JOINT HIGHWAY RESEARCH PROJECT
FHWA/IN/JHRP-86/18
Implementation Report (2)
STABL6 WITH REINFORCING LAYER OPTION
-- USER'S MANUAL --

D. N. Humphrey
R. D. Holtz
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TO:       H. L. Michael, Director
           Joint Highway Research Project
FROM:     R. D. Holtz, Research Engineer
           Joint Highway Research Project
DATE:     October 14, 1986
PROJECT:  C-36-36Q
FILE:     6-14-17

Attached is a user's manual on the HPR Part II research study entitled "Design of Reinforced Embankments." This report, a user's manual, is the implementation part of Task 5 of the approved work plan. The authors of the report are Mr. D. N. Humphrey and myself.

The popular stability analysis program STABL, which can be used to analyze ordinary unreinforced embankments on soft foundations, was modified so that reinforced embankments also could be considered. The new program, termed STABL6, uses the simplified Bishop's analysis method, and it is implemented on IBM PC-compatible micro computers. The User's Manual gives detailed input instructions as well as an example problem which illustrates the analysis of a typical reinforced highway embankment. The report should be useful to highway designers who wish to utilize simple limiting equilibrium analysis methods for design purposes.

Copies of the report will be submitted to the IDOH and FHWA for their review. I look forward to receiving their comments on the manual.

Sincerely yours,

R. D. Holtz, Ph.D., P.E.
Research Engineer

RDH/kr
Attachment
       J. M. Bell         R. A. Howden     B. K. Partridge
       M. E. Cantrall     M. K. Hunter     G. T. Satterly
       W. F. Chen         J. P. Isenbarger  C. R. Scholer
       W. L. Doich        J. F. McLaughlin  K. C. Sinha
       R. L. Eskew        K. M. Mellinger  C. A. Venable
       J. D. Fricker      R. D. Miles      T. D. White
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IMPLEMENTATION REPORT (2)

STABLE6 WITH REINFORCING LAYER OPTION
-- USER'S MANUAL --

by

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Graduate Instructor in Research

and

R. D. Holtz
Research Engineer

Joint Highway Research Project
Project No.: C-36-360
File No.: 6-14-17

Prepared as Part of an Investigation Conducted by
Joint Highway Research Project
Engineering Experiment Station
Purdue University

In cooperation with the
Indiana Department of Highways

Purdue University
West Lafayette, Indiana
October 14, 1986
The capability to analyze reinforced embankments has been incorporated into the STABL slope stability analysis program. The new program is called STABL6. This user's manual describes how the simplified Bishop's method was modified to include reinforcing layers. The modified program can analyze multiple reinforcing layers and allows the orientation of the reinforcing force to be specified. Input instructions and an example problem for the reinforcing layer option are given.
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HIGHLIGHT SUMMARY

The capability to analyze reinforced embankments has been incorporated into the STABL slope stability analysis program. The new program is called STABL6. This user's manual describes how simplified Bishop's method was modified to include reinforcing layers. The modified program can analyze multiple reinforcing layers and allows the orientation of the reinforcing force to be specified. Input instructions and an example problem for the reinforcing layer option are given.
INTRODUCTION

A slope stability program PC-STABL5 developed at Purdue University was modified to give it the capability to analyze embankments constructed on soft ground reinforced with one or more layers of reinforcement. This modified program is called PC-STABL6. It was developed as part of a study of design of reinforced embankments (Humphrey and Holtz, 1986a) that also included a finite element analysis procedure (Humphrey and Holtz, 1986b). PC-STABL5 is a general purpose limiting equilibrium slope stability analysis program with solution options that use the simplified Janbu method with circular, sliding block, or irregular shaped sliding surfaces or the simplified Bishop or Spencer methods with circular surfaces. Program operation is described in Siegel (1975a), Lovell, et al. (1984), and Carpenter (1985). Further details on program development are given in Siegel (1975b) and Boutrup (1978). The program is written in FORTRAN77 and operates on IBM-PC, IBM-XT, IBM-AT, or compatible computers.

The simplified Bishop analysis routine was modified to include the stabilizing moment provided by one or more
layers of reinforcement. The user inputs the location of each layer, the distribution of available force, and the direction in which the force acts. The circular trial surface may be specified or PC-STABL5's surface generation routine may be used.

