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16. Abstract

By presenting a method for estimating the remaining life of continuously reinforced concrete pavement (CRCP), this report provides a means for determining the optimum time to overlay such pavements. Previously, determinations of remaining pavement life relied solely on engineering judgment. And while subjective experience can often lead to satisfactory solutions, a standardized procedure — such as that provided by this study — will allow more objective assessments and, hence, more uniform results.

To develop a new procedure for estimating remaining pavement life, we used a failure prediction model that uses punchouts as the major failure criterion. This model, later calibrated against CRC pavement data by the Center for Transportation Research, can be used to generate a failure curve for a given pavement. The failure curve describes the relationship between punchouts (failures) and equivalent single axle loads (ESALs). If a certain number of failures per mile (FPM) is specified as the indicator for a failed pavement, and if the current number of failures per mile is known, then the number of remaining ESALs the pavement will withstand can be determined from the failure curve. From the number of remaining ESALs, the amount of remaining pavement life can be calculated using an appropriate traffic model.

The procedure summarized above was incorporated into the PAVLIF computer program. We used the program to run sample problems involving actual field data; the results from the samples compared favorably with actual observations. In one sample, PAVLIF predicted 6 years of remaining life for a CRC pavement section in Bowie County, TX. Another study of this same pavement section estimated a remaining life of 7 years, based on an extrapolation of the pavement's actual failure curve. Although PAVLIF produced favorable results for this sample (and for the other samples in this report), the program is calibrated only for certain types of pavement. Further testing and calibration of the program are required to expand its usefulness.

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A METHOD FOR ESTIMATING THE REMAINING LIFE OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

Steve Easley
Terry Dossey

Research Report Number 1244-12

Research Project 0-1244
Evaluation of the Performance of Texas Pavements Made with Different Aggregates

conducted for the

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

November 1994

IMPLEMENTATION STATEMENT

While no program can fully replace engineering judgment, the PAVLIF program developed in this study is nonetheless a useful tool for determining when to overlay continuously reinforced concrete pavement. Programs such as PRDS and MPRDS require remaining pavement life as one of the variables for calculating lifetime pavement costs; the procedure presented in this report can provide this information. In addition, remaining pavement life is also a required variable in the Texas Pavement Management Information System (PMIS) currently under development at TxDOT.

PREFACE

This report describes a method for estimating the remaining life of continuously reinforced concrete pavement (CRCP). This method was developed at the Center for Transportation Research (CTR) for the Texas Department of Transportation under Research Project 1244. Specifically, the report discusses the major failure modes of CRCP and the importance of overlays in slowing deterioration. The remaining-life estimation procedure presented is intended to help pavement managers determine when to overlay CRC pavements. To ensure speed and ease of use, we incorporated the procedure into a computer program called PAVLIF. The program uses punchouts as the failure criterion, since they represent a major manifestation of structural failure in CRC pavements. Thus, the goal of the program is to identify the relationship between punchouts and time for CRC pavements.

The authors thank the Texas Department of Transportation for their sponsorship of this project. The authors also thank those who assisted in the research and who made the development of this estimation method possible, specifically Moon Won and Young-Chan Suh. Finally, the authors are indebted to the CTR staff for their assistance in the preparation of this report.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

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Research Supervisor

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SUMMARY

By presenting a method for estimating the remaining life of continuously reinforced concrete pavement (CRCP), this report provides a means for determining the optimum time to overlay such pavements. Previously, determinations of remaining pavement life relied solely on engineering judgment. And while subjective experience can often lead to satisfactory solutions, a standardized procedure — such as that provided by this study — will allow more objective assessments and, hence, more uniform results.

To develop a new procedure for estimating remaining pavement life, we used a failure prediction model that uses punchouts as the major failure criterion. This model, later calibrated against CRC pavement data by the Center for Transportation Research, can be used to generate a failure curve for a given pavement. The failure curve describes the relationship between punchouts (failures) and equivalent single axle loads (ESALs). If a certain number of failures per mile (FPM) is specified as the indicator for a failed pavement, and if the current number of failures per mile is known, then the number of remaining ESALs the pavement will withstand can be determined from the failure curve. From the number of remaining ESALs, the amount of remaining pavement life can be calculated using an appropriate traffic model.

The procedure summarized above was incorporated into the PAVLIF computer program. Using the program to run sample problems involving actual field data, we obtained results that compared favorably with actual observations. In one sample, PAVLIF predicted 6 years of remaining life for a CRC pavement section in Bowie County, Texas. Another study of this same pavement section estimated a remaining life of 7 years, based on an extrapolation of the pavement's actual failure curve. Although PAVLIF produced favorable results for this sample (and for the other samples in this report), the program is calibrated only for certain types of pavement. Further testing and calibration of the program are required to expand its usefulness.

CHAPTER 1. INTRODUCTION

Continuously reinforced concrete (CRC) pavements deteriorate as a result of inappropriate construction, harsh environments, and heavy traffic loads. Overlaying the pavement surface can slow the deterioration process by reducing the stress level and/or by eliminating most or all of the dynamic loading on the pavement — though such action requires that pavement engineers know when precisely to overlay (Ref 3). In an effort to determine optimum overlay schedules, engineers have classified pavement life according to the three stages illustrated in Figure 1.1. The first stage (Stage I) is the early-age stage, the second (Stage II) is the stable stage, and the last (Stage III) represents the fatigue stage of the pavement's life (all measured with respect to mean crack spacing). Because pavements whose service life falls within Stage III fail relatively quickly, an overlay must be performed before the pavement enters this stage of its life (Ref 3). To estimate when this last stage will occur and, thus, when to overlay, it must be known how much longer the pavement will last without the overlay. In other words, the remaining life of the pavement must be known in order to determine the optimum overlay time.

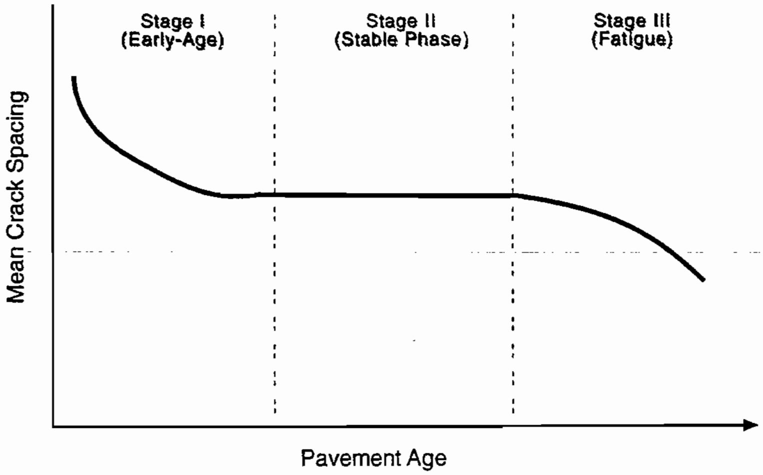


Figure 1.1 Stages in the life of a CRC pavement (Ref 3)

In the absence of standard methods for estimating the remaining life of a CRC pavement, pavement engineers have been expected to estimate remaining pavement life using only engineering judgment. While such subjective experience can often lead to satisfactory solutions, a standardized procedure would allow more objective assessments and, hence, more uniform results.

BACKGROUND

Pavement Failure

A pavement's life ends when it fails. In a previous study (Ref 6), two major modes of CRC pavement failure were identified: functional failure and structural failure. Functional failure occurs when a pavement is no longer able to provide acceptable ride quality. Structural failure relates to a breakdown of one or more of the pavement's structural components. Functional failure is often measured by the present serviceability index (PSI), a measure of the pavement's roughness. However, the PSI of a pavement does not necessarily indicate pavement distress and, thus, cannot always indicate when to rehabilitate a pavement. Therefore, another indicator, the distress index, is used to assess the structural condition of the pavement (Ref 4).

The primary variable in the distress index is the number of punchouts. A severe punchout is a structural failure that occurs when a piece of pavement separates from the main body and is displaced downward by traffic loads. Punchouts are most commonly formed by the intersection of two closely spaced transverse cracks, a longitudinal crack, and the pavement edge. This type of punchout is shown in Figure 1.2. Usually, punchouts are repaired by asphalt or portland cement concrete patches. Therefore, a useful indication of pavement distress can be obtained by adding the number of severe punchouts to the number of patches to give a composite indicator termed *failures*, often expressed in terms of failures per mile (FPM). In any case, when a sufficient number of failures occur, the pavement is considered to have failed. This type of failure caused by repeated stresses over a period of time is known as fatigue failure. In practice, 10 to 15 FPM indicate that structural failure has occurred (i.e., the pavement is at the end of its fatigue stage).

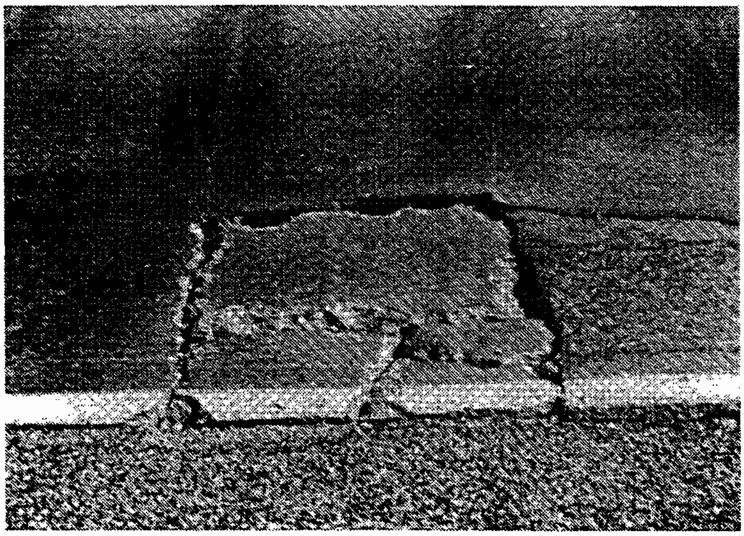


Figure 1.2 Punchout formed by two closely spaced transverse cracks, one longitudinal crack, and the pavement edge

Effects of Overlays on Pavement Performance

Overlaying a deteriorating CRC pavement can cost-effectively extend a pavement's useful life; that is, an overlay can restore the initial ride quality that has been lost through service and can reduce dynamic loading effects (which, if left untreated, would accelerate fatigue and reduce the remaining life of the pavement). In a recent CTR study (Ref 3), a CRC pavement overlaid with asphalt concrete pavement (ACP) in Bowie County, Texas, was investigated to determine the effects of the overlay. When the overlay to the 14-year-old pavement had been in place for 6 years, it was removed and analyzed to determine the effects of the overlay on the underlying CRC pavement. Prior to the overlay, the pavement section showed an average of ten failures per mile. Removing the ACP overlay revealed little evidence of additional punchouts. The results of the study suggest that overlays decrease the failure rate significantly. In this case, based on an extrapolation of the pre-overlay failure curve, the ACP overlay extended the effective life of the pavement by at least 6 years.

OBJECTIVES

The objective of this study was to develop a relatively simple method for estimating the remaining life of CRC pavements. Such a method would provide pavement engineers with a reasonably accurate estimate of when to overlay. Please note, however, that this method does not provide data or procedures for determining optimum thicknesses for overlays or any other design parameters. Such information must be determined by using other design procedures for bonded concrete overlays (BCO) or unbonded concrete overlays.

CHAPTER 2. PREVIOUS WORK

DEVELOPMENT OF A PUNCHOUT PREDICTION MODEL

The long-term performance of a pavement strongly depends on its early-age behavior. Early-age CRC pavement behavior depends on such factors as slab thickness, subbase stiffness, transverse crack spacing, and crack width. However, for given wheel loads, CRC pavement behavior can be considered to depend primarily on transverse crack spacing (Ref 6). Therefore, it is important to understand the relationship between early-age transverse crack spacing and pavement life. As discussed earlier, the end of a pavement's life is indicated by the accumulation of a given number of punchouts. The rate at which a pavement gains these structural failures depends on the magnitude of the fatigue stresses it experiences. These fatigue stresses — and, consequently, the pavement fatigue life — depend on transverse crack spacing (Ref 4).

A previous study (Ref 6) developed the CRCP-5 computer program for estimating the early-age transverse crack spacing of a CRC pavement and for predicting the relationship between punchouts per mile and accumulated equivalent single axle loads (ESALs). As stated earlier, punchouts occur when longitudinal cracks cross transverse cracks. Therefore, predicting punchouts is equivalent to predicting longitudinal cracks (Ref 6). To estimate the probability of longitudinal cracks (and therefore the probability of punchouts), the following procedure was used in the CRCP-5 program:

(1) Divide crack spacings into groups, such as 0-1 ft, 1-2 ft, etc.;
(2) Estimate the number of cracks per mile for each spacing group;
(3) Calculate the wheel load stresses in the transverse direction;
(4) For each wheel load stress, calculate the number of ESALs corresponding to various probabilities of fatigue failure;
(5) Calculate the number of punchouts for various numbers of ESALs by multiplying the number of cracks per mile by the corresponding probability of failure; and
(6) Complete steps (2) through (5) for the all crack spacing ranges and add the total number of punchouts.

The generally accepted form of the fatigue failure model used in step (4) to calculate ESALs is that used by Suh et al. (Ref 4):

$$N = A(f/s)^B \tag{2.1}$$

where:

N = number of load applications,

f = flexural strength,

s = flexural stress,

A = first fatigue coefficient, and

B = second fatigue coefficient (widely used value is 4.0).

The magnitude of the fatigue stress acting on the pavement is equivalent to the flexural stress in Eq 2.1. The word *flexural* is used to describe the types of forces that typically act on a pavement. Pavement is flexed, or bent, by traffic loads, with the resulting stresses on the pavement being part tension and part compression; these two stresses acting together represent flexural stress.

CALIBRATION OF THE PUNCHOUT PREDICTION MODEL

When the punchout prediction model was originally employed in CRCP-5, the first fatigue coefficient (A in Eq 2.1) was not calibrated. However, Suh (Ref 4) generated long-term distress curves with various reliabilities and swelling conditions for CRCP in terms of the number of failures using the Rigid Pavement Database at the Center for Transportation Research (Ref 1). Using these distress curves, the failure prediction model in the CRCP-5 computer program was calibrated for limestone (LS) and for siliceous river gravel (SRG). Figure 2.1 illustrates the failure curves for both aggregate types under different swelling conditions. Figure 2.2 shows an example of a failure curve for SRG with different reliabilities, while Figure 2.3 shows the same relationship for limestone.

