Condition Surveys of Bituminous Resurfacings Over Concrete Pavements

LEWIS W. CRUMP, Research Engineer, and
ALEXANDER J. BONE, Associate Professor
Joint Highway Research Project, Massachusetts Institute of Technology

This paper describes a technique for making and analyzing condition surveys of bituminous resurfacings over concrete pavements. Successive surveys provide a basis for evaluating the performance of different resurfacing types.

Survey sections include about 1,000 feet of typical pavement. The location and extent of all defects are measured in the field and recorded directly on forms prepared for that purpose. All cracks are classified by width and by their most likely cause, which can usually be determined quite accurately by observation or by inspection of construction and maintenance records.

Indices are computed from the field data and are used to compare the performance of the different resurfacings. They are computed for the incidence of cracking over transverse and longitudinal joints, over joints between concrete and adjacent bituminous shoulders, at construction joints in the resurfacing, and over cracks and other defects in the underlying concrete.

The survey method differs from those applicable to concrete pavements or to bituminous surfaces on flexible bases. Defects may be caused by deterioration of either the concrete or the bituminous resurfacing, or by the dissimilar properties of the two materials. The method has been developed and refined through 2 years of data collecting and has been successfully used on repeated surveys of 25 test sections totaling over 6 miles in length.

●THE condition survey has long been recognized as a useful tool for evaluating pavement performance in the field. It may be used to determine the present condition of a pavement, as is often done for sufficiency-rating purposes, or to determine the rate and nature of deterioration. The latter requires repeating surveys at regular intervals.

In making studies of bituminous resurfacings over concrete pavements, the need for condition surveys soon became obvious. While the occurrence of reflection cracking (cracking of the resurfacing immediately over joints, edges, and cracks in the underlying pavement) was readily recognized, little was generally known regarding its extent, cause, and rate of growth. The condition survey described in this paper has been designed to collect quantitative data on these factors. In addition, it is used to compare various types of resurfacings.

CONDITION CHARACTERISTICS TO BE MEASURED

The first step in setting up a survey is to determine what is to be measured. In evaluating resurfacings, the following condition characteristics are important:

Cracking

Cracking is the first serious defect that develops in resurfacings. Most of it is reflection cracking caused by the joints in the underlying concrete. Since reflection cracking is the primary objective of the study, it is desirable to have as much detail as possible about cracks. Location, size, and shape should be determined. Cracks also vary in appearance. Some tend to spall along the edges. Others tend to heal due to the kneading action of traffic. It is necessary to know whether the cracks have been sealed, and to note the presence of any excess sealing material on the adjacent surface. Information should also be recorded as to whether cracks are filled with dirt and sand.

Texture of Surface

Surface texture is an important clue to performance of the pavement. Uneven or wavy surfaces are indications of instability. The extent of any wavy surface should be noted, along with some quantitative indication of the axis, amplitude, and period of the waves.

It should be noted whether the surface is open or dense, rough or smooth. Surface texture will vary with the aggregate gradation and asphalt content of the mixes, as well as with construction procedures such as finishing and rolling. Surface texture often changes with age and may be a clue to densification by traffic or to scaling. Nonuniformities should be especially noted.

Local Defects

Local defects should be described fully to facilitate explanation of their occurrence and an appraisal of their influence on pavement performance. They include such items as localized areas of wear, ravelling, patches, shoving or unevenness, and fat spots

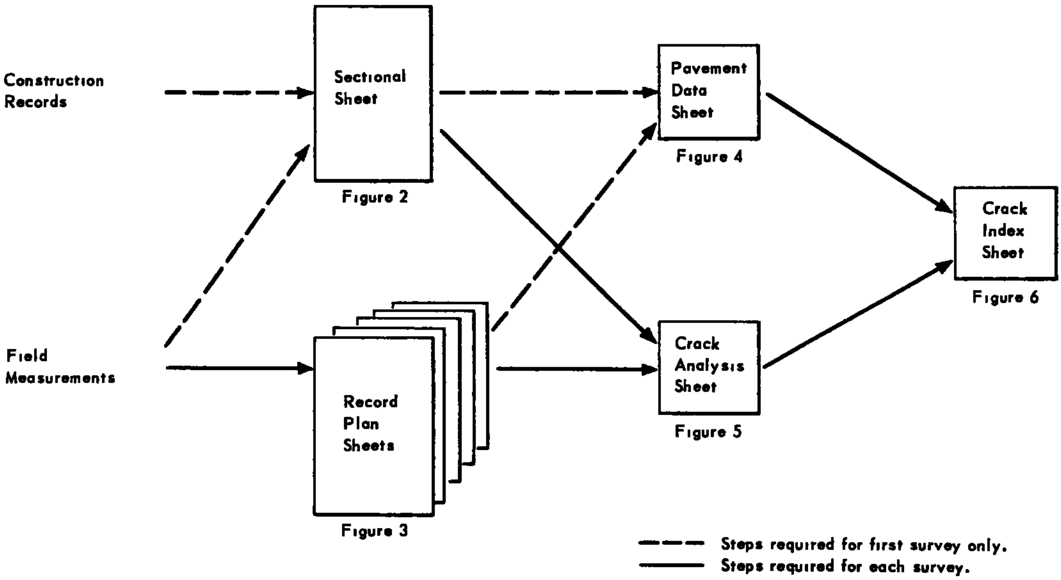


Figure 1. Data flow diagram for survey data of one section.

caused either by an excess of bitumen in the pavement or by oil drippings. Crawler tracks, accident scars, and other evidences of vehicle damage should also be recorded.

