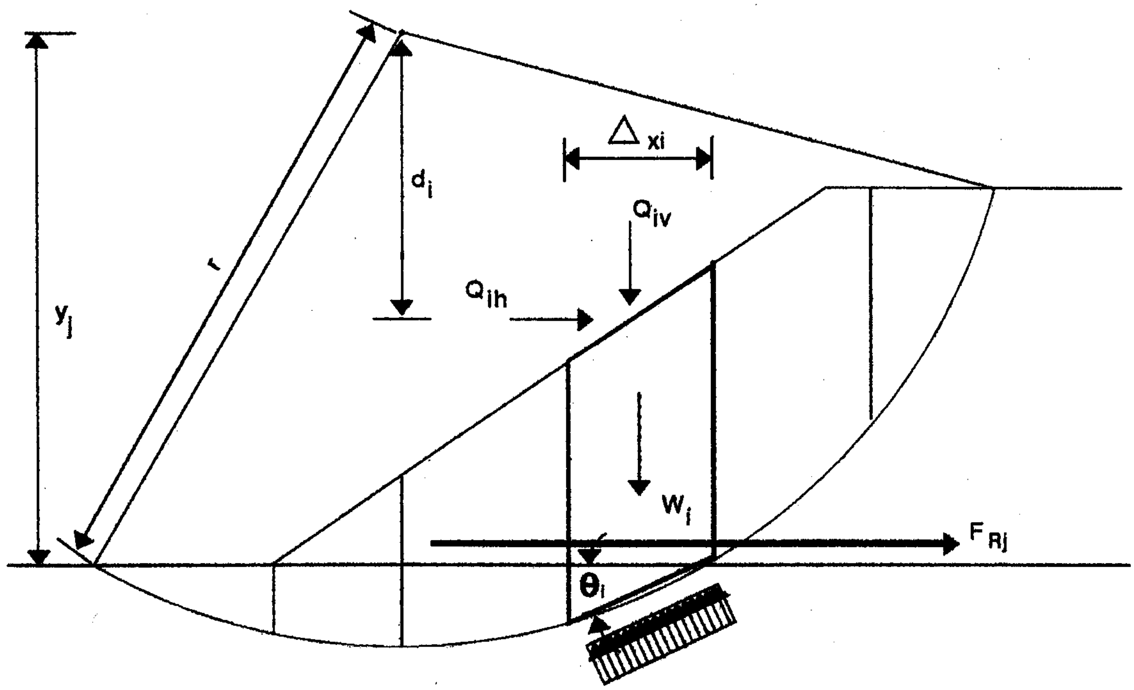
Commonwealth of Pennsylvania
Pennsylvania Department of Transportation

Bureau of Construction and Materials
Division of Materials and Testing

PASTABLM User's Guide

Slope Stability Analysis Program



Publication 318 **September 1996**

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I. INTRODUCTION

PASTABLM is a program written in FORTRAN and calculates the factor of safety against slope failure using a two-dimensional limiting equilibrium method. The calculation of the factor of safety against slope instability is performed using either the Simplified Bishop method of slices, which is applicable to circular shaped failure surfaces, the Simplified Janbu method of slices, which is applicable to failure surfaces of a general shape, or Spencer method of slices which is applicable to surfaces having a circular or general shape.

PASTABLM features unique random generation of potential failure surfaces for subsequent determination of the more critical failure surfaces and their corresponding factors of safety. Circular, irregular and sliding block surfaces may be generated and analyzed using either a random search technique or specific input of the coordinates of a given potential failure surface.

The program is capable of handling heterogeneous soil profiles, anisotropic soil strength parameters, excess pore water pressure due to shear, static groundwater and surface water, pseudo-static earthquake loading, surcharge and tieback loading, and reinforced slopes.

The tieback loading feature provides for the input of horizontal or inclined tieback or line loads for analyzing the overall stability of tied-back or braced slopes and retaining walls. PASTABLM has the ability to analyze slopes subjected to tieback or concentrated loads using the Simplified Janbu, Simplified Bishop or the Spencer methods of slices.

The reinforcing layer option provides for the input of layer locations and lengths, the distribution of available force, and the direction in which the force acts. The circular trial surface may be specified or PASTABLM's surface generation routine may be used.

Graphical output is provided as a visual aid to confirm the accuracy of problem input data. The standard output file contains a character plot automatically generated by the program.

Error messages are generated within the program to pinpoint locations where input data are inconsistent with PASTABLM's input requirements. Free format data input eases the task of input file preparation, resulting in a reduction of input errors.

This manual is intended to (1) summarize the background theory for STABLE (2) describe the creation of input files; (3) describe execution of PASTABLM on a microcomputer, along with the capabilities, error messages, and hardware and software requirements of the program; and (4) provide several example problems. The information is extracted, in part, from the references listed below:

1. "STABL User Manual", (Ref. 19); and

2. "Slope Stability Analysis with STABL4", (Ref. 16).

3. "PCSTABL 4 User Manual" (Ref. 6).

This documentation should be consulted for more details. Three other useful references are:

1. "Computer Analysis of General Slope Stability Problems," (Ref. 18);

2. "Computerized Slope Stability Analysis for Indiana Highways", Vol. 1, (Ref. 2); and

3. "Three-Dimensional Slope Stability Analysis", (Ref. 10).

II. BACKGROUND

The 2-D computer program STABL was developed at a time when most highway agencies analyzed slope stability using two common techniques: computer aided, grid-type circular searches; and block analyses for simple and specified surfaces. Circles were often assumed to be the appropriate shape for potential failure surfaces simply because there was no other shape which could be used for computerized searching.

In the last decade, improvements in 2-D slope stability analysis have proceeded in several directions. One of these is contained in STABL, in the form of computerized searching with non-circular shapes. The non-circular routines RANDOM and BLOCK were first reported by Siegel (Ref. 18) as well as a random (as opposed to a grid) type search with circles (CIRCL2). Favorable comparisons of the factor of safety (FOS) values generated by STABL with those for the same surfaces by other methods of slices were reported by Boutrup (Ref. 2).

STABL was placed on line for routine use in 1976 by the Indiana Department of Highways (IDOH), and after being reported in the open literature, the program began to be adopted by many agencies. STABL has been modified in minor ways, and users of the program have helped greatly in debugging operations. This microcomputer version of STABL is called PASTABLM.

Capabilities of PASTABLM

PASTABLM is a program that contains searching routines for shapes other than circles. Circular grid search routines are common; PASTABLM searches by generating circles, with randomly selected radii and centers limited by user-defined parameters as explained later.

The 2-D program uses a simplified method of slices and thereby minimizes iterative procedures in the solutions. The single limitation on boundary geometry is that there be no vertical or overturned (>90°) surfaces. Subsurface boundaries may demonstrate any degree of natural complexity, and up to ten piezometric surfaces may be specified. Also, options allow boundary and pseudo-static earthquake loadings to be considered in the analysis.

The circular potential sliding surface is appropriate when the subsurface materials are roughly homogeneous and isotropic. Block-type surfaces are probable when weak strata are present, and the critical surfaces tend to have a maximum length within these strata. Thus, we have cited two cases in which simplifying assumptions are appropriate. In the first case it is proper to assume a circular shape and iterate for the position of the critical surface. In the second case, the positions of the major portion of the sliding surface may be assumed, but the entry into the weak layer, the length of sliding surface in this layer, and the departure from it need to be iterated.

A far more common occurrence is the profile where neither shape nor position may be safely assumed and the analysis should both generate and compute FOS values for a wide variety of shapes and positions. The non-circular surface generating routine RANDOM is well suited to this requirement.

In using the searching routines CIRCL2, BLOCK (BLOCK2), and RANDOM, the positions of the surfaces are not obvious. With RANDOM, the shape generated is a further uncertainty, and plotting routines which resolve both uncertainties are necessary. These routines can both show the subsurface space searched and the portion of that space occupied by the more critical surfaces.

For more information, see References 6,16,19.

III. DATA REQUIRED BY PASTABLM

PASTABLM uses an input data file created using either 'STED" or any text editor that can produce an ASCII file on the user's data diskette. This input data file is identical to that used by the mainframe versions of STABL. A detailed description of all the input requirements is presented in this section. The first part presents detailed description of the data file. The next section describes the several items required at run time and the last section lists the error messages that are produced by data errors during execution of PASTABLM.

A. DATA FILE

The PASTABLM data file must be created prior to running the program, using any available text editor. The input is command oriented, within a free format file. The commands tell the program the type of data being input, and which type of analysis to perform. The file layout is identical to that used by the mainframe program, STABL4. Therefore mainframe data files could be downloaded to a diskette and used (or modified and then used) as input to PASTABLM.

1. FILE LAYOUT

PASTABLM uses command-oriented data input. Numerous options are available for use with the program, according to the user's specific requirements. These options are defined by command words (e.g., PROFIL, EQUAKE, etc.) for easy recognition, especially when checking input data. Different commands activate or deactivate different portions of the program, which also allows the user to control and perform the analysis economically. Generally, these commands may be categorized into four major divisions:

1. <u>Surface and subsurface geometry commands:</u>

   PROFIL - initiate problem; read boundary data defining ground surface and subsurface material interfaces.

   LIMITS - read data defining surface generation boundaries.

2. <u>Subsurface profile parameter commands:</u>

   SOIL - read isotropic soil parameter data.

   ANISO - read anisotropic soil parameter data.

   WATER - read data defining piezometric surfaces.

3. <u>Boundary load commands:</u>

   LOADS - read data defining surface boundary surcharge loads.

   TIES - read data defining tieback or bracing load data.

   EQUAKE - read pseudo-static earthquake coefficients and cavitation pressure.

   REINF - read data defining length and location of layers of reinforcement, reinforcing force distribution, and direction in which the force acts.

4. Analytical method command words:

SURFAC/SURBIS - read data defining a single trial failure surface (SURBIS only for circular shaped failure surfaces).

SPENCER - used in conjunction with either the SURFAC or SURBIS methods. For more information see Section III.A.i.

EXECUT - calculate factor of safety for single specified trial failure surface. Used only with SURFAC and SURBIS.

CIRCLE/CIRCL2 - generate circular surfaces and determine critical surfaces.

RANDOM - generate irregular surfaces and determine critical surfaces.

BLOCK/BLOCK2 - generate sliding block surfaces and determine critical surfaces.

Below is an example of how some commands might be sequenced.

```
PROFILE .. data (1)
SOIL    .. data (2)
SURFAC  .. data (3)
EXECUT                       Factor of safety calculation with
                             data (1), (2), and (3).

WATER   .. data (4)
EXECUT                       Factor of safety calculation with
                             data (1), (2), (3), (4).

SURFAC  .. data (5)          Replaces data (3) with data (5).
EQUAKE  .. data (6)
EXECUT                       Factor of safety calculations with
                             data (1), (2), (4), (5), (6).

WATER   .. suppress data (4)
EXECUT                       Factor of safety calculations with
                             data (1), (2), (5), (6).

WATER    .. reactivates data (4)
EQUAKE   .. data (7)         Replaces data (6) with data (7).
EXECUT                       Factor of safety calculations with
                             data (1), (2) (4), (5), and (7)
```

PROFILE	.. data (8)	Nullifies all previous data - initiates new problem.
EQUAKE	.. data (9)	
TIES	.. data (10)	
SOIL	.. data (11)	
SURFAC	.. data (12)	
EXECUT		

2. GENERAL RULES

The following sections detail the general rules that must be followed in the creation of data files.

a. Use of Data Commands

All commands may be used as often as desired; however there are some restrictions imposed regarding sequencing for execution.

Once a data command is invoked, the data remain in effect until replacement or suppression by another use of the same command. There are two exceptions to this. The first concerns the use of command PROFIL. The command prepares PASTABLM for a new problem by defining a new profile. As a result all data which may have been read by previous data commands will be lost. The second exception involves use of the analysis commands CIRCLE, BLOCK, and RANDOM. These commands are random generators and therefore cannot use individual failure surfaces generated with the SURFAC or SURBIS commands.

Temporary suppression of data previously entered along with the WATER, LOADS, LIMITS, or ANISO command is accomplished by a special use of the command. When a command name is specified without any data, PASTABLM suppresses the data associated with that particular command.

The data will remain suppressed until reactivated by a second use of the same command without any data specified. This is illustrated in the previous example where the second use of WATER suppresses data (4). If new data are read while old data are suppressed, the old data are lost for further use.

Isotropic soil parameters may be modified by specifying zero for the total number of soil types, followed by a value for the number of soil types which are to be changed. The soil type number and appropriate soil parameters must follow for each soil type modified. See Section III.A.4, SOIL for more details.

b. Minimum Data Required

Use of the analysis commands requires, as a minimum, definition of a problem's profile (PROFIL), and the soil parameters (SOIL), and a surface or search analysis command (SURFAC, SURBIS, CIRCLE, CIRCL2, RANDOM, BLOCK, BLOCK2). In addition, use of the SURFAC or SURBIS analysis commands require specifying the EXECUT command to initiate analysis of the specified surface.

c. Free-Format Input

All commands are entered on individual lines commencing with the first column using any text editor. During execution, if the computer cannot match the command with one which PASTABLM has been programmed to recognize, the command will be displayed with an error message as output, and execution will be terminated. Be certain the spelling of each command is correct.

Each line containing numerical data must be entered such that the first data item on a card commences with the first column. One and only one blank space should separate each subsequent data item on a line. PASTABLM directs the computer to read data from the next card when two or more blank spaces are encountered. If a gap of more than one blank space occurs between two adjacent data items, all remaining data items on the line will not be read. The result is a shift in all data subsequently read. Eventually, an indirect error will be generated.

PASTABLM requires that an integer contains no decimal point, while a real number must have a decimal point. For example an x-coordinate is 5 meters, then "5." or "5.0" must be entered. Conversely, specifying that there are three soil types (an integer variable) would be indicated as "3". The data for each command is explained in the next section, III.A.3, and their organization are outlined in Section III.A.4.
A new line of data should be started wherever a data line or command line is encountered.

3. INPUT DATA

The following paragraphs explain the input data used by PASTABLM. A detailed input guide showing the format used to input the data is found in the next section (III.4). The data falls into the following categories: profile boundaries, piezometric surfaces, soil parameters, boundary loads, earthquake loads, tieback loads, reinforcement layers, and failure surfaces.

a. Profile Boundaries

It is necessary to plot the problem's geometry to scale on a rectangular coordinate grid. Coordinate axes should be chosen carefully such that the total problem is defined within the first quadrant. This enables the graphic aspects of the program to function properly. For best resolution and interpretation of output data, the extent of coordinate limits should define the problem geometry, and permit analysis of the most critical failure surfaces, when using multiple surface generation commands. Potential failure surfaces developing beyond the toe or the crest of the slope must be accommodated (Figure 1). Deep trial failure surfaces passing below the horizontal axis are not allowed, nor are trial failure surfaces which extend beyond the defined ground surface in either direction. If any coordinate point defining the problem's geometry is detected by the program to lie outside the first quadrant, an appropriate error code is displayed and execution of PASTABLM is subsequently terminated.

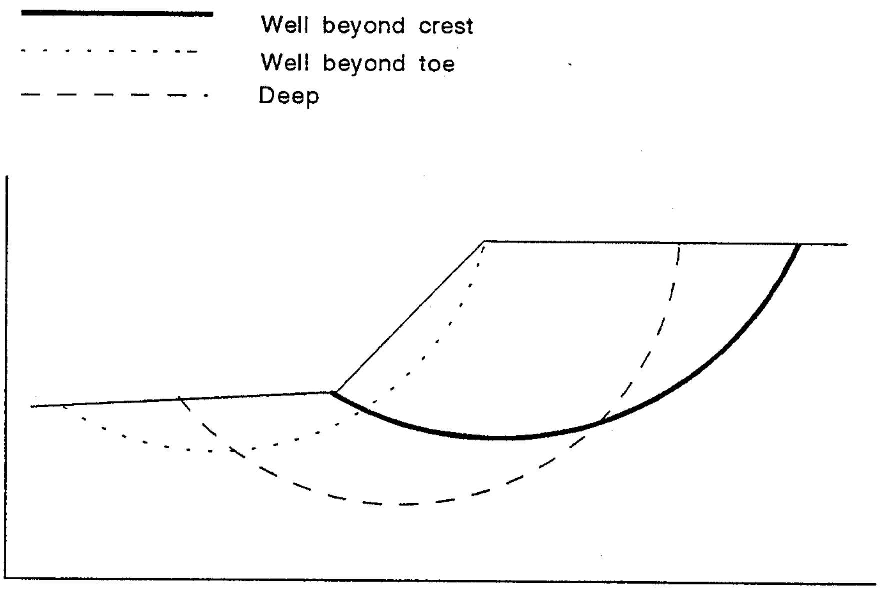
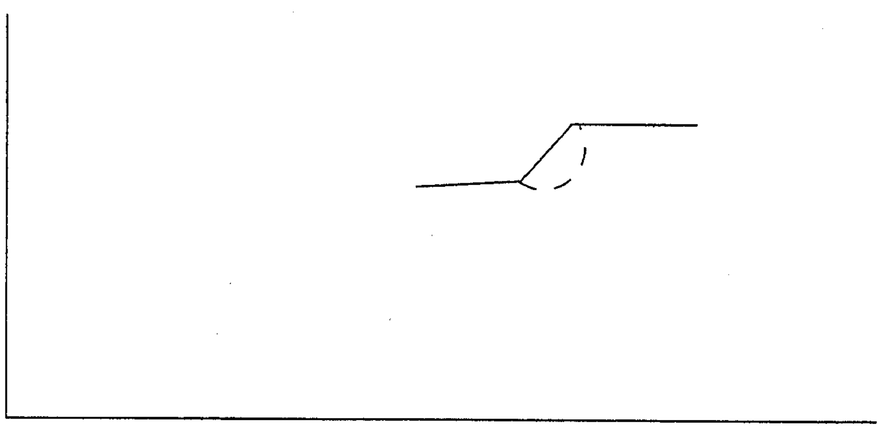
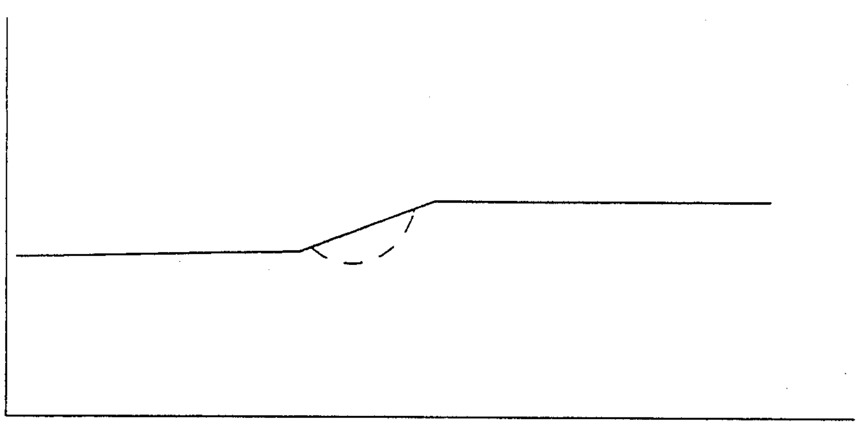


FIGURE 1. Extent of Potential Failure Surfaces



Coordinates too large in comparison with height and length of scope



Too much room allowed beyond toe and crest of slope in comparison to its height and length

FIGURE 2. Scaling resulting from correct but inadequate definition of problem

Situations where the resulting plotted profile would be too small in scale to be useful for interpretation are unacceptable (Figure 2). Figure 1 is an excellent example using well chosen coordinates where there is enough room for possible failure surface development, and the profile geometry is plotted to the largest scale possible within the allowed format. Failure to consider these factors prior to data input, may result in the necessity to revise the entire data input file.

The ground surface and subsurface demarcations between regions of differing soil parameters are approximated by straight line segments using the PROFILE command. Any configuration can be portrayed so long as the sloping ground surface faces the vertical axis and does not contain an overhang. Vertical boundaries should be specified slightly inclined to the right (e.g., Xleft = 100.0, Xright = 100.1) to avoid computational errors and failure of file execution.