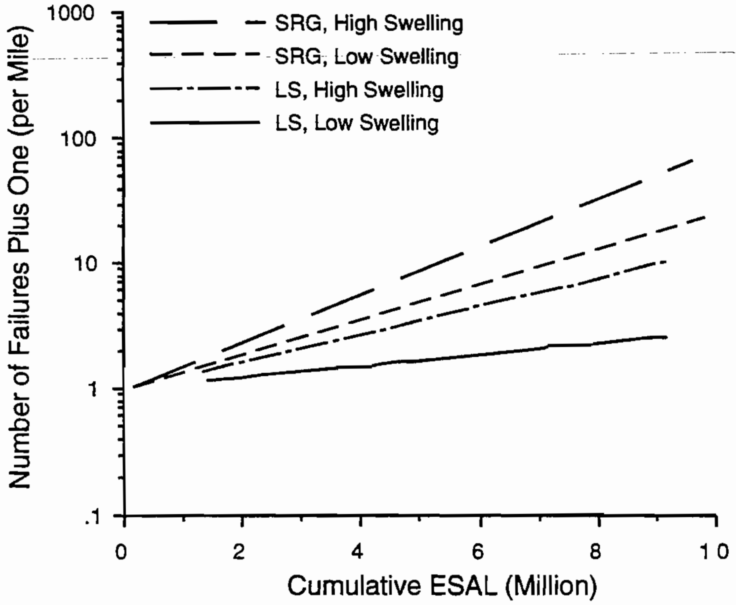


Figure 2.1 Mean failure curves for different coarse aggregate types and swelling conditions (1 mile=1.61 km) (Ref 4)

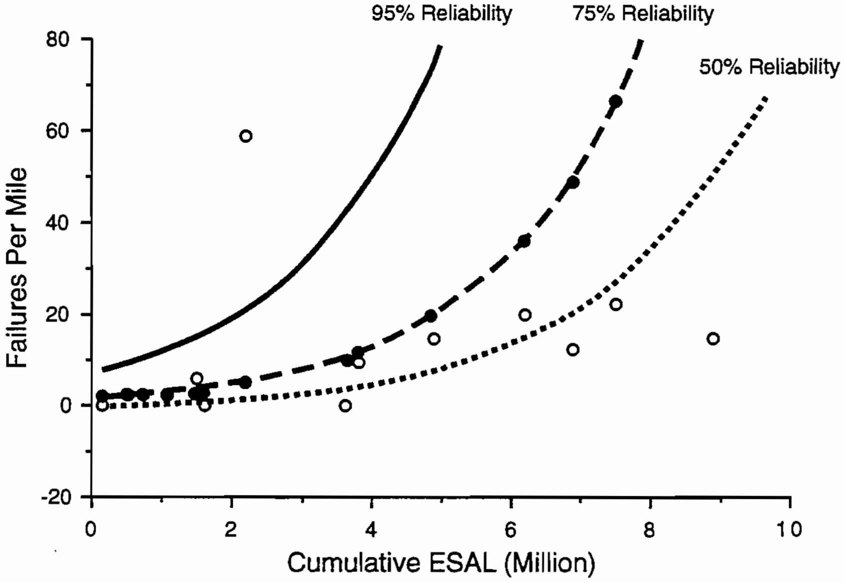


Figure 2.2 Failure curves with various reliabilities (SRG, High Swelling) (1 mile=1.61 km) (Ref 4)

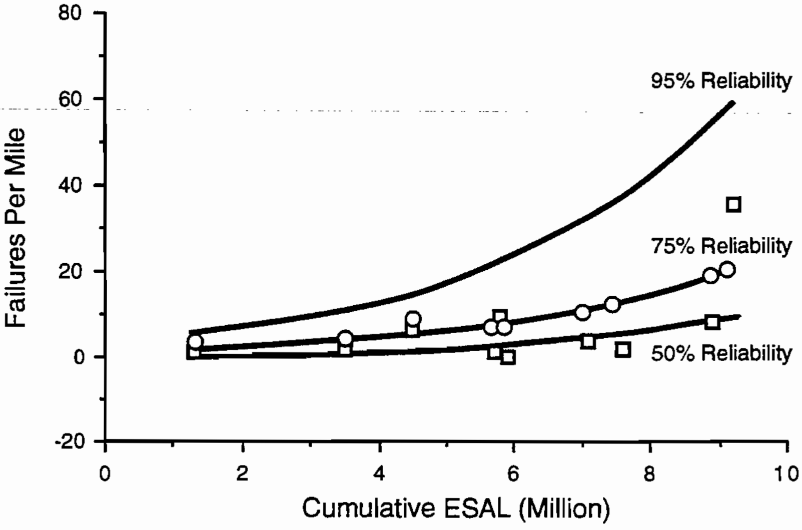


Figure 2.3 Failure curves with various reliabilities (LS, High Swelling) (1 mile=1.61 km) (Ref 4)

Based on the fatigue curves, the first fatigue coefficient (A) was calibrated for limestone and SRG for high and low swelling conditions. The coefficient A was varied until values were found that reproduced the best fits to the actual failure curves. It was found that using a coefficient of variance (CV) of 30 percent resulted in close fits in most cases (Ref 4). The A coefficient values are given in Figure 2.4.

Reliability / Swelling Condition / Coarse Agg. Type	SRG		LS	
	Yes	No	Yes	No
95 %	1.4	2.0	1.8	2.6
75 %	2.4	3.1	2.5	3.7
50 %	3.1	4.2	3.1	4.8

Figure 2.4 Coefficient A values that result in best fit to actual failure curves (Unit: million, CV: 30%) (Ref 4)

DEVELOPMENT OF TRAFFIC MODELS

We also used the Rigid Pavement Database to develop traffic regression models for CRC pavements (Ref 1). Four traffic models were developed for Interstate and U.S. highways from the database using data that were obtained mostly from sections of 20.3-cm (8-inch) CRC pavement. Therefore, all of the traffic models are calibrated for Interstate (IH) and federal (U.S.) highways in Texas having a thickness of 20.3 cm (8 inches). Table 2.1 describes all the variables used in these models; brief descriptions of the models are provided below.

Table 2.1 Description of variables for all models

Variable	Description
ADT	Average Daily Traffic
AADT	Annual Average Daily Traffic
PTRUCK	Percent Trucks
YR	Year Data Collected
HT	Highway Type (IH, U.S.)
PTAND	Percent Tandem Axles
DIST	SDHPT* District
ATHWL	Avg. 10 Heaviest Wheel Loads
ESAL2	Equivalent Single Axle Loads (both directions)
ADT85	1985 AADT
G	AADT Growth Rate

*State Department of Highways and Public Transportation, now Texas Department of Transportation (TxDOT)

Model 1

$$ESAL2=H1+225.02(ATHWL)+H2(ADT)+4.153(ADTPTRUCK)+H3(YR)+H4\ln(ADT) +2{,}202.66(PTAND)+957{,}460$$

where:

H1 = -4,986,000 for IH; 0 for U.S. Highway,
H2 = 7.0396 for IH; 69.78 for U.S. Highway,
H3 = 24,245.1 for IH; 11,072.2 for U.S. Highway, and
H4 = -62,238 for IH; -579,338 for U.S. Highway.

Of the four models, this model has the best fit to field data, with an R^2 of 0.95. However, the model uses truck data that were unavailable for most of the test sections at the time the model was developed (Ref 1). The scattergram for this regression model is shown in Figure 2.5.

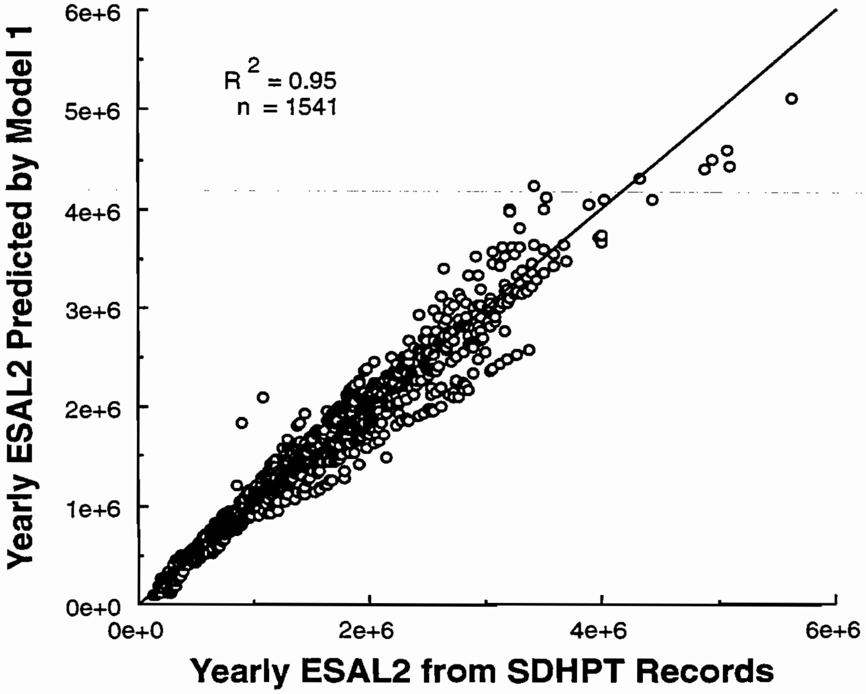


Figure 2.5 Scattergram for Model 1 (Ref 1) (Note: SDHPT, State Department of Highways and Public Transportation, now Texas Department of Transportation, or TxDOT)

Model 2

ESAL2 = H1+H2+12,037(YR)+H3(ADT)+H4+H5(YR)+H6(YR)-433,658

where:

H1 = -3,499,293 for IH; 0 for U.S. Highway,

H2 = 176,955 for District 1; -1,978,928 for District 3; -2,580,881 for District 4; -4,041,762 for District 9; -2,034,159 for District 13; 1,102,543 for District 19; 343,147 for District 20; 0 for District 24,

H3 = 114.23 for District 1; 80.46 for District 3; 33.02 for District 4; 53.37 for District 9; 70.91 for District 13; 63.36 for District 19; 150.09 for District 20; 183.04 for District 24,

H4 = 786,459 for IH Sections in District 1; 567,627 for IH Sections in District 13; 0 for all other sections,

H5 = 44,119 for IH; 0 for U.S. Highway, and

H6 = -12,172 for District 1; 26,769 for District 3; 41,802 for District 4; 62,560 for District 9; 22,873 for District 13; -7,951 for District 19; -16,829 for District 20; 0 for District 24.

Model 2 gives a fit with an R^2 of 0.91, as shown in the scattergram in Figure 2.6. This model was calibrated using only eight districts; therefore, predicting ESAL2 for other districts requires substituting values from known districts with similar trucking profiles (Ref 1).

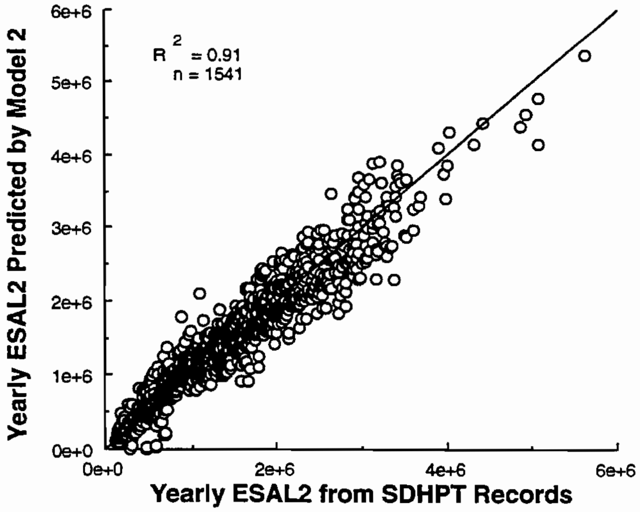


Figure 2.6 Scattergram for Model 2 (Ref 1) (Note: SDHPT, State Department of Highways and Public Transportation, now Texas Department of Transportation, or TxDOT)

Model 3

$$\begin{aligned}ESAL2 = {} & 46{,}056(YR)+H1+1{,}198{,}183(G)+477(ADT85)+H2(YR)-9{,}084(YR)(G)\\ & 1.3895(YR)(ADT85)+H3(G)+H4(ADT85)-136(G)(ADT85) +\\ & YR(G)(ADT85)+H5(G)(ADT85)-5{,}966{,}144\end{aligned}$$

where:

H1 = -1,083,536 for IH; 0 for U.S. Highway,

H2 = 59,544 for IH; 0 for U.S. Highway,

H3 = -471,910 for IH; 0 for U.S. Highway,

H4 = -350 for IH; 0 for U.S. Highway, and

H5 = 61.16 for IH; 0 for U.S. Highway.

As shown in Figure 2.7, Model 3 gives an R^2 value of 0.90.

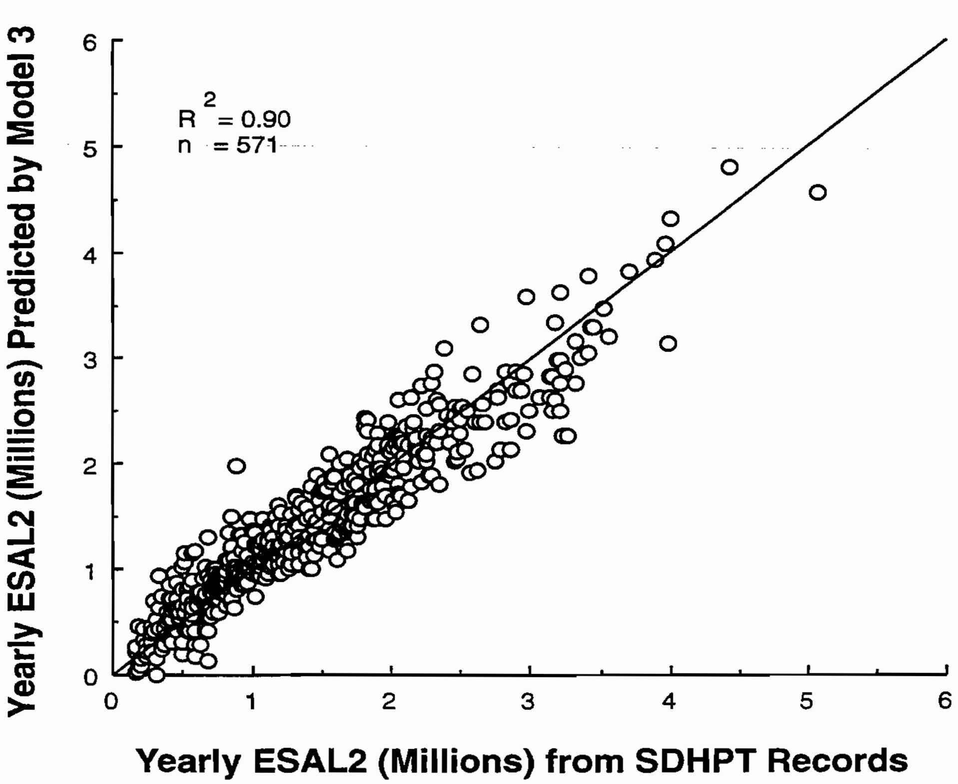


Figure 2.7 Scattergram for Model 3 (Ref 1) (Note: SDHPT, State Department of Highways and Public Transportation, now Texas Department of Transportation, or TxDOT)

Model 4

$$ESAL2 = 15{,}640(YR)-H1-205.19(ADT85)+H2(YR)+3.108(YR)(ADT85)-650{,}498$$

where:

$H1$ = 2,907,059 for IH; 0 for U.S. Highway, and
$H2$ = 44,723 for IH; 0 for U.S. Highway.

Model 4 gives an R^2 of 0.83. Although R^2 is relatively low, this model is the most convenient to use (i.e., it requires the least amount of variables). Its scattergram is shown in Figure 2.8.

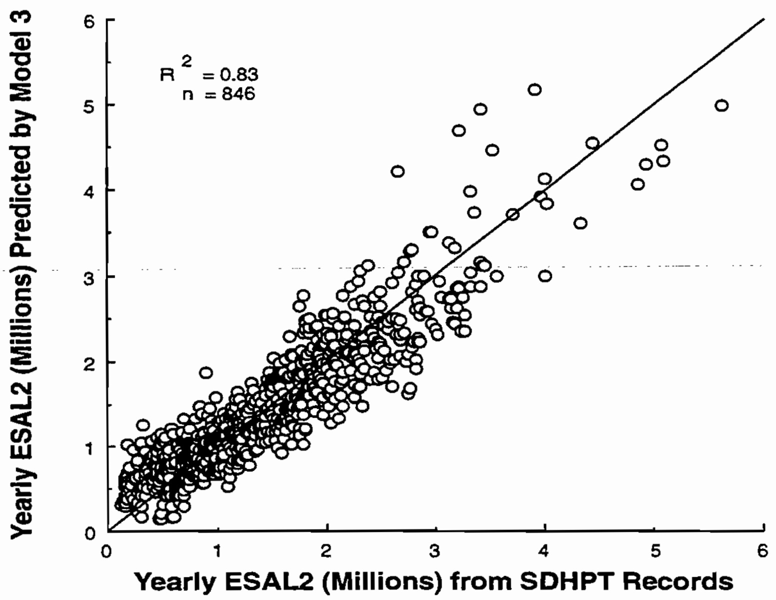


Figure 2.8 Scattergram for Model 4 (Ref 1) (Note: SDHPT, State Department of Highways and Public Transportation, now Texas Department of Transportation, or TxDOT)

All of the models used ADT85 as the reference point for traffic (since 1985 data were the most recent data available when the models were developed in 1986). If necessary, all models can be recalibrated using more recent ADT data.

CHAPTER 3. ESTIMATING PROCEDURE

By combining the previous research on failure prediction models and traffic models, we developed a procedure for estimating the remaining life of CRC pavements. The first step in this procedure is to estimate a failure curve for the pavement. The failure prediction model discussed in the previous chapter can be used to generate the failure curve for a given pavement. The model uses the actual early-age crack spacing distribution, pavement thickness, flexural strength, and swelling conditions to estimate the failure-versus-ESAL curve. If a certain number of failures per mile (FPM) is specified as the indicator for a failed pavement, and if the current number of failures per mile is known, then the number of remaining ESALs that the pavement will withstand can be determined from the failure curve, as shown in Figure 3.1. From the number of remaining ESALs, the amount of remaining pavement life in years can be calculated using one of the traffic models discussed earlier. The estimating procedure is summarized below.

(1) Determine the failure-vs.-ESAL relationship using the failure prediction model in Chapter 2.

(2) For a known current number of failures (severe punchouts and patches), estimate the current number of ESALs that the pavement has accumulated since its construction from the failure curve of (1), as shown in Figure 3.1.

(3) For a known failure criterion (15 FPM, for example), find the number of total ESALs that lead to structural failure of the pavement from the curve in step (1).

(4) Subtract the ESALs in (2) from the ESALs in (3); this is the remaining number of ESALs until pavement failure.

(5) Using a traffic model, translate the number of remaining ESALs into years of traffic; this is the remaining pavement life in years.

