FLEXIBLE PAVEMENT DESIGN SYSTEM (FPS) 19: USER'S MANUAL

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16. Abstract

FPS19 is the latest version of the flexible pavement design system developed by the Texas Transportation Institute for TxDOT. This version uses backcalculated elastic moduli of the pavement layer materials in the pavement design process. The MODULUS 5.1 backcalculation procedure generates the input layer moduli. The WESLEA linear elastic computer program, embedded within FPS19, computes pavement responses. The design equation used is the same as used in FPS11 and documented in TTI Report 32-11. The main design parameter is the Surface Curvature Index computed at the midpoint of a set of dual tires loaded to 40 Kn (9,000 lbs).

FPS19 is microcomputer-based and compatible with MS-DOS Windows 95 and Windows NT when running under the DOS window. TxDOT is implementing the FPS19 computer program statewide as part of its new flexible pavement design system.

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IMPLEMENTATION RECOMMENDATIONS

TxDOT is currently implementing a new Flexible Pavement Design System. A new pavement design program, FPS19, has been developed for TxDOT as its next generation program for flexible pavement design.

In order to implement this system:

1. Each district must use the Falling Weight Deflectometer and MODULUS 5.1 to obtain representative moduli values for its base and subgrade materials.
2. The Pavement Design Division should initiate a long-term monitoring program to follow the deterioration of selected pavements designed using this new procedure.

The FPS19 computer program contains several enhancements designed to make the FPS19 program more user-friendly, including interactive data input to facilitate the creation of the input data for a FPS19 design calculation.

Any technical questions regarding the FPS19 computer program should be directed to Tom Scullion at the address or phone number below:

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There is no invention or discovery conceived or reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design, or composition of matter; any new and useful improvement thereof; or any variety of plant which is or may be patentable under the patent law of the United States of America or any foreign country.

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SUMMARY

FPS19 is the latest version of the flexible pavement design system developed by the Texas Transportation Institute for TxDOT. This version uses backcalculated elastic moduli of the pavement layer materials in the pavement design process. The MODULUS 5.1 backcalculation procedure generates the input layer moduli. The WESLEA linear elastic computer program, embedded within FPS19, computes pavement responses. The design equation used is the same as used in FPS11 and documented in TTI Report 32-11. The main design parameter is the Surface Curvature Index computed at the midpoint of a set of dual tires loaded to 40 kn (9,000 lbs).

FPS19 is microcomputer-based and compatible with MS-DOS Windows 95 and Windows NT when running under a DOS window. TxDOT is implementing the FPS19 computer program statewide as part of its new flexible pavement design system.

CHAPTER I

INTRODUCTION

1.1 SYSTEM REQUIREMENTS

The following system requirements are recommended for running the FPS19 computer program:

* A 486 or better microcomputer, with a math coprocessor chip;
* A DOS operating system, version 5.0 or later;
* 640 kb of "LOW-DOS" RAM memory;
* A hard disk with 1 mb of usable storage available;
* An EGA or VGA graphics card with 256 kb of screen memory and a compatible RGB or monochrome monitor; and
* An optional dedicated printer.

The FPS19 program will run on a 386 level microcomputer, but the execution time will be extended for the older microcomputers. A 486 or Pentium microcomputer is recommended to obtain a reasonable execution time for the FPS19 program.

Printers that are on a network may have problems producing the outputs from the FPS19 program. If this is the case, you should save the outputs from each FPS19 run and print them at a later time.

The FPS19 program requires approximately 530 kb of memory. You should remove any memory resident devices not needed to run the FPS19 program to create the 530 kb of "low-DOS" memory that it requires. Use the DOS "MEM" command to determine the amount of memory available if the system will not run the FPS19 program.

This version of FPS19 can be run using the DOS operating system, WINDOWS 3.1, or a DOS window in WINDOWS 95 or WINDOWS NT.

1.2 FPS19 PROGRAM FILES

The FPS19 program is furnished on a 3 1/2" diskette and consists of 14 files. The files are listed below in alphabetical order.

*BEG.COM	*DESIGN6.DAT
*BRUN45.EXE	*DISPLAY.COM
*DEFAULT.DAT	*END.COM
*DESIGN1.DAT	*FPS19.BAT
*DESIGN2.DAT	*FIN58.EXE
*DESIGN3.DAT	*FSS58.EXE
*DESIGN4.DAT	*SCREENS.LBR

1.3 DESCRIPTION OF FPS19 PROGRAM FILES

A brief description of the 12 FPS19 program files is given below.

* **FPS19.BAT**	A DOS batch file that starts the FPS19 program.
* **BEG.COM**	A command file that marks RAM memory where the screen input file "DISPLAY.COM" is loaded.
* **BRUN45 .EXE**	Microsoft Quickbasic module that contains routines linked with and needed by the FIN58.EXE module that is written in MS Quickbasic.
* **DISPLAY.COM**	The screen input command file that manages the input from the screen fields to the program.
***END.COM**	A command file that unloads the "DISPLAY.COM" file from memory at the end of the program run.
* **DEFAULT.DAT**	A file that contains the input data from the last FPS19 run, which is displayed as a starting point for the current program run.

*** DESIGN1.DAT** A file that contains the default input data for a three-layer design ACP over flexible base over subgrade (Pavement Type = 1): Data in this file may be edited.

*** DESIGN2.DAT** A file that contains the default input data for a "black base" design, ACP over asphalt stabilized base over subgrade (Pavement Type = 2): Data in this file may be edited.

*** DESIGN3.DAT** A file that contains the default input data for a four-layer "black base" design, ACP over asphalt stabilized base over flexible base over subgrade (Pavement Type = 3): Data in this file may be edited.

*** DESIGN4.DAT** A file that contains the default input data for a stabilized subgrade design, ACP over flexible base over stabilized subgrade over unstabilized subgrade (Pavement Type = 4): Data in this file may be edited.

*** DESIGN6.DAT** A file containing the input data to run the FPS19 program for an overlay design only: Data in this file may be edited.

*** FIN58.EXE** The Quickbasic program module that displays the data input screens.

*** FSS58.EXE** The program module that does the pavement design calculations.

*** SCREENS.LBR** A library file that contains the data input screens.

The DESIGN.DAT files contain default moduli, poisson ratio, thickness, and cost data for each pavement type. They are displayed after you select the pavement type of interest. We recommended that you modify these files to include your commonly used values.

CHAPTER II

NEW FEATURES OF FPS19

2.1 PAVEMENT STRUCTURE CHARACTERIZATION

The major difference between the FPS19 pavement design program and the FPS11 pavement design program is that the FPS19 program uses the elastic modulus of the material rather than "stiffness coefficients" as the layer strength parameter. The analysis internal to FPS19 is based on layer elastic theory (see Appendix B for more detail). The MODULUS 5.1 program is recommended to calculate layer moduli values; refer to TTI Report 1987-1 for details.

To facilitate implementation within TxDOT, the data input screens for FPS19 closely resemble the format used for the existing FPS11 system. The current version of FPS11 has been in use for almost 20 years, and each district has been trained in obtaining the necessary inputs. Because of the way FPS19 analyzes the data, the functions in FPS11 that compared different materials for the same layer "head-to-head" are no longer available. Independent runs are used to compare pavements material contributions.

2.2 DATA INPUT ENHANCEMENTS

The FPS19 data inputs are through interactive screens, which allow you to quickly create the input data for an FPS19 program run. The data inputs from the last FPS19 program run are displayed in the screen data input fields as a starting point for you to edit or use as desired. This data that is displayed is from the "DEFAULT.DAT" file, which always contains the data inputs from the last FPS19 program run. It is possible for you to make all of your FPS19 program runs by editing the data displayed in the screen fields at the beginning of each FPS19 run.

There are several enhancements to the FPS19 data input process that should aid you in creating the input data for a program run. The data inputs for several typical pavement structure designs with typical design values have been provided in the default design data files (Figure 1).

PAVING MATLS. (CARD # 10)			COST	MODULUS	MIN	MAX	SALVGE	POISN	
LYR	CDE	MATL. NAME	PER CY	E (ksi)	DEPTH	DEPTH	PCT	RATIO	CHK
1	A	ASPH CONC PVMT	21.42	500.0	2.00	2.00	30.0	0.36	1
2	B	ASPH STAB BASE	13.93	400.0	4.00	10.00	90.0	0.34	1
3	C	FLEXIBLE BASE	4.40	60.0	10.00	20.00	75.0	0.33	1
4	D	SUBGRADE(200)	2.00	20.0		200.00	90.0	0.40	0

Figure 1. A Pre-Coded Four-Layer Design.

For ease of locating for editing, these files begin with "DESIGN" and are appended by the pavement type number shown on the first program screen. For example, DESIGN6.DAT corresponds to the default data file for overlay designs. Any edits to these files will change the default values shown while running FPS19. These typical pavement design inputs include the pavement structure, the layer thicknesses, the elastic modulus and Poisson's ratio of the layer materials, the salvage value of the layer materials, and the in-place cost of the layer materials that make up the pavement structure.

The typical pavement designs are listed below:

1) **A three-layer design**: ACP over flexible base over subgrade. This is the most commonly used design type; it includes all surface treated flexible base pavements, lightly stabilized base pavements, and pavements with low levels of subgrade stabilization.

2) **A three-layer "black base" design**: ACP over asphalt stabilized base over subgrade.

3) **A four-layer "black base" design**: ACP over asphalt stabilized base over flexible base over subgrade.

4) **A stabilized subgrade design**: ACP over flexible base over stabilized subgrade over non-stabilized, subgrade. This design is only used if the subbase is considered permanently stabilized or if the subbase is an imported material significantly different from the raw subgrade.

5) **An overlay design only**: ACP overlay over identified layers in backcalculated pavement structure.

The data input values for each material of the typical designs are typical values only, and the user can edit the values as desired. Any on-screen editing of any of the values while running the FPS19 program in the typical pavement design inputs is only in effect for the current FPS19 run (on-screen editing does not affect the default values).

One other enhancement to the data input process for FPS19 is that the you can save the input data you have created and recall the saved data or any other previously saved input data for a current FPS19 run.

You can also save the output from each FPS19 run to be printed at a later time if a printer is not available.

2.3 FUNCTION KEYS FOR DATA INPUT EDITING

A number of the function keys have been defined as editing keys in order to facilitate the data input process. The function keys (Figure 2) and the process that each key performs are discussed below.

In an attempt to make the data input for FPS19 as simple as possible, each cell of each data input screen displays a default data input value. In most cases, the data values displayed are from the last run of the FPS19 program.

The exception to this is that the materials input cells (Figure 1, for example) will display values contained in the design file corresponding to the pavement type shown on the project identification screen (Figure 3). The layer materials, thicknesses, in-place costs, modulus and Poisson ratio values, and salvage values for several common three- and four-layer pavement designs and an overlay design are recalled from the appropriate default design data

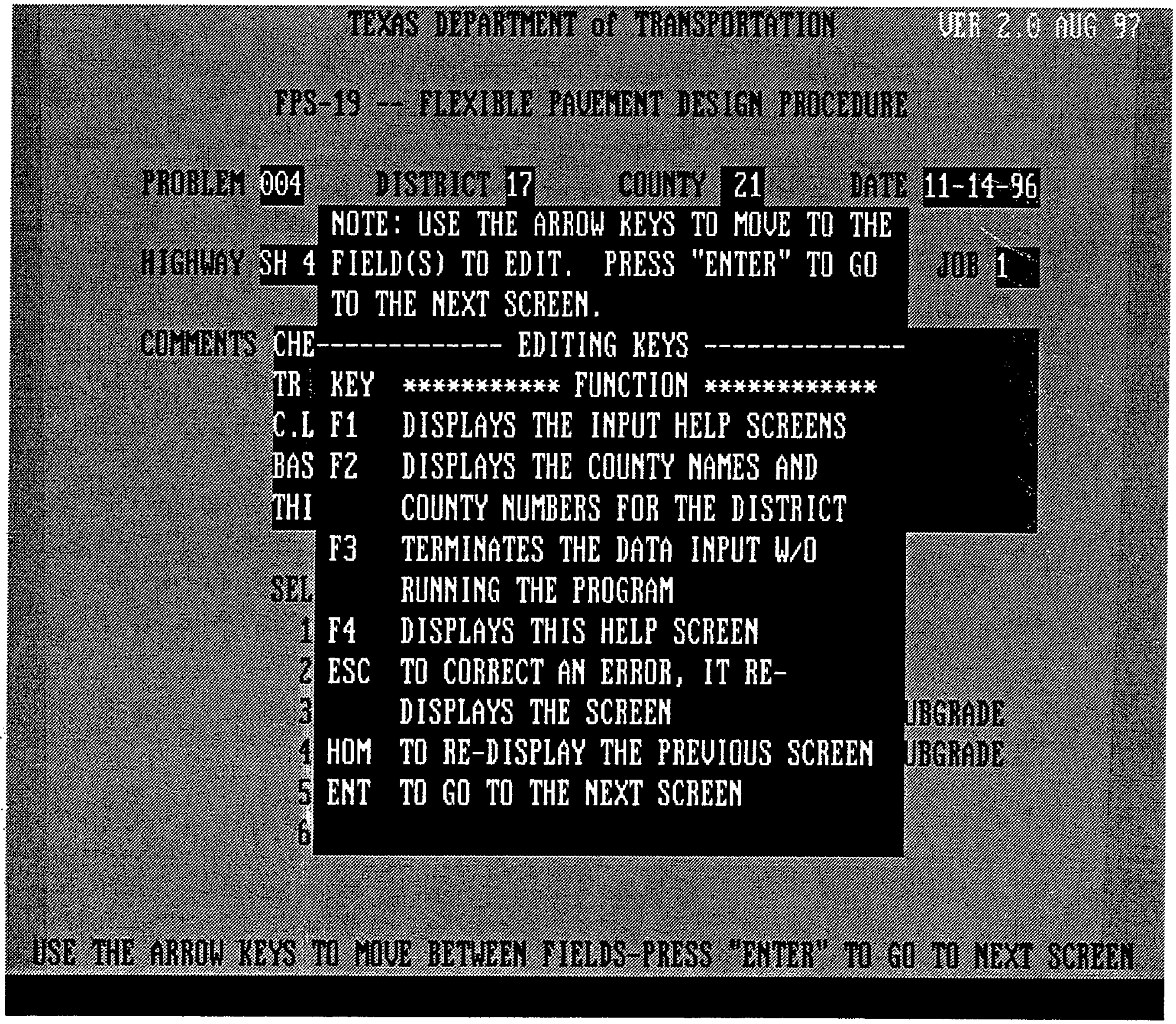


Figure 2. Function Keys for Data Input Editing.

