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TECHNICAL REPORT M-253
September 1978

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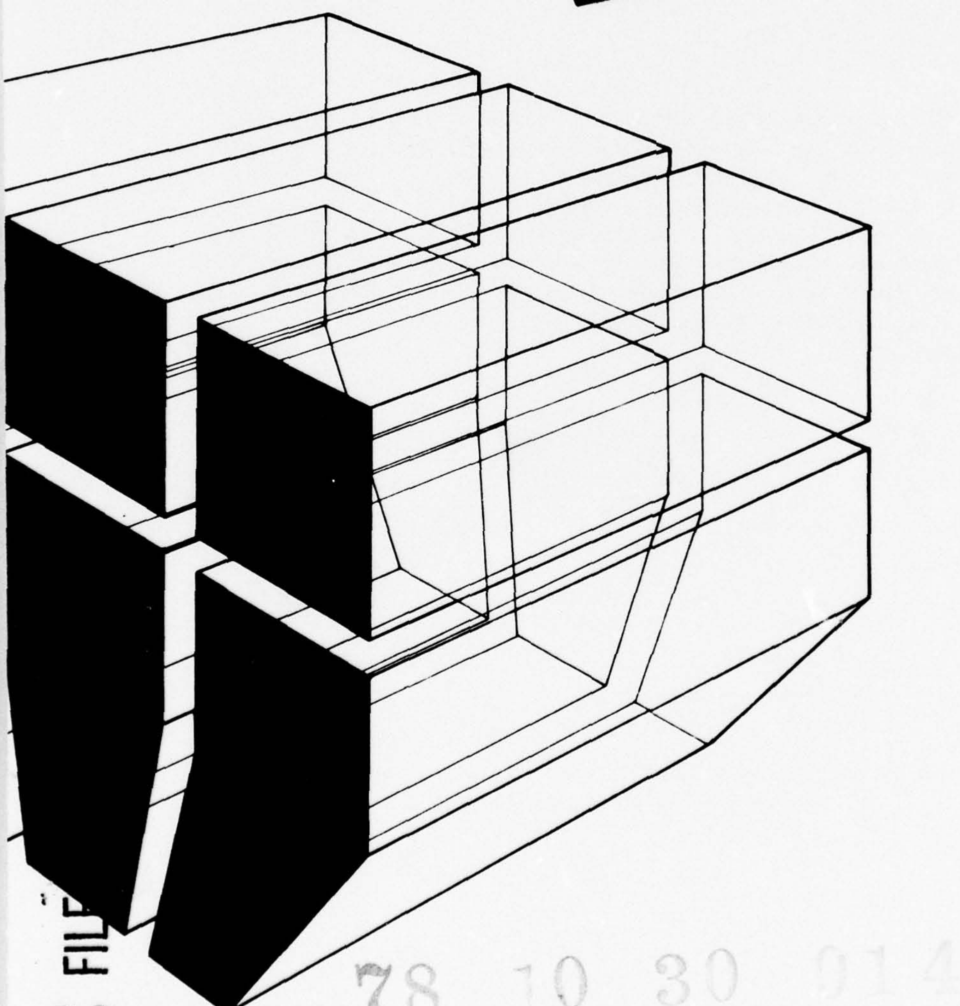
SYSTEMS APPROACH TO LIFE-CYCLE DESIGN OF PAVEMENTS—VOLUME I, LIFE2 USER'S MANUAL



by
E. S. Lindow

CERL

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This report is the first of a three-volume report which documents an automated system (LIFE2), for analyzing pavement designs and maintenance and repair strategies based on life-cycle costs. LIFE2 models existing Corps of Engineers criteria for designing both rigid and flexible pavements for airfields, roads, and streets. The program also includes analytical procedures for evaluating earthwork, drainage, and frost protection requirements, as well as maintenance costs. The resulting combinations of design schemes and maintenance strategies are ranked by total cost over the design life of the pavement.

Block 20 continued.

Volume I is the LIFE2 User's Manual, Volume II is the LIFE2 System Documentation, and Volume III is the LIFE2 Program Listing.

FOREWORD

This work was conducted as part of the RDT&E Army Program 6.37.34A, Project 4A763734DT08, "Military Construction Systems Development," Task 01, "Military Airfield Facilities," Work Unit 001, "Systems Approach to Life-Cycle Design of Pavements." The Technical Monitor was Mr. E. Dudka, DAEN-MCE-D, Advanced Technology Branch, Engineering Division, Military Construction, Office of the Chief of Engineers.

The work was conducted by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (CERL). The CERL principal investigator was Mr. E. S. Lindow. The LIFE1 computer program was developed by Drs. P. F. McManus and E. L. Marvin. Mr. J. J. Brown was responsible for programming and operation of the LIFE2 program.

Dr. G. Williamson is Chief of EM. COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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SYSTEMS APPROACH TO LIFE-CYCLE DESIGN OF PAVEMENTS— VOLUME I, LIFE2 USER'S MANUAL

1 INTRODUCTION

Background

Facility design and maintenance based on life-cycle cost analyses have been justified from economic and serviceability standards. The Armed Services Procurement Regulation acknowledges this by stating: "It is the policy of the Department of Defense to procure supplies and services from responsible sources at fair and reasonable prices calculated to result in the lowest ultimate overall cost to the Government."[1] To efficiently accommodate this guidance in pavement management activities, the Construction Engineering Research Laboratory (CERL) has developed a computerized system for performing life-cycle pavement analyses.

In the early 1970s, CERL began developing an automated system for designing airfield pavements based on life-cycle cost comparisons. The first iteration of this computer system, designated LIFE1, included procedures for performing rigid and flexible pavement and overlay designs for airfields, analyzing user costs and maintenance and repair costs on a macro scale, and combining design schemes and maintenance strategies into life-cycle cost rankings.[2,3]

Subsequently, the system was expanded to include life-cycle design of pavements for roads, streets, and other surfaced areas. This second iteration, LIFE2,[4] which this manual will replace, also included procedures for considering maintenance costs on the basis of individual M&R activities, thereby making the system more responsive and efficient in terms of data available to the user. Frost protection design criteria were computerized and incorporated in LIFE2. In addition, since earthwork and subsurfaces drainage costs vary according to the selected pavement thickness design, automated procedures for considering these costs were included as optional analyses to the user.

LIFE2 was field tested in 1976 at the Corps of Engineers' Fort Worth District Office. Based on results of the field test and recent updating of the pavement design criteria employed, minor modifications were made in the system. LIFE2 is now an implementable tool which can aid pavement managers in optimizing expenditures by basing decisions on life-cycle costs rather than solely on the least first cost.

Objective

The objective of this research is to develop and validate computer-aided procedures for evaluating alternative pavement design schemes and maintenance and repair strategies based on life-cycle costs. The resultant system should aid the pavement manager in analyzing flexible and rigid pavements for airfields, as well as for roads and streets. The analyses should consider all costs integral to the construction and operation of pavement facilities during their design lives.

Approach

The computer program LIFE2 was developed to meet the above objective. The program is based on Corps of Engineers pavement design methods and criteria. In amalgamating the manual procedures into an automated system, certain deviations and additions were necessary. However, for pavement conditions and design lives, structural thickness designs for LIFE2 and the manual procedure will be identical.

This report provides the LIFE2 user with the necessary information to set up, operate, and interpret results of the program. Chapter 2 explains the hardware and software used in LIFE2. Chapter 3 provides the operating procedures for the program. Chapter 4 summarizes how LIFE2 can aid the user in the pavement design and management decision-making process. The appendices contain a glossary of terms, a definition of the program input variables, a discussion of the vehicle data bank used in conjunction with LIFE2, a worksheet to facilitate input preparation, and an example problem.

Mode of Technology Transfer

The LIFE2 system was developed principally as an engineering tool for use by Corps of Engineers District

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[1] Armed Services Procurement Regulation 3-801 (Department of Defense, 1 July 1976).

[2] E. Marvin and P. McManus, *Life Cycle Analysis on an Airfield Pavement Facility*, Unpublished Report (Construction Engineering Research Laboratory [CERL], 1972).

[3] J. Willmer, et al., *User Manual for LIFE1 Computer Program*, Technical Report S-28/AD774849 (CERL, January 1974).

[4] E. Lindow, et al., *LIFE2 User's Manual*, Technical Report C-59/ADA023186 (CERL, January 1976).

Office personnel. The documents developed to effect technology transfer include:

Volume I–LIFE2 User's Manual

Volume II–LIFE2 System Documentation

Volume III–LIFE2 Program Listing.

Access to the LIFE2 program for Corps of Engineers personnel will be through the Corps' Engineering Computer Program Library (ECPL).* The procedure to be used is illustrated in Figure 1. For other users, the program and relevant documentation will be available from National Technical Information Service.

2 PROGRAMMING APPROACH

Traditionally, pavement design has been based on the least first cost (i.e., construction cost) which provides a serviceable structure for an anticipated life. The economics of maintenance and repairs (M&R) are not considered on this basis; however, when accrued over the pavement's anticipated life, these M&R costs can range from 25 to more than 100 percent of the initial construction cost of the facility, depending on the type of structure selected. Thus, to accurately compare design alternatives, the total cost of owning and operating the facility over its lifetime must be analyzed.

In pavement design, this type of analysis (termed life cycle design) becomes quite complex. The pavement is an intricate structural system having a wide range of interacting variables. These variables include properties of the component materials, section geometry, prevailing environment, traffic, construction quality, and M&R strategies. LIFE2 has been developed to account for these variables and their interactions when performing life-cycle economic analyses of pavement design alternatives.

The LIFE2 computer program models adopted Corps of Engineers pavement methods and criteria as published in the Department of the Army Technical Manual (TM) 5-800 series; Table 1 lists the applicable TMs on which the LIFE2 methodology is based. The program applies to both rigid and flexible design analyses for airfields, roads and streets, and parking areas. Figure 2 illustrates the framework of the LIFE2 methodology.**

*ECPL is located at the U.S. Army Waterways Experiment Station, Vicksburg, Mississippi.

Table 1
LIFE2 Applicable Publications

TM No.*	Title
5-818-2	Pavement Design for Frost Condition
5-820-2	Subsurface Drainage Facilities for Airfields
5-820-3	Drainage and Erosion Control Structures for Airfields and Heliports
5-820-4	Drainage for Areas Other Than Airfields
5-822-1	Roads, Streets, and Pavements Generally: Traffic Study Requirements
5-822-2	General Provisions and Geometric Design for Roads, Streets, Walks, and Open Storage Areas
5-822-5	Flexible Pavements for Roads, Streets, Walks, and Open Storage Areas
5-822-6	Rigid Pavements for Roads, Streets, Walks, and Open Storage Areas
5-824-1	Airfields Other Than Army–General Provisions for Airfield Design
5-824-2	Airfield Flexible Pavements–Air Force
5-824-3	Rigid Pavement for Airfields Other Than Army

*Technical Manual number. These documents are prepared by the Department of the Army and govern pavement design at military installations. Many civilian agencies have also adopted these procedures.

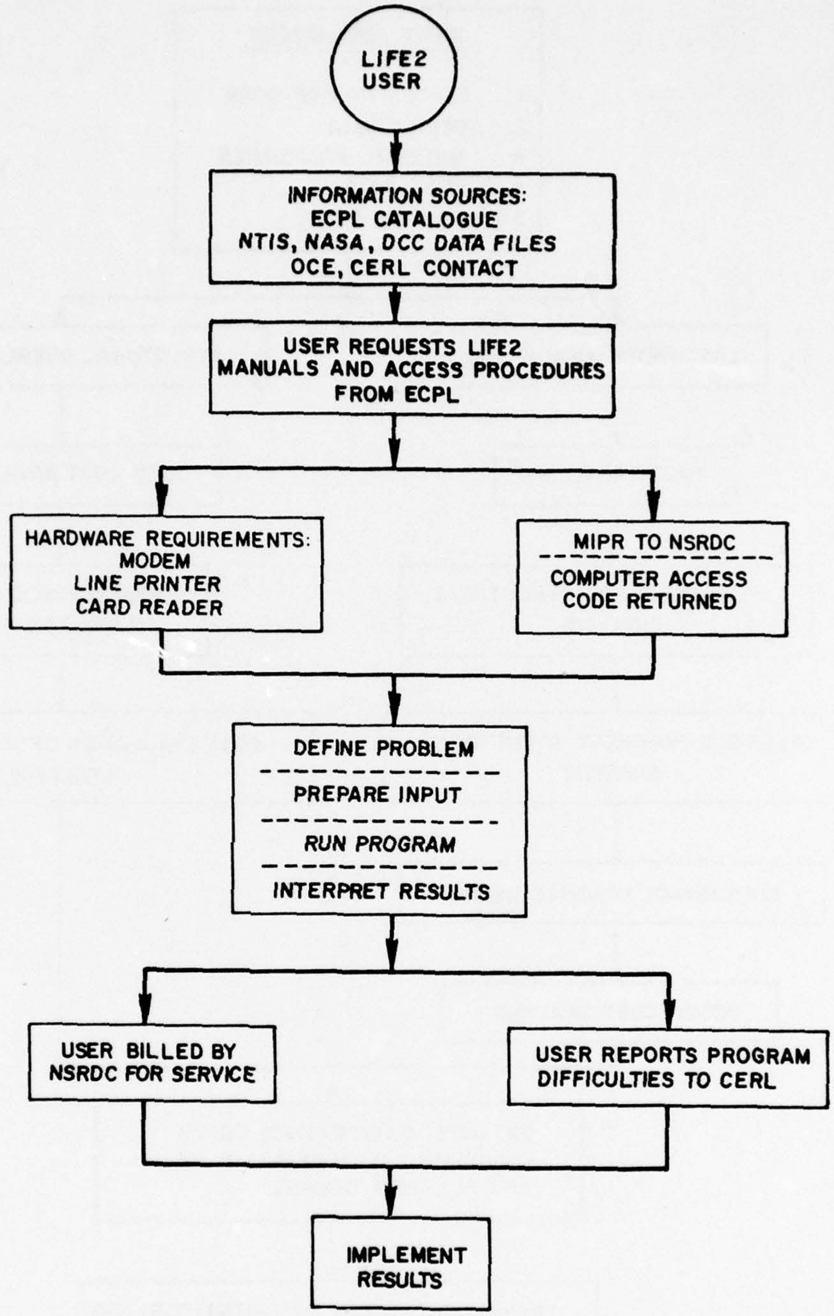
Program Format

LIFE2 is written in FORTRAN Extended for CDC-6000 series computers and is currently used on a CDC6600 computer in a remote batch mode. The program is available on magnetic tape or computer cards.

LIFE2 was developed using a program overlay† structure which reduces the amount of core memory storage required during execution. Figure 3 illustrates the modular framework of the LIFE2 program. The following paragraphs briefly describe the purpose of the zero overlay and each of the six primary program overlays.

**A detailed description of the design methods and criteria used is contained in: *Systems Approach to Life-Cycle Design of Pavements: Volume II–LIFE2 System Documentation.*

†See Glossary for definition.



KEY:

ECPL-CORPS ENGINEERING COMPUTER PROGRAM LIBRARY
MIPR-MILITARY INTERDEPARTMENTAL PURCHASE REQUEST
NSRDC-NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, BETHESDA, MD.
NTIS-NATIONAL TECHNICAL INFORMATION SERVICE

Figure 1. Flowchart of LIFE2 access procedure.

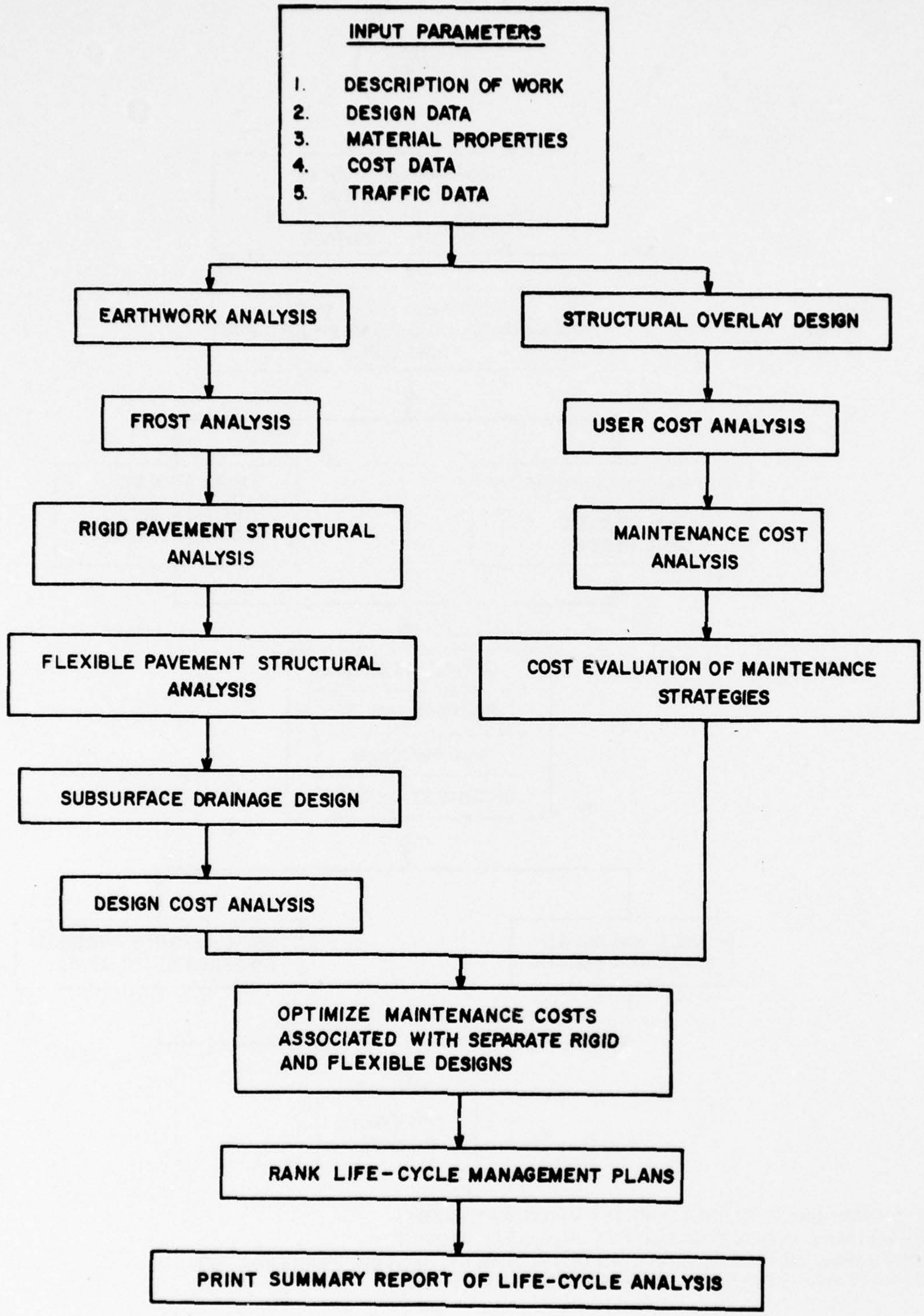


Figure 2. Framework of LIFE2 methodology.

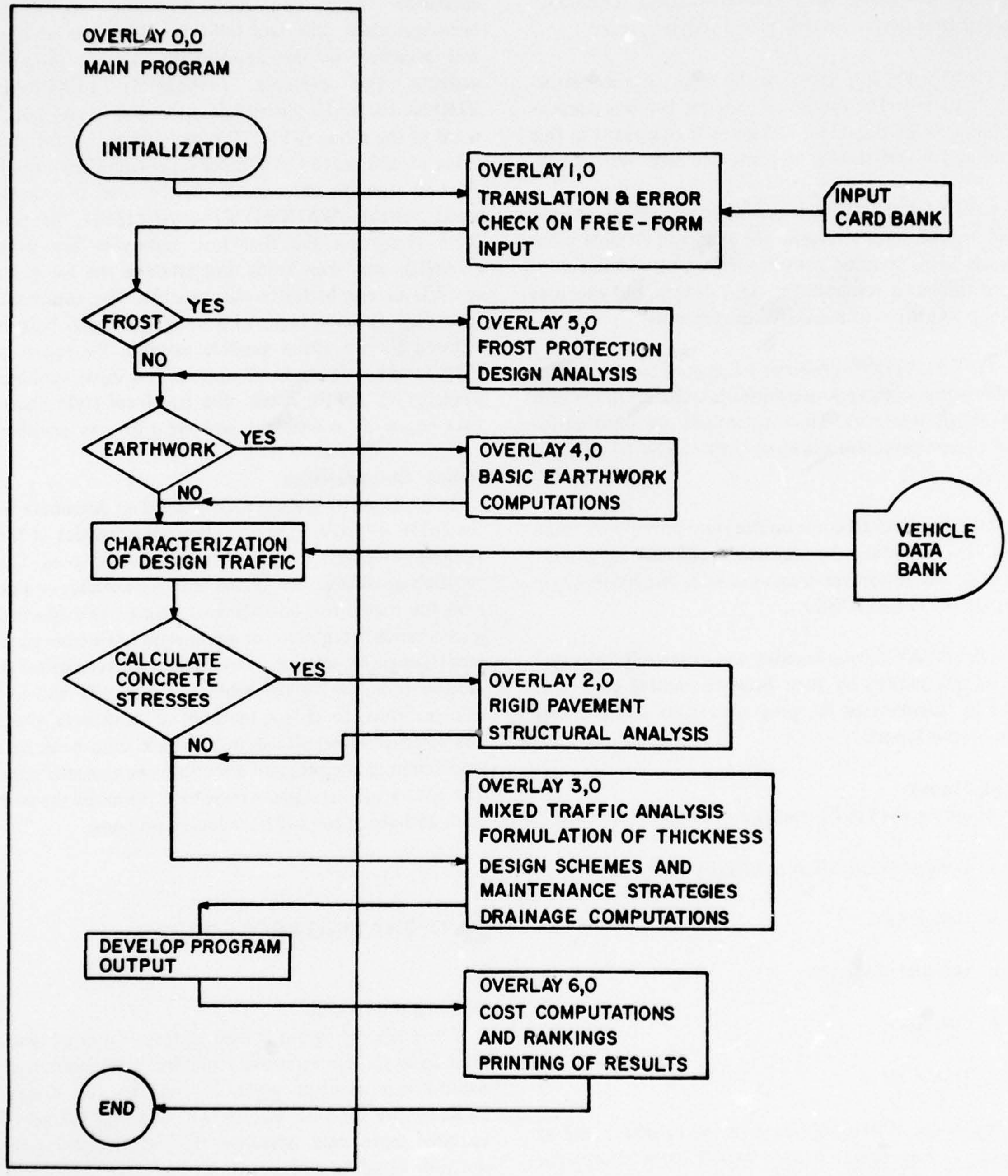


Figure 3. Framework of LIFE2 program overlays.

OVERLAY(0,0) is a control for calling the other program overlays. It remains in computer memory while the other overlays are loaded and unloaded.

OVERLAY(1,0) reads the input data from cards and checks for data errors. The error check is primarily to call attention to omissions and syntax errors.

OVERLAY(2,0) performs the rigid pavement structural analysis. The minimum concrete bending stress as a function of pavement thickness is computed in this overlay for slab resting on-grade and slab over asphalt.

OVERLAY(3,0) formulates thickness design schemes and maintenance strategies for rigid and flexible pavements. This module provides pavement thickness vs. base thickness tradeoff for rigid designs and executes suboptimization of maintenance strategies.

OVERLAY(4,0) performs earthwork computations, calculating earthwork quantities in cut and fill for zero pavement thickness. These quantities are adjusted for the design pavement thickness provided by OVERLAY (6,0).

OVERLAY(5,0) contains the frost protection design analysis, providing the required depth of frost protection for the applicable design method. This information is used in OVERLAY(3,0).

OVERLAY(6,0) computes and totals all costs and ranks alternatives by their total discounted cost. This overlay summarizes the program results and prepares the output report.

LIFE2 Input

Input for the LIFE2 program includes:

a. General information to identify the project

b. Design data

c. Material properties

d. Cost data

e. Traffic data.

Appendix B describes each of the variables used as input. A free-format is used for all input except for information required by the earthwork, frost, and drainage optional analyses. Appendix B also describes the fixed format used for these analyses.

The free-format allows the user to enter the appropriate name or symbol of an input variable followed by its value in any format. The program SCAN,[5] which is incorporated in OVERLAY(1,0) of LIFE2, enables the computer to identify specific words or word strings appearing on the input cards. When the variable has been identified, the data following the name are read and attached to the appropriate internal program variable. For example, CONCRETE.FLEXURAL.STRENGTH 650 is identified by the first letter of each word in the string (CFS). The program then attaches a value of 650 psi to the internal variable designating the flexural strength of concrete. In the case of a single-word variable—WANDER CHANNELIZED—the program recognizes the first four letters in the word (WAND), and then reads and attaches the following word(s) or number(s) to the variable. The computer-identified symbols (e.g., CFS or WAND) may be substituted for the entire variable name in the input. In light of the magnitude of options and input variables available to LIFE2 users, this free-form style makes data input as convenient and error-free as possible.