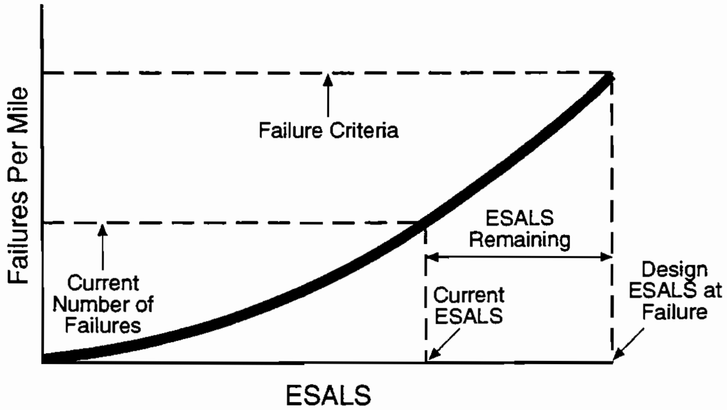


Figure 3.1 Example of estimating the current number of ESALs and remaining ESALs from the failure curve based on current failures per mile (1 mile=1.61 km)

CHAPTER 4. IMPLEMENTATION

THE PAVLIF PROGRAM

To incorporate the procedure described in the previous chapter into a convenient tool for estimating the remaining life of a CRC pavement, we developed the PAVLIF computer program for the IBM PC and its compatibles. Running PAVLIF requires, at a minimum, a VGA color monitor and 8.89 cm (3 1/2 inch) disk drive. Because the program uses only about 400K of memory, there are no special memory or storage requirements. The program will run in DOS 3.0 or better and does not require Microsoft Windows. The computer code for the program is listed in Appendix A. Figure 4.1 shows the title screen for PAVLIF, while Figure 4.2 illustrates the flow of the program.

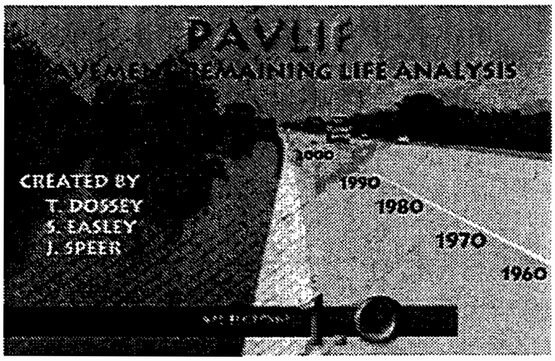


Figure 4.1 Title screen for the PAVLIF program

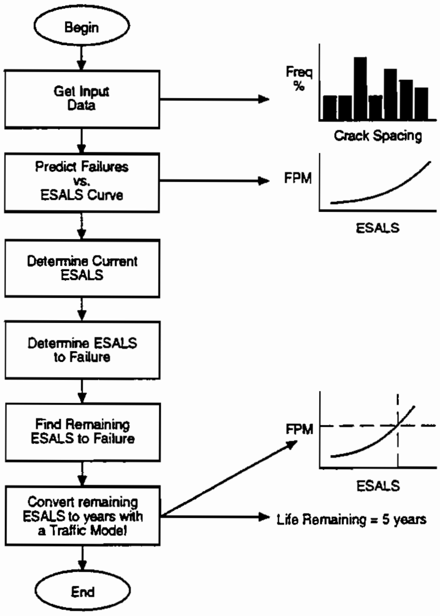
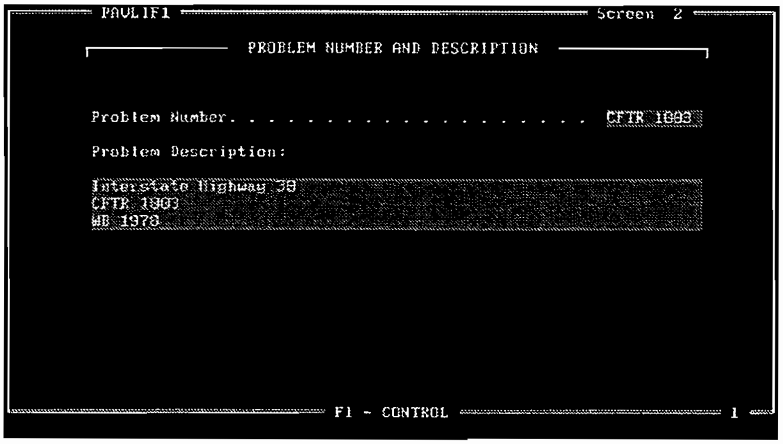


Figure 4.2 Logical flow of the PAVLIF computer program

Program Input

Information is entered into the program using a series of input screens. This section briefly describes each screen and discusses the data required by the program. The first input screen, illustrated in Figure 4.3, asks the user to identify a problem number and to provide a description of the problem. This information will show up on the output screen to help the user keep track of the work being done.



Problem Number. . . . . CFTR 1803

Problem Description:

Interstate Highway 39
CFTR 1803
WB 1978

Figure 4.3 Problem number and description screen

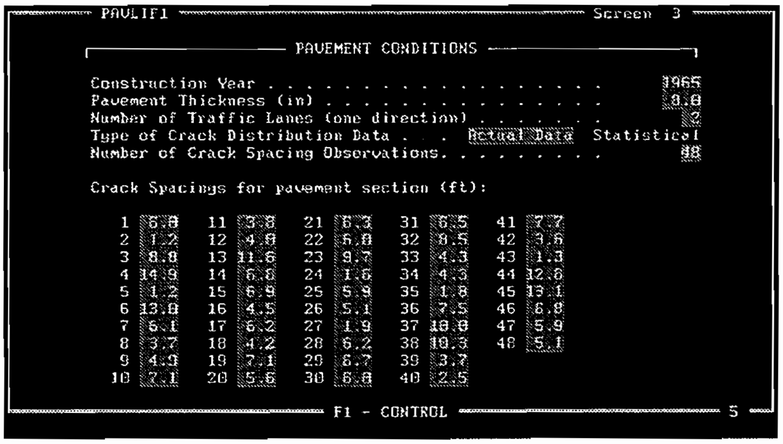
The next screen asks for data concerning the current condition of the pavement. As shown in Figure 4.4, the first variable listed is the construction year, with pavement thickness the next input variable. The pavement thickness, as stated earlier, is used in the failure prediction model (the failure prediction model is currently calibrated for 20.3-cm [8-inch] pavements only). The next variable is the number of traffic lanes, which is used in the traffic model. The ESAL2 calculation in the traffic model represents the ESALs for two directions. Thus, to calculate the ESALs in one direction (assuming symmetry) it is necessary to divide ESAL2 in half. In addition, a lane factor is used to estimate the cumulative ESALs for the right-hand lane. The ESALs for the right-hand lane are used in the program, since it is assumed that the right-hand lane receives the most truck traffic, causing it to deteriorate faster than the other lanes. Table 4.1 outlines the lane factors corresponding to different lane configurations. Equation 4.1 is used in the program to calculate the right-hand lane ESALs in one direction.

Table 4.1. Lane factors

Lanes (1-D)	Lane Factor
1	1
2	0.7
3	0.6
4	0.5

$$\text{ESALs} = (\text{ESAL2} / 2) \bullet \text{Lane Factor} \tag{4.1}$$

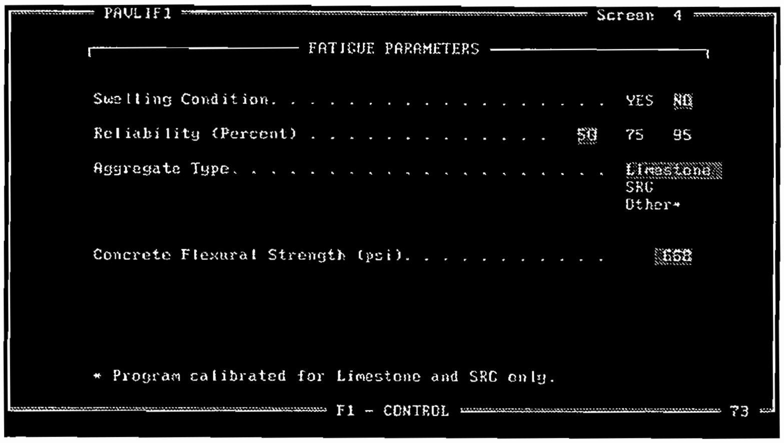
The next input item asks the user what type of crack spacing data are to be used in the program. If the actual crack spacing data are available, then the user inputs the number of observations and the program allocates an input field for each observation. If the actual data are not available but the mean and standard deviation of the crack spacing are known or can be approximated, then the user can choose the "Statistical" data option. If this option is chosen, input fields are allocated for the crack spacing mean and standard deviation. PAVLIF assumes the crack spacings are distributed normally.



```
PAVLIF1                                                           Screen  3
  ┌─────────────── PAVEMENT CONDITIONS ──────────────────────┐
  Construction Year . . . . . . . . . . . . . . . . .          1965
  Pavement Thickness (in) . . . . . . . . . . . . . .           8.0
  Number of Traffic Lanes (one direction) . . . . . .             2
  Type of Crack Distribution Data . . .  Actual Data  Statistical
  Number of Crack Spacing Observations. . . . . . . .            48

  Crack Spacings for pavement section (ft):

     1  6.0   11  3.8   21  6.3   31  6.5   41  7.7
     2  1.2   12  4.0   22  6.0   32  8.5   42  3.6
     3  8.0   13 11.6   23  9.7   33  4.3   43  1.3
     4 14.9   14  6.0   24  1.6   34  4.3   44 12.0
     5  1.2   15  6.9   25  5.9   35  1.8   45 13.1
     6 13.0   16  4.5   26  5.1   36  7.5   46  6.8
     7  6.1   17  6.2   27  1.9   37 10.0   47  5.9
     8  3.7   18  4.2   28  6.2   38 10.3   48  5.1
     9  4.9   19  7.1   29  6.7   39  3.7
    10  7.1   20  5.6   30  6.0   40  2.5
                          F1 - CONTROL                            5
```

Figure 4.4 Pavement data input screen

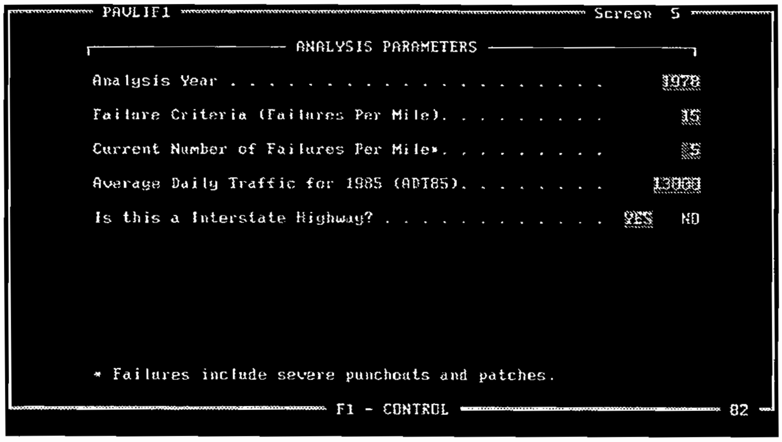
The next input screen, shown in Figure 4.5, concerns the fatigue characteristics of the pavement. The variables on this screen determine the value of the A coefficient of Eq 2.1. The A coefficient depends on swelling conditions, reliability, and aggregate type, as shown in Figure 2.4. The failure model is calibrated for limestone and SRG only. However, the "Other" option for aggregate type uses the average of the A coefficient values for SRG and limestone. The flexural strength is the last input field on this screen. Flexural strength is proportional to tensile strength, and therefore depends on aggregate type (Ref 2). The value for flexural strength is set according to the aggregate chosen, though this set value can be overridden by the user.



```
PAVLIF1                                              Screen 4

              FATIGUE PARAMETERS

Swelling Condition. . . . . . . . . . . . . . . . . .   YES  NO
Reliability (Percent) . . . . . . . . . . . . .  50   75   95
Aggregate Type. . . . . . . . . . . . . . . . . . . .   Limestone
                                                        SRC
                                                        Other*

Concrete Flexural Strength (psi). . . . . . . . . . .      650


* Program calibrated for Limestone and SRC only.
                        F1 - CONTROL                         73
```

Figure 4.5 Fatigue parameters screen

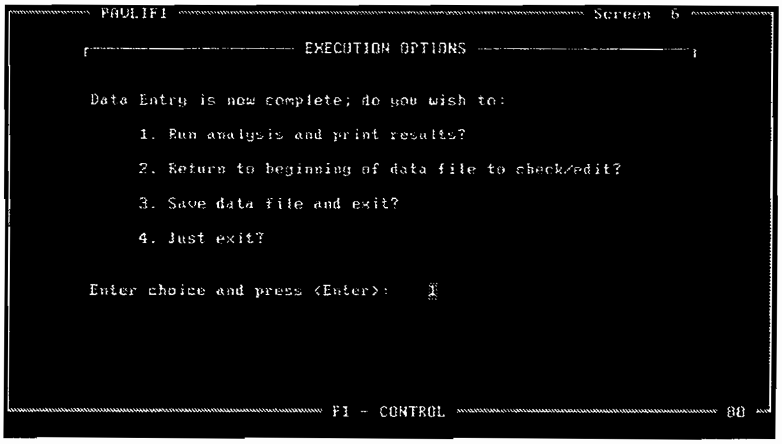
After the fatigue parameters are entered, the program advances to the next screen (Fig 4.6), which deals with the failure analysis variables. The first input field asks for the analysis year. The analysis year refers to the year during which the failure data were obtained. The next variable is the failure criterion — the number of failures per mile that constitute pavement failure. Failures in PAVLIF are defined as severe punchouts plus patches; typical values for the failure criterion range from 10 to 15 FPM. The third variable on this screen is the current number of failures that the pavement has accumulated during the time between its construction year and the analysis year. The next two variables, ADT85 and Highway Type, are for the traffic model. The PAVLIF program uses traffic Model 4 (described in Chapter 3). This model was used because it does not require the AADT growth rate (G in Models 1 and 3) — information that may be unavailable to the user.



```
PAVLIF1                                              Screen 5

              ANALYSIS PARAMETERS

Analysis Year . . . . . . . . . . . . . . . . . . . .     1978
Failure Criteria (Failures Per Mile). . . . . . . . .       15
Current Number of Failures Per Mile*. . . . . . . . .        5
Average Daily Traffic for 1985 (ADT85). . . . . . . .    13000
Is this a Interstate Highway? . . . . . . . . . . . .   YES  NO


* Failures include severe punchouts and patches.
                        F1 - CONTROL                         82
```

Figure 4.6 Input screen for failure analysis

Finally, after all data have been input, the last screen of the program, illustrated in Figure 4.7, offers five options. The user can save the data and run the problem, continue editing, or just exit the program. Option one is the default, which saves the input and runs the problem.

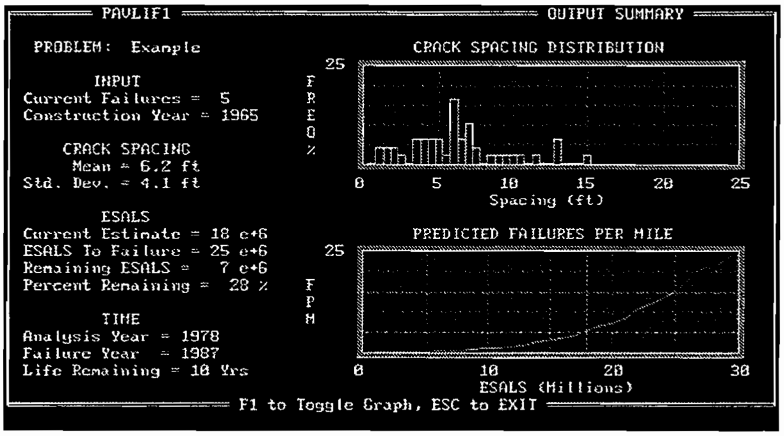


```
PAULIFI                                                    Screen 6

              EXECUTION OPTIONS

Data Entry is now complete; do you wish to:

     1. Run analysis and print results?

     2. Return to beginning of data file to check/edit?

     3. Save data file and exit?

     4. Just exit?

Enter choice and press <Enter>:

                              F1 - CONTROL                        80
```

Figure 4.7 Execution options

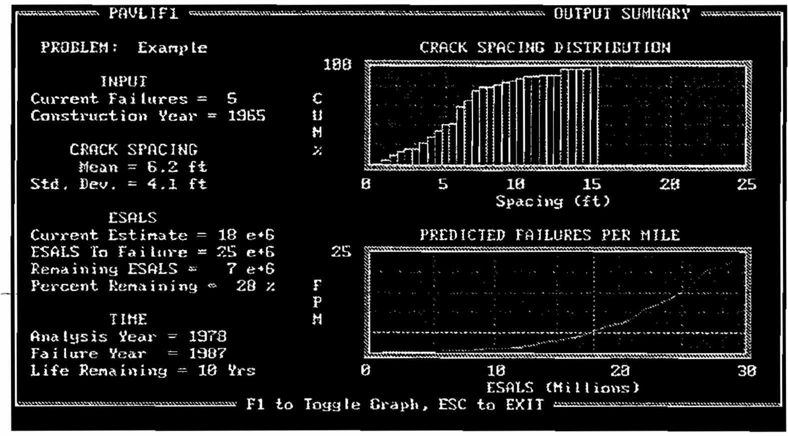
Program Output

The most important results generated by the program are summarized on an interactive, graphical output screen, shown in Figure 4.8. Two graphs are plotted on the right side of the screen. The top graph illustrates the crack spacing distribution. The bottom graph shows the relationship between failures and ESALs. Two sets of crosshairs on the bottom plot identify the current number of ESALs accumulated by the pavement (leftmost crosshairs) and the number of ESALs to pavement failure (rightmost crosshairs). The left side of the output summary screen provides information on the pavement characteristics, remaining ESALs, and remaining life of the pavement. As noted at the bottom of the output screen, the user can go back to the input screens by pressing <ESC> or can toggle between the individual and cumulative crack spacing distributions by pressing <F1>, as shown in Figure 4.9.



```
PAVLIF1                                              OUTPUT SUMMARY

 PROBLEM:  Example

       INPUT
Current Failures =  5
Construction Year = 1965

    CRACK SPACING
     Mean = 6.2 ft
Std. Dev. = 4.1 ft

        ESALS
Current Estimate = 18 e+6
ESALS To Failure = 25 e+6
Remaining ESALS =   7 e+6
Percent Remaining =  28 %

        TIME
Analysis Year = 1978
Failure Year  = 1987
Life Remaining = 10 Yrs

                 F1 to Toggle Graph, ESC to EXIT
```

Figure 4.8 The PAVLIF output summary screen



```
PAVLIF1                                              OUTPUT SUMMARY

 PROBLEM:  Example

       INPUT
Current Failures =  5
Construction Year = 1965

    CRACK SPACING
     Mean = 6.2 ft
Std. Dev. = 4.1 ft

        ESALS
Current Estimate = 18 e+6
ESALS To Failure = 25 e+6
Remaining ESALS =   7 e+6
Percent Remaining =  28 %

        TIME
Analysis Year = 1978
Failure Year  = 1987
Life Remaining = 10 Yrs

                 F1 to Toggle Graph, ESC to EXIT
```

Figure 4.9 PAVLIF output screen showing the cumulative crack spacing distribution

The user should exercise caution when using the PAVLIF program for the following reasons:

(1) The program assumes that the input crack spacing distribution represents the early-age cracking of the pavement.

