TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-86/18+387-2		

4. Title and Subtitle	5. Report Date
A USER'S GUIDE FOR PAVEMENT EVALUATION PROGRAMS RPEDD1 AND FPEDD1	July 1985
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Waheed Uddin, A. H. Meyer, and W. Ronald Hudson	Research Report 387-2
9. Performing Organization Name and Address	10. Work Unit No.
Center for Transportation Research The University of Texas at Austin Austin, Texas 78712-1075	11. Contract or Grant No. Research Study 3-8-84-387
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Texas State Department of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	Interim
	14. Sponsoring Agency Code

15. Supplementary Notes

Study conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration. Research Study Title: "Purchasing and Adapting a Falling Weight Deflectometer for Nondestructive Evaluation and Research on a Rigid Pavement in Texas"

16. Abstract

A general background of computer programs RPEDD1 (for rigid pavements) and FPEDD1 (for flexible pavements) is described. These programs are used for nondestructive evaluation of pavements based on the deflection basins measured by a Dynaflect or a falling weight deflectometer. A detailed input guide is presented as well as guidelines on implementation.

17. Key Words	18. Distribution Statement
pavements, rigid, flexible, nondestructive, Dynaflect, falling weight deflectometer, deflection insitu moduli, evaluation	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	56	

Form DOT F 1700.7 (8-69)

A USER'S GUIDE FOR PAVEMENT EVALUATION PROGRAMS RPEDD1 AND FPEDD1

by

Waheed Uddin
A. H. Meyer
W. Ronald Hudson

Research Report Number 387-2

Purchasing and Adapting a Falling Weight Deflectometer for Nondestructive Evaluation and Research on Rigid Pavement in Texas
Research Project 3-8-84-387

conducted for

Texas State Department of Highways
and Public Transportation

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

July 1985

The contents of this report reflect the views of the autnors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

This report is the second report related to nondestructive evaluation of pavements conducted under Research Project 3-8-84-387, "Purchasing and Adapting a Falling Weight Deflectometer for Nondestructive Evaluation and Research on Rigid Pavements in Texas". This research project is being conducted at the Center for Transportation Research, The University of Texas at Austin, as part of the Cooperative Highway Research Program sponsored by the State Department of Highways and Public Transportation and the Federal Highway Administration. This report forms a user's guide for the two self-iterative computer programs for pavement evaluation, developed and described in the preceding Research Report 387-1.

The authors gratefully acknowledge the valuable contributions of Professors K. H. Stokoe II, B. F. McCullough and J. M. Roesset of the Civil Engineering Department of The University of Texas at Austin. The authors are especially grateful to the staff of the Center for Transportation Research, who provided technical assistance and support. Appreciation is also extended to John Vernan for assistance and cooperation. The cooperation and interest of the technical staff of the Texas SDHPT involved in the research project are also appreciated.

Waheed Uddin
Alvin H. Meyer
W. Ronald Hudson

July, 1985

LIST OF REPORTS

Research Report 387-1, "A Structural Evaluation Methodology for Pavements Based on Dynamic Deflections," by Waheed Uddin, A. H. Meyer, and W. Ronald Hudson, presents the development of two computer programs, RPEDD1 and FPEDD1, for comprehensive structural evaluation of rigid and flexible pavements using dynamic deflection basin data, for use by Texas State Department of Highways and Public Transportation, July, 1985.

Research Report 387-2, "A User's Guide for Pavement Evaluation Programs RPEDD1 and FPEDD1," by Waheed Uddin, A. H. Meyer, and W. Ronald Hudson is a stand-alone user's manual for computer programs RPEDD1 and FPEDD1 developed and described in the preceding Research Report 387-1.

ABSTRACT

A general background of computer programs RPEDD1 (for rigid pavements) and FPEDD1 (for flexible pavements) is described. These programs are used for nondestructive evaluation of pavements based on the deflection basins measured by a Dynaflect or a falling weight deflectometer. A detailed input guide is presented as well as guidelines on implementation.

KEYWORDS: Pavements, rigid, flexible, nondestructive, Dynaflect, falling weight deflectometer, deflection insitu moduli, evaluation.

SUMMARY

This report has been prepared to serve as a user's guide for the structural evaluation of in-service pavements using computer programs RPEDD1 (for rigid pavements) and FPEDD1 (for flexible pavements). These programs were developed in Research Report 387-1 to analyze dynamic deflection basins measured# by a Dynaflect or a falling weight deflectometer. A brief description of general background, a detailed input guide, and guidelines on implementation are also presented in this report.

IMPLEMENTATION STATEMENT

The user's guide for the computer programs RPEDD1 (for rigid pavements) and FPEDD1 (for flexible pavements) should be immediately implemented by SDHPT. It will result in substantial savings in time and computational cost which is normally incurred using the existing pavement evaluation procedures for analyzing nondestructive test data measured by the Dynaflect and falling weight deflectometer. When implemented, the framework of the structural evaluation system recommended in this study is going to be an indispensable part of the overlay design systems used in Texas.

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

BACKGROUND

Nondestructive evaluation of pavements is performed using such dynamic load devices as a Dynaflect or a falling weight deflectometer. Reference 1 presents a methodology to analyze dynamic deflection basins measured by these devices. The framework proposed in this study for a structural evaluation system using dynamic deflection basins is comprised of several stages, as summarized below.

(1) The measured deflection basin is analyzed on an individual basis.

(2) Insitu moduli are determined using the self-iterative inverse application of layered theory.

(3) Insitu moduli determined from a Dynaflect deflection basin are then corrected by equivalent linear analysis to take into account nonlinear, strain-softening behavior of granular layers and cohesive subgrade.

(4) The final combination of corrected insitu moduli are then to be used to predict critical responses under a given design load configuration to make a remaining life analysis as discussed in detail in this chapter. The surface asphalt concrete modulus (for the flexible pavements) is corrected for temperature effect.

(5) The final outputs from the use of the computerized structural evaluation system are tables which summarize the results of critical responses, fatigue life, remaining life and final combination of corrected insitu moduli with respect to each test location along the roadway.

(6) Computer programs RPEDD1 and FPEDD1 were developed for rigid and flexible pavements. In the implementation/application phase of these computerized evaluation systems, plots of remaining life, subgrade modulus, and moduli of other layers with distance along

the pavement are to be used to delineate areas in need of major rehabilitation for overlay design.

COMPUTER PROGRAMS RPEDD1 AND FPEDD1

RPEDD1 (a rigid pavement structural evaluation system based on dynamic deflections) and FPEDD1 (a flexible pavement structural evaluation system based on dynamic deflections) were developed with the consideration of several features. A simplified flow diagram of the framework adapted in the later development of the computer programs is presented in Fig 1.1 and discussed in these sections.

Basic Input Data

Design load specifications and configuration are required for nonlinear characterization if a Dynaflect deflection basin is analyzed. Additionally, past traffic data in terms of cumulative 18-kip equivalent single axle loads are required. Specific guidelines practiced by different user agencies or AASHTO Interim Guides (Ref 2) can be used for this purpose. In Fig 1.1, IOPT4 is an input option to omit correction for nonlinear moduli and remaining life analysis.

Back Calculation of Insitu Moduli from Deflection Basin

Insitu moduli of pavement layers are determined by the self-iterative inverse application of ELSYM5. Separate routines have been developed for RPEDD1 (rigid pavements) and RPEDD1 (flexible pavements). These routines are based on the procedure described in Chapter 4 of Ref 1. The salient features of the self-iterative procedure are briefly repeated here.

(1) Handling the finite thickness of the subgrade layer (including a default procedure for consideration of a rigid bottom).
(2) Capability to analyze dynamic deflection basins measured either by the Dynaflect (standard configuration of five sensors) or by a

