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AN INTEGRATED PAVEMENT DESIGN PROCESSOR

by

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Research Report Number 123-22

A System Analysis of Pavement Design
and Research Implementation

Research Project 1-8-69-123

conducted for

The Texas Highway Department

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

by the

Highway Design Division
Texas Highway Department

Texas Transportation Institute
Texas A&M University

Center for Highway Research
The University of Texas at Austin

May 1974

DISCLAIMER

The contents of this report reflect the views of the authors 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. Reference to specific makes or models of computer equipment is made for identification only and does not imply endorsement by the sponsors of this report.

PREFACE

This report is one of a series issued under Research Study 1-8-69-123, "A Systems Analysis of Pavement Design and Research Implementation". The study is being conducted jointly by principal investigators and their staffs in three agencies -- The Texas Highway Department at Austin, The Center for Highway Research at Austin, and The Texas Transportation Institute at College Station, as a part of the cooperative research program with the Department of Transportation, Federal Highway Administration.

Included herein are the design, utilization, and implementation of an integrated pavement design processor (IPDP). The IPDP integrates a rigid pavement design system, an asphaltic concrete pavement overlay design system, and three versions of a flexible pavement design system--one based on the AASHO structural number concept, another based on Dynaflect deflection, and a third based on linear elastic theory. The IPDP has been developed as an on-line man-machine conversational decision and analysis framework. It is anticipated that the interactive, multi-optional, open-ended, broad-based, and user-oriented features of the IPDP will facilitate the implementation of the systems analysis of pavement design.

The cooperation and assistance given by many individuals in the Texas Transportation Institute are sincerely appreciated. Mr. Dale L. Schafer and Mr. Chester H. Michalak were particularly helpful throughout this research effort.

Special appreciation is extended to Mr. James L. Brown of the Texas Highway Department for technical advice and consultation in the preparation of an implementable pavement design processor.

Also, we are very grateful to all the companies who have supplied photographs of computer terminals and communication devices and given permission to reproduce these photographs.

LIST OF REPORTS

Report No. 123-1, "A Systems Approach Applied to Pavement Design and Research," by W. Ronald Hudson, B. Frank McCullough, F.H. Scrivner, and James L. Brown, describes a long-range comprehensive research program to develop a pavement systems analysis and presents a working systems model for the design of flexible pavements.

Report No. 123-2, "A Recommended Texas Highway Department Pavement Design System Users Manual," by James L. Brown, Larry J. Buttler, and Hugo E. Orellana, is a manual of instructions to Texas Highway Department personnel for obtaining and processing data for flexible pavement design system.

Report No. 123-3, "Characterization of the Swelling Clay Parameter Used in the Pavement Design System," by Arthur W. Witt, III, and B. Frank McCullough, describes the results of a study of the swelling clay parameter used in pavement design system.

Report No. 123-4, "Developing A Pavement Feedback Data System," R.C.G. Haas, describes the initial planning and development of a pavement feedback data system.

Report No. 123-5, "A Systems Analysis of Rigid Pavement Design," by Ramesh K. Kher, W.R. Hudson, and B.F. McCullough, describes the development of a working systems model for the design of rigid pavements.

Report No. 123-6, "Calculation of the Elastic Moduli of a Two Layer Pavement System from Measured Surface Deflections," by F.H. Scrivner, C.H. Michalak, and W.M. Moore, describes a computer program which will serve as a subsystem of a future Flexible Pavement System founded on linear elastic theory.

Report No. 123-6A, "Calculation of the Elastic Moduli of a Two Layer Pavement System from Measured Surface Deflections, Part II," by Frank H. Scrivner, Chester H. Michalak, and William M. Moore, is a supplement to Report No. 123-6 and describes the effect of a change in the specified location of one of the deflection points.

Report No. 123-7, "Annual Report on Important 1970-71 Pavement Research Needs," by B. Frank McCullough, James L. Brown, W. Ronald Hudson, and F.H. Scrivner, describes a list of priority research items based on findings from use of the pavement design system.

Report No. 123-8, "A Sensitivity Analysis of Flexible Pavement System FPS2," by Ramesh K. Kher, B. Frank McCullough, and W. Ronald Hudson, describes the overall importance of this system, the relative importance of the variables of the system and recommendations for efficient use of the computer program.

Report No. 123-9, "Skid Resistance Considerations in the Flexible Pavement Design System," by David C. Steitle and B. Frank McCullough, describes skid resistance consideration in the Flexible Pavement System based on the testing of aggregates in the laboratory to predict field performance and presents a nomograph for the field engineer to use to eliminate aggregates which would not provide adequate skid resistance performance.

Report No. 123-10, "Flexible Pavement System - Second Generation, Incorporating Fatigue and Stochastic Concepts," by Surendra Prakash Jain, B. Frank McCullough, and W. Ronald Hudson, describes the development of new structural design models for the design of flexible pavement which will replace the empirical relationship used at present in flexible pavement systems to simulate the transformation between the input variables and performance of a pavement.

Report No. 123-11, "Flexible Pavement System Computer Program Documentation," by Dale L. Schafer, provides documentation and an easily updated documentation system for the computer program FPS-9.

Report No. 123-12, "A Pavement Feedback Data System," by Oren G. Strom, W. Ronald Hudson, and James L. Brown, defines a data system to acquire, store, and analyze performance feedback data from in-service flexible pavements.

Report No. 123-13, "Benefit Analysis for Pavement Design System," by W. Frank McFarland, presents a method for relating motorist's costs to the pavement serviceability index and a discussion of several different methods of economic analysis.

Report No. 123-14, "Prediction of Low-Temperature and Thermal-Fatigue Cracking in Flexible Pavements," by Mohamed Y. Shahin and B. Frank McCullough, describes a design system for predicting temperature cracking in asphalt concrete surfaces.

Report No. 123-15, "FPS-11 Flexible Pavement System Computer Program Documentation," by Hugo E. Orellana, gives the documentation of a computer program FPS-11.

Report No. 123-16, "Fatigue and Stress Analysis Concepts for Modifying the Rigid Pavement Design System," by Piti Yimprasert and B. Frank McCullough, presents the development of a mathematical model for simulating the behavior of rigid pavement under repeated loads.

Report No. 123-17, "The Optimization of a Flexible Pavement System Using Lienar Elasticity," by Danny Y. Lu, Chia Shun Shih, and Frank H. Scrivner, describes the integration of the current Flexible Pavement System computer program and Shell Oil Company's program, BISTRO, for elastic layered systems, with special emphasis on economy of computation and on evaluation of structural feasibility of materials.

Report No. 123-18, "Probabilistic Design Concepts Applied to Flexible Pavement System Design," by Michael I. Darter and W. Ronald Hudson, describes the development and implementation of the probabilistic design approach and its incorporation into the Texas flexible pavement design system for new construction and asphalt concrete overlay.

Report No. 123-19, "The Use of Condition Surveys, Profile Studies and Maintenance Studies in Relating Pavement Distress to Pavement Performance," by Robert P. Smith and B. Frank McCullough, introduces the area of relating pavement distress to pavement performance, presents work accomplished in this area and gives recommendations for future research.

Report No. 123-20, "Implementation of a Complex Design System," by Larry J. Buttler and Hugo E. Orellana, describes the procedure used to implement a new Flexible Pavement Design System in the Texas Highway Department pavement design operations.

Report No. 123-21, "Rigid Pavement Design Systems, Input Guide for Program RPS2 in Use by the Texas Highway Department," by R. Frank Carmichael and B. Frank McCullough, describes the input of variables necessary to use in the Texas rigid pavement design system program, RPS2.

Report No. 123-22, "An Integrated Pavement Design Processor," by Danny Y. Lu, Chia Shun Shih, Frank H. Scrivner, and Robert L. Lytton, provides a comprehensive decision framework with a capacity to drive different pavement design programs at the user's command through interactive queries between the computer and the design engineer.

ABSTRACT

An integrated pavement design processor has been developed as a strategic approach to the design and management of construction and rehabilitation of pavements. The modular processor is a comprehensive decision framework with a capacity to drive different optimization routines at the user's command through interactive queries between the computer and the design engineer. The multi-option arrangements enable the design engineer to consider both rigid and flexible pavement systems simultaneously. The processor can be used for new pavement construction or existing pavement rehabilitation. In addition, three options for flexible pavement design are included to describe the structural subsystem desired: one based on AASHO structural number, another based on Dynaflect deflection, and the third based on linear elastic theory.

KEY WORDS: AASHO structural number, computer program, Dynaflect deflection, flexible pavement system, integrated pavement design processor, linear elastic theory, modular processor, pavement construction, pavement rehabilitation, rigid pavement system, strategic approach, systems analysis model for pavements.

SUMMARY

The ultimate success of any branch of research rests on its adaptability to practical application. Many pavement design systems have been developed since the late 1960's. The most annoying problems connected with program application are the requirements of massive data preparation by design engineers, tedious card punch formats and painstaking turn around processes. These procedures frequently represent overly cumbersome burdens to design engineers, thereby lessening their enthusiasm for the programs.

In an attempt to facilitate extension of the pavement analysis programs to full-scale implementation, an integrated pavement design processor was developed in this study. The processor integrates a rigid pavement design system, an asphaltic concrete pavement overlay design system, and three versions of a flexible pavement design system - one based on the AASHO structural number, another based on Dynaflect deflection, and the third based on linear elasticity.

More than 200 input variables have been organized and categorized into one integrated sequential format. Four alternative methods are designed for data entry.

1. terminal-mode data entry,
2. direct access to example data set,
3. direct access to user's data set, and
4. direct access to free data set.

The terminal-mode data entry method receives input values from the communication terminal by interactive queries between the computer and the user. The other three methods are based on direct access to data sets which are either stored by the user, or already have been built into the processor.

Comments and recommendations for input values are printed out immediately upon request through the terminal. Pavement optimization programs are executed by remote job entry.

The entire job execution is divided into four tasks: orientation, data preparation, pavement optimization, and termination. Utilization of the modular processor is uncomplicated, quite convenient, and does not entail detailed familiarity with computer programming and operation.

The processor is practical and adaptable to current pavement design procedures in Texas, and possibly could, with appropriate modifications, be used by other states as well.

IMPLEMENTATION STATEMENT

The integrated pavement design processor is an application-oriented tool for the design and management of pavement construction and rehabilitation. The ultimate goal of this research is to implement the processor in regular design operations.

Minimum hardware and software requirements to implement the processor developed in this study for the Texas Highway Department are described herein. The computer facility should be able to accept FORTRAN, direct access, and overlay linkage, with at least 60k bytes memory. The teleprocessing system should be able to execute interactive FORTRAN programs and initiate remote batch jobs The basic requirement of the terminal is at least 70 characters per line.

Four important features concerning the extension of the processor to full-scale implementation deserve special emphasis here: (1) processor security, (2) provision for simultaneous users, (3) further reduction of core requirement, and (4) selective print-out.

Potential implementation alternatives are detailed in Chapter V of this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

A comprehensive decision framework for the design and rehabilitation of pavements must enable the designer to consider both rigid and flexible pavement system programs. Familiarizing the professionals with the exisiting optimization procedures developed for both flexible and rigid pavements is recognized as one of the most difficult tasks in implementation of the systems approach. In many cases, progress towards full-scale implementation has been retarded by the cumbersome requirements of the massive data inputs and the lack of interactive features between the computer and the design professionals. As a result some skepticism has been expressed by practical professionals as to the real value of the systems approach. Therefore, a computer program package which incorporates the strategic approach and modular optimization process into an interactive, open-ended, broad-based, and user-oriented optimization procedure is needed to enhance the implementation of the systems approach to pavement design and management.

Objectives

The ultimate goal of this research is to devise a comprehensive decision framework which permits realistic decision-making in the design and rehabilitation of pavements. The specific objective of this study is to develop an integrated pavement design processor which includes a terminal-mode driver's segment, a rigid pavement design system, an asphaltic concrete pavement overlay design system, a flexible pavement design system based on AASHO structural numbers, a flexible pavement design system based on the Dynaflect deflection model, and a flexible pavement design system based on linear elastic theory.

Scope

The scope of this study includes the following basic tasks:

1. To make a state-of-the-art survey of important road tests as well as analytical and computer techniques used by previous researchers in the design and maintenance of pavement systems.
2. To develop a terminal-mode modular processor for highway pavement design and management systems optimization. Optimization routines included in the multi-optional processor as modules are: a rigid pavement design system [26], an asphaltic concrete pavement overlay design system [5], and three flexible pavement design systems that include one based on the AASHO structural number [30], one based on a Dynaflect deflection model [36, 44], and one based on linear elastic theory [29]. All input data to these five modules are organized and categorized in a man-machine conversational input system.
3. To provide an interactive user's guide for the utilization of the application-oriented processor.
4. To discuss the potential implementation alternatives for extending the utilization of the modular processor to different teleprocessing systems, communication terminals, and programming languages.

Following this introductory chapter, Chapter II presents a state-of-the-art survey of the systems analysis of pavement design. Chapters III, IV and V describe the design, utilization, and implementation, respectively, of the integrated pavement design processor. Chapter VI reports a summary and conclusions. Included in appendices are:

Appendix A - An illustrative example of the utilization of the processor

Appendix B - Program output of an example flexible pavement design problem

Appendix C - Code number of input variables

Appendix D - Dictionary of input variables in driver's segment

Appendix E - Disk requirement of the processor

Appendix F - JCL for driver's segment

Final Product

The final product of the study is a package of computer programs which is essentially an application-oriented modular processor with the capacity to drive different optimization routines at the user's command through interactive queries between the computer and the design engineers [28]. Many of the subjective decision-making judgements are readily incorporable. The depth and accuracy of the input data for specific optimization routines are also under a multi-option arrangement. Comments and recommendations for input values are printed out immediately upon request through real-time computer systems and terminal operated output devices. Different loopings are built in for the reevaluation and readjustment of the input data or for specific design criteria and constraints at the option of the design engineers or decision-makers. All of the optimization subsystems included in this entire strategic processor are in modular form. In other words, for each of the subsystems, the special interest and unique utilization features are retained. Thus, each of the modules can be used independently as a regular optimization program, while linkage with other optimization programs is also available.

CHAPTER II

SYSTEMS ANALYSIS OF PAVEMENT DESIGN

This chapter presents a state-of-the-art survey on the development of pavement design systems. Descriptions will be centered around the systems approach to the design and management of highway pavements developed in the following research projects:

Research Study 2-8-62-32*, "Extension of AASHO Road Test Results," conducted by Texas Transportation Institute.

Research Study 1-8-69-123*, "A System Analysis of Pavement Design and Research Implementation," conducted by Texas Highway Department, Texas Transportation Institute, and Center for Highway Research.

NCHRP Project 1-10**, "Translating AASHO Road Test Findings - Basic Properties of Pavement Components," conducted by Materials Research and Development, Inc.

NCHRP Project 1-10A**, "Systems Approach to Pavement Design - Implementation Phase," conducted by Texas Transportation Institute.

The goal of the work described herein is to integrate the existing pavement design systems into a modular processor.

A chronological record of the growth of the systems approach to highway pavement design can be diagrammed as shown in Figure 2.1. The developments shown in parallelograms are two significant road tests, the findings of which sparked the initial search for a means to apply optimization procedures to pavement design. The pavement design systems (computer programs) shown in rectangular boxes with single lines are the early versions of the developments in a systems appraoch to pavement design problems in Texas and in

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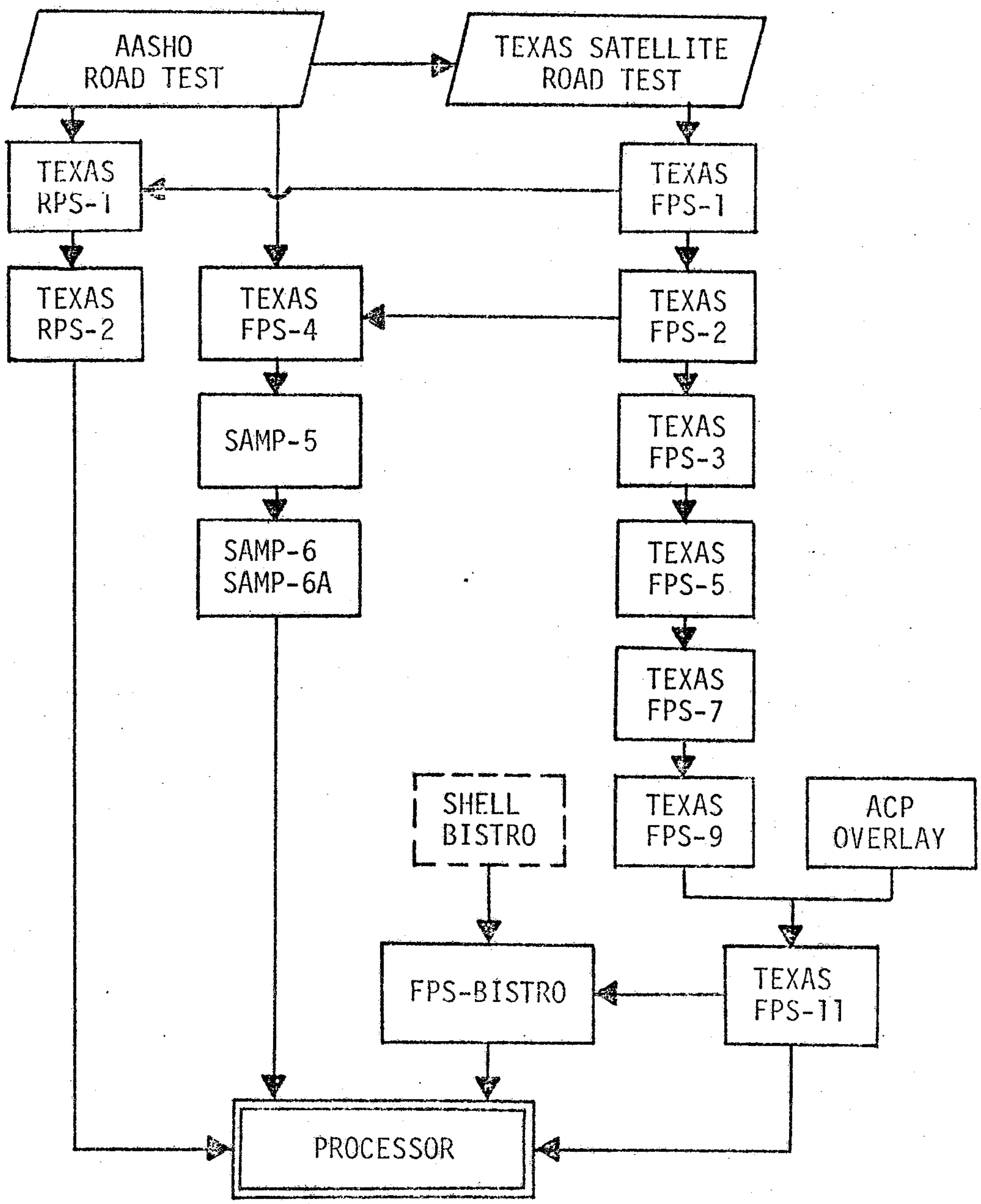


Figure 2.1 Chronological record of the growth of the systems approach to highway pavement design

National Cooperative Highway Research Program (NCHRP) projects 1-10 and 1-10A. The development shown in the rectangular box with dotted lines is an individual computer program adapted from a source other than from the studies mentioned above. The pavement design processor shown in the rectangular box with double lines is developed in this study.

The AASHO Road Test, which has been the most intensive and comprehensive highway pavement performance study, was completed in 1961. By late 1962, several states, including Texas, had begun research directed toward extending the AASHO Road Test, generally known as "satellite projects". In 1968, the Texas Satellite Road Test resulted in a flexible pavement design system, Texas FPS-1. Many improvements have been integrated into the initial version since then in Texas Study 123, the three agency project previously mentioned.

One of the accomplishments of the Texas Satellite Road Test was the development of an empirical deflection equation. Surface deflections caused by traffic loads are used to estimate flexible pavement serviceability at any desired time after construction. However, some pavement designers prefer the performance equation that resulted from the AASHO Road Test. Thus, the FPS system was split into two series. One series utilized pavement deflections to describe the pavement performance, while the other utilized AASHO structural numbers. FPS-1 and FPS-2 are the original and first revision, respectively, of the flexible pavement design system which utilized pavement deflection equations for predicting pavement performance. A numbering convention was adopted to be used for later versions of FPS. The pavement deflection method series were to use odd numbers for later revisions (3, 5, 7, ...), while the AASHO structural number method series were to use even numbers (4, 6, 8, ...).

The Texas FPS-4 design system was developed in 1969. This system is essentially a revision of Texas FPS-2, in which the deflection performance equation is replaced by the AASHO performance equation. In 1970, a research project sponsored by the NCHRP revised the FPS-4 and called it a Systems Analysis Model for Pavements (SAMP). This version was named SAMP5. Continuous efforts were devoted to the nationwide implementation of the SAMP system. Based on the experience of implementing the SAMP system in Florida, Kansas, and Louisiana, two versions of the SAMP series, SAMP6, and SAMP6A, were developed in 1973.

The systems approach to flexible pavement design has been viewed as a promising design procedure since Texas FPS-1 was developed. It was thus recognized that rigid pavement design procedures should also be organized into an operational systems model. In 1970, a rigid pavement design system, Texas RPS-1, was developed based on the findings of the AASHO Road Test in rigid pavements and the FPS analysis framework. This system was further revised into RPS-2 in 1973.

In 1970, an asphaltic concrete overlay design subsystem, ACP OVERLAY, was developed for pavement rehabilitation. In 1972, the ACP OVERLAY design subsystem was integrated into the Texas FPS-9 design system and became the Texas FPS-11 system which is currently being implemented in Texas.

The Shell BISTRO program, which was developed by Koninklijke/Shell-Laboratorium in Amsterdam, is a comprehensive analysis package of multi-layer, linear elastic structures. In 1973, the Shell BISTRO and Texas FPS-11 were integrated into a FPS-BISTRO system. In this study, a modular processor is developed to integrate RPS-2, SAMP6, SAMP6A, FPS-11, and FPS-BISTRO into one easily used multi-option system for on-line teleprocessing.

Important roads and road tests as well as systems analysis of highway pavement design are discussed in more detail in the following sections.

Important Roads and Road Tests

A historical background of roads and road building as described in Encyclopaedia Britannica [12] is summarized herein.

Prehistoric man can probably be credited with developing the first road system when he used the game trails made by wild animals to search for food, shelter, and to elude his enemies. As civilization advanced, man built short roads along the flat river plains for trade and for transporting building materials from quarries to building sites. The Royal Road, the first large scale road system, built by the Assyrians, extended 1,500 miles. At the height of the Roman Empire, the Roman road system totaled 50,000 miles of first class roads and 200,000 miles of connecting roads. The first roads built in the American Colonies followed Indian foot trails. Examples of these were Braddock's military road and the Wilderness Road.

Concrete was first used in building streets in England in the early 19th century. Asphalt for road surfaces was first used in France and Switzerland in the 1850's. In the United States, the first asphalt and concrete roads were built in Washington, D.C. in 1877 and in Ohio in 1893, respectively.

Modern high-speed highway construction started in 1920. Examples of these are the Italian autostrada built in 1924, the German autobahnen built during 1930-1942, and the U.S. Pennsylvania Turnpike and the Merritt Parkway completed in 1941.

Road construction in the early days were primarily based on past experiences. The resulting pavements had a very wide variance: they either failed short of the anticipated life, or were found to be grossly overdesigned, resulting in unnecessary costs. In order to overcome these difficulties, several road tests were conducted in the United States, from the late 1910's to the early 1960's, to advance the knowledge of pavement design. Table 2.1 shows a chronological evolution of these road tests.

The Arlington Test, conducted in 1919, appears to be the earliest documented attempt to study the behavior of pavements. The loading apparatus was a truck tire and spring mechanism that simulated impact loads of truck tires on the pavement. The Bates Road Test, conducted from 1920 to 1923, was the first to study the effects of actual traffic on existing pavements. Pavement engineers and designers studied the causes of pavement failures in order to obtain knowledge for future pavement design. The state of Illinois changed its rigid pavement design procedure as a result of this test, and many other states followed suite by adopting the thickened-edge, or "Bates section", for rigid pavements. Two long term experiments, the Pittsburgh Road Test and the Stockton Road Test, were conducted from 1930 to 1940 in California to study rigid and flexible pavements. Another long term experiment, the Hybla Valley study, was conducted from 1944 to 1954 in Virginia. These long term experiments provided pavement engineers and researchers with more information regarding pavement behavior. However, these findings have been expanded and refined by more recent research. For example, in the period immediately after World War II, the most elaborate road experiment was the Maryland Road Test [38] which cost $245,000. This test, conducted to furnish information needed to establish uniform size and weight limitations for motor

TABLE 2.1

IMPORTANT ROAD TESTS

NAME	YEAR	STATE	AGENCY	PAVEMENT TYPE
ARLINGTON TEST	1919	VIRGINIA	BPR	RIGID
BATES ROAD TEST	1920-23	ILLINOIS	BPR	RIGID
PITTSBURGH ROAD TEST	1930-40	CALIFORNIA	CSC	RIGID
STOCKTON ROAD TRACK	1930-40	CALIFORNIA	CE	FLEXIBLE
HYBLA VALLEY	1944-54	VIRGINIA	HRB,AI,BPR	FLEXIBLE
MARYLAND ROAD TEST	1950-51	MARYLAND	AASHO	RIGID
WASHO ROAD TEST	1952-53	IDAHO	WASHO	FLEXIBLE
AASHO ROAD TEST	1958-61	ILLINOIS	AASHO	FLEXIBLE, RIGID

AASHO - AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS

AI - ASPHALT INSTITUTE

BPR - BUREAU OF PUBLIC ROADS

CE - CORPS OF ENGINEERS

CSC - COLUMBIA STEEL CO.

HRB - HIGHWAY RESEARCH BOARD

WASHO - WESTERN ASSOCIATION OF STATE HIGHWAY OFFICIALS vehicles, is noted for the participations of many states, federal agencies, and private agencies, as well as the number, type, and complexity of tests and measurements.

The results of the six road tests, conducted from 1919 to 1951, did not satisfy the highway engineers need for more knowledge in the field of pavement design. However, these tests led to the two large scale road experiments: the WASHO Road Test and the AASHO Road Test.

The WASHO Road Test [50, 51] was conducted by the Western Association of State Highway Officials from 1952 to 1953 to determine the effects of various axle loads on certain flexible pavement designs. A site for the road test near Malad, Idaho was selected as being representative of the climatic and soil conditions of the Western United States. The WASHO Road Test, which cost $890,000, was the first experiment of its type to be performed under completely controlled conditions. The concept of using vertical pavement deflections under traffic loads as the principal criterion for measuring the strength of flexible pavements was initiated in this test with the advent of the Benkelman Beam. However, many important variables, such as weather and material properties, were not studied, partly because they had been ignored in the experimental design, and partly because of the lack of proper instruments for the necessary measurements.

The AASHO Road Test [48, 49] was conducted by the American Association of State Highway Officials from 1958 to 1961 to study the performance of highway structures of known layer thicknesses under known loads. This road test, supervised by the Highway Research Board of the National Academy of Sciences, was considered to be the most comprehensive experiment for highway pavement behavior and its characterization to date. Two of the more significant findings of this test are as follows:

1. Two empirical performance equations, one for flexible and one for rigid pavements, were developed to predict the pavement serviceability index in terms of design, axle type (single or tandem), axle load, and accumulated number of load applications.
2. An equation was developed to convert mixed traffic to an equivalent number of 18-kip single axle loads.

Since the completion and reporting of the AASHO Road Test, highway engineers have recognized the necessity of translating the findings to local conditions. Though the AASHO Road Test was a $27,000,000 research project, it answered only a few of the important design questions. The early attempts to design pavements based on the AASHO Road Test results [1, 2] also revealed the need for further information from environments differing from the environment at the Road Test. Thus, a series of satellite study projects were proposed to adapt the AASHO Road Test results to local environmental conditions. A nationwide study [22, 23] was also proposed to coordinate those efforts devoted to the satellite studies of pavement performance, but was never implemented as planned.

The Texas Satellite Road Test, conducted during 1962-68, adapted some of the AASHO Road Test results to Texas conditions through the medium of pavement deflection. A set of specific recommendations [43], based largely on early experiences in the Texas study, was published in 1968. Significant findings of this study [40, 41, 42, 44] were as follows:

1. A methodology was developed to estimate material stiffness from surface deflections caused by a standard surface loading.
2. An empirical equation was suggested to estimate the surface curvature of a flexible pavement subject to a standard loading based on stiffness coefficients and different combinations of layers and thicknesses.
3. A performance equation was developed to predict the pavement serviceability history in terms of surface curvature, traffic loads, temperature, swelling clay, and pavement age.
4. A set of functions was derived to calculate the present worth of the overall cost incurred over a selected period of time, including costs of initial construction, routine maintenance, seal coats, overlay construction, delays due to overlay construction and pavement salvage.

Furthermore, based on these findings, a computerized flexible pavement design system, Texas FPS-1, was also developed in 1968 [8, 44]. This system is based on the following general premise: it is the aim of the design engineer to provide from available materials a pavement that can be maintained above a specified level of serviceability, over a specified period of time, at the minimum overall cost. The detailed description of this flexible pavement system is presented in the following section.

Systems Analysis of Flexible Pavement Design Based on Dynaflect Deflection

Highway pavements can be viewed as complex structural systems involving many sets of variables describing the combinations of static and dynamic loading, environment, performance, construction, maintenance, rehabilitation, materials, pavement structure, and economics. A vast number of functional relationships and computations must also be included in the design and management considerations, and a complete analysis for pavement construction and rehabilitation should be conducted within a systems framework [15, 18]. In 1968, as a significant result of the Texas Satellite Road Test, a working design model employing the concepts of systems analysis [44] was developed. The initial effort was concentrated on the integration of all aspects to be considered, and streamlining all the computations into a systematic evaluation procedure. As the flexible highway pavement was the most commonly used pavement structure in Texas, it was selected as the first analysis target of the systems approach.

The objective of the developed flexible pavement design system was to select the optimal initial and overlay construction strategy which will result in minimum total cost over an analysis period. A computer program, Texas FPS-1, was the first version of the development in terms of taking into account all physical variables affecting pavement performance and all cost variables influencing pavement design and management decisions. Physical variables were analyzed in terms of how they would affect the serviceability-time relationship of the pavement. The deflection, traffic, and performance models, based on the AASHO Road Test and Texas Satellite Road Test results, were applied. Cost variables considered included initial construction, routine maintenance, overlay construction, users' contribution due to traffic delays during overlay construction, seal coat, and salvage values. All future costs, discounted to present value, were added to initial construction costs to form the overall cost. The optimization objective was to provide, at minimum cost, a pavement structure that was acceptable for normal travel.

Since the Texas FPS-1 system was developed, various refinements and modifications, based on the results of later research and the needs of the FPS users, have been incorporated into the initial version. Later versions of the deflection based FPS are: FPS-2, FPS-3, FPS-5, FPS-7, FPS-9, and FPS-11. Versions 2, 3, 5, and 7 were developed during 1969-70. Significant refinements and modifications were as follows:

1. Different paving materials might have different salvage percentages at the end of the analysis period.
2. Detour distance around the overlay zone was included in the cost model to calculate the users' costs during overlay periods.
3. Pavement serviceability index after initial construction needed not be the same as the serviceability after an overlay construction.
4. Two restraints of overlay thickness were included: minimum overlay thickness of each individual overlay construction, and accumulated maximum depth of all overlays during the analysis period.
5. Program and problem identifications were included in output pages.

Many important improvements were incorporated into FPS-9 [39], in 1972. Significant comprehensive revisions were as follows:

1. Portions of the FPS program were modularized to aid in future program modification efforts.

2. A more rational method of using swelling clay parameters in the projection of the serviceability index was included.
3. Certain input data previously required relating to traffic speeds were no longer required.
4. Tables of user's costs were expanded and updated.
5. The iteration scheme to estimate the performance time was improved by using the Newton-Raphson search.
6. Feasible initial designs which were of lesser strength at a higher initial cost were excluded from considerations.
7. A documentation system was also developed in a machine readable format in order to facilitate a continuous system to update the documentations of future FPS design systems.

The early FPS versions, including FPS-9, have considered simultaneously the new constructions and future rehabilitations for a predetermined analysis period. It was recognized that a separate system to optimize the rehabilitation strategies of existing pavements should also be devised. In 1970, an asphaltic concrete pavement overlay design system [5], named ACP OVERLAY, was developed, based on the same considerations as the original FPS system. The following two major revisions were included:

1. a simplified deflection equation, confirmed by field tests, to estimate the surface curvature of existing pavements, and
2. the deletion of initial construction considerations.

In 1972, the Texas FPS-9 and ACP OVERLAY programs were physically integrated into Texas FPS-11 [36]. Significant changes of FPS-11, as compared with FPS-9, were as follows:

1. The rehabilitation of existing flexible pavements was incorporated.
2. The reduction in serviceability due to swelling clay and other non-traffic causes were further revised.
3. A design confidence level was added.
4. Seal coats were excluded from design considerations.

The macro flow diagrams of the computation procedure included in Texas FPS-11 are shown in Figures 2.2 and 2.3. Figure 2.2 illustrates the initial construction and future overlay constructions. Figure 2.3 illustrates the present and future overlay constructions of existing pavements.

For a new pavement analysis, the FPS design system begins at reading, computing, and echo printing data, as shown in Figure 2.2. Possible initial designs are generated by iterating the different combination of design types and layer thicknesses. Each design type represents a combination of paving materials. The thickness of each material used to construct a specific layer starts from a minimum value and increments up to the maximum. The minimum and maximum thicknesses of each material are specified by the designer. The initial design is subjected to three designer-specified constraints:

1. maximum funds available for the initial construction,
2. maximum total thickness of the initial construction, and
3. minimum time to the first overlay construction.

