US Army Corps of Engineers

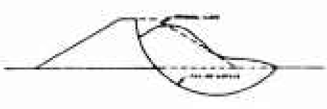
COMPUTER APPLICATIONS IN GEOTECHNICAL ENGINEERING (CAGE)
and
GEOTECHNICAL ASPECTS OF THE COMPUTER-AIDED STRUCTURAL ENGINEERING (G-CASE) PROJECTS

AD-A193 088

INSTRUCTION REPORT GL-87-1

USER'S GUIDE: UTEXAS2 SLOPE-STABILITY PACKAGE

Volume I
USER'S MANUAL



by

Earl V. Edris, Jr.

Geotechnical Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

and

Stephen G. Wright
Department of Civil Engineering
University of Texas at Austin
Austin, Texas 78712

August 1987

Final Report

GEOTECHNICAL LABORATORY

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Instruction Report GL-87-1	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION See reverse 6b. OFFICE SYMBOL (If applicable) WESGE-ET	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39180-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION DEPARTMENT OF THE ARMY 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) US Army Corps of Engineers Washington, DC 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO | TASK NO. | WORK UNIT ACCESSION NO

11. TITLE (Include Security Classification)

User's Guide: UTEXAS2 Slope-Stability Package; Volume I, User's Manual

12. PERSONAL AUTHOR(S)
Edris, Jr., Earl V.; Wright, Stephen G.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Volume I of a series	FROM ______ TO ______	August 1987	220

16. SUPPLEMENTARY NOTATION
See reverse

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Computer programs (LC) Slopes (Soil mechanics) UTEXAS2 (Computer program)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is the user's guide volume of the UTEXAS2 (University of Texas Analysis of Slopes - version 2) slope-stability package. This package describes a slope-stability program which can calculate the factor of safety by Spencer's method, simplified Bishop's procedure, force equilibrium procedure with Corps of Engineers Modified Swedish side-force assumption of parallel side forces at a user-specified inclination and force equilibrium procedure with Lowe and Karafiath's side force assumptions. The program will calculate the safety factor for either a prescribed shear surface or for a search of the critical shear surface. Both circular and noncircular shear surfaces can be evaluated. There are five options for the type of shear strength data and six options for specifying pore pressures. All analysis procedures and major features can be run in a single data file which is free-field format and utilizes command words. Graphics capability for displaying the input data

(Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) | 22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

A

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

6a. NAME OF PERFORMING ORGANIZATION (Continued).

USAEWES, Geotechnical Laboratory and
CAGE, G-CASE Slope-Stability Task Group

16. SUPPLEMENTARY NOTATION (Continued).

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. This report was prepared under the Computer Applications in Geotechnical Engineering (CAGE) and the Geotechnical Aspects of the Computer-Aided Structural Engineering (G-CASE) Projects. Appendix D is included in diskette form in an envelope attached to the back cover of this report.

19. ABSTRACT (Continued).

and the final shear surface is available. Special capabilities include "pseudo-static" seismic analysis, slope reinforcement, curved (multi-linear) shear strength envelope, anisotropic shear strength, and the ability to have multiple piezometric lines.

Keywords: soil stability; computer programs; software; computer applications

printout of diskette attached

A-1

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

PROGRAM INFORMATION

Description of Program UTEXAS2

UTEXAS2, called I0029 in the Conversationally Oriented Real-Time Program-Generating System (CORPS) library, is a slope stability program designed to analyze slopes by any of the following four methods, Spencer's procedure, simplified Bishop's procedure, force equilibrium procedure with Corps of Engineers Modified Swedish side-force assumption of parallel side forces at a user-specified inclination, and force equilibrium procedure with Lowe and Karafiath's side force assumption. The program will calculate the safety factor for either a prescribed shear surface or for a search of the critical shear surface. Both circular and non-circular shear surfaces can be evaluated.

Coding and Data Format

UTEXAS2 is written in FORTRAN and is operational on the following systems:

a. Micro-computers using MS-DOS operating system;

b. District office Harris 500 computers; and

c. Cybernet contract service.

Data for UTEXAS2 must be in a previously prepared data file. Output from the program is directed to a user specified file. Input and output graphics are available during program execution.

Keywords: Soil mechanics; Instruction manuals; Computer programs.

How to Use Program UTEXAS2

Directions for accessing the program on each of the three systems is provided below. It is assumed that the user can prepare the computer equipment, sign on the appropriate system or directory, and prepare a data file before attempting to use the program. In the example initiation of execution commands below, all user responses are underlined and each should be followed by a carriage return.

Micro-computer

The micro-computer needs at least 512K of memory, a hard disk, a math co-processor, and a graphics card that can be addressed from micro-GCS (e.g. enhanced graphics adapter,EGA, color graphics adapter,CGA, or Tecmar graphics cards).

The micro-computer version of UTEXAS2 is contained on one diskette in a compressed (archive) form. Copies of the diskette can be obtained from the CORPS librarian.

Before using this program for the first time, the user must uncompress (unarchive) it onto the hard disk. The program PKXARC is used to uncompress the program. An example of this procedure is:

Boot up the micro-computer with MS-DOS.
Insert the floppy disk into drive A.
Make a directory called STAB
<u>MD \STAB</u>
From A drive type
<u>PKXARC /R UTEXAS2 C:\STAB\</u>

After this initial procedure, the program name is entered to initiate execution. An example is

<u>UTEXAS2</u>

<u>Harris 500 System</u>

The log-on procedure is followed by a call to the program executable file, with the user typing the asterisk and file description.

<u>*CORPS.I0029</u>

to initiate execution of the program. An example is

"ACOE-ABLESVILLE (H500 V3.1)"
ENTER SIGN-ON
<u>1234ABC.GEOTECH</u>

**GOOD MORNING GEOTECHNICAL, IT'S 20 JULY 87 09:02:10
AED HARRIS 500 OPERATING HOURS 0700-1800 M-S
<u>*CORPS.I0029</u>

<u>CYBERNET System</u>

The log-on procedure is followed by a call to the CORPS procedure file

<u>OLD.CORPS/UN=CECELB</u>

to access the CORPS library. The file name of the program is used in the command

<u>BEGIN,.CORPS.I0029</u>

to initiate execution of the program. An example is:

87/07/20. 09.20.00. AC2F5DA
EASTERN CYBERNET CENTER SN904 NOS 1.4/531.669/20AD
FAMILY: <u>KOE</u>
USER NAME: <u>CEROXX</u>
PASSWORD -

```
XXXXXXXX
TERMINAL:      23, NAMIAF
RECOVER/CHARGE:  CHARGE, CEROEGC, CEROXX
$CHARGE
12.49.07. WARNING (various information messages may appear here)

07/20 FOR IMPORTANT INFO TYPE EXPLAIN, WARNING. (various
information messages may appear here)
OLD,CORPS/UN=CECELB
/BEGIN,,CORPS,I0029
```

How to Use CORPS

The CORPS system contains many other useful programs which may be catalogued from CORPS by use of the LIST command. The command to execute this on the Harris system are:

```
*CORPS
ARE YOU USING A PRINTER TERMINAL OR CRT?
ENTER P OR C
C
CORPS SYSTEM COMMANDS:
BRIEF - LIST EXPLANATION OF A PROGRAM.
EXECUTE - RUN A CORPS PROGRAM.
LIST - LIST THE AVAILABLE CORPS PROGRAMS.
STOP - EXIT FROM CORPS SYSTEM MACRO.
HELP - HELP AND EXPLANATION OF CORPS
       SYSTEM AND THE RUNNING OF ITS MACRO.

NOTE:  COMMANDS MAY BE ABBREVIATED TO THE
       FIRST LETTER OF THE COMMAND.

ENTER COMMAND(BRIEF,EXECUTE,LIST,HELP,STOP):
S
STOP
```

and on the Cybernet system, the commands are:

```
OLD,CORPS/UN=CECELB
BEGIN,CORPS
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM	PROGRAM NO.
UTEXAS2-University of Texas Analysis of Slopes-Version 2 (I0029)	

PREPARING AGENCY U.S. Army Engineer Waterways Experiment Station, Information Technology Lab and Geotechnical Lab, P.O. Box 631, Vicksburg, MS 39180-0631

AUTHOR(S)	DATE PROGRAM COMPLETED	STATUS OF PROGRAM: PHASE	STATUS OF PROGRAM: STAGE
Dr. Stephen G. Wright-Univ. of Texas, Austin; POC-Earl Edris, Geotech Lab and Reed Mosher, Information Tech Lab			OP

A. PURPOSE OF PROGRAM

UTEXAS 2 is a slope stability program designed to analyze slopes by any of four methods. The program will calculated the safety factor for either a prescribed shear surface or for a search of the critical shear surface. Both circular and non-circular shear surfaces can be evaluated.

B. PROGRAM SPECIFICATIONS

The UTEXAS2 program is written in FORTRAN 77. The CORPS time-sharing library file name is I0029.

C. METHODS

The four analysis procedures are: Spencer's method, Simplified Bishop's procedure, Modified Swedish procedure with the Corps' side force assumption, and Modified Swedish procedure with Lowe and Karafiath's side force assumption. There are five options for type of shear strength data utilized and six options for specifying pore pressures. All analysis procedures and major features can be run in a single data file.

D. EQUIPMENT DETAILS

Microcomputer with a least 512K memory, a hard disk, and a math co-processor. Time-sharing computer (CDC Cyber, or Harris 500) with Tektronix 4014 terminal or emulator for graphics.

E. INPUT-OUTPUT

Input - Data is supplied from a prepared data file which allows for free-field input and requires command words.
Output - Provides an echoprint of the input data and results of the analysis in an output file divided into a series of tables.

F. ADDITIONAL REMARKS

Graphics capability for displaying the input data and the final shear surface is available. A copy of the program and documentation may be obtained from the Engineering Computer Programs Library, WES, telephone: (601) 634-2581 or FTS 542-2581.

PREFACE

This report describes the user guidelines for implementing the two-dimensional slope-stability analysis package UTEXAS2. This user's guide is to be organized into three separate volumes. Instructions for data input and graphics, as well as details about the output, search procedures, and error message explanations, are covered herein. Four examples are included to illustrate the material in text. The work is a product of the US Army Corps of Engineers Slope-Stability Task Group. This group is a combined effort of the Computer Applications in Geotechnical Engineering (CAGE) and the Geotechnical Aspects of the Computer-Aided Structural Engineering (G-CASE) projects. Both projects are sponsored by the Engineering Division, Engineering and Construction Directorate of the Office, Chief of Engineers (OCE), Department of the Army.

The contents of this report resulted from a combined effort of the task group members:

Dr. Roger Brown, South Atlantic Division (Chairman)
Mr. Ben Foreman, Savannah District
Mr. David Hammer, Ohio River Division
Mr. Kevin Mahon, North Atlantic Division
Mr. Francke Walberg, Kansas City District
Dr. Tom Wolff, St. Louis District, currently Michigan State University
Mr. Earl Edris, Jr., US Army Engineer Waterways Experiment Station (WES)
Mr. David Wright, Southwestern Division
Dr. Robert Hall, WES
Mr. Reed Mosher, WES
Mr. Dale Munger, OCE, currently North Pacific Division
Mr. Bill Strohm, WES
Mr. Gene Wardlaw, Vicksburg District, currently Ware Lind Engineers Inc.

Dr. Ashok K. Chugh, Bureau of Reclamation, and Dr. Stephen G. Wright, University of Texas at Austin, while not members of the Corps of Engineers, attended all the meetings and provided valuable input to this report.

This report was assembled by Mr. Earl V. Edris, Jr., Soil Mechanics Division, Geotechnical Laboratory (GL), WES, and revised by the task group. Dr. Wright wrote the program user's manual, the contents of which make up Parts II and III and Appendix A of this report.

The CAGE project was under the general supervision of Dr. William F. Marcuson III, Chief, GL, WES. The G-CASE project was managed and coordinated by Dr. N. Radhakrishnan, Chief, Information Technology Laboratory (ITL), WES, and CASE project manager. The material for this report was edited by Mrs. Gilda Miller, Information Products Division, ITL.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

CONTENTS

The disk for this report can be obtained from:
U.S. Army Engineer Waterways Experiment Station,
Geotechnical Laboratory , P.O. Box 631,
Vickburg, MS 39180-0631
Per Ms. Tina Holmes, USAEWES/GL

~~* Appendix D is included in disk cover of this report.~~

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	metres
foot-pounds (force)	1.355818	metre-newtons or joules
pounds (force)	4.448222	newtons
pounds (force) per square foot	47.88026	pascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre

USER'S GUIDE: UTEXAS2 SLOPE-STABILITY PACKAGE

PART I: INTRODUCTION

Purpose of UTEXAS2

1. A large number of slope-stability computer programs have been developed over the past years. A survey of geotechnical computer programs being used by the Corps of Engineers (Edris and Vanadit-Ellis 1982) listed 37 different programs. Many of the programs were developed for specific purposes, and thus are often restricted in the range of problems that can be analyzed with them. Specific algorithms implemented are not readily apparent since many of the programs are not well documented. Systematic evaluation of the various programs is difficult due to their diversity and the different input data requirements.

2. For these reasons, a joint venture of the Computer Applications in Geotechnical Engineering (CAGE) and the Geotechnical Aspects of the Computer-Aided Structural Engineering project (G-CASE) was tasked by the Office, Chief of Engineers (OCE), Department of the Army, to develop a slope-stability package suitable for Corps-wide use. This package of slope-stability programs to be maintained and updated as part of the Corps computer library will offer the following benefits to the Corps:

- a. Provide documented material to the design engineer.
- b. Facilitate division review of district work and district and division reviews of architect-engineer firm work.
- c. Enable different analysis procedures to be conveniently used from a common input data file.

3. The criteria for this limit-equilibrium slope-stability package are contained in Miscellaneous Paper GL-85-8 (CAGE Task Group on Slope Stability 1985). This report concluded that:

- a. No program then in existence met all the criteria outlined in the report.
- b. The program UTEXAS (University of Texas Analysis of Slopes), developed by Dr. S. G. Wright for the Texas Highway Department, most nearly meets all the criteria.
- c. Capability and criteria modifications to UTEXAS would be faster and more cost effective than to write a new program.

The version of UTEXAS containing the additional capabilities is called UTEXAS2.

Historical Perspective of UTEXAS2 (Wright 1986a)

4. During the early 1970's a general computer program for slope-stability analyses, SSTAB1, was developed at the University of Texas at Austin. In the more than 10 years that the computer program SSTAB1 has been in use, a number of significant developments have taken place.

- a. A new standard for FORTRAN has been developed and implemented by the computer industry.
- b. New procedures have been developed for "searching" for critical noncircular shear surfaces in slope-stability calculations.
- c. Improvements have been made in some of the algorithms employed in computer programs for slope analyses.

5. In response to the developments which have taken place in the last decade, experience gained with the computer program SSTAB1, and the desire of the Texas State Department of Highways and Public Transportation to adopt a new computer program for slope-stability computations, Research Project 3-8-83-353 was initiated at The Center for Transportation Research at The University of Texas in September 1982. This project led to the development of a new computer program, UTEXAS, for slope-stability computations as reported by Wright and Roecker (1984a). The computer program UTEXAS contained several features which were not available in the earlier program SSTAB1 including:

- a. Introduction of an automatic search procedure for locating critical, general-shaped, noncircular shear surfaces based on the procedure first developed by Celestino and Duncan (1981).
- b. Addition of capabilities for multiple piezometric lines.
- c. Introduction of a curved shear strength (failure) envelope.
- d. Addition of a seismic coefficient for use in "pseudo-static" slope-stability computations.
- e. Restructure of the form of input data and development of an enhanced, free-field input scheme for data entry.

6. Beginning in late 1984 and continuing into 1985, meetings were held with Dr. Wright and members of the CAGE Committee of the Corps of Engineers to discuss possible modifications to the new computer program UTEXAS and adaptation of the program to Corps requirements. These discussions and the normal evolution associated with continuing use and experience with the computer

program have lead to the development of the most recent slope-stability computer program, UTEXAS2, which is described in this manual.

7. The current program, UTEXAS2, contains several modifications and additions to the program UTEXAS described by Wright and Roecker (1984a). The new program permits the user to select Spencer's procedure (Spencer 1967), the Simplified Bishop's procedure (Bishop 1955), the Corps of Engineers Modified Swedish procedure* (Department of the Army 1970), or the force equilibrium procedure with Lowe and Karafiath's side-force assumption (Lowe and Karafiath 1960) for computing the factor of safety. However, Spencer's procedure is strongly recommended for all computations. Several other modifications have been made including:

a. A strength option was added in which the shear strength may vary linearly with depth below a given horizontal reference datum. This reintroduced an option available in the early computer program SSTAB1, which was not available in UTEXAS, and added to the option in UTEXAS where the shear strength is allowed to vary linearly with depth below an arbitrary line (profile line).

b. The order of input for some of the shear strength data was changed. Specifically, the pore pressure data were reordered to follow the data on shear strength parameters, whereas the reverse order was used in the prior program UTEXAS.

c. Multiple groups of paired data may be entered either as several groups of data on a line or as individual groups of data on separate lines.

d. An optional limiting "steepness" for the shear surface has been added to the automatic search procedure for noncircular shear surfaces. This permits somewhat larger increments to be used for the search and improves the computational efficiency with no loss in accuracy.

e. The printed output has been reduced to an 80-column (maximum) format to permit more convenient viewing on most video display terminals, as well as printing on relatively inexpensive printers used in conjunction with microcomputers.

f. An option has been added permitting the user to request a "Short-Form" of output when automatic searches are performed to reduce the amount of output generated for previewing results. It is still recommended that the more complete output be examined to reduce the possibility of accepting erroneous results.

The original version of UTEXAS2 was first made available to the Corps of Engineers in September 1985 with the previously noted modifications (Wright 1985).

---

* For purposes of programming, the CAGE task group interpreted the Corps Modified Swedish procedure to be a force equilibrium analysis with parallel side forces at a user-specified inclination.

Since September 1985, some additional changes have been made to the program. The most significant change has been the addition of an option allowing the user to specify internal soil reinforcement, such as that provided by either geotextiles or tie rods. Most of the other recent changes represent relatively minor modifications to the program or corrections of errors which have been detected.

8. This program has incorporated into it as many features as possible to reduce the amount of time required to perform a complete stability analysis and to enable the user to perform a more thorough analysis in a minimum amount of time and cost. It is emphasized, however, that the program is still a tool for the engineer and not a panacea for slope-stability problems. The program is not intended to replace sound engineering judgment but must, in fact, be used in conjunction with engineering judgment to be effective.

Organization of User's Guide

9. The UTEXAS2 User's Guide is organized into three volumes to avoid a large and cumbersome report. The use of separate volumes also provides for the timely publication of the user required guidelines of the program. Volume I contains the user guidelines including instructions for input and output (Wright 1986a), graphics, illustrative examples, search procedure recommendations, and error message explanations, Appendix A (Wright 1986c). Volume II contains the theory and derivations of the equations used in the program (Wright 1986b). Volume III consists of example problems illustrating coding procedures for generic problem types and demonstrating the capabilities and versatility of the program.

PART II: DATA INPUT

Introduction

10. This part of the user's manual (Wright 1986a) describes the general operation and input data formats for the general-purpose slope-stability analysis computer program, UTEXAS2. The program is used to compute a factor of safety, F , defined as

$$F = \frac{s}{\tau} \tag{1}$$

where

s = available shear strength

τ = shear strength (shear stress) required for just-stable equilibrium

This definition of F is the definition most commonly employed for slope-stability analyses. The factor of safety is computed for an assumed shear (potential sliding) surface employing a procedure of slices. The program permits the user to select one of several analytical procedures for computing F . The procedures which may be selected are:

a. Spencer's procedure (1967).

b. Simplified Bishop's procedure (1955).

c. Force equilibrium procedure with Corps of Engineers Modified Swedish side-force assumption of parallel side forces at a user-specified inclination, EM 1110-2-1902 (Department of the Army 1970).

d. Force equilibrium procedure with Lowe and Karafiath's (1960) side force assumption.

Details regarding the implementation of these procedures are given in paragraphs 70 through 116, Tables 17 through 22, with descriptions of the specific input data used to select the procedures. The theoretical derivations of the equations used to compute the factors of safety by these procedures are presented in Volume II of the user's guide. Although the computer program contains several procedures for computing the factor of safety, Spencer's procedure is recommended and is automatically selected by the program unless input data designates otherwise. Spencer's procedure satisfies complete static equilibrium for each slice, and accordingly, it is the only statically complete procedure available in this computer program.

INTRODUCTION

11. The factor of safety may be computed using circular or general-shaped, noncircular shear surfaces. The shear surfaces may be specified as individual surfaces, one-by-one by the user, or the program can be directed to automatically search for a most critical shear surface having a minimum factor of safety. Regardless of the option chosen, generally the user will be most interested in the critical shear surface with the lowest factor of safety. While the program computes the safety factor to four significant digits, the user must be aware of the relative importance of these digits based on the degree of certainty of the input parameters (i.e., shear strength; pore pressures).

Descriptions of slope geometry and soil profile

12. The slope geometry and soil profile are described by a series of straight, "profile" lines whose end-point coordinates are input to the computer program. The material beneath a given profile line is assumed to have a given set of properties (shear strength, unit weight, etc.) until the next, lower profile line is encountered. A number of different characterizations of shear strengths and pore water pressures (ground water) can be selected by the user to describe a particular problem. In addition, the user may specify external loads on the surface of the slope to represent loads due to surface water, stockpiled materials, vehicles, etc. Internal reinforcement may also be specified.

13. The general requirements of data for the program, the terminology and nomenclature used, and an introduction to the input data are presented in paragraphs 15 through 23. The remainder of Part II describes specific groups of input data. The printed output produced by the program is described in Part III of this manual.

General recommendations for sudden drawdown analysis

14. This program can perform analyses for all loading conditions described in EM 1110-2-1902 (Department of the Army 1970) for which one calculation step is required. This covers all loading cases except sudden drawdown. The sudden drawdown loading described in the manual is a total stress analysis requiring two calculation steps. An effective stress approach for sudden drawdown analysis requires only one calculation step. Such approaches require that shear strength parameters are specified as effective stresses and

pore water pressures. The use of an effective stress approach is suggested until there is available a version of the program that will perform the two-step calculations.

General Description of Input Data Requirements

15. The sequence of input data, the coordinate system and units used, and the formats used by the computer program to read data are included in paragraphs 16 through 23.

Sequence of input

16. The input data are organized into a series of nine logical groups. The contents of individual groups are discussed group by group in paragraphs 28 through 116 and Tables 3 through 22. The user may choose any order in which one group of data is input relative to another group. The specific order selected is indicated to the computer program through the use of command words which are described in detail in paragraphs 24 through 27 and Tables 1 and 2. A number of the data groups are optional and may be omitted by the user, depending on the particular problem being solved.

Coordinate system

17. All coordinates are defined by using a right-hand coordinate system with the x axis being horizontal and positive to the right, and the y axis being vertical and positive in the upward direction. The origin of the coordinate system may be located arbitrarily. However, the origin should be in the vicinity of the slope, within a maximum distance of 10 times the slope height. This is recommended because moments are taken about the origin of the coordinate system, and numerical roundoff errors could result if the moment arms for forces become excessively large. No restriction is placed on the sign of the coordinate values or the orientation of the slope. Both positive and negative values may be used in the same problem.

Units for data

18. The input data should be in consistent units of length and force. Output formats are set up assuming that units will be in feet (for length) and pounds (for force). Units other than feet and pounds may be used; however, the computer output may overflow some output fields or have too few significant figures to be meaningful.

General recommendations and cautions regarding free water and submerged slopes

19. In several cases, it is possible to "model" conditions for submerged slopes in more than one way; however, in these cases, one way is usually considered preferable to others. In the case of slopes where free water

exists above the ground surface, the presence of free water might be modeled in either of two ways: (a) the water may be represented by a series of equivalent "Surface Pressures" (paragraphs 62 through 66, Tables 13 and 14, Group G Data for Surface Pressures), or (b) the water may be represented as any other material (e.g., soil) using appropriate "Profile Lines" (paragraphs 29 through 35, Tables 4 and 5, Group B Data for Profile Lines) and assigning zero strength and a unit weight equal to the unit weight of water for the material properties (paragraphs 36 through 45, Table 6, Group C Data for Material Properties). A very limited number of computations have been performed in which free water has been represented in both ways and the resulting factors of safety were essentially identical. However, this may not always be the case. IT IS STRONGLY RECOMMENDED THAT FREE WATER BE REPRESENTED BY "SURFACE PRESSURES" IN ALL CASES, i.e., by (a) above. There is at least one case, the use of a seismic coefficient, where the second alternative of representing the water as a material might lead to unintended results. In such a case, the seismic coefficient will be applied to all materials including water if represented as a material. In the manner of (b) above, the water as well as the soil will receive seismic forces, which may lead to unintended results.

20. The second comment regarding slopes with free water pertains to the case of submerged or partially submerged slopes and the use of submerged (buoyant) unit weights. The use of submerged unit weights is discussed in further detail in paragraphs 26 through 45, Table 6. However, in general THE USE OF SUBMERGED UNIT WEIGHTS IS NOT RECOMMENDED.

Dimensioned array size limits

21. A number of quantities which are input as data or calculated by the computer program are stored in dimensioned arrays. The computer program will check these quantities and issue an error message when a dimensioned array size is exceeded. Presently, the arrays are dimensioned according to convenient sizes for typical problems and it is anticipated that these sizes will change from time to time. Effective array sizes current with this report are given in Appendix B; however, the specific version of the computer program to which the user has access may utilize different array sizes.

Formats for reading input data

22. All numerical data are input and read in a "free-field" format. When more than one numerical value or alphanumeric character string is to be input on a given line of data, the values or character strings are separated

by one or more blanks. Commas are not allowed as separators. The first numerical value or alphanumeric character string on a line of data does not need to be left justified; the program will scan the line of input until the first nonblank character is located; thus, any amount of indentation is permissible. The program will check for the required number of numerical values on a line of input and will issue an error message if an insufficient number of quantities is input.

23. A number of the sets of input data described later involve several lines of similar data, which must be terminated by a blank line. A blank line is not the same as a line containing zeros; a blank line must contain no alphanumeric or special characters. For most editors and word processors, several spaces should be entered to create the blank lines.

Command Words

24. Command words are used in the input data to designate that a particular "group" of data (e.g., material properties, slope geometry, etc.) is to follow immediately. For example, the data defining the coordinates of lines used to describe the soil profile geometry are preceded by a line of input data with the command word "PROFILE LINES". The computer program will read this line of data and determine that data for the profile lines are to be read next. The user would then follow the command word "PROFILE LINES" with the Group B, Profile Line data, as described in paragraphs 29 through 35.

25. Command words are also used to direct the program to take action which may require no following data. For example, the special command word "COMPUTE" directs the program to temporarily stop reading data, check the data which have been read for correctness and completeness, and perform computations for the factor of safety. Once computations are complete, the program will then return to reading additional input data, if desired. The program attempts to read data until the end of file is encountered. Any additional data which are input after the command word "COMPUTE" may be for an entirely new problem or to simply change one item of data before the command word "COMPUTE" is reissued to execute a new series of computations. In general, all previous data are retained until new data are input by the user to change the old data or a special command word consisting of asterisks (***) is issued.

26. Several groups of data (Groups B, D, E, F, and G) may be input in two modes, Normal and Modify, which are selected through use of command words. The Normal mode is considered to be the normal mode of input and is initially assumed to be the input mode by the program. The Modify mode allows data within certain groups to be selectively changed without input of all data in the group. The user may randomly switch between Normal and Modify modes of input. The beginning user will probably choose to ignore the existence of the Modify mode.

27. The allowable command words and their meanings are described in Tables 1 and 2. Table 1 contains the command words which must be immediately followed by additional data. Table 2 contains the command words which require no further data. The command words are generally shown as being one or more words of different character length; however, <u>only the first three characters</u>

are actually read and used by the program. Leading blanks on a line are ignored, but all blanks following the first nonblank character are considered. The key first three characters of the command words are capitalized and underlined in Tables 1 and 2 to highlight their significance. The beginning user is encouraged to study each of the command words in Tables 1 and 2; the command words reflect many of the features and options of the computer program. To help the user quickly find a command word, this part of the manual is indexed at the top outside corners. For experienced users, a short form for data input is presented in Appendix C.

Table 1

Command Words which Designate and Require Additional Data to Immediately Follow

Command Word	Description and Meaning
HEAding	Designates that data which are to immediately follow contain a heading to be printed as an output heading. See Group A data description in paragraph 28.
PROfile line data	Designates that data which are to immediately follow are for the profile lines. See Group B data description in paragraphs 29 through 35, Tables 4 and 5.
MATerial property	Designates that data which are to immediately follow are for material (soil) properties. See Group C data description in paragraphs 36 through 45, Table 6.
PIEzometric line data	Designates that data which are to immediately follow are for piezometric lines. See Group D data description in paragraphs 46 through 50, Tables 7 and 8.
INTerpolation data for pore water pressures	Designates that data which are to immediately follow are for points used to interpolate pore water pressures. See Group E data description in paragraphs 51 through 54, Tables 9 and 10.
SLOpe geometry data	Designates that data which are to immediately follow are for the slope geometry. See Group F data description in paragraphs 55 through 61, Tables 11 and 12.
SURface pressure data	Designates that data which are to immediately follow are for normal and shear stresses acting on the surface of the slope. See Group G data description in paragraphs 62 through 66, Tables 13 and 14.
REInforcement data	Designates that data which are to immediately follow are for internal reinforcement in the soil. See Group H data description in paragraphs 67 through 69, Tables 15 and 16.
ANAlysis and computation data	Designates that data which are to immediately follow are for information needed for the stability computations. See Group J data description in paragraphs 70 through 116, Tables 17 through 22.

Table 2

Command Words Which Do Not Necessarily Require Additional Data to Follow

Command Word	Description and Meaning
*********	Three or more asterisks (***) may be optionally used to separate distinctly different sets of data and problems. Then, if an error is encountered in data for one problem, the program will skip the remaining data up to this line of asterisks and begin with the new set of data; all data specified previous to the line of asterisks are ignored for the next problem. (This is true regardless of whether or not errors are encountered.)
COMpute results	Designates that computations are to be performed. When this command word is read, the program checks all of the data currently read and proceeds with computations. Once computations have been completed, the program returns to reading command words and new data. Unless specifically directed (i.e., by three asterisks, (***)), all old data are retained and new data read simply replace selected old data. Thus, all or only a small part of data may be changed for the next problem.
NO compute	Designates that no computations are to be performed, but directs the program to perform the checks of input data and then resume reading input data. This is convenient for debugging data and the "NO COMPUTE" can later be reedited to "COMPUTE" to activate execution.
MODify mode	Designates that the program is to be placed in Modify mode for input of data: Certain groups of data (Groups B, D, E, F, G, and H) can be input in a Normal or Modify mode. In the Modify mode more selective changes to a portion of the data can be made, as described in later sections for each of the Groups where this option is available.
NORmal mode	Designates that the program is to be returned to the Normal mode after being in the Modify mode described above. These modes may be changed at any time and in any pattern. The normal mode is set initially and after "***" are encountered.
PRInt input data	Designates that all subsequent input data are to be printed. This is the default set initially and after "***" are encountered.

(Continued)

Table 2 (Concluded)

Command Word	Description and Meaning
SUPpress printing input data	Designates that all subsequent input data are not to be printed. Input data may be alternatively printed and suppressed among groups for a single problem, i.e., "PRI" and "SUP" could appear several times in the data for a single problem, if necessary.

Group A Data for Heading (Optional)

28. The Group A data consists of a three-line heading which is printed as an output heading above each output table. The heading may be changed at any stage of the input data, i.e., it can be changed between each group of data (B, C, D, etc.) or it can be left the same for all groups. To change the heading at any time, input the command word "HEA" (or "HEADING"). A blank heading is assumed both initially and immediately after "***" is encountered in the command words. The heading may be input while the program is operating in the Normal or Modify mode of input. There is no difference in the form of input of heading data for the two modes. The form of input is shown in Table 3.

Table 3

Group A - Heading Data Input Format

Input Line	Data Field	Variable/Description
1	1	(HEADNG(1)) - First line of heading; up to 65 characters including blanks.
2	1	(HEADNG(2)) - Second line of heading; up to 65 characters including blanks.
3	1	(HEADNG(3)) - Third line of heading; up to 65 characters including blanks.
		Resume input with command words after three lines of heading have been input. Three lines must be input, however, one or more of the lines may be blank.

Group B Data for Profile Lines

29. Group B data consist of the profile lines which are used to describe the geometry of the soil profile and slope cross section. Individual profile lines are defined by the coordinates of a series of points along each line from left to right. The points are assumed to be connected by straight lines to represent a continuous, piecewise linear line.

30. Beneath a given profile line, the soil or other material is considered to be of a given type until another profile line is encountered. Each line has a material type associated with it; the material type is specified as part of the input data for the profile line. The material type indicates which set of material properties (specified in the Group C data, paragraphs 36 through 45, Table 6) are to be used for the soil beneath the profile line. Several profile lines may be assigned the same material type.

31. Segments or portions of segments of two different profile lines cannot coincide. If two segments coincide, it is not possible for the program to logically determine which of the two segments (profile lines) is to be associated with the underlying material. An error message is printed when two profile line segments coincide.

32. The program allows the user to describe a soil profile with "Profile Lines" and, then, to consider several slope geometries "cut" from the soil profile. The slope geometry data are input as Group F data; several sets of Group F data may be input for a given set of profile lines. The option of considering several slopes in a given profile is useful for trial embankment and excavated slope design. In the case of embankments, the profile lines should include sufficient soil to encompass any potential embankment cross section; excess soil above the slope will be ignored. In the case of excavated slopes, the profile lines should define the original soil profile before excavation.

33. If the slope geometry (Group F) data are omitted (they are optional), the program will automatically generate the slope geometry by using the uppermost profile line segments to create the surface profile. However, once profile lines have been input and slope geometry data have been defined, by Group F data or by generating them from the profile line data, the slope geometry remains in effect until specific action is taken to change the slope geometry by entering new Group F data. Accordingly, if new profile lines are

entered, the previous slope geometry data will be retained, rather than new slope geometry data being automatically computed from the new profile line data. If new slope geometry data are required, they must be input as Group F data or a "null" set of slope geometry data must be input as described in paragraphs 55 through 61, Tables 11 and 12. New slope geometry data will be generated if a null set of data is entered.

34. Once a set of profile lines are defined, they ordinarily remain in effect until specifically replaced, one by one, by new data. As an example, suppose that five profile lines are initially defined and at a later time new data are input for just one profile line. The new data may replace one of the old profile lines, the other four profile lines being unchanged, or add to the old profile lines, creating a total of six profile lines. Whether the new data replace or add to the old data will depend on the number (NLINE) of the new profile line. If a line having the same number as the new line already exists, it will be replaced by the new data. If no line with the number of the new line exists, the new line is added to the previous lines. The only time profile line data are started entirely anew is when asterisks (***) have been input as a command word, shown in Table 2.

35. Group B data must immediately follow the command word "PRO" (or "PROFILE LINES"). The data may be input in the Normal or the Modify mode. Input for the Normal mode is described in Table 4; input for the Modify mode is described in Table 5.

Table 4

Group B - Profile Line Data Input Format - Normal Mode

Input Line	Data Field	Variable/Description
1	1	(NLINE) - Number of the profile line to be defined next, i.e., on Line(s) 2 below. Any sequence of numbering and input of profile lines may be used.
1	2	(MTYPE) - Number of the material type for the material below the profile line.
1	3	(LABEL) - Any alphanumeric character(s) or character string(s) to be printed as a label for the profile line. Can be as many characters and/or blanks as will fit on an 80-column line (including Fields 1 and 2) up to a maximum of 65 characters or blanks. Can also be entirely blank.
2	1	(XPROFL) - X coordinate of point on the profile line which is currently being defined.
2	2	(YPROFL) - Y coordinate of point on the profile line which is currently being defined.

Repeat Line(s) 2 for additional points on the profile line in a left-to-right sequence. More than one pair of coordinates (XPROFL, YPROFL) may be entered on a given line of input data if desired. Input a blank line to terminate data for the current profile line.

Repeat Lines 1 and 2, as sets, for additional profile lines. Lines may be input in any order. (Line numbers, NLINE, may be missing from a sequence; however, there appears to be little need for omitting numbers from a sequence.) Input two blank lines after the last line of nonblank profile line data to terminate all Group B data and return to input of command words.

Table 5

Group B - Profile Line Data Input Format - Modify Mode

Input Line	Data Field	Variable/Description
1	1	(NPROF) - Number of the profile line for which coordinate is to be changed.
1	2	(NPOINT) - Number of the point on the given profile line where coordinate is to be changed.
1	3	(XPROFL) - New value of X coordinate for point.
1	4	(YPROFL) - New value of Y coordinate for point.

Repeat Line(s) 1 for additional points whose coordinates are to be changed in Modify mode. More than one set of data (four quantities) may be entered on a given line; however, each line must contain integer multiples of four quantities, comprising complete data sets. Input a single blank line to terminate all Group B data and return to input of command words.

Group C Data For Material Properties

36. The Group C data consists of material properties, which include the unit weights, shear strengths, and description of how pore water pressures, if any, will be defined for each of the materials in the soil profile. Each profile line, as described previously in paragraphs 29 through 35, must have a set of material properties assigned to it; several profile lines may share a single set of material properties. Requirements for the material property data and the form of the input data are described in the following paragraphs.

Effective stress versus total stress analyses

37. The computer program permits analyses to be performed by using total or effective stresses to define shear strengths. In the case of total stresses, the shear strengths are expressed by the equation

$$s = c + (\sigma) \tan \phi \tag{2}$$

where

σ = total normal stress on the shear plane

c, ϕ = shear strength parameters expressed in terms of total stresses

For the case of effective stresses, the shear strengths are expressed by

$$s = \bar{c} + (\sigma - u) \tan \bar{\phi} \tag{3}$$

where

u = pore water pressure

$\sigma - u$ = effective normal stress

$\bar{c}, \bar{\phi}$ = shear strength parameters expressed in terms of effective stresses

In the input of data to the computer program, the values for "cohesion" and "friction angle" must be the appropriate total stress (c, ϕ) or effective stress ($\bar{c}$, $\bar{\phi}$) values. The only other distinction between total and effective stresses is made in the case of effective stress analyses. Here, appropriate pore water pressures (including zero as a special case) must be specified, while for total stress analyses pore water pressures must be specified as zero.

38. The distinction between total and effective stresses is made on a material-by-material basis. Thus, the shear strengths of some materials may be defined by using total stresses, while the shear strengths of other materials may be defined by using effective stresses.

Unit weights

39. The unit weight specified for each material should be the total unit weight (total weight divided by total volume). However, for two cases the submerged (buoyant) unit weight of soil may be used, although it is not necessary to use submerged unit weights in even these two cases. In general, the use of submerged unit weights is not recommended.

a. The first case where submerged unit weights may be used occurs for total stress analyses with ϕ equaling zero. In this case a submerged unit weight may be used for the portion of any soil which is submerged beneath water provided that there is no flow or tendency for flow (i.e., the hydraulic gradient is zero). If the submerged unit weight is used in this case, any surface loads due to the water which causes the submergence must not be specified as surface pressures (paragraphs 62 through 66, Tables 13 and 14 for description of surface pressures); the effects of the surface loads are already accounted for when the submerged unit weight is used. If there is flow of water (nonzero hydraulic gradient) or ϕ is not equal to zero, submerged unit weights must not be used for total stress analyses.

b. The second case where submerged unit weights may be used occurs in the case of effective stress analyses. Submerged unit weights may be used for the portion of any soil which is submerged provided that there is no flow of water and no hydraulic gradient. If the submerged unit weight is used, pore water pressures and any surface pressures due to the water must not be specified in the input data. The effects of pore water pressures and surface pressures are already accounted for when the submerged unit weights are used.

40. If submerged unit weights are used for one material, they must be used for all materials for which the use of submerged unit weights is allowable, i.e., they must be used for all portions of materials which are submerged.

Shear strength options

41. Five options are available for defining the shear strengths of any given material as follows:

a. Option 1. The shear strength is isotropic (shear strength is independent of the orientation of the failure plane) and is defined in a conventional manner, expressed by a Mohr-Coulomb cohesion, c , and friction angle, ϕ . For total stress analyses, the cohesion and friction angle should be the values of c and ϕ determined by using total stresses to plot the failure envelope. In the case of total stresses, the pore water pressures must be specified to be zero. For effective stress analyses, the values of c and ϕ ($\bar{c}$ and $\bar{\phi}$) should be values determined by using effective stresses to plot the failure envelope. In the case of effective stresses, appropriate pore water pressures will need to be specified and pore pressures may or may not be zero.

b. Option 2. The shear strength varies linearly with depth below the profile line(s) to which the data apply. The value of the shear strength at points along the profile line and the rate of increase in shear strength with depth below the profile line are input as data by the user. A negative value for the rate of "increase" is interpreted as a decrease in shear strength with depth below the profile line and an increase in shear strength above the profile line. The friction angle is assumed to be zero for Option 2 and the appropriate shear strength, depending on depth, is assigned as a cohesion value. Accordingly, this option will generally apply only to cases where undrained loading of saturated soils is involved and where the computations are being performed by using total stresses.

c. Option 3. The shear strength varies linearly with depth below a selected reference datum. The elevation (y) of the reference datum, the value of the shear strength at the elevation of the reference datum, and the rate of increase in shear strength with depth below the datum are input as data by the user. The shear strength is assumed to decrease with depth above the reference line at the same rate that it increases with depth below the profile line. Option 3 is very similar to Option 2. In the case of Option 3, the shear strength varies with depth below a horizontal datum, while for Option 2, the datum is the profile line, which may or may not be horizontal. All features of the input data for shear strength are otherwise identical for Options 2 and 3.

d. Option 4. The shear strength parameters c and ϕ, or $\bar{c}$ and $\bar{\phi}$, as described for Option 1, vary with the orientation of the failure plane. Values of c and ϕ are input for selected failure plane orientations and linear interpolation is used to obtain values at orientations between the specified values. The computer program will later assign appropriate values of c and ϕ to each slice based on the orientation of the base of the slice; the base of the slice is considered to represent the failure plane and the inclination of the base of the slice corresponds to the failure plane inclination (refer to paragraphs 70 through 116, Tables 17 through 22 regarding slices). Failure plane orientations are specified in the input data by angles measured in degrees from the horizontal plane. Values may range from negative to positive and should encompass the maximum anticipated range of failure plane (shear surface) inclinations. The computer program will not extrapolate from the input data for angles outside the range encompassed by the input data. When the failure plane inclination falls outside the range of the data, an error message will be issued by the program.

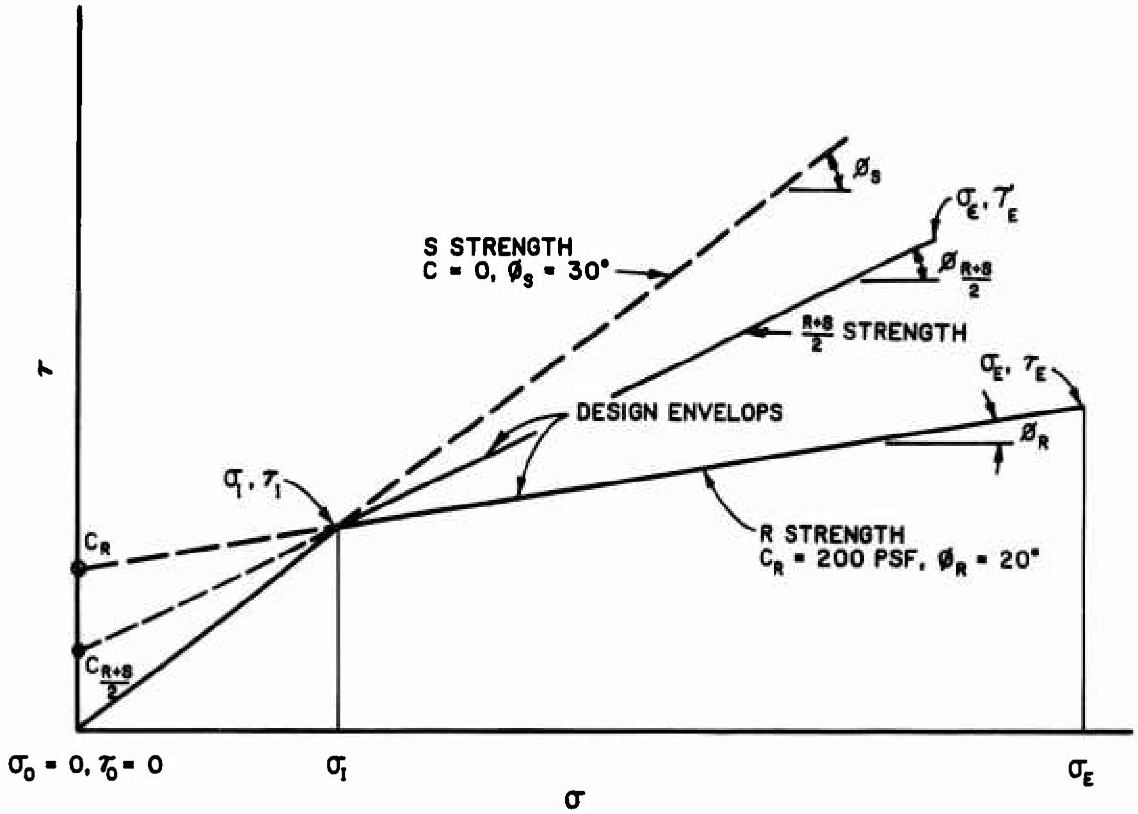
e. Option 5. The shear strength (Mohr-Coulomb type) envelope is nonlinear, i.e., it is not a single straight line. Values of shear strength(s) are input for various values of total or effective normal stress (σ or $\bar{\sigma}$) to define points on a nonlinear shear strength envelope. The points are assumed to be connected by straight lines to form a piecewise linear envelope. The computer program will later assign a shear strength to the base of each slice based on the total or effective normal stress on the base of the slice (paragraphs 70 through 116, Tables 17 through 22). An iterative procedure is used to assign the shear strengths because the computed normal stresses depend on the shear strength. The computed normal stresses also depend on the factor of safety. Accordingly, shear strengths defined by a nonlinear shear strength envelope are assigned at the time the factor of safety is computed. Because the solution for the factor of safety involves using a trial and error procedure, two levels of iteration are required when a nonlinear shear strength envelope is used: one level of iteration is for the factor of safety, and the other level is for the shear strength. This option is used to represent bilinear strength envelopes that are required for certain loading conditions. The R and S strength envelopes are used to generate the bilinear envelope. The strengths are generally provided in terms of c and ϕ, and $\bar{c}$ and $\bar{\phi}$. However, values of shear strength and normal stresses are needed to define the envelope. Figure 1 shows both the graphical and computational methods that can be used to obtain the necessary values. The envelope must be defined beyond the largest normal stress that is encountered during the analysis. The computer program will not extrapolate from the input data for values of the normal stress outside the range encompassed by the input data. This requires that negative normal stresses be set to zero shear stress as part of the shear strength description if negative normal stresses are calculated. When the normal stress falls outside the range of the data, an error message will be issued by the program.

Pore water pressure options

42. Six options are available for defining pore water pressures in individual materials as follows:

a. Option 1. No pore water pressures are to be used, i.e., total stresses are being used, or the pore water pressures are equal to zero.

b. Option 2. The pore water pressure is constant throughout the given material; the constant value of pore water pressure is then input. This option is seldom used.



EQUATIONS FOR σ_I, τ_I

$$\sigma_I \text{ TAN } \varnothing_S = \sigma_I \text{ TAN } \varnothing_R + C_R$$

OR

$$\sigma_I = \frac{C_R}{\text{TAN } \varnothing_S - \text{TAN } \varnothing_R}$$

$$\tau_I = \sigma_I \text{ TAN } \varnothing_R + C_R$$

OR

$$\tau_I = \sigma_I \text{ TAN } \varnothing_S$$

EQUATION FOR σ_E, τ_E FROM R ENVELOP

$$\tau_E = \sigma_E \text{ TAN } \varnothing_R + C_R$$

EQUATION FOR σ_E, τ_E FROM (R+S)/2 ENVELOP

$$\tau_E = \sigma_E \text{ TAN} \varnothing_{\frac{R+S}{2}} + C_{\frac{R+S}{2}}$$

Figure 1. Graphical and computational methods used for obtaining necessary values

c. Option 3. The pore water pressures are expressed by a constant, given value of the pore water pressure coefficient, r_u (Bishop and Morgenstern 1960). The pore water pressure coefficient is defined as

$$r_u = \frac{u}{\gamma h} \tag{4}$$

where

u = pore water pressure

γ = total unit weight of the soil

h = depth corresponding to pore pressure u

Therefore, γh is the total vertical stress (overburden pressure) corresponding to pore pressure, u. If this option is chosen, the value of r_u is then input. In computing pore water pressures using a value of r_u, the computer program calculates "h" due to the weight of overlying soil, but excludes any added vertical stress due to "surface pressures" which may be input as Group G data (paragraphs 62 through 66, Tables 13 and 14).

d. Option 4. The pore water pressure is defined by a piezometric line; piezometric line data must be input separately by use of Group D data as described in paragraphs 46 through 50, Tables 7 and 8. The material property data must include an identification number for the piezometric line to be used. In computing pore water pressures from the piezometric line the computer program determines the vertical distance between the point of interest and the piezometric line and multiplies this distance by the unit weight of water to arrive at the pore water pressure. Pore water pressures are assumed to be positive below the piezometric line and negative above the piezometric line (paragraphs 46 through 50, Tables 7 and 8 for more details).

e. Option 5. Pore water pressures are computed by interpolating pore water pressures from an irregular grid of pore pressure values, which are specified separately by Group E data, as described in paragraphs 51 through 54, Tables 9 and 10.

f. Option 6. Pore water pressures are computed by interpolating in a manner similar to that for Option 5, except that values of the pore water pressure coefficient, r_u, rather than actual values of pressure, are input and used for interpolation. The values of r_u are used and defined in the same manner as described for Option 3. Further description of the interpolation is presented in paragraphs 51 through 54, Tables 9 and 10. Option 6 is seldom used.

43. Normally, the computer program will set any negative value of pore water pressure to zero before proceeding with further calculations; however, the user can optionally override this feature (Line 5, Field 3, Table 6).

Form for data input

44. The form and guide for Group C data input are presented in Table 6. The Group C data must immediately follow the command word "MAT" (or "MATERIAL PROPERTIES"). Only the Normal mode of input is available for material properties and will be used regardless of whether the Normal or Modify mode is in effect.

45. Once data have been input for materials, they remain in effect until specifically replaced, material by material, with new data. If new data are input for only one material, after data for several materials have been previously input, then the new data will either replace the data for one material or add to the existing data. If the material type (MTYPE - Line 1, Field 1, Table 6) for the new material is identical to one previously defined, the new data will replace the previous data for this material only. If the material type for the new material has not been previously defined, the new data are added to the old data which were previously defined. Thus, while a Modify mode is not available for material property data, the Normal mode permits data to be selectively changed. The only times material property data are started entirely anew is when asterisks (***) have been input as a command word (Table 2).

Table 6

Group C - Material Property Data Input Format

Input Line	Data Field	Variable/Description
1	1	(MTYPE) - Number used to identify the material (= material type) for which data will follow on Line(s) 2 through 6. This number corresponds with the material type numbers input for profile lines in Group B data.
1	2	(LABEL) - Any alphanumeric character(s) or character string(s) to be printed as a label with data for the current material type. Can be as many characters and/or blanks as will fit on an 80-column line (including Field 1) up to a maximum of 65 characters. Can also be blank.
2	1	(GAMMA) - Unit weight for the current material.
3	1	(CHAR(1)) - A character, or character string beginning with an appropriate character, to designate the manner in which shear strengths are to be characterized. The acceptable characters or character strings and their interpretation are shown below. The key character which must be input is capitalized and underlined. (Note: Only the first nonblank character is recognized and used.)

Character String	Interpretation
Conventional shear	Shear strengths are expressed by conventional Mohr-Coulomb parameters, c and ϕ. Follow this line of data with Lines 4A below.
Linear increase	Shear strengths increase linearly with depth below the profile line, starting at a prescribed value along the profile line. Follow this line of data with Lines 4B below.

(Continued)

(Sheet 1 of 5)

Table 6 (Continued)

Input Line	Data Field	Variable/Description	
		Character String	**Interpretation**
		Reference	Shear strengths increase linearly with depth below a specified reference elevation. Follow this line of data with Lines 4C below.
		Anisotropic shear	Shear strengths vary with the orientation of the failure plane. Follow this line of data with Lines 4D below.
		Nonlinear Mohr-Coulomb envelope	The shear strength envelope is nonlinear. Follow this line of data with Lines 4E below.
4A	1	(COHESN) - Cohesion value, c , for the soil.	
4A	2	(PHIANG) - Angle of internal friction, , for the soil in degrees.	
		After the above Line 4A, proceed with Line 5.	
4B	1	(CPROFL) - Value of shear strength along the profile line.	
4B	2	(RATEIN) - Rate of increase in shear strength below the profile line, expressed as an increase in strength per unit of depth. (Units = force/length^2/length = force/length^3.)	
		After the above Line 4B, proceed with Line 5.	
4C	1	(YDATUM) - Y coordinate for the reference elevation used as a datum for shear strengths.	
4C	2	(CDATUM) - Value of shear strength at the elevation of the reference elevation.	

(Continued)

(Sheet 2 of 5)

Table 6 (Continued)

Input Line	Data Field	Variable/Description
4C	3	(RATEIN) - Rate of increase in shear strength below the reference elevation, expressed as an increase in strength per unit of depth. (Units = force/length^2/length = force/length^3.) After the above Line 4C, proceed with Line 5.
4D	1	(FPANGL) - Orientation of failure plane for set of shear strength values in Fields 2 and 3 (expressed as an angle, in degrees, measured from the horizontal) positive counter-clockwise. Both negative and positive values are allowed; typically, values may range from -90 degrees to +90 degrees.
4D	2	(COHESN) - Cohesion value, c, for current failure plane orientation.
4D	3	(PHIANG) - Angle of internal friction, ϕ, for current failure plane orientation, in degrees.
		Repeat Line 4D for additional anisotropic shear strength values in a sequence of increasing angles of failure plane orientation. More than one set (three values) of data can be entered on a given line; however, each line must contain integer multiples of three values, comprising complete data sets. Input a blank line to terminate the current anisotropic shear strength data and then continue with Line 5.
4E	1	(SIGMA) - Normal stress, σ or $\bar{\sigma}$, for point which is being defined on nonlinear failure envelope.
4E	2	(TAU) - Shear stress, τ, for point on nonlinear envelope.
		Repeat Line 4E for additional values to define a nonlinear failure envelope. Values must be input in a sequence of increasing values of normal stress. More than one pair of values (σ and τ) can be entered on a single line of input data, if desired. Input a blank line to terminate the current nonlinear failure envelope data.

(Continued)

(Sheet 3 of 5)

Table 6 (Continued)

Input Line	Data Field	Variable/Description
5	1 and 2	(CHAR) - Two characters separated by blanks, or two character strings separated by blanks, to designate how pore water pressures are to be defined for this material. The acceptable characters or character strings and their interpretation are shown below. The key characters which must be input are capitalized and underlined. (Note: Only the first character of any character string is recognized and used.)

Character String	Interpretation
NO pore pressure	Pore pressures are zero. (Only one character, N, is actually required in this case.) No Line 6 is required; see notes following Line 6.
Constant Pore pressure	Pore pressures are constant. Follow this line of data with Line 6 giving the value of the pore water pressure.
Constant R_u value	The value of the pore water pressure coefficient, r_u , is constant. Follow this line of data with Line 6 giving the value of the pore water pressure coefficient, r_u .
Piezometric Line	A piezometric line is used to define pore water pressures in this material. Follow this line of data with Line 6 giving the identification number of the piezometric line which is to be used. Note: Group D data must eventually be input.

(Continued)

(Sheet 4 of 5)

Table 6 (Concluded)

Input Line	Data Field	Variable/Description	
		Character String	**Interpretation**
		Interpolate Pore water pressure	Pore water pressures are to be determined by interpolation of values of pore water pressure. Note: Group E data must eventually be input, but no Line 6 is required below. See notes following Line 6.
		Interpolate R_u values	Pore water pressures are to be determined by interpolation of values of the pore water pressure coefficient, r_u . Note: Group E data must eventually be input, but no Line 6 is required below.
5	3	CHAR(3) - A character, or character string to designate if negative pore water pressures are to be acceptable in this material. Specify "N" (i.e., "Negative") if negative pore pressures are acceptable. Any other character (or blank) in this field will cause negative pore water pressures to be set to zero.	
6	1	Optional - Value of (1) the pore water pressure, (2) r_u , or (3) the identification number of the piezometric line depending on data on Line 5. Line 6 is not required in all cases and in such cases should be omitted.	

Repeat Lines 1 through 6, as sets, for data for additional material types. Material types may be input in any order. (Material type numbers, MTYPE, may actually be missing from a sequence; however, there appears to be little need for omitting numbers from a sequence.) Input a blank line after data for the last material have been input to terminate all Group C data; then return to input of command words.

(Sheet 5 of 5)

Group D Data for Piezometric Line (Optional)

46. The Group D data consist of the data for the piezometric lines. These data are required only when the material property data (paragraphs 36 through 45, Table 6) have designated that the pore water pressures in one or more materials are to be defined by a piezometric line.

47. The computer program allows several piezometric lines to be defined. The maximum number of lines depends on the size of arrays as given in Appendix B. Each piezometric line is assigned an identification number in the range of from 1 to the maximum number of piezometric lines allowed. The identification number is used with the material property data to associate a given piezometric line with a given material (Table 6, Line 6). Several materials may share and use the same piezometric line. The sequence and pattern for assigning numbers to piezometric lines is arbitrary and selected by the user.

48. Each piezometric line is defined by the coordinates of a series of points from left to right over the entire expanse of the material. An error will occur if the piezometric data does not extend far enough laterally to include the total area involved in the analysis. The points are assumed to be connected by straight lines to form a continuous, piecewise linear, piezometric line. Vertical segments of the piezometric lines are acceptable. THE PIEZOMETRIC LINE DOES NOT APPLY WATER PRESSURE TO THE SURFACE SLOPE.

49. Pore water pressures are calculated by taking the vertical distance between any point of interest and the corresponding point on the piezometric line and multiplying the distance by the unit weight of water (or other fluid). The unit weight of water (or other fluid) may be input with the piezometric line data (if different from 62.4 pcf*) and may be different for each piezometric line. A unit weight of 62.4 pcf will be assumed for any line for which a unit weight is not input. Pore pressures are considered to be negative above the piezometric line and positive below the piezometric line (Table 6, Line 5, Field 3, regarding negative pore water pressures).

50. Group D data for the piezometric line may be input in the Normal or Modify mode. The forms for data input in the Normal and Modify modes are presented in Tables 7 and 8, respectively.

---

* A table of factors for converting non-SI units of measurement to SI (metric) units is provided on page 4.

Table 7

Group D - Piezometric Line Data Input Format - Normal Mode

Input Line	Data Field	Variable/Description
1	1	(PZLINE) - Number used to identify the piezometric line.
1	2	(GAMMAW) - Unit weight of water (or other fluid) to be used with this piezometric line (optional). If omitted, a value of 62.4 pcf is assumed.
1	2 or 3	(LABEL) - Any alphanumeric character(s) or character string(s) to be printed on output as a label with data for the current piezometric line (optional). Must not start with a numeral (1, 2, 3, etc.)--this is required to distinguish if information in the second field is the unit weight of fluid or the label. Can be up to a maximum of 30 characters and/or blanks and must fit on an 80-column line (including Fields 1 and 2). Can also be blank.
2	1	(XPIEZL) - X coordinate of point on the piezometric line which is currently being defined.
2	2	(YPIEZL) - Y coordinate of point on the piezometric line which is currently being defined.

Repeat Line 2 for additional points on the piezometric line in a left-to-right (increasing x value) sequence. Vertical segments are allowed. More than one pair of coordinates (XPIEZL, YPIEZL) may be entered on a given line of input data if desired. Input a blank line to terminate data for the current piezometric line.

Repeat Lines 1 and 2, as sets, for additional piezometric lines. Lines may be input in any order. (Piezometric line numbers, PZLINE, may actually be missing from a sequence; however, there appears to be little need for this option of omitting numbers from a sequence.) Input two blank lines (including the blank Line 2 for the last piezometric line) to terminate all Group D data; then return to input of command words.

Table 8

Group D - Piezometric Line Data Input Format - Modify Mode

Input Line	Data Field	Variable/Description
1	1	(NLINE) - Number of the piezometric line for which coordinate is to be changed.
1	2	(NPOINT) - Number of the point on the given piezometric line where coordinate values are to be changed.
1	3	(XPIEZL) - New value of X coordinate for point.
1	4	(YPIEZL) - New value of Y coordinate for point.

Repeat Line 1 for additional points whose coordinates are to be changed in Modify mode. More than one set (4 values) of data may be entered on a given line of input data; however, each line must contain integer multiples of four values, comprising complete data sets. Input a blank line to terminate all Group D data in Modify mode; then return to input of command words.

Group E Data for Pore Water Pressure Interpolation (Optional)

51. The Group E data consist of a series of discrete values of pore water pressure (u) or pore water pressure coefficient (r_u). The values are specified at selected points and used to interpolate pore water pressures at desired points along the shear (potential sliding) surface. These data are required only when the material property data (paragraphs 36 through 45, Table 6) have designated that the pore water pressures in one or more materials are to be defined by interpolation. The maximum number of points allowed depends on the size of arrays as given in Appendix B. The procedure used for interpolation of pore water pressures is based on the procedure proposed by Chugh (1981) and appears to be an improvement over the interpolation procedure formerly employed by Wright (1982). The interpolation procedure is briefly described below.

Interpolation procedure

52. The pore pressures of interest are those along the shear surface. Therefore, pore water pressures are interpolated at a point corresponding to the center of the base of each vertical slice (paragraphs 70 through 116, Tables 17 through 22). The interpolation is carried out slice by slice for each slice whose base lies in a material where the pore pressure interpolation option was specified. The interpolation is initiated by locating the closest points to the point of interest (center of base of slice) which lie in each of the four quadrants surrounding the point of interest. The four quadrants are illustrated schematically in Figure 2. Once the closest points in each of the four quadrants are located, three of the four points are then selected (arbitrarily) and used to evaluate the coefficients a , b , and c in a linear interpolation function of the form

$$u = a + bx + cy \tag{5}$$

where

u = pore water pressure

x,y = coordinates of the point where the pore water pressure (u) exists

a,b,c = interpolation coefficients

Equation 5 is solved for the interpolation coefficients (a, b, and c) by using

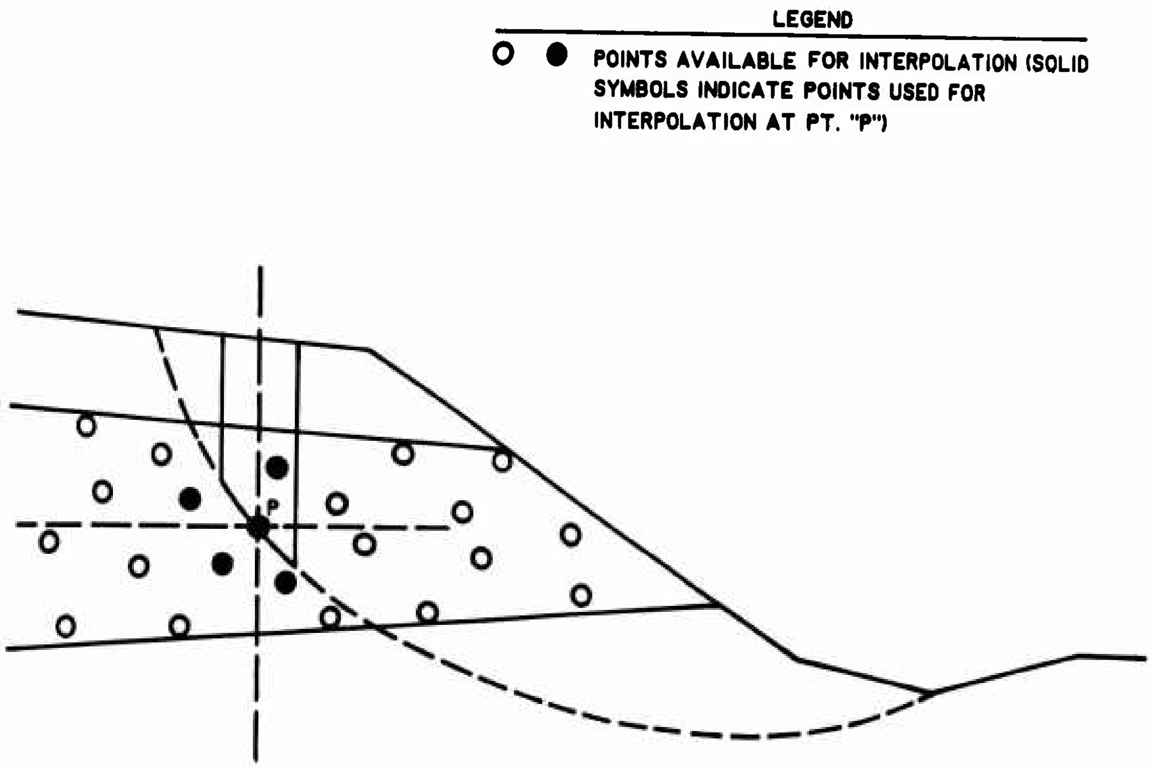


Figure 2. Illustration of pore pressure points used for interpolation (Wright 1985)

the known pore water pressures and corresponding coordinates of the three selected points. The values of the coefficients are next used in Equation 5 to calculate the pore water pressure at the center of the base of the slice. This process is then repeated by using another combination of three of the four points found previously and a new set of calculations is performed to calculate the pore water pressure at the center of the base of the slice. This sequence of calculations is performed a total of four times, each time using a different combination of three of the four points. Finally, after four values of pore water pressure have been determined by interpolation, the four values are averaged arithmetically, and the average value is used for the slice. This process is repeated for each slice (and each shear surface) where pore water pressures are to be calculated by interpolation.

53. In the case where the pore pressure coefficient, r_u, rather than the pore water pressure, u, is to be used for interpolation, the same procedures as those described above are used, except that u is replaced by r_u. Once an average value of r_u for the center of the base of the slice is obtained by interpolation, the average value is used to calculate the pore water pressure. Thus, the computer program interpolates r_u first, and then

calculates the pore water pressure, rather than calculating u first, and then interpolating values of u to the base of the slice.

Form of data input

54. The Group E data must immediately follow the command word "INT" (or "INTERPOLATION DATA"). The data may be input in the Normal or Modify mode. The forms of input for the Normal and Modify modes are presented in Tables 9 and 10, respectively.

Table 9

Group E - Pore Pressure Interpolation Data Format - Normal Mode

Input Line	Data Field	Variable/Description
1	1	(CHAR) - A single character, or a character string starting with the appropriate character, to designate if the data which will follow (on Line 2) represent values of pore water pressure or values of the dimensionless pore pressure coefficient, r_u. The character should be a "P" to indicate that values represent pore water pressure, or an "R" to indicate that values represent values of r_u. A blank line is interpreted to represent the end of all Group E data.
2	1	(XINTPT) - X coordinate for interpolation point.
2	2	(YINTPT) - Y coordinate for interpolation point.
2	3	(UINTPT) - Value of pore water pressure or pore pressure coefficient, r_u (depending on designation on Line 1), at the specified coordinate point.
2	4	(MINTPT) - Material type (with reference to Group C data) for which this specified pore pressure information is to be used. If zero, this information (point) will be used for all materials where pore pressures are interpolated, provided that the type of data (pore pressures, or r_u) at this point is consistent with what was indicated by the material data, e.g., if r_u values are to be interpolated, this line of data must contain an r_u value or it will not be used.

Repeat Line(s) 2 for additional points with data of a similar type (e.g., pore pressure or r_u). More than one set (four values) of data may be entered on a given line of input data; however, each line of input must contain an integer multiple of four values, comprising complete sets of data. Input a blank line to terminate data of one type (pore pressure or r_u), then follow with another Line 1. The data on Line 1 following the above Line(s) 2 may either designate another type of data (e.g., pore pressures versus r_u) and be followed by more Line(s) 2, or may serve to terminate all Group E data.

Table 10

Group E - Pore Pressure Interpolation Data Format - Modify Mode

Input Line	Data Field	Variable/Description
1	1	(CHAR) - A single character, or a character string beginning with the appropriate character, to designate whether the data which are to follow are to replace existing data, or are to be added to existing data. The character should be either an "R", to indicate that values are to be replaced, or an "A", to indicate that values are to be added. If the character is R, proceed with Line 2A to replace data; if the character is A, proceed with Lines 2B and 3 to add data. A blank character (blank line) is interpreted as the end of all Group E data designated by the current command word.
2A	1	(NPOINT) - Number identifying the number of the point which is to be replaced. (On previous input, the first point input was assumed to be point 1, the second input was assumed to be point 2, etc.)
2A	2	(XINTPT) - New X coordinate for point which is being replaced.
2A	3	(YINTPT) - New Y coordinate for point which is being replaced.
2A	4	(UINTPT) - New value of either pore water pressure or r_u at point which is being replaced. Note: The type of value (pore pressure or r_u) must be the same as it was originally at this point.
		Repeat Line(s) 2A for additional points which are to be replaced. More than one set (4 values) of data may be entered on a given line of input data if desired; however, each line of input must contain an integer multiple of four values, comprising complete sets of data. Input a blank line to terminate Line(s) 2A, then proceed with Line 1 again.
2B	1	(CHAR) - A single character, or a character string beginning with the appropriate character, to designate whether the data which are to

(Continued)

Table 10 (Concluded)

Input Line	Data Field	Variable/Description
		follow represent values of pore water pressure or values of the dimensionless pore water pressure coefficient, r_u . The character should be either a "P", to indicate that values represent pore water pressure, or an "R", to indicate that values represent values of r_u . A blank line is not allowed here.
3	1	(XINTPT) - X coordinate for interpolation point.
3	2	(YINTPT) - Y coordinate for interpolation point.
3	3	(UINTPT) - Value of pore water pressure or pore pressure coefficient, r_u (depending on designation on Line 2B), at the specified coordinate point.
3	4	(MINTPT) - Material type (with reference to Group C data) for which this specified pore pressure information is to be used. If zero, this information (point) will be used for all materials where pore pressures are interpolated, provided that the type of data (pore pressures or r_u) at this point is consistent with what was indicated by the material data, e.g., if r_u values are to be interpolated, this line of data must contain an r_u value or it will not be used.

Repeat Line(s) 3 for additional points with data of a similar type (e.g., pore pressure or r_u), which are to be added. More than one set (four values) of data may be entered on a given line of input data if desired; however, each line of input must contain an integer multiple of four values, comprising complete sets of data. Input a blank line to terminate data of one type (pore pressure or r_u), then proceed with Line 1 again.

Group F Data for Slope Geometry (Optional)

55. The Group F data are used (optionally) to define the slope geometry. As discussed in paragraphs 29 through 35 with the profile lines, the slope geometry data permit several different slope geometries to be "cut" in a given profile (set of profile lines). Any soil in the profile which lies above the surface defined by the slope geometry data is ignored. Thus, several slope geometries may be considered by simply changing the slope geometry (Group F) data.

56. Slope geometry data are also used to cancel a previous set of slope geometry when new profile line data are entered and it is desired to have new slope geometry generated from the profile line data. In such cases a "null" set of slope geometry data should be entered as described in the following paragraphs.

Description of data

57. The slope geometry data define the surface profile of the slope and consist of the coordinates of a series of points from left to right along the surface of the slope. The points are assumed to be connected by straight lines to form a continuous slope profile. All material (soil, rock, etc.) which has been defined by profile lines to exist above the surface of the slope, designated by the slope geometry data in Group F, is ignored. Thus, profile lines specified in Group B could define an original soil profile, and the slope geometry data could describe one or more excavated slope profiles within the original soil profile.

58. Both left- and right-facing slopes are allowed, and a single slope may contain both a left and a right face in its specified geometry. Vertical slopes and horizontal slopes are also allowed. In the case of a horizontal slope, loads would be applied by surface pressures and the problem becomes essentially one of bearing capacity.

Special note for flat slopes

59. Special care is required when using the computer program with very flat or horizontal slopes. An example of this situation is the analysis of bearing failure on a horizontal surface due to surcharge loads. The user must be aware however that this safety factor is not the same as the bearing capacity safety factor. The computer program determines the direction (left or right) of potential sliding by comparing the elevations of the two ends of the

shear surface. If the left end is higher than the right end, the direction of potential sliding is assumed to be to the right for the specific shear surface examined. Otherwise, the direction of potential sliding is assumed to be to the left. Thus, for horizontal slopes the direction of sliding is assumed to be to the left. Accordingly, for horizontal slopes shear surfaces should be directed to the left of the area of the applied surface loading. For flat, but not horizontal, slopes, the direction of sliding is assumed to be in the direction in which gravity would produce sliding, i.e., from high to low. If sliding in the opposite direction from gravity was possible due to relatively high surface pressures, special features of the program would have to be invoked. Specifically, a special "opposite sign convention option" must be activated by optional data in the Group J - Analysis/Computation data (Table 22, subcommand word "OPP").

Form for data input

60. The Group F data must immediately follow the command word "SLO" (or "SLOPE GEOMETRY"). The data may be input in the Normal or Modify modes. The forms of input for the Normal and Modify modes are presented in Tables 11 and 12, respectively.

61. A null set of slope geometry data is entered by first activating slope geometry data input by the command word "SLO". The slope geometry data are then immediately terminated by a blank line, i.e., no coordinates are actually entered.

Table 11

Group F - Slope Geometry Data Input Format - Normal Mode

Input Line	Data Field	Variable/Description
1	1	(XSLOPE) - X coordinate of slope point.
1	2	(YSLOPE) - Y coordinate of slope point.
		Repeat Line(s) 1 for additional points on the surface of the slope from left to right. More than one pair of coordinates (XSLOPE, YSLOPE) may be entered on a given line of input data if desired. Input a blank line to terminate slope geometry data (all Group F data); then return to input of command words. If only a blank line, not preceded by X and Y coordinates, is input, the slope geometry data are canceled, i.e., a null set of data are input. When slope geometry data are canceled, new coordinates defining the slope geometry will be computed by the computer program using the profile line data.

Table 12

Group F - Slope Geometry Data Input Format - Modify Mode

Input Line	Data Field	Variable/Description
1	1	(N) - Number of slope point whose coordinates are to be changed.
1	2	(XSLOPE) - New X coordinate value for the point.
1	3	(YSLOPE) - New Y coordinate value for the point.
		Repeat Line 1 for points with coordinates to be changed. More than one set of data (three quantities) may be entered on a given line; however, each line must contain integer multiples of three quantities, comprising complete data sets. Input a blank line to terminate current slope geometry data in Modify mode, then return to input of command words.

Group G Data for Surface Pressures (Optional)

62. Group G data consist of the surface pressures which are used to define stresses acting on the surface of the slope. THIS IS THE RECOMMENDED MANNER TO ACCOUNT FOR EXTERNAL WATER LOADS. The surface pressures are specified in terms of values of stress acting normal (perpendicular) to the slope and tangential (parallel) to the slope. The pressures are specified in the input data by specifying coordinates of points on the surface of the slope and the corresponding values of normal and shear stress at the point. For water loads, the normal stress is the height of water multiplied by its unit weight, and the shear strength is zero. Points are specified in a left-to-right sequence. The pressures are assumed to be zero to the left of the first point specified and to the right of the last point specified. The normal and shear stresses are assumed to vary linearly between specified points. If an abrupt change in stress occurs at a point, the coordinates of the point are input twice, first with the value of stress just to the left of the point and then with the value of the stress just to the right of the point.

63. Compression is considered to be positive for the normal stresses acting on the surface of the slope; tension is considered to be negative. The shear stresses are considered to be positive when they act to the right and negative when they act to the left.

64. The coordinates of points which are input to define the surface pressures should be specified as precisely on the surface of the slope as is practically possible. If the points do not coincide with the surface of the slope, an error condition may result and computations will be abandoned with an appropriate warning message.

65. <u>Surface pressures cannot be specified (input) on vertical segments of the slope,</u> because surface pressures are considered to produce loads on the tops of vertical slices. All loads on the vertical sides of slices are considered to be included in side forces and are computed as unknowns.

66. Surface pressure data must immediately follow the command word "SUR" (or "SURFACE PRESSURES"). The data may be input in the Normal or Modify mode. The forms of input for the Normal and Modify modes are presented in Tables 13 and 14, respectively.

Table 13

Group G - Surface Pressure Data Input Format - Normal Mode

Input Line	Data Field	Variable/Description
1	1	(XSURFP) - X coordinate value of point where stress acts.
1	2	(YSURFP) - Y coordinate value of point where stress acts.
1	3	(PNORML) - Normal stress at point.
1	4	(PSHEAR) - Shear stress at point.
		Repeat Line(s) 1 for additional points to define the surface pressures in a left-to-right sequence. More than one set of data (four quantities) may be entered on a given line; however, each line must contain integer multiples of four quantities, comprising complete data sets. Input a blank line to terminate the surface pressures data (all Group G data), then return to input of command words (paragraphs 24 through 27, Tables 1 and 2).

Table 14

Group G - Surface Pressure Data Input Format - Modify Mode

Input Line	Data Field	Variable/Description
1	1	(N) - Point number where coordinates and/or surface pressures are to be changed.
1	2	(XSURFP) - New X coordinate of point.
1	3	(YSURFP) - New Y coordinate of point.
1	4	(PNORML) - New normal stress at point.
1	5	(PSHEAR) - New shear stress at point.
		Repeat Line(s) 1 for additional points to modify previously defined surface pressure data points. Not all points need to be modified. More than one set of data (five quantities) may be entered on a given line; however, each line must contain integer multiples of five quantities, comprising complete data sets. Input a blank line to terminate the surface pressure data in Modify mode, then return to command words (paragraphs 24 through 27, Tables 1 and 2).

Group H Data for Reinforcement Lines (Optional)

67. Group H data are used to define internal reinforcement in the slope. Reinforcement is specified as individual lines of support within the slope cross section. A tensile force is considered to act along each line of reinforcement as an internal force. These reinforcement lines are defined by specifying coordinates along the lines in essentially the same manner as is done for soil profile lines. The value of the internal reinforcing effect is specified at each coordinate along the reinforcement line; the forces are assumed to vary linearly between coordinate points specified. Points specified are assumed to be connected by straight lines such that the reinforcement is considered to be a piecewise linear feature in the cross section. This reinforcement is considered to provide internal reinforcing forces in the soil mass only; it is not assumed to have weight or occupy physical space in the cross section, i.e., it is considered to be infinitesimally thin compared to the size of the slice.

68. The internal reinforcement is used to compute forces acting on the shear (sliding) surface. When the base of a particular slice crosses the reinforcement, a force is calculated and applied as a known force to the base of the slice. The known force due to reinforcement is considered to be a force in addition to any other force due to the stresses in the soil. Multiple reinforcement lines can occur in a single slice. Separate forces representing the normal and shear stresses in the soil are assumed to act on the base of each slice. Three separate options available to the user to designate how the reinforcement force will be calculated and applied to the base of the slice are illustrated in Figure 3 and described as follows:

a. Option 1. The full force specified in the reinforcement (FREINP) is determined and applied to the base of the slice in the direction of the reinforcement. This will generally result in the additional force's contribution to the shear component of resistance along the base of the slice and to the normal stress perpendicular to the base of the slice. The contribution to the normal stress will, in turn affect the shear strength in the soil around the reinforcement.

b. Option 2. The full force specified in the reinforcement (FREINP) is applied to the base of the slice in a direction parallel (tangential) to the shear surface (base of slice). This will result in the reinforcement's contribution only to the shear resistance along the base of the slice. The contribution to the shear resistance will be greater than in

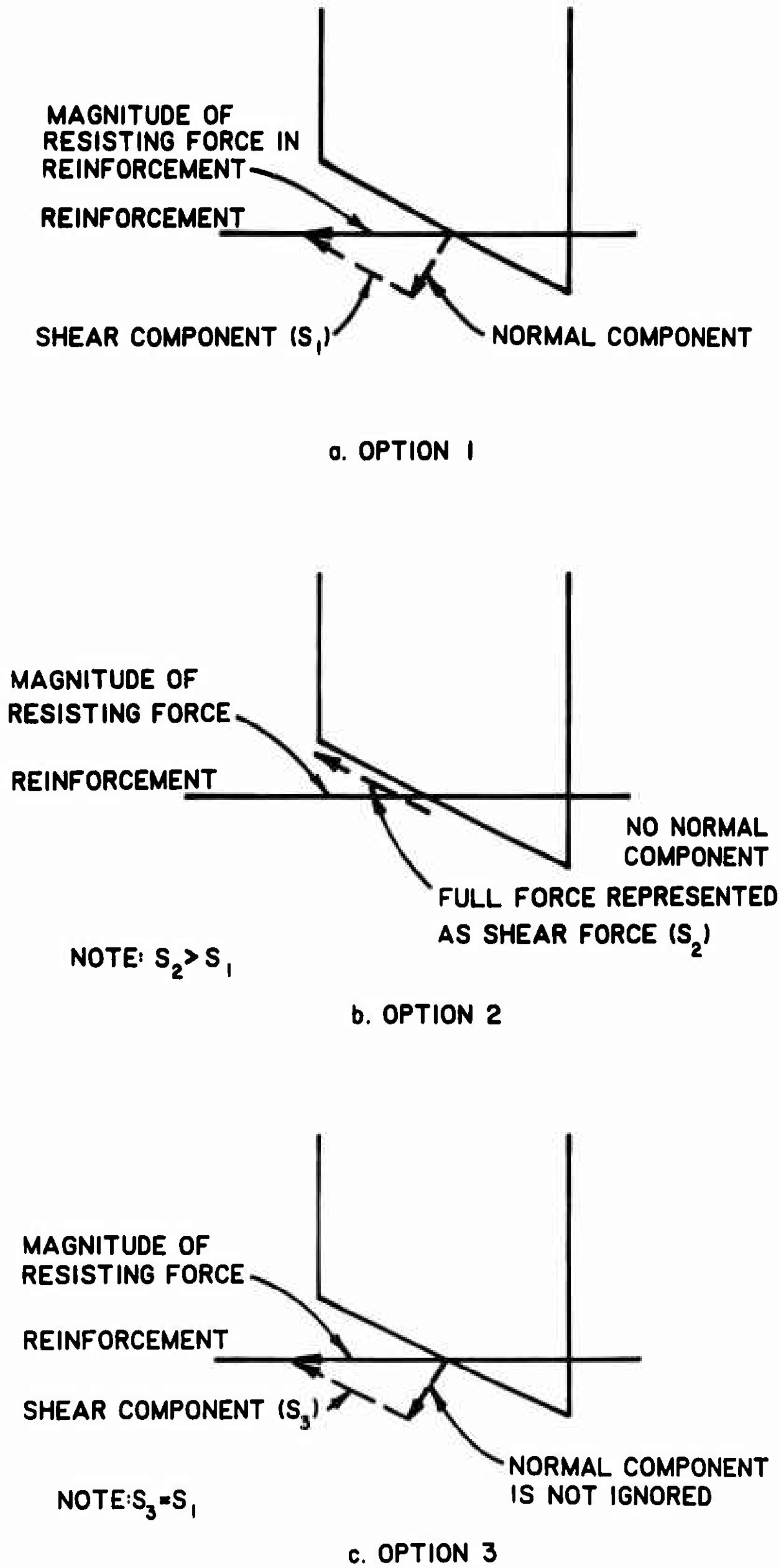


Figure 3. Illustration of force options for internal reinforcement

Option 1, but there will be no direct contribution to the normal force on the base of the slice.

c. Option 3. The component of the reinforcement force (FREINP) which is tangential to the shear surface will be applied as a force tangential to the shear surface, but the component of the force which is normal to the shear surface will be ignored. This will result in the same component of the reinforcement force being applied in shear, as was done in Option 1, and no component of the reinforcement force being applied as a normal force to the base of the slice, as is done in Option 2. This option should represent the smallest addition force contributed by the reinforcement of the three options available.

69. Group H data must immediately follow the command word "REI" (or "REINFORCEMENT LINES"). The data may be input in the Normal or the Modify mode. Input for the Normal mode is described in Table 15; input for the Modify mode is described in Table 16.

Table 15

Group H - Reinforcement Line Data Input Format - Normal Mode

Input Line	Data Field	Variable/Description
1	1	(NLINE) - Number of the reinforcement (fabric/tie-rod) line to be defined next, i.e., on Line(s) 2 below. Any sequence of numbering and input of reinforcement lines may be used.
1	2	(REOPTN) - A number from 1 to 3 used to indicate which option is to be used for computing and assigning the reinforcement force to the base of the slice, as follows: = 1 if the full force specified in the reinforcement (FREINP) is to be applied to the base of the slice in the direction of the reinforcement. = 2 if the full force specified in the reinforcement (FREINP) is to be applied to the base of the slice in a direction parallel (tangential) to the shear surface (base of slice). = 3 if the component of the force specified in the reinforcement (FREINP) which is tangential to the shear surface is to be applied as a force tangential to the shear surface while the component of the force which is normal to the shear surface is to be ignored.
2	1	(XREINP) - X coordinate of point on the reinforcement line which is currently being defined.
2	2	(YREINP) - Y coordinate of point on the reinforcement line which is currently being defined.
2	3	(FREINP) - Resisting force per unit width acting axially along the reinforcement line to the point being specified. Tensile reinforcing forces are considered positive; compressive forces are considered negative.

(Continued)

Table 15 (Concluded)

Input Line	Data Field	Variable/Description
		(a) Repeat Line(s) 2 for additional points on the reinforcement line in a left-to-right sequence. More than one pair of coordinates (XREINP, YREINP) may be entered on a given line; however, each line must contain integer multiples of three quantities, comprising complete data sets. Input a blank line to terminate data for the current profile line.
		(b) Repeat Lines 1 and 2, as sets, for additional reinforcement lines. Lines may be input in any order. (Line numbers, NLINE, may be missing from a sequence; however, there appears to be little need for omitting numbers from a sequence.) Input two blank lines after the last line of nonblank reinforcement line data to terminate <u>all</u> Group H data and return to input of command words.

Table 16

Group H - Reinforcement Line Data Input Format - Modify Mode

Input Line	Data Field	Variable/Description
1	1	(NLINE) - Number of the reinforcement (fabric/tie-rod) line for which coordinate is to be changed.
1	2	(NPOINT) - Number of the point on the given reinforcement line where coordinate is to be changed.
1	3	(XREINP) - New value of the X coordinate for point designated.
1	4	(YREINP) - New value of the Y coordinate for point designated.
1	5	(FREINP) - New value of the force in the reinforcement at the coordinate point designated.

Repeat Line(s) 1 for additional points whose coordinates are to be changed in Modify mode. More than one set of data (five quantities) may be entered on a given line; however, each line of data must contain integer multiples of five quantities, comprising complete data sets. Input a single blank line to terminate all Group H data and return to input of command words.

Group J Data for Analysis and Computations

70. The Group J input data define the shape of the shear (potential sliding) surfaces used to compute the factor of safety. This factor is normally computed using the procedure of slices developed by Spencer (1967) and extended by Wright (1969, 1975), although other procedures may be selected as described later in the following paragraphs. Regardless of the procedure used, the solution for the factor of safety involves subdividing the soil mass, which is bounded by the surface of the slope and an assumed shear surface, into a finite number of vertical slices and using an iterative procedure to compute the factor of safety. A number of trial shear surfaces must be tried to locate the surface which produces the minimum factor of safety.

71. In addition to defining the locations of the shear surfaces used to compute the factor of safety, the Group J input data also include data which determine the manner in which the soil mass is subdivided into vertical slices, the procedure used to compute the factor of safety, and several parameters which affect and/or control the iterative solution for the factor of safety. All of the Group J data are described here.

72. The computer program allows the user to specify individually selected shear surfaces, with the factor of safety computed for each or to designate that an automatic search be performed to locate a most critical shear surface with a minimum factor of safety. Shear surfaces may be circular or noncircular in shape for both individually specified surfaces and automatic searches. Individually specified shear surfaces are described below and followed by a description of the automatic searches. The procedure used to compute the factor of safety and several variables which the user may optionally select are described following the description of the shear surfaces and automatic search. Finally, in the last section, the format for the input data is described and presented.

Individually specified shear surfaces

73. Individually selected shear surfaces may be circular or noncircular. A combination of separate circular and noncircular shear surfaces may be selected and used to compute the factor of safety for a given problem. The shear surfaces may face to the left or the right of the slope, so that both faces may be analyzed for a given set of slope coordinate geometry. The data differs somewhat for circular shear surfaces and noncircular shear surfaces

and, accordingly, the two surface shapes are treated and described separately below.

74. Circular. The location of a given circular shear surface is defined in terms of the coordinates of the center and the radius of the circle. The X and Y coordinates of the center of the circle are specified as input data. The radius may be specified directly as input data or may be specified indirectly and calculated by the computer program using either of two indirect means. The two indirect means consist of specifying (with the input data for the circle) the coordinates of a point through which the circle passes or the elevation of a horizontal line to which the circle is tangent.

a. Subdivision into slices. The soil mass bounded by the circular shear surface and the surface of the slope is automatically subdivided into vertical slices by the computer program. The subdivision into slices is performed by using one of the following two means selected by the user:

(1) The mass is subdivided so that the angle which is subtended by the two radii extended to each side of the base of the slice (shear surface) does not exceed a certain, given value (SUBDEG). In most cases, many of the slices which are actually created will have a base which subtends an angle of less than the prescribed angle (SUBDEG) because of other constraints. For example, when the bottom of a slice tends to cross a boundary between two materials, a smaller base width is used to ensure that the base of the slice lies in no more than one material.

(2) The mass is subdivided so that the arc length along the base of each slice does not exceed a certain, given value, (ARCMAX). As in the first case, the actual arc length will be less than the value of ARCMAX for slices where other constraints dictate a narrower slice.

Initially, option (1) is selected and used as a default by the computer program. That is, slices are created using a constant subtended angle; a value of 3 deg is used for the angle. If the user desires another value for the subtended angle or the alternate option, a constant arc length (ARCMAX) should be selected. If either of the selected options and corresponding values of the parameters SUBDEG and ARCMAX results in more slices than the program can accommodate (due to the dimensioned size of arrays), the values of the angle or arc length will be successively doubled by the computer program until a small enough number of slices results.

b. Vertical ("tension") crack. A vertical ("tension") crack of selected depth (DCRACK) may be specified for each individually selected circular shear surface with the Group J input data for the surface. The vertical crack is considered by the computer program to be located at the point where the shear surface reaches a depth equal to the specified depth (DCRACK) below the surface of the slope near the upslope portion of the shear surface. Thus, the lateral position of the crack is determined indirectly based on the location of the circle, the specified crack depth, and the slope geometry. The upslope end of the shear surface is determined by the program by comparing the elevation of the two ends of the shear surface, the highest end (excluding the presence of a crack) is determined to be the upslope end. In the case of a horizontal ground surface, the right end of the shear surface is assumed to be the upslope end of the shear surface, i.e., a horizontal ground surface is treated like a left-facing slope.

75. In addition to specifying a crack, the user may specify that the crack contains water or some other fluid. The presence of water in the crack is specified in the input data by specifying the depth of water, DWATER, in the crack. The user may also specify the unit weight of the water or other fluid in the crack, GAMAWC; otherwise a unit weight of 62.4 pcf is assumed (Table 22, subcommand word "UNI"). The water specified in a crack is considered to produce a horizontal force in the crack equivalent to the force produced by hydrostatic pressures acting over the depth of water specified. However, such water is not considered to produce pore water pressures in the soil or any other form of loading; pore water pressures and other loads must be specified separately by means of other input data (e.g., piezometric line, surface pressures, etc.).

76. Noncircular (including wedge). The location of a noncircular shear surface is defined in the input data by specifying the X and Y coordinates of selected points along the shear surface from left to right. The specified points are assumed to be connected by straight lines; vertical segments may not be specified. Specific shear surface coordinates required by the computer program, e.g., where the shear surface crosses a soil profile line, do not need to be included in the input data. The coordinates needed by the program will be computed and added to the coordinates input by the user.

77. In specifying the end points for a noncircular shear surface, the user should carefully specify the end point coordinates as precisely on the surface of the slope as is practically possible. However, if the specified end point coordinates do lie above (outside of) the slope, the computer program will attempt to adjust the coordinates so that they are located more precisely on the slope. This is done by determining the intersection of the specified shear surface with the surface of the slope and then changing the

coordinates of the end point to those of the intersection point. However, the first two or last two end points on a shear surface must never both lie above the surface of the slope, or an error condition will result. No adjustment is made to the end point coordinates for a noncircular shear surface when the point lies below the surface of the slope; in such instances, a crack is assumed, as is described later.

a. Subdivision into slices. The soil mass above the noncircular shear surface is subdivided into a number of vertical slices by one of the following two means, which can be selected by the user as part of the input data:

(1) The soil mass is subdivided so that the length of the base of each slice does not exceed a specific maximum value (BASEMX). To accomplish this, the program first computes the coordinates which are required for other purposes, such as where the shear surface crosses a boundary between materials, and adds these required coordinates to the coordinates which were input. The program then checks the distance between each pair of adjacent points. If the prescribed length (BASEMX) is exceeded, the surplus distance between the pair of points is divided into a sufficient number of equal-length increments to meet the required maximum slice base length.

(2) The soil mass is subdivided to produce an approximate minimum number of slices, BASINC. The procedure used by the program takes the horizontal distance between the first and last points specified for the shear surface in the input data, divides the distance by the "minimum number of slices," BASINC, and then applies the computed distance as a maximum slice base length (equivalent to BASEMX) in the same manner as described for the first of the two options.

Initially, option (2) is selected and used as a default by the computer program. That is, slices are created by using a minimum of thirty slices (BASINC). If the user desires, another minimum number of slices or a maximum slice base length, BASEMX, may be selected. If either of the selected options and corresponding values of the parameters, BASEMX and BASINC, results in more slices than the program can accommodate (due to the dimensioned size of arrays), the "maximum number of slices" will be reduced or "maximum base length" will be increased until a small enough number of slices results.

b. Vertical ("tension") crack. A vertical ("tension") crack, similar to that described for a circular shear surface above, can be introduced for noncircular shear surfaces; however, the manner in which the crack is designated in the input data is different for noncircular shear surfaces. In the case of a circular shear surface, the crack depth (DCRACK) is specified as a quantity in the input data. In the case of a noncircular shear surface, the crack depth is not specifically input.

Instead, the coordinates of the noncircular shear surface should be terminated (in the case of a left-facing slope) or initiated (in the case of a right-facing slope) at a point some depth below the surface of the slope corresponding to the desired depth of the crack. A vertical crack is then assumed to extend from the last (or first) coordinate point specified to the top of the slope.

Automatic searches

78. Automatic searches may be performed by using circular or noncircular shear surfaces. The automatic search procedures used in the computer program are designed to aid the user in locating the most critical shear surface corresponding to a minimum factor of safety. However, considerable judgment must be exercised in using the automatic search procedures to ensure that the most critical shear surface has actually been located. Careful judgment is especially important when more than one "local" minima exist. The example problems in Part V illustrate how to ensure the global minimum has been found. The search procedures used are very different, depending on whether the shear surface is circular or noncircular, and, thus, the procedures are described separately below.

79. Circular shear surfaces. During an automatic search, the program uses one or more of the following three modes to locate the center of a critical circle:

Mode 1 - All circles pass through a given point with specified coordinates.

Mode 2 - All circles are tangent to a given horizontal line with specified elevation (Y coordinate).

Mode 3 - All circles have a given radius, which is specified as part of the input data.

By successively varying the three available modes of search according to the sequence of steps outlined below, the program is capable of locating an overall "critical" circle corresponding to a minimum value for the factor of safety.

a. Step 1. The critical circle is located for an initial mode of search, specified as input data. The initial mode of search may be Mode 1, 2, or 3, although Modes 1 and 2 are generally recommended for the initial mode. If Mode 1 is selected, the X and Y coordinates of the point through which the circles pass are specified. If Mode 2 is selected, the Y coordinate elevation of the horizontal tangent line must be specified. If Mode 3 is selected, the radius must be specified.

b. Step 2. Once the critical circle has been located for the initial mode of search, the mode of search is changed. If the initial mode of search was Mode 1 or 3, it is changed to Mode 2, and a horizontal tangent line is defined at the elevation of the bottom of the critical circle which was located using the previous mode (Modes 1 or 3). If Mode 2 is specified for the initial search, it is changed to Mode 3, and the radius of the critical circle found in the previous search Mode 2 is selected for subsequent use. If the difference between the values of the factor of safety for the two critical circles, located using the modes of Step 1 and Step 2, is less than 0.001, the critical circle is considered to be the most critical circle located in Step 2, and the search is completed. However, if the criterion is not satisfied, the search will continue to Step 3.

c. Step 3. After Step 2, the mode of search will be alternated between Modes 2 and 3, until the difference between the values of the minimum factors of safety for the critical circles found in successive modes is less than 0.001. Mode 1 will never be used beyond Step 1 and thus may only be used for the initial mode of search.

The program includes the option of terminating the search after Step 1 is completed (Table 22, subcommand word "STO").

80. When locating the overall critical circle, it may be desirable to impose some limiting depth below which the critical circle cannot pass. This may be achieved either by specifying a stratum of soil at the selected limiting depth and assigning a high shear strength to the particular stratum or by specifying an appropriate limiting elevation below which the critical circle is not allowed to pass. The selected limiting Y elevation is specified in the data input for the search as the variable YLIMIT.

81. For each mode of search, the location of the center of the critical circle is found by using a 3-by-3, 9-point, square grid. The center point of the first grid used for the initial mode of search is specified in the input data and should represent a best estimate of the X and Y coordinates of the center of the critical circle. The initial spacing between points in the 9-point grid is 30 times a specified distance (ACCURC). The distance (ACCURC) is entered as input data and may be considered to be the approximate accuracy with which the center of the critical circle is to be eventually determined. The location of the center point of the grid is shifted during the search until the center of the grid corresponds to the center of a circle which has a lower value for the factor of safety than any of the eight other circles whose centers are located on the perimeter of the grid. The 9-point grid is always shifted such that the center of the new grid is located at the point where the

lowest value of the factor of safety was determined using the previous grid. The spacing between grid points is also changed during the automatic search. The spacing is reduced from the initial spacing which is 30 times the specified distance (ACCURC) to spacings of 5, 3, and finally, 1 times the distance, ACCURC. Computed values for the factor of safety are stored by the program, and in most cases values are calculated only for those circles where values have not been previously computed. The search in a given mode is terminated and the next mode or other appropriate action is taken when the grid spacing has been reduced to the specified distance (ACCURC) and the center of the 9-point grid corresponds to the lowest factor of safety.

82. Experience with the "gridded" search procedure has shown that specified distances, ACCURC, ranging from 1 percent to 10 percent of the slope height work well for locating the critical circle. However, the selection of the actual distances used should be based on each individual problem to ensure that a critical circle is found. In any case, the distance should not exceed the thickness or smallest dimension of the smallest zone of soil which may influence the computed minimum factor of safety and critical shear surface.

83. During an automatic search, the program does not permit the search to "jump" from one face of the slope to another. For example, if the initial trial shear surface is for the left face of the slope, shear surfaces on the right face of the slope will be rejected and not considered.

84. In some cases it will be possible to find several local "critical" circles with minimum factors of safety. The center of each such locally critical circle will be surrounded by center points having higher values for the factor of safety. In such cases, when a given search is performed, only one of the locally critical circles will be searched out and located; the circle so found may not be the one with the absolute, lowest value for the factor of safety. In order to locate the circle with the absolute, lowest value for the factor of safety, several automatic searches will need to be performed using different starting points for the circles and, perhaps, different initial modes for the search. The values of the factor of safety for each of the "critical" circles located by these independently started searches must then be compared by the user to determine the actual value of the minimum factor of safety and the location of the overall critical circle. This will require that several sets of Group J data be specified for a given problem.

85. When the search option is used, the procedure for subdividing the

circle into slices is identical to the procedure described previously for individual circular shear surfaces. Similarly, a vertical (tension) crack depth may be specified and the crack may be designated to contain water or some other fluid, as described earlier for individually specified circular shear surfaces.

86. Noncircular shear surfaces (including wedge). An automatic search for a critical noncircular shear surface is performed using a procedure very similar to the procedure developed by Celestino and Duncan (1981). In this procedure the shear surface is systematically moved from an initial (starting) position, which is defined by the user, until a minimum factor of safety is calculated. The initial position of the shear surface is specified by the user and should correspond to the best estimate for the location of a critical shear surface. If the slope contains a thin seam of relatively weak material, through which the critical shear surface is expected to pass, the initial shear surface should be input so that it passes through the weaker material. The location of the initial shear surface is specified in the input data by a series of coordinates along the shear surface (from left to right), much as an individual shear surface is specified when no search is to be performed.

87. At the user's option, the coordinate points which are input to define the initial shear surface may be allowed to move during the search or may be considered fixed; however, in most cases all points would be considered to be movable. As the first step in an automatic search, each movable point on the shear surface is moved an incremental distance (specified by the input data) in each of two opposite directions (e. g., up and down). Points are moved one by one on a TEMPORARY basis and a factor of safety is calculated for the shear surface with each point at each of the two positions to which it is moved. Figure 4 illustrates the temporary movement of the points. When any one point is moved, all other points are left at their original (initial) positions. No points are permanently shifted during the first step of the automatic search. The direction in which points are moved may be specified by the user as input data for each point, or the computer program will automatically compute a direction for shifting each point. When the computer program computes a direction for shifting each point, the direction is taken as approximately normal (perpendicular) to each segment of the shear surface. This direction may thus change somewhat as the shear surface moves. When segments of the shear surface intersect at an angle, the point will move in a direction

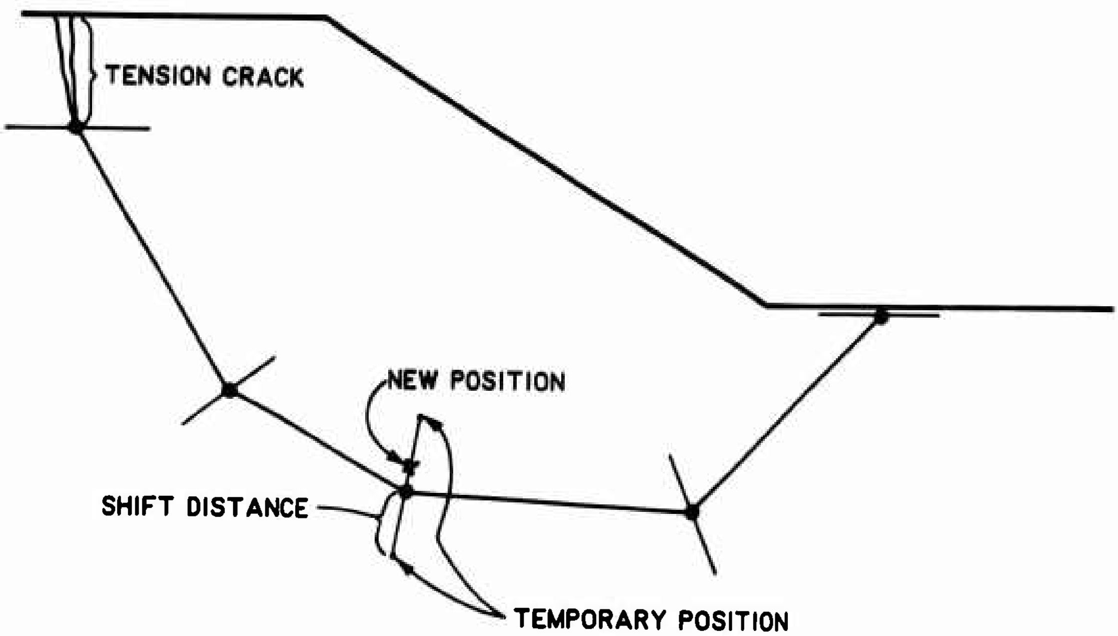


Figure 4. Temporary movement of the points

that bisects the angle of intersection. End points on the shear surface are moved along the slope, or parallel to the slope in the case of a vertical tension crack, and thus the user has no control over the direction of movement of the two end points of the shear surface.

88. Once each point on the shear surface has been shifted and the factor of safety has been computed for each shift, a new estimate for the position of the most critical shear surface is made and the initial shear surface is PERMANENTLY moved. The new estimate for the position of the shear surface is made using the procedure of Celestino and Duncan (1981); the factor of safety is assumed to vary parabolically with the position of the shear surface. Once the new estimate of position for the shear surface is made and the surface is moved, each point is again shifted in the manner used for the first step and the process is repeated to find yet another estimate for the critical shear surface.

89. Determination of the distance each point is temporarily shifted to compute the factor of safety is based on an initial incremental shift distance (DSHIFT), which is specified by input data. Initially, the points will be shifted a distance equal to the specified distance, DSHIFT. The distance shifted will later be reduced automatically by the computer program as the distance which the shear surface is permanently moved (as opposed to temporarily shifted) on each "step" or "trial" diminishes. (The actual distance the

shear surface is permanently moved on each step is controlled by the computer program.) The distance the shear surface is temporarily shifted is reduced from the initial value to 70 percent, 40 percent, and finally, 10 percent of the initial value. Thus, the "precision" in the final location of the shear surface will be approximately 10 percent of the specified initial distance, DSHIFT.

90. In most procedures of limit equilibrium slope analysis, the equilibrium equations used to compute the factor of safety will begin to yield unrealistic values for the stresses near the toe of shear surfaces which are inclined upward at angles much steeper than those which would be logical based on considerations of passive earth pressure. Trial shear surfaces can potentially become excessively steep in an automatic search unless some restriction is placed on the amount the shear surface is shifted during the trial and error search. Accordingly, in addition to specifying the distance, DSHIFT, used by the automatic search, the user may specify a maximum steepness to be allowed for the "toe" portion of the shear surface. The "toe" portion is considered to be any portion of the shear surface which is inclined upward in a direction opposite to the slope face. The maximum steepness allowed is specified by a value for the optional parameter (ALFMAX) in the input data for the noncircular shear surface. (A default value of 50 deg is assumed if no value is input.)

91. At the present time there is still relatively little experience with the search procedure used to locate a critical noncircular shear surface. Thus, judgment and some trial and error may be required in selecting an optimum value for the incremental shift distance, DSHIFT. Limited experience to date indicates that relatively large distances may be used provided the limiting steepness (ALFMAX) described above is not specified to be in excess of 50 deg (the default value). As previously described, the final distance used to shift the shear surface will be equal to 10 percent of the initial distance, DSHIFT. Thus, the initial distance should be selected such that the final distance will result in an acceptably refined location for the most critical shear surface. In general, it is anticipated that the location of the final shear surface will be determined to within no more than 10 to 25 percent of the thickness of the thinnest stratum through which the shear surface may pass. For example, if a stratum is 5 ft thick and an acceptable degree of resolution for the critical shear surface is selected to be

20 percent of the thickness of a stratum, the initial shift distance, DSHIFT, would be 10 ft (20 percent of 5 ft divided by 10 percent, where 10 percent represents the final fractional amount of DSHIFT used for the search).

92. A vertical crack, similar to the one described previously, may be used in an automatic search with noncircular shear surfaces. The crack is designated in essentially the same way as described for individually specified noncircular shear surfaces by terminating (or starting) the end point coordinates of the initial shear surface at some depth below the surface of the slope. The crack depth determined for the initial trial shear surface is assumed to apply to <u>all</u> of the noncircular shear surfaces attempted during a search. The crack depth (DCRACK) which can be input as a separate quantity in the input data for circular shear surfaces has no significance in the input data for noncircular shear surfaces.

<u>Seismic coefficient</u>

93. The computer program permits the user to perform "pseudo-static" analyses in which a horizontal body force is applied to each slice to simulate earthquake loading. This is accomplished using a single seismic coefficient (SEISCF) by which the weight of each slice is multiplied to obtain the horizontal body force. The body force is assumed to act through the approximate center of gravity for each slice. A positive seismic coefficient corresponds to a force acting to the left for the left face of a slope and to the right for the right face of a slope. The seismic coefficient is specified as part of the Group J data (Table 22, subcommand word "SEI"). The computer program assumes that there are no seismic forces (default) unless a seismic coefficient is input; however, once a value is input it remains in effect either until another value, including zero, is input with Group J data or asterisks (***) are encountered in the command words. No special treatment is given to shear strengths when a seismic coefficient is used; the shear strengths are defined and interpreted in the normal manner as described in paragraphs 36 through 45, Table 6. The only effect which a seismic coefficient has on the computations is to apply an added, horizontal body force on each slice.

<u>Computation for factor of safety</u>

94. The procedure used to compute the factor of safety may be selected by the user although Spencer's (1967) procedure is strongly recommended. The procedures available to the user are briefly described below followed by a discussion of input parameters.

95. Procedures for computing factor of safety. Four procedures are available for computing the factor of safety. The procedures available are: (a) Spencer's (1967) procedure, (b) the Simplified Bishop (1955) procedure, (c) force equilibrium procedure with the Corps of Engineers Modified Swedish side-force assumption, EM 1110-2-1902 (Department of the Army 1970), and (d) force equilibrium procedure with Lowe and Karafiath's (1960) side-force assumption. The Simplified Bishop procedure is restricted to computations with circular shear surfaces while the other procedures may all be used with circular or noncircular shear surfaces. Attempts to use the Simplified Bishop procedure for noncircular shear surfaces will result in an error condition and computations will not be attempted by the program.

96. Spencer's (1967) procedure. In Spencer's procedure, all side forces are assumed to have the same inclination and all requirements for static equilibrium are satisfied. The trial and error solution involves successive assumptions for the factor of safety and side-force inclination until both force and moment equilibriums are satisfied.

97. Simplified Bishop (1955) procedure. The side forces are assumed to act horizontally in the Simplified Bishop procedure. Thus, there are no shear forces on the vertical boundaries between slices. Equilibrium of forces in the vertical direction is satisfied for each slice, and equilibrium of moments about the center point of the circular shear surface is satisfied for the entire soil mass consisting of all slices. The trial and error solution for the factor of safety involves successive assumptions for the factor of safety until the moment equilibrium equation is satisfied (force equilibrium is implicitly satisfied).

98. Corps of Engineers Modified Swedish procedure, EM 1110-2-1902 (Department of the Army 1970). In the Modified Swedish procedure all side forces are assumed to have the same inclination (are parallel) and the inclination is assumed by the user. According to EM 1110-2-1902, the inclination is assumed to be equal to the average slope of the embankment; however, other, often flatter, inclinations are frequently assumed in practice. The Modified Swedish procedure satisfies equilibrium of forces in both the vertical and horizontal directions for individual slices, but does not satisfy moment equilibrium. This procedure may be unconservative and sometimes overestimate the factor of safety by as much as 50 percent or more. The results are sometimes very sensitive to the assumed inclination for the side forces. The trial and

error solution for the factor of safety involves successive assumptions for the factor of safety until equilibrium of forces is satisfied.

99. Lowe and Karafiath's (1960) procedure. Lowe and Karafiath's procedure is identical to the Corps of Engineers Modified Swedish, EM 1110-2-1902, (Department of the Army 1970) procedure except for the assumed inclinations of the side forces. In Lowe and Karafiath's procedure, the side forces are assumed to be inclined at the average slope of the ground (slope) surface directly above and the shear surface directly below each vertical slice boundary as shown in Figure 5. Thus, the side force inclinations generally vary from

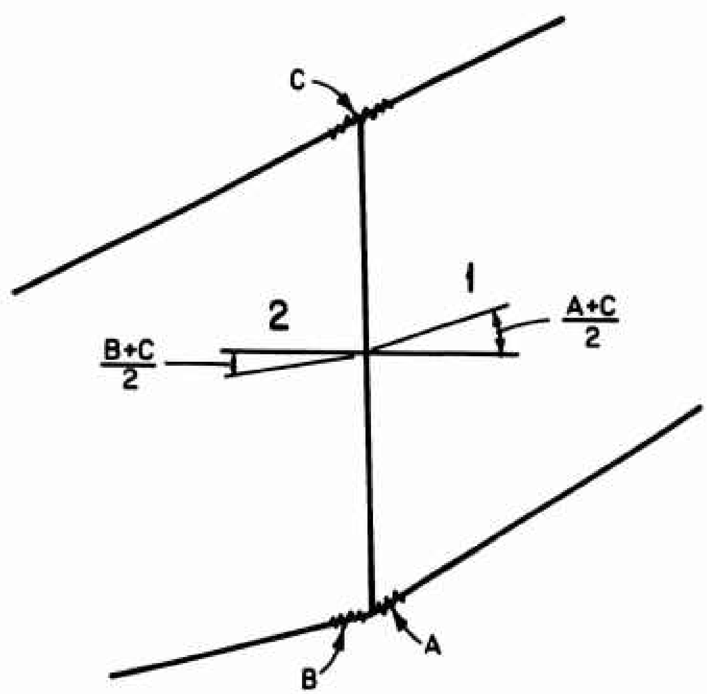


Figure 5. Side-force inclination for Lowe and Karafiath's procedure

slice to slice. (In the computer program, side-force inclinations are computed by averaging slopes, dy/dx , rather than angles.) The trial and error solution for the factor of safety in Lowe and Karafiath's procedure is identical to the one for the Modified Swedish procedure.

Solution parameters

100. All of the procedures for computing the factor of safety involve an iterative solution in which successive values are assumed for the factor of safety, and side-force inclination in the case of Spencer's (1967) procedure, until one or more equilibrium equations are satisfied. The iterative

solutions involve a number of "solution" parameters. The computer program assumes default values for the "solution" parameters with one exception: the side force inclination used in the Corps of Engineers Modified Swedish (Department of the Army 1970) procedure must be selected and input by the user; a default value is not assumed. Experience to date indicates that the default values assumed in the computer program have been adequate for most of the problems which have been worked. However, needs may arise to change some of the values from those assumed by the program. The most important parameters used in the solutions are described and discussed in further detail below.

101. The iterative solution for the factor of safety is initiated with initial trial values for the factor of safety, (FZERO) (and side-force inclination, (TZERO), in the case of Spencer's (1967) procedure). The trial values are then changed by successive approximations until <u>all</u> of the following conditions are satisfied, i.e., the solution converges:

a. Static equilibrium is satisfied within acceptable limits of accuracy. These limits are defined in terms of allowed imbalances, FIMBAL in the case of forces, and MIMBAL in the case of moments. The specific imbalance limits which are satisfied depend on the procedure being used to compute the factor of safety (Spencer (1967), Simplified Bishop (1955), etc.).

b. The value of the factor of safety changes by no more than 0.0001 on successive iterations. In the case of Spencer's procedure the side force inclination must also not change by more than 0.0001 radians on successive iterations.

If either of the above two conditions for convergence is not satisfied within a certain maximum number of iterations (MXITER), computations for the particular shear surface will be abandoned and the next shear surface will be considered.

102. The initial trial values (FZERO and TZERO), the force and moment imbalances (FIMBAL and MIMBAL), and the allowable number of iterations (MXITER) are all assigned default values by the computer program. The default values are given in Table 22 and any one or all of the values may be changed by the user through selective input of data. Several important features of the iterative solution for the factor of safety and side-force inclination as well as the variables FZERO, TZERO, FIMBAL, MIMBAL, and MXITER are described in the following paragraphs.

103. <u>Factor of safety.</u> The value of the factor of safety is permitted

to change only by a maximum of five-tenths (0.5) on successive iterations during the convergence procedure. This constraint is placed on the solution to ensure proper convergence. However, if a very inaccurate estimate is made and specified for the initial value of the factor of safety (FZERO), the correct value may not be reached within the prescribed maximum number of iterations and the solution will fail to converge. Similar problems with convergence may develop when an automatic search is being performed and a trial shear surface passes through a zone of very high shear strength, such as concrete or a firm (rock) stratum, which has been specified for the purpose of limiting the extent of the critical shear surface. In this case, a relatively large value for the factor of safety will be sought, but probably the value will not be reached by the program within the allowed number of iterations. Thus, an indication will be given on the printed output that the solution did not converge. In this case, the problem of a solution not converging for one of the trial shear surfaces attempted during an automatic search is normally of no practical consequence. The user should verify that, for the shear surfaces where the solution did not converge, the values for the factor of safety are relatively large.

104. In addition to the constraint described above for the change in the factor of safety on successive iterations (0.5), the value of the factor of safety is not permitted to become less than one-tenth (0.10). While this constraint should be of little practical consequence, the solution will be terminated when the value for the factor of safety reaches a value of one-tenth.

105. A considerable amount of experience has shown that the numerical solution for the factor of safety and side force inclination is better conditioned and more likely to converge when the initial trial value for the factor of safety overestimates, rather than underestimates, the correct value. In many cases, by simply increasing the initial estimate for the factor of safety (FZERO) the solution can be made to converge, where otherwise convergence was not achieved.

106. Side-force inclination Spencer's (1967) procedure. In Spencer's procedure the inclination of the resultant forces acting between the vertical slices is assumed to be the same for all slices and is calculated along with the factor of safety as part of the iterative solution. The angle of inclination of the side forces is measured from the horizontal plane and positive values are measured in a counterclockwise direction. The side force inclination

will normally be positive for a left-facing slope and negative for a right-facing slope.

107. In the iterative solution procedure, the value of the side force inclination is not permitted to change by more than 0.15 radians (approximately 8.6 deg) on successive iterations and will be adjusted accordingly by the program when this limit is reached. In addition, the side force is not permitted to reach an inclination steeper than either +80 deg for a left-facing slope or -80 deg for a right-facing slope. If these limits are reached, the iterative solution will be terminated with an appropriate message. Also, a side force inclination of less than -10 deg for a left-facing slope or greater than +10 deg for a right-facing slope will cause the solution to be terminated with an appropriate message.

108. Side-force inclination Modified Swedish (Department of the Army 1970) procedure. In the Corps of Engineers Modified Swedish procedure, the inclination of the side forces is assumed by the user. The value which is input to the computer program is interpreted to be the absolute value of the inclination, measured in degrees from the horizontal plane. The computer program will then assign an appropriate sign to the inclination angle which is input depending on the inclination of the slope face being considered by a particular shear surface. Positive values are measured in a counterclockwise direction. The program assigns a positive value for a left-facing or horizontal slope and a negative value for a right-facing slope.

109. Allowed force and moment imbalance. The allowed force and moment imbalances are used as one of the criteria for convergence as noted earlier. Depending on the specific procedure being used to compute the factor of safety, the solution will satisfy, within the specified imbalances, force equilibrium (Modified Swedish (Department of the Army 1970) procedure, Lowe and Karafiath's (1960) procedure), moment equilibrium (Simplified Bishop (1955)), or both force and moment equilibrium (Spencer's (1967) procedure). The Simplified Bishop procedure also satisfies force equilibrium in the vertical direction; however, it satisfies force equilibrium exactly, and thus the imbalance is zero.

110. The default values assumed by the computer program for force and moment equilibrium are 100 lb and 100 ft-lb, respectively. Experience with the computer program to date has shown that for most typical slopes analyzed, the value of the factor of safety is computed to within a minimum of four

significant figures (0.01 percent) of the exact solution using the assumed default values. (The values for the limits of force and moment imbalance may not be specified as zero, because roundoff error and use of a finite number of significant figures by the computer normally preclude computation of precisely zero values for verifying convergence.)

111. Iteration limit. When reasonable values are assumed for the initial trial values of the factor of safety and side force inclination, convergence to a solution is normally attained within from 3 to 10 iterations. This assumes that the factor of safety is estimated to within the correct value by approximately 1.5 and, in the case of Spencer's procedure, that the side force inclination is estimated to within 20 deg of the correct value. If the solution fails to converge within an apparently reasonable number of iterations, the user should examine the step-by-step output from the iterative solution to establish the reasons for nonconvergence. For an automatic search, step-by-step output from the iterative solution is available only for the final, most critical surface. Accordingly, when severe nonconvergence problems are encountered during an automatic search, the user should specify a single, individual shear surface and examine the step-by-step output from the iterative solution (Part III, Description and Explanation of Printed Output Tables, paragraph 143).

112. Special note for automatic searches. During an automatic search, some efficiency may be realized by changing the initial trial values used for the factor of safety (and side force inclination in the case of Spencer's (1967) procedure), from the values used at the start of the search. Improved estimates for the trial values can be obtained by using the values corresponding to the lowest factor of safety computed at any stage during the search. Such improved estimates can be used by activating an option in the computer program whereby the initial trial values will be set to those corresponding to the lowest factor of safety (Table 22, subcommand word "CHA"). Activation of this option may improve the efficiency of the calculations during a search, but can also cause problems with convergence of the numerical solution to correct values. The option should be used with caution, especially when an automatic search is being performed using noncircular shear surfaces.

Special note for nonlinear strength envelope

113. When the Mohr-Coulomb shear strength envelope is nonlinear, the

calculations for the factor of safety are repeated several times for each trial shear surface. Shear strengths are first estimated for each slice where a nonlinear envelope applies and a factor of safety is calculated. This permits the normal stresses on the shear surface to then be calculated (the normal stresses depend on the shear strength and the factor of safety) and new shear strengths are calculated. This process is repeated until a consistent set of values of shear strength and normal stress is found for each slice.

Form for data input

114. The Group J data are used to designate whether circular or noncircular shear (sliding) surfaces are to be used to compute the factor of safety. These data are also used to designate whether a single, individually specified shear surface is to be considered or an automatic search is to be performed to locate a most critical shear surface with a minimum factor of safety. Depending on the options selected (circular versus noncircular; search versus individual shear surface), certain additional information is required. For example, for a single circular shear surface, the coordinates of the center of the circle and the radius might be input.

115. In addition to the required data in Group J there are numerous quantities and options for which the computer program assumes default values, but which the user may change. Once the required data have been input, the user can designate, by optional subcommand words, which of the quantities and options he/she wishes to change from the default values. One of the optional quantities is the depth of vertical crack (DCRACK) to which the user may frequently wish to assign a value other than the default value of zero. Once any optional quantity has been defined by Group J input data, it remains as it has been defined until new Group J data specifically redefine or reset the optional quantity. Thus, new Group J data may be input, but if they do not specifically redefine the optional quantity from the value set by previous Group J data, the optional quantity remains as it was previously set. Thus, for example, once a crack depth is entered it remains in effect until redefined.

116. The Group J data must immediately follow the command word "ANA" (or "ANALYSIS/COMPUTATION"). The form for the required data, which must be input first, is presented in Tables 17 through 21. The form for the optional subcommand words and data which may follow the required data is presented in Table 22.

Table 17

Group J - Analysis and Computation Data Input

Format - Required Input Line 1

Input Line	Data Field	Variable/Description
1	1	(CHAR(1)) - A single character or a single, continuous character string beginning with one of the appropriate characters to indicate the shape of the shear surface as follows: "C" (or "CIRCULAR") - To designate that circular shear surfaces are to be used to compute the factor of safety. "N" (or "NONCIRCULAR") - To designate that noncircular shear surfaces are to be used to compute the factor of safety.
1	2	(CHAR(2)) - A single character or a single, continuous character string beginning with the appropriate character or blank to indicate whether a single shear surface or an automatic search is to be used for the analysis as follows: "S" (or SEARCH) to designate that an automatic search is to be performed to find a shear surface with a minimum factor of safety. " " (= blank) to designate that only a single shear surface is to be considered. Note: Additional single shear surfaces may be input by additional sets of Group J - Analysis/Computation data.

Depending on the characters input on Line 1, proceed as follows:

Characters Input	Interpretation - Required Additional Input
"C" " " (= blank)	Single circular shear surface; input Lines 2A, 3A, 4A, 5A, and 6A as required - See Table 18.
"N" " " (= blank)	Single noncircular shear surface; input Lines 2B and 3B - See Table 19.
"C" "S"	Search with circular shear surfaces; input Lines 2C, 3C, 4C, and 5C as required - See Table 20.
"N" "S"	Search with noncircular shear surfaces; input Lines 2D, 3D, and 4D - See Table 21.

Table 18

Group J - Analysis and Computation Data Input Format - Single Circular Shear Surface, Required Input Lines 2A through 6A

Input Line	Data Field	Variable/Description
2A	1	(XCENTR) - X coordinate for center of circle.
2A	2	(YCENTR) - Y coordinate for center of circle.
2A	3	(RADIUS) - Radius of circle. Note: The radius can be left blank and will then be computed by the program using data input on Lines 3A through 5A. If radius is blank, proceed with Line 3A. If not blank, skip Lines 3A through 5A and proceed to Line 6A.
3A	1	(CHAR(1)) - A single character or character string beginning with the appropriate character to indicate how the radius is to be defined as follows: "P" (or "POINT") to designate that the circle passes through a fixed point; proceed to Line 4A. "T" (or "TANGENT") to designate that the circle is to be tangent to a specified horizontal line; proceed to Line 5A.
4A	1	(XFIXED) - X coordinate value of point through which circle passes.
4A	2	(YFIXED) - Y coordinate value of point through which circle passes. After Line 4A, proceed to Line 6A below.
5A	1	(YTANLN) - Y coordinate of horizontal line to which circle is tangent. After Line 5A, proceed to Line 6A below.
6A	1	Use a blank line to terminate all Group J data and then proceed with command words when none of the optional quantities is to be defined or reset. If the optional quantities are to be input, omit this blank Line 6A and proceed directly with the subcommand words in Table 22.

Table 19

Group J - Analysis and Computation Data Input Format - Single Noncircular Shear Surface, Required Input Lines 2B and 3B

Input Line	Data Field	Variable/Description
2B	1	(X) - X coordinate of point used to define the noncircular shear surface.
2B	2	(Y) - Y coordinate of point used to define the noncircular shear surface.
		Repeat Line(s) 2B for additional points, from left to right, to define the noncircular shear surface. Input a blank line to terminate the data for the shear surface.
3B	1	When none of the optional quantities in the Group J data is to be defined or reset, input a blank line here as Line 3B to terminate all Group J data, and then proceed with the command words as described in Tables 1 or 2. (Note: In this case the Group J data will actually end in two blank lines, one Line 2B and one Line 3B.) If optional quantities in Group J are to be input, omit this blank Line 3B and proceed directly with the subcommand words as described in Table 22.

Table 20

Group J - Analysis and Computation Data Input Format - Automatic Search with Circular Shear Surfaces, Required Input Lines 2C Through 5C

Input Line	Data Field	Variable/Description
2C	1	(XSTART) - Starting X coordinate for center of circle used in search.
2C	2	(YSTART) - Starting Y coordinate for center.
2C	3	(ACCURC) - Accuracy for finding center of critical circle (= minimum grid spacing). Recommend 1 percent of slope height.
2C	4	(YLIMIT) - Y coordinate for limiting depth to which critical circle will be allowed to pass.
3C	1	(CHAR(1)) - Single character or continuous character string beginning with appropriate character to indicate what initial mode of search will be used as follows:
		"P" (Point) - Circles all pass through a common fixed point; proceed next to Line 4C-1.
		"T" (Tangent) - Circles all tangent to specified horizontal line; proceed next to Line 4C-2.
		"R" (Radius) - Circles all have the same radius; proceed next to Line 4C-3.
4C-1	1	(XFIXED) - X coordinate value of fixed point.
4C-1	2	(YFIXED) - Y coordinate value of fixed point.
		After Line 4C-1, proceed directly to Line 5C
4C-2	1	(YTANLN) - Y coordinate of horizontal line to which all circles are tangent.
		After Line 4C-2, proceed directly to Line 5C

(Continued)

Table 20 (Concluded)

Input Line	Data Field	Variable/Description
4C-3	1	(RADIUS) - Constant radius to be used in the initial mode of search. After Line 4C-3, proceed with Line 5C.
5C	1	When none of the optional quantities in the Group J data is to be defined or reset, input a blank line here as Line 5C to terminate all Group J data, and then proceed with the command words as described in Tables 1 and 2. If optional quantities in Group J are to be input, omit this blank Line 5C and proceed directly with the subcommand words as described in Table 22.

Table 21

Group J - Analysis and Computation Data Input Format

Automatic Search with Noncircular Shear Surfaces

Required Input Lines 2D through 4D

Input Line	Data Field	Variable/Description
2D	1	(X) - X coordinate of point used to define the initial, trial noncircular shear surface for the automatic search.
2D	2	(Y) - Y coordinate of point used to define the initial, trial noncircular shear surface for the automatic search.
2D	3	Information to designate if and how this point is to be shifted, as follows: - If blank, the point is considered to be moveable and it is moved in a direction approximately perpendicular to the shear surface at that point. - If a numerical value (nonblank) is input, the point is considered to be movable and the numerical value, which was input, is interpreted to define the direction in which the point is to be moved. The numerical value, i.e., the direction, should be an angle measured in degrees from the horizontal and being positive in the counterclockwise direction. - If the characters, FIX, are input in Field 3, then the point is assumed to be fixed and is not moved during the automatic search.
	Repeat Line(s) 2D for additional points, from left to right, to define the initial, trial, noncircular shear surface. Input a blank line of data (Line 2D) to terminate the coordinates for the initial, trial, noncircular shear surface and then proceed with Line 3D.	
3D	1	(DSHIFT) - Initial distance for shifting points on the noncircular shear surface in the automatic search. The final distance used to shift points (accuracy) will be 10 percent of this distance.

(Continued)

Table 21 (Concluded)

Input Line	Data Field	Variable/Description
3D	2	(ALFMAX) - Maximum steepness permitted for shear surface near toe portion of the slope. Expressed as an angle measured in degrees from the horizontal plane. This second variable on Line 3D is optional; the program will assume a default value of 50 deg if none is input.
4D	1	When none of the optional quantities in the Group J data is to be defined or reset, input a blank line here as Line 4D to terminate all Group J data, and then proceed with the command words as described in Tables 1 and 2. If optional quantities in Group J are to be input, omit this blank Line 4D and proceed directly with the subcommand words as described in Table 22.

Table 22

Group J - Analysis and Computation Data Input Format -

Optional Input Following Required Input

Input Line	Data Field	Variable/Description
1	1	(COMWRD) - Subcommand word consisting of a character string, the first three characters of which designate which optional quantity is to be defined or reset. The acceptable characters and the optional quantities which they designate are as follows:
		"FAC" (FACtor of safety) - An initial, trial value for the factor of safety will be input; proceed next to Line 2A.
		"SID" (SIDe force inclination) - An initial, trial value for the side force inclination will be input; proceed next to Line 2B.
		"ITE" (ITEration limit) - An iteration limit will be input; proceed next to Line 2C.
		"FOR" (FORce imbalance) - A value for allowable force imbalance will be input; proceed next to Line 2D.
		"MOM" (MOMent imbalance) - A value for allowable moment imbalance will be input; proceed next to Line 2E.
		"CHA" (CHAnge initial, trial factor of safety) - This designates that during an automatic search the initial trial value for the factor of safety will be automatically changed and assumed to be equal to the lowest value of the factor of safety computed at any point in the search. This can reduce the time required to compute the factor of safety, but can also lead to occasional convergence problems in the solution. If this option is not set, the initial trial value remains as the default/input value - See "FAC" above.

(Continued)

(Sheet 1 of 6)

Table 22 (Continued)

Input Line	Data Field	Variable/Description
		Proceed directly with additional subcommand words (Line 1) after this word. This command word acts as a toggle switch, turning the option on/off each time encountered.
	"OPP"	(OPPosite sign convention) - This designates that the opposite sign convention from the one assumed by the program based on a direction of potential sliding is to be used. See the special note for flat slopes in paragraphs 55 through 61. Proceed directly with additional subcommand words (Line 1) after this word. This command word acts as a toggle switch, turning the option on/off each time encountered.
	"SHO"	(SHOrt-form output) - This designates that the short-form of output table, rather than the long form, is to be printed for an automatic search. This command word acts as a toggle switch, turning the option on/off each time encountered.
	"SUB"	(SUBtended angle) - A value of subtended angle for slice generation with a circular shear surface will be input; proceed next to Line 2F.
	"ARC"	(ARC length) - A value of maximum arc length for slice generation with a circular shear surface will be input; proceed next to Line 2G.
	"CRA"	(CRAck depth) - A crack depth is to be input; proceed next to Line 2H.
	"BAS"	(BASe length) - A value of maximum slice base length for slice generation with a noncircular shear surface is to be input; proceed next to Line 2I.

(Continued)

(Sheet 2 of 6)

Table 22 (Continued)

Input Line	Data Field	Variable/Description	
		"INC"	(INCrements for slice generation) - A value for the number of increments for slice generation with a noncircular shear surface is to be input; proceed next to Line 2J.
		"STO"	(STOp) - Designates that an automatic search with circular shear surfaces is to be terminated after the initial mode has been completed (Line 3D, Table 21). After this subcommand word proceed directly with additional subcommand words, i.e., input another Line 1.
		"CRI"	(CRItical) - Designates that automatic search is to be continued (after the initial mode has been completed) to locate a most critical circle. This is the default unless set by "STO" above. After this subcommand word, proceed directly with additional subcommand words, i.e., input another Line 1.
		"WAT"	(WATer depth) - A depth of water in the vertical crack is to be input; proceed next to Line 2K.
		"UNI"	(UNIt weight of water) - A unit weight for water (or other fluid) in the vertical crack is to be input; proceed next to Line 2L.
		"SEI"	(SEIsmic Coefficient) - A value for the seismic coefficient will be input; proceed next to Line 2M.
		"PRO"	(PROcedure for computation of the factor of safety) - The procedure to be used to compute the factor of safety is to be input; proceed next to Line 2N.

Input a blank subcommand word to terminate all the Group J input data.

(Continued)

(Sheet 3 of 6)

Table 22 (Continued)

Input Line	Data Field	Variable/Description
2A	1	(FZERO) - Initial trial value of factor of safety used in iterative solution. A default value of 3.0 is used if none is input. After input return to Line 1.
2B	1	(TZERO) - Initial trial value of side force inclination used in iterative solution (in degrees). A default value of 15 deg is used if none is specified. After input return to Line 1.
2C	1	(MXITER) - Maximum number of iterations to be permitted in iterative solution for factor of safety. A default value of 40 is used if none is input. After input return to Line 1.
2D	1	(FIMBAL) - Maximum force imbalance permitted for convergence of iterative solution for factor of safety. A default value of 100 is used if none is input. After input return to Line 1.
2E	1	(MIMBAL) - Maximum moment imbalance permitted for convergence of iterative solution for factor of safety. A default value of 100 is used if none is input. After input return to Line 1.
2F	1	(SUBDEG) - Subtended angle for slice generation (in degrees). A default value of 3 deg is used if none is input. After input return to Line 1.
2G	1	(ARCMAX) - Maximum arc length for slice generation. See Line 2G for SUBDEG above regarding relevant default values. After input return to Line 1.
2H	1	(DCRACK) - Vertical (tension) crack depth. A default value of zero (no crack) is used if none is input. After input return to Line 1.
2I	1	(BASEMX) - Maximum slice base length for slice generation (noncircular shear surfaces only). See Line 2J for BASINC below regarding relevant default values. After input return to Line 1.

(Continued)

(Sheet 4 of 6)

Table 22 (Continued)

Input Line	Data Field	Variable/Description
2J	1	(BASINC) - Number of increments into which shear surface is subdivided for slice generation (non-circular shear surfaces only). A default value of 30 is used if none is input. After input return to Line 1.
2K	1	(DWATER) - Depth of water or other fluid in vertical crack. A default value of zero (no water) is used if none is input. After input return to Line 1.
2L	1	(GAMAWC) - Unit weight of water (or other fluid) in vertical crack. A default value of 62.4 is used if none is input. After input return to Line 1.
2M	1	(SEISCF) - Seismic coefficient. No (zero) seismic coefficient is assumed initially. After input return to Line 1.
2N	1	(METHOD) - A single character or a character string beginning with the appropriate character to indicate the procedure for computing the factor of safety as follows: "S" (or "SPENCER") for Spencer's (1967) procedure "B" (or "BISHOP") for the Simplified Bishop (1955) procedure. "C" (or "CORPS") for the Corps of Engineers Modified Swedish procedure, EM 1110-2-1902 (Department of the Army 1970). "L" (or "LOWE") for Lowe and Karafiath's (1960) procedure. Spencer's procedure is recommended and assumed as the default procedure. Note: If the Corps of Engineers' Modified Swedish procedure is selected, proceed to Line 3 for the side force inclination. Otherwise return to Line 1 after this line of input.

(Continued)

(Sheet 5 of 6)

Table 22 (Concluded)

Input Line	Data Field	Variable/Description
3	1	(CTHETA) - Constant value of side force inclination to be used in the Corps of Engineers' Modified Swedish procedure (measured in degrees from the horizontal plane). Sign will be assigned by the program, regardless of the sign of the input value.

(Sheet 6 of 6)

PART III: DESCRIPTION AND EXPLANATION OF PRINTED OUTPUT TABLES (Wright 1986a)

Types of Output Tables

117. Twenty-five different types of output tables are printed by the computer program into the user specified output file. The forms of these tables and the information which they contain are described in these paragraphs. Each type of table is identified by a table number for reference and identification in the following discussion. The table number is printed on the computer output at the beginning of each table and the number corresponds to the type of information which the table contains. Tables are printed in the order in which the information contained in the tables are input or generated by the computer program. Accordingly, tables will not necessarily be printed in the order of ascending or descending table numbers. Some tables may not be printed at all, and other tables may be printed several times, depending on the type of data which are input and the program options which are used.

Description of Output Tables

118. The first table (Table 1) contains general information pertaining to the computer program and is printed only once at the start of program execution. The next nine tables (2 through 10) contain data which are used to define the problem. These nine tables, with the exception of Table 10, contain data which are input by the user. Table 10 contains slope coordinate geometry data generated, optionally, by the computer program. Each of these tables (2 through 10) is printed separately any time the specific data contained in the table is changed by new input data. If a specific set of data is not changed, the corresponding table will not be printed. The remaining 15 tables (11 through 25) contain information which is generated by the program during computations. These 15 tables contain intermediate information, as well as the final solution. The contents of the 25 output tables are described in further detail below.

Output Table 1: Program header

119. Output Table 1 contains the computer program header message: the

program name (UTEXAS2), the version number of the program, and the program serial number. This table also contains a disclaimer and warning message.

Output Table 2: Input
data for profile lines

120. This table contains the input data used to describe the profile lines (Group B data). The table is printed only when new profile line data are input to the program. Any data which have been previously input and are to be retained when the new data are input will not be printed again. Instead, a note will be printed to the effect that previous data are retained and the user should refer to earlier output.

Output Table 3: Input
data for material properties

121. Output Table 3 contains the input data for material properties (Group C data). The table is printed only when new material property data are input. Any data for material which are retained from previous input will not be printed again. Instead, a message will be printed to designate the number of materials for which previous data are retained, and the user should refer to earlier printed output tables for the retained data.

Output Table 4: Input
data for piezometric lines

122. This table contains data for the piezometric lines (Group D data). The table is printed only when new piezometric line data are input to the program. Any data which have been previously input and are to be retained when the new data are input will not be printed again. Instead, a note will be printed to the effect that previous data are retained and the user should refer to earlier output.

Output Table 5: Input data
for pore pressure interpolation

123. This table contains the input data used for interpolation of pore water pressure or r_u values (Group E data). The table is printed whenever these data are input. If only some of the data are new and some other data input previously are retained, only the new data will be printed. A message will be printed indicating that previous data will not be printed again. The user should refer to earlier printed output for the data which are retained.

Output Table 6: Input
data for slope geometry

124. This table contains the coordinates defining the slope geometry (Group F data) when the coordinates are specifically defined as input data (Table 10). The table is printed whenever the coordinates are defined or redefined by input data. If only some of the coordinates are changed (as in the case of Modify mode), then only the new coordinates are printed; the coordinates which are not modified are not printed again. This table is printed only when the slope coordinates are defined specifically by Group F input data (Table 10 contains data for slope coordinates that are generated by the program).

Output Table 7: Input
data for surface pressures

125. Table 7 contains the input data used to define the pressures acting on the surface of the slope (Group G data). The table is printed only when these data are defined or redefined by new input data. If only some of the data values are changed by the input data (as in the case of Modify mode), then only the data values which are changed are printed.

Output Table 8: Input
data for reinforcement

126. This table contains the input data used to describe the internal soil reinforcement (Group H data). The table is printed only when new soil reinforcement data are input to the program. Any data which have been previously input and are to be retained when new data are input will not be printed again. Instead, a note will be printed to the effect that previous data are retained and the user should refer to earlier output.

Output Table 9: Input
data for analysis/computations

127. This table contains the information for the analysis and computations which is input by means of Group J data. The table is printed only when new Group J data are input. In addition to containing the values input as data, the table contains values of parameters which were set as default values by the program or were defined by previous input data.

Output Table 10: Slope geometry data
generated by the computer program

128. This table contains the slope geometry data and is printed when

the slope coordinates are generated by the computer program from the profile line coordinate data. The table is printed only when the program generates new slope geometry coordinates from profile lines; otherwise the table is not printed.

Output Tables 11, 12, and 13: Long-form of automatic search output (circles)

129. These tables are the normal output tables printed during an automatic search for a critical circular shear surface. The tables contain the center point coordinates, radius, and factor of safety for each trial circle attempted. In addition, a message may be printed for some trial circles. For example, messages are printed to indicate when a circle does not intersect the slope and when the numerical solution for the factor of safety does not converge.

130. Table 11 is printed when the search is being conducted with all circles passing through a given, fixed point; Table 12 is printed when the search is being conducted with all circles tangent to a given, horizontal line; Table 13 is printed when the search is conducted with all circles having the same radius. With the exception of the heading at the top of each of these tables, the forms of Tables 11, 12, and 13 are identical. When a search is performed to locate the overall most critical circle, several of these tables may be printed and some may be printed more than once. At the conclusion of each mode of search, i.e., at the end of each table, the coordinates of the most critical circle and corresponding values for the factor of safety and side force inclination found in the current mode are printed before continuing to the next mode or completion of the search.

Output Table 14: Short-form of automatic search output (circles)

131. Table 14 is the short-form output table for an automatic search with circular shear surfaces. The table contains a summary of the most critical circles found for each mode of search. The center-point coordinates and radii of the critical circles for each mode are printed with the corresponding minimum factor of safety.

Output Table 15: Summary of automatic search (circles)

132. This table is printed at the conclusion of an automatic search for a critical circular shear surface. The table contains the X and Y coordinates

of the center point of the critical circle, the radius of the critical circle, and the corresponding minimum factor of safety and side-force inclination. The table also contains the number of circles which were attempted and the number of circles for which the factor of safety could be successfully calculated. For example, some trial circles which are attempted may not intersect the slope, and thus are attempted, but the factor of safety is not calculated.

Output Table 16: Preliminary automatic
search information (noncircular surface)

133. This table is printed as part of the normal (long) form of search output at the start of an automatic search for a critical, noncircular shear surface. The table contains the value of the crack depth which has been computed based on the initial trial shear surface and slope geometry. The table will also contain any information pertaining to adjustments in the coordinates of the initial trial shear surface if the coordinates lie slightly above the surface of the slope. Finally, the table will contain the factor of safety and side-force inclination for the initial trial noncircular shear surface.

Output Table 17: Long-form of automatic
search output (noncircular surface)

134. This table is the normal output table printed during an automatic search to locate a critical, noncircular shear surface. This table is printed for each new trial position of the noncircular shear surface. One line of information is printed in the table each time that a point on the given trial shear surface is temporarily moved and the factor of safety is computed. Each line contains the temporary X and Y coordinates of the point which has been shifted and the corresponding factor of safety and side-force inclination along with any messages pertinent to the computations for the particular, temporary shear surface configuration, e.g., "SOLUTION FOR FACTOR OF SAFETY DID NOT CONVERGE WITHIN 40 ITERATIONS." Once all points have been temporarily shifted and the factor of safety has been computed, the newly estimated coordinates for each point on the shear surface are printed, followed by the factor of safety and side-force inclination computed for the newly estimated position of the shear surface. A new trial is then initiated, a new Table 17 is printed, and the output begins again as described above.

Output Table 18: Short-form of automatic search output (noncircular surfaces)

135. Table 18 is the short-form output table for an automatic search with noncircular shear surfaces. The table contains the coordinates for each trial position of the shear surface and the corresponding factor of safety, but does not contain the coordinates and factors of safety computed for each temporary move (shift) of individual points on the shear surface. Table 18 is printed only once for each problem, while output Table 17 is printed for each trial position of the shear surface.

Output Table 19: Summary of automatic search (noncircular surface)

136. This table is printed at the conclusion of an automatic search for a critical, noncircular shear surface. This table contains the number of trial positions used to locate the critical shear surface, the coordinates of the points defining the critical, noncircular shear surface found by the search, the minimum factor of safety, and the corresponding side-force inclination.

Output Tables 20, 21, and 22: Individual slice information

137. Tables 20, 21, and 22 contain information on the individual vertical slices into which the soil mass is subdivided for computing the factor of safety. When individual shear surfaces are specified one-by-one by the user as input data, these tables are printed for each shear surface. These tables are printed only for the most critical shear surface in the case where an automatic search is performed.

138. Table 20 contains eight columns of information. The first column contains the slice number. The next two columns contain the X and Y coordinates of the left edge, the center, and the right edge of the slice along the shear surface. The center coordinates of the slice are printed on the same line as the slice number and other slice information; the coordinates of the left and right edges of the slice are printed on lines by themselves, above and below the center coordinates, respectively.

139. The fourth column in Table 20 contains the slice weight followed, in the fifth column, by the material type for the material at the base of the slice. The sixth and seventh columns contain the cohesion and friction angle for the material at the base of the slice, except when the shear strength

envelope is nonlinear; in the case of a nonlinear envelope the words "NON-LINEAR ENVELOPE" are printed in the sixth and seventh columns. The eighth and final column of Table 20 contains the value of the pore water pressure at the center of the base of the slice.

140. Table 21 also contains eight columns of information pertaining to individual slices. The first column of Table 21 contains the slice number. The second column contains the X coordinate of the center of the base (midpoint) of the slice. The third column contains the seismic (pseudo-static) force computed from the seismic coefficient, and the fourth column contains the Y coordinate of the line of action of the seismic force corresponding to the X value in the second column. The fifth through eighth columns of Table 21 contain information pertaining to the forces acting on the top surface of each slice due to "surface pressures." The normal and shear (tangential) component of the forces and the X and Y coordinates of the location of the resultant force on the top of the slice are printed in these final four columns.

141. Table 22 contains six columns of information pertaining to soil reinforcement forces for individual slices. This table is printed only when soil reinforcement has been specified in the input data. The first column of the table contains the slice number. The next two columns contain the total horizontal and vertical forces, respectively, on the base of the slice due to all soil reinforcement which intersects the base of the slice. The fourth column contains the moment produced by the total soil reinforcement force about a point on the center of the base of the slice. The last two columns of the table contain the magnitude and direction of the resultant force due to all soil reinforcement which intersects the base of the slice. The magnitude is always expressed as a positive quantity. The direction is expressed as an angle of inclination measured in degrees from the horizontal, with positive angles being measured in the counterclockwise direction.

Output Table 23: Iterative solution for the factor of safety

142. Table 23 contains a detailed iteration-by-iteration summary of the trial and error calculations performed during computation of the factor of safety for a given shear surface. This table is printed every time that Tables 20 and 21 are printed, i.e., the table is printed for individual shear surfaces selected by the user, or for the most critical shear surface in the

case of an automatic search. The information contained in this table, other than the values for the final factor of safety and side force inclination, is ordinarily of interest only when difficulties are encountered in obtaining a solution for the factor of safety and the iterative solution fails to converge. In such case, the pattern by which the factor of safety and side-force inclination are varying in the iterative solution can be seen and corrective action can often be taken. Corrective action usually consists of altering the initial trial values used for the factor of safety and side-force inclination (Group J data, Part II, paragraphs 70 through 116, and Tables 17 through 22).

Output Tables 24 and 25: Final solution information

143. Tables 24 and 25 contain important information pertaining to the solution of the equilibrium equations for the factor of safety. The tables are printed whenever Tables 20, 21, and 23 are printed, provided that the solution for the factor of safety has converged.

144. The first portion of Table 24 contains six columns of information with one line of information printed for each slice. The first column contains the slice number followed by the X and Y coordinates of the center of the base of the slice in the second and third columns, respectively. A "total" normal stress, "effective" normal stress, and shear stress at the center of the base of the slice (shear surface) are printed in the fourth, fifth, and sixth columns, respectively. However, what is labeled as "total" and "effective" is not in all cases what may be implied by these labels as noted below:

- *a*. The "total" normal stress printed in the fourth column will actually be the effective normal stress if submerged unit weights are used for the soil; otherwise, the stress printed in the fourth column is the actual total normal stress.
- *b*. The "effective" normal stress printed in the fifth column is actually the "total" normal stress, minus any value of pore water pressure which has been defined by input data. Thus, in the case of total stress analyses, where no pore water pressures are specified, the "effective" normal stress printed in Table 24 will actually be the same as the "total" normal stress.

Compression is considered to be positive for the normal stresses; tension is considered to be negative. The shear stress is considered to be positive when it acts on the shear surface in a direction opposite to the direction of potential sliding of the soil mass; any reasonable value of shear stress should be positive.

145. Table 25 contains information pertaining to the forces between slices and is printed when Spencer's (1967) procedure, the Corps of Engineers Modified Swedish procedure, EM 1110-2-1902 (Department of the Army 1970), and Lowe and Karafiath's (1960) procedure are used to compute the factor of safety. Table 25 is not printed for the Simplified Bishop (1960) procedure. The first three columns of Table 25 contain the same type of information, regardless of the procedure employed. The first column contains the number of the slice. The second column contains the X coordinate of the right-hand side of the slice. The third column contains the total resultant side force at the right side of the slice; the resultant represents the vertical and horizontal components of the side force.

146. The remaining columns (after the first three columns) in Table 25 vary, depending on the specific procedures used to compute the factor of safety as follows:

a. Spencer's procedure. In the case of Spencer's procedure, column four contains the Y coordinate of the point of application of the resultant side force on the right side (vertical boundary) of the slice. The fifth column printed for Spencer's procedure contains additional information pertaining to the location of the side force on the vertical slice boundary as follows:

> A numerical value, e.g., 0.331, will be printed in the fifth column when the side force acts at a point on the boundary which lies between the shear surface and the surface of the slope. In such cases, the numerical value which is printed is the fractional distance above the shear surface to the point where the side force acts, expressed as a fraction of the total height of the vertical slice boundary. Thus, if the side force acts at the lower-third point of the slice boundary, a value of 0.333 will be printed. If the side force acts below the shear surface, the word "BELOW" is printed in the fifth column; if the side force acts above the surface of the slope, the word "ABOVE" is printed in the fifth column.

The final two columns (6 and 7) printed in Table 25 contain values of the stresses acting normal to the vertical slice boundary (i.e., horizontal stresses) at the top and bottom of the slice. These stresses are computed using the magnitude and location of the resultant side force and assuming a linear variation of stress with depth along the vertical boundary between slices. These stresses are seldom of any practical use and may not be valid.

b. Corps of Engineers Modified Swedish (Department of the Army 1970) and Lowe and Karafiath's (1960) procedures. In the case of these procedures, which satisfy force equilibrium only, the fifth column of Table 25 contains the side-force inclination. Table 25 has just five columns for these procedures.

147. Following the information described above for Tables 24 and 25, each of the tables contains additional, identical information pertaining to an automatic check of the solution and possible caution and warning messages. The first set of information which is printed at the end of both Tables 24 and 25 consists of four check sums for forces and moments, which are computed to verify the correctness of a solution. The values of the check sums should be small and not exceed values of the force and moment imbalances which are used as solution tolerances in the iterative calculations for the factor of safety and side-force inclination. (Note: Default values are used for these solution tolerances unless reset as part of the Group J data.)

148. The final set of information printed at the end of Tables 24 and 25 consists of warning and caution messages when certain conditions are detected in a solution. Caution level messages are designated by the word "CAUTION" and are printed when tensile stresses are detected from a solution for the upper portion of a shear surface near the crest (top) of the slope. Such tensile stresses may or may not be permissible, depending on the nature of the problem (e.g., short-term versus long-term stability) and the nature of the materials involved (e.g., clean sand versus highly cemented clay). However, tensile stresses should only be accepted with caution. Warning level messages are designated on the printed output by the word "WARNING" and are printed when tensile stresses are calculated in areas near the toe of the slope or when the shear stress acts in an apparently incorrect direction. Warning messages are printed twice for each warning and in most such cases the solution should be rejected.

PART IV: GRAPHICS

149. The graphics with UTEXAS2 provide for displaying the input data and a single shear surface input by the user or the final shear surface from a search. When UTEXAS2 is executed, the user is prompted for the name of the input and output files. After the data file is read and all data error checking has been performed successfully, the user is asked if graphic displays are wanted. If there are errors in the data file, plots will not be created. After the analyses are performed, the user will again be asked if plots are wanted. The graphics programs are set up to work with a Tektronic 4014 terminal or emulator.

150. The initial display consists of the soil profile data. Figure 6 shows an example of this plot which covers the entire range of X values. There are several options available for enhancing the plot by changing the scale or displaying the data associated with the command words. The following list of options and associated letters used to select the option is shown below. The last option listed ends the graphic session.

Valid Letter	Option
L	Displays all normal surface loads
S	Displays the slope geometry data
P	Displays all piezometric profiles
I	Displays the interpolation points
F	Displays shear (failure) surface generated by the program
T	Erases current plot and replots the entire soil profile
B	Displays data with different scale factors in the X and Y directions in order to provide the largest possible plot
W	Defines a window for enlarging a portion of the plot
E	Exits graphics and performs analysis

The options can be selected by entering the appropriate letter and entering a return or by moving the cross-hairs to the appropriate letter and entering a return. If a character other than those in the above list is entered, the program will indicate an invalid character and display the list of options.

151. Figures 7 and 8 show example plots illustrating the piezometric profiles and the normal surface loads. Figure 9 illustrates the slope

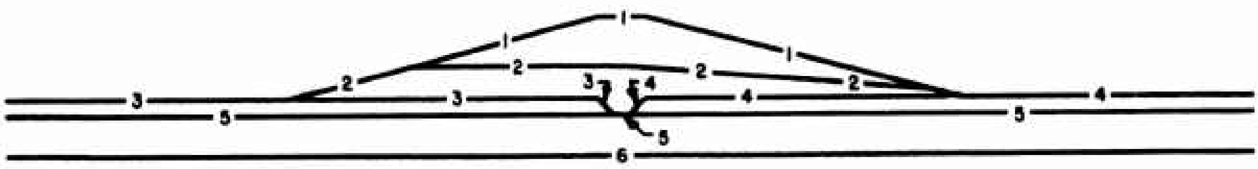


Figure 6. Plot of profile data for entire range of X values

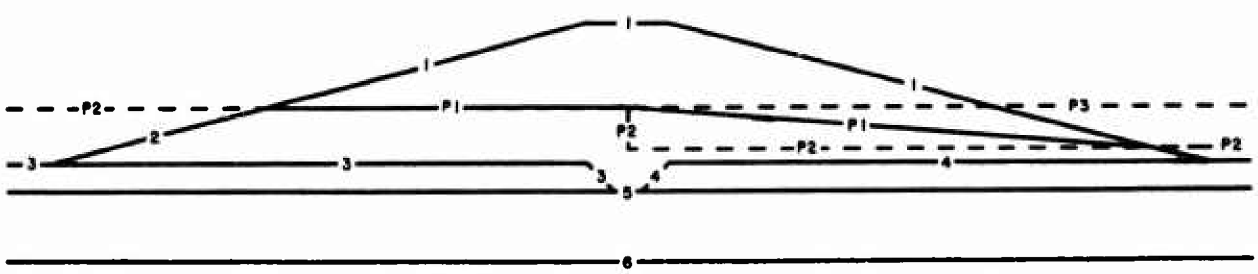


Figure 7. Plot illustrating piezometric profiles

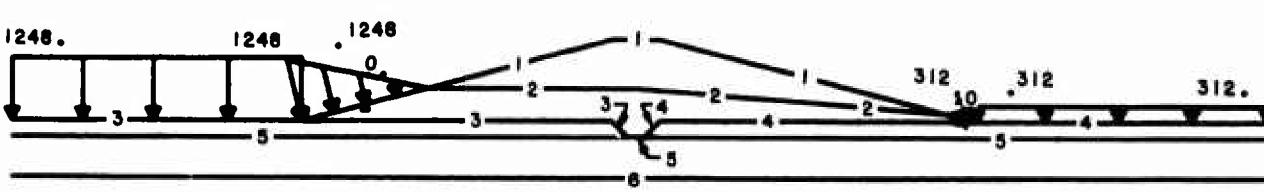


Figure 8. Plot illustrating normal surface loads

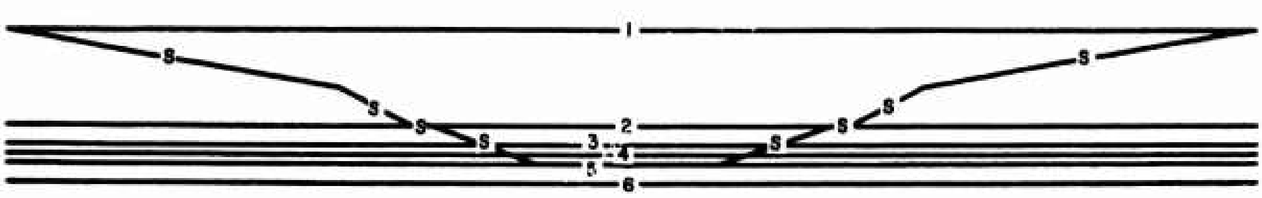


Figure 9. Plot illustrating slope geometry for a cut slope

geometry data for a cut slope example. For the embankment shown in the previous figures, the slope geometry data coincides with an existing soil profile. The plotting of this data over the soil profile results in being unable to read the profile numbers. Figure 10 shows an example plot for the pore pressure interpolation points. Figure 11 shows the initial, noncircular shear surface while Figure 12 shows the final surface after the search procedure. For circular shear surfaces, only the final surface from a search can be plotted. An example of this is shown in Figure 13. On these figures, the space between the profile data and the shear surface is the representation of the tension crack. Both Figures 12 and 13 were plotted after the analysis during the second plotting opportunity.

152. The window option is used to enlarge selected areas of the total cross section. For example, Figure 6 shows the entire cross section while Figure 7 shows just the embankment. The window option was also used for a number of the other figures. To use this option, the cross hairs must be moved to the lower left corner of the window area. Then enter the letter "W" and return. The program will display the letters "LL". The cross hairs are then moved to the upper right corner of the window, where any character is entered and then the return. After this second letter is entered, the screen is erased and the soil profile within the window is plotted. The user must then redraw the other options of interest.

153. Figure 14 illustrates a different scale option that provides the largest possible plot of the entire cross section. All profile and load data can be plotted on this type of plot. The "T" option is used to erase the screen and plot the entire soil profile again. This option is used to move between window plots, distorted section plots, and entire cross section plots.

154. When the user has completed all the plots and executed the "E" option, the program will then execute the stability analysis if the next command word is "COMPUTE". The "Break" key can be used if the user wants to end the program to modify or correct the input data.

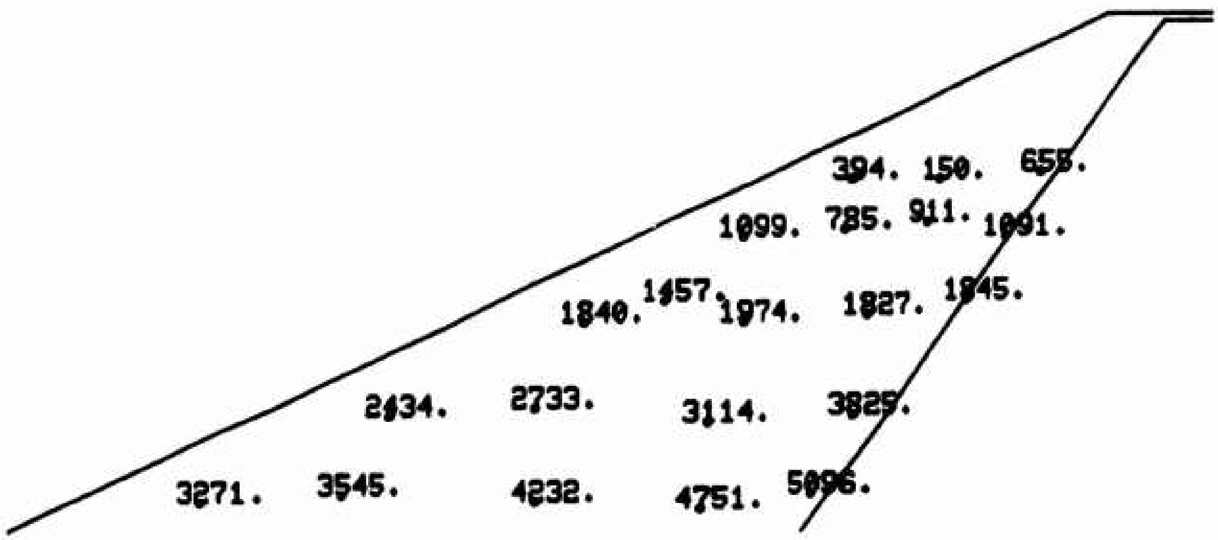


Figure 10. Plot for pore pressure interpolation points

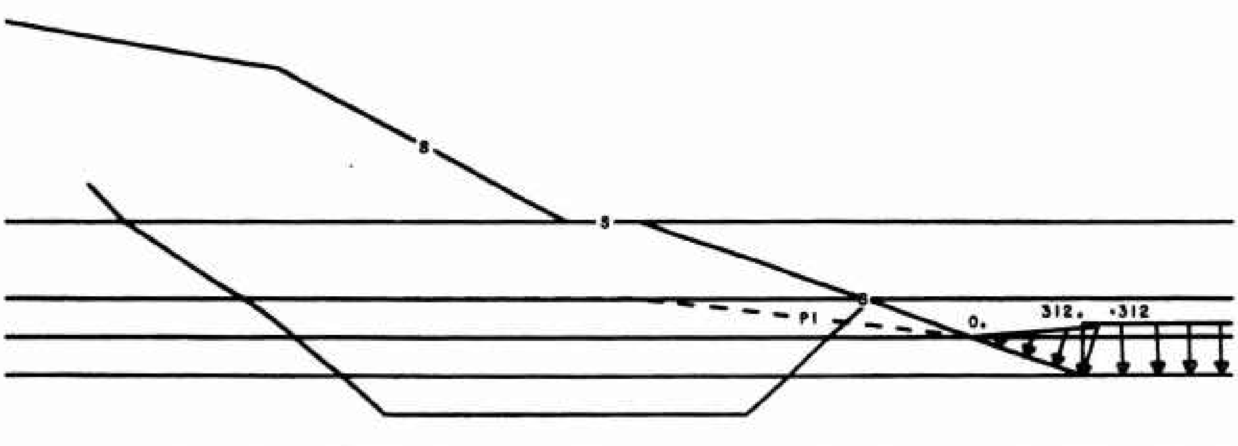


Figure 11. Plot of initial, noncircular shear surface

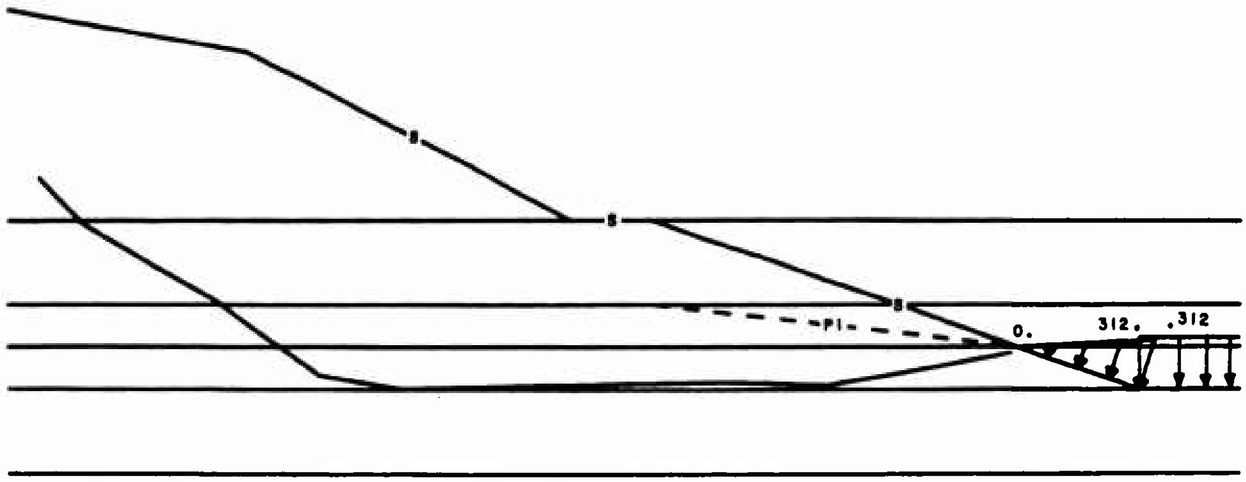


Figure 12. Plotting of final surface of initial, noncircular shear surface procedure

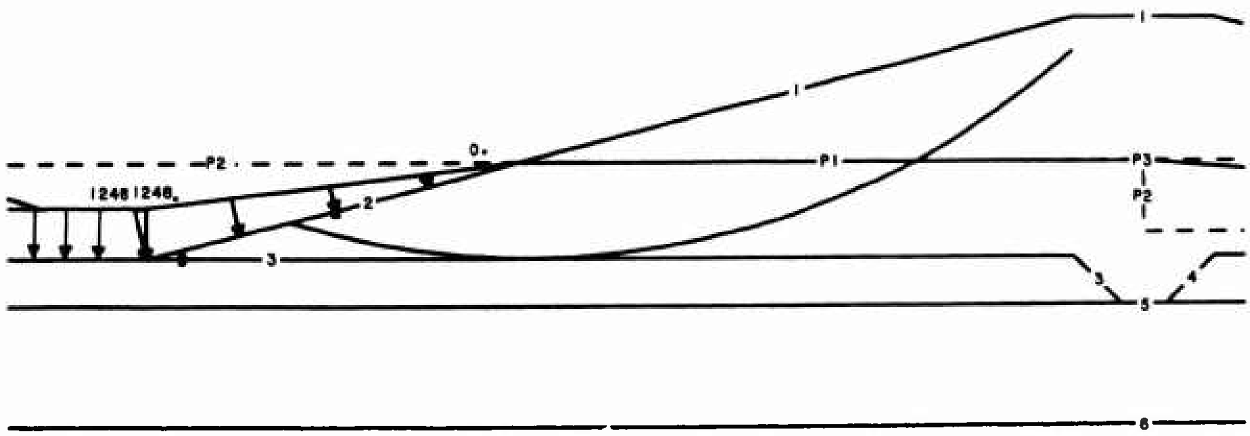


Figure 13. Plot of final surface after search procedure

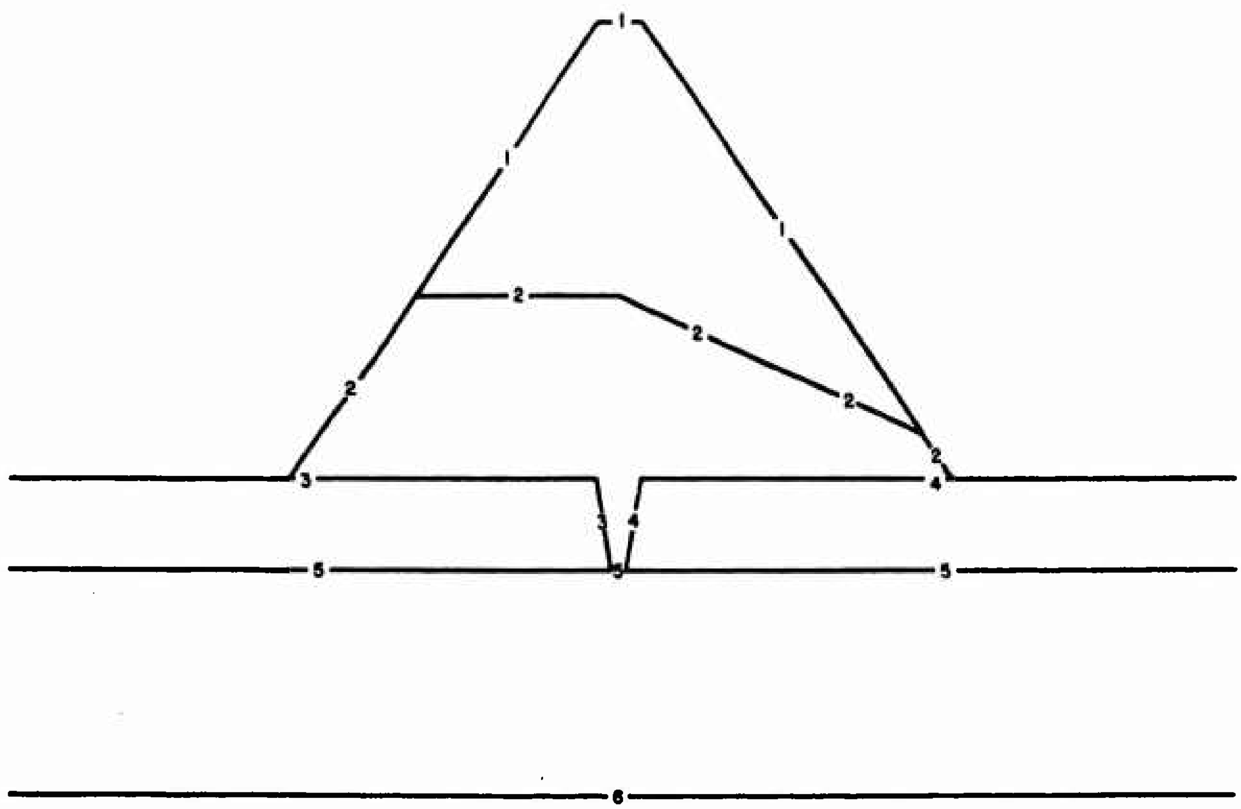


Figure 14. Scale option providing largest plot of cross section

PART V: CONCEPTUAL EXAMPLES

Purpose of Examples

155. The following examples are presented to illustrate the use of UTEXAS2. The most usable options are presented in the following paragraphs. Volume III, consisting of example problems illustrating coding procedures for generic problems, will illustrate the capabilities and the versatility of the program. For the examples in this section, the first two examples, an embankment and cut slope, are simple problems illustrating the minimum data file necessary to perform either a singular circular analysis or a noncircular analysis. The other examples, two loading conditions for an embankment and one loading condition for a cut slope, illustrate the searching capabilities of the program. Several parameters associated with the searching techniques are varied to illustrate their sensitivity.

Example 1: Embankment - Single Circular Analysis

156. This simple example describes the end-of-construction loading condition for a homogenous embankment on a sand foundation. The cross section and material properties are shown in Figure 15. This example represents the minimum data configuration to analyze a single circular shear surface.

157. The geometry is represented with two profile lines which in turn reference each material. Since this is a total stress analysis, there are no

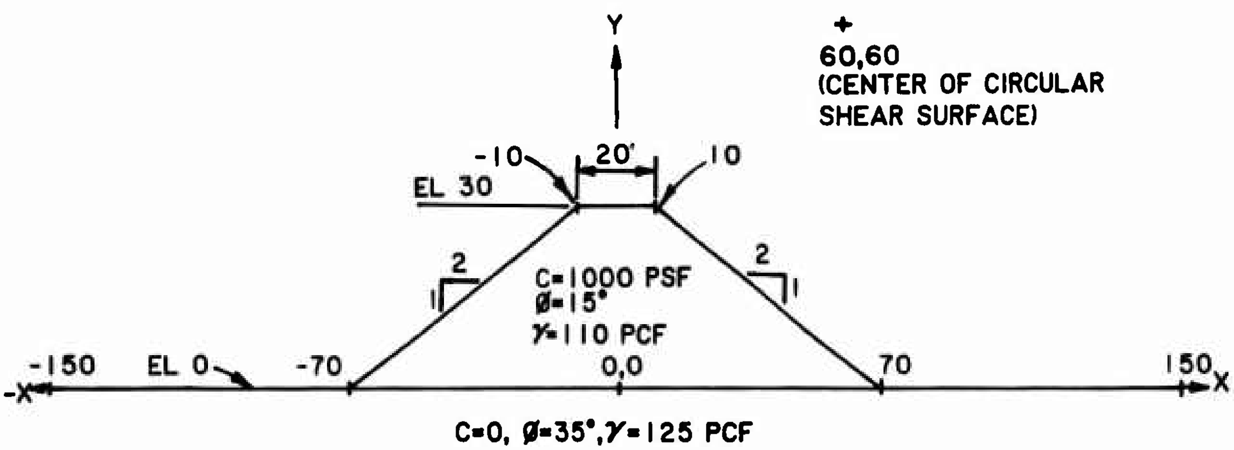


Figure 15. Example 1: Cross section

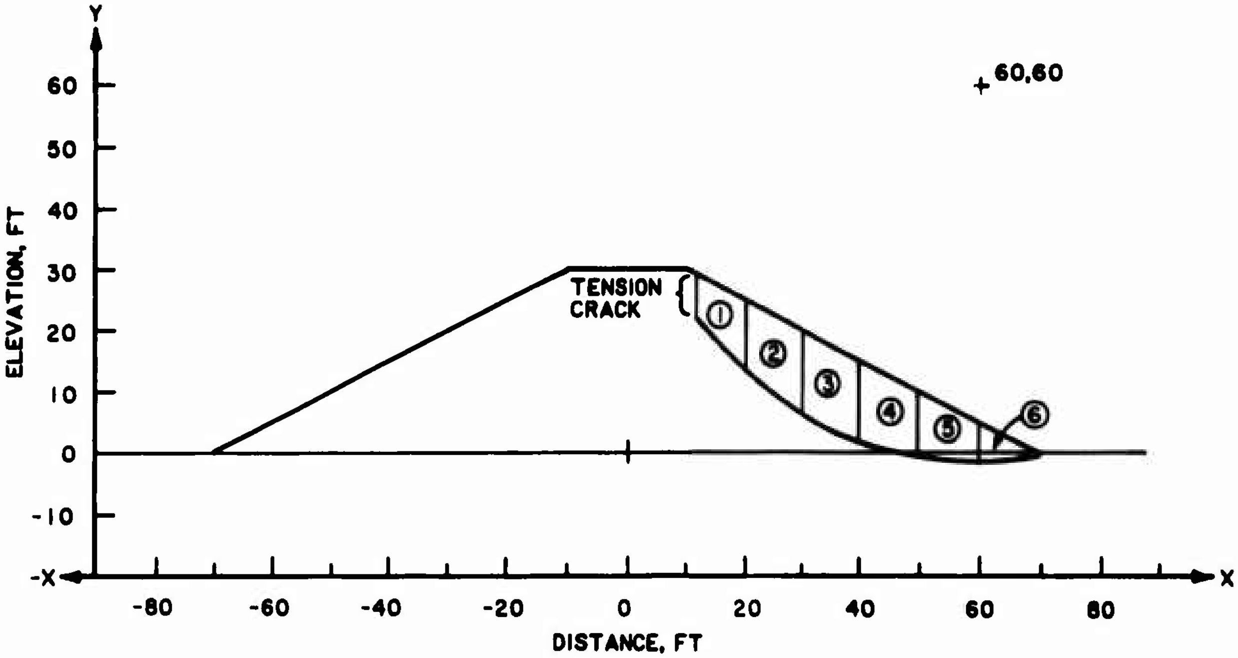
pore pressures. Also, conventional shear strengths are used to specify the cohesion and friction parameters. The analysis data specifies the center point of the circle and the radius. For this problem, the radius is specified by defining a point along the circle. Other options for defining the radius are specifying a horizontal elevation to which the circle would be tangent and specifying the radius itself. The complete input file is shown in Figure 16. Since the embankment is a clay material, a tension crack is assumed. A 6.3-ft deep tension crack is specified in the ANALYSIS/COMPUTATION data. This depth of crack is the maximum anticipated depth of a tension crack in this material. The user is referred to Volume II of the User's Guide for details