Special Conditions

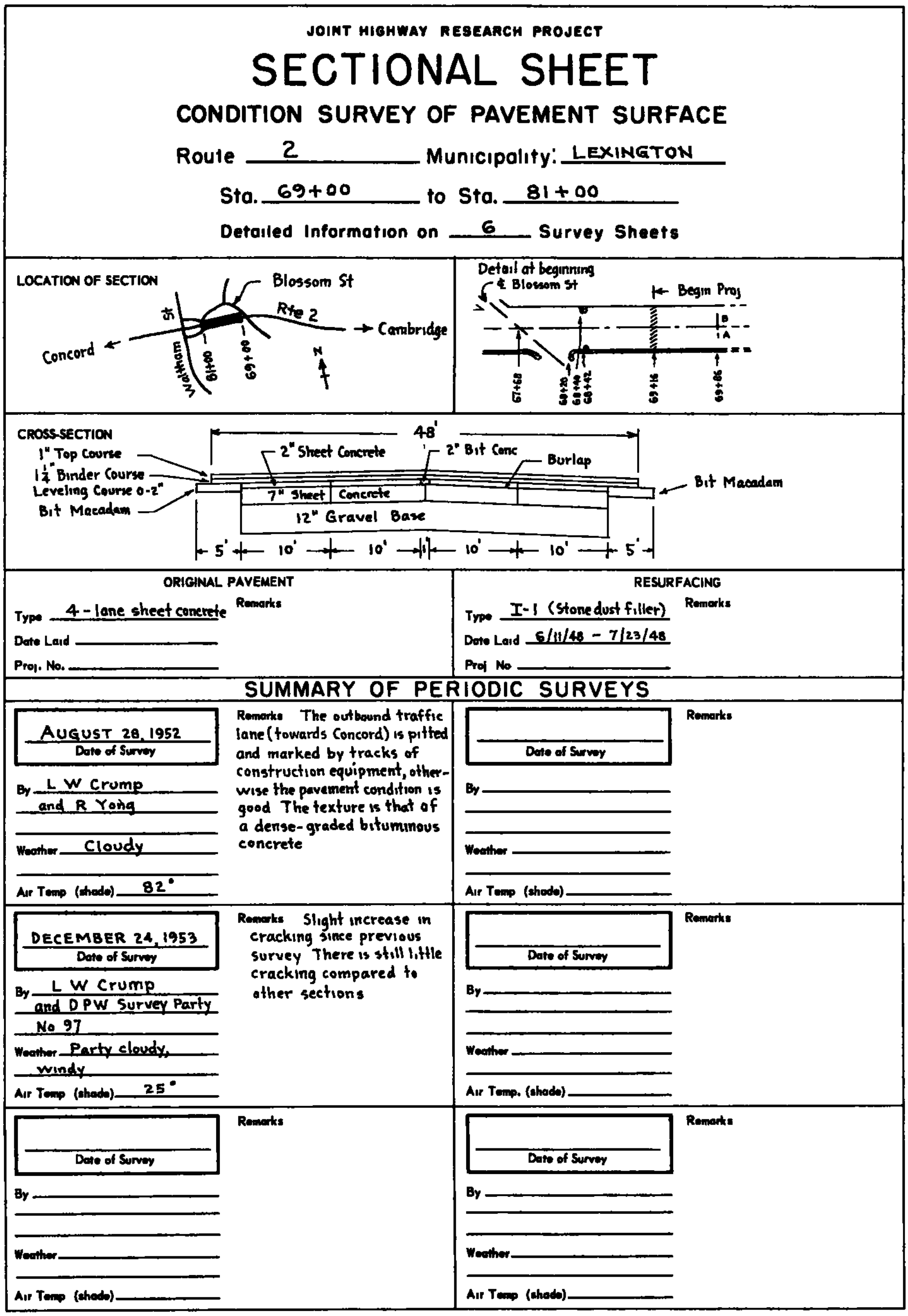
Any special conditions that might affect performance should be reported. Three types which should be looked for are unusual subgrade conditions, drainage conditions, and traffic patterns. The latter might include lateral placement of vehicles, unusual speeds, heavy truck traffic, presence of bus stops, stop signs, traffic signals, or truck turning areas. Traffic patterns at intersections should be noted if they are unusual.

Miscellaneous

Other factors that have a bearing on pavement performance should also be noted. It is better to have too much detail than too little. Extraneous data can be eliminated in the analysis, but missing data is seldom available at a later date.

OBTAINING AND RECORDING SURVEY DATA

Before laying out the survey procedure for resurfacings, a review was made of survey techniques developed for concrete pavements and for bituminous pavements on flexible bases. Most of these measure the size and seriousness of defects. In evaluating the defects in resurfacings, it is necessary to relate them to features in the underlying concrete. For this reason, a further classification, "cause," was established. The cause relates the defects to the joints, edges, and cracks in the concrete which are responsible for them.



