DEVELOPMENT OF CONCEPTS FOR PAVEMENT MANAGEMENT

INTERSTATE PILOT STUDY

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OFFICE OF MATERIALS

IOWA DEPARTMENT OF TRANSPORTATION

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ACKNOWLEDGEMENTS

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INTRODUCTION

Our highways are being subjected to increasing higher traffic volumes and weights which are causing a more rapid deterioration of the pavement structure than we have previously experienced. This development coupled with the accelerating rate of reduction in financial capability to rebuild, rehabilitate, or even adequately maintain the present systems has created programming needs which the present descriptive data based sufficiency rating system cannot meet. The Federal 3-R programs have focused considerable attention on this aspect of pavement management.

These programming needs are somewhat compounded by an apparent growing change in the User's attitude. As interstate driving experience accumulates the User's level of expectation in rideability and safety seems to raise, and a lower tolerance of interference with movements by internal or contract maintenance develops. This changing attitude may require future benefit-cost studies of zero-maintenance rehabilitation concepts particularly for high traffic volume sections or special designs. Zero-maintenance rehabilitation being defined as a planned surface improvement that is accomplished prior to the incipient failure of the pavement surface. Evaluation of this concept for continuously reinforced pavement with Class I aggregate seems appropriate at this time from the standpoint of possibly reducing life cycle costs.

This situation and current problems predicates the necessity to examine the possibilities of developing a more engineering oriented system for measuring and quantifying pavement condition and for quantifying pavement performance.

In recognition of these problems, Chief Engineer R. H. Given directed that an elemental procedure be initiated through the Office of Materials to outline methods by which we can measure pavement condition. The basic objective to enhance our engineering capability for a more effective pavement management system.

Initially a brief search of the literature in the pavement management area was conducted. A number of systems for identifying pavement conditions have been developed. The most exotic system was that being used by the New York Department of Transportation. It was based on psychophysical analysis to quantify ratings on standard test sections by panels composed of sixty to eighty people. These ratings were then correlated with vehicle-mounted profile measuring systems.

Sufficient evidence was not discovered in this brief search to alter the general opinion that the Serviceability (Present Serviceability Index-PSI) - Performance Concepts developed by the AASHO Road Test provides the optimum engineering basis for pavement management. Use of these concepts in Iowa has the additional advantage in that we have a reasonable quantity of historical data over a period of time on the change in pavement condition as measured by PSI's. Some additional benefits would be the ability to better assess our needs with respect to those being recommended to Congress by AASHTO Committees. These concepts have been the basis used for developing policies on dimensions and weight of vehicles and highway needs which the AASHTO Transport Committees have recommended to the United States House Committee on Ways and Means. The first recommendation based on these concepts was made in the mid 1960's. Iowa's participation in the evaluation for this recom-

mendation was under the direction of our present Director of Transportation, Mr. Raymond Kassel. PSI Indexes had to be derived from subjective surface ratings at that time. The most recent recommendation to Congress was made in November of 1977.

Based on the rationale expressed above, a pilot study of the major part of the rural interstate system was conducted. The Objective of the study was to measure pavement performance through the use of the Present Serviceability Index (PSI) - Pavement Performance concepts as developed by the AASHO Road Test and to explore the usefulness of this type of data as a pavement management tool.

Projects in the vicinity of the major urban centers were not included in this study due to the extra time that would be required to isolate accurate traffic data in these areas. Projects consisting of asphalt surface courses on crushed stone base sections were not included.

AASHO PRESENT SERVICEABILITY INDEX (PSI) AND PAVEMENT PERFORMANCE CONCEPTS

The principles of these concepts are pretty much common knowledge but will be briefly summarized for background to facilitate gaining a perspective of the data presented in this study.

The pavement rating system generated on the AASHO Road Test was devised to provide a means for determining the serviceability of a pavement surface at any point in time based on the User's viewpoint. This rating called the Present Serviceability Rating (PSR) was based on independent subjective ratings by members of a panel of highway users selected to represent different groups of highway users and specialists. The ratings were based on a five point scale which described the ability of the pavement to serve high speed truck and passenger traffic.

Objective measurements of the variations in longitudinal and transverse profiles, as well as the amount of cracking, patching, rutting, etc., were also measured on the test sections. By means of conventional statistical procedure, known as multiple regression analysis, a correlation was established between the subjective ratings by the panel and the objective physical measurements recorded. Separate equations were developed for flexible and rigid pavements and the equation results were defined as Present Serviceability Indexes (PSI). Serviceability histories of the test sections were defined by curves (Serviceability Performance Curves) based on Present Serviceability Indexes (PSI) versus Time.

Other mathematical relationships developed by the Road Test resulted in equations which interrelated pavement performance, pavement design, load and the number of load applications. These equa-

tions are equally important because they provide the capability to convert all axle load applications encountered in mixed traffic to an equivalent selected load category. This equivalent load category for any one design can then be substituted for time in the Serviceability Performance Curve to secure a Pavement Performance Curve and it can be said that the Present Serviceability Index (PSI) is some function of the load applications.

The usefulness of this type of Pavement Performance Curves in quantifying pavement needs, projecting the time of these needs, quantifying the effect of changes in axle loadings, assessing the effect of design features and variations in materials, construction and maintenance are obvious. More definitive life cycle costs could also be determined.

PAVEMENT PERFORMANCE ANALYSIS-GENERAL

Present serviceability index surveys have been performed by the Office of Materials on approximately one third of the interstate and primary system each year since 1968. The PSI data used was secured from the office files. Testing equipment and procedures will not be reviewed at this time.

During the review of the PSI measurements, it was noted that considerable test variance was generated at times by the sampling procedures used for the cracking, patching, rutting, etc., surveys. The data is secured from one representative 1/2 mile section for each 0 to 5 miles of profile measurements. This variance is not serious considering the limited weight placed on this factor in our present sufficiency rating system. If these measurements are to be used in a more meaningful manner, it is recommended that a stratified random sampling system be devised and that the surveys be performed the same year the profile measurements are taken. In recognition of the comparatively labor intensive and safety aspects of these surveys a trial test was conducted to ascertain if 35 mm pictures taken with infrared film would adequately identify the characteristics of concern. The test was very promising and should be further explored.

Traffic data was secured from the traffic survey books starting with the one issued in 1959. The selected traffic reports, along with the design section for each project was furnished to the Division of Planning and Research for computer computation of an equivalent 18-kip axle loading for each traffic survey year. A terminal service index of 2.5 was used for these computations. Accumulated

loadingswere then computed from this data for each PSI measurement. The design sections were obtained from the Office of Materials history records.

Since each pavement constructed even though it has the same structural design section is an entity in itself due to variations in the subgrade foundation, environment, materials, construction and maintenance, performance curves should be derived for each project constructed. Each project is essentially a satellite to the AASHO Road Test. This requires an initial PSI immediately after construction which we do not secure and a greater number of PSI measurements then has been routine to secure in order to define a performance curve. The maximum number of routine measurements on the oldest projects would range around four.

As an alternate method of evaluating, the data on each standard design section was grouped together to provide a larger data base from which to derive a statewide trend curve of performance for each design section. It was anticipated that comparison of the normal limited data on any project with the statewide trend curves could possibly result in a better perspective on the performance that could be expected on a project.

PERFORMANCE 10 INCH PORTLAND CEMENT CONCRETE PAVEMENT - CLASS II AGGREGATE

Figure 1 is a computer plot of PSI's versus accumulated equivalent 18-kip axle loads determined on approximately 200 miles of rural standard 10 inch interstate portland cement concrete pavement with Class II coarse aggregate. Contraction joint spacing - 76 feet 6 inches.

The curve in this figure is an estimate of the trend in overall performance that can be expected for this design. The curve was derived by regression analysis through the use of least squares procedures. It is pertinent to note that the performance relationship follows the same straight line curve relationship experienced on the AASHO Road Test. The overall trend curve is similar to the performance curve for 9 inch pavement on the AASHO Test Road.

The scatter of the plotted data is the first feature to catch the eye in this figure. Data scatter is always a matter of concern to an engineer. Part of this data scatter is due to testing variance. This testing variance has been reduced gradually during the last few years by the development of improvements in the calibration and testing procedures and improvement in the profile equipment being used. The significant improvement in the equipment was developed and patented by personnel from the Materials Office. There is a potential for a significant reduction in future measurements by implementing the sampling recommendations under the General Remarks in this report. Testing variance is important in deriving performance curves for individual projects but does not significantly affect the slope or position of the trend curve in this figure.

The other cause and probably major cause of the scatter is the variation in the performance of different projects which is to be expected.

Extension of the trend curve indicates that the average initial PSI immediately after construction is 3.9. The range of PSI's from 4.01 to 4.28 on the projects selected as candidates for the award of best primary jointed concrete pavement constructed in 1978 reasonably validates this projected figure. The trend curve strongly suggests that a warranted extension in the acceptable service life of the pavement could be achieved if the initial smoothness or PSI could be improved 0.5 of a point to a range around 4.4.

On the average, a reduction of 0.1 of a PSI point occurs for every approximate 1.1 million repetitions of equivalent 18-kip axle loads. A PSI of 3.5 is reached at about 4 million and a PSI of 3.1 is reached at about 9 million repetitions. The maximum repetitions accumulated on any of the sections studied was around 9 million.

It is of interest at this point to cite some information in a 1977 report by the Research and Development Unit of the Utah Department of Transportation. The report contains estimates that the annual benefits or reduction in costs based on reduced surfacing costs, reduced maintenance costs and reduced fuel costs are maximized when each pavement is rehabilitated at the point its PSI drops to 3.0.

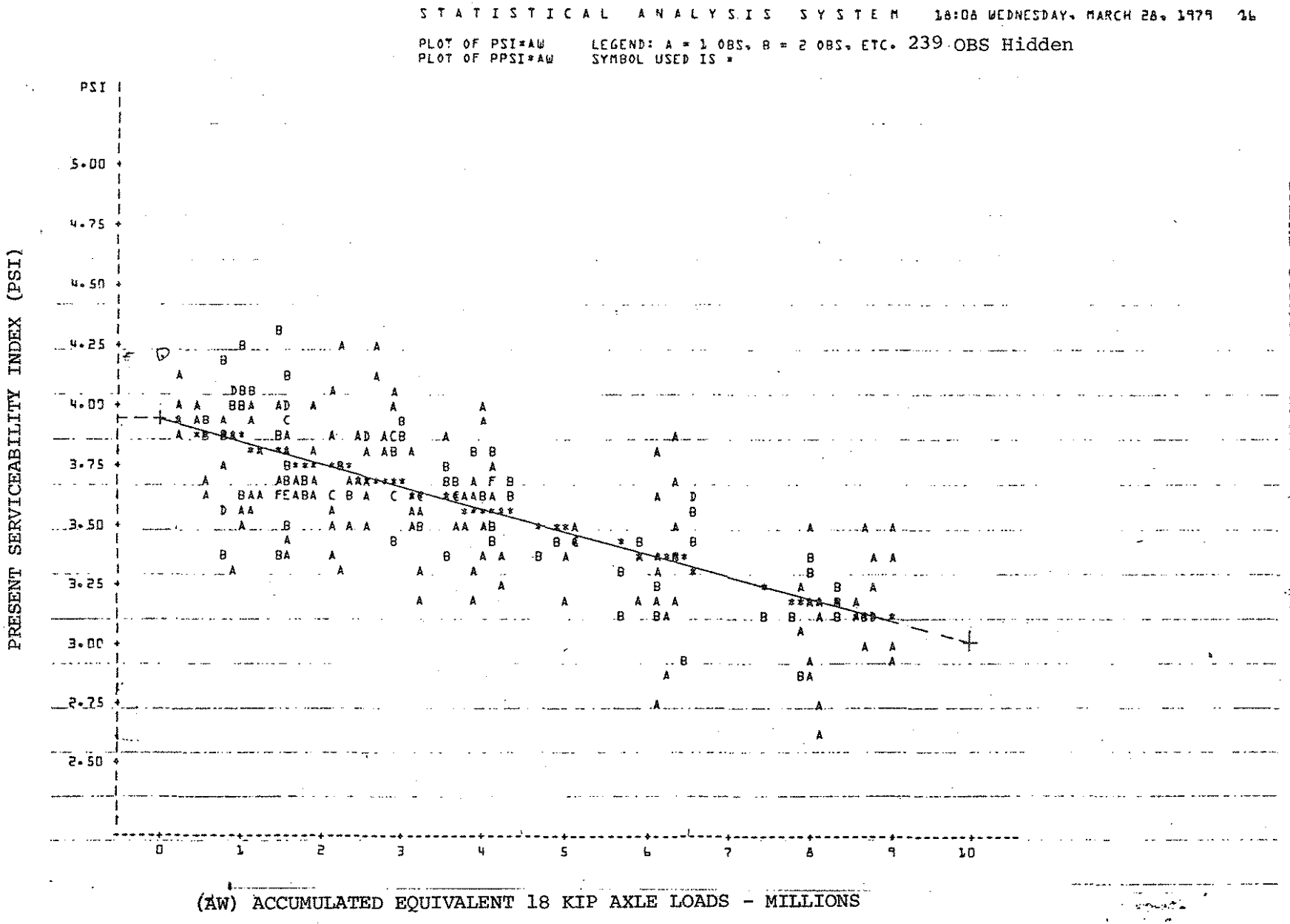
The limited rehabilitation construction on the rural sections studied of 10 inch standard pavement with Class II aggregate have occurred at about the 3 PSI level. The first project consisted of

an asphalt resurfacing in 1969 on a section of I-35 from just south of Des Moines to the south Polk County line. The average PSI just prior to construction was 3.25. The sections had been subjected to just slightly less than one million equivalent 18-kip axle loads. The pavement history sections are 8 and 9. The second project consisted of constructing lateral drains along the outer edge of the pavement of three project sections of I-80 in Poweshiek County in 1978. The Pavement History sections are 34, 35 and 36.

FIGURE 1

PERFORMANCE 10 INCH P.C. CONCRETE PAV.-CLASS II AGGREGATE

TREND CURVE-STATEWIDE PERFORMANCE



PERFORMANCE 10 INCH PORTLAND CEMENT CONCRETE PAVEMENT - CLASS I AGGREGATE

Figure 2 is a comparison of the performance of the 10 inch pavement with Class I aggregate to the overall performance curve for the 10 inch pavement with Class II aggregate. Sufficient data was not available to plot a trend curve for overall performance or to plot a performance curve for any one project with Class I aggregate. Figure 3 shows the geographic location of the Class I aggregate projects and has specific performance data on the projects.

Five projects were constructed which contain Bethany Falls (Winterset) coarse aggregate. This aggregate is classified as a medium D-cracking aggregate. The data indicates that performance curves for concrete with this aggregate would be similar to concrete with Class II aggregate until a PSI range of 3.5 is reached. At this point major repair has been performed on three projects with two of the five projects being resurfaced with asphalt concrete just prior to reaching a PSI of 3.

Two projects were constructed with Argentine coarse aggregate which is classified as having severe D-cracking characteristics. It is estimated that the PSI was at 3 or less at the time of resurfacing. Approximately 5 million loading repetitions had been accumulated at that time.

In summary of the performance data, rehabilitation based on our decisions to date, should be considered when a PSI range of 3.5 or less, or 5 million equivalent 18-kip axle load repetitions are reached. There is also some evidence that environment is an accelerating factor in deterioration of the pavement and thus age much in excess of 12 years should also be cause for review of the pavement condition.

