SCHOOL OF CIVIL ENGINEERING

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-81/18

DEVELOPMENT OF A SYSTEM FOR THE EVALUATION OF PAVEMENTS IN INDIANA

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INDIANA STATE HIGHWAY COMMISSION

Summary Report

DEVELOPMENT OF A SYSTEM FOR THE EVALUATION OF PAVEMENTS IN INDIANA

TO: H. L. Michael, Director
Joint Highway Research Project

September 30, 1981

Project: C-36-63G

FROM: E. J. Yoder, Research Engineer
Joint Highway Research Project

File: 9-7-7

The following report is submitted on the JHRP research study entitled "Development of a System for the Evaluation of Pavements in Indiana". This report has been authored by Professor E. J. Yoder.

This is a final report on the project and summarizes briefly the data previously prepared by Mohan and Metwali. This research is a cooperative venture in which the Indiana Department of Highways, Research and Training Center performed the field work using the road meter and Dynaflect.

The report by Metwali was first submitted under date of May 13, 1981. His report summarized the data obtained on the project and documentation of the analysis was contained in this report. For purpose of clarity, a minimum amount of documentation has been included in this report and only the salient conclusions and recommendations are presented.

This report highlights the various research projects carried out at Purdue University leading up to this study. A brief review of this particular study is presented. The conclusions are structured to fit the framework of a pavement management system that might be adopted by the Indiana Department of Highways.

This is the final report on this research project and it is submitted to the Indiana Department of Highways and FHWA for review and acceptance.

Respectfully submitted,

Eldon J. Yoder

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16. Abstract

The Indiana Department of Highways is presently setting up a Pavement Management System. As a part of this personnel at Purdue University in cooperation with the Indiana Department of Highways Research and Training Center has conducted a research project on methods for evaluating pavements utilizing roughness data and deflection data.

For this research four types of pavements were evaluated, flexible, overlay, jointed reinforced concrete and continuously reinforced concrete. The basic unit evaluated in the study is the construction contract and the research is based on using the road meter and Dynaflect for obtaining field data. Documentation for the research is contained in two Interim Reports submitted to the IDOH and FHWA. This report summarizes the important conclusions arrived at in the overall study. A brief review of events leading up to the research along with the basic framework for a Pavement Management System to be used in Indiana is presented.

Recommendations have been made on the number of tests to be made, location of tests and time of testing. This information can be used by the state as input data in their potential management system.

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Summary Report

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INTRODUCTION

The Joint Highway Research Project has been actively engaged over the past 20 years in developing techniques for measuring pavement condition utilizing roughometers and road meters. One of the first researches of this type in the state was reported by Michael and Makamura (6) in which serviceability ratings as determined by a panel of raters was correlated with roughometer measurements.

In 1964 Yoder and Milhouse (11) reported on a research project sponsored by the NCHRP in which various methods of measuring pavement condition were studied and use of panel ratings for calibration of roughness devices was also conducted. The 1964 project demonstrated that to be of most use, condition measurements (i.e. roughness, etc.) must be calibrated against road user opinions as established by panels. The pavement serviceability concept was first proposed by Carey and Irick (3) in 1960 at which time the original serviceability equations from the AASHO Road Test were correlated with serviceability ratings. These equations were later modified by the Purdue study in 1964.

The Highway Research Board in cooperation with Purdue University sponsored a conference on road meters in 1973 (8). In the proceedings of this conference, the latest information on the road meter including methods of calibrating the road meter were presented. Shortly after this, the Indiana State Highway Commission, through the Research and Training Center, purchased a PCA Road meter which was installed in a station wagon.

A Dynaflect was purchased and housed at the Research and Training Center (12) as a part of the evaluation of continuously reinforced concrete pavements in Indiana. As a result of the research projects mentioned above, evaluation of pavements in Indiana has concentrated on the use of the road meter for condition measurements and the Dynaflect for measuring the structural properties of pavements.

A cooperative research program between the Research and Training Center and Purdue University was undertaken in 1976. The purpose of this project was to develop a system for the evaluation of pavements in Indiana. The first interim report on the project was submitted in 1978 by Mohan (7) and the second interim report by Metwali in 1981 (5).

This summary report summarizes the salient conclusions presented by Mohan and Metwali and presents recommendations on test methods for evaluating pavements using the road meter and Dynaflect. Concepts of pavement management and use of a management system in Indiana are also discussed.

HISTORY AND SCOPE OF PROJECT

The overall scope of the project was aimed at obtaining factual information that could be used by the State in setting up techniques for evaluating pavements and how these data might be used in a pavement management system. Since the Indiana State Highway Commission owned, and was operating, the road meter and the Dynaflect it was decided early to concentrate major effort on the use of these two instruments.

The first step in the project was to calibrate the road meter against road user opinions. To do this, pavements within an area with its center at Lafayette and having a radius of 70 miles was studied. Pavements included both two lane and multi-lane facilities; pavement types were flexible, overlay, jointed concrete and continuously reinforced concrete. A total of 94 test sections each one kilometer in length were arranged in 5 travel loops and were evaluated. Only rural roads were included in the study.

