Research Report
KTC-95-24

Personal Computer (PC) Program for Analysis of Embankments with Tensile Elements

by

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and

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in cooperation with
Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
U.S. Department of Transportation

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Commonwealth of Kentucky
Transportation Cabinet
Frankfort, Kentucky 40622

Fred N. Mudge
Secretary of Transportation

Paul E. Patton
Governor

March 19, 1996

Mr. Paul E. Toussaint
Division Administrator
Federal Highway Administration
330 West Broadway, Frankfort, Kentucky 40602-0536

SUBJECT: ***Implementation Statement: Research Study KTC-95-24, "Personal Computer (PC) Program for Analysis of Embankments with Tensile Elements"***

Dear Mr. Toussaint:

The purpose of this research study was to develop a *comprehensive* PC-based slope stability computer program. This program, which is called **UKSLOPE,** can be used to design and analyze ***reinforced*** and ***unreinforced*** earth structures. The **UKSLOPE** stability computer program contains two, original theoretical slope stability, mathematical models. Complete derivations of the new, or modified, model equations and full discussions of the models, including assumptions, are contained in a research report written by Slepak and Hopkins (KTC-93-29, "Computer Program for Analysis of Embankments with Tensile Elements") and in an earlier research report by Hopkins in 1986 (UKTRP-86-2, "A Generalized Slope Stability Computer Program: User's Guide for HOPK-I"). The original models were programmed for the "main frame" computer. However, engineering personnel of the Cabinet requested that a PC-version be developed.

The Design portion of **UKSLOPE** generally follows guidelines developed by the Tensar® Corporation. However, some modifications and improvements to the original methods have been made. The "Stability Analysis" portion of **UKSLOPE** was developed using many algorithms contained in the older mainframe version. However, some new algorithms were developed for the new version. Main features of the computer program are as follows:

- **UKSLOPE** is a very user-friendly, menu-driven, computer program. Its Graphical User Interface offers a convenient way to enter data and to analyze the results.

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- The program can be used for both design and analysis of earth structures.
- Both reinforced and unreinforced earth structures can be analyzed by the program.
- A variety of limiting equilibrium methods can be used for stability analysis. These approaches, which can analyze both circular and noncircular failure surfaces, include methods that are newly developed and statically consistent, and the traditional method developed by Bishop (1954).
- Four options are offered to simulate pore pressures in an unstable soil mass. These options cover most practical cases.

Many example problems were considered in the research study. These examples were analyzed by both **UKSLOPE** and other computer programs. The results of the analyses show that **UKSLOPE** yields reasonable answers and can be used in practical applications.

Evaluation copies, or "Beta copies," of the **UKSLOPE** computer program have been transmitted to geotechnical engineers of the Kentucky Transportaion Cabinet, Georgia DOT, Alabama DOT, as well as the main engineering office of FHWA, Washington, D.C. Users in those agencies have volunteered to evaluate the stability program and provide comments to the authors. We anticipate that the evaluation period will last several months. Geotechnical engineers of the Kentucky Transportation Cabinet are using the computer program on a trial basis.

Sincerely,

J. M. Yowell

J. M. Yowell, P.E.
State Highway Engineer

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16. Abstract

UKSLOPE is a comprehensive, PC-based, slope stability computer program that can be used to design and analyze reinforced and unreinforced earth structures. The computer program consists of two parts: limit equilibrium models and a computerized method for determining the spacing, length, and number of tensile reinforcement elements. The design of reinforcement elements generally follows guidelines developed by the Tensar® Corporation. However, some modifications and improvements to the original methods have been made. The slope stability analysis portion of **UKSLOPE** is based partly on the original mainframe version. The following are the main features of the program:

- **UKSLOPE** is an extremely user-friendly, menu-driven, computer program. Its Graphical User Interface offers a convenient way to input data and to analyze the results.
- The program can be used for both design and analysis of earth structures.
- Both reinforced and unreinforced earth structures can be analyzed by the program.
- A variety of limiting equilibrium methods can be used for stability analysis. These models include newly developed *statically consistent methods*, which can be used to analyze both circular and noncircular failure surfaces, and also the traditional Bishop's method.
- Four options are offered to simulate pore pressures in an unstable soil mass. These options cover most practical cases.

Many example problems were considered in the research study. These examples were analyzed by both **UKSLOPE** and other computer programs. The results of the analyses show that **UKSLOPE** yields reasonable answers and can be used in practical applications.

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

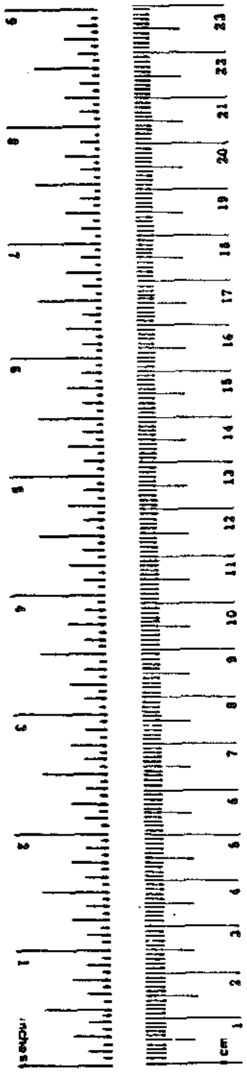
VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectares (10 000 m^2)	2.53	acres	ac

MASS (weight)

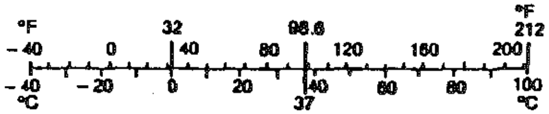
Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

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* SI is the symbol for the International System of Measurements

EXECUTIVE SUMMARY

The purpose of this research study was to develop a comprehensive, PC-based, slope stability computer program. This program, called **UKSLOPE**, can be used to design and analyze reinforced and unreinforced earth structures.

The computer program contains two parts. The first portion, or the "*design module*," can be used to design reinforcement elements of earth slopes. In this portion of the computer program, the number, lengths, and vertical spacings of geotextiles, geogrids, or tensile elements can be determined. This portion of **UKSLOPE** generally follows guidelines developed by the Tensar® Corporation. However, some modifications and improvements to the original methods have been made.

The second portion , or the " *stability analysis module*," of **UKSLOPE** contains several limiting equilibrium methods. Many portions and algorithms that were used in the original, main-frame version (Hopkins, 1986 and Slepak and Hopkins, 1993) have been included in **UKSLOPE**. Main features of **UKSLOPE** are as follows:

- **UKSLOPE** is a very user-friendly, menu-driven, computer program. Its Graphical User Interface offers a convenient way to enter data and to analyze the results.
- The computer program can be used for both design and analysis of earth structures.
- Both reinforced and unreinforced earth structures can be analyzed by the computer program.
- A variety of limiting equilibrium methods are included for stability analysis. These methods include newly developed, statically consistent methods (Slepak and Hopkins,1993 and 1995; Hopkins, 1986) which analyze both circular and noncircular failure surfaces, and the traditional method developed by Bishop (1954).
- Four options are offered to simulate pore pressures in an unstable soil mass. These options cover most practical cases.

Many example problems were considered in the research study. These examples were analyzed by both **UKSLOPE** and other computer programs. The results of the analyses show that **UKSLOPE** yields reasonable answers and could be used in practical applications.

TABLE OF CONTENTS

1. UKSLOPE COMPUTER PROGRAM. MAIN FEATURES.

UKSLOPE is a comprehensive PC-based slope stability computer program that can be used to design and analyze reinforced and unreinforced earth structures. The computer program contains two stability modules. In the first portion of the computer program, the "*Design module*" can be used to design reinforcement elements of earth slopes. This computer module is used to determine the number, lengths, and vertical spacings of geotextiles, geogrids, or tensile elements. This portion of **UKSLOPE** generally follows guidelines developed by the Tensar® Corporation (Tensar Technical Note, 1986a; Tensar Technical Note, 1986b). However, some modifications and improvements to the original methods have been made.

The second portion , or the " *Stability Analysis module*," of **UKSLOPE** contains several limiting equilibrium methods. Many routines and algorithms that were used in the original, main-frame version (Hopkins, 1986 and Slepak and Hopkins, 1993 and 1995) have been included in **UKSLOPE**. Detail description of the theoretical fundamentals of the program can be found in Slepak and Hopkins (1993). However, main features of the program are briefly outlined below. These are as follows:

- **UKSLOPE** is a very user-friendly, menu-driven, computer program. Its "Graphical User Interface" offers a convenient way to enter data and to analyze the results.
- The program can be used for both design and analysis of earth structures.
- Both reinforced and unreinforced earth structures can be analyzed by the program.
- A variety of limiting equilibrium methods are used for stability analysis. These approaches include newly developed, statically consistent methods (Slepak and Hopkins, 1993 and 1995; Hopkins, 1986) that can be used to analyze both circular and noncircular shear surfaces, and the traditional method developed by Bishop (1954).
- Four options are offered to simulate pore pressures in an unstable soil mass. These options cover most practical cases.

The *user's manual*, which contains general information, installation instructions, and operating instructions, is presented in **APPENDIX 1** and the computer program.

1.1 SUMMARY OF EXAMPLES.

In the following sections, different examples are analyzed. These examples were obtained from many different sources and were selected to illustrate the many conditions that **UKSLOPE** can handle. However, all the examples were analyzed earlier by Hopkins (1986) and Slepak and Hopkins (1993). Some examples show only critical shear surfaces located earlier in Hopkins (1986). The other examples are used to perform circular search analysis. In the latter case, contour lines of safety factors (a feature of **UKSLOPE**) are also shown on the cross-sections. In all cases, factors of safety of critical shear surfaces are compared to factors of safety obtained from the slope stability computer program, called **REAME**, that was developed by Huang (1994). Factors of safety for all the examples are summarized in Table 1.1. Factors of safety computed by the two different programs are very nearly identical. For convenience, data entry files for all the examples are given in **Appendix 2.**

1.2. HOMOGENEOUS SLOPE (Example 1 in Hopkins, 1986).

The cross-section of this example is shown in Figure 1.1.In this example, the shear surface is circular and the pore pressures are assumed equal to zero.

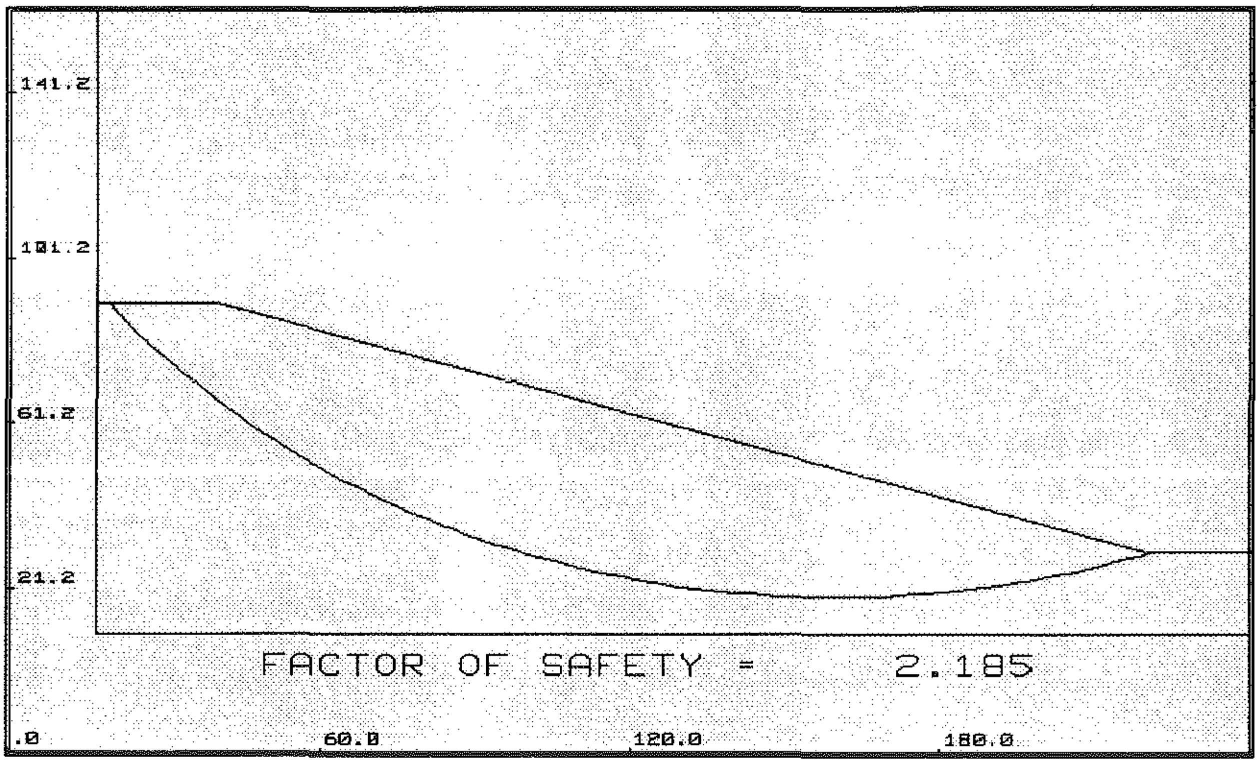

Figure 1.1. *Cross-section in example 1*

Table 1.1. Summary of factors of safety for the example problems.

	UKSLOPE			REAME		Parameters of Critical Circles Coordinates of Centers		
Example Number	**Bishop**	**Hopkins**	**Mod.**	**Bishop**	**Spencer**	**X**	**Y**	**Radius**
Example 1	2.185	2.183	2.185	2.185	2.184	160.00	194.00	175.000
Example 2	1.554	1.573	1.565	1.558	1.576	536.00	600.00	500.000
Example 3	-	1.623	1.630	-	1.656	Noncircular failure surface		
Example 5	-	1.356	1.361	-	1.411	Noncircular failure surface		
Example 6	1.328	1.323	1.327	1.328	1.307	75.00	50.00	50.000
Example 7	1.307	1.317	1.319	1.307	1.310	180.00	240.00	164.118
Example 7b	1.210	1.215	1.217	1.210	1.205	170.00	225.00	149.931
Example 8	1.220	1.254	1.264	1.219	1.190	349.00	204.00	153.999
Example 9	1.785	1.803	1.805	1.786	1.789	110.00	1050.00	120.000
Example 10	1.373	1.376	1.378	1.372	1.379	134.00	175.00	112.313
Example 12	-	0.976	0.984	-	1.053	Noncircular failure surface		
Example 13	1.589	1.593	1.593	1.589	1.593	1400.00	2050.00	1753.000
Example 14	1.363	1.365	1.368	1.362	1.363	137.00	530.00	30.000
Example 15	1.788	1.808	1.815	1.788	1.808	810.00	705.00	152.393
Example 15 (wedge)	-	1.919	1.942	-	2.094	Noncircular failure surface		
Example 16	1.032	1.044	1.042	1.030	1.044	400.00	700.00	142.928
Example 17	1.549	1.558	1.905	1.529	-	117.80	70.00	35.000
Example 17 (w/crack)	0.914	0.827	0.914	0.898	0.897	117.80	70.00	35.000
Billiard and Wu	0.987	-	0.986	0.986	0.986	297.00	106.00	217.767
Wright and Duncan	1.357	-	1.363	1.353	1.346	210.00	1400.00	23.990
Hadj-Hamoe (noncircul.)	-	-	1.322	-	-	Noncircular failure surface		
Hadj-Hamoe (circular)	1.271	-	1.318	1.309	1.309	235.00	40.00	70.000
45- degree slope	1.421	-	1.417	1.423	1.417	3.80	76.00	75.990

1.3. PARTIALLY SUBMERGED MULTILAYERED SLOPE (Example 2 in Hopkins, 1986)

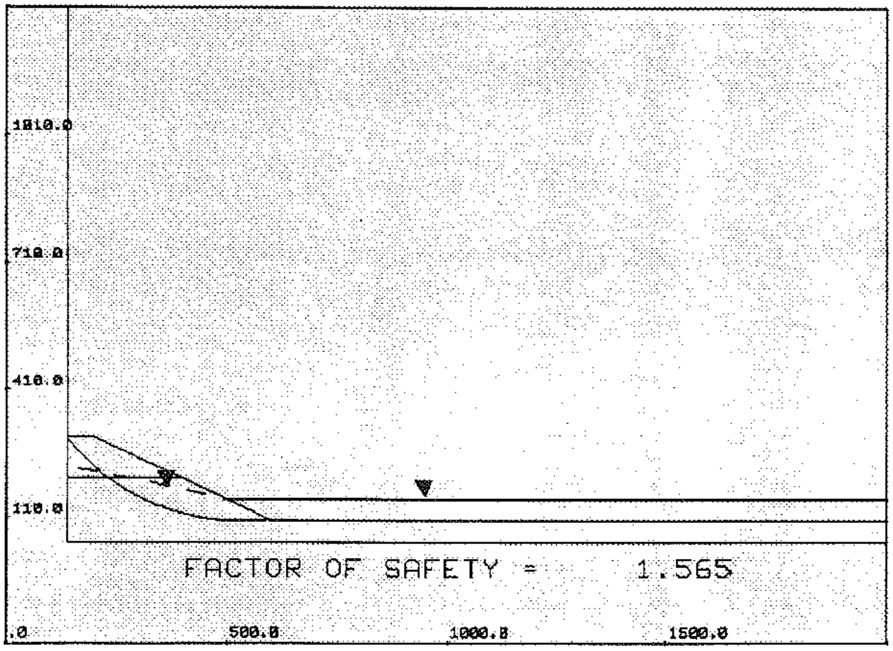

Figure 1.2. *Cross-section in example 2*

This example illustrates the method of handling a multilayered slope that is partially submerged, as shown in Figure 1.2. The example is from Whitman and Bailey (1967). The shear surface is circular. The ground-water level in the example is assumed to be approximated by a piezometric level. To satisfy equilibrium requirements, the hydrostatic thrust of the water resting against the slope must be used in the problem. The thrust, however, is computed by the program and need not be entered.