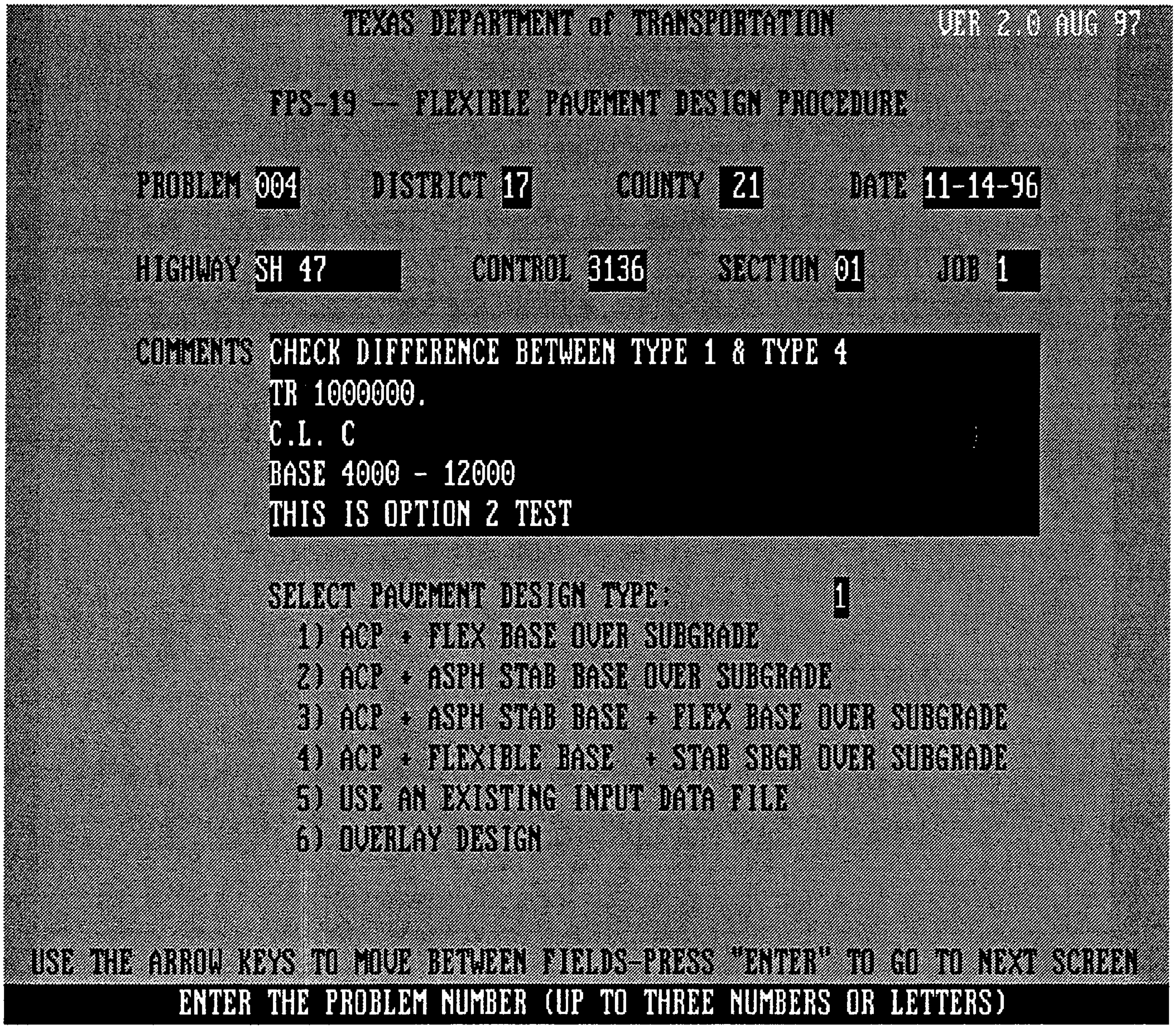


Figure 3. Project Identification Screen.

file and can be displayed in the appropriate data input cells. You can accept the values displayed in the input cells or edit the displayed data by using the arrow or function keys for editing.

Arrow keys: (Move within a Screen)

The data input method for each of the data input screens is "full screen" input. This means that when you push the "ENTER" key, all the data values that are displayed are validated and passed to the FPS19 program. For each data input screen, the cursor is positioned at the first data input field in the upper-left of the screen. Use the arrow keys to move the cursor horizontally and vertically between the data input fields. Type new values over the default displayed values. Do not press "ENTER" until all editing on a single screen has been completed.

F1 key: (Help Key)

Most all of the data input cells for the data input screens have a "help screen" associated with the cell. These help screens provide additional information or suggest typical data values to use for the particular data input. To view the help screen for any cell, just move the cursor to that cell and press the "F1" key. After viewing the help screen, press "ENTER" or "ESC" to return to the data input cell. The project identification screen has a universal help screen attached to each field that gives information about obtaining assistance with running the FPS19 program. The "SELECT PAVEMENT DESIGN TYPE" cell of the project identification screen has a help screen to explain the pavement design type. Each of the remaining data cells in the program have help screens associated with them.

F2 key: (County Numbers within District)

The TxDOT county number field on the project identification data input screen has a help screen with the county names and TxDOT county numbers for each TxDOT district. Press the "F2" key to view the county names and county numbers of the counties in the TxDOT district that are displayed in the TxDOT district cell. Press the "ENTER" key to return to the county cell.

F3 key: (Exit)

During the data input part of the program, you may decide to terminate the program without running the FPS19 program. Press the "F3" key to terminate FPS19 and return to the DOS prompt.

F4 key: (Display Editing Keys)

The editing function keys shown in Figure 2 can be displayed by pressing the "F4" key at any of the data input cells.

ESC key:

To change the data input value displayed in any of the data cells, just move the cursor to the cell and type in the data value you wish to use. To correct a typo, press the "ESC" key to return the cursor to the beginning of the cell, and then correct the typo.

HOME key:

You can return to the previous data input screen by pressing the "HOME" key. The displayed data values will be the edited data values, not the originally displayed data values. This key will also allow the analysis screen to be displayed again once the data is executed and the analysis has been reviewed once.

ENTER key: (Move to Next Screen)

When satisfied with the data values displayed in the cells of a data input screen, press "ENTER" to validate the data values and to advance to the next data input screen. The "ENTER" key also advances to each screen following data input, and it executes the data analysis module.

CHAPTER III

RUNNING THE FPS19 PROGRAM

3.1 RUNNING FPS19

Unless the FPS19 program is in the computer's path statement (for DOS systems), make the directory where the FPS19 program is located the current directory as in the example below.

Ex: C:> CD C:\FPS19, <cr>

Type "FPS19," <cr> at the C:\FPS19> prompt to start the program.

For Windows 95 and Windows NT systems, a DOS window needs to be launched before the above commands may be executed (the appropriate drive designation is substituted for the "C" drive).

3.2 PROJECT IDENTIFICATION SCREEN

The project identification screen (Figure 3) will be displayed upon start-up. This screen shows the input of the current problem run identification, input of up to five comment lines, and the selection of the type of design problem to be run.

A brief description of each data item is given below.

***PROBLEM**:	Enter up to three alphanumeric characters to identify the program run.
***DISTRICT**:	Enter the TxDOT district number (1 thru 25).
***COUNTY**:	Enter the TxDOT county number. Press the "F2" key to get a listing of the counties in the TxDOT district entered previously (Figure 4).
***DATE**:	Enter the date the program was run (optional).
***HIGHWAY**:	Enter the TxDOT highway name (up to 10 alphanumeric characters).
***CONTROL**:	Enter the TxDOT project control number.
***SECTION**:	Enter the TxDOT section number.

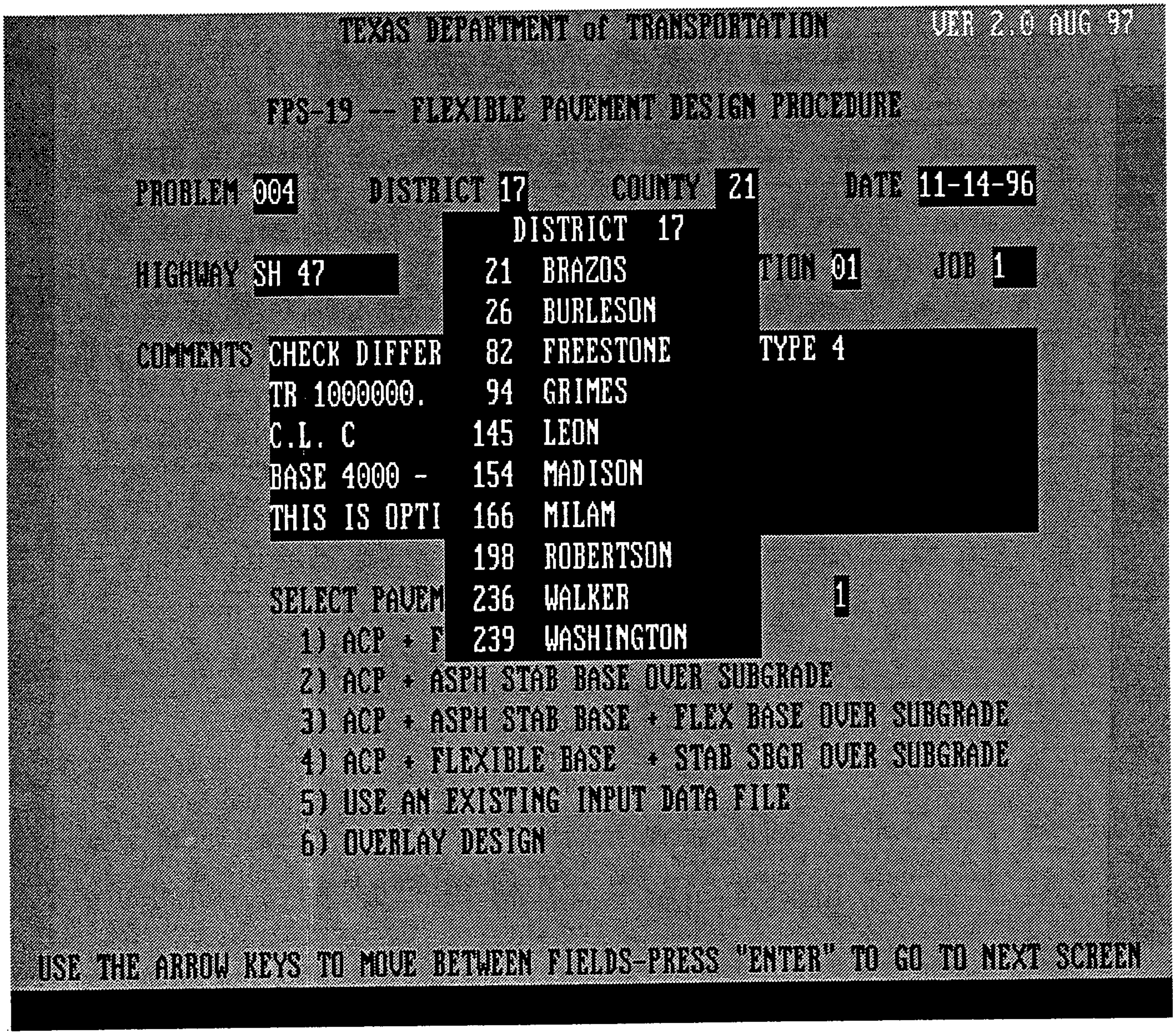


Figure 4. County Names and Numbers for the TxDOT District.

***JOB:** Enter the TxDOT job number.

***COMMENTS:** Enter up to five comment lines, containing up to 53 alphanumeric characters.

***SELECT PAVEMENT DESIGN TYPE:** Enter 1, 2, 3, 4, 5, or 6 to select the type of pavement design problem desired and to load the default input data to be modified in subsequent screens. If option 5 is selected, a window will open (Figure 5) to allow the user to enter the name of an input data file created previously that contains the input data to be displayed.

Use the arrow keys to position the cursor at any cell to change the value displayed. When all the cells for the project identification screen are correct, press "ENTER" to input the data and go to the next screen.

3.3 BASIC DESIGN CRITERIA, PROGRAM CONTROLS, TRAFFIC DATA, AND ENVIRONMENT AND SUBGRADE INPUTS

The second input data screen displayed is for the basic design criteria input data, the program control inputs, the traffic data inputs, and the environment and subgrade inputs (Figure 6).

Each of the data input cells on this screen and on the remaining input screens has a "Help" screen associated with each cell. This "Help" screen gives a description of the data item together with suggested or recommended values. To review the help screen for any cell, move the cursor to that cell and press the "F1" key. Figure 7 is the help screen for the "length of analysis period" data cell. After viewing the help screen, press "ENTER" to return to the data input screen. You can then input a value for the length of analysis period or use the value that is displayed.