Assigned with each surface and subsurface boundary is a soil type which represents a set of soil parameters describing the area projected beneath. Imaginary vertical lines, passing through the end points of each boundary, bound the area in lateral extent. The area below a boundary may or may not be bound at its bottom by another boundary, beneath which different soil parameters would be defined (Figure 3).

The program requires a chain of order by which boundary data must be prepared. The boundaries may be assigned temporary index numbers for ordering by the following procedure. The ground surface boundaries are numbered first, from left to right consecutively, starting with (1). All subsurface boundaries are then numbered in any manner as long as no boundary lies below another having a higher number. That is, at any position which a vertical line might be drawn, the temporary index numbers of all boundaries intersecting that line must increase in numerical order from the ground surface downward. For simplicity, the generation of profile boundaries should progress in the following convention: Left to right; top to bottom.

Boundary	Area	Soil Type
3	ABCDEF	2
5	GHIJK	1
15	-LM-	3

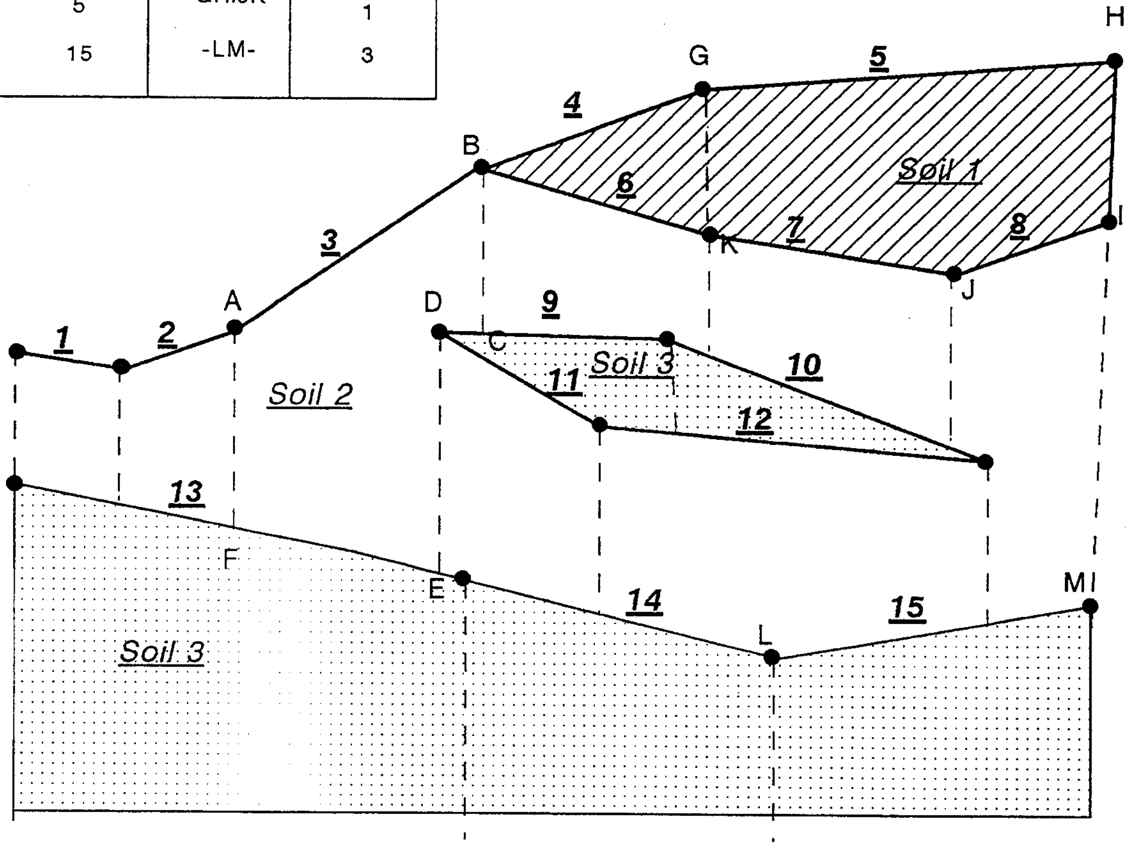


FIGURE 3. Relationship of Soil to Boundaries

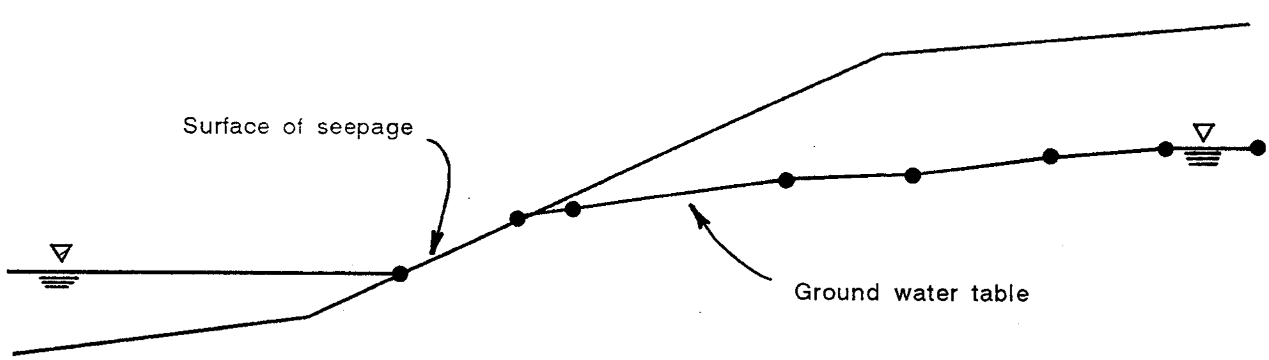


FIGURE 4. Water Surface Defined Across Entire Extent of Defined Problem

After all the boundaries have been temporarily indexed, the data for each boundary should be prepared in that order.

The data set describing a profile boundary line segment consists of X and Y coordinates of the left and right end points and a soil type number indicating the soil type beneath. The end points of each boundary are specified with the left point proceeding the right, and with the X coordinate of each point required to precede its complimentary Y coordinate.

b. Piezometric Surfaces

If the problem contains one or more piezometric surfaces which would intersect a potential failure surface, they can be approximated by a series of coordinate points connected by straight line segments, by using the WATER command. If used, the piezometric surfaces must be defined continuously across the horizontal extent of the region to be investigated for possible failure surfaces. Therefore, it is wise to extend the piezometric surfaces as far in each lateral direction as the ground surface is defined (Figure 4). Data for the coordinate points must be ordered progressing from left to right. Each point on a piezometric surface is defined by a X and Y coordinate specified in that order, similar to the profile boundaries.

The connecting line segments defining a piezometric surface may lie above the ground surface, below the surface within a defined soil type or cross multiple soil types, or lie coincident with the ground surface or any profile boundary. This enables expression of not only the ground water table but also surfaces of seepage, and still water surfaces defining bodies of water such as lakes and streams. The option of defining several piezometric surfaces makes it possible to model conditions of artisan or perched water tables.

The pore pressure at any point below the water surface is calculated using the pressure head, which is defined as the vertical distance from the point in question to the water surface.

Where a gradient exists, this assumption is generally conservative. However, near the surface of seepage, the assumption is unconservative. Artisan pressures found in heterogenous soil systems will further complicate the validity of the assumption. Since the error may be large for some flow regimes, other methods for handling the pore water pressures may be more appropriate and are described under the next section, soil parameters. When the water surface is above the ground surface, hydrostatic pressures generated by the elevated water surface are assumed to act upon the ground surface.

c. Soil Parameters

Each soil type is described by the following set of isotropic parameters defined with the SOIL command: the moist unit weight, the saturated unit weight, Mohr-Coulomb strength intercept (cohesion), the Mohr-Coulomb strength angle (phi value), a pore pressure parameter, a pore pressure constant, and an integer representing the number of the piezometric surface that applies to this soil. Anisotropy may also be modeled as described later.

The moist unit weight and the saturated unit weight are total unit weights, and both are specified to enable PASTABLM to handle zones divided by a water surface. In the case of a soil zone totally above the water surface, the saturated unit weight will not be used, even though the input requires some value to be present in the data file. Any value including zero will do. Similarly for the case where a soil zone is totally submerged, the moist unit weight will not be used. Again some value must be used for input.

Either an effective stress analysis (ϕ', c') or total stress analysis (c, $\phi = 0$) may be performed by using the appropriate value for the Mohr-Coulomb strength parameters.

Excess pore water pressure due to shear can be assumed to be related to the overburden by the single parameter r_u. The overburden does not include surcharge boundary loads.
The pore pressure constant u_c of a soil type defines a constant

pore pressure for any point within the soil described. Either or both of these two options for specifying pore pressures may be used, in combination with pore pressure related to a specified piezometric surface, to describe the pore pressure regime.

Soil types exhibiting anisotropic strength properties are described by assigning additional Mohr-Coulomb strength parameters to discrete ranges of direction with the ANISO command. The strength parameters would vary from one discrete direction range to another. The orientation of all line segments defining any potential failure surface can be referenced with respect to their inclination entirely within a range of direction between -90° and +90° with respect to horizontal. Therefore the selection of discrete ranges of direction is confined to these limits. The entire range of potential orientation must be assigned strength values. Each direction range of an anisotropic soil type is established by specifying the maximum (counterclockwise) inclination of the range (Figure 5). The data consist of this inclination limit and the Mohr-Coulomb strength angle and strength intercept for each discrete range. Data for each discrete range must be prepared progressing in counterclockwise order, starting with first range from -90° to cx1 (specifying cx1 as counterclockwise direction limit). The process is repeated for each soil type with anisotropic strength behavior.

d. Boundary Loads

Uniformly distributed boundary loads applied to the ground surface are specified with the LOADS command, by defining the following: their extent; intensity; and the direction of application, see (Figure 6). The limiting equilibrium model used for analysis treats the boundary loads as strip loads of infinite length. The major axis of each strip load is normal to the two-dimensional X-Y plane within which the geometry of slope stability problems is solved. Therefore the extent of a boundary load is its width in the two-dimensional plane.

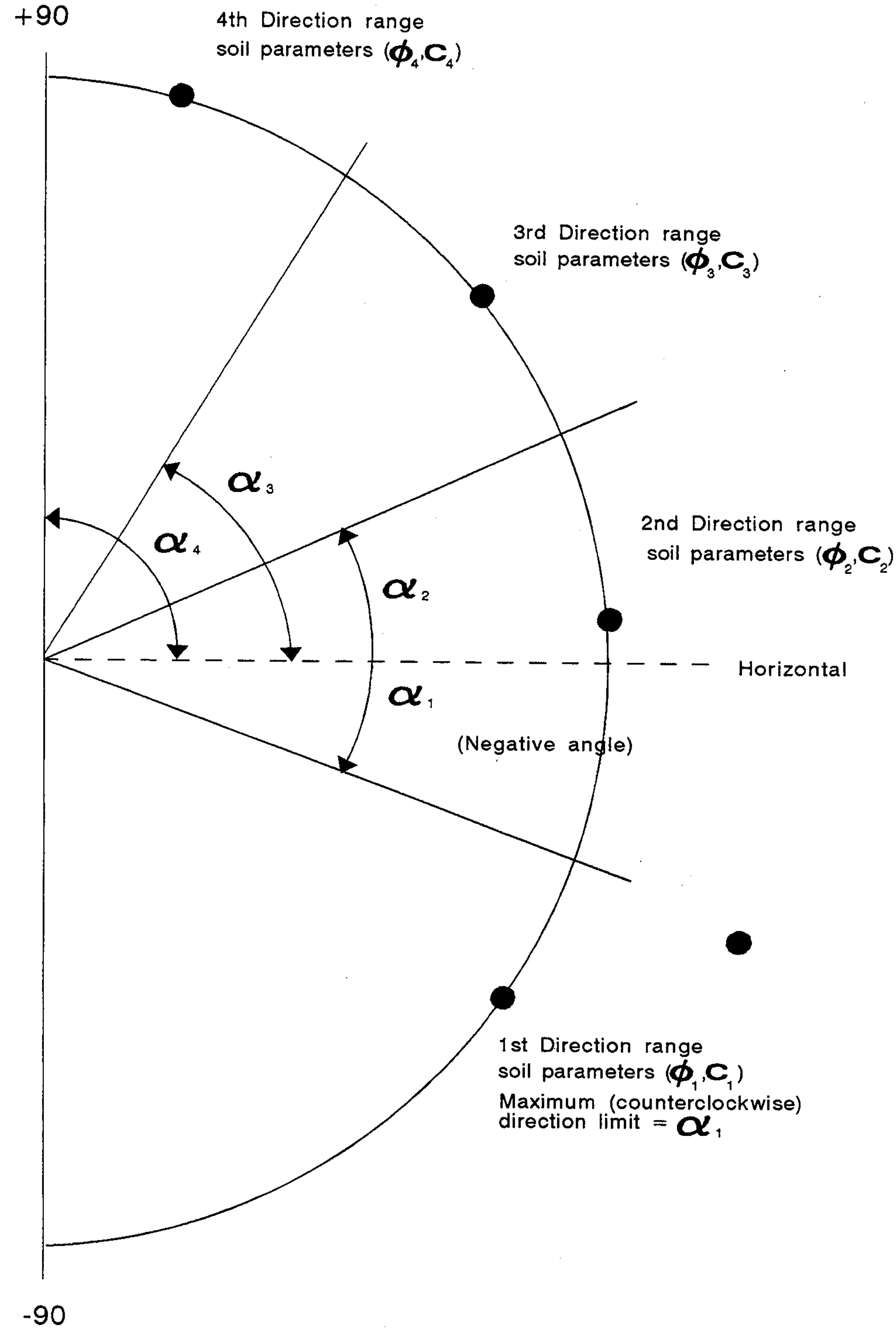


FIGURE 5. Strength Assignment to Four Discrete Direction Ranges for a Single Anisotropic Soil Type

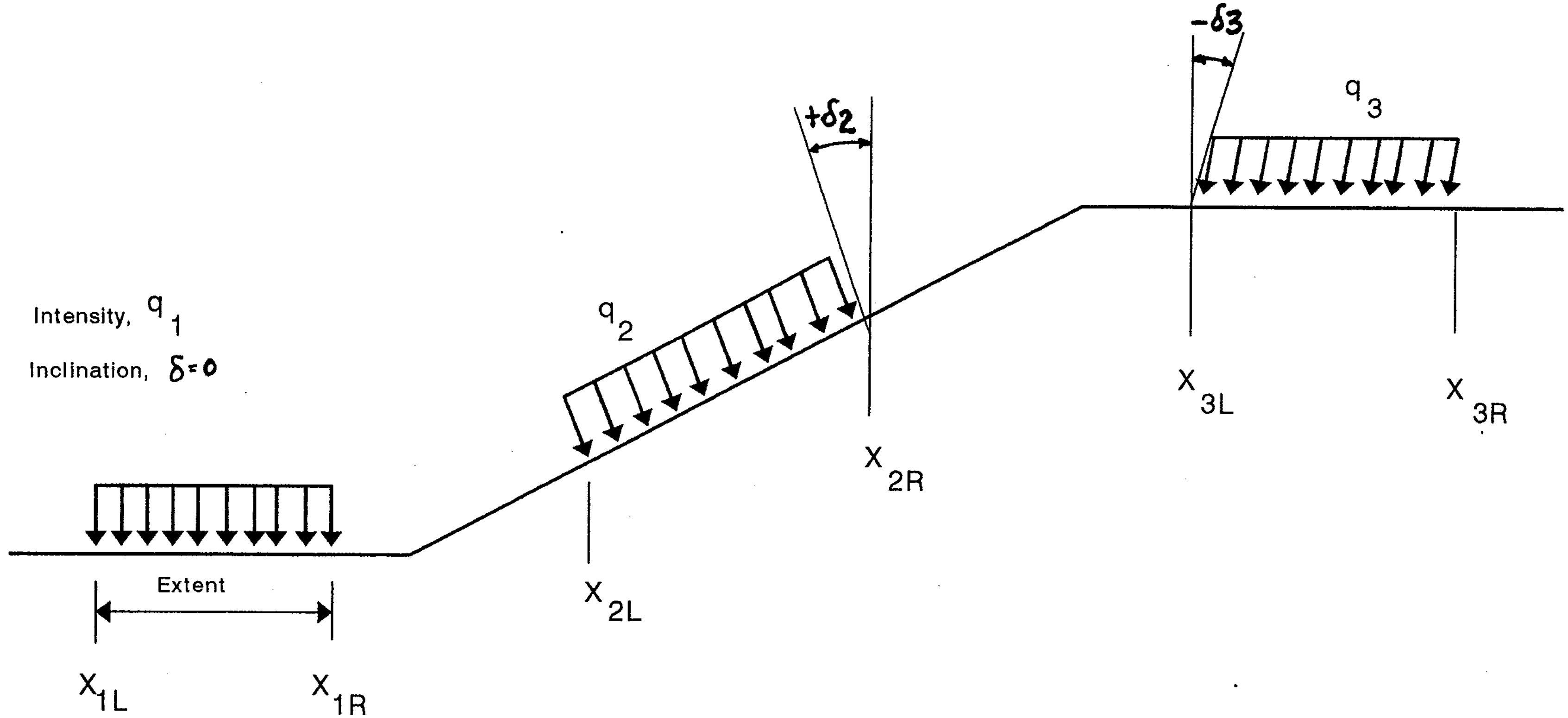


FIGURE 6. Definition of Surcharge Boundary Loads

Data for each boundary load consists of the left and right X coordinates which define the horizontal extent of load application, the intensity of the loading, and its inclination. The intensity specified should be in terms of the load acting on a horizontal projection of the ground surface rather than the true length of the ground surface. Inclination is specified positive counterclockwise from the vertical. The boundaries must be ordered from left to right and are not allowed to overlap. A boundary load whose intensity varies with position can be approximated by substituting a group of statically equivalent uniformly distributed loads, which abut one another. The sum of the widths of the substitute loads should equal the width of the load being approximated. The inclinations should be equivalent, and the intensities of substitute loads should vary as does the load being approximated.

e. Earthquake Loading

The use of earthquake coefficients allows for a pseudo-static representation of earthquake effects within the limiting equilibrium model. A direct relationship is assumed to exist between the pseudo-static earthquake force acting on the sliding mass, and the weight of the sliding mass. Specified horizontal and vertical coefficients are used to scale the horizontal and vertical components of the earthquake force, relative to the weight of the sliding mass. Positive horizontal and vertical earthquake coefficients indicate that the horizontal and vertical components of the earthquake force are directed leftward and upward, respectively. Negative coefficients are allowed.

The inertial forces due to the seismic coefficients are applied at the center of gravity of each slice. These forces do not change the pre-earthquake static pore pressures in the slope. If significant excess pore pressures changes or loss of shear strength is expected, or in the case of a "high-risk" slope, a complete dynamic analysis should be performed.