Vehicle Characteristics

In addition to the input data listed in Appendix B, operation of LIFE2 requires the characteristics of the vehicles for which the pavement is being designed. The vehicle's gross load weight per gear for airfields or axle load for roads, tire contact area, tire or axle spacing, and other data required for either rigid or flexible pavement design must be provided. Since this type of information is innate to the vehicle, it generally will not change. Thus, to reduce the bulk of input data, these characteristics are placed in a vehicle data bank and transferred to the program directly from magnetic tape, disc file, or card storage. Appendix C discusses the contents and use of the LIFE2 vehicle data bank.

3 OPERATING PROCEDURES

Defining the Problem

The LIFE2 program is used in three types of pavement analysis: least first-cost structural thickness design, maintenance strategy selection, and life-cycle design. Defining the type of analysis will establish the set of required input data. Selecting the proper options for decision variables and quantities for other input rele-

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[5] *SCAN, User's Manual* (University of Illinois, 1970).

gates the analysis to a specific project. To further define the problem, the user may vary certain input parameters while allowing others to remain constant. For example, the user may wish to evaluate various mix designs; in this case, the material properties input will change. Since this will require multiple program runs, the user can minimize computer time and cut cost by judicious input selection. For instance, if VEHICLE.TYPE, RANGE.OF.THICKNESS, and SUBGRADE.MODULUS remain unchanged, it will be economic to use the "read" option of RIGID.STRUCTURAL.ANALYSIS in subsequent runs.

Design Calculations

The design option generates alternative pavement construction schemes and determines the required component thickness for both rigid and flexible pavement designs. The solutions are then ranked by lowest estimated construction cost. Figure 4 is a block diagram describing the design calculations.

The design calculations provide the user with several options. The earthwork, drainage, and frost analyses can be performed by the program, circumvented by the user by cost or quantity specification, or excluded completely. In addition, the program can be restricted to either flexible or rigid designs; if it is not, it will generate both types. When designing rigid pavements, the user may input pavement stresses or have the program perform these calculations. Tradeoff between base thickness and slab thickness is also optional in rigid designs. When designing flexible pavements, the

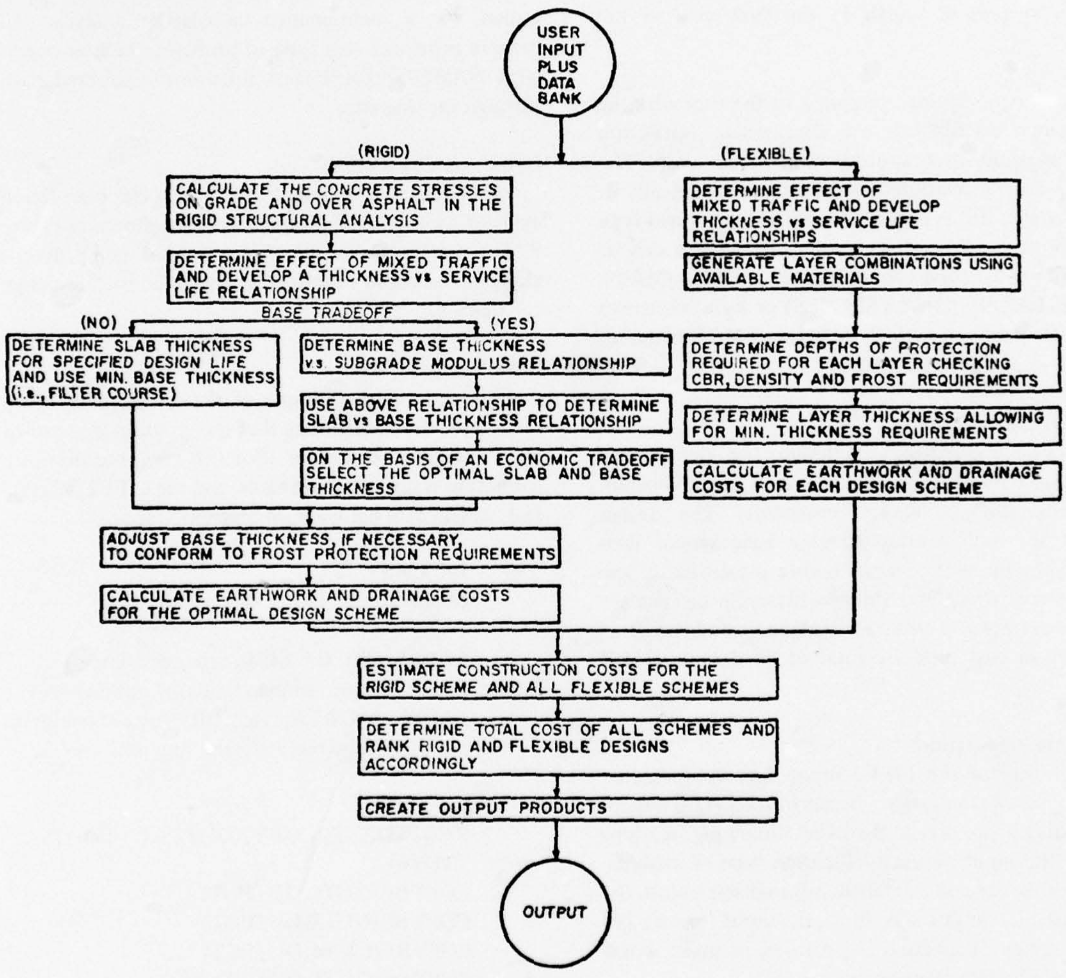


Figure 4. Design calculation procedure.

user may specify the combinations of layers desired or have the program use the input materials to generate all combinations.

In the design calculations, the computed thicknesses are assumed to provide a pavement that will remain serviceable for the entire design life. However, it should be noted that flexible pavements are designed for complete failure,* while rigid pavements are designed for initial failure.*

Maintenance Calculations

Figure 5 illustrates the procedure followed in the maintenance calculations. This procedure considers the pavement's overlay requirements, the M&R, and the user costs, ranking the various maintenance strategies by their total discounted costs (i.e., the costs are discounted to present worth in the first year of the strategy).

The principal options provided to the user with the maintenance calculations are the overlay restriction and the method of computing maintenance costs. The program can be restricted to design either flexible or rigid overlays; if it is not, it will select the optimal type for each time of overlay. Maintenance costs can be specified by cost curves for individual activities (MAINTENANCE.COST.ANALYSIS YES) or by a cost curve for a single parameter which includes all M&R activities (ROUTINE.MAINTENANCE).

Life-Cycle Calculations

Life-cycle calculations combine the design and maintenance procedures; Figure 6 is a block diagram illustrating the calculation procedure. The design schemes for each overlay strategy have service lives equal to the number of years before placement of the first overlay. Rigid and flexible life-cycle designs are saved separately and ranked by total adjusted cost (i.e., construction cost plus the total of all discount M&R costs).

Input Data Preparation

Preparation of the LIFE2 input data is predicated on the type of analysis to be performed (i.e., design, maintenance, or life-cycle). The following sections describe the input necessary for each type of analysis. Appendix B contains detailed information about the input variables and their options, the input format, and default values. Appendix D provides an input worksheet to aid in data preparation.

Design Calculation

Figure 7 illustrates the set of variables required for the design calculation analysis. To prepare input for this type of problem, the user begins with NAME.OF. BASE and follows the flow of the diagram through the branches chosen. At specific decision points, such as DESIGN.RESTRICTION, the option chosen stipulates the necessary set of data cards.

All blocks in the diagram use either variable or option names. The variables are enclosed in solid blocks, and the options are enclosed by boxes of dashed lines; boxes formed with long dashes separated by dots indicate data required by the associated variable option.

Maintenance Calculation

Figure 8 is a flow diagram of the data card set required for a maintenance calculation analysis. To prepare input for this type of problem, the user begins with NAME.OF.BASE and follows the selected path through the diagram.

Life-Cycle Calculation

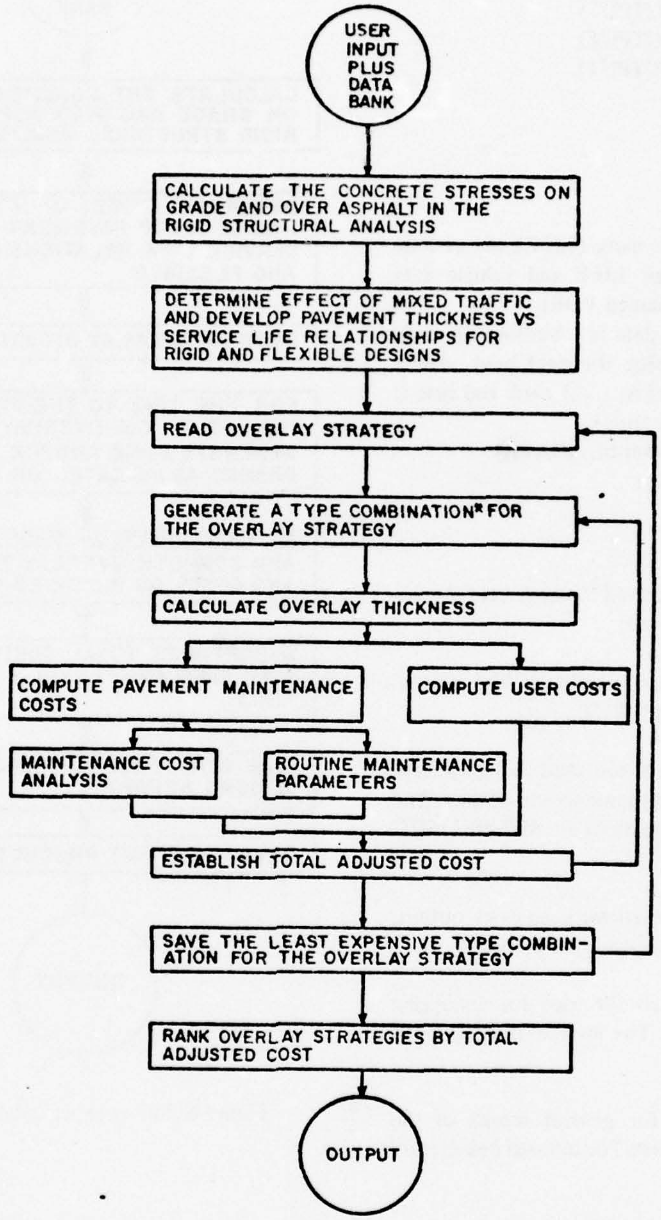
Input can be prepared for life-cycle calculation analysis by following the flow diagram shown in Figure 9. The user begins with NAME.OF.BASE and proceeds along the selected branches, as described for the design calculation.

Deck Setup

Following is an example of the LIFE2 deck setup for a typical run, assuming that the program is compiled on a CDC6600 computer. For this case, the input information is submitted on cards, and the LIFE2 program and vehicle data bank are on magnetic tapes.

```
        Job Card
        Charge Card
*
        LABEL (lfn, L = LIFE, tape parameters)
              (tape number/tape ring option)
        LABEL (ADATA, L = VDB, tape parameters)
              (tape number/tape ring option)
**
        lfn.
        REWIND(OUT1,OUT2,OUT3,OUT4,OUT5,
         OUT6)
        COPYBF(OUT1,OUTPUT)
        COPYBF(OUT3,OUTPUT)
        COPYBF(OUT4,OUTPUT)
        COPYBF(OUT5,OUTPUT)
        COPYBF(OUT6,OUTPUT)
        EXIT.
```

*See Glossary (Appendix A) for definitions.



*FOR EXAMPLE, IF THE OVERLAY STRATEGY SPECIFIES OVERLAYS AT 7 AND 15 YEARS, FOUR TYPE COMBINATIONS ARE POSSIBLE: BOTH FLEXIBLE, BOTH RIGID, RIGID AT 7 AND FLEXIBLE AT 15, AND FLEXIBLE AT 7 AND RIGID AT 15.

Figure 5. Maintenance calculation procedure.

```
        REWIND(OUT1,OUT2,OUT3,OUT4,OUT5,
         OUT6)
        COPYBF(OUT1,OUTPUT)
        COPYBF(OUT2,OUTPUT)
        COPYBF(OUT3,OUTPUT)
        COPYBF(OUT4,OUTPUT)
        COPYBF(OUT5,OUTPUT)
        COPYBF(OUT6,OUTPUT)
        7/8/9
***
        Input Deck
        6/7/8/9
```

Notes: 1) lfn = logical file name (LIFE2 object code on tape named LIFE and vehicle data bank on tape named VDB)

2) If the vehicle data is submitted on cards rather than using the data bank, delete LABEL (ADATA, . . .) card and insert:

```
  * VSN (tape label)
 ** COPYBR (Input, ADATA)
*** Vehicle data
      7/8/9
```

Input-Output Files

Twelve tape units are reserved for each LIFE2 computer run. Uses of each unit are:

Tape 1 – file for the input card deck. The internal designation is INPUT.

Tapes 2, 3, 5, 7 – scratch files used for temporary storage and communication of data. The internal designations are SF2, SF3, SF5, and SF7.

Tape 4 – file for the earthwork analysis output. The internal designation is OUT4.

Tape 6 – output scratch file used for debugging the program. The internal designation is OUT2.

Tape 8 – output file for general results of the LIFE2 program. The internal designation is OUT1.

Tape 9 – file for the frost analysis output. The internal designation is OUT3.

Tape 10 – input storage file for the Vehicle Data Bank. It can be stored on a tape or disc file. The internal designation is ADATA.

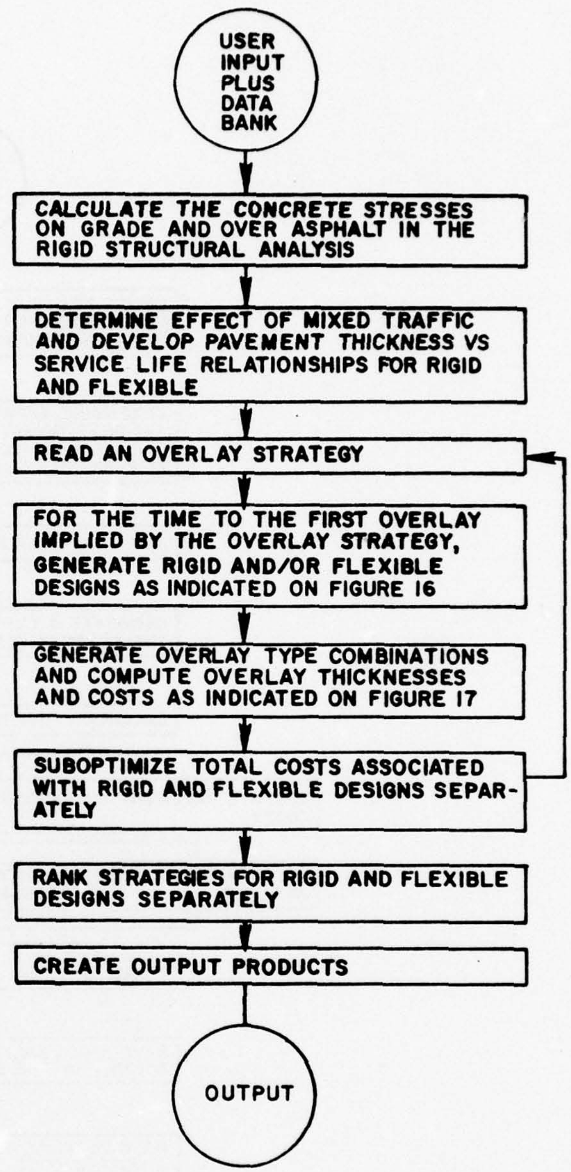


Figure 6. Life-cycle calculation procedure.

Tape 11 – output file for plotting of the earthwork mass diagram. The internal designation is OUT5.

Tape 12 – output file for the drainage analysis results. The internal designation is OUT6.

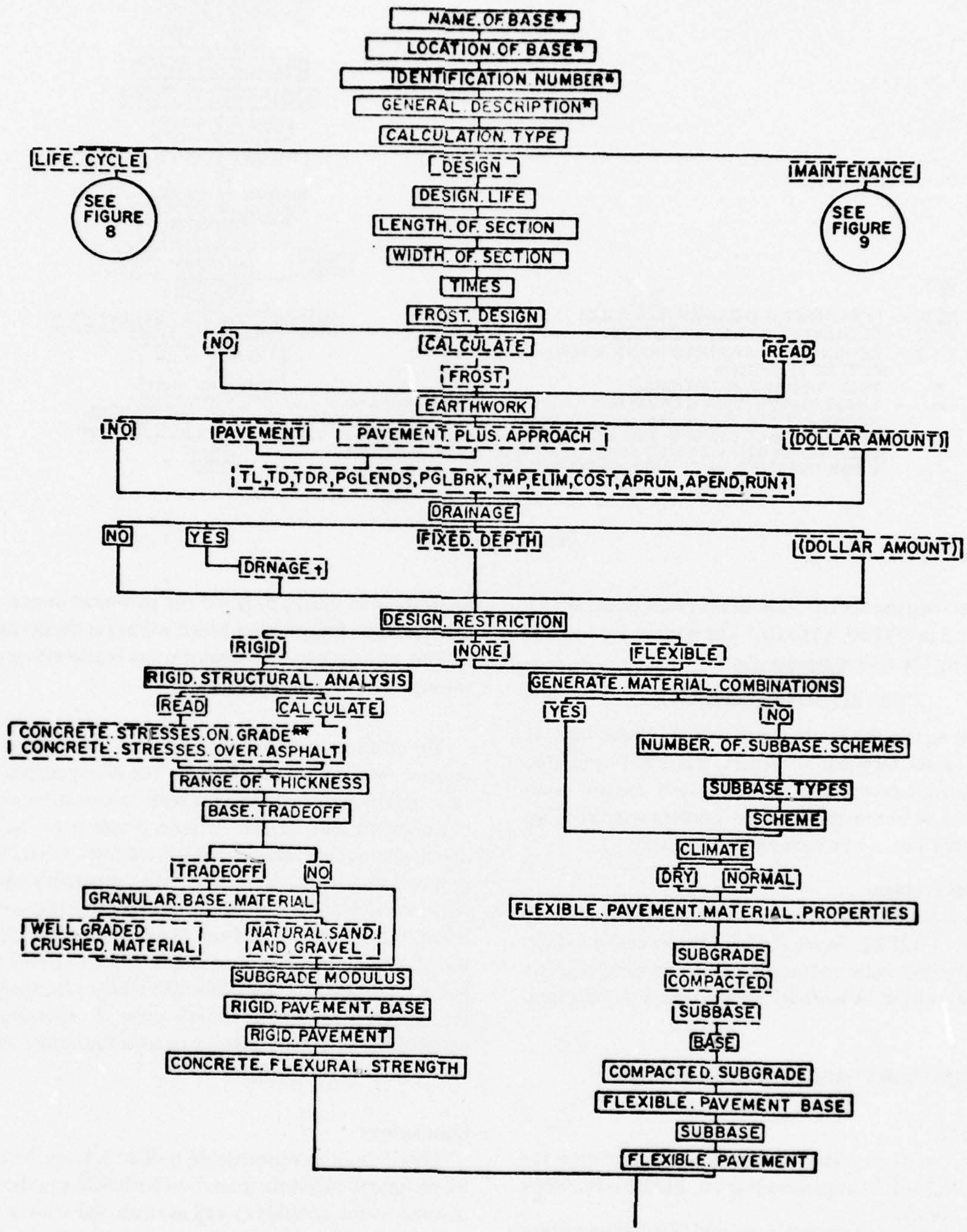


Figure 7. Input for DESIGN calculation.

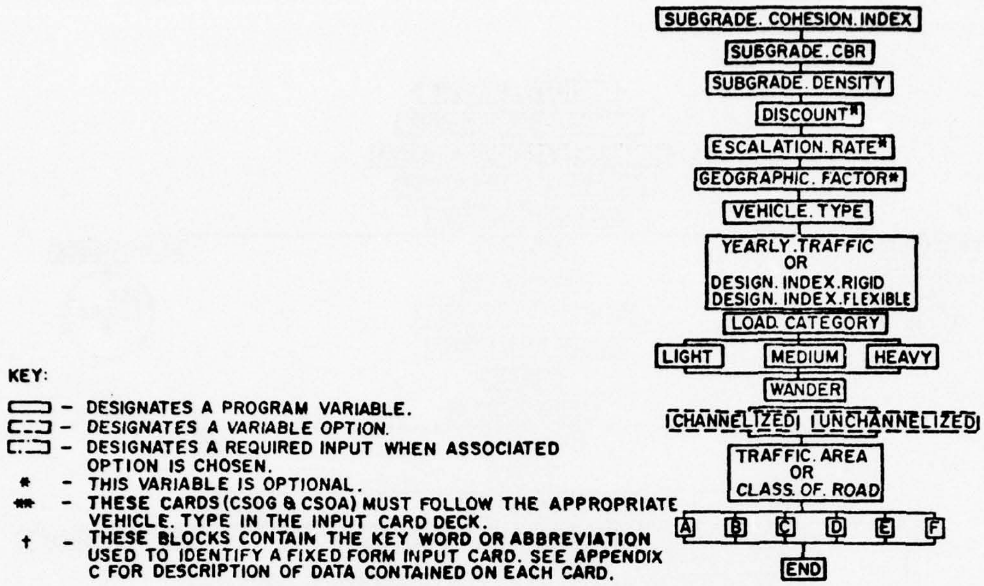


Figure 7 (cont'd).

Type assignments are made in the PROGRAM MAIN (. . .) card in OVERLAY(0,0).* The desired files can be printed by the following command:

COPYBF(OUT n, OUTPUT)

where n equals the internal designation of the tape. If an abnormal termination occurs, the EXIT card (see Deck Setup) causes the remaining job control commands to be executed. Thus, by printing selected files, an aborted run can be debugged more easily.

Example Problem

Appendix E contains an example problem illustrating the use of LIFE2. Input data for the example are explained individually to further clarify the variables. The program output is partially reproduced and discussed.

4 SUMMARY AND CONCLUSIONS

Summary

This report provides the necessary information for using the LIFE2 computer program. LIFE2 is intended to serve as an engineering aid for pavement design and management. Information which will aid in the decision-making process can be obtained quickly and efficiently through proper program usage.

The program provides the user with life-cycle, maintenance, and design calculations. The life-cycle calculation option provides the user with information about the required maintenance strategy implied by various design alternatives, as well as life-cycle costs, to facilitate economical design decisions. The program's maintenance calculation option can provide information to insure maximum return from M&R funds. If a service life is predetermined, or if a user does not feel that enough information is available for a life-cycle analysis, the design calculation option aids in selecting an economical pavement design based on the construction costs of alternative designs.

Conclusions

LIFE2 is an implementable tool which can be used by pavement engineers to analyze both rigid and flexible pavements for airfields as well as roads and streets. The program evaluates alternative pavement design schemes and/or maintenance and repair strategies and ranks them according to their life-cycle costs. Capability is

*A complete description of tapes used by individual routines and the contents of the tapes is included in *Systems Approach to Life-Cycle Design of Pavements: Volume II–LIFE2 System Documentation*.