```
heading           HEADING                        <- command word
page 20             Example 1 - Simple example
                     End of construction loading
                     Single circular shear surface
                  PROFILE LINES                  <- command word
                    1  1  Embankment
                    -70  0
profile line        -10 30
data                 10 30
page 21              70  0
                            } blank line
                    2  2  Foundation
                    -150  0
                     150  0
                             } 2 blank lines
                  MATERIAL PROPERTIES            <- command word
                    1  Embankment clay
                     110 = unit weight
material             Conventional shear strength
property              1000  15
data                 NO pore pressures
page 25             2  Foundation sand
                     125 = unit weight
                     Conventional shear strength
                      0  35
                     NO pore pressure
                                     } blank line
                  ANALYSIS/COMPUTATION           <- command word
                    Circular
analysis/            60  60
computation           Point
data                   70  0
page 57               CRACK <- subcommand word
                        6.3 <- depth of tension crack
                               } blank line
                  COMPUTE                        <- command word
```

Figure 16. Example 1: Input data file

about tension cracks. The default analysis procedure (Spencer's procedure) is used. The safety factor for the specified circle is 2.90. The computer results are included as file EXAM1.OUT in Appendix D.

158. Figure 17 shows the shear surface and the hand check for this circle. The Corps of Engineers Modified Swedish side-force inclination assumption (Department of the Army 1970) was used with the force equilibrium procedure to perform the hand check. The side-force inclination calculated by the Spencer procedure was used for the force equilibrium calculation. The UTEXAS2 input and output files for the Corps procedure, EXAM1H, are included in Appendix D.



Slice Coordinates

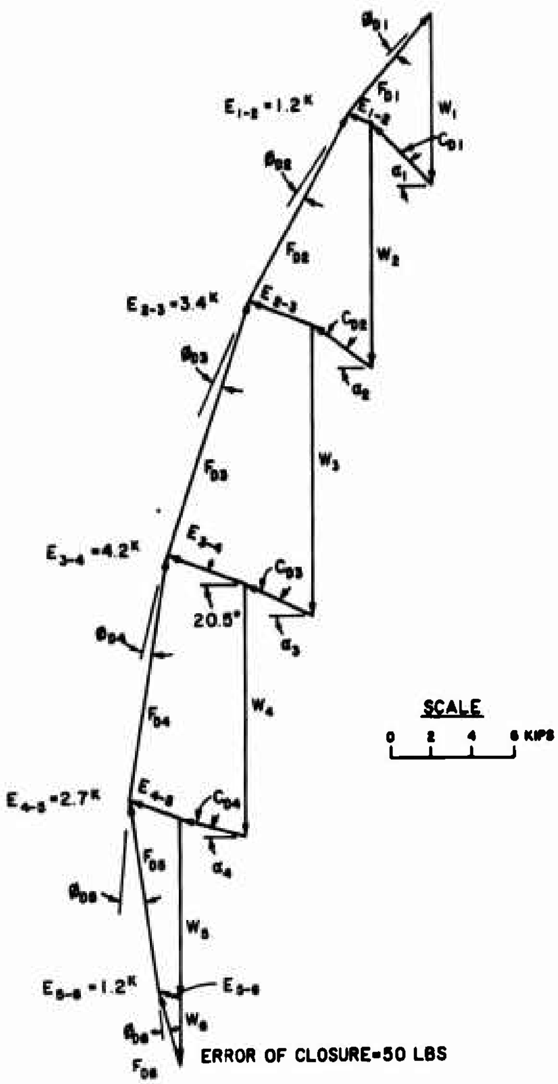
slice	X	y top	y bottom
	11.9	29.05	22.7
1			
	20.7	24.65	13.6
2			
	29.8	20.10	7.2
3			
	40.0	15.0	2.6
4			
	50.0	10.0	0.0
5			
	60.0	5.0	-0.8
6			
	70.0	0.0	0.0

Material Properties

Material	C(psf)	ϕ	C_D(psf)	ϕ_D	γ(pcf)
Embankment	1000	15°	345	5.3°	110
Foundation	0	35°	0	13.6°	125

Trial FS = 2.90

Figure 17. Example 1: Shear surface and hand check (Continued)



Force Polygon Data

Slice	Slice Width, b (ft)	Weight W (kips)	α	ΔL (ft)	C_D (k/ft)	ϕ_D
1	8.8	8.4	46.0°	12.7	4.38	5.3°
2	9.1	12.0	35.1°	11.1	3.83	5.3°
3	10.2	14.2	24.3°	11.2	3.86	5.3°
4	10.0	12.3	14.6°	10.3	3.55	5.3°
5	10.0	8.8	4.6°	10.0	-	13.6°
6	10.0	3.3	-4.6°	10.0	-	13.6°

Notes:

side force inclination = 20.5 (from Spencer procedure analysis)

b = horizontal width of slice

α = angle of slice base with horizontal

ΔL = length of slice base, base/cos α

CD = developed cohesive force, C_D *ΔL

Figure 17. (Concluded)

Example 2: Cut Slope - Single Noncircular Analysis

159. This simple example describes the undrained loading condition for a cut slope. The cross section and material properties are shown in Figure 18. This example represents the minimum data configuration to analyze a single noncircular shear surface using the slope geometry data.

160. The geometry is represented by three horizontal profile lines with the slope defined by the slope geometry data. Each profile line references a material with different profile lines referencing the same material. Since this is a total stress analysis, there are no pore pressures. Also, conventional shear strengths are used to specify the cohesion and friction parameters. The noncircular analysis data specifies the points used to define the shear surface. For this problem, four points were used to specify the shear surface. A 6.7-ft deep tension crack is assumed by beginning the noncircular shear surface at the bottom of the crack. This depth of tension crack is the maximum anticipated depth in this material. The user is referred to Volume II of the User's Guide for details about tension cracks. The default analysis procedure (Spencer's procedure) is used. The safety factor for the specified shear surface is 1.41. The computer results are included as file EXAM2.OUT in Appendix D. The complete input file is shown in Figure 19.

161. Figure 20 presents the hand check for this shear surface. The Corps of Engineers Modified Swedish side-force inclination assumption, EM 1110-2-1902 (Department of the Army 1970), was used with the force equilibrium procedure to perform the hand check. The side-force inclination calculated by the Spencer procedure was used for the force equilibrium calculations. The UTEXAS2 input and output files for the Corps procedure, EXAM2H, are included in Appendix D.

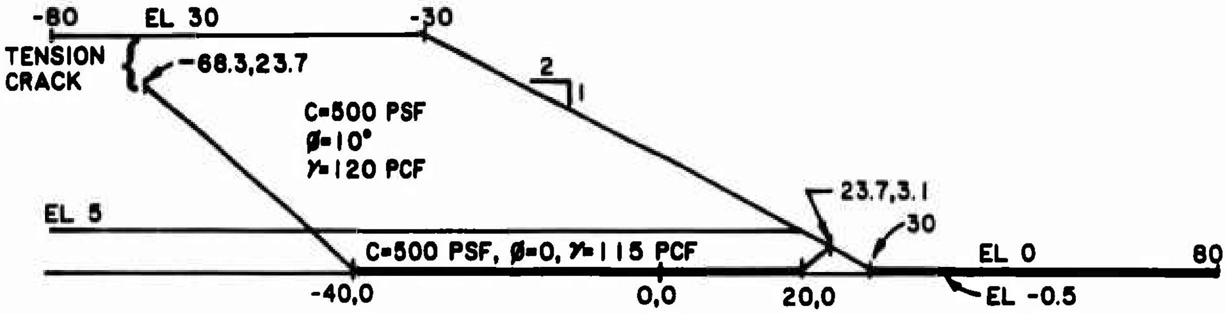
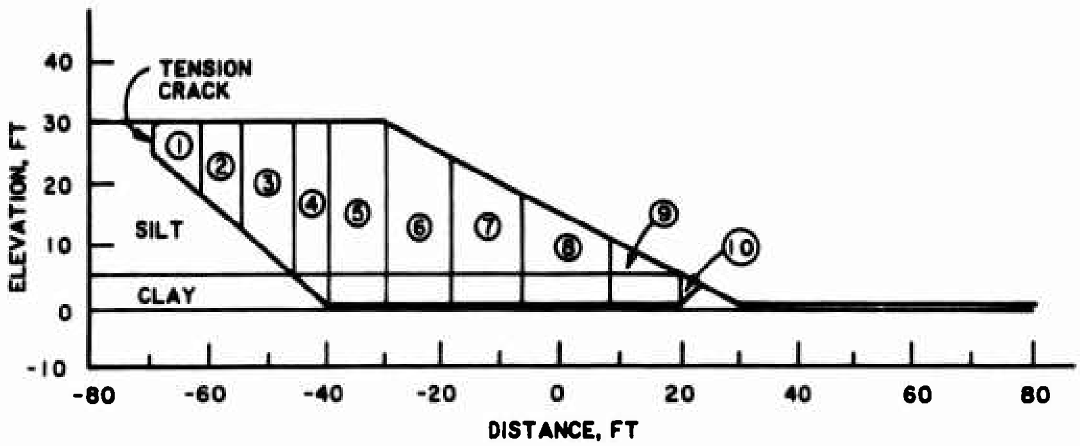


Figure 18. Example 2: Cross section

```
heading      HEADING                                   ← command word
page 20        Example 2 - Simple cut slope example
                Undrained condition
                Single noncircular shear surface
             PROFILE LINES                             ← command word
               1  1  Silt layer
               -80 30
                80 30
                            } blank line
profile        2  2  Clay layer
line data      -80 5
page 21         80 5
                            } blank line
               3  1  Silt foundation layer
               -80 -0.5
                80 -0.5
                              } 2 blank lines
             MATERIAL PROPERTIES                       ← command word
               1  Silt
                120 = unit weight
material        Conventional shear strength
property         500   10
data            NO pore pressure
page 25        2  Clay
                115 = unit weight
                Conventional shear strength
                 500   0
                NO pore pressure
                                   } blank line
slope        SLOPE GEOMETRY                            ← command word
geometry       -80 30
data           -30 30
page 46         30   0
                80   0
                            } blank line
             ANALYSIS/COMPUTATION                      ← command word
analysis/      Noncircular
computation     -68.3  23.7
data            -40     0
page 57          20     0
                 23.7   3.1
                                  } 2 blank lines
             COMPUTE                                   ← command word
```

Figure 19. Example 2: Input data file



Slice Coordinates

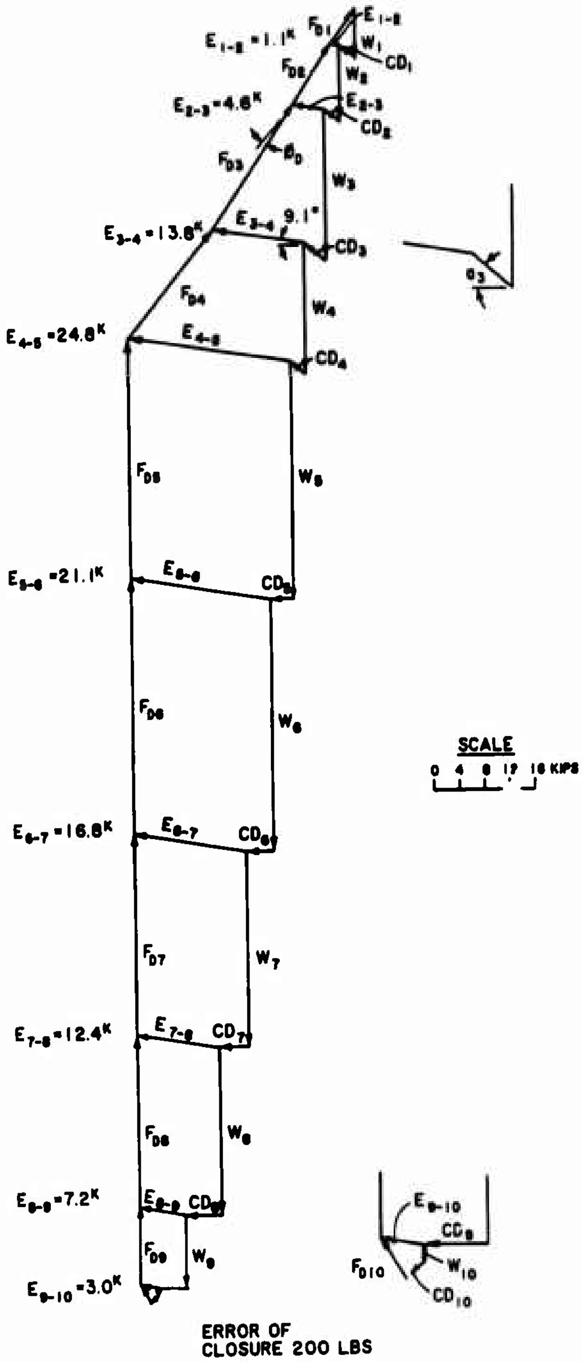
slice	X	y top	y bottom
	-68.3	30.0	23.7
1			
	-61.6	30.0	18.1
2			
	-54.9	30.0	12.5
3			
	-46.0	30.0	5.0
4			
	-40.0	30.0	0.0
5			
	-30.0	30.0	0.0
6			
	-18.2	24.1	0.0
7			
	-6.5	18.25	0.0
8			
	8.2	10.9	0.0
9			
	20.0	5.0	0.0
10			
	23.7	3.1	3.1

Material Properties

Material	C(psf)	ϕ	C_D(psf)	ϕ_D	γ(pcf)
Silt	500	10°	357	7.2°	120
Clay	500	0	357	0	115

Trial FS = 1.4

Figure 20. Example 2: Hand check (Continued)



Force Polygon Data						
Slice	Slice Width, b (ft)	Weight W(kips)	α	ΔL (ft)	C_D(k/ft)	ϕ_D
1	6.7	7.3	39.9°	8.7	3.11	7.2°
2	6.7	11.8	39.9°	8.7	3.11	7.2°
3	8.9	22.7	39.9°	11.6	4.14	7.2°
4	6.0	19.7	39.9°	7.8	2.78	0
5	10.0	35.8	0	10.0	3.57	0
6	11.8	38.0	0	11.8	4.21	0
7	11.7	29.4	0	11.7	4.18	0
8	14.7	25.3	0	14.7	5.25	0
9	11.8	11.0	0	11.8	4.21	0
10	3.7	1.1	-39.9°	4.8	1.71	7.2°

Notes:

side force inclination = 9.07° (from Spencer procedure analysis)

b = horizontal width of slice

α = angle of slice base with horizontal

ΔL = length of slice base, base/cos α

C_D = developed cohesive force, $C_D \cdot \Delta L$

Figure 20. (Concluded)

Example 3: Embankment - Circular Search

162. Stability computations for both end-of-construction and partial-pool loading conditions are performed for this example problem. The type of shear strength values required in EM 1110-2-1902 (Department of the Army 1970) is used for the appropriate loading conditions. Only circular shear surfaces are considered. Searches for the critical surface using each of the four analysis procedures are presented for both loading conditions along with details on how to perform the search procedure. The end-of-construction loading, case 1, illustrates the circular search sequence, and the effect of the different initial search modes, different starting points, the final grid spacing, and tension cracks. The partial pool loading, case 2, illustrates the incorporation of water loads and different piezometric levels into the analysis. A hand check for one analysis procedure of each loading condition will also be presented.

Embankment description

163. This example consists of a compacted impervious embankment on a sand and clay foundation with an impervious key trench through the sand layer. A cross section of the embankment and foundation is shown in Figure 21. The embankment is 50 ft high with a 1 (vertical) to 4 (horizontal) side slopes. The sand layer, 10 ft thick, and the foundation clay, 25 ft thick, is underlain by rock. The coordinate axes selected for this problem and the corresponding embankment coordinates are included in Figure 21. Table 23 lists the various unit weights and shear strength values for the material in this problem.

164. The geometry for this problem can be represented by five or six profile lines, depending on the hydrostatic loading for the particular condition being analyzed. The profile lines represent the upper boundary of a soil layer with a material under the line identified by the material type. Figures 22a and 23 show the embankment representation for each loading condition. The embankment material is represented as the first profile line. This profile extends only from embankment toe to toe, not over the entire profile. The second profile line represents the sand layer under the upstream portion of the embankment. Because the sand layer does not extend under the key trench and the program does not allow soil layers with zero thicknesses, it is recommended that the sand layer be represented as two profile lines. Thus,

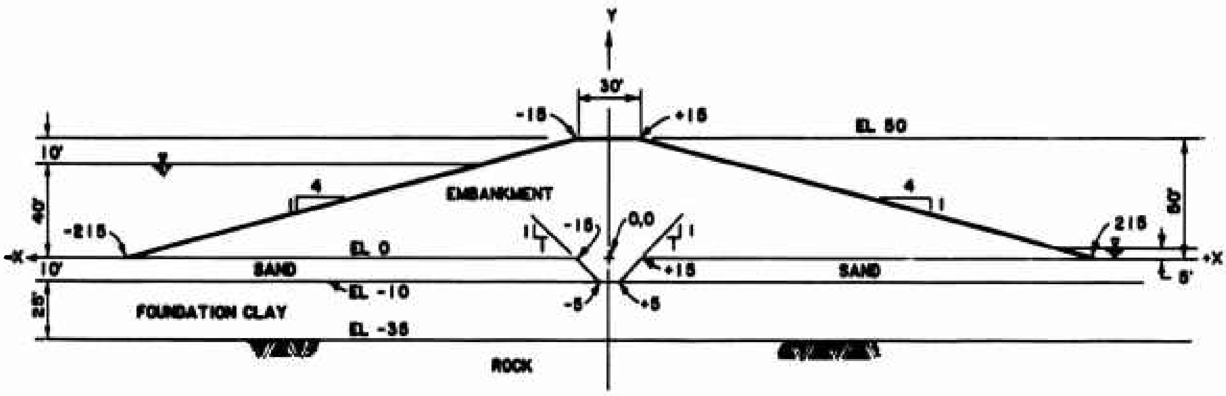
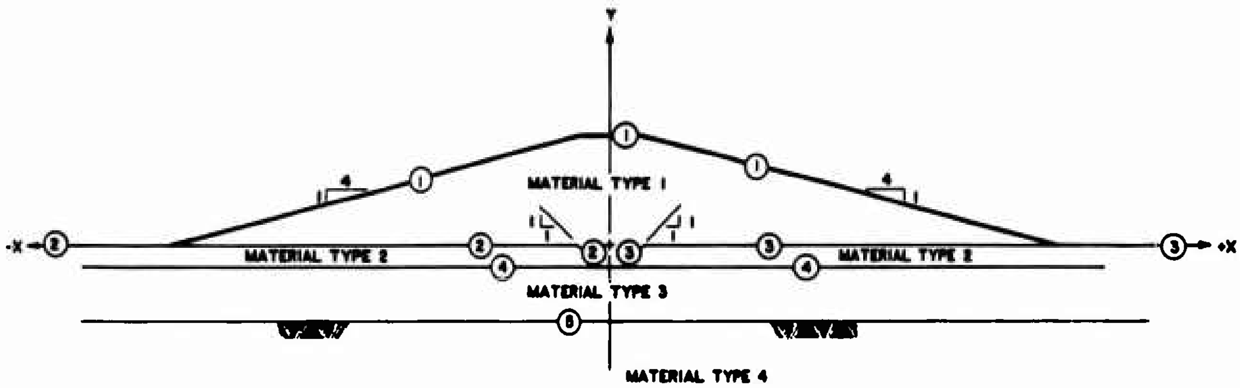


Figure 21. Example 3: Cross section

Table 23

Soil Properties for Example 3

			Q		R		S	
	γ_S	γ_M	C	Ø	C	Ø	C	Ø
EMBANKMENT	120	115	1,000	5	200	15	0	25
SAND	130	125	0	35	0	35	0	35
FOUNDATION CLAY	115	110	3,000	0	250	20	0	30
ROCK	165	160	0	45	0	45	0	45



a. Embankment representation profile data

heading page 20

```
HEADING                              ←— command word
  Example 3 - Circular search
   Clay embankment on 10 foot sand layer
   Sand is over 25 foot of clay over rock
PROFILE LINES                        ←— command word
  1  1  Embankment surface
  -215  0
   -15 50
    15 50
   215  0
            } blank line
  2  2  Upstream sand layer
  -400  0
   -15  0
    -5 -10
            } blank line
  3  2  Downstream sand layer
     5  -10
    15    0
   400    0
            } blank line
  4  3  Foundation clay
  -400  -10
   400  -10
            } blank line
  5  4  Rock
  -400  -35
   400  -35
            } 2 blank lines
```

profile line data page 21

b. Profile data for end-of-construction loading

Figure 22. Loading condition for Example 3

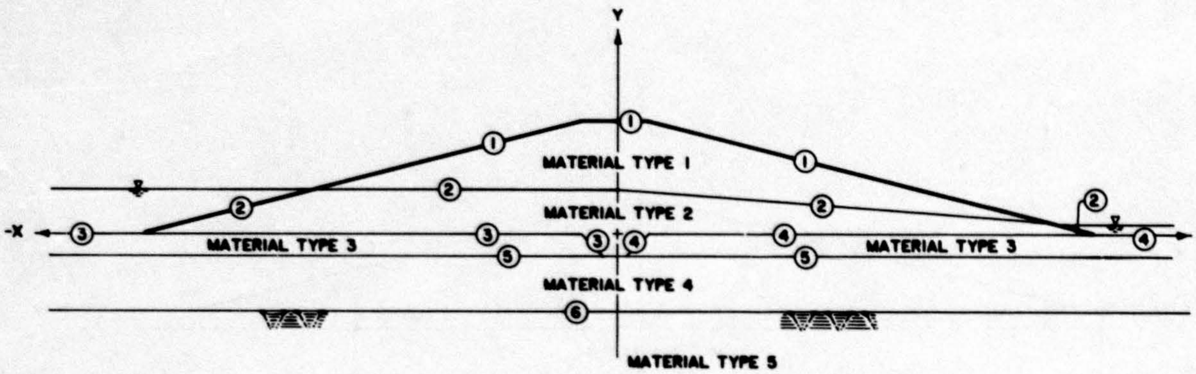


Figure 23. Partial pool case for Example 3

Profile Line 3 represents the sand layer under the downstream portion of the embankment. The material type would be the same for Profile Lines 2 and 3. The top of the foundation clay is represented by Profile Line 4, while the top of rock is Profile Line 5. If a phreatic surface exists, then the embankment material should be represented as two material types with the phreatic line separating the material types. The profile representing the dry embankment would start at the intersection of the water level and the embankment and continue along the surface to the intersection on the other side. The order that the profile lines are defined is not important, but it is necessary that the lines be defined from left to right in increasing x order. The profile data for the end-of-construction loading is shown in Figure 22b.

Case 1 - End of construction

165. For this case, the Q strength values and the appropriate unit weights listed in Table 23 are used. There is no pore water pressure in the embankment. The ground water level is assumed to be at elevation 0.0 which is the top of the sand layer. Thus, the sand and the foundation clay are saturated with saturated unit weights used in the analyses. The listing of the material property input data is shown as Figure 24. The same piezometric level can be used for different materials.

166. For both the end-of-construction and partial pool cases, searches for the critical shear surface were performed. The initial circle center point and final grid spacing were specified. A listing of the necessary analysis data for both a toe and tangent circle is shown in Figure 25. The final grid spacing of 1 percent of the slope height is recommended. Thus, for this example the spacing would be 0.5 ft.

167. There are two types of circular shear surfaces that are analyzed

heading page 20

```
HEADING                          ← command word
  Case 1 - End of Construction (Q strength)
   No pore pressures in embankment
   Groundwater table elevation 0.0
```

material properties page 25

```
MATERIAL PROPERTY                ← command word
  1  Embankment Q strength
   115 = moist unit weight
   Conventional shear strength
    1000  5
   NO pore pressures
  2  Sand layer
   130 = saturated unit weight
   Conventional shear strength
    0  35
   Piezometric Line
    1  Piez line for groundwater
  3  Foundation clay
   115 = saturated unit weight
   Conventional shear strength
    3000  0
   Piezometric Line
    1  Piez line for groundwater
  4  Rock
   165 = saturated unit weight
   Conventional shear strength
    0  45
   Piezometric Line
    1  Piez line for groundwater
                                 } blank line
```

piezometric data pae 37

```
PIEZOMETRIC LINE DATA            ← command word
  1  62.4  Groundwater table
  -400  0
   400  0
                 } 2 blank lines
```

Figure 24. Material property and piezometric line input data

heading page 20

```
HEADING                    ← command word
  Example 3 - case 1
   Modified Swedish (Corps method)
   Search for critical shear surface
```

analysis/computation data page 57