(2) The models used in the method were calibrated primarily for 20.3-cm (8-inch) CRC pavements in Texas, with limestone or SRG aggregates only.

(3) The traffic models were calibrated from 1985 traffic data. The results produced by these relatively out-dated traffic data may not be as accurate as those produced by more current data.

EXAMPLE PROBLEMS

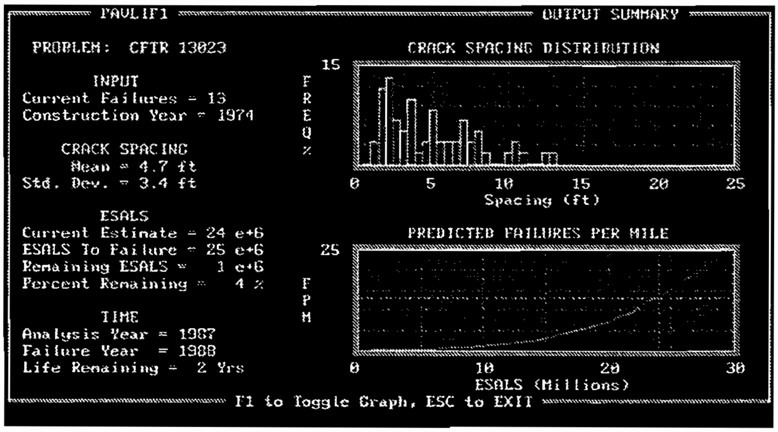
Three examples using actual field data are presented in this section. Data from the Rigid Pavement Database were extracted for these examples for Center for Transportation Research (CFTR) Sections 13023, 19019, and 1003. Appendix B includes a copy of the condition survey data for Section 19019, while Appendix C includes the crack spacing data for all three sections. The crack spacing data for the three sections were recorded in 1978.

Example 1: CFTR Section 13023

This two-lane, US highway pavement section was constructed in August 1974. It has a thickness of 20.3 cm (8 inches) and was made with an SRG aggregate. It has an asphalt-treated subbase, and the subgrade swelling conditions are low for this pavement section. The failure criterion in this example was set at 15 failures per mile (FPM).

It was assumed that the cracking data taken in 1978 for this Section were approximately its early-age (Stage I in Fig 1.1) crack spacing distribution. This was assumed for two reasons: First, at the time of the 1978 condition survey, the pavement was only 4 years old. Second, the condition survey showed there were very few minor punchouts, no severe punchouts, and no patches present in 1978, indicating very little pavement distress.

The analysis year used in this example was 1987. The condition survey from that year indicated the pavement had sustained an average of approximately 13 FPM. As shown in Figure 4.10, PAVLIF predicted a remaining pavement life of 2 years, with failure occurring in 1988. According to the database, the pavement was overlaid in August 1987. At the time of the overlay, it is likely that additional severe punchouts had occurred, because at the time of the 1987 condition survey there were approximately 160 minor punchouts per mile.



```
PAVLIF1                                    OUTPUT SUMMARY

 PROBLEM:  CFTR 13023

       INPUT
Current Failures = 13
Construction Year = 1974

    CRACK SPACING
     Mean = 4.7 ft
Std. Dev. = 3.4 ft

         ESALS
Current Estimate = 24 e+6
ESALS To Failure = 25 e+6
Remaining ESALS =   1 e+6
Percent Remaining =   4 %

         TIME
Analysis Year = 1987
Failure Year  = 1988
Life Remaining =  2 Yrs

              F1 to Toggle Graph, ESC to EXIT
```

Figure 4.10 Results for CFTR Section 13023

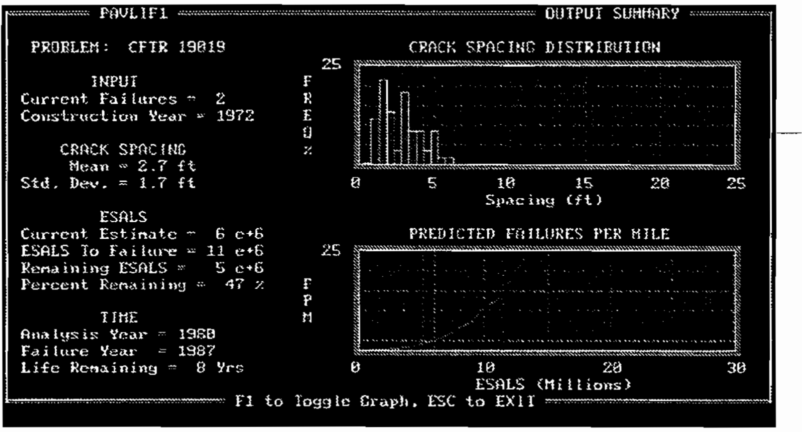
Example 2: CFTR Section 19019

This two-lane pavement section on IH-30 was constructed in May 1972. It has a thickness of 20.3 cm (8 inches). It was made with an SRG aggregate and has a cement-treated subbase. The subgrade swelling conditions are high for this pavement section.

This is the same pavement section discussed in Chapter 1. In the previous study that analyzed this section, the failure criterion was set at 10 FPM. In order to compare the results of the study with the results of the program, the failure criterion for this example was also set at 10 FPM.

The crack spacing data for this section were obtained 6 years after the pavement was constructed. The pavement was probably within its stable phase (Stage II) in 1978 because there were few minor punchouts, no severe punchouts, and one patch per mile.

The results of this example are illustrated in Figure 4.11. The analysis year was 1980, at which time two failures per mile had developed. The failure curve for this section is relatively steep, indicating rapid failure. The estimated remaining life was 6 years, with failure occurring in 1985. That means the total life of the pavement was estimated at 13 years (1972-1985). The study performed on this pavement section estimated a total life of 14 years (if there had been no overlay in 1982), based on the actual failure curve generated from the 1984 survey data (Ref 3). This means there was a good correlation between the program and actual results, even when the crack spacing data were taken from a later phase of pavement life (instead of the early-age phase).



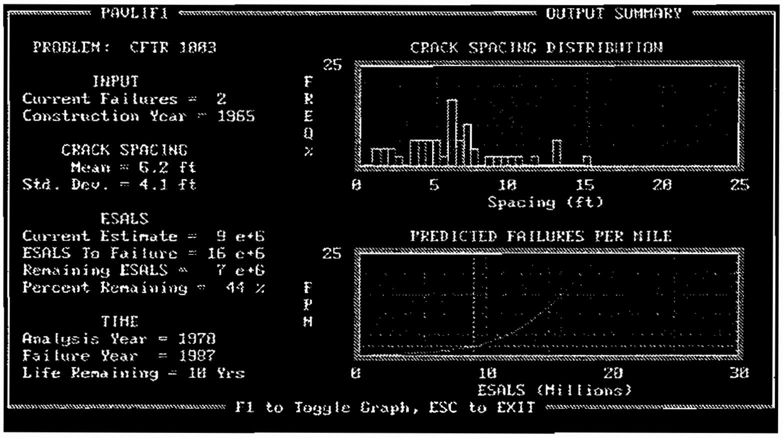
```
PAVLIF1                                                OUTPUT SUMMARY

 PROBLEM:  CFTR 19019

      INPUT
Current Failures =  2
Construction Year = 1972

    CRACK SPACING
      Mean = 2.7 ft
Std. Dev. = 1.7 ft

       ESALS
Current Estimate =  6 e+6
ESALS To Failure = 11 e+6
Remaining ESALS =   5 e+6
Percent Remaining =  47 %

       TIME
Analysis Year = 1980
Failure Year  = 1987
Life Remaining =  8 Yrs

                  F1 to Toggle Graph, ESC to EXIT
```

Figure 4.11 Results for CFTR Section 19019

Example 3: CFTR Section 1003

This two-lane IH-30 pavement section was constructed in January 1965. It has a thickness of 20.3 cm (8 inches) and was made with a limestone aggregate. It has a cement-treated subbase and the subgrade swelling conditions are high. In 1978, the year during which crack spacing data were obtained, this pavement section was probably in the stable portion of its life (Stage II in Fig 1.1), based on the condition survey from 1978, which showed about 2 FPM.

Figure 4.12 illustrates the results for this example. In 1978, the pavement showed an average of about 2 FPM. Based on the failure curve for this pavement, the program estimated a remaining life of 10 years, with failure occurring in 1987. In 1984, the pavement showed about eleven FPM. If the section had not been overlaid in August of 1986, it is likely that at least fifteen FPM would have occurred by 1987, based on the failure rate exhibited in 1984. Again, there was a good correlation between the program and actual condition survey data, though the cracking data were from Stage II in the pavement's life.



```
PAVLIF1                                          OUTPUT SUMMARY

 PROBLEM:  CFTR 1003

       INPUT
Current Failures =  2
Construction Year = 1965

     CRACK SPACING
      Mean = 6.2 ft
Std. Dev. = 4.1 ft

        ESALS
Current Estimate =  9 e+6
ESALS To Failure = 16 e+6
Remaining ESALS =   7 e+6
Percent Remaining =  44 %

        TIME
Analysis Year = 1978
Failure Year  = 1987
Life Remaining = 10 Yrs

                    F1 to Toggle Graph, ESC to EXIT
```

Figure 4.12 Results for CFTR Section 1003

Based on this and the preceding example, it is probably valid to use crack spacing data that are not from the early-age phase of the pavement's life — that is, stable phase data are acceptable. However, the data used should be taken from the earliest point within the stable phase. Data can be taken from the stable phase only if the crack spacing has not altered from its early-age phase to a degree that would significantly alter the results predicted by the failure model (i.e., the fatigue stage has not yet begun).

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to create a convenient tool to help pavement managers determine the optimum times to overlay. This chapter presents the conclusions and recommendations of this study.

The method for estimating the remaining life of continuously reinforced concrete (CRC) pavements was developed by combining previous research on failure prediction models and traffic models. The failure prediction models are used to generate an estimated failure curve for a given pavement. The failure curve describes the relationship between failures (severe punchouts and patches) and equivalent single axle loads (ESALs). If a given number of failures per mile (FPM) indicates a failed pavement, and if the current number of failures per mile is known, then the number of remaining ESALs the pavement will withstand can be determined from the failure curve. From the number of remaining ESALs, the amount of remaining pavement life in years can be calculated using a traffic model. The procedure summarized above was developed into the PAVLIF computer program.

CONCLUSIONS

The following are conclusions drawn from this study:

(1) Obtaining an accurate estimate of remaining pavement life depends heavily on the quality of the early-age crack spacing data. Again, long-term pavement performance has been shown to depend significantly on early-age cracking, and this method uses crack spacing as its main predictor.

(2) If early-age crack spacing data are not available, crack spacing data obtained during the stable portion of the pavement's life (Stage II) will work almost or equally as well. Determining if the pavement is in Stage II depends on the amount of distress it displays at the time. Little distress indicates the pavement is probably within Stage II and that the crack spacings have not changed substantially since the early-age portion of the pavement's life.

(3) Crack spacing data taken from a late point in the pavement's life cause PAVLIF to under-predict the remaining life.

(4) The failure prediction model is sensitive to the thickness of the pavement. This is due to the fact that it was calibrated from mostly 20.3-cm (8-inch) pavements. The user should exercise caution when analyzing pavements of other thicknesses.

(5) The total pavement life can be predicted by setting the current number of failures to zero and setting the analysis year equal to the construction year.

(6) The accuracy of the predictions of remaining life in years made by PAVLIF depends on the validity of the traffic model used. Again, PAVLIF uses traffic Model 4; this model may not be rigorous enough for some applications, and a more complex model may be necessary. A future version of the program will offer the user a better variety of traffic models.

(7) Developing and testing this estimating procedure would have been impossible without the Rigid Pavement Database. The importance of keeping long-term records of pavement performance is evident.

RECOMMENDATIONS

The following recommendations concern the continuing development of this method and the PAVLIF computer program.

(1) The program should be calibrated for aggregates other than limestone and SRG. Adding more aggregate types to the failure predictions would broaden the usefulness of the program.

(2) The failure prediction model is currently well-calibrated for 20.3-cm (8-inch) pavements only. The method should be calibrated for other thicknesses as well.

(3) The traffic models presented in this report were calibrated from 1985 traffic data. More recent traffic data should be gathered to update the traffic models.

(4) PAVLIF does not directly account for any effects caused by extreme weather conditions (i.e., droughts, abnormal precipitation and temperatures), although they were indirectly incorporated when the failure prediction model was calibrated using the Rigid Pavement Database. Environmental factors should be directly incorporated as variables to estimate their long-term impacts on pavement life.

REFERENCES

1. Dossey, T., and A. Weissmann, "A Continuously Reinforced Concrete Database," Research Report 472-6, Center for Transportation Research, The University of Texas at Austin, November 1989.
2. Dossey, T., and B. Frank McCullough, "Rationale for the Test Type in Quality Control of Rigid Pavement," Submitted for Publication, Transportation Review Board, Washington, D.C., 1995.
3. McCullough, B. F., T. Dossey, Jose Weissmann, and Yoon-Ho Cho, "A Case Study of Overlay Performance on CRCP Pavement Located on IH-30, Bowie County," Research Report 1342-1, Center for Transportation Research, The University of Texas at Austin, February 1994.
4. Suh, Young-Chan, and B. Frank McCullough, "Early Age Behavior of Continuously Reinforced Concrete Pavement and Calibration of the Failure Prediction Model in the CRCP-7 Computer Program," Research Report 1244-3, Center for Transportation Research, The University of Texas at Austin, March 1992.
5. Texas Department of Transportation, "Pavement Management Information System Rater's Manual," TxDOT, May 1992.
6. Won, M. C., "A Mechanistic Analysis of Continuously Reinforced Concrete Pavement Considering Material Characteristics, Variability, and Fatigue," Research Report 1169-2, Center for Transportation Research, The University of Texas at Austin, March 1991.

