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16. Abstract

This report describes the development, use, and applicability of a rigid pavement rehabilitation design system, RPRDS, developed for use by the Texas State Department of Highways and Public Transportation. Like other pavement design systems, RPRDS makes use of the systems approach to incorporate a number of pavement design and analytical models into a computer program, RPRDS-1, for the generation, analysis, and comparison of numerous pavement design strategies. Unlike other pavement design systems, RPRDS considers only structural rehabilitation, i.e., overlay construction, where the design model used is an improved and extended version of the ARE, Inc./FHWA and Texas State Department of Highways and Public Transportation rigid pavement overlay design procedures, RPOD1 and RPOD2. In addition, provision is made in RPRDS for the consideration of other factors which affect pavement performance and accompany overlay construction. These include ACP, CRCP, and JCP type overlays; concrete shoulder construction; and variable concrete flexural strength; as well as variable overlay thickness.

Basically, RPRDS generates a number of feasible overlay design strategies based on user inputs, performs a present value cost analysis on each, and then presents those which are optimal. The other design and analytical models used to complete this task include (1) a distress/maintenance prediction model, (2) a traffic delay cost (during overlay construction) model, and (3) a model for the prediction of overlay construction cost.

It is hoped that this paper will provide not only a description of RPRDS but also some basis for its use nationwide.

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by

Stephen B. Seeds, B.F. McCullough, and W.R. Hudson

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Implementation of Rigid Pavement Overlay and Design System

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conducted for

Texas
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CENTER FOR TRANSPORTATION RESEARCH

BUREAU OF ENGINEERING RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN

January 1982

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.

PREFACE

This report was completed at The University of Texas Center for Transportation Research, under Project 3-8-79-249, as part of the Cooperative Research Program between The University of Texas and the Texas State Department of Highways and Public Transportation. One of the main objectives of the project is the implementation of the Texas Rigid Pavement Overlay Design (RPOD) procedure. This report represents one phase of this implementation, the incorporation of RPOD into a rigid pavement rehabilitation design system (RPRDS).

The bulk of this report was prepared with the aid of The University of Texas Decsystem-10 computer, to ease the task of review and modification for possible publication. Thanks are extended to all those who helped in the preparation of this report: Eve Falcon, Elaine Hamilton and Sue Tarpley for typing; Julie Muckelroy, Jimmy Holmes, and Ana Aranofsky for drafting; and Barbara Allen for coordination. Gratitude is also expressed to the many students who provided technical advice and assistance during the study, particularly, Arthur Taute, David Potter, David Luhr, and Bary Eagleson. Thanks are also extended to Gerald Peck and Richard Rogers at the Texas SDHPT for their advice and cooperation.

LIST OF PREVIOUS REPORTS

Report No. 249-1, "Improvements to the Material Characterization and Fatigue Life Prediction Methods of the Texas Rigid Pavement Overlay Design Procedure," by Arthur Taute, B. Frank McCullough, and W. Ronald Hudson, presents certain improvements to the Texas Rigid Pavement Overlay Design Procedure (PROD2) with regard to materials characterization and fatigue life predictions.

ABSTRACT

This report describes the development, use, and applicability of a rigid pavement rehabilitation design system, RPRDS, developed for use by the Texas State Department of Highways and Public Transportation. Like other pavement design systems, RPRDS makes use of the systems approach to incorporate a number of pavement design and analytical models into a computer program, RPRDS-1, for the generation, analysis, and comparison of numerous pavement design strategies. Unlike other pavement design systems, RPRDS considers only structural rehabilitation, i.e., overlay construction, where the design model used is an improved and extended version of the ARE, Inc./FHWA and Texas State Department of Highways and Public Transportation rigid pavement overlay design procedures, RPOD1 and RPOD2. In addition, provision is made in RPRDS for the consideration of other factors which affect pavement performance and accompany overlay construction. These include ACP, CRCP, and JCP type overlays; concrete shoulder construction; and variable concrete flexural strength; as well as variable overlay thickness.

Basically, RPRDS generates a number of feasible overlay design strategies based on user inputs, performs a present value cost analysis on each, and then presents those which are optimal. The other design and analytical models used to complete this task include (1) a distress/maintenance prediction model, (2) a traffic delay cost (during

overlay construction) model, and (3) a model for the prediction of overlay construction cost.

It is hoped this paper will provide not only a description of RPRDS but also some basis for its use nationwide.

KEYWORDS: Overlay, rehabilitation, design system, fatigue, damage, remaining life, distress prediction, cost analysis.

SUMMARY

Many of the pavements which make up our Interstate Highway System are approaching the end of their serviceable lifetimes. Consequently, the need arose for a rational rehabilitation design method. One method, RPOD, a mechanistic rigid pavement overlay design procedure developed under the sponsorship of the FHWA, seemed to be very practical to the Texas State Department of Highways and Public Transportation, and was therefore modified, adapted and partially implemented into department practice.

This report discusses the next logical step in the evolutionary process of development and implementation of this new procedure: its incorporation into a system program for the analysis of alternative rehabilitation strategies. This first generation program, RPRDS-1, allows the highway design engineer to consider several factors associated with overlay design and construction in the selection of an optimum rehabilitation strategy. The most significant of these factors include overlay type, time of placement, maintenance costs, traffic delay costs, construction costs, and time value of money. Finally, RPRDS-1 is designed to be modular in nature so as to ease the systematic process of feedback modification and improvement.

IMPLEMENTATION STATEMENT

A rigid pavement rehabilitation design system (RPRDS) has been developed for the Texas State Department of Highways and Public Transportation as the next major phase in the implementation of the Department's rigid pavement overlay design (RPOD) procedure. Since most of the models incorporated into RPRDS may be expected. The RPRDS-1 computer program was developed using ANSII Fortran standards and should, therefore, run atuomatically on the State Department of Highways and Public Transportation's IBM computer.

The system should be introduced, gradually, by trial application on several design projects in the various districts. Then, as confidence in the procedure grows, it can be implemented on a statewide basis. Finally, the program should be continually improved and modified based upon feedback from the districts and any advancements in the state-of-the-art.

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CHAPTER 1. INTRODUCTION

BACKGROUND

There are many factors which affect the design and performance of a roadway. Some of these are traffic, load, material properties, temperature, moisture, availability of raw materials, construction methods and controls, costs, and the variations of many of these, both in time and space. Due to the large number of these factors and the fact that many of them interact with each other, any rational pavement design method which attempts to consider them will necessarily be complex. However, this was not the case for the early pavement design methods.

Because of a lack of precise analytical techniques for predicting pavement response and performance, these early methods were very simple and thus unable to adequately consider many of the important factors. They depended mainly on experience and empiricism; i.e., the view that what has worked in the past will work in the future. The fact that they were simple does not imply, however, that they were always erroneous. In fact, the methods did provide designs which were adequate for many cases. Unfortunately, their simplicity set a precedent which has become very hard to change, even with the development of modern computers to handle the new, complex analytical techniques. It may also be stated that, although these early design methods did provide adequate designs, they did not necessarily provide ones which were optimal as far as performance and economics are concerned.

Compared to other areas of engineering, the analysis and design of highway (and airport) pavements is in its infancy. Recognition of the nation's large investment in its highway system is probably the factor most responsible for the research and development made thus far in this area. This research and development began with the design and analysis of new pavements and has only recently been extended to overlays and other forms of rehabilitation.

The AASHO Road Test (Ref 4), conducted in the early 1960's, provided the most complete experimental data upon which to base a rational pavement design method. The AASHTO Interim Guide for Design of Pavement Structures - 1972 (Ref 5) is a result of combining the data obtained from the experiment with pavement response models available at the time. Though these response models, i.e., the Spangler and Westergaard Equations, were relatively simple, they did consider some of the key factors which affect pavement performance. This along with the fact that they were correlated with a large amount of field data insured reasonableness and wide use of the design method.

Another significant development at the AASHO Road Test was the attempt to define pavement failure. The term "failure" is very ambiguous when used in connection with pavement design because pavements seldom "fail", at least not in the traditional catastrophic sense. The approach adopted at the Road Test was the serviceability concept, which provided not only for the point where a pavement becomes unserviceable and/or ceases to provide adequate service to the user but also for the concept of pavement performance. Performance, which is the serviceability history of a pavement, allows the designer to compare alternative designs based on an overall level of service provided during their lifetimes. This comparison may, in some cases, be more important than the total cost comparison.

In spite of these efforts at the AASHO Road Test, "failure" continues to be used loosely to identify everything from a localized pavement defect to a point during the pavement's life when maintenance costs become excessive. The reasons for these different definitions are sometimes excusable, however, since the development of different types of design and analytical models require different definitions for failure criteria.

With the development of these better design methods, it was recognized that it was possible to develop a procedure for analyzing a large number of feasible pavement design alternatives on an economic basis. This method, known as the systems approach to pavement design (Ref 10), attempts to systematically consider most of the factors which have an effect on pavement performance and cost. In Texas, this approach has manifested itself in two design systems, the Flexible Pavement System, FPS (Refs 12 and 8), and the Rigid Pavement System, RPS (Refs 11 and 7). Both have been significantly modified to improve their capabilities for predicting total cost and reliability of the designs. Since a large portion of the new pavements constructed in Texas are asphaltic concrete, FPS has been widely used and is, consequently, highly developed. Most PCC pavements, on the other hand, were constructed well before the development of RPS and, therefore, RPS has not been fully implemented in Texas.

Most PCC pavements were built in the 1950's and early 1960's, many of which are suffering or have begun to suffer significant distress and loss of structural integrity. Fortunately, the Federal Highway Administration (FHWA) recognized that these pavements (particularly those on the Interstate network) were approaching the end of their service life and would soon require major rehabilitation. Consequently, they sponsored a project in 1975 to develop a design method for pavement rehabilitation. The result was the Rigid Pavement Overlay Design procedure (RPOD) completed in 1977 (Ref 1). RPOD represents the first practical mechanistic design procedure since it uses advanced analytical techniques (layer theory and plate theory) to predict pavement response and extend the use of the AASHO Road Test data to the design of overlays.

Since there was very little data on the performance of overlays, it was necessary to develop new failure criteria for use in RPOD. According to the new criteria, when a pavement reaches a certain level of distress (i.e., initial class 3 and 4 cracking for PCC pavements), it loses its load-carrying capacity and begins to deteriorate rapidly. Although this point does not necessarily lie in a region of unacceptable serviceability, it does correspond to a level below which there would be excessive development of severe distress manifestations. This, in turn, implies high maintenance costs and, eventually, poor riding quality.

The Texas State Department of Highways and Public Transportation (SDHPT) considered the FHWA procedure viable and launched their own project to adapt the procedure for use in Texas (Ref 9), begin its implementation into department practice, and to develop a systems program for rigid pavement rehabilitation which uses the new procedure as its design model.

OBJECTIVES OF THE STUDY

The goal of this study, then, is to develop a rigid pavement rehabilitation design system in the form of a computer program (RPRDS-1) which can provide the user with specific criteria for the selection of an optimal rigid pavement rehabilitation strategy for a given project. The specific objectives for achieving this goal are as follows:

(1) The system should use the most recent version of the Texas SDHPT rigid pavement overlay design procedure as its primary method of rehabilitation.

(2) The system should be able to consider many of the factors which influence a design strategy. Moreover, the system should be able to consider several levels of the factors over which the designer has control, i.e. overlay type and thickness, shoulder construction, etc.

(3) The system should use the available proven models for distress/maintenance prediction and overall cost prediction to insure consistency with other existing design systems.

(4) The computer program which performs the analysis should be modular in nature and amenable to future modification. It should also be written to insure compatability with most computers. This includes minimizing computer time and storage requirements.

SCOPE

This report includes: (a) the systems methodology and its application in rigid pavement rehabilitation (Chapter 2), (b) descriptions of each of the specific models incorporated into the RPRDS-1 computer program (Chapters 2, 3, 4 and 5), (c) a user's manual to describe the input and output of the program (Chapter 6), (d) a summary of the results of the study (Chapter 7), (e) conclusions drawn from the study results (Chapter 7), and finally (f) recommendations for improvements and further work on the design system.

CHAPTER 2. RIGID PAVEMENT REHABILITATION DESIGN SYSTEM - RPRDS

Chapter 1 discusses the history of the development of pavement design methods from the early empirical methods up to the methods which took advantage of the systems approach to pavement design and finally the FHWA and Texas SDHPT overlay design procedures (Refs 1 and 9). Logically, the next step in the chain of development is the incorporation of the new overlay design procedures into a comprehensive pavement rehabilitation design system. This is the main goal of this study.

SYSTEMS METHODOLOGY

Haas and Hudson (Ref 32) provide a detailed description of the systems methodology. They state generally that

> the structure or framework of any problem-solving process should provide for systematic incorporation of all the technical, economic, social, and political factors of interests. Moreover, it should be a logical simulation of the progression of activities involved in efficiently solving a problem.

In effect,

> systems methodology comprises a body of knowledge that has been developed for efficient planning, design, and implementation of new systems, and for structuring the state of knowledge on an existing system or modeling its operation.

The systems methodology is not as complicated as it may sound. It is basically a method for handling or managing a network of interrelated problems and/or tasks on a global basis to achieve the maximum utility or benefit. This may mean, in some cases, accepting a suboptimal solution to one problem for the benefit of the entire system. Therein lies the contrast with the piecemeal approach to problem-solving that is prevalent in many of today's decision making and management processes.

Figure 2.1 provides an illustration of how the components of the systems methodology fit together. Haas and Hudson state:

> In this general form, it (Fig 2.1) is applicable to a wide variety of engineering and other problems. The diagram illustrates that the recognition of a problem comes from some perceived inadequacy or need in the environment. It leads to a definition of the problem that involves a more in-depth understanding. This provides the basis for proposing alternative solutions. These alternatives are then analyzed in order to predict their probable outputs or consequences. Evaluation of the outputs is the next step in order that an optimal solution may be chosen. Implementation involves putting this solution into service, and its operation. Feedback for improving the future solutions, or checking on how well the system is fulfilling its function, is provided by periodic performance measurements.

Also, since new problems are always developing and the feedback from the solutions to old problems is continuous, the process shown in Fig 2.1 is continuous, and it is hoped, this will lead to constant improvement of the system.

Another factor associated with the systems approach is its ability to analyze a problem at different levels, depending on how the system is formulated. For the case of highway pavement analysis, systems programs have been developed for two basic levels of application, project and network. Project level systems programs generally provide criteria for the selection of an optimum pavement design strategy for a specific section of road. On the other hand, systems programs at the network level are basically

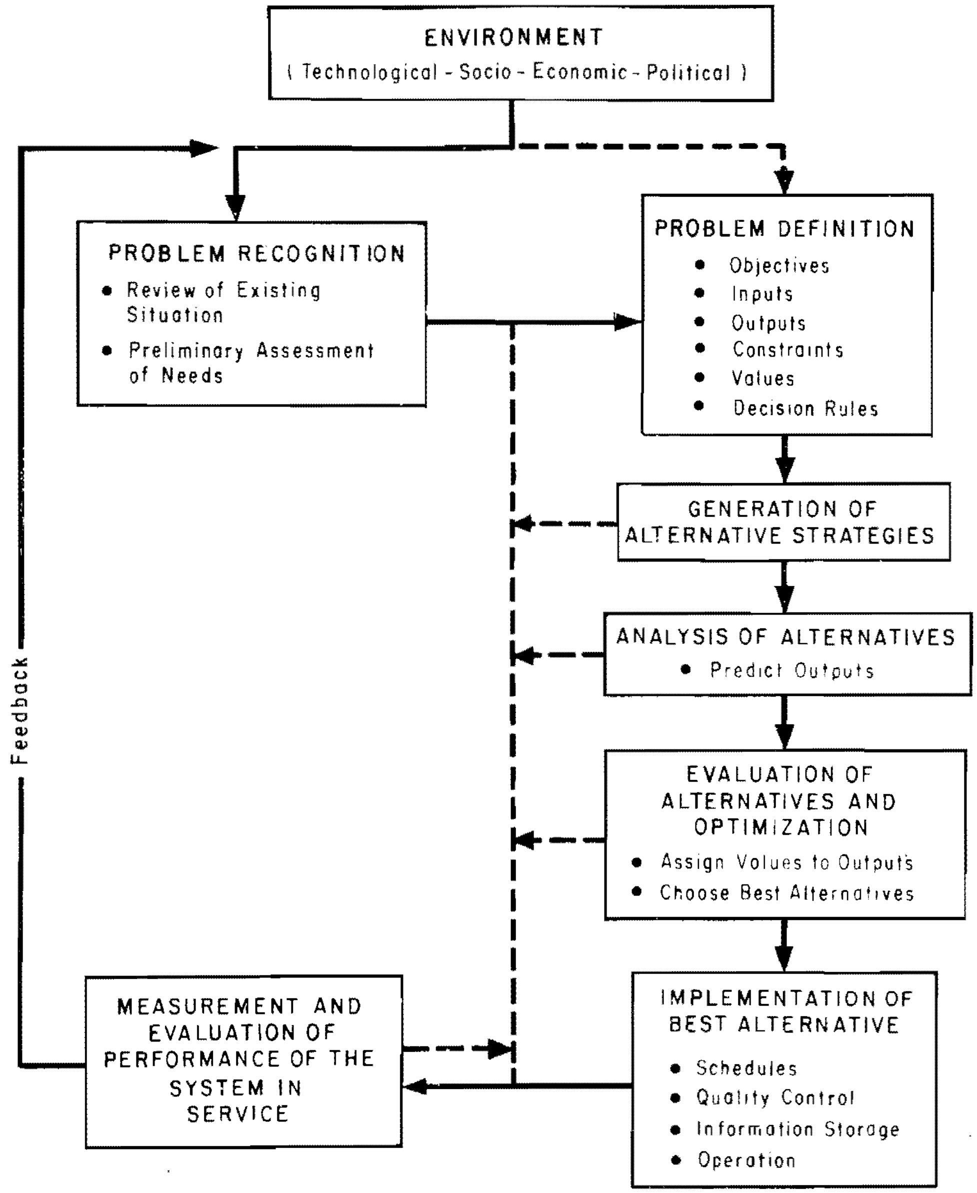


Fig 2.1. Major phases and components of the systems method (Ref 32).

management oriented. (Examples of management type functions include the establishment of priorities for various design or construction projects, the best use for funds in a limited budget, and the selection of optimum maintenance policies for the entire network.) Obviously, the advantage of a network level system is its ability to minimize total overall costs while maximizing utility. The disadvantage of network level systems, however, is that their design models are necessarily simple and therefore do not adequately consider all the factors associated with design at the project level. This separation between the two system levels also exists for pavement rehabilitation and makes it necessary to define what system level RPRDS was designed for.

RPRDS-1

Ideally, a systems model for pavement rehabilitation should encompass the entire management and decision making process for design, construction, and maintenance for both the project and network levels. Unfortunately, such a system is not presently possible, politically or technologically. Consequently, the first version of the Rigid Pavement Rehabilitation Design System, RPRDS-1, begins at the project level. At this level, the problem or task is to select a pavement rehabilitation strategy for a given length of roadway which will provide the maximum service to the user over a given period of time and at a minimum overall cost.

Basically, RPRDS-1 attempts to solve this problem by analyzing a large number of rehabilitation strategies on a total cost basis where the primary method of rehabilitation considered is overlay construction. Though there are some other promising methods, such as pressure grouting, precast slab repair, polymer concrete patching, prestressed concrete overlays, and flexible overlays with either a sulfur or sulfur-asphalt binder, they cannot be considered in RPRDS-1 at this time due to a lack of experience and performance data on these methods. The methods that are considered in RPRDS-1, however, include a multitude of factors dealing with overlay construction such as (1) concrete shoulder construction, (2) type of overlay (ACP, CRCP and JCP), (3) number of overlays (one or two during the analysis period), (4) aggregate type, (5) overlay thickness, and (6) flexural strength. These are all discussed in later chapters.

It is appropriate now to present a general flowchart of RPRDS-1 (Fig 2.2) and discuss the logical structure and components of the program.

First of all, the inputs to the system are read and printed by the INPUT routine. These inputs are summarized as follows:

(1) Any data which affect the performance of an overlay strategy (i.e., material properties, layer thicknesses, construction methods, maintenance, etc.).

(2) Cost data (i.e., materials, construction, maintenance, user, discount rate, etc.).

(3) Constraints (i.e., analysis period, mimimum time between overlays, maximum overlay thickness, etc.).

Detailed discussion of these is presented in the RPRDS-1 User's Manual in Chapter 6.

Next, the interior pavement responses required for the appropriate overlay design strategies are generated by the CONRSP routine. Discussion of

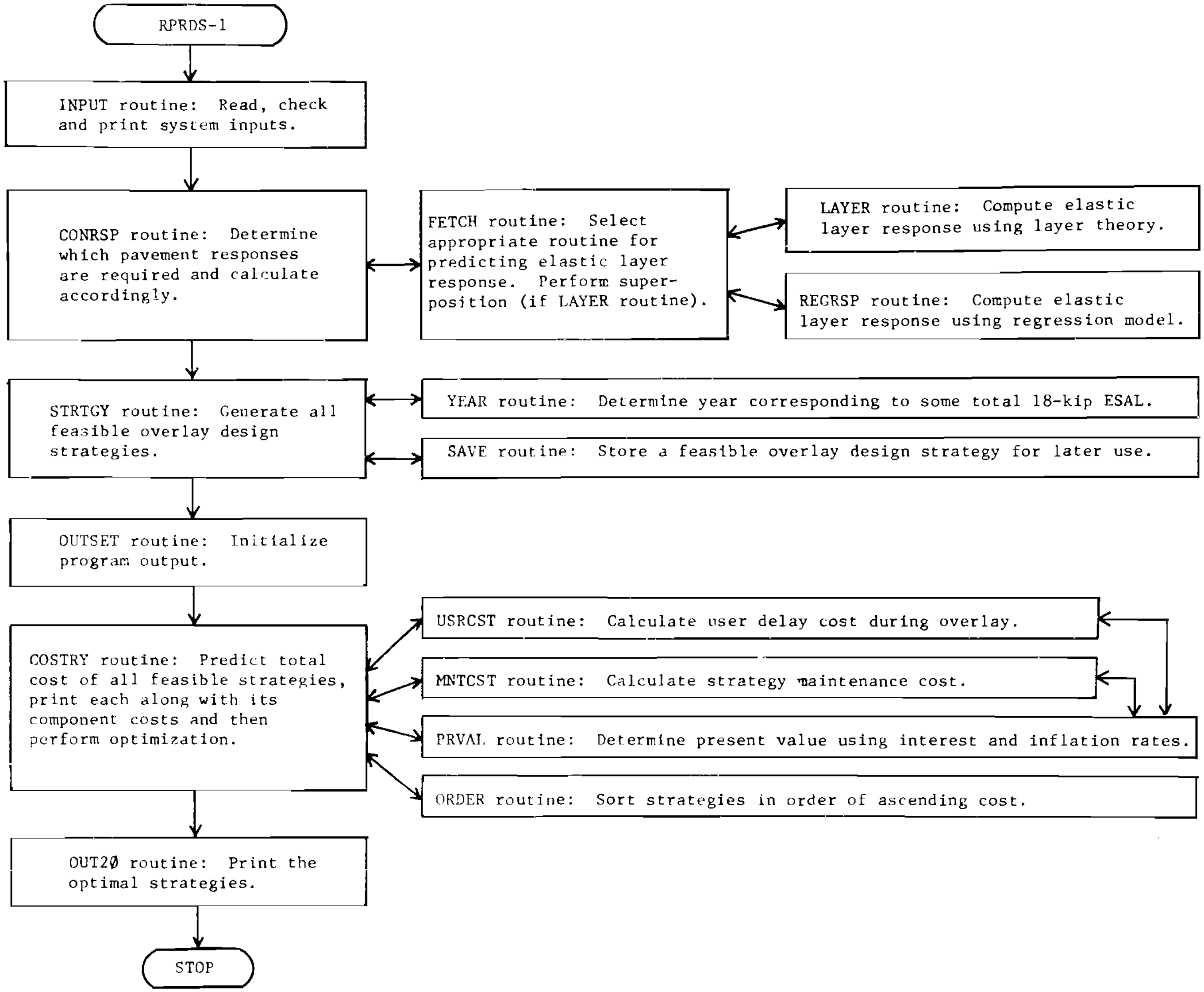


Fig 2.2. General flow diagram of the rigid pavement rehabilitation design system computer program, RPRDS-1.

the specific function of this routine and the routines it uses to predict the required responses, FETCH, LAYER, and REGRSP, is presented in Chapter 3.

Thirdly, all feasible overlay design strategies (i.e., those which meet the constraints) are generated by the STRTGY routine. The discussion of (a) fatigue life prediction and the available overlay design strategies, (b) the method of distress prediction, and (c) how feasible strategies are selected and stored is presented in Chapter 4.

Fourth, each feasible overlay design strategy is analyzed (by the COSTRY routine) on the basis of net present value where (a) overlay construction costs, (b) user delay costs during overlay construction (TDCSY routine), (c) maintenance costs (MNTCST routine), (d) value of extended life, (e) salvage value, and (f) a form of discount rate (PRVAL routine) are considered. In the process, strategies which have the least overall cost are stored in order of increasing cost (ORDER routine). This analysis is discussed in Chapter 5.

Fifth, the details and predicted costs of the optimal strategies are printed for user inspection by the OUTSET, PRNTST, and OUT20 routines. The discussion of how the output of the RPRDS-1 program should be interpreted so that the best overall rehabilitation alternative can be selected is presented in the RPRDS-1 User's Manual in Chapter 6 of this report.

Finally, Chapter 7 provides a summary of the results of this study and the applicability of RPRDS-1 to overlay design problems. Chapter 7 also provides some conclusions that can be derived from the results of the study and some recommendations for improvements and further work in this area.

CHAPTER 3. PREDICTION OF PAVEMENT RESPONSE

In order to predict how a pavement structure will perform during its lifetime, it is necessary in any rational or mechanistic design method to predict how the pavement will respond under load. The purpose of this chapter then, is to describe the mechanism through which these responses, i.e., stress, strain, and displacement, are generated for use in RPRDS-1. Accordingly, three specific topics concerning pavement response prediction will be discussed.

The first is the RPRDS-1 routine called CONRSP (see Fig 2.2) which controls the generation of the required responses. This includes identifying the types of pavement structures that can be considered and the responses required for each.

The second topic discussed is the approach used for predicting pavement response in RPRDS-1, which is a combination of elastic layer theory and the finite element method to achieve maximum precision with minimum computation time. The third topic addressed is elastic layer theory, the history of its development and its use in two submodels incorporated into RPRDS-1.

CONTROL ROUTINE FOR GENERATING RESPONSES

RPRDS-1 can consider a variety of different overlay strategies (as discussed in Chapter 2). Since this multitude of possible strategies requires an even larger number of pavement responses for predicting their lifetimes, it was not considered feasible to calculate or recalculate responses every time they are needed. Consequently, a computer routine, CONRSP, was developed for RPRDS-1 to generate the required responses. It is capable of (1) making the appropriate decisions on what responses are required for each strategy, (2) preparing the necessary inputs to calculate each response, (3) calling the appropriate routine to calculate the response, and (4) storing the response for later use. A simplified flowchart of this routine is presented in Appendix A of this report.

A method of coding each required response was developed and is used in the CONRSP flowchart. In this code, the first letter indicates whether a given response is a stress, S, or strain, E. The second character, a number, indicates the location in the pavement of the response. A zero indicates a response in the original pavement, a one indicates a response in the first structural overlay, and a two indicates a response in the second structural overlay. The next characters in the string (shown in Table 3.1 identify the pavement structure. The subscript, i, at the end of a string means that the response takes on multiple values depending on the thickness of first overlay. The subscript, ij, means that the response depends on the thicknesses of both the first and second overlays.

Figure 3.1, which is a section of the CONRSP flowchart in Appendix A, is provided to help illustrate this coding method. In the bottom box of this figure, one of the pavement structures considered in RPRDS-1 is illustrated.

TABLE 3.1. CHARACTERS OF A CODE WHICH IDENTIFY A PARTICULAR PAVEMENT STRUCTURE FOR WHICH RESPONSES ARE DETERMINED

Characters	First Overlay	Second Overlay	Remarks
(None)	(None)	(None)	No overlays
A	AC	(None)	
AA	AC	AC	
AP	AC	PCC	
AP1	AC	PCC	Original PCC uncracked
AP2	AC	PCC	Original PCC cracked
BP	Bonded PCC	(None)	
BPA	Bonded PCC	AC	
UP	Unbonded PCC	(None)	
UP1	Unbonded PCC	(None)	Original PCC uncracked
UP2	Unbonded PCC	(None)	Original PCC cracked
UPA	Unbonded PCC	AC	
UPA1	Unbonded PCC	AC	Original PCC uncracked
UPA2	Unbonded PCC	AC	Original PCC cracked

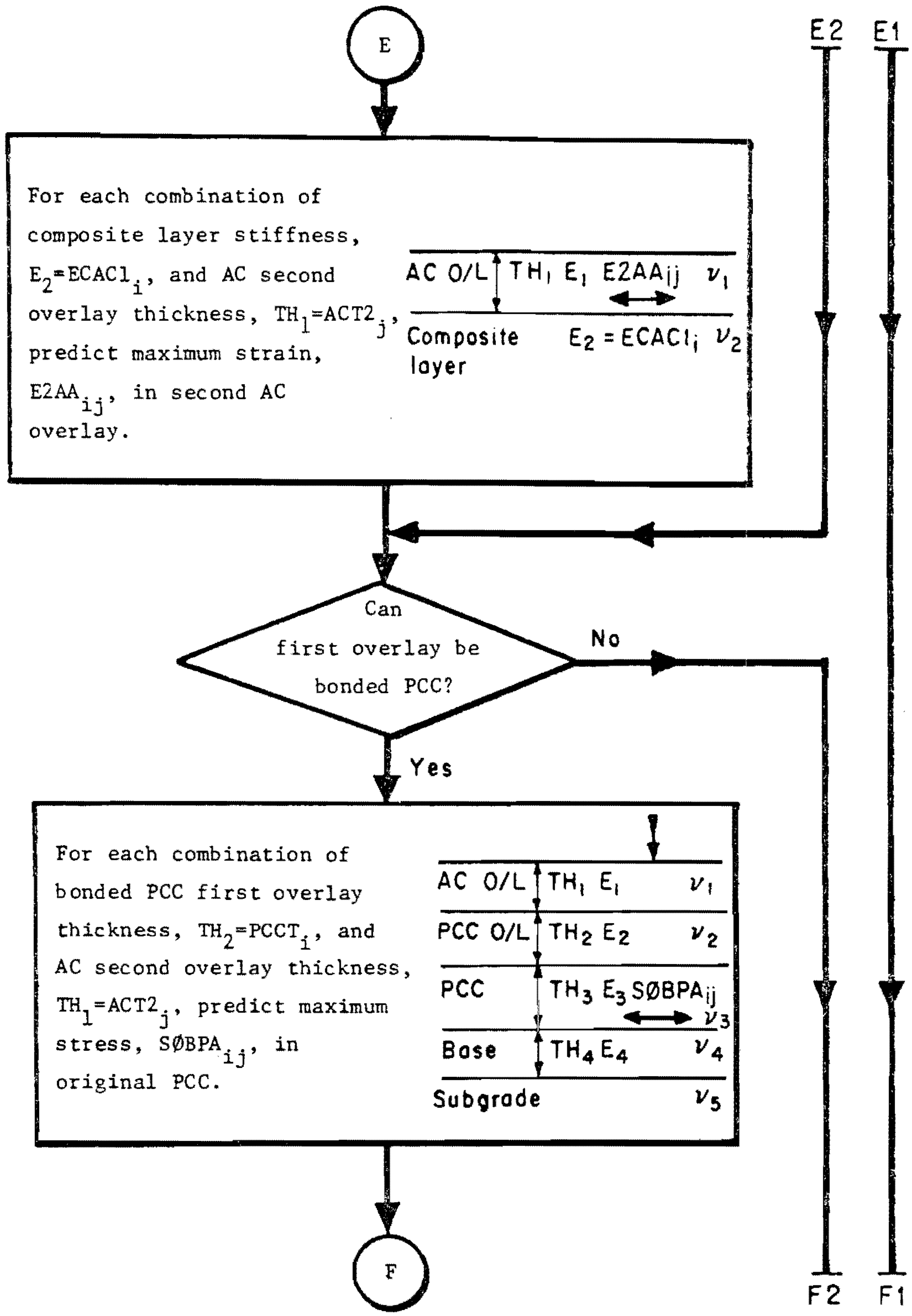


Fig 3.1. Section of CONRSP flowchart, illustrating the method for coding the required responses.

Note that it consists of the original PCC pavement, a bonded PCC first overlay, and an AC second overlay. The desired response, coded SOBPA , is shown at the bottom of the third layer. Since the first letter of the code is an S, the response is a stress; and, since the second character is a O, this stress exists in the original pavement. Referring to Table 3.1, then, it is evident that the next three characters, BPA, indicate that the first overlay consists of bonded PCC while the second consists of asphaltic concrete. The subscript, ij, indicates that this stress corresponds to the i-th thickness of the first overlay and the j-th thickness of the second overlay. The other variables depicted in the figure, TH, E, and V, represent (respectively) the layer thicknesses, elastic moduli, and Poisson's ratios used to calculate the desired response. Using this coding method, it should be apparent then, that E2AA in the top box of Fig 3.1 represents a strain in an AC second overlay where the first overlay was also AC.

Inspection of the flowchart in Appendix A (and the top box of Fig 3.1) shows that in some cases, a cracked pavement structure will be characterized as a single composite layer (with a composite stiffness) prior to placing of an AC overlay. This method of characterization, developed by Schnitter (Ref 9), insures that the AC overlay will carry the load which cannot be carried by the underlying cracked layers. The composite stiffness is determined by matching the 18-kip single axle deflections of the cracked and composite pavement structures. This is discussed in greater detail in Chapter 4.

APPROACH TO PREDICTING CRITICAL PAVEMENT RESPONSE

RPRDS-1 uses a combination of elastic layer theory and the finite element method to predict the critical pavement response required for estimating the lifetime of an overlay strategy. This approach is similar to that adopted for use in the FHWA and Texas SDHPT overlay design procedures (Refs 1, 3, and 9). The combination of the two methods was necessary because (1) layer theory cannot predict pavement response at a discontinuity such as a pavement edge or crack and (2) computer models based on finite element theory require too much data preparation and computer time for practical use in RPRDS-1.

The marriage of the two methods can briefly be described as follows. First, prediction models based on layer theory are used to predict the pavement response for the interior condition (away from an edge, corner or crack). Then this interior response is adjusted for the other conditions using relationships developed from finite element theory in which the response at a discontinuity is correlated with the interior response. For example, if the stress near a pavement edge were required, it would be determined by computing the interior stress using the layer theory model and then multiplying by an edge stress factor developed from finite element theory.

A description of elastic layer theory is provided in the next section of this chapter; however, a description of the finite element method and its use in RPRDS-1 is not discussed until Chapter 4.

ELASTIC LAYER THEORY

The development of layer theory, as documented by McCullough (Ref 2), began with the Bouissinesq solution of stresses and deflection for what is technically considered a one-layer problem. Burmister (Ref 16) extended the solution to two layers assuming no slippage at the interface and conceptually established the solution for three-layered problems. He also developed a formulation for the state of stress directly beneath the wheel load (Ref 17). Unlike the Bouissinesq approach, Burmister considered the modulus of elasticity (Young's modulus) of the layers, a factor which has a considerable effect on the state of stress and strain in the pavement structure. Hank and Scrivner (Ref 18) and Peattie and Jones (Ref 19) provided the physical solution to Burmister's conceptual solution for the three-layered problem and also solved for the complete state of stress and strain in the pavement structure. Hank and Scrivner also provided the solution for the case of varying friction between the layers.

The advent of the computer in the 1960's provided the means for the solution to multi-layered problems. Chevron Research Corporation developed the CHEV5L (5 layer) and CHEV15L (15 layer) computer programs which permitted the determination of the complete state of stress at any point in the pavement structure (Ref 20). Both treated elastic moduli, Poisson's ratio, and thicknesses of the layers as variables and both also assumed full friction at the interfaces between the layers. They were limited, however, to predicting only stress and deflection and the consideration of only one vertical load at the surface. Ahlborn (Ref 21) extended the CHEV5L program to develop ELSYM5 which could predict strain and could handle up to ten vertical loads. In this program, the principle of superposition was used to predict the effect of multiple loads at any one point. Additionally, ELSYM5 was capable of using a Mohr's circle type analysis to compute the principal stresses and strains at any point.

The Shell Oil Company, meanwhile, also developed a computer program, BISAR (an improved version of their earlier BISTRO program), for analyzing the state of stress and strain in multi-layered elastic systems (Refs 22 and 23). It not only had the capability to handle multiple loads and multiple layers, but it could also consider varying degrees of friction at the interfaces between the layers and horizontal as well as vertical surface loads. This made BISAR the most flexible and the most precise computer model available for elastic layer simulation. Unfortunately, all these capabilities make BISAR relatively slow and unsuitable for use in RPRDS-1.

The pertinent assumptions inherent in elastic layer theory and all of these computer models are as follows:

(1) The theory of linear elasticity (and all its inherent assumptions) are applicable.

(2) Each layer extends to an infinite distance horizontally and the materials of each are assumed to be weightless, homogeneous, and isotropic.

(3) The surface of the top layer is assumed to be free of normal and shearing stresses outside the loaded area.

(4) Stresses, strains, and deflections in the bottom layer must be equal to zero at infinite depth.

The third and fourth assumptions are certainly valid for pavement applications and although the second assumption never applies to cases in the field, its effects may be neglected or indirectly considered when applying adjustments from finite element theory to the response. These adjustments are discussed in Chapter 4.

There are two alternatives available in RPRDS-1 for predicting interior response. Both are based on elastic layer theory and the first, the LAYER submodel, is a computer model similar to ELSYM5 (Ref 21). Unlike ELSYM5, it can consider only one load. It does, however, give the same results as ELSYM5 for a one-load problem and is approximately 30 percent faster.

The second alternative for predicting interior response is the LAYER regression submodel called REGRSP. It represents a series of regression equations developed from the LAYER submodel and is approximately five times faster. Unfortunately, though they are quite accurate, their results, when used in conjunction with the fatigue equations, are often significantly different from those using the LAYER submodel. Consequently, it is recommended that the LAYER submodel be used for any practical application of RPRDS-1 on highway design problems.

LAYER Submodel

The computer model in RPRDS-1 used to predict the precise elastic response is a version of the CHEV15L program which has gone through several modifications. The first resulted in the LAYER15 program (Refs 20,and 24), which was then modified at Texas A & M University (Ref 26) for compatibility with IBM machines. The version used here, labelled LAYER, represents a modified version of LAYER15. The allowable number of layers was decreased from fifteen to eight to reduce computer storage requirements. The program was also modularized to fit within the RPRDS-1 framework.

LAYER was selected for use in RPRDS-1 mainly because of its minimal computer time and storage requirements. The problem of multiple loads was overcome by considering the effect of superposition externally from LAYER. Also, it was decided that there was no need for considering variable friction between the layers since McCullough (Ref 2) determined that the effect was negligible for pavement applications.

The model can basically be described using Fig 3.2. An elastic layer system which simulates the pavement structure may consist of up to eight layers in which the thickness, D, elastic modulus, E, and Poisson's ratio, ν , for each must be defined. The coordinate system is two-dimensional axis symmetric where r represents the horizontal (or radial) axis and z the vertical axis. The origin (r=0, z=0) is at the surface directly beneath the load. The load is defined by some magnitude, F, with some pressure, p. Note also that the model is independent of units (so long as they are consistent).

The response at any point (r,z) consists of radial stresses and strains (along a horizontal line passing through the z-axis), tangential stresses and strains (along a horizontal line perpendicular to a line passing through the z-axis), shear stresses and strains, bulk stresses and strains, and, finally, vertical stress and vertical displacement.

The load used to predict the responses required by RPRDS-1 is a simulated 18-kip single axle used in the FHWA and Texas SDHPT overlay design procedures (Ref 1, 3, 9). Figure 3.3 provides an illustration of the 18-kip single load and how it is simulated. The figure also shows how the total response at a given point is determined using the principle of superposition.

Although the actual 18-kip single axle consists of four tires, the simulation used considers only two tires, or one-half the axle. This is to remain consistent with the fatigue equations (Refs 6 and 31), which were

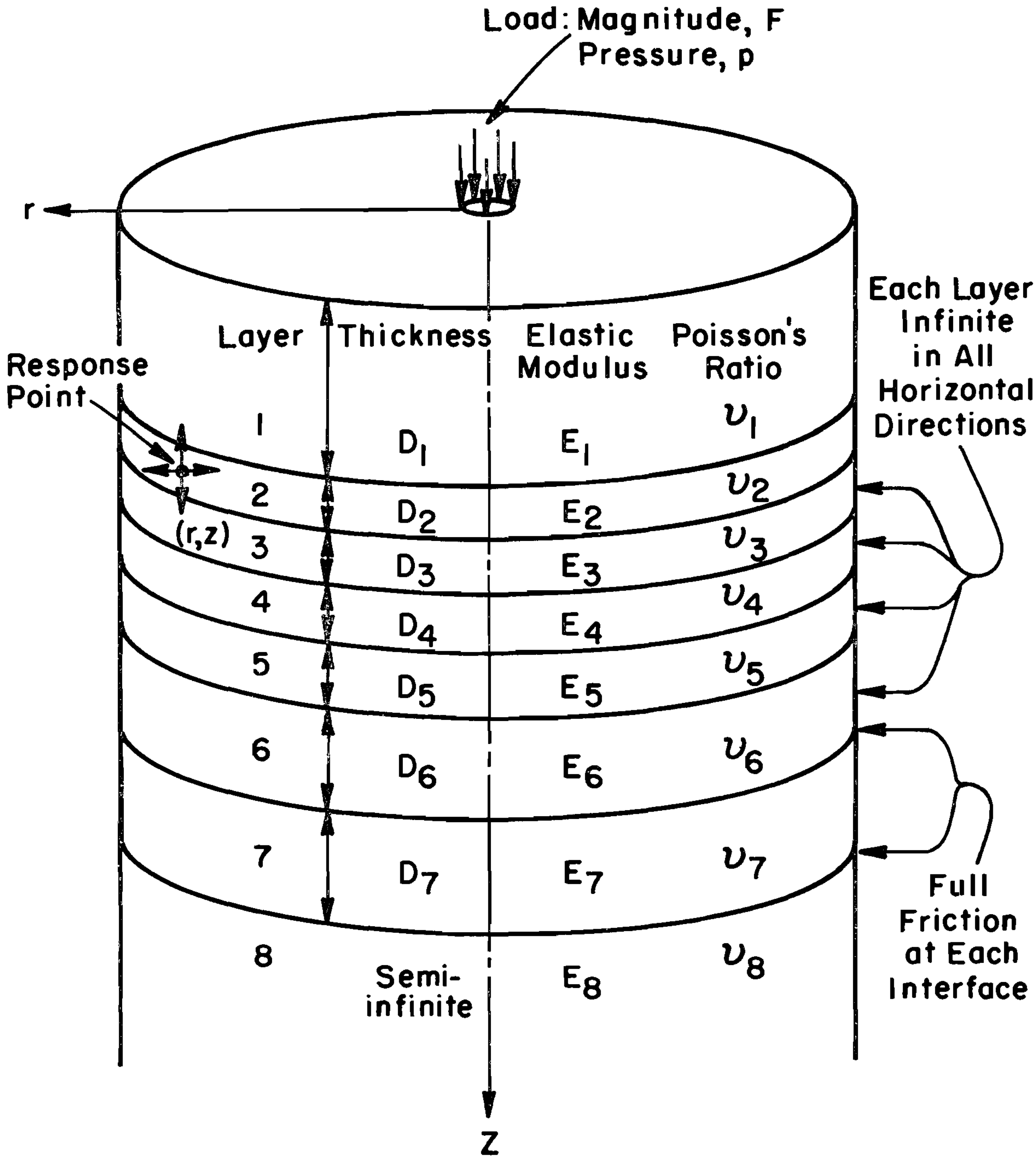
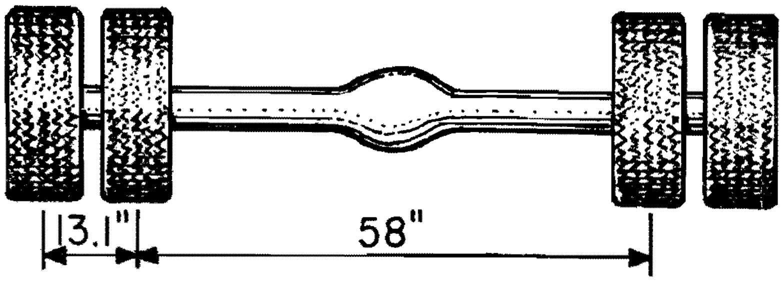
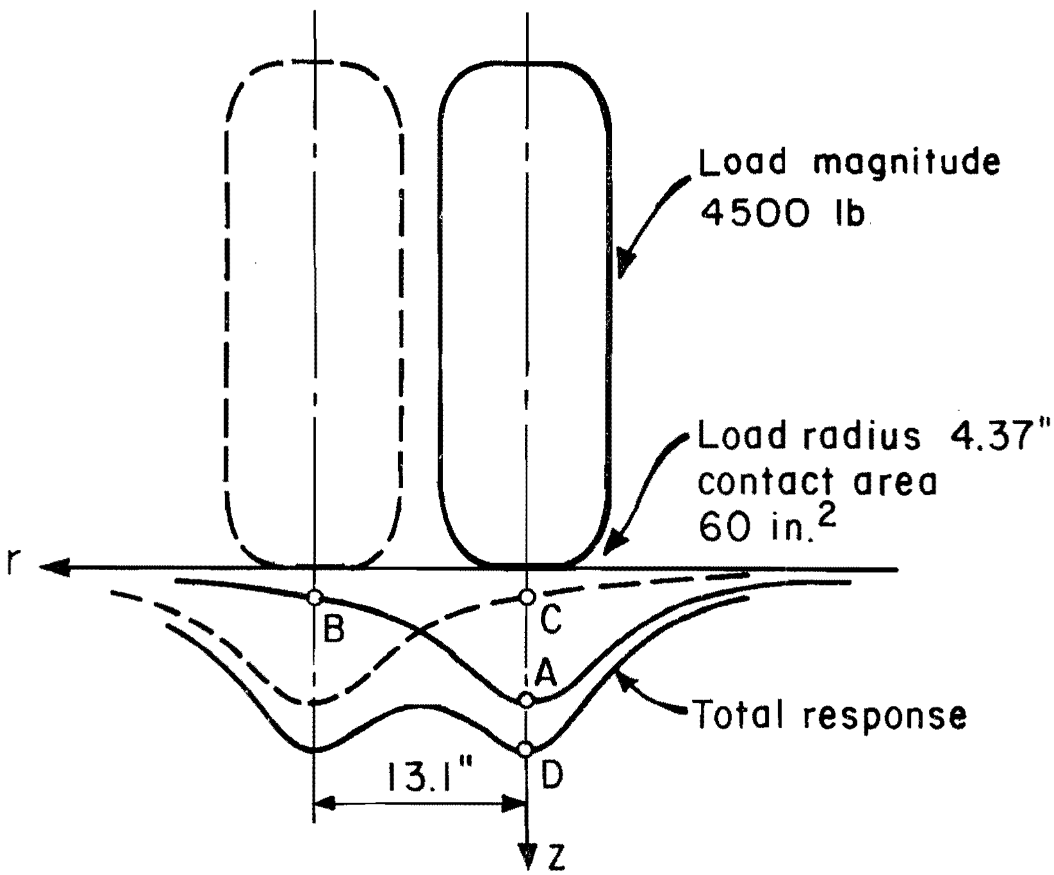


Fig 3.2. Illustration of an elastic layer system.



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



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

Fig 3.3. Standard 18-kip axle configuration and simulation used in RPRDS-1.

developed using this half-axle simulation. Part (b) of Fig 3.3, then, illustrates how the total response (due to the two loads) at a particular point is determined. Point A represents the maximum response due to a single load. Since there is some effect (point C) due to the second load nearby, it must be estimated and then added to the response at point A to get the total response, point D. Also, since the two loads are identical, the effect of point C is equivalent to that at point B. Therefore, the total response at point D is simply the algebraic sum of the responses at points A and B due to a single load. It should be noted, however, that this superposition of responses gets much more complicated for multiple load configurations.

LAYER Regression Submodel (REGRSP)

This submodel was developed as part of this study in an effort to reduce RPRDS-1 computer time requirements and in anticipation of the need to incorporate some measure of reliability into the program. Comparison of this submodel (called REGRSP) with the other available model (LAYER) shows that REGRSP takes less than one-fifth the computer time with greater than 85 percent (generally 95 percent) accuracy. Unfortunately, due to the precision required by the equations for predicting pavement fatigue lives, there is usually a significant difference between the fatigue lives predicted by each submodel. Consequently, the LAYER submodel is strongly recommended for specific highway design applications. The REGRSP submodel is more than accurate enough, however, for use in developing a reliability model for the RPRDS-1 program.

Basically, the REGRSP submodel consists of 12 regression equations (presented in Appendix B) which predict a particular response in one of the various pavement structures considered in RPRDS-1. These equations were developed from designed experiments on the LAYER submodel where advantage is taken of the fact that (1) the design 18-kip single axle load is fixed (as in Fig 3.3), (2) the effect of superposition of loads on the design axle can be considered within each equation, and (3) the variation of Poisson's ratio for each of the layer materials has little effect on the predicted response.

The specific procedure followed for the development of each equation is simple. It should be noted here, however, that each equation represents an expression for a single response within a particular pavement structure. This may help to avoid confusion later when the case arises in which there are two responses required from a particular pavement structure.

The first step of the procedure was to select a particular pavement structure and the location of the desired response. These were selected on the basis of what responses were required by RPRDS-1 to predict the fatigue lives of the available strategies.

The second step, then, was to design an experiment (Refs 27 and 28) where the significant factors (the independent variables) which affect the response (dependent variable) predicted by LAYER could be varied to produce a factorial of LAYER solutions. Three equally spaced levels (high, medium, and low) of each significant factor were used in the experiments. Less significant factors, such as Poisson's ratio, were fixed according to the types of materials making up the layers of the pavement structure. In the experiments where there were more than five significant factors, a full factorial of solutions would have required exorbitant amounts of computer time and money, (3 or 59,049 LAYER solutions for the ten-factor case); consequently, fractional factorials as recommended by Connor and Zelen

(Ref 27) were used to generate the required set of LAYER solutions. This resulted in 243 observations (data points) in all but one of the experiments.

The third step of the procedure was to perform an analysis of variance on the data. This was accomplished using a computer program, SUMSQ2 (Ref 29), which computes the sums of squares about the grand mean for all main effects (original factors), both linear and quadratic, and the two-factor interactions of each. So, for a term such as the interaction between layer one thickness, D , and layer two modulus squared, (E) , a large sums of squares indicates that the term explains much of the variation observed in the data. The objective, then, was to select the terms which explained the most variation and use them in the equation to predict response. However, a practical limit of 20 terms (less than one-tenth the number of observations) was imposed on each multi-factor regression equation.

Preliminary results showed that most of the variation of a linear dependent variable could not be explained with the available terms. Consequently, it was necessary to try to explain the variation using different transformations of the dependent variable. Trial and error showed that a considerable amount of the variation (greater than 98 percent) in the log (base 10) of the response could be explained. Therefore, this transformation was used in all of the experiments.

The fourth and final step of the procedure was to perform a stepwise regression analysis on the data using the log transform of the response as the dependent variable and the terms which explained most of its variation. The STEP01 computer program (Ref 30) was used to perform the regression analysis. Significant information about the constraints on each equation and plots of the accuracy of each equation, as well as the regression equations, themselves are presented in Appendix B of this report.

Another coding system was developed to aid in identifying each equation. The first letter indicates whether the response is a stress, S, or strain, E. The second letter (if there is one) indicates whether the first PCC overlay is bonded, B, or unbonded, U, by means of a bond breaker. The first number indicates how many different layers are considered and the second number identifies in which layer (counting from the top down) the response is determined. The letter C at the end of a code means that an underlying concrete layer is considered to be cracked.

There are two other important things that were discussed previously but should be emphasized again. One is that the equations are based on a fixed axle load, as shown in Fig 3.3, and the other is that the effect of superposition is considered within the equations.

CHAPTER 4. GENERATION OF FEASIBLE OVERLAY DESIGN STRATEGIES

The purpose of this chapter, basically, is to show how feasible overlay design strategies are generated. Accordingly, several topics dealing with design constraints and fatigue life prediction will be discussed. Note here, too, that this chapter specifically describes the components of the routine called STRTGY, which is incorporated into RPRDS-1 (refer to Fig 2.2) to generate the feasible overlay design strategies.

DESIGN CONSTRAINTS

There are several types of design constraints which differentiate between overlay design strategies which are feasible and those which are not. These constraints are, for the most part, defined by the highway designer and therefore are largely subjective. The constraints which are considered within the Rigid Pavement System, RPS (Ref 7), include

(1) maximum funds available for initial construction,

(2) maximum allowable slab thickness,

(3) minimum allowable time to first overlay,

(4) minimum allowable time between overlays,

(5) length of analysis period or minimum life of strategy,

(6) maximum ACP and PCC overlay thicknesses, and

(7) minimum ACP and PCC overlay thicknesses.

All of these types of constraints seem practical for use in any type of pavement design system; therefore, a discussion of their applicability and use in RPRDS-1 is in order.

To begin with, it should be pointed out that RPS is a design system for pavements which are to be constructed from scratch, whereas RPRDS-1 is a design system for pavement rehabilitation only. Though RPS can consider strategies where an overlay is required during the analysis period, the model it uses to predict the life of such an alternative is very primitive and may be subject to gross inaccuracy. The model RPS uses for PCC overlay design is an extension of the Corps of Engineers method for airfield pavements (Refs 13 and 15), while the method for ACP overlay design is based on an equivalent thickness concept (Ref 11). In any case, RPRDS-1 is recommended for design of rehabilitation for existing rigid pavements, but, due to its nature, some of the constraints which are considered in RPS are not considered in RPRDS-1. Such is the case for the first three constraints listed.

The constraints on maximum funds available for initial construction and maximum allowable slab thickness do not apply in RPRDS-1 as it is assumed that a rigid pavement structure already exists. This also applies to some extent to the constraint on the minimum allowable time to first overlay. In most overlay design problems, the existing pavement is available for an "immediate" overlay, and, consequently, it doesn't matter how long ago it was constructed. The constraint is still considered indirectly, however, since the program requires that the designer specify certain levels of pavement life at which the first overlay may be placed.

The fourth constraint listed is the minimum allowable time between overlays. This is considered directly within RPRDS-1. Any strategy in which a second overlay is required too soon after the first overlay will be eliminated from further consideration.

Due to the type of maintenance cost model used in RPRDS-1, the fifth constraint, minimum strategy life, is handled differently than in RPS. RPRDS-1 allows the user to specify some maximum period of heavy maintenance, which, in effect, allows some strategies to be considered which do not quite last the analysis period without some period of heavy maintenance. The result is that only strategies which require a longer period of heavy maintenance to last the analysis period are removed from further consideration. This is explained in further detail in Chapter 5.

The sixth and seventh constraints listed are the maximum and minimum thicknesses of ACP and PCC overlays. These constraints are also considered within RPRDS-1, but in a slightly different way. First of all, RPRDS-1 requires that the designer select the specific thicknesses of ACP and PCC overlay to be considered. Therefore, infeasible thicknesses are eliminated immediately. Second, the program allows the designer to specify a maximum total overlay thickness. Consequently, a strategy in which the combined thickness of two overlays is so great that it does not provide adequate bridge clearance will be eliminated.

Finally, RPRDS-1 attempts to limit the number of thickness design alternatives by omitting those which provide excessive lifetimes. Once a feasible thickness design is generated, no further designs are considered in which only the overlay thickness is greater. For example, if a 4-inch ACP overlay is found to be feasible, there is no need to consider a 5-inch overlay.

In summary, an RPRDS-1 strategy is constrained by how long it will last, the total allowable thickness of overlay, and the time at which a second overlay (if used) is placed.

PREDICTION OF FATIGUE LIFE

The basic method used in RPRDS-1 for predicting the fatigue life of an overlay design strategy is that suggested by McCullough (Ref 2) and developed by Austin Research Engineers, Inc., for the Federal Highway Administration (Ref 1). That original method has experienced significant improvements during adaptation and implementation for the Texas SDHPT. The process of improvement and adaptation began with a study by Schnitter, Hudson, and McCullough (Ref 9). Further improvements to the design method were accomplished by Taute (Ref 31) in the areas of materials characterization and fatigue relationships for CRCP. The latter accomplishments were a result of practical implementation on several overlay projects in Texas.

Finally, there were several improvements which took place as a part of this study to consider some factors not considered before. These include concrete shoulder construction, two overlays (instead of just one) to provide the desired lifetime, and the consideration of the additional life left in an overlay after the original PCC loses its load carrying capacity.

The effect of all of these improvements along with the basic approach to fatigue life prediction are discussed in this section.

Details of the Approach

The overall approach to predicting the fatigue life of a pavement structure is very simple, even for the case of an overlaid pavement structure. The reader may, however, find the jargon and the logic difficult at first to understand. Therefore, this discussion will begin with the simplest problem imaginable, a two layer pavement structure, concrete and subgrade, subject to cyclic loading of a fixed magnitude. This is analogous to a repeated load flexural beam test in the lab.

First, an estimate of the maximum tensile stress in the concrete is obtained from the available analytical methods. In this case, the method used is elastic layer theory with finite element adjustments for the particular types of discontinuities considered. The use of this analytical method requires the determination of thicknesses of each layer; material properties, elastic modulus, and Poisson's ratio for each layer, and the flexural strength of the concrete.

Then, the maximum tensile stress and concrete flexural strength are used in a fatigue equation (discussed later) based on AASHO Road Test data. The result, then, is an estimated number of load cycles the structure will carry before it reaches the level of "failure" inherent in the fatigue equation. This may be when 10 percent of the surface area is cracked.

The discussion of elastic layer theory and how it is used to predict response was presented in Chapter 3 while the discussion of how material properties are to be determined is presented in Chapter 6 (the RPRDS-1 User's Manual). Discussion of how fatigue lives are predicted for the various types of overlay strategies considered in RPRDS-1, the finite element adjustments to elastic layer stresses, and the fatigue equation used is presented later in this chapter, but, first, it is important to complete the discussion of the approach to fatigue life prediction.

The discussion above describes how RPRDS-1 predicts the fatigue life for the simplest possible case, the original pavement structure. This should, however, provide the foundation necessary for understanding how the fatigue lives are predicted for the more complex overlay problems.

As mentioned previosly, McCullough (Ref 2) first suggested the approach to predicting the fatigue life of an overlaid pavement and, later, Austin Research Engineers, Inc., developed it for the Federal Highway Administration (Ref 1). The method assumes that Miner's linear damage hypothesis is valid for such applications and uses it to develop the concepts of pavement damage and remaining life.

The term damage is used to identify a certain amount of pavement deterioration. Damage due to the cyclic application of a constant stress level may be mathematically expressed by the following relationship

$$d_i = n_i/N_i \tag{4.1}$$

where

n_i = number of applied cycles at some i^{th} constant stress,

N_i = allowable number of cycles at that i^{th} constant stress, and

d_i = damage experienced by the pavement after n_i cycles.

For example, if the allowable number of cycles to failure, N_i , was 100 and the number of applied cycles, n_i , was 40, then the damage, d_i , experienced by the structure due to those 40 applications would be 0.40 or 40 percent.

The linear damage assumption, now, says that the individual damages, d_i , may be algebraically summed to determine the total damage due to the application of a variety of stress levels. This may be expressed mathematically as

$$d_T = \sum_{i=1}^{m} d_i = \sum_{i=1}^{m} (n_i/N_i) \tag{4.2}$$

where n_i and N_i are as defined before and

d_T = total damage due to the application of a variety of stress levels, i, and

m = number of different stress levels.

In the example, if the damage due to 600 cycles of another stress level (in which the allowable number of cycles was one thousand) is accumulated according to Miner's hypothesis, then, the total damage the structure would suffer is

$$d_T = 0.40 + 600/1000 = 1.0$$

Or, in other words, the damage to the structure is 100 percent, which implies that it has reached the failure level inherent in the fatigue equation.

Now, to illustrate how this is used to predict the fatigue life of a structure after it is overlaid, consider the example of placing a bonded PCC overlay on an existing PCC which has already experienced some fatigue damage. Equation 4.2 will become

$$d_T = n_1/N_1 + n_2/N_2 \tag{4.3}$$

where

N_1 = fatigue life obtained from the fatigue equation using predicted maximum stress due to the design 18-kip single axle load on the original pavement (see Fig 4.1a),

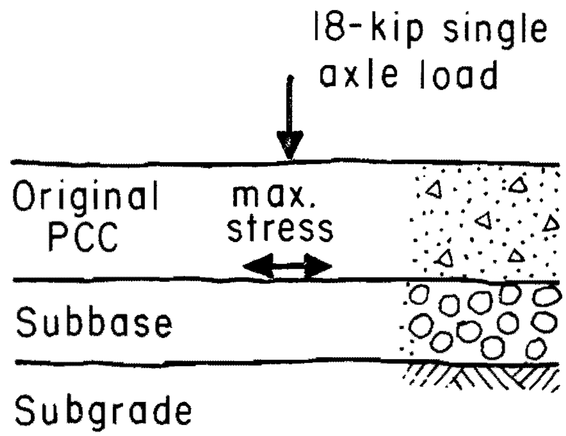
n_1 = the number of 18-kip equivalent single axle loads (ESAL) the original pavement was subjected to before overlay (this is determined from past traffic estimates),

N_2 = fatigue life obtained from the fatigue equation using the predicted maximum stress in the original PCC due to an 18-kip single axle load on the overlaid structure (see Fig 4.1b),

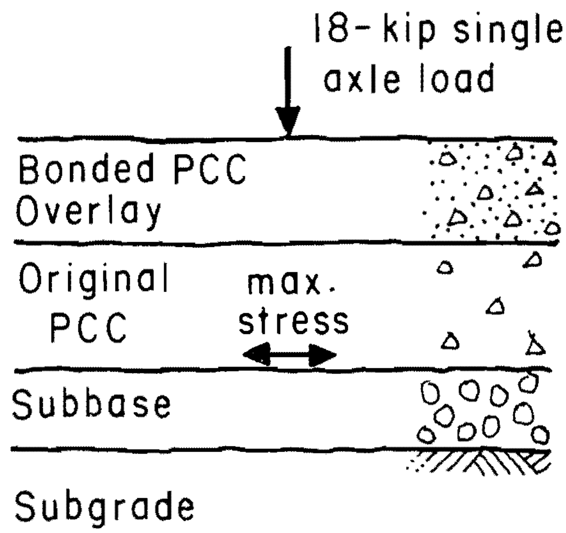
n_2 = the number of 18-kip ESAL the pavement structure can carry after overlay, and

d_T = 1.0, since the damage to the pavement at the end of its lifetime is 100 percent.

The meaning of each term can be expressed graphically in a plot of damage versus 18-kip cycles as shown in Fig 4.2a. Line 1 represents the deterioration (or fatigue) of the original PCC. Line 2 represents the deterioration of the original PCC if the bonded PCC overlay was placed before any damage to the original PCC had occurred. It should be apparent now, that line 3 must represent the deterioration of the original PCC in which the

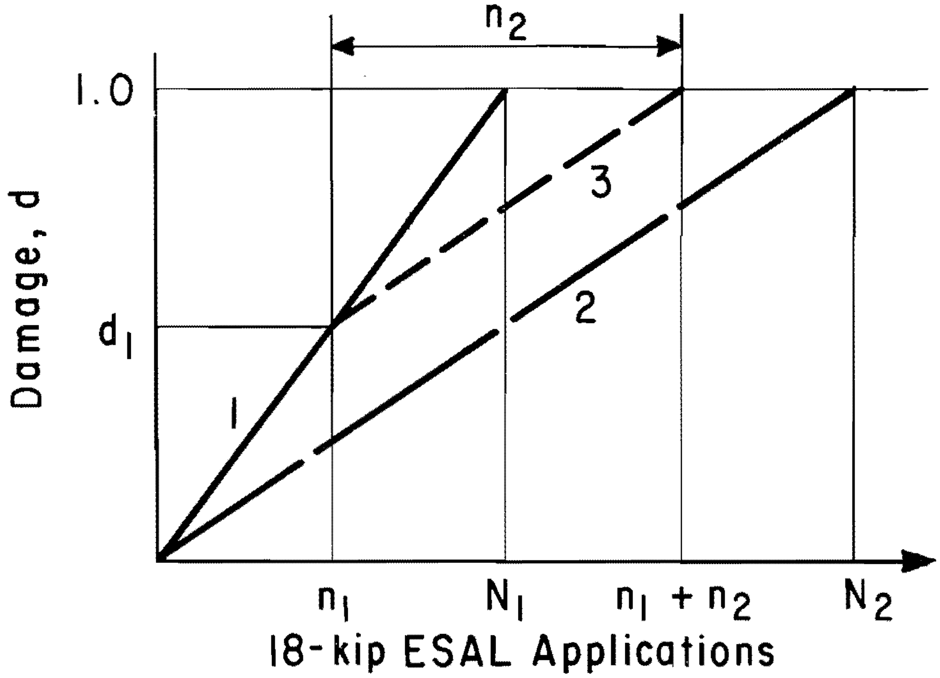


(a) Maximum stress in original PCC before overlay.

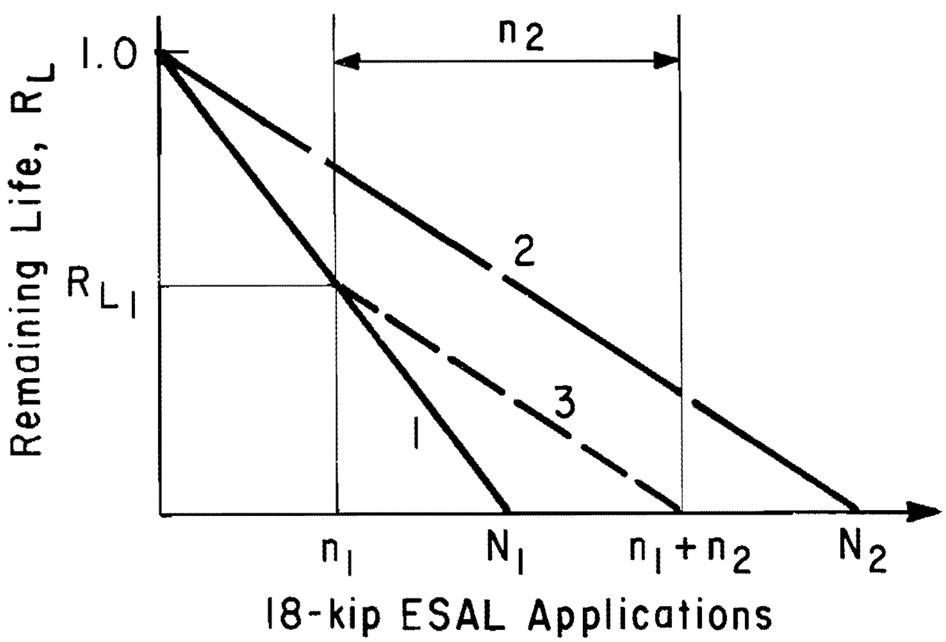


(b) Maximum stress in original PCC after bonded PCC overlay is considerably lower than before overlay.

Fig 4.1. Illustration of the maximum stresses in original PCC layer before and after a bonded PCC overlay.



(a) Plot of damage versus 18-kip ESAL applications.



(b) Plot of remaining life versus 18-kip ESAL applications.

Fig 4.2. Graphs illustrating the deterioration of the original PCC for the bonded PCC overlay example.

bonded PCC overlay was placed after n_1 cycles of the 18-kip single axle load. It should be apparent, also, that the slopes of lines 2 and 3 are identical. Finally, it should be noted that it is the slopes of these lines that are the most affected by the different overlay strategies.

Since n_2, the life of the pavement structure after overlay, in this case is the number required to estimate the year in which the strategy will "fail", its value can be determined by rearranging Eq 4.3:

$$n_2 = (d_T - n_1/N_1)\ N_2 \tag{4.4}$$

where d_T , N_1 , n_1 , and N_2 are know quantities.

Now that the equation for predicting the fatigue life of the original PCC after overlay has been derived, an explanation of the concept of remaining life is in order.

Remaining life may be defined as the amount of damage left in a pavement layer after it has been subjected to cyclic loading. It is the term in parentheses in Eq 4.4, $d_T - n_1/N_1$, where d_T is equal to one. The notation adopted for remaining life is R_L; therefore,

$$R_L = 1 - d_1 = 1 - n_1/N_1 \ . \tag{4.5}$$

It can be expressed as either a fraction or a percent. If Fig 4.2a were plotted with remaining life on the vertical axis, it would result in the graph shown in Fig 4.2b.

There are two reasons why the remaining life concept was adopted. One was to allow the designer to estimate the amount of life left in a pavement where there is little past traffic data available. The second and more important reason is that remaining life is considered to be highly correlated with data gathered from field observations or condition surveys of the distressed pavement. The development of such a relationship would help eliminate the need for precise past traffic information and allow the designer to rely on up-to-date surveys of in-service pavements for overlay design problems.

Improvements to the Approach

Up to now, the discussion has been on the approach to predicting the fatigue life of a single concrete layer, the original PCC. In general, this is the extent of the FHWA and Texas SDHPT design procedures (Refs 1 and 9); the life of a specific overlay design strategy is expressed only in terms of the fatigue life of a single load carrying layer. This approach is certainly conservative, but, in some cases, it may be too conservative. An extension of the approach is to consider the life left in the overlay after the original PCC loses its load-carrying capacity.

The extension of the approach can be described with the aid of Fig 4.3. At the time of overlay placement, the original PCC has already experienced a certain amount of damage and, therefore, is at some level of remaining life, R_{L_e}, which is well below 100 percent. The overlay, however, has experienced no damage and has a remaining life of 100 percent. Then as fatigue applications due to heavy trucks continue, the overlay will deteriorate to a point, R_{L_o}, where the original PCC would have no load

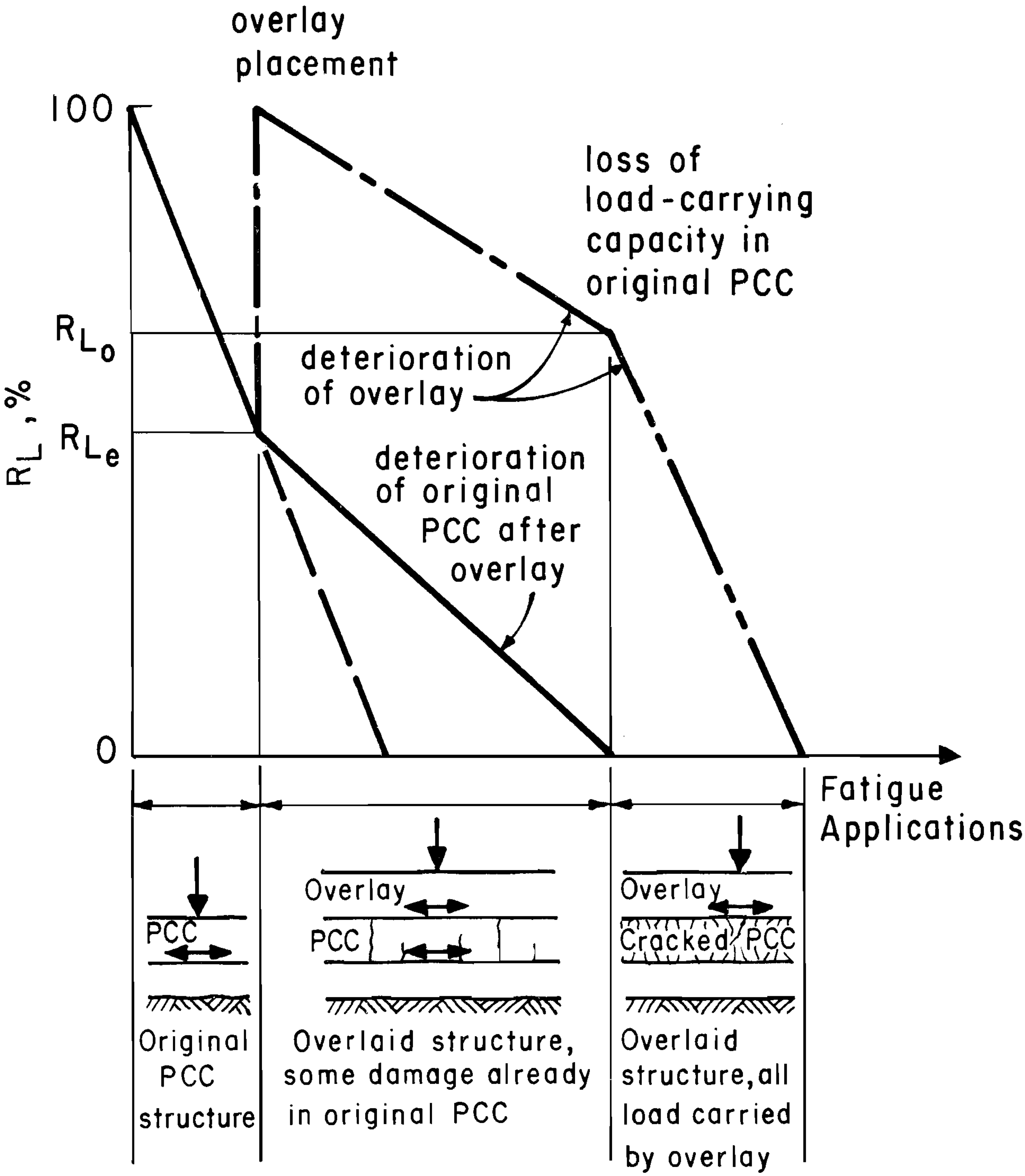


Fig 4.3. Graph of remaining life versus fatigue applications, which illustrates how the approach to predicting the pavement fatigue life (after overlay) was extended to consider the additional life left in the overlay after the original PCC loses its load-carrying capacity.

carrying capacity. The fact that the original PCC has become totally damaged does not necessarily mean the overlay has. Depending on the type of overlay and how it was placed, the structure may yet be able to carry a significant number of load applications. This is definitely the case for ACP and unbonded PCC overlays.

Since the load-carrying capacity of a layer is dependent on the amount of cracking it has incurred, remaining life must be a function of cracking. So, when predicting how the overlay will deteriorate, it is important to consider how cracking in the underlying PCC layer will affect the cracking (and therefore remaining life) of the overlay. In the bonded PCC overlay example discussed previously, experience has shown that any crack which exists or originates in the original PCC will always propagate up through the bonded PCC overlay. (This is known as reflection cracking and may be explained by the existence of stress concentrations above a crack once it is initiated). After a short period of time, the cracking and remaining life of the bonded PCC overlay will be identical to that of the original PCC. Accordingly, by the time the original PCC reaches the level of no remaining life, the bonded PCC overlay will also. This is illustrated in Fig 4.4.

As for the ACP and unbonded PCC overlays, their deterioration is as shown previously in Fig 4.3. Generally, the remaining life for both overlay types will be significantly high at the point when the original PCC reaches the level of zero remaining life. The explanations for this high level of remaining life for each overlay type are, however, quite different.

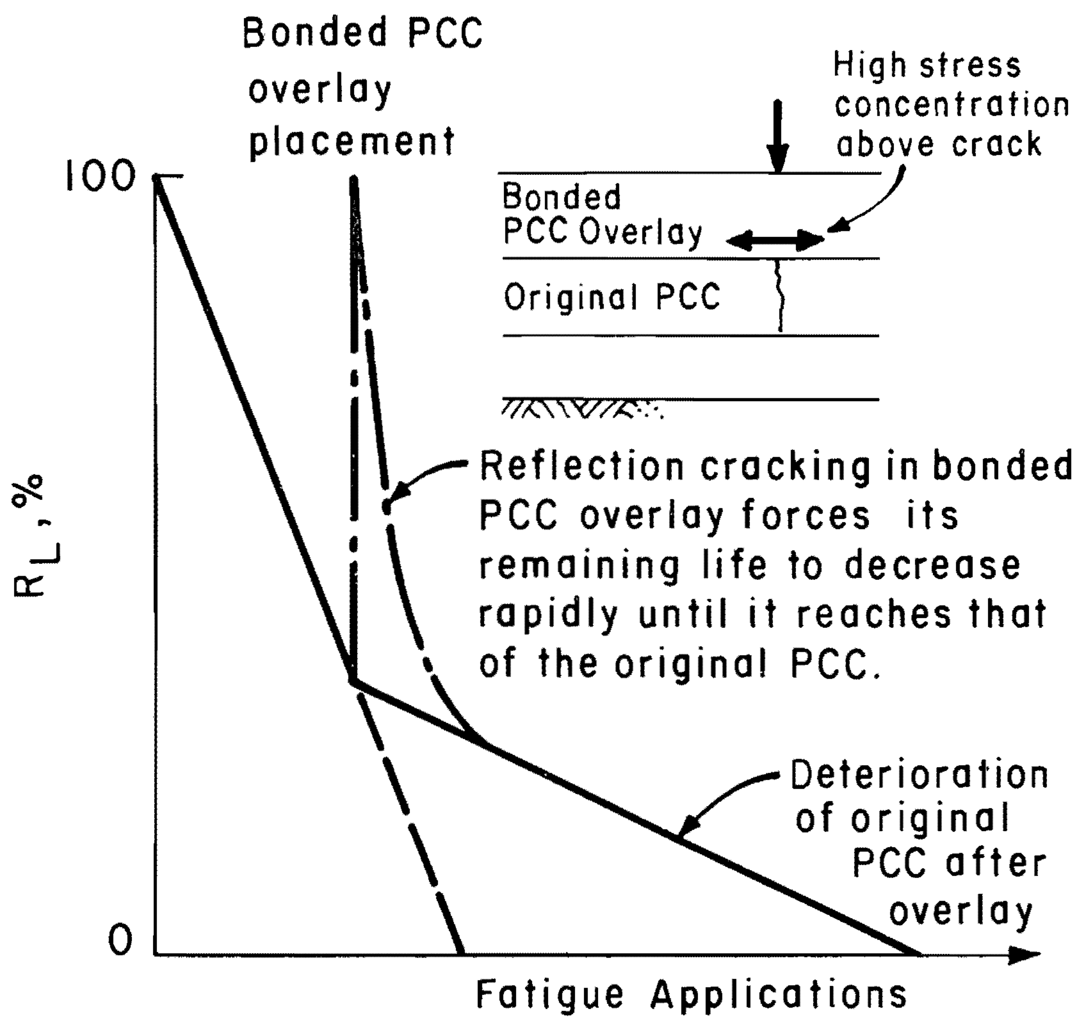


Fig 4.4. Graph of remaining life versus fatigue applications which illustrates effect of reflection cracking on the deterioration of a bonded PCC overlay.

For the case of the unbonded PCC overlay, the fact that there is a bond breaker between the two PCC layers (to help absorb any differential movement which may lead to reflection cracking) insures that the overlay will deteriorate primarily due to its own fatigue. In fact, the tensile stresses which cause fatigue in the overlay can be computed using elastic layer theory (with finite element adjustments for discontinuities). The bond breaker which separates the two PCC layers usually consists of a thin layer of low-stiffness asphaltic concrete which not only helps shield reflection cracking but also acts as a level-up course.

Unlike an unbonded PCC overlay, an ACP overlay comes into intimate contact with the surface of the original PCC, much like a bonded PCC overlay. But, unlike those of the bonded PCC overlay, material properties peculiar to asphaltic concrete help keep it from reflecting a crack which may exist in the underlying PCC. Results of an experimental overlay project on an existing CRCP along IH-45 in Walker County, Texas, obtained from studies by McCullough (Ref 2) and McCullough and Chesney (Ref 33) and from several condition surveys of the project (conducted by the Center for Highway Research at The University of Texas) indicate that structural ACP overlays (those at least 3 inches thick) are much less susceptible to reflection cracking than bonded PCC overlays, particularly on existing CRC pavements. For one thing, asphaltic concrete is not as brittle as portland cement concrete and can develop greater horizontal tensile strains (i.e., those due to temperature drop related movements of the underlying pavement) without cracking (so long as the underlying horizontal movements at the crack are not as large as they are at the joint of a JCP). Secondly, asphaltic concrete tends to relax and heal itself at higher temperatures, which, in turn, interrupts the reflection cracking process. Finally, it is apparent that since CRC pavements depend on aggregate interlock for load transfer across a crack, there is little differential vertical movement across the crack and therefore the induced vertical shear strains in an ACP overlay are low. The combination of all these tends to limit the reflection of underlying cracks through an ACP overlay as long as the underlying PCC pavement has some load-carrying capacity. Even so, reflection cracking is still the ultimate mechanism of distress which destroys the structural integrity of the ACP overlay. Since this is not the usual process of fatigue, it was necessary to adopt a different approach to predicting the allowable number of 18-kip single axle cycles an ACP overlay can carry.

Earlier, it was pointed out that an ACP overlay is placed so that it will "stick" to the existing surface (a delamination between the two layers may lead to serious problems with pop-outs). Because of this, the ACP overlay, theoretically, can not carry any bending tensile stresses (or strains) since most of it, if not all, is above the neutral axis of the two-layer combination (see Fig 4.5). This is even true for the case in which the original PCC has no load carrying capacity, since the effective stiffness of the two layers is almost the same. The stiffness of the original PCC, however, is usually not indicative of the kind of tensile stresses and strains it can carry since it is based only on measured Benkelman Beam deflections at the AASHO Road Test. Recognizing this, Schnitter (Ref 9) developed a model which does not allow the underlying PCC to carry any tensile stresses if it is cracked and has no load-carrying capacity. In the model, the cracked pavement below the ACP overlay is characterized as a single semi-infinite layer with a composite stiffness. Then, a fatigue strain which hopefully simulates the reflection cracking strain is calculated and used in the ACP fatigue equation. The composite stiffness is determined

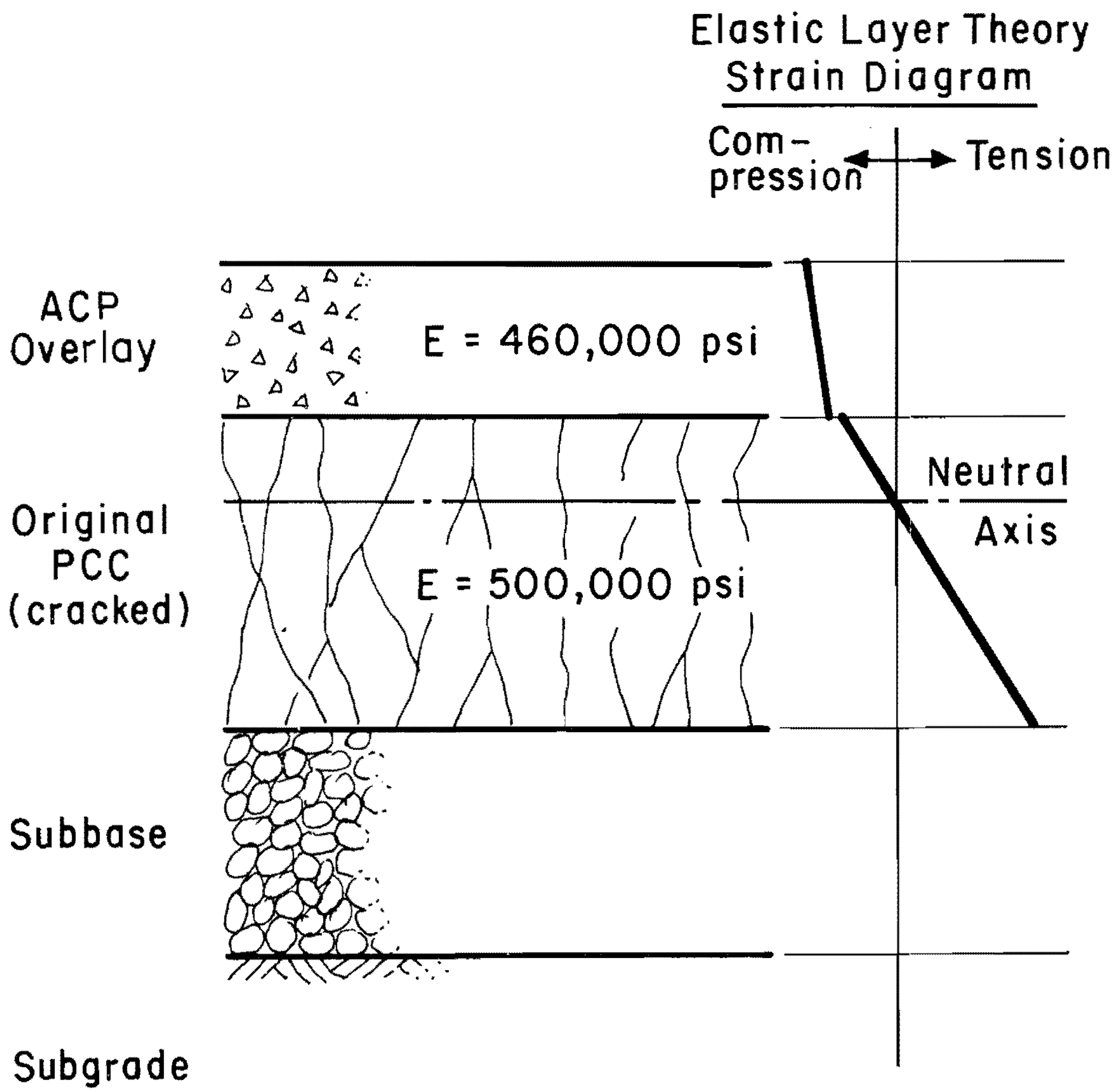


Fig 4.5. Strain diagram for a cracked PCC structure with an ACP overlay.

by matching the deflection under the design 18-kip single axle load for the composite and cracked structures. This model is illustrated in Fig 4.6 and is similar to the approach used in the AASHTO Interim Guide (Ref 5) for determining a composite k-value for a subbase layer on top of a subgrade.

The model temporarily solves the problem for an ACP overlay on an existing PCC pavement. Unfortunately, it does not solve the problem of an ACP overlay on a PCC pavement which still has load-carrying capacity. For this case, it is necessary to assume that the damage incurred by the overlay due to a single load cycle is equivalent to that incurred by the underlying PCC (or, in other words, assume the rate of deterioration of the ACP overlay is the same as that of the original PCC). Though this assumption is not necessarily conservative, it was found that its effects, when it is used in conjunction with the AC fatigue equation, were negligible for ACP overlays less than 8 inches thick. Still, a better overall approach would be to estimate the maximum strains which cause reflection cracking using finite element theory and then correlate them with field measurements of load transfer, horizontal movement at the crack or joint, and 18-kip equivalent single axle traffic. The lack of this data, however, makes it impossible to develop such a relationship at this time.

Available Overlay Strategies

Now that the background of the overlay design model has been presented, it is convenient to discuss the overlay design strategies available in RPRDS-1. Figure 4.7 illustrates the alternatives which are possible with regard to the type of the existing pavement and the type of overlay. Note that a two-overlay strategy can be considered but that at least one of the

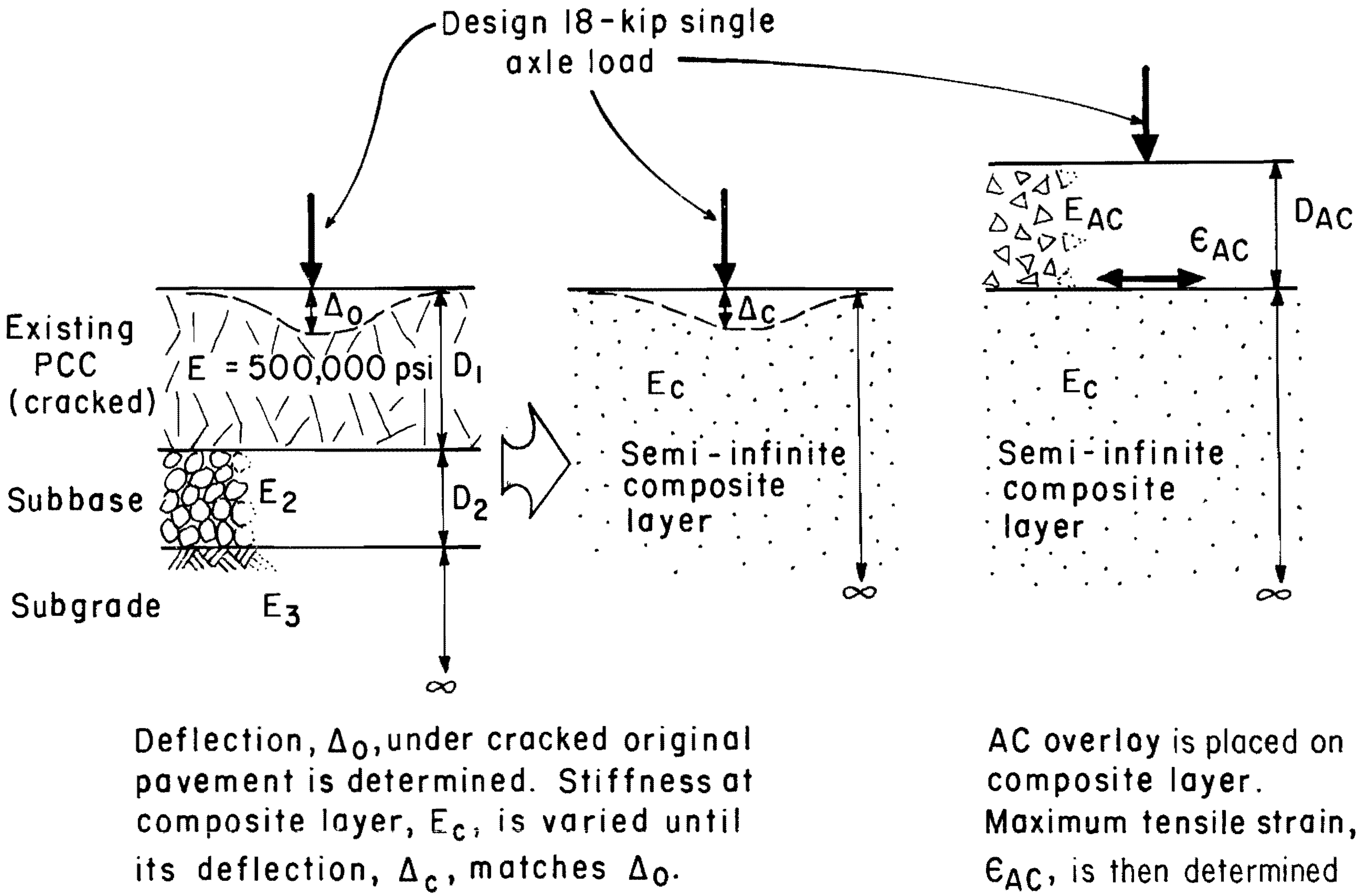


Fig 4.6. Illustration of the method for determining the tensile strain in an ACP overlay on a cracked PCC pavement.

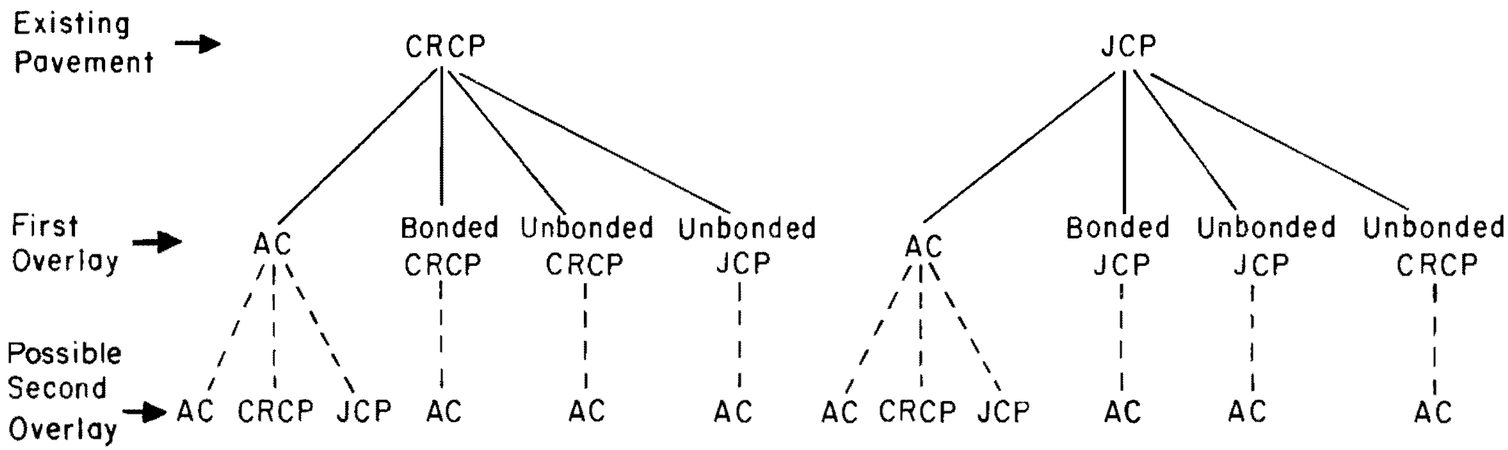


Fig 4.7. Illustration of the overlay design strategies available in RPRDS-1 with regard to existing pavement and overlay type.

two must consist of asphaltic concrete. Though the discussion of the approach to predicting fatigue life did not cover the method for a two-overlay combination, it will become apparent later when the specific models for each possible design are presented.

Besides the type of overlay, the other variable components of an overlay strategy include

(1) remaining life of the existing surface layer at time of overlay placement,

(2) overlay thickness,

(3) flexural strength of a PCC overlay, and

(4) concrete shoulder construction.

The remaining life of the existing surface layer at the time of overlay construction is considered to be an important component of a strategy since it corresponds to a particular future year which, due to discount rate, may significantly affect the net present value of a given strategy. The method in which the future year is determined for a given value of remaining life is discussed later in this chapter.

The other three variable components are considered because of their effect on the life of a given strategy. There are two things, however, that should be kept in mind about the overlay flexural strength and concrete shoulder construction components. The first is that although concrete flexural strength is highly correlated with concrete stiffness (elastic modulus), the variation of the stiffness is not taken into consideration because of the additional computer time and storage it would require. Also, there is some question as to the validity of varying the overlay's flexural strength since the concrete fatigue equation (discussed later) is based only on the mean flexural strength of the AASHO Road Test sections (690 psi).

The second important thing to keep in mind is that concrete shoulder construction can be considered only if a concrete overlay is to be constructed at the same time. This leaves out the option of constructing a concrete shoulder at grade with the original structure. This option is not considered practical or economically feasible due to the amount of work involved with tying the PCC shoulder into the original structure.

The best way to show how each component is considered and at the same time present the equations which predict the fatigue life of each possible strategy is to present a flowchart of the RPRDS-1 routine (STRTGY) which performs the analysis. The flowchart of STRTGY is presented in Appendix C.

Each strategy that is generated is identified by ten different indices. A feasible strategy is stored with this set of indices and other design factors relating to time of overlay placement and time of overlay failure (loss of load carrying capacity). This set of indices is described below.

(1) IRL1 - Index of the remaining life of the original pavement at the time of the first overlay. IRL1 varies from 1 to NRL1 for each user-specified remaining life (10 maximum).

(2) IOV1 - Index to the type of first overlay (1=ACP, 2=Bonded CRCP, 3=Unbonded CRCP, 4=Bonded JCP, 5=Unbonded JCP).

(3) IC1 - Index which identifies whether a concrete shoulder is constructed at the time of first overlay (0=No, 1=Yes). Concrete shoulder construction cannot be considered if the first overlay is ACP.

(4) IFR1 - Index to the level of the flexural strength of the first overlay. IFR1 varies from 1 to NFROV, the number of user-specified flexural strengths to consider (5 maximum). IFR1 will be zero if the first overlay is ACP.

(5) IOV1T - Index to the thickness of first overlay. IOV1T varies from 1 to NACT1 for an ACP first overlay and from 1 to NPCCT for a PCC first overlay (8 maximum for both cases).

(6) IRL2 - Index of the remaining life of the first overlay at the time of the second overlay. IRL2 varies from 1 to NRL2 for each user-specified remaining life (10 maximum). IRL2 is zero if a second overlay is not part of the strategy.

(7) IOV2 - Index to the type of second overlay (1=ACP, 2=CRCP, 3=JCP).

(8) IC2 - Index which identifies whether a concrete shoulder is constructed at the time of second overlay (0=No, 1=Yes). Concrete shoulder construction cannot be considered if the second overlay is ACP.

