JOINT HIGHWAY RESEARCH PROJECT
JHRP-87/12
Informational Report
PLACEMENT RATES FOR HIGHWAY EMBANKMENTS WITH VERTICAL AND HORIZONTAL DRAINAGE

A.G. Altschaefl
S. Thevanayagam
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A.G. Altschaeffl
S. Thevanayagam
Informational Report on
Placement Rates for Highway Embankments
with Vertical and Horizontal Drainage

Prepared for
State of Indiana, Department of Highways

By
A. C. Altschaeffl
S. Thevanayagam

March 1987
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1. Introduction

"Modified Sand" is a computer program for the general analysis of an embankment foundation on a soft soil with consideration of vertical and horizontal consolidation without any sand drain installations. This is a modified version of the program SAND (Krizek and Krugmann, 1972) that can be used to analyze this problem with consideration of vertical sand drains. The solution technique in the modified program remains the same as in the original program.

1.1 Capabilities of Modified Sand

This program optimizes the rate at which a specific highway embankment can be constructed on soft soil. This problem involves the computation of stresses and pore pressures in the subsoil, the dissipation of these pore pressures, the corresponding increase in shear resistance and stability of the embankment.

The embankment load which is assumed to act vertically, induces pore pressures in the subsoil which are computed using Theory of Elasticity and Skempton's pore pressure parameters (A, B). These pore pressures dissipate according to three dimensional consolidation theory which takes into account the effect of gas and variable soil parameters. The solution of consolidation equations are solved numerically by treating it as an eigenvalue problem. As the pore water pressure dissipates the effective stresses in the subsoil will increase giving a simultaneous
increase in shearing resistance. Settlements are computed from the dissipated pore pressures.

There are two options available.

Option 1: (For ISP = 0) -- The program determines the times at which each lift whose resulting shapes are input can be constructed without exceeding the bearing capacity of the subsoil and after a specified fraction of a reference settlement has occurred. Settlements and average degree of consolidation are output for specified points in a graphical form.

Option 2: (ISP = 1) -- The lifts and times of lift application are input and the program determines the dissipation of pore pressures and settlements for specified points. Bearing capacity of the foundation soil is not analyzed.

2. Description of the Program

Described in the subsequent sections is the set of computer programs which can be used to analyze an embankment foundation on a soft soil with consideration of vertical and horizontal consolidation. Individual routines, consisting of main program "Modified Sand" are written in FORTRAN 77. Program listing is attached in Appendix A. The programs have been tested in IBM PC XT and VAX 11/780 at Purdue University.

Each subsection of the program is given below explaining the following:
1. Purpose of the program.

2. Usage of the program.

3. Block names.

4. Description of parameters.

5. Method of solution or calculation.

6. Subroutines required.

In addition a list of sequence of input of data into the main program is given.

Two sample problems which illustrate most of the special features of the programs and solutions to these problems are attached.

2.1 The Main Program Modified SAND

Purpose of the Programs:

SAND -- To analyze an embankment foundation on a soft soil for stability and/or settlements and consolidation behavior with consideration of horizontal and vertical drainage.

Block Names and Lengths:

SAPOD/ IOUTP,W,HH,GLOAD,CLOAD,NARC,NRAD; length: 7 words
SADI1/ LAYER,IBCV,MHE,M,N,IDC,NDR,ISUM; XET(41); length: 49 words
SADI2/ FIMPV,RC,RK,C,RO,RE,TA,ISP,IVAR; length: 29 words
SACSE/ ROC,ROCL,SVM,P,PC,PLOG,PO,PCO,IAV,IK,ISAT,AAV,AAH; length: 54 words
SAC01/ AVOC,KVO,KHO,EOPUS,PU,SKHM,SKVM,CCC,NNN,ICOEF; length: 10 words
SAC02/ PCV(10),CVIN(10),PCH(10),CHIN(10),ICV,KOUNT,HF; length: 43 words
SADET/ XSTAB(51),YSTAB(11),DX,DY,YWM,TGPHI; length: 66 words

These blocks are only defined in program SAND

SAPOD is needed in subroutines DETFS, DISP, INIT, PORE, and VARYR
SADI1 and SADI2 are needed in subroutine DISP
SACSE is needed in subroutines COEF and SETL
SAC01 and SAC02 are needed in subroutine COEF
SADET is needed in subroutine DETFS

Description of Parameters

On the following pages are described the parameters which are input by the user; quantities listed in labelled COMMON blocks are given in the respective subroutines. This list is given in alphabetical order. Section (3) provides the list where data cards of the parameters appear in the sequence in which they are needed in the programs. The asterisk * refers to a note at the end of the list.

A
- Skempton's pore pressure coefficient

AVO
- constant coefficient of compressibility to be used in the settlement computations; in the case of two layers, AVO applies to the upper layer; dimension; ft/lb

AX(I)
- subinterval limits to be input as decimal fractions of reference value W; I=1,NI where NI < 5
B - Skempton's pore pressure coefficient

BLANK - symbol to be used in the resulting plots

C - fraction of the reference load at time TA, which is applied at time equal to zero; may vary between 0.0 and 1.0

CC - compression index; negative slope of the void ratio versus effective stress curve (virgin part of the curve); in the case of two layers, CC is the compression index of the upper layer

CLOAD - undrained strength of the embankment oil

dimension - psf

CO(I) - initial undrained strength of the subsoil; I=1, NC where NC < MYE < 11. If NC < MYE, Lagrangean interpolation is used to compute the undrained strengths at MYE equally spaced depths. If NC = MYE, the input values must be provided at equally spaced points where I=1 and I=MYE coincide with the surface and the bottom of the compressible layer, respectively; dimension - psf

COUNT* - marker to indicate the last residual pore water pressure data card; this parameter is zero on all residual pore water pressure data cards, except on the last card, where it must take value different from zero

CP(I) - (c/p)-ratios of the subsoil; I=1, NC; see remarks under CO(I)

CH - constant coefficient of consolidation in horizontal direction; in case of two layers, CH applies to the upper layer; dimension - ft²/day

CHIN(I) - variable coefficients of consolidation in horizontal direction; I=1, ICV < 10; stress-dependent coefficients of consolidation in horizontal direction are obtained within subroutine COEF by interpolation between the CHIN-values; dimension - ft²/day
CV - constant coefficient of consolidation in the vertical direction; in case of two layers, CV applies to the upper layer; dimension - ft$^2$/day

CVIN(I) - variable coefficients of consolidation in the vertical direction; $i=1$, ICV $<$ 10; stress-dependent coefficients of consolidation in the vertical direction are obtained within subroutine COEF by interpolation between the CVIN-values; dimension - ft$^2$/day

DMAX - maximum step size to be used in the variation of XC and YC in the search procedure for the minimum factor of safety; dimension - feet

DMIN - minimum step size to be used in the variation of XC and YC in the search procedure for the minimum factor of safety; dimension - feet

EO - initial void ratio; in the case of two layers, EO applies to the upper layer

FSI - factor of safety which is required at the time of application of a new load

GAMMA - effective unit weight of the subsoil, constant over the thickness of the compressible layer; this value is needed in the settlement computations using the compression index; if GAMMA=0, input of MYE effective overburden stresses at equally spaced depths must be input; dimension - pcf

GLOAD - unit weight of the embankment soil, dimension - pcf

GRID - symbol to be used in the resulting plots to mark the 10% coordinates; proposed to be the letter I

H - thickness of the compressible layer; if $H=0$, the program is terminated;
if \( H = 99 \), a branch is made to the beginning of the programs; dimension - feet

\( HC \) - Henry's constant of gas solubility, 
- \( HC = 0.020 \) for atmospheric air, 
- \( HC = 0.029 \) for methane, \( HC = 2.84 \) for hydrogen sulfide (at 68°F)

\( HI \) - thickness of the "impedance layer" underlying the compressible soil; the "impedance layer" must have a freely draining lower surface, a coefficient of compressibility which is negligibly small compared to that of the consolidating soil, and a permeability of the same order of magnitude as that of the consolidation soil; dimensions - feet

\( IAB \) - identifier where -
- \( IAB = 0 \) - Skempton's pore pressure coefficients A and B as defined for the last load are also used to compute the pore water pressures due to the load addition
- \( IAB = 1 \) - redefine A and B

\( IAV \) - identifier where -
- \( IAV = 0 \) - use a constant coefficient of compressibility in the settlement computations
- \( IAV = 1 \) - use the compression indices in the settlement computations

\( IBCV \) - identifier where -
- \( IBCV = 1 \) - impeded vertical drainage at the bottom of the consolidating layer
- \( IBCV = 2 \) - free vertical drainage at the bottom of the consolidating layer
- \( IBCV = 3 \) - no vertical drainage at the bottom of the consolidating layer

\( ICV \) - number of data pairs \((PCV(I), CVIN(I))\) and \((PCR(I), CRIN(I))\) through which Lagrangean interpolation polynomials are passed; 
\( 0 < ICV < 10 \)

\( IDEN(I) \) - identifier corresponding to the I-th load step, where
IDEN(I)<0 - the excess pore water pressures due to the first load step are set equal to the input residual pore water pressures
IDEN(I)=0 - the excess pore water pressures due to the I-th load are computed by means of subroutine PORE
IDEN(I)=1 - the excess pore water pressures due to the I-th load are set equal to those computed for the reference load. Note, that this requires that Skempton's coefficients A and B are identical in both cases;
IDEN(I)<0 allows the check of an existing installation for which the excess pore water pressures just after load application are known from field measurements; I=1, NL

IEND - number of horizontal coordinates XT; IEND is computed, if ISP=0; IEND < 20

IK - identifier where
IK=0 - constant coefficients of permeability
IK=1 - the radial and vertical coefficients are variable; the void ratio versus the logarithm of the coefficient of permeability is a straight line

IRP - identifier where
IRP=0 - no residual pore water pressures are input
IRP=1 - residual pore water pressures at points (W'TXT, H'YE) are input columnwise
IRP=2 - residual pore water pressures at arbitrary points are input

ISAT - identifier where
ISP=0 - settlements, the process of consolidation, and the stability are analyzed; in program SAND, the times at which a new load step can be applied are determined;
ISP=1 - settlements and the process of consolidation are analyzed, and the times of load application are required as input parameters in program SAND; ISP=1 also requires the output of the time-dependent pore water pressures at MRE'MYE
points of the solution domain of the sand drain installations with axes at the user-defined locations XT

ITBL - number of times TB(I), defined in a DATA-statement, for which the pore water pressures and settlements are determined; times TB always start at the time of application of a new load step in SAND; ITBL < 45