```
ANALYSIS/COMPUTATION       ← command word
  Circular Search
   101  180  0.5  -60
   Tangent
    -1.0
   PROCEDURE               ← subcommand word
    Corps
     14.0
                           } blank line
COMPUTE                    ← command word
```

Figure 25. Analyses data for toe and tangent circles

in this case. The first will be for circles passing through the embankment toe. The second type will be circles that are tangent to the base of the embankment. The type of circular shear surface search will be dependent upon the initial search mode. All analysis procedures are used for each type of these circular shear surfaces. The minimum factor of safety of each circle type for each analysis procedure based on the starting center of $x = 101$ and $y = 180$ is listed in Table 24. For comparisons, the circle coordinates, radius, and side-force inclinations are included in the table. For this example, the material property combination is such that the circles tangent to the base of the embankment are critical. The variation of the safety factor due to the analysis procedure is much greater for the toe circles than the tangent circles. Toe and tangent circles will be different and general trends of safety factors and analysis procedures cannot be inferred for different types of circles. The listing of the safety factor to thousandths in the tables and figures is for illustrative purposes only and the exact values will depend upon the computer utilized for the computation.

168. Tension cracks were not used for the analyses listed in Table 24. However, a caution was listed in most of the outputs (Output Table 22) indicating negative effective or total normal stresses on the shear surface at points along the upper half were encountered. This indicated that a tension crack was needed. The analyses were redone using a tension crack of 7 ft. These results are listed in Table 25. The tension cracks slightly reduce the minimum safety factor.

169. For the toe circles, three of the four analysis procedures calculated approximately the same circle. The other procedure calculated a circle greatly different. This may indicate a localized minimum value was calculated and not the true minimum for this type of circle. To evaluate if only local minimums were calculated, another search should be performed, starting at a different location. The results from searches initiated at $x = 170$ and $y = 350$ are shown in Table 26. The circles tangent to the base of the embankment did not change, indicating that the calculated value is the true minimum. The toe circle analysis did generate lower results indicating that local minimums were calculated in Tables 24 and 25. To verify that the true minimum has been found, several different initial values were used in the search process. Table 27 lists the initial and critical centers. Figure 26 shows the critical shear surfaces listed in Tables 25 and 26 plotted on the

Table 24

Minimum Safety Factor and Circle Coordinates for Toe and Tangent Circles

Initial Starting Point x = 101 and y = 180, No Tension Crack*

			Analysis Procedures			
					Force Equilibrium	
			Spencer	Bishop	Corps Modified Swedish Side-Force Assumption	Lowe and Karafiath Side-Force Assumption
Toe Circles	Minimum factor of safety		3.167	3.181	2.699	3.225
	Circle coordinates	X	116.5	115.5	172.0	117.0
		Y	143.5	145.0	365.5	144.0
	Radius		178.4	179.9	370.8	178.9
	Side-force inclination		8.16°	Horiz	14.0°	Varies
Circles Tangent to Base of Embankment	Minimum factor of safety		2.538	2.538	2.628	2.580
	Circle coordinates	X	101.0	101.0	109.0	105.0
		Y	170.5	170.5	193.0	182.5
	Radius		170.5	170.5	193.0	182.5
	Side-force inclination		7.84°	Horiz	14.0°	Varies

* Final grid spacing is 0.5 ft.

Table 25

Minimum Safety Factor and Circle Coordinates for Toe and Tangent Circles

Initial Starting Point x = 101 and y = 180, 7-ft Tension Crack*

			Analysis Procedures			
					Force Equilibrium	
			Spencer	Bishop	Corps Modified Swedish Side-Force Assumption	Lowe and Karafiath Side-Force Assumption
Toe Circles	Minimum factor of safety		3.154	3.168	2.642	3.209
	Circle coordinates	X	116.0	115.5	172.5	117.0
		Y	143.0	144.5	352.5	143.5
	Radius		177.9	179.4	357.2	178.4
	Side-force inclination		8.24°	Horiz	14.0°	Varies
Circles Tangent to Base of Embankment	Minimum factor of safety		2.490	2.491	2.577	2.531
	Circle coordinates	X	102.0	102.0	110.0	105.5
		Y	163.0	163.0	185.0	174.0
	Radius		163.0	163.0	185.0	174.0
	Side-force inclination		8.45°	Horiz	14.0°	Varies

* Final grid spacing is 0.5 ft.

Table 26

Minimum Safety Factor and Circle Coordinates for Toe and Tangent Circles

Initial Starting Point x = 170 and y = 350, 7-ft Tension Crack*

			Analysis Procedures			
					Force Equilibrium	
			Spencer	Bishop	Corps Modified Swedish Side-Force Assumption	Lowe and Karafiath Side-Force Assumption
Toe Circles	Minimum factor of safety		2.614	2.569	2.642	2.623
	Circle coordinates	X	171.5	170.0	172.5	172.0
		Y	352.5	334.5	352.5	355.0
	Radius		357.2	340.3	357.2	359.6
	Side-force inclination		11.09°	Horiz	14.0°	Varies
Circles Tangent to Base of Embankment	Minimum force of safety		2.490	2.491	2.577	2.531
	Circle coordinates	X	102.0	102.0	110.0	105.3
		Y	163.0	163.0	185.0	174.0
	Radius		163.0	163.0	185.0	174.0
	Side-force inclination		8.45°	Horiz	14.0°	Varies

* Final grid spacing is 0.5 ft.

Table 27

Effects of Different Starting Points*

Initial Type of Search	Search Starting Point X	Search Starting Point Y	Final Results Safety Factor	Final Results X	Final Results Y	Final Results Radius	Total Number of Circles Tried	Total Number of Circles Calculated
Tangent to elevation 0.0**	101	180	2.490	102	163	163	95	95
	170	350	2.490	102	163	163	312	312
	50	260	2.490	102	163	163	128	128
	60	150	2.490	102	163	163	91	91
	140	130	2.490	102	163	163	121	121
	180	150	2.490	102	163	163	105	105
Toe circle	101	180	3.154	116	143	177.9	127	94
	170	350	2.614	171.5	352.5	357.2	312	312
	50	260	Indeterminate					
	60	150	Indeterminate					
	140	130	3.151	122.5	134	169	128	97
	180	150	2.614	171.5	351	355.8	307	307

* Spencer's procedure with 7-ft tension crack.

** All elevations (el) cited herein are in feet referred to National Geodetic Vertical Datum (NGVD) of 1929.

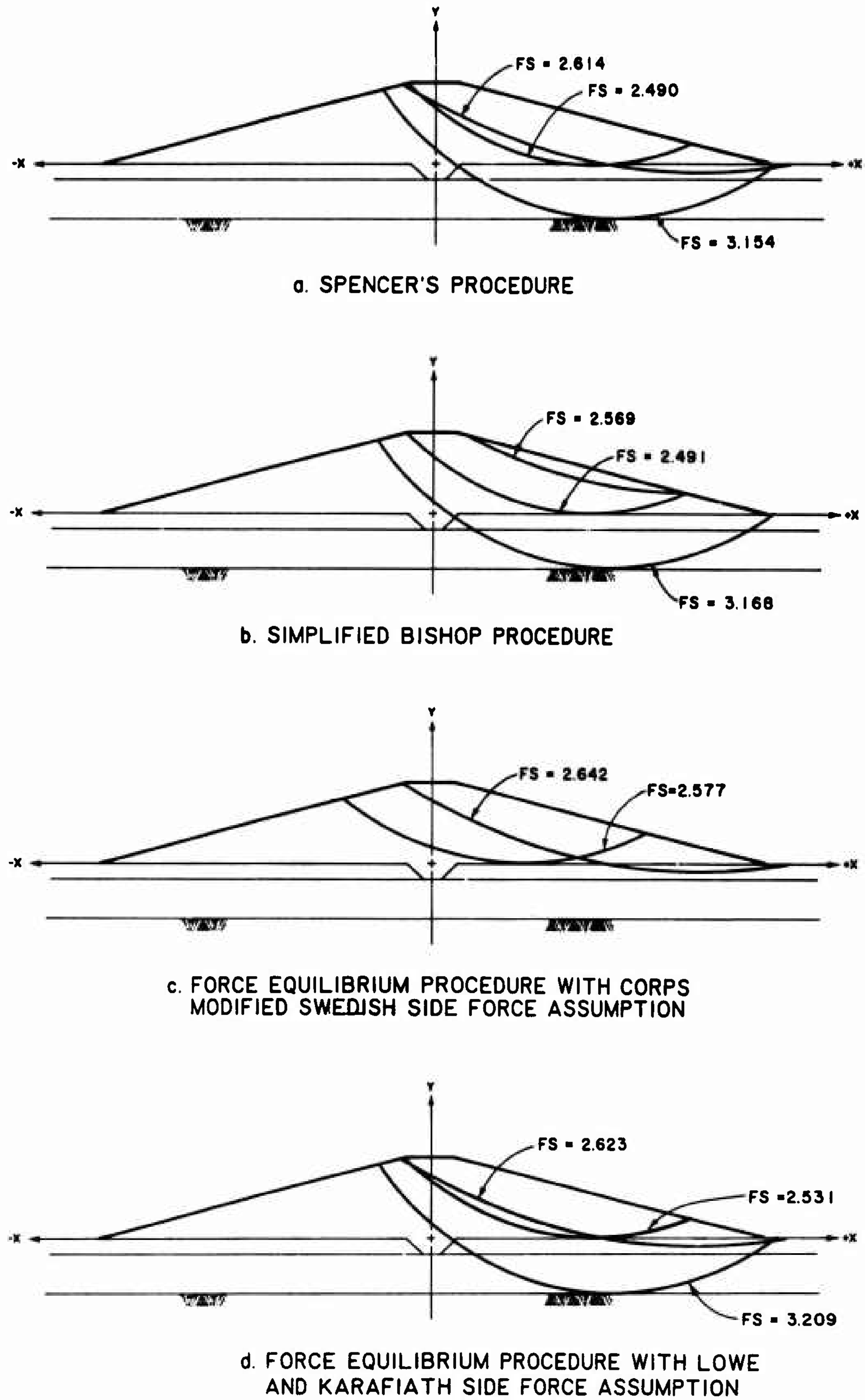


Figure 26. Critical shear surfaces plotted on the cross section

cross section for all of the analysis procedures.

170. When performing a circular search, the initial search mode is important because it establishes the sequence of the search. There are three modes that the user could select. They are tangent to a horizontal line, through a particular point, and constant radius. The initial search mode establishes whether a toe circle or an embankment circle will be analyzed. In general, a single critical circle should be determined for any search mode. However, the searching sequence can locate minimums that exist making the search procedure "think" that the minimum value is found when, in fact, only a local minimum has been found. The matrix in Table 28 indicates the sequence that the various search modes were performed for different initial modes. For several cases, the initial mode was varied with no difference in the final results. However, the number of circles analyzed varied. Included in the table is the minimum safety factor for each search mode and the number of circles analyzed. For the cases in Table 28, 91 to 350 circular analyses were performed for each case. Different initial search modes shown in Table 28 illustrate the potential differences in the minimum safety factor that could occur. The constant radius mode is not recommended for the initial mode of search.

171. There are two important input values in the data for the circular search other than the initial mode of search. These values are the accuracy or final spacing of the search grid and the starting point of the search. To illustrate the effect of the grid spacing, several searches were performed using various initial search modes and varying the final grid spacing. The initial center for all searches was the same, while the final grid spacing was varied from 5 to 1 to 0.5 ft (1 percent of the slope height). The results of these analyses are shown in Table 29 which also includes the final centers and the number of circles analyzed. The initial search mode initiates the sequence of the search which in turn effects the minimum safety factor obtained.

172. The search procedure should come in to the same point irrespective of the initial center the user selects. However, because of local minimums the user must ensure that the true minimum has been determined. The type of circular analysis depends on the initial search mode selected, the initial search center point, and the final grid spacing. The user should look at several circular searches from different locations with at least one search totally within the embankment. Also, the final grid spacing should be 1 percent of the slope height. The initial search mode and location require

Table 28

Sequence of Search Modes for Circles Listed in Table 25

Type of Circle	Analysis Procedure		Search Mode			Total Number of Circles	
			Pass Through Given Point	Tangent to Horizontal Line	Constant Radius	Tried	Calculated
Toe circles	Spencer		1(3.168)	2(3.154)	3(3.154)	127	94
	Bishop		1(3.183)	2(3.168)	3(3.168)	127	94
	Force equilibrium	Corps Modified Swedish side-force inclination EM 1110-2-1902, (Department of the Army 1970)	1(2.651)	2(2.648) 4(2.642)	3(2.643) 5(2.642)	356	350
		Lowe and Karafiath (1960) side-force inclination	1(3.228)	2(3.209)	3(3.209)	134	101
Circles tangent to base of embankment	Spencer			1(2.490)	2(2.490)	95	95
	Bishop			1(2.491)	2(2.491)	95	95
	Force equilibrium	Corps Modified Swedish side-force inclination EM 1110-2-1902 (Department of the Army 1970)		1(2.577)	2(2.577)	96	96
		Lowe and Karafiath-side-force inclination (1960)		1(2.531)	2(2.531)	91	91

Table 29

Effects of Final Grid Spacing*

Final Grid Spacing	Initial Search Mode	Minimum Safety Factor	Circle Coordinates X	Circle Coordinates Y	Radius	Total Number of Circles Tried	Total Number of Circles Calculated
5	Tangent 0	2.629	106	185	185	70	58
	Tangent -10	2.723	166	295	300	101	90
	Tangent -20	2.629	111	200	200	118	103
	Point 215,0	2.708	166	360	363.3	119	107
	Radius 180	2.629	106	185	185	103	84
1	Tangent 0	2.628	109	193	193	84	82
	Tangent -10	2.700	170	347	353	335	329
	Tangent -20	2.628	109	193	193	140	137
	Point 215,0	2.700	172	374	378.3	272	270
	Radius 180	2.628	109	193	193	117	114
0.5	Tangent 5	2.628	109	193	193	221	221
	Tangent 0	2.628	109	193	193	92	92
	Tangent -1	2.698	171.5	364	369	819	819
	Tangent -5	2.698	171.5	364	369	170	170
	Tangent -10	2.699	170	349.5	355	379	379
	Tangent -20	2.699	170	349.5	355	425	425
	Point 215,0	2.699	172	365.5	370.8	377	377
	Radius 180	2.628	109	193	193	140	140

* Modified Swedish procedure - Corps side-force inclination of 14°, no tension. Crack initial search point is X = 101 and Y = 180.

engineering input and cannot be done blindly.

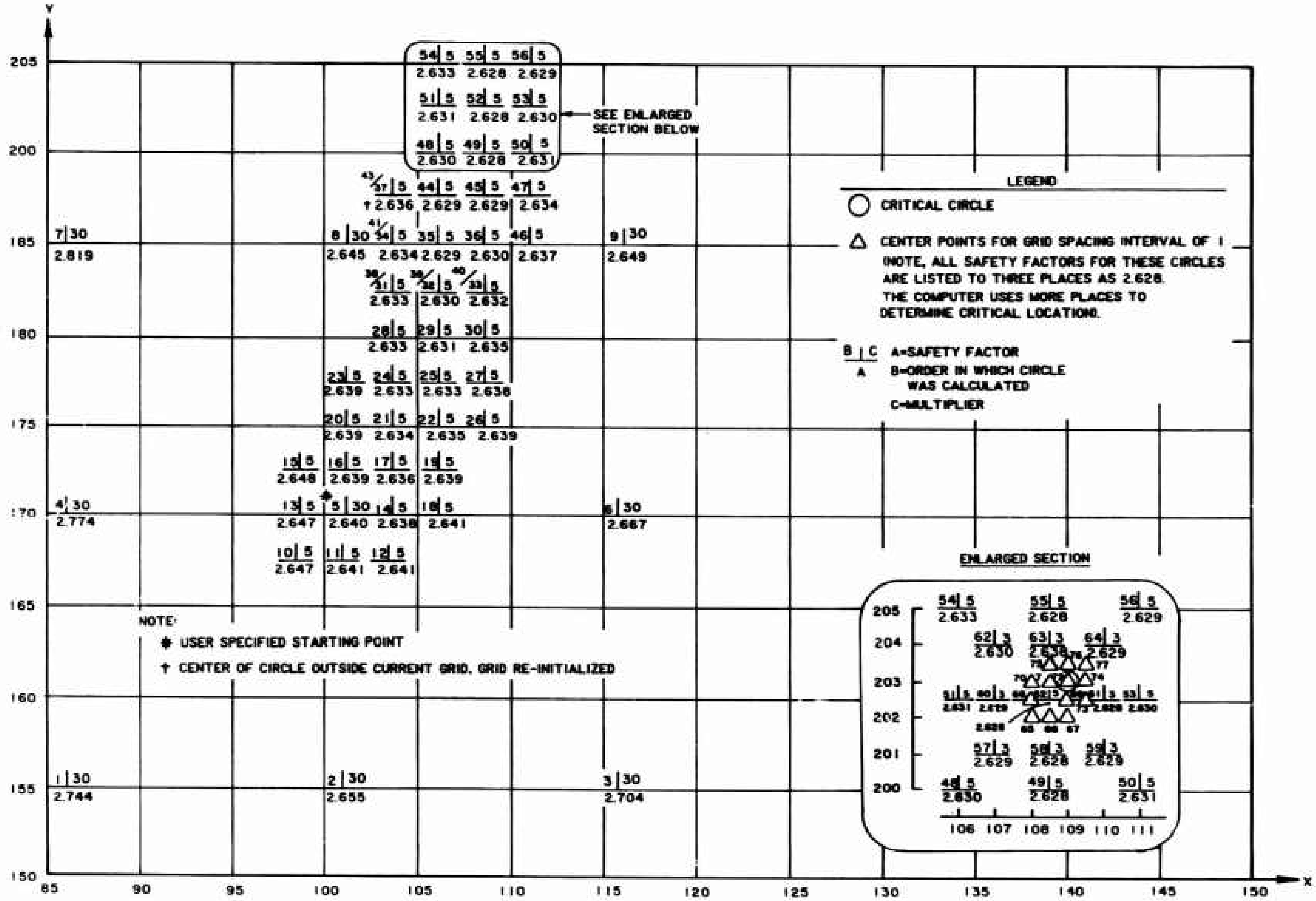
173. Both the tangent and radius search modes are illustrated in Figure 27 for the force equilibrium procedure with the Corps Modified Swedish side force inclination. For each center, the order of calculation, the grid spacing interval, and the safety factor are shown. This illustrates the process that the program uses to select the center points. The initial search mode shown in Figure 27a illustrates the process when the critical center value does not fall within the initial grid space. The radius search mode shown in Figure 27b, illustrates the process when the critical center value is located within the initial grid.

174. The total input data file has been shown in Figures 22, 24, and 25. The computer generated output of the search for the critical shear surface that was tangent to the base of the embankment using Spencer's procedure is included as file EXAM3A.OUT in Appendix D. A graphical hand check of the Spencer results for the final circular shear surface of the search procedure is shown in Figure 28. For this hand check, the side force inclination of 8.45 deg calculated by Spencer's procedure was used in the construction of the force polygons. All slices and forces were calculated independently of the computer analyses. An independent verification of the Bishop procedure is shown in Figure 29. Both the spreadsheet results and column definitions are shown in these two figures.

Case 2 - Partial pool case

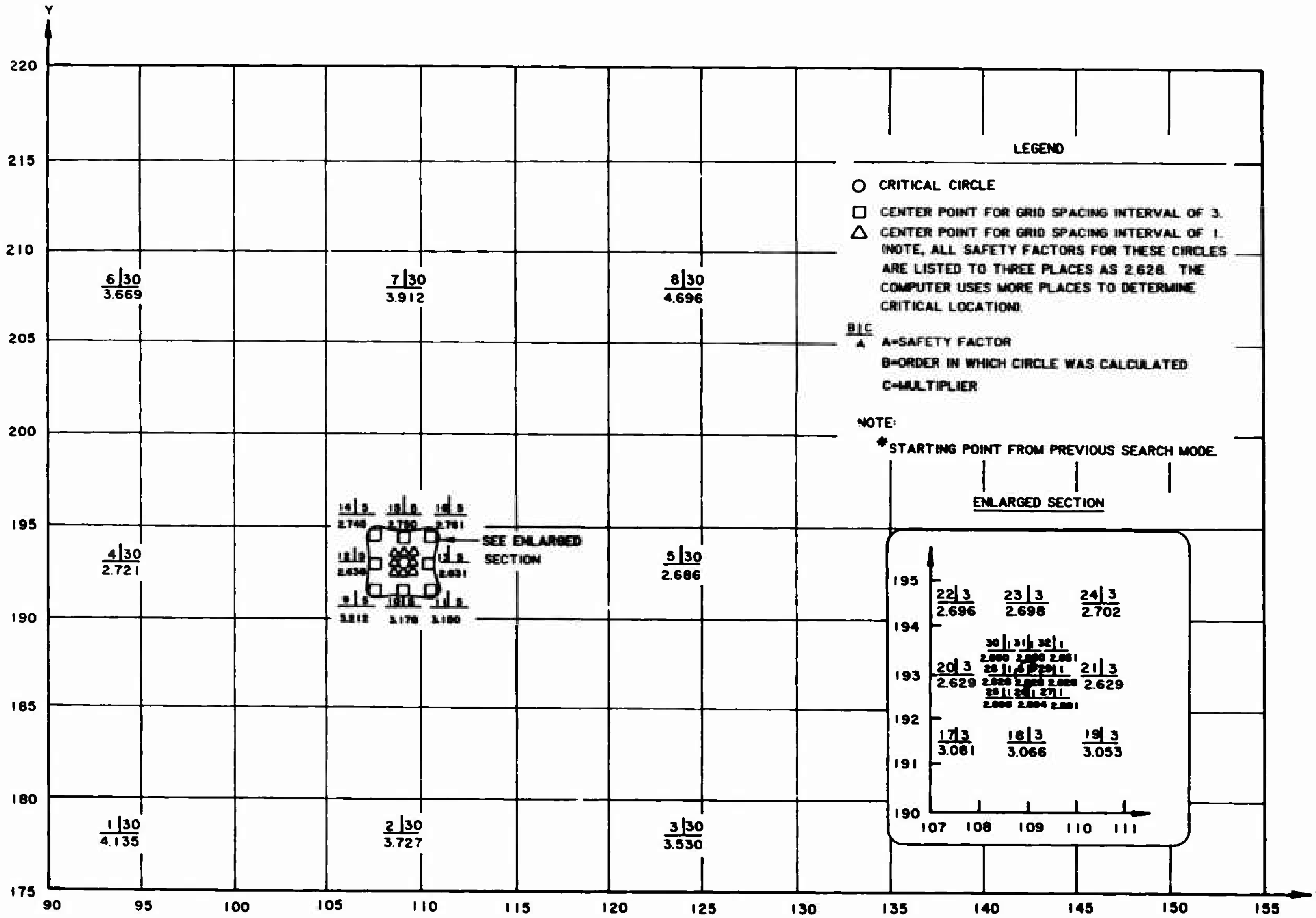
175. For this case, the (R + S)/2 strength envelope is used for the embankment and foundation clay and the S strength for the sand layer. Figure 30a and 30b illustrates this envelope and shows how the values are determined. The R and S strengths and the appropriate unit weights are listed in Table 23. An example of the cross section representation and profile data is shown in Figure 23. Since part of the embankment is saturated, the embankment should be represented as two materials with the same strength but different unit weights.

176. For this loading case, the phreatic surface is modeled as a straight line from the upstream partial pool level to the center line of the embankment and from there a straight line to the tailwater elevation at the embankment toe. The pore pressure in the sand layer is equal to the pool elevation upstream of the center line and the tailwater elevation downstream of the center line. Since the sand layer is discontinuous, the pore pressure can



a. Tangent mode

Figure 27. Plots of circle center coordinates for Corps of Engineers Modified Swedish Procedures, EM 1110-2-1902 (Department of the Army 1970) of tangent circle analysis (Continued)



b. Radius search mode

Figure 27. (Concluded)

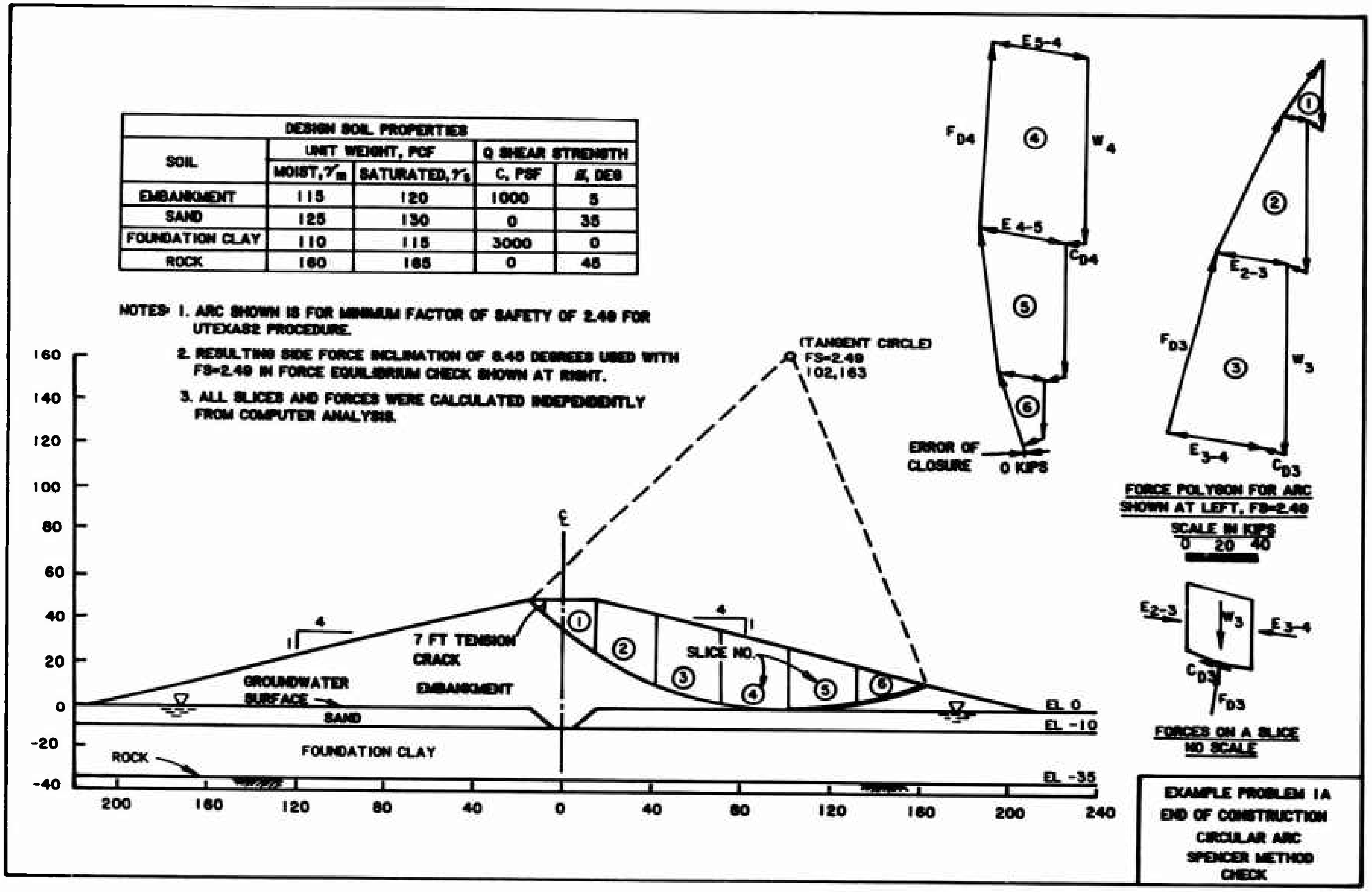


Figure 28. Hand check of Spencer's procedure output

SLICE	c' pcf 1	tan phi' 2	b 3	h 4	Gamma * h 5	Alpha deg 6	d*f* sin alph 7	Ru * gam*h 8 (Ru*5)	gam*h - u 9 (5-8)	10 (2*9)	11 (1+10)	12 (3*11)	F. S. 2.49118 13	14 (12/13)
1	1000.00	.0875	13.50	12.80	1472.00	39.60	12666.89	.00	1472.00	128.78	1128.78	15238.58	.7928990	19218.81
2	1000.00	.0875	10.00	21.50	2472.50	34.50	14004.40	.00	2472.50	216.32	1216.32	12163.16	.8440179	14411.01
3	1000.00	.0875	15.00	27.20	3128.00	29.00	22747.28	.00	3128.00	273.66	1273.66	19104.97	.8916458	21426.63
4	1000.00	.0875	15.00	31.00	3565.00	23.30	21151.80	.00	3565.00	311.90	1311.90	19678.46	.9323376	21106.57
5	1000.00	.0875	15.00	32.80	3772.00	17.60	17108.10	.00	3772.00	330.01	1330.01	19950.11	.9638097	20699.22
6	1000.00	.0875	15.00	33.00	3795.00	12.00	11835.38	.00	3795.00	332.02	1332.02	19980.29	.9854493	20275.31
7	1000.00	.0875	15.00	31.80	3657.00	6.60	6304.88	.00	3657.00	319.95	1319.95	19799.19	.9974093	19850.62
8	1000.00	.0875	12.00	29.80	3427.00	2.10	1506.94	.00	3427.00	299.82	1299.82	15597.89	1.000615	15588.29
9	1000.00	.0875	13.00	26.10	3001.50	-2.10	-1429.82	.00	3001.50	262.60	1262.60	16413.77	.9980415	16445.97
10	1000.00	.0875	15.00	21.70	2495.50	-7.40	-4821.14	.00	2495.50	218.33	1218.33	18274.92	.9871479	18512.84
11	1000.00	.0875	15.00	15.20	1748.00	-12.50	-5675.05	.00	1748.00	152.93	1152.93	17293.95	.9686948	17852.84
12	1000.00	.0875	19.00	6.00	690.00	-19.10	-4289.83	.00	690.00	60.37	1060.37	20146.98	.9334572	21583.18

Sum Column 7 91109.82

Sum Column 14 226971.34

$$F.\,S. = \frac{\Sigma\,(\text{Column } 14)}{\Sigma\,(\text{Column } 7)} = 2.4911841$$

Definition of Columns

1 and 2 - material parameters

3 and 4 - slice width and height

5 - overburden pressure at the center of slice base

6 - base inclination of slice

7 - (gamma*h*b) * sin (alpha) or column 5 * column 3 * sin (column 6)

8 - pore pressure head, Ru * (gamma *h)

9 - (gamma*h) - pore pressure or column 5 - column 8

10 - column 2 * column 9

11 - column 1 + column 10

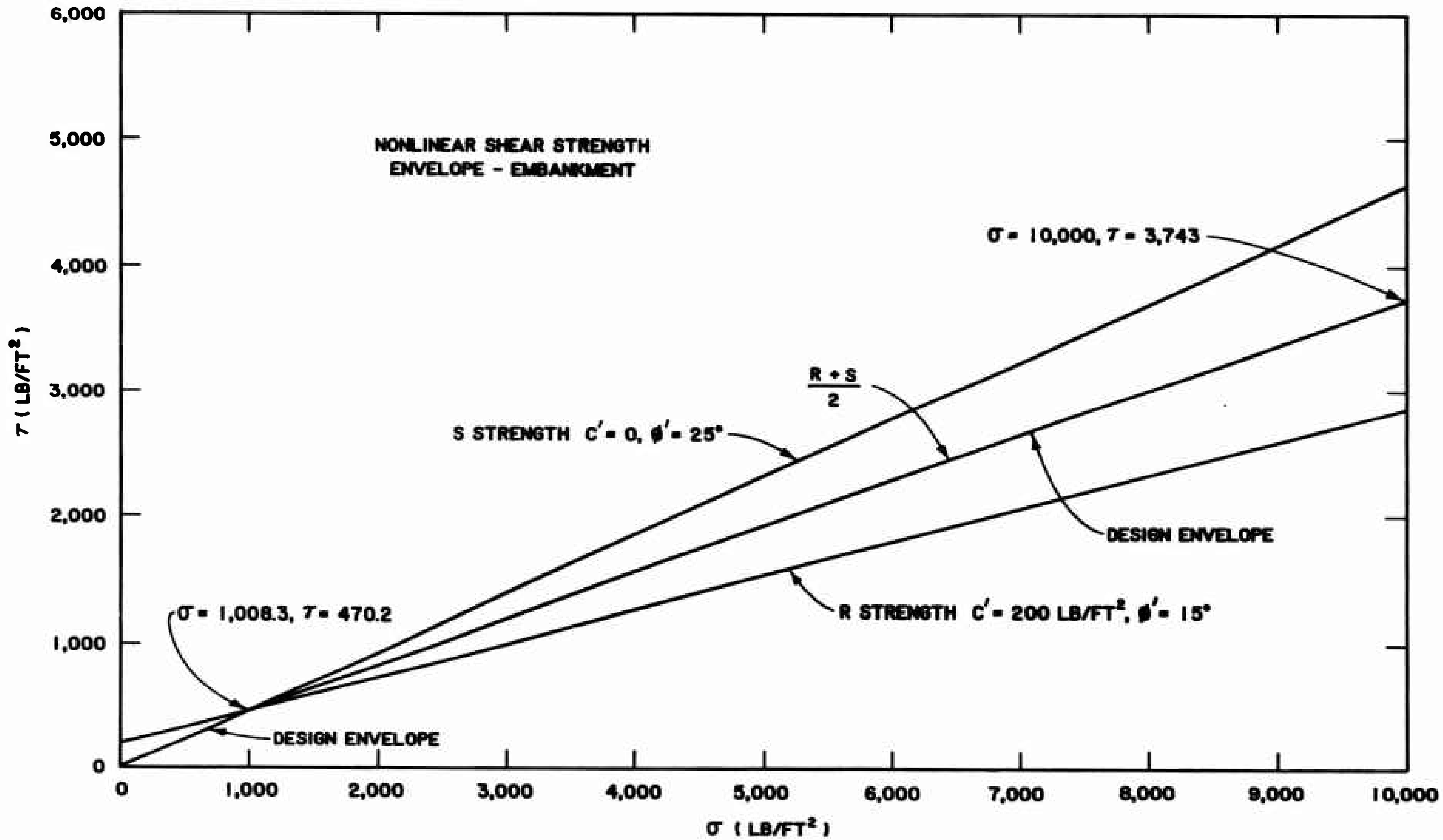
12 - column 3 * column 11

13 - $m_\alpha = \cos\alpha\,(1 + \tan\alpha \tan\phi')$ or cos (column 6) $\left(1 + \frac{\tan(\text{col } 6) * \tan(\text{col } 2)}{F.S.}\right)$

14 - column 12/m_α or column 12/column 13

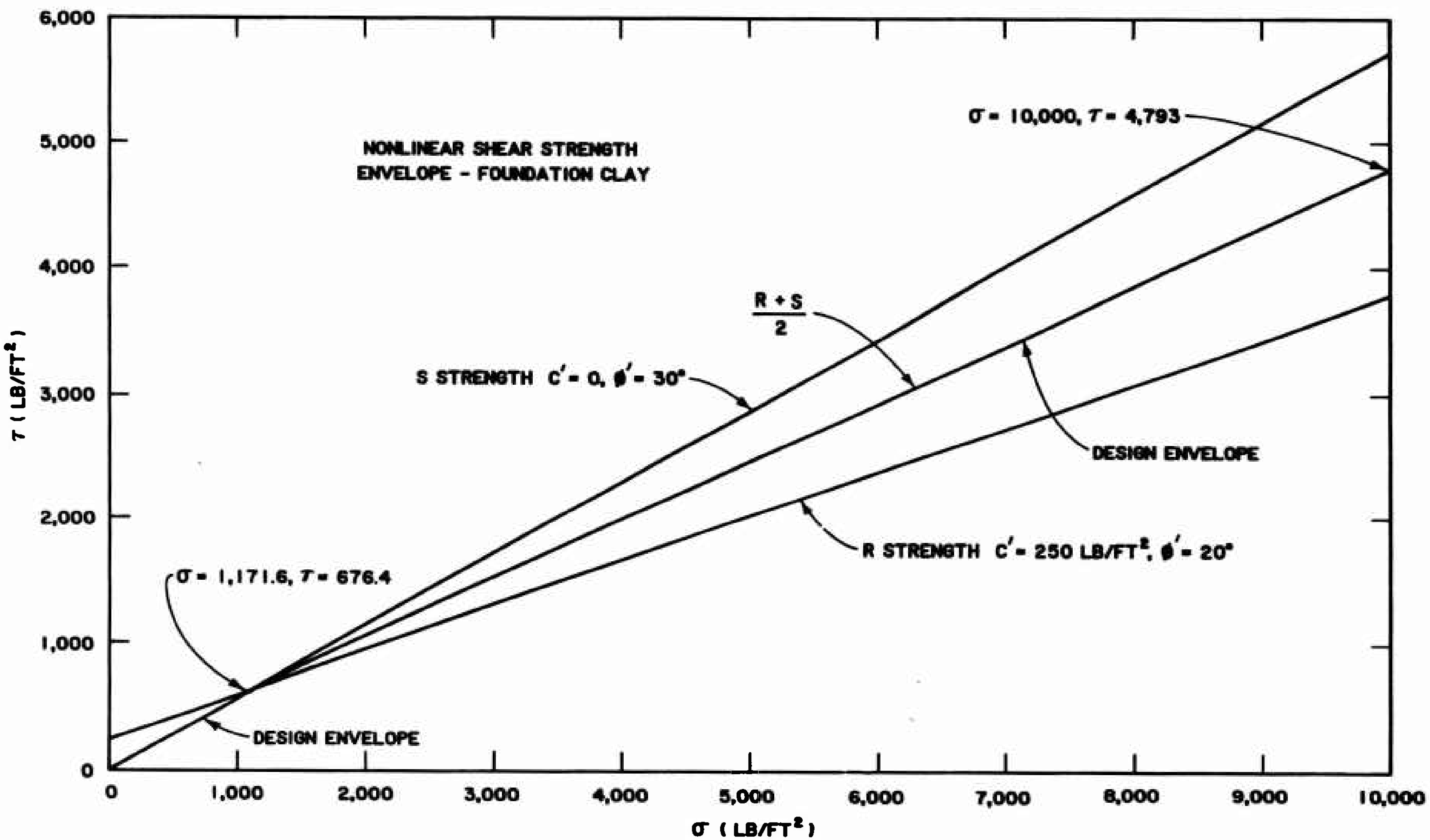
$$F.S. = \frac{\Sigma[b\,(c' + (\gamma h - u)\tan\phi')/m_\alpha]}{\Sigma \gamma h b \ \sin\alpha}$$

Figure 29. Independent verification by Bishop procedure using a spreadsheet



a. Embankment

Figure 30. Nonlinear shear strength envelope (Continued)



b. Foundation clay

Figure 30. (Concluded)

be represented with one piezometric line which has a sharp change at the center line. The pore pressure for the foundation clay and the rock is modeled the same as the embankment. Figure 31 illustrates the various piezometric lines for a pool elevation of 20 ft.

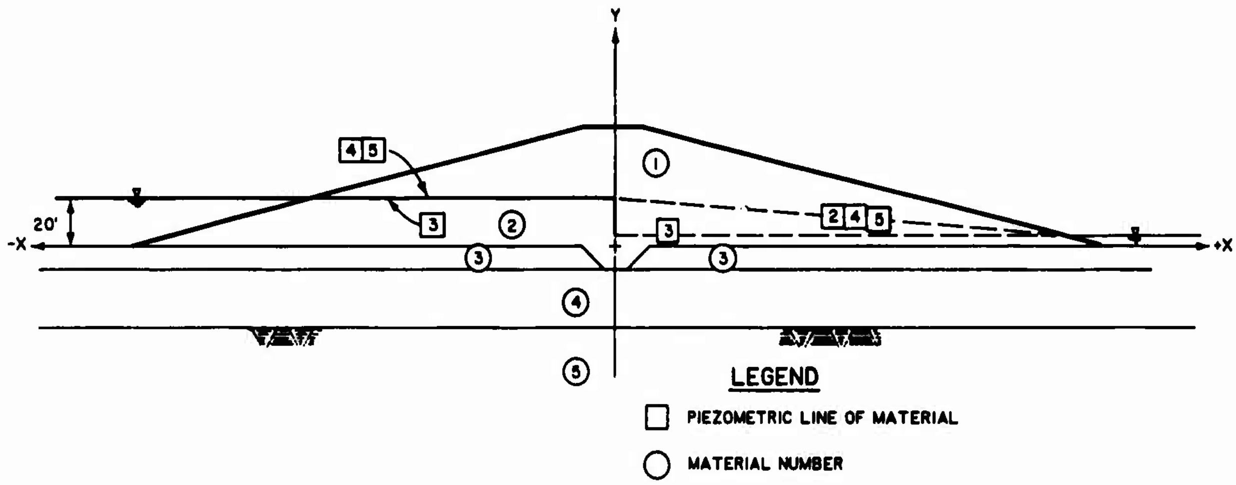
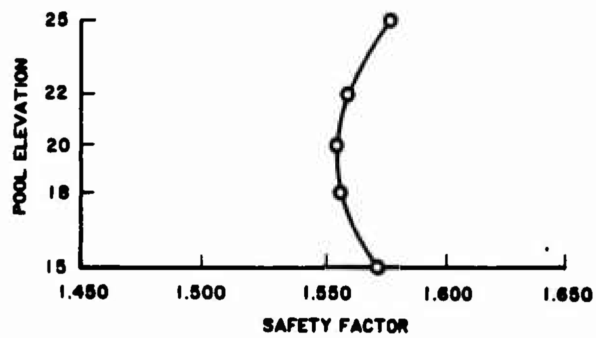


Figure 31. Illustration of various piezometric lines for pool elevation of 20 ft

177. The analysis is performed for several pool elevations with the safety factor plotted as a function of reservoir level to determine the minimum safety factor. For each pool level, a search for the critical circular shear surface is performed. This procedure allows circles with different center points for different pool elevations. Figures 32 through 35 show the tabular and graphic results of the total partial pool analysis for all analysis procedures.

178. When an embankment contains moist and saturated zones, the proper representation would utilize two materials with the same strength but different unit weights. An alternative to this is to use one material to represent both the moist and saturated portions. The variation in the safety factor is a function of the difference in the weight components. The effect of modeling this example embankment with one or two materials is shown in Table 30 where the results from the 20-ft partial pool case are compared. Both series of analyses are identical except that the embankment is represented with either one or two materials. The safety factor variation for this example is very small. However, the amount of difference in the safety factors depends on the percentage of the embankment which is moist and saturated, and the difference between the two unit weights.

POOL ELEVATION	MINIMUM SAFETY FACTOR	CIRCLE COORDINATES		RADIUS	SIDE FORCE INCLINATION
		X	Y		
15 FT	1.571	-145.0	199.5	199.5	11.62°
18 FT	1.556	-139.0	185.5	185.5	10.79°
20 FT	1.554	-136.0	181.5	181.5	10.23°
22 FT	1.558	-131.5	174.0	174.0	9.77°
25 FT	1.576	-135.5	192.0	192.0	8.79°



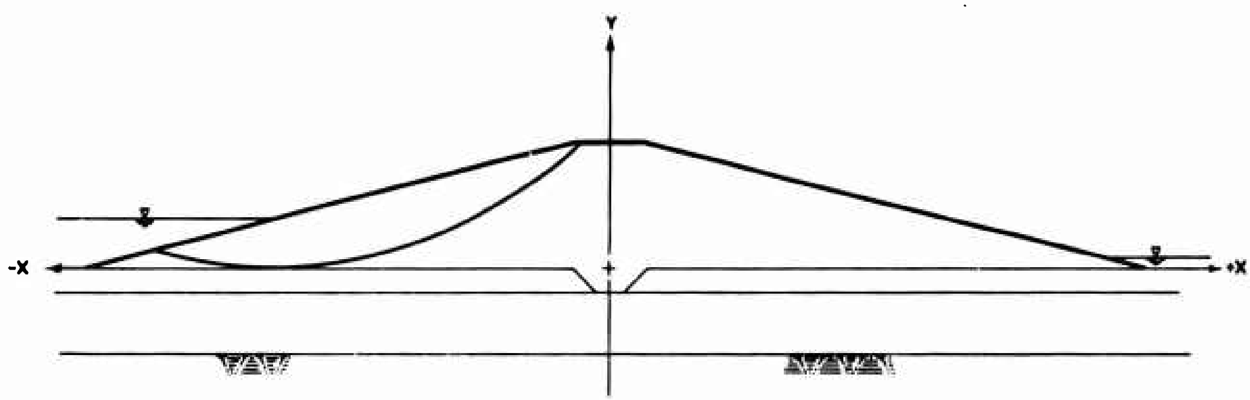
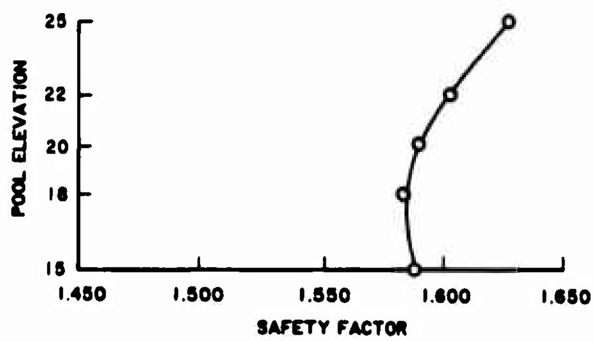


Figure 32. Partial pool analysis for Spencer's procedure (final grid spacing - 0.5, no tension crack)

POOL ELEVATION	MINIMUM SAFETY FACTOR	CIRCLE COORDINATES X	CIRCLE COORDINATES Y	RADIUS	SIDE FORCE INCLINATION
15 FT	1.587	-147.0	206.0	206.0	14.0°
18 FT	1.583	-143.0	198.5	198.5	14.0°
20 FT	1.589	-140.0	195.0	195.0	14.0°
22 FT	1.603	-136.5	194.5	194.5	14.0°
25 FT	1.626	-125.0	182.0	175.5	14.0°



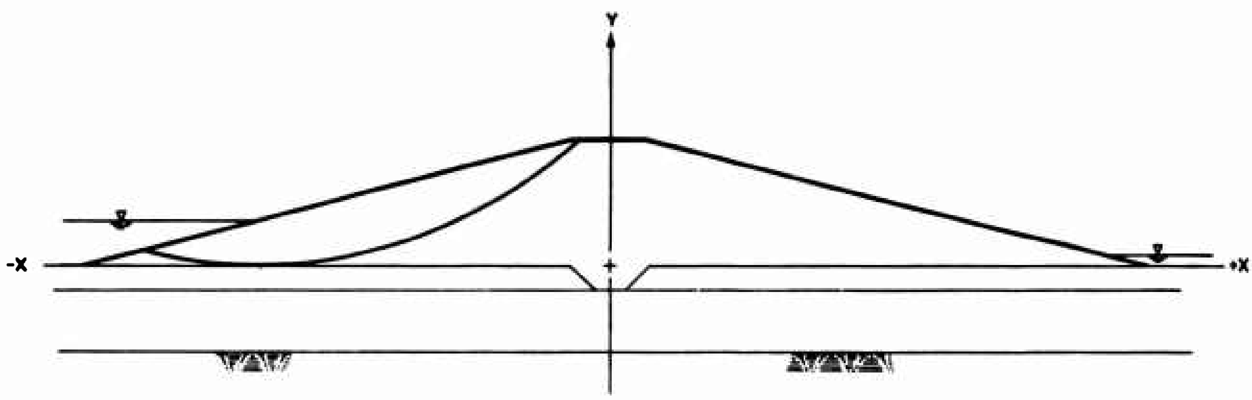


Figure 33. Partial pool analysis for force equilibrium procedure with Corps Modified Swedish side-force inclination (no tension crack)

POOL ELEVATION	MINIMUM SAFETY FACTOR	CIRCLE COORDINATES		RADIUS
		X	Y	
15 FT	1.566	-146.5	201.5	201.5
18 FT	1.550	-138.0	183.5	183.5
20 FT	1.547	-136.0	181.0	181.0
22 FT	1.550	-132.0	174.0	174.0
25 FT	1.568	-135.5	192.0	192.0

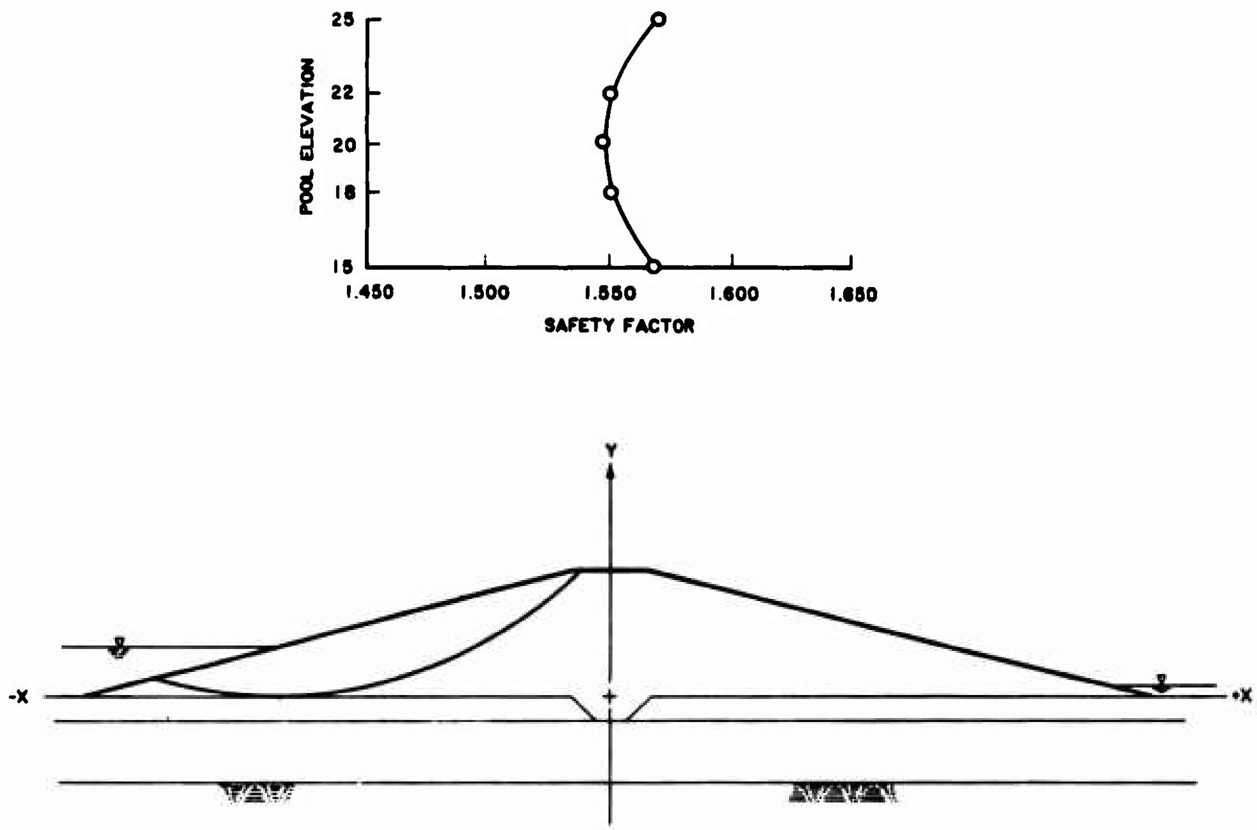
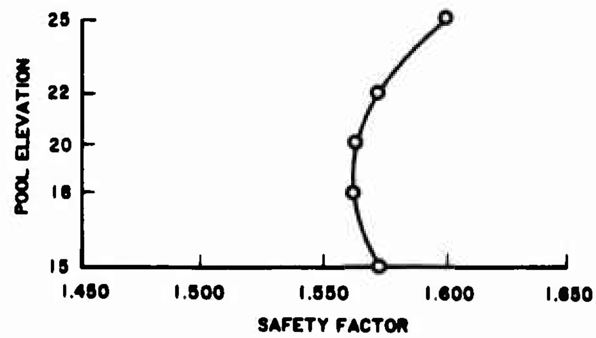


Figure 34. Partial pool analyses for Bishop's procedure
(no tension crack, final grid spacing - 0.5 ft)

POOL ELEVATION	MINIMUM SAFETY FACTOR	CIRCLE COORDINATES X	CIRCLE COORDINATES Y	RADIUS
15 FT	1.573	-144.0	196.0	196.0
18 FT	1.562	-137.5	182.5	182.5
20 FT	1.563	-134.0	177.5	177.5
22 FT	1.572	-131.0	174.0	174.0
25 FT	1.599	-133.5	194.0	192.5



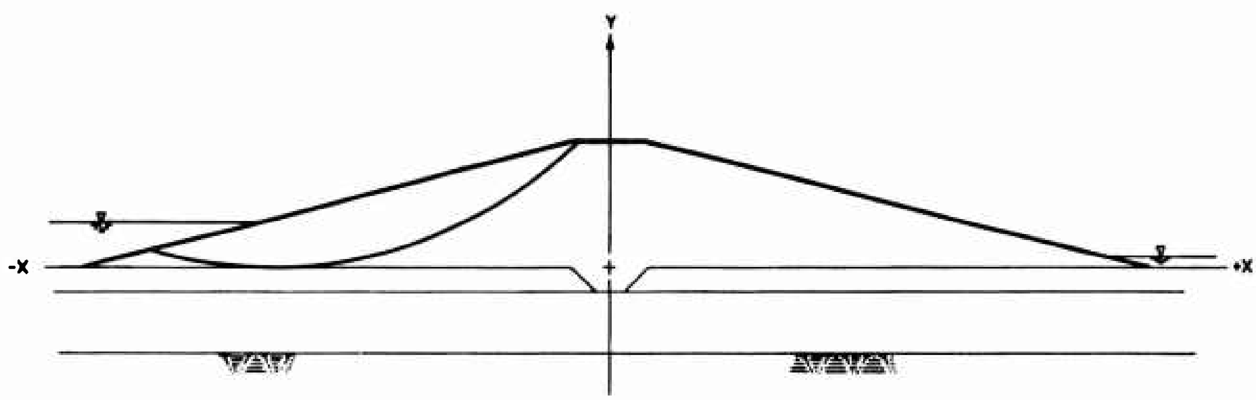


Figure 35. Partial pool analysis for force equilibrium procedure with Lowe and Karafiath's side-force inclination

Table 30

Effects of Modeling Embankment--One Profile With One Unit Weight

(No Tension Crack Pool, el 20)

	Analysis Procedure	Min FS*	Critical Circle Data X	Y	R	Side Inclination
Embankment as 2 materials	Spencer	1.554	-136	181.5	181.5	10.23°
	Bishop	1.547	-136	181	181	Horiz
	Corps Modified Swedish	1.589	-140	195	195	14.0°
	Lowe and Karafiath	1.563	-134	177.5	177.5	Varies
Embankment as one saturated material	Spencer	1.530	-134.5	176.5	176.5	10.38°
	Bishop	1.523	-134.5	176.0	176.0	Horiz
	Corps Modified Swedish	1.564	-138.5	190	190	14.0°
	Lowe and Karafiath	1.538	-133	174	174	Varies

* Minimum factor of safety.

179. The complete input data file is shown in Figure 36. The computer results are included as file EXAM3B.OUT in Appendix D. The tables and force polygon of a hand check for one pool level are shown in Figure 37.

```
heading       HEADING                                   <-- command word
page 20         Example 3 - Circular search
                 Clay embankment on 10 foot sand layer
                 Sand is over 25 foot of clay over rock
              PROFILE LINES                             <-- command word
                1  1  Embankment surface
                -215  0
                 -15 50
                  15 50
                 215  0
                             } blank line
                2  2  Upstream sand layer
                -400  0
                 -15  0
profile           -5 -10
line                         } blank line
data            3  2  Downstream sand layer
page 21           5  -10
                 15    0
                400    0
                             } blank line
                4  3  Foundation clay
                -400  -10
                 400  -10
                             } blank line
                5  4  Rock
                -400  -35
                 400  -35
                             } 2 blank lines

heading       HEADING                                   <-- command word
page 20         Case 2 - Partial pool
                 Phreatic surface in embankment
                 Additional piezometric line in sand
              MATERIAL PROPERTY                         <-- command word
                1  Moist embankment
                 115 = moist unit weight
                 Nonlinear strength envelope
                  -1000    0
                      0    0
                   1008.3  470.2
                  10000   3743.0
material                           } blank line
property         Piezometric Line
data              1  Phreatic surface
page 25         2  Saturated embankment
                 120 = saturated unit weight
                 Nonlinear strength envelope
                  -1000    0
                      0    0
                   1008.3  470.2
```

Figure 36. Partial-pool data file, for pool level of 20 ft and all analysis procedures (Sheet 1 of 3)

```
material property data page 25

   10000   3743.0
                        } blank line
  Piezometric Line
   1  Phreatic surface
 3  Sand layer
  130 = saturated unit weight
  Conventional shear strength
   0  35
  Piezometric Line
   2
 4  Foundation clay
  115 = saturated unit weight
  Nonlinear strength envelope
   -1000   0
       0   0
    1171.6  676.4
   10000   4793.2
                        } blank line
  Piezometric Line
   1
 5  Rock
  165 = saturated unit weight
  Conventional shear strength
   0  45
  Piezometric Line
   1
                        } blank line

piezometric data page 37

PIEZOMETRIC LINE DATA          <-- command word
 1  62.4  Phreatic surface
  -400  20
  -135  20
     0  20
   100  12.3
   195   5
   400   5
           } blank line
 2        Sand piezometric surface
  -400  20
     0  20
     0   5
   400   5
           } 2 blank lines

surface pressure data page 49

SURFACE PRESSURES    pool      <-- command word
 -400   0  1248  0
 -215   0  1248  0
 -135  20     0  0
  195   5     0  0
  215   0   312  0
  400   0   312  0
                    } blank line

heading page 20

HEADING                        <-- command word
 Search for critical circle - pool level = 20 ft
 Spencer's analysis procedure
```

Figure 36. (Sheet 2 of 3)

```
 Tangent search mode - elev. 0
```

analysis/ computation data page 57

```
ANALYSIS/COMPUTATION        command word
 Circular Search
  -150  170  0.5  -50
  Tangent
   0
  SHORT
  PROCEDURE
   Spencer
                            blank line
COMPUTE                     command word
```

heading page 20

```
HEADING                     command word
 Search for critical circle - pool level = 20 ft
 Corps Modified Swedish analysis procedure
 Tangent search mode - elev. 0
```

analysis/ computation data page 57

```
ANALYSIS/COMPUTATION        command word
 Circular Search
  -175  240  0.5  -50
  Tangent
   0
  PROCEDURE
   Corps
    14.0
                            blank line
COMPUTE                     command word
```

heading page 20

```
HEADING                     command word
 Search for critical circle - pool level = 20 ft
 Bishop's analysis procedure
 Tangent search mode - elev. 0
```

analysis/ computation data page 57

```
ANALYSIS/COMPUTATION
 Circular Search
  -140  170  0.5  -50
  Tangent
   0
  PROCEDURE
   Bishop
                            blank line
COMPUTE                     command word
```

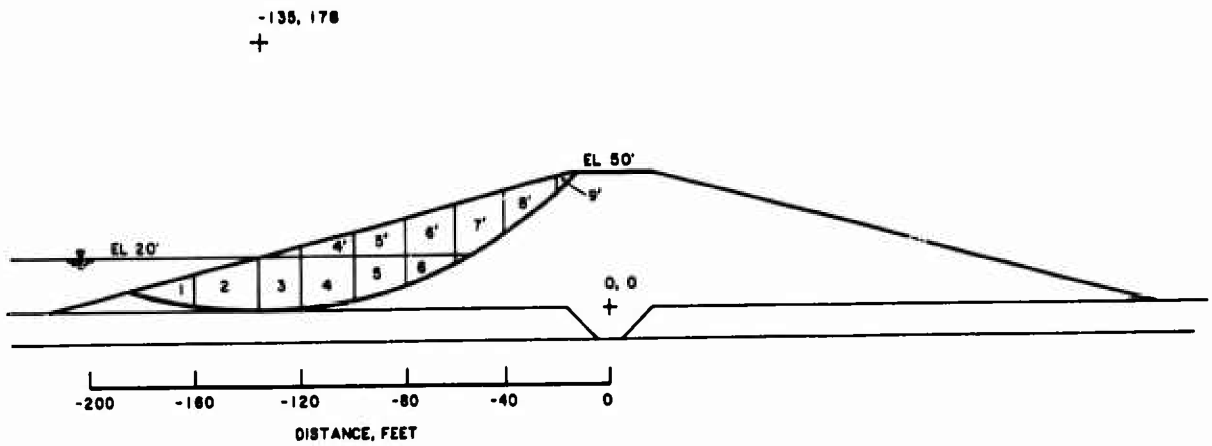
heading page 20

```
HEADING                     command word
 Search for critical circle - pool level = 20 ft
 Lowe and Karafiath's analysis procedure
 Tangent search mode - elev. 0
```

analysis/ computation data page 57

```
ANALYSIS/COMPUTATION
 Circular Search
  -160  230  0.5  -50
  Tangent
   0
  PROCEDURE
   Lowe
                            blank line
COMPUTE                     command word
```

Figure 36. (Sheet 3 of 3)



Slice Geometry

Slice No.	Slice Width, b	Slice Height Left	Slice Height Right
1	24	0	11
2	24	11	20
3	16	20	19
3'	16	0	4
4	20	19	16
4'	20	4	9
5	20	16	11
5'	20	9	14
6	20	11	3
6'	20	14	19
7	20	3	0
7'	20	19	16
8	20	16	7
9	8	7	0

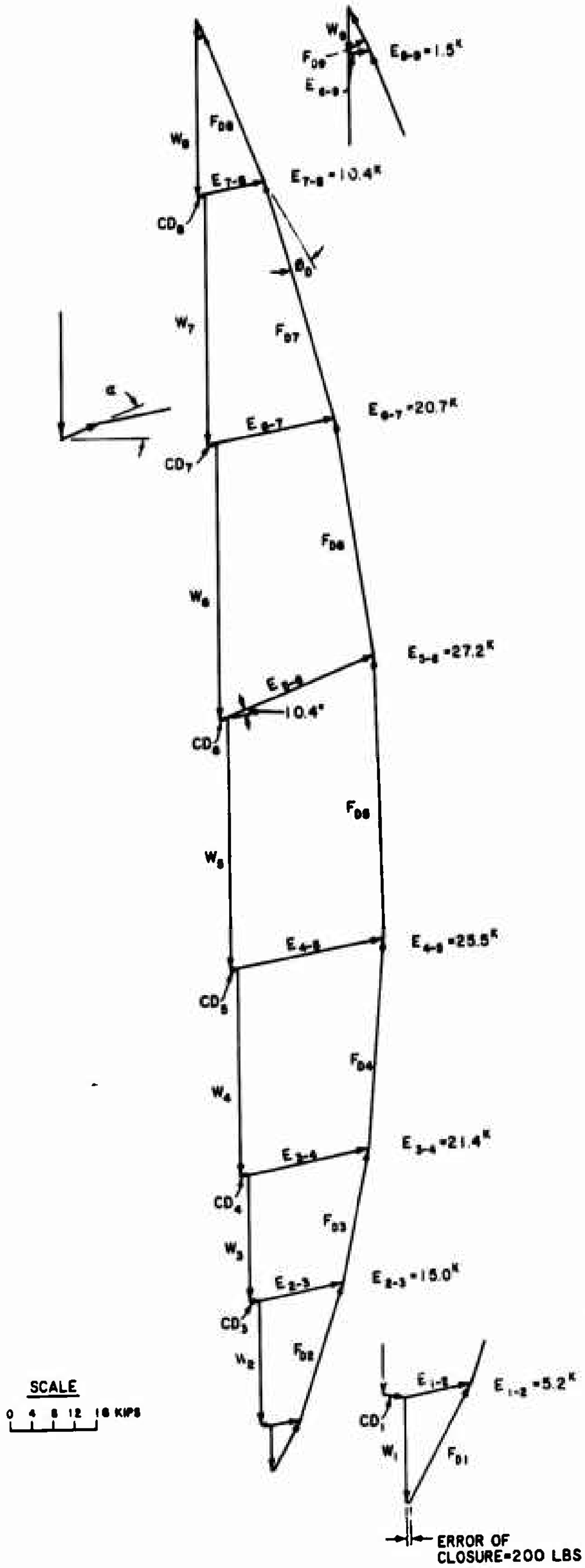
Material Properties

	Tan ϕ			Cohesion			Unit WT	
Soil	R	S	$\frac{R+S}{2}$	R	S	$\frac{R+S}{2}$	γ_s	γ_{sub}
Embankment	.268	.466	.367	200	0	100	120	57.6
FNDN Sand	.700	.700	.700	0	0	0	130	67.6
FNDN Clay	.364	.577	.471	250	0	125	115	52.6

Developed Strengths for Trail FS = 1.53

	Tan ϕ_D		ϕ_D		Cohesion	
Soil	S	$\frac{R+S}{2}$	S	$\frac{R+S}{2}$	S	$\frac{R+S}{2}$
Embankment	.305	.240	17.0	13.5	0	65.4

Figure 37. Hand check for Example 3, partial pool using force equilibrium procedure with Corps Modified Swedish side-force inclination (Continued)



Force Polygon Data

Slice No.	Slice Weight, w(kips)	ΔL	α	C_D	CD(k/ft)
1	7.6	25	-12.5°	0.0	0.0
2	21.4	25	-5.0°	65.4	1.6
3	21.8	17	2.0°	65.4	1.1
4	35.8	21	9.0°	65.4	1.4
5	43.2	21	14.5°	65.4	1.4
6	47.7	22	22.0°	65.4	1.4
7	43.7	23	29.0°	65.4	1.5
8	27.6	25	35.0°	65.4	1.6
9	3.4	12	41.0°	0.0	0.0

Notes:

Slices 1 and 9 use ϕ_D S-STR

Slices 2 thru 8 use ϕ_D R+S/2 STR

ΔL = length of slice base, b/cos α

Assume constant angle of side force inclination = 10.4°

Figure 37. (Concluded)

Example 4: Cut Slope - Noncircular Search

180. Stability computations for the undrained condition are performed for this example problem. Both circular and noncircular shear surfaces are considered. Searches for the critical location of both types of shear surfaces are presented. Spencer's analysis procedure will be used for both the circular searches and the noncircular searches. Details concerning the effects of stratification, initial shift distance, and the number and location of points used to define the shear surface are provided for the noncircular search. A method to evaluate the variation of the base width is presented.

Slope description

181. This example slope, shown in Figure 38, consists of a total of five sand and clay layers. The top two layers are clay over a sand layer with the sand divided by a thin layer of fat clay. The example models a channel because the slope is symmetrical about the center line which is the zero point of the x axis. A cross section of the left side of the cut slope is shown in Figure 38. The steep portion of the slope is 40 ft tall with 1 (vertical) to 3 (horizontal) slopes for the lower half of the cut below a 10-ft wide bench. The upper half of the cut has a slope of 1 to 2. The coordinate axes are the channel center line X and the top of rock Y. The ground-water table is at the top of the upper sand layer until near the cut where it lowers to the bottom of the upper sand layer at the point it emerges from the slope. There is 5 ft of water in the channel. Table 31 lists the various unit weights and shear strength values for the materials in this problem.

182. The geometry for this problem can be represented in two ways. The profile lines can describe the horizontal and slope portions of each profile. However, this representation does not allow the user to easily change the slope angle. The other method of modeling this geometry is to have the profile lines describe only the horizontal boundaries. The top layer would be a horizontal line at el 80. The cut slope is modeled with slope geometry data which describes just the slope profile. This method of representation allows the user to easily vary the slopes and evaluate the results. This latter method of describing the cross section is shown in Figure 39. The ground-water table is modeled as a piezometric line. The portion of the data file up to the ANALYSIS/COMPUTATION data is shown in Figure 40.

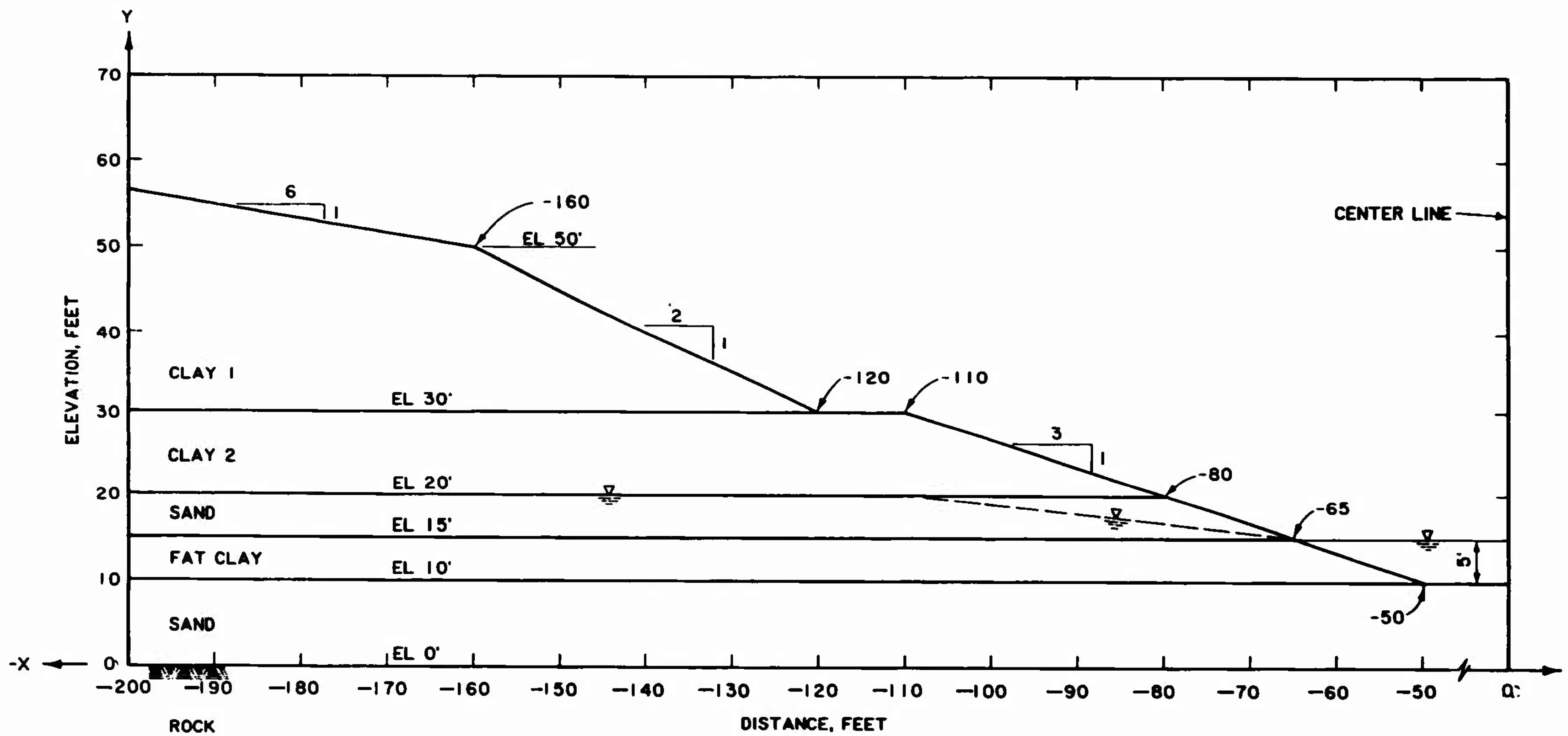


Figure 38. Example 4 - cross section

Table 31

Soil Properties for Example 4

	γ_s , pcf	γ_m , pcf	C , psf	$\phi°$
Clay 1	120	115	1,500	5
Clay 2	120	115	1,000	0
Sand	125	120	0	30
Fat Clay	120	115	500	0
Rock	165	165	0	45

Circular shear surface

183. Searches for the critical circular shear surface were performed using Spencer's procedure. The first of three series of analyses was initiated from the same point (X = -120 and Y = 110) with a final grid spacing of 0.4 ft. All searches began in the tangent mode at different elevations, and tension cracks were used. The depth of tension cracks varied from 5 to 20 ft for shallow to deeper circles. Once a search is begun, the depth of the tension crack is held constant. Table 32 lists the results of this analysis. The four local minimums found in this analysis are shown in Figure 41. A second series of analyses varied the initiation point of the search. The results of these analyses are summarized in Table 33. These analyses illustrate that the first series of analyses found the true minimum and not just a local minimum.

Noncircular shear surface

184. All the data up to the ANALYSIS/COMPUTATION data are the same for noncircular shear surfaces as for circular shear surfaces. The shear surface and associated data is specified in the ANALYSIS/COMPUTATION data group. For a single shear surface analysis, only the X and Y coordinates of the surface are necessary. For noncircular searches, the X and Y coordinates of the initial surface are required. In addition, the direction of movement of each point in the shear surface can be specified. The user specifies one of three options describing the movement. The point is either completely movable, nonmovable (fixed), or movable in a particular direction. This direction of movement is specified by an angle in degrees from the horizontal with

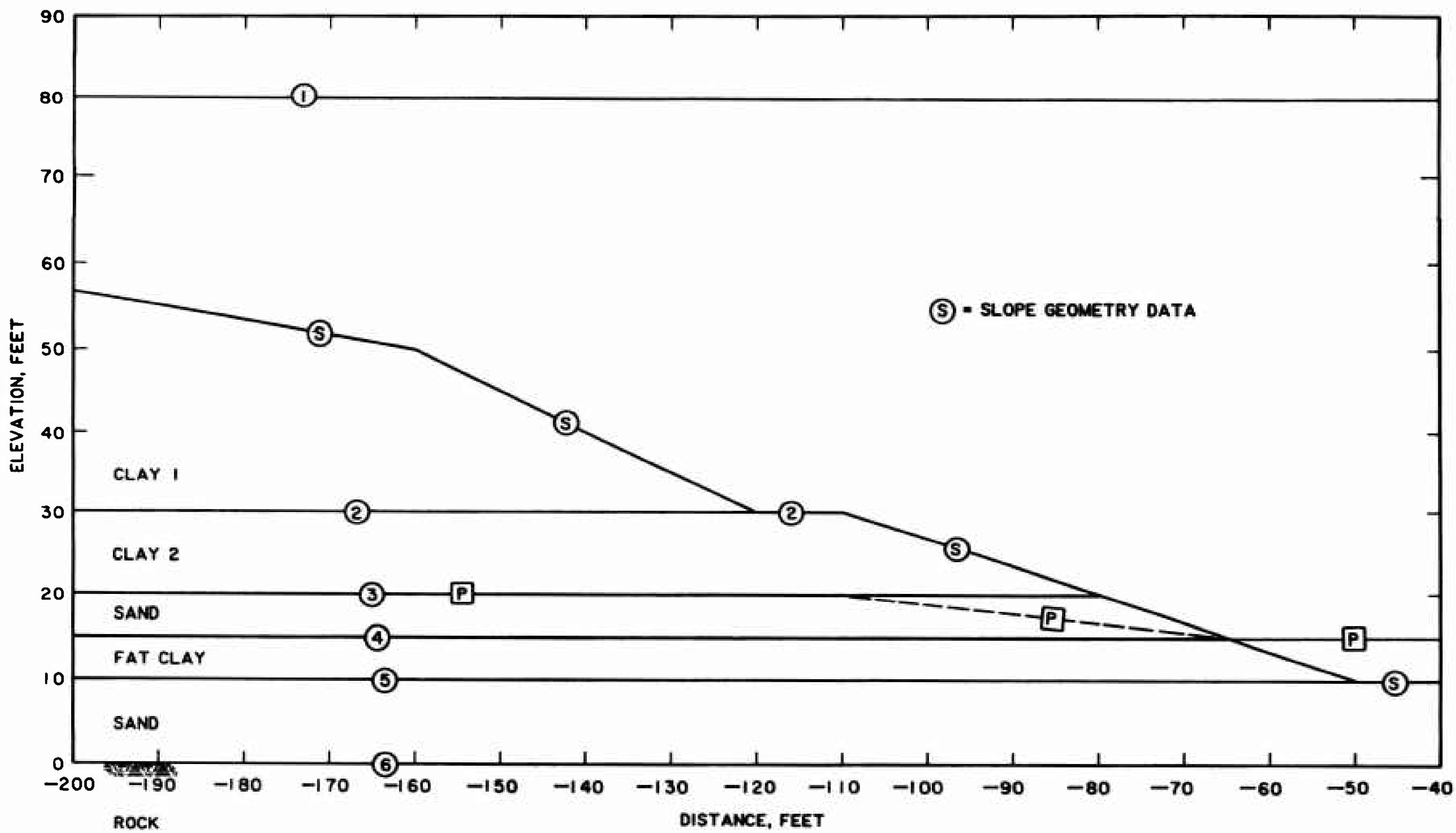


Figure 39. Profile data representation for Example 4

```
heading      HEADING                              <— command word
page 20        Example 4 - Noncircular search
                Natural slope or cut slope problem
                Contains five layers over rock
             PROFILE LINES                        <— command word
               1   1   Clay 1
               -340    80
                340    80
                           } blank line
               2   2   Clay 2
               -340    30
                340    30
                           } blank line
               3   3   Upper sand
profile        -340    20
line            340    20  } blank line
data           4   4   Fat clay
page 21        -340    15
                340    15
                           } blank line
               5   5   Lower sand
               -340    10
                340    10
                           } blank line
               6   6   Rock
               -340    0
                340    0
                           } 2 blank lines
             HEADING                              <— command word
heading        Undrained strengths
page 20        Water table in upper sand layer     } blank line
             MATERIAL PROPERTY                    <— command word
               1  Clay 1
                115 = moist unit weight
                Conventional shear strength
                 1500   5
                NO pore pressure
               2  Clay 2
                115 = moist unit weight
                Conventional shear strength
                 1000   0
material        NO pore pressure
property       3  Upper sand layer
data            125 = saturated unit weight
page 25         Conventional shear strength
                 0   30
                Piezometric Line
                 1
               4  Fat clay
                120 = saturated unit weight
                Conventional shear strength
```

Figure 40. Initial portion of cut slope example data profile (Continued)

material property data page 25

```
 500  0
Piezometric Line
 1
5  Lower sand layer
125 = saturated unit weight
Conventional shear strength
 0  30
Piezometric Line
 1
6  Rock
165 = saturated unit weight
Conventional shear strength
 0  45
Piezometric Line
 1
```

blank line

piezometric data page 37

```
PIEZOMETRIC LINE DATA
 1  62.4  Water table
 -340  20
 -110  20
  -65  15
   65  15
  110  20
  340  20
```

← *command word*

2 blank lines

surface pressure data page 49

```
SURFACE PRESSURE   pool
 -65  15    0  0
 -50  10  312  0
  50  10  312  0
  65  15    0  0
```

← *command word*

blank line

slope geometry data page 46