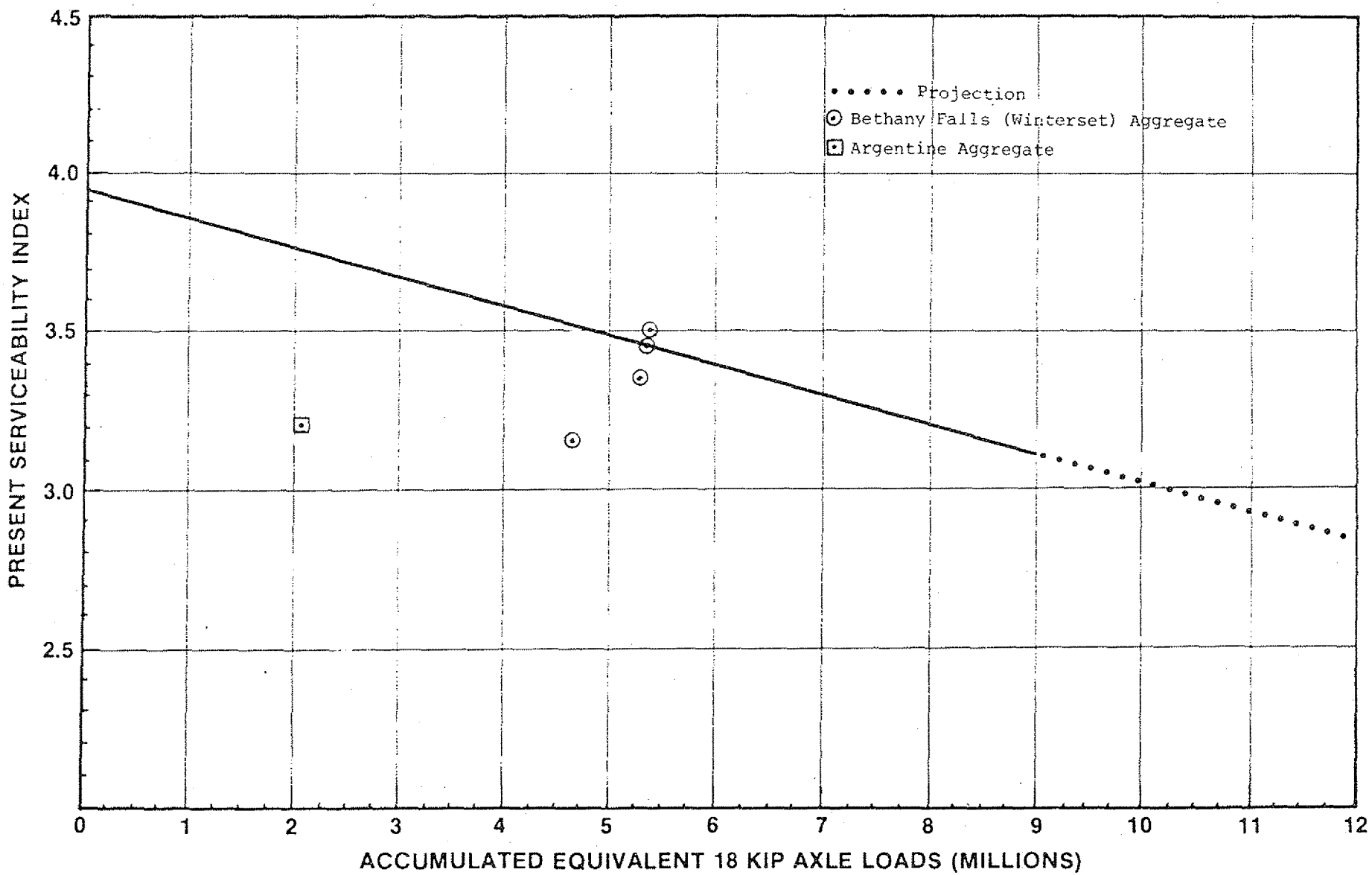
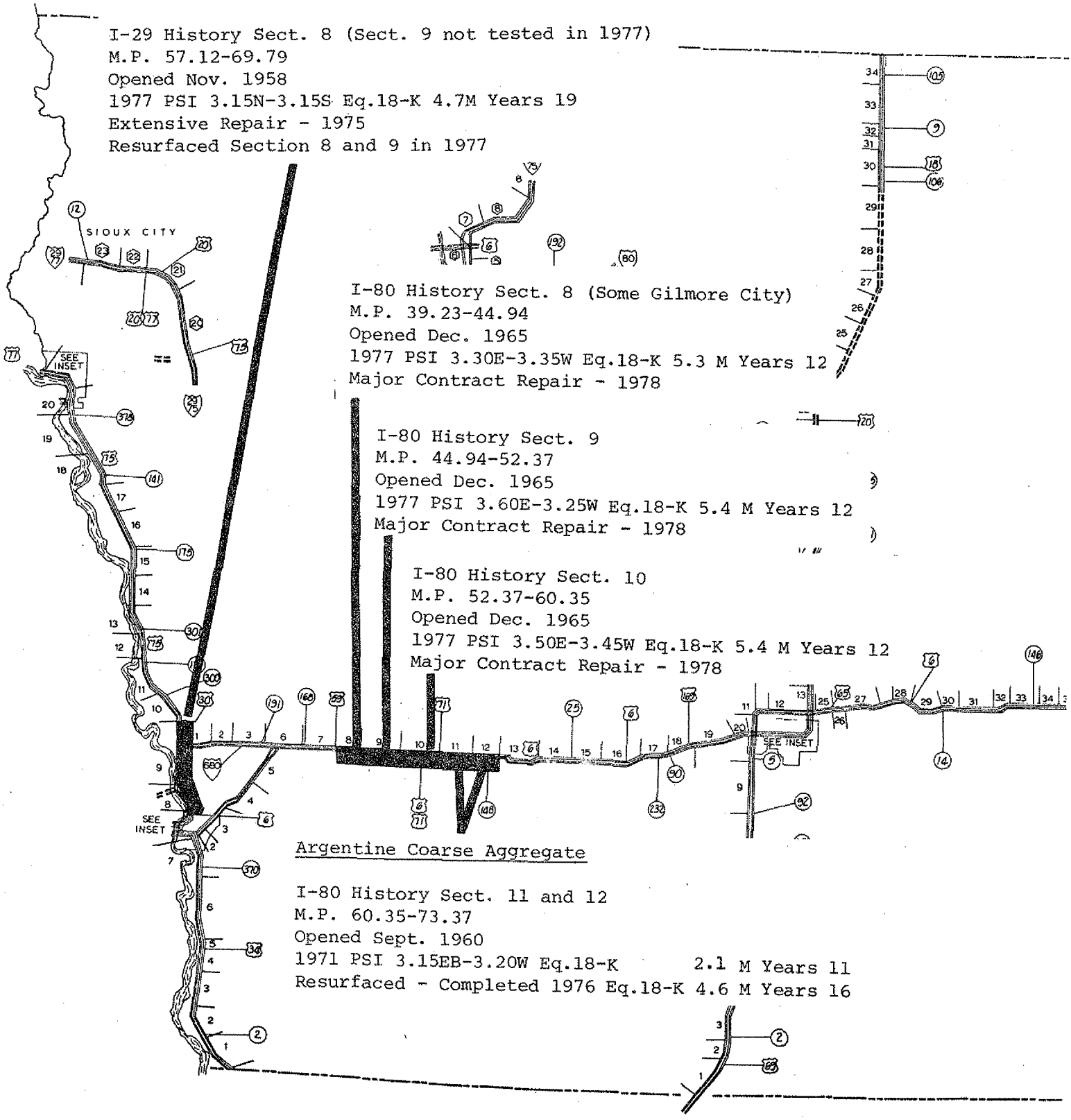


FIGURE 2

PERFORMANCE COMPARISON OF 10 INCH P.C. CONCRETE WITH CLASS I AGGREGATE TO OVERALL PERFORMANCE CURVE WITH CLASS II AGGREGATE

FIGURE 3



PERFORMANCE 10 INCH PORTLAND CEMENT CONCRETE
PAVEMENT WITH CLASS I AGGREGATE
CONTRACTION JOINT SPACING - 76 FT. 6 INCHES

PERFORMANCE OF FULL DEPTH ASPHALT CONCRETE PAVEMENTS

Figure 4 is a comparison of the performance of full depth asphalt concrete sections to the overall performance curve for the 10 inch portland cement pavements with Class II aggregate. Figure 5 shows the geographic location of the 5 interstate projects and has specific performance data on the projects. Again, sufficient data was not available to plot a trend curve for overall performance or to plot performance curves for any one project.

All five projects are showing superior performance to overall trend performance of the 10 inch portland cement concrete. It is interesting to note that the 4 projects with a 17 inch thickness at initial construction and a 2¼ inch stage resurfacing placed after 4 years of service are performing better than the project constructed with an initial thickness of 20½ inches. The latter project was resurfaced with a 3 inch asphalt concrete course in 1976. The average PSI just prior to resurfacing was 3.7.

Rehabilitation of the latter project was necessary to restore the surface condition which was showing signs of distress due to hardening of the asphalt and the poor skid characteristics due to a fine grained aggregate used in the mix. The mix designs at the time of initial construction favored strong stabilities and thus were more susceptible to oxidation and surface hardening with time.

The service age ranges around 15 years.