(9) IFR2 - Index to the level of flexural strength of the first overlay. IFR2 varies from 1 to NFROV, the number of user-specified flexural strengths to consider (5 maximum). IFR2 will be zero if the second overlay is ACP.

(10) IOV2T - Index to the thickness of second overlay. IOV2T varies from 1 to NACT2 for an ACP second overlay and from 1 to NPCCT for a PCCT second overlay (8 maximum for both cases).

There are several submodels used by the STRTGY routine which are not explained in Appendix C. These include

(1) the fatigue equations,

(2) the method for adjusting the elastic layer stresses for the particular discontinuities associated with a given alternative, and

(3) the method for predicting the year corresponding to some cumulative traffic.

They are discussed next, in the order shown.

The Fatigue Equations

The term fatigue equation is used in this context to identify the relationship between the response of a pavement under load (i.e., stress or strain) and the number of cycles of that load the pavement can carry before it reaches some failure criteria. RPRDS-1 uses three fatigue equations: two for portland cement concrete (PCC) and one for asphaltic concrete (AC).

PCC Equations. The concrete fatigue equations used in RPRDS-1 are the result of an anaysis performed by Taute (Ref 31) on AASHO Road Test data (Ref 4) and data from statewide condition surveys in Texas (Ref 44). They represent an improvement over the original equation developed by Austin Research Engineers (ARE) for the Federal Highway Administration (Ref 1), since the seasonal variation of subgrade strength was taken into account during their development. One of the equations also attempts to account for the better moisture environment provided by the placement of an overlay. These two equations along with the original ARE equation are shown in Fig 4.8. In order to better understand the use of these equations in RPRDS-1, it is useful to first describe (and contrast) their development.

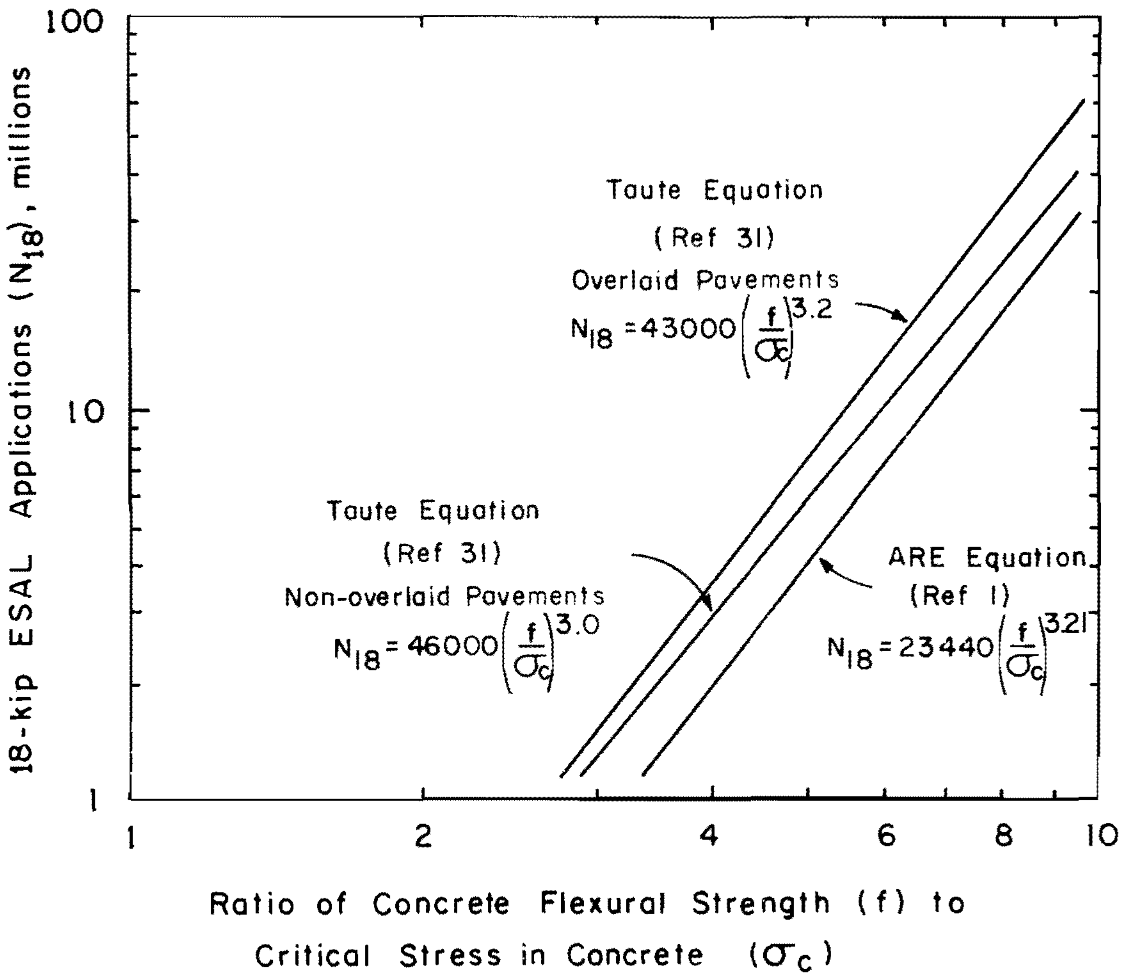


Fig 4.8. PCC fatigue equations.

Development of the ARE equation began with the characterization of the material properties of the PCC sections at the Road Test. The significant aspects that should be pointed out here are that a mean subgrade stiffness (elastic modulus) of 5000 psi and a concrete flexural strength, f, of 690 psi were used for all sections in the analysis.

The elastic layer program, ELSYM5 (Ref 21), was then used to predict the critical stress, 0_c , under the simulated 18-kip axle load for each section. (Note that since the outer wheel path for approximately 90 percent of the applications was well away from the pavement edge, an interior stress condition was assumed. This, in turn, eliminated the need for adjustments for higher stress conditions near the edge.) Equivalency factors developed at the Road Test were then used to estimate the equivalent 18-kip single axle applications, N_{18}, carried by each section. A regression anaysis was then performed to determine the "best-fit" line through this data. Also, it should be pointed out that the failure criterion used for this equation was the point when the pavement first exhibited Class 3 and 4 cracking.

A slightly different approach was used by Taute (Ref 31) to develop the two new PCC equations. First of all, a higher level of distress (a cracking index of 50 feet per 1000 square feet, AASHO definition) was selected for the failure criteria for non-overlaid pavements. This point seemed to correspond with a point (determined from the statewide condition survey of CRCP in Texas) where distress levels began to increase rapidly. This point is assumed to correspond to a loss of pavement load-carrying capacity and no remaining life.

Next, the strength of the subgrade was characterized (using Benkelman Beam deflections) for two main seasons, one when the subgrade was firm and the other when the subgrade was weakened due to spring thaw. Like the ARE development, a mean value of 690 psi was used for the concrete flexural strength for all sections since little variation was observed in the data. Once again, ELSYM5 was used to predict the interior concrete stress for both seasons; however, some adjustments were applied in estimating the average critical stress, O_c, for each section. These adjustments were to account for the distribution of wheel loads across the pavement. It is important to note, also, that these stresses were determined using a simulation of the actual axle loads used at the Road Test and not a simulation of the 18-kip equivalent single axle used in the ARE development. This eliminated the need for using AASHO equivalency factors to estimate the equivalent 18-kip single axle traffic on each section. (Some equivalency factors were used, however, to account for the difference in load duration between single and tandem axles.)

The next step of the iterative process was to estimate an equivalent critical stress for each section, using Miner's linear damage hypothesis and the traffic and critical stresses for each season. A regression analysis was then performed to generate a new fatigue equation using the equivalent critical stress as an independent variable and the total traffic as the dependent variable. The iterative process would continue until the new fatigue equation differed insignificantly from the assumed fatigue equation.

Though this equation was developed with as few limiting assumptions as possible, Taute points out four factors to consider when using it:

(1) The AASHO rigid pavement sections were all jointed and had only granular subbases which often exhibited extreme amounts of pumping.

(2) The effects of spring thaw at the Road Test were severe, which may not be the cases in many areas, especially in Texas.

(3) The Road Test sections had only granular shoulders, which are certainly not common on today's Interstate Highway system.

(4) There was very little traffic encroachment near the pavement edge at the Road Test, which is, once again, not the case for many of today's highways.

Furthermore, this equation is recommended for use only with non-overlaid pavements or those which have poor moisture environments.

For overlaid pavements, Taute recommends the use of the second PCC equation (shown in Fig 4.8). This equation is basically an adjustment of the first equation based on results that showed that overlaid pavements in Texas were far exceeding their design life predicted by the previous design method (Ref 9). This was attributed to the improved moisture environment provided by overlay placement. Because of this, the new equation is also used in RPRDS-1 for predicting the life of pavements which have a concrete shoulder, since they are not subject to water ponding at the pavement edge.

AC Equation. The fatigue equation used in RPRDS-1 for the design of asphaltic concrete (AC) overlays is the original one developed by Austin Research Engineers, Inc. (ARE), for the Federal Highway Administration (Ref 6). Like the PCC equations, this one was based on data from the AASHO Road Test (Ref 4); however, this one was not based directly on field data. The AC equation represents a correlation with the AASHO cracking equation (Eq 4.6) which is a function of the pavement structure and axle load:

$$\log W_c = 5.484 + 7.275 \log(0.33D_1 + 0.10D_2 + 0.08D_3 + 1) + 2.947 \log L_2 - 3.136 \log(L_1 + L_2) \quad (4.6)$$

where

W_c = allowable load applications before Class 2 cracking (the failure criteria),

D_1 , D_2, D_3 = pavement layer thicknesses,

L_1 = axle load, and

L_2 = 1 for single axle configuration and 2 for tandem.

The AASHO equation had a squared correlation coefficient of 0.79 and the AC equation used here (see Fig 4.9), which attempts to model it using elastic layer theory, has a squared correlation coefficient of 0.93. The materials characterization method used to develop the AC equation is similar to that used to develop the ARE concrete fatigue equation. Table 4.1 shows the characteristics used in the elastic layer analysis.

It should be noted that the critical tensile strains predicted for the AASHO Road Test sections were relatively high (greater than 10 in./in.). This, in turn, limits the application of the AC fatigue equation used in RPRDS-1 to ACP overlay thicknesses of less than 8 inches.

Finite Element Adjustments

As discussed in an earlier section of this chapter, elastic layer theory is used to predict pavement response in RPRDS-1. Unfortunately, real pavements are not as simple as those modelled by elastic layer theory. They have joints, cracks, edges, corners, nonuniform support, and other similar types of discontinuities which have a large effect on pavement response. This section, then, describes how finite-element adjustment factors were developed to account for these types of discontinuities in overlay design.

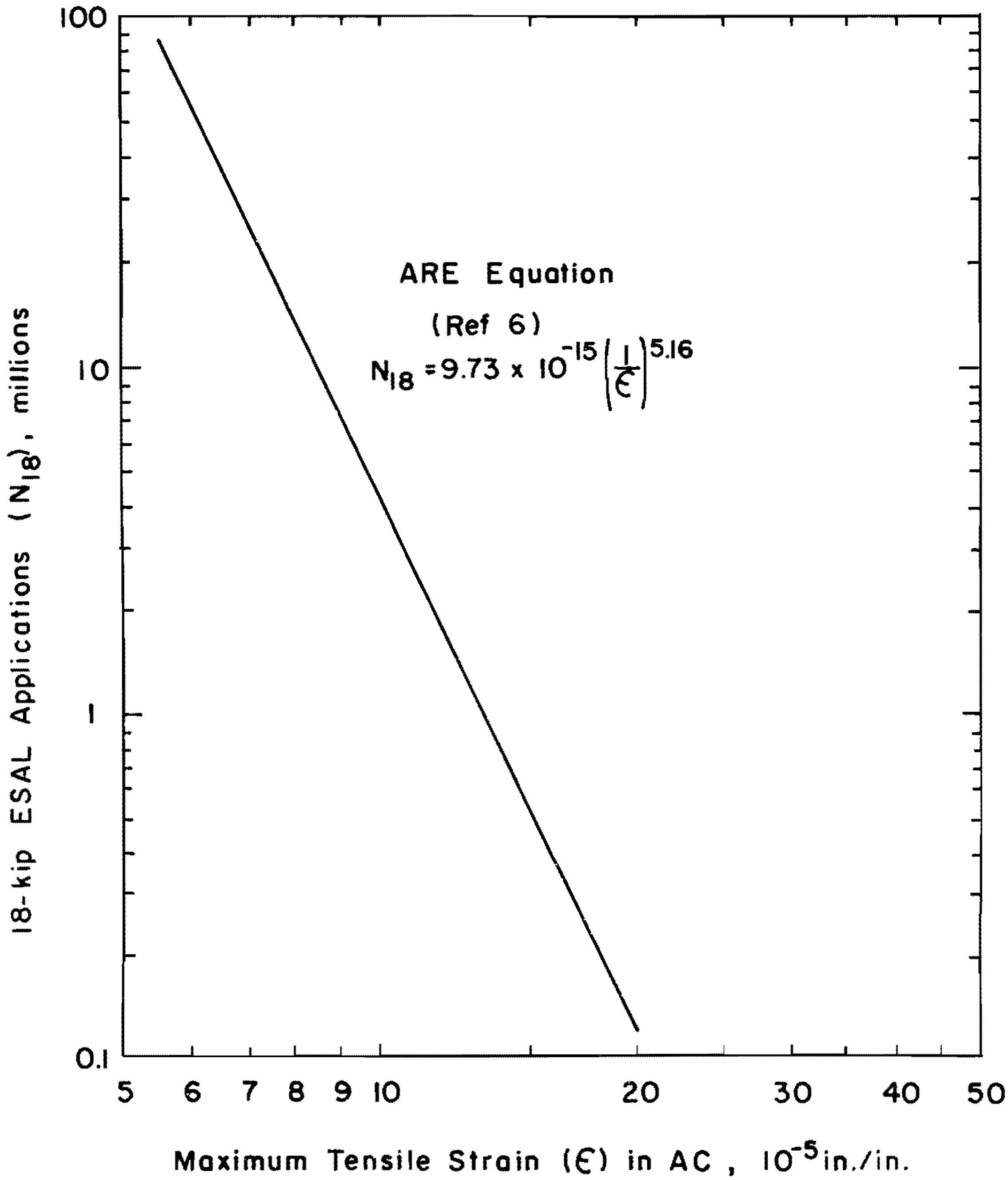


Fig 4.9. AC fatigue equation used in RPRDS-1.

TABLE 4.1. CHARACTERISTICS OF THE AASHO ROAD TEST FLEXIBLE SECTIONS WHICH WERE USED IN THE DEVELOPMENT OF THE AC FATIGUE EQUATION

Layer	Elastic Modulus, psi	Poisson's Ratio	Range of Thickness, in.
AC Surface	460,000	.30	1 - 6
Base	40,000	.40	0 - 9
Subbase	20,000	.40	0 - 16
Subgrade	5,000	.45	Semi-infinite in all cases

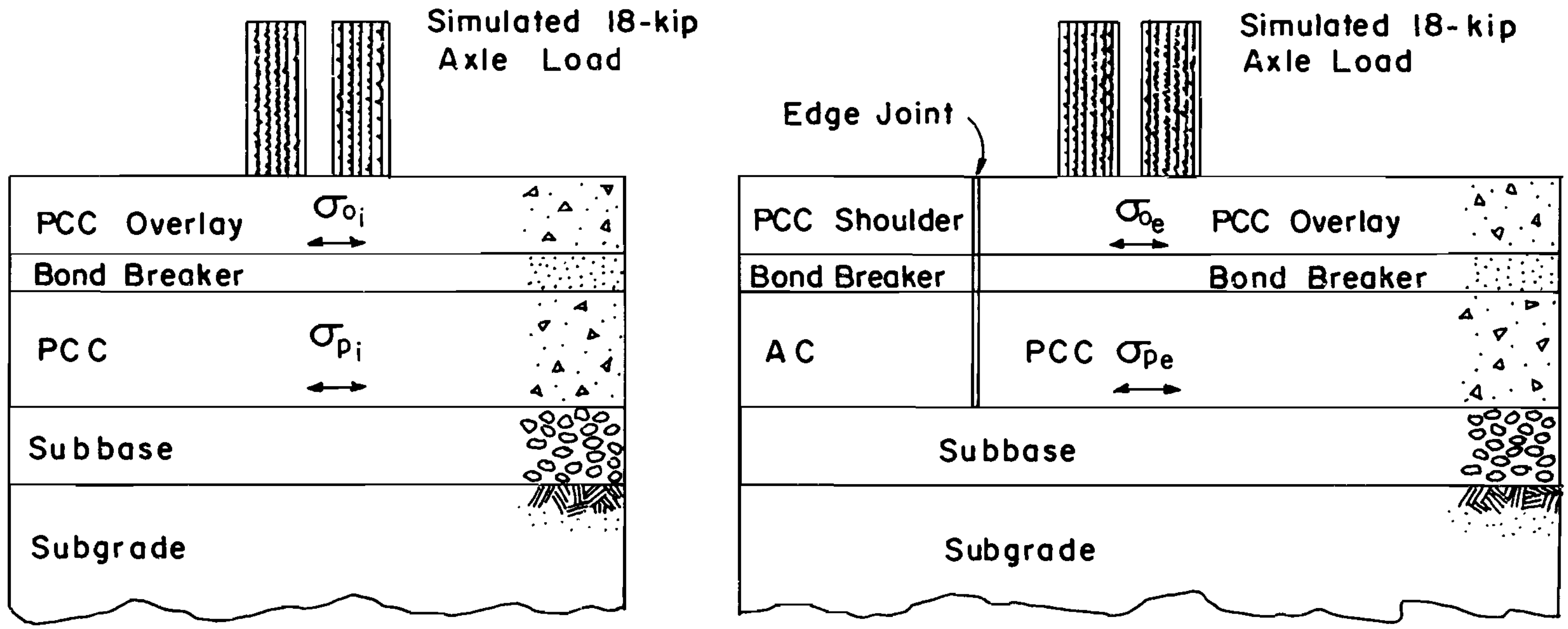
There are several computer models which use finite-element theory to solve engineering problems and the one used in this study is similar to most. It is called SAP-2 (Static Analysis Program - Version 2) and was developed at the University of California at Berkeley (Ref 40). Some thought was also given to using the discrete-element method incorporated into SLAB49 (Refs 41 and 42) as used in the development of the original design procedure (Ref 1), but it was rejected since SLAB49 is basically for a single slab PCC pavement and can not consider multiple overlays.

The approach used to develop a set of adjustment factors to account for pavement discontinuities was to (1) run SAP-2 to determine the response for an interior slab condition (this is similar to the elastic layer response due to differences in modelling the load and the subgrade), then (2) run SAP-2 for the critical loading condition (near the pavement edge or corner) to determine the critical response, and finally, (3) calculate the adjustment factor by taking the ratio of the critical response to the interior response. This adjustment factor was then used to adjust the interior response predicted by elastic layer theory.

Figure 4.10 illustrates these different stresses in an unbonded PCC overlay on an existing PCC pavement. Figure 4.10a shows the interior tensile stresses developed in the overlay and existing pavement due to a simulated 18-kip axle load. Figure 4.10b illustrates the edge stresses in both PCC layers for the case when there is a PCC shoulder. The critical stress factors for both PCC layers, in this case, are simply the ratio of the edge stress to the interior stress:

For the original PCC pavement,

$$C_P = \sigma_{P_e} / \sigma_{P_i} , \qquad (4.7)$$



(a) interior condition

(b) edge condition (with PCC shoulder)

Fig 4.10. Illustration of interior and edge stress conditions for one of the overlay strategies considered in RPRDS-1 (an existing PCC pavement with an unbonded PCC overlay with PCC shoulders). The ratio of edge to interior stress is used for adjusting stresses predicted by elastic layer theory.

and for the PCC overlay,

$$C_o = \sigma_{o_e} / \sigma_{o_i} \quad . \tag{4.8}$$

Figure 4.11 shows how the pavement structure in Fig 4.10b is modelled in SAP-2 to determine the interior and edge stresses. The figure also shows typical plan, front, and side views of the modal frame as well as the elements, loads, and boundary conditions which make up the model. It should be pointed out, also, that every advantage of symmetry is taken in modelling the structure. This is illustrated particularly in the side view of Fig 4.11 which represents half of the longitudinal profile of the structure. The other half is modelled without the additional elements and nodes (which increase computation time dramatically) by (1) fixing movement in or out of a transverse vertical plane in the structure under the load and (2) fixing the rotation about the transverse axes in the transverse vertical plane. Rotations are also fixed about vertical axes in the transverse vertical plane, as shown in Fig 4.11.

By varying some of the variables which affect the ratio of the critical to interior stresses the most (such as concrete, subgrade, and subbase stiffness), a range of critical to interior stress ratios can be determined. A summary of these ranges (as developed in this study) is provided in Table 6.3 of the RPRDS-1 User's Manual for all possible overlay combinations considered by RPRDS-1. Some guidelines for selecting the appropriate stress factors are also provided in the User's Manual.

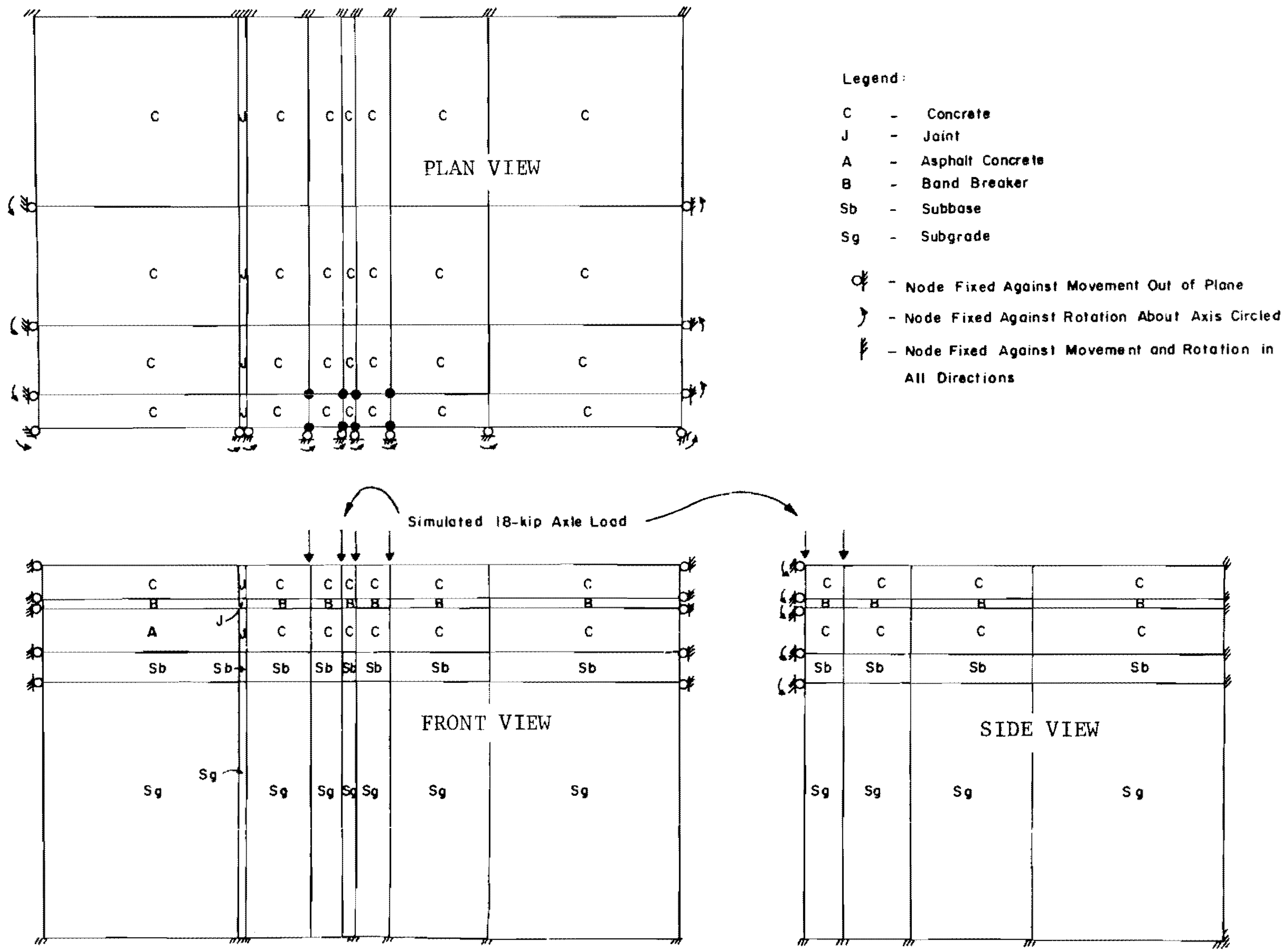


Fig 4.11. Illustration of pavement model used in SAP-2 to predict stresses for the pavement structure shown in Fig 4.10.

Year Corresponding to Cumulative Traffic

This section describes how RPRDS-1 computes the year (relative to year zero of the analysis period) corresponding to some cumulative 18-kip ESAL traffic. This model is used to estimate the approximate year of overlay placement and the year in which a strategy will "fail." This model is contained within the YEAR routine in RPRDS-1 and is illustrated in Fig 4.12.

Basically, the equation used by the Texas State Department of Highways and Public Transportation to compute the average daily traffic (ADT) at some future year is used here to compute the future year given the cumulative traffic. The equation for the future traffic is

$$W_i = W_0 (1 + iG) \tag{4.9}$$

where

W_i = yearly traffic in i^{th} year,

W_0 = initial yearly traffic,

i = future year, and

G = traffic growth rate (expressed as a fraction).

The total cumulative traffic, W, in year i, may be expressed by the summation of W_j as j goes from 1 to i. Then by replacing the summation with an equivalent mathematical expression, Eq 4.9 can be rearranged to give the year corresponding to the cumulative traffic:

$$i = \frac{-2 - G + \sqrt{(2 + G)^2 + 8GW/W_0}}{2G} \tag{4.10}$$

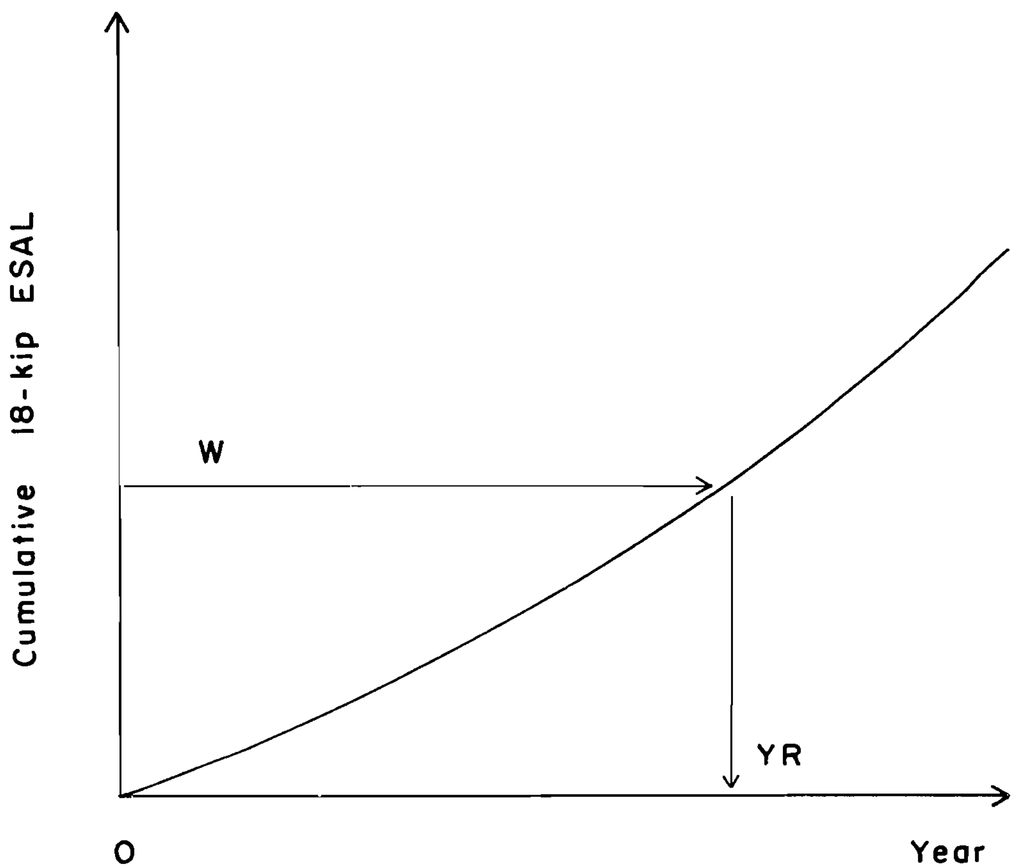


Fig 4.12. Illustration of how the year (YR) corresponding to some future cumulative 18-kip ESAL traffic (W) is determined.

This equation cannot be solved, however, if the traffic growth rate, G, is equal to zero. In this case, the following equation is used:

$$i = W/W_0 \tag{4.11}$$

SUMMARY

As pointed out earlier, the purpose of this chapter is to describe how feasible overlay design strategies are generated in RPRDS-1. Now that the components of the routine (STRTGY) used to generate these feasible strategies have been discussed, it is useful to provide a brief summary of how these components fit together.

First of all, it is necessary to generate a candidate strategy, keeping in mind some of the constraints on overlay thickness. To do this, certain cumulative 18-kip ESAL applications must be obtained: (1) the traffic from year zero to the time of overlay placement and (2) the traffic from year zero to the time of overlay failure. These 18-kip ESAL traffic values are determined by first combining the results of layer theory and the finite element analyses to predict the required critical responses. These critical responses are then used in conjunction with the fatigue equations and the fatigue life prediction models to obtain the 18-kip ESAL traffic values.

Next, the years corresponding to these 18-kip ESAL traffic values are determined (using the YEAR routine), so that a check for feasibility can be made using the remaining time constraints. If the candidate strategy meets these remaining constraints, it is stored as a feasible strategy for later cost analysis and optimization.

CHAPTER 5. COST ANALYSIS OF EACH FEASIBLE STRATEGY

The purpose of this chapter is to provide a description of how the individual and total costs for each feasible overlay design strategy are determined. The structure of the routine, COSTRY, within the RPRDS-1 program which performs this analysis is so simple that a detailed flowchart of the routine is not warranted. Figure 2.2 and 5.1 should provide the reader a good idea of what the individual costs are as well as the order in which they are determined.

Inspection of Fig 5.1 shows that there are several different cost submodels required to estimate the component costs of each strategy. These components include traffic delay cost (associated with overlay construction), overlay construction cost, distress/maintenance cost, value of extended life (beyond the end of the analysis period), and salvage value. The latter two are actually negative costs since they represent a future return on the investment made in a particular rehabilitation strategy.

Each of these cost submodels, along with the method for determining net present value and the method of optimization, is discussed below.

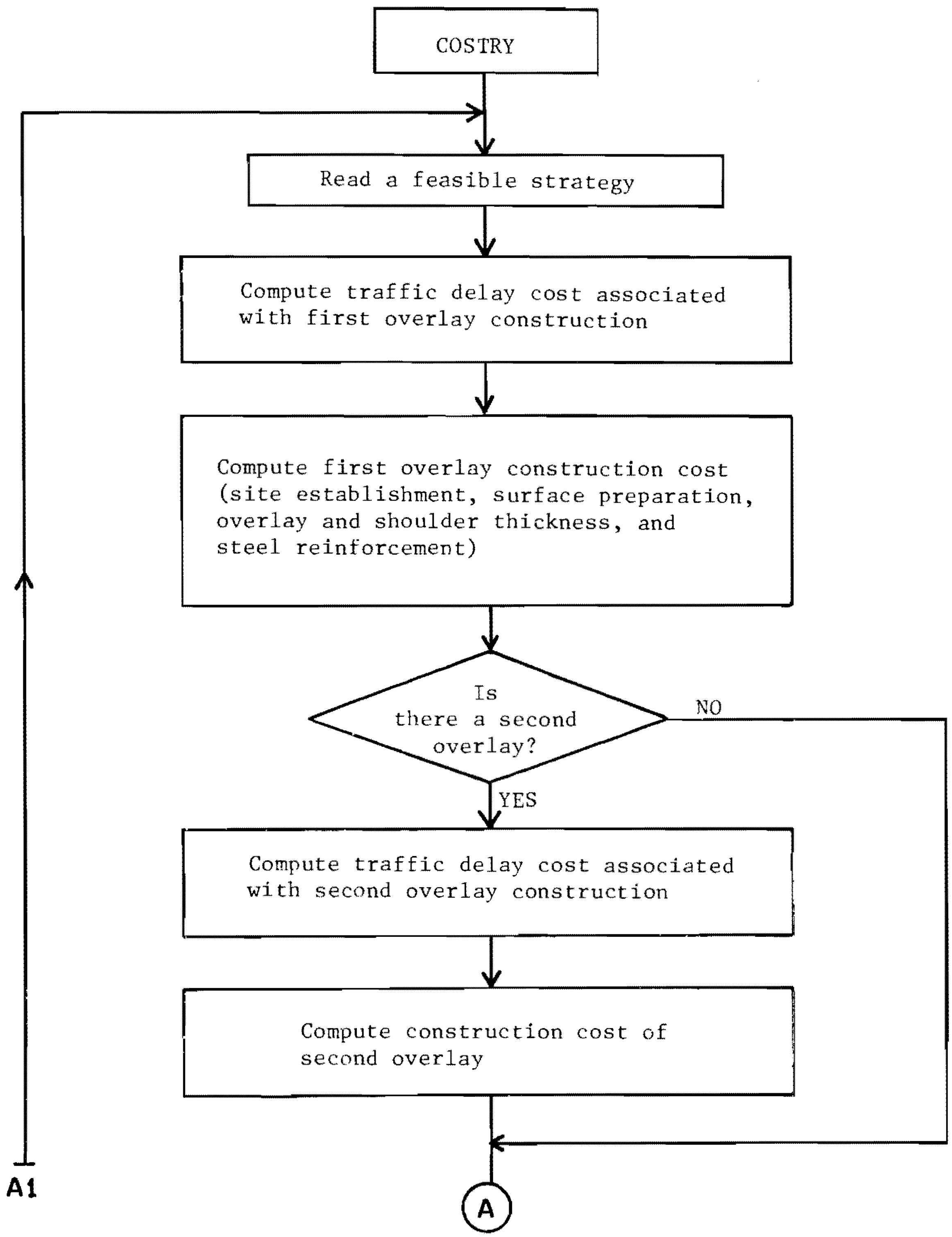


Fig 5.1. General flowchart of the cost analysis, COSTRY, routine.

(Continued)

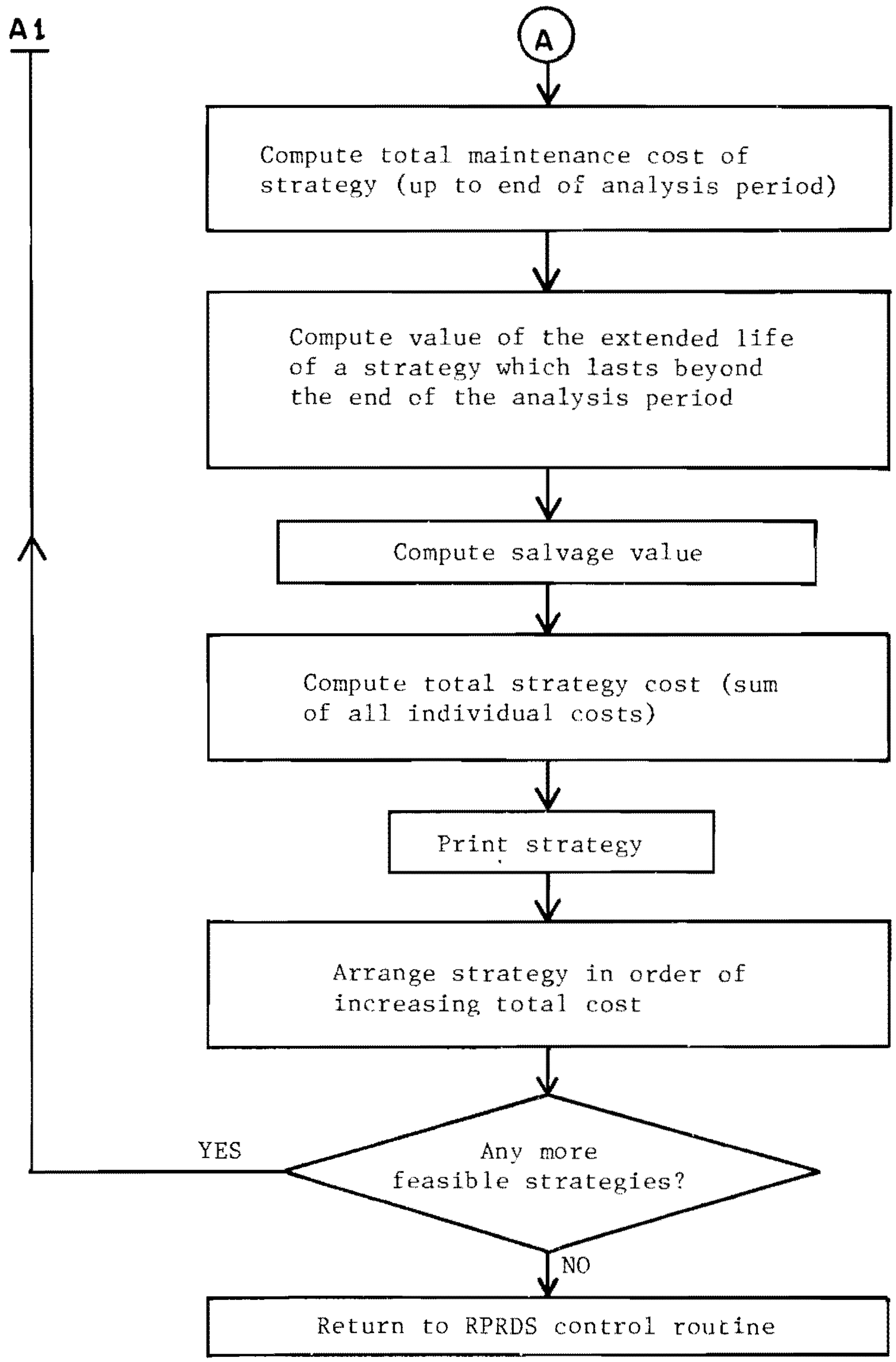


Fig 5.1. (Continued).

TRAFFIC DELAY COST SUBMODEL

This model was originally developed by Scrivner, Moore, McFarland, and Carey (Ref 12). It has been continually updated and modified with each version of the Rigid Pavement System, RPS. Carmichael (Ref 7) made the most significant improvement, in 1974, while Daniel (Ref 43) has provided the most up-to-date user delay costs (1978) for Texas conditions. With the exception of some minor changes to incorporate the routine into the framework of RPRDS-1, the traffic delay cost routine (TDCSY) is the same as that used by Daniel. Since the development of this routine is well documented in these previous studies, only a cursory description of its method of predicting costs is presented here. A detailed description of the inputs required by the model is, however, provided in Chapter 6, the RPRDS-1 User's Manual.

Basically, the model first predicts the delay times incurred by each vehicle as it passes through the restricted overlay zone. Daily distributions of traffic for rural and urban areas of Texas, as well as the incremental user delay costs per unit time, are built into the routine. These, along with the user-specified traffic volumes and periods during which the delays will occur, are used to determine the total overall traffic delay cost. The cost is then converted to a per square yard basis and is brought back to net present value using the PRVAL routine discussed later in this chapter.

It should be pointed out, also, that the routine is capable of predicting what the vehicle delay times are, so long as the user provides information regarding traffic volume, overlay construction rate, detour models, and traffic speed profiles through the restricted zone. Once again, Chapter 6 discusses in detail the selection of these inputs required by the model.

OVERLAY CONSTRUCTION COST SUBMODEL

The cost of overlay construction can be broken down further into four categories, site establishment cost, pavement surface preparation cost, overlay and shoulder thickness, and steel reinforcement. Each is determined on a per square yard basis and numerically summed to give the total overlay construction cost. The submodel which estimates these costs is incorporated directly into the COSTRY routine. A description of how each of these costs is determined is provided next.

Site-Establishment Cost

This refers to the cost of mobilizing the men and equipment necessary to perform the overlay construction. It does not include the cost of right-of-way or any other cost which is not dependent on the type of overlay to be constructed. Since RPRDS-1 predicts costs on a per square yard basis, the value of this cost is divided by the total pavement area in the project before summation.

Surface-Preparation Cost

This refers to the cost of any cleaning and milling which must be performed on an existing surface prior to overlay. It is entered on a per square yard basis and is therefore ready for immediate summation.

Overlay and Shoulder Thickness Cost

First of all, the cost of shoulder construction is included in RPRDS-1 since the capability exists for considering the effect of a PCC shoulder (in lieu of a flexible or ACP shoulder) on the overlay strategy's fatigue life. The calculation of the shoulder construction cost is handled in the same way as that of the overlay thickness cost; that is, the cost of a certain thickness of overlay (or shoulder) consists of a fixed cost (dollars per square yard) and a variable cost (dollars per square yard per inch of thickness).

The fixed cost takes care of the cost of any traffic detour arrangements which need to be made and the cost of machinery and manpower required to perform the actual construction. Examples of the latter include the cost of vibrating and surface finishing for PCC overlays, and compaction, rolling, and surface finishing for ACP overlays. The units of fixed cost are dollars per square yard.

The variable cost accounts for the differences in thickness between different overlay strategies. Consequently, the units of variable cost are dollars per square yard per inch.

In addition to the thickness cost, the construction cost submodel also considers the increased volume of material required for level-up and the cost of bond breaker placement for unbonded PCC overlay strategies.

Steel Reinforcement Cost Submodel

Unlike the Rigid Pavement System, RPS (discussed earlier), RPRDS-1 does not use a sophisticated model for the prediction of the steel reinforcement percentages required by PCC pavements. Instead, it must rely on the designer's empirical estimates of the steel percentages required for the different overlay types.

There are two reasons why RPRDS-1 must use this simple method. The first is that the design here is for PCC overlays, a case where the method used in RPS (for new PCC pavements) is not applicable. The second, and more important, reason is that existing models for the design of reinforcement in PCC overlays are not at the stage where they can be easily incorporated into a design system. In any case, the method used here is more than adequate for use in the cost estimates. It is the responsibility of the user or designer to determine the required steel design in the event that a PCC overlay strategy is selected.

Basically, the steel percentages selected by the user (which should include transverse as well as longitudinal steel) are used to estimate the volume and weight of steel in a square yard of overlay. The cost per square yard is then calculated by multiplying the weight of steel per square yard by the cost per pound of steel, another user input.

DISTRESS/MAINTENANCE COST SUBMODEL

The purpose of this section is to describe how maintenance costs are predicted in RPRDS-1. Due to the interaction between the occurrence of pavement distress and the need for maintenance, some discussion is also provided on distress prediction. Also, since distress and maintenance are so confounded, it should be pointed out that the two are combined and considered simultaneously in RPRDS-1 in the MNTCST routine.

This submodel was developed in this study on the basis of an analysis by Taute (Ref 31) of a statewide condition survey of CRC pavements in Texas (Ref 44). As a result, it is largely exogenous and requires a lot of user input on the rates of distress occurrence during different stages of a pavement's life. Fortunately, however, this approach is general enough to allow for future improvements in the areas of distress prediction.

Method for Calculating Maintenance Costs

The mechanics of the model are simple. The user first defines the rate of distress occurrence and the cost for a single repair on the existing pavement. Then for each overlay type considered the user must specify (1) the cost of repairing a typical distress manifestation (or defect) which may occur, (2) the rates at which these defects occur during two stages of the fatigue life of the overlay, and (3) the rates of defect occurrence for any number of years (after the end of the fatigue life) the user wishes to consider to extend the life of a given overlay strategy (these additional years considered represent a period of heavy maintenance). With this information, the program will increment its way through the life of a strategy, multiplying the number of defects which occur during a given year by the cost of repairing them and then bringing them back to net present value. Then, when the end of the anaysis period is reached, these yearly costs are accumulated to give the maintenance costs for the existing pavement and overlay(s), as well as the total maintenance cost of the strategy. Note here that, since the costs are computed after every year, there is an inherent assumption that maintenance will occur after every year. This is not a bad assumption, however, since it is only used to compute the present value of any future maintenance costs. If maintenance does occur less often, the error may be considered negligible, especially in view of the fact that the error in distress prediction may be much more significant.

Distress Prediction

As pointed out earlier, the basis of the distress/maintenance cost submodel is a statewide condition survey of CRC pavements in Texas (Ref 44). In an analysis of this data performed by Taute (Ref 31), a pattern of distress development in these CRC pavements was observed. This pattern is illustrated in the graph shown in Fig 5.2. The vertical axis represents the total number of defects (i.e., punchouts or patches) which may occur in a typical mile of CRCP and the horizontal axis represents a normalized scale of the predicted fatigue life of that CRCP. As can be seen, no defects occur between 0 and 20 percent of the fatigue life, while they occur at a rate of one per mile per year between 20 and 60 percent and at a rate of 2 per mile per year between 60 and 100 percent of the pavement's fatigue life. Obviously, since these distress levels are low, the corresponding maintenance costs will be low. But, as the pavement is subjected to traffic beyond the end of its predicted fatigue life, its distress will increase dramatically. The geometric progression which was observed in the survey data is also shown in Fig 5.2. This section of the CRCP distress curve corresponds to a period of heavy maintenance which the user may want to consider to allow a certain design strategy to last the analysis period.

Before concluding this discussion of distress and maintenance, there is one important point which should be considered by the user when using the model; the data obtained from the Texas condition survey were from existing

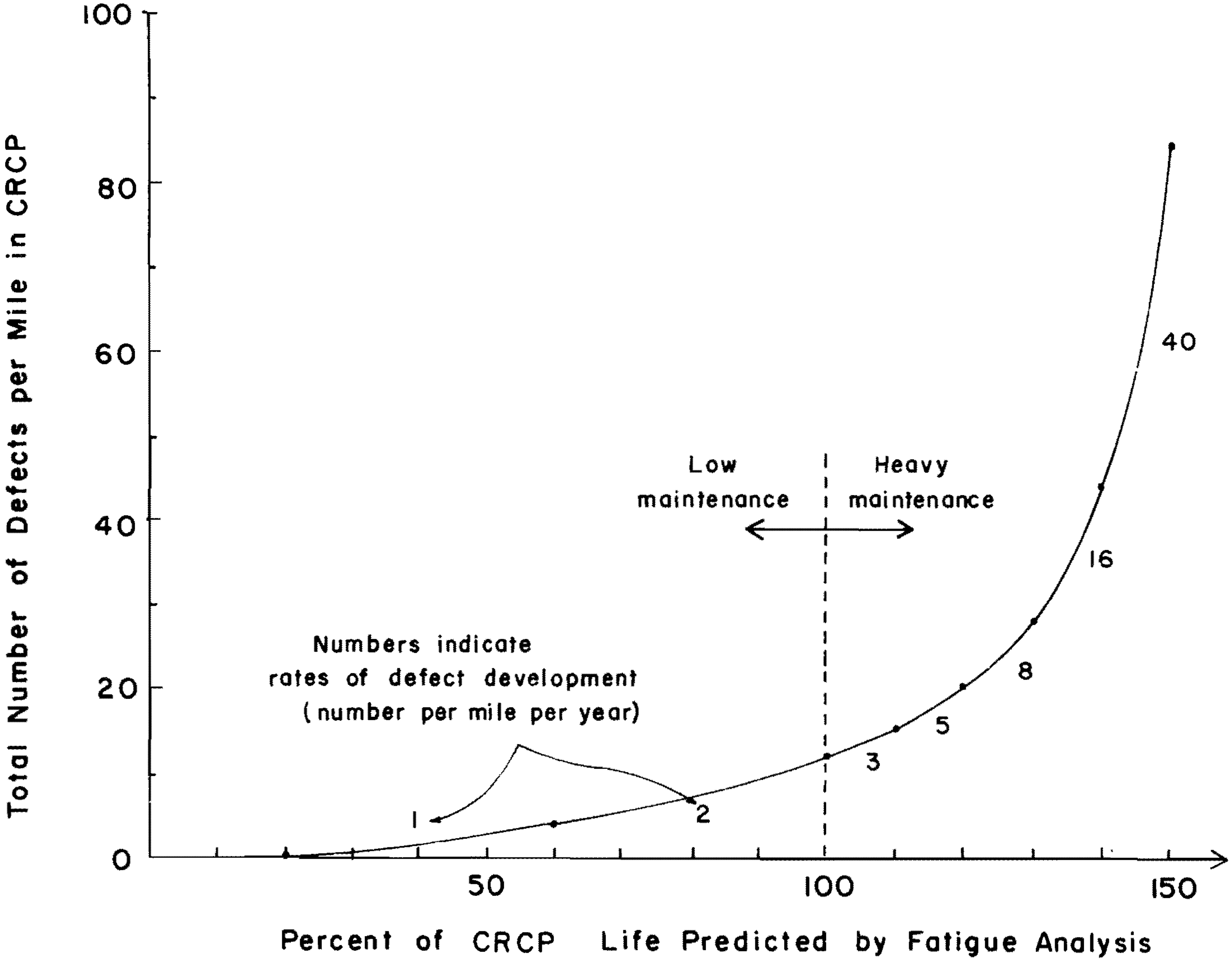


Fig 5.2. Normalized graph of the development of CRCP defects in Texas.

CRC pavements only. This means that there is some question as to the validity of applying these results to CRCP overlays of rigid pavements. Hopefully, this and the two other reports (Refs 31 and 44) will provide the user enough background to aid in the selection of appropriate values for both CRCP overlays and ACP overlays on CRCP. Unfortunately, no background can be provided here for JCP overlays or ACP overlays on JCP.

VALUE OF EXTENDED LIFE

This quantity represents a future return (negative cost) resulting from the additional years of service past the end of the analysis period that some strategies will provide due to the fact that they are "over-designs." This is different from salvage value and comes about because of the nature of the input thicknesses in RPRDS-1. While one overlay thickness strategy may not last the analysis period, the next overlay strategy, which may be only one inch thicker, may last an additional five to ten years depending on the traffic. Obviously, it is not reasonable to eliminate these strategies from consideration (since the cost of the additional inch of thickness may be small) nor is it fair not to consider the value of these additional years of service.

Consequently, provision is made in RPRDS-1 for the user to assign some value (on a per square yard basis) to each additional year of service. These values are brought back to present value using the combined interest and inflation rate model discussed later.

The RPRDS-1 User's Manual in Chapter 6 will provide the user some guidance in the selection of the value of extended life. It should be noted here, however, that some consideration should be given to (1) the fact that there is greater uncertainty in costs and traffic in the years past the analysis period, (2) the fact that maintenance costs were not computed for these additional years of service, and (3) the fact that salvage value is computed at the year the pavement reaches the end of its life and not at the end of the analysis period.

SALVAGE VALUE

This is another quantity that represents future return (negative cost). It accounts for the value of the overlay structure after it reaches the end of its life. Note (as pointed out earlier) that this does not necessarily correspond to the end of the analysis period since some strategies may last significantly longer.

Salvage value is computed by multiplying the total cost of overlay construction (in dollars per square yard) by a percentage specified by the user and once again returning this value to net present value. Note here that only the value of overlay construction cost is considered. (Original pavement construction cost need not be considered since it would be the same for all strategies.)

NET PRESENT VALUE

This submodel is used to account for the time value of money, namely, inflation and the opportunity cost of capital (prime interest). Ideally, the present value of some inflated future cost can be determined by first determining what the future cost would be due to inflation and then calculating the amount of money that should be invested now to accrue interest and pay for that future cost. This can be done using specified values of interest and inflation, but, since these tend to fluctuate over the years, a better approach would be to use the difference between the two rates to compute net present value. There seems to be a little more stability in this value and the mathematical error in using it is negligible (a second order term is not considered). The expression for computing net present value using this method is shown below:

$$NPV = PC/(1 + d)^n \quad (5.1)$$

where

NPV = net present value,

PC = present cost,

d = difference between interest and inflation (expressed as a fraction), and

n = year in which the future cost is incurred.

Generally, the opportunity cost of capital (prime interest) is greater than inflation. Therefore, the net present value of a future cost for some item is less than today's cost for the same item. Consequently, there is a tendency for future rehabilitation strategies to be more optimal than early strategies when there is a large difference between prime interest rate and the rate of inflation. The offsetting factor for overlay construction, however, is that the overlay required at some future date may be considerably thicker and, therefore, much more expensive than an overlay constructed at an earlier date.

METHOD OF OPTIMIZATION

The method of optimization used in RPRDS-1 is very simple and the same as that used in other pavement design systems. Basically, RPRDS-1 will order the top 20 strategies (ORDER routine) in order of increasing net present value. Then after all feasible strategies are printed, these top 20 are printed in an easily readable form (OUT20 routine).

SUMMARY

This chapter was intended to provide a brief but concise description of how the individual and total costs for each strategy are determined. Hopefully, this has been accomplished. Summarizing, each individual cost is computed on a per square yard basis and brought back to net present value before summing to get total strategy cost. Then, each of the strategy's individual costs is printed in the program's output to give the user an idea of what the major constituents of the total costs are.

CHAPTER 6. RPRDS-1 USER'S MANUAL

The overall objective of this report is to develop a design system for rigid pavement rehabilitation by combining the Texas SDHPT Rigid Pavement Overlay Design (RPOD) procedure (Refs 9 and 31) developed initially for the Federal Highway Administration by Austin Research Engineers, Inc. (Ref 1) and some other design and cost models into a computer program, RPRDS-1, which could economically analyze a large number of feasible overlay design strategies. Chapters 1 through 5 have discussed in detail, the individual models and their development, improvement and incorporation into the first version of the rigid pavement rehabilitation design system, RPRDS-1. The purpose of Chapter 6, then, is to provide the user of the RPRDS-1 computer program a detailed description of how to use the program and how to interpret its results. Accordingly, guidelines for the selection of the inputs required (as well as some description of how the inputs are treated) will be presented. Then, in order to both illustrate the capabilities of the program and to discuss its output, a sample problem (complete with output from a single run) is presented.

Before beginning the description of the inputs, however, it is first useful to briefly discuss the most recent version of Texas SDHPT RPOD procedure since many of the same inputs are required by RPRDS-1.

TEXAS SDHPT RPOD PROCEDURE

The significant steps of this procedure are illustrated in the flow diagram shown in Fig 6.1. A short discussion of each of these is provided below. They are not, however, intended to replace the reports referenced earlier.

Step 1: Select the design criteria. This includes 18-kip equivalent single axle load (ESAL) traffic estimates (past and projected), lane and directional distribution factors, overlay and shoulder types to be considered, available aggregates, bond breaker criteria, construction methods, geometric constraints, and any other criteria which constrain the overlay design.

Step 2: Conduct condition survey of the pavement in order to classify and quantify the cracking and other distress modes observed. The soil type in the area should also be inspected and classified.

Step 3: Gather Dynaflect deflection data at approximately 100-foot intervals along the length of the project. Readings should be taken from all five sensors and the data should distinguish between measurements made at midslab and those made at discontinuities such as joints or cracks.

Step 4: Select design sections. This is done be analyzing the Dynaflect deflection profiles where the sensor 5 and the difference between sensor 1 and sensor 5 are plotted for each longitudinal Dynaflect measurement. Figure 6.2 provides an

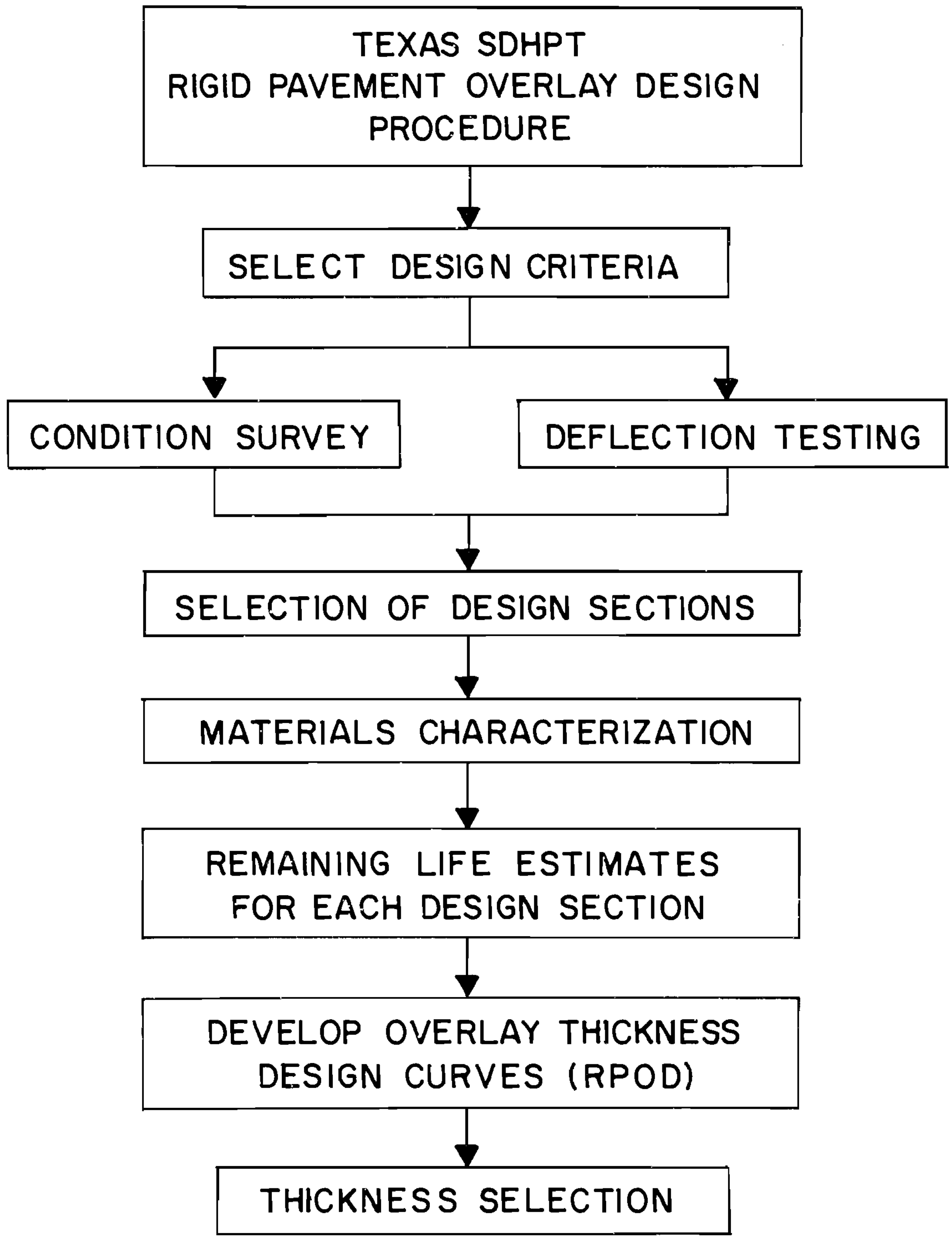


Fig 6.1. Flowchart of the Texas SDHPT Rigid Pavement Overlay Design procedure (Ref 31).

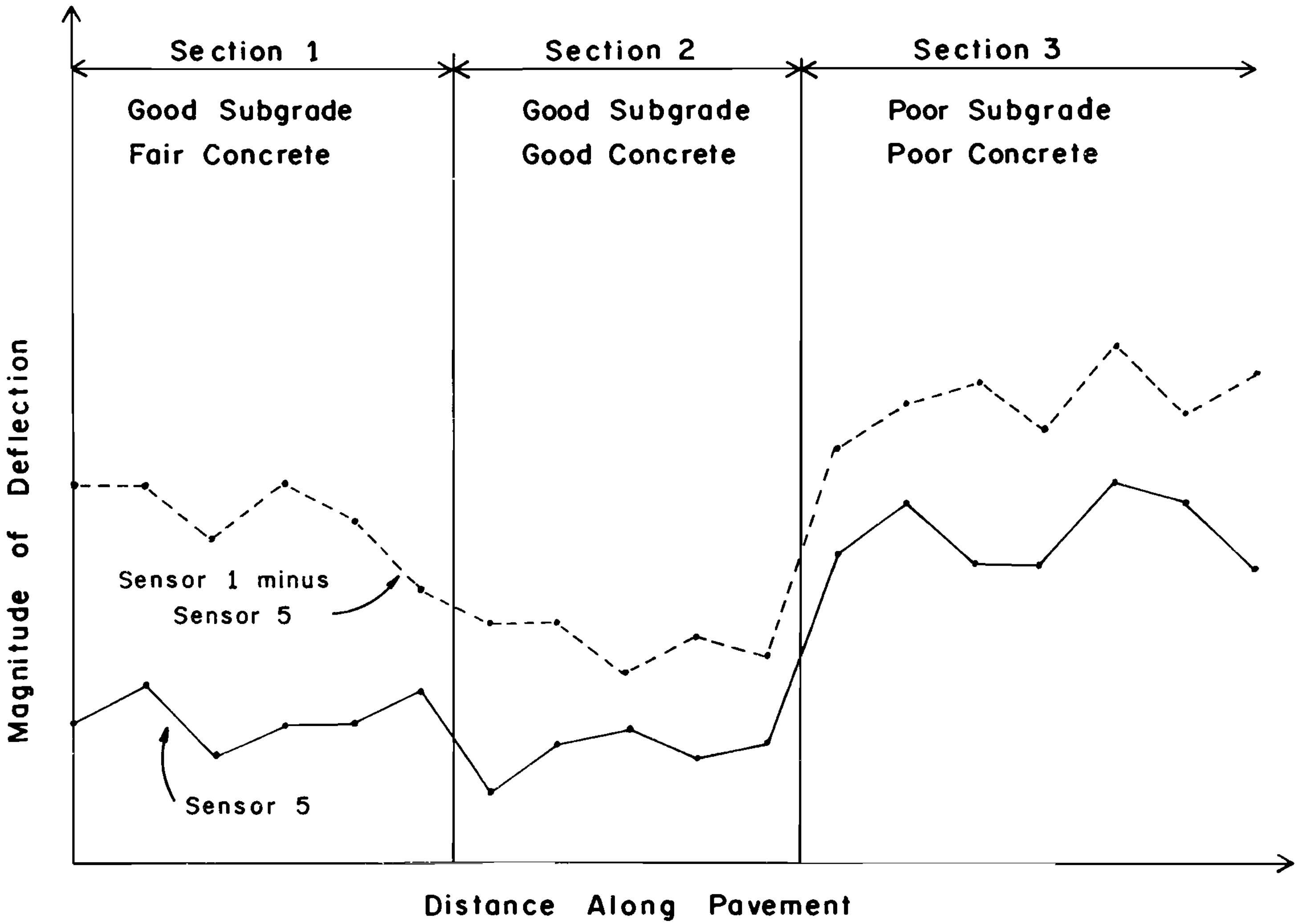


Fig 6.2. Deflection profile illustrating the procedure for selecting overlay design sections.

ideal illustration of how the sections are divided. Keep in mind that the sensor 5 reading is indicative of the variation of subgrade stiffness while sensor 1 minus sensor 5 indicates the variation of stiffness in the stronger pavement layers (particularly the concrete).

Step 5: Characterize the material properties of the pavement and subgrade, i.e., concrete flexural strength and the elastic properties for all layers in each section. This should be done by a combination of lab testing (i.e., indirect tensile tests on portland cement concrete and other bound layers and resilient modulus tests on subgrade and base materials) and Dynaflect deflection basin fitting (e.g., for a design Dynaflect deflection basin in each section, select elastic material properties of each layer which correspond to the best "fitted" basin predicted by elastic layer theory. Results of the lab tests should be used to home in on the solution). Adjustments to these layer moduli should then be made for stress sensitivity (since the design axle load is much heavier than the Dynaflect load) and predicted temperature conditions.

Step 6: Estimate the fraction of remaining life left in the existing pavement for each design section. This is obtained from estimates of the life of the existing pavement, past traffic estimates (Step 1), existing pavement condition (Step 2), and subgrade strength (Step 5).

Step 7: Use the rigid pavement overlay design (RPOD-2) computer model to generate overlay thickness designs for each design section. Note that several design curves may be generated for a particular design section due to the range in acceptable design criteria.

Step 8: Select the overlay thickness required for each design section using the design future traffic and the design curves generated in Step 7. If alternative designs exist, the optimum should be selected based on projected cost and performance comparisons.

Note that the last sentence in Step 8 describes the need to compare alternative overlay design strategies, which is the purpose of RPRDS-1.

DESCRIPTION OF RPRDS-1 INPUT VARIABLES

The inputs to RPRDS-1 have been divided into 11 broad categories for ease of description. These eleven categories include

(1) Project Description,
(2) Original Pavement,
(3) Traffic Variables,
(4) Time Constraints,
(5) Remaining Life Variables,
(6) Overlay Characteristics,
(7) Overlay Construction Cost Variables,
(8) Traffic Delay Cost Variables,
(9) Distress/Maintenance Cost Variables,
(10) Cost Returns, and
(11) Combined Interest and Inflation Rate.

For each of these headings, one or more data cards is required. Each separate input variable is assigned a number which corresponds to the order of the card on which it is placed and its order on the card. For example, the directional distribution factor, which falls under the category of Traffic Variables, is the fifth variable on the ninth card in the data, and, therefore, it is identified by the number 9.5. This method of classification will be adhered to in the later discussion of each variable.

The inputs required for a single problem are contained within 60 data cards (plus one to terminate program execution). The input guide which identifies the input field and the location of each variable in the data set is presented in Appendix D. It does not provide the detailed description of each variable that is presented here.

Project Description

1.1 Title Card. This card should provide information regarding the type, location, and date of the project, as well as the name or initials of the program user.

Original Pavement

The following cards are for the identification and description of the original pavement structure.

2.1 Surface Type. This variable identifies the type of existing pavement surface, either CRCP or JCP. This variable is used as part of a check which keeps a bonded CRCP overlay from being placed on an existing JCP or a bonded JCP overlay from being placed on an existing CRCP. Note also that the program cannot handle an existing overlay unless it is considered as part of an overlay design strategy. In other words, the variable must define the type of original concrete surface.

2.2 Concrete Shoulder. This variable acts as a switch on which PCC fatigue equation (see Chapter 4) to use to predict the fatigue life (number of 18-kip ESAL cycles to loss of pavement load-carrying capacity) of the existing pavement. An existing rigid pavement with a concrete shoulder is in a much better moisture environment than one without a concrete shoulder. The specification of an existing concrete shoulder, then, allows the program to account for its lower rate of deterioration by using the PCC fatigue equation developed for these conditions.

2.3 Number of Pavement Lanes. This variable identifies the number of existing pavement lanes (in one direction). It is used primarily for estimating the quantity and area of overlay. It is also used in estimating traffic delay costs during overlay construction.

2.4 Number of Pavement Layers. This variable identifies the number of separate pavement layers (including subgrade) in the original pavement structure. For each layer, thicknesses and elastic properties (elastic modulus and Poisson's ratio) will be required for estimating pavement responses. A maximum of five existing layers may be considered.

3.1 Project Length. This variable defines the length of the project. It is used mainly to compute overlay quantities. Depending on the trade-offs between long and short projects, the project length may range from a one-half-mile section selected from Dynaflect profiles (see Step 4 of Texas SDHPT RPOD procedure) up to a 10-mile section which will require an overlay which is thicker overall (due to larger variations in the design data) but more consistent.

3.2 Lane Width. This variable defines the average width of the existing pavement lanes. It is also used to compute overlay quantities.

3.3 Total Shoulder Width. This variable is used primarily to compare the cost of flexible shoulder versus concrete shoulder construction at the time of overlay. Consequently, the total width refers to the width of shoulder (inside and out) which may be constructed with portland cement concrete in lieu of asphaltic concrete.

4.0 Pavement Thicknesses. This card may contain up to five values which represent the thicknesses of each pavement layer, including the subgrade. The thickness of the bottom layer is always assumed to be semi-infinite, and, therefore, it may be left blank. Note, too, that the bottom layer does not necessarily have to be subgrade; it can be some type of rigid base or bedrock below the subgrade. Bedrock should not normally be considered, however, since it has very little effect on the stresses and strains carried by the load-carrying layer.

The thicknesses of each layer should be determined from measurements of cores taken in the field. If this is not possible, initial construction specifications may be used.

5.0 Elastic Moduli. This card contains the elastic moduli of each of the layers which make up the pavement structure. Taute, McCullough, and Hudson (Ref 31) recommend a method of materials characterization which is a combination of lab testing and Dynaflect deflection basin fitting for estimating the elastic moduli of each layer. This was described briefly in

Step 5 of the Texas RPOD procedure earlier in this chapter, but the user should still refer to the reference for further detail.

These values are used to compute the remaining life of the existing pavement. Consequently, they should be representative of the pavement in an uncracked condition, (i.e., concrete modulus should be greater than 3,000,000 psi).

6.0 Poisson's Ratios. Like the elastic moduli, this value should be defined for each existing layer, including the subgrade. Since the variation of Poisson's ratio has little effect on the predicted responses, however, Table 6.1 may be used to select appropriate values according to material type.

7.1 Concrete Flexural Strength. This value should be representative of the existing pavement's flexural strength over the remaining years of its service life. Accordingly, it should be estimated from correlations with the concrete tensile strength determined from the indirect tensile test (Ref 9). Alternatively, it may be estimated from correlations with the concrete stiffness and aggregate type (Refs 37 and 38) or even from past records of the strength at construction.

The flexural strength entered is used in the PCC fatigue equations (Chapter 4) to estimate the additional number of 18-kip cycles that can be carried by the existing concrete pavement. This value should always be specified, but a value of 500 psi may be used if the existing pavement has less than 10 percent remaining life.

7.2 Critical Stress Factors. This value is also used in the PCC fatigue equations to estimate the additional life left in the existing pavement. It

TABLE 6.1 RECOMMENDED VALUES OF POISSON'S RATIO FOR DIFFERENT PAVEMENT MATERIALS

Material Type	Range of Poisson's Ratio
Portland cement concrete	.15 - .20
Asphaltic concrete	.25 - .35
Cement stabilized base	.20 - .30
Asphalt stabilized base	.25 - .35
Unbound granular base	.40
Granular subgrade	.40
Clayey or silty subgrades	.45

TABLE 6.2 EXISTING PAVEMENT CRITICAL STRESS FACTORS

Existing Pavement Type	Existing PCC Shoulders	Range of Critical Stress Factor
CRCP	No	1.20 - 1.25
	Yes	1.05 - 1.10
JCP (with load transfer)	No	1.25 - 1.30
	Yes	1.10 - 1.20
JCP (without load transfer	No	1.50 - 1.60
	Yes	1.40 - 1.50

represents the ratio of the critical stress to the interior stress in the existing pavement (Chapter 4). This value should always be specified, even if the existing pavement has no remaining life. Table 6.2 provides ranges of this value for different types of existing pavement. The low level for each category should be used if the results of the condition survey indicate that the existing pavement has performed well. Likewise, a high level should be used if poor performance has been observed.

7.3 Concrete Stiffness After Cracking. This value represents the elastic modulus of the existing PCC after it loses its load-carrying capacity. A value of 800,000 psi is recommended if the existing pavement is CRCP. A range of 300,000 to 500,000 psi is recommended for jointed pavements. The high level should be used normally, unless there is excessive pumping or a high joint to interior deflection ratio (greater than 1.5). It may also be necessary to use a lower value if severely distressed areas will not be repaired prior to overlay. This variable should not be left blank.

8.1 Number of Defects. This value is the number of defects (per mile) which are present in the existing pavement. This number is used to estimate the cost of repairs which are to be performed on the existing pavement prior to overlay. This number is not required if these repairs will not be performed or if they are not to be considered.

8.2 Repair Cost. This value should be the total cost for repairing a defect in the existing pavement. It is not required if repairs will not be made prior to overlay.

8.3 Rate of Defect Development. This value represents the rate of development of defects over the remainder of the service life of the existing pavement. It is used to compute the cost of repairs that will be performed to the existing pavement prior to some future overlay. A value recommended for CRC existing pavements is 2 per year per mile. Due to a lack of data, no recommendation is made for jointed pavements (see Chapter 5). This value is not required if no repairs are to be made prior to overlay.

Traffic Variables

The data on the following card relate to the traffic, both vehicle and truck, that is to be carried by the facility over the analysis period.

9.1 Average Daily Traffic. This value (ADT) should be the present average number of vehicles per day carried by the facility. It is used to predict the user delay cost associated with construction of some future overlay (see Chapter 5).

9.2 ADT Growth Rates. This value represents the yearly rate of growth of ADT. Note that a linear type growth is assumed, which is commensurate with Texas SDHPT practice.

9.3 Initial Yearly 18-kip ESAL. This value is the number of yearly 18-kip equivalent single axle loads (18-kip ESAL) presently being carried by the facility in both directions. This quantity is used to predict the life (in years) of a given rehabilitation strategy and is, therefore, always required.

9.4 18-kip ESAL Growth Rate. Like the ADT growth rate, this value is used to estimate traffic growth over the analysis period. In this case, however, it is used to project the growth of 18-kip ESAL, which may be different from the growth of ADT. Note, too, that if this value is left blank, zero growth is assumed.

9.5 Directional Distribution Factor. Certain highways, such as those near a seaport, have shown a marked difference in distribution of traffic in one direction from the other. Even though the vehicle distribution may be split evenly, there may be heavier trucks and, therefore, greater 18-kip equivalencies moving in one direction. The directional distribution factor, expressed as a percent of the total 18-kip ESAL traffic in both directions, is used to account for this possibility. Note that if this value is not 50 percent, then the optimum designs generated by RPRDS are only for the direction being considered.

9.6 Lane Distribution Factor. This factor accounts for the distribution of truck traffic across the facility (in one direction). Since most of the heavy traffic is carried by the inside lane, it is generally the "design" lane. The lane distribution factor then defines what percent of the 18-kip ESAL traffic is carried by the design lane. This factor usually has a value of 90 to 95 percent for four-lane facilities and may be as low as 70 percent for eight-lane facilities.

Time Constraints

10.1 Analysis Period. This constraint defines how many years (from the present) the user desires the facility to last (See Chapter 4). This value is generally 20 years.

10.2 Minimum Time Between Overlays. This constraint specifies the minimum number of years that can be allowed between two overlays. This value should not be greater than the analysis period. Also, if a second overlay will not be considered, this value is not required.

10.3 Maximum Number of Years of Heavy Maintenance. According to the relationship between the fatigue life and the rate of distress occurrence developed by Taute (Ref 31) and discussed in Chapter 4, it may be feasible to consider strategies which may require a period of heavy maintenance to last the analysis period. Accordingly, this value defines the maximum number of years of heavy maintenance (maximum of 10 years) the user may wish to consider to allow a strategy to last the analysis period. Note that for each additional year, distress increases rapidly, and therefore maintenance costs will increase correspondingly. It should also be noted that the user must provide data on these distress rates (in the Distress/Maintenance Cost Variables Section) for each additional year considered. Since, at this time, very little reliable data exist, the user may not consider this option until more data become available.

Remaining Life Variables

The remaining life data on these two cards are used to define specific times at which an overlay may be placed. Recall that remaining life corresponds to some level of damage in the surface (load-carrying) layer, and, consequently, remaining life is related to accumulated 18-kip ESAL traffic and a corresponding future year (see Chapter 4).

11.1 Number of Original Pavement Remaining Life Values. This number defines how many different values of remaining life of the original pavement at which the first overlay may be placed. This number should be at least one (otherwise an overlay will never be placed). This maximum limit on this number is 10.

11.2 Minimum Existing Pavement Remaining Life. Since it is not practical to bond a PCC overlay to an existing PCC pavement which has a very low level of remaining life (due to problems with reflection cracking), this constraint is provided. For user-specified values of remaining life below this value, bonded PCC overlays will not be considered. It does not affect ACP or unbonded PCC overlays. A practical range for this value is between 10 and 20 percent.

11.3 Original Pavement Remaining Life Values. These values of remaining life of the existing pavement identify points during the life of the original pavement at which the first overlay may be placed. Variable 11.1 defined how many of these values will be entered. They must be entered in order of decreasing magnitude and the first is assumed to correspond to year zero of the analysis period (Taute, Ref 31, provides some information on the relationship between remaining life and the level of distress observed in the existing pavement). It is suggested that these values be entered in increments of no less than 10 percent, with the last value equal to zero.

12.1 Number of First Overlay Remaining Life Values. This number is similar to that used in variable 11.1. It defines how many different values of remaining life in the first overlay at which the second overlay may be placed. The maximum limit is 10. This value should be zero if two-overlay strategies are not desired.

12.2 First Overlay Remaining Life Values. These values of remaining life of the first overlay identify points during the life of the pavement structure at which a second overlay may be placed. Variable 12.1 defines how many of these values will be entered. As in 11.3, they must be entered in order of decreasing magnitude. It is suggested that, for practical design problems where a second overlay is to be considered, the list of these values should begin with 70 percent and decrease in 10 percent increments. This card may be left blank if no two-overlay strategies are to be considered.

Overlay Characteristics

The information required for the following cards and variables is used to identify what types of overlay strategies are to be considered and to define the pertinent properties for each alternative (see Chapter 4).

13.0 Types of First Overlay. This card identifies the types of first overlay that are to be considered. Five different types are available: (1) ACP, (2) bonded CRCP, (3) unbonded CRCP, (4) bonded JCP, and (5) unbonded JCP. It should be pointed out that any or all may be considered in a single run.

In cases where the user is interested in comparing various type overlays where there is some uncertainty about the relative costs between the two, it is recommended that separate RPRDS-1 runs be made for the different overlay types. This will allow the user to compare optimum overlay strategies of the various types considered, keeping in mind their cost uncertainty.

14.0 Types of Second Overlay. This card identifies the types of second overlay that are to be considered. There are three different types available: (1) ACP, (2) CRCP, and (3) JCP. Note that for strategies where the second overlay is CRCP or JCP, the first overlay will always be ACP since

RPRDS-1 can only consider one PCC overlay during the analysis period. Also, this card may be left blank if no two-overlay strategies are to be considered.

15.1 Number of ACP First Overlay Thicknesses. This value defines how many different ACP first overlay thicknesses are due to be considered. A maximum of eight is allowed.

15.2 Number of ACP Second Overlay Thicknesses. RPRDS-1 allows the user to select a different set of thicknesses to use for the second ACP overlay. (This is useful, since the user may be constrained to one thickness for the first overlay). This value defines how many second ACP overlay thicknesses are to be considered. A maximum of eight is allowed.

15.3 Number of PCC Overlay Thicknesses. This value defines how many PCC thicknesses are to be considered. The thicknesses apply to both CRCP and JCP overlays, whether they make up the first overlay or the second overlay. A maximum of eight is allowed.

16.0 ACP First Overlay Thicknesses. This card identifies what ACP thicknesses (in inches) to use for the first overlay. The number of these different thicknesses is set in variable 15.1. These thicknesses should be entered in order of increasing magnitude. The first should be no less than 2 inches (a minimum for structural rehabilitation) and the largest thickness should be no greater than 8 inches. This card may be left blank if an ACP first overlay is not to be considered.

17.0 ACP Second Overlay Thicknesses. This card identifies what ACP thicknesses (in inches) to use for the second overlay. The number of these different thicknesses is set in variable 15.2. Once again, these thicknesses should be entered in order of increasing magnitude with the first no less than 2 inches and the last no greater than 8 inches. This card may be left blank if an ACP second overlay is not to be considered.

18.0 PCC Overlay Thicknesses. This card identifies what CRCP and/or JCP thicknesses (in inches) to use for either the first or second PCC overlay. The number of these different thicknesses is set in variable 15.3. These thicknesses should be entered in order of increasing magnitude, with the first no less than 5 inches (a minimum practical construction thickness). The maximum practical thickness is left up to the designer.

19.1 Allowable Total Overlay Thickness. This variable acts as a constraint on those two-overlay strategies in which the combined thickness of both overlays may be too large for bridge clearance (or some other similar factor). Consequently, those strategies in which the combined thickness is greater than this allowable will not be considered. This value should not be left blank if two-overlay strategies are to be considered.

19.2 Average Level-up Thickness. This value is used to compute the cost of the additional overlay thickness required for level-up. It has no effect on the fatigue life calculations or the constraint on total overlay thickness. Also, it is assumed that this value applies to both first and second overlays, regardless of type.

19.3 Bond Breaker Thickness. This variable is used in the fatigue life calculations for unbonded PCC overlays. A value of one inch is recommended. This value should not be left blank if an unbonded PCC overlay strategy is to be considered.

20.1 ACP Overlay Design Stiffness. This variable defines the ACP elastic modulus to use for pavement response calculations. Various methods are available for predicting what this value should be for given environmental conditions. Kasianchuk's traffic-weighted mean stiffness method (Ref 25) is recommended. The range on this value should be between 300,000 and 500,000 psi. A value of 400,000 psi is recommended for Texas conditions if no other data are available.

20.2 Poisson's Ratio, ACP Overlay. This variable is also used to predict pavement response. Its variation has very little effect on the predicted responses; however, it cannot be ignored. A value of 0.30 is recommended (see Table 6.2).

20.3 PCC Overlay Design Stiffness. This variable defines the elastic modulus of the portland cement concrete for both CRCP and JCP overlays. The variation of this value has a significant effect on the prediction of pavement response, and, therefore, it should be estimated with a good degree of accuracy. The factor which most affects this value is the type of aggregate used in the mix. If a crushed stone aggregate is used, this value is generally in the range of 4,000,000 to 5,000,000 psi. If a siliceous river gravel is used, this value will probably be in the range of 5,000,000 to 7,000,000 psi (Refs 37 and 38). The ACI equation (Ref 39),

$$Ec = 57000\sqrt{f'c}$$

where

Ec = concrete elastic modulus, psi, and

f'c = concrete compressive strength, psi,

may also be used to estimate the stiffness (elastic modulus) of the concrete if concrete compressive strengths are available.

<u>20.4 Poisson's Ratio, PCC Overlay.</u> This value is also used to predict pavement response. Like the Poisson's ratio for the ACP overlay, its variation has little effect on pavement response. Therefore, a value of 0.15 is recommended.

<u>20.5 Bond Breaker Stiffness.</u> A bond breaker is used for unbonded PCC overlays to help prevent reflection cracking. Consequently, a low stiffness asphaltic concrete layer is recommended for design (a value of 100,000 psi or lower).

<u>20.6 Poisson's Ratio, Bond Breaker.</u> Since this layer consists of a low stiffness asphaltic concrete, a value of 0.35 is recommended. Once again, its variation has little effect on the predicted pavement responses.

<u>21.1 Number of Overlay Flexural Strengths.</u> RPRDS-1 allows the designer to consider up to five different concrete flexural strengths in the various PCC overlay design strategies. An increased flexural strength may make a significant difference in the predicted life of a strategy, and, therefore, it may be worthy of consideration. It should be realized, however, that the concrete fatigue equations are based on a mean value measured at the AASHO Road Test, 690 psi, which limits the range of inference to between 600 and 800 psi. Also, since an increased cement content is necessary to achieve a

higher flexural strength, the designer must later input the cost associated with these different concrete strengths.

21.2 Number of Flexural Strength for Bonded PCC Overlays. Since the flexural strength of bonded PCC overlays has no effect on the fatigue life of those strategies, only one strength need be considered. Consequently, this number identifies which flexural strength in the list (of those to be considered in card 22.0) is to be used for a bonded PCC overlay. For example, if three flexural strengths are to be considered and the strength which would normally be used for a bonded PCC overlay is the second in the list, the user should enter a 2 for this variable.

22.0 PCC Overlay Flexural Strengths. These values should be entered in increasing order (in psi). As discussed under variable 21.1, the limits of flexural strength that may be considered is 600 to 800 psi. This card may be left blank if no PCC overlays are to be considered.

Pavement Stress Factors After Overlay

This section of overlay characteristics deals with the selection of stress factors (ratios of critical stress to interior slab stress) for all possible overlay combinations selected by the user. Though there may be several of these combinations, the selection of the appropriate stress factors for each is simple. Basically, all the user must do is refer to Table 6.3, which identifies the inputs required for cards 23 through 40. Each card represents a particular overlay combination where the critical stress to be computed is located in either the existing pavement or the PCC overlay. Most of these cards also allow the specification of a second stress

TABLE 6.3 CRITICAL STRESS FACTORS FOR THE VARIOUS EXISTING PAVEMENT-OVERLAY-SHOULDER COMBINATIONS CONSIDERED IN RPRDS-1.

Card/ Variable No.	First Overlay Type	Second Overlay Type	Location of Critical Stress	Overlay Shoulder Type	Ratio of Critical to Interior Stress	
					CRCP Existing Pavement	JCP Existing Pavement
23.1	ACP	none	Exist. Pavt.	ACP	1.20 - 1.30	1.40 - 1.50
24.1	ACP	CAP	Exist. Pavt.	ACP		
25.1	ACP	CRCP	Exist. Pavt.	ACP		
25.2	ACP	CRCP	Exist. Pavt.	CRCP		
26.1	ACP	CRCP	CRCP Overlay	ACP		
26.2	ACP	CRCP	CRCP Overlay	CRCP		
27.1	ACP	JCP	Exist. Pavt.	ACP		
27.2	ACP	JCP	Exist. Pavt.	JCP		
28.1	ACP	JCP	JCP Overlay	ACP		
28.2	ACP	JCP	JCP Overlay	JCP		
29.1	Bonded CRCP	none	Exist. Pavt.	ACP		
29.2	Bonded CRCP	none	Exist. Pavt.	CRCP		
30.1	Bonded CRCP	ACP	Exist. Pavt.	ACP		
30.2	Bonded CRCP	ACP	Exist. Pavt.	CRCP		
31.1	Bonded JCP	none	Exist. Pavt.	ACP		
31.2	Bonded JCP	none	Exist. Pavt.	JCP		
32.1	Bonded JCP	ACP	Exist. Pavt.	ACP		
32.2	Bonded JCP	ACP	Exist. Pavt.	JCP		
33.1	Unbonded CRCP	none	Exist. Pavt.	ACP		
33.2	Unbonded CRCP	none	Exist. Pavt.	CRCP		
34.1	Unbonded CRCP	none	CRCP Overlay	ACP		
34.2	Unbonded CRCP	none	CRCP Overlay	CRCP		
35.1	Unbonded CRCP	ACP	Exist. Pavt.	ACP		
35.2	Unbonded CRCP	ACP	Exist. Pavt.	CRCP		
36.1	Unbonded CRCP	ACP	CRCP Overlay	ACP		
36.2	Unbonded CRCP	ACP	CRCP Overlay	CRCP		
37.1	Unbonded JCP	none	Exist. Pavt.	ACP		
37.2	Unbonded JCP	none	Exist. Pavt.	JCP		

(continued)

TABLE 6.3 (Continued).

Card/ Variable No.	First Overlay Type	Second Overlay Type	Location of Critical Stress	Overlay Shoulder Type	Ratio of Critical to Interior Stress: CRCP Existing Pavement	Ratio of Critical to Interior Stress: JCP Existing Pavement
38.1	Unbonded JCP	none	JCP Overlay			
38.2	Unbonded JCP	none	JCP Overlay			
39.1	Unbonded JCP	ACP	Exist. Pavt.			
39.2	Unbonded JCP	ACP	Exist. Pavt.			
40.1	Unbonded JCP	ACP	JCP Overlay			
40.2	Unbonded JCP	ACP	JCP Overlay			

factor (for the same overlay combination) to simulate the effect of a PCC shoulder constructed along with the PCC overlay.

The user should use Table 6.3 to select the stress ratio required from the column corresponding to the type of existing pavement. Any stress factor left blank or specified to be zero will keep RPRDS-1 from considering the corresponding overlay strategy. This is an important point because an error of this type will probably go unnoticed since these strategies will appear to be infeasible in the RPRDS-1 program output. It is recommended, then, that the user pay close attention to selecting and recording these variables.

For a detailed description of how these stress factors were developed, see Chapter 4.

41.1 Method of Response Prediction. This variable defines the method in which the pavement responses are to be determined either by the elastic layer submodel, LAYER, or the elastic layer regression submodel, REGRSP. Use of the REGRSP submodel allows the user to familiarize himself with the operation of the program and the particular overlay design problem using a minimum of computer time. However, the LAYER submodel should be used if the program is to be used for the selection of an optimal rehabilitation design strategy. See Chapter 3 for a detailed description of the LAYER and REGRSP submodels.

Overlay Construction Cost Variables

This begins the description of the inputs associated with the cost of an overlay strategy. None of the remaining inputs that will be discussed has any effect on the performance (i.e., fatigue life) prediction of an overlay strategy.

The next seven cards (numbers 42.0 through 49.0) define the variables associated with overlay construction cost.

<u>42.0 Site Establishment Cost.</u> This card identifies the cost associated with establishing the overlay site. This cost is considered because the cost of mobilizing manpower and equipment may differ according to overlay type. Consequently, there are five different costs that may be specified. Variables 42.1, 42.2, and 42.3 represent the costs for ACP, CRCP, and JCP equipment, respectively. In cases where both PCC and ACP construction equipment are required for a particular strategy, such as a CRCP overlay with an ACP bond breaker and ACP shoulder, variables 42.4 and 42.5 are provided. They may be used to reflect a lower equipment unit cost when the two types are required. It should be noted that each represents a total cost for the entire project, regardless of length.

<u>43.0 Pavement Surface Preparation Cost.</u> This cost should represent the cost of preparing the pavement surface (i.e., cleaning and milling) prior to overlay placement. Variable 43.1 applies to the existing pavement while variables 43.2, 43.3, and 43.4 apply to the first overlay prior to the second and may be neglected if no two-overlay strategies are to be considered. Note that the units on this cost are dollars per square yard of surface area.

<u>44.1 Fixed Cost of ACP Overlay Construction.</u> This input defines the fixed component of the ACP overlay placement cost. It is used along with the variable cost to predict the total placement cost. This method allows some flexibility to account for the sensitivity of placement cost to overlay thickness. The units of fixed cost are dollars per square yard while the units for variable cost are dollars per square yard per inch of thickness.

An example is to specify a fixed cost of 6.00 dollars per square yard and a variable cost of 0.50 dollar per square yard per inch, so that the cost of a 6-inch ACP overlay would be 6.00 + (6x0.50) or 9.00 dollars per square yard.

44.2 Variable Cost of ACP Overlay Construction. This variable, along with the fixed component (variable 44.1) is used to compute the total cost of ACP overlay placement. The units of variable cost are dollars per square yard per inch.

44.3 Fixed Cost of Flexible Shoulder Construction. This input defines the fixed component of flexible shoulder placement cost. The units are dollars per square yard and it is similar in application to variable 44.1.

44.4 Variable Cost of Flexible Shoulder Construction. This input defines the variable component of flexible shoulder construction. Its units are dollars per square yard per inch. See the description of variables 44.1 and 44.2 for further discussion on fixed and variable costs.

44.5 Cost of Bond Breaker Construction. Unlike ACP overlay and flexible shoulder placement cost, the cost for bond breaker placement has only one component since only one thickness (variable 19.3) is ever considered. Consequently, the units of this variable are dollars per square yard.

45.0 CRCP Fixed Costs. These inputs define the fixed component of CRCP overlay placement cost. They are similar in nature to variable 44.1, with one exception. The user must specify a fixed cost for each PCC flexural strength specified in card 22.0. Once again, the units are dollars per square yard. This card should be left blank if no CRCP overlays are to be considered.

46.0 CRCP Variable Costs. These inputs define the variable component of CRCP overlay placement cost. They correspond to the fixed cost specified for each PCC flexural strength to be used for CRCP overlay construction. The units are dollars per square yard per inch. This card should be left blank if no CRCP overlays are to be considered.

47.0 JCP Fixed Costs. These inputs define the fixed component of JCP overlay placement cost. They are similar in nature to variable 44.1. The difference is that the user must specify a fixed cost for each PCC flexural strength specified in card 22.0. The units are dollars per square yard. This card should be left blank if no JCP overlays are to be considered.

48.0 JCP Variable Costs. These inputs define the variable component of JCP overlay placement cost. They correspond to the fixed cost specified for each PCC flexural strength to be used for JCP overlay construction. The units are dollars per square yard per inch. This card should be left blank if no JCP overlays are to be considered.

49.1 Total CRCP Overlay Steel Percentage. This variable defines the total percentage of steel, both longitudinal and transverse required in a CRCP overlay. Generally, this value ranges between 0.5 and 0.7 percent for CRCP overlays but may be left blank if no CRCP overlays are to be considered.

49.2 Total JCP Overlay Steel Percentage. This variable defines the total steel percentage, both longitudinal and transverse, required in a JCP overlay. Generally, this value ranges between zero and 0.4 percent for JCP overlays. (The higher end represents a jointed reinforced concrete pavement, JRCP.) This variable may be left blank if no JCP overlays are to be considered.

49.3 Cost of Steel Reinforcement. This variable defines the cost per unit weight of steel used in a reinforced concrete overlay. The user need not consider the cost of placement if it was considered in the fixed cost of placement. The units of this variable are dollars per pound. Also, it may be left blank if no PCC overlays are to be considered.

Traffic Delay Cost Variables

This section describes the variables associated with user costs arising from traffic delay during overlay construction. The traffic delay cost model is discussed in Chapter 5. Basically, the model attempts to predict the length of delay as well as the number of vehicles that are delayed due to overlay construction. Then, built-in unit costs are used to estimate the total delay cost. To predict this total cost, the user must provide information on the size and length of the overlay project, its location, how traffic is to be handled, estimates of present traffic volumes, average vehicle speeds, and overlay construction rates. Each of the variables which make these up are described next.

50.1 Location of Project. The model uses "built-in" average daily distributions of traffic to predict the amounts of traffic which will be delayed during the periods when traffic is detoured or constricted. Since these average daily distributions are different in rural areas than in urban, the user must specify which of the two best applies to his conditions.

50.2 Model Number for Handling trafffic. Since the delay duration and the number of vehicles delayed are dependent upon the method in which traffic is detoured, it is necessary for the user to specify which method will be used. The choices available are shown in Fig 6.3.

50.3 Number of Open Lanes, Overlay Direction. This variable specifies how many lanes are open to traffic in the overlay direction. This includes detour lanes, the lane provided by the shoulder (if it is used to carry traffic), and a lane which may be shared with traffic in the non-overlay direction. This variable should never be zero.

50.4 Number of Open Lanes, Non-Overlay Direction. This variable specifies how many lanes are open to traffic in the non-overlay direction. Unless it is necessary to close a lane in this direction due to encroachment of overlay construction equipment and personnel, this variable should be equal to variable 2.3.

51.1 Time of Day Overlay Construction Begins. This variable, along with the next, is used to define the period during the day during which traffic will be delayed. In the case of PCC overlays, where traffic may be detoured for two weeks or more, this period should cover the entire day. For ACP overlays, however, these variables may correspond to the beginning and ending of construction since the overlay lanes may be opened to traffic immediately after the hour that construction ends. Note that the hours are specified using military time where 4:00 a.m. is 0400 hours, 4:00 p.m. is 1600 hours, etc.

