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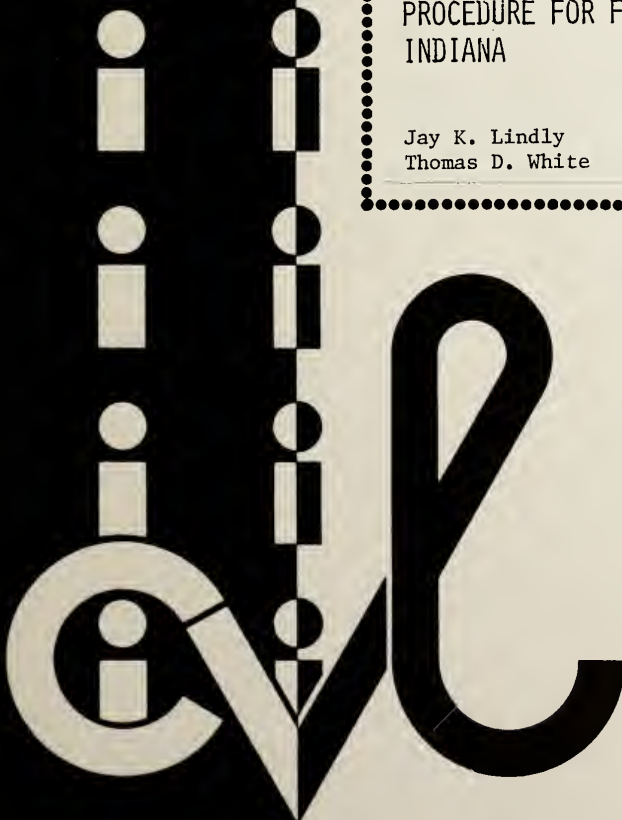
DEVELOPMENT OF AN OVERLAY DESIGN
PROCEDURE FOR FLEXIBLE PAVEMENTS IN
INDIANA

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PURDUE UNIVERSITY

JOINT HIGHWAY RESEARCH PROJECT

DEVELOPMENT OF AN OVERLAY DESIGN PROCEDURE FOR FLEXIBLE PAVEMENTS IN INDIANA

Jay K. Lindly
Thomas D. White

Executive Summary

DEVELOPMENT OF AN OVERLAY DESIGN PROCEDURE FOR FLEXIBLE PAVEMENTS

IN INDIANA

TO: H. L. Michael, Director   October 21, 1987
      Joint Highway Research Project

                                            Project: C-36-55G

FROM: Thomas D. White, Research Engineer
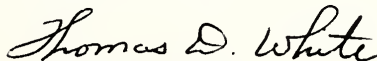   Joint Highway Research Project   File: 2-12-7

Attached is the Final Report on the HPR Part II study titled, "Development of an Overlay Design Procedure for Flexible Pavements in Indiana." This study presents the results of a study that evaluated nondestructive testing equipment and utilized data collected from the existing highway system to develop a proposed overlay design procedure for flexible pavements.

The overlay design procedure involves conducting a parallel analysis to determine overlay thickness required for added structural capacity or to provide functional mitigation of distress.

This report is forwarded to IDOH and FHWA in fulfillment of the objectives of the study.

                          Sincerely yours,

                          Thomas D. White

                          Thomas D. White
                          Research Engineer

TDW/rrp

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DEVELOPMENT OF AN OVERLAY DESIGN PROCEDURE FOR FLEXIBLE PAVEMENTS IN INDIANA
EXECUTIVE SUMMARY