1.4. ZONED EARTH DAM ON INCOMPRESSIBLE FOUNDATION (Example 3 in Hopkins, 1986)

This example illustrates the method of handling a zoned earth dam located on an incompressible foundation, as shown in Figure 1.3. The example is after Janbu (1969). The earth dam consists of a rock fill, filter, and clay core. The assumed shear surface is non-circular and passes through the core, filter, and rock fill. A

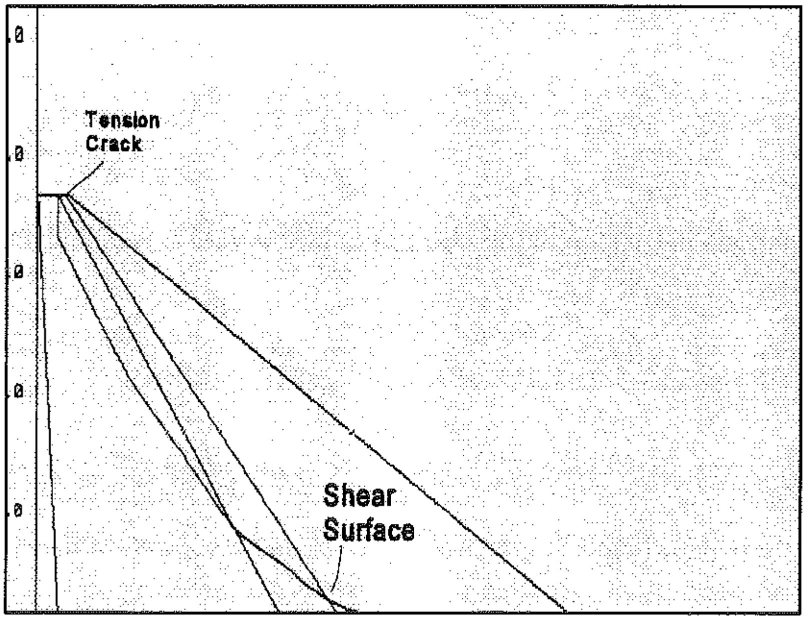

Figure 1.3. *Cross-section in example 3*

tension crack having a theoretical depth of 3.6 meters is assumed to exist in the upper portion of the potential failure mass; the crack is assumed to be filled with water. Consequently, the water in the crack exerts a hydrostatic force against the potential failure mass. This force, however, is computed by the program and need not be entered.

The objective of the analysis is to estimate the short-term or end-of-construction stability of the dam using an effective stress analysis. In this particular problem, the pore pressure is a dependent variable controlled by the magnitude of the stresses tending to instability. In problems of this type, it is oftentimes convenient to use a pore-pressure ratio, rather than the actual pore pressure. Since the rock fill will drain instantaneously, pore pressures in this material during construction are zero and ru will be equal to zero. However, pore pressures will develop in the clay core and filter during construction because those materials have low permeabilities.

1.5. SLOPING CORE DAM (Example 5 in Hopkins, 1986)

In a sloping core dam, the failure surface may be non-circular, as illustrated in Figure 1.4. In this example, the dam consists of an outer shell composed of cohesionless high-strength material and a sloping core composed of cohesive clay. Pore pressures are assumed equal to zero.

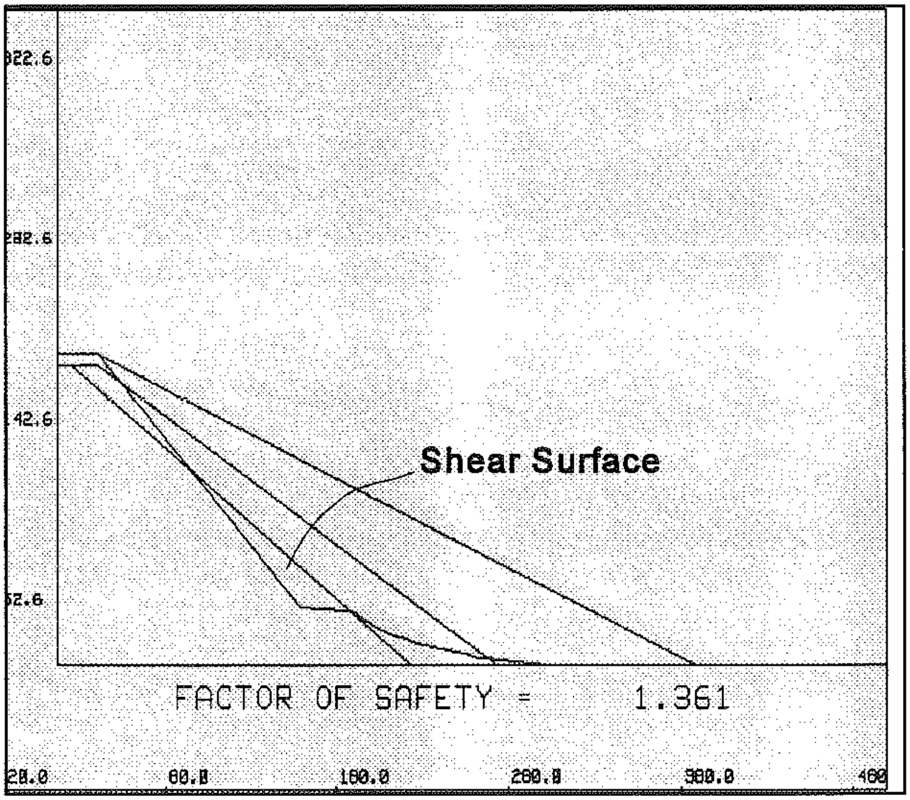

Figure 1.4. *Cross-section in example 5*

The shear surface in this problem is assumed to be tangent along the back slope of the core and to emerge in the lower portion of the shell material as illustrated.

1.6. MULTILAYERED SLOPE (Example 6 in Hopkins, 1986)

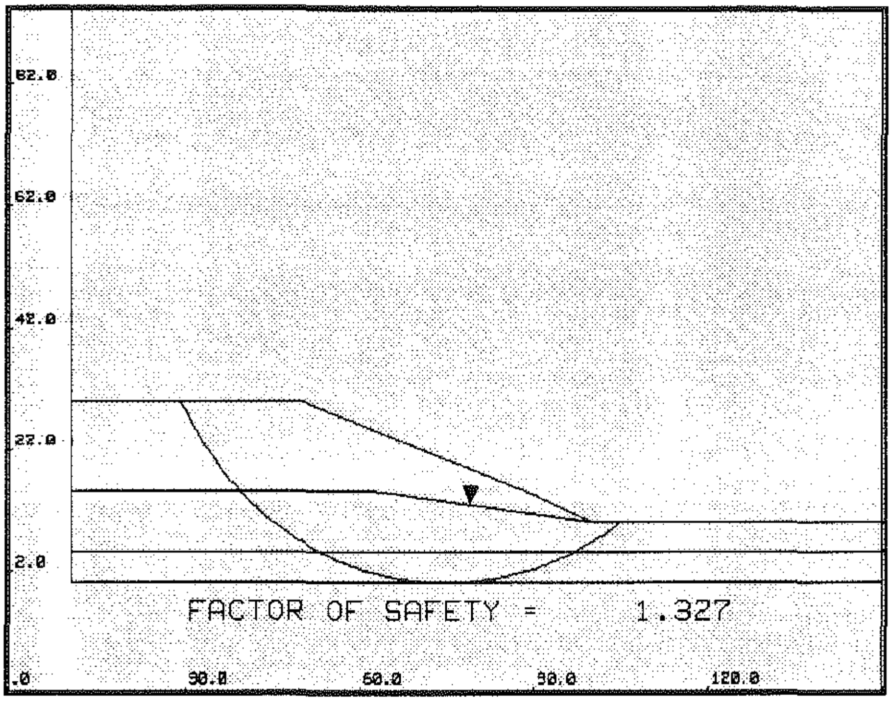

Figure 1.5. *Cross-section in example 6*

This example considers a multilayered slope selected from Peck, Hansen, and Thornburn's (1974) book. Only one circular shear surface was used. A cross section is shown in Figure 1.5.

1.7. EMBANKMENT ON SOFT GROUND (Example 7 in Hopkins, 1986)

This example illustrates the use of different pore pressure options. The example was selected from the ICES LEASE-I User's Manual (1969) and is a typical problem in the design of embankments on soft clay. A cross section is given in Figure 1.6. An effective stress analysis (Example 7) and a total stress analysis (Example 7b) were performed. Critical failure surfaces are shown in Figures 1.6 and 1.7 respectively.

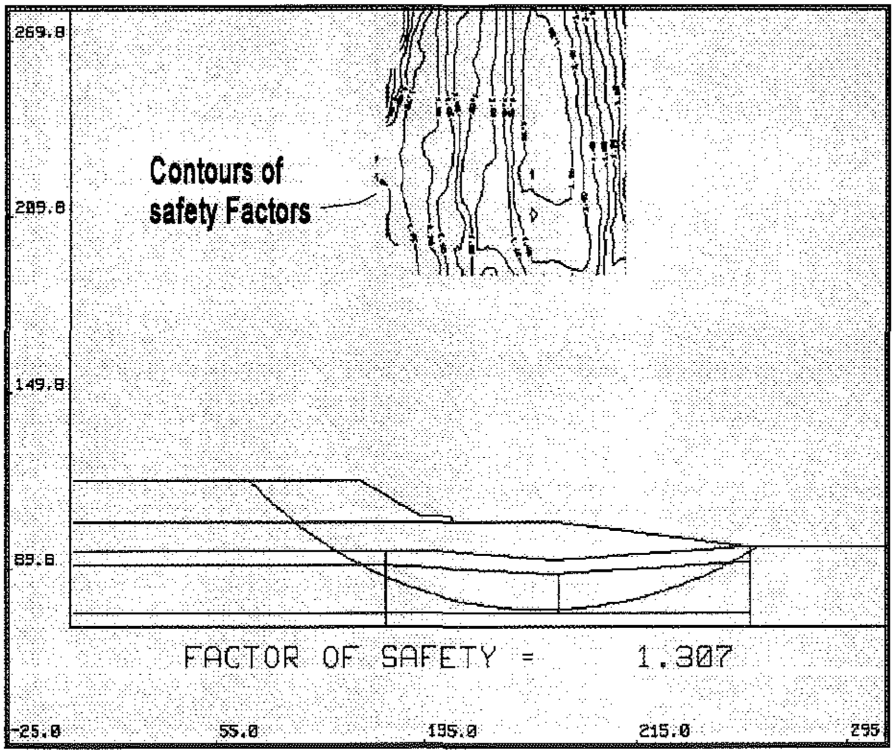

Figure 1.6. *Cross-section in example 7. Effective stress analysis*

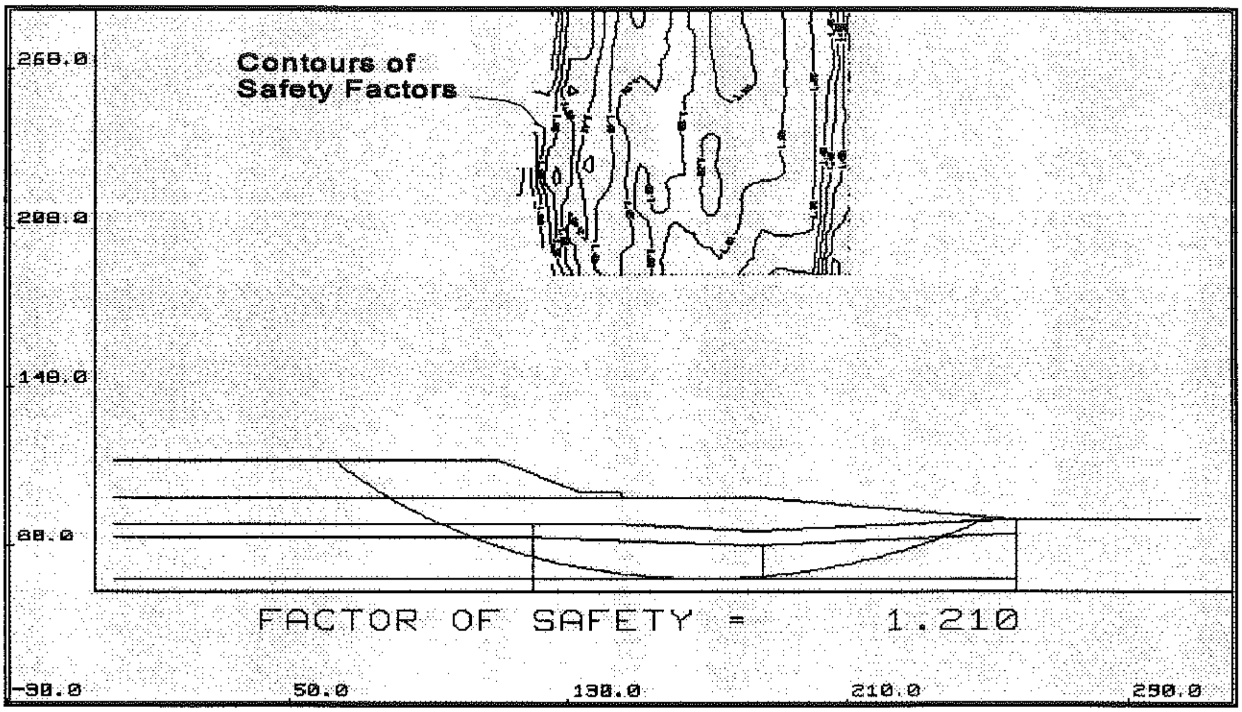

Figure 1.7. *Cross-section in example 7. Total stress analysis.*

1.8. EMBANKMENT ON A CLAY FOUNDATION (Example 8 in Hopkins, 1986)

A cross section of this example is shown in Figure 1.8. The example was analyzed by Wright (1974).