For the road meter calibration study, a 20 person team was organized to rate the pavement sections. An effort was made to include members of both sexes of all age groups. Car sizes ranged from small to large and the drivers were engineers and lay persons.

Acceptability ratings and PSI equations were presented by Mohan on the basis of this study. Since just one panel was used in the rating for the entire project, it was necessary to perform all road meter tests throughout this project utilizing the original station wagon mounted meter.

Also, as a part of the first phase, deflection measurements using the Dynaflect were made on a selected group of pavements. Major effort was expended in delineating the optimum position of test on the pavement. To accomplish this, tests were made at the pavement edge and pavement interior of all the pavements. It was concluded from this study that testing, using the Dynaflect, should be conducted in the vicinity of the outside edge.

Tentative correlations relating the fall and spring deflection values were presented. The purpose of this study was to permit the measurement of deflection at any time of the year and then to relate these to the spring values which are considered to be the critical values for evaluation purposes.

The second phase of the study was undertaken in 1979 for the purpose of clarifying some of the information collected during the first phase. Major effort during the second phase of the study was centered on variability of test measurements so that recommendations could be made relative to the number of tests required to obtain statistically sound information. At the time of the second phase, it was decided after consultation with engineers of the ISHC and FHWA, to concentrate most of the effort on a contract section as the optimum length of section to be tested. In the evaluation of pavements, it is necessary to select a homogenous section and it is believed, that in lieu of detailed subgrade information and construction data, the contract section offers the best possibility for a homogenous section.

During the second phase, effort was further expended on correlating the panel ratings with road meter ratings and new equations were developed. Recommendations were formulated and presented by Metwali (5) relative to the number of tests required and the optimum location of these tests.

FRAMEWORK OF A MANAGEMENT SYSTEM

A pavement maintenance management system to be of use to the State must allow for the optimum use of equipment. The utility of the road meter is that it permits the evaluation of a large mileage of pavements in a relatively short period of time. Therefore the road meter's best use can be for a first sorting of pavements that need attention. The road meter indicates what pavements are rough but it states nothing of the cause of the roughness and hence its use is to "flag down" sections that require detailed investigation.

The same can be said, to a lesser extent, for the friction tester in that a large mileage of pavements can be inventoried fairly rapidly, but here, continuous data cannot be obtained and spot tests must be made. Also, due to the relative cost of the friction tester it is generally conceded by the profession that the first run of condition tests should be made with some other device.

Sequence of Testing

Figure 1 in the appendix shows a flow diagram outlining the sequence of testing envisioned for a management system. Road meter information on serviceability would either be obtained on the entire system or at least on all candidates for evaluation. There is little need, for example, for testing pavements that are known to be in excellent condition and which will require no maintenance for a considerable amount of time except to establish serviceability trends.

The screening process to be done by the computer first sorts out those pavements needing immediate attention so that maintenance budgets and priorities for the very near future can be made up. Further, those pavements which should be considered for future maintenance are also selected. This sorting would be done on the basis of the Acceptable Serviceability Index (ASI).

Considering first those pavements with serviceability indices below the acceptable, the pavements would next be sorted on the basis of concrete, overlay pavements and flexible pavements. For concrete and overlay pavements, selective Dynaflect tests might be made for determining underseal requirements and other factors but essentially the overlay and maintenance requirements would be done on the basis of past experience.

For flexible pavements, the overlay requirements would be determined on the basis of Dynaflect measurements using one of the acceptable methods in use at the present time (for example the Asphalt Institute, Reference 2).

The immediate maintenance requirements and maintenance costs on the basis of serviceability would next be combined with the needs on the basis of friction tests. For those pavements having serviceability indices above the acceptable, the next sort would be on the basis of friction testing so that those having friction numbers at or below the critical could be immediately put into the group of pavements needing prompt attention. Priorities and costs for the present and near future would next be established.

For those pavements not requiring immediate attention (serviceability and friction test numbers above the critical) it is next necessary to estimate the remaining friction and serviceability life. After these estimates are made, maintenance needs, by years, for the future can be determined, and priorities and costs for the future can be established.

Selection Criteria

The flow of analysis as shown in Figure 1 is based upon determining certain critical values during the testing program. This research has concentrated on serviceability as determined by the road meter and structural evaluation as determined by the Dynaflect. Personnel at the Research and Training center have made an extensive study of the frictional resistance of Indiana pavements and these data are presently available for immediate use. Critical values and means of estimating the frictional life of a pavement has been established. Additional criteria are as follows:

1. Test section length to be evaluated. The optimum length of test section to be evaluated is a construction contract. This is believed to be the most homogenous section with regard to soil type, traffic, construction, and material type.
2. Acceptable serviceability index (ASI). On the basis of the work in this study as well as previous work, the acceptable serviceability index for primary pavements is recommended to be 2.5 and for secondary pavements 2.0.
3. Maintenance requirements for concrete and overlay pavements. There is no generally accepted method available at the present time in which deflection measurements can be used for determining overlay requirements for these pavements. Majidzadeh, Ilves, and May (4) reported on methods of designing overlays for concrete pavements. They evaluated several methods and concluded that none of the methods were completely satisfactory at the present time. The

most widely used method is that of AASHTO (1). Therefore, deflection measurements need not as a rule be made except in cases where selective testing for undersealing and other factors may be desirable. Overlay requirements can be determined on the basis of the AASHTO Interim Guide (1).