by

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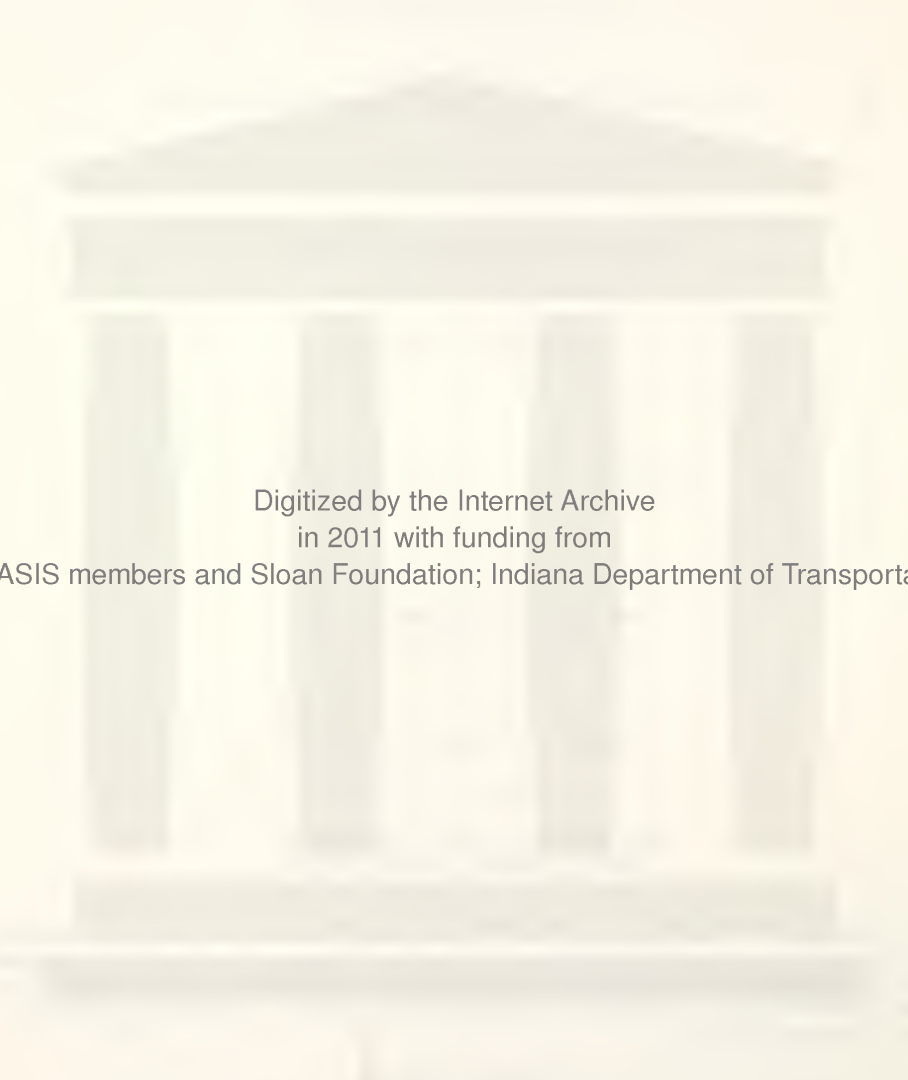
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16. Abstract   A Procedure for designing the thickness of asphaltic concrete overlays of flexible pavements was developed at Purdue University in response to a request from the Indiana Department of Highways (IDOH). The research included testing on 30 flexible pavement test sections. Two approaches to the problem were taken: an empirical approach which calculates the overlay thickness required to provide functional performance (ride quality and resistance to distress) over the life of the pavement, and a structural overlay method which calculates thickness required to prevent structural failure.

Flexible overlay design Method 2 of the 1986 AASHTO Guide for the Design of Pavement Structures was selected for structural capacity design. Method 2 uses NDT deflection data input to calculate overlay thickness. A negative value for overlay thickness indicates that sufficient structural capacity is present without adding an overlay.

The functional performance approach used Indiana flexible pavement historical data to produce a regression equation relating overlay thickness to traffic, design life of the overlay, pavement condition at the end of the design life, and estimated subgrade CBR. Various NDT deflection measurements, climate zone data, and pavement layer thickness variables were included in a variety of empirical analyses, but they were not significant in the analyses.