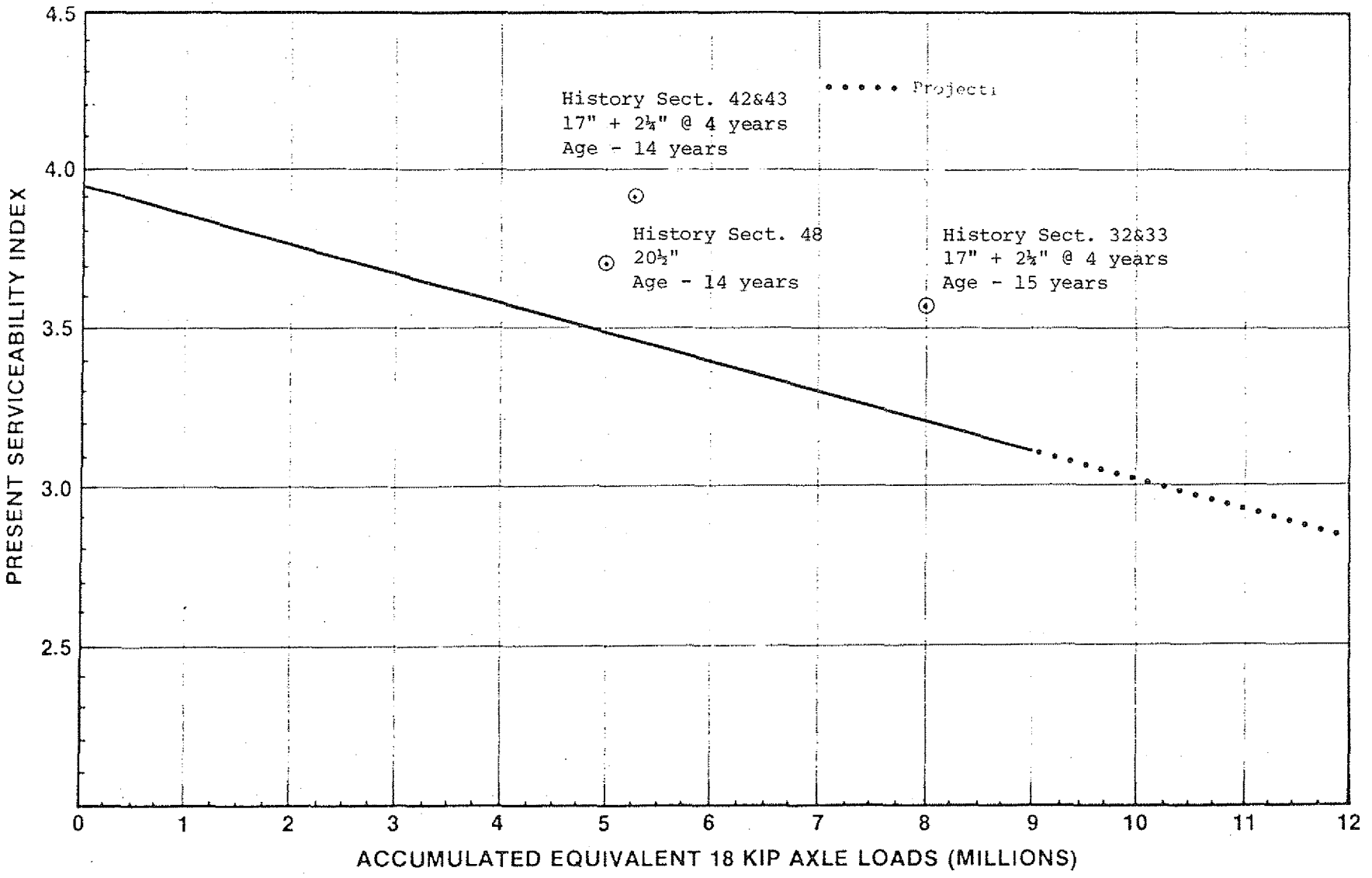
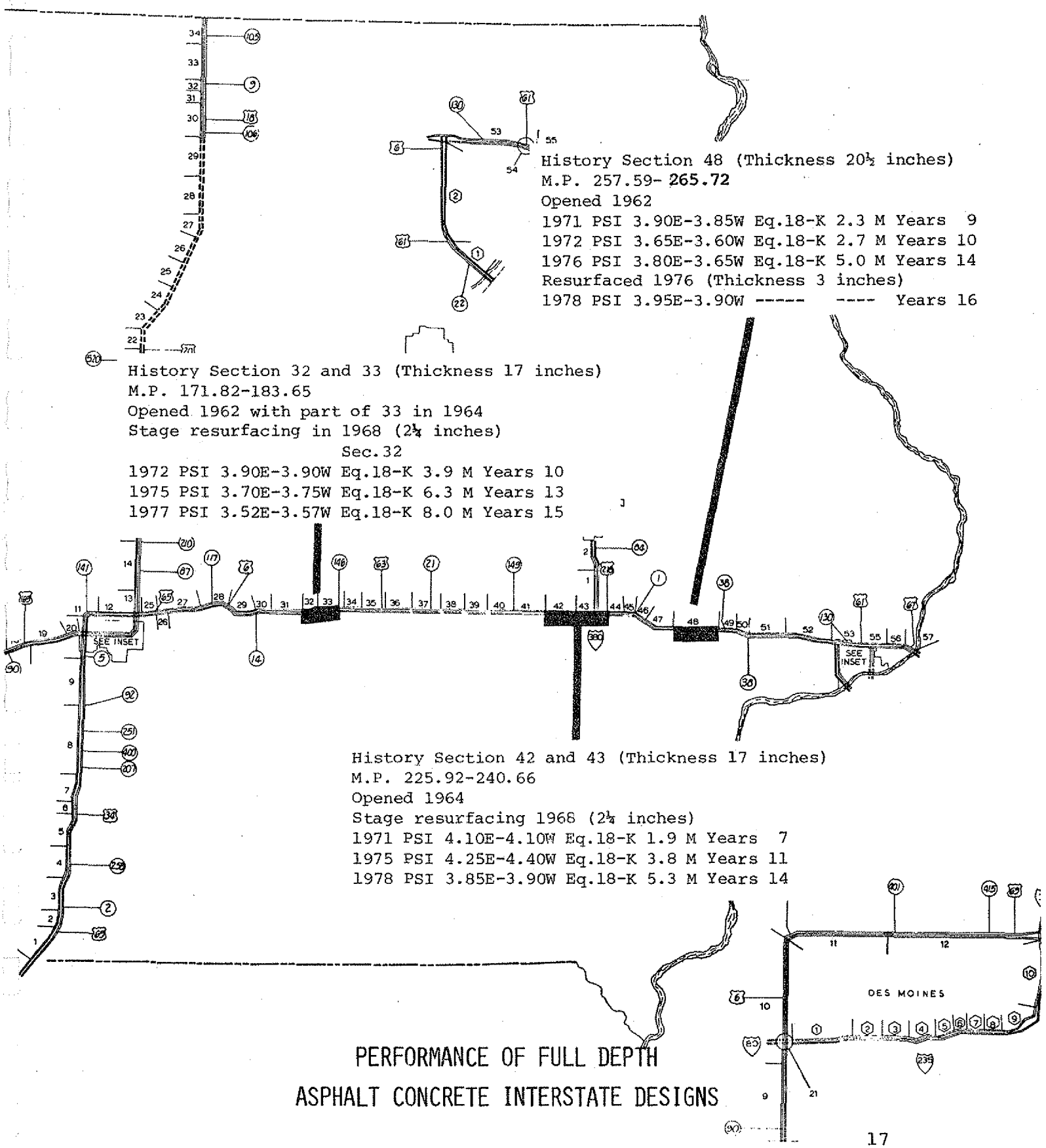