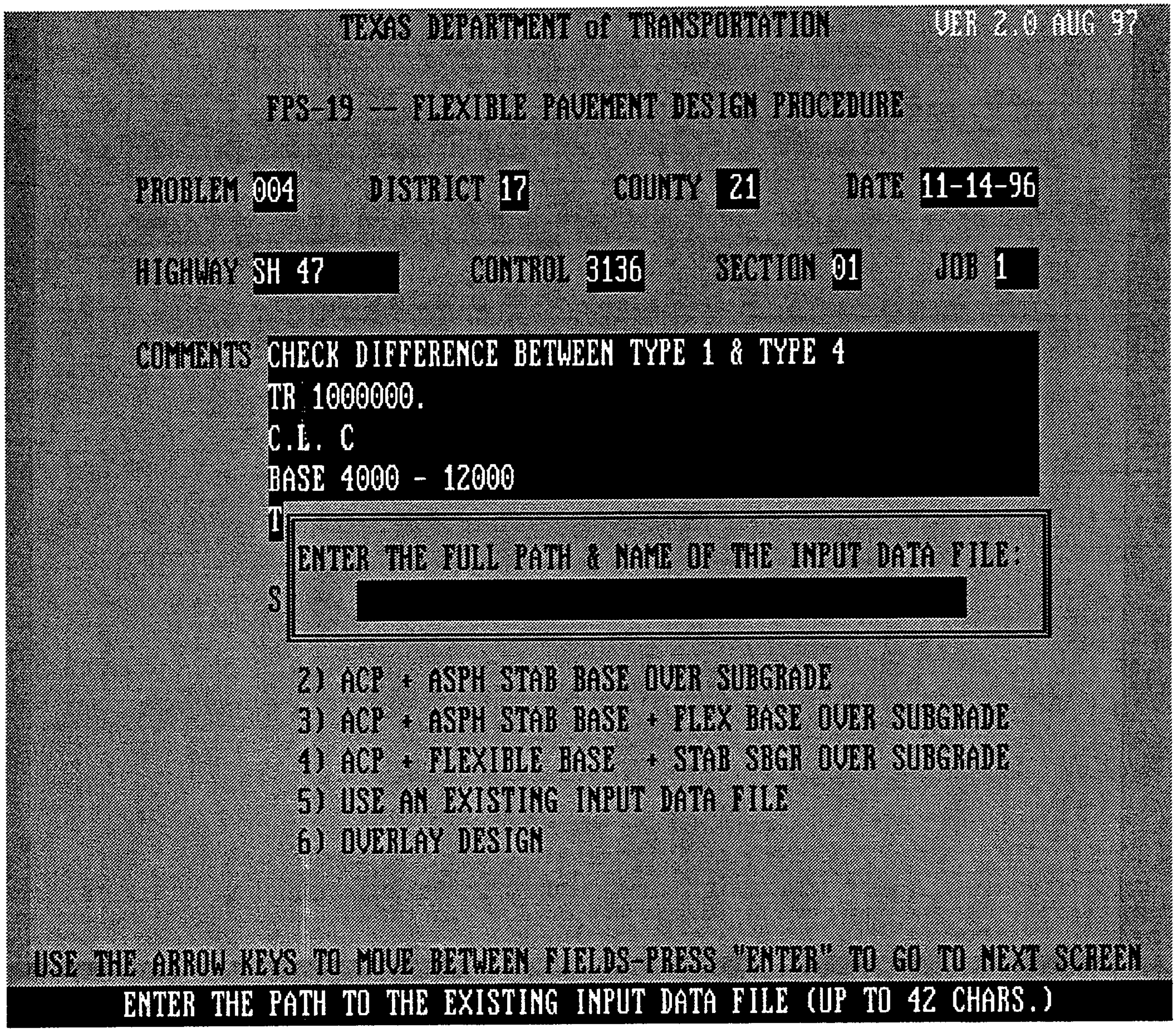


Figure 5. Select an Existing Input Data File.

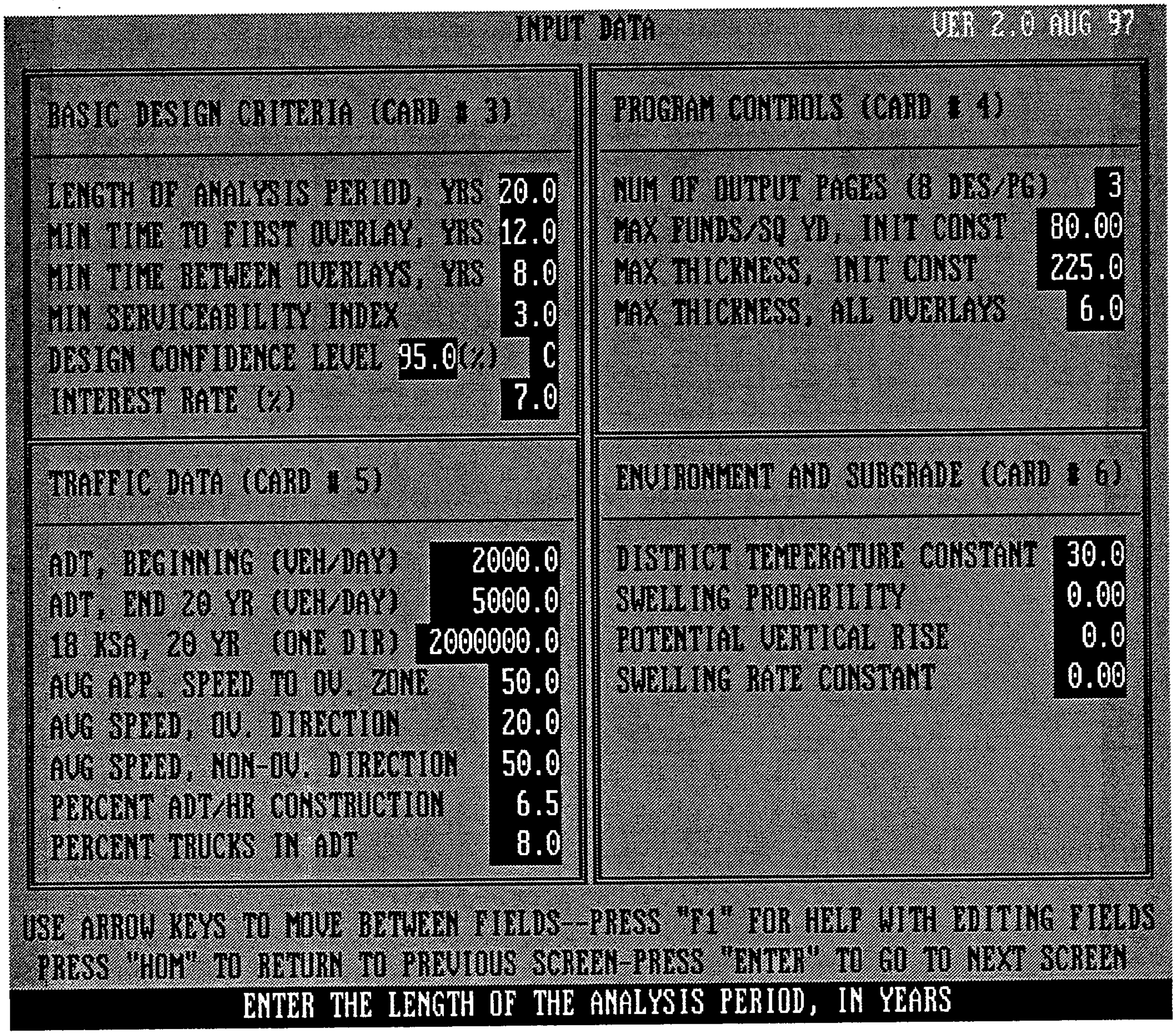


Figure 6. **Basic Design Criteria, Program Controls, Traffic Data, and Environment and Subgrade Inputs.**

CL - Length of analysis period

The following recommendations are given for this input:

a. For Interstate Funded Highways use a twenty-year analysis period beginning with the date of anticipated approval of PS & E by the Federal Highway Administration.

b. A thirty-year analysis period can be used for urban arterial streets and expressways with gradelines such that the pavement will not likely be destroyed (due to alignment revisions) during the analysis period.

c. For temporary connections, detours, and other short life expectancy pavements use an analysis period that equals the expected life of the pavement.

d. Use twenty years for all other facilities (most highways, Farm and Ranch roads).

ENTER THE LENGTH OF THE ANALYSIS PERIOD, IN YEARS

Figure 7. Help Screen for Length of Analysis Period Input Field.

Basic Design Criteria

A brief description of the basic design criteria inputs is given below.

* **Length of analysis period (years)** — usually 20 years for intermediate highways, 30 years for urban materials, and 10 years for farm to market highways.
* **Minimum time to first overlay (years)** — the length of time that the initial design must last. Use 10 years as the initial input for this variable and adjust up or down according to district preferences.
* **Minimum time between overlays (years)** — eight years is the recommended period for this input.
* **Minimum serviceability index** — this input pertains to the smoothness of the pavement surface at the end of the design period. Use 3.0 for all major routes, 2.5 for U.S., state, and FM routes, and 2.0 for low volume FM routes (ADT < 1000).
* **Design confidence level** — this input ranges from level A (80% C.L.) to level E (99.9% C.L.).

Table 1. Guidelines on Selecting Confidence Levels.

Confidence Level	Percentile	Recommended Usage
A	80	Low volume FM's < 500ADT, no major increase in traffic anticipated
B	90	Intermediate FM's, low volume SH and US Routes
C	95	Most design work, routes that are anticipated to have significant growth
D	99	High Volume Urban IH. This level will result in substantially thicker initial design thicknesses.

* **Interest rate (%)** — this input is used to discount future expenditures so that sufficient funds will be available for overlays, maintenance, and salvage value. Use 7% as the interest rate input.

Program Controls

The program control data inputs are described as below.

* **Problem type** — this input is always set to "1" (this corresponds to the FPS11 "card 4.1" and is not displayed).
* **Number of summary output pages** — you can request from one to three pages of the least cost design strategies to be printed (three pages, eight designs per page).
* **Maximum funds available per S.Y. for initial construction ($)** — this input should realistically reflect the amount of funds available. A low figure decreases the number of designs and the least cost design may be missed.
* **Maximum total thickness of initial construction** — this input should be greater than the total maximum thickness of all the pavement layers. A smaller than realistic value for this input can limit the number of designs and can result in a less than optimal design.
* **Maximum total thickness of all overlays (inches)** — this input is subject to the geometrics of the pavement cross section. The cost of a half inch level-up is always included in the overlay cost, but the half inch thickness is not to be included in this data input. Use a realistic value for the maximum overlay thickness so as not to restrict the design calculations.

Traffic Data

The FPS19 traffic data inputs are listed below.

* **ADT at the beginning of the analysis period (veh/day) — the Average Daily Traffic at the beginning of 20 years** — used in the traffic equation to determine the distribution of 18 kip single axle loads and for calculating traffic delay costs during overlay construction.
* **ADT at the end of 20 years (veh/day) — the Average Daily Traffic at the end of 20 years** — used in the traffic equation to determine the distribution of 18 kip single axle loads and for calculating traffic delay costs during overlay construction.

* **One direction cumulative 18 KSA at the end of 20 years** — this value is furnished by the Transportation Planning & Programming Division.
* **Average approach speed to the overlay zone** — this input is used to compute traffic delay costs during overlay operations.
* **Average speed through overlay zone (overlay direction) (mph)** — the reduced speed (through speed overlay direction) that vehicles must maintain when traveling through the restricted zone.
* **Average speed through overlay zone (non-overlay direction) (mph)** — the reduced speed (through speed non-overlay direction) that vehicles must maintain while traveling through the restricted zone.
* **Percent of ADT arriving each hour of construction** — Transportation Planning Division can furnish this input based on the time of day that the construction occurs. For most cases use 6% (6.0) for rural highways and 5% (5.0) for urban highways.
* **Percent trucks in ADT** — this input is used to select the appropriate cost and capacity tables used in the program.

Environment and Subgrade Inputs

The environment and subgrade data inputs are briefly described below.

* **District temperature constant** — the mean daily temperature above 32°F; it ranges from 9°F in the Amarillo District to 38°F in the Pharr District. Input is used in the traffic equation and represents the susceptibility of the asphalt to cracking under traffic in cold weather. A value for each TxDOT district has been calculated and is displayed based on the TxDOT district number entered previously.
* **Swelling probability**[1] — this input should be a fraction between 0 and 1, which represents the proportion of the project length that is likely to experience serviceability loss due to swelling clay.

[1]When these inputs are used, pavement structures are often unreasonably thick. A typical use for these inputs is to see how swelling will affect the roughness of a pavement.

* **Potential vertical rise**[2] — a measure of how much the surface of the clay bed can rise if it is supplied with all the moisture it can absorb. This input value can be estimated for a locale based on the total amount of differential heave observed or expected to occur over a long period of time or from the results of a PVR analysis.
* **Swelling rate constant**[2] — this input is used to calculate how fast swelling takes place. Typical input values are between 0.04 for tight soil with good drainage to 0.20 for cracked, open soil with poor drainage, high rainfall, or underground seeps.

As it is with the previous data input screens, you should use the arrow keys to move the cursor to the cell(s) to edit. You can return to the previous data input screen by pressing the "HOME" key. When all the data inputs are correct, press "ENTER" to validate the inputs and to display the next input screen.

3.4 CONSTRUCTION AND MAINTENANCE, DETOUR DESIGN, AND PAVING MATERIAL DATA

The third data input screen is for the construction and maintenance inputs, the detour design for overlays, and the paving materials (Figure 8).

Construction and Maintenance Data

The construction and maintenance inputs are listed and discussed briefly below.

* **Initial serviceability index** — this depends on the materials used and construction practices. A statewide average of 4.2 for ACP is realistic, and surface treatments are 3.8. For a thick ACP, the initial serviceability can be as high as 4.8.

[1]When these inputs are used, pavement structures are often unreasonably thick. A typical use for these inputs is to see how swelling will affect the roughness of a pavement.