IVAR - identifier where
  IVAR=0 - use constant coefficients of consolidation
  IVAR=1 - use variable coefficients of consolidation which are obtained either by interpolation between CHIN(I) and CVIN(I) or by varying the coefficient of compressibility and/or the coefficients of permeability

JND - number of points for which output is required
  JND < 10

JSP(I) - indices of the JND points for which output is required; I=1, JND < 10; the output is for points XE(JSP(I)), where XE and MX equally spaced coordinates between and including the limits W'AX(1) and W'AX(NI); for example, specification of JSP(I)=1 and JSP(JND)=MX causes the output of information at the limits W'AX(1) and W'AX(NI), respectively

KHO - initial coefficient of permeability in the horizontal direction; dimension - ft/day

LAYER - number which indicates the location of a layer interface; LAYER=KK means that the layer interface is located at a depth below ground surface which is equal to Y=H*(KK-1)/(MYE-1); if only one layer is to be considered, set LAYER=0; the program requires that 3 < LAYER < (MYE-3); LAYER causes a layer interface to be considered in the consolidation and the settlement analyses only

LND - number of weeks to be plotted on the time axis of the output figures

MINP - number of points defining the contour of the embankment load; MINP < 20
MHE - number of equally spaced points in the horizontal direction; MHE < 40
MX - number of equally spaced points XE in the horizontal direction between the limits AX(I) and AX(NI); MX < 51
MXT(I) - number of unequally spaced points XT between the consecutive limits AX(I) and AX(I+1); I=1, (NI-1) < 4; maximum value of any MXT(I) must be values MXT(I) must not exceed IEND=20
MYE - number of equally spaced points in the vertical direction, including the surface and the bottom of the compressible layer; MYE < 12
NC - number of initial undrained shear strengths, CO(I), and (c/p)-ratios, CP(I); NC < MYE < 11
NI - number of interval limits AX(I); NI < 5
NL - number of load steps; NL < 6
NRAD - number of trial arcs to be used with each trial center (XC,YC) in the stability analysis; NRAD > 1
NS - number of load strips used to approximate the actual embankment load; NS < 20
P(I) - present overburden effective stresses at MYE equally spaced depths, including the surface; I=1, MYE < 12; dimension - psf
PC(I) - preconsolidation stresses at MYE equally spaced depths, including the surface; I=1, MYE < 12; dimension - psf
PCH(I) - effective stresses at which the horizontal coefficients of consolidation, CHIN(I), are defined; I=1, ICV < 10; dimension - psf
PCV(I) - effective stresses at which the vertical coefficients of consolidation, CVIN(I), are defined; I=1, ICV < 10; dimension - psf
PU  - initial pore gas pressure; if PU is not defined during input, it is set equal to the sum of the atmospheric pressure plus one-half the thickness of the compressible layer times the unit weight of water; dimension = psf

RAV  - coefficient of compressibility of the lower layer divided by that of the upper layer

RC  - vertical coefficient of consolidation of the lower layer divided by that of the upper layer

RCC  - virgin compression index of the lower layer divided by that of the upper layer

REO  - initial void ratio of the lower layer divided by that of the upper layer

RK  - vertical coefficient of permeability of the lower layer divided by that of the upper layer

note, if RC and RAV are specified, 

$$RK = RC \times RAV \times (1 + E0) / (1 + E0 \times RE0)$$

RKV  - vertical coefficient of permeability of the consolidating soil divided by that of the underlying impedance layer

ROC  - recompression index divided by the virgin compression index; in case of two layers, ROC applies to the upper layer

ROCL  - recompression index of the lower layer divided by the virgin compression index of the upper layer

S  - degree of saturation to be input as a decimal fraction

SKH  - slope of the void ratio versus the logarithm of the horizontal coefficient of permeability curve

SKV  - slope of the void ratio versus the logarithm of the vertical coefficient of permeability curve

SPECS  - fraction of the consolidation settlement due to the reference load; this settlement must have occurred before a new load is applied (program SAND)

SPECU  - when the non-dissipated average pore water pressures become less than 5% of the total average
pore water pressures existing just after application of the last load at IEND*SPECU points XT, subsequent loads are disregarded; the rationale for this procedure is that no significant increase in strength and/or settlement can be expected after an average degree of consolidation of 95% has been reached under the applied load at a number of points; in selecting the magnitude of SPECU, which is input as a decimal fraction, it should be noted that the degrees of consolidation in the case of constant coefficients of consolidation will be the same for different points XT, as long as the drainage boundary conditions are the same

**STAR** - symbol to be used in the resulting plots to mark the coordinate axes; proposed to be the asterisk *

**SYMB(I)** - symbols to be used in the resulting plots to present points of the computed curves; the letters U, C, O, and T are proposed for the average decree of consolidation, the consolidation settlement, the initial, and the total settlement versus time curves, respectively. It should be noted that T plots on top of O, which plots on top of C, which plots on top of U; this means, that only T will show, when the four values are identical; I=1,2 in the case of complete saturation, and I=1,4 in the case of partial saturation User can use any other letters as symbols

**TA** - available construction time; in SAND, this is the time at which the final load must have been applied; dimension - days

**TgPHI** - tangent of the angle of internal friction of the drainage blanket, if there is one

**TL(I)** - times of load application in the case where ISP=1; I=1, NL < 6; dimension - days

**TMIN** - time which must have passed after a load application before the first stability analysis is made to determine, whether the next load can be applied; dimension - days

**U** - residual pore water pressure; dimension - psf
\( W \) - reference value in the horizontal direction; dimension - feet

\( X^* \) - horizontal distance from the center line at which the residual pore water pressure is known; dimension - feet

\( XC \) - X-coordinate of the center of the first trial arc; if \( XC=0 \) is input, the programs select a starting value; dimension - feet

\( XINP(I) \) - X-coordinates of the points defining the embankment contour; \( I=1, \text{MINP} < 20 \); dimension - feet

\( XT(I) \) - X-coordinates of the points at which the settlements and the consolidation behavior are determined; if \( ISP=0 \), \( XT(I) \) are computed for \( I=1 \) through \( MXT(J) \); if \( ISP=1 \), \( XT(I), I=1, IEND < 20 \) are input as fractions of \( W \)

\( Y^* \) - vertical distance below the ground surface at which the residual pore water pressure \( U \) is known; positive downward; dimension - feet

\( YC \) - Y-coordinate of the center of the first trial arc; positive upward; dimension - feet

\( YINP(I) \) - Y-coordinates of the points defining the embankment contour; positive upward; \( I=1, \text{MINP} < 20 \); dimension - feet

\( YWM \) - thickness of a drainage blanket placed on the surface of the compressible soil layer; dimension - feet

\( ZZ \) - distance between the maximum \( YINP(I) \) and the minimum value \( YC \) permissible in the stability analyses; dimension - feet

* The residual pore water pressures are first arranged such that points having the same X-coordinate are grouped in the order of ascending Y-coordinates. Data sets are then input in the order of ascending \( X \), whereby the last card is identified by COUNT \# 0.
Method

The programs facilitate the analysis of an embankment foundation on a soft, compressible soil layer, which is underlain by a firm stratum. The approach involves the consideration of the following problems: (a) stress and pore pressure distribution within the soft layer due to a symmetrical vertically acting embankment load at the surface, (b) the dissipation of excess pore water pressures subject to different flow conditions including horizontal flow, (c) the computation of settlements, and (d) the stability of the embankment-subsoil system with consideration of the gain in shear strength as consolidation proceeds.

The programs are designed to solve several cases during the same program execution, wherefore some computations are performed before data for a specific case are input. To save computer time and storage, computations are only done for a limited number of locations in the horizontal direction, and information at intermediate points is obtained by interpolation.

PROGRAM SAND -- After computation of the pore water pressures and settlements due to a reference load, which in most cases will be identical with the final load, essentially two options are available by means of index ISP. If ISP=0, the embankment contours of the different load steps are input and the program determines the times at which new load steps can be applied. The criteria incorporated into the programs are: (1) a defined portion of the reference settlement at the point closest to the center line of the embankment must have occurred, and/or
(2) a specified factor of safety must be assured at the time of a new load application. To avoid unnecessarily numerous stability analyses, a time TMIN measured from the last load application can be defined, and stability analyses are not performed for times less than TMIN, although settlements and degrees of consolidation are computed. For the same reason, the program contains the restriction that all subsequent load steps are disregarded if 95% consolidation has occurred at a specified number of points under the acting load. The rationale is that only a minor increase in strength and settlements can be expected due to dissipation of the remaining excess pore water pressures, and the times required will likely be prohibitive.

If ISP=1, the different load contours, as well as the times of load application, must be input, and the program analyzes the consolidation process and the settlements without performing any stability analyses. Use of ISP=1 also produces the output of the pore water pressures at MYE*IEND points of a vertical cut through the locations XT*W.

The computed information is first stored internally on two internal files for each step of load. A total of 6 steps of loads are allowed.

The program can handle analysis of multiple embankments in a single run. This is done by putting H = 99 at the end of the data cards for the previous embankment. On the other hand by specifying H = 0 the program is terminated.
The output, in addition to that given for ISP=0, includes the excess pore water pressures at MYE*JND points of a vertical section through the subsoil.

**Remarks**

The average degree of consolidation is defined in the programs as the integral over the dissipated pore water pressures divided by the integral over the excess pore water pressure build-up under the reference load.

The increase in the effective stresses at the time of load application in the case of a partially saturated soil is assumed to be equal to the difference between the pore water pressures obtained for B=1.0 and B<1.0, where B is Skempton's pore pressure coefficient.

To account for the fact that the swelling index is normally considerably smaller than the compression index, negative pore water pressures, which might result after surcharge removal, are neglected in program SAND.

**Subroutines Required**

- COEF (UAVD,UAVE,OMEGA,PHI,LI,IL,OMED,PHID,NN)
- DISP (U,LI,OMEGA,PHI,T,UAVE,LIFT,MYE,IEND,XT,SV)
- GAIN (UA,R,SU,MYE,MXT,MXE,MX,NIM,CO,CP,III)
- GENS (S,M)
- INIT (XINP,YINP,MINP,XC,YC,YY,ZZ,DMIN)
- LAGR (X,Y,M,JST,XX,YY,N)
2.2 Subroutine APROX

Purpose

To approximate the embankment contour by a number of strips of constant thickness

Usage

CALL APROX (X, Y, MN, N, D)

Block Names

POAPI/ALPHA(30), L

Description of Parameters

X, Y - coordinates of the points defining the embankment contour; must be provided such that X(1) = 0 < X(2) < .... < X(MN)

MN - number of points X, Y; MN < 20

N - number of approximating strips

D - thickness of the approximating strip

ALPHA - returned lengths of the strips

L - number of values ALPHA, L < 30

Statement Functions Required

C0NK(K0,SKM);VARK(K0,SKM);PSI(AA,K)
2.3 Subroutine DETFS

Purpose

To determine the factor of safety of an embankment resting on a soft subsoil.

Usage

CALL DETFS(XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FS)

Block Names

INDET/RHO(19), TAU(19), PSI(19)
SAPOD/IOUTF*; W*; H*; GLOAD, CLOAD, NARC, NRAD*
SADET/XSTAB(51), YSTAB(11), DX, DY, YWM, TGPHI
* Parameters marked by an asterisk are not needed in this subroutine

Description of Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
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<tbody>
<tr>
<td>XC</td>
<td>X-coordinate of the center of the circular slip surface</td>
</tr>
<tr>
<td>YC</td>
<td>corresponding Y-coordinate</td>
</tr>
<tr>
<td>R</td>
<td>radius of the circular slip surface</td>
</tr>
<tr>
<td>XINP</td>
<td>X-coordinates of the points defining the embankment contour</td>
</tr>
<tr>
<td>YINP</td>
<td>corresponding Y-coordinates</td>
</tr>
<tr>
<td>MINP</td>
<td>number of points (XINP,YINP)</td>
</tr>
<tr>
<td>MX</td>
<td>number of equally spaced grid points in the X-direction</td>
</tr>
</tbody>
</table>
MYE - number of equally spaced grid points in the Y-direction

SU - undrained shear strengths at (MX*MYE) grid points

FS - factor of safety to be provided

RHO - slopes of the lines connecting consecutive points XINP/YINP

TAU - parameters defined in subroutine INIT; TAU=1+RHO^2

PSI - Y-value at X=0 for the lines connecting consecutive points XINP/YINP

GLOAD - unit weight of the embankment soil

CLOAD - undrained strength of the embankment soil

NARC - one-half the number of subarcs within the subsoil

XSTAB - X-coordinates of the grid points

YSTAB - Y-coordinates of the grid points

DX - interval in the X-direction

DY - interval in the Y-direction

YWM - thickness of the drainage blanket

TGPHI - tangent of the angle of internal friction of the soil in the drainage blanket

Method

A total stress analysis is performed to evaluate the factor of safety of an embankment which consists of cohesive soil and a cohesionless drainage blanket. The undrained strengths of the subsoil are input at MX*MYE grid points, and the strength available along the portion of the circular slip surface that passes through the subsoil is obtained at the centers of 2*NARC subarcs
by interpolation between the strengths SU at adjacent grid points. Resisting the driving moments are first computed with the assumption that the embankment consists entirely of frictionless soil. The so-obtained ratio of moments is then used as the initial estimate in the iteration for the correct factor of safety, in which the drainage blanket is considered.

Statement Functions Required

FUNA (A,B), FUNB (B), FUNC (A,B,C)

Remarks

The coordinates YINP,YC,YWM and PSI are positive upward, wherein YSTAB is positive downward with the coordinate origin at the surface of the soft layer.

2.4 Subroutine DISP

Purpose

To determine the excess pore water pressures at arbitrary times for step loading conditions.

Usage

CALL DISP(U,LI,OMEGA,PHI,T,UAVE,LIFT,MYE,IEND,XT,SV)

Block Names

SAPOD/IOUSP,W*,H*,GLOAD*,CLOAD*,NARC*,NRAD*;
SADIL/LAYER,IBCVMHE,M,N,IDC,NDR,ISUM,XET(41);
**Description of Parameters**

**U** - pore water pressures to be determined; for LI=1,5,6 this vector contains the additional pore water pressures for the new load, when subroutine DISP is called

**LI=1** - determines vectors A and B for the load addition

**LI=2** - determines the pore water pressures due to step-wise constant loads

**LI=3** - determines vectors A and B for times between load applications in the case where the "consolidation factor" is variable

**LI=5** - first lift; first execution of subroutine DISP

**OMEGA** - "consolidation factors" for radial flow; product of the gas factor and the radial coefficient of consolidation

**PHI** - "consolidation factors" for vertical flow; product of the gas factor and the vertical coefficient of consolidation

**T** - time

**UAVE** - average pore water pressures

**LIFT** - number of lifts applied at and before time T

**MYE** - number of points equally spaced in the vertical direction at which the pore water pressures are computed

**MHE** - number of points equally spaced in the horizontal direction at which the pore water pressures are computed < 40

**IEND** - number of elements in vectors OMEGA, PHI, UAVE and XT
XT - points in the horizontal direction for which OMEGA and PHI are input and UAVE is computed

SV - mathematical molecule of the extended Simpson's or trapezoidal rules in the vertical direction

IOUTP - logical output unit

LAYER - index indicating the depth of a layer interface; LAYER > 3

IBCV=1 - vertical drainage; impeded drainage at the lower boundary surface

IBCV=2 - vertical drainage; free drainage at the lower boundary surface

IBCV=3 - vertical drainage; no drainage at the lower boundary surface

M - number of eigenvalues for the vertical problem

N - number of eigenvalues for the horizontal problem

IDC=1 - vertical flow only at all points XT

IDC=2 - vertical plus horizontal flow at all points XT

ISUM - number of elements of vector U

FIMPV - "impedance factor" for vertical flow; FIMPV = (RKV*HI/DY) / (1.+RKV*HI/DY), as defined in SAND

RC - ratio of the vertical coefficients of consolidation of the lower and upper layer

RK - ratio of the vertical coefficients of permeability of the lower and upper layer

ISP=1 - compute and print the pore water pressures at all MYE*MRE points of the solution domain for IEND locations XT; return the averages taken at MYE depths over the circular area of influence as vector U; return the overall average at IEND locations XT as vector UAVE

ISP=0 - suppress the printing
IVAR=0  - constant "consolidation factors"
IVAR=1  - variable "consolidation factors"

Method

The consolidation problem is treated as an eigenvalue problem.

Subroutines Required

EFGEN(PSI,T,EIG,IVAR,MM,NN,D,LI)
MAMUL(A,D,B,C,N,IS,II)
MODAL(LAYER,IBC,N,FIMP,RC,RK,XO,XE,EIG,X,XI,F)
MPRD(A,B,R,N,M,L,IAS,IBS,IRS)

Remarks

Storage reservations are made to account for IEND < 40 and a maximum of 6 step loads.

2.5 Subroutine LINT

Purpose

To interpolate between arbitrarily spaced data points by use of interpolation or extrapolation.

Usage

Call LINT(X,Y,N1,M,XX,YY,N)
Description of Parameters

X  - vector of arguments for which the values of the function are interpolated
Y  - resulting vector of interpolated values of the function
N1 - number of arguments in X
M  - index of the last value of Y
XX - vector of arguments for which the values of the function are known
YY - vector of known values of the function
N  - number of arguments in XX

2.6 Subroutine HDIST

Purpose

To calculate the horizontal distance from the CL to the point where the pore pressure is 0.1% of the maximum pore pressure under the embankment.

Usage

Call HDIST(UB,XT,IEND,ICV,CHIN,DXSQ,AAH,MHE,W, XET,IPOR,HF,MYE,POR)

Description of Parameters

UB  - pore pressure at (MYE*IEND) points under the embankment
XT  - X-coordinate of the points at which the settlements and consolidation behavior are determined
IEND - number of horizontal coordinates XT
ICV  - number of data pairs (PCV(I),CVIN(I)) and (PCH(I),CHIN(I)) through which Lagrangian interpolation polynomials are passed.

CHIN  - variable coefficient of consolidation in horizontal direction

DXSQ  - (DELTA H** 2.)

AAH  - (1. + E0) / (GAMMA WATER x (DELTA H)** 2.)

MHE  - number of horizontal grid points

W  - Reference width

XET  - X-coordinates of the equidistant points in the horizontal direction

IPOR  - indicator to specify the value of POR
   = 1 , POR is specified by the user
   = 0 , program evaluates POR

HF  - = 1 , If horizontal flow is considered
   = 0 , If no horizontal flow is allowed

MYE  - number of points in the vertical direction

POR  - horizontal drainage distance / [XT(IEND)*W]

2.7 Subroutine COEF

Purpose

To determine the gas factor and the coefficients of consolidation.

Usage

COEF-UAUD,UAVE,OMEGA PHI,LI,IL,OMED,PHID,NN]

Block Names

SACSE/ROC,ROCL,SVM,P,PC,PLOQ,PO,PCO,LAV,IK,ISAT,AAV,AAH
SAC1/AVO,KVO,KHO,EOPUS,PU,SKHM,SKvm,CCC,NNN,ICOEFF
SAC02/PCV(10),CXIN(10),PCR(10),CHIN(10),ICV,KOUNT,HF
Description of Parameters

UAVD - average pore pressure before consolidation

UAVE - average pore pressure at some time after consolidation

OMEGA - consolidation factors of horizontal flow, product of the gas factor and the horizontal coefficient of consolidation

PHI - consolidation factor for vertical flow, product of the gas factor and the vertical coefficient of consolidation

IL - indicator
  =1 - calculate the parameters for vertical flow
  #1 - calculate the parameters for horizontal flow

LI - identifier; if LI=3, OMED and PHID are computed

NN - number of points where OMEGA, PHI, OMED and PHID are required

OMED - difference between the radial consolidation factor computed in a previous execution of this subroutine and the value computed in this execution of the subroutine

PHID - difference between the vertical consolidation factor computed in a previous execution of this subroutine and the value computed in this execution of the subroutine

IEND - number of elements in arrays UAVD, UAVE, OMEGA, PHI, OMED, PHID

ROC - ratio between the recompression and the virgin compression indices

PO - average initial vertical effective stress

PCO - average preconsolidation stress

IAV=0 - constant coefficient of compressibility
IAV=1 - variable coefficient of compressibility
IK=0 - constant coefficient of permeability
IK=1 - variable coefficient of permeability
ISAT=0 - 100% saturation
ISAT=1 - partial saturation
AAV - factor defined in program SAND; $AAV = (1 + E_0)/(62.43 * D_Y^2)$
AAH - factor defined in program SAND; $AAH = (1 + E_0)/(62.43 * D_H^2)$
AVO - initial or constant coefficient of compressibility
KVO - initial coefficient of permeability in the vertical direction
KRO - initial coefficient of permeability in the radial direction
EOPUS - factor defined in program SAND; $EOPUS = E_0 \cdot PU \cdot (1 - S) \cdot (1 - HC)$
PU - initial pore gas pressure
SKVM - factor defined in program SAND; $SKVM = CC/SKV$, if IAV=1 and $SKVM = 2.3026 \cdot AVO/SKV$, if IAV=0
SKHM - factor defined in program SAND; $SKHM = CC/SKH$, if IAV=1 and $SKHM = 2.3026 \cdot AVO/SKH$, if IAV=0
CCC - compression index times 0.4343
NNN - number of locations with radial and vertical drainage conditions
ICOEF=1 - IK=0, IAV=0 or IAV=1
ICOEF=2 - IK=1, IAV=0
ICOEF=3 - IK=1, IAV=1
ICOEF=4 - the coefficient of consolidation is obtained by interpolation
PCV  - effective stresses for which the vertical coefficients of consolidation are input
CVIN - vertical coefficients of consolidation at PCV
PCH  - effective stresses for which the radial coefficients of consolidation are input
CHIN - radial coefficients of consolidation at PCH
ICV  - number of PCV, CVIN, PCR, and CRIN; ICV < 10
KOUNT=0 - second or subsequent executions of this subroutine
KOUNT=1 - first use of this subroutine

Method and Reference

Depending on the values of the indices ISAT, IK, IAV, and ICOEF, the values of the "consolidation factors" for radial and vertical flow are determined for the average increases in effective stresses (UAVD-UAVE) at IEND locations. Relationships considered include: (bi-) linear void ratio versus logarithm of effective stress or constant coefficient of compressibility; linear void ratio versus logarithm of coefficient of permeability; and arbitrary coefficient of consolidation versus effective stress relationships.