```
SLOPE GEOMETRY
 -340  80
 -160  50
 -120  30
 -110  30
  -50  10
   50  10
  110  30
  120  30
  160  50
  340  80
```

← *command word*

blank line

Figure 40. (Concluded)

Table 32

Circular Searches Using Spencer's Procedure and Varying Tangent Elevation

(Starting Point for Search X = -120 , Y = 110

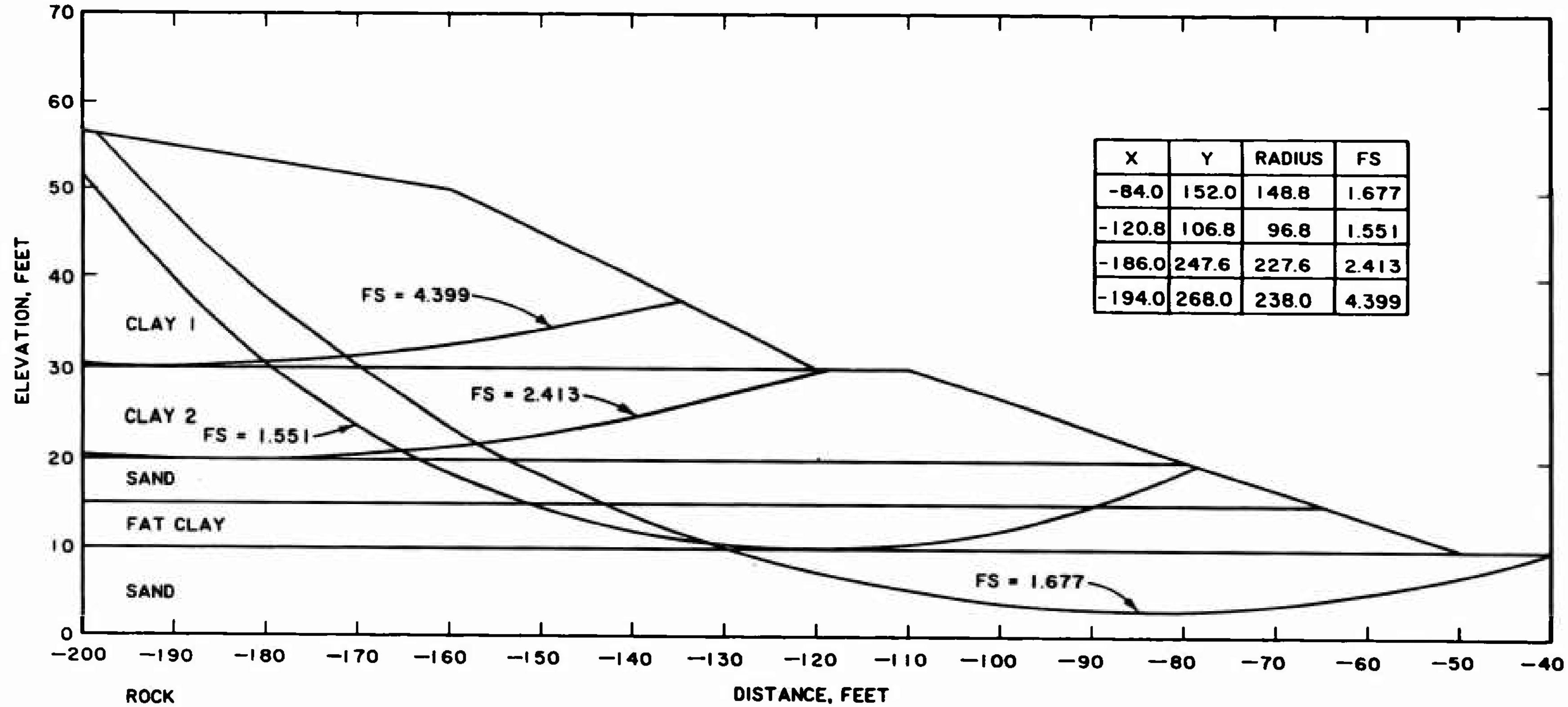
Final Grid Spacing = 0.4)

Tangent Elevation of Initial Search, ft	Minimum FS*	Circle Coordinates X, ft	Y, ft	Radius, ft	Side-Force Inclination, deg	Tension Crack Depth, ft
-5	1.677	-83.6	153.2	150.6	-11.22	20
0	1.677	-84.0	152.0	148.8	-11.27	20
5	1.677	-83.8	154.2	150.8	-11.27	20
10	1.551	-120.8	106.8	96.8	-7.63	20
15	1.677	-83.6	155.2	152.2	-11.20	20
20	2.413	-186.0	247.6	227.6	-7.15	10
25	1.570	-120.0	104.0	93.8	-7.70	15
30	4.399	-194.0	268.0	238.0	-7.98	5

* Minimum factor of safety.

counterclockwise being positive. After all the surface points are entered, an initial shift distance and maximum steepness of the toe portion are input. Usually the default value of 50 deg is used for the maximum steepness angle in which case no input is required. The initial shift distance is the initial increment that the shear surface points are moved. During the search, the shift distance is reduced to 70 percent, 40 percent, and finally 10 percent of the initial value. Tension cracks are specified by starting or ending the shear surface at the bottom of the crack. For noncircular surfaces, the crack depth option is not utilized. The tension crack will be the same depth for all analyses. Both end points of the shear surface are moved parallel to the outer slope unless they are fixed. An initial estimate of a noncircular shear surface, developed from the results of the circular analysis, and the input data necessary for a search are shown in Figure 42.

185. The noncircular search procedure will generate surfaces that are not identical and safety factors that are within about a 5 percent range. The series of analyses described with this example will illustrate several important points of which the user should be aware and/or evaluate.



X	Y	RADIUS	FS
-84.0	152.0	148.8	1.677
-120.8	106.8	96.8	1.551
-186.0	247.6	227.6	2.413
-194.0	268.0	238.0	4.399

Figure 41. Final circular shear surfaces for different initial tangent elevations

Table 33

Summary of Search Analyses for Critical Circular Shear Surface

Using Spencer's Procedure

Initial Circle Data				Final Circle Data				
X	Y	Tangent Elevation ft	Minimum FS*	X, ft	Y, ft	Radius ft	Side-Force Inclination deg	Tension Crack Depth ft
-120	110	10	1.551	-120.8	106.8	96.8	-7.63	20
-90	100	10	1.551	-120.8	106.8	96.8	-7.63	20
-160	150	10	1.551	-120.8	106.8	96.8	-7.63	20
-120	110	0	1.677	-84.0	152.0	148.8	-11.27	20
-80	140	0	1.677	-84.0	152.0	148.8	-11.27	20
-160	90	0	1.677	-84.0	152.0	148.8	-11.27	20
-120	110	20	2.413	-186.0	247.6	227.6	-7.15	10
-95	85	20	2.412	-186.2	247.0	227.0	-7.15	10
-140	140	20	2.413	-186.0	247.6	227.6	-7.15	10
-120	110	30	4.399	-194.0	268.0	238.0	-7.98	5
-130	80	30	1.671	-124.8	116.0	106.0	-0.98	5
-140	130	30	4.369	-188.0	286.0	256.0	-8.20	5
-90	140	30	4.369	-188.0	286.0	256.0	-8.20	5

* Minimum factor of safety.

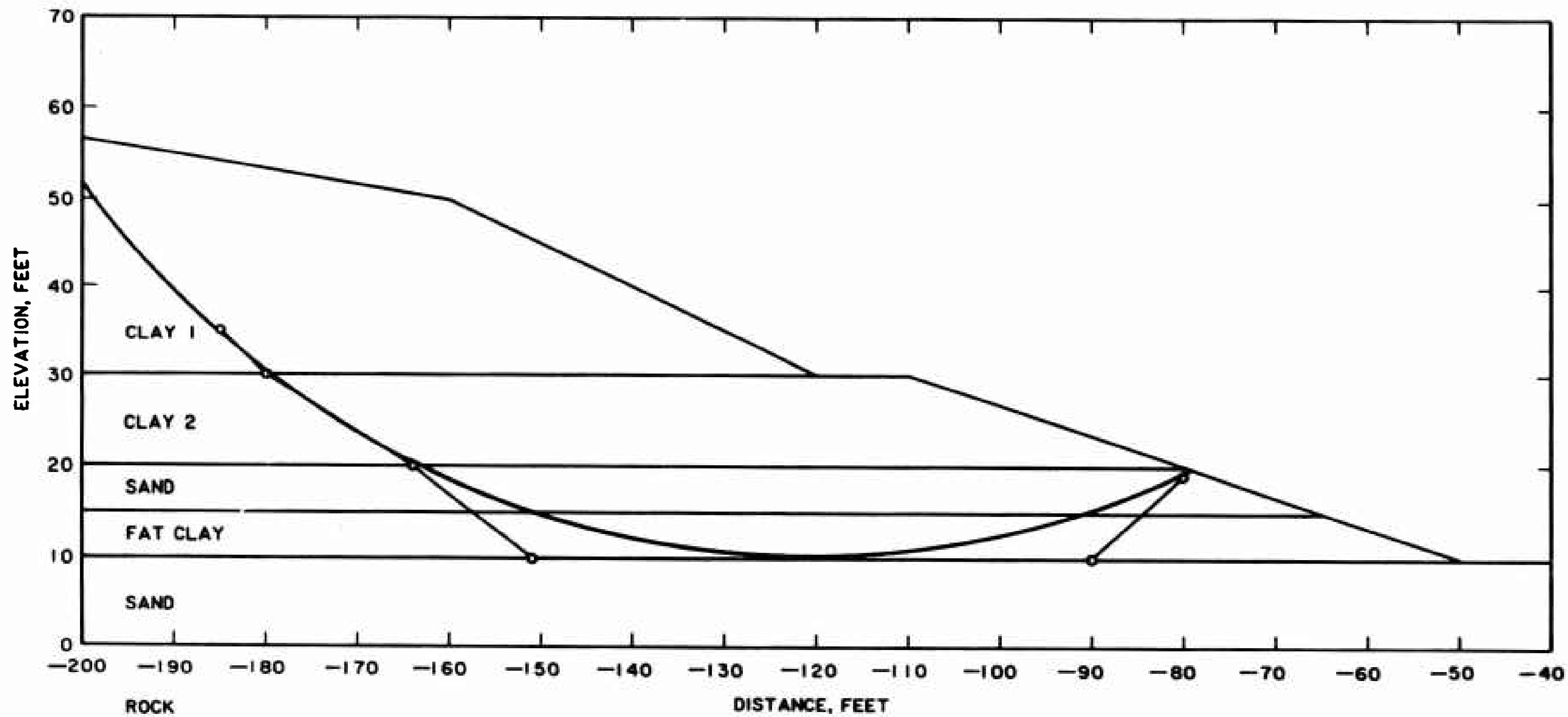


Figure 42. Initial noncircular shear surface

186. The first series of analyses will illustrate the movement of the initial shear surface and the effect of the shift distance. For these analyses, the elevation of the flat portion of the shear surface was varied with the initial positions shown in Figure 43. All surfaces are defined by six points with the initial shift distance set to 10 ft. This value was selected so that the final surfaces would be within a 1-ft band. The smallest layer is 5 ft thick, and a resolution of 20 percent is necessary to obtain the 1-ft band. Since this 1-ft band is to be 10 percent of the initial shift distance, the input for the initial distance is 10 ft. A tension crack of 20 ft was used for all cases except for surface 5 where a 15 ft crack was used. Table 34 lists both the initial and final shear surfaces from the analyses. The 1-ft band location of the final surfaces is shown in Figure 43. For this example, all surfaces moved to the lower foot of the fat clay layer. However, the user should select the most appropriate surface for any given problem since this movement may not occur if there is a large variation in the strata thickness.

187. To evaluate the initial shift distance, it was varied from 2 to 20 ft for surfaces 1 and 2. Also, for the other surfaces listed in Table 34, the shift distance was changed to 5 ft. Table 35 summarizes the safety factors for all the various surfaces. Only relatively small changes in the safety factor occurred for changes in the shift distance. By decreasing the shift distance, the band for the final shear surface decreases along with the area searched. For some of the larger shift distances, errors occurred when the second point from the toe was shifted outside the slope. A number of analyses had negative stresses, indicating that a deeper tension crack was necessary. However, for illustrative purposes, the initial surface shown in Table 34 was not changed. In general, the safety factors tend to decrease as the shift distance decreases. However, for this example problem, a shift distance of 10 ft will be used for the other analyses because a resolution or band width of 1-ft is sufficient.

188. The second series of analyses evaluates the effect of the number of points used to define the shear surface. An initial shear surface defined by 13 points was used in a search for the final surface. Using the same initial points, subgroups of 4, 6, 7, 8, 9, and 11 points were used in searches for the final surface. All points were movable during the search, with an initial shift distance of 10 ft. Table 36 lists the initial points that were

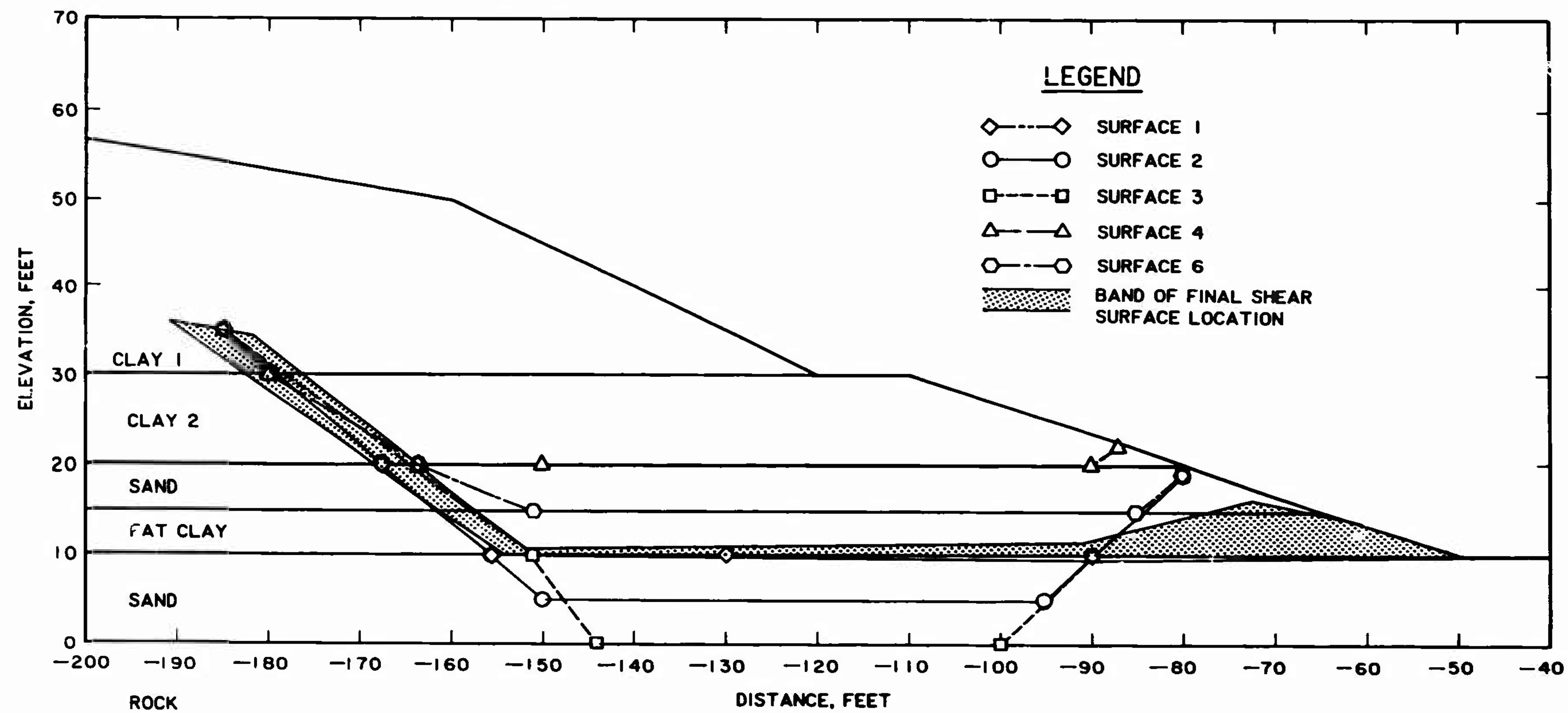


Figure 43. Initial noncircular shear surface and final location band illustrating the shear surface movement during the search process

Table 34

Variation of Base Elevation; Initial Shift Distance = 10 ft

Surface 1, FS* = 1.371				Surface 2 FS = 1.330				Surface 3 FS = 1.332			
Initial		Final		Initial		Final		Initial		Final	
X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
-185	35	-188.0	35.0	-185	35	-190.7	36.0	-185	35	-182.0	34.5
-167.5	20	-168.0	20.3	-167.5	20	-171.4	14.7	-151	10	-156.4	11.7
-155.5	10	-154.6	10.1	-155.5	10	-155.4	11.2	-144	0	-135.8	10.8
-130	10	-130.0	10.4	-150	5	-145.4	10.1	-100	0	-104.2	11.0
-90	10	-91.3	11.4	-95	5	-99.2	10.9	-90	10	-89.2	9.3
-80	19	-72.2	16.4	-80	19	-72.3	16.4	-80	19	-42.4	10.0

Surface 4 FS = 1.397				Surface 5** FS = 1.346			
Initial		Final		Initial		Final	
X	Y	X	Y	X	Y	X	Y
-185	35	-185.3	35.0	-190	41	-194.4	41.7
-180	30	-180.2	30.5	-180	30	-181.2	28.1
-164	20	-165.3	20.4	-164	20	-167.6	14.7
-150	20	-149.4	11.0	-150	20	-149.9	10.0
-90	20	-89.1	10.0	-90	20	-89.1	10.4
-87	22	-70.9	16.6	-87	22	-70.9	16.6

Surface 6 FS = 1.371				Surface 7† FS = 1.347			
Initial		Final		Initial		Final	
X	Y	X	Y	X	Y	X	Y
-185	35	-182.7	34.6	-185	35	-181.4	34.4
-180	30	-179.5	30.5	-180	30	-178.7	31.1
-164	20	-163.5	20.9	-164	20	-163.6	20.4
-151	15	-151.9	10.5	-151	14.5	-152.2	10.0
-85	15	-84.7	10.0	-85	15.5	-84.1	10.0
-80	19	-69.0	15.3	-80	19	-70.8	15.9

* Factor of safety.
** 15-ft tension crack.
† Attempted crossover.

Table 35

Effect of Initial Shift Distance

Surface*	Initial Shift Distance, ft	Safety Factor
1	20	1.555
	15	1.393
	10	1.371
	5	1.305
	2	1.348
2	20	--
	15	1.341
	10	1.330
	5	1.313
	2	1.304
3	10	1.332
	5	1.315
4	10	1.397
	5	1.314
5	10	1.346
	5	1.357
6	10	1.371
	5	1.368
7	10	1.347
	5	1.360

* Initial surfaces are defined in Table 34.

used in the various subgroups, and the final results. The initial and selected final surfaces are shown in Figure 44. For the surfaces with 6 to 13 points, the safety factor was about constant with a minimum occurring for the nine-point surface. The surface using four points generated a safety factor about 4 percent larger than the other surfaces.

189. In addition to the number of points defining a shear surface, the distribution of the points along the surface was also evaluated. Two cases were analyzed for the six-point surface. In the first case, four points were located along the base. For the second case, four points were used to define the intersection of different materials along the active portion of the surface. For both cases, the movement of the points was not restricted. There is a 5 percent difference in the final safety factors. This indicates that when a few points are used to define the surface, more points should be

Table 36

Effects of the Number of Points Used to Define the Shear Surface

Initial Point Coordinates		4-Point Surface FS* = 1.409			6-Point Surface FS* = 1.429			6-Point Surface FS* = 1.357			8-Point Surface FS* = 1.349			13-Point Surface FS* = 1.359		
		Points Used	Final Location		Points Used	Final Location		Points Used	Final Location		Points Used	Final Location		Points Used	Final Location	
X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
-185.0	35.0	✓	-186.0	35	✓	-182.7	34.6	✓	-181.0	34.3	✓	-184.7	35.0	✓	-183.0	34.7
-178.2	30.0				✓	-179.0	31.2							✓	-178.4	29.7
-164.6	20.0				✓	-164.2	21.1				✓	-164.9	20.3	✓	-164.2	20.8
-157.8	15.0										✓	-158.6	13.6	✓	-158.2	14.0
-151.0	10.0	✓	-150.5	10.9	✓	-150.3	11.2	✓	-151.5	10.6	✓	-149.7	10.6	✓	-150.1	12.1
-140.0	10.0													✓	-140.1	10.6
-130.0	10.0							✓	-129.3	10.1				✓	-130.3	10.2
-120.0	10.0													✓	-119.9	10.6
-110.0	10.0							✓	-110.2	10.2	✓	-111.0	10.8	✓	-109.9	11.7
-100.0	10.0													✓	-100.3	11.2
-90.0	10.0	✓	-91.2	10.7	✓	-94.5	10.9	✓	-91.5	10.7	✓	-91.8	10.0	✓	-92.2	12.0
-85.5	15.0										✓	-84.0	12.2	✓	-84.5	14.5
-80.0	19.0	✓	-73.4	16.8	✓	-64.8	13.9	✓	-72.1	16.4	✓	-72.6	16.5	✓	-72.9	16.6
A**			B**			C**			D**			E**			F**	

Initial Point Coordinates		9-Point Surface FS* = 1.343			11-Point Surface FS* = 1.349			7-Point Surface FS* = 1.347			7-Point Surface FS* = 1.413		
		Points Used	Final Location		Points Used	Final Location		Points Used	Final Location		Points Used	Final Location	
X	Y		X	Y		X	Y		X	Y		X	Y
-185.0	35.0	✓	-182.0	34.5	✓	-182.4	34.6	✓	-180.6	34.3	✓	-182.9	34.7
-178.2	30.0							✓	-177.2	30.5	✓	-178.3	30.0
-164.6	20.0	✓	-165.8	18.8	✓	-164.7	20.5	✓	-164.2	20.8	✓	-165.8	20.0
-157.8	15.0	✓	-158.5	13.5	✓	-158.6	13.5	✓	-158.4	14.13	✓	-159.2	15.0
-151.0	10.0	✓	-149.7	11.1	✓	-150.8	11.7	✓	-150.4	11.0	✓	-120.5	10.0
-140.0	10.0				✓	-140.0	10.2						
-130.0	10.0	✓	-130.0	10.1	✓	-130.0	10.2						
-120.0	10.0												
-110.0	10.0	✓	-110.1	10.6	✓	-110.2	11.1						
-100.0	10.0				✓	-100.0	11.0						
-90.0	10.0	✓	-92.4	10.9	✓	-92.8	12.1	✓	-94.7	10.4	✓	-120.5	10.0
-85.5	15.0	✓	-83.7	11.9	✓	-83.3	12.9						
-80.0	19.0	✓	-71.3	16.1	✓	-71.1	16.2	✓	-73.5	16.8	✓	-54.9	10.6
			G**			H**			I**			J**	

* Factor of safety.
** Letters A through J designate the shear surface.

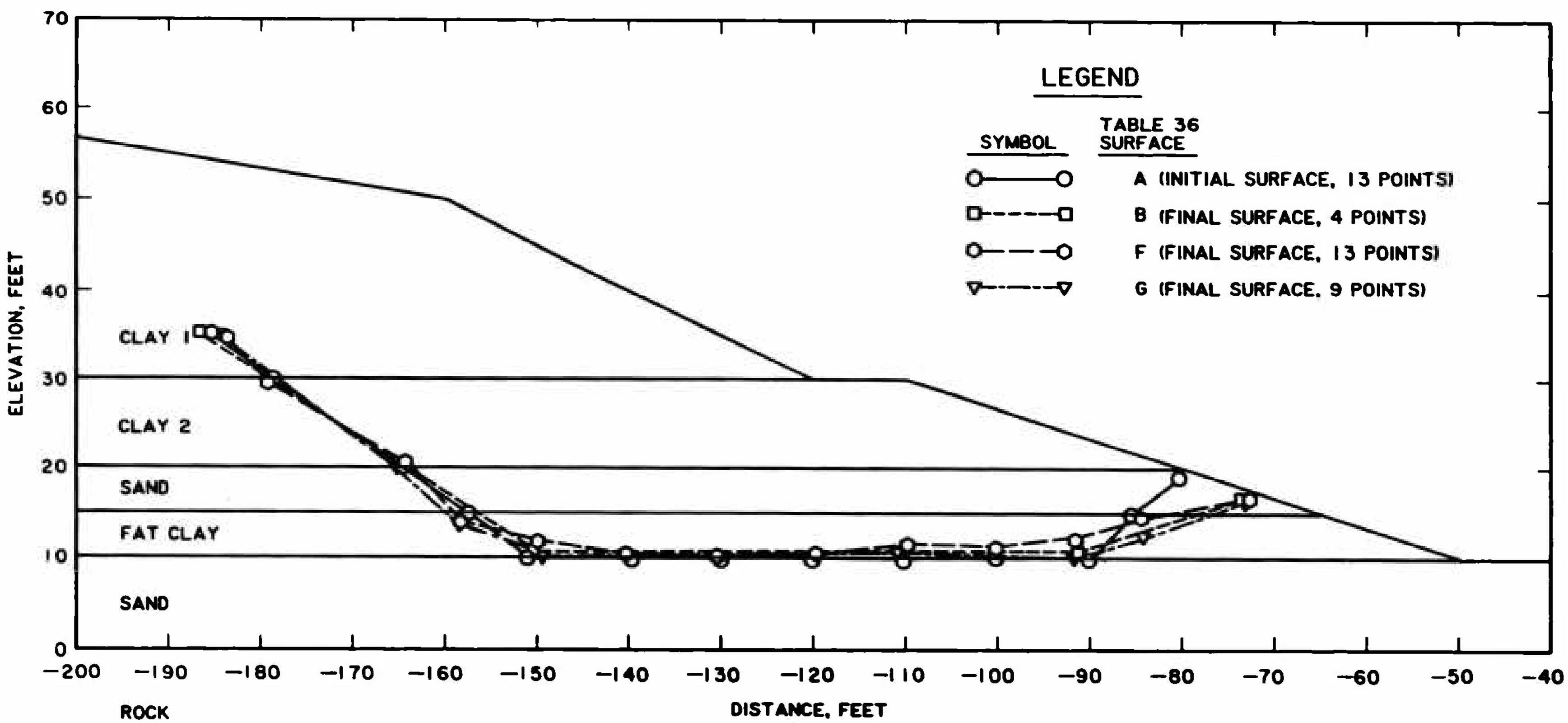


Figure 44. Initial and selected final shear surfaces illustrating the different surfaces resulting from varying the number of points used to define the shear surface

located along the base than are used to define the active portion of the surface. Figure 45 compares the active portion of the final surface for both six-point shear surfaces.

190. The two seven-point surfaces listed in Table 36 were used to illustrate analyses where the movement of the points was limited. For both seven-point surfaces, points are located at every soil layer intersection. The first seven-point surface allowed the points to move in any direction. The second analysis restricted the points to movement only along the soil layers. For the second analysis (surface J in Table 36), it should be noted that the final surface does not contain a central block. The search resulted in a surface consisting only of an active and a passive wedge. Both final active wedge surfaces are included in Figure 45. There is approximately a 5 percent difference in the safety factor for this example when the points along the active wedge are restricted in their movement.

191. The last series of analyses deals with varying the width and location of the flat portion of the shear surface. There are two methods available to perform these analyses. The first is to perform searches for different base widths where the user inputs different surfaces. The other method is to restrict the direction of movement for the base end points as was illustrated for surface J in Table 36. For this series of analyses, the base widths will be varied by keeping one base point constant and varying the other. Four points will be used to define the shear surface. Table 37 lists the results where the right base point was varied. A minimum safety factor occurred for a base width of between 80 and 90 ft. Table 38 lists the results for the analyses where the right base point changed. For this case a minimum never occurred. This happens because there is only the constant cohesion parameter to define the shear strength of the fat clay, and the increase of the driving force due to the added weight of a longer base width is offset by the increased resistance force. Plots of the results listed in Tables 37 and 38 are shown in Figure 46. Based on the results of this plot and additional information about the surface profile and the horizontal extent of the stratum, the user could determine whether or not a problem exists.

192. In summary, the user must evaluate and select the best noncircular shear surface. Selecting the proper base elevation and width along with using an appropriate number and distribution of points, the user can develop the initial shear surface for a search. A range of 5 percent or more can exist

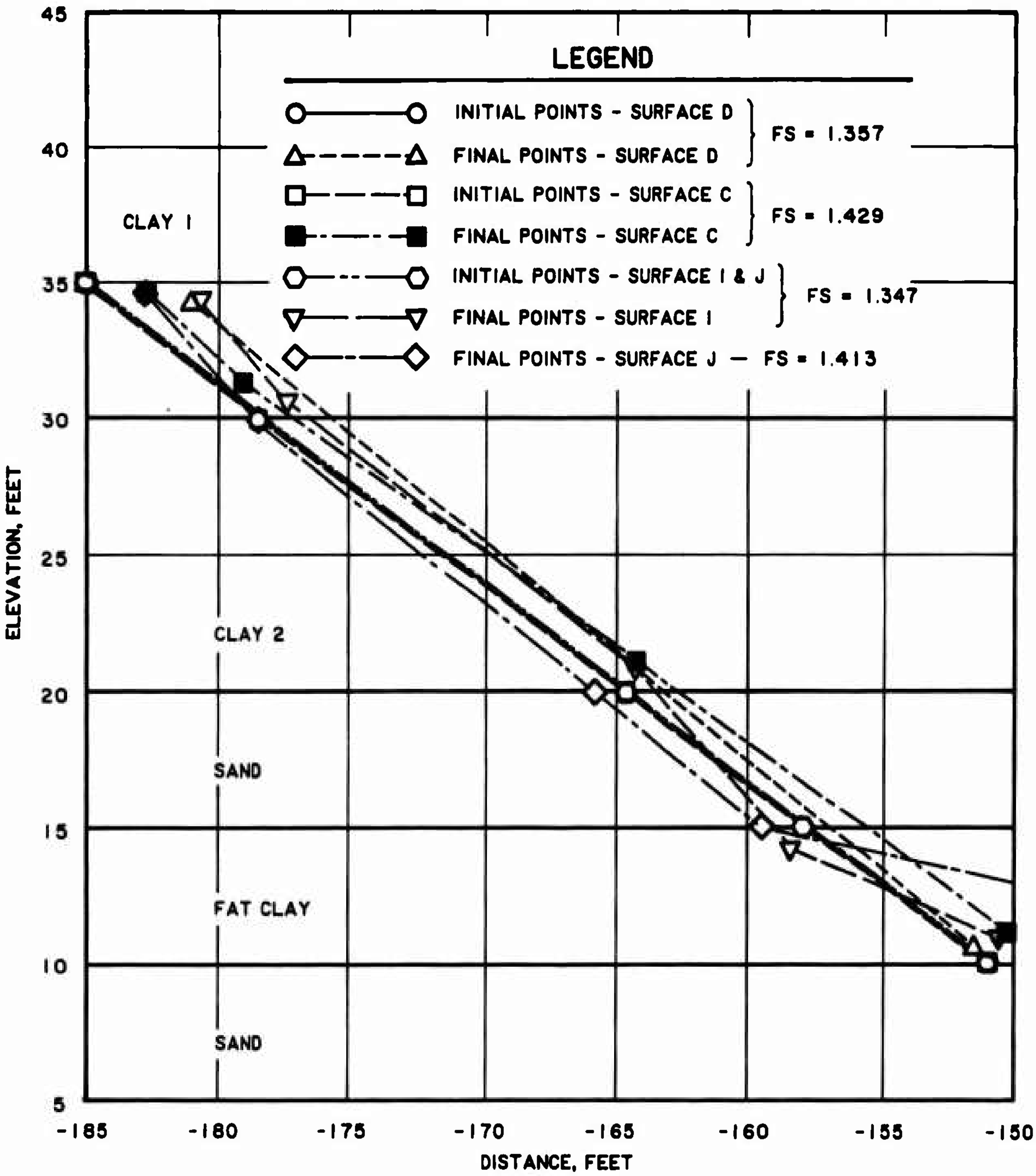


Figure 45. Active wedge portion of initial and final shear surfaces for analyses using six and seven points, illustrating the movement of points across soil boundaries

Table 37

Results of Analyses Involving Varied Right Base Point

Surface	Initial Points X	Initial Points Y	Final Points X	Final Points Y	Base Width, ft	Safety Factor
1	-185.0	35.0	-186.0	35.2	Initial 61	1.409
	-151.0	10.0	-150.5	10.9		
	-90.0	10.0	-91.2	10.7	Final 59.3	
	-80.0	19.0	-73.4	16.8		
2	-185.0	35.0	-185.0	35.0	Initial 40	1.616
	-150.0	10.0	-149.5	11.0		
	-110.0	10.0	-111.0	11.0	Final 38.5	
	-93.0	24.0	-85.4	21.5		
3	-185.0	35.0	-174.2	33.0	Initial 80	1.334
	-150.0	10.0	-149.3	11.8		
	-70.0	10.0	-69.7	9.4	Final 79.6	
	-65.0	14.5	-41.7	10.0		
4	-185.0	35.0	-173.2	33.0	Initial 90	1.334
	-150.0	10.0	-149.3	12.0		
	-60.0	10.0	-59.7	9.2	Final 89.6	
	-57.0	12.0	-42.9	10.0		
5	-185.0	35.0	-174.2	33.2	Initial 95	1.343
	-150.0	10.0	-149.2	12.2		
	-55.0	10.0	-54.9	8.8	Final 94.3	
	-52.0	10.7	-42.8	10.0		
6	-185.0	35.0	-174.4	33.2	Initial 70	1.413
	-150.0	10.0	-149.4	10.8		
	-80.0	10.0	-85.2	9.8	Final 64.2	
	-72.0	16.5	-70.6	16.0		

Table 38

Results of Analyses Involving Changing Left Base Point

Surface	Initial Points X	Initial Points Y	Final Points X	Final Points Y	Base Width, ft	Safety Factor
1	-185.0	35.0	-186.0	35.2	Initial 61	1.409
	-151.0	10.0	-150.5	10.9		
	-90.0	10.0	-91.2	10.7	Final 59.3	
	-80.0	19.0	-73.4	16.8		
2	-165.0	35.0	-177.9	37.2	Initial 40	1.631
	-130.0	10.0	-130.0	10.2		
	-90.0	10.0	-94.2	10.2	Final 35.8	
	-80.0	19.0	-74.4	17.2		
3	-220.6	39.0	-221.6	39.2	Initial 90	1.382
	-180.0	10.0	-179.5	10.9		
	-90.0	10.0	-91.2	10.7	Final 88.3	
	-80.0	19.0	-73.4	16.8		
4	-175.0	35.0	-168.9	34.0	Initial 50	1.465
	-140.0	10.0	-139.8	10.1		
	-90.0	10.0	-94.7	10.8	Final 45.1	
	-80.0	19.0	-72.6	16.5		
5	-197.0	36.3	-198.0	36.5	Initial 70	1.394
	-160.0	10.0	-159.5	10.9		
	-90.0	10.0	-91.2	10.7	Final 68.3	
	-80.0	19.0	-73.4	16.8		
6	-209.0	37.7	-210.0	37.9	Initial 80	1.391
	-170.0	10.0	-169.5	10.9		
	-90.0	10.0	-91.2	10.7	Final 78.3	
	-80.0	19.0	-73.4	16.8		
7	-235.6	42.6	-236.6	42.8	Initial 100.0	1.376
	-190.0	10.0	-189.5	10.9		
	-90.0	10.0	-91.2	10.7	final 98.3	
	-80.0	19.0	-73.4	16.8		

(Continued)

Table 38 (Concluded)

Surface	Initial Points X	Initial Points Y	Final Points X	Final Points Y	Base Width, ft	Safety Factor
8	-248.7	44.8	-249.7	45.0	Initial 110	1.364
	-200.0	10.0	-199.5	10.9		
	-90.0	10.0	-91.2	10.7	Final 108.3	
	-80.0	19.0	-73.4	16.8		
9	-261.8	47.0	-262.8	47.2	Initial 120	1.351
	-210.0	10.0	-209.6	10.9		
	-90.0	10.0	-91.2	10.7	Final 118.4	
	-80.0	19.0	-73.4	16.8		
10	-247.7	49.1	-275.7	49.3	Initial 130	1.336
	-220.0	10.0	-219.6	10.9		
	-90.0	10.0	-91.2	10.7	Final 128.4	
	-80.0	19.0	-73.4	16.8		
11	-235.6	42.6	-216.0	39.3	Initial 120	1.368
	-190.0	10.0	-188.2	14.1		
	-70.0	10.0	-70.4	8.4	Final 117.8	
	-65.0	14.5	-47.5	10.0		
12	-313.9	55.7	-314.9	55.9	Initial 160	1.288
	-250.0	10.0	-249.6	10.9		
	-90.0	10.0	-91.2	10.7	Final 158.4	
	-80.0	19.0	-73.4	16.8		
13	-333.4	58.9	-334.4	59.1	Initial 175	1.262
	-265.0	10.0	-264.6	10.9		
	-90.0	10.0	-91.2	10.7	Final 173.4	
	-80.0	19.0	-73.4	16.8		

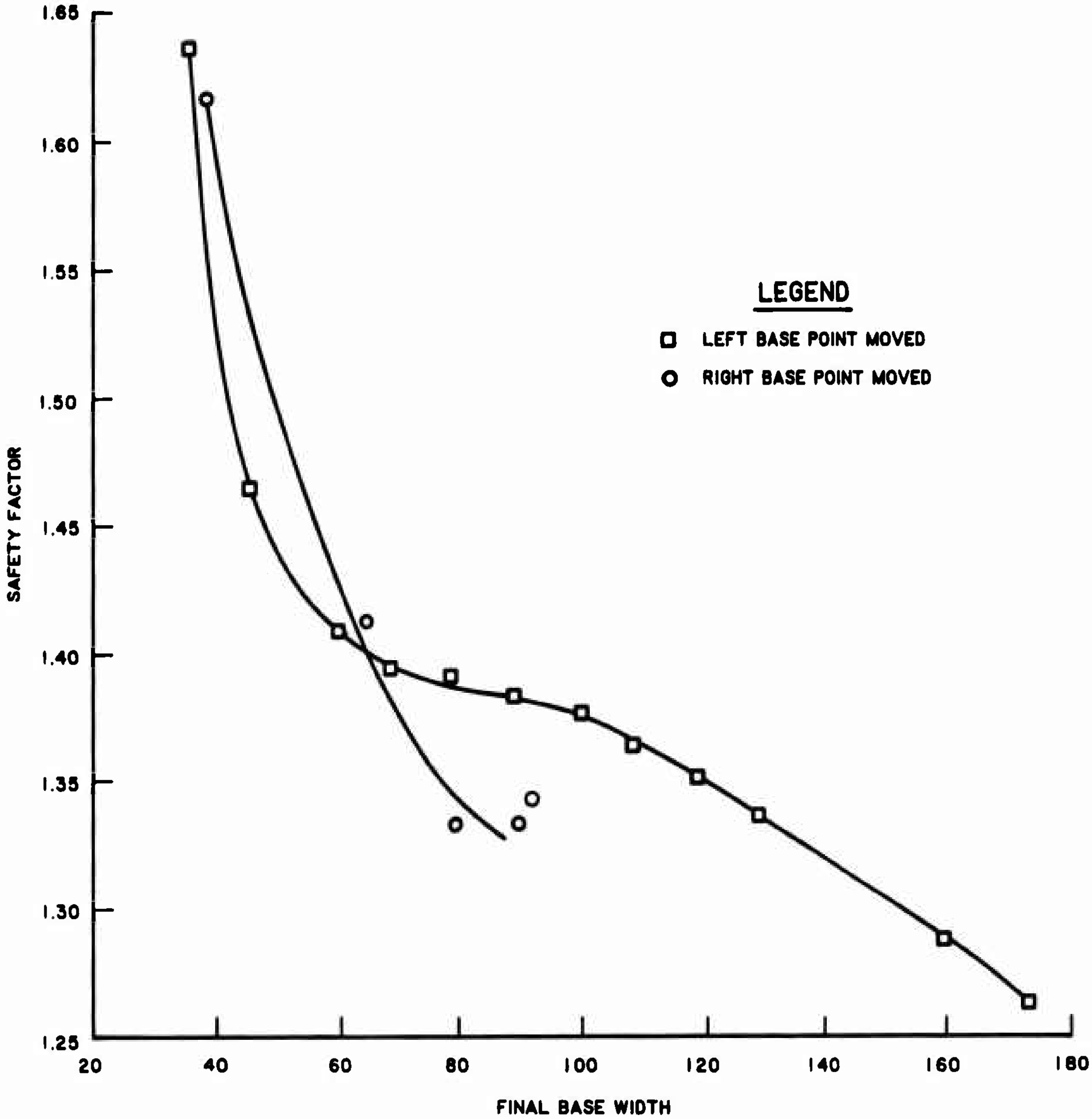


Figure 46. Plots of results of base-width analyses

for the safety factor. Also, the depth of the tension crack may need to be varied more than it was in the examples. The final search consisted of a 10-point surface shown in Figure 47. The final safety factor for this analysis is 1.28. The computer results are included as file EXAM4.OUT in Appendix D.

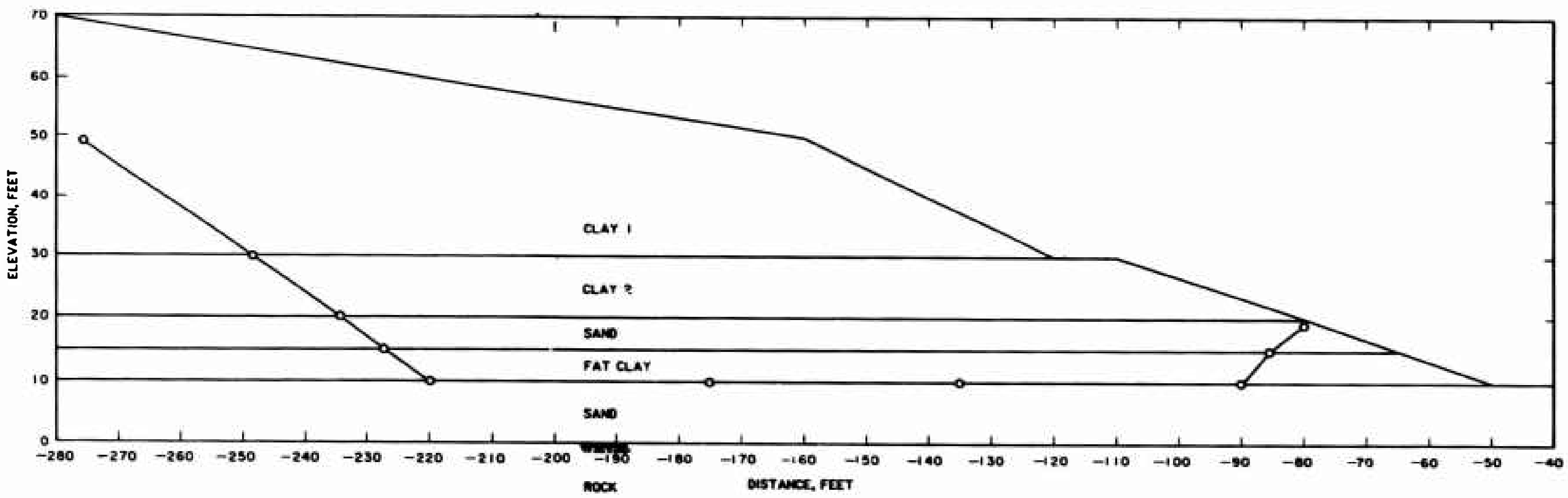


Figure 47. Final noncircular shear surface for cut slope example

REFERENCES

Bishop, A. W. 1955. "The Use of the Slip Circle in the Stability Analysis of Slopes," Geotechnique, Vol 5, No. 1, pp 7-17.

Bishop, A. W., and Morgenstern, Norbert. 1960. "Stability Coefficients for Earth Slopes," Geotechnique, Vol 10, No. 4, pp 129-150.

CAGE Task Group on Slope Stability. 1985. "Criteria for Limit Equilibrium Slope Stability Package," Miscellaneous Paper No. GL-85-8, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Celestino, T. B., and Duncan, J. M. 1981. "Simplified Search for Noncircular Slip Surfaces," Proceedings, Tenth International Conference on Soil Mechanics and Foundation Engineering, Stockholm, Vol 3, pp 391-394.

Chugh, Ashok K. 1981. "Pore Water Pressure in Natural Slopes," International Journal for Numerical and Analytical Methods in Geomechanics, Vol 5, No. 4, pp 449-454.

Headquarters, Department of the Army. 1970. "Engineering and Design - Stability of Earth and Rock-Fill Dams," EM 1110-2-1902, Washington, DC.

Edris, E. V., Jr., and Vanadit-Ellis, W. 1982. "Geotechnical Computer Program Surveys," Miscellaneous Paper GL-82-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Lowe, J., III, and Karafiath, L. 1960. "Stability of Earth Dams Upon Drawdown," Proceedings, First Panamerican Conference on Soil Mechanics and Foundation Engineering, Mexico City, Vol 2, pp 537-552.

Spencer, E. 1967. "A Method of Analysis of the Stability of Embankments Assuming Parallel Inter-Slice Forces," Geotechnique, Vol 17, No. 1, pp 11-26.

Wright, Stephen G. 1969. "A Study of Slope Stability and the Undrained Shear Strength of Clay Shales," Ph.D dissertation, University of California, Berkeley, California.

Wright, S. G. 1975. "Evaluation of Slope Stability Analysis Procedures," Preprint No. 2616, American Society of Civil Engineers National Convention, Denver, Colo.

Wright, Stephen G. 1982. "Documentation for SSTABI - A General Computer Program for Slope Stability Analyses," Geotechnical Engineering Software GS82-1, Geotechnical Engineering Center, Bureau of Engineering Research, The University of Texas, Austin, Tex.

Wright, Stephen G., and Roecker, J. D. 1984a. "UTEXAS: A Computer Program for Slope Stability Calculations," Research Report 353-1, Center for Transportation Research, The University of Texas, Austin, Tex.

__________. 1984b. "Example Problems for Slope Stability Computations with the Computer Program UTEXAS," Research Report 353-2, Center for Transportation Research, The University of Texas, Austin, Tex.

Wright, Stephen G. 1985. "UTEXAS2 - A Computer Program for Slope Stability Calculations," Report to US Army Engineer District, Fort Worth, Tex.

Wright, Stephen G. 1986a. "UTEXAS2 - A Computer Program for Slope Stability Calculations," Geotechnical Engineering Software HS86-1, Geotechnical Engineer Center, Bureau of Engineering Research, The University of Texas, Austin, Tex.

__________. 1986b. "Limit Equilibrium Slope Stability Equations Used in the Computer Program UTEXAS2," Geotechnical Engineering Software GS86-2, Geotechnical Engineering Center, Bureau of Engineering Research, The University of Texas, Austin, Tex.

__________. 1986c. "Summary of Printed Error Messages for UTEXAS2," Geotechnical Engineering Software, Geotechnical Engineering Center, Bureau of Engineering Research, The University of Texas, Austin, Tex.

APPENDIX A: SUMMARY AND EXPLANATION OF PRINTED ERROR MESSAGES FOR UTEXAS2 (Wright, 1986)

* A *

ABOVE INTERPOLATION POINT NUMBER NOT LEGAL - REJECTED - MAX. ALLOWED = __
The number of the interpolation point indicated on the line of data preceding this message exceeds the maximum number of points allowed by the dimensioned size of the program's arrays. Either the number of points must be reduced or the size of the program's arrays must be increased by a programmer.

ALL GRID POINTS HAD AN INDETERMINATE FACTOR OF SAFETY - SEARCH ABORTED
The factor of safety could not be computed for any of the nine points in the initial grid for the automatic search. Either the data are in error such that no valid solutions can be found or the initial estimate for the critical circle may be far from the correct location. Input data should be checked for validity and/or a new initial estimate for the critical circle should be input. If none of the solutions for the factor of safety converged, an insight into what happened may be gained by performing computations for just one selected circle (no automatic search).

* B *

BAD ARC LENGTH AND/OR SUBTENDED ANGLE FOR SUBDIVIDING CIRCLE INTO SLICES
Both the arc length and subtended angle for subdividing a circular shear surface into slices are zero or negative. One of the values must be positive. Input data for one of these variables should be changed.

BAD BASE LENGTH OR NUMBER OF INCREMENTS FOR SUBDIVIDING NONCIRCULAR SHEAR SURFACE INTO SLICES
Both the base length and number of increments for subdividing a noncircular shear surface into slices are zero or negative. One of the values must be positive. Input data for one of these variables should be changed.

BAD INITIAL INCREMENTAL DISTANCE FOR SHIFTING POINTS ON NONCIRCULAR SHEAR SURFACE DURING SEARCH - DSHIFT = __
The incremental distance specified for shifting points in the automatic search for a critical noncircular shear surface is zero or negative. A positive, nonzero value must be input.

BAD MAXIMUM NUMBER OF ITERATIONS = __
The maximum number of iterations specified for use in the iterative solution is either zero, negative, or exceeds 1,000. The value must range from 1 to 1,000, inclusive.

NOTE: References cited in this appendix are included in the References at the end of the main text.

BAD RADIUS FOR CIRCLE - RADIUS = __
The information specified to designate the radius for an individual circular shear surface (no automatic search) indicates that the radius is zero or negative.

BAD REQUIRED ACCURACY (GRID SPACING) FOR LOCATING CRITICAL CENTER - ACCURACY = __
The specified grid spacing to be used for an automatic search to locate a critical circular shear surface is zero or negative.

BAD TRIAL VALUE FOR FACTOR OF SAFETY = __
The initial trial value which has been specified for the factor of safety is zero or negative. A positive, nonzero value must be input.

* C *

CAUTION - COMPRESSIVE FORCE IN REINFORCEMENT LINE NO. __ AT POINT NO. __
The program has detected a compressive force (negatively signed input value) in the reinforcement line number indicated at the point number shown. This message is printed only to alert the reader to an apparent nontypical value in the input data; however, no error has occurred and the input and results of subsequent computations may be entirely correct.

CAUTION - DATA FOR MATERIAL TYPE __ ARE NOT USED
This message indicates that the data for the designated material are not assigned to any of the profile lines. This information is for information only and indicates that the designated material property data will not be used for the current set of profile lines.

CAUTION - DATA FOR INTERPOLATION POINT NO. __ ARE NOT USED
This message indicates that for the designated point where data were defined for use in interpolating pore water pressures either the associated material type does not exist (there are no material property data) or pore water pressures are to be determined by means other than interpolation for the associated material. This message is for information only and indicates that the designated piezometric line data will not be used for the current set of material properties.

CAUTION - DATA FOR PIEZOMETRIC LINE NO. __ ARE NOT USED
This message indicates that the data for the designated piezometric line are not assigned to any of the materials for which data have been input. This message is for the information only and indicates that the designated piezometric line data will not be used for the current set of material properties.

***** CAUTION ***** EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR SURFACE IS NEGATIVE AT POINTS ALONG THE UPPER ONE HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED
This message is printed at the end of the final output tables when the computed total or effective stress is negative along the upper one half of the shear surface. The upper one half of the shear surface is defined as the portion of the shear surface where the x coordinate lies between the crest-most value and the average of the left-most and right-most values. This message should be self-explanatory.

CAUTION - FACTOR OF SAFETY WAS NOT COMPUTED FOR SOME SHEAR SURFACES NEAR CRITICAL SURFACE - CHECK PREVIOUS OUTPUT

It was not possible to compute the factor of safety when one of the points was shifted during the last incremental shifting of the noncircular shear surface (prior to detecting the probable critical shear surface). The user should carefully examine why the factor of safety was not computed for the points which were shifted. If the factor of safety was not computed because a much stronger material was encountered, the results may be valid. Otherwise the results may be in error.

***** CAUTION ***** FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS ALONG THE UPPER ONE HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED

This message is printed at the end of in the final output tables when the computed forces between slices are negative along the upper one half of the shear surface. The upper one half of the shear surface is defined as the portion of the shear surface where the x coordinate lies between the crest-most value and the average of the left-most and right-most values. This message should be self-explanatory.

***** CAUTION ***** SOME OF THE FORCES BETWEEN SLICES ACT AT POINTS ABOVE THE SURFACE OF THE SLOPE OR BELOW THE SHEAR SURFACE - EITHER A TENSION CRACK MAY BE NEEDED OR THE SOLUTION MAY NOT BE A VALID SOLUTION

This message is printed at the end of the final output tables for Spencer's procedure when the position of the side forces (line of thrust) lies outside the limits indicated. When the line of thrust lies outside these limits near the crest of the slope, it is usually indicative of tensile stresses - a tension crack may be needed. When the line of thrust lies outside the limits of the slope and shear surface near the toe of the slope, it is often indicative of a shear surface which is excessively steep near the toe of the slope - the shear surface may need to be flattened near the toe of the slope.

CAUTION - INITIAL TRIAL SHEAR SURFACE IS BELOW SLOPE NEAR THE TOE OF THE SLOPE A DISTANCE = __

SOLUTION WILL BE ERRONEOUS IF THIS DISTANCE IS VERY LARGE

The end point coordinate of the initial trial noncircular shear surface at the toe of the shear surface is below the surface of the slope. This will cause the program to place a vertical slice boundary at the toe of the slope in the same manner that a vertical crack is modeled near the crest of the slope. The results may be erroneous. This error is printed when the shear surface end point is at a distance of 0.01 (in coordinate units, whatever they are) or more below the surface of the slope or ground. The user should attempt to re-input the coordinates of the shear surface so that they lie more precisely on the surface of the slope.

CAUTION - SHEAR SURFACE STEEPNESS IS WITHIN 1 DEGREE OF THE LIMITING STEEPNESS NEAR THE TOE OF THE SLOPE

The most critical shear surface located by the automatic search is within one degree of the maximum steepness permitted by the input data (or automatic default value of 50 degrees) at the toe of the slope. The search may have been restricted from examining a steeper shear surface which may have been reasonable and more critical. The user should be careful in selecting the limiting steepness. If the shear surface is allowed to become too steep, erroneous values may be computed for the factor of safety. However, the surface must be allowed to become steep enough that the most critical shear surface is detected.

CAUTION - UNIT WEIGHT FOR MATERIAL TYPE __ IS NEGATIVE OR ZERO
This message indicates that the designated material has been assigned zero or a negative value for the unit weight of the material. This message is for information only - a negative or zero unit weight is allowed. (A negative unit weight means that the weight forces will act upward, rather than downward).

CENTER OF CRITICAL CIRCLE COULD NOT BE FOUND AFTER TRYING __ GRIDS IN CURRENT ARRAY - SEARCH ABORTED
The program allows a set number of grids (30) to be used in any given search "array". If this number is exceeded, this message is printed and the search is aborted. For each mode of search a new search "array" is used and in a given mode of search more than one "array" may be used. The user does not need to be concerned about how many "arrays" are actually used; the purpose of this message and "error trap" is to avoid having the search become caught in an infinite loop. The message should normally not occur. If it does, the allowed number of grids (MAXGRD) can be changed internally in the program by an experienced programmer.

CIRCLE DOES NOT INTERSECT SLOPE
The center point and radius for the circle are such that the circle does not intersect the slope.

COMPUTED SHIFT DISTANCES FOR NEWLY ESTIMATED SHEAR SURFACE FACTORED BY __ TO PREVENT OVER-SHIFT
The computer program has estimated a new position for the trial noncircular shear surface which involves more shifting of the surface than the program allows (excessive shift distances, excessive steepness, etc.). The program has applied a uniform factor to the computed shift distances for each point and proportionately reduced the distance which they were shifted. This message may be considered a "normal" message and does not designate an error condition.

COULD NOT SOLVE SUFFICIENT EQUATIONS TO INTERPOLATE PORE WATER PRESSURES
This message is printed when none of the interpolation equations used to determine pore water pressures at the center of the base of the slice could be solved (due to ill-conditioned interpolation equations). It is only applicable and printed when the interpolation option is being used to define pore water pressures. The message is not normally expected to be issued, but if this error occurs it can probably be overcome by slightly rearranging the location of the points. The slice which triggered this error will be indicated by a previous line of information when this message occurs.

CRITICAL SHEAR SURFACE NOT LOCATED TO SPECIFIED TOLERANCES WITHIN __ TRIES
The automatic search for a critical noncircular shear surface is permitted a preprogrammed number of attempts to locate the critical shear surface. (The number of attempts is indicated in the actual printed error message.) When the number of trials exceeds the preprogrammed number, the search is aborted and this message is printed. The user should either increase the size of the increment used to shift the noncircular shear surface in the input data or the

computer program must be modified internally to permit a larger number of attempts to be used before this message is issued and the search is aborted.

* D *

DENOMINATOR IN EQUATIONS FOR FACTOR OF SAFETY WAS SMALL FOR __ SLICES - FIRST AND LAST SLICES WHERE DENOMINATOR WAS LOW - __ __
A quantity which appears in the denominator of the equations used to compute the factor of safety has become small and there is a chance that an unreasonable solution may be obtained. The user should carefully examine the result for the stresses computed and printed in the final output tables for the individual slices. Ordinarily this message occurs when one of the following conditions exists: (1) There are excessive amounts of tension near the crest of the slope - a crack probably needs to be introduced, (2) Excessively high compressive stresses or various degrees of tensile stresses may exist near the toe of the slope - this unreasonable condition is likely to be indicative of a shear surface which is excessively steep near the toe of the slope, or (3) In cases where the solution for the factor of safety will not converge, the estimated value for the trial factor of safety may be excessively low - the assumed initial trial value may need to be increased.

DEPTH OF CRACK IS GREATER THAN DEPTH OF CIRCLE
The program terminates each circular shear surface at the point where the upslope (highest) end of the shear surface lies a distance equal to the specified crack depth (DCRACK) below the surface of the slope or ground. If the crack depth is greater than the greatest depth of the circle, it is impossible to terminate the end of the shear surface at a depth equal to the crack depth. Accordingly, this message will be printed.

* E *

END-OF-FILE READ IN SUBROUTINE INPUT1
The program has encountered the end of the data input file while it was attempting to read a heading (Group A data).

ERROR - A BLANK LINE WAS INPUT TO DESIGNATE HOW PORE WATER PRESSURES ARE TO BE DEFINED FOR MATERIAL __
A blank line was input with the data for the material type indicated to designate how the pore water pressures are to be defined. This error could occur if the last set of material property data were terminated with a blank line before the pore pressures have been designated.

ERROR AT SLICE __ X = __ Y = __
This message is printed when an error is detected for a particular slice. The x and y coordinates are the coordinates at the center of the base of the slice. This message will be followed by a second line of information giving more details of the specific error.

ERROR - CENTER OF FIRST GRID IS BELOW CREST OF SLOPE
Y FOR GRID = __ Y FOR CREST = __
SEARCH ABORTED
The initial estimate for the center of the critical circle, used as a starting point for an automatic search with circular shear surfaces, lies below the

crest of the slope. The crest of the slope is defined as the highest point on the slope geometry data. Although the computer program allows the center of circles to fall below the crest of the slope, the program does not allow the starting point for the search to fall below the crest of the slope. The initial estimate for the center of the critical circle needs to be modified.

ERROR COUNT LIMIT REACHED - MORE ERRORS MAY EXIST
This message indicates that the number of errors encountered while reading the data for use in interpolating pore water pressures has exceeded a preprogrammed limit in the computer program, which causes error further error checking to be abandoned. This message is designed to prevent the program from generating an excessive number of lines of output when there appears to be a major error in an extensive amount of the data. The user should correct the errors which have been printed in previous messages to this one and proceed again to execute the program with the revised data.

ERROR - END OF INITIAL TRIAL NONCIRCULAR SHEAR SURFACE AT X = __ IS ABOVE A VERTICAL SEGMENT OF THE SLOPE
One of the end points on the initial trial noncircular shear surface lies above the slope at a point where the slope is vertical. The program is unable to adjust the end-point coordinate to bring the point back on to the slope where the end point must lie. There is probably an error in either the initial trial noncircular shear surface data or the slope geometry (or soil profile line) data.

ERROR FOR DATA FOR MATERIAL TYPE __
NOT ENOUGH ANISOTROPIC SHEAR STRENGTH DATA
The data for this material indicate that the shear strength is anisotropic, yet there are less than two points to define how the shear strength varies with the orientation of the failure plane. At least two points are required.

ERROR FOR DATA FOR MATERIAL TYPE __
NOT ENOUGH DATA FOR PORE PRESSURE INTERPOLATION
The data for the material type indicated designated that the pore water pressures were to be determined by interpolation of values from "gridded" data. However, there were not at least 4 appropriate data points input for pore pressure interpolation. Data for at least 4 points are required for interpolation of pore pressures in each material where this option is used. Either the material property data must be revised to indicate how pore water pressures are to be determined in the material indicated, or additional data for interpolation of pore water pressures must be input.

ERROR FOR DATA FOR MATERIAL TYPE __
NOT ENOUGH POINTS ON NONLINEAR STRENGTH ENVELOPE
The data for this material indicate that the shear strength envelope is to be nonlinear (curved) yet there are less than two points to define the shear strength envelope. At least two points are required.

ERROR FOR DATA FOR MATERIAL TYPE __
SOMETHING IS WRONG WITH THE NEEDED PIEZOMETRIC LINE DATA - NO OR ERRONEOUS DATA FOR LINE NO. __
The data for the material type indicated designated that the pore water pressures were to be determined from the piezometric line whose number is

indicated in this message. However, there is either no data for the piezometric line or only one point was used to define the piezometric surface. At least two coordinates are required to define a piezometric line. Either the material property data need to be altered to correctly indicate how pore water pressures are to be defined for this material or the piezometric line data need to be revised/corrected.

ERROR FOR DATA FOR MATERIAL TYPE __
SOMETHING WRONG WITH MATERIAL DATA AND/OR PORE PRESSURE INTERPOLATION POINT NO. __
INCONSISTENCY REGARDING WHETHER PORE PRESSURE OR R-SUB-U DATA
The data for the material type indicated designated that the pore water pressures were to be determined by interpolation of values from "gridded" data. However, the material data indicated that values for interpolation were to be in terms of pressure, while the interpolation data indicate that the value for the designated material are values of the dimensionless pore pressure coefficient r-sub-u OR vice-versa. If pore pressure values are indicated in the material property input data, then the data for interpolation associated with this material must also be in terms of pore pressure (not r-sub-u), and similarly when values of the pore pressure coefficient r-sub-u are being used. Either the material property data or the pore pressure interpolation data must be revised for consistency.

ERROR FOR DATA FOR MATERIAL TYPE __
THE FOLLOWING ANISOTROPIC STRENGTH VALUES ARE OUT-OF-ORDER
POINT __ FAIL. PL. ORIENT. = __
POINT __ FAIL. PL. ORIENT. = __
The data defining the anisotropic shear strength values for this material are not in the proper sequence. Values must be input in the sequence of increasing values for the failure plane orientation angle. The two point numbers and corresponding failure plane orientations indicated in the printed message represent the two points where the improper sequence was detected. The anisotropic shear strength data points must be corrected.

ERROR FOR DATA FOR MATERIAL TYPE __
THE FOLLOWING POINTS FOR NONLINEAR STRENGTH ENVELOPE ARE OUT-OF-ORDER
POINT __ SIGMA = __ TAU __
POINT __ SIGMA = __ TAU __
The data defining the nonlinear (curved) shear strength envelope for this material are not in the proper sequence. Values must be input in the sequence of increasing values of the normal stress (SIGMA). The two point numbers and corresponding values of normal and shear stress in the printed message represent the two points where the improper sequence was detected. The points defining the nonlinear shear strength envelope must be corrected.

ERROR FOR NEW ESTIMATE OF SHEAR SURFACE
ERROR IN COMPUTING FACTOR OF SAFETY
An error has occurred in computing the factor of safety for the newly estimated trial noncircular shear surface during the automatic search. This message will be followed by additional message lines with more detailed information which should permit the user to detect the probable cause of the error. If the incremental distance used to shift the shear surface in the search is already at the minimum distance to be used, the search will be aborted when

this error occurs. However, if the incremental distance used for shifting is not yet at the minimum when this error occurs, the distance used for shifting will be reduced and a new attempt will be made to find a new trial shear surface.

ERROR FOR NEW ESTIMATE OF SHEAR SURFACE
ERROR IN DETERMINING PROPERTIES FOR INDIVIDUAL SLICES
An error has occurred in determining the soil properties assigned to the individual slices for the newly estimated trial noncircular shear surface during the automatic search. This message will be followed by additional message lines with more detailed information which should permit the user to detect the probable cause of the error. If the incremental distance used to shift the shear surface in the search is already at the minimum distance to be used, the search will be aborted when this error occurs. However, if the incremental distance used for shifting is not yet at the minimum when this error occurs, the distance used for shifting will be reduced and a new attempt will be made to find a new trial shear surface.

ERROR FOR NEW ESTIMATE OF SHEAR SURFACE
ERROR IN GENERATING COORDINATES FOR SHEAR SURFACE
An error has occurred in generating the coordinates along the newly estimated trial noncircular shear surface during the automatic search. This message will be followed by additional message lines with more detailed information which should permit the user to detect the probable cause of the error. If the incremental distance used to shift the shear surface in the search is already at the minimum distance to be used, the search will be aborted when this error occurs. However, if the incremental distance used for shifting is not yet at the minimum when this error occurs, the distance used for shifting will be reduced and a new attempt will be made to find a new trial shear surface.

ERROR FOR NEW ESTIMATE OF SHEAR SURFACE
SHEAR SURFACE IS FOR OPPOSITE SLOPE FACE
The new estimate for the position of the trial noncircular shear surface lies on the opposite slope face from the initial shear surface estimated to start the search. If the incremental distance used to shift the shear surface in the search is already at the minimum distance to be used, the search will be aborted when this error occurs. However, if the incremental distance used for shifting is not yet at the minimum when this error occurs, the distance used for shifting will be reduced and a new attempt will be made to find a new trial shear surface.

ERROR FOR PIEZOMETRIC LINE NO. __
NOT ENOUGH POINTS
Only one coordinate point has been entered to define the piezometric line indicated. At least two coordinates are required to define a piezometric line. Data for the piezometric line should be corrected.

ERROR FOR PIEZOMETRIC LINE NO. __
POINT ON THE FOLLOWING SEGMENT ARE OUT-OF-ORDER
POINT __ X = __ Y = __
POINT __ X = __ Y = __
The coordinate points for the piezometric line indicated are not in the sequence of increasing x coordinate value. The two points with numbers and

coordinates printed in the error message are the two points which are not in the proper order. Points must be specified in a left-to-right sequence, although x coordinates may be repeated to define a vertical piezometric line segment.

ERROR FOR PORE PRESSURE INTERPOLATION POINT NO. __
MATERIAL TYPE = __ IS NOT ALLOWED
The material type indicated for the designated pore pressure interpolation data point is either zero, negative, or exceeds the maximum number of material types allowed by the dimensioned size of arrays in the computer program. The material type for the pore pressure interpolation point needs to be corrected.

ERROR FOR PROFILE LINE NO. __ - POINTS OUT-OF-ORDER
POINT __ X = __ Y = __
POINT __ X = __ Y = __
The profile line coordinate points are not in the sequence of increasing x coordinate value. The two points with numbers and coordinates printed in the error message are the two points which are not in the proper order.

ERROR FOR REINFORCEMENT LINE NO. __ - POINTS OUT-OF-ORDER
POINT __ X = __ Y = __
POINT __ X = __ Y = __
The reinforcement line coordinate points are not in the sequence of increasing x coordinate value. The two points with numbers and coordinates printed in the error message are the two points which are not in the proper order.

ERROR FOR THE ABOVE POINT
PIEZOMETRIC LINE NO. NOT ALLOWED - MAX. ALLOWED = __
The piezometric line number which has been specified for a piezometric line which is to be modified is either zero, negative, or exceeds the maximum number of piezometric lines allowed by the dimensioned capacity of the program's arrays. This message will be preceded by the line of data for the profile line which caused the error.

ERROR FOR THE ABOVE POINT
PIEZOMETRIC LINE NOT PREVIOUSLY DEFINED
The piezometric line number specified for a piezometric line which is to be modified has not been previously defined and, thus, cannot be modified. This message will be preceded by the line of data for the piezometric line which caused the error.

ERROR FOR THE ABOVE POINT
PIEZOMETRIC LINE POINT NOT PREVIOUSLY DEFINED
The point on the specified piezometric line which is to be modified has not been previously defined and, thus, cannot be modified. The number of the point specified is either zero, negative, or exceeds the number of points which has been previously defined for the designated piezometric line. This message will be preceded by the line of data for the piezometric line which caused the error.

ERROR FOR THE ABOVE POINT
PROFILE LINE NO. NOT ALLOWED - MAX. ALLOWED = __
The profile line number which has been specified for a profile line which is to be modified is either zero, negative, or exceeds the maximum number of profile lines allowed by the dimensioned capacity of the program. This message will be preceded by the line of data for the profile line which caused the error.

ERROR FOR THE ABOVE POINT
PROFILE LINE NOT PREVIOUSLY DEFINED
The profile line number specified for a profile line which is to be modified has not been previously defined and, thus, cannot be modified. This message will be preceded by the line of data for the profile line which caused the error.

ERROR FOR THE ABOVE POINT
PROFILE LINE POINT NOT PREVIOUSLY DEFINED
The point on the specified profile line which is to be modified has not been previously defined and, thus, cannot be modified. The number of the point specified is either zero, negative, or exceeds the number of points which has been previously defined for the designated profile line. This message will be preceded by the line of data for the profile line which caused the error.

ERROR FOR THE FOLLOWING SLOPE COORDINATES - POINTS OUT-OF-ORDER
POINT __ X = __ Y = __
POINT __ X = __ Y = __
The slope coordinate points are not in the sequence of increasing x coordinate value. The two points with numbers and coordinates printed in the error message are the two points which are not in the proper order.

ERROR FOR THE FOLLOWING SURFACE PRESSURE POINTS
POINT __ X = __ Y = __
POINT __ X = __ Y = __
NONZERO PRESSURE ON VERTICAL SLOPE
Surface pressures cannot be specified on a vertical slope. A vertical slope will coincide with a portion of a vertical boundary between slices and forces on all such vertical boundaries are considered to be "lumped" together in the side forces. If surface pressures must be specified on a vertical boundary, the slope should be given a very slight inclination from the vertical, such that surface pressures can be legally specified.

ERROR FOR THE FOLLOWING SURFACE PRESSURE POINTS
POINT __ X = __ Y = __
POINT __ X = __ Y = __
THE POINTS ARE OUT-OF-ORDER
The coordinates of the points where the surface pressures are specified are not in the sequence of increasing x coordinate value. The two points with numbers and coordinates printed in the error message are the two points which are not in the proper order.

ERROR IN COMPUTING SHIFT INVOLVING MOVING POINT A DISTANCE __ ALONG OR PARALLEL TO SLOPE
An error has been detected when moving one of the two end points of the non-circular shear surface along the slope or parallel to the slope(in the case of a vertical crack). This message should be followed by additional message lines with further details of the error - See other error descriptions in this listing of error messages.

ERROR IN CURVED FAILURE ENVELOPE AT SLICE __ - NORMAL STRESS = __
NORMAL STRESS OUTSIDE RANGE OF VALUES FOR ENVELOPE
The computed normal stress on the base of the slice (slice number indicated) is either less than the lowest normal stress specified in the input data to define the nonlinear shear strength envelope or greater than the largest values specified in the input data for the envelope. The range of values used in the input data may need to be extended or, in the case where the normal stresses are tensile it may be more appropriate to introduce a vertical crack, rather than to extend the failure envelope into the range of negative (tensile) normal stresses.

ERROR IN DATA DESIGNATING IF POINTS ARE TO BE ADDED OR REPLACED -
THE FOLLOWING LINE OF DATA WAS INPUT -

_____
THE LINE SHOULD BE BLANK OR CONTAIN A CHARACTER STRING BEGINNING WITH THE LETTER A OR R
NOTE - TWO BLANK LINES ARE REQUIRED TO TERMINATE ALL DATA FOR PORE WATER PRESSURE INTERPOLATION
The program has attempted to read a line of data for interpolation of pore water pressures designating whether the values which are to follow are to be added to the existing data for pore pressure interpolation or are to replace existing data for pore pressure interpolation (the Modify mode of input is in effect). Either the line of data must contain a character string beginning with the letter "A" (for Add) or "R" (for Replace), or the line of input must be blank. This error may occur when the user has intended to terminate all of the data for interpolation of pore water pressures, but has forgotten to include two blank lines following the last numerical values input.

ERROR IN DATA DESIGNATING IF PORE WATER PRESSURES OR R-SUB-U VALUES ARE TO BE INPUT - THE FOLLOWING LINE OF DATA WAS INPUT -

_____
THE LINE SHOULD BE BLANK OR CONTAIN A CHARACTER STRING BEGINNING WITH THE LETTER P OR R
NOTE - TWO BLANK LINES ARE REQUIRED TO TERMINATE ALL DATA FOR PORE WATER PRESSURE INTERPOLATION
The program has attempted to read a line of data for interpolation of pore water pressures designating whether the values which are to follow are values of pressures or the dimensionless coefficient r-sub-u. Either the line of data must contain a character string beginning with the letter "P" or "R", or the line of input must be blank. This error may occur when the user has intended to terminate all of the data for interpolation of pore water pressures, but has forgotten to include two blank lines following the last numerical values input.

ERROR IN READING CONSTANT PORE PRESSURE
Some form of format related error has been encountered while the program was reading the line of data containing the value of the pore water pressure when the pore water pressures have been designated as being constant within the current material. This message will be preceded by another message giving more specific detail pertaining to this error.

ERROR IN READING CONSTANT R-SUB-U
Some form of format related error has been encountered while the program was reading the line of data containing the value of the pore pressure coefficient r-sub-u when the pore water pressures have been designated as being defined by a constant value of r-sub-u within the current material. This message will be preceded by another message giving more specific detail pertaining to this error.

ERROR IN READING COORDINATES OR POINT FOLLOWING POINT __ ON PIEZOMETRIC LINE NO. __
Some form of formatting error has been encountered while reading the coordinates of points on the piezometric line. The point number indicated in the above error message is the number of the point which was last read successfully. This message will be preceded by another message giving more detail.

ERROR IN READING DATA FOR PORE PRESSURE INTERPOLATION
Some form of formatting error has been encountered while reading the data containing the x,y coordinates, pressure (or r-sub-u value) and material type for one of the data points to be used for interpolation of values of pore water pressure (or r-sub-u). This message will be preceded by another message giving more detail.

ERROR IN READING DATA FOR REPLACEMENT POINT
Some form of formatting error has been encountered while reading the data containing the point number, x and y coordinates, pressure (or r-sub-u value) and material type for one of the pore pressure interpolation data points which is being modified (the Modify mode of input is in effect). This message will be preceded by another message giving more detail.

ERROR IN READING DATA TO MODIFY PIEZOMETRIC LINE COORDINATES
Some form of formatting error has been encountered while reading the data containing the line number, point number and new coordinates for a piezometric line point which is to be modified. This message will be preceded by another message giving more detail.

ERROR IN READING DATA TO MODIFY PROFILE LINE COORDINATES
Some form of formatting error has occurred while reading the data containing the line number, point number and new coordinates for a profile line point which is to be modified. This message will be preceded by another message giving more detail.

ERROR IN READING FIRST LINE OF DATA (MATERIAL TYPE/LABEL) FOR ONE OF THE SETS OF MATERIAL DATA
Some form of formatting error has been encountered while reading the data containing the number and the label for one of the sets of material property

data. This message will be preceded by another message giving more detail regarding the source of the error.

ERROR IN READING PIEZOMETRIC LINE NUMBER
Some form of format related error has been encountered while the program was reading the line of data containing the number of the piezometric line when the pore pressures have been designated as being defined by a piezometric line for the current material. This message will be preceded by another message giving more specific detail pertaining to this error.

ERROR IN READING PROFILE LINE COORDINATES
Some form of formatting error has occurred while reading the coordinates of points on the profile line. This message will be preceded by another message giving more detail.

ERROR IN READING PROFILE LINE NUMBER AND/OR MATERIAL TYPE
Some form of formatting error has occurred while reading the profile line number or material type. This message will be preceded by another message giving more detail.

ERROR IN READING SHEAR STRENGTH DATA
Some form of formatting error has been encountered while reading a line of data containing the shear strength values for the current material. This message will be preceded by another message giving more detail.

ERROR IN READING THE NUMBER OF THE PIEZOMETRIC LINE TO BE INPUT
Some form of format related error has been encountered while the program was reading the data used to define the piezometric line. The line of data containing the number of the piezometric line (and, optionally, the unit weight of fluid for the piezometric line) contains some form of improperly formatted data. This message will be preceded by another message giving more specific detail pertaining to this error.

ERROR IN READING UNIT WEIGHT
Some form of formatting error has occurred while reading the unit weight for the current material. This message will be preceded by another message giving more detail.

ERROR - NO MATERIAL PROPERTY DATA
The program has been directed to perform computations by the Command Word "COMPUTE" or the Command Word "NO COMPUTE" has been entered before any material property data have been entered. Data for at least one material are required for the program to perform computations.

ERROR - NO ANALYSIS/COMPUTATION (GROUP H) DATA
The program has been directed to perform computations by the Command Word "COMPUTE" or the Command Word "NO COMPUTE" has been entered before any data have been entered for the analysis and computations.

ERROR - NO PROFILE LINE DATA
The program has been directed to perform computations by the Command Word "COMPUTE" or the Command Word "NO COMPUTE" has been entered before any profile

line data have been entered. Data for at least one profile are required for the program to perform computations.

ERROR - SEGMENT NO. __ OF PROFILE LINE NO. __ AND SEGMENT NO. __ OF PROFILE LINE NO. __ COINCIDE

Two profile lines have segments which coincide for at least a portion of their length. This is not allowed - the program cannot determine which of the two profile lines is applicable to the material below the profile line segment where the two lines coincide. Note: The order in which profile lines are numbered and input has no effect. Each profile line is treated entirely independently of the other.

ERROR - SHEAR SURFACE WAS STEEPER THAN PRESCRIBED MAXIMUM INCLINATION ALLOWED NEAR TOE AND COULD NOT BE ADJUSTED TO A FLATTER ANGLE

INPUT DATA PROBABLY NEED TO BE CHANGED

During the automatic search for a critical noncircular shear surface the inclination of the shear surface near the toe of the slope has exceeded the prescribed maximum allowable inclination and could not be adjusted by the program. Ordinarily this error will occur because the initial trial noncircular shear surface was excessively steep near the toe of the slope. Either the initial trial shear surface should be changed or the limiting (allowable) steepness should be increased. The default limiting steepness is 50 degrees and unless specifically specified otherwise by the user as part of the input data the default value will be used.

ERROR - THE MATERIAL TYPE NUMBER INPUT WAS = __

NOT ALLOWED - MAXIMUM NUMBER ALLOWED = __

The material type number input was either zero, negative, or exceeded the maximum number of materials allowed by the program's dimensioned size of arrays. The array size is indicated in the printed error message. Either the data need to be corrected or the size of the arrays must be increased by a programmer.

ERROR - THE PIEZOMETRIC LINE NUMBER INPUT WAS = __

NOT ALLOWED - MAXIMUM NUMBER ALLOWED = __

The piezometric line number input was either zero, negative, or exceeded the maximum number allowed by the dimensioned size of the program's arrays. The array size is indicated in the printed error message. Either the data need to be corrected or the size of arrays must be increased by a programmer.

ERROR - THE PROFILE LINE NUMBER INPUT WAS = __

NOT ALLOWED - MAXIMUM NUMBER ALLOWED = __

The profile line number input was either zero, negative, or exceeded the maximum number allowed by the dimensioned size of the program's arrays. The array size is indicated in the printed error message. Either the data need to be corrected or the size of arrays must be increased by a programmer.

ERROR - TOO MANY PROFILE LINE POINTS - MAX. ALLOWED = __

The number of profile line coordinate points has exceeded the capacity of the program as determined by the dimensioned size of arrays used to store the coordinate values. The maximum number of points allowed on any line is indicated in the error message. The user must either change the input data or the dimensioned size of arrays must be increased by an experienced programmer. As an alternative to increasing the dimensioned size of arrays the user may break the profile line into a number of smaller portions, each with the acceptable number of points.

ERROR - YOU HAVE ATTEMPTED TO DEFINE (REINPUT) A PROFILE LINE WHICH WAS JUST DEFINED
The data for the profile line which was just entered were previously entered in the same batch of data following the Command Word "PROfile line data". It does not make sense to define and then redefine profile lines without an intermediate set of computations. Accordingly, any attempt to do so is considered an error by the program. Data must be corrected in an appropriate manner.

ERROR - YOU HAVE ATTEMPTED TO DEFINE (REINPUT) A SET OF MATERIAL PROPERTIES WHICH WAS JUST DEFINED
The data for the material properties which was just entered were previously entered in the same batch of data following the Command Word "MATerial property data". It does not make sense to define and then redefine material properties without an intermediate set of computations. Accordingly, any attempt to do so is considered an error by the program. Data must be corrected in an appropriate manner.

* F *

FACTOR OF SAFETY BECAME SMALLER THAN __
The factor of safety has become smaller than the minimum (preprogrammed) value allowed by the computer program. The minimum value allowed is indicated in the error message.

FATAL ERROR FOR INITIAL TRIAL CIRCLE FOR AUTOMATIC SEARCH
SEARCH ABORTED - See Message on Next Line(s)
The program has encountered an error while attempting to generate the coordinates along the initial trial circular shear surface which is to be used for an automatic search. Information printed on subsequent line after this message should give more details concerning the problem.

FATAL ERROR FOR INITIAL TRIAL SURFACE - SEARCH ABORTED
ERROR IN COMPUTING FACTOR OF SAFETY
An error has occurred in computing the factor of safety for the initial trial noncircular shear surface used in an automatic search. This message will be followed by additional message lines with more detailed information which should permit the user to detect the probable cause of the error.

FATAL ERROR FOR INITIAL TRIAL SURFACE - SEARCH ABORTED
ERROR IN DETERMINING PROPERTIES FOR INDIVIDUAL SLICES
An error has occurred in determining the soil properties assigned to the individual slices for the initial trial noncircular shear surface used in an automatic search. This message will be followed by additional message lines with more detailed information which should permit the user to detect the probable cause of the error.

FATAL ERROR FOR INITIAL TRIAL SURFACE - SEARCH ABORTED
ERROR IN GENERATING COORDINATES FOR SHEAR SURFACE
An error has occurred in generating the coordinates along the initial trial noncircular shear surface used in an automatic search. This message will be followed by additional message lines with more detailed information which should permit the user to detect the probable cause of the error.

FATAL ERROR FOR SLICE __ - DENOMINATOR IN EQUATIONS FOR FACTOR OF SAFETY BECAME SMALLER THAN ALLOWED - DENOMINATOR = __
A quantity which appears in the denominator of the equations used to compute the factor of safety has become excessively small and there is a chance that division by a number approaching zero may occur. Accordingly, the iterative solution for the factor of safety has been aborted. Ordinarily this message occurs when one of the following conditions exists: (1) There are excessive amounts of tension near the crest of the slope - a crack probably needs to be introduced or (2) Excessively high compressive stresses or various degrees of tensile stresses may exist near the toe of the slope - this unreasonable condition is likely to be indicative of a shear surface which is excessively steep near the toe of the slope.

FINAL NUMBER OF SHEAR SURFACE COORDINATES EXCEEDED THE ALLOWABLE MAXIMUM
MAXIMUM NUMBER ALLOWED = __
The combined number of noncircular shear surface coordinates (= number of slices plus one) which were specified by the input data and are required (e.g. where the shear surface crosses a profile line) has exceeded the dimensioned size of arrays. The computer program cannot eliminate coordinates specified by the input data or required by the program. Thus, this message is a fatal error which requires that the shear surface be abandoned. The user must either reduce the number of specified coordinates on the shear surface (or number of profiles lines, etc.) or the dimensioned size of arrays used to store the shear surface coordinates and information for individual slices must be increased.

FOR TRIAL NUMBER __ WITH A NONLINEAR STRENGTH ENVELOPE THE MAXIMUM PERCENT CHANGE IN SHEAR STRENGTH WAS __ - AT SLICE __
An iterative procedure is used to arrive at the shear strengths using a nonlinear shear strength envelope: A shear strength is estimated, the factor of safety and corresponding normal stresses on the shear surface (base of slices) are calculated, and a new estimate of the shear strength is made. This message is printed after each iteration in which the shear strength is adjusted (actually on each "iteration" there are also several iterations to compute the factor of safety for the given estimate of the shear strength). This message indicates the number of the trial, the maximum percent change in shear strength (based on an examination of the changes for all slices) and the number of the slice where the maximum change occurred. The "percent change" is computed by taking the difference between the shear strength assumed and the new shear strength computed (using in both cases the normal stress calculated with the assumed shear strength) and dividing the difference by the largest of the two shear strength values (assumed and new estimate).

* I *

ILLEGAL MATERIAL TYPE FOR PROFILE LINE __ - MATERIAL TYPE = __
The material type specified in the input data for the designated profile line is zero, negative, or exceeds the maximum number of materials allowed.

ILLEGAL VALUES FOR ALLOWED FORCE AND/OR MOMENT IMBALANCE - RESPECTIVE VALUES = __ __
The specified value of either (or both) the allowable force imbalance is (are) zero or negative. Both the values must be positive, nonzero quantities.

INSUFFICIENT PIEZOMETRIC LINE DATA - PIEZOMETRIC LINE NO. __
This message indicates that the piezometric line data does not extend far enough laterally to include the base of a particular slice. The base of the slice has been detected to lie in a material where pore water pressures are to be determined from a piezometric line, but the data are insufficient. The piezometric line data need to be extended to cover this slice. The slice which triggered this error will be indicated by a previous line of information when this message occurs.

ILLEGAL PROCEDURE FOR COMPUTING FACTOR OF SAFETY
PROCEDURE NOT ALLOWED FOR NONCIRCULAR SHEAR SURFACES
The procedure which has been selected for computing the factor of safety (Simplified Bishop) is not applicable to noncircular shear surfaces. Noncircular shear surfaces have been specified for this procedure. Either the procedure must be changed or circular shear surfaces must be used.

* N *

NEGATIVE CRACK DEPTH NOT ALLOWED
A negative value has been detected for the depth of vertical crack to be used with a circular shear surface. The crack depth must be zero or positive.

NEGATIVE DEPTH FOR FLUID IN CRACK IS NOT ALLOWED
The specified depth for the fluid in the vertical crack is negative. The depth of fluid must be either zero or positive.

NEGATIVE UNIT WEIGHT FOR FLUID IN CRACK IS NOT ALLOWED
The specified unit weight for the fluid in a vertical crack is negative. The unit weight of fluid must be either zero or positive.

NO ANISOTROPIC STRENGTH DATA FOR FAILURE PLANE ANGLE OF __ DEGREES
This message indicates that the inclination of the base of a slice, which corresponds to a "failure plane inclination," falls outside the range of values for which anisotropic shear strength values have been input. The computer program will not extrapolate values. The user should input values for a wider range of failure plane inclinations to overcome this error. The slice which triggered this error will be indicated by a previous line of information when this message occurs.

NO DATA FOR MATERIAL TYPE __ FOR PROFILE LINE NO. __
No material property data were input for the material type indicated. The material type indicated has been designated as the material type for the profile

line whose number is given in this error message. Either the wrong material type has been input for the designated profile line or material data have been improperly omitted from the input data.

NO NUMERICAL VALUE INPUT FOR NUMBER OF THE PIEZOMETRIC LINE TO BE USED
The program did not detect a leading numerical value on the line of input data where the number of the piezometric line to be used for this material was expected (for the case where the pore pressures for the current material have been designated as being defined by a piezometric line). Something is wrong with the data for the piezometric line number or the piezometric line number has been omitted from the data for the current material. This message could occur if the pore pressures for the last (final) set of material data are specified as being defined by a piezometric line and, then, the data are terminated by a blank line before the value of the pore water pressure has been entered.

NO NUMERICAL VALUE INPUT FOR PORE PRESSURE
The program did not detect a leading numerical value on the line of input data where the value of the pore water pressure was expected (for the case where the pore pressures for the current material have been designated as being defined by a constant value of pressure). Something is wrong with the data for the pore pressure or the pore pressure has been omitted from the data for the current material. This message could occur if the pore pressures for the last (final) set of material data are specified as being constant and, then, the data are terminated by a blank line before the value of the pore water pressure has been entered.

NO NUMERICAL VALUE INPUT FOR R-SUB-U
The program did not detect a leading numerical value on the line of input data where the value of the pore pressure coefficient was expected (for the case where the pore pressures for the current material have been designated as being defined by a constant value of the pore pressure coefficient, r-sub-u). Something is wrong with the data for the pore pressure coefficient or the pore pressure coefficient has been omitted from the data for the current material. This message could occur if the pore pressures for the last (final) set of material data have been specified as being defined by a constant value of the pore pressure coefficient and, then, the data have been terminated by a blank line before the value of the pore pressure coefficient has been entered.

NO NUMERICAL VALUE INPUT FOR UNIT WEIGHT
The program did not detect a leading numerical value on the line of input data where the unit weight of the material was expected. Something is wrong with the data for the unit weight or the unit weight has been omitted from the data for the current material.

NO NUMERICAL VALUE INPUT TO DESIGNATE THE NUMBER OF THE PIEZOMETRIC LINE WHICH IS BEING (TO BE) DEFINED
0 VALUE(S) WAS/WERE INPUT - 1 IS/ARE REQUIRED
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

NOTE - TWO BLANK LINES REQUIRED TO TERMINATE ALL PIEZOMETRIC LINE DATA
The program did not detect a numerical value on the line of input data where the number of the piezometric line was expected. There is some error in the

input data used to define the individual piezometric lines. This error could occur if the sets of coordinates for the last piezometric line defined are not terminated by two blank lines before resuming with Command Words.

NO PROFILE DATA FOR SLICE
No profile lines were found to exist for any of the portion of the slice above the base of the slice. (The slice which triggered this error will be indicated by a previous line of information when this message occurs.)

NO PROFILE DATA FOR TOP OF SLICE
There are no profile lines crossing some upper portion of the slice. (The slice which triggered this error will be indicated by a previous line of information when this message occurs). It is possible that this message may be printed due to roundoff error where the program computes that the top of the slice is a very small distance above the uppermost profile line. This may indicate that one of the tolerances in the program used to "trap" round-off errors needs to be adjusted for the particular computer system being used. Care should be used in adjusting such tolerances or other errors may be introduced.

NOT ENOUGH NUMERICAL VALUES FOR COHESION AND FRICTION ANGLE
The program has attempted to read a cohesion value and friction angle for a material with the shear strength defined in the "conventional" manner and encountered less than two numerical values on the line of input data. Two numerical values are required on the line of input data for "conventional" shear strength characterization.

NOT ENOUGH NUMERICAL VALUES INPUT FOR LINE OR ANISOTROPIC SHEAR STRENGTH DATA
__ VALUE(S) WAS/WERE INPUT - EVEN MULTIPLES OF 3 ARE REQUIRED -
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

_____

The line of input data defining the variation in shear strength with the orientation of the failure plane did not contain an even multiple of three values for failure plane orientation and strength parameters. This error may be encountered when the user has intended to terminate the anisotropic shear strength values, but has omitted the blank line to terminate the values.

NOT ENOUGH NUMERICAL VALUES WERE INPUT TO DEFINE COORDINATES OR A POINT ON THE PIEZOMETRIC LINE
__ VALUES(S) WAS/WERE INPUT __ EVEN MULTIPLES OF 2 ARE REQUIRED -
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

____

NOTE - BLANK LINE REQUIRED TO TERMINATE DATA
The line of input data defining the coordinates of points along the piezometric line did not contain an even multiple of two values, representing pairs of x,y values. This error may be encountered when the user has intended to terminate the coordinates for a given profile line, but has omitted the blank line required to terminate the data.

NOT ENOUGH NUMERICAL VALUES INPUT TO DEFINE INTERPOLATION POINT
__ VALUE(S) WAS/WERE INPUT - EVEN MULTIPLES OF 4 ARE REQUIRED -
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

____
NOTE - A BLANK LINE IS REQUIRED TO TERMINATE THE CURRENT SERIES OF INTERPOLATION DATA
NOTE - TWO BLANK LINES ARE REQUIRED TO TERMINATE ALL DATA FOR PORE WATER PRESSURE INTERPOLATION
The line of input data containing the data points to be used for interpolation of values of either pore water pressure or r-sub-u line did not contain an even multiple of four values (x,y coordinates, pressure or r-sub-u value, and material type). This error may be encountered when the user has intended to terminate the interpolation data, but has omitted the necessary blank line or lines.

NOT ENOUGH NUMERICAL VALUES INPUT TO DEFINE LINEAR VARIATION IN STRENGTH WITH DEPTH BELOW GIVEN REFERENCE ELEVATION
The program has attempted to read the value of the shear strength at a designated reference elevation, the value of the reference elevation, and the rate at which the shear strength increases with depth below the reference elevation for the current material. Less than three numerical values were encountered on the line of input data; at least three numerical values must be contained on a single line of the input data.

NOT ENOUGH NUMERICAL VALUES INPUT TO DEFINE LINEAR VARIATION IN STRENGTH WITH DEPTH BELOW PROFILE LINE
The program has attempted to read the value of the shear strength along the profile line and the rate at which the shear strength increases with depth below the profile line for the current material. Less than two numerical values were encountered on the line of input data; at least two numerical values must be contained on a single line of the input data.

NOT ENOUGH NUMERICAL VALUES WERE INPUT TO DEFINE COORDINATES OF THE CURRENT PROFILE LINE POINT
__ VALUE(S) WAS/WERE INPUT - EVEN MULTIPLES OF 2 ARE REQUIRED -
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

____
NOTE - BLANK LINE REQUIRED TO TERMINATE DATA
The line of input data for coordinates on the current profile line did not contain an even multiple of two values for coordinates. This error may be encountered when the user has intended to terminate the profile line coordinates, but has omitted the blank line to terminate the data for the given profile line.

NOT ENOUGH NUMERICAL VALUES WERE INPUT TO DEFINE THE CURRENT POINT ON THE NONLINEAR SHEAR STRENGTH ENVELOPE
__ VALUE(S) WAS/WERE INPUT - EVEN MULTIPLES OF 2 ARE REQUIRED -
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

____
The line of input data defining the points on a nonlinear (curved) shear strength envelope did not contain an even multiple of two values. This error may be encountered when the user has intended to terminate the values defining

the nonlinear shear strength envelope, but has omitted the blank line to terminate the values.

NOT ENOUGH NUMERICAL VALUES WERE INPUT TO DEFINE THE PROFILE LINE NUMBER AND MATERIAL TYPE
__ VALUE(S) WAS/WERE INPUT - 2 IS/ARE REQUIRED
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

NOTE - TWO BLANK LINES REQUIRED TO TERMINATE ALL PROFILE LINE DATA
The line of input data to define the number of the profile line and associated material type (Group B data) did not contain a pair of numerical values. Two numerical values are required; the first for the profile line number, the second for the material type. This error may be encountered when the user has intended to terminate the profile line data and return to input of Command Words, but has omitted the two blank lines to terminate all profile line data.

NOT ENOUGH NUMERICAL VALUES WERE INPUT TO IDENTIFY THE MATERIAL TYPE CURRENTLY BEING DEFINED
__ VALUE(S) WAS/WERE INPUT - 1 IS/ARE REQUIRED
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

NOTE - BLANK LINE REQUIRED TO TERMINATE DATA
The program was attempting to read the number of the material type for a set of material property data; however, the line of input data did not contain a leading numerical value. The material type is apparently missing from a line of input data. This error may be encountered when the user intended to terminate the material property data and return to reading Command Words, but has omitted a blank line at the end of the material property data.

NOT ENOUGH NUMERICAL VALUES WERE INPUT TO MODIFY THE COORDINATES OF THE CURRENT PROFILE LINE POINT
__ VALUE(S) WAS/WERE INPUT - EVEN MULTIPLES OF 4 ARE REQUIRED -
THE ERROR WAS DETECTED FOR THE FOLLOWING LINE OF INPUT

NOTE - BLANK LINE REQUIRED TO TERMINATE DATA
The line of input data to modify the coordinates of a point or points on profile lines did not contain a suitable number of quantities. This error may be encountered when the user has intended to terminate the data modifying profile line coordinates, but has omitted the blank line which terminates the data in Modify Mode.

NOT ENOUGH (OR NO) SLOPE DATA
There is no slope data. Probably only one data point was entered to define the slope geometry, otherwise the program would have automatically generated data from the profile line data.

NOT ENOUGH POINTS FOR NONCIRCULAR SHEAR SURFACE
The number of points on either an individually selected noncircular shear surface or the initial trial noncircular shear surface for an automatic search is less than two. At least two coordinate points are required to define a noncircular shear surface. Additional data points should be added to the input data.

NOT ENOUGH POINTS FOR PROFILE LINE NO. __ - NO. OF POINTS = __
Only one point has been entered for the profile line indicated. At least two coordinate points are required to define a profile line.

NOT ENOUGH POINTS FOR REINFORCEMENT LINE NO. __ - NO. OF POINTS = __
Only one point has been entered for the reinforcement line indicated. At least two coordinate points are required to define a reinforcement line.

NOT ENOUGH POINTS TO INTERPOLATE FOR PORE PRESSURE
The program could not find one point in at least three of the four quadrants surrounding the point on the center of the base of the slice where pore water pressures are being determined by interpolation. Additional points may need to be added to the interpolation data, especially along the boundaries (edges) of zones where pore water pressures are to be determined by interpolation. (Note: Points can actually lie outside the material in which they are being used for interpolation.) The slice which triggered this error will be indicated by a previous line of information when this message occurs.

NOT ENOUGH SURFACE PRESSURE POINTS
Only one point has been entered to define the surface pressures on the slope. Surface pressures must be defined at at least two coordinate points.

NUMBER OF REQUIRED SHEAR SURFACE COORDINATES EXCEEDED THE ALLOWABLE STORAGE CAPACITY OF ARRAYS (X AND Y) - MAX. ALLOWED = __
In generating the coordinates for a circular shear surface the program computes, stores, and discards duplicates of coordinates of points on the shear surface which are required, e.g. where the shear surface intersects the profile lines. This message is printed when the number of points stored exceeds the dimensioned capacity of the program for the total number of points on a shear surface (= maximum number of slices minus one). The size of the arrays used to store shear surface coordinates, as well as a variety of other information for individual slices, needs to be changed.

NUMBER OF REQUIRED PLUS SPECIFIED SHEAR SURFACE COORDINATES STORED ON A TEMPORARY BASIS EXCEEDED THE ALLOWABLE STORAGE CAPACITY - MAX. ALLOWED = __
In generating the coordinates for a shear surface the program computes and stores, on a temporary basis, coordinates of points on the shear surface which are required, e.g. where the shear surface intersects the profile lines (the computed points which are stored may include some duplicates); the coordinates which were specified in the input data are added to the required coordinates and stored in the temporary storage arrays. This message is printed when the number of points stored exceeds the dimensioned size of the temporary storage arrays. The size of the temporary storage arrays (XSTORD and YSTORD) needs to be increased in the computer program.

NUMBER OF REQUIRED SHEAR SURFACE COORDINATES STORED ON A TEMPORARY BASIS EXCEEDED THE ALLOWABLE STORAGE CAPACITY - MAX. ALLOWED = __
In generating the coordinates for a shear surface the program computes and stores, on a temporary basis, coordinates of points on the shear surface which are required, e. g. where the shear surface intersects the profile lines (The computed points which are stored may include some duplicates). This message is printed when the number of points stored exceeds the dimensioned size of

the temporary storage arrays. The size of the temporary storage arrays (XSTORD and YSTORD) needs to be increased in the computer program.

* O *

Only one slice generated - CIRCLE REJECTED
The specified (or default) value of either the subtended angle or slice arc length used to subdivide the circular shear surface into slices was sufficiently large that only one slice was generated. Either the values of the parameters which control the slice generation should be altered to increase the number of slices generated or the circle is one that just barely intersects the slope and is of no interest to the user. The user should ascertain if this message (error?) is of practical significance for the problem being solved.

Opposite slope face - CIRCLE REJECTED
This message is printed for a given trial circle attempted during an automatic search when the circle falls on the opposite slope face from the circle which was specified in the input data as the initial trial circle. The program does not permit the automatic search to "jump" from one slope face to another.

* S *

SHEAR SURFACE COORDINATE AT X = __ AND Y = __ WAS SHIFTED BEYOND LIMITS OF THE SLOPE
During the automatic search with noncircular shear surfaces the program has attempted to shift one of the end points on the shear surface beyond the end points of the lines defining the slope geometry. The data defining the slope geometry probably need to be extended further. The x and y coordinates of the shear surface point which was being shifted are printed with this message.

SHEAR SURFACE IS ON OPPOSITE SLOPE FACE - REJECTED
During an automatic search for a critical noncircular shear surface a trial shear surface has fallen on the opposite slope face from the slope face for which the search was initiated. The program does not permit the search to "jump" slope faces from the one for which the search was initiated. If the opposite face is to be analyzed, a search should be initiated with an initial trial noncircular shear surface on the opposite slope face.

SHEAR SURFACE SEGMENT BETWEEN POINTS __ and __ CROSSES SLOPE BETWEEN POINTS __ AND __ AFTER SHIFT - THIS TRIAL SHEAR SURFACE WAS REJECTED
As indicated, when a point on the shear surface was temporarily shifted, the point resulted in a segment of the shear surface intersecting a segment of the lines defining the slope geometry. The temporary shift was not used - this message normally does not result in an error in the final solution unless it occurs on the final shifting, just prior to locating the critical shear surface. If the error occurs on the final shifting, another shear surface configuration of direction for shifting some points may be needed to find the most critical shear surface.

SOLUTION FOR FACTOR OF SAFETY DID NOT CONVERGE WITHIN __ ITERATIONS
The iterative solution for the factor of safety did not converge within the prescribed maximum number of iterations allowed. The user may need to

increase the allowable number of iterations. Convergence is sometimes improved by overestimating the value of the factor of safety rather than underestimating the value. Convergence problems are sometimes caused when (1) there is excessive tension near the crest of the slope (a vertical crack may need to be introduced) and (2) when the shear surface is excessively steep near the toe of the slope (the shear surface inclination should approach that expected for a critical "passive" wedge as determined by earth pressure theories).

SOMETHING IS WRONG IN DO LOOP 260 IN SUBROUTINE INTERP
This error message should never be printed. It indicates that the program has become confused while interpolating pore water pressures at the base of a particular slice. The program cannot determine in which quadrant an interpolation point lies. The user should contact S. G. Wright if this message ever occurs. The slice which triggered this error will be indicated by a previous line of information when this message occurs.

SOMETHING IS WRONG WITH A SMALL TOLERANCE CHECK IN CALCFS
QI = __ SMALLQ = __
MCENTB = __ SMALLM = __
One of the error tolerances which is computed by the program and used to check to avoid division by zero is inconsistent with other numerical values. This error occurs in the iterative solution for the factor of safety using Spencer's procedure - the user should contact S. G. Wright for remedy if this problem and message occurs. This error message should not ordinarily be printed.

SOMETHING IS WRONG WITH RADII IN SUBROUTINE SERCH1 BETWEEN STATEMENTS 640 and 700
This error message should never be printed. The program has become confused or obtained erroneous results pertaining to the radius of the critical circle. The user should contact S. G. Wright if this error occurs.

SPECIFIED INPUT FOR MAX. SLICE BASE LENGTH AND SLICE SUBDIVISION RESULTED IN MORE THAN __ COORDINATES - MAX. SLICE BASE LENGTH RESET TO __
Either the maximum slice base length or approximate maximum number of slices used for subdivision of the noncircular shear surface into slices resulted in more slices than the program was capable of accommodating by the dimensioned size of arrays. Accordingly, either the maximum slice base length was successively doubled or the approximate maximum number of slices was reduced by a factor of two until a sufficiently small enough number of shear surface coordinates (slices) was generated by the program. This message is for the user's information and does not indicate that an error condition has occurred.

SPECIFIED SUBTENDED ANGLE /OR/ SLICE ARC LENGTH RESULTED IN MORE THAN __ SLICES - SUBTENDED ANGLE RESET TO __ DEGREES
Either the subtended angle or arc length used for subdivision of the circular shear surface into slices resulted in more slices than the program was capable of accommodating by the dimensioned size of arrays. Accordingly, either the subtended angle or slice arc length was successively doubled until a sufficiently small enough number of shear surface coordinates (slices) was generated by the program. This message is for the user's information and does not indicate that an error condition has occurred.

SURFACE PRESSURE COORDINATES DO NOT COINCIDE WITH SLOPE
The program has determined that the coordinates used to define the surface pressures acting on the slope do not coincide with the slope geometry data (as defined by slope geometry input data or computed by the program from the profile line data). This error may result from input of a new set of profile line data without a new set of slope geometry data - once the program has computed or read a set of slope geometry data, the data are not changed until specifically directed by the user by (1) new slope geometry data, (2) a set of "null" slope geometry data as described in the User's Manual, or (3) by separating data sets by the Command Word "***". The slice which triggered this error will be indicated by a previous line of information when this message occurs.

* T *

THE FOLLOWING PAIR OF NONCIRCULAR SHEAR SURFACE POINTS DEFINE A VERTICAL SEGMENT OR ARE OUT-OF-ORDER
POINT __ X = __ Y = __
POINT __ X = __ Y = __
The coordinate points which define an individually selected noncircular shear surface or the initial trial noncircular shear surface for an automatic search are not in the proper sequence of increasing x coordinate value. The two points whose numbers and coordinates are printed in the error message are the two points which are not in the proper order. Vertical segments are not allowed for the shear surface.

THE PROGRAM WAS ATTEMPTING TO READ A COMMAND WORD AND ENCOUNTERED AN UNRECOGNIZABLE CHARACTER STRING FOR THE COMMAND WORD
THE LINE OF INPUT = __________
FIRST THREE CHARACTERS INTERPRETED AS '___'
The program was expecting to and has attempted to read a Command Word; however, the line of input encountered could not be interpreted as one of the acceptable Command Words. A Command Word may have been misspelled. Also, input data in one of the "Groups", e.g. profile lines, may have been terminated prematurely (perhaps by an extra blank line), causing the program to return to reading Command Words. An extraneous blank line at the end of all input data will also cause this error message to be printed. The message prints the entire content of the line of input which caused this error as well as the three "Command Word" characters which the program interpreted from the line of input data.

TOO MANY POINTS FOR ANISOTROPIC STRENGTHS - MAX. ALLOWED = __
The number of data points selected and entered to define the variation in shear strength with failure plane orientation for an anisotropic material has exceeded the maximum number allowed by the dimensioned size of the program's arrays. Either the number of data points must be reduced or the size of arrays must be increased by a programmer.

TOO MANY POINTS FOR NONLINEAR ENVELOPE - MAX. ALLOWED = __
The number of data points selected and entered to define nonlinear (curved) failure envelope has exceeded the maximum number allowed by the dimensioned size of the program's arrays. Either the number of data points must be reduced or the size of arrays must be increased by a programmer.

TOO MANY POINTS FOR PIEZOMETRIC LINE NO. __ - MAX. ALLOWED = __
The number of data points selected and entered to define the piezometric line (number indicated in the error message) has exceeded the maximum number allowed by the dimensioned size of the program's arrays. Either the number of data points must be reduced or the size of arrays must be increased by a programmer. Note: If the number of points required to define a piezometric line exceed the number allowed by the dimensioned size of the arrays, it may be possible to split the piezometric line into two separate lines, with the number of points on each line not exceeding the designated maximum; this may also require splitting the material/profile lines into two parts, each part being associated with an appropriate piezometric line.

TOO MANY PROFILE LINES CROSS SLICE - MAX. ALLOWED = __
This message is printed when the number of profile lines which cross a particular slice exceed the dimensioned capacity of arrays ISTORD and YSTORD in Subroutine SLICES - the number of profile lines must be reduced or the dimensioned size of the arrays ISTORD and YSTORD must be increased. (The slice which triggered this error will be indicated by a previous line of information when this message occurs.)

* U *

UNRECOGNIZABLE CHARACTERS WERE INPUT TO DESIGNATE HOW THE PORE WATER PRESSURES ARE TO BE DEFINED FOR MATERIAL __
INPUT LINE = _____
The first two character strings which were read as input to designate how the pore water pressures are to be defined for the material indicated did not start with one of the acceptable character pairs: C P (for Constant Pore pressure), C R (for Constant R-sub-u), N (- one character only - for No pore pressures/total stresses), I P (for Interpolation of Pore pressure values), or I R (for Interpolation of R-sub-u values).

UNRECOGNIZABLE CHARACTERS WERE INPUT TO DESIGNATE HOW THE SHEAR STRENGTH IS TO BE DEFINED FOR MATERIAL __
INPUT LINE = _____
The character string which was read as input to designate how the shear strength was to be defined for the material indicated did not start with one of the acceptable characters: A (for Anisotropic), C (for Conventional), I (for Isotropic - same as conventional), L (for Linear increase in strength with depth below the profile line with which these material data are associated), N (for Nonlinear shear strength envelope), or R (for linear increase in shear strength with depth below designated Reference elevation).

* V *

VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM __ TO __ DEGREES
The value of the side force inclination has fallen outside the preprogrammed limits during the iterative solution for the factor of safety using Spencer's procedure. The allowable limits are printed with this error message. Some of the possible causes for this error message being printed are: (1) There are excessive amounts of tension near the crest of the slope - a crack probably needs to be introduced; (2) Excessively high compressive stresses or various degrees of tensile stresses may exist near the toe of the slope - this

unreasonable condition is likely to be indicative of a shear surface which is excessively steep near the toe of the slope; (3) The estimated value for the trial factor of safety may be excessively low - the assumed initial trial value may need to be increased; or (4) The shear strength along the upper portion of the shear surface may be very high relative to the shear strength along other portions of the shear surface such that the slope is "hanging" by the upper zones of soil - factors of safety calculated by limit equilibrium procedures may not be meaningful and more careful attention may need to be given to the strength which can actually be "mobilized" in the much stronger soil zone.

* W *

///// WARNING ///// EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR SURFACE IS NEGATIVE AT POINTS ALONG THE LOWER ONE HALF OF THE SHEAR SURFACE - SOLUTION MAY NOT BE A VALID SOLUTION
This message is printed at the end of the final output tables when the computed total or effective stress is negative along the lower one half of the shear surface. The lower one half of the shear surface is defined as the portion of the shear surface where the x coordinate lies between the toe-most value and the average of the left-most and right-most values. This message and the associated problem will typically occur when the shear surface is excessively steep near the toe of the slope. Ordinarily, any solution where this message is printed should be considered unreasonable.

///// WARNING ///// FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS ALONG THE LOWER ONE HALF OF THE SHEAR SURFACE - SOLUTION MAY NOT BE A VALID SOLUTION
This message is printed at the end of the final output tables when the computed forces between slices are negative along the lower one half of the shear surface. The lower one half of the shear surface is defined as the portion of the shear surface where the x coordinate lies between the toe-most value and the average of the left-most and right-most values. This message and the associated problem will typically occur when the shear surface is excessively steep near the toe of the slope. Ordinarily, any solution where this message is printed should be considered unreasonable.

***** WARNING ***** ONE OF CHECK SUMS IS TOO LARGE
Once the factor of safety is computed the program performs several checks on the final computed values. The checks consist of (1) a summation of forces in the vertical direction (all procedures), (2) a summation of forces in the horizontal direction (Spencer's and the force equilibrium procedures only), (3) a summation of moments (Spencer's and the simplified Bishop procedures only), and (4) a shear strength check which consists of summing the differences between the shear force computed from the static equilibrium equations and the shear force computed from the Mohr-Coulomb equations for each slice. The summations of forces must not exceed the allowable force imbalance specified for the convergence tolerance and the summation of moments must not exceed the specified moment imbalance for convergence. If any of the summations do not satisfy these criteria, this message is printed.

///// WARNING ///// SHEAR STRESS AT SOME POINTS ALONG THE SHEAR SURFACE IS NEGATIVE - SOLUTION MAY NOT BE A VALID SOLUTION

This message is printed at the end of the final output tables when the computed shear stress is negative, i.e., when the computed shear stress acts in the opposite direction from the direction expected based on the direction of sliding. This error will occur when the normal stress on the base on the slice becomes excessively negative. A solution should ordinarily be rejected when this error occurs. The error may occur when (1) there is excessive tension near the crest of the slope - a tension crack may be needed, or (2) the shear surface is excessively steep near the toe of the slope - the shear surface may need to be flattened near the toe of the slope.

APPENDIX B: ARRAY SIZE LIMITS (Wright 1986a)*

1. The number of the input variables for this computer program are stored in fixed-size, dimensioned arrays. Accordingly, the number of some quantities is limited by the dimensioned size of these arrays. If any data exceed the dimensioned array sizes in the program, an appropriate error message will be issued and computations will be interrupted with an appropriate action being taken by the program depending on the severity of the error.

2. The array size limits given in this appendix existed at the time this documentation was written and are supplied for guidance. The actual array sizes may have been altered in the version of the program to which the user has access.

3. The following limitations are governed by the size of dimensioned arrays:

Maximum number of profile lines (MAXPRL): 20

Maximum number of points on a given individual profile line (MAXPLP): 15

Maximum number of materials (MAXMAT): 20

Maximum number of failure plane orientations used to define anisotropic shear strength values for a given material AND maximum number of points used to define a nonlinear (curved) shear strength envelope (MAXMPT): 19

Maximum number of piezometric lines (MAXPZL): 4

Maximum number of points on a given individual piezometric line (MAXPZP): 30

Maximum number of "gridded" points for interpolation of pore water pressures - all points (MAXINP): 300

Maximum number of points used to define the slope geometry (MAXSLP): 50

Maximum number of points used to define surface pressures (MAXSUP): 50

Maximum number of soil reinforcement lines (MAXRFL): 40

Maximum number of points on a given individual soil reinforcement line (MAXRLP): 5

Maximum number of coordinates on the shear surface, including points which are generated by the computer program = maximum number of slices <u>plus</u> one (MAXSSP): 100

---

* References cited in this appendix are included in the References at the end of the main text.

Maximum number of coordinate points specified by input data to define a noncircular shear surface for an automatic search (MAXNCP): 30

APPENDIX C: DATA INPUT SHORT FORM

HEAding
  line 1 of heading
  line 2 of heading
  line 3 of heading

PROfile lines
  1 (line number) 1 (material type) optional label
  x coordinate y coordinate
  blank line ends profile line
  blank line ends profile data group

MATerial property
  1 (material number) optional material label
  unit weight
  type of shear strength data - 1 character - SEE TABLE C1
    shear strength data
  type of piezometric data - 2 characters - SEE TABLE C2
    piezometric data
  blank line ends material property data group

PIEzometric line data - optional
  piezometric line number unit weight (optional) optional label
  x coordinate y coordinate
  blank line ends piezometric line
  blank line ends piezometric line data group

INTerpolation data for pore pressures
  type of data - pore pressure or r-sub-u data
  x coordinate y coordinate pressure/r-sub-u value material (0 for all)
  blank line ends current data
  blank line ends interpolation data group

SLOpe geometry - optional
  x coordinate y coordinate
  blank line ends slope geometry data group

SURface pressure - optional
  x coordinate y coordinate normal stress shear stress
  blank line ends surface pressure data group

REInforcement lines - optional
  reinforcement line number option for computing and assigning reinforcement
    force (1, 2, or 3)
  x coordinate y coordinate axially resisting force
  blank line ends current data
  blank line ends reinforcement line data

ANAlysis/computation
  type of surface search/no search - 2 characters - SEE TABLE C3 surface and
    search data
  blank line unless optional input quantities - SEE TABLE C4

COMpute

Table C1

Type of Shear Strength Data

Conventional shear strength
    input:
        cohesion parameter internal friction angle

Linear increase with depth
    input:
        cohesion parameter along profile line
          rate of increase

Reference - shear strength increases with depth
          below a reference plane
    input:
        reference elevation c parameter rate of increase

Anisotropic shear strength
    input:
        failure plane orientation c parameter phi angle
        blank line ends strength values

Nonlinear Mohr-Coulomb envelope
    input:
        normal stress shear stress
        blank line ends strength envelope

Table C2

Type of Piezometric Data

NO pore pressure
    input:
        none

Constant Pore pressure
    input:
        value of pore pressure

Constant R-sub-u value
    input:
        value of r-sub-u

Piezometric Line
    input:
        identification number of the piezometric line -
          MUST enter PIEzometric data

Interpolate Pore water pressure
    input:
        no data following this choice -
          MUST enter INTerpolation data

Interpolate R-sub-u values
    input:
        no data following this choice -
          MUST enter INTerpolation data

Table C3

Type of Shear Surface and Analysis

Circular "_"(=blank) single surface
    input:
        x coord for center   y coord for center   radius of circle
        1 char to define radius if not entered on previous line:
            Point - circle passes through a fixed point -
                        MUST input on next line the x and y coordinates of the
                             fixed point
            Tangent - circle is tangent to a horizontal line -
                        MUST input on next line the y coordinate of the line
        blank line to end all ANALYSIS/COMPUTATION data or proceed to optional
        input quantities subcommand words

Circular Search
    input:
all { 1) starting x coord for center 2) starting y coord for center
on { 3) accuracy or minimum grid spacing (recommend 1% of slope height)
one { 4) y coord for limiting depth for circles
line{   1 character indicating type of initial search
            Point - circles pass through a fixed point -
                  MUST input next line of: x coord   y coord for fixed point
            Tangent - circles all tangent to a horizontal line -
                  MUST input next line of: y coord of horizontal line
            Radius - circles all have the same radius -
                  MUST input next line of: radius value
        blank line to end all ANALYSIS/COMPUTATION data or proceed to optional
        input quantities subcommand words

Noncircular "_"(=blank) single surface
    input:
        x coord   y coord to define the noncircular shear surface
        blank line to end shear surface data
        blank line to end all ANALYSIS/COMPUTATION data or proceed to optional
        input quantities subcommand words

Noncircular Search
    input:
        x coord   y coord to define shear surface information about how point
          can be shifted
            - if blank, point is moveable and is moved perpendicular to the
              shear surface
            - if numerical value, point is moveable and the input value
              defines the direction of movement. The value should be an angle
              measurement in degrees from the horizontal with counterclockwise
              being positive
            - if FIX, point is not moved during search

(Continued)

Table C3 (Concluded)

	blank line to end shear surface data
both on one line	1) initial shift distance note: final shift distance or accuracy will be 10% of this distance 2) maximum steepness permitted for shear surface near toe portion - optional default value of 50 deg is used if none input
	blank line to end all analysis/computation data or proceed to optional input quantities subcommand words

Table C4

Type of Optional Input Quantities

FACtor of safety
input: initial trial value for factor of safety
(default is 3.0)

SIDe force inclination
input: initial trial value for side-force inclination, in deg
(default is 15 deg)

ITEration limit
input: maximum number of iterations
(default is 40)

FORce imbalance
input: maximum force imbalance permitted for convergence
(default is 100)

MOMent imbalance
input: maximum moment imbalance permitted for convergence
(default is 100)

CHAnge initial trial factor of safety
input: none (default is off)
The initial trial value is the default/input value for each search type.

OPPosite sign convention
input: none (default is off)
Toggles sign convention from assumed one in the program to the opposite convention.

SHOrt-form output
input: none (default is off)
Toggles short-form versus long-form output.

SUBtended angle
input: subtended angle for slice generation (default is 3 deg) requires circular shear surface

ARC length
input: maximum arc length for slice generation (default is length generated by 3 deg subtended angle) requires circular shear surface

CRAck length
input: vertical (tension) crack depth
(default is no crack)

(Continued)

Table C4 (Concluded)

BASe length
    input: maximum slice base length for slice generation (default is length generated by 30 slices) requires noncircular shear surface

INCrements for slice generation
    input: number of increments to subdivide the shear surface (default is 30) requires a noncircular shear surface

STOp
    input: none Stops an automatic search with a circular shear surface after the initial mode is completed. (default is off)

CRItical
    input: none This continues the automatic search after a STOP has been issued. (default is on)

WATer depth
    input: depth of water or other fluid in vertical crack (default is zero, no water)

UNIt weight of water
    input: unit weight of water or other fluid in vertical crack (default is 62.4)

SEIsmic coefficient
    input: seismic coefficient (default is 0)

PROcedure for computation of F
    input: single character indicating one of the following procedures:
        Spencer's procedure (default value)
        Bishop procedure
        Corps of Engineers' Modified Swedish side force assumption with force equilibrium
            procedure REQUIRES next line:
                side force inclination - measured in degrees from the horizontal
        Lowe for Lowe and Karafiath's side force assumption with force equilibrium procedure

input a blank line to end all optional input quantities

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER APPLICATIONS IN GEOTECHNICAL ENGINEERING (CAGE) PROJECT

	Title	Date
Miscellaneous Paper GL-79-19	Results of Geotechnical Computer Usage Survey	Aug 1979
Miscellaneous Paper GL-82-1	Geotechnical Computer Program Survey	Mar 1982
Instruction Report GL-83-1	Geotechnical Construction Control Data Base System	Apr 1983
Instruction Report GL-84-1	Boring Information and Subsurface Data Base Package, User's Guide	Sep 1984
Miscellaneous Paper GL-85-8	Criteria for Limit Equilibrium Slope-Stability Program Package	May 1985
Instruction Report GL-85-1	Microcomputer Boring and Subsurface Data Package, User's Guide	Sep 1985
Instruction Report GL-85-2	Piezometer Data Base Package, User's Guide	Oct 1985
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package, User's Manual	Jul 1987

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-81-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide: Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide: Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80: A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982
Instruction Report K-82-7	User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Instruction Report K-83-1	User's Guide: Computer Program With Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-83-2	User's Guide: Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide: Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-2	User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
Instruction Report K-84-7	User's Guide: Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT)	Aug 1984
Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-11	User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics	Sep 1984
Technical Report K-84-3	Computer-Aided Drafting and Design for Corps Structural Engineers	Oct 1984
Technical Report ATC-86-5	Decision Logic Table Formulation of ACI 318-77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II	Jun 1986
Technical Report ITL-87-2	A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs	Jan 1987
Instruction Report ITL-87-1	User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUFRAM)	Apr 1987
Instruction Report ITL-87-2	User's Guide: For Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-83	May 1987
Technical Report ITL-87-6	Finite-Element Method Package for Solving Steady-State Seepage Problems	May 1987
Instruction Report ITL-87-3	User's Guide: A Three Dimensional Stability Analysis/Design Program (3DSAD), Report 1, Revision 1: General Geometry Module	Jun 1987
Instruction Report ITL-87-4	User's Guide: 2-D Frame Analysis Link Program (LINK2D)	Jun 1987
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 1: Initial and Refined Finite Element Models (Phases A, B, and C), Volumes I and II Report 2: Simplified Frame Model (Phase D) Report 3: Alternate Configuration Miter Gate Finite Element Studies—Open Section Report 4: Alternate Configuration Miter Gate Finite Element Studies—Closed Sections	Aug 1987

(Continued)

File: EXAM1.IN

```
HEADING
  Example 1 - Simple example
   End of construction loading
   Single circular shear surface
PROFILE LINES
  1  1  Embankment
  -70  0
  -10 30
   10 30
   70  0

  2  2  Foundation
  -150  0
   150  0


MATERIAL PROPERTIES
  1  Embankment clay
   110 = unit weight
   Conventional shear strength
    1000  15
   NO pore pressures
  2  Foundation sand
   125 = unit weight
   Conventional shear strength
    0  35
   NO pore pressure

ANALYSIS/COMPUTATION
  Circular
   60  60
    Point
     70  0
    CRACK
      6.3

COMPUTE
```

File: EXAM1.OUT

```
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT

          TABLE NO. 1
          ******************************************
          * COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
          * Originally Coded By Stephen G. Wright  *
          * Version No. 1.209                      *
          * Last Revision Date  2/3/87             *
          * Serial No. 00004                       *
          * (C) Copyright 1985 Stephen G. Wright   *
          * All Rights Reserved                    *
          ******************************************

          **************************************************************
          *                                                            *
          *     RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
          * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
          * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
          * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
          * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
          * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
          * PROGRAM BEFORE ATTEMPTING ITS USE.                         *
          *                                                            *
          *     NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
          * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
          * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
          * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
          *                                                            *
          **************************************************************
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
            Example 1 - Simple example
             End of construction loading
             Single circular shear surface

          TABLE NO.  2
          *************************
          * NEW PROFILE LINE DATA *
          *************************

          PROFILE LINE  1 - MATERIAL TYPE =  1
          Embankment

               Point       X             Y

                 1       -70.000        0.000
                 2       -10.000       30.000
                 3        10.000       30.000
                 4        70.000        0.000

          PROFILE LINE  2 - MATERIAL TYPE =  2
```

```
Foundation

     Point      X             Y

       1      -150.000        0.000
       2       150.000        0.000

All new profile lines defined - No old lines retained
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
  Example 1 - Simple example
   End of construction loading
   Single circular shear surface

TABLE NO.  3
******************************
* NEW MATERIAL PROPERTY DATA *
******************************

DATA FOR MATERIAL TYPE  1
Embankment clay

     Unit weight of material =  110.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     Cohesion - - - - - - - -     1000.000
     Friction angle - - - - -   15.000 degrees

     No (or zero) pore water pressures

DATA FOR MATERIAL TYPE  2
Foundation sand

     Unit weight of material =  125.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     Cohesion - - - - - - - -        0.000
     Friction angle - - - - -   35.000 degrees

     No (or zero) pore water pressures

All new material properties defined - No old data retained
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
  Example 1 - Simple example
   End of construction loading
   Single circular shear surface

TABLE NO.  9
*********************************
* NEW ANALYSIS/COMPUTATION DATA *
*********************************

Circular Shear Surface(s)
```

Computations Performed for Single Shear Surface

Center Coordinates for Center of Circle -
X = 60.000
Y = 60.000

Circle Passes Throught the Point at -
X = 70.000
Y = 0.000
Radius = 60.828

Depth of crack = 6.300

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Initial trial estimate for side force inclination = 15.000 degrees
(Applicable to Spencer's procedure only)

Maximum number of iterations allowed for
calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Maximum subtended angle to be used for subdivision of the
circle into slices = 3.00 degrees

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000

Procedure used to compute the factor of safety: SPENCER
1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 1 - Simple example
End of construction loading
Single circular shear surface

TABLE NO. 10
****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA
WERE GENERATED BY THE PROGRAM

Slope Coordinates -

Point	X	Y
1	-150.000	0.000
2	-70.000	0.000
3	-10.000	30.000
4	10.000	30.000
5	70.000	0.000
6	150.000	0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 1 - Simple example

End of construction loading

Single circular shear surface

TABLE NO. 20

```
*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	11.9	22.7					
1	12.9	21.5	1558.6	1	1000.00	15.00	0.0
	13.9	20.3					
2	15.0	19.1	1979.4	1	1000.00	15.00	0.0
	16.1	17.9					
3	17.2	16.8	2388.6	1	1000.00	15.00	0.0
	18.3	15.7					
4	19.5	14.6	2776.0	1	1000.00	15.00	0.0
	20.7	13.6					
5	22.0	12.6	3131.5	1	1000.00	15.00	0.0
	23.2	11.6					
6	24.5	10.6	3445.8	1	1000.00	15.00	0.0
	25.8	9.7					
7	27.1	8.8	3710.7	1	1000.00	15.00	0.0
	28.5	8.0					
8	29.8	7.2	3918.3	1	1000.00	15.00	0.0
	31.2	6.4					
9	32.7	5.7	4062.3	1	1000.00	15.00	0.0
	34.1	5.0					
10	35.5	4.3	4137.1	1	1000.00	15.00	0.0
	37.0	3.7					
11	38.5	3.1	4138.4	1	1000.00	15.00	0.0
	40.0	2.6					
12	41.5	2.1	4063.0	1	1000.00	15.00	0.0
	43.0	1.6					
13	44.5	1.2	3909.0	1	1000.00	15.00	0.0
	46.1	0.8					
14	47.6	0.5	3675.7	1	1000.00	15.00	0.0

```
          49.2      0.1
   15     49.6      0.1       890.1    1    1000.00    15.00         0.0
          50.0      0.0
   16     51.6     -0.2      3282.7    2       0.00    35.00         0.0
          53.2     -0.4
   17     54.7     -0.6      2892.3    2       0.00    35.00         0.0
          56.3     -0.7
   18     57.9     -0.8      2421.7    2       0.00    35.00         0.0
          59.5     -0.8
   19     59.8     -0.8       327.3    2       0.00    35.00         0.0
          60.0     -0.8
   20     61.6     -0.8      1785.0    2       0.00    35.00         0.0
          63.2     -0.7
   21     64.8     -0.6      1158.8    2       0.00    35.00         0.0
          66.4     -0.5
   22     67.9     -0.3       471.4    2       0.00    35.00         0.0
          69.5     -0.1
1        UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
           Example 1 - Simple example
            End of construction loading
            Single circular shear surface

         TABLE NO. 20
         *****************************************************************
         * INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
         * SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
         *****************************************************************

         Slice                      Slice   Matl.           Friction    Pore
           No.     X        Y       Weight  Type  Cohesion    Angle   Pressure

          69.5     -0.1
   23     69.8      0.0         8.8    2       0.00    35.00         0.0
          70.0      0.0
   24     70.0      0.0         0.0    1    1000.00    15.00         0.0
          70.0      0.0
1        UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
           Example 1 - Simple example
            End of construction loading
            Single circular shear surface

         TABLE NO. 21
         *****************************************************************
         * INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
         * SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
         *****************************************************************

                                                 FORCES DUE TO SURFACE PRESSURES
                                       Y for
         Slice             Seismic   Seismic    Normal   Shear
           No.      X       Force     Force      Force    Force        X        Y
```

1	12.9	0.	25.0	0.	0.	0.0	0.0
2	15.0	0.	23.3	0.	0.	0.0	0.0
3	17.2	0.	21.6	0.	0.	0.0	0.0
4	19.5	0.	19.9	0.	0.	0.0	0.0
5	22.0	0.	18.3	0.	0.	0.0	0.0
6	24.5	0.	16.7	0.	0.	0.0	0.0
7	27.1	0.	15.1	0.	0.	0.0	0.0
8	29.8	0.	13.6	0.	0.	0.0	0.0
9	32.7	0.	12.2	0.	0.	0.0	0.0
10	35.5	0.	10.8	0.	0.	0.0	0.0
11	38.5	0.	9.4	0.	0.	0.0	0.0
12	41.5	0.	8.2	0.	0.	0.0	0.0
13	44.5	0.	7.0	0.	0.	0.0	0.0
14	47.6	0.	5.8	0.	0.	0.0	0.0
15	49.6	0.	5.1	0.	0.	0.0	0.0
16	51.6	0.	4.5	0.	0.	0.0	0.0
17	54.7	0.	3.5	0.	0.	0.0	0.0
18	57.9	0.	2.6	0.	0.	0.0	0.0
19	59.8	0.	2.1	0.	0.	0.0	0.0
20	61.6	0.	1.7	0.	0.	0.0	0.0
21	64.8	0.	1.0	0.	0.	0.0	0.0
22	67.9	0.	0.4	0.	0.	0.0	0.0
23	69.8	0.	0.0	0.	0.	0.0	0.0
24	70.0	0.	0.0	0.	0.	0.0	0.0

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 1 - Simple example

End of construction loading

Single circular shear surface

TABLE NO. 23

****

* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *

* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE *

****

Iter-ation	Trial Factor of Safety	Trial Side Force Inclination (degrees)	Force Imbalance (lbs.)	Moment Imbalance (ft.-lbs.)	Delta-F	Delta Theta (degrees)
1	3.00000	-15.0000	-0.1080E+04	0.3084E+05		
First-order corrections to F and THETA					-0.914E-01	-0.737E+01
Second-order correction - Iteration 1					-0.904E-01	-0.737E+01
Second-order correction - Iteration 2					-0.904E-01	-0.737E+01
2	2.90961	-22.3721	0.1530E+02	-0.5010E+04		
First-order corrections to F and THETA					-0.102E-01	0.182E+01
Second-order correction - Iteration 1					-0.100E-01	0.182E+01
Second-order correction - Iteration 2					-0.100E-01	0.182E+01
3	2.89957	-20.5519	-0.6469E-01	-0.6568E+02		
First-order corrections to F and THETA					-0.179E-03	0.265E-01

```
Second-order correction - Iteration  1 ........ -0.177E-03 0.262E-01
Second-order correction - Iteration  2 ........ -0.175E-03 0.258E-01
Second-order correction - Iteration  3 ........ -0.172E-03 0.255E-01
Second-order correction - Iteration  4 ........ -0.170E-03 0.251E-01
Second-order correction - Iteration  5 ........ -0.168E-03 0.248E-01
Second-order correction - Iteration  6 ........ -0.166E-03 0.245E-01
Second-order correction - Iteration  7 ........ -0.163E-03 0.241E-01
Second-order correction - Iteration  8 ........ -0.161E-03 0.238E-01
Second-order correction - Iteration  9 ........ -0.159E-03 0.234E-01
Second-order correction - Iteration 10 ........ -0.157E-03 0.231E-01
SECOND-ORDER CORRECTIONS DID NOT CONVERGE
IN  10 ITERATIONS - FIRST-ORDER CORRECTIONS
USED

   4   2.89940   -20.5254  0.7165E-03 -0.1228E-01
First-order corrections to F and THETA .........  0.907E-07-0.481E-06

FACTOR OF SAFETY - - - - - - - - -     2.899
SIDE FORCE INCLINATION - - - - -      -20.53
NUMBER OF ITERATIONS - - - - - -       4
1 UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
  Example 1 - Simple example
   End of construction loading
   Single circular shear surface

TABLE NO. 24
*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety =  2.899     Side Force Inclination = -20.53 Degrees

       -------- VALUES AT CENTER OF BASE OF SLICE---------
```

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	12.9	21.5	312.8	312.8	373.8
2	15.0	19.1	455.6	455.6	387.0
3	17.2	16.8	590.6	590.6	399.5
4	19.5	14.6	716.2	716.2	411.1
5	22.0	12.6	830.8	830.8	421.7
6	24.5	10.6	933.0	933.0	431.1
7	27.1	8.8	1021.5	1021.5	439.3
8	29.8	7.2	1095.1	1095.1	446.1
9	32.7	5.7	1152.6	1152.6	451.4
10	35.5	4.3	1193.1	1193.1	455.2
11	38.5	3.1	1215.4	1215.4	457.2
12	41.5	2.1	1218.6	1218.6	457.5

13	44.5	1.2	1201.8	1201.8	456.0
14	47.6	0.5	1163.9	1163.9	452.5
15	49.6	0.1	1131.1	1131.1	449.4
16	51.6	-0.2	1045.3	1045.3	252.4
17	54.7	-0.6	946.6	946.6	228.6
18	57.9	-0.8	817.6	817.6	197.4
19	59.8	-0.8	731.1	731.1	176.6
20	61.6	-0.8	627.6	627.6	151.6
21	64.8	-0.6	423.9	423.9	102.4
22	67.9	-0.3	180.2	180.2	43.5
23	69.8	0.0	22.5	22.5	5.4
24	70.0	0.0	253.7	253.7	368.3

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.00 (= 0.146E-02)
SHOULD NOT EXCEED 0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = 0.00 (= 0.156E-02)
SHOULD NOT EXCEED 0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = 0.02 (= 0.249E-01)
SHOULD NOT EXCEED 0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.00 (= 0.944E-03)
SHOULD NOT EXCEED 0.100E+03

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 1 - Simple example
End of construction loading
Single circular shear surface

TABLE NO. 25
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *
****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 2.899 Side Force Inclination = -20.53 Degrees

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	13.9	19.	21.1	0.110	-3.0	7.5
2	16.1	280.	18.8	0.098	-40.9	98.8
3	18.3	728.	17.0	0.129	-82.5	216.8
4	20.7	1305.	15.2	0.152	-120.0	340.6
5	23.2	1954.	13.6	0.170	-151.5	460.8
6	25.8	2616.	12.0	0.184	-177.1	572.3
7	28.5	3237.	10.5	0.195	-196.8	671.2
8	31.2	3767.	9.1	0.204	-210.8	754.4
9	34.1	4158.	7.7	0.212	-218.9	818.5

10	37.0	4374.	6.5	0.218	-220.4	859.7
11	40.0	4382.	5.4	0.225	-213.6	872.9
12	43.0	4162.	4.4	0.234	-195.5	850.4
13	46.1	3701.	3.6	0.247	-159.8	780.3
14	49.2	2999.	3.0	0.276	-94.3	641.8
15	50.0	2783.	2.9	0.288	-70.3	591.6
16	53.2	2425.	2.1	0.284	-76.2	588.7
17	56.3	1929.	1.4	0.282	-73.3	551.7
18	59.5	1354.	0.9	0.284	-61.3	478.9
19	60.0	1263.	0.8	0.285	-58.5	464.3
20	63.2	692.	0.5	0.297	-33.9	345.9
21	66.4	231.	0.3	0.353	11.2	176.0
22	69.5	5.	0.1	0.409	6.3	21.3
23	70.0	0.	0.3	ABOVE	49192364.0	**********
24	70.0	0.	-9.1	BELOW	0.0	0.0

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION     -        0.00  (= 0.146E-02)
     SHOULD NOT EXCEED    0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION   -        0.00  (= 0.156E-02)
     SHOULD NOT EXCEED    0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN  -        0.02  (= 0.249E-01)
     SHOULD NOT EXCEED    0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM    -        0.00  (= 0.944E-03)
     SHOULD NOT EXCEED    0.100E+03

***** CAUTION ***** SOME OF THE FORCES BETWEEN SLICES ACT AT POINTS
                    ABOVE THE SURFACE OF THE SLOPE OR BELOW THE
                    SHEAR SURFACE - EITHER A TENSION CRACK MAY BE
                    NEEDED OR THE SOLUTION MAY NOT BE A VALID SOLUTION.


END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED
```

File: EXAM1H.IN

```
HEADING
  Example 1 - Simple example
   End of construction loading
   Single circular shear surface
PROFILE LINES
  1  1  Embankment
  -70  0
  -10 30
   10 30
   70  0

  2  2  Foundation
  -150  0
   150  0


MATERIAL PROPERTIES
  1  Embankment clay
   110 = unit weight
   Conventional shear strength
    1000  15
   NO pore pressures
  2  Foundation sand
   125 = unit weight
   Conventional shear strength
    0  35
   NO pore pressure

ANALYSIS/COMPUTATION
  Circular
   60  60
    Point
     70  0
    CRACK
      6.3
    PROcedure
     Corps
      20.5

COMPUTE
```

File: EXAM1H.OUT

```
1        UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT

         TABLE NO. 1
         *****************************************
         * COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
         * Originally Coded By Stephen G. Wright  *
         * Version No. 1.209                      *
         * Last Revision Date  2/3/87             *
         * Serial No. 00004                       *
         * (C) Copyright 1985 Stephen G. Wright   *
         * All Rights Reserved                    *
         *****************************************

         ************************************************************
         *                                                          *
         *      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
         * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
         * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
         * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
         * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
         * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
         * PROGRAM BEFORE ATTEMPTING ITS USE.                         *
         *                                                          *
         *      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
         * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
         * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
         * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
         *                                                          *
         ************************************************************
1        UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
           Example 1 - Simple example
            End of construction loading
            Single circular shear surface

         TABLE NO.  2
         ***********************
         * NEW PROFILE LINE DATA *
         ***********************

         PROFILE LINE  1 - MATERIAL TYPE =  1
         Embankment

              Point      X             Y

                1       -70.000        0.000
                2       -10.000       30.000
                3        10.000       30.000
                4        70.000        0.000

         PROFILE LINE  2 - MATERIAL TYPE =  2
```

```
Foundation

     Point      X             Y

       1      -150.000         0.000
       2       150.000         0.000

All new profile lines defined - No old lines retained
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
  Example 1 - Simple example
   End of construction loading
   Single circular shear surface

TABLE NO.  3
******************************
* NEW MATERIAL PROPERTY DATA *
******************************

DATA FOR MATERIAL TYPE  1
Embankment clay

     Unit weight of material =  110.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     Cohesion - - - - - - - -    1000.000
     Friction angle - - - - -  15.000 degrees

     No (or zero) pore water pressures

DATA FOR MATERIAL TYPE  2
Foundation sand

     Unit weight of material =  125.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     Cohesion - - - - - - - -       0.000
     Friction angle - - - - -  35.000 degrees

     No (or zero) pore water pressures

All new material properties defined - No old data retained
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
  Example 1 - Simple example
   End of construction loading
   Single circular shear surface

TABLE NO.  9
*********************************
* NEW ANALYSIS/COMPUTATION DATA *
*********************************

Circular Shear Surface(s)
```

Computations Performed for Single Shear Surface

Center Coordinates for Center of Circle -
X = 60.000
Y = 60.000

Circle Passes Throught the Point at -
X = 70.000
Y = 0.000
Radius = 60.828

Depth of crack = 6.300

Procedure used to compute the factor of safety: CORPS
Specified side force inclination = 20.50 degrees

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Maximum number of iterations allowed for
calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Maximum subtended angle to be used for subdivision of the
circle into slices = 3.00 degrees

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000
1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 1 - Simple example
End of construction loading
Single circular shear surface

TABLE NO. 10
****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA
WERE GENERATED BY THE PROGRAM

Slope Coordinates -

Point	X	Y
1	-150.000	0.000
2	-70.000	0.000
3	-10.000	30.000
4	10.000	30.000
5	70.000	0.000
6	150.000	0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 1 - Simple example

End of construction loading

Single circular shear surface

TABLE NO. 20

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
*******************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	11.9	22.7					
1	12.9	21.5	1558.6	1	1000.00	15.00	0.0
	13.9	20.3					
2	15.0	19.1	1979.4	1	1000.00	15.00	0.0
	16.1	17.9					
3	17.2	16.8	2388.6	1	1000.00	15.00	0.0
	18.3	15.7					
4	19.5	14.6	2776.0	1	1000.00	15.00	0.0
	20.7	13.6					
5	22.0	12.6	3131.5	1	1000.00	15.00	0.0
	23.2	11.6					
6	24.5	10.6	3445.8	1	1000.00	15.00	0.0
	25.8	9.7					
7	27.1	8.8	3710.7	1	1000.00	15.00	0.0
	28.5	8.0					
8	29.8	7.2	3918.3	1	1000.00	15.00	0.0
	31.2	6.4					
9	32.7	5.7	4062.3	1	1000.00	15.00	0.0
	34.1	5.0					
10	35.5	4.3	4137.1	1	1000.00	15.00	0.0
	37.0	3.7					
11	38.5	3.1	4138.4	1	1000.00	15.00	0.0
	40.0	2.6					
12	41.5	2.1	4063.0	1	1000.00	15.00	0.0
	43.0	1.6					
13	44.5	1.2	3909.0	1	1000.00	15.00	0.0
	46.1	0.8					
14	47.6	0.5	3675.7	1	1000.00	15.00	0.0
	49.2	0.1					
15	49.6	0.1	890.1	1	1000.00	15.00	0.0

	50.0	0.0					
16	51.6	-0.2	3282.7	2	0.00	35.00	0.0
	53.2	-0.4					
17	54.7	-0.6	2892.3	2	0.00	35.00	0.0
	56.3	-0.7					
18	57.9	-0.8	2421.7	2	0.00	35.00	0.0
	59.5	-0.8					
19	59.8	-0.8	327.3	2	0.00	35.00	0.0
	60.0	-0.8					
20	61.6	-0.8	1785.0	2	0.00	35.00	0.0
	63.2	-0.7					
21	64.8	-0.6	1158.8	2	0.00	35.00	0.0
	66.4	-0.5					
22	67.9	-0.3	471.4	2	0.00	35.00	0.0
	69.5	-0.1					

Example 1 - Simple example
End of construction loading
Single circular shear surface

TABLE NO. 20

```
********************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
********************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	69.5	-0.1					
23	69.8	0.0	8.8	2	0.00	35.00	0.0
	70.0	0.0					
24	70.0	0.0	0.0	1	1000.00	15.00	0.0
	70.0	0.0					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 1 - Simple example
End of construction loading
Single circular shear surface

TABLE NO. 21

```
********************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
********************************************************************
```

				FORCES DUE TO SURFACE PRESSURES			
Slice No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
1	12.9	0.	25.0	0.	0.	0.0	0.0
2	15.0	0.	23.3	0.	0.	0.0	0.0

3	17.2	0.	21.6	0.	0.	0.0	0.0
4	19.5	0.	19.9	0.	0.	0.0	0.0
5	22.0	0.	18.3	0.	0.	0.0	0.0
6	24.5	0.	16.7	0.	0.	0.0	0.0
7	27.1	0.	15.1	0.	0.	0.0	0.0
8	29.8	0.	13.6	0.	0.	0.0	0.0
9	32.7	0.	12.2	0.	0.	0.0	0.0
10	35.5	0.	10.8	0.	0.	0.0	0.0
11	38.5	0.	9.4	0.	0.	0.0	0.0
12	41.5	0.	8.2	0.	0.	0.0	0.0
13	44.5	0.	7.0	0.	0.	0.0	0.0
14	47.6	0.	5.8	0.	0.	0.0	0.0
15	49.6	0.	5.1	0.	0.	0.0	0.0
16	51.6	0.	4.5	0.	0.	0.0	0.0
17	54.7	0.	3.5	0.	0.	0.0	0.0
18	57.9	0.	2.6	0.	0.	0.0	0.0
19	59.8	0.	2.1	0.	0.	0.0	0.0
20	61.6	0.	1.7	0.	0.	0.0	0.0
21	64.8	0.	1.0	0.	0.	0.0	0.0
22	67.9	0.	0.4	0.	0.	0.0	0.0
23	69.8	0.	0.0	0.	0.	0.0	0.0
24	70.0	0.	0.0	0.	0.	0.0	0.0

```
1       UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
          Example 1 - Simple example
           End of construction loading
           Single circular shear surface

        TABLE NO. 23
        ******************************************************************
        * INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
        * OF SAFETY BY THE CORPS OF ENGINEERS MODIFIED SWEDISH PROCEDURE *
        ******************************************************************

                        Trial Factor      Force Imbalance
        Iteration        of Safety            (lbs.)          DELTA-F

            1             3.00000           0.796E+03      -0.104

            2             2.89573          -0.287E+02       0.350E-02

            3             2.89923          -0.369E-01       0.451E-05

        FACTOR OF SAFETY - - - - - - - -     2.899
        SIDE FORCE INCLINATION - - - - -    -20.50
        NUMBER OF ITERATIONS - - - - - -     3
1       UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
          Example 1 - Simple example
           End of construction loading
           Single circular shear surface

        TABLE NO. 24
        ***********************************************
```

* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *
****

CORPS OF ENGINEERS' PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 2.899

-------- VALUES AT CENTER OF BASE OF SLICE--------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	12.9	21.5	312.8	312.8	373.8
2	15.0	19.1	455.6	455.6	387.0
3	17.2	16.8	590.7	590.7	399.5
4	19.5	14.6	716.2	716.2	411.1
5	22.0	12.6	830.8	830.8	421.7
6	24.5	10.6	933.0	933.0	431.2
7	27.1	8.8	1021.5	1021.5	439.3
8	29.8	7.2	1095.1	1095.1	446.1
9	32.7	5.7	1152.7	1152.7	451.5
10	35.5	4.3	1193.1	1193.1	455.2
11	38.5	3.1	1215.4	1215.4	457.3
12	41.5	2.1	1218.6	1218.6	457.5
13	44.5	1.2	1201.7	1201.7	456.0
14	47.6	0.5	1163.8	1163.8	452.5
15	49.6	0.1	1131.0	1131.0	449.4
16	51.6	-0.2	1045.3	1045.3	252.4
17	54.7	-0.6	946.5	946.5	228.6
18	57.9	-0.8	817.5	817.5	197.4
19	59.8	-0.8	731.0	731.0	176.6
20	61.6	-0.8	627.5	627.5	151.5
21	64.8	-0.6	423.8	423.8	102.4
22	67.9	-0.3	180.2	180.2	43.5
23	69.8	0.0	22.5	22.5	5.4
24	70.0	0.0	253.5	253.5	368.3

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.00 (= 0.166E-02)
SHOULD NOT EXCEED 0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = 0.00 (= 0.267E-02)
SHOULD NOT EXCEED 0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.04 (= 0.361E-01)
SHOULD NOT EXCEED 0.100E+03

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 1 - Simple example
End of construction loading
Single circular shear surface

TABLE NO. 25

```
**********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
**********************************************
```

CORPS OF ENGINEERS' PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 2.899

----- VALUES AT RIGHT SIDE OF SLICE ----

Slice No.	X-Right	Side Force	Side Force Inclination (degrees)
1	13.9	19.	-20.50
2	16.1	280.	-20.50
3	18.3	728.	-20.50
4	20.7	1305.	-20.50
5	23.2	1954.	-20.50
6	25.8	2616.	-20.50
7	28.5	3237.	-20.50
8	31.2	3766.	-20.50
9	34.1	4158.	-20.50
10	37.0	4373.	-20.50
11	40.0	4382.	-20.50
12	43.0	4161.	-20.50
13	46.1	3701.	-20.50
14	49.2	2998.	-20.50
15	50.0	2783.	-20.50
16	53.2	2425.	-20.50
17	56.3	1929.	-20.50
18	59.5	1353.	-20.50
19	60.0	1262.	-20.50
20	63.2	691.	-20.50
21	66.4	231.	-20.50
22	69.5	5.	-20.50
23	70.0	0.	-20.50
24	70.0	0.	-20.50

///// WARNING ///// FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS ALONG THE LOWER ONE-HALF OF THE SHEAR SURFACE - SOLUTION MAY NOT BE A VALID SOLUTION.

///// WARNING ///// FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS ALONG THE LOWER ONE-HALF OF THE SHEAR SURFACE - SOLUTION MAY NOT BE A VALID SOLUTION.