An initial design is classified as infeasible and thus rejected, if it does not satisfy any one of the three constraints. The overlay routine is bypassed if a feasible initial design can last through the entire analysis period. Otherwise, an overlay is scheduled for construction as soon as a pavement falls to the minimum serviceability index level specified by the designer. The trial overlay thickness increments from a minimum to a maximum value spe-

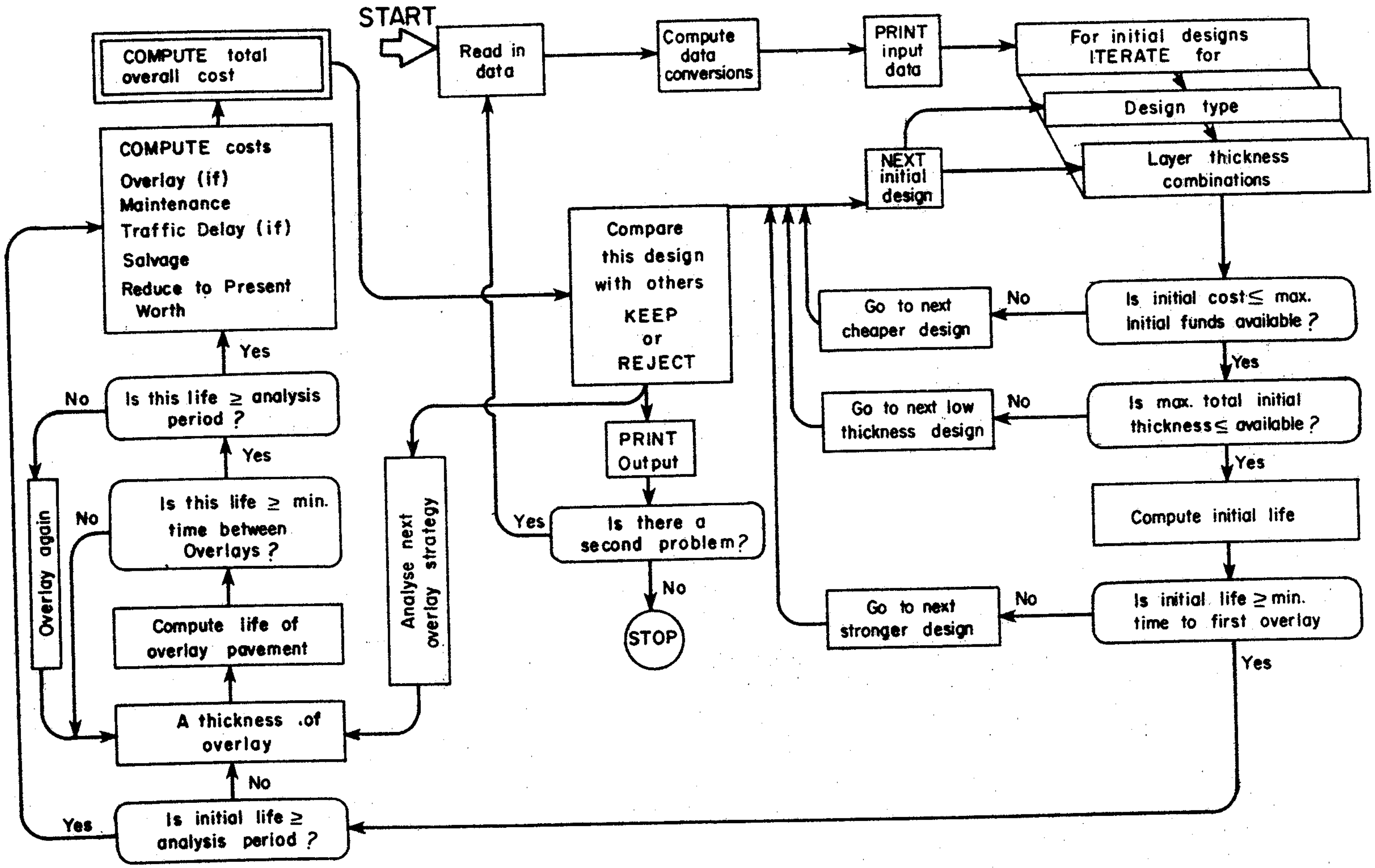


Fig. 2.2 Summary Flow Diagram of Flexible Pavement Design System

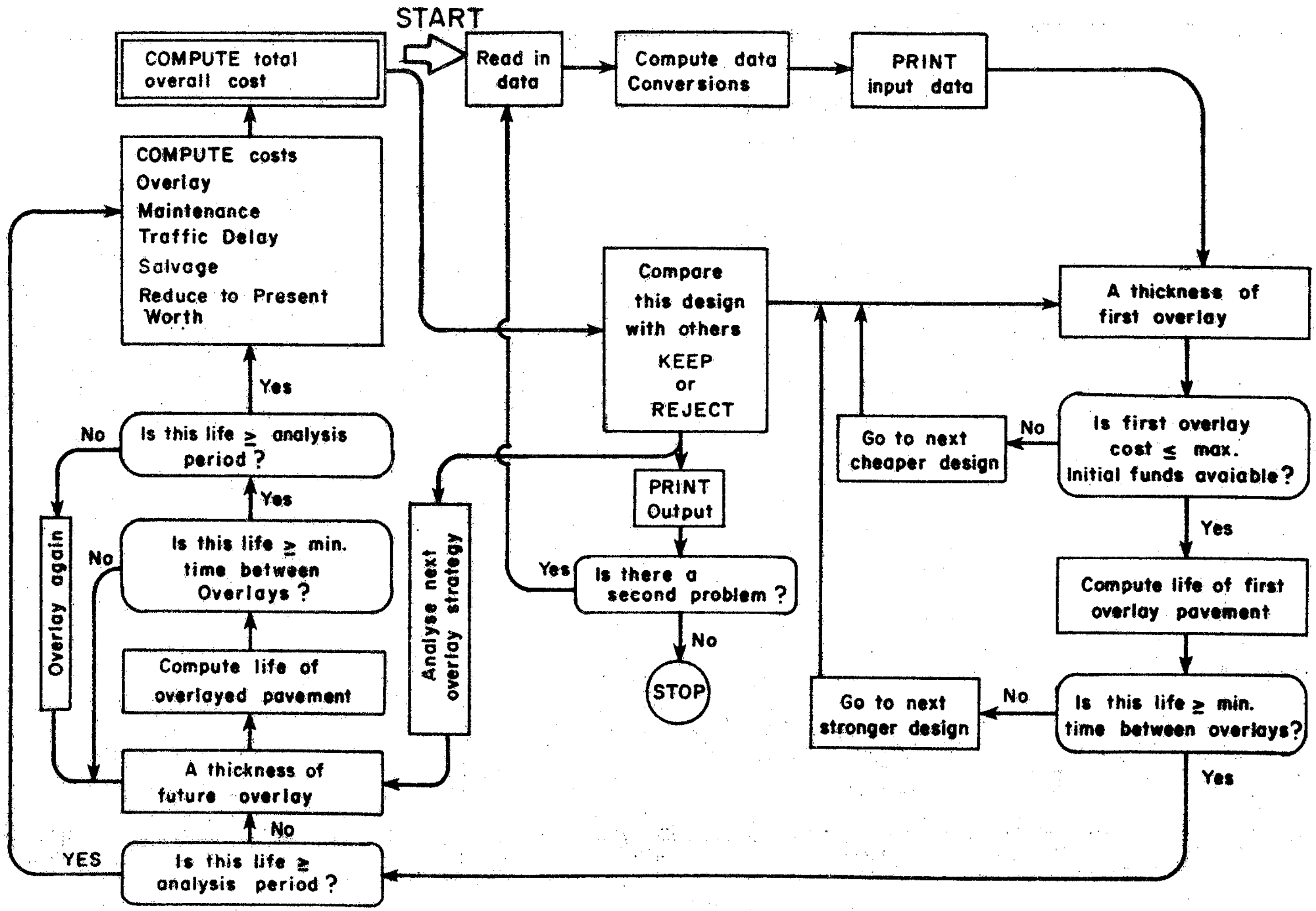


Fig. 2.3 Summary Flow Diagram of Asphaltic Concrete Pavement Overlay Design System

cified by the designer, if the life of the rehabilitated pavement is less than the minimum time between overlays specified by the designer. If the life satisfies the minimum time requirement but the total life does not last the desired analysis period, another overlay construction is needed. A complete design strategy is a feasible initial design combined with future feasible overlay designs. The overlay construction cost, routine maintenance cost, user's cost due to traffic delay during overlay construction, and salvage value of each design strategy are all included in the total cost calculation and discounted to the present worth. The computer program keeps generated information of each design strategy until the first n designs are stored. The number, n, is the desired number of better feasible designs in the final summary report. For each design after the n-th design, the total costs of the designs in storage are scanned and the design which has the maximum total cost is determined. If the total cost of the new design is less than this cost, the new design is accepted and it takes the place of the design with the highest total cost. Otherwise, the new design is rejected and the program analyzes the next design. After all possible design strategies of a design type are iterated, the design system will select the most favored design of this design type in terms of the minimum cost and will print out detailed informations of this design. After all design types are iterated, a summary table of design strategies in order of increasing total cost will also be printed.

Figure 2.3 is essentially the same as Figure 2.2, except that the initial construction is replaced by the first overlay construction. The generation of initial designs and the constraint of initial thickness are deleted.

In early 1971, a new Pavement Design Section was created within the Highway Design Division of the Texas Highway Department. A major mission of this section is to implement the FPS. The procedure used to implement the FPS in the Texas Highway Department pavement design operations was reported in 1973 [7]. During the implementation phase, a sensitivity analysis of the Texas FPS-2 [27] was conducted to provide researchers with a working knowledge of the FPS system. Based on the experience of application of the FPS to real problems, a user's manual [4, 47] was also compiled to enhance the implementation. During 1970-72, ten of the twenty-six districts in Texas participated in the implementation. A pavement feedback data system [14,45] was developed in 1972 to acquire, store, and analyze performance data from in-service flexible pavements. It was found that the Texas FPS-11 design system is more practical and realistic than the older versions.

Meanwhile, experience in implementing FPS in Texas revealed the necessity of recognizing uncertainties in the input variables as well as in the various models appearing in the system. As a result, stochastic processes were introduced into the FPS-11 and a proposed new system, FPS-13 [10].

Systems Analysis of Flexible Pavement Design Based on AASHO Structural Number

The Texas Satellite Road Test resulted in a performance equation which estimates the pavement serviceability based on the "surface curvature index". The surface curvature index is calculated from material stiffness which are estimated from the surface deflections measured by Dynaflect on existing pavements containing materials like those proposed for use in the new project. The flexible pavement design system discussed in the preceding section is based on this performance equation. However, some pavement engineers prefer the flexible pavement performance equation that resulted from the AASHO Road Test. The Texas FPS-4 system was revised from the deflection-based Texas FPS-2 system in 1969, by incorporating the AASHO structural numbers, instead of the Dynaflect deflections, to estimate the pavement performance [17, 32].

In order to extend the flexible pavement design system for nationwide implementations, a National Cooperative Highway Research Program (NCHRP) project [16] converted the FPS-4 into the SAMP5 systems analysis model for pavements (SAMP) in 1970.

During 1972-73, another NCHRP project [30] was conducted to implement the SAMP5 system in three cooperating states: Florida, Kansas, and Louisiana. Due to different design requirements in each state, many revisions of the SAMP5 system were made for the three cooperating states. The revised design system was named SAMP6. Significant additions and revisions were as follows:

1. separating the strength and cost estimates for wearing surface and overlay materials;
2. including a method of calculating full cross-section volumes (including shoulders);
3. adding two unit cost models which allowed unit costs to decrease with increasing thickness;
4. providing two alternative maintenance cost models;
5. including the costs of bitumen, prime coats, tack coats, and upgrading of earth shoulders as distinct components of material cost;
6. including stochastics of AASHO flexible pavement equation to determine reliability; and

7. adding new environmental deterioration of serviceability which was based on the expansive clay model of FPS-11.

The basic flow diagram of the SAMP6 system is the same as that of the FPS-11 diagrammed in Figure 2.2, except that the SAMP6 does not allow the overlay design of existing pavements.

Later, a SAMP6A system was developed to include the selection of shoulder materials. In addition to the development of the SAMP6 system, the program documentation, user's manual, sensitivity analysis, and pavement feedback data systems were completed during the project period. The SAMP6 system was found to agree with the design practice in states other than Texas reasonably well.

Systems Analysis of Flexible Pavement Design Based on Linear Elasticity

Two series of the existing flexible pavement design system have been reviewed in preceding sections. The significant difference between the two series is the pavement performance equation. One series uses pavement surface deflections to predict the pavement life, while the other series uses AASHO structural numbers. Either the surface deflections or the structural numbers, used to describe pavement performance potential, are estimated from empirical rules.

It is known, however, that in some cases pavement optimizations based solely on the empirical rules and historical data are obviously in error. Thus, it has been recognized that a theoretical approach to the optimization of pavements is urgently needed. Many versions of programming routines [13, 34, 37, 53] have been developed for the use of linear elasticity in pavement structure analyses. However, many researchers have felt that the application of linear elastic theory is severely limited by the unacceptable amount of computation time required [6, 24]. In 1973, a linear elasticity based flexible pavement design system, FPS-BISTRO [29], was developed. Computation time requirements have been reduced significantly by streamlined computations and efficient interpolations.

A general flow diagram of this linear elasticity-based flexible pavement design system is shown in Figure 2.4. The system starts by reading, computing, and echo printing data. Possible initial designs are generated by iterating the different combinations of design types and layer thicknesses. Each design type represents a combination of paving materials. The thickness of each material used to construct a specific layer starts from a minimum value and increments up to the maximum. The minimum and maximum thicknesses of each material are specified by the designer. The initial design is subjected to four designer-specified constraints:

1. maximum funds available for the initial construction,
2. maximum total thickness of the initial construction,
3. minimum time to the first overlay construction, and
4. maximum strengths of materials.

An initial design is classified infeasible and thus rejected, if it does not satisfy any one of the four constraints. The overlay routine is bypassed if a feasible initial design can last through the entire analysis period. Otherwise, an overlay is scheduled for construction as soon as a pavement falls to the minimum serviceability index level. The trial overlay thickness increments from a minimum to a maximum value specified by the designer, if the life of the rehabilitated pavement is less than the minimum time between

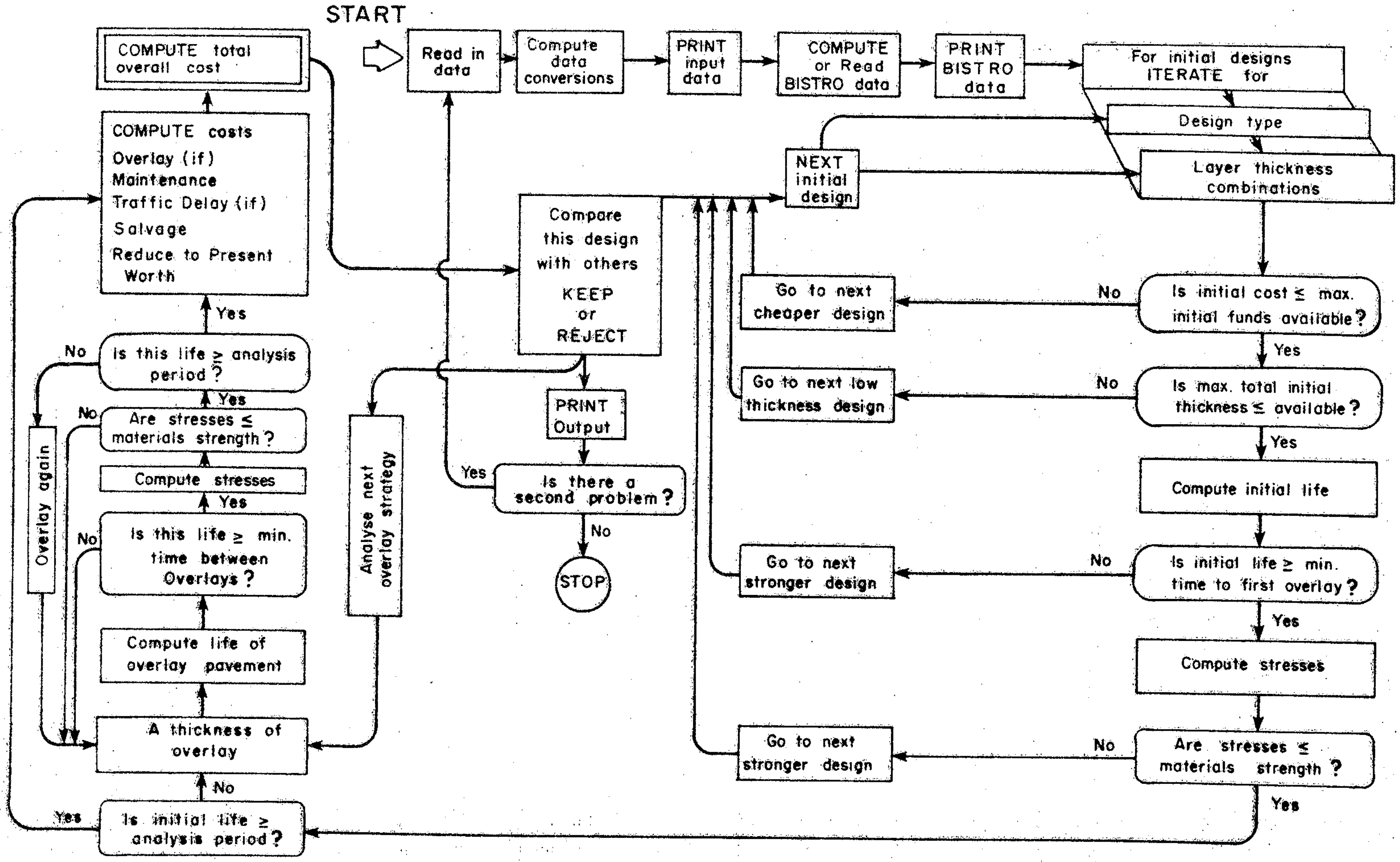


Fig. 2.4 Summary Flow Diagram of Flexible Pavement Design System Using Linear Elasticity

overlays, or if the stresses within pavement structures caused by traffic loads are greater than the limiting materials strength. If the design satisfies the two constraints but the total life of the pavement does not last the desired analysis period, another overlay construction is needed. The overlay construction costs, routine maintenance cost, user's cost due to traffic delay during overlay construction, and salvage value of each design strategy are all included in the total cost calculation and discounted to the present worth. Each design is compared with others. A designer-specified number of better designs with lower total cost are kept. After all possible design strategies are iterated, a summary table of design strategies in order of increasing total cost will also be printed.

Compared with the flexible pavement design system diagrammed in Figure 2.2, two significant revisions must be noted.

1. Surface deflections are calculated from linear elasticity, rather than estimated from an empirical equation derived from Dynaflect experiments.
2. Major and minor principal stresses at interfacial positions are calculated from linear elasticity to check the strength of paving materials and the subgrade for both initial and overlay constructions.

Systems Analysis of Rigid Pavement Design

In 1971, a conceptual rigid pavement design system [26], Texas RPS-1, was developed, based on the results of the AASHO Road Test for the rigid pavement and the systematic computation framework developed in flexible pavement design.

In addition to the general categories of considerations on loads, environments, performance, construction, maintenance, rehabilitation, properties of paving materials and subgrade, as well as economics, included in the flexible pavement system, the rigid pavement system also takes into account different types of concrete, overlay, reinforcement, and joints. A summary flow diagram of the Texas RPS-1 design system is illustrated in Figure 2.5. After all input data are read, checked, and echo printed, the design system starts to generate possible initial designs. Two alternative pavement types are included in the rigid pavement system: jointed and continuously reinforced concrete pavements. Each initial design is characterized by a combination of pavement type, concrete thickness, sets of concrete properties, sets of subbase properties, and subbase thickness. The initial design is subjected to three constraints specified by the designer:

1. maximum total thickness of initial construction,
2. minimum time to the first overlay construction, and
3. maximum funds available for the initial construction.

A design is classified as infeasible and thus rejected if it does not satisfy any one of the three constraints. Each feasible initial design which does not last the analysis period is overlayed with Portland cement or asphaltic concrete. As soon as a design falls to the minimum serviceability index level, an overlay is required. The trial thickness of overlay starts from a minimum value and increments up to the maximum. The minimum, maximum, and incremental thicknesses are specified by the designer. The overlay life is also subjected to a designer-specified constraint. If the life is less than the minimum time between overlays, the overlay thickness is increased. If the life satisfies the minimum time requirement but the total life does not last the

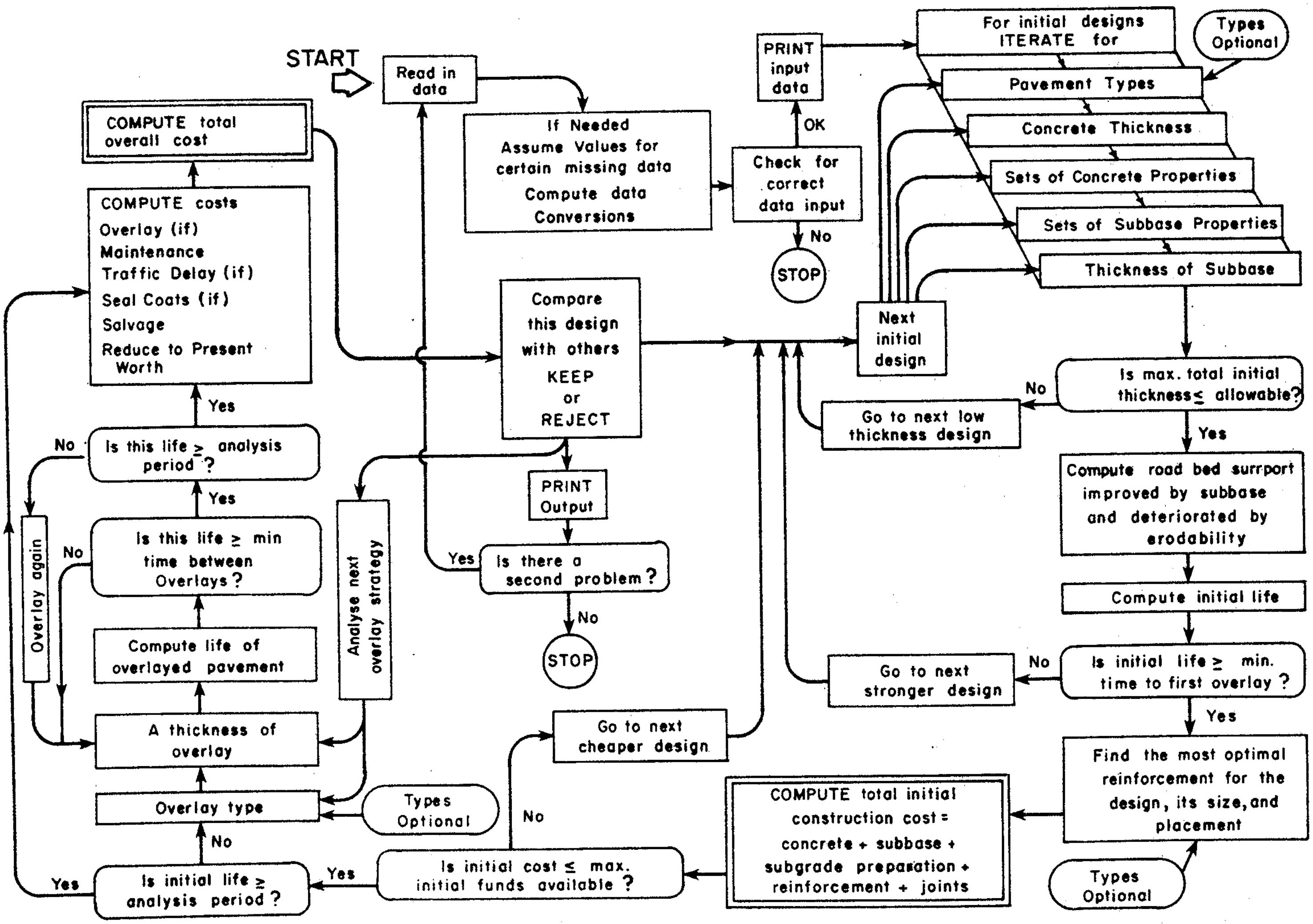


Fig. 2.5 Summary Flow Diagram of Rigid Pavement Design System (Ref. 26)

analysis period, another overlay construction is required. The overlay construction cost, routine maintenance cost, user's cost due to traffic delay during overlay construction, seal coat cost, and salvage value of each complete design strategy are all included in the total cost calculation and discounted to the present worth. If the total cost of a design is less than the total cost of any design in storage, the new design is accepted and it takes the place of the design with the highest total cost. Otherwise, the new design is rejected and the program analyzes the next design. After all possible design strategies are iterated, a summary table of feasible design strategies is printed following the order of increasing total cost.

The second version of the rigid pavement design system, Texas RPS-2, was developed in 1973. Additional stochastic variables [25] were included in the design procedures. The final report of this study is still in process.

CHAPTER III

THE DESIGN OF THE PROCESSOR

Essentially, this project is channeled toward developing a multi-optional modular processor for designing and managing pavement construction and rehabilitation. When perfected the processor will provide highway engineers and researchers with a broad decision analysis framework featuring an uncomplicated conversational mode. In order to realize this goal, the processor must enable design engineers and researchers to simultaneously consider three critical areas:

1. rigid and flexible pavement systems
2. new pavement construction and existing pavement rehabilitation
3. empirical and theoretical descriptions of structural behavior

Included in the modular processor are a driver's segment in teleprocessing mode and five pavement design programs in a batch job mode. The processor further provides five major choices for optimizing pavement systems management:

1. rigid pavement design option
2. asphaltic concrete pavement overlay design option
3. flexible pavement design option using the AASHO structural number
4. flexible pavement design option using Dynaflect deflection
5. flexible pavement design option using linear elasticity

More than 200 input variables of the modular processor are organized into 200 categories. Simplicity and convenience, together with instant assistance and guidance, are salient features of the four alternative methods of data entry which will minimize the user's efforts in the preparation and reevaluation of input values. For the first run of a pavement design problem, the user may select either a terminal-mode or a direct access method of data entry to one of give example data sets built into the processor. After optional listing and revision, the input data file will be stored either in an individual data set assigned to the user or in a free data set, at the user's command. For future runs of a similar problem, the user can utilize a direct access method of data entry to either the user's data set or the free data set.

The input data file received from the communication terminal will be reorganized to create data card images. By using the remote job entry method, one of the five pavement design programs stored in the computer job library will read in the input data from card images and print out the results from a specified printing device.

Modular Structure and Logic Flow Design

Included in the processor are six modules: a driver's segment and five pavement design programs. Figure 3.1 shows the modular composition and the structure of the processor.

The driver's segment is programmed in the FORTRAN IV language. The Texas A&M version of the Baylor Executive System for Teleprocessing (BEST) has been selected for on-line teleprocessing. Details of the teleprocessing utilization are discussed in the next chapter. A subroutine, TPIO, is called in the MAIN program of the driver's segment to handle the input from a communication terminal and output to the same terminal, instead of handling the input from a card reader and output to the normal output route.

Five independent FORTRAN programs are stored in the off-line job library for this modular processor. Program RPS-2 is the second version of a rigid pavement design system. Program SAMP6 is the sixth version of a systems

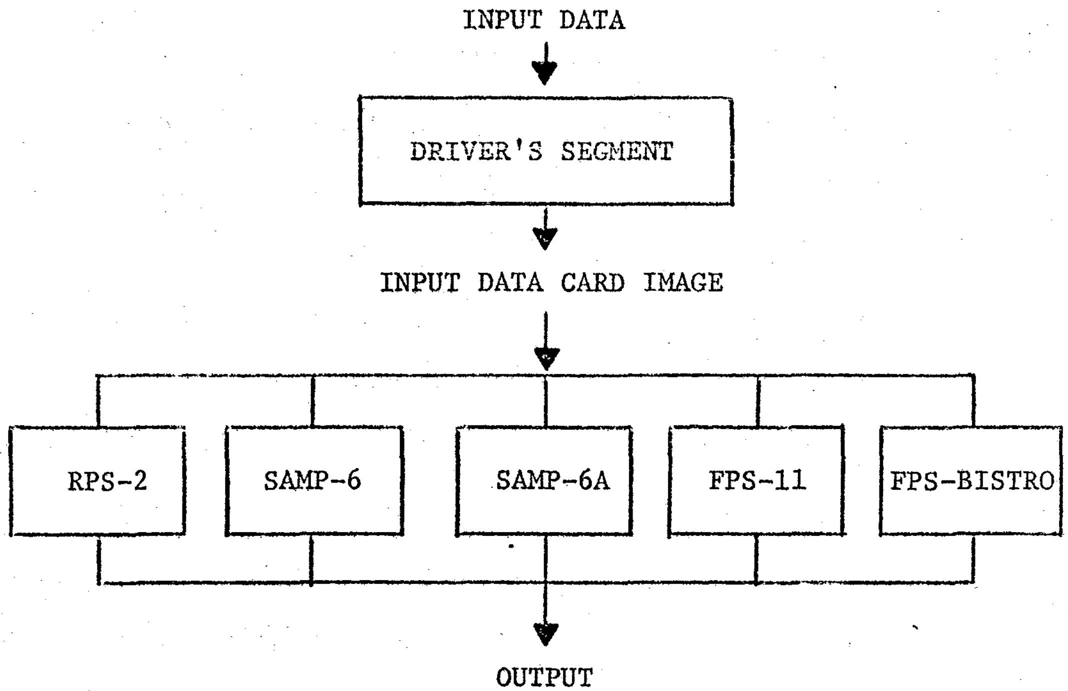


Figure 3.1 Modular composition and structure of the processor

analysis model for pavements. Program SAMP6A is the same as the program SAMP6 with the additional capability to select shoulder materials. The SAMP programs are the flexible pavement design systems using the AASHO structural number. Program FPS-11 is the eleventh version of a flexible pavement design system using Dynaflect deflection. An asphaltic concrete pavement overlay design system is also included in FPS-11. Program FPS-BISTRO, is a flexible pavement design system using linear elasticity.

Table 3.1 shows various options of the processor and corresponding pavement design program(s) to accomplish each design option.

Input data are fed into the driver's segment through interactive queries or from data files. After optional listing, revision, and storage of the input data file, a set of 80-columns-data-card images are created by the driver's segment. Thus the five optimization programs can use the data from the set of card images. After the execution of the pavement design program has been completed, the output stream is directed to a printing device specified by the user.

Input Design

The adequacy and simplicity of input design for the utilization of the modular processor is emphasized by its design. With various conveniences linked into it, the application of the processor to real design problems will be enhanced. Since the modular processor is an integration of five pavement design programs, input design becomes a fairly complicated task. More than 200 input variables are involved for the processing of the five pavement design programs, however, most variables are common to more than one program. The modular processor integrated the five input systems and groups the 233 input variables into 20 categories.

TABLE 3.1

MULTIPLE OPTIONS OF THE PROCESSOR

OPTION	PAVEMENT DESIGN SYSTEM	PROGRAM
1	RIGID PAVEMENT DESIGN SYSTEM	RPS-2
2	ASPHALTIC CONCRETE PAVEMENT OVERLAY DESIGN SYSTEM	FPS-11
3	FLEXIBLE PAVEMENT DESIGN SYSTEM USING AASHO STRUCTURAL NUMBER	SAMP-6, SAMP-6A
4	FLEXIBLE PAVEMENT DESIGN SYSTEM USING DYNAFLECT DEFLECTION	FPS-11
5	FLEXIBLE PAVEMENT DESIGN SYSTEM USING LINEAR ELASTICITY	FPS-BISTRO

Included in Category 1 are problem identifications and comments. Extensive use of the modular processor will result in large numbers of runs on different projects. As an aid to filing and record keeping, it has been found useful to include a fairly complete description of the problem and the project. Each pavement design problem is generally identified by the problem number, problem title, date of computer run, and specific identifications of the pavement construction project to include: district number, county name, control number, section number, and highway number, as well as investigation and planning expense prior to construction (IPE) number. Comments are included for further explanations of a specific problem and project.

The processor provides certain program controls and restraints to the user. Category 2 groups program controls and miscellaneous input. This category can be further divided into the following groups:

1. Certain important time, cost, and geometric variables;
2. Different types of pavement, overlay, and reinforcement;
3. Different models for the analysis of cross section, cost, asphaltic shoulder, and selection of shoulder material;
4. Accuracy levels and design confidence levels; and
5. Controls of output amount and form.

Program restraints are included in Category 3. Restraints in funds, thicknesses of initial construction and overlays, and desired pavement performance time periods provide an ample solution space. Pavement designs which satisfy these restraints are regarded as feasible; infeasible designs are thus excluded from consideration.

The modular processor is built around the concept of the serviceability index which measures pavement performance based upon its riding quality.

Pavement performance is a function of its structure, environment, and accumulated traffic. The modular processor evaluates pavement structure based on the environmental variables, desired pavement performance, and accumulated traffic, which are grouped in Categories 4, 5, and 6, respectively. The environment is characterized by region, temperature, and the general roughness that a pavement surface may develop. The performance variables indicate the serviceability index of a new pavement, the minimum serviceability index for normal driving, and the serviceability index after an overlay construction. The initial serviceability index decreases with time as a result of environmental and traffic influences. When the serviceability index has dropped to a certain minimum level, some major maintenance effort must be applied to return the riding quality to an acceptable level. Traffic projection is based on average daily usage at the beginning and end of the analysis period, as well as the cumulative 18-kip single axle (KSA) prediction during the interval.

Traffic delay variables in the analysis period itself (grouped in Category 7) are used to estimate the user's costs. These variables describe the detour method, construction time, percent of arriving traffic, driving speed, etc.

Included in Category 8 are variables related to two alternative maintenance cost models. Model 1 is a simple linear model relating maintenance cost to time, after initial construction or overlay. Model 2 assumes that maintenance cost is also related to pavement age, but also considers periods of freezing temperature, labor wages, and equipment rental rates.

Categories 9, 10, 11, 12 and 13 include, respectively, the variables related to the concrete, reinforcement, joints, subbase materials, and seal coats for rigid pavement construction. Concrete is primely described by flexural strength, elastic modulus, weight, tensile strength, cost, salvage percent, and limiting thicknesses. Reinforcement includes bar steel, wire mesh steel, and tie bar steel. Each steel type is described by an identification number, tensile yield point strength, and cost information. Transverse and longitudinal joints are described by cost information and spacing. Each subbase material is identified by material name, erodability factor, friction factor, material modulus, cost, salvage percent, and limiting thicknesses. Seal coat variables include limiting time periods of seal coat application and cost information.

Included in Category 14 are variables related to existing flexible pavement and proposed asphatic concrete overlay. These input variables include the surface curvature index, composite thickness, in-place value, and salvage value of the existing pavement, together with the in-place cost, salvage value, and level-up of the proposed asphaltic concrete overlay. These variables are deleted for new pavement construction.

Paving materials for flexible pavement constructions are grouped in Category 15. Included for each paving material is a number identifying the order in the structure where the material is used, a code letter identifying the material, the name of the material, the material properties, limiting thicknesses, cost information, salvage value, and various asphalt variables. It must be noted that variables used to describe material properties differ for the three flexible pavement design options. The AASHO based system utilizes strength coefficient and soil support value, the Dynaflect deflection based system employs stiffness coefficient, and the linear elasticity based system implements elastic modulus, Poisson's ratio, and three parameters of the Texas triaxial test model [29].

