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THE APPLICATION OF AERIAL STRIP PHOTOGRAPHY TO HIGHWAY AND AIRPORT ENGINEERING

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SYNOPSIS

This paper is a report of one of the continuing researches in pavement performance conducted by the Joint Highway Research Project of Purdue University cooperating with the State Highway Commission of Indiana. It presents a method of gathering pavement performance data by the use of aerial strip photography. This method of aerial photography offers a quick, convenient method of making a permanent record of the essential features of pavement performance that heretofore could only be obtained by visual inspection in the field.

Aerial strip photography differs from conventional aerial photography in that a continuous, uninterrupted strip photograph is produced instead of a series of individual overlapping photographs. The continuous uninterrupted exposure of photographic film (as much as 200 ft. in length) is made possible through the use of a specially designed aerial camera which is adapted to low altitude photography at high airplane speeds. Thus, large-scale strip photographs, up to 1 in. equals 25 ft., covering a strip of terrain several miles in length can be obtained in a relatively short time. These features of aerial strip photography make it well suited to highway problems since the scale and coverage of the photograph can be adapted to the required detail and right-of-way width.

This method of gathering pavement performance data quickly and accurately makes a detailed permanent record of performance. A few of the performance details that can be recorded by aerial strip photography are: blow-up patches, cracks, and corner breaks on concrete pavements and base failures and surface patches on bituminous surfaces. These features are recorded with remarkable detail.

Strip photography also permits coverage of performance information from widely separated locations and therefore enhances the study of contributing factors of pavement performance, such as types and sources of materials, and factors of traffic and design. Pavement performance data recorded on strip photographs also may be used by administrative officials in evaluating their maintenance and reconstruction needs.

Aerial strip photography also has several other potential applications to highway and airport engineering including; location surveys of a reconnaissance nature, clearing estimates, property evaluation, and assessment problems. The technique of gathering pavement performance data through the use of strip photography is highly significant in view of the immediate need for performance information in the advanced planning of highway programs.

Research has shown that pavement performance data provide a logical and expedient method of analyzing materials and construction problems encountered by highway and airport engineers. An approach to materials and construction problems from the point of view of pavement performance is well adapted to research methods since it has the distinct advantage of presenting the basic problem under field conditions. Its use permits an analysis of the problem with respect to soil areas, traffic and design, type and source of materials, and any of the other factors which may contribute to pavement performance.

Thus, from a practical viewpoint, pavement performance surveys provide the basic fundamentals for organized research on many of our highway problems. Many state highway organizations have initiated research programs in which laboratory and field research are coordinated with the results of pavement performance surveys. It is anticipated that an ever-increasing use will be made of performance data as a means of evaluating many materials and construction problems. However, the present methods of gathering pavement performance data are tedious and often time-consuming since in many instances the study of a particular problem may require periodic surveys on several miles of pavement.

Thus, where the problem warrants detailed treatment, the task of securing the necessary performance data becomes one of major proportions. A method of aerial strip photography was developed during the war which offers a quick, convenient method of recording the essential features of pavement performance. A few of the performance details that can be recorded by means of strip photograph include blow-up patches, cracks, and corner breaks on concrete pavements; and base failures and surface patches on bituminous surfaces. Although this new technique has several other potential uses in highway and airport engineering, its unique application to pavement performance surveys is highly significant because of the immediate need for performance information in the advanced planning of highway programs.

AERIAL STRIP PHOTOGRAPHY

The technique of aerial strip photography was developed during the war for the armed forces and was used in counter-intelligence and general military planning. With the cessation of hostilities, this method of photography was made available for peacetime planning and engineering of highways and airports, as well as for other works of civil engineering.