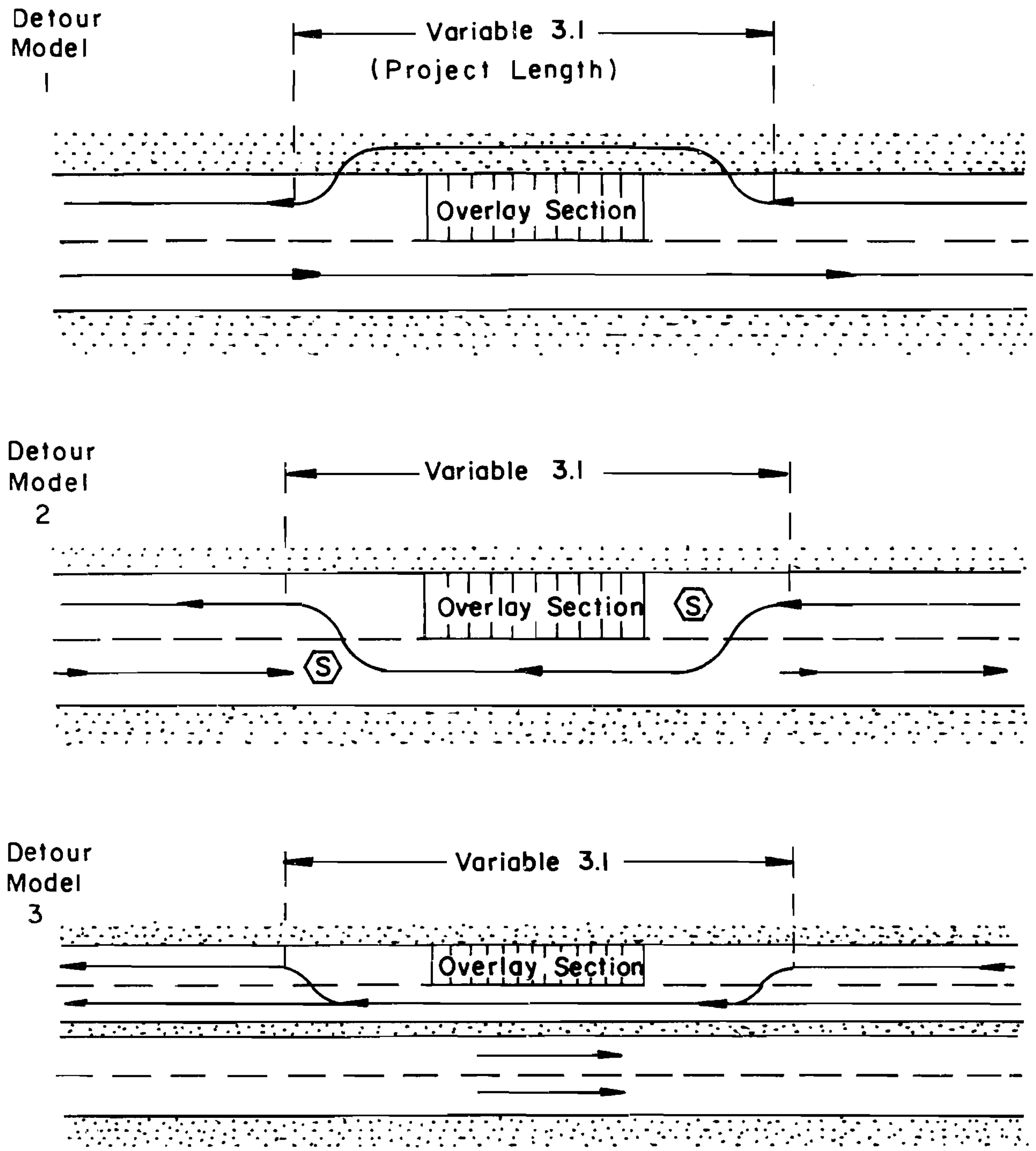


Fig 6.3. Illustration of the detour models available in RPRDS-1 for use in estimating traffic delay cost.

(Continued)

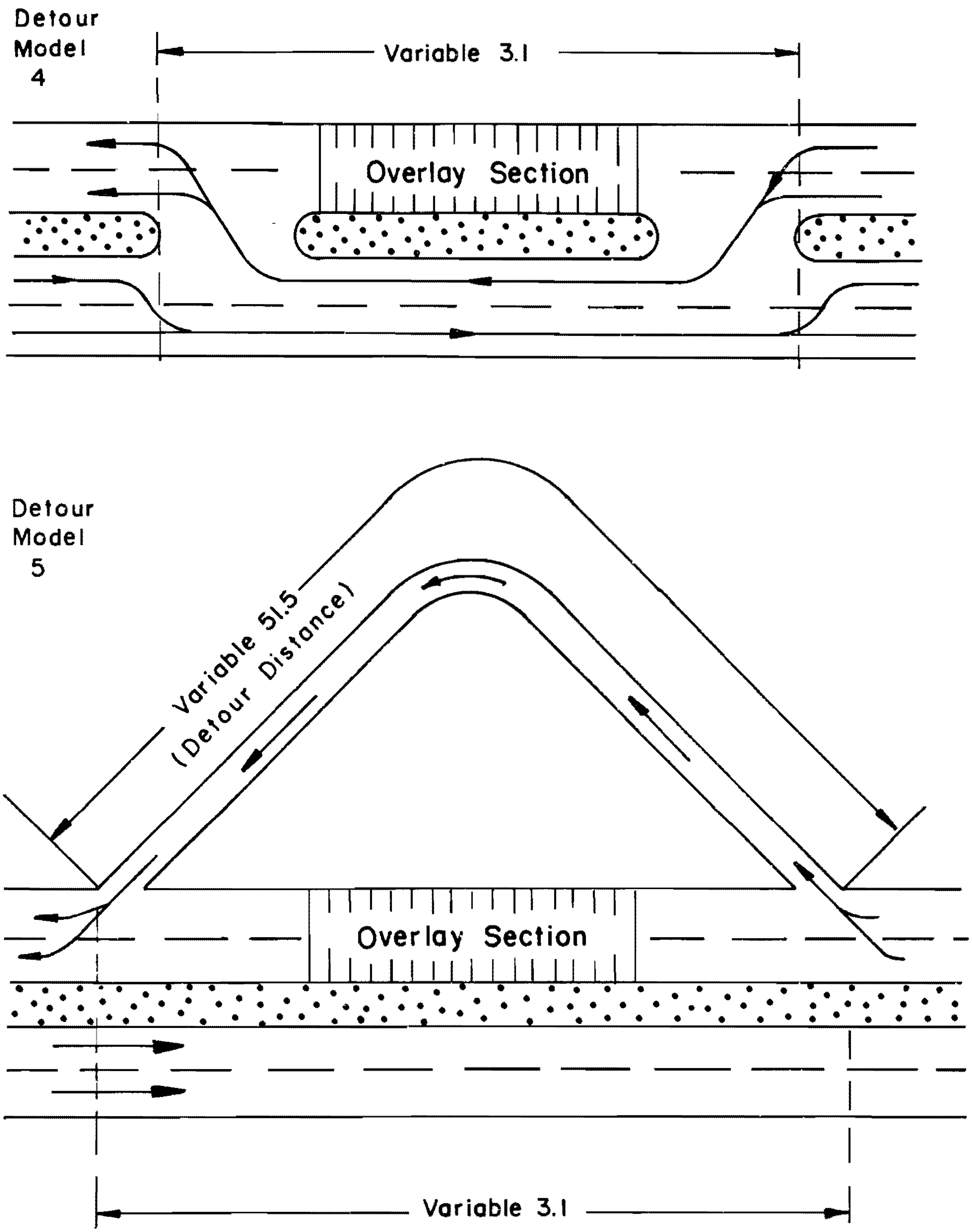


Fig 6.3.. (Continued).

51.2 Time of Day Overlay Construction Ends. This variable and the preceding one are used to specify a total daily traffic delay period. Its units are also in military time (see variable 51.1).

51.3 Hours Per Day Overlay Construction Occurs. This variable is used to determine how many days it will take to complete overlay construction. This variable is not necessarily the difference (in standard hours) between variables 51.2 and 51.1, since they define the period during the day during which traffic will be delayed. The value of this variable must be greater than zero.

51.4 Number of Days Concrete Is Allowed to Cure. This variable is used to account for the additional period of traffic delay after PCC overlay construction for concrete curing.

51.5 Detour Distance. This variable defines a length over which traffic will be detoured. It applies to model 5 only (see Fig 6.3).

52.1 Average Approach Speed. This variable, along with the others on card 52, is used to calculate how much time each vehicle will be delayed due to the reduction of speed through the overlay zone. This variable is basically the average speed of traffic under unrestricted conditions.

52.2 Average Speed, Overlay Direction. This variable defines the average speed of vehicles traveling through the restricted zone in the overlay direction. It is used with variable 52.1 to calculate the vehicle delay due to reduced speed.

52.3 Average Speed, Non-Overlay Direction. This variable defines the average speed of vehicles traveling through the restricted zone in the non-overlay direction. It is used with variable 52.1 to calculate the vehicle delay due to reduced speed and may be equal to variable 52.1 if traffic in the non-overlay direction is not disturbed.

53.1 Distance Traffic Is Slowed, Overlay Direction. This variable accounts for the length over which traffic is slowed in the overlay direction during overlay construction. Its value is not necessarily the length of the project since the restricted zone may be much shorter.

53.2 Distance Traffic Is Slowed, Non-Overlay Direction. This variable is similar to variable 53.1 except that it is for traffic in the non-overlay direction. In many cases where traffic is not disturbed in the non-overlay direction, this variable will have a value of zero.

53.3 Percent of Vehicles Stopped, Overlay Direction. In some cases where traffic is heavy or forced to share a traffic lane (such as in detour model 2, Fig 6.3), the closing of a single lane for overlay construction may force many vehicles to slow down and stop. This variable attempts to account for the percentage of these vehicles which are stopped, due to either traffic or overlay construction equipment and personnel.

53.4 Percent of Vehicles Stopped, Non-Overlay Direction. This variable is the same as variable 53.3 except that it is for the non-overlay direction. Depending on the detour model, the value may vary from zero to the value for the overlay direction.

53.5 Average Vehicle Delay, Overlay Direction. This variable defines the average amount of delay incurred by stopped vehicles (during the stopped period only). This variable, along with variable 53.3, defines the total amount of vehicle stop time during overlay construction in the overlay direction. This value is then added to the time lost due to slowing down, to get the total vehicle delay time in the overlay direction.

53.6 Average Vehicle Delay, Non-Overlay Direction. This variable is the same as variable 53.5 except that it is for the non-overlay direction. This value may be zero if no delay occurs in the non-overlay direction.

54.1 Asphaltic Concrete Production Rate. This variable along with the overlay thickness and length of construction day is used to compute the total number of days required to complete overlay construction. It is assumed, then, that this calculated number of days is the period over which the traffic delays will occur. Note that the units of this variable are in cubic yards per hour so that a thick overlay will require more construction time than a thin overlay.

54.2 CRCP Production Rate. This variable is the same as variable 54.1 except that it is for a CRCP overlay. Note that the placement of steel reinforcement may have an effect on this value.

54.3 JCP Production Rate. This variable is the same as variable 54.1 and 54.2 except that it is for a JCP overlay. Also, some consideration should be given here to the time required for joint preparation as well as for the placement of steel reinforcement.

54.4 Bond Breaker Production Rate. This variable is similar to the production rates discussed previously. In fact, the value for this variable may be the same as that for an ACP overlay (variable 54.1). The difference is that this variable will be used to estimate construction time required for a bond breaker used in an unbonded PCC overlay strategy.

Distress/Maintenance Cost Variables

This set of data is used to compute the maintenance cost of each feasible strategy. Basically, the data required on the next four cards (55 through 58) consist of the cost to repair a defect and the yearly rates of defect or distress development for different periods during the life of the strategy. These values are entered for four possible overlay combinations, (1) CRCP, (2) JCP, (3) ACP on CRCP, and (4) ACP on JCP, which correspond to the four cards required.

For use in this application, the life of a pavement overlay strategy is divided into several periods as a result of work done by Taute (Ref 31). The first is the zero distress rate period (between zero and 20 percent of the overlay life) where very few (if any) severe distress manifestations will occur. The second period (between 20 and 60 percent of the overlay life) is the initial distress rate period, where distress develops at a slow but significant rate. The third period (between 60 and 100 percent of the overlay life) represents a secondary rate of distress development, which will occur up to the end of the overlay fatigue life. From this point out to the maximum allowable number of years of heavy maintenance (variable 10.3), the periods consist of one year intervals, where distress development should increase geometrically. The user, then, must define values for the initial distress rate, the secondary distress rate and the distress rate, for each year up to the maximum allowable number of years of heavy maintenance.

Further detailed discussion of this is provided in Chapter 5, but some recommended values for CRCP overlays and ACP/CRCP overlays are provided below. Unfortunately, no recommendations are made for JCP overlays, due to the lack of field data. Also, it should be pointed out that all of these data (in cards 55 through 58) may be left blank if the user does not wish to consider maintenance cost.

<u>55.1 CRCP Overlay Distress Repair Cost.</u> This variable should represent the cost of repairing a severe distress manifestation such as a punchout in a CRCP overlay. This cost should reflect the manpower, material, and equipment required to repair a single severe defect.

<u>55.2 Initial CRCP Overlay Distress Rate.</u> This variable defines the initial CRCP distress rate that is exhibited during the period between 20 and 60 percent of the overlay life. Results of statewide condition surveys in Texas (Ref 31) indicate that this value is about one per mile per year.

<u>55.3 Secondary CRCP Overlay Distress Rate.</u> This variable defines the secondary CRCP distress rate that is exhibited during the period between 60 and 100 percent of the overlay fatigue life. Results of statewide condition surveys in Texas indicate that this value is about two per mile per year.

<u>55.4 CRCP Overlay Distress Rate for Each Year After Loss of Pavement Load-Carrying Capacity.</u> This actually consists of a set of CRCP distress rates, one for each year up to the maximum allowable number of years of heavy maintenance (variable 10.3). Once again, results of the statewide Texas condition survey indicate the following progression for each year after the loss of pavement load-carrying capacity: first year - 3 per mile, second - 5 per mile, third - 8 per mile, fourth - 16 per mile, and fifth year - 40 per

mile. (It is recommended that heavy maintenance of CRCP not be considered for more than five years.)

56.1 JCP Overlay Distress Repair Cost. This variable should represent the cost of repairing a distress manifestation, such as a defective joint or badly cracked slab in a JCP overlay. This cost should reflect the manpower, material, and equipment required to repair a single severe defect.

56.2 Initial JCP Overlay Distress Rate. This variable defines the initial JCP distress rate that is exhibited during the period between 20 and 60 percent of the overlay fatigue life. Due to a lack of field data and the fact that the definition of a JCP severe distress manifestation is highly subjective, no recommendation is made for this value. It is hoped that future research will provide better information on which to base a recommendation.

56.3 Secondary JCP Overlay Distress Rate. This variable defines the secondary JCP distress rate that is exhibited during the period between 60 and 100 percent of the overlay fatigue life. For the same reasons given in variable 56.2, no recommendation is made for this value.

56.4 JCP Overlay Distress Rate for Each Year After Loss of Pavement Load-Carrying Capacity. This actually consists of a set of JCP distress rates, one for each year up to the maximum allowable number of years of heavy maintenance (variable 10.3). For the same reasons given in variable 56.2, no recommendation is made for these values.

57.1 Distress Repair Cost, ACP Overlay on CRCP. This variable should represent the cost of repairing a distress manifestation in an ACP overlay over a CRCP. Once again, this cost should reflect the manpower, material, and equipment required to repair a single defect. Examples of such defects include punchouts and potholes. The cost of ACP repairs, however, should be relatively low compared to PCC pavement repairs.

57.2 Initial ACP/CRCP Overlay Distress Rate. This variable defines the initial distress rate for an ACP overlay (on a CRCP) for the period between 20 and 60 percent of the overlay fatigue life. The results of an experimental CRCP with an ACP overlay on IH-45 in Walker County, Texas (Ref 31), have shown good ACP overlay performance with little distress. On the other hand, other ACP overlay projects in Texas have shown poor performance. Due to the fact that there is a large variation in field data, no recommendation is made here for this value. It should, however, be at least as high as the recommended initial CRCP distress rate (one per mile per year).

57.3 Secondary ACP/CRCP Overlay Distress Rate. This variable defines the secondary distress rate for an ACP overlay (on a CRCP) for the period between 60 and 100 percent of the overlay fatigue life. As discussed in variable 57.2, there is a lot of variation in the results of field observations of this overlay combination and, therefore, no recommendation is made here. The value of this variable, however, should be at least as high as the recommended secondary CRCP distress rate (two per mile per year).

57.4 ACP/CRCP Overlay Distress Rate for Each Year After Loss of Pavement Load-Carrying Capacity. This consists of a set of ACP/CRCP distress rates, one for each year up to the maximum allowable number of years of heavy maintenance (variable 10.3). For the same reasons discussed in variables

57.1 and 57.2, no recommendation is made for these values. They should, however, be at least as high as those distress rates for a CRCP (variable 55.4).

58.1 Distress Repair Cost, ACP Overlay on JCP. This variable should represent the cost of repairing a distress manifestation in an ACP overlay over a JCP. The cost should reflect the manpower, material, and equipment required to repair a single defect. An example of such a defect would be a pothole. Also, the cost of such a repair should be relatively low compared to PCC pavement repairs.

58.2 Initial ACP/JCP Overlay Distress Rate. This variable defines the initial distress rate for an ACP overlay (on a JCP) for the period between 20 and 60 percent of the overlay fatigue life. Due to the lack of information on ACP overlay performance on JCP, no recommendation is made for this value. This value should, however, be as least as high as that used for the initial JCP distress rate (variable 56.2).

58.3 Secondary ACP/JCP Overlay Distress Rate. This variable defines the secondary distress rate for an ACP overlay (on a JCP) for the period between 60 and 100 percent of the overlay fatigue life. Once again, this value should be at least as high as that used for the secondary JCP overlay distress rate (variable 56.3).

58.4 ACP/JCP Overlay Distress Rate for Each Year After Loss of Pavement Load-Carrying Capacity. This consists of a set of ACP/JCP distress rates, one for each year up to the maximum allowable number of years of heavy maintenance (variable 10.3). As before, no recommendation is made here, but the values should be at least as high as those used for a JCP overlay (variable 56.4).

Cost Returns

There are two input variables that fall under the heading of cost returns. They are both included on card 59 and they are both used to estimate the return (a negative cost) from an overlay design strategy at the end of the analysis period (see Chapter 5).

59.1 Salvage Value. This variable refers to the value (expressed as a percent of the construction cost) an overlay structure has after it has reached the end of its life. Salvage value may refer to the value the pavement has as a base layer for some future overlay, or it may refer to the value the concrete and steel have for other uses. Note, however, that it refers to the value of the overlay only, and that the computed value for the future year is brought back to net present value.

59.2 Value of Each Year of Extended Life. Due to the nature of the method for generating overlay design strategies in RPRDS-1, all strategies do not last the same period of time. In fact, some may last well beyond the analysis period. Accordingly, the purpose of this variable is to account for the additional life so that feasible strategies with different lifetimes may be compared on a somewhat equal basis (see Chapter 5).

The selection of the value of the extended life should be based on the estimated cost of the optimum strategy and some other factors pointed out in Chapter 5: 1) the present availability of funds for initial construction, 2) the uncertainty in costs and traffic beyond the analysis period, 3) the fact that RPRDS only computes maintenance costs up to the end of the analysis period, and 4) the fact that salvage value is computed at the end of the strategy life and not at the end of the analysis period.

Consider the following example. The analysis period is 20 years and the designer expects that the cost of the optimum strategy will be about ten dollars per square yard. Though the project is paid for at the time of initial construction, the average value for each year of service is fifty cents per square yard. Considering some of the factors listed above, the value of extended life may range from zero to 20 cents per square yard per year. Using a value of ten cents per square yard per year in the example, the cost of a strategy that lasts twenty-four years would be reduced by approximately forty cents per square yard, depending on interest and inflation factors. This may result in a favorable comparison with other strategies that last only 20 years.

If on the other hand, the user elects not to consider the value of extended life (especially in cases where construction funds are limited), he may do so by specifying a value of zero for this variable.

Combined Interest And Inflation Rate

60.1 Interest Rate Minus Inflation Rate. This variable is the numeric difference between the interest rate and inflation rate that may be expected during the analysis period (see Chapter 5). This variable is used to determine the net present value of some cost incurred at some future date.

The estimation of this value may be illustrated by the following example. If the average prime interest rate (or the opportunity cost of capital) anticipated during the analysis period is 18 percent and inflation is 13 percent, then the value of this variable would be the difference between the two, or 5 percent.

It is important to note that a high value will favor stage (or delayed) overlay construction strategies while a low value will favor early overlay construction strategies.

DESCRIPTION OF RPRDS-1 PRINTOUT

The printout of the RPRDS-1 program can be divided into two parts, the input summary and the output. The input summary is, basically, an echo print of all the inputs specified by the user, complete with any error diagnostics detected by the INPUT routine. (Note here that any error in the data will cause the program to terminate execution, but only after it completes its error scan of the input data.)

The output of the program basically consists of a list of all the feasible strategies that were generated plus a full-page printout for each of the optimal 20 strategies. The list of feasible strategies (provided first) allows the user to inspect all of those that were generated. The full-page printouts of the optimal strategies provided afterwards, then, allow the user to inspect the best strategies and select one or two for use as his recommended design.

A sample of the RPRDS-1 printout for an example problem (discussed next) is provided in Appendices F (Input Summary) and G (Output).

RPRDS-1 EXAMPLE PROBLEM

In order to give the user an idea of how to operate the RPRDS-1 program, an example problem was prepared using some design data from an overlay design project where the Texas SDHPT rigid pavement overlay design (RPOD) procedure was first used. The project is located at the northern intersection of IH-410 and IH-35 in San Antonio, Texas. This intersection is known as the Fratt Interchange and the section under consideration is a jointed concrete pavement just north of the interchange.

In the example problem, all the data were selected from either this design project or from information contained within this chapter. The RPRDS-1 input guide (Appendix D) was then used to code the data to run the program. The coded data are presented in Appendix E, and the input summary generated by the program (as discussed earlier) is presented in Appendix F. The user should be able to relate all the data used in this example problem back to the discussion of the RPRDS-1 inputs presented earlier in this chapter. However, it is useful to point out some of the significant aspects about the data:

(1) Original pavement structure is JCP.

(2) Layer moduli were determined using the Dynaflect basin fitting procedure, since no laboratory tests were available.

(3) The projected 18-kip ESAL traffic estimates over the analysis period were very large.

(4) The possibility of up to five years of heavy overlay maintenance to last the analysis period was considered.

(5) Original pavement had carried a lot of traffic, and, therefore, its present remaining life was estimated to be quite low (30 percent).

(6) Two first overlay types were considered, ACP and unbonded CRCP.

(7) Two second overlay types were considered, ACP and CRCP.

(8) Two levels of PCC flexural strength for the CRCP overlay strategies were considered.

(9) All cost estimates were based on judgement. (Therefore, the user should be sure to use his own estimates.)

(10) The CRCP steel reinforcement percentages were based on experience and engineering judgement. (The user should always use a reliable design method to predict the actual steel percentage required if a PCC overlay strategy is selected.)

(11) Finally, salvage value and the value of each year of extended life (past the end of the analysis period) were considered.

RPRDS-1 Output

The output from the program for the example problem is presented in Appendix G. The first four pages of this output represent the list of all feasible strategies that were generated and considered. (The first page provides a description of each column in this list). Note that 183 feasible strategies were generated and that the total net present value (column 28) ranged from a minimum of $13.56 per square yard (strategy 182) to a maximum of $18.42 per square yard (strategy 152). Note also that all possible overlay combinations of those specified were generated and that the bulk of these required two overlays during the analysis period.

The last part of the output following this list of feasible strategies, is the 20 most optimum strategies (only the top ten are presented in Appendix G). Inspection of the most optimum strategy (that with the least total net present value) shows that it consists of a single six-inch unbonded CRCP overlay (with a PCC shoulder) that is placed at year two of the analysis period, i.e., when the original pavement has no remaining life. Note that the strategy is projected to last 30 years, where the value of the extended life (the additional ten years of service) is worth $0.73 per square yard. (This value, along with the salvage value, $0.50 per square yard, actually reduces the total net present value.)

Inspection of the next eight optimal strategies shows that all consist of the same 6-inch unbonded CRCP strategy as the first. The only basic differences are the remaining life at the time of overlay placement, the design PCC flexural strength, and the type of shoulder construction.

It isn't until the ninth optimal strategy that an ACP overlay strategy comes in. Inspection of this strategy shows that two ACP overlays are actually required, the first 6 inches (placed at year one) and the second 4 inches (placed at year eight). Note, finally, that in optimal strategy 10, (which is similar to 9), the predicted fatigue life is only 18 years. This means that this strategy would require two years of heavy maintenance near the end of the analysis period.

SUMMARY

The purpose of this chapter is to provide the user with a detailed description of the use and application of the rigid pavement rehabilitation design system computer program, RPRDS-1. Discussion was first provided on the Texas SDHPT rigid pavement overlay design (RPOD) procedure, which makes up the basic rehabilitation design method in RPRDS-1. This discussion was then used as a background for the next topic: the detailed description of the RPRDS-1 input variables, which discusses the restraints on the inputs, how the inputs are used in the program, and how they may be determined. Finally, an example problem was presented in order to illustrate the application of the program on an actual rehabilitation design project in Texas.

CHAPTER 7. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER RESEARCH

SUMMARY

The main objective of this study was to develop a design system for rigid pavement rehabilitation using the systems methodology as a guide for the process of selecting, modifying, improving, and incorporating appropriate design and cost models into a comprehensive computer program (RPRDS-1) for the analysis of rigid pavement rehabilitation strategies. Accordingly, a summary of the significant aspects and accomplishments of this study is provided here.

A review of the practices followed by many highway and transportation agencies indicated several methods of rigid pavement rehabilitation which should be considered in a rigid pavement rehabilitation design system. These include undersealing joints or cracks, pressure grouting, conventional ACP and PCC overlay placement, new overlay types (sulfur-asphalt, rubber-asphalt, and sulflex), and replacement of worn-out sections by either cast-in-place or precast slabs. Unfortunately, none of these methods (with the exception of overlay placement) has a rational design method suitable for use in RPRDS-1. Consequently, at the present time, only overlay placement can be considered within the system framework of RPRDS-1. As a result of efforts by the Federal Highway Administration (FHWA) and the Texas State Department of Highways and Public Transportation (Texas SDHPT), much work has been accomplished (Refs 1, 3, and 9) towards the development of a rigid pavement overlay design procedure (RPOD). This procedure forms the basis for the design model used within RPRDS-1.

Basically, the procedure in RPRDS-1 uses

(1) a combination of layer theory and finite element theory to predict pavement response under load and
(2) fatigue models based on pavement response and Miner's linear damage hypothesis to estimate the life of an overlay strategy.

These, in turn, allow for the consideration of several other factors associated with overlaying as a means for rehabilitation. These include

(1) overlay type,
(2) time of placement,
(3) varying overlay thickness,
(4) varying overlay strength,
(5) concrete shoulder construction, and
(6) multiple overlays.

With all these available options, a large number of pavement rehabilitation strategies can be generated. However, many of them may be eliminated from consideration if they do not meet the user-specified constraints.

Several cost models are incorporated into RPRDS-1 to analyze the economy of each feasible strategy and allow the user to select the optimum. Basically, these cost models include

(1) overlay construction cost,
(2) maintenance cost,

(3) traffic delay cost (during overlay construction), and

(4) salvage value.

Each of these was discussed in Chapter 5.

The output of the program is divided into three components (as discussed in Chapter 6):

(1) a summary of all the user-specified inputs,

(2) a list of all of the feasible strategies that were generated with both the design and cost components, and

(3) a summary of the twenty most optimum rehabilitation strategies for inspection by the user.

The RPRDS-1 computer program was developed with the aid of The University of Texas CDC Cyber 170 computer. The program requires a field length of approximately 70,000 (octal) to compile and 102,000 (octal) to run. Furthermore, every effort was made to insure that the program would be transportable to other computer installations, including IBM.

CONCLUSIONS

Based upon the main result of this study, i.e., the development of the rigid pavement rehabilitation design system, RPRDS-1, the following specific conclusions can be made:

(1) It is possible to apply the systems approach to the design and analysis of rigid pavement rehabilitation. More specifically, it is possible to incorporate the Texas SDHPT RPOD procedure into a

comprehensive systems program to aid the highway engineer in the selection of optimum rigid pavement rehabilitation strategies.

(2) Since the components which make up RPRDS-1 (a) consist of the latest in analytical methods for predicting pavement response and performance and (b) are based on observed field data, RPRDS-1 will provide practical and reliable solutions for a multitude of different overlay problems.

Since RPRDS-1 has only recently been completed, it is difficult at this time to make any other conclusions relative to how it will perform. Only time and extensive use of the program will provide a basis for any further conclusions.

RECOMMENDATIONS FOR FURTHER RESEARCH

Several areas of needed research were recognized during the development of RPRDS-1. Some of these represent uncertainty in some of the models which are based on little or questionable data. Others represent suggestions for detailed analysis of RPRDS-1 as well as extending its capabilities.

Improved Fatigue Models

First, it is recommended that an improved fatigue model be developed for ACP overlays since the existing model in RPRDS-1 is not based on observations of ACP overlays on rigid pavements. Perhaps the results of experimental overlay projects can be used to verify or improve it for rigid pavement application. Also, it should be recognized that the cracking in an ACP overlay on a rigid pavement is probably the result of a combination of fatigue and reflection cracking.

Continued observation and surveys of rigid pavements are also recommended, so as to provide some verification of the PCC fatigue models developed thus far.

Distress Models for Overlays

Information on the rate of distress development over the life of an overlay strategy is used in RPRDS-1 to compute the maintenance cost of the strategy. Though the results of statewide condition surveys in Texas have provided some information on CRC pavements, it needs to be verified for CRCP overlays through the data feedback process. More importantly, data should be collected on the distress rates of JCP and ACP overlays to insure an equal comparison with CRCP overlay strategies. This again calls for a review of the data available from other states as well as continued observation of in-service pavements.

Additional Rehabilitation Methods

RPRDS-1 considers only one method of rehabilitation, overlay placement. In order to achieve a total comprehensive rehabilitation design system, other methods should be incorporated as more rational design models are developed.

Sensitivity Analysis

In order to identify the relative importance of each of the inputs to RPRDS-1 and to get an idea of their effect on the results, a sensitivity analysis of the program should be conducted. Such a study would show which input variables require precise determination as well as those which may require less attention.

Reliability

It is also recommended that at some point, some measure of reliability be incorporated into the program. Such an improvement would allow the consideration of the inherent variability of many of the inputs on the predicted lifetimes and costs of each strategy. This, in turn, would emphasize the strategies which have a greater degree of certainty.

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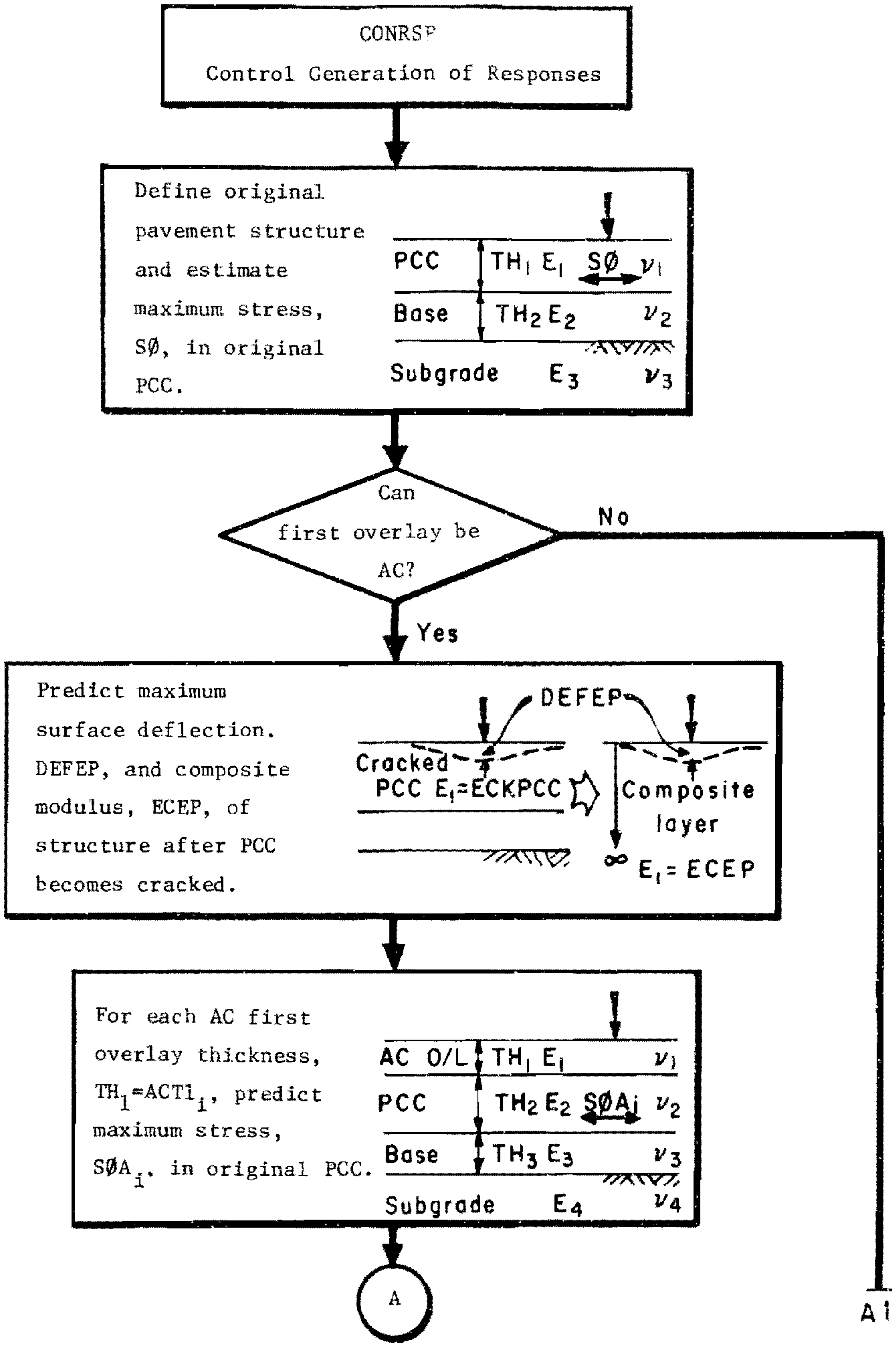
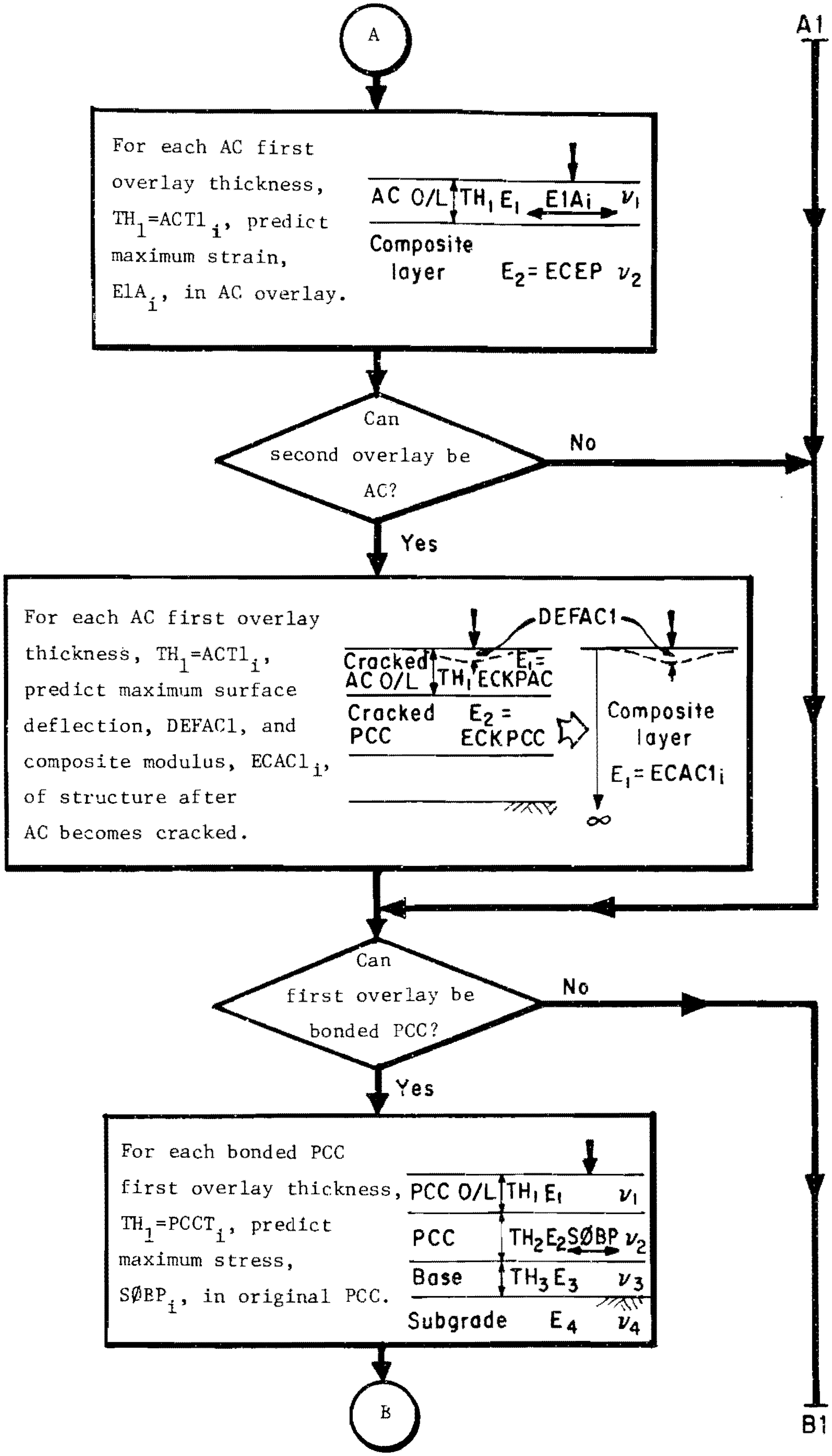
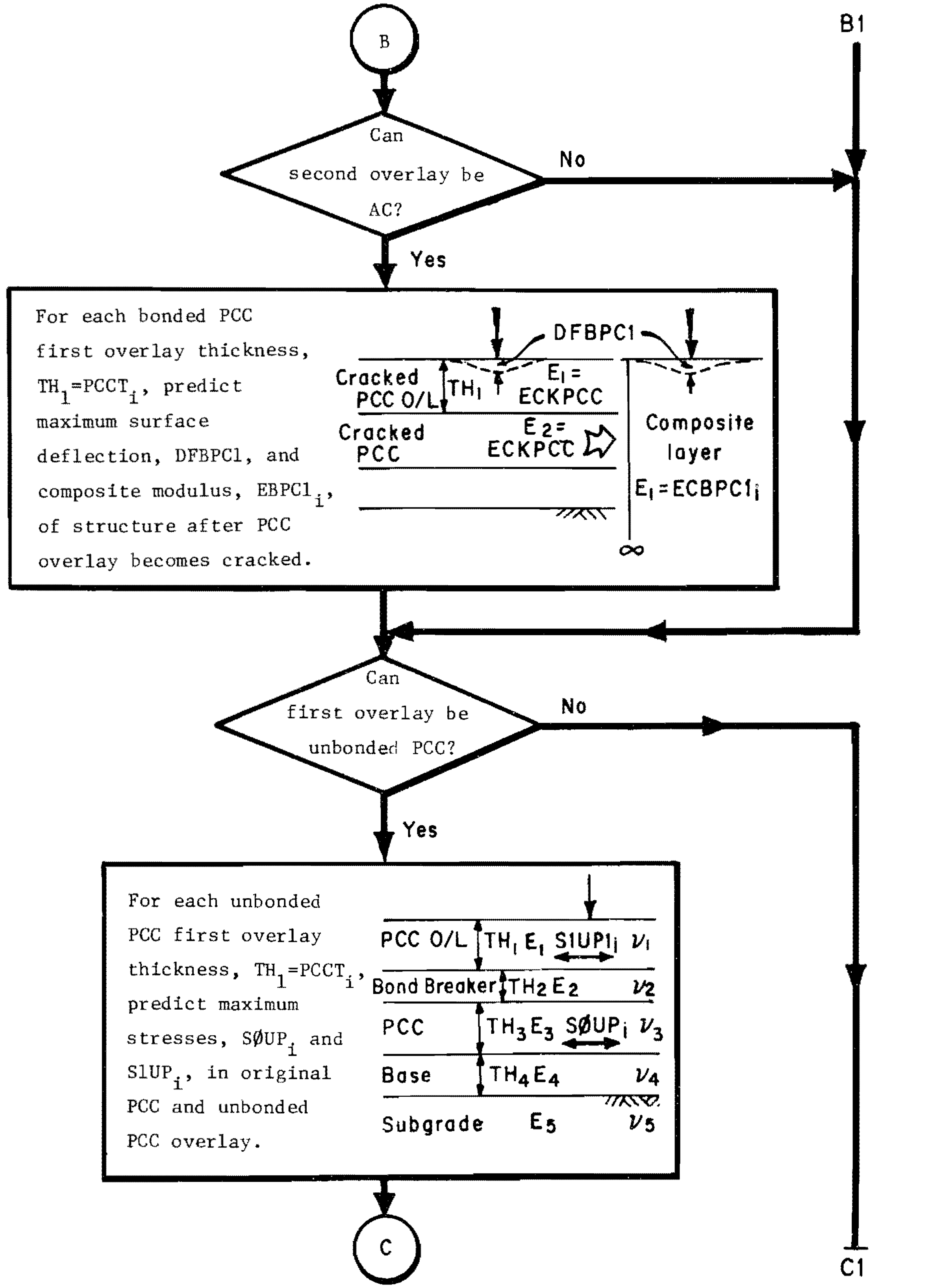
APPENDIX A

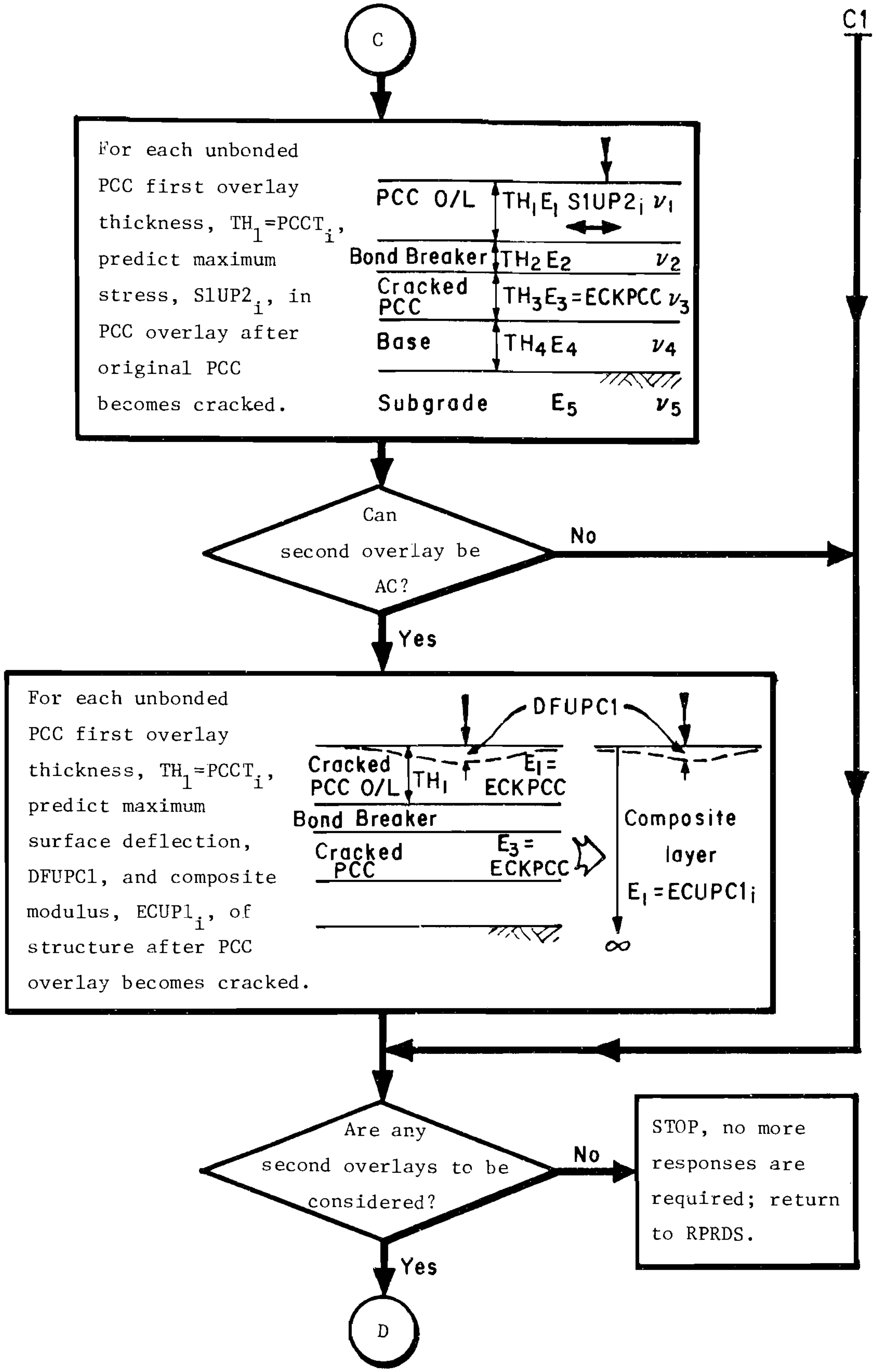
FLOW DIAGRAM OF CONRSP ROUTINE

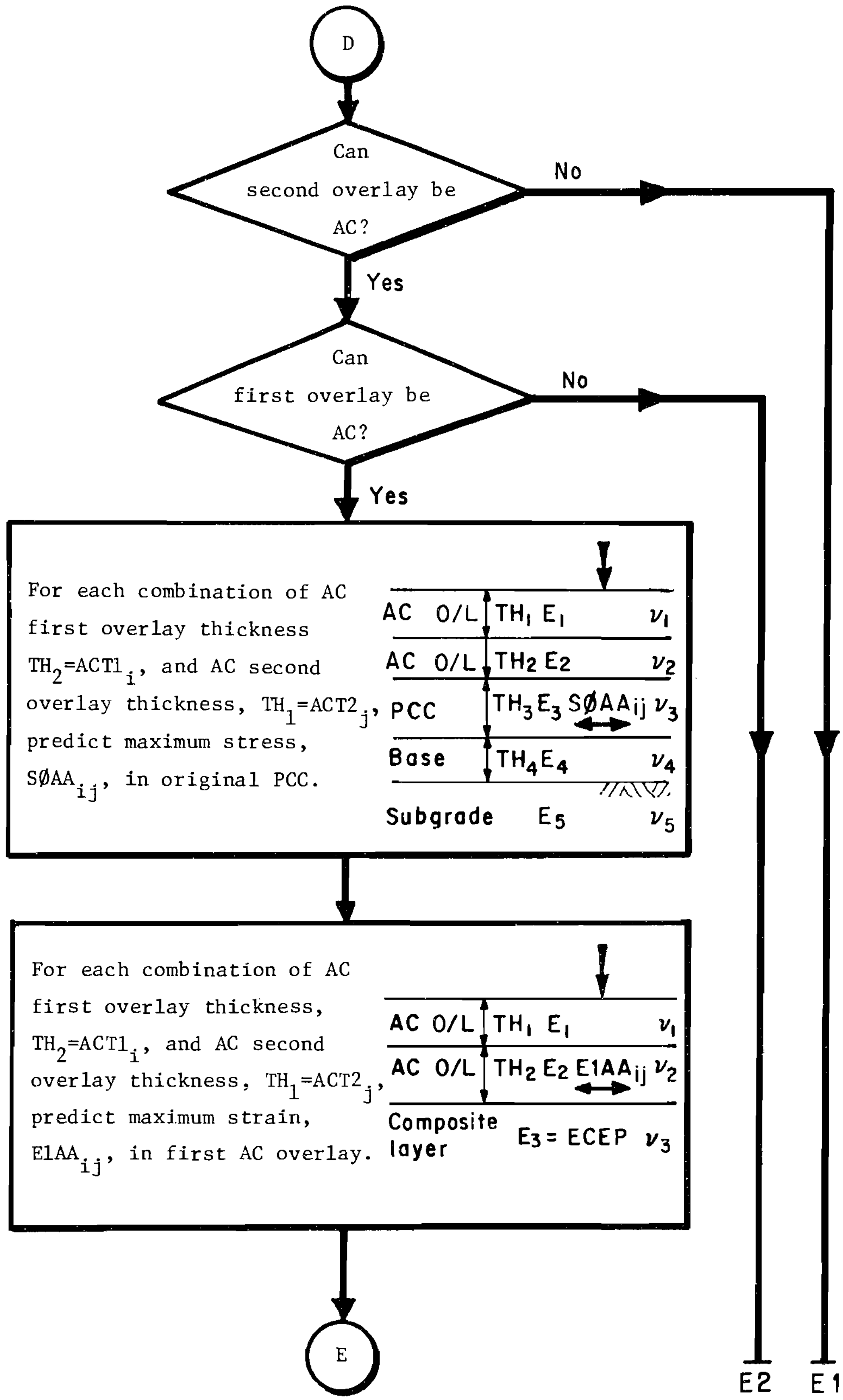
APPENDIX A. FLOW DIAGRAM OF CONRSP ROUTINE

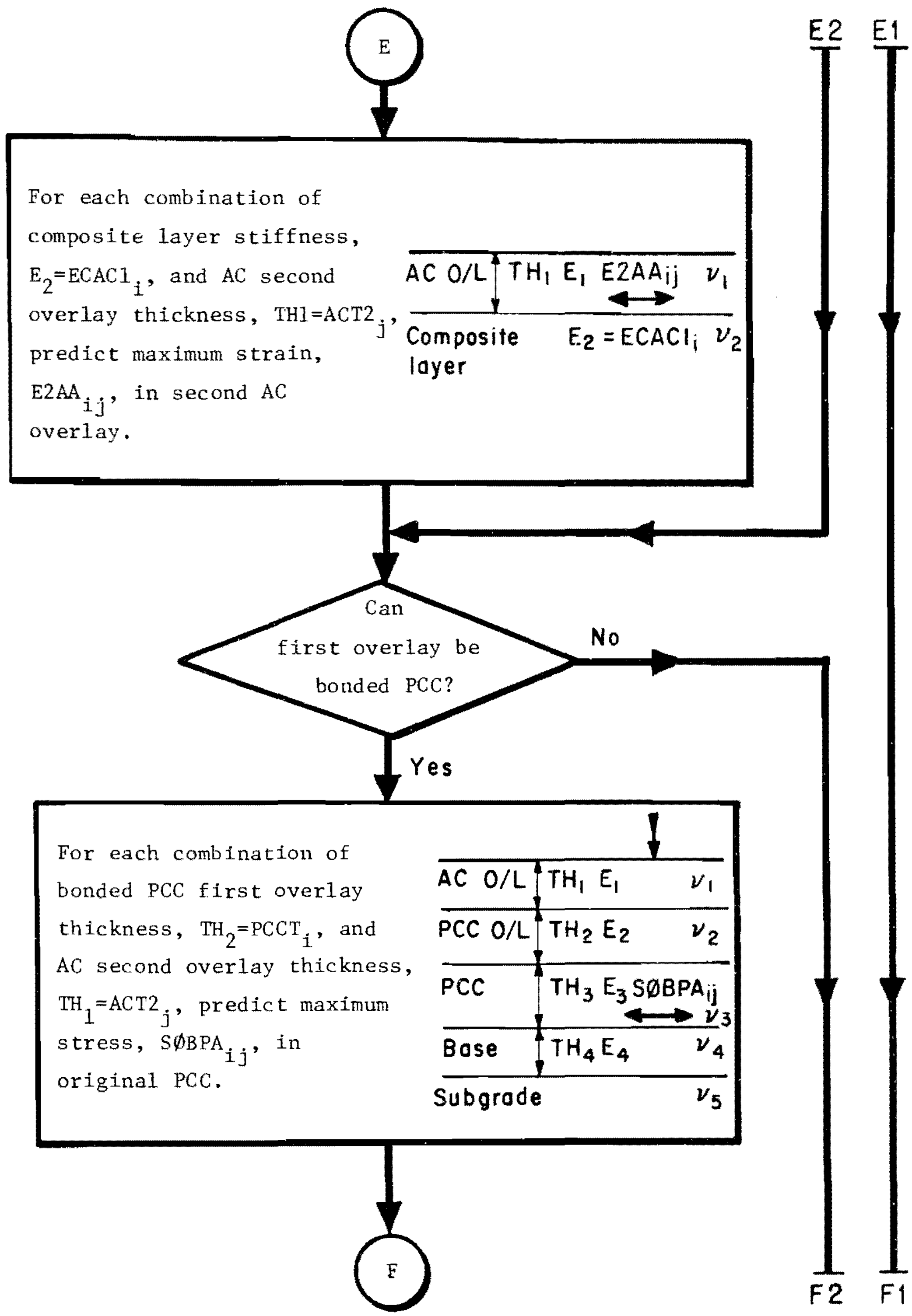


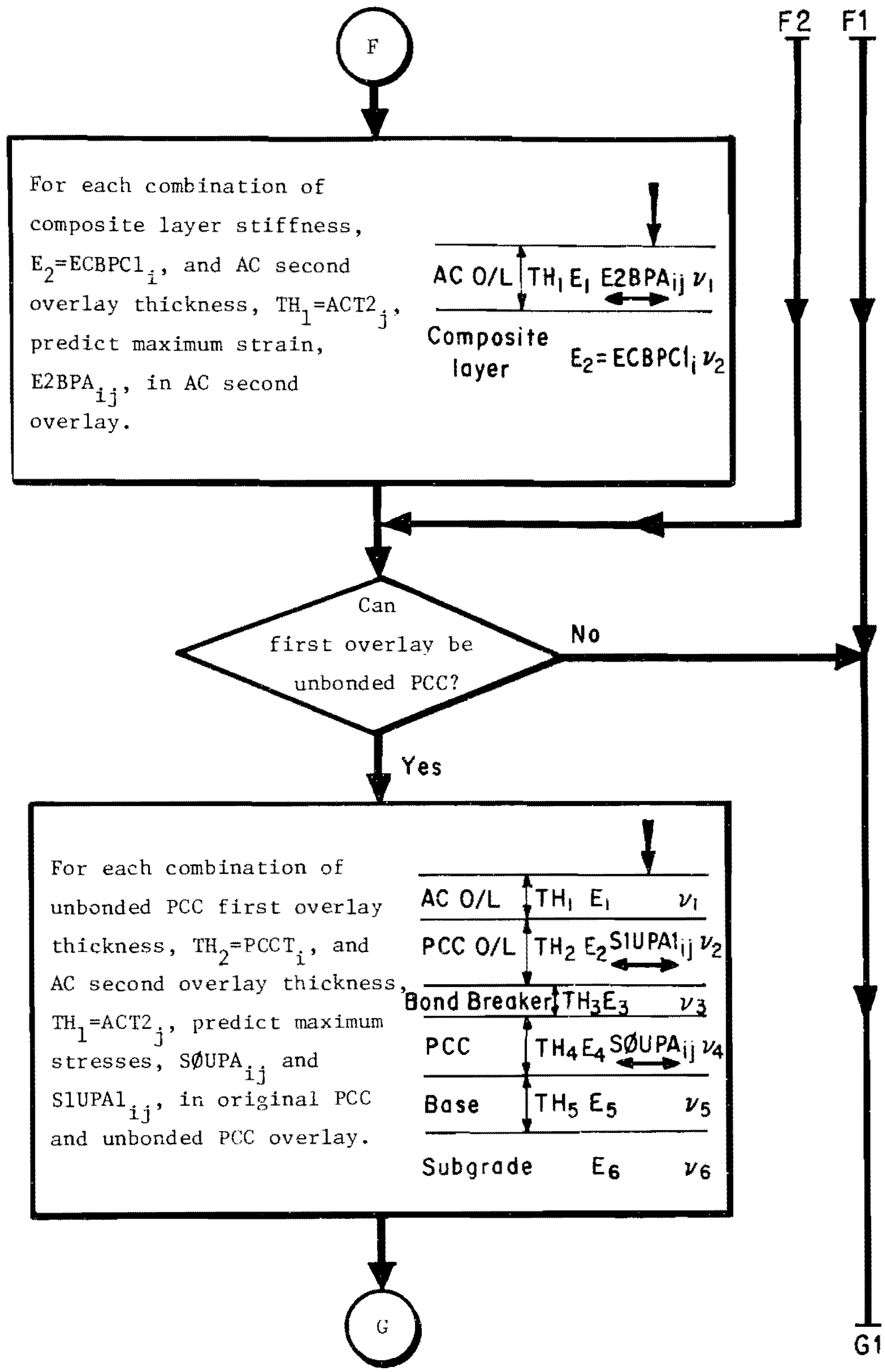

A
A1
For each AC first overlay thickness, TH1=ACT1i, predict maximum strain, E1Ai, in AC overlay.
AC O/L
TH1 E1
E1Ai
ν1
Composite layer
E2= ECEP ν2
Can second overlay be AC?
No
Yes
For each AC first overlay thickness, TH1=ACT1i, predict maximum surface deflection, DEFAC1, and composite modulus, ECAC1i, of structure after AC becomes cracked.
DEFAC1
Cracked AC O/L
TH1
E1= ECKPAC
Cracked PCC
E2 = ECKPCC
Composite layer
E1= ECAC1i
∞
Can first overlay be bonded PCC?
No
Yes
For each bonded PCC first overlay thickness, TH1=PCCTi, predict maximum stress, SØBPi, in original PCC.
PCC O/L
TH1 E1
ν1
PCC
TH2 E2 SØBP ν2
Base
TH3 E3
ν3
Subgrade
E4
ν4
B
B1

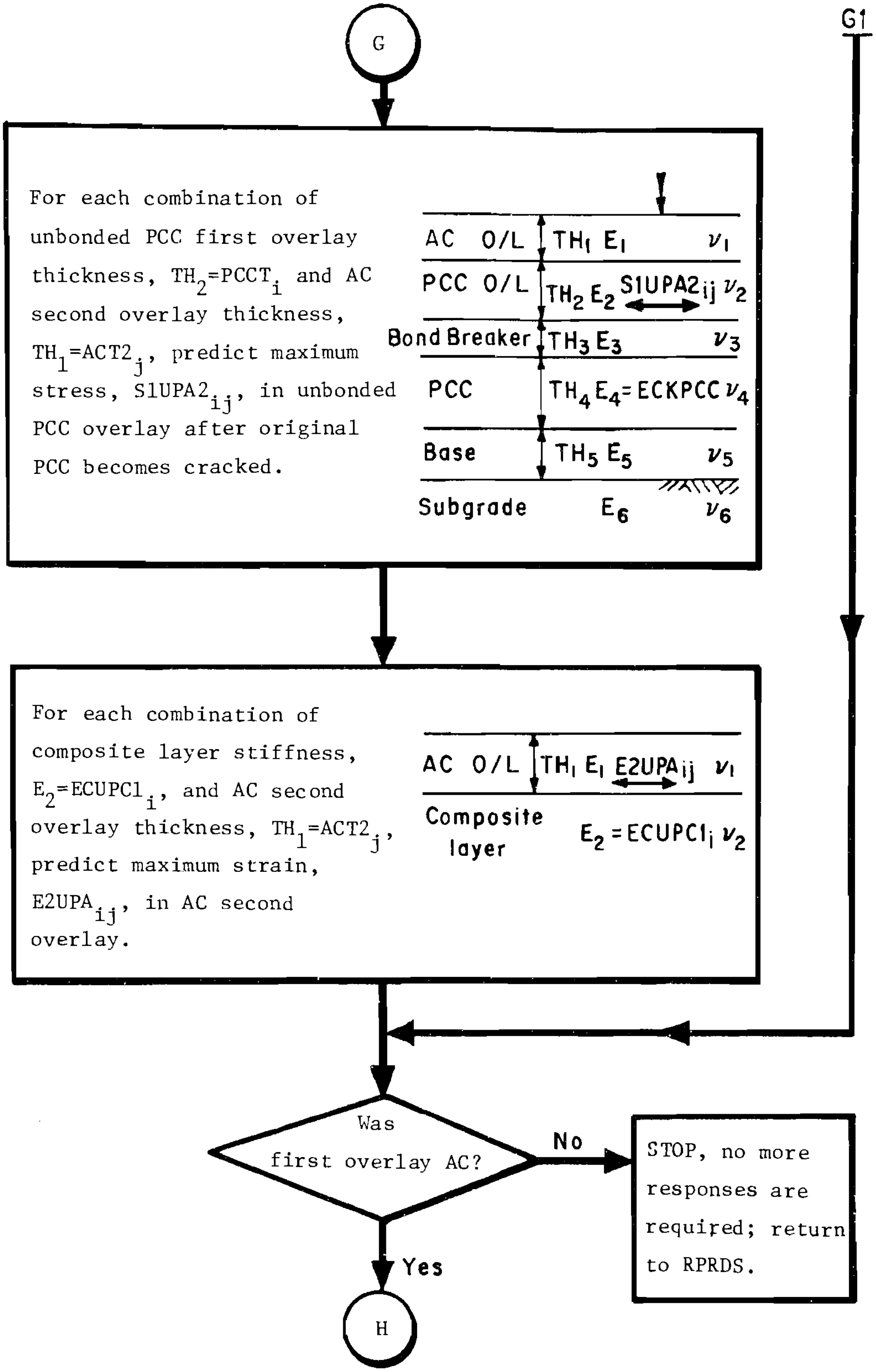

B
B1
Can second overlay be AC?
No
Yes
For each bonded PCC first overlay thickness, TH1=PCCTi, predict maximum surface deflection, DFBPC1, and composite modulus, EBPC1i, of structure after PCC overlay becomes cracked.
DFBPC1
Cracked PCC O/L
TH1
E1 = ECKPCC
Cracked PCC
E2 = ECKPCC
Composite layer
E1 = ECBPC1i
∞
Can first overlay be unbonded PCC?
No
Yes
For each unbonded PCC first overlay thickness, TH1=PCCTi, predict maximum stresses, SØUPi and S1UPi, in original PCC and unbonded PCC overlay.
PCC O/L
TH1 E1 S1UP1i ν1
Bond Breaker
TH2 E2 ν2
PCC
TH3 E3 SØUPi ν3
Base
TH4 E4 ν4
Subgrade
E5 ν5
C
C1

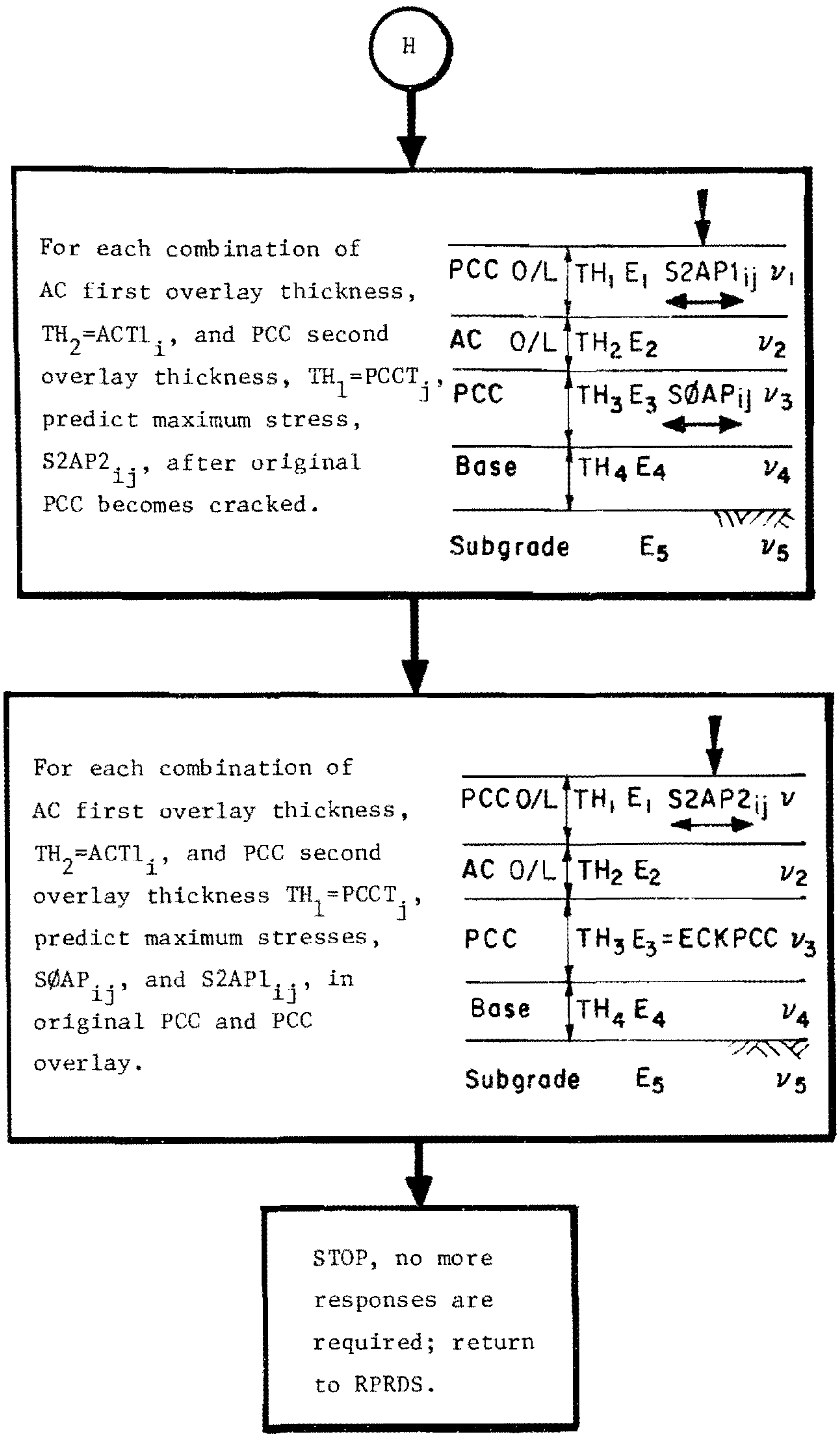

C
C1
For each unbonded PCC first overlay thickness, TH1=PCCTi, predict maximum stress, S1UP2i, in PCC overlay after original PCC becomes cracked.
PCC O/L
TH1 E1 S1UP2i ν1
Bond Breaker
TH2 E2 ν2
Cracked PCC
TH3 E3=ECKPCC ν3
Base
TH4 E4 ν4
Subgrade
E5 ν5
Can second overlay be AC?
No
Yes
For each unbonded PCC first overlay thickness, TH1=PCCTi, predict maximum surface deflection, DFUPC1, and composite modulus, ECUP1i, of structure after PCC overlay becomes cracked.
DFUPC1
Cracked PCC O/L
TH1
E1 = ECKPCC
Bond Breaker
Cracked PCC
E3 = ECKPCC
Composite layer
E1 = ECUPC1i
∞
Are any second overlays to be considered?
No
Yes
STOP, no more responses are required; return to RPRDS.
D


D
Can second overlay be AC?
No
Yes
Can first overlay be AC?
No
Yes
For each combination of AC first overlay thickness TH2=ACT1i, and AC second overlay thickness, TH1=ACT2j, predict maximum stress, SØAAij, in original PCC.
AC O/L TH1 E1 ν1
AC O/L TH2 E2 ν2
PCC TH3 E3 SØAAij ν3
Base TH4 E4 ν4
Subgrade E5 ν5
For each combination of AC first overlay thickness, TH2=ACT1i, and AC second overlay thickness, TH1=ACT2j, predict maximum strain, E1AAij, in first AC overlay.
AC O/L TH1 E1 ν1
AC O/L TH2 E2 E1AAij ν2
Composite layer E3 = ECEP ν3
E
E2
E1


E
E2
E1
For each combination of composite layer stiffness, E2=ECAC1i, and AC second overlay thickness, TH1=ACT2j, predict maximum strain, E2AAij, in second AC overlay.
AC O/L
TH1 E1 E2AAij ν1
Composite layer
E2 =ECAC1i ν2
Can first overlay be bonded PCC?
No
Yes
For each combination of bonded PCC first overlay thickness, TH2=PCCTi, and AC second overlay thickness, TH1=ACT2j, predict maximum stress, SØBPAij, in original PCC.
AC O/L
TH1 E1 ν1
PCC O/L
TH2 E2 ν2
PCC
TH3 E3 SØBPAij ν3
Base
TH4 E4 ν4
Subgrade
ν5
F
F2
F1


F
F2
F1
For each combination of composite layer stiffness, E2=ECBPC1i, and AC second overlay thickness, TH1=ACT2j, predict maximum strain, E2BPAij, in AC second overlay.
AC O/L
TH1 E1 E2BPAij ν1
Composite layer
E2=ECBPC1i ν2
Can first overlay be unbonded PCC?
No
Yes
For each combination of unbonded PCC first overlay thickness, TH2=PCCTi, and AC second overlay thickness, TH1=ACT2j, predict maximum stresses, SØUPAij and S1UPA1ij, in original PCC and unbonded PCC overlay.
AC O/L
TH1 E1 ν1
PCC O/L
TH2 E2 S1UPA1ij ν2
Bond Breaker
TH3 E3 ν3
PCC
TH4 E4 SØUPAij ν4
Base
TH5 E5 ν5
Subgrade
E6 ν6
G
G1


G
G1
For each combination of unbonded PCC first overlay thickness, TH2=PCCTi and AC second overlay thickness, TH1=ACT2j, predict maximum stress, S1UPA2ij, in unbonded PCC overlay after original PCC becomes cracked.
AC O/L
TH1 E1 ν1
PCC O/L
TH2 E2 S1UPA2ij ν2
Bond Breaker
TH3 E3 ν3
PCC
TH4 E4=ECKPCC ν4
Base
TH5 E5 ν5
Subgrade
E6 ν6
For each combination of composite layer stiffness, E2=ECUPC1i, and AC second overlay thickness, TH1=ACT2j, predict maximum strain, E2UPAij, in AC second overlay.
AC O/L
TH1 E1 E2UPAij ν1
Composite layer
E2=ECUPC1i ν2
Was first overlay AC?
No
STOP, no more responses are required; return to RPRDS.
Yes
H


H
For each combination of AC first overlay thickness, TH2=ACT1i, and PCC second overlay thickness, TH1=PCCTj, predict maximum stress, S2AP2ij, after original PCC becomes cracked.
PCC O/L TH1 E1 S2AP1ij ν1
AC O/L TH2 E2 ν2
PCC TH3 E3 SØAPij ν3
Base TH4 E4 ν4
Subgrade E5 ν5
For each combination of AC first overlay thickness, TH2=ACT1i, and PCC second overlay thickness TH1=PCCTj, predict maximum stresses, SØAPij, and S2AP1ij, in original PCC and PCC overlay.
PCC O/L TH1 E1 S2AP2ij ν
AC O/L TH2 E2 ν2
PCC TH3 E3=ECKPCC ν3
Base TH4 E4 ν4
Subgrade E5 ν5
STOP, no more responses are required; return to RPRDS.

APPENDIX B

REGRESSION MODELS FOR PREDICTING PAVEMENT RESPONSE

APPENDIX B. REGRESSION MODELS FOR PREDICTING PAVEMENT RESPONSES

This appendix provides all of the regression models developed as a part of this study to predict pavement response. Twelve models are presented and coded as follows:

(1) E21

(2) S31

(3) S41

(4) SB42

(5) SU51

(6) SU51C

(7) SB52

(8) SB53

(9) SU53

(10) SU62

(11) SU62C

(12) SU64

The first equation is for predicting strain in an asphalt concrete layer while the rest are for predicting stress in the concrete layers of various rigid pavement structures.

The following information is provided for each regression model:

(1) an illustration of the pavement structure and the location of the predicted response,

(2) the details of the experiment used to generate the equation, i.e., the inference space over which the equation may be applied,

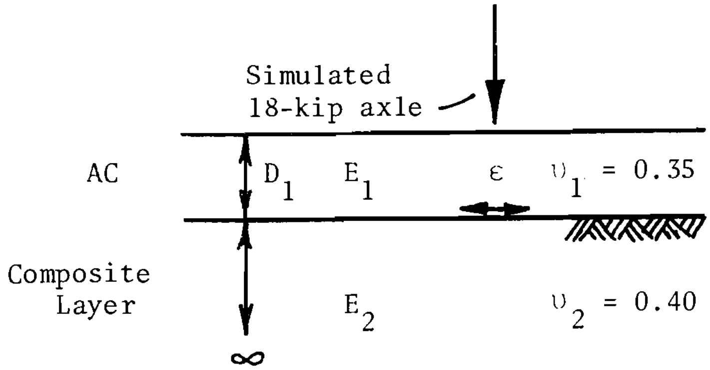
(3) the terms, coefficients and predictive accuracy of each equation, and

(4) an illustration (from the experimental data), of the predictive accuracy of the equation.

Pavement Structure

and Response:

(Code: E21)



Details of the Experiment:

1. Full factorial, 3 factors, no. of observations = 3^3 = 27
2. Levels of the significant factors:

Factors	Levels: High	Medium	Low
E_1 (psi)	800,000	500,000	200,000
E_2 (psi)	60,000	40,000	20,000
D_1 (in)	10	7	4

Prediction Equation - E21:

$\log_{10} \sigma = \Sigma$ (Term x Coefficient)

$r^2 = 0.994$

std. error = 0.0204

Term	Coefficient
Intercept	$-\ 2.835 \times 10^{0}$
E_1	$-\ 9.309 \times 10^{-7}$
E_2	$-\ 7.530 \times 10^{-6}$
D_1	$-\ 5.870 \times 10^{-2}$
$(E_1)^2$	$+\ 4.108 \times 10^{-13}$
$E_1 \times E_2$	$+\ 4.035 \times 10^{-12}$
$E_1 \times D_1$	$-\ 2.356 \times 10^{-8}$

Fig B.1. E21 Regression model: for predicting tensile strain in an asphalt concrete surface layer.

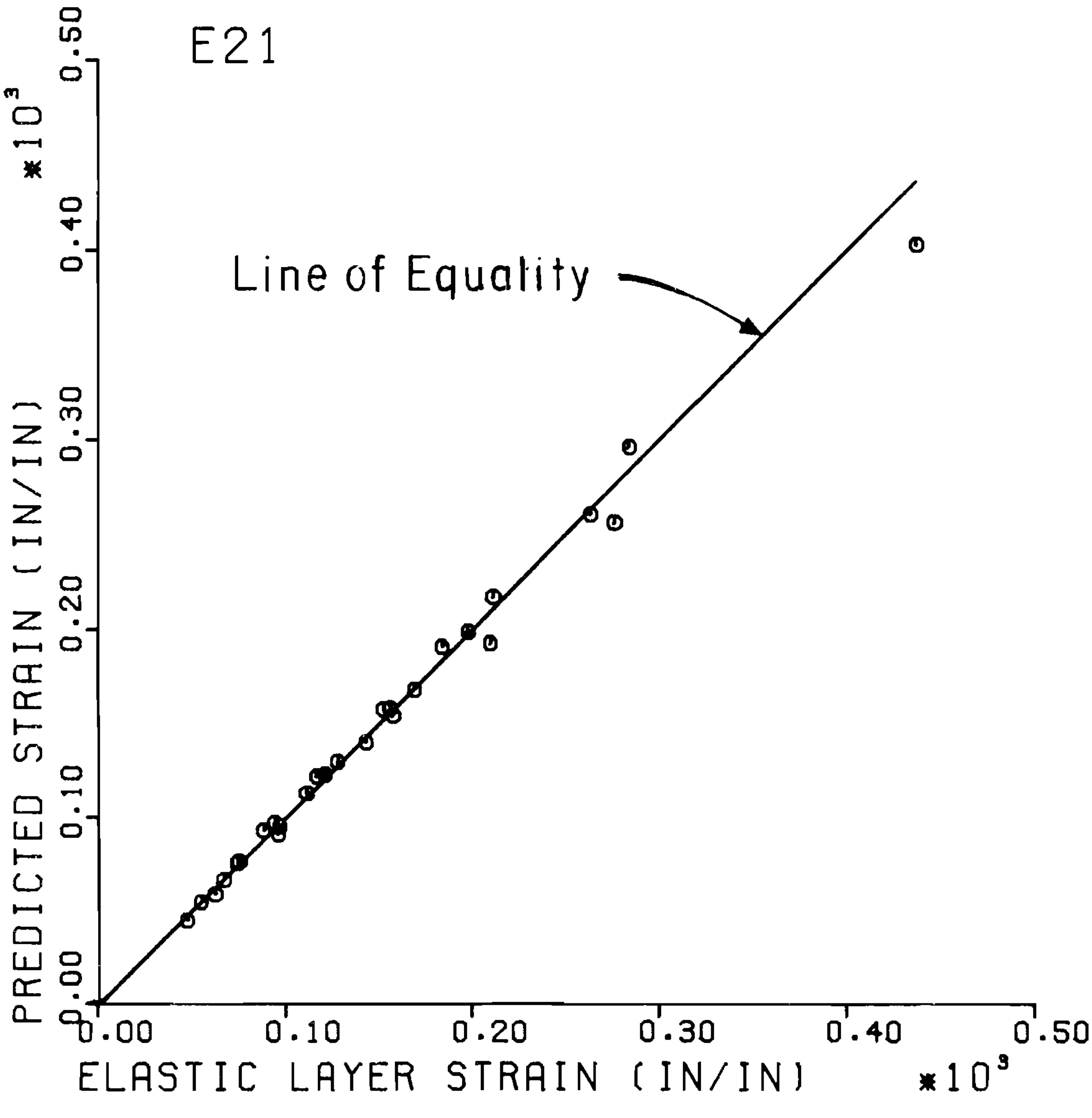
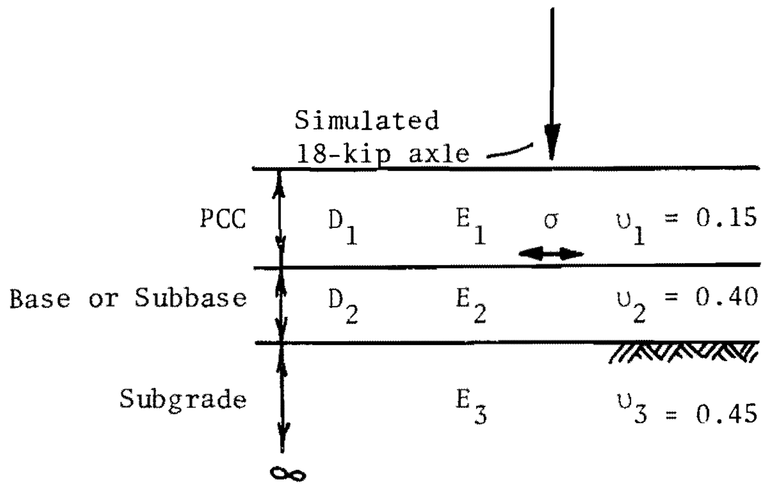


Fig B.2. Illustration of predictive accuracy of E21 Equation.

Pavement Structure

and Response:

(Code: S31)



Details of the Experiment:

1. Full factorial, 5 factors, no. of observations = 3^5 = 243
2. Levels of the significant factors:

Factors		Levels		
		High	Medium	Low
E_1	(psi)	6,500,000	5,000,000	3,500,000
E_2	(psi)	600,000	320,000	40,000
E_3	(psi)	20,000	11,000	2,000
D_1	(in)	10	8	6
D_2	(in)	12	9	6

(continued)

Fig B.3. S31 Regression model: for predicting concrete stress in a 3-layer concrete pavement.

Prediction Equation - S31:

$\log_{10} \sigma = \Sigma$ (Term x Coefficient)

$r^2 = 0.989$

std. error = 0.0202

Term	Coefficient
Intercept	$+ 2.880 \times 10^{0}$
E_1	$+ 1.972 \times 10^{-8}$
E_2	$- 1.210 \times 10^{-6}$
E_3	$- 1.720 \times 10^{-5}$
D_1	$- 8.113 \times 10^{-2}$
$E_2 \times D_2$	$- 5.097 \times 10^{-8}$
$E_2 \times D_1$	$+ 6.121 \times 10^{-8}$
$E_1 \times E_2$	$+ 7.135 \times 10^{-14}$
$(E_3)^2$	$+ 3.818 \times 10^{-10}$
$(E_2)^2$	$+ 3.312 \times 10^{-13}$
$E_2 \times E_3$	$+ 5.034 \times 10^{-12}$

Fig B.3. (continued)

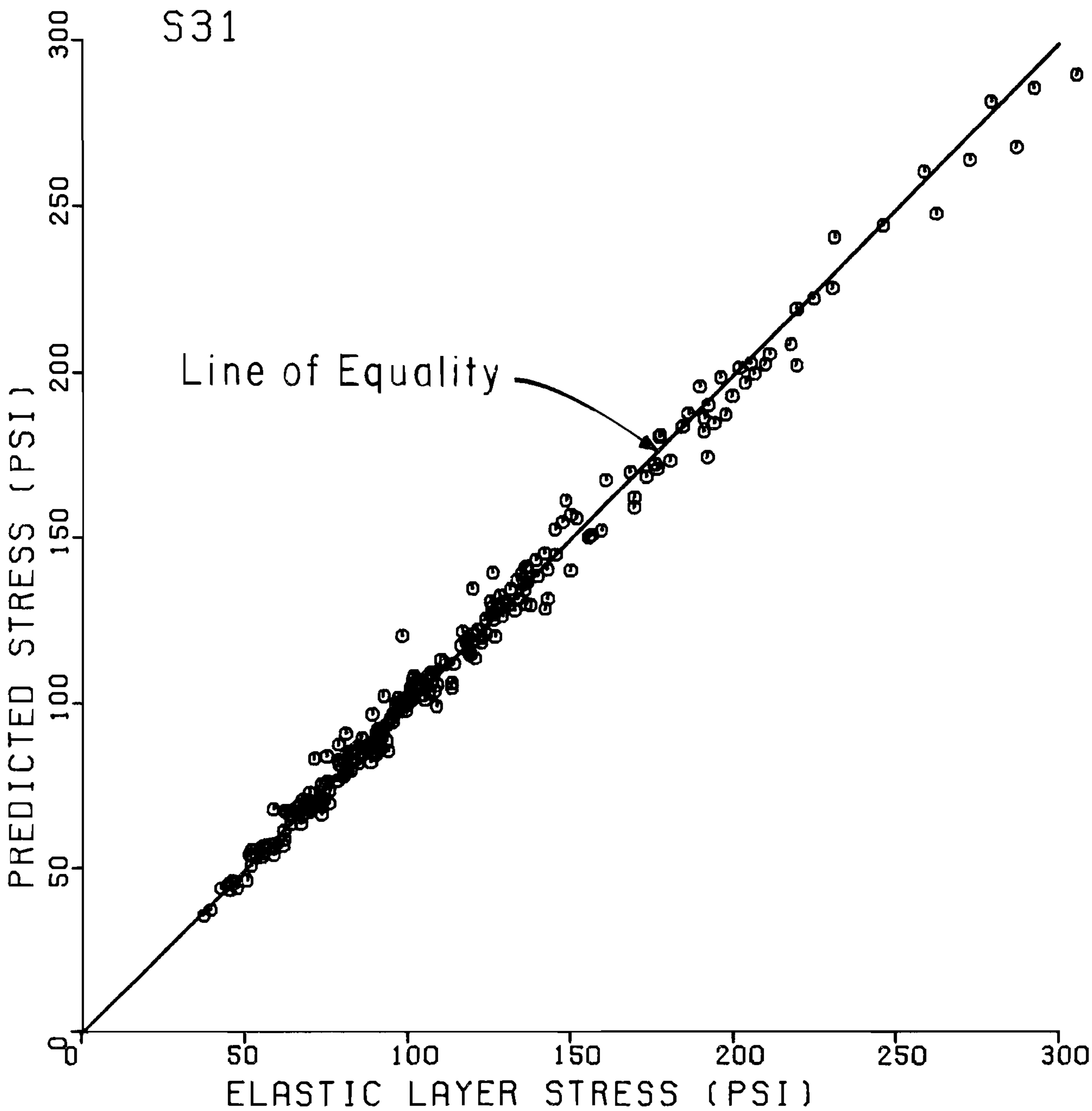
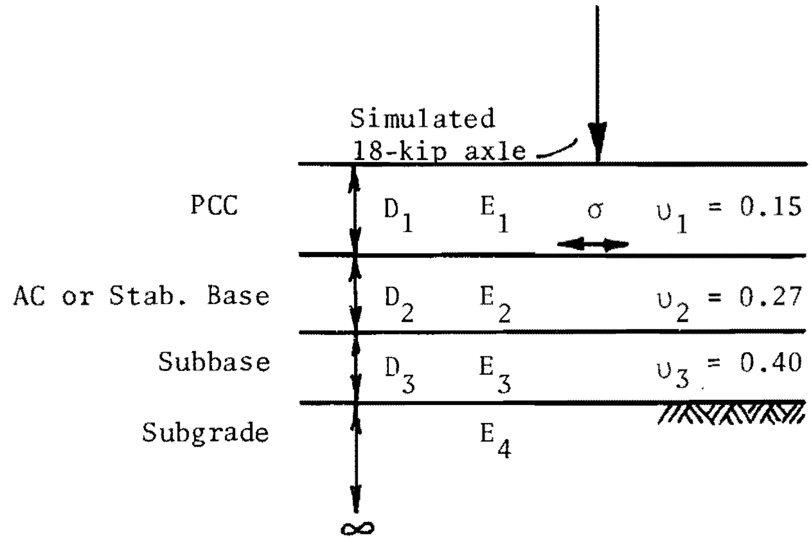


Fig B.4. Illustration of predictive accuracy of S31 equation.

Pavement Structure

and Response:

(Code: S41)



Details of the Experiment:

1. Fractional factorial, 7 factors, no. of observations = $\frac{1}{9} \times 3^7 = 243$
2. Levels of the significant factors:

Factors	Levels High	Medium	Low
E_1 (psi)	6,500,000	5,000,000	3,500,000
E_2 (psi)	800,000	500,000	200,000
E_3 (psi)	500,000	270,000	40,000
E_4 (psi)	20,000	11,000	2,000
D_1 (in)	10	8	6
D_2 (in)	10	8	6
D_3 (in)	12	9	6

(continued)

Fig B.5. S41 Regression Model: for predicting stress in 4-layer concrete pavement.

Prediction Equation - S41:

$\log_{10}$ = (Term x Coefficient)

$r^2 = 0.987$

std. error = 0.0203

Term	Coefficient
Intercept	$+ 2.660 \times 10^{0}$
E_1	$+ 3.326 \times 10^{-8}$
E_2	$- 9.386 \times 10^{-7}$
E_3	$- 6.715 \times 10^{-7}$
E_4	$- 5.279 \times 10^{-6}$
D_1	$- 5.911 \times 10^{-2}$
D_2	$- 1.153 \times 10^{-2}$
$E_1 \times E_2$	$+ 5.406 \times 10^{-14}$
$E_2 \times D_1$	$+ 3.909 \times 10^{-8}$
$(E_3)^2$	$+ 4.712 \times 10^{-13}$
$E_3 \times E_4$	$+ 8.343 \times 10^{-12}$
$E_2 \times D_2$	$- 3.106 \times 10^{-8}$
$E_3 \times D_2$	$+ 3.016 \times 10^{-8}$
$E_3 \times D_3$	$- 2.718 \times 10^{-8}$
$E_4 \times D_1$	$- 6.465 \times 10^{-7}$
$(E_4)^2$	$+ 1.959 \times 10^{-10}$
$(E_2)^2$	$+ 1.826 \times 10^{-13}$

Fig B.5. (Continued)

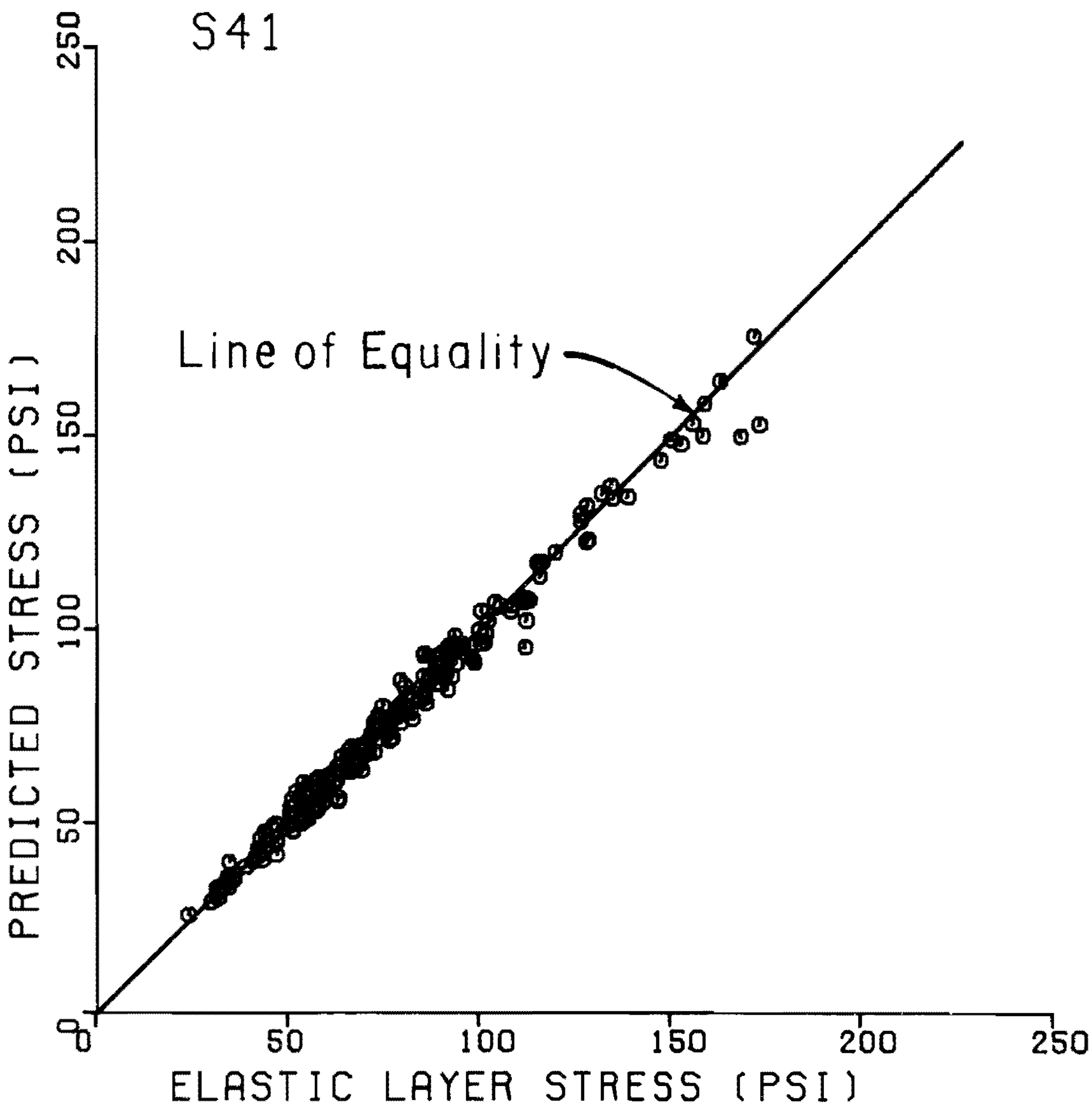
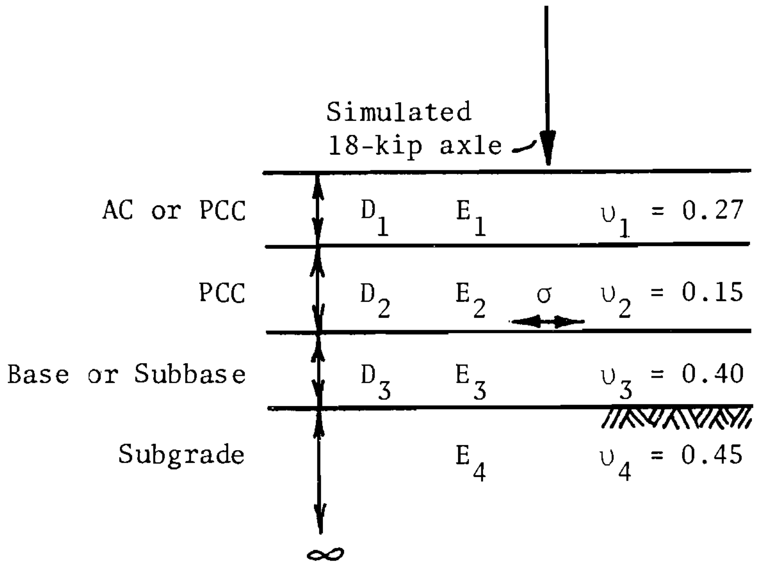


Fig B.6. Illustration of predictive accuracy of S41 equation.

Pavement Structure

and Response:

(Code: SB42)



Details of the Experiment:

1. Fractional factorial, 7 factors, no. of observations = $\frac{1}{9} \times 3^7 = 243$
2. Levels of the significant factors:

Factors	Levels: High	Medium	Low
E_1 (psi)	6,250,000	3,250,000	250,000
E_2 (psi)	6,500,000	5,000,000	3,500,000
E_3 (psi)	600,000	320,000	40,000
E_4 (psi)	20,000	11,000	2,000
D_1 (in)	8	6.5	5
D_2 (in)	10	8	6
D_3 (in)	12	9	6

(continued)

Fig B.7. 5B42 Regresion Model: for predicting stress in a 5-layer concrete pavement with a bonded overlay.

Prediction Equation - SB42:

$$\log_{10} \sigma = \Sigma(\text{Term x Coefficient})$$

$r^2 = 0.987$

std. error = 0.0213

Term	Coefficient
Intercept	$+ 2.667 \times 10^{0}$
E_1	$- 9.509 \times 10^{-8}$
E_2	$+ 3.368 \times 10^{-8}$
E_3	$- 6.977 \times 10^{-7}$
E_4	$- 1.644 \times 10^{-5}$
D_1	$- 2.719 \times 10^{-2}$
D_2	$- 5.441 \times 10^{-2}$
D_3	$- 5.797 \times 10^{-3}$
$(E_1)^2$	$+ 8.702 \times 10^{-15}$
$E_3 \times D_3$	$- 3.814 \times 10^{-8}$
$E_1 \times E_3$	$+ 9.055 \times 10^{-14}$
$(E_4)^2$	$+ 3.764 \times 10^{-10}$
$E_2 \times E_3$	$+ 4.602 \times 10^{-14}$
$E_3 \times D_2$	$+ 3.225 \times 10^{-8}$
$E_1 \times D_1$	$- 2.891 \times 10^{-9}$
$E_1 \times D_3$	$+ 1.323 \times 10^{-9}$
$E_3 \times (E_1)^2$	$- 8.115 \times 10^{-21}$

Fig B.7. (Continued)

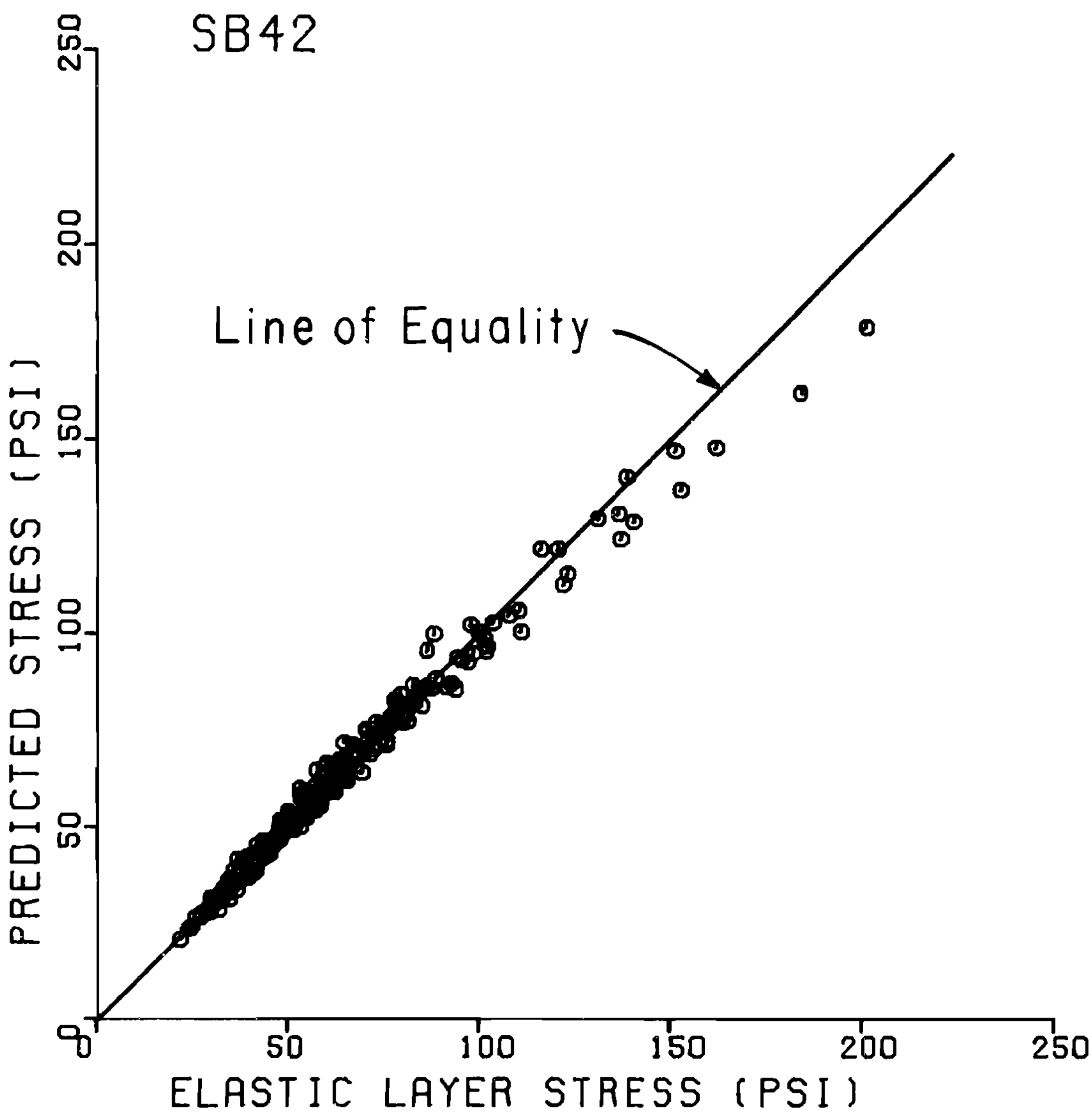
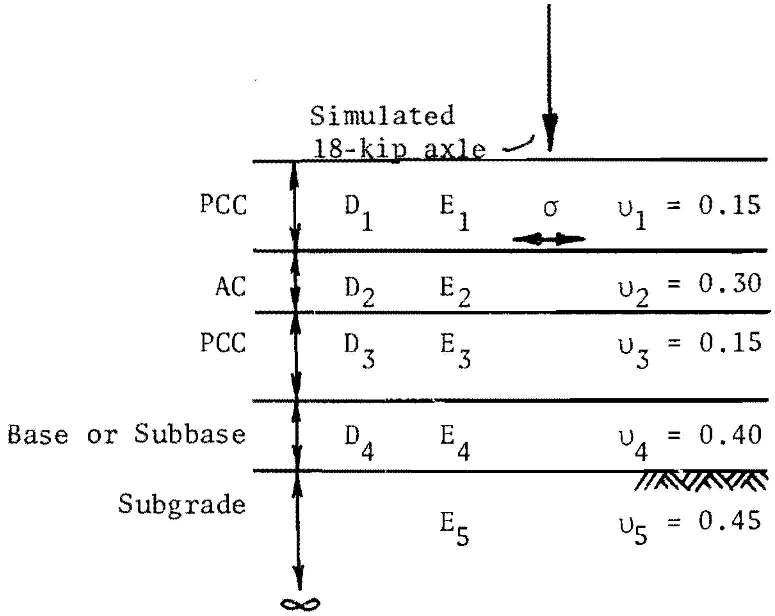


Fig B.8. Illustration of predictive accuracy of 5B42 equation.