Different variables are used for each design options; the rigid pavement system utilizes a subgrade modulus of reaction, Texas triaxial class, friction factor, and erodability factor. (Subgrade properties are grouped in Category 16.) Cost of subgrade preparation for rigid pavement construction is also included. For the flexible pavement systems, variables used to describe the subgrade properties are the same as those used to describe the paving material properties, except that the strength coefficient is deleted.

Overlay variables are grouped in Category 17. Asphaltic concrete production rate and compacted density are required for flexible pavement design systems. The rigid pavement system requires variables associated with the asphalt and Portland cement concrete production rate, various costs, salvage value, asphalt concrete modulus value, Portland cement concrete coefficient for the Corps of Engineers' formula, and level-up thickness. In SAMP systems, overlay variables include: asphalt concrete production rate and compacted density, together with name, strength, various thickness and cost variables, salvage value, and various asphalt variables of overlay material.

The costs and limiting dimensions on several of the bituminous material variables associated with construction and maintenance activities are grouped in Category 18. These variables include tack coat and prime coat costs as well as the maximum depth of those layers which will not require a tack coat. These variables are deleted if the entire cross section is not considered.

The shoulder materials, their costs, slopes, and construction can affect the choice of an optimum pavement. The SAMP systems make provision for including shoulder and cross section variables, which are grouped in Category 19. This category can be further divided into three groups:

1. Various dimensions of pavement cross section;

2. Name, thickness, cost, salvage, cross-section, adjustment volume, and various asphalt variables of each shoulder material; and

3. Name, cost, salvage, and cross-section adjustment volume of fill material.

In most flexible pavements, the asphaltic concrete used for the wearing surface differs in its gradation and strength coefficient from the asphaltic concrete or black base beneath it. Provision has been made in SAMP systems for considering separately the structural characteristics of this layer. Wearing surface variables, grouped in Category 20, include the production rate, material name, strength coefficient, thickness, in-place cost, salvage percent, and various asphalt variables.

As shown in Table 3.2, a total of 233 input variables for this modular processor are grouped into 20 categories. A cross sign, X, under an option indicates that the input variable is needed for that specific option. Otherwise, a dash sign, -, is used. For example, a total of 120 variables are required for option 1, while a total of 52, 123, 57, and 65 variables are required for options 2, 3, 4, and 5, respectively.

In order to modularize programming of a data input system, one or more categories of input variables are integrated into a subroutine. A total of seven subroutines have been developed for this purpose. Table 3.3 delineates the input data categories required in each of seven subroutines. The subroutine STAO prints heading, introduction, and instructions of the modular processor, and inputs the project identification and comments. All the other six subroutines are designed only for different data input. Meanwhile, similar to Table 3.2, a cross sign, X, in Table 3.3 means the category of input variables is required for that option shown above the column, while a dash

TABLE 3.2

INPUT DESIGN OF THE PROCESSOR

INPUT VARIABLES	OPTIONS 1	2	3	4	5
-01- PROBLEM IDENTIFICATION AND COMMENTS					
PROBLEM NUMBER	X	X	X	X	X
PROBLEM TITLE	X	-	X	-	-
DISTRICT NUMBER	-	X	-	X	X
COUNTY NAME	-	X	-	X	X
CONTROL NUMBER	-	X	-	X	X
SECTION NUMBER	-	X	-	X	X
HIGHWAY NUMBER	-	X	-	X	X
DATE OF COMPUTER RUN	-	X	-	X	X
IPE NUMBER FOR THE PROJECT	-	X	-	X	X
COMMENTS	-	X	X	X	X
-02- PROGRAM CONTROLS AND MISCELLANEOUS INPUTS					
LENGTH OF THE ANALYSIS PERIOD	X	X	X	X	X
INTEREST RATE OR TIME VALUE OF MONEY	X	X	X	X	X
TOTAL NUMBER OF LANES	X	X	X	X	X
WIDTH OF EACH LANE	X	X	X	X	X
TYPE(S) OF RIGID PAVEMENT	X	-	-	-	-
TYPE(S) OF RIGID PAVEMENT OVERLAY	X	-	-	-	-
TYPE(S) OF RIGID PAVEMENT REINFORCEMENT	X	-	-	-	-
CROSS SECTION MODEL USED	-	-	X	-	-
COST MODEL USED	-	-	X	-	-
ASPHALTIC SHOULDER MODEL USED	-	-	X	-	-
ACCURACY LEVEL FOR ANALYSIS OF LINEAR ELASTICITY	-	-	-	-	X
DESIGN CONFIDENCE LEVEL	X	X	-	X	X
COEFFICIENT OF VARIATION	-	-	X	-	-
CONFIDENCE LEVEL INDICATOR	-	-	X	-	-
NUMBER OF BETTER FEASIBLE DESIGNS DESIRED	X	X	X	X	X
LONG FORM OR SHORT FORM OF OUTPUT DESIRED	X	-	-	-	-
VERSION OF PROGRAM	-	-	X	-	-

TABLE 3.2 (CONTINUED)

INPUT VARIABLES	OPTIONS 1	2	3	4	5
-03- PROGRAM RESTRAINTS					
MAX FUNDS FOR INITIAL CONSTRUCTION	X	-	X	X	X
MAX FUNDS FOR THE FIRST OVERLAY	-	X	-	-	-
MAX TOTAL THICKNESS OF INITIAL CONSTRUCTION	X	-	X	X	X
MIN TIME TO THE FIRST OVERLAY	X	-	X	X	X
MIN TIME BETWEEN OVERLAYS	X	X	X	X	X
MAX ACCUMULATED THICKNESS OF ALL AC OVERLAYS	X	X	X	X	X
MIN THICKNESS OF A SINGLE AC OVERLAY	X	X	-	X	X
MAX ACCUMULATED THICKNESS OF ALL PCC OVERLAYS	X	-	-	-	-
MIN THICKNESS OF A SINGLE PCC OVERLAY	X	-	-	-	-
-04- ENVIRONMENT					
REGIONAL FACTOR	-	-	X	-	-
DISTRICT TEMPERATURE CONSTANT	-	X	-	X	X
SWELLING PROBABILITY	X	X	X	X	X
POTENTIAL VERTICAL RISE	X	X	X	X	X
SWELLING RATE CONSTANT	X	X	X	X	X
-05- PERFORMANCE					
INITIAL SERVICEABILITY INDEX	X	-	X	X	X
MINIMUM SERVICEABILITY INDEX	X	X	X	X	X
SERVICEABILITY INDEX AFTER AN OVERLAY	X	X	X	X	X
INITIAL SERVICEABILITY INDEX, STANDAND DEVIATION	X	-	-	-	-
MINIMUM SERVICEABILITY INDEX, STANDARD DEVIATION	X	-	-	-	-
-06- TRAFFIC GROWTH					
CUMULATIVE 18 KSA DURING ANALYSIS PERIOD	X	X	X	X	X
ADT AT BEGINNING OF ANALYSIS PERIOD	X	X	X	X	X
AXLE GROWTH FACTOR	X	-	-	-	-
AVERAGE DAILY TRAFFIC GROWTH RATE	X	-	-	-	-
DIRECTIONAL DISTRIBUTION FACTOR	X	-	-	-	-
LANE DISTRIBUTION FACTOR	X	-	-	-	-
ADT AT END OF ANALYSIS PERIOD	-	X	X	X	X

TABLE 3.2 (CONTINUED)

INPUT VARIABLES	OPTIONS 1	2	3	4	5
-07- TRAFFIC DELAY DURING OVERLAY PERIOD					
DETOUR MODEL USED DURING OVERLAYING	X	X	X	X	X
DISTANCE OVER WHICH TRAFFIC IS SLOWED					
(1) IN OVERLAY DIRECTION	X	X	X	X	X
(2) IN NONOVERLAY DIRECTION	X	X	X	X	X
DETOUR DISTANCE OF THE ALTERNATIVE ROUTE	X	X	X	X	X
PERCENT OF ADT ARRIVING DURING EACH HOUR	X	X	X	X	X
OVERLAY CONSTRUCTION TIME	X	X	X	X	X
NUMBER OF OPEN LANES IN RESTRICTED ZONE					
(1) IN OVERLAY DIRECTION	X	X	X	X	X
(2) IN NONOVERLAY DIRECTION	X	X	X	X	X
PROJECT LOCATION, RURAL OR URBAN	X	-	X	-	-
PERCENT TRUCKS IN ADT	-	X	-	X	X
PERCENT OF VEHICLES STOPPED					
(1) IN OVERLAY DIRECTION	X	-	X	-	-
(2) IN NONOVERLAY DIRECTION	X	-	X	-	-
AVERAGE DELAY PER VEHICLE STOPPED					
(1) IN OVERLAY DIRECTION	X	-	X	-	-
(2) IN NONOVERLAY DIRECTION	X	-	X	-	-
AVERAGE APPROACH SPEED OF VEHICLES	X	X	X	X	X
AVERAGE SPEED THROUGH RESTRICTED ZONE					
(1) IN OVERLAY DIRECTION	X	X	X	X	X
(2) IN NONOVERLAY DIRECTION	X	X	X	X	X
-08- MAINTENANCE					
TYPE OF MAINTENANCE MODEL	-	-	X	-	-
DAYS OF FREEZING TEMPERATURE PER YEAR	X	-	X	-	-
COMPOSITE LABOR WAGE FOR MAINTENANCE	X	-	X	-	-
COMPOSITE EQUIPMENT RENTAL RATE FOR MAINTENANCE	X	-	X	-	-
COST OF MATERIALS FOR MAINTENANCE	X	-	X	-	-
FIRST YEAR COST OF ROUTINE MAINTENANCE	-	X	X	X	X
ANNUAL INCREMENTAL INCREASE IN MAINTENANCE COST	-	X	X	X	X

TABLE 3.2 (CONTINUED)

INPUT VARIABLES	OPTIONS				
	1	2	3	4	5
-09- CONCRETE					
NUMBER OF CONCRETE TYPES	X	-	-	-	-
NUMBER OF DAYS, CONCRETE STRENGTH WAS MEASURED	X	-	-	-	-
POSITION OF LOADS FOR FLEXURAL STRENGTH TEST	X	-	-	-	-
CONCRETE FLEXURAL STRENGTH, MEAN VALUE	X	-	-	-	-
WEIGHT OF CONCRETE	X	-	-	-	-
MODULUS OF ELASTICITY OF CONCRETE	X	-	-	-	-
TENSILE STRENGTH OF CONCRETE	X	-	-	-	-
INITIAL COST OF CONSTRUCTION EQUIPMENT	X	-	-	-	-
UNIT COST OF CONCRETE	X	-	-	-	-
COST OF SURFACING CONCRETE	X	-	-	-	-
SALVAGE PERCENT AT END OF ANALYSIS PERIOD	X	-	-	-	-
MINIMUM ALLOWABLE CONCRETE THICKNESS	X	-	-	-	-
MAXIMUM ALLOWABLE CONCRETE THICKNESS	X	-	-	-	-
STANDARD DEVIATION OF THICKNESS OF CONCRETE	X	-	-	-	-
PRACTICAL INCREMENT, CONCRETE CAN BE POURED	X	-	-	-	-
CONCRETE FLEXURAL STRENGTH, PERCENT CONFIDENCE	X	-	-	-	-
ELASTIC MODULUS OF CONCRETE, STANDARD DEVIATION	X	-	-	-	-
-10- REINFORCEMENTS					
BAR STEEL, I.D. NUMBER	X	-	-	-	-
BAR STEEL, TENSILE YOELD POINT STRENGTH	X	-	-	-	-
BAR STEEL, COST	X	-	-	-	-
WIRE MESH STEEL, I.D. NUMBER	X	-	-	-	-
WIRE MESH STEEL, TENSILE YIELD POINT STRENGTH	X	-	-	-	-
WIRE MESH STEEL, COST	X	-	-	-	-
TIE BAR STEEL, I.D. NUMBER	X	-	-	-	-
TIE BAR STEEL, TENSILE YIELD POINT STRENGTH	X	-	-	-	-
TIE BAR STEEL, COST	X	-	-	-	-
BAR NUMBERS TO BE TRIED	X	-	-	-	-
LONGITUDINAL MESH SPACINGS TO BE TRIED	X	-	-	-	-
TRANSVERSE MESH SPACINGS TO BE TRIED	X	-	-	-	-
TIE BAR NUMBERS TO BE TRIED	X	-	-	-	-

TABLE 3.2 (CONTINUED)

INPUT VARIABLES	OPTIONS 1	2	3	4	5
-11- JOINTS					
COST OF TRANSVERSE JCINT	X	-	-	-	-
COST OF LONGITUDINAL JOINT	X	-	-	-	-
LOWER VALUE OF TRANSVERSE JOINT SPACING	X	-	-	-	-
UPPER VALUE OF TRANSVERSE JOINT SPACING	X	-	-	-	-
INCREMENT OF SPACING FOR TRANSVERSE JOINT	X	-	-	-	-
NUMBER OF TRANSVERSE JOINTS	X	-	-	-	-
STANDARD DEVIATION OF CONTINUITY FACTOR J	X	-	-	-	-
-12- SUBBASE MATERIALS FOR RIGID PAVEMENTS					
NUMBER OF SUBBASE TYPES	X	-	-	-	-
DESCRIPTION OF SUBBASE	X	-	-	-	-
ERODABILITY FACTOR FOR THE SUBBASE	X	-	-	-	-
FRICTION FACTOR FOR SUBBASE	X	-	-	-	-
SUBBASE MATERIAL MODULUS VALUE	X	-	-	-	-
INITIAL COST OF CONSTRUCTION EQUIPMENT	X	-	-	-	-
COST OF COMPACTED SUBBASE	X	-	-	-	-
SALVAGE PERCENT AT END OF ANALYSIS PERIOD	X	-	-	-	-
MINIMUM ALLOWABLE SUBBASE THICKNESS	X	-	-	-	-
MAXIMUM ALLOWABLE SUBBASE THICKNESS	X	-	-	-	-
PRACTICAL INCREMENT, SUBBASE CAN BE POURED	X	-	-	-	-
-13- SEAL COATS					
TIME TO FIRST SEAL COAT AFTER AN AC OVERLAY	X	-	-	-	-
TIME BETWEEN SEAL COATS	X	-	-	-	-
COST PER LANE-MILE OF A SEAL COAT	X	-	-	-	-
-14- EXISTING PAVEMENT AND PROPOSED ACP OVERLAY					
SCI OF THE EXISTING PAVEMENT	-	X	-	-	-
STANDARD DEVIATION OF SCI	-	X	-	-	-
COMPOSITE THICKNESS OF THE EXISTING PAVEMENT	-	X	-	-	-
IN-PLACE COST OF PROPOSED ACP	-	X	-	-	-
PROPOSED ACP'S SALVAGE VALUE	-	X	-	-	-
IN-PLACE VALUE OF EXISTING PAVEMENT	-	X	-	-	-
EXISTING PAVEMENT'S SALVAGE VALUE	-	X	-	-	-
LEVEL-UP REQUIRED FOR THE FIRST OVERLAY	-	X	-	-	-

TABLE 3.2 (CONTINUED)

INPUT VARIABLES	OPTIONS 1	2	3	4	5
-15- PAVING MATERIALS FOR FLEXIBLE PAVEMENTS					
NUMBER OF PAVING MATERIALS	-	-	X	X	-
LAYER DESIGNATION NUMBER	-	-	X	X	X
LETTER CODE OF MATERIAL	-	-	X	X	X
MATERIAL NAME	-	-	X	X	X
IN-PLACE COST	-	-	-	X	X
STIFFNESS COEFFICIENT	-	-	-	X	-
STRENGTH COEFFICIENT	-	-	X	-	-
SOIL SUPPORT VALUE	-	-	X	-	-
MINIMUM ALLOWABLE THICKNESS	-	-	X	X	X
MAXIMUM ALLOWABLE THICKNESS	-	-	X	X	X
SALVAGE VALUE	-	-	X	X	X
ELASTIC MODULUS	-	-	-	-	X
POISSON RATIO	-	-	-	-	X
U VALUE OF TEXAS TRIAXIAL TEST MODEL	-	-	-	-	X
T VALUE OF TEXAS TRIAXIAL TEST MODEL	-	-	-	-	X
C VALUE OF TEXAS TRIAXIAL TEST MODEL	-	-	-	-	X
MINIMUM IN-PLACE COST	-	-	X	-	-
MAXIMUM IN-PLACE COST	-	-	X	-	-
LAYER INCREMENT	-	-	X	-	-
TACK COAT APPLICATION RATE	-	-	X	-	-
PRIME COAT APPLICATION RATE	-	-	X	-	-
AC APPLICATION RATE	-	-	X	-	-
ASPHALTIC CONTENT PER CENT	-	-	X	-	-
-16- SUBGRADE PROPERTIES					
SUBGRADE K, MEAN VALUE	X	-	-	-	-
SUBGRADE K, STANDARD DEVIATION	X	-	-	-	-
TEXAS TRIAXIAL CLASS, MEAN VALUE	X	-	-	-	-
FRICTION FACTOR FOR SUBGRADE	X	-	-	-	-
ERODABILITY FACTOR FOR SUBGRADE	X	-	-	-	-
COST OF SUBGRADE PREPARATION	X	-	-	-	-
SOIL SUPPORT VALUE	-	-	X	-	-
STIFFNESS COEFFICIENT	-	-	-	X	-
ELASTIC MODULUS	-	-	-	-	X
POISSON RATIO	-	-	-	-	X
U VALUE OF TEXAS TRIAXIAL TEST MODEL	-	-	-	-	X
T VALUE OF TEXAS TRIAXIAL TEST MODEL	-	-	-	-	X
C VALUE OF TEXAS TRIAXIAL TEST MODEL	-	-	-	-	X

TABLE 3.2 (CONTINUED)

INPUT VARIABLES	OPTIONS 1	2	3	4	5
-17- OVERLAYS					
ASPHALT CONCRETE PRODUCTION RATE	X	X	X	X	X
ASPHALT CONCRETE COMPACTED DENSITY	-	X	X	X	X
EQUIPMENT COST FOR AC OVERLAY	X	-	-	-	-
COST OF ASPHALT CONCRETE	X	-	-	-	-
SALVAGE PERCENT OF AC AT END OF ANALYSIS PERIOD	X	-	-	-	-
ASPHALT CONCRETE MODULUS VALUE	X	-	-	-	-
CONCRETE PRODUCTION RATE	X	-	-	-	-
CONCRETE COEFFICIENT FOR CE'S FORMULA	X	-	-	-	-
ANY ADDITIONAL COST	X	-	-	-	-
LEVEL-UP THICKNESS	X	-	X	-	-
OVERLAY DESCRIPTION	-	-	X	-	-
OVERLAY STRENGTH COEFFICIENT	-	-	X	-	-
MINIMUM THICKNESS	-	-	X	-	-
MAXIMUM THICKNESS	-	-	X	-	-
MINIMUM IN-PLACE COST	-	-	X	-	-
MAXIMUM IN-PLACE COST	-	-	X	-	-
SALVEGE PERCENT	-	-	X	-	-
OVERLAY INCREMENT	-	-	X	-	-
TACK COAT APPLICATION RATE	-	-	X	-	-
PRIME COAT APPLICATION RATE	-	-	X	-	-
AC APPLICATION RATE	-	-	X	-	-
ASPHALTIC CONTENT PER CENT	-	-	X	-	-
COST TO UPGRADE AFTER AN OVERLAY	-	-	X	-	-
WIDTH OF PAVEMENT AND SHOULDERS TO BE UPGRADED	-	-	X	-	-
-18- TACK, PRIME, AND BITUMINOUS VARIABLES					
TACK COAT COST	-	-	X	-	-
PRIME COAT COST	-	-	X	-	-
BITUMINOUS MATERIAL COST	-	-	X	-	-
MAX LAYER FOR NO TACK COATS	-	-	X	-	-
MAX DEPTH OF EACH LIFT	-	-	X	-	-

TABLE 3.2 (CONTINUED)

INPUT VARIABLES	OPTIONS 1	2	3	4	5
-19- SHOULDER AND CROSS SECTION					
WIDTH OF OUTSIDE SHOULDER	-	-	X	-	-
WIDTH OF INSIDE SHOULDER	-	-	X	-	-
CROSS SECTION WIDTH OUTSIDE OF OUTSIDE SHOULDER	-	-	X	-	-
CROSS SECTION WIDTH OUTSIDE OF INSIDE SHOULDER	-	-	X	-	-
NUMBER OF SHOULDER MATERIALS	-	-	X	-	-
NAME OF SHOULDER MATERIAL	-	-	X	-	-
DEPTH OF SHOULDER	-	-	X	-	-
IN-PLACE COST OF SHOULDER MATERIAL	-	-	X	-	-
SALVAGE PERCENT OF SHOULDER	-	-	X	-	-
TACK COAT APPLICATION RATE	-	-	X	-	-
PRIME COAT APPLICATION RATE	-	-	X	-	-
AC APPLICATION RATE	-	-	X	-	-
ASPHALTIC CONTENT PER CENT	-	-	X	-	-
ADJUSTMENT VOLUME	-	-	X	-	-
NAME OF FILL MATERIAL	-	-	X	-	-
IN-PLACE COST OF FILL MATERIAL	-	-	X	-	-
SALVAGE PERCENT OF FILL MATERIAL	-	-	X	-	-
ADJUSTMENT VOLUME OF FILL MATERIAL	-	-	X	-	-
WIDTH OF OUTSIDE PAVEMENT LAYERS	-	-	X	-	-
WIDTH OF INSIDE PAVEMENT LAYERS	-	-	X	-	-
WIDTH OF OUTSIDE SHOULDER LAYERS	-	-	X	-	-
WIDTH OF INSIDE SHOULDER LAYERS	-	-	X	-	-
-20- WEARING SURFACE					
WEARING SURFACE PRODUCTION RATE	-	-	X	-	-
WEARING SURFACE DESCRIPTION	-	-	X	-	-
WEARING SURFACE STRENGTH COEFFICIENT	-	-	X	-	-
WEARING SURFACE THICKNESS	-	-	X	-	-
WEARING SURFACE IN-PLACE COST	-	-	X	-	-
WEARING SURFACE SALVAGE PERCENT	-	-	X	-	-
TACK COAT APPLICATION RATE	-	-	X	-	-
PRIME COAT APPLICATION RATE	-	-	X	-	-
AC APPLICATION RATE	-	-	X	-	-
ASPHALTIC CONTENT PER CENT	-	-	X	-	-

TABLE 3.3

INPUT DATA CATEGORIES REQUIRED IN EACH SUBROUTINE

SUBROUTINE NAME	CATEGORY NUMBER	CATEGORY OF INPUT VARIABLES	OPTIONS 1	2	3	4	5
STA0	1	PROBLEM IDENTIFICATION AND COMMENTS	X	X	X	X	X
STA1	2	PROGRAM CONTROLS AND MISCELLANEOUS INPUTS	X	X	X	X	X
	3	PROGRAM RESTRAINTS	X	X	X	X	X
	4	ENVIRONMENTAL DATA	X	X	X	X	X
STA2	5	PERFORMANCE DATA	X	X	X	X	X
	6	TRAFFIC GROWTH DATA	X	X	X	X	X
	7	TRAFFIC DELAY DATA DURING OVERLAY PERIOD	X	X	X	X	X
	8	MAINTENANCE DATA	X	X	X	X	X
NEX1	9	CONCRETE DATA	X	-	-	-	-
	10	REINFORCEMENT DATA	X	-	-	-	-
	11	JOINT DATA	X	-	-	-	-
	12	SUBBASE MATERIALS DATA FOR RIGID PAVEMENTS	X	-	-	-	-
	13	SEAL COAT DATA	X	-	-	-	-
NEX2	14	EXISTING PAVEMENT AND PROPOSED ACP OVERLAY DATA	-	X	-	-	-
STA3	15	PAVING MATERIALS DATA FOR FLEXIBLE PAVEMENTS	-	-	X	X	X
	16	SUBGRADE PROPERTIES	X	-	X	X	X
	17	OVERLAY DATA	X	X	X	X	X
NEX3	18	TACK, PRIME, AND BITUMINOUS DATA	-	-	X	-	-
	19	SHOULDER AND CROSS SECTION DATA	-	-	X	-	-
	20	WEARING SURFACE DATA	-	-	X	-	-

sign, -, indicates otherwise. Therefore, subroutines STA0, STA1, STA2, and STA3 are used for each option, but subroutines NEX1, NEX2, and NEX3 are used only for options 1, 2, and 3, respectively.

Driver's Segment

The driver's segment is designed to perform the following six major tasks:

1. printing the heading, introductory descriptions, and instructions of the modular processor;
2. driving four alternative methods of data entry for five major options of pavement design;
3. creating data card images for individual pavement design programs;
4. printing a list of input data files;
5. providing a procedure for data revisions; and
6. storing the data file for future uses.

Figure 3.2 shows a flow diagram of the driver's segment. As shown in the figure, some tasks are optional. Users who do not need one or more optional tasks can by-pass them easily.

The driver's segment starts with the printing of the heading. Then, the user has the option of requesting print-outs of thirteen introductory lines and twenty-nine lines of instructions and examples. The preface covers a brief outline of the structure and design of the modular processor. The instructions and illustrative examples are designed to describe all the following three types of input formats: (1) character input; (2) choice input; and (3) numerical input. The character input is essentially an "A-

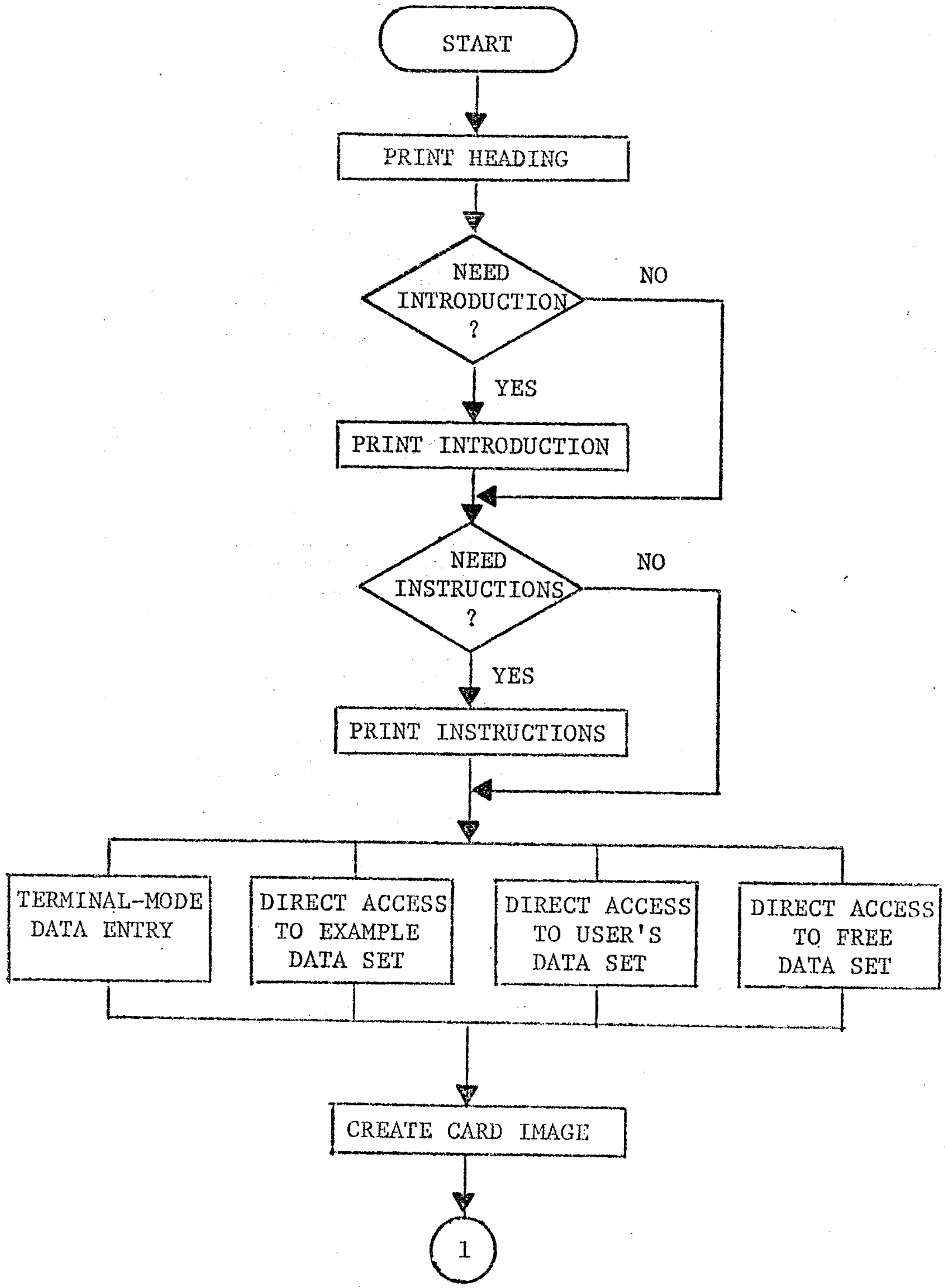


Figure 3.2 Flow diagram of driver's segment

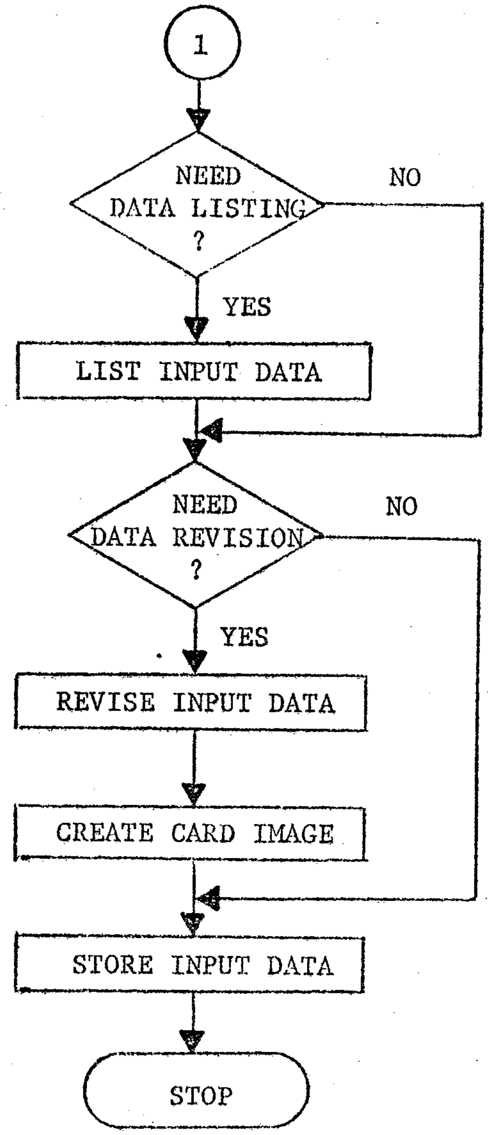


Figure 3.2 (continued)

format" in FORTRAN language. The computer will print the maximum allowable numbers of characters after it requests the inputs. Choice input is either a "I1-format" or "A1-format" in FORTRAN, depending upon convenience and requirements in the program. For instance, when the user is instructed to type 1 for rigid pavement design or 2 for flexible pavement design, the "I1-format" is used. As the computer asks: "Do you need a list of input data files?", the user may respond either "YES" or "NO". The program reads only the first character "Y" or "N" in "A1-format". The numerical input is an "F10.0-format" in FORTRAN. A maximum of nine numbers is allowed. Also, a decimal point must be included. Users who are familiar with the outline and input formats may by-pass the introduction and instruction print-outs.

There are four alternative methods designed for data entry:

1. terminal-mode data entry,
2. direct access to example data set,
3. direct access to user's data set, and
4. direct access to free data set.

The terminal-mode data entry method receives input values from the communication terminal by interactive queries between the computer and the user. The other three methods are based on direct access to data sets stored in on-line disk tracks either by the user or with the processor.

The data image is the only basic interface between the driver's segment and five pavement design programs. Input data entered in the driver's segment are organized into 80-column-data-card formats and stored in on-line disk tracks before the termination of the driver's segment. Then the remote job entry task provides a set of job control languages to call a specific pavement design program from the computer system job library, and direct the program to read input data from the card image rather than from the normal card reader.

A list of input data files is also optional. The list includes a code number for each input variable, as well as its name and input value. Terminal listing may take 5 to 10 minutes; however, users may by-pass the listing procedure if the data list is not needed. The data list provides a hard copy record of well-organized input data so that the processor user can (1) check the input data either keyed from the communication terminal or entered by direct access to data files; and (2) keep a record of all input data for future reference.

The procedure for the data revision is simple. The user need only type the code number and the new input value of the variable, the data value will be revised accordingly. Meanwhile, a code number, 99.99, will terminate the revision procedure. The driver's segment will also automatically revise the input value on the input data card image.

Prior to terminating the driver's segment, the processor will store the current data file in either the user's individual data set, or a free data set at the user's command. The user may then recall the data file from the storage space if he so desires.

The dirver's segment has been programmed in FORTRAN IV language. It takes approximately 200k bytes of computer memory to execute the driver's segment. In general, a teleprocessing program with large core requirements will barely receive sufficient core space for execution, especially during a busy period. The need to reduce the core requirement for the driver's segment is thus readily recognized. Two major tasks have been accomplished to achieve this purpose, (1) program modularization, and (2) overlay linkage

[19]. At first, the driver's segment is modularized into one small MAIN program and eighteen subroutines; Figure 3.3 shows the relationships among the MAIN program and subroutines. The MAIN program calls fifteen subroutines: TPIO, STA0, STA1, STA2, STA3, NEX1, NEX2, NEX3, CDMG, MON1, MON2, MON3, SUN1, SUN2, SUN3. Subroutine STA3 calls subroutine TTTM, which in turn calls subroutine FBSR. And subroutine FBSR calls subroutine ASSN. The core requirement to execute the driver's segment is the summation of the cores required to execute the MAIN program and each subroutine. With the aid of overlay linkage, the overall core requirement is reduced to 60K bytes of computer memory. Figure 3.4 illustrates the overlay linkage arrangement of the driver's segment. The MAIN program and eighteen subroutines are grouped into eleven segments. Segment 1 is classified as level 1 in linkage. Segments 2 to 11 are classified as level 2. The ten segments in level 2 share the same core spaces. For instance, Segment 7 will occupy the common core spaces of level 2 when subroutine CDMG is called. If subroutine MON2 is called after the execution of subroutine CDMG is completed, segment 7 is deleted from common core spaces and Segment 9 replaces it. The overall core requirement to execute the driver's segment equals the summation of cores required for level 1 and level 2. Level 1 space is the core summation of MAIN program and subroutine TPIO. TPIO, which is a library subroutine of the Texas A&M's version of BEST teleprocessing system, handles the input-output of the communication terminal, and must be placed at the top level. Level 2 space equals to the maximum core requirement of segments 2 to 11. The overall core requirement is 60k bytes of computer memory. The execution of the driver's segment takes about two seconds central processing unit (CPU) time.