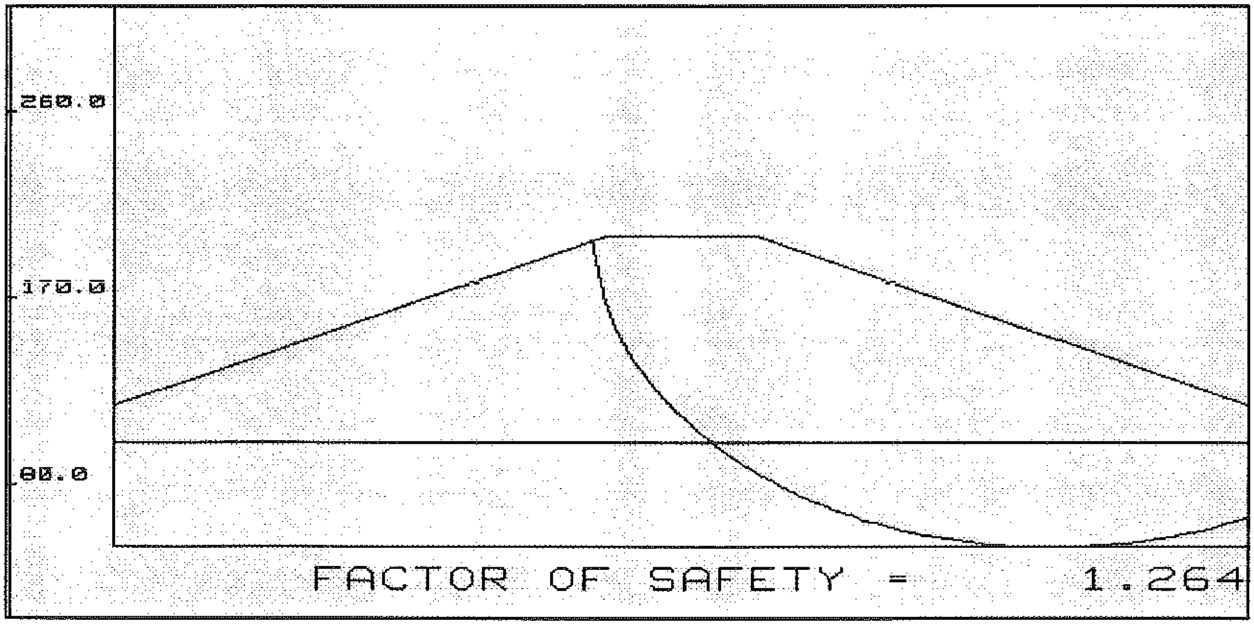

Figure 1.8. *Cross-section in example 8*

1.9. SIDE-HILL HIGHWAY EMBANKMENT SLOPE (Example 9 in Hopkins, 1986)

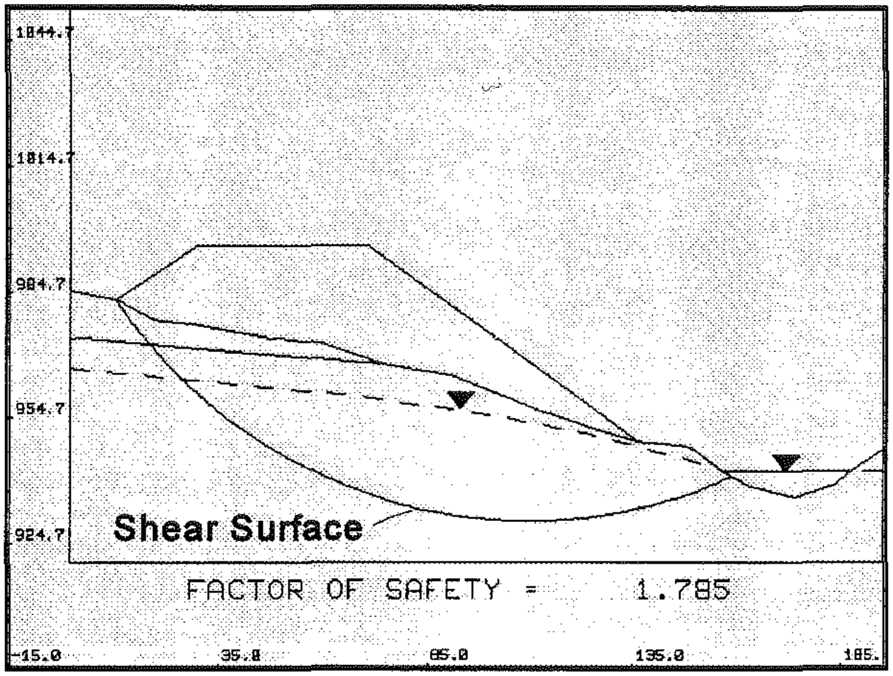

Figure 1.9. *Cross-section in example 9*

The cross-section for this example is shown in Figure 1.9.

1.10. LONG-TERM STABILITY OF A CUT IN SOFT CLAY (Example 10 in Hopkins, 1986)

This example was selected from the **STABL** User's Guide (1975). The cross-section and the results of circular search analysis are shown in Figure 1.10.

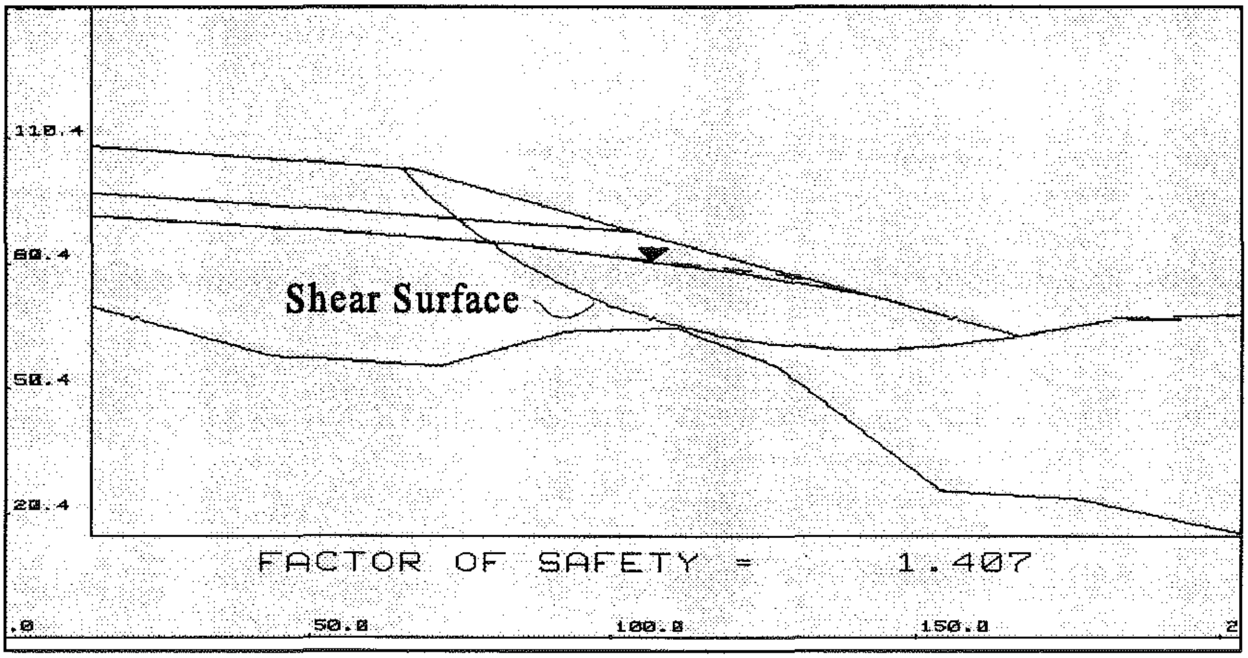

Figure 1.10. *Cross-section in example 10*

1.11. HIGHWAY (SLIDING WEDGE) EMBANKMENT FAILURE (Example 12 in Hopkins, 1986)

The highway slope failure in Figure 1.11 is a typical example of many highway failures encountered in mountainous terrain. The failure mass is frequently a sliding wedge. Slope inclinometers were installed to locate the shear zone of the slide and to track movements of the sliding mass. As shown by inclinometer data, the major portion of the failure zone was located in the shallow foundation soils. Considerable movement of the sliding mass occurred during the monitoring period. Consequently, a plane of weakness existed in the embankment and foundation. The water table or phreatic surface was determined from ground-water levels in the slope inclinometer casing.

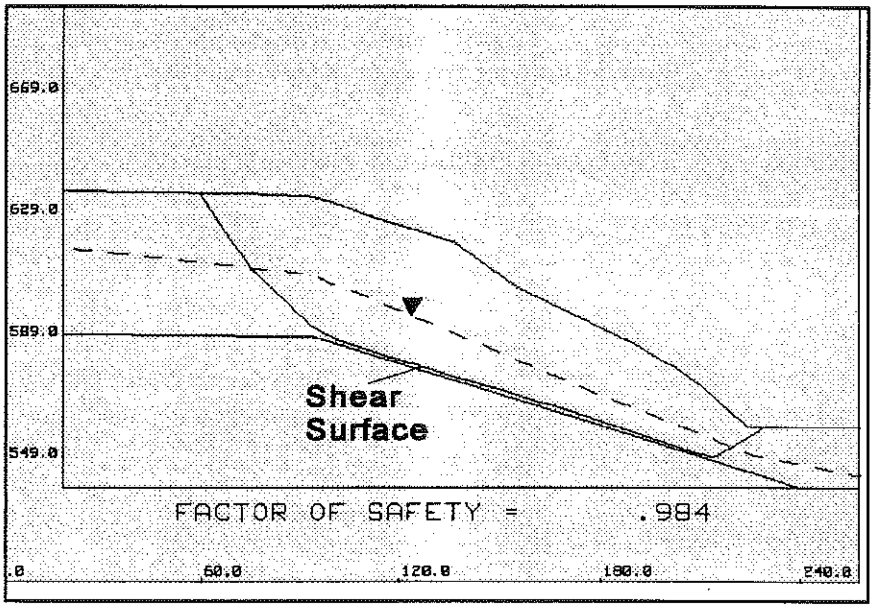

Figure 1.11. *Cross-section in example 12*

1.12. HOLLOW FILL SLOPE (Example 13 in Hopkins, 1986)

The hollow fill shown in Figure 1.12 was selected to test the pseudo-statical earthquake routine. This problem involves a circular failure surface and a homogeneous coal disposal fill.

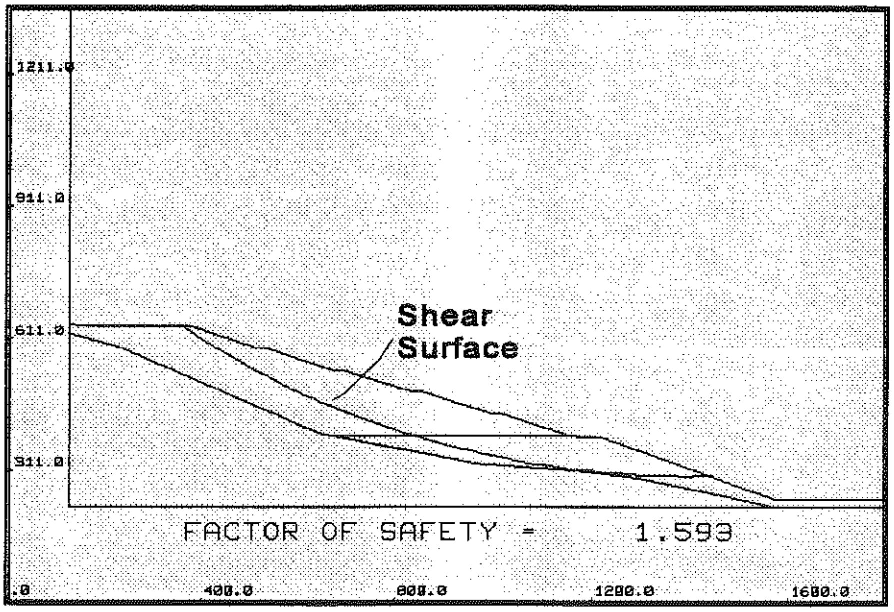

Figure 1.12. *Cross-section in example 13*

1.13. EARTH DAM WITH STEADY-STATE SEEPAGE (Example 14 in Hopkins, 1986)

A cross section of this example is shown in Figure 1.13. The example appears in Lambe and Whitman's 1969 book.

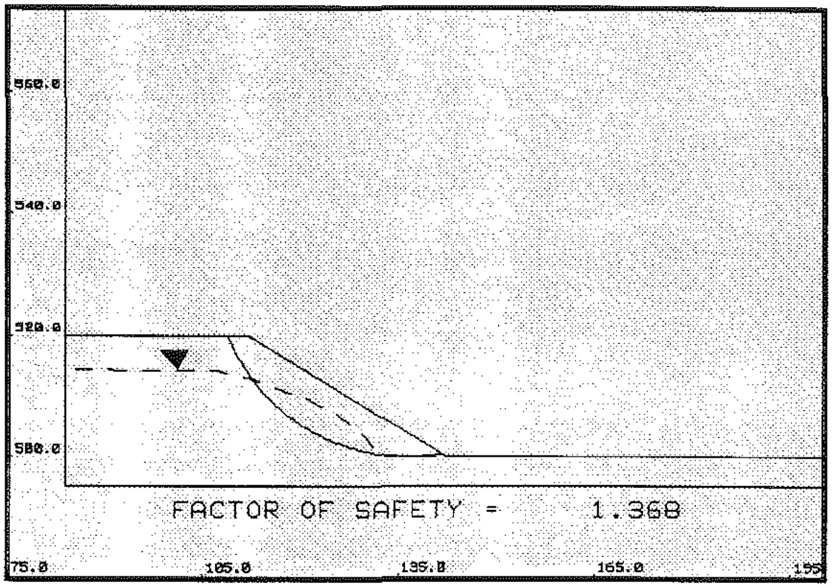

Figure 1.13. *Cross-section in example 14*

1.14 MILL CREEK DAM, DOWNSTREAM SLOPE (Example 15 in Hopkins, 1986)

A cross section of the downstream slope of Mill Creek dam is shown in Figure 1.14. Originally, the dam was intended to have a core constructed of clay and shells (located upstream and downstream of the core) constructed of durable rock. Unfortunately, no transitional filters were constructed between the clay core and rock shell contacts. However, nondurable shales, which had weathered over the period of time dam had been in service, were used to construct the rock shells. Essentially, the dam behaved as a 'homogeneous' structure, although not by design. Piezometers were installed to locate the phreatic surface. The downstream slope was analyzed using

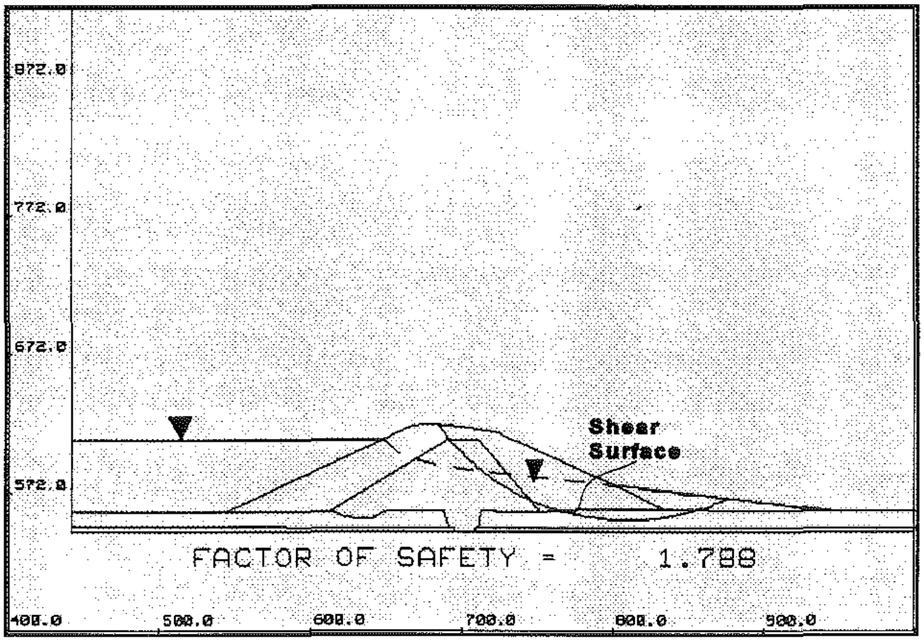

Figure 1.14. *Cross-section in example 15.*

both circular and noncircular wedge type shear surfaces. The results are shown in Figures 1.14 and 1.15 respectively.

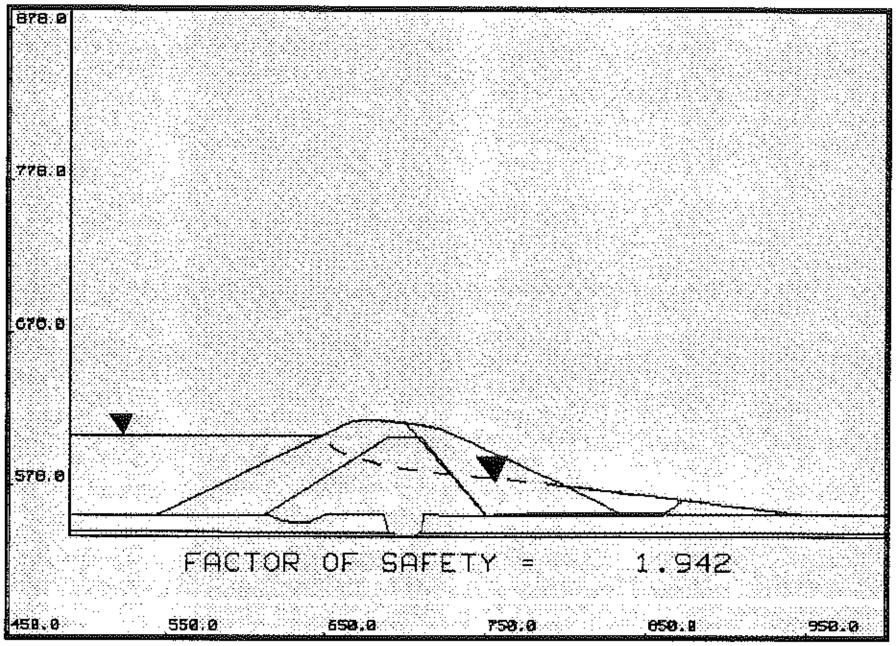

Figure 1.15. *Cross-section in example 15; wedge type failure surface*

1.15. MILL CREEK DAM, UPSTREAM SLOPE (Example 16 in Hopkins, 1986)

The upstream slope of the Mill Creek Dam described in the previous section was analyzed to study the affect of rapid drawdown on stability. Lowering of the pool might occur in the event of an emergency situation or when repairs of the dam are required. The phreatic surface in the rapid drawdown analyses was assumed to follow along the face of the upstream slope. Permeability tests on the shell materials (essentially weathered clay shales) Yielded values of 1.3 x 10-8 centimeters per second. Therefore, little drainage would occur during a short draw downperiod. Results of rapid-drawdown analyses are shown in Figure 1.16.