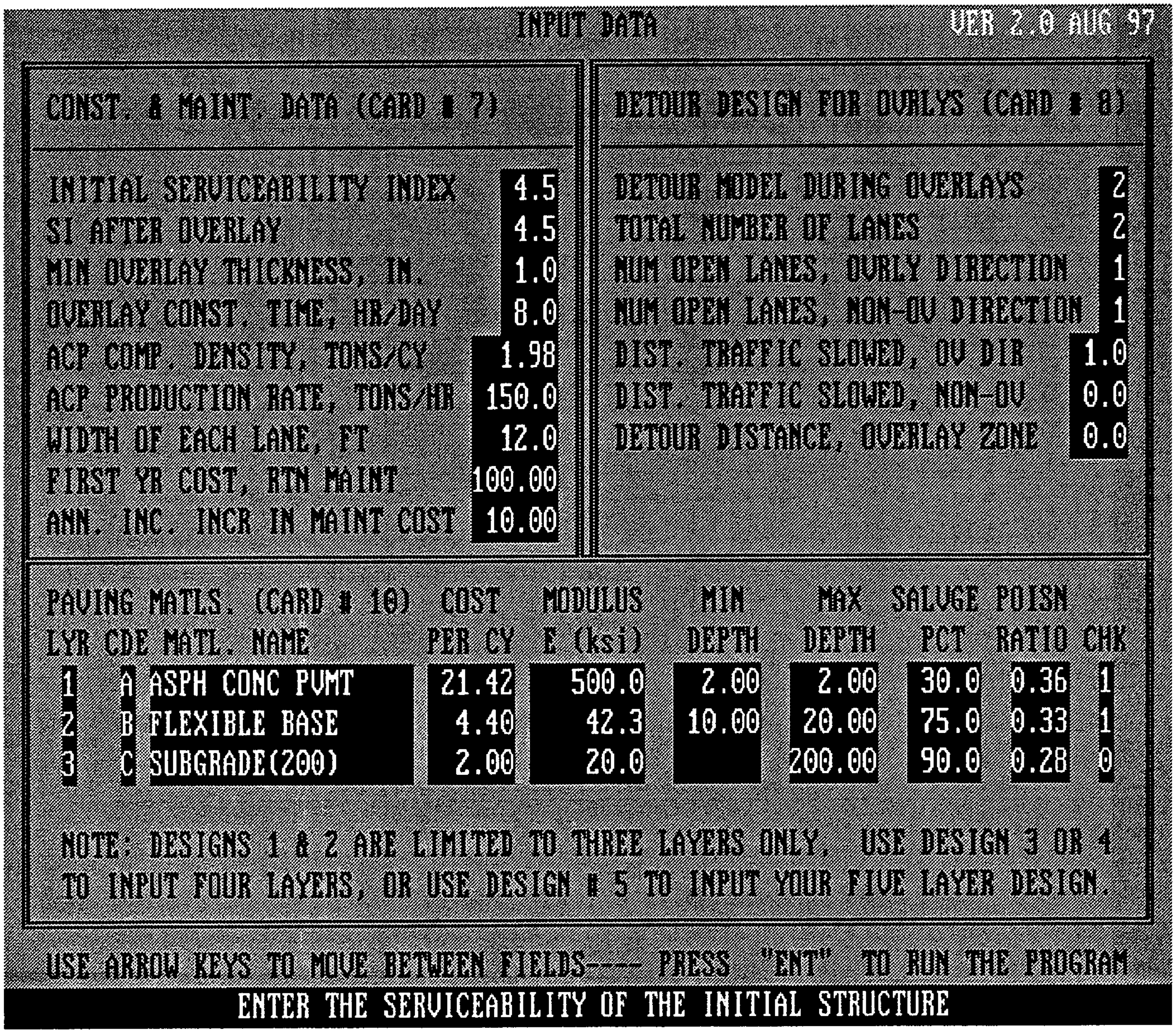


Figure 8. Construction and Maintenance, Detour Design, and Paving Material Inputs.

* **Serviceability index after overlaying** — this input is generally the same as the serviceability index for initial construction, but you must input the value. This value cannot be less than the minimum serviceability index. For most cases, a value of 4.0 is recommended.
* **Minimum overlay thickness** — this input is usually determined by the aggregate gradation specified for future overlays. A one-half inch level-up is automatically added to this thickness and is included in the overlay costs, but is not considered when the strength of the layer is calculated.
* **Overlay construction time (hrs/day)** — the expected number of hours per day that overlay operations take place. This input is used in calculating the number of cars that will be delayed by the overlaying, which affects traffic delay costs.
* **Asphalt concrete production rate (tons/hr)** — used to calculate the time it will take to place an overlay and to determine the number of cars delayed by the overlaying, which affects traffic delay costs.
* **Width of each lane (ft)** — this input is used to calculate the rate of overlaying and affects the number of vehicles that are slowed or delayed due to the overlay work.
* **First year cost of routine maintenance (dollars/lane mile)** — the average cost of routine maintenance for the first year after initial or overlay construction. A statewide average value is $100 per lane mile.
* **Annual incremental increase in maintenance cost (dollars/lane mile)** — the annual incremental increase in routine maintenance cost during each year after initial or overlay construction is assumed to increase at a uniform rate. This cost varies from $10 to $100 per lane mile.

Detour Design Data

The detour design inputs are included on this input screen and are listed below.

* **Detour model used during overlaying** — there are five different methods of handling traffic during overlay operations. There are two methods for two-lane roads (with and without shoulders), and three methods with four or more lanes.

The user should insert the number of the method that will be used for handling traffic during overlay operations.

* **Total number of lanes of the facility** — this input is for main lanes only and is used in determining traffic delay costs during overlay operations.
* **Number of lanes open in the overlay direction** — this input depends on the method of handling traffic during overlaying and the number of lanes of the highway.
* **Number of lanes open in the non-overlay direction** — this input depends on the method of handling traffic during overlaying and the number of lanes of the highway.
* **Distance traffic is slowed (overlay direction)(miles)** — this input is used in calculating the time that vehicles are delayed due to overlaying operations and is input in miles.
* **Distance traffic is slowed (non-overlay direction)(miles)** — this input is used in calculating the time that vehicles are delayed due to overlaying operations and is input in miles.
* **Detour distance around the overlay zone (miles)** — this input is only valid for traffic handling method five. Leave blank unless traffic handling method five is to be used, in which case the input is the distance in miles that the traffic is detoured around the overlay zone.

Paving Material Data

The paving material inputs are listed below.

* **Layer designation number** — each construction material that is input to the computer program must be accompanied by a unique layer designation number that indicates the layer in which the material will be used. Each material is also assigned a unique letter code so that the material can be identified in the output summary table. The layer numbering is done in sequence from top to bottom. Surface materials are 1, base materials are 2, etc. The subgrade should be

numbered as the last layer (3 for three-layer design, 4 for four-layer design, etc.).

* **Letter code of material** — a unique letter code is assigned to each material that is input (including the subgrade) so that the material can be identified in the output summary table.

* **Name of material** — use the space provided to describe the material in each layer.

* **In-place cost/completed C.Y. ($)** — the in-place cost of materials determine the cost of initial construction, cost of overlay construction, and salvage return. A change in the cost of any material may result in a different optimal design for that combination.

* **Elastic modulus of the material (ksi)** — this is an important variable of design because of its function: to represent the structure of the material in the solution process. The MODULUS backcalculation program can be used to determine modulus values of materials in existing pavements from Falling Weight Deflectometer tests run on these pavements if you do not have an idea of what modulus to use for a material. The value that is displayed in this field will be the value from a previous problem, or it will be a default value according to the type of pavement design you selected. You are cautioned to make a reasonable input for each material modulus because of the effect these values have on the final solution. Companion Report 1987-1 includes a discussion on obtaining moduli. Appendix B to this report describes the current default values.

* **Minimum allowable thickness of initial construction (inches)** — the minimum thickness should be carefully selected to prevent thicknesses that are impractical to construct.

* **Maximum allowable thickness of initial construction (inches)** — the minimum and maximum layer inputs determine the range of thicknesses to be considered for each material. The maximum thickness should be carefully selected to prevent thicknesses that are impractical to construct. Wide ranges of thicknesses will cause excessive computation time.

* **Material's salvage value as % of original cost** — for salvage purposes, you should estimate the value of each material at the end of the analysis period and convert this value to a percent of its original construction value. For example, a granular base may retain 80% of its originally invested value, while only 30% of the value of asphaltic concrete may be usable at the end of the analysis period. The present worth of the salvaged materials is used in comparing total costs of alternate designs. It should be remembered that this value has been discounted for the entire length of the analysis period. It may be a negative value.
* **Poisson's Ratio of the material** — this input is used in the structural analysis of each design. Use the help screen for values to use for this input.
* **Check** — this input checks the number of materials for a given problem. A number 1 (one) must be input for all materials except for the subgrade material, which must have a 0 (zero) input in this field.

The "depth to a stiff layer" or subgrade thickness is input on the subgrade line in the "max depth" column. This number normally comes directly from MODULUS.

This completes the inputs for a single problem for the FPS19 program. You have the full range of the editing keys to go back to previous input screens or to move the cursor with the arrow keys to change input values. When you are satisfied with the data inputs, press the "ENTER" key to continue the FPS19 program.

3.5 SAVING THE INPUT DATA AND/OR THE OUTPUT DATA

After pressing the "ENTER" key, a screen will be displayed (Figure 9) which asks if the input data is to be saved. If you select "Y," a window will open (Figure 10) for you to input up to 42 alphanumeric characters for a path and filename. The filename can be edited by pressing the "ESC" key to correct misspelling or to change the name. Press "ENTER" when the correct filename to save the input data has been entered. **Note**: The input for emphasis data is always stored in the "DEFAULT.DAT" file, even if you supply a filename to save the input data. The "DEFAULT.DAT" file is overwritten for each run of the FPS19 program, and it

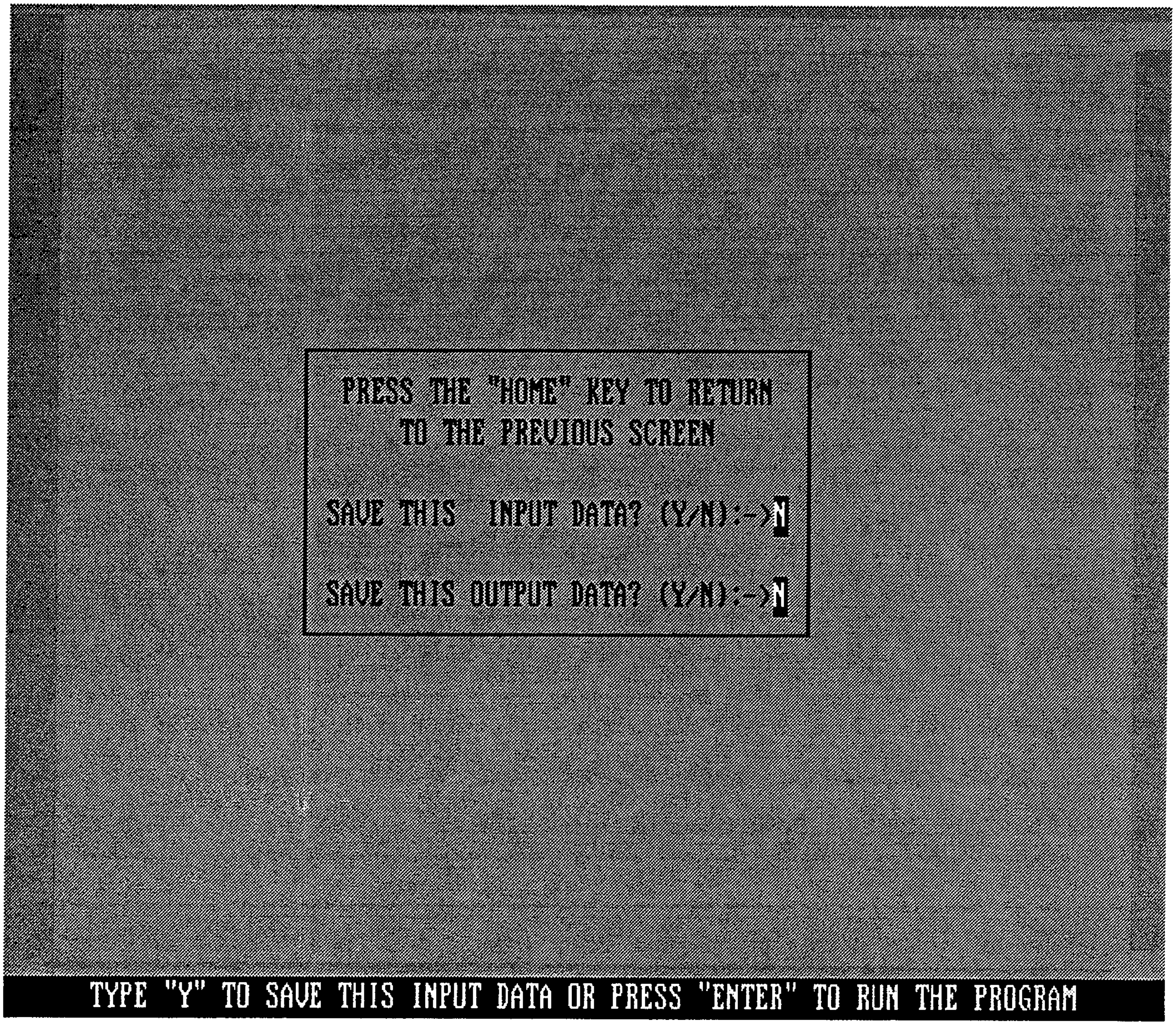


Figure 9. Save the Input Data.