4. Maintenance requirements for flexible pavements. All pavements with serviceability indices below the acceptable value should be tested with the Dynaflect. Overlay requirements can be determined using methods available at the present time including that of the Asphalt Institute (2).

5. Estimating remaining serviceability life. This is a critical stage in the process. Each pavement has its own discrete serviceability-time relationship. Until a sufficient amount of data are available to establish these trends for each pavement, it can be assumed that the serviceability trend follows the AASHTO curve. It is necessary that the prediction account for truck axle loads, structural capacity of the pavement and subgrade type.

OPTIMUM TESTING PROCEDURES FOR INDIANA

One of the major thrusts of this research has been to delineate testing procedures applicable to Indiana conditions. These procedures have centered on use of the road meter, including methods of calibration, number of tests required per section of pavement and the effects of seasonal variations on road meter data.

Relative to the Dynaflect, the research effort concentrated on variability of data over a contract section, correlation of seasonal values and the number of tests required for the various pavement types. A major concern dealt with the framework of time within which to make measurements since, conceptually, structural evaluation should be based on the spring measurements and it is most difficult to determine an adequate number of observations during this time period.

ROAD METER

The road meter instrument is capable of making a sweep survey of the entire system or as a minimum, all pavements that are likely candidates for consideration of maintenance in the near future. The purpose of using the road meter is twofold:

1. Locating those pavements needing attention in the immediate future for further evaluation on a structural basis.
2. Cataloging serviceability vs. time information for the highway network with the end point of predicting the point in time in the future when work will be required for each pavement. This information can be used for planning strategies.

Calibration of Road Meter

At the conception of the research project the Indiana Department of Highways owned and operated one road meter housed at the Research and Training Center. The original road meter was calibrated using a panel of raters in this study. It is important to note that the instrument must be recalibrated occasionally and as a bare minimum all future instruments must be calibrated using one of the several techniques. It is recommended that each new road meter be calibrated against a panel of raters. For reference, the New York Department of Transportation calibrates each road meter immediately upon its purchase using a panel of approximately 20 individuals. The results of this research has suggested that about 20 raters would be optimum.

Figure 2 in the appendix shows the road meter equations developed in this study.

Time of Obtaining Data

The study of seasonal variation of road meter data for Indiana climatic conditions has suggested that some variations exist among the data on a seasonal basis but that this variation is negligible and within the accuracy of the meter itself. So long as data are obtained no earlier in the spring than several weeks after the complete spring thaw and no later in the fall than the first freeze there was no significant difference statistically relative to seasonal variations of road meter readings (see Figure 3).

Number of Passes Required

In the interest of obtaining data on a statewide basis it is desirable to amass a large amount of information. A study relating the number of road meter passes to the accuracy of the data obtained indicated that just one pass of the road meter is required (see Figure 4). Therefore, this makes it possible to plan a sweep with the road meter without undue back tracking and costly time delays.

Direction of Travel

Studies of transverse variability of road meter readings on two lane pavements have shown that just one direction of travel is required for adequate data. This enhances the planning of field investigations for optimizing the amount of time required.

For four lane pavements, however, it is necessary to test each direction of traffic in the traffic lane. Some judgment must be used on this in that if three directional lanes are used it might be desirable to use the center lane rather than the outside depending upon the distribution of truck traffic.

DYNAFLECT TESTING

One of the major concerns of this research project was to establish the variability of Dynaflect test data so that the optimum number of tests could be established. The variability study was done for the flexible pavements by determining tolerable limits of life expectancy of a designed overlay if the true deflection was not estimated correctly. Also for Indiana conditions, it is desirable to use spring deflection measurements for evaluation. However, time constra-nts generally will not permit obtaining a large amount of data and, hence, seasonal variations of measurements were determined so that spring values can be estimated from others.

Time of Year to Make Measurements

As mentioned above, it is desirable to use Spring measurements as the critical ones for evaluation purposes. This requires that tests be made within a fairly small time-frame which often times precludes performing the test. Data in Figure 5 show the relationships established for a frost area of the midwest.

For seasonal frost areas deflection tests should be made during the spring melt period if at all possible. If time precludes this, data in Figure 5 can be used as a correction for flexible pavements. To minimize error and interpretation from the graphs the tests should be made as close to the actual Spring melt period as possible. May and June appears to be a desirable period since the corrections here are minimal.