APPENDIX A
PAVLIF COMPUTER SOURCE CODE

```
REM**********************************************************************
REM*
REM*  PROGRAM PAVLIF1 - Version 1.0, October 1994
REM*  Center for Transportation Research
REM*  University of Texas at Austin
REM*  Programmed by Terry Dossey, Steve Easley
REM*  Copyright 1994 - All rights reserved
REM*
REM**********************************************************************
REM
 DIM f(160, 7), FF(30), dat$(160), a(160)
 DIM chem2p(50)
 DIM x(160): REM Temporary storage
 DIM ft(9), fc(9), em(9), zz(9), sactc(30): REM Default 28-day concrete properties
 DIM FTC(3, 8), FCC(3, 8), EMC(3, 8), ZZC(3, 8): REM Concrete prop. coefficients
 DIM CPX(3001): REM for rannor
REM**************** Define Base 10 Log function ***********************
 DEF FNlog10 (x1) = LOG(x1) / LOG(10)
REM**************** SOME HANDY CONSTANTS ******************************
 bl$ = STRING$(80, " "): REM 80 Blanks
 ab$ = " abcdefghijklmnopqrstuvwxyz": ab$ = ab$ + UCASE$(ab$)
 ab$ = ab$ + "'!@#$%^&*()-_+=/?:;<>.,[]\{ }|0123456789": REM Valid alphanumerics
 NU$ = "0123456789.+-": REM Valid numeric digits
 df$ = "PAVLIF1.DAT":     REM Default save file name
 openflg = 0
REM**************** TRAP ALL ERRORS ***********************************
 ON ERROR GOTO 99000: REM ERROR HANDLER
 SCREEN 1
 GOSUB 95000: REM Initialize field data
 REM ************* MAIN PROCESS ****************************************
1  fin = 0: SCREEN 1: WIDTH 80: SCREEN 0: COLOR 15, 1, 8: CLS
 REM ----- Start w/screen 2, field 1 -----------------------
 fx = 1: SCR = 2: C = 1: S4 = 1: S3 = 1: GOSUB 12000: LOCATE f(1, 1), f(1, 2), 1, 0, 7
 REM ---- CALL INPUT SUBROUTINE ---------------------------
2  GOSUB 90300: REM START
 REM ************ INPUT FINISHED, PERFORM EXECUTION CHOICE *************
 CHOICE = VAL(dat$(88))
 IF CHOICE = 4 THEN COLOR 15, 8, 8: CLS : END:   REM User abort
 IF CHOICE = 2 THEN GOTO 1:         REM Check /Edit
 REM ----- Save worksheet on disk - (Choice 1 or 3) -----------
 GOSUB 93000: IF ER = 0 THEN GOTO 3: REM Test for disk error
 REM ----- Worksheet not saved, return to last screen ---------
 C = 1: fx = 88: SCR = 6:  COLOR 15, 1, 8: GOSUB 16000:
 LOCATE f(88, 1), f(88, 2), 1: GOTO 2
```

```
3 IF CHOICE = 3 THEN COLOR 15, 8, 8: CLS : END:    REM Save file & Exit
  REM ----- Choice 1 - Run Analysis and print results --------
 COLOR 15, 8, 8: CLS : GOTO 80000: END: REM goto remlife prog
11000 REM*****************  Screen 1  ********************************
    RETURN
11500 REM****** SUB TO PRINT BLOCK LETTERS *************
     LOCATE x, Y: L = LEN(a$): FOR i = 1 TO L: x$ = MID$(a$, i, 1)
     IF x$ = "*" THEN x$ = CHR$(206)
     PRINT x$; : NEXT:  x = x + 1: RETURN
     END
12000 REM************* SCREEN 2 SUBROUTINE *****************
     IF C = 0 THEN GOTO 12035
    REM --- PRINT TITLES -------
     SCR = 2: x$ = " PROBLEM NUMBER AND DESCRIPTION "
     GOSUB 90200: REM Screen Header
     lm = 10: r = 7: LL = 55: x$ = "Problem Number": GOSUB 90600
     r1 = 7: r2 = 7: c1 = 62: c2 = 65: GOSUB 90700
     LOCATE 9, lm: PRINT "Problem Description:"
12035 REM --- UPDATE FIELDS ----
     f1 = 1: f2 = 4: GOSUB 94800: REM Field update sub
     RETURN
13000 REM************ SCREEN 3 SUBROUTINE  *******************
     IF C = 0 THEN GOTO 13055
     REM --- PRINT TITLES ----
     x$ = "PAVEMENT CONDITIONS": GOSUB 90200: REM ------ Screen Header --------
     LL = 55: lm = 10
     x$ = "Construction Year": r = 5: GOSUB 90600
     x$ = "Pavement Thickness (in)": r = 6: GOSUB 90600
     x$ = "Number of Traffic Lanes (one direction)": r = 7: GOSUB 90600
     x$ = "Type of Crack Distribution Data": r = 8: GOSUB 90600
     r1 = 8: r2 = 8: c1 = 48: c2 = 70: GOSUB 90700
     f1 = 5: f2 = 7: GOSUB 94800: REM Update all fields on screen 3
13055 FOR i = 10 TO 72: a(i) = -1: NEXT i
     IF a(9) = 2 THEN GOSUB 13070
     IF a(8) = 2 THEN GOSUB 13060
     f1 = 8: f2 = 72: GOSUB 94800: REM Update all fields on screen 3
     IF a(9) = 2 THEN f1 = 10: f2 = 10: GOSUB 94800: REM repair field 10
     RETURN
13050 REM ---- Subroutine to number the CS fields -------------------
     FOR i = 0 TO 5: FOR J = 1 TO 10: d = i * 10 + J: d$ = STR$(d): IF d < 10 THEN d$ = " " + d$
     IF d > VAL(dat$(12)) THEN d$ = "   "
     LOCATE 12 + J, 11 + 10 * i: PRINT d$: NEXT: NEXT
     RETURN
13060 REM ---- Subroutine to activate CS Fields
```

```
    a(12) = 1
    x$ = "Number of Crack Spacing Observations": r = 9: GOSUB 90600
    FOR J = 13 TO 72: a(J) = 1: NEXT J
    FOR J = (13 + VAL(dat$(12))) TO 72: a(J) = -1: NEXT J
    GOSUB 13050: REM number the CS fields
    LOCATE 11, 10: PRINT "Crack Spacings for pavement section (ft): "
    r1 = 10: r2 = 10: c1 = 5: c2 = 75: GOSUB 90700
    RETURN
13070 REM ---- Subroutine to activate Stat fields
    a(11) = 1: a(10) = 1
    FOR i = 0 TO 5: FOR J = 1 TO 10: d$ = "   "
    LOCATE 12 + J, 11 + 10 * i: PRINT d$: NEXT: NEXT
    x$ = "Mean Crack Spacing (ft)": r = 9: GOSUB 90600
    x$ = "Crack Spacing Standard Deviation (ft)": r = 10: GOSUB 90600
    r1 = 11: r2 = 11: c1 = 5: c2 = 70: GOSUB 90700
    RETURN
14000 REM************ SCREEN 4 SUBROUTINE ***************************
    IF C = 0 THEN GOTO 14055
   REM ------ PRINT TITLES ----------------------------------------
    x$ = "FATIGUE PARAMETERS": GOSUB 90200: REM Draw Screen box
    LL = 55: lm = 10
    r = 6: x$ = "Swelling Condition": GOSUB 90600
    r = 8: x$ = "Reliability (Percent)":  GOSUB 90600
    r1 = 8: r2 = 8: c1 = 58: c2 = 65: GOSUB 90700
    r = 10: x$ = "Aggregate Type": GOSUB 90600
    r = 15: x$ = "Concrete Flexural Strength (psi)": GOSUB 90600
    LOCATE 22, 10: PRINT "* Program calibrated for Limestone and SRG only."
14055 IF z = 1 AND fx > 77 AND fx < 81 AND a(80) = 2 AND openflg = 0 THEN dat$(81) = STR$(-19.236 + 1.5915 * 444)
    IF z = 1 AND fx > 77 AND fx < 81 AND a(79) = 2 AND openflg = 0 THEN dat$(81) = STR$(-19.236 + 1.5915 * 455)
    IF z = 1 AND fx > 77 AND fx < 81 AND a(78) = 2 AND openflg = 0 THEN dat$(81) = STR$(-19.236 + 1.5915 * 432)
    f1 = 73: f2 = 81: GOSUB 94800
    RETURN
15000 REM******************* SCREEN 5 SUBROUTINE ********** 22 - 23 ************
    IF C = 0 THEN GOTO 15050
    REM ---- Analysis Parameters
    x$ = "ANALYSIS PARAMETERS": GOSUB 90200
    LL = 55: lm = 10
    r = 5: x$ = "Analysis Year": GOSUB 90600
    r = 7: x$ = "Failure Criteria (Failures Per Mile)": GOSUB 90600
    r = 9: x$ = "Current Number of Failures Per Mile*": GOSUB 90600
    LOCATE 22, 10: PRINT "* Failures include severe punchouts and patches."
    r = 11: x$ = "Average Daily Traffic for 1985 (ADT85)": GOSUB 90600
    r = 13: x$ = "Is this a Interstate Highway?": GOSUB 90600
    REM******* volatile fields ***********************************
```

```
15050 f1 = 82: f2 = 87: GOSUB 94800: REM Update non-volatile fields
    RETURN
16000 REM************* SCREEN 6 - EXECUTION OPTIONS ********************
    REM ----- Non-volatile screen data -----------------------------
    x$ = "EXECUTION OPTIONS": GOSUB 90200
    LOCATE 6, 10: PRINT "Data Entry is now complete; do you wish to:"
    LOCATE 8, 15: PRINT "1. Run analysis and print results?"
    LOCATE 10, 15: PRINT "2. Return to beginning of data file to check/edit?"
    LOCATE 12, 15: PRINT "3. Save data file and exit?"
    LOCATE 14, 15: PRINT "4. Just exit?"
    LOCATE 17, 10: PRINT "Enter choice and press <Enter>:"
    f1 = 88: f2 = 88: GOSUB 94800: REM Update field
20200 REM ----- Volatile screen data --------
    RETURN

    REM*******************************************************************
    REM*          GENERAL SUBROUTINES                              *
    REM*******************************************************************
90000 REM******* Get keypress, put into A$ *********************************
    a$ = INKEY$: IF a$ = "" THEN GOTO 90000
     n = LEN(a$): a = ASC(LEFT$(a$, 1)): B = ASC(RIGHT$(a$, 1))
    RETURN
90100 REM******* PRESS ANY KEY TO CONTINUE SUB *******
    LOCATE 24, 22: PRINT "Press (Almost) Any Key to Continue ...";
    GOSUB 90000: RETURN

90200 REM******* GENERAL SCREEN HEADER SUB ******************
    REM -- scr is screen number, x$ is title
    CLS : B$ = STRING$(8, 205): a$ = STR$(SCR)
    PRINT CHR$(213); B$; " PAVLIF1 "; STRING$(42, 205); " Screen ";
    B2$ = B$: IF SCR > 9 THEN B2$ = LEFT$(B$, 7)
    PRINT a$; " "; B2$; CHR$(184)
    FOR i = 1 TO 22: PRINT CHR$(179); TAB(80); CHR$(179): NEXT
    PRINT CHR$(212); STRING$(32, 205); " F1 - CONTROL "; STRING$(32, 205); CHR$(190);
    LOCATE 3, 9: a = INT((60 - LEN(x$)) / 2): B$ = STRING$(a, 196)
    PRINT CHR$(218); B$; " "; x$; " "; B$ + CHR$(196); CHR$(191)
    RETURN
90300 REM****** SCREEN INPUT SUBROUTINE *********************************
    REM FX = Current field number
    REM ----- Show Field Number in Lower Right Screen Corner  -----------
    zz1 = CSRLIN: zz2 = POS(0): LOCATE 24, 75: PRINT fx; : LOCATE zz1, zz2
    REM ----- Get keypress and ASCII code -----------------------
90320 z = 0: GOSUB 90000: REM Wait for keypress
    REM ------ If ENTER pressed on toggle field, select field -------
```

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    IF (a = 32 OR a = 13) AND f(fx, 4) = 2 THEN z = 1: GOSUB 92300: SOUND 2000, .2: GOTO 90300
    REM ----- If movement key, perform movement ------------------
    GOSUB 91100: REM Check for movement key (tab, arrow, etc)
    REM ---- Perform movement, check for end of entry -------
    IF x = 1 THEN GOSUB 91000: IF fin = 1 THEN RETURN: GOTO 90300
    IF f(fx, 4) > 1 THEN GOTO 90300: REM Toggle field, dont allow entry
    REM ------------- FIELD ENTRY -------------------------
    IF f(fx, 4) = 1 THEN V$ = NU$ ELSE V$ = ab$: REM Select valid character set
    IF 0 = INSTR(V$, a$) THEN GOTO 90300: REM Invalid char.
    REM ---- User has pressed a valid key, started field entry --------
    z = 1: C$ = a$: old$ = dat$(fx): f1 = fx: f2 = fx: L = f(fx, 3)
    r = f(fx, 1): C = f(fx, 2): LOCATE r, C: COLOR 15, 3, 8: PRINT LEFT$(C$ + bl$, f(fx, 3)): COLOR 15, 1, 8
    IF L = LEN(C$) THEN a = 13: GOTO 90402: REM Out of room, press enter
90375 LOCATE r, C + LEN(C$): GOSUB 90000: REM Wait for keypress
    n = LEN(a$): a = ASC(LEFT$(a$, 1)): B = ASC(RIGHT$(a$, 1))
    REM ---- Oops, user made a typing error --------------------------
    OOPS = (a = 8 OR n = 2 AND B = 75 OR n = 2 AND B = 83): LB = LEN(C$)
    IF NOT OOPS OR LB <= 0 THEN GOTO 90392: REM User didn't press delete
    C$ = LEFT$(C$, LB - 1): LOCATE r, C: COLOR 15, 3, 8: PRINT LEFT$(C$ + bl$, L)
    COLOR 15, 1, 8: GOTO 90375: REM Return for next keypress
90392 REM ---- If key ok, add to string and print -------------------------
    IF 0 = INSTR(V$, a$) THEN GOTO 90400: REM Branch on invalid keypress
    C$ = C$ + a$: LOCATE r, C: COLOR 15, 3, 8: PRINT LEFT$(C$ + bl$, f(fx, 3))
    COLOR 15, 1, 8: LOCATE r, C + LEN(C$)
    IF L = LEN(C$) THEN a = 13: GOTO 90402: REM Out of room, press enter
90400 GOSUB 91100: IF x <> 1 THEN GOTO 90375: REM Ignore invalid key
90402 REM ---- Check for range of numeric ----------------
    IF f(fx, 4) = 0 THEN GOTO 90450
    d = VAL(C$): IF d < f(fx, 6) OR d > f(fx, 7) THEN BEEP: C$ = old$: B = 0: a = 0
90450 REM ---- Save data and update field ----------------
    dat$(fx) = C$: f1 = fx: f2 = fx: GOSUB 94800: C = 0: SOUND 1000, .2
    GOSUB 91200: REM Update screen
    GOSUB 91000: IF fin = 1 THEN RETURN: REM All over
    GOTO 90300: REM Perform movement and reset for next field

90500 REM****** FORMAT STRING ***********************************************
    REM - x$ = STRING TO BE FORMATTED
    REM - ND = NUMBER OF DECIMAL PLACES
    REM - L  = LENGTH
    s$ = "": x = VAL(x$): IF x < 0 THEN s$ = "-"
    x = INT(ABS(x) * 10 ^ ND + .500001): x$ = LTRIM$(STR$(x))
    d$ = ".": IF ND = 0 THEN d$ = ""
    M = LEN(x$) - ND: IF M < 0 THEN M = 0
    x$ = s$ + LEFT$(x$, M) + d$ + RIGHT$("00000" + x$, ND)
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    IF VAL(x$) = 0 AND ND > 0 THEN x$ = "0" + x$
    x$ = RIGHT$(bl$ + x$, L)
    RETURN
90600 REM********** ADD TRAILING DOTS TO CHARACTER STRING **********
    REM -- x$ = String, LM = left margin, LL = length, R=Row
   do$ = ". . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . ."
    L = LEN(x$): IF 2 * INT(L / 2) <> L THEN do$ = " " + do$
    LL = 64 - lm
    x$ = LEFT$(x$ + do$, LL): LOCATE r, lm: PRINT x$: RETURN
90700 REM********** BLANK SELECTED RECTANGLE ON SCREEN ********************
    REM --- RI = 1st row, R2 = last row, C1 = 1st col, C2 = last col
    x$ = STRING$(c2 - c1 + 1, " ")
    FOR i = r1 TO r2: LOCATE i, c1: PRINT x$: NEXT: RETURN
91000 REM********** PERFORM SCREEN MOVEMENT *******************************
   REM ----- Check for F1 keypress -----------------
    IF n = 2 AND B = 59 THEN GOSUB 92400: RETURN
    old = SCR: C = 0: FO = fx: SI = 1: fin = 0
   REM ----- Next field if tab, enter, down arrow, or -> -----------------------
    IF a = 9 OR n = 2 AND (B = 77 OR B = 80) OR a = 13 THEN DIR = 1: fx = fx + 1: GOTO 91050
    REM ----- Previous field if BSP, <-, up arrow or shift tab -----------------
    IF a = 8 OR n = 2 AND (B = 75 OR B = 15 OR B = 72) THEN DIR = -1: fx = fx - 1: GOTO 91050
   REM ----- Next screen if page down key ------------------------------
    IF n = 2 AND B = 81 THEN fx = FF(SCR + 1): DIR = 1: GOTO 91050
    REM ----- Previous screen if page up key -----------
    IF n = 2 AND B = 73 THEN fx = FF(SCR - 1): DIR = 1: GOTO 91050
91050 IF fx < 1 THEN fx = 1: REM Can't back up past screen 2 (field 1)
91055 REM ---- Skip over deactivated fields -----------
    IF fx > 88 THEN fin = 1: RETURN: REM End of entry, return finish code
    REM IF A(FX) = 0 THEN FX = FX + DIR: GOTO 91050
    IF a(fx) < 1 THEN fx = fx + DIR: GOTO 91050
    GOSUB 94000: IF SCR <> old THEN C = 1: REM C=1 if screen has changed
    REM ---- Handle backing up to a completely inactive screen -----------
    IF n = 2 AND B = 73 AND C = 0 AND fx > 1 THEN SI = SI + 1: fx = FF(SCR - SI): GOTO 91050
    IF C = 1 THEN GOSUB 91200: REM Screen update