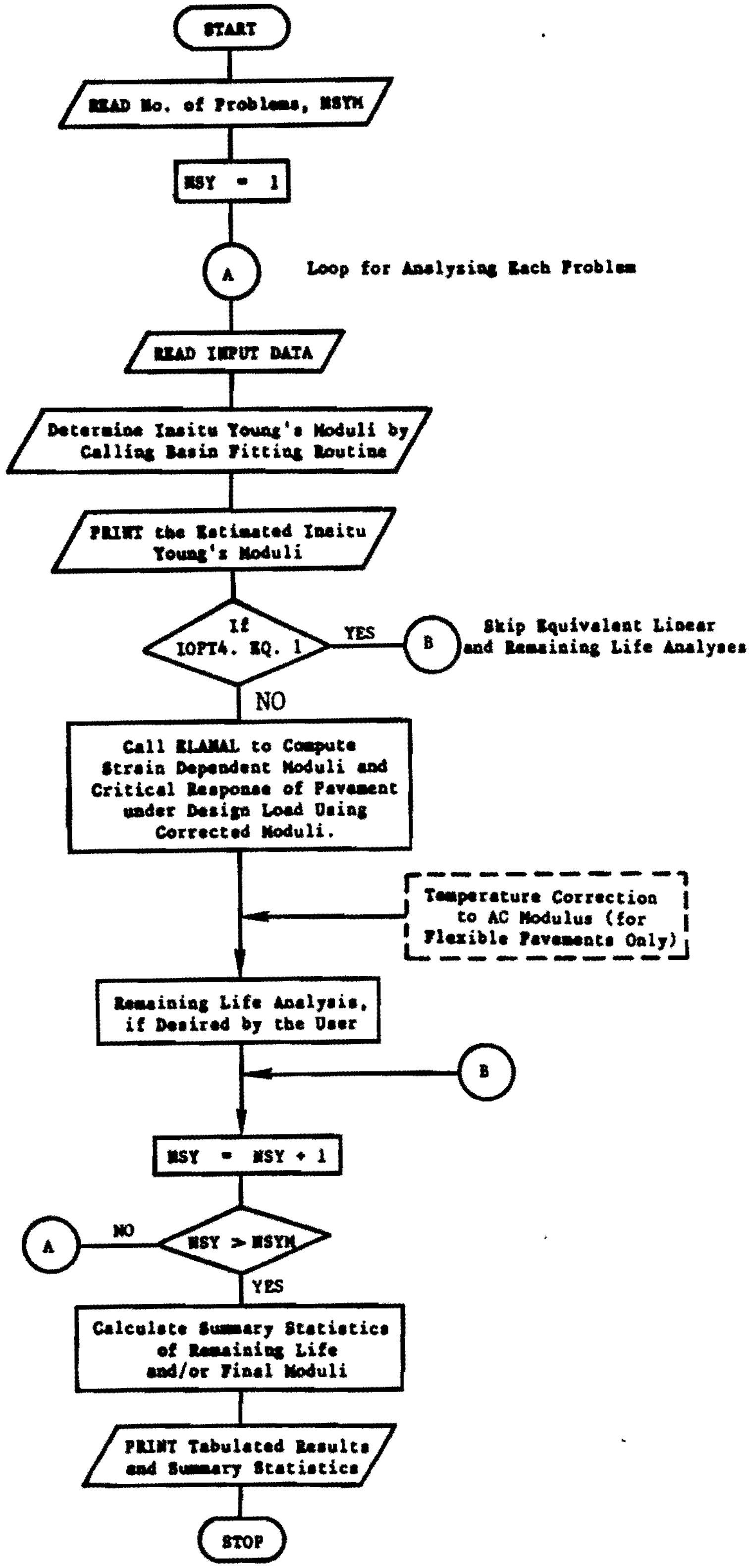


Fig 1.1. Simplified flow diagram of the proposed structural evaluation program based on dynamic deflection.

Falling Weight Deflectometer (not more than seven or less than six sensors) with one sensor under the center of load. The remaining are recommended to be placed one foot apart on a line extending outwards in a perpendicular direction to ensure unique combinations of moduli.

(3) Handling a three or four-layered pavement model.

(4) Capability to determine a unique set of insitu moduli by generating initial seed moduli through a default procedure.

(5) Better efficiency and using a lesser number of iterations to keep the computational cost to a minimum.

(6) The deflection basin fitting algorithm is not user dependent because zero input values are recommended for seed moduli.

Corrections for Nonlinear Behavior of Pavement Sublayers

The self-iterature procedure for equivalent linear analysis developed in Ref 1 is basically the same for rigid and flexible pavements.

Nonlinear, Strain-Sensitive Moduli. The equivalent linear analysis approach is based on an iterative use of ELSYM5 and generalized curves of E/E_{max} versus shear strain curves developed using the concept of nonlinear strain-softening materials when the shear strain induced by the design load in these layers exceeds certain threshold strain values. This approach is drawn from the dynamic/seismic response analysis procedure and is well accepted in the field of geotechnical engineering.

Insitu Moduli of Stabilized Layers. The insitu moduli determined for granular materials and cohesive soils which have been stabilized by asphaltic materials, cement, or lime are considered to be insensitive to shear strain and not to exhibit nonlinear behavior. Therefore no corrections are applied to the insitu moduli of such pavement layers.

Temperature Correction

The insitu asphaltic concrete modulus determined from the analysis of the deflection basin measured on a flexible pavement is corrected for temperature sensitivity using the procedure described in Ref 1. The corrected modulus corresponds to asphaltic concrete stiffness at the design temperature. This step is performed after correcting the strain-dependent nonlinear moduli.

Remaining Life Analysis

The final combinations of (corrected) insitu pavement moduli is assumed to represent effective insitu stiffnesses (Young's moduli) under the design load. The existing pavement at this test location is again modelled as a layered "linearly" elastic system for further evaluation. At this stage of structural evaluation existing pavement is analyzed for its remaining life at each test location. The critical pavement responses determined for the computations of fatigue life and remaining life are made before applying temperature correction to surface asphalt concrete modulus in FPEDD1.

Output

All the results from the analysis of individual deflection basins are printed. At the end, a summarized output is also produced. Table 1.1 presents a summary of output. Note that if IOPT4 is specified a value of one, the equivalent linear analysis and remaining analysis are omitted by both RPEDD1 and FPEDD1.

TABLE 1.1. SUMMARY OF DETAILED OUTPUT (REF 1)

OUTPUT VARIABLES	DESCRIPTION
Identification and Initial Information	Problem No., Title, NDT Device (FWD/Dynaflect); Station, Test Date; No. of Layers; Type of Layer Above Subgrade (for Rigid Pavements); Type of Base and Subbase Layers (for Flexible Pavements).
Input System Parameters	Maximum No. of Iterations; Tolerances for Discrepency in Deflections (TOLR1 and TOLR2); Tolerances for Change in Moduli (TOLR31, TOLR32, TOLR33).
Layering Information	(Repeated for each layer, starting from the surface layer.) Layer No.; Thickness (Inches); Poisson's Ratio (No value in thickness indicates semi-infinite subgrade).
	Input Seed Modulus in psi (if input is zero, then default seed modulus is printed).
E(MAX)	Maximum allowable value of modulus in psi (default value is printed if there is no input).
E(MIN)	Minimum allowable value of modulus in psi (default value is printed if there is no input).
UNWTI	Unit weight of subgrade soil (lb /cu. ft.)
Sensor No.	Sensor no. 1 assigned to the first sensor closest to the test load (5 sensors for Dynaflect and 6 or 7 sensors for FWD).
Measured Deflection	At each sensor in mils.
Calculated Deflection	At each sensor in mils.
HERRP (Based on Seed Moduli)	Largest absolute discrepency in measured and calculated deflections (in percent).
ITERATIONS BEGIN	Message when further iterations are stopped; also total number of iterations attempted in this run.

(continued)

TABLE 1.1. (CONTINUED)

OUTPUT VARIABLES	DESCRIPTION
Results of Iterations	Message about skipping results of each iteration if IOPT1 is zero. In that case, only summary of best iteration is printed. If IOPT1 was 1, then summary of each iteration and finally of best iteration are presented.
Young's Moduli	For each layer (in psi).
Measured Deflections	In mils.
Calculated Deflections	In mils.
HERRP	The largest discrepency in percent.
Design Single Axle-Load Data	Load per tire (lb); Tire pressure (psi).
Other Pavement Data	For Rigid Pavements: flexural strength; rigid pavement type; shoulder type. For Flexible Pavements: test temperature and design temperature (°F)
RESULTS OF EQUIVALENT LINEAR ANALYSIS	Corrected values of Young's moduli.
TEMPERATURE CORRECTION (Only for Flexible Pavements)	Corrected value of Young's modulus of AC surface.
REMAINING LIFE	Printed in percent (only when IOPT2 was entered as 1). A value of 999.0 is printed if no positive value of remaining life could be determined.
NEXT PROBLEM	All the above output repeated for each successive problem.
SUMMARY OF STRUCTURAL EVALUATION	Following summary outputs printed for each deflection basin analyzed. (1) Station (2) Maximum Deflection (in mils; under design load) (3) Maximum critical response at bottom of surface layer (a) Tensile Stress (for rigid pavements) (b) Tensile Strain (for flexible pavements) (4) Deviator stress on top of subgrade, psi

(continued)

TABLE 1.1. (CONTINUED)

OUTPUT VARIABLES	DESCRIPTION
	(5) Bulk stress in middle of subbase layer (psi) (6) Past traffic in 18-kip ESAL (as entered in input) (7) Maximum theoretical 18-kip ESAL applications (8) Remaining life, percent (9) Final values of Young's Moduli
Summary Statistics	Mean, standard deviation and coefficient of variation (percent) for remaining life, and final moduli

CHAPTER 2. INPUT GUIDE

This chapter briefly discusses acquisition of input data required for the computer programs. A detailed input guide is then presented for RPEDD1 and FPEDD1.

DATA ACQUISITION

This section describes the data necessary to prepare the input for these computer programs.

Nondestructive Test Data

For the Dynaflect test, default values of standard load and geophone configurations are provided in the programs. In the case of the falling weight deflectometer, the radius of the loading plate used in the test should be recorded. The FWD peak force recorded during the measurement of each deflection basin is also required in input. Configuration of geophones is also recorded if the default values are not used in the test.

During each test, dynamic deflections are measured at each geophone in both the Dynaflect and the FWD to define the deflection basin. The programs require deflections to be coded in mils (1/1000's of an inch).

Acquisition of Pavement Data

Pavement Type and Cross Section. This information includes rigid pavement type (jointed concrete pavement, continuously reinforced concrete pavement), shoulder type, and number of layers in the pavement structure. Layering information can be obtained from construction plans and design cross section but preferably should be supported by field evidence, such as from extracted cores. The SASW test is another method for obtaining layering information. If there is any evidence of the existence of a rock layer at a shallow depth (within 20 to 30 feet), then it is important to know the precise depth, as discussed in Ref 1.

Pavement Condition Data. Pavement condition should also be recorded at each test location, especially if signs of severe distress are obvious on the pavement surface. Information obtained from a recently performed condition survey can also be utilized for this purpose.

Material Data. Information should be acquired about the type of material used in intermediate layers (base and/or subbase materials). It is essential to know whether these materials are stabilized or can be considered as unbound granular materials. This information is used in the basin fitting routine as well as for nonlinear characterization. Any data available from laboratory characterization of all materials will also be useful later to ascertain allowable ranges of maximum and minimum moduli for each layer.

