

COMPARISON OF AGGREGATE AND
BITUMINOUS TREATED BASES
I 75 SOUTH OF GRAYLING



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**TESTING AND RESEARCH DIVISION
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I 75 SOUTH OF GRAYLING

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INTRODUCTION

The purpose of the project was to develop a method for relating bituminous base thickness to aggregate base thickness of equal strengths. The project was divided into three general phases: 1) development of a testing procedure to determine the quasi-elastic or resilient modulus of base materials; 2) the theoretical establishment of thickness equivalency factors; and, 3) verification of findings of the first two phases by field observation of highway test sections.

Theoretical analysis studies, development of laboratory testing methods and preparation of appropriate computer programs have been described in previous research reports (1, 2, 3, 4). In addition, some of the laboratory and field testing procedures developed during this project have been used, after progressive modification, in other research projects (5, 6, 7).

For the theoretical studies, Hsia (3) concluded that base thickness equivalency could be based on elastic layer theory and level of subgrade compressive strain. He presented a series of curves for determining the equivalent thickness of different base materials that would yield equal limiting subgrade compressive strain which he assumed would result in equal pavement performance. Kuo (4) developed more complete equivalency relationships, based on elastic layer theory and the limiting of tensile strains at the bottom of the bituminous layers in addition to limiting compressive subgrade strains. His method considers the ability of the pavement to resist fatigue cracking and subgrade failure which results in excessive rutting in the wheel paths. Thickness equivalency charts were presented for two Michigan flexible pavement standard cross-sections, and combinations of granular base and bituminous base thicknesses could be selected from these design charts.

It is important to note that the thickness equivalents developed in the above reports are based on structural load factors alone. The environmental factors (frost heave, thermal cracking, etc.) which for Michigan's climatic conditions are important controlling factors in pavement performance, are not taken into account. For this reason, the periodic inspection and evaluation of field test sections has continued in order that both environmental and load application effects could be determined. This report, which should conclude the project, is concerned primarily, with the condition of the field test sections during approximately 12 years of service, and prior to their planned reconstruction.

The location and general layout of the bituminous base and the aggregate base test sections are shown in Figure 1. Each section is approximately six miles long and forms a part of the I 75 freeway construction south of Grayling. The test sections, designated A and B, were both constructed in the fall of 1970 but the aggregate base section was not opened to traffic until the spring of 1974, about three and one-half years after traffic was allowed on the bituminous base section.

Cross-sections of the two test areas are shown in Figure 2. It should be noted that the sections are not identical, even apart from the contrasting uses of aggregate and bituminous treated aggregate for the bases. The selected subbases are different (22AA and 23A modified), the sections were constructed under the supervision of different project engineers, and by different contractors. These factors, plus the difference in the time each was opened to traffic, made the two sections not entirely comparable. More comparable test sections for comparing aggregate and bituminous treated aggregate bases were constructed by the Department in 1976 as part of nearby areas of M 20 and M 66 (5, 6) in which techniques developed during the I 75 studies were used.

This report covers field testing results for the I 75 test sections obtained at various times during the period 1978 to 1983. Earlier test results for the project, using different testing techniques, are not included.