2.8 Subroutine EFGEN

Purpose

To generate the time-dependent matrix D.

Usage

CALL EFGEN(PSI,T,EIG,IVAR,MM,NN,D,LI)
Description of Parameters

PSI - vector containing MM "consolidation factors"
T - time at which diagonal matrix D is computed
EIG - vector containing the eigenvalues

IVAR=0 - constant "consolidation factor"; PSI consists of one element only
IVAR=1 - variable "consolidation factor"; PSI consists of MM elements

MM - number of elements PSI (in most other routines, this parameter is called IEND)
NN - number of eigenvalues
D - diagonal matrix to be determined

Method

The elements of the diagonal matrix D are given by exp
(PSI(J)*EIG(I)*T), wherefore D has a total of MM*NN elements.
However, if IVAR=0, D(K)=D(K+NN)=...=D(K+(MM-1)*NN).

2.9 Subroutine GAIN

Purpose

To determine the gain in shear strength.

Usage

CALL GAIN(UA,R,SU,MYE,MXT,MXE,MX,NIM,CO,CP,III)
Description of Parameters

UA - vector of dissipated pore water pressures at points (XT,XE)

R - auxiliary matrix necessary to compute the dissipated pore water pressures at points (XE,YE) from a knowledge of those at points (XT,YE)

SU - resultant undrained strengths at points (XE,YE)

MYE - number of equally spaced points in vertical direction

MXT(I) - number of points XT between the interval limits AX(I) and AX(I+1)

MXE(I) - number of points XE between the interval limits AX(I) and AX(I+1)

MX - sum of MXE(I) for I=1,NIM

NIM - number of subintervals

cO - vector containing MYE undrained initial shear strength values

CP - vector containing MYE (c/p)-ratios

III=1 - all elements of array UA are assumed to be equal to zero

III=0 - some or all elements of array UA differ from zero

Method

The strength values SU are obtained as the sum of the initial shear strengths plus the products of the (c/p)-ratios and the dissipated pore water pressures.

2.10 Subroutine FUNCT
Purpose

This subroutine computes the values of the integrands for the argument theta.

Usage

CALL FUNCT(THETA,ETA,K,SIGX,SIGY,TAU)

Block Names

POFUN/Q(258),ETHST(258)

Description of Parameters

K  - index necessary to select the proper quantities Q and ETH, which have been precomputed for the same argument THETA

SIGX  - value of the integrand of the equation for the horizontal normal stress

SIGY  - value of the integrand of the equation for the vertical normal stress

TAU  - value of the integrand of the equation for the shear stress

Q  - precomputed vector whose elements are equal to the sum of (sin \( a_1 \theta \))/\( b \)

ETH  - precomputed vector whose elements are equal to exp (\( \theta \))

Method

The subroutine makes use of the fact that the hyperbolic sine and cosine functions can be expressed in terms of the exponential function.
2.11 Subroutine GENER

Purpose

To determine the coefficients and the roots of the characteristic equation.

Usage

CALL GENER(P,F,X,N)

Description of Parameters

P  - tridiagonal matrix whose lower off-diagonal elements are equal to -1.0
F  - auxiliary matrix used during the computations
X  - roots of the characteristic equation; these are the eigenvalues
N  - degree of the characteristic equation

Subroutines Required

RROOT (A,X,N)

2.12 Subroutine GENS

Purpose

To generate the mathematical molecules which are used in a numerical integration.

Usage

CALL GENS(S,M)
Description of Parameters

S  - resulting mathematical molecule
M  - number of pivotal points

Method

For the case of vertical flow, the elements of vector S are either computed by the extended Simpson rule or the extended trapezoidal rule assuming equal spacing; the use of Simpson's rule requires that M be an odd number.

2.13 Subroutine INIT

Purpose

To select starting values for the stability analysis and define three vectors which are repeatedly used in subroutine DETFS.

Usage

CALL INIT(XINP,YINP,MINP,XC,YC,YY,ZZ,DMIN)

Block Names

SAPOD/IOUTP*,W*,H,GLOAD*,LOAD*,NARC*,NRAD*;
INDET/RHO(19),TAU(19),PSI(19);
* parameters marked by * are not needed in this routine
Description of Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XINP</td>
<td>X-coordinates of the points defining the embankment contour</td>
</tr>
<tr>
<td>YINP</td>
<td>Y-coordinates of the points defining the embankment contour</td>
</tr>
<tr>
<td>MINP</td>
<td>Number of points (XINP,YINP)</td>
</tr>
<tr>
<td>XC</td>
<td>X-coordinate of the center of the first trial slip surface</td>
</tr>
<tr>
<td>YC</td>
<td>Corresponding Y-coordinate</td>
</tr>
<tr>
<td>YY</td>
<td>Minimum permissible value for YC</td>
</tr>
<tr>
<td>ZZ</td>
<td>Difference between the maximum YINP-value and YY</td>
</tr>
<tr>
<td>DMIN</td>
<td>Minimum increment to be used in the direct search procedure</td>
</tr>
<tr>
<td>H</td>
<td>Thickness of the compressible layer</td>
</tr>
<tr>
<td>RHO</td>
<td>Slopes of the lines which connect consecutive points (XINP,YINP)</td>
</tr>
<tr>
<td>TAU</td>
<td>$\text{TAU} = 1 + RHO^{**2}$</td>
</tr>
<tr>
<td>PSI</td>
<td>Y-value at X=0 for the lines connecting consecutive points (XINP,YINP)</td>
</tr>
</tbody>
</table>

Method

When the center of the first trial failure arc is not input from SAND, YC is set equal to YY and XC is defined as one-half of the sum of the X-values obtained when two circles with radius $R = YY + H$ pass through (XINP(I),YINP(I)) and the toe of the embankment, respectively. The vectors RHO, TAU, and PSI are computed once for repeated use in subroutine DETFS.
2.14 **Subroutine INTEG**

**Purpose**

To compute approximate values of the stress integrals between the limits B and infinity.

**Usage**

CALL INTEG(ETA,XI,B,AR)

**Block Names**

PCAPI/ALPHA(30), L;

**Description of Parameters**

- **ETA** - Y-coordinate divided by the thickness of the compressible layer
- **XI** - X-coordinate divided by the thickness of the compressible layer
- **B** - lower integration limit
- **AR** - resulting array with six integral values
- **ALPHA** - length of the load strips divided by the thickness of the compressible layer
- **L** - number of ALPHA's

2.15 **Subroutine LAGR**

**Purpose**

To interpolate between arbitrarily spaced data points by use of the Lagrangean polynomial.
Usage

CALL LAGR(X,Y,M,JST,XX,YY,N)

Description of Parameters

X - vector of arguments for which the values of the function are interpolated
Y - resulting vector of interpolated values of the function
X - number of arguments X
JST - index of the first value Y to be interpolated
XX - vector of arguments for which the values of the function are known
YY - vector of known values of the function
N - number of arguments XX

Method

A Lagrangean polynomial of degree (N-1) is passed through the data points (XX,YY) and then evaluated for M arguments X. See, for example, the book by CARNAHAN, LUTHER, AND WILKES (1969).

2.16 Subroutine MAMUL

Purpose

To perform the matrix multiplication: (general matrix)* (diagonal matrix)*(column vector).
Usage

CALL MAMUL(A,D,B,C,N,IS,II)

Description of Parameters

A - general square matrix
D - diagonal matrix
B - column vector
C - resulting column vector
N - order of matrices A and D and length of vectors B and C
IS - index of the first element of vector B
II - index of the first element of matrix D, whose diagonal elements only are stored one-dimensionally

Method

The subroutine utilizes the fact that all matrices are stored one-dimensionally, so that the I-th element of vector C becomes

$$C(I) = \sum_{k=1}^{N} A(I+K\cdot N-N)\cdot B(IS-1+K)\cdot D(II-1+K)$$

2.17 Subroutine MATR
Purpose

To generate matrix XM, the elements of whose rows are equal to integer powers of the differences between the elements of vector XV and constant A.

Usage

CALL MATR(IS,IE,M,XV,A,XM)

Description of Parameters

IS - index of the first element of vector XV
IE - index of the last element of vector XV
M - number of rows of matrix XM
XV - vector with (IE-IS+1) elements
A - constant to be subtracted from all elements XV
XM - resulting M by (IE-IS+1) matrix

Method and Reference

Given the vector XV with elements

XV(IS),XV(IS+1),...,XV(IE),

the M by (IE-IS+1) matrix is generated and stored one-dimensionally, such that

XM (K+I*M-M) = (XV(IS+I-1)-A)**(K-1).

Program Length

45 words

2.18 Subroutine MINV
Purpose

To invert a general matrix.

Usage

CALL MINV(A,N,D)

Block Names and Lengths

None

Description of Parameters

A - input matrix destroyed in computation and replaced by the resultant inverse
N - order of matrix A; N < 25
D - resulting determinant

Method and Reference

The standard Gaub-Jordan method is used. This subroutine is a slightly modified version of subroutine MINV, as given in the IBM Application Program, 1130 Scientific Subroutine Package (1130-CM-02X), Programmer's Manual, Form H20-0252-0, White Plains, New York, 1966.

2.19 Subroutine MODAL
Purpose

To determine matrix P, its eigenvalues, the corresponding modal matrix, and the inverse of the modal matrix.