Overlaid Pavements. The programs are basically designed to evaluate non-overlaid pavements. If the deflections test is made on overlaid rigid pavement, it can still be evaluated by specifying the total thickness of concrete layers in the input as the first layer if the overlay is bonded concrete overlay type. In the case of unbonded overlay, the user should provide the initial seed and permissible ranges of moduli for this layer. The ways actual overlaid pavements are to be idealized for input to the program are illustrated in Fig 2.1. In case of a flexible overlay, (Fig 2.2) the FPEDD1 program should be used to analyze measured deflection basins. For composite pavements, the FPEDD1 program can be used by considering the original PCC slab (overlaid with an asphaltic concrete layer) as a stabilized layer.

Traffic Information

Past traffic data should be converted to 18-kip ESAL. If RPEDD1 is being used only for insitu material characterization, then traffic data are not required and the option for the remaining life analysis need not be used.

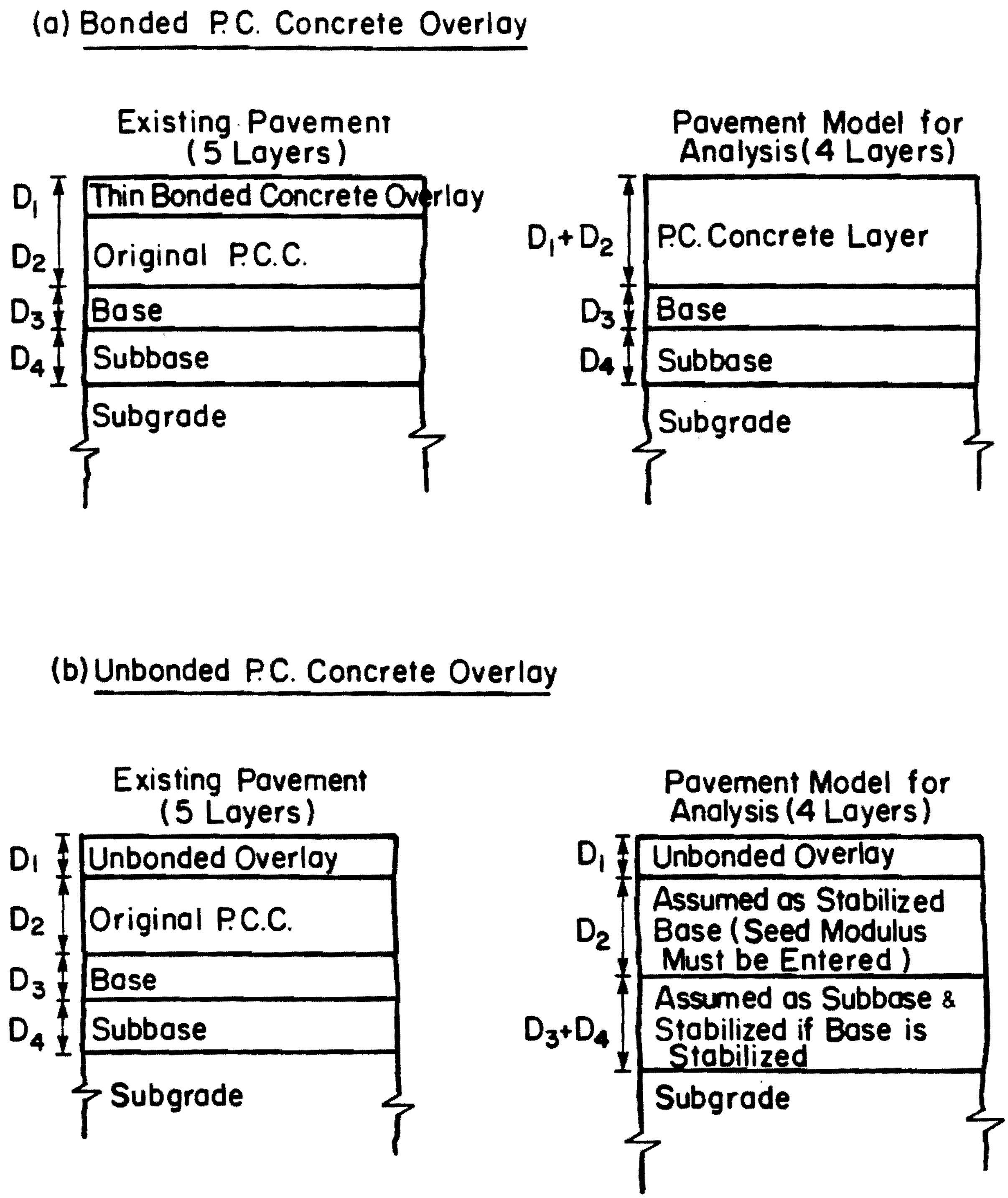


Fig 2.1. Idealized pavement models for rigid pavements overlaid with concrete layer.

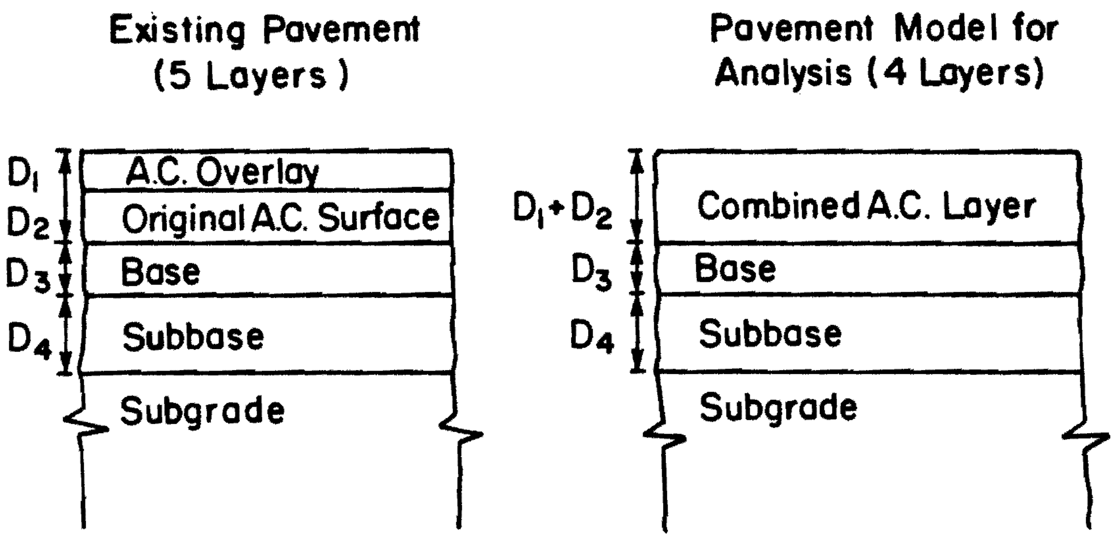


Fig 2.2. Idealized pavement model for a flexible pavement overlaid with one or more AC layers.

Design Load Configuration

If the user wants to specify a design load other than the default configuration (Fig 2.3), that is possible by using the option for user-specified design load.

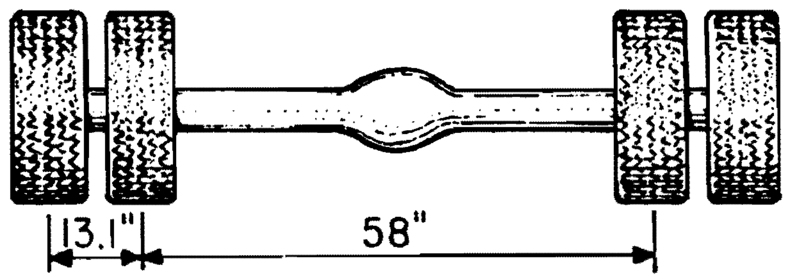
The asphaltic concrete (AC) modulus in flexible pavement is temperature sensitive. The insitu derived AC modulus is based on the test temperature at which deflection basin was measured. For subsequent use in overlay design or even for making comparisons, it is recommended to correct the insitu modulus from test temperature to a design temperature. Therefore, it is necessary to obtain information about the design temperature (the default value is 70°F). The test temperature is taken as temperature at the mid-depth of AC layer. It can be estimated from a record of climatological data using computer program FTEMP, which is described in by Uddin et al (Ref 1).

INPUT GUIDE

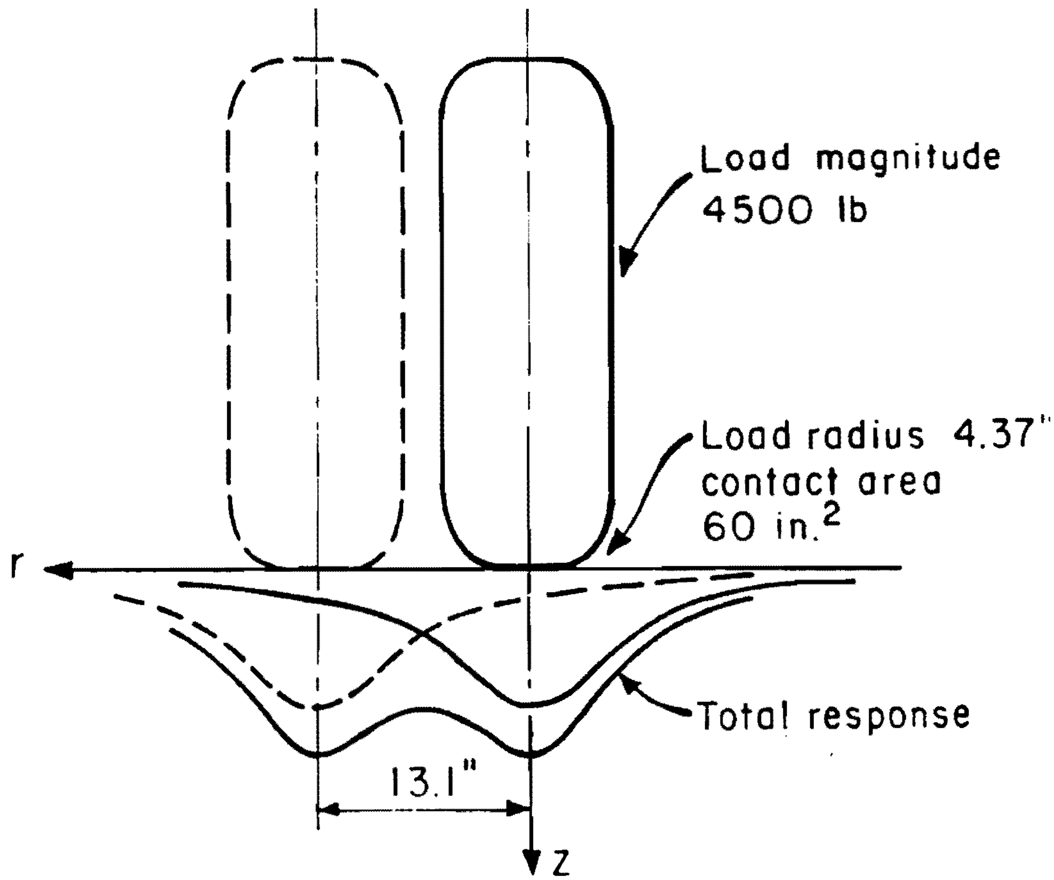
A detailed input guide, summary formats, and examples of applications are presented in this section.