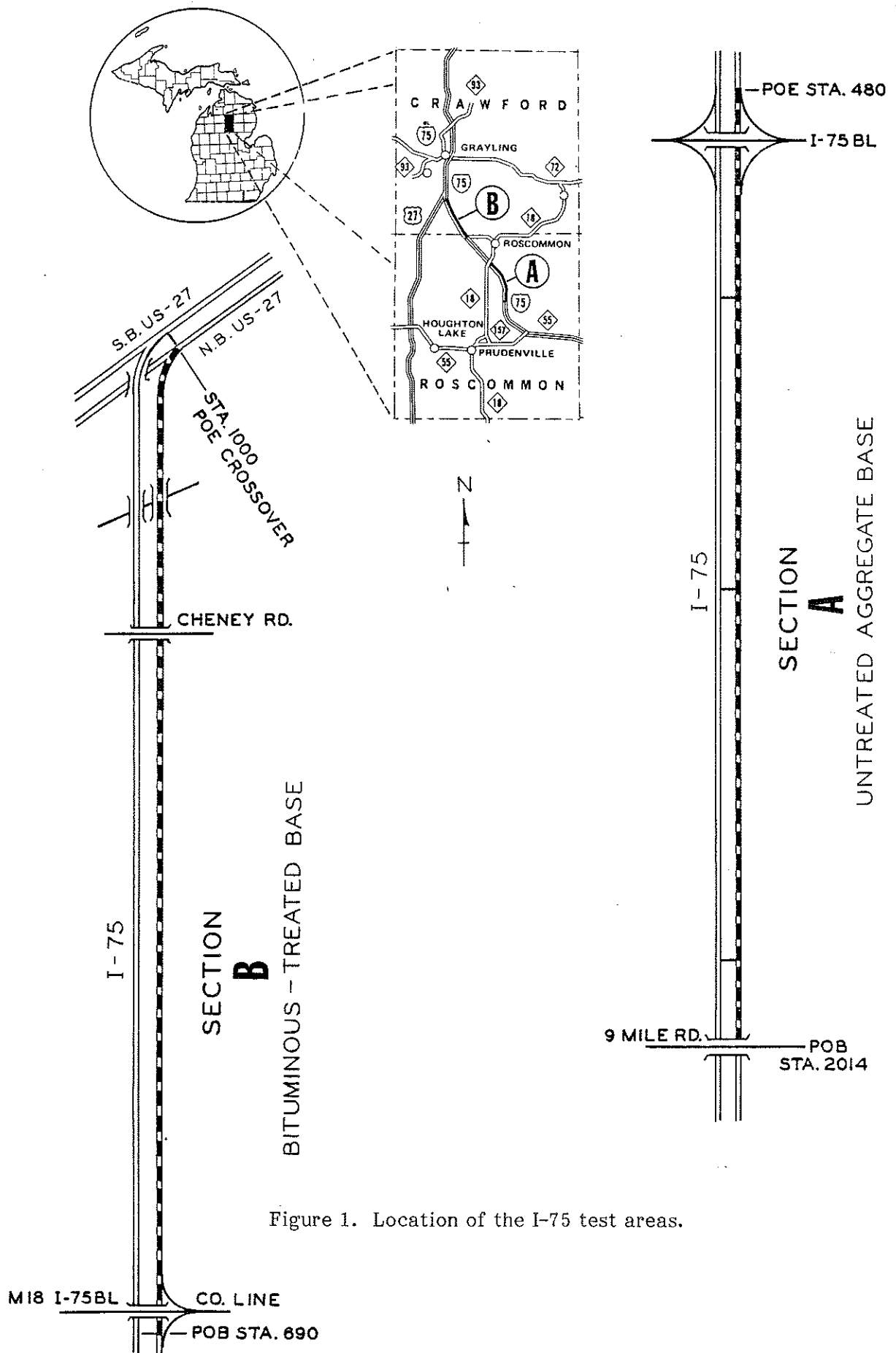
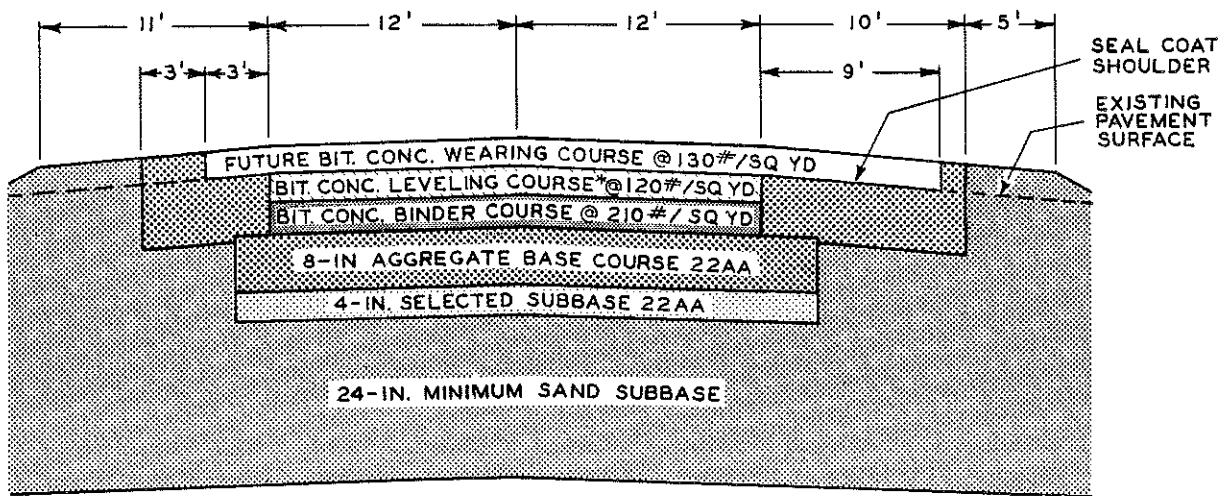
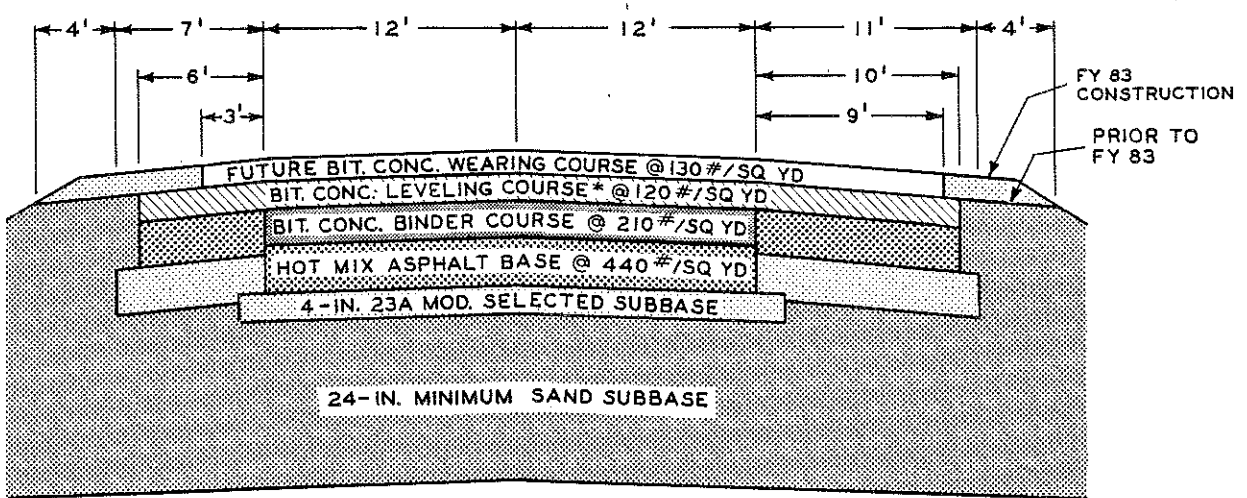