Usage

CALL MODAL(LAYER, IBC, N, FIMP, RC, RD, XO, XE, EIG, X, XI, F)

Description of Parameters

- **LAYER=1** - radial drainage conditions
- **LAYER=2** - vertical drainage conditions; homogeneous soil profile
- **LAYER > 3** - vertical drainage conditions; two-layered soil profile with layer interface at YE(LAYER)
- **IBC=1** - vertical flow; impeded drainage at the bottom
- **IBC=2** - vertical flow; free drainage at the bottom
- **IBC=3** - vertical flow; no drainage at the bottom
- **N** - number of eigenvalues
- **FIMP** - "impedance factor"; for vertical flow
  \( \frac{RKV*HI/DY}{1+RKV*HI/DY} \)
- **RC** - ratio of the vertical coefficients of consolidation of the lower and the upper layers
- **RK** - ratio of the vertical coefficients of permeability of the lower and the upper layers
- **XO** - lower boundary of the solution domain
- **XC** - upper boundary of the solution domain
- **EIG** - resultant eigenvalues
- **X** - resultant modal matrix
XI - inverse of the resultant model matrix
F - auxiliary matrix

Method and Reference

For IBC=2 and IBC=3, the eigenvalues and the modal matrix can be computed directly for a homogeneous soil profile. In all other cases, the auxiliary matrix D and matrix P, whose eigenvalues are determined in subroutine GENER, must be generated before the modal matrix X can be set up. Finally, the inverse of the modal matrix is computed by use of subroutine MINV.

Subroutines Required

GENER(P,F,X,N)
MINV(A,N,D)

Remarks

The lower off-diagonal elements of matrix P, which are equal to -1.0, are not stored.

2.20 Subroutine MPRD

Purpose

To multiply two matrices to form a resultant matrix.

Usage

CALL MPRD(A,B,R,N,M,L,IAS,IBS,IRS)
Description of Parameters

A - first input matrix
B - second input matrix
R - output matrix
N - number of rows of matrices A and R
M - number of columns of matrix A and number of rows of matrix B
L - number of columns of matrices B and R
IAS - index of the first element of matrix A
IBS - index of the first element of matrix B
IRS - index of the first element of matrix R

Method

The M by L matrix B is premultiplied by the N by M matrix A and the result is stored in the N by L matrix R. The indices IAS, IBS, and IRS allow the multiplication of submatrices of A and B, and the product is stored as a submatrix of R.

Remarks

Matrix R cannot be in the same location as matrices A or B.

2.21 Subroutine PORE

Purpose

To compute the elastic stresses and pore water pressures within a layer of finite thickness for a symmetrical vertical load.
Usage

CALL PORE(XINP,YINP,M,NST,CX,IX,CY,IY,U,ABAR,BBAR)

Block Names

SAPOD/IOUTP,W,H,GLOAD,CLOAD*,NARC*,NRAD*
POAPI/ALPHA(30),L;
POFUN/QST(129),ETHST(129);
* parameters marked by an asterisk are not needed in this subroutine

Description of Parameters

XINP - X-coordinates of the points defining the embankment contour

YINP - corresponding Y-coordinates

M - number of points (XINP,YINP)

NST - number of approximating load strips

CX - X-coordinates divided by the reference value W, for which the stresses are to be computed

IX - number of CX-values

CY - Y-coordinates divided by the thickness of the compressible layer H, for which the stresses are to be computed

IY - number of CY-values

U - resulting excess pore water pressures (1X*1Y < 220 elements)

ABAR - Skempton's pore pressure coefficient A

BBAR - Skempton's pore pressure coefficient B

IOUTP - logical output unit
W - reference length in X-direction
H - thickness of the compressible layer
GLOAD - unit weight of the embankment soil
ALPHA - lengths of the load strips which approximate the actual embankment load
L - number of values ALPHA
QST - resulting vector whose elements are repeatedly used in subroutine FUNCT
ETH - resulting vector whose elements are repeatedly used in subroutine FUNCT

Method and Reference

The total stresses within a compressible layer are computed by use of elastic theory for plane strain conditions and a symmetric vertical loading. Poisson's ratio is set equal to 0.5, and the underlying stratum is assumed to be rough and rigid. Because of the complex nature of the stress integrals, a numerical integration procedure, based on either Simpson's rule of Filon's formulae, has been chosen for their evaluation.

Subroutines Required

APROX(X,Y,MN,N,D)
FUNCT(THETA,ETA,K,SIGX,SIGY,TAU)
INTEG(ETA,XI,B,AR)

Remarks

The coordinates YINP are positive upward, whereas ETO is positive downward with the coordinate origin at the surface of the compressible layer. ETA is positive upward with the origin at the bottom of the compressible layer.
2.22 Subroutine RROOT

Purpose

To compute the real roots of the characteristic equation.

Usage

CALL RROOT(COF,XR,M)

Description of Parameters

COF - input vector containing the \((M+1)\) coefficients of the polynomial

XR - resulting \(M\) roots of the polynomial

M - degree of the polynomial

2.23 Subroutine SETL

Purpose

To compute settlements for constant or variable coefficients of compressibility.

Usage

CALL SETL(U,SETTL,IEND,KKK,MYE,F,FUP,FLO,KIAV)

Block Names and Lengths

SACSE/ROC,ROCL,SVM,P,PC,PLOG,PO*,PCO*,IAV*,IK*,ISAT*,AAV*,AAH
* parameters marked by an asterisk are not needed in this subroutine
Description of Parameters

U - input vector of dissipated pore water pressures with (MYE*IEND) elements

SETTL - resulting vector of settlements

IEND - number of elements of SETTL

KKK - number of points in the upper layer in the vertical direction

MYE - total number of points in the vertical direction

F - multiplying factor; if F=1.0, the consolidation settlements are computed; if F=1/B, where B is Skempton's pore pressure parameter, total settlements are computed

FUP - parameter for the upper layer; contains the soil parameters

FLO - parameter for the lower layer; contains the soil parameters

KIAV=1 - a constant coefficient of compressibility is used

KIAV=2 - a variable coefficient of compressibility is used

ROC - ratio between the recompression and the virgin compression indices for the upper layer

ROCL - recompression index of the lower layer divided by the virgin compression index of the lower layer

SVM - modified mathematical molecule for integration in the vertical direction with MYE or (MYE+1) elements

P - present overburden effective stress at MYE points

PC - preconsolidation stresses at MYE points

PLOG - natural logarithm of the ratio between the preconsolidation and the overburden stresses
Method

The computations are performed first for the upper layer; then, the displacements of the lower layer are evaluated by making the same computations with redefined parameters. A lower layer must be considered only if $KKK < MYE$.

2.24 Subroutine STAB

Purpose

To search automatically for the minimum factor of safety.

Usage

CALL STAB(XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FX,D,DM,YY)

Description of Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XC</td>
<td>X-coordinate of the center of the circular slip circle</td>
</tr>
<tr>
<td>YC</td>
<td>corresponding Y-coordinate</td>
</tr>
<tr>
<td>R</td>
<td>radius of the circular slip surface</td>
</tr>
<tr>
<td>XINP</td>
<td>X-coordinates of the points defining the embankment contour</td>
</tr>
<tr>
<td>YINP</td>
<td>corresponding Y-coordinates</td>
</tr>
<tr>
<td>MINP</td>
<td>number of points (XINP,YINP)</td>
</tr>
<tr>
<td>MX</td>
<td>number of equally spaced grid points in horizontal direction</td>
</tr>
</tbody>
</table>
MYE - number of equally spaced grid points in the vertical direction

SU - undrained shear strengths at (MX*MYE) grid points

FX - resulting factor of safety

D - maximum step size to be used in the search procedure

DM - minimum step size to be used in the search procedure

YY - minimum permissible value for YC

Method and Reference

The programmed method embraces two tactical manoeuvres, the "exploratory move" and the "pattern move". Starting from the input base point (XC,YC), an exploratory move is made by varying first XC and then YC. If this move is successful, a pattern move is performed, followed again by a pattern move, if it was successful, and by an exploratory move, if it was not successful. This procedure is repeated until the minimum has been detected, whereafter the step size, by which XC and YC are varied, is decreased. When the minimum factor of safety is found by use of the smallest step size, DM, it is checked to determined whether the corresponding slip circle outcrops in front of the toe of the embankment. If it does not, an additional search is started and the smaller of the obtained minimum factors of safety is returned together with the coordinates and the radius of the corresponding arc.
Subroutines Required

VARYR(YC,XC,R,XINP,YINP,MINP,MX,MYE,SU,FS,DMIN,YY)

Remarks

The input data XC and YC are destroyed and replaced by the coordinates of the arc which gives the minimum factor of safety.

The step size is decreased in the subroutine by dividing by 2; it is, thus, possible that the smallest step size used is less than the input value DM.

2.25 Subroutine VARYR

Purpose

To vary the radii of trial arcs which have the same center coordinates and to compute the associated factors of safety.

Usage

CALL VARYR(YC,XC,R,XINP,YINP,MINP,MX,MYE,SU,FS,DMIN,YY)

Block Names

SAPOD/OUTP*,w*,H,GLOAD*,CLOAD*,NARC*,NRAD;
* parameters marked by an asterisk are not needed in this subroutine

Description of Parameters

YC - Y-coordinate of the center of the circular slip surfaces
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XC</td>
<td>corresponding X-coordinate</td>
</tr>
<tr>
<td>R</td>
<td>resulting radius of the arc which gives the minimum factor of safety for the center (XC,YC)</td>
</tr>
<tr>
<td>XINP</td>
<td>X-coordinate of the points defining the embankment contour</td>
</tr>
<tr>
<td>YINP</td>
<td>corresponding Y-coordinates</td>
</tr>
<tr>
<td>MX</td>
<td>number of equally spaced grid points in the horizontal direction</td>
</tr>
<tr>
<td>MYE</td>
<td>number of equally spaced grid points in the vertical direction</td>
</tr>
<tr>
<td>SU</td>
<td>undrained shear strengths at (MX*MYE) grid points</td>
</tr>
<tr>
<td>FS</td>
<td>resulting factor of safety</td>
</tr>
<tr>
<td>DMIN</td>
<td>minimum step size to be used in the search procedure</td>
</tr>
<tr>
<td>YY</td>
<td>minimum permissible value for YC</td>
</tr>
<tr>
<td>H</td>
<td>thickness of the soft soil layer</td>
</tr>
<tr>
<td>NRAD</td>
<td>number of trial radii to be used at the input center (XC,YC)</td>
</tr>
</tbody>
</table>

**Method and References**

After determination of the maximum and minimum possible radii, RMAX and RMIN, respectively, the factors of safety are computed for NRAD radii \( R = R_{MAX} - I \times (R_{MAX} - R_{MIN}) / (NRAD - 1) \). The minimum value of the so-obtained NRAD factors of safety is returned to the calling program.