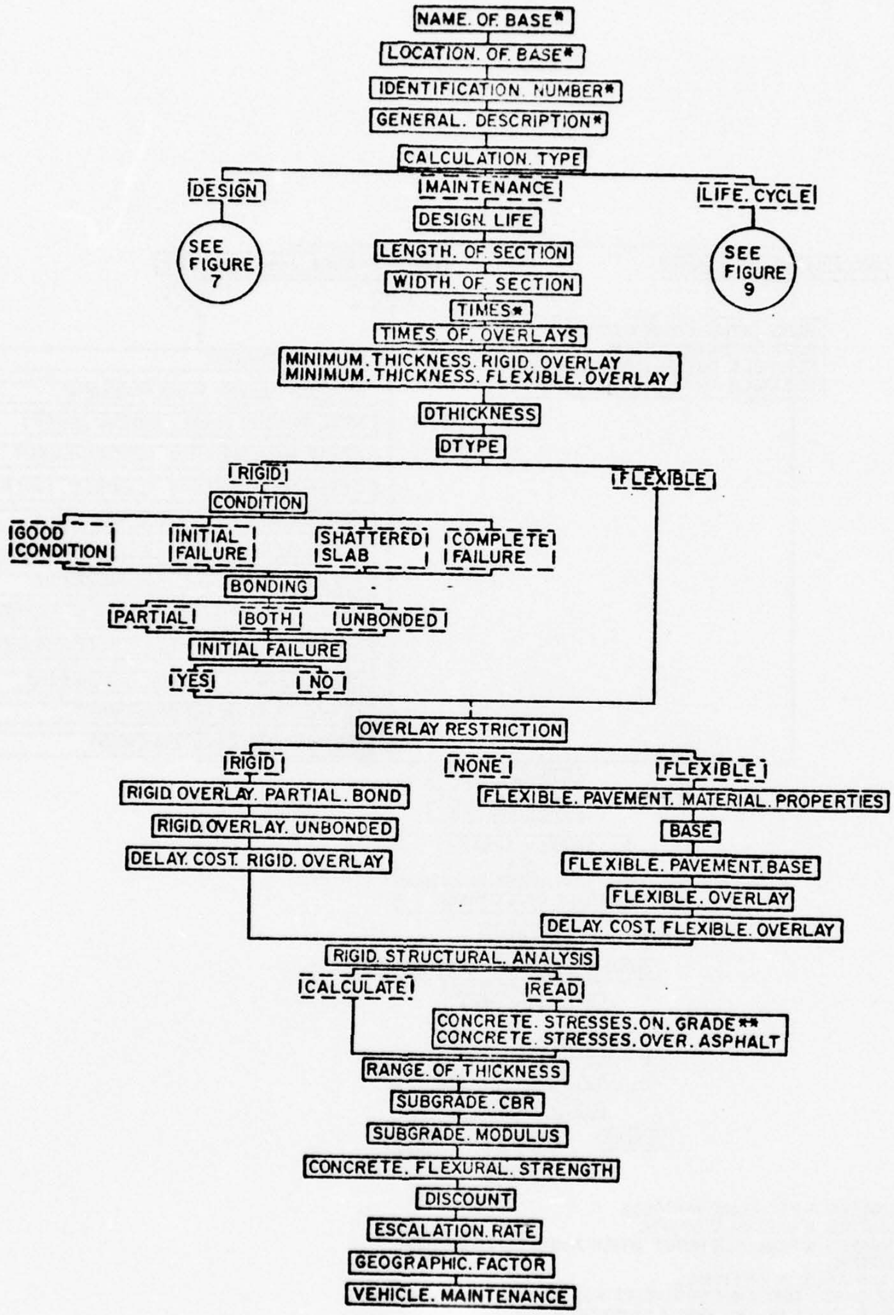


Figure 8. Input for MAINTENANCE calculation.

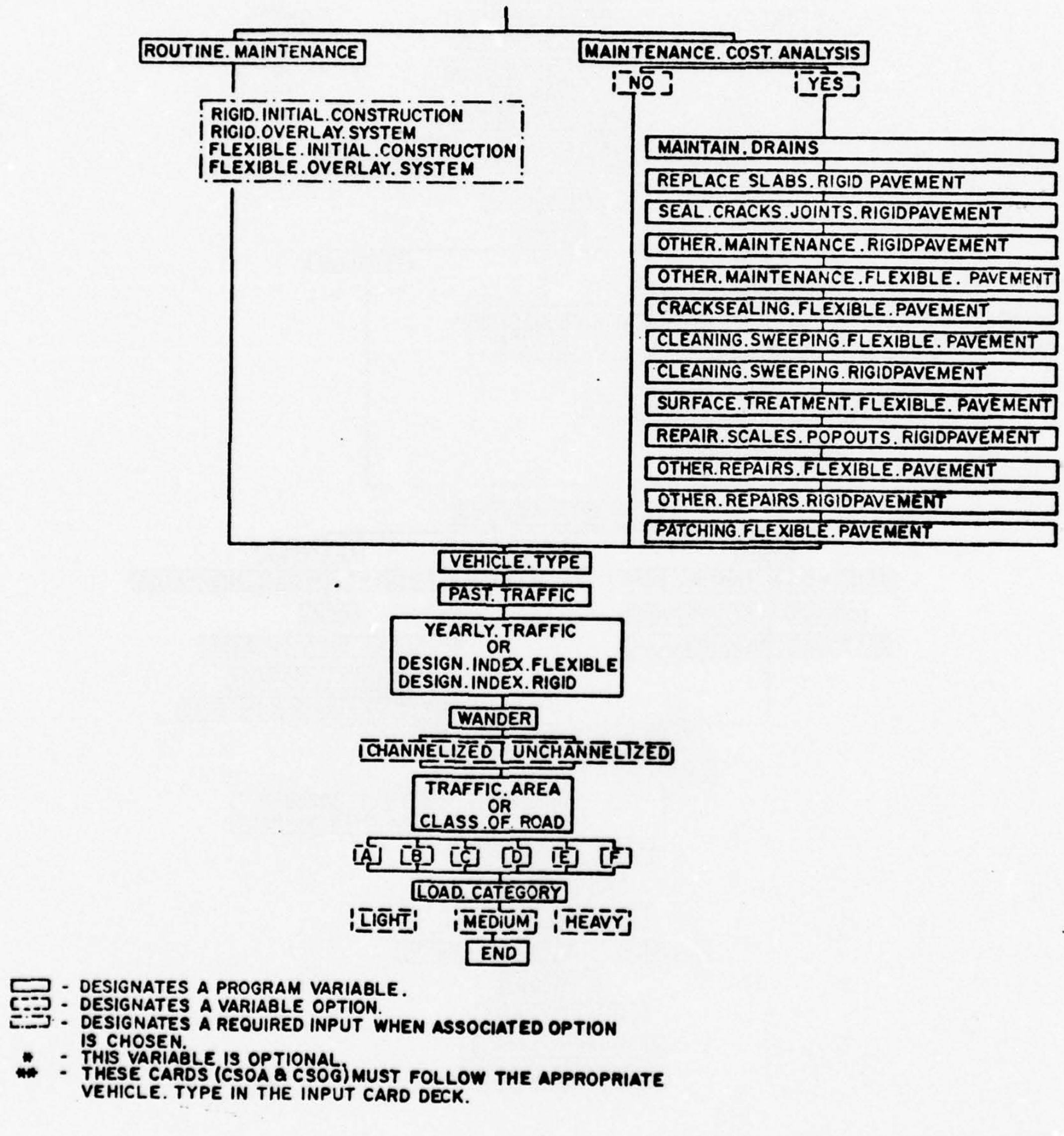


Figure 8 (cont'd).

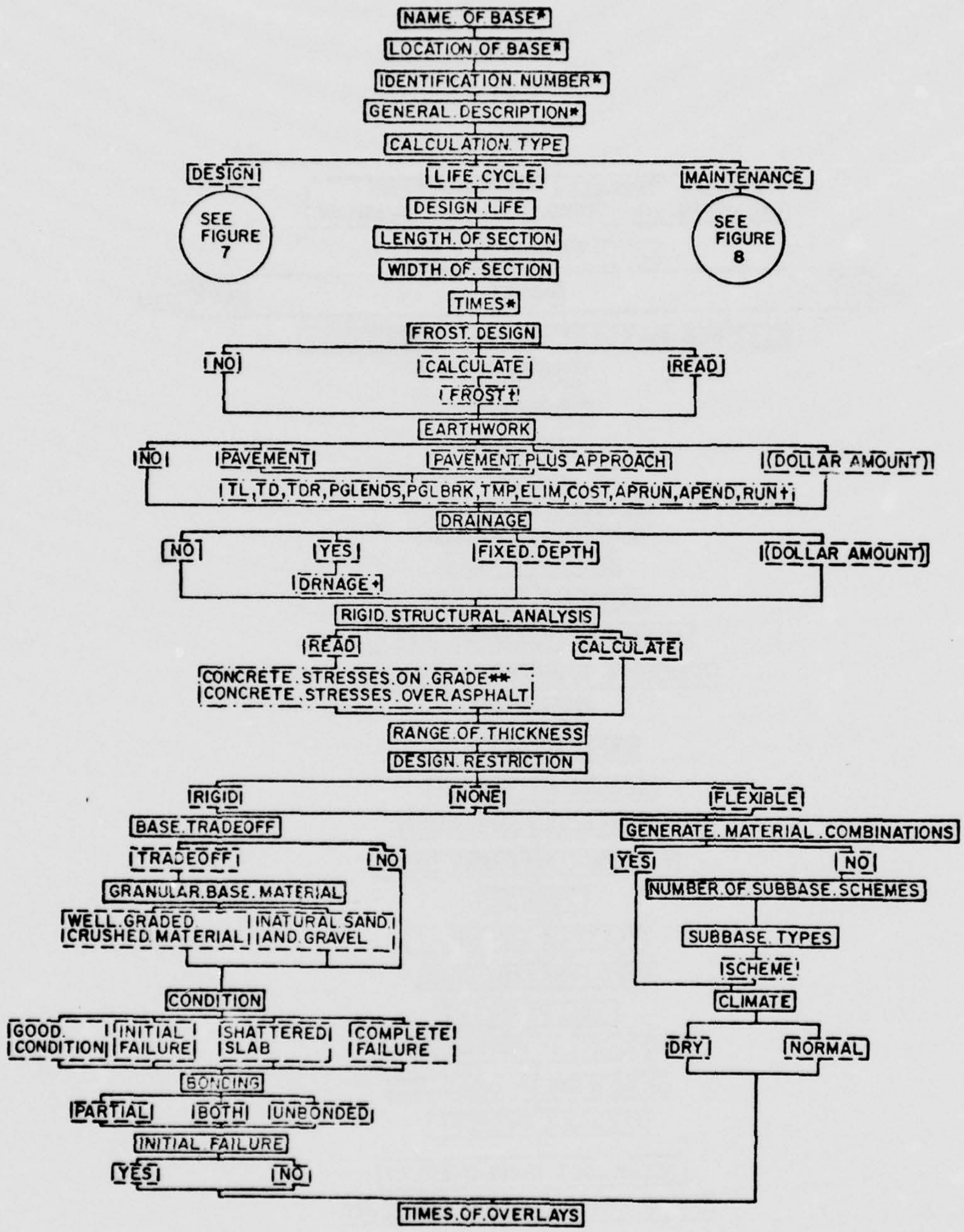


Figure 9. Input for LIFE-CYCLE calculation.

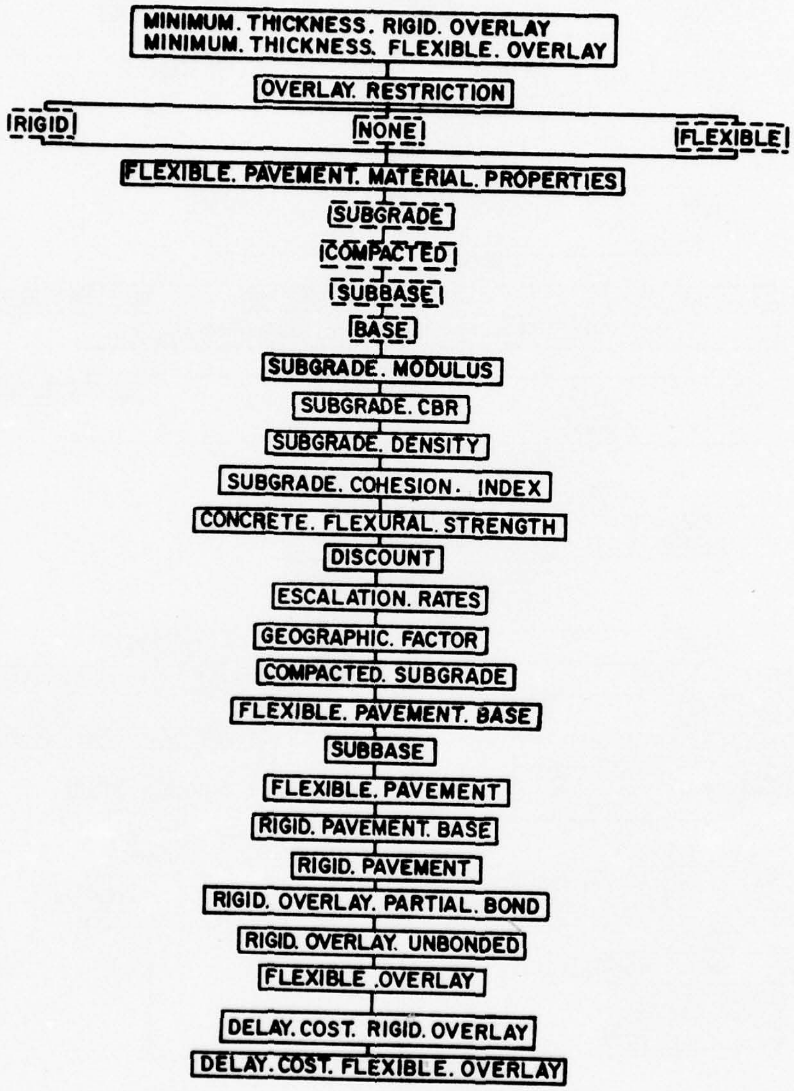
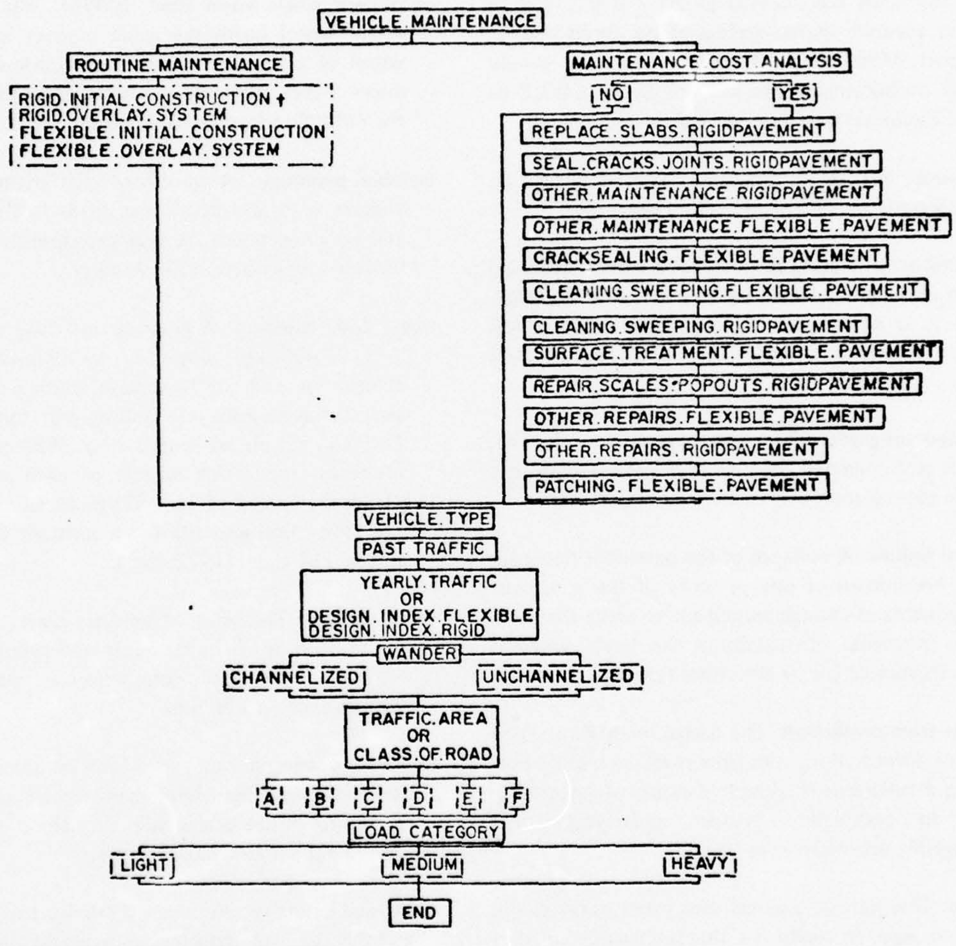


Figure 9 (cont'd).



KEY:

- DESIGNATES A PROGRAM VARIABLE.
- DESIGNATES A VARIABLE OPTION.
- DESIGNATES A REQUIRED INPUT WHEN ASSOCIATED OPTION IS CHOSEN
- * - THIS VARIABLE IS OPTIONAL.
- ** - THESE CARDS (CSOG & CSOA) MUST FOLLOW THE APPROPRIATE VEHICLE.TYPE IN THE INPUT CARD DECK.
- † - THESE BLOCKS CONTAIN THE KEY WORD OR ABBREVIATION USED TO IDENTIFY A FIXED FORM INPUT CARD. SEE APPENDIX C FOR DESCRIPTION OF DATA CONTAINED ON EACH CARD.

Figure 9 (cont'd).

provided for determining the cost of earthwork, pavement construction, subsurface drainage, maintenance and repair activities, and user-related expenditures incurred during the life of the facility.

APPENDIX A: GLOSSARY OF TERMS

The following alphabetical glossary is included to insure an accurate understanding of the terms used in this report. While most of these terms have widely accepted definitions, some are unique to LIFE2 or Corps of Engineers pavement design procedures.

base course: Natural or processed materials placed on the subgrade or subbase beneath a pavement.

CBR: California Bearing Ratio. CBR is a semi-empirical index of a material's ability to resist shear deformation. It is determined by a penetration-type test (Military Standard MIL-STD-621A, test method 101).

compacted subgrade: The upper part of the subgrade, which is compacted to a density greater than that of the natural soil.

complete failure: A collapse of the pavement structure or a breakdown of one or more of the pavement components of enough magnitude to make the pavement incapable of sustaining the loads imposed upon its surface (i.e., a structural failure).

complete frost protection: The design method in which surface deformation from frost is eliminated by providing a sufficient thickness of nonfrost-susceptible base to completely protect underlying frost-susceptible materials from freezing.

coverage: One pass of a wheel over every point in the tracking lane. In roadways, this is normally equated to a PASS, since traffic is highly channelized.

design index: An index used in designing pavements for roads which represents all traffic expected to use the facility during its life. It is based on typical traffic magnitudes and compositions, reduced to equivalents in terms of repetitions of an 18,000-lb (72.00-kg), single-axle dual-tire load.

design life: The length of time (in years) for which a pavement facility is being designed, including programmed rehabilitation. At the end of this period, the physical life of the facility is considered to be ended, i.e., the pavement structure has deteriorated to a point where total reconstruction would be necessary.

design scheme: A combination of pavement material layers which are to be considered in the structural thickness computations.

equivalent single-wheel load (ESWL): The load on a single wheel (with the same contact area as one wheel of a multiple-wheel configuration) that produces a maximum deflection equal to that beneath the multiple-wheel configuration.

flexible pavement: A pavement that maintains close contact with and distributes loads to the subgrade and which depends on aggregate interlock, particle friction, and cohesion for stability.

heavy load category: A gross aircraft load of 480,000 lb (192,000 kg) supported by twin-twin wheels abreast on each of two main landing gears of an aircraft having a bicycle landing gear configuration. The twin wheels are spaced 37 in. (939 mm) center-to-center; the inside wheels of each set of twin wheels are spaced 62 in. (1575 mm) center-to-center; and each main gear tire has a constant tire contact area of 267 sq in. (1722 cm^2).

initial failure: The point at which a crack, originating at the bottom of the structure and propagating upward to the surface, commences to spall or ravel (i.e., a functional failure).

life-cycle design: An analysis which considers the construction, operation, and maintenance of a facility during its entire design life. In LIFE2, cost is the dependent variable in the analysis.

light load category: A gross aircraft load of 60,000 lb (24,000 kg) is supported by a single wheel with a constant tire-contact area of 100 sq in. (645 cm^2) on each of the two main landing gears of an aircraft with a tricycle landing gear configuration.

limited subgrade frost protection: The design method which attempts to hold surface deformations to small, acceptable values, instead of eliminating them completely. This is the normal method of design.

maintenance: An activity necessary to keep a pavement operable at its present structural condition (e.g., patching, sealing joints).

maintenance strategy: A composite of an overlay strategy, routine maintenance, vehicle maintenance, and overlay delay costs.

medium load category: A gross aircraft load of 320,000 lb (128,000 kg) supported by twin tandem wheels on each of two main landing gears of an aircraft having a tricycle landing gear configuration. The twin wheels are spaced 32.5 in. (825.5 mm) center-to-center, and each main gear tire has a constant tire-contact area of 208 in. (1342 cm^2).

overlay delay costs: Costs incurred during structural pavement overlay construction resulting from shifting of operations to other pavement facilities or to another base.

overlay pavement: Pavement superimposed on existing pavement and base to reinforce its load-carrying capacity.

overlay strategy: Points in time when structural pavement overlays are scheduled to be constructed.

pass: One operation of a vehicle—in airfield usage, a take-off and a landing; in road usage, one movement of the vehicle over the design section.

pavement: A surface of prepared or manufactured material superimposed upon the base, subbase, or subgrade either as a structural member or as a weather- and abrasion-resistant medium.

pavement management: The entire process of providing an adequate paved surface for transportation facilities, including design, construction, maintenance, rehabilitation, and replacement.

program overlay: In computer terminology, a program overlay is a subprogram of the main system which resembles a complete computer program. When called by the main program, the overlay is loaded and executes a specific analysis, using data transferred from common storage or from external inputs.

reduced subgrade strength: A frost design method based on allowing a reduction in subgrade strength during thawing periods.

repair: Structural restoration of a failed or fading section of pavement to enable fulfillment of its designated purpose (e.g., overlay).

rigid pavement: A pavement structure that distributes loads to the subgrade; one of its courses is a portland cement concrete slab having relatively high bending resistance.

routine maintenance: A cost category intended to reflect a pattern of routine maintenance and repair activities that might take place during a pavement's service life. It would include such activities as surface treatments, patching, joint and crack sealing, slab jacking, and thin overlays. An estimate of expenditures for such activities must be determined over time by the program user and input as a piece-wise linear function of duration. The maintenance must be comprehensive enough so that a pavement remains serviceable throughout its life.

service life: The length of time (in years) that a pavement facility is used for its major intended function without extensive rebuilding (e.g., structural overlaying).

subbase: A layer used in a pavement system between the subgrade and the base course.

subgrade: The natural soil or the fill material upon which a pavement, base, or subbase course is constructed.

subsurface drainage system: A subsurface draining system comprising facilities to collect and dispose of water occurring below the surface of the ground (pavement) and constituting a threat to health or to adequacy, stability, or proper maintenance of structures, pavements, grounds, and utilities. Subsurface draining facilities include open-jointed, perforated, or porous collector pipes, conduits, observation risers, cleanouts, filters, blind drains, outlet structures, and appurtenant works as required.

type A traffic area: Pavement facilities that receive the channelized traffic and full design weight of heavy multiple-wheel bomber and cargo aircraft.

type B traffic area: Facilities in which the traffic is more evenly distributed over the full width of the pavement but which receive the full weight of the aircraft during operations.

type C traffic area: Facilities in which the traffic volume is low or in which the weight of the operating aircraft is generally less than the design weight.

type D traffic area: Facilities in which the traffic volume is extremely low and the weight of operating aircraft is considerably lower than the design weight.

vehicle maintenance: A cost estimate which includes expected costs of vehicle repairs necessitated by pavement roughness and expected costs due to the probability of accidents caused by slipperiness.

APPENDIX B: PROGRAM VARIABLES

Variables used in the LIFE2 program are divided into two categories: free-form and fixed-form input.

In free-form input, the variable name must begin within a card's first nine columns. If the variable contains more than one word, a period must be used to separate each. The variable's option or value must begin with the next nine card columns. There must be at least one blank column between the variable and its value; blanks may not appear within a variable name or its value. More than one variable may be placed on the same data card if the second variable begins within nine columns of the first; however, the program ignores data in columns 73-80. If the program encounters ten or more blank spaces, it skips to the next card and searches for a new variable.

The fixed format is used to provide data for three variables: EARTHWORK, DRAINAGE, and FROST.DESIGN.

In addition to format requirements, the following sequence requirements must be followed:

1. DESIGN.LIFE must precede VEHICLE.TYPE.

2. VEHICLE.TYPE must immediately precede YEARLY.TRAFFIC and PAST.TRAFFIC for the specific aircraft or DESIGN.INDEX for roadway pavements.

3. If the RIGID.STRUCTURE.ANALYSIS option is READ, the CSOA and CSOG cards must immediately follow YEARLY.TRAFFIC for the vehicle being considered.

4. FLEXIBLE.PAVEMENT.MATERIAL.PROPERTIES *must precede all cost data.*

5. The SUBGRADE, COMPACTED, SUBBASE, and BASE information cards must directly follow the FLEXIBLE.PAVEMENT.MATERIAL.PROPERTY header card.

6. The complete set of data must be followed by a card having the word END punched within its first nine columns. This card indicates the end of the punched-card input deck and is separate from the control language end-of-information or separator cards.