Figure 1. Location of the I-75 test areas.



AGGREGATE BASE



BITUMINOUS BASE

NOT TO SCALE

* BITUMINOUS CONCRETE LEVELING COURSES
 MODIFIED TO SERVE AS WEARING SURFACE
 AS PART OF STAGE CONSTRUCTION CONCEPT.

Figure 2. Cross-sections of the test pavements

1978 AND 1981 FIELD TESTING

A cracking survey of the I 75 test sections was conducted in 1978 by the Research Services Unit and Benkelman beam deflections and pavement rutting measurements were made in 1981.

Figure 3 shows the cracking survey results in which the cracking is expressed as total lineal feet for each entire six-mile test section. The aggregate base contained less longitudinal cracks but more transverse cracks than did the bituminous treated base.

Figure 4 shows the Benkelman beam deflection values for the test sections. These measurements were made using the Laboratory's deflection measuring system described in Ref. (7). In this method, each test section is divided into three subsections for the purpose of measurement. All deflections were corrected to a 70 F temperature base. Results of these tests show a slight advantage for the bituminous treated base and this is also reflected in Figure 5 which shows a higher percentage of spreadability for the deflection basin of the bituminous treated base.

Rut depth measurements show an advantage for the bituminous treated base although both best sections are well within satisfactory condition limits (Fig. 6).

1983 ANALYTICAL SURVEY

In 1983 E. C. Novak, Jr., of the Research Laboratory, proposed an analytical survey procedure for determining the condition of Michigan's flexible pavements. The purpose of that study was to provide an objective method for collecting pavement condition information necessary for determining the most appropriate repair procedures to be used and to establish a reasonable priority for conducting such reconstruction work. The methods used and the significance of the data obtained are described fully in Ref. (8).

The survey is based on the premise that surface distress features (various forms of cracking, rutting, etc.) are treated as symptoms that can be used to identify the fundamental cause of distress. From these data the survey results are also used to establish structural pavement performance, a Pavement Condition Rating and a Pavement Service Rating which is indicative of the pavement's rate of deterioration.

The subject test sites were evaluated by this analytical survey method. Information obtained from the survey method is summarized in Figures 7 through 11. Interpretation of these data and method of sampling, follow descriptions given in Ref. (8).