**Subroutines Required**

DETFS(XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FS)
3. **Input Data**

The main program is written in an interactive manner so that the user will be able to input the following data.

1. Name of the input file (length limited to 50 spaces)

2. Name of the output file (length limited to 50 spaces)

3. Number of symbols to be used in the output graph after execution

4. The characters that are used in the output graph after execution

On execution of the program the following messages will appear on the screen one by one and the user should input the corresponding data.

1. Specify the name of the input file

2. Specify the name of the output file

3. Specify the number of symbols to be used (usually 4)

4. Specify the characters - blank, star, grid, symb(I) I=1, mmm

After specifying these data, the program will use the data on the specified input file and write the results on the specified output file.
Proposed characters are:

Blank - a blank space
Star - *
Grid - I

Symb(1) = U - for avg. degree of consolidation as a percentage of reference load
Symb(2) = C - consolidation settlement as a percentage of that of reference load
Symb(3) = O - immediate settlement as a percent of that of reference load
Symb(4) = T - total settlement as a percent of that of reference load

(See sample problems for the proper use of these)

This section illustrates the sequence of input data in the main program. A free format style is used. These input data must be given in an input file (the name of the input file is specified by the user).

(a) Input data corresponding to the mesh-generation for the numerical solution, in the compressible layer and type of analysis required.

1. MYE,MHE,ISP,HF,POR,IPOR

MYE - number of equivally spaced points in the vertical direction, including the surface
and the bottom of the compressible layer
in the finite difference mesh in the
compressible soil \( MYE < 12 \)

\[ MHE \] - number of points in the horizontal direction
(mesh points) in the compressible soil
\( (MHE < 40) \)

\[ ISP \] - identifier where
\( ISP = 0 \) - settlements, the process of
consolidation and the stability
are analyzed
\( ISP = 1 \) - settlements and the process of
consolidation are analyzed. Times
of load application are required
as input parameters

\[ HF \] - identifier where
\( HF = 0.0 \) - horizontal flow is neglected in
the process of consolidation
\( HF = 1.0 \) - horizontal flow is not neglected
in the process of consolidation

\[ POR \] - ratio horizontal drainage distance divided
by \( (XT(IEND)*W) \) in the case of \( ISP = 1 \), and
Set \( POR = 1.0 \) if this is not known

\[ IPOR \] - identifier where
\( IPOR = 1 \) - The user provides the value of \( POR \)
\( IPOR = 0 \) - the user provides \( POR = 1.0 \)
the program will calculate the
value of \( POR \)

2. \( JND \) (add this card only if \( ISP = 0 \))

\[ JND \] - number of points in the horizontal
direction for which output are required
\( JND < 10 \)

3. \( (JSP(K), K=1, JND) \) (add this card only if \( ISP = 0 \))

\[ JSP(K) \] - indices of the \( JND \) points for which
output is required. \( K = 1, JND < 10 \); the
output is for points \( XE(JSP(K)) \), where \( XE \)
are \( MX \) equally spaced coordinates between
and including the limits AX(1)W and AX(NI)W; for example, specification of JSP(1)=1, JSP(JND)=MX causes the output of information at the limits WAX(1) and WAX(NI) respectively.

4. LND

LND - number of weeks to be plotted on the time axis of the graphical output

5. MX, NI (add this card only if ISP=0)

MX - number of equidistant points in the X-direction between limits AX(I) and AX(NI)
MX < 51 User may choose MX as equal to MHE

NI - number of interval limits AX(I); NI < 5

Notes:

AX(NI)W is the last point (which is considered in the analysis) in the horizontal direction from the CL. AX(1)=0.0 is the centerline of the embankment.

This horizontal distance between AX(1) and AX(NI) is divided into NI subdivisions. Each subdivision is further divided into MXT points. User may typically use 3-4 subdivisions for each interval between AX(I)W and AX(I+1)W. (Ref. Krizek and Krugman, 1972 for details.)

6. (AX(I)=1, NI) (add this card only if ISP=0)

AX(I) - sub-interval limits as decimal fractions of reference value W (select values such that a smooth curve along the pore pressure vs. AX(I)W will give the expected shape of the pore pressure distribution)
(Hint - let contour points of the embankment be some of the AX(I)W)
7. (MXT(I), I=1, NI-1) (add this card only if ISP=0)

MXT(I) - number of unequivalently spaced points XT between the consecutive limits AX(I) and AX(I+1). I=1, NI-1. Maximum value of MXT(I) < 10. Sum of all MXT(I) < 20

8. IEND (add this card only if ISP=1)

IEND - number of points in the horizontal direction for which output are required

9. (XT(I), I=1, IEND) (add this card only if ISP=1)

XT(I) - X-coordinates of the points at which the settlements and the consolidation behavior are determined
Output are printed for points at distance XT(I)*W

10. H, GLOAD, CLOAD, W, YWM, TGMH

H - thickness of the compressible layer dimension (ft)
If H=0 the program is terminated

GLOAD - unit weight of the embankment soil (pcf)

CLOAD - undrained strength of the embankment soil (psf)

W - reference value in the horizontal direction (ft)
YWM - thickness of a drainage blanket placed on the surface of the compressible soil layer (ft)

TGPHI - tangent of the angle of internal friction of the drainage blanket, if there is one

11. IBCV, LAYER

IBCV - identifier where
   IBCV=1 - impeded drainage at \( Y=H \)
   =2 - free drainage at \( Y=H \)
   =3 - no drainage at \( Y=H \)

LAYER - number which indicates the location of a layer interface; e.g.
   LAYER=KK means that the layer interface is located at a depth below ground surface which is equal to \( Y=H*(KK-1) \)
   If only one type of soil is to be considered SET LAYER=0
   4 LE' LAYER' LE' (MYE-3)

12. HI,RKV (add this card only if IBCV=1)

HI - thickness of impedance layer

RKV - ratio of vertical permeabilities
   \[ \frac{K(\text{drainage soil})}{K(\text{impedance layer})} \]

13. RK,RC,REO,RAV,RCC,ROCL (add this card only if LAYER > 3)

RK - ratio of vertical permeabilities
K(lower soil)
K(upper soil)

RC - ratio of (vertical) coeff. of consolidation \(c_v\)
   \[
   \frac{c_v}{c_v} \text{ (lower soil)}
   \]
   \[
   \frac{c_v}{c_v} \text{(upper soil)}
   \]

ROCL - ratio of recompression index of lower soil
   to that of upper soil

REO - ratio of initial void ratios
   \[
   \frac{e_o}{e_o} \text{(lower soil)}
   \]
   \[
   \frac{e_o}{e_o} \text{(upper soil)}
   \]

RCC - ratio of virgin compression index \(c_c\)
   \[
   \frac{c_c}{c_c} \text{(lower soil)}
   \]
   \[
   \frac{c_c}{c_c} \text{(upper soil)}
   \]

RAV - ratio of coefficient of compressibility \(a_v\)
   \[
   \frac{a_v}{a_v} \text{(lower soil)}
   \]
   \[
   \frac{a_v}{a_v} \text{(upper soil)}
   \]

14. IVAR, IAV, ICV

All these are identifiers where

IVAR=0 - use constant coeff. of consolidation

IVAR=1 - use variable coeff. of consolidation
   which are obtained either by
   interpolation between CHIN(I)
   and CVIN(I) or by varying the
   coeff. of compressibility and/or
   the coefficient of permeability
   (i.e., if ICV > 0)

IAV=0 - use a constant coeff. of compressibility
   in the settlement computations

IAV=1 - use the compression indices in the
   settlement computations

ICV - number of data pairs [PCV(I), CVIN(I)]
   and [PCH(I), CHIN(I)] through which
Lagrangean/Linear interpolation polynomials are passed
$0 < ICV < 0$

15. EO, A

EO  - initial void ratio of the upper soil
A   - Skempton's pore pressure coefficient (A)

16. AVO (add this card only if IAV=0)

AVO  - constant coeff. of compressibility to be used in the settlement computations; in the case of two layers AVO applies to the upper layer (ft$^2$/lb)

17. CC, ROC, GAMMA (add this card only if IAV=1)

CC    - virgin compression index (in the case of two layers this applies to the upper layer)
ROC   - ratio of recompression index to the virgin compression index (in the case of two layers - upper layer)
GAMMA - effective unit weight of the subsoil, constant over the thickness of the compressible layer
         If GAMMA=0, input of MYE effective overburden stress at equivalently spaced depths must be input (pcf)

18. P(I), PC(I) (add this card only if GAMMA=0) (total of MYE cards)
P(I) - present overburden effective stress at MYE equally spaced depths, including the surface MYE < 12 (psf)

PC(I) - preconsolidation stresses at MYE equally spaced depths, including surface, MYE < 12 (psf)

19. CV, CH (add this card only if IVAR=0 and ICV=0)

CV - constant coeff. of consolidation in the vertical direction (in the case of two layer-upper layer) (ft²/day)

CH - constant coeff. of consolidation in the horizontal direction (in the case of two layers-upper layer) (ft²/day)

20. PCV(I),CVIN(I),PCH(I),CHIN(I) (add this card only if IVAR=1 and ICV>0) (ICV number of cards)

PCV(I) - effective stresses at which the vertical coeff. of consolidation CVIN(I) are defined ICV < 10 (psf)

PCH(I) - effective stresses at which the horizontal coeff. of consolidation CHIN(I) are defined (psf) ICV < 10

CVIN(I) - variable coefficients of consolidation in the vertical direction (interpolation is done in subroutine coef) (ft²/day) ICV < 10

CHIN(I) - variable coeff. of consolidation in the horizontal direction (interpolation is done in subroutine coef) (ft²/day) (ICV < 10)

21. KVO,KHO (add this card only if IVAR=1 and ICV=0)
KVO - initial coeff. of permeability in the horizontal direction
KHO - initial coeff. of permeability in the vertical direction (ft/day)

22. ISAT, IK (add this card only if IVAR=1 and ICV > 0)
These are identifiers where

ISAT=0 - complete saturation
   =1 - partial saturation; requires Skempton's pore pressure parameter B < 1.0

IK=0 - constant coefficient of permeability
   =1 - horizontal and vertical permeabilities are variables; void ratio vs. the logarithm of the coeff. of permeability is a straight line

23. S, PU, HC, B (add this card only if IVAR=1, ICV > 0 and ISAT=1)

S - degree of saturation to be input as a decimal fraction < 1.0
PU - initial pore gas pressure, if PU is not defined during input, it is set equal to the sum of the atmosphere pressure plus one half the thickness of the compressible layer times the unit weight of water (psf)
HC - Henry's constant of gas solubility, HC=0.020 for atmospheric air, HC=0.029 for methane, HC=2.84 for hydrogen sulfide (at 68°F)
B - Skempton's pore pressure coefficient (B)

24. SKV, SKH (add this card only if IVAR=1, ICV>0, IK=1)
SKV - slope of the void ratio vs. logarithm of vertical coeff. of permeability

SKH - slope of the void ratio vs. logarithm of horizontal coeff. of permeability

25. NC (add this card only if ISP=0)

NC - number of initial undrained shear strengths, CO(I), and (c/p)-ratios, CP(I);
NC < MYE < 12

26. Y UA(I), UB(I) (add this card only if ISP=0) (total of NC cards)

Y - vertical distance below the ground surface at which the initial shear strengths are given (positive downwards) (ft)

UA(I) - initial undrained shear strength CO(I) at depth Y (psf)

UB(I) - (c/p)-ratio at depth Y

* At this point the program will write the data on the OUTPUTFILE.