    REM --- If a(fx)=0 now, then field has been turned off beneath cursor
    REM --- by Screen Update routine.  Since prior field may have activated
    REM --- Only thing to do is retreat to top of screen and try again
    IF a(fx) = 0 THEN fx = FF(SCR): C = 0: old = SCR: GOTO 91055

    LOCATE f(fx, 1), f(fx, 2), 1, 0, 7
    RETURN
91100 REM********* CHECK FOR MOVEMENT KEYPRESS ************************
    x = 0: IF n = 2 THEN GOTO 91120
```

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    IF a = 9 OR a = 13 OR a = 8 THEN x = 1
    RETURN
91120 IF B = 77 OR B = 80 OR B = 75 OR B = 15 OR B = 72 OR B = 81 OR B = 73 OR B = 59 THEN x = 1
    RETURN
91200 REM********* PERFORM SCREEN UPDATE *******************************
    LOCATE , , 0: REM Kill cursor
    ON SCR GOSUB 11000, 12000, 13000, 14000, 15000, 16000
    LOCATE , , 1: REM Restore cursor
    RETURN
92300 REM********* SELECT A TOGGLE FIELD *******************************
REM   IF f(fx, 6) = 1 AND a(21) = 2 THEN a(21) = 2: GOTO 92325
    IF f(fx, 6) = 1 AND a(fx) = 2 THEN a(fx) = 1: GOTO 92325: REM On/Off
    a(fx) = 2: K = fx + 1
92310 ok = (f(K, 5) = f(fx, 5) AND f(K, 4) = 2): IF ok AND a(K) = 2 THEN a(K) = 1
    IF ok THEN K = K + 1: GOTO 92310
    K = fx - 1
92320 ok = (f(K, 5) = f(fx, 5) AND f(K, 4) = 2): IF ok AND a(K) = 2 THEN a(K) = 1
    IF ok THEN K = K - 1: GOTO 92320
92325 GOSUB 91200: REM Screen update
     LOCATE f(fx, 1), f(fx, 2): RETURN

92400 REM********* DO F1 POP-UP MENU *************************************
    COLOR 15, 5, 8: lmp = 22: tp = 6: REM Color, l. margin, top
    FOR ii = tp TO tp + 13: LOCATE ii, lmp - 2, 0: PRINT SPACE$(29): NEXT
    LOCATE tp, lmp - 2: PRINT STRING$(9, 205); " HELP MENU "; STRING$(9, 205)
    LOCATE tp + 2, lmp: PRINT "F1 - This Control Menu"
    LOCATE tp + 4, lmp: PRINT "F2 - Get Saved Worksheet"
    LOCATE tp + 6, lmp: PRINT "F3 - Save This Worksheet"
    LOCATE tp + 8, lmp: PRINT "F4 - Not Used"
    LOCATE tp + 10, lmp: PRINT "F5 - Return to Editing"
    LOCATE tp + 12, lmp: PRINT "F6 - Exit Program Now"
92405 GOSUB 90000: REM Get keypress
   REM ----- Scan for active function keys ---------------------
    IF a = 27 THEN GOTO 92490: REM ESC key, Back to edit
    IF n <> 2 THEN GOTO 92405
    IF B = 60 THEN GOSUB 93200: GOTO 92490: REM F2, Get Saved Worksheet
    IF B = 61 THEN GOSUB 93000: GOTO 92490: REM F3, Save this Worksheet
    IF B = 62 THEN GOSUB 92500: GOTO 92490: REM F4, Directory
    IF B = 63 THEN GOTO 92490: REM F5, Back to edit
    IF B = 64 THEN COLOR 15, 8, 8: CLS : END: REM Abort Program
    GOTO 92405
92490 REM ----- Go back to screen in progress --------------------
    COLOR 15, 1, 8: C = 1: GOSUB 91200:
    LOCATE f(fx, 1), f(fx, 2), 1, 0, 7
```

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    RETURN
92500 REM********* F4 SUBROUTINE (Not used currently) ********************
    CLS : SHELL "dir *.dat": GOSUB 90100
    RETURN
93000 REM********* WRITE WORKSHEET TO DISK *******************************
    x1$ = "SAVE ": X2$ = "Saving worksheet to disk:": ER = 0
    GOSUB 93300: IF ER = 1 THEN RETURN: REM Get file name from user
    WRITE #1, "PAVLIF V1.0"
     FOR i = 1 TO 88: WRITE #1, f(i, 6), f(i, 7), a(i), dat$(i): NEXT
93100 CLOSE #1
    ON ERROR GOTO 99000
    RETURN
93200 REM********* GET WORKSHEET FROM DISK *******************************
    x1$ = "READ ": X2$ = "Retrieving a Saved Worksheet:": ER = 0
    GOSUB 93300: IF ER = 1 THEN RETURN: REM Get file name from user
    REM ----- Check for valid worksheet format -----------------
    INPUT #1, xx$: IF xx$ = "PAVLIF V1.0" THEN GOTO 93205
    REM ----- Not valid ------
    COLOR 15, 4, 8
    LOCATE 17, 40: CLOSE #1: BEEP: PRINT "Not a PAVLIF worksheet!": SLEEP 3: RETURN
    REM ----- Valid, continue reading ------
93205 FOR i = 1 TO 88: INPUT #1, f(i, 6), f(i, 7), a(i), dat$(i): NEXT
    CLOSE #1
93207 fx = 1: SCR = 2: C = 1
    ON ERROR GOTO 99000
    RETURN

93300 REM********* GET DISK FILE NAME ***********************************
    COLOR 15, 6, 1: lmp = 29: tp = 12: REM Color, l. margin, top
    FOR ii = tp TO tp + 6: LOCATE ii, lmp - 2, 0: PRINT SPACE$(52): NEXT
    LOCATE tp, lmp - 2: PRINT STRING$(20, 205); " DISK "; x1$; STRING$(21, 205)
    LOCATE tp + 2, lmp: PRINT X2$: ld = INT(LEN(df$) / 2)
    COLOR 15, 8, 1: LOCATE tp + 6, lmp + 14 - ld: PRINT "  Press ENTER for ";
    PRINT UCASE$(df$) + "  ": COLOR 15, 6, 1
    LOCATE tp + 4, lmp: INPUT "File name"; f$
    f$ = LTRIM$(f$): IF f$ = "" THEN f$ = df$ ELSE df$ = f$
    LOCATE tp + 4, lmp + 11: PRINT LEFT$(f$ + bl$, 20): SLEEP 1
    ON ERROR GOTO 93400
    IF x1$ = "READ " THEN OPEN f$ FOR INPUT AS #1: fin = 0: openflg = 1
    IF x1$ = "SAVE " THEN OPEN f$ FOR OUTPUT AS #1
93399 RETURN

93400 REM------ Handle any disk error -------------
    LOCATE 17, 40: ER = 1: BEEP: COLOR 15, 4, 8
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    IF ERR = 64 THEN PRINT "ERROR - Bad file name": GOTO 93405
    IF ERR = 61 THEN PRINT "ERROR - Disk full": GOTO 93405
    IF ERR = 71 THEN PRINT "Disk not ready - try again  ": GOTO 93405
    IF ERR = 72 THEN PRINT "ERROR - Bad disk media": GOTO 93405
    IF ERR = 68 THEN PRINT "ERROR - No such disk drive": GOTO 93405
    IF ERR = 53 THEN PRINT "ERROR - File not found": GOTO 93405
    IF ERR = 75 OR ERR = 76 THEN PRINT "ERROR - Bad Path": GOTO 93405
    IF ERR = 70 THEN PRINT "ERROR - Write Protected": GOTO 93405
    IF ERR = 62 THEN PRINT "Not PAVLIF1 input file": GOTO 93405
    PRINT "Unknown Disk error - try again"
93405 SLEEP 3
    CLOSE #1
    RESUME 93399
93800 REM******* Sort layer thickness entries ****************************
    REM X(f) is # of layers, x(f+1) is 1st thickness
    n = x(f): FOR i = f + 1 TO f + n: FOR J = i TO f + n: REM Bubble sort
    IF x(i) > x(J) THEN SWAP x(i), x(J)
    NEXT: NEXT
    RETURN
94000 REM********* DETERMINE WHICH SCREEN FROM FIELD NUMBER ***************
    FOR i = 1 TO 20
    IF fx < FF(i) THEN SCR = i - 1: RETURN
    NEXT i: RETURN
    REM********* GET FIELD # FOR NEXT SCREEN *****************************
    FF = FF(SCR + 1): RETURN
94800 REM****** UPDATE SELECTED SCREEN FIELDS ******************************
    REM F1 - First field to update, F2 - Last field to update
    REM L = Length , T=data type (0-Alpha 1-Numeric 2-Toggle)
    bl$ = STRING$(80, " "): REM LOCATE , , 0: REM kill
    FOR i = f1 TO f2
    LOCATE f(i, 1), f(i, 2): L = f(i, 3): T = f(i, 4)
    REM --- Hidden field ----
    REM IF A(I) = 0 AND F(I, 4) < 2 THEN x$ = LEFT$(bl$, L): COLOR 15, 1, 8: PRINT x$: GOTO 94835
    x$ = dat$(i)

REM --- Alphabetic field ----
    IF T = 0 THEN x$ = LEFT$(x$ + bl$, L): COLOR 15, 3, 8: PRINT x$: GOTO 94835