JOINT HIGHWAY RESEARCH PROJECT

SECTIONAL SHEET

CONDITION SURVEY OF PAVEMENT SURFACE

Route 2 Municipality: LEXINGTON

Sta. 69+00 to Sta. 81+00

Detailed Information on 6 Survey Sheets

ORIGINAL PAVEMENT		RESURFACING	
Type 4-lane sheet concrete	Remarks	Type I-1 (Stone dust filler)	Remarks
Date Laid		Date Laid 6/11/48 - 7/23/48	
Proj. No.		Proj No	

SUMMARY OF PERIODIC SURVEYS

	Remarks		Remarks
AUGUST 28, 1952 (Date of Survey); By L W Crump and R Yong; Weather Cloudy; Air Temp (shade) 82°	The outbound traffic lane (towards Concord) is pitted and marked by tracks of construction equipment, otherwise the pavement condition is good. The texture is that of a dense-graded bituminous concrete	Date of Survey; By; Weather; Air Temp (shade)	
DECEMBER 24, 1953 (Date of Survey); By L W Crump and D PW Survey Party No 97; Weather Party cloudy, windy; Air Temp (shade) 25°	Slight increase in cracking since previous survey. There is still little cracking compared to other sections	Date of Survey; By; Weather; Air Temp. (shade)	
Date of Survey; By; Weather; Air Temp (shade)		Date of Survey; By; Weather; Air Temp (shade)	

Figure 2. Typical sectional sheet for condition survey of bituminous resurfacing.

Possible Techniques

Four possible techniques of making the survey were considered. Each was evaluated as to reliability in measuring the condition characteristics desired and as to ease and economy of operation. The four methods were aerial photography, ground photography, visual observation with results plotted to scale on plan sheets, and visual observation with data recorded as field notes. Neither type of photography will show up cracks in bituminous pavement in their natural state. Painting the cracks to emphasize them is feasible only where the road can be closed to traffic, for any tracking of the fresh paint by vehicle tires would result in hopeless confusion. Since visual inspection of surrounding conditions is necessary to adequately describe many of the defects, there appeared to be no advantage in collecting part of the data by photographic means.

Having decided upon visual observation as the survey technique, consideration was given to the best way of recording the data in the field simply, yet in the desired detail. The method adopted is to plot the defects to scale on grid-plan record sheets. The data is subsequently analyzed systematically to determine overall trends. Figure 1 shows the relation of the various sheets used in the fieldwork and in the analysis. Figures 2 to 6 show the actual forms used.

Selection of Survey Sections

In determining the length of highway which may be properly represented by a sample section, the following factors must be considered: (1) type of original pavement and condition at time of resurfacing; (2) type of resurfacing, date laid, and construction conditions; (3) subgrade and drainage conditions; and (4) geometric design, traffic volumes, wheel loads, etc.

The entire roadway should be inspected to determine the limits of areas within which the above factors are consistent. Once these areas are established, sample sections can be selected in each at a location which appears to be representative and which is convenient for the field work.

The sample of highway adopted as a survey section is usually 1,000 feet long. This has been found to be an adequate sample size from which to evaluate reflection cracking.

Collecting Basic Data on the Section

Before making the surveys, all available construction records should be reviewed to secure basic pavement data. This information is recorded on the sectional sheet (Figure 2) and provides a basis for classifying and evaluating the data collected in the field survey. Basic data include the section location, dates of construction and resurfacing, subgrade and drainage characteristics, traffic data, and all details of pavement design.

Field Procedure

The field procedure consists of systematically locating and recording the defects. A temporary grid, corresponding to the grid on the record sheets (Figure 3), is established on the pavement with two intersecting tapes. Defects are plotted to scale and identified by appropriate symbols shown on the record sheets. The width of cracks is measured visually in units of 0.01 foot and recorded on the sheets with a letter code.[1] While this is only approximate, the meandering alinement of the cracks makes more precise determinations impossible. The step-by-step procedure, together with details of the personnel and equipment required, is given in Appendix A.

Description of the Record Sheet

On the record sheet there are three identical grids, which are used for successive surveys of the same area. This type of sheet has proved more satisfactory than one having a single grid on which the various surveys are superimposed. On the sheets shown, each grid corresponds to 200 feet of highway. Thus, several sheets are needed for each section. The scale is 25 feet to the inch, which is satisfactory for moderate amounts of deterioration. Larger-scale sheets should be used for badly deteriorated pavements.

---

[1] The crack width code described has been used for several years by the authors. Convenience justifies its continuance in their organization, but they recommend that any future classifications be based on tenths of inches, not hundredths of feet.