END-OF-FILE ENCOUNTERED WHILE READING COMMAND WORDS - END OF PROBLEM(S) ASSUMED

File: EXAM2.IN

```
HEADING
  Example 2 - Simple cut slope example
   Undrained condition
   Single noncircular shear surface
PROFILE LINES
  1  1  Silt layer
  -80 30
   80 30

  2  2  Clay layer
  -80 5
   80 5

  3  1  Silt foundation layer
  -80 -0.5
   80 -0.5


MATERIAL PROPERTIES
  1  Silt
  120 = unit weight
  Conventional shear strength
   500  10
  NO pore pressure
  2  Clay
  115 = unit weight
  Conventional shear strength
   500  0
  NO pore pressure

SLOPE GEOMETRY
  -80 30
  -30 30
   30  0
   80  0

ANALYSIS/COMPUTATION
  Noncircular
   -68.3  23.7
   -40     0
    20     0
    23.7   3.1


COMPUTE
```

File: EXAM2.OUT

```
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT

          TABLE NO. 1
          ******************************************
          * COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
          * Originally Coded By Stephen G. Wright  *
          * Version No. 1.209                      *
          * Last Revision Date  2/3/87             *
          * Serial No. 00004                       *
          * (C) Copyright 1985 Stephen G. Wright   *
          * All Rights Reserved                    *
          ******************************************

          ***************************************************************
          *                                                             *
          *     RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
          * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
          * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
          * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
          * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
          * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
          * PROGRAM BEFORE ATTEMPTING ITS USE.                          *
          *                                                             *
          *     NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
          * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
          * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
          * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                   *
          *                                                             *
          ***************************************************************
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
            Example 2 - Simple cut slope example
             Undrained condition
             Single noncircular shear surface

          TABLE NO.  2
          *************************
          * NEW PROFILE LINE DATA *
          *************************

          PROFILE LINE  1 - MATERIAL TYPE =  1
          Silt layer

               Point       X             Y

                 1       -80.000        30.000
                 2        80.000        30.000

          PROFILE LINE  2 - MATERIAL TYPE =  2
          Clay layer
```

```
     Point      X              Y

       1      -80.000         5.000
       2       80.000         5.000

PROFILE LINE  3 - MATERIAL TYPE =  1
Silt foundation layer

     Point      X              Y

       1      -80.000        -0.500
       2       80.000        -0.500

All new profile lines defined - No old lines retained
```

```
1       UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
          Example 2 - Simple cut slope example
           Undrained condition
           Single noncircular shear surface
```

```
TABLE NO.  3
*******************************
* NEW MATERIAL PROPERTY DATA *
*******************************

DATA FOR MATERIAL TYPE  1
Silt

     Unit weight of material =  120.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     Cohesion - - - - - - - -     500.000
     Friction angle - - - - -  10.000 degrees

     No (or zero) pore water pressures

DATA FOR MATERIAL TYPE  2
Clay

     Unit weight of material =  115.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     Cohesion - - - - - - - -     500.000
     Friction angle - - - - -   0.000 degrees

     No (or zero) pore water pressures

All new material properties defined - No old data retained
```

```
1       UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
          Example 2 - Simple cut slope example
           Undrained condition
           Single noncircular shear surface
```

TABLE NO. 6
****
* NEW SLOPE GEOMETRY DATA *
****

All new data input - No old data retained

Slope Coordinates -

Point	X	Y
1	-80.000	30.000
2	-30.000	30.000
3	30.000	0.000
4	80.000	0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 2 - Simple cut slope example
Undrained condition
Single noncircular shear surface

TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

Noncircular Shear Surface(s)

Computations Performed for Single Shear Surface

Shear Surface Coordinates -

Point	X	Y
1	-68.300	23.700
2	-40.000	0.000
3	20.000	0.000
4	23.700	3.100

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Initial trial estimate for side force inclination = 15.000 degrees
(Applicable to Spencer's procedure only)

Maximum number of iterations allowed for
calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Number of increments for slice subdivision = 30

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000

Procedure used to compute the factor of safety: SPENCER

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 20

```
*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-68.3	23.7					
1	-67.2	22.8	1938.7	1	500.00	10.00	0.0
	-66.1	21.8					
2	-65.0	20.9	2439.7	1	500.00	10.00	0.0
	-63.8	20.0					
3	-62.7	19.0	2940.8	1	500.00	10.00	0.0
	-61.6	18.1					
4	-60.5	17.2	3441.9	1	500.00	10.00	0.0
	-59.4	16.2					
5	-58.3	15.3	3942.9	1	500.00	10.00	0.0
	-57.1	14.4					
6	-56.0	13.4	4444.0	1	500.00	10.00	0.0
	-54.9	12.5					
7	-53.8	11.5	4945.1	1	500.00	10.00	0.0
	-52.7	10.6					
8	-51.6	9.7	5446.2	1	500.00	10.00	0.0
	-50.4	8.7					
9	-49.3	7.8	5947.2	1	500.00	10.00	0.0
	-48.2	6.9					
10	-47.1	5.9	6448.4	1	500.00	10.00	0.0
	-46.0	5.0					
11	-45.0	4.2	6161.2	2	500.00	0.00	0.0
	-44.0	3.3					
12	-43.0	2.5	6542.6	2	500.00	0.00	0.0
	-42.0	1.7					
13	-41.0	0.8	6924.1	2	500.00	0.00	0.0
	-40.0	0.0					

14	-38.7	0.0	8937.5	2	500.00	0.00	0.0
	-37.5	0.0					
15	-36.2	0.0	8937.5	2	500.00	0.00	0.0
	-35.0	0.0					
16	-33.7	0.0	8937.5	2	500.00	0.00	0.0
	-32.5	0.0					
17	-31.2	0.0	8937.5	2	500.00	0.00	0.0
	-30.0	0.0					
18	-28.5	0.0	10255.2	2	500.00	0.00	0.0
	-27.1	0.0					
19	-25.6	0.0	9736.2	2	500.00	0.00	0.0
	-24.1	0.0					
20	-22.6	0.0	9217.1	2	500.00	0.00	0.0
	-21.2	0.0					
21	-19.7	0.0	8698.1	2	500.00	0.00	0.0
	-18.2	0.0					
22	-16.8	0.0	8179.1	2	500.00	0.00	0.0
	-15.3	0.0					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 20

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*******************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-15.3	0.0					
23	-13.8	0.0	7660.0	2	500.00	0.00	0.0
	-12.4	0.0					
24	-10.9	0.0	7141.0	2	500.00	0.00	0.0
	-9.4	0.0					
25	-7.9	0.0	6622.0	2	500.00	0.00	0.0
	-6.5	0.0					
26	-5.0	0.0	6102.9	2	500.00	0.00	0.0
	-3.5	0.0					
27	-2.1	0.0	5583.9	2	500.00	0.00	0.0
	-0.6	0.0					
28	0.9	0.0	5064.9	2	500.00	0.00	0.0
	2.4	0.0					
29	3.8	0.0	4545.8	2	500.00	0.00	0.0
	5.3	0.0					
30	6.8	0.0	4026.8	2	500.00	0.00	0.0
	8.2	0.0					
31	9.7	0.0	3507.8	2	500.00	0.00	0.0
	11.2	0.0					
32	12.6	0.0	2988.8	2	500.00	0.00	0.0

	14.1	0.0					
33	15.6	0.0	2469.7	2	500.00	0.00	0.0
	17.1	0.0					
34	18.5	0.0	1950.7	2	500.00	0.00	0.0
	20.0	0.0					
35	20.9	0.8	800.5	2	500.00	0.00	0.0
	21.9	1.5					
36	22.8	2.3	273.9	2	500.00	0.00	0.0
	23.7	3.1					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 21

```
*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

				FORCES DUE TO SURFACE PRESSURES			
Slice No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
1	-67.2	0.	26.4	0.	0.	0.0	0.0
2	-65.0	0.	25.4	0.	0.	0.0	0.0
3	-62.7	0.	24.5	0.	0.	0.0	0.0
4	-60.5	0.	23.6	0.	0.	0.0	0.0
5	-58.3	0.	22.6	0.	0.	0.0	0.0
6	-56.0	0.	21.7	0.	0.	0.0	0.0
7	-53.8	0.	20.8	0.	0.	0.0	0.0
8	-51.6	0.	19.8	0.	0.	0.0	0.0
9	-49.3	0.	18.9	0.	0.	0.0	0.0
10	-47.1	0.	18.0	0.	0.	0.0	0.0
11	-45.0	0.	17.1	0.	0.	0.0	0.0
12	-43.0	0.	16.3	0.	0.	0.0	0.0
13	-41.0	0.	15.5	0.	0.	0.0	0.0
14	-38.7	0.	15.1	0.	0.	0.0	0.0
15	-36.2	0.	15.1	0.	0.	0.0	0.0
16	-33.7	0.	15.1	0.	0.	0.0	0.0
17	-31.2	0.	15.1	0.	0.	0.0	0.0
18	-28.5	0.	14.7	0.	0.	0.0	0.0
19	-25.6	0.	14.0	0.	0.	0.0	0.0
20	-22.6	0.	13.2	0.	0.	0.0	0.0
21	-19.7	0.	12.5	0.	0.	0.0	0.0
22	-16.8	0.	11.8	0.	0.	0.0	0.0
23	-13.8	0.	11.0	0.	0.	0.0	0.0
24	-10.9	0.	10.3	0.	0.	0.0	0.0
25	-7.9	0.	9.6	0.	0.	0.0	0.0
26	-5.0	0.	8.8	0.	0.	0.0	0.0
27	-2.1	0.	8.1	0.	0.	0.0	0.0

28	0.9	0.	7.3	0.	0.	0.0	0.0
29	3.8	0.	6.6	0.	0.	0.0	0.0
30	6.8	0.	5.9	0.	0.	0.0	0.0
31	9.7	0.	5.1	0.	0.	0.0	0.0
32	12.6	0.	4.4	0.	0.	0.0	0.0
33	15.6	0.	3.6	0.	0.	0.0	0.0
34	18.5	0.	2.9	0.	0.	0.0	0.0
35	20.9	0.	2.7	0.	0.	0.0	0.0
36	22.8	0.	3.0	0.	0.	0.0	0.0

```
1      UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
         Example 2 - Simple cut slope example
          Undrained condition
          Single noncircular shear surface

       TABLE NO. 23
       ******************************************************************
       * INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
       * OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
       ******************************************************************

                Trial     Trial
               Factor   Side Force    Force      Moment              Delta
       Iter-     of    Inclination  Imbalance   Imbalance   Delta-F   Theta
       ation   Safety   (degrees)    (lbs.)    (ft.-lbs.)          (degrees)

         1    3.00000   -15.0000 -0.2118E+05 -0.1530E+06
       First-order corrections to F and THETA ......... -0.323E+01 0.387E+01
       Values factored by 0.155E+00 - Deltas too large  -0.500E+00 0.600E+00

         2    2.50000   -14.3998 -0.1720E+05 -0.1291E+06
       First-order corrections to F and THETA ......... -0.185E+01 0.371E+01
       Values factored by 0.271E+00 - Deltas too large  -0.500E+00 0.100E+01

         3    2.00000   -13.3955 -0.1131E+05 -0.9498E+05
       First-order corrections to F and THETA ......... -0.803E+00 0.335E+01
       Values factored by 0.622E+00 - Deltas too large  -0.500E+00 0.208E+01

         4    1.50000   -11.3115 -0.1715E+04 -0.4257E+05
       First-order corrections to F and THETA ......... -0.905E-01 0.214E+01
       Second-order correction - Iteration   1 ........ -0.855E-01 0.214E+01
       Second-order correction - Iteration   2 ........ -0.855E-01 0.214E+01

         5    1.41447    -9.1715  0.8853E+01 -0.1935E+04
       First-order corrections to F and THETA ......... -0.900E-03 0.102E+00
       Second-order correction - Iteration   1 ........ -0.900E-03 0.103E+00

         6    1.41357    -9.0690  0.4883E-03  0.1281E+01
       First-order corrections to F and THETA .........  0.804E-06-0.681E-04

       FACTOR OF SAFETY - - - - - - - -      1.414
       SIDE FORCE INCLINATION - - - - -      -9.07
       NUMBER OF ITERATIONS - - - - - -      6
```

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 24

```
********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY

Factor of Safety = 1.414 Side Force Inclination = -9.07 Degrees

-------- VALUES AT CENTER OF BASE OF SLICE---------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	-67.2	22.8	515.9	515.9	418.1
2	-65.0	20.9	700.1	700.1	441.0
3	-62.7	19.0	884.3	884.3	464.0
4	-60.5	17.2	1068.5	1068.5	487.0
5	-58.3	15.3	1252.7	1252.7	510.0
6	-56.0	13.4	1436.9	1436.9	532.9
7	-53.8	11.5	1621.1	1621.1	555.9
8	-51.6	9.7	1805.3	1805.3	578.9
9	-49.3	7.8	1989.5	1989.5	601.9
10	-47.1	5.9	2173.7	2173.7	624.9
11	-45.0	4.2	2519.3	2519.3	353.7
12	-43.0	2.5	2688.4	2688.4	353.7
13	-41.0	0.8	2857.4	2857.4	353.7
14	-38.7	0.0	3631.5	3631.5	353.7
15	-36.2	0.0	3631.5	3631.5	353.7
16	-33.7	0.0	3631.5	3631.5	353.7
17	-31.2	0.0	3631.5	3631.5	353.7
18	-28.5	0.0	3543.2	3543.2	353.7
19	-25.6	0.0	3366.8	3366.8	353.7
20	-22.6	0.0	3190.3	3190.3	353.7
21	-19.7	0.0	3013.8	3013.8	353.7
22	-16.8	0.0	2837.3	2837.3	353.7
23	-13.8	0.0	2660.9	2660.9	353.7
24	-10.9	0.0	2484.4	2484.4	353.7
25	-7.9	0.0	2307.9	2307.9	353.7
26	-5.0	0.0	2131.5	2131.5	353.7
27	-2.1	0.0	1955.0	1955.0	353.7
28	0.9	0.0	1778.5	1778.5	353.7
29	3.8	0.0	1602.0	1602.0	353.7
30	6.8	0.0	1425.6	1425.6	353.7
31	9.7	0.0	1249.1	1249.1	353.7
32	12.6	0.0	1072.6	1072.6	353.7

33	15.6	0.0	896.2	896.2	353.7
34	18.5	0.0	719.7	719.7	353.7
35	20.9	0.8	906.8	906.8	353.7
36	22.8	2.3	578.2	578.2	353.7

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION    =       0.00  (= 0.439E-02)
     SHOULD NOT EXCEED    0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION  =       0.01  (= 0.991E-02)
     SHOULD NOT EXCEED    0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN =      -1.21  (=-0.121E+01)
     SHOULD NOT EXCEED    0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM   =       0.00  (= 0.158E-02)
     SHOULD NOT EXCEED    0.100E+03
```

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 25

```
*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY

Factor of Safety = 1.414   Side Force Inclination = -9.07 Degrees

-------------- VALUES AT RIGHT SIDE OF SLICE --------------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	-66.1	32.	22.6	0.093	-5.5	13.1
2	-63.8	360.	20.8	0.089	-52.0	122.8
3	-61.6	985.	19.4	0.114	-107.5	270.9
4	-59.4	1907.	18.1	0.134	-163.3	436.7
5	-57.1	3126.	16.7	0.150	-217.1	611.6
6	-54.9	4642.	15.3	0.162	-268.2	791.5
7	-52.7	6455.	14.0	0.173	-316.9	974.3
8	-50.4	8564.	12.6	0.181	-363.3	1158.9
9	-48.2	10971.	11.2	0.188	-407.8	1344.6
10	-46.0	13674.	9.9	0.194	-450.6	1530.9
11	-44.0	17213.	8.4	0.190	-547.9	1822.8
12	-42.0	21038.	7.0	0.190	-632.1	2098.5
13	-40.0	25148.	5.7	0.191	-706.2	2361.8
14	-37.5	24252.	5.5	0.185	-712.2	2308.8
15	-35.0	23357.	5.3	0.178	-715.7	2253.4
16	-32.5	22461.	5.2	0.172	-717.0	2195.7
17	-30.0	21566.	5.0	0.167	-715.9	2153.3

18	-27.1	20512.	4.7	0.166	-713.6	2133.6
19	-24.1	19459.	4.5	0.166	-710.9	2131.2
20	-21.2	18405.	4.3	0.167	-707.8	2128.4
21	-18.2	17352.	4.1	0.168	-704.0	2125.0
22	-15.3	16298.	3.8	0.169	-699.6	2120.9
23	-12.4	15245.	3.6	0.171	-694.1	2115.9
24	-9.4	14191.	3.4	0.172	-687.4	2109.7
25	-6.5	13138.	3.2	0.174	-679.0	2101.9
26	-3.5	12084.	3.0	0.177	-668.2	2091.9
27	-0.6	11031.	2.8	0.180	-654.3	2078.7
28	2.4	9977.	2.6	0.185	-635.6	2061.1
29	5.3	8924.	2.4	0.191	-609.9	2036.6
30	8.2	7870.	2.2	0.200	-573.1	2001.4
31	11.2	6817.	2.0	0.213	-517.6	1948.0
32	14.1	5763.	1.9	0.234	-428.5	1861.9
33	17.1	4710.	1.7	0.270	-272.0	1709.5
34	20.0	3656.	1.7	0.343	42.3	1401.9
35	21.9	1570.	2.5	0.366	119.4	1108.8
36	23.7	0.	-524.1	BELOW	3050.5	-3050.6

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION    -      0.00  (= 0.439E-02)
     SHOULD NOT EXCEED    0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION  -      0.01  (= 0.991E-02)
     SHOULD NOT EXCEED    0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN -     -1.21  (=-0.121E+01)
     SHOULD NOT EXCEED    0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM   -      0.00  (= 0.158E-02)
     SHOULD NOT EXCEED    0.100E+03

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED
```

File: EXAM2H.IN

```
HEADING
  Example 2 - Simple cut slope example
   Undrained condition
   Single noncircular shear surface
PROFILE LINES
  1  1  Silt layer
  -80 30
   80 30

  2  2  Clay layer
  -80 5
   80 5

  3  1  Silt foundation layer
  -80 -0.5
   80 -0.5


MATERIAL PROPERTIES
  1  Silt
  120 - unit weight
  Conventional shear strength
   500  10
  NO pore pressure
  2  Clay
  115 - unit weight
  Conventional shear strength
   500  0
  NO pore pressure

SLOPE GEOMETRY
  -80 30
  -30 30
   30  0
   80  0

ANALYSIS/COMPUTATION
  Noncircular
   -68.3  23.7
   -40     0
    20     0
    23.7   3.1

  PROcedure
   Corps
    9.07

COMPUTE
```

File: EXAM2H.OUT

```
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT

          TABLE NO. 1
          *******************************************
          * COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
          * Originally Coded By Stephen G. Wright  *
          * Version No. 1.209                      *
          * Last Revision Date  2/3/87             *
          * Serial No. 00004                       *
          * (C) Copyright 1985 Stephen G. Wright   *
          * All Rights Reserved                    *
          *******************************************

          ***************************************************************
          *                                                             *
          *      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
          * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
          * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
          * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
          * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
          * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
          * PROGRAM BEFORE ATTEMPTING ITS USE.                         *
          *                                                             *
          *      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
          * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
          * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
          * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
          *                                                             *
          ***************************************************************
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
            Example 2 - Simple cut slope example
             Undrained condition
             Single noncircular shear surface

          TABLE NO.  2
          *************************
          * NEW PROFILE LINE DATA *
          *************************

          PROFILE LINE  1 - MATERIAL TYPE =  1
          Silt layer

               Point       X             Y

                 1       -80.000       30.000
                 2        80.000       30.000

          PROFILE LINE  2 - MATERIAL TYPE =  2
          Clay layer
```

Point	X	Y
1	-80.000	5.000
2	80.000	5.000

PROFILE LINE 3 - MATERIAL TYPE = 1
Silt foundation layer

Point	X	Y
1	-80.000	-0.500
2	80.000	-0.500

All new profile lines defined - No old lines retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 2 - Simple cut slope example
Undrained condition
Single noncircular shear surface

TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1
Silt

Unit weight of material = 120.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 500.000
Friction angle - - - - - 10.000 degrees

No (or zero) pore water pressures

DATA FOR MATERIAL TYPE 2
Clay

Unit weight of material = 115.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 500.000
Friction angle - - - - - 0.000 degrees

No (or zero) pore water pressures

All new material properties defined - No old data retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 2 - Simple cut slope example
Undrained condition
Single noncircular shear surface

TABLE NO. 6

****
* NEW SLOPE GEOMETRY DATA *
****

All new data input - No old data retained

Slope Coordinates -

Point	X	Y
1	-80.000	30.000
2	-30.000	30.000
3	30.000	0.000
4	80.000	0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 9

****
* NEW ANALYSIS/COMPUTATION DATA *
****

Noncircular Shear Surface(s)

Computations Performed for Single Shear Surface

Shear Surface Coordinates -

Point	X	Y
1	-68.300	23.700
2	-40.000	0.000
3	20.000	0.000
4	23.700	3.100

Procedure used to compute the factor of safety: CORPS

Specified side force inclination = 9.07 degrees

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Maximum number of iterations allowed for calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Number of increments for slice subdivision = 30

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 20

****

* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *

* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *

****

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-68.3	23.7					
1	-67.2	22.8	1938.7	1	500.00	10.00	0.0
	-66.1	21.8					
2	-65.0	20.9	2439.7	1	500.00	10.00	0.0
	-63.8	20.0					
3	-62.7	19.0	2940.8	1	500.00	10.00	0.0
	-61.6	18.1					
4	-60.5	17.2	3441.9	1	500.00	10.00	0.0
	-59.4	16.2					
5	-58.3	15.3	3942.9	1	500.00	10.00	0.0
	-57.1	14.4					
6	-56.0	13.4	4444.0	1	500.00	10.00	0.0
	-54.9	12.5					
7	-53.8	11.5	4945.1	1	500.00	10.00	0.0
	-52.7	10.6					
8	-51.6	9.7	5446.2	1	500.00	10.00	0.0
	-50.4	8.7					
9	-49.3	7.8	5947.2	1	500.00	10.00	0.0
	-48.2	6.9					
10	-47.1	5.9	6448.4	1	500.00	10.00	0.0
	-46.0	5.0					
11	-45.0	4.2	6161.2	2	500.00	0.00	0.0
	-44.0	3.3					
12	-43.0	2.5	6542.6	2	500.00	0.00	0.0
	-42.0	1.7					
13	-41.0	0.8	6924.1	2	500.00	0.00	0.0
	-40.0	0.0					
14	-38.7	0.0	8937.5	2	500.00	0.00	0.0
	-37.5	0.0					

15	-36.2	0.0	8937.5	2	500.00	0.00	0.0
	-35.0	0.0					
16	-33.7	0.0	8937.5	2	500.00	0.00	0.0
	-32.5	0.0					
17	-31.2	0.0	8937.5	2	500.00	0.00	0.0
	-30.0	0.0					
18	-28.5	0.0	10255.2	2	500.00	0.00	0.0
	-27.1	0.0					
19	-25.6	0.0	9736.2	2	500.00	0.00	0.0
	-24.1	0.0					
20	-22.6	0.0	9217.1	2	500.00	0.00	0.0
	-21.2	0.0					
21	-19.7	0.0	8698.1	2	500.00	0.00	0.0
	-18.2	0.0					
22	-16.8	0.0	8179.1	2	500.00	0.00	0.0
	-15.3	0.0					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 20

```
******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
******************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-15.3	0.0					
23	-13.8	0.0	7660.0	2	500.00	0.00	0.0
	-12.4	0.0					
24	-10.9	0.0	7141.0	2	500.00	0.00	0.0
	-9.4	0.0					
25	-7.9	0.0	6622.0	2	500.00	0.00	0.0
	-6.5	0.0					
26	-5.0	0.0	6102.9	2	500.00	0.00	0.0
	-3.5	0.0					
27	-2.1	0.0	5583.9	2	500.00	0.00	0.0
	-0.6	0.0					
28	0.9	0.0	5064.9	2	500.00	0.00	0.0
	2.4	0.0					
29	3.8	0.0	4545.8	2	500.00	0.00	0.0
	5.3	0.0					
30	6.8	0.0	4026.8	2	500.00	0.00	0.0
	8.2	0.0					
31	9.7	0.0	3507.8	2	500.00	0.00	0.0
	11.2	0.0					
32	12.6	0.0	2988.8	2	500.00	0.00	0.0
	14.1	0.0					
33	15.6	0.0	2469.7	2	500.00	0.00	0.0

	17.1	0.0					
34	18.5	0.0	1950.7	2	500.00	0.00	0.0
	20.0	0.0					
35	20.9	0.8	800.5	2	500.00	0.00	0.0
	21.9	1.5					
36	22.8	2.3	273.9	2	500.00	0.00	0.0
	23.7	3.1					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 2 - Simple cut slope example
Undrained condition
Single noncircular shear surface

TABLE NO. 21

```
*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

						FORCES DUE TO SURFACE PRESSURES	
Slice No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
1	-67.2	0.	26.4	0.	0.	0.0	0.0
2	-65.0	0.	25.4	0.	0.	0.0	0.0
3	-62.7	0.	24.5	0.	0.	0.0	0.0
4	-60.5	0.	23.6	0.	0.	0.0	0.0
5	-58.3	0.	22.6	0.	0.	0.0	0.0
6	-56.0	0.	21.7	0.	0.	0.0	0.0
7	-53.8	0.	20.8	0.	0.	0.0	0.0
8	-51.6	0.	19.8	0.	0.	0.0	0.0
9	-49.3	0.	18.9	0.	0.	0.0	0.0
10	-47.1	0.	18.0	0.	0.	0.0	0.0
11	-45.0	0.	17.1	0.	0.	0.0	0.0
12	-43.0	0.	16.3	0.	0.	0.0	0.0
13	-41.0	0.	15.5	0.	0.	0.0	0.0
14	-38.7	0.	15.1	0.	0.	0.0	0.0
15	-36.2	0.	15.1	0.	0.	0.0	0.0
16	-33.7	0.	15.1	0.	0.	0.0	0.0
17	-31.2	0.	15.1	0.	0.	0.0	0.0
18	-28.5	0.	14.7	0.	0.	0.0	0.0
19	-25.6	0.	14.0	0.	0.	0.0	0.0
20	-22.6	0.	13.2	0.	0.	0.0	0.0
21	-19.7	0.	12.5	0.	0.	0.0	0.0
22	-16.8	0.	11.8	0.	0.	0.0	0.0
23	-13.8	0.	11.0	0.	0.	0.0	0.0
24	-10.9	0.	10.3	0.	0.	0.0	0.0
25	-7.9	0.	9.6	0.	0.	0.0	0.0
26	-5.0	0.	8.8	0.	0.	0.0	0.0
27	-2.1	0.	8.1	0.	0.	0.0	0.0
28	0.9	0.	7.3	0.	0.	0.0	0.0
29	3.8	0.	6.6	0.	0.	0.0	0.0

30	6.8	0.	5.9	0.	0.	0.0	0.0
31	9.7	0.	5.1	0.	0.	0.0	0.0
32	12.6	0.	4.4	0.	0.	0.0	0.0
33	15.6	0.	3.6	0.	0.	0.0	0.0
34	18.5	0.	2.9	0.	0.	0.0	0.0
35	20.9	0.	2.7	0.	0.	0.0	0.0
36	22.8	0.	3.0	0.	0.	0.0	0.0

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 23

```
*******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY THE CORPS OF ENGINEERS MODIFIED SWEDISH PROCEDURE *
*******************************************************************
```

Iteration	Trial Factor of Safety	Force Imbalance (lbs.)	DELTA-F
1	3.00000	0.235E+05	-3.32
Reduced value - Delta was too large			-0.500
2	2.50000	0.192E+05	-1.90
Reduced value - Delta was too large			-0.500
3	2.00000	0.129E+05	-0.823
Reduced value - Delta was too large			-0.500
4	1.50000	0.253E+04	-0.916E-01
5	1.40844	-0.160E+03	0.513E-02
6	1.41356	-0.564E+00	0.182E-04
7	1.41358	0.198E-03	-0.639E-08

FACTOR OF SAFETY - - - - - - - - 1.414

SIDE FORCE INCLINATION - - - - - -9.07

NUMBER OF ITERATIONS - - - - - - 7

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 2 - Simple cut slope example

Undrained condition

Single noncircular shear surface

TABLE NO. 24

```
********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
********************************************
```

CORPS OF ENGINEERS' PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.414

-------- VALUES AT CENTER OF BASE OF SLICE---------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	-67.2	22.8	515.9	515.9	418.1
2	-65.0	20.9	700.1	700.1	441.0
3	-62.7	19.0	884.3	884.3	464.0
4	-60.5	17.2	1068.5	1068.5	487.0
5	-58.3	15.3	1252.7	1252.7	510.0
6	-56.0	13.4	1436.9	1436.9	532.9
7	-53.8	11.5	1621.1	1621.1	555.9
8	-51.6	9.7	1805.3	1805.3	578.9
9	-49.3	7.8	1989.5	1989.5	601.9
10	-47.1	5.9	2173.7	2173.7	624.9
11	-45.0	4.2	2519.3	2519.3	353.7
12	-43.0	2.5	2688.3	2688.3	353.7
13	-41.0	0.8	2857.4	2857.4	353.7
14	-38.7	0.0	3631.5	3631.5	353.7
15	-36.2	0.0	3631.5	3631.5	353.7
16	-33.7	0.0	3631.5	3631.5	353.7
17	-31.2	0.0	3631.5	3631.5	353.7
18	-28.5	0.0	3543.2	3543.2	353.7
19	-25.6	0.0	3366.8	3366.8	353.7
20	-22.6	0.0	3190.3	3190.3	353.7
21	-19.7	0.0	3013.8	3013.8	353.7
22	-16.8	0.0	2837.3	2837.3	353.7
23	-13.8	0.0	2660.9	2660.9	353.7
24	-10.9	0.0	2484.4	2484.4	353.7
25	-7.9	0.0	2307.9	2307.9	353.7
26	-5.0	0.0	2131.5	2131.5	353.7
27	-2.1	0.0	1955.0	1955.0	353.7
28	0.9	0.0	1778.5	1778.5	353.7
29	3.8	0.0	1602.1	1602.1	353.7
30	6.8	0.0	1425.6	1425.6	353.7
31	9.7	0.0	1249.1	1249.1	353.7
32	12.6	0.0	1072.6	1072.6	353.7
33	15.6	0.0	896.2	896.2	353.7
34	18.5	0.0	719.7	719.7	353.7
35	20.9	0.8	906.8	906.8	353.7
36	22.8	2.3	578.2	578.2	353.7

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.01 (= 0.699E-02)
SHOULD NOT EXCEED 0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = 0.01 (= 0.137E-01)
SHOULD NOT EXCEED 0.100E+03

SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.01 (= 0.147E-01)
SHOULD NOT EXCEED 0.100E+03

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 2 - Simple cut slope example
Undrained condition
Single noncircular shear surface

TABLE NO. 25

```
*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
```

CORPS OF ENGINEERS' PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.414

----- VALUES AT RIGHT SIDE OF SLICE ----

Slice No.	X-Right	Side Force	Side Force Inclination (degrees)
1	-66.1	32.	-9.07
2	-63.8	360.	-9.07
3	-61.6	985.	-9.07
4	-59.4	1907.	-9.07
5	-57.1	3126.	-9.07
6	-54.9	4642.	-9.07
7	-52.7	6455.	-9.07
8	-50.4	8565.	-9.07
9	-48.2	10971.	-9.07
10	-46.0	13674.	-9.07
11	-44.0	17213.	-9.07
12	-42.0	21038.	-9.07
13	-40.0	25148.	-9.07
14	-37.5	24252.	-9.07
15	-35.0	23357.	-9.07
16	-32.5	22461.	-9.07
17	-30.0	21566.	-9.07
18	-27.1	20512.	-9.07
19	-24.1	19459.	-9.07
20	-21.2	18405.	-9.07
21	-18.2	17352.	-9.07
22	-15.3	16298.	-9.07
23	-12.4	15245.	-9.07
24	-9.4	14191.	-9.07
25	-6.5	13138.	-9.07
26	-3.5	12084.	-9.07
27	-0.6	11031.	-9.07
28	2.4	9977.	-9.07
29	5.3	8924.	-9.07
30	8.2	7870.	-9.07

31	11.2	6817.	-9.07
32	14.1	5763.	-9.07
33	17.1	4710.	-9.07
34	20.0	3656.	-9.07
35	21.9	1570.	-9.07
36	23.7	0.	-9.07

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

File: EXAM3A.IN

```
HEADING
  Example 3 - Circular search
   Clay embankment on 10 foot sand layer
   Sand is over 25 foot of clay over rock
PROFILE LINES
  1  1  Embankment surface
  -215  0
   -15 50
    15 50
   215  0

  2  2  Upstream sand layer
  -400  0
   -15  0
    -5 -10

  3  2  Downstream sand layer
    5  -10
   15    0
  400    0

  4  3  Foundation clay
  -400  -10
   400  -10

  5  4  Rock
  -400  -35
   400  -35


HEADING
  Case 1 - End of Construction (Q strength)
   No pore pressures in embankment
   Groundwater table elevation 0.0
MATERIAL PROPERTY
  1  Embankment Q strength
   115 = moist unit weight
   Conventional shear strength
    1000  5
   NO pore pressures
  2  Sand layer
   130 = saturated unit weight
   Conventional shear strength
    0  35
   Piezometric Line
    1  Piez line for groundwater
  3  Foundation clay
   115 = saturated unit weight
   Conventional shear strength
    3000  0
```

```
   Piezometric Line
    1  Piez line for groundwater
  4  Rock
   165 = saturated unit weight
   Conventional shear strength
    0  45
   Piezometric Line
    1  Piez line for groundwater

PIEZOMETRIC LINE DATA
  1  62.4  Groundwater table
  -400  0
   400  0


HEADING
  Example 3 - case 1
   Modified Swedish (Corps method)
   Search for critical shear surface
ANALYSIS/COMPUTATION
  Circular Search
   101  180  0.5  -60
   Tangent
     0.0
   CRACK
    7.0
   PROCEDURE
    Spencer

COMPUTE
```

File: EXAM3A.OUT

```
1        UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT

         TABLE NO. 1
         *******************************************
         * COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
         * Originally Coded By Stephen G. Wright  *
         * Version No. 1.209                      *
         * Last Revision Date  2/3/87             *
         * Serial No. 00004                       *
         * (C) Copyright 1985 Stephen G. Wright   *
         * All Rights Reserved                    *
         *******************************************

         ***************************************************************
         *                                                             *
         *      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
         * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
         * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
         * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
         * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
         * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
         * PROGRAM BEFORE ATTEMPTING ITS USE.                         *
         *                                                             *
         *      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
         * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
         * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
         * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
         *                                                             *
         ***************************************************************
1        UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
           Example 3 - Circular search
            Clay embankment on 10 foot sand layer
            Sand is over 25 foot of clay over rock

         TABLE NO.  2
         *************************
         * NEW PROFILE LINE DATA *
         *************************

         PROFILE LINE  1 - MATERIAL TYPE =  1
         Embankment surface

              Point       X             Y

                1      -215.000        0.000
                2       -15.000       50.000
                3        15.000       50.000
                4       215.000        0.000

         PROFILE LINE  2 - MATERIAL TYPE =  2
```

Upstream sand layer

Point	X	Y
1	-400.000	0.000
2	-15.000	0.000
3	-5.000	-10.000

PROFILE LINE 3 - MATERIAL TYPE = 2
Downstream sand layer

Point	X	Y
1	5.000	-10.000
2	15.000	0.000
3	400.000	0.000

PROFILE LINE 4 - MATERIAL TYPE = 3
Foundation clay

Point	X	Y
1	-400.000	-10.000
2	400.000	-10.000

PROFILE LINE 5 - MATERIAL TYPE = 4
Rock

Point	X	Y
1	-400.000	-35.000
2	400.000	-35.000

All new profile lines defined - No old lines retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Case 1 - End of Construction (Q strength)
No pore pressures in embankment
Groundwater table elevation 0.0

TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1
Embankment Q strength

Unit weight of material = 115.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 1000.000
Friction angle - - - - - 5.000 degrees

No (or zero) pore water pressures

DATA FOR MATERIAL TYPE 2
Sand layer

Unit weight of material = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.000
Friction angle - - - - - 35.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 3
Foundation clay

Unit weight of material = 115.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 3000.000
Friction angle - - - - - 0.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 4
Rock

Unit weight of material = 165.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.000
Friction angle - - - - - 45.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

All new material properties defined - No old data retained
1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Case 1 - End of Construction (Q strength)
No pore pressures in embankment
Groundwater table elevation 0.0

TABLE NO. 4
****
* NEW PIEZOMETRIC LINE DATA *
****

Line No.	Point	X	Y	
1 - Unit weight of water =			62.40	Groundwater table
1	1	-400.000	0.000	Groundwater table
1	2	400.000	0.000	Groundwater table

All new piezometric lines defined - No old lines retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 3 - case 1

Modified Swedish (Corps method)

Search for critical shear surface

TABLE NO. 9

****

* NEW ANALYSIS/COMPUTATION DATA *

****

Circular Shear Surface(s)

Automatic Search Performed

Starting Center Coordinate for Search at -

X = 101.000

Y = 180.000

Required accuracy for critical center (= minimum spacing between grid points) = 0.500

Critical shear surface not allowed to pass below Y = -60.000

For the initial mode of search all circles are tangent to horizontal line at -

Y = 0.000

Depth of crack = 7.000

Procedure used to compute the factor of safety: SPENCER

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Initial trial estimate for side force inclination = 15.000 degrees
(Applicable to Spencer's procedure only)

Maximum number of iterations allowed for calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Initial trial values for factor of safety (and side force inclination
for Spencer's procedure) will be kept constant during search

Maximum subtended angle to be used for subdivision of the
circle into slices = 3.00 degrees

Search will be continued to locate a more critical shear
surface (if one exists) after the initial mode is complete

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 3 - case 1
Modified Swedish (Corps method)
Search for critical shear surface

TABLE NO. 10
****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA
WERE GENERATED BY THE PROGRAM

Slope Coordinates -

Point	X	Y
1	-400.000	0.000
2	-215.000	0.000
3	-15.000	50.000
4	15.000	50.000
5	215.000	0.000
6	400.000	0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 3 - case 1
Modified Swedish (Corps method)
Search for critical shear surface

TABLE NO. 12
INFORMATION FOR CURRENT MODE OF SEARCH - All Circles Are Tangent
to a Horizontal Line at Y = 0.000

Center Coordinates   Factor   Side Force
                                    of   Inclination

X	Y	Radius	Safety	(degrees)	Iterations
86.00	165.00	165.00	2.571	-7.22	4
101.00	165.00	165.00	2.491	-8.36	4
116.00	165.00	165.00	2.541	-9.31	4
86.00	180.00	180.00	2.616	-6.94	3
101.00	180.00	180.00	2.499	-8.16	4
116.00	180.00	180.00	2.522	-9.14	4
86.00	195.00	195.00	2.670	-6.68	3
101.00	195.00	195.00	2.518	-7.94	4
116.00	195.00	195.00	2.516	-8.95	3
86.00	150.00	150.00	2.541	-7.48	4
101.00	150.00	150.00	2.494	-8.55	4
116.00	150.00	150.00	2.580	-9.40	4
98.50	162.50	162.50	2.493	-8.22	4
101.00	162.50	162.50	2.491	-8.39	4
103.50	162.50	162.50	2.491	-8.56	3
98.50	165.00	165.00	2.494	-8.19	4
103.50	165.00	165.00	2.491	-8.53	3
98.50	167.50	167.50	2.496	-8.15	4
101.00	167.50	167.50	2.492	-8.32	4
103.50	167.50	167.50	2.491	-8.49	3
98.50	160.00	160.00	2.493	-8.25	4
101.00	160.00	160.00	2.491	-8.42	4
103.50	160.00	160.00	2.492	-8.59	3
98.50	157.50	157.50	2.492	-8.28	4
101.00	157.50	157.50	2.491	-8.45	4
103.50	157.50	157.50	2.493	-8.63	4
99.50	158.50	158.50	2.491	-8.34	4
101.00	158.50	158.50	2.491	-8.44	4
102.50	158.50	158.50	2.491	-8.54	4
99.50	160.00	160.00	2.491	-8.32	4
102.50	160.00	160.00	2.491	-8.52	4
99.50	161.50	161.50	2.492	-8.30	4
101.00	161.50	161.50	2.490	-8.40	4
102.50	161.50	161.50	2.491	-8.50	3
99.50	163.00	163.00	2.492	-8.28	4
101.00	163.00	163.00	2.491	-8.38	4
102.50	163.00	163.00	2.490	-8.48	3
104.00	161.50	161.50	2.492	-8.61	3
104.00	163.00	163.00	2.491	-8.59	3
101.00	164.50	164.50	2.491	-8.36	4
102.50	164.50	164.50	2.490	-8.46	3
104.00	164.50	164.50	2.491	-8.57	3

101.00	166.00	166.00	2.491	-8.34	4
102.50	166.00	166.00	2.490	-8.44	3
104.00	166.00	166.00	2.491	-8.55	3
102.00	164.00	164.00	2.490	-8.44	4
102.50	164.00	164.00	2.490	-8.47	3
103.00	164.00	164.00	2.490	-8.50	3
102.00	164.50	164.50	2.490	-8.43	4
103.00	164.50	164.50	2.490	-8.50	3
102.00	165.00	165.00	2.490	-8.42	4
102.50	165.00	165.00	2.490	-8.46	3
103.00	165.00	165.00	2.490	-8.49	3
102.00	163.50	163.50	2.490	-8.44	4
102.50	163.50	163.50	2.490	-8.48	3
103.00	163.50	163.50	2.490	-8.51	3
101.50	163.00	163.00	2.490	-8.42	4
102.00	163.00	163.00	2.490	-8.45	4
101.50	163.50	163.50	2.490	-8.41	4
101.50	164.00	164.00	2.490	-8.40	4
101.50	162.50	162.50	2.490	-8.42	4
102.00	162.50	162.50	2.490	-8.46	4
102.50	162.50	162.50	2.490	-8.49	3

At the end of the current mode of search the most critical
circle which was found has the following values -
X-center = 102.00 Y-center = 163.00 Radius = 163.00
Factor of Safety = 2.490 Side Force Inclination = -8.45

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 3 - case 1
Modified Swedish (Corps method)
Search for critical shear surface

TABLE NO. 13
INFORMATION FOR CURRENT MODE OF SEARCH - All Circles Have the
Same Radius - Radius = 163.000

Center Coordinates X	Center Coordinates Y	Radius	Factor of Safety	Side Force Inclination (degrees)	Iterations
87.00	148.00	163.00	3.788	-7.95	4
102.00	148.00	163.00	3.474	-9.31	4
117.00	148.00	163.00	3.354	-10.39	4
87.00	163.00	163.00	2.556	-7.34	4
117.00	163.00	163.00	2.553	-9.38	4
87.00	178.00	163.00	3.436	-8.43	4

102.00	178.00	163.00	3.658	-9.67	4
117.00	178.00	163.00	4.402	-9.87	6

99.50	160.50	163.00	3.067	-9.33	3
102.00	160.50	163.00	3.042	-9.47	3
104.50	160.50	163.00	3.019	-9.61	3
99.50	163.00	163.00	2.492	-8.28	4
104.50	163.00	163.00	2.492	-8.62	3
99.50	165.50	163.00	2.598	-8.45	4
102.00	165.50	163.00	2.601	-8.62	4
104.50	165.50	163.00	2.607	-8.80	4

100.50	161.50	163.00	2.952	-9.25	3
102.00	161.50	163.00	2.940	-9.34	3
103.50	161.50	163.00	2.930	-9.42	3
100.50	163.00	163.00	2.491	-8.35	4
103.50	163.00	163.00	2.491	-8.55	3
100.50	164.50	163.00	2.553	-8.45	4
102.00	164.50	163.00	2.554	-8.55	4
103.50	164.50	163.00	2.556	-8.66	4

101.50	162.50	163.00	2.771	-9.02	3
102.00	162.50	163.00	2.769	-9.05	3
102.50	162.50	163.00	2.767	-9.08	3
101.50	163.00	163.00	2.490	-8.42	4
102.50	163.00	163.00	2.490	-8.48	3
101.50	163.50	163.00	2.511	-8.45	4
102.00	163.50	163.00	2.511	-8.48	4
102.50	163.50	163.00	2.511	-8.52	4

At the end of the current mode of search the most critical
circle which was found has the following values -
X-center = 102.00 Y-center = 163.00 Radius = 163.00
Factor of Safety = 2.490 Side Force Inclination = -8.45

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 3 - case 1
Modified Swedish (Corps method)
Search for critical shear surface

TABLE NO. 15
***** FINAL CRITICAL CIRCLE INFORMATION *****

X Coordinate of Center - - - - - - -	102.000
Y Coordinate of Center - - - - - - -	163.000
Radius - - - - - - - - - - - - - - -	163.000
Factor of Safety - - - - - - - - - -	2.490
Side Force Inclination - - - - - - -	-8.45

Number of circles tried - - - - - -	95
No. of circles F calc. for - - - - -	95

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Example 3 - case 1
Modified Swedish (Corps method)

Search for critical shear surface

TABLE NO. 20

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*******************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-8.3	43.0					
1	-6.7	41.5	3231.7	1	1000.00	5.00	0.0
	-5.0	40.0					
2	-1.7	37.3	9597.3	1	1000.00	5.00	0.0
	1.6	34.6					
3	3.3	33.3	6562.4	1	1000.00	5.00	0.0
	5.0	32.0					
4	8.5	29.6	16431.5	1	1000.00	5.00	0.0
	12.0	27.1					
5	13.5	26.1	8264.9	1	1000.00	5.00	0.0
	15.0	25.2					
6	18.7	23.0	22015.8	1	1000.00	5.00	0.0
	22.3	20.8					
7	26.1	18.8	24676.4	1	1000.00	5.00	0.0
	29.9	16.8					
8	33.8	15.0	26981.3	1	1000.00	5.00	0.0
	37.6	13.2					
9	41.6	11.7	28880.1	1	1000.00	5.00	0.0
	45.6	10.1					
10	49.6	8.7	30329.4	1	1000.00	5.00	0.0
	53.6	7.3					
11	57.7	6.2	31293.8	1	1000.00	5.00	0.0
	61.9	5.0					
12	66.0	4.1	31745.8	1	1000.00	5.00	0.0
	70.2	3.1					
13	74.4	2.4	31666.3	1	1000.00	5.00	0.0
	78.6	1.7					
14	82.8	1.2	31045.3	1	1000.00	5.00	0.0
	87.1	0.7					
15	91.3	0.4	29881.3	1	1000.00	5.00	0.0
	95.6	0.1					
16	98.8	0.1	21416.3	1	1000.00	5.00	0.0
	102.0	0.0					
17	106.3	0.1	26558.6	1	1000.00	5.00	0.0
	110.5	0.2					
18	114.8	0.6	23965.4	1	1000.00	5.00	0.0
	119.0	0.9					
19	123.3	1.4	20902.5	1	1000.00	5.00	0.0
	127.5	2.0					
20	131.7	2.8	17409.5	1	1000.00	5.00	0.0
	135.9	3.6					

21	140.0	4.6	13533.6	1	1000.00	5.00	0.0
	144.2	5.6					
22	148.3	6.8	9329.1	1	1000.00	5.00	0.0
	152.4	8.0					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 3 - case 1

Modified Swedish (Corps method)

Search for critical shear surface

TABLE NO. 20

```
*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	152.4	8.0					
23	156.4	9.4	4856.6	1	1000.00	5.00	0.0
	160.4	10.8					
24	162.6	11.7	703.1	1	1000.00	5.00	0.0
	164.7	12.6					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Example 3 - case 1

Modified Swedish (Corps method)

Search for critical shear surface

TABLE NO. 21

```
*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

				FORCES DUE TO SURFACE PRESSURES			
Slice No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
1	-6.7	0.	45.8	0.	0.	0.0	0.0
2	-1.7	0.	43.7	0.	0.	0.0	0.0
3	3.3	0.	41.7	0.	0.	0.0	0.0
4	8.5	0.	39.8	0.	0.	0.0	0.0
5	13.5	0.	38.1	0.	0.	0.0	0.0
6	18.7	0.	36.0	0.	0.	0.0	0.0
7	26.1	0.	33.0	0.	0.	0.0	0.0
8	33.8	0.	30.2	0.	0.	0.0	0.0
9	41.6	0.	27.5	0.	0.	0.0	0.0
10	49.6	0.	25.0	0.	0.	0.0	0.0
11	57.7	0.	22.7	0.	0.	0.0	0.0
12	66.0	0.	20.7	0.	0.	0.0	0.0
13	74.4	0.	18.8	0.	0.	0.0	0.0

14	82.8	0.	17.1	0.	0.	0.0	0.0
15	91.3	0.	15.7	0.	0.	0.0	0.0
16	98.8	0.	14.6	0.	0.	0.0	0.0
17	106.3	0.	13.6	0.	0.	0.0	0.0
18	114.8	0.	12.8	0.	0.	0.0	0.0
19	123.3	0.	12.2	0.	0.	0.0	0.0
20	131.7	0.	11.8	0.	0.	0.0	0.0
21	140.0	0.	11.6	0.	0.	0.0	0.0
22	148.3	0.	11.7	0.	0.	0.0	0.0
23	156.4	0.	12.0	0.	0.	0.0	0.0
24	162.6	0.	12.4	0.	0.	0.0	0.0

TABLE NO. 23

```
****************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
****************************************************************

        Trial     Trial
        Factor  Side Force    Force      Moment                 Delta
Iter-    of    Inclination  Imbalance   Imbalance   Delta-F     Theta
ation  Safety   (degrees)    (lbs.)    (ft.-lbs.)             (degrees)

   1   3.00000  -15.0000 -0.1212E+05 -0.3058E+06
First-order corrections to F and THETA ......... -0.634E+00 0.757E+01
Values factored by 0.788E+00 - Deltas too large  -0.500E+00 0.597E+01

   2   2.50000   -9.0350  0.1084E+02 -0.5953E+05
First-order corrections to F and THETA ......... -0.973E-02 0.585E+00
Second-order correction - Iteration   1 ........ -0.968E-02 0.585E+00
Second-order correction - Iteration   2 ........ -0.968E-02 0.585E+00

   3   2.49032   -8.4501 -0.1343E-01 -0.6114E+02
First-order corrections to F and THETA ......... -0.106E-04 0.607E-03
Second-order correction - Iteration   1 ........ -0.102E-04 0.579E-03

   4   2.49031   -8.4495  0.8789E-02 -0.2778E+01
First-order corrections to F and THETA ......... -0.206E-06 0.256E-04

FACTOR OF SAFETY - - - - - - - -      2.490
SIDE FORCE INCLINATION - - - - -      -8.45
NUMBER OF ITERATIONS - - - - - -      4
```


TABLE NO. 24

```
**********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
**********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 2.490   Side Force Inclination = -8.45 Degrees

-------- VALUES AT CENTER OF BASE OF SLICE---------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	-6.7	41.5	583.1	583.1	422.0
2	-1.7	37.3	1034.9	1034.9	437.9
3	3.3	33.3	1475.5	1475.5	453.4
4	8.5	29.6	1895.4	1895.4	468.1
5	13.5	26.1	2285.2	2285.2	481.8
6	18.7	23.0	2556.7	2556.7	491.4
7	26.1	18.8	2854.9	2854.9	501.9
8	33.8	15.0	3109.1	3109.1	510.8
9	41.6	11.7	3317.3	3317.3	518.1
10	49.6	8.7	3477.9	3477.9	523.7
11	57.7	6.2	3589.3	3589.3	527.7
12	66.0	4.1	3650.2	3650.2	529.8
13	74.4	2.4	3659.3	3659.3	530.1
14	82.8	1.2	3615.7	3615.7	528.6
15	91.3	0.4	3518.3	3518.3	525.2
16	98.8	0.1	3391.0	3391.0	520.7
17	106.3	0.1	3215.7	3215.7	514.5
18	114.8	0.6	2966.6	2966.6	505.8
19	123.3	1.4	2661.3	2661.3	495.1
20	131.7	2.8	2299.2	2299.2	482.3
21	140.0	4.6	1879.7	1879.7	467.6
22	148.3	6.8	1402.4	1402.4	450.8
23	156.4	9.4	866.5	866.5	432.0
24	162.6	11.7	415.3	415.3	416.1

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION    =      0.01  (= 0.118E-01)
     SHOULD NOT EXCEED    0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION  =      0.02  (= 0.156E-01)
     SHOULD NOT EXCEED    0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN =      2.98  (= 0.298E+01)
     SHOULD NOT EXCEED    0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM   =      0.01  (= 0.523E-02)
     SHOULD NOT EXCEED    0.100E+03
1    UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
       Example 3 - case 1
        Modified Swedish (Corps method)
```

Search for critical shear surface

TABLE NO. 25

```
*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 2.490 Side Force Inclination = -8.45 Degrees

			--------------- VALUES AT RIGHT SIDE OF SLICE ---------------			
Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	-5.0	333.	41.3	0.124	-41.6	107.8
2	1.6	3102.	37.2	0.169	-196.7	595.4
3	5.0	5416.	35.1	0.174	-284.2	879.5
4	12.0	11492.	31.4	0.189	-431.4	1424.4
5	15.0	14523.	29.9	0.195	-488.4	1666.8
6	22.3	22161.	26.6	0.213	-578.4	2180.1
7	29.9	29801.	23.6	0.232	-610.9	2612.3
8	37.6	37033.	20.9	0.247	-611.3	2967.4
9	45.6	43491.	18.5	0.259	-590.7	3256.4
10	53.6	48862.	16.3	0.270	-555.7	3484.8
11	61.9	52891.	14.3	0.279	-510.1	3655.5
12	70.2	55387.	12.6	0.287	-456.3	3769.8
13	78.6	56231.	11.2	0.295	-395.9	3827.9
14	87.1	55374.	10.1	0.302	-329.9	3829.9
15	95.6	52843.	9.3	0.309	-259.1	3775.4
16	102.0	49895.	8.9	0.314	-202.9	3697.0
17	110.5	44731.	8.5	0.321	-124.4	3541.9
18	119.0	38373.	8.5	0.329	-41.6	3328.3
19	127.5	31142.	8.7	0.338	45.9	3054.9
20	135.9	23436.	9.2	0.350	139.4	2719.7
21	144.2	15727.	10.0	0.365	241.8	2319.1
22	152.4	8562.	11.0	0.388	361.3	1844.2
23	160.4	2553.	12.0	0.422	474.5	1316.5
24	164.7	0.	196.4	ABOVE********************		

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.01 (= 0.118E-01)
    SHOULD NOT EXCEED 0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = 0.02 (= 0.156E-01)
    SHOULD NOT EXCEED 0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = 2.98 (= 0.298E+01)
    SHOULD NOT EXCEED 0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.01 (= 0.523E-02)
    SHOULD NOT EXCEED 0.100E+03

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

File: EXAM3B.IN

```
HEADING
  Example 3 - Circular search
   Clay embankment on 10 foot sand layer
   Sand is over 25 foot of clay over rock
PROFILE LINES
  1  1  Embankment surface
  -215  0
   -15 50
    15 50
   215  0

  2  2  Upstream sand layer
  -400  0
   -15  0
    -5 -10

  3  2  Downstream sand layer
    5  -10
   15    0
  400    0

  4  3  Foundation clay
  -400  -10
   400  -10

  5  4  Rock
  -400  -35
   400  -35


HEADING
  Case 2 - Partial pool
   Phreatic surface in embankment
   Additional piezometric line in sand
MATERIAL PROPERTY
  1  Moist embankment
   115 = moist unit weight
   Nonlinear strength envelope
    -1000   0
        0   0
     1008.3  470.2
    10000   3743.0

    Piezometric Line
     1  Phreatic surface
  2  Saturated embankment
   120 = saturated unit weight
   Nonlinear strength envelope
    -1000   0
        0   0
```

```
 1008.3  470.2
10000   3743.0

Piezometric Line
  1  Phreatic surface
3  Sand layer
 130 - saturated unit weight
 Conventional shear strength
  0  35
 Piezometric Line
  2
4  Foundation clay
 115 - saturated unit weight
 Nonlinear strength envelope
  -1000   0
      0   0
   1171.6  676.4
  10000   4793.2

  Piezometric Line
   1
5  Rock
 165 - saturated unit weight
 Conventional shear strength
  0  45
 Piezometric Line
  1

PIEZOMETRIC LINE DATA
  1  62.4  Phreatic surface
   -400  20
   -135  20
      0  20
    100  12.3
    195   5
    400   5

  2        Sand piezometric surface
   -400  20
      0  20
      0   5
    400   5


SURFACE PRESSURES    pool
  -400   0  1248  0
  -215   0  1248  0
  -135  20     0  0
   195   5     0  0
   215   0   312  0
   400   0   312  0
```

```
HEADING
  Search for critical circle - pool level = 20 ft
  Spencer's analysis procedure
  Tangent search mode - elev. 0
ANALYSIS/COMPUTATION
  Circular Search
  -150   170   0.5   -50
  Tangent
   0
  SHORT
  PROCEDURE
   Spencer

COMPUTE
HEADING
  Search for critical circle - pool level = 20 ft
  Corps Modified Swedish analysis procedure
  Tangent search mode - elev. 0
ANALYSIS/COMPUTATION
  Circular Search
  -175   240   0.5   -50
  Tangent
   0
  PROCEDURE
   Corps
    14.0

COMPUTE
HEADING
  Search for critical circle - pool level = 20 ft
  Bishop's analysis procedure
  Tangent search mode - elev. 0
ANALYSIS/COMPUTATION
  Circular Search
  -140   170   0.5   -50
  Tangent
   0
  PROCEDURE
   Bishop

COMPUTE
HEADING
  Search for critical circle - pool level = 20 ft
  Lowe and Karafiath's analysis procedure
  Tangent search mode - elev. 0
ANALYSIS/COMPUTATION
  Circular Search
  -160   230   0.5   -50
  Tangent
   0
  PROCEDURE
   Lowe
```

COMPUTE

File: EXAM3B.OUT

```
1          UTEXAS2 - VER. 1.209 -   2/3/87   - SN00004 - (C) 1985 S. G. WRIGHT

           TABLE NO. 1
           *****************************************
           * COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
           * Originally Coded By Stephen G. Wright  *
           * Version No. 1.209                      *
           * Last Revision Date  2/3/87             *
           * Serial No. 00004                       *
           * (C) Copyright 1985 Stephen G. Wright   *
           * All Rights Reserved                    *
           *****************************************

           ************************************************************
           *                                                          *
           *      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
           * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
           * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL  *
           * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE  *
           * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER *
           * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS     *
           * PROGRAM BEFORE ATTEMPTING ITS USE.                        *
           *                                                          *
           *      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
           * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR *
           * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS *
           * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                 *
           *                                                          *
           ************************************************************
1          UTEXAS2 - VER. 1.209 -   2/3/87   - SN00004 - (C) 1985 S. G. WRIGHT
                                  Example 3 - Circular search
                                   Clay embankment on 10 foot sand layer
                                   Sand is over 25 foot of clay over rock

           TABLE NO.  2
           *************************
           * NEW PROFILE LINE DATA *
           *************************

           PROFILE LINE  1 - MATERIAL TYPE =  1
           Embankment surface

                Point      X              Y

                  1      -215.000         0.000
                  2       -15.000        50.000
                  3        15.000        50.000
                  4       215.000         0.000

           PROFILE LINE  2 - MATERIAL TYPE =  2
```

Upstream sand layer

Point	X	Y
1	-400.000	0.000
2	-15.000	0.000
3	-5.000	-10.000

PROFILE LINE 3 - MATERIAL TYPE = 2
Downstream sand layer

Point	X	Y
1	5.000	-10.000
2	15.000	0.000
3	400.000	0.000

PROFILE LINE 4 - MATERIAL TYPE = 3
Foundation clay

Point	X	Y
1	-400.000	-10.000
2	400.000	-10.000

PROFILE LINE 5 - MATERIAL TYPE = 4
Rock

Point	X	Y
1	-400.000	-35.000
2	400.000	-35.000

All new profile lines defined - No old lines retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Case 2 - Partial pool
Phreatic surface in embankment
Additional piezometric line in sand

TABLE NO. 3

****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1
Moist embankment

Unit weight of material = 115.000

---- NONLINEAR SHEAR STRENGTH ENVELOPE ----

Point Normal Stress Shear Stress

1	-1000.000	0.000
2	0.000	0.000
3	1008.300	470.200
4	10000.000	3743.000

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 2
Saturated embankment

Unit weight of material = 120.000

---- NONLINEAR SHEAR STRENGTH ENVELOPE ----

Point	Normal Stress	Shear Stress
1	-1000.000	0.000
2	0.000	0.000
3	1008.300	470.200
4	10000.000	3743.000

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 3
Sand layer

Unit weight of material = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - - 0.000
Friction angle - - - - - 35.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 2
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 4
Foundation clay

Unit weight of material = 115.000

---- NONLINEAR SHEAR STRENGTH ENVELOPE ----

Point	Normal Stress	Shear Stress
1	-1000.000	0.000
2	0.000	0.000
3	1171.600	676.400
4	10000.000	4793.200

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 5
Rock

Unit weight of material = 165.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.000
Friction angle - - - - - 45.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

All new material properties defined - No old data retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Case 2 - Partial pool
Phreatic surface in embankment
Additional piezometric line in sand

TABLE NO. 4

****
* NEW PIEZOMETRIC LINE DATA *
****

Line No.	Point	X	Y	
1 - Unit weight of water =			62.40	Phreatic surface
1	1	-400.000	20.000	Phreatic surface
1	2	-135.000	20.000	Phreatic surface
1	3	0.000	20.000	Phreatic surface
1	4	100.000	12.300	Phreatic surface
1	5	195.000	5.000	Phreatic surface
1	6	400.000	5.000	Phreatic surface
2 - Unit weight of water =			62.40	Sand piezometric surface
2	1	-400.000	20.000	Sand piezometric surface
2	2	0.000	20.000	Sand piezometric surface
2	3	0.000	5.000	Sand piezometric surface
2	4	400.000	5.000	Sand piezometric surface

All new piezometric lines defined - No old lines retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Case 2 - Partial pool
Phreatic surface in embankment
Additional piezometric line in sand

TABLE NO. 7

****
* NEW SURFACE PRESSURE DATA *
****

ALL NEW DATA INPUT - NO OLD DATA RETAINED

Surface Pressures -

Point	X	Y	Normal Pressure	Shear Stress
1	-400.000	0.000	1248.000	0.000
2	-215.000	0.000	1248.000	0.000
3	-135.000	20.000	0.000	0.000
4	195.000	5.000	0.000	0.000
5	215.000	0.000	312.000	0.000
6	400.000	0.000	312.000	0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Search for critical circle - pool level = 2

Spencer's analysis procedure

Tangent search mode - elev. 0

TABLE NO. 9

****
* NEW ANALYSIS/COMPUTATION DATA *
****

Circular Shear Surface(s)

Automatic Search Performed

Starting Center Coordinate for Search at -

X = -150.000

Y = 170.000

Required accuracy for critical center (= minimum
spacing between grid points) = 0.500

Critical shear surface not allowed to pass below Y = -50.000

For the initial mode of search
all circles are tangent to horizontal line at -

Y = 0.000

Short form of output will be used for search

Procedure used to compute the factor of safety: SPENCER

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Initial trial estimate for side force inclination = 15.000 degrees
(Applicable to Spencer's procedure only)

Maximum number of iterations allowed for
calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Initial trial values for factor of safety (and side force inclination
for Spencer's procedure) will be kept constant during search

Maximum subtended angle to be used for subdivision of the
circle into slices = 3.00 degrees

Depth of crack = 0.000

Search will be continued to locate a more critical shear
surface (if one exists) after the initial mode is complete

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Search for critical circle - pool level = 2
Spencer's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 10
****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA
WERE GENERATED BY THE PROGRAM

Slope Coordinates -

Point	X	Y
1	-400.000	0.000
2	-215.000	0.000
3	-15.000	50.000
4	15.000	50.000
5	215.000	0.000
6	400.000	0.000

CAUTION - DATA FOR MATERIAL TYPE 5 ARE NOT USED

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Search for critical circle - pool level = 2
Spencer's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 14

****
* SHORT-FORM TABLE FOR SEARCH WITH CIRCULAR SHEAR SURFACES *
****

Mode		Center Coordinates of Critical Circle X	Y	Radius	Factor of Safety	Side Force Inclin.
2	Tangent Line at Y = 0.0	-133.000	172.500	172.500	1.520	10.30
3	Constant Radius of R = 172.5	-135.500	168.500	172.500	1.513	9.74
2	Tangent Line at Y = -4.0	-137.000	173.500	177.500	1.513	9.72

TABLE NO. 15

***** FINAL CRITICAL CIRCLE INFORMATION *****

X Coordinate of Center - - - - - - - -137.000
Y Coordinate of Center - - - - - - - 173.500
Radius - - - - - - - - - - - - - - - 177.500
Factor of Safety - - - - - - - - - - 1.513
Side Force Inclination - - - - - - - 9.72

Number of circles tried - - - - - - 155
No. of circles F calc. for - - - - - 155

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Spencer's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 20

****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-193.7	5.3					
1	-189.3	3.9	2532.1	1	NONLINEAR	ENVELOPE	1001.9
	-184.9	2.6					
2	-180.4	1.4	7482.9	1	NONLINEAR	ENVELOPE	1158.2
	-175.9	0.3					
3	-175.2	0.2	1558.9	1	NONLINEAR	ENVELOPE	1238.5

	-174.5	0.0				
4	-169.9	-0.9	12783.4	2	NONLINEAR ENVELOPE	1301.8
	-165.3	-1.7				
5	-160.7	-2.3	16959.2	2	NONLINEAR ENVELOPE	1394.3
	-156.1	-3.0				
6	-151.5	-3.3	20627.6	2	NONLINEAR ENVELOPE	1456.8
	-146.9	-3.7				
7	-142.2	-3.9	23740.4	2	NONLINEAR ENVELOPE	1489.0
	-137.6	-4.0				
8	-137.3	-4.0	1570.1	2	NONLINEAR ENVELOPE	1497.6
	-137.0	-4.0				
9	-136.0	-4.0	5501.1	2	NONLINEAR ENVELOPE	1497.2
	-135.0	-4.0				
10	-130.4	-3.8	26849.1	2	NONLINEAR ENVELOPE	1486.0
	-125.7	-3.6				
11	-121.1	-3.2	28570.6	2	NONLINEAR ENVELOPE	1449.2
	-116.5	-2.8				
12	-111.9	-2.1	29650.4	2	NONLINEAR ENVELOPE	1382.1
	-107.3	-1.5				
13	-103.4	-0.7	25491.8	2	NONLINEAR ENVELOPE	1294.5
	-99.5	0.0				
14	-95.0	1.1	30004.2	1	NONLINEAR ENVELOPE	1179.4
	-90.5	2.2				
15	-86.1	3.5	29383.9	1	NONLINEAR ENVELOPE	1027.5
	-81.6	4.9				
16	-77.2	6.4	28185.3	1	NONLINEAR ENVELOPE	846.6
	-72.8	8.0				
17	-68.6	9.8	26443.7	1	NONLINEAR ENVELOPE	637.1
	-64.3	11.6				
18	-60.1	13.6	24203.7	1	NONLINEAR ENVELOPE	399.6
	-55.9	15.6				
19	-51.9	17.8	21217.0	1	NONLINEAR ENVELOPE	137.0
	-47.9	20.0				
20	-43.9	22.4	18499.9	1	NONLINEAR ENVELOPE	0.0
	-40.0	24.9				
21	-36.1	27.5	15122.3	1	NONLINEAR ENVELOPE	0.0
	-32.3	30.2				
22	-28.6	33.0	11505.5	1	NONLINEAR ENVELOPE	0.0
	-25.0	35.8				

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Search for critical circle - pool level = 2
Spencer's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 20

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
*******************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure

	-25.0	35.8				
23	-21.4	38.9	7730.8	1	NONLINEAR ENVELOPE	0.0
	-17.9	41.9				
24	-16.5	43.2	2140.1	1	NONLINEAR ENVELOPE	0.0
	-15.0	44.6				
25	-12.3	47.3	1713.6	1	NONLINEAR ENVELOPE	0.0
	-9.5	50.0				

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Spencer's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 21

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
*******************************************************************
```

				FORCES DUE TO SURFACE PRESSURES			
Slice No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
1	-189.3	0.	5.2	7754.	0.	-189.4	6.4
2	-180.4	0.	5.1	6572.	0.	-180.5	8.6
3	-175.2	0.	5.1	893.	0.	-175.2	10.0
4	-169.9	0.	5.2	5125.	0.	-170.1	11.2
5	-160.7	0.	5.6	3811.	0.	-161.0	13.5
6	-151.5	0.	6.2	2457.	0.	-151.9	15.8
7	-142.2	0.	7.1	1079.	0.	-143.2	17.9
8	-137.3	0.	7.6	21.	0.	-137.3	19.4
9	-136.0	0.	7.8	32.	0.	-136.3	19.7
10	-130.4	0.	8.6	0.	0.	-130.4	21.2
11	-121.1	0.	10.1	0.	0.	-121.1	23.5
12	-111.9	0.	11.8	0.	0.	-111.9	25.8
13	-103.4	0.	13.6	0.	0.	-103.4	27.9
14	-95.0	0.	15.5	0.	0.	-95.0	30.0
15	-86.1	0.	17.9	0.	0.	-86.1	32.2
16	-77.2	0.	20.4	0.	0.	-77.2	34.4
17	-68.6	0.	23.2	0.	0.	-68.6	36.6
18	-60.1	0.	26.2	0.	0.	-60.1	38.7
19	-51.9	0.	29.3	0.	0.	-51.9	40.8
20	-43.9	0.	32.6	0.	0.	-43.9	42.8
21	-36.1	0.	36.1	0.	0.	-36.1	44.7
22	-28.6	0.	39.8	0.	0.	-28.6	46.6
23	-21.4	0.	43.6	0.	0.	-21.4	48.4
24	-16.5	0.	46.4	0.	0.	-16.5	49.6
25	-12.3	0.	48.6	0.	0.	-12.3	50.0

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Spencer's analysis procedure

Tangent search mode - elev. 0

TABLE NO. 23

```
******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
******************************************************************

        Trial     Trial
        Factor  Side Force    Force      Moment               Delta
Iter-     of    Inclination  Imbalance  Imbalance   Delta-F    Theta
ation   Safety   (degrees)    (lbs.)    (ft.-lbs.)           (degrees)

   1    3.00000   15.0000  0.3849E+05 -0.7569E+06
First-order corrections to F and THETA .........  -0.325E+01-0.137E+02
Values factored by 0.154E+00 - Deltas too large  -0.500E+00-0.211E+01

   2    2.50000   12.8890  0.3120E+05 -0.6181E+06
First-order corrections to F and THETA .........  -0.173E+01-0.639E+01
Values factored by 0.290E+00 - Deltas too large  -0.500E+00-0.185E+01

   3    2.00000   11.0385  0.1973E+05 -0.4002E+06
First-order corrections to F and THETA .........  -0.669E+00-0.184E+01
Values factored by 0.747E+00 - Deltas too large  -0.500E+00-0.138E+01

   4    1.50000    9.6613 -0.6614E+01 -0.1418E+05
First-order corrections to F and THETA .........   0.179E-02 0.163E+00
Second-order correction - Iteration   1 ........   0.179E-02 0.163E+00

   5    1.50179    9.8244 -0.3662E-02  0.1298E+02
First-order corrections to F and THETA .........  -0.144E-05-0.146E-03

For trial number  2 with a nonlinear strength envelope the maximum
percent change in shear strength was   100.000 - at slice   1
```

TABLE NO. 23

```
******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
******************************************************************

        Trial     Trial
        Factor  Side Force    Force      Moment               Delta
Iter-     of    Inclination  Imbalance  Imbalance   Delta-F    Theta
ation   Safety   (degrees)    (lbs.)    (ft.-lbs.)           (degrees)

   1    1.50179    9.8244 -0.6634E+03  0.2550E+05
First-order corrections to F and THETA .........   0.110E-01-0.105E+00
Second-order correction - Iteration   1 ........   0.111E-01-0.105E+00
Second-order correction - Iteration   2 ........   0.111E-01-0.105E+00

   2    1.51287    9.7192  0.3943E-01  0.1139E+03
```

First-order corrections to F and THETA .... -0.148E-04-0.127E-02
Second-order correction - Iteration 1 .... -0.149E-04-0.128E-02

3 1.51286 9.7180 -0.1038E-01 -0.8131E+00
First-order corrections to F and THETA 0.323E-06 0.118E-04

For trial number 3 with a nonlinear strength envelope the maximum percent change in shear strength was 0.000 - at slice 8

TABLE NO. 23

```
*****************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
*****************************************************************
```

Iteration	Trial Factor of Safety	Trial Side Force Inclination (degrees)	Force Imbalance (lbs.)	Moment Imbalance (ft.-lbs.)	Delta-F	Delta Theta (degrees)
1	1.51286	9.7180	-0.1038E-01	-0.8131E+00		

First-order corrections to F and THETA 0.323E-06 0.118E-04

FACTOR OF SAFETY - - - - - - - - - 1.513
SIDE FORCE INCLINATION - - - - - 9.72
NUMBER OF ITERATIONS - - - - - - 1

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Spencer's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 24

```
*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.513 Side Force Inclination = 9.72 Degrees

-------- VALUES AT CENTER OF BASE OF SLICE---------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	-189.3	3.9	1276.6	274.8	84.7
2	-180.4	1.4	1714.9	556.8	171.6
3	-175.2	0.2	1938.8	700.3	215.9
4	-169.9	-0.9	2128.2	826.4	254.7
5	-160.7	-2.3	2411.8	1017.4	313.0
6	-151.5	-3.3	2620.5	1163.8	348.2

7	-142.2	-3.9	2762.4	1273.4	374.6
8	-137.3	-4.0	2818.9	1321.3	386.1
9	-136.0	-4.0	2828.5	1331.2	388.5
10	-130.4	-3.8	2928.0	1442.0	415.1
11	-121.1	-3.2	3076.8	1627.6	459.8
12	-111.9	-2.1	3159.7	1777.6	495.9
13	-103.4	-0.7	3181.7	1887.2	522.3
14	-95.0	1.1	3152.4	1973.0	542.9
15	-86.1	3.5	3071.4	2043.8	559.9
16	-77.2	6.4	2935.0	2088.4	570.7
17	-68.6	9.8	2745.7	2108.5	575.5
18	-60.1	13.6	2505.7	2106.1	574.9
19	-51.9	17.8	2220.3	2083.3	569.4
20	-43.9	22.4	1903.4	1903.4	526.2
21	-36.1	27.5	1562.3	1562.3	444.1
22	-28.6	33.0	1192.9	1192.9	355.2
23	-21.4	38.9	806.9	806.9	248.7
24	-16.5	43.2	529.8	529.8	163.3
25	-12.3	47.3	219.6	219.6	67.7

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.01 (= 0.144E-01)
SHOULD NOT EXCEED 0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = 0.02 (= 0.173E-01)
SHOULD NOT EXCEED 0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = 0.35 (= 0.350E+00)
SHOULD NOT EXCEED 0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.01 (= 0.512E-02)
SHOULD NOT EXCEED 0.100E+03

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Spencer's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 25
```
*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.513 Side Force Inclination = 9.72 Degrees

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	-184.9	6219.	5.3	0.551	1614.9	857.1
2	-175.9	13356.	5.2	0.513	1496.9	1279.6

3	-174.5	14477.	5.2	0.509	1483.9	1332.6
4	-165.3	21819.	5.1	0.482	1352.5	1689.6
5	-156.1	28722.	5.2	0.460	1216.5	1985.3
6	-146.9	34618.	5.5	0.443	1082.6	2204.8
7	-137.6	39180.	6.0	0.428	942.7	2364.4
8	-137.0	39414.	6.0	0.428	934.4	2371.9
9	-135.0	40178.	6.2	0.425	905.2	2396.5
10	-125.7	43056.	7.1	0.412	776.1	2493.1
11	-116.5	44772.	8.2	0.402	663.7	2552.4
12	-107.3	45179.	9.7	0.394	568.1	2565.0
13	-99.5	44463.	11.2	0.388	499.5	2536.8
14	-90.5	42403.	13.3	0.383	431.3	2458.5
15	-81.6	39146.	15.7	0.380	376.0	2333.3
16	-72.8	34889.	18.4	0.378	331.7	2165.7
17	-64.3	29911.	21.4	0.377	295.6	1963.7
18	-55.9	24556.	24.7	0.377	261.6	1741.7
19	-47.9	19307.	28.2	0.375	216.0	1531.3
20	-40.0	14116.	31.9	0.370	162.9	1310.6
21	-32.3	9187.	35.9	0.368	119.8	1047.6
22	-25.0	4971.	40.1	0.364	77.3	761.7
23	-17.9	1795.	44.5	0.358	34.8	444.3
24	-15.0	832.	46.8	0.441	104.2	218.4
25	-9.5	0.	-53.3	BELOW	0.0	0.0

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.01 (= 0.144E-01)
SHOULD NOT EXCEED 0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = 0.02 (= 0.173E-01)
SHOULD NOT EXCEED 0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = 0.35 (= 0.350E+00)
SHOULD NOT EXCEED 0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.01 (= 0.512E-02)
SHOULD NOT EXCEED 0.100E+03

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Corps Modified Swedish analysis procedure
Tangent search mode - elev. 0

TABLE NO. 9

```
*********************************
* NEW ANALYSIS/COMPUTATION DATA *
*********************************
```

Circular Shear Surface(s)

Automatic Search Performed

Starting Center Coordinate for Search at -
X = -175.000
Y = 240.000

Required accuracy for critical center (= minimum
spacing between grid points) = 0.500

Critical shear surface not allowed to pass below Y = -50.000

For the initial mode of search
all circles are tangent to horizontal line at -
Y = 0.000

Procedure used to compute the factor of safety: CORPS
Specified side force inclination = 14.00 degrees

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Maximum number of iterations allowed for
calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Initial trial values for factor of safety (and side force inclination
for Spencer's procedure) will be kept constant during search

Short form of output will be used for search

Maximum subtended angle to be used for subdivision of the
circle into slices = 3.00 degrees

Depth of crack = 0.000

Search will be continued to locate a more critical shear
surface (if one exists) after the initial mode is complete

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000

CAUTION - DATA FOR MATERIAL TYPE 5 ARE NOT USED
1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Corps Modified Swedish analysis procedure
Tangent search mode - elev. 0

TABLE NO. 14
****
* SHORT-FORM TABLE FOR SEARCH WITH CIRCULAR SHEAR SURFACES *

****

Mode		Center Coordinates of Critical Circle X	Y	Radius	Factor of Safety	Side Force Inclin.
2	Tangent Line at Y = 0.0	-137.500	188.000	188.000	1.555	14.00
3	Constant Radius of R = 188.0	-137.500	187.500	188.000	1.555	14.00

TABLE NO. 15
***** FINAL CRITICAL CIRCLE INFORMATION *****
X Coordinate of Center - - - - - - - - -137.500
Y Coordinate of Center - - - - - - - - 187.500
Radius - - - - - - - - - - - - - - - - - 188.000
Factor of Safety - - - - - - - - - - - 1.555
Side Force Inclination - - - - - - - - 14.00

Number of circles tried - - - - - - - 207
No. of circles F calc. for - - - - - - 207

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Corps Modified Swedish analysis procedure
Tangent search mode - elev. 0

TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-188.6	6.6					
1	-183.9	5.4	2639.8	1	NONLINEAR	ENVELOPE	912.6
	-179.1	4.2					
2	-174.3	3.2	7750.9	1	NONLINEAR	ENVELOPE	1048.4
	-169.5	2.2					
3	-164.6	1.5	12409.2	1	NONLINEAR	ENVELOPE	1152.8
	-159.7	0.8					
4	-155.5	0.4	14166.7	1	NONLINEAR	ENVELOPE	1222.5
	-151.2	0.0					
5	-146.3	-0.2	19694.3	2	NONLINEAR	ENVELOPE	1262.4
	-141.4	-0.5					
6	-139.4	-0.5	8631.4	2	NONLINEAR	ENVELOPE	1278.0
	-137.5	-0.5					
7	-136.2	-0.5	5807.7	2	NONLINEAR	ENVELOPE	1278.7
	-135.0	-0.5					
8	-130.1	-0.3	24351.8	2	NONLINEAR	ENVELOPE	1266.0