(c) Following data corresponds to the REFERENCE LOAD.

27. MINP,NS

MINP - the number of points where the coordinates of the embankment will be given. This defines the contour of the embankment (MINP < 20)

NS - number of load strips to approximate the actual embankment load (NS < 20)
28. XINP(I), YINP(I) (total of MINP cards)

XINP(I) - X-coordinates of the points defining the embankment contour (ft)  
(MINP < 20)

YINP(I) - Y-coordinates of the points defining the embankment contour (ft)  
(MINP < 20)

(d) Following data corresponds to the load application (i.e. each step of load to the embankment).

29. NL,(IDEN(I),I=1,NL)

NL - number of load strips (NL < 6)

IDEN(I) - identifier corresponding to the Ith load strip; where

IDEN(I) < 0  - the excess pore pressure due to the first load step are equal to the input residual pore pressure

IDEN(I) = 0  - the excess pore water pressure due to the Ith load are computed by means of subroutine PORE

IDEN(I) = 1  - the excess pore pressure due to the Ith load are set equal to those computed for the reference load. Note, that this requires that Skempton's coefficients A and B are identical in both cases

IDEN(I) < 0  - allows the check of an existing installation for which the excess pore pressures just after load application are known from field measurements

30. (TL(I),I=1,NL) (add this card only if ISP=1)
TL(I) - times of load application (i.e. each step of load) in case where ISP=1
   NL < 6 (days)

31. FSI,SPEC(1),SPECU(1),TA,DMAX,DMIN,XC,YC,ZZ (add this card only if ISP=0)

FSI - factor of safety required at the time of application of the first load

SPECS(1) - specified fraction of the consolidation settlement due to the reference load. This settlement must have occurred before a new load is applied.

SPECU(1) - when the non-dissipated average pore pressures become less than 5% of the total average pore pressure just after the application of the last load at IEND*SPECU points XT the subsequent loads are disregarded. SPEC is a decimal fraction. IEND is the total number of points in the X-direction created by the program (see Sec. 2.1)

TA - available construction time. This is the time at which the final load must have been applied (days)

DMAX - maximum step size to be used in the variation of XC and YC in the search procedure for the minimum factor of safety (ft)

DMIN - minimum step size to be used in the variation of XC and YC in the search procedure for the minimum factor of safety (ft)

XC - X-coordinate of the center of the first trial arc, If XC=0 is input, the program selects a starting value (ft)

YC - Y-coordinate of the center of the first trial arc, If YC=0 is input, the program selects a starting value (ft) (Note - positive upward)
32. NARC, NRAD (add this card only if ISP=0)

NARC  - one-half the number of subarcs within the subsoil to be used in subroutine DETFS; NARC > 1

NRAD  - number of trial arcs to be used with each trial center (XC,YC) in the stability analysis; NRAD > 1

33. MINP, NS, IAB (gives data corresponding to the first load)

MINP  - same as defined earlier - corresponding to the first load

NS    - same as defined earlier - corresponding to the first load

IAB   - identifier where
   IAB=0  - Skempton's pore pressure coefficients A and B as defined for the last load are also used to compute the pore pressures due to the load addition
   IAB=1  - redefine A and B (i.e. assign new values for A and B)

34. XINP(I), YINP(I) (total of MINP cards)

XINP(I)  - as defined earlier - corresponding to the first load

YINP(I)  - as defined earlier - corresponding to the first load

35. A, B (add this card only if IBA=1)

A, B  - corresponding Skempton's pore pressure parameters (new)
At this point of the program, if satisfactory FS is not reached, within the available construction time, for the first load the program is terminated (i.e., no loads can be added to the existing embankment). Note - this is for ISP=0

(e) The following data refers to the residual pore pressures under the embankment.

36. IRP

IRP - identifier where
IRP=0 - no residual pore pressures are input
IRP=1 - residual pore pressure at points
(W’XT, H’YE) are input columnwise
IRP=2 - residual pore pressure at arbitrary points are input

37. (UC(I),I=1,ISUM) (add this card only if IRP=1)

UC(I) - residual pore pressures under the embankment at points (WcodtXT, H*YE) are input columnwise (psf)

38. X,Y,UA(I),COUNT (add this card only if IRP=2) (number of cards depends on number of arbitrary pore pressures to be given)

X - the X-coordinate at which residual pore pressure UA(I) is specified

Y - the Y-coordinate at which residual pore pressure UA(I) is specified

COUNT - identifier where
COUNT=0.0 - in all the cards except the last card
COUNT=1.0 - the last data card on residual pore pressure

At this point of the program, the internal file unit 1 will be rewinded to initiate the recording of the output data. The program calculates the required parameters corresponding to the first load.
Steps in this section should specify second and following loads for a total of (NL-1) lifts with proper values corresponding to each step of load, i.e. total of NL load applications NL < 6 are allowed.

(f) The following data corresponds to the second and following loads. [This data should cover (NL-1) loading steps.]

39. MINP, NS, IAB (gives data corresponding to the 2nd load step)

\[
\begin{align*}
\text{MINP} &= \text{as defined earlier - corresponding to the 2nd load step} \\
\text{NS} &= \text{as defined earlier - corresponding to the 2nd load step} \\
\text{IAB} &= \text{as defined earlier - corresponding to the 2nd load step}
\end{align*}
\]

40. XINP(I), YINP(I) (gives the contour of the embankment for the 2nd or following load steps) (total number of cards = MINP)

\[
\begin{align*}
\text{XINP(I)} &= \text{as defined earlier - corresponding to the load step} \\
\text{YINP(I)} &= \text{2nd or following load step}
\end{align*}
\]

41. A, B (add this card only if IAB=1)

\[
\begin{align*}
A &= \text{pore pressure parameters} \\
B &= \text{as defined earlier - corresponding to the load step}
\end{align*}
\]

42. FSI, SPECS(0), SPECU, TMIN, XC, YC, ZZ (add this card only if ISP=0)

\[
\begin{align*}
\text{FSI} &= \text{specified required factor of safety for the 2nd load step} \\
\text{SPECS(0)} &= \text{specified fraction of the consolidation settlement due to reference load that must}
\end{align*}
\]
have occurred before the addition of the next load step.

**SPECU(LL)** - if an average degree of consolidation of 95% due to the LIFT-TH load is obtained at SPECU(LIFT)*IEND points XT without a sufficient factor of safety for the present load (i.e. LLth load) the LIFTth load is taken to be the last load and NL is set at NL=LIFT (i.e. the present load will not be added to the embankment). SPECU is input as a decimal fraction (see Sec. 2.1)

**TMIN** - time which must have passed after a load application before the first stability is made to determine whether the next load can be applied. (This saves unnecessary computer time in calculating FS before sufficient pore pressure is dissipated.)

**XC**
**YC**
**ZZ** - as defined previously - corresponding to the LLth load

**Note:** The program can handle analysis of multiple embankments in a single run.

This is done by adding the card No. 10 at the end of the cards for the previous embankment but with replacing H = 99.

This makes the program to goto the beginning of cards. For second or following embankments data cards should be repeated from 1-42 as in the case of first embankment.

To terminate the program at the end of analysis of nth embankment, simply add the card #10 with H = 0 at the end of data cards for the n th embankment.

4. **Sample Problems**

Two sample problems have been prepared to show some of the features of the computer programs. In the first problem, only a settlement analysis for a specified load history is required, whereas the second problem simulates actual design conditions.
using soil data and cross-section from an unpublished report by the STATE OF ILLINOIS, DIVISION OF HIGHWAYS (1967).

4.1 Sample Problem for Settlement Analysis (Sample Problem #1)

In this first problem the load, which includes a surcharge of 5 feet, is applied at time TL(1)=60 days, and the surcharge is removed at time TL(2)=160 days. The geometry is given in Figure 4.1, and the soil parameters, which are assumed to vary during consolidation, are compiled in Table 4.1 and in Figure 4.2. Output of pore water pressures is required at specified points under the embankment. The input sequence for the soil parameters, the geometry, and the load characteristics follows the list of data cards given in Section 3 for program "Modified SAND" with ISP=1, and the contents of the data cards are listed in Table 4.2 in Appendix A.

The computer output has been abridged, where it was repetitive in nature, and is reproduced in Figure 4.3 in Appendix A.

4.2 Sample Design Problem (Sample Problem #2)

The geometry for this problem is depicted in Figure 4.4 together with a summary of the soil conditions deduced from the boring log shown in Figure 4.5 and the consolidation test data of Figure 4.6. To account for the smaller initial void ratio and larger coefficients of consolidation near the ground surface, it was decided to introduce a layer interface at a depth of \((H-H')=5.2\) feet, corresponding to LAYER=3.
The design must satisfy the following requirements: (1) No settlements due to primary consolidation must occur after surcharge removal; in addition, some settlements due to secondary compression should be eliminated; (2) the construction time is not to exceed 12 months; and (3) the factor of safety against instability of the embankment-subsoil system must be equal to or greater than 1.15 during construction and 1.25 under the final load.

The input sequence for the soil parameters, the geometry, and the load characteristics follows the input data in Section 3 for program Modified SAND with ISP=0, and the contents of the data cards are listed in Table 4.3 (Appendix A). The final output includes average degrees of consolidation for a point at the center of the embankment and another point close to the embankment toe, and is reproduced in Figure 4.7 (Appendix A).

4.3 Summary and Conclusions

The objectives of this study were (a) to elucidate the practical and theoretical bases for using the controlled rate of construction technique to design a highway embankment underlain by soft ground, and (b) to synthesize presently available procedures in a comprehensive computer program in which special attention is given to the horizontal and vertical drainage, without sand drain installations. An existing program SAND which considers sand drains has been modified for this purpose.
To facilitate the mathematical treatment, the overall problem was conveniently divided into four parts, which deal with (a) the initial increase in excess pore water pressures caused by an increase of the vertical load on the surface of the compressible layer, (b) the process whereby these pore water pressures are dissipated with time, (c) the associated settlements, and (d) the stability of the embankment-foundation system.