Different colors can be used to advantage. The form has lettering and border in black and the grids in light blue. The field data are recorded in black pencil lines over the

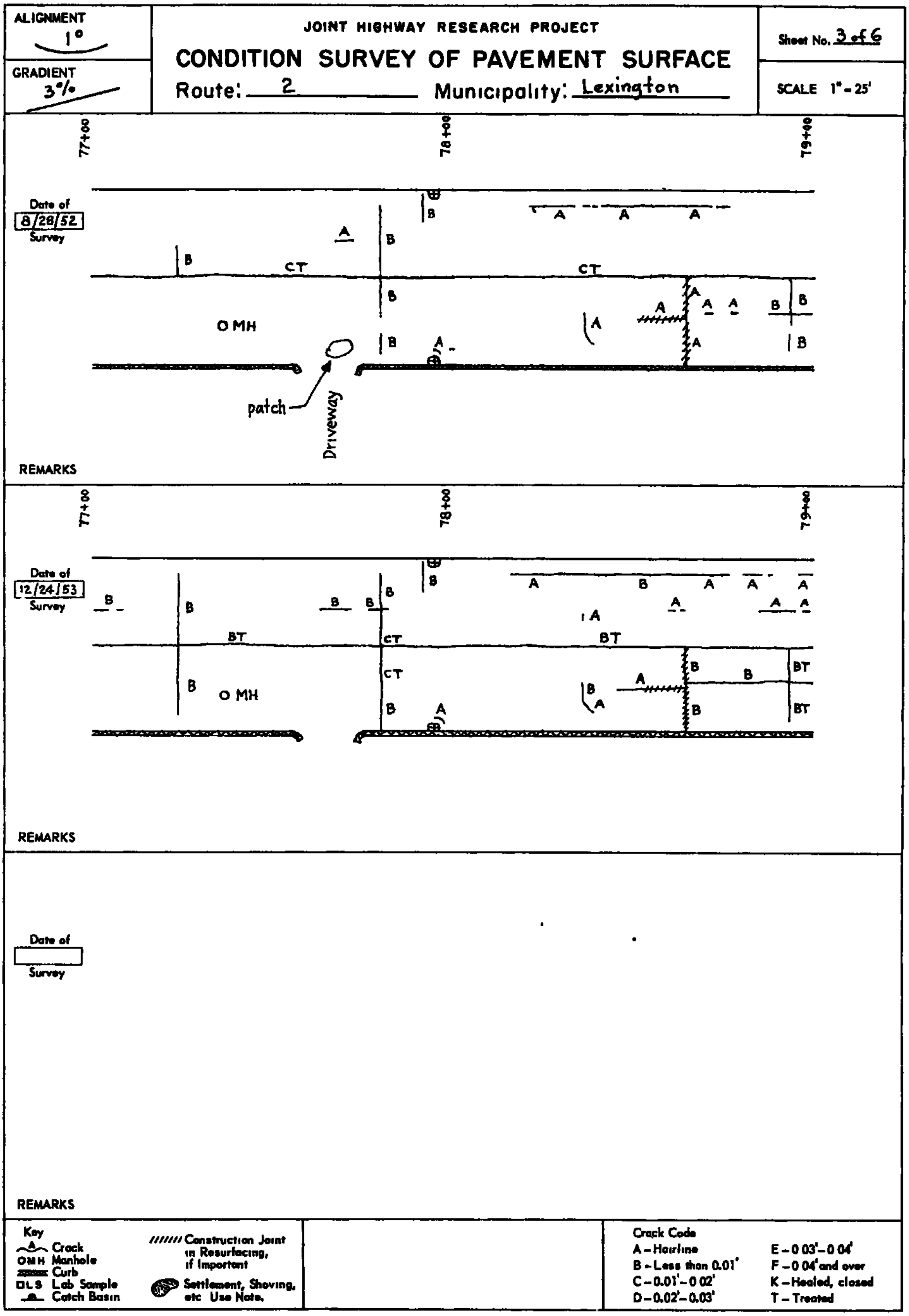


Figure 3. Typical record plan sheet for condition survey of bituminous resurfacing.

blue grid, thus, avoiding confusion between grid lines and cracks. As an aid in classifying and analyzing cracks, a third color may be used to delineate the outlines of the underlying concrete slabs.

JOINT HIGHWAY RESEARCH PROJECT
M. I. T. – Mass. D.P.W.
CONDITION SURVEY OF BITUMINOUS PAVEMENT SURFACE

11	
Section	
5.5	8

PAVEMENT DATA SHEET

Route 2 Town Lexington
Sta. 69 + 00 to 81 + 00

MEASUREMENTS OF THE SECTION

1. Length of section at ℄, in ft. 1,200
2. Width of resurfacing, in ft 48
3. Area of total resurfacing, in sq. ft.
   length x width 57,600
   other areas
   .... –
   .... –
   Total area (sq. ft.) 57,600
4. Area of resurfaced concrete, in sq. ft.
   length x width 48,000
   other areas
   .... –
   Total concrete area (sq. ft.) 48,000
5. Number of standard slabs*, Line No. 4 Total / 570 842

NUMBER AND LENGTH OF TRANSVERSE JOINTS

6. Number of transverse joints, 10 ft. wide 84
7. Number of joint ends adjacent to bituminous shoulder (or lane) 42
8. Total length of transverse joint, in ft. 840

LENGTH OF LONGITUDINAL JOINT, IN FT., BETWEEN

9. adjacent slabs 3,600
10. slab and bituminous shoulder 2,400
11. slab and bituminous center lane .... –
12. Total length of longitudinal joint, in ft 6,000

* Standard slabs are 10 ft. by 57 ft. E T. 12/54

Figure 4. Typical pavement data sheet.