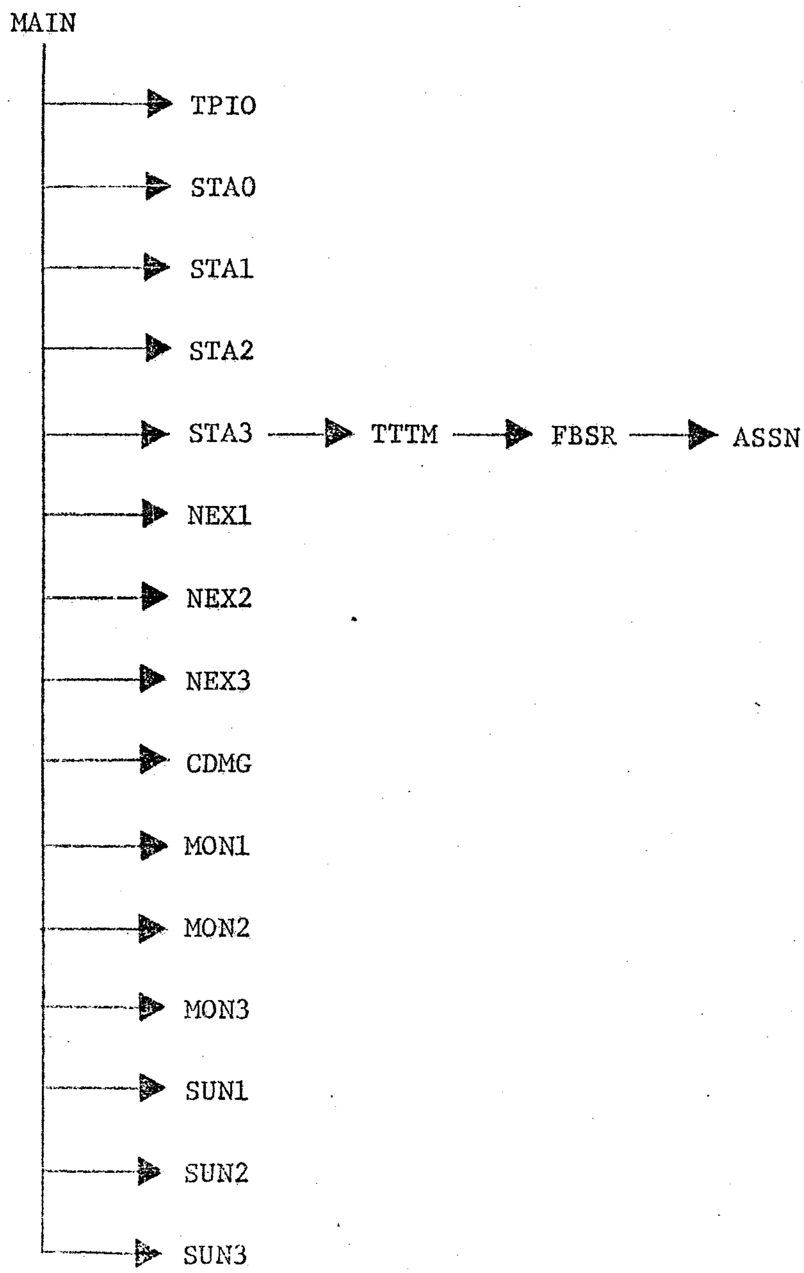


Figure 3.3 Relationships among MAIN program and subroutines of the driver's segment

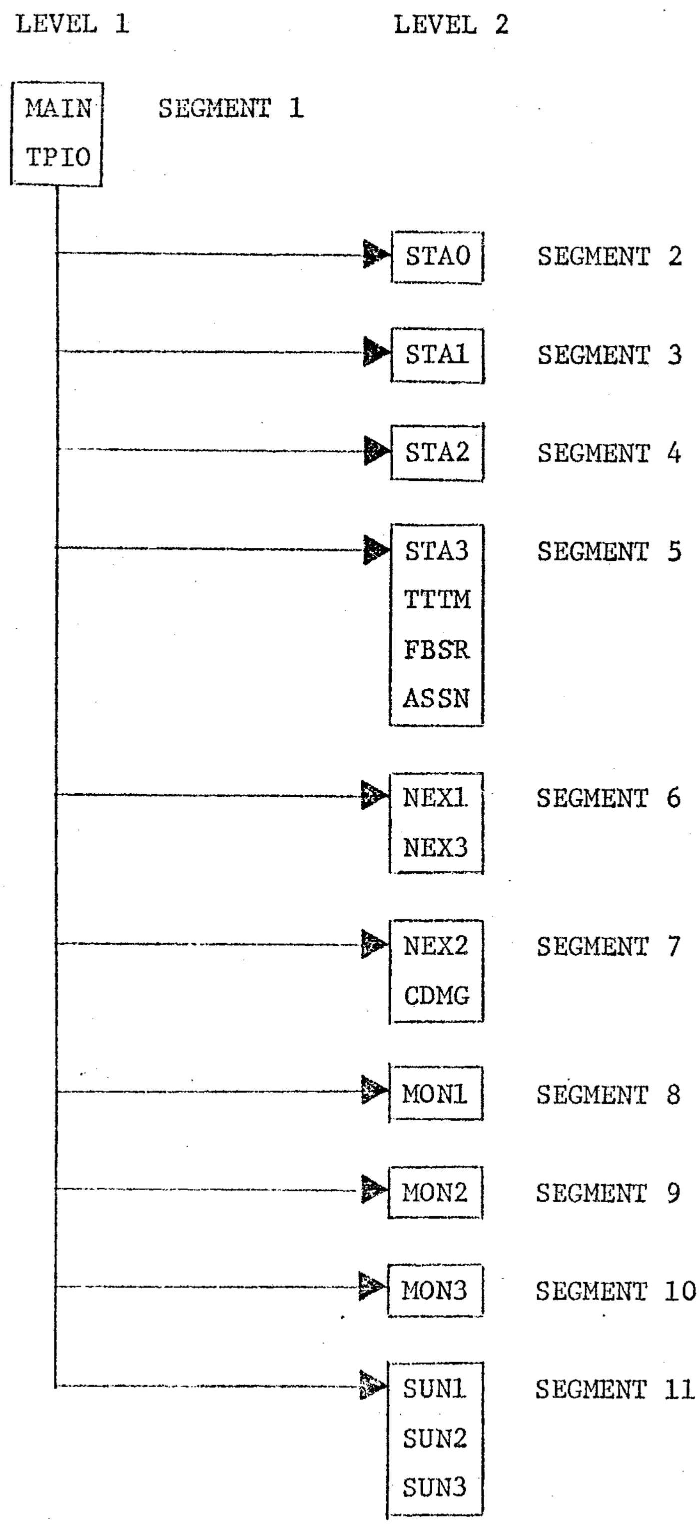


Figure 3.4 Overlay linkage arrangement of the driver's segment

Data Entry

Processor data entry is one of the most intricate elements in the design of the driver's segment. As mentioned above, input data can be entered into the driver's segment through one of four alternative methods:

1. terminal-mode interactive queries
2. direct access to example data set
3. direct access to user's data set
4. direct access to free data set.

After optional listing, revision, and storage processing, the input data file is reorganized to create data card images on on-line disk tracks. Pavement design programs can thus read in data from such card images instead of data cards from a card reader. The four alternative methods of data entry are discussed specifically in this section.

The terminal-mode data entry is designed in a conversational style system with interactive queries between the computer and the user. Initially the computer prints an input variable from the terminal device, and awaits an input value; the user responds from the terminal's keyboard. The computer then prints the input variables sequentially until all values have been received from the terminal.

More than 200 variables in 20 categories are included in this processor. Comments and recommendations for input values are also stored in the driver's segment. Thus providing a "manual" abetting the users access to the computer. After the computer prints a variable, the user can either enter his input value or respond via a special signal requesting immediate guidance. In most cases, the "help" signal is either a question mark or a number of 99.9 based on the instructions printed after the input variable. Users who are familiar with input variables may by-pass all comments and recommendations. For an engineer or design professional not acquainted with the pavement design programs, these aids provide him an educational tool within the confines of his office, thereby, enabling him to utilize them at his own pace.

Figure 3.5 depicts the terminal-mode data entry sequence. The user is first requested to enter input values for eight categories of variables: problem identification and comments, program controls and miscellaneous inputs, program restraints, environmental data, performance data, traffic growth data, traffic delay data during overlay period, and maintenance data. Should the rigid pavement system (option 1) be selected, the processor will direct the user to the data entry of the following five variable classes: concrete data, reinforcement data, joints data, subbase materials data for rigid pavements, and seal coat data. If one of the three flexible pavement systems (options 3, 4 and 5) is selected, paving materials and properties sets for flexible pavements will be required input. If the user is interested in asphaltic concrete pavement overlay design systems (option 2), the processor directs entry of existing pavement and proposed overlay data. In addition, data entry of subgrade properties is required for all new pavement constructions (options 1, 3, 4 and 5). For flexible pavement systems using the AASHO structural number (option 3), three additional categories of input data are necessary: shoulder and cross section data and wearing surface data, plus tack, prime and bituminous data.

The other alternative data entry methods are facilitated by direct access to a sequential on-line data file. The current version of the modular processor has a capacity to store up to 20 sets of input data. Each set

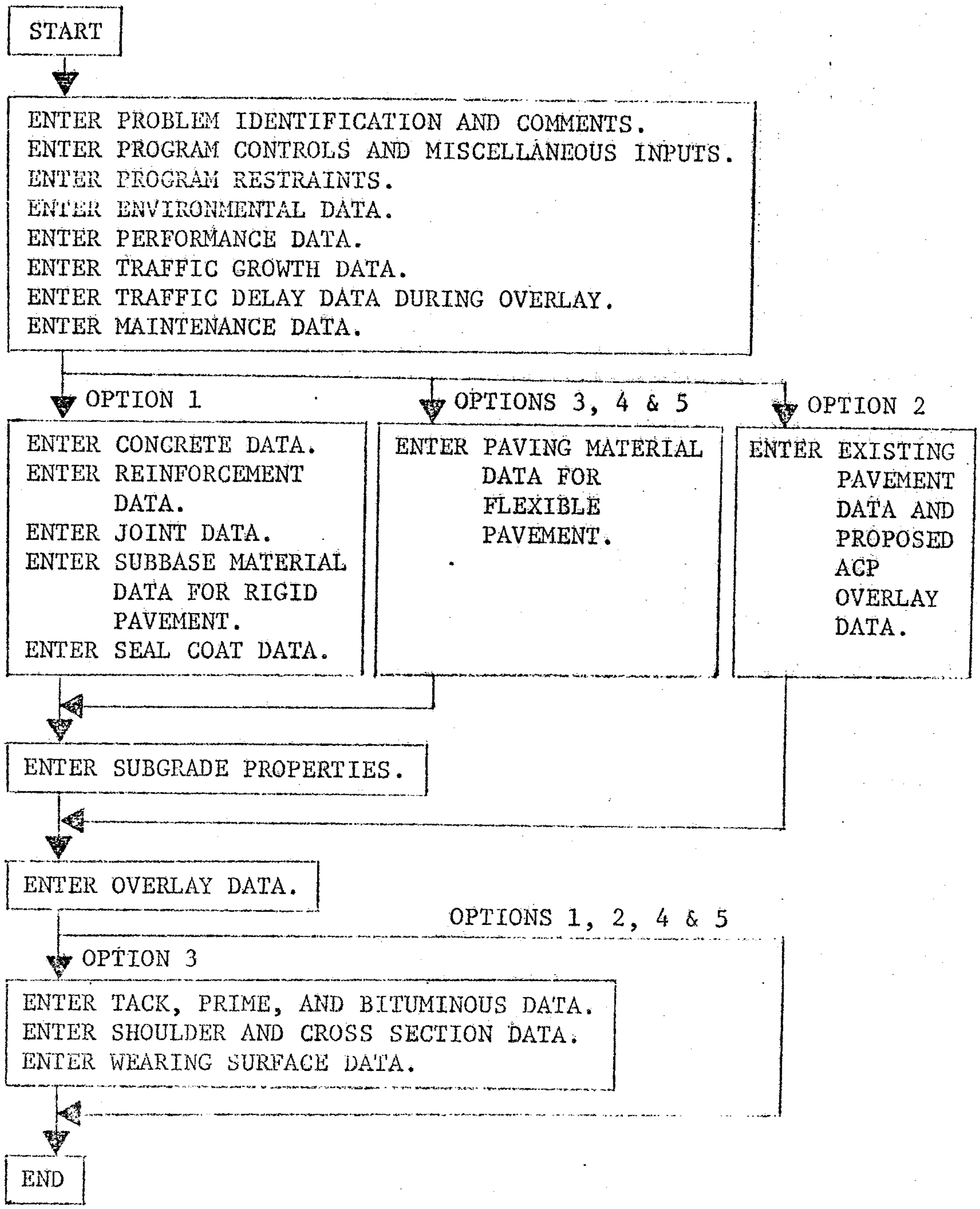


Figure 3.5 Sequence of terminal-mode data entry

occupies one record space and each record space requires an on-line disk track. The first five record numbers are reserved for example data sets while the sixth is used as a free set. The other fourteen records (numbers 7-20) can be assigned to an individual user for private data set(s).

The five example data sets (Table 3.4) serve as illustrative examples of the major options built into the modular processor. The example data set provides sample input values for user guidance. Utilization of these example data sets will minimize the effort of actual data entry especially when the user tries a problem including several values common to the example inputs.

The user's data set consists of special data files for specific problems. Following data entry and optional data revisions, the user may wish to store the special data file for future executions. Utilization of a user's data set will minimize the user's efforts on data entry, especially for the cases involving only a few changes from an original input data set. After all data entry and revisions, the user may still substitute a new data file for the original or retain the original data file and store the new material in another record or a free data record.

The free data set permits temporary housing of the user's data file, thereby facilitating direct access to it, should the user not rent record space. However, this set will be destroyed by any subsequent user's input. Still, providing a free data set will enable the user to employ the modular processor without the extra burden involved in renting a record space.

Data Listing, Revision, and Storage

A list of input data is normally very helpful to users of one of the direct access methods of data entry. Through a terminal, input data stored

TABLE 3.4

ARRANGEMENTS OF EXAMPLE DATA SETS

RECORD NUMBER	EXAMPLE INPUT DATA FOR THE FOLLOWING DESIGN SYSTEM
1	RIGID PAVEMENT SYSTEM
2	ASPHALTIC CONCRETE PAVEMENT OVERLAY SYSTEM
3	FLEXIBLE PAVEMENT SYSTEM USING AASHO STRUCTURAL NUMBER
4	FLEXIBLE PAVEMENT SYSTEM USING DYNAFLECT DEFLECTION
5	FLEXIBLE PAVEMENT SYSTEM USING LINEAR ELASTICITY

in the example data set, user's data set, or free data set can be printed out. Since the data set is stored in the disk tracks, listing the data prior to executing the pavement design program serves as a check on input values and determines if any revisions are necessary.

To users of the terminal-mode data entry method, a list of the input data files may provide a well organized print-out for quick review. Input data errors resulting from typing mistakes, erroneous format, or other reasons can thus be detected. The data listing and revision features provide processor users a chance to correct the input error before executing the pavement design program.

Also, delineating the input data will identify the code number for each input value. As the user must know the code number to effect revision, the data list assures greater significance in processor utilization.

The code number is in the form of "XX.YY.ZZ", where XX is the category number, YY is the data set number, and ZZ is the item number. If the variables of a category are restricted to only one data set, the data set number, YY, is deleted. The form is simply "XX.ZZ". For instance, a code number of 10.02.08 is used in the rigid pavement system to designate the minimum allowed thickness of subbase using material number 2. The first two digits, 10, means the 10th category of input variables in the rigid pavement design system, i.e., subbase materials. The second two digits, 02, means material number 2. The last two digits, 08, means the 8th variable in the 10th category, i.e., minimum allowed thickness.

Three subroutines are designed for the listing of the input data file. Subroutine MON1 is specially designed for a rigid pavement problem, Subroutine MON3 for a flexible pavement problem using an AASHO structural number, and subroutine MON2 is intended for the remaining options which include: asphaltic concrete pavement overlay designs, flexible pavement design by Dynaflect deflection, and flexible pavement design based on linear elasticity.

One of the modular processor's salient features is the simplified data revision and reevaluation. For each revision, one need only type in the code number and the new value. A code number 99.99 will immediately terminate the revision procedure. For users of the terminal-mode data entry, this feature also provides an opportunity for correcting input errors, while those using an example data set, user's data set, or the free data set, can minimize the labor entailed in modifying a data set.

Three subroutines have been developed revising the input data file. Subroutine SUN1 reworks the input data of a rigid pavement design problem, subroutine SUN3 revises flexible pavement design based on an AASHO structural number, and subroutine SUN2 pertains to other options including asphaltic concrete pavement overlay design, flexible pavement design by Dynaflect deflection, and flexible pavement design based on linear elasticity.

The data storage procedure is quite simple. Before terminating the driver's segment, the user simply enters a pre-assigned record number for retaining the input data as a user's data set, thereby completing the storage process. Should this procedure not be followed, the machine will automatically house the material in a free data set, thus increasing the likelihood of its accidental destruction by subsequent users.

Salient Characteristics

The integrated processor was essentially designed to achieve full-scale implementation of a systems approach to pavement design. Therefore, simplicity, convenience, and efficiency would be heavily considered in measuring the effectiveness of the processor. The primary features designed into the modular processor to effect the three concerns mentioned are described below.

1. Multiple Option Arrangements. The modular processor includes five major pavement design options: (1) rigid pavement design; (2) asphaltic concrete pavement overlay design; (3) flexible pavement design based on AASHO structural number; (4) flexible pavement design based on Dynaflect deflections; and (5) flexible pavement design based on linear elasticity. Many minor options are also included in each pavement design option. Minor options include: concrete pavement types, overlay types, reinforcement types, accuracy levels for analysis of linear elasticity, design confidence levels, pavement cross section models, cost models, shoulder types, traffic detour models, maintenance models, etc.

2. Instant Responsiveness. Comments and recommendations for input values will be printed out immediately upon request through the real-time computer system and terminal operated output device. The user does not need a printed manual for input information. The application-oriented processor counsels and directs the user in his pavement design efforts. In fact, the processor can print out a figure upon the user's request to illustrate the pavement cross section.

3. Streamlined Input Mechanism. Normally, more than 200 variables are considered in the design and management of pavement construction and rehabilitation. All these variables have been organized and categorized into one integrated sequential format. Instruc-

tions and examples of the conversation-style input information are also stored in the processor as user's reference. Since the communication terminal can be operated by any typist with a minimum of additional training, it enables a professional designer to concentrate upon the optimization of a pavement design system, rather than upon the mechanism of coding the input data.

4. Office Operations. The remote terminal device is essentially an electronic typewriter equipped with an acoustic coupler. Generally, the terminal is portable, enabling it to be emplaced quite a distance from a computing center. The computer teleprocessing system can thus be utilized through normal telephone lines, Permitting design engineers to stay in their own office and concentrate on design problems without battling the inherent confusion of a computing center. Professional personnel are further spared the inconvience of waiting for computer printouts.

5. Interactive Training. The strategic modular processor is in itself an educational tool for beginning users. Full instructions can be reached at the other end of the telephone line. The processor features a simple input method, which encourages the users to continue the learning process. The conversation-style input system overcomes the cumbersome requirements of massive data input and the lack of interactive features between the computer and the design engineers. Also, the processor will familiarize professionals with the existing optimization procedures through mere interactive queries, rather than tiresome formal lectures.

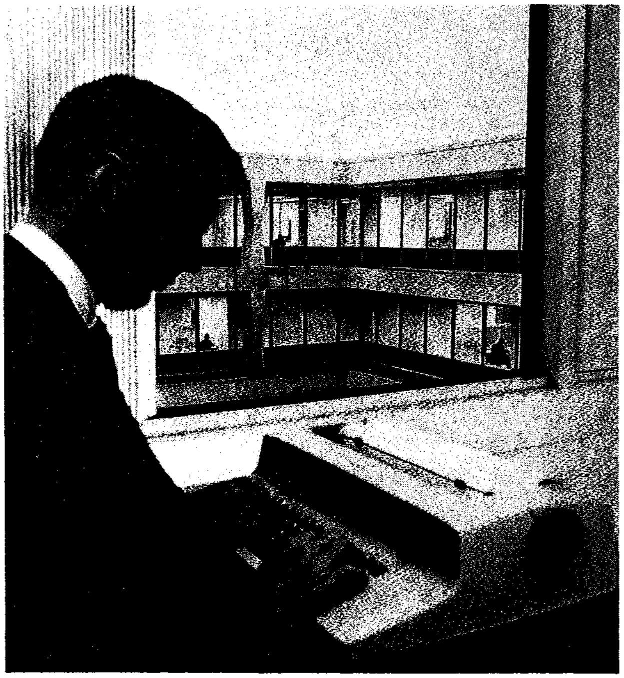
6. Open-Ended Design. Currently, the modular processor includes five major pavement design programs; however, the processor structure is open-ended. Any new procedure can be added to the program package without altering original components, and an old program can be independently replaced by a new one. Of course, some changes in terms of additions or modifications are required for the driver's segment.
7. Modular Independence. All the optimization programs included in this processor are in modular form. For each of the individual programs, the special interest and unique utilization features are retained as they were before integration into the processor. Thus, each of the modules can be utilized individually as a regular optimization program.
8. Data Reevaluation and Readjustment. After the entry of all input data, the user may request a list of input variable names, code numbers and values. Modifications of the data file can easily be performed by calling the code number and reentering the input value. Since the input data can be stored in on-line disk tracks, reevaluation and readjustment of the input data can be easily achieved by certain runs of the processor.
9. Direct Access to Data File. There are three major types of data sets utilized in this modular processor: example data set, user's data set, and free data set. Direct access to any of these data files will minimize the efforts required for modifying input data between problems. Also, the user may store his special set of data files for future executions.

CHAPTER IV

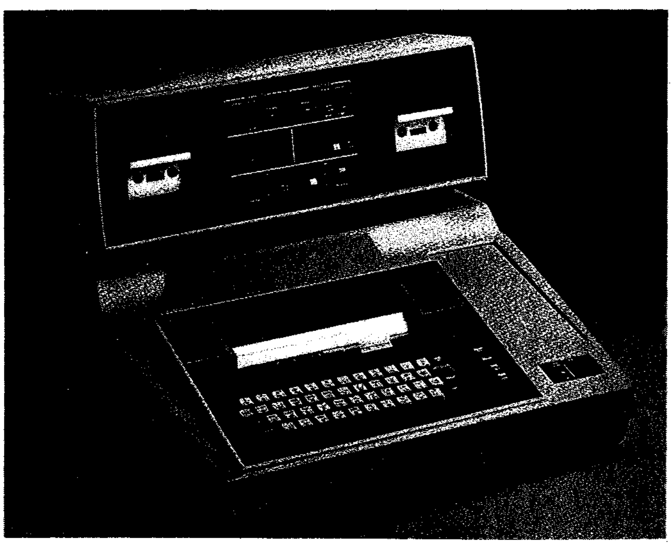
THE UTILIZATION OF THE PROCESSOR

Utilization of the modular processor is uncomplicated, quite convenient, and does not demand detailed familiarity with computer programming and operation. The processor is designed to guide the user in solving a complex pavement design problem with minimum effort. Further, only a slight amount of additional training is required to instruct typists in communication terminal operation, thereby enabling the engineer to focus upon the optimization of pavement design rather than the mechanics of coding input data. Some typical computer terminals and communication devices are shown in Figure 4.1.

Detailed procedures for implementing the modular processor are delineated in Figure 4.2. The entire job execution can be divided into four tasks: orientation, data preparation, pavement optimization, and termination. Orientation encompasses preliminary data preparation, the "dial-up" to secure access to the computer, and "sign-on" of the teleprocessing system. Data preparation includes the execution of the driver's segment and is thus the most involved portion of the entire operation. Users have four data entry alternatives. An interactive terminal entry mode may be implemented, or one of three direct access modes will suffice. Operating personnel may request, or bypass, the listing and revision of the data file and store the information in a user's data set or a free data set. The processor then will generate an input data card image upon an on-line data set, which essentially is an interface, or buffer, between data preparation and pavement optimization. Pavement design programs held within the job library will direct the computer to read-in the data from the card image, and print output information according to the requests received via remote job entry. Project completion

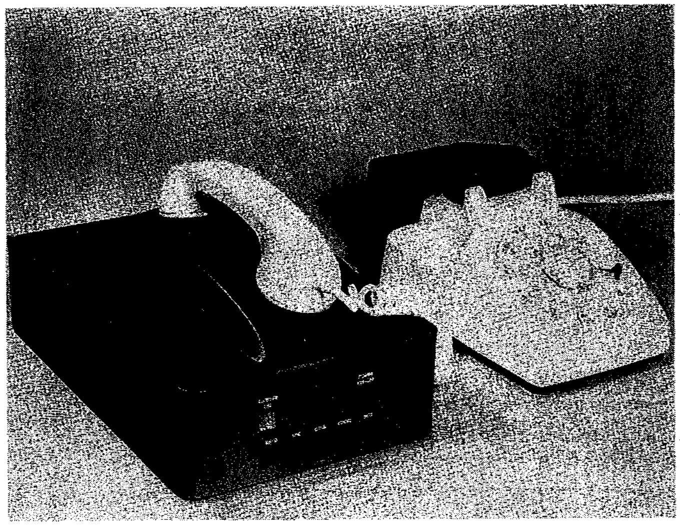


(a) IBM 2741 Terminal

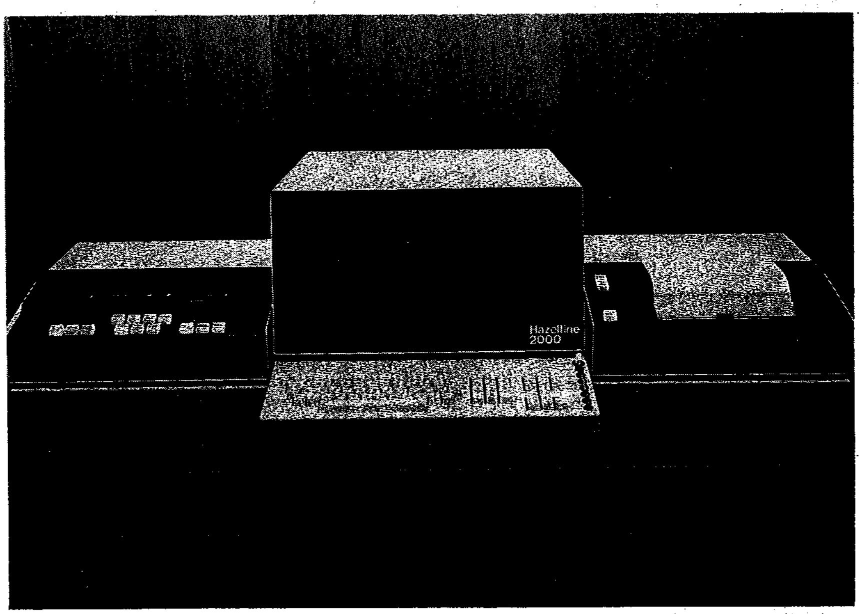


(b) "Silent 700* "Model 733 ASR Data Terminal
*Trademark of Texas Instruments Incorporated

Figure 4.1 Computer Terminals and Communication Devices



(c) Omnitec 703A Acoustic Coupler



(d) Hazeltine 2000 Terminal

Figure 4.1 (Continued)

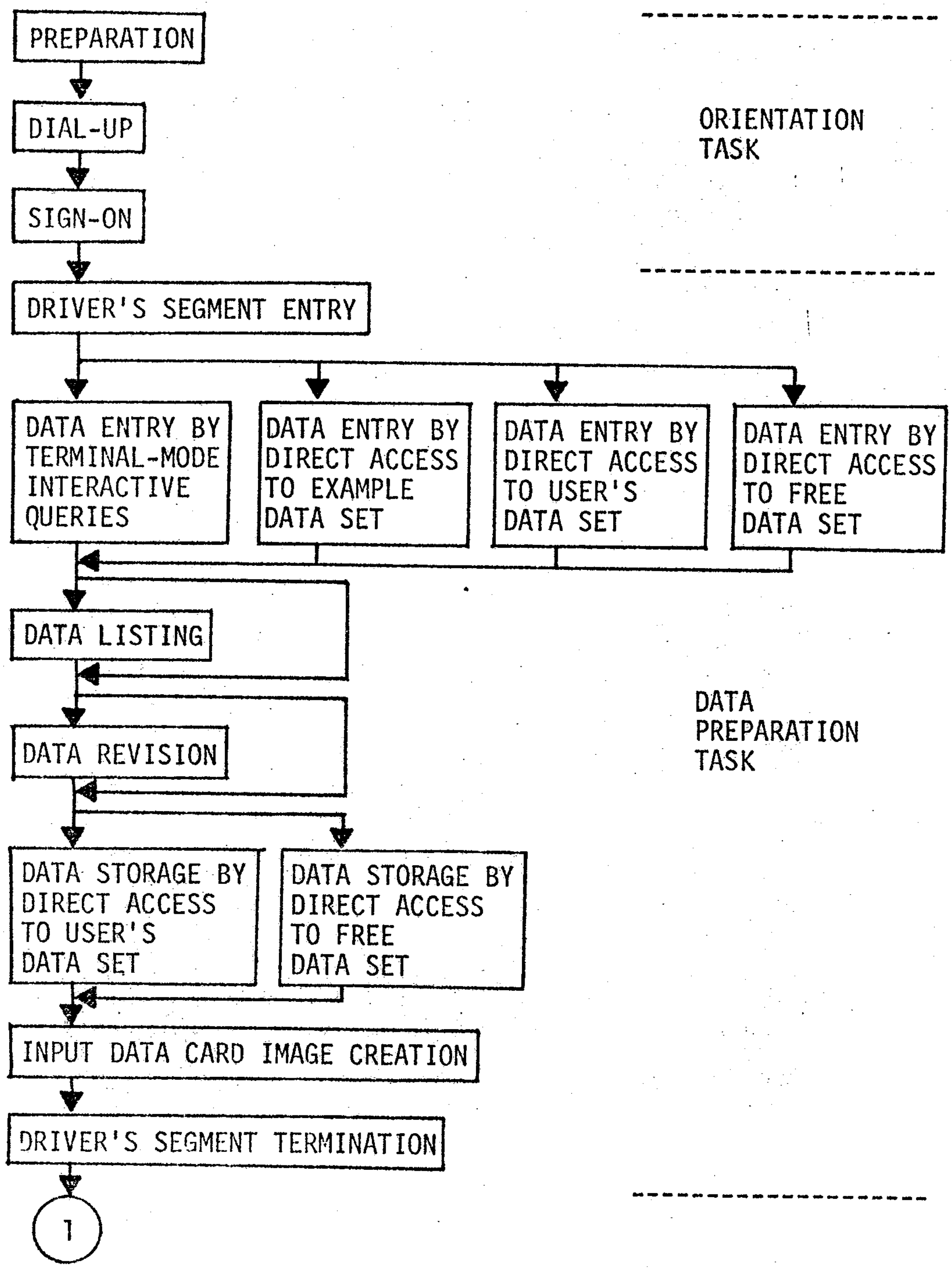


Figure 4.2 Heirarchical structure for modular process

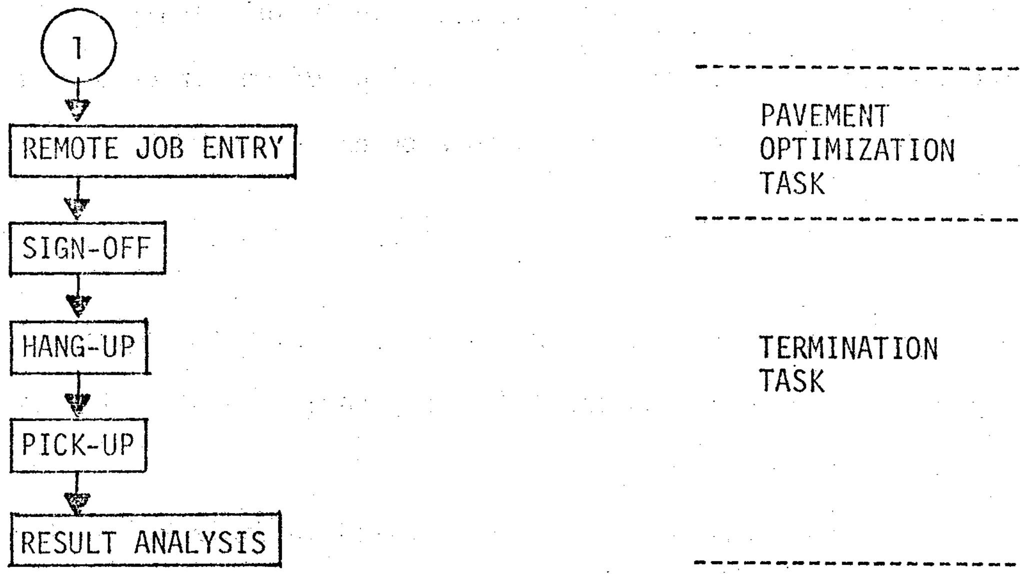


Figure 4.2 (continued)

includes "sign-off" of the teleprocessing system, termination of the telephone communication, pick-up of program outputs, and result analysis.

This chapter will discuss the utilization of the processor in detail, an illustrative example is included as Appendix A.

Orientation Task

The orientation task familiarizes the user with the execution of both the driver's segment and pavement design programs. Specific subtasks are described herein.

Organization of basic input data as cited in Table 3.1 is the first subtask prior to actually utilization of the modular processor. A test run using example data sets may be required if it is found that such action will facilitate user understanding of the data requirements. In addition, a test run using the data entry by interactive queries will further familiarize the user with the features and configurations of the processor. By use of interactive queries, the processor permits the elimination of punched data cards which are normally required for conventional batch jobs. Thus, the input information can directly be extracted from field data sheets, letters, pencilled notes, office forms, sets of plans, etc.

Requests for authorization to utilize the processor and data processing services are also encompassed within the orientation; normally, an account number together with a password are minimum requirements.