This report is a user's manual for analysis of reinforced embankments with PC-STABL6. Only aspects of the program specific to the reinforcement option are covered. The user is referred to the references noted above for general instructions on program use. In the following, the method used to incorporate the stabilizing effect of the reinforcing layer is described and an outline of the solution procedure is given. Appendix A lists references cited. Appendix B gives an example problem. The data input format is detailed in Appendix C. Error codes used by the reinforcing layer routines are given in Appendix D. Appendix E lists the modifications made to PC-STABL5 and two new subroutines that were added. Modifications to the routine to output problem geometry on a Hewlett-Packard 7470A two pen plotter are listed in Appendix F.

ANALYSIS OF REINFORCING LAYERS WITH SIMPLIFIED BISHOPS METHOD

Background

Tensile reinforcing layers provide a resisting moment which increases embankment stability. This effect was
incorporated into the simplified Bishop (1955) 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.

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. 1. The reinforcing force $F_R$ acting at the intersection of the slip surface and the reinforcement is also shown. $F_R$ has units of force/unit width. 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):
Figure 1: Simplified Bishop method of slices including horizontal reinforcing force showing forces acting on $i^{th}$ slice.
\[ SF = \frac{\sum_{i=1}^{n} \left( c_i \Delta x_i + \frac{[W_i + O_{iv} - u_i \Delta x_i \tan \phi_i]}{\cos \theta_i + (\sin \theta_i \tan \phi_i)/SF} \right)}{\sum_{i=1}^{n} (W_i + O_{iv}) \sin \theta_i - \left( \sum_{i=1}^{n} Q_{ih} d_i \right)/r - \left( \sum_{j=1}^{m} F_{Rj} y_j \right) / (rSF)} \]  

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
- \( \Delta x_i \) = width of \( i \)th slice
- \( \theta_i \) = inclination of base of \( i \)th slice
- \( c_i \) = cohesion on base of \( i \)th slice
- \( \phi_i \) = 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. This equation was implemented in STABL5.
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. 2. 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 across the full width of 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. 3.

The right most intersection of each reinforcing layer and 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. 2). It is possible for the toe of some trial circles
Figure 2 Location of reinforcement and distribution of force and inclination factor.
Figure 3  Orientation of reinforcement force.
to intersect a layer a second time but this is assumed to have no effect on stability.

The moment arm \( (y) \) is a function of the trial circle radius \((r)\), the slope of the reinforcement \((\psi)\), the inclination factor, the coordinates of the circle center \((x_c, y_c)\), and the coordinates of the intersection \((x_I, y_I)\) as shown on Fig. 2. For a horizontal layer and \( I_f = 0.0 \), \( y = y_c - y_I \) and for \( I_f = 1.0 \), \( y = r \). For other cases

\[
A = \text{atan}[(x_c-x_I)/(y_c-y_I)] \tag{2}
\]

\[
y = r \sin[\pi/2 - A + \psi + I_f(A-\psi)] \tag{3}
\]

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. An example problem using the SURBIS option is shown in Appendix B. Input instructions are given in Appendix C and error codes are listed in Appendix D.

STABL5 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.
SUMMARY

A modification to a general purpose slope stability program STABL5 is described which gives it the capability to analyze reinforced embankments constructed on soft ground. The modification is based on the simplified Bishop method of slices. Multiple reinforcing layers with specified distributions of available force may be used. The equations and procedures used in the implementation are given. An example problem, input instructions, error codes, and modifications to STABL5 are given in the appendices.

ACKNOWLEDGEMENTS

Financial support for this research was provided by the Indiana Department of Highways and the Federal Highway Administration through the Joint Highway Research Project of Purdue University. This support is gratefully acknowledged.