Number of Readings

A statistical study was made relative to variation of deflection measurements within a construction contract. This was done by dividing the section into subsections one mile in length. The analysis showed that the variation of the measured deflection parameters between the different 1-mile locations within a contract section was statistically significant for all the pavements included in the study. Therefore, sampling a short stretch within a contract is not expected to give representative results and the optimum procedure for making the Dynaflect measurements requires that the tests be distributed along the length of the section under evaluation.

Asphalt Pavements

The Dynaflect testing intensity for asphalt pavements was determined by a sensitivity analysis of the underdesign and overdesign that might result in the overlay if there is an error in measurement of the deflection. The background information for this is shown in Figure 6. For high traffic volume flexible pavements (ADT > 5,000) an intensity of ten test locations per mile appears to be adequate. For low volume with lesser traffic this can be reduced to five tests per mile.

The test locations can be randomly located along the section of pavement to be evaluated and for evaluation purposes the design deflection should be equal to the average plus two standard deviations (2).

Jointed Concrete and Overlay Pavements

The presence of joints in jointed concrete pavements and reflection cracks in overlay pavements requires that tests be made at two positions at each test station. Jointed concrete pavements should be tested at a joint position and at a mid-span position. Overlay pavements should be tested at a reflection crack and at a mid-span position (i.e. a good area where there is no cracking).

For jointed and overlay pavements the optimum intensity of testing is ten tests per mile. For four lane pavements and greater, each direction of travel must be evaluated and the tests made in the traffic or outside lane.

Continuously Reinforced Concrete Pavements

Frequency of testing for the CRC pavements of ten tests per mile is the optimum value. These may be randomly spaced on the longitudinal but as in the case of all the pavements, the tests should be made in the traffic lane and for multi-lane pavements each direction of travel should be evaluated.

RECOMMENDATIONS FOR FUTURE WORK

The Indiana Department of Highways is well on its way to compiling a catalog of road information to be used in a pavement management system. A method of estimating remaining service life of pavements was presented by Penn (9). The method of Penn does not include all of the factors desirable in an analysis of this type. The structural number of pavements has been generalized as has been the effect of traffic. It is recommended that additional work be done to more clearly define serviceability trends for Indiana pavements. A method for estimating serviceability trends on the basis of just several readings should be developed.

The primary factor affecting serviceability is truck traffic as measured by the equivalent axle load concept (EAL). The classification of trucks and use of truck weight data in Indiana can be enhanced and it is recommended that further study be undertaken in this regard.

Priority programming has been a topic of continuing study in many states. It is recommended that a study be undertaken to establish techniques for establishing priorities based upon serviceability trends.