Table B1 is an index for finding the page in the Variable Name Section on which a specific variable is defined. The description of input for the example problem in Appendix E can be used to further clarify input preparation.

Free-Form Variable Descriptions

Variables using free-form input are defined in this section; where applicable, the variable's allowable options are given and defined. To provide a logical pattern for input preparation, the related variables are categorically arranged as follows:

1. General information

2. Design data

3. Material properties

4. Cost data

5. Traffic data.

Table B1
Variable Names

Free-Form Input Variable	Abbreviation	Page
BASE.TRADEOFF	BT	31
BONDING	BOND	33
CALCULATION.TYPE	CT	30
CLASS.OF.ROAD	COR	41
CLEANING.SWEEPING.FLEXIBLE.PAVEMENT	CSFP	39
CLEANING.SWEEPING.RIGIDPAVEMENT	CSR	39
CLIMATE	CLIM	33
COMPACTED.SUBGRADE	CS	35
CONCRETE.FLEXURAL.STRENGTH	CFS	35
CONCRETE.STRESSES.ON.GRADE	CSOG	31
CONCRETE.STRESSES.OVER.ASPHALT	CSOA	30
CONDITION	COND	34
CRACKSEALING.FLEXIBLE.PAVEMENT	CFP	38
DELAY.COST.FLEXIBLE.OVERLAY	DCFO	36
DELAY.COST.RIGID.OVERLAY	DCRO	36
DESIGN.INDEX.FLEXIBLE	DIF	40
DESIGN.INDEX.RIGID	DIR	40
DESIGN.LIFE	DL	30
DESIGN.RESTRICTION	DR	31
DISCOUNT	DISC	36
DRAINAGE	DRAI	32
DTHICKNESS	DTHI	34
DTYPE	DTYP	33
EARTHWORK	EART	32
ESCALATION.RATE	ER	36
FLEXIBLE.OVERLAY	FO	36
FLEXIBLE.PAVEMENT	FP	36
FLEXIBLE.PAVEMENT.BASE	FPB	36
FLEXIBLE.PAVEMENT.MATERIAL.PROPERTIES	FPMP	34
FROST.DESIGN	FD	31
GENERAL.DESCRIPTION	GD	30
GENERATE.MATERIAL.COMBINATIONS	GMC	32
GEOGRAPHIC.FACTOR	GF	36
GRANULAR.BASE.MATERIAL	GBM	35
IDENTIFICATION.NUMBER	IN	29
INITIAL.FAILURE	IF	34
LENGTH.OF.SECTION	LOS	30
LOAD.CATEGORY	LC	40
LOCATION.OF.BASE	LOB	29
MAINTENANCE.COST.ANALYSIS	MCA	37
MAINTAIN.DRAINS	MD	37
MINIMUM.THICKNESS.FLEXIBLE.OVERLAY	MTFO	33
MINIMUM.THICKNESS.RIGID.OVERLAY	MTRO	33
NAME.OF.BASE	NOB	29
NUMBER.OF.SUBBASE.SCHEMES	NOSS	32
OTHER.MAINTENANCE.FLEXIBLE.PAVEMENT	OMFP	38
OTHER.MAINTENANCE.RIGIDPAVEMENT	OMR	38
OTHER.REPAIRS.FLEXIBLE.PAVEMENT	ORFP	39
OTHER.REPAIRS.RIGIDPAVEMENT	ORR	39
OVERLAY.RESTRICTION	OR	31
PAST.TRAFFIC	PT	40
PATCHING.FLEXIBLE.PAVEMENT	PFP	38
RANGE.OF.THICKNESS	ROT	31

Table B1 (cont'd)

Free-Form Input Variable	Abbreviation	Page
REPAIR.SCALES.POPOUTS.RIGIDPAVEMENT	RSPR	38
REPLACE.SLABS.RIGIDPAVEMENT	RSR	39
RIGID.OVERLAY.PARTIAL.BOND	ROPB	36
RIGID.OVERLAY.UNBONDED	ROU	36
RIGID.PAVEMENT	RP	36
RIGID.PAVEMENT.BASE	RPB	36
RIGID.STRUCTURAL.ANALYSIS	RSA	30
ROUTINE.MAINTENANCE	RM	37
SEAL.JOINTS.CRACKS.RIGIDPAVEMENT	SJCR	38
SUBBASE	SUBB	36
SUBBASE.TYPES	ST	32
SUBGRADE.CBR	SC	35
SUBGRADE.COHESION.INDEX	SCI	35
SUBGRADE.DENSITY	SD	35
SUBGRADE.MODULUS	SM	35
SURFACE.TREATMENT.FLEXIBLE.PAVEMENT	STFP	38
TIMES	TIME	31
TIMES.OF.OVERLAYS	TOO	33
TRAFFIC.AREA	TA	41
VEHICLE.MAINTENANCE	VM	37
VEHICLE.TYPE	VT	40
WANDER	WAND	40
WIDTH.OF.SECTION	WOS	30
YEARLY.TRAFFIC	YT	40

General Information

Variable	*Description*
NAME.OF.BASE	The name of the installation in which the pavement is to be located. The name must be enclosed in quotes and can be no longer than 20 characters.[a]*
LOCATION.OF.BASE	The installation's location (state, district, country). The location must be enclosed in quotes and can be no longer than 32 characters.[a]
IDENTIFICATION.NUMBER	The project's identification number must be enclosed in quotes and cannot be longer than 12 characters.[a]

*Footnotes are provided at the end of this section.

Variable	*Description*
GENERAL.DESCRIPTION	This variable allows up to 10 output lines for a general description of the project. One card may contain a maximum of 60 characters; two cards constitute one line of output. Thus, the maximum field is 1200 characters. Quotes must be placed at the beginning and end of each portion of a statement on every card. The description may be alphanumeric; however, a dollar sign may not be used.[a]

Design Data

CALCULATION.TYPE	Specifies the type of analysis to be performed.[b] Options: DESIGN MAINTENANCE LIFE.CYCLE
DESIGN.LIFE	The design life of the pavement in years. This variable must precede the definition of traffic (i.e., VEHICLE. TYPE) in the input.[b]
LENGTH.OF.SECTION	The length of pavement in the section being considered (in feet).[b]
WIDTH.OF.SECTION	The width of pavement in the section being considered (in feet).[b]
RIGID.STRUCTURAL.ANALYSIS	Provides the option of having rigid pavement stresses (CSOA and CSOG) either calculated* or read. In the READ option, the user can omit redundant calculations by using results from a previous run as input. (Both CSOA and CSOG must be input in this option regardless of the type of problem.) CALCULATE produces a set of stresses (in psi) for 10 pavement thicknesses based on RANGE.OF.THICKNESS. Options: READ CALCULATE Default:[c] CALCULATE
CONCRETE.STRESSES.OVER.ASPHALT	A set of 10 rigid pavement stresses used when the READ options of RSA are selected. To use results of a previous run, the problem must have the same VEHICLE.TYPE, RANGE.OF.THICKNESS, and SUBGRADE.MODULUS as that of the previous run. Since the stresses are unique to VEHICLE.TYPE, they must be placed immediately after YEARLY.TRAFFIC for that vehicle.[f]

*The stress calculations follow the method presented in W. C. Kreger, ***Computerized Aircraft Ground Flotation Analysis–Edge-Loaded Rigid Pavement***, Report ERR-FW-572 (General Dynamics Corp., 1967).

Variable	*Description*
CONCRETE.STRESSES.ON.GRADE	CSOG has the same requirements as CSOA. Note that both must be input when using the READ option.[f]
DESIGN.RESTRICTION	Option code stipulating restrictions on the type of pavement design.[d] Options: NONE RIGID FLEXIBLE Default: NONE
OVERLAY.RESTRICTION	Option code stipulating restrictions on the type of overlay to be considered.[e] Options: NONE RIGID FLEXIBLE Default: NONE
RANGE.OF.THICKNESS	Minimum and maximum thicknesses expected to be encountered in the design of rigid pavements or overlays. This range is used to establish units for the CSOA and CSOG calculations.[b]
TIMES	Years during the design life in which the user desires a required pavement thickness to be calculated. This variable is used to develop thickness vs. time (service life) curves. The first value must be 1, and the maximum value must equal the design life. The number of points must not exceed 20. If this variable is not part of the input, the program selects 6 equally spaced values (e.g., 1, 4, 8, 12, 16, and 20 would be used for a design life of 20).[a]
BASE.TRADEOFF	In rigid pavement design, this variable provides the option of having the program consider a tradeoff between the thickness of base course and the thickness of PCC slab.[d] Options: NO TRADEOFF Default: NO
FROST.DESIGN	This option code specifies whether frost criteria will be considered in the design.[d] CALCULATE determines the required depth of frost protection for each design scheme. READ is followed by the user's estimate of the required depth of protection (in inches). Both the rigid and the flexible design schemes will use this quantity as the required depth of nonfrost-susceptible material. Options: NO CALCULATE[h] READ Default: NO

Variable	*Description*
EARTHWORK	An option code which determines whether an earthwork analysis will be performed for the various pavement thickness designs. PAVEMENT computes the earthwork quantity for the paved areas only. PAVEMENT.PLUS. APPROACH includes the earthwork in airfield approach zones. The final option is to input the cost in dollars (without the dollar sign) as an integer number. This cost will be included as a lump sum in every design scheme (i.e., earthwork is then a constant). Options: NO PAVEMENT[h] PAVEMENT.PLUS.APPROACH[h] (dollar amount) Default: NO
DRAINAGE	This option code determines whether the cost of subsurface drainage will be included in the project analysis.[d] YES determines the cost, if any, of subsurface drainage for each thickness design. FIXED.DEPTH must be followed by the required depth (in inches) to the underdrain (from top of subgrade to center of pipe). The final option is the user's estimate of the total cost of underdrains (input as an integer without the dollar sign). This will be included as a lump sum in every design scheme (i.e., drainage is then a constant). Options: NO YES[h] FIXED.DEPTH[h] (dollar amount) Default: NO
GENERATE.MATERIAL.COMBINATIONS	Option code which specifies whether subbase combinations for the design of flexible pavements will be generated by the program or input by the user.[d] Options: YES NO Default: YES (i.e., all combinations generated by the program).
NUMBER.OF.SUBBASE.SCHEMES	If the material combinations are input (i.e., GMC option NO), this variable must be used to specify the number of subbase schemes being considered by the user. Each scheme designates the combination of subbases to be used in the design.[d]
SUBBASE.TYPES	This variable is the heading used for reading the subbase schemes desired by the user. This is necessary if GMC option NO is selected. The heading is followed by a series

Variable	*Description*
	of statements (up to 20) specifying SCHEME, a sequence number, and the numbers of the subbase materials which are to be considered in combination in that scheme. The subbase material numbers are those assigned to the material in the variable FLEXIBLE.PAVEMENT.MATERIAL.PROPERTIES.[d]
CLIMATE	Option code for considering moisture conditions in the design of flexible pavements. The DRY option is selected if the annual precipitation is less than 15 in. (381 mm), the water table is at least 15 ft (4.5 m) below finished grade, and if the moisture content of the subgrade is not anticipated to exceed the optimum. This option reduces the total pavement thickness above the subgrade by 20 percent.[d] Options: NORMAL DRY Default: NORMAL
TIMES.OF.OVERLAYS	This variable is the heading for the input of overlay strategies (i.e., the projected time spacing for overlays). The heading is followed by a series of statements (up to 10) specifying STRATEGY, a sequence number, and the years when the user predicts the need for structural overlays. If the sequence number is followed by blanks, it is assumed that an overlay will not be required during the design life of the pavement.[c]
MINIMUM.THICKNESS.FLEXIBLE.OVERLAY	A decimal number specifying the minimum allowable thickness for a flexible overlay.[c] Default: 4.0
MINIMUM.THICKNESS.RIGID.OVERLAY	A decimal number specifying the minimum allowable thickness for a rigid overlay.[e] Default: 5.0
BONDING	This variable designates whether the bonding between a rigid overlay and a rigid existing pavement will be partial or unbonded.[e] The program will select the more economical of the two when the option is BOTH. Options: PARTIAL UNBONDED BOTH Default: BOTH
DTYPE	Defines the existing pavement type.[e] Options: RIGID FLEXIBLE

Variable	*Description*
DTHICKNESS	Defines the thickness of the existing pavement—total thickness if DTYPE is FLEXIBLE, and slab thickness if DTYPE is RIGID.[e]
INITIAL.FAILURE	Specifies whether a flexible overlay over a rigid pavement system will be designed for initial failure. If YES, the F factor in the overlay design equation is set to 1.0; if NO, the factor is determined based on the modulus of subgrade reaction.[e] Options: YES NO Default: YES
CONDITION	Option code for classifying the condition of the existing rigid pavement; this will be used to calculate the required thickness of the overlay.[e] Based on this classification, the C factor in the applicable thickness design equation will be given the following values: INITIAL.FAILURE – C = 0.75 for rigid overlay C = 1.00 for flexible overlay SHATTERED.SLAB – C = 0.50 for rigid overlay C = 0.75 for flexible overlay COMPLETE.FAILURE – C = 0.35 for rigid overlay Flexible overlays will not be considered. GOOD.CONDITION – C = 1.00 for rigid overlay C = 1.00 for flexible overlay Options: GOOD.CONDITION INITIAL.FAILURE SHATTERED.SLAB COMPLETE.FAILURE Default: GOOD.CONDITION

Material Properties

FLEXIBLE.PAVEMENT.MATERIAL.PROPERTIES	This variable is the heading for input of the properties of flexible pavement design materials. This heading must immediately precede the list of material variables and all cost data in the input deck. The material variables included under this heading are SUBGRADE, COMPACTED, SUBBASE, and BASE. BASE is limited to two materials; other layers may have up to nine materials to be considered by the program. The properties necessary for each material are: SUBGRADE (number) (CBR) (density) (thickness) (cohesion) (frost susceptibility); SUBBASE (number) (CBR) (density) (cohesion) (frost susceptibility); BASE (number) (CBR).

Variable	*Description*
	These properties are interpreted as follows: (1) Number is the sequence assigned to differentiate between alternative materials in a layer. (2) The sequence numbers for SUBGRADE must be arranged beginning with the lowest layer. (3) CBR and density are the values expected in the field after compacting the material to the construction specification. Density is in percent of CE55 maximum dry density. (4) The thickness of each SUBGRADE layer must be input (in inches). (5) Cohesion is specified as either cohesive or cohesionless. This property defines the post-construction condition of the materials. (6) Frost susceptibility is designated as FS (frost susceptible) or NFS (nonfrost-susceptible). (7) BASE CBR must be 50, 80, or 100.
SUBGRADE.COHESION.INDEX	Defines the cohesion and frost susceptibility of the natural subgrade material.[d] Options: COHESIONLESS FS or NFS COHESIVE FS or NFS
SUBGRADE.CBR	Defines the CBR of the subgrade material in the natural undisturbed state.[b]
SUBGRADE.DENSITY	Defines the density of the undisturbed subgrade material. It is expressed as percent of CE55 maximum dry density (up to a maximum of 100 percent).[d]
SUBGRADE.MODULUS	Defines the modulus of subgrade reaction (in pci).[b]
GRANULAR.BASE.MATERIAL	Describes the base material. This variable is necessary for BASE.TRADEOFF in the rigid pavement design.[d]* Options: WELL.GRADED.CRUSHED.MATERIAL NATURAL.SAND.AND.GRAVEL
CONCRETE.FLEXURAL.STRENGTH	Defines the design flexural strength of the portland cement concrete to be used (in psi).[b]

Cost Data

COMPACTED.SUBGRADE	These data define a thickness (inches) vs. cost ($) curve for each material considered. The data string includes: variable name; sequence number (coinciding with that assigned in FPMP); an alphanumeric description in quotes (optional—no longer than 28 characters); and a set of

*_Rigid Pavements for Airfields Other Than Army_, TM 5-824-3 (Department of the Army, 7 December 1970).

Variable	*Description*
	thickness vs. cost pairs (up to nine pairs to define the curve). The use of data corresponding to 1 in. (25.4 mm) of material is not intended to imply that material would be placed at 1 in. (25.4 mm) at that price, but rather to set an end point to the cost function. (See Figure B1.) For values greater than the input data, linear extrapolation of the final curve segment is performed for all cost data.
FLEXIBLE.PAVEMENT.BASE	Same as above.
SUBBASE	Same as above.
RIGID.PAVEMENT.BASE	Same as above.
FLEXIBLE.OVERLAY	Same as above.
FLEXIBLE.PAVEMENT	Same as above.
RIGID.OVERLAY.PARTIAL.BOND	Same as above.
RIGID.OVERLAY.UNBONDED	Same as above.
RIGID.PAVEMENT	Same as above. This relationship is also used to compute the cost of rigid overlays over flexible pavement.
DELAY.COST.FLEXIBLE.OVERLAY	A lump sum (in dollars) reflecting the cost of closing the facility during construction of a flexible overlay.[e] Default: 0.0
DELAY.COST.RIGID.OVERLAY	A lump sum (in dollars) reflecting the cost of closing the facility during construction of a rigid overlay.[e] Default: 0.0
DISCOUNT	Rate (given as a decimal) used to express costs in terms of present worth. This value may include the escalation rate. Default: 0.0
ESCALATION.RATE	Rate (given as a decimal) used to escalate dollar amounts to account for the effects of inflation. Default: 0.0
GEOGRAPHIC.FACTOR	Factor used to adjust costs to account for variation in a project's geographic location. Default: 1.00

Variable	*Description*
VEHICLE.MAINTENANCE	This variable allows the user to include an estimate of anticipated vehicle maintenance costs caused by pavement roughness, slipperiness, or structural failures.[e] It is input as a time (years) vs. cost ($) curve. Up to nine pairs of time and cost data can be used to define the curve. The maximum time used must be greater than the maximum service life of the facility. Time for this variable is reset at zero after completion of each structural overlay or reconstruction activity. (See Figure B2).
ROUTINE.MAINTENANCE	This variable is a general estimate of the cost/sq yd which is anticipated to be incurred between structural upgradings (overlay or reconstruction) to maintain a functionally serviceable facility.[e] It is input as a time (years) vs. cost ($/sq yd) curve. Up to nine pairs of time and cost data can be used to define the curve. The maximum time used must be greater than the maximum service life of the facility. Since the cost of maintaining various pavement systems differs, this variable is divided into four categories, each having a cost curve. An example of input showing the four categories is:

```
ROUTINE.MAINTENANCE RIGID.INITIAL.CONSTRUCTION      1   .01   20   .03
ROUTINE.MAINTENANCE RIGID.OVERLAY.SYSTEM            1   .01   20   .08
ROUTINE.MAINTENANCE FLEXIBLE.INITIAL.CONSTRUCTION   1   .01   20   .05
ROUTINE.MAINTENANCE FLEXIBLE.OVERLAY.SYSTEM         1   .01   20   .12
```

The abbreviations RIC, ROS, FIC, and FOS can be used in place of the category names in the input. (See Figure B3.)

Default: (all ROUTINE.MAINTENANCE costs are defaulted to zero)

MAINTENANCE.COST.ANALYSIS	Option code which specifies whether a maintenance cost analysis will be performed. Options: YES NO Default: NO
MAINTAIN.DRAINS	The estimated cost of maintaining the drainage system. The decimal following the variable is the cost/sq yd of pavement. The second number, an integer, is the year in which this cost will be applied in the analysis. For example, MAINTAIN.DRAINS 0.95 3 indicates that a cost of $0.95 times the pavement area will be applied every third year (i.e., in year 3, 6, 9, etc.). (See Figure B4.) Default: .0 1

Variable	*Description*
SEAL.JOINTS.CRACKS.RIGIDPAVEMENT	The estimated cost of sealing joints and cracks in rigid pavements. This variable is input in the same manner as MAINTAIN.DRAINS. Default: .02 7
OTHER.MAINTENANCE.FLEXIBLE.PAVEMENT	This variable provides the user with the flexibility of accounting for the cost of flexible pavement maintenance activities other than those specifically listed as variables. It is input in the same manner as MAINTAIN.DRAINS. Default: .0 1
OTHER.MAINTENANCE.RIGIDPAVEMENT	This variable is the same as that listed for OTHER.MAINTENANCE.FLEXIBLE.PAVEMENT except that it describes rigid pavement maintenance. Default: .0 1
CRACKSEALING.FLEXIBLE.PAVEMENT	As the estimated cost of cracksealing for flexible pavements, this variable is followed by one decimal number which is the cost per sq yd. This cost is accrued annually. Default: .01
SURFACE.TREATMENT.FLEXIBLE.PAVEMENT	This variable is an estimate of surface treatments applied to flexible pavements. It is followed by one decimal number, which is the surface treatment cost per sq yd. The cost is applied as follows: if an overlay is not planned within the first 8 years, a surface treatment is placed during the fifth year; if an overlay is not planned during the sixth to thirteenth years, surface treatment is placed during the tenth year, etc. If an overlay is scheduled within the 8-year period, the surface treatment is deleted, and the next 8-year period is begun from the time of the overlay; when the design life ends within the 8-year period, no surface treatment is placed, and the calculations stop. Default: 0.41
PATCHING.FLEXIBLE.PAVEMENT	The cost estimate for this variable is given as cost per sq yd of pavement. This cost is applied during each year of the design life. Default: .02
REPAIR.SCALING.POPOUTS.RIGIDPAVEMENT	This variable is an estimate of the cost to repair scaling and popouts. The input value is in $/sq yd. This cost is applied using the relationship: $\text{Cost} = A\,(1. + \frac{B-4}{22})C$

Variable	*Description*
	where A = input value in $/sq yd B = year being considered C = pavement area. B, the year being considered, is reset to zero at each overlay. Default: .01
REPLACE.SLABS.RIGIDPAVEMENT	The periodic cost of replacing rigid pavement slabs is estimated by this variable. The input value is in $/sq yd/in. The yearly cost is determined within the program by the product of the input value, the total pavement thickness, the pavement area, and a yearly factor. The yearly factor is the percentage of slabs to be replaced in any given year. From past data,* the yearly factors are:

Year	4	6	8	10	12	14	16	18	20	22	24
Factor	.04	.13	.28	.31	.51	.99	1.16	1.41	1.21	.88	.41

	Default: 2.0
OTHER.REPAIRS.RIGIDPAVEMENT	This variable provides the user with the capability of accounting for repairs other than those specifically listed. The cost estimate is input by the year in which the cost is incurred, followed by a lump sum dollar amount. Costs can be input for up to 10 years. Time is reset to zero at each overlay. Default: 1 0.
OTHER.REPAIRS.FLEXIBLE.PAVEMENT	This variable is the same as the preceding variable, except that it considers flexible pavement repairs. Default: 1 .0
CLEANING.SWEEPING.FLEXIBLE.PAVEMENT	This variable is an estimate of the cleaning and sweeping operation for flexible pavements. The input is in $/sq yd of pavement. The cost is applied by the relationship: Cost = (pavement area)(input value)(year of the activity). The year of the activity is reset to zero at each overlay. Thus, the cost of this activity is a linear progression from the start of the design life to the time of the first overlay. Default: .0
CLEANING.SWEEPING.RIGIDPAVEMENT	This is the same as the previous variable, except that the operation is for rigid pavements. Default: .0

**Maintenance Cost Predictions for Airfield Pavements*, Unpublished Report (CERL, 1974).

Variable	*Description*
	Traffic Data
VEHICLE.TYPE	A unique descriptive name of the type of vehicle for which the facility is being designed. This name must correspond with a matching set of data in the Vehicle Data Bank (see Appendix C). For airfield projects, this variable is the name of the aircraft (e.g., BOEING-707). For highway projects, this variable is designated as ROAD. LOAD. It can be alphanumeric with a maximum of 12 characters. Ten is the maximum number of vehicle types accepted in one run by the program. Note that blanks are not allowed in the vehicle name.
YEARLY.TRAFFIC	This variable must immediately follow the corresponding VEHICLE.TYPE card for airfield problems. It is the estimated number of aircraft passes per year—one value is listed for each year in the design life. The values may continue on a second card.[i]
DESIGN.INDEX.FLEXIBLE	This variable represents the traffic volume predicted for roadway flexible pavement design. It is given as a single value from 1 to 10 (see TM 5-822-5 for calculation). DIF and DIR must immediately follow the VEHICLE.TYPE *ROAD.LOAD* card.
DESIGN.INDEX.RIGID	Same as DIF except for roadway rigid pavement design (see TM 5-822-6 for its calculation).
PAST.TRAFFIC	A single numerical value estimating the traffic (passes for airfields and 18 kip EAL for roads) previously applied to the facility by a specific vehicle type. It must follow the corresponding vehicle type in the input. This variable indirectly indicates the present pavement condition.[e,i] Default: 0
LOAD.CATEGORY	This variable is the user's qualitative estimate of the traffic magnitude and is required only for airfield design. It is used to determine minimum thickness of surface and base course. (See Glossary [Appendix A] for a definition of the option.) Options: LIGHT MEDIUM HEAVY Default: LIGHT
WANDER	Specifies the traffic pattern on the facility being designed. The CHANNELIZED option should be used for roads. Options: CHANNELIZED UNCHANNELIZED Default: CHANNELIZED

Variable	*Description*
TRAFFIC.AREA	In airfield design, this variable specifies the design loading concentration.[b] Four categories are defined: A, B, C, and D. The Glossary contains specifications for each traffic area. For further description, consult TM 5-824-3. *Options:* A B C D
CLASS.OF.ROAD	This variable defines the class of roads A through F, based on the design volume of traffic.[b] Specifications for selecting the class of road are contained in TM 5-822-2. Options: A B C D E F

Notes:

a. May be omitted.
b. Must be part of the input.
c. A default value is the value in the option code which is assumed by the program if that variable is not part of the input.
d. Unnecessary when the calculation type is MAINTENANCE.
e. Unnecessary when the calculation type is DESIGN.
f. Necessary only if the READ option of RIGID.STRUCTURAL.ANALYSIS is chosen.
g. *If this option is selected, the input deck must include the appropriate fixed-form data card.*
h. Repeated for each VEHICLE.TYPE.