FIGURE 4

PERFORMANCE COMPARISON OF FULL DEPTH ASPHALT CONSTRUCTION

WITH OVERALL PERFORMANCE CURVE FOR 10 INCH P.C. CONCRETE PAVEMENT

FIGURE 5



PERFORMANCE OF FULL DEPTH
ASPHALT CONCRETE INTERSTATE DESIGNS

PERFORMANCE OF 8 INCH CONTINUOUSLY REINFORCED PORTLAND CEMENT CONCRETE PAVEMENT - CLASS II AGGREGATE

Figure 6 is a computer plot of PSI's versus accumulated equivalent 18-kip axle loads determined on approximately 216 miles of rural 8 inch continuously reinforced portland cement concrete interstate pavement with Class II aggregate.

The curve in this figure is an estimate of the trend in overall performance that can be expected for this design. The curve was derived by regression analysis in the same manner as used for the 10 inch standard pavement and the same straight line relationship between PSI's and axle loadings developed. Comparison with the AASHO Road Test performance cannot be made because continuous reinforced pavement sections were not included in the experimental sections.

The previous comments on the scatter of data also apply to Figure 6. The PSI's on this type of design are only reasonably valid because the coefficients for the equations were not validated. Doctor Frank McCullough of the University of Texas has just completed a project studying the relation of the various types of distress on continuous reinforced pavement to the PSI formulas. The pertinent parts of this study which has not been released are being forwarded to us. It is anticipated this data will enable us to develop more meaningful performance survey data on this type of pavement. This deficiency in the measuring system for this type of pavement is not critical except when D-cracking aggregate is used because the age and loadings have not reached a point of generating serious distress.

Extension of the trend curve indicates that the average initial PSI immediately after construction is about 4.2. The maximum equivalent 18-kip axle load repetitions accumulated on the sections studied was around 5.5 million.

Figure 7 is a comparison of the trend performance curve with that for 10 inch standard pavement. The slope of the curve is greater and the level of performance falls below the performance of standard pavement at about 4 million load repetitions and a PSI just over 3.6.

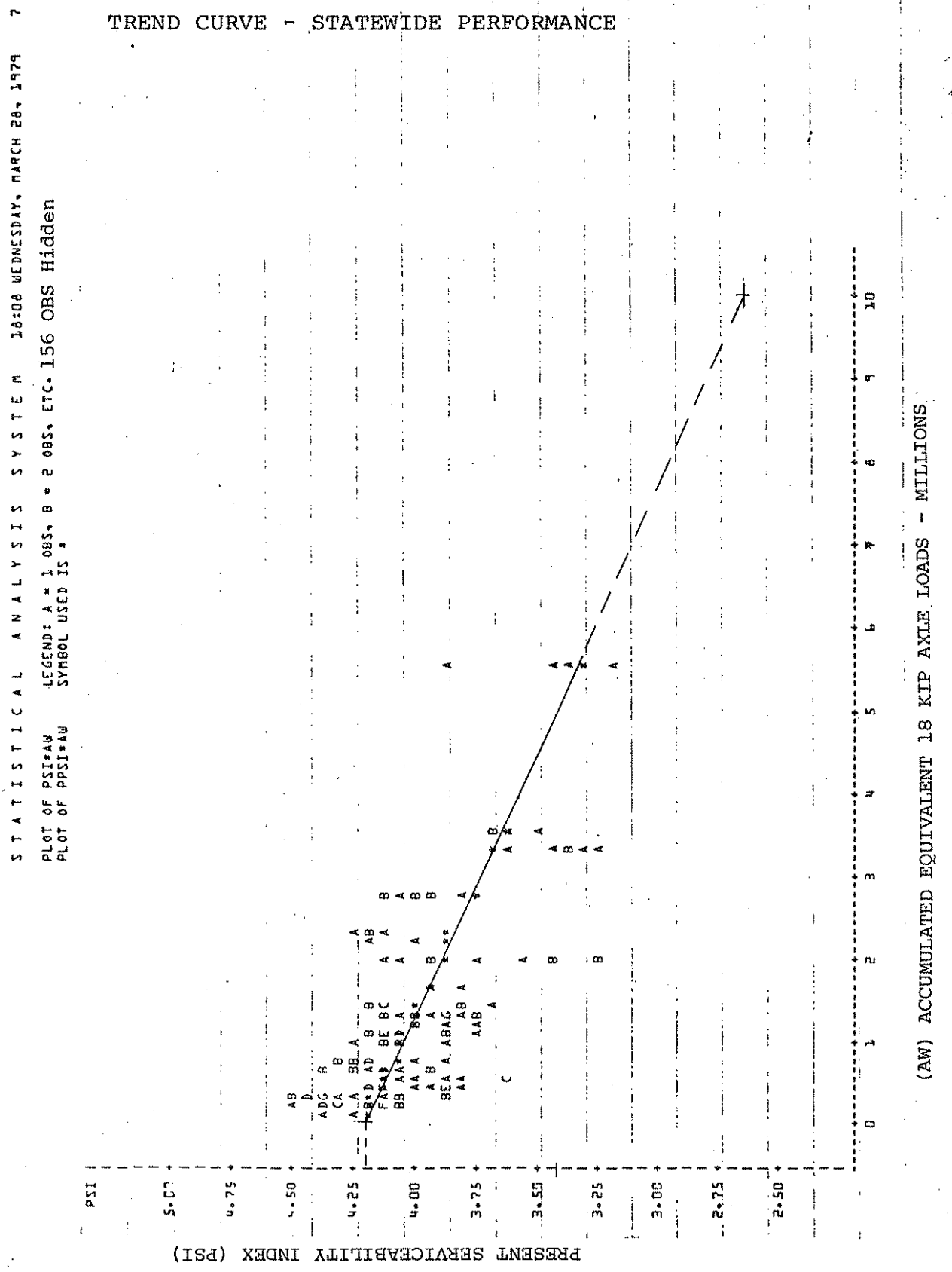
On the average, a reduction of 0.1 of a PSI point occurs for every 0.6 million in equivalent 18-kip axle loads repetitions as compared to 1.1 million for standard pavement. If a PSI of 3.0 is selected as a decision point for considering rehabilitation, the curves indicate that the standard 10 inch pavement will tolerate about 2½ million additional axle loads before reaching the 3.0 level.