ANALYSIS OF THE SURVEY

Computation of Crack Indices

Nearly all the defects discovered in the pavements for which this survey was designed are cracks of various types. To insure a uniform, systematic grouping system for cracks, a standard "Crack Analysis Sheet" has been designed. This is shown in Figure 5 and each item is described in detail in Appendix C. One sheet is used for each survey of each section. The cracks are classified by cause, and each cause group further subdivided by width. There are nine cause classifications and six width classifications, giving a total of 54 groups. Usually all of these do not apply to any one pavement section. The actual grouping process consists of systematically going through the record sheets and summing the lengths of cracks in each of the 54 groups. The sums are determined graphically by plotting the lengths of the cracks in each group consecutively along the edge of a strip of paper.

The Pavement Data Sheet (Figure 4) lists basic information about the resurfacing and the underlying concrete pavement in a survey section. A detailed description of this sheet is given in Appendix B. Data are obtained from the sectional sheet and from record plan sheets as a part of the first survey of each section. Much of it can be inferred from the crack patterns.

The data on the analysis sheets is used in conjunction with that on the pavement data sheet to compute a series of indices, which have been developed to facilitate comparisons of various surveys. These indices are recorded on the standard Crack Index Sheet (Figure 6), one of which is used to summarize each survey. Detailed definitions of the indices are given in Appendix D.

Section	11
A.A.G.	[illegible]
Survey Number	3

JOINT HIGHWAY RESEARCH PROJECT

M.I.T. - Mass D.P.W.

CONDITION SURVEY OF BITUMINOUS PAVEMENT SURFACE

CRACK ANALYSIS SHEET

Route 2 Town Lexington

Sta. 69+00 to 81+00

Date of Survey Dec 24, 1953

GENERAL CRACK DATA

13. Number of transverse joints, 10 ft. wide, with some kind of crack over them 83
14. Number of transverse crack extensions over bituminous shoulder (or lane) 29

LENGTH OF CRACKS, IN FT.

Type → / Width ↓	Transverse					Longitudinal					Misc.	Total
	Over transverse joints	Not over joint, but over concrete	Extensions over bituminous shoulder (or lane)	In construction joint in resurfacing	Total	Over joint between adjacent slabs	Over joint between slab and shoulder	Over joint between slab and bituminous center lane	In construction joint in resurfacing	Total	All cracks not listed otherwise	All cracks
	15	16	17	18	19	20	21	22	23	24	25	26
A	52	10	11	19	92	310	163		—	473	20	585
B	513	—	50	2	565	273	859		—	1132	—	1697
C	213	—	—	—	213	—	—		—	—	—	213
D	10	—	—	—	10	—	—		—	—	—	10
E	—	—	—	—	—	—	—		—	—	—	—
F	—	—	—	—	—	—	—		—	—	—	—
Total	783	10	61	21	880	583	1022		—	1605	20	2505

E.T. 12/54

Figure 5. Typical crack analysis sheet.

11	Section
J.S.	E
3	Survey Number

CRACKS OVER INTERIOR OF SLABS

Linear feet per slab.
(Transverse cracks only) 0.1

CRACKS IN CONSTRUCTION JOINTS IN RESURFACING

Feet per 1000 sq. ft.
Transverse 0.36
Longitudinal 0

EXTENSIONS OVER BITUMINOUS SHOULDER (or LANE)

LENGTH Average length of transverse crack extension 2.1

FREQUENCY. Number of crack extensions / Number of joint ends adjacent to bituminous shoulder (or lane) 0.7

JOINT HIGHWAY RESEARCH PROJECT

M.I.T.-Mass. D.P.W.

CONDITION SURVEY OF BITUMINOUS PAVEMENT SURFACE

CRACK INDEX SHEET

Route 2 Town Lexington
Sta. 69+00 to 81+00
Date of Survey Dec 24, 1953

CRACKS OVER JOINTS

Width	TRANSVERSE Percent of length of transverse joint cracked	LONGITUDINAL: Percent of Length cracked			
		Of longitudinal joint between adjacent slabs	Of longitudinal joint between slab and adjacent bituminous shoulder	Of longitudinal joint between slab and adjacent bituminous center lane	Of total longitudinal joint
A	6	9	7		8
B	61	8	36		19
C	25	–	–		–
D	1	–	–		–
E	–	–	–		–
F	–	–	–		–
Total	94	17	43		27

E.T 12/54

Figure 6. Typical crack index sheet.

In general, each index compares the amount of cracking of a certain type with a measure of the features of the underlying pavement to which this cracking is related. Cracking over joints is expressed by the percentage ratio between the length of crack and the length of joint, as for example, "percent of length cracked of transverse joint." Cracking over the concrete, but not at joints, is expressed as the average length of crack per unit area of concrete. Cracking of the construction joints in the resurfacing is expressed by the ratio of length of crack to area of resurfacing. Such cracking is not related to the concrete but is purely a phenomenon of the resurfacing itself.