Fixed-Form Variable Descriptions

In the free-form input, the user is presented with three options which, if called, require additional data to complete the analysis. The three options are: FROST.DESIGN, EARTHWORK, and DRAINAGE.

Frost Design

Figure B5 is a layout sheet depicting the fixed format data card required when the CALCULATE option of FROST.DESIGN is called. Following is a description of each variable on the card:

Card Columns	*Variable*	*Description*
1-5	Frost Heading	The word FROST in columns 1-5 signifies to the program that frost data is available.
6		Blank.
7-12	Design Load	Enter Design Load (right-justified) in the six-column field (in pounds). Do not enter decimal point.
13	Configuration Code	Enter a single-digit numerical code in the range 1 to 8 to describe the Design Load Configuration. Codes are:

Card Columns	Variable	Description
		1 = Single Wheel—100 sq in. (645 cm^2) contact area.
		2 = Twin Assembly Tricycle Gear, 20-in. (508-mm) spacing, 267 sq in. (1722 cm^2) in area for each wheel.
		3 = Twin Assembly Tricycle Gear, 37-in. (940-mm) spacing, 267 sq in. (1722 cm^2) contact area for each wheel.
		4 = Single Tandem Assembly Tricycle Gear, 60-in. (1524-mm) spacing, 400 sq in. (2580 cm^2) contact area for each wheel.
		5 = Twin Tandem Assembly Tricycle Gear, 31 X 63 in. (787 X 1600 mm) spacing, 267 sq in. (1722 cm^2) contact area for each wheel.
		6 = Twin Assembly Bicycle Gear, 37-in. (940-mm) spacing, 267 sq in. (1722 cm^2) contact area for each wheel.
		7 = Twin Assembly Bicycle Gear, 37- to 62-in. (940- to 1574-mm) spacing, 267 sq in. (1722 cm^2) contact area for each wheel.
		8 = Road Load.
14-15	Traffic Area Code	A single, right-justified, alphanumeric character. (For airfields the traffic area [A through E] and for roads, the design index [1 through 10], with 0 representing design index of 10).
16		Blank.
17-21	Design Freezing Index	Design Freezing Index entered right-justified (in degree days).*
22-24	Total Depth of Frost Penetration	Total Depth of Frost Penetration entered right-justified (in inches).*
25-30		Blank.
31	Minor	This field is used to indicate whether the pavement is of minor classification. See TM 5-818-2, p 6, Table 2. Code is: X = Minor Classification Blank = Not Minor Classification
32	Frost Group	Enter a single-digit Frost Group code in the range of 1 to 4 to describe the engineer's judgment of the subgrade composition with respect to frost design conditions. See TM 5-818-2 for definitions. 1 = F1

*The user must use either Design Freezing *or* Total Depth (not both).

Card Columns	Variable	Description
		2 = F2
		3 = F3
		4 = F4
33-34	Moisture	Enter the percentage of water content of the subgrade material (right-justified). The following moisture content ranges must be used for the respective dry weights:

γd(pcf)	m/c(%)
100	5-20
101-115	5-15
116-134	5-7
135	2-7
136-150	2-5

Card Columns	Variable	Description
35-39	Horizontal Variability	Enter a single-digit numerical code in the range of 1 to 4 to indicate Horizontal Variability. Codes are:
		1 = Uniform
		2 = Slightly Variable
		3 = Variable
		4 = Extremely Variable
41-42	Moisture Content	Enter the percentage of water content of the Base Course Material (right-justified).
43-45	Dry Unit Weight	Enter the Dry Unit Weight of the Base Course Material. Value must be in the range of 100 to 150 pcf (pounds per cubic foot) (1602 to 2403 kg/m^3). See relationship given in description of moisture variable.
46-47		Blank.
48-80	Comments	Enter any comments which will appear on the report.

Earthwork

Fixed format data cards are required if the PAVEMENT or the PAVEMENT.PLUS.APPROACH options are called for the variable EARTHWORK. Figure B6 illustrates the 11 card types used. The contents of each card are defined below.

Card Type	Card Columns	Description
A	1-2	TL–(Terrain Line) Identifies heading for end points of survey base line.
	3-10	Blank.
	11-20	North-south coordinate of base line starting point.
	21-30	East-west coordinate of base line starting point.
	31-40	North-south coordinate of base line end point.
	41-50	East-west coordinate of base line end point.
B	1-2	TD–(Terrain Data)* Identifying heading for the coordinates and elevations of original ground cross section. Limited to 100 cross sections with 20 points per cross section.
	3-10	Blank.
	11-20	Distance (in feet) along the base line (proceeding up-station) from the origin to the point of the cross section.
	21-30	Transverse distance from the base line to the cross section elevation point–(+) for right and (–) for left of base line.
	31-40	Elevation of the cross section point.
	41-50	Blank.
	51-60	Distance along base line for next cross section point.
	61-70	Transverse distance to next point.
	71-80	Elevation of next point.
C	1-3	TDR–(Terrain Data Read)* Identifying heading for determining cross section elevations directly from the survey data.
	4-10	Blank.
	11-20	Distance along base line to the point of the cross section.
	21-30	Transverse distance to cross section point.
	31-40	Height of the instrument.
	41-50	Rod reading at the point.

*This card is repeated as often as necessitated by the data.

Card Type	*Card Columns*	*Description*
D	1-7	PGLENDS–(Profile Grade Line End Points) Identifying heading for coordinates and elevations of the beginning and end of the pavement center line.
	8-10	Blank.
	11-20	North-south coordinate of the profile grade line starting point.
	21-30	East-west coordinate of the profile grade line starting point.
	31-40	Elevation of the starting point.
	41-50	Blank.
	51-60	North-south coordinate of the profile grade line end point.
	61-70	East-west coordinate of the profile grade line end point.
	71-80	Elevation of the end point.
E	1-6	PGLBRK–(Profile Grade Line Break Points)* Identifying heading for the distance to and elevation of break points (i.e., changes in slope) in the profile grade line. Limited to nine break points.
	7-10	Blank.
	11-20	Distance from the PGL starting point to the first break point.
	21-30	Elevation of the first break point.
	31-40	Distance to second break point.
	41-50	Elevation of second break point.
	51-60	Distance to third break point from starting point of PGL.
	61-70	Elevation of third break point.
	71-80	Blank.
F	1-3	TMP–(Template) Identifies heading for defining the width of earthwork used in calculations.
	4-10	Blank.
	11-20	Distance from PGL to left edge of section entered as a negative number.

*These data may be repeated up to three cards.

Card Type	Card Columns	Description
	21-23	0.0–a constant.
	24-30	Blank.
	31-40	Distance from PGL to right edge of section entered as a positive number.
	41-43	0.0–a constant.
	44-80	Blank.
G	1-4	ELIM–(Elevation Limits) Identifies heading which establishes limits on highest and lowest elevations to be considered in the calculations.
	5-10	Blank.
	11-20	Upper elevation limit established by specifying increment (in feet) above highest elevation point in the terrain data.
	21-30	Lower elevation limit established by specifying increment (in feet) below the lowest elevation point in the terrain data.
	31-80	Blank.
H	1-4	COST–Identifies card containing cost of cut and fill.
	5-10	Blank.
	11-20	Cost of excavation in $/cubic yard.
	21-30	Cost of fill in-place in $/cubic yard.
I	1-5	APRUN–(Approach Zone)* Identifies heading for the approach zone plan geometry.
	6-10	Blank.
	11	Approach zone number–1 through 9.
	12-20	Blank.
	21-30	Length of prism for volume calculations in the approach zone.
	31-40	Width of approach zone.
	41-80	Blank.

*This card may be repeated as necessary to account for changes in the glide slope or width of approach. Up to nine zones may be used.

Card Type	*Card Columns*	*Description*
J	1-5	APEND (Approach Zone End Points)* Identifies heading for coordinates and elevations of the approach zone end points.
	6-10	Blank.
	11	Approach zone number (1 to 9) coinciding with number on card type H.
	12-20	Blank.
	21-30	North-south coordinates of the beginning of the approach zone section.
	31-40	East-west coordinates of the beginning of the approach zone section.
	41-50	Elevation of the beginning point.
	51-60	North-south coordinate of the end of the approach zone section.
	61-70	East-west coordinate of the end of the approach zone section.
	71-80	Elevation of the end point.
K	1-3	RUN--(Run Card) Identifies heading for commands regarding options. Must be last card of the Earthwork fixed-format data.
	4-10	Blank.
	11-20	Length (in feet) of prism to be used in the earthwork volume calculations.
	21	Extrapolation option code. When earthwork calculations exceed the furthest point in the original ground cross section, the program can be requested to extend the cross section by an extrapolation of the final two points in the section. Options: O–No extrapolation allowed. E–Extrapolation with message indicating where extrapolation occurred. X–Extrapolation without message.
	22	Mass diagram option code. Options: P–A plot of the mass diagram will be placed on tape OUT5. Block–No mass diagram plot is calculated.

*This card may be repeated as necessary to account for changes in the glide slope or width approach. Up to nine zones may be used.

Card Type	*Card Columns*	*Description*
	23-30	Blank.
	31-40	Distance from the starting point of PGL at which earthwork computations begin.
	41-50	Distance from the starting point of PGL at which earthwork computations end. Note: The length of the earthwork calculations must be less than or equal to the length of PGL.
	51-80	Blank.

Drainage

Figure B7 depicts the fixed-format input card which is required if the YES option of the variable DRAINAGE is chosen. Each item on the card is defined below. The geometry of the section required as input is shown in Figure B8.

Card Columns	*Description*
1-6	DRAINAGE--Identifies heading used to signify drainage data card.
7-10	Blank.
11-13	Depth to ground water table from the top of pavement (in inches). (Right-justified integer.) If larger than 999 in. (2515 mm), enter 999.
14-16	Blank.
17-20	The effective porosity of the base course material expressed as a decimal.
21-25	The drainage length (see Figure B8) expressed to the nearest tenth of a foot.
26-33	The permeability of the base course (in feet/min.). This value is expressed in E notation (e.g., 2.2×10^{-5} = 2.2 E-5).
34-38	Vertical height of cross slope (see Figure B8) expressed as a decimal in inches.
39-43	Longitudinal length of drainage line (right-justified integer). The default value is the length of section from the free-form input.
44-48	The unit cost for trench excavation (in \$/cu yd) which may have two decimal places.
49-53	The in-place unit cost for filter material (\$/cu yd) which may have two decimal places.

Card Columns	*Description*
54-58	The in-place unit cost of underdrain pipe ($/lineal foot) which may have two decimal places.
59-63	The longitudinal slope of the pipe expressed as a four-place decimal. The minimum slope, which is also the default value, is 0.0015.
64-68	The Manning Roughness Factor expressed as a three-place decimal. Usual values are .013 for a smooth pipe and .024 for a corrugated pipe.
69	The number of sides to which the pipe outlets drain. 0–Outlets not considered. 1–All outlets drain to one side. 2–Outlets drain to both sides.
70-72	The average length of outlet pipe (in feet) as a right-justified integer. The default is 25 ft (7.5 m).
73-80	Blank.

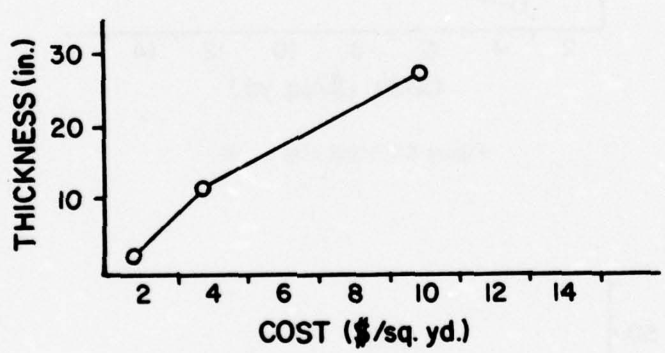


Figure B1. Construction material cost curve.

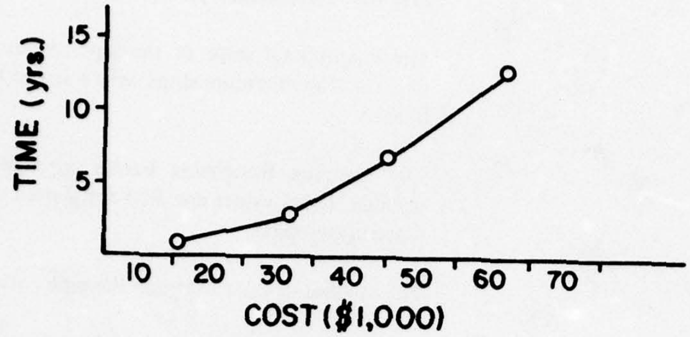


Figure B2. Vehicle maintenance cost curve.

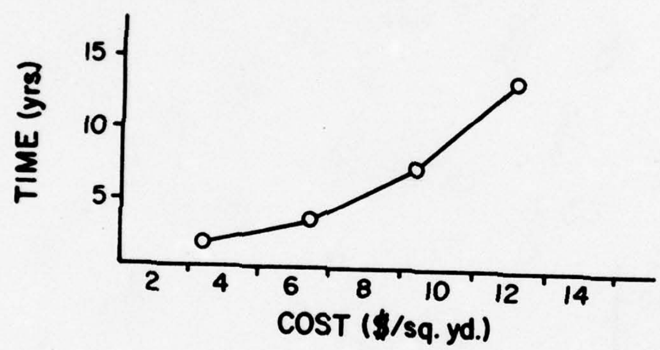


Figure B3. M&R cost curve.

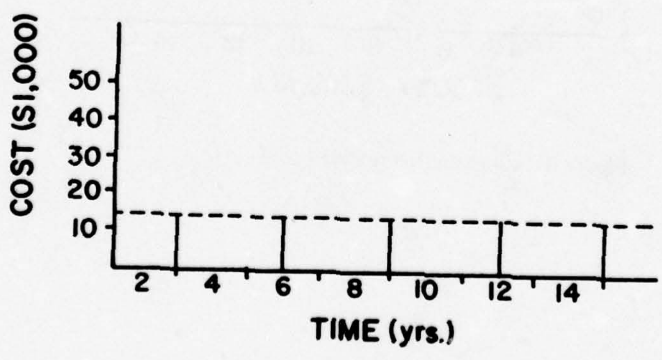


Figure B4. M&R periodic costs.

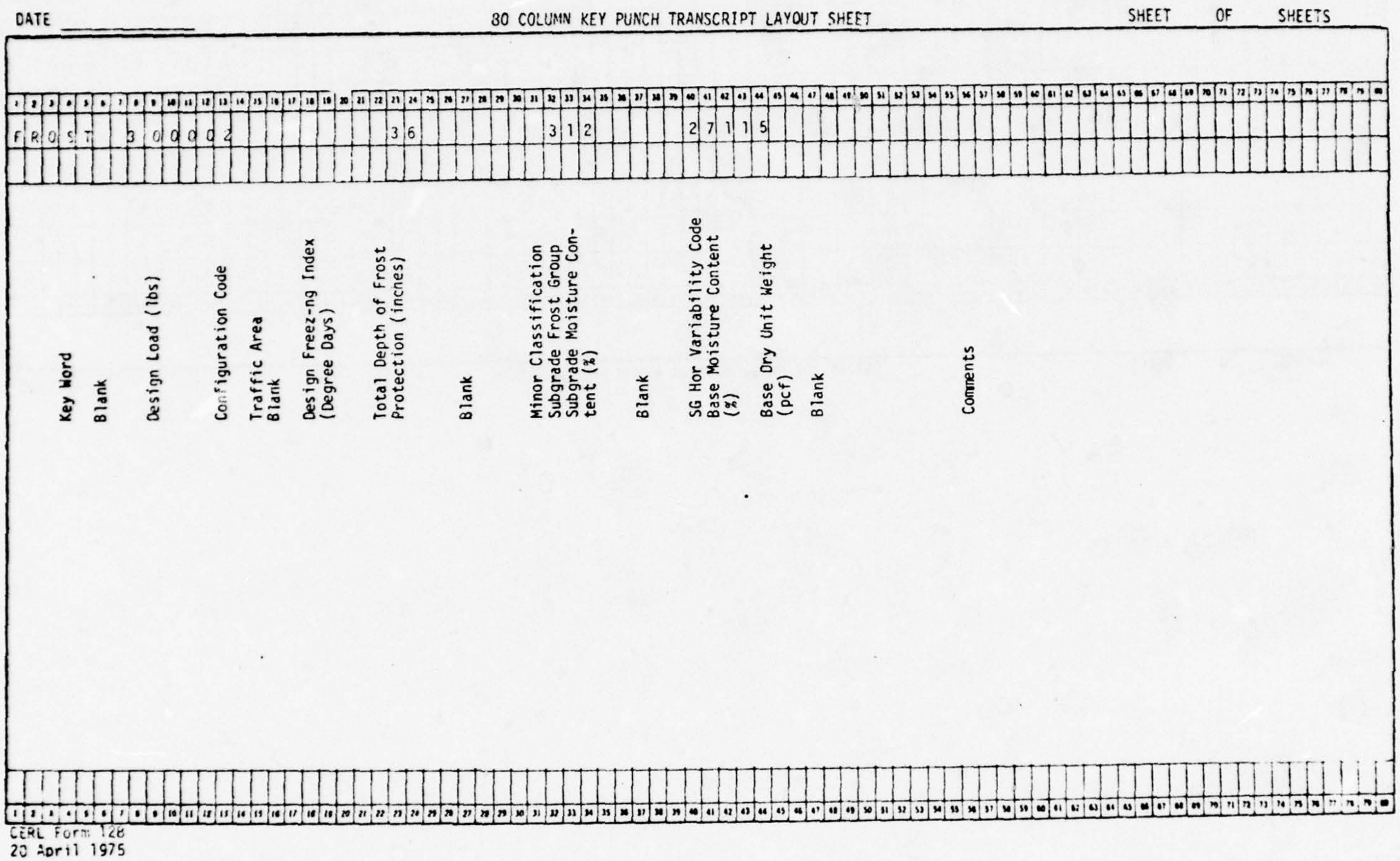


Figure B5. Typical data for fixed format FROST card.

DATE ______ 80 COLUMN KEY PUNCH TRANSCRIPT LAYOUT SHEET SHEET OF SHEETS

Cols 1–10	Cols 11–20	Cols 21–30	Cols 31–40	Cols 41–50	Cols 51–60	Cols 61–70	Cols 71–80
TL	4430	1120	7455.0	5320.			
TD	600.	-20.	434.6		600.	-50.	455.2
TDR	350.	55.0	336.44	4.45			
PGLENDS	13000.	6400.	202.		13200.	8500.	208.
PGLBRK	1000.	203.	2000.	203.5	3000.	205.0	
TMP	-50.0	0.0	50.0	0.0			
ELIM	2.0	5.0					
COST	1.66	2.21					
APRUN	2	30.	450.				
APEND	2	3600.	400.	520.6	3600.	11400.	534.6
RUN	30.0	EP	0.0	1000.			

Figure B6. Typical examples of 11 types of fixed format input cards used with EARTHWORK.

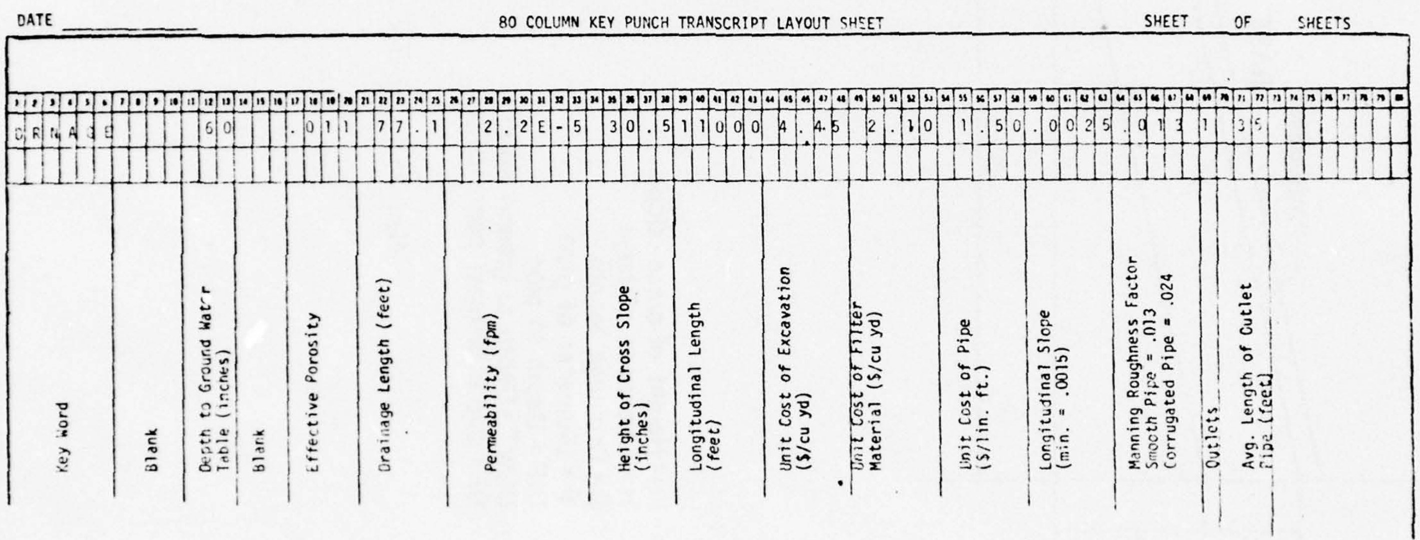
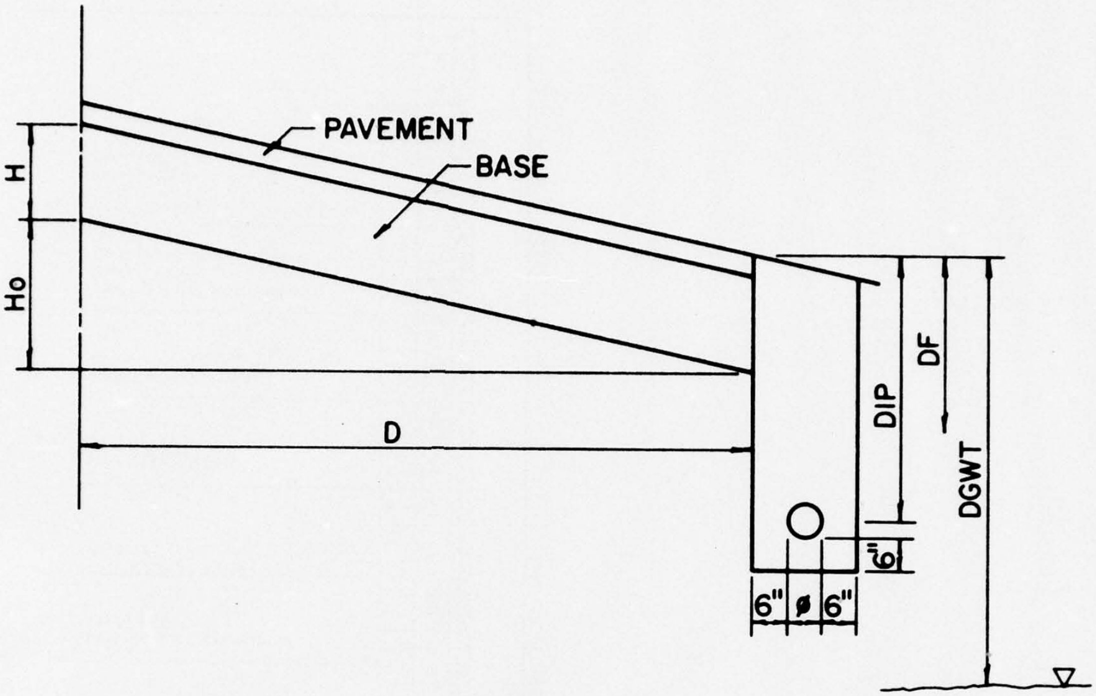


Figure B7. Typical data for fixed format DRAINAGE card.