FIGURE 6

PERFORMANCE OF 8 INCH CONTINUOUSLY REINFORCED P.C. CONCRETE PAVEMENT

CLASS II AGGREGATE

TREND CURVE - STATEWIDE PERFORMANCE



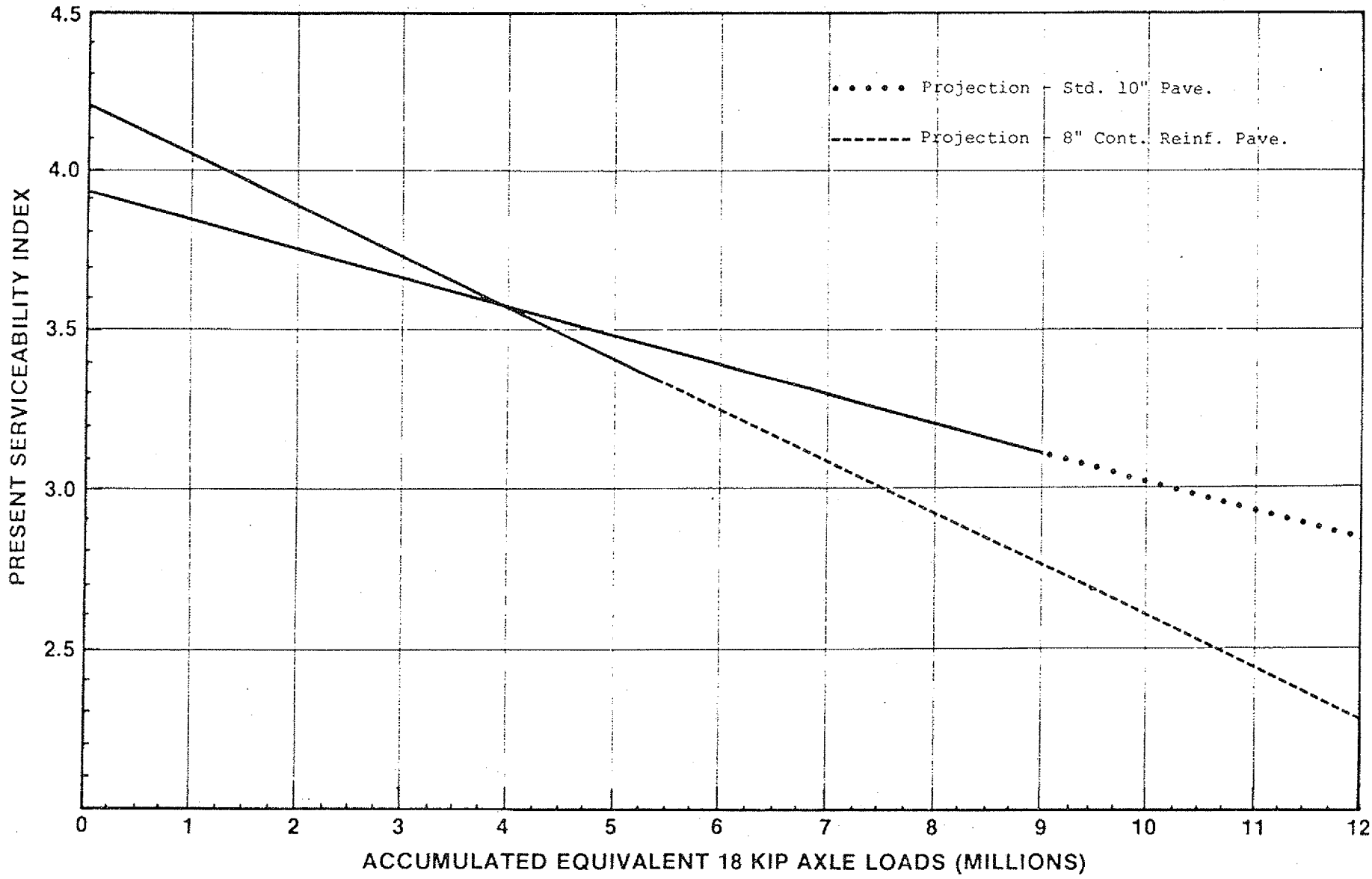


FIGURE 7

COMPARISON OF OVERALL PERFORMANCE CURVES FOR 10 INCH STANDARD P.C. CONCRETE PAVEMENT AND 8 INCH CONTINUOUSLY REINFORCED

PERFORMANCE 8 INCH CONTINUOUSLY REINFORCED PORTLAND CEMENT CONCRETE WITH CLASS I AGGREGATE

A total of 10 projects were constructed with concrete containing Bethany Falls (Winterset) aggregate which is classified as having medium D-cracking characteristics.
This study included 4 of these projects. Figure 8 shows the geographic location of these projects and has specific performance data.

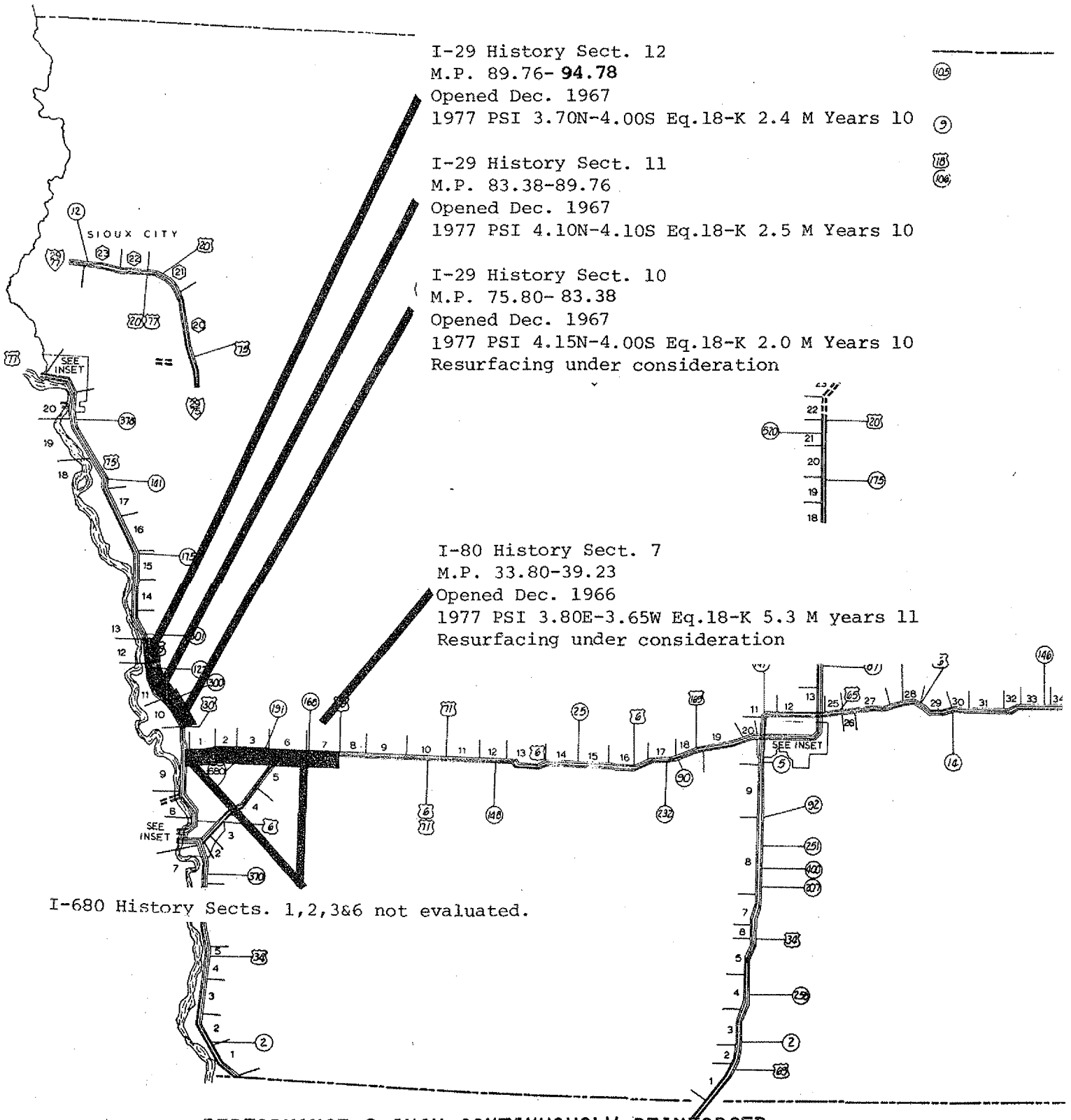
As noted in the discussion on this type of pavement when Class I aggregate is used, the relationship between PSI's and loading is not definitive due to the deficiency in measuring stress patterns in the present survey procedures. Upon receipt of the research information from Texas University, modification of survey procedures will be studied.

Due to the rapid rate D-cracking deterioration develops after it becomes noticeably visible and the effect of the deterioration on the performance of the continuous reinforcement, zero-maintenance rehabilitation should be evaluated as an alternate action strategy.

In summary of Figure 8, the average PSI for the two projects reviewed for resurfacing were 4.1 and 3.7. The two projects are 10 and 11 years in age and have an accumulated 18-kip loading of 2.0 and 5.3 million respectively.

A straight line curve of depreciation much beyond the present condition of the pavements discussed would not be expected.

FIGURE 8



PERFORMANCE 8 INCH CONTINUOUSLY REINFORCED PORTLAND CEMENT CONCRETE WITH CLASS I AGGREGATE (LOGAN)

BETHANY FALLS (WINTERSET)

FINDINGS

1. The Present Serviceability Index survey procedures should be modified as noted to reduce sampling variability in the ratings.
2. The performance curves derived substantiate that the Serviceability Indexes have adequate potential to justify their use for determining the rate of change in serviceability of an individual pavement section.
3. The capability of performance curves - present serviceability indexes versus accumulated equivalent axle loads - to quantify pavement needs and project the time of these needs was demonstrated. Their usefulness in assessing the effect of design features, variations in materials, construction and maintenance and in quantifying the effect of changes in axle loadings are obvious. The effect of aggregate characteristics was illustrated.
4. The limited rehabilitation construction on the rural sections of 10 inch standard p.c. pavement have occurred at about the 3 PSI level of serviceability.
5. Based on the overall performance curves, the PSI depreciates at the rate of 0.1 of a point for every 1.1 million repetitions of equivalent 18-kip axle loads for p.c. standard 10 inch pavement with Class II aggregate and 0.6 million for 8 inch standard continuously reinforced pavement. The level of serviceability of the continuously reinforced drops below that of the standard at approximately 4 million repetitions and a PSI of just over 3.6.
6. Due to the observed rapid rate that D-cracking deterioration develops after it becomes noticeably visible and the possible effect of the deterioration in the performance of continuous reinforcement or structural adequacy, zero-maintenance reha-

bilitation should be evaluated for cost effectiveness and as an alternate strategy for these pavements.

7. The full depth asphalt sections are showing superior performance to the overall trend performance of the 10 inch portland cement concrete sections up through 8 million accumulated axle loads.

8. In summary, this pilot study has demonstrated the capability of the Present Serviceability Index - Pavement Performance concepts as outlined for measuring and quantifying pavement condition and performance. It demonstrated the usefulness of this type of data as a basis for a user-engineering oriented pavement management system. This type of system could be implemented as a satellite pavement management program to augment the present systems with minimum programming requirements. Any programming should also include ADT and SN skid index data.

RECOMMENDATIONS

1. Should there be a desire to explore further or use the pavement management concepts evaluated, the Division of Planning and Research should conduct additional pilot studies on pavements with other design sections. The studies should include a range of composite sections (resurfaced pavements), full depth asphalt primary sections and 10 inch p.c. concrete sections with a contraction joint spacing of 20 feet.
2. The design performance projection curves now being used should be compared to the derived overall performance curves.
3. The relationship of maintenance costs to the projected performance data in this report should be evaluated.
4. Develop a stratified random sampling system for the PSI surveys and explore the use of infrared film in lieu of complete physical surveys.
5. A future study of the crack and patch factor in the PSI formula for continuous reinforced pavements should be conducted.
6. This study points out the need to review the state of the art and possibly develop new procedures applicable to Iowa's needs in two specific areas.

   A. There appears to be a need for a method by which equivalent 18-kip or other selected loads could be economically and quickly estimated without significant extension of load meter studies. A study by the Virginia Research Council explores some of the approaches to this problem.

B. The other area of need is a review of the various cost analysis systems available which would be particularly sensitive to Iowa's conditions in assessing the best use of funds. Of particular concern are life cycle costs. The Iowa Type Survivor Curves published by the Iowa State University Engineering Research Institute has been suggested by G. W. Anderson as one of the systems with some possible potential.

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