Input Data

A summary of formats for input data appears in Figs 2.4 and 2.5 for RPEDD1 and FPEDD1. Several of the input variables have built-in default values in the program. All the input variables are explained in this section. All integers (I-format) must be right justified. F-formats are for real values. Whenever default is mentioned, the user can choose not to enter any value. Input seed moduli should be entered only if the user strongly feels that these values are reliable (based on laboratory or field tests). All card types are explained in the following. Except for card types 5, 7, and 10, the rest of the cards are similar for both programs.

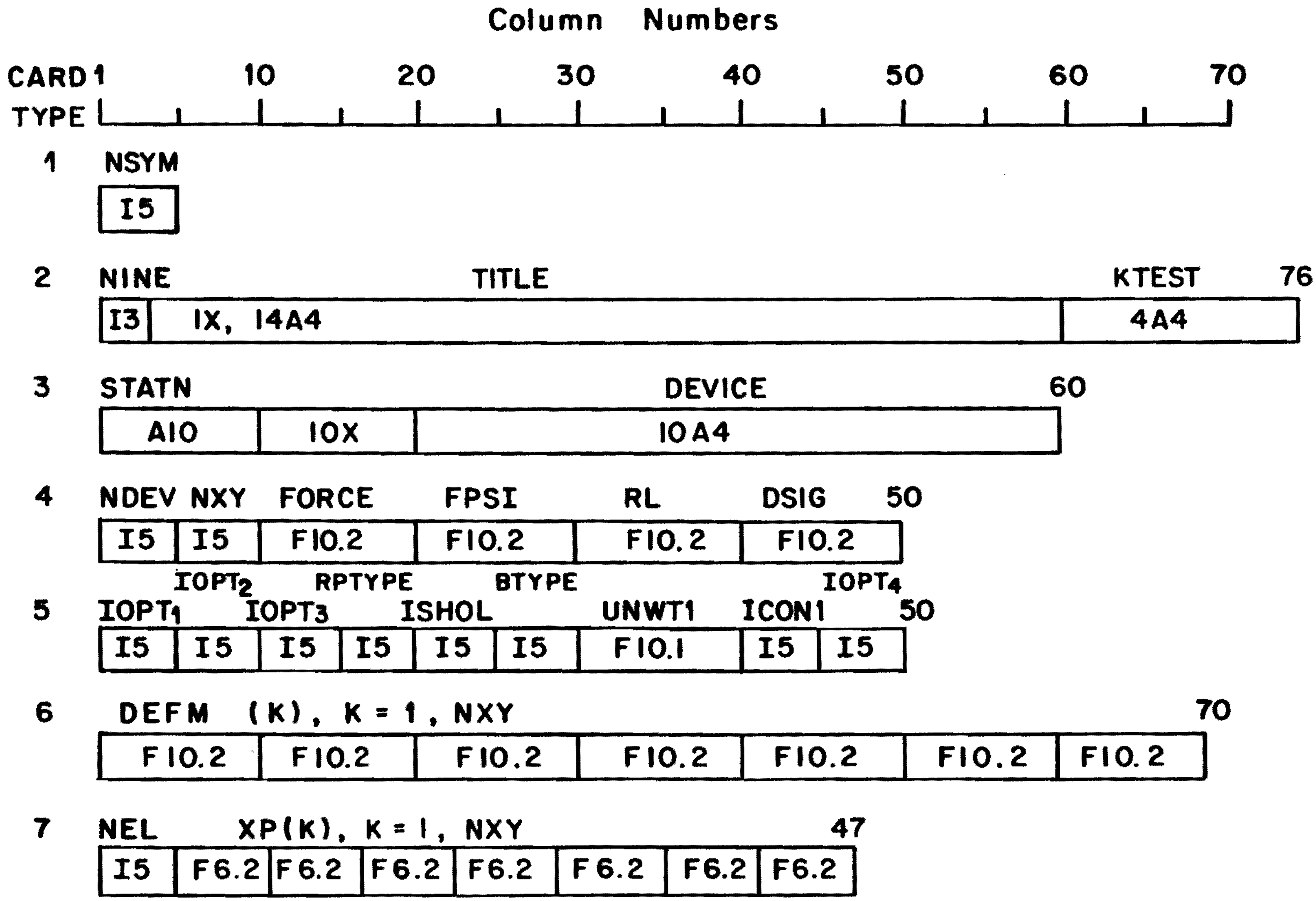


(a) Standard 18-kip axle: 4 tires, each 4500 lb at 75 psi tire pressure.



(b) Simulated 18-kip axle load (half the standard axle) and illustration of superposition of responses.

Fig 2.3. Standard 18-kip axle configuration for default design load.



(continued)

Fig 2.4. Summary of formats of input data for RPEDD1.

005 305

CARD TYPE							
8	LN(I)	TH(I)	V(I)	ESEED(I)	E MAX(I)	EMIN(I)	60
	I10	F10.2	F10.2	F10.0	F10.0	F10.0	

CARD TYPE 8 TO BE REPEATED FOR EACH LAYER (I=1,NEL)

9	MITER	TOLR1	TOLR2	TOLR 31	TOLR 32	TOLR33	55
	I5	F10.3	F10.3	F10.3	F10.3	F10.3	

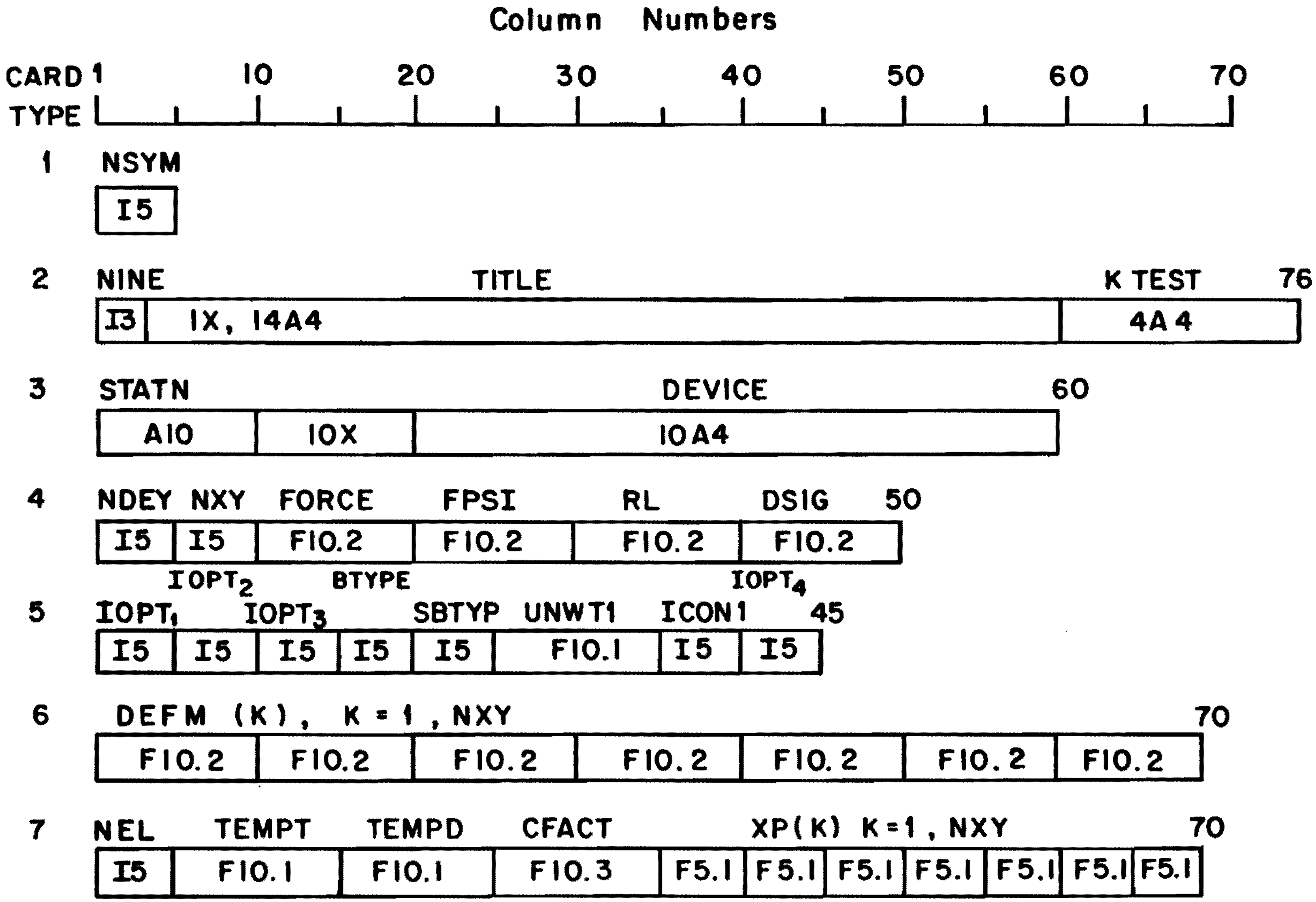
10	NDAXL	DLOAD	TIREP	FLEST	PTRAFF	60
	I5	F15.0	F10.1	F10.1	I20	

*11	NDLOD	DXL(1)	DYL(1)	DXL(2)	DXL(2)	NDNXY	DXP(1)	DYP(1)	DXP(2)	DYP(2)	DXP(3)	DYP(3)	66
	I3	F6.1	F6.1	F6.1	F6.1	I3	F6.1	F6.1	F6.1	F6.1	F6.1	F6.1	

* IF NDAXL ≠ 1 ; SKIP CARD TYPE 11.