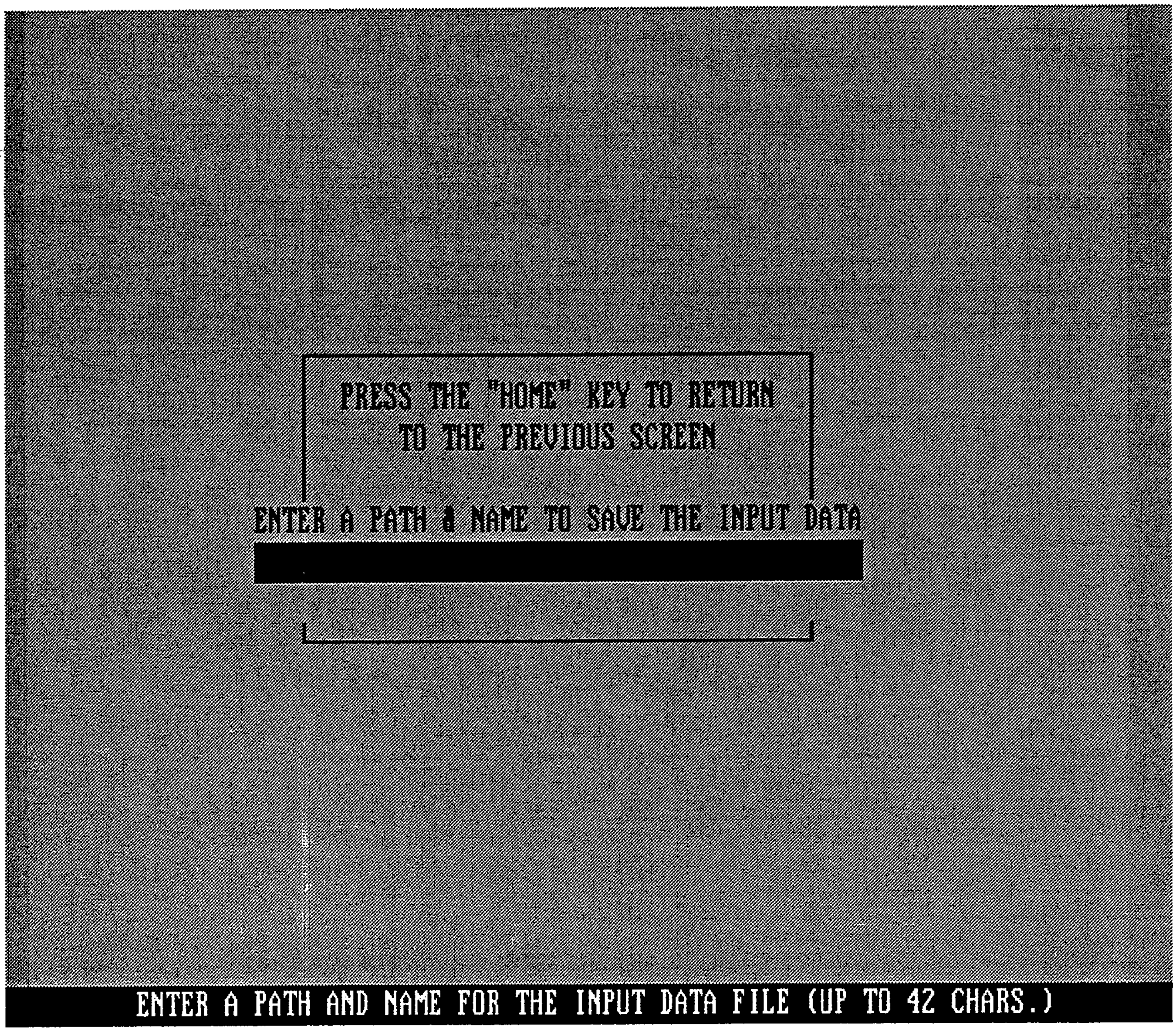


Figure 10. Enter a Name to Save the Input Data.

is best to save the input data if you desire to run the same data again. If the input data is not to be saved in a filename for further runs, press "ENTER" for the option to save the FPS19 program output in a named file.

If you elect to save the FPS19 output in a named file, a window will open (Figure 11) for you to input up to 42 alphanumeric characters for a path and filename. The filename can be edited by pressing the "ESC" key to correct misspelling or to change the name. Press "ENTER" when you have entered the correct filename to save the output. **Note**: The output from each FPS19 run is automatically stored in the "FPS19.OUT" file unless a named output file is specified as above.

The next screen displayed informs you that the FPS19 program is running (Figure 12).

3.6 SCREEN DISPLAY OF BEST STRATEGIES

After the FPS19 program has calculated and ranked the designs, a summary of the best design strategies in the order of increasing total cost is displayed on the screen. Up to 24 of the lowest cost designs will be displayed, eight designs at a time. Press "ENTER" to display the next screen of design summaries. Because of the limitation of the screen size, the design strategy summary outputs are displayed as two separate outputs. The first summary output (Figure 13) includes the material arrangement, the design costs, the total cost, the number of layers, and the thicknesses of the layers. The second summary output (Figure 14) lists the number of performance periods, the performance period times (in years), the overlay policy(s), and the swelling clay loss of serviceability for each of the strategies shown previously. You can view this screen display of the summary output again by pressing the "HOME" key to re-display the first summary output page. It should be noted that the number of feasible strategies that will be calculated is dependent on the data input. If there are no feasible designs for the data input, a message will be displayed (Figure 15) to inform you of this. In this case the input conditions are too restrictive to arrive at a feasible solution. You generally need to increase maximum thicknesses of layers or change material types.

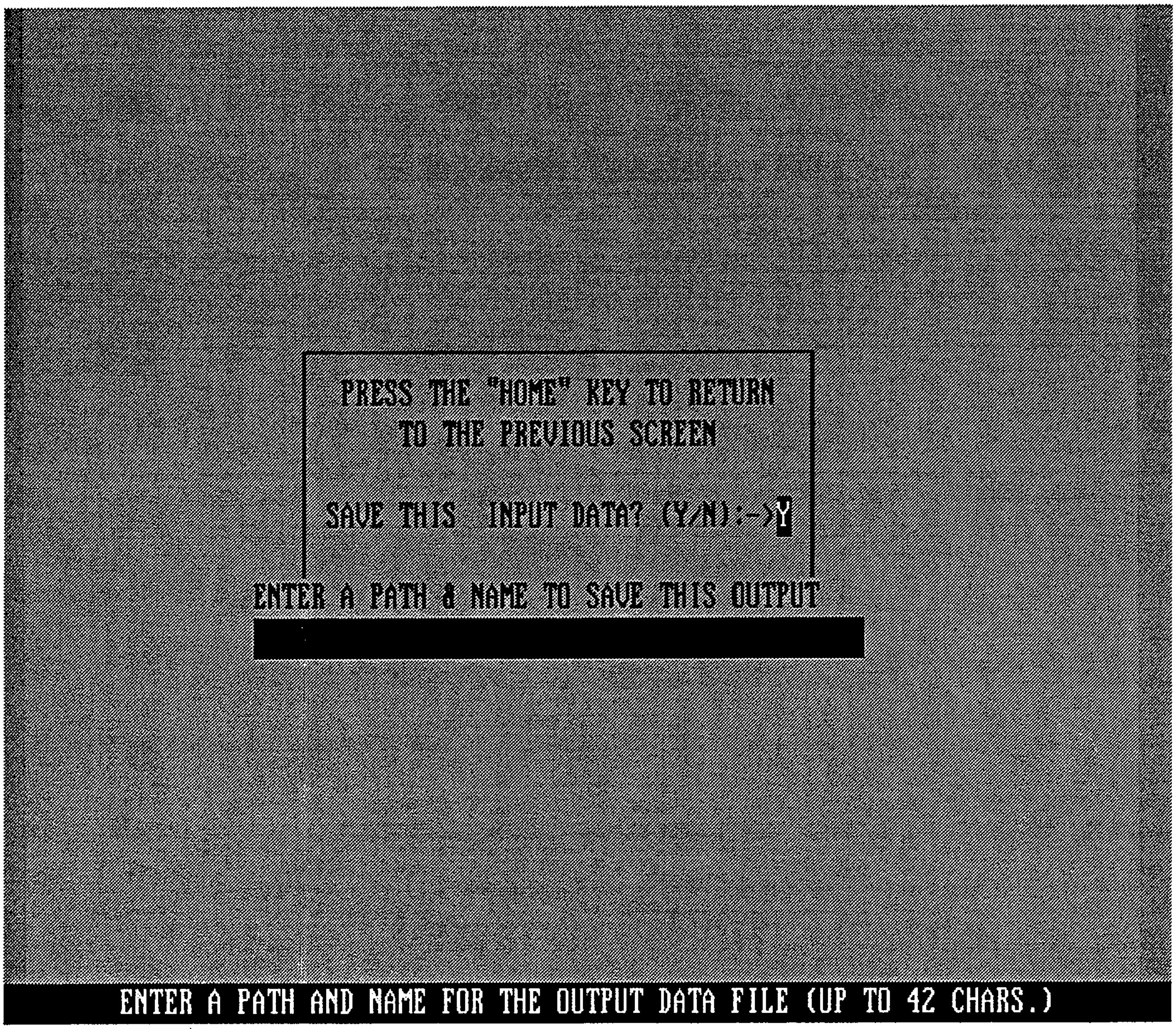


Figure 11. Enter a Name to Save the Output Data.

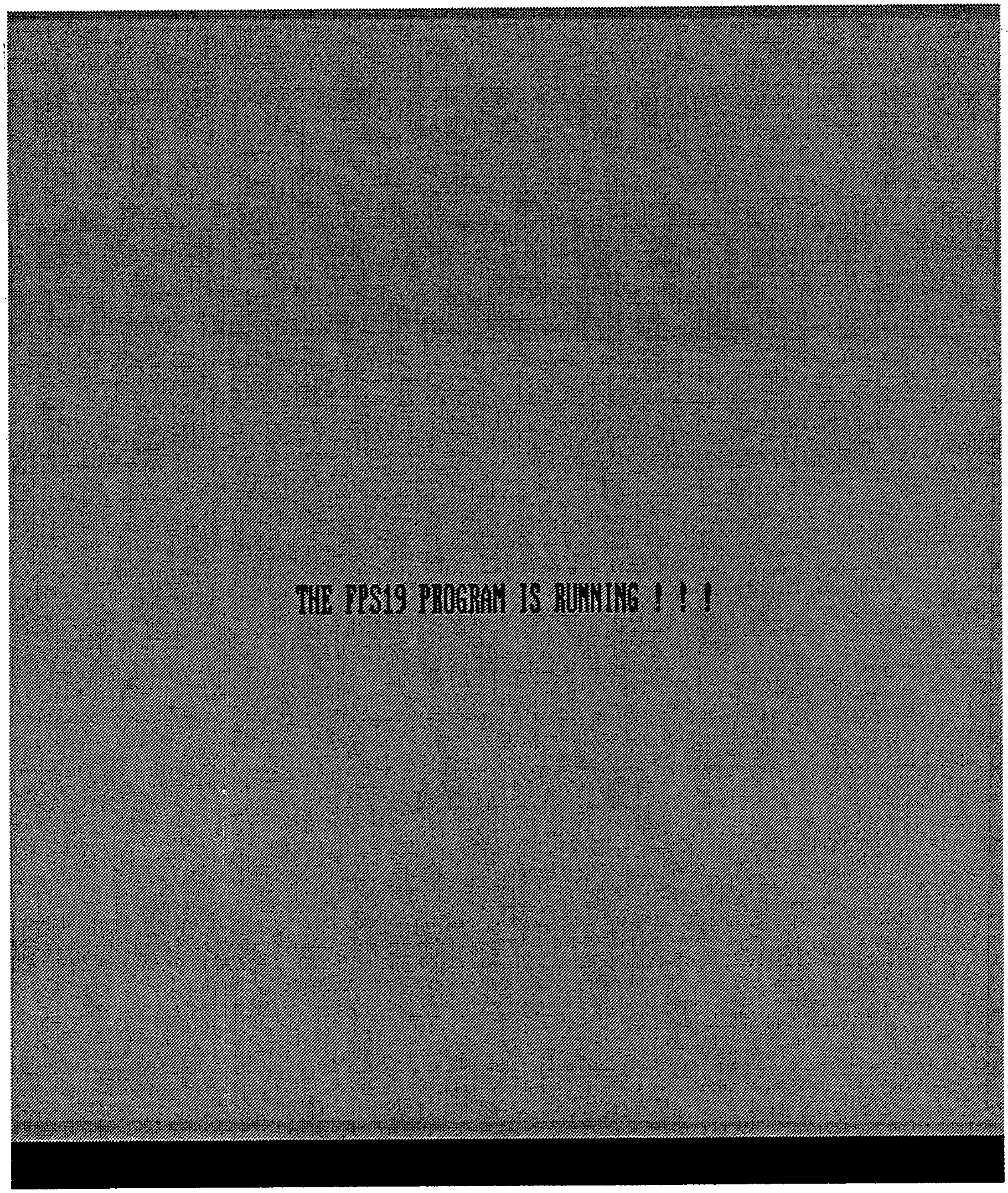
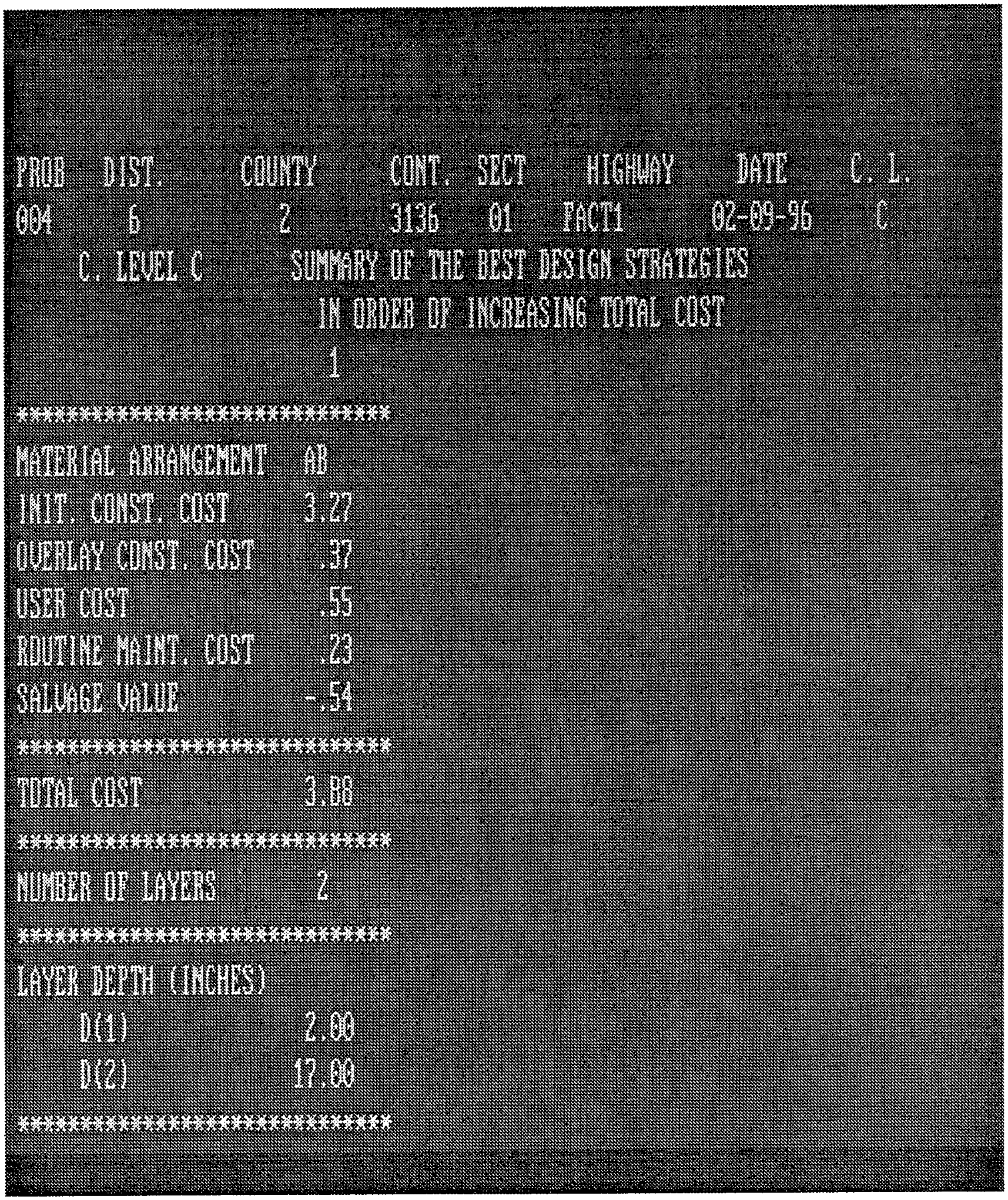