Aerial strip photography differs from the conventional aerial photography in that a continuous, uninterrupted strip photograph is produced instead of a series of overlapping photographs. The continuous uninterrupted exposure of photographic film (as much as 200 ft. in length) is made possible through the use of a specially designed aerial camera which is adapted to low altitude photography at high airplane speeds. Thus, large-scale strip photographs (up to 1 in. equals 25 ft.) covering a strip of terrain several miles in length can be obtained in a relatively short time. These features of aerial strip photography make it well suited to highway problems since the scale and coverage of the photograph can be adapted to the required detail and right-of-way width.

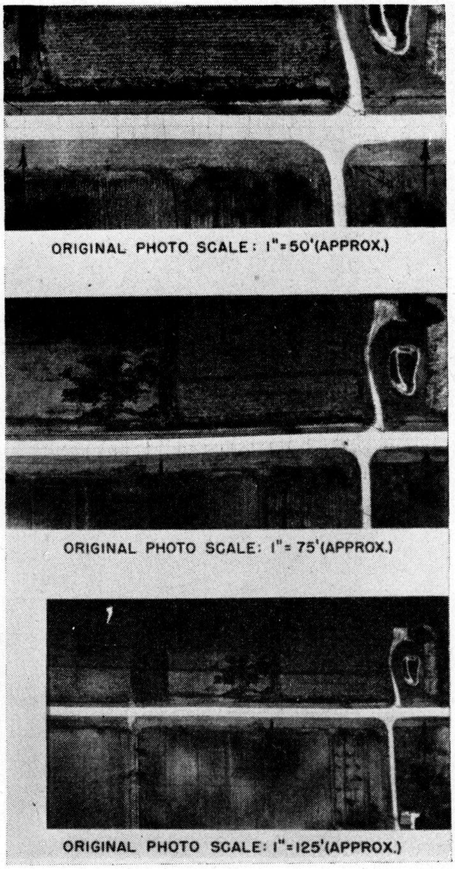

Figure 1. Three Aerial Strip Photographs with Different Photo Scales Covering the Same Highway Location

In Figure 1 three strip photos are shown which cover the same highway location but have different scales. The upper strip photo had an original scale of 1 in. to 50 ft. (reduced to 1 in.=approx. 176 ft. in Fig. 1) and is well adapted to pavement performance surveys since the cracks and corner-breaks are shown in detail. The lower strip photo which had a scale of 1 in. to 125 ft. covers a wider strip of terrain along the highway. Strip photos of this scale are well adapted to study of location and drainage problems, etc.; also, it will be noted that this photo shows the soil pattern of light and dark surface soils and therefore has application to soil survey work. The strip photo with the intermediate scale of 1 in. to 75 ft. has application to intermediate highway problems.

To obtain stereoscopic photographs an aerial camera with a double lens system is used which exposes duplicate images on each half of the film width with the necessary separation to facilitate stereo-coverage of the terrain shown in the strip photographs. Figure 2 illustrates a stereoscopic strip photo. Note that duplicate images on the upper and lower portions of the strip photo are displaced slightly in the longitudinal direction. This slight displacement between the duplicate images permits an impression to be gained of the topography of the terrain and the relative height of objects in the photographs by viewing the duplicate strip photographs through a special mirror-type stereoscope. This feature of aerial strip photography broadens its application in that it facilitates the correlation of pavement performance with cut and fill sections where such correlation exists.