(FOR THE NEXT PROBLEM ; REPEAT CARD TYPE 2 TO 11) .

Fig 2.4. (continued)



(continued)

Fig 2.5. Summary of formats of input data for FPEDD1.

CARD TYPE 1

8

LN(I)	TH(I)	V(I)	ESEED(I)	E MAX(I)	EMIN(I)	60
I10	F10.2	F10.2	F10.0	F10.0	F10.0	

CARD TYPE 8 TO BE REPEATED FOR EACH LAYER (I=1,NEL)

9

MITER	TOLR1	TOLR2	TOLR 31	TOLR 32	TOLR33	55
I5	F10.3	F10.3	F10.3	F10.3	F10.3	

10

NDAXL	DLOAD	TIREP	PTRAFF	50
I5	F15.0	F10.1	I20	

*11

NDLOD	DXL(1)	DYL(1)	DXL(2)	DXL(2)	NDNXY	DXP(1)	DYP(1)	DXP(2)	DYP(2)	DXP(3)	DYP(3)	66
I3	F6.1	F6.1	F6.1	F6.1	I3	F6.1	F6.1	F6.1	F6.1	F6.1	F6.1	

* IF NDAXL ≠ 1 ; SKIP CARD TYPE 11.

(FOR THE NEXT PROBLEM ; REPEAT CARD TYPE 2 TO 11) .

Fig 2.5. (continued)

Card 1

NSYM: Total number of deflection basins to be entered for analysis (maximum of 50).

Card 2

NINE: 999 (must be entered). It is a flag to indicate the start of the next problem.

TITLE: Identification information.

KTEST: Date of test.

Card 3

STATN: Station at which the deflection basin was measured.

DEVICE: Name of NDT device.

Card 4

NDEV: Code for NDT device (1 for Dynaflect; 2 for FWD).

NXY: Number of sensors where deflections were measured (it should be entered only for FWD, at least 6).

FORCE: Peak force of FWD-force signal (in lb).

FPSI: Peak stress of FWD at surface (can be left blank if FORCE and RL are entered).

RL: Radius of FWD loading plate (in inches).

DSIG: Duration of FWD force signal (default is 25 msec).

Card 5 (For RPEDD1)

IOPT1: Option for output of back-calculated Young's moduli. (0 for summary only; 1 for detailed output.)

IOPT2: 0 to skip remaining life analysis, 1 to make remaining life analysis.

IOPT3: 0 for ignoring the default procedure to create a rigid layer, 1 to activate the default procedure to create a rigid layer at a finite thickness of subgrade.

RRTYPE: Type of rigid pavement (0 for JCP/JRCP, 1 for CRCP).

ISHOL: Shoulder type (0 for JCP/JRCP, 1 for CRCP).

BTYPE: Type of layer above subgrade (1 for granular, 2 for stabilized).

UNWT1: Unit weight of subgrade soil (lb/cft). An approximate value can be used if no test data are available.

ICON1: Condition of concrete pavement (0 normal, not severely damaged; 1 severely cracked).

IOPT4: 0 for making a complete analysis, 1 to skip equivalent linear analysis as well as remaining life analysis (it overrides IOPT2).

<u>Card 5</u> (For FPEDD1)

IOPT1: Option for output of back-calculated Young's moduli (0 for summary only, 1 for detailed output).

IOPT2: 0 to skip remaining life analysis, 1 to make remaining life analysis.

IOPT3: 0 for ignoring the default procedure to create a rigid layer, 1 to activate the default procedure to create a rigid layer at a finite thickness of subgrade.

BTYPE: Type of base layer (1 for granular, 2 for stabilized).

SBTYP: Type of subbase layer (above subgrade), (0 for a three layer pavement, 1 for granular, 2 for stabilized).

UWIT1: Unit weight of subgrade soil (lb/cft). An approximate value can be used if no test data are available.

ICON1: Condition of the pavement; (0 for normal, not severely damaged; 1 for severely cracked, class 2 or 3 cracking).

IOPT4: 0 for making a complete analysis, 1 to skip equivalent linear analysis as well as remaining life analysis. (It overrides IOPT2.)

Card 6

DEFM(k): Measured deflections in mils, starting from the first sensor (not exceeding 7 sensors).

Card 7 (For RPEDD1)

NEL: Number of layers in the idealized pavement model including subgrade (not less than 2 and not exceeding 4; see additional discussion in the next section).

XP(k): Radial distance of FWD sensors from the center of the loading plate, starting from the first sensor and not exceeding 7 sensors.

Card 7 (For FPEDD1)

NEL: Number of layers in the idealized pavement model including subgrade (not less than 2 and not exceeding 4; see additional discussion in the next section).

TEMPT: Test temperature of surface AC layer, °F.

TEMPD: Design temperature of AC pavement, °F (default is 70°F).

CFACT: Ratio of AC stiffness at design temperature to the stiffness at test temperature based on laboratory M_R vs temperature relationship. If not known, leave blank, the program will activate a default procedure to make the temperature correction.

XP(k): Radial distance of FWD sensors from the center of the loading plate, starting from the first sensor and not exceeding 7 sensors.

Card 8

(Note: Card type 8 is to be repeated for each pavement layer; starting from the surface layer). I ranges from 1 to NEL.

LN(I): Layer number (must be entered).

TH(I): Thickness in inches (must be entered; blank or zero for semi-infinite subgrade).

V(I): Poisson's ratio (must be entered; Table 2.1 can be consulted for guidance).

ESEED(I): Initial estimate (seed value) of Young's modulus in psi. (Generally 0 should be entered here; this will ensure convergence to a unique solution.)

EMAX(I): Maximum allowable value of Young's modulus (see Table 2.2 for default values).

EMIN(I): Minimum allowable values of Young's modulus (see Table 2.2 for default values).

Card 9

(Note: All values in this card can be entered as zero or left blank.)

MITER: Maximum number of iterations for each trial (default is 10). A second trial is activated if the maximum difference is computed and measured deflections are greater than 10 percent.

TOLR1: Tolerance for individual deflections, in mils (default is 0.05 mils).

TOLR2: Tolerance for the absolute total error at all sensors in computed and measured deflections (default is 2 percent).

TOLR31: Tolerance for the modulus of the surface asphaltic concrete layer (default is 4 percent).

TOLR32: Tolerance for moduli of intermediate layers (default is 3 percent).

TOLR33: Tolerance for the subgrade modulus (default is 0.05 percent).

Card 10

NDAXL: Zero or blank for default design load as illustrated in Fig 2.3. (In this case the next card, type 11, is to be omitted.)

TABLE 2.1. RECOMMENDED VALUES OF POISSON'S RATIO FOR DIFFERENT PAVEMENT MATERIALS

Material Type	Range of Poisson's Ratio	Recommended Value
Portland cement concrete	.15 - .20	0.15
Asphaltic concrete	.25 - .35	0.35
Cement stabilized base	.20 - .30	0.30
Asphalt stabilized base	.25 - .35	0.35
Unbound granular base	.20 - .50	0.40
Granular subgrade	.30 - .50	0.40
Clayey or silty subgrades	.40 - .50	0.45
Lime treated subgrade		0.40

TABLE 2.2. DEFAULT VALUES OF MAXIMUM AND MINIMUM RANGES OF MODULI OF PAVEMENT LAYERS

MODULI		RIGID PAVEMENTS	FLEXIBLE PAVEMENTS
E_1	Maximum	6,500,000 psi *(5,000,000)	1,110,000 psi * (100,000)
	Minimum	2,000,000 psi *(1,000,000)	80,000 psi * (50,000)
E_2	Maximum	2,000,000 psi	** 300,000 psi *** 90,000
	Minimum	50,000 psi	** 80,000 psi *** 25,000
E_3	Maximum	500,000 psi	** 250,000 psi *** 70,000
	Minimum	30,000 psi	** 25,000 psi *** 20,000
E_4	Maximum	70,000 psi	70,000 psi
	Minimum	5,000 psi	10,000 psi

* Default values to be assumed when ICON1 = 1 is entered in input (badly cracked surface layer).

** Stabilized layer.

*** Granular material.

(E_1 is for the surface layer, E_2 and E_3 are for intermediate layers, and E_4 represents the modulus of subgrade.)

Enter 1 for the user specified design load. (Card type 11 must be completed.)

DLOAD: Design load per tire in lb (assuming single axle, dual tires). The default value is 4500 lb.

*FLEST: Flexural strength of concrete in psi (must be entered if remaining life calculation is asked by the user).

TIREP: Tire pressure in psi (default value is 75 psi).