KEY: Ho = Height of cross-slope
H = Thickness of base
D = Drainage length
ø = Diameter of pipe
DIP = Depth to pipe
DGWT = Depth to ground water
DF = Depth of frost penetration

Figure B8. Typical underdrainage cross section.

APPENDIX C: VEHICLE DATA BANK

Pavement design requires knowledge of the characteristics of vehicular traffic anticipated to use the facility. Most of the traffic data required in the LIFE2 analysis is innate to the type of vehicle for which the facility is designed and therefore is not subject to change. Thus, to decrease the user input requirements, vehicle characteristic information can be compiled in a data bank. This appendix describes the format and contents of the vehicle data bank used by the LIFE2 program. This data bank contains the necessary traffic information (except for volumes) for considering roadway pavements as well as airfield pavements. Procedures for updating information in the data bank and for adding other vehicles is provided in Volume II.

Data Format

Thirteen cards are necessary to code the information for each type of vehicle. The first eight cards pertain to rigid pavement design, while the last five pertain to flexible pavement design. The data bank uses a fixed format.

Items contained in each card and the required input format are described on pp 56, 57.*

Vehicle Data Bank Contents

The vehicle data bank presently used with the LIFE2 program contains information about 33 vehicles. This includes information for 32 aircraft and one set of data for road design. Vehicles contained in the data bank are:

Road-Load		
Heavy-Load	C-124C	
Medium-Load	C-130E	KC-97G
Light-Load	C-135A	KC-135A
Special-Load	C-140A	Boeing-707
B-47E	C-141A	Boeing-727
B-52	F-4E	Boeing-747
B-57B	F-104G	DC-8-10
C-7A	F-11A	DC-9-30
C-8A	A-7D	DC-10-10
C-54G	A-26A	Convair-880
C-123K	HC-130H	C-5A

Figure C3 is a computer printout of the vehicle data bank contents. The information, as shown, conforms to the format given in the *Data Format* section.

Use of the Data Bank

The vehicle data bank used with the LIFE2 program can be a multiple file (as presented in the *Vehicle Data Bank Contents* section) or a retained singular file for an individual project.

The multiple file would contain data about vehicles which could be required as design traffic. This file can be retained on a computer card deck, a magnetic tape, or a computer disc file. The entire file would then be called by LIFE2 and searched for the required vehicle types.

The singular file would be developed for a specific project. It would contain only the vehicles being considered as design traffic for a specific problem. The data (coded as in the *Data Format* section) should be placed on computer cards and input after the LIFE2 control cards.

*Although the descriptions sometimes use aircraft terminology, they are applicable to roadway vehicles. Data for C-5A aircraft, if used, should always appear as the last vehicle in the data bank, because of its unsymmetrical landing gear configuration. The complete vehicle data bank must be followed by a card having a dollar sign ($) in column 1.

Card Type	Item	Card Column	Input Format	Description
A	1	1	A1	Dollar sign ($) required to signify beginning of data for a particular vehicle.
	2	2-13	A12	VEHICLE.TYPE
	3	31-40	A9	RIGID
		41-49		Blank
	4	50-59	F10.5	Pass/coverage ratio for channelized traffic.
	5	60-69	F10.5	Pass/coverage ratio for unchannelized traffic.
	6	77-78	I2	Designates type of gear: 01 for tricycle; 02 for bicycle. Specify 01 for road design.
	7	79-80	I2	Designates wheel type: 02 for twin-tandem; 00 for all others (including Road Load).
B	1	1-50	A50	VEHICLE.TYPE
C	1	1-10	F10.0	Weight/gear for airfields and weight/axle for roads (lb).
	2	20-30	F10.0	Wheel contact area (sq in.).
	3	31-40	F5.0	Number of gammas (set equal to 1; i.e., only one gear location will be considered in LIFE2–see Figure C1).
D	1	1-10	F10.0	a } Gear spacing parameters–see Figure C2.
	2	11-20	F10.0	b } Gear spacing parameters–see Figure C2.
	3	21-30	F10.0	c } Gear spacing parameters–see Figure C2.
	4	31-40	F10.0	d } Gear spacing parameters–see Figure C2.
	5	41-50	F10.0	Number of deltas (set equal to 1; i.e., only one gear location will be considered in LIFE2–see Figure C1).
	6	51-60	F10.0	Number of σ-G pairs; i.e., extra pairs of pavement stress and the correlative gear load to be considered (set equal to 0).
E	1	1-10	F10.0	n_a } Gear spacing parameters–see Figure C2.
	2	11-20	F10.0	n_b } Gear spacing parameters–see Figure C2.
	3	21-30	F10.0	n_c } Gear spacing parameters–see Figure C2.
	4	31-40	F10.0	n_d } Gear spacing parameters–see Figure C2.

Card Type	Item	Card Column	Input Format	Description
	5	41-50	F10.0	ϕ_e The tire print width/tire print length. (Default value is 1.667 if not entered.)
F	1	1-10	F1-10	Beta. This parameter provides control for determining the number of points used to determine the shape of the tire print perimeter. (Set equal to 75.)
G	1	1-10	F10.0	Gamma. A gear location parameter—see Figure C1.
H	1	1-10	F10.0	Delta. A gear location parameter—see Figure C1.
I				Duplicate of card type A, except FLEXIBLE replaces RIGID in columns 31-40.*
J	1-7	1-70	7E10.0	Equivalent single-wheel loads for seven pavement thicknesses.**
K	1-7	1-70	7E10.0	Equivalent single-wheel loads for seven pavement thicknesses.
L	1-6	1-60	6E10.0	Equivalent single-wheel loads for six pavement thicknesses.
M	1	1-10	F10.0	Tire contact area for one wheel (sq in.).
	2	11-20	F10.0	Number of wheels used to compute equivalent single-wheel loads.

*For twin-tandem wheels, the pass-to-coverage ratio for flexible pavements is one-half that of rigid pavements; however, in coding these data, the rigid value is used on both Card A and Card I, and the reduction is performed in the program.

**Card types J, K, and L contain the relationship of ESWL to pavement thickness. The thicknesses used in airfield design are: 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, and 150. For road design, the thicknesses are: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 22, 24, 28, 32, and 36.

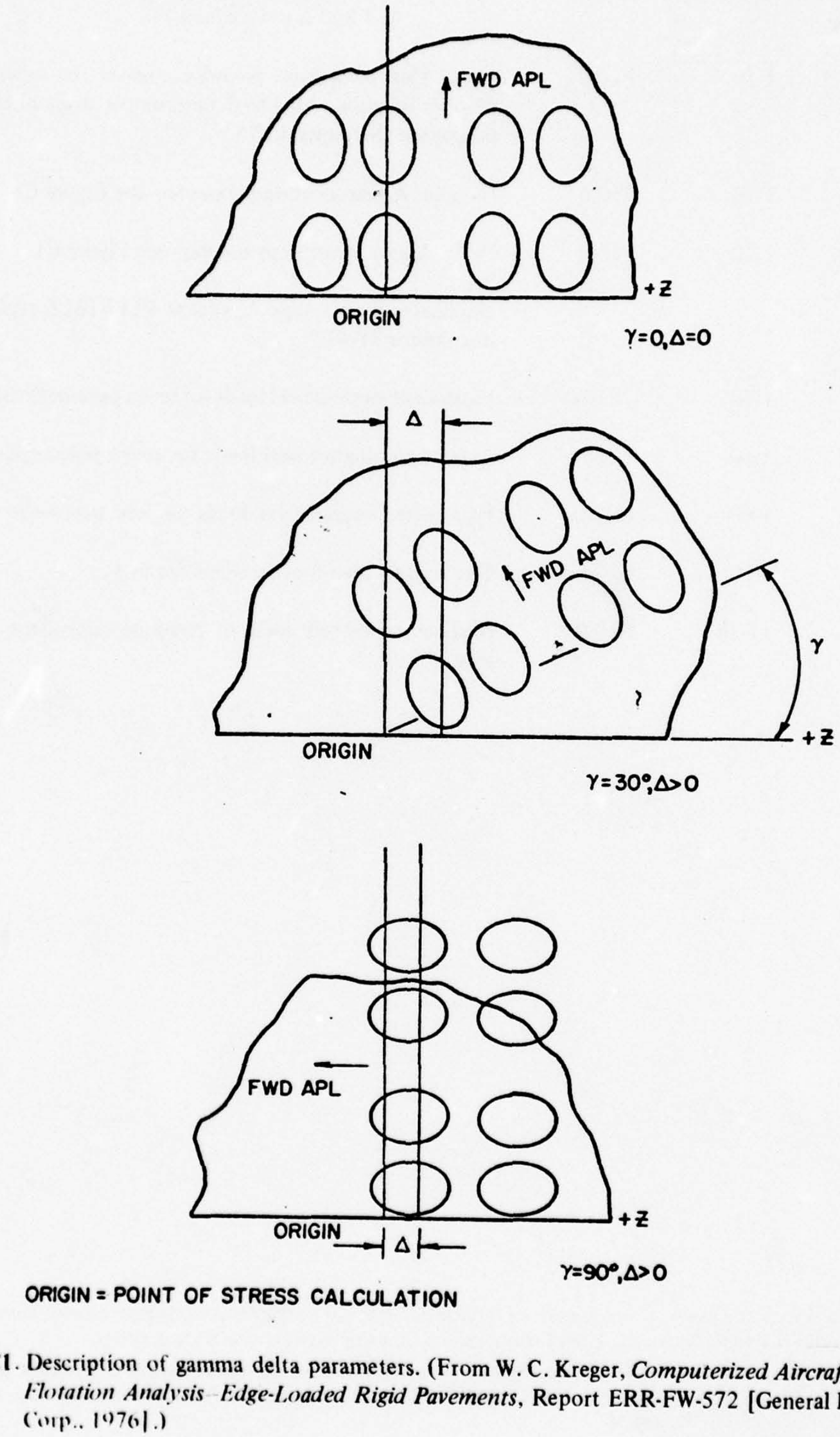


Figure C1. Description of gamma delta parameters. (From W. C. Kreger, *Computerized Aircraft Ground Flotation Analysis–Edge-Loaded Rigid Pavements*, Report ERR-FW-572 [General Dynamics Corp., 1976].)

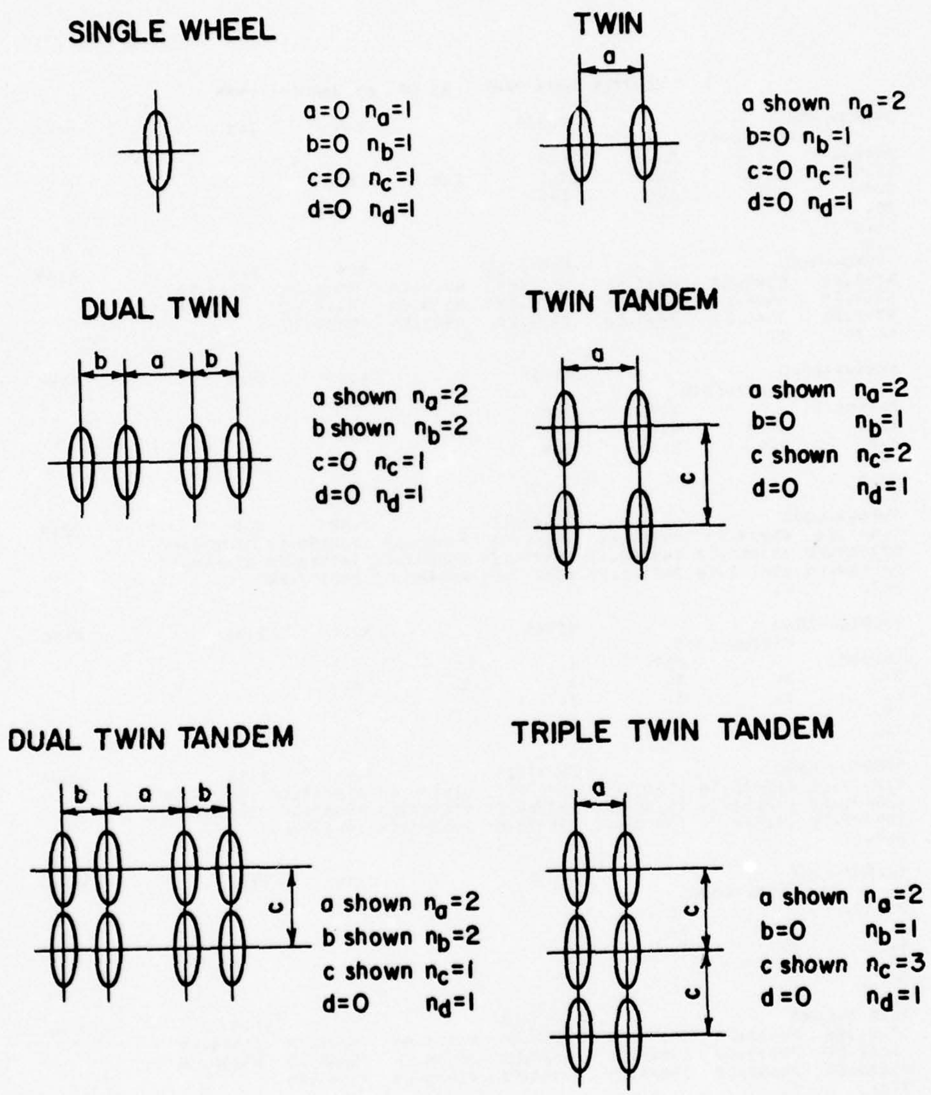


Figure C2. Wheel configuration spacing parameters. (From W. C. Kreger, *Computerized Aircraft Ground Flotation Analysis–Edge-Loaded Rigid Pavements*, Report ERR-FW-572 [General Dynamics Corp., 1967].)

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                    VEHICLE DATA BANK   AS OF  01 JANUARY 1978

$ROAD-LOAD                          RIGID               1.0        1.0                 0100
          ROAD-LOAD
30000.               54.0       1.0
58.5      . 13.5     0.0        0.0        1.0       0.0
2.0       2.0        1.0        1.0
75.
90.0
0.0
$ROAD-LOAD                          FLEXIBLE            1.0        1.0                 0100
5303.E0   5363.E0    5462.E0    5592.E0    5746.E0   5916.E0   6112.E0
6317.E0   6534.E0    6761.E0    7679.E0    8159.E0   8427.E0   8588.E0
8761.E0   8846.E0    8893.E0    8922.E0    8941.E0   8954.E0
64.29     2.

$HEAVY-LOAD                         RIGID               1.68       2.0                 0200
          HEAVY-LOAD
265000.0             267.0      1.0
62.0      37.0       0.0        0.0        1.0       0.0
2.0       2.0        1.0        1.0
75.
90.0
0.0
$HEAVY-LOAD                         FLEXIBLE            1.68       2.0                 0200
94887.E0  95229.E0   95786.E0   96544.E0   97486.E0  104290.E0 113290.E0
123367.E0 133860.E0 145083.E0 165064.E0 182058.E0 197360.E0 211688.E0
225069.E0 236172.E0 245321.E0 259217.E0 268982.E0 272777.E0
267.      4.

$MEDIUM-LOAD                        RIGID               3.14       5.62                0100
          MEDIUM-LOAD
100000.              267.       1.
37.       0.         0.         0.         1.        0.
2.        1.         1.         1.
75.
90.
0.
$MEDIUM-LOAD                        FLEXIBLE            3.14       5.62                0100
112405.E0 112638.E0 113019.E0 113538.E0 114185.E0 118887.E0 125143.E0
132721.E0 142152.E0 151397.E0 167364.E0 176988.E0 183024.E0 186997.E0
189727.E0 191674.E0 193105.E0 195022.E0 196207.E0 196636.E0
267.      2.

$LIGHT-LOAD                         RIGID               8.58       17.0                0100
          LIGHT-LOAD
25000.               100.       1.
0.        0.         0.         0.         1.        0.
1.        1.         1.         1.
75.
90.
0.
$LIGHT-LOAD                         FLEXIBLE            8.58       17.0                0100
25000.E0  25000.E0   25000.E0   25000.E0   25000.E0  25000.E0  25000.E0
25000.E0  25000.E0   25000.E0   25000.E0   25000.E0  25000.E0  25000.E0
25000.E0  25000.E0   25000.E0   25000.E0   25000.E0  25000.E0
100.      1.

$SPECIAL-LOAD                       RIGID               4.92       9.80                0100
          SPECIAL-LOAD
53000.               241.       1.
```

Figure C3. Vehicle data bank contents–September 1977.

```
0.        0.        0.        0.        1.
1.        1.        1.        1.
75.
90.
0.
$SPECIAL-LOAD                 FLEXIBLE            4.92      9.80                0100
53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0
53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0
53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0
241.      1.

$B-47E                        RIGID               1.57      2.81                0200
          B-47E
129000.             280.      1.
37.       0.        0.        0.        1.        0.
2.        1.        1.        1.
75.
90.
.0
$B-47E                        FLEXIBLE            1.57      2.81                0200
36361.E0  36435.E0  36556.E0  36720.E0  36925.E0  38424.E0  40429.E0
43023.E0  45889.E0  48889.E0  53940.E0  57006.E0  58950.E0  60239.E0
61130.E0  61767.E0  62238.E0  62869.E0  63261.E0  63403.E0
280.      2.

$B-52                         RIGID               1.68      2.0                 0200
          B-52
265000.0            267.0     1.0
62.0      37.0      0.0       0.0       1.0       0.0
2.0       2.0       1.0       1.0
75.
90.0
0.0
$B-52                         FLEXIBLE            1.68      2.0                 0200
94887.E0  95228.E0  95786.E0  96544.E0  97486.E0  104290.E0 113290.E0
123367.E0 133860.E0 145083.E0 165064.E0 182058.E0 197360.E0 211688.E0
225069.E0 236172.E0 245321.E0 259217.E0 268982.E0 272777.E0
267.      4.

$B-57B                        RIGID               6.47      12.83               0100
          B-57B
27500.              182.      1.
0.        0.        0.        0.        1.
1.        1.        1.        1.
75.
90.
0.
$B-57B                        FLEXIBLE            6.47      12.83               0100
27500.E0  27500.E0  27500.E0  27500.E0  27500.E0  27500.E0  27500.E0
27500.E0  27500.E0  27500.E0  27500.E0  27500.E0  27500.E0  27500.E0
27500.E0  27500.E0  27500.E0  27500.E0  27500.E0  27500.E0
182.      1.

$C-7A                         RIGID               2.78      5.42                0100
          C-7A
12500.              152.      1.
20.       0.        0.        0.        1.
2.        1.        1.        1.
75.
90.
0.
$C-7A                         FLEXIBLE            2.78      5.42                0100
7154.E0   7191.E0   7251.E0   7331.E0   7429.E0   8200.E0   9191.E0
10077.E0   10648.E0   11073.E0   11459.E0   11689.E0   11817.E0   11899.E0
11954.E0  11992.E0  12020.E0  12056.E0  12078.E0  12086.E0
152.      2.
```

Figure C3 (cont'd).

```
$C-8A                               RIGID              3.16      6.10               0100
         C-8A
17500.              218.      1.
23.       0.        0.        0.        1.
2.        1.        1.        1.
75.
90.
0.
$C-8A                               FLEXIBLE           3.16      6.10               0100
9822.E0   9860.E0   9921.E0   10003.E0  10106.E0  10945.E0  12051.E0
13237.E0  14094.E0  14663.E0  15392.E0  155775.E0 16000.E0  16143.E0
16238.E0  16305.E0  16354.E0  16418.E0  16457.E0  16471.E0
218.      2.

$C-54G                              RIGID              3.05      5.75               0100
         C-54G
38500.              250.      1.
29.       0.        0.        0.        1.
2.        1.        1.        1.
75.
90.
0.
$C-54G                              FLEXIBLE           3.05      5.75               0100
22244.E0  22326.E0  22427.E0  22564.E0  22734.E0  23965.E0  25887.E0
27997.E0  30261.E0  32045.E0  34325.E0  35623.E0  36413.E0  36924.E0
37270.E0  37515.E0  37694.E0  37932.E0  38079.E0  38131.E0
250.      2.

$C-123K                             RIGID              5.23      10.38              0100
         C-123K
25300.              275.      1.
0.        0.        0.        0.        1.
1.        1.        1.        1.
75.
90.
0.
$C-123K                             FLEXIBLE           5.23      10.38              0100
25300.E0  25300.E0  25300.E0  25300.E0  25300.E0  25300.E0  25300.E0
25300.E0  25300.E0  25300.E0  25300.E0  25300.E0  25300.E0  25300.E0
25300.E0  25300.E0  25300.E0  25300.E0  25300.E0  25300.E0
275.      1.

$C-124C                             RIGID              2.19      3.77               0100
         C-124C
50500.              640.      1.
44.       0.        0.        0.        1.
2.        1.        1.        1.
75.
90.
0.
$C-124C                             FLEXIBLE           2.19      3.77               0100
58302.E0  58360.E0  58459.E0  58599.E0  58784.E0  60373.E0  62846.E0
65792.E0  69176.E0  72843.E0  79795.E0  84732.E0  88218.E0  90717.E0
92543.E0  93905.E0  94942.E0  96381.E0  97301.E0  97640.E0
640.      2.

$C-130E                             RIGID              4.36      8.72               0100
         C-130E
83700.              440.      1.
0.        0.        60.       0.        1.        0.
1.        1.        2.        1.
75.
90.
0.
$C-130E                             FLEXIBLE           4.36      8.72               0100
```

Figure C3 (cont'd).

```
45921.E0  45967.E0  46042.E0  46146.E0  46276.E0  47259.E0  49637.E0
50257.E0  52027.E0  54086.E0  58576.E0  63413.E0  67974.E0  71282.E0
73693.E0  75486.E0  76847.E0  78728.E0  79927.E0  80368.E0
440.      2.

$C-135A                       RIGID               3.36      6.06               0100
          C-135A
131900.             230.      1.
36.       0.        60.       0.        1.
2.        1.        2.        1.
75.
90.
0.
$C-135A                       FLEXIBLE            3.36      6.06               0100
131900.E0 131900.E0 131900.E0 131900.E0 131900.E0 131900.E0 131900.E0
131900.E0 131900.E0 131900.E0 131900.E0 131900.E0 131900.E0 131900.E0
131900.E0 131900.E0 131900.E0 131900.E0 131900.E0 131900.E0
230.      1.

$C-140A                       RIGID               6.85      12.89              0100
          C-140A
17500.              43.       1.
14.5      0.        0.        0.        1.
2.        1.        1.        1.
75.
90.
0.
$C-140A                       FLEXIBLE            6.85      12.89              0100
9995.E0   10119.E0  10307.E0  10543.E0  10814.E0  12657.E0  14585.E0
15683.E0  16299.E0  16670.E0  17069.E0  17265.E0  17375.E0  17442.E0
17486.E0  17517.E0  17539.E0  17568.E0  17585.E0  17591.E0
43.       2.

$C-141A                       RIGID               3.44      6.38               0102
          C-141A
14900.              208.      1.
32.5      0.        48.       0.        1.        0.
2.        1.        2.        1.
75.
90.
0.
$C-141A                       FLEXIBLE            3.44      6.38               0102
47977.E0  48222.E0  48620.E0  49153.E0  49821.E0  54507.E0  60850.E0
68411.E0  77296.E0  86174.E0  101875.E0 113752.E0 122058.E0 127953.E0
132227.E0 135395.E0 137793.E0 141100.E0 143202.E0 143974.E0
208.      4.

$F-4E                         RIGID               8.58      17.                0100
          F-4E
27000.              102.      1.
0.        0.        0.        0.        1.        0.
1.        1.        1.        1.
75.
90.
0.
$F-4E                         FLEXIBLE            8.58      17.                0100
27000.E0  27000.E0  27000.E0  27000.E0  27000.E0  27000.E0  27000.E0
27000.E0  27000.E0  27000.E0  27000.E0  27000.E0  27000.E0  27000.E0
27000.E0  27000.E0  27000.E0  27000.E0  27000.E0  27000.E0
102.      1.