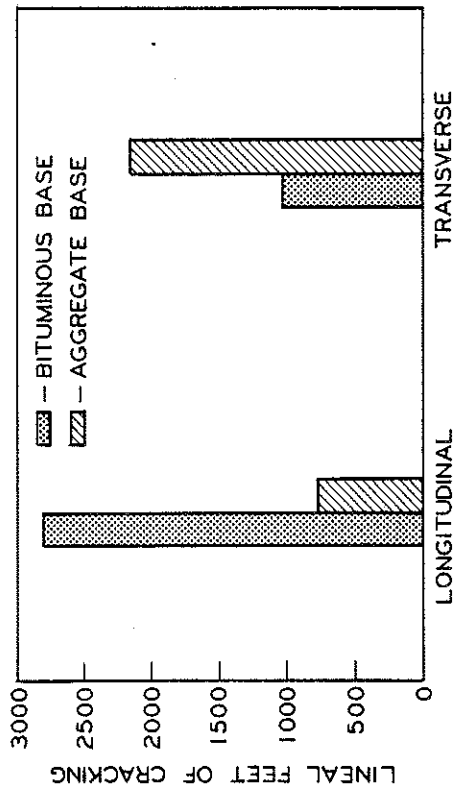


Figure 3. Cracking survey results - 1978.

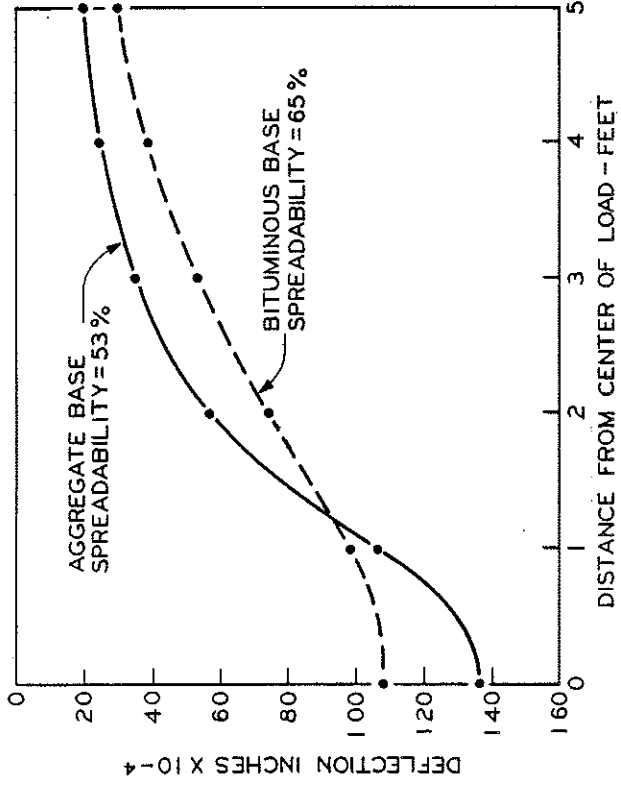


Figure 5. Deflection Basins for the test sections - Fall 1981.

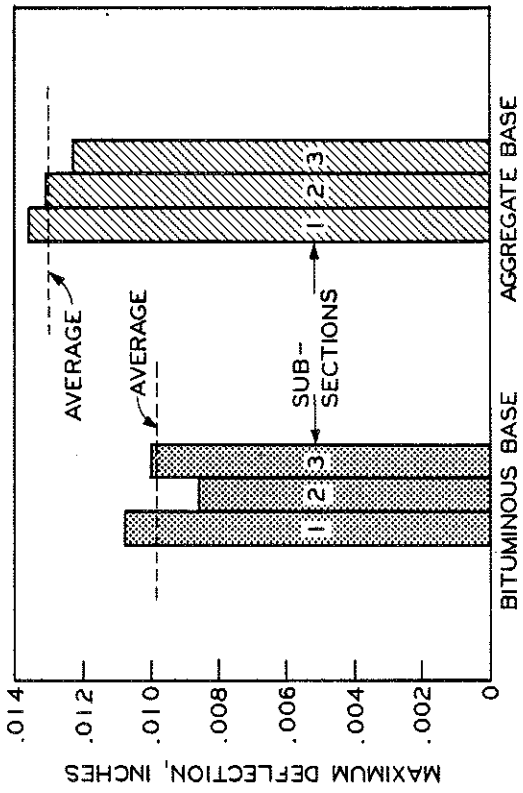


Figure 4. Deflection values corrected to 70° F - Fall 1981.