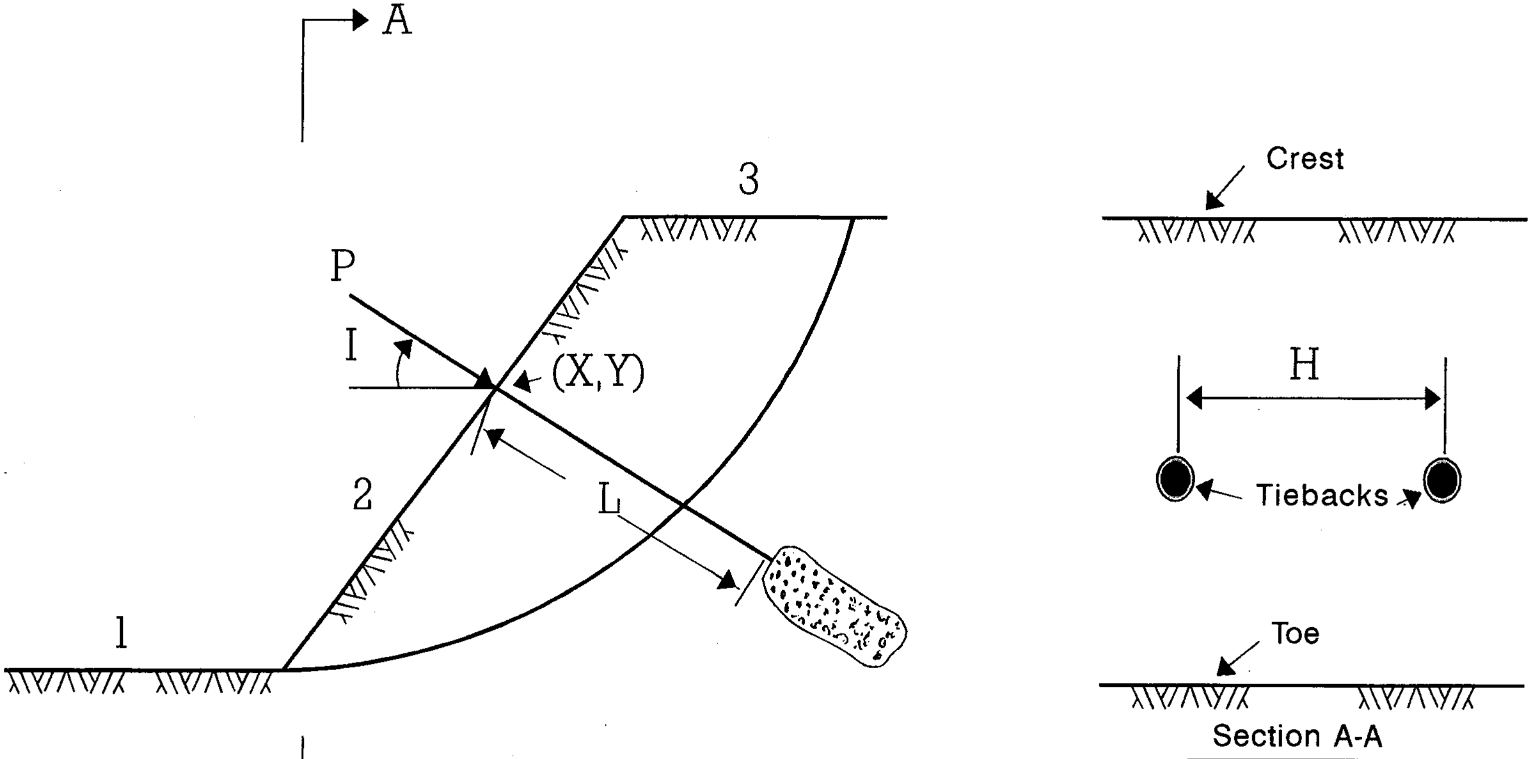
Examples of slope stability analysis encountering pseudo-static earthquake loads are described in Reference 2, Section 4.5.4.

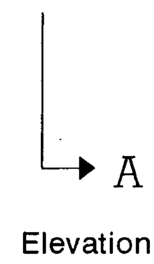
f. Tieback Loading

Tieback or other types of concentrated loads are input using the TIES command. The loading is modeled by specifying the following: the ground surface boundary number where the load is to be applied; the Y coordinate of the point of application on the ground surface; the magnitude of the point load; the horizontal spacing between point loads; the inclination of the load as measured clockwise from the horizontal axis; and the length of the tieback tendon (see Figure 7). For concentrated boundary loads such as strut loads in a braced excavation, which do not extend into the ground like tiebacks, the free length of the tieback is zero. An equivalent line load is calculated for each tieback load specified assuming a uniform distribution of load horizontally between point loads.

PASTABLM distributes the force from a concentrated load throughout the soil mass to the whole failure surface, and hence to all slices of the sliding mass. The tieback input option was modified to allow for the input of concentrated loads applied to a horizontal ground surface boundary. In addition, concentrated loads may now be inclined at an angle between 0 and 180 degrees from the horizontal. The input parameters for a tieback load have been changed to also include the input of the X coordinate of the load applied to the ground surface. Either the X coordinate of the point of application of the tieback load can be specified and the Y coordinate calculated, or the Y coordinate can be specified and the X coordinate calculated. If the user desires, both the X and Y coordinates may be input.

If only the X coordinate is specified, a value of zero must be input for the Y coordinate. When the program encounters a zero Y coordinate, it will automatically calculate the proper Y for the X coordinate and boundary specified. Likewise, if only the Y coordinate is specified, a value of zero must be input for the X coordinate, and the program automatically calculates the X coordinate.





Tieback Input Parameters

2	Ground surface boundary number where tieback load is applied
X	X coordinate of point of application (m)
Y	Y coordinate of point of application (m)
P	Magnitude of load per tieback (kN/m)
H	Horizontal spacing between tiebacks (m)
I	Inclination of tieback load (deg)
L	Free length of tieback (m)

FIGURE 7. Tieback Input Parameters

The user may also input both the X and Y coordinates of the point of application of the tieback load on the ground surface boundary, however, the coordinates specified must be sufficiently accurate so that the program will recognize an intersection of the X and Y coordinates specified with the ground surface boundary indicated. If the difference between the coordinates specified by the user and the coordinates calculated by the program is greater than 0.001, then an error message will be displayed, and the program execution stopped.

g. Reinforcing Layers

1) Background

Tensile reinforcing layers provide a resisting moment which increases embankment stability. This effect was incorporated into the simplified Bishop, 1955, (Reference. 1), method of analysis. It was assumed that the reinforcement provides only a resisting moment and does not alter the stresses on the assumed slip surface. Finite element analyses confirmed that the reinforcement has an insignificant effect on normal stresses on the portion of the failure surface passing through the embankment (Humphrey and Holtz, 1986a).

Furthermore, the soil strength and available reinforcing force are assumed to be mobilized simultaneously. The implications of this assumption should be critically examined when the foundation soils reach a peak shear strength at small strain followed by strain softening. Further implications arise when extensible reinforcements are used (e.g. geogrids, geotextiles). In these instances, only residual shear strength values may be used for design.

In the simplified Bishop method a circular shaped slip surface is assumed and divided into a number of slices. A slip surface and the forces acting on a typical slice are shown in Fig. 8. The reinforcing force F_R acting at the intersection of the slip surface and the reinforcement is also shown.

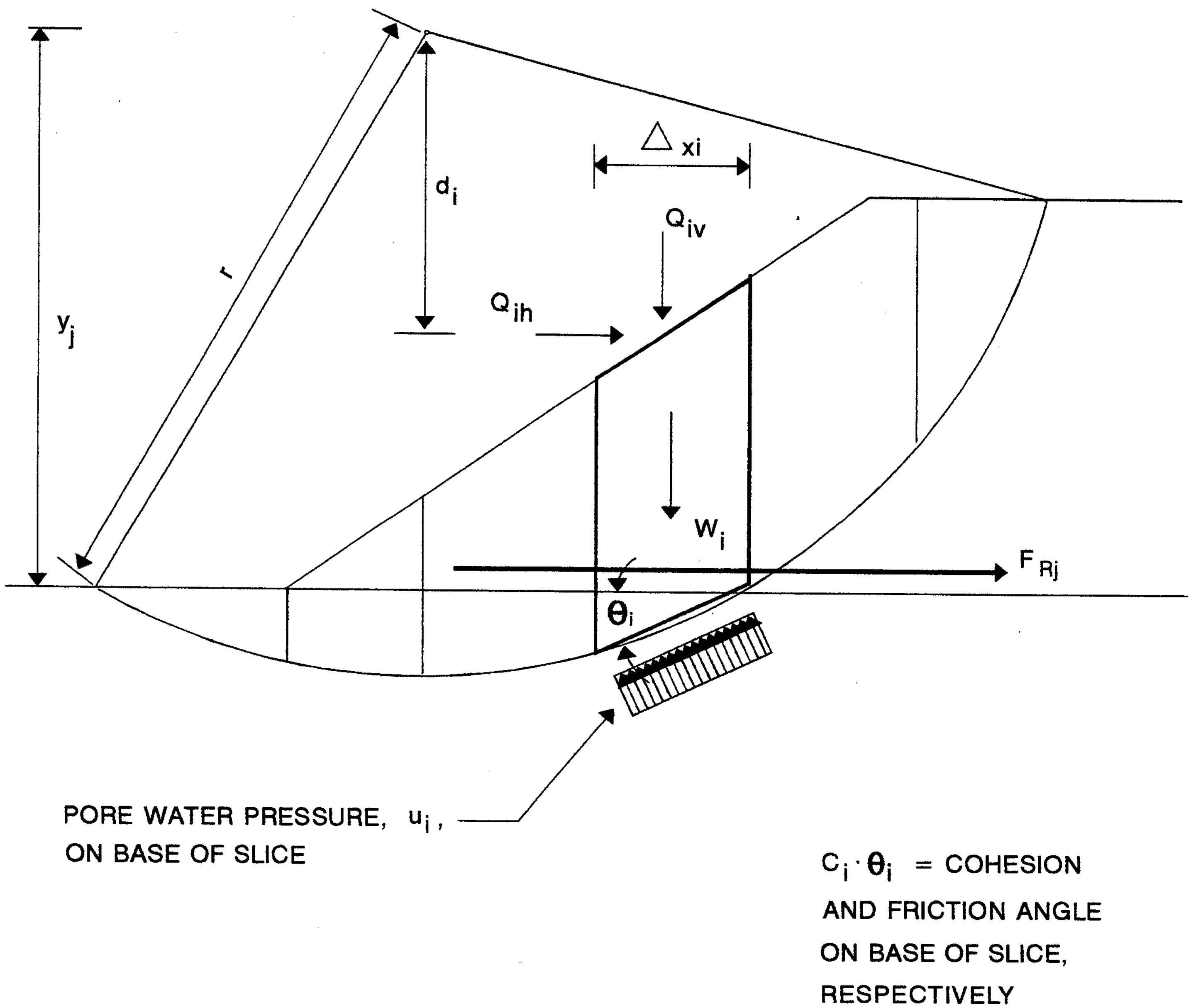


FIGURE 8 Simplified Bishop method of slices including horizontal reinforcing force showing forces acting on i^{th} slice.

$$SF = \frac{\displaystyle\sum_{I=1}^{n} \left[\frac{c_i \ \Delta x_i + [W_i + Q_{iv} - u_i \ \Delta x_i] \ \tan\phi_i}{\cos\theta_i + (\sin\theta_i \ \tan\phi_i) \ / \ SF} \right]}{\left[\displaystyle\sum_{I=1}^{n} (W_i + Q_{iv}) \ \sin\theta_i \right] - \left[(\displaystyle\sum_{I=1}^{n} Q_{ih} \ d_i) \ / \ r \right] - \left[(\displaystyle\sum_{j=1}^{m} F_{Rj} \ y_j) \ / \ r \ SF) \right]} \quad (1)$$

where:

W_i = weight of the i^{th} slice
Q_{iv} = vertical surface load applied to the i^{th} slice
Q_{ih} = horizontal surface load applied to the i^{th} slice
d_i = moment arm of Q_{ih}
u_i = pore water pressure acting on base of i^{th} slice
Δx_i = width of i^{th} slice
θ_i = inclination of base of i^{th} slice
c_i = cohesion on base of i^{th} slice
ϕ_i = friction angle on base of i^{th} slice
r = radius of assumed trial circle
n = number of slices
F_{Rj} = force in j^{th} reinforcing layer
y_j = moment arm for j^{th} reinforcing layer
m = number of reinforcing layers
SF = safety factor

The safety factor which satisfies Eq. 1 is found by trial and error.

F_R has units of force per unit width (kN/m). It provides a resisting moment equal to F_R times its moment arm, y, about the center of the circle. If there are multiple reinforcing layers, the total resisting moment is the sum of the resisting moment provided by each layer. This additional resisting moment is included in the equation for the safety factor (Ingold, 1982; Humphrey and Holtz, 1986.

2) Implementation

To use the reinforcing option, the location of each layer is specified by a series of X,Y coordinates starting at the left end of the reinforcement and moving to the right as shown in Fig. 9. In a typical application the left end of the layer would be at the embankment toe or the face of the slope and would extend into the embankment. The layer may be horizontal or inclined, however the user must employ judgment on the applicability of the analysis method if the layers are more than moderately inclined. It is the user's responsibility to define a reasonable reinforcement geometry.

The available force and orientation of the force is specified at each point defining the reinforcing layer. Similar procedures were used by Duncan, et al. (1985). Suggestions on choice of the available force and its orientation are given in Humphrey and Holtz (1986a). The orientation of the force is specified by the inclination factor I_f. I_f varies from 0.0 which specifies that the force acts in the direction of the reinforcement, to 1.0 which specifies that it acts tangent to the slip surface as shown in fig. 10.

During program execution, the intersection of each reinforcing layer with the trial surface is located. Then the force (F_{Rj}) and inclination factor (I_{fj}) at the intersection is found by linear interpolation between the adjacent specified points (Fig 9). It is possible for the toe of some trial circles to intersect a layer a second time but this is assumed to have no effect on stability.

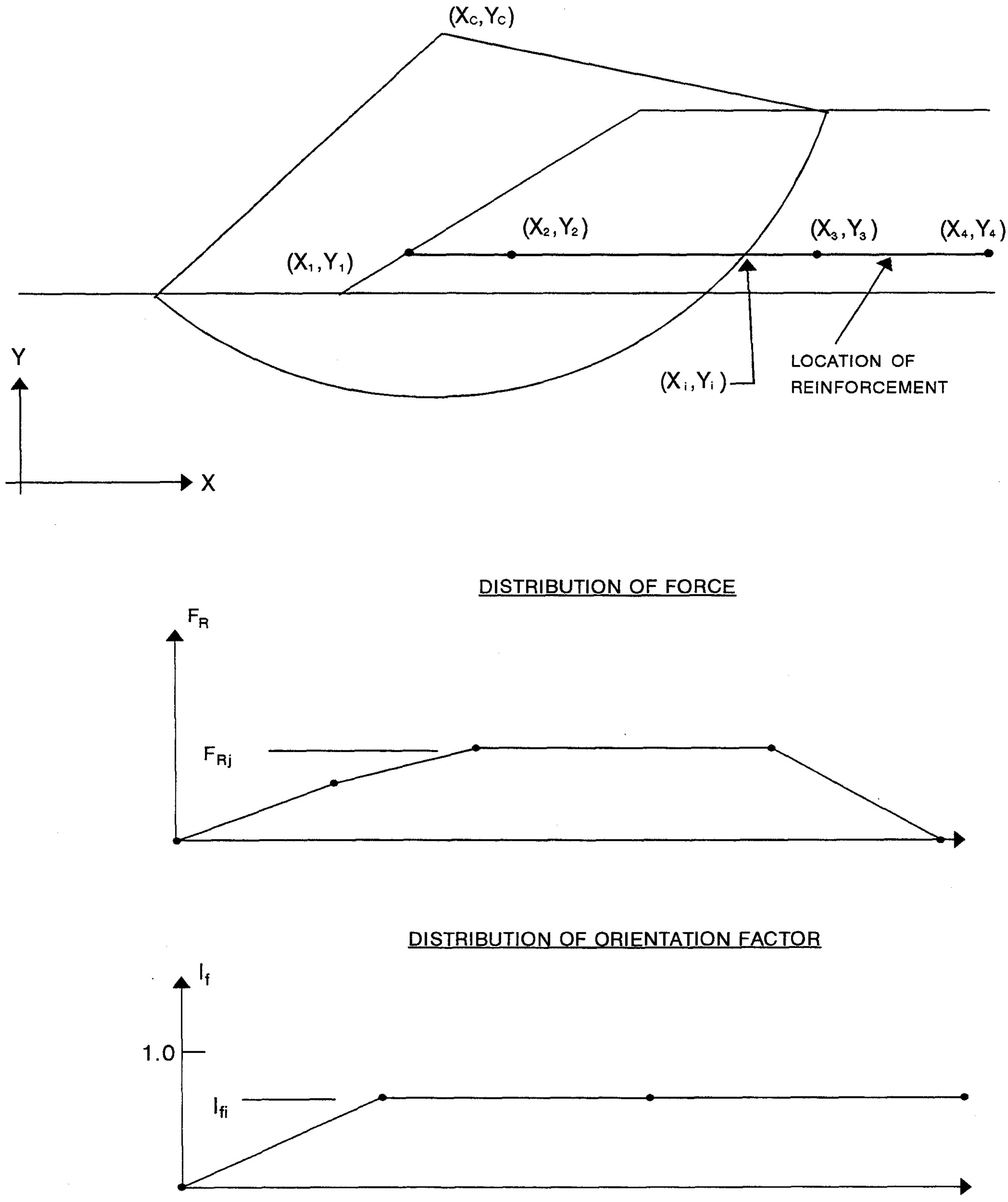


Figure 9 Location of Reinforcement and Distribution of Force and Inclination Factor

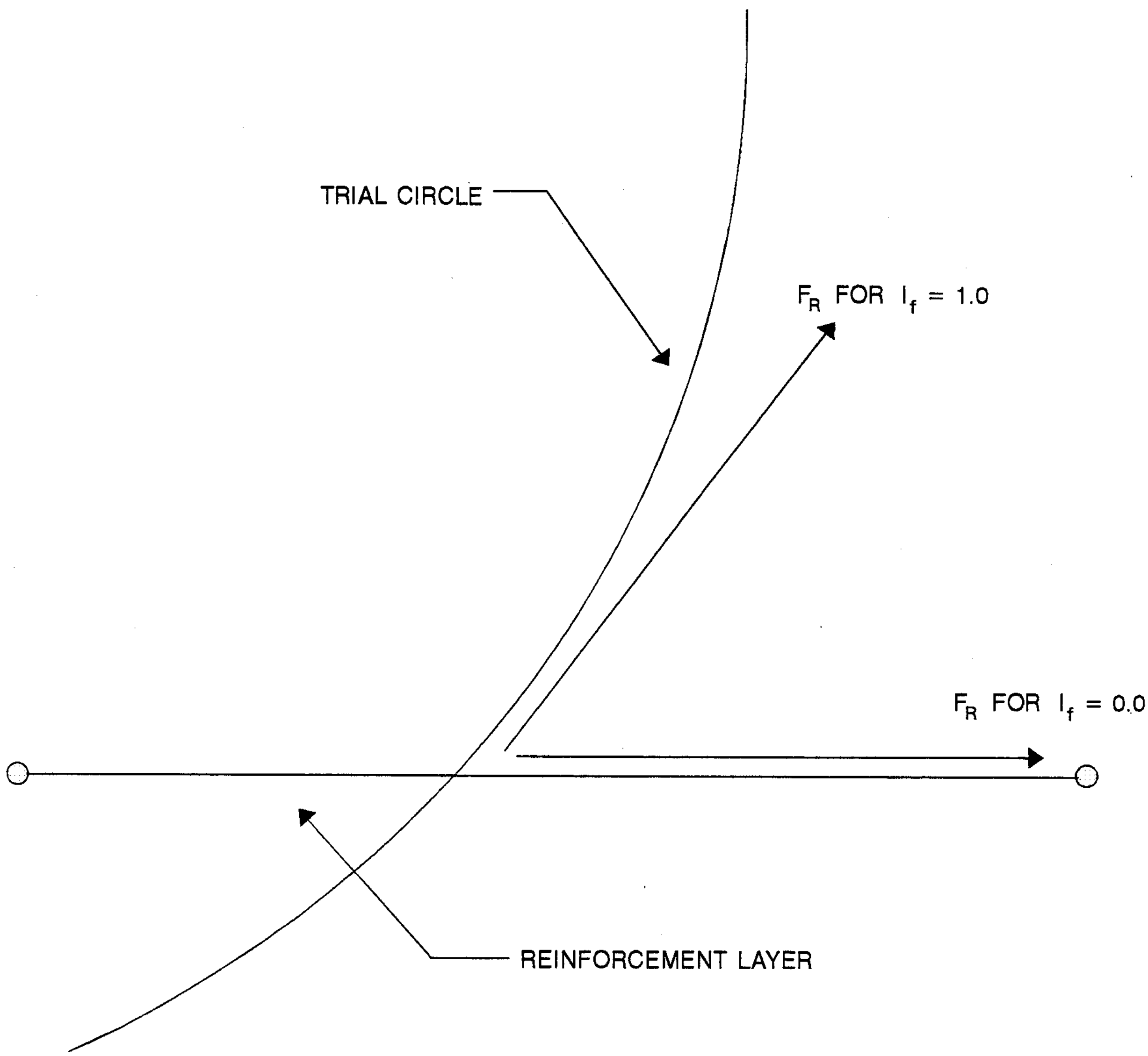


FIGURE 10 Orientation of Reinforcement Force

The moment arm (y) is a function of the trial circle radius (r), the slope of the reinforcement (ψ), the inclination factor (I_f), the coordinates of the circle center (x_c, y_c), and the coordinates of the intersection (x_i, y_i) as shown on Fig. 9. For a horizontal layer with $I_f = 0.0$, $y = y_c - y_i$; for $I_f = 1.0$, $y = r$. For other cases,

$$A = \operatorname{atan}[x_c - x_i) / (y_c - y_i)] \qquad (2)$$

$$y = r \sin[\pi/2 - A + \psi + I_f(A-\psi)] \qquad (3)$$

The reinforcing option is implemented only for the simplified Bishop method. This restricts solution options to SURBIS for a single specified trial circle or CIRCL2 for multiple circles generated using a random technique.