Figure 12. FPS19 Program Running Message.



```
PROB  DIST.     COUNTY     CONT.  SECT    HIGHWAY     DATE     C. L.
004     6          2       3136    01    FACT1      02-09-96     C
     C. LEVEL C       SUMMARY OF THE BEST DESIGN STRATEGIES
                        IN ORDER OF INCREASING TOTAL COST
                         1
*****************************
MATERIAL ARRANGEMENT   AB
INIT. CONST. COST     3.27
OVERLAY CONST. COST    .37
USER COST              .55
ROUTINE MAINT. COST    .23
SALVAGE VALUE         -.54
*****************************
TOTAL COST            3.88
*****************************
NUMBER OF LAYERS       2
*****************************
LAYER DEPTH (INCHES)
     D(1)             2.00
     D(2)            17.00
*****************************
```

Figure 13. Screen Display of Best Designs, Part I.

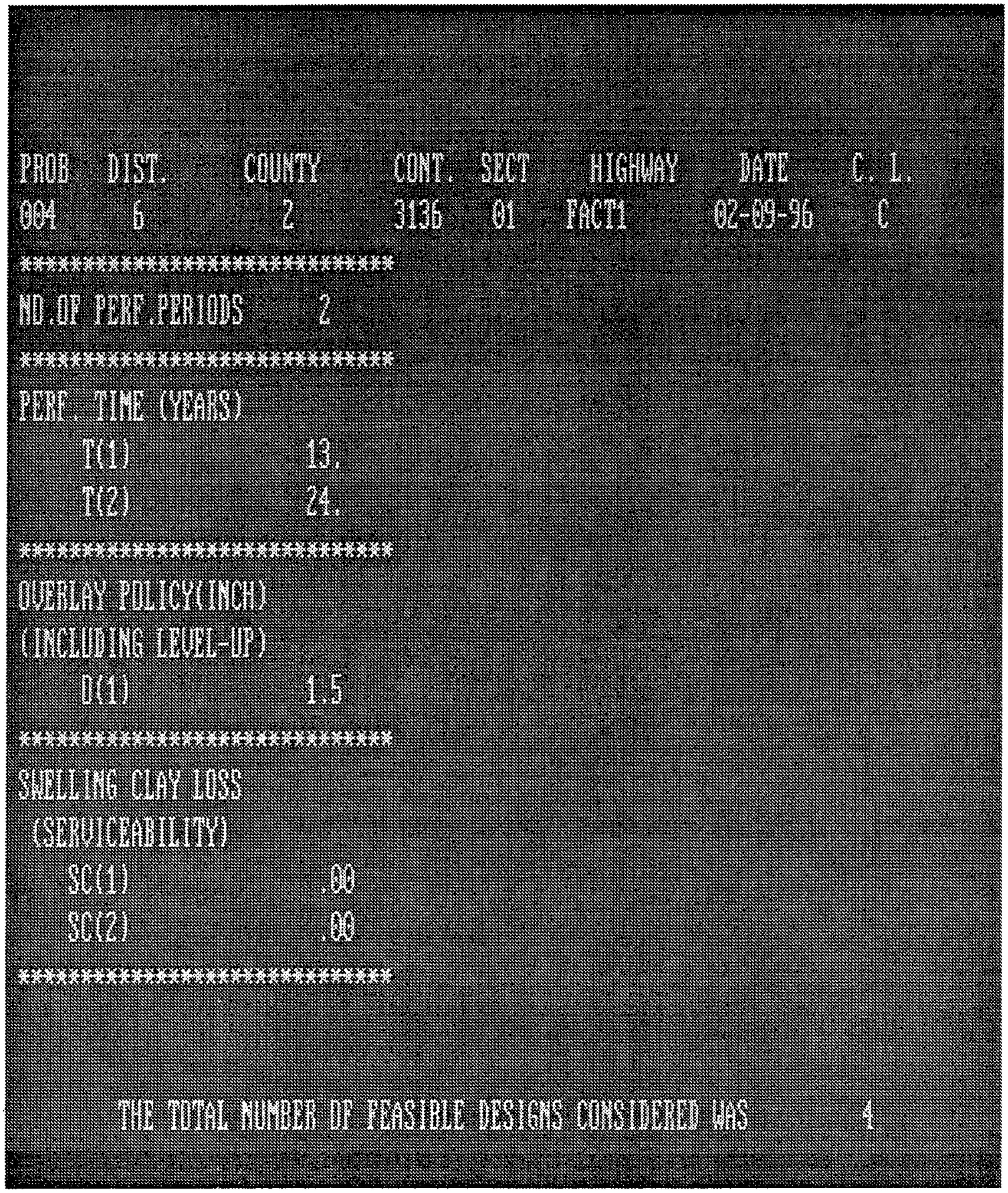


Figure 14. Screen Display of Best Designs, Part II.

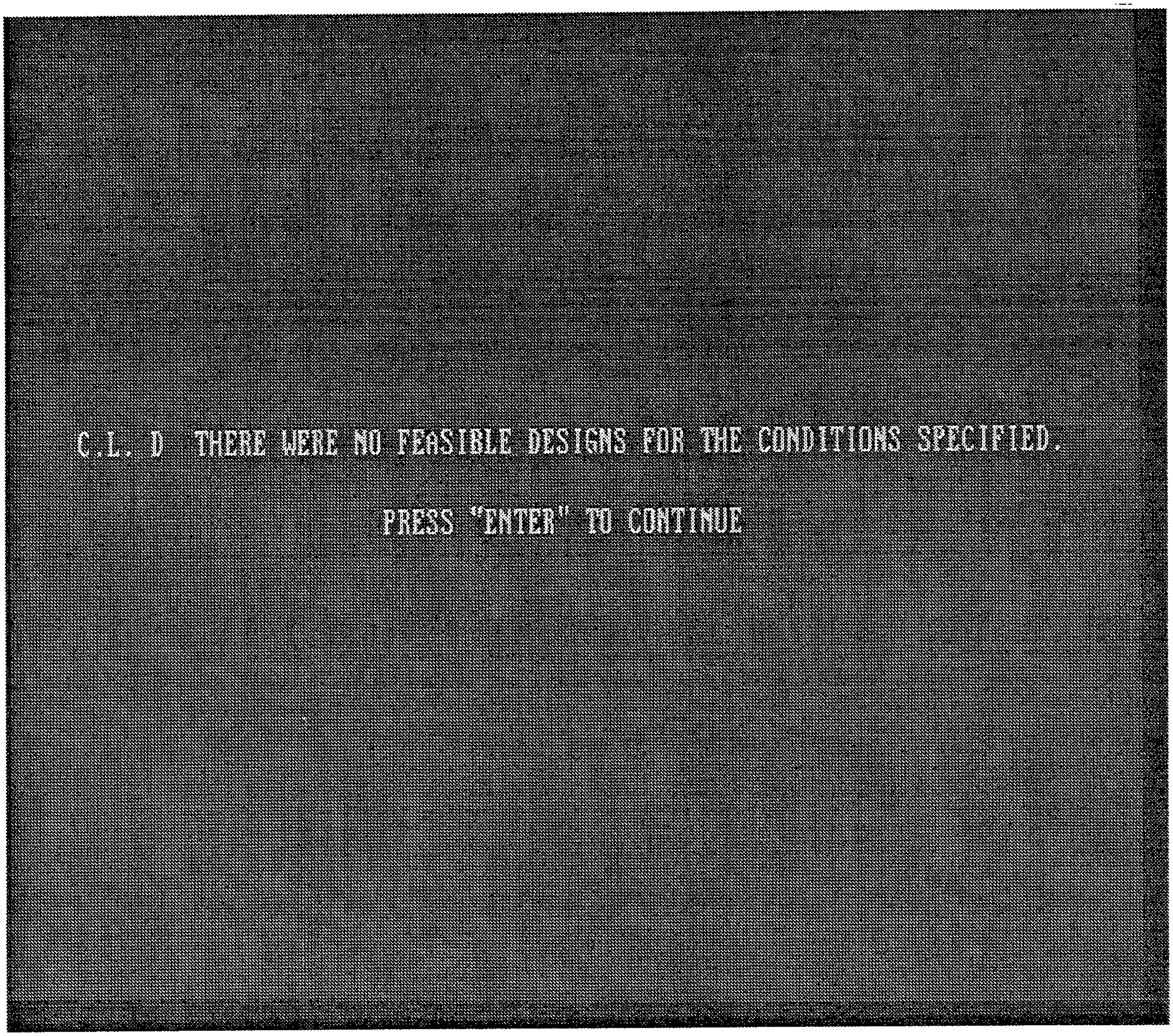


Figure 15. No Feasible Designs Message.

3.7 PRINT THE FILE

The next screen displayed after the summary of best strategies prompts you to print the file (Figure 16). If you select this option, the full FPS19 output will be printed and correctly formatted, just as if the output had been saved in a file and printed at a later time. The full output for the current problem will always be saved in the "FPS19.OUT" file unless you have specified a particular name for saving the FPS19 output in the output data filename field (Figure 11). You can obtain the full output of the current FPS19 run by either exiting the FPS19 program and printing the "FPS19.OUT" file or printing the saved output file, if you selected this option.

3.8 RUN ANOTHER PROBLEM

The final screen displayed for an FPS19 run gives you the option to run a new problem, to run the FPS19 program again with the same data, or to stop the FPS19 program (Figure 17).

Selecting "1", to run a new problem, and then pressing "ENTER" will return you to the project identification screen. The data inputs displayed are the values from the previous FPS19 program run. The exceptions to this are that the materials screen inputs are reset to their default values, and they will be changed if an existing data file is specified.

Selecting "2", to run again with the same data, will return to the basic design criteria input screen. The data values displayed are from the previous FPS19 program run. These data values can be edited or used as is. If the user is allowing FPS19 to calculate the base layer moduli for pavement type 1, a change to the subgrade modulus using option "2" will not cause a change in the base modulus calculation. After all the data has been entered, but before the program execution begins, the previous program run comments are re-displayed for you to change to reflect any changes in the data for this problem from the previous problem.

Selecting "3" and pressing "ENTER" will end the FPS19 program and return to the DOS prompt.

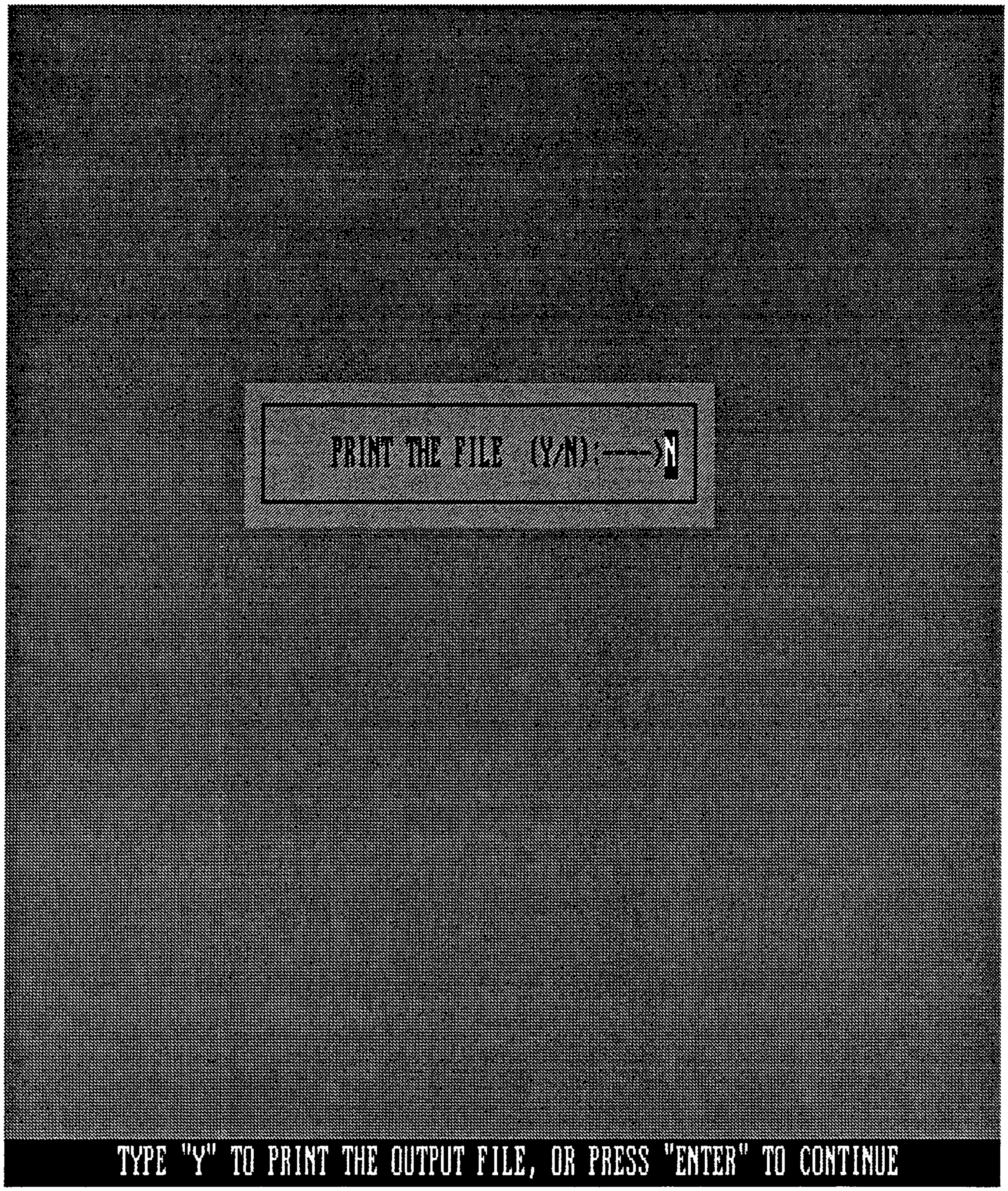


Figure 16. Print the File.