$F-104G                       RIGID               11.10     22.0               0100
          F-104G
13500.              63.       1.
0.        0.        0.        0.        1.
1.        1.        1.        1.
```

Figure C3 (cont'd).

```
75.
90.
0.
$F-104G                                FLEXIBLE               11.10      22.0                 0100
13500.E0  13500.E0  13500.E0  13500.E0  13500.E0  13500.E0  13500.E0
13500.E0  13500.E0  13500.E0  13500.E0  13500.E0  13500.E0  13500.E0
13500.E0  13500.E0  13500.E0  13500.E0
63.       1.

$F-111A                                RIGID                  4.92       9.80                 0100
          F-111A
53000.              241.      1.
0.        0.        0.        0.        1.
1.        1.        1.        1.
75.
90.
0.
$F-111A                                FLEXIBLE               4.92       9.80                 0100
53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0
53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0
53000.E0  53000.E0  53000.E0  53000.E0  53000.E0  53000.E0
241.      1.

$A-7D                                  RIGID                  11.10      22.0                 0100
          A-7D
17500.              62.       1.
0.        0.        0.        0.        1.
1.        1.        1.        1.
75.
90.
0.
$A-7D                                  FLEXIBLE               11.10      22.0                 0100
17500.E0  17500.E0  17500.E0  17500.E0  17500.E0  17500.E0  17500.E0
17500.E0  17500.E0  17500.E0  17500.E0  17500.E0  17500.E0  17500.E0
17500.E0  17500.E0  17500.E0  17500.E0  17500.E0  17500.E0
62.       1.

$A-26A                                 RIGID                  5.37       10.70                0100
          A-26A
18500.              262.      1.
0.        0.        0.        0.        1.
1.        1.        1.        1.
75.
90.
0.
$A-26A                                 FLEXIBLE               5.37       10.70                0100
18500.E0  18500.E0  18500.E0  18500.E0  18500.E0  18500.E0  18500.E0
18500.E0  18500.E0  18500.E0  18500.E0  18500.E0  18500.E0  18500.E0
18500.E0  18500.E0  18500.E0  18500.E0  18500.E0  18500.E0
262.      1.

$HC-130H                               RIGID                  4.58       9.14                 0100
          HC-130H
83700.              364.      1.
0.        0.        50.       0.        1.
1.        1.        2.        1.
75.
90.
0.
$HC-130H                               FLEXIBLE               4.58       9.14                 0100
83700.E0  83700.E0  83700.E0  83700.E0  83700.E0  83700.E0  83700.E0
83700.E0  83700.E0  83700.E0  83700.E0  83700.E0  83700.E0  83700.E0
83700.E0  83700.E0  83700.E0  83700.E0  83700.E0  83700.E0
364.      1.

$KC-97G                                RIGID                  3.41       6.11                 0100
```

Figure C3 (cont'd).

```
          KC-97G
88800.                247.      1.
37.5      0.          0.        0.        1.
2.        1.          1.        1.
75.
90.
0.
$KC-97G                         FLEXIBLE            3.41      6.11                0100
49760.E0  49887.E0  50062.E0  50339.E0  50595.E0  52725.E0  55568.E0
59261.E0  63099.E0  67208.E0  73945.E0  78154.E0  80879.E0  82711.E0
83991.E0  84915.E0  85600.E0  86525.E0  87102.E0  87312.E0
247.      2.

$KC-135A                        RIGID               3.36      6.06                0102
          KC-135A
142000.               230.      1.
36.       0.          60.       0.        1.        0.
2.        1.          2.        1.
75.
0.
-1.
$KC-135A                        FLEXIBLE            3.36      6.06                0102
44339.E0  44529.E0  44838.E0  45256.E0  45773.E0  49435.E0  54189.E0
60129.E0  66660.E0  73772.E0  86740.E0  98094.E0  107520.E0 114452.E0
119626.E0 123526.E0 126520.E0 130708.E0 133406.E0 134403.E0
230.      4.

$BOEING-707                     RIGID               3.24      6.0                 0102
          BOEING-707
120564.0  177.3                 1.0
 34.0      0.0        56.0      0.0       1.0       0.0
2.0       2.0         2.0       1.0
75.
90.
0.0
$BOEING-707                     FLEXIBLE            3.24      6.0                 0102
177.3     4.
37177.E0  37363.E0  37662.E0  38064.E0  38556.E0  41963.E0  46283.E0
51494.E0  57209.E0  63809.E0  75645.E0  85872.E0  93693.E0  99347.E0
103511.E0 106628.E0 109005.E0 112305.E0 114416.E0 115194.E0
177.3     4.

$BOEING-727                     RIGID               3.25      6.00                0100
     BOEING-727
80000.                237.      1.
34.       0.          0.        0.        1.
       2.         1.        1.        1.
75.
90.
0.
$BOEING-727                     FLEXIBLE            3.25      6.00                0100
45029.E0  45136.E0  45312.E0  45551.E0  45847.E0  47979.E0  50970.E0
54561.E0  58425.E0  62537.E0  68447.E0  71891.E0  74016.E0  75399.E0
76343.E0  77012.E0  77503.E0  78157.E0  78561.E0  78706.E0
237.      2.

$BOEING-747                     RIGID               3.70      5.16                0102
          BOEING-747
338000.               207.5     1.0
106.0     44.0        58.0      0.0       1.0       0.0
2.0       2.0         2.0       1.0
75.
90.
0.0
$BOEING-747                     FLEXIBLE            3.70      5.16                0102
63166.E0  63632.E0  64388.E0  65407.E0  66657.E0  75379.E0  86460.E0
```

Figure C3 (cont'd).

```
98698.E0  111930.E0 126165.E0 155234.E0 183357.E0 209052.E0 232337.E0
253767.E0 273810.E0 292896.E0 328316.E0 360004.E0 374702.E0
207.5      16.

$DC-8-10                        RIGID              3.14      5.92              0102
      DC-8-10
132150.              228.       1.
30.        0.        55.        0.
2.         1.        2.         1.
75.
90.
0.
$DC-8-10                        FLEXIBLE           3.14      5.92              0102
43767.E0  43978.E0  44321.E0  44747.E0  45362.E0  49464.E0  54999.E0
61880.E0  69530.E0  76692.E0  88887.E0  99254.E0  106903.E0 112566.E0
116817.E0 120056.E0 122563.E0 126103.E0 128408.E0 129265.E0
228.       4.

$DC-9-30                        RIGID              3.58      6.90              0100
      DC-9-30
51300.               165.       1.
26.        0.        0.         0.         1.
2.         1.        1.         1.
75.
90.
0.
$DC-9-30                        FLEXIBLE           3.58      6.90              0100
30655.E0  30770.E0  30956.E0  31206.E0  31513.E0  33740.E0  36734.E0
40205.E0  43566.E0  45947.E0  48836.E0  50406.E0  51335.E0  51924.E0
52319.E0  52596.E0  52797.E0  53063.E0  53225.E0  53283.E0
165.       2.

$DC-10-10                       RIGID              3.64      5.80              0102
      DC-10-10
204250.              295.       1.
54.        0.        64.        0.    .    1.
2.         1.        2.         1.
75.
90.
0.
$DC-10-10                       FLEXIBLE           3.64      5.80              0102
62524.E0  62709.E0  63011.E0  63423.E0  63935.E0  67660.E0  72636.E0
78317.E0  84675.E0  92289.E0  104492.E0 126379.E0 141415.E0 153054.E0
162050.E0 169046.E0 174540.E0 182412.E0 187605.E0 189549.E0
295.       4.

$CONVAIR-880                    RIGID              3.68      7.16              0100
      CONVAIR-880
87400.               122.       1.
21.5       0.        45.        0.         1.
2.         1.        2.         1.
75.
90.
0.
$CONVAIR-880                    FLEXIBLE           3.68      7.16              0100
28142.E0  28385.E0  28773.E0  29289.E0  29910.E0  34038.E0  39873.E0
45877.E0  51408.E0  56064.E0  64606.E0  70984.E0  75206.E0  78084.E0
80110.E0  81579.E0  82673.E0  84156.E0  85083.E0  85420.E0
122.       4.