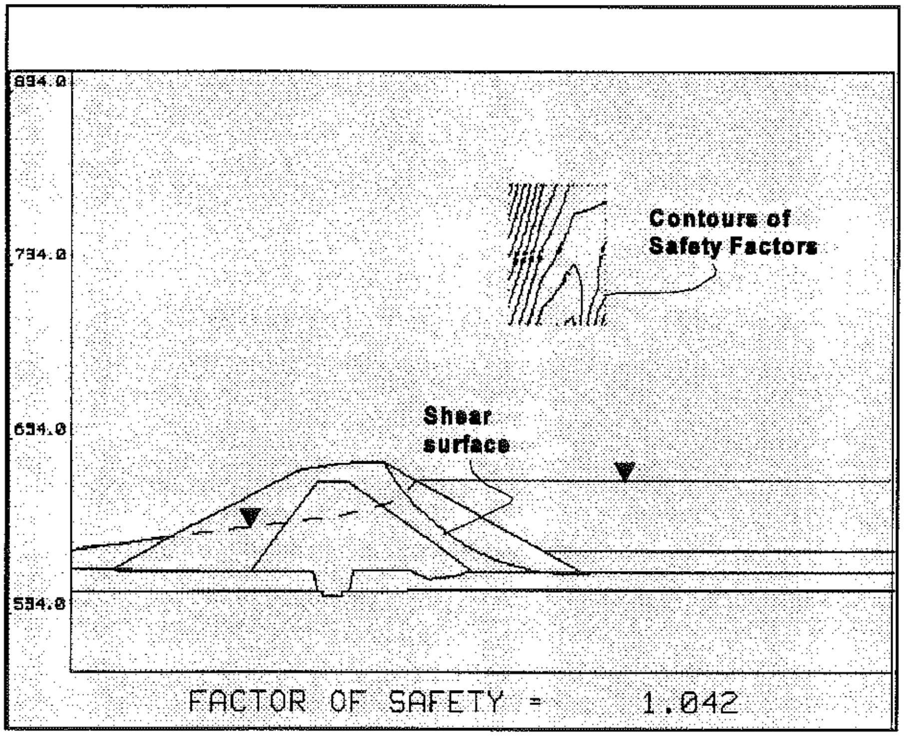

Figure 1.16. *Cross-section in example 16*

1.16. EMBANKMENT ON A SOFT CLAY FOUNDATION (Example 17 in Hopkins, 1986)

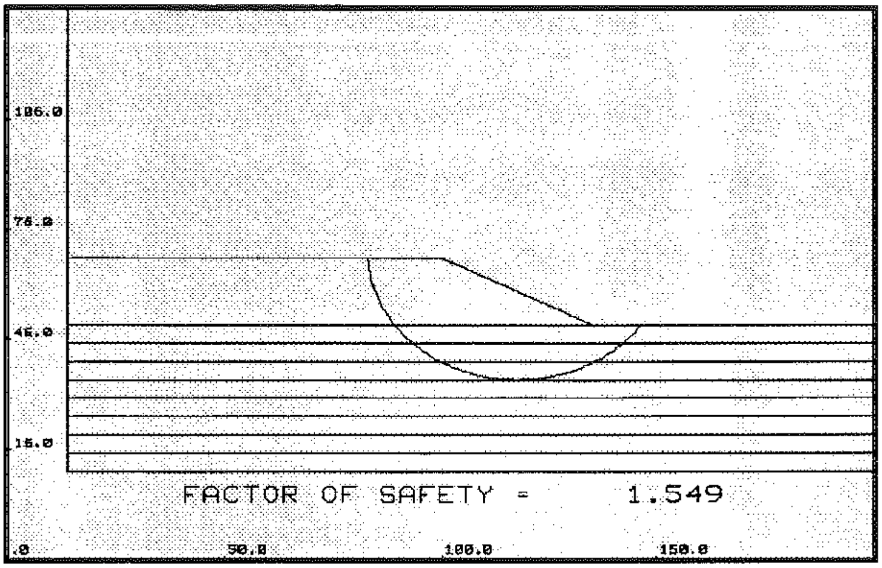

Figure 1.17. *Cross-section in example 17*

This example is a hypothetical embankment on a soft clay foundation, as shown in Figure 1.17. Unlike the previous examples, large differences exist among the factors of safety computed by different methods (see Table 1.1). For example, Bishop's method yielded a factor of safety of 1.549 whereas the Modified Perturbation Method yielded a value of 1.905. The Modified Spencer Method (by REAME) did not converge.

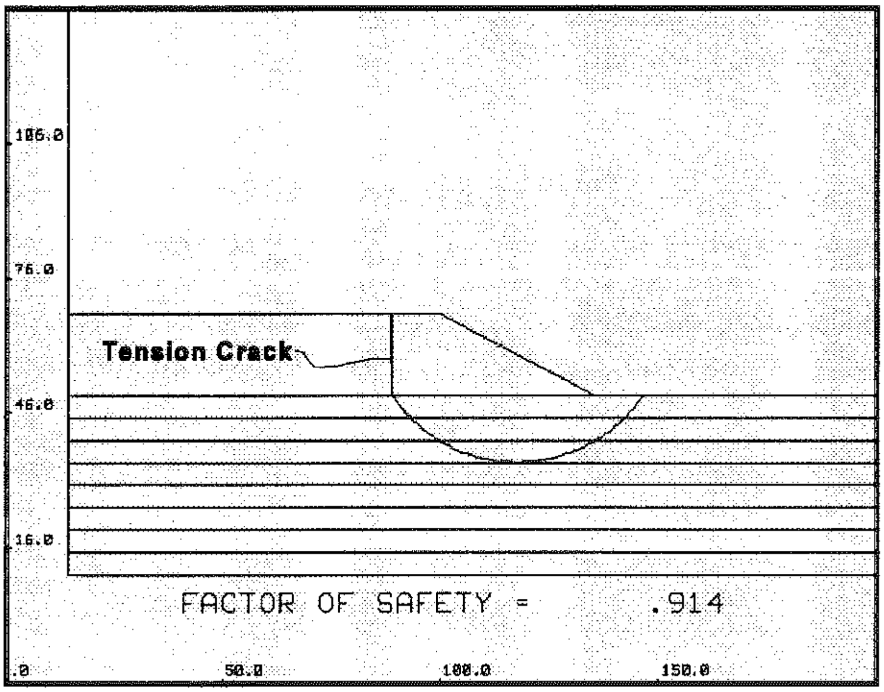

Figure 1.18. *Cross-section in example 17 (with tension crack)*

This example was also analyzed assuming a tension crack in the embankment (Figure 1.18). Two observations can be made from the analysis. First, the factors of safety (see Table 1.1) for the embankment with tension crack are much lower than the ones previously determined. Secondly, the factors of safety for different methods are all near 0.9. Therefore, the analysis with a tension crack is more reliable for this example, and it shows that the embankment could fail.

1.17 LOAD TEST OF A LARGE-SCALE GEOTEXTILE-REINFORCED RETAINING WALL. Billiard and Wu (1991) example.

Billiard and Wu (1991) performed a controlled load test to investigate the performance of a geotextile-reinforced retaining wall until a failure state was reached. The test wall geometry is illustrated in Figure 1.19. This test wall was erected in the laboratory using a typical sequential construction technique. The test wall was loaded by applying incremental vertical surcharge loads on the top surface until excessive deformation of the facing had occurred. To provide insight into the behavior of the retaining wall under load, the wall was instrumented to measure the strain of the geotextile and deflections of the top surface and vertical face. The wall was constructed using a low weight spun bonded nonwoven polypropylene geotextile with a wide width tensile strength of 420 lbs/ft at 60% elongation. The soil was a gravelly sand (cohesionless) having a ϕ angle of 39°. Placement unit weight of the sand was estimated to be approximately 95 pcf. The test wall at failure (surcharge load q=

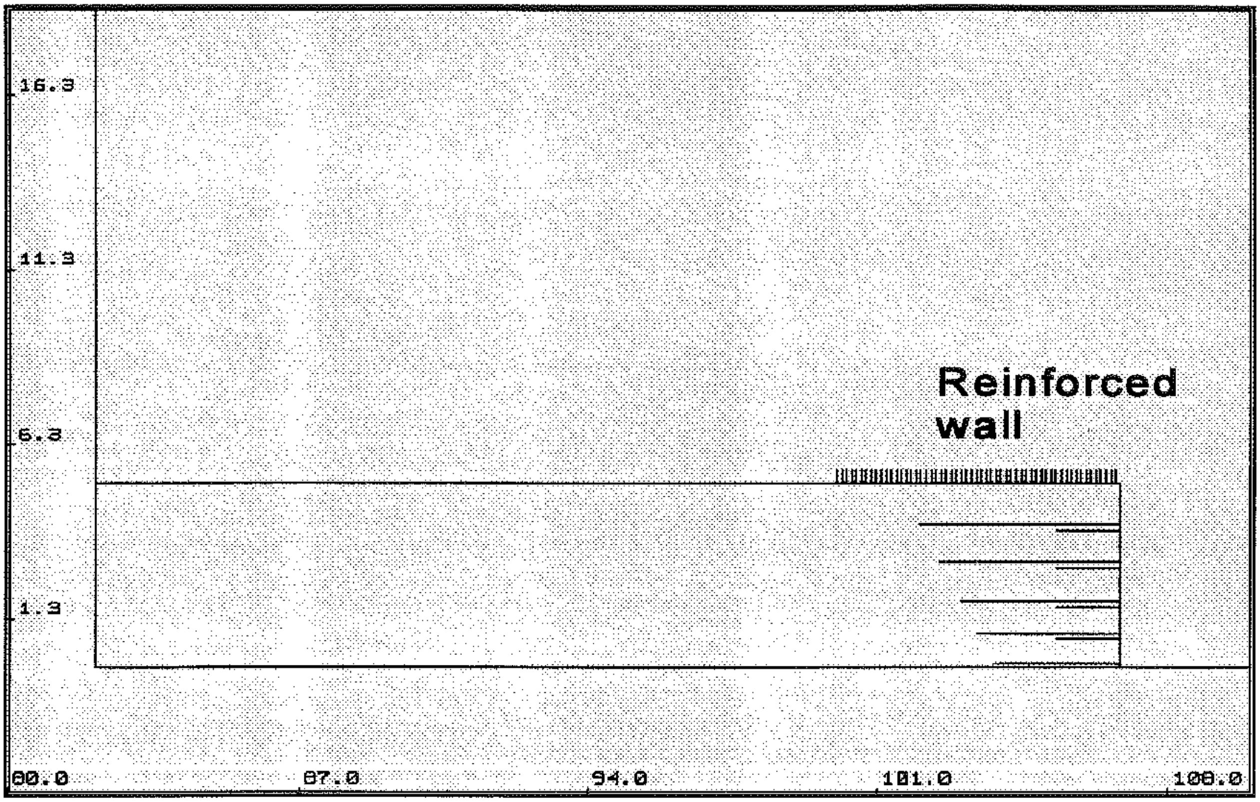

Figure 1.19. *Cross-section in Billiard and Wu example*

2,660 psf) was analyzed by different methods. The results are shown in Figure 1.20 and Table 1.1. The factors of safety are near 1.0 which is an indication of failure.

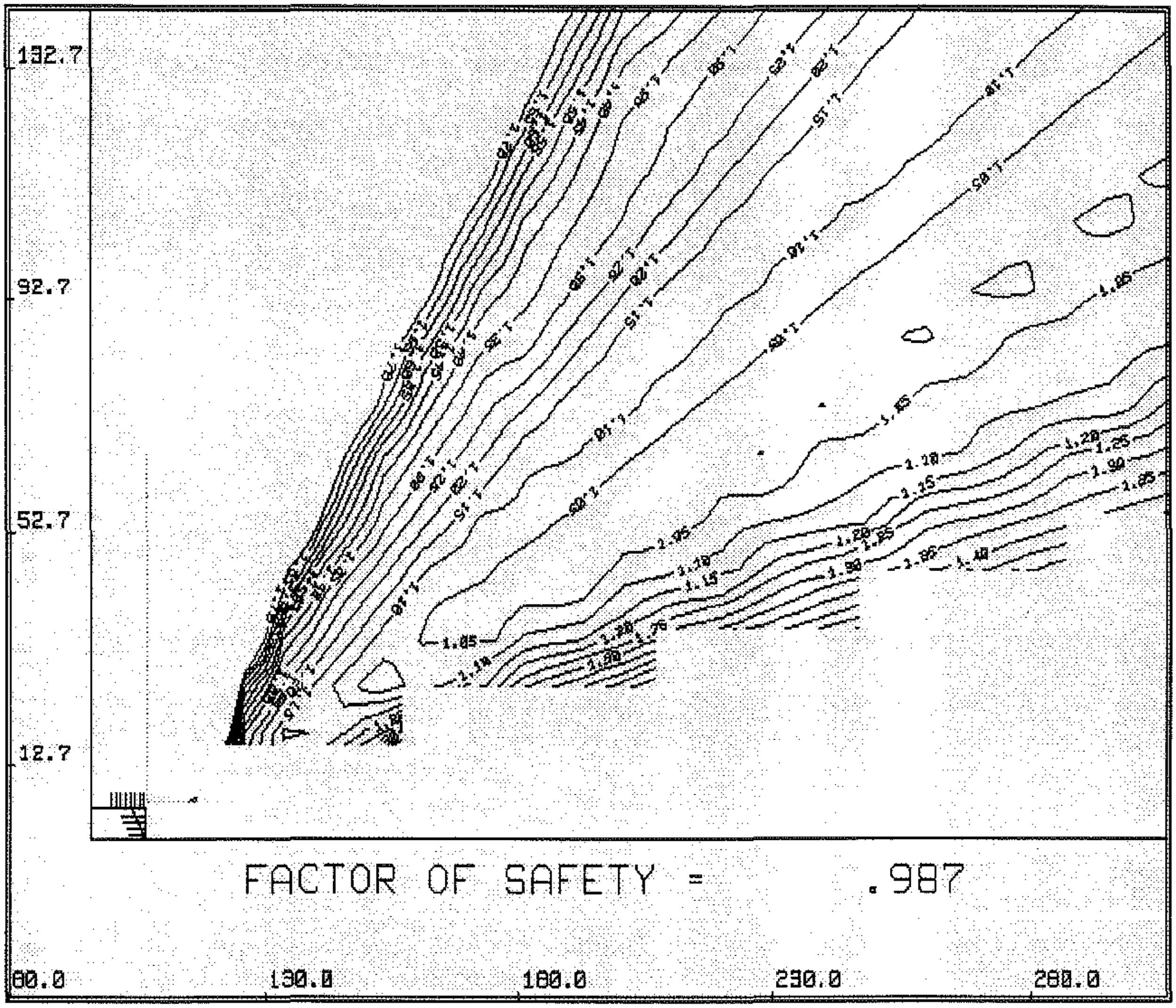

Figure 1.20. ***Cross-section and critical circle at failure in Billiard and Wu example***

1.18 WRIGHT AND DUNCAN'S (1991) EXAMPLE.

This example consists of a 10-ft. high cohesionless fill resting on a 10-ft. layer of saturated (ϕ=0) clay, as shown in Figure 1.21. Much stronger soils are assumed to exist below the clay. The fill has an angle of internal friction (ϕ) of 35 degrees and a total unit weight of 105 pcf. The clay has a uniform undrained shear strength of 200 psf. One layer of reinforcement is placed at the base of the fill on the surface of the clay. The reinforcement carries a constant force of 3,000 lbs/ft. This example is the