Requests for user's data set are also part of the orientation. The user's data set is not required, but may become very helpful later on. Although the data may be stored in the free data set, there is no guarantee that the data file will not be destroyed by other users. Record spaces to store the user's input data for future executions and/or references can be obtained at low cost.

Some secretarial-type preparations are required for the communication terminal. Although not especially demanding, these pre-requisites encompass adjustment of typing papers, margin setting, and line spacing. In addition, the terminal operation key must be assigned in the remote rather than local mode; and the power switch on the terminal and acoustic coupler, if present, must be switched on.

A dial-up procedure is needed for a remote terminal in order to establish contact with the teleprocessing system. If the teleprocessing system is connected, a low buzz should be audible. The user can then place the telephone handset into the acoustic coupler, and commence teleprocessing operations.

Three control statements must be entered through the keyboard of the terminal to serve as the "sign-on" for the teleprocessing system:

```
$$EOT
$$ACCOUNT(user,dpsr,name)
$$PASSWORD(word)
```

The $$EOT statement clears the terminal of any unfinished jobs, thereby resetting its operations status. The $$ACCOUNT statement provides basic accounting information encompassing

user - user number;

dpsr - data processing service request number; and

name - name of the terminal operator, up to 8 characters.

The user number and data processing service request number are normally assigned by the Data Processing Center upon request. The $$PASSWORD statement protects the user's account. The meaning of "word" is given below:

word - any password up to 8 characters, which can be arbitrarily assigned by the user and changed at will.

The computer will print O.K. if each entry statement is acceptable: otherwise, error messages will be printed. After the four control statements are accepted by the computer, the operator may start executing the drivers segment.

Data Preparation Task

The data preparation task is essentially execution of the driver's segment stored in the computer. The following control statements are needed to call and execute this segment:

$$DDNAMES(FT01F001,FT08F001,FT09F001)

$$EXECUTE(USER0004,60000,S,C)

The $$DDNAMES statement indicates that three sets of on-line disk tracks will be used for the execution of the driver's segment. When entered, the message control program of the teleprocessing system will check to insure that no other active users have indicated that they are using the same DDnames. If any of the three DDnames is being used, the terminal operator will be notified. In case more than one user may have to be involved simultaneously, minor mofications of the processor may be made. The data file stores in these on-line disk tracks are as follows:

FT01F001 - input card image;

FT08F001 - five example data sets, one free data set, and fourteen user's data sets; and

FT09F001 - three example BISTRO data sets, and seventeen user's BISTRO data sets.

The DDname, FT09F001, is optional and can be deleted if the user does not use the linear elasticity version of the flexible pavement design system.

The $$EXECUTE statement begins execution of the driver's segment. If the central core storage available at execution time is not adequate, the terminal operator will be notified; the operator may then try again later. Four parameters are used in the $$EXECUTE statement. USER0004 is the actual name of the program (load module) to be executed. The second field, 60000 specifies that a maximum of 60,000 bytes of memory will be used. The third field, S, indicates that the driver's segment is able to handle only one terminal at a time. If a second terminal requests the use of the program during the execution period, the second terminal will be informed that the program is busy and therefore unavailable. Details concerning the possibility of serving more than one user simultaneously will be discussed in Chapter V. The fourth field, C, notes that the program is conversational and may therefore, obtain a high priority for execution.

After the $$DDNAMES and $$EXECUTE statements are accepted, the computer prints the title of the modular processor and a request for specific data or decisions segmentially. Following the reply from the user, the computer will ask for further data or decisions. This interactive query process will continue until the needs of the processor are satisfied.

There are four alternatives in data entry: the first three are direct access to the example, user's, and free data sets, and the fourth is terminal-mode interactive queries. After the data entry, the user may request or bypass a complete listing of the input data file, with code numbers assigned to each input value, and the revision of any input value, the user may further store the current data file in a user's data set by direct access; otherwise, the computer will store the file in a free data set automatically. The processor then creates input data card images on a reserved set of on-line disk tracks based on the current data file, terminates the driver's segment, and prints the CPU time used so far. A normal operation generally takes only two seconds of CPU time. The user may now start executing the optimization of the desired pavement design system.

Pavement Optimization Task

The pavement optimization task is based upon a remote job entry mode. Five pavement design programs are stored in the job library and occupy approximately 100 off-line disk tracks. These programs are: RPS-2, SAMP6, SAMP6A, FPS-11, and FPS-BISTRO.

Two utilization functions of teleprocessing, $$UPDATE and $$RJEIN are needed to execute pavement design programs. the $$UPDATE function activates teleprocessing disk data sets for record modification. The use of the $$UPDATE function in the modular processor prepares sets of job control language (JCL) for remote job entry. Sets of example JCL to execute different pavement design programs are shown in Figures 4.3, 4.4, 4.5, 4.6, and 4.7. The first statement of each JCL set provides accounting information and job classifications. The field after the two slashes represents the job name. From left to right, the five parameters enclosed in parentheses are a DPSR (data processing service request) number; the box number where the user's output is to be returned; a time limit in minutes for the entire job; a limit on the number of lines (in thousands) of printed output to be generated by the job; and the identification number used to separate computer charges. The field enclosed in quotes specifies the user's name followed by optional comments. The /*PASSWORD statement specifies the protective password assigned by the user of the DPSR number. The /*CLASS statement establishes the class of core

```
//RPS2    JOB   (Y033,1-E,1,2,1),'LU'
/*PASSWORD      DANNYLU
/*CLASS         A
/*ROUTE         PRINTER3
//STEP1  EXEC   PGM=RPS2,REGION=100K
//STEPLIB  DD   DSN=USER.Y033.IEN.LU.JOBLIB,DISP=SHR
//FT05F001 DD   DSN=TP.Y033.IEN.LU.CRDIMG,DISP=SHR
//FT06F001 DD   SYSOUT=A
/*
```

Figure 4.3 Example JCL to execute RPS-2 program

```
//SAMP6   JOB   (Y033,1-E,1,2,1),'LU'
/*PASSWORD      DANNYLU
/*CLASS         A
/*ROUTE         PRINTER3
//STEP1  EXEC   PGM=SAMP6,REGION=100K
//STEPLIB  DD   DSN=USER.Y033.IEN.LU.JOBLIB,DISP=SHR
//FT05F001 DD   DSN=TP.Y033.IEN.LU.CRDIMG,DISP=SHR
//FT06F001 DD   SYSOUT=A
/*
```

Figure 4.4 Example JCL to execute SAMP-6 program

```
//SAMP6A  JOB   (Y033,1-E,1,2,1),'LU'
/*PASSWORD      DANNYLU
/*CLASS         A
/*ROUTE         PRINTER3
//STEP1  EXEC   PGM=SAMP6A,REGION=100K
//STEPLIB  DD   DSN=USER.Y033.IEN.LU.JOBLIB,DISP=SHR
//FT05F001 DD   DSN=TP.Y033.IEN.LU.CRDIMG,DISP=SHR
//FT06F001 DD   SYSOUT=A
/*
```

Figure 4.5 Example JCL to execute SAMP-6A program

```
//FPS11    JOB  (Y033,1-E,1,2,1),'LU'
/*PASSWORD      DANNYLU
/*CLASS         H
/*ROUTE         PRINTER3
//STEP1   EXEC  PGM=FPS11,REGION=200K
//STEPLIB  DD   DSN=USER.Y033.IEN.LU.JOBLIB,DISP=SHR
//FT05F001 DD   DSN=TP.Y033.IEN.LU.CRDIMG,DISP=SHR
//FT06F001 DD   SYSOUT=A
/*
```

Figure 4.6 Example JCL to execute FPS-11 program

```
//FPSB     JOB  (Y033,1-E,3,2,1),'LU'
/*PASSWORD      DANNYLU
/*CLASS         H
/*ROUTE         PRINTER3
//STEP1   EXEC  PGM=FPSB,REGION=200K
//STEPLIB  DD   DSN=USER.Y033.IEN.LU.JOBLIB,DISP=SHR
//FT05F001 DD   DSN=TP.Y033.IEN.LU.CRDIMG,DISP=SHR
//FT09F001 DD   DSN=TP.Y033.IEN.LU.BISTRO,DISP=SHR
//FT06F001 DD   SYSOUT=A
/*
```

Figure 4.7 Example JCL to execute FPS-BISTRO program requirements for the job. Class A ranges from 0 to 110K bytes, whereas class H spans 112K to 200K bytes. The /*ROUTE statement indicates the printer desired. The password, class, and print train all originate in the sixteenth space. The //STEP1 statement specifies the program to be executed and maximum core requirements. The //STEPLIB statement specifies the DSname of the off-line disk tracks which store the five programs for pavement optimization. The //FT04F001 and //FT09F001 statements specify the DSnames of the on-line disk tracks which provide an input data file for pavement design program. The //FT05F001 statement stores the input data card image, while the //FT09F001 statement, which stores the BISTRO data file, can be deleted if the linear elasticity version of the flexible pavement design system is not used. The //FT06F001 statement routes the output data sets and the last statement of each JCL set indicates job termination.

The utility function, $$UPDATE, will store user's JCL sets in an on-line partitioned data set. Once the JCL sets have been stored, the user can call the DDname and member of the partitioned data set instead of entering the whole JCL statements for any additional remote job entry.

The $$RJEIN function of the teleprocessing system provides the ability to enter batch jobs from a remote terminal to the computer. The jobs are thus executed in the batch portion in the same fashion as any conventional batch job. After receiving the DDname and member of a partitioned data set storing a particular set of JCL, the computer will load the job and print 'JOB WAS SUCCESSFULLY LOADED TO SYSTEM' or 'JOB WAS NOT LOADED TO SYSTEM' with a return code for error-shooting. The user may now go the the next task-termination.

Termination Task

After the remote job entry executes a specific pavement design program, the termination task, including sign-off, hang-up, pick-up, and result analysis, follows. The user must signal a $$EOT control statement for sign-off. The $$EOT statement effects termination of the teleprocessing system. After the termination message is received, the computer will print out the CPU (Central Processing Unit) time in seconds consumed by the job. Normal operation of the processor takes only two to four seconds CPU time. The hang-up procedure which applies only to dial-up terminals requires a $$HANGUP control statement. This statement will disconnect the remote terminal. The user may then lift the handset from the acoustic coupler and place it back onto the telephone. Program outputs can be picked up from any print train assigned by the user in the JCL of the remote job.

A utility function, $$STAT, of the Texas A&M version of the Baylor Executive System for Teleprocessing (BEST) may facilitate the determination of the status of a batch job running under the computer operating system. The $$STAT will identify the job number, its priority and routing, and any applicable classification. Further, the code notes whether a job is in execution, printing/punching, or is awaiting either step. The user may choose a "STATUS" option which will report to the user all jobs in the computer system, or a "LOCATE" option which reports information only on the job in question. Users of this integrated pavement design processor desiring to ascertain the status of a pavement optimization job, or wishing to know when the results will be ready, implement this utility function.

A control statement, $$END, may be entered any time between sign-on and sign-off to terminate a portion of the execution. The computer will automatically print out the CPU time consumed.

A control statement, $$TIME, can be entered when the processor is executing a job through the terminal. The computer will then print out the applicable CPU time.

Simplicity and convenience are the major advantages of utilizing this processor at the District level in the overall pavement design system. An engineer concerned with design problems may operate the terminal himself, or submit his notes to a technical assistant who will handle the mechanics of terminal operation. Program user's manuals cluttered with coding details for input data cards will thus become obsolete.

CHAPTER V

THE IMPLEMENTATION OF THE PROCESSOR

The project was intended to facilitate implementation of the processor in regular design operations. This chapter will discuss the usage potential of the integrated pavement design processor in two respects: software and hardware. Discussion of software will concentrate on implementation with respect to the design of the modular processor as well as different teleprocessing systems and programming languages. Remarks on the hardware will concern potential alternatives regarding different makes or models of computer equipment and communication terminals. Also to be discussed are the adaptability and practicality of the processor, and some modifications that may be required for its extension to full-scale implementation.

Comments on Processor Design

Among the five major alternative pavement design systems that have been included in the modular processor, the rigid pavement system, asphaltic concrete pavement overlay system, and the flexible pavement system using Dynaflect deflection are currently being employed by the Texas Highway Department. The flexible pavement system using the AASHO structural number concept has been implemented on a trial basis in Florida, Louisiana, and Kansas. However, these four pavement design systems have only been utilized in conventional batch mode. Moreover, one of the most annoying problems in applying these programs is the requirement for massive data preparation by design engineers. Tedious card punching formats and painstaking turn-around processes often become a cumbersome burden to engineers, thus dampening their enthusiam for the program. The modular processor developed herein is based on a remote teleprocessing mode which seeks to overcome the aforementioned problems. The interactive feature of the processor will assist and simplify the data preparation task. Input variables are properly organized and categorized into conversational input formats, thereby enabling engineers with limited data processing experience to use the processor effectively.

The linear elastic theory based flexible pavement design procedure has not yet been applied to actual situations. This delay has resulted from several factors, among them: the high cost of computation time, uncertainties regarding the values of the elastic constants and limiting strengths of materials, and possibly, some skepticism toward the use of mechanistic theory in a field heretofore dominated by the exercise of experience, empiricism, and engineering judgement. However, the state of flexible pavement design and material characterization has advanced enough to sustain an analytical estimate of the maximum stresses and strains of layered pavement structures, as well as a check of these against the limiting strengths of materials [33]. To reduce the computer time requirement, a stress-and-strain table of the more common basic designs could be constructed by gradually storing the results of different runs of the streamlined linear elastic program. The multi-dimension interpolation method [29] could thus be applied to check all other trial designs. The computation of the stress-and-strain table may of itself be very costly, but long-term savings may be realized if the approach is adopted as a practical method by highway engineers.

This modular processor has been especially devised for use by personnel of the Texas Highway Department. Comments and recommendations for input values of the five alternative pavement design systems, based on Texas practices, have been included in the driver's segment. Undoubtedly, some revision will be needed if application of the processor in states other than Texas is desired. In addition, due to the specific design requirements in each state, the pavement performance model, traffic projection model, and cost estimation model programmed in the processor may also require alteration.

Comments on Teleprocessing Systems

The integrated pavement design processor was developed in concert with the hardware and software services available at the Data Processing Center (DPC), Texas A&M University, College Station. The DPC at the Texas A&M University operates presently an IBM 360/65 and an IBM 370/145 system. Three teleprocessing systems are available to users [52]. They are BEST (Baylor Executive System for Teleprocessing), APL (A Programming Language), and TSO (Time-Sharing Option).

BEST [46] was chosen for the teleprocessing of the integrated pavement design processor as it has been widely utilized at Texas A&M University. BEST was first developed by the Computer Science Department of the Baylor University College of Medicine. This system was extensively modified at Texas A&M University for local use. It runs in an OS/MVT (Operating System/ Multi-programming with a Variable number of Tasks) environment. OS views the teleprocessing system as one job, with the programs executed through the teleprocessing system as subtasks. The teleprocessing monitor schedules the execution of jobs as well as handling their input/output and termination. It thus enables the users to write and execute programs, as well as enter and modify data, from remote terminals while permitting him to interact with the computer.

APL is a powerful interactive teleprocessing language and is available through several commercial time-sharing firms, however, it is not as widely available as time-sharing FORTRAN. It is a relatively new computer language, distinctly different, and if used to implement the modular processor would possibly deter future modification and maintenance by programmers unfamiliar with APL. Other problems would be involved with some portions of the processor coded in different computer languages and the cost involved in re-programming all programs into APL would exceed the benefits expected. Therefore, APL teleprocessing was not utilized for the modular pavement design processor.

The TSO teleprocessing system was developed by IBM and its popularity may increase in the future as it is a general purpose system. It was not seriously considered for use with the modular processor because the implementation of the TSO system at Texas A&M University is somewhat limited at this time. However, TSO and other teleprocessing systems which are able to execute FORTRAN programs with remote batch capability are compatible with the modular processor.

Comments on Programming Languages

The Texas A&M version of the Baylor Executive System for Teleprocessing (BEST) accommodates all programs in FORTRAN, PL/1, COBOL, and assembly language. FORTRAN has been selected for programming the integrated pavement design processor since it is convenient to maintain, and is compatible with existing pavement optimization systems. Moreover, engineers are generally more familiar with the FORTRAN language than with others. Utilizing FORTRAN in the processor will enable design engineers to effect minor modifications for their needs. Excepting FORTRAN, the IBM assembly language was the only other system seriously considered for programming the modular processor. It is easily adapted to any teleprocessing system on the IBM 360 and 370 computers, and requires minimal core storage. However, assembly language is specific to particular computers and not normally adaptable to other computers. Also, the maintenance and modification of the processor in assembly language would entail greater difficulty than required by FORTRAN.

The direct access capability programmed into the driver's segment of the processor is an IBM product [20]. Direct access statements permit a programmer to read and write records in any sequence within a data set, thereby contrasting with the familiar sequential input/output statements. Using direct access statements, a programmer can proceed directly to any point in the data set, process a record, and move to any other point without having to process the records in between. Unfortunately, the direct access input/output statements are not basic to FORTRAN. Should direct access not be available, some modifications are needed to convert the direct access statements in the driver's segment to sequential input/output statements.

Comments on Communication Terminals

An attempt has been made to facilitate independence of the processor from the types of terminals that might be used with it. Although terminals have certain common features (for instance, keyboards, line interfaces, and control functions), some specific criteria must be considered in selecting a terminal for implementing the processor. There are hundreds of terminal models [9, 11, 21, 35] on the current market. Since computer terminal selection is based on various characteristics, i.e., cost, display rate, hard-copy option, magnetic cassette tape adaption, maintenance, portability, etc. [31], various types of terminals must be considered before full-scale implementation of the processor is undertaken.

Table 5.1 compares five typical terminal types for: maximum display rate, length of line, portability, noise, hard copy option and cost. The Teletype 33, Cope 1030, and Texas Instruments Silent 700 (Model 735) are typewriter terminals. Teletype 33 is representative of terminals presently in district offices. Cope 1030 utilizes the IBM Selectric typewriter and is representative of the portable, IBM compatible, type of terminal. The TI 700 is a suitcase size, light-weight terminal using special paper. Cathode Ray Tube (CRT) terminal types are represented on Table 5.1 by the Hazeltine 2000 and Sanders 720. Not included are the "intelligent terminals" [3], such as the Datapoint 5500 and Sycor 340, because their versatility does not sufficiently benefit the processor to justify their higher cost. Of course this type terminal, justified for other uses, may also be used for less demanding tasks such as the processor.

The maximum display rates of the Teletype 33, Cope 1030, and TI Silent 700 are 10, 15, and 30 characters per second, respectively. The display rate of typewriter terminals is often too slow for fast and efficient man-machine conversations. To use a faster printer, say 120 characters per second, would be more expensive. CRT terminals, such as Hazeltine 2000 and Sanders 720, have overcome this problem easily. The display rate of CRT terminals depends on the delivery capability of the communication device. In general, the display rate of a remote CRT terminal equipped with an acoustic coupler is limited to 30 characters per second. The display rate of a directly wired

TABLE 5.1

COMPARISON OF TYPICAL TERMINAL MODELS

Terminal Model	Teletype 33	COPE 1030	TI Silent 700	Hazeltine 2000	Sanders 720
Type	Typewriter	Typewriter	Typewriter	CRT	CRT
Maximum Display Rate	10 cps	15 cps	30 cps	30* or 120** cps	30* or 120** cps
Length of Line	72 cpl	130 cpl	80 cpl	80 cpl	80 cpl
Portability	Poor	Fair	Excellent	Fair	Poor
Noise	Noisy	Average	Silent	Silent	Silent
Hard Copy	Standard	Standard	Standard	Optional	Optional
Cost	Low	Average	Average	Low***	Variable***

* remote terminal equipped with acoustic coupler

** local terminal or remote terminal equipped with modem

*** additional cost required for hard copy device local CRT terminal or remote CRT terminal with modem reaches 120 characters per second or more.

The Cope 1030 has the greatest line width, 130 characters per line. TI Silent 700, Hazeltine 2000, and Sanders 720 permit 80 characters per line. The Teletype 33 is limited to 72 characters per line. However, the processor requires only a maximum of 70 characters per line.

Both Teletype 33 and Sanders 720 are heavy and bulky. Although Cope 1030 and Hazeltine 2000 are portable, TI 700 handles more easily as it is about the size and weight of a medium suitcase.

TI 700 and CRT terminals are silent during operation. The typing of data input and output display by Cope 1030 is relatively noisy, about the same as an ordinary electric typewriter; Teletype 33 is especially noisy during operations.

Hard copy is standard for typewriter terminals. Hard copy devices can be connected to CRT terminals for essential data printout. In general, CRT terminals also provide editing functions such as substitution, addition, and deletion of characters. The paper required for terminal print-outs depends on the maximum number of characters per line and maximum number of lines per page. In addition to these requirements the TI 700 requires thermal sensitive paper.

Teletype 33, Cope 1030, TI 700, and Hazeltine 2000 are stand-alone terminals, while Sanders 720 is classified as a cluster type. Cluster terminals require a controller which connects a group of terminals to a computer. The average cost of each cluster terminal depends on the number of terminals connected to the same controller. Among the four stand-alone terminals, Teletype 33 and Hazeltine 2000 are low-cost, in the range of $45-75 per month. Cope 1030 and TI 700 range between $100-$150 per month; Sanders 720 is about the same price if a cluster of terminals are used. Hard copy devices, optional for CRT terminals, necessitate additional costs and lessen portability.

Compromises of various terminal characteristics will normally dictate the final selection of terminals. Hazeltine 2000 terminals or their equivalent, equipped with a hard copy device, seem to be the best for the implementation of the integrated pavement design processor. If lower cost or greater portability are desired, the TI 700 or its equivalent could be recommended

Extension for Full-Scale Implementation

The modular processor is intended to be a management tool for selecting design, maintenance, and rehabilitation strategies that will optimize operations of pavements over long periods of time. Four important features concerning the extension of the processor to full-scale implementation deserve special emphasis here: (1) processor security, (2) provision for simultaneous users, (3) further reduction of core requirement, and (4) selective print-out.

Processor Security

The current processor does not provide protection for the security of the program package and data sets. The following passwords should be included in the processor to protect the system from unauthorized utilization, revision, or destruction:

1. password to execute the driver's segment and the five pavement design programs;
2. password for direct access to example data sets and user's data sets; and

3. password to revise the built-in data and instructions.

If an incorrect password is given, the job will not be processed. The password must not appear in any part of the print-outs. In addition, the processor should remind the user to erase a password when it is entered from the terminal. Also these passwords must be easily revisable by the password owners from a terminal, to offset the possibility of password compromise.

Provision for Simultaneous Users

Presently the processor can handle only one terminal at a time. If a second terminal asks to use the same processor when it is already in execution, the second terminal is informed that the processor is busy. However, the BEST teleprocessing system has a convenient feature facilitating simultaneous use of a program. A control program of BEST is able to load one or more additional programs and permit the execution of each from a separate terminal. Modifications required to adapt the current processor for simultaneous usage include: (1) providing an individual data card image area for each user rather than a common area; and (2) increasing the number of on-line data sets. The current processor consists of three sets of on-line disk tracks: FT01F001, FT09F001, and FT09F001. If a terminal has indicated that all sets are being used, another terminal will not be able to execute the driver's segment. In this situation, a duplicate of the three sets of on-line disk tracks is needed for the second user to execute the second copy of the processor.

Further Reduction of Core Requirement

In order to serve more users, a data processing center generally will not accept a teleprocessing program with a large core requirement. The program modularization and overlay linkage previously mentioned have reduced the core requirement of the driver's segment from 200K to 60K bytes. Further reductions can be accomplished by storing comments and recommendations for input values in direct access data files to minimize the FORMAT statements which require most core storages. In addition to reducing core requirements, other advantages accruing from storing FORMAT statements in direct access data files include: (1) easier adaption of the processor to other teleprocessing systems, (2) easier modification and maintenance of the program, and (3) easier re-programming of the processor in assembly or other programming languages.

Selective Print-Out

The current design of the modular processor directs the output of a pavement design program, executed by remote job entry, to a printer. Naturally, if a user does not have immediate access to a printer, he would prefer the program output returned to his original terminal. In order to overcome the difficulty arising from the slow printing speed of a typewriter terminal, a driver's output segment would be installed to select program print-outs. Modifications would be required to direct the program output stream to on-line disk tracks other than to a normal printer. A small teleprocessing program, driver's output segment, would then input the data from on-line disk tracks and print out the user-requested portion to the terminal.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In essence, this study represents an attempt to improve the quality of comprehensive systems analysis for the design and management of pavement construction and rehabilitation. Its final product is an integrated pavement design processor.

In Chapter I, an overview of the problem and the need for this study are discussed. The objectives and scope of the research area, as well as a brief description of the final product, are also described.

Chapter II presents a survey of the development of pavement design systems. The need for an integrated pavement design processor to facilitate the implementation of various pavement optimization systems is stressed.

Chapter III studies an integrated pavement design processor in which **five** pavement design systems are fused into one program package; further, a driver's segment to facilitate interactive man-machine conversations is described. This processor provides four alternative methods of data entry: one based on interactive queries and three utilizing direct access to on-line data sets. Data listing, revision, and storage are under the user's command through terminal operations.

Chapter IV focuses upon the utilization of the modular processor itself. The entire job execution is divided into four tasks: orientation, data preparation, pavement optimization, and termination. Utilization of the modular processor is uncomplicated, quite convenient, and does not entail detailed familiarity with computer programming and operation.

Chapter V discusses potential implementation of the processor. Compatibility of processor design, different teleprocessing systems and programming languages, as well as different makes or models of computer equipment and communication terminal are investigated. Extension of the processor to full-scale implementation is also considered. The processor is practical and adaptable to current pavement design procedures in Texas, and could possibly, with appropriate modifications, be used by other states as well.

Specific conclusions are as follows:

1. Various pavement design systems can be integrated into one open-ended processor. Each module of the processor can be utilized independently. Meanwhile, any new pavement design system can be added to the processor without any change of the original components.
2. Pavement design procedures can be simplified by on-line data processing. Instant assistance can be obtained through man-manchine interactions. In fact, the pavement design processor is in itself an educational tool.
3. The core requirement of a teleprocessing program can be reduced significantly by overlay linkage.
4. The integrated pavement design processor is a multi-optional, broad-based, and application-oriented decision framework. The processor will facilitate the implementation of systems analysis of pavement design and management.

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APPENDIX A

AN ILLUSTRATIVE EXAMPLE OF THE UTILIZATION OF THE PROCESSOR

As mentioned in the main body of this report, the final product of this study is an integrated pavement design processor. This appendix illustrates the utilization of the modular processor. Procedures for utilizing the processor are presented in Chapter IV.

A Cope typewriter terminal (UCC-1030), equivalent to IBM 2741 terminal, equipped with an acoustic coupler is used in this example. The selectric typing ball and keyboard of the terminal were originally designed for APL operations. This terminal can be used for the teleprocessing of both BEST and APL at Texas A&M University. It must be noted that the two dollar signs, $$, normally used before each control statement and utility function of the BEST are replaced by two left bracket signs, [[, if the control statement and utility function are entered from a terminal with an APL keyboard. In addition, a control statement, [[KEYBOARD, must be entered at the very beginning to specify the type of typing ball and keyboard. The illustrated example is shown beginning on page A-3. Lines typed by the user are designated by the symbol, ▶.

Six control statements are entered at the beginning. They are: KEYBOARD, EOT, ACCOUNT, PASSWORD, DDNAMES, and EXECUTE. Explanations have been detailed in Chapter IV. After receiving each control statement, the teleprocessing system responds OK. Then the driver's segment prints the processor title and starts interactive queries, step-by-step, between the person at the remote terminal and the distant computer.

After all requested input values are entered from the terminal, the driver's segment provides options to print a list of input data file (p. A-20), and to revise any input data (p. A-23). After receiving a record number to store the current data file in on-line disk tracks, the driver's segment is automatically terminated (p. A-23). The CPU time consumed so far will also be printed.

Upon request, the [[UPDATE utility function prints the full instructions to set up a set of JCL statements to execute the flexible pavement design systems, FPS-BISTRO (p. A-24). The JCL statements, except the statement, /*FORMS, have been explained in Chapter IV. The /*FORMS statement which specifies the forms of type, number of parts, and code number of the paper for program outputs, is optional. The whole set of JCL statements are stored in a partitioned data set. The DDname and member are LUPROG(FPSB). After receiving the ←END statement, the [[UPDATE function terminates (p. A-26). The CPU time consumed in this portion is printed.

The [[RJEIN function provides the capability of remote job entry. After the DDname and member are received, the job is loaded in seconds and a message is printed at the terminal (p. A-26). Then the user enters [[EOT and [[HANGUP to terminate the modular processor. The computer responds with OK and the CPU time consumed by the remote job entry. The program output will be printed by the PRINTER3 specified in the JCL, and can be picked up later from Box 1-E, as specified in JCL by the user.

The program output of this example problem is shown in Appendix B.

```
▶ [[KEYBOARD/APL/
...OK        CPU TIME =000001 SEC
..OK
▶ [[EOT
...OK        CPU TIME =000001 SEC
▶ [[ACCOUNT(DLU1,Y033,LU)
..OK
▶ [[PASSWORD(DANNYLU)
..OK
▶ [[DDNAMES(FT01F001,FT08F001,FT09F001)
..OK
▶ [[EXECUTE(USER0004,60000,S,C)
..OK

TEXAS HIGHWAY DEPARTMENT
     INTEGRATED PAVEMENT DESIGN PROCESSOR
     -- A STRATEGIC APPROACH TO THE DESIGN AND MANAGEMENT OF
        PAVEMENT CONSTRUCTION AND REHABILITATION
TYPE ? FOR INTRODUCTION
▶ ?

INTRODUCTION
THE INTEGRATED PAVEMENT DESIGN PROCESSOR (IPDP) HAS BEEN DEVELOPED
AS A STRATEGIC APPROACH TO THE DESIGN AND MANAGEMENT OF CONSTRUCTION
AND REHABILITATION OF PAVEMENTS.  THE IPDP IS A COMPREHENSIVE DECISION
FRAMEWORK WITH A CAPACITY TO DRIVE DIFFERENT OPTIMIZATION ROUTINES AT
THE USER'S COMMAND THROUGH INTERACTIVE QUERIES BETWEEN THE COMPUTER
AND THE DESIGN ENGINEER.  THE MULTI-OPTION ARRANGEMENTS ENABLE THE
DESIGN ENGINEER TO CONSIDER BOTH RIGID AND FLEXIBLE PAVEMENT SYSTEMS
SIMULTANEOUSLY.  IPDP CAN BE USED FOR NEW PAVEMENT CONSTRUCTION OR
EXISTING PAVEMENT REHABILITATION.  IN ADDITION, THREE OPTIONS FOR
FLEXIBLE PAVEMENT DESIGN ARE INCLUDED TO DESCRIBE THE STRUCTURAL
SUBSYSTEM DESIRED: (1) BASED ON AASHO STRUCTURAL NUMBER, (2) BASED ON
DYNAFLECT DEFLECTION, AND (3) BASED ON LINEAR ELASTIC THEORY.
TYPE ? FOR INSTRUCTIONS AND EXAMPLES
▶ ?

INSTRUCTIONS AND EXAMPLES OF COMPUTER QUERIES AND USER RESPONSES
THERE ARE THREE DIFFERENT FORMATS FOR INPUTTING YOUR DATA TO THE
INTEGRATED PAVEMENT DESIGN PROCESSOR.
```

```
(1) CHOICE FORMAT
EXAMPLE 1.
INSTRUCTION BY COMPUTER:
TYPE 1 FOR RIGID PAVEMENT DESIGN, 2 FOR FLEXIBLE PAVEMENT DESIGN.
RESPONSE BY USER:
2
EXAMPLE 2.
INSTRUCTION BY COMPUTER:
DO YOU NEED A PROGRAM TO CALCULATE COEFFICIENTS OF
     TEXAS TRIAXIAL MODEL?
RESPONSE BY USER:
YES
(2) CHARACTER FORMAT
EXAMPLE 3.
INSTRUCTION BY COMPUTER:
TYPE THE HIGHWAY NAME - 10 CHAR MAX
RESPONSE BY USER:
SH360
(3) NUMERICAL FORMAT - EACH NUMBER SHOULD INCLUDE A DECIMAL POINT,
                        10 DIGITS MAX.
EXAMPLE 4.
INSTRUCTION BY COMPUTER:
TYPE ONE-DIRECTION CUMULATIVE 18 KSA DURING ANALYSIS PERIOD
RESPONSE BY USER:
8272800.
TYPE 1 FOR TERMINAL-MODE DATA ENTRY, 2 FOR MASTER DATA SET, 3 FOR
     USER'S DATA SET, 4 FOR FREE DATA SET.
▶ 1

TYPE 1 FOR RIGID PAVEMENT DESIGN, 2 FOR FLEXIBLE PAVEMENT DESIGN.
▶ 2

TYPE 2 FOR EXISTING PAVEMENT REHABILITATION
     3 FOR NEW PAVEMENT CONSTRUCTION
▶ 3

TYPE 3 FOR FLEXIBLE PAVEMENT USING AASHO STRUCTURAL NUMBER
     4 FOR FLEXIBLE PAVEMENT USING DYNAFLECT DEFLECTION
     5 FOR FLEXIBLE PAVEMENT USING LINEAR ELASTICITY
▶ 5
```

```
DO YOU NEED A BISTRO PROGRAM?  TYPE YES OR NO.
     OR, TYPE ? FOR FURTHER INFORMATIONS.
▶ ?

THE FLEXIBLE PAVEMENT SYSTEM USING LINEAR ELASTICITY HAS BEEN
DEVELOPED FOR 3-LAYER DESIGN PROBLEMS.  THE ANALYSIS OF LINEAR
ELASTICITY NEEDS A PROGRAM BISTRO.  BISTRO EVALUATES 25 BASIC
DESIGNS SO THAT ALL OTHER TRIAL DESIGNS CAN BE INTERPOLATED FROM
THE BASIC DESIGNS.  THREE SETS OF BISTRO OUTPUTS ARE STORED IN
THE MODULAR PROCESSOR.
-RECORD 1
     ACCURACY LEVEL FOR ANALYSIS OF LINEAR ELASTICITY
         (1=EXCELLENT,2=GOOD,3=FAIR)                                    1
                                  TOP LAYER            BASE        SUBGRADE
         ELASTIC MODULUS (PSI)    240000.00       150000.00        24000.00
         POISSON'S RATIO               0.50            0.50            0.50
     MIN THICKNESS OF TOP LAYER OF INITIAL DESIGN                      1.00
     MAX THICKNESS OF TOP LAYER OF INITIAL DESIGN + ACCUMULATED
         MAX DEPTH OF ALL OVERLAYS, EXCLUDING LEVEL UP                16.00
     MIN THICKNESS OF SECOND LAYER OF INITIAL DESIGN                   4.00
     MAX THICKNESS OF SECOND LAYER OF INITIAL DESIGN                  20.00
-RECORD 2
     ACCURACY LEVEL FOR ANALYSIS OF LINEAR ELASTICITY
         (1=EXCELLENT,2=GOOD,3=FAIR)                                    2
                                  TOP LAYER            BASE        SUBGRADE
         ELASTIC MODULUS (PSI)    500000.00        50000.00        20000.00
         POISSON'S RATIO               0.50            0.50            0.50
     MIN THICKNESS OF TOP LAYER OF INITIAL DESIGN                      0.33
     MAX THICKNESS OF TOP LAYER OF INITIAL DESIGN + ACCUMULATED
         MAX DEPTH OF ALL OVERLAYS, EXCLUDING LEVEL UP                27.00
     MIN THICKNESS OF SECOND LAYER OF INITIAL DESIGN                   4.00
     MAX THICKNESS OF SECOND LAYER OF INITIAL DESIGN                  20.00
-RECORD 3
     ACCURACY LEVEL FOR ANALYSIS OF LINEAR ELASTICITY
         (1=EXCELLENT,2=GOOD,3=FAIR)                                    2
                                  TOP LAYER            BASE        SUBGRADE
         ELASTIC MODULUS (PSI)    100000.00        50000.00        20000.00
         POISSON'S RATIO               0.50            0.50            0.50
     MIN THICKNESS OF TOP LAYER OF INITIAL DESIGN                      0.33
     MAX THICKNESS OF TOP LAYER OF INITIAL DESIGN + ACCUMULATED
         MAX DEPTH OF ALL OVERLAYS, EXCLUDING LEVEL UP                27.00
```

```
      MIN THICKNESS OF SECOND LAYER OF INITIAL DESIGN                 4.00
      MAX THICKNESS OF SECOND LAYER OF INITIAL DESIGN                20.00
 TYPE THE RECORD NUMBER WITH DECIMAL POINT IF YOU WISH TO USE ONE
 OF THE THREE SETS OF BISTRO OUTPUTS.  OTHERWISE, TYPE 99.9
▶ 1.

 *** PROJECT IDENTIFICATION AND COMMENTS REQUIRED
 TYPE THE PROBLEM NUMBER - 3 CHAR MAX
▶  1

 TYPE THE DISTRICT NUMBER - 2 CHAR MAX
▶ 2

 TYPE THE COUNTY NAME - 14 CHAR MAX
▶      ABC

 TYPE THE CONTROL NUMBER - 4 CHAR MAX
▶ 3210

 TYPE THE SECTION NUMBER - 2 CHAR MAX
▶ 12

 TYPE THE HIGHWAY NAME - 10 CHAR MAX
▶    SH360

 TYPE TODAY'S DATE - 8 CHAR MAX
▶ 12-04-73

 TYPE THE IPE NUMBER - 4 CHAR MAX
▶  152

 TYPE PROJECT COMMENTS - MAX 7 LINES, 70 CHAR/LINE.
     IF LESS THAN 7 LINES, TYPE EOCC TO TERMINATE.
         1    1    2    2    3    3    4    4    5    5    6    6    7
 ....5....0....5....0....5....0....5....0....5....0....5....0....5....0
▶  AN ILLUSTRATIVE EXAMPLE FOR THE UTILIZATION
▶       OF THE PROCESSOR
▶ EOCC
```

```
*** PROGRAM CONTROLS REQUIRED
TYPE LENGTH OF THE ANALYSIS PERIOD (YEAR),
     OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

A. FOR INTERSTATE HIGHWAYS, USE 20.0 YEARS.
B. FOR OTHER IMPORTANT URBAN ARTERIAL STREETS AND EXPRESSWAYS WITH
   GRADELINES SUCH THAT THE PAVEMENT WILL NOT LIKELY BE DESTROYED
   DURING THE ANALYSIS PERIOD, USE 30.0 YEARS.
C. FOR FARM OR RANCH TO MARKET HIGHWAYS, USE 10.0 YEARS.
D. FOR TEMPORARY CONNECTIONS, DETOURS, AND OTHER SHORT LIFE EXPECTANCY
   PAVEMENTS, USE THE EXPECTED LIFE OF THE PAVEMENT.
E. FOR ALL OTHER FACILITIES (MOST HIGHWAYS), USE 20.0 YEARS.
▶ 20.0

TYPE INTEREST RATE (PERCENT PER YEAR), OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

7.0 PERCENT IS RECOMMENDED.
▶ 7.0

TYPE TOTAL NUMBER OF LANES
▶ 4.

TYPE WIDTH OF EACH LANE (FEET)
▶ 12.

TYPE ACCURACY LEVEL FOR ANALYSIS OF LINEAR ELASTICITY,
     1=EXCELLENT, 2=GOOD, 3=FAIR
▶ 1

TYPE DESIGN CONFIDENCE LEVEL, A = 50 PERCENT, B = 80 PERCENT, C = 95
     PERCENT, D = 99 PERCENT, E = 99.9 PERCENT, F = 99.99 PERCENT,
     G = 99.999 PERCENT.  TYPE ? FOR INSTRUCTIONS.
▶ ?
```