Simultaneous use of the two design methods was recommended to IDOH. If values from both methods are positive, the larger value governs the design. If the structural value is negative, a thickness equal to the functional performance design may be milled and recycled back to the pavement.

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Overlay design, flexible pavements, Nondestructive testing, Pavement Performance	No restrictions. This document is available to the public through the National Technical Information Service, Springfield Virginia 22161

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Executive Summary

Development of an Overlay Design Procedure for Flexible Pavements in Indiana

A survey of Federal-Aid Primary (FAP) roads in Indiana was conducted in 1985 as part of an HRP Part II study titled "Development of an Overlay Design Procedure for Pavements in Indiana". As a result of this survey, approximately 3180 lane-miles of flexible pavement (no portland cement concrete) were identified. That mileage is represented in 431 pavements of varying cross-sections whose lengths may range from under one-quarter mile to over 10 miles. In many cases these 431 sections have been overlaid several times. For example, almost 75 percent of the sections have been overlaid at least three times since initial construction and over 25 percent have been overlaid five or more times.

Flexible pavement overlay frequency is expected to remain high. The Indiana Department of Highways (IDOH) is currently using a 10-year design life in their overlay thickness calculations. On the basis of this expected life, over 300 lane-miles per year of FAP flexible pavement could be overlaid.

Currently, the IDOH is using an overlay thickness design based on the AASHO Interim Guide for the Design of Flexible Pavement Structures. A typical overlay design involves calculating several overlay thicknesses which vary

depending on the magnitude of the layer coefficient assigned to the pavement layers. One recent design example provided possible overlay thicknesses ranging from 0.5 inches to 4.25 inches; the designer was required to select a design thickness within that range.

Due to the frequency and expense of overlays and the lack of precision in its current overlay design method, IDOH funded the subject research.

OVERVIEW OF RESEARCH

The first step in this research was to develop an inventory of all the flexible pavement sections in the FAP road system. The FAP system contains about 55% of the pavements maintained by the IDOH, including state roads, U.S. highways, and Interstates. During the inventory, the following data were stored in a computer data base for each flexible pavement section: pavement cross-section, traffic, climate zone, and overlay age. Other data such as subgrade type and layer strength data would have been excellent additions to the data base, but they were not readily obtainable at that time.

In the next step, statistical design of experiment techniques were used to select thirty, 1250 ft. long pavement test sections which were representative of the flexible pavement sections throughout the state. Values for present

serviceability index (PSI) were obtained for each test section from the IDOH, and values for pavement condition index (PCI) were calculated based on a field survey of the types and extents of surface distresses. On many sections, as many as four type of non-destructive test (NDT) equipment were used to test each section. The NDT equipment included:

1) Dynaflect. A Dynaflect and technician was made available to the research team by the IDOH Research & Training Center (R&T).

2) Road Rater 400 (RR400). A RR400 and a technician were made available by the Kentucky Transportation Research Center.

3) Road Rater 2000 (RR2000). A RR2000 and a technician were made available from the Kentucky Department of Transportation.

4) Dynatest Falling Weight Deflectometer (FWD). An FWD device was obtained on loan from the U.S. Army Corps of Engineers Waterways Experiment Station.

NDT testing was conducted twice in 1986 -- once in the spring and once in the summer/fall -- so that seasonal differences in NDT results could be considered. Each 1250' long test section was tested in at least six locations within its length. Five-day temperature history and

pavement surface temperature during testing was obtained for all NDT testing. This temperature data was utilized to normalize deflections to a common temperature. In addition, cores and subgrade samples were collected from all sections and tested.

The accumulated data were analyzed both by empirical and structural methods. In the empirical method, statistical analysis was applied to the data to determine "what worked", and under what conditions. In the structural method, the NDT data were analyzed using a flexible pavement overlay design procedure in the 1986 AASHTO Guide for Design of Pavement Structures.