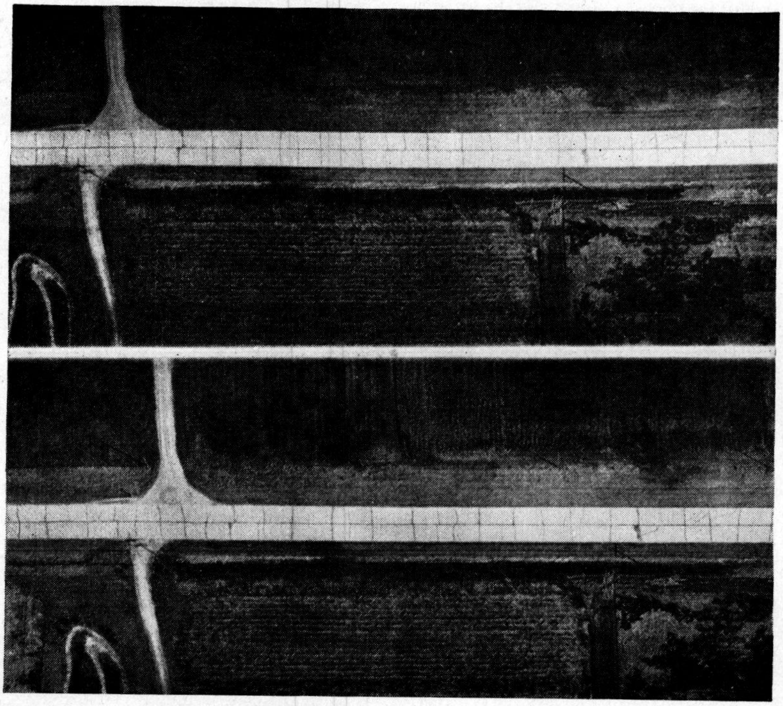

Figure 2. Stereoscopic Strip Photograph

PERFORMANCE SURVEYS

The present needs for pavement performance information for the evaluation of our many materials and construction problems, makes the application of aerial strip photography to this phase of highway and airport engineering an outstanding one which has an immediate practical use. With this in mind, the Joint Highway Research Project, cooperating with the Indiana State Highway Commission initiated a limited strip photography program during 1946. Strip photographs were obtained for a number of highway locations, including bituminous surface treatment, rock asphalt resurfacing, and concrete pavements.

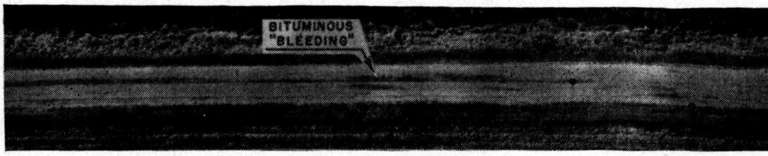

Figure 3. Fat Spots Caused by Bleeding of Bituminous Surface Treatment

Figure 4. Base Failures on Rock Asphalt Pavement

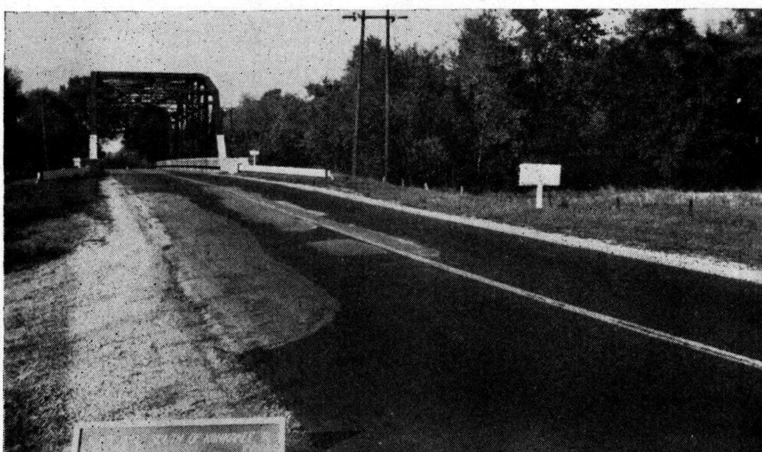

Figure 5. Ground View of Base Failures Shown in Figure 4

Figure 6. The weight and intensity of traffic is a major factor in highway performance. The influence of this variable is self-evident on this dual-lane highway where the lower lane has been subjected to the heavier traffic.

A section of a strip photo covering a secondary highway, Indiana SR No. 8, in which bituminous surface treatment was employed is shown in Figure 3. The dark areas shown on the pavement surface are areas in which the bituminous material has bled to the surface, causing fat spots in the surface course. This type of performance data is often difficult to gather by field inspection, yet it is significant to note that the location and extent of these fat spots are shown in detail on the strip photo.