It was found that many transverse-reflection cracks extended into the resurfacing over the bituminous shoulder adjacent to the old concrete pavement instead of ending at the edge of the concrete as might be expected. Crack extensions were also found over bituminous center lanes used in "dual" type pavement.[2] Many of these crack extensions were 2 or 3 feet long, some as much as 6 feet, running to the edge of the resurfacing. Indices were set up to measure their frequency of occurrence and average length.

In the Massachusetts pavements for which these surveys were designed, only expansion joints are used in the transverse direction. There are no contraction joints and no warping joints. In pavements having more than one type of transverse joint, the cracks over each type should be analyzed separately.

Comparison of Periodic Surveys

Data from periodic surveys of the same section can be compared by means of the indices and, also, by a direct comparison of defects plotted from successive surveys on the field record sheets. The indices for various types of cracking, being ratios with a fixed denominator, can be tabulated or plotted for comparative purposes.

The successive record of various sections taken thus far shows a definite progression of reflection cracking in the early years. Different types of cracking develop at different rates, but all types tend to increase with each additional climatic cycle. For instance, by the third year many pavements have cracks over more than 75 percent of the length of transverse joint. A few reach 95 to 100 percent in 3 or 4 years. Successive surveys then show progressive growth of crack width after each annual temperature cycle, rather than an increase in length of cracking.

Surveys made in different seasons show a cyclical change in crack width following the annual temperature cycle. Cracks are widest in the winter and early spring. In certain sections, they close during the summer and narrow cracks tend to "heal," especially in the wheel tracks. The indices of total cracking and the indices of width distribution both show these trends. In comparing the crack widths, allowances must be made for unusual annual cycles and for wide temperature variations between days on which surveys were made.

The most-significant results shown by the surveys made to date is that resurfacings laid in the fall usually do not crack until their second winter. Those laid in the spring and summer almost always begin to crack during the first winter. The amount of cracking present in late-season resurfacings after 2 years is about the same as that present in early-season resurfacings after only a year. This conclusion is derived primarily from surveys of experimental pavements but is further borne out by less-formal observation of many other resurfacing projects.

Comparison of Different Surface Types

The performance of different types of resurfacing materials can be compared by their indices. Comparisons of present condition can be made directly. These would show the relative susceptibility of the various materials to different types of cracking. The crack width comparisons are especially valuable in this respect. Cracks in some mixes tend to ravel faster than in others, and this is reflected in the apparent width at the surface.

The best comparison of performance is made by relating the crack indices for the pavements at the same age. Since the climatic cycle tends to be fairly repetitive each

[2] Dual type pavements have two lanes of concrete separated by one or two lanes of bituminous macadam. Many of these are used in Massachusetts.

year, valid comparisons can be made among pavements laid in different years. Unusual extremes in the annual climatic cycle and wide variations in temperature on the day of survey must of course be considered in making the comparisons. Different types of resurfacing mixes have been found to show somewhat different rates of crack development.

EVALUATION OF THE SURVEY TECHNIQUE

Sample Size

The 1,000-foot survey section adopted as a sample of pavement has been found adequate. Comparisons were made between two such samples of each of several different pavements. The indices derived for each of the two samples agreed closely, indicating that one sample adequately represents a given pavement.

Precision of Data

There are sources of error inherent in any process of measuring and computing. In the survey technique described in this paper, the two-most-important sources are the field measurement and recording and the process of graphical addition.

The locations and lengths of defects are recorded to the nearest foot. This is sufficient to give reasonable precision to the computed indices, and yet is consistent with reasonable field progress. Small errors in the alinement of the transverse tape are negligible. Factors such as uphill taping, vertical irregularities, and determination of the exact end of fine cracks can be ignored. Small irregularities in the alinement of cracks also disappear. It must be pointed out, however, that very-short cracks tend to be plotted too long.

For the indices which are expressed as percentages, the following rules for precision are recommended: (1) Indices greater than one percent shall be expressed to the nearest whole percent. (2) Indices less than one percent shall be expressed to one significant figure. This precision is consistent with that of the original data.

The data-recording process in the field and the graphical addition in the analysis are both susceptible to personal errors. In the first of these, the chance of error is minimized by preliminary marking of the defects followed by subsequent recording of the data, which provides double coverage. In the second, error is minimized by careful duplicate checking until the computers become familiar with the process. The correlation between independent totals is usually quite close with experienced personnel.

The Need for Engineering Judgment

The survey and its resulting indices alone show certain factual quantitative data relative to the deterioration of resurfacings. Considerable judgment is needed to interpret some of the results. The width indications are one example of this. The experienced engineer can evaluate the seriousness of various width cracks by their surface appearance. But to base conclusions on the coded indices, he must be familiar with what a "B" crack looks like. As another example, the edges of the white lines used to delineate traffic lanes show a coarseness which closely resembles the ravelled edges of cracks. Often it is impossible to distinguish a crack located adjacent to the painted lines. For this reason, much care must be used in interpreting the "percent of length cracked of longitudinal joint between adjacent slabs," since the centerline marking often occurs directly over the center joint between slabs.