Pavement Structure

and Response:

(Code: SU51)



Details of the Experiment:

1. Fractional factorial, 9 factors, no. of observations = $\frac{1}{81} \times 3^9 = 243$
2. Levels of the significant factor:

Factors		Levels: High	Medium	Low
E_1	(psi)	6,500,000	5,000,000	3,500,000
E_2	(psi)	550,000	300,000	50,000
E_3	(psi)	6,500,000	5,000,000	3,500,000
E_4	(psi)	600,000	320,000	40,000
E_5	(psi)	20,000	11,000	2,000
D_1	(in)	8	7	6
D_2	(in)	7	4	1
D_3	(in)	10	8	6
D_4	(in)	12	9	6

(continued)

Fig B.9. SU51 Regression Model: for predicting stress in unbonded concrete overlay of 5-layer concrete pavement.

Prediction Equation - SU51:

$\log_{10} \sigma = \Sigma$ (Term x Coefficient)

$r^2 = 0.986$

std. error = 0.0317

Term	Coefficient
Intercept	$+ 2.461 \times 10^{0}$
E_1	$+ 4.790 \times 10^{-8}$
E_2	$- 2.780 \times 10^{-6}$
E_3	$- 2.149 \times 10^{-8}$
E_4	$- 5.871 \times 10^{-8}$
D_1	$- 5.780 \times 10^{-2}$
D_2	$+ 3.569 \times 10^{-2}$
D_3	$- 3.495 \times 10^{-2}$
$(E_2)^2$	$+ 1.161 \times 10^{-12}$
$E_1 \times E_2$	$+ 1.093 \times 10^{-13}$
$E_2 \times D_2$	$+ 1.583 \times 10^{-7}$
$D_2 \times D_3$	$+ 4.019 \times 10^{-3}$
$E_3 \times D_2$	$+ 4.103 \times 10^{-9}$
$E_2 \times (D_2)^2$	$- 1.483 \times 10^{-8}$
$E_2 \times D_1$	$+ 5.646 \times 10^{-8}$
$E_2 \times E_3$	$- 3.550 \times 10^{-14}$
$D_1 \times D_2$	$- 4.068 \times 10^{-3}$
$E_2 \times E_5$	$+ 4.396 \times 10^{-12}$
$E_1 \times (D_2)^2$	$- 7.478 \times 10^{-10}$

Fig B.9. (Continued)

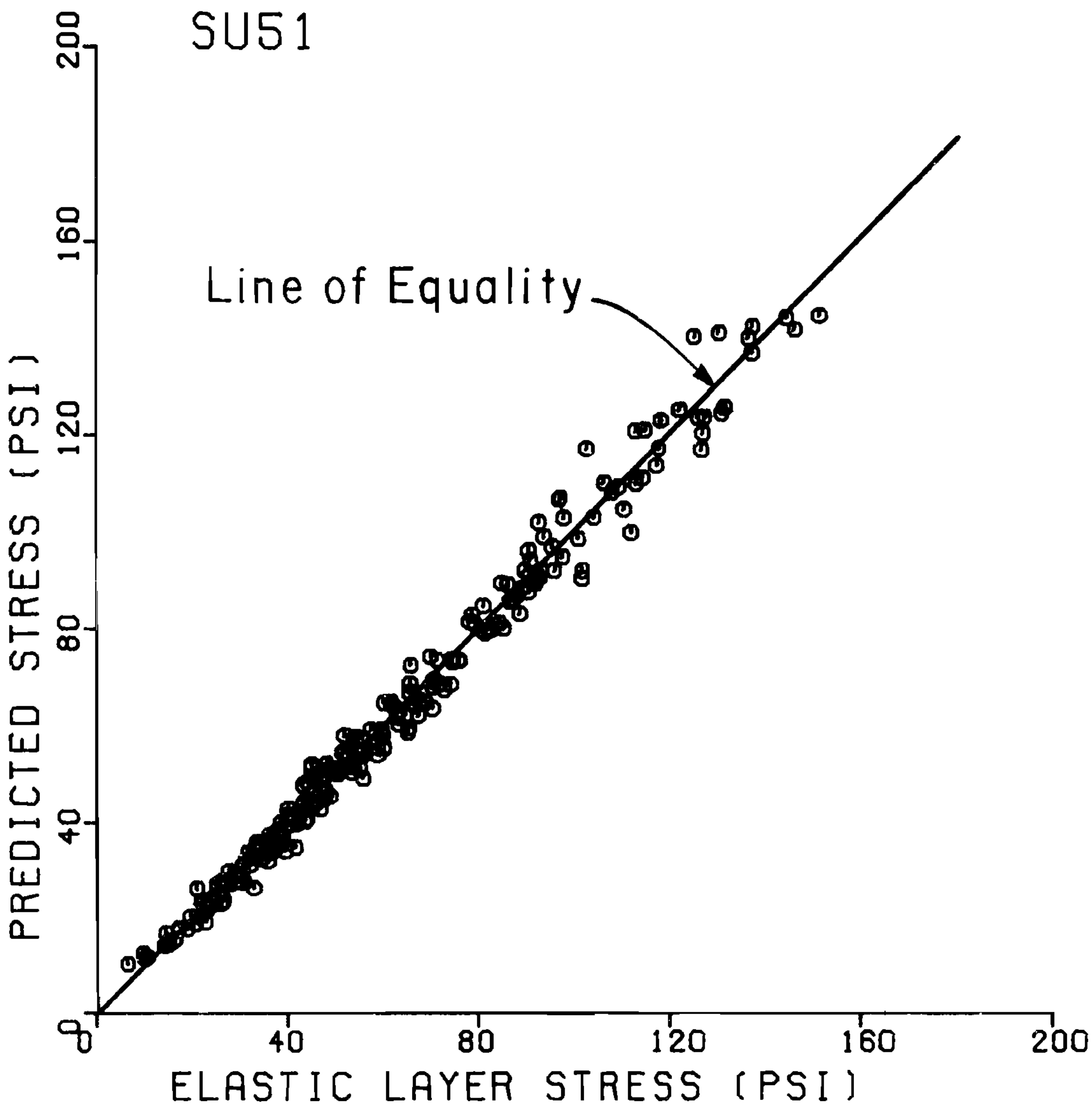
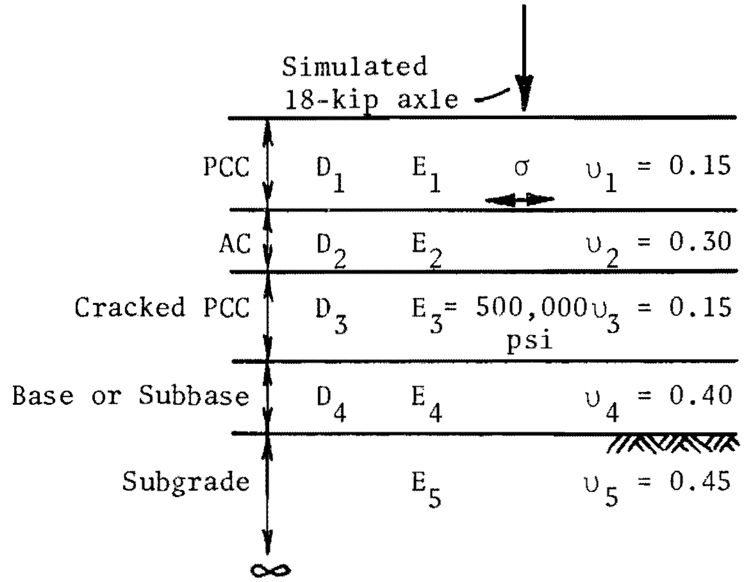


Fig B.10. Illustration of predictive accuracy of SU51 equation.

Pavement Structure

and Response:

(Code: SU51C)



Details of the Experiment:

1. Fractional factorial, 8 factors, no. of observations = $\frac{1}{27} \times 3^8 = 243$
2. Levels of the significant factors:

Factors		Levels		
		High	Medium	Low
E_1	(psi)	6,500,000	5,000,000	3,500,000
E_2	(psi)	550,000	300,000	50,000
E_4	(psi)	500,000	270,000	40,000
E_5	(psi)	20,000	11,000	2,000
D_1	(in)	8	7	6
D_2	(in)	7	4	1
D_3	(in)	10	8	6
D_4	(in)	12	9	6

Note: E_3 in experiment was fixed at 500,000 psi to simulate cracked PCC.

(continued)

Fig B.11. SU51C Regression Model: for predicting stress in unbonded concrete overlay of 5-layer concrete pavement (original PCC cracked).

Prediction Equation - SU51C:

$\log_{10} \sigma = \Sigma$ (Term x Coefficient)

$r^2 = 0.986$

std. error = 0.0189

Term	Coefficient
Intercept	$+ 2.696 \times 10^{0}$
E_1	$+ 3.354 \times 10^{-8}$
E_2	$- 1.455 \times 10^{-6}$
E_4	$- 5.530 \times 10^{-7}$
E_5	$- 4.660 \times 10^{-6}$
D_1	$- 7.299 \times 10^{-2}$
D_3	$- 2.170 \times 10^{-2}$
D_4	$- 1.899 \times 10^{-3}$
$E_2 \times D_2$	$- 5.900 \times 10^{-8}$
$(E_2)^2$	$+ 8.141 \times 10^{-13}$
$E_1 \times E_2$	$+ 6.601 \times 10^{-14}$
$E_4 \times D_2$	$+ 2.420 \times 10^{-8}$
$E_2 \times D_1$	$+ 5.436 \times 10^{-8}$
$(E_4)^2$	$+ 3.316 \times 10^{-13}$
$E_4 \times E_5$	$+ 5.807 \times 10^{-12}$
$D_2 \times D_3$	$+ 1.066 \times 10^{-3}$
$E_4 \times D_4$	$- 1.267 \times 10^{-8}$
$E_4 \times D_3$	$+ 1.869 \times 10^{-8}$
$E_5 \times D_2$	$+ 2.859 \times 10^{-7}$
$E_2 \times E_4$	$- 1.273 \times 10^{-13}$

Fig B.11. (Continued)

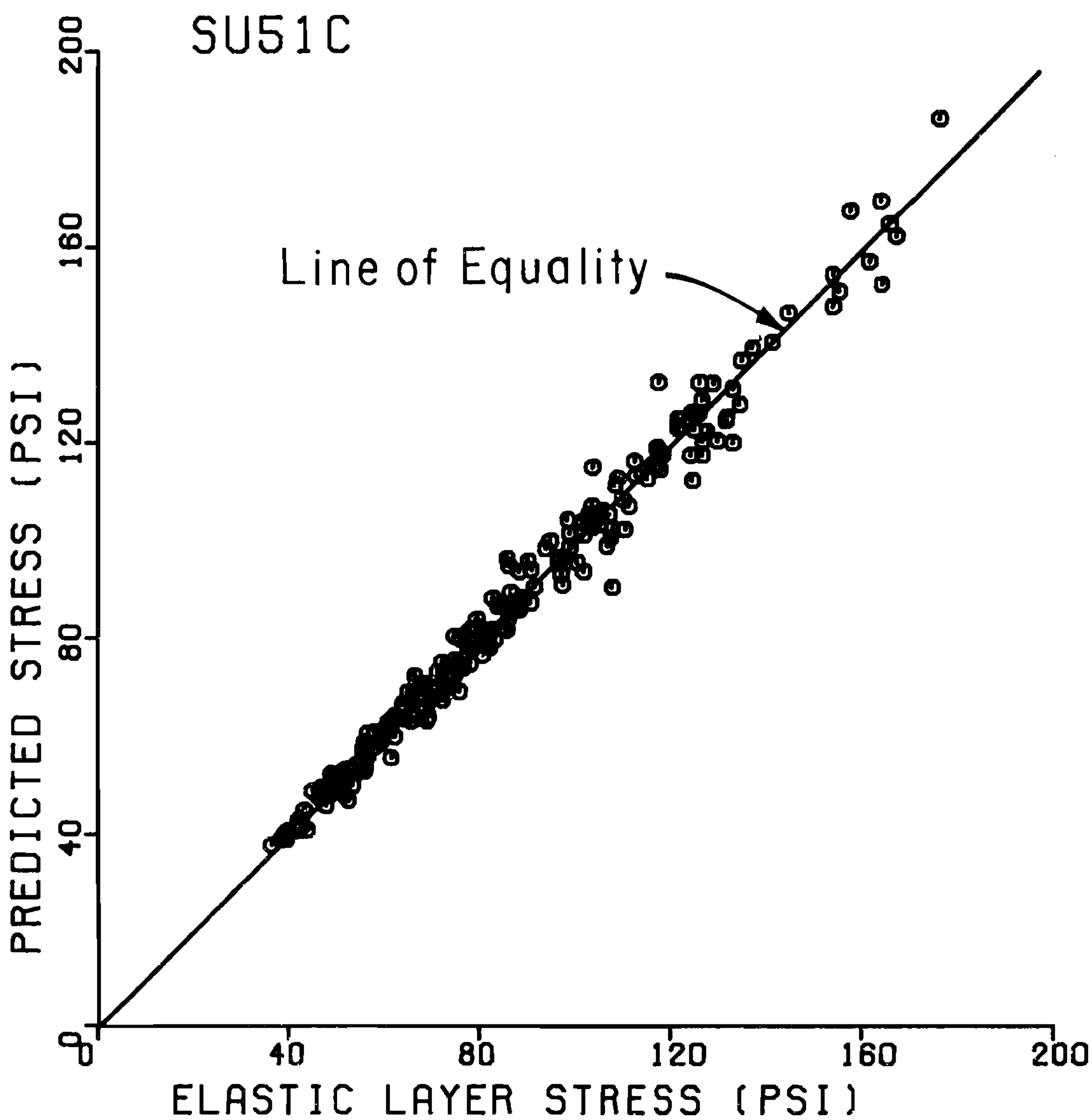
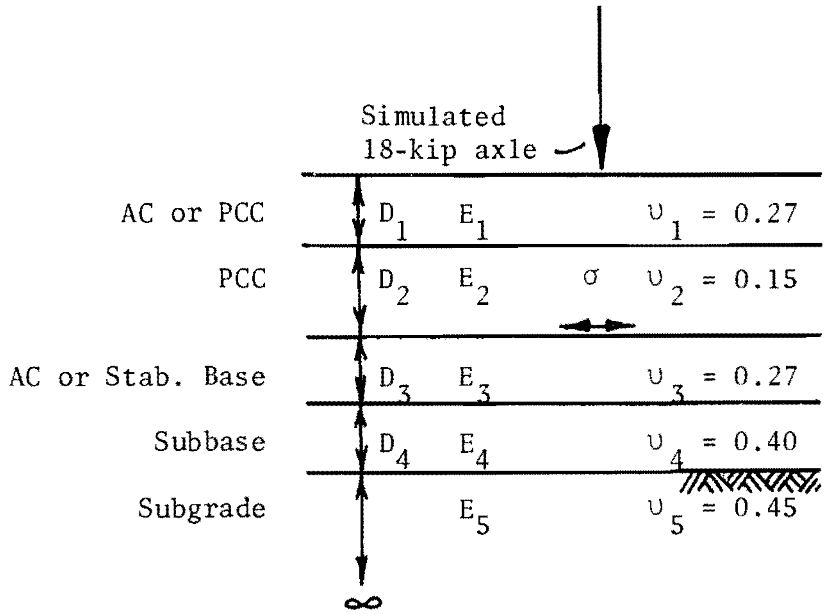


Fig B.12. Illustration of predictive accuracy of SU51C equation.

Pavement Structure and Response:

(Code: SB52)



Details of the Experiment:

1. Full factorial, 9 factors, no. of observations = $\frac{1}{81} \times 3^9 = 243$
2. Levels of the significant factors:

Factors	High	Medium	Low
	Levels		
E_1 (psi)	6,250,000	3,250,000	250,000
E_2 (psi)	6,500,000	5,000,000	3,500,000
E_3 (psi)	800,000	650,000	500,000
E_4 (psi)	500,000	270,000	40,000
E_5 (psi)	20,000	11,000	2,000
D_1 (in)	8	6	4
D_2 (in)	8	7	6
D_3 (in)	10	8	6
D_4 (in)	12	9	6

(continued)

Fig B.13. SB52 Regression Model: for predicting stress in 5-layer concrete pavement with bonded overlay.

Prediction Equation - SB52

$\log_{10} \sigma = \Sigma$(Term x Coefficient)

$r^2 = 0.983$

std. error = 0.0202

Term	Coefficient
Intercept	$+ 2.173 \times 10^{0}$
E_1	$- 3.538 \times 10^{-8}$
E_2	$+ 7.741 \times 10^{-8}$
E_4	$- 5.965 \times 10^{-7}$
E_5	$- 1.472 \times 10^{-5}$
D_1	$- 2.788 \times 10^{-2}$
D_2	$- 3.204 \times 10^{-2}$
D_4	$- 6.584 \times 10^{-3}$
$(E_4)^2$	$+ 3.372 \times 10^{-13}$
$E_4 \times E_5$	$+ 7.174 \times 10^{-12}$
$E_4 \times D_3$	$+ 1.787 \times 10^{-8}$
$E_1 \times E_4$	$+ 2.296 \times 10^{-14}$
$E_4 \times D_4$	$- 2.377 \times 10^{-8}$
$E_1 \times E_2$	$- 2.750 \times 10^{-15}$
$E_1 \times E_3$	$- 2.551 \times 10^{-14}$
$E_3 \times D_3$	$- 4.774 \times 10^{-8}$
$E_1 \times D_3$	$+ 1.195 \times 10^{-9}$
$E_1 \times D_1$	$- 1.399 \times 10^{-9}$
$(E_1)^2$	$+ 2.168 \times 10^{-15}$
$E_1 \times E_5$	$- 2.598 \times 10^{-13}$
$(E_5)^2$	$+ 2.346 \times 10^{-10}$
$E_5 \times D_4$	$+ 3.573 \times 10^{-7}$

Fig B.13. (Continued)

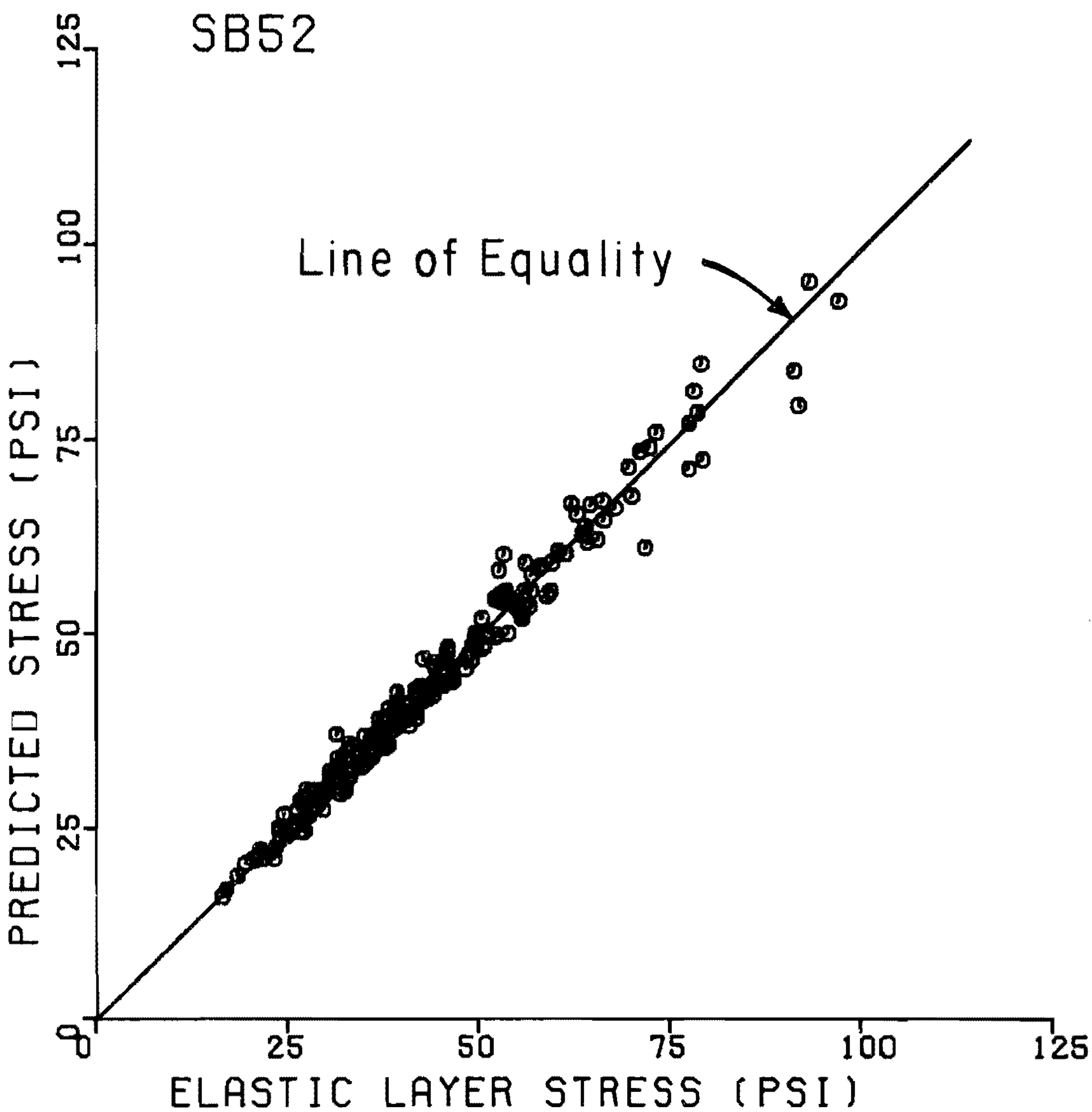
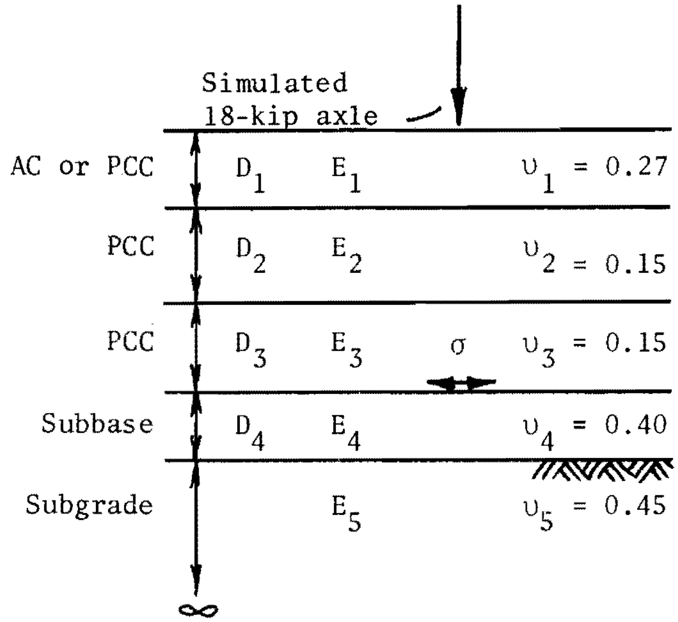


Fig B.14. Illustration of predictive accuracy of SB52 equation.

Pavement Structure

and Response:

(Code: SB53)



Details of the Experiment:

1. Fractional factorial, 9 factors, no. of observations = $\frac{1}{81} \times 3^9 = 243$
2. Levels of the significant factors:

Factors		Levels High	Medium	Low
E_1	(psi)	6,250,000	3,250,000	250,000
E_2	(psi)	6,500,000	5,000,000	3,500,000
E_3	(psi)	6,500,000	5,000,000	3,500,000
E_4	(psi)	600,000	320,000	40,000
E_5	(psi)	20,000	11,000	2,000
D_1	(in)	8	6	4
D_2	(in)	8	7	6
D_3	(in)	10	8	6
D_4	(in)	12	9	6

(continued)

Fig B.15. SB53 Regression Model: for predicting stress in original PCC of 5-layer concrete pavement.

Prediction Equation - SB53:

$\log_{10} \sigma = \Sigma$ (Term x Coefficient)

$r^2 = 0.988$

std. error = 0.0167

Term	Coefficient
Intercept	$+ 2.256 \times 10^{0}$
E_1	$- 4.030 \times 10^{-8}$
E_2	$- 6.979 \times 10^{-9}$
E_3	$+ 3.705 \times 10^{-8}$
E_4	$- 1.970 \times 10^{-7}$
E_5	$- 1.464 \times 10^{-5}$
D_1	$- 1.614 \times 10^{-2}$
D_2	$- 3.452 \times 10^{-2}$
D_3	$- 3.388 \times 10^{-2}$
$(E_1)^2$	$+ 4.159 \times 10^{-15}$
$E_4 \times D_4$	$- 2.820 \times 10^{-8}$
$E_1 \times D_1$	$- 3.127 \times 10^{-9}$
$(E_5)^2$	$+ 3.159 \times 10^{-10}$
$E_3 \times E_4$	$+ 2.993 \times 10^{-14}$
$E_1 \times E_4$	$+ 1.410 \times 10^{-14}$

Fig B.15. (Continued)

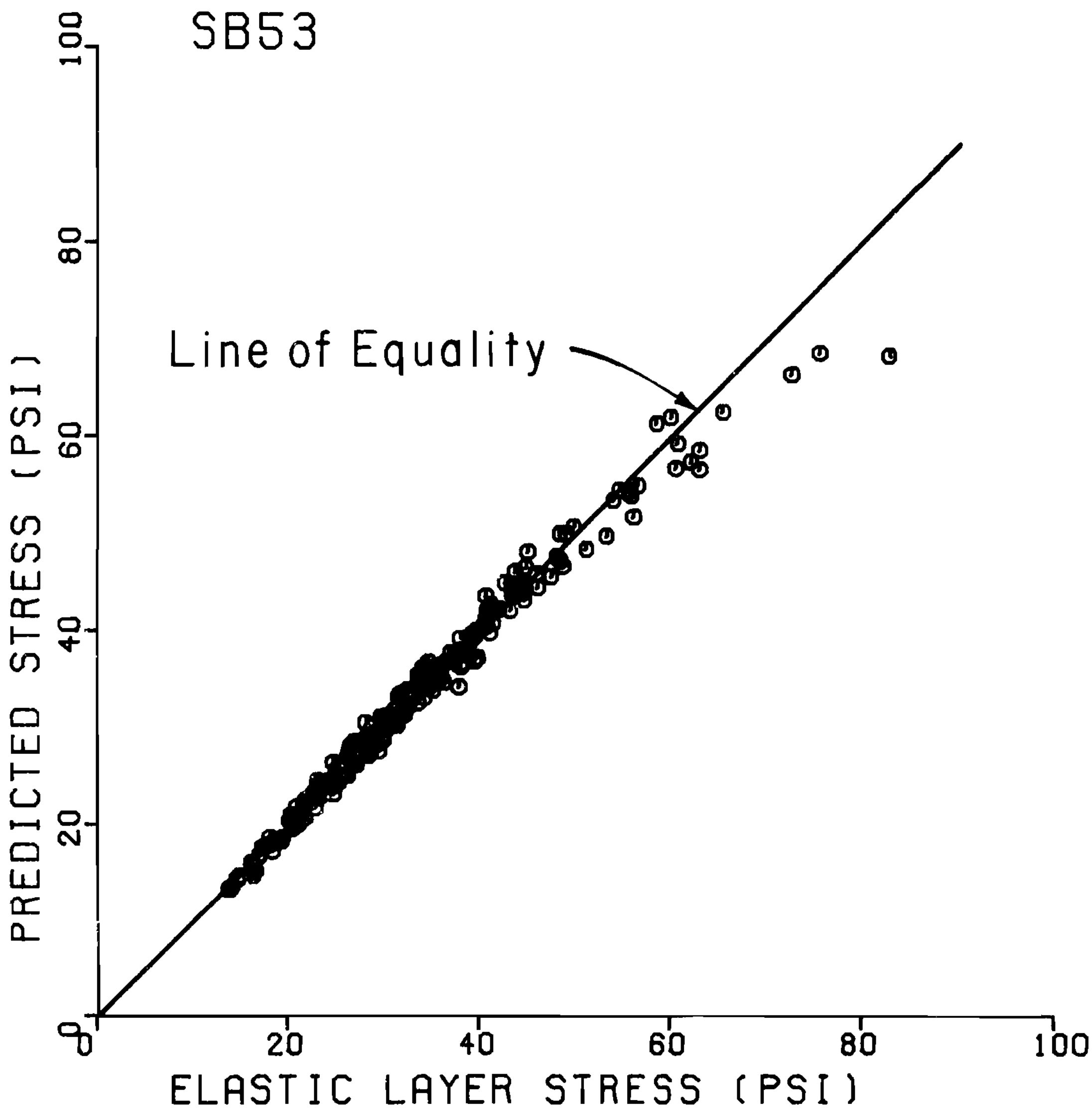
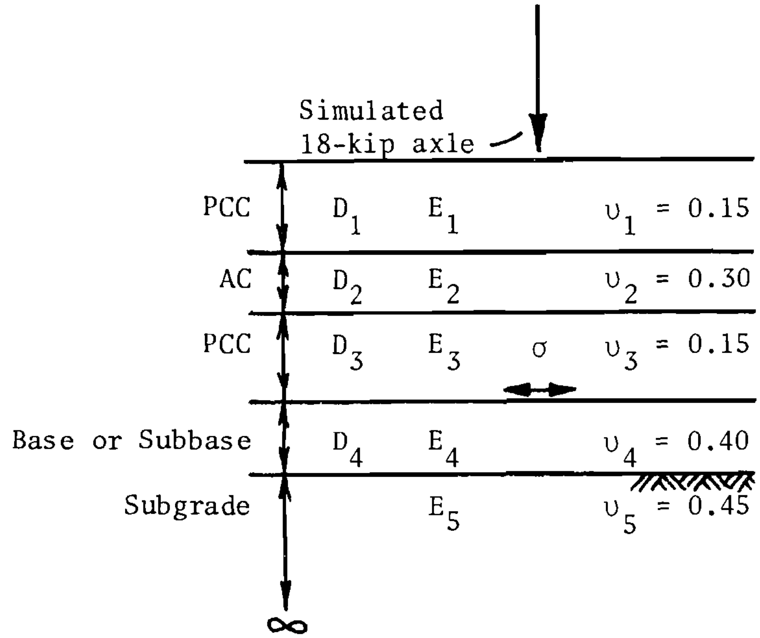


Fig B.16. Illustration of predictive accuracy of SB53 equation.

Pavement Structure

and Response:

(Code: SU53)



Details of the Experiment:

1. Fractional factorial, 9 factors, no. of observations = $\frac{1}{81} \times 3^9 = 243$
2. Levels of the significant factors:

Factors		Levels High	Medium	Low
E_1	(psi)	6,500,000	5,000,000	3,500,000
E_2	(psi)	550,000	300,000	50,000
E_3	(psi)	6,500,000	5,000,000	3,500,000
E_4	(psi)	600,000	320,000	40,000
E_5	(psi)	20,000	11,000	2,000
D_1	(in)	8	7	6
D_2	(in)	7	4	1
D_3	(in)	10	8	6
D_4	(in)	12	9	6

(continued)

Fig B.17. SU53 Regression Model: for predicting stress in original PCC of 5-layer concrete pavement with an unbonded PCC overlay.

Prediction Equation - SU53:

$$\log_{10} \sigma = \Sigma(\text{Term} \times \text{Coefficient})$$

$r^2 = 0.983$

std. error = 0.0215

Term	Coefficient
Intercept	$+ 2.453 \times 10^{0}$
E_1	$- 1.730 \times 10^{-8}$
E_3	$+ 4.018 \times 10^{-8}$
E_4	$- 5.075 \times 10^{-7}$
E_5	$- 1.566 \times 10^{-5}$
D_1	$- 4.548 \times 10^{-2}$
D_2	$- 4.037 \times 10^{-2}$
D_3	$- 3.535 \times 10^{-2}$
D_4	$- 3.833 \times 10^{-3}$
$E_4 \times D_4$	$- 3.892 \times 10^{-8}$
$E_2 \times E_4$	$+ 2.597 \times 10^{-13}$
$(E_5)^2$	$+ 3.087 \times 10^{-10}$
$E_3 \times E_4$	$+ 4.087 \times 10^{-14}$
$E_4 \times D_3$	$+ 2.717 \times 10^{-8}$
$E_2 \times D_3$	$- 2.861 \times 10^{-8}$
$D_2 \times D_3$	$+ 1.739 \times 10^{-3}$
$E_2 \times D_4$	$+ 1.071 \times 10^{-8}$
$E_2 \times E_5$	$+ 3.848 \times 10^{-12}$

Fig B.17. (Continued)

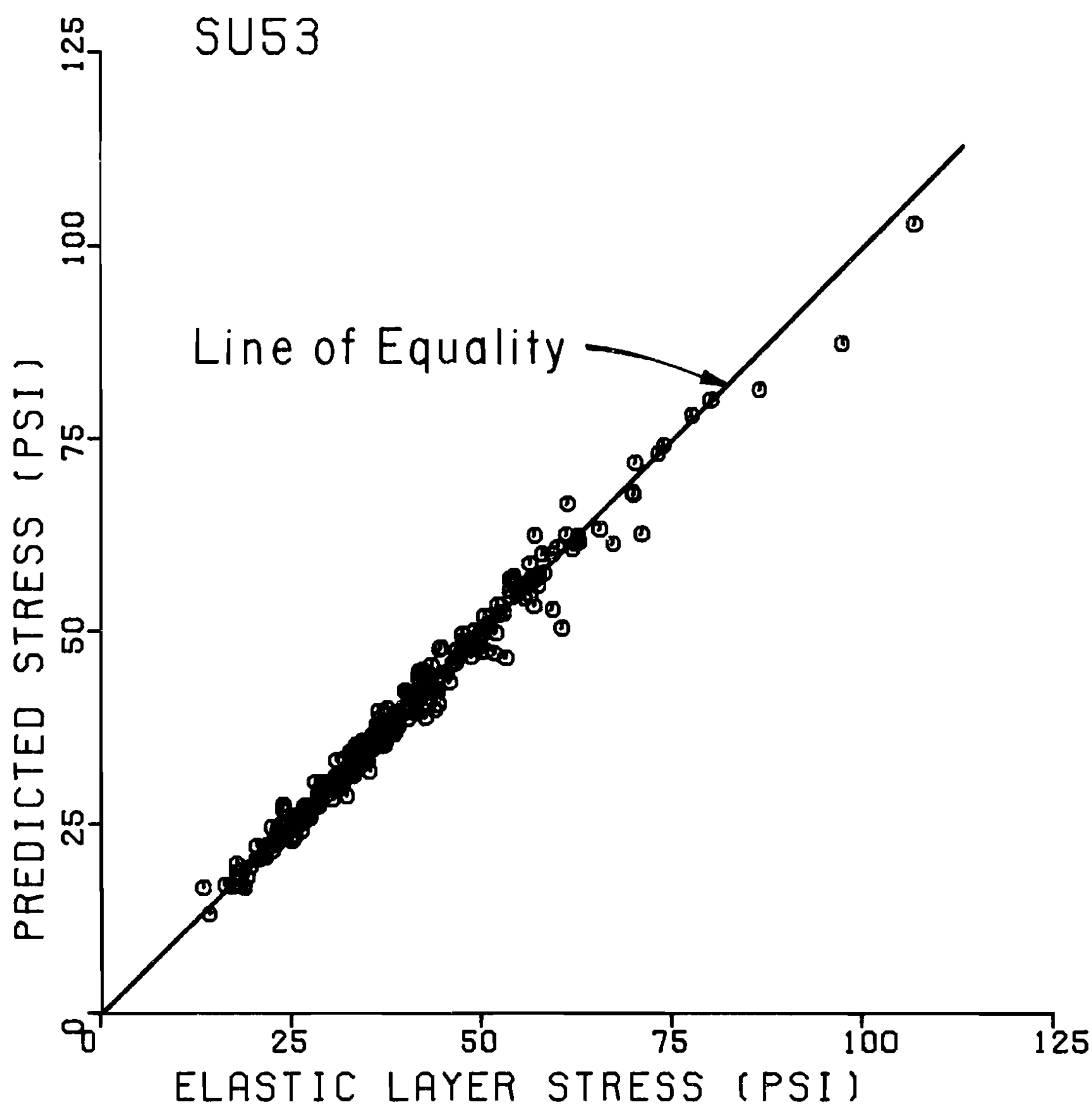
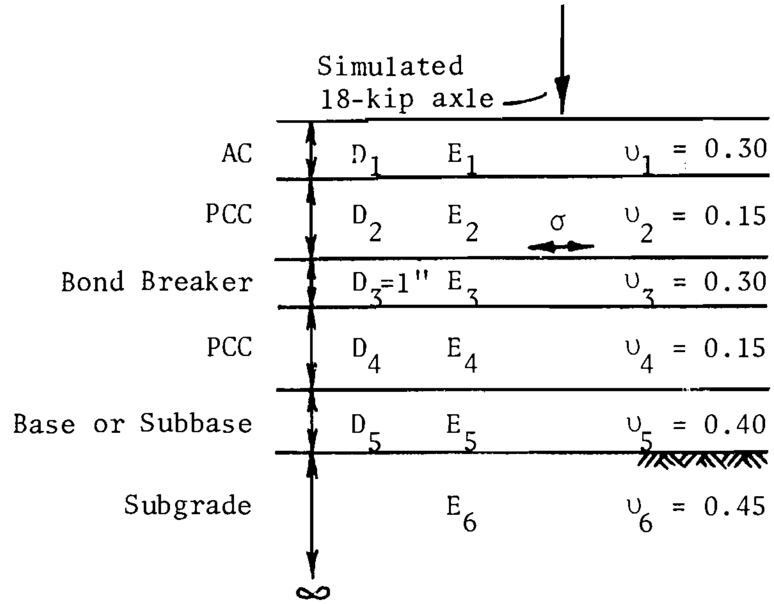


Fig B.18. Illustration of predictive accuracy of SU53 equation.

Pavement Structure

and Response:

(Code: SU62)



Details of the Experiment:

1. Fractional factorial, 10 factors, no. of observations = $\frac{1}{243} \times 3^{10} = 243$
2. Levels of the significant factors:

Factors		Levels: High	Medium	Low
E_1	(psi)	800,000	500,000	200,000
E_2	(psi)	6,500,000	5,000,000	3,500,000
E_3	(psi)	200,000	110,000	20,000
E_4	(psi)	6,500,000	5,000,000	3,500,000
E_5	(psi)	600,000	320,000	40,000
E_6	(psi)	20,000	11,000	2,000
D_1	(in)	8	6	4
D_2	(in)	8	7	6
D_4	(in)	10	8	6
D_5	(in)	12	9	6

(continued)

Note: D_3 in experiment was fixed at 1" to simulate a thin bond breaker.

Fig B.19. SU62 Regression Model: for predicting stress in concrete overlay of 6-layer concrete pavement.

Prediction Equation - SU62:

$\log_{10} \sigma = \Sigma$ (Term x Coefficient)

$r^2 = 0.987$

std. error = 0.0260

Term	Coefficient
Intercept	$+ 2.471 \times 10^{0}$
E_1	$- 9.153 \times 10^{-8}$
E_2	$+ 4.652 \times 10^{-8}$
E_3	$- 4.790 \times 10^{-6}$
E_5	$- 1.098 \times 10^{-7}$
D_1	$- 3.761 \times 10^{-2}$
D_2	$- 5.153 \times 10^{-2}$
D_4	$- 1.926 \times 10^{-2}$
D_5	$- 3.928 \times 10^{-3}$
$(E_3)^2$	$+ 8.508 \times 10^{-12}$
$E_2 \times E_3$	$+ 2.205 \times 10^{-13}$
$E_3 \times D_4$	$- 1.166 \times 10^{-7}$
$E_3 \times E_4$	$- 1.620 \times 10^{-13}$
$E_3 \times D_2$	$+ 1.440 \times 10^{-7}$
$E_1 \times E_3$	$+ 4.716 \times 10^{-13}$

Fig B.19. (Continued)

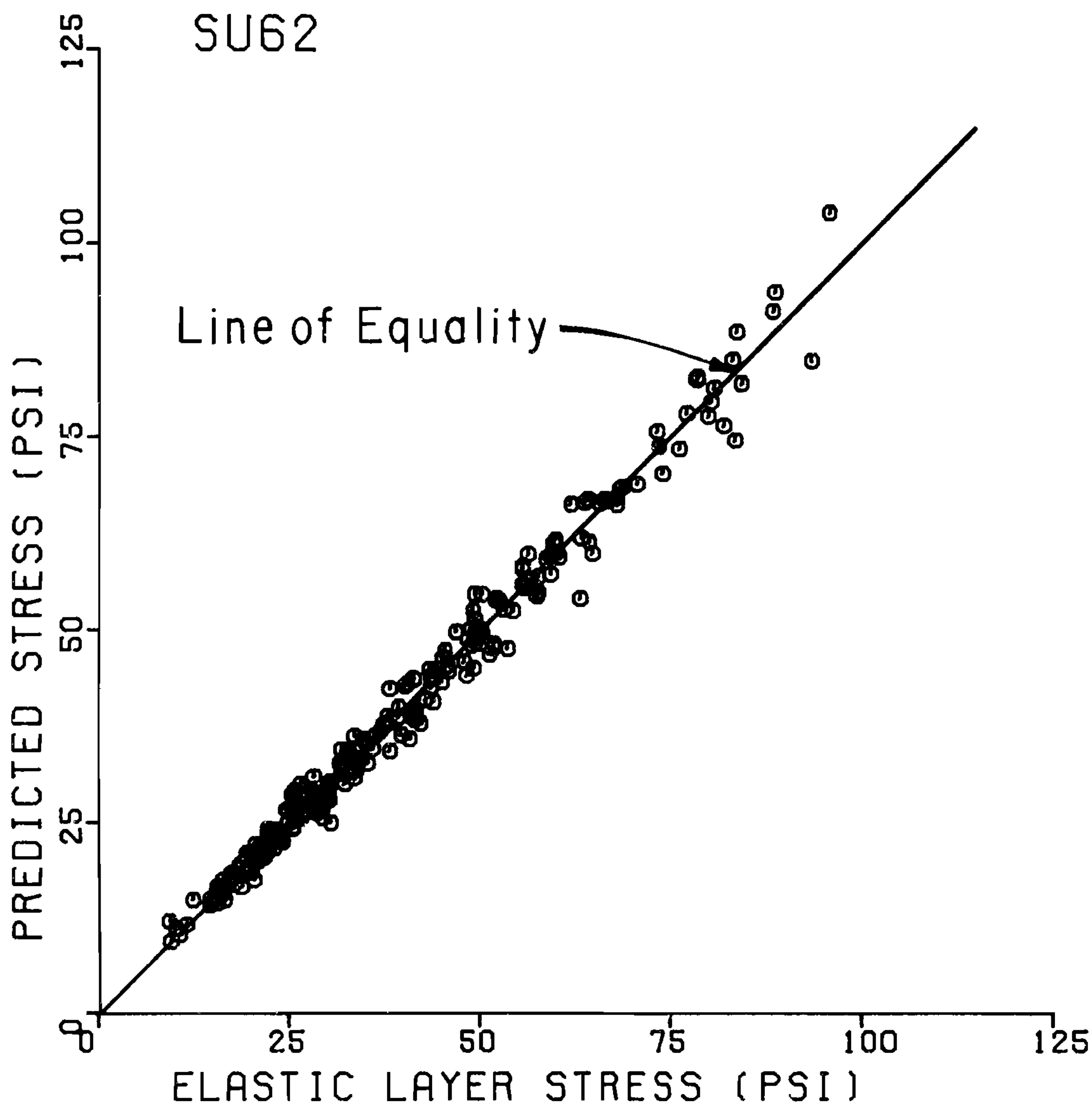
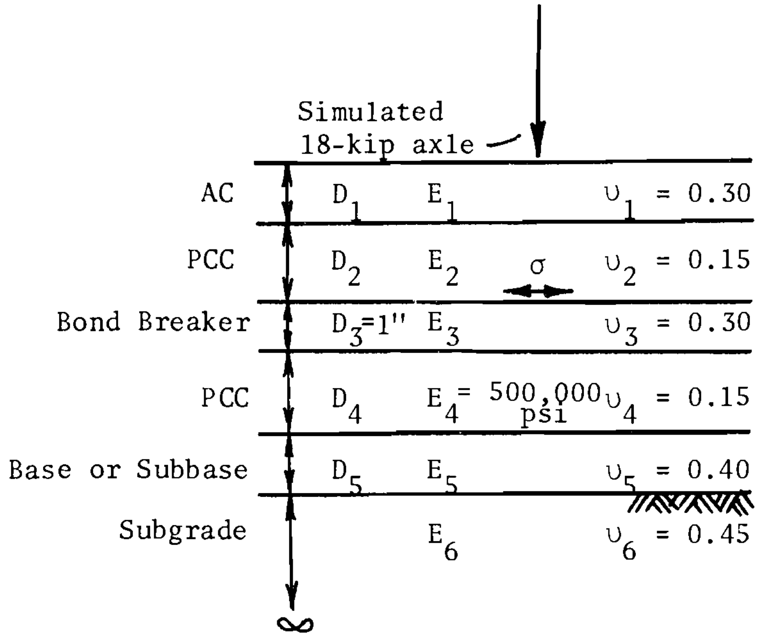


Fig B.20. Illustration of predictive accuracy of SU62 equation.

Pavement Structure

and Response:

(Code: SU62C)



Details of the Experiment:

1. Fractional factorial, 9 factors, no. of observation = $\frac{1}{81} \times 3^9 = 243$
2. Levels of the significant factors:

Factors		Levels High	Medium	Low
E_1	(psi)	800,000	500,000	200,000
E_2	(psi)	6,500,000	5,000,000	3,500,000
E_3	(psi)	200,000	110,000	20,000
E_5	(psi)	500,000	270,000	40,000
E_6	(psi)	20,000	11,000	2,000
D_1	(in)	8	6	4
D_2	(in)	8	7	6
D_4	(in)	10	8	6
D_5	(in)	12	9	6

(continued)

Note: D_3 in this experiment was fixed at 1" to simulate a thin bond breaker. E_4 was fixed at 500,000 psi to simulate cracked PCC.

Fig B.21. SU62C Regression Model: for predicting stress in concrete overlay of 6-layer concrete pavement (original PCC cracked).

Prediction Equation - SU62C:

$\log_{10} \sigma = \Sigma$ (Term x Coefficient)

$r^2 = 0.988$

std. error = 0.0167

Term	Coefficient
Intercept	$+ 2.686 \times 10^{0}$
E_1	$- 1.034 \times 10^{-7}$
E_2	$+ 4.675 \times 10^{-8}$
E_3	$- 2.873 \times 10^{-6}$
E_5	$- 5.247 \times 10^{-7}$
E_6	$- 1.705 \times 10^{-5}$
D_1	$- 3.231 \times 10^{-2}$
D_2	$- 5.267 \times 10^{-2}$
D_4	$- 2.267 \times 10^{-2}$
D_5	$- 6.684 \times 10^{-3}$
$(E_3)^2$	$+ 5.357 \times 10^{-12}$
$E_5 \times E_6$	$+ 8.304 \times 10^{-12}$
$(E_5)^2$	$+ 4.216 \times 10^{-13}$
$E_3 \times E_5$	$- 6.900 \times 10^{-13}$
$E_2 \times E_3$	$+ 1.037 \times 10^{-13}$
$E_5 \times D_5$	$- 2.004 \times 10^{-8}$
$(E_6)^2$	$+ 1.903 \times 10^{-10}$
$E_6 \times D_5$	$+ 3.434 \times 10^{-7}$
$E_5 \times D_4$	$+ 1.987 \times 10^{-8}$
$E_3 \times D_2$	$+ 9.607 \times 10^{-8}$
$E_6 \times D_4$	$+ 4.388 \times 10^{-7}$
$E_3 \times D_4$	$- 4.152 \times 10^{-8}$
$E_1 \times E_3$	$+ 2.548 \times 10^{-13}$

Fig B.21. (Continued)

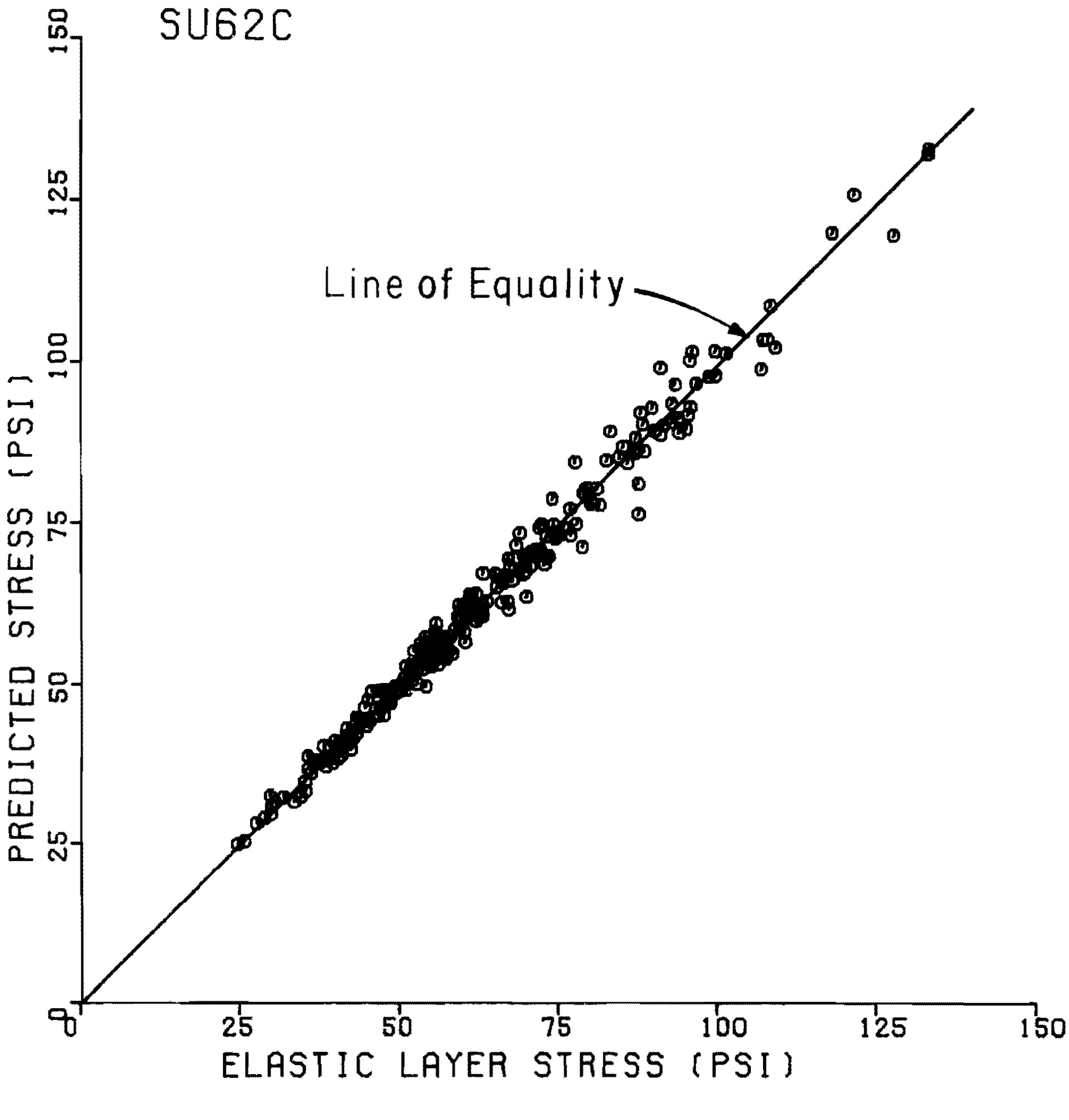
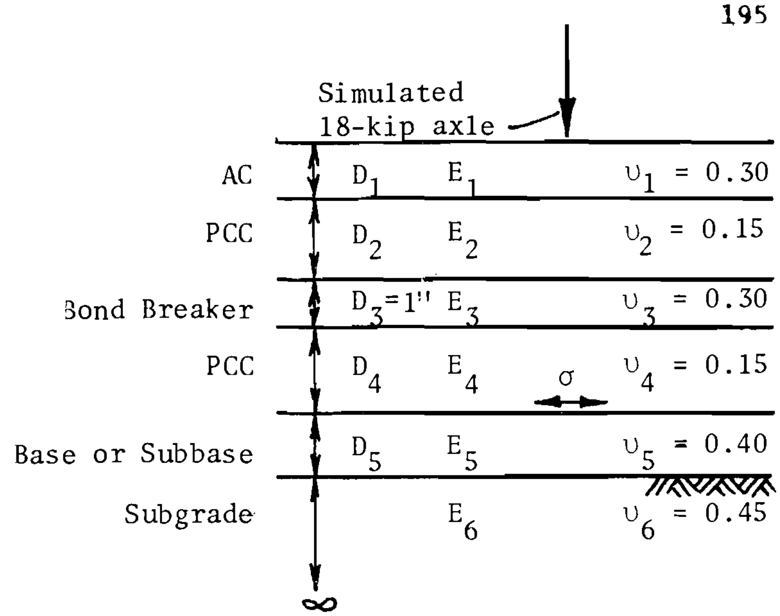


Fig B.22. Illustration of predictive accuracy of SU62C equation.

Pavement Structure

and Response:

(Code: SU64)



Details of the Experiment:

1. Fractional factorial, 10 factors, no. of observations = $\frac{1}{243} \times 3^{10} = 243$
2. Levels of the significant factors:

Factors		High	Medium	Low
		Levels		
E_1	(psi)	800,000	500,000	200,000
E_2	(psi)	6,500,000	5,000,000	3,500,000
E_3	(psi)	200,000	110,000	20,000
E_4	(psi)	6,500,000	5,000,000	3,500,000
E_5	(psi)	600,000	320,000	40,000
E_6	(psi)	20,000	11,000	2,000
D_1	(in)	8	6	4
D_2	(in)	8	7	6
D_4	(in)	10	8	6
D_5	(in)	12	9	6

Note: D_3 in experiment was fixed at 1" to simulate a thin bond breaker.

(continued)

Fig B.23. SU64 Regression Model: for predicting stress in original PCC of 6-layer concrete pavement.

Prediction Equation - SU64:

$\log_{10} \sigma = \Sigma$ (Term x Coefficient)

$r^2 = 0.983$

std. error = 0.0204

Term	Coefficient
Intercept	$+ 2.257 \times 10^{0}$
E_2	$- 1.226 \times 10^{-8}$
E_3	$+ 7.180 \times 10^{-7}$
E_4	$+ 4.318 \times 10^{-8}$
E_5	$- 4.756 \times 10^{-7}$
E_6	$- 1.776 \times 10^{-5}$
D_1	$- 1.155 \times 10^{-2}$
D_2	$- 4.257 \times 10^{-2}$
D_4	$- 2.253 \times 10^{-2}$
D_5	$- 4.381 \times 10^{-3}$
$E_5 \times D_5$	$- 4.004 \times 10^{-8}$
$(E_6)^2$	$+ 3.490 \times 10^{-10}$
$E_4 \times E_5$	$+ 3.949 \times 10^{-14}$
$E_5 \times D_4$	$+ 2.659 \times 10^{-8}$
$E_3 \times E_5$	$+ 5.826 \times 10^{-13}$
$E_3 \times D_4$	$- 7.963 \times 10^{-8}$
$(E_3)^2$	$- 2.212 \times 10^{-12}$
$E_3 \times E_6$	$+ 1.148 \times 10^{-11}$
$E_1 \times D_1$	$- 1.533 \times 10^{-8}$
$E_3 \times D_5$	$+ 3.088 \times 10^{-8}$

Fig B.23. (Continued)

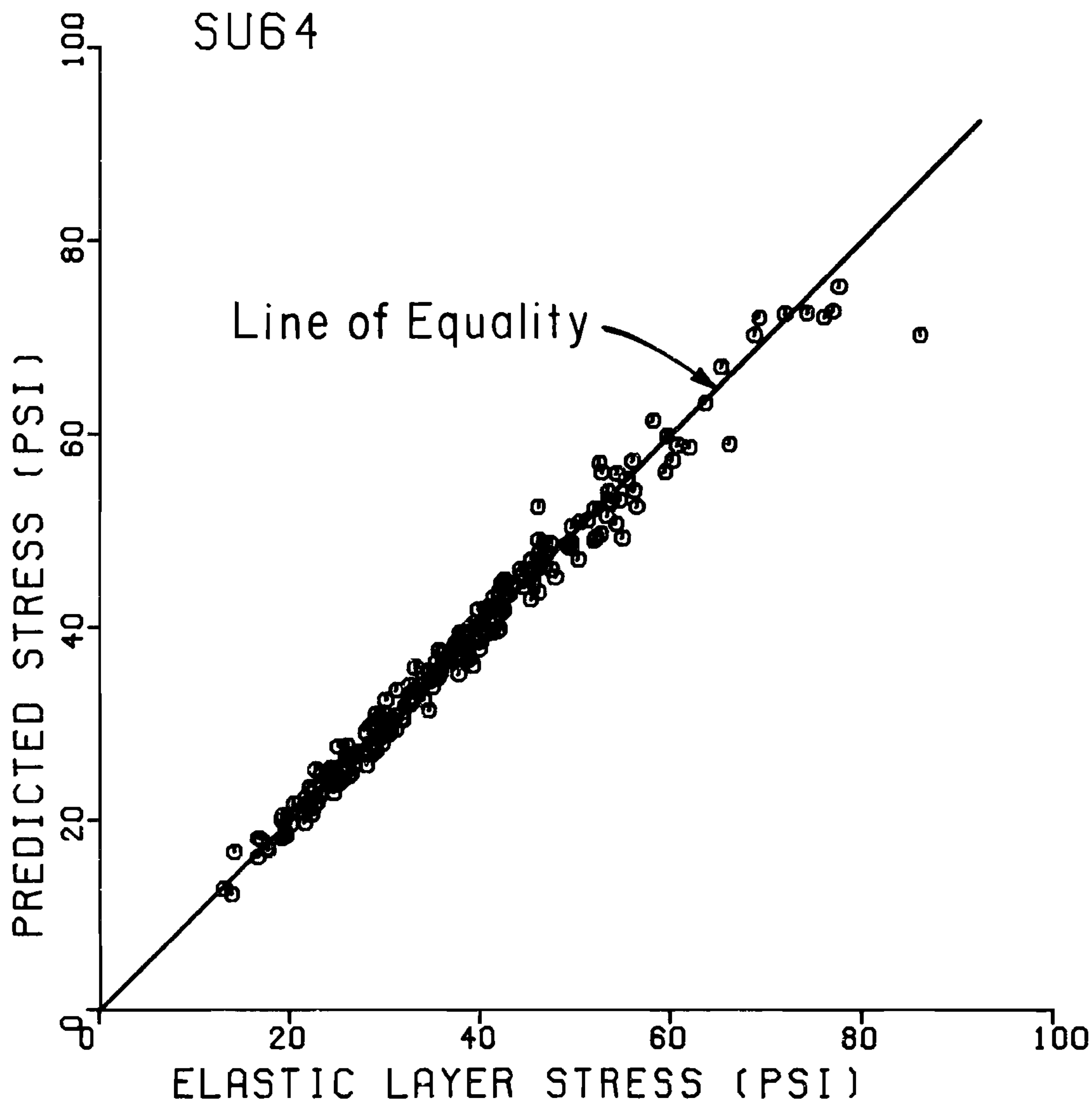


Fig B.24. Illustration of predictive accuracy of SU64 equation.

APPENDIX C

FLOW DIAGRAM FOR STRTGY ROUTINE

APPENDIX C. FLOW DIAGRAM OF STRTGY ROUTINE

STRTGY - Generates all feasible overlay design strategies for RPRDS

↓

Define 18-kip ESAL* fatigue equations (defined by statement functions)

PCC equation - poor environment:

$$SFATIG\ (FR,\ C,\ S) = 0.046 \times \left(\frac{FR}{C \times S}\right)^{3.0}$$

PCC equation - good environment:

$$OFATIG\ (FR,\ C,\ S) = 0.043 \times \left(\frac{FR}{C \times S}\right)^{3.2}$$

ACP equation:

$$EFATIG\ (EPS) = 9.73 \times 10^{-21} \times (EPS)^{-5.16}$$

*NOTE: 18-kip ESAL fatigue applications are in millions.

↓

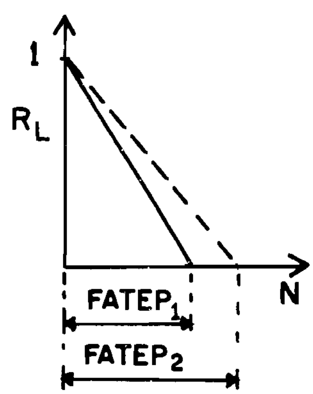
Compute fatigue life of original pavement, both for poor and good environments.

Poor environment:

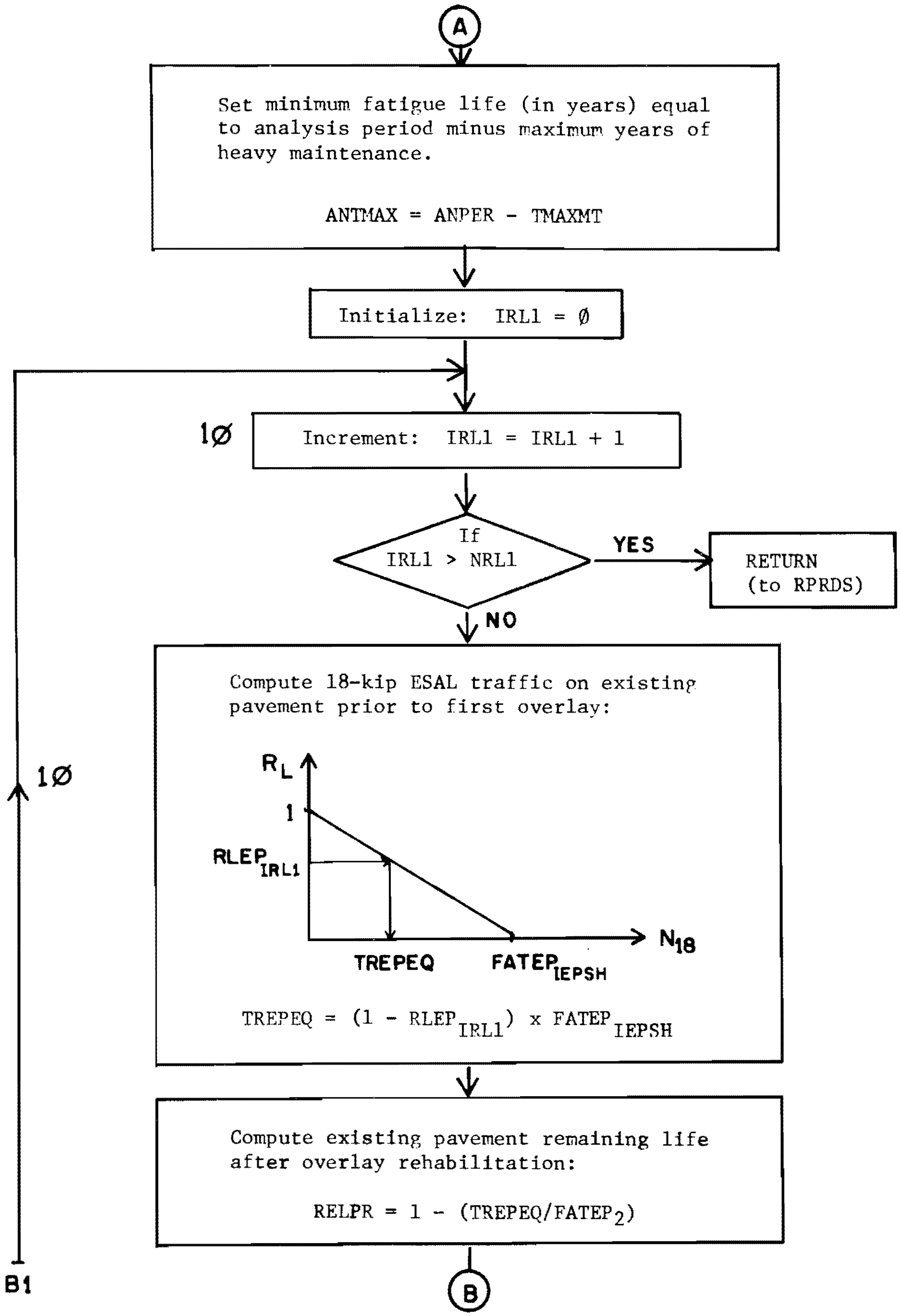
$$FATEP_1 = SFATIG\ (FREP,\ CEP,\ S\emptyset)$$

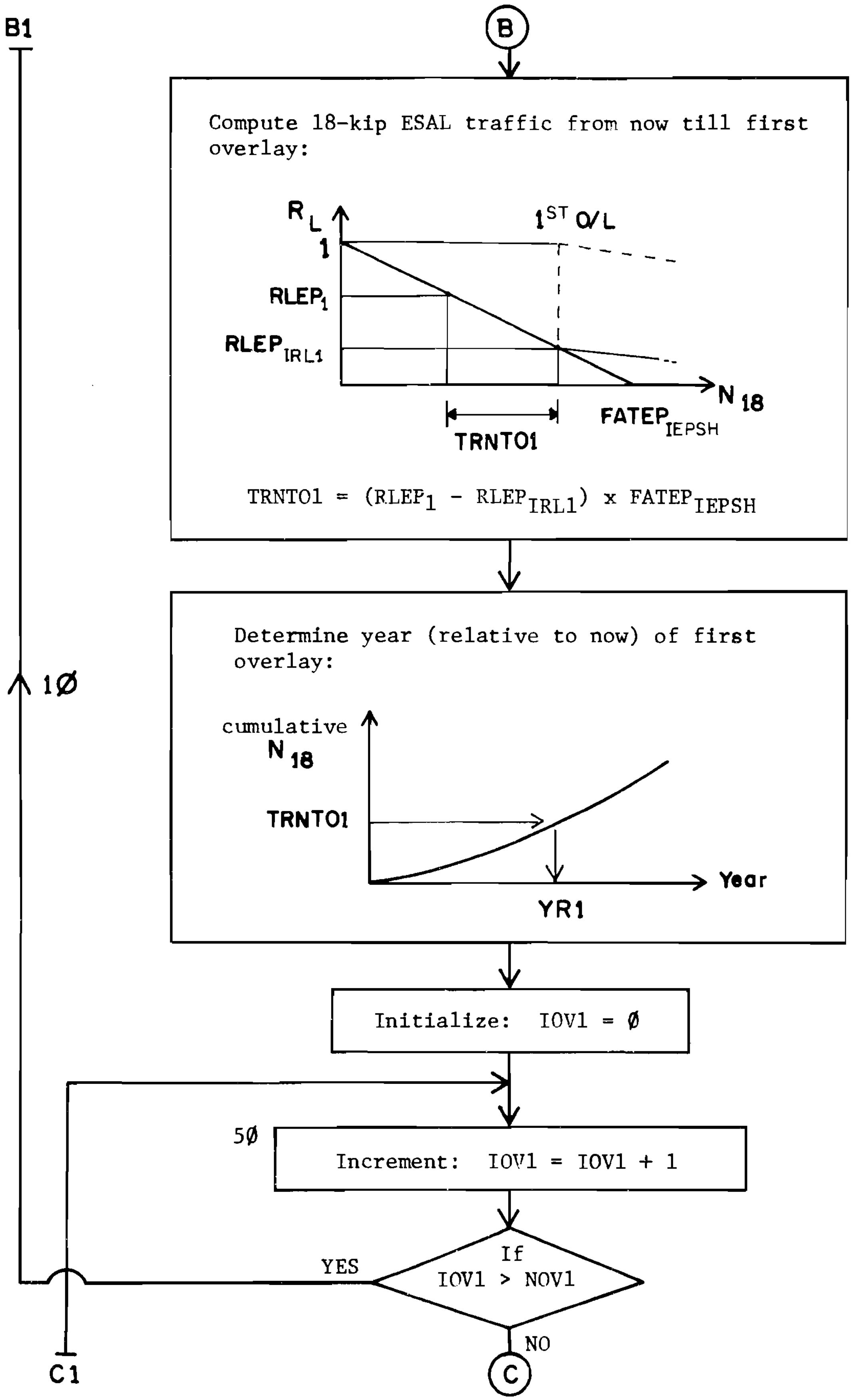
Good environment:

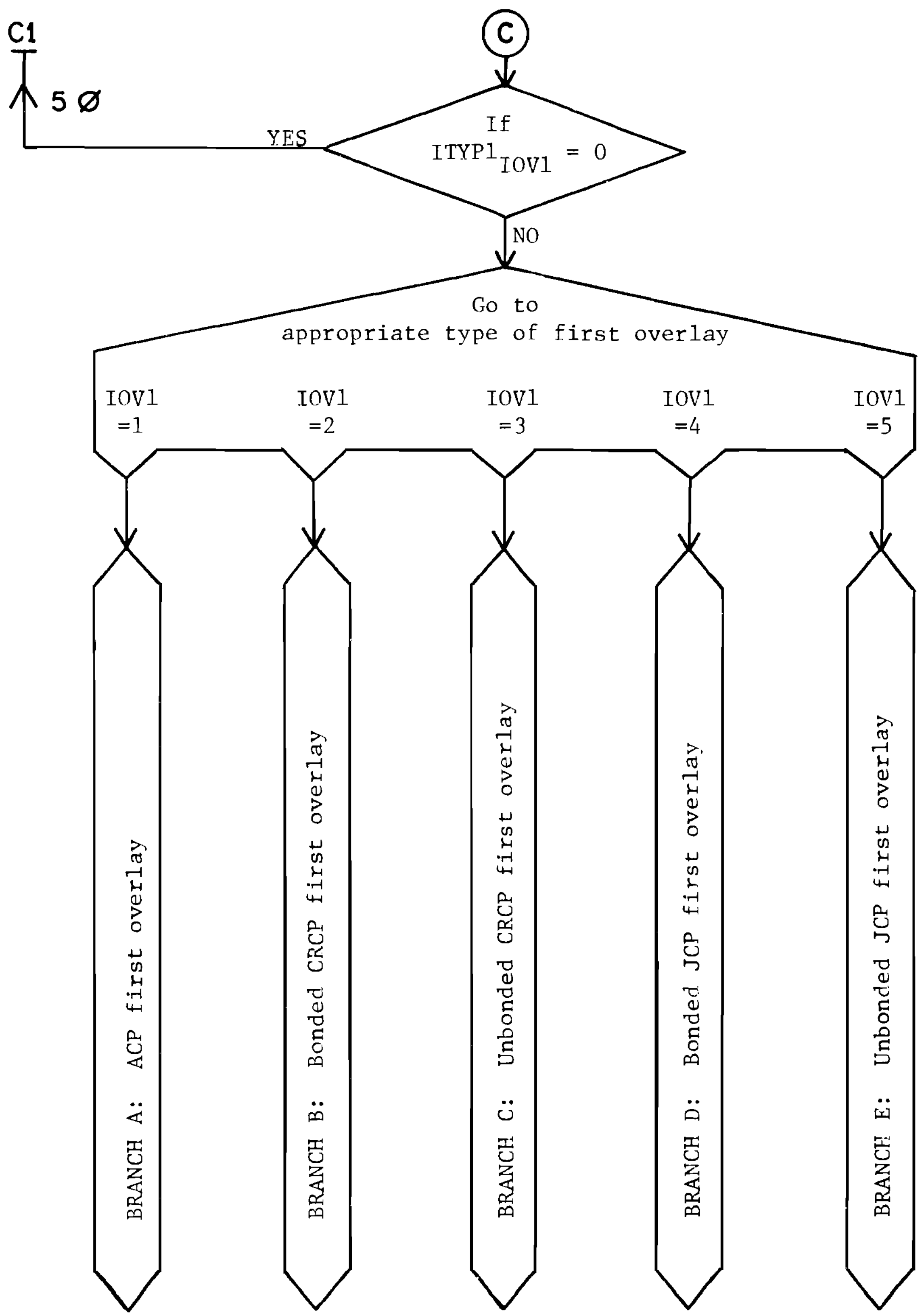
$$FATEP_2 = OFATIG\ (FREP,\ CEP,\ S\emptyset)$$

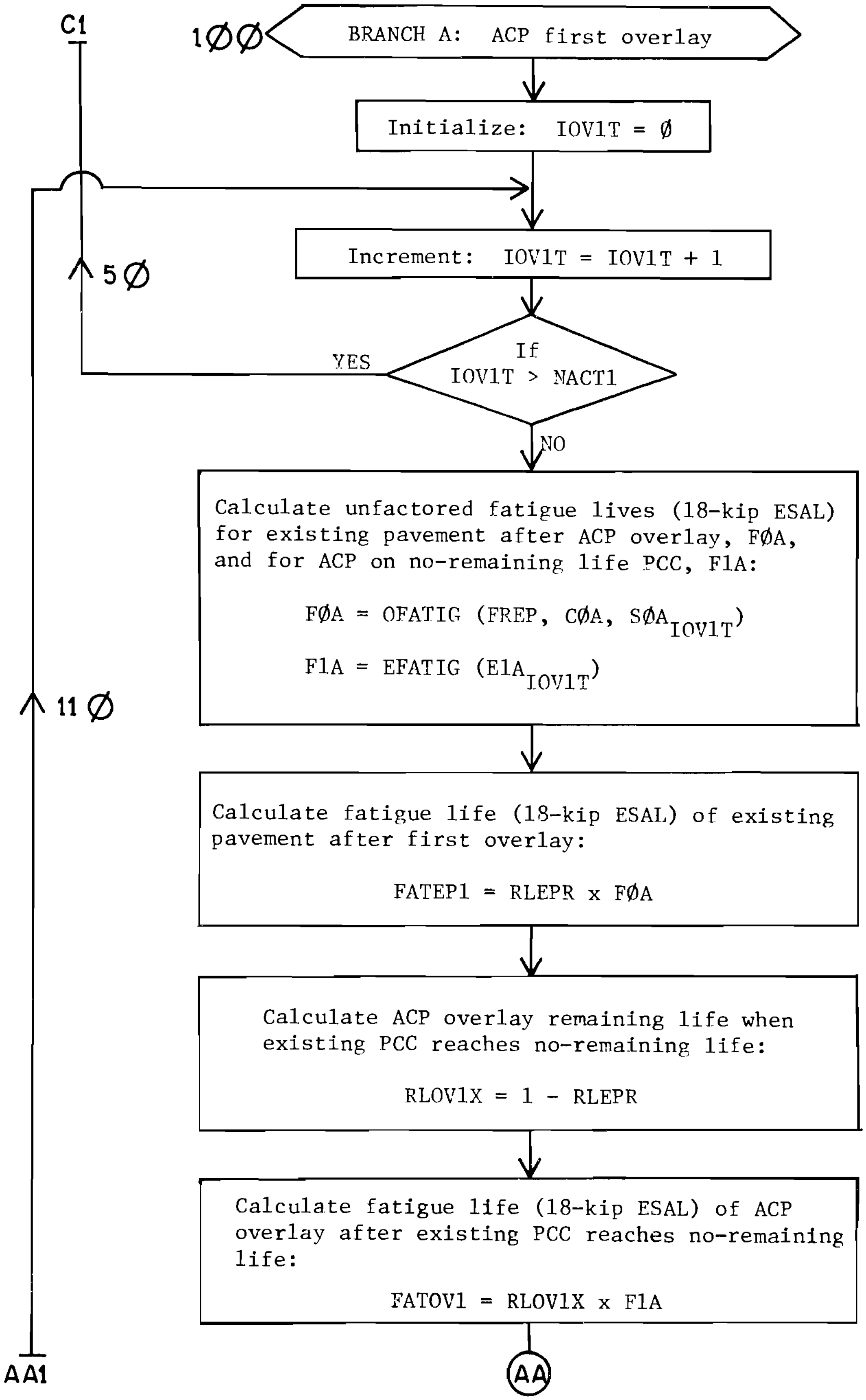


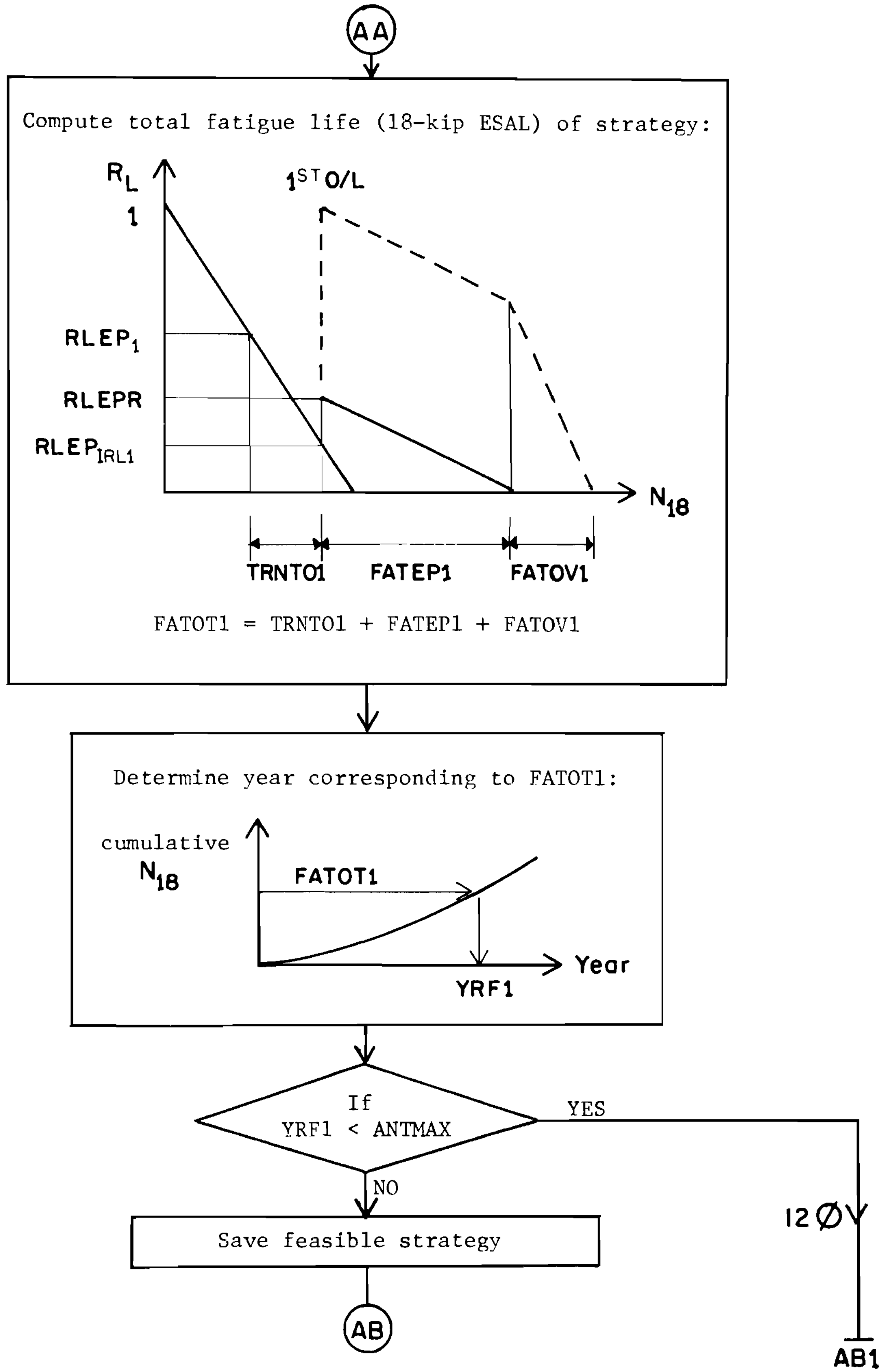
(A)

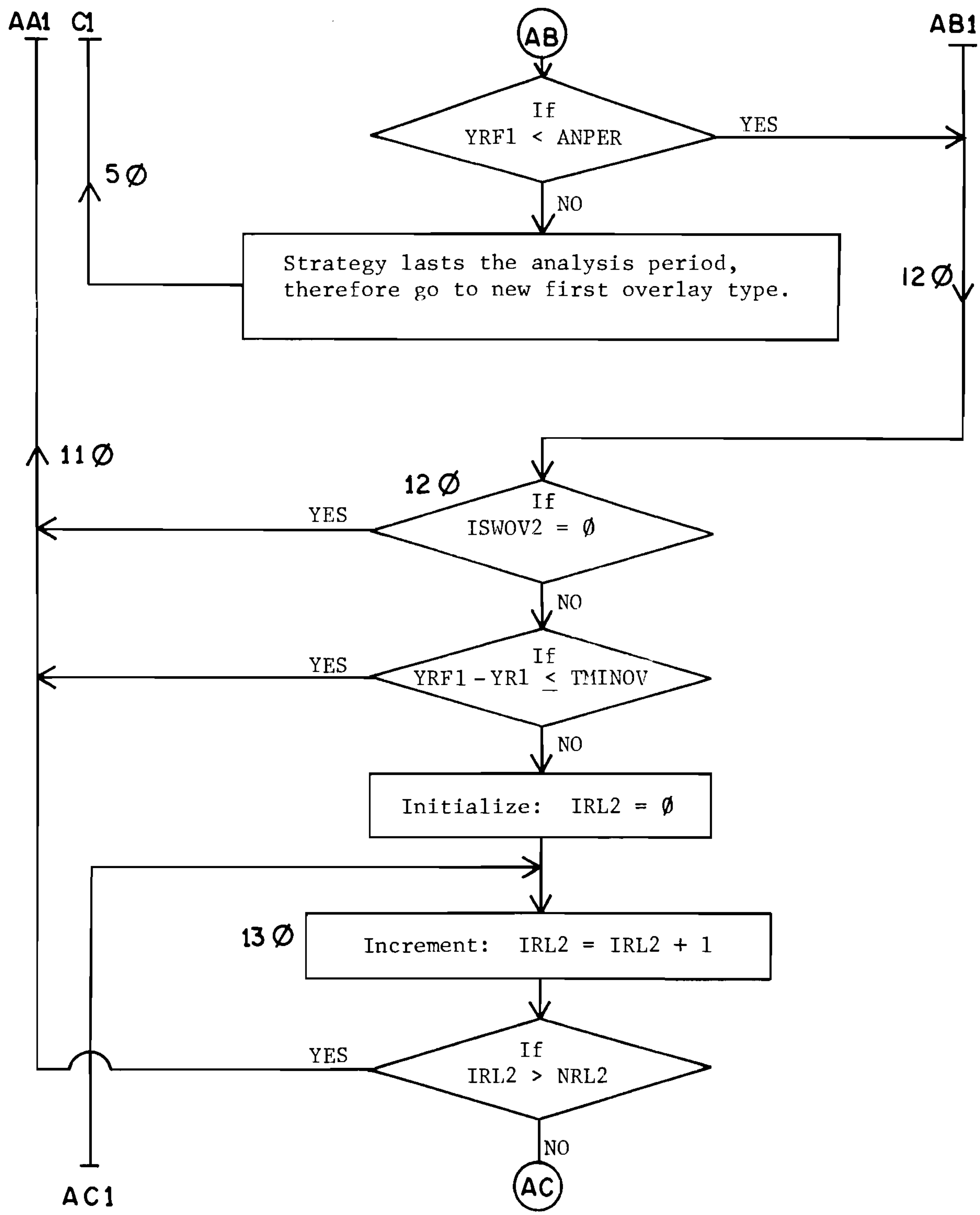

A
Set minimum fatigue life (in years) equal to analysis period minus maximum years of heavy maintenance.
ANTMAX = ANPER - TMAXMT
Initialize: IRL1 = Ø
1Ø
Increment: IRL1 = IRL1 + 1
If IRL1 > NRL1
YES
RETURN (to RPRDS)
NO
Compute 18-kip ESAL traffic on existing pavement prior to first overlay:
RL
1
RLEPIRL1
N18
TREPEQ
FATEPIEPSH
TREPEQ = (1 - RLEPIRL1) x FATEPIEPSH
Compute existing pavement remaining life after overlay rehabilitation:
RELPR = 1 - (TREPEQ/FATEP2)
1Ø
B1
B


B1
B
Compute 18-kip ESAL traffic from now till first overlay:
R_L
1
1^{ST} O/L
$RLEP_1$
$RLEP_{IRL1}$
N_{18}
TRNTO1
$FATEP_{IEPSH}$
$TRNTO1 = (RLEP_1 - RLEP_{IRL1}) \times FATEP_{IEPSH}$
Determine year (relative to now) of first overlay:
1Ø
cumulative N_{18}
TRNTO1
Year
YR1
Initialize: IOV1 = Ø
5Ø
Increment: IOV1 = IOV1 + 1
If IOV1 > NOV1
YES
NO
C1
C


C
C1
5 Ø
If
ITYP1 IOV1 = 0
YES
NO
Go to
appropriate type of first overlay
IOV1 =1
IOV1 =2
IOV1 =3
IOV1 =4
IOV1 =5
BRANCH A: ACP first overlay
BRANCH B: Bonded CRCP first overlay
BRANCH C: Unbonded CRCP first overlay
BRANCH D: Bonded JCP first overlay
BRANCH E: Unbonded JCP first overlay

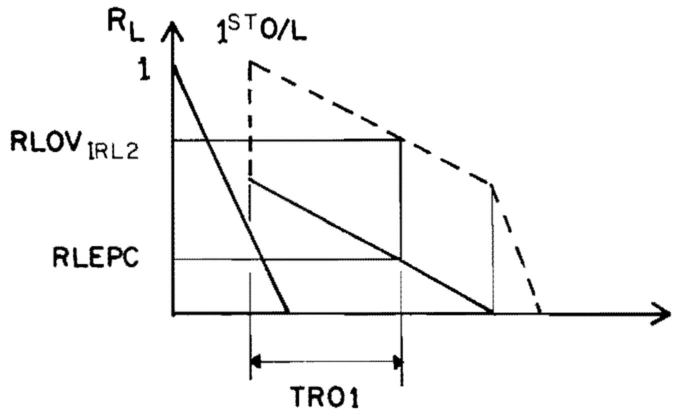

C1
1ØØ
BRANCH A: ACP first overlay
Initialize: IOV1T = Ø
Increment: IOV1T = IOV1T + 1
5Ø
YES
If IOV1T > NACT1
NO
Calculate unfactored fatigue lives (18-kip ESAL) for existing pavement after ACP overlay, FØA, and for ACP on no-remaining life PCC, F1A:
FØA = OFATIG (FREP, CØA, SØA_IOV1T)
F1A = EFATIG (E1A_IOV1T)
11Ø
Calculate fatigue life (18-kip ESAL) of existing pavement after first overlay:
FATEP1 = RLEPR x FØA
Calculate ACP overlay remaining life when existing PCC reaches no-remaining life:
RLOV1X = 1 - RLEPR
Calculate fatigue life (18-kip ESAL) of ACP overlay after existing PCC reaches no-remaining life:
FATOV1 = RLOV1X x F1A
AA1
AA


AA
Compute total fatigue life (18-kip ESAL) of strategy:
RL
1
1ST O/L
RLEP1
RLEPR
RLEP1RL1
N18
TRNTO1
FATEP1
FATOV1
FATOT1 = TRNTO1 + FATEP1 + FATOV1
Determine year corresponding to FATOT1:
cumulative
N18
FATOT1
Year
YRF1
If
YRF1 < ANTMAX
YES
NO
Save feasible strategy
12Ø
AB
AB1


AA1
C1
AB
AB1
If
YRF1 < ANPER
YES
NO
5Ø
Strategy lasts the analysis period, therefore go to new first overlay type.
12Ø
11Ø
12Ø
If
ISWOV2 = Ø
YES
NO
If
YRF1 - YR1 ≤ TMINOV
YES
NO
Initialize: IRL2 = Ø
13Ø
Increment: IRL2 = IRL2 + 1
If
IRL2 > NRL2
YES
NO
AC1
AC

(AC)

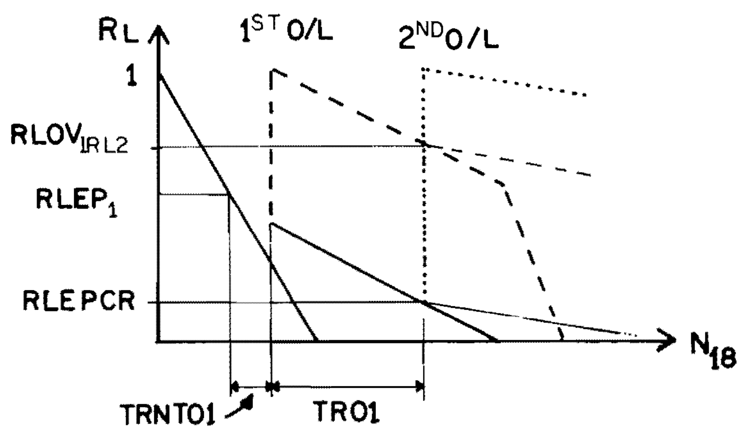
Compute existing pavement remaining life corresponding to overlay remaining life. Also compute traffic (18-kip ESAL) on first overlay prior to second:



Set remaining life of existing PCC at second overlay (and after repairs) equal to RLEPC:

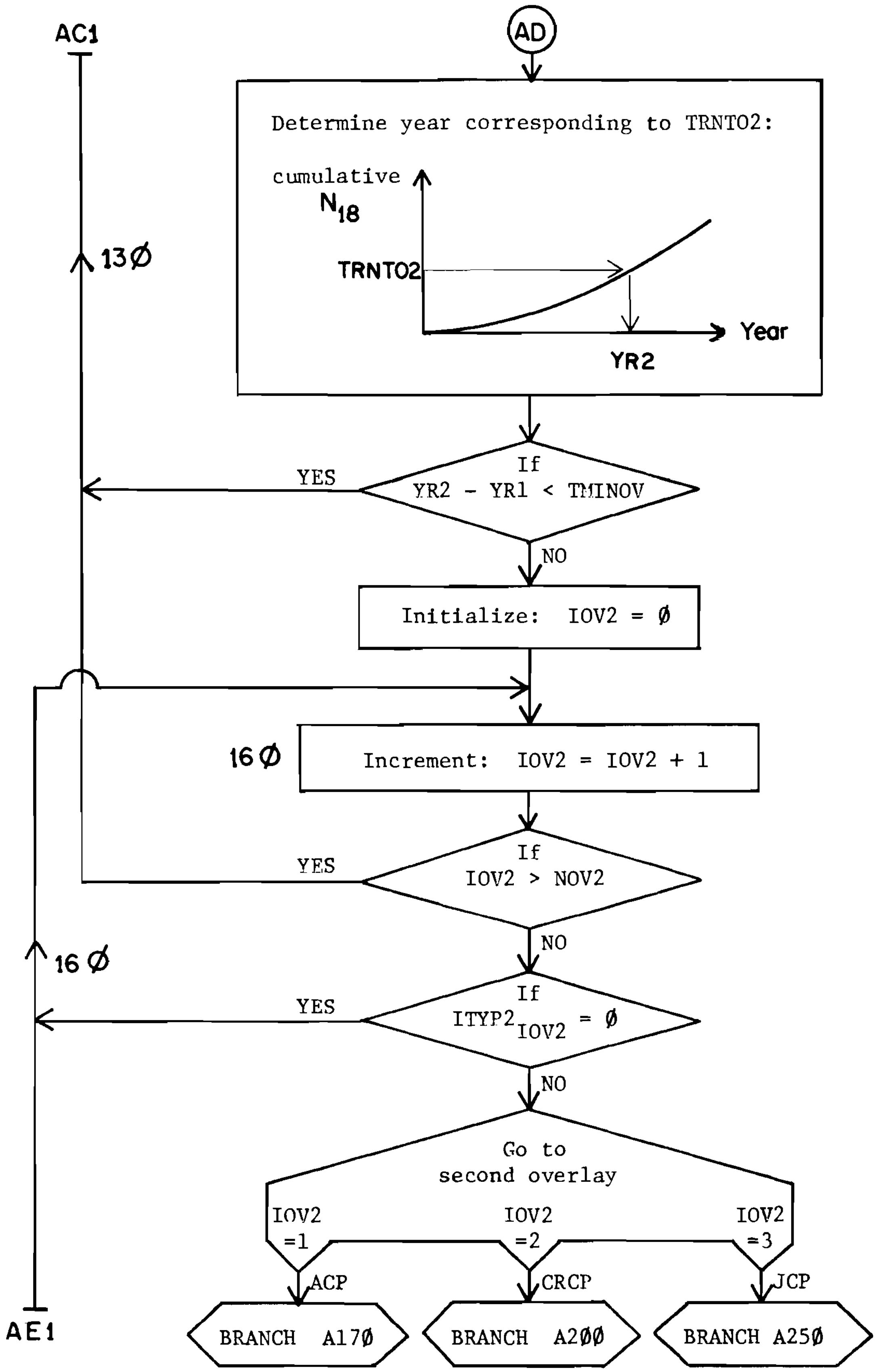
RLEPCR = RLEPC

Compute 18-kip ESAL traffic from now till second overlay:



TRNTO2 = TRNTO1 + TRO1

(AD)

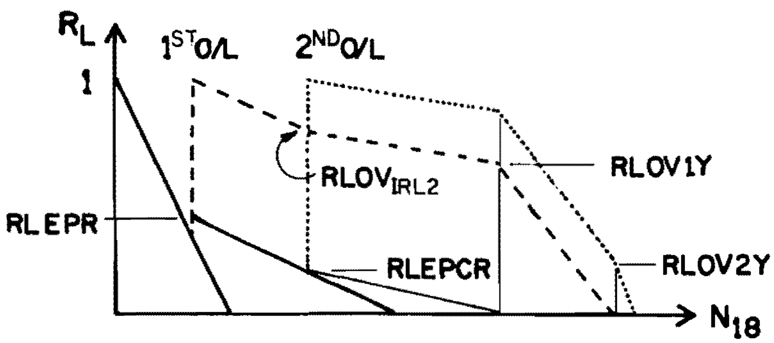

AC1
AD
Determine year corresponding to TRNTO2:
cumulative
N_{18}
TRNTO2
Year
YR2
130
YES
If
YR2 - YR1 < TMINOV
NO
Initialize: IOV2 = 0
160
Increment: IOV2 = IOV2 + 1
YES
If
IOV2 > NOV2
NO
160
YES
If
$ITYP2_{IOV2} = 0$
NO
Go to
second overlay
IOV2 =1
IOV2 =2
IOV2 =3
ACP
CRCP
JCP
BRANCH A170
BRANCH A200
BRANCH A250
AE1

AE1

BRANCH A17Ø:

ACP first overlay, ACP second overlay

Calculate remaining life of first ACP overlay, RLOV1Y, when existing pavement has no-remaining life. Also calculate remaining life of second ACP overlay, RLOV2Y, when first ACP overlay has no-remaining life:



$$RLOV1Y = RLOV_{IRL2} - RLEPCR$$

$$RLOV2Y = 1 - RELPCR - RLOV1Y$$

Initialize: IOV2T = Ø

18Ø Increment: IOV2T = IOV2T + 1

If IOV2T > NACT2 — YES: to 16Ø (AE1); NO: continue

If $ACT1_{IOV1T} + ACT2_{IOV2T} > ALOVT$ — YES: to 16Ø (AE1); NO: AF

AF1

AF

(AF)

Calculate unfactored fatigue lives (18-kip ESAL) for existing pavement after second ACP overlay, FØAA, for first ACP overlay on no-remaining life PCC, F1AA, and for second ACP overlay on no-remaining life first ACP overlay, F2AA:

$$\mathrm{F\emptyset AA} = \mathrm{OFATIG}\ (\mathrm{FREP},\ \mathrm{C\emptyset AA},\ \mathrm{S\emptyset AA}_{\mathrm{IOV1T},\ \mathrm{IOV2T}})$$

$$\mathrm{F1AA} = \mathrm{EFATIG}\ (\mathrm{E1AA}_{\mathrm{IOV1T},\ \mathrm{IOV2T}})$$

$$\mathrm{F2AA} = \mathrm{EFATIG}\ (\mathrm{E2AA}_{\mathrm{IOV1T},\ \mathrm{IOV2T}})$$

↓

Compute fatigue life (18-kip ESAL) of existing pavement after second ACP overlay:

$$\mathrm{FATEP2} = \mathrm{RLEPCR} \times \mathrm{F\emptyset AA}$$

↓

Compute fatigue life (18-kip ESAL) of first ACP overlay after no-remaining life in existing PCC:

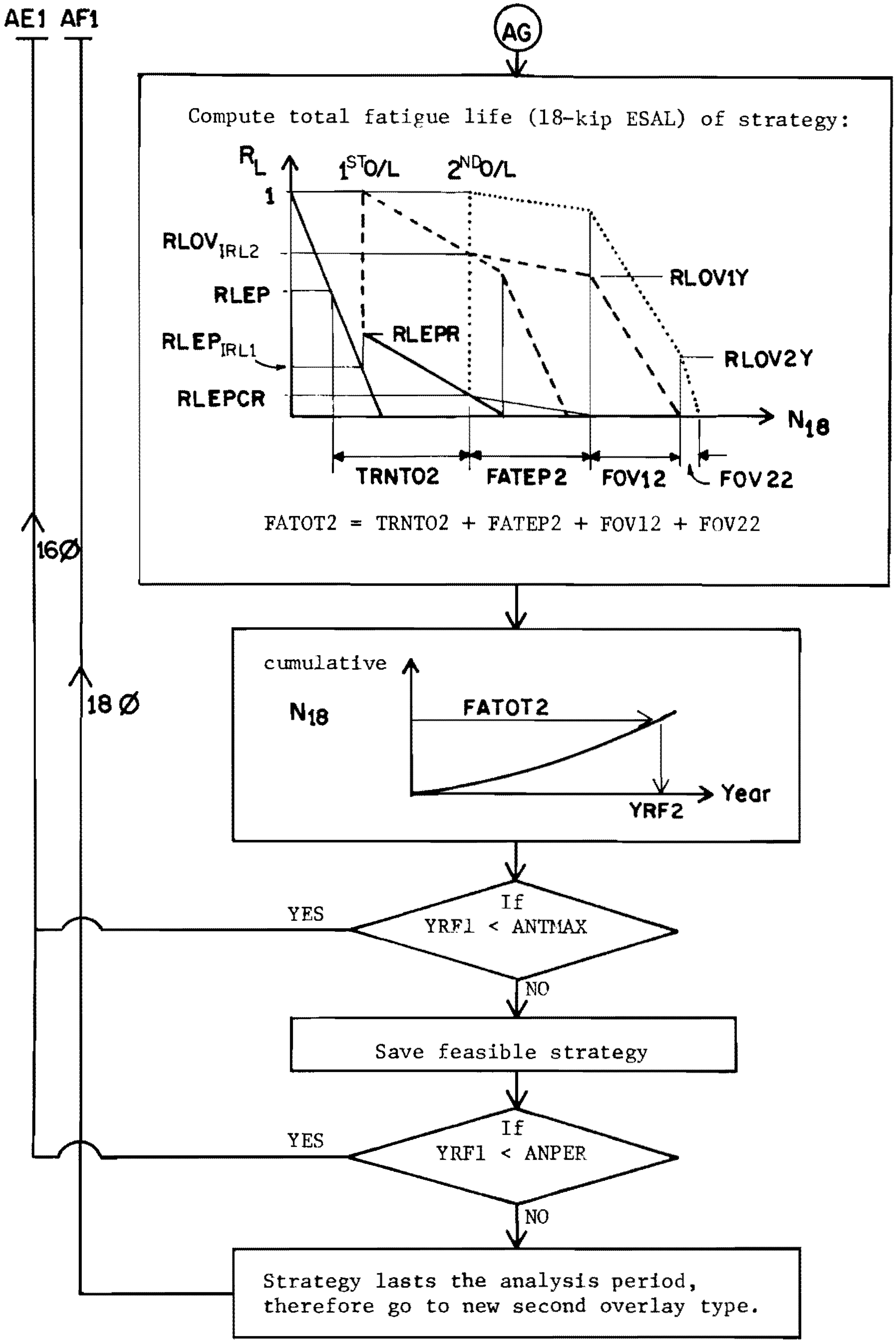
$$\mathrm{FOV12} = \mathrm{RLOV1Y} \times \mathrm{F1AA}$$

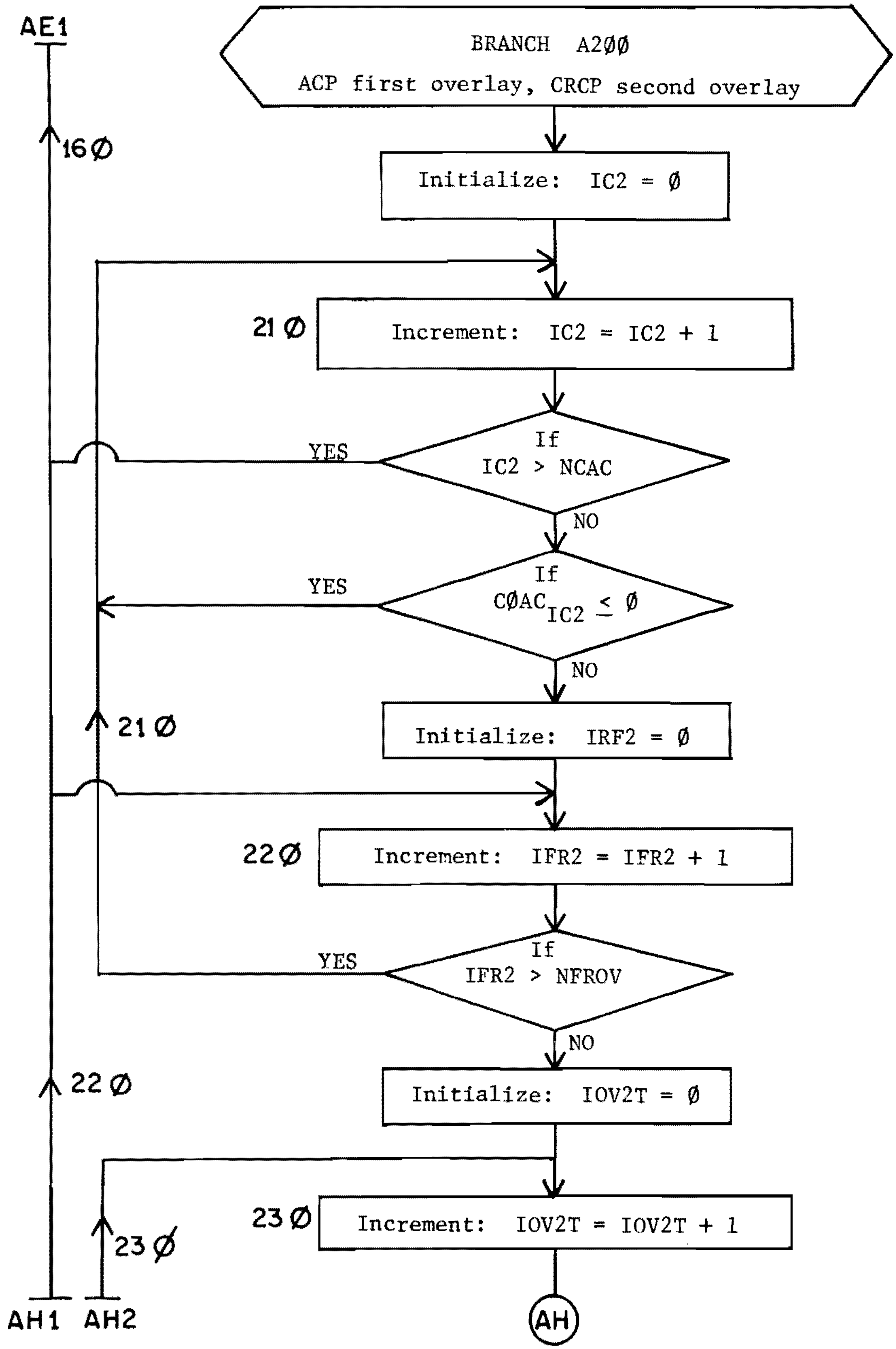
↓

Compute fatigue life (18-kip ESAL) of second ACP overlay after no-remaining life in first ACP overlay:

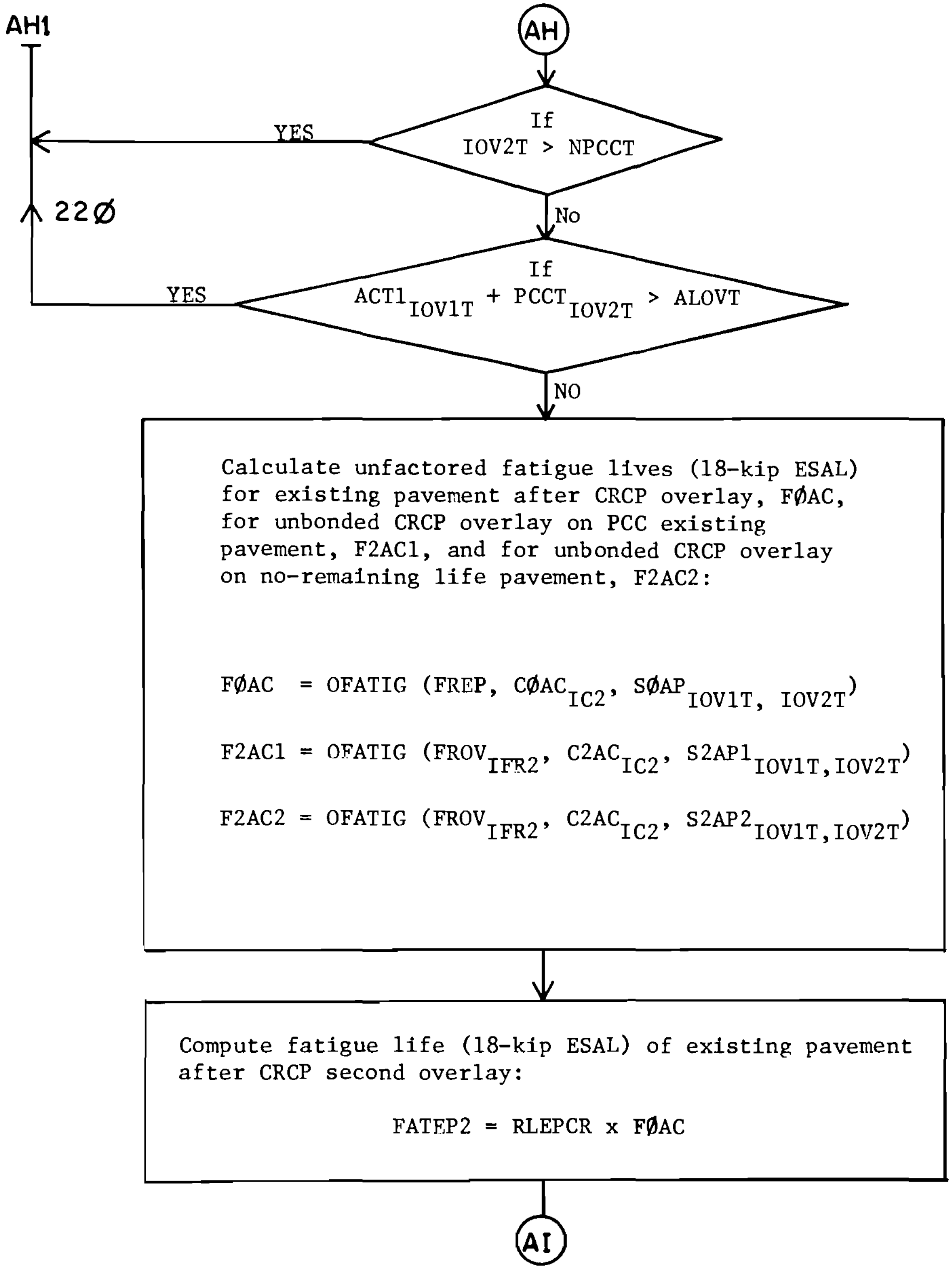
$$\mathrm{FOV22} = \mathrm{RLOV2Y} \times \mathrm{F2AA}$$

(AG)


AE1
AF1
AG
Compute total fatigue life (18-kip ESAL) of strategy:
R_L
1
1^{ST} O/L
2^{ND} O/L
$RLOV_{IRL2}$
RLEP
$RLEP_{IRL1}$
RLEPCR
RLEPR
RLOV1Y
RLOV2Y
N_{18}
TRNTO2
FATEP2
FOV12
FOV22
FATOT2 = TRNTO2 + FATEP2 + FOV12 + FOV22
16Ø
18 Ø
cumulative
N_{18}
FATOT2
Year
YRF2
YES
If
YRF1 < ANTMAX
NO
Save feasible strategy
YES
If
YRF1 < ANPER
NO
Strategy lasts the analysis period, therefore go to new second overlay type.