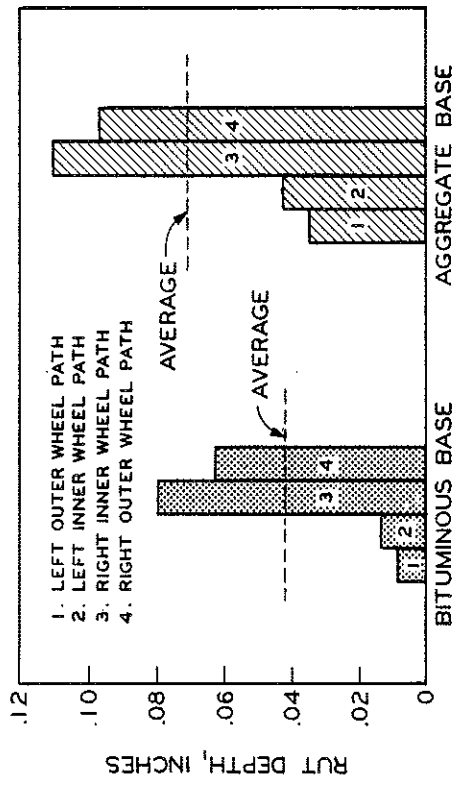


Figure 6. Rut depth values - Fall 1981.

Rut Depth Measurement

Rut depths were measured using the Laboratory's rut-depth indicator and the forms of the rutting noted. Rut depth values represent the average of measurements made in each wheel path for the desired lane. Because rut depth values were higher in the driving lane than in the passing lane the higher, more critical, values were used. As shown in Figure 7, none of the rutting in the test sections was serious (less than a 0.2 in. average maximum). There was less rutting, however, in the bituminous base section.

Pavement Cracking

Figure 8 shows the severity of longitudinal, edge and alligator cracking expressed as cracking intensity—the length of each cracking type contained in a 200-ft section of pavement. These forms of cracking run in the direction of traffic.

Longitudinal cracking is found at either the centerline of the pavement, the center of a lane, or the center of the wheel paths and is considered to be caused by either a low resistance of the bituminous concrete to softening of its supporting base, or to longitudinal weakness planes due to overlapping of the asphalt surface layers near the pavement centerline during construction.

Edge cracking occurs at the edge of a pavement and can be caused by either low base shear resistance or by a base that is subject to softening, at which time it fails to provide adequate support at the pavement edge.

Alligator cracking generally refers to long narrow areas of intense cracking, usually in the wheel path, but which can occur over an entire pavement surface. This form of distress is caused by fatigue cracking of the bituminous concrete surfacing and should not affect pavement riding quality providing the base performs well. If the base does not perform well alligator cracking is usually followed by a rapid increase in roughness and a need for repairs. As shown in Figure 8, all of the three crack forms occurred in both types of base construction and fall within the medium range of cracking intensity (below 50 percent). For the edge and alligator types of cracking, however, the cracking intensity is significantly less for the bituminous base section. Of the three types of cracking shown in Figure 8, the alligator cracking is considered to be the most detrimental to pavement performance. These results indicate that both the aggregate and bituminous base pavements are subject to a moderate degree to base volume change. The greater thickness of the aggregate base section accounts for its being subject to significantly greater cracking intensity. Edge cracking indicates the shoulder gravel provides low lateral pavement support.

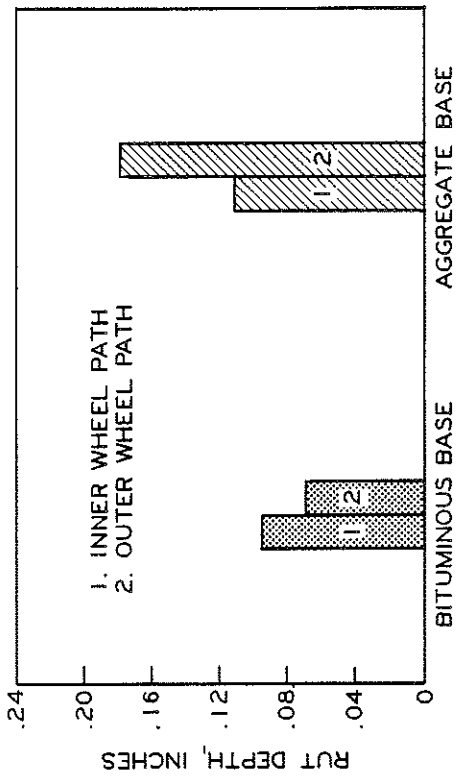


Figure 7. Rut depth values in driving lanes - 1983.