A portion of a strip photo covering a highway location on Indiana SR No. 43 where rock asphalt resurfacing has been employed is shown in Figure 4. On this particular highway location numerous failures of the rock asphalt surface have taken place because of weak base support. Accordingly these areas of surface failure have received maintenance and are shown in remarkable detail on the strip photo. Figure 5 is a ground view of the SR 43 location shown in the strip photo.

concluded that the difference in performance on the upper and lower traffic lanes must be attributed to a corresponding differential in the volume and intensity of traffic.

From the strip photos shown in Figures 3, 4, and 6 covering three types of pavement surfaces, some of the benefits to be gained from the use of aerial strip photographs as a method of gathering pavement performance data are more or less self-evident. Probably the most tangible benefit of this method is that strip photography quickly and accurately makes a permanent record of the pavement performance. In many instances certain pavement performance data all but defies written description. Engineers often have difficulty in gathering this type of performance information. Those familiar with the task of gathering pavement performance data will no doubt have a keen appreciation of the application of strip photography to performance surveys as well as the accuracy with which the strip photograph records performance details.

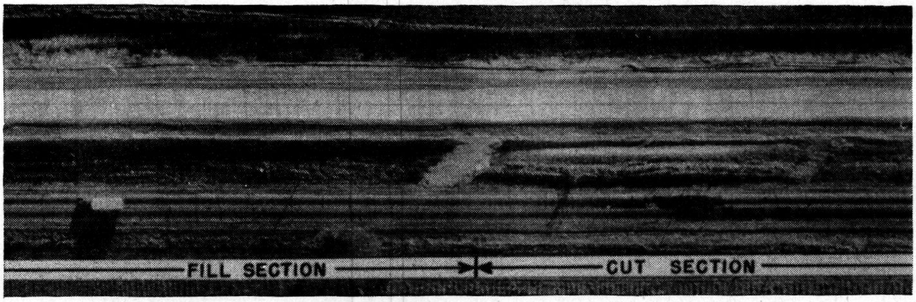

Figure 7. Contrasts in Pavement Performance in Cut and Fill Sections

In Figure 6 a section of a strip photo covering a dual-lane concrete pavement is shown. These two lanes have the same design, and were constructed the same season under the same contract. However, the influence of the traffic variable upon pavement performance is clearly indicated in the strip photo. It will be noted that the oil streaks are confined to the outside lanes thereby indicating that the outside or traffic lanes carry the larger volumes of traffic, as compared to the inner or passing lanes.

It will also be noted that the lower traffic lane has received a considerable amount of maintenance in the form of bituminous skin patches. The fact that these skin patches are confined to the outside lane again indicates that the outside or traffic lane carries the larger volume of traffic. Likewise, a comparison between the two outside traffic lanes on the basis of the maintenance required indicates that the lower traffic lane has carried heavier traffic. Therefore, on the basis of the information recorded by the strip photo it is

The soil texture of the subgrade is an important factor contributing to pavement performance. For this reason, a few strip photos have been included which demonstrate the influence of soil texture upon pavement performance by showing the pavement conditions. Figure 7 shows a portion of a strip photo covering a location on US No. 41 in northern Indiana. In the upper portion of the strip photo is a newly constructed concrete pavement. From the standpoint of detail it is significant to note that the screed markings on this new pavement are recorded in the photo. In the lower portion of the strip photo is an older concrete pavement which has had several years of service under heavy traffic. A comparison of the pavement condition in the cut and fill sections will show an outstanding contrast in performance under these two conditions. The pavement in the cut section has been patched over a considerable area while that in the fill section is entirely free from this type of maintenance. The poor pavement performance in the cut sections shows up in the form of slab pumping. Figure 8 shows a ground view of the pavement performance in the cut section shown in Figure 7. This contrast in performance must logically be attributed to the corresponding contrasts in soil textures and moisture conditions encountered in the cut and fill sections.