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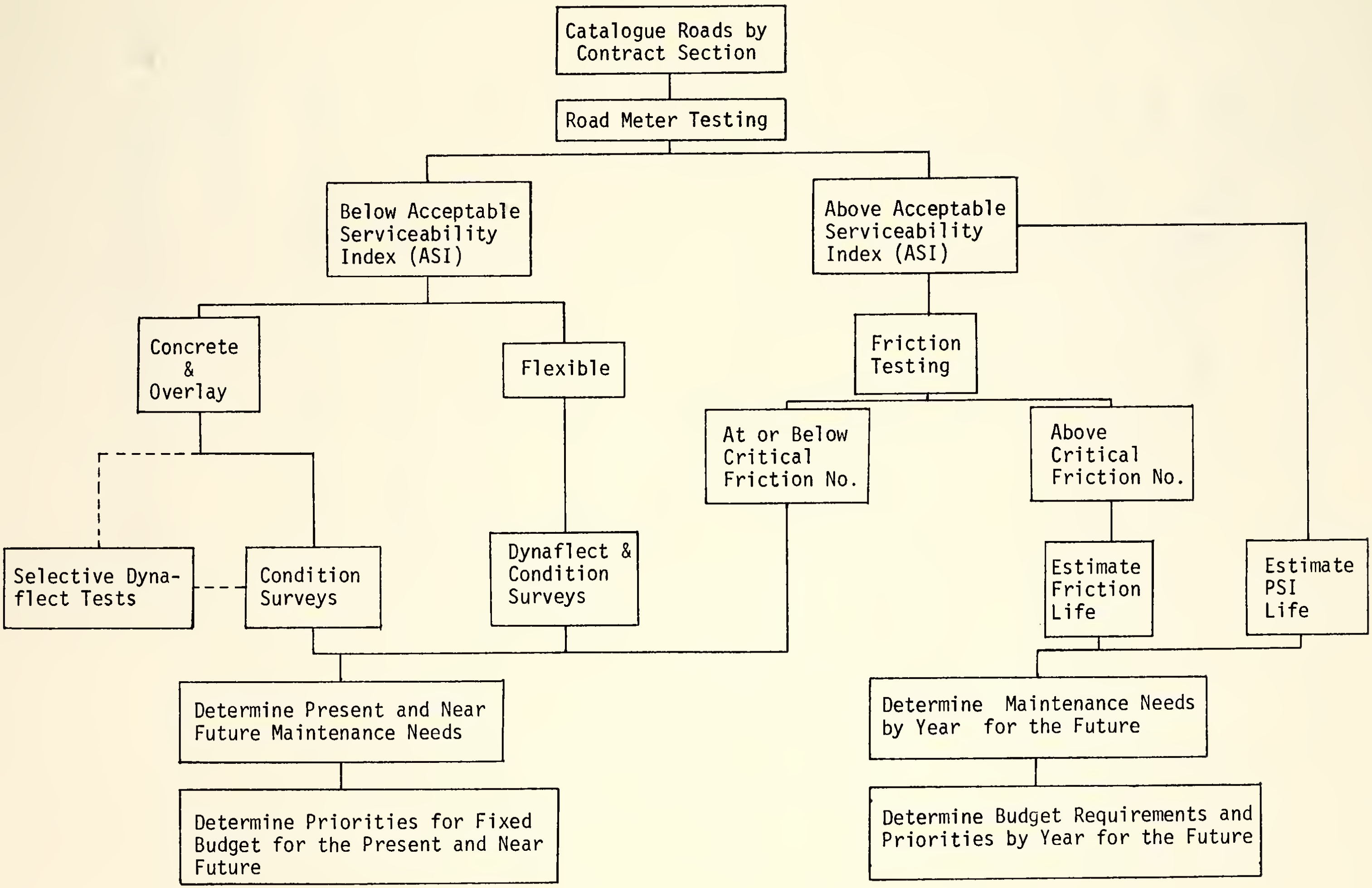
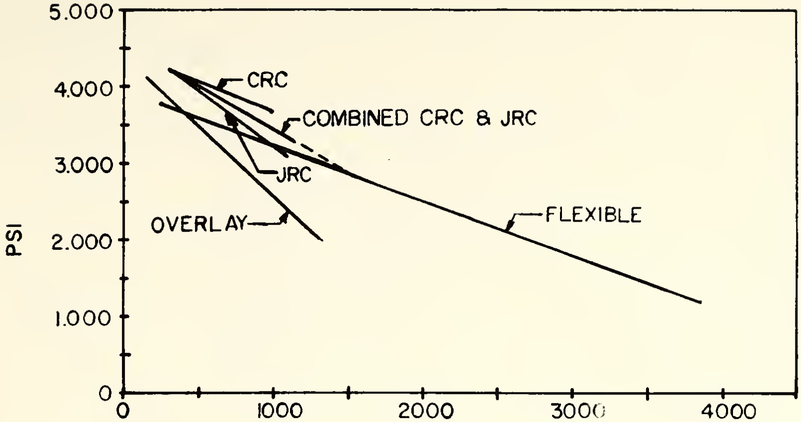
APPENDIX

FIGURE 1 SEQUENCE OF TESTING FOR PMS





(a) RELATIONSHIP OF ROADMETER COUNTS AND PSI.

PAVEMENT	MODEL	R^2
ASPHALT	PSI = 3.94 − 0.00072C	0.79
OVERLAY	PSI = 4.37 − 0.00174C	0.77
JRC	PSI = 4.69 − 0.00141C	0.88
CRC	PSI = 4.40 − 0.00070C	0.59
JRC&CRC (COMBINED)	PSI = 4.58 − 0.00114 C	0.71

(b) PSI EQUATIONS

FIGURE 2. SERVICEABILITY EQUATIONS FOR ROADMETER

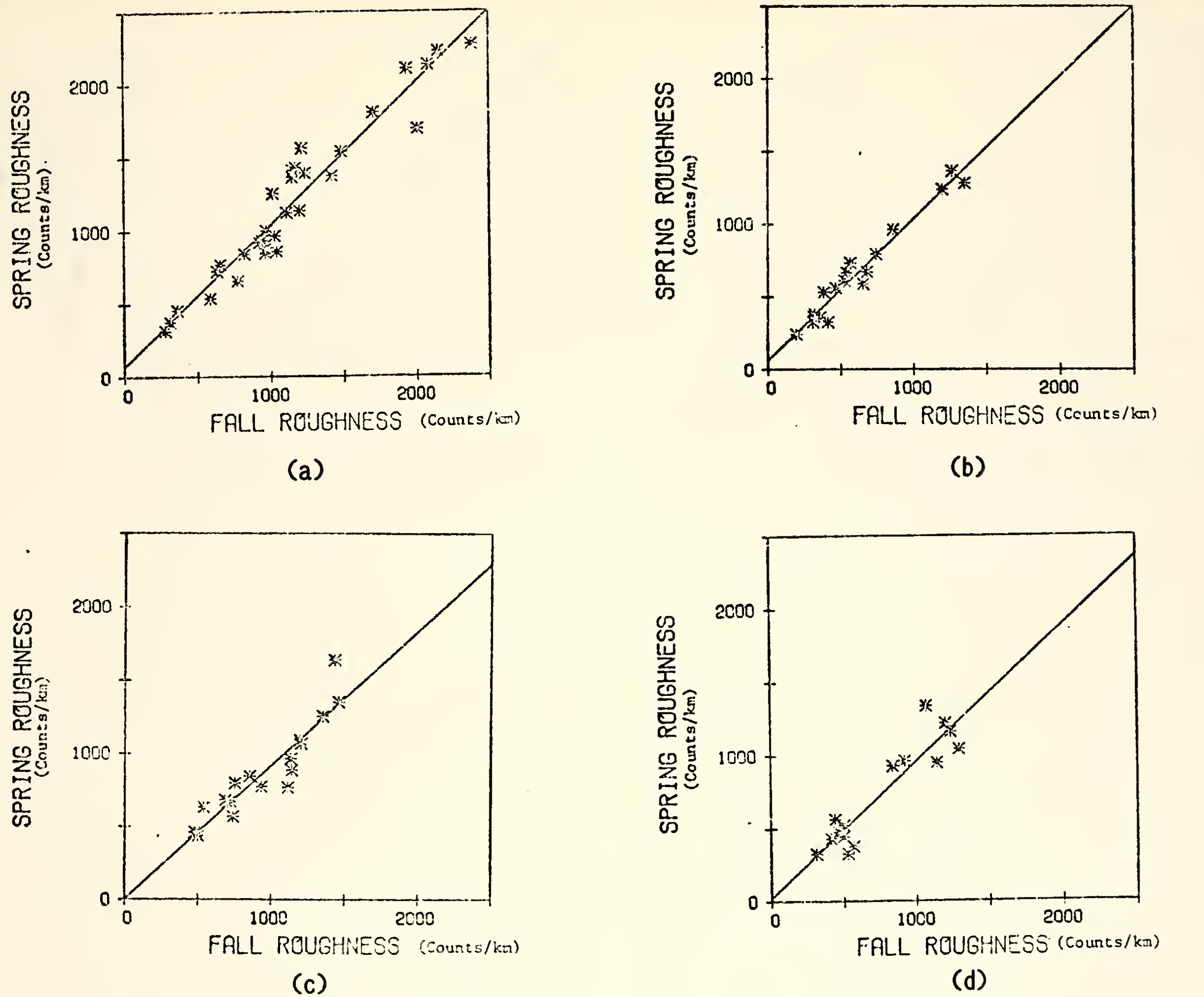


FIG. 3 FALL vs. SPRING ROADMETER DATA. (a)ASPHALT, (b) OVERLAY, (c) JOINTED CONCRETE and(d) CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