PASTABLM has the capability to analyze many different types of problems. Some combinations of solution options may produce unrealistic results, for example using the reinforcing and tieback options together. The user should exercise good judgment in this regard.

h. Failure Surfaces

If the failure of a slope is being studied and the location of the actual failure surface is known, PASTABLM offers the option of specifying the known surface as an individual surface for analysis through use of the SURFAC or SURBIS command. The EXECUT command must be used to initiate execution of the SURFAC or SURBIS command. Another situation for which this option would be useful is when the geologic pattern and shear strength data indicate one or more well defined weak paths along which failure would be expected.

An individual failure surface is approximated by straight line segments defined by a series of points. The end points of the specified trial failure surface are checked for proper location within the horizontal extent of the defined ground surface. The Y coordinates for these two points need not be correctly specified. PASTABLM directs the calculation of the Y coordinate, for each of these two points, from the intersection of a vertical line defined by the specified X coordinate and the ground surface. Data for the coordinate points must be ordered from left to right. Sufficient coordinate points must be specified to accurately model the failure surfaces.

If the location of the failure surface is not known, PASTABLM can generate any specified number of trial failure surfaces in a random fashion. The only limitation is computation time and cost. Usually 100 surfaces is adequate. As each acceptable surface is generated, the corresponding factor of safety is calculated.

The ten most critical are accumulated and sorted by the values of their factors of safety. After all the specified number of surfaces are successfully generated and analyzed, the ten most critical surfaces are plotted so the pattern may be studied.

The searching routines which generate circular (CIRCLE/CIRCL2 commands) and irregular shaped (RANDOM command) trial failure surfaces are basically similar in use, and are therefore discussed together.

Trial failure surfaces are generated from the left to the right. Each surface is composed of a series of straight line segments of equal length, except for the last segment which most likely will be shorter. The length used for the line segments is specified. When using CIRCLE or CIRCL2 the line segments must be short enough to provide accurate calculation of slope stability.

Generation of an individual trial failure surface begins at an initiation point on the ground surface. The direction, to which the first line segment defining the trial failure surface will extend, is chosen randomly between two direction limits. An angle of 5° less than the inclination of the ground surface to the right of the initiation point would be one limit, while an angle of -45° to the horizontal would be another limit (Figure 11). The first line segment can fall anywhere between these two limits, but the random technique of choosing its position is biased so that it will lie closer to the -45° limit more often than the other.

By specifying zero values for both of the direction limits, the direction limits as described above are automatic. However, the counterclockwise and clockwise direction limits, instead of being calculated under PASTABLM's direction, may be specified.

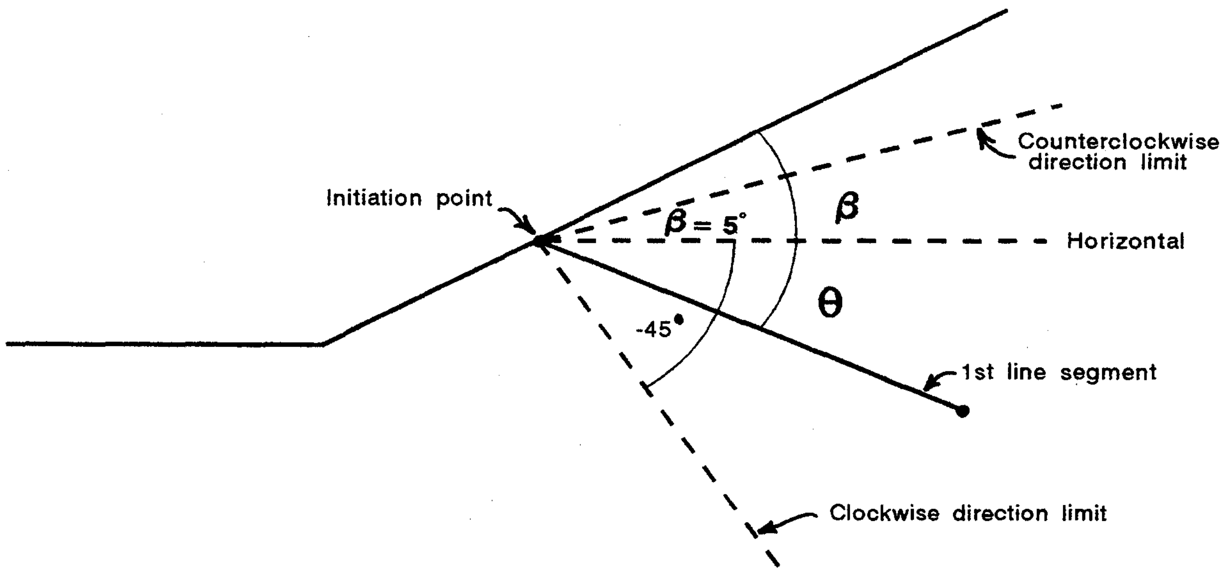


FIGURE 11 Generation of First Line Segment

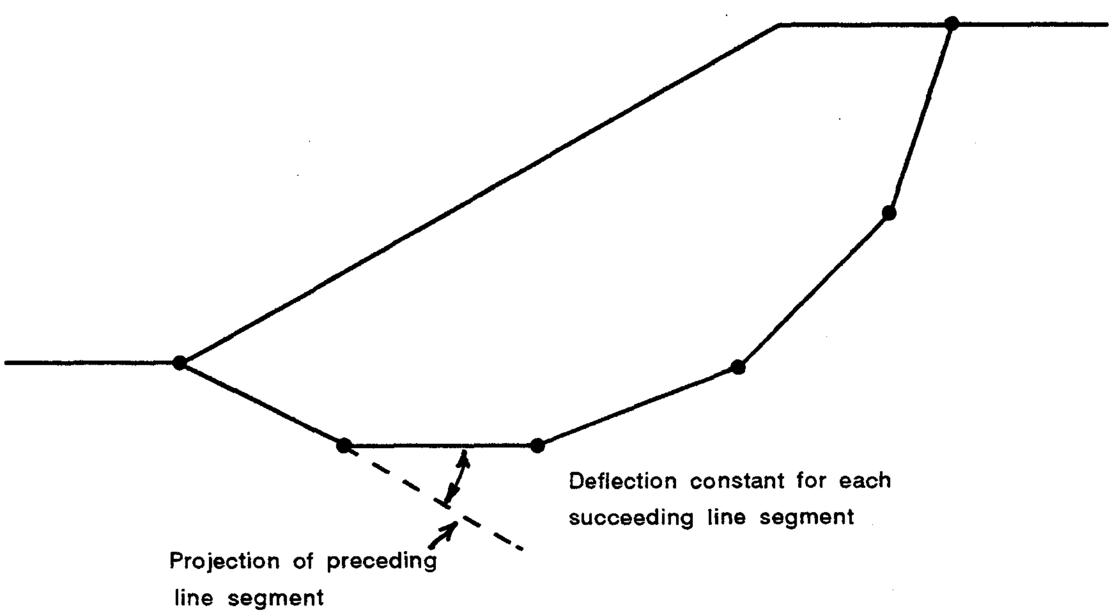


FIGURE 12 Circular Surface Generation

After a preliminary search for the critical surface, it is usually found that all or most of the ten most critical surfaces have about the same angle of inclination for the initial line segments. By restricting the initial line segment within direction limits having a directional range smaller than that which would be used automatically by PASTABLM, and at inclinations which would bracket the initial line segments of surfaces previously determined to be critical, subsequent searches can be conducted more efficiently.

After establishment of the first line segment, a circular shaped trial failure surface is generated by changing the direction of each succeeding line segment by some constant angle (Figure 12) until an intersection of the trial failure surface with the ground surface occurs. In effect, the chords of a circle are generated rather than the circle itself. The constant angle of deflection is obtained randomly.

An irregular shaped surface is generated somewhat differently after establishment of the first line segment. The direction of each succeeding line segment is chosen randomly within limits determined by the direction of the preceding line segment. Surfaces with reverse curvature are likely, and if a very short length is used for the line segments, a significant amount of kinkiness in the surfaces will be inevitable. Some reverse curvature is desirable but extreme kinkiness is not. To avoid the second case the length of the line segment selected should in general not be shorter than 1/4 the height of the slope.

When using either of these generation techniques to search for a critical failure surface, the following scheme is employed. PASTABLM directs computation of a specified number of initiation points along the ground surface. The initiation points are equally spaced horizontally between two specified points, which are the leftmost and rightmost initiation points. Only the X coordinates of these two points, specified in left-right order, are required. From each initiation point, a specified number of trial failure surfaces are generated.

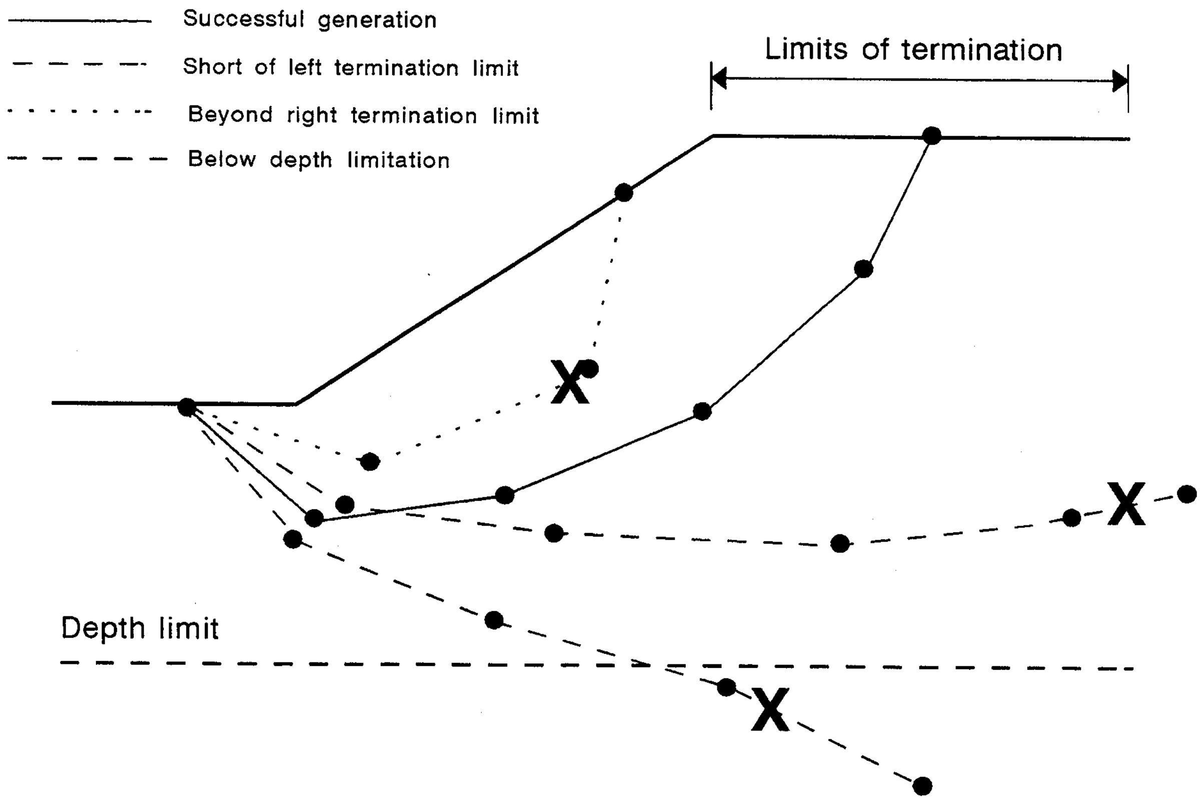


FIGURE 13. Trial Failure Surface Acceptance Criteria

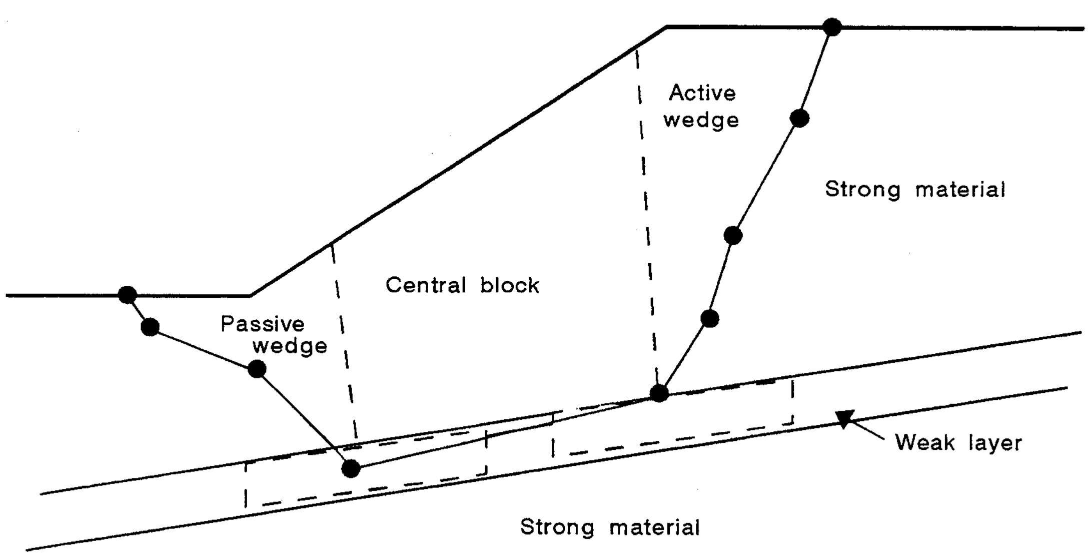


FIGURE 14. Simple Sliding Block Problem

If the left point coincides with the right, a single initiation point results, from which all surfaces are generated. The total number of surfaces generated will equal the product of the number of initiation points, and the number of surfaces generated from each.

Termination limits are specified to minimize the chance of proceeding with a calculation of the factor of safety for an unlikely failure surface. If a generated trial failure surface terminates at the ground surface short of the left termination limit (Figure 13), the surface is rejected prior to calculation of a factor of safety and a replacement is generated. If a generating surface goes beyond the right termination limit, it will be rejected requiring a replacement. The termination limits are also specified in left-right order. Critical failure surfaces resulting at the left initiation point, or the right termination point, may indicate the need to broaden or shift the search limits.

A depth limitation is imposed by specifying an elevation below which no surface is allowed to extend. This is used, for example, to eliminate calculation of the factor of safety for generated surfaces that would extend into a strong horizontal bedrock layer. When a shallow failure surface is expected, the use of the depth limitation prevents generation and analysis of deep trial failure surfaces.

An additional type of search limitation, the LIMITS command, may be imposed to handle situations such as variable elevation of bedrock or delimiting a weak zone and confining the search for a critical surface to that area.

A sliding block trial failure surface generators, BLOCK or BLOCK2, provides a means through which a concentrated search for the critical failure surface may be performed within a well defined weak zone of a soil profile.

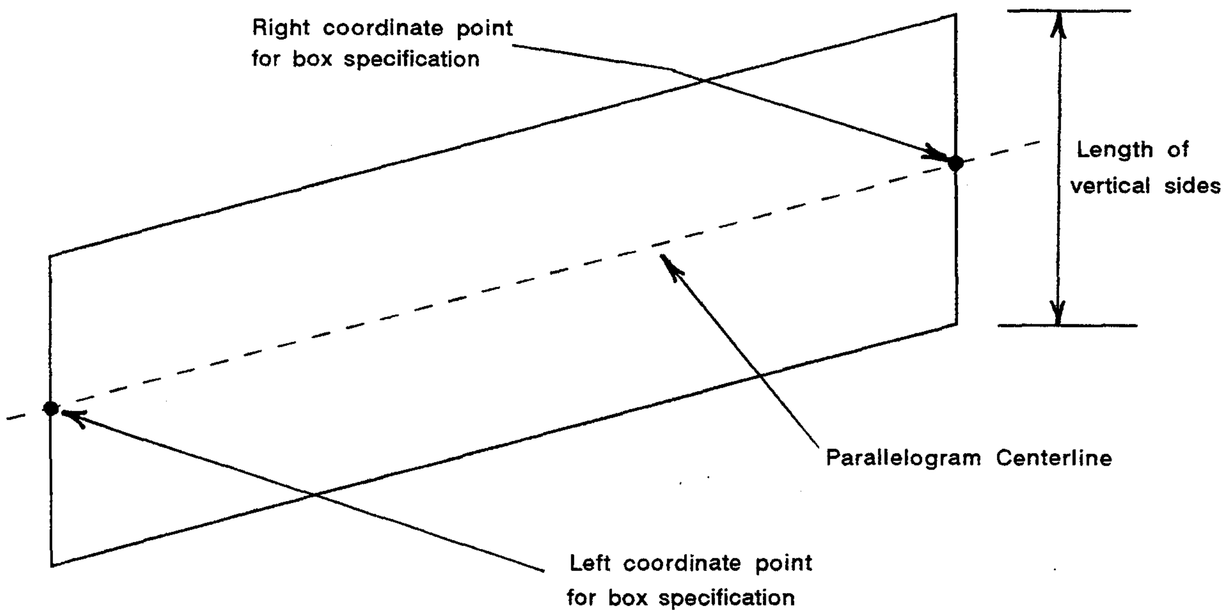


FIGURE 15 Sliding Block Box Specification

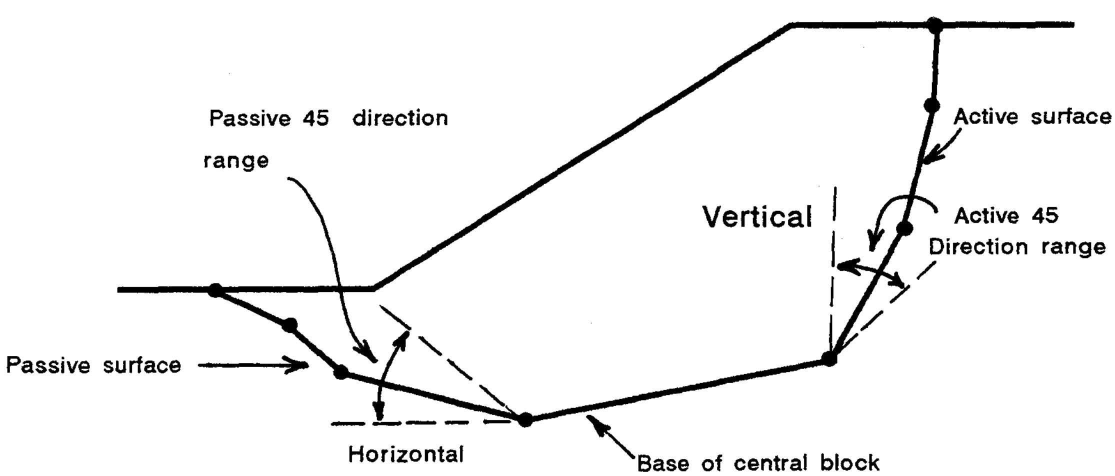


FIGURE 16. Generation of Active and Passive Sliding Surfaces

In a simple problem involving a sliding block shaped failure surface (Figure 14), the following procedure is used. Two boxes are established within the weak layer with the intent that from within each, a point will be chosen randomly. Once chosen, the two points define a line segment which is then used as the base of the central block of the sliding mass. Any point within each box has equal likelihood of being chosen. Therefore, a random orientation, position and width of the central block is obtained.