AE1
BRANCH A2ØØ
ACP first overlay, CRCP second overlay
16Ø
Initialize: IC2 = Ø
21Ø
Increment: IC2 = IC2 + 1
YES
If
IC2 > NCAC
NO
YES
If
CØAC$_{IC2}$ ≤ Ø
NO
21Ø
Initialize: IRF2 = Ø
22Ø
Increment: IFR2 = IFR2 + 1
YES
If
IFR2 > NFROV
NO
22Ø
Initialize: IOV2T = Ø
23Ø
23Ø
Increment: IOV2T = IOV2T + 1
AH1
AH2
AH


AH1
AH
If
IOV2T > NPCCT
YES
No
220
If
ACT1 IOV1T + PCCT IOV2T > ALOVT
YES
NO
Calculate unfactored fatigue lives (18-kip ESAL) for existing pavement after CRCP overlay, FØAC, for unbonded CRCP overlay on PCC existing pavement, F2AC1, and for unbonded CRCP overlay on no-remaining life pavement, F2AC2:
FØAC = OFATIG (FREP, CØAC IC2, SØAP IOV1T, IOV2T)
F2AC1 = OFATIG (FROV IFR2, C2AC IC2, S2AP1 IOV1T,IOV2T)
F2AC2 = OFATIG (FROV IFR2, C2AC IC2, S2AP2 IOV1T,IOV2T)
Compute fatigue life (18-kip ESAL) of existing pavement after CRCP second overlay:
FATEP2 = RLEPCR x FØAC
AI

(AI)

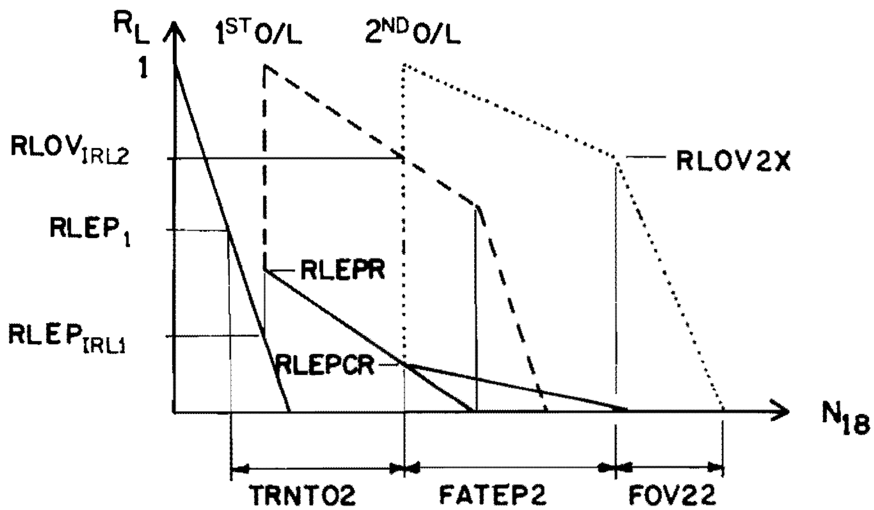
Compute remaining life of CRCP overlay after original PCC reaches no remaining life:

RLOV2X = 1 - FATEP2/F2AC1

Compute fatigue life (18-kip ESAL) of CRCP overlay after original PCC reaches no-remaining life:

FOV22 = RLOV2X x F2AC2

Compute total fatigue life (18-kip ESAL) of strategy:

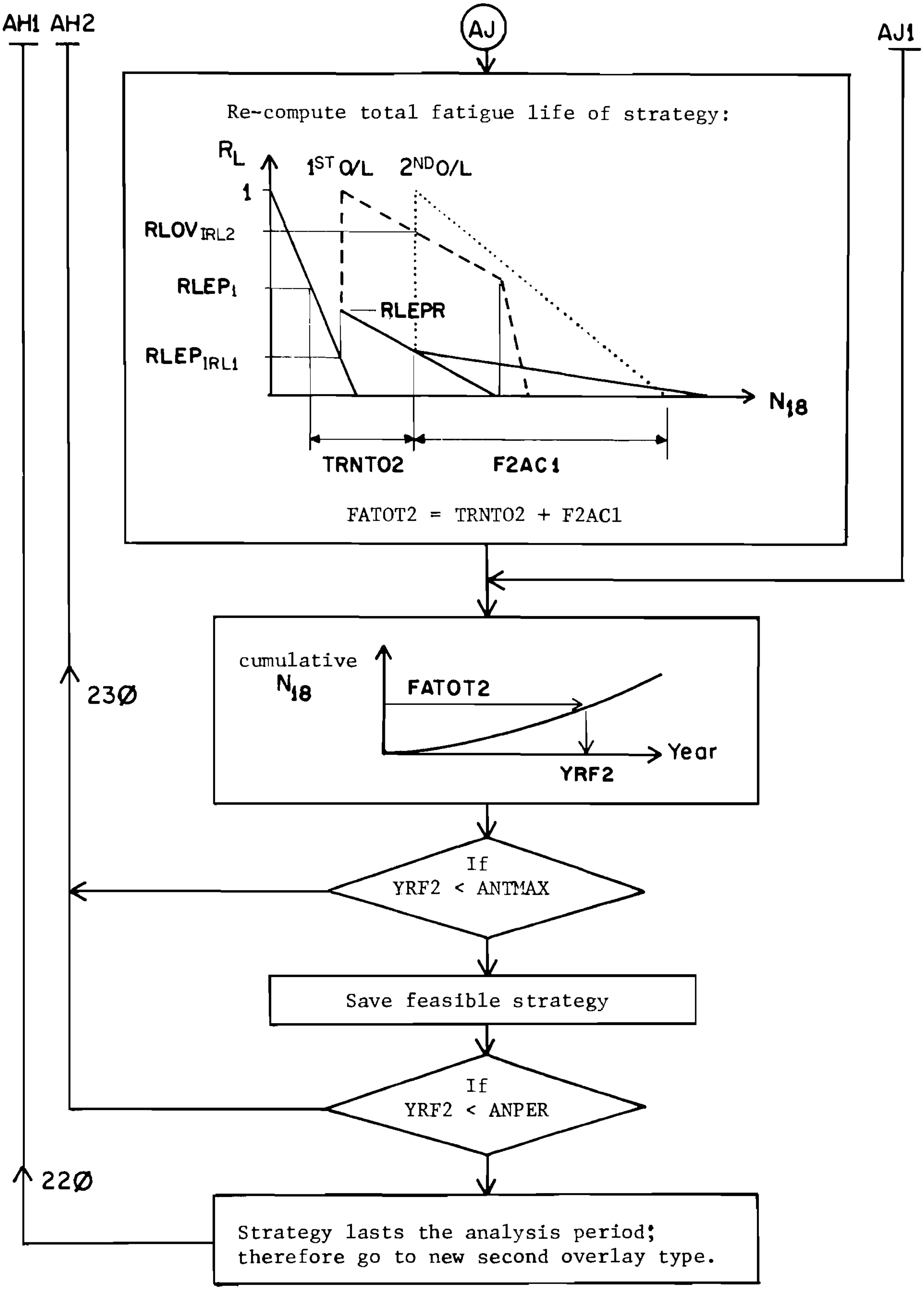


FATOT2 = TRNTO2 + FATEP2 + FOV22

If RLOV2X < Ø

YES → (AJ)

NO → AJ1

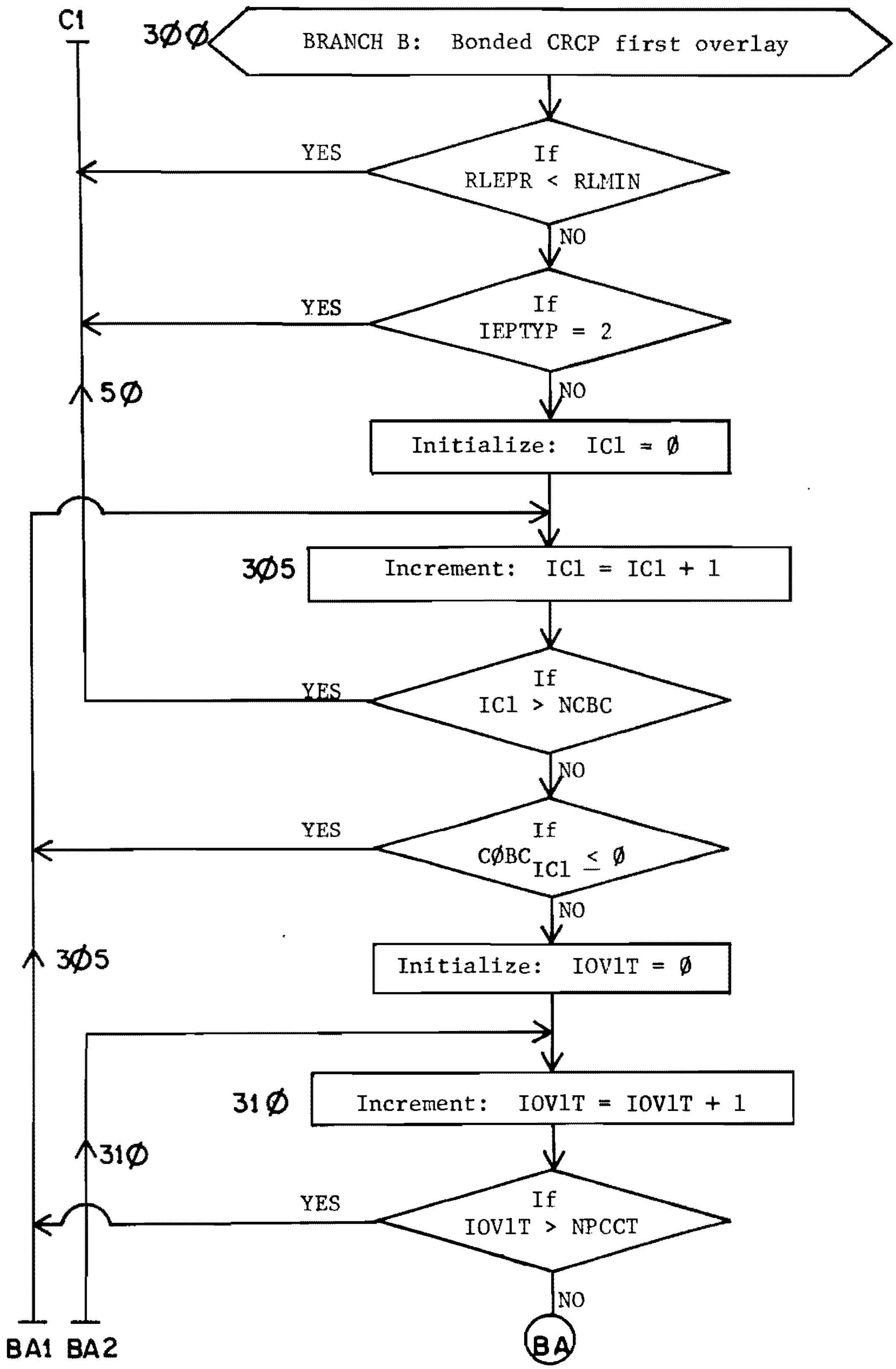

AH1 AH2
AJ
AJ1
Re-compute total fatigue life of strategy:
R_L
1
1^{ST} O/L
2^{ND} O/L
$RLOV_{IRL2}$
$RLEP_1$
RLEPR
$RLEP_{IRL1}$
N_{18}
TRNTO2
F2AC1
FATOT2 = TRNTO2 + F2AC1
cumulative N_{18}
FATOT2
Year
YRF2
230
If YRF2 < ANTMAX
Save feasible strategy
If YRF2 < ANPER
220
Strategy lasts the analysis period; therefore go to new second overlay type.

BRANCH A25Ø

ACP first overlay, JCP second overlay

This branch is almost identical to BRANCH A2ØØ. In order to construct this branch, the following substitutions should be made in BRANCH A2ØØ:

1. JCP overlay for CRCP overlay,
2. 26Ø for 21Ø,
3. 27Ø for 22Ø,
4. 28Ø for 23Ø,
5. NCAJ for NCAC,
6. CØAJ for CØAC,
7. C2AJ for C2AC,
8. FØAJ for FØAC,
9. F2AJ1 for F2AC1, and
10. F2AJ2 for F2AC2.


C1
3ØØ
BRANCH B: Bonded CRCP first overlay
YES
If RLEPR < RLMIN
NO
YES
If IEPTYP = 2
NO
5Ø
Initialize: IC1 = Ø
3Ø5
Increment: IC1 = IC1 + 1
YES
If IC1 > NCBC
NO
YES
If CØBC IC1 ≤ Ø
NO
3Ø5
Initialize: IOV1T = Ø
31Ø
Increment: IOV1T = IOV1T + 1
31Ø
YES
If IOV1T > NPCCT
NO
BA
BA1 BA2

BA

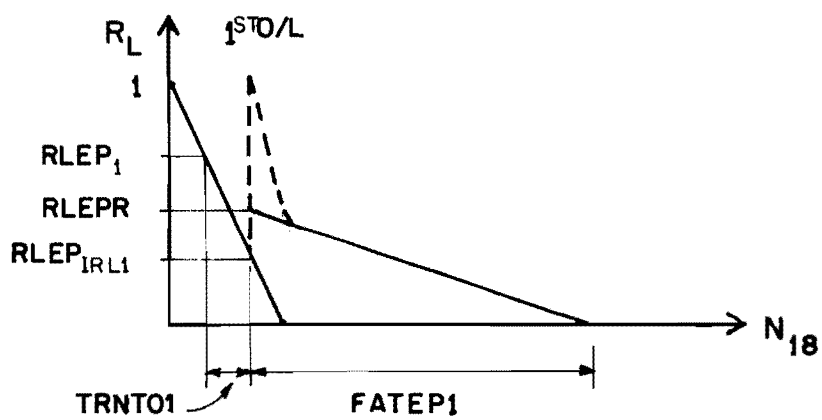
Calculate unfactored fatigue life (18-kip ESAL) for existing pavement with bonded CRCP overlay:

$$F\emptyset BC = OFATIG\ (FREP,\ C\emptyset BC_{IC1},\ S\emptyset BP_{IOV1T})$$

Calculate fatigue life (18-kip ESAL) of existing pavement after first overlay:

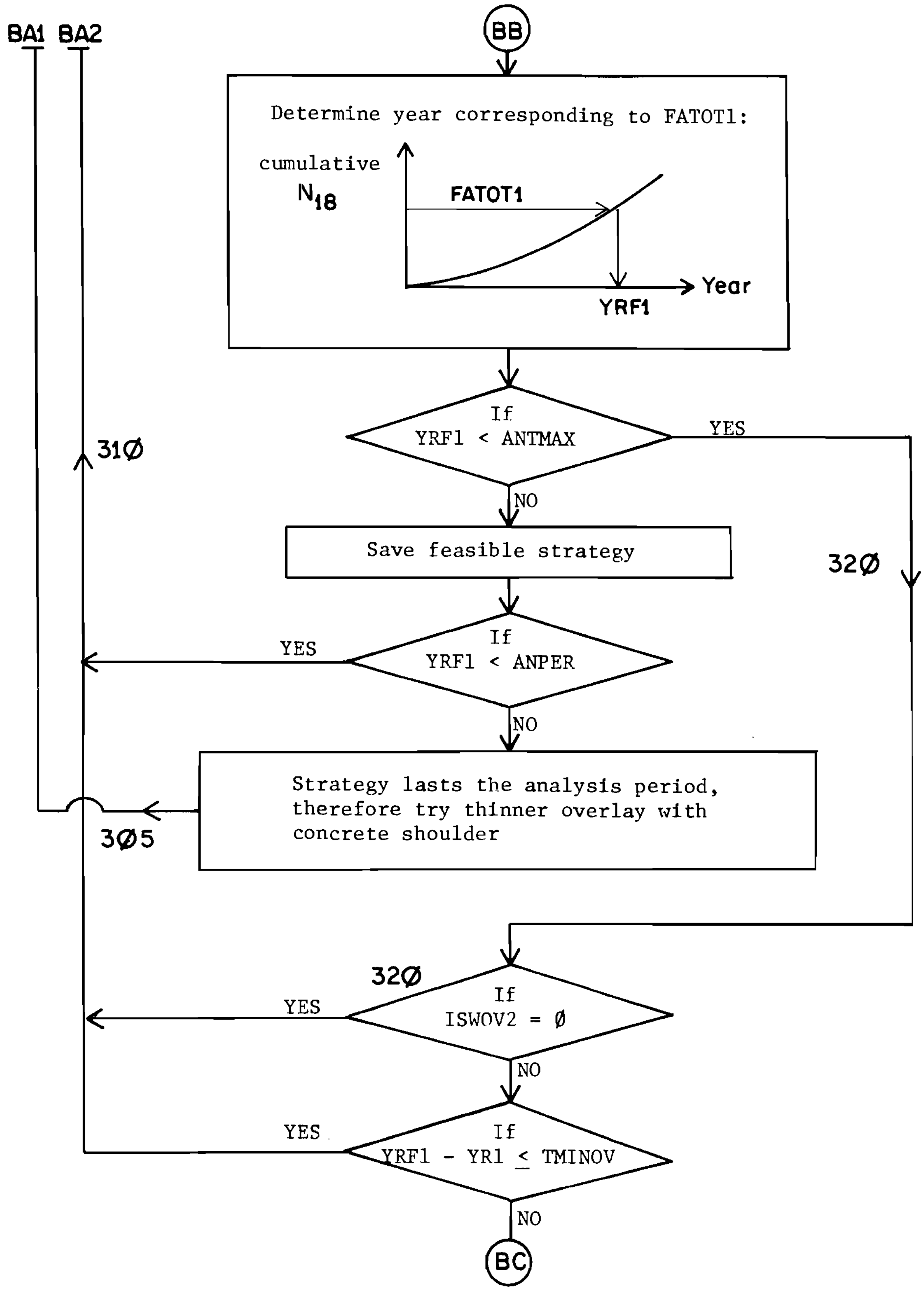
$$FATEP1 = RLEPR \times F\emptyset BC$$

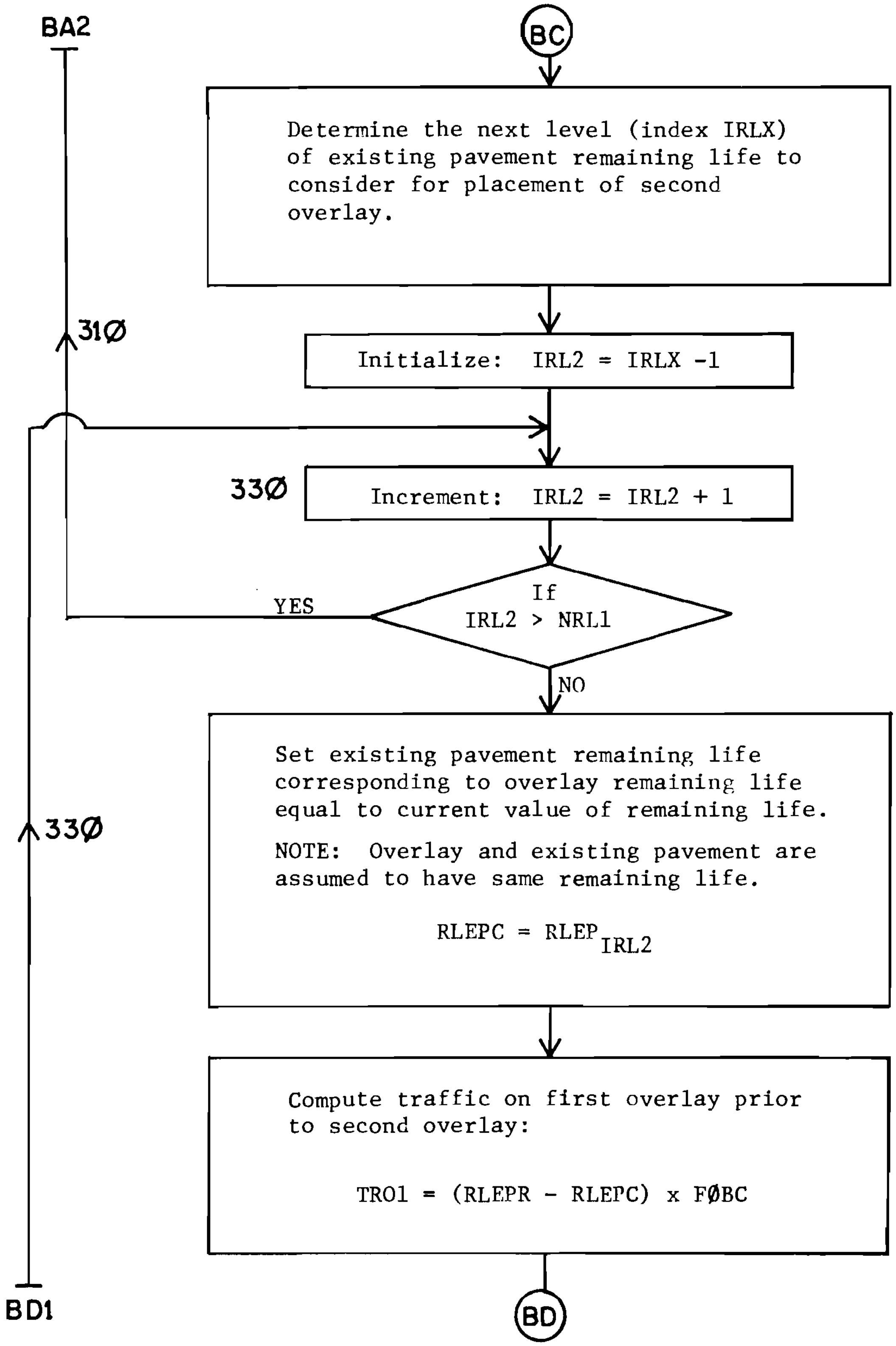
Compute total fatigue life (18-kip ESAL) of strategy:



$$FATOT1 = TRNTO1 + FATEP1$$

BB


BA1
BA2
BB
Determine year corresponding to FATOT1:
cumulative
N18
FATOT1
Year
YRF1
If
YRF1 < ANTMAX
YES
NO
310
Save feasible strategy
320
If
YRF1 < ANPER
YES
NO
Strategy lasts the analysis period, therefore try thinner overlay with concrete shoulder
305
320
If
ISWOV2 = 0
YES
NO
If
YRF1 - YR1 ≤ TMINOV
YES
NO
BC



BA2
BC
Determine the next level (index IRLX) of existing pavement remaining life to consider for placement of second overlay.
310
Initialize: IRL2 = IRLX -1
330
Increment: IRL2 = IRL2 + 1
YES
If IRL2 > NRL1
NO
Set existing pavement remaining life corresponding to overlay remaining life equal to current value of remaining life.
NOTE: Overlay and existing pavement are assumed to have same remaining life.
RLEPC = RLEP IRL2
330
Compute traffic on first overlay prior to second overlay:
TRO1 = (RLEPR - RLEPC) x FØBC
BD1
BD

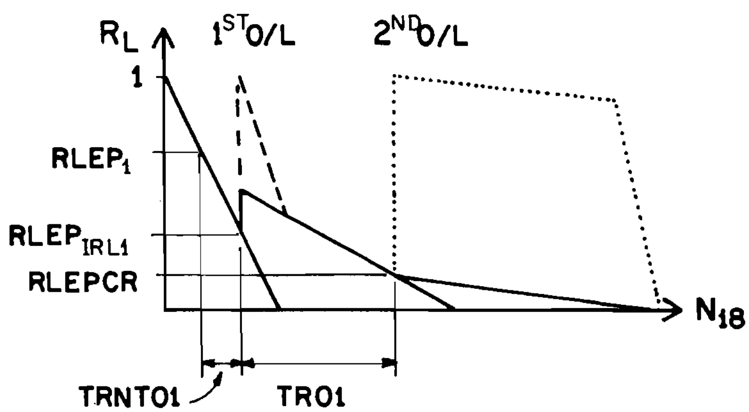
BD1

(BD)

Set remaining life of existing PCC at second overlay (and after repairs) equal to RLEPC:

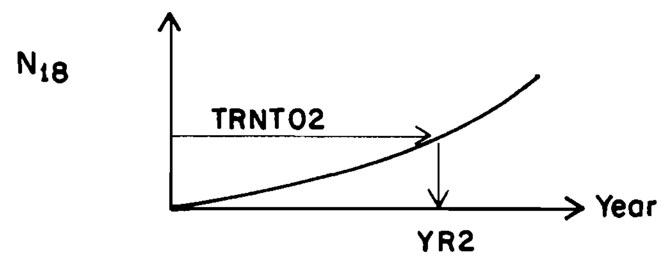
RLEPCR = RELPC

Compute 18-kip ESAL traffic from now till second overlay:



TRNTO2 = TRNTO1 + TRO1

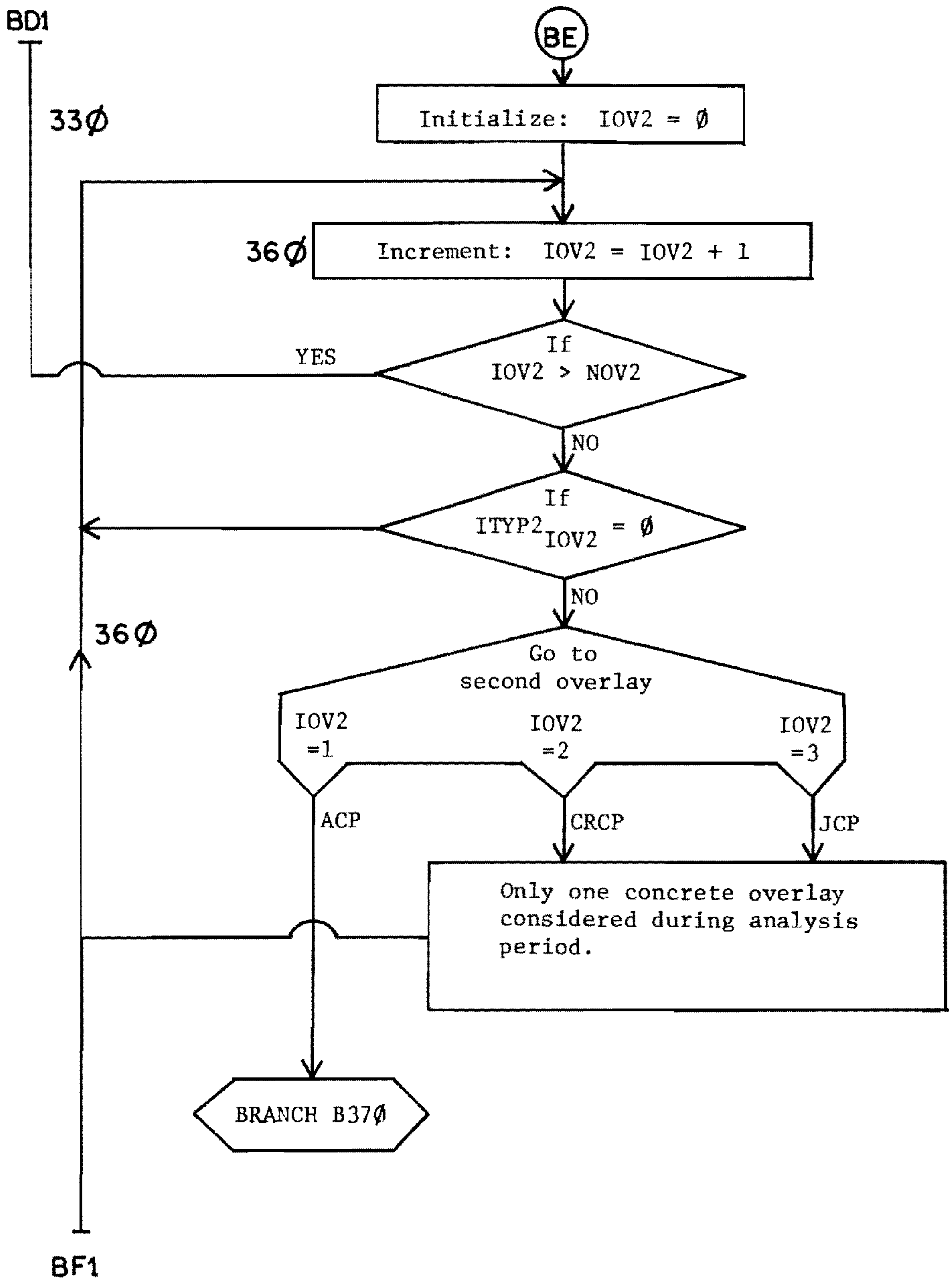
Determine year corresponding to TRNTO2:

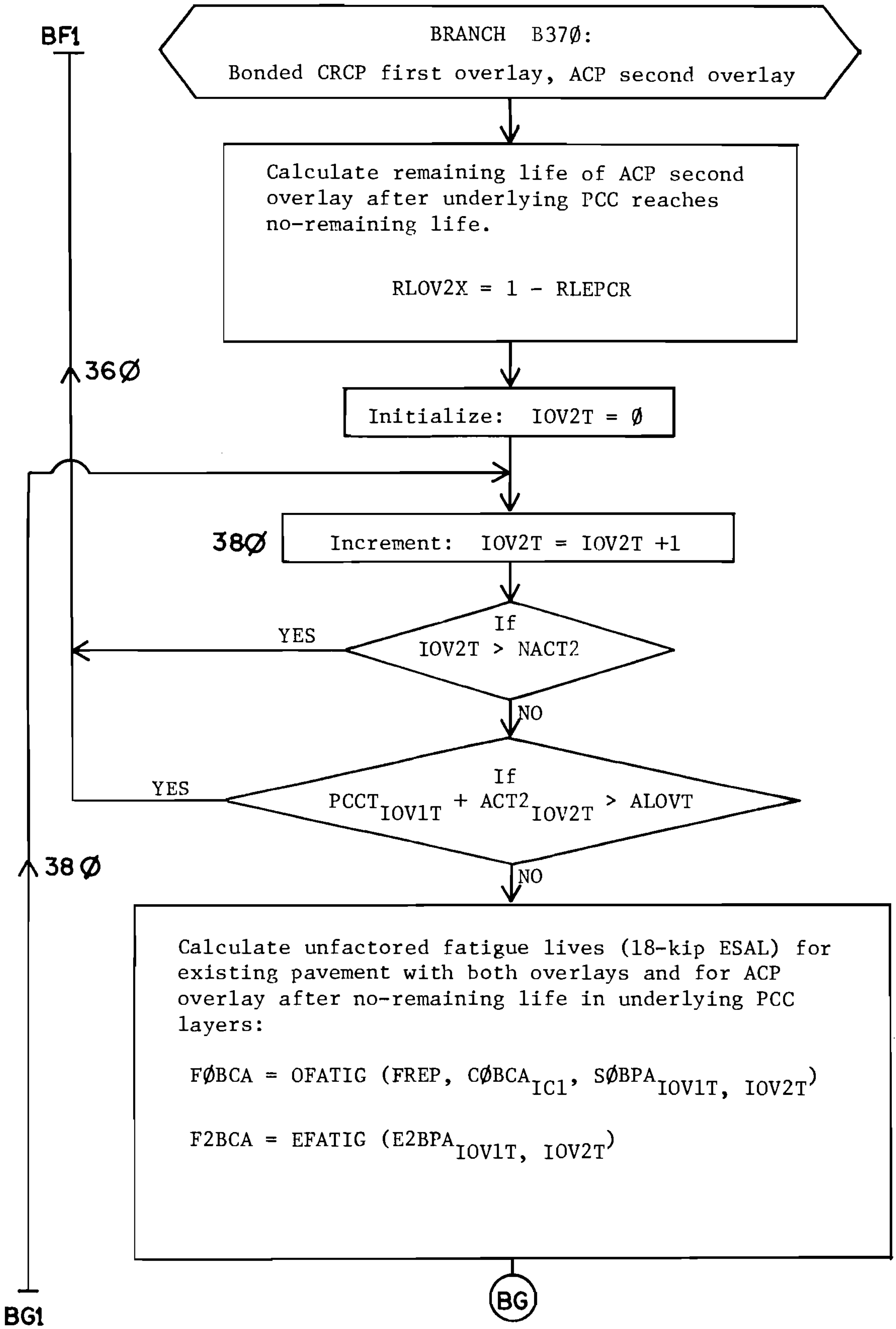


If YR2 - YR1 < TMINOV

YES → 330 → BD1

NO → (BE)


BD1
330
BE
Initialize: IOV2 = 0
360
Increment: IOV2 = IOV2 + 1
YES
If
IOV2 > NOV2
NO
If
ITYP2 IOV2 = 0
NO
360
Go to
second overlay
IOV2
=1
IOV2
=2
IOV2
=3
ACP
CRCP
JCP
Only one concrete overlay
considered during analysis
period.
BRANCH B370
BF1


BF1
BRANCH B370:
Bonded CRCP first overlay, ACP second overlay
Calculate remaining life of ACP second overlay after underlying PCC reaches no-remaining life.
RLOV2X = 1 - RLEPCR
360
Initialize: IOV2T = 0
380
Increment: IOV2T = IOV2T +1
YES
If IOV2T > NACT2
NO
YES
If $PCCT_{IOV1T} + ACT2_{IOV2T} > ALOVT$
380
NO
Calculate unfactored fatigue lives (18-kip ESAL) for existing pavement with both overlays and for ACP overlay after no-remaining life in underlying PCC layers:
$F0BCA = OFATIG\ (FREP,\ C0BCA_{IC1},\ S0BPA_{IOV1T,\ IOV2T})$
$F2BCA = EFATIG\ (E2BPA_{IOV1T,\ IOV2T})$
BG1
BG

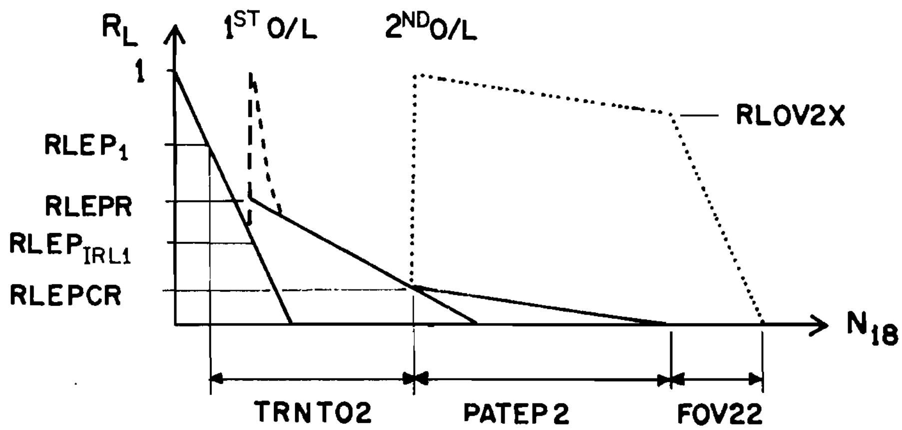
(BG)

Calculate fatigue lives (18-kip ESAL) for existing PCC and for ACP overlay after no-remaining life in underlying PCC layers:

FATEP2 = RLEPCR x FØBCA

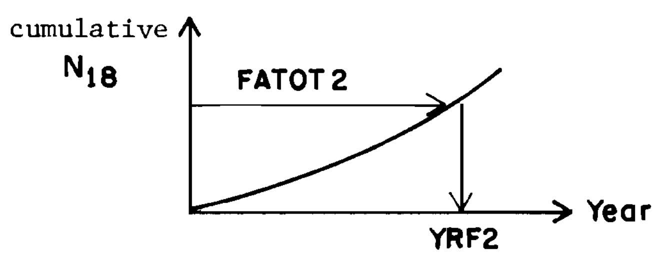
FOV22 = RLOV2X x F2BCA

Compute total fatigue life (18-kip ESAL) of strategy:

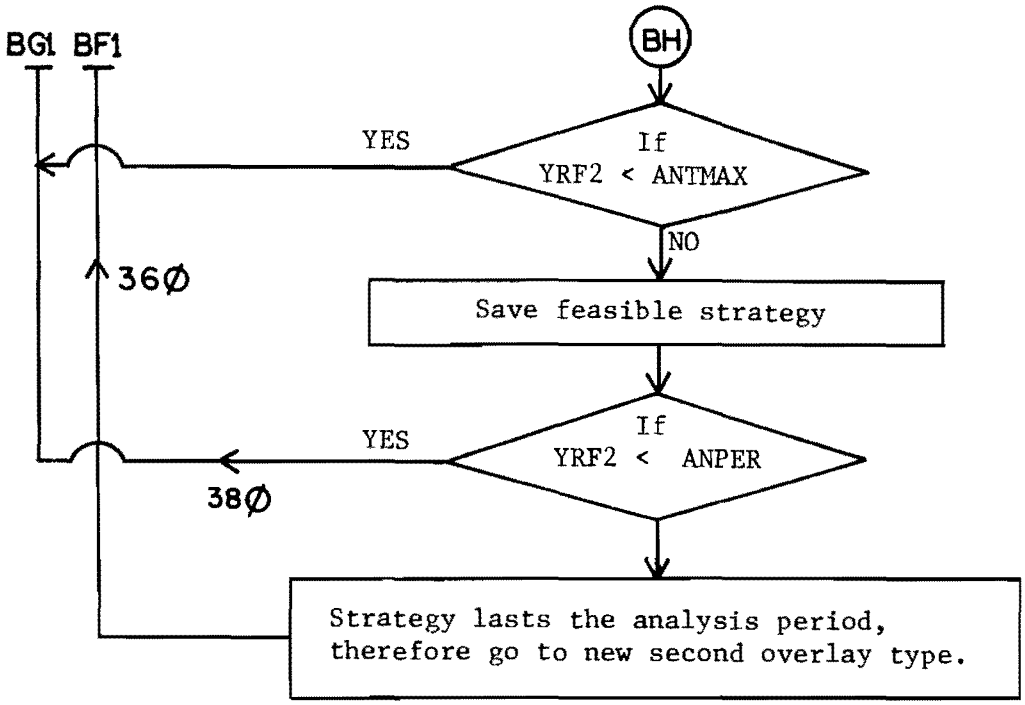


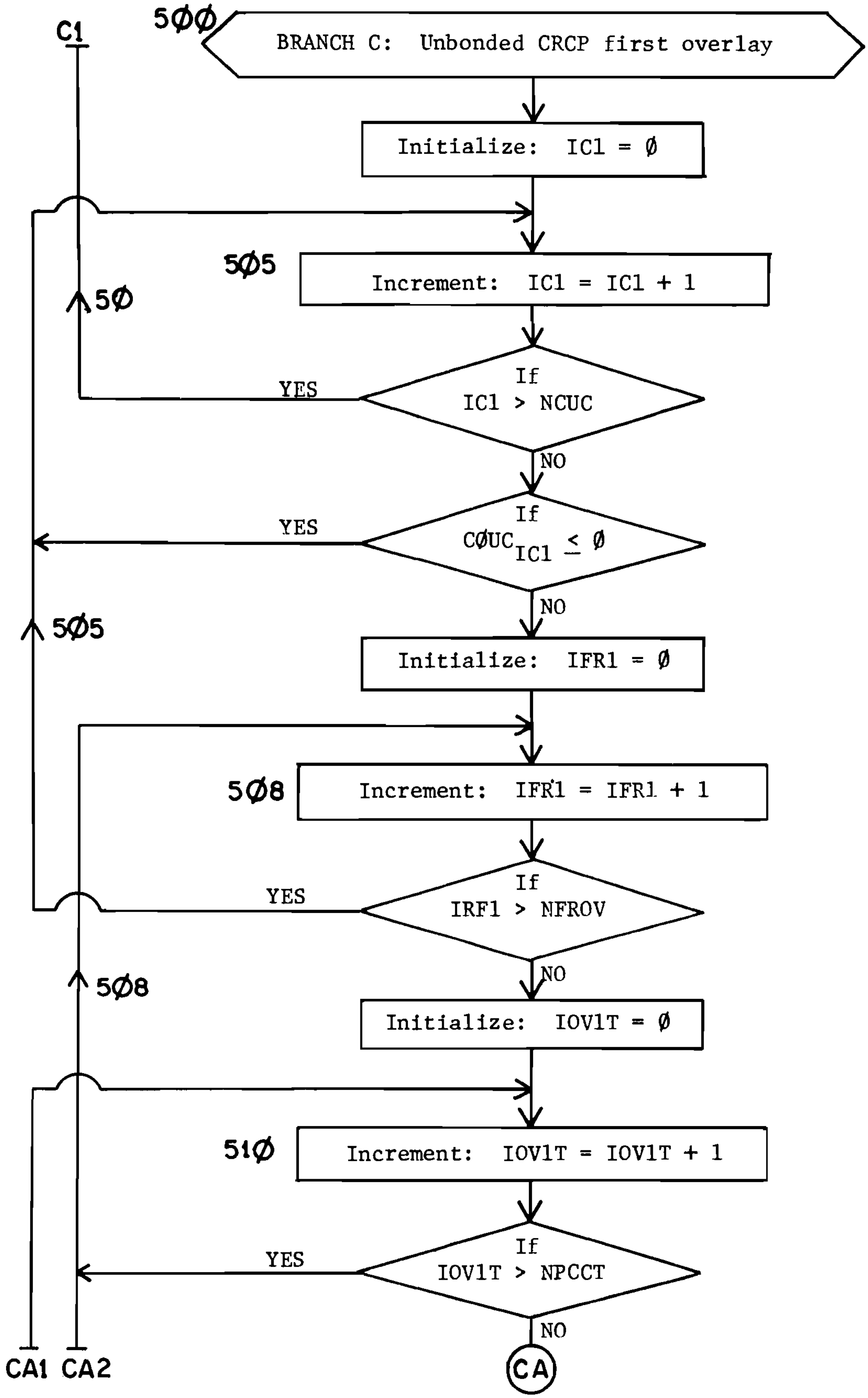
FATOT2 = TRNTO2 + FATEP2 + FOV22

Determine year corresponding to FATOT2:



(BH)


BG1
BF1
BH
YES
If
YRF2 < ANTMAX
NO
360
Save feasible strategy
YES
If
YRF2 < ANPER
380
Strategy lasts the analysis period,
therefore go to new second overlay type.



BRANCH C: Unbonded CRCP first overlay
5ØØ
C1
Initialize: IC1 = Ø
5Ø5
Increment: IC1 = IC1 + 1
5Ø
If IC1 > NCUC
YES
NO
If CØUC$_{IC1}$ ≤ Ø
YES
NO
5Ø5
Initialize: IFR1 = Ø
5Ø8
Increment: IFR1 = IFR1 + 1
If IRF1 > NFROV
YES
NO
5Ø8
Initialize: IOV1T = Ø
51Ø
Increment: IOV1T = IOV1T + 1
If IOV1T > NPCCT
YES
NO
CA1
CA2
CA

(CA)

Calculate unfactored fatigue lives (18-kip ESAL) for existing pavement after overlay, for CRCP overlay when remaining life in underlying PCC, and for CRCP overlay when no remaining life in underlying PCC:

$$\text{FØUC} = \text{OFATIG}\ (\text{FREP},\ \text{CØUC}_{\text{IC1}},\ \text{SØUP}_{\text{IOV1T}})$$

$$\text{F1UC1} = \text{OFATIG}\ (\text{FROV}_{\text{IFR1}},\ \text{C1UC}_{\text{IC1}},\ \text{S1UP1}_{\text{IOV1T, IOV2T}})$$

$$\text{F1UC2} = \text{OFATIG}\ (\text{FROV}_{\text{IFR1}},\ \text{C1UC}_{\text{ICL}},\ \text{S1UP2}_{\text{IOV1t, IOV2T}})$$

↓

Calculate fatigue life (18-kip ESAL) of existing pavement after overlay:

$$\text{FATEP1} = \text{RLEPR} \times \text{FØUC}$$

↓

Calculate remaining life of unbonded CRCP overlay after no-remaining life in existing PCC:

$$\text{RLOV1X} = 1 - \text{FATEP1}/\text{F1UC1}$$

↓

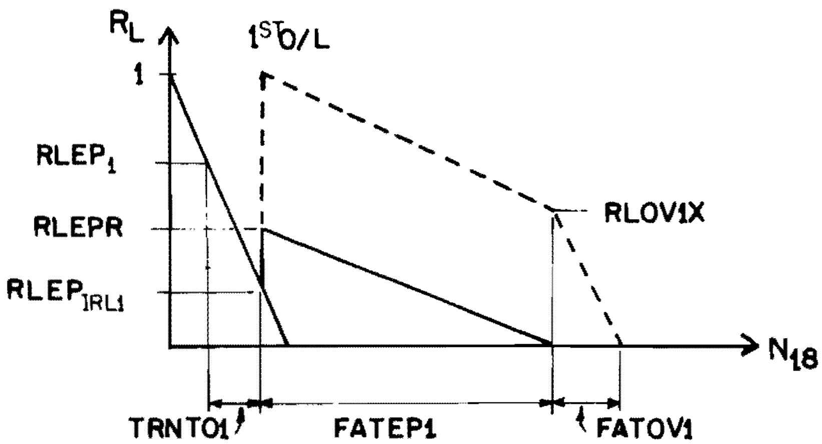
Calculate fatigue life (18-kip ESAL) of unbonded CRCP overlay after no-remaining life in existing PCC:

$$\text{FATOV1} = \text{RLOV1X} \times \text{F1UC2}$$

(CB)

CB

Compute total fatigue life (18-kip ESAL) of strategy:



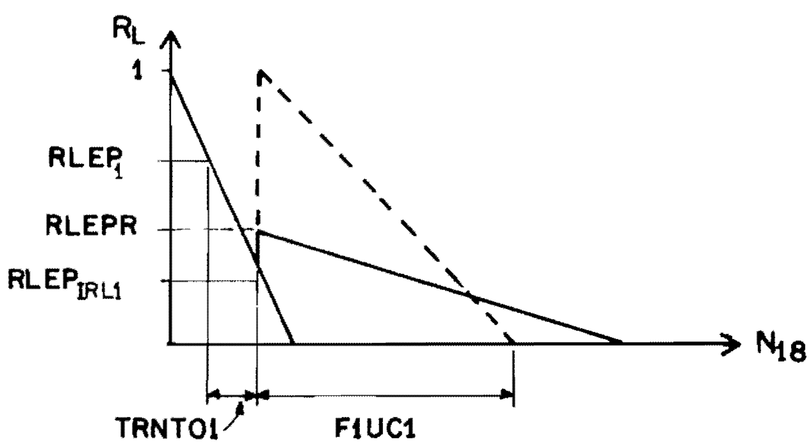
FATOT1 = TRNTO1 + FATEP1 + FATOV1

If RLOV1X < Ø

NO → CC1

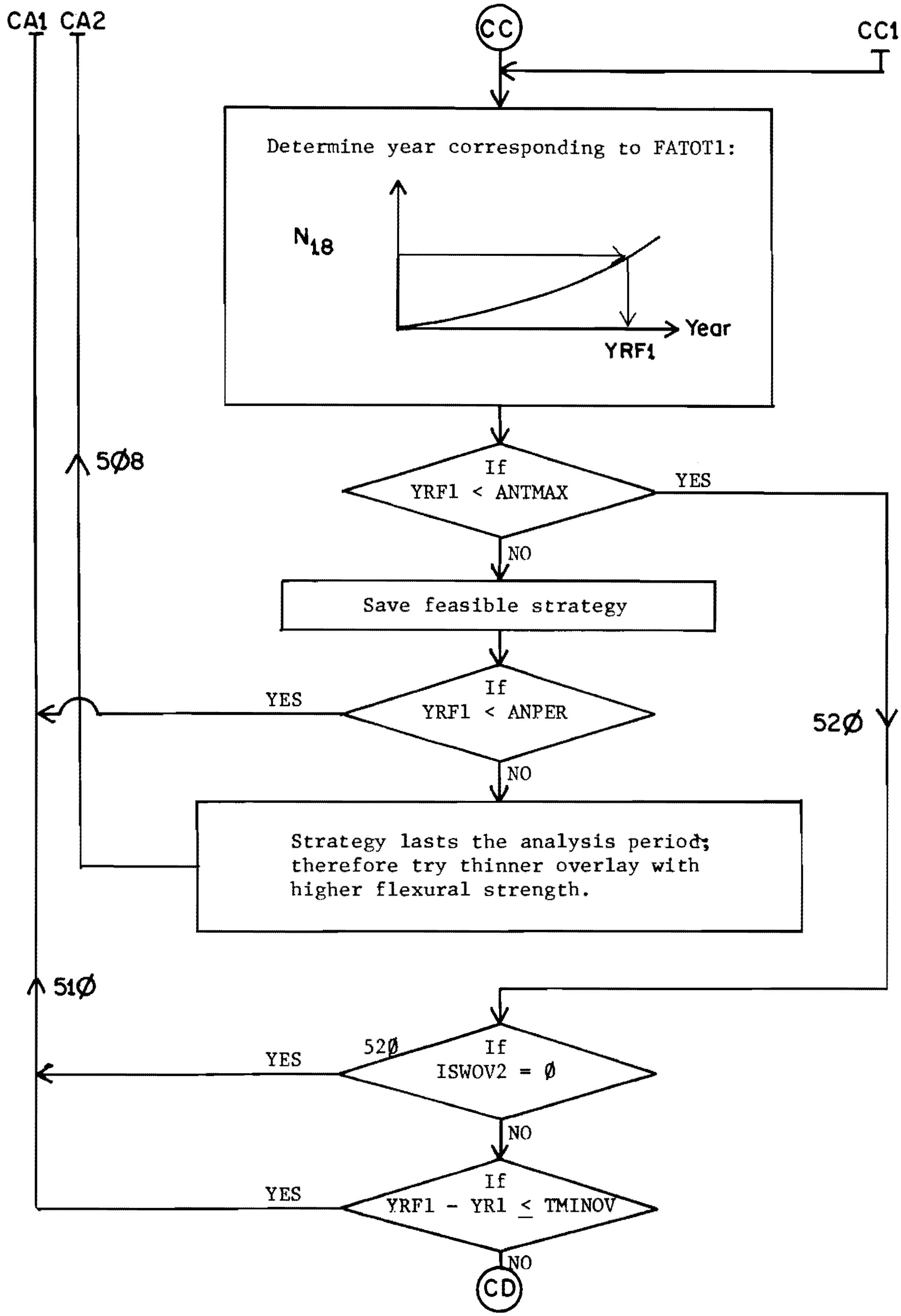
YES

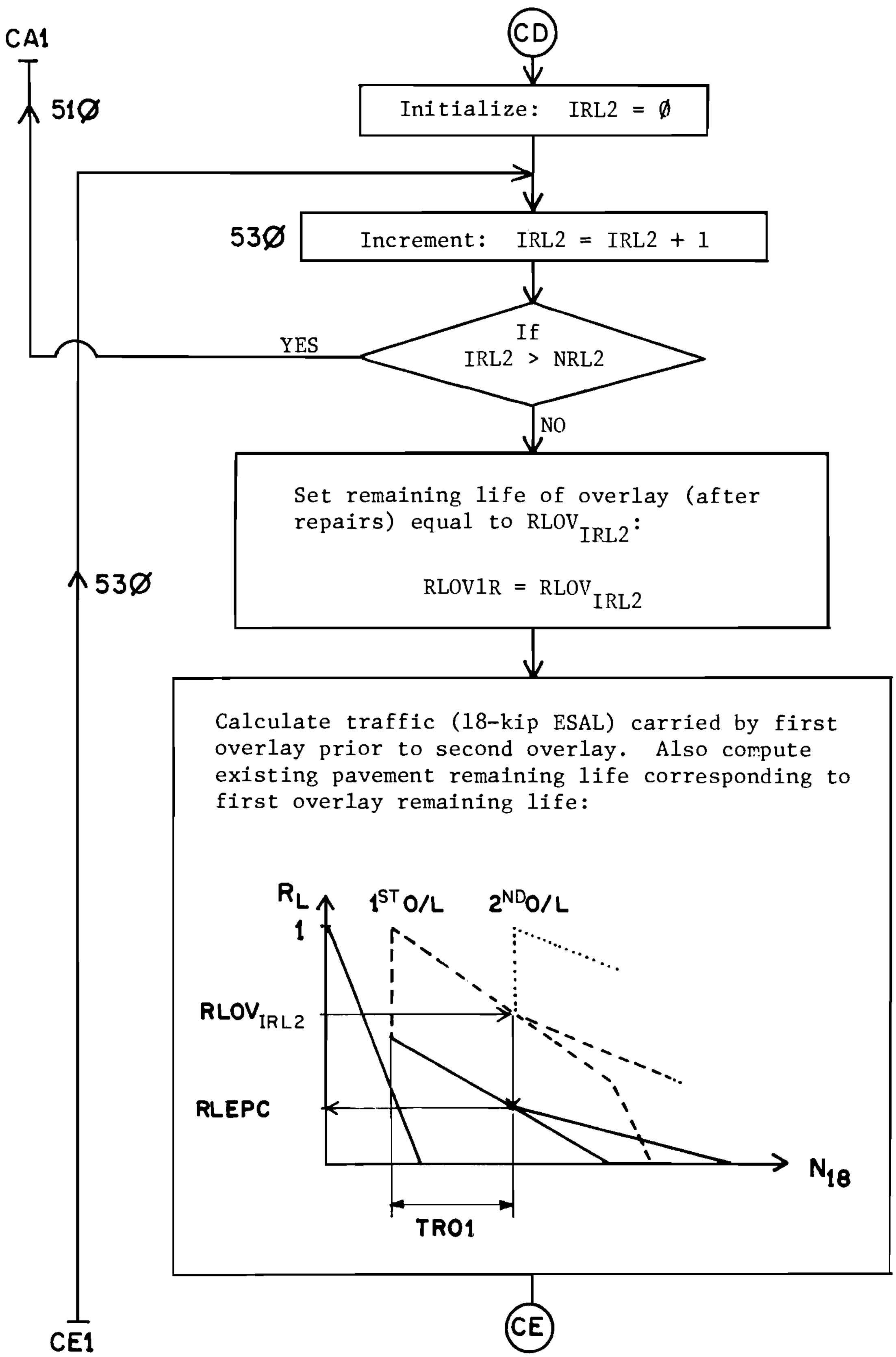
Re-compute total fatigue life (18-kip ESAL) of strategy:



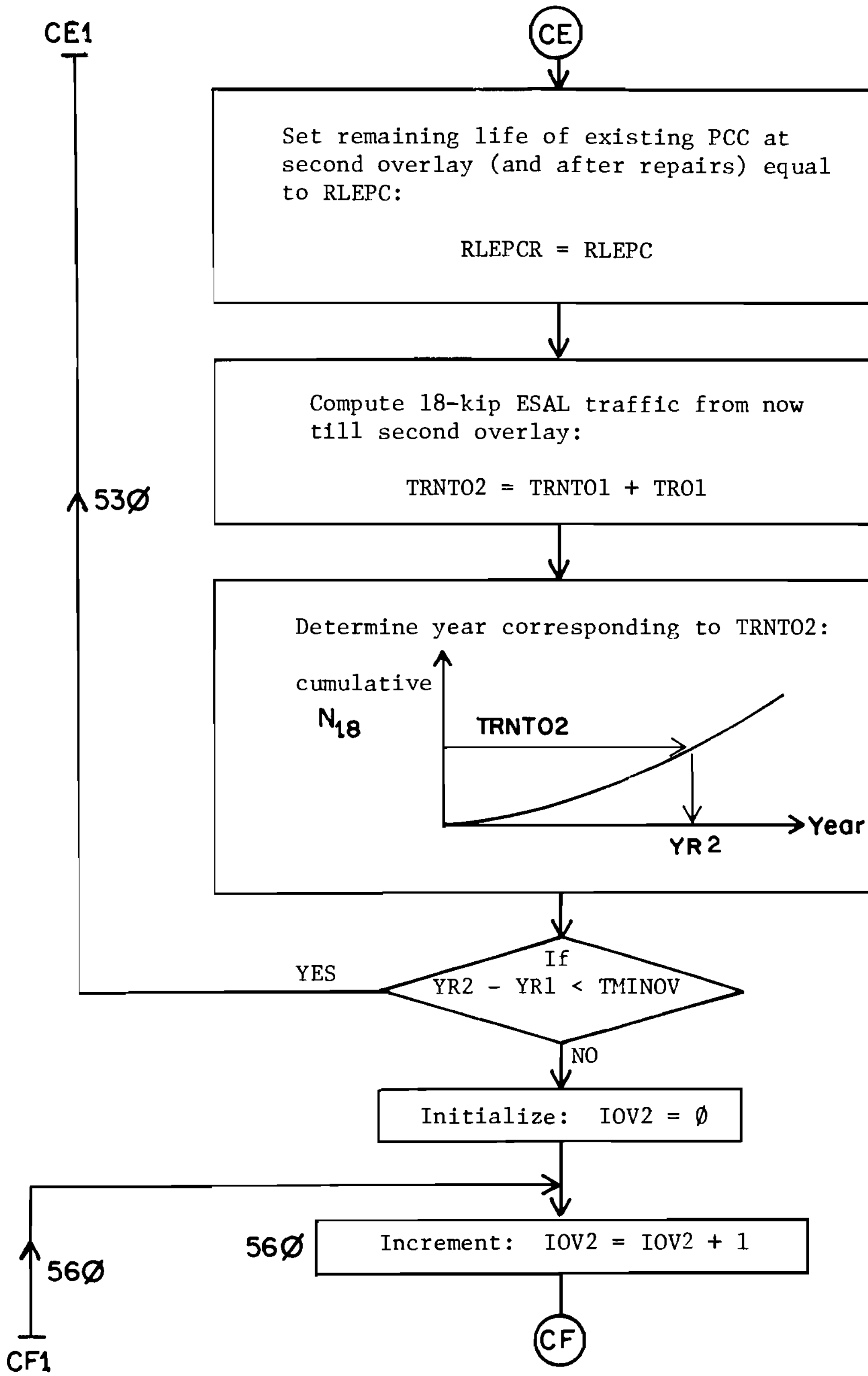
FATOT1 = TRNTO1 + F1UC1

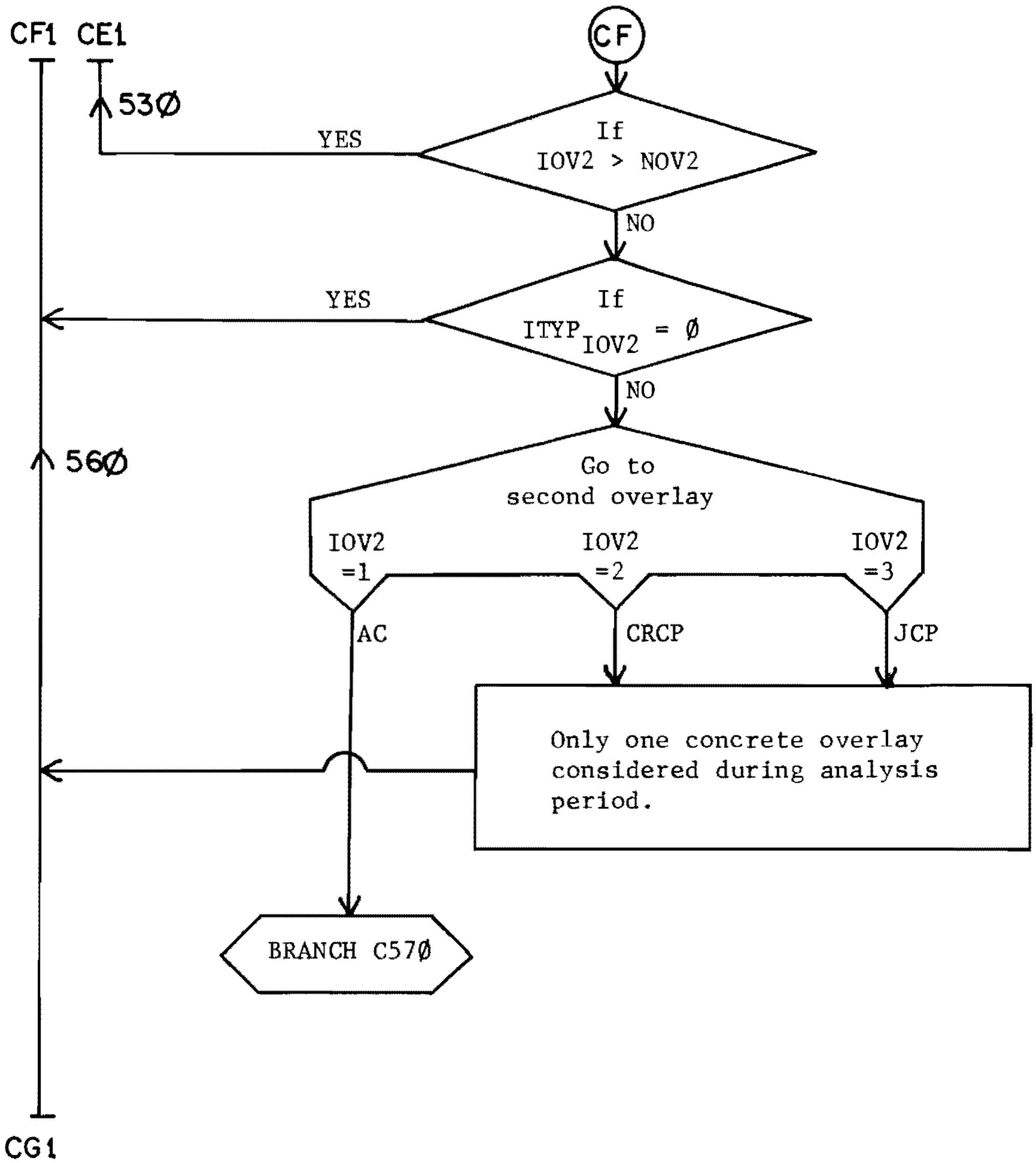
CC

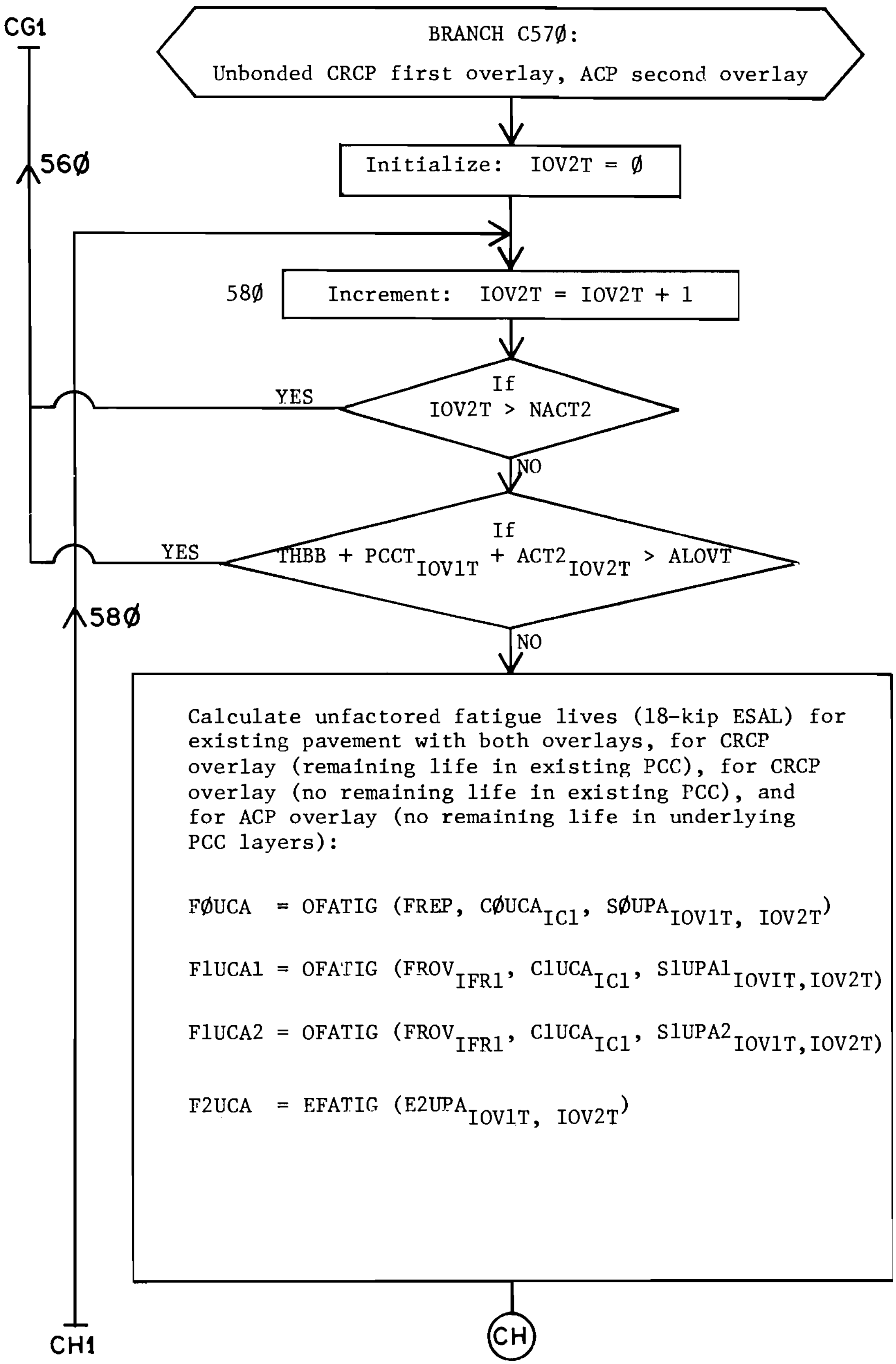

CA1 CA2
CC
CC1
Determine year corresponding to FATOT1:
N18
Year
YRF1
508
If
YRF1 < ANTMAX
YES
NO
Save feasible strategy
If
YRF1 < ANPER
YES
NO
520
Strategy lasts the analysis period; therefore try thinner overlay with higher flexural strength.
510
520
If
ISWOV2 = Ø
YES
NO
If
YRF1 - YR1 ≤ TMINOV
YES
NO
CD



CD
CA1
51Ø
Initialize: IRL2 = Ø
53Ø
Increment: IRL2 = IRL2 + 1
YES
If IRL2 > NRL2
NO
Set remaining life of overlay (after repairs) equal to RLOV$_{IRL2}$:
RLOV1R = RLOV$_{IRL2}$
53Ø
Calculate traffic (18-kip ESAL) carried by first overlay prior to second overlay. Also compute existing pavement remaining life corresponding to first overlay remaining life:
R_L
1
1ST O/L
2ND O/L
RLOV$_{IRL2}$
RLEPC
N_{18}
TR01
CE1
CE


CE1
CE
Set remaining life of existing PCC at second overlay (and after repairs) equal to RLEPC:
RLEPCR = RLEPC
Compute 18-kip ESAL traffic from now till second overlay:
TRNTO2 = TRNTO1 + TRO1
53Ø
Determine year corresponding to TRNTO2:
cumulative
N_{18}
TRNTO2
Year
YR2
YES
If
YR2 - YR1 < TMINOV
NO
Initialize: IOV2 = Ø
56Ø
Increment: IOV2 = IOV2 + 1
56Ø
CF1
CF


CF1
CE1
530
CF
YES
If
IOV2 > NOV2
NO
YES
If
ITYP IOV2 = 0
NO
560
Go to
second overlay
IOV2 =1
IOV2 =2
IOV2 =3
AC
CRCP
JCP
Only one concrete overlay considered during analysis period.
BRANCH C570
CG1


CG1
BRANCH C57Ø:
Unbonded CRCP first overlay, ACP second overlay
56Ø
Initialize: IOV2T = Ø
58Ø
Increment: IOV2T = IOV2T + 1
YES
If
IOV2T > NACT2
NO
YES
If
THBB + PCCT_IOV1T + ACT2_IOV2T > ALOVT
58Ø
NO
Calculate unfactored fatigue lives (18-kip ESAL) for existing pavement with both overlays, for CRCP overlay (remaining life in existing PCC), for CRCP overlay (no remaining life in existing PCC), and for ACP overlay (no remaining life in underlying PCC layers):
FØUCA = OFATIG (FREP, CØUCA_IC1, SØUPA_IOV1T, IOV2T)
F1UCA1 = OFATIG (FROV_IFR1, C1UCA_IC1, S1UPA1_IOV1T,IOV2T)
F1UCA2 = OFATIG (FROV_IFR1, C1UCA_IC1, S1UPA2_IOV1T,IOV2T)
F2UCA = EFATIG (E2UPA_IOV1T, IOV2T)
CH1
CH

(CH)

Calculate fatigue life (18-kip ESAL) of existing PCC (after ACP second overlay). Also calculate fatigue life left in CRCP overlay (assuming remaining life in existing PCC):

FATEP2 = RLEPCR x FØUCA

FOV12X = RLOV1R x F1UCA1

↓

Compute remaining life left in CRCP overlay after loss of remaining life in existing PCC:

RLOV1Y = (FOV12X - FATEP2)/F1UCA1

↓

Calculate fatigue life (18-kip ESAL) of CRCP overlay after loss of remaining life in existing PCC:

FOV12 = RLOV1Y x F1UCA2

↓

Calculate remaining life in ACP overlay after no-remaining life in underlying PCC layers:

RLOV2Y = 1 - RLOV1R

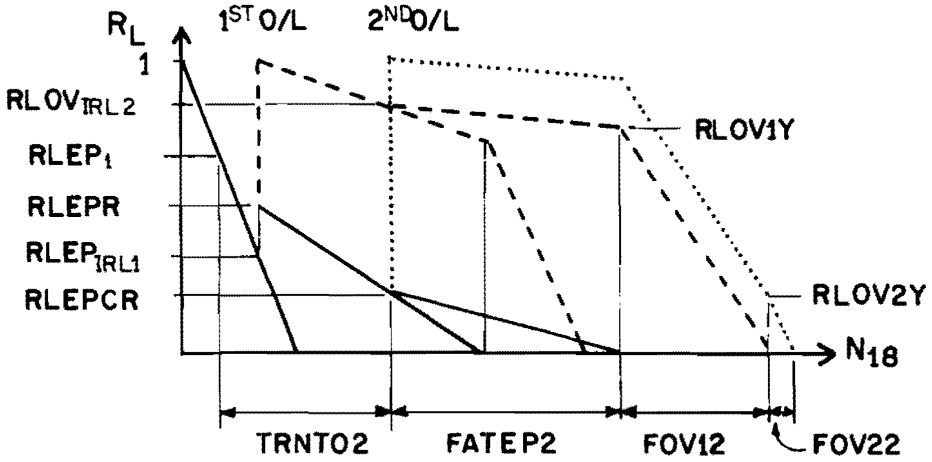
↓

Calculate fatigue life (18-kip ESAL) of ACP overlay after no-remaining life in underlying PCC layers:

FOV22 = RLOV2Y x F2UCA

(CI)

CI



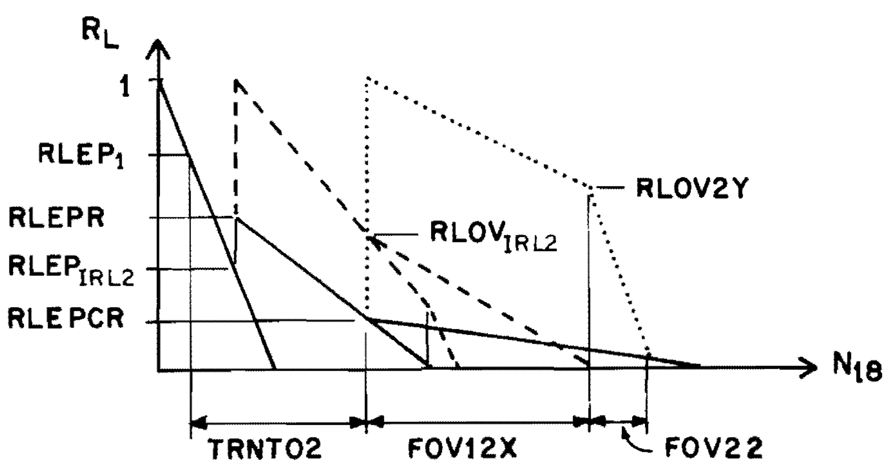
FATOT2 = TRNTO2 + FATEP2 + FOV12 + FOV22

If RLOV1Y < Ø

NO

YES

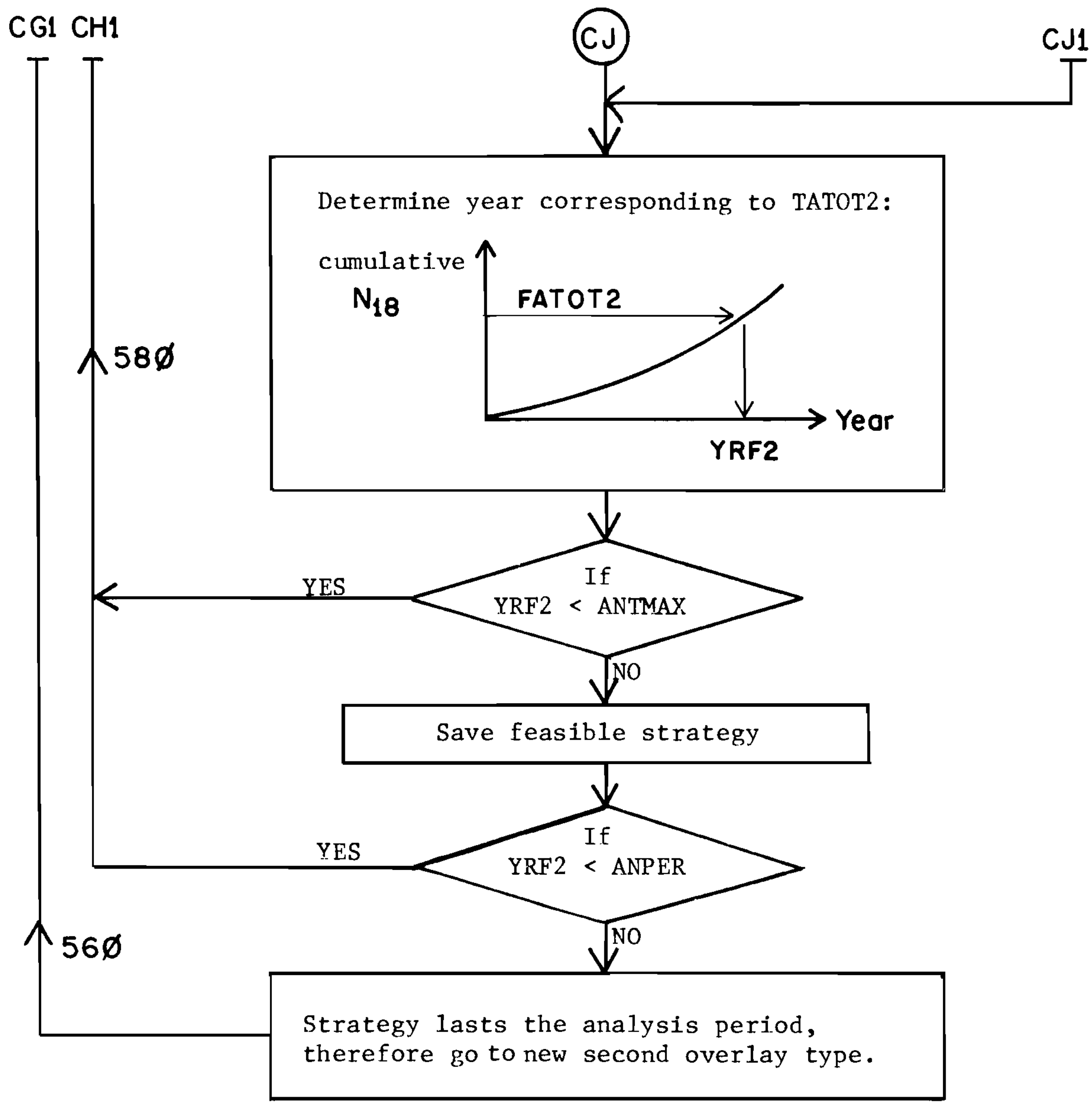
Re-compute total fatigue life (18-kip ESAL) of strategy:



FATOT2 = TRNTO2 + FOV12X + FOV22

CJ

CJ1


CG1 CH1
CJ
CJ1
Determine year corresponding to TATOT2:
cumulative
N18
FATOT2
Year
YRF2
580
YES
If
YRF2 < ANTMAX
NO
Save feasible strategy
YES
If
YRF2 < ANPER
NO
560
Strategy lasts the analysis period,
therefore go to new second overlay type.

9ØØ BRANCH D: Bonded JCP first overlay

This branch is almost identical to BRANCH B. In order to construct this branch, the following substitutions should be made in BRANCH B (and its accompanying BRANCH B37Ø):

1. JCP overlay for CRCP overlay,
2. a 1 for the 2 in second diamond,
3. 7ØØ for 3ØØ,
4. 7Ø5 for 3Ø5,
5. 71Ø for 31Ø,
6. 72Ø for 32Ø,
7. 73Ø for 33Ø,
8. 76Ø for 36Ø,
9. BRANCH D77Ø for BRANCH B37Ø,
10. 78Ø for 38Ø,
11. NCBJ for NCBC,
12. CØBJ for COBC,
13. CØBJA for COBCA,
14. FØBJ for FØBC,
15. FØBJA for FØBCA, and
16. F2BJA for F2BCA.

BRANCH E: Unbonded JCP first overlay

This branch is almost identical to BRANCH C. In order to construct this branch, the following substitutions should be made in BRANCH C (and its accompanying BRANCH C57Ø):

1. JCP overlay for CRCP overlay
2. 9ØØ for 5ØØ,
3. 9Ø5 for 5Ø5,
4. 9Ø8 for 5Ø8,
5. 91Ø for 51Ø,
6. 92Ø for 52Ø,
7. 93Ø for 53Ø
8. 96Ø for 56Ø,
9. BRANCH E97Ø for BRANCH C57Ø,
10. 98Ø for 58Ø,
11. NCUJ for NCUC,
12. CØUJ for CØUJ,
13. C1UJ for C1UC,
14. CØUJA for CØUCA,
15. C1UJA for C1UCA,
16. FØUJ for FØUC,
17. F1UJ1 for F1UC1,
18. F1UJ2 for F1UC2,
19. FØUJA for FØUCA,
20. F1UJA1 for F1UCA1,
21. F1UJA2 for F1UCA2, and
22. F2UJA for F2UCA.

APPENDIX D

RPRDS-1 INPUT GUIDE

APPENDIX D. RPRDS-1 INPUT GUIDE

This input guide represents a summary of the input data required for RPRDS-1 and a guide for recording it on cards (or card images) for use by the program. This section is not intended to provide a detailed description of each input variable (see RPRDS-1 User's Manual, Chapter 6), but merely show how the data sould be organized for running one or several rigid pavement rehabilitation design problems.

The data for a single problem are divided into eleven categories for ease of input:

(1) Project Description,

(2) Original Pavement,

(3) Traffic Variables,

(4) Time Constraints,

(5) Remaining Life Variables,

(6) Overlay Characteristics,

(7) Overlay Constructon Cost Variables,

(8) Traffic Delay Cost Variables,

(9) Distress/Maintenance Cost Variables

(10) Cost Returns, and

(11) Combined Interest and Inflation Rate.

Each variable within these categories is assigned a variable number according to the number of the card it appears on and its order on the card. This assigned number makes it easy to locate the variable, both in the program output and in the User's Manual (Chapter 6), where it is discussed in great detail.

In order to generate a card deck to run the RPRDS-1 program, the user should follow the guide, provided next, which defines each input variable. There are three important things to note, however, when following the guide.

The first is that each variable (except for the title) is entered in five or ten-column fields within each card.

The second is that each variable (except for the title) should be entered as either a real or integer value. If a variable is real, it should be entered with a decimal point and may be entered anywhere in its field. If the variable is an integer, it must be entered without the decimal point and must also be right-justified (furthest to the right) in its field.

The third item to note is that a format summary for all the data (which illustrates the relative location of each input variable) is provided at the end of this section as an aid in coding the data.

<u>Project Description</u>

Card No. 1:
- 1.1 Title card, alphanumeric, col. 1-80.

<u>Original Pavement</u>

Card No. 2:
- 2.1 Surface type, integer, col. 1-5. (1=CRCP, 2=JCP)
- 2.2 Concrete shoulder, integer, col. 6-10. (1=No, 2=Yes)
- 2.3 No. of lanes in one direction, integer, col. 11-15.
- 2.4 No. of pavement layers, integer, col. 16-20. (maximum of 5)

Card No. 3:
- 3.1 Project length (miles), real, col. 1-10.

3.2 Lane width (feet), real, col. 11-20.
3.3 Total shoulder width (feet), real, col. 21-30.

Card No. 4:
4.0 Thicknesses of existing layers (inches):
4.1 Concrete surface layer, real, col. 1-10.
4.2 Second layer, real, col. 11-20.
4.3 Third layer, real, col. 21-30.
4.4 Fourth layer, real, col. 31-40.
4.5 Fifth layer, real, col. 41-50.

Card No. 5:
5.0 Elastic moduli of existing layers (psi):
5.1 Concrete surface layer (psi), real, col. 1-10.
5.2 Second layer, real, col. 11-20.
5.3 Third layer, real, col. 21-30.
5.4 Fourth layer, real, col. 31-40.
5.5 Fifth layer, real, col. 41-50.

Card No. 6:
6.0 Poisson's ratios for existing layers:
6.1 Concrete surface layer, real, col. 1-10.
6.2 Second layer, real, col. 11-20.
6.3 Third layer, real, col. 21-30.
6.4 Fourth layer, real, col. 31-40.
6.5 Fifth layer, real, col. 41-50.

Card No. 7:
7.1 Concrete flexural strength (psi), real, col. 1-10.
7.2 Critical stress factor, real, col. 11-20.
7.3 Concrete stiffness after cracking (psi), real, col. 21-30.

Card No. 8:
8.1 Number of existing defects per mile, real, col. 1-10.
8.2 Cost of repairing a defect (dollars), real, col. 11-20.
8.3 Rate of defect development (number per year per mile), real, col. 21-30.

Traffic Variables

Card No. 9:
9.1 Average daily traffic (vehicles per day), real, col. 1-10.
9.2 Average daily traffic growth rate (percent), real, col. 11-20.
9.3 Initial yearly 18-kip equivalent single axle loads (millions), real, col. 21-30.
9.4 18-kip ESAL growth rate (percent), real, col. 31-40.
9.5 Directonal distribution factor (percent), real, col. 41-50.
9.6 Lane distribution factor (percent), real, col. 51-60.

Time Constraints

Card No. 10:

10.1 Analysis period (years), real, col. 1-10.

10.2 Minimum time between overlays (years), real, col. 11-20.

10.3 Maximum allowable years of heavy maintenance after loss of structural load-carrying capacity, real, col. 21-30. (Maximum of 10 years)

Remaining Life Variables

Card No. 11:

11.1 Number of original pavement remaining life values to consider, integer, col. 1-5. (Maximum of 10)

11.2 Minimum existing pavement remaining life at which bonded PCC overlay may be placed (percent), real, col. 6-10.

11.3 Values of original pavement remaining life (percent) at which first overlay may be placed (in descending order):

1 first remaining life, real, col. 11-15.
2 second remaining life, real, col. 16-20.
3 third remaining life, real, col. 21-25.
4 fourth remaining life, real, col. 26-30.
5 fifth remaining life, real, col. 31-35.
6 sixth remaining life, real, col. 36-40.
7 seventh remaining life, real, col. 41-45.
8 eighth remaining life, real, col. 46-50.
9 ninth remaining life, real, col. 51-55.
10 tenth remaining life, real, col. 56-60.