APPENDIX A - REFERENCES


APPENDIX B - EXAMPLE PROBLEM

This is a simple example on the use of the reinforcing layer option for a 6-foot high embankment with a 2h:1v side slope as shown in Fig. B-1. The embankment fill is cohesionless with a unit weight of 125 pcf and a friction angle $\phi$ of 30°. The foundation is soft clay with a unit weight of 115 pcf and an undrained shear strength of 125 psf. The water table is assumed to be very deep. The embankment is reinforced with a single layer located at its base. The available force is specified to be zero at the toe increasing to 500 lb/ft under the central portion of the embankment as shown in Fig. B-1. The force is assumed to act in the direction of the reinforcement so the Inclination factor is 0.0. The safety factor is calculated for the trial circle shown in Fig. B-1.

The following input file was prepared using the instructions in Siegel (1975a) and Appendix C. The output for the problem is shown on the following pages. A plot of problem geometry generated using PLOTSTBL.BAS on a Hewlett-Packard 7470A plotter is also shown.
Figure B-1 Example problem.
Input for example

PROFIL
REINFORCED EMBANKMENT - EXAMPLE
4 3
0. 11. 14. 11. 2
14. 11. 26. 17. 1
26. 17. 45. 17. 1
14. 11. 45. 11. 2
SOIL
2
125. 125. 0. 30. 0. 0. 0
115. 115. 125. 0. 0. 0. 0
REINF
1
3
14. 11. 0. 0.
26. 11. 500. 0.
45. 11. 500. 0.
SURBIS
13
6.00 11.00
8.12 8.88
10.61 7.20
13.37 6.03
16.30 5.40
19.30 5.33
22.26 5.84
25.06 6.90
27.62 8.48
29.83 10.51
31.61 12.92
32.90 15.63
33.25 17.00
EXECUT
Output for example

** PCSTABL5 **

by
Purdue University

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

Run Date: 6/13/86
Time of Run: 8:30 PM
Run By: D. Humphrey
Input Data Filename: example.in
Output Filename: example.out
Plotted Output Filename: example.plt

PROBLEM DESCRIPTION  REINFORCED EMBANKMENT - EXAMPLE

BOUNDARY COORDINATES

3 Top Boundaries
4 Total Boundaries

<table>
<thead>
<tr>
<th>Boundary No.</th>
<th>X-Left (ft)</th>
<th>Y-Left (ft)</th>
<th>X-Right (ft)</th>
<th>Y-Right (ft)</th>
<th>Soil Type Below Bnd</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>11.00</td>
<td>14.00</td>
<td>11.00</td>
<td>2</td>
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<td>1</td>
</tr>
<tr>
<td>3</td>
<td>26.00</td>
<td>17.00</td>
<td>45.00</td>
<td>17.00</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>14.00</td>
<td>11.00</td>
<td>45.00</td>
<td>11.00</td>
<td>2</td>
</tr>
</tbody>
</table>

ISOTROPIC SOIL PARAMETERS

2 Type(s) of Soil

<table>
<thead>
<tr>
<th>Soil Type No.</th>
<th>Total Unit Wt. (pcf)</th>
<th>Saturated Unit Wt. (pcf)</th>
<th>Cohesion (psf)</th>
<th>Friction Angle (deg)</th>
<th>Pore Pressure Constant (psf)</th>
<th>Pressure Surface Plez. Surface No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>125.0</td>
<td>125.0</td>
<td>0.0</td>
<td>30.0</td>
<td>0.00</td>
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</tr>
<tr>
<td>2</td>
<td>115.0</td>
<td>115.0</td>
<td>125.0</td>
<td>0.0</td>
<td>0.00</td>
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</tbody>
</table>
Output for example (cont.)

REINFORCING LAYER(S)

1 REINFORCING LAYER(S) SPECIFIED

REINFORCING LAYER NO.  1

3 POINTS DEFINE THIS LAYER

<table>
<thead>
<tr>
<th>POINT NO.</th>
<th>X-COORD</th>
<th>Y-COORD</th>
<th>FORCE</th>
<th>INCLINATION FACTOR</th>
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<td>0.000</td>
</tr>
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Trial Failure Surface Specified By 13 Coordinate Points

<table>
<thead>
<tr>
<th>Point No.</th>
<th>X-Surf (ft)</th>
<th>Y-Surf (ft)</th>
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<tbody>
<tr>
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<td>6.00</td>
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<tr>
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<td>8.88</td>
</tr>
<tr>
<td>3</td>
<td>10.61</td>
<td>7.20</td>
</tr>
<tr>
<td>4</td>
<td>13.37</td>
<td>6.03</td>
</tr>
<tr>
<td>5</td>
<td>16.30</td>
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<td>5.33</td>
</tr>
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<td>7</td>
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<td>13</td>
<td>33.25</td>
<td>17.00</td>
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</table>