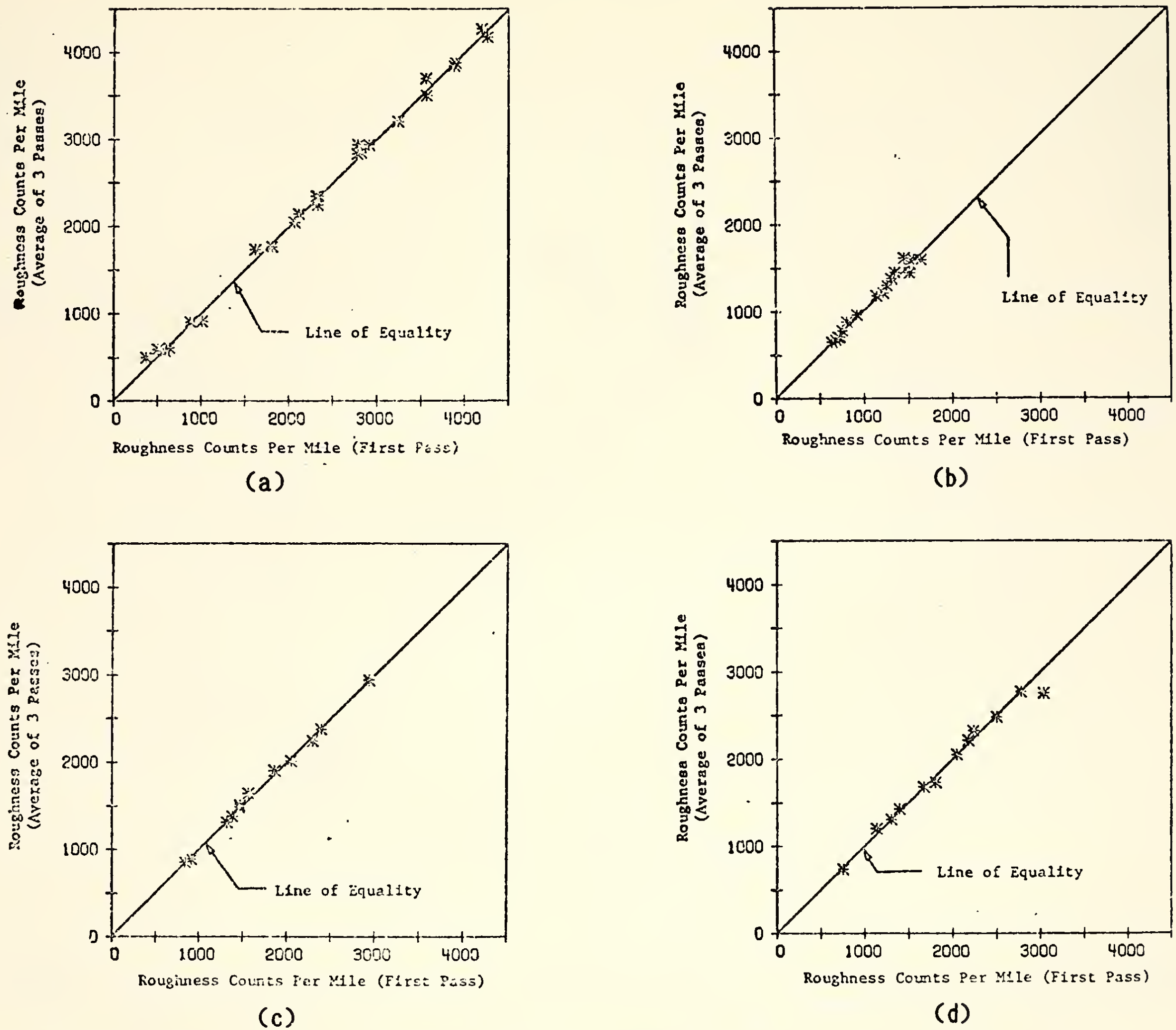


FIG.4 ROADMETER COUNTS ON FIRST PASS vs. COVERAGE OF THREE PASSES (a) ASPHALT, (b) OVERLAY, (c) JOINTED CONCRETE and (d) CONTINUOUSLY REINFORCED CONCRETE

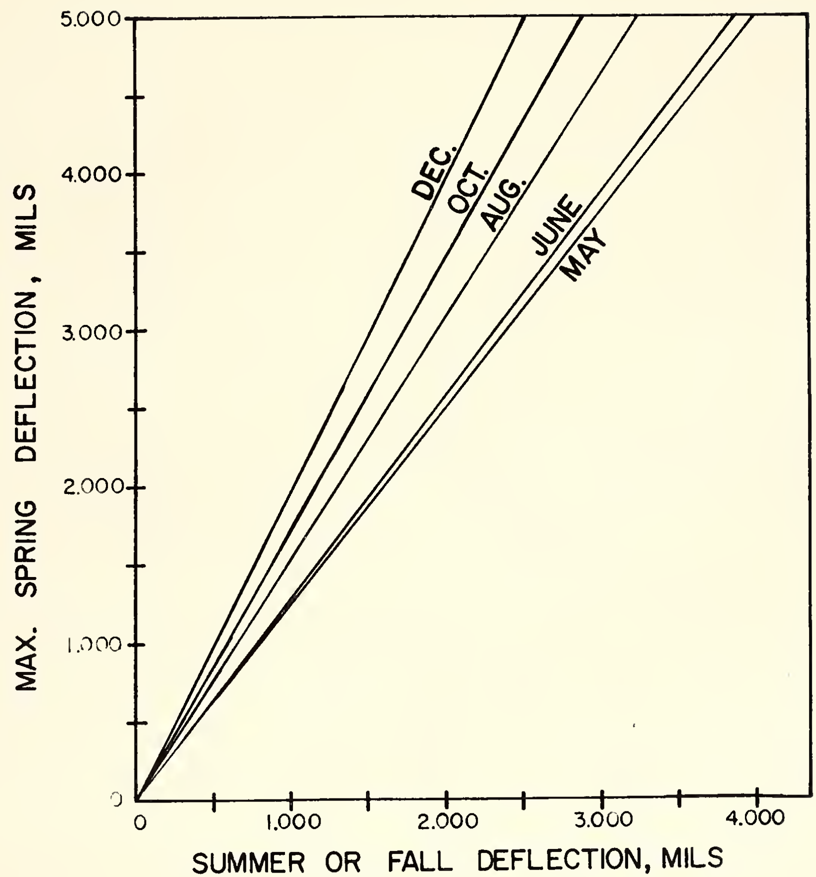


FIGURE 5. RELATIONSHIP BETWEEN DEFLECTIONS MEASURED IN THE SUMMER AND FALL AND MAXIMUM SPRING DEFLECTION FOR ASPHALT PAVEMENTS (DATA FROM REFERENCE 10).