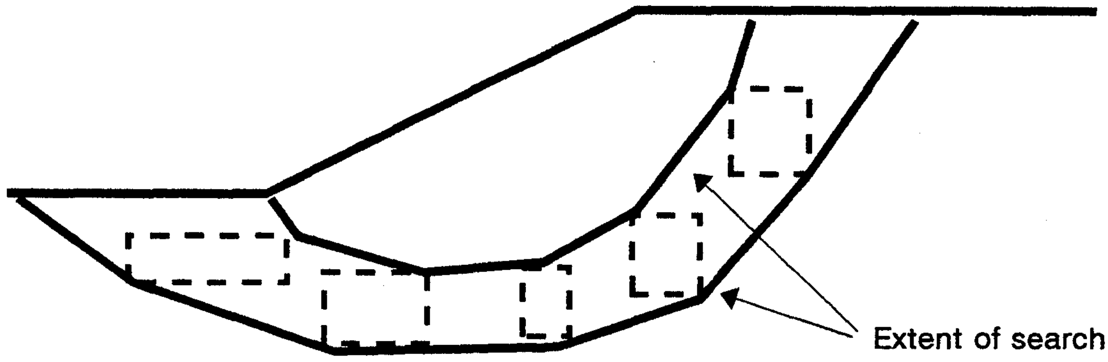
The boxes are required to be parallelograms with vertical slides. The top and bottom of a box may have any common inclination. Each box is specified by the length of its vertical sides, and two coordinate points which define the intersections of its centerline with its vertical sides (Figure 15). After the base of the central block is created, the active and passive portions of the trial failure surface are generated using line segments of equal specified length by techniques similar to those used by the circle and irregular trial failure surface generators.

Starting at the left end of the central block's base, a line segment of specified length is randomly directed between the limits of 0° and 45°, with respect to the horizontal (Figure 16). The chosen direction is biased towards selection of an angle closer to 45°. This process is repeated as necessary until intersection of a line segment with the ground surface occurs, completing the passive portion of the trial surface.

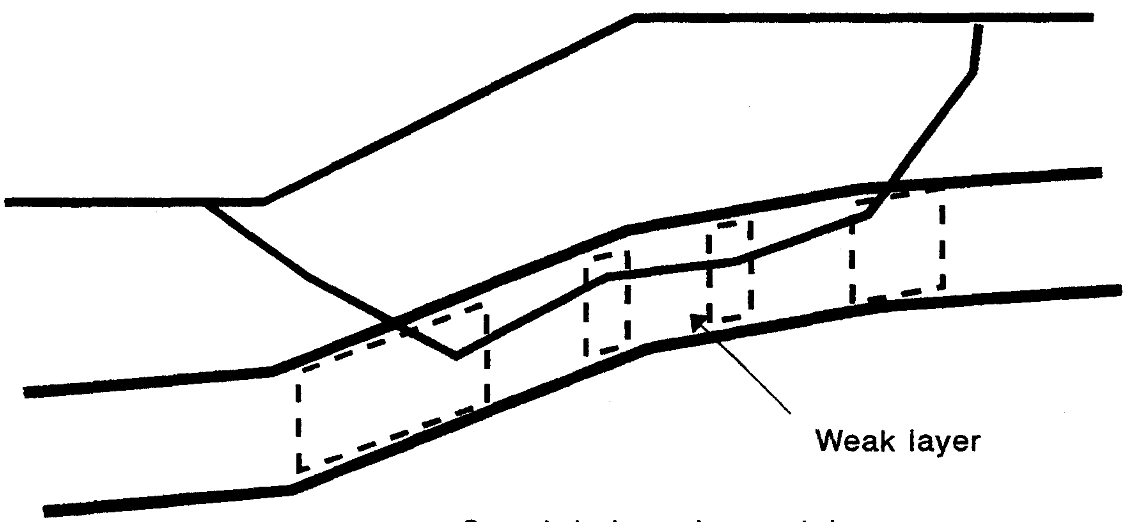
For the active portion of the trial failure surface, a similar process is used with the limits for selection of the random direction being 0° and 45° with respect to the vertical (Figure 15). The chosen direction is biased towards selection of an angle nearer 45°.

A modified version of the sliding block surface generator, named BLOCK2, generates active and passive portions of the sliding block surface according to the Rankine theory.

PASTABLM allows the use of more than two boxes for the formation of the central block (Figure 17).



Intensive search of critical zone previously defined by CIRCLE or RANDOM



Search in irregular weak layer

FIGURE 17. Sliding Block Generator using more than Two Boxes

The search may be limited to an irregularly shaped weak zone this way. Another application might be to conduct a search within a zone previously defined as being critical by use of the analysis command RANDOM. Degenerate cases of parallelogram boxes are permitted. For example, if the two points specified as the intersections of a parallelogram's centerline with its vertical sides are identical, and the length of the parallelogram's vertical sides is non-zero, then a vertical line segment, in effect, is defined. When a trial failure surface is generated, each point along the vertical line segment's length has an equal likelihood of becoming a point defining the surface. The vertical line segment could further degenerate into a point if a zero value is specified for the length of the parallelogram's vertical sides. Then all surfaces generated would pass through the single point.

One more case of a degenerate parallelogram is a line segment whose inclination and position is that of the parallelogram's centerline. For this case, the length of the vertical sides is zero, but the intersections of the parallelogram's centerline with its vertical sides are not identical. Again, any point along the length of the line segment has equal likelihood of becoming a point defining a generated trial failure surface.

i. Failure Surfaces cont. 'Spencer's Method'

Spencer's method of slices has been incorporated into PASTABLM to enhance the versatility of the program. Spencer's method satisfies both force and moment equilibrium of a sliding mass of soil, whereas the Simplified Janbu and Simplified Bishop methods satisfy only force or moment equilibrium, respectively. Detailed information concerning the derivation, and method of solution of Spencer's method of slices implemented in STABL5 and PCSTABL5 may be found in references 7 and 8.

The Spencer option may be invoked by specifying the command "SPENCR" and an estimate of the slope angle. The SPENCR command precedes specification of the surface type and method of solution; i.e. SURFAC, SURBIS, CIRCLE, CIRCL2, RANDOM, BLOCK or BLOCK2. One half of the user input slope angle is used by the program as an initial estimate of the slope of the interslice forces.

Since significantly more computation time is required for analysis of potential failure surfaces using Spencer's method of slices than either the Simplified Bishop or Simplified Janbu methods, the most efficient use of PASTABLM's capabilities will be realized if the user first investigates a number of potential failure surfaces using one of PASTABLM's random surface generation techniques, which determine the factor of safety using either the Simplified Janbu or Simplified Bishop method of slices.

Once critical potential failure surfaces have been identified, they may be analyzed using the SPENCR option in conjunction with either the SURFAC or SURBIS option, to obtain a factor of safety (FOS) satisfying both force and moment (i.e., complete) equilibrium. The reasonableness of the solution obtained, may be evaluated through examination of the line of thrust calculated by the Spencer routines.

When a user input potential failure surface is analyzed, the program outputs the value of the factor of safety with respect to force equilibrium (Ff), the value of the factor of safety with respect to moment equilibrium (Fm), and the angle of the interslice forces (theta) calculated during iteration, along with the value of FOS and theta satisfying complete equilibrium.

When a user input potential failure surface is analyzed, the coordinates of the line of thrust, the ratio of the height of the line of thrust above the sliding surface to the slice height for each slice, and the values of the interslice forces are all output. This information allows the user to quickly determine whether or not the line of thrust, and hence the solution, is satisfactory.

The Spencer option may also be used with the PASTABLM options that generate surfaces randomly. However, when the Spencer option is used in conjunction with randomly generated surfaces, only the FOS and angle of the interslice forces satisfying complete equilibrium, are output for the ten most critical surfaces. Information regarding the line of thrust, interslice forces or values of Ff, Fm and theta calculated during iteration is not output for randomly generated surfaces, hence the reasonableness of a solution obtained for a randomly generated surface will not be readily apparent.

When the reasonableness of the solution of a randomly generated surface is desired, the surface should be analyzed using the SPENCR option in conjunction with either the SURBIS or SURFAC option.

4. INPUT GUIDE

The following tables detail the data input requirements for PASTABLM. Each table describes the input necessary to enter, modify, suppress, and/or reactivate the data associated with a command. The first line of the table gives the Command Line information, consisting of the Command Code, e.g., PROFIL. The data associated with that command follows. Each "DATA LINE" corresponds to a new line in the input file. The data to be input are described and listed in order that they appear on the line together with the data type (integer or real). For example, the second line after a PROFIL Command is the data line containing (in order) the total number of boundaries and the number of surface boundaries. Both of these data are integers.

Input for Profile

COMMAND LINE	**PROFIL**	Command Code
DATA LINE	Title	Any alphanumeric characters, up to 80 long. The description will in the output two lines of forty characters
DATA LINE	Integer	Total number of boundaries
	Integer	Number of surface boundaries
DATA LINE	Real	X coordinate of left end of boundary (m)
	Real	Y coordinate of left end of boundary (m)
	Real	X coordinate of right end of boundary (m)
	Real	Y coordinate of right end of boundary (m)
	Integer	Soil type index number for material immediately beneath boundary

Note: Repeat preceding data line for each boundary.

Input for Soil Types

COMMAND LINE	**SOIL**	Command Code
DATA LINE	Integer	Number of soil types
DATA LINE	Real	Moist unit weight (kN/m^3)
	Real	Saturated unit weight (kN/m^3)
	Real	Isotropic strength intercept (kPa)
	Real	Isotropic strength angle (deg)
	Real	Pore pressure parameter
	Real	Pore pressure constant (kPa)
	Integer	Piezometric surface index number

Note: Repeat preceding data line for each soil type.

Input for Modifying Soil Types (if specified)

COMMAND LINE	**SOIL**	Command Code
DATA LINE	Integer	Number zero (0)
	Integer	Number of soil types to be modified
DATA LINE	Integer	Soil type number
	Real	Moist unit weight (kN/m^3)
	Real	Saturated unit weight (kN/m^3)
	Real	Isotropic strength intercept (kPa)
	Real	Isotropic strength angle (deg)
	Real	Pore pressure parameter
	Real	Pore pressure constant (kPa)
	Integer	Piezometric surface index number

Note: Repeat preceding data line for each soil type modified.

Input for Strength Anisotropy (if specified)

COMMAND LINE	**ANISO**	Command Code
DATA LINE	Integer	Number of anisotropic soil types
DATA LINE	Integer	Soil type index number
	Integer	Number of directional strength parameter data sets

Note: Repeat preceding data line and the following set of data LINEs for each anisotropic soil type.

DATA LINE	Real	Counterclockwise direction limit (deg)
	Real	Strength intercept (kPa)
	Real	Strength angle (deg)

Note: Repeat preceding data line for each range of direction.

Input for Suppressing or Reactivating Strength Anisotropy (if specified)

COMMAND LINE	**ANISO**	Command Code
DATA LINE	Integer	Number zero (0)

Input for Piezometric Surfaces* (if specified)

COMMAND LINE	**WATER**	Command Code
DATA LINE	Integer	Number of piezometric surfaces defined
	Real	Unit weight of water [if zero (0.) is specified, 9.81 (kN/m^3) is assumed].

Note: Repeat the following set of data lines for each piezometric surface.

DATA LINE	Integer	Number of points defining the water surface
DATA LINE	Real	X coordinate of points on water surface (m)
	Real	Y coordinate of points on water surface (m)

Note: Repeat preceding data line for each point on the piezometric surface.

* If one or more piezometric surfaces are specified, each soil type defined under command code SOIL must be assigned a piezometric surface index number of one of the piezometric surfaces defined, even though some soil types may be located totally above their piezometric surface. If no piezometric surface is specified, any number can be used as a piezometric surface index number for soil (Ref. 19).

Input for Suppressing or Reactivating Piezometric Surfaces (if specified)

COMMAND	**WATER**	Command Code
DATA LINE	Integer	Number zero (0)

Input for Boundary Loads (if specified)

COMMAND LINE	**LOADS**	Command Code
DATA LINE	Integer	Number of boundary loads
DATA LINE	Real	X coordinate of left end of boundary load (m)
	Real	X coordinate of right end of boundary load (m)
	Real	Intensity of boundary load (kPa)
	Real	Angle inclination of boundary load positive counterclockwise from vertical (deg)

Note: Repeat preceding data line for each boundary load.

Input for Suppressing or Reactivating Boundary Loads (if specified)

COMMAND LINE	**LOADS**	Command Code
DATA LINE	Integer	Number zero (0)

Input for Trial Surface Generation Limits (if specified)

COMMAND LINE	**LIMITS**	Command Code
DATA LINE	Integer	Total number of generation boundaries
	Integer	Number of generation boundaries which deflect upward
DATA LINE	Real	X coordinate of left end of generation boundary (m)
	Real	Y coordinate of left end of generation boundary (m)
	Real	X coordinate of right end of generation boundary (m)
	Real	Y coordinate of right end of generation boundary (m)

Note: Repeat preceding data line for each generation boundary.

Input for Suppressing or Reactivating Trial Surface Generation Limits (if specified)

COMMAND LINE	**LIMITS**	Command Code
DATA LINE	Integer	Number zero (0)

Input for Earthquake Load (if specified)

COMMAND LINE	**EQUAKE**	Command Code
DATA LINE	Real	Earthquake coefficient for horizontal acceleration (defined positive outwards from face of slope)*
	Real	Earthquake coefficient for vertical acceleration (defined positive upwards)*
	Real	Cavitation pressure (kPa)

*Negative values may be specified.

Input for Tieback Loads (if specified)

COMMAND LINE	**TIES**	Command Code
DATA LINE	Integer	Number of tieback loads
DATA LINE	Integer	Boundary number where tieback load is applied
	Real	X coordinate of the point of application of tieback load (m)
	Real	Y coordinate of the point of application of tieback load (m)
	Real	Load per tieback (kN)
	Real	Horizontal spacing between tiebacks (m)
	Real	Inclination of tieback load as measured clockwise from the horizontal plane (deg)
	Real	Free length of tieback (m) (Equal to zero if other than a tieback load)

Note: Repeat preceding data line for each tieback load.

Input for Suppressing or Reactivating Tieback Loads (if specified)

COMMAND LINE	**TIES**	Command Code
DATA LINE	Integer	Number zero (0)

TIES Input Restrictions

For completeness, all TIES input restrictions are given below.

1. The point of application of a tieback on the ground surface may not be at a ground surface boundary node. Use a slight offset from the node, (i.e. 70.01 instead of 70).

2. No more than 10 tieback loads can be specified; however, they can be in any order.

3. The inclination of a tieback must be equal to or greater than zero degrees and less than 180 degrees as measured clockwise from the horizontal.

4. The horizontal spacing between tiebacks must be greater than or equal to 1 meter.

5. The length of a tieback must be equal to or greater than zero meters. Zero is used for loads other than tieback type of loads.

Input for Reinforcing Layers (if specified)

COMMAND LINE	**REINF**	Command Code
DATA LINE	Integer	Number of reinforcing layers

Note: Repeat the following set of data lines for each reinforcing layer.

DATA LINE	Integer	Number of points defining the reinforcing layer
DATA LINE	Real	X coordinate of point on reinforcing layer (m)
	Real	Y coordinate of point on reinforcing layer (m)
	Real	Force in reinforcement at point, force/unit width, (kN/m)
	Real	Inclination factor: between 0.0 and 1.0; = 0.0 force acts in plane of reinforcement; = 1.0 force acts tangent to failure surface.

Note: Repeat preceding data line for each point defining the reinforcing layer.

Input for Suppressing of Reactivating Reinforcing Layers

COMMAND LINE	**REINF**	Command Code
DATA LINE	Integer	Number zero (O)

REINF Input Restrictions

1. No more than 40 reinforcing layers can be specified.
2. A reinforcing layer must be specified by at least 2 but not more than 40 points.
3. The reinforcing force must be positive.
4. The inclination factor must be between 0.0 and 1.0. A factor of 0.0 specifies that the reinforcing force acts in the direction of the reinforcement. A factor of 1.0 specifies that the force acts tangent to the failure surface.

Input for SPENCR Option (if specified)

COMMAND LINE	**SPENCR**	Command Code
DATA LINE	Real	Estimate of approximate slope angle with respect to horizontal (deg)

SPENCR Input Restrictions

The only input restrictions require that specification of the "SPENCR" option occur prior to specification of the method of surface generation and solution, i.e., SURFAC, CIRCL2, etc., and that the slope angle be greater than zero (deg) and less than or equal to 90 (deg).

Input for Specific Failure Surface (if specified)

COMMAND LINE	**SURFAC**	Command Code (or **SURBIS***)
DATA LINE	Integer	Number of points defining the failure surface
DATA LINE	Real	X coordinate of point on failure surface (m)
	Real	Y coordinate or point on failure surface (m)

Note: Repeat preceding data line for each point on the failure surface.

Input for Analysis of Specified Trial Surface (if specified)

COMMAND LINE	**EXECUT**	Command Code

For analysis of specified trial surface; follows X-Y coordinates (used with SURFAC or SURBIS.

*SURBIS for circular failure surfaces, Modified Bishop Factor of Safety

Input for Circular Surface Searching (if specified)

COMMAND LINE	**CIRCLE**	Command Code (or **CIRCL2***)
DATA LINE	Integer	Number of initiation points
	Integer	Number of surfaces to be generated from each initiation point
DATA LINE	Real	X coordinate of leftmost initiation point (m)
	Real	X coordinate of rightmost initiation point (m)
	Real	X coordinate of left termination limit (m)
	Real	X coordinate of right termination limit (m)
DATA LINE	Real	Minimum elevation of surface development (m)
	Real	Length of segments defining surfaces (m)
	Real	Counterclockwise direction limit for surface initiation (deg)
	Real	Clockwise direction limit for surface initiation (deg)

List for Irregular Surface Searching (if specified)

COMMAND LINE	**RANDOM**	Command Code
DATA LINE	Integer	Number of initiation points
	Integer	Number of surfaces to be generated from each initiation point
	Real	X coordinate of leftmost initiation point (m)
	Real	X coordinate of rightmost initiation point (m)
	Real	X coordinate of left termination limit (m)

*CIRCL2 for Modified Bishop Factor of Safety

DATA LINE	Real	X coordinate of right termination limit (m)
	Real	Minimum elevation of surface development (m)
	Real	Length of segments defining surfaces (m)
	Real	Counterclockwise direction limit for surface initiation (deg)
	Real	Clockwise direction limit for surface initiation (deg)

Input for Block Surface Searching (if specified)

COMMAND LINE	**BLOCK**	Command Code or **BLOCK2***)
DATA LINE	Integer	Total number of surfaces to be generated
	Integer	Number of boxes used to generate base of central block
	Real	Length of segments defining surfaces (m)
DATA LINE	Real	X coordinate of left end of centerline defining the box (m)
	Real	Y coordinate of left end of centerline defining the box (m)
	Real	X coordinate of right end of centerline defining the box (m)
	Real	Y coordinate of right end of centerline defining the box (m)
	Real	Length of vertical side of the box (m)

Note: Repeat preceding data line for each box.

*BLOCK2 is a sliding block surface generator modified from BLOCK, the difference being that BLOCK2 generates active and passive portions of the sliding blocks according to the Rankine Theory, where BLOCK generates these more randomly.

5. INPUT DATA SHEETS

The following eight pages contain data sheets to assist in file creation. The input data sheets are modeled after the input guide, section III.4.

PASTABLM input data sheets with associated commands:

Page 1 of 7 **PROFIL**
Page 2 of 7 **SOIL** and **ANISO**
Page 3 of 7 **WATER** and **LOADS**
Page 4 of 7 **LIMITS** and **EQUAKE**
Page 5 of 7 **TIES** and **REINF**
Page 6 of 7 **SPENCR**, **SURFAC**, **SURBIS**, and **EXECUT**
Page 7 of 7 **CIRCLE**, **CIRCL2**, **RANDOM**, **BLOCK**, **BLOCK2**
Page Supplemental for additional Reinforcement (**REINF**) Layers.