Circle Center At X = 18.1 ; Y = 21.0 and Radius, 15.7

Factor Of Safety For The Preceding Specified Surface = 1.079

WARNING - Factor Of Safety Is Calculated By The Modified Bishop Method. This Method Is Valid Only If The Failure Surface Approximates A Circle.
Output for example (cont.)

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<th>A</th>
<th>X</th>
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X

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Example plot from Hewlett-Packard 7470A plotter.
APPENDIX C - DATA INPUT FORMAT FOR REINFORCING LAYERS

C.1 Input for Reinforcing Layers

COMMAND CARD REINF Command Code

DATA CARD Integer Number of reinforcing layers

NOTE: Repeat the following set of data cards for each reinforcing layer.

DATA CARD Integer Number of points defining the reinforcing layer

DATA CARD Real X coordinate of point on reinforcing layer

Real Y coordinate of point on reinforcing layer

Real Force in reinforcement at point (force/unit width)

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 card for each point defining the reinforcing layer.

C.2 Input for Suppressing of Reactivating Reinforcing Layers

COMMAND CARD REINF Command Code

DATA CARD Integer Number zero (0)

C.3 Input Restrictions

1. No more than 10 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.
APPENDIX D - 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 10. 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.
APPENDIX E - MODIFICATIONS TO PC-STABL5

This appendix describes modifications made to PC-STABL5 which was originally compatible with Microsoft FORTRAN, Version 3.21 (MS-FORTRAN). The modifications were made for two reasons. The first were changes to make the program compatible with Ryan-McFarland, Version 2.00 FORTRAN (RM-FORTRAN). These were mostly minor such as commas in format statements and are listed below. In addition, MS-FORTRAN uses a special $NOFLOATCALLS statement at the beginning of each program unit; these were made inactive in the RM-FORTRAN version by substituting CNOFLOATCALLS. The MS-FORTRAN version writes program output simultaneously to a file (unit 6) and to the screen (unit *). This was done with two WRITE statements, one for each unit. This scheme is not compatible with RM-FORTRAN since it treats unit 6 and unit * as the same unit. To eliminate the problem all WRITE statements to unit * were made inactive by inserting 'c **' in columns 1-4. The second reason for the changes was to incorporate the reinforcing layer option. The modifications are listed below. They included minor modifications to several existing subroutines and the addition of two new subroutines.
Modifications to main program STABL5

Add after stbl 12
c 1986 Modifications for reinforcing layer option (PCSTABL6)
c Dana N. Humphrey, Graduate Research Assistant, May 1986.
c Add after stbl 160
common /blk23/lreinf,nreinf,nrpts(10),xreinf(10,40),
yreinf(10,40),rforce(10,40),rlnclf(10,40),rmoms
Add after stbl 168
real load,limit,kcoef,inclin,length
integer sltp,bn
Replace existing jrcmay85 following stbl 172 with
 1 'LIMITS','ANISO','SURBIS','SPENCER','REINF'/
Add after stbl 200
lreinf=0
rmoms=0.
Replace existing jrcmay85 following stbl 324 with
 23 do 12 i=1,18
Replace existing jrcmay85 following stbl 328 with
   1 13,30,35),1
Replace existing jrcmay85 following stbl 350 with
c *** write(*,102)(keyw(i),i=1,18)
   write(6,102)(keyw(i),i=1,18)
Add after stbl 510
35 call relinf
go to 11

Modifications to subroutine BLOCK2

Add after blk2 56
real limit

Modifications to subroutine EXECUT

Add before exec 46
common /blk23/lreinf,nreinf,nrpts(10),xreinf(10,40),
yreinf(10,40),rforce(10,40),rlnclf(10,40),rmoms
Add after exec 62
if(lreinf.eq.1)call relinf2