CONCLUSION

The condition survey outlined in this paper can be a useful research tool if used with reasonable care and skill. The sample size adopted is adequate to give a reasonable precision to the data. The individual defects have been grouped and arranged in such form that they can be analyzed in any degree of detail desired. While judgment is required in interpreting any such collection of information, the method described for analyzing the data facilitates the closer examination of certain parts of it. It records conditions as they appear at the time of survey and reduces the otherwise incomprehensible mass of data to simple figures which can be interpreted meaningfully.

ACKNOWLEDGEMENTS

The condition surveys are part of a study of reflection cracking being conducted by the Joint Highway Research Project, established at the Massachusetts Institute of Technology by a grant from the Massachusetts Department of Public Works for research in the field of highway engineering. The maintenance and survey divisions of the Department of Public Works are cooperating in making the surveys.

The authors wish to express their sincere appreciation to R. E. Pyne and J. McCarthy, assistant maintenance engineers; the district survey supervisors; and others who have helped to set up and carry out these surveys. V. J. Roggeveen, professor; S. M. Breuning, research assistant; E. Tons, research engineer, all of the Joint Highway Research Project staff, have contributed many helpful suggestions.

Appendix A

FIELD PROCEDURE

Personnel

The field survey requires four men, one of whom should be an engineer. The organization used by the Joint Highway Research Project includes one of their engineers and a regular survey party of the Massachusetts Department of Public Works. The engineer directs the operation and takes notes. Two men handle the transverse tape. The remaining man marks defects with lumber crayon to facilitate recording. He also directs traffic.

Equipment

The following equipment is used in the field: one 100-foot cloth tape; several 50-foot cloth tapes; two pins or weights for securing the 100-foot tape; portable "Men Working" signs, or other suitable protection devices; strips of cloth to be used as tape handles; light truck or other conveyance; clipboard, data sheets, lumber crayon, etc.

Cloth tapes are used in preference to metallic or steel tapes so that they will break if caught on vehicles, thus avoiding the danger of the user's being dragged into the path of traffic.

Preliminary Preparation of Survey Forms

When a section of pavement is being surveyed for the first time, the only preliminary preparation necessary is to establish the limits of the section and to tie them in to an established system of stationing, if there is one. For succeeding surveys the road edge and permanent features, such as intersections, curbs, manholes, catchbasins, driveways, culverts, and highway boundary monuments, should be drawn on the sheets before the field survey begins. Enough information should be included so that locations on the road can be established easily. Each sheet should have at least one distance reference, since taping with cloth tapes can accumulate considerable error unless checked frequently.

Detailed Procedure

The first step in the field procedure is to locate the point of beginning and to reestablish the stationing from the references. The next step is to locate defects on the pavement by systematic visual inspection. Convenient areas are panels 100 feet long by one-half the width of the roadway, bounded by even station marks and the centerline and edge of the pavement. Inconspicuous defects and the boundaries of defective areas should be emphasized with lumber crayon.

A temporary grid is established on the panel by using the two tapes at right angles to each other. The 100-foot tape is stretched along the centerline (along the median curb on divided highways), between even station marks, the zero end being placed at the lower numbered station. The 50-foot tape is stretched across half of the roadway, with the zero end at the centerline. Defects are thus located by station-plus and offset from the centerline. On two-lane roads the 100-foot tape is placed on one side and the entire width of the pavement is surveyed in one pass.

The 100-foot tape remains in place for some time, and it has been found expedient to secure it with nails, pins, or weights. The 50-foot tape is moved along as the data are recorded. It is held by two men and runs from one man's hand, under his instep, across the road, under the other man's instep, and up to his hand. Strips of cloth are attached to the ends for handles. These must be weak enough so that they will break if the tape should be suddenly carried away by the traffic, which is freely passing over it.

The defects are plotted to scale on the record sheets as the recorder comes to them. This is the slowest function, and necessarily sets the pace for the entire procedure. The chainmen can be of great assistance by calling out locations to the recorder. Experienced chainmen can also determine the width of cracks and the descriptions of the various other defects. With a trained, cooperative four- or five-man crew, all functions proceed simultaneously and continuously, interrupted only by an unusually heavy barrage of traffic.

Appendix B

DESCRIPTION OF THE PAVEMENT DATA SHEET

Numbers refer to item numbers on the form.

Measurements of the Section

1. Length of the section at centerline, in feet.
2. Width of resurfacing, in feet. Any variations in width should be noted.
3. Area of total resurfacing, in square feet. Other areas include all areas not enclosed in the rectangle bounded by the length and width. The boundaries of the section should be rigidly defined.
4. Area of resurfaced concrete, in square feet. This area includes only that part of the resurfacing which is actually underlain by the original concrete slabs.
5. Number of standard slabs. A standard slab, in Massachusetts, is 10 feet wide and 57 feet long. The number of standard slabs is equal to the area of resurfaced concrete divided by 570 sq. ft.

Number and Length of Transverse Joints

6. Number of transverse joints 10 feet wide. The usual width of the slabs encountered in old concrete pavements in Massachusetts is 10 feet. Equivalent 10-foot joints should be used if slabs of odd width are encountered.
7. Number of joint ends adjacent to bituminous shoulder (or lane). This includes joint ends adjacent to either shoulders or bituminous center lanes of "dual" type pavements. This figure represents the number of potential locations of transverse crack extensions over bituminous material.
8. Total length of transverse joint, in feet.