	-125.2	-0.1					
9	-124.5	0.0	3566.1	2	NONLINEAR	ENVELOPE	1251.0
	-123.8	0.0					
10	-118.9	0.5	26511.4	1	NONLINEAR	ENVELOPE	1217.6
	-114.0	1.0					
11	-109.1	1.7	27691.9	1	NONLINEAR	ENVELOPE	1140.9
	-104.3	2.5					
12	-99.5	3.5	28188.8	1	NONLINEAR	ENVELOPE	1032.4
	-94.6	4.5					
13	-89.9	5.7	28011.2	1	NONLINEAR	ENVELOPE	892.4
	-85.1	6.9					
14	-80.4	8.4	27179.7	1	NONLINEAR	ENVELOPE	721.3
	-75.7	9.9					
15	-71.1	11.7	25726.2	1	NONLINEAR	ENVELOPE	519.6
	-66.5	13.4					
16	-62.0	15.4	23693.6	1	NONLINEAR	ENVELOPE	287.8
	-57.5	17.4					
17	-54.8	18.7	13222.3	1	NONLINEAR	ENVELOPE	82.2
	-52.1	20.0					
18	-47.8	22.3	19345.8	1	NONLINEAR	ENVELOPE	0.0
	-43.5	24.7					
19	-39.3	27.3	16076.6	1	NONLINEAR	ENVELOPE	0.0
	-35.1	29.8					
20	-31.0	32.6	12463.7	1	NONLINEAR	ENVELOPE	0.0
	-27.0	35.4					
21	-23.1	38.4	8591.2	1	NONLINEAR	ENVELOPE	0.0
	-19.2	41.4					
22	-17.1	43.1	3036.5	1	NONLINEAR	ENVELOPE	0.0
	-15.0	44.9					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Corps Modified Swedish analysis procedure
Tangent search mode - elev. 0

TABLE NO. 20

```
*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-15.0	44.9					
23	-12.1	47.4	1677.8	1	NONLINEAR	ENVELOPE	0.0
	-9.3	50.0					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Corps Modified Swedish analysis procedure
Tangent search mode - elev. 0

TABLE NO. 21

```
************************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
************************************************************************
```

				FORCES DUE TO SURFACE PRESSURES			
Slice No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
1	-183.9	0.	6.6	7496.	0.	-184.0	7.7
2	-174.3	0.	6.7	6096.	0.	-174.5	10.1
3	-164.6	0.	7.1	4633.	0.	-164.8	12.5
4	-155.5	0.	7.6	2799.	0.	-155.8	14.8
5	-146.3	0.	8.5	1784.	0.	-147.0	17.0
6	-139.4	0.	9.2	276.	0.	-139.7	18.8
7	-136.2	0.	9.6	50.	0.	-136.7	19.6
8	-130.1	0.	10.5	0.	0.	-130.1	21.2
9	-124.5	0.	11.3	0.	0.	-124.5	22.6
10	-118.9	0.	12.3	0.	0.	-118.9	24.0
11	-109.1	0.	14.1	0.	0.	-109.1	26.5
12	-99.5	0.	16.2	0.	0.	-99.5	28.9
13	-89.9	0.	18.5	0.	0.	-89.9	31.3
14	-80.4	0.	21.0	0.	0.	-80.4	33.6
15	-71.1	0.	23.8	0.	0.	-71.1	36.0
16	-62.0	0.	26.8	0.	0.	-62.0	38.2
17	-54.8	0.	29.4	0.	0.	-54.8	40.0
18	-47.8	0.	32.1	0.	0.	-47.8	41.8
19	-39.3	0.	35.6	0.	0.	-39.3	43.9
20	-31.0	0.	39.3	0.	0.	-31.0	46.0
21	-23.1	0.	43.2	0.	0.	-23.1	48.0
22	-17.1	0.	46.3	0.	0.	-17.1	49.5
23	-12.1	0.	48.7	0.	0.	-12.1	50.0

```
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
                              Search for critical circle - pool level = 2
                              Corps Modified Swedish analysis procedure
                              Tangent search mode - elev. 0

          TABLE NO. 23
          ************************************************************************
          * INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
          * OF SAFETY BY THE CORPS OF ENGINEERS MODIFIED SWEDISH PROCEDURE *
          ************************************************************************

                          Trial Factor       Force Imbalance
          Iteration        of Safety             (lbs.)         DELTA-F

              1             3.00000           -0.345E+05      -2.79
          Reduced value - Delta was too large ............ -0.500

              2             2.50000           -0.271E+05      -1.52
          Reduced value - Delta was too large ............ -0.500
```

3	2.00000	-0.159E+05	-0.572

Reduced value - Delta was too large .... -0.500

4	1.50000	0.267E+04	0.537E-01
5	1.55373	0.930E+02	0.201E-02
6	1.55574	0.122E+00	0.263E-05

For trial number 2 with a nonlinear strength envelope the maximum percent change in shear strength was -0.827 - at slice 5

TABLE NO. 23

```
*****************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY THE CORPS OF ENGINEERS MODIFIED SWEDISH PROCEDURE *
*****************************************************************
```

Iteration	Trial Factor of Safety	Force Imbalance (lbs.)	DELTA-F
1	1.55574	-0.287E+02	-0.622E-03
2	1.55512	0.173E-01	0.374E-06

For trial number 3 with a nonlinear strength envelope the maximum percent change in shear strength was 0.000 - at slice 7

TABLE NO. 23

```
*****************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY THE CORPS OF ENGINEERS MODIFIED SWEDISH PROCEDURE *
*****************************************************************
```

Iteration	Trial Factor of Safety	Force Imbalance (lbs.)	DELTA-F
1	1.55512	0.118E-02	0.256E-07

```
FACTOR OF SAFETY - - - - - - - - -     1.555
SIDE FORCE INCLINATION - - - - -       14.00
NUMBER OF ITERATIONS - - - - - -       1
1        UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
                              Search for critical circle - pool level = 2
                              Corps Modified Swedish analysis procedure
                              Tangent search mode - elev. 0
```

TABLE NO. 24

```
********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
```

****

CORPS OF ENGINEERS' PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.555

-------- VALUES AT CENTER OF BASE OF SLICE--------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	-183.9	5.4	1208.0	295.4	88.6
2	-174.3	3.2	1609.5	561.1	168.3
3	-164.6	1.5	1925.8	773.0	231.8
4	-155.5	0.4	2151.6	929.1	278.6
5	-146.3	-0.2	2309.3	1047.0	311.4
6	-139.4	-0.5	2394.8	1116.9	327.8
7	-136.2	-0.5	2420.7	1142.1	333.7
8	-130.1	-0.3	2527.0	1261.0	361.5
9	-124.5	0.0	2632.7	1381.7	389.8
10	-118.9	0.5	2701.9	1484.2	413.8
11	-109.1	1.7	2783.7	1642.8	450.9
12	-99.5	3.5	2800.6	1768.3	480.2
13	-89.9	5.7	2755.6	1863.3	502.5
14	-80.4	8.4	2651.6	1930.3	518.2
15	-71.1	11.7	2491.6	1972.1	527.9
16	-62.0	15.4	2278.7	1990.9	532.3
17	-54.8	18.7	2075.2	1992.9	532.8
18	-47.8	22.3	1841.3	1841.3	497.3
19	-39.3	27.3	1528.1	1528.1	424.0
20	-31.0	32.6	1183.4	1183.4	343.3
21	-23.1	38.4	817.0	817.0	245.0
22	-17.1	43.1	526.1	526.1	157.8
23	-12.1	47.4	207.4	207.4	62.2

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.02 (= 0.164E-01)
SHOULD NOT EXCEED 0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = 0.01 (= 0.120E-01)
SHOULD NOT EXCEED 0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.02 (= 0.198E-01)
SHOULD NOT EXCEED 0.100E+03

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Corps Modified Swedish analysis procedure
Tangent search mode - elev. 0

TABLE NO. 25
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *

****

CORPS OF ENGINEERS' PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.555

----- VALUES AT RIGHT SIDE OF SLICE ----

Slice No.	X-Right	Side Force	Side Force Inclination (degrees)
1	-179.1	5768.	14.00
2	-169.5	12161.	14.00
3	-159.7	18460.	14.00
4	-151.2	23414.	14.00
5	-141.4	28111.	14.00
6	-137.5	29586.	14.00
7	-135.0	30416.	14.00
8	-125.2	33069.	14.00
9	-123.8	33360.	14.00
10	-114.0	34825.	14.00
11	-104.3	35084.	14.00
12	-94.6	34104.	14.00
13	-85.1	31951.	14.00
14	-75.7	28790.	14.00
15	-66.5	24874.	14.00
16	-57.5	20536.	14.00
17	-52.1	17854.	14.00
18	-43.5	13373.	14.00
19	-35.1	8940.	14.00
20	-27.0	5010.	14.00
21	-19.2	1935.	14.00
22	-15.0	726.	14.00
23	-9.3	0.	14.00

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Bishop's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

Circular Shear Surface(s)

Automatic Search Performed

Starting Center Coordinate for Search at -
X = -140.000
Y = 170.000

```
Required accuracy for critical center (= minimum
spacing between grid points) =      0.500

Critical shear surface not allowed to pass below Y =     -50.000

For the initial mode of search
all circles are tangent to horizontal line at -
                                           Y =      0.000

Procedure used to compute the factor of safety: BISHOP

----------------------------------------------------------------
THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety =  3.000

Maximum number of iterations allowed for
calculating the factor of safety =  40

Allowed force imbalance for convergence =     100.000

Allowed moment imbalance for convergence =     100.000

Initial trial values for factor of safety (and side force inclination
for Spencer's procedure) will be kept constant during search

Short form of output will be used for search

Maximum subtended angle to be used for subdivision of the
circle into slices =  3.00 degrees

Depth of crack =       0.000

Search will be continued to locate a more critical shear
surface (if one exists) after the initial mode is complete

Depth of water in crack =       0.000

Unit weight of water in crack =    62.400

Seismic coefficient = 0.000

CAUTION - DATA FOR MATERIAL TYPE  5 ARE NOT USED
```

```
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
                                Search for critical circle - pool level = 2
                                Bishop's analysis procedure
                                Tangent search mode - elev. 0

          TABLE NO. 14
          ************************************************************
          * SHORT-FORM TABLE FOR SEARCH WITH CIRCULAR SHEAR SURFACES *
          ************************************************************
```

Mode		Center Coordinates of Critical Circle X	Y	Radius	Factor of Safety	Side Force Inclin.
2	Tangent Line at Y = 0.0	-133.500	173.000	173.000	1.512	Horiz.
3	Constant Radius of R = 173.0	-136.000	169.000	173.000	1.505	Horiz.
2	Tangent Line at Y = -4.0	-137.500	174.000	178.000	1.505	Horiz.

TABLE NO. 15
***** FINAL CRITICAL CIRCLE INFORMATION *****
X Coordinate of Center - - - - - - - -137.500
Y Coordinate of Center - - - - - - - 174.000
Radius - - - - - - - - - - - - - - - 178.000
Factor of Safety - - - - - - - - - - 1.505
Side Force Inclination - - - - - - - Horiz.

Number of circles tried - - - - - - 152
No. of circles F calc. for - - - - - 152

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Bishop's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-194.1	5.2					
1	-189.6	3.9	2539.8	1	NONLINEAR	ENVELOPE	1006.8
	-185.2	2.5					
2	-180.6	1.4	7503.8	1	NONLINEAR	ENVELOPE	1162.4
	-176.1	0.2					
3	-175.6	0.1	1234.3	1	NONLINEAR	ENVELOPE	1240.5
	-175.0	0.0					
4	-170.4	-0.9	12679.0	2	NONLINEAR	ENVELOPE	1301.8
	-165.9	-1.7					
5	-161.2	-2.3	16873.9	2	NONLINEAR	ENVELOPE	1394.5
	-156.6	-3.0					
6	-152.0	-3.3	20558.8	2	NONLINEAR	ENVELOPE	1456.9
	-147.3	-3.7					
7	-142.7	-3.9	23685.3	2	NONLINEAR	ENVELOPE	1489.1

	-138.0	-4.0					
8	-137.8	-4.0	1422.4	2	NONLINEAR	ENVELOPE	1497.6
	-137.5	-4.0					
9	-136.2	-4.0	6857.5	2	NONLINEAR	ENVELOPE	1497.1
	-135.0	-4.0					
10	-130.3	-3.8	26903.2	2	NONLINEAR	ENVELOPE	1484.8
	-125.7	-3.6					
11	-121.0	-3.2	28601.1	2	NONLINEAR	ENVELOPE	1446.2
	-116.4	-2.7					
12	-111.8	-2.1	29653.8	2	NONLINEAR	ENVELOPE	1377.4
	-107.2	-1.4					
13	-103.6	-0.7	23706.1	2	NONLINEAR	ENVELOPE	1291.7
	-100.0	0.0					
14	-95.4	1.1	29976.3	1	NONLINEAR	ENVELOPE	1179.3
	-90.9	2.2					
15	-86.5	3.5	29358.6	1	NONLINEAR	ENVELOPE	1027.2
	-82.0	4.9					
16	-77.6	6.4	28159.9	1	NONLINEAR	ENVELOPE	845.9
	-73.2	8.0					
17	-68.9	9.8	26415.3	1	NONLINEAR	ENVELOPE	636.0
	-64.6	11.6					
18	-60.4	13.6	24169.8	1	NONLINEAR	ENVELOPE	398.0
	-56.2	15.6					
19	-52.2	17.8	21001.7	1	NONLINEAR	ENVELOPE	136.0
	-48.2	20.0					
20	-44.3	22.4	18476.7	1	NONLINEAR	ENVELOPE	0.0
	-40.3	24.9					
21	-36.5	27.5	15090.0	1	NONLINEAR	ENVELOPE	0.0
	-32.6	30.2					
22	-28.9	33.0	11462.0	1	NONLINEAR	ENVELOPE	0.0
	-25.2	35.9					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Search for critical circle - pool level = 2
Bishop's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 20

```
****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
****************************************************************
```

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-25.2	35.9					
23	-21.7	38.9	7674.5	1	NONLINEAR	ENVELOPE	0.0
	-18.2	41.9					
24	-16.6	43.4	2263.9	1	NONLINEAR	ENVELOPE	0.0
	-15.0	44.9					
25	-12.4	47.4	1538.4	1	NONLINEAR	ENVELOPE	0.0
	-9.8	50.0					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Bishop's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 21

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
*******************************************************************
```

Slice No.	X	Seismic Force	Y for Seismic Force	FORCES DUE TO SURFACE PRESSURES Normal Force	Shear Force	X	Y
1	-189.6	0.	5.1	7826.	0.	-189.7	6.3
2	-180.6	0.	5.0	6636.	0.	-180.8	8.6
3	-175.6	0.	5.0	719.	0.	-175.6	9.9
4	-170.4	0.	5.1	5220.	0.	-170.6	11.1
5	-161.2	0.	5.5	3898.	0.	-161.5	13.4
6	-152.0	0.	6.1	2537.	0.	-152.4	15.6
7	-142.7	0.	7.0	1151.	0.	-143.6	17.8
8	-137.8	0.	7.6	23.	0.	-137.8	19.3
9	-136.2	0.	7.8	50.	0.	-136.7	19.6
10	-130.3	0.	8.6	0.	0.	-130.3	21.2
11	-121.0	0.	10.1	0.	0.	-121.0	23.5
12	-111.8	0.	11.8	0.	0.	-111.8	25.8
13	-103.6	0.	13.6	0.	0.	-103.6	27.9
14	-95.4	0.	15.5	0.	0.	-95.4	29.9
15	-86.5	0.	17.8	0.	0.	-86.5	32.1
16	-77.6	0.	20.4	0.	0.	-77.6	34.3
17	-68.9	0.	23.2	0.	0.	-68.9	36.5
18	-60.4	0.	26.1	0.	0.	-60.4	38.6
19	-52.2	0.	29.3	0.	0.	-52.2	40.7
20	-44.3	0.	32.6	0.	0.	-44.3	42.7
21	-36.5	0.	36.1	0.	0.	-36.5	44.6
22	-28.9	0.	39.8	0.	0.	-28.9	46.5
23	-21.7	0.	43.6	0.	0.	-21.7	48.3
24	-16.6	0.	46.5	0.	0.	-16.6	49.6
25	-12.4	0.	48.7	0.	0.	-12.4	50.0

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Bishop's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 23

```
*******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY THE SIMPLIFIED BISHOP PROCEDURE                    *
*******************************************************************
```

Iteration	Trial Factor of Safety	Moment Imbalance (ft.-lbs.)	DELTA-F
1	3.00000	-0.680E+07	-2.93
Reduced value - Delta was too large			-0.500
2	2.50000	-0.540E+07	-1.63
Reduced value - Delta was too large			-0.500
3	2.00000	-0.334E+07	-0.651
Reduced value - Delta was too large			-0.500
4	1.50000	-0.435E+04	-0.487E-03
5	1.49951	-0.884E+02	-0.989E-05

For trial number 2 with a nonlinear strength envelope the maximum percent change in shear strength was 100.000 - at slice 1

TABLE NO. 23

```
******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY THE SIMPLIFIED BISHOP PROCEDURE                   *
******************************************************************
```

Iteration	Trial Factor of Safety	Moment Imbalance (ft.-lbs.)	DELTA-F
1	1.49950	0.464E+05	0.518E-02
2	1.50468	0.948E+03	0.106E-03
3	1.50479	0.131E+02	0.147E-05

For trial number 3 with a nonlinear strength envelope the maximum percent change in shear strength was 0.000 - at slice 3

TABLE NO. 23

```
******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY THE SIMPLIFIED BISHOP PROCEDURE                   *
******************************************************************
```

Iteration	Trial Factor of Safety	Moment Imbalance (ft.-lbs.)	DELTA-F
1	1.50479	0.197E+01	0.221E-06

FACTOR OF SAFETY - - - - - - - - 1.505
SIDE FORCE INCLINATION - - - - - Horiz.
NUMBER OF ITERATIONS - - - - - - 1

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Search for critical circle - pool level = 2
Bishop's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 24

****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)   *
****

SIMPLIFIED BISHOP PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.505

-------- VALUES AT CENTER OF BASE OF SLICE---------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	-189.6	3.9	1150.8	144.1	44.6
2	-180.6	1.4	1573.9	411.5	127.5
3	-175.6	0.1	1789.8	549.4	170.2
4	-170.4	-0.9	1976.8	675.0	209.2
5	-161.2	-2.3	2273.2	878.7	272.3
6	-152.0	-3.3	2504.7	1047.8	322.0
7	-142.7	-3.9	2672.9	1183.8	354.9
8	-137.8	-4.0	2744.2	1246.6	370.1
9	-136.2	-4.0	2759.9	1262.8	374.0
10	-130.3	-3.8	2873.0	1388.2	404.4
11	-121.0	-3.2	3040.2	1593.9	454.1
12	-111.8	-2.1	3143.4	1766.1	495.8
13	-103.6	-0.7	3185.0	1893.4	526.5
14	-95.4	1.1	3176.3	1997.0	551.6
15	-86.5	3.5	3116.7	2089.6	574.0
16	-77.6	6.4	2998.4	2152.5	589.2
17	-68.9	9.8	2822.4	2186.4	597.4
18	-60.4	13.6	2589.8	2191.9	598.8
19	-52.2	17.8	2306.3	2170.3	593.5
20	-44.3	22.4	1989.6	1989.6	549.8
21	-36.5	27.5	1645.3	1645.3	466.6
22	-28.9	33.0	1264.1	1264.1	374.3
23	-21.7	38.9	857.0	857.0	265.6
24	-16.6	43.4	555.2	555.2	172.1
25	-12.4	47.4	226.4	226.4	70.1

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.00 (= 0.564E-03)
    SHOULD NOT EXCEED 0.100E+03
SUM OF MOMENTS ABOUT CENTER OF CIRCLE = 7.60 (= 0.760E+01)
    SHOULD NOT EXCEED 0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.07 (= 0.726E-01)

SHOULD NOT EXCEED 0.100E+03

Sum of Forces in Horizontal Direction = -0.497E+04
NOTE: Simplified Bishop procedure does not satisfy equilibrium
of forces in the horizontal direction

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Lowe and Karafiath's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

Circular Shear Surface(s)

Automatic Search Performed

Starting Center Coordinate for Search at -
X = -160.000
Y = 230.000

Required accuracy for critical center (= minimum
spacing between grid points) = 0.500

Critical shear surface not allowed to pass below Y = -50.000

For the initial mode of search
all circles are tangent to horizontal line at -
Y = 0.000

Procedure used to compute the factor of safety: LOWE

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Maximum number of iterations allowed for
calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Initial trial values for factor of safety (and side force inclination
for Spencer's procedure) will be kept constant during search

Short form of output will be used for search

Maximum subtended angle to be used for subdivision of the circle into slices = 3.00 degrees

Depth of crack = 0.000

Search will be continued to locate a more critical shear surface (if one exists) after the initial mode is complete

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000

CAUTION - DATA FOR MATERIAL TYPE 5 ARE NOT USED

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Lowe and Karafiath's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 14

****
* SHORT-FORM TABLE FOR SEARCH WITH CIRCULAR SHEAR SURFACES *
****

Mode	Center Coordinates of Critical Circle X	Y	Radius	Factor of Safety	Side Force Inclin.
2 Tangent Line at Y = 0.0	-131.500	170.000	170.000	1.528	Varies
3 Constant Radius of R = 170.0	-133.500	167.500	170.000	1.526	Varies
2 Tangent Line at Y = -2.5	-133.000	169.000	171.500	1.526	Varies

TABLE NO. 15

***** FINAL CRITICAL CIRCLE INFORMATION *****

X Coordinate of Center - - - - - - - -133.000
Y Coordinate of Center - - - - - - - 169.000
Radius - - - - - - - - - - - - - - - 171.500
Factor of Safety - - - - - - - - - - 1.526
Side Force Inclination - - - - - - - Varies

Number of circles tried - - - - - - 212
No. of circles F calc. for - - - - - 211

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Lowe and Karafiath's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 20

****

* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *

****

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-188.3	6.7					
1	-184.0	5.3	2373.6	1	NONLINEAR	ENVELOPE	915.3
	-179.8	4.0					
2	-175.4	2.9	7017.0	1	NONLINEAR	ENVELOPE	1067.9
	-171.1	1.8					
3	-166.7	0.9	11332.8	1	NONLINEAR	ENVELOPE	1192.2
	-162.2	0.0					
4	-162.2	0.0	111.1	1	NONLINEAR	ENVELOPE	1247.6
	-162.2	0.0					
5	-157.7	-0.6	15318.4	2	NONLINEAR	ENVELOPE	1288.4
	-153.3	-1.3					
6	-148.8	-1.7	18844.5	2	NONLINEAR	ENVELOPE	1354.7
	-144.4	-2.1					
7	-139.9	-2.3	21859.7	2	NONLINEAR	ENVELOPE	1391.8
	-135.4	-2.5					
8	-135.2	-2.5	984.1	2	NONLINEAR	ENVELOPE	1403.1
	-135.0	-2.5					
9	-134.0	-2.5	5256.1	2	NONLINEAR	ENVELOPE	1403.6
	-133.0	-2.5					
10	-128.5	-2.4	24884.2	2	NONLINEAR	ENVELOPE	1396.7
	-124.0	-2.3					
11	-119.5	-1.9	26618.1	2	NONLINEAR	ENVELOPE	1367.4
	-115.1	-1.6					
12	-110.6	-1.0	27754.3	2	NONLINEAR	ENVELOPE	1308.8
	-106.2	-0.4					
13	-105.0	-0.2	7479.4	2	NONLINEAR	ENVELOPE	1260.1
	-103.8	0.0					
14	-99.4	0.9	28367.0	1	NONLINEAR	ENVELOPE	1193.1
	-95.0	1.8					
15	-90.7	2.9	28232.1	1	NONLINEAR	ENVELOPE	1069.1
	-86.3	4.0					
16	-82.0	5.3	27537.0	1	NONLINEAR	ENVELOPE	916.6
	-77.7	6.6					
17	-73.5	8.2	26307.2	1	NONLINEAR	ENVELOPE	736.2
	-69.3	9.8					
18	-65.2	11.5	24577.4	1	NONLINEAR	ENVELOPE	528.2
	-61.1	13.3					
19	-57.1	15.3	22391.2	1	NONLINEAR	ENVELOPE	293.4
	-53.0	17.3					
20	-50.6	18.6	12782.0	1	NONLINEAR	ENVELOPE	84.6
	-48.1	20.0					
21	-44.2	22.3	17990.9	1	NONLINEAR	ENVELOPE	0.0
	-40.4	24.6					

22	-36.7	27.2	14870.0	1	NONLINEAR ENVELOPE		0.0
	-33.0	29.7					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level - 2
Lowe and Karafiath's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 20

****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-33.0	29.7					
23	-29.4	32.4	11513.9	1	NONLINEAR ENVELOPE		0.0
	-25.8	35.1					
24	-22.4	38.0	7997.7	1	NONLINEAR ENVELOPE		0.0
	-19.0	40.9					
25	-17.0	42.7	3083.7	1	NONLINEAR ENVELOPE		0.0
	-15.0	44.5					
26	-12.3	47.3	1722.9	1	NONLINEAR ENVELOPE		0.0
	-9.5	50.0					

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level - 2
Lowe and Karafiath's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 21

****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

				FORCES DUE TO SURFACE PRESSURES			
Slice No.	X	Seismic Force	Y for Seismic Force	Normal Force	Shear Force	X	Y
1	-184.0	0.	6.5	6759.	0.	-184.2	7.7
2	-175.4	0.	6.4	5652.	0.	-175.6	9.9
3	-166.7	0.	6.5	4481.	0.	-166.9	12.0
4	-162.2	0.	6.6	32.	0.	-162.2	13.2
5	-157.7	0.	6.8	3248.	0.	-158.0	14.2
6	-148.8	0.	7.4	1987.	0.	-149.3	16.4
7	-139.9	0.	8.2	702.	0.	-141.2	18.4
8	-135.2	0.	8.7	1.	0.	-135.3	19.9
9	-134.0	0.	8.8	0.	0.	-134.0	20.2
10	-128.5	0.	9.6	0.	0.	-128.5	21.6
11	-119.5	0.	10.9	0.	0.	-119.5	23.9

12	-110.6	0.	12.5	0.	0.	-110.6	26.1
13	-105.0	0.	13.6	0.	0.	-105.0	27.5
14	-99.4	0.	14.9	0.	0.	-99.4	28.9
15	-90.7	0.	17.0	0.	0.	-90.7	31.1
16	-82.0	0.	19.3	0.	0.	-82.0	33.2
17	-73.5	0.	21.8	0.	0.	-73.5	35.4
18	-65.2	0.	24.5	0.	0.	-65.2	37.4
19	-57.1	0.	27.4	0.	0.	-57.1	39.5
20	-50.6	0.	29.9	0.	0.	-50.6	41.1
21	-44.2	0.	32.5	0.	0.	-44.2	42.7
22	-36.7	0.	35.9	0.	0.	-36.7	44.6
23	-29.4	0.	39.4	0.	0.	-29.4	46.4
24	-22.4	0.	43.1	0.	0.	-22.4	48.2
25	-17.0	0.	46.1	0.	0.	-17.0	49.5
26	-12.3	0.	48.6	0.	0.	-12.3	50.0

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Search for critical circle - pool level = 2
Lowe and Karafiath's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 23

```
*********************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY LOWE AND KARAFIATH'S PROCEDURE                     *
*********************************************************************
```

Iteration	Trial Factor of Safety	Force Imbalance (lbs.)	DELTA-F
1	3.00000	-0.466E+05	-2.76
Reduced value - Delta was too large			-0.500
2	2.50000	-0.366E+05	-1.55
Reduced value - Delta was too large			-0.500
3	2.00000	-0.221E+05	-0.617
Reduced value - Delta was too large			-0.500
4	1.50000	0.115E+04	0.191E-01
5	1.51908	0.132E+02	0.223E-03
6	1.51930	-0.318E-02	-0.538E-07

For trial number 2 with a nonlinear strength envelope the maximum percent change in shear strength was 100.000 - at slice 1

TABLE NO. 23

```
*********************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY LOWE AND KARAFIATH'S PROCEDURE                     *
*********************************************************************
```

Iteration	Trial Factor of Safety	Force Imbalance (lbs.)	DELTA-F
1	1.51930	0.371E+03	0.625E-02
2	1.52556	0.141E+01	0.240E-04
3	1.52558	-0.590E-02	-0.100E-06

For trial number 3 with a nonlinear strength envelope the maximum percent change in shear strength was 0.000 - at slice 26

TABLE NO. 23

```
*****************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY BY LOWE AND KARAFIATH'S PROCEDURE                    *
*****************************************************************
```

Iteration	Trial Factor of Safety	Force Imbalance (lbs.)	DELTA-F
1	1.52558	-0.192E-02	-0.326E-07

FACTOR OF SAFETY - - - - - - - - 1.526
SIDE FORCE INCLINATION - - - - - Varies
NUMBER OF ITERATIONS - - - - - - 1

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Search for critical circle - pool level = 2
Lowe and Karafiath's analysis procedure
Tangent search mode - elev. 0

TABLE NO. 24

```
********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
********************************************
```

LOWE AND KARAFIATH'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.526

-------- VALUES AT CENTER OF BASE OF SLICE--------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	-184.0	5.3	1044.9	129.7	39.6
2	-175.4	2.9	1492.8	424.8	129.9
3	-166.7	0.9	1869.6	677.3	207.0
4	-162.2	0.0	5331.3	4083.7	1041.9
5	-157.7	-0.6	2202.8	914.4	279.5

6	-148.8	-1.7	2479.6	1125.0	336.0
7	-139.9	-2.3	2645.9	1254.1	366.9
8	-135.2	-2.5	3419.1	2016.0	548.6
9	-134.0	-2.5	2848.1	1444.5	412.3
10	-128.5	-2.4	2894.4	1497.7	425.0
11	-119.5	-1.9	3087.6	1720.2	478.1
12	-110.6	-1.0	3165.2	1856.4	510.6
13	-105.0	-0.2	3385.2	2125.0	574.6
14	-99.4	0.9	3192.7	1999.6	544.7
15	-90.7	2.9	3163.0	2093.9	567.2
16	-82.0	5.3	3047.8	2131.2	576.1
17	-73.5	8.2	2873.4	2137.2	577.5
18	-65.2	11.5	2645.2	2116.9	572.7
19	-57.1	15.3	2363.2	2069.8	561.5
20	-50.6	18.6	2138.7	2054.1	557.7
21	-44.2	22.3	1839.2	1839.2	506.5
22	-36.7	27.2	1493.9	1493.9	424.1
23	-29.4	32.4	1129.3	1129.3	337.1
24	-22.4	38.0	763.4	763.4	233.4
25	-17.0	42.7	475.8	475.8	145.5
26	-12.3	47.3	187.3	187.3	57.2

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION     =       0.01  (= 0.107E-01)
     SHOULD NOT EXCEED    0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION   =       0.02  (= 0.241E-01)
     SHOULD NOT EXCEED    0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM    =       0.03  (= 0.274E-01)
     SHOULD NOT EXCEED    0.100E+03
```

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Search for critical circle - pool level = 2

Lowe and Karafiath's analysis procedure

Tangent search mode - elev. 0

```
TABLE NO. 25
*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
```

LOWE AND KARAFIATH'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY

Factor of Safety = 1.526

----- VALUES AT RIGHT SIDE OF SLICE ----

Slice No.	X-Right	Side Force	Side Force Inclination (degrees)
1	-179.8	4773.	-0.96
2	-171.1	10589.	0.64

3	-162.2	16801.	1.82
4	-162.2	16961.	2.60
5	-153.3	23118.	3.74
6	-144.4	28730.	5.25
7	-135.4	33228.	6.38
8	-135.0	33487.	6.86
9	-133.0	34393.	7.41
10	-124.0	37663.	8.60
11	-115.1	39959.	10.07
12	-106.2	40969.	11.27
13	-103.8	41143.	12.21
14	-95.0	40500.	13.42
15	-86.3	38620.	14.92
16	-77.7	35577.	16.45
17	-69.3	31583.	18.01
18	-61.1	26927.	19.60
19	-53.0	21957.	21.09
20	-48.1	18875.	22.46
21	-40.4	13999.	24.04
22	-33.0	9332.	25.85
23	-25.8	5290.	27.73
24	-19.0	2138.	29.50
25	-15.0	803.	28.38
26	-9.5	0.	0.00

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

File: EXAM4.IN

```
HEADING
  Example 4 - Noncircular search
   Natural slope or cut slope problem
   Contains five layers over rock
PROFILE LINES
  1  1  CLAY 1
  -340 80
   340 80

  2  2  CLAY 2
   -340 30
    340 30

  3  3  UPPER SAND
   -340 20
    340 20

  4  4  FAT CLAY
   -340 15
    340 15

  5  5  LOWER SAND
   -340 10
    340 10

  6  6  ROCK
   -340 0
    340 0


HEADING
  Undrained strengths
  Water table in upper sand layer

MATERIAL PROPERTY
  1 CLAY 1
    115 - moist unit weight
    CONVENTIONAL SHEAR STRENGTH
    1500 5
    NO PORE PRESSURE
  2 CLAY 2
    115 - moist unit weight
    CONVENTIONAL SHEAR STRENGTH
    1000 0
    NO PORE PRESSURE
  3 UPPER SAND LAYER
    125 - saturated unit weight
    CONVENTIONAL SHEAR STRENGTH
    0  30
    PIEZOMETRIC LINE
```

```
    1
  4 FAT CLAY
    120 = saturated unit weight
    CONVENTIONAL SHEAR STRENGTH
    500 0
    PIEZOMETRIC LINE
    1
  5 LOWER SAND LAYER
    125 = saturated unit weight
    CONVENTIONAL SHEAR STRENGTH
    0 30
    PIEZOMETRIC LINE
    1
  6 ROCK
    165 = saturated unit weight
    CONVENTIONAL SHEAR STRENGTH
    0  45
    PIEZOMETRIC LINE
    1

PIEZOMETER LINE DATA
   1  62.4  Water table
   -340 20
   -110 20
    -65 15
     65 15
    110 20
    340 20


SURFACE PRESSURES   pool
  -65 15    0 0
  -50 10  312 0
   50 10  312 0
   65 15    0 0

SLOPE GEOMETRY
  -340 80
  -160 50
  -120 30
  -110 30
   -50 10
    50 10
   110 30
   120 30
   160 50
   340 80

HEADING
  Spencer's method
   Search for critical noncircular surface
```

```
ANALYSIS/COMPUTATION
  NONCIRCULAR SEARCH
   -275.7 49.3
   -248.3 30
   -234.2 20
   -227.1 15
   -220.0 10
   -175 10
   -135 10
   -90 10
   -85.5 15
   -80 19

     10
  PROCEDURE
   SPENCER

COMPUTE
```

File: EXAM4.OUT

```
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT

          TABLE NO. 1
          ******************************************
          * COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
          * Originally Coded By Stephen G. Wright  *
          * Version No. 1.209                      *
          * Last Revision Date  2/3/87             *
          * Serial No. 00004                       *
          * (C) Copyright 1985 Stephen G. Wright   *
          * All Rights Reserved                    *
          ******************************************

          **************************************************************
          *                                                            *
          *      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
          * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
          * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
          * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
          * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
          * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
          * PROGRAM BEFORE ATTEMPTING ITS USE.                         *
          *                                                            *
          *      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
          * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
          * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
          * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
          *                                                            *
          **************************************************************
1         UTEXAS2 - VER. 1.209 -  2/3/87  - SN00004 - (C) 1985 S. G. WRIGHT
            Example 4 - Noncircular search
             Natural slope or cut slope problem
             Contains five layers over rock

          TABLE NO.  2
          *************************
          * NEW PROFILE LINE DATA *
          *************************

          PROFILE LINE  1 - MATERIAL TYPE =  1
          CLAY 1

               Point       X            Y

                 1      -340.000       80.000
                 2       340.000       80.000

          PROFILE LINE  2 - MATERIAL TYPE =  2
          CLAY 2
```

Point	X	Y
1	-340.000	30.000
2	340.000	30.000

PROFILE LINE 3 - MATERIAL TYPE = 3
UPPER SAND

Point	X	Y
1	-340.000	20.000
2	340.000	20.000

PROFILE LINE 4 - MATERIAL TYPE = 4
FAT CLAY

Point	X	Y
1	-340.000	15.000
2	340.000	15.000

PROFILE LINE 5 - MATERIAL TYPE = 5
LOWER SAND

Point	X	Y
1	-340.000	10.000
2	340.000	10.000

PROFILE LINE 6 - MATERIAL TYPE = 6
ROCK

Point	X	Y
1	-340.000	0.000
2	340.000	0.000

All new profile lines defined - No old lines retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Undrained strengths
Water table in upper sand layer

TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1
CLAY 1

Unit weight of material = 115.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 1500.000
Friction angle - - - - - 5.000 degrees

No (or zero) pore water pressures

DATA FOR MATERIAL TYPE 2
CLAY 2

Unit weight of material = 115.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 1000.000
Friction angle - - - - - 0.000 degrees

No (or zero) pore water pressures

DATA FOR MATERIAL TYPE 3
UPPER SAND LAYER

Unit weight of material = 125.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.000
Friction angle - - - - - 30.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 4
FAT CLAY

Unit weight of material = 120.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 500.000
Friction angle - - - - - 0.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 5
LOWER SAND LAYER

Unit weight of material = 125.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.000
Friction angle - - - - - 30.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

DATA FOR MATERIAL TYPE 6
ROCK

Unit weight of material = 165.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
Cohesion - - - - - - - - 0.000
Friction angle - - - - - 45.000 degrees

Pore water pressures defined by piezometric line
Number of the piezometric line used = 1
Negative pore pressures set to zero

All new material properties defined - No old data retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Undrained strengths
Water table in upper sand layer

TABLE NO. 4
****
* NEW PIEZOMETRIC LINE DATA *
****

Line No.	Point	X	Y	
1 - Unit weight of water =			62.40	Water table
1	1	-340.000	20.000	Water table
1	2	-110.000	20.000	Water table
1	3	-65.000	15.000	Water table
1	4	65.000	15.000	Water table
1	5	110.000	20.000	Water table
1	6	340.000	20.000	Water table

All new piezometric lines defined - No old lines retained

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Undrained strengths
Water table in upper sand layer

TABLE NO. 7
****
* NEW SURFACE PRESSURE DATA *
****

ALL NEW DATA INPUT - NO OLD DATA RETAINED

Surface Pressures -

Point	X	Y	Normal Pressure	Shear Stress
1	-65.000	15.000	0.000	0.000
2	-50.000	10.000	312.000	0.000
3	50.000	10.000	312.000	0.000
4	65.000	15.000	0.000	0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Undrained strengths
Water table in upper sand layer

TABLE NO. 6
****
* NEW SLOPE GEOMETRY DATA *
****

All new data input - No old data retained

Slope Coordinates -

Point	X	Y
1	-340.000	80.000
2	-160.000	50.000
3	-120.000	30.000
4	-110.000	30.000
5	-50.000	10.000
6	50.000	10.000
7	110.000	30.000
8	120.000	30.000
9	160.000	50.000
10	340.000	80.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

Noncircular Shear Surface(s)

Automatic Search Performed

Coordinates of points on shear surface which are to be shifted -

Point	X	Y	Shift Angle
1	-275.700	49.300	angle to be computed - moveable
2	-248.300	30.000	angle to be computed - moveable
3	-234.200	20.000	angle to be computed - moveable
4	-227.100	15.000	angle to be computed - moveable
5	-220.000	10.000	angle to be computed - moveable
6	-175.000	10.000	angle to be computed - moveable
7	-135.000	10.000	angle to be computed - moveable
8	-90.000	10.000	angle to be computed - moveable
9	-85.500	15.000	angle to be computed - moveable
10	-80.000	19.000	angle to be computed - moveable

Initial distance for shifting points on shear surface = 10.000
Maximum steepness permitted for toe of shear surface = 50.00 degrees

Procedure used to compute the factor of safety: SPENCER

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

Initial trial estimate for the factor of safety = 3.000

Initial trial estimate for side force inclination = 15.000 degrees
(Applicable to Spencer's procedure only)

Maximum number of iterations allowed for
calculating the factor of safety = 40

Allowed force imbalance for convergence = 100.000

Allowed moment imbalance for convergence = 100.000

Initial trial values for factor of safety (and side force inclination
for Spencer's procedure) will be kept constant during search

Number of increments for slice subdivision = 30

Depth of water in crack = 0.000

Unit weight of water in crack = 62.400

Seismic coefficient = 0.000

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 16

```
*******************************************
* INITIAL COMPUTED INFORMATION FOR SEARCH *
* WITH NONCIRCULAR SHEAR SURFACE          *
```

****

CAUTION - INITIAL TRIAL SHEAR SURFACE IS BELOW SLOPE NEAR
THE TOE OF THE SLOPE A DISTANCE = 1.00
SOLUTION WILL BE ERRONEOUS IF THIS DISTANCE IS
VERY LARGE

Crack depth computed to be - - - 19.98

FOR INITIAL TRIAL NONCIRCULAR SHEAR SURFACE
Factor of Safety - - - - - - - - 2.910
Side Force Inclination - - - - - -10.12
Number of Iterations - - - - - - 4

TABLE NO. 17
****
* SEARCH TRIAL NUMBER 1 *
****

INCREMENTAL SHIFT DISTANCE USED TO COMPUTE DERIVATIVES = 10.00

Point	X	Y	Factor of Safety	Side Force Inclination	Iterations
1	-285.56	50.94	2.891	-10.14	4
1	-265.84	47.66	2.967	-9.96	4
2	-254.07	21.83	2.980	-9.53	4
2	-242.53	38.17	3.430	-9.63	6
3	-239.97	11.83	3.358	-10.36	5
3	-228.43	28.17	4.136	-10.91	8
4	-232.86	6.82	5.418	-14.67	7
4	-221.34	23.18	4.528	-12.18	10
5	-223.32	0.57	5.196	-14.26	9
5	-216.68	19.43	2.824	-10.15	4
6	-175.00	0.00	2.977	-10.11	4
6	-175.00	20.00	2.473	-8.57	4
7	-135.00	0.00	2.727	-9.95	4
7	-135.00	20.00	2.979	-9.51	4
8	-94.86	18.74	2.885	-10.12	4
8	-89.92	9.86	2.914	-10.10	4
9	-85.61	15.12	2.914	-10.10	4
9	-84.65	14.08	2.899	-10.16	4
10	-81.37	19.46	2.926	-10.00	4
10	-70.51	15.84	2.881	-10.34	3

Maximum distance shifted for new estimate of shear
surface is 10.000 at point 1

Coordinates For New Estimate of Shear Surface

Point X Y

1	-285.56	50.94
2	-250.51	26.88
3	-235.54	18.10
4	-226.48	15.88
5	-216.68	19.43
6	-175.00	20.00
7	-135.00	0.00
8	-94.86	18.74
9	-84.65	14.08
10	-70.51	15.84

FOR NEW ESTIMATE OF SHEAR SURFACE
Factor of Safety - - - - - - - - 3.170
Side Force Inclination - - - - - -10.27
Number of Iterations - - - - - - 5

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 17
****
* SEARCH TRIAL NUMBER 2 *
****

INCREMENTAL SHIFT DISTANCE USED TO COMPUTE DERIVATIVES = 7.00

Point	X	Y	Factor of Safety	Side Force Inclination	Iterations
1	-282.60	50.45	2.894	-10.14	4
1	-268.80	48.15	2.943	-10.03	4
2	-252.34	24.28	2.902	-9.72	4
2	-244.26	35.72	3.191	-10.02	4
3	-238.24	14.28	3.056	-9.99	4
3	-230.16	25.72	3.332	-10.67	4
4	-231.13	9.28	3.697	-11.75	5
4	-223.07	20.72	3.452	-11.19	4
5	-222.32	3.40	3.929	-12.36	6
5	-217.68	16.60	2.481	-9.44	4
6	-175.00	3.00	2.906	-10.04	4
6	-175.00	17.00	2.061	-8.03	5
7	-135.00	3.00	2.748	-10.03	4
7	-135.00	17.00	2.682	-10.07	4
8	-93.40	16.12	2.807	-10.49	3
8	-89.89	9.81	2.916	-10.09	4
9	-85.65	15.16	2.915	-10.10	4
9	-84.91	14.36	2.899	-10.16	4
10	-81.37	19.46	2.926	-10.00	4
10	-73.36	16.79	2.887	-10.29	4

Maximum distance shifted for new estimate of shear
surface is 7.000 at point 2

Coordinates For New Estimate of Shear Surface

Point	X	Y
1	-282.60	50.45
2	-252.34	24.28
3	-235.18	18.61
4	-226.73	15.53
5	-217.68	16.60
6	-175.00	17.00
7	-135.00	17.00
8	-93.40	16.12
9	-84.91	14.36
10	-73.36	16.79

FOR NEW ESTIMATE OF SHEAR SURFACE
Factor of Safety - - - - - - - - 3.295
Side Force Inclination - - - - - -9.91
Number of Iterations - - - - - - 4

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 17
****
* SEARCH TRIAL NUMBER 3 *
****

INCREMENTAL SHIFT DISTANCE USED TO COMPUTE DERIVATIVES = 4.00

Point	X	Y	Factor of Safety	Side Force Inclination	Iterations
1	-279.65	49.96	2.900	-10.14	4
1	-271.75	48.64	2.926	-10.08	4
2	-250.61	26.73	2.873	-9.92	4
2	-245.99	33.27	3.032	-10.16	4
3	-236.51	16.73	3.060	-10.19	4
3	-231.89	23.27	3.013	-10.38	4
4	-229.40	11.73	2.976	-10.13	4
4	-224.80	18.27	3.162	-10.67	4
5	-221.33	6.23	3.326	-11.13	4
5	-218.67	13.77	2.044	-7.98	5
6	-175.00	6.00	2.880	-10.04	4
6	-175.00	14.00	1.595	-6.87	6
7	-135.00	6.00	2.798	-10.10	3

7	-135.00	14.00	2.382	-10.77	4
8	-91.94	13.50	2.753	-10.69	4
8	-89.94	9.89	2.914	-10.10	4
9	-85.58	15.09	2.913	-10.11	4
9	-84.82	14.26	2.899	-10.16	4
10	-80.95	19.32	2.920	-10.05	4
10	-76.21	17.74	2.894	-10.25	4

Maximum distance shifted for new estimate of shear surface is 4.000 at point 1

Coordinates For New Estimate of Shear Surface

Point	X	Y
1	-279.65	49.96
2	-250.61	26.73
3	-233.99	20.30
4	-227.78	14.04
5	-218.67	13.77
6	-175.00	14.00
7	-135.00	14.00
8	-91.94	13.50
9	-84.82	14.26
10	-76.21	17.74

FOR NEW ESTIMATE OF SHEAR SURFACE
Factor of Safety - - - - - - - - 1.430
Side Force Inclination - - - - - -6.89
Number of Iterations - - - - - - 6

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 17
****
* SEARCH TRIAL NUMBER 4 *
****

INCREMENTAL SHIFT DISTANCE USED TO COMPUTE DERIVATIVES = 4.00

Point	X	Y	Factor of Safety	Side Force Inclination	Iterations
1	-283.59	50.62	1.439	-6.79	6
1	-275.70	49.30	1.426	-6.94	6
2	-252.65	23.29	1.458	-7.14	6
2	-248.57	30.17	1.459	-6.55	6
3	-236.28	17.02	1.473	-7.31	6
3	-231.70	23.58	1.573	-7.72	6

4	-229.62	10.49	1.579	-8.38	6
4	-225.93	17.59	1.515	-7.54	6
5	-218.72	9.77	1.503	-7.47	6
5	-218.62	17.77	2.361	-11.67	5
6	-175.01	18.00	2.499	-9.38	4
6	-174.99	10.00	1.383	-6.32	6
7	-135.02	10.00	1.350	-6.66	7
7	-134.98	18.00	2.012	-7.08	5
8	-92.13	17.49	1.538	-6.48	6
8	-91.75	9.50	1.432	-7.02	6
9	-85.81	18.14	1.455	-6.70	6
9	-83.83	10.39	1.463	-6.81	6
10	-80.00	19.00	1.456	-6.70	6
10	-72.41	16.47	1.426	-6.93	6

Maximum distance shifted for new estimate of shear
surface is 4.000 at point 1

Coordinates For New Estimate of Shear Surface

Point	X	Y
1	-275.70	49.30
2	-250.62	26.71
3	-234.60	19.42
4	-227.53	14.52
5	-218.69	12.07
6	-174.99	10.00
7	-135.02	10.00
8	-91.85	11.57
9	-84.90	14.56
10	-72.41	16.47

FOR NEW ESTIMATE OF SHEAR SURFACE
Factor of Safety - - - - - - - - 1.288
Side Force Inclination - - - - - -6.24
Number of Iterations - - - - - - 7

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 17
****
* SEARCH TRIAL NUMBER 5 *
****

INCREMENTAL SHIFT DISTANCE USED TO COMPUTE DERIVATIVES = 4.00

Point	X	Y	Factor of Safety	Side Force Inclination	Iterations

1	-279.65	49.96	1.294	-6.15	7
1	-271.75	48.64	1.288	-6.27	7
2	-252.87	23.40	1.341	-6.48	7
2	-248.38	30.02	1.302	-5.89	7
3	-236.59	15.95	1.353	-6.89	7
3	-232.62	22.89	1.323	-6.26	7
4	-229.27	10.92	1.319	-6.60	7
4	-225.78	18.12	1.412	-7.01	6
5	-219.33	8.12	2.275	-11.49	5
5	-218.05	16.01	1.590	-8.67	6
6	-175.08	6.00	2.311	-9.80	4
6	-174.90	14.00	1.338	-6.83	7
7	-135.10	14.00	1.369	-6.44	7
7	-134.95	6.00	1.899	-8.26	5
8	-92.76	15.46	1.319	-6.03	7
8	-90.94	7.67	1.538	-6.68	7
9	-86.02	18.40	1.356	-5.82	7
9	-83.78	10.71	1.290	-6.29	7
10	-76.21	17.74	1.291	-6.20	7
10	-68.62	15.21	1.298	-6.18	7

Maximum distance shifted for new estimate of shear
surface is 1.874 at point 9

Coordinates For New Estimate of Shear Surface

Point	X	Y
1	-274.09	49.03
2	-249.97	27.68
3	-234.31	19.92
4	-228.05	13.45
5	-218.52	13.12
6	-174.95	11.81
7	-135.05	11.53
8	-92.20	13.08
9	-84.37	12.76
10	-73.48	16.83

FOR NEW ESTIMATE OF SHEAR SURFACE
Factor of Safety - - - - - - - - - 1.335
Side Force Inclination - - - - - -6.51
Number of Iterations - - - - - - 7

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 17
****
* SEARCH TRIAL NUMBER 6 *

****

INCREMENTAL SHIFT DISTANCE USED TO COMPUTE DERIVATIVES = 1.00

Point	X	Y	Factor of Safety	Side Force Inclination	Iterations
1	-276.69	49.46	1.289	-6.22	7
1	-274.71	49.14	1.287	-6.25	7
2	-251.18	25.88	1.294	-6.30	7
2	-250.06	27.54	1.285	-6.17	7
3	-235.10	18.55	1.304	-6.39	7
3	-234.11	20.28	1.276	-6.13	7
4	-227.96	13.62	1.279	-6.17	7
4	-227.09	15.42	1.317	-6.47	7
5	-218.85	11.08	1.288	-6.20	7
5	-218.53	13.05	1.290	-6.30	7
6	-175.01	9.00	2.041	-8.90	5
6	-174.97	11.00	1.299	-6.38	7
7	-135.04	11.00	1.306	-6.30	7
7	-135.01	9.00	1.884	-8.16	5
8	-92.08	12.54	1.292	-6.21	7
8	-91.62	10.59	1.286	-6.26	7
9	-85.18	15.52	1.293	-6.19	7
9	-84.62	13.60	1.287	-6.25	7
10	-73.36	16.79	1.288	-6.23	7
10	-71.46	16.15	1.288	-6.24	7

Maximum distance shifted for new estimate of shear surface is 1.000 at point 4

Coordinates For New Estimate of Shear Surface

Point	X	Y
1	-274.71	49.14
2	-250.06	27.54
3	-234.11	20.28
4	-227.96	13.62
5	-218.74	11.77
6	-174.98	10.49
7	-135.03	10.47
8	-91.62	10.59
9	-84.62	13.60
10	-72.38	16.46

FOR NEW ESTIMATE OF SHEAR SURFACE
Factor of Safety - - - - - - - - 1.280
Side Force Inclination - - - - - -6.22
Number of Iterations - - - - - - 7

Spencer's method
Search for critical noncircular surface

TABLE NO. 17
****
* SEARCH TRIAL NUMBER 7 *
****

INCREMENTAL SHIFT DISTANCE USED TO COMPUTE DERIVATIVES = 1.00

Point	X	Y	Factor of Safety	Side Force Inclination	Iterations
1	-275.70	49.30	1.282	-6.19	7
1	-273.73	48.97	1.279	-6.23	7
2	-250.62	26.70	1.283	-6.27	7
2	-249.51	28.37	1.281	-6.15	7
3	-234.72	19.49	1.283	-6.25	7
3	-233.50	21.08	1.293	-6.28	7
4	-228.50	12.78	1.290	-6.31	7
4	-227.42	14.46	1.282	-6.23	7
5	-218.85	10.78	1.280	-6.16	7
5	-218.63	12.76	1.284	-6.30	7
6	-174.99	9.49	1.767	-8.55	6
6	-174.96	11.49	1.292	-6.36	7
7	-135.03	11.47	1.300	-6.28	7
7	-135.03	9.47	1.610	-7.30	6
8	-91.83	11.57	1.284	-6.19	7
8	-91.41	9.62	1.340	-6.32	6
9	-84.93	14.54	1.283	-6.19	7
9	-84.30	12.65	1.278	-6.24	7
10	-73.33	16.78	1.280	-6.21	7
10	-71.43	16.14	1.281	-6.22	7

Maximum distance shifted for new estimate of shear surface is 1.000 at point 10

Coordinates For New Estimate of Shear Surface

Point	X	Y
1	-273.73	48.97
2	-249.88	27.81
3	-234.32	20.01
4	-227.77	13.92
5	-218.85	10.78
6	-174.97	10.96
7	-135.03	10.91
8	-91.72	11.02
9	-84.30	12.65

10	-73.33	16.78

FOR NEW ESTIMATE OF SHEAR SURFACE
Factor of Safety - - - - - - - - 1.291
Side Force Inclination - - - - - -6.27
Number of Iterations - - - - - - 7

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 19
****
* FINAL CRITICAL SHEAR SURFACE (FOUND AFTER 7 TRIAL POSITIONS) *
****

X	Y
-274.71	49.14
-250.06	27.54
-234.11	20.28
-227.96	13.62
-218.74	11.77
-174.98	10.49
-135.03	10.47
-91.62	10.59
-84.62	13.60
-72.38	16.46

Factor of Safety = 1.280

Side Force Inclination = -6.22

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

Slice No.	X	Y	Slice Weight	Matl. Type	Cohesion	Friction Angle	Pore Pressure
	-274.7	49.1					
1	-272.5	47.2	10816.0	1	1500.00	5.00	0.0
	-270.3	45.3					
2	-268.2	43.4	12372.7	1	1500.00	5.00	0.0
	-266.0	41.5					

3	-263.8	39.6	13929.4	1	1500.00	5.00	0.0
	-261.6	37.7					
4	-259.4	35.7	15486.1	1	1500.00	5.00	0.0
	-257.2	33.8					
5	-255.1	31.9	17042.6	1	1500.00	5.00	0.0
	-252.9	30.0					
6	-251.5	28.8	11796.2	2	1000.00	0.00	0.0
	-250.1	27.5					
7	-247.4	26.3	23387.7	2	1000.00	0.00	0.0
	-244.7	25.1					
8	-242.1	23.9	24324.1	2	1000.00	0.00	0.0
	-239.4	22.7					
9	-236.8	21.5	25260.5	2	1000.00	0.00	0.0
	-234.1	20.3					
10	-234.0	20.1	1270.2	2	1000.00	0.00	0.0
	-233.8	20.0					
11	-232.7	18.7	11532.4	3	0.00	30.00	78.0
	-231.5	17.5					
12	-230.4	16.2	12151.3	3	0.00	30.00	234.0
	-229.2	15.0					
13	-228.6	14.3	6952.6	4	500.00	0.00	355.0
	-228.0	13.6					
14	-225.7	13.2	25610.0	4	500.00	0.00	426.8
	-223.4	12.7					
15	-221.0	12.2	25714.9	4	500.00	0.00	484.6
	-218.7	11.8					
16	-215.6	11.7	34630.9	4	500.00	0.00	519.2
	-212.5	11.6					
17	-209.4	11.5	34019.6	4	500.00	0.00	530.7
	-206.2	11.4					
18	-203.1	11.3	33408.2	4	500.00	0.00	542.1
	-200.0	11.2					
19	-196.9	11.1	32796.8	4	500.00	0.00	553.6
	-193.7	11.0					
20	-190.6	10.9	32185.5	4	500.00	0.00	565.1
	-187.5	10.9					
21	-184.4	10.8	31574.1	4	500.00	0.00	576.5
	-181.2	10.7					
22	-178.1	10.6	30962.9	4	500.00	0.00	588.0
	-175.0	10.5					

Spencer's method

Search for critical noncircular surface

TABLE NO. 20

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*******************************************************************
```

Slice Slice Matl. Friction Pore

No.	X	Y	Weight	Type	Cohesion	Angle	Pressure
	-175.0	10.5					
23	-172.5	10.5	24244.9	4	500.00	0.00	593.8
	-170.0	10.5					
24	-167.5	10.5	23768.4	4	500.00	0.00	593.9
	-165.0	10.5					
25	-162.5	10.5	23291.8	4	500.00	0.00	594.0
	-160.0	10.5					
26	-156.9	10.5	27702.9	4	500.00	0.00	594.1
	-153.8	10.5					
27	-150.6	10.5	25464.3	4	500.00	0.00	594.3
	-147.5	10.5					
28	-144.4	10.5	23225.9	4	500.00	0.00	594.5
	-141.3	10.5					
29	-138.2	10.5	20987.4	4	500.00	0.00	594.6
	-135.0	10.5					
30	-132.5	10.5	15222.6	4	500.00	0.00	594.2
	-130.0	10.5					
31	-127.5	10.5	13770.4	4	500.00	0.00	593.4
	-125.0	10.5					
32	-122.5	10.5	12318.3	4	500.00	0.00	592.5
	-120.0	10.5					
33	-117.5	10.5	11563.3	4	500.00	0.00	591.6
	-115.0	10.5					
34	-112.5	10.5	11554.8	4	500.00	0.00	590.7
	-110.0	10.5					
35	-106.9	10.5	13425.5	4	500.00	0.00	568.5
	-103.9	10.6					
36	-100.8	10.6	11974.3	4	500.00	0.00	524.9
	-97.7	10.6					
37	-94.7	10.6	10523.2	4	500.00	0.00	481.4
	-91.6	10.6					
38	-89.9	11.3	5051.5	4	500.00	0.00	400.6
	-88.1	12.1					
39	-86.4	12.8	3950.3	4	500.00	0.00	282.7
	-84.6	13.6					
40	-82.3	14.1	3773.7	4	500.00	0.00	173.9
	-80.0	14.7					
41	-79.3	14.8	851.5	4	500.00	0.00	109.3
	-78.6	15.0					
42	-76.4	15.5	1805.3	3	0.00	30.00	47.2
	-74.2	16.0					
43	-73.3	16.2	353.7	3	0.00	30.00	0.0
	-72.4	16.5					

TABLE NO. 21
****

* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

Slice No.	X	Seismic Force	Y for Seismic Force	FORCES DUE TO SURFACE PRESSURES Normal Force	Shear Force	X	Y
1	-272.5	0.	58.0	0.	0.	-272.5	68.8
2	-268.2	0.	55.7	0.	0.	-268.2	68.0
3	-263.8	0.	53.4	0.	0.	-263.8	67.3
4	-259.4	0.	51.2	0.	0.	-259.4	66.6
5	-255.1	0.	48.9	0.	0.	-255.1	65.8
6	-251.5	0.	47.0	0.	0.	-251.5	65.2
7	-247.4	0.	45.4	0.	0.	-247.4	64.6
8	-242.1	0.	43.8	0.	0.	-242.1	63.7
9	-236.8	0.	42.1	0.	0.	-236.8	62.8
10	-234.0	0.	41.2	0.	0.	-234.0	62.3
11	-232.7	0.	40.4	0.	0.	-232.7	62.1
12	-230.4	0.	38.8	0.	0.	-230.4	61.7
13	-228.6	0.	37.7	0.	0.	-228.6	61.4
14	-225.7	0.	36.8	0.	0.	-225.7	60.9
15	-221.0	0.	36.0	0.	0.	-221.0	60.2
16	-215.6	0.	35.2	0.	0.	-215.6	59.3
17	-209.4	0.	34.6	0.	0.	-209.4	58.2
18	-203.1	0.	34.0	0.	0.	-203.1	57.2
19	-196.9	0.	33.4	0.	0.	-196.9	56.1
20	-190.6	0.	32.8	0.	0.	-190.6	55.1
21	-184.4	0.	32.2	0.	0.	-184.4	54.1
22	-178.1	0.	31.6	0.	0.	-178.1	53.0
23	-172.5	0.	31.1	0.	0.	-172.5	52.1
24	-167.5	0.	30.6	0.	0.	-167.5	51.2
25	-162.5	0.	30.2	0.	0.	-162.5	50.4
26	-156.9	0.	29.2	0.	0.	-156.9	48.4
27	-150.6	0.	27.7	0.	0.	-150.6	45.3
28	-144.4	0.	26.1	0.	0.	-144.4	42.2
29	-138.2	0.	24.6	0.	0.	-138.2	39.1
30	-132.5	0.	23.2	0.	0.	-132.5	36.3
31	-127.5	0.	22.0	0.	0.	-127.5	33.8
32	-122.5	0.	20.7	0.	0.	-122.5	31.3
33	-117.5	0.	20.1	0.	0.	-117.5	30.0
34	-112.5	0.	20.1	0.	0.	-112.5	30.0
35	-106.9	0.	19.6	0.	0.	-106.9	29.0
36	-100.8	0.	18.7	0.	0.	-100.8	26.9
37	-94.7	0.	17.7	0.	0.	-94.7	24.9
38	-89.9	0.	17.3	0.	0.	-89.9	23.3
39	-86.4	0.	17.5	0.	0.	-86.4	22.1
40	-82.3	0.	17.4	0.	0.	-82.3	20.8
41	-79.3	0.	17.3	0.	0.	-79.3	19.8

Search for critical noncircular surface

TABLE NO. 21

```
*********************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
*********************************************************************
```

Slice No.	X	Seismic Force	Y for Seismic Force	Forces due to surface pressures: Normal Force	Shear Force	X	Y
42	-76.4	0.	17.2	0.	0.	-76.4	18.8
43	-73.3	0.	17.0	0.	0.	-73.3	17.8

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT

Spencer's method

Search for critical noncircular surface

TABLE NO. 23

```
*********************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE     *
*********************************************************************
```

Iter-ation	Trial Factor of Safety	Trial Side Force Inclination (degrees)	Force Imbalance (lbs.)	Moment Imbalance (ft.-lbs.)	Delta-F	Delta Theta (degrees)
1	3.00000	-15.0000	-0.7051E+05	-0.3141E+07		
First-order corrections to F and THETA					-0.378E+01	0.258E+01
Values factored by 0.132E+00 - Deltas too large					-0.500E+00	0.341E+00
2	2.50000	-14.6587	-0.5930E+05	-0.2680E+07		
First-order corrections to F and THETA					-0.223E+01	0.280E+01
Values factored by 0.224E+00 - Deltas too large					-0.500E+00	0.626E+00
3	2.00000	-14.0326	-0.4263E+05	-0.2015E+07		
First-order corrections to F and THETA					-0.105E+01	0.318E+01
Values factored by 0.475E+00 - Deltas too large					-0.500E+00	0.151E+01
4	1.50000	-12.5191	-0.1533E+05	-0.1008E+07		
First-order corrections to F and THETA					-0.240E+00	0.411E+01
Second-order correction - Iteration 1					-0.211E+00	0.411E+01
Second-order correction - Iteration 2					-0.210E+00	0.411E+01
Second-order correction - Iteration 3					-0.210E+00	0.411E+01
5	1.28990	-8.4112	0.4015E+03	-0.2261E+06		
First-order corrections to F and THETA					-0.986E-02	0.222E+01

```
Second-order correction - Iteration   1 ........ -0.980E-02 0.222E+01
Second-order correction - Iteration   2 ........ -0.980E-02 0.222E+01

   6  1.28011    -6.1919 -0.1261E+01  0.2422E+04
First-order corrections to F and THETA .........  0.131E-03-0.233E-01
Second-order correction - Iteration   1 ........  0.131E-03-0.233E-01

   7  1.28024    -6.2152 -0.7538E-02  0.1583E+00
First-order corrections to F and THETA ......... -0.629E-07-0.150E-05

FACTOR OF SAFETY - - - - - - - - -      1.280
SIDE FORCE INCLINATION - - - - -       -6.22
NUMBER OF ITERATIONS - - - - - -        7
1      UTEXAS2 - VER. 1.209 -  2/3/87   - SN00004 - (C) 1985 S. G. WRIGHT
         Spencer's method
           Search for critical noncircular surface


TABLE NO. 24
********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
********************************************

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety =  1.280     Side Force Inclination =  -6.22 Degrees

       -------- VALUES AT CENTER OF BASE OF SLICE---------
```

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
1	-272.5	47.2	1374.1	1374.1	1265.6
2	-268.2	43.4	1684.6	1684.6	1286.8
3	-263.8	39.6	1995.1	1995.1	1308.0
4	-259.4	35.7	2305.6	2305.6	1329.2
5	-255.1	31.9	2616.1	2616.1	1350.4
6	-251.5	28.8	3282.3	3282.3	781.1
7	-247.4	26.3	3932.9	3932.9	781.1
8	-242.1	23.9	4100.7	4100.7	781.1
9	-236.8	21.5	4268.4	4268.4	781.1
10	-234.0	20.1	3658.3	3658.3	781.1
11	-232.7	18.7	3231.6	3153.6	1422.2
12	-230.4	16.2	3447.9	3213.9	1449.4
13	-228.6	14.3	4554.1	4199.2	390.6
14	-225.7	13.2	5400.2	4973.4	390.6
15	-221.0	12.2	5422.5	4937.9	390.6
16	-215.6	11.7	5552.8	5033.5	390.6
17	-209.4	11.5	5455.3	4924.6	390.6
18	-203.1	11.3	5357.8	4815.7	390.6
19	-196.9	11.1	5260.3	4706.7	390.6

20	-190.6	10.9	5162.8	4597.8	390.6
21	-184.4	10.8	5065.3	4488.8	390.6
22	-178.1	10.6	4967.9	4379.9	390.6
23	-172.5	10.5	4898.2	4304.5	390.6
24	-167.5	10.5	4802.8	4208.9	390.6
25	-162.5	10.5	4707.3	4113.3	390.6
26	-156.9	10.5	4480.3	3886.2	390.6
27	-150.6	10.5	4121.7	3527.4	390.6
28	-144.4	10.5	3763.1	3168.6	390.6
29	-138.2	10.5	3404.5	2809.9	390.6
30	-132.5	10.5	3082.6	2488.4	390.6
31	-127.5	10.5	2792.7	2199.4	390.6
32	-122.5	10.5	2502.8	1910.4	390.6
33	-117.5	10.5	2357.0	1765.4	390.6
34	-112.5	10.5	2355.3	1764.6	390.6
35	-106.9	10.5	2236.0	1667.5	390.6
36	-100.8	10.6	1999.0	1474.1	390.6
37	-94.7	10.6	1762.0	1280.7	390.6
38	-89.9	11.3	1733.0	1332.4	390.6
39	-86.4	12.8	1403.2	1120.6	390.6
40	-82.3	14.1	976.1	802.2	390.6

1

-------- VALUES AT CENTER OF BASE OF SLICE---------

Slice No.	X-center	Y-center	Total Normal Stress	Effective Normal Stress	Shear Stress
41	-79.3	14.8	769.2	659.9	390.6
42	-76.4	15.5	493.6	446.4	201.3
43	-73.3	16.2	232.7	232.7	104.9

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = 0.02 (= 0.172E-01)
SHOULD NOT EXCEED 0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = 0.03 (= 0.261E-01)
SHOULD NOT EXCEED 0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = -2.03 (=-0.203E+01)
SHOULD NOT EXCEED 0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = 0.01 (= 0.522E-02)
SHOULD NOT EXCEED 0.100E+03

1 UTEXAS2 - VER. 1.209 - 2/3/87 - SN00004 - (C) 1985 S. G. WRIGHT
Spencer's method
Search for critical noncircular surface

TABLE NO. 25
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *

****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
Factor of Safety = 1.280 Side Force Inclination = -6.22 Degrees

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
1	-270.3	-271.	47.0	0.073	18.2	-41.5
2	-266.0	561.	41.5	0.002	-42.3	84.9
3	-261.6	2495.	39.7	0.071	-133.5	302.9
4	-257.2	5530.	37.2	0.104	-233.8	573.4
5	-252.9	9668.	34.6	0.128	-333.0	874.8
6	-250.1	15594.	32.1	0.122	-524.4	1351.8
7	-244.7	20979.	30.1	0.128	-658.0	1727.3
8	-239.4	26772.	28.3	0.137	-772.9	2086.0
9	-234.1	32973.	26.5	0.147	-871.7	2430.1
10	-233.8	33812.	26.3	0.148	-881.6	2470.6
11	-231.5	38638.	25.1	0.171	-841.5	2570.9
12	-229.2	43946.	23.8	0.189	-812.8	2690.3
13	-228.0	49755.	22.6	0.187	-908.3	2982.1
14	-223.4	52974.	21.5	0.184	-986.2	3186.8
15	-218.7	56214.	20.5	0.181	-1061.2	3388.8
16	-212.5	54783.	20.0	0.179	-1070.8	3380.4
17	-206.2	53335.	19.6	0.176	-1079.8	3370.0
18	-200.0	51868.	19.1	0.173	-1088.3	3357.6
19	-193.7	50384.	18.6	0.171	-1096.1	3342.9
20	-187.5	48881.	18.2	0.168	-1103.3	3325.9
21	-181.2	47360.	17.7	0.165	-1109.6	3306.2
22	-175.0	45822.	17.3	0.162	-1115.1	3283.8
23	-170.0	43870.	17.0	0.159	-1107.2	3225.3
24	-165.0	41918.	16.8	0.156	-1097.7	3163.2
25	-160.0	39966.	16.5	0.155	-1088.5	3126.0
26	-153.8	37525.	16.2	0.158	-1078.4	3128.0
27	-147.5	35083.	15.9	0.164	-1066.4	3162.2
28	-141.3	32640.	15.6	0.171	-1048.6	3200.0
29	-135.0	30197.	15.3	0.180	-1021.5	3241.4
30	-130.0	28184.	15.1	0.189	-989.6	3274.4
31	-125.0	26176.	14.9	0.200	-943.7	3308.5
32	-120.0	24172.	14.7	0.208	-895.7	3285.2
33	-115.0	22174.	14.5	0.205	-874.2	3138.1
34	-110.0	20176.	14.3	0.200	-845.7	2962.7
35	-103.9	17730.	14.1	0.206	-773.9	2799.9
36	-97.7	15289.	14.0	0.223	-657.1	2638.6
37	-91.6	12852.	13.9	0.250	-482.6	2406.4
38	-88.1	8859.	14.6	0.236	-484.5	2144.1
39	-84.6	5364.	15.2	0.207	-510.5	1852.9
40	-80.0	2488.	15.7	0.195	-385.6	1314.8

1

-------------- VALUES AT RIGHT SIDE OF SLICE --------------

Slice No.	X-Right	Side Force	Y-Coord. of Side Force Location	Fraction of Height	Sigma at Top	Sigma at Bottom
41	-78.6	1694.	15.9	0.207	-281.4	1023.5
42	-74.2	297.	16.3	0.154	-154.6	442.6
43	-72.4	0.	-15.0	BELOW	-1.8	1.8

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION     =      0.02  (= 0.172E-01)
     SHOULD NOT EXCEED    0.100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION   =      0.03  (= 0.261E-01)
     SHOULD NOT EXCEED    0.100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN  =     -2.03  (=-0.203E+01)
     SHOULD NOT EXCEED    0.100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM    =      0.01  (= 0.522E-02)
     SHOULD NOT EXCEED    0.100E+03

***** CAUTION ***** FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS
                    ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE -
                    A TENSION CRACK MAY BE NEEDED.


END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED
```

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Concluded)

	Title	Date
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 5: Alternate Configuration Miter Gate Finite Element Studies—Additional Closed Sections Report 6: Elastic Buckling of Girders in Horizontally Framed Miter Gates Report 7: Application and Summary	Aug 1987
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package: Volume I, User's Manual	Aug 1987