B. RUN TIME DATA

After PASTABLM begins execution and a title is displayed on the screen, the user is asked to input run identification and file information. PASTABLM requests the date, time, and user's name which are echoed on the output for run identification purposes only. The program then requests the input data and output file names. These must be entered in valid DOS format. The standard output can be directed to the printer by specifying "PRN" as the first (standard) output file name. The second output file name requested is for pen-plotted output. This optional output file is used as input to PLOT to generate pen plots on an HP plotter. If this file is not required, the user must enter "none", and no file is created. The computer PLOT program was part of STABL6 computer program and is not covered in this publication.

C. ERROR MESSAGES

PASTABLM checks all data, as they are being read in, for consistency with program requirements. If an inconsistency is found in data submitted, PASTABLM points it out by displaying an error indication. Unless the error is of a severe nature that demands immediate termination of execution, the program continues reading data and checking for more errors until a point is reached in execution where termination is required as a consequence of previously determined errors.

The errors are coded and referenced to descriptions in the next section. Each input error has a two digit number prefixed with two letters, associating the error with a particular command or class of errors. The prefixes are listed below and are detailed on the pages that follow.

SQ - Command SeQuence errors
FR   Free-form Reader errors
PF - error associated with command PROFIL
WA - error associated with command WATER
SP - error associated with command SPENCR
SF - error associated with command SURFAC
LM - error associated with command LIMITS

LD - error associated with command LOADS
SL - error associated with command SOIL
AI - error associated with command ANISO
RC - error associated with command RANDOM and CIRCLE
BK - error associated with command BLOCK
TI - error associated with command TIES
RF - error associated with command REINF

Command Sequence Errors

SQ01 - A command other than PROFIL has been used as the first command in the execution sequence. The first command must be PROFIL. PROFIL initializes PASTABLM prior to reading all data pertinent to the definition of a problem. All data that would have been read prior to encountering the first use of command PROFIL would have been nullified and would not have been made available to PASTABLM for the purpose of analyzing the first problem.

SQ02 - An attempt to compute the factor of safety of a specified trail failure surface with command EXECUT has been aborted. The isotropic soil parameters describing the soil types of the current problem do not exist. After each use of command PROFIL in an execution sequence, the isotropic soil parameters of each soil type must be specified by use of command SOIL before command EXECUT may be used. Each time a new problem is introduced in an execution sequence by command PROFIL, the soil parameters describing soil types of preceding problems are no longer available for use.

SQ03 - An attempt to compute the factor of safety of an unspecified trial failure surface with command EXECUT has been aborted. After each use of command PROFIL, CIRCLE, RANDOM or BLOCK, a trial failure surface must be specified with command SURFACE before command EXECUT may be used.

SQ04 - The command ANISO has been used without the isotropic soil parameters being defined. Anisotropic strength data may not be specified unless the isotropic parameters have been defined by command SOIL after the last use of command PROFIL

SQ05 - An attempt to use one of the commands, RANDOM, CIRCLE, or BLOCK has been aborted. The isotropic soil parameters describing the soil types of the current problem do not exist. After each use of command PROFIL in an execution sequence, the isotropic soil parameters of each soil type must be specified by use of command SOIL before any of the above mentioned commands may be used. Each time a new problem is introduced in an execution sequence by command PROFIL, the soil parameters describing soil types of preceding problems are no longer available for use.

Free-form Reader Error Codes

FR01 - Data are insufficient to continue execution. An attempt was made to read beyond the last data item specified. Check for missing data items or for gaps between data items on each line larger than one blank space. This error only occurs at the end of an execution sequence within the data provided with the last command used.

FR02 - The line of data displayed begins with one or more blank spaces or may be entirely blank. The first item of data of each line is required to begin in the first column. Lines entirely blank are not permitted.

FR03 - Within the line of data displayed, a decimal point has been detected for a number of read as an integer. An First check if any numbers intended to be integers contain a decimal point. If not, check if error is indirectly caused by a placement of data read. Causes of displacements are discussed below.

FR04 - Within the line of data displayed, a minus sign has been detected for a number read as an integer. All integers are required to be positive. Negative integers are never required as input for PASTABLM. This error may be caused indirectly by displacement of data read. Causes of displacements are discussed below.

FR05 - Within the line of data displayed, an illegal character has been detected for a number read as an integer. Only numeric characters and decimal points are allowed. If a command word is displayed, the data provided with the previous command was not sufficient to complete its execution. Check for a displacement of data read. Causes of displacements are discussed below.

FR06 - Within the line of data displayed, a decimal point was not detected for a number read as a real number. A real number is required to contain a decimal point. First check if any numbers intended to be real numbers lack decimal points. If not, check if error is indirectly caused by a displacement of data read. Causes of displacements are discussed below.

FR07 - Within the line of data displayed, an illegal character has been detected for a number read as a real number. Only numeric characters, decimal point, and minus sign are allowed. If a command word is displayed, the data provided with the previous command was not sufficient to complete its execution. Check for a displacement of data read. Causes of displacements are discussed below. Displacements of data read are caused either by inadvertently omitting items of data or by leaving gaps between items of data larger than one blank space. Data items following a gap larger than one blank space are not read. Instead, data from that next line are read in their place, producing a displacement of data from that point on.

At some point following the displacement, an error will be produced indirectly. A real number might be read as an integer, or vice versa, producing error FR03 or FR06 respectively.

A negative real number read as an integer will also produce error FR04. When a displacement occurs, and if none of the above errors are produced, the numeric data will be exhausted and finally a command word will be read as numeric data producing error FR05 or FR07 depending upon whether an integer or real number was being read.

If cause of displacement is not found in the displayed line of data, check the preceding lines of data.

PROFIL Error Codes

PF01 - The number of ground surface boundaries exceeds the total number of profile boundaries. The number of profile boundaries must be less than or equal to the total number of profile boundaries.

PF02 - The number of profile boundaries specified may not exceed 100. The problem must be either redefined so fewer profile boundaries are used, or the dimensioning of the program must be increased to accommodate the problem so defined.

PF03 - A negative coordinate has been specified for the profile boundary indicated. All problem geometry must be located within the 1st quadrant.

PF04 - The coordinates of the end points of the profile boundary indicated have not been specified in the required order. The coordinates of the left end point must precede those of the right.

PF05 - The ground surface boundaries indicated are not properly ordered or are not continuously connected. The ground surface boundaries must be specified from left to right and the ground surface described must be continuous.

PF06 - The required subsurface boundary order is unsatisfied for the two boundaries indicated. Of boundaries which overlap horizontally, those above the others must be specified first.

WATER Error Codes

WA01 - An attempt has been made to suppress or reactivate undefined water surface data. Data must be defined by a prior use of command WATER before they can be suppressed. Suppressed data can not be reactivated if command PROFIL has been used in the execution sequence subsequent to their suppression. Command PROFIL nullifies all data read prior to their use whether the data are active or suppressed.

WA02 - The number of points specified to define the water surface exceeds 40. The problem must be either redefined so fewer points are used, or the dimensioning of the program must be increased to accommodate the problem as defined.

WA03 - Only one point has been specified to define the water surface. A minimum of two points is required.

WA04 - A negative coordinate has been specified for the water surface point indicated. All problem geometry must be located within the 1st quadrant.

WA05 - The water surface point indicates is not to the right of the points specified prior to it. The points defining the water surface must be specified in left to right order.

SPENCR Error Codes

SP01 - An incorrect value for the approximate slope angle has been specified. The slope angle specified must be greater than zero (deg) and less than 90 (deg).

SURFAC Error Codes

SF01 - The number of points specified to define a trial failure surface exceeds 100. The problem must be either redefined so fewer points are used, or the dimensioning of the program must be increased to accommodate the problem as defined.

SF02 - Only one point has been specified to define the trial failure surface. A minimum of two points is required.

SF03 - A negative coordinate has been specified for the trial failure surface point indicated. All problem geometry must be located within the 1st quadrant.

SF04 - The trial failure surface point indicate is not to the right of the points specified prior to fit. The points defining the trial failure surface must be specified in left to right order, and no two points are allowed to define a vertical line.

SF05 - The first point specified for the trial failure surface is not within the horizontal extent of the defined ground surface. All points defining a trail failure surface must be within the horizontal extent of the defined ground surface.

LIMITS Error Codes

LM01 - An attempt has been made to suppress or reactivate undefined surface generation boundary data. Data must be defined by a prior use of command LIMITS before they can be suppressed. Suppressed data can not be reactivated if command PROFIL has been used in the execution sequence subsequent to their suppression. Command PROFIL nullifies all data read prior to their use whether the data are active or suppressed.

LM02 - The number of surface generation boundaries specified to deflect upward exceeds the total number of boundaries specified. The number of upward deflecting boundaries must not exceed the total number of boundaries.

LM03 - The number of surface generation boundaries specified exceeds 20. The problem must be either redefined so fewer surface generation boundaries are used, or the dimensioning of the program must be increased to accommodate the problem as defined.

LM04 - A negative coordinate has been specified for the surface generation boundary indicated. All problem geometry must be located within the 1st quadrant.

LM05 - The coordinates of the end points of the surface generation boundary indicated have not been specified in the required order. The coordinates of the left end point must precede those of the right.

LOADS Error Codes

LD01 - An attempt has been made to suppress or reactivate undefined surcharge boundary loads. Data must be defined by a prior use of command LOADS before they can be suppressed. Suppressed data can not be reactivated if command PROFIL has been used in the execution sequence subsequent to their suppression. Command PROFIL nullifies all data read prior to their use, whether the data are active or suppressed.

LD02 - The number of surcharge boundary loads specified exceeds 10. The problem must be either redefined so fewer loads are used, or the dimensioning of the program must be increased to accommodate the problem as defined.

LD03 - A negative coordinate has been specified for the surcharge boundary load indicated. All problem geometry must be located within the 1st quadrant.

LD04 - The X coordinates defining the horizontal extent of the surcharge boundary load indicated have not been specified in the required order. The X coordinate of the left end of the load must precede the X coordinate of the right end.

LD05 - The surcharge boundary load indicated is not to the right of all the loads specified prior to it or overlaps one or more of them. The loads must be specified left to right and are not allowed to overlap.

SOIL Error Codes

SL01 - The profile boundary indicated with the error message has an undefined soil type index. The number of soil types specified must be greater than or equal to each soil type index which has been assigned to profile boundaries.

SL02 - The number of soil types may not exceed 20. The problem must be either redefined so fewer soil types are used, or the dimensioning of the program must be increased to accommodate the problem as defined

SL03 - An attempt has been made to change the parameters of one or more soil types which are undefined. No soil types have been defined since the last use of command PROFIL. When a new problem is introduced by command PROFIL, the soil parameters, describing soil types of preceding problems in the execution sequence, are no longer available for use and cannot therefore be changed.

SL04 - The number of soil types to be changed is greater than the total number of soil types already defined. This implies changing isotropic soil parameters of soil types which have been specified and therefore is not permitted. The number of soil types to be changed must be less than or equal to the number of soil types specified by a previous use of command SOIL. Each soil type must be previously specified, before its parameters may be changed.

SL05 - An attempt has been made to change the parameters describing an unspecified soil type. The soil type must be defined before it may be modified. The index of each soil type to be changed must be less than the total number of soil types.

ANISO Error Codes

AI01 - An attempt has been made to suppress or reactivate undefined anisotropic strength data. Data must be defined by a prior use of command ANISO before they can be suppressed. Suppressed data can not be reactivated if command PROFIL has been used in the execution sequence subsequent to their suppression. Command PROFIL nullifies all data read prior to their use whether the data are active or suppressed.

AI02 - The number of anisotropic soil types specified may not exceed the number of soil types specified by command SOIL.

AI03 - The number of anisotropic soil types specified exceeds 5. The problem must be either redefined so fewer anisotropic soil types are used, or the dimensioning of the program must be increased to accommodate the problem as defined.

AI04 - The soil type index indicated is greater than the number of soil types specified by command SOIL. The index of each anisotropic soil type must be less than or equal to the number of soil types specified.

AI05 - The number of direction ranges specified for the anisotropic soil type indicated is less than 2 or exceeds 10. No soil type should be defined anisotropic with number of direction ranges less than 2, as this means soil is isotropic. Also no soil type should exceed 10 direction ranges. If this is desired, the dimensions of the program must be increased.

AI06 - The counterclockwise limit of each direction range must be specified in counterclockwise order, if the anisotropic strength is to be properly defined for the anisotropic soil type indicated.

AI07 - The total direction range for the anisotropic soil type indicated has not been completely defined. The counterclockwise limit of the last direction range specified must be 90 degrees.

RANDOM and CIRCLE Error Codes

RC01 - The first initiation point lies to the left of the defined ground surface. The x coordinate of the first initiation point must be specified so all trial failure surfaces generated will intersect the defined ground surface when they initiate.

RC02 - The first and last initiation points are not correctly specified. They must be specified in left-right order.

RC03 - The last initiation point lies to the right of the defined ground surface. The x coordinate of the last initiation point must be specified so all trial failure surfaces generated will intersect the defined ground surface when they initiate.

RC04 - The right termination limit lies to the right of the defined ground surface. The right termination limit must be specified so all trial failure surfaces generated will intersect the defined ground surface when they terminate.

RC05 - The left and right termination limits are not correctly specified. They must be specified in left-right order.

RC06 - The last initiation point lies to the right of the right termination limit. It is impossible to successfully generate any trial failure surfaces, when the initiation point lies to the right of the right termination limit.

RC07 - The depth limitation for trial failure surface development is negative. The depth limitation must be set at or above the x axis so the generated trial failure surfaces will not be allowed to develop below it.

RC08 - The length specified for the line segments used to generate trial failure surfaces is less than or equal to zero. The length must be greater than zero.

RC09 - An initiation point is below the depth limitation. The depth limitation must be set lower to enable the successful generation of trial failure surfaces from all initiation points.

RC10 - The number of points defining a generated trial failure surface exceeds 100. The length specified for the line segments must be increased.

RC11 - 200 attempts to generate a single trial failure surface have failed. The search limitations are either too restrictive, or they actually prevent successful generation of a trial failure surface from one or more of the initiation points. Check and revise the search limitations or use an alternative trial surface generator.

RC12 - Fewer than 10 trail failure surfaces have been specified to be generated. A minimum of 10 must be generated.

RC13 - The angle specified as clockwise direction limit for surface generation is larger than the angle specified as counterclockwise direction limit. This is not correct. Check to see if angles have been reversed.

BLOCK Error Codes

BK01 - The number of boxes specified for a sliding block search exceeds 10. The problem must be either redefined so fewer points are used, or the dimensioning of the program must be increased to accommodate the problem as defined

BK02 - The length specified for the line segments used to generate the active and passive portions of the trial failure surfaces is less than or equal to zero. The length must be greater than zero.

BK03 - The two coordinate points specified to define the centerline of the box indicated have not been specified correctly. The left point must be specified first.

BK04 - The box indicated and the one specified before it are not properly ordered, or they overlap. All boxes must be specified in left to right order and the boxes are not allowed to overlap one another.

BK05 - The box indicated is wholly or partially defined outside of the 1st quadrant. All problem geometry must be located within the 1st quadrant.

BK06 - The box indicated is wholly or partially above the defined ground surface. Each box must be defined totally below the ground surface.

BK07 - It is not possible to complete the passive portion of the failure surface from part of or all of the first box specified. The first box specified must be entirely to the right of a fictitious line extended downward at forty-five degrees with horizontal from the left end of the defined ground surface. Note: **No** BK08 Error code.

BK09 - The number of points defining a generated trial failure surface exceeds 100. The length specified for the line segments of the active and passive portions of the generated trial failure surfaces must be increased.

BK10 - 200 attempts to generate a single trial failure surface have failed. The search limitations are either too restrictive or they actually prevent successful generation of a trail failure surface. Check and revise the search limitations or use an alternate trial surface generator.

BK11 - Fewer than 10 trial failure surfaces have been specified to be generated. A minimum of 10 must be generated.

BK12 - The point(s) calculated on active or passive portion of the sliding block is not within the horizontal extent of the defined ground surface. Either the specified boxes should be changed or the geometry of the problem should be extended to include the point(s) in question.

TIES Error Codes

TI01 - An attempt has been made to suppress or reactivate undefined tieback loads. Data must be defined by a prior use of command TIES before they can be suppressed. Suppressed data can not be reactivated if command PROFIL has been used in the execution sequence subsequent to their use, whether the data are active or suppressed.

TI02 - The number of tieback loads specified exceeds 10. The problem must either be redefined so fewer tieback loads are used, or dimensioning of the program must be increased to accommodate the problem as defined.

TI03 - A negative coordinate has been specified for the tieback load indicated or the calculated Y coordinate of the end of the tieback is negative. All problem geometry must be located within the 1st quadrant.

TI04 - The inclination limits have been exceeded for the tieback load indicated. The inclination of a tieback load must be equal to or greater than zero (deg) and less than 180 (deg) as measured clockwise from the horizontal.

TI05 - The point of application of the tieback load specified does not lie on the ground surface boundary specified. Check the boundary number specified and the X and Y coordinate of the point of application of the tieback load indicated.

TI06 - The horizontal spacing between tiebacks for the row of tiebacks indicated is incorrect. The horizontal spacing between tiebacks must be greater than or equal to 1 meter.

TI07 - The length of the tieback indicated is incorrect. The length of a tieback must be greater than or equal to zero (m). Zero is used for loads other than tieback type of loads.

REINF Error Codes

RF01 - An attempt has been made to suppress or reactivate undefined reinforcing layers. Data must be defined by prior use of command REINF before they can be suppressed. Suppressed data can not be reactivated if command PROFIL has been used in the execution sequence subsequent to use of REINF, whether the data are active or suppressed.

RF02 - The number of reinforcing layers specified exceeds 40. The problem must either be redefined so fewer reinforcing layers are used or dimensioning of the program must be increased to accommodate the problem as defined.

RF03 - The number of points defining a reinforcing layer exceeds 40. The problem must be either redefined so fewer points are used or the dimensioning of the program must be increased to accommodate the problem as defined.

RF04 - A negative coordinate has been specified for the reinforcing layer and Point number Indicated. All problem geometry must be located within the first quadrant.

RF05 - A negative reinforcing force has been specified for the reinforcing layer and point number indicated. The reinforcing force must be zero or positive.

RF06 - An inadmissible inclination factor has been specified for the reinforcing layer and point number indicated. The inclination factor must be between 0.0 and 1.0.

RF07 - The reinforcing layer and point number indicated is not to the right of the points specified prior to it. The points defining the reinforcing layer must be specified in left to right order.

RF08 - The reinforcing layer indicated is specified by only one point. The reinforcing layer must be specified by at least two points.

RF09 - An attempt has been made to use the reinforcing layer option with the simplified Janbu method of analysis. The reinforcing layer option can only be used with the simplified Bishop method of analysis.

IV. PROGRAM OPERATION

PASTABLM is an easy program to operate. The first step is the creation of input data files using any text editor. Data files are described in Section III.A.

Operation of PASTABLM is very straight-forward. After an input file has been created using a text editor, the user types "PASTABLM" in either uppercase or lowercase letters followed by a return. The program will be loaded into memory and will prompt the user for the current date, time, name of the user, input filename, output filename, and filename for subsequent plotting of output. Note that the input and output files do not need to be on the same diskette or disk drive with PASTABLM. Disk drive specifications may be used when invoking PASTABLM (i.e., B:PASTABLM), or when specifying input and output files (i.e., A:EXAMPLE1.OUT). If an invalid or nonexistent input filename is specified, the operating system will display an error message to the screen and return the user to the DOS prompt.

Filenames for the output file and the optional plotted output file may be any legal DOS filename. Output may be sent directly to the printer by specifying "PRN" as the filename.

Note that an existing output file on a diskette will be overwritten if an existing output filename is reused. To avoid overwriting existing files, use unique names for each output. All responses to prompts may be uppercase or lowercase characters, including numbers and legal DOS filename symbols. The program will write the output to the screen and the output file simultaneously. This includes the input parameters, method of analysis, and results. When running a problem which analyzes many surfaces, no output will be written to the screen while trial failure surfaces are being generated and analyzed. After all surfaces have been generated and analyzed, and the ten most critical factors of safety sorted, the program will resume displaying the results to the screen.

V. SAMPLE INPUT/OUTPUT

The examples presented in this section are supplied on the distribution diskette for PASTABLM, as are their resulting output files.

Each example follows a similar format. First is a listing of the input data set and the sample terminal session showing what the user responded when prompted by the terminal during execution of PASTABLM. PASTABLM echoes the output to the screen as it creates the output file. This echo is not shown. The last part is the output file. The character plot generated on the printer has been marked for the user to aid in confirming the input configuration.

A. EXPLANATION OF GRAPHICAL OUTPUT

PASTABLM generates a character plot. The resolution is low; characters are spaced ten per division along the vertical axis and six per division along the horizontal axis. As a result, more than one point may be scaled within the same plot position. When this occurs, the point with the highest priority will be represented by its print character. Print characters used by PASTABLM and the points they represent are listed below in order of priority, with highest priority first.

*	end points of ground surface and subsurface profile boundaries.
L	end points defining surface generation boundaries.
W	points defining the water surface
1	points defining the most critical generated surface
2	points defining the second most critical generated surface
3	points defining the third most critical generated surface
4	points defining the fourth most critical generated surface
5	points defining the fifth most critical generated surface
6	points defining the sixth most critical generated surface
7	points defining the seventh most critical generated surface
8	points defining the eighth most critical generated surface
9	points defining the ninth most critical generated surface
0	points defining the tenth most critical generated surface
.	points defining the remaining generated surfaces
S	points defining a specified trial failure surface
/	points defining the location of surcharge boundary loads
T	points defining the location of tieback loads
R	points defining the location of reinforcement layers

The location of uniformity distributed surcharge boundary loads are represented with a combination of slashes and numerals. Load inclinations are not indicated on print character plots.

The plots are intended to be viewed with the printed output rotated 90° counterclockwise, so the left side of each print character is face down. Viewing a plot at this orientation, the numbers above slashes represent the left ends of a corresponding surcharge boundary loads. Likewise numbers below slashes represent the right ends of corresponding surcharge boundary loads.

If the extent of a surcharge load is narrow, both the left and right end may appear within the same horizontal print position. The number of that surcharge boundary load then appears both above and below a single slash. Occasionally, when surcharge boundary loads of narrow extent are located adjacent to other loads, some load numbers may be absent.

B. EXAMPLES

The following examples are placed in this publication to give the user a general understanding in the use of this program.

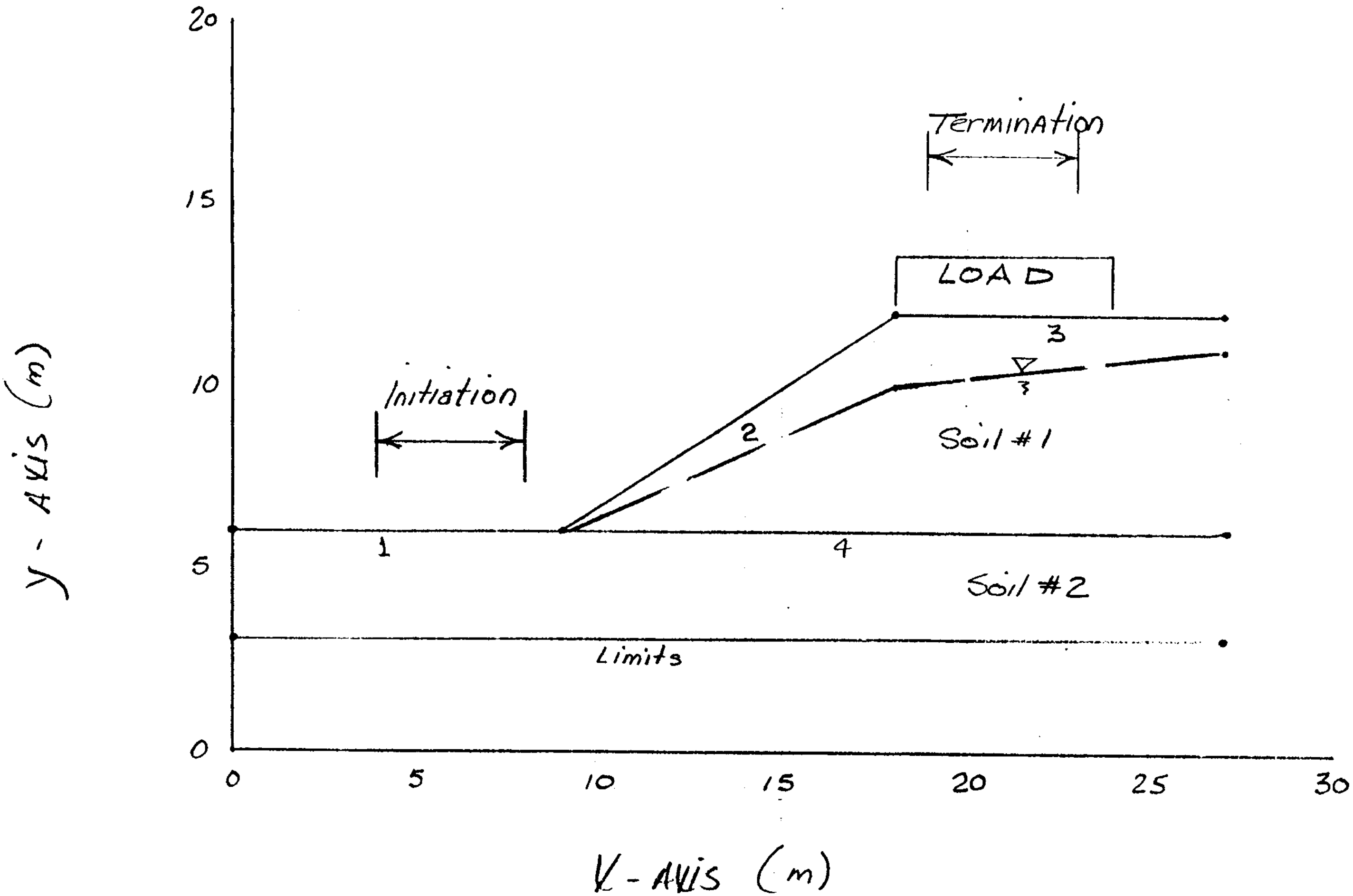
Example 1: A 1:1.5 slope placed on existing ground using optional WATER and LOAD Commands. The CIRCLE command was used for the analysis method.

Example 2: A near vertical wall placed with 2 rows of tieback anchors, utilizing the optional WATER and TIES commands. Analysis method used was SURFAC.

Example 3: A 12 layer geosynthetic reinforced 1:1.5 slope placed on existing ground. The SURBIS command was used for the analysis method.

EXAMPLE 1

B. Example 1 (Initial drawing for analysis)



B. Example 1 (Computer Session)

```
C:\TESTING>PASTABLM
Date...........................  08/27/96

Time of Run....................  10:10 AM

Your Name or Initials..........  KJR

Input Data Filename............  EXAMPLE1.IN

Output Filename................  EXAMPLE1.OUT

Plotted Output Filename
(Enter "None" if not desired)....  EXAMPLE1.PLT
Stop - Program terminated.

C:\TESTING>
```

Example 1 (Input data file)

```
PROFIL
Metric versions with a 1:1.5 Slope
4 3
0. 6. 9. 6. 2
9. 6. 18. 12. 1
18. 12. 27. 12. 1
9. 6. 27. 6. 2
SOIL
2
19.63 20.41 6.20 22. 0. 0. 0
18.84 19.63 9.58 20. 0. 0. 0
WATER
1 0.
4
0. 6.
9. 6.
18. 10.
27. 11.
LOADS
1
18. 24. 12.0 0.0
LIMITS
1 0
0. 3. 27. 3.
CIRCLE
5 5
4. 8. 19. 23.
0. 1. 0. 0.
```

** PASTABLM **

Adapted From PCSTABL6
by
Pennsylvania Department of Transportation
Geotechnical Section
(Metricated 7/96)

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date:	08/27/96
Time of Run:	10:10 AM
Run By:	KJR
Input Data Filename:	EXAMPLE1.IN
Output Filename:	EXAMPLE1.OUT
Plotted Output Filename:	EXAMPLE1.PLT

PROBLEM DESCRIPTION   Metric versions with a 1:1.5 Slope

BOUNDARY COORDINATES

3 Top Boundaries
4 Total Boundaries

Boundary No.	X-Left (m)	Y-Left (m)	X-Right (m)	Y-Right (m)	Soil Type Below Bnd
1	.00	6.00	9.00	6.00	2
2	9.00	6.00	18.00	12.00	1
3	18.00	12.00	27.00	12.00	1
4	9.00	6.00	27.00	6.00	2

ISOTROPIC SOIL PARAMETERS

2 Type(s) of Soil

Soil Type No.	Total Unit Wt. (kN/m3)	Saturated Unit Wt. (kN/m3)	Cohesion Intercept (kPa)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (kPa)	Piez. Surface No.
1	19.6	20.4	6.2	22.0	.00	.0	0
2	18.8	19.6	9.6	20.0	.00	.0	0

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water =   9.81 kN/m3

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (m)	Y-Water (m)
1	.00	6.00
2	9.00	6.00
3	18.00	10.00
4	27.00	11.00

BOUNDARY LOAD(S)

1 Load(s) Specified

Load No.	X-Left (m)	X-Right (m)	Intensity (kPa)	Deflection (deg)
1	18.00	24.00	12.0	.0

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

Searching Routine Will Be Limited To An Area Defined By 1 Boundaries
Of Which The First 0 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (m)	Y-Left (m)	X-Right (m)	Y-Right (m)
1	.00	3.00	27.00	3.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

25 Trial Surfaces Have Been Generated.

5 Surfaces Initiate From Each Of 5 Points Equally Spaced
Along The Ground Surface Between X = 4.00 m.
and X = 8.00 m.

Each Surface Terminates Between X = 19.00 m.
and X = 23.00 m.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = .00 m.

1.00 m. Line Segments Define Each Trial Failure Surface.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	8.00	6.00
2	8.98	5.79
3	9.97	5.68
4	10.97	5.68
5	11.97	5.80
6	12.94	6.02
7	13.88	6.35
8	14.79	6.78
9	15.64	7.30
10	16.42	7.92
11	17.14	8.62
12	17.77	9.39
13	18.32	10.23
14	18.77	11.13
15	19.09	12.00

*** 1.165 ***

Failure Surface Specified By 20 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	6.00	6.00
2	6.89	5.54
3	7.82	5.18
4	8.79	4.91
5	9.77	4.74
6	10.77	4.67
7	11.77	4.70
8	12.76	4.83
9	13.73	5.05
10	14.68	5.38
11	15.59	5.79
12	16.45	6.30
13	17.26	6.89
14	18.00	7.56
15	18.68	8.29
16	19.28	9.10
17	19.79	9.95
18	20.22	10.86
19	20.55	11.80
20	20.60	12.00

*** 1.239 ***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	8.00	6.00
2	8.96	5.73
3	9.94	5.53
4	10.94	5.42
5	11.94	5.39
6	12.94	5.43
7	13.93	5.56
8	14.90	5.77
9	15.86	6.06
10	16.79	6.43
11	17.69	6.87
12	18.55	7.38
13	19.37	7.95
14	20.13	8.60
15	20.84	9.30
16	21.50	10.06
17	22.08	10.87
18	22.60	11.72
19	22.74	12.00

*** 1.268 ***

Failure Surface Specified By 20 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	7.00	6.00
2	7.84	5.46
3	8.74	5.01
4	9.68	4.67
5	10.65	4.43
6	11.64	4.30
7	12.64	4.28
8	13.63	4.37
9	14.61	4.57
10	15.57	4.88
11	16.48	5.29
12	17.34	5.79
13	18.14	6.39
14	18.87	7.08
15	19.52	7.83
16	20.09	8.66
17	20.56	9.54
18	20.92	10.47
19	21.19	11.44
20	21.28	12.00

*** 1.285 ***

Failure Surface Specified By 20 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	7.00	6.00
2	7.83	5.45
3	8.72	4.99
4	9.66	4.63
5	10.62	4.38
6	11.61	4.24
7	12.61	4.21
8	13.61	4.29
9	14.59	4.49
10	15.54	4.79
11	16.46	5.20
12	17.32	5.70
13	18.12	6.30
14	18.85	6.98
15	19.50	7.75
16	20.06	8.57
17	20.52	9.46
18	20.88	10.39
19	21.14	11.36
20	21.23	12.00

*** 1.293 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	7.00	6.00
2	7.86	5.49
3	8.76	5.06
4	9.70	4.72
5	10.67	4.47
6	11.66	4.31
7	12.66	4.25
8	13.66	4.28
9	14.65	4.41
10	15.62	4.63
11	16.57	4.94
12	17.49	5.35
13	18.36	5.83
14	19.18	6.40
15	19.95	7.05
16	20.65	7.76
17	21.28	8.54
18	21.83	9.37
19	22.30	10.25
20	22.69	11.17
21	22.94	12.00

*** 1.336 ***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	6.00	6.00
2	6.76	5.35
3	7.58	4.78
4	8.46	4.30
5	9.38	3.92
6	10.35	3.64
7	11.33	3.47
8	12.33	3.41
9	13.33	3.45
10	14.32	3.60
11	15.28	3.85
12	16.22	4.21
13	17.11	4.67
14	17.94	5.22
15	18.71	5.85
16	19.41	6.57
17	20.03	7.35
18	20.56	8.20
19	20.99	9.10
20	21.33	10.05
21	21.56	11.02
22	21.69	12.00

*** 1.383 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	8.00	6.00
2	8.82	5.43
3	9.70	4.95
4	10.62	4.56
5	11.58	4.28
6	12.57	4.10
7	13.56	4.03
8	14.56	4.07
9	15.55	4.21
10	16.52	4.46
11	17.46	4.81
12	18.35	5.26
13	19.19	5.80
14	19.97	6.43
15	20.67	7.14
16	21.30	7.92
17	21.83	8.77
18	22.28	9.66
19	22.62	10.60
20	22.87	11.57
21	22.93	12.00

*** 1.398 ***

Failure Surface Specified By 21 Coordinate Points

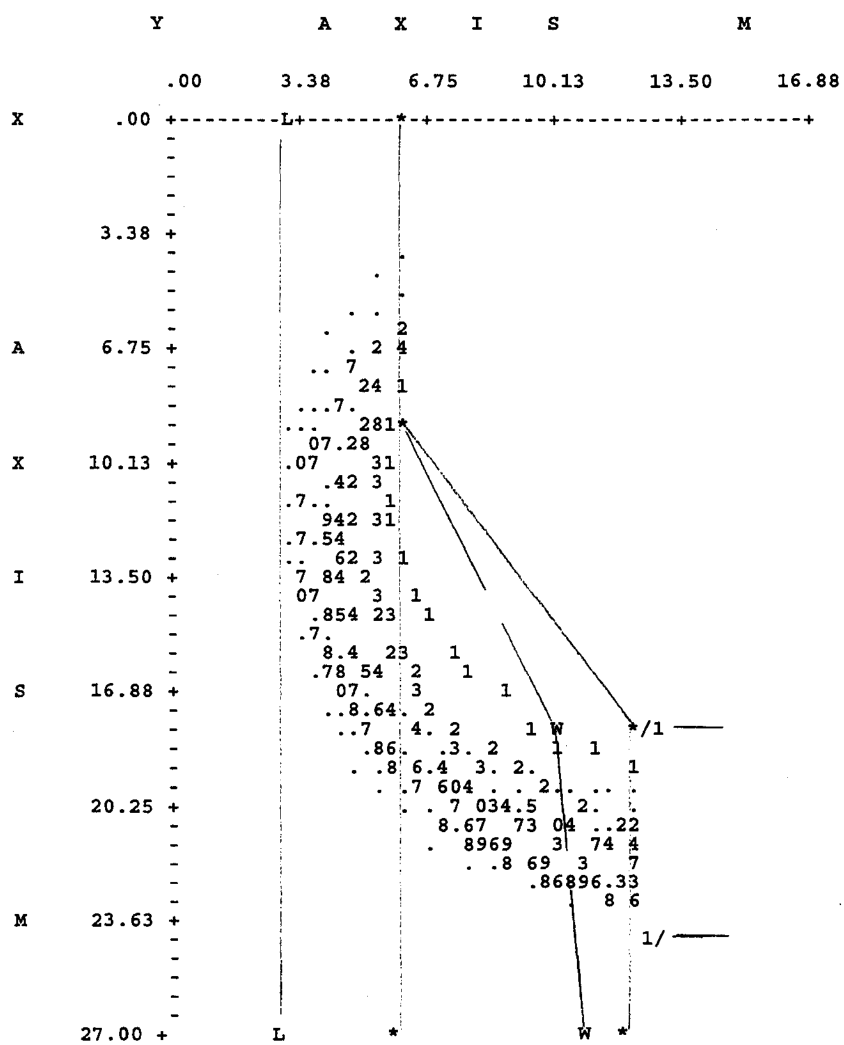
Point No.	X-Surf (m)	Y-Surf (m)
1	8.00	6.00
2	8.80	5.40
3	9.67	4.90
4	10.58	4.50
5	11.54	4.21
6	12.52	4.02
7	13.52	3.95
8	14.52	3.98
9	15.51	4.13
10	16.47	4.40
11	17.40	4.76
12	18.28	5.23
13	19.11	5.80
14	19.86	6.46
15	20.54	7.19
16	21.13	8.00
17	21.62	8.87
18	22.02	9.79
19	22.30	10.75
20	22.48	11.73
21	22.50	12.00

*** 1.400 ***

Failure Surface Specified By 22 Coordinate Points

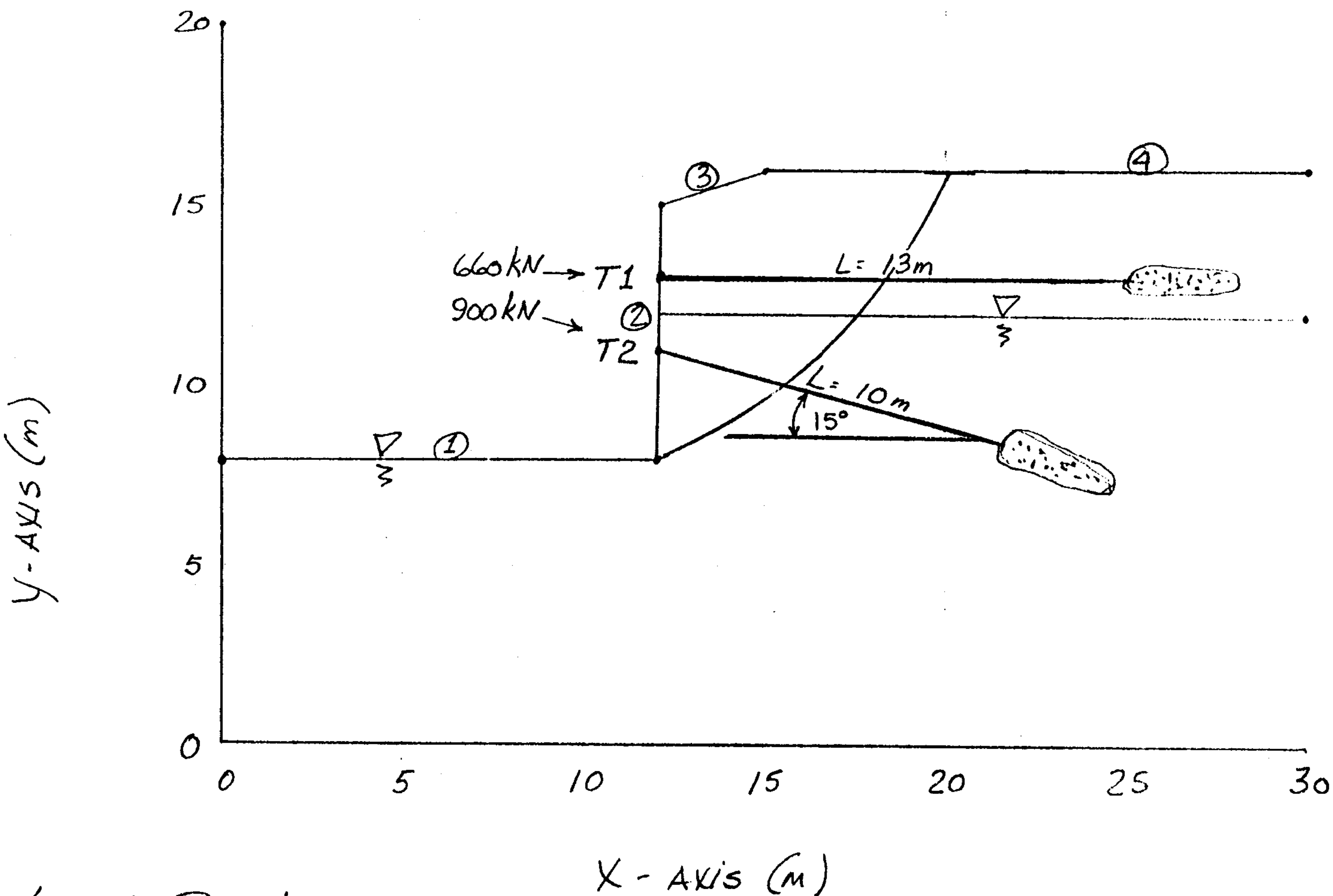
Point No.	X-Surf (m)	Y-Surf (m)
1	6.00	6.00
2	6.73	5.32
3	7.54	4.73
4	8.40	4.23
5	9.32	3.83
6	10.28	3.53
7	11.26	3.35
8	12.26	3.27
9	13.25	3.31
10	14.24	3.46
11	15.21	3.72
12	16.14	4.08
13	17.02	4.55
14	17.85	5.12
15	18.61	5.77
16	19.29	6.50
17	19.88	7.31
18	20.38	8.17
19	20.78	9.09
20	21.07	10.05
21	21.25	11.03
22	21.33	12.00

*** 1.406 ***


Y A X I S M
.00
3.38
6.75
10.13
13.50
16.88
X
A
X
I
S
M
.00
3.38
6.75
10.13
13.50
16.88
20.25
23.63
27.00
L
W
*/1
1/

EXAMPLE 2

C. Example 2 (Initial drawing for analysis)



Legend ④ = boundary No.

C. Example 2 (Computer Session)

```
C:\TESTING>PASTABLM
Date............................  08/27/96

Time of Run.....................  11:40 AM

Your Name or Initials...........  KJR

Input Data Filename.............  EXAMPLE2.IN

Output Filename.................  EXAMPLE2.OUT

Plotted Output Filename
(Enter "None" if not desired)....  EXAMPLE2.PLT
Stop - Program terminated.

C:\TESTING>
```

Example 2 (Input data file)

```
PROFIL
EXAMPLE 2, TIEBACK OPTION
4 4
0. 8. 12. 8. 1
12. 8. 12.1 15. 1
12.1 15. 15. 16. 1
15. 16. 30. 16. 1
SOIL
1
19.63 20.41 4.79 28. 0. 0. 1
WATER
1 0.
4
0. 8.
12. 8.
12.05 12.
30. 12.
TIES
2
2 0. 13. 660. 10. 0. 13.
2 0. 11. 900. 10. 15. 10.
SURFAC
8
12. 8.
13.8 8.9
15.5 10.
17. 11.3
18.5 12.65
19.75 14.2
20.9 15.8
21. 16.
EXECUT
```

** PASTABLM **

Adapted From PCSTABL6
by
Pennsylvania Department of Transportation
Geotechnical Section
(Metricated 7/96)

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date:	08/27/96
Time of Run:	11:40 AM
Run By:	KJR
Input Data Filename:	EXAMPLE2.IN
Output Filename:	EXAMPLE2.OUT
Plotted Output Filename:	EXAMPLE2.PLT

PROBLEM DESCRIPTION   EXAMPLE 2, TIEBACK OPTION

BOUNDARY COORDINATES

4 Top Boundaries
4 Total Boundaries

Boundary No.	X-Left (m)	Y-Left (m)	X-Right (m)	Y-Right (m)	Soil Type Below Bnd
1	.00	8.00	12.00	8.00	1
2	12.00	8.00	12.10	15.00	1
3	12.10	15.00	15.00	16.00	1
4	15.00	16.00	30.00	16.00	1

ISOTROPIC SOIL PARAMETERS

1 Type(s) of Soil

Soil Type No.	Total Unit Wt. (kN/m3)	Saturated Unit Wt. (kN/m3)	Cohesion Intercept (kPa)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (kPa)	Piez. Surface No.
1	19.6	20.4	4.8	28.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 9.81 kN/m3

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (m)	Y-Water (m)
1	.00	8.00
2	12.00	8.00
3	12.05	12.00
4	30.00	12.00

TIEBACK LOAD(S)

2 Tieback Load(s) Specified

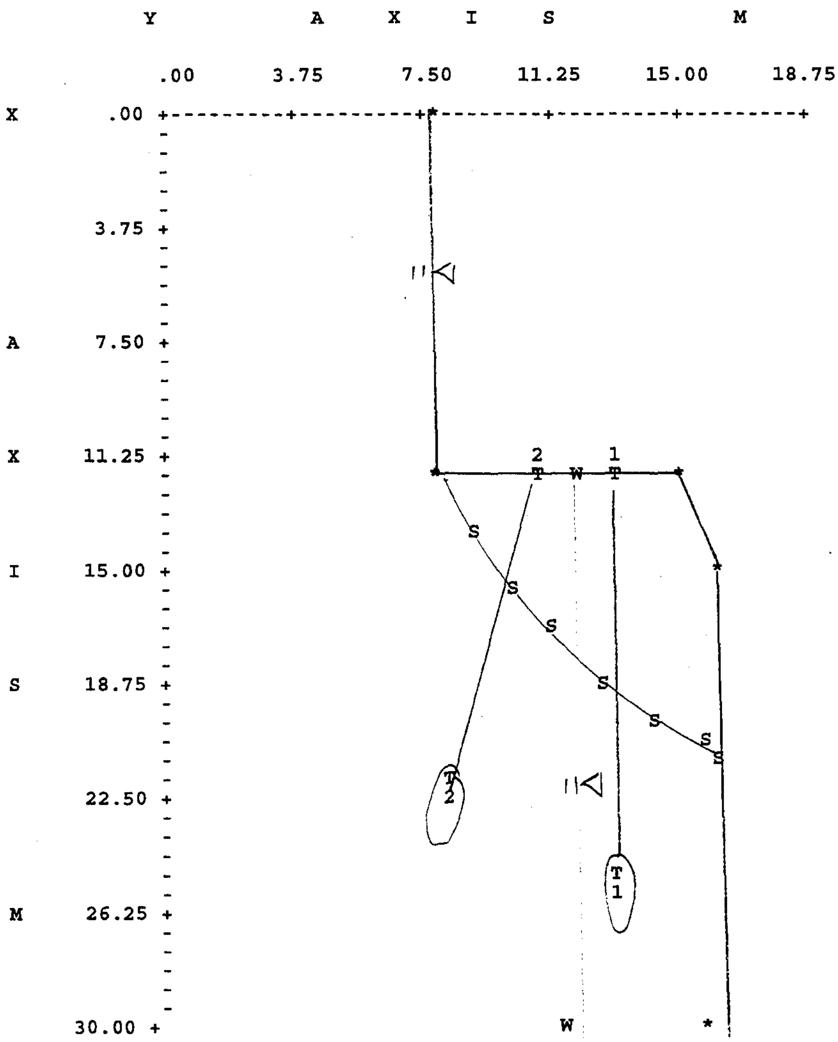
Tieback No.	X-Pos (m)	Y-Pos (m)	Load (kN)	Spacing (m)	Inclination (deg)	Length (m)
1	12.07	13.00	660.0	10.0	.00	13.0
2	12.04	11.00	900.0	10.0	15.00	10.0

NOTE - An Equivalent Line Load Is Calculated For Each Row Of Tiebacks Assuming A Uniform Distribution Of Load Horizontally Between Individual Tiebacks.

Trial Failure Surface Specified By 8 Coordinate Points

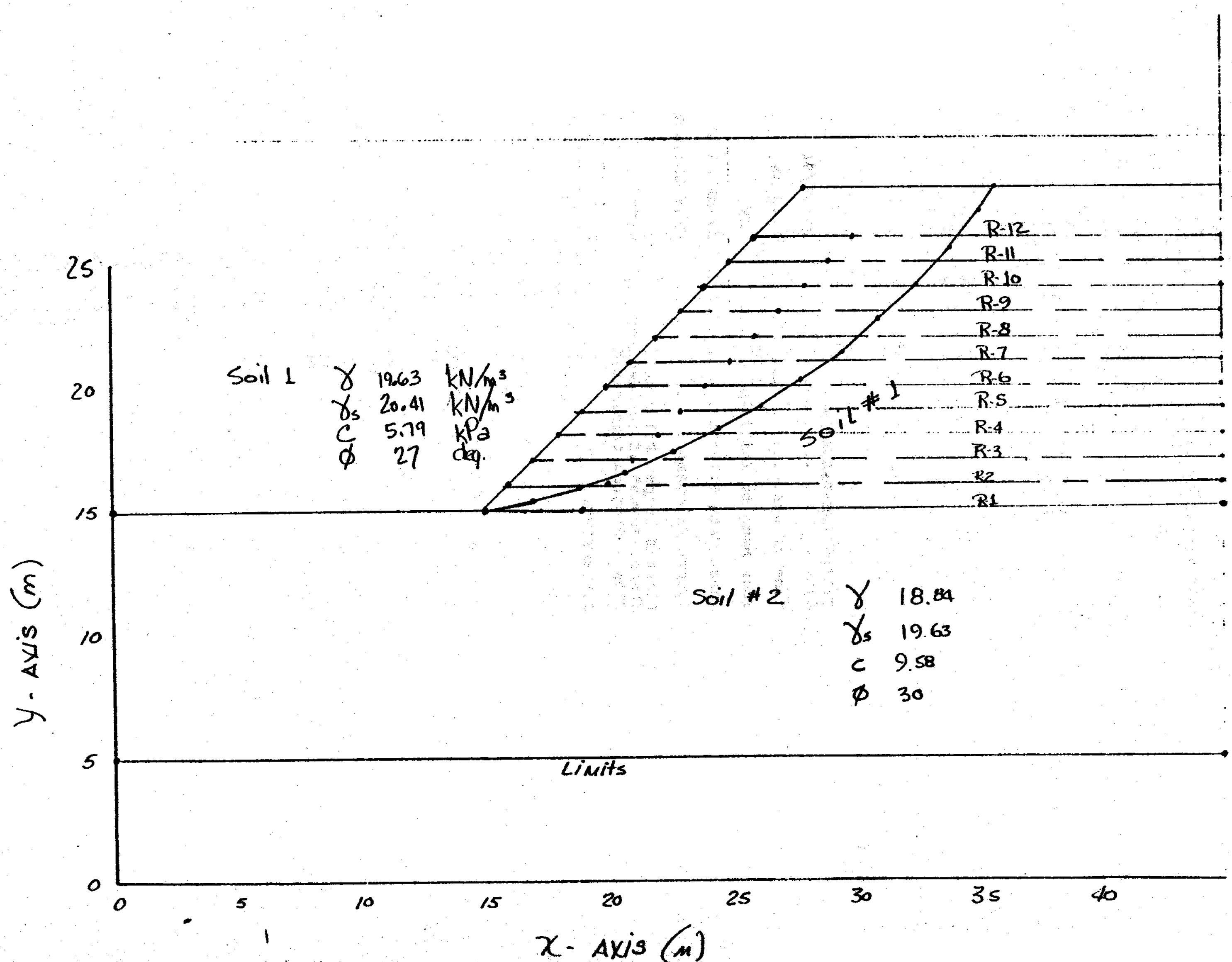
Point No.	X-Surf (m)	Y-Surf (m)
1	12.00	8.00
2	13.80	8.90
3	15.50	10.00
4	17.00	11.30
5	18.50	12.65
6	19.75	14.20
7	20.90	15.80
8	21.00	16.00

Factor Of Safety For The Preceding Specified Surface = 1.224



EXAMPLE 3

D. Example 3 (Initial drawing for analysis)



D. Example 3 (Computer Session)

```
C:\TESTING>PASTABLM
Date............................  08/28/96

Time of Run.....................  8:40 AM

Your Name or Initials...........  KJR

Input Data Filename.............  EXAMPLE3.IN

Output Filename.................  EXAMPLE3.OUT

Plotted Output Filename
(Enter "None" if not desired)....  NONE
Stop - Program terminated.

C:\TESTING>
```

Example 3 (Input data file)

```
PROFIL
Example 3, 1:1.5 slope, 12 layers reinf.
4 3
0. 15. 15. 15. 2
15. 15. 28. 28. 1
28. 28. 45. 28. 1
15. 15. 45. 15. 2
SOIL
2
19.63 20.41 5.79 27. 0. 0. 1
18.84 19.63 9.58 30. 0. 0. 1
REINF
12
3
15. 15. 0. 0.
19. 15. 7.295 0.
45. 15. 7.295 0.
3
16. 16. 0. 0.
20. 16. 7.295 0.
45. 16. 7.295 0.
3
17. 17. 0. 0.
21. 17. 7.295 0.
45. 17. 7.295 0.
3
18. 18. 0. 0.
22. 18. 7.295 0.
45. 18. 7.295 0.
3
19. 19. 0. 0.
23. 19. 7.295 0.
45. 19. 7.295 0.
3
20. 20. 0. 0.
24. 20. 7.295 0.
45. 20. 7.295 0.
3
21. 21. 0. 0.
25. 21. 7.295 0.
45. 21. 7.295 0.
3
22. 22. 0. 0.
26. 22. 7.295 0.
45. 22. 7.295 0.
3
23. 23. 0. 0.
27. 23. 7.295 0.
45. 23. 7.295 0.
3
24. 24. 0. 0.
28. 24. 7.295 0.
45. 24. 7.295 0.
3
25. 25. 0. 0.
29. 25. 7.295 0.
45. 25. 7.295 0.
3
26. 26. 0. 0.
30. 26. 7.295 0.
45. 26. 7.295 0.
LIMITS
1 0
0. 5. 45. 5.
SURBIS
14
15. 15.
17. 15.4
18.9 15.9
20.8 16.5
22.7 17.3
24.5 18.2
26.2 19.1
27.9 20.2
29.5 21.4
31.0 22.7
32.5 24.0
33.9 25.5
35.1 27.0
35.8 28.0
EXECUT
```

** PASTABLM **

Adapted From PCSTABL6
by
Pennsylvania Department of Transportation
Geotechnical Section
(Metricated 7/96)

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date:	08/28/96
Time of Run:	8:40 AM
Run By:	KJR
Input Data Filename:	EXAMPLE3.IN
Output Filename:	EXAMPLE3.OUT

PROBLEM DESCRIPTION Example 3, 1:1.5 slope, 12 layers reinf.

BOUNDARY COORDINATES

3 Top Boundaries
4 Total Boundaries

Boundary No.	X-Left (m)	Y-Left (m)	X-Right (m)	Y-Right (m)	Soil Type Below Bnd
1	.00	15.00	15.00	15.00	2
2	15.00	15.00	28.00	28.00	1
3	28.00	28.00	45.00	28.00	1
4	15.00	15.00	45.00	15.00	2

ISOTROPIC SOIL PARAMETERS

2 Type(s) of Soil

Soil Type No.	Total Unit Wt. (kN/m3)	Saturated Unit Wt. (kN/m3)	Cohesion Intercept (kPa)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (kPa)	Piez. Surface No.
1	19.6	20.4	5.8	27.0	.00	.0	1
2	18.8	19.6	9.6	30.0	.00	.0	1

REINFORCING LAYER(S)

12 REINFORCING LAYER(S) SPECIFIED

REINFORCING LAYER NO. 1

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	15.00	15.00	.00	.000
2	19.00	15.00	7.30	.000
3	45.00	15.00	7.30	.000

REINFORCING LAYER NO. 2

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	16.00	16.00	.00	.000
2	20.00	16.00	7.30	.000
3	45.00	16.00	7.30	.000

REINFORCING LAYER NO. 3

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	17.00	17.00	.00	.000
2	21.00	17.00	7.30	.000
3	45.00	17.00	7.30	.000

REINFORCING LAYER NO. 4

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	18.00	18.00	.00	.000
2	22.00	18.00	7.30	.000
3	45.00	18.00	7.30	.000

REINFORCING LAYER NO. 5

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	19.00	19.00	.00	.000
2	23.00	19.00	7.30	.000
3	45.00	19.00	7.30	.000

REINFORCING LAYER NO. 6

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	20.00	20.00	.00	.000
2	24.00	20.00	7.30	.000
3	45.00	20.00	7.30	.000

REINFORCING LAYER NO. 7

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	21.00	21.00	.00	.000
2	25.00	21.00	7.30	.000
3	45.00	21.00	7.30	.000

REINFORCING LAYER NO. 8

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	22.00	22.00	.00	.000
2	26.00	22.00	7.30	.000
3	45.00	22.00	7.30	.000

REINFORCING LAYER NO. 9

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	23.00	23.00	.00	.000
2	27.00	23.00	7.30	.000
3	45.00	23.00	7.30	.000

REINFORCING LAYER NO. 10

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	24.00	24.00	.00	.000
2	28.00	24.00	7.30	.000
3	45.00	24.00	7.30	.000

REINFORCING LAYER NO. 11

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	25.00	25.00	.00	.000
2	29.00	25.00	7.30	.000
3	45.00	25.00	7.30	.000

REINFORCING LAYER NO. 12

3 POINTS DEFINE THIS LAYER

POINT NO.	X-COORD (m)	Y-COORD (m)	FORCE (kN/m)	INCLINATION FACTOR
1	26.00	26.00	.00	.000
2	30.00	26.00	7.30	.000
3	45.00	26.00	7.30	.000

Searching Routine Will Be Limited To An Area Defined By 1 Boundaries Of Which The First 0 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (m)	Y-Left (m)	X-Right (m)	Y-Right (m)
1	.00	5.00	45.00	5.00

Trial Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (m)	Y-Surf (m)
1	15.00	15.00
2	17.00	15.40
3	18.90	15.90
4	20.80	16.50
5	22.70	17.30
6	24.50	18.20
7	26.20	19.10
8	27.90	20.20
9	29.50	21.40
10	31.00	22.70
11	32.50	24.00
12	33.90	25.50
13	35.10	27.00
14	35.80	28.00

Circle Center At X = 9.5 m; Y = 47.9 m; Radius = 33.4 m

Factor Of Safety For The Preceding Specified Surface = 1.125

WARNING - Factor Of Safety Is Calculated By The Modified Bishop Method. This Method Is Valid Only If The Failure Surface Approximates A Circle.

```
           Y            A     X     I     S              M

            .00      5.63     11.25     16.88     22.50     28.13

X       .00 +--------L+---------+------*--+---------+---------+
            -
            -
            -
            -
            -
      5.63  +
            -
            -
            -
            -
            -
A     11.25 +
            -
            -
            -
            -                          *
            -                           R
X     16.88 +                          S  R
            -                               R
            -                          RS     R
            -                           R       R
            -                            SR      R
            -                               R      R
I     22.50 +                              S
            -                                 R      R
            -                               S   R      R
            -                                    R      R
            -                                 S    R      R
            -                                        R
S     28.13 +                                   S      R      *
            -                                     S     R
            -                                              R
            -                                       S
            -
            -                                          S
      33.75 +                                            S
            -                                               S
            -                                                 S
            -
            -
            -
M     39.38 +
            -
            -
            -
            -
            -
      45.00 +        L                 *R R R R RR R R RR R   *
```

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