PTRAFF: Cumulative past traffic in 18-kip ESAL (must be entered if remaining life is to be computed).

*(This input is required only for RPEDD1 and omitted for RPEDD1).

Card 11

NDLOD: Number of loads (e.g., 2 for the default design load simulating dual tires in Fig 2.3).

DXL(1): Position of x-coordinate for first load.

DYL(1): Position of y-coordinate for first load.

DXL(2): Position of x-coordinate for second load.

DYL(2): Position of y-coordinate for second load.

NDNXY: Number of locations where pavement response is to be calculated under the user specified design load (enter 3).

DXP(1): Position of x-coordinate of the nearest location for response.

DYP(1): Position of y-coordinate of the nearest location for response.

DXP(2): Position of x-coordinate of the intermediate location for response.

DYP(2): Position of y-coordinate of the intermediate location for response.

DXP(3): Position of x-coordinate of the farthest location for response.

DYP(3): Position of y-coordinate of the farthest location for response.

(Note: All distances in Card 11 are in inches.)

Idealized Pavement Structure

A major aspect of the RPEDD1 program is that it handles a three or four layer pavement. Therefore, the actual pavement structures are to be idealized by an equivalent three or four layered pavement. Examples of some of these cases are illustrated in Figs 2.1 and 2.2. If the actual pavement is of two layers only, then a third layer should be created out of the subgrade and BTYPE should be assigned a value of 1. For pavements of more than four layers, intermediate layers can be combined into one layer so as to make four layered pavements. Program FPEDD1 can be used for insitu material characterization of composite pavements (rigid pavement overlaid with asphaltic concrete layer) within the following constraints:

(1) The top layer should be a combined overlaid AC layer.

(2) The second layer is a PC concrete layer. An ESEED value must be assigned for this layer (say 4,000,000 psi). EMAX and EMIN must also be entered by the user.

(3) BTYPE must be assigned a value of Z.

(4) IOPT2 must be zero.

EXAMPLE APPLICATIONS

An example of partial output for RPEDD1 program is presented in Appendix A. Results of the analysis of only the first basin are reproduced in th table which also includes the final tabulated summary output. Fig 2.6 illustrates plots of moduli along the test section based on the summary output. These plots shown the analysis of FWD as well as Dynaflect deflection basins measured almost at the same time.

An example of a partial output from FPEDD1 is presented in Ref 1. The basic form of output is similar to the output of RPEDD1. A summary output of FPED1 is also printed in Appendix A, which also illustrates summary statistics.

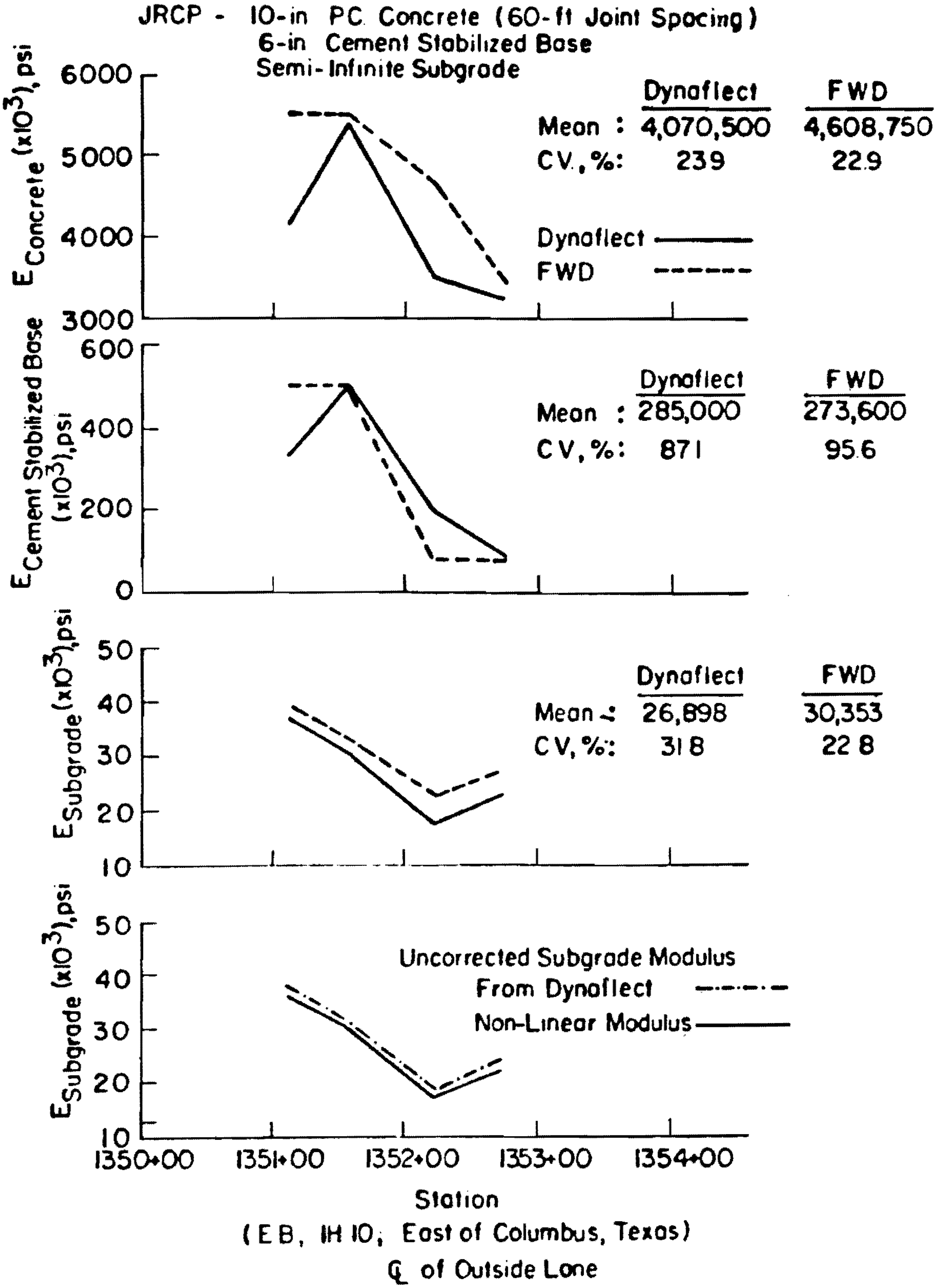


Fig 2.6. Example applications of RPEDD1 on a JRC pavement (Ref 1).

SUMMARY

The data required to prepare inputs for computer programs RPEDD1 and FPEDD1 were summarized in this chapter, followed by a detailed input guide.

CHAPTER 3. APPLICATION/IMPLEMENTATION

Detailed guidelines for application/implementation of computer programs RPEDD1 and FPEDD1 are presented in Ref 1. These guidelines are summarized in this chapter.

APPLICATION

The summary outputs from the computer programs RPEDD1 and FPEDD1 could be sued to generate plots such as illustrated in Fig 3.1. These plots provide a global look on the structural condition of the existing pavement.

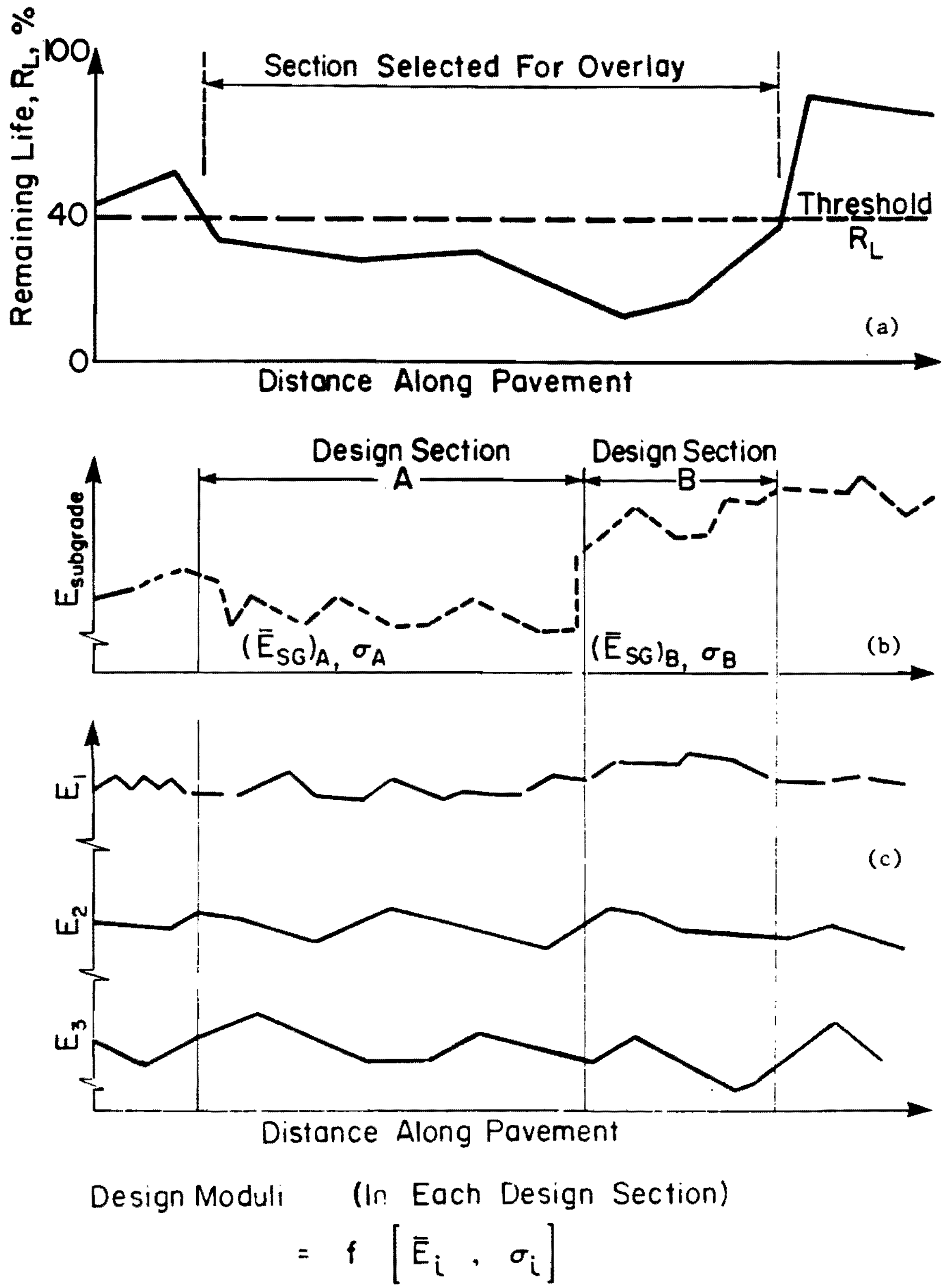
Application of Pavement Maintenance/Rehabilitation Needs

An important decision to be made on the project level has to do with delineating pavement sections according to their maintenance or rehabilitation needs. To provide a rational and mechanistic method for delineation of pavement sections which are to be considered for structural strengthening, the following approach is recommended.

