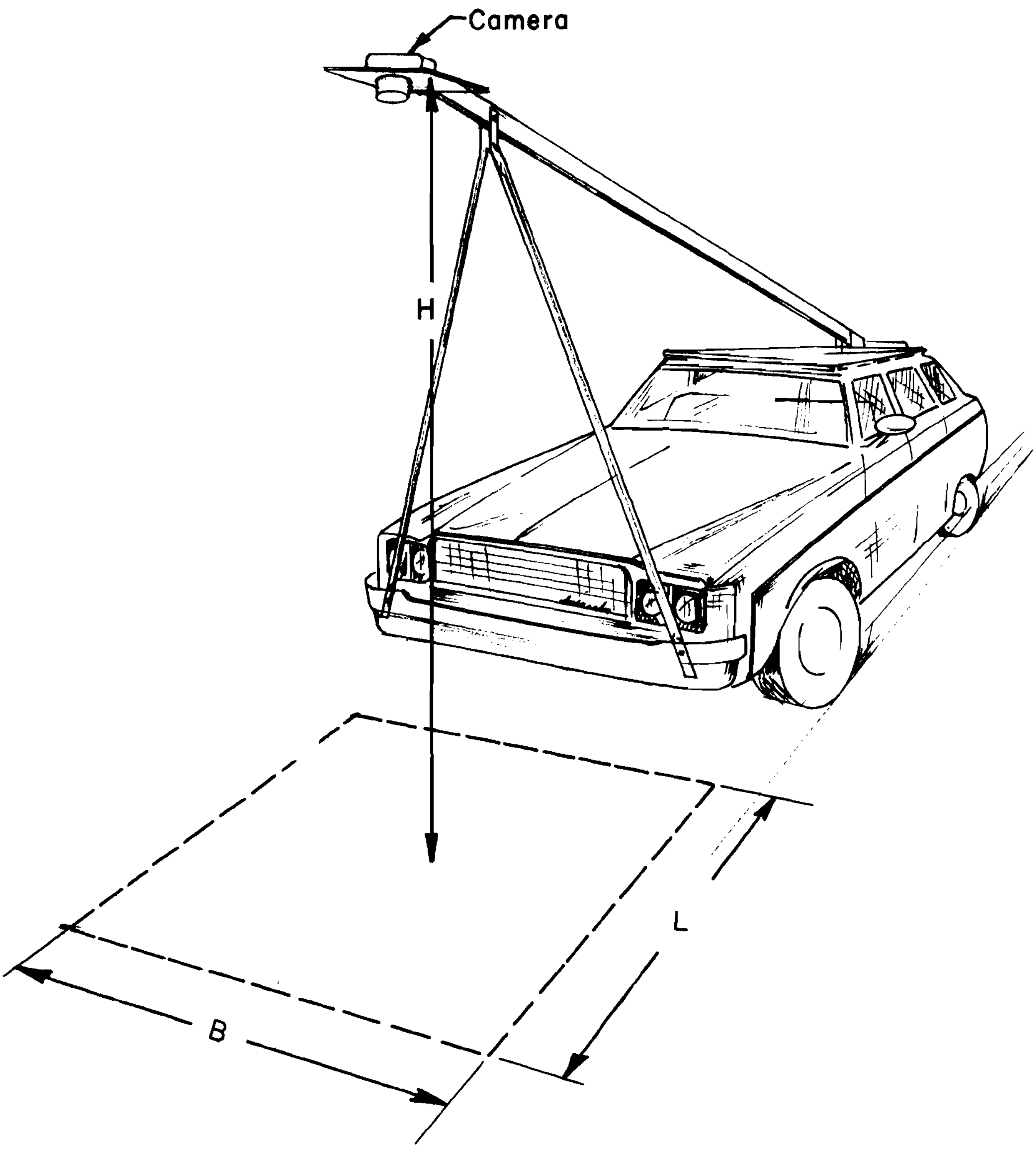

Fig 3.1. Relative position of camera on vehicle.

TABLE 3.1. THE APPROXIMATE RELATIONSHIP BETWEEN THE FRAME SIZE, CAMERA HEIGHT, AND TYPE OF LENS.