Figure 8. Ground View of Maintenance Patching and Pumping Slabs in Cut Section Shown in Figure 7

A portion of a strip photo covering a location on Indiana SR No. 25 in northern Indiana is shown in Figure 9. The pavement condition as shown in this strip photo again emphasizes the influence of soil texture upon pavement performance. It is significant to note that a large area of the pavement in the cut section has been patched and that these maintenance operations are lacking in the fill section. A corresponding ground view of the pavement condition in the cut section is shown in Figure 10. The poor performance of this concrete pavement shows up in the form of map-cracking and disintegration of the concrete similar to that shown in Figure 11. Although the differential in the concrete performance must be attributed to contrasts in the soil textures encountered in the cut and fill section, current researches at the Joint Highway Research Project have shown that map-cracking and disintegration of concrete are correlated with source of coarse aggregate and relative moisture conditions associated with soil textures.

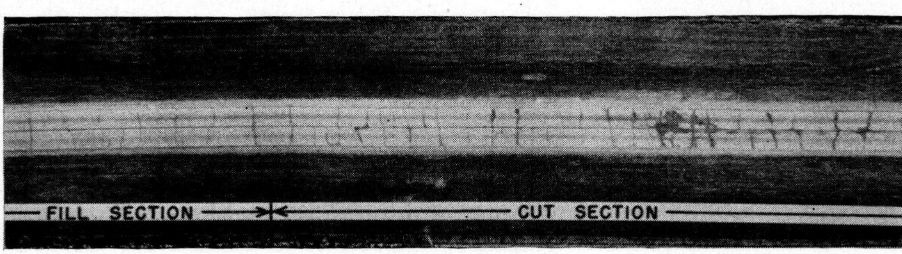

Figure 9. The contrasts in the pavement performance in the cut sections and fill sections of this highway location have been correlated with the source of coarse aggregate and the relative moisture associated with soil textures.

The influence of soil texture and the associated moisture conditions upon pavement performance is further illustrated by strip photos covering adjacent cut sections on US 31 in southern Indiana (Fig. 12 and 14). Figure 12 covers a cut section on a sand subgrade. At this location the highway cuts through a sand dune. Note that this section of pavement is showing good performance. The good pavement condition for this section is also shown in Figure 13 which is a corresponding

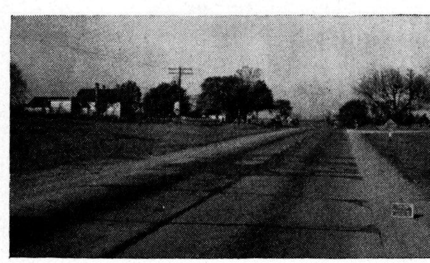

Figure 10. Ground View of the Poor Pavement Performance in Cut Section (See Fig. 9)

ground view. In an adjacent section, where the highway goes through a railroad underpass, another and deeper cut section is encountered. In this cut section the subgrade soil is a plastic silty-clay. Figure 14 records the pavement performance in this cut section.

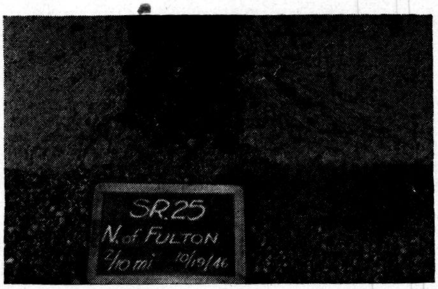

Figure 11. Close-up of Severe Map Cracking in Cut Section (See Fig. 9 and 10)