    REM --- Numeric field -------
    REM $$ note - b changed to bz to correct field problem 5/19/93 td
    f = 7: Bz = 1: REM No entry allowed - background blue, letters gray
    IF a(i) = 1 THEN f = 15: Bz = 3: REM Entry allowed, backgr. aqua
    IF a(i) < 0 THEN f = 1: Bz = 1: REM Totally hidden
```

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IF T = 1 THEN ND = f(i, 5): GOSUB 90500: COLOR f, Bz, 8: PRINT x$: GOTO 94835
   REM --- Toggle field ----
   f = 7: Bz = 1: REM Not an option - background blue, letters gray
   IF a(i) = 1 THEN f = 15: Bz = 1: REM Option ok, not selected
   IF a(i) = 2 THEN f = 15: Bz = 3: REM Option selected
   IF f(i, 7) = 1 AND a(i) = 0 THEN f = 1: Bz = 1: REM Completely hide field
   COLOR f, Bz, 8: PRINT x$
94835 NEXT i: COLOR 15, 1, 8: RETURN
95000 REM****** INITIALIZE SCREEN FIELDS **********************************
   REM -- Row, Col, Length, A/N, Decimals, Low lim, Up lim, A(I), default
   REM -- A/N: 0 = alpha, 1=num, 2=toggle
   REM -- NOTE -> For toggle fields, F(*,5) is group number
   REM -- F(*,6) is 1 for non-grouped, F(*,7) is 1 to totally hide
   REM -- A(I) = Select vector - 0=hidden, 1=visible, 2=selected
  REM ----------- Items for screen 2 ------------1-4------------------
   DATA 7,63,10,0,0,0,0,1,"":                REM Prob no.
   DATA 11,10,63,0,0,0,0,1,"":               REM Prob desc. 1
   DATA 12,10,63,0,0,0,0,1,"":               REM Prob desc. 2
   DATA 13,10,63,0,0,0,0,1,"":               REM Prob desc. 3
  REM ----------- Items for screen 3 ------------5 - 72-----------------
   DATA 5,69,4,1,0,1950,1994,1,"1965":       REM Const Year
   DATA 6,69,4,1,1,1,18,1,"8":               REM Thickness
   DATA 7,71,2,1,0,1,5,1,"2":                REM Num Lanes
   DATA 8,49,11,2,5,0,0,2,"Actual Data":     REM CS data type 1
   DATA 8,62,11,2,5,0,0,1,"Statistical":     REM CS data type 2
   DATA 9,69,4,1,1,1,19,-1,"5.1":            REM xmean
   DATA 10,69,4,1,1,0,19,-1,"2.3":           REM standard deviation
   DATA 9,71,2,1,0,1,60,-1,"48":             REM Num Observ

   DATA 13,15,4,1,1,1,30,1,"6":              REM crk spc 1
   DATA 14,15,4,1,1,1,30,1,"1.2":            REM crk spc 2
   DATA 15,15,4,1,1,1,30,1,"8.8":            REM crk spc 3
   DATA 16,15,4,1,1,1,30,1,"14.9":           REM crk spc 4
   DATA 17,15,4,1,1,1,30,1,"1.2":            REM crk spc 5
   DATA 18,15,4,1,1,1,30,1,"13":             REM crk spc 6
   DATA 19,15,4,1,1,1,30,1,"6.1":            REM crk spc 7
   DATA 20,15,4,1,1,1,30,1,"3.7":            REM crk spc 8
   DATA 21,15,4,1,1,1,30,1,"4.9":            REM crk spc 9
   DATA 22,15,4,1,1,1,30,1,"7.1":            REM crk spc 10
   DATA 13,25,4,1,1,1,30,1,"3.8":            REM crk spc 11
   DATA 14,25,4,1,1,1,30,1,"4":              REM crk spc 12
   DATA 15,25,4,1,1,1,30,1,"11.6":           REM crk spc 13
   DATA 16,25,4,1,1,1,30,1,"6.8":            REM crk spc 14
   DATA 17,25,4,1,1,1,30,1,"6.9":            REM crk spc 15
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DATA 18,25,4,1,1,1,30,1,"4.5":          REM crk spc 16
DATA 19,25,4,1,1,1,30,1,"6.2":          REM crk spc 17
DATA 20,25,4,1,1,1,30,1,"4.2":          REM crk spc 18
DATA 21,25,4,1,1,1,30,1,"7.1":          REM crk spc 19
DATA 22,25,4,1,1,1,30,1,"5.6":          REM crk spc 20
DATA 13,35,4,1,1,1,30,1,"6.3":          REM crk spc 21
DATA 14,35,4,1,1,1,30,1,"6":          REM crk spc 22
DATA 15,35,4,1,1,1,30,1,"9.7":          REM crk spc 23
DATA 16,35,4,1,1,1,30,1,"1.6":          REM crk spc 24
DATA 17,35,4,1,1,1,30,1,"5.9":          REM crk spc 25
DATA 18,35,4,1,1,1,30,1,"5.1":          REM crk spc 26
DATA 19,35,4,1,1,1,30,1,"1.9":          REM crk spc 27
DATA 20,35,4,1,1,1,30,1,"6.2":          REM crk spc 28
DATA 21,35,4,1,1,1,30,-1,"6.7":          REM crk spc 29
DATA 22,35,4,1,1,1,30,-1,"6":          REM crk spc 30
DATA 13,45,4,1,1,1,30,-1,"6.5":          REM crk spc 31
DATA 14,45,4,1,1,1,30,-1,"8.5":          REM crk spc 32
DATA 15,45,4,1,1,1,30,-1,"4.3":          REM crk spc 33
DATA 16,45,4,1,1,1,30,-1,"4.3":          REM crk spc 34
DATA 17,45,4,1,1,1,30,-1,"1.8":          REM crk spc 35
DATA 18,45,4,1,1,1,30,-1,"7.5":          REM crk spc 36
DATA 19,45,4,1,1,1,30,-1,"10":          REM crk spc 37
DATA 20,45,4,1,1,1,30,-1,"10.3":          REM crk spc 38
DATA 21,45,4,1,1,1,30,-1,"3.7":          REM crk spc 39
DATA 22,45,4,1,1,1,30,-1,"2.5":          REM crk spc 40
DATA 13,55,4,1,1,1,30,-1,"7.7":          REM crk spc 41
DATA 14,55,4,1,1,1,30,-1,"3.6":          REM crk spc 42
DATA 15,55,4,1,1,1,30,-1,"1.3":          REM crk spc 43
DATA 16,55,4,1,1,1,30,-1,"12.8":          REM crk spc 44
DATA 17,55,4,1,1,1,30,-1,"13.1":          REM crk spc 45
DATA 18,55,4,1,1,1,30,-1,"6.8":          REM crk spc 46
DATA 19,55,4,1,1,1,30,-1,"5.9":          REM crk spc 47
DATA 20,55,4,1,1,1,30,-1,"5.1":          REM crk spc 48
DATA 21,55,4,1,1,1,30,-1,"5":          REM crk spc 49
DATA 22,55,4,1,1,1,30,-1,"5":          REM crk spc 50
DATA 13,65,4,1,1,1,30,-1,"5":          REM crk spc 51
DATA 14,65,4,1,1,1,30,-1,"5":          REM crk spc 52
DATA 15,65,4,1,1,1,30,-1,"5":          REM crk spc 53
DATA 16,65,4,1,1,1,30,-1,"5":          REM crk spc 54
DATA 17,65,4,1,1,1,30,-1,"5":          REM crk spc 55
DATA 18,65,4,1,1,1,30,-1,"5":          REM crk spc 56
DATA 19,65,4,1,1,1,30,-1,"5":          REM crk spc 57
DATA 20,65,4,1,1,1,30,-1,"5":          REM crk spc 58
DATA 21,65,4,1,1,1,30,-1,"5":          REM crk spc 59
```

```
    DATA 22,65,4,1,1,1,30,-1,"5":              REM crk spc 60

    REM ------------ ITEMS FOR SCREEN 4 - Fatigue ---- 73 - 81 ------
    DATA 6,65,3,2,3,0,0,1,"YES":                   REM Swelling
    DATA 6,70,3,2,3,0,0,2,"NO":                    REM No Swelling
    DATA 8,60,2,2,4,0,0,2,"50":                    REM 50
    DATA 8,65,2,2,4,0,0,1,"75":                    REM 75
    DATA 8,70,2,2,4,0,0,1,"95":                    REM 95
    DATA 10,65,10,2,1,0,0,2,"Limestone ":             REM ag type 1
    DATA 11,65,10,2,1,0,0,1,"SRG       ":             REM ag type 2
    DATA 12,65,10,2,1,0,0,1,"Other*    ":             REM ag type 3
    DATA 15,68,4,1,0,0,9999,1,"668":                 REM Flexural Strength

    REM ---------- ITEMS FOR SCREEN 5 --------------82 - 87--------------

    DATA 5,69,4,1,0,1960,1994,1,"1978":              REM Analysis yr
    DATA 7,71,2,1,0,1,30,1,"15":                     REM Failure crit.
    DATA 9,71,2,1,0,0,30,1,"5":                      REM Current FPM
    DATA 11,68,5,1,0,3000,20000,1,"13000":              REM adt85
    DATA 13,65,3,2,0,0,0,2,"YES":                     REM Interstate yes
    DATA 13,71,3,2,0,0,0,1,"NO":                      REM Interstate no
    REM ----------- ITEMS FOR SCREEN 6 --------------- 88 - 88 -------
    DATA 17,45,1,1,0,1,4,1,"1":                      REM Execution options

    REM -- Read field data ---------
    FOR i = 1 TO 88: FOR J = 1 TO 7
    READ f(i, J): NEXT J: READ a(i), dat$(i): NEXT i


    REM -- Read first field number for each screen --
    DATA 0,1,5,73,82,88,999
    FOR i = 1 TO 7: READ FF(i): NEXT i

RETURN


REM ********************************************************************


80000 REM ** Subroutine for Doing all of the rem life calcs and output

REM*******************************************************************
REM*                                            *
```

```
REM* PAVLIF Version 1.0 October 1994                    *
REM* Center for Transportation Research - UT Austin       *
REM* Programmed by S. Easley & T. Dossey                *
REM*                                    *
REM*******************************************************************


SCREEN 9
DIM up(60), low(60), freq(60), cum(60), esal(10), fpm(10)
DIM crackfreq(90), xnor(90), tcs(90), crackcum(90)
DIM n(90), NC(90), nn(90), signn(90), np(90), CS(90)

COLOR 15, 1: SCR = 11: x$ = "OUTPUT SUMMARY"

GOSUB 80100: REM read System and Concrete Parameters
GOSUB 80200: REM read crack spacing data
GOSUB 80300: REM Draw Screen Frame and Label Everything
GOSUB 80400: REM Do Crack Spacing Dist.
GOSUB 80500: REM GOTO punchout routine
GOSUB 80600: REM Interpolate to find % Remaining Life
GOSUB 80700: REM plot failures V. Esals
IF esalsleft > 0! AND grthan90 = 0 THEN GOSUB 80750: REM Find Number of years remaining and print Results
GOSUB 80800: REM Write Output to Screen
SOUND 2000, .2
80001 GOSUB 80900
REM ------- Check for F1 Keypress -------------
IF nn = 1 AND a = 27 THEN GOTO 80002
IF nn < 2 OR B <> 59 THEN GOTO 80001
IF dist$ <> "C" THEN dist$ = "C" ELSE dist$ = "F"
SOUND 2000, .2: REM 2 KHz tone for .2 sec
GOSUB 80400: GOTO 80001: REM Switch between crack spacing graphs
80002 VIEW: CLS : IF grthan90 = 0 THEN GOSUB 82000: REM print output to file
x = 0: fx = 1: dist$ = "F": RESTORE 81000: RESET: GOTO 1: REM go back to input driver

80100 REM Read System Parameters
prob$ = dat$(1): IF prob$ = "" THEN prob$ = "Untitled"
COEFVA = 30!
    FOR i = 75 TO 77: IF a(i) = 2 THEN xr$ = dat$(i)
    NEXT i
    REM -- use SRG values
    IF a(79) = 2 THEN
    IF xr$ = "95" THEN coefa = 2!: IF a(73) = 2 THEN coefa = 1.4
    IF xr$ = "75" THEN coefa = 3.1: IF a(73) = 2 THEN coefa = 2.4
    IF xr$ = "50" THEN coefa = 4.2: IF a(73) = 2 THEN coefa = 3.1
```

```
    END IF
    REM -- use LS values
    IF a(78) = 2 THEN
    IF xr$ = "95" THEN coefa = 2.6: IF a(73) = 2 THEN coefa = 1.8
    IF xr$ = "75" THEN coefa = 3.7: IF a(73) = 2 THEN coefa = 2.5
    IF xr$ = "50" THEN coefa = 4.8: IF a(73) = 2 THEN coefa = 3.1
    END IF
    REM -- use Other values
    IF a(80) = 2 THEN
    IF xr$ = "95" THEN coefa = 2.3: IF a(73) = 2 THEN coefa = 1.6
    IF xr$ = "75" THEN coefa = 3.4: IF a(73) = 2 THEN coefa = 2.45
    IF xr$ = "50" THEN coefa = 4.5: IF a(73) = 2 THEN coefa = 3.1
    END IF
    coefa = coefa * 1000000!

COEFB = 4!: flex = VAL(dat$(81)): d = VAL(dat$(6))
adt85 = VAL(dat$(85)): numlanes = CINT(VAL(dat$(7)))
ayr = CINT(VAL(dat$(82)) - 1900)
interstate$ = "N": IF a(86) = 2 THEN interstate$ = "Y"
cyr = CINT(VAL(dat$(5)) - 1900): yr = ayr
currentfpm = CINT(VAL(dat$(84))): fpmfail = CINT(VAL(dat$(83)))
npflg = 0: flag1 = 0: flag2 = 0: grthan90 = 0
RETURN

80200 REM read CS Data and convert to freq percents
IF a(9) = 2 THEN GOTO 80250: REM generate normal dist. around mean,STD
xmean = 0!: maxcf = 0: sumsq = 0!
FOR i = 1 TO 90: crackfreq(i) = 0: crackcum(i) = 0: NEXT i
numcrks = VAL(dat$(12))
FOR i = 13 TO 12 + numcrks: CS(i) = VAL(dat$(i)): xmean = xmean + CS(i) / numcrks
crackfreq(CINT(CS(i) / .5)) = crackfreq(CINT(CS(i) / .5)) + 100! / numcrks
IF CINT(CS(i) / .5) > maxcf THEN maxcf = CINT(CS(i) / .5)
NEXT i
sumsq = 0: FOR i = 1 TO numcrks: sumsq = sumsq + (xmean - CS(i)) ^ 2: NEXT i
STD = SQR(sumsq / (numcrks - 1))
crackcum(1) = crackfreq(1)
FOR i = 2 TO maxcf: crackcum(i) = crackfreq(i) + crackcum(i - 1): NEXT i
GOTO 80255

80250 REM --- user input of mean,STD -> generate normal dist.
maxcf = 40
xmean = VAL(dat$(10)): STD = VAL(dat$(11))
maxxx = 0: sumcf = 0
FOR i = .5 TO 20 STEP .5
```

```
crackfreq(CINT(i / .5)) = .5 * 100! * (EXP(-(i - xmean) ^ 2 / (2 * STD ^ 2))) / (SQR(2 * 3.14) * STD)
IF crackfreq(CINT(i / .5)) > maxxx THEN maxxx = crackfreq(CINT(i / .5))
sumcf = sumcf + crackfreq(CINT(i / .5))
NEXT i
IF sumcf < 100! THEN : deltacf = (100 - sumcf) / 40: FOR i = 1 TO 40: crackfreq(i) = crackfreq(i) + deltacf: NEXT i
crackcum(1) = crackfreq(1)
FOR i = 2 TO maxcf: crackcum(i) = crackfreq(i) + crackcum(i - 1): NEXT i
80255 RETURN

80300 REM************* DRAW OUTPUT SCREEN FRAME *************************
CLS : B$ = STRING$(8, 205): V$ = " PAVLIF1" + VER$ + " "
PRINT CHR$(213); B$; V$; STRING$(37, 205); " OUTPUT SUMMARY ";
B2$ = B$: PRINT B2$; CHR$(184)
FOR i = 1 TO 22: PRINT CHR$(179); TAB(80); CHR$(179): NEXT
PRINT CHR$(212); STRING$(22, 205); " F1 to Toggle Graph, ESC to EXIT "; STRING$(23, 205); CHR$(190);
REM************ PRINT NUMERIC RESULTS ************************
F52$ = "##.##": F54$ = ".####": F50$ = "#####": F51$ = "###.#"
COLOR 14, 1: LOCATE 3, 4: PRINT "PROBLEM:  ";
COLOR 15, 1: PRINT prob$: COLOR 15, 1
REM************ LABEL EVERYTHING ******************************
COLOR 14, 1: LOCATE 5, 10: PRINT "INPUT": COLOR 15, 1
LOCATE 6, 3: PRINT USING "Current Failures = ##"; currentfpm
LOCATE 7, 3: PRINT USING "Construction Year = ####"; cyr + 1900
COLOR 14, 1: LOCATE 9, 7: PRINT "CRACK SPACING": COLOR 15, 1
LOCATE 10, 3: PRINT USING "     Mean = #.#"; xmean; : PRINT " ft"
LOCATE 11, 3: PRINT USING "Std. Dev. = #.#"; STD; : PRINT " ft"
COLOR 14, 1: LOCATE 13, 11: PRINT "ESALS": COLOR 15, 1
COLOR 14, 1: LOCATE 19, 11: PRINT "TIME": COLOR 15, 1
RETURN

80400 REM************* DRAW CRACK SPACING DISTRIBUTION *****************
    VIEW
    VIEW (290, 45)-(610, 135), 7: REM Shadow 1
    VIEW (294, 49)-(606, 131), 15: REM Shadow 2
    VIEW (295, 50)-(605, 130), 8: REM Graph Window 1
    REM WINDOW (0, 0)-(100, 75)
    REM VIEW: VIEW (284, 43)-(602, 126), 9, 1

    LOCATE 3, 43: COLOR 14, 1: PRINT "CRACK SPACING DISTRIBUTION": COLOR 15, 1
    REM --------- Use Correct Label for Type of Distribution ---------
    TYPE$ = "FREQ%": IF dist$ = "C" THEN TYPE$ = " CUM%"
    COL = 3: IF dist$ = "C" THEN COL = 5

    REM --------- Determine Vertical Scale ----------------------------
```

```
    maxf = 0: FOR i = 1 TO maxcf: IF maxf < crackfreq(i) THEN maxf = crackfreq(i)
    NEXT i
    top = 10: IF maxf > top THEN top = 15: IF maxf > top THEN top = 25: IF maxf > top THEN top = 50: IF maxf > top THEN top = 100
    IF dist$ = "C" THEN top = 100
    LOCATE 4, 33: PRINT USING "###"; top
    WINDOW (0, 0)-(25, top)

    REM --------- Draw dotted grid lines ---------------------------
    FOR i = 1 TO 5: Y = top / 5 * i: LINE (0, Y)-(25, Y), 7, , &H8888
    IF i < 5 THEN LINE (5 * i, 0)-(5 * i, top), 7, , &H1111
    NEXT

    REM --------- Draw bars and fill -------------------------------
    n = maxcf
    low(1) = .25: up(1) = .75
    FOR i = 2 TO n: low(i) = low(i - 1) + .5: up(i) = up(i - 1) + .5: NEXT i
    FOR i = 1 TO n: x = crackfreq(i): IF dist$ = "C" THEN x = crackcum(i)
    LINE (Iow(i), 0)-(up(i), x), COL, BF
    LINE (low(i), 0)-(low(i), x): LINE (low(i), x)-(up(i), x)
    LINE (up(i), x)-(up(i), 0): NEXT

    LOCATE 11, 36: PRINT " 0      5      10      15      20      25"
    LOCATE 12, 51: PRINT "Spacing (ft)"
    FOR i = 5 TO 9: LOCATE i, 32: PRINT MID$(TYPE$, i - 4, 1): NEXT
    RETURN


80500  REM punchout subroutine
    FOR i = 1 TO 30: READ xnor(i): NEXT i
    FOR i = 1 TO 40: tcs(i) = i * .5: NEXT i
    FOR i = 1 TO 10: n(i) = 0: np(i) = 0: NC(i) = 0: nn(i) = 0: signn(i) = 0!: NEXT i
    noct = 5280! / xmean
    FOR ird = 0 TO 90
     IRDD = ird * 1!: n(ird) = IRDD * 1000000!: SUM = 0!
     FOR J = 1 TO 7
       temp = crackfreq(J) / 100!: NC(J) = noct * temp: SX = tcs(J)
      ab = EXP(9.84736) * (1! / d) ^ 1.8143 * (1! / SX) ^ .44766
       nn(J) = coefa * (flex / ab) ^ COEFB: signn(J) = nn(J) * COEFVA / 100!
       x = (n(ird) - nn(J)) / signn(J)
     IF x < -3! THEN GOTO 80502
     IY = CINT(10 * x - .5)
     IF IY = 0 THEN IY = 1
     IF IY > 30 THEN IY = 30
     IF IY < 0 THEN GOTO 80504
```

```
      p = xnor(IY): GOTO 80505
80504  p = 1! - xnor(-IY)
80505  PO = p * NC(J): SUM = SUM + PO
80502 NEXT J
      np(ird) = SUM
    NEXT ird
    RETURN

80600 REM Find % Remaining Life
    i = 1
    DO
     REM --- interpolate to find current and remaining esals
     IF CINT(np(i)) = fpmfail THEN : esalsfail = n(i): flag1 = 1
     IF CINT(np(i)) > fpmfail AND flag1 = 0 THEN : esalsfail = n(i - 1) + (n(i) - n(i - 1)) / (np(i) - np(i - 1)) * (fpmfail - np(i - 1)): flag1
= 1
     IF CINT(np(i)) = currentfpm THEN : esalsnow = n(i): flag2 = 1
     IF CINT(np(i)) > currentfpm AND flag2 = 0 THEN : esalsnow = n(i - 1) + (n(i) - n(i - 1)) / (np(i) - np(i - 1)) * (currentfpm - np(i -
1)): flag2 = 1
     i = i + 1
    LOOP UNTIL flag1 = 1 AND flag2 = 1 OR i > 90
    IF i > 90 THEN grthan90 = 1: GOTO 80610: REM - SET ERROR FLAG
    IF currentfpm = 0 THEN esalsnow = 0
    remlife = (esalsfail - esalsnow) / esalsfail
    esalsleft = esalsfail - esalsnow
80610 RETURN


80700 REM************* PLOT FAILURES VS ESALS *************************
     VIEW: VIEW (290, 198)-(610, 290), 7
     VIEW (294, 202)-(606, 286), 15
     VIEW (295, 203)-(605, 285), 8
     REM VIEW (290, 193)-(608, 275), 7: REM Shadow 1
     REM VIEW (284, 198)-(602, 280), 8: REM Graph Window 1
     REM VIEW: VIEW (284, 198)-(602, 280), 9, 1
     LOCATE 14, 43: COLOR 14, 1: PRINT "PREDICTED FAILURES PER MILE": COLOR 15, 1
     REM --- Determine Vertical Scale -------------
     max = fpmfail: top = 1
     IF max > 1 THEN top = 10: IF max > 10 THEN top = 25
     IF max > 25 THEN top = 50: IF max > 50 THEN top = 100
     rt = 30: IF esalsfail / 1000000! > 30 THEN rt = 40
     IF esalsfail / 1000000! > 40 THEN rt = 50
     IF esalsfail / 1000000! > 50 THEN rt = 60
     IF esalsfail / 1000000! > 60 THEN rt = 70
     IF esalsfail / 1000000! > 70 THEN rt = 80
```

```
    IF esalsfail / 1000000! > 80 THEN rt = 90
    LOCATE 15, 33: PRINT USING "###"; top
    WINDOW (0, 0)-(rt, top)
    LINE (0, fpmfail)-(rt, fpmfail), 12, , &H3333
    LINE (0, currentfpm)-(rt, currentfpm), 11, , &H3333
    LINE (esalsnow / 1000000!, 0)-(esalsnow / 1000000!, top), 11, , &H3333
    LINE (esalsfail / 1000000!, 0)-(esalsfail / 1000000!, top), 12, , &H3333
    FOR i = 2 TO 90
    IF np(i) <= fpmfail THEN LINE (n(i - 1) / 1000000!, np(i - 1))-(n(i) / 1000000!, np(i)), 10
    IF npflg = 1 THEN LINE (n(i - 1) / 1000000!, np(i - 1))-(n(i) / 1000000!, np(i)), 12
    IF np(i) >= fpmfail AND npflg = 0 THEN LINE (n(i - 1) / 1000000!, np(i - 1))-(n(i) / 1000000!, np(i)), 12: npflag = 1
    NEXT
    FOR i = 1 TO 5: Y = top / 5 * i: IF i < 5 THEN LINE (0, Y)-(rt, Y), 7, , &H8888
    NEXT
    FOR i = 1 TO rt / 5: LINE (5 * i, 0)-(5 * i, top), 7, , &H1111: NEXT

    IF rt = 30 THEN LOCATE 22, 36: PRINT " 0         10         20         30"
    IF rt = 40 THEN LOCATE 22, 36: PRINT " 0      10      20      30      40"
    IF rt = 50 THEN LOCATE 22, 36: PRINT " 0     10     20    30     40     50"
    IF rt = 60 THEN LOCATE 22, 36: PRINT " 0    10    20    30    40   50    60"
    IF rt = 70 THEN LOCATE 22, 36: PRINT " 0   10   20   30  40   50  60   70"
    IF rt = 80 THEN LOCATE 22, 36: PRINT " 0      20      40      60      80"
    IF rt = 90 THEN LOCATE 22, 36: PRINT " 0         30         60         90"
    LOCATE 23, 50: PRINT "ESALS (Millions)"
    FOR i = 16 TO 20: LOCATE i, 32: PRINT MID$(" FPM ", i - 15, 1): NEXT
    RETURN


80750 REM *** determine how many years remain based on remaining esals
    REM *** and traffic model 4
    factor = 1
    IF numlanes = 2 THEN factor = .7
    IF numlanes = 3 THEN factor = .6
    IF numlanes = 4 THEN factor = .5
    h1 = 0: h2 = 0
    IF interstate$ = "Y" THEN h1 = 2907059!: h2 = 44723!
    numyrs = 1
    esalsf = 0!
80751 esal2 = 15640 * yr - h1 - 205.19 * adt85 + h2 * yr + 3.108 * (yr * adt85) - 650498
    esalsf = esalsf + esal2 / 2 * factor
    IF esalsf < esalsleft THEN numyrs = numyrs + 1: yr = yr + 1: GOTO 80751
    RETURN

80800 REM **** do output to screen
```

```
IF grthan90 = 0 THEN
 LOCATE 14, 3: PRINT USING "Current Estimate = ##"; esalsnow / 1000000!; : PRINT " e+6"
 LOCATE 15, 3: PRINT USING "ESALS To Failure = ##"; esalsfail / 1000000!; : PRINT " e+6"
 LOCATE 16, 3: PRINT USING "Remaining ESALS =  ##"; esalsleft / 1000000!; : PRINT " e+6"
 LOCATE 17, 3: PRINT USING "Percent Remaining = ### %"; remlife * 100!
 LOCATE 20, 3: PRINT USING "Analysis Year = ####"; ayr + 1900
 LOCATE 22, 3: PRINT USING "Life Remaining = ## Yrs"; numyrs
 LOCATE 21, 3: PRINT USING "Failure Year  = ####"; yr + 1900
 GOTO 80850
END IF
LOCATE 14, 3: PRINT "ESALS To Failure > 90"
LOCATE 16, 3: PRINT "More than 90 ESALS"
LOCATE 17, 3: PRINT "required to fail pavement."
LOCATE 19, 3: PRINT "Reduce failure criteria or"
LOCATE 20, 3: PRINT "or reduce the pavement"
LOCATE 21, 3: PRINT "thickness. "
80850 RETURN

80900 REM************* GET KEYPRESS *************************************
    a$ = INKEY$: IF a$ = "" THEN GOTO 80900
     nn = LEN(a$): a = ASC(LEFT$(a$, 1)): B = ASC(RIGHT$(a$, 1)): RETURN

82000 REM ***** print output to a file with echo and results
    lfile = LEN(f$) - 1
    spc$ = "            "
    p$ = f$
    FOR i = 1 TO lfile: IF MID$(f$, i, 1) = "." THEN p$ = MID$(f$, 1, i - 1)
    NEXT
    p$ = p$ + ".out"
    OPEN p$ FOR OUTPUT AS #10
     datatype$ = "Actual Crack Spacings": IF a(9) = 2 THEN datatype$ = "Statistical"
    PRINT #10, "************************************************************"
     PRINT #10, spc$, "PAVLIF Program Output     "; : PRINT #10, USING "Date: &&&&&&&&&&"; DATE$
    PRINT #10, "************************************************************": PRINT #10, ""
     PRINT #10, USING "Problem Number: &&&&&&&&&&"; prob$: PRINT #10, ""
     PRINT #10, "Problem Description:"
      PRINT #10, dat$(2): PRINT #10, dat$(3): PRINT #10, dat$(4): PRINT #10, ""
   PRINT #10, "----------------------------------------------"
    PRINT #10, spc$, "INPUT DATA"
   PRINT #10, "----------------------------------------------"
     PRINT #10, ""
     PRINT #10, USING "Construction Year = ####"; cyr + 1900
      PRINT #10, USING "Number of Lanes (one direction) = ##"; numlanes
      PRINT #10, "Type of Data: "; datatype$
```

```
IF a(9) = 2 THEN PRINT #10, USING "Mean Crack Spacing (ft) = ##.#"; xmean
IF a(9) = 2 THEN PRINT #10, USING "Standard Deviation (ft) = ##.#"; STD
IF a(8) = 2 THEN
 PRINT #10, "": PRINT #10, "        Crack Spacing Distrbution": PRINT #10, ""
 PRINT #10, "   Crack Spacing(ft)      Frequency(%)"
 PRINT #10, "   -----------------      ------------"
 FOR i = .5 TO 20 STEP .5
 PRINT #10, USING "         ##.#"; i; : PRINT #10, USING "                ##.#"; crackfreq(i / .5)
 NEXT i
 PRINT #10, ""
 PRINT #10, USING "Mean Crack Spacing = ##.# ft"; xmean
 PRINT #10, USING "Standard Deviation = ##.# ft"; STD
END IF
PRINT #10, ""
swel$ = "YES": IF a(74) = 2 THEN swel$ = "NO"
hwy$ = "YES": IF a(87) = 2 THEN hwy$ = "NO"
reliab$ = "50": IF a(76) = 2 THEN reliab$ = "75"
IF a(77) = 2 THEN reliab$ = "95"
aggr$ = "Limestone": IF a(79) = 2 THEN aggr$ = "SRG"
IF a(80) = 2 THEN aggr$ = "Other"
PRINT #10, "Swelling Condition: "; swel$
PRINT #10, USING "Reliability = && %"; reliab$
PRINT #10, "Aggregate Type: "; aggr$
PRINT #10, USING "Flexural Strength = ### psi"; flex
PRINT #10, USING "Analysis Year = ####"; ayr + 1900
PRINT #10, USING "Failure Criterion (FPM)  = ##"; fpmfail
PRINT #10, USING "Current Failures (FPM) = ##"; currentfpm
PRINT #10, USING "1985 Average Daily Traffic = ######"; adt85
PRINT #10, "Interstate Highway?:  "; hwy$
PRINT #10, ""
PRINT #10, "------------------------------------------------------------"
PRINT #10, spc$, "  RESULTS  "
PRINT #10, "------------------------------------------------------------"
PRINT #10, ""
PRINT #10, "***** ESALS *****": PRINT #10, ""
PRINT #10, USING "Current Estimate = ## million"; esalsnow / 1000000!
PRINT #10, USING "ESALS to Failure = ## million"; esalsfail / 1000000!
PRINT #10, USING "Remaining ESALS =  ## million"; esalsleft / 1000000!
PRINT #10, USING "Percent Remaining = ### %"; remlife * 100!
PRINT #10, ""
PRINT #10, "***** TIME ******": PRINT #10, ""
PRINT #10, USING "Failure Year = ####"; yr + 1900
IF numyrs > 1 THEN PRINT #10, USING "Life Remaining = ## years"; numyrs
```

```
    IF numyrs < 1 THEN PRINT #10, USING "Life Remaining = ## year"; numyrs
    CLOSE #10
    RETURN

99000 REM************** ERROR HANDLER ************************************
    COLOR 15, 4, 8: CLS : BEEP: BEEP: BEEP
    LOCATE 6, 37: PRINT "- SORRY -"
    LOCATE 10, 10: PRINT "  An Unforseeable error has occurred.  A restart operation"
    LOCATE 12, 10: PRINT "will be attempted to  preserve any data you may have entered."
    LOCATE 14, 10: PRINT "   Please contact customer service if the problem recurs."
    LOCATE 16, 30: PRINT "*** Error #"; ERR; " ***"
    REM GOSUB 90100: COLOR 15, 1, 8: RESUME 1
    END

81000
DATA5398,.5793,.6179,.6554,.6915,.7257,.7580,.7881,.8159,.8413,.8643,.8849,.9032,.9192,.9332,.9432,.9554,.9641,.9713,.9772,.9821,.9861,.9
893,.9918,.9938,.9953,.9965,.9974,.9981,.9987
```