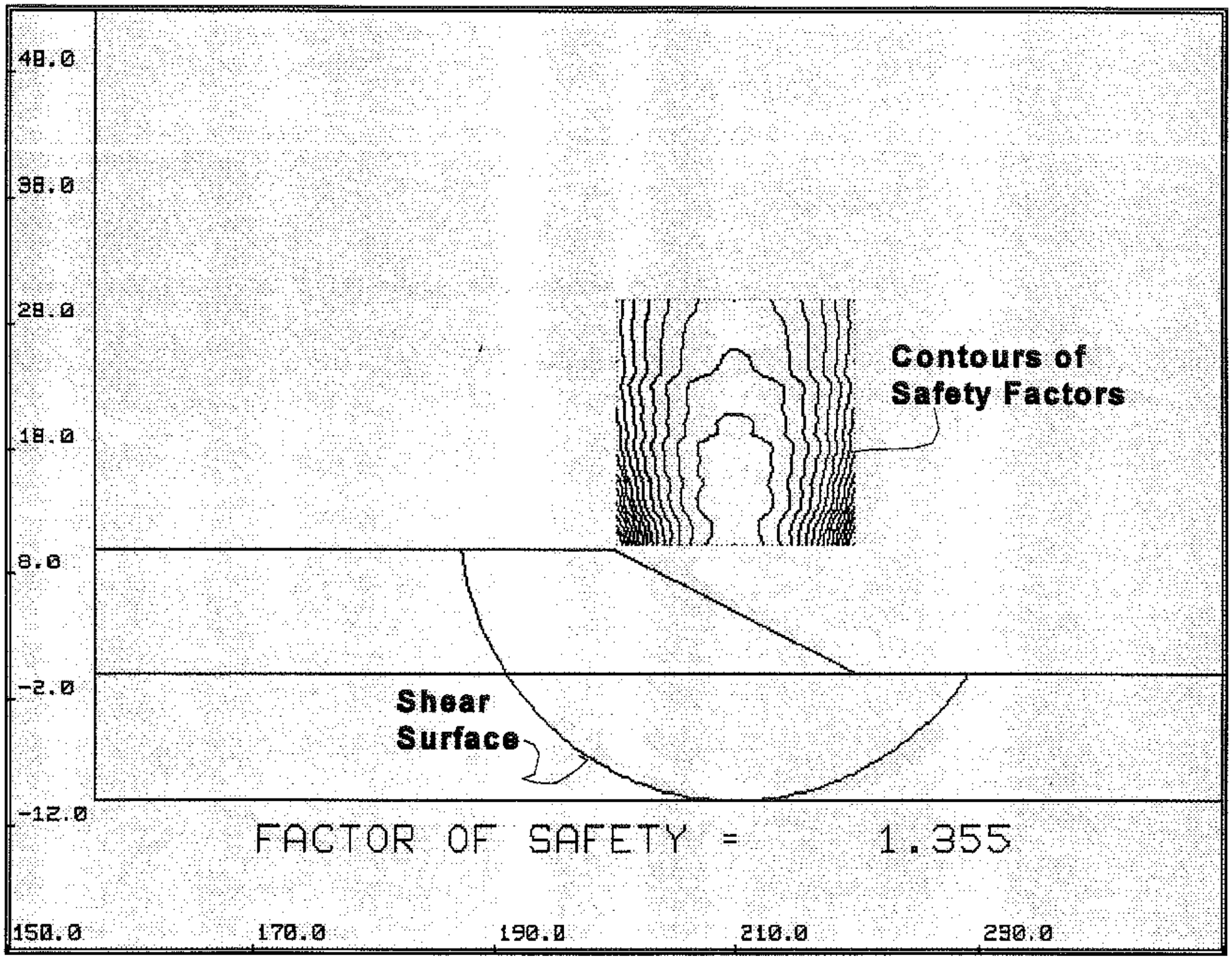

Figure 1.21. *Cross-section in Wright and Duncan's example*

Wright and Duncan's (1991) example 2. Circular search analyses were performed with this example using different methods.

1.19 HADJ-HAMOE et al (1990) EXAMPLE.

This example deals with the stability analysis of a hurricane protection levee constructed in Louisiana. The test section is 350 ft long, 10 ft high, 10 ft wide at the crown, and 136 ft wide at the base, including the two stabilizing berms. The levee is constructed with a central core of hauled semicompacted clay fill placed on a working pad of hauled sand fill. The stabilizing berms are constructed of hauled uncompacted clay fill placed from the sand pad. The reinforcement consists of two layers of high-density polyethylene Tensar SR 2 geogrids. This example was analyzed using both circular and noncircular (wedge type) shear surfaces. The results are shown in Figures1.22 and 1.23.

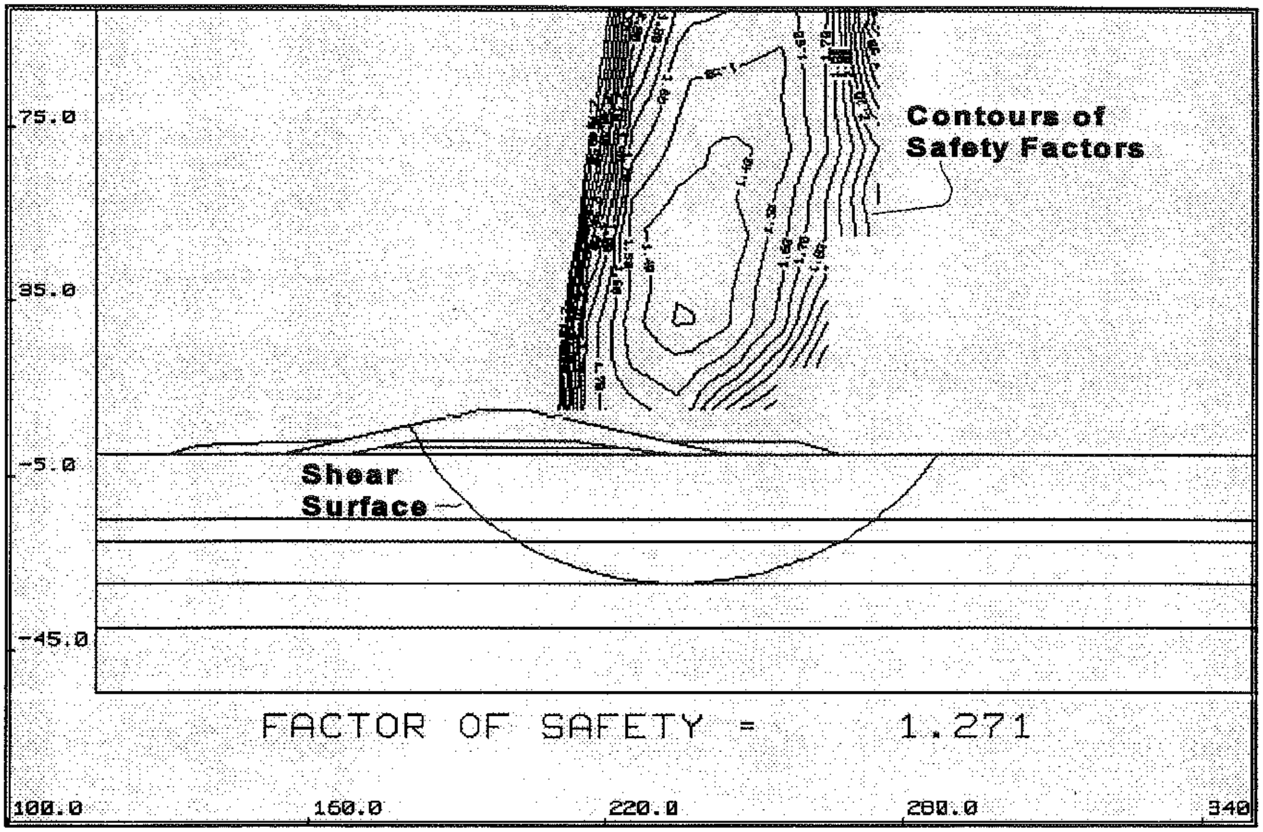

Figure 1.22. ***Cros-section in Hadj-Hamoe example; circular search analysis***

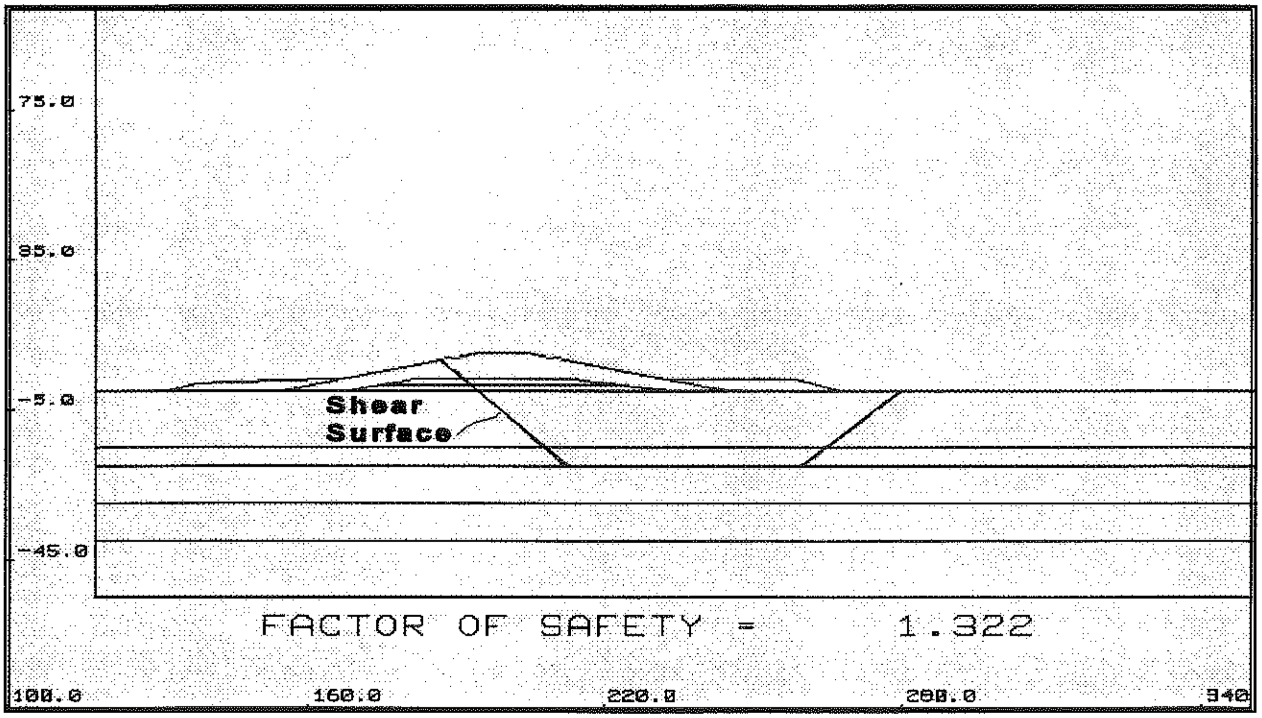

Figure 1.23. ***Cross-section in Hadj-Hamoe example; noncircular failure surface***

1.2. A 45-DEGREE REINFORCED SLOPE.

This 45-degree reinforced slope shown in Figure 1.24 was designed using the "Design portion" of **UKSLOPE** assuming the factor of safety of 1.3. Then it was analyzed using different limiting equilibrium methods. The results are shown in Figure 1.24.

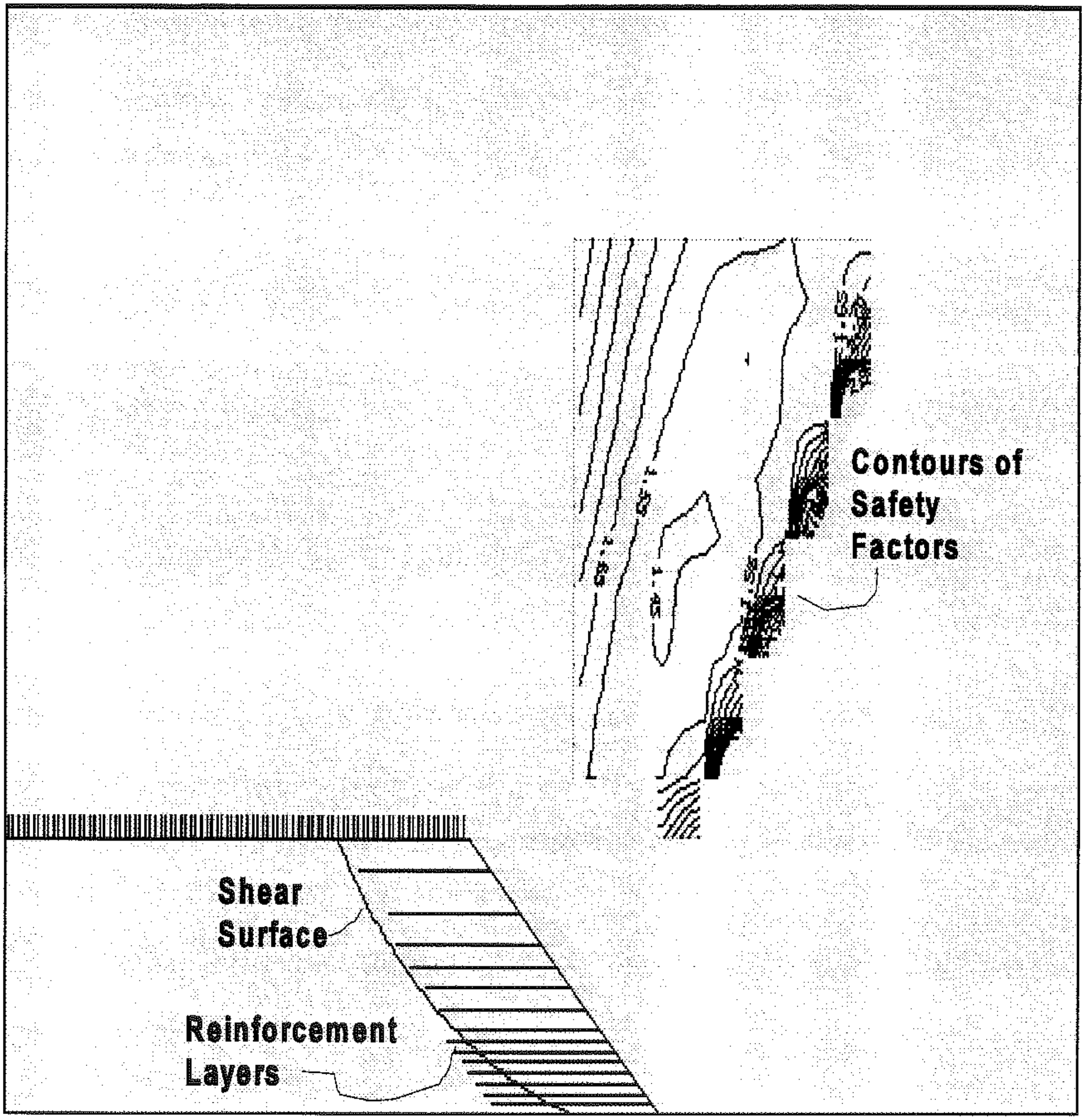

Figure 1.24. A *45-degree reinforced slope*

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APPENDIX 1. UKSLOPE USER'S MANUAL.

Welcome to **UKSLOPE**, Version 1.4, a powerful computer program for design and stability analysis of reinforced and unreinforced earth structures.

A.1.1. GENERAL INFORMATION.

This software is designed to run under MS DOS on an IBM PC, 386 processor or higher. It is a VERY user-friendly menu-driven program that has a lot of features for graphical input and output. We hope you will enjoy using this software. However, if you experience problems using this software or you are not sure how to use certain features, please do not hesitate to contact the developers, Tommy C. Hopkins, P.E., and Mikhail E. Slepak, Ph.D.,P.E. We will be happy to answer all your questions.

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A.1.2. INSTALLATION.

To install the software:

1. Create a new subdirectory for **UKSLOPE** files and make it current.

2. Insert the distribution disk in A: drive and type a:\install.

A.1.3. RUNNING THE PROGRAM.

To run the program:

1. From DOS. Make the subdirectory containing **UKSLOPE** files current and type: reinforc.

2. From MS Windows. From Program Manager select file, run, and then type the complete path of the executable file (...\reinforc.exe).

A.1.4. PREPARING INPUT DATA.

You will see the first screen displaying general information about the program. Press any key and Main Menu will be displayed.

A.1.4. 1. MAIN MENU.

The Main Menu consists of three items: "STABILITY ANALYSIS", "TENSILE ELEMENTS DESIGN", and "HELP". To navigate between the items use arrow keys; to make a selection press "Enter" or type the first character. The text line displayed to the right of the highlighted item gives a brief explanation of the item.

Select "STABILITY ANALYSIS" to compute a factor of safety for reinforced or unreinforced earth structure. Stability analysis can be performed for the most general case involving complex geometry, external loads, pore water pressures, etc. However, if you are analyzing a case with relatively simple geometry you may reduce the number of input data significantly. See Stability Analysis section for more details.

Select "TENSILE ELEMENTS DESIGN" for preliminary determination of reinforcement layout. Only relatively simple reinforced slopes and retaining walls can be considered using this option. You will find the complete set of limitations under the Design Menu section. If your case can not be treated as "simple", you may design your earth structure by iteratively using "STABILITY ANALYSIS." You could also use "STABILITY ANALYSIS" to check your preliminary slope design. After you have completed "TENSILE ELEMENTS DESIGN", the program will automatically pass all the design features to "STABILITY ANALYSIS". Hence, you could compute the actual factor of safety for the preliminary designed reinforced slope without having to input any extra data. See the Stability Analysis section for more details.

A.1.4.1.1. STABILITY ANALYSIS.

"STABILITY ANALYSIS" option is used to compute a factor of safety for reinforced or unreinforced earth structure. You could analyze both right and left-oriented slopes. In both cases the coordinate system is selected in such a way that X-coordinate is increasing from left to right, Y-coordinate is increasing from bottom to top. Right-oriented slopes are assumed to slide from left to right; left-oriented slopes are assumed to slide from left to right.

Stability analysis can be performed for the most general case involving complex geometry, external loads, pore water pressures, etc. However, if you are analyzing a case with relatively simple geometry you may reduce the number of input data significantly. After you have selected "STABILITY ANALYSIS" from Main Menu a pop up window will ask you if you would like to initialize variables for Stability Analysis using simplified slope geometry. Type 'y' for "yes" or press any other key for "no". Selecting "yes" will lead you to Simplified Slope Geometry Data Entry Screen. Selecting "no" will prompt you for an input data file name. Type in a file name or press F1 to select it from a list of Stability Analysis files in the current directory. You could display up to 1,000 file names. All Stability Analysis files have extensions ".sta". You do not have to type in that extension, the program will automatically append this extension to the file name you entered. You could leave the file name blank. In this case no files will be read. Press ENTER to display Stability Analysis Menu.

A.1.4.1.1.1. SIMPLIFIED SLOPE GEOMETRY DATA ENTRY SCREEN.

Notice that if during the current session you ran slope "TENSILE ELEMENTS DESIGN", all the data in this screen will be automatically initialized. Hence, you could compute the actual factor of safety for the preliminary designed reinforced slope without having to input any extra data. Slope orientation is always initialized to "RIGHT" by default. You could change any of the data by simply typing it in. At any time you could press ESC to go back to Main Menu. Press F2 after you fill in all data boxes. If you input invalid data, you will be prompted about an error. Correct the error and press F2 again. That will lead you to Stability Analysis Menu.

A.1.4.1.1.2. STABILITY ANALYSIS MENU.

When you work with Stability Analysis your final destination will always be Stability Analysis Menu. If you chose Simplified Slope Geometry then Stability Analysis variables are initialized using data from Simplified Slope Geometry Data Entry Screen. If you did not choose Simplified Slope Geometry, then Stability Analysis variables are initialized with the file data or with blanks if a file name was not specified.

Stability Analysis Menu consists of the following items: "PROBLEM CONTROL", "GROUND LINE", "C PHI GAMA", "BOUNDARY LINES", "WATER", "LINE OF THRUST", "VERTICAL LOADS", "END FORCES", "SEISMIC ANALYSIS", "FAILURE SURFACE(S)", "TENSION CRACK", "REINFORCEMENT", "=EXECUTE", "X-Y

VIEW", and "OUTPUT FILE VIEW".

To navigate between the items use arrow keys; to make a selection press "Enter" or type the first character. The text line displayed to the right of the highlighted item gives a brief explanation of the item. Press ESC at any time to return to Main Menu.

A vertical bar located to the left of the menu window shows the current status of an item. Originally the bar is blue. When you select an item a portion of the bar changes its color to green, thus letting you know which data you have or have not edited. Selecting an item in Stability Analysis Menu will open a Data Entry Screen. From this screen you could preview the current cross-section (F4), get help (F1), and execute slope stability program (F2). If you pressed F2, you will be prompted for an output file name. Enter a file name or press ESC for none. If you have entered valid data, the program will execute. Otherwise, it will prompt you about an error. Correct the error and run the program again or press ESC to exit.

A.1.4.1.1.2.1. PROBLEM CONTROL.

Selecting PROBLEM CONTROL will display Problem Control Data Entry Screen.

Problem identification. Type in any text identifying the problem.

Reinforcement. Select "yes" if the problem involves reinforcement or “no" otherwise.

Method. Select any of the following limiting equilibrium methods.

Bishop's method can be used for circular analysis in both reinforced and unreinforced cases. Although this method is not statically consistent, it was proven to yield reasonable answers in cases involving circular failure surfaces.

Hopkins' method, proposed by one of the developers of this software, (Tommy C. Hopkins) can be used for circular and noncircular analysis in unreinforced cases only. This method is essentially a modification of the Janbu's method. However, to overcome convergence problems usually arising while using Janbu's method, this method makes use of a special numerical technic to compute derivatives of interslice forces at each iteration. Strictly speaking, this method is not statically consistent. However, it yields reasonable factors of safety in a variety of practical problems.

Modified Perturbation method proposed by one of the developers of this software (Mikhail E. Slepak) is a statically consistent method. It can be used in reinforced and unreinforced analysis involving both circular and noncircular failure surfaces. It is free of convergence problems and yields reasonable factors of safety in a variety of practical problems.

Thrust line can be computed or specified by input.

Failure surface can be circular or noncircular.

Pullout resistances can be calculated assuming either free or fixed reinforcement end. Reinforcement end is considered fixed if it is attached to facing elements, and free otherwise.

Unit weight of water. Units of all input-output data in the stability analysis program are those implied by the numerical value used for the unit weight of water. For example, 0.0624 kip/(cubic ft) implies English system; 9.8 kN/(cubic m) implies metric system. Default value is 0.0624.

Number of slices - any even integer between 2 and 598, default value is 76.

A.1.4.1.1.2.2. GROUND LINE.

Selecting GROUND LINE will open Ground Line Data Entry Screen. Enter X- and Y- coordinates of the Ground Line. The program will automatically assign a number of points on the Ground Line based on the number of rows with nonblank X-coordinates. A row with blank X-coordinate and all the consecutive rows will be ignored. If the Y-coordinate of the first point is greater or equal than the Y-coordinate of the last point, then the program will treat the slope as right-oriented. Otherwise, it will treat the slope as left-oriented.

A.1.4.1.1.2.3. C PHI GAMA.

Selecting "C PHI GAMA" will open Soil Layers Properties Data Entry Screen. Each row in this screen represents a soil layer. Enter Cohesion, Friction angle, unit weight, and pore pressure factor for each layer. The program will automatically assign a number of layers based on the number of rows with nonblank cohesions. A row with blank cohesion and all the consecutive rows will be ignored.

Depending on the value of PORE PRESSURE FACTOR (RU) in the fourth column of the data entry screen, different options can be invoked:

1. RU < 1.
    Pore pressures in a given soil layer are defined using the pore-pressure ratio (RU).

2. RU = 1.5.
    Pore pressures in a given layer are defined by a piezometric line.

3. RU = 2.5.
    Pore pressures are defined by an infinitely sloping groundwater level. In this case RU = 2.5 is selected for layer 1; for all other layers RU = 0 should be specified.

4. RU = 3.5.
    Pore pressures are defined by assuming the ground water level within a slope is a piezometric line. In this case RU = 3.5 is selected for layer 1; for all other layers RU = 0 should be specified.

Options 1 and 2 can be intermixed.

To specify water layer use c=0, phi=0, gamma=0, Ru>2.

A.1.4.1.1.2.4. BOUNDARY LINES.

Selecting BOUNDARY LINES will open Boundary Lines Submenu. This submenu has as many items as the number of layers specified in Soil Layers Properties Data Entry Screen. Selecting an item will open a Boundary Line Data Entry Screen for the specified layer. Enter X- and Y- coordinates of the Boundary Layer Line. The program will automatically assign a number of points on the Boundary Layer Line based on the number of rows with nonblank X-coordinates. A row with blank X-coordinate and all the consecutive rows will be ignored. Notice that X-coordinates of the first and the last points on a Boundary Layer Line should coincide with X-coordinates of the first and the last points on the Ground Line.

A.1.4.1.1.2.5. WATER.

Selecting WATER will open Water Table Data Entry Screen or Piezometric Lines Submenu (depending on the Pore pressure factors specified in Soil Layers Properties Data Entry Screen). This submenu has as many items as the number of layers with Pore Pressure factors specified as 1.5. Selecting an item will open a Piezometric Line Data Entry Screen for the specified layer. Enter X- and Y-coordinates of the Water

Table or Piezometric Line. The program will automatically assign a number of points on the line based on the number of rows with nonblank X-coordinates. A row with blank X-coordinate and all the consecutive rows will be ignored. Notice that X-coordinates of the first and the last points on the Water Table or Piezometric Line should coincide with X-coordinates of the first and the last points on the Ground Line.

A.1.4.1.1.2.6. LINE OF THRUST.

If Thrust Line parameter in Problem Control Screen was specified "compute," then selecting LINE OF THRUST will open Thrust Line Data Entry Screen. Enter thrust line ratio between 0 and 1.

If Thrust Line parameter in Problem Control Screen was specified "by input," then selecting LINE OF THRUST will open Thrust Line Coordinates Data Entry Screen. Enter X- and Y- coordinates of the Thrust Line. The program will automatically assign a number of points on Thrust Line based on the number of rows with nonblank X-coordinates. A row with blank X-coordinate and all the consecutive rows will be ignored. Notice that X-coordinates of the first and the last points on Thrust Line should coincide with X-coordinates of the first and the last points on the Ground Line.

A.1.4.1.1.2.7. VERTICAL LOADS.

Selecting VERTICAL LOADS will open Vertical Loads Data Entry Screen. Enter X-coordinates and magnitudes of external vertical distributed loads diagram. Concentrated forces are not considered in this computer program. The program will automatically assign a number of points on the diagram based on the number of rows with nonblank X-coordinates. A row with blank X-coordinate and all the consecutive rows will be ignored.

A.1.4.1.1.2.8. END FORCES.

Selecting **END FORCES** will open End Boundary Forces Data Entry Screen. Enter magnitudes of horizontal and vertical forces acting on the left and right boundaries.

A.1.4.1.1.2.9. SEISMIC ANALYSIS.

Selecting SEISMIC ANALYSIS will open Earthquake Forces Data Entry Screen. Enter Seismic coefficient and seismic ratio.

A.1.4.1.1.2.10. FAILURE SURFACE(S).

If circular failure surface was specified in Problem Control Data Entry Screen, then selecting FAILURE SURFACE(S) will open Circular Search Analysis Data Entry Screen. Enter coordinates of search grid, increments, coordinates of starting point, radius for a given circle, and minimum height of slices.

Depending on the value of RADIUS FOR A GIVEN CIRCLE (RGC), page 2 of the data entry screen, two options can be invoked:

1. RGC = 0.
   Circular search analysis is performed. If you specified nonzero MINIMUM HEIGHT OF SLICES (MHS), then all circles with maximum height of slices less than MHS will be ignored.

2. RGC > 0.
   Only one circle is analyzed. Its radius = RGC, its center is at upper left corner of search grid. In this case, lower right corner coordinates of greed search should coincide with upper left corner coordinates; increments, coordinates of starting point, and minimum height of slices are ignored.

If noncircular failure surface was specified in Problem Control Data Entry Screen, then selecting FAILURE SURFACE(S) will open Failure Surface Coordinates Data Entry Screen. Enter X- and Y- coordinates of the Failure Surface. The program will automatically assign a number of points on the Failure Surface based on the number of rows with nonblank X-coordinates. A row with blank X-coordinate and all the consecutive rows will be ignored.

A.1.4.1.1.2.11. TENSION CRACK.

Selecting TENSION CRACK will open Tension Crack Data Entry Screen. Enter Tension Crack Depth and Portion of Tension Crack Depth Filled With Water.

A.1.4.1.1.2.12. REINFORCEMENT.

Selecting REINFORCEMENT will open Reinforcement Data Entry Screen. Each row in this screen represents a reinforcement layer. Enter Lengths, X-coordinates of end points, Elevations, Interaction Coefficients, and Reinforcement Allowable Tensile Strength. The program will automatically assign a number of reinforcement layers based on the number of rows with nonblank Lengths. A row with blank Length and all the consecutive rows will be ignored.

A.1.4.1.1.2.13. "=EXECUTE".

Selecting "=EXECUTE" will execute Slope Stability program. You will be prompted for an output file name. Enter a file name or press ESC for none. If you have entered valid data the program will execute. Otherwise, it will prompt you about an error. Correct the error and run the program again or press ESC to exit.

A.1.4.1.1.2.14. "X-Y VIEW".

Selecting "X-Y VIEW" will allow you to display and print out the cross-section, contour lines, and the critical failure surface.

A.1.4.1.1.2.15. OUTPUT FILE VIEW.

Selecting OUTPUT FILE VIEW will display output file on the screen.

A.1.4.1.2. TENSILE ELEMENTS DESIGN MENU.

Selecting TENSILE ELEMENTS DESIGN from Main Menu will open Design Menu. This menu consists of the following items: "SLOPE DESIGN", "WALL DESIGN", "UNITS", "HELP", "SLOPE FILE VIEW", and "WALL FILE VIEW". To navigate between the items use arrow keys; to make a selection press "Enter" or type the first character. The text line displayed to the right of the highlighted item gives a brief explanation of the item.

With some modifications, reinforced slope and retaining wall design methods follow guidelines developed by Tensar Corporation. These methods are limited to slopes and walls with simple geometry consisting of cohesionless soils only. If your case can not be treated as "simple," you may design your earth structure by iteratively using "STABILITY ANALYSIS."

A.1.4.1.2.1. SLOPE DESIGN.

Select this option to design reinforced slope. The program will prompt you for an input data file name. Type in a file name or press F1 to select it from a list of Slope files in the current directory. You could display up to 1,000 file names. All Slope files have extensions ".slo". You do not have to type in that extension, the program will automatically append this extension to the file name you entered. You could leave the file name blank. In this case no files will be read. Press ENTER to display Slope Data Entry Screen. For more information you may want to press F1 and/or F4. Press F2 to execute the Slope Design Program. If you have entered valid data, the program will execute. Otherwise, it will prompt you about an error. Correct the error and run the program again or press ESC to exit. After the program has executed you will be prompted for an output file name. Enter a file name or press ESC for none. The slope design method used in this program presumes the following requirements are satisfied:

1. The soil is reinforced with horizontal layers of geosynthetics.
2. The c=0 (cohesionless soils) only analysis is appropriate.
3. The soil has uniform strength properties throughout the entire slope.
4. The slope face is planar and the top of the slope is horizontal.
5. Positive drainage is provided to assure that pore water pressure in the slope is zero.
6. No seismic forces are acting.
7. The slope foundation is competent.
8. Surcharge loads, if any, act uniformly on the top of the slope.

If any of these requirements are not satisfied you may design the slope by iteratively using "STABILITY ANALYSIS."

You could also use "STABILITY ANALYSIS" to check your preliminary slope design. After you have completed Slope Design the program will automatically pass all the design features to "STABILITY ANALYSIS". All you have to do is select STABILITY ANALYSIS, SIMPLIFIED GEOMETRY. Variable initialization will be automatically done for you by the program. Hence, you could compute the actual factor of safety for the preliminary designed reinforced slope without having to input any extra data.

A.1.4.1.2.2. WALL DESIGN.

Select this option to design reinforced retaining walls. The program will prompt you for an input data file name. Type in a file name or press F1 to select it from a list of Slope files in the current directory. You could display up to 1,000 file names. All Wall files have extensions ".wal". You do not have to type in that extension, the program will automatically append this extension to the file name you entered. You could leave the file name blank. In this case no files will be read. Press ENTER to display Wall Data Entry Screen. For more information you may want to press F1 and/or F4. Press F2 to execute the Wall Design Program. If you have entered valid data, the program will execute. Otherwise, it will prompt you about an error. Correct the error and run the program again or press ESC to exit. After the program has executed, you will be prompted for an output file name. Enter a file name or press ESC for none. The wall design method used in this program presumes the following requirements are satisfied:

1. The soil is reinforced with horizontal layers of geosynthetics.
2. Both the reinforced and retained fills are constructed with cohesionless soils and a c=0 only analysis is appropriate.
3. A maximum wall friction angle of 34 degrees is used for design.
4. Uniform soil properties exist within each distinct zone (wall fill, retained back fill, and foundation).
5. The wall face is at a vertical to 10 degrees batter angle.
6. Positive drainage is provided to assure that pore water pressure within and on the reinforced wall is zero.
7. No seismic forces are acting upon the structure.
8. Surcharge loads, if any, act uniformly on the top of the wall.

If any of these requirements are not satisfied, you may design the wall by iteratively using "STABILITY ANALYSIS."

A.1.4.1.2.3. "UNITS."

Use this option to select ENGLISH or METRIC system of units.

A.1.4.1.2.4. "SLOPE FILE VIEW."

Selecting this option will display output file for slope design.

A.1.4.1.2.5. "WALL FILE VIEW."

Selecting this option will display output file for wall design.

APPENDIX 2. INPUT DATA FILES FOR THE EXAMPLES.