Length of Longitudinal Joint in Feet

9. Length of longitudinal joint between adjacent slabs.
10. Length of longitudinal joint between slab and bituminous shoulder.
11. Length of longitudinal joint between slab and adjacent bituminous center lane. Many pavements in Massachusetts are of the "dual" type, having two lanes of concrete pavements separated by one or two center lanes of bituminous macadam.
12. Total length of longitudinal joint. The sum of Items 9, 10, and 11.

Appendix C

DESCRIPTION OF CRACK ANALYSIS SHEET

Numbers refer to item number on the form.

General Crack Data

13. Number of transverse joints 10 feet wide having some kind of crack over them. This is a very rough index of transverse reflection cracking which can be determined from a quick inspection of the record sheets. It can be found without the usual process of graphical addition.

14. Number of transverse crack extensions over bituminous shoulder (or lane). This figure is a count of the number of crack extensions without regard to either length or width. See Item 17.

Length of Cracks, in Feet

15. Length of transverse cracks over transverse joints. For each width class the length of crack is found by graphical addition.

16. Length of transverse cracks not over joints, but over concrete. This includes all transverse cracks lying over the original concrete. Cracks oriented 45 degrees or less from the transverse direction are considered transverse.

17. Length of transverse crack extensions over bituminous shoulder (or lane). An "extension over bituminous shoulder (or lane)" occurs when a crack extends across the junction between a concrete slab and an adjacent bituminous strip. The extension is only that part over the adjacent strip, the part over concrete being included in a previous category. Cracks over bituminous bases which are not extensions of cracks over concrete are not included. In this item, "bituminous" includes any base which is not cement concrete.

18. Length of transverse cracks in construction joint in resurfacing. This includes only cracks in construction joints where two runs of the paver butt together. Usually this jointing can only be identified in the top course of the resurfacing.

19. Total linear feet of transverse cracks. This is the sum of Items 15, 16, 17, and 18.

20. Length of longitudinal cracks over joints between adjacent slabs.

21. Length of longitudinal cracks over joints between slab and shoulder. This group includes all cracks occurring over the outside edges of slabs.

22. Length of longitudinal cracks over joints between slab and bituminous center lane. This group is used only for resurfacings of original pavements of the "dual" type. The condition represented by this item is similar to that at slab edges adjacent to bituminous shoulders.

23. Length of longitudinal cracks in construction joint in resurfacing. This group includes all cracks in construction joints between adjacent runs of the paver. Usually it is necessarily limited to construction joints in the top course.

24. Total length of longitudinal cracks. This is the total of Items 20, 21, 22, and 23.

25. Miscellaneous - All cracks not listed otherwise. This group includes cracks around manholes, over pipes, over settled areas, cracks over concrete that are oriented more than 45 degrees from the transverse direction, and any other cracks not previously included.

26. Total length of all cracks. This is the sum of Items 19, 24, and 25.

Appendix D

CRACK INDEX SHEET
DESCRIPTIONS AND FORMULAS FOR THE INDICES

Item numbers refer to items on Pavement Data Sheet and on the Crack Analysis Sheet.

Cracking Over Interior of Slabs

The index is expressed as "linear feet per slab." It is computed by dividing the total of Item 16 by Item 5. Since Item 16 includes only transverse cracks, only these are shown by the index.

This index is a measure of reflection cracking over transverse cracks in the concrete. A direct correlation cannot be made by length since the length of cracks in the underlying concrete is difficult to determine in resurfaced pavements. This index is highest where slabs are badly broken due to poor foundation conditions.

Cracking of Construction Joints in Resurfacing

There are two indices, one for transverse construction joints and one for longitudinal joints. The first is found by:

$$\frac{\text{Item 18}}{\text{Item 3}} \times 1000$$

and the second by:

$$\frac{\text{Item 23}}{\text{Item 3}} \times 1000$$

The cracking shown by these figures is primarily a function of the care used in laying the resurfacing material and the conditions prevailing when this was done.

Extensions Over Bituminous Shoulder (or Lane)

Two indices are used to measure the occurrence of this phenomenon. The first gives the average length of the extensions (Item 17 total divided by Item 14), and the second the frequency of occurrence, expressed as the ratio of extended crack ends to the number of locations where crack extensions potentially could occur (Item 14 divided by Item 7

Cracking Over Joints

Each of the indices below is computed for each width of crack. The index for the total is the sum of the indices for the various widths.

Percent of length of transverse joint cracked. This is computed by dividing the figure in each width class of Item 15 by Item 8 and converting to percent.

Percent of length cracked of longitudinal joint between adjacent slabs. This is computed by dividing the figures in Item 20 by Item 9 and converting to percent.

Percent of length cracked of longitudinal joint between slab and adjacent bituminous shoulder. This is computed by dividing the figures in Item 21 by Item 10 and converting to percent.

Percent of length cracked of longitudinal joint between slab and adjacent bituminous center lane. This is computed by dividing the figures in Item 22 by Item 11 and converting to percent.

Percent of length cracked of total longitudinal joint. This is computed by dividing the sum of the figures in Items 20, 21, and 22 by Item 12 and converting to percent. It is not the sum of the three previous indices.