APPENDIX B
CONDITION SURVEY DATA SAMPLE (SECTION 19019)

CFTR Section 19019 Condition Data

CFTR	YR	DIR	MP										SPO <20	SPO >20	ACP	PCP
19019	1980	WB	198.0	17.200	50	2	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	197.8	17.000	55	2	1	0	1	0	0	0	0	0	.00	0
19019	1980	WB	197.6	16.800	51	2	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	197.4	16.600	44	1	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	197.2	16.400	45	0	0	0	2	0	1	0	0	0	.00	0
19019	1980	WB	197.0	16.200	52	2	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	196.8	16.000	62	1	0	0	1	0	1	0	0	0	.00	0
19019	1980	WB	196.6	15.800	49	0	0	0	3	0	0	0	0	0	.00	0
19019	1980	WB	196.4	15.600	42	0	0	0	1	0	0	0	0	0	.00	0
19019	1980	WB	196.2	15.400	55	0	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	196.0	15.200	39	0	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	195.8	15.000	41	0	0	0	1	0	0	0	1	0	.00	0
19019	1980	WB	195.6	14.800	48	5	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	195.4	14.600	33	0	1	0	3	0	0	0	0	0	.00	0
19019	1980	WB	195.2	14.400	44	3	0	0	7	0	0	0	0	0	.00	0
19019	1980	WB	195.0	14.200	50	3	1	0	0	0	0	0	0	0	.00	0
19019	1980	WB	194.8	14.000	36	1	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	194.6	13.800	31	1	0	0	6	0	0	0	0	0	.00	0
19019	1980	WB	194.4	13.593	51	0	0	0	7	0	0	0	0	0	.00	0
19019	1980	WB	194.2	13.393	51	1	0	0	2	0	0	0	0	0	.00	0
19019	1980	WB	194.0	13.193	44	0	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	193.8	12.993	56	0	0	0	0	0	0	0	1	0	.00	0
19019	1980	WB	193.6	12.793	41	1	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	193.4	12.593	36	0	0	0	3	0	1	0	0	1	.00	0
19019	1980	WB	193.2	12.393	25	2	0	0	5	0	0	0	0	2	.00	0
19019	1980	WB	193.0	12.193	40	0	1	0	11	0	0	0	0	1	.00	0
19019	1980	WB	192.8	11.993	55	3	1	0	2	0	0	0	0	0	.00	0
19019	1980	WB	192.6	11.793	50	2	0	0	3	0	0	0	0	0	.00	0
19019	1980	WB	192.4	11.593	47	3	0	0	9	0	0	0	0	0	.00	0
19019	1980	WB	192.2	11.393	36	0	0	0	2	0	0	0	0	1	.00	0
19019	1980	WB	192.0	11.193	24	1	0	0	8	0	0	0	0	0	.00	0
19019	1980	WB	191.8	10.993	33	1	0	0	10	0	0	0	0	0	.00	0
19019	1980	WB	191.6	10.793	36	0	0	0	4	0	0	0	0	0	.00	0
19019	1980	WB	191.4	10.593	41	8	0	0	10	0	0	0	0	1	.00	0
19019	1980	WB	191.2	10.393	47	0	0	0	0	0	0	0	0	0	.00	0
19019	1980	WB	191.0	10.193	31	0	0	0	1	0	0	0	0	0	.00	0
19019	1980	WB	190.8	9.993	39	1	0	0	2	0	0	0	0	0	.00	0

19019	1980	WB	190.6	9.793	39	1	0	0	0	0	0	0	0	0	.0 0	0
19019	1980	WB	190.4	9.593	38	1	0	0	1	0	0	0	0	0	.0 0	0
19019	1980	WB	190.2	9.393	33	1	0	0	0	0	0	0	0	0	.0 0	0
19019	1980	WB	190.0	9.193	32	0	0	0	0	0	0	0	0	3	.0 0	0
19019	1980	WB	189.8	8.993	10	1	0	0	2	0	0	0	0	0	.0 0	0
19019	1980	WB	189.6	8.793	35	4	0	0	0	0	0	0	0	0	.0 0	0
19019	1980	WB	189.4	8.593	30	0	0	0	0	0	1	0	0	0	.0 0	0
19019	1980	WB	189.2	8.393	36	2	0	0	1	0	1	0	0	0	.0 0	0
19019	1980	WB	189.0	8.193	48	9	0	0	0	0	0	0	0	0	.0 0	0
19019	1980	WB	188.8	7.993	52	0	0	0	0	0	0	0	0	0	.0 0	0
19019	1980	WB	188.6	7.793	43	5	0	0	4	0	0	0	0	0	.0 0	0
19019	1980	WB	188.4	7.593	38	3	0	0	0	0	0	0	0	1	.0 0	0
19019	1980	WB	188.2	7.393	7	0	0	0	0	0	0	0	0	0	.0 0	0

Severe Punchouts: 5

Asphalt Patches : 2

PCP Patches : 10

Total Failures : 17

Total Miles : 9.8

Failures Per Mile: 1.7 = 2.0

APPENDIX C

CRACK SPACING DATA FOR EXAMPLES

01003 1978 WB 142.2 33.323 CRACK SPACING
6.0 1.2 8.8 14.9 1.2 13.0 6.1 3.7 4.9 7.1 3.8 4.0 11.6 6.8 6.9 4.5
6.2 4.2 7.1 5.6 6.3 6.0 9.7 1.6 5.9 5.1 1.9 6.2 6.7 6.0 6.5 8.5
4.3 4.3 1.8 7.5 10.0 10.3 3.7 2.5 7.7 3.6 1.3 12.8 13.1 6.8 5.9 5.1

19019 1978 EB 194.8 13.993 CRACK SPACING
2.0 2.0 1.0 2.5 1.9 1.6 3.7 2.2 3.0 1.5 3.8 3.0 2.8 1.6 1.1 3.3
5.0 3.4 2.8 3.5 2.0 3.2 3.3 2.3 2.6 4.8 1.3 2.9 1.1 1.3 4.1 1.8
3.3 1.3 4.1 3.1 3.2 1.6 3.6 3.2 3.1 2.9 2.7 3.7 2.7 2.1 3.0 2.9
2.8 3.4 1.8 3.3 2.0 3.3 1.2 2.0 5.1 1.6 3.3 3.8 5.5 3.4 3.2 3.7
2.9 2.0 2.3 3.3 1.2 4.3 3.3 3.4 1.9 3.0 2.7 2.6 1.5 1.5 2.6 2.3
3.7 2.8 3.3 .8 2.0 2.3 1.9 1.6 2.2 4.2 2.1 2.0 3.5 3.3 2.1 3.5
3.0 6.3 3.2 2.9 3.6 1.7 4.6 2.2 1.4 3.5 2.6 1.5 .0 .0 .0 .0

13023 1978 NB 21.4 22.457 CRACK SPACING
1.3 5.3 3.2 8.1 2.6 3.4 10.7 4.8 5.6 3.6 1.6 3.1 7.1 2.1 4.9 2.2
3.3 1.9 6.3 2.1 13.2 1.0 12.3 8.0 2.4 1.8 7.8 8.3 7.2 1.9 3.7 5.2
1.5 7.7 3.8 7.0 4.9 4.7 4.9 1.9 7.4 .8 2.5 6.8 6.6 10.3 6.2 2.1
6.0 10.8 1.3 10.1 4.6 1.3 1.5 3.7 2.9 2.5 1.7 7.3 2.3 9.8 .0 .0