Card No. 12:

12.1 Number of first overlay remaining life values to consider, integer, col. 1-5. (Maximum of 10)

12.2 Values of first overlay remaining life (percent) at which second overlay may be placed (in descending order):

1 first remaining life, real, col. 11-15.
2 second remaining life, real, col. 16-20.
3 third remaining life, real, col. 21-25.
4 fourth remaining life, real, col. 26-30.
5 fifth remaining life, real, col. 31-35.
6 sixth remaining life, real, col. 36-40.
7 seventh remaining life, real, col. 41-45.
8 eighth remaining life, real, col. 46-50.
9 ninth remaining life, real, col. 51-55.
10 tenth remaining life, real, col. 56-60.

Overlay Characteristics

Card No. 13:

13.0 Types of first overlay to consider (0=No, 1=Yes):

13.1 ACP, integer, col. 1-5.

13.2 Bonded CRCP, integer, col. 6-10.

13.3 Unbonded CRCP, integer, col. 11-15.

13.4 Bonded JCP, integer, col. 16-20.
13.5 Unbonded JCP, integer, col. 21-25.

Card No. 14:
14.0 Types of second overlay to consider (0=No, 1=Yes):
14.1 ACP, integer, col. 1-5.
14.2 CRCP, integer, col. 6-10.
14.3 JCP, integer, col. 11-15.

Card No. 15:
15.1 Number of ACP first overlay thicknesses to consider, integer, col. 1-5. (Maximum of 8)
15.2 Number of ACP second overlay thinckesses to consider, integer, col. 6-10. (Maximum of 8)
15.3 Number of PCC overlay thicknesses to consider, integer, col. 11-15. (Maximum of 8)

Card No. 16:
16.0 ACP first overlay thicknesses (inches) in ascending order:
16.1 first thickness, real, col. 1-10.
16.2 second thickness, real, col. 11-20.
16.3 third thickness, real, col. 21-30.
16.4 fourth thickness, real, col. 31-40.
16.5 fifth thickness, real, col. 41-50.
16.6 sixth thickness, real, col. 51-60.
16.7 seventh thickness, real, col. 61-70.
16.8 eighth thickness, real, col. 71-80.

Card No. 17:
17.0 ACP second overlay thicknesses (inches) in ascending order:
17.1 first thickness, real, col. 1-10.
17.2 second thickness, real, col. 11-20.
17.3 third thickness, real, col. 21-30.
17.4 fourth thickness, real, col. 31-40.
17.5 fifth thickness, real, col. 41-50.
17.6 sixth thickness, real, col. 51-60.
17.7 seventh thickness, real, col. 61-70.
17.8 eighth thickness, real, col. 71-80.

Card No. 18:
18.0 PCC overlay thicknesses (inches) in ascending order:
18.1 first thickness, real, col. 1-10.
18.2 second thickness, real, col. 11-20.
18.3 third thickness, real, col. 21-30.
18.4 fourth thickness, real, col. 31-40.
18.5 fifth thickness, real, col. 41-50.
18.6 sixth thickness, real, col. 51-60.
18.7 seventh thickness, real, col. 61-70.
18.8 eighth thickness, real, col. 71-80.

Card No. 19:
19.1 Allowable total overlay thickness (inches), real, col. 1-10.

19.2 Average level-up thickness (inches), real, col. 11-20.
19.3 Bond breaker thickness (inches), real, col. 21-30.

Card No. 20:
20.1 ACP overlay design stiffness (psi), real, col. 1-10.
20.2 Poisson's ratio, ACP overlay, real, col. 11-20.
20.3 PCC overlay design stiffness (psi), real, col. 21-30.
20.4 Poisson's ratio, PCC overlay, real, col. 31-40.
20.5 Bond breaker stiffness (psi), real, col. 41-50.
20.6 Poisson's ratio, bond breaker, real, col. 51-60.

Card No. 21:
21.1 Number of overlay flexural strengths to consider, integer, col. 1-5. (Maximum of 5)
21.2 Number which identifies which flexural strenth in the list to use for bonded PCC overlay, integer, col. 6-10.

Card No. 22:
22.0 PCC overlay flexural strengths (psi) in ascending order:
22.1 first flexural strength, real, col. 1-10.
22.2 second flexural strength, real, col. 11-20.
22.3 third flexural strength, real, col. 21-30.
22.4 fourth flexural strength, real, col. 31-40.
22.5 fifth flexural strength, real, col. 41-50.

Card Numbers 23 through 40:

These cards define critical stress factors (ratios of critical stress to interior stress) for various overlay and shoulder combinations. These factors also depend on which concrete layer in the structure they apply to, therefore, in the descriptions below, the first term provided represents the layer to which the stress factor applies. The second term describes the overlay combination and the third term describes the shoulder type.

23.1 Existing pavement, single ACP overlay, ACP shoulder, real, col. 1-10.

24.1 Existing pavement, two ACP overlays, ACP shoulder, real, col. 1-10.

25.1 Existing pavement, first overlay-ACP and second-CRCP, ACP shoulder, real, col. 1-10.

25.2 Existing pavement, first overlay-ACP and second-CRCP, CRCP shoulder, real, col. 11-20.

26.1 CRCP overlay, first overlay-ACP and second-CRCP, ACP shoulder, real, col. 1-10.

26.2 CRCP overlay, first overlay-ACP and second-CRCP, CRCP shoulder, real, col. 11-20.

27.1 Existing pavement, first overlay-ACP and second-JCP, ACP shoulder, real, col. 1-10.

27.2 Existing pavement, first overlay-ACP and second-JCP, JCP shoulder, real, col. 11-20.

28.1 JCP overlay, first overlay-ACP second-JCP, ACP shoulder, real, col. 1-10.

28.2 JCP overlay, first overlay-ACP second-JCP, JCP shoulder, real, col. 11-20.

29.1 Existing pavement, single bonded CRCP overlay, ACP shoulder, real, col. 1-10.

29.2 Existing pavement, single bonded CRCP overlay, CRCP shoulder, real, col. 11-20.

30.1 Existing pavement, first overlay-bonded CRCP and second-ACP, ACP shoulder, real, col. 1-10.

30.2 Existing pavement, first overlay-bonded CRCP and second-ACP, CRCP shoulder, real, col. 11-20.

31.1 Existing pavement, single bonded JCP overlay, ACP shoulder, real, col. 1-10.

31.2 Existing pavement, single bonded JCP overlay, JCP shoulder, real, col. 11-20.

32.1 Existing pavement, first overlay-bonded JCP and second ACP, ACP shoulder, real, col. 1-10.

32.2 Existing pavement, first overlay-bonded JCP and second ACP, JCP shoulder, real, col. 11-20.

33.1 Existing pavement, single unbonded CRCP overlay, ACP shoulder, real, col. 1-10.

33.2 Existing pavement, single unbonded CRCP overlay, CRCP shoulder, real, col. 11-20.

34.1 CRCP overlay, single unbonded CRCP overlay, ACP shoulder, real, col. 1-10.

34.2 CRCP overlay, single unbonded CRCP overlay, CRCP shoulder, real, col. 11-20.

35.1 Existing pavement, first overlay-unbonded CRCP and second-ACP, ACP shoulder, real, col. 1-10.

35.2 Existing pavement, first overlay-unbonded CRCP and second-ACP, CRCP shoulder, real, col. 11-20.

36.1 CRCP overlay, first overlay-unbonded CRCP and second-ACP, ACP shoulder, real, col. 1-10.

36.2 CRCP overlay, first overlay-unbonded CRCP and second-ACP, CRCP shoulder, real, col. 11-20.

37.1 Existing pavement, single unbonded JCP overlay, ACP shoulder, real, col. 1-10.

37.2 Existing pavement, single unbonded JCP overlay, JCP shoulder, real, col. 11-20.

38.1 JCP overlay, single unbonded JCP overlay, ACP shoulder, real, col. 1-10.

38.2 JCP overlay, single unbonded JCP overlay, JCP shoulder, real, col. 11-20.

39.1 Existing pavement, first overlay-unbonded JCP and second-ACP, ACP shoulder, real, col. 1-10.

39.2 Existing pavement, first overlay-unbonded JCP and second-ACP, JCP shoulder, real, col. 11-20.

40.1 JCP overlay, first overlay-unbonded JCP and second-ACP, ACP shoulder, real, col. 1-10.

40.2 JCP overlay, first overlay-unbonded JCP and second-ACP, JCP shoulder, real, col. 11-20.

Card No. 41:
41.1 Switch on method of response predicton, integer, col. 1-5. (1=LAYER submodel, 2=LAYER regression submodel)

<u>Overlay Constructon Cost Variables</u>

Card No. 42:
42.0 Site establishment costs (dollars):
42.1 ACP equipment, real, col. 1-10.
42.2 CRCP equipment, real, col. 11-20.
42.3 JCP equipment, real, col. 21-30.
42.4 ACP and CRCP equipment combined, real, col. 31-40.
42.5 ACP and JCP equipment combined, real, col. 41-50.

Card No. 43:
43.0 Pavement surface preparation costs (dollars per square yard):
43.1 Existing pavement, real, col. 1-10.
43.2 ACP overlay, real, col. 11-20.
43.3 CRCP overlay, real, col. 21-30.
43.4 JCP overlay, real, col. 31-40.

Card No. 44:

44.1 Fixed cost of ACP overlay constructon (dollars per square yard), real, col. 1-10.

44.2 Variable cost of ACP overlay construction (dollars per square yard per inch), real, col. 11-20.

44.3 Fixed cost of flexible shoulder construction (dollars per square yard), real, col. 21-30.

44.4 Variable cost of flexible shoulder construction (dollars per square yard per inch), real, col. 31-40.

44.5 Cost of bond breaker construction (dollars per square yard), real, col. 41-50.

Card No. 45:

45.0 CRCP fixed cost for each flexural strength (dollars per square yard):

45.1 first, real, col. 1-10.

45.2 second, real, col. 11-20.

45.3 third, real, col. 21-30.

45.4 fourth, real, col. 31-40.

45.5 fifth, real, col. 41-50.

Card No. 46:

46.0 CRCP variable cost for each flexural strength (dollars per square yard per inch):

46.1 first, real, col. 1-10.

46.2 second, real, col. 11-20.

46.3 third, real, col. 21-30.

46.4 fourth, real, col. 31-40.

46.5 fifth, real, col. 41-50.

Card No. 47:

47.0 JCP fixed cost for each flexural strength (dollars per square yard):

47.1 first, real, col. 1-10.

47.2 second, real, col. 11-20.

47.3 third, real, col. 21-30.

47.4 fourth, real, col. 31-40.

47.5 fifth, real, col. 41-50.

Card No. 48:

48.0 JCP variable cost for each flexural strength (dollars per square yard per inch):

48.1 first, real, col. 1-10.

48.2 second, real, col. 11-20.

48.3 third, real, col. 21-30.

48.4 fourth, real, col. 31-40.

48.5 fifth, real, col. 41-50.

Card No. 49:

49.1 Total steel percentage required in CRCP overlays, real, col. 1-10.

49.2 Total steel percentage required in JCP overlays, real, col. 11-20.

49.3 Cost of steel reinforcement (dollars per pound), real, col. 21.30.

Traffic Delay Cost Variables

Card No. 50:

50.1 Location of project, integer, col. 1-5. (1=rural, 2=urban)

50.2 Model number for handling traffic, integer, col. 6-10. (See User's Manual, Chapter 6)

50.3 Number of open lanes, overlay direction, integer, col. 11-15.

50.4 Number of open lanes, non-overlay direction, integer, col. 16-20.

Card No. 51:

51.1 Military time of day overlay construction begins, real, col. 1-10. (e.g. 900. for 9:00 am)

51.2 Military time of day overlay construction ends, real, col. 11-20. (e.g. 1600. for 4:00 pm)

51.3 Hours per day overlay construction occurs, real, col. 21-30.

51.4 Number of days concrete is allowed to cure, real, col. 31-40.

51.5 Detour distance for detour model number 5 (miles), real, col. 41-50.

Card No. 52:

52.1 Average approach speed (mph), real, col. 1-10.

52.2 Average speed in overlay direction (mph), real, col. 11-20.

52.3 Average speed in non-overlay direction (mph), real, col. 21-30.

Card No. 53:

53.1 Distance traffic is slowed in overlay direction (miles), real, col. 1-10.

53.2 Distance traffic is slowed in non-overlay direction (miles), real, col. 11-20.

53.3 Percent of vehicles stopped in overlay direction, real, col. 21-30.

53.4 Percent of vehicles stopped in non-overlay direction, real, col. 31-40.

53.5 Average vehicle delay in overlay direction (hours), real, col. 41-50.

53.6 Average vehicle delay in non-overlay direction (hours), real, col. 51-60.

Card No. 54:

54.1 ACP production rate (cubic yards per hour), real, col. 1-10.

54.2 CRCP production rate (cubic yards per hour), real, col. 11-20.

54.3 JCP production rate (cubic yards per hour), real, col. 21-30.
54.4 Bond breaker production rate (cubic yards per hour), real, col. 31-40.

Distress/Maintenance Cost Variables

Card No. 55:
55.1 CRCP overlay distress repair cost (dollars), real, col. 1-5.
55.2 Initial CRCP overlay distress rate (number per mile per year), real, col. 6-10.
55.3 Secondary CRCP overlay distress rate (number per mile per year), real, col. 11-15.
55.4 CRCP overlay distress rate (number per mile) for each year after loss of pavement load-carrying capacity:
1 first year after, real, col. 16-20.
2 second year after, real, col. 21-25.
3 third year after, real, col. 26-30.
4 fourth year after, real, col. 31-35.
5 fifth year after, real, col. 36-40.
6 sixth year after, real, col. 41-45.
7 seventh year after, real, col. 46-50.
8 eighth year after, real, col. 51-55.
9 ninth year after, real, col. 56-60.
10 tenth year after, real, col. 61-65.

Card No. 56:
56.1 JCP overlay distress repair cost (dollars), real, col. 1-5.
56.2 Initial JCP overlay distress rate (number per mile per year), real, col. 6-10.
56.3 Secondary JCP overlay distress rate (number per mile per year), real, col. 11-15.
56.4 JCP overlay distress rate (number per mile) for each year after loss of pavement load-carrying capacity:
1 first year after, real, col. 16-20.
2 second year after, real, col. 21-25.
3 third year after, real, col. 26-30.
4 fourth year after, real, col. 31-35.
5 fifth year after, real, col. 36-40.
6 sixth year after, real, col. 41-45.
7 seventh year after, real, col. 46-50.
8 eighth year after, real, col. 51-55.
9 ninth year after, real, col. 56-60.
10 tenth year after, real, col. 61-65.

Card No. 57:
57.1 Distress repair cost (dollars) for an ACP overlay on CRCP, real, col. 1-5.
57.2 Initial ACP/CRCP distress rate (number per mile per year), real, col. 6-10.

57.3 Secondary ACP/CRCP distress rate (number per mile per year), real, col. 11-15.

57.4 ACP/CRCP distress rate (number per mile) for each year after loss of pavement load-carrying capacity:

1 first year after, real, col. 16-20.
2 second year after, real, col. 21-25.
3 third year after, real, col. 26-30.
4 fourth year after, real, col. 31-35.
5 fifth year after, real, col. 36-40.
6 sixth year after, real, col. 41-45.
7 seventh year after, real, col. 46-50.
8 eighth year after, real, col. 51-55.
9 ninth year after, real, col. 56-60.
10 tenth year after, real, col. 61-65.

Card No. 58:

58.1 Distress repair cost (dollars) for an ACP overlay on JCP, real, col. 1-5.

58.2 Initial ACP/JCP distress rate (number per mile per year), real, col. 6-10.

58.3 Secondary ACP/JCP distress rate (number per mile per year), real, col. 11-15.

58.4 ACP/JCP distress rate (number per mile) for each year after loss of pavement load-carrying capacity:

1 first year after, real, col. 16-20.
2 second year after, real, col. 21-25.
3 third year after, real, col. 26-30.
4 fourth year after, real, col. 31-35.
5 fifth year after, real, col. 36-40.
6 sixth year after, real, col. 41-45.
7 seventh year after, real, col. 46-50.
8 eighth year after, real, col. 51-55.
9 ninth year after, real, col. 56-60.
10 tenth year after, real, col. 61-65.

Cost Returns

Card No. 59:

59.1 Salvage value, percent of overlay construction cost, real, col. 1-10.

59.2 Value of each year of extended life (dollars per square yard per year), real, col. 11-20.

Combined Interest and Inflation Rate

Card No. 60:

60.1 Interest rate minus inflation rate (percent), real, col. 1-10.

This concludes the input of data for a single problem. For an additional problem, the user should begin again with card no. 1, otherwise the last card should have STOP in columns 1 through 4.

Format for RPRDS-1 data input:

<table>
<tr><th>CARD No.</th><th colspan="16">COLUMN NUMBERS
1   10   20   30   40   50   60   70   80</th></tr>
<tr><td>1</td><td colspan="16">1.1</td></tr>
<tr><td>2</td><td>2.1</td><td>2.2</td><td>2.3</td><td>2.4</td></tr>
<tr><td>3</td><td colspan="2">3.1</td><td colspan="2">3.2</td><td colspan="2">3.3</td></tr>
<tr><td>4</td><td colspan="2">4.1</td><td colspan="2">4.2</td><td colspan="2">4.3</td><td colspan="2">4.4</td><td colspan="2">4.5</td></tr>
<tr><td>5</td><td colspan="2">5.1</td><td colspan="2">5.2</td><td colspan="2">5.3</td><td colspan="2">5.4</td><td colspan="2">5.5</td></tr>
<tr><td>6</td><td colspan="2">6.1</td><td colspan="2">6.2</td><td colspan="2">6.3</td><td colspan="2">6.4</td><td colspan="2">6.5</td></tr>
<tr><td>7</td><td colspan="2">7.1</td><td colspan="2">7.2</td><td colspan="2">7.3</td></tr>
<tr><td>8</td><td colspan="2">8.1</td><td colspan="2">8.2</td><td colspan="2">8.3</td></tr>
<tr><td>9</td><td colspan="2">9.1</td><td colspan="2">9.2</td><td colspan="2">9.3</td><td colspan="2">9.4</td><td colspan="2">9.5</td><td colspan="2">9.6</td></tr>
<tr><td>10</td><td colspan="2">10.1</td><td colspan="2">10.2</td><td colspan="2">10.3</td></tr>
<tr><td>11</td><td>11.1</td><td>11.2</td><td>11.31</td><td>11.32</td><td>11.33</td><td>11.34</td><td>11.35</td><td>11.36</td><td>11.37</td><td>11.38</td><td>11.39</td><td>11.310</td></tr>
<tr><td>12</td><td>12.1</td><td>X</td><td>12.21</td><td>12.22</td><td>12.23</td><td>12.24</td><td>12.25</td><td>12.26</td><td>12.27</td><td>12.28</td><td>12.29</td><td>12.210</td></tr>
<tr><td>13</td><td>13.1</td><td>13.2</td><td>13.3</td><td>13.4</td><td>13.5</td></tr>
<tr><td>14</td><td>14.1</td><td>14.2</td><td>14.3</td></tr>
<tr><td>15</td><td>15.1</td><td>15.2</td><td>15.3</td></tr>
</table>

(continued)

COLUMN NUMBERS

CARD No.	1–10	20	30	40	50	60	70	80
16	16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8
17	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8
18	18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8
19	19.1	19.2	19.3					
20	20.1	20.2	20.3	20.4	20.5	20.6		
21	21.1	21.2							
22	22.1	22.2	22.3	22.4	22.5			
23	23.1							
24	24.1							
25	25.1	25.2						
26	26.1	26.2						
27	27.1	27.2						
28	28.1	28.2						
29	29.1	29.2						
30	30.1	30.2						
31	31.1	31.2						
32	32.1	32.2						

(continued)

COLUMN NUMBERS

1 10 20 30 40 50 60 70 80

CARD No.					
33	33.1	33.2			
34	34.1	34.2			
35	35.1	35.2			
36	36.1	36.2			
37	37.1	37.2			
38	38.1	38.2			
39	39.1	39.2			
40	40.1	40.2			
41	41.1				
42	42.1	42.2	42.3	42.4	42.5
43	43.1	43.2	43.3	43.4	
44	44.1	44.2	44.3	44.4	44.5
45	45.1	45.2	45.3	45.4	45.5
46	46.1	46.2	46.3	46.4	46.5
47	47.1	47.2	47.3	47.4	47.5
48	48.1	48.2	48.3	48.4	48.5
49	49.1	49.2	49.3		

(continued)

COLUMN NUMBERS

CARD No.	1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65
50	50.1	50.2	50.3	50.4									
51	51.1		51.2		51.3		51.4		51.5				
52	52.1		52.2		52.3								
53	53.1		53.2		53.3		53.4		53.5		53.6		
54	54.1		54.2		54.3		54.4						
55	55.1	55.2	55.3	55.41	55.42	55.43	55.44	55.45	55.46	55.47	55.48	55.49	55.410
56	56.1	56.2	56.3	56.41	56.42	56.43	56.44	56.45	56.46	56.47	56.48	56.49	56.410
57	57.1	57.2	57.3	57.41	57.42	57.43	57.44	57.45	57.46	57.47	57.48	57.49	57.410
58	58.1	58.2	58.3	58.41	58.42	58.43	58.44	58.45	58.46	58.47	58.48	58.49	58.410
59	59.1		59.2										
60	60.1												

This concludes the data input for a single problem. For an additional problem, the user should begin again with card no. 1; otherwise the following should be the last card entered:

STOP

APPENDIX E

CODED DATA FOR RPRDS-1 EXAMPLE PROBLEM

IDENTIFICATION [illegible] TEST (CON[illegible]) CODED BY SES DATE [illegible] 1980 PAGE 2 OF 4

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
3.	4.	5.	6.				
6.	6.5	7.	7.5	8.			
14.	0.5	1.0					
300000.	0.30	4500000.	0.15	50000.	0.30		
2 1							
600.	650.						
1.40							
1.40							
1.25	1.05						
1.25	1.05						
.01	.100						
.00	.00						
.00	.00						
.00	.00						
.0[illegible]	.00						
.0[illegible]	.[illegible]						

APPENDEX E. CODED DATA FOR . . .

IDENTIFICATION R[illegible] TEST - REDESIGN FOR [illegible] INTER[illegible] OVER[illegible] PROJECT [illegible]   CODED BY S[illegible]   DATE Nov 1980   PAGE 1 OF 4

RPRDS1 TEST - REDESIGN FOR [illegible] TCH[illegible] O/L PROJECT, S A TX, SBS/11/80

1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–75	76–80
2	1	4	3												
	0.5		12.		3.										
	10.3		14.		3.										
	5000000.		50000.		6000.										
	1.5		0.45		0.15										
	600.		1.40		[illegible].										
	10.		1000.		4.										
	56000.		2.		1.20		3.		58.		70.				
	20.		51.		5.										
4	10.	30.	20.	10.	[illegible].										
1		80.	60.	40.	20.	[illegible].									
1	0														
		0													
3	4	5													
	4.		5.		6.										

IDENTIFICATION [illegible] CODED BY SEE DATE NOV. 1980 PAGE 3 OF 4

1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
1.25	1.05						
1.25	1.05						
1.25	1.05						
1.25	1.05						
.03	.00						
.00	.00						
.00	.00						
.00	.00						
1							
10000.	20000.	20000.	25000.	25000.			
0.20	0.120	[illegible]	0.20				
2.00	1.00	4.00	0.50	8.00			
4.00	0.00						
[illegible]	1.30						
.00	.00						
.00	.00						

IDENTIFICATION ______ CODED BY ______ DATE Nov. 1980 PAGE 4 OF 4

1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60
	0.5		0.0		0.50						
2	5	2	4								
	900.		1600.		6.		14.		2.5		
	55.		40.		55.						
	3.0		0.0		10.		0.		.002		.000
	43.		60.		0.		40.				
2000.	1.	2.	3.	5.	9.	16.	20.				
0.	0.	0.	0.	0.	0.	0.	0.				
500.	1.	2.	3.	5.	9.	16.	20.				
100.	5.	10.	20.	40.	80.	160.	400.				
	10.		0.125								
	5.										
STOP											

APPENDIX F

RPRDS-1 EXAMPLE PROBLEM-INPUT SUMMARY

APPENDIX F. RPRDS-1 SAMPLE PROBLEM-INPUT SUMMARY

RPRDS1 - RIGID PAVEMENT REHABILITATION DESIGN SYSTEM - VERSION 1, NOV 1980
CENTER FOR TRANSPORTATION RESEARCH
UNIVERSITY OF TEXAS AT AUSTIN

****
R P R D S   I N P U T   S U M M A R Y
****

NOTE - VARIABLE NUMBERS CORRESPOND TO THOSE IN RPRDS USERS MANUAL

PROJECT DESCRIPTION
****

1.1 TITLE
RPRDS1 TEST - REDESIGN FOR FRATT INTCHNG O/L PROJECT, S A TX, SBS/11/80

ORIGINAL PAVEMENT
****

2.1	SURFACE TYPE	JCP
2.2	CONCRETE SHOULDER	NO
2.3	NO. OF LANES (ONE DIRECTION)	4
2.4	NO. OF PAVEMENT LAYERS	3
3.1	PROJECT LENGTH, MILES	2.50
3.2	LANE WIDTH, FEET	12.0
3.3	TOTAL SHOULDER WIDTH, FEET	3.

PAVEMENT STRUCTURE

LAYER NO.	4.0 THICKNESS (IN)	5.0 ELASTIC MODULUS (PSI)	6.0 POISSONS RATIO
1	10.5	5000000.	.15
2	14.0	50000.	.40
3	SEMI-INFINITE	6000.	.45

7.1	CONCRETE FLEXURAL STRENGTH, PSI	600.
7.2	CRITICAL STRESS FACTOR	1.40
7.3	CONCRETE STIFFNESS AFTER CRACKING, PSI	500000.
8.1	NO. OF EXISTING DEFECTS PER MILE	10.
8.2	COST OF REPAIRING A DEFECT, DOL	2000.
8.3	RATE OF DEFECT DEVELOPMENT, NO./YR/MILE	4.

TRAFFIC VARIABLES
****

9.1	AVERAGE DAILY TRAFFIC (ADT)	56000.
9.2	ADT GROWTH RATE, PERCENT	2.00
9.3	INITIAL YEARLY 18-KIP ESAL, MILLIONS	1.200
9.4	18-KIP ESAL GROWTH RATE, PERCENT	3.00
9.5	DIRECTIONAL DISTRIBUTION FACTOR, PERCENT	58.0
9.6	LANE DISTRIBUTION FACTOR, PERCENT	70.0

TIME CONSTRAINTS
****

10.1	ANALYSIS PERIOD, YEARS	20.0
10.2	MINIMUM TIME BETWEEN OVERLAYS, YEARS	5.0
10.3	MAXIMUM ALLOWABLE YEARS OF HEAVY MAINTENANCE AFTER LOSS OF STRUCTURAL LOAD-CARRYING CAPACITY	5.0

REMAINING LIFE VARIABLES
****

11.1 NO. OF ORIGINAL PAVEMENT REMAINING LIFE VALUES TO CONSIDER 4

11.2 MINIMUM EXISTING PAVEMENT REMAINING LIFE BELOW WHICH A BONDED PCC OVERLAY MAY NOT BE PLACED 1Ø.

11.3 VALUES OF ORIGINAL PAVEMENT REMAINING LIFE AT WHICH FIRST OVERLAY MAY BE PLACED

NO.	REMAINING LIFE (PERCENT)
1	3Ø.
2	2Ø.
3	1Ø.
4	Ø.

12.1 NO. OF FIRST OVERLAY REMAINING LIFE VALUES TO CONSIDER 5

12.2 VALUES OF FIRST OVERLAY REMAINING LIFE AT WHICH SECOND OVERLAY MAY BE PLACED

NO.	REMAINING LIFE (PERCENT)
1	8Ø.
2	6Ø.
3	4Ø.
4	2Ø.
5	Ø.

OVERLAY CHARACTERISTICS
****

```
13.0  TYPES OF FIRST OVERLAY TO CONSIDER
        .1  ACP             - YES
        .2  BONDED CRCP     -  NO
        .3  UNBONDED CRCP   - YES
        .4  BONDED JCP      -  NO
        .5  UNBONDED JCP    -  NO

14.0  TYPES OF SECOND OVERLAY TO CONSIDER
        .1  ACP   - YES
        .2  CRCP  - YES
        .3  JCP   -  NO

15.0  NO. OF DIFFERENT OVERLAY THICKNESS TO CONSIDER
        .1  ACP FIRST OVERLAY   -    3
        .2  ACP SECOND OVERLAY  -    4
        .3  PCC OVERLAY         -    5

16.0  ACP FIRST OVERLAY THICKNESSES, INCHES
        .1     4.0
        .2     5.0
        .3     6.0

17.0  ACP SECOND OVERLAY THICKNESSES, INCHES
        .1     3.0
        .2     4.0
        .3     5.0
        .4     6.0

18.0  PCC OVERLAY THICKNESSES, INCHES
        .1     6.0
        .2     6.5
        .3     7.0
        .4     7.5
        .5     8.0
```

19.1	ALLOWABLE TOTAL OVERLAY THICKNESS, INCHES	14.0
19.2	AVERAGE LEVEL-UP THICKNESS, INCHES	.5
19.3	BOND BREAKER THICKNESS, INCHES	1.0
20.1	ACP OVERLAY DESIGN STIFFNESS, PSI	300000.
20.2	POISSONS RATIO, ACP OVERLAY	.30
20.3	PCC OVERLAY DESIGN STIFFNESS, PSI	4500000.
20.4	POISSONS RATIO, PCC OVERLAY	.15
20.5	BOND BREAKER STIFFNESS, PSI	50000.
20.6	POISSONS RATIO, BOND BREAKER	.30
21.1	NO. OF OVERLAY FLEXURAL STRENGTHS TO CONSIDER	2
21.2	NO. WHICH IDENTIFIES WHICH FLEXURAL STRENGTH IN THE LIST TO USE FOR A BONDED PCC OVERLAY	1

22.0 PCC OVERLAY FLEXURAL STRENGTH(S), PSI

.1 600.

.2 650.

*** PAVEMENT STRESS FACTORS AFTER OVERLAY ***

	FIRST OVERLAY TYPE	SECOND OVERLAY TYPE	CRITICAL STRESS LOCATION	OVERLAY SHOULDER TYPE	CRIT./INTER. STRESS FACTOR
23.1	ACP	(NONE)	EX PAVT	ACP	1.40
24.1	ACP	ACP	EX PAVT	ACP	1.40
25.1	ACP	CRCP	EX PAVT	ACP	1.25
25.2	ACP	CRCP	EX PAVT	CRCP	1.05
26.1	ACP	CRCP	CRCP O/L	ACP	1.25
26.2	ACP	CRCP	CRCP O/L	CRCP	1.05
27.1	ACP	JCP	EX PAVT	ACP	0.00
27.2	ACP	JCP	EX PAVT	JCP	0.00
28.1	ACP	JCP	JCP O/L	ACP	0.00
28.2	ACP	JCP	JCP O/L	JCP	0.00
29.1	BOND CRC	(NONE)	EX PAVT	ACP	0.00
29.2	BOND CRC	(NONE)	EX PAVT	CRCP	0.00
30.1	BOND CRC	ACP	EX PAVT	ACP	0.00
30.2	BOND CRC	ACP	EX PAVT	CRCP	0.00
31.1	BOND JCP	(NONE)	EX PAVT	ACP	0.00
31.2	BOND JCP	(NONE)	EX PAVT	JCP	0.00
32.1	BOND JCP	ACP	EX PAVT	ACP	0.00
32.2	BOND JCP	ACP	EX PAVT	JCP	0.00
33.1	UNBD CRC	(NONE)	EX PAVT	ACP	1.25
33.2	UNBD CRC	(NONE)	EX PAVT	CRCP	1.05
34.1	UNBD CRC	(NONE)	CRCP O/L	ACP	1.25
34.2	UNBD CRC	(NONE)	CRCP O/L	CRCP	1.05
35.1	UNBD CRC	ACP	EX PAVT	ACP	1.25
35.2	UNBD CRC	ACP	EX PAVT	CRCP	1.05
36.1	UNBD CRC	ACP	CRCP O/L	ACP	1.25
36.2	UNBD CRC	ACP	CRCP O/L	CRCP	1.05
37.1	UNBD JCP	(NONE)	EX PAVT	ACP	0.00
37.2	UNBD JCP	(NONE)	EX PAVT	JCP	0.00
38.1	UNBD JCP	(NONE)	JCP O/L	ACP	0.00
38.2	UNBD JCP	(NONE)	JCP O/L	JCP	0.00
39.1	UNBD JCP	ACP	EX PAVT	ACP	0.00
39.2	UNBD JCP	ACP	EX PAVT	JCP	0.00
40.1	UNBD JCP	ACP	JCP O/L	ACP	0.00
40.2	UNBD JCP	ACP	JCP O/L	JCP	0.00

NOTE - STRATEGIES WITH A ZERO VALUE FOR THE CRITICAL TO INTERIOR STRESS FACTOR WILL NOT BE CONSIDERED.

41.1 1 - LAYER PACKAGE USED TO PREDICT RESPONSE.

OVERLAY CONSTRUCTION COST VARIABLES
****

42.0 SITE ESTABLISHMENT COST, DOL

.1	ACP EQUIPMENT	10000.
.2	CRCP EQUIPMENT	20000.
.3	JCP EQUIPMENT	20000.
.4	ACP AND CRCP EQUIPMENT	25000.
.5	ACP AND JCP EQUIPMENT	25000.

43.0 PAVEMENT SURFACE PREPARATION COSTS, DOL/SY

.1	EXISTING PAVEMENT	.20
.2	ACP OVERLAY	.20
.3	CRCP OVERLAY	.20
.4	JCP OVERLAY	.20

44.1	FIXED COST OF ACP OVERLAY CONSTRUCTION, DOL/SY	2.00
44.2	VARIABLE COST OF ACP OVERLAY CONSTR., DOL/SY/IN	1.00
44.3	FIXED COST OF FLEXIBLE SHOULDER CONSTR., DOL/SY	4.00
44.4	VARIABLE COST OF FLEX. SHOULDER CONSTR., DOL/SY/IN	.50
44.5	COST OF BOND BREAKER CONSTRUCTION, DOL/SY	2.00

45.0 CRCP FIXED COST FOR EACH FLEXURAL STRENGTH

	FLEXURAL STRENGTH (PSI)	FIXED COST (DOL/SY)
.1	600.	4.00
.2	650.	4.00

46.0 CRCP VARIABLE COST FOR EACH FLEXURAL STRENGTH

	FLEXURAL STRENGTH (PSI)	VARIABLE COST (DOL/SY/IN)
.1	600.	1.20
.2	650.	1.30

8

47.0 JCP FIXED COST FOR EACH FLEXURAL STRENGTH

	FLEXURAL STRENGTH (PSI)	FIXED COST (DOL/SY)
.1	600.	0.00
.2	650.	0.00

48.0 JCP VARIABLE COST FOR EACH FLEXURAL STRENGTH

	FLEXURAL STRENGTH (PSI)	VARIABLE COST (DOL/SY/IN)
.1	600.	0.00
.2	650.	0.00

49.1	TOTAL STEEL PERCENTAGE REQUIRED IN CRCP OVERLAYS	.60
49.2	TOTAL STEEL PERCENTAGE REQUIRED IN JCP OVERLAYS	0.00
49.3	COST OF STEEL REINFORCEMENT, DOL/LB	.50

TRAFFIC DELAY COST VARIABLES
****

50.1	LOCATION OF PROJECT (1=RURAL,2=URBAN)	2
50.2	MODEL NO. FOR HANDLING TRAFFIC	5
50.3	NO. OF OPEN LANES, OVERLAY DIRECTION	2
50.4	NO. OF OPEN LANES, NON-OVERLAY DIRECTION	4
51.1	MILITARY TIME OVERLAY CONSTRUCTION BEGINS	900.
51.2	MILITARY TIME OVERLAY CONSTRUCTION ENDS	1600.
51.3	HOURS PER DAY OVERLAY CONSTRUCTION OCCURS	6.0
51.4	NO. OF DAYS CONCRETE IS ALLOWED TO CURE	14.
51.5	DETOUR DISTANCE TO USE IN MODEL 5, MILES	2.5
52.1	AVERAGE APPROACH SPEED, MPH	55.
52.2	AVERAGE SPEED, OVERLAY DIRECTION, MPH	40.
52.3	AVERAGE SPEED, NON-OVERLAY DIRECTION, MPH	55.
53.1	DISTANCE TRAFFIC IS SLOWED, OVERLAY DIRECTION, MILES	3.0
53.2	DISTANCE TRAFFIC IS SLOWED, NON-OVERLAY DIR., MILES	0.0
53.3	PERCENT OF VEHICLES STOPPED, OVERLAY DIRECTION	10.0
53.4	PERCENT OF VEHICLES STOPPED, NON-OVERLAY DIRECTION	0.0
53.5	AVERAGE VEHICLE DELAY, OVERLAY DIRECTION, HRS	.00200
53.6	AVERAGE VEHICLE DELAY, NON-OVERLAY DIRECTION, HRS	0.00000
54.1	ACP PRODUCTION RATE, CY/HR	42.
54.2	CRCP PRODUCTION RATE, CY/HR	60.
54.3	JCP PRODUCTION RATE, CY/HR	0.
54.4	BOND BREAKER PRODUCTION RATE, CY/HR	40.

DISTRESS/MAINTENANCE COST VARIABLES
****

55.1 DISTRESS REPAIR COST, CRCP OVERLAY, DOL 2000.00
55.2 INITIAL CRCP OVERLAY DISTRESS RATE, NO./MI/YR 1.0
55.3 SECONDARY CRCP OVERLAY DISTRESS RATE, NO./MI/YR 2.0
55.4 CRCP OVERLAY DISTRESS RATE FOR EACH YEAR AFTER LOSS OF PAVEMENT LOAD-CARRYING CAPACITY

YEAR AFTER FAILURE	DISTRESS RATE (NO./MILE)
1	3.0
2	5.0
3	8.0
4	16.0
5	40.0

56.1 DISTRESS REPAIR COST, JCP OVERLAY, DOL 0.00
56.2 INITIAL JCP OVERLAY DISTRESS RATE, NO./MI/YR 0.0
56.3 SECONDARY JCP OVERLAY DISTRESS RATE, NO./MI/YR 0.0
56.4 JCP OVERLAY DISTRESS RATE FOR EACH YEAR AFTER LOSS OF PAVEMENT LOAD CARRYING CAPACITY

YEAR AFTER FAILURE	DISTRESS RATE (NO./MILE)
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0

57.1 DISTRESS REPAIR COST, ACP OVERLAY ON CRCP, DOL 500.00
57.2 INITIAL ACP/CRCP DISTRESS RATE, NO./MI/YR 1.0
57.3 SECONDARY ACP/CRCP DISTRESS RATE, NO./MI/YR 2.0
57.4 ACP/CRCP DISTRESS RATE FOR EACH YEAR AFTER LOSS OF PAVEMENT LOAD-CARRYING CAPACITY

YEAR AFTER FAILURE	DISTRESS RATE (NO./MILE)
1	3.0
2	5.0
3	8.0
4	16.0
5	40.0

58.1 DISTRESS REPAIR COST, ACP OVERLAY ON JCP, DOL 100.00
58.2 INITIAL ACP/JCP DISTRESS RATE, NO./MI/YR 5.0
58.3 SECONDARY ACP/JCP DISTRESS RATE, NO./MI/YR 10.0
58.4 ACP/JCP DISTRESS RATE FOR EACH YEAR AFTER LOSS OF PAVEMENT LOAD CARRYING CAPACITY

YEAR AFTER FAILURE	DISTRESS RATE (NO./MILE)
1	20.0
2	40.0
3	80.0
4	160.0
5	400.0

COST RETURNS
****

59.1 SALVAGE VALUE, PERCENT OF OVERLAY CONSTRUCTION COST 10.0
59.2 VALUE OF EACH YEAR OF EXTENDED LIFE, DOL/SY/YR .25

COMBINED INTEREST AND INFLATION RATE
****

60.1 INTEREST RATE MINUS INFLATION RATE, PERCENT 5.0

APPENDIX G

RPRDS-1 EXAMPLE PROBLEM-OUTPUT

APPENDIX G. RPRDS-1 EXAMPLE PROBLEM-OUTPUT

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R P R D S   O U T P U T
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THE FOLLOWING IS A LIST OF THE COMPONENTS WHICH MAKE UP A FEASIBLE OVERLAY
DESIGN STRATEGY.  THE COLUMN NUMBERS REFER TO THE COLUMN HEADINGS ON THE
LIST OF FEASIBLE STRATEGIES WHICH BEGIN ON THE NEXT PAGE.  THE DESCRIPTIONS
IN THESE HEADINGS ALSO CORRESPOND TO THOSE IN THE LIST OF OPTIMAL STRATEGIES
WHICH SUCCEED THE LIST OF FEASIBLE STRATEGIES.

 COL      COMPONENT OF STRATEGY
 NO.
 --- -----------------------------------------------------------------------------------------------------------------

  0. STRATEGY NO.
  1. EXISTING PAVEMENT REMAINING LIFE AT TIME OF FIRST OVERLAY PLACEMENT (PERCENT)
  2. APPROXIMATE YEAR OF FIRST OVERLAY PLACEMENT
  3. TOTAL 18-KIP ESAL FATIGUE CYCLES BETWEEN YEAR ZERO AND YEAR OF FIRST OVERLAY PLACEMENT, MILLIONS
  4. PRESENT VALUE OF EXISTING PAVEMENT MAINTENANCE COST (DOL/SQ YD)
  5. FIRST OVERLAY TYPE
        1 = ASPHALTIC CONCRETE
        2 = BONDED CRCP
        3 = UNBONDED CRCP
        4 = BONDED JCP
        5 = UNBONDED JCP
     NOTE - A * AFTER NUMBER INDICATES PCC SHOULDER REQUIRED
  7. THICKNESS OF FIRST OVERLAY (INCHES)
  8. FLEXURAL STRENGTH OF FIRST OVERLAY (PSI)
  9. APPROXIMATE YEAR OF LOSS OF PAVEMENT LOAD-CARRYING CAPACITY AFTER FIRST OVERLAY
 10. TOTAL 18-KIP ESAL FATIGUE CYCLES BETWEEN YEAR ZERO AND YEAR OF FIRST OVERLAY FAILURE
 11. PRESENT VALUE OF COST OF FIRST OVERLAY CONSTRUCTION (DOL/SQ YD)
 12. PRESENT VALUE OF TRAFFIC DELAY COSTS DURING FIRST OVERLAY CONSTRUCTION (DOL/SQ YD)
 13. PRESENT VALUE OF FIRST OVERLAY MAINTENANCE COST (DOL/SQ YD)
 14. REMAINING LIFE OF FIRST OVERLAY AT TIME OF SECOND OVERLAY PLACEMENT (PERCENT)
 15. APPROXIMATE YEAR OF SECOND OVERLAY PLACEMENT
 16. TOTAL 18-KIP ESAL FATIGUE CYCLES BETWEEN YEAR ZERO AND YEAR OF SECOND OVERLAY PLACEMENT, MILLIONS
 17. SECOND OVERLAY TYPE
        1 = ASPHALTIC CONCRETE
        2 = CRCP
        3 = JCP
     NOTE - A * AFTER NUMBER INDICATES PCC SHOULDER REQUIRED
 19. THICKNESS OF SECOND OVERLAY (INCHES)
 20. FLEXURAL STRENGTH OF SECOND OVERLAY (PSI)
 21. APPROXIMATE YEAR OF LOSS OF PAVEMENT LOAD-CARRYING CAPACITY AFTER SECOND OVERLAY
 22. TOTAL 18-KIP ESAL FATIGUE CYCLES BETWEEN YEAR ZERO AND YEAR OF SECOND OVERLAY FAILURE
 23. PRESENT VALUE OF COST OF SECOND OVERLAY CONSTRUCTION (DOL/SQ YD)
 24. PRESENT VALUE OF TRAFFIC DELAY COSTS DURING SECOND OVERLAY CONSTRUCTION (DOL/SQ YD)
 25. PRESENT VALUE OF SECOND OVERLAY MAINTENANCE COST (DOL/SQ YD)
 26. PRESENT VALUE OF THE EXTENDED LIFE (DOL/SQ YD)
 27. SALVAGE VALUE OF OVERLAY LAYERS (DOL/SQ YD)
 28. TOTAL NET PRESENT VALUE OF STRATEGY (DOL/SQ YD)
```

0	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	19	20	21	22	23	24	25	26	27	28
1	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.22	.13	60	6.2	3.4	1	6.0	0	18	11.3	6.47	.27	.32	0.00	.56	14.37
2	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.22	.13	60	6.2	3.4	2	6.0	600	27	19.2	8.91	.57	.43	.61	.47	16.70
3	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.13	60	6.2	3.4	2	6.0	650	31	22.9	9.36	.58	.33	.84	.40	16.99
4	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.13	60	6.2	3.4	2*	6.0	600	39	31.0	9.06	.58	.26	1.17	.27	16.41
5	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.13	60	6.2	3.4	2*	6.0	650	45	37.5	9.54	.58	.22	1.33	.21	16.75
6	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.13	40	6.8	3.7	2	6.0	600	24	16.5	8.64	.57	.46	.33	.55	16.73
7	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.13	40	6.8	3.7	2	6.0	650	28	20.2	9.08	.57	.36	.67	.46	16.82
8	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.13	40	6.8	3.7	2*	6.0	600	34	26.0	8.78	.57	.29	.98	.34	16.27
9	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.13	40	6.8	3.7	2*	6.0	650	40	32.5	9.25	.57	.22	1.21	.26	16.52
10	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.18	20	6.9	3.8	2	6.0	600	24	16.5	8.62	.57	.46	.33	.55	16.76
11	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.18	20	6.9	3.8	2	6.0	650	28	20.2	9.05	.57	.36	.67	.46	16.85
12	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.18	20	6.9	3.8	2*	6.0	600	34	26.0	8.76	.57	.29	.98	.34	16.30
13	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.18	20	6.9	3.8	2*	6.0	650	40	32.5	9.23	.57	.22	1.21	.26	16.55
14	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.18	0	6.9	3.8	2	6.0	600	24	16.5	8.60	.57	.45	.41	.54	16.67
15	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.18	0	6.9	3.8	2	6.0	650	28	20.2	9.04	.57	.36	.67	.46	16.83
16	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.18	0	6.9	3.8	2*	6.0	600	34	26.0	8.74	.57	.26	.98	.34	16.26
17	30	0.0	0.0	.71	1	4.0	0	6.9	3.8	6.82	.29	.18	0	6.9	3.8	2*	6.0	650	40	32.5	9.21	.57	.22	1.21	.26	16.53
18	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	60	7.1	3.9	1	5.0	0	18	12.0	5.50	.29	.20	0.00	.56	14.45
19	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	60	7.1	3.9	1	6.0	0	27	18.7	6.18	.35	.10	.55	.42	14.69
20	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	60	7.1	3.9	2	6.0	600	28	20.1	8.52	.56	.36	.67	.47	17.32
21	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	60	7.1	3.9	2	6.0	650	32	23.9	8.95	.56	.29	.89	.40	17.54
22	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	60	7.1	3.9	2*	6.0	600	40	32.3	8.66	.56	.22	1.21	.26	16.99
23	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	60	7.1	3.9	2*	6.0	650	46	38.8	9.12	.56	.18	1.38	.21	17.30
24	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	40	7.9	4.4	1	5.0	0	15	9.6	5.29	.29	1.07	0.00	.56	15.12
25	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	40	7.9	4.4	1	6.0	0	22	14.5	5.95	.34	.11	.18	.54	14.72
26	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	40	7.9	4.4	2	6.0	600	25	17.2	8.20	.55	.41	.41	.55	17.23
27	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	40	7.9	4.4	2	6.0	650	29	21.0	8.61	.55	.29	.73	.46	17.29
28	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	40	7.9	4.4	2*	6.0	600	35	26.8	8.34	.55	.25	1.02	.34	16.80
29	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	40	7.9	4.4	2*	6.0	650	41	33.4	8.78	.55	.18	1.24	.26	17.04
30	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	20	8.0	4.4	1	6.0	0	16	9.9	5.92	.34	1.07	0.00	.68	15.76
31	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	20	8.0	4.4	2	6.0	600	25	17.3	8.16	.55	.41	.41	.55	17.19
32	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	20	8.0	4.4	2	6.0	650	29	21.0	8.57	.55	.29	.73	.46	17.25
33	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	20	8.0	4.4	2*	6.0	600	35	26.9	8.29	.55	.22	1.02	.34	16.73
34	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	20	8.0	4.4	2*	6.0	650	41	33.4	8.73	.55	.18	1.24	.26	16.99
35	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	0	8.1	4.5	2	6.0	600	25	17.3	8.12	.55	.36	.41	.55	17.09
36	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	0	8.1	4.5	2	6.0	650	29	21.1	8.53	.55	.29	.73	.46	17.20
37	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	0	8.1	4.5	2*	6.0	600	35	26.9	8.25	.55	.22	1.02	.34	16.69
38	30	0.0	0.0	.71	1	5.0	0	8.1	4.5	7.79	.36	.16	0	8.1	4.5	2*	6.0	650	41	33.5	8.69	.55	.18	1.24	.26	16.95
39	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.14	60	8.2	4.6	1	3.0	0	15	9.1	3.91	.17	1.08	0.00	.53	14.68
40	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.14	60	8.2	4.6	1	4.0	0	20	12.9	4.56	.23	.12	0.00	.56	14.39
41	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.14	60	8.2	4.6	2	6.0	600	29	21.3	8.07	.54	.26	.73	.47	17.73
42	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.14	60	8.2	4.6	2	6.0	650	33	25.0	8.48	.54	.25	.93	.40	17.99
43	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.14	60	8.2	4.6	2*	6.0	600	42	33.7	8.21	.54	.18	1.24	.26	17.47
44	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.14	60	8.2	4.6	2*	6.0	650	47	40.3	8.64	.54	.15	1.40	.20	17.77
45	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.16	40	9.2	5.2	1	4.0	0	17	10.6	4.35	.22	.49	0.00	.56	14.56
46	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.16	40	9.2	5.2	1	5.0	0	23	15.4	4.97	.27	.09	.26	.51	14.63
47	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.16	40	9.2	5.2	2	6.0	600	26	18.2	7.70	.53	.29	.48	.55	17.55
48	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.16	40	9.2	5.2	2	6.0	650	30	22.0	8.09	.53	.25	.78	.46	17.68
49	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.16	40	9.2	5.2	2*	6.0	600	36	27.9	7.82	.53	.18	1.06	.34	17.20
50	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.16	40	9.2	5.2	2*	6.0	650	42	34.5	8.24	.53	.15	1.27	.26	17.45
51	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	20	9.4	5.3	1	5.0	0	17	10.6	4.91	.27	.49	0.00	.60	15.18
52	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	20	9.4	5.3	1	6.0	0	22	15.2	5.52	.33	.09	.26	.55	15.25
53	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	20	9.4	5.3	2	6.0	600	26	18.3	7.61	.52	.28	.55	.54	17.44
54	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	20	9.4	5.3	2	6.0	650	30	22.1	8.00	.52	.22	.78	.46	17.61
55	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	20	9.4	5.3	2*	6.0	600	36	28.1	7.74	.52	.18	1.06	.34	17.15
56	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	20	9.4	5.3	2*	6.0	650	42	34.7	8.15	.52	.15	1.27	.26	17.40
57	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	0	9.7	5.5	2	6.0	600	26	18.5	7.52	.52	.28	.55	.54	17.34

58	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	0	9.7	5.5	2	6.0	650	30	22.3	7.90	.52	.22	.78	.45	17.51
59	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	0	9.7	5.5	2*	6.0	600	36	28.2	7.65	.52	.18	1.06	.33	17.06
60	30	0.0	0.0	.71	1	6.0	0	9.7	5.5	8.76	.43	.20	0	9.7	5.5	2*	6.0	650	43	34.8	8.05	.52	.15	1.27	.26	17.30
61	30	0.0	0.0	.71	3	6.0	600	25.3	17.2	13.38	.77	.78												.41	.48	14.76
62	30	0.0	0.0	.71	3	6.0	650	29.2	20.7	13.95	.77	.67												.67	.51	14.93
63	30	0.0	0.0	.71	3*	6.0	600	38.6	30.0	13.73	.77	.48												1.14	.50	14.06
64	30	0.0	0.0	.71	3*	6.0	650	44.2	36.1	14.33	.77	.43												1.30	.52	14.43
65	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	60	6.4	3.4	1	6.0	0	17	11.0	6.42	.36	.32	0.00	.56	14.47
66	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	60	6.4	3.4	2	6.0	600	24	16.2	8.85	.58	.47	.33	.56	16.93
67	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	60	6.4	3.4	2	6.0	650	28	19.9	9.30	.58	.37	.61	.47	17.09
68	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	60	6.4	3.4	2*	6.0	600	34	25.7	8.99	.58	.30	.93	.34	16.52
69	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	60	6.4	3.4	2*	6.0	650	40	32.2	9.47	.58	.25	1.21	.26	16.76
70	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	40	6.4	3.5	2	6.0	600	24	16.2	8.83	.58	.47	.33	.55	16.91
71	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	40	6.4	3.5	2	6.0	650	28	19.9	9.28	.58	.37	.61	.47	17.08
72	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	40	6.4	3.5	2*	6.0	600	34	25.7	8.98	.58	.29	.93	.34	16.51
73	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.10	40	6.4	3.5	2*	6.0	650	40	32.2	9.45	.58	.25	1.21	.26	16.74
74	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.15	20	6.4	3.5	2	6.0	600	24	16.2	8.81	.58	.46	.33	.55	16.95
75	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.15	20	6.4	3.5	2	6.0	650	28	19.9	9.26	.58	.37	.61	.47	17.11
76	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.15	20	6.4	3.5	2*	6.0	600	34	25.7	8.96	.58	.29	.93	.34	16.54
77	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.15	20	6.4	3.5	2*	6.0	650	40	32.2	9.43	.58	.25	1.21	.26	16.77
78	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.15	0	6.5	3.5	2	6.0	600	24	16.3	8.79	.57	.46	.33	.55	16.92
79	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.15	0	6.5	3.5	2	6.0	650	28	20.0	9.24	.57	.37	.61	.47	17.08
80	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.15	0	6.5	3.5	2*	6.0	600	34	25.8	8.94	.57	.29	.98	.34	16.47
81	20	.8	.4	.98	1	4.0	0	6.5	3.5	6.56	.28	.15	0	6.5	3.5	2*	6.0	650	40	32.3	9.41	.57	.25	1.21	.26	16.75
82	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	60	7.2	4.0	1	5.0	0	18	11.7	5.48	.29	.30	0.00	.56	14.49
83	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	60	7.2	4.0	1	6.0	0	27	18.7	6.16	.35	.10	.55	.42	14.62
84	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	60	7.2	4.0	2	6.0	600	24	16.8	8.48	.56	.40	.41	.57	17.45
85	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	60	7.2	4.0	2	6.0	650	29	20.5	8.91	.56	.30	.67	.47	17.62
86	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	60	7.2	4.0	2*	6.0	600	35	26.4	8.63	.56	.26	.98	.35	17.10
87	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	60	7.2	4.0	2*	6.0	650	41	32.9	9.08	.56	.22	1.21	.26	17.37
88	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	40	7.3	4.0	1	5.0	0	15	9.3	5.45	.29	1.11	0.00	.56	15.27
89	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	40	7.3	4.0	1	6.0	0	21	14.1	6.13	.35	.13	.18	.55	14.86
90	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	40	7.3	4.0	2	6.0	600	24	16.9	8.44	.56	.39	.41	.56	17.41
91	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	40	7.3	4.0	2	6.0	650	29	20.6	8.87	.56	.30	.67	.47	17.57
92	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	40	7.3	4.0	2*	6.0	600	35	26.5	8.58	.56	.26	.98	.35	17.06
93	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	40	7.3	4.0	2*	6.0	650	41	33.0	9.04	.56	.22	1.21	.26	17.33
94	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	20	7.4	4.1	1	6.0	0	15	9.5	6.10	.35	1.07	0.00	.60	15.90
95	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	20	7.4	4.1	2	6.0	600	24	16.9	8.40	.56	.39	.41	.56	17.37
96	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	20	7.4	4.1	2	6.0	650	29	20.7	8.83	.56	.30	.67	.47	17.53
97	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	20	7.4	4.1	2*	6.0	600	35	26.5	8.54	.56	.26	.98	.34	17.02
98	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	20	7.4	4.1	2*	6.0	650	41	33.1	8.99	.56	.22	1.21	.26	17.28
99	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	0	7.5	4.1	2	6.0	600	25	17.0	8.36	.56	.39	.41	.56	17.33
100	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	0	7.5	4.1	2	6.0	650	29	20.7	8.78	.56	.30	.67	.47	17.48
101	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	0	7.5	4.1	2*	6.0	600	35	26.6	8.50	.56	.25	.98	.34	16.97
102	20	.8	.4	.98	1	5.0	0	7.5	4.1	7.50	.35	.15	0	7.5	4.1	2*	6.0	650	41	33.1	8.95	.56	.21	1.24	.26	17.20
103	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	60	8.2	4.6	1	4.0	0	19	12.6	4.56	.23	.14	0.00	.56	14.34
104	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	60	8.2	4.6	1	5.0	0	28	19.8	5.21	.28	.07	.61	.40	14.53
105	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	60	8.2	4.6	2	6.0	600	25	17.6	8.08	.54	.33	.48	.57	17.87
106	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	60	8.2	4.6	2	6.0	650	29	21.4	8.49	.54	.26	.73	.48	18.06
107	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	60	8.2	4.6	2*	6.0	600	36	27.3	8.21	.54	.22	1.02	.35	17.58
108	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	60	8.2	4.6	2*	6.0	650	42	33.9	8.65	.54	.18	1.24	.27	17.84
109	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	40	8.5	4.7	1	4.0	0	16	10.1	4.51	.22	1.04	0.00	.56	15.19
110	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	40	8.5	4.7	1	5.0	0	22	15.0	5.15	.28	.11	.26	.53	14.73
111	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	40	8.5	4.7	2	6.0	600	25	17.7	7.98	.54	.35	.48	.56	17.80
112	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	40	8.5	4.7	2	6.0	650	30	21.5	8.38	.54	.26	.73	.47	17.95
113	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	40	8.5	4.7	2*	6.0	600	36	27.4	8.11	.54	.22	1.02	.35	17.47
114	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	40	8.5	4.7	2*	6.0	650	42	34.1	8.54	.54	.18	1.24	.26	17.73
115	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	20	8.7	4.9	1	5.0	0	16	10.1	5.09	.28	1.03	0.00	.60	15.78
116	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	20	8.7	4.9	1	6.0	0	22	14.7	5.72	.33	.11	.18	.57	15.40
117	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	20	8.7	4.9	2	6.0	600	26	17.9	7.89	.54	.35	.48	.56	17.70
118	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	20	8.7	4.9	2	6.0	650	30	21.7	8.28	.54	.26	.73	.47	17.85
119	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	20	8.7	4.9	2*	6.0	600	36	27.6	8.02	.54	.22	1.02	.34	17.37

120	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.13	20	8.7	4.9	2*	6.0	650	42	34.2	8.44	.54	.18	1.27	.26	17.59
121	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.18	0	9.0	5.0	2	6.0	600	26	18.0	7.79	.53	.34	.48	.55	17.65
122	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.18	0	9.0	5.0	2	6.0	650	30	21.8	8.18	.53	.25	.73	.47	17.79
123	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.18	0	9.0	5.0	2*	6.0	600	36	27.7	7.92	.53	.21	1.02	.34	17.32
124	20	.8	.4	.98	1	6.0	0	9.0	5.0	8.43	.43	.18	0	9.0	5.0	2*	6.0	650	42	34.4	8.34	.53	.15	1.27	.26	17.51
125	20	.8	.4	.98	3	6.0	600	25.2	17.1	12.88	.76	.74												.41	.48	14.47
126	20	.8	.4	.98	3	6.0	650	26.7	18.4	13.43	.76	.69												.55	.51	14.81
127	20	.8	.4	.98	3*	6.0	600	38.2	29.5	13.22	.76	.47												1.10	.50	13.83
128	20	.8	.4	.98	3*	6.0	650	40.4	31.9	13.80	.76	.43												1.17	.52	14.28
129	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	60	6.6	3.6	1	5.0	0	18	11.3	5.64	.30	.31	0.00	.56	14.62
130	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	60	6.6	3.6	1	6.0	0	26	18.3	6.35	.36	.09	.55	.43	14.75
131	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	60	6.6	3.6	2	6.0	600	24	16.4	8.74	.57	.46	.33	.58	17.80
132	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	60	6.6	3.6	2	6.0	650	28	20.2	9.18	.57	.36	.67	.48	17.90
133	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	60	6.6	3.6	2*	6.0	600	34	26.0	8.89	.57	.29	.98	.35	17.35
134	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	60	6.6	3.6	2*	6.0	650	41	32.6	9.36	.57	.25	1.21	.27	17.64
135	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	40	6.7	3.6	1	6.0	0	21	13.7	6.31	.36	.13	.09	.57	15.08
136	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	40	6.7	3.6	2	6.0	600	24	16.5	8.70	.57	.46	.33	.57	17.75
137	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	40	6.7	3.6	2	6.0	650	28	20.2	9.14	.57	.36	.67	.48	17.85
138	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	40	6.7	3.6	2*	6.0	600	34	26.1	8.84	.57	.29	.98	.35	17.31
139	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	40	6.7	3.6	2*	6.0	650	41	32.6	9.31	.57	.22	1.21	.27	17.56
140	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	20	6.8	3.7	1	6.0	0	15	9.1	6.28	.35	1.10	0.00	.60	16.07
141	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	20	6.8	3.7	2	6.0	600	24	16.6	8.65	.57	.46	.41	.57	17.63
142	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	20	6.8	3.7	2	6.0	650	28	20.3	9.09	.57	.36	.67	.48	17.80
143	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	20	6.8	3.7	2*	6.0	600	34	26.2	8.80	.57	.29	.98	.35	17.26
144	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	20	6.8	3.7	2*	6.0	650	41	32.7	9.26	.57	.22	1.21	.27	17.51
145	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	0	6.9	3.8	2	6.0	600	24	16.6	8.61	.57	.45	.41	.57	17.59
146	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	0	6.9	3.8	2	6.0	650	28	20.4	9.05	.57	.36	.67	.48	17.76
147	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	0	6.9	3.8	2*	6.0	600	34	26.2	8.75	.57	.26	.98	.35	17.19
148	10	1.5	.8	1.24	1	5.0	0	6.9	3.8	7.23	.35	.12	0	6.9	3.8	2*	6.0	650	41	32.8	9.22	.57	.22	1.21	.27	17.46
149	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	60	7.5	4.1	1	4.0	0	19	12.1	4.73	.23	.20	0.00	.56	14.53
150	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	60	7.5	4.1	1	5.0	0	27	19.3	5.41	.29	.08	.61	.41	14.68
151	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	60	7.5	4.1	2	6.0	600	25	17.1	8.38	.56	.39	.41	.58	18.26
152	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	60	7.5	4.1	2	6.0	650	29	20.9	8.80	.56	.30	.67	.49	18.42
153	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	60	7.5	4.1	2*	6.0	600	35	26.8	8.52	.56	.25	1.02	.36	17.88
154	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	60	7.5	4.1	2*	6.0	650	41	33.5	8.97	.56	.21	1.24	.27	18.15
155	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	40	7.7	4.3	1	4.0	0	15	9.6	4.68	.23	1.08	0.00	.56	15.35
156	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	40	7.7	4.3	1	5.0	0	22	14.5	5.34	.29	.12	.18	.54	14.95
157	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	40	7.7	4.3	2	6.0	600	25	17.3	8.28	.55	.39	.41	.58	18.15
158	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	40	7.7	4.3	2	6.0	650	29	21.1	8.69	.55	.29	.73	.48	18.25
159	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	40	7.7	4.3	2*	6.0	600	35	27.0	8.41	.55	.25	1.02	.35	17.77
160	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	40	7.7	4.3	2*	6.0	650	41	33.6	8.86	.55	.19	1.24	.27	18.01
161	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	20	8.0	4.4	1	5.0	0	15	9.7	5.28	.28	1.07	0.00	.60	15.96
162	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	20	8.0	4.4	1	6.0	0	21	14.3	5.94	.34	.11	.18	.58	15.56
163	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	20	8.0	4.4	2	6.0	600	25	17.4	8.18	.55	.38	.48	.57	17.98
164	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	20	8.0	4.4	2	6.0	650	29	21.2	8.59	.55	.29	.73	.48	18.15
165	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	20	8.0	4.4	2*	6.0	600	35	27.1	8.31	.55	.22	1.02	.35	17.63
166	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	20	8.0	4.4	2*	6.0	650	42	33.8	8.75	.55	.18	1.24	.27	17.90
167	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	0	8.2	4.6	2	6.0	600	25	17.6	8.08	.54	.33	.48	.57	17.82
168	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	0	8.2	4.6	2	6.0	650	29	21.4	8.49	.54	.26	.73	.48	18.01
169	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	0	8.2	4.6	2*	6.0	600	36	27.3	8.21	.54	.22	1.02	.35	17.53
170	10	1.5	.8	1.24	1	6.0	0	8.2	4.6	8.13	.42	.14	0	8.2	4.6	2*	6.0	650	42	33.9	8.65	.54	.18	1.24	.27	17.79
171	10	1.5	.8	1.24	3	6.0	600	22.5	14.8	12.42	.74	.77												.18	.48	14.50
172	10	1.5	.8	1.24	3	6.0	650	24.1	16.1	12.94	.74	.72												.33	.51	14.80
173	10	1.5	.8	1.24	3*	6.0	600	34.0	25.3	12.74	.74	.47												.93	.50	13.76
174	10	1.5	.8	1.24	3*	6.0	650	36.3	27.6	13.30	.74	.46												1.02	.52	14.20
175	0	2.3	1.2	1.24	1	6.0	0	7.5	4.1	7.83	.41	.12	0	7.5	4.1	2	6.0	600	25	17.1	8.38	.56	.39	.41	.58	17.94
176	0	2.3	1.2	1.24	1	6.0	0	7.5	4.1	7.83	.41	.12	0	7.5	4.1	2	6.0	650	29	20.9	8.81	.56	.30	.67	.49	18.10
177	0	2.3	1.2	1.24	1	6.0	0	7.5	4.1	7.83	.41	.12	0	7.5	4.1	2*	6.0	600	35	26.8	8.52	.56	.25	1.02	.36	17.55
178	0	2.3	1.2	1.24	1	6.0	0	7.5	4.1	7.83	.41	.12	0	7.5	4.1	2*	6.0	650	41	33.5	8.97	.56	.21	1.24	.27	17.83
179	0	2.3	1.2	1.24	3	6.0	600	19.6	12.5	11.97	.72	.87												0.00	.48	14.32
180	0	2.3	1.2	1.24	3	6.5	600	22.7	15.0	12.49	.76	.75												.26	.51	14.47
181	0	2.3	1.2	1.24	3	6.0	650	21.3	13.9	12.47	.72	.79												.09	.51	14.63
182	0	2.3	1.2	1.24	3*	6.0	600	29.6	21.4	12.28	.72	.54												.73	.50	13.56
183	0	2.3	1.2	1.24	3*	6.0	650	32.0	23.3	12.82	.72	.50												.84	.52	13.92

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UNIVERSITY OF TEXAS AT AUSTIN

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OPTIMAL STRATEGY NO. 1

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	0.
2.	YEAR OF 1ST OVERLAY PLACEMENT	2.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	1.17
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	1.24
5.	1ST OVERLAY TYPE	UNB CRCP
6.	TYPE OF SHOULDER	PCC
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	600.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	29.6
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	21.03
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	12.28
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.72
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.54
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	---
15.	YEAR OF 2ND OVERLAY PLACEMENT	---
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	---
17.	2ND OVERLAY TYPE	---
18.	TYPE OF SHOULDER	---
19.	2ND OVERLAY THICKNESS, INCHES	---
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	---
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	---
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	---
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	---
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	---
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	---
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	.73
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.50
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	13.56

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OPTIMAL STRATEGY NO. 2

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	10.
2.	YEAR OF 1ST OVERLAY PLACEMENT	2.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	.78
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	1.24
5.	1ST OVERLAY TYPE	UNB CRCP
6.	TYPE OF SHOULDER	PCC
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	600.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	34.0
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	25.29
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	12.74
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.74
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.47
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	---
15.	YEAR OF 2ND OVERLAY PLACEMENT	---
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	---
17.	2ND OVERLAY TYPE	---
18.	TYPE OF SHOULDER	---
19.	2ND OVERLAY THICKNESS, INCHES	---
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	---
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	---
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	---
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	---
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	---
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	---
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	.93
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.50
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	13.76

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OPTIMAL STRATEGY NO. 3

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	20.
2.	YEAR OF 1ST OVERLAY PLACEMENT	1.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	.39
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	.98
5.	1ST OVERLAY TYPE	UNB CRCP
6.	TYPE OF SHOULDER	PCC
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	600.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	38.2
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	29.55
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	13.22
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.76
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.47
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	---
15.	YEAR OF 2ND OVERLAY PLACEMENT	---
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	---
17.	2ND OVERLAY TYPE	---
18.	TYPE OF SHOULDER	---
19.	2ND OVERLAY THICKNESS, INCHES	---
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	---
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	---
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	---
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	---
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	---
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	---
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	1.10
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.50
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	13.83

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OPTIMAL STRATEGY NO. 4

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	0.
2.	YEAR OF 1ST OVERLAY PLACEMENT	2.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	1.17
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	1.24
5.	1ST OVERLAY TYPE	UNB CRCP
6.	TYPE OF SHOULDER	PCC
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	650.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	32.0
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	23.34
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	12.82
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.72
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.50
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	---
15.	YEAR OF 2ND OVERLAY PLACEMENT	---
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	---
17.	2ND OVERLAY TYPE	---
18.	TYPE OF SHOULDER	---
19.	2ND OVERLAY THICKNESS, INCHES	---
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	---
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	---
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	---
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	---
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	---
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	---
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	.84
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.52
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	13.92

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OPTIMAL STRATEGY NO. 5

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	30.
2.	YEAR OF 1ST OVERLAY PLACEMENT	0.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	0.00
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	.71
5.	1ST OVERLAY TYPE	UNB CRCP
6.	TYPE OF SHOULDER	PCC
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	600.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	38.6
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	30.00
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	13.73
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.77
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.48
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	---
15.	YEAR OF 2ND OVERLAY PLACEMENT	---
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	---
17.	2ND OVERLAY TYPE	---
18.	TYPE OF SHOULDER	---
19.	2ND OVERLAY THICKNESS, INCHES	---
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	---
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	---
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	---
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	---
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	---
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	---
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	1.14
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.50
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	14.06

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OPTIMAL STRATEGY NO. 6

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	10.
2.	YEAR OF 1ST OVERLAY PLACEMENT	2.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	.78
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	1.24
5.	1ST OVERLAY TYPE	UNB CRCP
6.	TYPE OF SHOULDER	PCC
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	650.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	36.3
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	27.60
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	13.30
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.74
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.46
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	---
15.	YEAR OF 2ND OVERLAY PLACEMENT	---
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	---
17.	2ND OVERLAY TYPE	---
18.	TYPE OF SHOULDER	---
19.	2ND OVERLAY THICKNESS, INCHES	---
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	---
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	---
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	---
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	---
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	---
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	---
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	1.02
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.52
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	14.20

RPRDS1 - RIGID PAVEMENT REHABILITATION DESIGN SYSTEM - VERSION 1, NOV 1980
CENTER FOR TRANSPORTATION RESEARCH
UNIVERSITY OF TEXAS AT AUSTIN

PROJECT DESCRIPTION
RPRDS1 TEST - REDESIGN FOR FRATT INTCHNG O/L PROJECT, S A TX, 8BS/11/80

OPTIMAL STRATEGY NO. 7

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	20.
2.	YEAR OF 1ST OVERLAY PLACEMENT	1.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	.39
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	.98
5.	1ST OVERLAY TYPE	UNB CRCP
6.	TYPE OF SHOULDER	PCC
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	650.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	40.4
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	31.86
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	13.80
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.76
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.43
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	---
15.	YEAR OF 2ND OVERLAY PLACEMENT	---
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	---
17.	2ND OVERLAY TYPE	---
18.	TYPE OF SHOULDER	---
19.	2ND OVERLAY THICKNESS, INCHES	---
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	---
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	---
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	---
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	---
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	---
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	---
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	1.17
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.52
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	14.28

RPRDS1 - RIGID PAVEMENT REHABILITATION DESIGN SYSTEM - VERSION 1, NOV 1980
CENTER FOR TRANSPORTATION RESEARCH
UNIVERSITY OF TEXAS AT AUSTIN

PROJECT DESCRIPTION
RPRDS1 TEST - REDESIGN FOR FRATT INTCHNG O/L PROJECT, S A TX, SBS/11/80

OPTIMAL STRATEGY NO. 8

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	0.
2.	YEAR OF 1ST OVERLAY PLACEMENT	2.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	1.17
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	1.24
5.	1ST OVERLAY TYPE	UNB CRCP
6.	TYPE OF SHOULDER	FLEX
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	600.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	19.6
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	12.54
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	11.97
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.72
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.87
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	---
15.	YEAR OF 2ND OVERLAY PLACEMENT	---
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	---
17.	2ND OVERLAY TYPE	---
18.	TYPE OF SHOULDER	---
19.	2ND OVERLAY THICKNESS, INCHES	---
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	---
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	---
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	---
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	---
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	---
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	---
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	0.00
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.48
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	14.32

RPRDS1 - RIGID PAVEMENT REHABILITATION DESIGN SYSTEM - VERSION 1, NOV 1980
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UNIVERSITY OF TEXAS AT AUSTIN

PROJECT DESCRIPTION
RPRDS1 TEST - REDESIGN FOR FRATT INTCHNG O/L PROJECT, S A TX, SBS/11/80

OPTIMAL STRATEGY NO. 9

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	20.
2.	YEAR OF 1ST OVERLAY PLACEMENT	1.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	.39
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	.98
5.	1ST OVERLAY TYPE	ACP
6.	TYPE OF SHOULDER	FLEX
7.	1ST OVERLAY THICKNESS, INCHES	6.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	0.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	9.0
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	5.02
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	8.43
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.43
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.13
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	60.
15.	YEAR OF 2ND OVERLAY PLACEMENT	8.
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	4.57
17.	2ND OVERLAY TYPE	ACP
18.	TYPE OF SHOULDER	FLEX
19.	2ND OVERLAY THICKNESS, INCHES	4.0
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	0.0
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	19.7
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	12.57
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	4.56
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.23
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	.14
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	0.00
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.56
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	14.34

RPRDS1 - RIGID PAVEMENT REHABILITATION DESIGN SYSTEM - VERSION 1, NOV 1980
CENTER FOR TRANSPORTATION RESEARCH
UNIVERSITY OF TEXAS AT AUSTIN

PROJECT DESCRIPTION
RPRDS1 TEST - REDESIGN FOR FRATT INTCHNG O/L PROJECT, S A TX, SBS/11/80

OPTIMAL STRATEGY NO. 10

	COMPONENT OF STRATEGY	QUANTITY
1.	EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCENT	30.
2.	YEAR OF 1ST OVERLAY PLACEMENT	0.
3.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIONS	0.00
4.	COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD	.71
5.	1ST OVERLAY TYPE	ACP
6.	TYPE OF SHOULDER	FLEX
7.	1ST OVERLAY THICKNESS, INCHES	4.0
8.	PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI	0.0
9.	FATIGUE LIFE AFTER 1ST OVERLAY, YEARS	6.9
10.	FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS	3.78
11.	1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD	6.82
12.	1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.22
13.	1ST OVERLAY MAINTENANCE COST, DOL/SQ YD	.13
14.	1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT	60.
15.	YEAR OF 2ND OVERLAY PLACEMENT	6.
16.	TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIONS	3.35
17.	2ND OVERLAY TYPE	ACP
18.	TYPE OF SHOULDER	FLEX
19.	2ND OVERLAY THICKNESS, INCHES	6.0
20.	PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI	0.0
21.	FATIGUE LIFE AFTER 2ND OVERLAY, YEARS	18.1
22.	FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS	11.32
23.	2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD	6.47
24.	2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD	.27
25.	2ND OVERLAY MAINTENANCE COST, DOL/SQ YD	.32
26.	VALUE OF EXTENDED LIFE, DOL/SQ YD	0.00
27.	OVERLAY SALVAGE VALUE, DOL/SQ YD	.56
28.	TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD	14.37

APPENDIX H

RPRDS-1 PROGRAM LISTING

```
CS    PROGRAM RPRDS1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2)
CCC
C     RPRDS1 - RIGID PAVEMENT REHABILITATION DESIGN SYSTEM, VERSION 1
C
C          THIS PROGRAM WAS DEVELOPED BY THE CENTER FOR TRANSPORTATION
C     RESEARCH (AT THE UNIVERSITY OF TEXAS AT AUSTIN) UNDER THE COOPER-
C     ATIVE RESEARCH PROGRAM BETWEEN THE TEXAS STATE DEPARTMENT OF
C     HIGHWAYS AND PUBLIC TRANSPORTATION (SDHPT) AND THE UNIVERSITY OF
C     TEXAS. DOCUMENTATATION FOR THE DEVELOPMENT AND USE OF THIS
C     PROGRAM IS PRESENTED IN CFTR RESEARCH REPORT NO. 249-2, BY
C     STEPHEN B SEEDS, W R HUDSON, AND B F MCCULLOUGH.
C
C          THIS PROGRAM WAS DEVELOPED FOR POSSIBLE USE BY THE TEXAS
C     SDHPT BUT DOES NOT IMPLY ACCEPTANCE AS POLICY OR STANDARD OF THE
C     DEPARTMENT.  ANY USER SHOULD ACCEPT RESPONSIBILITY FOR THE
C     ACCURACY OF THE INPUTS AND VALIDITY OF THE RESULTS.
C
C-----------------------------------------------------------------------
C
      COMMON /NSAVE/ NSAVE1, NSAVE2
C
    1 CONTINUE
      CALL INPUT
      IF (NSAVE1 .GT. 0) GO TO 10
      CALL CONRSP
      CALL STRTGY
   10 CONTINUE
      CALL SETOUT
      CALL COSTRY
      CALL OUT22
      GO TO 1
C
      END
      BLOCK DATA
CC
C     BLOCK DATA - PRESET STORAGE
C
      COMMON /LAYCOM/ WGT, PST, NR, RR(2), NZ, ZZ(5)
C
      COMMON /ELPROP/
     0 ECKPCC, ECKAC, VCOMP,
     1 EOVAC, VOVAC, FACFAT,
     2 EOVPCC, VOVPCC,
     3 EBB, VBB
C
      COMMON /CFACT/
     0 CFP,
     1 C0A, C0AA, NCAC, CMAC(2), C2AC(2), NCAJ, CMAJ(2), C2AJ(2),
     2 NCBC, C0BC(2), C0BCA(2),
     3 NCBJ, C0BJ(2), C0BJA(2),
     4 NCUC, C0UC(2), C1UC(2), C0UCA(2), C1UCA(2),
     5 NCUJ, C0UJ(2), C1UJ(2), C0UJA(2), C1UJA(2)
C
      COMMON /OVTYP/ ISWOV1, NOV1, ITYP1(5), ISWOV2, NOV2, ITYP2(3)
C
      COMMON /MAINT/ DSTNEP, DSTCEP, DSTREP, FRACTA, FRACTR
C
      COMMON /TOP22/ NSTMAX, NSTORD, KSTR(20,10), XSTR(20,10)
C
C     PROGRAM CONSTANTS
C
      DATA NOV1, NOV2 / 5, 3 /
      DATA NSTMAX / 20 /
      DATA WGT, PST / 4500., 75. /
      DATA NR, RR / 2, 0.9, 13.11 /
      DATA ECKAC, FACFAT / 529000., 360000. /
      DATA FRACTA, FRACTR / 0.2, 0.6 /
      DATA VCOMP / 0.44 /
      DATA NCAC  / 2 /
      DATA NCAJ  / 2 /
      DATA NCBC  / 2 /
      DATA NCBJ  / 2 /
      DATA NCUC  / 2 /
      DATA NCUJ  / 2 /
C
      END
```

```
      SUBROUTINE INPUT
CC
C     INPUT - READ, CHECK, AND ECHO PRINT INPUT DATA
C
      COMMON /EPTYP/ IEPTYP, IERSH
C
      COMMON /PROJCT/ NLANE, WL, OVLEN, SHWDTH
C
      COMMON /EXPVMT/ NEXL, EPVT(5), VPVT(5), THPVT(5)
C
      COMMON /FLEXST/ ERFP, NEROV, EROV(5), IERBND
C
      COMMON /MAINT/ DSTNEP, DSTCEP, DSTREP, FRACTA, FRACTR
C
      COMMON /TRAFIC/ ADT, GR, E18YR0, E18GR
C
      COMMON /TIME/ ANPER, TMINOV, TMAXMT
C
      COMMON /RSPNTR/ IRSPNT
C
      COMMON /REMLIF/ NRL1, RLEP(10), NRL2, RLOV(10), RLMIN
C
      COMMON /OVTYP/ ISWOV1, NOV1, ITYP1(5), ISWOV2, NOV2, ITYP2(3)
C
      COMMON /OVTHIK/ NACT1, ACT1(8), NACT2, ACT2(8), NPCCT, PCCT(8)
     0              , ALOVT, AVGLUT, THBB
C
      COMMON /ELPROP/
     0 ECKPCC, ECKAC, VCOMP,
     1 EOVAC, VOVAC, FACFAT,
     2 EOVPCC, VOVPCC,
     3 EBB, VBB
C
      COMMON /CFACT/
     0 CFP,
     1 C0A, C0AA, NCAC, CMAC(2), C2AC(2), NCAJ, C0AJ(2), C2AJ(2),
     2 NCBC, C0BC(2), C0BCA(2),
     3 NCBJ, C0BJ(2), C0BJA(2),
     4 NCUC, C0UC(2), C1UC(2), C0UCA(2), C1UCA(2),
     5 NCUJ, C0UJ(2), C1UJ(2), C0UJA(2), C1UJA(2)
C
```

```
      COMMON /CONSTC/ EQCACP, EQCCRC, EQCJCP, EQCACR, EQCAC1
     0                , PSPC1X, PSPC2X(5), FCAC, VCAC, FCRB, FCACSH
     1                , VCACSH, FCCRC(5), VCCRC(5), FCJCP(5), VCJCP(5)
C
      COMMON /REINF/ SRPCRC, SRPJCP, SRCOST
C
      COMMON /TDC/ ILOC, MODEL, NOLO, NOLN, N1, N2, HPDC, DAYCUR, DDOZ,
     1             DTSD, DTSN, AAS, ASOD, ASND, PVSD, PVSN, DFQD, DFQN
C
      COMMON /HPSY/ HSYAC1(8), HSYAC2(8), HSYCRC(8), HSYJCP(8), HSYAB
C
      COMMON /DISTRS/ DCCRC, DRCRCA, DRCRCB, DRCRC(10)
     0                , DCJCP, DRJCPA, DRJCPB, DRJCP(10)
     1                , DCACC, DRACCA, DRACCB, DRACC(10)
     2                , DCACJ, DRACJA, DRACJB, DRACJ(10)
C
      COMMON /SALVAG/ PCSALV, YVEXL
C
      COMMON /INTRST/ DISCRT
C
      COMMON /NSAVE/ NSAVE1, NSAVE2
C
      COMMON /PROBLM/ IDESC(20)
C
      COMMON /TOP20/ NSTMAX, NSTORD, KSTR(20,10), XSTR(20,10)
C
      COMMON /ERROR/ NERR
C
      DIMENSION MEPTYP(2), NOYES(2)
C
      DATA ISTOP / 4HSTOP /
      DATA MEPTYP / 4HCRCP, 4H JCP /
      DATA NOYES / 4H  NO, 4H YES /
C
C     INITIALIZATION
      NSAVE1 = 0
      NSAVE2 = 0
      NSTORD = 0
      NERR = 0
C
C     READ PROJECT DESCRIPTION, START ECHO PRINTS
C
      READ(5,1000) IDESC
 1000 FORMAT(20A4)
      IF (IDESC(1) .EQ. ISTOP) CALL EXIT
      WRITE(6,2000) IDESC
C
C     READ INPUTS ASSOCIATED WITH EXISTING PAVEMENT
C
      READ(5,1100) IEPTYP, IEPSH, NLANE, NEXL, NSAVE1
 1100 FORMAT(16I5)
      WRITE(6,2100) MEPTYP(IEPTYP), NOYES(IEPSH), NLANE, NEXL
      IF (IEPTYP .LT. 1 .OR. IEPTYP .GT. 2) CALL ERR( 2.1 )
      IF (IEPSH .LT. 1 .OR. IEPSH .GT. 2) CALL ERR( 2.2 )
      IF (NEXL .GT. 5) CALL ERR( 2.4 )
      READ(5,1200) OVLEN, WL, SHWDTH
 1200 FORMAT(8F10.0)
      WRITE(6,2200) OVLEN, WL, SHWDTH
      READ(5,1200) THPVT
      READ(5,1200) EPVT
      READ(5,1200) VPVT
      NEXL1 = NEXL - 1
      WRITE(6,2300) (I, THPVT(I), EPVT(I), VPVT(I), I=1,NEXL1)
      WRITE(6,2400) NEXL, EPVT(NEXL), VPVT(NEXL)
      READ(5,1200) FREP, CEP, FCKPCC
      WRITE(6,2500) FREP, CEP, FCKPCC
      IF (FREP .LE. 0.0) CALL ERR( 7.1 )
      IF (CEP .LE. 0.0) CALL ERR( 7.2 )
      IF (FCKPCC .LE. 0.0) CALL ERR( 7.3 )
      READ(5,1200) DSTNEP, DSTCEP, DSTREP
      WRITE(6,2600) DSTNEP, DSTCEP, DSTREP
C
C     READ INPUTS REGARDING TRAFFIC ESTIMATES AND PROJECTIONS
C
      READ(5,1200) ADT, GR, E18Y0T, E18GRP, DDF, DFLANE
      WRITE(6,2700) ADT, GR, E18Y0T, E18GRP, DDF, DFLANE
      IF (ADT .LE. 0.0) CALL ERR( 9.1 )
      IF (E18Y0T .LE. 0.0) CALL ERR( 9.3 )
      IF (DDF .LE. 0.0 .OR. DDF .GT. 100.0) CALL ERR( 9.5 )
      IF (DFLANE .LE. 0.0 .OR. DFLANE .GT. 100.0) CALL ERR( 9.6 )
      E18GR = E18GRP*0.01
      E18YR0 = .0001*DDF*DFLANE*E18Y0T
C
C     READ TIME CONSTRAINTS
C
      READ(5,1200) ANPER, TMINOV, TMAXMT
      WRITE(6,2800) ANPER, TMINOV, TMAXMT
      IF (ANPER .LE. 0.0) CALL ERR( 10.1 )
      IF (TMINOV .GT. ANPER) CALL ERR( 10.2 )
      IF (TMAXMT .GT. 10.0) CALL ERR( 10.3 )
C
C     READ VALUES OF EXISTING PAVEMENT REMAINING LIFE AT WHICH FIRST
C     OVERLAY MAY BE PLACED
C
      READ(5,1300) NRL1, RLMIN, RLEP
 1300 FORMAT(I5,15F5.0)
      WRITE(6,2900) NRL1, RLMIN
      IF (NRL1 .GT. 0 .AND. NRL1 .LT. 11) GO TO 50
      CALL ERR( 11.1 )
      NRL1 = 10
   50 CONTINUE
      IF (RLMIN .LT. 0.0 .OR. RLMIN .GT. 100.0) CALL ERR( 11.2 )
      WRITE(6,2950) (I, RLEP(I), I=1,NRL1)
      RLMIN = RLMIN*0.01
      DO 100 I=1,NRL1
      RLEP(I) = RLEP(I)*0.01
  100 CONTINUE
C
C     READ VALUES OF FIRST OVERLAY REMAINING LIFE AT WHICH SECOND
C     OVERLAY MAY BE PLACED
C
      READ(5,1400) NRL2, RLOV
 1400 FORMAT(I5,5X,10F5.0)
      WRITE(6,3000) NRL2
      IF (NRL2 .LT. 11) GO TO 150
      CALL ERR( 12.1 )
      NRL2 = 10
  150 CONTINUE
      IF (NRL2 .EQ. 0) GO TO 210
      WRITE(6,2950) (I, RLOV(I), I=1,NRL2)
      DO 200 I=1,NRL2
      RLOV(I) = RLOV(I)*0.01
  200 CONTINUE
      GO TO 220
```