(1) Establish a threshold value of remaining life (based on structural evaluation) below which consideration must be given to the designing of an overlay thickness. For example, for CRC pavements, 40 percent can be taken as the threshold limit of remaining life.

(2) Delineate the sections along the length of the pavement for consideration of overlay design that in general show a computed remaining life equal to or less than the threshold value. This step is illustrated in Fig 3.1(a).

(3) To achieve efficiency and cost reduction in designing overlays, several recently developed procedures rely on dividing the stretch of pavement to be overlaid into several design sections. Then,



005 63

Fig 3.1. Application/implementation of structural evaluation programs.

using the design values of insitu moduli and other parameters representative of each section, the overlay thickness is designed for that section. In general, a deflection parameter is used to identify the design section. The approach proposed in this study is to used the subgrade modulus, E_{SG} profile, as illustrated in Fig 3.1(b). E_{SG} values in the final output are representative of insitu nonlinear moduli under design load condition. Guidelines in the selection of design sections are briefly described in the following.

(a) Select preliminary design sections for visual examination of the E_{SG} plot along the length of pavement considered for overlay design. This selection is basically based on an approximate graphical contrast observed in the relative stiffness of the subgrade as shown in Fig 3.1(b).

(b) Compute the mean value and a standard deviation of E_{SG} for each design section.

(c) Perform hypothesis testing to find if the difference in the means of two adjacent sections is statistically significant. Appropriate statistical tests are to be used, recognizing that the variances of E_{SG} in the two sections may or may not be the same. A detailed procedure of hypothesis testing is presented in Appendix E of Ref 1. If the difference din means is not significant, the two sections can be pooled into one combined section and then tested against the next "selected" section.

Once the design sections have been established, the next step is to evaluate the design moduli.

Overlay Design-Evaluation of Insitu Design Moduli

Before proceeding to a comprehensive overlay design, design insitu moduli are to be evaluated for each established design section. The design value of insitu moduli are important input for any overlay design and field variability should be taken into account, using known statistical methods. The design modulus of each layer of existing pavement in a design section can be determined from the mean value, standard deviation, and a preselected value of confidence level (say 95-97 percent). The recommended procedure for computing design moduli is also presented in Appendix E of Ref 1.

IMPLEMENTATION OF STRUCTURAL EVALUATION SYSTEM

The implementation phase of the output generated from the computerized structural evaluation system based on dynamic deflections and their applications warrants special emphasis. All the concepts and recommended procedures have been discussed in Ref 1. A self-explanatory summary is presented in the simplified flow diagram illustrated in Fig 3.2.

SUMMARY

A framework for structural evaluation of pavements, applicable to both rigid and flexible types, has been presented in this chapter. Guidelines for processing and managing information related to the evaluated pavement are presented so that rational decisions can be made concerning rehabilitation needs. Methodologies are also recommended for identifying design sections and determining design insitu moduli for subsequent use in comprehensive overlay design.

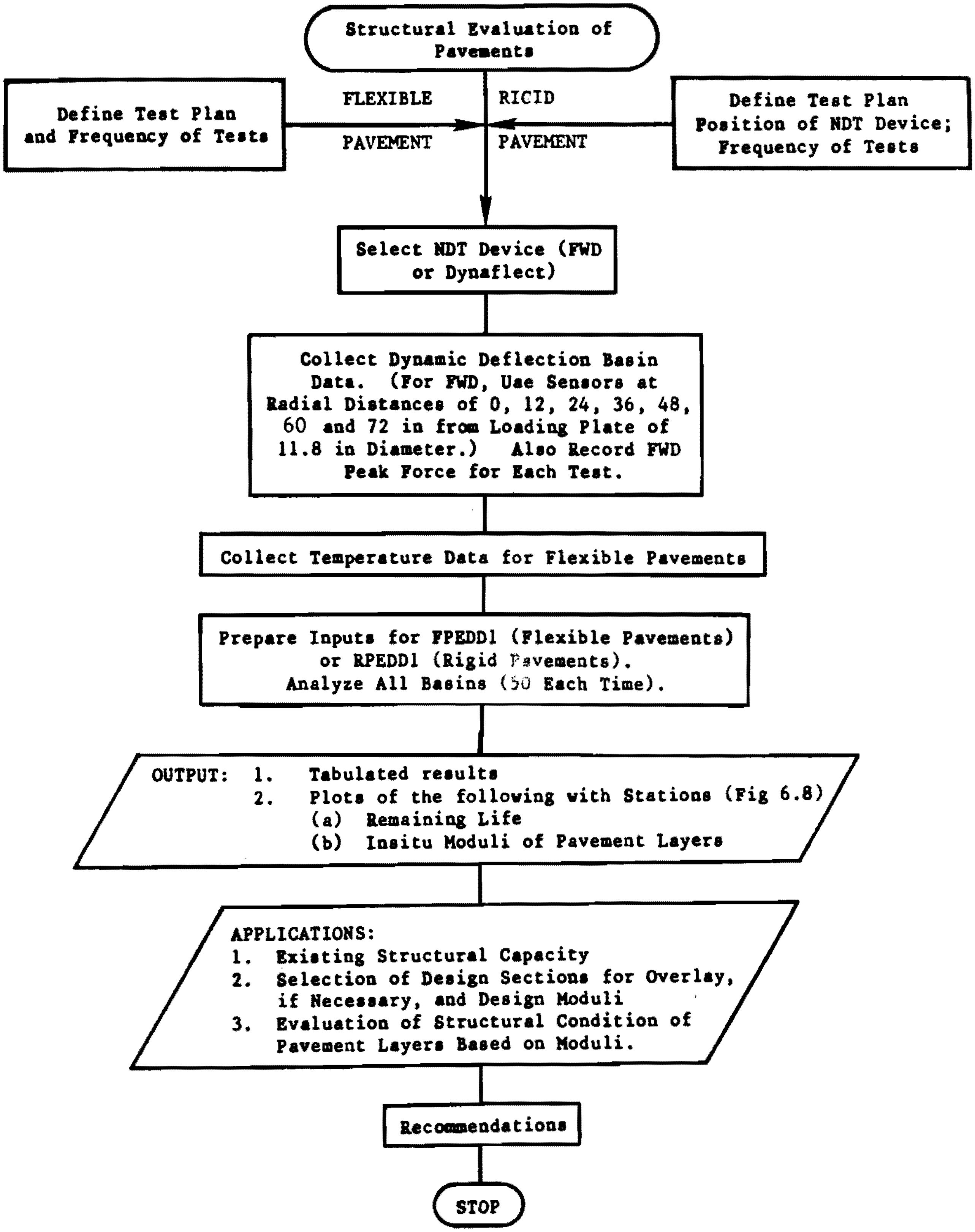


Fig 3.2. A conceptual flow diagram for implementation of the proposed structural evaluation systems (Ref 1).

005 326

REFERENCES

1. Uddin, Waheed, A. H. Meyer, W. Ronald Hudson, and K. H. Stokoe II, "A Structural Evaluation Methodology for Pavements Based on Dynamic Deflections," Research Report 387-1, Center for Transportation Research, The University of Texas at Austin, Austin, Texas, July 1985.
2. "AASHTO Interim Guide for Design of Pavement Structures - 1972," American Association of State Highway and Transportation Officials, 1981.

APPENDIX A

EXAMPLE OUTPUTS OF RPEDD1 AND FPEDD1

APPENDIX A. EXAMPLE OUTPUTS OF RPEDD1 AND FPEDD1

This appendix presents examples of partial outputs of computer programs RPEDD1 (for rigid pavements) and FPEDD1 (for flexible pavements). The detailed results are presented in Ref 1.