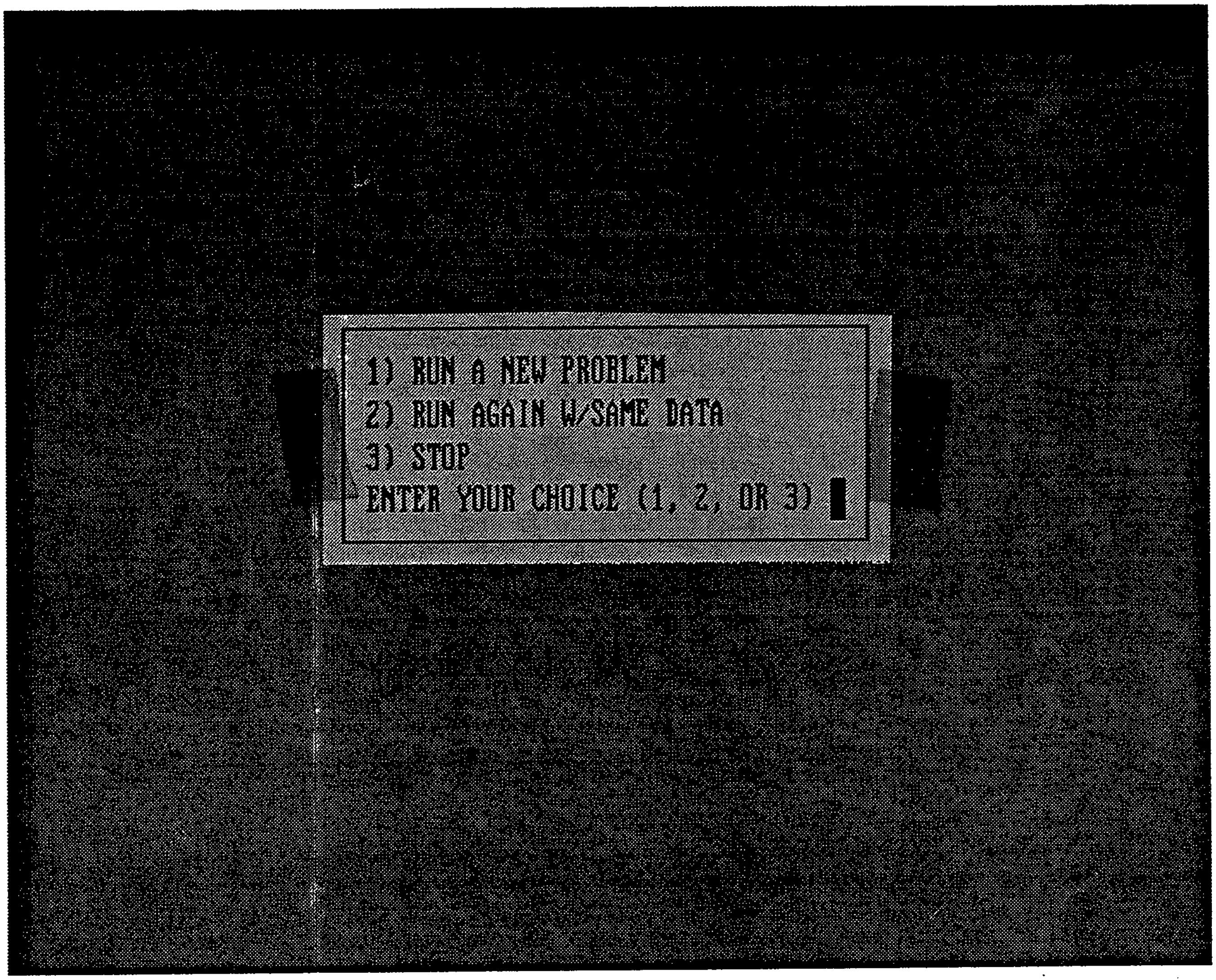


Figure 17. Run Another Problem.

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Scrivner, F. H., Moore, W. M., McFarland, W. F., and Carey, G. R., "A Systems Approach to the Flexible Pavement Design Problem," Research Report 32-11, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1968.

Scrivner, F. H., and Michalak, C. H., "Flexible Pavement Performance Related to Deflections, Axle Applications, Temperature and Foundation Movements," Research Report 32-13, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1969.

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APPENDIX A

PROGRAM INSTALLATION GUIDE

COMPATIBILITY

The FPS19 program has been written in a combination of languages to ensure its compatibility with today's personal computers. One of the principal components of displaying the screens in the program is a screen generator, Hi-Screen Pro. Future operating systems may not support this screen generator, but currently, Microsoft© DOS, Windows 3.1, Windows 95, and Windows NT (3.51 and 4.0) are compatible; FPS19 will run under any of these platforms.

The appearance of FPS19 while running in different environments differs only in the way the operating systems (or overlays) handle "DOS" operations. All DOS versions 5.0 and later will display the program full-screen. The later platforms, such as Windows 3.1 to Windows NT, display the program in a window that is running DOS or a simulation of DOS.

The minimum system requirements are:

- 486DX or better microcomputer.
- DOS operating system, version 5.0 or later, Windows 95, or Windows NT (3.51 or 4.0).
- Minimum of 530 kb or free "low-DOS" RAM (not applicable for Windows 95 and NT).
- A hard disk with a minimum of 1MB of usable storage available.
- Minimum of an EGA or VGA graphics card with 256 kb of screen memory, and a compatible monitor.
- Optional dedicated printer.

INSTALLATION

For all operating systems, a directory is created on the hard drive. The program files are copied to this directory and are executed from it.

Program Files

The FPS 19 program is furnished on a 3 1/2" diskette and consists of 14 files. The following files are the minimum needed to execute the program (other text files are created when the program is executed).

BEG.COM	1,096	5/2/89
BRUN45.EXE	77,440	9/28/88
DEFAULT.DAT	801	6/16/98
DESIGN1.DAT	231	6/9/97
DESIGN2.DAT	231	6/9/97
DESIGN3.DAT	308	6/9/97
DESIGN4.DAT	308	6/9/97
DESIGN6.DAT	385	6/9/97
DISPLAY.COM	35,078	5/12/89
END.COM	383	5/2/89
FIN58.EXE	73,424	9/10/97
FPS19.BAT	36	4/18/97
FSS58.EXE	282,640	9/9/97
SCREENS.LBR	110,256	9/17/97

It is always advisable to make a backup copy of the FPS19 diskette in case the program files need to be reloaded.

Copying the Program

To make a copy of the program, either create the directory in DOS using the MAKE DIRECTORY (md) command and specify the directory name (FPS19) or create the directory using the File Manager or file Explorer. If all files are listed with the names as shown above, copy the files from the diskette to the new directory. There are no installation procedures required to execute FPS19.

The following DOS commands may be helpful for inexperienced DOS users attempting to copy the FPS19 program for execution (these commands may also be used in a DOS box when using a Windows environment):

a. Insert the FPS19 diskette into the disk drive (assumes the 3 1/2" drive is drive A).

b. From the C:> prompt, make the FPS19 directory. Type: **md c:\FPS19**, ENTER.

c. Change to the FPS19 directory: **cd\FPS19**, ENTER.

This will create the following display: C:\FPS19>.

d. Copy the FPS19 program files to the FPS19 subdirectory: **Copy A:*.*.**

Program Execution

No further installation, beyond copying the listed files, is required to execute FPS19. The execution method depends on the operating system being used to execute the program. There are many ways to execute the programs in Windows 3.1, Windows 95, and Windows NT; however, only the most common methods will be discussed. The Windows environment offers the option of launching applications by locating and clicking on icons corresponding to the application desired. Please see the operating system user manual for instructions on creating icons to execute FPS19.

DOS users:

Change to the directory where the program has been copied and execute FPS19. The following commands are examples that may be used:

a. From the C:\> prompt, type: **cd\FPS19**, ENTER.

b. Type **FPS19**, ENTER to execute the program.

Windows 3.1 and Windows NT vs. 3.51 users:

There are a number of ways to execute FPS19 in these environments.

a. The program is executed through a DOS window invoked by double-clicking the MS-DOS icon within the Windows environment. By doing so, a window will appear that will have a DOS prompt as though the DOS environment were being used. Execution of FPS19 this way is the same as the execution procedures described for DOS users above.

b. The program may be executed from the Program Manager. From the menu bar at the top of the Program Manager window, select the **File** menu. From the **File** menu, select the **Run** option, which will display a command line dialogue box.

In the dialogue box, type the command for executing the program as though it were being typed at the prompt in the DOS environment. The following example may be used if the program resides in the FPS19 directory on the C: drive:

C:\FPS19\FPS19.BAT.

NOTE: When using this method, the full path and filename must be used.

c. The program may be executed from the File Manager. Once in the File Manager, locate the FPS19 directory containing the FPS19 program files. Once located, double clicking the FPS19.BAT file will launch the DOS window and cause the program execution. Upon termination of the program, the DOS window will close.

d. The program may also be executed with an icon from the Program Manager. Although the process of doing this is not described here, it is one of the most efficient ways to execute the program. Once the FPS19 icon is present, generally, moving the mouse pointer to the icon and double-clicking the right mouse button will automatically execute the program. The program will be run out of a DOS window that will accept typical DOS commands. Upon termination of the program, the DOS window will close. Please see the operating software user manual for further detail.

<u>Windows 95 and Windows NT vs. 4.0:</u>

Execution of FPS19 under these operating systems is similar to execution in Windows 3.1 and Windows NT vs. 3.51, except differently named applications are used to execute the program.

a. Both systems have similar MS-DOS icons that will invoke a DOS box. Once the DOS box is running, execution of FPS19 is as described in the paragraphs above.

b. Both systems have an option to locate the FPS19 program files using the Explorer application. The Explorer (95 or NT) is found by selecting Start on the menu bar and selecting Programs. Under Programs, selection of Explorer will display the file structure of your computer's drives. Locate the FPS19 subdirectory and the program files; double-clicking the FPS19.BAT file will launch a DOS box and execute FPS19.

c. Similar to the procedure described above, FPS19 may be executed from a command line, provided that the path to where the program resides is known. To execute the program using this method, select Start on the menu bar and then select Run. Selecting the Run option will display a command line dialogue box. The following command line will execute FPS19 provided the program files are located in the FPS19 directory on the C: drive:

C:\FPS19\FPS19.BAT.

NOTE: When using this method, the full path and filename must be used.

d. The program may also be executed with an icon. Please see the operating software user manual for further detail on executing applications using icons.

APPENDIX B

FPS19 PERFORMANCE MODELS AND DEFAULT MODULI VALUES

INTRODUCTION

The TxDOT developed its Flexible Pavement Design System in the 1960's, following an extensive study of the performance of Texas pavements. This work was documented in the suite of research reports in the 23 and 32 series. The focal point of these efforts was research report 32-11, *A Systems Approach to the Flexible Pavement Design Problem.* The system described in that report was implemented in the FPS 11 design program. This is one of the earliest implemented mechanistic design procedures. The layer strength inputs were "stiffness coefficients" calculated from analysis of Dynaflect deflection bowls, and the critical pavement response in the performance prediction model is the computed Surface Curvature under the design wheel load. This surface curvature is used to predict the loss of present serviceability index with time caused by wheel loads; the loss caused by expansive clays was also considered in the expanded PSI prediction model. A reliability term was added to permit the designer to account for the variability found in the design process.

This system was implemented in the early 1970's and for over 20 years has been the standard flexible pavement design program of the TxDOT. The system was tuned to handle the wide variety of materials and pavement structures found in Texas. When new base types were used, a new "stiffness coefficient" was generated based on both the observed performance and Dynaflect test results. In general the system was judged to be performing well, and the Pavement Design Division provided support and training to the district offices responsible for the design work. However, in the 1980's, several events occurred that necessitated the need to develop an updated design system. First, TxDOT replaced its Dynaflects with a fleet of Falling Weight Deflectometers. Second, backcalculation schemes were developed to compute insitu elastic moduli values from the FWD deflection bowls, and third, there was an interest within the Design Division of TxDOT to move to a more mechanistic procedure which would permit the estimation of both rutting and load associated cracking in addition to PSI. This led to the initiation of Project 455 in the late 1980's to develop an improved Flexible Pavement Design program.