Type of Lens	Height of Camera (Feet)		
	10	8	6
35 mm	10.0 X 6.8*	8.0 X 5.4	6.0 X 4.0
28 mm	12.5 X 8.2	10.0 X 6.7	7.5 X 4.9
24 mm	15.0 X 10.0	12.0 X 8.0	9.0 X 6.0

*Dimensions of roadway recorded on film. The first number is L and the second is B (See Fig 3.1). Thus, 10.0 X 6.8 indicates the longitudinal distance recorded is 10 feet and the transverse, 6.8 feet.

1 foot = 0.3048 meters

TABLE 3.2. THE RELATIONSHIP BETWEEN VEHICLE SPEED, CAMERA SPEED, AND FRAME LENGTH TO GET A CONTINUOUS FILM STRIP OF PAVEMENT.

Frame Length L (feet)	Vehicle Speed, M.P.H.			Shutter Speed, (sec.)
	5 FPS*	4.5 FPS*	4.0 FPS*	
12	40.9	36.8	32.7	
11	37.5	33.8	30.0	1/2000
10	34.1	30.1	27.3	
9	30.7	27.6	24.6	
8	27.3	24.6	21.8	1/1000
7	23.9	21.5	19.1	
6	20.5	18.4	16.4	
5	17.1	15.3	13.6	
4	13.7	12.3	10.9	

*Speed of execution in frames per second.

1 foot = 0.3048 meters.

1 m.p.h. = 1.6 km/h.

borderlines for shutterspeed were determined from trial runs that will be discussed later.

The type of camera equipment to be used, therefore, depends on the requirements of the surveyor and analyst. The shutterspeed, speed with which a camera can take pictures, as well as vehicle speed, is highly correlated. Generally, it will be found that cameras are capable of between 4.0 and 5.0 frames per second, which is the range of execution depicted in Table 3.2.

It is now possible to determine vehicle speed from the tables with the camera characteristics a known factor.

Trial Runs

A motor driven camera capable of 4.5 frames per second was used in some trial runs on a section of CRCP. Markers were painted on the highway at 10-foot (3.0-m) intervals. An attempt was made to take pictures such that no overlap or gap existed between different exposures; thus it would be possible to determine crack spacing accurately.

Two different types of lenses were used, which enabled photographing the section at different speeds without altering the camera height. Several types of film were used, but the biggest difference was found between the black and white and the colored film. As can be expected, the different types of black and white film just produced a difference in quality regarding grain since the shutterspeed/lens opening combination did not have an effect on the quality nor on the focusing.

Runs were made at different times of the day and it was found that an aperture of 5.6 was the maximum used for a shutterspeed of 1/1000 second with afternoon sunshine on a white pavement. The quality of light drastically changes toward sundown and an aperture of 2.3 for a 1/1000-second shutterspeed was necessary before sundown for a 160 ASA film. Therefore, it is anticipated that a 3.5 aperature will be required in combination with a 1/2000-second shutterspeed and a 160 ASA filmspeed for full daylight photography.

Results from this study are depicted in Figs 3.2 through 3.5, where the subscripts explain the conditions during photographing. Figure 3.2 depicts an edge view or a view as seen from a vehicle travelling on the shoulder simulating the Project 21 survey technique. Figure 3.3 was taken at 10

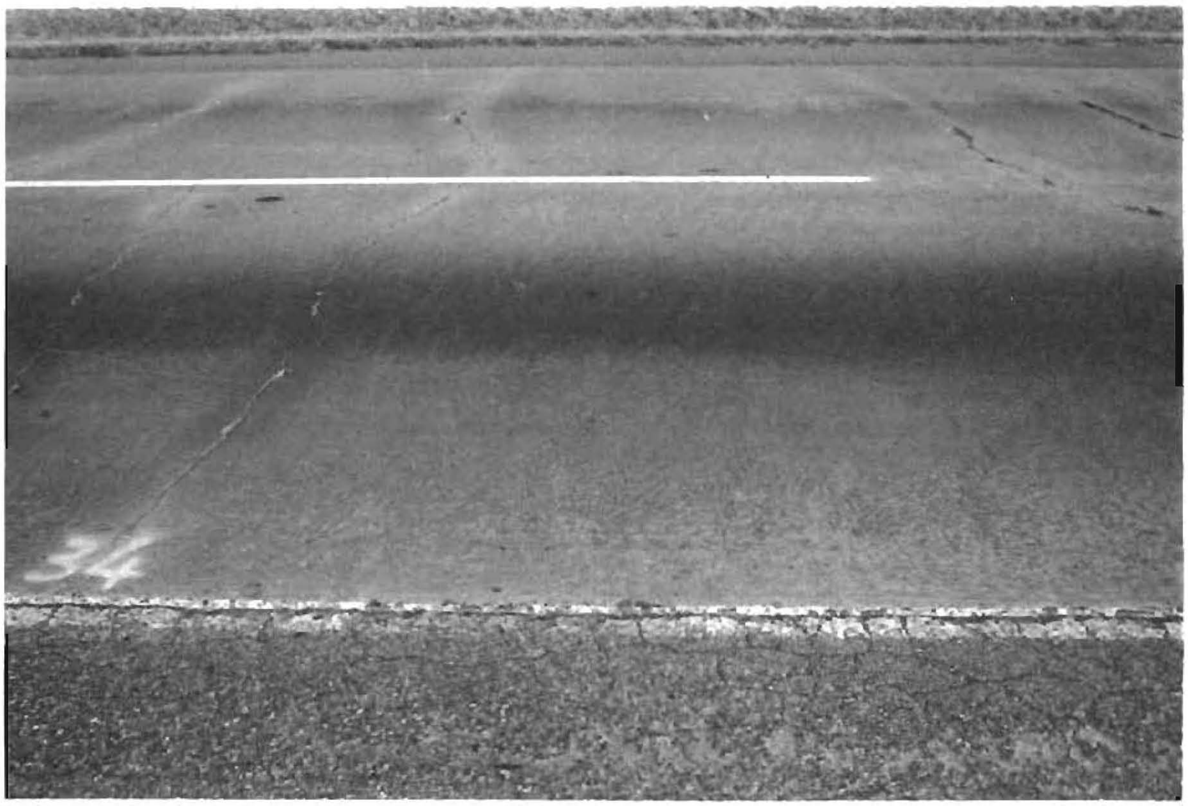

Fig 3.2. View from the shoulder
(Project 21 Survey).

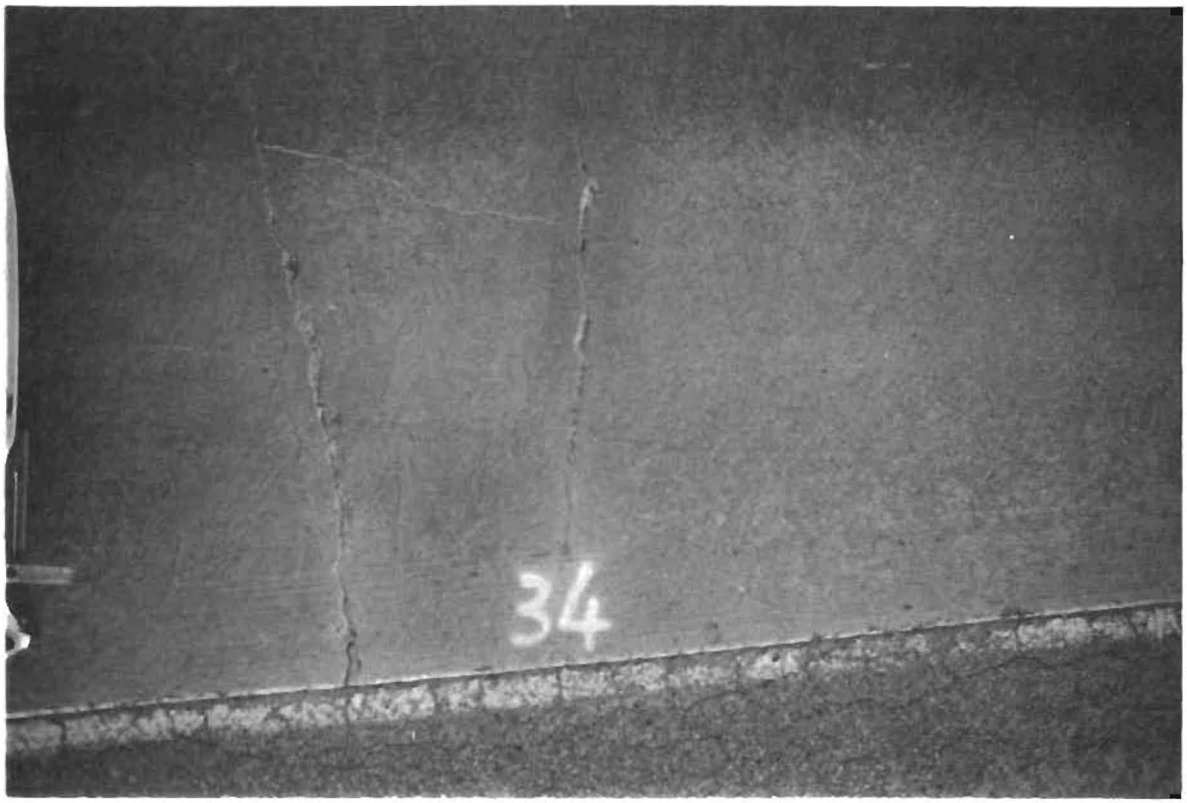

Fig 3.3. Picture taken from boom as shown in Fig 3.1 - 24-mm lens, 10 mph(16 km/h).

Fig 3.4. Picture taken from boom shown in Fig 3.1.
-28-mm lens, 24 mph (38 km/h).

Fig 3.5. Picture taken from boom shown in Fig 3.1
-24-mm lens, 33 mph (53 km/h).

miles per hour (16 km/h) with a 24-mm lens and a 3.5 aperature at a 1/1000-second shutterspeed using a 400 ASA film from 8 feet (2.4 m) above the pavement. The time was late afternoon with no cloud cover.

A picture taken at 24 miles per hour (38 km/h) with a 28-mm lens, 2.5 aperture, and 1/1000-second shutterspeed on a 125 ASA film is shown in Fig 3.4. Compare this with Fig 3.5, which shows a picture at 33 miles per hour (53 km/h) with a 24 mm lens, 2.8 aperture, and 1/1000-shutterspeed on the same film, and the increase in blur is noticeable. However, the quality can be improved considerably in increasing shutterspeed, which will make Fig 3.4 look like 3.3 if a 1/2000-second shutterspeed can be used. Since the pictures in Figs 3.4 and 3.5 were taken two hours before sundown, the critical aperture occurs at a 1/2000-second shutterspeed. This places certain restrictions on the capabilities of the camera equipment as well as the time of the day and weather conditions under whihc the study is performed.

Color film was also used in the study, but, since reproduction is difficult, the results are not shown in this report. However, the same results were found with color film as was indicated above. The color film was superior for defining and contrasting pumping at the pavemetn edge, which made this film type superior to black and white.

In conclusion, it can be said that a moving photographic record of distress is possible. No sacrifice is made in the quality of the survey, as can be seen from the pictures shown. The distress in the picture, minor spalling and the initiation of minor punchouts, is some of the most important, but also the most difficult, distress to recognize. Photographic survey seems to pass the test in this respect.

Picture Sequence

One of the most important aspects of any photo-logging method is a technique for sequencing pictures and also identifying the exact location on the project. This was accomplished by two techniques. For a project, an initial photograph of a pad, is taken as shown in Fig 3.6. This shows the essential descriptive features of the project, such as project number, limits, lane direction, and lane being photographed. For individual pictures in the given project, the record is tied to the milepost. A digital mechanical

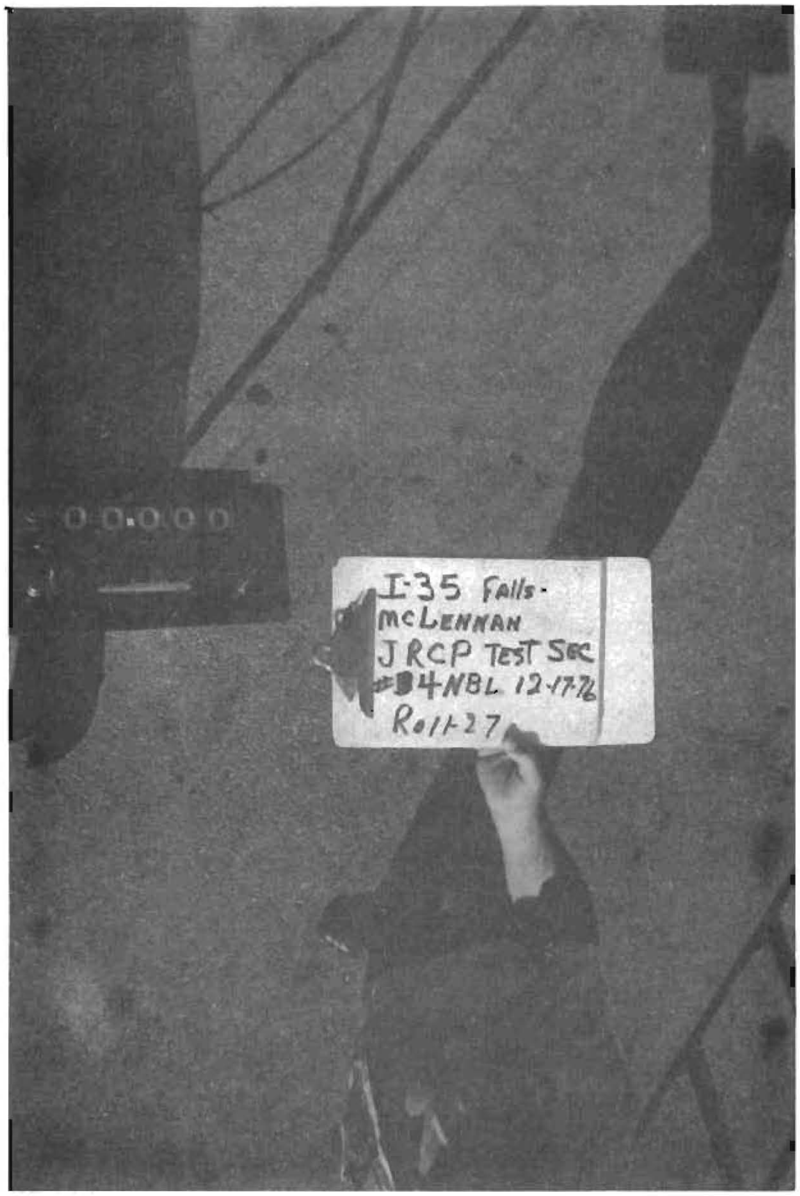

Fig 3.6. Photograph of pad showing descriptive features of the project.

reader was mounted on the camera frame at approximately three feet from the camera. In this manner, a digital readout is picked up in each individual photograph. This is also illustrated in Fig 3.6. The left side of the photograph shows the digital readout. Thus, by setting the milepoint for the start of the project in the digital readout and tying it to the speedometer, every photograph has a record of milepoint recorded to the nearest .001 of a mile. Also, by this simple addition a permanent record of the location and a sequence for the photographs are acheived.

CHAPTER 4. ANALYSIS OF THE PHOTO SURVEY

The pictures that result from a photographic survey can be used in several ways. Primarily, the aim is to utilize the pictures in a condition survey of the Project 21 type and if possible to include an estimation of mean crack spacing as well as the distribtuion of crack spacing. This chapter will be devoted to a condition survey analysis on the basis of the definitions of distress as used in Project 21 (Ref 1). Subsequently, a sample selection of a project will be discussed, together with a comparison in cost between a photographic survey and a Project wl type survey. Finally some proposals for a proper photographic survey will be made.

Condition Survey

Trial runs on a section of CRCP in Falls-McLennan counties provided the opportunity to compare a regular Project 21 survey with a photographic survey. Since the pictures were taken in a continuous strip, estimate of mena crack spacing is also possible, by correlating vehicle speed and the speed of the camera in taking pictures. Since there were no gaps or overlaps between pictures and since the length L of the pavement photographed can be determined, it is possible to estimate crack spacing on each picture.

The quantitative estimation of distress on the Project 21 surey is done in terms of categories, as shown in Fig 4.1, a form sued in the condition survey. Categories, such as 1 through 5, 5 through 20, 20 through 50, and 50 through 100 percent of the length that shows distress, leave room for improvement in accuracy since the actual percentage of length distressed can be measured from pictures. It comes, therefore, as no surprise that the Project 21 survey and the photo survey render the same results if surveying records on a form as in Fig 4.1 are compared. The precise amount of distress can, however, be pinpointed in a photo survey and no categories are necessary as is the case in the Project 21 survey.