$C-5A                           RIGID              1.62      2.18              0102
      C-5A
181200.              285.       1.
 0.        0.        0.         0.         1.        0.
 0.        0.        0.         0.         0.        6.
60.5  32.5  26.5  32.5  -26.5 32.5  -60.5 32.5  24.0  -32.5
-24.0 -32.5
75.        0.        0.         0.         0.
90.
0.
$C-5A                           FLEXIBLE           1.62   .  2.18              0102
42859.E0  43074.E0  43426.E0  43905.E0  44501.E0  48834.E0  54594.E0
61062.E0  67823.E0  74623.E0  88384.E0  101770.E0 114416.E0 124892.E0
133424.E0 140424.E0 146129.E0 154662.E0 160557.E0 162824.E0
285.       6.
$
```

Figure C3 (cont'd).

APPENDIX D:
LIFE2 INPUT WORKSHEET

A LIFE2 input worksheet has been developed to facilitate program input preparation. This worksheet appears on the following pages and has been designed for local reproduction. It contains a listing of all program variables arranged categorically as per Appendix B. Instructions to the designer and to the keypuncher are also provided on the worksheet.

LIFE2 PROGRAM INPUT

Project:	Section:
Date:	Trial No.:
Designer:	

Instructions

Designer: Fill in input value or option desired for each variable to be used in the analysis in accordance with the LIFE2 User Manual. Strike out variables which are not required or for which the default value is desired.

Keypuncher: This data is in free format. Columns 73-80 are not to be used. Do not leave more than 9 blanks at the beginning of a card or between any entries on a card. Dollar signs ($) may never be used. The italicized headings should not be coded and blank cards should not be included.

General Information

Variable	*Input or Option*
NAME.OF.BASE	
LOCATION.OF.BASE	
IDENTIFICATION.NUMBER	
GENERAL.DESCRIPTION	

Design Data

Variable	*Input or Option*
CALCULATION.TYPE	
DESIGN.LIFE	
LENGTH.OF.SECTION	
WIDTH.OF.SECTION	
RIGID.STRUCTURAL.ANALYSIS	
DESIGN.RESTRICTION	
RANGE.OF.THICKNESS	

Variable	*Input or Option*
TIMES	
BASE.TRADEOFF	
FROST.DESIGN	
DRAINAGE	
EARTHWORK	
CLIMATE	
GENERATE.MATERIAL.COMBINATIONS	
NUMBER.OF.SUBBASE.SCHEMES	
SUBBASE.TYPES	
SCHEME 1	
SCHEME 2	
SCHEME 3	
SCHEME 4	
OVERLAY.RESTRICTION	
MINIMUM.THICKNESS.FLEXIBLE.OVERLAY	
MINIMUM.THICKNESS.RIGID.OVERLAY	
TIMES.OF.OVERLAYS	
STRATEGY 1	
STRATEGY 2	
STRATEGY 3	
STRATEGY 4	
STRATEGY 5	
STRATEGY 6	
BONDING	
DTYPE	
DTHICKNESS	
INITIAL.FAILURE	
CONDITION	
FLEXIBLE.PAVEMENT.MATERIAL.PROPERTIES	
SUBGRADE	
COMPACTED	
SUBBASE	
BASE	

Variable	Input or Option
SUBGRADE.COHESION.INDEX	
SUBGRADE.CBR	
SUBGRADE.DENSITY	
SUBGRADE.MODULUS	
GRANULAR.BASE.MATERIAL	
CONCRETE.FLEXURAL.STRENGTH	

Cost Data

Variable	Input or Option
COMPACTED.SUBGRADE	
FLEXIBLE.PAVEMENT.BASE	
SUBBASE	
RIGID.PAVEMENT.BASE	
FLEXIBLE.PAVEMENT	
FLEXIBLE.OVERLAY	
RIGID.OVERLAY.PARTIAL.BOND	
RIGID.OVERLAY.UNBONDED	
DELAY.COST.FLEXIBLE.OVERLAY	
DELAY.COST.RIGID.OVERLAY	
DISCOUNT	
ESCALATION.RATE	
GEOGRAPHIC.FACTOR	
VEHICLE.MAINTENANCE	
ROUTINE.MAINTENANCE RIGID.INITIAL.CONSTRUCTION	
ROUTINE.MAINTENANCE RIGID.OVERLAY.SYSTEM	
ROUTINE.MAINTENANCE FLEXIBLE.INITIAL.CONSTRUCTION	
ROUTINE.MAINTENANCE FLEXIBLE.OVERLAY.SYSTEM	
MAINTENANCE.COST.ANALYSIS	
MAINTAIN.DRAINS	
SEAL.JOINTS.CRACKS.RIGIDPAVEMENT	
CRACKSEALING.FLEXIBLE.PAVEMENT	
CLEANING.SWEEPING.RIGIDPAVEMENT	

Variable		*Input or Option*
CLEANING.SWEEPING.FLEXIBLE.PAVEMENT		
PATCHING.FLEXIBLE.PAVEMENT		
REPLACE.SLABS.RIGIDPAVEMENT		
SURFACE.TREATMENT.FLEXIBLE.PAVEMENT		
REPAIR.SCALING.POPOUTS.RIGIDPAVEMENT		
OTHER.MAINTENANCE.RIGIDPAVEMENT		
OTHER.MAINTENANCE.FLEXIBLE.PAVEMENT		
OTHER.REPAIRS.RIGIDPAVEMENT		
OTHER.REPAIRS.FLEXIBLE.PAVEMENT		

Traffic Data

Variable		*Input or Option*
For road design	VEHICLE.TYPE	
	DESIGN.INDEX	
	CLASS.OF.ROAD	
For airfield design	VEHICLE.TYPE	
	YEARLY.TRAFFIC	
	PAST.TRAFFIC	
	CONCRETE.STRESSES.OVER.ASPHALT	
	CONCRETE.STRESSES.ON.GRADE	
	VEHICLE.TYPE	
	YEARLY.TRAFFIC	
	PAST.TRAFFIC	
	CONCRETE.STRESSES.OVER.ASPHALT	
	CONCRETE.STRESSES.ON.GRADE	
	LOAD.CATEGORY	
	WANDER	
	TRAFFIC.AREA	
END OF INFORMATION		

APPENDIX E:
LIFE2 EXAMPLE PROBLEM

This appendix provides a life-cycle design analysis for an airfield runway to exemplify use of the LIFE2 program. The program input is described followed by an explanation of the output.

Input

NAME.OF.BASE " "

(The user may insert the name of the base or area in which the project is to be constructed. The name must be enclosed in quotes.)

LOCATION.OF.BASE " "

(The user may insert the location of the project in quotes.)

IDENTIFICATION.NUMBER "EXAMPLE PROBLEM"

(The user may insert an agency or organizational identification number [in quotes] for this project.)

GENERAL.DESCRIPTION "AIRFIELD RUNWAY LIFE-CYCLE DESIGN"

(The user may insert a general description of the project [in quotes].)

CALCULATION.TYPE LIFE-CYCLE

DESIGN.LIFE 25

LENGTH.OF.SECTION 90

WIDTH.OF.SECTION 90

FROST.DESIGN READ 30

(The READ option bypasses the frost design analysis and can be used when depth of frost penetration is known for the project site. The 30 in the example is the depth in inches which will be used in the program as a constraint for complete protection against frost penetrating the subgrade.)

EARTHWORK PAVEMENT

(The PAVEMENT option indicates that the program will calculate the earthwork quantities and costs for the paved area. This option requires an additional set of data on fixed format cards which appear later in the input deck.)

DRAINAGE YES

(YES specifies that the analysis will consider whether underdrains are necessary. This option requires an additional set of data on fixed format cards which appear later in the input deck.)

RIGID.STRUCTURAL.ANALYSIS READ

(This indicates that CSOG and CSOA are known and will be included as input. The stresses are input with the associated VEHICLE.TYPE.)

RANGE.OF.THICKNESS 15 35

(This is the user's estimate of the range of thickness of rigid pavement for which the structural analysis data [CSOA and CSOG] may be required in the problem.)

DESIGN.RESTRICTION NONE

(Both rigid and flexible design schemes are to be considered.)

BASE.TRADEOFF TRADEOFF

(This indicates that a tradeoff between base thickness and rigid slab thickness is to be executed.)

GRANULAR.BASE.MATERIAL NATURAL.SAND.AND.GRAVEL

(In performing the TRADEOFF, a revised subgrade modulus will be determined for each base thickness the program considers. The revised value is derived from data appropriate to a base material that is categorized as NATURAL.SAND.AND.GRAVEL.)

CONDITION SHATTERED.SLAB

(The calculation of overlays for rigid pavement designs generated in this run assumes that the structural condition at the time of the overlay can be classified as SHATTERED.SLAB [see definition in Appendix B].)

BONDING BOTH

(The program will consider both partial and unbonded conditions for rigid overlays on rigid pavement. The least expensive will be selected for each strategy.)

INITIAL.FAILURE YES

(This specifies that flexible overlays on rigid pavement will be designed for initial failure, thereby establishing the overlay design factor.)

GENERATE.MATERIAL.COMBINATIONS YES

(In flexible pavement design, the program will generate all possible layer combinations.)

CLIMATE NORMAL

OVERLAY.RESTRICTION NONE

(Both flexible and rigid overlays will be considered.)

MINIMUM.THICKNESS.FLEXIBLE.OVERLAY 4.0

MINIMUM.THICKNESS.RIGID.OVERLAY 6.0

(These two cards specify the minimum allowable overlay thicknesses; calculated thicknesses less than the minimums will be revised to those thicknesses.)

TIMES.OF.OVERLAYS

STRATEGY 1

STRATEGY 2 10 20

STRATEGY 3 14 20

(The above data indicate that three overlay strategies are being considered; no overlay in the design life, overlays at 10 and 20 years; and overlays at 14 and 20 years.)

FLEXIBLE.PAVEMENT.MATERIAL.PROPERTIES

SUBGRADE 1 5 96 12 COHESIVE FS

(This card specifies that the subgrade material has a CBR of 5 and a density of 96 percent of maximum for a depth of 12 in. [305 mm], and that it is cohesive and frost-susceptible.)

COMPACTED 1 15 100 COHESIONLESS NFS

(This card specifies that the compacted subgrade [select material layer] has a CBR of 15, in-place density of 100 percent, and that it is cohesionless and nonfrost-susceptible.)

SUBBASE 1 50 100 COHESIONLESS NFS

SUBBASE 2 30 100 COHESIONLESS NFS

SUBBASE 3 22 100 COHESIVE FS

(The SUBBASE cards provide the CBR, in-place density, cohesion, and frost-susceptibility data for three available materials.)

BASE 1 100

(The base material has a CBR of 100.)

SUBGRADE.MODULUS 75

SUBGRADE.CBR 5

SUBGRADE.DENSITY 90

SUBGRADE.COHESION.INDEX COHESIVE FS

(This set of subgrade cards provides the characteristics of the naturally occurring roadbed material.)

CONCRETE.FLEXURAL.STRENGTH 600

DISCOUNT 0.10

(Rate used to discount costs to present worth.)

ESCALATION.RATE 0.05

(Rate used to account for the effect of inflation.)

GEOGRAPHIC.FACTOR 0.95

(This indicates that the unit costs used in the problem are 5 percent higher than the anticipated costs at the project site.)

COMPACTED.SUBGRADE 1 1 .10 30 1.15

FLEXIBLE.PAVEMENT.BASE 1 1 .35 50 17.50

SUBBASE 1 1 .60 40 8.00

SUBBASE 2 1 .50 40 6.00

SUBBASE 3 1 .35 40 5.10

FLEXIBLE.PAVEMENT 1 .75 40 30

RIGID.PAVEMENT.BASE 1 .50 40 8.00

RIGID.PAVEMENT 1 1 30 35

RIGID.OVERLAY.PARTIAL.BOND 1 1.1 30 33

RIGID.OVERLAY.UNBONDED 1 1.2 30 34

FLEXIBLE.OVERLAY 1 .65 20 13.

(The above 11 cards present cost data for each material which will be considered in this problem.)

DELAY.COST.RIGID.OVERLAY 35000

DELAY.COST.FLEXIBLE.OVERLAY 15000

(These two variables provide the estimated cost incurred by users of the facility during cessation of operations for constructing an overlay.)

VEHICLE.MAINTENANCE 1 1000 15 10000 25 50000

(This is an estimate of the cost function which defines user costs incurred from rough or failing pavements.)

ROUTINE.MAINTENANCE RIC 1 .01 10 .10 25 .35

ROUTINE.MAINTENANCE ROS 1 .01 10 .17 25 .33

ROUTINE.MAINTENANCE FIC 1 .01 10 .08 25 .40

ROUTINE.MAINTENANCE FOS 1 .01 10 .20 25 .40

(The above four variables define the estimated cost functions for total maintenance and repair activities for four conditions:
RIC –rigid initial construction
ORS–rigid overlay system
FIC –flexible initial construction
FOS–flexible overlay system.)

VEHICLE.TYPE HEAVY-LOAD

YEARLY.TRAFFIC 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500

CONCRETE.STRESSES.ON.GRADE 881.7 730.6 623.3 533.3 462.8 403.5 354.7 318.7 287.7 261.4

CONCRETE.STRESSES.OVER.ASPHALT 722.8 598.7 503.1 431.8 379.8 336.6 301.0 271.1 244.5 220.2

(The above two cards list concrete stresses on-grade and over asphalt for 10 pavement thicknesses. These data are required for each VEHICLE.TYPE when the READ option of RIGID.STRUCTURAL.ANALYSIS is selected.)

VEHICLE.TYPE C-5A

YEARLY.TRAFFIC 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500 500

CONCRETE.STRESSES.ON.GRADE 428.4 361.6 312.1 273.5 240.4 212.4 189.5 170.9 155.5 142.6

CONCRETE.STRESSES.OVER.ASPHALT 332.9 281.6 241.6 211.7 188.0 169.4 153.4 139.3 126.8 116.0

TL 5540.0 250.0 870.0 4920.0

PGLENDS 5500.0 250.0 550.0 1000.0 4660.0 560.0

TD 0.0 –100.0 547.3 0.0 –60.0 547.5

TD 0.0 0.0 547.5 0.0 40.5 547.9

TD 0.0 95.0 548.2

TD 500.0 –100.0 547.1 500.0 –50.0 547.1

TD 500.0 0.0 547.5 500.0 60.0 547.9

TD 500.0 100.0 548.1

TD 1000.0 –99.0 547.3 1000.0 –50.0 547.5

TD 1000.0 0.0 547.6 1000.0 70.0 547.9

TD 1000.0 100.0 548.3

TD 1500.0 –100.0 547.5 1500.0 –50.0 547.8

TD 1500.0 0.0 547.9 1500.0 50.0 548.2

TD 1500.0 100.0 548.4

TD 2000.0 –99.0 547.4 2000.0 –50.0 547.5

TD 2000.0 0.0 547.9 2000.0 100.0 547.9

TD 3000.0 –101.0 547.5 3000.0 –45.0 547.9

TD 3000.0 0.0 548.1 3000.0 52.0 548.3

TD 3000.0 97.0 548.5

TD 4000.0 –97.0 547.9 4000.0 –55.0 548.3

TD 4000.0 0.0 548.5 4000.0 50.0 548.7

TD 4000.0 105.0 549.0

TD 5000.0 –100.0 548.4 5000.0 –50.0 548.8

TD 5000.0 0.0 549.3 5000.0 50.0 549.7

TD 5000.0 100.0 550.1

TDR 6000.0 –100.0 559.3 4.2

TDR 6000.0 –55.0 559.3 3.9

TDR 6000.0 0.0 559.3 3.5

TDR 6000.0 47.0 559.3 3.3

TDR 6000.0 105.0 559.3 3.1

TDR 6600.0 –100.0 562.8 4.8

TDR 6600.0 −51.0 562.8 4.5

TDR 6600.0 0.0 562.8 4.3

TDR 6600 49.0 562.8 4.0

TDR 6600.0 103.0 562.8 3.7

PGLBRK 5000.0 556.0

TMP −45.0 0.0 45.0 0.0

ELIM 2.0 2.0

COST 1.15 1.40

RUN 75.0 EP 0.0 6300.0

(The preceding cards from TL to RUN contain the fixed-format earthwork data. Appendix B describes these data.)

WANDER UNCHANNELIZED

TRAFFIC.AREA A

(The runway section being considered is classified as traffic area A, based on the loads it will carry.*)

LOAD.CATEGORY MEDIUM

(Based on the traffic projections, the load category is medium.** This variable establishes minimum thickness requirements for the pavement.)

DRNAGE 60 .011 45 22E-04 4.00 6300 3.35 2.50 2.20 .0020 0.130 1 35

(This card provides the fixed-format data for the drainage analysis. Appendix B explains these data.)

END OF DATA

Results

Figures E1 through E9 are extracts of the LIFE2 output for the example problem using the preceding data.

Figure E1 presents the pavement thickness vs. service life array. The years during the design life used in this array are taken from the input variable TIMES. In flexible pavement design, the pavement thicknesses given are those required to provide structural adequacy above the material with a corresponding CBR. For example, subbase material 3 in the input has a CBR of 22; for the cumulative traffic to the 25th year, this material requires 19.5 in. (495 mm) of material above this subbase layer based on its structural properties.† In rigid pavement design, the required slab thickness is provided at each service life for the subgrade material with a modulus of reaction of 75 pci (2076 g/cm^3) for this example.** The program uses this array to determine required thicknesses of the materials for designing pavements which will be functional to the various TIMES.OF.OVERLAYS. It should be stressed that these are structural requirements and that the actual design thickness for each material may be controlled by density or frost protection requirements.

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*See TM 5-824-1 for a complete definition of traffic areas and load categories.

**See TM 5-824-2 for the Corps of Engineers' flexible pavement design method for airfields.

†See TM 5-824-3 for the Corps of Engineers' rigid pavement design method for airfields.

Figure E2 summarizes the life-cycle costs for each combination of design scheme and maintenance strategy. The costs of construction and maintenance during the facility's life are combined to give the total life-cycle cost (adjusted to present worth). The results are separated into rigid designs and flexible designs and ranked according to their life-cycle cost. In this example, six overlay strategies are considered—three with rigid initial construction and three with flexible initial construction (based on the variable TIMES.OF.OVERLAYS). Only the optimal scheme (i.e., pavement design) is provided for each rigid pavement strategy. In the flexible pavement results, seven schemes are given for each strategy. These represent all possible layer combinations for the materials available.

Figures E3 and E4 show the suboptimized solutions for overlay strategies 5 and 6. These strategies provide for an overlay in the 14th and the 20th years. Strategy 5 is used for rigid initial construction, and strategy 6 is used for flexible initial construction. The optimal overlay type and thickness are given for each solution. This type of output is presented for each strategy evaluated by the program.

Figures E5 and E6 provide the design schemes associated with the overlay strategies presented in Figures E3 and E4. Figure E5 is the construction cost analysis for the optimal rigid pavement design associated with strategy 5. A base tradeoff was performed resulting in a reduction of the slab thickness by employing 6 in. (152 mm) of base. Figure E6 presents the seven flexible design schemes associated with strategy 6. Note that there is a variation in earthwork costs because of differences in total thickness and that drainage is required for three of the schemes. This type of output is provided for each design scheme analyzed by the program.

The volume of cut and fill and total earthwork cost is provided in the output for each design scheme. Figure E7 illustrates this output. Figure E8 is the earthwork mass diagram plotted by the program as a user option.

Figure E9 summarizes the drainage analysis performed by the program. If drainage is required, its construction cost becomes a line item in the design scheme analysis (see Figure E6) and is included in the total cost of construction for that scheme.

REQUIRED THICKNESS OF PROTECTION VERSUS SERVICE LIFE RELATIONSHIP FOR FLEXIBLE PAVEMENT MATERIALS WITH CBR-S USED IN THIS RUN

DENSITY AND/OR FROST REQUIREMENTS MAY CONTROL THICKNESS REQUIREMENTS

	SERVICE LIFE					
CBR	1.	5.	10.	15.	20.	25.
5.	40.0	47.1	50.2	51.8	52.9	53.8
15.	19.0	22.4	23.8	24.6	25.1	25.6
22.	14.7	17.1	18.1	18.7	19.1	19.5
30.	11.9	13.9	14.8	15.2	15.5	15.8
50.	7.7	9.1	9.7	10.1	10.3	10.4
100.	4.1	4.7	5.0	5.1	5.2	5.3

TOTAL FLEXIBLE PAVEMENT THICKNESS VERSUS SERVICE LIFE RELATIONSHIP FOR THE SUBGRADE CBR USED IN THIS RUN

	SERVICE LIFE					
CBR	1.	5.	10.	15.	20.	25.
5.	40.0	47.1	50.2	51.8	52.9	53.8

RIGID PAVEMENT THICKNESS(PCC) VERSUS SERVICE LIFE RELATIONSHIP FOR THE SUBGRADE MODULUS(K) USED IN THIS RUN

	SERVICE LIFE					
SUBGRADE MODULUS	1.	5.	10.	15.	20.	25.
75.	24.4	25.8	26.5	27.0	27.4	27.7

Figure E1. Pavement thickness vs. service life array.

SUMMARY OF RIGID CONSTRUCTION SCHEMES AND CORRESPONDING OVERLAY STRATEGIES
IN ASCENDING ORDER OF TOTAL ADJUSTED COSTS

SCHEME NO	STRATEGY NO	CONSTRUCTION COST	ADJUSTED STRATEGY COST	TOTAL ADJUSTED COSTS
9	3	1937411.99	289197.09	2226609.08
17	5	1956162.45	278549.72	2234712.17
1	1	2005400.21	284716.04	2290116.26

SUMMARY OF FLEXIBLE CONSTRUCTION SCHEMES AND CORRESPONDING OVERLAY STRATEGIES
IN ASCENDING ORDER OF TOTAL ADJUSTED COSTS

SCHEME NO	STRATEGY NO	CONSTRUCTION COST	ADJUSTED STRATEGY COST	TOTAL ADJUSTED COSTS
19	6	613372.46	273007.23	886379.69
20	6	615881.89	273007.23	888889.13
11	4	612714.43	284842.25	897556.68
12	4	614619.82	284842.25	899462.08
21	6	656589.59	273007.23	929596.82
23	6	670650.30	273007.23	943657.53
3	2	658019.69	285959.79	943979.48
4	2	660529.12	285959.79	946488.91
13	4	663872.83	284842.25	948715.08
15	4	669388.23	284842.25	954230.48
24	6	686130.94	273007.23	959138.17
16	4	686130.94	284842.25	970973.19
22	6	702551.32	273007.23	975558.55
5	2	700319.94	285959.79	986279.73
14	4	702551.32	284842.25	987393.58
7	2	715297.52	285959.79	1001257.31
8	2	729861.29	285959.79	1015821.07
6	2	746281.67	285959.79	1032241.46
18	6	860233.05	273007.23	1133240.28
10	4	860233.05	284842.25	1145075.31
2	2	903963.40	285959.79	1189923.19

Figure E2. Life-cycle costs.

YR	MAINTENANCE COST	OVERLAY THICKNESS(IN)	OVERLAY COST	USER COSTS	TOTAL COST	ADJUSTED COST
1	598.50		0.00	950.00	1548.50	1481.82
2	1197.00		0.00	1560.71	2757.71	2525.32
3	1795.50		0.00	2171.43	3966.93	3476.21
4	2394.00		0.00	2782.14	5176.14	4340.51
5	2992.50		0.00	3392.86	6385.36	5123.94
6	3591.00		0.00	4003.57	7594.57	5831.84
7	4189.50		0.00	4614.29	8803.79	6469.27
8	4788.00		0.00	5225.00	10013.00	7040.99
9	5326.50		0.00	5835.71	11222.21	7551.48
10	5985.00		0.00	6446.43	12431.43	8004.94
11	6982.50		0.00	7057.14	14039.64	8651.21
12	7980.00		0.00	7667.86	15647.86	9226.98
13	8977.50		0.00	8278.57	17256.07	9737.11
14	9975.00	4 F	170610.00	8889.29	189474.29	102310.97
15	598.50		0.00	950.00	1548.50	800.14
16	1862.00		0.00	1560.71	3422.71	1692.43
17	3125.50		0.00	2171.43	5296.93	2506.38
18	4389.00		0.00	2782.14	7171.14	3247.10
19	5652.50		0.00	3392.86	9045.36	3919.37
20	6916.00	4 F	170610.00	4003.57	181529.57	75269.94
21	598.50		0.00	950.00	1548.50	614.43
22	1862.00		0.00	1560.71	3422.71	1299.61
23	3125.50		0.00	2171.43	5296.93	1924.64
24	4389.00		0.00	2782.14	7171.14	2493.43
25	5652.50		0.00	3392.86	9045.36	3009.67
TOTALS	$ 105603.50	8	$ 341220.00	$ 94592.86	$ 540816.36	$ 278549.72

THIS STRATEGY IS APPROPRIATE FOR USE WITH A RIGID DESIGN

F OR R REPRESENTS FLEXIBLE OR RIGID OVERLAYS

A NUMBER IN PARENTHESES FOLLOWING FLEXIBLE IS THE THICKNESS OF BASE MATERIAL IN THE OVERLAY SYSTEM

FOR RIGID, P IN PARENTHESES MEANS PARTIAL BOND AND U MEANS UNBONDED

Figure E3. Suboptimized solution for overlay strategy 5.

YR	MAINTENANCE COST	OVERLAY THICKNESS(IN)	OVERLAY COST	USER COSTS	TOTAL COST	ADJUSTED COST
1	598.50		0.00	950.00	1548.50	1481.82
2	1064.00		0.00	1560.71	2624.71	2403.53
3	1529.50		0.00	2171.43	3700.93	3243.11
4	1995.00		0.00	2782.14	4777.14	4005.93
5	2460.50		0.00	3392.86	5853.36	4697.03
6	2926.00		0.00	4003.57	6929.57	5321.19
7	3391.50		0.00	4614.29	8005.79	5882.88
8	3857.00		0.00	5225.00	9082.00	6386.33
9	4322.50		0.00	5835.71	10158.21	6835.51
10	4788.00		0.00	6446.43	11234.43	7234.16
11	6064.80		0.00	7057.14	13121.94	8085.72
12	7341.60		0.00	7667.86	15009.46	8850.53
13	8618.40		0.00	8278.57	16896.97	9534.48
14	9895.20	4 F	170610.00	8889.29	189394.49	102267.88
15	598.50		0.00	950.00	1548.50	800.14
16	1862.00		0.00	1560.71	3422.71	1692.43
17	3125.50		0.00	2171.43	5296.93	2506.38
18	4389.00		0.00	2782.14	7171.14	3247.10
19	5652.50		0.00	3392.86	9045.36	3919.37
20	6916.00	4 F	170610.00	4003.57	181529.57	75269.94
21	598.50		0.00	950.00	1548.50	814.43
22	1862.00		0.00	1560.71	3422.71	1299.61
23	3125.50		0.00	2171.43	5296.93	1924.64
24	4389.00		0.00	2782.14	7171.14	2493.43
25	5652.50		0.00	3392.86	9045.36	3009.67
TOTALS	$ 97023.50	8	$ 341220.00	$ 94592.86	$ 532836.36	$ 273007.23

THIS STRATEGY IS APPROPRIATE FOR USE WITH SEVERAL FLEXIBLE DESIGNS

F OR R REPRESENTS FLEXIBLE OR RIGID OVERLAYS

A NUMBER IN PARENTHESES FOLLOWING FLEXIBLE IS THE THICKNESS OF BASE MATERIAL IN THE OVERLAY SYSTEM

FOR RIGID. P IN PARENTHESES MEANS PARTIAL BOND AND U MEANS UNBONDED

Figure E4. Suboptimized solution for overlay strategy 6.

LAYER NO	DESCRIPTION	THICKNESS(IN)	COST/SY	TOTAL COST
1	RIGID PAVEMENT	26.0	28.79	1814074.14
2	RIGID PAVEMENT BASE	6.0	1.39	87473.08
TOTAL THIS SECTION		32.0	40.47	$ 1901547.21

TOTALS FOR ALL SECTIONS	AREA = 63000 SY	COSTS = $ 1901547.21
EARTHWORK COSTS		$ 54615.24
DRAINAGE COSTS		$ 0.00
TOTAL ALL CONSTRUCTION		$ 1956162.45

Figure E5. Rigid construction cost analysis for scheme 17 associated with overlay strategy 5.

Scheme 18

LAYER NO	DESCRIPTION	THICKNESS(IN)	COST/SY	TOTAL COST
1	FLEXIBLE PAVEMENT	6.0	3.56	224437.50
2	1ST FLEXIBLE PAVEMENT BASE	25.0	8.31	523687.50
3	THIRD SUBBASE	6.0	.91	57394.62
4	FIRST COMPACTED SUBGRADE	6.0	.27	16819.91
TOTAL THIS SECTION		42.0	13.05	$ 822339.53

TOTALS FOR ALL SECTIONS	AREA = 63000 SY	COSTS = $ 822339.53
EARTHWORK COSTS		$ 37893.52
DRAINAGE COSTS		$ 0.00
TOTAL ALL CONSTRUCTION		$ 860233.05

Scheme 19

LAYER NO	DESCRIPTION	THICKNESS(IN)	COST/SY	TOTAL COST
1	FLEXIBLE PAVEMENT	5.0	3.56	224437.50
2	1ST FLEXIBLE PAVEMENT BASE	7.0	2.33	146632.50
3	SECOND SUBBASE	6.0	1.14	72126.92
4	FIRST COMPACTED SUBGRADE	22.0	.82	51491.64
TOTAL THIS SECTION		40.0	7.85	$ 494688.56

TOTALS FOR ALL SECTIONS	AREA = 63000 SY	COSTS = $ 494688.56
EARTHWORK COSTS		$ 40584.51
DRAINAGE COSTS		$ 78099.39
TOTAL ALL CONSTRUCTION		$ 613372.46

Figure E6. Flexible construction cost analysis for schemes associated with overlay strategy 6.

Scheme 20

LAYER NO	DESCRIPTION	THICKNESS(IN)	COST/SY	TOTAL COST
1	FLEXIBLE PAVEMENT	5.0	3.56	224437.50
2	1ST FLEXIBLE PAVEMENT BASE	6.0	2.00	125685.00
3	FIRST SUBBASE	6.0	1.47	92690.77
4	FIRST COMPACTED SUBGRADE	23.0	.85	53658.62
TOTAL THIS SECTION		40.0	7.88	$ 496471.89

TOTALS FOR ALL SECTIONS	AREA = 63000 SY	COSTS = $ 496471.89
EARTHWORK COSTS		$ 40584.51
DRAINAGE COSTS		$ 78825.50
TOTAL ALL CONSTRUCTION		$ 615881.89

Scheme 21

LAYER NO	DESCRIPTION	THICKNESS(IN)	COST/SY	TOTAL COST
1	FLEXIBLE PAVEMENT	5.0	3.56	224437.50
2	1ST FLEXIBLE PAVEMENT BASE	7.0	2.33	146632.50
3	SECOND SUBBASE	18.0	2.75	173411.54
4	THIRD SUBBASE	6.0	.91	57394.62
5	FIRST COMPACTED SUBGRADE	6.0	.27	16819.91
TOTAL THIS SECTION		42.0	9.82	$ 618696.07

TOTALS FOR ALL SECTIONS	AREA = 63000 SY	COSTS = $ 618696.07
EARTHWORK COSTS		$ 37893.52
DRAINAGE COSTS		$ 0.00
TOTAL ALL CONSTRUCTION		$ 656589.59

Figure E6 (cont'd).

Scheme 22

LAYER NO	DESCRIPTION	THICKNESS(IN)	COST/SY	TOTAL COST
1	FLEXIBLE PAVEMENT	5.0	3.56	224437.50
2	1ST FLEXIBLE PAVEMENT BASE	6.0	2.00	125685.00
3	FIRST SUBBASE	19.0	3.81	240320.77
4	THIRD SUBBASE	6.0	.91	57394.62
5	FIRST COMPACTED SUBGRADE	6.0	.27	16819.91
TOTAL THIS SECTION		42.0	10.55	$ 664657.80

TOTALS FOR ALL SECTIONS AREA = 63000 SY COSTS = $ 664657.80

EARTHWORK COSTS $ 37893.52

DRAINAGE COSTS $ 0.00

TOTAL ALL CONSTRUCTION $ 702551.32

Scheme 23

LAYER NO	DESCRIPTION	THICKNESS(IN)	COST/SY	TOTAL COST
1	FLEXIBLE PAVEMENT	5.0	3.56	224437.50
2	1ST FLEXIBLE PAVEMENT BASE	6.0	2.00	125685.00
3	FIRST SUBBASE	6.0	1.47	92690.77
4	SECOND SUBBASE	6.0	1.14	72126.92
5	FIRST COMPACTED SUBGRADE	17.0	.65	40656.72
TOTAL THIS SECTION		40.0	8.82	$ 555596.92

TOTALS FOR ALL SECTIONS AREA = 63000 SY COSTS = $ 555596.92

EARTHWORK COSTS $ 40584.51

DRAINAGE COSTS $ 74468.87

TOTAL ALL CONSTRUCTION $ 670650.30

Figure E6 (cont'd).

Scheme 24

LAYER NO	DESCRIPTION	THICKNESS(IN)	COST/SY	TOTAL COST
1	FLEXIBLE PAVEMENT	5.0	3.56	224437.50
2	1ST FLEXIBLE PAVEMENT BASE	6.0	2.00	125685.00
3	FIRST SUBBASE	6.0	1.47	92690.77
4	SECOND SUBBASE	13.0	2.08	131209.62
5	THIRD SUBBASE	6.0	.91	57394.62
6	FIRST COMPACTED SUBGRADE	6.0	.27	16819.91
TOTAL THIS SECTION		42.0	10.29	$ 648237.41

TOTALS FOR ALL SECTIONS	AREA = 63000 SY	COSTS = $ 648237.41
EARTHWORK COSTS		$ 37893.52
DRAINAGE COSTS		$ 0.00
TOTAL ALL CONSTRUCTION		$ 686130.94

Figure E6 (cont'd).

DESIGN SCHEME 17 THICKNESS OF 32.00 INCHES

THE ESTIMATED COST PER CUBIC YARD OF CUT IS $ 1.150 THE NET VOLUME OF CUT IS 386. CUBIC YARDS

THE ESTIMATED COST OF CUT IS $ 443.50

THE ESTIMATED COST PER CUBIC YARD OF FILL IS $ 1.400 THE NET VOLUME OF FILL IS 38694. CUBIC YARDS

THE ESTIMATED COST OF FILL IS $ 54171.74

THE TOTAL COST FOR APPROACH ZONES IS $ 0.00

THE TOTAL COST OF EARTHWORK IS ESTIMATED AT $ 54615.24

Figure E7. Output for design scheme 17.

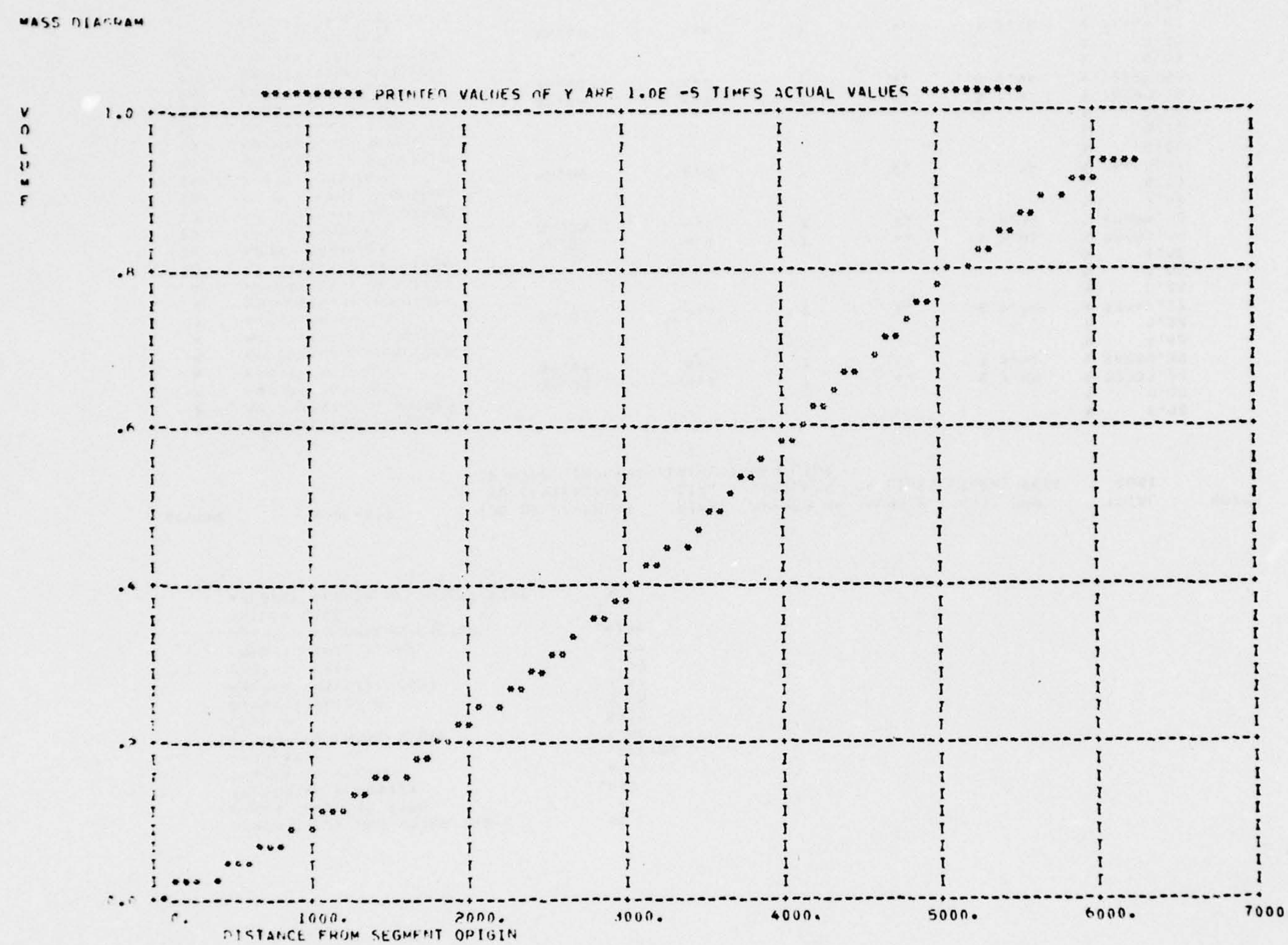

Figure E8. Earthwork mass diagram.

DEPTH TO GROUND WATER TABLE	60
USERS DEPTH TO PIPE	0
EFFECTIVE POROSITY	.011
DRAINAGE LENGTH	45.0
PERMEABILITY	.22E-04
HEIGHT OF CROSS SLOPE	4.00
LENGTH	6300
EXCAVATION COST	3.35
FILTER MATERIAL COST	2.50
COST OF PIPE	2.20
LONGITUDINAL SLOPE	.0020
MANNING ROUGHNESS FACTOR	.0130
OUTLET CODE	1
AVERAGE LENGTH OF OUTLET PIPE	35

SCHEME	ANALYSIS	TOP OF PAVEMENT TO CENTERLINE OF PIPE (INCHES)	PIPE DIA. (INCHES)	NUMBER OF OUTLETS PER LINE	NUMBER OF LINES	COST PER LINEAL FOOT	TOTAL COST	NOTES
1	NO DRAINAGE REQUIRED						$ 0.00	
2	NO DRAINAGE REQUIRED						$ 0.00	
3	FROST CONTROLS	36.00	6.0	7	4.	$ 2.89	$ 77373.29	
4	FROST CONTROLS	36.00	6.0	7	4.	$ 2.91	$ 78099.39	
5	NO DRAINAGE REQUIRED						$ 0.00	
6	NO DRAINAGE REQUIRED						$ 0.00	
7	FROST CONTROLS	36.00	6.0	7	4.	$ 2.75	$ 73742.77	
8	NO DRAINAGE REQUIRED						$ 0.00	
9	NO DRAINAGE REQUIRED						$ 0.00	
10	NO DRAINAGE REQUIRED						$ 0.00	
11	FROST CONTROLS	36.00	6.0	7	4.	$ 2.91	$ 78099.39	
12	FROST CONTROLS	36.00	6.0	7	4.	$ 2.94	$ 78825.50	
13	NO DRAINAGE REQUIRED						$ 0.00	
14	NO DRAINAGE REQUIRED						$ 0.00	
15	FROST CONTROLS	36.00	6.0	7	4.	$ 2.78	$ 74468.87	
16	NO DRAINAGE REQUIRED						$ 0.00	
17	NO DRAINAGE REQUIRED						$ 0.00	
18	NO DRAINAGE REQUIRED						$ 0.00	
19	FROST CONTROLS	36.00	6.0	7	4.	$ 2.91	$ 78099.39	
20	FROST CONTROLS	36.00	6.0	7	4.	$ 2.94	$ 78825.50	
21	NO DRAINAGE REQUIRED						$ 0.00	
22	NO DRAINAGE REQUIRED						$ 0.00	
23	FROST CONTROLS	36.00	6.0	7	4.	$ 2.78	$ 74468.87	
24	NO DRAINAGE REQUIRED						$ 0.00	

Figure E9. Drainage analysis summary.

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