EMPIRICAL DATA ANALYSIS

In the empirical data analysis, statistical analysis techniques were used to obtain a regression relationship between most recent overlay thickness (the dependent variable) and a variety of independent variables for the 30 flexible pavement test sections studied. Such a regression relationship (equation) can be used to predict required thickness for future overlays for pavements similar to the 30 test sections.

Independent variables addressed in the analysis included climate zone, "base asphalt" thickness (the thickness of asphalt beneath the most recent overlay), and

traffic, which are factors on which the design of experiment was based. The independent variables also included the following factors as covariates for which data was collected but which were not used to design the experiment or as a basis to select the test sections:

1.   Most recent overlay age (years)

2.   Subbase thickness (in.) In this research, "subbase" describes all aggregate between the bituminous layer and the subgrade.

3.   Equivalent asphalt thickness of base asphalt and subbase (in.)

4.   Total pavement thickness (from top of pavement to the subgrade) (in.)

5.   Estimated CBR (%)

6.   Maximum NDT deflection reading (from "sensor 0" directly under the load) for both spring and summer/fall (mils)

7.   Present Serviceability Index (PSI)

8.   Pavement Condition Index (PCI)

The following regression equation was selected for empirical design:

$$\text{olay} = 0.7592 + 0.00145(\text{tottrk})^2 + 0.00379(\text{age})^2$$
$$+ 0.000162(\text{pci})^2 - 0.000429(\text{cbr})^2$$

where:

olay = calculated thickness of required, new
overlay in inches

tottrk = (trucks/day)(365)(age)/365,000

age = design life of new overlay (years)

pci = desired PCI value at the end of the design
life of the new overlay

cbr = estimated subgrade CBR (%)

The equation has been verified for the following range of design values:

1. Anticipated overlay age: 5-20 years

2. Anticipated daily trucks: 50-3000

3. Total trucks: less than 32.2. Note: total trucks is defined as (trucks/day) (overlay age) (365)/365,000. If total trucks exceeds 32.2, the calculated overlay value may exceed the thickest overlay typically found on Indiana pavements: 3.0 inches.

4. PCI: PCI is normally specified as 35, which approximates to a PSI value of 2.5.

5. CBR: 0-40%.

If a reliability-based design is desired, Table 1 presents thickness values which may be added to overlay thicknesses determined from the equation to attain given reliabilities.

Table 1. Thickness Increments to Reach Reliabilities

Reliability (%)	Thickness (in.)
95	0.9
90	0.7
85	0.6
75	0.4

AASHTO GUIDE METHOD

Two NDT-based methods for designing structural overlay requirements for flexible pavements are provided in the 1986 AASHTO Guide. In this research, Method 2 was selected for calculating structural overlay thickness. Method 2 uses two NDT deflections: temperature-adjusted deflection directly under load and un-adjusted deflection seven feet from load.

If the result from the 1986 AASHTO Guide method is a negative structural overlay requirement, the existing pavement structural capacity is sufficient to support future traffic without an overlay.

COMPARISON

Table 2 compares the results of the empirical method and the AASHTO method for ten pavement test sections.

The empirical calculation always adds overlay thickness. The table presents overlay thickness values between 0.8 inches and 2.2 inches, which are within the range of overlays studied in this research.

The results of the AASHTO overlay analysis indicate that five out of the ten test sections (those with negative overlays) do not require additional structural overlay. These results are quite reasonable considering the traffic levels and present asphalt thicknesses. Two sections (L13 and L14) already have quite thick asphalt layers but only carry average traffic. The other three sections (F13, F16, S16) have average existing asphalt thicknesses but carry low traffic. Results for four of the sections (L14, F13, F16, S16) indicate that modest reductions in asphalt thickness (0 inches to 1.2 inches) would be acceptable, suggesting that increase in pavement asphalt thickness over time has been greater than required for structural capacity. The calculation for L13 indicates that 11.5 inches of the existing 12.7 inches of asphalt could be removed. Such action should not be taken, and that value is unacceptable. However, the L13 pavement cross section is 12.7 inches of asphalt above 25

Table 2.   AASHTO vs. Empirical Equation
Overlay Thickness Results.