District	Control	Section	Highway	County	Leave Blank	Date Mo. Day Yr.
						- -

Leave Blank	Location From	To	Raters

Mile Post	Mile Point	Transverse Cracks % M				Transverse Cracks % S				Localized Cracks % M				Localized Cracks % S				Spalling % M				Spalling % S				Pumping % M				Pumping % S				Punch Outs in feet M				Punch Outs in feet S				Repair Patches Square feet A.C.				Repair Patches Square feet P.C.C.				Ride
		1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-5	5-20	20-50	50-100	1-3	4-9	10-19	> 20	1-3	4-9	10-19	> 20	1-15	16-120	121-240	>241	1-15	16-120	121-240	>241	

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

M - Minor S - Severe A.C. - Asphalt P.C.C. - Portland Cement

Condition of Shoulder ______________________________

General Comments ______________________________

Fig 4.1. CRCP Performance Survey Form.

Mean Crack Spacing

The dimensions of the pavement that is represented in an individual picture are known from Table 3.1. It is, therefore, an easy exercise to estimate or even measure the distances between cracks on the picture and, by combining the continuous series of pictures of one section together, to get a value for mean crack spacing for a section.

Results from the photo survey, which entails a 360-feet (110-m) section, can be compared with a 1200-foot (366-m) survey of crack spacing that was done with a measuring wheel or rolartape in 1974. The altter rendered a mean crack spacing of 7.05 feet (2.15-m) and the photo survey a value of 6.9 feet (2.10 m).

The difference in value can be attributed to several causes:

(1) The crack spacing has changed since 1974 and mroe cracks have appeared, which will reduce the mean crack spacing.

(2) A sample of 360 feet (110 m) of a 1200-foot (360-m) section seems to be inaccurate and does not result in exactly the same mean crack spacing.

However, the accuracy attained is as good as can be expected, from an engineering point of view. In fact, a reduction of the sampling section may be proposed.

Length of Sections

The condition survey that was done nationally for Project 1-15 (Ref 4) was based on a 1200-foot (360-m) section, which was considered to be representi-tive of a project. The range in length of project varyies greatly. In Texas, projects can be as short as 0.38 miles (0.61 km) and can reach a length of 16 miles (25.7 km), but in every case 1200-foot (360-m) sample sections were used, which was satisfactory. The soundness of this deciosn is illustrated in the previous paragraph, which indicated a minute difference in mean crack spacing between 1200-foot (360-m) and 360-foot (110-m) sections.

The use of 360-foot (110-m) sections as representative of the condition of one miel (1.6 km) of highway pavement seems justified. The reduction of the sample length to 300 feet (91-m) can probably be justified too, but smaller section lengths are not advisable.

A section length of 300 feet (91 m) represents the crack spacing, the condition of the cracks in terms of spalling, and possibly the occurrence of pumping on a regular basis. Since the vehicle speed is in the order of 30 miles per hour (48 km/h), it is possible to detect and count the structural failures in the form of punchouts and repair patches. A categorical survey of structural failure is possible if a limited spectrm is used in terms of size, e.g., small, medium, and large, where medium may range from 20 square feet (2 m^2) to 100 square feet (9.29 m^2) for repair patches and from 3 feet (1 m) to 6 feet (2 m) in length for punchouts. The more obvious manifestations of pumping are also detectable at this speed and can be noted while travelling between 300-foot (91-m) sections.

In summary, it can be said that 300-foot (91-m) sections provide an accurate enough sample of 1 mile (1.6 km) sections of highway in terms of cracking, spalling, and pumping. Photographing these 300-foot (91-m) sections provides an excellent record of pavement condition from which any survey is possible.

Cost Comparison

Both the Project 21 and the photographic surveys require a two-man team with a motorized vehicle. The big difference between the two types of operations is the speed of execution. The Project 21 survey is performed at around 5 to 7 miles per hour (8 to 11 km/h), whereas the photographic survey is done at above 30 miles per hour (48 km/h). It needs to be kept in mind that a real survey still needs to be done on the resulting pictures of the photographic survey, but in a trial run it was estimated that the survey rate is about 20 to 30 miles per hour (32 to 48 km/h) if 300-foot (91-m) sections are considered. An additional disadvantage of the Project 21 survey is the requirement of a 10 percent control survey by outside teams.