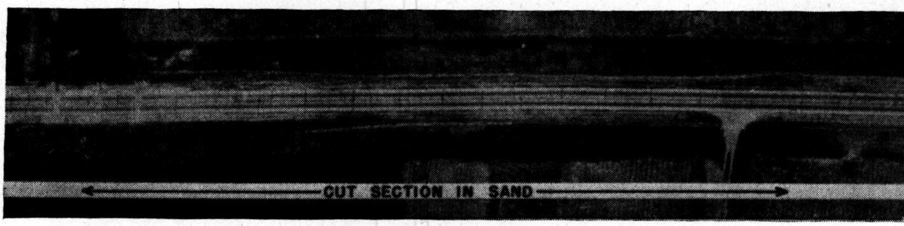

Figure 12. Good Pavement Performance on Sand Subgrade in Cut Section

Note that numerous patches have been made. A ground view of the pavement condition and patches in this silty-clay cut is shown in Figure 15. Note that the poor pavement performance is restricted to the cut section where the silty-clay subgrade soil is encountered. The contrast in the pavement performance in these two adjacent cut sections is attributed to the contrasts in soil textures of the sand and silty-clay subgrades. However, the poor performance of the pavement in the silty-clay cut section has been caused by pumping joints which is a problem of concrete pavement design where silty-clay and clay-like subgrades are encountered.

In Figure 16 two strip photos covering different highway locations in cut sections are shown. The upper strip photo covers a cut section on Indiana SR 25 located in northern Indiana. The poor performance of this pavement shows up in the form of concrete disintegration which is unusually severe in the cut sections (see Fig. 9). The concrete disintegration has been attributed to the source of coarse aggregate employed. The lower strip photo covers a cut section on Indiana SR 29 located in central Indiana. Both of these pavements are constructed without joints and are therefore subject to transverse cracking. However, except for the development of transverse cracks, the SR 29 pavement is showing good performance in both cut and fill sections. These two concrete pavements are of the same design and are approximately the same age. Likewise, these two pavements are located on comparable subgrade soils and carry comparable traffic. Since both of the pavement locations are in cut sections, the striking contrasts in their performance demonstrates the significance of coarse aggregate to concrete performance. Likewise, the contrast in the performance of these two pave-

Figure 13. Ground View of Pavement Performance Shown in Figure 12—At this location the grade line cuts through a sand dune.

ments indicates that cut sections do not always produce poor pavement performance.

The strip photos in the foregoing illustrations demonstrate a few of the different types of pavement performance data that can be recorded by aerial strip photography. Since these performance data can be gathered by this method in a relatively short time, it is therefore possible to gather performance data on a number of widely separated highway locations. This is a distinct advantage since gathering data by conventional methods of field inspection on widely separated locations frequently requires several weeks or months.

It has long been recognized that many of the deficiencies in pavement performance have a nation-wide significance to our federal highway system; that many materials and construction problems are not limited to political boundaries but often prevail throughout large areas or regions. Therefore, with pavement condition records in the form of strip photographs from widely separated locations, engineers could more effectively evaluate the factors contributing to performance such as types and sources of materials, climatic influences, subgrade soils, traffic, and design.

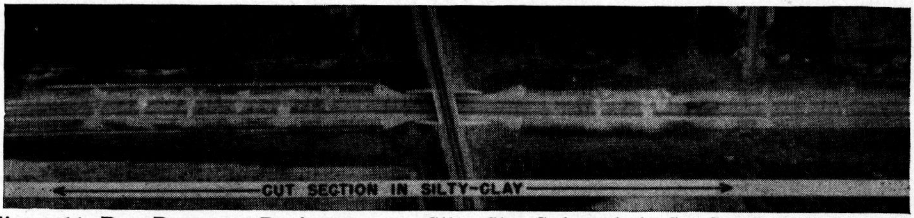

Figure 14. Poor Pavement Performance on Silty-Clay Subgrade in Cut Section—This section of pavement is adjacent to the location shown in Figure 12. The poor performance has been caused by pumping joints.

Performance data recorded on strip photographs of existing highways can also be used in the administration of highway departments as well as in the study of materials and constructions problems. One such use of strip photographs by administrative officials is in the periodic evaluation of their maintenance and reconstruction needs. Here again the evaluation could be made by comparing strip photographs showing past maintenance and performance of the highways under consideration. Decisions on surface retirement could be treated in a similar manner. It is frequently difficult to render decisions on the maintenance and reconstruction needs of a highway system, since several widely separated locations are usually involved. A comparison of strip photographs covering these locations would facilitate evaluation of conditions of performance and maintenance.

LOCATION SURVEYS

Aerial strip photography also has a potential application to location surveys on new highway construction. Although there is a slight difference between the graphic representations on an aerial strip photograph and a corresponding planimetric map, ground distances can be determined from large-scale strip photographs with fair accuracy. Also, equipment is available for determining with fair accuracy the height of objects as well as the height of the ground profile from stereo strip-photographs. These features of aerial strip photographs added to the fact that the scale and coverage of the photograph can be ad-

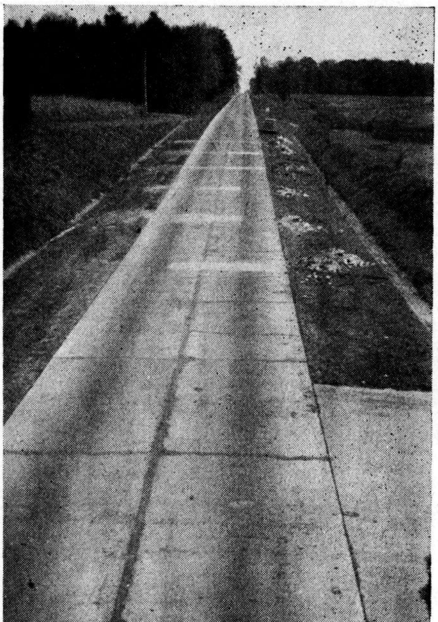

Figure 15. Ground View of Poor Pavement Performance Shown in Figure 14—Note that the patching is confined to the deep cut-section where a silty-clay soil is encountered.

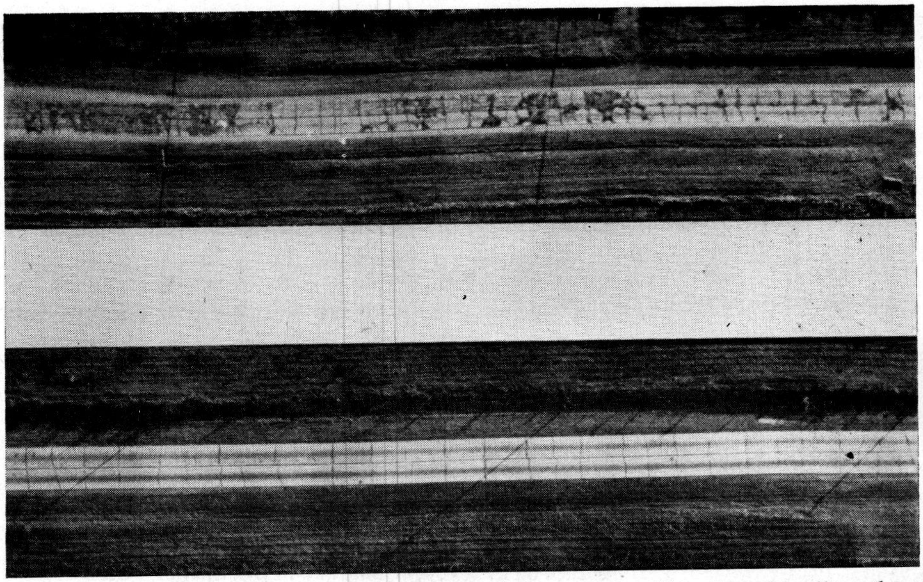

Figure 16. These two pavements have the same design, comparable subgrade soils and traffic, and are approximately the same age. The differences in the physical characteristics of the course aggregates used in the two pavements have produced corresponding differences in performance. The upper and lower photos are of Indiana SR 25 and 29 respectively.

Figure 17. Topographical information for location surveys can be obtained from strip photos with a considerable saving in cost and time.

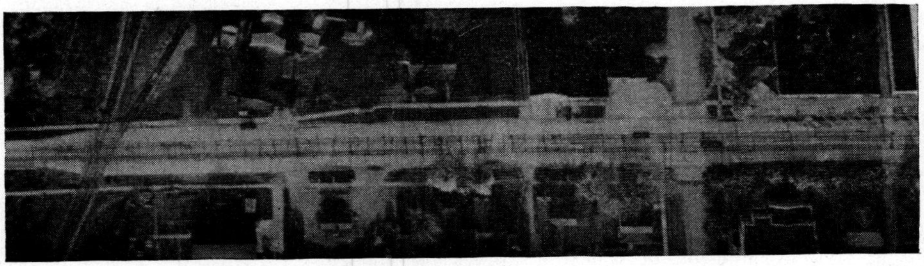

Figure 18. Aerial strip photographs also have application to city planning, property evaluation, and assessment problems.

justed to the desired detail or right-of-way width, make many of the possible applications to location work self-evident.

Because of limitations in precision, applications of strip photography for surveys of a reconnaissance nature are the most practical.

In these instances, the use of strip photography can effect a considerable saving of time and expense. An application of this type is frequently encountered in by-pass locations where the high cost of right-of-way in urban and suburban areas often makes it necessary to consider alternate locations in order that the most feasible and economical location can be adopted. Likewise, where the choice of a highway location is contingent upon the clearing of timber, a reasonably accurate estimate of size and number of trees involved can be made from a strip photograph covering the location.

Another application of strip photographs to location surveys is in obtaining topographical information. When done in the field this work consists mainly of the location of fence lines, access drives, trees, etc., and only moderate accuracy is required. With the use of strip photographs this same work can be performed with corresponding accuracy and considerably less cost. Those familiar with field survey work will no doubt appreciate the benefits of this use of strip photographs. Other applications of aerial strip photography to location work include reconnaissance surveys for the location of power transmission lines and pipe lines and any other installation which requires a narrow, cross-country right-of-way.

A COMPARATIVE STUDY OF DATA FROM THE COOPERATIVE INVESTIGATION OF JOINT SPACING

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and

Harry D. Cashell, *Associate Highway Engineer*

Public Roads Administration

SYNOPSIS

In 1945 the Highway Research Board published a special bulletin containing progress reports from each of the six States participating in the cooperative investigation of the spacing of expansion joints in pavements with closely spaced contraction joints. Also included in the bulletin is the related study of the structural effectiveness of transverse joints of the weakened-plane type. The reported data are presented in this paper as a summary analysis with the main objective of ascertaining common developments.

Since construction of the experimental pavements in 1940 and 1941, all States have made measurements and observations of the following: (1) temperature variations; (2) changes in the widths of the joints; (3) changes in pavement elevation; and (4) condition of the pavement and joints. However, because of the short time that the pavements have been in service, the present comparative study of the data has been limited to the reported daily, seasonal and progressive or permanent changes in the widths of expansion and contraction joints.

The most important developments observed in the study of the movements at the joints are: (1) expansion joints close progressively with time, the amount of permanent closure being greatest during the first annual cycle; (2) closure of expansion joints apparently continues until all available expansion space has been used up; (3) contraction joints open progressively with time, the rate of opening being greatest during the early life of the pavement; (4) the magnitude of the permanent opening of contraction joints decreases with an increase in the spacing of expansion joints, other conditions being equal.

In the related study of the structural behavior of weakened-plane contraction joints it was found that: (1) in the presence of interfacial pressure, much less than might develop in pavements under conditions of restrained expansion, weakened-plane joints are very effective in reducing critical stresses; and (2) without interfacial pressure, aggregate interlock is an uncertain means of stress control regardless of type and size of coarse aggregate.