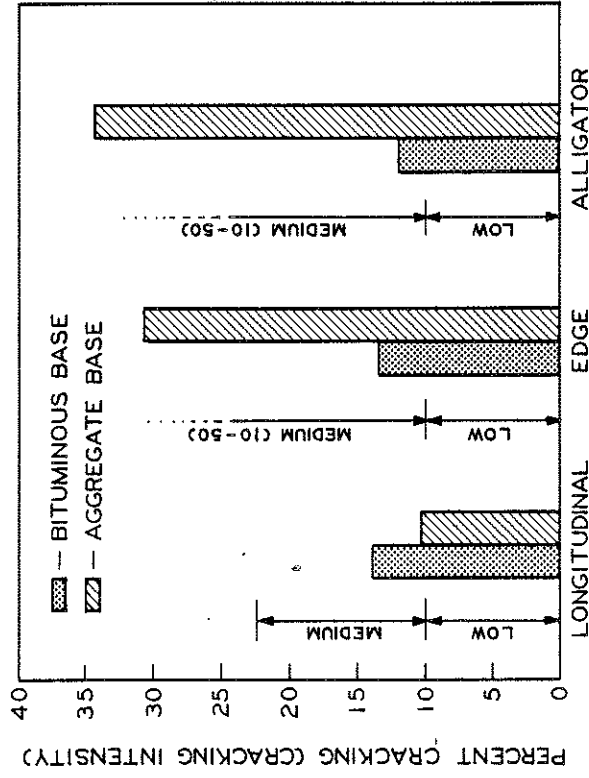


Figure 8. Pavement Cracking - 1983.

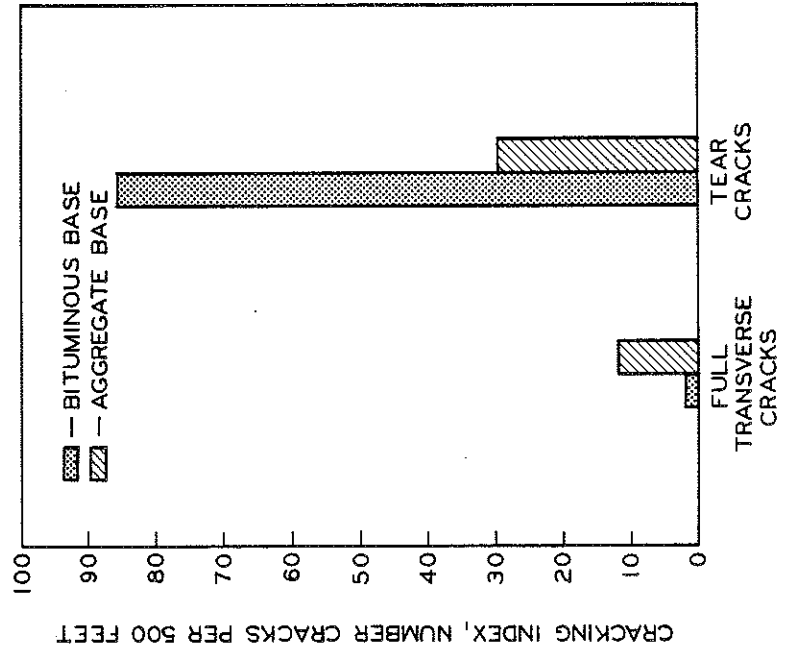


Figure 9. Full transverse and tear cracking indexes.

Figure 9 shows the severity of full transverse, and tear cracking in the pavement sections, expressed as Cracking Index - the number of full transverse cracks in a 500-ft length of two-lane pavement, and as Tear Index - the number of tear cracks occurring in a 500-ft length of two-lane pavement. Full transverse cracks extend across both lanes of a two-lane pavement. Tear cracks are transverse in direction but do not extend across a wheel path.

Transverse cracking is, primarily, a measure of the bituminous concrete performance. Pavements that crack transversely at an early age are considered to be surfaced by low tensile strength bituminous concrete having a low resistance to fatigue or alligator cracking and, hence, requiring early repair. Full transverse cracking is a more significant factor in pavement performance than tear cracking. Figure 9 shows less full transverse cracking for the bituminous base section. These results indicate that both sections were constructed with temperature sensitive asphalt but the bituminous base section has a high asphalt content which provides greater long term durability. This is another reason for the somewhat better performance of the bituminous base section.

Pavement Condition Rating (PCR)

Based on the analytical survey data a pavement condition rating can be established which rates the pavement on a scale of 0 to 100, with 100 representing a perfect pavement. Those pavement distress features having the most effect on performance have been fully presented by Novak in Ref. (8).