```
  210 CONTINUE
      WRITE(6,3600)
  220 CONTINUE
C
C     READ FIRST AND SECOND OVERLAY TYPES TO CONSIDER
C
      READ(5,1100) ITYP1
      IT1 = ITYP1(1) + 1
      IT2 = ITYP1(2) + 1
      IT3 = ITYP1(3) + 1
      IT4 = ITYP1(4) + 1
      IT5 = ITYP1(5) + 1
      WRITE(6,3100) NOYES(IT1), NOYES(IT2), NOYES(IT3), NOYES(IT4),
     +              NOYES(IT5)
      DO 250 IOV=1,NOV1
      AOV = IOV
      OV = 13.0 + 0.1*AOV
      IF (ITYP1(IOV) .LT. 0 .OR. ITYP1(IOV) .GT. 1) CALL ERR( OV )
  250 CONTINUE
      READ(5,1100) ITYP2
      IT1 = ITYP2(1) + 1
      IT2 = ITYP2(2) + 1
      IT3 = ITYP2(3) + 1
      WRITE(6,3200) NOYES(IT1),NOYES(IT2),NOYES(IT3)
      DO 260 IOV=1,NOV2
      AOV = IOV
      OV = 14.0 + 0.1*AOV
      IF (ITYP2(IOV) .LT. 0 .OR. ITYP2(IOV) .GT. 1) CALL ERR( OV )
  260 CONTINUE
      ISWOV2 = 1
      IF(ITYP2(1).EQ.0 .AND. ITYP2(2).EQ.0 .AND. ITYP2(3).EQ.0)ISWOV2=0
C
C     READ OVERLAY THICKNESSES AND ELASTIC PROPERTIES
C
      READ(5,1100) NACT1, NACT2, NPCCT
      WRITE(6,3300) NACT1, NACT2, NPCCT
      IF (NACT1 .GT. 8) CALL ERR( 15.1 )
      IF (NACT2 .GT. 8) CALL ERR( 15.2 )
      IF (NPCCT .GT. 8) CALL ERR( 15.3 )
      READ(5,1200) ACT1
      WRITE(6,3400)
      IF (NACT1 .EQ. 0) GO TO 300
      WRITE(6,3500) (I, ACT1(I), I=1,NACT1)
      IF (ACT1(1) .LT. 2.0) CALL ERR( 16.1 )
      IF (ACT1(NACT1) .GT. 8.0) CALL ERR( 16.2 )
      GO TO 310
  300 CONTINUE
      WRITE(6,3600)
  310 CONTINUE
      READ(5,1200) ACT2
      WRITE(6,3700)
      IF (NACT2 .EQ. 0) GO TO 320
      WRITE(6,3500) (I, ACT2(I), I=1,NACT2)
      IF (ACT2(1) .LT. 2.0) CALL ERR( 17.1 )
      IF (ACT2(NACT2) .GT. 8.0) CALL ERR( 17.2 )
      GO TO 330
  320 CONTINUE
      WRITE(6,3600)
  330 CONTINUE
      READ(5,1200) PCCT
      WRITE(6,3800)
      IF (NPCCT .EQ. 0) GO TO 340
      WRITE(6,3500) (I, PCCT(I), I=1,NPCCT)
      GO TO 350
  340 CONTINUE
      WRITE(6,3600)
  350 CONTINUE
      READ(5,1200) ALOVT, AVGLUT, THRR
      WRITE(6,3900) ALOVT, AVGLUT, THRR
      IF (ISWOV2 .EQ. 1 .AND. ALOVT .LT. 4.0) CALL ERR( 19.1 )
      READ(5,1200) EOVAC, VOVAC, EOVPCC, VOVPCC, ERR, VRR
      WRITE(6,4000) EOVAC, VOVAC, EOVPCC, VOVPCC, ERR, VRR
C
C     READ PCC OVERLAY FLEXURAL STRENGTHS TO CONSIDER
C
      READ(5,1100) NFROV, IFRRND
      WRITE(6,4100) NFROV, IFRRND
      IF (NFROV .GT. 5) CALL ERR( 21.1 )
      IF (ITYP1(2) .EQ. 0 .AND. ITYP1(4) .EQ. 0) GO TO 360
      IF (NFROV .GT. 0 .AND. IFRRND .GT. NFROV) CALL ERR( 21.2 )
      IF (NFROV .GT. 0 .AND. IFRRND .LT. 1) CALL ERR( 21.2 )
  360 CONTINUE
      READ(5,1200) FROV
      IF (NFROV .EQ. 0) GO TO 400
      WRITE(6,4200) (I, FROV(I), I=1,NFROV)
      GO TO 410
  400 CONTINUE
      WRITE(6,3600)
  410 CONTINUE
C
C     READ STRESS FACTORS FOR THE VARIOUS OVERLAY COMBINATIONS
C
      WRITE(6,4300)
      READ(5,1200) C0A
      WRITE(6,4400) C0A
      READ(5,1200) C0AA
      WRITE(6,4500) C0AA
      READ(5,1200) C0AC
      WRITE(6,4600) C0AC
      READ(5,1200) C2AC
      WRITE(6,4700) C2AC
      READ(5,1200) C0AJ
      WRITE(6,4800) C0AJ
      READ(5,1200) C2AJ
      WRITE(6,4900) C2AJ
      READ(5,1200) C0RC
      WRITE(6,5000) C0RC
      READ(5,1200) C0RCA
      WRITE(6,5100) C0RCA
      READ(5,1200) C0RJ
      WRITE(6,5200) C0RJ
      READ(5,1200) C0RJA
      WRITE(6,5300) C0RJA
      READ(5,1200) C0UC
      WRITE(6,5400) C0UC
      READ(5,1200) C1UC
      WRITE(6,5500) C1UC
      READ(5,1200) C0UCA
      WRITE(6,5600) C0UCA
      READ(5,1200) C1UCA
      WRITE(6,5700) C1UCA
      READ(5,1200) C0UJ
      WRITE(6,5800) C0UJ
      READ(5,1200) C1UJ
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      WRITE(6,5900) C1UT
      READ(5,1200) CQUJA
      WRITE(6,6000) CQUJA
      READ(5,1200) C1UJA
      WRITE(6,6100) C1UJA
      WRITE(6,6200)
C
C     READ POINTER TO DESIRED METHOD OF RESPONSE PREDICTION
C
      READ(5,1100) IPSPNT
      IF (IPSPNT .EQ. 2) GO TO 500
      WRITE(6,6300)
      IF (IPSPNT .NE. 1) CALL ERR( 41,1 )
      GO TO 510
  500 CONTINUE
      WRITE(6,6400)
  510 CONTINUE
C
C     READ OVERLAY CONSTRUCTION COST VARIABLES
C
      READ(5,1200) EQCACP, EQCCPC, EQCJCP, EQCACR, EQCACJ
      WRITE(6,6500) EQCACP, EQCCPC, EQCJCP, EQCACR, EQCACJ
      READ(5,1200) PSPC1X, PSPCAC, PSPCCR, PSPCJC
      WRITE(6,6600) PSPC1X, PSPCAC, PSPCCR, PSPCJC
      PSPC2X(1) = PSPCAC
      PSPC2X(2) = PSPCCP
      PSPC2X(3) = PSPCCR
      PSPC2X(4) = PSPCJC
      PSPC2X(5) = PSPCJC
      READ(5,1200) FCAC, VCAC, FCACSH, VCACSH, FCRB
      WRITE(6,6700) FCAC, VCAC, FCACSH, VCACSH, FCRB
      READ(5,1200) FCCRC
      WRITE(6,6800)
      IF (NFROV .EQ. 0) GO TO 600
      WRITE(6,6900) (I, FROV(I), FCCRC(I), I=1,NFROV)
      GO TO 610
  600 CONTINUE
      WRITE(6,3400)
  610 CONTINUE
      READ(5,1200) VCCRC
      WRITE(6,7000)
      IF (NFROV .EQ. 0) GO TO 620
      WRITE(6,7050) (I, FROV(I), VCCRC(I), I=1,NFROV)
      GO TO 630
  620 CONTINUE
      WRITE(6,3500)
  630 CONTINUE
      READ(5,1200) FCJCP
      WRITE(6,7100)
      IF (NFROV .EQ. 0) GO TO 640
      WRITE(6,6900) (I, FROV(I), FCJCP(I), I=1,NFROV)
      GO TO 650
  640 CONTINUE
      WRITE(6,3600)
  650 CONTINUE
      READ(5,1200) VCJCP
      WRITE(6,7200)
      IF (NFROV .EQ. 0) GO TO 660
      WRITE(6,7050) (I, FROV(I), VCJCP(I), I=1,NFROV)
      GO TO 670
  660 CONTINUE
      WRITE(6,3600)
  670 CONTINUE
      READ(5,1200) SRPCRC, SRPJCP, SRCOST
      WRITE(6,7300) SRPCRC, SRPJCP, SRCOST
C
C     READ TRAFFIC DELAY COST VARIABLES
C
      WRITE(6,7400)
      READ(5,1100) TLOC, MODEL, NOLO, NOLN
      WRITE(6,7500) TLOC, MODEL, NOLO, NOLN
      IF (TLOC .LT. 1 .OR. TLOC .GT. 2) CALL ERR( 50,1 )
      IF (MODEL .LT. 1 .OR. MODEL .GT. 5) CALL ERR( 50,2 )
      IF (NOLO .LE. 0) CALL ERR( 50,3 )
      IF (NOLN .LE. 0) CALL ERR( 50,4 )
      READ(5,1200) AN1, AN2, HPDC, DAYCUR, DDDZ
      WRITE(6,7600) AN1, AN2, HPDC, DAYCUR, DDDZ
      IF (AN2+AN1 .LE. 2.0) CALL ERR( 51,1 )
      IF (HPDC .LE. 0.0) CALL ERR( 51,3 )
      N1 = AN1+0.01
      N2 = AN2+3.01
      READ(5,1200) AAS, ASOD, ASND
      WRITE(6,7700) AAS, ASOD, ASND
      READ(5,1200) DTSO, DTSN, PVSO, PVSN, DEQO, DEQN
      WRITE(6,7800) DTSO, DTSN, PVSO, PVSN, DEQO, DEQN
      IF (PVSO .GT. 100.0) CALL ERR( 53,3 )
      IF (PVSN .GT. 100.0) CALL ERR( 53,4 )
      READ(5,1200) CYHAC, CYHCRC, CYHJCP, CYHRB
      WRITE(6,7900) CYHAC, CYHCRC, CYHJCP, CYHRB
      IF (NACT1 .EQ. 0) GO TO 710
      DO 700 I=1,NACT1
      HSYAC1(I) = ACT1(I)/(CYHAC*36.0)
  700 CONTINUE
  710 CONTINUE
      IF (NACT2 .EQ. 0) GO TO 730
      DO 720 I=1,NACT2
      HSYAC2(I) = ACT2(I)/(CYHAC*36.0)
  720 CONTINUE
  730 CONTINUE
      IF (NPCCT .EQ. 0) GO TO 770
      IF (ITYP1(2) .EQ. 0 .AND. ITYP1(3) .EQ. 0 .AND. ITYP2(2) .EQ. 0)
     + GO TO 750
      DO 740 I=1,NPCCT
      HSYCPC(I) = PCCT(I)/(CYHCRC*36.0)
  740 CONTINUE
  750 CONTINUE
      IF (ITYP1(4) .EQ. 0 .AND. ITYP1(5) .EQ. 0 .AND. ITYP2(3) .EQ. 0)
     + GO TO 770
      DO 760 I=1,NPCCT
      HSYJCP(I) = PCCT(I)/(CYHJCP*36.0)
  760 CONTINUE
  770 CONTINUE
      IF (THRB .LE. 0.0) GO TO 780
      HSYRB = THRB/(CYHRB*36.0)
  780 CONTINUE
C
C     READ OVERLAY DISTRESS AND MAINTENANCE COST VARIABLES
C
      READ(5,1500) DCCRC, DRCRCA, DRCRCB, DRCRC
 1500 FORMAT(16F5.0)
      WRITE(6,8000) DCCRC, DRCRCA, DRCRCB
      MAXMT = THMAXMT
      IF (MAXMT .LE. 0) GO TO 800
      WRITE(6,8050) (I, DRCRC(I), I=1,MAXMT)
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      GO TO 810
  800 CONTINUE
      WRITE(6,3600)
  810 CONTINUE
      READ(5,1500) DCJCP, DRJCPA, DRJCPB, DRJCP
      WRITE(6,8100) DCJCP, DRJCPA, DRJCPB
      IF (MAXMT .LE. 0) GO TO 820
      WRITE(6,8050) (I, DRJCP(I), I=1,MAXMT)
      GO TO 830
  820 CONTINUE
      WRITE(6,3600)
  830 CONTINUE
      READ(5,1500) DCACC, DRACCA, DRACCB, DRACC
      WRITE(6,8200) DCACC, DRACCA, DRACCB
      IF (MAXMT .LE. 0) GO TO 840
      WRITE(6,8250) (I, DRACC(I), I=1,MAXMT)
      GO TO 850
  840 CONTINUE
      WRITE(6,3600)
  850 CONTINUE
      READ(5,1500) DCACJ, DRACJA, DRACJB, DRACJ
      WRITE(6,8300) DCACJ, DRACJA, DRACJB
      IF (MAXMT .LE. 0) GO TO 860
      WRITE(6,8050) (I, DRACJ(I), I=1,MAXMT)
      GO TO 870
  860 CONTINUE
      WRITE(6,3600)
  870 CONTINUE
C
C     READ VARIABLES ASSOCIATED WITH OVERLAY SALVAGE VALUE AND
C     VALUE OF EXTENDED LIFE
C
      READ(5,1200) PCSALV, YVEXL
      WRITE(6,8400) PCSALV, YVEXL
      IF (PCSALV .GT. 100.0) CALL ERR( 59,1 )
C
C     READ DISCOUNT RATE
C
      READ(5,1200) DISCRT
      WRITE(6,8500) DISCRT
      IF (DISCRT .GT. 100.0) CALL ERR( 60,1 )
C
      IF (NERR .EQ. 0) GO TO 900
      WRITE(6,9000) NERR
      STOP
  900 CONTINUE
C
      RETURN
C
 2000 FORMAT(1H1
     +///5X,74HRPRDS1 - RIGID PAVEMENT REHABILITATION DESIGN SYSTEM - VE
     +RSION 1, NOV 1980
     +  /5X,34HCENTER FOR TRANSPORTATION RESEARCH
     +  /5X,29HUNIVERSITY OF TEXAS AT AUSTIN
     +///5X,37(1H*)
     +  /5X,37HR R D S   I N P U T   S U M M A R Y
     +  /5X,37(1H*)
     +///5X,65HNOTE - VARIABLE NUMBERS CORRESPOND TO THOSE IN RPRDS USER
     +S MANUAL
     +////7X,19HPROJECT DESCRIPTION
     +  /7X,19(1H*)
     + //9X,11H 1.1  TITLE/7X,20A4)
 2100 FORMAT(
     + //7X,17HORIGINAL PAVEMENT
     +  /7X,17(1H*)
     + //9X,18H 2.1  SURFACE TYPE,43X,A4
     +  /9X,23H 2.2  CONCRETE SHOULDER,38X,A4
     +  /9X,34H 2.3  NO. OF LANES (ONE DIRECTION),27X,I4
     +  /9X,28H 2.4  NO. OF PAVEMENT LAYERS,33X,I4)
 2200 FORMAT(
     +  /9X,27H 3.1  PROJECT LENGTH, MILES,28X,F10.2
     +  /9X,22H 3.2  LANE WIDTH, FEET,33X,F10.1
     +  /9X,32H 3.3  TOTAL SHOULDER WIDTH, FEET,23X,F10.0 )
 2300 FORMAT(
     +  /9X,48H       PAVEMENT STRUCTURE
     +  /9X,48H                                    5.0
     +  /9X,48H                        4.0      ELASTIC     6.0
     +  /9X,48H              LAYER  THICKNESS   MODULUS  POISSONS
     +  /9X,48H               NO.     (IN)       (PSI)     RATIO
     +  /9X,48H              ----- ----------- -------- --------
     +/(19X,I2,F11.1,5X,F10.0,F7.2)  )
 2400 FORMAT(19X,I2,3X,13HSEMI-INFINITE,F19.0,F7.2)
 2500 FORMAT(
     + //9X,37H 7.1  CONCRETE FLEXURAL STRENGTH, PSI,18X,F10.0
     +  /9X,28H 7.2  CRITICAL STRESS FACTOR,25X,F12.2
     +  /9X,44H 7.3  CONCRETE STIFFNESS AFTER CRACKING, PSI,9X,F12.0 )
 2600 FORMAT(
     +  /9X,38H 8.1  NO. OF EXISTING DEFECTS PER MILE,16X,F11.0
     +  /9X,37H 8.2  COST OF REPAIRING A DEFECT, DOL,16X,F12.0
     +  /9X,45H 8.3  RATE OF DEFECT DEVELOPMENT, NO./YR/MILE,9X,F11.0 )
 2700 FORMAT(1H1//77X,1H2
     + //7X,17HTRAFFIC VARIABLES
     +  /7X,17(1H*)
     + //9X,33H 9.1  AVERAGE DAILY TRAFFIC (ADT),22X,F10.0
     +  /9X,30H 9.2  ADT GROWTH RATE, PERCENT,25X,F10.2
     +  /9X,42H 9.3  INITIAL YEARLY 18-KIP ESAL, MILLIONS,13X,F10.3
     +  /9X,38H 9.4  18-KIP ESAL GROWTH RATE, PERCENT,17X,F10.2
     +  /9X,46H 9.5  DIRECTIONAL DISTRIBUTION FACTOR, PERCENT,9X,F10.1
     +  /9X,39H 9.6  LANE DISTRIBUTION FACTOR, PERCENT,16X,F10.1 )
 2800 FORMAT(
     + //7X,16HTIME CONSTRAINTS
     +  /7X,16(1H*)
     + //9X,28H10.1  ANALYSIS PERIOD, YEARS,27X,F10.1
     +  /9X,42H10.2  MINIMUM TIME BETWEEN OVERLAYS, YEARS,13X,F10.1
     +  /9X,56H10.3  MAXIMUM ALLOWABLE YEARS OF HEAVY MAINTENANCE AFTER
     +  /9X,47H      LOSS OF STRUCTURAL LOAD-CARRYING CAPACITY,9X,F9.1 )
 2900 FORMAT(1H1//77X,1H3
     + //7X,24HREMAINING LIFE VARIABLES
     +  /7X,24(1H*)
     + //9X,45H11.1  NO. OF ORIGINAL PAVEMENT REMAINING LIFE
     +  /9X,24H      VALUES TO CONSIDER,35X,I6
     +  /9X,52H11.2  MINIMUM EXISTING PAVEMENT REMAINING LIFE BELOW
     +  /9X,50H      WHICH A BONDED PCC OVERLAY MAY NOT BE PLACED,F15.0
     +  /9X,57H11.3  VALUES OF ORIGINAL PAVEMENT REMAINING LIFE AT WHICH
     +  /9X,33H      FIRST OVERLAY MAY BE PLACED )
 2950 FORMAT(
     +  /9X,55H                                              REMAINING
     +  /9X,55H                                       NO.      LIFE
     +  /9X,55H                                             (PERCENT)
     +  /9X,55H                                       ---  ---------
     + /(53X,I2,F10.0) )
 3000 FORMAT(
     +  /9X,41H12.1  NO. OF FIRST OVERLAY REMAINING LIFE
     +  /9X,24H      VALUES TO CONSIDER,35X,I6
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     + /9X,53H12.2  VALUES OF FIRST OVERLAY REMAINING LIFE AT WHICH
     + /9X,34H      SECOND OVERLAY MAY BE PLACED )
3100 FORMAT(1H1//77X,1H4
     + //7X,23HOVERLAY CHARACTERISTICS
     + /7X,23(1H*)
     + //9X,44H13.0  TYPES OF FIRST OVERLAY TO CONSIDER
     + /9X,27H          .1  ACP           =,A4
     + /9X,27H          .2  BONDED CRCP   =,A4
     + /9X,27H          .3  UNBONDED CRCP =,A4
     + /9X,27H          .4  BONDED JCP    =,A4
     + /9X,27H          .5  UNBONDED JCP  =,A4 )
3200 FORMAT(
     + /9X,41H14.0  TYPES OF SECOND OVERLAY TO CONSIDER
     + /9X,18H          .1  ACP  =,A4
     + /9X,18H          .2  CRCP =,A4
     + /9X,18H          .3  JCP  =,A4 )
3300 FORMAT(
     + /9X,54H15.0  NO. OF DIFFERENT OVERLAY THICKNESS TO CONSIDER
     + /9X,32H          .1  ACP FIRST OVERLAY  =,I5
     + /9X,32H          .2  ACP SECOND OVERLAY =,I5
     + /9X,32H          .3  PCC OVERLAY        =,I5 )
3400 FORMAT(
     + /9X,43H16.0  ACP FIRST OVERLAY THICKNESSES, INCHES )
3500 FORMAT(17X,1H.,I1,F7.1)
3600 FORMAT(17X,6H(NONE) )
3700 FORMAT(
     + /9X,44H17.0  ACP SECOND OVERLAY THICKNESSES, INCHES )
3800 FORMAT(
     + /9X,37H18.0  PCC OVERLAY THICKNESSES, INCHES )
3900 FORMAT(1H1//77X,1H5
     +///9X,47H19.1  ALLOWABLE TOTAL OVERLAY THICKNESS, INCHES,9X,F9.1
     + /9X,47H19.2  AVERAGE LEVEL-UP THICKNESS, INCHES       ,9X,F9.1
     + /9X,47H19.3  BOND BREAKER THICKNESS, INCHES           ,9X,F9.1 )
4000 FORMAT(
     + /9X,47H20.1  ACP OVERLAY DESIGN STIFFNESS, PSI        ,9X,F9.0
     + /9X,47H20.2  POISSONS RATIO, ACP OVERLAY              ,9X,F9.2
     + /9X,47H20.3  PCC OVERLAY DESIGN STIFFNESS, PSI        ,9X,F9.0
     + /9X,47H20.4  POISSONS RATIO, PCC OVERLAY              ,9X,F9.2
     + /9X,47H20.5  BOND BREAKER STIFFNESS, PSI              ,9X,F9.0
     + /9X,47H20.6  POISSONS RATIO, BOND BREAKER             ,9X,F9.2 )
4100 FORMAT(
     + /9X,51H21.1  NO. OF OVERLAY FLEXURAL STRENGTHS TO CONSIDER,9X,I5
     + /9X,53H21.2  NO. WHICH IDENTIFIES WHICH FLEXURAL STRENGTH IN
     + /9X,46H      THE LIST TO USE FOR A BONDED PCC OVERLAY,14X,I5
     + //9X,43H22.0  PCC OVERLAY FLEXURAL STRENGTH(S), PSI )
4200 FORMAT(17X,1H.,I1,F7.0 )
4300 FORMAT(1H1//77X,1H6
     + //9X,57H*** PAVEMENT STRESS FACTORS AFTER OVERLAY ***
     + //9X,57H     FIRST     SECOND   CRITICAL   OVERLAY  CRIT./INTER.
     + /9X,57H     OVERLAY   OVERLAY   STRESS   SHOULDER     STRESS
     + /9X,57H      TYPE      TYPE    LOCATION    TYPE       FACTOR
     + /9X,56H    --------  -------  --------  --------  -----------)
4400 FORMAT(
     + /9X,41H23.1      ACP     (NONE)    EX PAVT     ACP,F11.2 )
4500 FORMAT(
     +  9X,41H24.1      ACP       ACP     EX PAVT     ACP,F11.2 )
4600 FORMAT(
     + /9X,41H25.1      ACP       CRCP    EX PAVT     ACP,F11.2
     + /9X,41H25.2      ACP       CRCP    EX PAVT    CRCP,F11.2 )
4700 FORMAT(
     +  9X,41H26.1      ACP       CRCP   CRCP O/L     ACP,F11.2
     + /9X,41H26.2      ACP       CRCP   CRCP O/L    CRCP,F11.2 )
4800 FORMAT(
     + /9X,41H27.1      ACP       JCP     EX PAVT     ACP,F11.2
     + /9X,41H27.2      ACP       JCP     EX PAVT     JCP,F11.2 )
4900 FORMAT(
     +  9X,41H28.1      ACP       JCP     JCP O/L     ACP,F11.2
     + /9X,41H28.2      ACP       JCP     JCP O/L     JCP,F11.2 )
5000 FORMAT(
     + /9X,41H29.1  BOND CRC   (NONE)    EX PAVT     ACP,F11.2
     + /9X,41H29.2  BOND CRC   (NONE)    EX PAVT    CRCP,F11.2 )
5100 FORMAT(
     +  9X,41H30.1  BOND CRC     ACP     EX PAVT     ACP,F11.2
     + /9X,41H30.2  BOND CRC     ACP     EX PAVT    CRCP,F11.2 )
5200 FORMAT(
     + /9X,41H31.1  BOND JCP   (NONE)    EX PAVT     ACP,F11.2
     + /9X,41H31.2  BOND JCP   (NONE)    EX PAVT     JCP,F11.2 )
5300 FORMAT(
     +  9X,41H32.1  BOND JCP     ACP     EX PAVT     ACP,F11.2
     + /9X,41H32.2  BOND JCP     ACP     EX PAVT     JCP,F11.2 )
5400 FORMAT(
     + /9X,41H33.1  UNBD CRC   (NONE)    EX PAVT     ACP,F11.2
     + /9X,41H33.2  UNBD CRC   (NONE)    EX PAVT    CRCP,F11.2 )
5500 FORMAT(
     +  9X,41H34.1  UNBD CRC   (NONE)   CRCP O/L     ACP,F11.2
     + /9X,41H34.2  UNBD CRC   (NONE)   CRCP O/L    CRCP,F11.2 )
5600 FORMAT(
     +  9X,41H35.1  UNBD CRC     ACP     EX PAVT     ACP,F11.2
     + /9X,41H35.2  UNBD CRC     ACP     EX PAVT    CRCP,F11.2 )
5700 FORMAT(
     +  9X,41H36.1  UNBD CRC     ACP    CRCP O/L     ACP,F11.2
     + /9X,41H36.2  UNBD CRC     ACP    CRCP O/L    CRCP,F11.2 )
5800 FORMAT(
     + /9X,41H37.1  UNBD JCP   (NONE)    EX PAVT     ACP,F11.2
     + /9X,41H37.2  UNBD JCP   (NONE)    EX PAVT     JCP,F11.2 )
5900 FORMAT(
     +  9X,41H38.1  UNBD JCP   (NONE)    JCP O/L     ACP,F11.2
     + /9X,41H38.2  UNBD JCP   (NONE)    JCP O/L     JCP,F11.2 )
6000 FORMAT(
     +  9X,41H39.1  UNBD JCP     ACP     EX PAVT     ACP,F11.2
     + /9X,41H39.2  UNBD JCP     ACP     EX PAVT     JCP,F11.2 )
6100 FORMAT(
     +  9X,41H40.1  UNBD JCP     ACP     JCP O/L     ACP,F11.2
     + /9X,41H40.2  UNBD JCP     ACP     JCP O/L     JCP,F11.2 )
6200 FORMAT(
     + /9X,55HNOTE - STRATEGIES WITH A ZERO VALUE FOR THE CRITICAL TO
     + /9X,53H       INTERIOR STRESS FACTOR WILL NOT BE CONSIDERED. )
6300 FORMAT(
     +///9X,49H41.1  1 = LAYER PACKAGE USED TO PREDICT RESPONSE. )
6400 FORMAT(
     + //9X,56H41.1  2 = REGRESSION EQUATIONS USED TO PREDICT RESPONSE.)
6500 FORMAT(1H1//77X,1H7
     + //7X,35HOVERLAY CONSTRUCTION COST VARIABLES
     + /7X,35(1H*)
     + //9X,34H42.0  SITE ESTABLISHMENT COST, DOL
     + /9X,35H          .1  ACP EQUIPMENT          ,F10.0
     + /9X,35H          .2  CRCP EQUIPMENT         ,F10.0
     + /9X,35H          .3  JCP EQUIPMENT          ,F10.0
     + /9X,35H          .4  ACP AND CRCP EQUIPMENT,F10.0
     + /9X,35H          .5  ACP AND JCP EQUIPMENT ,F10.0 )
6600 FORMAT(
     + /9X,48H43.0  PAVEMENT SURFACE PREPARATION COSTS, DOL/SY
     + /9X,30H          .1  EXISTING PAVEMENT,5X,F10.2
     + /9X,30H          .2  ACP OVERLAY      ,5X,F10.2
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     +  /9X,30H              ,3  CRCP OVERLAY      ,5X,F10.2
     +  /9X,30H              .4  JCP OVERLAY       ,5X,F10.2 )
 6700 FORMAT(
     +  /9X,56H44.1  FIXED COST OF ACP OVERLAY CONSTRUCTION, DOL/SY    ,
     +F9.2
     +  /9X,56H44.2  VARIABLE COST OF ACP OVERLAY CONSTR., DOL/SY/IN   ,
     +F9.2
     +  /9X,56H44.3  FIXED COST OF FLEXIBLE SHOULDER CONSTR., DOL/SY   ,
     +F9.2
     +  /9X,56H44.4  VARIABLE COST OF FLEX. SHOULDER CONSTR., DOL/SY/IN,
     +F9.2
     +  /9X,56H44.5  COST OF BOND BREAKER CONSTRUCTION, DOL/SY         ,
     +F9.2 )
 6800 FORMAT(
     +  /9X,48H45.0  CRCP FIXED COST FOR EACH FLEXURAL STRENGTH )
 6900 FORMAT(
     +  /9X,50H                    FLEXURAL         FIXED COST
     +  /9X,50H                 STRENGTH (PSI)      (DOL/SY)
     +  /9X,50H                 --------------      ---------
     + /(18X,1H.,I1,F12.0,6X,F11.2) )
 7000 FORMAT(
     +  /9X,51H46.0  CRCP VARIABLE COST FOR EACH FLEXURAL STRENGTH )
 7050 FORMAT(
     +  /9X,50H                    FLEXURAL       VARIABLE COST
     +  /9X,50H                 STRENGTH (PSI)    (DOL/SY/IN)
     +  /9X,50H                 --------------    -------------
     + /(18X,1H.,I1,F12.0,6X,F11.2) )
 7100 FORMAT(1H1//77X,1H8
     +///9X,47H47.0  JCP FIXED COST FOR EACH FLEXURAL STRENGTH )
 7200 FORMAT(
     +  /9X,50H48.0  JCP VARIABLE COST FOR EACH FLEXURAL STRENGTH )
 7300 FORMAT(
     +  /9X,55H49.1  TOTAL STEEL PERCENTAGE REQUIRED IN CRCP OVERLAYS ,
     + F10.2
     +  /9X,55H49.2  TOTAL STEEL PERCENTAGE REQUIRED IN JCP OVERLAYS  ,
     + F10.2
     +  /9X,55H49.3  COST OF STEEL REINFORCEMENT, DOL/LB              ,
     + F10.2 )
 7400 FORMAT(1H1//77X,1H9
     +///7X,28HTRAFFIC DELAY COST VARIABLES
     +  /7X,28(1H*) )
 7500 FORMAT(
     +  /9X,47H50.1  LOCATION OF PROJECT (1=RURAL,2=URBAN)    ,13X,I5
     +  /9X,47H50.2  MODEL NO. FOR HANDLING TRAFFIC           ,13X,I5
     +  /9X,47H50.3  NO. OF OPEN LANES, OVERLAY DIRECTION     ,13X,I5
     +  /9X,47H50.4  NO. OF OPEN LANES, NON-OVERLAY DIRECTION ,13X,I5 )
 7600 FORMAT(
     +  /9X,47H51.1  MILITARY TIME OVERLAY CONSTRUCTION BEGINS,9X,F9.0
     +  /9X,47H51.2  MILITARY TIME OVERLAY CONSTRUCTION ENDS  ,9X,F9.0
     +  /9X,47H51.3  HOURS PER DAY OVERLAY CONSTRUCTION OCCURS,9X,F9.1
     +  /9X,47H51.4  NO. OF DAYS CONCRETE IS ALLOWED TO CURE  ,9X,F9.0
     +  /9X,47H51.5  DETOUR DISTANCE TO USE IN MODEL 5, MILES ,9X,F9.1 )
 7700 FORMAT(
     +  /9X,47H52.1  AVERAGE APPROACH SPEED, MPH              ,9X,F9.0
     +  /9X,47H52.2  AVERAGE SPEED, OVERLAY DIRECTION, MPH    ,9X,F9.0
     +  /9X,47H52.3  AVERAGE SPEED, NON-OVERLAY DIRECTION, MPH,9X,F9.0 )
 7800 FORMAT(
     +  /9X,58H53.1  DISTANCE TRAFFIC IS SLOWED, OVERLAY DIRECTION, MILE
     +S,F7.1
     +  /9X,58H53.2  DISTANCE TRAFFIC IS SLOWED, NON-OVERLAY DIR., MILES
     + ,F7.1
     +  /9X,58H53.3  PERCENT OF VEHICLES STOPPED, OVERLAY DIRECTION
     + ,F7.1
     +  /9X,58H53.4  PERCENT OF VEHICLES STOPPED, NON-OVERLAY DIRECTION
     + ,F7.1
     +  /9X,58H53.5  AVERAGE VEHICLE DELAY, OVERLAY DIRECTION, HRS
     + ,F7.5
     +  /9X,58H53.6  AVERAGE VEHICLE DELAY, NON-OVERLAY DIRECTION, HRS
     + ,F7.5 )
 7900 FORMAT(
     +  /9X,41H54.1  ACP PRODUCTION RATE, CY/HR            ,12X,F12.0
     +  /9X,41H54.2  CRCP PRODUCTION RATE, CY/HR           ,12X,F12.0
     +  /9X,41H54.3  JCP PRODUCTION RATE, CY/HR            ,12X,F12.0
     +  /9X,41H54.4  BOND BREAKER PRODUCTION RATE, CY/HR,12X,F12.0 )
 8000 FORMAT(1H1//76X,2H10
     + //7X,35HDISTRESS/MAINTENANCE COST VARIABLES
     +  /7X,35(1H*)
     + //9X,45H55.1  DISTRESS REPAIR COST, CRCP OVERLAY, DOL,10X,F10.2
     +  /9X,51H55.2  INITIAL CRCP OVERLAY DISTRESS RATE, NO./MI/YR,F14.1
     +  /9X,53H55.3  SECONDARY CRCP OVERLAY DISTRESS RATE, NO./MI/YR,F12
     +.1
     +  /9X,57H55.4  CRCP OVERLAY DISTRESS RATE FOR EACH YEAR AFTER LOSS
     +  /9X,40H      OF PAVEMENT LOAD-CARRYING CAPACITY )
 8050 FORMAT(
     +  /9X,39H                 YEAR AFTER    DISTRESS RATE
     +  /9X,39H                  FAILURE        (NO./MILE)
     +  /9X,39H                 ----------    -------------
     + /(22X,I5,4X,F13.1) )
 8100 FORMAT(
     +  /9X,44H56.1  DISTRESS REPAIR COST, JCP OVERLAY, DOL,10X,F11.2
     +  /9X,50H56.2  INITIAL JCP OVERLAY DISTRESS RATE, NO./MI/YR,F15.1
     +  /9X,52H56.3  SECONDARY JCP OVERLAY DISTRESS RATE, NO./MI/YR,F13.
     +1
     +  /9X,57H56.4  JCP OVERLAY DISTRESS RATE FOR EACH YEAR AFTER LOSS
     +  /9X,40H      OF PAVEMENT LOAD CARRYING CAPACITY )
 8200 FORMAT(1H1//76X,2H11
     +///9X,52H57.1  DISTRESS REPAIR COST, ACP OVERLAY ON CRCP, DOL,F13.
     +2
     +  /9X,53H57.2  INITIAL ACP/CRCP DISTRESS RATE, NO./MI/YR   ,F15.1
     +  /9X,54H57.3  SECONDARY ACP/CRCP DISTRESS RATE, NO./MI/YR ,F15.1
     +  /9X,53H57.4  ACP/CRCP DISTRESS RATE FOR EACH YEAR AFTER LOSS
     +  /9X,40H      OF PAVEMENT LOAD-CARRYING CAPACITY )
 8300 FORMAT(
     +  /9X,51H58.1  DISTRESS REPAIR COST, ACP OVERLAY ON JCP, DOL,F14.2
     +  /9X,50H58.2  INITIAL ACP/JCP DISTRESS RATE, NO./MI/YR    ,F15.1
     +  /9X,54H58.3  SECONDARY ACP/JCP DISTRESS RATE, NO./MI/YR  ,F15.1
     +  /9X,52H58.4  ACP/JCP DISTRESS RATE FOR EACH YEAR AFTER LOSS
     +  /9X,40H      OF PAVEMENT LOAD CARRYING CAPACITY )
 8400 FORMAT(
     + //7X,12HCOST RETURNS
     +  /7X,12(1H*)
     + //9X,57H59.1  SALVAGE VALUE, PERCENT OF OVERLAY CONSTRUCTION COST
     +,F8.1
     +  /9X,52H59.2  VALUE OF EACH YEAR OF EXTENDED LIFE, DOL/SY/YR,F13.
     +2 )
 8500 FORMAT(
     + //7X,36HCOMBINED INTEREST AND INFLATION RATE
     +  /7X,36(1H*)
     + //9X,49H60.1  INTEREST RATE MINUS INFLATION RATE, PERCENT,4X,
     +F12.1 )
 9000 FORMAT(///9H   ///// ,I3,34H FATAL INPUT DATA ERRORS DETECTED.,1X,
     + 18HEXECUTION ABORTED.,9X,5H///// )
C
      END
```

```
      SUBROUTINE ERR( VARNO )
CC
C     ERR - RECORD INPUT VARIABLE ERROR ON OUTPUT FILE
C
      COMMON /ERROR/ NERR
C
      NERR = NERR + 1
      WRITE(6,1000) VARNO
 1000 FORMAT(26H    ///// ERROR IN VARIABLE,F5.1,
     + 53H, SEE RPRDS=1 INPUT GUIDE AND/OR USERS MANUAL.  ///// )
C
      RETURN
      END
```

```
      SUBROUTINE CONRSP
CC
C     CONRSP - CONTROL ROUTINE FOR GENERATING THE PAVEMENT
C              RESPONSES REQUIRED FOR EACH STRATEGY.
C
C     ENTRY/  NEXL   = NO. OF LAYERS IN EXISTING PAVEMENT.
C             EPVT   = ELASTIC MODULI OF EXISTING PAVEMENT LAYERS.
C             VPVT   = POISSONS RATIOS OF EXISTING PAVEMENT LAYERS.
C             THPVT  = THICKNESSES OF EXISTING PAVEMENT LAYERS.
C             WGT    = WEIGHT OF SINGLE TIRE ON DESIGN AXLE LOAD.
C             PST    = DESIGN LOAD TIRE PRESSURE.
C             NOV1   = NO. OF POSSIBLE FIRST OVERLAY TYPES.
C             ITYP1  = NO/YES SWITCHES ON TYPES OF FIRST OVERLAY.
C             ISWOV2 = NO/YES SWITCH ON IF SECOND OVERLAY CONSIDERED.
C             NOV2   = NO. OF POSSIBLE SECOND OVERLAY TYPES.
C             ITYP2  = NO/YES SWITCHES ON TYPES OF SECOND OVERLAY.
C             NACT1  = NO. OF AC FIRST OVERLAY THICKNESSES CONSIDERED.
C             ACT1   = AC FIRST OVERLAY THICKNESSES.
C             NACT2  = NO. OF AC SECOND OVERLAY THICKNESSES CONSIDERED.
C             ACT2   = AC SECOND OVERLAY THICKNESSES.
C             NPCCT  = NO. OF PCC OVERLAY THICKNESSES CONSIDERED.
C             PCCT   = PCC OVERLAY THICKNESSES.
C             ALOVT  = ALLOWABLE TOTAL OVERLAY THICKNESS.
C             ECKPCC = STIFFNESS OF CRACKED PCC.
C             ECKAC  = STIFFNESS OF CRACKED AC.
C             VCOMP  = POISSONS RATIO FOR COMPOSITE LAYER.
C             EOVAC  = ELASTIC MODULUS OF AC OVERLAY.
C             VOVAC  = POISSONS RATIO FOR AC OVERLAY.
C             EACFAT = ELASTIC MODULUS OF AC USED IN FATIGUE EQUATION.
C             EOVPCC = ELASTIC MODULUS OF PCC OVERLAY.
C             VOVPCC = POISSONS RATIO FOR PCC OVERLAY.
C             EBB    = BOND BREAKER STIFFNESS.
C             VBB    = POISSONS RATIO FOR BOND BREAKER.
C             THBB   = BOND BREAKER THICKNESS.
C
C     EXIT/   S0     = STRESS IN ORIGINAL PCC, NO OVERLAYS.
C             S0A    = STRESS IN ORIGINAL PCC, AC OVERLAY.
C             E1A    = STRAIN IN AC OVERLAY AFTER ORIGINAL PCC CRACKED.
C             S0AA   = STRESS IN ORIGINAL PCC, AC/AC OVERLAYS.
C             E1AA   = STRAIN IN FIRST AC OVERLAY AFTER ORIGINAL PCC
C                      CRACKED, AC/AC OVERLAYS.
C             E2AA   = STRAIN IN SECOND AC OVERLAY AFTER ORIGINAL PCC
C                      AND FIRST AC OVERLAY BECOME CRACKED.
C             S0AP   = STRESS IN ORIGINAL PAVEMENT, AC/PCC OVERLAYS.
C             S2AP1  = STRESS IN PCC SECOND OVERLAY, AC/PCC OVERLAYS.
C             S2AP2  = STRESS IN PCC SECOND OVERLAY AFTER ORIGINAL
C                      PCC BECOMES CRACKED, AC/PCC OVERLAYS.
C             S0BP   = STRESS IN ORIGINAL PCC, BONDED PCC OVERLAY.
C             S0BPA  = STRESS IN ORIGINAL PCC, BONDED PCC/AC OVERLAYS.
C             E2BPA  = STRAIN IN AC SECOND OVERLAY AFTER ORIGINAL PCC
C                      AND BONDED PCC SECOND OVERLAY BECOME CRACKED.
C             S0UP   = STRESS IN ORIGINAL PCC, UNBONDED PCC OVERLAY.
C             S1UP1  = STRESS IN UNBONDED PCC OVERLAY.
C             S1UP2  = STRESS IN UNBONDED PCC OVERLAY AFTER ORIGINAL
C                      PCC BECOMES CRACKED.
C             S0UPA  = STRESS IN ORIGINAL PCC, UNBONDED PCC/AC OVERLAYS.
C             S1UPA1 = STRESS IN UNBONDED PCC FIRST OVERLAY, AC SECOND
C                      OVERLAY.
C             S1UPA2 = STRESS IN UNBONDED PCC FIRST OVERLAY AFTER
C                      ORIGINAL PCC BECOMES CRACKED, AC SECOND OVERLAY.
C             E2UPA  = STRAIN IN AC SECOND OVERLAY AFTER ORIGINAL PCC
C                      AND UNBONDED PCC FIRST OVERLAY BECOME CRACKED.
C
      COMMON /OVTYP/ ISWOV1, NOV1, ITYP1(5), ISWOV2, NOV2, ITYP2(3)
C
      COMMON /OVTHIK/ NACT1, ACT1(8), NACT2, ACT2(8), NPCCT, PCCT(8)
     0               , ALOVT, AVGLUT, THBB
C
      COMMON /EXPVMT/ NEXL, EPVT(5), VPVT(5), THPVT(5)
C
      COMMON /LAYSYS/ NS, TH(8), E(8), V(8)
C
      COMMON /LAYCOM/ WGT, PST, NR, RR(2), NZ, ZZ(5)
C
      COMMON /ELPROP/
     0 ECKPCC, ECKAC, VCOMP,
     1 EOVAC, VOVAC, EACFAT,
     2 EOVPCC, VOVPCC,
     3 EBB, VBB
C
      COMMON /PAVRSP/
     0 S0,
     1 S0A(8), E1A(8),
     2 S0AA(8,8), E1AA(8,8),  E2AA(8,8),
     3 S0AP(8,8), S2AP1(8,8), S2AP2(8,8),
     4 S0BP(8),
     5 S0BPA(8,8), E2BPA(8,8),
     6 S0UP(8), S1UP1(8), S1UP2(8),
     7 S0UPA(8,8), S1UPA1(8,8), S1UPA2(8,8), E2UPA(8,8)
C
      DIMENSION RESP(2), ECAC1(8), ECBPC1(8), ECUPC1(8)
C
C     STATEMENT FUNCTION FOR CHARACTERIZING CRACKED PAVEMENT
C     AS A SINGLE LAYER WITH A COMPOSITE MODULUS.
      ECOMP( DEF ) = 683.625/DEF
C
C     STRESS IN ORIGINAL PAVEMENT, NO OVERLAY.
C
CS    WRITE(2,6)
```

```
C$  6 FORMAT(/5X,*S1*)
      NS = NEXL
      DO 10 I=1,NEXL
      E(I) = EPVT(I)
      V(I) = VPVT(I)
      TH(I) = THPVT(I)
   10 CONTINUE
      NZ = 1
      ZZ(1) = THPVT(1)
      CALL FETCH( 1, RESP )
      S0 = RESP(1)
      IF(ITYP1(1) .EQ. 0) GO TO 50
C
C     COMPOSITE MODULUS AFTER ORIGINAL PCC CRACKED. REQUIRED
C     ONLY IF AN AC 1ST OVERLAY IS A POSSIBLE STRATEGY.
      E(1) = ECKPCC
      IF (E(2) .GT. E(1)) E(2)=E(1)
      ZZ(1) = 0.0
      CALL FETCH( 3, RESP )
      DEFEP = RESP(1)
      ECEP = ECOMP( DEFEP )
C
C     PAVEMENT RESPONSES AFTER FIRST OVERLAY (AND BEFORE SECOND).
C
C     FIRST OVERLAY = AC, STRESS IN ORIGINAL PCC.
C$    WRITE(2,16)
C$ 16 FORMAT(/5X,*S0A*)
      NS = NEXL + 1
      DO 20 I=1,NEXL
      E(L+1) = EPVT(L)
      V(L+1) = VPVT(L)
      TH(L+1) = THPVT(L)
   20 CONTINUE
      E(1) = EOVAC
      V(1) = VOVAC
      NZ = 1
      DO 30 I=1,NACT1
      TH(1) = ACT1(I)
      ZZ(1) = TH(1) + TH(2)
      CALL FETCH( 1, RESP )
      S0A(I) = RESP(1)
   30 CONTINUE
C
C     FIRST OVERLAY = AC, STRAIN IN AC AFTER ORIGINAL PCC CRACKED
C     AND COMPOSITE MODULUS AFTER AC CRACKED.
C$    WRITE(2,36)
C$ 36 FORMAT(/5X,*E1A*)
      NS = 2
      E(2) = ECEP
      V(2) = VCOMP
      NZ = 1
      DO 40 I=1,NACT1
      E(1) = EACFAT
      TH(1) = ACT1(I)
      ZZ(1) = TH(1)
      CALL FETCH( 2, RESP )
      E1A(I) = RESP(1)
      IF (ITYP2(1) .EQ. 0) GO TO 40
      E(1) = ECKAC
      ZZ(1) = 0.0
      CALL FETCH( 3, RESP )
      DEFAC1 = RESP(1)
      ECAC1(I) = ECOMP( DEFAC1 )
   40 CONTINUE
C
   50 CONTINUE
      IF (ITYP1(2) .EQ. 0)  GO TO 80
C
C     FIRST OVERLAY = BONDED PCC. STRESSSESS IN ORIGINAL PCC
C     AND COMPOSITE MODULUS AFTER BOTH PCC LAYERS CRACKED.
C$    WRITE(2,56)
C$ 56 FORMAT(/5X,*S0BP*)
      NS = NEXL + 1
      DO 60 I=1,NEXL
      E(L+1) = EPVT(L)
      V(L+1) = VPVT(L)
      TH(L+1) = THPVT(L)
   60 CONTINUE
      V(1) = VOVPCC
      NZ = 1
      DO 70 I=1,NPCCT
      E(1) = EOVPCC
      E(2) = EPVT(1)
      E(3) = EPVT(2)
      TH(1) = PCCT(I)
      ZZ(1) = TH(1) + TH(2)
      CALL FETCH( 1, RESP )
      S0BP(I) = RESP(1)
      IF (ITYP2(1) .EQ. 0) GO TO 70
      E(1) = ECKPCC
      E(2) = ECKPCC
      IF (E(3) .GT. E(2)) E(3)=E(2)
      ZZ(1) = 0.0
      CALL FETCH( 3, RESP )
      DEBPC1 = RESP(1)
      ECBPC1(I) = ECOMP( DEBPC1 )
   70 CONTINUE
C
   80 CONTINUE
      IF (ITYP1(3) .EQ. 0 .AND. ITYP1(5) .EQ. 0) GO TO 120
C
C     FIRST OVERLAY = UNBONDED PCC. STRESSES IN ORIGINAL PCC AND PCC
C     OVERLAY.
C$    WRITE(2,86)
C$ 86 FORMAT(/5X,*S0UP*)
      NS = NEXL + 2
      DO 90 I=1,NEXL
      E(L+2) = EPVT(L)
      V(L+2) = VPVT(L)
      TH(L+2) = THPVT(L)
   90 CONTINUE
      E(1) = EOVPCC
      V(1) = VOVPCC
      E(2) = EBB
      V(2) = VBB
      TH(2) = THBB
      NZ = 2
      DO 100 I=1,NPCCT
      TH(1) = PCCT(I)
      ZZ(1) = TH(1)
      ZZ(2) = TH(1) + TH(2) + TH(3)
      CALL FETCH( 1, RESP )
      S0UP(I) = RESP(2)
      S1UP1(I) = RESP(1)
```

```
  100 CONTINUE
C     FIRST OVERLAY - UNBONDED PCC, STRESS IN PCC OVERLAY AFTER
C     ORIGINAL PCC CRACKED. ALSO, COMPOSITE MODULUS AFTER BOTH PCC
C     LAYERS CRACKED.
      E(3) = ECKPCC
      IF (E(4) .GT. E(3))  E(4)=E(3)
      NZ = 1
      DO 110 I=1,NPCCT
      TH(1) = PCCT(I)
      E(1) = EOVPCC
      ZZ(1) = TH(1)
      CALL FETCH( 1, RESP )
      S1UP2(I) = RESP(1)
      IF (ITYP2(1) .EQ. 0) GO TO 110
      E(1) = ECKPCC
      ZZ(1) = 0.0
      CALL FETCH( 3, RESP )
      DEUPC1 = RESP(1)
      ECUPC1(I) = ECOMP( DEUPC1 )
  110 CONTINUE
C
  120 CONTINUE
      IF (ISWOV2 .EQ. 0) RETURN
C
C     PAVEMENT RESPONSES AFTER SECOND OVERLAY.
C
      IF (ITYP2(1) .EQ. 0) GO TO 300
C
C     SECOND OVERLAY = AC.
      IF (ITYP1(1) .NE. 1) GO TO 170
C     STRESS IN ORIGINAL PCC AFTER 1ST AND 2ND AC OVERLAYS.
C     NOTE THAT THE TWO AC OVERLAYS ARE COMBINED TO MINIMIZE
C     COMPUTATION TIME.
C$    WRITE(2,126)
C$126 FORMAT(/5X,*S0AA*)
      NS = NEXL + 1
      DO 130 L=1,NEXL
      E(L+1) = EPVT(L)
      V(L+1) = VPVT(L)
      TH(L+1) = THPVT(L)
  130 CONTINUE
      E(1) = EOVAC
      V(1) = VOVAC
      NZ = 1
      DO 140 I=1,NACT1
      DO 140 J=1,NACT2
      TH(1) = ACT1(I) + ACT2(J)
      IF (TH(1) .GT. ALOVT) GO TO 140
      ZZ(1) = TH(1) + TH(2)
      CALL FETCH( 1, RESP )
      S0AA(I,J) = RESP(1)
  140 CONTINUE
C     STRAIN IN 1ST AC OVERLAY AFTER 2ND AC OVERLAY AND AFTER
C     ORIGINAL PCC CRACKED.
C$    WRITE(2,146)
C$146 FORMAT(/5X,*E1AA*)
      NS = 3
      E(1) = EOVAC
      V(1) = VOVAC
      E(2) = EACFAT
      V(2) = VOVAC
      E(3) = ECEP
      V(3) = VCOMP
      TH(3) = 0.0
      NZ = 1
      DO 150 I=1,NACT1
      TH(2) = ACT1(I)
      DO 150 J=1,NACT2
      TH(1) = ACT2(J)
      IF (ACT1(I)+ACT2(J) .GT. ALOVT) GO TO 150
      ZZ(1) = TH(1) + TH(2)
      CALL FETCH( 2, RESP )
      E1AA(I,J) = RESP(1)
  150 CONTINUE
C     STRAIN IN 2ND AC OVERLAY AFTER 1ST AC OVERLAY AND ORIGINAL
C     PCC BECOME CRACKED.
C$    WRITE(2,156)
C$156 FORMAT(/5X,*E2AA*)
      NS = 2
      E(1) = EACFAT
      V(1) = VOVAC
      V(2) = VCOMP
      TH(2) = 0.0
      NZ = 1
      DO 160 I=1,NACT1
      E(2) = ECAC1(I)
      DO 160 J=1,NACT2
      IF (ACT1(I)+ACT2(J) .GT. ALOVT) GO TO 160
      TH(1) = ACT2(J)
      ZZ(1) = TH(1)
      CALL FETCH( 2, RESP )
      E2AA(I,J) = RESP(1)
  160 CONTINUE
C
  170 CONTINUE
      IF (ITYP1(2) .EQ. 0 .AND. ITYP1(4) .EQ. 0) GO TO 210
C
C     STRESS IN ORIGINAL PAVEMENT AFTER BONDED PCC 1ST OVERLAY,
C     AC 2ND OVERLAY.
C$    WRITE(2,176)
C$176 FORMAT(/5X,*S0BPA*)
      NS = NEXL + 2
      DO 180 L=1,NEXL
      E(L+2) = EPVT(L)
      V(L+2) = VPVT(L)
      TH(L+2) = THPVT(L)
  180 CONTINUE
      E(1) = EOVAC
      V(1) = VOVAC
      E(2) = EOVPCC
      V(2) = VOVPCC
      NZ = 1
      DO 190 I=1,NPCCT
      TH(2) = PCCT(I)
      DO 190 J=1,NACT2
      IF (PCCT(I)+ACT2(J) .GT. ALOVT) GO TO 190
      TH(1) = ACT2(J)
      ZZ(1) = TH(1) + TH(2) + TH(3)
      CALL FETCH( 1, RESP )
      S0BPA(I,J) = RESP(1)
  190 CONTINUE
C
C     STRAIN IN 2ND OVERLAY (AC) AFTER ORIGINAL PAVEMENT AND BONDED
C     PCC 1ST OVERLAY BECOME CRACKED.
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```
C$    WRITE(2,196)
C$196 FORMAT(/5X,*E2APA*)
      NS = 2
      E(1) = EACFAT
      V(1) = VOVAC
      V(2) = VCOMP
      TH(2) = 0.0
      NZ = 1
      DO 200 I=1,NPCCT
      E(2) = ECBPC1(I)
      DO 200 J=1,NACT2
      IF (PCCT(I)+ACT2(J) .GT. ALOVT) GO TO 200
      TH(1) = ACT2(J)
      ZZ(1) = TH(1)
      CALL FETCH( 2, RESP )
      E2APA(I,J) = RESP(1)
  200 CONTINUE
C
  210 CONTINUE
      IF (ITYP1(3) .EQ. 0 .AND. ITYP1(5) .EQ. 2) GO TO 300
C
C     STRESSES IN ORIGINAL PAVEMENT AND UNBONDED PCC 1ST OVERLAY
C     AFTER 2ND AC OVERLAY.
C$    WRITE(2,216)
C$216 FORMAT(/5X,*SOUPA*)
      NS = NEXL + 3
      DO 220 L=1,NEXL
      E(L+3) = EPVT(L)
      V(L+3) = VPVT(L)
      TH(L+3) = THPVT(L)
  220 CONTINUE
      E(1) = EOVAC
      V(1) = VOVAC
      E(2) = EOVPCC
      V(2) = VOVPCC
      E(3) = EBB
      V(3) = VBB
      TH(3) = THBB
      NZ = 2
      DO 230 I=1,NPCCT
      TH(2) = PCCT(I)
      DO 230 J=1,NACT2
      IF (THBB+PCCT(I)+ACT2(J) .GT. ALOVT) GO TO 230
      TH(1) = ACT2(J)
      ZZ(1) = TH(1) + TH(2)
      ZZ(2) = TH(1) + TH(2) + TH(3) + TH(4)
      CALL FETCH( 1, RESP )
      S2UPA(I,J) = RESP(2)
      S1UPA1(I,J) = RESP(1)
  230 CONTINUE
C
C     STRESS IN UNBONDED PCC 1ST OVERLAY WITH 2ND AC OVERLAY AFTER
C     ORIGINAL PCC CRACKED.
C$    WRITE(2,236)
C$236 FORMAT(/5X,*S1UPA2*)
      E(4) = ECKPCC
      IF (E(5) .GT. E(4)) E(5)=E(4)
      NZ = 1
      DO 240 I=1,NPCCT
      TH(2) = PCCT(I)
      DO 240 J=1,NACT1
      IF (THBB+PCCT(I)+ACT2(J) .GT. ALOVT) GO TO 240
      TH(1) = ACT2(J)
      ZZ(1) = TH(1) + TH(2)
      CALL FETCH( 1, RESP )
      S1UPA2(I,J) = RESP(1)
  240 CONTINUE
C
C     STRAIN IN AC SECOND OVERLAY AFTER ORIGINAL PCC AND UNBONDED
C     PCC 1ST OVERLAY BECOME CRACKED.
C$    WRITE(2,206)
C$206 FORMAT(/5X,*E2UPA*)
      NS = 2
      E(1) = EACFAT
      V(1) = VOVAC
      V(2) = VCOMP
      TH(2) = 0.0
      NZ = 1
      DO 250 I=1,NPCCT
      E(2) = ECUPC1(I)
      DO 250 J=1,NACT2
      IF (THBB+PCCT(I)+ACT2(J) .GT. ALOVT) GO TO 250
      TH(1) = ACT2(J)
      ZZ(1) = TH(1)
      CALL FETCH( 2, RESP )
      E2UPA(I,J) = RESP(1)
  250 CONTINUE
C
  300 CONTINUE
C
C     SECOND OVERLAY = PCC
C
      IF (ITYP1(1) .NE. 1) GO TO 400
C
C     STRESS IN ORIGINAL PCC AND PCC 2ND OVERLAY.
C     (FIRST OVERLAY = AC)
C$    WRITE(2,306)
C$306 FORMAT(/5X,*S2AP*)
      NS = NEXL + 2
      DO 310 L=1,NEXL
      E(L+2) = EPVT(L)
      V(L+2) = VPVT(L)
      TH(L+2) = THPVT(L)
  310 CONTINUE
      E(1) = EOVPCC
      V(1) = VOVPCC
      E(2) = EOVAC
      V(2) = VOVAC
      NZ = 2
      DO 320 I=1,NACT1
      TH(2) = ACT1(I)
      DO 320 J=1,NPCCT
      IF (ACT1(I)+PCCT(J) .GT. ALOVT) GO TO 320
      TH(1) = PCCT(J)
      ZZ(1) = TH(1)
      ZZ(2) = TH(1) + TH(2) + TH(3)
      CALL FETCH( 1, RESP )
      S2AP(I,J) = RESP(2)
      S2AP1(I,J) = RESP(1)
  320 CONTINUE
C
C     STRESS IN PCC 2ND OVERLAY AFTER ORIGINAL PCC CRACKED.
C     (FIRST OVERLAY = AC).
C$    WRITE(2,326)
```

```
C5326 FORMAT(/5X,*S2AP2*)
      F(3) = ECKPCC
      IF (F(4) .GT. F(3)) F(4)=F(3)
      NZ = 1
      DO 330 I=1,NACT
      TH(2) = ACT1(I)
      DO 330 J=1,NPCT
      IF (ACT1(I)+PCCT(J) .GT. ALOVT) GO TO 330
      TH(1) = PCCT(J)
      ZZ(1) = TH(1)
      CALL FETCH( 1, RESP )
      S2AP2(I,J) = RESP(1)
  330 CONTINUE
C
  400 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE FETCH( IRTYP, RESP )
CC
C     FETCH - FETCH ELASTIC RESPONSE FROM DESIRED ELASTIC LAYER MODEL
C
C     ENTRY/  IRTYP  = TYPE OF RESPONSE DESIRED.
C                    = 1. FOR MAXIMUM STRESS,
C                    = 2. FOR MAXIMUM STRAIN,
C                    = 3. FOR MAXIMUM DEFLECTION.
C             TRSPNT = POINTER TO THE METHOD FOR CALCULATING RESPONSE,
C                    = 1. IF LAYER SUBROUTINE PACKAGE TO BE USED.
C                    = 2. IF LAYER REGRESSION MODELS TO BE USED.
C             NZ     = NUMBER OF DEPTHS WHERE RESPONSE DESIRED.
C
C     EXIT/   RESP   = VALUE OF THE RESPONSE AT THE DEPTHS REQUESTED.
C
      COMMON /LAYCOM/ WGT, PST, NR, RR(2), NZ, ZZ(5)
C
      COMMON /RESPNS/ SZ(2,5), ST(2,5), SR(2,5), SS(2,5), SW(2,5),
     >JT(2,5), LN(5), DZ(2,5), FT(2,5), ER(2,5), ES(2,5), FR(2,5)
C
      COMMON /RSPNTR/ TRSPNT
C
      DIMENSION RESP(2)
C
      IF (IRTYP .EQ. 3) GO TO 1
      IF (TRSPNT .EQ. 2) GO TO 100
C
C     IF USE OF REGRESSION EQUATIONS NOT DESIRED OR A DEFLECTION
C     IS DESIRED, CALL LAYER PACKAGE FOR DESIRED RESPONSES. NOTE
C     THAT SUPERPOSITION IS USED TO ACCOUNT FOR EFFECT OF TWO LOADS.
    1 CONTINUE
      CALL LAYER
      GO TO ( 10, 20, 30 ), IRTYP
   10 CONTINUE
C     STRESS RESPONSE
      RESP(1) = SR(1,1) + AMAX1( ST(2,1), SR(2,1) )
      RESP(2) = 1.00
      IF (NZ .EQ. 2) RESP(2) = SR(1,2) + AMAX1( ST(2,2), SR(2,2) )
      RETURN
   20 CONTINUE
C     STRAIN RESPONSE
      RESP(1) = ER(1,1) + AMAX1( ET(2,1), ER(2,1) )
      RESP(2) = 1903.
      RETURN
   30 CONTINUE
C     DEFLECTION RESPONSE
      RESP(1) = DZ(1,1) + DZ(2,1)
      RESP(2) = 1403.
      RETURN
  100 CONTINUE
C
C     USE REGRESSION MODELS FOR RESPONSE, IF DESIRED (AND IF
C     POSSIBLE). NOTE THAT FOR REGRESSION MODELS, NO
C     SUPERPOSITION IS REQUIRED.
      CALL REGRSP( IRTYP, RESP )
      IF (RESP(1) .LE. 0.0) GO TO 1
C
      RETURN
      END
```

```
      SUBROUTINE LAYER
CC
C     LAYER - ELASTIC LAYERED SYSTEM SIMULATION
C
C          THIS PACKAGE WAS ADAPTED FROM THE LAYER15 PROGRAM
C     DEVELOPED BY CHEVRON RESEARCH AND CALIFORNIA RESEARCH CORP.
C     REFS.  *ANALYSIS OF STRESS AND DISPLACEMENTS IN AN N-LAYERED
C               ELASTIC SYSTEM UNDER LOAD UNIFORMLY DISTRIBUTED ON A
C               CIRCULAR AREA*, CALIF. RESEARCH CORP., J. MICHELOW,
C               SEPTEMBER 1963.
C              *NUMERICAL COMPUTATIONS ...*, CALIF. RESEARCH CORP.,
C               H. WARREN AND W. L. DIECKMAN, SEPTEMBER 24, 1963.
C     NOTE - THE ACTUAL VERSION WHICH APPEARS HERE WAS PREVIOUSLY
C     MODIFIED BY THE TEXAS TRANSPORTATION INSTITUTE AT TEXAS A&M
C     UNIVERSITY (BY COGILL, MICHALAK, AND SHAFER, DEPT OF PAVEMENT
C     DESIGN) FOR USE ON IBM 360/365.
C
C     LATEST REVISION - CENTER FOR TRANSP. RESEARCH, UNIVERSITY OF
C     TEXAS AT AUSTIN, NOV 1980, S B SEEDS.  IT CAN HANDLE ONLY
C     8-LAYER SYSTEMS WITHOUT CHANGING DIMENSIONS.  ALSO, A NEW
C     SUBROUTINE (COFE) SUPPLIED BY CHEVRON WAS INCORPORATED INTO
C     THE PACKAGE TO IMPROVE SPEED AND ACCURACY FOR PROBLEMS WITH
C     MORE THAN 5 LAYERS.  UNFORTUNATELY, COFE CANNOT HANDLE 1-LAYER
C     PROBLEMS UNLESS THEY ARE SIMULATED WITH 2 LAYERS.
C
C*****************************************************************
CC
C     /LAYSYS/ - ELASTIC LAYERED SYSTEM DESCRIPTION
C
      COMMON /LAYSYS/ NS, TH(8), E(8), V(8)
C
C       NS      = NO. OF ELASTIC LAYERS
C       TH      = THICKNESSES FOR EACH LAYER (TOP TO BOTTOM)
C       E       = ELASTIC MODULI FOR EACH LAYER
C       V       = POISSONS RATIO FOR EACH LAYER
```

```
CC
C     /LAYCOM/ - COMMUNICATIONS BLOCK FOR LAYER PACKAGE
C
      COMMON /LAYCOM/ WGT, PST, NR, RR(2), NZ, ZZ(5)
C
C       WGT      = LOAD MAGNITUDE
C       PST      = LOAD PRESSURE
C       NR       = NO. OF RADIAL POINTS WHERE RESULTS ARE DESIRED
C       RR       = ARRAY OF RADIAL POINTS WHERE RESULTS ARE DESIRED
C       NZ       = NO. OF DEPTHS WHERE RESULTS ARE DESIRED
C       ZZ       = ARRAY OF DEPTHS WHERE RESULTS ARE DESIRED
CC
C     /RESPNS/ - ELASTIC SYSTEM RESPONSE
C
      COMMON /RESPNS/ SZ(2,5), ST(2,5), SR(2,5), SS(2,5), SB(2,5),
     +IT(2,5), LN(5), DZ(2,5), ET(2,5), ER(2,5), ES(2,5), EB(2,5)
C
C       SZ       = VERTICAL STRESS
C       ST, ET = TANGENTIAL STRESSES AND STRAINS
C       SR, ER = RADIAL STRESSES AND STRAINS
C       SS, ES = SHEAR STRESSES AND STRAINS
C       SB, EB = BULK STRESSES AND STRAINS
C       DZ       = VERTICAL DISPLACEMENT
C       LN       = LAYER NO. FOR WHICH RESPONSES DETERMINED
C       IT       = SUBROUTINE CALCIN SWITCH
CC
C     BLANK COMMON USED AS WORKING STORAGE
C
      COMMON H(7), R, Z, AR, ARP, N, L, ITN, P, SF, NTEST, IR, IZ,
     +        AZ(184), AJ(184), RJ1(184), RJ0(184),
     +        A(184,8), B(184,8), C(184,8), D(184,8)
C
      ITN = 46
      ITN4 = 4*ITN
      N = NS - 1
      AR = SQRT(0.3183098862*WGT/PST)
      ARP = AR*PST
C
C     DETERMINE DEPTHS TO EACH INTERFACE
      H(1) = TH(1)
      IF (N .LE. 1) GO TO 25
      DO 20 I=2,N
   20 H(I) = H(I-1) + TH(I)
   25 CONTINUE
C
C     START ON NEW R
      DO 100 IR=1,NR
      R = RR(IR)
C     CALCULATE THE PARTITION
      CALL PART
C     CALCULATE THE COEFFICIENTS
      DO 40 I=1,ITN4
      P = AZ(I)
      CALL COFE(I)
      IF (R .LE. 1.0) GO TO 30
      PR = P*R
      CALL BESSEL(0,PR,Y)
      RJ0(I) = Y
      CALL BESSEL(1,PR,Y)
      RJ1(I) = Y
   30 PA = P*AR
      CALL BESSEL(1,PA,Y)
      AJ(I) = Y
   40 CONTINUE
C
C     START ON NEW Z
      DO 80 IZ=1,NZ
      Z = ZZ(IZ)
C     FIND LAYER CONTAINING Z
      L = 0
   50 L = L + 1
      IF (L .EQ. NS) GO TO 60
      IF (Z .GT. H(L)) GO TO 50
   60 CONTINUE
      LN(IZ) = L
C
C     DETERMINE RESPONSE
      CALL CALCIN
   80 CONTINUE
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE COFE(KIN)
CC
C     COFE - THIS SUBROUTINE REPLACES THE ORIGINAL COEE SUBROUTINE
C            IN THE LAYER PACKAGE.  COFE IS A MODIFIED VERSION OF COEE
C            (BY L J PAINTER, MAY 1980) TO IMPROVE THE SPEED AND
C            ACCURACY OF PROBLEMS WITH MORE THAN FIVE LAYERS.
C
C     NOTE - COFE WAS CHANGED ONCE AGAIN (BY S B SEEDS, NOV 1984) FOR
C            COMPATIBILITY WITH THE CURRENT UNIV OF TEXAS VERSION OF
C            THE LAYER PROGRAM.
C
      COMMON /LAYSYS/ NS, TH(8), E(8), V(8)
      COMMON H(7), R, Z, AR, ARP, N, L, ITN, P, SF, NTEST, IR, IZ,
     +        AZ(184), AJ(184), RJ1(184), RJ0(184),
     +        A(184,8), B(184,8), C(184,8), D(184,8)
      DIMENSION PM(7,4,4), X(8,4,4), SC(7), EM(7)
      DIMENSION Q(2,2)
C
         IC = KIN
CS*MY         SET UP MATRIX X =DT*MT*KI*K*M*D
C     COMPUTE THE MATRICES X(K)
    1 DO 10 K=1,N
      T1=E(K)*(1.0+V(K+1))/(E(K+1)*(1.0+V(K)))
      T1M=T1-1.0
      PH=P*H(K)
      PH2=PH*2.0
      VK2=2.0*V(K)
      VKP2=2.0*V(K+1)
      VK4=2.0*VK2
      VKP4=2.0*VKP2
      VKK8=8.0*V(K)*V(K+1)
C
      X(K,1,1)=VK4-3.0-T1
      X(K,2,1)=0.0
      X(K,3,1)=T1M*(PH2-VK4+1.0)
      X(K,4,1)=-2.0*T1M*P
```

```
C
      T3=PH2*(VK2-1.0)
      T4=VKK8+1.0-3.0*VKP2
      T5=PH2*(VKP2-1.0)
      T6=VKK8+1.0-3.0*VK2
C
      X(K,1,2)=(T3+T4-T1*(T5+T6))/P
      X(K,2,2)=T1*(VKP4-3.0)-1.0
      X(K,4,2)=T1M*(1.0-PH2-VKP4)
C
      X(K,3,4)=(T3-T4-T1*(T5-T6))/P
C
      T3=PH2+PH-VKK8+1.0
      T4=PH2*(VK2-VKP2)
C
      X(K,1,4)=(T3+T4+VKP2-T1*(T3+T4+VK2))/P
      X(K,3,2)=    (-T3+T4-VKP2+T1*(T3-T4+VK2))/P
C
      X(K,1,3)=T1M*(1.0-PH2-VK4)
      X(K,2,3)=2.0*T1M*P
      X(K,3,3)=VK4-3.0-T1
      X(K,4,3)=0.0
C
      X(K,2,4)=T1M*(PH2-VKP4+1.0)
      X(K,4,4)=T1*(VKP4-3.0)-1.0
C     K = K
   10 CONTINUE
C     COMPUTE THE PRODUCT MATRICES PM
      SC(N)=4.0*(V(N)-1.0)
      IF (N-2) 13,11,11
   11 DO 12 K1=2,N
      M=NS-K1
      SC(M)=SC(M+1)*4.0*(V(M)-1.0)
   12 CONTINUE
   13 CONTINUE
C
      Q(1,1)=1.
      Q(2,2)=1.
      Q(1,2)=0.
      QQ     =P*2.*H(N)
      IF (QQ-172.) 15,15,16
   15 CONTINUE
      D(1,2)=EXP(-QQ)
C     D(2,1) IS NOT NEEDED FOR INITIALIZING THE PM MATRIX
   16 CONTINUE
C      20 LOOP INITIALIZES PM(N,,)
      DO 20 M=1,4
      LL=(M+1)/2
      DO 20 J=3,4
      PM(N,M,J)= X(N,M,J) *      D(LL,2)
   20 CONTINUE
C     NEXT LINE INSERTED TO AVOID PROBLEM WITH 2-LAYER SYSTEMS
      IF (N .LT. 2) GO TO 30
      DO 26 K1=2,N
      K=NS-K1
      KK=K+1
      QQ     =P*2.*H(K)
      IF (QQ-172.) 22,22,23
   22 CONTINUE
      D(2,1)=EXP(QQ)
      Q(1,2)=1./D(2,1)
      GO TO 24
   23 CONTINUE
      D(1,2)=0.
      D(2,1)=1.E20
   24 CONTINUE
      DO 25 M=1,4
      LL=(M+1)/2
      DO 25 J=3,4
      PM(K,M,J)=( X(K,M,1) * PM(KK,1,J)
     2             +X(K,M,2) * PM(KK,2,J) ) * Q(LL,1)
     3          +( X(K,M,3) * PM(KK,3,J)
     4             +X(K,M,4) * PM(KK,4,J) ) * Q(LL,2)
   25 CONTINUE
   26 CONTINUE
C     SOLVE FOR C(NS) AND D(NS)
   30 CONTINUE
      T3=2.0*V(1)
      T4 =T3-1.0
      FM(1)= P*(PM(1,1,3)+PM(1,3,3)) + T3*(PM(1,2,3)-PM(1,4,3))
      FM(2)= P*(PM(1,1,3)-PM(1,3,3)) + T4*(PM(1,2,3)+PM(1,4,3))
      FM(3)= P*(PM(1,1,4)+PM(1,3,4)) + T3*(PM(1,2,4)-PM(1,4,4))
      FM(4)= P*(PM(1,1,4)-PM(1,3,4)) + T4*(PM(1,2,4)+PM(1,4,4))
      DFAC=SC(1)/((FM(1)*FM(4)-FM(3)*FM(2))*P*P)
          A(LC,NS) = 0.0
          B(LC,NS) = 0.0
          C(LC,NS) = -FM(3)*DFAC
          D(LC,NS) =  FM(1)*DFAC
C     BACKSOLVE FOR THE OTHER A,B,C,D
      DO 91 K1=1,N
      A(LC,K1)=(PM(K1,1,3)*C(LC,NS)+PM(K1,1,4)*D(LC,NS))/SC(K1)
      B(LC,K1)=(PM(K1,2,3)*C(LC,NS)+PM(K1,2,4)*D(LC,NS))/SC(K1)
      C(LC,K1)=(PM(K1,3,3)*C(LC,NS)+PM(K1,3,4)*D(LC,NS))/SC(K1)
   91 D(LC,K1)=(PM(K1,4,3)*C(LC,NS)+PM(K1,4,4)*D(LC,NS))/SC(K1)
C
      RETURN
      END
```

```
      SUBROUTINE CALCIN
      COMMON /LAYSYS/ NS, TH(8), E(8), V(8)
      COMMON /RESPNS/ SZ(2,5), ST(2,5), SR(2,5), SS(2,5), SB(2,5),
     +JT(2,5), LN(5), DZ(2,5), ET(2,5), ER(2,5), ES(2,5), EB(2,5)
      COMMON H(7), R, Z, AR, ARP, N, L, ITN, P, SF, NTEST, IR, IZ,
     +        AZ(184), AJ(184), RJ1(184), RJ0(184),
     +        A(184,8), B(184,8), C(184,8), D(184,8)
      DIMENSION W(4), TEST(11)
      DATA IBLNK, ISTAR / 1H , 1H* /
C
          W(1) = 0.3478548
          W(2) = 0.6521451
          W(3) = W(2)
          W(4) = W(1)
      VL=2.0*V(L)
      EL=(1.0+V(L))/E(L)
      VL1=1.0-VL
      CSZ=0.0
      CST=0.0
      CSR=0.0
      CTR=0.0
```

```
      COM=0.0
      CMU=0.0
      NTS1 = NTEST + 1
      ITS = 1
      JT(IR,IZ) = IBLNK
      DO 40 I=1,ITN
C     INITIALIZE THE SUB-INTEGRALS
      RSZ=0.0
      RST=0.0
      RSR=0.0
      RTR=0.0
      ROM=0.0
      RMU=0.0
C     COMPUTE THE SUB-INTEGRALS
         K = 4*(I-1)
      DO 30 J=1,4
         J1 = K + J
      P=AZ(J1)
      EP=EXP (P*Z)
      T1=B(J1,L)*EP
      T2=D(J1,L)/EP
      T1P=T1+T2
      T1M=T1-T2
      T1=(A(J1,L)+B(J1,L)*Z)*EP
      T2=(C(J1,L)+D(J1,L)*Z)/EP
      T2P=P*(T1+T2)
      T2M=P*(T1-T2)
      WA=AJ(J1)*W(J)
      IF (R) 20,20,15
   15 BJ1=BJ1(J1)*P
      BJ0=BJ0(J1)*P
      RSZ=RSZ+WA*P*BJ0*(VL1*T1P-T2M)
      ROM=ROM+WA*EL*BJ0*(2.0*VL1*T1M-T2P)
      RTR=RTR+WA*P*BJ1*(VL*T1M+T2P)
      RMU=RMU+WA*EL*BJ1*(T1P+T2M)
      RSR=RSR+WA*(P*BJ0*((1.0+VL)*T1P+T2M)-BJ1*(T1P+T2M)/R)
      RST=RST+WA*(VL*P*BJ0*T1P+BJ1*(T1P+T2M)/R)
      GO TO 30
C     SPECIAL ROUTINE FOR R = ZERO
   20 PP=P*P
      RSZ=RSZ+WA*PP*(VL1*T1P-T2M)
      ROM=ROM+WA*EL*P*(2.0*VL1*T1M-T2P)
      RST=RST+WA*PP*((VL+0.5)*T1P+0.5*T2M)
      RSR=RST
   30 CONTINUE
C
       SF = (AZ(K+4) - AZ(K+1))/1.7222726
      CSZ=CSZ+RSZ*SF
      CST=CST+RST*SF
      CSR=CSR+RSR*SF
      CTR=CTR+RTR*SF
      COM=COM+ROM*SF
      CMU=CMU+RMU*SF
         RSZ = 2.0*RSZ+AR*SF
      TESTH = ABS(RSZ) - 1.0E-4
      IF (ITS-NTS1 ) 31,32,32
   31 CONTINUE
      TEST(ITS) = TESTH
      ITS = ITS+1
      GO TO 40
   32 CONTINUE
      TEST(NTS1) = TESTH
      DO 33 J = 1,NTEST
      IF (TESTH-TEST(J)) 35,36,36
   35 CONTINUE
      TESTH = TEST(J)
   36 CONTINUE
      TEST(J) = TEST(J+1)
   33 CONTINUE
      IF (TESTH) 50,50,40
   40 CONTINUE
      JT(IR,IZ) = ISTAR
   50 CSZ=CSZ*ARP
      CST=CST*ARP
      CTR=CTR*ARP
      CSR=CSR*ARP
      COM=COM*ARP
      CMU=CMU*ARP
      RSTS = CSZ+CST+CSR
      RST  = RSTS * (1.0-2.0*V(L))/F(L)
      RDS=(CSR-V(L)*(CSZ+CST))/F(L)
      TST=(CST-V(L)*(CSZ+CSR))/F(L)
      SST=2.0*(1.0+V(L))*CTR/F(L)
C
      SZ(IR,IZ) = CSZ
      ST(IR,IZ) = CST
      SR(IR,IZ) = CSR
      SS(IR,IZ) = CTR
      S9(IR,IZ) = RSTS
      ER(IR,IZ) = RDS
      ET(IR,IZ) = TST
      ES(IR,IZ) = SST
      E9(IR,IZ) = RST
      DZ(IR,IZ) = COM
      RETURN
      END
```

```
      SUBROUTINE PART
      COMMON W(7), R, Z, AR, ARP, N, L, ITN, P, SF, NTEST, IR, IZ,
     +       AZ(184), AJ(184), BJ1(184), BJ0(184),
     +       A(184,8), B(184,8), C(184,8), D(184,8)
      DIMENSION BZ(100)
C
C        ** COMPUTE ZEROS OF J1(X) AND J0(X), SET UP GAUSS CONSTANTS **
      BZ(1) = 0.0
      BZ(2) = 1.0
      BZ(3) = 2.4048
      BZ(4) = 3.8317
      BZ(5) = 5.5201
      BZ(6) = 7.0156
      K = ITN+1
         DO 2 I=7,K,2
          T = I/2
          TD = 4.0*T - 1.0
    2     BZ(I) = 3.141592 *(T - 0.25 + 0.050661/TD
     1            -0.053041/TD**3 + 0.262051/TD**5)
         DO 3 I=8,ITN,2
          T = (I-2)/2
          TD = 4.0*T + 1.0
```

```
3        BZ(I) = 3.141592 *(I + 0.25 - 0.151982/TD                        PA  23
 1              + 0.015399/TD**3 - 0.245270/TD**5)                         PA  24
      G1=0.8611363                                                         PA  25
      G2=0.3399810                                                         PA  26
      ZE = AB                                                              PA  27
      NTEST = 2                                                            PA  28
      IF (B) 8,8,9                                                         PA  29
    9 CONTINUE                                                             PA  30
      NTEST = AB/B + 1.0E-4                                                PA  31
      IF (NTEST) 6,6,5                                                     PA  32
    6 CONTINUE                                                             PA  33
      NTEST = B/AB + 1.0E-4                                                PA  34
      ZE = B                                                               PA  35
    5 CONTINUE                                                             PA  36
      NTEST = NTEST + 1                                                    PA  37
      IF (NTEST-10) 8,8,7                                                  PA  38
    7 CONTINUE                                                             PA  39
      NTEST = 10                                                           PA  40
    8 CONTINUE                                                             PA  41
C          ** COMPUTE POINTS FOR LEGENDRE-GAUSS INTEGRATION **             PA  42
      K = 1                                                                PA  43
       ZE = 2.0*ZE                                                         PA  44
       SZ2 = 0.0                                                           PA  45
      DO 28 I=1,ITN                                                        PA  46
        SZ1 = SZ2                                                          PA  47
        SZ2 = BZ(I+1)/ZE                                                   PA  48
          SF = SZ2 - SZ1                                                   PA  49
C** THE VARIABLE *PM* IN LINES 51, 54, 55, 56, 57 HAS BEEN CHANGED         PA  50
C**  >HHC, 4/1/68) TO *PN* IN ORDER CIRCUMVENT ERROR IEY007I TO CONFLICTPA  51
          PN = SZ2 +                                                       PA  52
      SG1=SF*G1                                                            PA  53
      SG2=SF*G2                                                            PA  54
      AZ(K)=PN-SG1                                                         PA  55
       AZ(K+1)=PN-SG2                                                      PA  56
       AZ(K+2)=PN+SG2                                                      PA  57
       AZ(K+3)=PN+SG1                                                      PA  58
         K = K + 4                                                         PA  59
   28 CONTINUE                                                             PA  60
      RETURN                                                               PA  61
      END                                                                  PA  62
```

```
      SUBROUTINE BESSEL(NT, XT, Y)                                         BE   1
      DIMENSION PZ(6),QZ(6),P1(6),Q1(6),D(23)                              BE   2
C                                                                          BE   3
      PZ(1)=1.0                                                            BE   4
      PZ(2) = -1.125E-4                                                    BE   5
      PZ(3) = 2.871403 E-7                                                 BE   6
      PZ(4) = -2.344065 E-9                                                BE   7
      PZ(5) = 3.904684 E-11                                                BE   8
      PZ(6) = -1.153613 E-12                                               BE   9
C                                                                          BE  10
      QZ(1) = -5.0E-3                                                      BE  11
      QZ(2) = 4.6875E-6                                                    BE  12
      QZ(3) = -2.325585 E-8                                                BE  13
      QZ(4) = 2.830708 E-10                                                BE  14
      QZ(5) = -6.391209 E-12                                               BE  15
      QZ(6) = 2.312970 E-13                                                BE  16
C                                                                          BE  17
C                                                                          BE  18
      P1(1) = 1.0                                                          BE  19
      P1(2) =  1.875E-4                                                    BE  20
      P1(3) = -3.691406 E-7                                                BE  21
      P1(4) =  2.771323 E-9                                                BE  22
      P1(5) = -4.511442 E-11                                               BE  23
      P1(6) =  1.275946 E-12                                               BE  24
C                                                                          BE  25
      Q1(1) =  1.5E-2                                                      BE  26
      Q1(2) = -6.5625E-6                                                   BE  27
      Q1(3) =  2.842382 E-8                                                BE  28
      Q1(4) = -3.266202 E-10                                               BE  29
      Q1(5) =  7.143116 E-12                                               BE  30
      Q1(6) = -2.532705 E-13                                               BE  31
C                                                                          BE  32
C                                                                          BE  33
      PI = 3.141592                                                        BE  34
      PI2 = 2.0*PI                                                         BE  35
C                                                                          BE  36
C                                                                          BE  37
      N = NT                                                               BE  38
      Y = XT                                                               BE  39
      IF (Y-T.0) 10,10,160                                                 BE  40
C                                                                          BE  41
   10 X2 = 0.5*Y                                                           BE  42
      FAC=-X2*X2                                                           BE  43
      IF (N) 11,11,14                                                      BE  44
   11 C=1.0                                                                BE  45
      Y=C                                                                  BE  46
      DO 13 I=1,34                                                         BE  47
      T=I                                                                  BE  48
      C=FAC*C/(T*T)                                                        BE  49
      TEST = ABS(C) - 1.0E-8                                               BE  50
      IF (TEST) 17,17,12                                                   BE  51
   12 Y=Y+C                                                                BE  52
   13 CONTINUE                                                             BE  53
   14 C=X2                                                                 BE  54
      Y=C                                                                  BE  55
      DO 16 I=1,34                                                         BE  56
      T=I                                                                  BE  57
      C=FAC*C/(T*(T+1.0))                                                  BE  58
      TEST = ABS(C) - 1.0E-8                                               BE  59
      IF (TEST) 17,17,15                                                   BE  60
   15 Y=Y+C                                                                BE  61
   16 CONTINUE                                                             BE  62
   17 RETURN                                                               BE  63
  160 IF (N) 161,161,164                                                   BE  64
C                                                                          BE  65
C                                                                          BE  66
  161 DO 162 I=1,6                                                         BE  67
      D(I) = PZ(I)                                                         BE  68
      D(I+10) = QZ(I)                                                      BE  69
  162 CONTINUE                                                             BE  70
      GO TO 163                                                            BE  71
C                                                                          BE  72
  164 DO 165 I=1,6                                                         BE  73
      D(I) = P1(I)                                                         BE  74
      D(I+10) = Q1(I)                                                      BE  75
  165 CONTINUE                                                             BE  76
  163 CONTINUE                                                             BE  77
      T1 = 25.0/Y                                                          BE  78
```

```
      T2=T1*T1
      P = D(6)*T2+D(5)
      DO 170 I=1,4
      J = 5-I
      P = P*T2+D(J)
  170 CONTINUE
      Q = D(16)*T2+D(15)
      DO 171 I=1,4
      J = 5-I
      Q = Q*T2+D(J+10)
  171 CONTINUE
      Q = Q*T1
C
      T4 = SQRT (X*PI)
      T6 = SIN (X)
      T7 = COS (X)
C
      IF (N) 180,180,185
C
  180 T5 = ((P-Q)*T6 + (P+Q)*T7)/T4
      GO TO 99
  185 T5 = ((P+Q)*T6 - (P-Q)*T7)/T4
   99 Y = T5
      RETURN
      END



      SUBROUTINE REGRSP( IRTYP, RESP )
CC
C     REGRSP - USE ELASTIC LAYER REGRESSION MODELS TO PREDICT CRITICAL
C              PAVEMENT RESPONSE UNDER A SIMULATED 18-KIP AXLE LOAD
C              (TWO 4500 LB, 75 PSI TIRES SPACED AT 13.1 INCHES).
C
C     ENTRY/  IRTYP  = TYPE OF RESPONSE DESIRED.
C                    = 1, FOR MAXIMUM STRESS.
C                    = 2, FOR MAXIMUM STRAIN.
C             NZ     = NUMBER OF DEPTHS WHERE RESPONSE DESIRED.
C             ZZ     = DEPTHS WHERE RESPONSES ARE DESIRED.
C             NS     = NUMBER OF LAYERS IN SYSTEM.
C             TH     = LAYER THICKNESSES.
C             E      = LAYER MODULI.
C             V      = POISSONS RATIOS FOR EACH LAYER.
C
C     EXIT/   RESP   = VALUE OF THE RESPONSE AT THE DEPTHS REQUESTED.
C                      IT IS IMPORTANT TO NOTE THAT IF A REGRESSION
C                      MODEL IS NOT AVAILABLE FOR THE RESPONSE DESIRED,
C                      CONTROL WILL BE RETURNED TO THE CALLING ROUTINE
C                      WITH ZERO VALUES FOR THE RESPONSES DESIRED.
C
      COMMON /LAYSYS/ NS, TH(8), E(8), V(8)
C
      COMMON /LAYCOM/ WGT, PSI, NR, RR(2), NZ, ZZ(5)
C
      DIMENSION RESP(2)
C
      DO 1000 IZ=1,NZ
      RESP(IZ) = 0.0
      THSUM = 0.0
      DO 10 LAY=1,NS
      THSUM = THSUM + TH(LAY)
      IF (THSUM .EQ. ZZ(IZ)) GO TO 50
   10 CONTINUE
      GO TO 1000
   50 CONTINUE
      GO TO ( 100 , 600 ), IRTYP
  100 CONTINUE
C
C     STRESS MODELS
C
      IF (NS .EQ. 2) GO TO 1000
      IF (NS .NE. 3) GO TO 200
      IF (LAY .NE. 1) GO TO 1000
C
C     3 LAYERS, STRESS IN 1ST. (S31)
      RESP(IZ) = 10.0**(                      + 2.880E+00
     + + 1.972E-08 * E(1)                     - 1.210E-06 * E(2)
     + - 1.720E-05 * E(3)                     - 8.113E-02 * TH(1)
     + - 5.097E-09 * E(2) * TH(2)             + 6.121E-08 * E(2) * TH(1)
     + + 7.135E-14 * E(1) * E(2)              + 3.818E-10 * E(3)**2
     + + 3.312E-13 * E(2)**2                  + 5.034E-12 * E(2) * E(3)    )
      GO TO 1000
  200 CONTINUE
      IF (NS .NE. 4) GO TO 300
      IF (LAY .NE. 1) GO TO 210
C
C     4 LAYERS, 2ND=AC OR STAB. BASE, STRESS IN 1ST. (S41)
      RESP(IZ) = 10.0**(                      + 2.660E+00
     + + 3.326E-08 * E(1)                     - 9.386E-07 * E(2)
     + - 6.715E-07 * E(3)                     - 5.279E-06 * E(4)
     + - 5.211E-02 * TH(1)                    - 1.153E-02 * TH(2)
     + + 5.406E-14 * E(1) * E(2)              + 3.909E-08 * E(2) * TH(1)
     + + 4.712E-13 * E(3)**2                  + 8.343E-12 * E(3) * E(4)
     + - 3.106E-08 * E(2) * TH(2)             + 3.016E-08 * E(3) * TH(2)
     + - 2.718E-08 * E(3) * TH(3)             - 6.465E-07 * E(4) * TH(1)
     + + 1.959E-10 * E(4)**2                  + 1.826E-13 * E(2)**2        )
      GO TO 1000
  210 CONTINUE
      IF (LAY .NE. 2) GO TO 1000
C
C     4 LAYERS, STRESS IN 2ND. (S842)
      RESP(IZ) = 10.0**(                      + 2.667E+00
     + - 9.509E-08 * E(1)                     + 3.368E-08 * E(2)
     + - 6.977E-07 * E(3)                     - 1.640E-05 * E(4)
     + - 2.719E-02 * TH(1)                    - 5.441E-02 * TH(2)
     + - 5.797E-03 * TH(3)                    + 8.702E-15 * E(1)**2
     + - 3.814E-08 * E(3) * TH(3)             + 9.955E-14 * E(1) * E(3)
     + + 3.764E-10 * E(4)**2                  + 4.602E-14 * E(2) * E(3)
     + + 3.225E-08 * E(3) * TH(2)             - 2.891E-09 * E(1) * TH(1)
     + + 1.323E-09 * E(1) * TH(3)             - 8.115E-21 * E(3) * E(1)**2 )
      GO TO 1000
  300 CONTINUE
      IF (NS .NE. 5) GO TO 400
      IF (LAY .NE. 2) GO TO 310
C
C     5 LAYERS, 3RD=AC OR STAB. BASE, STRESS IN 2ND. (S852)
      RESP(IZ) = 10.0**(                      + 2.173E+00
     + - 3.538E-08 * E(1)                     + 7.701E-08 * E(2)
     + - 5.965E-07 * E(4)                     - 1.472E-05 * E(5)
     + - 2.788E-02 * TH(1)                    - 3.204E-02 * TH(2)
     + - 6.584E-03 * TH(4)                    + 3.372E-13 * E(4)**2
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```
     + + 7.174E-12 * E(4) * E(5)            + 1.787E-08 * E(4) * TH(3)
     + + 2.296E-14 * E(1) * E(4)            - 2.377E-08 * E(4) * TH(4)
     + - 2.752E-15 * E(1) * E(2)            + 2.551E-14 * E(1) * E(3)
     + - 4.774E-08 * E(3) * TH(3)           + 1.195E-09 * E(1) * TH(4)
     + - 1.399E-09 * E(1) * TH(1)           + 2.168E-15 * E(1)**2
     + - 2.598E-13 * E(1) * E(5)            + 2.346E-14 * E(5)**2
     + + 3.573E-07 * E(5) * TH(4)                                    )
      GO TO 1000
  310 CONTINUE
      IF (LAY .NE. 3) GO TO 330
      IF (E(2) .LT. 1.0E6) GO TO 320
C
C     5 LAYERS, 2ND=PCC, STRESS IN 3RD. (SR53)
      RESP(I7) = 10.0**(                + 2.256E+00
     + - 4.030E-08 * E(1)               - 6.970E-09 * E(2)
     + + 3.705E-08 * E(3)               - 1.070E-07 * E(4)
     + - 1.464E-05 * E(5)               - 1.614E-02 * TH(1)
     + - 3.452E-02 * TH(2)              - 3.388E-02 * TH(3)
     + + 4.159E-15 * E(1)**2            - 2.820E-08 * E(4) * TH(4)
     + - 3.127E-09 * E(1) * TH(1)       + 3.159E-10 * E(5)**2
     + + 2.003E-14 * E(3) * E(4)        + 1.410E-14 * E(1) * E(4)    )
      GO TO 1000
  320 CONTINUE
C
C     5 LAYERS, 2ND=AC, STRESS IN 3RD. (SU53)
      RESP(I7) = 10.0**(                + 2.453E+00
     + - 1.730E-08 * E(1)               + 4.018E-08 * E(3)
     + - 5.475E-07 * E(4)               - 1.566E-05 * E(5)
     + - 4.508E-02 * TH(1)              - 4.037E-02 * TH(2)
     + - 3.535E-02 * TH(3)              - 3.833E-03 * TH(4)
     + - 3.892E-08 * E(4) * TH(4)       + 2.597E-13 * E(2) * E(4)
     + + 3.087E-10 * E(5)**2            + 4.087E-14 * E(3) * E(4)
     + + 2.717E-08 * E(4) * TH(3)       - 2.861E-08 * E(2) * TH(3)
     + + 1.739E-03 * TH(2) * TH(3)      + 1.071E-08 * E(2) * TH(4)
     + + 3.408E-12 * E(2) * E(5)                                     )
      GO TO 1000
  330 CONTINUE
      IF (LAY .NE. 1) GO TO 1000
      IF (E(3) .LT. 1.0E6) GO TO 340
C
C     5 LAYERS, 2ND=AC, 3RD=PCC, STRESS IN 1ST. (SU51)
      RESP(I7) = 10.0**(                + 2.461E+00
     + + 4.790E-08 * E(1)               - 2.780E-06 * E(2)
     + - 2.149E-08 * E(3)               - 5.871E-08 * E(4)
     + - 5.787E-02 * TH(1)              + 3.569E-02 * TH(2)
     + - 3.495E-02 * TH(3)              + 1.161E-12 * E(2)**2
     + + 1.093E-13 * E(1) * E(2)        + 1.583E-07 * E(2) * TH(2)
     + + 4.019E-03 * TH(2) * TH(3)      + 4.103E-09 * E(3) * TH(2)
     + - 1.483E-08 * E(2) * TH(2)**2    + 5.646E-08 * E(2) * TH(1)
     + - 3.559E-14 * E(2) * E(3)        - 4.068E-03 * TH(1) * T-(2)
     + + 4.396E-12 * E(2) * E(5)        - 7.478E-10 * E(1) * TH(2)**2)
      GO TO 1000
  340 CONTINUE
C
C     5 LAYERS, 2ND=AC, 3RD=CRACKED PCC, STRESS IN 1ST. (SU51C)
      RESP(I7) = 10.0**(                + 2.696E+00
     + + 3.354E-08 * E(1)               - 1.455E-06 * E(2)
     + - 5.539E-07 * E(4)               - 4.660E-06 * E(5)
     + - 7.299E-02 * TH(1)              - 2.179E-02 * TH(3)
     + - 1.892E-03 * TH(4)              - 5.909E-08 * E(2) * TH(2)
     + + 3.141E-13 * E(2)**2            + 6.691E-14 * E(1) * E(2)
     + + 2.929E-08 * E(4) * TH(2)       + 5.436E-08 * E(2) * TH(1)
     + + 3.316E-13 * E(4)**2            + 5.807E-12 * E(4) * E(5)
     + + 1.466E-03 * TH(2) * TH(3)      - 1.267E-08 * E(4) * TH(4)
     + + 1.869E-08 * E(4) * TH(3)       + 2.859E-07 * E(5) * TH(2)
     + - 1.273E-13 * E(2) * E(4)                                     )
      GO TO 1000
  400 CONTINUE
      IF (NS .NE. 6) GO TO 1000
      IF (E(1) .GT. 1.0E6) GO TO 1000
      IF (E(3) .GT. 1.0E6) GO TO 1000
      IF (LAY .NE. 4) GO TO 410
      IF (E(2) .LT. 1.0E6) GO TO 1000
C
C     6 LAYERS, 1ST=AC, 2ND=PCC, 3RD=AC, STRESS IN 4TH. (SU64)
      RESP(I7) = 10.0**(                + 2.257E+00
     + - 1.226E-08 * E(2)               + 7.180E-07 * E(3)
     + + 4.318E-08 * E(4)               - 4.756E-07 * E(5)
     + - 1.776E-05 * E(6)               - 1.155E-02 * TH(1)
     + - 4.257E-02 * TH(2)              - 2.253E-02 * TH(4)
     + - 4.381E-03 * TH(5)              - 4.004E-08 * E(5) * TH(5)
     + + 3.404E-14 * E(6)**2            + 3.949E-14 * E(4) * E(5)
     + + 2.659E-08 * E(5) * TH(4)       + 5.826E-13 * E(3) * E(5)
     + - 7.963E-08 * E(3) * TH(4)       - 2.212E-12 * E(3)**2
     + + 1.108E-11 * E(3) * E(6)        - 1.533E-08 * E(1) * TH(1)
     + + 3.488E-08 * E(3) * TH(5)                                    )
      GO TO 1000
  410 CONTINUE
      IF (LAY .NE. 2) GO TO 1000
      IF (E(4) .LT. 1.0E6) GO TO 420
C
C     6 LAYERS, 1ST=AC, 3RD=AC, 4TH=PCC, STRESS IN 2ND. (SU62)
      RESP(I7) = 10.0**(                + 2.471E+00
     + - 9.153E-08 * E(1)               + 4.652E-08 * E(2)
     + - 4.790E-06 * E(3)               - 1.098E-07 * E(5)
     + - 3.761E-02 * TH(1)              - 5.153E-02 * TH(2)
     + - 1.926E-02 * TH(4)              - 3.928E-03 * TH(5)
     + + 8.508E-12 * E(3)**2            + 2.205E-13 * E(2) * E(3)
     + - 1.166E-07 * E(3) * TH(4)       - 1.620E-13 * E(3) * E(4)
     + + 1.440E-07 * E(3) * TH(2)       + 4.716E-13 * E(1) * E(3)    )
      GO TO 1000
  420 CONTINUE
C
C     6 LAYERS, 1ST=AC, 3RD=AC, 4TH=CRACKED PCC, STRESS IN 2ND. (SU62C)
      RESP(I7) = 10.0**(                + 2.686E+00
     + - 1.034E-07 * E(1)               + 4.675E-08 * E(2)
     + - 2.873E-06 * E(3)               - 5.247E-07 * E(5)
     + - 1.705E-05 * E(6)               - 3.231E-02 * TH(1)
     + - 5.267E-02 * TH(2)              - 2.267E-02 * TH(4)
     + - 6.680E-03 * TH(5)              + 5.357E-12 * E(3)**2
     + + 8.394E-12 * E(5) * E(6)        + 4.216E-13 * E(5)**2
     + - 6.930E-13 * E(3) * E(5)        + 1.037E-13 * E(2) * E(3)
     + - 2.404E-08 * E(5) * TH(5)       + 1.903E-10 * E(6)**2
     + + 3.434E-07 * E(6) * TH(5)       + 1.987E-08 * E(5) * TH(4)
     + + 9.407E-08 * E(3) * TH(2)       + 4.388E-07 * E(6) * TH(4)
     + - 4.152E-08 * E(3) * TH(4)       + 2.548E-13 * E(1) * E(3)    )
      GO TO 1000
  600 CONTINUE
C
C     STRAIN MODEL(S)
C
      IF (NS .NE. 2) GO TO 1000
      IF (LAY .NE. 1) GO TO 1000
C
```

```
C     2 LAYERS, STRAIN IN 1ST. (E21)
      RESP(17) = 10.0**(                      - 2.835E+00
     + - 9.309E-07 * E(1)                     - 7.530E-06 * E(2)
     + - 5.870E-02 * TH(1)                    + 4.108E-13 * E(1)**2
     + + 4.035E-12 * E(1) * E(2)              - 2.356E-28 * E(1) * TH(1)
 1000 CONTINUE
C
      RETURN
      END