Modifications to subroutine FACTR

Add after fctr 148
common /blk23/lreinf,nreinf,nrpts(10),xreinf(10,40),
yreinf(10,40),rforce(10,40),rlnclf(10,40),rmoms
Replace existing fctr 296 with
do 10 j=1,20
Replace existing fctr 314 with
if(lreinf.eq.1)then
  bottom=sumb-rmoms/(radius*fold)
if(bottom.gt.0.)then
  fnew= sumt/bottom
  fnew=(fold+fnew)/2.
else
  fnew=2.*fold
endif
else
  fnew=sumt/sumb
endif
Add after fctr 322
foldx=fold
Replace existing fctr 338 with
110x,'Factor Of Safety Calculation Has Gone Through 20 Iterations'
dnhju186
Replace existing fctr 346 and 348 with
  if(lsearc.eq.0) write(6,108)fs,foldx
c *** if(lsearc.eq.0) write(*,108)fs,foldx
108 format(//10x,'Factor of Safety for the Preceding Surface is ',
  'Between',f6.3,' and',f6.3)
dnhju186
Replace existing fctr 374 and 376 with
write(6,108)fs,foldx
c *** write(*,108)fs,foldx
Add before fctr 386
rmoms=0.
Replace existing fctr 414 with
110x,'*** The Above Factor Of Safety Is Misleading ***')
dnhmay86
Replace existing fctr 430 through 438 with
110x,'The Factor Of Safety For The Trial Failure Surface Defined'//
110x,'By The Coordinates Listed Below Is Misleading.'///
dnhmay86
110x,'Failure Surface Defined By',13,' Coordinate Points'///
dnhmay86
112x,'Point',6x,'X-Surf',6x,'Y-Surf',/
113x,'No.',8x,'(ft)',8x,'(ft)',//)
dnhmay86

Modifications to subroutine FSPENC

Replace existing fspn 726 with
110x,'*** The Above Factor Of Safety Is Misleading ***')
dnhmay86
Replace existing fspn 742 through fspn 750 with
110x,'The Factor Of Safety For The Trial Failure Surface Defined'//
110x,'By The Coordinates Listed Below Is Misleading.'///
dnhmay86
110x,'Failure Surface Defined By',13,' Coordinate Points'///
dnhmay86
112x,'Point',6x,'X-Surf',6x,'Y-Surf',/
113x,'No.',8x,'(ft)',8x,'(ft)',//)
dnhmay86
Replace existing fspn 780 and fspn 782 with
201 write(6,202)
c *** write(*,202)
dnhmay86
Modifications to subroutine PLOTIN

Add after plot 62

common /blk23/ireinf,nreinf,nrpts(10),xreinf(10,40),
yreinf(10,40),rforce(10,40),rincf(10,40),rmoms

Replace existing plot 66 with
dimension pittr(11)

Replace existing plot 76 with
  1 'SRF','TEN','RNF','NPL','END'

Replace existing plot 96 with
write(7,100)pittr(10)

Add after plot 376

  1 plot reinforcing layers, if applicable

  3 if(ireinf.eq.0)go to 49
    write(7,113)nreinf
    do 45 n=1,nreinf
      x=xreinf(n,1)/scl
      y=yreinf(n,1)/scl
      write(7,115)x,y
    nn=nrpts(n)
    do 45 i=2,nn
      x=xreinf(n,i)/scl
      y=yreinf(n,i)/scl
      write(7,115)x,y
    continue

Replace existing plot 384 with
  49 if(lblk.eq.0)go to 9

Modifications to subroutine PLTN

Add after pltn 62

common /blk23/ireinf,nreinf,nrpts(10),xreinf(10,40),
yreinf(10,40),rforce(10,40),rincf(10,40),rmoms

Replace existing pltn 64 with
dimension pit(49,51),symb(21),axls(9),scl(9)

Add after pltn 66
real load, inclin, length
integer bn

Add after pltn 68
character pit*1

Replace existing pltn 72 with
  1 'W','L','S','.','/',',','T','R'

Add after pltn 366

  10 if(ireinf.eq.0)go to 39
    do 36 i=1,nreinf
      nn = nrpts(i)
do 36 j=1,nn
   call postn(xreinf(i,j),yreinf(i,j),ix,ly)
   plt(ix-1,ly)=symb(i)
   plt(ix,ly)=symb(2i)
36 continue

Replace existing pltn 374 with
39 do 8 i=1,nbnd

Modifications to subroutine PROF1L

Add after prof 98
   real load,limit,inclin,bn,length
Replace existing prof 150 with
   1 29x,'Purdue University')
Replace existing prof 172 with
   1 10x,'Output Filename: ',a)
Replace existing prof 176 with
   201 format(10x,'Plotted Output Filename: ',a)

Modifications to subroutine RANDOM

Replace existing rand 620 with
   110x,'Sliding Block Is',f6.1,//)

Modifications to subroutine READER

Add after read 46
   character m*1

Modifications to subroutine SCALER

Add after scal 64
   real load,inclin,length
   integer bn

Modifications to subroutine SLICES

Add before slic 50
   real load

Modifications to subroutine SOILWT

Add after slwt 40
   integer sltp
Modifications to subroutine TIES

Replace existing ties 222 with
105 format(/,10x,14h*** ERROR - ,4h4 ERROR - ,5x,4hTie ,13,/)  dnhmay86

Modifications to subroutine TRANS

Add after tran 68
Integer sltp  dnhmay86

Modifications to subroutine WEIGHT

Replace existing lines wght 200 through wght 208 with
110x,******** INPUT ERROR - Trial Failure Surface ********/  dnhmay86
110x,******** Extends Above The ********/  dnhmay86
110x,****** Ground Surface ********/  dnhmay86
110x,******** /)  dnhmay86

New subroutine REINF

SUBROUTINE REINF
C C -----------------------------
C C -----------------------------
C C -----------------------------
C C -----------------------------
C C SUBROUTINE REINF
C C -----------------------------
C C -----------------------------
C C -----------------------------
C C -----------------------------
C C FUNCTIONS -
C C -----------------------------
C C READ THE NUMBER OF REINFORCING LAYERS.
C C IF EQUAL TO ZERO, EXISTING REINFORCING LAYER DATA IS SUPPRESSED
C OR REACTIVATED IF PREVIOUSLY SUPPRESSED.
C C IF GREATER THAN ZERO, READS, CHECKS, STORES, AND PRINTS
C REINFORCING LAYER DATA.
C C -----------------------------
C C -----------------------------
C C CNOFLOATCALLS
C COMMON /BLK01/IANGL,IBLK,IFEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
1 IMIN,REFIN,RFORCE,RFOR,RFORCE,RFORCE,RFORCE,RFORCE,
1 ISURF,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,
1 CBLK,CPLT
C COMMON /BLK23/IREINF,NREINF,NRPTS(10),XREINF(10,40),
^ YREINF(10,40),RFORCE(10,40),RINCLF(10,40),RINCLF
DIMENSION ERROR(8)
CHARACTER ERROR*4
DATA ERROR/'RF01','RF02','RF03','RF04','RF05','RF06','RF07','RF08'/
READ NUMBER OF REINFORCING LAYERS

CALL READER(DUMMY,NREIN,0)

CHECK FOR REINFORCING LAYER DATA SUPPRESSION

IF(NREIN.EQ.0) THEN
  IF(IREINF.NE.0) THEN
    IREINF=0
  ENDIF
  WRITE(*,108)
  WRITE(6,108)
  108 FORMAT(/,,10X,'REINFORCING LAYER DATA LAYER DATA HAS BEEN SUPPRESSED')
ENDIF

CHECK IF DATA DEFINED BEFORE REACTIVATING IT

ELSE IF(NREINF.EQ.0) THEN
  WRITE(*,101)ERROR(1)
  WRITE(6,101)ERROR(1)
  101 FORMAT(/,10X,14H ERROR - ,A4,6H ***,/) 
  EXIT=1
ENDIF

REACTIVATE SUPPRESSED DATA

ELSE
  IREINF=1
  WRITE(*,109)
  WRITE(6,109)
  109 FORMAT(/,,10X,'SUPPRESSED REINFORCING LAYER DATA HAS BEEN REACTIVATED')
ENDIF

PRINT NUMBER OF REINFORCING LAYERS

WRITE(*,103)NREINF
WRITE(6,103)NREINF
  103 FORMAT(1H1,
  ',9X,'REINFORCING LAYER(S)','-13X,12,' REINFORCING LAYER(S) SPECIFIED')

CHECK REINFORCING LAYER STORAGE LIMIT

IF(NREINF.GT.10) THEN
  WRITE(*,101)ERROR(2)
  WRITE(6,101)ERROR(2)
  CALL QUIT
ENDIF

DO 20 I=1,NREINF


C READ NUMBER OF POINTS DEFINING LAYER
C -----------------------------------------------
    CALL READER(DUMMY, NRPTS(I), 0)
C -----------------------------------------------
C CHECK FOR AT LEAST TWO POINTS
C -----------------------------------------------
    IF(NRPTS(I).LT.2)THEN
        WRITE(*,101)ERROR(8)
        WRITE(6,101)ERROR(8)
        EXIT=1
    ENDIF
C -----------------------------------------------
C CHECK POINT STORAGE LIMIT
C -----------------------------------------------
    IF(NRPTS(I).GT.40)THEN
        WRITE(*,101)ERROR(3)
        WRITE(6,101)ERROR(3)
        CALL QUIT
    ENDIF
C -----------------------------------------------
C PRINT REINFORCING LAYER DATA HEADINGS
C -----------------------------------------------
    WRITE(*,102) 1, NRPTS(I)
    WRITE(6,102) 1, NRPTS(I)
    102 FORMAT(/,,
           ' 10X,' 'REINFORCING LAYER NO. ',13//
           ' 10X,' 'POINTS DEFINE THIS LAYER',//
           ' 15X,' 'POINT', 'X-COORD', 'Y-COORD', 'FORCE', '3X,
           ' INCLINATION'/
           ' 16X,' 'FACTOR'/)
C -----------------------------------------------
C READ AND CHECK REINFORCING LAYER DATA
C -----------------------------------------------
XP=-TOL
YP=-TOL
DO 10 N=1,NRPTS(I)
    CALL READER(XREINF(I,N),IDUMMY,1)
    CALL READER(YREINF(I,N),IDUMMY,1)
    CALL READER(RFORCE(I,N),IDUMMY,1)
    CALL READER(RINCLF(I,N),IDUMMY,1)
C -----------------------------------------------
C CHECK FOR 1ST QUADRANT LOCATION
C -----------------------------------------------
        WRITE(*,104)ERROR(4),1,N
        WRITE(6,104)ERROR(4),1,N
        104 FORMAT(/,10X,14H*** ERROR - ,A4,6H***** 5X,
               ' LAYER NO.', 13,5X, 'POINT NO.', 13)
        EXIT=1
    ENDIF
C -----------------------------------------------
C CHECK FOR POSITIVE REINFORCING FORCE
C -----------------------------------------------
    IF(RFORCE(I,N).LE.-TOL)THEN
C *** WRITE(*,104)ERROR(5),I,N
WRITE(6,104)ERROR(5),I,N
IEXIT=1
ENDIF

C CHECK LIMITS OF INCLINATION FACTOR
C
C *** WRITE(*,104)ERROR(6),I,N
WRITE(6,104)ERROR(6),I,N
IEXIT=1
ENDIF

C CHECK FOR POSITIVE SPACING
C
IF(XREINF(I,N).LT.XP OR. YREINF(I,N).LT.YP)THEN
C *** WRITE(*,104)ERROR(7),I,N
WRITE(6,104)ERROR(7),I,N
IEXIT=1
ENDIF
XP=XREINF(I,N)
YP=YREINF(I,N)
10 CONTINUE

C PRINT REINFORCING LAYER DATA
C
C *** WRITE(*,106) (N,XREINF(I,N),YREINF(I,N),RFORCE(I,N),RINCLF(I,N),
C *** N=1,NRPTS(I))
WRITE(6,106) (N,XREINF(I,N),YREINF(I,N),RFORCE(I,N),RINCLF(I,N),
N=1,NRPTS(I))
106 FORMAT(15X,I3,3X,3F10.2,F10.3)
20 CONTINUE
RETURN
END

New subroutine REINF2

SUBROUTINE REINF2
C
C SUBROUTINE REINF2
C
C FUNCTIONS -
C
LOCATES INTERSECTION BETWEEN TRIAL SURFACE AND REINFORCING LAYER(S).
C
CALCULATES RESISTING MOMENT PROVIDED BY REINFORCING LAYER(S).
C
C
CNOFLOATCALLS
COMMON /BLK01/IANGL,IBLK,EXIT,ICIRC,ILIMIT,ISELECT,IREAD,ISEARC,
IBLK2,ISOL,ISTR,ISURF,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIES,ITIE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IF(RINCLI.GE.1.-TOL)THEN
   RARM=RADIUS
ELSE
   C
   C CALCULATE CENTER OF CIRCLE
   C
   X1=SURF(1,1)
   Y1=SURF(1,2)
   X2=SURF(2,1)
   Y2=SURF(2,2)
   X3=SURF(3,1)
   Y3=SURF(3,2)
   XHALF2=(X2 + X3)/2.0
   YHALF2=(Y2 + Y3)/2.0
   XCNTR=((X1*X1-X2*X2)*(Y3-Y2) - (X2*X2-X3*X3)*(Y2-Y1) + (Y3-Y1)
          *(Y2-Y1)*(Y3-Y2))/2.0*((X1-X2)*(Y3-Y2) - (X2-X3)*
          (Y2-Y1))
   YCNTR=(X2-X3)/(Y3-Y2)*(XCNTR - XHALF2) + YHALF2
   C
   C CALCULATE MOMENT ARM FOR FORCE NOT TANGENT TO CIRCLE
   C
   A1=ATAN((YREINF(I,J)-YREINF(I,J1))/(XREINF(I,J)-XREINF(I,J1)))
   A2=ATAN((XINT-XCNTR)/(YCNTR-YINT))
   A3=A1+RINCLI*(A2-A1)
   A4=1.570796327-A2+A3
   RARM=RADIUS*SIN(A4)
ENDIF

C
C CALCULATE AND SUM RESISTING MOMENT
C
RMOM=RFORCI*RARM
RMOMS=RMOMS+RMOM
30 CONTINUE
RETURN
END
The modifications which were made to PLOTSTBL.BAS to give it the capability to plot the location of reinforcing layers are listed below. An 'A' in the first column indicates that the line should be added to the existing program and 'R' indicates that the line should replace the existing line.

Modifications to PLOTSTBL.BAS

R 530 DIM PLT$(11)
R 730 FOR I=1 TO 11
R 1090 FOR J=1 TO 11
R 1110 ON J GOTO 1140,1360,1570,1750,1940,2152,2310,2450,2131,2600,2700
A 2131 REM -------------------------------
A 2132 REM PLOT REINFORCING LAYERS, IF APPLICABLE
A 2133 REM -------------------------------
A 2134 IF PROMPT$="y" THEN GOSUB 2900
A 2135 INPUT #2,NREINF%
A 2136 FOR I=1 TO NREINF%
A 2137 INPUT #2,NN%
A 2138 GOSUB 2830
A 2139 PRINT #1, "PU,PA";X#,Y#;
R 2140 PRINT #1, "SI,.15,.2"
A 2141 PRINT #1, "CP-.5,0;DI;LBR"+CHR$(3)
A 2142 PRINT #1, "PU,PA";X#,Y#;
A 2143 FOR J=2 TO NN%
A 2144 GOSUB 2830
A 2145 GOSUB 2770
A 2146 PRINT #1, "CP-.5,0;DI;LBR"+CHR$(3)
A 2147 PRINT #1, "PU,PA";X#,Y#;
A 2148 NEXT J
A 2149 NEXT I
R 2150 GOSUB 2770
A 2151 GOTO 1130
A 2152 REM -------------------------------
A 2153 REM PLOT SEARCH BOXES FOR BLOCK, IF APPLICABLE
R 2950 FOR JJ=1 TO 9
R 2970 ON J GOSUB 3000,3030,3060,3090,3120,3150,3180,3210,3241
A 3241 INPUT "SELECT PEN FOR PLOTTING REINFORCING LAYERS (1 OR 2) ";XX
A 3242 GOSUB 3250
A 3243 RETURN
A 3401 DATA RNF