Condition ratings of 50 or below indicate the pavement to be in a terminal condition and to require rehabilitation. Ratings of 70 or more indicate the pavement to be in an acceptable condition. Those pavements rated between 50 to 70 are considered to be in questionable condition. The purpose of the Pavement Condition Rating is to establish the priority order for pavement repairs.

Figure 10 indicates that the aggregate base and bituminous base test sections have equal pavement condition ratings and both are in the questionable area of acceptability.

Pavement Service Rating (PSR)

The purpose of the Pavement Service Rating is to establish the priority order for pavement repair of those pavements whose condition ratings are approximately the same and lie between 50 and 70. This rating is based on the volume of traffic carried, rate of pavement deterioration and present condition. The PSR may vary from near 0 to a value in excess of 5. A 0 PSR value indicates the pavement to be in perfect condition while a 5 value indicates a normal rate of deterioration in which the pavement would reach a PCR of 5 within a 20 year period, when subjected to the highest ADT within its category. The PSR values for pavements requiring repair should, typically, be greater than 5.

Figure 11 shows the PSR values for the two test sections. Both pavements have equal pavement condition ratings (PCR); however, the PSR indicates the bituminous base pavement is deteriorating at a more rapid rate. Hence, if the bituminous base pavement had not been resurfaced in the summer of 1983 its condition, in time, should have been worse than that of the aggregate base section.

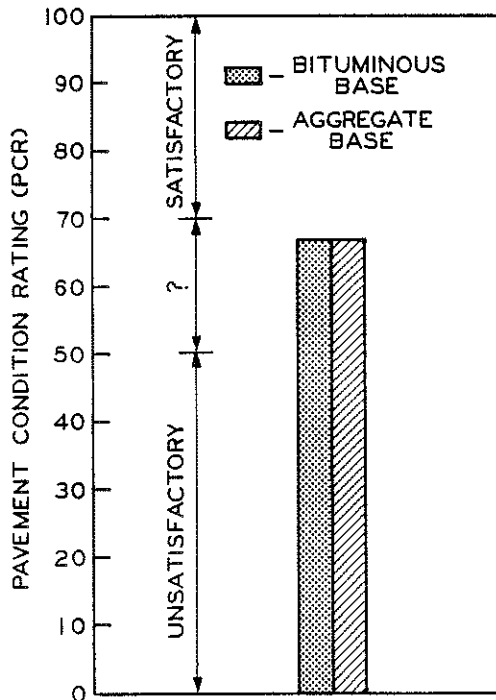


Figure 10. Pavement condition rating values (PCR).

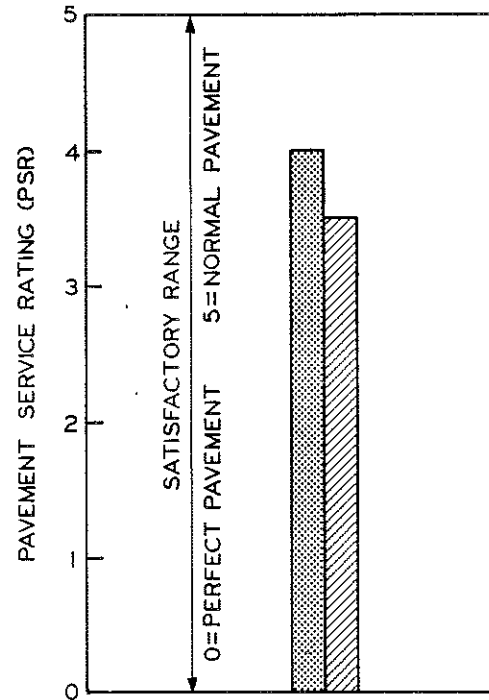


Figure 11. Pavement service rating values (PSR).

Figures 12 and 13 show the PCR and PSR values for the two test sections and for three other areas in the immediate vicinity of these sections. These additional sections include two bituminous base sections (C and D) and one untreated aggregate base section (E), constructed during 1971 to 1973 and opened to traffic in the spring of 1974. The bituminous base sections are similar in construction to test section A and the aggregate base section similar to test section B. These show the pavement condition ratings to be about the same for the bituminous treated and the aggregate bases (Fig. 12). The pavement service ratings (Fig. 13) show a mixed rate of deterioration among bituminous and aggregate base sections. Sections D and E are deteriorating at a significantly greater rate than are the other sections (Fig. 13).

