

The Value of Pavement Performance Surveys

TILTON E. SHELBURNE

Research Engineer, Joint Highway Research Project
Purdue University

Post-war planning is the theme of practically all recent engineering meetings. This Thirtieth Annual Purdue Road School is no exception. You have already heard some interesting discussions on highway post-war planning. Other papers will be presented at the following sessions dealing with this very timely subject. Engineers are generally agreed that considerable thought should be given to this most important subject of the post-war planning of our highway systems. From the information that has been advanced it appears that for the first three or four years after the war considerably more money will be available for highway work than was spent in the last several years before Pearl Harbor. During this war period, when construction has been curtailed to a minimum, many of our highways serving the war effort are being taxed to the utmost. The theory that highways are expendable has been advanced by some, and from our observations during the "break-up" last spring this seems to be true.

Many of our state highway departments have been organized since World War I. In Indiana, our State Highway Commission was organized in 1919. The first pavements were built that year. Not too much factual information was available for the engineers charged with the responsibility of designing and building these early roads. Rapid progress has been made during the past twenty years; yet we have only begun to place highway design and construction on a truly scientific basis. For the purpose of this paper I would like to discuss with you one of the ways in which research can contribute to our knowledge of the art of road building.

In Indiana, as in other states, many of the pavements are now at an age in which differences in performance are quite apparent. Some of our roads are now showing definite signs of distress under the climatic and traffic conditions to which they are exposed. Why are certain sections failing? Why are other pavements of comparable age still giving good performance? Research can contribute greatly to the art

of road design and construction by identifying the various factors contributing to the failure of the road bed or pavement. Likewise, those roads which have given and are continuing to give excellent service for a long period of time are equally important. Thus, from an analysis of both good and poor performance much information can be collected that will be invaluable for use in the design and construction of our highways of tomorrow.

Since one of the largest laboratories in the world for highway research may be found in the highway system of any state, it appears that the most logical method of attack for furthering our knowledge of road design would be an attempt to obtain all possible information on the performance of highways as they are used in Indiana. Performance surveys are practicable for both flexible and rigid pavements. We have made numerous performance surveys on Indiana roads. Time will not permit a complete discussion of all of these; however, I would like to tell you about some of them. Let us consider first the flexible pavements or secondary roads.

FLEXIBLE PAVEMENTS

In the State highway system are approximately 4,400 miles of secondary roads. These contain wide extremes in pavement and pavement-base types and in most cases wide variations in the thickness design of the types, with a range sufficient to produce a high percentage of failures during the time of a severe spring break-up. Surveys of pavement performance made in a short period during a bad spring break-up are a feasible method of evaluating the supporting power of soil-pavement combinations and of pavement or pavement-base thicknesses.

Such a survey was made in 1943 by Mr. K. B. Woods and the author in co-operation with the personnel of the districts throughout Indiana.¹ As you will recall, the break-up in the spring of 1943 was unusually severe, being exceeded in severity in recent years only by the 1936 break-up. From an analysis of weather conditions it appears that bad winters, from a highway standpoint, consist of prolonged cold weather immediately preceded by sufficient wet weather to create a high moisture content in the subgrade. In the spring of 1943 we were fortunate in having about three weeks of sunshine and drying winds immediately following the frost's leaving the ground. If there had been

¹ Shelburne, T. E. and Woods, K. B.—"1943 Survey of Secondary Roads (Spring Break-Up)", unpublished report submitted to Advisory Board, April, 1943.

three weeks of rainy weather instead, the damage no doubt would have been infinitely greater.

This survey was made in the latter part of February, during March, and in the early part of April. Approximately 1,800 miles of secondary roads were inspected and rated according to condition. With the co-operation of the districts we were able to concentrate on the roads showing distress. Considerable progress was made on evaluating the various soil types for use as highway subgrades and base-thickness requirements, but further investigations are necessary before definite recommendations can be made. We concentrated mostly on the failures. It is just as important to know the thicknesses of those roads which did not show signs of distress this past spring. Additional work is necessary to secure this information. Until this information is secured we will not have a complete story; however, I would like to discuss briefly our methods of making the survey and point out some pertinent results.

Notes concerning the type and location of failures, soils, and other pertinent information were taken while driving along the road. All failures were logged by speedometer. Base and surface thicknesses were determined frequently in both failed and unfailed areas of most roads. As each road section was inspected and logged, an estimate was made of the degree of distress on the basis of the following arbitrary evaluations:

Excellent Performance. Roads showing no break-ups and in perfect condition.

Good Performance. Roads showing only a slight amount of distress such as some occasional alligator cracking or surface ravelling.

Slight Distress. Roads with less than five percent of the total area showing base and surface movement.

Secondary Distress. Roads showing five to twenty percent of the area with movement in the base and surface.

Primary Failure. Roads with over twenty percent showing base and surface movement.

These evaluations were strictly the result of observations made, in most cases, in company with representatives of the various district offices. It does not necessarily follow that these evaluations can be used for determining the most feasible type of reconstruction. The surveys conducted in the latter part of March and the first part of April were, in many instances, made on roads that had already been "patched out". These later surveys for the most part showed that some subgrade

soils had recovered remarkably well under the drying influences, and at the time were reasonably firm. The Maintenance Department did an excellent job throughout the state of capitalizing on the break in weather, and through this process probably saved many hundred miles of roads that, left untreated and open, would have permitted coming rains to soften the subgrade and the distress to continue. As a result of these efforts, the traveling public little realizes the critical condition of many roads during the spring break-up.

Analysis of the data indicated that of the 4,400 miles of roads in the secondary system, approximately 1,300, or thirty percent, showed by inspection or were reported distressed. The locations of these roads are plotted on a map of Indiana showing soil parent materials. (See Fig. 1 on insert.) Your attention is called to the large mileage of failures in the Wisconsin-drift area. This area is very extensive, since it covers approximately twenty percent of the entire state, and includes



Fig. 2. Typical failure of a secondary road where the grade line cuts into parent material—rolling topography of the Wisconsin-drift area.

the southern portions of the LaPorte and Ft. Wayne Districts and the northern and central portions of the Crawfordsville and Greenfield Districts. As you will recall, most of this area is gently undulating to rolling topography.

In the rolling topography of the Wisconsin-drift area the roads which followed the ground line showed generally good performance. Obviously, at the present, it is not good engineering to build roads in this type of topography without making cuts to provide reasonable grades and good alignment. The survey showed definitely that deep cuts into parent materials in this Wisconsin-drift area almost always resulted in poor performance (Fig. 2). It appears at the present time that such sections should be strengthened by porous insulation courses that are well drained, or by an increase in the base thickness.

In the gently undulating areas of the Wisconsin drift numerous failures were found in slight cuts. The total mileage of failures in



Fig. 3. Good performance of a flexible pavement placed on granular soil (Fox).



Fig. 4. An example of good performance of a flexible pavement on granular soil (Bellefontaine).

this area exceeded that of any other area in the state. A feasible correction for roads in this area is a raised profile, eliminating the slight cuts into the "B" horizon.

Another area that deserves attention is the shallow-sand-on-glacial-till area which is confined almost entirely to the LaPorte District in parts of the following counties: LaPorte, St. Joseph, Marshall, Starke, Fulton, Pulaski, Jasper, and White. Not only were secondary roads found to be suffering considerably—primarily because of the moisture conditions—but also several primary roads were found to be in severe distress.

Although rather limited in extent, the lacustrine soil areas generally require special attention in regard to the location of the grade line, which should be raised a foot or two above the ground level. This is true for both secondary and high-type pavements.

In the Illinoian-drift area some failures of secondary roads were found in the rolling topography in the deeper cuts where the road bed rested upon a claypan layer or "B" horizon. It is significant that those portions of the roads in this soil area were satisfactory when no cuts were made. Considerably more failures were found in the level or gently undulating topography of the Illinoian-drift soil area, particularly where the grade line was not elevated above the surrounding ground.

The best secondary roads inspected were those in sand and gravel areas. (See Figs. 3 and 4.) You will recall that these areas are quite extensive in northern Indiana. Furthermore, a considerable mileage of roads on granular terraces and other gravel or gravel-like deposits was found to be giving excellent performance.

These surveys emphasized the wide range in the supporting power of the soils within the state. The results re-emphasized the need for special treatments of some soils in the various soil areas. Such a procedure is a feasible method of establishing design data for secondary roads. While the supporting power of the subgrade soil is of primary importance as regards the design of flexible pavements, it is likewise important in the performance of rigid pavements.

RIGID PAVEMENTS

Since the formation of the State Highway Commission, many miles of portland cement concrete pavements have been built. These represent about forty percent of the entire State system. Fig. 5 shows the construction mileage of concrete pavements by years. During this 24-year period many changes have been made in the pavement design.

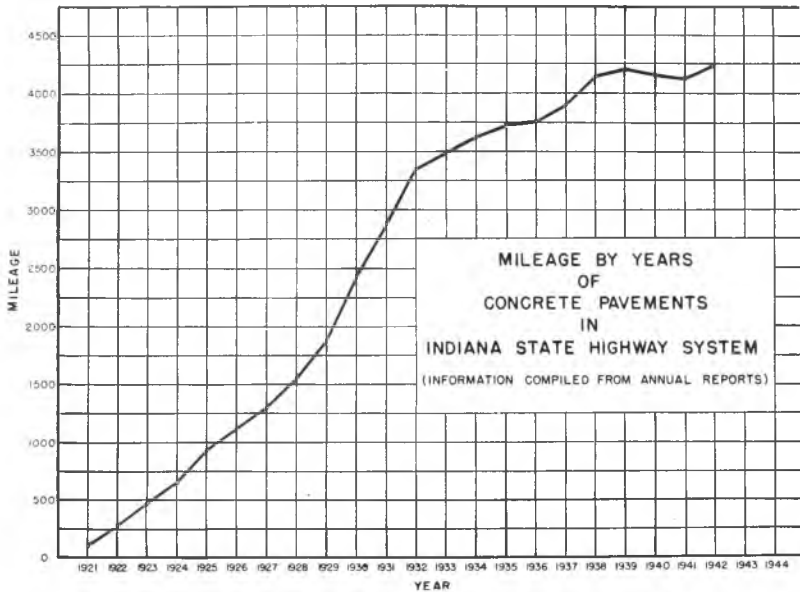


Fig. 5. Mileage of concrete pavements in Indiana, by years.

Many of you will recall that four years ago at this Road School Mr. M. R. Keefe presented a paper reviewing the changes in pavement design since the formation of the Commission.² In pavement sections alone a considerable range in design has transpired during this 24-year period. For example, pavements of the following sections are to be found in our State system: 6-8-6, 7-8-7, 8-inch uniform, 7-inch uniform, 8-5-8, 9-6-9, 9-7-9, and 9-8-9. Also, in 1922, a short section of 10-inch uniform pavement known as the ideal section was built on U. S. 30 just east of Dyer. This particular section was built on a sand subgrade and is still giving good service after twenty-two years.

Innovations have been made not only in design but also in materials and methods of construction. Research has added to our knowledge and led to advanced practices. Improvements in construction methods have been made, such as batching by weight instead of volume, splitting the coarse aggregates into two sizes to prevent segregation, and the use of vibratory finishing equipment. These are only a few examples of progress made in concrete pavement construction. There are still many features of concrete pavements not thoroughly understood, and

² Keefe, M. R.—“Pavement Design”, *Proceedings of the Twenty-Sixth Annual Road School*, Extension Series No. 47, Purdue University, July, 1940, pp. 47-52.

these must be studied and solved before the ultimate in performance can be attained.

One problem of concrete pavement performance is that of pumping. Last year we reported some studies that were being conducted on pumping.³ Since that time we have made performance surveys to determine the extent and seriousness of the pumping problem in Indiana. About six per cent of the State highway pavements were found to be pumping. Only roads which carry large volumes of heavy industrial traffic are subject to this action and those only where certain types of subgrade soils are encountered. In Indiana the subgrade soils that are most susceptible are as follows: lacustrine deposits, unweathered parent materials of the Wisconsin drift, unweathered shales, and soils with claypan or "B" horizon development. With a knowledge of the soils susceptible to pumping, corrective provisions can be made in the design of new pavements where heavy traffic is anticipated.

Of primary importance to concrete pavement performance is the problem of durability. Likewise, some highway departments have been concerned with scaling of concrete pavements. In recent years much research has been conducted on the use of air-entrained or blended cements to improve the durability characteristics of concrete mixtures.

Another problem in the design of concrete pavements that has not been solved to the satisfaction of all engineers is the use and spacing of expansion joints. As you will recall, Indiana has built a greater mileage of concrete pavements without transverse joints than with them, since they were not used generally until 1935, when the Public Roads Administration required them on all roads involving federal funds. Approximately seventy-five percent of the concrete pavements in Indiana do not have transverse joints. Enough information is available to prove or disprove the value of this feature. It is claimed that one purpose of expansion joints is to prevent blow-ups.

We have recently secured data from the Maintenance Department concerning the blow-ups during the past five years on Indiana pavements. These have been spotted on a state highway map. (See Fig 6 on insert.) You will note that some sections of roads have more blow-ups than others. From our studies to date it is indicated that blow-ups are associated with the type and source of aggregate employed. On some sections of pavements built by the same contractor and where the only difference is the coarse aggregate, we find decided differences in the

³ Shelburne, T. E.—"Pumping of Rigid Pavements Under War-Time Traffic", *Proceedings of the Twenty-Ninth Annual Road School*, Extension Series No. 55, Purdue University, March, 1943, pp. 49-65.

occurrence of blow-ups. For example, on one road built in 1930 without transverse joints there are no blow-ups in seventeen miles of pavement where one coarse aggregate was used; however, there are eleven blow-ups in the remaining 2.4 miles, where coarse aggregate of another type was employed.



Fig. 7. Typical example of severe map cracking associated with a blowup.

On the roads which have numerous blow-ups we have found that map cracking is associated. (This is shown in Fig. 7.) While the use of some of the coarse aggregates resulting in numerous blow-ups is not now permitted for concrete work, there is need for a determination of the causes so that we may be better able to judge other aggregates adequately. We know of no better way of judging an aggregate than by analyzing its service record.

In 1939, Kentucky conducted an extensive performance survey on its concrete pavements.⁴ It was found that failure of certain pavements was due to the use of chert gravel obtained from the Tennessee and Cumberland Rivers in western Kentucky. The use of these aggregates resulted in unsound pavements having numerous blow-ups and well-developed map cracking. From these studies it was concluded that "chert gravel found to produce unsatisfactory pavement in Kentucky may be eliminated by two specifications: (a) Coarse aggregate shall not show an absorption greater than three percent when subjected to A.S.T.M. Standard Test C95-36. (b) Concrete in which any aggregate is incorporated shall not show a reduction in flexural strength greater than 30 percent when subjected to 40 cycles of freezing and thawing in the presence of water." It is reported that other states, including Michigan, Ohio, and Tennessee, have recently made performance surveys of their concrete pavements.

⁴ Cantrill, Curtis and Campbell, Louis—"Selection of Aggregates for Concrete Pavement Based on Service Records", *Proceedings, American Society for Testing Materials*, 1939, Vol. 39, pp. 937-949.

These are only a few of the ways in which performance surveys of existing pavements may be utilized to solve design problems. An extensive survey of all concrete pavements in Indiana would be extremely helpful in:

1. Establishing information for setting up detailed research projects,
2. Providing a factual analysis of concrete pavement performance in Indiana, thus presenting a perspective not otherwise available,
3. Aiding in making changes in design or specifications,
4. Establishing the life expectancy of concrete pavements, and
5. Compiling useful information which can be used in conjunction with resurfacing projects.

I have stressed the importance of performance surveys as a means of learning how to build better roads. Why not evaluate the factors responsible for pavement performance before we start on a new cycle of road construction?