Section Number	AASHTO Overlay (in.)	Empirical Equation Overlay (in.)	Trucks/ Day	Current Total Asph. Thickness (in.)
L-10	1.6	1.3	398	5.9
L-11	5.3	1.4	443	7.9
L-13	-11.5	1.0	577	12.7
L-14	-0.2	1.3	686	11.6
L-15	1.3	1.2	196	8.1
L-16	2.1	1.1	863	7.1
F-13	-1.1	0.8	438	7.5
F-16	-0.0	1.5	549	6.4
S-16	-0.6	1.3	177	8.0
V-07	1.4	2.2	1989	11.2

inches of subbase over a sandy subgrade (estimated CBR of 28). The asphalt thickness build-up over time on such a strong foundation does appear excessive for the relatively low traffic volume, but removal of 11.5 inches of asphalt is not indicated.

Four of the other five results in Table 5.6 indicate that moderate (1.3 inch to 2.1 inch) structural overlays are required for future traffic. The value for the fifth remaining section (L11) specifies a 5.3 inch structural overlay. Indiana experience has shown that a three inch maximum overlay is usually appropriate, so 5.3 inches is probably excessive. However, the AASHTO calculation for L11 was greatly affected by an unusual circumstance: a peat subgrade. In this situation, if L11 has been performing satisfactorily with thinner previous overlays and if no alligator cracking is present, the 5.3 inch value should be discounted and a thinner overlay accepted based on a functional evaluation.

The two sections of uncommon cross-section (L13 and L11) which produced extreme overlay values demonstrate that engineering judgment and knowledge of local conditions must be used with the 1986 AASHTO Guide procedure when selecting overlay thicknesses for unusual situations.

CONCLUSIONS

The empirical equation calculates an overlay thickness

which provides adequate functional performance (ride quality and resistance to development of distress) during the overlay design life. When pavement rehabilitation is needed, additional overlay is always added. This practice of adding overlays for functional, not structural purposes appears to have produced excess structural capacity in a significant proportion of flexible primary highway system pavements in Indiana. Use of the functional and structural design methods together will produce a more effective and economical overlay design procedure than that currently used.

The AASHTO structural overlay method 2 can be used to determine the required overlay thickness for increased structural capacity. Structural overlay thickness may be positive or negative when compared with the existing pavement thickness. If the structural overlay thickness is positive then its magnitude is compared with the functional overlay thickness required. The greater of these two thicknesses is specified. If the required structural thickness is less than the existing pavement thickness then the required overlay, relative to the existing pavement thickness, is negative.

There are several options if the structural overlay is negative or positive but less than the functional overlay. First, the required functional overlay thickness may be

specified.   Second,   advantage may be taken of the existing structure and various milling and/or recycling options to obtain greater economy for the desired level of functional and structural performance.   If the required structural overlay is positive but smaller than the functional overlay, the pavement may be milled to a depth equal to the functional thickness minus the required structural overlay thickness.   Subsequently, the full required functional overlay is applied to the milled surface and may consist of either a new or a combination of recycled and new material.

If the structural value is negative, a thickness up to the functional overlay thickness may be milled and replaced with new or a combination of recycled and new material.

It may also be acceptable to mill a thickness greater than the functional overlay before recycling and/or overlay if significant excess structural capacity exists.   However, engineering judgment should be used when setting the depth of the milling operation.

FURTHER RESEARCH

During the course of the project, three areas were identified for further research:

1. A need exists to develop a reliable computer program to back-calculate pavement layer elastic moduli from NDT deflections. Back-calculation is the basis of AASHTO Guide Method 1; in this research, Method 2 was used instead of Method 1 because a reliable back-calculation program was not identified.

2. Due to the significance of subgrade characteristics, better and more detailed assessments of subgrade strength are required.

3. An investigation to determine the effect of base and subbase layers weakened by spring thaw moisture saturation on pavement structural capacity must be undertaken.