Project 455 was a five-year effort, which lead to the development of the TFPS computer model for performing flexible pavement thickness designs. The technical background of TFPS, as well as several document case studies, were summarized in TTI report 455-1, which was presented to TxDOT in 1992. TFPS provided many important upgrades to the existing modeling capabilities and offered great potential for future development. However, TxDOT decided that the new system was not ready for full-scale implementation. It was concluded that the mechanistic empirical procedures could not adequately handle the vast array of material types and pavement structures designed by TxDOT. TFPS could not adequately handle the very thin surface treated pavements common to most Texas districts; it also had trouble with the chemically stabilized bases which have become common in Texas. In some instances, it was reported that the system supplied to TxDOT was unstable with certain pavement configurations because a small change in pavement modulus could result in a large change in predicted pavement life.

The failure of TFPS to meet the needs of TxDOT was a major concern to TxDOT. While it had a fleet of FWDs and a reasonable backcalculation procedure (MODULUS), it had no design procedure it could recommend for every day district use. At that stage, Mr. Bob Briggs, then with TxDOT's Pavements Division, initiated a research project to determine if it was feasible to modify the FPS 11 system to utilize input from Falling Weight Deflectometers. The FPS19 program is the outcome of that study. Details of FPS19 are given in this appendix. However, it should be acknowledged that FPS19 is viewed as the first step in implementing FWD-based design procedures. TxDOT must continue with the research needed to improve all facets of its pavement design procedures, including enhancing the original TFPS system.

PERFORMANCE EQUATION

The performance equation introduced in TTI Research Report 32-11 included a term assumed to represent the effect on serviceability loss of both load associated damage and differential foundation movements. The full equation is repeated below.

$$Q_2 = \frac{0.134\ (N_k - N_{k-1})S^2}{\bar{\alpha}} + Q_2'(1 - e^{-b_k(t_k - t_{k-1})}) \tag{1}$$

The definitions of the variables appearing in Equation 1 listed below are from Report 32-11. A performance period, a phrase occurring frequently in the definitions, is the interval between the time of initial or overlay construction to the time the next overlay is required. The performance periods are numbered consecutively, the first period being the time interval between initial construction and the first overlay. Equation 1 applies to the k^{th} performance period.

Performance Variables

t = time (years) since original construction.

P = the serviceability index at time, t.

P_1 = the expected maximum value of P, occurring only immediately after initial or overlay construction.

P_2 = the specified value of P at which an overlay will be applied.

P_2' = swelling clay parameter — the assumed value of P at $t = \infty$ in the absence of traffic. In general, $0 \le P_2' \le P_1$.

b_k = a swelling clay parameter applying to the k^{th} performance period.

t_k = the value of t at the end of the k^{th} performance period, or the beginning of the next period. $t_0 = 0$.

N = number of 18 kip ESAL.

N_k = the value of N at the end of the k^{th} performance period. $N_0 = 0$.

Q = the serviceability loss function, $= \sqrt{5 - P} - \sqrt{5 - P_1}$.

Q_2 = Q when $P = P_2$.

$Q_2' = \sqrt{5 - P_2'} - \sqrt{5 - P_1}$.

α = a daily temperature constant = ½ (maximum daily temperature + minimum daily temperature) - 32°F.

$\bar{\alpha}$ = the effective value of α for a typical year in a given locality, defined by the formula for the harmonic mean:

$$\bar{\alpha} = \frac{n}{\sum_{i=1}^{n} (\frac{1}{\alpha_1})} ,$$

where n is the number of days in a year, and α_1 is the value of α for the i^{th} day of the year. To obtain an approximate value of $\overline{\alpha}$ for this report, the formula was used with n = 12, and α_1 = the mean value of for the i^{th} month averaged over a 10 year period.

S = Surface Curvature Index as shown in Figure 1, under slowly moving design load (similar to Benkelman Beam Loading).

Computation of Surface Curvature Index

The S value in Equation 1 is the critical parameter that governs required pavement thickness. As described above, it is the computed value measured on the pavement surface between slowly moving dual tires loaded to 40 kn (9,000 lbs).

The S value is computed in both FPS11 and FPS19 based on the strengths obtained under both Dynaflect and FWD loading. In FPS11, a regression equation was developed (TTI Report 32-13) relating S^1 and measured under a Dynaflect to S as measured under an 18 kips single axle, as shown below:

$$S = 20\, S^1 \tag{2}$$

This is a great simplification, as it is known that the relationship is <u>not</u> independent of pavement type. Nevertheless, inside FPS11 equations were included to calculate S^1 from the input layer stiffness coefficients. The design value S was obtained by use of Equation 2.

In FPS 19 a different approach is taken. The input layer moduli values and thicknesses are used within WESLEA linear elastic program to compute the Surface Curvature Index under the design load. This computed value is then adjusted to account for both (a) the difference between FWD and Truck Loading and (b) the effect of speed. These adjustments were generated by use of the equations developed in TTI Report 1184-2, Volume 2 (Akram, Scullion & Smith, Sept. 1992). In that study both thin and thick flexible pavements were instrumented with Multi-depth Deflectometers and loaded with both FWD and truck loads traveling at 90 km (55 mph). One important part of Report 1184 was to use the FWD data to backcalculate layer

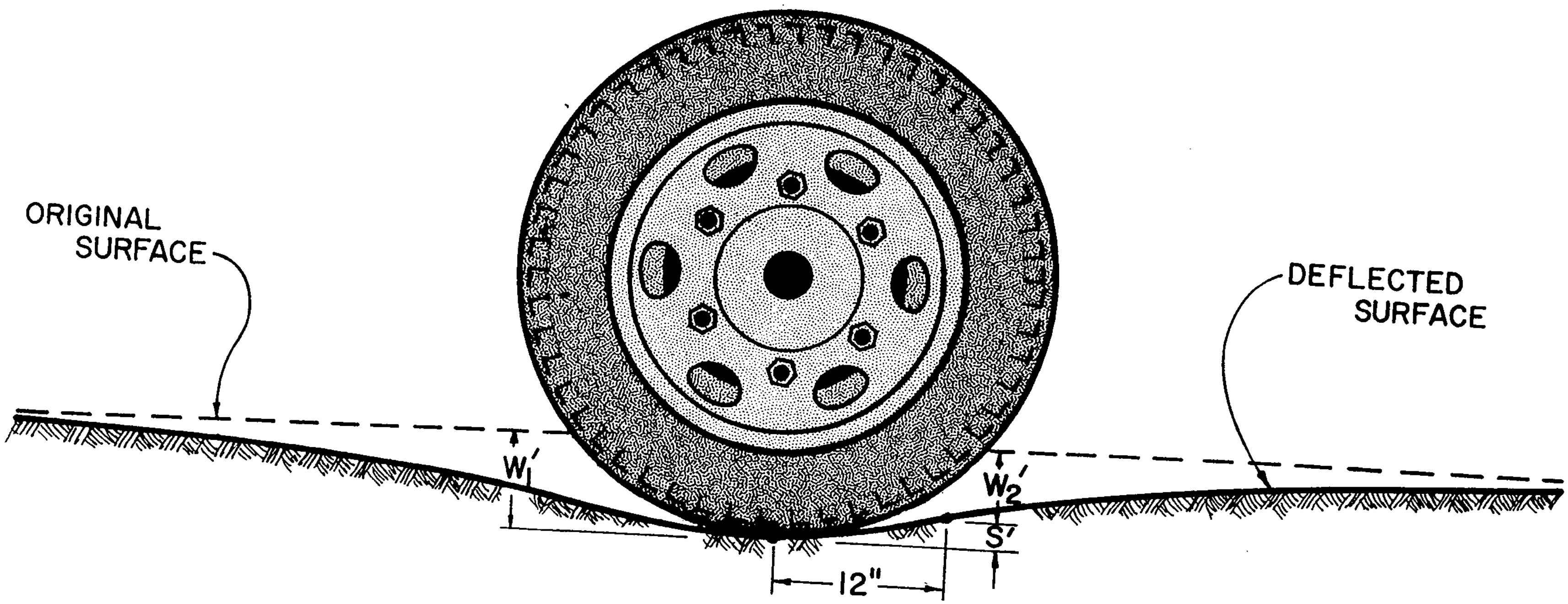

Figure B-1. The Deflection Difference, S, Used as a Measure of Surface Curvature (Report 32-13).

moduli values and then to use the values to predict what deflections and vertical compressive trains would occur at depth under truck loading. These computed deflections and strains were then compared with those measured with the Multi-depth Deflectometer. The correlation between the predicted and measured strains was surprisingly good. However, it was concluded that, in general, the FWD prediction slightly underestimated the high-speed truck measured values by an average of 16%.

A second phase of the 1184 report was to relate SCI to vehicle speed. A factorial series of runs were made on both the thin and thick pavements at various speeds, tire pressures, and axle load. For the above situation the following two regression equations were developed.

Thin Pavement

$$SCI = 1.6116 - 0.0086\,(Sp) + 0.0308\,(Tp) + 0.9005\,(Ld) + 0.0028\,(Pr) \tag{3}$$

Thick Pavement

$$SCI = 0.7017 - 0.0135\,(Sp) + 0.0042\,(Tp) + 0.3307\,(Ld) + 0.0001(Pr) \tag{4}$$

where:

SCI	=	Surface Curvature Index (mils);
Sp	=	Vehicle Speed (mph);
Ld	=	Axle Load (kips);
Pr	=	Tire Pressure (psi); and
Tp	=	Temperature of Asphalt (°F).

The equations themselves demonstrate that the SCI measured under a slowly moving truck will be greater than that under a truck traveling at highway speeds. Also, the effect of truck speed will be more significant on pavements with thick asphalt layer than those with thin surfacings. The speed of loading results of Report 1184 was summarized in the following equation, which was incorporated into FPS 19.

$$SCI_D = SCI * (1 + F) \tag{5}$$

where:

SCI_D = the speed corrected SCI value to be used in design equation;

SCI = 1.16 * SCI_c;

SCI_c = SCI computed from WESLEA using FWD backcalculated layer moduli;

F = (4h - 5)/100; acceptable range min = 0, max = 0.35; and

h = thickness of all ACP layers.

In summary, within FPS19:

1. The SCI is computed using WESLEA with moduli values obtained from FWD testing.
2. This value is increased by 16% to account for the observed average differences between FWD and Truck Loading.
3. Using Equation (5), a factor is generated to account for the impact of vehicle speed. This factor ranges from 0% for thin pavements to 35% for thick asphalt pavements.

Default Moduli Values

To effectively use FPS19, each Texas district must test the variety of pavement materials used in its district with a Falling Weight Deflectometer. For new pavement design, district specific moduli values should be developed for each base type used. The subgrade moduli values should also be input from FWD analysis.

However, in order to assist with the implementation of FPS19, a series of default moduli values are stored in the DEFAULT.DAT files for each pavement type. These default values are described below.

Subgrade Moduli Values

As described in TTI Report 1989-1, a subgrade strength classification is available for each Texas county from the Pavement Management System (PMIS). This classification is based on the network level FWD data stored within the system. The classification is a 1 through 5 scale, with 1 being very strong, and 5 being very weak. A value of 1 would be interpreted to mean that, on average, the subgrade strength values within this county have been generally classified as very good.

This classification was incorporated into FPS19, the 1 through 5 classification was translated into moduli values of 20, 16, 12, 8, and 4 ksi. Therefore, once the user specifies the county number for which the pavement is being designed, one of these default values will be loaded within the system. Under normal operating procedures, this default value will be overwritten with a project specific value.

Granular Base Moduli Values

The Corps of Engineers equation, shown below, is used in Pavement Type = 1 only, to compute a granular base moduli value.

$$E_B = E_S\,(1 + 9.07 \log h_b - 1.85 \log h_b \log E_s) \tag{6}$$

where:

E_S = Subgrade Modulus (ksi);

E_B = Base Modulus (ksi); and

h_b = Thickness of Base in inches.

In general this equation generates factors of between 2.5 and 4, predicting that the modulus of the base will be 2.5 to 4 times the modulus of the subgrade. This is consistent with values found in Texas on unstabilized granular materials.

Equation 6 also indicates that the base modulus is also a function of granular base thickness. This relationship is used in Pavement Type 1 (thin AC over granular base) designs in FPS19. If the user inputs the base and subgrade modulus from FWD testing, the relationship in Equation 6 is still used to account for the beneficial effect of increasing base thickness.

Thick Granular Bases (Pavement Type = 1 only)

Several districts prefer to use very thick granular bases in preference to stabilized subbases. Granular base thicknesses of greater than 400 mm (16 in) are not uncommon in some districts. To accommodate very thick granular bases within FPS19, for bases greater than 250 mm (10 in), the base will be broken into two layers. Equation 6 will be used to calculate the modulus for the lower base. For the upper-base, the E_s value from equation 6 would be set to the value of the 250 mm lower-base value and higher modulus computed for the upper-base thickness greater than 250 mm.

For example, if E_s = 16 ksi, then the following E_B values would be computed using the Corps of Engineers equation, with the additional layer added for bases thicker than 250 mm (h_b):

If	h_b = 150 mm (6 in)	$\Rightarrow$	E_B = 32 ksi
	h_b = 250 mm (10 in)	$\Rightarrow$	E_B = 36.7 ksi
	h_b = 300 mm (12 in)	$\Rightarrow$	E_B = 36.7 ksi (lower 250 mm)
			E_B = 43.5 ksi (upper 50 mm)

The experienced microcomputer user need only to create a directory on the hard drive and copy the 14 files from the source diskette to this directory.

For the inexperienced microcomputer user, the source diskette contains an INSTALL.BAT file that will create a directory named "FPS19" on the "C" hard drive and copy the FPS19 files from the diskette to the hard drive.

To use the automatic installation, follow the steps listed below (this assumes the "A" drive is the 3 1/2" diskette drive and the system is at the DOS C:> prompt).

1) Insert the source diskette in the "A" diskette drive.
2) Make the "A" drive the active drive.

   Ex: C:> A:, cr
3) Run the INSTALL.BAT program.

   Ex: A:> INSTALL, cr

The DOS prompt “C:\FPS19>” should be showing if the FPS19 installation was successful.

Ex: C:FPS19>

4) Remove the source diskette from the “A” drive. Verify that the 14 files from the source diskette were copied to the "FPS19" directory.

Ex: C:FPS19> DIR/W, cr

It is always advisable to make a back-up copy of the FPS19 source diskette in case the program files need to be reloaded.