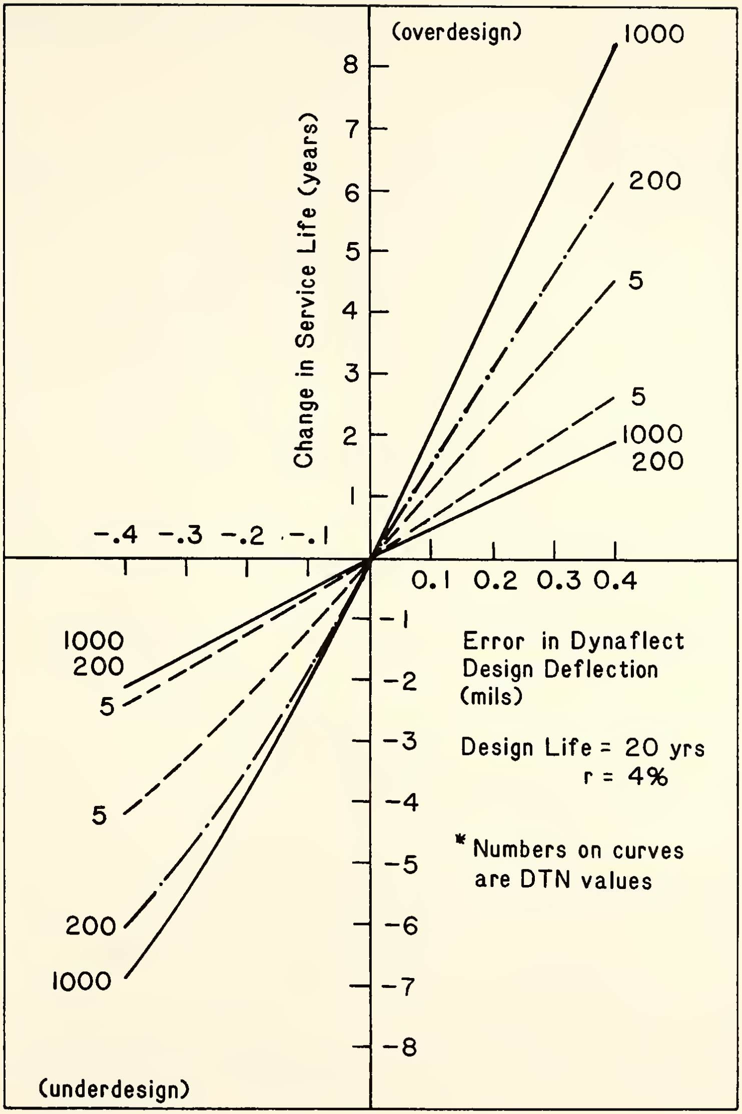


FIGURE 6. CHANGE IN SERVICE LIFE OF RESURFACE AS A FUNCTION OF ERROR IN DYNAFLECT DESIGN DEFLECTION.

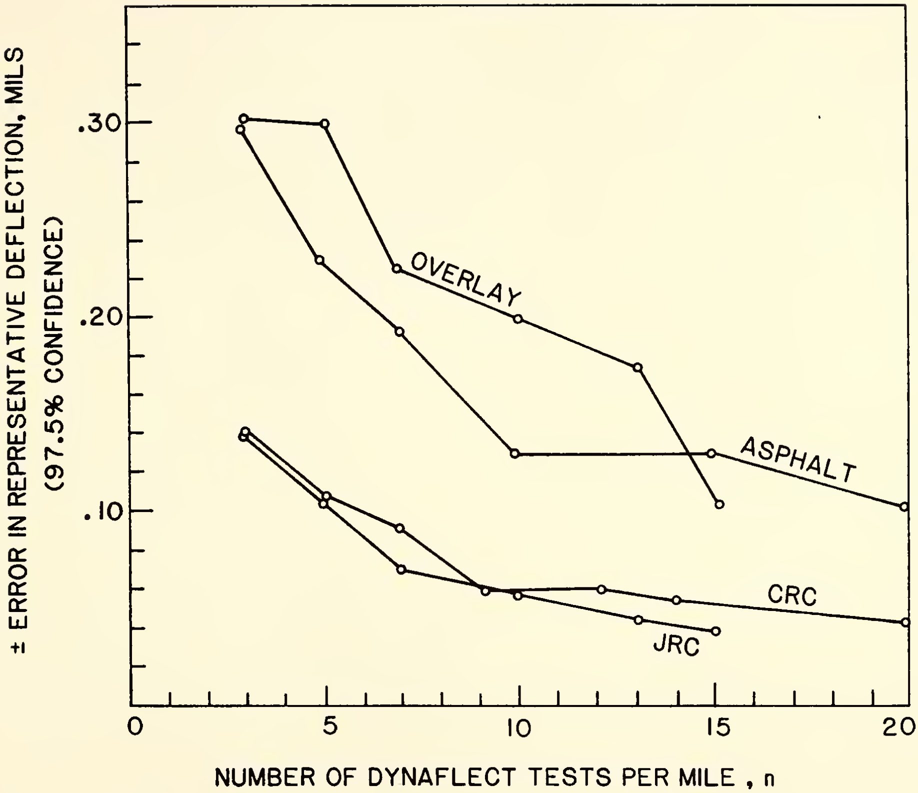


FIGURE 7. ERROR IN REPRESENTATIVE DEFLECTION vs. NUMBER OF DYNAFLECT TESTS PER MILE

COVER DESIGN BY ALDO GIORGINI