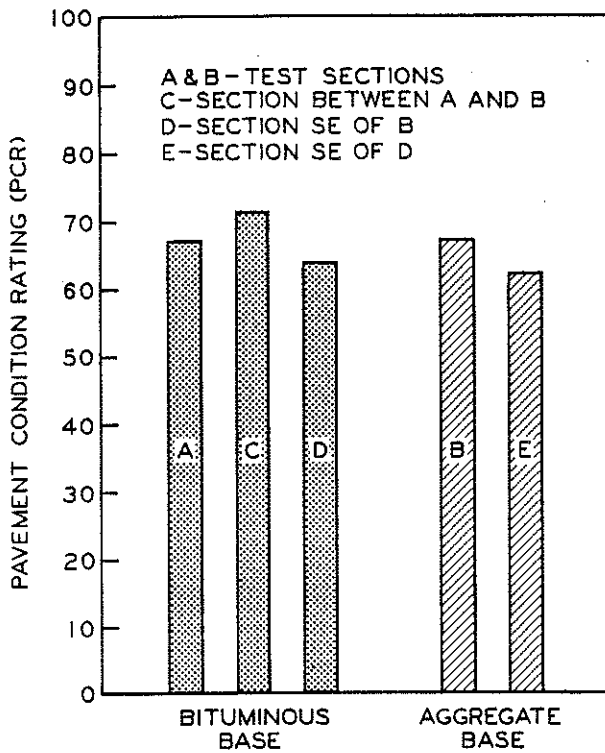


Figure 12. PCR values for different bituminous and aggregate bases.

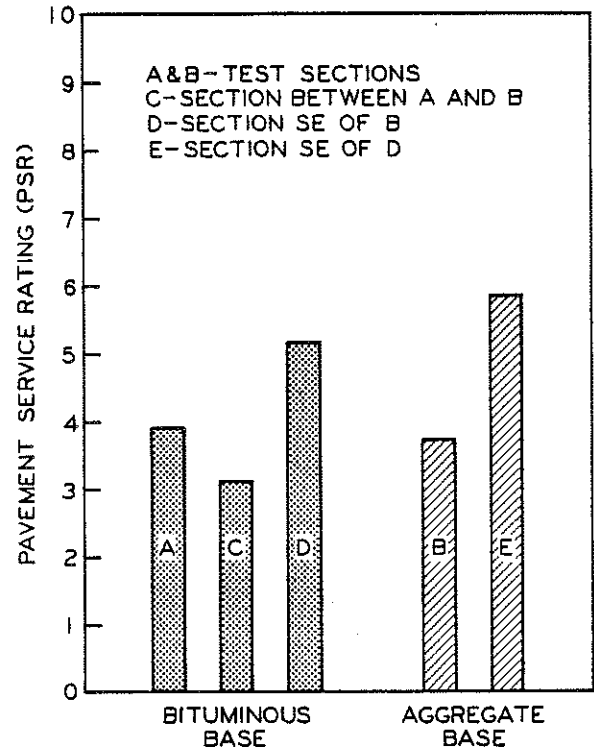


Figure 13. PSR values for different bituminous and aggregate bases.

CONCLUSIONS

The following conclusions can be drawn concerning pavement designs that include bituminous and aggregate base course materials. These conclusions are based on laboratory studies and approximately 12 years of field performance evaluation.

1) Equivalency factors for base layers are not constant factors. They are instead, functions of the stiffness and thickness of the other layers of the pavement section as well as the mechanical properties of the base material itself.

2) Thickness equivalency charts for aggregate and bituminous treated aggregate bases were developed by Kuo (4) for two standard Michigan flexible pavement sections. These charts permit equating the thickness of bituminous treated bases to that of aggregate bases to obtain equivalent structural pavement performance. Environmental factors such as frost heave, moisture variation, thermal cracking, etc., must be dealt with as a separate design analysis.

3) Long-term field studies, in which the pavement cross-sections described in this report and in Ref. (6) have been exposed to both traffic loading and environmental effects, indicate that the thinner (4-in.) bituminous base sections performed as well as those constructed with a normally used thickness of graded aggregate base (about 8 in.). Some of the tests indicated a small advantage for the bituminous base but the difference was not considered significant.

4) The selection of an aggregate base or a thinner combination of aggregate and bituminous base would appear to depend upon economic rather than structural considerations.

5) In comparing different pavement designs it is important that the quality of the materials used be carefully controlled in order that the environmental effects can be minimized. This is particularly true of flexible pavements where the durability of the bituminous and aggregate materials used can exert a significant effect on pavement performance.

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