TABLE A.1. EXAMPLE OF PARTIAL OUTPUT FOR RPEDD1

```
1

     **********************************
     *                                *
     *           R P E D D 1          *
     *                                *
     **********************************

     RIGID PAVEMENT EVALUATION PROGRAM
     PROGRAM WRITTEN BY MAHBUB UDDIN
        VERSION : 1.0  APRIL 14,1984
     CENTER FOR TRANSPORTATION RESEARCH
     THE UNIVERSITY OF TEXAS AT AUSTIN


 MEASURED DEFLECTION BASIN (PROBLEM NO.  2 )

     JRCP - EAST OF SAN BERNARD RIVER IH10 EB

         DYNAFLECT               STATION:                   3  AUG.1984

     3   LAYERS SYSTEM        BTYPE =  2  (TYPE OF LAYER ABOVE SUBGRADE :)
                                          ( 1 = GRANULAR ; 2 = STABILIZED )

                  ********* INPUT SYSTEM PARAMETERS *********


ALLOWABLE NUMBER                                TOLERANCES
 OF ITERATIONS         TOLR1        TOLR2       TOLR31       TOLR32      TOLR33

       8                .005        1.500        4.000        2.000        .100
                                   PERCENT      PERCENT      PERCENT     PERCENT
                  ******************************************


 LAYER NO.      THICKNESS  POISSONS           ESEED         E(MAX)         E(MIN)
                (INCHES)    RATIO             (PSI)          (PSI)          (PSI)

    1               10.00      .15          3036251.       6500000.       2000000.
    2                6.00      .30           392630.        500000.         20000.
    3                          .45            20179.         70000.          5000.
       UNIT WEIGHT OF SUBGRADE SOIL     115.0LBS. PER CU. FT.
       **********************************************************


          SENSOR NO.              1        2        3        4        5

      MEASURED DEFLECTIONS
              (MILS)            .280     .260     .230     .220     .180

    CALCULATED DEFLECTIONS
              (MILS)            .336     .310     .270     .230     .202

         MERRP (PERCENT)      22.150
    (BASED ON SEED MODULI VALUES)


    *****                 *****
    ***** ITERATIONS BEGIN *****
    *****                 *****


     STOPPED - NO FURTHER DECREASE IN MAXIMUM PRCENT ERROR IN DEFLECTION


     TOTAL ITERATIONS ATTEMPTED IN THIS RUN ARE     3
        ******************************************


    IOPT1 =   0 ENFORCED ; RESULT OF EACH INDIVIDUAL ITERATION IS NOT PRINTED ***
```

005 42

(continued)

TABLE A.1. (CONTINUED)

```
******* SUMMARY OF BEST ITERATION ( No. 3 ) *******

  YOUNGS MODULI(PSI)   5398102.1     500000.0      31026.1

   MEASURED DEFLECTIONS
            (MILS)           .280   .260   .230   .220   .180

  CALCULATED DEFLECTIONS
            (MILS)           .284   .272   .241   .209   .179

       MERRP (PERCENT)      4.920

 ************************************************************************
  DESIGN SINGLE AXLE LOAD DATA

  LOAD PER TIRE (LBS.) =      4500.0    FLEX. STRENGTH:   650.0 PSI
  TIRE PRESSURE (PSI)  =        75.0

  RIGID PAVEMENT TYPE :   1             SHOULDER TYPE :   1
   ( 0 = JCP OR JRCP )                  ( 0 = WITHOUT CONCRETE SHOULDER )
   ( 1 = CRCP        )                 ( 1 = WITH CONCRETE SHOULDER )

*********EQUIVALENT LINEAR ANALYSIS FOR CORRECTION OF YOUNGS MODULI*********

  **** SUBGRADE (NATURAL SOIL) MODULUS CORRECTED FOR NON LINEAR BEHAVIOUR ****

       CORRECTED VALUES OF YOUNGS MODULI (PSI)
           5398102.     500000.      30480.
1

******************** SUMMARY OF STRUCTURAL EVALUATION ********************

 STATION DEF.MAX.H. STRESS DEV.STRESS  FINAL VALUES OF YOUNGS MODULI (PSI)

          (MILS)   (PSI)     (PSI)

 1       2  2.7   .641E+02  -.217E+01    4169000.   332500.    36940.
 2       3  2.8   .659E+02  -.173E+01    5398000.   500000.    30480.
 3       4  5.0   .820E+02  -.176E+01    3515000.   118400.    17530.
 4       5  4.3   .796E+02  -.210E+01    3200000.    89500.    22600.

                             *** MEAN :  4070500.   260100.    26890.

                             STD DEV :  972670.3  193190.5    8555.0

                             C V (%) :       23.9      74.3      31.8


   RIGID PAVEMENT EVALUATION PROGRAM
   PROGRAM WRITTEN BY WAHEED UDDIN
      VERSION : 1.0  APRIL 14,1984
   CENTER FOR TRANSPORTATION RESEARCH
   THE UNIVERSITY OF TEXAS AT AUSTIN
```

TABLE A.2. EXAMPLE OF PARTIAL OUTPUT FOR FPEDD1

************************ SUMMARY OF STRUCTURAL EVALUATION ************************

	STATION	DEF.MAX.H. (MILS)	STRAIN IN./IN.	DEV.STRESS (PSI)	B.STRESS (PSI)	CUM.TRAFFIC	MAX.AXLES APP.	REM. LIFE PERCENT	FINAL VALUES OF YOUNGS MODULI(PSI)			
1	0	13.0	.184E-03	-.229E+01	-.811E+01	1366560	1821899	25.0	198600.	32300.	27100.	15900.
2	20	15.4	.231E-03	-.261E+01	-.828E+01	1366560	568030	0	173500.	24200.	20000.	17100.
3	40	11.3	.166E-03	-.249E+01	-.712E+01	1366560	3108395	56.0	344300.	23100.	20000.	29100.
4	60	7.4	.117E-03	-.285E+01	-.729E+01	1366560	19113697	92.9	624100.	21030.	23030.	37800.
5	80	12.0	.175E-03	-.246E+01	-.986E+01	1366560	2371811	42.4	215800.	32600.	37600.	19900.
6	100	14.0	.231E-03	-.286E+01	-.894E+01	1366560	559131	0	207200.	20000.	20003.	21300.
7	120	16.7	.198E-03	-.233E+01	-.640E+01	1366560	1247314	0	173500.	31730.	20030.	11700.
8	140	13.3	.162E-03	-.275E+01	-.779E+01	1366560	3476030	63.7	382700.	20030.	20000.	25600.
9	160	13.7	.252E-03	-.336E+01	-.999E+01	1366560	357521	0	173500.	20000.	20000.	30700.
10	180	14.1	.252E-03	-.321E+01	-.970E+01	1366560	358236	0	174000.	20000.	20030.	26900.
11	200	13.3	.119E-03	-.235E+01	-.339E+01	1366560	26751064	94.9	173500.	70000.	20000.	15400.
12	220	11.5	.154E-03	-.227E+01	-.574E+01	1366560	4567191	70.1	299000.	33230.	20030.	18300.
13	240	14.6	.222E-03	-.231E+01	-.819E+01	1366560	734632	0	231000.	20000.	20000.	16100.
14	260	16.4	.254E-03	-.263E+01	-.890E+01	1366560	348518	0	173500.	20000.	20000.	15800.
15	280	4.8	.595E-04	-.232E+01	-.426E+01	1366560	618936836	99.8	103112.	20000.	20030.	32329.
16	300	17.4	.254E-03	-.242E+01	-.855E+01	1366560	345584	0	173500.	20000.	20000.	13100.
17	320	12.7	.221E-03	-.335E+01	-.910E+01	1366560	710663	0	225100.	20000.	20000.	26000.
18	340	[illegible]	.156E-03	-.271E+01	-.658E+01	1366560	4238412	67.0	289009.	33110.	20000.	26500.
19	360	9.3	.162E-03	-.322E+01	-.782E+01	1366560	3546579	61.5	305000.	20500.	20003.	40900.
20	380	10.9	.160E-03	-.254E+01	-.665E+01	1366560	3730320	63.4	311700.	29000.	20000.	22200.
21	400	14.8	.241E-03	-.276E+01	-.997E+01	1366560	458132	0	176600.	21500.	25400.	18900.
22	420	14.9	.168E-03	-.187E+01	-.520E+01	1366560	2894084	52.8	252800.	32800.	20000.	11100.
23	460	12.4	.200E-03	-.276E+01	-.830E+01	1366560	1183032	0	267100.	20410.	23030.	21700.
24	480	8.8	.101E-03	-.186E+01	-.561E+01	1366560	40575094	96.6	612400.	35700.	30300.	17600.
25	500	13.7	.237E-03	-.299E+01	-.976E+01	1366560	490349	0	195000.	20000.	22400.	23400.
26	540	16.2	.254E-03	-.267E+01	-.896E+01	1366560	347845	0	173500.	20000.	20030.	16400.
27	560	14.5	.215E-03	-.257E+01	-.815E+01	1366560	810445	0	187200.	25800.	21100.	17700.
28	580	10.0	.153E-03	-.265E+01	-.748E+01	1366560	4752422	71.2	654700.	20000.	20000.	24500.
29	600	17.8	.198E-03	-.193E+01	-.610E+01	1366560	1251476	0	268800.	31700.	20000.	10000.
30	620	13.0	.204E-03	-.267E+01	-.824E+01	1366560	1064415	0	405700.	20000.	20000.	19600.
31	640	11.9	.252E-03	-.419E+01	-.109E+02	1366560	363798	0	268800.	20000.	23030.	67400.
32	660	10.9	.169E-03	-.285E+01	-.707E+01	1366560	2810940	51.4	382600.	32500.	20000.	27700.
33	680	9.8	.156E-03	-.271E+01	-.978E+01	1366560	4257798	67.9	420900.	33230.	38100.	27900.
							* MEAN :	32.6	297436.	26959.	21003.	23257.
							STD DEV :	36.9	151894.9	9800.0	4732.6	11171.7
							C V(%):	113.4	51.1	36.6	21.6	48.0

**** PLEASE RECALCULATE SUMMARY STATISTICS FOR REMAINING LIFE IF 999.0 APPEARS IN THE OUTPUT ****

FLEX. PAVEMENT EVALUATION PROGRAM
PROGRAM WRITTEN BY WAHEED UDDIN
VERSION : 1.0 APRIL 16,1984
CENTER FOR TRANSPORTATION RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN