SCHOOL OF
CIVIL ENGINEERING
INDIANA
DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH REPORT

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SLOPE STABILITY ANALYSIS WITH
STABL4

SUMMARY INFORMATIONAL REPORT

C.W. Lovell
S.S. Sharma
J.R. Carpenter

PURDUE UNIVERSITY

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INTRODUCTION TO SLOPE STABILITY ANALYSIS WITH STABL4

To: R.L. Eskew, Chairman
Joint Highway Research Project
Advisory Board

October 10, 1984

File: 6-14-12

From: H.L. Michael, Director
Joint Highway Research Project

The attached report is an Informational one which summarized much of the work done by the authors in developing an implementation package of the STABL materials for the Federal Highway Administration. This work was performed under a FHWA contract with Purdue University by the authors under the direction of Professor C.W. Lovell.

This summary report is submitted for information and use by IDOH personnel and for sale when requests are submitted to us. Under the implementation program plans of FHWA they will provide copies of the report in the format submitted by us to them under the contract to governmental agencies, but will advise all others (consultants, researchers, etc.) to contact Purdue for copies of the STABL4 materials. Materials supplied will be a copy of the attached report and a tape of the STABL4 program at a price which will cover our costs of handling this activity.

Comments and questions relative to the Report should be directed to Professor Lovell at the Civil Engineering Building, Purdue University, phone (317) 494-5034.

Respectfully submitted,

Harold L. Michael, Director
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INTRODUCTION
to
SLOPE STABILITY ANALYSIS
WITH STABL4

by

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INTRODUCTION

STABL is a computer program for the general analysis of slope stability by a two dimensional (2-D) limiting equilibrium method. The program uses the method of slices to analyze the slope and calculates the factor of safety (FOS) according to the simplified Janbu or Bishop methods for non-circular and circular surfaces, respectively. A unique feature of the program allows random surfaces to be generated, allowing the user to determine the critical, minimum FOS more easily.

DEVELOPMENT OF STABL

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 (1975a) as well as a random (as opposed to a grid) type search with circles (CIRCL2). Favorable comparisons of the FOS values generated by STABL with those for the same surfaces by other methods of slices were reported by Boutrup (1977).

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 (References 11, 2, 3, 4, 12), the program began to be adopted by many agencies. STABL has been modified in minor ways over the past eight years, and users of the program have helped greatly in debugging operations. The present version of STABL is called STABL4.

CAPABILITIES OF STABL

STABL is the only known program to contain searching routines for shapes other than circles. Circular grid search routines are common; STABL searches by generating circles, with randomly selected radii and centers limited by user-defined parameters as explained later. A number of programs can determine the FOS for any specified non-circular shape, but only STABL can both generate general shapes and determine their FOS values.

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 ($>90^\circ$) 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 grossly 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 sub-surface space searched and the portion of that space occupied by the more critical surfaces.

COMPUTER REQUIREMENTS

STABL is written in FORTRAN IV and has been successfully used on the following computer systems:

1. CDC 6500-6600
2. IBM 360/370
3. VAX 11/780

With some modifications, STABL may also be converted for use on a micro-computer (Ref. 10). However, the versions available from Purdue University should be compatible with most systems which can compile the FORTRAN IV language.

On the CDC system, the program requires a field length of approximately 70,000 to 80,000 words for storage and execution. The CPU time for "average" runs is generally 16 to 32 seconds for approximately 100 circular surfaces and may be up to 128 seconds for 100 irregular surfaces. However, the cost of each run is directly proportional to the complexity of the surface and sub-surface geometries and will be a unique feature for each individual analysis.

DESCRIPTION OF STABL

Assumptions

STABL assumes that the instability to be prevented would be two-dimensional. In reality, all sliding failures must be 3-D, with the end/edge resistance furnishing additional safety against instability. For more quantitative information on the comparison of $(FOS)_{3D}$ to $(FOS)_{2D}$, see Chen (1981) and Lovell (1982). In general, $(FOS)_{3D} > (FOS)_{2D}$, but the difference may be small, and in certain special cases $(FOS)_{2D} > (FOS)_{3D}$. Where the stability problem is perceived to be definitely 3-D, the engineer is encouraged to use the BLOCK3 or LEMIX codes of Chen (1981).

STABL uses simplified methods of slices for determination of FOS. The alternative requires solutions with extensive iteration and the consequent problems of nonconvergence in these iterations. Boutrup (1977)

has shown that the simplified methods after Janbu and Bishop give reasonably precise values of FOS.

Agencies staffed with appropriate mathematical and software skills can insert any desired slices solution into the program...simplified or total equilibrium. STABL is a stability analysis system, of which the method of slices detail, is a small part.

The selection of a center of moments for the slices analysis is an intriguing point. In the simplified approaches, the free body is not iterated into equilibrium, and accordingly, the FOS value is peculiar to the center selected. This is true even for the circle, where the circle center is arbitrarily selected in the simplified Bishop method. For other shapes, there is usually no "center" to select for moments. After much study of this question (Carter, 1971; Siegel, 1975a, Boutrup, 1977), the circle center is used for CIRCL2, and a very long moment arm is used for BLOCK, BLOCK2, and RANDOM. The latter choice means that these noncircular surfaces are analyzed with the same slice assumptions as the simplified Janbu method.

Both of these slices methods contain the FOS value in implicit form, which requires an initial iteration for FOS. This iteration is greatly expedited if it is entered with a reasonable value of FOS. This can ordinarily be accomplished by means of a Taylor type chart (Reference 13), where the real problem has been suitably simplified to permit approximate chart solutions.

STABL values may be checked for a specific failure surface in several ways. CIRCL2 should yield about the same FOS (for the same

circle) as any other computerized analysis for circles. To determine that this is indeed the case, the new user of STABL can run CIRCL2 in parallel with his present method. BLOCK or BLOCK2 can be checked approximately (for a specific block) either manually or perhaps by existing charts. RANDOM is amenable to approximate manual checks.

Input Options

Numerous options are available for use with the STABL 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. Surface and subsurface geometry, with command words

PROFIL

LIMITS

2. Subsurface profile parameters, with command words

SOIL

ANISO

WATER

3. Boundary loads, with command words

LOADS

TIES (Available in STABL4 only)

EQUAKE

4. Analytical methods, with command words

SURFAC/SURBIS

CIRCL2

RANDOM

BLOCK

BLOCK2

The command PROFIL is used to label input data of the slope geometry and any subsurface boundaries forming the soil strata. Up to one hundred different boundaries can be specified. If the user is trying to confine critical surfaces within certain zones, the command LIMITS may be used. This prevents the generation of critical planes beyond the defined limiting boundary, such as competent rock underlying the slope. Of course, one could simply introduce the rock as a soil type with a high strength, which would effectively lead to higher factors of safety (FOS) for surfaces passing through the rock. However, the LIMITS option, by eliminating the surfaces which would have passed through the rock, is more efficient since computer time is not wasted in computing a high FOS. Additionally, an upper limiting boundary, which will force planes downwards, may also be specified. This is useful for stability analysis of retaining structures such as sheet piles, anchored bulkheads, reinforced earth walls, etc.

In order to define subsurface conditions, the command SOIL is used to assign for up to 20 soil types the soil parameters which include unit weights, $c-\phi$ parameters and pore pressures. If the user feels that the strength properties are significantly anisotropic, the command ANISO allows one to define the strength parameters in up to 10 sectors, the appropriate values being selected according to the plane of interest. The WATER option is used to define up to 10 different piezometric levels

within the slope geometry. These can be successfully used to assign perched water tables and also to simulate pore pressure distributions within the soil strata.

External boundary loads which may be applied to the slope are defined by the command, LOADS. This allows input of up to 10 loads, as a surcharge intensity, in any direction. A boundary load of varying intensity may be approximated by a set of equivalent uniformly distributed loads abutting each other. Tieback or concentrated loads applied to the slope are defined by the command, TIES. This option allows input of up to 10 horizontal or inclined concentrated loads applied to the profile surface. The TIES option is fully described in Appendix F and is available only in the most recent version of STABL, STABL4. For a pseudo-static earthquake analysis, the command EQuAKE is used to assign vertical and horizontal coefficients to simulate the design earthquake.

Four different methods of analyzing the stability of a slope are available for use in STABL. The commands SURFAC (for Janbu Analysis) or SURBIS (for Bishop analysis) are used for determining the FOS for a specific critical failure surface defined by coordinates input by the user. However, if the user is at an initial investigation phase, the commands RANDOM (irregular surfaces) and CIRCL2 (circular surfaces) may be specified to utilize the program's unique capability to generate critical failure surfaces in a random manner. The user only needs to define the initiation and termination limits of the failure surfaces. If block-type analysis is also required, the BLOCK or BLOCK2 options allow the user to generate random blocks for analysis. For these

blocks, the user can manipulate the size of the block zones to arrive at the minimum FOS.

Thus, by specifying the geometry and soils of the slope, the user can perform numerous operations, using three different types of critical failure surfaces, to arrive at the most probable value for the FOS for the slope. Additionally, all the commands, except for PROFIL and the analysis commands, may be turned "off" or "on" which allows use of the same input data for the entire stability analysis, without having to create multiple data sets.

Data is input as "free-format", beginning in the first column (left justified), with items being separated by one space. This facilitates data entry as it does not restrict the user to certain column widths which sometimes lead to format errors. Also, STABL is compatible with any unit systems which the user may prefer to utilize for analysis. Providing consistent units of length and mass are used, the program will function without error. For example one may use the following:

Coordinates:	feet (ft)	metres (m)
Unit Weights:	pounds/cubic foot (pcf)	kilograms/cubic metre (kg/m ³)
Strength Intercept:	pounds/square foot (psf)	kilograms/square metre (kg/m ²)
Pore Pressure:	pounds/square foot (psf)	kilograms/square metre (kg/m ²)
Unit Weight of Water:	62.4 pcf	1000 kg/m ³

Searching Routines

Each slope to be analyzed is made left-facing and placed in a first quadrant position so that all coordinates will have positive values. In order to make the computer generation and search reasonably efficient, a number of restrictions are placed on the surfaces:

(1) They should enter and exit the surface boundary at reasonable positions. This is accomplished by assigning initiation and termination limits. See Figure 1.

(2) They should not go deeper than a depth limit, usually represented by a hard layer. See Figure 1.

(3) They should be composed of straight line segments, not so long as to fail to represent real changes in surface shape, and not so short as to produce "kinkyness" in shape. Guidelines have been worked out through experience.

(4) The generated surfaces shall appear to be kinematically acceptable, i.e., when examined, movement along them appears logical.

(5) While surfaces are generated in a random fashion, there must be some bias inserted to obtain acceptable shapes.

Figure 2 shows schematically how the first line segment is generated. Without appropriate upper and lower limits, the surface could immediately assume an illogical shape and position. The direction of the first line segment is determined within the limits by a random number generator in the program. As shown in Figure 3, the second seg-

FIGURE 1. TRIAL FAILURE SURFACE ACCEPTANCE CRITERIA

FIGURE 2. GENERATION OF FIRST LINE SEGMENT

FIGURE 3. GENERATION OF SECOND LINE SEGMENT

ment of the potential failure surface has an assigned upper limit and a lower limit which is generated in a random but somewhat biased direction. The direction of the segment is again randomly generated within the limits.

If a circle is being generated (CIRCL2), it has been defined by the random generation of the first two segments (chords). The program will complete the generation of the circle and determine its FOS. For the irregular surface generation (RANDOM), random choices continue to be made as for the second segment until the surface is totally generated; it is then analyzed for the FOS.

Some surfaces will violate the depth or termination limits (Figure 1) and will be discarded. Surface generation is accomplished in a batch mode, with the generation continuing until the desired number is accomplished, or until a large number of attempts have been made without total success.

The searching procedures described above are appropriate for CIRCL2 and the RANDOM, but may not be economical where weak layers govern the location of critical sliding surfaces. In such cases, grided "boxes" are superimposed on the weak layers. As shown in Figure 4, boxes are specified to overlie a weak layer wherever that layer changes in direction.

Points are randomly chosen within the specified boxes, and connected by straight lines. The surfaces are completed at the ends by random generation (BLOCK) or by assuming that these ends are simple Rankine type surfaces ($45 \pm \frac{\phi}{2}$), as in BLOCK2. The routine BLOCK is

FIGURE 4. SLIDING BLOCK GENERATOR USING MORE THAN TWO BOXES

illustrated in Figure 5, where the random limits cause the active side segments to be $>-45^{\circ}$, and the passive side segments to be $\leq -45^{\circ}$. BLOCK2 is somewhat simpler than BLOCK, and has tended to be used more. Since the boxes can degenerate to points or lines, the program can be used for cracks, joints, or fissures.

As emphasized further in the next section, interaction between searching routines and plotting routines is required. When arbitrary assumptions are made with respect to selection of a searching mode, initiation zone, termination zone, depth limit, box position and the like, the plotting routines have a capability to reveal this.

Plotting Routines

The use of plotting routines is essential to the random generation of surfaces in STABL. These plots will indicate: the shapes generated; the subsurface space searched; and the positions of generated surfaces which have the lower values of FOS. Surfaces are generally generated in batches.

The plot of all surfaces in a batch which involved 10 irregular surfaces from each of 5 initiation points is shown in Figure A2 in Appendix A. Also, an accompanying plot, which depicts ten critical surfaces with the lowest FOS, is shown in Figure A3. Depending upon the practical problem involved, the engineer may decide to change the initiation limits, termination limits, or depth limits to "explore" other areas for a more critical surface. He may even decide to use different generation modes, i.e., BLOCK (BLOCK2) or CIRCL2.

FIGURE 5. GENERATION OF ACTIVE AND PASSIVE SLIDING SURFACES USING BLOCK OPTION

In any reasonably complex problem, multiple man-machine interactions are required, and are anticipated in the procedures of STABL. The engineer should avoid promising the final results of an analysis based upon the computer "turn around" time for a single run.

Error Messages

In a comprehensive program such as STABL it is likely that errors will be committed in data/analysis input and commands. Most data errors will be detected by the program and the user is notified by an error message and a print-out of the line of erroneous data. These error messages are documented in the User Manual (Ref. 10), and allow the user to quickly correct mistakes with a minimum amount of time spent searching the input data. Additionally, data are checked and verified continuously during execution of the program to minimize the risk of incorrect or misleading output.

Recent Changes

Appendices E and F contain modifications effected in STABL during the past year. One of these is a change in the pseudo-static earthquake option, which eliminates the increase of pore pressures for an effective stress analysis. Appendix F contains an improvement which makes it more convenient to use near-horizontal boundary forces, such as those produced by tiebacks.

COMPARISON WITH OTHER PROGRAMS

This topic has been approached in two ways (Siegel, 1975a; Boutrup, 1977). The first is to simplify the problem in terms of boundary and

subsurface conditions, and to compare values of minimum FOS generated by searching with a variety of available programs. Since only STABL searches with shapes other than circles, the comparison comes down to values generated by the various circular methods of slices. The Geotechnical Engineering literature contains many such comparisons, which show that the simplified Bishop assumption used in CIRCL2 compares well with the longer and more iterative total equilibrium approaches. Research at Purdue shows the same results.

A second approach is to generate critical surfaces, in relatively complex problems, by using the non-circular searching modes in STABL. This is followed by generating FOS values, for the specific surface defined by STABL, by other available methods. Putting aside the probability that the engineer would fail to find the most critical surface by specifying possibility after possibility, the simplified Janbu approach of STABL gives somewhat conservative (low) values of FOS.

It is well to remember two facts relative to comparisons. Firstly, there is no analysis method which gives the correct value for FOS for reasonably complex problems. Since there is no method for determining the true answer, there is no way of assigning errors to any practical method. Secondly, comparisons vary with the part of the data field being examined, i.e., relative values change with the specific set of examples.

Neither of the two difficulties discussed above need perplex the engineer using STABL. When STABL is being considered as a replacement

for extant methods, they can be run in parallel with each other, and answers compared.

SUMMARY

The STABL slope stability system allows computerized searching for a variety of shapes for potential sliding surfaces. All such surfaces are represented as a series of straight lines, and the line directions are chosen in a pseudo-random manner. The analyses proper use simplified Bishop or simplified Janbu methods of slices to determine FOS values.

Plotting routines are necessary to assess the exact shapes and positions of generated sliding surfaces and to determine whether it is probable that the more critical sliding surfaces have been generated and analyzed. Error messages allow checks on input and execution steps.

The STABL system should be entered with reasonable estimates of the minimum FOS, so that iteration of the implicit expressions for FOS is minimized. The estimates may be obtained from existing chart solutions of the real problem in simplified form. The CIRCL2 searching option in STABL should yield values of FOS which compare closely with those of other circular searches. The BLOCK and RANDOM options in STABL are likely to produce somewhat lower values of FOS than specific surface analyses by other methods. One reason for this difference is the probability that a limited number of specific surfaces will not identify the critical sliding surfaces. The STABL searches should do a reasonable job of accomplishing this objective.

The latest documentation relating to STABL is presented in Appendix B. Appendices E and F contain recommended changes in the program with respect to the earthquake option, and the convenient entry of near-horizontal tieback forces into the calculations of FOS.

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APPENDIX A

EXAMPLE PROBLEM

The stability of the slope shown in Figure A1 was investigated using STABL. The example subsurface profile consists of 3 soil types for the irregular surface and circular surface analysis. For the block analysis, a "weak" seam was introduced, as soil type 4, to illustrate this option. A high groundwater level was assigned to the slope.

The irregular surface search was confined to zones where the randomly generated surface would initiate and terminate between $x = 25$ to 45 ft (7.62 to 13.72 m) and $x = 140$ to 185 ft (42.67 to 56.39 m), respectively. The 50 surfaces which were successfully generated between these user-defined limits are shown in Figure A2. A summary of the ten most critical surfaces is shown in Figure A3 with the surface representing the minimum factor of safety being "highlighted" with asterisks (*).

A similar search was also performed for 50 circular surfaces with the same initiation and termination limits as used for the irregular surface search. The 50 surfaces are shown in Figure A4 and the summary in Figure A5.

The "weak" seam, which was introduced into the subsurface profile, usually leads to failure represented by block or wedge shapes. The central portion of the block failure was limited between the two boxes, judiciously placed, to "force" generation of block surfaces along the "weak" layer. As can be seen from Figure A6, the major portion of all

* stratum consisting of Soil Type 4 was used for the 'block' analysis, only.

Figure A1 Example Slope Geometry and Subsurface Profile

Table A1 Summary of Soil Properties Used in Example

Soil Type #	Total Unit Wt. (pcf)	Sat. Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)
1	125.0	129.0	0.0	38.0
2	120.0	127.0	400.0	21.0
3	128.0	132.0	600.0	26.0
4	124.0	128.0	200.0	16.0

For S.I. conversion, use :

1 psf = 47.873 Pascals (or 4.882 kg/sq. metre)

1 pcf = 16.018 kg/ cubic metre

50 SURFACES HAVE BEEN GENERATED

Figure A2 Irregular Surface Search

10 MOST CRITICAL OF SURFACES GENERATED

MINIMUM FACTOR OF SAFETY = 1.404

Figure A3 Ten Most Critical Surfaces, Irregular

50 SURFACES HAVE BEEN GENERATED

Figure A4 Circular Surface Search

10 MOST CRITICAL OF SURFACES GENERATED

MINIMUM FACTOR OF SAFETY = 1.535

Figure A5 Ten Most Critical Surfaces, Circular

50 SURFACES HAVE BEEN GENERATED

Figure A6 Block Surface Search

block surfaces was confined to the "weak" layer. Figure A7 presents a summary of the most critical surfaces.

The three most critical irregular, circular and block surfaces were also analyzed further for earthquake loads. Seismic coefficients with a value of 0.02 were used with the vertical loading being downwards and the horizontal loading outwards from the slope. The change in factors of safety are shown in Figures A8 to A10.

Thus, based on a first run, we can summarize the minimum factors of safety for different critical surface types:

TYPE OF CRITICAL SURFACE	FACTOR OF SAFETY	
	STATIC CASE	EARTHQUAKE LOADS
Irregular	1.40	1.30
Circular	1.54	1.42
Block	1.12	1.03

After one has examined the output of the initial run, the user can evaluate the extent of the search for the "most" critical surface and decide if further investigations are required.

10 MOST CRITICAL OF SURFACES GENERATED

MINIMUM FACTOR OF SAFETY = 1.122

Figure A7 Ten Most Critical Surfaces, Block

FACTOR OF SAFETY FOR SPECIFIED SURFACE = 1.303

Figure A8 Pseudo Earthquake Analysis of Most Critical Irregular Surface

FACTOR OF SAFETY FOR SPECIFIED SURFACE = 1.416

Figure A9 Pseudo Earthquake Analysis of Most Critical Circular Surface

FACTOR OF SAFETY FOR SPECIFIED SURFACE = 1.031

Figure A10 Pseudo Earthquake Analysis of Most Critical Block Surface

APPENDIX B

STABL DOCUMENTATION

1. STABL Program, available on unlabelled 9-track tape for IBM or CDC Fortran codes at the required:

1. recording density, in bpi
2. fixed block size (URL=80)
3. conversion format (EBCDIC or ASCII)

2. Listing of program
3. STABL User Manual, JHRP-75-9
4. Computer Analysis of General Slope Stability Problems, JHRP-75-8
5. Computerized Slope Stability Analysis for Indiana Highways, Vol. 1, JHRP-77-25
6. Vol. 2 (1977 Program Listing), JHRP-77-26
7. Three-Dimensional Slope Stability Analysis, JHRP-81-17

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APPENDIX C

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Attn : Roger Pruitt
Phone: 404-363-7567
5. Kansas State Department of Transportation
Bureau of Computer Services
10th Floor, State Office Building
Topeka, Kansas 66612
Attn : John Lebbert
Phone: 913-296-3657
6. Idaho Department of Transportation
Information and Data Processing
P. O. Box 7129
Boise, Idaho 83707
Attn : Ron Cole
Phone: 208-334-2551

7. Iowa Department of Transportation
Ames, Iowa
Attn : Bruce L. Brakke, Division Bridge Engineer
Phone:
8. Louisiana Department of Transportation
P. O. Box 44245
Baton Rouge, Louisiana 70804
Attn : J. B. Esnard, Soils Design Engineer
Phone: 504-342-7623
9. Minnesota Department of Transportation
State Transportation Building
St. Paul, Minnesota 55155
Attn : Virgil V. Mikkelsen, Foundation Engineer
Phone: 612-296-2304
10. Mississippi State Highway Department
P. O. Box 1850
Jackson, Mississippi 39205
Attn : Mr. L. Ray Marler
Phone: 601-354-7211
11. Nebraska Department of Roads
P. O. Box 94759
Lincoln, Nebraska 68509
Attn: A. R. Kennedy
Phone: 402-473-4752
12. Nevada Department of Transportation
Materials and Testing Division
1263 South Stewart Street
Carson City, Nevada 89712
Attn : Ted Beeston
Phone:
13. New Jersey Department of Transportation
1035 Parkway Avenue CN600
Trenton, New Jersey 08625
Attn : Anil Mehta
Phone: 609-292-3574

14. State of New Mexico Highway Department
Bureau of Materials
P. O. Box 1149
Santa Fe, New Mexico 87504-1149
Attn : Richard Lueck
Phone: 505-983-1149
15. North Carolina Department of Transportation
Division of Highways
P. O. Box 25201
Raleigh, North Carolina 27611
Attn : Mr. Larry Colbert
Phone: 919-733-2075
16. Oklahoma Department of Transportation
Design Support Unit
200 N. E. 21st Street, Room 2C9
Oklahoma City, Oklahoma 73105
Attn : Charles Whittle
Phone:
17. Oregon Department of Transportation
Bridge Section
Oregon DOT Building
Salem, Oregon 97310
Attn : John Marks
Phone: 503-378-6551
18. Texas State Department of Highways and Public Transportation
11th and Brazos
Austin, Texas 78701
Attn : Mr. Wayne Henneberger
Phone:
19. Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101
Attn : Chien-Tan Chang
Phone: 703-285-2357
20. Utah Department of Highways
4501 South 2700 West
Salt Lake City, Utah 84119
Attn : Loren Rausher
Phone: 801-965-4196

21. Washington State Department of Transportation
Materials Laboratory
P. O. Box 167
Olympia, Washington 98504
Attn : Leroy Wilson
Phone: 206-753-7100

22. Wisconsin Department of Transportation
3502 Kinsman Boulevard
P. O. Box 7878
Madison, Wisconsin 53704-7878
Attn : Gary Whited
Phone: 608-246-3249

23. Wyoming Highway Department
Cheyenne, Wyoming 82002
Attn : Bill Sherman, Chief Engineering Geologist
Phone: 307-777-7801

APPENDIX D

COMMENTS ABOUT SAFETY FACTORS FOR SAMPLE PROBLEMS

Some concern has been expressed about the discrepancy between the safety factors given in the User Manual for the sample problems and those computed by the Users. These differences are due to use of STABL on non-CDC computers and thus, we would like to offer an explanation for these variations.

The factors of safety, for surfaces generated using random numbers, will depend somewhat on the sequence of such numbers and the method of computation. The example problems presented in the User Manual were analyzed on a CDC computer, using a library function to generate the required random numbers. The library function available for VAX computers will provide the same sequence of random numbers. Thus, the results shown in the example problems may be duplicated only if the program is executed on a CDC or VAX computer. For other cases (e.g., IBM computers), the function, RANF, within the program source code is used to generate the sequence of random numbers. However, since such a sequence of random numbers will be different from the one generated by a CDC or VAX library function, different potential failure surfaces will be analyzed by the program. Consequently, a different minimum factor of safety will be computed and the critical surface will differ somewhat from the one presented in the examples.

APPENDIX E

MODIFICATIONS AND REVISIONS OF STABL

Some additional changes have been made in the last 18 months, due to a much more extensive use of STABL for teaching purposes and also as a result of interaction between the Users and Purdue University. Most of these changes are minor and only improve the operation of the program. However, a significant modification is proposed for the portion of the program dealing with the pseudo-static earthquake analysis.

The existing program lowered factors of safety (FOS) for the effective stress analysis where excess, positive pore pressures were considered in the analysis. As mentioned on p. 14 of the User Manual (JHRP-75-9), (Ref. 10), the program considers the generation of excess pore pressures based on a seismic coefficient. These pressures are computed according to the inertial forces generated by the seismic coefficient (see p. 126, JHRP-77-25, Ref. 1). We feel that this is not particularly realistic, especially as it applies only to effective stress analysis. Conventionally, the selected seismic coefficient will be expected to account for such effects, as well as a loss of strength during an earthquake.

Thus, we have revised the program to include only the effects of additional inertial forces induced by the specified seismic coefficients, without changing the static pore pressures. For this revised method, the following changes are proposed:

1. Change the statement on line WGHT 704 to read:
`IF(RU(SOILTP).EQ.0..AND.CU(SOILTP).EQ.0.)GO TO 23`
2. LINES WGHT 708, 710, 712 should be deleted.

Also note that a value for the cavitation pressure is required when using the EQUAKE option (see p. 41 in User Manual, Ref. 10). However, the following errata should be inserted in the User Manual to replace the second paragraph on p. 14:

The inertial forces due to the seismic coefficients are 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.

There are other minor changes which do not affect the FOS computations. These are listed below:

1. In subroutine PROFIL:

Line PROF1151 should read: `CALL READER(DUMMY,NP(K),0)`
(date of change, 4-9-84)

2. In subroutine RANDOM:

Line RAND1130 should read: `WRITE(6,110)ERROR(20)`
(date of change, 4-9-84)

after line RAND1830, insert these 3 lines:

`IF(MB .NE. 1) WRITE(6,136)`
 136 `FORMAT(10X,' * * SAFETY FACTORS ARE CALCULATED BY THE '`
1 `'MODIFIED JANBU METHOD * *',//)`
(date of change, 1-9-84)

3. In subroutine RANSUF:

Line RANS 766 should read: IF(ILIMIT.EQ.0) GO TO 2

Line RANS 798 should read: GO TO 8

After line RANS1376, insert: IF(SURF(K,1).LT.BPT)GO TO 3

After line RANS1464, insert: IF(SURF(K,1).LT.BPT)GO TO 3
(date of change, 3-1-83)

4. In subroutine FACTR:

After line FCTR 492, insert: IF(A1(I).LT.0.0)A1(I)=0.0
(date of change, 3-1-83)

5. For those Users with random generator subroutine RANF,

Line RANF 4 should read: DATA XN,SEED/131072,27487/

After line RANF 8, insert: IF(SEED.LT.0)SEED=SEED+XN
(date of change, 3-1-83)

NOTE: All of the above are FORTRAN statements and should be inserted according to conventional programming rules into their correct column fields.

APPENDIX F
INPUT OF TIEBACK LOADS

F.1 Introduction

The use of tiebacks in geotechnical engineering and construction for stability of slopes and support of excavations has increased substantially within the last several years. As a result, the need for a method of analyzing the overall stability of slopes and retaining walls subjected to horizontal or inclined concentrated loads has become more evident. Until now, the input of horizontal or inclined concentrated loads acting on a near vertical slope was somewhat difficult in STABL. In addition the factor of safety was not formulated for this type of loading and thus, did not fully account for the distribution of force to the failure surface caused by concentrated boundary loads.

Therefore, to increase the versatility of STABL, new routines have been created within STABL to permit input of horizontal or inclined concentrated loads. These routines were created specifically for the input of tieback loads but may be easily used for any type of concentrated load applied to the ground surface. The latest version of STABL, STABL4, contains the new routines which utilize Flamant's Formulas as proposed by Morlier and Tenier (1982) and the modified Bishop method of analysis for circular failure surfaces, and the simplified Janbu method of analysis for non-circular failure surfaces. The tieback option may be used with either random or specific failure surface generation methods for irregular, block or circular failure surfaces. Throughout this appendix and within STABL4 the word "tieback" is used to mean tieback or other types of concentrated loads applied to the ground surface.

Tieback or other types of concentrated loads are input by specifying 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, Figure F1. For concentrated boundary loads such as strut loads in a braced excavation which do not extend into the ground like tiebacks, the 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.

A short description of the new tieback routines is presented to help the User understand the method and assumptions used in STABL4 for analyzing slopes subjected to concentrated loads. Two example problems are also presented to demonstrate the input of horizontal and inclined loads and the effect of concentrated loads on the factor of safety against slope failure. The example problems include input and output data and plots. In addition, the input format for concentrated loads is presented along with input restrictions, error codes, and a listing of the additions and modifications to STABL3 required to update that version to STABL4.

F.2 Description of New Tieback Routines

Unlike other slope stability programs, STABL4 distributes the force from a concentrated load throughout the soil mass to the whole failure

Tieback Input Parameters

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

FIGURE F1 - TIEBACK INPUT PARAMETERS

surface and hence to all slices of the sliding mass. Other slope stability programs on the other hand, only take a concentrated load into account on the slice on which it acts. This distribution of load throughout the soil mass is a unique feature of STABL4.

First an equivalent line load is calculated for a row of tiebacks by dividing the specified tieback load (point load) by the corresponding horizontal spacing between tieback loads. The resulting line load is called TLOAD, Figure F2, and is inclined from the horizontal by an angle INCLIN. The radial stress on the midpoint of a slice is calculated using Flamant's Formula (Morlier and Tenier, 1982):

$$\sigma_r = \frac{2(TLOAD)\cos(TTHETA)}{(\pi)(DIST)}$$

where

σ_r	=	Radial stress
TLOAD	=	Equivalent tieback line load
TTHETA	=	Angle between the line of action of the tieback and the line between the point of application of the tieback on the ground surface and the midpoint of a slice.
π	=	pi
DIST	=	Distance between the point of application of the tieback on the ground surface and the midpoint of a slice.

The radial force, PRAD, at the midpoint of the base of the slice due to the concentrated load is calculated by multiplying the radial stress by the length of the base of the slice:

$$PRAD = \frac{2(TLOAD)\cos(TTHETA)}{(\pi)(DIST)} \cdot \frac{(DX)}{\cos(ALPHA)}$$

FIGURE F2 - TRANSFER OF CONCENTRATED LOAD TO FAILURE SURFACE

where

PRAD	=	Radial force on base of slice due to concentrated load
ALPHA	=	Inclination of base of slice
DX	=	Slice width

Note that the radial stress produced on the base of the slice by the concentrated load is proportional to the load applied (TLOAD) and the width of the slice (DX), inversely proportional to the distance between the point of application of the load and the midpoint of the base of the slice (DIST), and dependent upon the angle between the line of action of the load and the line between the point of application of the load and the midpoint of the base of the slice (TTHETA). Therefore, slices which are in line with the direction of the concentrated load will receive a larger portion of the total load than will slices which are farther away and whose angle TTHETA is large.

The radial force PRAD is distributed in the same manner to all the slices of the sliding mass. The radial forces on all the slices are then summed in the direction of the concentrated load, PSUM, and compared with the applied load, TLOAD. Since the sum of radial forces for a failure surface, PSUM, is not always exactly equal to the applied load due to slope geometry and the shape of the failure surface, the radial force applied to the base of each slice is modified as follows:

$$PRAD = TLOAD/PSUM$$

The refined radial force for each slice, PRAD, is broken into its components normal and tangential to the base of the slice for calcula-

tion of the factor of safety. The normal and tangential components of the force due to the concentrated load are respectively:

$$PNORM = (PRAD)\cos(ALPHA)$$

$$PTAN = (PRAD)\sin(ALPHA)$$

The same process is repeated for all additional rows of tiebacks. The sum of the normal components and the sum of the tangential components due to all rows of tiebacks are then used in the slice equilibrium equations for calculating the factor of safety.

There is a special case where the tieback loads will not be distributed to quite all the slices of the sliding mass and is shown in Figure F3. Figure F3 shows the limit of the stress distribution for a benched slope. The force due to the applied load is not distributed to the slices of the far left or the slices of the far right since this would require distribution of load through air and not the soil mass.

Examples showing the use of the new tieback routines in STABL4 are presented in the next section.

F.3 Examples Using Concentrated Loads

The details of the examples presented are not of concern since the primary purpose of the examples is to demonstrate the use of the new routines for concentrated loads. It should be noted that the critical failure surface and the minimum factor of safety will change in most instances due to the introduction of concentrated horizontal or inclined loads. In addition, the examples presented herein only analyze a specified failure surface for the sake of simplicity and clarity. A random

FIGURE F3 - LIMIT OF STRESS DISTRIBUTION DUE TO CONCENTRATED LOAD

search should always be performed to find the new critical failure surface and corresponding minimum factor of safety against overall slope failure.

The profile shown in Figure F4 represents a proposed excavation in a silty sand with vertical sides supported by steel sheet piling. It has been determined that the critical failure surface is circular and exits the slope at the toe of the sheeting. The minimum factor of safety for overall stability was determined to be 0.451 for the critical surface with center at (41 ft, 76 ft) (12.50 m, 23.16 m) and radius 41.9 ft (12.77 m).

Two methods of support have been proposed. The first method involves using two rows of tiebacks and the second method involves using a bracing system inside the excavation.

F.3.1 Example Problem #1

It has been determined that two rows of tiebacks are required for local stability of the wall (Figure F5). The first (upper) row of tiebacks will be horizontal and the free length of the tiebacks will be 40 ft (12.19 m). The first row of tiebacks will each carry a load of 150,000 lbs (68,040 kg) and will be spaced 10 ft (3.05 m) apart horizontally. The second (lower) row of tiebacks will be inclined 15 degrees as measured clockwise from the horizontal and will have a free length of 30 ft (9.14 m). Each tieback in this row will carry a load of 200,000 lbs (90,720 kg) and will also be at a 10 ft (3.05 m) horizontal spacing. Both rows of tiebacks will transfer their loads to the sheeting using horizontal steel beams for wales. Therefore, the assumption of a

FACTOR OF SAFETY FOR SPECIFIED SURFACE = 0.451

FIGURE F4 - GENERAL PROFILE FOR EXAMPLE PROBLEMS

uniform distribution of load between the tiebacks will be reasonable for this case since the action of the wale will cause an equivalent horizontal line load to be formed for each row of tiebacks.

It is desired to know what effect the tiebacks have on the factor of safety of the previously mentioned critical failure surface. Therefore, the program will be run using a specified circular failure surface and the input data shown in Figure F6. The output for this run is given in Figures F7, F8 and F9.

Note that if the unbonded portion of any tieback does not intersect the failure surface, i.e., terminates within the sliding mass as in tiebacks #1 and #2 of Figure F10, the load from that particular row of tiebacks will not be considered in the factor of safety calculation. Only the load from tieback #3 of Figure F10 would be considered in the factor of safety calculation since the failure surface intersects the unbonded portion of tieback #3.

As will be seen in the next example, the length of a "tieback" for a braced system of support is equal to zero and all concentrated loads will be considered for all failure surfaces in the factor of safety calculation.

F.3.2 Example Problem #2

The second method of support proposed involves using bracing to provide local and overall stability to the wall (Figure F11). The bracing system will consist of horizontal struts bearing against steel wales which transfer their loads to the sheet piling. The first level of


```

PROFIL
TIERACK EXAMPLE PROBLEM #1
4 4
10. 35. 50. 35. 1
50. 35. 50.1 60. 1
50.1 60. 80. 62. 1
80. 62. 93. 62. 1
SOIL
1
120. 125. 0. 18. 0. 0. 1
WATER
1 62.4
4
10. 35.
50. 35.
50.01 50.
82. 51.
TIES
2
2 53. 150000. 10. 0. 40.
2 48. 200000. 10. 15. 30.
SURBIS
7
50. 35.2
56. 36.8
64. 40.9
70. 45.1
74. 49.
78. 54.1
82.3 62.
EXECUT

```

FIGURE F6 - INPUT DATA FOR EXAMPLE #1

--SLOPE STABILITY ANALYSIS--
SIMPLIFIED JANBU METHOD OF SLICES
OR SIMPLIFIED BISHOP METHOD

PROBLEM DESCRIPTION TIERBACK EXAMPLE PROBLEM #1

BOUNDARY COORDINATES

4 TDP BOUNDARIES
4 TOTAL BOUNDARIES

BOUNDARY NO.	X-LEFT (FT)	Y-LEFT (FT)	X-RIGHT (FT)	Y-RIGHT (FT)	SOIL TYPE BELOW BND
1	10.00	35.00	50.00	35.00	1
2	50.00	35.00	50.10	60.00	1
3	50.10	60.00	80.00	62.00	1
4	80.00	62.00	93.00	62.00	1

ISOTROPIC SOIL PARAMETERS

1 TYPE(S) OF SOIL

SOIL TYPE NO.	TOTAL UNIT WT. (PCF)	SATURATED UNIT WT. (PCF)	COHESION INTERCEPT (PSF)	FRICTION ANGLE (DEG)	PORE PRESSURE PARAMETER	PRESSURE CONSTANT (PSF)	PIEZOMETRIC SURFACE NO.
1	120.0	125.0	0	18.0	0	0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

UNIT WEIGHT OF WATER = 62.40

PIEZOMETRIC SURFACE NO. 1 SPECIFIED BY 4 COORDINATE POINTS

POINT NO.	X-WATER (FT)	Y-WATER (FT)
1	10.00	35.00
2	50.00	35.00
3	50.01	50.00
4	82.00	51.00

TIERBACK LOAD(S)

2 TIERBACK LOAD(S) SPECIFIED

TIERBACK NO.	X-POS (FT)	Y-POS (FT)	LOAD (LBS)	SPACING (FT)	INCLINATION (DEG)	LENGTH (FT)
1	50.07	53.00	150000.0	10.0	0	40.0
2	50.05	48.00	200000.0	10.0	15.00	30.0

FIGURE F7 - OUTPUT FOR EXAMPLE #1

TRIAL FAILURE SURFACE SPECIFIED BY 7 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	50.00	35.00
2	56.00	36.80
3	64.00	40.90
4	70.00	45.10
5	74.00	49.00
6	78.00	54.10
7	82.30	62.00

CIRCLE CENTER AT X = 41.0 ; Y = 76.0 AND RADIUS, 41.9

FACTOR OF SAFETY FOR THE PRECEDING SPECIFIED SURFACE = 1.870

WARNING - FACTOR OF SAFETY IS CALCULATED BY THE MODIFIED BISHOP METHOD. THIS METHOD IS VALID ONLY IF THE FAILURE SURFACE APPROXIMATES A CIRCLE.

FIGURE F8 - OUTPUT FOR EXAMPLE #1 (Continued)

FACTOR OF SAFETY FOR SPECIFIED SURFACE = 1.870

FIGURE 10 - INTERSECTION OF TIEBACK WITH FAILURE SURFACE

FIGURE F11 - EXAMPLE PROBLEM #2 PROFILE

struts will carry 150,000 lbs/strut (68,040 kg/strut) and will be spaced 10 ft (3.05 m) apart. The second level of struts will carry 200,000 lbs/strut (90,720 kg/strut) and will be spaced 10 ft (3.05 m) apart. Again the assumption of a uniform distribution load between the struts is reasonable due to wale action.

Again the program is run using the input data shown in Figure F12 for the braced excavation and a specified failure surface and the output is given in Figures F13, F14 and F15. As mentioned in Example #1, the length of a "tieback" for a concentrated load such as the load produced by a row of struts is input as zero. All concentrated loads with length zero will be used for the calculation of the factor of safety for all failure surfaces.

F.4.1 Data Input Format for Tieback Loads (if specified)

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

Note: Repeat preceding data card for each tieback load.

```

PROFIL
TIEBACK EXAMPLE PROBLEM #2
4 4
10. 35. 50. 35. 1
50. 35. 50.1 60. 1
50.1 60. 80. 62. 1
80. 62. 93. 62. 1
SOIL
1
120. 125. 0. 18. 0. 0. 1
WATER
1 62.4
4
10. 35.
50. 35.
50.01 50.
82. 51.
TIES
2
2 53. 150000. 10. 0. 0.
2 48. 200000. 10. 0. 0.
SURBIS
7
50. 35.2
56. 36.8
64. 40.9
70. 45.1
74. 49.
78. 54.1
82.3 62.
EXECUT

```

FIGURE F12 - INPUT DATA FOR EXAMPLE #2

--SLOPE STABILITY ANALYSIS--
SIMPLIFIED JANBU METHOD OF SLICES
OR SIMPLIFIED BISHOP METHOD

PROBLEM DESCRIPTION TIERACK EXAMPLE PROBLEM #2

BOUNDARY COORDINATES

4 TOP BOUNDARIES
4 TOTAL BOUNDARIES

BOUNDARY NO.	X-LEFT (FT)	Y-LEFT (FT)	X-RIGHT (FT)	Y-RIGHT (FT)	SOIL TYPE BELOW END
1	10.00	35.00	50.00	35.00	1
2	50.00	35.00	50.10	60.00	1
3	50.10	60.00	80.00	62.00	1
4	80.00	62.00	93.00	62.00	1

ISOTROPIC SOIL PARAMETERS

1 TYPE(S) OF SOIL

SOIL TYPE NO.	TOTAL UNIT WT. (PCF)	SATURATED UNIT WT. (PCF)	COHESION INTERCEPT (PSF)	FRICTION ANGLE (DEG)	PORE PRESSURE PARAMETER	PRESSURE CONSTANT (PSF)	PIEZOMETRIC SURFACE NO.
1	120.0	125.0	0	18.0	0	0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

UNIT WEIGHT OF WATER = 62.40

PIEZOMETRIC SURFACE NO. 1 SPECIFIED BY 4 COORDINATE POINTS

POINT NO.	X-WATER (FT)	Y-WATER (FT)
1	10.00	35.00
2	50.00	35.00
3	50.01	50.00
4	82.00	51.00

TIERACK LOAD(S)

2 TIERACK LOAD(S) SPECIFIED

TIERACK NO.	X-POS (FT)	Y-POS (FT)	LOAD (LBS)	SPACING (FT)	INCLINATION (DEG)	LENGTH (FT)
1	50.07	53.00	150000.0	10.0	0	0
2	50.05	48.00	200000.0	10.0	0	0

FIGURE F13 - OUTPUT FOR EXAMPLE #2

TOTAL FAILURE SURFACE SPECIFIED BY 7 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	50.00	35.00
2	56.00	36.80
3	64.00	40.90
4	70.00	45.10
5	74.00	49.00
6	78.00	54.10
7	82.30	62.00

CIRCLE CENTER AT X = 41.0 ; Y = 76.0 AND RADIUS, 41.9

FACTOR OF SAFETY FOR THE PRECEDING SPECIFIED SURFACE = 2.071

WARNING - FACTOR OF SAFETY IS CALCULATED BY THE MODIFIED BISHOP METHOD. THIS METHOD IS VALID ONLY IF THE FAILURE SURFACE APPROXIMATES A CIRCLE.

FIGURE F14 - OUTPUT FOR EXAMPLE #2 (Continued)

FACTOR OF SAFETY FOR SPECIFIED SURFACE = 2.071

F.4.2 Input for Suppressing or Reactivating Tieback Loads (if specified)

COMMAND CARD	TIES	Command Code
DATA CARD	Integer	Number zero (0)

F.5 Input Restrictions

1. The point of application of a tieback on the ground surface may not be at a ground surface boundary node. Use a slight vertical offset, (i.e. 70.01 instead of 70).
2. No more than 10 tieback loads can be specified but they can be in any order.
3. The inclination of a tieback must be equal to or greater than zero degrees and less than 90 degrees as measured clockwise from the horizontal.
4. The horizontal spacing between tiebacks must be greater than or equal to 1 ft (or 1 metre if using SI units).
5. The length of a tieback must be equal to or greater than zero ft. Zero is used for loads other than tieback type of loads.

F.6 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 90 (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 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 ft (or 1 metre if using SI units).
- TI07 - The length of the tieback indicated is incorrect. The length of a tieback must be greater than or equal to zero (ft). Zero is used for loads other than tieback type of loads.

F.7 List of Program Additions and Modifications

The following pages list the program lines which have been modified and new lines which are required for calculation of the factor of safety considering the presence of concentrated loads. There are two new sub-routines, TIES and TRANS. Program lines which have been modified for the input of concentrated loads are denoted by JRCMAR84 which indicates that they were modified by James R. Carpenter, March 1984.

The last two pages of this section list the lines which must be interchanged in and/or added to STABL4 to run the program on an IBM computer.

CHARGES FOR PROGRAM STABL3:

C	PROGRAM STABL4	STBL 4
C		STBL 6
C		JRCMAR84
C		STBL 10
C		STBL 12
C		STBL 14
C	AUTHOR --	STBL 16
C		STBL 18
C	RONALD A. SIEGEL, GRADUATE RESEARCH ASSISTANT, 1975.	STBL 20
C	REVISED BY --	STBL 22
C		OCT76EO
C		OCT76EO
C	EVA BOUTRUP, GRADUATE RESEARCH ASSISTANT, JANUARY 1978.	JAN78EO
C	REVISED BY --	OCT76EO
C		MGOODMAN
C	MARTIN GOODMAN, GRADUATE RESEARCH ASSISTANT, AUGUST 1982.	JRCMAR84
C	REVISED BY --	MGOODMAN
C		JRCMAR84
C	JAMES R. CARPENTER, GRADUATE RESEARCH ASSISTANT, MARCH 1984.	JRCMAR84
C		JRCMAR84
C	SPONSOR --	STBL 24
C		STBL 26
C		STBL 224
C	OUT DATA DEFINING AN INDIVIDUAL TRIAL FAILURE SURFACE.	STBL 226
C		JRCMAR84
C	TIES	JRCMAR84
C	SUBROUTINE THAT READS IN, CHECKS, STORES, AND PRINTS OUT TIERACK ANCHOR LOAD DATA.	JRCMAR84
C		STBL 228
C	TOL	STBL 230
C	TOLERANCE CONSTANT TO ACCOUNT FOR MACHINE ROUNDING.	

```

C
COMMON /BLK01/ IANGL,IBLK, IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
1 TELK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,IRD,TOL
COMMON /BLK15/ M,MB
DIMENSION KEYW(16),ERROR(5)
DATA KEYW/6HPROFIL,5HLOADS,4HTIES,5HWATER,6HSURFAC,6HEXCUT,
1 6HEQUAKE,4HISOIL,6HRANDOM,6HCIRCLE,6HCIRCL2,5HLOCK,6HBLOCK2,
1 6HLIMITS,5HANISO,6HSURRIS/
DATA ERROR/4HSQ01,4HSQ02,4HSQ03,4HSQ04,4HSQ05/
TOL=.0001

```

```

STBL 244
STBL 246
JRCMAR04
STBL 249
JRCMAR04
JRCMAR04
JRCMAR04
JRCMAR04
STBL 256
STBL 258

```

```

STBL 354
STBL 356
JRCMAR04
JRCMAR04
JRCMAR04
STBL 362
STBL 364

```

```

C
C
23 DO 12 I=1,16
IF(MKEYW,EQ,KEYW(I))GO TO (1,2,28,3,4,5,6,7,9,10,8,14,18,15,16,
1 13),I
12 CONTINUE

```

```

1 10X,'*****',A6,' - ILLEGAL COMMAND *****'//
1 10X,'*****'//
WRITE(6,102)(KEYW(I),I=1,16)
102 FORMAT(//,10X,'LEGAL COMMANDS - ',A6,/, (27X,A6))
CALL QUIT

```

```

STBL 380
STBL 382
JRCMAR04
STBL 386
STBL 388

```

```

2 CALL LOADS
GO TO 11
28 CALL TIES
GO TO 11
3 CALL WATER
GO TO 11

```

```

STBL 394
STBL 396
JRCMAR04
JRCMAR04
STBL 398
STBL 400

```


CHANGES FOR SUBROUTINE READER:

```

C
COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
1 IRLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
COMMON /BLK08/NSLICE,X(300)
DIMENSION M(80),N(14),A(10),IA(10),ERROR(7)
READ 144
READ 146
JRCMAR84
READ 150
READ 152

```

CHANGES FOR SUBROUTINE PROFIL:

```

C ISURF CONTROL CODE WHICH INDICATES DEFINITION OF SPECIFIED PROF 208
C TRIAL FAILURE SURFACE. PROF 210
C JRCMAR84
C ITIES CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM JRCMAR84
C HANDLING THE TIEBACK ANCHOR LOADS SPECIFIED BY JRCMAR84
C SURROUTINE TIES. JRCMAR84
C ITP ARRAY CONTAINING SOIL TYPE INDICES FOR EACH BOUNDARY. PROF 212
C PROF 214

```

```

C NSURC NUMBER OF BOUNDARY LOADS SPECIFIED. PROF 274
C PROF 276
C NTIES NUMBER OF TIEBACK ANCHOR LOADS SPECIFIED. JRCMAR84
C
C NTOP NUMBER OF GROUND SURFACE BOUNDARIES. JRCMAR84
C PROF 278
C PROF 280

```

```

DIMENSION TITLE(4), DESCR(4), ERROR(11).
COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
1 IRLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
COMMON /BLK02/ENDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NEND,
1 NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20)
PROF 344
PROF 346
JRCMAR84
PROF 350
PROF 352

```

PROF 362
PROF 364
JRCMAR84
JRCMAR84
JRCMAR84
PROF 366
PROF 368

```

1      PHIA(10,10)
      COMMON /BLK11/CAVT,KCOEF,VKCOEF
      COMMON /BLK16/NTIES,INCLIN(10),FLOAD(10),SPACE(10),TLOAD(10),
1      XTIE(10),YTIE(10),BN(10),LENGTH(10),XEND(10),
1      YEND(10)
1      DATA ERROR/4HFF01,4HFF02,4HFF03,4HFF04,4HFF05,4HFF06,4HSL01,
1      4HSL02,4HSL03,4HSL04,4HSL05/

```

PROF 380
PROF 382
JRCMAR84
PROF 384
PROF 386

```

      NPZ=0
      NSURC=0
      NTIES=0
      NLIMIT=0
      NSAL=0

```

PROF 400
PROF 402
JRCMAR84
PROF 404
PROF 406

```

      IWAT=0
      ISURC=0
      ITIES=0
      ILIMIT=0
      ISOIL=0

```

CHANGES FOR SUBROUTINE ANISO:

```

C
      COMMON /BLK01/IANG1,IBLK,IEXIT,ICIRC,ILIMIT,IFLOT,IREAD,ITSEARC,
1      IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
      COMMON /BLK02/ENDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NEND,
1      NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20)

```

ANIO 154
ANIO 156
JRCMAR84
ANIO 160
ANIO 162

IF GREATER THAN ZERO, READS, CHECKS, STORES, AND PRINTS	TIES	30
	TIES	32
ITERACK ANCHOR LOAD DATA.	TIES	34

DEFINITIONS -

BN
ARRAY CONTAINING THE BOUNDARY NUMBERS CORRESPONDING
TO THE POINT OF APPLICATION OF EACH TIEBACK LOAD

C	INTSC3	ENTRY POINT INTO SUBROUTINE INTSC3 WHICH DETERMINES	TIES 102
C		WHETHER OR NOT A LINE SEGMENT AND A HORIZONTAL LINE	TIES 104
C		INTERSECT AND CALCULATES THE COORDINATES OF THE	TIES 106
C		INTERSECTION.	TIES 108
C			TIES 110
C	ITIES	CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM	TIES 112
C		HANDLING THE TIERACK ANCHOR LOADS SPECIFIED BY	TIES 114
C		SUBROUTINE TIES.	TIES 116
C			TIES 118
C	J	INDEX VARIABLE FOR ARRAY SUBSCRIPTING.	TIES 120
C			TIES 122
C	LENGTH	ARRAY CONTAINING VALUES OF THE LENGTH OF EACH	TIES 124
C		TIERACK SPECIFIED.	TIES 126
C			TIES 128
C	NTIE	NUMBER READ AS NUMBER OF TIERACK ANCHOR LOADS	TIES 130
C		SPECIFIED.	TIES 132
C			TIES 134
C	NTIES	NUMBER OF TIERACK ANCHOR LOADS SPECIFIED.	TIES 136
C			TIES 138
C	PLOAD	ARRAY CONTAINING THE VALUES OF THE TIERACK ANCHOR	TIES 140
C		POINT LOADS APPLIED TO THE GROUND SURFACE FOR	TIES 142
C		EACH TIERACK ANCHOR SPECIFIED.	TIES 144
C			TIES 146
C	QUIT	SUBROUTINE THAT DISPLAYS A TERMINATION MESSAGE,	TIES 148
C		TERMINATES PLOTTING, AND TERMINATES EXECUTION OF	TIES 150
C		THE PROGRAM.	TIES 152
C			TIES 154
C	RD	FACTOR FOR CONVERSION OF DEGREES TO RADIANS.	TIES 156
C			TIES 158
C	READER	SUBROUTINE THAT READS INTEGER OR REAL DATA IN	TIES 160
C		FREE FORMAT.	TIES 162
C			TIES 164
C	SIN	STANDARD FUNCTION THAT CALCULATES THE SINE OF AN	TIES 166
C		ANGLE.	TIES 168
C			TIES 170
C	SPACE	ARRAY CONTAINING THE VALUES OF THE HORIZONTAL	TIES 172


```

REAL INCLIN,LENGTH
INTEGER RN
-----
READ NUMBER OF TIERACK ANCHOR LOADS
-----
CALL READER(DUMMY,NTIE,0)
-----
CHECK FOR TIERACK LOAD DATA SUPPRESSION
-----
IF(NTIE.NE.0)GO TO 9
IF(ITIES.EQ.0)GO TO 10
ITIES=0
WRITE(6,10B)
10B FORMAT(///,
110X,'TIERACK ANCHOR LOAD DATA HAS BEEN SUPPRESSED')
RETURN
-----
CHECK IF DATA DEFINED BEFORE
SUPPRESSING OR REACTIVATING IT
-----
10 IF(NTIES.GT.0)GO TO 12
WRITE(6,101)ERROR(1)
101 FORMAT(/,10X,14H**** ERROR - ,A4,6H ****,/)
IEXIT=1
-----
REACTIVATE SUPPRESSED DATA
-----
12 ITIES=1

```

TIES 246
TIES 248
TIES 250
TIES 252
TIES 254
TIES 256
TIES 258
TIES 260
TIES 262
TIES 264
TIES 266
TIES 268
TIES 270
TIES 272
TIES 274
TIES 276
TIES 278
TIES 280
TIES 282
TIES 284
TIES 286
TIES 288
TIES 290
TIES 292
TIES 294
TIES 296
TIES 298
TIES 300
TIES 302
TIES 304
TIES 306
TIES 308
TIES 310
TIES 312
TIES 314
TIES 316


```

C
      NO B I=1, NTIES
      CALL READER(DUMMY,BN(I),0)
      CALL READER(YTIE(I),IDUMMY,1)
      CALL READER(PLDAD(I),IDUMMY,1)
      CALL READER(SPACE(I),IDUMMY,1)
      CALL READER(INCLIN(I),IDUMMY,1)
      CALL READER(LENGTH(I),IDUMMY,1)
C
C-----
C CHECK FOR 1ST QUADRANT LOCATION
C-----
C
      IF(YTIE(I).GT.-TOL)GO TO 3
      120 WRITE(6,105)ERROR(3),I
      105 FORMAT(/,10X,14H**** ERROR - ,A4,6H *****5X,4HTIES,I3,/)
      IEXIT=1
C
C-----
C CHECK TIERACK INCLINATION LIMITS
C-----
C
      3 IF(INCLIN(I).GE.0.,AND.INCLIN(I).LE.90.)GO TO 16
      WRITE(6,105)ERROR(4),I
      IEXIT=1
C
C-----
C CALCULATE THE X COORDINATE OF THE CURRENT TIERACK
C-----
C
      16 INTS=0
      J=BN(I)
      CALL INTSC3(ENDS(J,1),ENDS(J,2),ENDS(J,3),ENDS(J,4),0.,0.,
      1 0.,0.,XTIE(I),YTIE(I),INTS)
      IF(INTS.EQ.1)GO TO 17
      WRITE(6,105)ERROR(5),I
      TIES 390
      TIES 391
      TIES 394
      TIES 397
      TIES 398
      TIES 400
      TIES 401
      TIES 404
      TIES 406
      TIES 408
      TIES 410
      TIES 412
      TIES 414
      TIES 418
      TIES 420
      TIES 422
      TIES 424
      TIES 426
      TIES 428
      TIES 430
      TIES 432
      TIES 434
      TIES 436
      TIES 438
      TIES 440
      TIES 442
      TIES 444
      TIES 446
      TIES 448
      TIES 450
      TIES 452
      TIES 454
      TIES 456
      TIES 458
      TIES 460
      TIES 462

```

```

TIES 464
TIES 464
TIES 468
TIES 470
TIES 472
TIES 474
TIES 476
TIES 478
TIES 480
TIES 482
TIES 484
TIES 486
TIES 488
TIES 490
TIES 492
TIES 494
TIES 496
TIES 498
TIES 500
TIES 502
TIES 504
TIES 506
TIES 508
TIES 510
TIES 512
TIES 514
TIES 516
TIES 518
TIES 520
TIES 522
TIES 524
TIES 526
TIES 528
TIES 530
TIES 532
TIES 534

```

```

      IEXIT=1
      -----
      CHECK FOR POSITIVE SPACING AND LENGTH OF TIERACK
      -----

17 IF (SPACE(I),GE,1.)GO TO 18
   WRITE(6,105)ERROR(6),I
   IEXIT=1

18 IF (LENGTH(I),GE,0.)GO TO 19
   WRITE(6,105)ERROR(7),I
   IEXIT=1
      -----
      PRINT TIERBACK ANCHOR LOAD DATA
      -----

19 WRITE(6,104)(I,XTIE(I),YTIE(I),PLOAD(I),SPACE(I),INCLIN(I),
1      LENGTH(I))
104 FORMAT(12X,12,3X,F13.2,F11.1,F9.1,F14.2,F13.1)
      -----
      CALCULATE EQUIVALENT LINE LOAD FOR EACH ROW OF TIERBACKS
      -----

      TLOAD(I)=PLOAD(I)/SPACE(I)
      INCLIN(I)=INCLIN(I)*RD
      -----
      CALCULATE THE END COORDINATES OF EACH TIERBACK AND CHECK
      FOR FIRST QUADRANT LOCATION OF END POINTS OF EACH TIERBACK
      -----

      IF (LENGTH(I),EQ,0.)GO TO B
      XEND(I)=XTIE(I)+LENGTH(I)*COS(INCLIN(I))
      YEND(I)=YTIE(I)-LENGTH(I)*SIN(INCLIN(I))

```

```

TIES 536
TIES 538
TIES 540
TIES 542
TIES 544
TIES 546
TIES 548
EQKE 2
EQKE 4

```

```

SUBROUTINE EQUAKE

```

C

CHANGES FOR SUBROUTINE LIMITS:

```

LIMIT 128
LIMIT 130
JRCMAR84
LIMIT 134
LIMIT 136

```

```

COMMON /BLK01/IANG1,IBLK,IEXIT,ICIRC,ILIMIT,JPLOT,IREAD,ISEARC,
1. IHLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
COMMON /BLK06/LIMIT(20,4),NLIMIT,NLMT
DIMENSION ERROR(5)

```

C

CHANGES FOR SUBROUTINE INTSC3:

```

ISCT 34
ISCT 36
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
ISCT 38
ISCT 40

```

C AND CALCULATES ITS COORDINATES.

C ENTRY INTSC3 *****

C CHECKS FOR INTERSECTION OF A LINE SEGMENT WITH A HORIZONTAL
C LINE AND CALCULATES ITS COORDINATES.

C
C
C
C
C
C
C
C

ISCT 122
ISCT 124
JRCMAR84
ISCT 128
ISCT 130

COMMON /BLK01/TANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
1 IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL

INTS=0

IF((X1-X).GT.TOL.OR.(X-X2).GT.TOL)INTS=0
RETURN

ENTRY INTSC2

INTS=0
IF(ABS(X1-X2).LT.TOL)RETURN

ISCT 224
ISCT 226
JRCMAR84
ISCT 227
ISCT 228
ISCT 229
JRCMAR84
ISCT 230
ISCT 232

IF((X1-X).LT.TOL.AND.(X-X2).LT.TOL)INTS=1
RETURN

ENTRY INTSC3

INTS=0
IF(ABS(X1-X2).LT.TOL)RETURN

ISCT 252
ISCT 254
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84

CHECK FOR AN INTERSECTION BETWEEN A
LINE SEGMENT AND A HORIZONTAL LINE

JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
ISCT 256
SURF 2

SURF 142
SURF 144
JRCMAR84
SURF 148
SURF 150

MGOODMAN
MGOODMAN
MGOODMAN
JRCMAR84
JRCMAR84
MGOODMAN
SURF 416
RAND 2

R12=(Y1-Y2)/(X1-X2)
A12=Y1-R12*X1
X=(Y-A12)/R12
IF((Y1-Y).LT.TOL.AND.(Y-Y2).LT.TOL)INTS=1
RETURN
END
SUBROUTINE SURFAC

CHANGES FOR SUBROUTINE SURFAC:

C

COMMON /BLK01/ IANG1, IBLK, IEXIT, ICIRC, ILIMIT, IPLOT, IREAD, ISEARC,
1 IBLK2, ISOIL, ISTR, ISURC, ISURF, ITIES, IWAT, RD, TOL
COMMON /BLK02/ ENDS(100,4), C(20), GAMMA(20), GSAT(20), ITP(100), NEND,
1 NSOIL, NTOP, PHI(20), RU(20), CU(20), NP(20)

2 (Y2-Y1)))
YCNR = (X2-X3)/(Y3-Y2)*(XCNR - XHALF2) + YHALF2
RADIUS = SQRT((XCNR - X2)**2 + (YCNR - Y2)**2)
WRITE(6,107) XCNR, YCNR, RADIUS
107 FORMAT(/,10X,'CIRCLE CENTER AT X = ',F6.1,' ; Y = ',F6.1,
1 ', AND RADIUS, ',F6.1)
104 RETURN
END
SUBROUTINE RANDOM

CHANGES FOR SUBROUTINE RANDOM:

C CALLS SUBROUTINES PLTN, ENTRY PLT4, AND PLOTIN TO PLOT PROFILE RAND 34
 C AND, IF SPECIFIED, THE PIEZOMETRIC SURFACES, SEARCHING LIMITS, RAND 36
 C BOUNDARY LOADS, AND TIERACK LOADS. JRCMAR84
 C RAND 40
 C SELECTS INITIATION POINTS AND DIRECTIONAL LIMITATIONS FOR TRIALRAND 42

C RAND 66
 C RAND 68
 C JRCMAR84
 C JRCMAR84
 C RAND 72
 C RAND 74
 C CALLS SUBROUTINE PLOTIN TO REPEAT PLOT OF PROFILE AND, IF
 C SPECIFIED, PIEZOMETRIC SURFACES, SEARCHING LIMITS,
 C BOUNDARY LOADS, AND TIERACK LOADS.
 C CALLS SUBROUTINES ENTRY PLT3 AND ENTRY PLOTN3 TO PLOT THE

C RAND 614
 C RAND 616
 C JRCMAR84
 C RAND 620
 C RAND 622
 C COMMON /BLK01/IANG1,IRLK,IEXT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
 C IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
 C COMMON /BLK02/RNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NEND,
 C NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)

CHANGES FOR SUBROUTINE RANSUF:

C RANS 626
 C RANS 628
 C JRCMAR84
 C RANS 632
 C RANS 634
 C COMMON /BLK01/IANG1,IRLK,IEXT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
 C IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
 C COMMON /BLK02/RNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NEND,
 C NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)

CHANGES FOR SUBROUTINE RLKSUF:

C COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
 1 IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
 COMMON /BLK02/ENTS(100,4),C(20),GAMMA(20),VSAT(20),ITP(100),NBND,
 1 NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)

RLKS 238
 RLKS 240
 JRCMAR84
 RLKS 244
 RLKS 246

CHANGES FOR SUBROUTINE BLOCK2:

C COMMON /BLK01/IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
 1 IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
 COMMON /BLK02/ENTS(100,4),C(20),GAMMA(20),VSAT(20),ITP(100),NBND,
 1 NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)

BK2- 276
 BK2- 278
 JRCMAR84
 BK2- 282
 BK2- 284

CHANGES FOR SUBROUTINE EXECUT:

C AFFECTED BY THE SEARCHING SUBROUTINES RANDOM AND
 C BLOCK.
 C
 C ITIES CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM
 C HANDLING THE TIERBACK ANCHOR LOADS SPECIFIED BY
 C SUBROUTINE TIES.
 C
 C PLOTIN SUBROUTINE WHICH PLOTS WITH A PLOTTING DEVICE THE

EXEC 52
 EXEC 54
 JRCMAR84
 JRCMAR84
 JRCMAR84
 JRCMAR84
 EXEC 56
 EXEC 58

C C SLICES SUBROUTINE WHICH DIVIDES SLIDING MASS INTO SLICES.
 C TRANS SUBROUTINE WHICH TRANSFERS THE EQUIVALENT LINE LOAD

EXEC 84
 EXEC 98
 JRCMAR84
 JRCMAR84

```

C      FOR EACH TIERBACK TO THE BASE OF EACH SLICE USING
C      FLAMANTS'S FORMULAS.
C
C      WEIGHT      SUBROUTINE WHICH CALCULATES THE TOTAL WEIGHT OF EACH
C

```

```

JRCMAR84
JRCMAR84
EXEC 100
EXEC 102

```

```

C      COMMON /BLK01/IANG1,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
C      1      IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
C      -----
C

```

```

EXEC 112
EXEC 114
JRCMAR84
EXEC 118
EXEC 120

```

```

CALL SLICES
CALL WEIGHT
IF(ITIES.EQ.1)CALL TRANS
CALL FACTR
IF(ISEARC.EQ.1)RETURN

```

```

EXEC 130
EXEC 132
JRCMAR84
EXEC 134
EXEC 136

```

CHANGES FOR SUBROUTINE SLICES:

```

C      COMMON /BLK01/IANG1,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,
C      1      IBLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
C      COMMON /BLK02/ENDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NRND,
C      1      NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20)

```

```

SLIC 208
SLIC 210
JRCMAR84
SLIC 214
SLIC 216

```


CHANGES FOR SUBROUTINE WEIGHT:

C
COMMON /BLK01/IANGL,IBLK,IEIT,ICIRC,ILIMIT,JPLLOT,IREAD,ISEARC,
1 IRLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL
COMMON /BLK02/ENDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NEND,
1 NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20)
WGHT 398
WGHT 400
JRCMAR84
WGHT 404
WGHT 406

NEW SUBROUTINE TRANS:

RETURN
END
SUBROUTINE TRANS

SUBROUTINE TRANS

FUNCTIONS -

TRANSFERS THE EQUIVALENT LINE LOAD FOR EACH TIERBACK TO THE
BASE OF EACH SLICE USING FLAMANT'S FORMULAS.

DEFINITIONS -

ALPHA ARRAY CONTAINING VALUES OF THE ANGLES OF THE BASE
OF EACH SLICE.

ALPHA1 ARRAY CONTAINING ANGLES USED TO CALCULATE THE NORMAL
AND TANGENTIAL COMPONENTS OF THE TIERBACK FORCES AT
THE BASE OF EACH SLICE.

SLWT 160
SLWT 162
TRAN 2
TRAN 4
TRAN 6
TRAN 8
TRAN 10
TRAN 12
TRAN 14
TRAN 16
TRAN 18
TRAN 20
TRAN 22
TRAN 24
TRAN 26
TRAN 28
TRAN 30
TRAN 32
TRAN 34
TRAN 36
TRAN 38
TRAN 40
TRAN 42
TRAN 44

C	ATAN	STANDARD FUNCTION THAT CALCULATES THE ARCTANGENT OF AN ANGLE.	TRAN 46
C			TRAN 48
C			TRAN 50
C	BN	ARRAY CONTAINING THE BOUNDARY NUMBERS CORRESPONDING TO THE POINT OF APPLICATION OF EACH TIEBACK LOAD	TRAN 52
C			TRAN 54
C			TRAN 56
C			TRAN 58
C	BND5	ARRAY CONTAINING THE COORDINATES OF THE END POINTS DEFINING THE GROUND SURFACE AND SUBSURFACE BOUNDARIES.	TRAN 60
C			TRAN 62
C			TRAN 64
C			TRAN 66
C	CORR	ARRAY CONTAINING CORRECTION FACTORS TO MAKE THE SUM OF THE TIEBACK FORCES ON TRIAL FAILURE SURFACE EQUAL TO THE APPLIED LOAD FOR EACH TIEBACK SPECIFIED.	TRAN 68
C			TRAN 70
C			TRAN 72
C			TRAN 74
C	COS	STANDARD FUNCTION THAT CALCULATES THE COSINE OF AN ANGLE.	TRAN 76
C			TRAN 78
C			TRAN 80
C	DEV	ARRAY CONTAINING VALUES OF ANGLES BETWEEN THE HORIZONTAL PLANE AND THE LINE BETWEEN THE POINT OF APPLICATION OF A TIEBACK AND THE CENTER OF THE BASE OF A SLICE FOR EACH SLICE.	TRAN 82
C			TRAN 84
C			TRAN 86
C			TRAN 88
C			TRAN 90
C	DIST	ARRAY CONTAINING VALUES OF THE DISTANCE BETWEEN THE POINT OF APPLICATION OF A TIEBACK AND THE CENTER OF THE BASE OF A SLICE.	TRAN 92
C			TRAN 94
C			TRAN 96
C			TRAN 98
C	DX	ARRAY CONTAINING VALUES OF THE WIDTH OF EACH SLICE.	TRAN 100
C			TRAN 102
C	FLAG	FLAG USED TO CONTROL CALCULATION OF THE Y COORDINATE OF THE BASE OF EACH SLICE.	TRAN 104
C			TRAN 106
C			TRAN 108
C	I	INDEX VARIABLE USED FOR ARRAY SUBSCRIPTING.	TRAN 110
C			TRAN 112
C	INCLIN	ARRAY CONTAINING VALUES OF TIEBACK INCLINATION AS MEASURED CLOCKWISE FROM THE HORIZONTAL PLANE	TRAN 114
C			TRAN 116

C	FOR EACH TIERACK LOAD SPECIFIED.	TRAN 118
C		TRAN 120
C	CONTROL CODE WHICH SIGNALS WHETHER AN INTERSECTION	TRAN 122
C	HAS OCCURRED OR NOT.	TRAN 124
C		TRAN 126
C	SUBROUTINE WHICH DETERMINES WHETHER OR NOT TWO LINE	TRAN 128
C	SEGMENTS INTERSECT AND CALCULATES THE COORDINATES	TRAN 130
C	OF THE INTERSECTION.	TRAN 132
C		TRAN 134
C	ENTRY POINT INTO SUBROUTINE INTSCT WHICH DETERMINES	TRAN 136
C	WHETHER OR NOT A LINE SEGMENT AND A VERTICAL LINE	TRAN 138
C	INTERSECT AND CALCULATES THE COORDINATES OF THE	TRAN 140
C	INTERSECTION.	TRAN 142
C		TRAN 144
C	VARIABLE USED FOR ARRAY SUBSCRIPTING.	TRAN 146
C		TRAN 148
C	VARIABLE USED FOR ARRAY SUBSCRIPTING.	TRAN 150
C		TRAN 152
C	ARRAY CONTAINING VALUES OF THE LENGTH OF EACH	TRAN 154
C	TIERACK SPECIFIED.	TRAN 156
C		TRAN 158
C	NUMBER OF SLICES THAT SLIDING MASS IS DIVIDED INTO.	TRAN 160
C		TRAN 162
C	NUMBER OF POINTS DEFINING A TRIAL FAILURE SURFACE.	TRAN 164
C		TRAN 166
C	NUMBER OF TIERACK ANCHOR LOADS SPECIFIED.	TRAN 168
C		TRAN 170
C	NUMBER OF GROUND SURFACE BOUNDARIES.	TRAN 172
C		TRAN 174
C	90 DEGREES IN RADIANS.	TRAN 176
C		TRAN 178
C	PI.	TRAN 180
C		TRAN 182
C	ARRAY CONTAINING VALUES OF THE UNRESOLVED TIERACK	TRAN 184
C	FORCE ON THE BASE OF EACH SLICE.	TRAN 186
C		TRAN 188
C	ARRAY CONTAINING VALUES OF THE SUM OF THE TIERACK	TRAN 190

C	FORCES ON THE BASE OF EACH SLICE OVER THE WHOLE	TRAN 192
C	TRIAL FAILURE SURFACE FOR THE CURRENT TIEBACK LOAD.	TRAN 194
C		TRAN 196
C	RD FACTOR OF CONVERSION FROM DEGREES TO RADIAN.	TRAN 198
C		TRAN 200
C	SIN STANDARD FUNCTION THAT CALCULATES THE SINE OF AN	TRAN 202
C	ANGLE.	TRAN 204
C		TRAN 206
C	SQRT STANDARD FUNCTION THAT CALCULATES THE SQUARE ROOT	TRAN 208
C	OF A NUMBER.	TRAN 210
C		TRAN 212
C	SURF ARRAY CONTAINING THE X AND Y COORDINATES OF POINTS	TRAN 214
C	DEFINING THE TRIAL FAILURE SURFACE.	TRAN 216
C		TRAN 218
C	TLOAD ARRAY CONTAINING VALUES OF EQUIVALENT HORIZONTAL LINE	TRAN 220
C	LOADS FOR EACH TIEBACK ANCHOR SPECIFIED ASSUMING A	TRAN 222
C	UNIFORM DISTRIBUTION OF LOAD TO THE GROUND SURFACE	TRAN 224
C	BETWEEN TIEBACKS.	TRAN 226
C		TRAN 228
C	TNORM ARRAY CONTAINING VALUES OF THE TOTAL TIEBACK LOAD	TRAN 230
C	ACTING NORMAL TO THE BASE OF EACH SLICE FOR ALL	TRAN 232
C	TIEBACK LOADS SPECIFIED.	TRAN 234
C		TRAN 236
C	TTAN ARRAY CONTAINING VALUES OF THE TOTAL TIEBACK LOAD	TRAN 238
C	ACTING TANGENT TO THE BASE OF EACH SLICE FOR ALL	TRAN 240
C	TIEBACK LOADS SPECIFIED.	TRAN 242
C		TRAN 244
C	TTHETA ARRAY CONTAINING VALUES OF ANGLES BETWEEN THE LINE	TRAN 246
C	OF ACTION OF A TIEBACK AND THE LINE BETWEEN THE	TRAN 248
C	POINT OF APPLICATION OF A TIEBACK AND THE CENTER OF	TRAN 250
C	THE BASE OF A SLICE FOR EACH SLICE.	TRAN 252
C		TRAN 254
C	X ARRAY CONTAINING THE X COORDINATES OF THE CENTER OF	TRAN 258
C	THE BASE OF EACH SLICE.	TRAN 260
C		TRAN 262
C	XEND ARRAY CONTAINING VALUES OF THE CALCULATED X	TRAN 264
C	COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.	TRAN 266

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C      XINT      X COORDINATE OF INTERSECTION OF TWO LINE SEGMENTS.      TRAN 268
C      XTIE      ARRAY CONTAINING VALUES OF THE X COORDINATE OF THE      TRAN 270
C      POINT OF APPLICATION ON THE GROUND SURFACE OF EACH      TRAN 272
C      TIEBACK ANCHOR LOAD SPECIFIED.      TRAN 274
C      YB        ARRAY CONTAINING VALUES OF THE Y COORDINATE OF THE      TRAN 276
C      BASE OF EACH SLICE.      TRAN 278
C      YEND      ARRAY CONTAINING VALUES OF THE CALCULATED Y      TRAN 280
C      COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.      TRAN 282
C      YINT      Y COORDINATE OF INTERSECTION OF TWO LINE SEGMENTS.      TRAN 284
C      YTIE      ARRAY CONTAINING VALUES OF THE Y COORDINATE OF THE      TRAN 286
C      POINT OF APPLICATION ON THE GROUND SURFACE OF EACH      TRAN 288
C      TIEBACK ANCHOR LOAD SPECIFIED.      TRAN 290
C      -----      TRAN 292
C      YINT      Y COORDINATE OF INTERSECTION OF TWO LINE SEGMENTS.      TRAN 294
C      YEND      ARRAY CONTAINING VALUES OF THE Y COORDINATE OF THE      TRAN 296
C      POINT OF APPLICATION ON THE GROUND SURFACE OF EACH      TRAN 298
C      TIEBACK ANCHOR LOAD SPECIFIED.      TRAN 300
C      -----      TRAN 302
C      YINT      Y COORDINATE OF INTERSECTION OF TWO LINE SEGMENTS.      TRAN 304
C      YEND      ARRAY CONTAINING VALUES OF THE Y COORDINATE OF THE      TRAN 306
C      POINT OF APPLICATION ON THE GROUND SURFACE OF EACH      TRAN 308
C      TIEBACK ANCHOR LOAD SPECIFIED.      TRAN 310
C      -----      TRAN 312
C      COMMON /BLK01/ IANGL,IRLK,IEIX,ICIRC,ILIMIT,IPLOT,TREAD,ISEARC,      TRAN 314
C      1 IRLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,IRD,TOL      TRAN 316
C      COMMON /BLK02/ ENDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NEND,      TRAN 318
C      1 NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20)      TRAN 320
C      COMMON /BLK05/ NSURF,SURF(100,2)      TRAN 322
C      COMMON /BLK08/ NSLICE,X(300)      TRAN 324
C      COMMON /BLK09/ ALPHA(200),BETA(200),DX(200),SLTP(200),UALPHA(200),      TRAN 326
C      1 UBETA(200),WTT(200)      TRAN 328
C      COMMON /BLK16/ NTIES,INCLIN(10),FLOAD(10),SPACE(10),TLOAD(10),      TRAN 330
C      1 XTIE(10),YNTIE(10),BN(10),LENGTH(10),XEND(10),      TRAN 332
C      1 YEND(10)      TRAN 334
C      COMMON /BLK17/ ALPHA1(200),CORR(10),DEV(200),DIST(200),      TRAN 336
C      1 FNORM(200),PRAD(200),FSUM(200),FIAN(200),      TRAN 338
C      1 TTTHETA(200),YB(200)      TRAN 340
C      COMMON /BLK18/ TNORM(200),TTAN(200)

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TRAN 342 REAL INCLIN,LENGTH
TRAN 344 INTEGER BN
TRAN 346 FLAG=0.
TRAN 348 PI=3.1415927
TRAN 350 PERFEN=90.*RD
TRAN 352 DO 1 J=1,NSLICE
TRAN 354 TNORM(J)=0.
TRAN 356 TTAN(J)=0.
TRAN 358
TRAN 360 1 CONTINUE
TRAN 362 DO 2 I=1,NTIES
TRAN 364
TRAN 366 -----
TRAN 368 CHECK TO SEE IF END OF TIEBACK EXTENDS
TRAN 370 BEYOND TRIAL FAILURE SURFACE
TRAN 372 -----
TRAN 374 IF(LENGTH(I).EQ.0.)GO TO 7
TRAN 376 DO 3 L=2,NSURF
TRAN 378 CALL INTSC2(XTIE(I),YTIE(I),XEND(I),YEND(I),SURF(L-1,I),
TRAN 380 1 SURF(L-1,2),SURF(L,1),SURF(L,2),XINT,YINT,INTS)
TRAN 382 IF(INTS.EQ.1)GO TO 7
TRAN 384
TRAN 386 3 CONTINUE
TRAN 388 GO TO 2
TRAN 390 7 PSUM(I)=0.
TRAN 392 DO 4 J=1,NSLICE
TRAN 394
TRAN 396 -----
TRAN 398 CALCULATE Y COORDINATE OF BASE OF SLICE
TRAN 400 -----
TRAN 402 IF(FLAG.EQ.1.)GO TO 10
TRAN 404 DO 5 L=2,NSURF
TRAN 406 CALL INTSC2(SURF(L-1,1),SURF(L-1,2),SURF(L,1),SURF(L,2),
TRAN 408 1 0.,0.,0.,0.,X(J),YB(J),INTS)
TRAN 410 IF(INTS.EQ.1)GO TO 10
TRAN 412
TRAN 414 5 CONTINUE

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C      CALCULATE TIEBACK LOAD ON BASE OF SLICE
C      -----
C      PRAD(J)=2*TL0AD(I)*DX(J)*COS(TTHETA(J))/(DIST(J)*PI*COS(ALPHA(J)))
C      PSUM(I)=PSUM(I)+PRAD(J)*COS(TTHETA(J))
C      4 CONTINUE
C      FLAG=1.
C      -----
C      CALCULATE TIEBACK BASE FORCE CORRECTION FACTOR
C      -----
C      CORR(I)=TLOAD(I)/PSUM(I)
C      -----
C      CALCULATE THE NORMAL AND TANGENTIAL COMPONENTS
C      OF THE TIEBACK LOAD AT THE BASE OF EACH SLICE
C      -----
C      DO 8 J=1,NSLICE
C      PRAD(J)=PRAD(J)*CORR(I)
C      ALPHA1(J)=PERPEN-ALPHA(J)-DEV(J)
C      PNORM(J)=PRAD(J)*COS(ALPHA1(J))
C      PTAN(J)=PRAD(J)*SIN(ALPHA1(J))
C      -----
C      SUM TIEBACK LOADS ON EACH SLICE FOR ALL TIEBACKS
C      -----
C      TNORM(J)=TNORM(J)+PNORM(J)
C      TTAN(J)=TTAN(J)+PTAN(J)
C      8 CONTINUE
C      2 CONTINUE
C      RETURN
C      END
C      SUBROUTINE FACTR
C      -----
C      FCTR      2      4
C      FCTR      2      4

```


CHANGES FOR SUBROUTINE FACTR:

C	A4	TERM USED IN FACTOR OF SAFETY CALCULATION	FACTR 76
C			MGOODMAN
C	A5	TERM USED IN FACTOR OF SAFETY CALCULATION	MGOODMAN
C			MGOODMAN
C	A6	TERM USED IN FACTOR OF SAFETY CALCULATION	JRCMAR84
C			JRCMAR84
C	BETA	ARRAY CONTAINING VALUES OF THE ANGLE OF THE TOP OF EACH SLICE.	MGOODMAN
C			FACTR 78
C			FACTR 80
C	TAN	STANDARD FUNCTION THAT CALCULATES THE SINE OF AN ANGLE.	FACTR 300
C			FACTR 302
C	TNORM	ARRAY CONTAINING VALUES OF THE TOTAL TIEBACK LOAD ACTING NORMAL TO THE BASE OF EACH SLICE FOR ALL TIEBACK LOADS SPECIFIED.	JRCMAR84
C			JRCMAR84
C	TP	TANGENT OF ANGLE PHI.	JRCMAR84
C			FACTR 304
C	TTAN	ARRAY CONTAINING VALUES OF THE TOTAL TIEBACK LOAD ACTING TANGENT TO THE BASE OF EACH SLICE FOR ALL TIEBACK LOADS SPECIFIED.	JRCMAR84
C			JRCMAR84
C	UALPHA	ARRAY CONTAINING VALUES OF THE HYDROSTATIC FORCE	JRCMAR84
C			FACTR 308
C			FACTR 310
C	COMMON /BLK01/	IANG1,IRLK,ITEXT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,IRLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IWAT,RD,TOL	FACTR 334
C	1	COMMON /BLK02/	ENDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NBND,NSOIL,NTOP,PHI(20),RU(20),CU(20),NP(20)
C	1		FACTR 336
C			JRCMAR84
C			FACTR 340
C			FACTR 342

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1      COMMON /BLK15/ M,MR
      COMMON /BLK18/TNORM(200),TTAN(200)
      COMMON /BLK20/RADIUS
      COMMON /BLK21/HIGHT(200),HGHTERQ(200)
      DIMENSION A1(200),A2(200),A3(200)
      EQUIVALENCE (ALPHA(1),A1(1)), (BETA(1),A2(1)), (DX(1),A3(1))

      PERPEN,SURFS(100,2,12),TSURF,YBPT,YEPT,YMIN
      FCTR 365
      FCTR 363
      JRCMAR84
      MGOODMAN
      MGOODMAN
      FCTR 364
      FCTR 366

      FCTR 456
      FCTR 458
      MGOODMAN
      MGOODMAN
      MGOODMAN
      MGOODMAN
      JRCMAR84
      JRCMAR84
      FCTR 462
      FCTR 464
      JRCMAR84
      FCTR 468
      FCTR 469
      MGOODMAN
      MGOODMAN
      MGOODMAN
      JRCMAR84
      JRCMAR84
      MGOODMAN
      MGOODMAN
      MGOODMAN
      MGOODMAN
      MGOODMAN
      MGOODMAN
      JRCMAR84
      JRCMAR84
      FCTR 470
      FCTR 472

      IF (MR.EQ.1) GO TO 40

      SIMPLIFIED JANBU A-TERMS

      A0 = CSLICE*DX(I) + TP*(WTT(I)*(1.0-VKCOEF) + (TNORM(I)-UALPHA(I))
1      *CA + UBETA(I)*CB + F(I)*CD)
      A1(I) = A0/CA**2
      A2(I)=WTT(I)*(TA+KCOEF-VKCOEF*TA)+UBETA(I)*(CB*TA-SB)+F(I)*(CD*TA-SB)+
1      SD - TTAN(I)/CA
      A3(I)=TA*TP
      SUMB = SUMB + A2(I)
      GO TO 2

      SIMPLIFIED BISHOP A-TERMS

      A1(I) = CSLICE*DX(I)/CA + TP/CA*(WTT(I)*(1.0-VKCOEF) - TTAN(I))*SA
1      + F(I)*CD + UBETA(I)*CB + (TNORM(I) - UALPHA(I))*CA)
      A2(I) = TP*TA
      A3(I) = (WTT(I)*(1.0-VKCOEF) + UBETA(I)*CB + F(I)*CD)*SA
      A4 = (UBETA(I)*SB + F(I)*SD)*(CA-HIGHT(I)/RADIUS)
      A5 = KCOEF*WTT(I)*(CA-HGHTERQ(I)/RADIUS)
      A6 = TTAN(I)
      SUMB = SUMB + A3(I) - A4 + A5 - A6
2      CONTINUE

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CHANGES FOR SUBROUTINE SCALER:

C	HANDLING THE SURCHARGE LOADS SPECIFIED BY SUBROUTINE	SCAL 56
C	LOADS.	SCAL 58
C		JRCMAR84
C	CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM	JRCMAR84
C	HANDLING THE TIEBACK ANCHOR LOADS SPECIFIED BY	JRCMAR84
C	SUBROUTINE TIES.	JRCMAR84
C		SCAL 60
C	THAT CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM	SCAL 62
C		
C	NSURC NUMBER OF BOUNDARY LOADS SPECIFIED.	SCAL 98
C		JRCMAR84
C	NTIES NUMBER OF TIEBACK ANCHOR LOADS SPECIFIED.	JRCMAR84
C		SCAL 100
C	NTOP NUMBER OF GROUND SURFACE BOUNDARIES.	SCAL 102
C		
C	SURC ARRAY CONTAINING X COORDINATES OF THE END POINTS	SCAL 114
C	DEFINING THE EXTENT OF LOADING.	SCAL 116
C		JRCMAR84
C	XEND ARRAY CONTAINING VALUES OF THE CALCULATED X	JRCMAR84
C	COORDINATE OF THE END OF EACH TIEBACK SPECIFIED.	JRCMAR84
C		SCAL 118
C	XPIEZ ARRAY CONTAINING X COORDINATES OF POINTS DEFINING	SCAL 120
C		
C	COMMON /BLK01/IANG1,IRLK,JEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC,	SCAL 144
1	IRLK2,ISOIL,ISTR,ISURC,ISURF,ITIES,IMAT,IRDTOL	SCAL 146
C	COMMON /BLK02/ENDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NRND,	JRCMAR84
1	NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20)	SCAL 150
		SCAL 152

SCAL 164
SCAL 166
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
SCAL 168
SCAL 170

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1 PERPEN,SURFS(100,2,12),TSURF,YBPT,YEPT,YMIN
COMMON /BLK14/SCALE
COMMON /BLK16/NTIES,INCLIN(10),FLOAD(10),SPACE(10),TLOAD(10),
1 XTIE(10),YTIE(10),BN(10),LENGTH(10),XEND(10),
1 YEND(10)
1 REAL MAXX,MAXY,LIMIT

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C

SCAL 208
SCAL 210
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
JRCMAR84
SCAL 214
SCAL 216

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IF(LIMIT(1,3).GT.MAXX)MAXX=LIMIT(1,3)
6 CONTINUE
5 IF(NTIES.EQ.0)GO TO 12
DO 11 I=1,NTIES
IF(XEND(I).GT.MAXX)MAXX=XEND(I)
11 CONTINUE
12 IF(ISURC.EQ.0)GO TO 7
IF(SURC(NSURC,2).GT.MAXX)MAXX=SURC(NSURC,2)
DO 9 I=1,NSURC

```

CHANGES FOR SUBROUTINE PLOTIN:

C	AFFECTED BY SEARCHING LIMITS ESTABLISHED BY	PLOT 76
C	SUBROUTINE LIMITS.	PLOT 78
C		JRCMAR84
C	INCLIN	JRCMAR84
C	ARRAY CONTAINING VALUES OF TIEBACK INCLINATION	JRCMAR84
C	AS MEASURED CLOCKWISE FROM THE HORIZONTAL PLANE	JRCMAR84
C	FOR EACH TIEBACK SPECIFIED.	JRCMAR84
C		PLOT 80
C	IFPLOT	PLOT 82
C	CONTROL CODE WHICH CONTROLS TRANSLATION OF AXES FOR	

C	HANDLING THE SURCHARGE LOADS SPECIFIED BY SUBROUTINE	PLOT 98
C	LOADS.	PLOT 100
D		JRCMAR84
C	CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM	JRCMAR84
C	HANDLING THE TIERACK ANCHOR LOADS SPECIFIED BY	JRCMAR84
C	SUBROUTINE TIES.	JRCMAR84
C		PLOT 102
C	CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM	PLOT 104
C		
C	MAXI. MAXIMUM INTENSITY OF THE BOUNDARY LOADS SPECIFIED.	PLOT 128
C		PLOT 130
C		JRCMAR84
C	MAXIL. MAXIMUM INTENSITY OF THE EQUIVALENT LINE LOADS	JRCMAR84
C	FOR ALL TIERACKS SPECIFIED.	JRCMAR84
C		PLOT 132
C	N VARIABLE USED TO TEMPORARILY STORE THE NUMBER OF	PLOT 134
C		
C	DEFINING EACH OF THE TEN MOST CRITICAL TRIAL	PLOT 166
C	SURFACES.	PLOT 168
C		JRCMAR84
C	NTIES NUMBER OF TIERACK ANCHOR LOADS SPECIFIED.	JRCMAR84
C		PLOT 170
C	NTOP NUMBER OF GROUND SURFACE BOUNDARIES.	PLOT 172
C		
C	EACH OF THE TEN MOST CRITICAL TRIAL SURFACES.	PLOT 214
C	EXTERNAL SUBROUTINE THAT ACTIVATES THE PLOTTING PEN	PLOT 216
C	TO PLOT CHARACTERS OR ON-CENTER SYMBOLS.	NOV76ERO
C		NOV76ERO
C		JRCMAR84
C	TL A SCALED EQUIVALENT LINE LOAD FOR A GIVEN TIERACK.	JRCMAR84

C		JRCMAR84	
C	TLOAD	ARRAY CONTAINING VALUES OF EQUIVALENT HORIZONTAL LINE	JRCMAR84
C		LOADS FOR EACH TIERBACK ANCHOR SPECIFIED ASSUMING A	JRCMAR84
C		UNIFORM DISTRIBUTION OF LOAD TO THE GROUND SURFACE	JRCMAR84
C		BETWEEN TIERBACKS.	JRCMAR84
C			NOV76EEO
C	W	SCALED WIDTH OF A BOX FOR FOR SLIDING BLOCK SEARCH.	PLOT 218
C			PLOT 220
C			
C	X	X COORDINATE OF GEOMETRY POINT TO BE PLOTTED.	PLOT 226
C			PLOT 228
C			JRCMAR84
C	XEND	ARRAY CONTAINING VALUES OF THE CALCULATED X	JRCMAR84
C		COORDINATE OF THE END OF EACH TIERBACK SPECIFIED.	JRCMAR84
C			PLOT 230
C	XL	ARRAY CONTAINING VALUES OF THE X COORDINATE OF THE	PLOT 232
C			
C			
C	XR	ARRAY CONTAINING VALUES OF THE X COORDINATE OF THE	PLOT 244
C		RIGHT END OF EACH BOX CENTERLINE.	PLOT 246
C			JRCMAR84
C	XTIE	ARRAY CONTAINING CALCULATED VALUES OF THE X	JRCMAR84
C		COORDINATE OF THE POINT OF APPLICATION ON THE GROUND	JRCMAR84
C		SURFACE OF EACH TIERBACK ANCHOR LOAD SPECIFIED.	JRCMAR84
C			PLOT 248
C	X1	SCALED X COORDINATE OF A CORNER OF A BOX FOR SLIDING	PLOT 250
C		BLOCK SEARCH.	PLOT 252
C			PLOT 254
C	Y	Y COORDINATE OF GEOMETRY POINT TO BE PLOTTED.	PLOT 256
C			JRCMAR84
C	YEND	ARRAY CONTAINING VALUES OF THE CALCULATED Y	JRCMAR84
C		COORDINATE OF THE END OF EACH TIERBACK SPECIFIED.	JRCMAR84
C			PLOT 258
C	YL	ARRAY CONTAINING VALUES OF THE Y COORDINATE OF THE	PLOT 260


```

CALL SYMBOL(X,Y,0.07,1HT,0.,1)
8 CONTINUE
-----
PLOT TIERACK LOADS, IF APPLICABLE
-----
31 IF(JTIES.EQ.0)GO TO 3
   MAXTL=TLOAD(1)
   IF(NTIES.EQ.1)GO TO 32
   DO 33 I=2,NTIES
     IF(TLOAD(I).GT.MAXTL)MAXTL=TLOAD(I)
33 CONTINUE
32 DO 34 I=1,NTIES
   X=XTIE(I)/SCALE
   Y=YTIE(I)/SCALE
   CALL SYMBOL(X,Y,0.07,1HT,0.,1)
   CALL PLOT(X,Y,3)
   TL=.3*TLLOAD(I)/MAXTL
   DX=TL*CODS(INCLIN(I))
   DY=TL*SIN(INCLIN(I))
   X=X-DX
   Y=Y+DY
   CALL PLOT(X,Y,2)
   CALL SYMBOL(X,Y,0.07,1HT,0.,1)
   CALL PLOT(X,Y,3)
   IF(LENGTH(I).EQ.0.)GO TO 34
   X=XEND(I)/SCALE
   Y=YEND(I)/SCALE
   CALL PLOT(X,Y,2)
   CALL SYMBOL(X,Y,0.07,1HT,0.,1)
34 CONTINUE

```


CHANGES FOR SUBROUTINE PLTN:

C	HANDLING THE SURCHARGE LOADS SPECIFIED BY SUBROUTINE	PLTN 82
C	LOADS.	PLTN 84
C		JRCMAR84
C	ITIES CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM	JRCMAR84
C	HANDLING THE TIERBACK ANCHOR LOADS SPECIFIED BY	JRCMAR84
C	SUBROUTINE TIES.	JRCMAR84
C		PLTN 86
C	IMAT CONTROL CODE WHICH ACTIVATES PORTIONS OF THE PROGRAM	PLTN 88
C	DEFINING EACH OF THE TEN MOST CRITICAL TRIAL	PLTN 164
C	SURFACES.	PLTN 166
C		JRCMAR84
C	NTIES NUMBER OF TIERBACK ANCHOR LOADS SPECIFIED.	JRCMAR84
C		PLTN 168
C	PLJ ARRAY CONTAINING THE CHARACTER PLOT MATRIX.	PLTN 170
C		
C	TOL TOLERANCE CONSTANT TO ACCOUNT FOR MACHINE ROUNDING.	PLTN 210
C		PLTN 212
C	XEND ARRAY CONTAINING VALUES OF THE CALCULATED X	JRCMAR84
C	COORDINATE OF THE END OF EACH TIERBACK SPECIFIED.	JRCMAR84
C		PLTN 214
C	XPIEZ ARRAY CONTAINING X-COORDINATES OF POINTS DEFINING	PLTN 216
C	WATER SURFACE.	PLTN 218
C		JRCMAR84
C	XTIE ARRAY CONTAINING CALCULATED VALUES OF THE X	JRCMAR84
C	COORDINATE OF THE POINT OF APPLICATION ON THE GROUND	JRCMAR84
C	SURFACE OF EACH TIERBACK ANCHOR LOAD SPECIFIED.	JRCMAR84
C		PLTN 220
C	YPIEZ ARRAY CONTAINING Y-COORDINATES OF POINTS DEFINING	PLTN 222
C	WATER SURFACE.	PLTN 224
C		JRCMAR84
C	YEND ARRAY CONTAINING VALUES OF THE CALCULATED Y	JRCMAR84

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C      COORDINATE OF THE END OF EACH TIERACK SPECIFIED.      JRCMAR84
C      PLIN 226
C      YSURC      ARRAY CONTAINING THE CALCULATED Y COORDINATES OF THE PLIN 228
C      ENDS OF THE BOUNDARY LOADS ON THE GROUND SURFACE.      PLIN 230
C      JRCMAR84
C      YTIE      ARRAY CONTAINING INPUTTED VALUES OF THE Y COORDINATE JRCMAR84
C      OF THE POINT OF APPLICATION ON THE GROUND SURFACE OF JRCMAR84
C      EACH TIERACK ANCHOR LOAD SPECIFIED.      JRCMAR84
C      PLIN 232
C      PLIN 234
C      PLIN 236
C
C      COMMON /BLK01/ IANGL,IBLK,IEXIT,ICIRC,ILIMIT,IPLOT,IREAD,ISEARC, PLIN 238
C      1      IBLK2,ISOIL,ISTR,TSURC,ISURF,ITIES,IMAT,RU,TOL PLIN 240
C      COMMON /BLK02/ BNDS(100,4),C(20),GAMMA(20),GSAT(20),ITP(100),NRND, JRCMAR84
C      1      NSOIL,NTOP,PHI(20),RU(20),CU(20),NF(20) PLIN 244
C      PLIN 246
C
C      1      PERPEN,SURFS(100,2,12),TSURF,YDPT,YEPT,YNIN PLIN 258
C      COMMON /BLK14/ SCLE PLIN 260
C      COMMON /BLK16/ NTIES,INCLIN(10),FLOAD(10),SPACE(10),TLOAD(10), JRCMAR84
C      1      XTIE(10),YTIE(10),BNC(10),LENGTH(10),XEND(10), JRCMAR84
C      1      YEND(10) JRCMAR84
C      DIMENSION FLT(49,51),SYMB(20),AXIS(9),SCL(9) JRCMAR84
C      REAL LIMIT PLIN 264
C      DATA SYMB/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1H ,1H+,1H-,1H*, PLIN 266
C      1      1HU,1HL,1HS,1H,1H/,1HT/ JRCMAR84
C      DATA AXIS/1HX,1H ,1HA,1HX,1HI,1HS,1H ,1HF,1HT/ PLIN 270
C      PLIN 272
C

```

```

      IYY=IY
23 CONTINUE
      -----
      POSITION POINTS DEFINING TIERACK LOADS, IF APPLICABLE
      -----
30 IF(CITIES,EQ,0)GO TO 10
   DO 32 I=1,NTIES
      CALL POSTN(XTIE(I),YTIE(I),IX,IY)
      PLT(IX-1,IY)=SYMB(I)
      PLT(IX,IY)=SYMB(20)
      IF(LENGTH(I),EQ,0.)GO TO 32
      CALL POSTN(XEND(I),YEND(I),IX,IY)
      PLT(IX,IY)=SYMB(20)
      PLT(IX+1,IY)=SYMB(I)
32 CONTINUE
      -----

```

LINE TO INTERCHANGE IN STABL4
TO RUN PROGRAM ON AN IBM COMPUTER

PROGRAM STABL4

```

      DIMENSION KEYW(16),ERROR(5),WAR(100)
      REAL*8 MKEYW,KEYW
      TOL=.001
      CALL PLOTS(WAR,400)

```

JRCMAR84
 STBL 251 (ADD)
 STBL 258
 STBL 292

SUBROUTINE PROFIL

```

      DIMENSION TITLE(10),DESCR(10), ERROR(11)
      113 FORMAT(20A4)
      112 FORMAT(//,10X,'PROBLEM DESCRIPTION ',10A4,/32X,10A4,/)

```

PROF 344
 PROF 440
 PROF 443

SUBROUTINE INTSCT

```

      ENTRY INTSCT(X1,Y1,X2,Y2,X3,Y3,X4,Y4,X,Y,INTS)
      ENTRY INTSCT(X1,Y1,X2,Y2,X3,Y3,X4,Y4,X,Y,INTS)

```

ISCT 220
 JRCMAR84

SUBROUTINE RANDOM

```

      CALL NUMBER (1.5,6.0,0.1,FLOAT(TAL),0.,-1)
      CALL NUMBER (3.8,5.7,0.1,FSS(1),0.,3)

```

RAND1859
 RAND1868

SUBROUTINE PLOTIN

CALL AXIS(0.,0.,6HX-AXIS,-6,B,0.,0.,SCLE,1.,1,1,0.,125)
CALL AXIS(0.,0.,6HY-AXIS,6,5,1,5708,0.,SCLE,1.,1,1,0.,125)
CALL NUMBER(4.95,5.7,0.1,FS,0.,3)

PLOT 364
PLOT 366
PLOT 567

LINES TO ADD TO STARL4 TO RUN
PROGRAM ON AN IBM COMPUTER

FUNCTION RANF (ADD AFTER SUBROUTINE PSTN)

FUNCTION RANF(X)
INTEGER XN,SEED
DATA XN,SEED/131072,27487/
SEED=MOD(SEED*78125,XN)
IF (SEED .LT. 0) SEED=SEED+XN
RANF=FLOAT(SEED)/FLOAT(XN)
RETURN
END

RANF 2
RANF 4
3-1-83
RANF 8
3-1-83
RANF 12
RANF 14
RANF 16

NOTE: Some of the above changes reflect adjustments to use the Calcomp plotter on local system (ISHC-IBM360). They may have to be adjusted accordingly for other systems.

COVER DESIGN BY ALDO GIORGINI