A.2.1. Example 1

```
051695EXAMPLE 1: HOMOGENEOUS SLOPE
NO
MODIFIED PERTURBATION
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   20    0
      .000    90.000
    20.000    90.000
    40.000    90.000
   220.000    30.000
   240.000    30.000
9999999999
      .000    30.000      .130      .000
9999999999
      .000    10.000
   240.000    10.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
   160.000   194.000   160.000   194.000     5.000     5.000
5.000
   220.000    30.000   175.000      .000
      .000      .000
```

A.2.2. EXAMPLE 2.

```
112095WHITMAN AND BAILEY EXAMPLE
NO
MODIFIED PERTURBATION
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   15   10
      .000   300.000
   200.000   300.000
   400.000   200.000
   500.000   150.000
  2000.000   150.000
```

```
9999999999
      .000        .000        .062      3.500
     1.500      20.000        .126       .000
     1.000      33.000        .130       .000
9999999999
      .000     300.000
   200.000     300.000
   400.000     200.000
   500.000     150.000
   600.000     100.000
  2000.000     100.000
9999999999
      .000     200.000
   400.000     200.000
   500.000     150.000
   600.000     100.000
  2000.000     100.000
9999999999
      .000      50.000
  2000.000      50.000
9999999999
      .000     250.000
   300.000     200.000
   500.000     150.000
  2000.000     150.000
9999999999
      .333
9999999999
      .000        .000        .000       .000
      .000        .000
    536.000     600.000     536.000     600.000       5.000      5.000
5.000
   136.000     300.000    500.000        .000
      .000        .000
```

A.2.3. EXAMPLE 3

```
051695EXAMPLE 3: (AFTER JANBU)
NO
MODIFIED PERTURBATION
COMPUTE
NONCIRCULAR
FULL
N/A
    1.0000     76    20     0
    17.000      50.500
    19.500      50.500
    20.500      50.500
    21.000      50.500
```

```
    90.000    10.000
   110.000    10.000
9999999999
      .000    45.000     2.100      .000
      .000    38.620     2.100      .150
     2.000    30.920     2.100      .350
      .000    40.400     2.100      .000
9999999999
    17.000    50.500
    19.500    50.500
    20.500    50.500
    58.200    10.000
   110.000    10.000
9999999999
    17.000    50.500
    19.500    50.500
    50.400    10.000
   110.000    10.000
9999999999
    17.000    50.500
    20.000    10.000
   110.000    10.000
9999999999
    17.000     5.000
   110.000     5.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
    19.500    46.900
    28.000    35.200
    41.000    22.400
    52.500    16.400
    66.000    12.600
    78.600    10.000
    90.000    10.000
9999999999
     3.600     1.000
```

A.2.4. EXAMPLE 5

```
112095SLOPING CORE DAM - AFTER WRIGHT - EX. 5
NO
MODIFIED PERTURBATION
COMPUTE
NONCIRCULAR
FULL
```

```
N/A
     .0624   76    15    10
      .000  180.000
    40.000  180.000
   388.750   25.000
   500.000   25.000
9999999999
      .000   38.000       .133       .000
     1.000   11.000       .133       .000
     1.000   11.000       .133       .000
9999999999
      .000  174.200
    24.820  174.200
    40.000  174.200
   273.750   25.000
   500.000   25.000
9999999999
      .000  174.200
    24.820  174.200
   223.750   25.000
   500.000   25.000
9999999999
      .000   25.000
   500.000   25.000
9999999999
      .333
9999999999
      .000     .000       .000       .000
      .000     .000
    40.000  180.000
   158.130   54.100
   191.500   51.500
   201.000   45.000
   222.500   37.500
   234.500   34.500
   249.000   32.000
   266.000   28.500
   306.500   25.100
   388.750   25.000
9999999999
      .000     .000
```

A.2.5. EXAMPLE 6

```
112095EXAMPLE 6; MULTILAYERED SLOPE: PECK
NO
MODIFIED PERTURBATION
COMPUTE
```

```
CIRCULAR
FULL
N/A
     .0624   76   15   10
      .000    30.000
    50.000    30.000
    88.500    15.000
   100.000    10.000
   150.000    10.000
9999999999
      .000    35.000      .120      .000
      .200    18.000      .115      .000
      .400      .000      .115      .000
9999999999
      .000    15.000
    62.500    15.000
   100.000    10.000
   150.000    10.000
9999999999
      .000     5.000
   150.000     5.000
9999999999
      .000      .000
   150.000      .000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
    75.000    50.000    75.000    50.000      .000      .000
.000
      .000      .000    50.000      .000
      .000      .000
```

A.2.6. EXAMPLE 7

```
051595ICES LEASE EXAMPLE (EFFECTIVE STRESS ANALYSIS)
NO
BISHOP'S
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   20    0
      .000   120.000
   110.000   120.000
   134.000   108.000
   145.000   108.000
```

```
   146.000   106.000
   186.000   106.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    30.000      .110     1.500
      .000    30.000      .127     1.500
      .000    30.000      .101      .650
      .000    30.000      .101      .620
      .000    30.000      .101      .800
      .000    30.000      .101      .800
      .000    30.000      .101      .850
      .250      .000      .101      .700
      .000    30.000      .101      .700
      .000    30.000      .101      .000
9999999999
      .000   106.000
   186.000   106.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    96.000
   145.000    96.000
   186.000    93.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    91.000
   120.000    91.000
   120.000    96.000
   145.000    96.000
   186.000    93.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    91.000
   120.000    91.000
   186.000    88.000
   258.000    92.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    75.000
   120.000    75.000
   120.000    91.000
   186.000    88.000
   258.000    92.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    75.000
```

```
   120.000    75.000
   186.000    75.000
   186.000    88.000
   258.000    92.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    75.000
   120.000    75.000
   186.000    75.000
   258.000    75.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    70.000
   120.000    70.000
   120.000    75.000
   186.000    75.000
   258.000    75.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    70.000
   120.000    70.000
   186.000    70.000
   258.000    70.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    70.000
   310.000    70.000
9999999999
      .000   104.000
   190.000   104.000
   258.000    96.000
   310.000    96.000
9999999999
      .000   104.000
   190.000   104.000
   258.000    96.000
   310.000    96.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
    110.000   290.000    210.000   190.000      5.000      5.000
4.000
   186.000    88.000      .000     5.000
      .000      .000
```

A.2.7. EXAMPLE 7b

```
051595ICES LEASE EXAMPLE (TOTAL STRESS ANALYSIS)
NO
BISHOP'S
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   20     0
      .000  120.000
   110.000  120.000
   134.000  108.000
   145.000  108.000
   146.000  106.000
   186.000  106.000
   258.000   97.500
   310.000   97.500
9999999999
      .000   30.000       .110      1.500
      .000   30.000       .127      1.500
      .500     .000       .101       .000
      .360     .000       .101       .000
      .300     .000       .101       .000
      .280     .000       .101       .000
      .200     .000       .101       .000
      .650     .000       .101       .000
      .450     .000       .101       .000
      .250     .000       .101       .000
9999999999
      .000  106.000
   186.000  106.000
   258.000   97.500
   310.000   97.500
9999999999
      .000   96.000
   145.000   96.000
   186.000   93.000
   258.000   97.500
   310.000   97.500
9999999999
      .000   91.000
   120.000   91.000
   120.000   96.000
   145.000   96.000
   186.000   93.000
   258.000   97.500
   310.000   97.500
9999999999
```

```
      .000    91.000
   120.000    91.000
   186.000    88.000
   258.000    92.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    75.000
   120.000    75.000
   120.000    91.000
   186.000    88.000
   258.000    92.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    75.000
   120.000    75.000
   186.000    75.000
   186.000    88.000
   258.000    92.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    75.000
   120.000    75.000
   186.000    75.000
   258.000    75.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    70.000
   120.000    70.000
   120.000    75.000
   186.000    75.000
   258.000    75.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    70.000
   120.000    70.000
   186.000    70.000
   258.000    70.000
   258.000    97.500
   310.000    97.500
9999999999
      .000    70.000
   310.000    70.000
9999999999
      .000   104.000
   190.000   104.000
   258.000    96.000
```

```
   310.000    96.000
9999999999
      .000   104.000
   190.000   104.000
   258.000    96.000
   310.000    96.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
    110.000   290.000   210.000   190.000     5.000     5.000
4.000
   186.000    88.000      .000     5.000
      .000      .000
```

A.2.8. EXAMPLE 8

```
 51595WRIGHT EX.SL.1 P-197; EXAMPLE 8.
NO
MODIFIED PERTURBATION
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   20    0
      .000   100.000
   200.000   200.000
   250.000   200.000
   450.000   100.000
   500.000   100.000
9999999999
      .000    40.000      .140      .000
     2.500      .000      .125      .000
9999999999
      .000   100.000
   500.000   100.000
9999999999
      .000    50.000
   500.000    50.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
    349.000   204.000   349.000   204.000     5.000     5.000
5.000
      .000      .000   153.999      .000
      .000      .000
```

A.2.9. EXAMPLE 9

```
112095SIDE-HILL HIGHWAY EMBANKMENT SLOPE (AFTER HARDIN)
NO
BISHOP'S
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   15   10
      .000   985.000
    11.000   983.000
    30.000   996.000
    71.000   996.000
   136.500   949.000
   147.000   948.000
   150.000   947.000
   157.000   942.000
   187.500   942.000
   195.500   947.000
9999999999
      .000      .000      .062      3.500
      .200    34.000      .130       .000
      .000    38.000      .125       .000
      .100    31.000      .122       .000
9999999999
      .000   985.000
    11.000   983.000
    30.000   996.000
    71.000   996.000
   136.500   949.000
   147.000   948.000
   150.000   947.000
   157.000   942.000
   163.000   938.500
   174.500   935.500
   183.500   938.500
   187.500   942.000
   195.500   947.000
9999999999
      .000   985.000
    11.000   983.000
    20.000   978.000
    29.500   977.000
    40.000   975.000
    50.000   973.500
    60.000   972.500
    75.000   967.500
    91.000   965.000
```

```
   101.000   961.000
   111.000   957.000
   126.000   952.000
   136.500   949.000
   147.000   948.000
   150.000   947.000
   157.000   942.000
   163.000   938.500
   174.500   935.500
   183.500   938.500
   187.500   942.000
   195.500   947.000
9999999999
      .000   974.000
    75.000   967.500
    91.000   965.000
   101.000   961.000
   111.000   957.000
   126.000   952.000
   136.500   949.000
   147.000   948.000
   150.000   947.000
   157.000   942.000
   163.000   938.500
   174.500   935.500
   183.500   938.500
   187.500   942.000
   195.500   947.000
9999999999
      .000   880.000
   195.500   880.000
9999999999
      .000   966.500
    67.500   960.000
   103.000   955.000
   124.000   951.000
   146.000   945.500
   157.000   942.000
   187.500   942.000
   195.500   942.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
   110.000  1050.000   110.000  1050.000     5.000     5.000
5.000
      .000      .000   120.000      .000
      .000      .000
```

A.2.10. EXAMPLE 10

```
112095LONG TERM STABILITY-CUT (FROM STABL USERS GUIDE)
NO
MODIFIED PERTURBATION
COMPUTE
NONCIRCULAR
FULL
N/A
     .0624   76   15   10
      .000   110.000
    67.000   103.000
   104.000    88.000
   142.000    73.000
   167.000    63.000
   183.000    67.000
   205.000    68.000
9999999999
      .000      .500       .116      3.500
      .500    14.000       .116       .000
      .500    14.000       .124       .000
9999999999
      .000    99.000
   104.000    88.000
   142.000    73.000
   167.000    63.000
   183.000    67.000
   205.000    68.000
9999999999
      .000    93.000
    65.000    87.000
    83.000    85.000
   101.000    82.000
   122.000    78.000
   142.000    73.000
   167.000    63.000
   183.000    67.000
   205.000    68.000
9999999999
      .000    76.000
    44.000    58.000
    72.000    56.000
    92.000    64.000
   111.000    65.000
   127.000    56.000
   154.000    26.000
   176.000    24.000
   205.000    15.000
9999999999
      .000    93.000
```

```
    65.000    87.000
    83.000    85.000
   101.000    82.000
   127.000    78.000
   142.000    73.000
   167.000    63.000
   183.000    67.000
   205.000    68.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
    65.000   103.000
    69.230    96.960
    75.890    89.240
    82.740    82.260
    90.620    76.100
    99.120    70.840
   108.150    66.550
   117.600    63.270
   127.250    61.040
   137.280    59.890
   147.280    59.840
   157.230    60.880
   167.000    63.000
9999999999
      .000      .000
```

A.2.11. EXAMPLE 12

```
112095FRANKFORT PROBLEM:  EXAMPLE 12.
NO
MODIFIED PERTURBATION
COMPUTE
NONCIRCULAR
FULL
N/A
     .0624   76   15   10
      .000   638.000
    75.000   636.500
    93.000   636.000
   100.000   634.000
   110.000   630.000
   136.000   621.000
   155.000   606.000
   180.000   592.500
   190.000   587.500
   200.000   581.000
```

```
   202.000   580.000
   210.000   573.500
   224.000   560.000
   258.000   560.000
9999999999
      .000    23.800      .125     3.500
9999999999
      .000   591.000
    94.000   590.000
   240.000   540.000
   258.000   540.000
9999999999
      .000   621.000
    74.500   612.500
    94.000   610.000
   100.000   607.000
   110.000   603.000
   136.000   591.000
   179.000   571.000
   200.000   562.000
   202.000   561.000
   210.500   557.500
   214.000   556.000
   225.000   551.000
   258.000   544.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
    59.500   636.800
    74.500   612.500
    94.000   593.000
   100.000   589.500
   110.000   585.500
   136.000   576.800
   155.500   570.500
   180.000   562.000
   190.000   558.500
   200.000   554.500
   212.500   550.500
   214.000   550.000
   225.500   557.500
   229.000   560.000
9999999999
      .000      .000
```

A.2.12. EXAMPLE 13

```
071795HOLLOW COAL WASTE DISPOSAL FILL
```

```
NO
HOPKINS'
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   20     0
      .000   653.000
    62.000   642.000
   376.000   640.000
   516.000   589.000
   536.000   589.000
   676.000   539.000
   696.000   539.000
   836.000   489.000
   856.000   489.000
   996.000   439.000
  1016.000   439.000
  1154.000   389.000
  1221.000   386.000
  1576.000   245.000
  1800.000   245.000
9999999999
      .409    30.300     .105      .000
      .000    32.000     .106      .000
9999999999
      .000   653.000
    62.000   642.000
   236.000   588.000
   446.000   491.000
   646.000   394.000
   676.000   389.000
  1154.000   389.000
  1221.000   386.000
  1576.000   245.000
  1800.000   245.000
9999999999
      .000   653.000
    62.000   642.000
   236.000   588.000
   446.000   491.000
   646.000   394.000
   676.000   389.000
   963.000   326.000
  1172.000   310.000
  1296.000   293.000
  1396.000   271.000
  1576.000   227.000
  1800.000   227.000
9999999999
      .333
```

```
9999999999
      .000       .000       .000       .000
      .100       .500
  1400.000   2050.000   1400.000   2050.000      40.000      40.000
20.000
  1000.000    400.000   1753.000       .000
      .000       .000
```

A.2.13. EXAMPLE 14

```
112095EX. 1A;LAMBE/WHIT.,P.359 F.S.=1.31(BISHOP-75SLICES
NO
MODIFIED PERTURBATION
COMPUTE
CIRCULAR
FULL
N/A
     .0624    76   15   10
      .000    520.000
   112.000    520.000
   142.500    500.000
   200.000    500.000
9999999999
      .090     32.000       .125      3.500
9999999999
      .000    495.000
   200.000    495.000
9999999999
      .000    515.000
   107.500    514.000
   112.500    512.700
   115.000    511.750
   117.500    510.750
   120.000    510.000
   122.000    509.000
   123.750    508.000
   125.750    507.000
   127.000    505.750
   128.500    504.500
   130.000    503.250
   131.250    501.250
   132.750    500.500
   133.000    500.000
   200.000    500.000
9999999999
      .333
9999999999
      .000       .000       .000       .000
      .000       .000
```

```
   137.000   530.000   137.000   530.000      .000      .000
.000
      .000      .000    30.000      .000
      .000      .000
```