WILL THE HIGHWAY BE OPERATING AT GREATER THAN 50 PERCENT OF CAPACITY SOMETIME WITHIN THE ANALYSIS PERIOD?
▶ *YES*

WILL THE HIGHWAY REMAIN RURAL THROUGHOUT THE ANALYSIS PERIOD?
▶ *NO*

DESIGN CONFIDENCE LEVEL E IS RECOMMENDED.
▶ *D*

TYPE NUMBER OF SUMMARY OUTPUT PAGES DESIRED (8 DESIGNS/PAGE) - MAX 3.0
▶ 3.0

*** *PROGRAM RESTRAINTS REQUIRED*
TYPE MAX FUNDS FOR INITIAL CONSTRUCTION (DOLLARS/SQ.YD.)
▶ 4.

TYPE MAX TOTAL THICKNESS OF INITIAL CONSTRUCTION (IN.)
▶ 16.

TYPE MIN TIME TO THE FIRST OVERLAY (YEARS), OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

6.0 *YEARS IS RECOMMENDED. IF, BECAUSE OF LIMITED AVAILABLE FUNDS OR EXTENSIVE SWELLING CLAY ACTIVITY, THIS RESULTS IN NO SOLUTIONS OR UNACCEPTABLE SOLUTIONS, THE* 6.0 *YEAR RESTRAINT MUST BE RELAXED.*
▶ 3.

TYPE MIN TIME BETWEEN OVERLAYS (YEARS), OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

6.0 *YEARS IS RECOMMENDED. IF, BECAUSE OF LIMITED AVAILABLE FUNDS OR EXTENSIVE SWELLING CLAY ACTIVITY, THIS RESULTS IN NO SOLUTIONS OR UNACCEPTABLE SOLUTIONS, THE* 6.0 *YEAR RESTRAINT MUST BE RELAXED.*
▶ 3.

TYPE MAX ACCUMULATED THICKNESS OF ALL AC OVERLAYS (IN.)
▶ 8.

TYPE MIN THICKNESS OF A SINGLE AC OVERLAY (IN.)
▶ 2.

*** ENVIRONMENTAL DATA REQUIRED
TYPE DISTRICT TEMPERATURE CONSTANT, OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

A TABLE OF DISTRICT TEMPERATURE CONSTANTS IS SHOWN AS FOLLOWS:

DIST	TEMP CONST	DIST	TEMP CONST	DIST	TEMP CONST	DIST	TEMP CONST	DIST	TEMP CONST
1	21.0	6	23.0	11	28.0	16	36.0	21	38.0
2	22.0	7	26.0	12	33.0	17	30.0	22	31.0
3	22.0	8	26.0	13	33.0	18	26.0	23	25.0
4	9.0	9	28.0	14	31.0	19	25.0	24	24.0
5	16.0	10	24.0	15	31.0	20	32.0	25	19.0

▶ 22.

TYPE SWELLING PROBABILITY, OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

THE PROBABILITY IS A FRACTION BETWEEN 0.0 AND 1.0 REPRESENTING THE PROPORTION OF A PROJECT THAT IS EXPECTED TO EXPERIENCE ENVIRONMENTALLY CAUSED ROUGHNESS.
▶ 0.9

TYPE POTENTIAL VERTICAL RISE (INCHES), OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

EXTREMELY ACTIVE EXPANSIVE CLAYS HAVE A MAXIMUM VERTICAL RISE IN THE ORDER OF 10.0 TO 20.0 INCHES. EVEN LARGER HEAVES MAY BE EXPECTED FROM FROST ACTION.
▶ 4.

TYPE SWELLING RATE CONSTANT, OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

THIS CONSTANT LIES BETWEEN 0.04 AND 0.20, THE LARGER VALUE
REPRESENTING THE MOST SEVERE CASE.
▶ 0.1

*** PERFORMANCE DATA REQUIRED
TYPE INITIAL SERVICEABILITY INDEX, OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

INITIAL SERVICEABILITY INDICES HAVE A STATEWIDE AVERAGE OF ABOUT 4.2 .
SURFACE TREATMENT MAY BE NEAR 3.8 AND A VERY SMOOTH ACP OR CRCP
MIGHT BE AS HIGH AS 4.8 .
▶ 4.2

TYPE MINIMUM SERVICEABILITY INDEX, OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

USE 3.0 ON HIGHWAY WITH LEGAL POSTED SPEEDS IN EXCESS OF 45 MPH.
USE 2.5 FOR THOSE POSTED 45 MPH OR LESS. USE 2.0 IF SIGNAL SPACING,
STOP SIGNS, DIPS, ETC. PREVENT DRIVERS FROM OPERATING FASTER THAN
20 MPH.
▶ 3.0

TYPE SERVICEABILITY INDEX AFTER AN OVERLAY,
OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

THE SERVICEABILITY INDEX AFTER AN OVERLAY IS ABOUT THE SAME
AS THAT OF INITIAL CONSTRUCTION.
▶ 4.2

*** TRAFFIC GROWTH DATA REQUIRED
TYPE ADT IN BOTH DIRECTIONS AT BEGINNING OF ANALYSIS PERIOD
(VEHICLES/DAY)
▶ 10000.

TYPE ADT IN BOTH DIRECTIONS AT END OF 20 YEARS (VEHICLES/DAY)
▶ 20000.

```
TYPE ONE-DIRECTION CUMULATIVE 18 KSA DURING 20 YEARS
▶ 5000000.

*** TRAFFIC DELAY DATA REQUIRED DURING OVERLAY
TYPE DETOUR MODEL USED, OR TYPE 0 (ZERO) FOR INSTRUCTIONS.
▶ 0

MODEL NO. 1 IS FOR TWO LANE ROAD.  TRAFFIC IS DIRECTED ALONG SHOULDER.
MODEL NO. 2 IS FOR TWO LANE ROAD.  TRAFFIC IS DIRECTED ALONG
            THE NON-OVERLAY LANE IN OPPOSITE DIRECTION.
MODEL NO. 3 IS FOR ROADS WITH FOUR LANES OR MORE.  TRAFFIC IS DIRECTED
            ALONG A NON-OVERLAY LANE IN SAME DIRECTION.
MODEL NO. 4 IS FOR ROADS WITH FOUR LANES OR MORE.  TRAFFIC IS DIRECTED
            ALONG A NON-OVERLAY LANE IN OPPOSITE DIRECTION.
MODEL NO. 5 IS FOR ROADS WITH FOUR LANES OR MORE.  TRAFFIC IS DIRECTED
            ALONG AN ALTERNATE ROUTE.
▶ 3

TYPE DISTANCE OVER WHICH TRAFFIC IS SLOWED (MILES)
     IN OVERLAY DIRECTION
▶ 0.5

     IN NON-OVERLAY DIRECTION
▶ 0.5

TYPE PERCENT OF ADT ARRIVING DURING EACH HOUR,
     OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

IN THE ABSENCE OF BETTER INFORMATION, USE 6.0 PERCENT FOR RURAL
     HIGHWAY AND 5.0 PERCENT FOR URBAN HIGHWAY.
▶ 5.5

TYPE OVERLAY CONSTRUCTION TIME (HOURS/DAY)
▶ 10.

TYPE NUMBER OF OPEN LANES IN RESTRICTED ZONE
     IN OVERLAY DIRECTION
▶ 1.
```

IN NON-OVERLAY DIRECTION
▶ 2.

TYPE PERCENT TRUCK IN ADT
▶ 8.

TYPE AVERAGE APPROACH SPEED OF VEHICLES (MPH)
▶ 60.

TYPE AVERAGE SPEED THRU RESTRICTED ZONE (MPH)
IN OVERLAY DIRECTION
▶ 30.

IN NON-OVERLAY DIRECTION
▶ 60.

*** MAINTENANCE DATA REQUIRED
TYPE FIRST YEAR COST OF ROUTINE MAINTENANCE (DOLLARS/LANE-MILE)
OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

AS AN EXAMPLE, THE FIRST YEAR COST VARIES FROM 25.0 TO 50.0 DOLLARS
PER LANE-MILE.
▶ 50.

TYPE ANNUAL INCREMENTAL INCREASE IN MAINTENANCE COST (DOLLARS/LANE-
MILE) OR TYPE 99.9 FOR INSTRUCTIONS.
▶ 99.9

AS AN EXAMPLE, THE ANNUAL INCREMENTAL INCREASE VARIES FROM 10.0 TO
30.0 DOLLARS PER LANE-MILE.
▶ 20.

*** PAVING MATERIALS DATA REQUIRED FOR FLEXIBLE PAVEMENTS
THE FLEXIBLE PAVEMENT USING LINEAR ELASTICITY IS FIXED FOR 3-LAYER
DESIGN. TWO PAVING MATERIALS ARE CONSIDERED. MATERIAL NO.1 IS
FOR THE TOP LAYER. MATERIAL NO.2 IS FOR THE SECOND LAYER.
FOR THE MATERIAL NO. 1
TYPE THE LAYER DESIGNATION NUMBER
▶ 1

TYPE THE LETTER CODE OF MATERIAL - 1 CHAR
▶ A

TYPE MATERIAL NAME - 18 CHAR MAX
▶ ASPHALTIC CONCRETE

TYPE IN-PLACE COST (DOLLARS/CU.YD.)
▶ 13.

TYPE MIN ALLOWABLE THICKNESS (IN.)
▶ 1.

TYPE MAX ALLOWABLE THICKNESS (IN.)
▶ 8.

TYPE SALVAGE PERCENT, OR TYPE 99.9 TO PRINT A TABLE OF
EXAMPLE SALVAGE PERCENT.
▶ 99.9

THE FOLLOWING TABLE SHOWS SALVAGE VALUE AS A PERCENT OF INITIAL COST.

PERCENT OF ROAD MEETING PRESENT DESIGN STANDARDS	0 TO 25			25 TO 50			50 TO 75			75 TO 100		
ANALYSIS PERIOD (YEARS)	10	20	30	10	20	30	10	20	30	10	20	30
TYPE OF MATERIAL												
1. SUBBASE	30	25	20	55	50	45	80	75	70	95	90	85
2. GRANULAR BASE MATERIAL	20	15	10	40	35	30	60	55	50	80	75	70
3. TREATED BASE	25	10	0	35	20	10	45	30	20	55	40	30
4. ASPHALT SURFACE	10	0	0	25	10	0	35	20	10	45	30	10

▶ 25.

TYPE ELASTIC MODULUS (PSI)
▶ 240000.

TYPE POISSON'S RATIO
▶ 0.5

DO YOU KNOW U, T, AND C VALUES OF TEXAS TRIAXIAL TEST MODEL?
▶ NO

```
--- ESTIMATE COEFFICIENTS OF TEXAS TRIAXIAL TEST MODEL
     U = UNCONFINED COMPRESSIVE STRENGTH
     T = LATERAL TENSILE STRENGTH
     C = DIMENSIONLESS PARAMETER
TYPE UNCONFINED COMPRESSIVE STRENGTH, U.
▶ 143.9

TYPE NUMBER OF LATERAL PRESSURES (OTHER THAN ZERO PRESSURE) USED -
     MAX 6.0
▶ 5.

FOR THE DATA POINT NO. 1
TYPE LATERAL STRESS
▶ 3.

TYPE VERTICAL STRESS AT FAILURE
▶ 160.5

FOR THE DATA POINT NO. 2
TYPE LATERAL STRESS
▶ 5.

TYPE VERTICAL STRESS AT FAILURE
▶ 155.6

FOR THE DATA POINT NO. 3
TYPE LATERAL STRESS
▶ 10.

TYPE VERTICAL STRESS AT FAILURE
▶ 160.6

FOR THE DATA POINT NO. 4
TYPE LATERAL STRESS
▶ 15.

TYPE VERTICAL STRESS AT FAILURE
▶ 190.9
```

```
    FOR THE DATA POINT NO. 5
    TYPE LATERAL STRESS
▶ 20.

    TYPE VERTICAL STRESS AT FAILURE
▶ 206.7

    U = 143.9      T =  49.3      C = 1.000      STD.ERROR = 7.151
    DO YOU ACCEPT THE U, T, AND C VALUES?
▶ NO

    TYPE 1 TO TRY ANOTHER SET OF DATA. TYPE 2 TO ENTER YOUR OWN SELECTIONS
         OF U, T, AND C.
▶ 2

    TYPE U VALUE OF TEXAS TRIAXIAL TEST MODEL (PSI)
▶ 200.

    TYPE T VALUE OF TEXAS TRIAXIAL TEST MODEL (PSI)
▶ 40.

    TYPE C VALUE OF TEXAS TRIAXIAL TEST MODEL
▶ 0.8

    FOR THE MATERIAL NO. 2
    TYPE THE LAYER DESIGNATION NUMBER
▶ 2

    TYPE THE LETTER CODE OF MATERIAL - 1 CHAR
▶ B

    TYPE MATERIAL NAME - 18 CHAR MAX
▶ BLACK BASE

    TYPE IN-PLACE COST (DOLLARS/CU.YD.)
▶ 11.

    TYPE MIN ALLOWABLE THICKNESS (IN.)
▶ 4.
```

```
TYPE MAX ALLOWABLE THICKNESS (IN.)
▶ 20.

TYPE SALVAGE PERCENT, OR TYPE 99.9 TO PRINT A TABLE OF
     EXAMPLE SALVAGE PERCENT.
▶ 70.

TYPE ELASTIC MODULUS (PSI)
▶ 150000.

TYPE POISSON'S RATIO
▶ 0.5

DO YOU KNOW U, T, AND C VALUES OF TEXAS TRIAXIAL TEST MODEL?
▶ NO

--- ESTIMATE COEFFICIENTS OF TEXAS TRIAXIAL TEST MODEL
     U = UNCONFINED COMPRESSIVE STRENGTH
     T = LATERAL TENSILE STRENGTH
     C = DIMENSIONLESS PARAMETER
TYPE UNCONFINED COMPRESSIVE STRENGTH, U.
▶ 149.2

TYPE NUMBER OF LATERAL PRESSURES (OTHER THAN ZERO PRESSURE) USED -
     MAX 6.0
▶ 4.

FOR THE DATA POINT NO. 1
TYPE LATERAL STRESS
▶ 5.

TYPE VERTICAL STRESS AT FAILURE
▶ 153.7

FOR THE DATA POINT NO. 2
TYPE LATERAL STRESS
▶ 10.
```

```
  TYPE VERTICAL STRESS AT FAILURE
▶ 229.8

  FOR THE DATA POINT NO. 3
  TYPE LATERAL STRESS
▶ 15.

  TYPE VERTICAL STRESS AT FAILURE
▶ 305.8

  FOR THE DATA POINT NO. 4
  TYPE LATERAL STRESS
▶ 20.

  TYPE VERTICAL STRESS AT FAILURE
▶ 318.4

  U = 149.2     T =  18.2     C = 1.000     STD.ERROR = *****
  DO YOU ACCEPT THE U, T, AND C VALUES?
▶ NO

  TYPE 1 TO TRY ANOTHER SET OF DATA. TYPE 2 TO ENTER YOUR OWN SELECTIONS
       OF U, T, AND C.
▶ 2

  TYPE U VALUE OF TEXAS TRIAXIAL TEST MODEL (PSI)
▶ 120.

  TYPE T VALUE OF TEXAS TRIAXIAL TEST MODEL (PSI)
▶ 30.

  TYPE C VALUE OF TEXAS TRIAXIAL TEST MODEL
▶ 0.8

  *** SUBGRADE PROPERTIES REQUIRED
  TYPE ELASTIC MODULUS (PSI)
▶ 24000.

  TYPE POISSON'S RATIO
▶ 0.5
```

```
   DO YOU KNOW U, T, AND C VALUES OF TEXAS TRIAXIAL TEST MODEL?
▶ NO

   --- ESTIMATE COEFFICIENTS OF TEXAS TRIAXIAL TEST MODEL
         U = UNCONFINED COMPRESSIVE STRENGTH
         T = LATERAL TENSILE STRENGTH
         C = DIMENSIONLESS PARAMETER
   TYPE UNCONFINED COMPRESSIVE STRENGTH, U.
▶ 17.8

   TYPE NUMBER OF LATERAL PRESSURES (OTHER THAN ZERO PRESSURE) USED -
         MAX 6.0
▶ 5.

   FOR THE DATA POINT NO. 1
   TYPE LATERAL STRESS
▶ 3.

   TYPE VERTICAL STRESS AT FAILURE
▶ 25.3

   FOR THE DATA POINT NO. 2
   TYPE LATERAL STRESS
▶ 5.

   TYPE VERTICAL STRESS AT FAILURE
▶ 27.3

   FOR THE DATA POINT NO. 3
   TYPE LATERAL STRESS
▶ 10.

   TYPE VERTICAL STRESS AT FAILURE
▶ 37.8

   FOR THE DATA POINT NO. 4
   TYPE LATERAL STRESS
▶ 15.
```

```
   TYPE VERTICAL STRESS AT FAILURE
▶ 46.6

   FOR THE DATA POINT NO. 5
   TYPE LATERAL STRESS
▶ 20.

   TYPE VERTICAL STRESS AT FAILURE
▶ 51.5

   U =  17.8      T =   4.7      C = 0.653      STD.ERROR = 0.029
   DO YOU ACCEPT THE U, T, AND C VALUES?
▶ NO

   TYPE 1 TO TRY ANOTHER SET OF DATA. TYPE 2 TO ENTER YOUR OWN SELECTIONS
        OF U, T, AND C.
▶ 2

   TYPE U VALUE OF TEXAS TRIAXIAL TEST MODEL (PSI)
▶ 16.

   TYPE T VALUE OF TEXAS TRIAXIAL TEST MODEL (PSI)
▶ 4.

   TYPE C VALUE OF TEXAS TRIAXIAL TEST MODEL
▶ 0.6

   *** OVERLAY DATA REQUIRED
   TYPE AC PRODUCTION RATE (TONS/HOUR)
▶ 75.

   TYPE AC COMPACTED DENSITY (TONS/C.Y.)
▶ 1.8

   TYPE ? FOR A LIST OF INPUT DATA FILE
▶ ?

   --- --- ---
   TURN TO NEXT PAGE AND PRESS RETURN KEY
```

FLEXIBLE PAVEMENT DESIGN SYSTEM BASED ON LINEAR ELASTICITY

PROJECT IDENTIFICATION

****

01.01	PROBLEM NUMBER	1
01.02	DISTRICT NUMBER	2
01.03	COUNTY NAME	ABC
01.04	CONTROL NUMBER	3210
01.05	SECTION NUMBER	12
01.06	HIGHWAY NAME	SH360
01.07	DATE	12-04-73
01.08	IPE NUMBER	152

COMMENTS ABOUT THIS PROBLEM

****

02.01	AN ILLUSTRATIVE EXAMPLE FOR THE UTILIZATION
02.02	OF THE PROCESSOR

BASIC DESIGN CRITERIA

****

03.01	LENGTH OF THE ANALYSIS PERIOD (YEARS)	20.0
03.02	MINIMUM TIME TO FIRST OVERLAY (YEARS)	3.0
03.03	MINIMUM TIME BETWEEN OVERLAYS (YEARS)	3.0
03.04	MINIMUM SERVICEABILITY INDEX P2	3.0
03.05	DESIGN CONFIDENCE LEVEL	D
03.06	INTEREST RATE OR TIME VALUE OF MONEY (PERCENT)	7.0

PROGRAM CONTROLS AND CONSTRAINTS

****

04.01	PROBLEM TYPE (1=FPS-DYNAFLECT,2=ACP OVERLAY,3=FPS-BISTRO,4=FPS-BISTRO WITH BASIC DESIGNS)	4
04.02	NUMBER OF OUTPUT PAGES DESIRED (8 DESIGNS/PAGE)	3
04.03	MAX FUNDS PER SQ.YD. FOR INITIAL DESIGN	4.00
04.04	MAX THICKNESS OF INITIAL CONSTRUCTION (INCHES)	16.0
04.05	ACCUMULATED MAX DEPTH OF ALL OVERLAYS (IN)	8.0
04.06	ACCURACY LEVEL FOR ANALYSIS OF LINEAR ELASTICITY (1=EXCELLANT,2=GOOD,3=FAIR)	1

TRAFFIC DATA

****

05.01	ADT AT START OF ANALYSIS PERIOD (VEHICLES/DAY)	10000.
05.02	ADT AT END OF TWENTY YEARS (VEHICLES/DAY)	20000.
05.03	20.-YEAR ACCUMULATED NO. OF EQUIVALENT 18-KSA	5000000.
05.04	AVE APPROACH SPEED TO THE OVERLAY ZONE(MPH)	60.0
05.05	AVE SPEED THROUGH OVERLAY ZONE IN OV.DIR. (MPH)	30.0
05.06	AVE SPEED THROUGH OVERLAY ZONE IN N.OV.DIR. (MPH)	60.0
05.07	PROPORTION OF ADT ARRIVING	5.5
05.08	PERCENT TRUCKS IN ADT	8.0

ENVIRONMENT AND SUBGRADE
****

06.01	DISTRICT TEMPERATURE CONSTANT	22.0
06.02	SWELLING PROBABILITY	0.90
06.03	POTENTIAL VERTICAL RISE (INCHES)	4.00
06.04	SWELLING RATE CONSTANT	0.10
06.06	ELASTIC MODULUS OF SUBGRADE	24000.
06.07	POISSON RATIO OF SUBGRADE	0.50
06.08	TRIAXIAL U VALUE OF SUBGRADE	16.0
06.09	TRIAXIAL T VALUE OF SUBGRADE	4.0
06.10	TRIAXIAL C VALUE OF SUBGRADE	0.600

CONSTRUCTION AND MAINTENANCE DATA
****

07.01	SERVICEABILITY INDEX OF THE INITIAL STRUCTURE	4.2
07.02	SERVICEABILITY INDEX P1 AFTER AN OVERLAY	4.2
07.03	MINIMUM OVERLAY THICKNESS (INCHES)	2.0
07.04	OVERLAY CONSTRUCTION TIME (HOURS/DAY)	10.0
07.05	ASPHALTIC CONCRETE COMPACTED DENSITY (TONS/C.Y.)	1.80
07.06	ASPHALTIC CONCRETE PRODUCTION -ATE (TONS/HOUR)	75.0
07.07	WIDTH OF EACH LANE (FEET)	12.0
07.08	FIRST YEAR COST OF ROUTINE MAINTENANCE	50.00
07.09	ANNUAL INCREMENTAL INCREASE IN MAINTENANCE COST	20.00

DETOUR DESIGN FOR OVERLAYS
****

08.01	TRAFFIC MODEL USED DURING OVERLAYING	3
08.02	TOTAL NUMBER OF LANES OF THE FACILITY	4

08.03 *NUMBER OF OPEN LANES IN OV.DIR.*	1
08.04 *NUMBER OF OPEN LANES IN N.OV.DIR.*	2
08.05 *DISTANCE TRAFFIC IS SLOWED IN OV.DIR. (MILES)*	0.50
08.06 *DISTANCE TRAFFIC IS SLOWED IN N.OV.DIR. (MILES)*	0.50
08.07 *DETOUR DISTANCE AROUND THE OVERLAY ZONE (MILES)*	0.0

PAVING MATERIALS INFORMATION

****

10.01.01 *LAYER NUMBER*	1
10.01.02 *LETTER CODE*	*A*
10.01.03 *MATERIAL NAME*	*ASPHALTIC CONCRETE*
10.01.04 *IN-PLACE COST*	13.00
10.01.06 *MINIMUM THICKNESS*	1.00
10.01.07 *MAXIMUM THICKNESS*	8.00
10.01.08 *SALVAGE PERCENT*	25.00
10.01.09 *ELASTIC MODULUS*	240000.
10.01.10 *POISSON RATIO*	0.50
10.01.11 *U VALUE OF TRIAXIAL MODEL*	200.0
10.01.12 *T VALUE OF TRIAXIAL MODEL*	40.0
10.01.13 *C VALUE OF TRIAXIAL MODEL*	0.800
10.02.01 *LAYER NUMBER*	2
10.02.02 *LETTER CODE*	*B*
10.02.03 *MATERIAL NAME*	*BLACK BASE*
10.02.04 *IN-PLACE COST*	11.00
10.02.06 *MINIMUM THICKNESS*	4.00
10.02.07 *MAXIMUM THICKNESS*	20.00
10.02.08 *SALVAGE PERCENT*	70.00
10.02.09 *ELASTIC MODULUS*	150000.
10.02.10 *POISSON RATIO*	0.50
10.02.11 *U VALUE OF TRIAXIAL MODEL*	120.0
10.02.12 *T VALUE OF TRIAXIAL MODEL*	30.0
10.02.13 *C VALUE OF TRIAXIAL MODEL*	0.800

--- --- ---

TURN TO NEXT PAGE AND PRESS RETURN KEY

```
  TYPE ? FOR REVISIONS(S) OF INPUT DATA FILE
▶ ?

  TWO QUESTIONS ARE ASKED FOR EACH DATA REVISION : (1) THE CODE NUMBER
       OF THE INPUT VARIABLE, AND (2) THE NEW INPUT DATA.  TYPE
       CODE NUMBER 99.99 TO TERMINATE.
  CODE NUMBER?
▶ 03.06

  INPUT DATA?
▶ 6.

  CODE NUMBER?
▶ 99.99

  TYPE THE RECORD NUMBER WITH DECIMAL POINT OF YOUR DATA SET WHERE YOU
       WISH TO STORE THE CURRENT DATA FILE.  OTHERWISE, TYPE 0 (ZERO).
▶ 15.

  END OF DRIVER'S SEGMENT
  IT IS A GREAT PLEASURE TO SERVE YOU.
  ..END OF JOB    CPU TIME =000003 SEC
```

```
▶ [[UPDATE
  ..OK

  UPDT110R -- IF YOU WANT FULL INSTRUCTIONS TYPE ←?
▶ ←?

  UPDT000I -- UPDATE ACCEPTS THE FOLLOWING COMMANDS
  ←INPUT DDNAME ..OR.. ←INPUT DDNAME(MEMBER)
  ←OUTPUT DDNAME ..OR.. ←OUTPUT DDNAME(MEMBER)
  ←INPUT DSN=XXX..(UP TO 44 CHARACTERS)
  ←OUTPUT DSN=XXX..(UP TO 44 CHARACTERS)
  ←DISPLAY XXXXXXXX ..OR.. TO XXXXXXXX
  ←DELETE XXXXXXXX ..OR.. TO XXXXXXXX
  ←REPLACE XXXXXXXX ..OR.. TO XXXXXXXX
  →HIT EOB TO CONTINUE←
  E←ADD AFTER XXXXXXXX
  ←ADD TO END
  ←SET INC TO XXXXXXXX
  ←SET SEQ TO XX FOR XX
  ←TABS KEY=X(--,--,--,--)
     WHERE X IS THE CHARACTER USED TO CAUSE TAB
     AND THE DASHES ARE THE COLUMN NUMBERS
     WHERE THE TABS ARE TO BE SET
  ←END

▶ ←ADD TO END

  UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ //FPSB        JOB(Y033,1-E,3,2,1),'LU'

  UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ /*PASSWORD       DANNYLU

  UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ /*CLASS          H
```

```
UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ /*ROUTE        PRINTER3

UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ //STEP1  EXEC  PGM=FPSB,REGION=200K

UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ //STEPLIB  DD  DSN=USER.Y033.IEN.LU.JOBLIB,DISP=SHR

UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ //FT09F001 DD  DSN=TP.Y033.IEN.LU.BISTRO,DISP=SHR

UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ //FT05F001 DD  DSN=TP.Y033.IEN.LU.CRDIMG,DISP=SHR

UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ //FT06F001 DD  SYSOUT=A

UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ /*

UPDT090R -- ENTER STATEMENTS TO BE ADDED
▶ +DISPLAY

//FPSB      JOB(Y033,1-E,3,2,1),'LU'                                   00000001
/*PASSWORD     DANNYLU                                                 00000002
/*CLASS        H                                                       00000003
/*ROUTE        PRINTER3                                                00000004
//STEP1  EXEC  PGM=FPSB,REGION=200K                                    00000005
//STEPLIB  DD  DSN=USER.Y033.IEN.LU.JOBLIB,DISP=SHR                    00000006
//FT09F001 DD  DSN=TP.Y033.IEN.LU.BISTRO,DISP=SHR                      00000007
//FT05F001 DD  DSN=TP.Y033.IEN.LU.CRDIMG,DISP=SHR                      00000008
//FT06F001 DD  SYSOUT=A                                                00000009
/*                                                                     00000010
```

```
    UPDT080R -- REQUESTED FUNCTION PERFORMED ... ENTER NEXT REQUEST
  ► ←ADD AFTER 4

    UPDT090R -- ENTER STATEMENTS TO BE ADDED
  ► /*FORMS          14101000

    UPDT090R -- ENTER STATEMENTS TO BE ADDED
  ► ←OUTPUT LUPROG(FPSB)

    UPDT080R -- REQUESTED FUNCTION PERFORMED ... ENTER NEXT REQUEST
  ► ←END

    UPDT0160I -- IT HAS BEEN A PLEASURE TO SERVE YOU
    ..END OF JOB     CPU TIME =000000 SEC

  ► [[RJEIN
    ..OK

    REMOTE JOB ENTRY TO HASP

    TYPE EOB IF YOU WISH TO ENTER A PROGRAM FROM THIS TERMINAL (9999 STMT MAX)

    OR ENTER DDNAME OF SEQUENTIAL DATA SET CONTAINING A SOURCE PROGRAM

    OR ENTER DDNAME AND MEMBER OF A PARTITIONED DATA SET
        (FORMAT - DDNAME(MEMBER))
  ► LUPROG(FPSB)

    JOB WAS SUCCESSFULLY LOADED
  ► [[END
    ...OK        CPU TIME =000001 SEC
  ► [[EOT
    ...OK        CPU TIME =000001 SEC
  ► [[HANGUP
    ...OK        CPU TIME =000001 SEC
```

APPENDIX B

PROGRAM OUTPUT OF AN EXAMPLE FLEXIBLE PAVEMENT DESIGN PROBLEM

Contained in this appendix is the program output from an example flexible pavement design problem. The first two pages are the listing of many input parameters describing problem identifications, problem comments, basic design criteria, program controls and constraints, traffic data, environment and subgrade, construction and maintenance data, detour design for overlay, as well as materials information. The next three pages are the listing of the surface curvature index as well as major and minor principal stresses and strains at layer interfacial points of twnety-five basic three-layer designs. Following these is the optimal design calculated by the linear elasticity version of the Texas Flexible Pavement Design System. Finally, twelve feasible designs are tabulated on a summary table in the order of increasing total cost.