The cost of the camera equipment is \$2,000 to \$2500, which includes all film magazines and the loading equipment. Film bought in 100-foot (32-m) rolls costs \$28.00 per roll, and developing costs \$15.00 per roll. Assuming there are approximately one thousand miles (1600 km) of CRCP to be surveyed. Averaging 50 miles (80 km) per day a survey by this method would cost approximately \$6000, whereas Project 21 type survey with one team doing ten percent for statistical comparison and uniformity would cost approximately \$10,000.

Based on this cost study, it seems as if the photographic survey is more economical, although it is based on only a 6 percent coverage, compared to a 100 percent coverage for the Project 21 survey. However, the additional advantage of determining mean crack spacing and having visual records of the pavement condition for future reference can hardly be expressed in terms of dollars.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

A photographic survey of the condition of a CRCP pavement is possible, provided the correct combination of vehicle speed and equipment is selected. This type of survey may be the only way of assessing the structural performance of pavements in urban areas where the traffic density discourages any visual condition survey, as was made in rural Texas under Project 21. The sacrifice in quality from a visual to a photographic survey is none, but the quality is tied to the sample size which is taken. In the event of 300-foot (91-m) sections being taken every mile, the quality of the survey is still high and a slight cost saving materializes. However, considerable gain is to be reaped from a photographic survey since permanent records of pavement condition can be established as well as an accurate determination of the mean and the distribution of crack spacing.

The coverage of pavement for each individual picture depends on the height of the camera and the type of lens used. A continuous strip of pictures without any gap or overlap can be produced by incorporating an electric motor-drive on the camera. A film advance speed of around 4.5 frames per second, a camera height of about 10 feet (3.0 m) and the usage of a 28-mm lens make it possible to produce a continuous film strip of the pavement at a vehicle speed of around 30.1 miles per hour (48.4 km/h). Clarity of the pavement surface depends on shutterspeed to a great extent, and it is recommended that a shutterspeed of 1/2000 second be used when the survey is done at speeds greater than 30 miles per hour (48 km/h).

In order to establish a means of identification, it is recommended that sample sections be taken at known points, such as mileposts. Identification of individual pictures is possible by the incorporation of a trip recorder on the outside of the vehicle such that the recorder is photographed at the same time that pictures are taken of the pavement surface. It is acknowledged that the proposed way of identification sounds crude, but in a cost comparison the proposed method is about 25 percent of the cost of other photologging systems which include an extensive identification system but which have the severe restriction of a shutterspeed of only 1/500 seconds.

The experimental work described in this report is not intended to serve as a specification but merely attempts to show the real possibility of a condition survey in the form of a photographic study. The proposed method is very inexpensive compared to other systems and is intended to provide the maximum benefit for the least cost. Wider applications such as photographing jointed and flexible pavements have not been investigated but pose no problem. The use of color film is proposed in all surveys since it enhances the recognitions of foreign matter on the pavements as well as the definition of minor types of distress. This type of film may also assist in the photography of other types of pavements.

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THE AUTHORS

Pieter J. Strauss received his B.Sc. in Civil Engineering at the University of Pretoria, South Arrica, in 1966. He has had several years experience as a consulting engineer in South Africa, during which time he supervised the construction of several highway and airport projects. He was also closely associated with the evaluation and design of rehabilitation work on the major airports in South Afrioa. He joined the Center for Highway Research, The University of Texas at Austin, as a research assistant in 1973. In 1975 he completed his M. S. degree and in 1976 he completed his Ph.D. degree with research in the field of the structural performance of continuously reinforced concrete pavements. He is a member of several professional societies.

James F. Long is a Technical Staff Assistant, IV at the Center for Highway Research, The University of Texas at Austin. His experience includes four years in the field of highway and laboratory data acquisition for pavement condition surveys, one year in operation and calibration of the Mays roadmeter for use in Pavement Roughness Programs, two years in the operation, calibration and maintenance of the General Motors Profilometer, and one year of work on the development and operation of a system for obtaining pavement condition surveys using a 35mm motor driven camera.

B. Frank McCullough is a Professor of Civil Engineering at The Univeristy of Texas at Austin. He has strong interests in pavements and pavement design and has developed design methods for continuously reinforced concrete pavements currently used by the State Department of Highways and Public Transportation, U. S. Steel Corporation, and others. He has also developed overlay design methods now being used by the FAA, U. S. Air Force, and the FHWA. During the nine years with the State Department of Highways and Public Transportation, he was active in a variety of research and design activities. He has authored over 100 publications which have appeared in national journals.