A.2.14. EXAMPLE 15

```
112095MILL CREEK DAM-CIRCULAR ANALYSIS
NO
BISHOP'S
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   15   10
      .000   610.500
   648.000   610.500
   658.500   615.500
   668.000   620.500
   683.000   621.000
   700.000   619.500
   722.000   616.000
   800.000   578.000
   950.000   559.000
  1100.000   559.000
9999999999
      .000      .000      .062     3.500
      .573    28.000      .135      .000
      .271    30.600      .135      .000
      .305    25.900      .132      .000
      .000    33.800      .131      .000
9999999999
      .000   558.000
   544.000   558.000
   648.000   610.500
   658.500   615.500
   668.000   620.500
   683.000   621.000
   700.000   619.500
   722.000   616.000
   800.000   578.000
   950.000   559.000
  1100.000   559.000
9999999999
      .000   558.000
   544.000   558.000
   648.000   610.500
   658.500   615.500
```

```
    668.000    620.500
    683.000    621.000
    700.000    619.500
    722.000    616.000
    800.000    578.000
    835.000    560.000
    950.000    559.000
   1100.000    559.000
9999999999
       .000    558.000
    544.000    558.000
    612.000    558.000
    690.000    610.000
    710.000    610.000
    751.000    558.000
    790.000    560.000
    835.000    560.000
    950.000    559.000
   1100.000    559.000
9999999999
       .000    558.000
    544.000    558.000
    612.000    558.000
    615.000    558.000
    623.000    555.000
    640.000    554.000
    651.000    559.000
    687.000    559.000
    690.000    547.000
    694.000    547.000
    694.000    544.000
    706.000    544.000
    710.000    547.000
    712.000    559.000
    751.000    558.000
    790.000    560.000
    835.000    560.000
    950.000    559.000
   1100.000    559.000
9999999999
       .000    548.000
    548.000    548.000
    690.000    547.000
    694.000    547.000
    694.000    544.000
    706.000    544.000
    710.000    547.000
    950.000    547.000
   1100.000    547.000
9999999999
       .000    610.500
```

```
   648.000   610.500
   652.000   606.000
   656.000   602.000
   664.000   598.000
   680.000   593.000
   700.000   589.000
   807.000   577.000
   843.000   572.000
   871.000   569.000
   950.000   559.000
  1100.000   559.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
   810.000   705.000   810.000   705.000      .000      .000
.000
      .000      .000   152.393      .000
      .000      .000
```

A.2.15. EXAMPLE 15 (WEDGE)

```
112095MILL CREEK DAM-WEDGE ANALYSIS
NO
MODIFIED PERTURBATION
COMPUTE
NONCIRCULAR
FULL
N/A
     .0624   76   15   10
      .000   610.500
   648.000   610.500
   658.500   615.500
   668.000   620.500
   683.000   621.000
   700.000   619.500
   722.000   616.000
   800.000   578.000
   950.000   559.000
  1100.000   559.000
9999999999
      .000      .000      .062     3.500
      .573    28.000      .135      .000
      .271    30.600      .135      .000
      .305    25.900      .132      .000
      .000    33.800      .131      .000
```

```
9999999999
      .000   558.000
   544.000   558.000
   648.000   610.500
   658.500   615.500
   668.000   620.500
   683.000   621.000
   700.000   619.500
   722.000   616.000
   800.000   578.000
   950.000   559.000
  1100.000   559.000
9999999999
      .000   558.000
   544.000   558.000
   648.000   610.500
   658.500   615.500
   668.000   620.500
   683.000   621.000
   700.000   619.500
   722.000   616.000
   800.000   578.000
   835.000   560.000
   950.000   559.000
  1100.000   559.000
9999999999
      .000   558.000
   544.000   558.000
   612.000   558.000
   690.000   610.000
   710.000   610.000
   751.000   558.000
   790.000   560.000
   835.000   560.000
   950.000   559.000
  1100.000   559.000
9999999999
      .000   558.000
   544.000   558.000
   612.000   558.000
   615.000   558.000
   623.000   555.000
   640.000   554.000
   651.000   559.000
   687.000   559.000
   690.000   547.000
   694.000   547.000
   694.000   544.000
   706.000   544.000
   710.000   547.000
   712.000   559.000
```

```
   751.000   558.000
   790.000   560.000
   835.000   560.000
   950.000   559.000
  1100.000   559.000
9999999999
      .000   548.000
   548.000   548.000
   690.000   547.000
   694.000   547.000
   694.000   544.000
   706.000   544.000
   710.000   547.000
   950.000   547.000
  1100.000   547.000
9999999999
      .000   610.500
   648.000   610.500
   652.000   606.000
   656.000   602.000
   664.000   598.000
   680.000   593.000
   700.000   589.000
   807.000   577.000
   843.000   572.000
   871.000   569.000
   950.000   559.000
  1100.000   559.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
   700.000   619.500
   751.000   558.000
   860.000   558.000
   874.000   568.000
9999999999
      .000      .000
```

A.2.16. EXAMPLE 16

```
112095MILL CREEK DAM- UPSTREAM SLOPE
NO
MODIFIED PERTURBATION
COMPUTE
CIRCULAR
FULL
```

```
N/A
     .0624   76   15   10
      .000   559.000
   150.000   578.000
   228.000   616.000
   250.000   619.500
   267.000   621.000
   282.000   620.500
   302.000   610.500
   382.230   570.000
   980.000   570.000
   980.000      .000
9999999999
      .000      .000      .062     3.500
      .573    28.000      .135      .000
      .271    30.600      .135      .000
      .305    25.900      .132      .000
      .000    33.800      .131      .000
9999999999
      .000   559.000
   150.000   578.000
   228.000   616.000
   250.000   619.500
   267.000   621.000
   282.000   620.500
   302.000   610.500
   382.230   570.000
   406.000   558.000
   980.000   558.000
9999999999
      .000   559.000
   115.000   560.000
   150.000   578.000
   228.000   616.000
   250.000   619.500
   267.000   621.000
   282.000   620.500
   302.000   610.500
   382.230   570.000
   406.000   558.000
   980.000   558.000
9999999999
      .000   559.000
   115.000   560.000
   199.000   558.000
   240.000   610.000
   260.000   610.000
   338.000   558.000
   406.000   558.000
   980.000   558.000
9999999999
```

```
      .000   559.000
   115.000   560.000
   119.000   558.000
   238.000   558.000
   240.000   547.000
   244.000   547.000
   244.000   544.000
   256.000   544.000
   256.000   547.000
   260.000   547.000
   263.000   559.000
   299.000   559.000
   310.000   554.000
   327.000   555.000
   335.000   558.000
   338.000   558.000
   406.000   558.000
   980.000   558.000
9999999999
      .000   547.000
   240.000   547.000
   244.000   547.000
   244.000   544.000
   256.000   544.000
   256.000   547.000
   260.000   547.000
   406.000   548.000
   980.000   548.000
9999999999
      .000   559.000
   150.000   578.000
   251.000   589.000
   272.000   594.000
   286.000   598.000
   292.000   601.000
   298.000   606.000
   302.000   610.500
   382.230   570.000
   980.000   570.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
    360.000   780.000   420.000   700.000    20.000    20.000
5.000
   332.000   580.000      .000      .000
      .000      .000
```

A.2.17. EXAMPLE 17

```
112095CHIRAPUNTA/DUNCAN: FIG. 34
NO
BISHOP'S
COMPUTE
CIRCULAR
FULL
N/A
     .0624   76   15    10
      .000    68.100
    80.000    68.100
   100.000    68.100
   135.640    50.000
   500.000    50.000
9999999999
     2.000    15.000       .126       .000
      .250      .000       .095       .000
      .300      .000       .095       .000
      .350      .000       .095       .000
      .400      .000       .095       .000
      .450      .000       .095       .000
      .500      .000       .095       .000
      .550      .000       .095       .000
      .600      .000       .095       .000
9999999999
      .000    50.000
   500.000    50.000
9999999999
      .000    45.000
   500.000    45.000
9999999999
      .000    40.000
   500.000    40.000
9999999999
      .000    35.000
   500.000    35.000
9999999999
      .000    30.000
   500.000    30.000
9999999999
      .000    25.000
   500.000    25.000
9999999999
      .000    20.000
   500.000    20.000
9999999999
      .000    15.000
   500.000    15.000
```

```
9999999999
      .000     10.000
   500.000     10.000
9999999999
      .333
9999999999
      .000       .000       .000       .000
      .000       .000
   117.800     70.000    117.800     70.000      5.000      5.000
4.000
      .000       .000     35.000       .000
      .000       .000
```

A.2.18. EXAMPLE 17 (WITH TENSION CRACK)

```
112095CHIRAPUNTA/DUNCAN: FIG. 34, TENSION CRACK
NO
BISHOP'S
COMPUTE
CIRCULAR
FULL
N/A
     .0624    76   15    10
      .000     68.100
    80.000     68.100
   100.000     68.100
   135.640     50.000
   500.000     50.000
9999999999
     2.000     15.000       .126       .000
      .250       .000       .095       .000
      .300       .000       .095       .000
      .350       .000       .095       .000
      .400       .000       .095       .000
      .450       .000       .095       .000
      .500       .000       .095       .000
      .550       .000       .095       .000
      .600       .000       .095       .000
9999999999
      .000     50.000
   500.000     50.000
9999999999
      .000     45.000
   500.000     45.000
9999999999
      .000     40.000
   500.000     40.000
```

```
9999999999
      .000    35.000
   500.000    35.000
9999999999
      .000    30.000
   500.000    30.000
9999999999
      .000    25.000
   500.000    25.000
9999999999
      .000    20.000
   500.000    20.000
9999999999
      .000    15.000
   500.000    15.000
9999999999
      .000    10.000
   500.000    10.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
   117.800    70.000   117.800    70.000     5.000     5.000
4.000
      .000      .000    35.000      .000
    18.100      .000
```

A.2.19. BILLIARD AND WU EXAMPLE

```
      WU EXAMPLE (GEOS.'91,P.537-548)
YES
BISHOP'S
COMPUTE
CIRCULAR

FIXED REINFORCEMENT END
     .0624    76
    80.000     5.200
   106.800     5.200
   106.800     -.100
   110.000     -.100
9999999999
      .000    39.000      .095      .000
9999999999
    80.000     -.100
   110.000     -.100
```

```
9999999999
      .333
   100.000     2.660
   106.800     2.660
9999999999
      .000      .000      .000      .000
      .000      .000
   107.000   206.000   307.000     6.000    10.000    10.000
5.000
   106.800     -.050      .000      .200
      .000      .000
     6.800   106.800     5.190      .900      .900      .420
     4.800   106.800     4.000      .900      .900      .420
     1.500   106.800     3.830      .900      .900      .420
     4.300   106.800     2.900      .900      .900      .420
     1.500   106.800     2.730      .900      .900      .420
     3.800   106.800     1.800      .900      .900      .420
     1.500   106.800     1.630      .900      .900      .420
     3.400   106.800      .850      .900      .900      .420
     1.500   106.800      .700      .900      .900      .420
     3.000   106.800      .000      .900      .900      .420
9999999999
```

A.2.20. WRIGHT AND DUNCAN EXAMPLE

```
112095WRIGHT AND DUNCAN, TRR 1330, EXAMPLE 2, SECOND ITER
YES
BISHOP'S
COMPUTE
CIRCULAR
FULL
FREE REINFORCEMENT END
     .0624   76   15   10
   150.000    10.000
   200.000    10.000
   220.000      .000
   250.000      .000
9999999999
      .000    35.000      .105      .000
      .200      .000      .100      .000
9999999999
   150.000      .000
   250.000      .000
9999999999
   150.000   -10.000
   250.000   -10.000
9999999999
```

```
      .333
9999999999
      .000       .000        .000       .000
      .000       .000
   200.000     30.000    220.000     10.000      1.000      1.000
5.000
   200.000     10.000       .000      5.000
      .000       .000
    70.000    220.000       .000       .900       .900      3.000
9999999999
```

A.2.21. HADJ-HAMOE EXAMPLE (CIRCULAR)

```
07 495HADJ-HAMOE EXAMPLE,TRR,1277,1990,80-89,CIRCULAR
YES
BISHOP'S
COMPUTE
CIRCULAR
FULL
FREE REINFORCEMENT END
     .0624    76   15    5
   100.000       .000
   132.000       .000
   138.000      2.000
   167.000      3.000
   195.000     10.000
   205.000     10.000
   233.000      3.000
   259.000      3.000
   268.000       .000
   350.000       .000
9999999999
      .200       .000       .100       .000
      .400       .000       .105       .000
      .000     30.000       .120       .000
      .150       .000       .074       .000
      .150       .000       .095       .000
      .200       .000       .098       .000
      .275       .000       .098       .000
      .400       .000       .098       .000
9999999999
   100.000       .000
   155.000       .000
   167.000      3.000
   195.000     10.000
   205.000     10.000
```

```
   233.000     3.000
   245.000      .000
   350.000      .000
9999999999
   100.000      .000
   168.000      .000
   181.600     3.000
   214.400     3.000
   234.000      .000
   350.000      .000
9999999999
   100.000      .000
   350.000      .000
9999999999
   100.000   -15.000
   350.000   -15.000
9999999999
   100.000   -20.000
   350.000   -20.000
9999999999
   100.000   -30.000
   350.000   -30.000
9999999999
   100.000   -40.000
   350.000   -40.000
9999999999
   100.000   -55.000
   350.000   -55.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
   195.000   210.000   350.000    10.000    10.000    10.000
5.000
   195.000    10.000      .000     1.000
      .000      .000
    32.800   214.400     3.000     1.000     1.000     2.350
    49.200   224.200     1.500     1.000     1.000     2.350
9999999999
```

A.2.22. HADJ-HAMOE EXAMPLE (NONCIRCULAR)

```
07 495HADJ-HAMOE EXAMPLE,TRR,1277,1990,80-89,NONCIRCULAR
YES
MODIFIED PERTURBATION
```

```
COMPUTE
NONCIRCULAR
FULL
FREE REINFORCEMENT END
     .0624   76   15    5
   100.000       .000
   132.000       .000
   138.000      2.000
   167.000      3.000
   195.000     10.000
   205.000     10.000
   233.000      3.000
   259.000      3.000
   268.000       .000
   350.000       .000
9999999999
      .200       .000       .100       .000
      .400       .000       .105       .000
      .000     30.000       .120       .000
      .150       .000       .074       .000
      .150       .000       .095       .000
      .200       .000       .098       .000
      .275       .000       .098       .000
      .400       .000       .098       .000
9999999999
   100.000       .000
   155.000       .000
   167.000      3.000
   195.000     10.000
   205.000     10.000
   233.000      3.000
   245.000       .000
   350.000       .000
9999999999
   100.000       .000
   168.000       .000
   181.600      3.000
   214.400      3.000
   234.000       .000
   350.000       .000
9999999999
   100.000       .000
   350.000       .000
9999999999
   100.000    -15.000
   350.000    -15.000
9999999999
   100.000    -20.000
   350.000    -20.000
9999999999
   100.000    -30.000
```

```
   350.000   -30.000
9999999999
   100.000   -40.000
   350.000   -40.000
9999999999
   100.000   -55.000
   350.000   -55.000
9999999999
      .333
9999999999
      .000      .000      .000      .000
      .000      .000
   187.000     7.990
   212.000   -20.000
   260.000   -20.000
   280.000      .000
9999999999
      .000      .000
    32.800   214.400     3.000     1.000     1.000     2.350
    49.200   224.200     1.500     1.000     1.000     2.350
9999999999
```

A.2.23. 45-DEGREES REINFORCED SLOPE

```
12 89545.0 degrees slope
YES
BISHOP'S
COMPUTE
CIRCULAR
FULL
FIXED REINFORCEMENT END
   62.4000   76   15   10
  -152.000    38.000
   -38.000    38.000
      .000      .000
    76.000      .000
9999999999
      .000    32.000   125.000      .000
9999999999
  -152.000      .000
    76.000      .000
9999999999
      .333
  -152.000   240.000
   -38.000   240.000
9999999999
```

```
       .000       .000       .000       .000
       .000       .000
   -19.000    114.000     57.000     38.000      7.600      7.600
9.500
   -19.000     19.000       .000       .000
       .000       .000
    29.039      -.667       .667       .900       .900   1000.000
    29.039     -2.000      2.000       .900       .900   1000.000
    29.039     -3.333      3.333       .900       .900   1000.000
    29.039     -4.667      4.667       .900       .900   1000.000
    29.039     -6.000      6.000       .900       .900   1000.000
    29.039     -7.333      7.333       .900       .900   1000.000
    29.039     -8.667      8.667       .900       .900   1000.000
    29.039    -10.000     10.000       .900       .900   1000.000
    29.039    -11.333     11.333       .900       .900   1000.000
    29.039    -12.667     12.667       .900       .900   1000.000
    26.348    -14.000     14.000       .900       .900   1000.000
    26.348    -16.667     16.667       .900       .900   1000.000
    26.348    -19.333     19.333       .900       .900   1000.000
    26.348    -22.000     22.000       .900       .900   1000.000
    26.348    -24.667     24.667       .900       .900   1000.000
    23.656    -28.667     28.667       .900       .900   1000.000
    23.656    -34.000     34.000       .900       .900   1000.000
9999999999
```