TEXAS HIGHWAY DEPARTMENT
FPS - BISTRO
FLEXIBLE PAVEMENT DESIGN USING LINEAR ELASTICITY

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1	2	ABC	3210	12	SH360	12-04-73	152	1

****
COMMENTS ABOUT THIS PROBLEM

AN ILLUSTRATIVE EXAMPLE FOR THE UTILIZATION
OF THE PROCESSOR
****

BASIC DESIGN CRITERIA
****

LENGTH OF THE ANALYSIS PERIOD (YEARS)	20.0
MINIMUM TIME TO FIRST OVERLAY (YEARS)	3.0
MINIMUM TIME BETWEEN OVERLAYS (YEARS)	3.0
MINIMUM SERVICEABILITY INDEX P2	3.0
DESIGN CONFIDENCE LEVEL	D
INTEREST RATE OR TIME VALUE OF MONEY (PERCENT)	6.0

PROGRAM CONTROLS AND CONSTRAINTS
****

NUMBER OF SUMMARY OUTPUT PAGES DESIRED (8 DESIGNS/PAGE)	3
MAX FUNDS AVAILABLE PER SQ.YD. FOR INITIAL DESIGN (DOLLARS)	4.00
MAXIMUM ALLOWED THICKNESS OF INITIAL CONSTRUCTION (INCHES)	16.0
ACCUMULATED MAX DEPTH OF ALL OVERLAYS (INCHES) (EXCLUDING LEVEL-UP)	8.0

TRAFFIC DATA
****

ADT AT BEGINNING OF ANALYSIS PERIOD (VEHICLES/DAY)	10000.
ADT AT END OF TWENTY YEARS (VEHICLES/DAY)	20000.
ONE-DIRECTION 20.-YEAR ACCUMULATED NO. OF EQUIVALENT 18-KSA	5000000.
AVERAGE APPROACH SPEED TO THE OVERLAY ZONE(MPH)	60.0
AVERAGE SPEED THROUGH OVERLAY ZONE (OVERLAY DIRECTION) (MPH)	30.0
AVERAGE SPEED THROUGH OVERLAY ZONE (NON-OVERLAY DIRECTION) (MPH)	60.0
PROPORTION OF ADT ARRIVING EACH HOUR OF CONSTRUCTION (PERCENT)	5.5
PERCENT TRUCKS IN ADT	8.0

ENVIRCNMENT AND SUBGRADE
****

DISTRICT TEMPERATURE CONSTANT	22.0
SWELLING PROBABILITY	0.90
POTENTIAL VERTICAL RISE (INCHES)	4.00
SWELLING RATE CONSTANT	0.10

TEXAS HIGHWAY DEPARTMENT
FPS - BISTRO
FLEXIBLE PAVEMENT DESIGN USING LINEAR ELASTICITY

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1	2	ABC	3210	12	SH360	12-04-73	152	2

INPUT DATA CONTINUED

CONSTRUCTION AND MAINTENANCE DATA
****

SERVICEABILITY INDEX OF THE INITIAL STRUCTURE	4.2
SERVICEABILITY INDEX P1 AFTER AN OVERLAY	4.2
MINIMUM OVERLAY THICKNESS (INCHES)	2.0
OVERLAY CONSTRUCTION TIME (HOURS/DAY)	10.0
ASPHALTIC CONCRETE COMPACTED DENSITY (TONS/C.Y.)	1.80
ASPHALTIC CONCRETE PRODUCTION RATE (TONS/HOUR)	75.0
WIDTH OF EACH LANE (FEET)	12.0
FIRST YEAR COST OF ROUTINE MAINTENANCE (DOLLARS/LANE-MILE)	50.00
ANNUAL INCREMENTAL INCREASE IN MAINTENANCE COST (DOLLARS/LANE-MILE)	20.00

DETOUR DESIGN FOR OVERLAYS
****

TRAFFIC MODEL USED DURING OVERLAYING	3
TOTAL NUMBER OF LANES OF THE FACILITY	4
NUMBER OF OPEN LANES IN RESTRICTED ZONE (OVERLAY DIRECTION)	1
NUMBER OF OPEN LANES IN RESTRICTED ZONE (NON-OVERLAY DIRECTION)	2
DISTANCE TRAFFIC IS SLOWED (OVERLAY DIRECTION) (MILES)	0.50
DISTANCE TRAFFIC IS SLOWED (NON-OVERLAY DIRECTION) (MILES)	0.50
DETOUR DISTANCE AROUND THE OVERLAY ZONE (MILES)	0.0

MATERIALS INFORMATION
****

LAYER	MATERIALS CODE	NAME	COST PER CY	MIN. DEPTH	MAX. DEPTH	SALVAGE, PCT.
1	A	ASPHALTIC CONCRETE	13.00	1.00	8.00	25.00
2	B	BLACK BASE	11.00	4.00	20.00	70.00

LAYER	MATERIALS CODE	NAME	ELASTIC MODULUS	POISSON RATIO	TEXAS TRIAXIAL TEST U	T	C
1	A	ASPHALTIC CONCRETE	240000.	0.50	200.0	40.0	0.800
2	B	BLACK BASE	150000.	0.50	120.0	30.0	0.800
		SUBGRADE	24000.	0.50	16.0	4.0	0.600

TEXAS HIGHWAY DEPARTMENT
FPS - BISTRO
FLEXIBLE PAVEMENT DESIGN USING LINEAR ELASTICITY

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1	2	ABC	3210	12	SH360	12-04-73	152	3

BASIC-DESIGNS INFORMATION (ACCURACY:EXCELLENT)

NO	D(1)	D(2)	SCI	DEPTH	LAYER	SIGMA1	SIGMA3	EPSLN1	EPSLN3
1	1.0	4.0	0.323						
				1.0	1	-0.721E 02	-0.781E 02	0.239E-04	-0.137E-04
				1.0	2	-0.728E 02	-0.778E 02	0.317E-04	-0.179E-04
				5.0	2	0.854E 02	-0.252E 02	0.417E-03	-0.689E-03
				5.0	3	-0.747E 01	-0.253E 02	0.417E-03	-0.701E-03
2	2.0	4.0	0.268						
				2.0	1	-0.170E 02	-0.663E 02	0.106E-03	-0.203E-03
				2.0	2	-0.354E 02	-0.665E 02	0.106E-03	-0.206E-03
				6.0	2	0.705E 02	-0.198E 02	0.342E-03	-0.560E-03
				6.0	3	-0.529E 01	-0.200E 02	0.342E-03	-0.575E-03
3	4.0	4.0	0.186						
				4.0	1	0.223E 02	-0.420E 02	0.146E-03	-0.256E-03
				4.0	2	-0.164E 01	-0.422E 02	0.146E-03	-0.260E-03
				8.0	2	0.488E 02	-0.130E 02	0.234E-03	-0.383E-03
				8.0	3	-0.306E 01	-0.132E 02	0.234E-03	-0.399E-03
4	8.0	4.0	0.104						
				8.0	1	0.244E 02	-0.173E 02	0.965E-04	-0.164E-03
				8.0	2	0.894E 01	-0.176E 02	0.965E-04	-0.168E-03
				12.0	2	0.272E 02	-0.684E 01	0.127E-03	-0.214E-03
				12.0	3	-0.136E 01	-0.699E 01	0.127E-03	-0.224E-03
5	16.0	4.0	0.061						
				16.0	1	0.139E 02	-0.530E 01	0.432E-04	-0.765E-04
				16.0	2	0.676E 01	-0.543E 01	0.432E-04	-0.787E-04
				20.0	2	0.121E 02	-0.288E 01	0.540E-04	-0.962E-04
				20.0	3	-0.470E 00	-0.294E 01	0.540E-04	-0.100E-03
6	1.0	8.0	0.172						
				1.0	1	-0.663E 02	-0.793E 02	0.314E-04	-0.502E-04
				1.0	2	-0.708E 02	-0.795E 02	0.343E-04	-0.531E-04
				9.0	2	0.456E 02	-0.119E 02	0.218E-03	-0.357E-03
				9.0	3	-0.268E 01	-0.121E 02	0.218E-03	-0.371E-03
7	2.0	8.0	0.155						
				2.0	1	-0.241E 02	-0.712E 02	0.102E-03	-0.193E-03
				2.0	2	-0.417E 02	-0.713E 02	0.102E-03	-0.195E-03
				10.0	2	0.394E 02	-0.101E 02	0.187E-03	-0.307E-03
				10.0	3	-0.215E 01	-0.103E 02	0.187E-03	-0.321E-03
8	4.0	8.0	0.125						
				4.0	1	0.890E 01	-0.472E 02	0.127E-03	-0.223E-03
				4.0	2	-0.120E 02	-0.474E 02	0.127E-03	-0.227E-03
				12.0	2	0.298E 02	-0.747E 01	0.140E-03	-0.233E-03
				12.0	3	-0.148E 01	-0.764E 01	0.140E-03	-0.245E-03
9	8.0	8.0	0.084						
				8.0	1	0.142E 02	-0.207E 02	0.814E-04	-0.136E-03
				8.0	2	0.131E 01	-0.210E 02	0.814E-04	-0.142E-03
				16.0	2	0.187E 02	-0.455E 01	0.852E-04	-0.147E-03
				16.0	3	-0.816E 00	-0.465E 01	0.852E-04	-0.154E-03

TEXAS HIGHWAY DEPARTMENT
FPS - BISTRO
FLEXIBLE PAVEMENT DESIGN USING LINEAR ELASTICITY

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1	2.	ABC	3210	12	SH360	12-04-73	152	4

BASIC-DESIGNS INFORMATION (ACCURACY:EXCELLENT)

NO	D(1)	D(2)	SCI	DEPTH	LAYER	SIGMA1	SIGMA3	EPSLN1	EPSLN3
10	16.0	8.0	0.057						
				16.0	1	0.912E 01	-0.672E 01	0.359E-04	-0.631E-04
				16.0	2	0.330E 01	-0.690E 01	0.359E-04	-0.661E-04
				24.0	2	0.933E 01	-0.219E 01	0.408E-04	-0.744E-04
				24.0	3	-0.337E 00	-0.222E 01	0.408E-04	-0.771E-04
11	1.0	12.0	0.119						
				1.0	1	-0.591E 02	-0.795E 02	0.431E-04	-0.843E-04
				1.0	2	-0.667E 02	-0.795E 02	0.431E-04	-0.849E-04
				13.0	2	0.278E 02	-0.695E 01	0.130E-03	-0.217E-03
				13.0	3	-0.136E 01	-0.711E 01	0.130E-03	-0.229E-03
12	2.0	12.0	0.115						
				2.0	1	-0.214E 02	-0.720E 02	0.111E-03	-0.206E-03
				2.0	2	-0.403E 02	-0.721E 02	0.111E-03	-0.206E-03
				14.0	2	0.249E 02	-0.614E 01	0.116E-03	-0.195E-03
				14.0	3	-0.115E 01	-0.628E 01	0.116E-03	-0.205E-03
13	4.0	12.0	0.101						
				4.0	1	0.687E 01	-0.486E 02	0.127E-03	-0.220E-03
				4.0	2	-0.139E 02	-0.487E 02	0.127E-03	-0.222E-03
				16.0	2	0.201E 02	-0.488E 01	0.919E-04	-0.157E-03
				16.0	3	-0.866E 00	-0.499E 01	0.919E-04	-0.166E-03
14	8.0	12.0	0.074						
				8.0	1	0.108E 02	-0.221E 02	0.779E-04	-0.128E-03
				8.0	2	-0.137E 01	-0.224E 02	0.779E-04	-0.132E-03
				20.0	2	0.136E 02	-0.325E 01	0.608E-04	-0.108E-03
				20.0	3	-0.543E 00	-0.332E 01	0.608E-04	-0.113E-03
15	16.0	12.0	0.055						
				16.0	1	0.696E 01	-0.761E 01	0.333E-04	-0.578E-04
				16.0	2	0.162E 01	-0.779E 01	0.333E-04	-0.608E-04
				28.0	2	0.737E 01	-0.172E 01	0.318E-04	-0.590E-04
				28.0	3	-0.259E 00	-0.174E 01	0.318E-04	-0.608E-04
16	1.0	16.0	0.099						
				1.0	1	-0.534E 02	-0.796E 02	0.570E-04	-0.107E-03
				1.0	2	-0.632E 02	-0.796E 02	0.570E-04	-0.107E-03
				17.0	2	0.188E 02	-0.458E 01	0.859E-04	-0.148E-03
				17.0	3	-0.822E 00	-0.468E 01	0.859E-04	-0.156E-03
17	2.0	16.0	0.098						
				2.0	1	-0.185E 02	-0.723E 02	0.119E-03	-0.217E-03
				2.0	2	-0.387E 02	-0.723E 02	0.119E-03	-0.218E-03
				18.0	2	0.172E 02	-0.414E 01	0.780E-04	-0.135E-03
				18.0	3	-0.715E 00	-0.424E 01	0.780E-04	-0.142E-03
18	4.0	16.0	0.090						
				4.0	1	0.700E 01	-0.491E 02	0.128E-03	-0.222E-03
				4.0	2	-0.140E 02	-0.492E 02	0.128E-03	-0.223E-03
				20.0	2	0.144E 02	-0.343E 01	0.646E-04	-0.114E-03
				20.0	3	-0.566E 00	-0.351E 01	0.646E-04	-0.119E-03

TEXAS HIGHWAY DEPARTMENT
FPS - BISTRO
FLEXIBLE PAVEMENT DESIGN USING LINEAR ELASTICITY

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1	2	ABC	3210	12	SH360	12-04-73	152	5

BASIC-DESIGNS INFORMATION (ACCURACY:EXCELLENT)

NO	D(1)	D(2)	SCI	DEPTH	LAYER	SIGMA1	SIGMA3	EPSLN1	EPSLN3
19	8.0	16.0	0.069						
				8.0	1	0.959E 01	-0.229E 02	0.771E-04	-0.126E-03
				8.0	2	-0.244E 01	-0.231E 02	0.771E-04	-0.129E-03
				24.0	2	0.103E 02	-0.244E 01	0.454E-04	-0.824E-04
				24.0	3	-0.385E 00	-0.248E 01	0.454E-04	-0.855E-04
20	16.0	16.0	0.053						
				16.0	1	0.583E 01	-0.817E 01	0.322E-04	-0.553E-04
				16.0	2	0.699E 00	-0.834E 01	0.322E-04	-0.582E-04
				32.0	2	0.596E 01	-0.138E 01	0.255E-04	-0.479E-04
				32.0	3	-0.205E 00	-0.140E 01	0.255E-04	-0.492E-04
21	1.0	20.0	0.089						
				1.0	1	-0.498E 02	-0.796E 02	0.654E-04	-0.121E-03
				1.0	2	-0.610E 02	-0.796E 02	0.654E-04	-0.121E-03
				21.0	2	0.136E 02	-0.325E 01	0.606E-04	-0.107E-03
				21.0	3	-0.548E 00	-0.331E 01	0.606E-04	-0.112E-03
22	2.0	20.0	0.090						
				2.0	1	-0.164E 02	-0.724E 02	0.124E-03	-0.226E-03
				2.0	2	-0.374E 02	-0.724E 02	0.124E-03	-0.226E-03
				22.0	2	0.126E 02	-0.298E 01	0.558E-04	-0.997E-04
				22.0	3	-0.486E 00	-0.304E 01	0.558E-04	-0.104E-03
23	4.0	20.0	0.084						
				4.0	1	0.756E 01	-0.494E 02	0.130E-03	-0.226E-03
				4.0	2	-0.138E 02	-0.494E 02	0.130E-03	-0.226E-03
				24.0	2	0.108E 02	-0.254E 01	0.476E-04	-0.860E-04
				24.0	3	-0.398E 00	-0.259E 01	0.476E-04	-0.894E-04
24	8.0	20.0	0.067						
				8.0	1	0.913E 01	-0.233E 02	0.771E-04	-0.125E-03
				8.0	2	-0.289E 01	-0.234E 02	0.771E-04	-0.128E-03
				28.0	2	0.809E 01	-0.189E 01	0.350E-04	-0.647E-04
				28.0	3	-0.287E 00	-0.192E 01	0.350E-04	-0.669E-04
25	16.0	20.0	0.053						
				16.0	1	0.521E 01	-0.852E 01	0.317E-04	-0.541E-04
				16.0	2	0.170E 00	-0.868E 01	0.317E-04	-0.568E-04
				36.0	2	0.492E 01	-0.114E 01	0.209E-04	-0.397E-04
				36.0	3	-0.166E 00	-0.115E 01	0.209E-04	-0.405E-04

TEXAS HIGHWAY DEPARTMENT
FPS - BISTRO
FLEXIBLE PAVEMENT DESIGN USING LINEAR ELASTICITY

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1	2	ABC	3210	12	SH360	12-04-73	152	6

THE OPTIMAL DESIGN FOR THE MATERIALS UNDER CONSIDERATION--

FOR INITIAL CONSTRUCTION THE DEPTHS SHOULD BE
ASPHALTIC CONCRETE 7.00 INCHES
BLACK BASE 4.50 INCHES

THE LIFE OF THE INITIAL STRUCTURE = 3.95 YEARS
THE OVERLAY SCHEDULE IS
2.50 (INCH(ES) (INCLUDING 0.5 INCH LEVEL-UP) AFTER 3.95 YEARS.
2.50 (INCH(ES) (INCLUDING 0.5 INCH LEVEL-UP) AFTER 8.59 YEARS.
2.50 (INCH(ES) (INCLUDING 0.5 INCH LEVEL-UP) AFTER 14.48 YEARS.
TOTAL LIFE = 21.21YEARS

THE SCI OF THE INITIAL STRUCTURE = 0.114
SCI IN EACH PERFORMANCE PERIOD IS
(1) 0.114
(2) 0.091
(3) 0.076
(4) 0.067

MAJOR AND MINOR PRINCIPAL STRESSES OF THE INITIAL CONSTRUCTION

DEPTH	LAYER	MAJOR	MINOR
7.00	1	0.245E 02	-0.215E 02
7.00	2	0.757E 01	-0.218E 02
11.50	2	0.295E 02	-0.749E 01
11.50	3	-0.154E 01	-0.764E 01

AT THE OPTIMAL SOLUTION,THE FOLLOWING
BOUNDARY RESTRICTIONS ARE ACTIVE--

NONE

TEXAS HIGHWAY DEPARTMENT
FPS - BISTRO
FLEXIBLE PAVEMENT DESIGN USING LINEAR ELASTICITY

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1	2	ABC	3210	12	SH360	12-04-73	152	7

SUMMARY OF THE BEST DESIGN STRATEGIES
IN ORDER OF INCREASING TOTAL COST

	1	2	3	4	5	6	7	8
MATERIAL ARRANGEMENT	AB	AB	AB	AB	AB	AB	AB	AB
INIT. CONST. COST	3.90	3.97	3.93	4.00	3.92	3.87	3.94	3.90
OVERLAY CONST. COST	1.65	1.68	1.63	1.68	1.91	2.15	1.87	2.13
USER COST	0.09	0.09	0.09	0.09	0.11	0.12	0.11	0.12
ROUTINE MAINT. COST	0.15	0.15	0.15	0.15	0.15	0.14	0.15	0.14
SALVAGE VALUE	-0.67	-0.76	-0.65	-0.74	-0.82	-1.02	-0.80	-1.00
TOTAL COST	5.13	5.14	5.15	5.19	5.26	5.26	5.27	5.29
NUMBER OF LAYERS	2	2	2	2	2	2	2	2
LAYER DEPTH (INCHES)								
D(1)	7.00	5.50	7.50	6.00	4.50	1.00	5.00	1.50
D(2)	4.50	6.50	4.00	6.00	7.50	11.50	7.00	11.00
NO.OF PERF.PERIODS	4	4	4	4	4	5	4	5
PERF. TIME (YEARS)								
T(1)	3.9	3.7	4.1	3.9	3.5	3.6	3.6	3.5
T(2)	8.6	8.1	9.0	8.4	7.6	7.0	7.8	7.1
T(3)	14.5	13.7	15.0	14.1	13.6	11.2	13.3	11.4
T(4)	21.2	20.2	21.8	20.8	20.5	16.4	20.4	16.8
T(5)						22.5		23.1
OVERLAY POLICY(INCH) (INCLUDING LEVEL-UP)								
O(1)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
O(2)	2.5	2.5	2.5	2.5	3.5	2.5	2.5	2.5
O(3)	2.5	2.5	2.5	2.5	2.5	2.5	3.5	2.5
O(4)						2.5		2.5
SWELLING CLAY LOSS (SERVICEABILITY)								
SC(1)	0.39	0.38	0.41	0.39	0.36	0.36	0.37	0.36
SC(2)	0.30	0.29	0.31	0.30	0.28	0.24	0.29	0.25
SC(3)	0.23	0.23	0.22	0.23	0.25	0.20	0.23	0.21
SC(4)	0.14	0.15	0.13	0.14	0.15	0.16	0.16	0.16
SC(5)						0.11		0.10

TEXAS HIGHWAY DEPARTMENT
FPS - BISTRO
FLEXIBLE PAVEMENT DESIGN USING LINEAR ELASTICITY

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1	2	ABC	3210	12	SH360	12-04-73	152	8

SUMMARY OF THE BEST DESIGN STRATEGIES
IN ORDER OF INCREASING TOTAL COST

	9	10	11	12
*************************				
MATERIAL ARRANGEMENT	AB	AB	AB	AB
INIT. CONST. COST	3.99	3.93	3.89	3.96
OVERLAY CONST. COST	1.97	2.10	2.02	2.08
USER COST	0.11	0.12	0.11	0.12
ROUTINE MAINT. COST	0.15	0.14	0.15	0.14
SALVAGE VALUE	-0.92	-0.98	-0.84	-0.96
*************************				
TOTAL COST	5.29	5.31	5.33	5.34
*************************				
NUMBER OF LAYERS	2	2	2	2
*************************				
LAYER DEPTH (INCHES)				
D(1)	3.00	2.00	4.00	2.50
D(2)	9.50	10.50	8.00	10.00
*************************				
NO.OF PERF.PERIODS	4	5	4	5
*************************				
PERF. TIME (YEARS)				
T(1)	3.6	3.5	3.5	3.5
T(2)	8.0	7.2	7.4	7.3
T(3)	13.6	11.7	13.3	12.0
T(4)	20.2	17.3	20.1	17.8
T(5)		23.8		24.5
*************************				
OVERLAY POLICY(INCH) (INCLUDING LEVEL-UP)				
O(1)	3.5	2.5	2.5	2.5
O(2)	2.5	2.5	3.5	2.5
O(3)	2.5	2.5	2.5	2.5
O(4)		2.5		2.5
*************************				
SWELLING CLAY LOSS (SERVICEABILITY)				
SC(1)	0.36	0.36	0.35	0.36
SC(2)	0.30	0.26	0.28	0.27
SC(3)	0.23	0.22	0.25	0.22
SC(4)	0.15	0.16	0.16	0.16
SC(5)		0.10		0.10
*************************				

THE TOTAL NUMBER OF FEASIBLE DESIGNS CONSIDERED WAS 12

APPENDIX C

CODE NUMBER OF INPUT VARIABLES

Three coding systems are deviced to facilitate input data revisions. Systems R and S are used for the rigid pavement design option and the AASHO structural number based flexible pavement design option, respectively. System F is used for the asphaltic concrete pavement overlay design option and two other flexible pavement design options: (1) based on Dynaflect deflection, and (2) based on linear elasticity. Code numbers of the three systems are presented in the following pages.

SYSTEM R

RIGID PAVEMENT DESIGN OPTION

Problem Identification

01.01 Problem Number
01.02 Problem Title

Program Controls

02.01 Pavement Type (1=Jointed, 2=Reinforced, 0=Both)
02.02 Overlay Type (1=PCC, 2=AC, 0=Both)
02.03 Reinforcement Type (1=Deformed Bars, 2=Welded Wire PCC Mesh 0=Both)
02.04 Form of Output (1=Short Form, 0=Long Form)
02.05 Number of Designs Desired

Traffic Growth and Distribution

03.01 Axle Growth
03.02 ADT Growth Rate
03.03 Directional Distribution Factor
03.04 Lane Distribution Factor
03.05 Initial Average Daily Traffic
03.06 Total 18 Kip Axles For Analysis Period

Designer's Decisions or Restraints

04.01 Maximum Initial Funds Available, Dollars
04.02 Max Initial Thickness, Slab Plus Subbase, Inches
04.03 Min Time To First Overlay, Years
04.04 Min Time Between Overlays, Years
04.05 Max Total AC Overlay Thickness, Inches
04.06 Min AC Overlay Thickness at One Time, Inches
04.07 Max Total Conc Overlay Thickness, Inches
04.08 Min Conc Overlay Thickness at One Time, Inches
04.09 Length of Analysis Period, Years
04.10 Average Level Up Thickness, Inches
04.11 Confidence Level

Performance Variables

05.01 Initial Serviceability Index
05.02 Terminal Serviceability Index
05.03 Serviceability Index After An Overlay
05.04 Probability of Conjunction of Bad Soil and Site
05.05 Exponential Exponent For Swelling Clay Deterioration
05.06 Swelling Activity, Estimated Differential Movement

Traffic Delay Cost Variables

06.01	Distance Over Which Traffic is Slowed,	OV. Direct.
06.02		N.OV. Direct.
06.03	Detour Distance Around Overlay Zone	
06.04	ADT Arriving Each Hour of Construction	
06.05	No. of Hours/Day Overlay Construction Occurs	
06.06	No. of Open Lanes in Restricted Zone,	OV. Direct.
06.07		N.OV. Direct.
06.08	Project Location (1=Rural, 2=Urban)	
06.09	Percent Vehicles Stopped by Road Equip,	OV. Direct.
06.10		N.OV. Direct.
06.11	Avg Delay Caused by Road Equip., Hours,	OV. Direct.
06.12		N.OV. Direct.
06.13	Average Approach Speed to Overlay Area	
06.14	Avg Speed Through Overlay Zone, MPH,	OV. Direct.
06.15		N.OV. Direct.
06.16	Traffic Model	

Concrete Materials

07.00.00	Number of Concrete Type
07.01.01	Age of Testing Concrete No.1
07.01.02	Measuring Point of Concrete No.1
07.01.03	Flexural Strength of Concrete No.1
07.01.04	Weight of Concrete No.1
07.01.05	Elastic Modulus of Concrete No.1
07.01.06	Tensile Strength of Concrete No.1
07.01.07	Construction Equipment Cost of Concrete No.1
07.01.08	Cost Per Cubic Yard of Concrete No.1
07.01.09	Cost of Surfacing Concrete No.1
07.01.10	Salvage Percent of Concrete No.1
07.02.01	Age of Testing Concrete No.2
07.02.02	Measuring Point of Concrete No.2
07.02.03	Flexural Strength of Concrete No.2
07.02.04	Weight of Concrete No.2
07.02.05	Elastic Modulus of Concrete No.2
07.02.06	Tensile Strength of Concrete No.2
07.02.07	Construction Equipment Cost of Concrete No.2
07.02.08	Cost Per Cubic Yard of Concrete No.2
07.02.09	Cost of Surfacing Concrete No.2
07.02.10	Salvage Percent of Concrete No.2
07.03.01	Age of Testing Concrete No.3
07.03.02	Measuring Point of Concrete No.3
07.03.03	Flexural Strength of Concrete No.3
07.03.04	Weight of Concrete No.3
07.03.05	Elastic Modulus of Concrete No.3
07.03.06	Tensile Strength of Concrete No.3

07.03.07 Construction Equipment Cost of Concrete No.3
07.03.08 Cost Per Cubic Yard of Concrete No.3
07.03.09 Cost of Surfacing Concrete No.3
07.03.10 Salvage Percent of Concrete No3

Concrete Dimension

08.01 Minimum Allowable Concrete Thickness
08.02 Maximum Allowable Concrete Thickness
08.03 Practical Increment For Pouring Concrete

Subgrade Materials

09.01 Subgrade K
09.02 Texas Triaxial Class
09.03 Subgrade Friction Factor
09.04 Subgrade Erodability Factor
09.05 Cost Per Lane Mile of Subgrade Preparation

Subbase Materials

10.00.00 Number of Subbase Type
10.01.01 Description of Subbase Type 1
10.01.02 Erodability Factor of Subbase Type 1
10.01.03 Friction Factor of Subbase Type 1
10.01.04 Elastic Modulus of Subbase Type 1
10.01.05 Construction Equipment Cost of Subbase Type 1
10.01.06 Cost/Compacted Cu Yd of Subbase Type 1
10.01.07 Salvage Percent Value of Subbase Type 1
10.01.08 Min Allowed Thickness of Subbase Type 1
10.01.09 Max Allowed Thickness of Subbase Type 1
10.01.10 Increment For Subbase Type 1
10.02.01 Description of Subbase Type 2
10.02.02 Erodability Factor of Subbase Type 2
10.02.03 Friction Factor of Subbase Type 2
10.02.04 Elastic Modulus of Subbase Type 2
10.02.05 Construction Equipment Cost of Subbase Type 2
10.02.06 Cost/Compacted Cu Yd of Subbase Type 2
10.02.07 Salvage Percent Value of Subbase Type 2
10.02.08 Min Allowed Thickness of Subbase Type 2
10.02.09 Max Allowed Thickness of Subbase Type 2
10.02.10 Increment For Subbase Type 2
10.03.01 Description of Subbase Type 3
10.03.02 Erodability Factor of Subbase Type 3
10.03.03 Friction Factor of Subbase Type 3
10.03.04 Elastic Modulus of Subbase Type 3
10.03.05 Construction Equipment cost of Subbase Type 3
10.03.06 Cost/Compacted Cu Ud of Subbase Type 3
10.03.07 Salvage Percent Value of Subbase Type 3
10.03.08 Min Allowed Thickness of Subbase Type 3
10.03.09 Max Allowed Thickness of Subbase Type 3
10.03.10 Increment for Subbase Type 3

Longitudinal Bar Steel (LBS)

11.01.01 Identification Number of LBS No.1
11.01.02 Tensile Yield Pt Str of LBS No.1
11.01.03 Cost/Lb of Bar Steel of LBS No.1
11.02.01 Identification Number of LBS No.2
11.02.02 Tensile Yield Pt Str of LBS No.2
11.02.03 Cost/LB of Bar Steel of LBS No.2
11.03.01 Identification Number of LBS No.3
11.03.02 Tensile Yield Pt Str of LBS No.3
11.03.03 Cost/Lb of Bar Steel of LBS No.3
11.04.01 Identification Number of LBS No.4
11.04.02 Tensile Yield Pt Str of LBS No.4
11.04.03 Cost/Lb of Bar Steel of LBS No.4

Transverse Bar Steel (TBS)

11.05.01 Identification Number of TBS No.1
11.05.02 Tensile Yield PT Str of TBS No.1
11.05.03 Cost/Lb of Bar Steel of TBS No.1
11.06.01 Identification Number of TBS No.2
11.06.02 Tensile Yield Pt Str of TBS No.2
11.06.03 Cost/Lb of Bar Steel of TBS No.2
11.07.01 Identification Number of TBS No.3
11.07.02 Tensile Yield Pt Str of TBS No.3
11.07.03 Cost/Lb of Bar Steel of TBS No.3
11.08.01 Identification Number of TBS No.4
11.08.02 Tensile Yield Pt Str of TBS No.4
11.08.03 Cost/Lb of Bar Steel of TBS No.4

Wire Mesh (WM)

11.11.01 Identification Number of WM No.1
11.11.02 Tensile Yield Pt Str of WM No.1
11.11.03 Cost/Lb of Ball Steel of WM No.1
11.12.01 Identification Number of WM No.2
11.12.02 Tensile Yield Pt Str of WM No. 2
11.12.03 Cost/Lb of Ball Steel of WM No.2
11.13.01 Identification Number of WM No.3
11.13.02 Tensile Yield Pt Str of WM No.3
11.13.03 Cost/Lb of Ball Steel of WM No.3
11.14.01 Identification Number of WM No.4
11.14.02 Tensile Yield Pt Str of WM No.4
11.14.03 Cost/Lb of Ball Steel of WM No.4

Tie Bar Steel (TBS)

11.21.01 Identification Number of TBS No.1
11.21.02 Tensile Yield Pt Str of TBS No.1
11.21.03 Cost/Lb of Ball Steel of TBS No.1

11.22.01 Identification Number of TBS No.2
11.22.02 Tensile Yield Pt Str of TBS No.2
11.22.03 Cost/Lb of Ball Steel of TBS No.2
11.23.01 Identification Number of TBS No.3
11.23.02 Tensile Yield Pt Str of TBS No.3
11.23.03 Cost/Lb of Ball Steel of TBS No.3
11.24.01 Identification Number of TBS No.4
11.24.02 Tensile Yield Pt Str of TBS No.4
11.24.03 Cost/Lb of Ball Steel of TBS No.4

Steel Size

11.31.01 First Bar Number To Be Tried
11.31.02 Second Bar Number To Be Tried
11.31.03 Third Bar Number To Be Tried
11.31.04 Fourth Bar Number To Be Tried
11.32.01 First Longitudinal Wire Spacing To Be Tried
11.32.02 Second Longitudinal Wire Spacing To Be Tried
11.32.03 Third Longitudinal Wire Spacing To Be Tried
11.32.04 Fourth Longitudinal Wire Spacing To Be Tried
11.33.01 First Transverse Wire Spacing To Be Tried
11.33.02 Second Transverse Wire Spacing To Be Tried
11.33.03 Third Transverse Wire Spacing To Be Tried
11.33.04 Fourth Transverse Wire Spacing To Be Tried
11.34.01 First Tie Bar Number To Be Tried
11.34.02 Second Tie Bar Number To Be Tried
11.34.03 Third Tie Bar Number To Be Tried
11.34.04 Fourth Tie Bar Number To Be Tried