      SUBROUTINE STRTGY
CC
C     STRTGY - GENERATES ALL FEASIBLE OVERLAY DESIGN STRATEGIES
C
      COMMON /EPTYP/ IEPTYP, IERSH
C
      COMMON /TRAFIC/ ADT, GR, F18YRP, F18GP
C
      COMMON /TIME/ ANPER, TMINOV, TMAXMT
C
      COMMON /OVTYP/ ISWOV1, NOV1, ITYP1(5), ISWOV2, NOV2, ITYP2(3)
C
      COMMON /REMLIF/ NRL1, RLEP(10), NRL2, RLOV(10), RLMIN
C
      COMMON /FLEXST/ FREP, NFROV, FROV(5), IFRBND
C
      COMMON /OVTHIK/ NACT1, ACT1(8), NACT2, ACT2(8), NPCCT, PCCT(8)
     0               , ALOVT, AVGLHT, THBB
C
      COMMON /CFACT/
     0 CEP,
     1 C0A, C0AA, NCAC, C0AC(2), C2AC(2), NCAT, C0AT(2), C2AJ(2),
     2 NCBC, C0BC(2), C0BCA(2),
     3 NCBJ, C0BT(2), C0BJA(2),
     4 NCUC, C0UC(2), C1UC(2), C0UCA(2), C1UCA(2),
     5 NCUJ, C0UJ(2), C1UJ(2), C0UJA(2), C1UJA(2)
C
      COMMON /PAVRSP/
     0 S0,
     1 S0A(8), E1A(8),
     2 S0AA(8,8), E1AA(8,8),  E2AA(8,8),
     3 S0AP(8,8), S2AP1(8,8), S2AP2(8,8),
     4 S0BP(8),
     5 S0BPA(8,8), E2BPA(8,8),
     6 S0UP(8), S1UP1(8), S1UP2(8),
     7 S0UPA(8,8), S1UPA1(8,8), S1UPA2(8,8), E2UPA(8,8)
C
      COMMON /ELPROP/
     0 ECKPCC, ECKAC, VCOMP,
     1 EOVAC, VOVAC, FACFAT,
     2 EOVPCC, VOVPCC,
     3 EBB, VBB
C
      DIMENSION FATEP(2)
C
      DATA 0M / 999. /
C
C     STATEMENT FUNCTIONS WHICH PREDICT PAVEMENT FATIGUE LIVES
C     IN MILLIONS OF 18-KIP ESAL.
C
C     PCC FATIGUE EQUATIONS (STRESS BASED)
C     **POOR MOISTURE ENVIRONMENT
      SFATIG( FR, C, S ) = 0.005 * (FR/(C*S))**3
C     **GOOD MOISTURE ENVIRONMENT
      OFATIG( FR, C, S ) = 0.043 * (FR/(C*S))**3.2
C
C     AC FATIGUE EQUATION (STRAIN BASED)
      EFATIG( EPS ) = 9.73E-21 * ( 1.0/EPS )**5.16
C
      FATEP(1) = SFATIG( FREP, CEP, S0 )
      FATEP(2) = OFATIG( FREP, CEP, S0 )
C$    WRITE(2,1) FREP, CEP, S0, FATEP
C$  1 FORMAT(30X,3F10.2,2F10.3)
C$    WRITE(2,2) S0A,E1A,S0AA,E1AA,E2AA,S0AP,S2AP1,S2AP2,S0BP,S0BPA,
C$   +E2BPA,S0UP,S1UP1,S1UP2,S0UPA,S1UPA1,S1UPA2,E2UPA
C$  2 FORMAT(/5X,*S0A*/5X,8E11.3//5X,*E1A*/5X,8E11.3//5X,*S0AA*,
C$   + 8(/5X,8E11.3)//5X,*E1AA*,8(/5X,8E11.3)//5X,*E2AA*,8(/5X,8E11.3)
C$   + //5X,*S0AP*,8(/5X,8E11.3)//5X,*S2AP1*,8(/5X,8E11.3)//5X,*S2AP2*,
C$   + 8(/5X,8E11.3)//5X,*S0BP*/5X,8E11.3//5X,*S0BPA*,8(/5X,8E11.3)
C$   + //5X,*E2BPA*,8(/5X,8E11.3)//5X,*S0UP*/5X,8E11.3//5X,*S1UP1*
C$   + /5X,8E11.3//5X,*S1UP2*/5X,8E11.3//5X,*S0UPA*,8(/5X,8E11.3)
C$   + //5X,*S1UPA1*,8(/5X,8E11.3)//5X,*S1UPA2*,8(/5X,8E11.3)
C$   + //5X,*E2UPA*,8(/5X,8E11.3) )
C
      ANTMAX = ANPER - TMAXMT
      IRL1 = 0
   10 CONTINUE
      IRL1 = IRL1 + 1
      IF (IRL1 .GT. NRL1) RETURN
      TREPED = (1.0-RLEP(IRL1))*FATEP(IEPSH)
      RLEPR = 1.0 - TREPED/FATEP(2)
      TRNTO1 = (RLEP(1) - RLEP(IRL1))*FATEP(IEPSH)
      YR1 = YEAR( TRNTO1, F18YR0, F18GR )
      IOV1 = 0
   50 CONTINUE
      IOV1 = IOV1 + 1
      IF (IOV1 .GT. NOV1) GO TO 10
      IF (ITYP1(IOV1) .EQ. 0) GO TO 50
      GO TO ( 100, 300, 500, 700, 900 ), IOV1
C**********************************************************************
  100 CONTINUE
C
C     FIRST OVERLAY - AC
C
      IOV1T = 0
  110 CONTINUE
      IOV1T = IOV1T + 1
      IF (IOV1T .GT. NACT1) GO TO 50
      F0A = OFATIG( FREP, C0A, S0A(IOV1T) )
      F1A = EFATIG( E1A(IOV1T) )
      FATEP1 = RLEPR*F0A
      RLOV1X = 1.0 - RLEPR
      FATOV1 = RLOV1X*F1A
      FATOT1 = TRNTO1 + FATEP1 + FATOV1
      YRF1 = YEAR( FATOT1, F18YR0, F18GR )
C$    CALL SAVE2(IRL1,IOV1,1.0,IOV1T,0,0,0,0,0,
C$   + TRNTO1,YR1,FATOT1,YRF1,0M,0M,0M,0M)
      IF (YRF1 .LT. ANTMAX) GO TO 120
      CALL SAVE1(IRL1,IOV1,0,0,IOV1T,0,0,0,0,0,
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     + TRNTO1,YR1,FATOT1,YRF1,RM,RM,RM,RM)
       IF (YRF1 .LT. ANPER) GO TO 120
       GO TO 50
   120 CONTINUE
       IF (ISWOV2 .EQ. 0) GO TO 110
       IF (YRF1-YR1 .LE. TMINOV) GO TO 110
       IRL2 = 0
   130 CONTINUE
       IRL2 = IRL2 + 1
       IF (IRL2 .GT. NRL2) GO TO 110
       IF (RLOV(IRL2) .LT. RLOV1X) GO TO 140
       TRO1 = (1.0 - RLOV(IRL2))*F0A
       RLEPC = (FATEP1 - TRO1)/F0A
       GO TO 150
   140 CONTINUE
       TRO1 = FATEP1 + (RLOV1X - RLOV(IRL2))*F1A
       RLEPC = 0.0
   150 CONTINUE
       RLEPCR = RLEPC
       TRNTO2 = TRO1 + TRNTO1
       YR2 = YEAR( TRNTO2, F1BYR0, F1BGR )
       IF (YR2-YR1 .LT. TMINOV) GO TO 130
       IOV2 = 0
   160 CONTINUE
       IOV2 = IOV2 + 1
       IF (IOV2 .GT. NOV2) GO TO 130
       IF (ITYP2(IOV2) .EQ. 0) GO TO 160
       GO TO ( 170, 200, 250 ), IOV2
   170 CONTINUE
C
C      FIRST OVERLAY = AC, SECOND OVERLAY = AC
       RLOV1Y = RLOV(IRL2) - RLEPCR
       IF (RLOV1Y .LT. 0.0) RLOV1Y=0.0
       RLOV2Y = 1.0 - RLEPCR - RLOV1Y
       IOV2T = 0
   180 CONTINUE
       IOV2T = IOV2T + 1
       IF (IOV2T .GT. NACT2) GO TO 160
       IF (ACT1(IOV1T)+ACT2(IOV2T) .GT. ALOVT) GO TO 160
       F0AA = OFATIG( FREP, C0AA, S0AA(IOV1T,IOV2T) )
       F1AA = FFATIG( E1AA(IOV1T,IOV2T) )
       F2AA = FFATIG( F2AA(IOV1T,IOV2T) )
       FATEP2 = RLEPCR*F0AA
       FOV12 = RLOV1Y*F1AA
       FOV22 = RLOV2Y*F2AA
       FATOT2 = TRNTO2 + FATEP2 + FOV12 + FOV22
       YRF2 = YEAR( FATOT2, F1BYR0, F1BGR )
CS     CALL SAVE2(IRL1,IOV1,0,0,IOV1T,IRL2,IOV2,0,0,IOV2T,
CS   + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
       IF (YRF2 .LT. ANTMAX) GO TO 180
       CALL SAVE1(IRL1,IOV1,0,0,IOV1T,IRL2,IOV2,0,0,IOV2T,
     + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
       IF (YRF2 .LT. ANPER) GO TO 180
       GO TO 160
   200 CONTINUE
C
C      FIRST OVERLAY = AC, SECOND OVERLAY = CRCP
       IC2 = 0
   210 CONTINUE
       IC2 = IC2 + 1
       IF (IC2 .GT. NCAC) GO TO 160
       IF (C2AC(IC2) .LE. 0.0) GO TO 210
       IFR2 = 0
   220 CONTINUE
       IFR2 = IFR2 + 1
       IF (IFR2 .GT. NFROV) GO TO 210
       IOV2T = 0
   230 CONTINUE
       IOV2T = IOV2T + 1
       IF (IOV2T .GT. NPCCT) GO TO 220
       IF (ACT1(IOV1T)+PCCT(IOV2T) .GT. ALOVT) GO TO 220
       F0AC = OFATIG( FREP, C0AC(IC2), S0AP(IOV1T,IOV2T) )
       F2AC1 = OFATIG( FROV(IFR2), C2AC(IC2), S2AP1(IOV1T,IOV2T) )
       F2AC2 = OFATIG( FROV(IFR2), C2AC(IC2), S2AP2(IOV1T,IOV2T) )
       FATEP2 = RLEPCR*F0AC
       RLOV2X = 1.0 - FATEP2/F2AC1
       FOV22 = RLOV2X*F2AC2
       FATOT2 = TRNTO2 + FATEP2 + FOV22
       IF (RLOV2X .LT. 0.0) FATOT2 = TRNTO2 + F2AC1
       YRF2 = YEAR( FATOT2, F1BYR0, F1BGR )
CS     CALL SAVE2(IRL1,IOV1,0,0,IOV1T,IRL2,IOV2,IC2,IFR2,IOV2T,
CS   + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
       IF (YRF2 .LT. ANTMAX) GO TO 230
       CALL SAVE1(IRL1,IOV1,0,0,IOV1T,IRL2,IOV2,IC2,IFR2,IOV2T,
     + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
       IF (YRF2 .LT. ANPER) GO TO 230
       GO TO 220
   250 CONTINUE
C
C      FIRST OVERLAY = AC, SECOND OVERLAY = JCP
       IC2 = 0
   260 CONTINUE
       IC2 = IC2 + 1
       IF (IC2 .GT. NCAJ) GO TO 160
       IF (C0AJ(IC2) .LE. 0.0) GO TO 260
       IFR2 = 0
   270 CONTINUE
       IFR2 = IFR2 + 1
       IF (IFR2 .GT. NFROV) GO TO 260
       IOV2T = 0
   280 CONTINUE
       IOV2T = IOV2T + 1
       IF (IOV2T .GT. NPCCT) GO TO 270
       IF (ACT1(IOV1T)+PCCT(IOV2T) .GT. ALOVT) GO TO 270
       F0AJ = OFATIG( FREP, C0AJ(IC2), S0AP(IOV1T,IOV2T) )
       F2AJ1 = OFATIG( FROV(IFR2), C2AJ(IC2), S2AP1(IOV1T,IOV2T) )
       F2AJ2 = OFATIG( FROV(IFR2), C2AJ(IC2), S2AP2(IOV1T,IOV2T) )
       FATEP2 = RLEPCR*F0AJ
       RLOV2X = 1.0 - FATEP2/F2AJ1
       FOV22 = RLOV2X*F2AJ2
       FATOT2 = TRNTO2 + FATEP2 + FOV22
       IF (RLOV2X .LT. 0.0) FATOT2 = TRNTO2 + F2AJ1
       YRF2 = YEAR( FATOT2, F1BYR0, F1BGR )
CS     CALL SAVE2(IRL1,IOV1,0,0,IOV1T,IRL2,IOV2,IC2,IFR2,IOV2T,
CS   + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
       IF (YRF2 .LT. ANTMAX) GO TO 280
       CALL SAVE1(IRL1,IOV1,2,0,IOV1T,IRL2,IOV2,IC2,IFR2,IOV2T,
     + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
       IF (YRF2 .LT. ANPER) GO TO 280
       GO TO 270
C*********************************************************************
   300 CONTINUE
C
C      FIRST OVERLAY = BONDED CRCP
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C
      IF (RLFPR .LT. RLMIN) GO TO 50
      IF (IFRTYP .EQ. 2) GO TO 50
      IC1 = 0
  305 CONTINUE
      IC1 = IC1 + 1
      IF (IC1 .GT. NCHC) GO TO 50
      IF (CHRC(IC1) .LE. 0.0) GO TO 305
      IOV1T = 0
  310 CONTINUE
      IOV1T = IOV1T + 1
      IF (IOV1T .GT. NPCCT) GO TO 305
      FRRC = DFATIG( FREP, CHRC(IC1), SRRP(IOV1T) )
      FATEP1 = RLFPR*FRRC
      FATOT1 = TRNTO1 + FATEP1
      YRF1 = YEAR( FATOT1, E1AYRR, F18GR )
CS    CALL SAVE2(IRL1,IOV1,IC1,IERRND,IOV1T,0,0,0,0,0,
CS   + TRNTO1,YR1,FATOT1,YRF1,RM,RM,RM,RM)
      IF (YRF1 .LT. ANTMAX) GO TO 320
      CALL SAVE1(IRL1,IOV1,IC1,IERRND,IOV1T,0,0,0,0,0,
     + TRNTO1,YR1,FATOT1,YRF1,RM,RM,RM,RM)
      IF (YRF1 .LT. ANPER) GO TO 310
      GO TO 305
  320 CONTINUE
      IF (ISWOV2 .EQ. 0) GO TO 310
      IF (YRF1-YR1 .LE. THINOV) GO TO 310
      DO 325 IPLX=1,NRL1
      IF (RLFPR .GE. RLFR(IPLX)) GO TO 326
  325 CONTINUE
      IPLX = NRL1
  326 CONTINUE
      IRL2 = IPLX - 1
  330 CONTINUE
      IRL2 = IRL2 + 1
      IF (IRL2 .GT. NRL1) GO TO 310
      RLFPC = RLFR(IRL2)
      TRO1 = (RLFPR - RLFPC)*FRRC
      RLFPCP = RLFPC
      TRNTO2 = TRO1 + TRNTO1
      YR2 = YEAR( TRNTO2, E1AYRR, E18GR )
      IF (YR2-YR1 .LT. THINOV) GO TO 330
      IOV2 = 0
  360 CONTINUE
      IOV2 = IOV2 + 1
      IF (IOV2 .GT. NOV2) GO TO 330
      IF (ITYP2(IOV2) .EQ. 0) GO TO 360
      GO TO ( 370, 400, 450 ), IOV2
  370 CONTINUE
C
C     FIRST OVERLAY - BONDED CRCP, SECOND OVERLAY = AC
      RLOV2X = 1.0 - RLFPCP
      IOV2T = 0
  380 CONTINUE
      IOV2T = IOV2T + 1
      IF (IOV2T .GT. NACT2) GO TO 360
      IF (PCCT(IOV1T)+ACT2(IOV2T) .GT. ALOVT) GO TO 360
      F0RCA = DFATIG( FREP, CHRCA(IC1), S0RPA(IOV1T,IOV2T) )
      F2RCA = FFATIG( F2RPA(IOV1T,IOV2T) )
      FATEP2 = RLFPCP*F0RCA
      FOV22 = RLOV2X*F2RCA
      FATOT2 = TRNTO2 + FATEP2 + FOV22
      YRF2 = YEAR( FATOT2, E1AYRR, E18GR )
CS    CALL SAVE2(IRL1,IOV1,IC1,IERRND,IOV1T,IRL2,IOV2,0,0,IOV2T,
CS   + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
      IF (YRF2 .LT. ANTMAX) GO TO 380
      CALL SAVE1(IRL1,IOV1,IC1,IERRND,IOV1T,IRL2,IOV2,0,0,IOV2T,
     + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
      IF (YRF2 .LT. ANPER) GO TO 380
      GO TO 360
  400 CONTINUE
C
C     FIRST OVERLAY - BONDED CRCP, SECOND OVERLAY = CRCP
C *** PROGRAM CAN HANDLE ONLY ONE CONCRETE OVERLAY DURING ANALYSIS
C *** PERIOD.
      GO TO 360
  450 CONTINUE
C
C     FIRST OVERLAY - BONDED CRCP, SECOND OVERLAY = JCP
C *** PROGRAM CAN HANDLE ONLY ONE CONCRETE OVERLAY DURING ANALYSIS
C *** PERIOD.
      GO TO 360
C*********************************************************************
  500 CONTINUE
C
C     FIRST OVERLAY - UNBONDED CRCP
C
      IC1 = 0
  505 CONTINUE
      IC1 = IC1 + 1
      IF (IC1 .GT. NCUC) GO TO 50
      IF (CRUC(IC1) .LE. 0.0) GO TO 505
      IER1 = 0
  508 CONTINUE
      IER1 = IER1 + 1
      IF (IER1 .GT. NEROV) GO TO 505
      IOV1T = 0
  510 CONTINUE
      IOV1T = IOV1T + 1
      IF (IOV1T .GT. NPCCT) GO TO 508
      FRUC = DFATIG( FREP, CRUC(IC1), SRUP(IOV1T) )
      F1UC1 = DFATIG( FROV(IER1), C1UC(IC1), S1UP1(IOV1T) )
      F1UC2 = DFATIG( FROV(IER1), C1UC(IC1), S1UP2(IOV1T) )
      FATEP1 = RLFPR*FRUC
      RLOV1X = 1.0 - FATEP1/F1UC1
      FATOV1 = RLOV1X*F1UC2
      FATOT1 = TRNTO1 + FATEP1 + FATOV1
      IF (RLOV1X .LT. 0.0) FATOT1 = TRNTO1 + F1UC1
      YRF1 = YEAR( FATOT1, E1AYRA, E18GR )
CS    CALL SAVE2(IRL1,IOV1,IC1,IER1,IOV1T,0,0,0,0,0,
CS   + TRNTO1,YR1,FATOT1,YRF1,RM,RM,RM,RM)
      IF (YRF1 .LT. ANTMAX) GO TO 520
      CALL SAVE1(IRL1,IOV1,IC1,IER1,IOV1T,0,0,0,0,0,
     + TRNTO1,YR1,FATOT1,YRF1,RM,RM,RM,RM)
      IF (YRF1 .LT. ANPER) GO TO 510
      GO TO 508
  520 CONTINUE
      IF (ISWOV2 .EQ. 0) GO TO 510
      IF (YRF1-YR1 .LE. THINOV) GO TO 510
      IRL2 = 0
  530 CONTINUE
      IRL2 = IRL2 + 1
      IF (IRL2 .GT. NRL2) GO TO 510
      RLOV1P = RLOV(IRL2)
      IF (RLOV(IRL2) .LT. RLOV1X) GO TO 540
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      TR01 = (1.0 - RLOV(IRL2))*F1UC1
      RLEPC = (FATEP1 - TR01)/F0UC
      GO TO 550
  540 CONTINUE
      TR01 = FATEP1 + (RLOV1X - RLOV(IRL2))*F1UC2
      RLEPC = 1.0
  550 CONTINUE
      RLEPCR = RLEPC
      TRNT02 = TR01 + TRNT01
      YR2 = YEAR( TRNT02, F18YR0, F18GR )
      IF (YR2-YR1 .LT. TMINOV) GO TO 530
      IOV2 = 0
  560 CONTINUE
      IOV2 = IOV2 + 1
      IF (IOV2 .GT. NOV2) GO TO 530
      IF (ITYP2(IOV2) .EQ. 0) GO TO 560
      GO TO ( 570, 600, 650 ), IOV2
  570 CONTINUE
C
C     FIRST OVERLAY - UNBONDED CRCP, SECOND OVERLAY = AC
      IOV2T = 0
  580 CONTINUE
      IOV2T = IOV2T + 1
      IF (IOV2T .GT. NACT2) GO TO 560
      IF (THBB+PCCT(IOV1T)+ACT2(IOV2T) .GT. ALOVT) GO TO 560
      F0UCA = OFATIG( FREP, C0UCA(IC1), S0UPA(IOV1T,IOV2T) )
      F1UCA1 = OFATIG( FROV(IER1), C1UCA(IC1), S1UPA1(IOV1T,IOV2T) )
      F1UCA2 = OFATIG( FROV(IER1), C1UCA(IC1), S1UPA2(IOV1T,IOV2T) )
      F2UCA = FFATIG( F2UPA(IOV1T,IOV2T) )
      FATEP2 = RLEPCR*F0UCA
      FOV12X = RLOV1R*F1UCA1
      RLOV1Y = (FOV12X - FATEP2)/F1UCA1
      FOV12 = RLOV1Y*F1UCA2
      RLOV2Y = 1.0 - RLOV1R
      FOV22 = RLOV2Y*F2UCA
      FATOT2 = TRNT02 + FATEP2 + FOV12 + FOV22
      IF (RLOV1Y .LT. 0.0) FATOT2 = TRNT02 + FOV12X + FOV22
      YRF2 = YEAR( FATOT2, F18YR0, F18GR )
C$    CALL SAVE2(IRL1,IOV1,IC1,IER1,IOV1T,IRL2,IOV2,0,0,IOV2T,
C$   + TRNT01,YR1,FATOT1,YRF1,TRNT02,YR2,FATOT2,YRF2)
      IF (YRF2 .LT. ANTMAX) GO TO 580
      CALL SAVE1(IRL1,IOV1,IC1,IER1,IOV1T,IRL2,IOV2,0,1,IOV2T,
     + TRNT01,YR1,FATOT1,YRF1,TRNT02,YR2,FATOT2,YRF2)
      IF (YRF2 .LT. ANPER) GO TO 580
      GO TO 560
  600 CONTINUE
C
C     FIRST OVERLAY - UNBONDED CRCP, SECOND OVERLAY = CRCP
C *** PROGRAM CAN HANDLE ONLY ONE CONCRETE OVERLAY DURING ANALYSIS
C *** PERIOD.
      GO TO 560
  650 CONTINUE
C
C     FIRST OVERLAY = UNBONDED CRCP, SECOND OVERLAY = JCP
C *** PROGRAM CAN HANDLE ONLY ONE CONCRETE OVERLAY DURING ANALYSIS
C *** PERIOD.
      GO TO 560
C*********************************************************************
  700 CONTINUE
C
C     FIRST OVERLAY = BONDED JCP
C
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      IF (RLEPR .LT. RLMIN) GO TO 50
      IF (IERTYP .EQ. 1) GO TO 50
      IC1 = 0
  705 CONTINUE
      IC1 = IC1 + 1
      IF (IC1 .GT. NCBJ) GO TO 50
      IF (C0BJ(IC1) .LE. 0.0) GO TO 705
      IOV1T = 0
  710 CONTINUE
      IOV1T = IOV1T + 1
      IF (IOV1T .GT. NPCCT) GO TO 705
      F0BJ = OFATIG( FREP, C0BJ(IC1), S0BP(IOV1T) )
      FATEP1 = RLEPR*F0BJ
      FATOT1 = TRNT01 + FATEP1
      YRF1 = YEAR( FATOT1, F18YR0, F18GR )
C$    CALL SAVE2(IRL1,IOV1,IC1,IERBND,IOV1T,0,0,0,0,0,
C$   + TRNT01,YR1,FATOT1,YRF1,RM,RM,RM,RM)
      IF (YRF1 .LT. ANTMAX) GO TO 720
      CALL SAVE1(IRL1,IOV1,IC1,IERBND,IOV1T,0,0,0,0,0,
     + TRNT01,YR1,FATOT1,YRF1,RM,RM,RM,RM)
      IF (YRF1 .LT. ANPER) GO TO 710
      GO TO 705
  720 CONTINUE
      IF (ISWOV2 .EQ. 0) GO TO 710
      IF (YRF1-YR1 .LT. TMINOV) GO TO 710
      DO 725 IRLX=1,NRL1
      IF (RLEPR .GE. RLEP(IRLX)) GO TO 726
  725 CONTINUE
      IRLX = NRL1
  726 CONTINUE
      IRL2 = IRLX - 1
  730 CONTINUE
      IRL2 = IRL2 + 1
      IF (IRL2 .GT. NRL1) GO TO 710
      RLEPC = RLEP(IRL2)
      TR01 = (RLEPR - RLEPC)*F0BJ
      RLEPCR = RLEPC
      TRNT02 = TR01 + TRNT01
      YR2 = YEAR( TRNT02, F18YR0, F18GR )
      IF (YR2-YR1 .LT. TMINOV) GO TO 730
      IOV2 = 1
  760 CONTINUE
      IOV2 = IOV2 + 1
      IF (IOV2 .GT. NOV2) GO TO 730
      IF (ITYP2(IOV2) .EQ. 0) GO TO 760
      GO TO ( 770, 800, 850 ), IOV2
  770 CONTINUE
C
C     FIRST OVERLAY - BONDED JCP, SECOND OVERLAY - AC
      RLOV2X = 1.0 - RLEPCR
      IOV2T = 0
  780 CONTINUE
      IOV2T = IOV2T + 1
      IF (IOV2T .GT. NACT2) GO TO 760
      IF (PCCT(IOV1T)+ACT2(IOV2T) .GT. ALOVT) GO TO 760
      F0BJA = OFATIG( FREP, C0BJA(IC1), S0BPA(IOV1T,IOV2T) )
      F2BJA = FFATIG( F2BPA(IOV1T,IOV2T) )
      FATEP2 = RLEPCR*F0BJA
      FOV22 = RLOV2X*F2BJA
      FATOT2 = TRNT02 + FATEP2 + FOV22
      YRF2 = YEAR( FATOT2, F18YR0, F18GR )
C$    CALL SAVE2(IRL1,IOV1,IC1,IERBND,IOV1T,IRL2,IOV2,0,0,IOV2T,
```

```
CS   + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
      IF (YRF2 .LT. ANTMAX) GO TO 780
      CALL SAVE1(IRL1,IOV1,IC1,IERBND,IOV1T,IRL2,IOV2,0,0,IOV2T,
     + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
      IF (YRF2 .LT. ANPER) GO TO 780
      GO TO 760
  800 CONTINUE
C
C     FIRST OVERLAY = BONDED JCP, SECOND OVERLAY = CRCP
C *** PROGRAM CAN HANDLE ONLY ONE CONCRETE OVERLAY DURING ANALYSIS
C *** PERIOD.
      GO TO 760
  850 CONTINUE
C
C     FIRST OVERLAY = BONDED JCP, SECOND OVERLAY = JCP
C *** PROGRAM CAN HANDLE ONLY ONE CONCRETE OVERLAY DURING ANALYSIS
C *** PERIOD.
      GO TO 760
C**************************************************************************
  900 CONTINUE
C
C     FIRST OVERLAY = UNBONDED JCP
C
      IC1 = 0
  905 CONTINUE
      IC1 = IC1 + 1
      IF (IC1 .GT. NCUJ) GO TO 50
      IF (CPUJ(IC1) .LE. 0.0) GO TO 905
      IER1 = 0
  908 CONTINUE
      IER1 = IER1 + 1
      IF (IER1 .GT. NEROV) GO TO 905
      IOV1T = 0
  910 CONTINUE
      IOV1T = IOV1T + 1
      IF (IOV1T .GT. NPCCT) GO TO 908
      FAUL = DFATIG( FREP, COUJ(IC1), SOUP(IOV1T) )
      F1UJ1 = DFATIG( FROV(IER1), C1UJ(IC1), S1UP1(IOV1T) )
      F1UJ2 = DFATIG( FROV(IER1), C1UJ(IC1), S1UP2(IOV1T) )
      FATER1 = RLFPR*FAULT
      RLOV1X = 1.0 - FATER1/F1UJ1
      FATOV1 = RLOV1X*F1UJ2
      FATOT1 = TRNTO1 + FATER1 + FATOV1
      IF (RLOV1X .LT. 0.0) FATOT1 = TRNTO1 + F1UJ1
      YRF1 = YEAR( FATOT1, F1RYR0, E18GR )
CS    CALL SAVE2(IRL1,IOV1,IC1,IER1,IOV1T,0,0,0,0,0,
CS   + TRNTO1,YR1,FATOT1,YRF1,RM,RM,RM,RM)
      IF (YRF1 .LT. ANTMAX) GO TO 920
      CALL SAVE1(IRL1,IOV1,IC1,IER1,IOV1T,0,0,0,0,0,
     + TRNTO1,YR1,FATOT1,YRF1,RM,RM,RM,RM)
      IF (YRF1 .LT. ANPER) GO TO 910
      GO TO 908
  920 CONTINUE
      IF (ISWOV2 .EQ. 0) GO TO 910
      IF (YRF1-YR1 .LE. THINOV) GO TO 910
      IRL2 = 0
  930 CONTINUE
      IRL2 = IRL2 + 1
      IF (IRL2 .GT. NRL2) GO TO 910
      RLOV1P = RLOV(IRL2)
      IF (RLOV(IRL2) .LT. RLOV1X) GO TO 940
      TRO1 = (1.0 - RLOV(IRL2))*F1UJ1
      RLFPC = (FATER1 - TRO1)/FAULT
      GO TO 950
  940 CONTINUE
      TRO1 = FATER1 + (RLOV1X - RLOV(IRL1))*F1UJ2
      RLFPC = 0.0
  950 CONTINUE
      RLFPCR = RLFPC
      TRNTO2 = TRO1 + TRNTO1
      YR2 = YEAR( TRNTO2, F1RYR0, E18GR )
      IF (YR2-YR1 .LT. THINOV) GO TO 930
      IOV2 = 0
  960 CONTINUE
      IOV2 = IOV2 + 1
      IF (IOV2 .GT. NOV2) GO TO 930
      IF (ITYP2(IOV2) .EQ. 0) GO TO 960
      GO TO ( 972, 1000, 1050 ), IOV2
  972 CONTINUE
C
C     FIRST OVERLAY = UNBONDED JCP, SECOND OVERLAY = AC
      IOV2T = 0
  980 CONTINUE
      IOV2T = IOV2T + 1
      IF (IOV2T .GT. NACT2) GO TO 960
      IF (THBR+PCCT(IOV1T)+ACT2(IOV2T) .GT. ALOVT) GO TO 960
      F2UJA = DFATIG( FREP, C2UJA(IC1), S2UPA(IOV1T,IOV2T) )
      F1UJA1 = DFATIG( FROV(IER1), C1UJA(IC1), S1UPA1(IOV1T,IOV2T) )
      F1UJA2 = DFATIG( FROV(IER1), C1UJA(IC1), S1UPA2(IOV1T,IOV2T) )
      F2UJA = EFATIG( E2UPA(IOV1T,IOV2T) )
      FATER2 = RLFPCR*F2UJA
      FOV12X = RLOV1P*F1UJA1
      RLOV1Y = (FOV12X - FATER2)/F1UJA1
      FOV12 = RLOV1Y*F1UJA2
      RLOV2Y = 1.0 - RLOV1P
      FOV22 = RLOV2Y*F2UJA
      FATOT2 = TRNTO2 + FATER2 + FOV12 + FOV22
      IF (RLOV1Y .LT. 0.0) FATOT2 = TRNTO2 + FOV12X + FOV22
      YRF2 = YEAR( FATOT2, F1RYR0, E18GR )
CS    CALL SAVE2(IRL1,IOV1,IC1,IER1,IOV1T,IRL2,IOV2,0,0,IOV2T,
CS   + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
      IF (YRF2 .LT. ANTMAX) GO TO 980
      CALL SAVE1(IRL1,IOV1,IC1,IER1,IOV1T,IRL2,IOV2,0,0,IOV2T,
     + TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2)
      IF (YRF2 .LT. ANPER) GO TO 980
      GO TO 960
 1000 CONTINUE
C
C     FIRST OVERLAY = UNBONDED JCP, SECOND OVERLAY = CRCP
C *** PROGRAM CAN HANDLE ONLY ONE CONCRETE OVERLAY DURING ANALYSIS
C *** PERIOD.
      GO TO 960
 1050 CONTINUE
C
C     FIRST OVERLAY = UNBONDED JCP, SECOND OVERLAY = JCP
C *** PROGRAM CAN HANDLE ONLY ONE CONCRETE OVERLAY DURING ANALYSIS
C *** PERIOD.
      GO TO 960
C**************************************************************************
C
      END
```

```
      FUNCTION YEAR( W, W0, G )
CC
C     YEAR - DETERMINES THE FUTURE YEAR CORRESPONDING TO AN ACCUMULATED
C             YEARLY TRAFFIC
C
C     ENTRY/   W0      = YEARLY TRAFFIC PRIOR TO YEAR ZERO.
C              G       = GROWTH RATE OF W0 PER YEAR, EXPRESSED AS A
C                          FRACTION.
C              W       = ACCUMULATED YEARLY TRAFFIC FOR WHICH THE FUTURE
C                          CORRESPONDING YEAR IS DESIRED.
C
C     EXIT/    YEAR    = FUTURE YEAR CORRESPONDING TO THE ACCUMULATED
C                          YEARLY TRAFFIC, W.
C
C     NOTE - THE EQUATION USED TO PREDICT THE YEARLY TRAFFIC, W(I), IN
C     SOME FUTURE YEAR, I, IS AS FOLLOWS,
C
C     W(I) = W0 * ( 1 + (I*G) )
C
      IF (G .EQ. 0.0) GO TO 10
C
C     THE EQUATION FOR THE YEAR CORRESPONDING TO THE ACCUMULATED
C     TRAFFIC (WHEN G IS NOT EQUAL TO ZERO) IS,
C
      YEAR = ( (-2.0-G) + SQRT( (2.0+G)**2 + 8.0*G*W/W0 ) ) / (2.0*G)
C
      RETURN
C
   10 CONTINUE
C
C     THE EQUATION FOR THE CASE WHEN G IS EQUAL TO ZERO IS,
C
      YEAR = W/W0
C
      RETURN
      END
```

```
      SUBROUTINE SAVE1( I1, I2, I3, I4, I5, I6, I7, I8, I9, I10,
     +                  A1, A2, A3, A4, A5, A6, A7, A8 )
C
      COMMON /NSAVE/ NSAVE1, NSAVE2
C
      NSAVE1 = NSAVE1 + 1
      WRITE(1,1000) NSAVE1,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,A1,A2,A3,A4,
     + A5,A6,A7,A8
 1000 FORMAT(1H ,I6,10I3,4(F8.3,F7.2))
      RETURN
      END
```

```
      SUBROUTINE SAVE2( I1, I2, I3, I4, I5, I6, I7, I8, I9, I10,
     +                  A1, A2, A3, A4, A5, A6, A7, A8 )
C
      COMMON /NSAVE/ NSAVE1, NSAVE2
C
      NSAVE2 = NSAVE2 + 1
      WRITE(2,1000) NSAVE2,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,A1,A2,A3,A4,
     + A5,A6,A7,A8
 1000 FORMAT(1H ,I6,10I3,4(F8.3,F7.2))
      RETURN
      END
```

```
      SUBROUTINE SETOUT
CC
C     SETOUT - INITIALIZE OUTPUT OF STRATEGIES
C
      WRITE(6,1000)
 1000 FORMAT(1H1
     +////7X,23(1H*)
     +   /7X,23H* R U S   O U T P U T
     +   /7X,23(1H*) )
      WRITE(6,2000)
 2000 FORMAT(    //7X,74HTHE FOLLOWING IS A LIST OF THE COMPONENTS WHICH
     +MAKE UP A FEASIBLE OVERLAY/7X,72HDESIGN STRATEGY.  THE COLUMN NUMB
     +ERS REFER TO THE COLUMN HEADINGS ON THE/7X,75HLIST OF FEASIBLE STR
     +ATEGIES WHICH BEGIN ON THE NEXT PAGE.  THE DESCRIPTIONS/7X,
     +76HIN THESE HEADINGS ALSO CORRESPOND TO THOSE IN THE LIST OF OPTIM
     +AL STRATEGIES/7X,44HWHICH SUCCEED THE LIST OF FEASIBLE STRATEGIES.
     +//
     +/8X,29HCOL     COMPONENT OF STRATEGY/8X,3HNO./8X,8H---  ,135(1H-) )
      WRITE(6,2100)
 2100 FORMAT(
     1/8X,16H 0. STRATEGY NO.
     2/8X,81H 1. EXISTING PAVEMENT REMAINING LIFE AT TIME OF FIRST OVERL
     +AY PLACEMENT (PERCENT)
     3/8X,47H 2. APPROXIMATE YEAR OF FIRST OVERLAY PLACEMENT
     4/8X,100H 3. TOTAL 18-KIP ESAL FATIGUE CYCLES BETWEEN YEAR ZERO AND
     + YEAR OF FIRST OVERLAY PLACEMENT, MILLIONS
     5/8X,67H 4. PRESENT VALUE OF EXISTING PAVEMENT MAINTENANCE COST (DO
     +L/SQ YD)
     6/8X,22H 5. FIRST OVERLAY TYPE
     +/8X,29H         1 = ASPHALTIC CONCRETE
     +/8X,22H         2 = BONDED CRCP
     +/8X,24H         3 = UNBONDED CRCP
     +/8X,21H         4 = BONDED JCP
     +/8X,23H         5 = UNBONDED JCP
     +/8X,59H     NOTE - A * AFTER NUMBER INDICATES PCC SHOULDER REQUIRED
     +)
      WRITE(6,2200)
 2200 FORMAT(
     7/8X,39H 7. THICKNESS OF FIRST OVERLAY (INCHES)
     8/8X,44H 8. FLEXURAL STRENGTH OF FIRST OVERLAY (PSI)
     9/8X,83H 9. APPROXIMATE YEAR OF LOSS OF PAVEMENT LOAD-CARRYING CAPA
     +CITY AFTER FIRST OVERLAY
     0/8X,88H10. TOTAL 18-KIP ESAL FATIGUE CYCLES BETWEEN YEAR ZERO AND
     +YEAR OF FIRST OVERLAY FAILURE
     1/8X,67H11. PRESENT VALUE OF COST OF FIRST OVERLAY CONSTRUCTION (DO
```

```
     +L/SQ YD)
     2/8X,86H12, PRESENT VALUE OF TRAFFIC DELAY COSTS DURING FIRST OVERL
     +AY CONSTRUCTION (DOL/SQ YD)
     *)
      WRITE(6,2300)
 2300 FORMAT(
     3 8X,63H13, PRESENT VALUE OF FIRST OVERLAY MAINTENANCE COST (DOL/SQ
     + YD)
     4/8X,81H14, REMAINING LIFE OF FIRST OVERLAY AT TIME OF SECOND OVERL
     +AY PLACEMENT (PERCENT)
     5/8X,48H15, APPROXIMATE YEAR OF SECOND OVERLAY PLACEMENT
     6/8X,101H16, TOTAL 18-KIP ESAL FATIGUE CYCLES BETWEEN YEAR ZERO AND
     + YEAR OF SECOND OVERLAY PLACEMENT, MILLIONS
     7/8X,23H17, SECOND OVERLAY TYPE
     +/8X,29H        1 = ASPHALTIC CONCRETE
     +/8X,15H        2 = CRCP
     +/8X,14H        3 = JCP
     +/8X,52H     NOTE - A * AFTER NUMBER INDICATES PCC SHOULDER REQUIRED
     8/8X,44H19, THICKNESS OF SECOND OVERLAY (INCHES)
     *)
      WRITE(6,2400)
 2400 FORMAT(
     9 8X,45H20, FLEXURAL STRENGTH OF SECOND OVERLAY (PSI)
     0/8X,84H21, APPROXIMATE YEAR OF LOSS OF PAVEMENT LOAD-CARRYING CAPA
     +CITY AFTER SECOND OVERLAY
     1/8X,89H22, TOTAL 18-KIP ESAL FATIGUE CYCLES BETWEEN YEAR ZERO AND
     +YEAR OF SECOND OVERLAY FAILURE
     2/8X,68H23, PRESENT VALUE OF COST OF SECOND OVERLAY CONSTRUCTION (D
     +OL/SQ YD)
     3/8X,87H24, PRESENT VALUE OF TRAFFIC DELAY COSTS DURING SECOND OVER
     +LAY CONSTRUCTION (DOL/SQ YD)
     4/8X,64H25, PRESENT VALUE OF SECOND OVERLAY MAINTENANCE COST (DOL/S
     +Q YD)
     *)
      WRITE(6,2500)
 2500 FORMAT(
     5 8X,52H26, PRESENT VALUE OF THE EXTENDED LIFE (DOL/SQ YD)
     6/8X,47H27, SALVAGE VALUE OF OVERLAY LAYERS (DOL/SQ YD)
     7/8X,51H28, TOTAL NET PRESENT VALUE OF STRATEGY (DOL/SQ YD)
     *)
      WRITE(6,3000)
 3000 FORMAT(1H1//132H    0    1    2    3    4  5    7    8    9   10    1
     +1   12   13   14   15   16  17  19   20  21  22    23   24    25
     + 26    27    28 )
      WRITE(6,3100)
 3100 FORMAT(    /132H --- --- ---- ---- ---- -- ---- --- ---- ---- ---
     +-- ---- ---- --- ---- ---- -- ---- --- --- ---- ----- ---- ----- -
     +---- ---- ------)
C
      RETURN
      END


      SUBROUTINE COSTRY
CC
C     COSTRY - COST ANALYSIS OF EACH FEASIBLE OVERLAY DESIGN STRATEGY
C
      COMMON /EPTYP/ IEPTYP, IEPSH
C
      COMMON /PROJCT/ NLANE, WL, OVLEN, SHWDTH
C
      COMMON /HPSY/ HSYAC1(8), HSYAC2(8), HSYCRC(8), HSYJCP(8), HSYRB
C
      COMMON /OVTHIK/ NACT1, ACT1(8), NACT2, ACT2(8), NPCCT, PCCT(8)
     0               , ALOVT, AVGLUT, THRB
C
      COMMON /CONSTC/ EOCACP, EOCCRC, EOCJCP, EOCACR, EOCAC1
     0               , PSPC1X, PSPC2X(5), FCAC, VCAC, FCRB, FCACSH
     1               , VCACSH, FCCRC(5), VCCRC(5), FCJCP(5), VCJCP(5)
C
      COMMON /PETNE/ SRPCRC, SRPJCP, SRCOST
C
      COMMON /MAINT/ DSTNEP, DSTCEP, DSTREP, FRACTA, FRACTR
C
      COMMON /DISTPS/ DCCRC, DRCRCA, DRCRCB, DRCRC(10)
     0               , DCJCP, DRJCPA, DRJCPB, DRJCP(10)
     1               , DCACC, DRACCA, DRACCB, DRACC(10)
     2               , DCACJ, DRACJA, DRACJB, DRACJ(10)
C
      COMMON /SALVAG/ PCSALV, YVEXL
C
      COMMON /INTRST/ DISCRT
C
      COMMON /TIME/ ANPER, TMINOV, TMAXMT
C
      COMMON /NSAVE/ NSAVE1, NSAVE2
C
      COMMON /STRCOM/ IRL1, IOV1, IC1, IFR1, IOV1T
     0               , IRL2, IOV2, IC2, IFR2, IOV2T
     1               , TRNTO1, YR1, FATOT1, YRF1
     2               , TRNTO2, YR2, FATOT2, YRF2
     3               , FPMNTC, CC1, TDC1, OVMTC1, CC2, TDC2, OVMTC2
     4               , TVEXL, SALV, TOTCST
C
      DATA BM / 999. /
C
      IF (NSAVE1 .LE. 0) GO TO 900
      ALANE = NLANE
      OVWDTH = ALANE*WL
      SYS = (1760.*OVLEN)*(SHWDTH/3.)
      SYO = (1760.*OVLEN)*(OVWDTH/3.)
      SYT = SYS + SYO
      SYST = SYS/SYT
      SYOT = SYO/SYT
C
      REWIND 1
      DO 500 ISTR=1,NSAVE1
      READ(1,1) IRL1,IOV1,IC1,IFR1,IOV1T,IRL2,IOV2,IC2,IFR2,IOV2T,
     +          TRNTO1,YR1,FATOT1,YRF1,TRNTO2,YR2,FATOT2,YRF2
    1 FORMAT(7X,10I3,4(F8.0,F7.0))
C
C     COMPUTE COSTS ASSOCIATED WITH OVERLAY/SHOULDER CONSTRUCTION
C
      GO TO ( 10, 20, 30, 40, 50 ), IOV1
   10 CONTINUE
C
C     FIRST OVERLAY - AC
      TDC1 = TDCSY( YR1, 1, HSYAC1(IOV1T) )
      SEC1X = EOCACP/SYT
      OVCC1X = (FCAC+(AVGLUT+ACT1(IOV1T))*VCAC)*SYOT
```

```
     +        + (FCACSH+(AVGLUT+ACT1(IOV1T))*VCACSH)*SYST
      SRC1X = 0.0
      GO TO 60
   20 CONTINUE
C
C     FIRST OVERLAY - BONDED CRCP
      TDC1 = TDCSY( YR1, 2, HSYCRC(IOV1T) )
      IF (TC1 .NE. 1) GO TO 25
      SEC1X = FQCACR/SYT
      OVCC1X = (FCCRC(IFR1)+(AVGLUT+PCCT(IOV1T))*VCCRC(IFR1))*SYOT
     +        + (FCACSH+(AVGLUT+PCCT(IOV1T))*VCACSH)*SYST
      SRC1X = 0.0
      GO TO 60
   25 CONTINUE
      SEC1X = FQCCRC/SYT
      OVCC1X = FCCRC(IFR1)+(AVGLUT+PCCT(IOV1T))*VCCRC(IFR1)
      SRC1X = 0.0
      GO TO 60
   30 CONTINUE
C
C     FIRST OVERLAY - UNBONDED CRCP
      TDC1 = TDCSY( YR1, 1, HSYBB )
     +     + TDCSY( YR1, 2, HSYCRC(IOV1T) )
      SEC1X = FQCACR/SYT
      IF (TC1 .NE. 1) GO TO 35
      OVCC1X = (FCBB+FCCRC(IFR1)+PCCT(IOV1T)*VCCRC(IFR1))*SYOT
     +        + (FCACSH+(AVGLUT+PCCT(IOV1T))*VCACSH)*SYST
      SRC1X = 0.0
      GO TO 60
   35 CONTINUE
      OVCC1X = FCBB+FCCRC(IFR1)+PCCT(IOV1T)*VCCRC(IFR1)
      SRC1X = 0.0
      GO TO 60
   40 CONTINUE
C
C     FIRST OVERLAY - BONDED JCP
      TDC1 = TDCSY( YR1, 2, HSYJCP(IOV1T) )
      IF (TC1 .NE. 1) GO TO 45
      SEC1X = FQCACJ/SYT
      OVCC1X = (FCJCP(IFR1)+(AVGLUT+PCCT(IOV1T))*VCJCP(IFR1))*SYOT
     +        + (FCACSH+(AVGLUT+PCCT(IOV1T))*VCACSH)*SYST
      SRC1X = 0.0
      GO TO 60
   45 CONTINUE
      SEC1X = FQCJCP/SYT
      OVCC1X = FCJCP(IFR1)+(AVGLUT+PCCT(IOV1T))*VCJCP(IFR1)
      SRC1X = 0.0
      GO TO 60
   50 CONTINUE
C
C     FIRST OVERLAY - UNBONDED JCP
      TDC1 = TDCSY( YR1, 1, HSYBB )
     +     + TDCSY( YR1, 2, HSYJCP(IOV1T) )
      SEC1X = FQCACJ/SYT
      IF (TC1 .NE. 1) GO TO 55
      OVCC1X = (FCBB+FCJCP(IFR1)+PCCT(IOV1T)*VCJCP(IFR1))*SYOT
     +        + (FCACSH+(AVGLUT+PCCT(IOV1T))*VCACSH)*SYST
      SRC1X = 0.0
      GO TO 60
   55 CONTINUE
      OVCC1X = FCBB+FCJCP(IFR1)+PCCT(IOV1T)*VCJCP(IFR1)
      SRC1X = 0.0
   60 CONTINUE
      CC1X = SEC1X + PSPC1X + OVCC1X + SRC1X
      CC1 = PRVAL( CC1X, YR1, DISCRT )
C
      TDC2 = 0.0
      CC2 = 0.0
      OVCC2X = 0.0
      IF (IOV2 .EQ. 0) GO TO 200
      GO TO ( 110, 120, 130 ), IOV2
  110 CONTINUE
C
C     SECOND OVERLAY - AC
      TDC2 = TDCSY( YR2, 1, HSYAC2(IOV2T) )
      SEC2X = FQCACP/SYT
      OVCC2X = (FCAC+(AVGLUT+ACT2(IOV2T))*VCAC)*SYOT
     +        + (FCACSH+(AVGLUT+ACT2(IOV2T))*VCACSH)*SYST
      SRC2X = 0.0
      GO TO 160
  120 CONTINUE
C
C     SECOND OVERLAY - CRCP
      TDC2 = TDCSY( YR2, 2, HSYCRC(IOV2T) )
      IF (TC2 .NE. 1) GO TO 125
      SEC2X = FQCACR/SYT
      OVCC2X = (FCCRC(IFR2)+(AVGLUT+PCCT(IOV2T))*VCCRC(IFR2))+SYOT
     +        + (FCACSH+(AVGLUT+PCCT(IOV2T))*VCACSH)*SYST
      SRC2X = 0.0
      GO TO 160
  125 CONTINUE
      SEC2X = FQCCRC/SYT
      OVCC2X = FCCRC(IFR2)+(AVGLUT+PCCT(IOV2T))*VCCRC(IFR2)
      SRC2X = 0.0
      GO TO 160
  130 CONTINUE
C
C     SECOND OVERLAY - JCP
      TDC2 = TDCSY( YR2, 2, HSYJCP(IOV2T) )
      IF (TC2 .NE. 1) GO TO 135
      SEC2X = FQCACJ/SYT
      OVCC2X = (FCJCP(IFR2)+(AVGLUT+PCCT(IOV2T))*VCJCP(IFR2))+SYOT
     +        + (FCACSH+(AVGLUT+PCCT(IOV2T))*VCACSH)*SYST
      SRC2X = 0.0
      GO TO 160
  135 CONTINUE
      SEC2X = FQCJCP/SYT
      OVCC2X = FCJCP(IFR2)+(AVGLUT+PCCT(IOV2T))*VCJCP(IFR2)
      SRC2X = 0.0
  160 CONTINUE
      CC2X = SEC2X + PSPC2X(IOV1) + OVCC2X + SRC2X
      CC2 = PRVAL( CC2X, YR2, DISCRT )
  200 CONTINUE
C
C     COMPUTE MAINTENANCE COST FOR EACH STRATEGY
C
      GO TO ( 210, 220, 230, 240, 250 ), IOV1
  210 CONTINUE
      IF (IOV2 .EQ. 0) GO TO 211
      GO TO ( 211, 214, 217 ), IOV2
  211 CONTINUE
      GO TO ( 212, 213 ), IEPTYP
  212 CONTINUE
      CALL MNTCST( YR1, YRF1, YR2, YRF2, DRACC, DRACCA, DRACCB, DRACC,
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     + DCACC, DRACCA, DRACCB, DRACC, EPMNTC, OVMTC1, OVMTC2 )
      GO TO 260
  213 CONTINUE
      CALL MNTCST( YR1, YRF1, YR2, YRF2, DCACJ, DRACJA, DRACJB, DRACJ,
     + DCACJ, DRACJA, DRACJB, DRACJ, EPMNTC, OVMTC1, OVMTC2 )
      GO TO 260
  214 CONTINUE
      GO TO ( 215, 216 ), IEPTYP
  215 CONTINUE
      CALL MNTCST( YR1, YRF1, YR2, YRF2, DCACC, DRACCA, DRACCB, DRACC,
     + DCCRC, DRCRCA, DRCRCB, DRCRC, EPMNTC, OVMTC1, OVMTC2 )
      GO TO 260
  216 CONTINUE
      CALL MNTCST( YR1, YRF1, YR2, YRF2, DCACJ, DRACJA, DRACJB, DRACJ,
     + DCCRC, DRCRCA, DRCRCB, DRCRC, EPMNTC, OVMTC1, OVMTC2 )
      GO TO 260
  217 CONTINUE
      GO TO ( 218, 219 ), IEPTYP
  218 CONTINUE
      CALL MNTCST( YR1, YRF1, YR2, YRF2, DCACC, DRACCA, DRACCB, DRACC,
     + DCJCP, DRJCPA, DRJCPB, DRJCP, EPMNTC, OVMTC1, OVMTC2 )
      GO TO 260
  219 CONTINUE
      CALL MNTCST( YR1, YRF1, YR2, YRF2, DCACJ, DRACJA, DRACJB, DRACJ,
     + DCJCP, DRJCPA, DRJCPB, DRJCP, EPMNTC, OVMTC1, OVMTC2 )
      GO TO 260
  220 CONTINUE
  230 CONTINUE
      CALL MNTCST( YR1, YRF1, YR2, YRF2, DCCRC, DRCRCA, DRCRCB, DRCRC,
     + DCACC, DRACCA, DRACCB, DRACC, EPMNTC, OVMTC1, OVMTC2 )
      GO TO 260
  240 CONTINUE
  250 CONTINUE
      CALL MNTCST( YR1, YRF1, YR2, YRF2, DCJCP, DRJCPA, DRJCPB, DRJCP,
     + DCACJ, DRACJA, DRACJB, DRACJ, EPMNTC, OVMTC1, OVMTC2 )
  260 CONTINUE
C     CONVERT MAINTENANCE COST FROM DOLLARS/MILE TO DOLLARS/SY
      EPMNTC = EPMNTC/(1760.*OVWDTH/3.)
      OVMTC1 = OVMTC1/(1760.*OVWDTH/3.)
      OVMTC2 = OVMTC2/(1760.*OVWDTH/3.)
C
C     COMPUTE VALUE OF THE STRATEGY LIFE BEYOND THE ANALYSIS PERIOD
C
      NANPER = ANPER + 1.5
      NYRF = YRF2 + 0.5
      IF (YRF2 .GE. BM) NYRF=YRF1+0.5
      TVEXL = 0.0
      IF (NYRF .LT. NANPER) GO TO 310
      DO 300 IYR=NANPER,NYRF
      YR = IYR
      TVEXL = TVEXL + PRVAL( YVEXL, YR, DISCRT )
  300 CONTINUE
  310 CONTINUE
C
C     COMPUTE SALVAGE VALUE AT END OF LIFE
C
      YRF = YRF2
      IF (YRF2 .GE. BM) YRF=ANPER
      YRSALV = AMAX1( ANPER, YRF )
      SALVX = (PCSALV/100.0)*(OVCC1X+OVCC2X)
      SALV = PRVAL( SALVX, YRSALV, DISCRT )
C
C     COMPUTE TOTAL STRATEGY COST
C
      TOTCST = EPMNTC+CC1+TDC1+OVMTC1+CC2+TDC2+OVMTC2-TVEXL-SALV
C
C     PRINT EACH FEASIBLE STRATEGY
      CALL PRNTST( ISTR )
C
C     OPTIMIZE BY ARRANGING IN ORDER OF INCREASING COST
C
      CALL ORDER
C
  500 CONTINUE
      RETURN
C
  900 CONTINUE
      WRITE(6,1000)
 1000 FORMAT(//10X,43H*** SORRY, NO FEASIBLE STRATEGIES COULD BE
     1 10HGENERATED. //10X,38H*** CHECK CONSTRAINTS AND/OR INCREASE
     2 29HRANGE OF OVERLAY THICKNESSES. )
      STOP
C
      END
```

```
      FUNCTION TDCSY( YR, IDOV, HPSY )
CC
C     TDCSY - COMPUTES TRAFFIC DELAY COST DURING OVERLAY CONSTRUCTION
C
C     ENTRY/ ILOC    = LOCATION OF ROADWAY,
C                    = 1, RURAL AREA, OR
C                    = 2, URBAN AREA.
C            MODEL   = MODEL NUMBER DESCRIBING HOW TRAFFIC IS HANDLED.
C                      (SEE USERS MANUAL)
C            IDOV    = TYPE OF OVERLAY,
C                    = 1, ASPHALTIC CONCRETE,
C                    = 2, PORTLAND CEMENT CONCRETE.
C            YR      = YEAR IN WHICH OVERLAY OCCURS.
C            DISCRT  = DISCOUNT RATE (DIFFERENCE BETWEEN PRIME INTEREST
C                      RATE AND INFLATION RATE), PERCENT.
C            NOLO    = NO. OF OPEN LANES, OVERLAY DIRECTION.
C            NOLN    = NO. OF OPEN LANES, NON-OVERLAY DIRECTION.
C            N1      = TIME OF DAY OVERLAY CONSTRUCTION BEGINS.
C            N2      = TIME OF DAY OVERLAY CONSTRUCTION ENDS.
C            HPDC    = HOURS PER DAY OVERLAY CONSTRUCTION OCCURS.
C            DAYCUR  = NO. OF DAYS PCC IS ALLOWED TO CURE.
C            DDDZ    = DETOUR DISTANCE, MILES. (MODEL 5 ONLY)
C            DTSO    = DISTANCE OVER WHICH TRAFFIC IS SLOWED, OVERLAY
C                      DIRECTION, MILES.
C            DTSN    = DISTANCE OVER WHICH TRAFFIC IS SLOWED,
C                      NON-OVERLAY DIRECTION, MILES.
C            AAS     = AVERAGE APPROACH SPEED TO OVERLAY ZONE, MPH.
C            ASOD    = AVERAGE SPEED THRU RESTRICTED ZONE, OVERLAY
C                      DIRECTION, MPH.
C            ASND    = AVERAGE SPEED THRU RESTRICTED ZONE, NON-OVERLAY
C                      DIRECTION, MPH.
C            PVSO    = PERCENT VEHICLES STOPPED BY ROAD EQUIPMENT,
C                      OVERLAY DIRECTION.
C            PVSN    = PERCENT VEHICLES STOPPED BY ROAD EQUIPMENT,
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C                     NON-OVERLAY DIRECTION.
C           DEQO    = AVERAGE DELAY PER VEHICLE STOPPED IN RESTRICTED
C                     ZONE, OVERLAY DIRECTION, HOURS.
C           DEQN    = AVERAGE DELAY PER VEHICLE STOPPED IN RESTRICTED
C                     ZONE, NON-OVERLAY DIRECTION, HOURS.
C           HPSY    = OVERLAY CONSTRUCTION RATE, HOURS/SY.
C           NLANE   = NO. OF OVERLAY LANES.
C           WL      = LANE WIDTH, FEET.
C           OVLEN   = OVERLAY LENGTH, MILES.
C           ADT     = INITIAL AVERAGE DAILY TRAFFIC, BOTH DIRECTIONS.
C                     (DELAY COSTS WILL BE COMPUTED ON THE BASIS THAT
C                     THE ADT IS SPLIT EVENLY IN BOTH DIRECTIONS)
C           GR      = TRAFFIC GROWTH RATE, PERCENT PER YEAR.
C
C     EXIT/ TDCSY   = PRESENT VALUE OF FUTURE TRAFFIC DELAY COST DUE
C                     TO OVERLAY CONSTRUCTION, DOLLARS/SY.
C
C     NOTE - THIS ROUTINE IS AN MODIFICATION OF ONE CALLED TDC3 IN THE
C           RIGID PAVEMENT SYTEM, RPS3, DEVELOPED BY CARMICHAEL AND
C           DOCUMENTED IN CFHR 123-26, *MODIFICATION AND IMPLEMENTATION
C           OF THE RIGID PAVEMENT DESIGN SYSTEM*.  SOME COST IMPROVE-
C           MENTS WERE INCORPORATED BY DANIEL AND DOCUMENTED IN
C           CFHR 177-14, *A METHEDOLOGY TO DETERMINE AN OPTIMUM TIME
C           TO OVERLAY*.  SOME IMPROVEMENTS WERE ALSO MADE FOR INCORP-
C           ORATION INTO RPRDS-1 BY SEEDS, *RIGID PAVEMENT REHABIL-
C           ITATION DESIGN SYSTEM*, MASTERS THESIS, 1980, UNIVERSITY
C           OF TEXAS.  TWO ADDITIONAL ROUTINES ARE PART OF THE PACKAGE,
C           VPHCAL (DISTRIBUTION OF ADT FOR TEXAS) AND PRVAL (NET
C           PRESENT VALUE OF SOME FUTURE COST).
C
      COMMON /TDC/ ILOC, MODEL, NOLO, NOLN, N1, N2, HPDC, DAYCUR, DOOZ,
     1             DTSO, DTSN, AAS, ASOD, ASND, PVSO, PVSN, DEQO, DEQN
C
      COMMON /PROJCT/ NLANE, WL, OVLEN, SHWDTH
C
      COMMON /TRAFIC/ ADT, GR, E18YR0, E18GR
C
      COMMON /INTRST/ DISCRT
C
      DIMENSION AVPH(24)
      DIMENSION CCSR(6,7), CCSU(6,7), CURS(12,2), COD(1,2), CAP(4,3)
C
C
C        THE FOLLOWING ARE TABLES CONTAINING THE USER COSTS.
C
C
C    COST OF SLOWING DOWN IN A RURAL AREA IN TEXAS,
C
C
C     EXCESS COST ABOVE CONTINUING AT INITIAL SPEED
C     IT INCLUDES OPERATING AS WELL AS TIME COST OF SPEED CHANGE CYCLE
C     **DOLLARS PER 1000 CYCLES **
      DATA CCSR/ 15.312, 322.889, 57.014, 91.006, 140.831, 217.839,
     1        0., 17.010, 38.836, 71.577, 119.690, 193.322, 2*0., 27.518,
     2        51.398, 97.434, 167.124, 3*0., 28.543, 72.177, 137.379,
     3        4*0., 43.862, 101.939, 5*0., 58.704, 6*0./
C
C    COST OF SLOWING DOWN IN AN URBAN AREA
C
      DATA CCSU/13.606, 21.268, 35.238, 54.267, 81.323, 122.614, 0.,
     1        10.123, 23.230, 41.012, 67.474, 106.685, 2*0., 11.748,
     2        28.870, 53.508, 88.750, 3*0., 15.557, 38.759, 72.721, 4*0.,
     3        21.4225, 53.457, 5*0., 29.694, 6*0./
C
C    COST OF OPERATING AT A UNIFORM SPEED IN TEXAS
C     DIFFERENCE OF TWO VALUES GIVES THE EXCESS COST OF OPERATING AT
C     REDUCED SPEED
C     IT INCLUDES OPERATING AS WELL AS TIME COST
C     ** DOLLARS PER 1000 VEHICLE MILES **
C
      DATA CURS/1355.69, 711.04, 495.42, 387.68, 323.71, 282.30,
     1        253.32, 233.17, 218.77, 208.74, 202.29, 199.07, 1257.62,
     2        654.95, 455.77, 356.11, 296.65, 257.64, 230.55, 211.14,
     3        196.94, 186.57, 179.23, 174.80/
C
C    COST OF IDLING
C     IT INCLUDES OPERATING AS WELL TIME COST
C     ** DOLLARS PER 1000 VEHICLE HOURS **
C
      DATA COD / 6324.42, 5896.77/
C
C    CAPACITY TABLE
C     OUTPUT AND RECOVERY RATES, VEHICLES PER HOUR IN ONE DIRECTION
C     USED TO CALCULATE PO1,PN1,DO1 AND DN1 FOR MODEL NOS 3,4 AND 5
C
      DATA CAP / 1350., 3000., 1400., 3000., 2700., 4500., 2800.,
     1        4700., 4350., 6210., 4500., 6400. /
C     COMPUTE FINAL ADT IN OVERLAY AND NON-OVERLAY DIRECTION. NOTE
C     THAT CODE REQUIRES A 50-50 SPLIT IN EACH DIRECTION.
                VPD = 0.5 * ADT * ( 1.0 + YR*GR/100. )
           IF (AAS .GT. 60.0) AAS = 60.0
           IF (ASOD .GT. 60.0) ASOD = 60.0
           IF (ASND .GT. 60.0) ASND = 60.0
                LO = ASOD/10.0
                LO1 = ASOD*2.0/10.0
                LN = ASND/10.0
                LN1 = ASND*2.0/10.0
                K = AAS/10.0
                K1 = AAS*2.0/10.0
                ALO = LO
                ALO1 = LO1
                ALN = LN
                ALN1 = LN1
                AK = K
                AK1 = K1
      ALANES = NLANE
      SYARDS = (1760.*OVLEN) * ((WL/3.0)*(ALANES))
      IF (IDOV.EQ.2) GO TO 994
      HTCAD = HPSY * SYARDS
      DAYACC = HTCAD/HPDC
      GO TO 995
  994 HTCCO = HPSY * SYARDS
      DAYPCC = HTCCO/HPDC
  995 CONTINUE
      CALL VPHCAL( VPD, AVPH )
      IREDUC = 0
      ITIMOV = 1
      N2DUM = N2-1
      NUM1 = N1
  996 DCHT = 0.0
      DO 999 I=N1,N2DUM
      VPH = AVPH(I)
C   ****
C   MODEL NUMBER ONE
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C  ****
            P01 = 0.
            PN1 = 0.
            D01 = 0.
            DN1 = 0.
C
C       ABOVE VALUES ARE BEING GIVEN FOR MODEL NUMBER ONE BUT THESE
C       VALUES ARE ALSO USED FOR OTHER MODELS IN CASE SEPERATE VALUES
C       OF THESE VARIABLES ARE NOT COMPUTED FOR THEM
            P02 = PVS0/100.
            PN2 = PVSN/100.
            D02 = DEO0
            DN2 = DEON
            D = 1./12.
         GO TO (790,750,760,770,760), MODEL
C  ****
C  MODEL NUMBER TWO
C  ****
 750        A = DTSO/ASOD
            AQ = A*VPH
            P01 = 0.5*(1.-EXP(-AQ))**2
            PN1 = P01
            D01 = (1.+EXP(2.*AQ))*(EXP(AQ)-AQ-1.)/(2.*VPH*P01
     1           *(EXP(2.*AQ)-EXP(AQ)+1.))
            DN1 = D01
         GO TO 790
C  ****
C  MODEL NUMBERS THREE AND FIVE
C  ****
 760        OUTRAT = CAP(2*ILOC-1, NOLO)
            RECRAT = CAP(2*ILOC, NOLO)
         IF (VPH .LE. OUTRAT) GO TO 790
      RECVPH=AMAX1(1.0,RECRAT-VPH)
            P01 = HPDC*(VPH-OUTRAT)/(2.*VPH*D)
         IF (P01 .GT. 1.) P01 = 1.
            D01 = HPDC*(VPH-OUTRAT)*(RECRAT-OUTRAT)/(2.*VPH*P01
     1 *(RECVPH))
         GO TO 790
C  ****
C  MODEL NUMBER FOUR
C  ****
 770        OUTRAT = CAP(2*ILOC-1, NOLO)
            RECRAT = CAP(2*ILOC, NOLO)
         IF (VPH .LE. OUTRAT) GO TO 780
      RECVPH=AMAX1(1.0,RECRAT-VPH)
            P01 = HPDC*(VPH-OUTRAT)/(2.*VPH*D)
         IF (P01 .GT. 1.) P01 = 1.
            D01 = HPDC*(VPH-OUTRAT)*(RECRAT-OUTRAT)/(2.*VPH*P01
     1 *(RECVPH))
 780        OUTRAT = CAP(2*ILOC-1, NOLN)
            RECRAT = CAP(2*ILOC, NOLN)
         IF (VPH .LE. OUTRAT) GO TO 790
            PN1 = HPDC*(VPH-OUTRAT)/(2.*VPH*D)
         IF (PN1 .GT. 1.) PN1 = 1.
            DN1 = HPDC*(VPH-OUTRAT)*(RECRAT-OUTRAT)/(2.*VPH*PN1
     1           *(RECRAT-VPH))
 790     CONTINUE
C
C  START COLLECTING ALL PERTINENT INFORMATION ABOUT DIFFERENT TYPES OF
C  DELAY COSTS. THE FOLLOWING ARE THE DIFFERENT TYPES OF TRAFFIC DELAY
C  COSTS PER VEHICLE
C
         GO TO (800,810), ILOC
C  COST OF STOPPING FROM APPROACH SPEED IN A RURAL AREA.
 800        C01 = (CCSR(K, 1)+(CCSR(K+1, 1)-CCSR(K, 1))*(AAS
     1           /10.-AK))/1000.0
            CN1 = C01
C  COST OF SLOWING TO THRU SPEED IN A RURAL AREA.
            C041 = CCSR(K, LO+1)+(CCSR(K+1, LO+1)-CCSR(K, LO
     1           +1))*(AAS/10.-AK)
            C042 = CCSR(K, LO+2)+(CCSR(K+1, LO+2)-CCSR(K, LO
     1           +2))*(AAS/10.-AK)
            C04 = (C041-(C041-C042)*(ASOD/10.-ALO))/1000.0
            CN41 = CCSR(K, LN+1)+(CCSR(K+1, LN+1)-CCSR(K, LN
     1           +1))*(AAS/10.-AK)
            CN42 = CCSR(K, LN+2)+(CCSR(K+1, LN+2)-CCSR(K, LN
     1           +2))*(AAS/10.-AK)
            CN4 = (CN41-(CN41-CN42)*(ASND/10.-ALN))/1000.0
         GO TO 820
C  COST OF STOPPING FROM APPROACH SPEED IN IN URBAN AREA.
 810        C01 = (CCSU(K, 1)+(CCSU(K+1, 1)-CCSU(K, 1))*(AAS
     1           /10.-AK))/1000.0
            CN1 = C01
C  COST OF SLOWING TO THRU SPEED IN AN URBAN AREA.
            C041 = CCSU(K, LO+1)+(CCSU(K+1, LO+1)-CCSU(K, LO
     1           +1))*(AAS/10.-AK)
            C042 = CCSU(K, LO+2)+(CCSU(K+1, LO+2)-CCSU(K, LO
     1           +2))*(AAS/10.-AK)
            C04 = (C041-(C041-C042)*(ASOD/10.-ALO))/1000.0
            CN41 = CCSU(K, LN+1)+(CCSU(K+1, LN+1)-CCSU(K, LN
     1           +1))*(AAS/10.-AK)
            CN42 = CCSU(K, LN+2)+(CCSU(K+1, LN+2)-CCSU(K, LN
     1           +2))*(AAS/10.-AK)
            CN4 = (CN41-(CN41-CN42)*(ASND/10.-ALN))/1000.0
C  COST OF DELAY DUE TO CONGESTION OUTSIDE THE RESTRICTED AREA.
 820        C02 = D01*COD(1, ILOC)/1000.
            CN2 = DN1*COD(1, ILOC)/1000.
         IF (MODEL .EQ. 5) GO TO 830
C  COST OF DRIVING AT A REDUCED SPEED.
            C031 = CURS(LO1, ILOC)-(CURS(LO1, ILOC)-CURS(LO1
     1           +1, ILOC))*(ASOD*2.0/10.-ALO1)/2.0
            C032 = CURS(K1, ILOC)-(CURS(K1, ILOC)-CURS(K1+1,
     1           ILOC))*(AAS*2.0/10.-AK1)/2.0
            C03 = (C031-C032)*DTSO/1000.0
            CN31 = CURS(LN1, ILOC)-(CURS(LN1, ILOC)-CURS(LN1
     1           +1, ILOC))*(ASND*2.0/10.-ALN1)/2.0
            CN3 = (CN31-C032)*DTSN/1000.0
C  EXCESS COST OF STOPPING FROM THRU SPEED + COST OF IDLE TIME, ALL
C  WITHIN THE RESTRICTED AREA.
         GO TO 840
 830        C031 = CURS(LO1, ILOC)-(CURS(LO1, ILOC)-CURS(LO1
     1           +1, ILOC))*(ASOD*2.0/10.-ALO1)/2.0
            C032 = CURS(K1, ILOC)-(CURS(K1, ILOC)-CURS(K1+1,
     1           ILOC))*(AAS*2.0/10.-AK1)/2.0
            C03 = (C031*DDOZ-C032*DTSO)/1000.0
            CN31 = CURS(LN1, ILOC)-(CURS(LN1, ILOC)-CURS(LN1
     1           +1, ILOC))*(ASND*2.0/10.-ALN1)/2.0
            CN32 = CURS(K1, ILOC)-(CURS(K1, ILOC)-CURS(K1+1,
     1           ILOC))*(AAS*2.0/10.-AK1)/2.0
            CN3 = (CN31-CN32)*DTSN/1000.0
 840     GO TO (850,860), ILOC
 850        C05 = (CCSR(LO, 1)+(CCSR(LO+1, 1)-CCSR(LO, 1))*(ASOD
     1           /10.-ALO)+D02*COD(1, ILOC))/1000.
            CN5 = (CCSR(LN, 1)+(CCSR(LN+1, 1)-CCSR(LN, 1))*(ASND
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     1              /10.-ALN)+DN2*COD(1, ILOC))/1000.
           GO TO 870
 860            CO5 = (CCSU(LO, 1)+(CCSU(LO+1, 1)-CCSU(LO, 1))*(ASOD
     1              /10.-ALO)+DO2*COD(1, ILOC))/1000.
                CN5 = (CCSU(LN, 1)+(CCSU(LN+1, 1)-CCSU(LN, 1))*(ASND
     1              /10.-ALN)+DN2*COD(1, ILOC))/1000.
C  START TOTAL COST COMPUTATIONS
C        DCH IS TOTAL TRAFFIC DELAY COST PER HOUR OF OVERLAY CONSTR.
  870 IF (IREDUC.EQ.1) GO TO 879
      DCH = VPH*(PO1*(CO1+CO2+CO3)+(1.-PO1)*(CO3+CO4)+PO2
     1    *CO5) + VPH*(PN1*(CN1+CN2+CN3)+(1.-PN1)*(CN3+CN4)
     2    +PN2*CN5)
      GO TO 881
  879 DCH = VPH*(CO3+CO4+CN3+CN4)
  881  DCHT = DCH + DCHT
  999 CONTINUE
      IF (IDOV.NE.2) GO TO 2000
      GO TO (1000,1001,1002,1003),ITIMOV
 1000 N1 = N2DUM + 1
      N2DUM = 24
      DCH1 = DCHT
      IREDUC = 1
      ITIMOV = 2
      GO TO 996
 1001 N1 = 1
      N2DUM = NUM1-1
      DCH2 = DCHT
      IREDUC = 1
      ITIMOV = 3
      GO TO 996
 1002 N1 = 1
      N2DUM = 24
      DCH3 = DCHT
      IREDUC = 1
      ITIMOV = 4
      GO TO 996
 1003 DCH4 = DCHT
      DCHTOT = (DCH1+DCH2+DCH3)*(DAYPCC) + DCH4*(DAYCUR)
      TDCSYF = DCHTOT/SYARDS
      GO TO 3000
 2000 CONTINUE
      TDCSYF = (DAYACC * DCHT) / SYARDS
 3000 CONTINUE
      TDCSY = PRVAL( TDCSYF, YR, DISCRT )
      IF (TDCSY .LT. 0.0) TDCSY=0.0
C
      RETURN
      END



      SUBROUTINE VPHCAL( VPD, VPH )
CC
C     VPHCAL - CALCULATES DISTRIBUTION OF AVERAGE DAILY TRAFFIC BY
C              THE HOUR FOR TEXAS CONDITIONS
C
C     ENTRY/ VPD    = TOTAL NUMBER OF VEHICLES PER DAY.
C
C     EXIT/  VPH    = NUMBER OF VEHICLES IN EACH HOUR OF THE DAY.
C
      DIMENSION PERADT(24),VPH(24)
      DATA PERADT / 1.044,0.691,0.522,0.509,0.606,1.605,3.174,6.334,
     1              6.081,5.938,5.961,6.035,5.691,6.127,6.382,6.894,
     2              8.110,7.806,6.117,4.400,3.269,2.669,2.401,1.621  /
      DO 10 I=1,24
         VPH(I) = VPD*PERADT(I)/100.0
   10 CONTINUE
      RETURN
      END



      SUBROUTINE MNTCST( YR1, YRF1, YR2, YRF2, DSTCO1, DSTR1A, DSTR1B,
     . DSTR1, DSTCO2, DSTR2A, DSTR2B, DSTR2, EPMNTC, OVMTC1, OVMTC2 )
CC
C     MNTCST - COMPUTE PRESENT VALUE OF MAINTENANCE COST FOR A GIVEN
C              OVERLAY DESIGN STRATEGY
C
      COMMON /TIME/ ANPER, TMINOV, TMAXMT
C
      COMMON /INTRST/ DISCRT
C
      COMMON /MAINT/ DSTNEP, DSTCEP, DSTREP, FRACTA, FRACTB
C
      DIMENSION DSTR1(10), DSTR2(10)
C
C     EXISTING PAVEMENT MAINTENANCE COSTS (UNTIL FIRST OVERLAY)
      YR = 0.0
      EPMNTC = DSTNEP+DSTCEP
      IF (YR1 .LE. 0.0) GO TO 15
      EPDCX = DSTREP+DSTCEP
   10 CONTINUE
      YR = YR + 1.0
      EPMNTC = EPMNTC + PRVAL( EPDCX, YR, DISCRT )
      IF (YR .LE. YR1-0.5) GO TO 10
   15 CONTINUE
C
C     FIRST OVERLAY MAINTENANCE COSTS
      YR = YR1 + FRACTA*(YRF1-YR1)
      YRB = YR1 + FRACTB*(YRF1-YR1)
      OVMTC1 = 0.0
      OVDC1X = DSTCO1*DSTR1A
   20 CONTINUE
      IF (YR .GT. ANPER+0.5) GO TO 70
      IF (YR .GT. YR2+0.5) GO TO 100
      OVMTC1 = OVMTC1 + PRVAL( OVDC1X, YR, DISCRT )
      YR = YR + 1.0
      IF (YR .GE. YRB) GO TO 30
      GO TO 20
   30 CONTINUE
      OVDC1X = DSTCO1*DSTR1B
   40 CONTINUE
      IF (YR .GT. ANPER+0.5) GO TO 70
      IF (YR .GT. YR2+0.5) GO TO 100
      OVMTC1 = OVMTC1 + PRVAL( OVDC1X, YR, DISCRT )
      YR = YR + 1.0
      IF (YR .GT. YRF1-0.5) GO TO 50
      GO TO 40
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   50 CONTINUE
      IYRF = 1
   60 CONTINUE
      IF (YR .GT. ANPER+0.5) GO TO 70
      IF (YR .GT. YR2+0.5) GO TO 100
      OVDC1X = DSTCD1*DSTR1(IYRF)
      OVMTC1 = OVMTC1 + PRVAL( OVDC1X, YR, DISCRT )
      IYRF = IYRF + 1
      YR = YR + 1.0
      IF (IYRF .LE. 10) GO TO 60
      OVMTC1 = 1.0E+20
   70 CONTINUE
      OVMTC2 = 0.0
      RETURN
  100 CONTINUE
C
C     SECOND OVERLAY MAINTENANCE COSTS
      YR = YR2 + FRACTA*(YRF2-YR2)
      YRB = YR2 + FRACTB*(YRF2-YR2)
      OVMTC2 = 0.0
      OVDC2X = DSTCD2*DSTR2A
  110 CONTINUE
      IF (YR .GT. ANPER+0.5) GO TO 170
      OVMTC2 = OVMTC2 + PRVAL( OVDC2X, YR, DISCRT )
      YR = YR + 1.0
      IF (YR .GE. YRB) GO TO 120
      GO TO 110
  120 CONTINUE
      OVDC2X = DSTCD2*DSTR2B
  130 CONTINUE
      IF (YR .GT. ANPER+0.5) GO TO 170
      OVMTC2 = OVMTC2 + PRVAL( OVDC2X, YR, DISCRT )
      YR = YR + 1.0
      IF (YR .GT. YRF2-0.5) GO TO 140
      GO TO 130
  140 CONTINUE
      IYRF = 1
  150 CONTINUE
      IF (YR .GT. ANPER+0.5) GO TO 170
      OVDC2X = DSTCD2*DSTR2(IYRF)
      OVMTC2 = OVMTC2 + PRVAL( OVDC2X, YR, DISCRT )
      IYRF = IYRF + 1
      YR = YR + 1.0
      IF (IYRF .LE. 10) GO TO 150
      OVMTC2 = 1.0E+20
C
  170 CONTINUE
      RETURN
      END
```

```
      FUNCTION PRVAL( FUTCST, YR, DISCRT )
CC
C     PRVAL - COMPUTE NET PRESENT VALUE OF SOME FUTURE COST GIVEN
C             SOME DISCOUNT RATE
C
C     ENTRY/ FUTCST = VALUE OF FUTURE COST TO BE DISCOUNTED.
C            YR     = YEAR IN WHICH FUTURE COST IS INCURRED.
C            DISCRT = DISCOUNT RATE (DIFFERENCE BETWEEN PRIME INTEREST
C                     RATE AND INFLATION RATE), PERCENT.
C     EXIT/  PRVAL  = NET PRESENT VALUE OF FUTURE COST.
C
      PRVAL = FUTCST/(1.0+DISCRT/100.0)**YR
C
      RETURN
      END
```

```
      SUBROUTINE ORDER
CC
C     ORDER - ARRANGE STRATEGIES IN ORDER OF INCREASING TOTAL COST
C
      COMMON /TOP20/ NSTMAX, NSTORD, KSTR(20,10), XSTR(20,18)
C
      COMMON /STRCOM/ K(10), X(18)
C
C     SORT BY TOTAL COST, X(18)
      IF (NSTORD .GT. 0) GO TO 10
      N = 1
      GO TO 70
   10 CONTINUE
      DO 20 J=1,NSTORD
      N = NSTORD-J+1
      IF (X(18) .GT. XSTR(N,18)) GO TO 30
   20 CONTINUE
      N = 0
   30 CONTINUE
      N = N+1
      IF (N .GT. NSTMAX) RETURN
      IF (NSTORD .EQ. NSTMAX) NSTORD=NSTMAX-1
      IF (N .EQ. NSTMAX) GO TO 70
      DO 60 I=N,NSTORD
      IBAK = NSTORD-I+N
      DO 40 L=1,10
      KSTR(IBAK+1,L) = KSTR(IBAK,L)
   40 CONTINUE
      DO 50 L=1,18
      XSTR(IBAK+1,L) = XSTR(IBAK,L)
   50 CONTINUE
   60 CONTINUE
   70 CONTINUE
      DO 80 L=1,10
      KSTR(N,L) = K(L)
   80 CONTINUE
      DO 90 L=1,18
      XSTR(N,L) = X(L)
   90 CONTINUE
      NSTORD = NSTORD+1
C
      RETURN
      END
```

```
      SUBROUTINE PRNTST( ISTR )
CC
C     PRNTST - PRINT ALL STRATEGIES USING A UNIFORM FORMAT
C
      COMMON /STRCOM/ IRL1, IOV1, IC1, IFR1, IOV1T
     0               , IRL2, IOV2, IC2, IFR2, IOV2T
     1               , TRNTO1, YR1, FATOT1, YRF1
     2               , TRNTO2, YR2, FATOT2, YRF2
     3               , EPMNTC, CC1, TDC1, OVMTC1, CC2, TDC2, OVMTC2
     4               , TVEXL, SALV, TOTCST
C
      COMMON /REMLIF/ NRL1, RLEP(10), NRL2, RLOV(10), RLMIN
C
      COMMON /OVTHIK/ NACT1, ACT1(8), NACT2, ACT2(8), NPCCT, PCCT(8)
     0               , ALOVT, AVGLUT, THBB
C
      COMMON /FLEXST/ FREP, NFROV, FROV(5), IFRAND
C
      DIMENSION IFORMT(30), IFRM2Y(13), IFRM2N(13), ICS(2)
C
      DATA IFORMT /
     + 4H(1X,,4HI4, ,4HI4, ,4HF5.1,4H,F5.,4H1,F5,4H.2,I,4H2,A1,4H,F5.,
     + 4H1,I4,4H,F5.,4H1,F5,4H.1,F,4H6.2,,4HF5.2,4H,F5.,4H2,  ,
     + 13*1H ,4HF6.2,4H,F5.,4H2,F7,4H,2) /
C
      DATA IFRM2Y /
     + 4H  I4,4H,F5.,4H1,F5,4H.1,I,4H2,A1,4H,F5.,4H1,I4,4H,I4,,4HF5.1,
     + 4H,F6.,4H2,F5,4H.2,F,4H6.2,/
C
      DATA IFRM2N / 4H52X,,12*1H  /
C
      DATA ICS / 1H , 1H* /
C
      IRLEP = 100.0*RLEP(IRL1)
      IF (IOV2 .NE. 0) GO TO 100
C
C     STRATEGY WITH NO SECOND OVERLAY REQUIRED
      DO 10 I=18,30
      IFORMT(I) = IFRM2N(I-17)
   10 CONTINUE
      IF (IOV1 .GT. 1) GO TO 50
C     FIRST OVERLAY = AC
      WRITE(6,IFORMT) ISTR, IRLEP, YR1, TRNTO1, EPMNTC, IOV1,
     + ICS(1), ACT1(IOV1T), IFR1, YRF1, FATOT1, CC1, TDC1, OVMTC1,
     + TVEXL, SALV, TOTCST
      RETURN
   50 CONTINUE
C     FIRST OVERLAY = PCC
      IFLXS1 = FROV(IFR1)
      WRITE(6,IFORMT) ISTR, IRLEP, YR1, TRNTO1, EPMNTC, IOV1,
     + ICS(IC1), PCCT(IOV1T), IFLXS1, YRF1, FATOT1, CC1, TDC1, OVMTC1,
     + TVEXL, SALV, TOTCST
      RETURN
  100 CONTINUE
C
C     TWO OVERLAY STRATEGY
      IRLOV = 100.0*RLOV(IRL2)
      IYRF2 = YRF2
      DO 110 I=18,30
      IFORMT(I) = IFRM2Y(I-17)
  110 CONTINUE
      IF (IOV1 .GT. 1) GO TO 200
      IF (IOV2 .GT. 1) GO TO 150
C     FIRST AND SECOND OVERLAYS = AC
      WRITE(6,IFORMT) ISTR, IRLEP, YR1, TRNTO1, EPMNTC, IOV1,
     + ICS(1), ACT1(IOV1T), IFR1, YRF1, FATOT1, CC1, TDC1, OVMTC1,
     + IRLOV, YR2, TRNTO2, IOV2, ICS(1), ACT2(IOV2T), IFR2,
     + IYRF2, FATOT2, CC2, TDC2, OVMTC2, TVEXL, SALV, TOTCST
      RETURN
  150 CONTINUE
C     FIRST OVERLAY = AC, SECOND OVERLAY = PCC
      IFLXS2 = FROV(IFR2)
      WRITE(6,IFORMT) ISTR, IRLEP, YR1, TRNTO1, EPMNTC, IOV1,
     + ICS(1), ACT1(IOV1T), IFR1, YRF1, FATOT1, CC1, TDC1, OVMTC1,
     + IRLOV, YR2, TRNTO2, IOV2, ICS(IC2), PCCT(IOV2T), IFLXS2,
     + IYRF2, FATOT2, CC2, TDC2, OVMTC2, TVEXL, SALV, TOTCST
      RETURN
  200 CONTINUE
      IF (IOV2 .GT. 1) GO TO 250
C     FIRST OVERLAY = PCC, SECOND OVERLAY = AC
      IFLXS1 = FROV(IFR1)
      WRITE(6,IFORMT) ISTR, IRLEP, YR1, TRNTO1, EPMNTC, IOV1,
     + ICS(IC1), PCCT(IOV1T), IFLXS1, YRF1, FATOT1, CC1, TDC1, OVMTC1,
     + IRLOV, YR2, TRNTO2, IOV2, ICS(1), ACT2(IOV2T), IFR2,
     + IYRF2, FATOT2, CC2, TDC2, OVMTC2, TVEXL, SALV, TOTCST
      RETURN
  250 CONTINUE
C     TWO PCC OVERLAYS - STRATEGY NEVER CONSIDERED
      RETURN
      END
```

```
      SUBROUTINE OUT20
CC
C     OUT20 - PRINT THE TOP TWENTY STRATEGIES
C
      COMMON /PROBLM/ IDESC(20)
C
      COMMON /TOP20/ NSTMAX, NSTORD, KSTR(20,10), XSTR(20,10)
C
      COMMON /REMLIF/ NRL1, RLEP(10), NRL2, RLOV(10), RLMIN
C
      COMMON /OVTHIK/ NACT1, ACT1(8), NACT2, ACT2(8), NPCCT, PCCT(8)
     0               , ALOVT, AVGLUT, THBB
C
      COMMON /FLEXST/ FREP, NFROV, FROV(5), IFRAND
C
      DIMENSION ITYOV1(2,5), ITYOV2(2,3), ITYSH(2)
      DATA ITYOV1 / 4H    , 4H ACP,
     +              4HBND , 4HCRCP,
     +              4HUNB , 4HCRCP,
     +              4HBOND, 4H JCP,
     +              4HUNBD, 4H JCP/
      DATA ITYOV2 / 4H    , 4H ACP,
     +              4H    , 4HCRCP,
     +              4H    , 4H JCP/
      DATA ITYSH  / 4HFLEX, 4H PCC/
C
      NSTM = NSTMAX
```

```
      IF (NSTORD .LT. NSTMAX) NSTM=NSTORD
      DO 10 ISTR=1,NSTM
      IRL1 = KSTR(ISTR,1)
      IOV1 = KSTR(ISTR,2)
      IC1 = KSTR(ISTR,3)
      IFR1 = KSTR(ISTR,4)
      IOV1T = KSTR(ISTR,5)
      IRL2 = KSTR(ISTR,6)
      IOV2 = KSTR(ISTR,7)
      IC2 = KSTR(ISTR,8)
      IFR2 = KSTR(ISTR,9)
      IOV2T = KSTR(ISTR,10)
      TRNTO1 = XSTR(ISTR,1)
      YR1 = XSTR(ISTR,2)
      FATOT1 = XSTR(ISTR,3)
      YRF1 = XSTR(ISTR,4)
      TRNTO2 = XSTR(ISTR,5)
      YR2 = XSTR(ISTR,6)
      FATOT2 = XSTR(ISTR,7)
      YRF2 = XSTR(ISTR,8)
      EPMNTC = XSTR(ISTR,9)
      CC1 = XSTR(ISTR,10)
      TDC1 = XSTR(ISTR,11)
      OVMTC1 = XSTR(ISTR,12)
      CC2 = XSTR(ISTR,13)
      TDC2 = XSTR(ISTR,14)
      OVMTC2 = XSTR(ISTR,15)
      TVEXL = XSTR(ISTR,16)
      SALV = XSTR(ISTR,17)
      TOTCST = XSTR(ISTR,18)
C
      WRITE(6,1000) IGESC, ISTR
      XRLEP = RLEP(IRL1)*100.
      WRITE(6,1100) XRLEP, YR1, TRNTO1, EPMNTC
      IF (IC1 .EQ. 0) IC1=1
      THOV1 = ACT1(IOV1T)
      IF (IOV1 .NE. 1) THOV1 = PCCT(IOV1T)
      FROV1 = 0.
      IF (IFR1 .GT. 0) FROV1 = FROV(IFR1)
      WRITE(6,1200) (ITYOV1(J,IOV1),J=1,2), ITYSH(IC1), THOV1, FROV1
      WRITE(6,1300) YRF1, FATOT1, CC1, TDC1, OVMTC1
      IF (IOV2 .EQ. 0) GO TO 5
      XRLOV = RLOV(IRL2)*100.
      WRITE(6,1400) XRLOV, YR2, TRNTO2
      IF (IC2 .EQ. 0) IC2=1
      THOV2 = ACT2(IOV2T)
      IF (IOV2 .NE. 1) THOV2 = PCCT(IOV2T)
      FROV2 = 0.
      IF (IFR2 .GT. 0) FROV2 = FROV(IFR2)
      WRITE(6,1500) (ITYOV2(J,IOV2),J=1,2), ITYSH(IC2), THOV2, FROV2
      WRITE(6,1600) YRF2, FATOT2, CC2, TDC2, OVMTC2
      GO TO 6
    5 CONTINUE
      WRITE(6,1410)
      WRITE(6,1510)
      WRITE(6,1610)
    6 CONTINUE
      WRITE(6,1700) TVEXL, SALV, TOTCST
   10 CONTINUE
C
      RETURN
 1000 FORMAT(1H1
     +///5X,74HRPRDS1 - RIGID PAVEMENT REHABILITATION DESIGN SYSTEM - VE
     +RSION 1, NOV 1980
     +  /5X,34HCENTER FOR TRANSPORTATION RESEARCH
     +  /5X,29HUNIVERSITY OF TEXAS AT AUSTIN///
     +5X,19HPROJECT DESCRIPTION/5X,20A4///
     +5X,20HOPTIMAL STRATEGY NO.,I4//
     +15X,21HCOMPONENT OF STRATEGY,33X,8HQUANTITY/9X,59(1H-),1X,8(1H-) )
 1100 FORMAT(/
     +5X,61H 1.  EXISTING PAVEMENT REMAINING LIFE AT 1ST OVERLAY, PERCEN
     +T,F11.0/
     +5X,34H 2.  YEAR OF 1ST OVERLAY PLACEMENT,28X,F10.0/
     +5X,62H 3.  TOTAL 18-KIP ESAL CYCLES (NOW TILL 1ST OVERLAY), MILLIO
     +NS,F10.2/
     +5X,53H 4.  COST OF MAINTAINING EXISTING PAVEMENT, DOL/SQ YD,9X,
     +F10.2)
 1200 FORMAT(
     +5X,21H 5.  1ST OVERLAY TYPE,43X,2A4/
     +5X,21H 6.  TYPE OF SHOULDER,47X,A4/
     +5X,34H 7.  1ST OVERLAY THICKNESS, INCHES,28X,F10.1/
     +5X,46H 8.  PCC FLEXURAL STRENGTH OF 1ST OVERLAY, PSI,16X,F10.1)
 1300 FORMAT(
     +5X,42H 9.  FATIGUE LIFE AFTER 1ST OVERLAY, YEARS,20X,F10.1/
     +5X,60H10.  FATIGUE LIFE AFTER 1ST OVERLAY, 18-KIP ESAL IN MILLIONS
     +,F12.2/
     +5X,45H11.  1ST OVERLAY CONSTRUCTION COST, DOL/SQ YD,17X,F10.2/
     +5X,46H12.  1ST OVERLAY TRAFFIC DELAY COST, DOL/SQ YD,16X,F10.2/
     +5X,44H13.  1ST OVERLAY MAINTENANCE COST, DOL/SQ YD,18X,F10.2)
 1400 FORMAT(/
     +5X,55H14.  1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT,7X,
     +F10.0/
     +5X,34H15.  YEAR OF 2ND OVERLAY PLACEMENT,28X,F10.0/
     +5X,62H16.  TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIO
     +NS,F10.2)
 1410 FORMAT(/
     +5X,55H14.  1ST OVERLAY REMAINING LIFE AT 2ND OVERLAY, PERCENT,14X,
     +3H---/
     +5X,34H15.  YEAR OF 2ND OVERLAY PLACEMENT,35X,3H---/
     +5X,62H16.  TOTAL 18-KIP ESAL CYCLES (NOW TILL 2ND OVERLAY), MILLIO
     +NS,7X,3H---)
 1500 FORMAT(
     +5X,21H17.  2ND OVERLAY TYPE,43X,2A4/
     +5X,21H18.  TYPE OF SHOULDER,47X,A4/
     +5X,34H19.  2ND OVERLAY THICKNESS, INCHES,28X,F10.1/
     +5X,46H20.  PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI,16X,F10.1)
 1510 FORMAT(
     +5X,21H17.  2ND OVERLAY TYPE,48X,3H---/
     +5X,21H18.  TYPE OF SHOULDER,48X,3H---/
     +5X,34H19.  2ND OVERLAY THICKNESS, INCHES,35X,3H---/
     +5X,46H20.  PCC FLEXURAL STRENGTH OF 2ND OVERLAY, PSI,23X,3H---)
 1600 FORMAT(
     +5X,42H21.  FATIGUE LIFE AFTER 2ND OVERLAY, YEARS,20X,F10.1/
     +5X,60H22.  FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS
     +,F12.2/
     +5X,45H23.  2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD,17X,F10.2/
     +5X,46H24.  2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD,16X,F10.2/
     +5X,44H25.  2ND OVERLAY MAINTENANCE COST, DOL/SQ YD,18X,F10.2)
 1610 FORMAT(
     +5X,42H21.  FATIGUE LIFE AFTER 2ND OVERLAY, YEARS,27X,3H---/
     +5X,60H22.  FATIGUE LIFE AFTER 2ND OVERLAY, 18-KIP ESAL IN MILLIONS
     +,9X,3H---/
     +5X,45H23.  2ND OVERLAY CONSTRUCTION COST, DOL/SQ YD,24X,3H---/
     +5X,46H24.  2ND OVERLAY TRAFFIC DELAY COST, DOL/SQ YD,23X,3H---/
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     +5X,44H25.  2ND OVERLAY MAINTENANCE COST, DOL/SQ YD,25X,3H---)
 1740 FORMAT(/
     +5X,38H26.  VALUE OF EXTENDED LIFE, DOL/SQ YD,24X,F10.2/
     +5X,37H27.  OVERLAY SALVAGE VALUE, DOL/SQ YD,25X,F10.2//
     +5X,51H28.  TOTAL NET PRESENT VALUE OF STRATEGY, DOL/SQ YD,11X,
     +F10.2)
C
      END
```

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