Overlay

12.01 Initial Cost Per Lane Mile of Equipment For Overlays
12.02 Cost/Cu Yd Of In Place Compacted Asphalt Concrete
12.03 Salvage Percent Value Of Asphalt Concrete
12.04 Asphalt Concrete Modulus Value
12.05 Production Rate of Compacted Asphalt Concrete
12.06 Concrete Production Rate
12.07 Concrete Coefficient
12.08 Random Additional Cost/Sq Yd For Anything

Seal Coats

13.01 Time To First Seal Coat After AC Overlay
13.02 Time Between Seal Coats
13.03 Cost Per Lane Mile Of A Seal Coat

Joints

14.01 Cost/Ft Of Trans. Joint, Sawing, Dowels, And/Or Sealing
14.02 Cost/Ft Of Long. Joint, Sealing
14.03 Range of Spacing For Transverse Joints, Lower Value
14.04 Upper Value

14.05 Increment Of Spacing To Be Tried For Transverse Joints
14.06 No. Of Trans. Const. Or Wrapping Joints/Mile For Crop

Maintenance, Dimensions And Miscellaneous

15.01 Days Of Freezing Temperature Per Year
15.02 Composite Labor Wage For Maintenance Operations
15.03 Composite Equipment Rental Rate For Maint. Operation
15.04 Cost Of Materials For Maintenance Operations
15.05 Rate of Interest Or Time Value Of Money
15.06 Width Of Each Lane
15.07 Total Number Of Lanes In Both Directions

Confidence Level Variables

16.01 Percent Confident Of Variation Of Flexural Strength
16.02 Standard Deviation Of Concrete Elastic Modulus
16.03 Standard Deviation Of Subgrade K Value
16.04 Standard Deviation Of Continuity Factor J
16.05 Standard Deviation Of Initial Serviceability
16.06 Standard Deviation Of Terminal Serviceability
16.07 Standard Deviation of Concrete Thickness

SYSTEM S

AASHO STRUCTURAL NUMBER BASED
FLEXIBLE PAVEMENT DESIGN OPTION

Problem Identification

01.01	Problem Number
01.02	Problem Title
01.03	Problem Comment

Program Control And Miscellaneous Variables

02.01	Number Of Output Pages (10 Designs/Page)
02.02	Total Number Of Lanes
02.03	Length Of Analysis Period (Years)
02.04	Width Of Each Lane (Feet)
02.05	Interest Rate (Percent)
02.06	Level-Up Thickness (In.)
02.07	Wearing Surface Production Rate (Tons/Hour)

Environmental And Serviceability Variables

03.01	Regional Factor
03.02	Initial Serviceability Index
03.03	Serviceability Index Of An Overlay
03.04	Terminal Serviceability Index
03.05	Swelling Probability
03.06	Potential Vertical Rise (In.)
03.07	Swelling Rate Constant

Load And Traffic Variables

04.01	ADT At Start Of Analysis Period
04.02	ADT At End Of Analysis Period
04.03	Accumulated Number Of Equivalent 18-Kip Axles
04.04	Percent Of ADT Thru Overlay Zone
04.05	Type of Road (1=Rural, 2=Urban)
04.06	Coefficient Of Variation
04.07	Confidence Level Indicator

Constraint Variables

05.01	Min Time To First Overlay
05.02	Min Time Between Overlays
05.03	Max Funds For Initial Construction
05.04	Max Thickness Of Initial Construction (in.)
05.05	Max Thickness Of All Overlays (In.)
05.06	Cost/Cu. Yd. To Upgrade After An Overlay
05.07	Width Of Pavement And Shoulder To Be Upgraded (Ft)

Traffic Delay Variables

06.01	AC Production Rate (Tons/Hour)
06.02	AC Compacted Density (Tons/C.Y.)
06.03	Distance Traffic Is Slowed In OV. Dir.
06.04	N. OV. Dir.
06.05	Distance Around Overlay Zone (Miles)
06.06	Hours/Day Overlay Construction Takes Place
06.07	Number Of Open Lanes In OV. Dir.
06.08	N. OV. Dir.
07.01	Percent Vehicles Stopped In OV. Dir.
07.02	Percent Vehicles Stopped In N.OV. Dir
07.03	Average Delay In OV. Dir.
07.04	Average Delay In N.OV. Dir.
07.05	Average Approach Speed
07.06	Average Speed Thru Overlay Area In OV. Dir.
07.07	Average Speed Thru Overlay Area In N.OV. Dir.
07.08	Traffic Model

Maintenance Variables

08.01	Maintenance Model (1-Explicit, 2-NCHRP)
08.02	Initial Annual Routine Cost (Dollars/Lane Mile)
08.03	Annual Increase In Costs (Dollars/Lane Mile)
08.04	Days Temperature Remains 32F. Per Year
08.05	Composite Labor Wage (Dollars/Hr)
08.06	Composite Equipment Rental Rate
08.07	Relative Material Cost

Cross Section Model, Cost and Shoulder Variables

09.01	Cross Section Model
09.02	Cost Model
09.03	Asphaltic Shoulder Model
09.04	Width of Outside Shoulder (Ft)
09.05	Width Of Inside Shoulder (Ft)
09.06	Cross Section Width Outside Of Outside Shoulder (Ft)
09.07	Cross Section Width Outside Of Inside Shoulder (Ft)

Additional Width (Feet) Of Layers Relative To Layer One

10.01.01	Outside Width Of Layer 1
10.02.01	Inside Width Of Layer 1
10.03.01	Outside Width Of Shoulder Layer 1
10.04.01	Inside Width Of Shoulder Layer 1
10.01.02	Outside Width Of Layer 2
10.02.02	Inside Width Of Layer 2
10.03.02	Outside Width Of Shoulder Layer 2
10.04.02	Inside Width Of Shoulder Layer 2

10.01.03 Outside Width Of Layer 3
10.02.03 Inside Width Of Layer 3
10.03.03 Outside Width Of Shoulder Layer 3
10.04.03 Inside Width Of Shoulder Layer 3
10.01.04 Outside Width Of Layer 4
10.02.04 Inside Width Of Layer 4
10.03.04 Outside Width Of Shoulder Layer 4
10.04.04 Inside Width Of Shoulder Layer 4

Tack, Prime, And Bituminous Variables

11.01 Tack Coat Cost (Dollar/Gal)
11.02 Prime Coat Cost (Dollar/Gal)
11.03 Bituminous Material Cost (Dollars/Gal)
11.04 Max Layer Depth For No Tack Coats (In.)
11.05 Max Depth of Each Lift (In.)

Wearing Surface

12.01 Materials
12.02 Strength Coefficient
12.03 Depth
12.04 Cost/Cu. Yd.
12.05 Salvage Percent
12.06 Tack Coat Application Rate
12.07 Prime Coat Application Rate
12.08 Asphalt Application Rate
12.09 Asphalt Content

Overlay

13.01 Material
13.02 Strength Coefficient
13.03 Min Depth
13.04 Min Cost/Cu. Yd.
13.05 Max Depth
13.06 Max Cost/Cu. Yd.
13.07 Salvage Percent
13.08 Increment
13.09 Tack Coat Application Rate
13.10 Prime Coat Application Rate
13.11 Asphalt Application Rate
13.12 Asphalt Content

Paving Material

14.01.01 Layer Number Of Material No.1
14.01.02 Code Of Material No.1
14.01.03 Name Of Material No.1
14.01.04 Strength Coefficient Of Material No.1
14.01.05 Soil Support Value Of Material No.1

14.01.06 Minimum Depth Of Material No.1
14.01.07 Minimum Cost/Cu. Yd. Of Material No.1
14.01.08 Maximum Depth Of Material No.1
14.01.09 Maximum Cost/Cu. Yd. Of Material No.1
14.01.10 Salvage Percent Of Material No.1
14.01.11 Increment Of Material No.1
14.01.12 Tack Coat Application Rate Of Material No.1
14.01.13 Prime Coat Application Rate Of Material No.1
14.01.14 Asphalt Application Rate Of Material No.1
14.01.15 Asphalt Content Of Material No.1
14.02.01 Layer Number Of Material No. 2
14.02.02 Code Of Material No. 2
14.02.03 Name Of Material No. 2
14.02.04 Strength Coefficient Of Material No. 2
14.02.05 Soil Support Value Of Material No. 2
14.02.06 Minimum Depth Of Material No. 2
14.02.07 Minimum Cost/Cu. Yd. Of Material No. 2
14.02.08 Maximum Depth Of Material No. 2
14.02.09 Maximum Cost/Cu. Yd. Of Material No. 2
14.02.10 Salvage Percent Of Material No. 2
14.02.11 Increment Of Material No. 2
14.02.12 Tack Coat Application Rate Of Material No. 2
14.02.13 Prime Coat Application Rate Of Material No. 2
14.02.14 Asphalt Application Rate Of Material No. 2
14.02.15 Asphalt Content Of Material No. 2
14.03.01 Layer Number of Material No. 3
14.03.02 Code Of Material No. 3
14.03.03 Name Of Material No. 3
14.03.04 Strength Coefficient Of Material No. 3
14.03.05 Soil Support Value Of Material No. 3
14.03.06 Minimum Depth Of Material No. 3
14.03.07 Minimum Cost/Cu. Yd. Of Material No. 3
14.03.08 Maximum Depth Of Material No. 3
14.03.09 Maximum Cost/Cu. Yd. Of Material No. 3
14.03.10 Salvage Percent Of Material No. 3
14.03.11 Increment Of Material No. 3
14.03.12 Tack Coat Application Rate Of Material No. 3
14.03.13 Prime Coat Application Rate Of Material No. 3
14.03.14 Asphalt Application Rate Of Material No. 3
14.03.15 Asphalt Content Of Material No. 3

Subgrade

15.01 Soil Support Value

Shoulder

16.01.01 Name of Shoulder Material No. 1
16.01.02 Depth Of Shoulder Material No. 1
16.01.03 Cost/Cu. Yd. Of Shoulder Material No. 1
16.01.04 Salvage Percent Of Shoulder Material No. 1

16.01.05 Tack Coat Application Rate Of Shoulder Material No. 1
16.01.06 Prime Coat Application Rate Of Shoulder Material No. 1
16.01.07 Asphalt Application Rate Of Shoulder Material No. 1
16.01.08 Asphalt Content Of Shoulder Material No. 1
16.01.09 Adjustment Volume Of Shoulder Material No. 1
16.02.01 Name Of Shoulder Material No. 2
16.02.02 Depth Of Shoulder Material No. 2
16.02.03 Cost/ Cu. Yd. Of Shoulder Material No. 2
16.02.04 Salvage Percent Of Shoulder Material No. 2
16.02.05 Tack Coat Application Rate Of Shoulder Material No. 2
16.02.06 Prime Coat Application Rate Of Shoulder Material No. 2
16.02.07 Asphalt Application Rate Of Shoulder Material No. 2
16.02.08 Asphalt Content Of Shoulder Material No. 2
16.02.09 Adjustment Volume Of Shoulder Material No. 2
16.03.01 Name Of Shoulder Material No. 3
16.03.02 Depth Of Shoulder Material No. 3
16.03.03 Cost/Cu. Yd. Of Shoulder Material No. 3
16.03.04 Salvage Percent Of Shoulder Material No. 3
16.03.05 Tack Coat Application Rate Of Shoulder Material No. 3
16.03.06 Prime Coat Application Rate Of Shoulder Material No. 3
16.03.07 Asphalt Application Rate Of Shoulder Material No. 3
16.03.08 Asphalt Content Of Shoulder Material No. 3
16.03.09 Adjustment Volume Of Shoulder Material No. 3

Fill Material

17.01 Material
17.02 Cost/Cu. Yd.
17.03 Salvage Percent
17.04 Adjustment Volume

SYSTEM F

ASPHALTIC CONCRETE PAVEMENT OVERLAY DESIGN OPTION
DYNAFLECT DEFLECTION BASED FLEXIBLE PAVEMENT DESIGN OPTION
LINEAR ELASTICITY BASED FLEXIBLE PAVEMENT DESIGN OPTION

Project Identification

01.01	Problem Number
01.02	District Number
01.03	County Name
01.04	Control Number
01.05	Section Number
01.06	Highway Name
01.07	Date
01.08	IPE Number

Problem Comments

02.01	Line 1
02.02	Line 2
02.03	Line 3
02.04	Line 4
02.05	Line 5
02.06	Line 6
02.07	Line 7

Basic Design Criteria

03.01	Length Of The Analysis Period (Years)
03.02	Minimum Time To First Overlay (Years)
03.03	Minimum Time Between Overlays (Years)
03.04	Minimum Serviceability Index P2
03.05	Design Confidence Level
03.06	Interest Rate Or Time Value Of Money (Percent)

Program Controls And Constraints

04.01	Problem Type (1=FPS-Dynaflect, 2=ACP Overlay, 3=FPS-BISTRO, 4=FPS-BISTRO With Basic Designs)
04.02	Number Of Output Pages Desired (8 Designs/Page)
04.03	Max Funds Per Sq. Yd. For Initial Design
04.04	Max Thickness Of Initial Construction (Inches)
04.05	Accumulated Max Depth Of All Overlays (In)
04.06	Accuracy Level For Analysis Of Linear Elasticity

Traffic Data

05.01	ADT At Start Of Analysis Period (Vehicles/Day)
05.02	ADT At End Of Twenty Years (Vehicles/Day)

05.03	20.-Year Accumulated No. Of Equivalent 18-KSA
05.04	Ave Approach Speed To The Overlay Zone (MPH)
05.05	Ave Speed Through Overlay Zone In Ov. Dir. (MPH)
05.06	Ave Speed Through Overlay Zone In N.OV. Dir. (MPH)
05.07	Proportion Of ADT Arriving
05.08	Percent Trucks In ADT

Environment And Subgrade

06.01	District Temperature Constant
06.02	Swelling Probability
06.03	Potential Vertical Rise (Inches)
06.04	Swelling Rate Constant
06.05	Subgrade Stiffness Coefficient
06.06	Elastic Modulus Of Subgrade
06.07	Poisson's Ratio Of Subgrade
06.08	Triaxial U Value Of Subgrade
06.09	Triaxial T Value Of Subgrade
06.10	Triaxial C Value Of Subgrade

Construction And Maintenance Data

07.01	Serviceability Index Of The Initial Structure
07.02	Serviceability Index P1 After An Overlay
07.03	Minimum Overlay Thickness (Inches)
07.04	Overlay Construction Time (Hours/Day)
07.05	Asphaltic Concrete Compacted Density (Tons/C.Y.)
07.06	Asphaltic Concrete Production - ATE (Tons/Hour)
07.07	Width Of Each Lane (Feet)
07.08	First Year Cost Of Routine Maintenance
07.09	Annual Incremental Increase In Maintenance Cost

Detour Design For Overlays

08.01	Traffic Model Used During Overlaying
08.02	Total Number Of Lanes Of The Facility
08.03	Number Of Open Lanes In Ov. Dir.
08.04	Number Of Open Lanes In N.Ov. Dir.
08.05	Distance Traffic Is Slowed In Ov. Dir. (Miles)
08.06	Distance Traffic Is Slowed In N. Ov. Dir. (Miles)
08.07	Detour Distance Around The Overlay Zone (Miles)

Existing Pavement And Proposed ACP

09.01	The Average SCI Of The Existing Pavement
09.02	The Standard Deviation Of SCI
09.03	The Composite Thickness Of The Existing Pavement (In)
09.04	The In-Place Cost/C.Y. of Proposed ACP (Dollars)
09.05	Salvage Value Of Proposed ACP (Percent)
09.06	In-Place Value Of Existing Pavement (Dollars/C.Y.)
09.07	Salvage Value Of Existing Pavement (Percent)
09.08	Level-Up Required For The First Overlay (In)

Paving Materials Information

10.01.01 Layer Number Of Material No. 1
10.01.02 Letter Code Of Material No. 1
10.01.03 Name Of Material No. 1
10.01.04 In-Place Cost Of Material No. 1
10.01.05 Stiffness Coefficient Of Material No. 1
10.01.06 Minimum Thickness Of Material No. 1
10.01.07 Maximum Thickness Of Material No. 1
10.01.08 Salvage Percent Of Material No. 1
10.01.09 Elastic Modulus Of Material No. 1
10.01.10 Poisson's Ratio Of Material No. 1
10.01.11 U Value Of Triaxial Model Of Material No. 1
10.01.12 T Value Of Triaxial Model Of Material No. 1
10.01.13 C Value Of Triaxial Model Of Material No. 1
10.02.01 Layer Number Of Material No. 2
10.02.02 Letter Code Of Material No. 2
10.02.03 Name Of Material No. 2
10.02.04 In-Place Cost Of Material No. 2
10.02.05 Stiffness Coefficient Of Material No. 2
10.02.06 Minimum Thickness Of Material No. 2
10.02.07 Maximum Thickness Of Material No. 2
10.02.08 Salvage Percent Of Material No. 2
10.02.09 Elastic Modulus Of Material No. 2
10.02.10 Poisson's Ratio Of Material No. 2
10.02.11 U Value Of Triaxial Model Of Material No. 2
10.02.12 T Value Of Triaxial Model Of Material No. 2
10.02.13 C Value Of Triaxial Model Of Material No. 2
10.03.01 Layer Number Of Material No. 3
10.03.02 Letter Code Of Material No. 3
10.03.03 Name Of Material No. 3
10.03.04 In-Place Cost Of Material No. 3
10.03.05 Stiffness Coefficient Of Material No. 3
10.03.06 Minimum Thickness Of Material No. 3
10.03.07 Maximum Thickness Of Material No. 3
10.03.08 Salvage Percent Of Material No. 3
10.03.09 Elastic Modulus Of Material No. 3
10.03.10 Poisson's Ratio Of Material No. 3
10.03.11 U Value Of Triaxial Model Of Material No. 3
10.03.12 T Value Of Triaxial Model Of Material No. 3
10.03.13 C Value Of Triaxial Model Of Material No. 3

APPENDIX D

DICTIONARY OF INPUT VARIABLES IN DRIVER'S SEGMENT

Variable Name	Input Variable
A(1)	Problem Number
A(2)	District Number
A(3) - A(6)	County Name
A(7)	Control Number
A(8)	Section Number
A(9) - A(11)	Highway Number
A(12) - A(13)	Date of Computer Run
A(14)	IPE Number For The Project
AA(I, J)	Problem Title And Comments
AW(I, 1)	Outside Width Of Pavement Layer I
AW(I, 2)	Inside Width Of Pavement Layer I
AW(I, 3)	Outside Width Of Shoulder Layer I
AW(I, 4)	Inside Width Of Shoulder Layer I
B(1)	Length Of The Analysis Period
B(2)	Interest Rate Or Time Value Of Money
B(3)	Total Number Of Lanes
B(4)	Width Of Each Lane
B(5)	Design Confidence Level
B(6)	Number Of Better Feasible Designs Desired
B(11)	Long Form Or Short Form Of Output Desired
B(12)	Coefficient Of Variation
C(2)	Max Funds For Initial Construction, or Max Funds For the First Overlay
C(3)	Max Total Thickness Of Initial Construction
C(4)	Min Time To The First Overlay
C(5)	Min Time Between Overlays
C(6)	Max Accumulated Thickness Of All AC Overlays
C(7)	Min Thickness Of A Single AC Overlay
C(8)	Max Accumulated Thickness Of All PCC Overlays
C(9)	Min Thickness Of A Single PCC Overlay
D(1)	Regional Factor
D(2)	Days Of Freezing Temperature Per Year
D(3)	District Temperature Constant
D(4)	Swelling Probability
D(5)	Potential Vertical Rise
D(6)	Swelling Rate Constant

Variable Name	Input Variable
E(1)	Cumulative 18 KSA During Analysis Period
E(2)	ADT At Beginning Of Analysis Period
E(3)	Axle Growth Factor
E(4)	Average Daily Traffic Growth Rate
E(5)	Directional Distribution Factor
E(6)	Lane Distribution Factor
E(7)	ADT At End Of Analysis Period
	Distance Over Which Traffic Is Slowed
F(1)	(1) In Overlay Direction
F(2)	(2) In NonOverlay Direction
F(3)	Detour Distance Of The Alternative Route
F(4)	Percent Of ADT Arriving During Each Hour
F(5)	Overlay Construction Time
	Number of Open Lanes In Restricted Zone
F(6)	(1) In Overlay Direction
F(7)	(2) In NonOverlay Direction
F(8)	Percent Trucks In ADT
	Percent Of Vehicles Stopped
F(9)	(1) In Overlay Direction
F(10)	(2) In NonOverlay Direction
	Average Delay Per Vehicle Stopped
F(11)	(1) In Overlay Direction
F(12)	(2) In NonOverlay Direction
F(13)	Average Approach Speed Of Vehicles
	Average Speed Through Restricted Zone
F(14)	(1) In Overlay Direction
F(15)	(2) In NonOverlay Direction
G(1)	Initial Serviceability Index
G(2)	Minimum Serviceability Index
G(3)	Serviceability Index After An Overlay
G(4)	Initial Serviceability Index, Standard Deviation
G(5)	Minimum Serviceability Index, Standard Deviation
H(1)	Minimum Allowable Concrete Thickness
H(2)	Maximum Allowable Concrete Thickness
H(3)	Standard Deviation Of Thickness Of Concrete
H(4)	Practical Increment, Concrete Can be Poured
H(5)	Concrete Flexural Strength, Percent Confidence
H(6)	Elastic Modulus Of Concrete, Standard Deviation
HH(I, 1)	Number Of Days, Concrete No. I Strength Was Measured
HH(I, 2)	Flexural Strength Of Concrete No. I

Variable Name	Input Variable
HH(I, 3)	Weight Of Concrete No. I
HH(I, 4)	Modulus Of Elasticity Of Concrete No. I
HH(I, 5)	Tensile Strength Of Concrete No. I
HH(I, 6)	Initial Cost Of Construction Equipment of Concrete No. I
HH(I, 7)	Unit Cost Of Concrete No. I
HH(I, 8)	Cost Of Surfacing Concrete No. I
HH(I, 9)	Salvage Percent Of Concrete No. I
KI	Pavement Design Option
K(2)	Type(s) Of Rigid Pavement
K(3)	Type(s) Of Rigid Pavement Overlay
K(4)	Type(s) Of Rigid Pavement Reinforcement
K(5)	Accuracy Level For Analysis Of Linear Elasticity
K(6)	Detour Model Used During Overlaying
K(7)	Project Location, Rural Or Urban
K(8)	Types Of Maintenance Model
K(9)	Confidence Level Indicator
K(10)	Cross Section Model Used
K(11)	Cost Model Used
K(12)	Asphaltic Shoulder Model Used
K(13)	Version Of Program, SAMP6 Or SAMP6A
KH(I)	Position Of Loads For Flexural Strength Test of Concrete No. I
KMNT	Number of Comment Cards
LR(I)	Layer Designation Number Of Flexible Pavement Material No. I
NH	Number Of Concrete Type
NQ	Number Of Subbase Type Of Rigid Pavement
NR	Number Of Paving Material For Flexible Pavement
NSH	Number Of Shoulder Material
P(1)	Cost Of Transverse Joint
P(2)	Cost Of Longitudinal Joint
P(3)	Lower Value Of Transverse Joint Spacing
P(4)	Upper Value Of Transverse Joint Spacing
P(5)	Increment Of Spacing For Transverse Joint
P(6)	Number Of Transverse Joints
P(7)	Standard Deviation Of Continuity Factor J
Q(I, 1) - A(I, 3)	Description Of Subbase No. I
Q(I, 4)	Erodability Factor For The Subbase No. I
Q(I, 5)	Friction Factor For Subbase No. I

Variable Name	Input Variable
Q(I, 6)	Modulus Value Of Subbase No. I
Q(I, 7)	Initial Cost Of Construction Equipment Of Subbase No. I
Q(I, 8)	Cost Of Compacted Subbase No. I
Q(I, 9)	Salvage Percent of Subbase No. I
Q(I, 10)	Minimum Allowable Thickness of Subbase No. I
Q(I, 11)	Maximum Allowable Thickness of Subbase No. I
Q(I, 12)	Thickness Increment Of Subbase No. I
R(I, 1)	Letter Code Of Material No. I
R(I, 2) - R(I, 7)	Name Of Material No. I
R(I, 8)	In-Place Cost Of Material No. I
R(I, 9)	Stiffness Coefficient Of Material No. I
R(I, 10)	Strength Coefficient Of Material No. I
R(I, 11)	Soil Support Value Of Material No. I
R(I, 12)	Minimum Allowable Thickness Of Material No. I
R(I, 13)	Maximum Allowable Thickness Of Material No. I
R(I, 14)	Salvage Value Of Material No. I
R(I, 15)	Elastic Modulus Of Material No. I
R(I, 16)	Poisson's Ratio Of Material No. I
R(I, 17)	U Value Of Texas Triaxial Test Model Of Material No. I
R(I, 18)	T Value Of Texas Triaxial Test Model Of Material No. I
R(I, 19)	C Value Of Texas Triaxial Test Model Of Material No. I
R(I, 20)	Minimum In-Place Cost Of Material No. I
R(I, 21)	Maximum In-Place Cost Of Material No. I
R(I, 22)	Layer Increment Of Material No. I
R(I, 23)	Tack Coat Application Rate Of Material No. I
R(I, 24)	Prime Coat Application Rate Of Material No. I
R(I, 25)	AC Application Rate Of Material No. I
R(I, 26)	Asphaltic Content Per Cent Of Material No. I
S(1)	SCI Of The Existing Pavement
S(2)	Standard Deviation Of SCI
S(3)	Composite Thickness Of The Existing Pavement
S(4)	In-Place Cost Of Proposed ACP
S(5)	Proposed ACP'S Salvege Value
S(6)	In-Place Value Of Existing Pavement
S(7)	Existing Pavement's Salvage Value
S(8)	Level-Up Required For The First Overlay
SD(1)	Width Of Outside Shoulder
SD(2)	Width Of Inside Shoulder
SD(3)	Cross Section Width Outside Of Outside Shoulder
SD(4)	Cross Section Width Outside Of Inside Shoulder
SD(5)	Fill Material Requirement

Variable Name	Input Variable
SD(6) - SD(9)	Name Of Fill Material
SD(10)	In-Place Cost Of Fill Material
SD(11)	Salvage Percent Of Fill Material
SD(12)	Adjustment Volume Of Fill Material
SSD(I, 1) - SSD(I, 4)	Name Of Shoulder Material No. I
SSD(I, 5)	Depth Of Shoulder No. I
SSD(I, 6)	In-Place Cost Of Shoulder Material No. I
SSD(I, 7)	Salvage Percent Of Shoulder Material No. I
SSD(I, 8)	Tack Coat Application Rate Of Shoulder Material No. I
SSD(I, 9)	Prime Coat Application Rate Of Shoulder Material No. I
SSD(I, 10)	AC Application Rate Of Shoulder Material No. I
SSD(I, 11)	Asphaltic Content Per Cent Of Shoulder Material No. I
SSD(I, 12)	Adjustment Volume Of Shoulder Material No. I
T(1)	Subgrade K, Mean Value
T(2)	Subgrade K, Standard Deviation
T(3)	Texas Triaxial Class Of Subgrade
T(4)	Friction Factor For Subgrade
T(5)	Erodability Factor For Subgrade
T(6)	Cost Of Subgrade Preparation
T(7)	Stiffness Coefficient Of Subgrade
T(8)	Elastic Modulus Of Subgrade
T(9)	Poisson's Ratio Of Subgrade
T(10)	U Value Of Texas Triaxial Test Model Of Subgrade
T(11)	T Value Of Texas Triaxial Test Model Of Subgrade
T(12)	C Value Of Texas Triaxial Test Model Of Subgrade
T(13)	Soil Support Value Of Subgrade
TP(1)	Tack Coat Cost
TP(2)	Prime Coat Cost
TP(3)	Bituminous Material Cost
TP(4)	Max Layer For No Tack Coats
TP(5)	Max Depth Of Each Lift
U(1)	Asphalt Concrete Production Rate
U(2)	Asphalt Concrete Compacted Density
U(3)	Equipment Cost For AC Overlay
U(4)	Cost Of Asphalt Concrete
U(5)	Salvage Percent Of AC At End Of Analysis Period
U(6)	Asphalt Concrete Modulus Value

Variable Name	Input Variable
U(7)	Concrete Production Rate
U(8)	Concrete Coefficient For CE'S Formula
U(9)	Any Additional Cost For Overlay
U(10)	Level-Up Thickness For Overlay
U(11) - U(14)	Overlay Description
U(15)	Overlay Strength Coefficient
U(16)	Minimum Overlay Thickness
U(17)	Minimum In-Place Overlay Cost
U(18)	Maximum Overlay Thickness
U(19)	Maximum In-Place Overlay Cost
U(20)	Salvage Percent Of Overlay
U(21)	Overlay Increment
U(22)	Tack Coat Application Rate Of Overlay
U(23)	Prime Coat Application Rate Of Overlay
U(24)	AC Application Rate Of Overlay
U(25)	Asphaltic Content Per Cent Of Overlay
U(26)	Cost To Upgrade After An Overlay
U(27)	Width Of Pavement And Shoulders To be Upgraded
V(1)	Time To First Seal Coat After An AC Overlay
V(2)	Time Between Seal Coats
V(3)	Cost Per Lane-Mile Of A Seal Coat
W(1)	Composite Labor Wage For Maintenance
W(2)	Composite Equipment Rental Rate For Maintenance
W(3)	Cost Of Materials For Maintenance
W(4)	First Year Cost Of Routine Maintenance
W(5)	Annual Incremental Increase In Maintenance Cost
WS(1)	Wearing Surface Production Rate
WS(2) - WS(5)	Wearing Surface Description
WS(6)	Wearing Surface Strength Coefficient
WS(7)	Wearing Surface Thickness
WS(8)	Wearing Surface In-Place Cost
WS(9)	Wearing Surface Salvage Percent
WS(10)	Tack Coat Application Rate Of Wearing Surface
WS(11)	Prime Coat Application Rate Of Wearing Surface
WS(12)	AC Application Rate Of Wearing Surface
WS(13)	Asphaltic Content Per Cent Of Wearing Surface
ZZ(1, J, 1) - ZZ(1, J, 3)	I.D. Number Of Longitudinal Bar Steel No. J
ZZ(1, J, 4)	Tensile Yield Point Strength Of Longitudinal Bar Steel No. J

Variable Name	Input Variable
ZZ(1, J, 5)	Cost of Longitudinal Bar Steel No. J
ZZ(2, J, 1) - ZZ(2, J, 3)	I.D. Number of Transverse Bar Steel No. J
ZZ(2, J, 4)	Tensile Yield Point Strength of Transverse Bar Steel No. J
ZZ(2, J, 5)	Cost of Transverse Bar Steel No. J
ZZ(3, J, 1) - ZZ(3, J, 3)	I.D. Number of Wire Mesh No. J
ZZ(3, J, 4)	Tensile Yield Point Strength of Wire Mesh No. J
ZZ(3, J, 5)	Cost of Wire Mesh No. J
ZZ(4, J, 1) - ZZ(4, J, 3)	I.D. Number of Tie Bar Steel No. J
ZZ(4, J, 4)	Tensile Yield Point Strength of Tie Bar Steel No. J
ZZ(4, J, 5)	Cost of Tie Bar Steel No. J
Z(I, 1)	Bar Numbers to be Tried of Trial Number I
Z(I, 2)	Longitudinal Mesh Spacings to be Tried of Trial Number I
Z(I, 3)	Transverse Mesh Spacings to be Tried of Trial Number I
Z(I, 4)	Tie Bar Numbers to be tried of Trial Number I

APPENDIX E

DISK REQUIREMENT OF THE PROCESSOR

The disk requirement of the processor is listed on the following page. The current version of the processor requires 120 off-line and 73 on-line disk tracks. The Data Processing Center at Texas A&M University charges 4¢ per month for each off-line disk track and 16¢ per month for each on-line disk track, that is, a minimum cost of $16.48/month is needed to set up the processor for utilization. (Prices quoted as of May 1974.)

DISK REQUIREMENT OF THE PROCESSOR

Data Set Name	On-Line/ Off-Line	Length (tracks)	Data Set Organ	Record Format	Record Size	Purpose
USER.Y033.IEN.LU.JOBLIB	Off-Line	120	Part.	Undef.	N/A	Program load modules: RPS-2, SAMP6 SAMP6A FPS-11, and FPS-BISTRO
TP.USERLIB(USER0004)	On-Line	20	Part.	Undef.	N/A	Program load module: Driver's Segment
TP.Y033.IEN.LU.BISTRO	On-Line	20	D.A.	Fixed	700	3 example and 17 user's BISTRO data sets
TP.Y033.IEN.LU.CRDIMG	On-Line	3	Seq.	Fixed	80	80-column-card-image for program input
TP.Y033.IEN.LU.MASTER	On-Line	20	D.A.	Fixed	1000	5 example, 1 free and 14 user's input data set
TP.Y033.IEN.LU.PROG	On-Line	5	Part.	Fixed	80	JCL for remote batch job entry.
TP.Y033.IEN.LU.SEQ1	On-Line	5	Seq.	Fixed	80	JCL for remote batch job entry.

APPENDIX F

JCL FOR DRIVER'S SEGMENT

The following JCL was used to compile, link-edit, and execute the driver's segment of the integrated pavement design processor onto disk. The driver's segment can then be executed from a terminal.

```
//jobname    Job etc.
/*CLASS      H
//  EXEC  FORTGTP,REGION=200K,PARM.LKED='OVLY'
//FORT.SYSIN  DD  *
```

Driver's Segment Source Deck

```
//LKED.SYSLMOD  DD  DSN=TP.USERLIB(USER0004),DISP=SHR
//LKED.SYSIN  DD  *
  ENTRY     MAIN
  INSERT    MAIN,TPIO
  OVERLAY   ONE
  INSERT    STA0
  OVERLAY   ONE
  INSERT    STA1
  OVERLAY   ONE
  INSERT    STA2
  OVERLAY   ONE
  INSERT    STA3,TTTM,FBSR,ASSN
  OVERLAY   ONE
  INSERT    NEX1,NEX3
  OVERLAY   ONE
  INSERT    NEX2,CDMG
  OVERLAY   ONE
  INSERT    MON1
  OVERLAY   ONE
  INSERT    MON2
  OVERLAY   ONE
  INSERT    MON3
  OVERLAY   ONE
  INSERT    SUN1,SUN2,SUN3
/*
```