Based on the effective stress principle, the stress increases associated with primary consolidation are taken to be equal to the dissipated pore water pressures. The latter are computed by means of Skempton's pore pressure coefficients \( A \) and \( B \) and a solution for the total stresses due to a symmetric vertical load acting on a linearly elastic layer of finite thickness, which, in turn, is underlain by a rough rigid substratum. The dissipation of excess pore water pressures is evaluated by use of a consolidation theory which accounts for horizontal and vertical drainage conditions, anisotropic permeability, time-dependent variations of the soil parameters, and partial saturation. As a result of the increases in effective stresses due to the dissipation of pore water pressures, the strength of the subsoil increases, and this is considered in a stability analysis in terms of total stresses by use of the \( c/p \)-ratio.
It is economically possible to establish a number of design charts, which include (a) excess pore pressure distribution curves, (b) consolidation-time curves, (c) stability charts, (d) graphs of maximum embankment height versus thickness of the compressible layer, and (e) relationships for equivalent uniform strength after complete consolidation versus thickness of the subsoil. However, this is beyond the scope of this report.

Since the computational technique used in the "Modified Sand" remains the same as in the original program sand the following remarks are valid.

A. With regard to the computation of the initial excess pore water pressure distribution, the following conclusions can be drawn:

1. The form of the stress equations requires the numerical integration of oscillating integrands, and convergence of the extended Simpson's rule or Filon's formulae with interval halving depends on the geometry of the problem. Poorest convergence was obtained in cases of heavily oscillating integrands when the ratio of the load width to the thickness of the compressible layer was large.

2. When the pore pressure coefficient B is held constant and equal to unity, the influence of the pore pressure coefficient A increases as the thickness of the compressible layer increases, and the average pore water pressures are larger and extend farther in the horizontal direction when A is larger.
3. As the compressible layer becomes thinner relative to the load width, closer agreement is obtained between the applied vertical load and the resulting average pore pressure distribution.

4. The influence of shear stresses causes some concentration of average pore water pressures near the edges of the load.

B. With regard to the computation of primary consolidation settlements, direct proportionality between the average degree of consolidation and the resulting settlement will occur only when constant coefficients of consolidation and a constant coefficient of compressibility are used.

C. With regard to the stability analyses, the following conclusions can be drawn from a critical comparison of the charts in the report (Krizek and Krugman, 1972):

1. Depending on the geometry of the embankment and the soil parameters of the embankment and the subsoil, the assumption of a circular slip surface will give reliable factors of safety only for sufficiently large subsoil thicknesses.

2. The stabilizing influence of flattening the embankment slope decreases as the thickness of the subsoil increases.
3. The slip circle resulting in a minimum factor of safety generally tends to penetrate the soft subsoil as deep as possible.

4. The factor of safety is not proportional to the height of the embankment, but, given identical soil parameters, it depends on the ratio of the embankment height and the thickness of the compressible layer.

Reference

Fig. 4.1 Contour of the Embankment Configuration for the Sample Problem 1
Figure 4.2 Soil Characteristics of a Sample from Depth of 8 ft below Ground
Table 4.1 Soil Data for the First Sample Problem

<table>
<thead>
<tr>
<th>Soil Parameter</th>
<th>Embankment</th>
<th>Subsoil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit weight (pcf)</td>
<td>125</td>
<td>58.8</td>
</tr>
<tr>
<td>Initial coefficient of permeability (feet/day)</td>
<td></td>
<td>(K_{HO} = 6.26 \times 10^{-3}) (K_{VO} = 3.08 \times 10^{-3})</td>
</tr>
<tr>
<td>Slope of the void ratio versus log coefficient of permeability curve</td>
<td></td>
<td>SKH = 0.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SKV = 0.40</td>
</tr>
<tr>
<td>Initial void ratio, (e_o)</td>
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<td>1.175</td>
</tr>
<tr>
<td>Compression index, (C_C)</td>
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<td>1.18</td>
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<tr>
<td>Skempton's pore pressure coefficients</td>
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<td>(A = 0.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(B = 0.95)</td>
</tr>
<tr>
<td>Degree of saturation, (S)</td>
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<td>(S = 0.98)</td>
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<tr>
<td>Henry's coefficient of gas solubility, (HC)</td>
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<td>70.0,0.0</td>
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Table 4.2 Data Cards for Sample Problem 1
Abridged output for Sample Problem 1

THE PORE WATER PRESSURES ARE COMPUTED AT

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<th>YE/H</th>
<th>0.000</th>
<th>0.100</th>
<th>0.200</th>
<th>0.300</th>
<th>0.400</th>
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<tbody>
<tr>
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<td>0.600</td>
<td>0.700</td>
<td>0.800</td>
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<tr>
<td>YE/H</td>
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<tr>
<td>XT/W</td>
<td>0.000</td>
<td>0.100</td>
<td>0.200</td>
<td>0.300</td>
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<td>0.700</td>
<td>0.900</td>
<td>1.500</td>
<td>1.600</td>
</tr>
</tbody>
</table>

THE SUBSOIL IS DESCRIBED BY THE FOLLOWING PARAMETERS WHICH ARE GIVEN FOR THE UPPER LAYER IN CASE OF STRATIFICATION

TOTAL THICKNESS H = 16.000 FEET
reference for X-COORD W = 100.000 FEET

SKEMPTON PORE PRESSURE COEFFICIENTS ARE
A = 0.50 AND B = 0.95

DEGREE OF SATURATION IS S = 0.980
HENRY'S CONSTANT OF GAS SOLUBILITY HC = 0.200
INITIAL PORE GAS PRESSURE IS PU = 0.2616E+04 PSF

INITIAL VOID RATIO = 1.175

THE COMPRESSION INDEX IS = 0.1180E+01
RECOMPRESSION INDEX/CC ROC = 1.000

INITIAL EFFECTIVE P AND PRECOMPRESSION STRESSES PC AS USED IN THE COMPUTATIONS

<table>
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<th>Y IN FT</th>
<th>P IN PSF</th>
<th>PC IN PSF</th>
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</thead>
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<td>11.200</td>
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<td>12.800</td>
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<tr>
<td>14.400</td>
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<td>846.72</td>
</tr>
<tr>
<td>16.000</td>
<td>940.80</td>
<td>940.80</td>
</tr>
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</table>

NOTE - P(1) AND PC(1) MAY HAVE BEEN CHANGED as compared to input values to avoid over flow

THE INITIAL PERMEABILITIES ARE INVERTICAL DIRN. KVO = 0.3080E-02 FT/DAY
HORIZONTAL DIRN KHO = 0.6250E-02 FT/DAY
THE SLOPES OF THE E Vs LOG(K) - CURVES ARE

| IN VERTICAL DIRN, SKV = 0.400 |
| IN HORI. DIRN, SKH = 0.350 |

THE DRAINAGE CONDITIONS ARE
NO DRAINAGE AT THE BOTTOM

REFERENCE LOAD

SKEMPTON PORE PRESSURE COEFFICIENTS ARE
A = 0.50 AND B = 0.95

THE LOAD CHARACTERISTICS ARE GIVEN BY
THE UNIT WEIGHT GLOAD = 125.00 PCF
THE COHESION, CLOAD = 1000.00 PSF
THICKNESS OF THE DRAINAGE BLANKET YWM = 2.00 FT
THE TANGENT OF THE ANGLE OF INTERNAL
FRICITION TGPHI = 0.0000

MINP = 3 COOR POINTS XINP/YINP

0.00 FEET 5.00 FEET
40.00 FEET 5.00 FEET
70.00 FEET 0.00 FEET

THE ACTUAL LOAD IS APPROXIMATED BY 5 LOADS
OF EQ INTENSITY WHICH EXTEND FROM X=0 TO ALPHA(I)
IF ALPHA(I) IS NEGATIVE, THIS LOAD IS SUBTRACTED

ALPHA( 1) = 67.000 FEET
ALPHA( 2) = 61.000 FEET
ALPHA( 3) = 55.000 FEET
ALPHA( 4) = 49.000 FEET
ALPHA( 5) = 43.000 FEET

THE AVERAGE PORE PRESSURES, UAVER(I)
THE CONSOLIDATION SETTLEMENTS, SETRC(I) AND
THE TOTAL SETTLEMENTS, SETRT(I), AT XT(I) ARE

XT FEET UAVER (PSF) SETRC FT. SETRT FT
0.00 585.99 3.781 3.896
10.00 585.24 3.777 3.892
20.00 581.91 3.761 3.876
30.00 573.86 3.728 3.842
40.00 540.09 3.604 3.715
50.00 410.90 2.975 3.074
70.00 112.84 1.131 1.180
90.00 37.77 0.515 0.539
150.00 2.43 0.037 0.039
160.00 1.52 0.023 0.024

THE NUMBER OF LIFTS IS NL = 2

SINCE ISP=1 TIMES OF LOAD APPLICATION
ARE INPUT TO BE

TL( 1) = 60. DAYS
TL( 2) = 160. DAYS

RESIDUAL PORE PRESSURES ARE IN PUT AS

X (FEET) Y (FEET) UC (PSF)
35.000 4.000 75.000
35.000 15.000 75.000
105.000 8.500 25.000

LOAD NO 1 APPLIED AT TL= 60. DAYS

******************************************************************
SKEMPTON PORE PRESSURE COEFFICIENTS ARE 
A= 0.50 AND B= 0.95

THE LOAD CHARACTERISTICS ARE GIVEN BY 
THE UNIT WEIGHT GLOAD= 125.00 PCF 
THE COHESION , CLOAD= 1000.00 PSF 
THICKNESS OF THE DRAINAGE BLANKET YWM= 2.00 FT 
THE TANGENT OF THE ANGLE OF INTERNAL 
FRICTION TGPHI= 0.0000 
MINP= 4 COOR POINTS XINP/YINP 
0.00 FEET 10.00 FEET 
30.00 FEET 10.00 FEET 
40.00 FEET 5.00 FEET 
70.00 FEET 0.00 FEET 

THE ACTUAL LOAD IS APPROXIMATED BY 10 LOADS 
OF EQ INTENSITY WHICH EXTEND FROM X=0 TO ALPHA(I) 
IF ALPHA(I) IS NEGATIVE, THIS LOAD IS SUBTRACTED 

ALPHA( 1) = 67.000 FEET 
ALPHA( 2) = 61.000 FEET 
ALPHA( 3) = 55.000 FEET 
ALPHA( 4) = 49.000 FEET 
ALPHA( 5) = 43.000 FEET 
ALPHA( 6) = 39.000 FEET 
ALPHA( 7) = 37.000 FEET 
ALPHA( 8) = 35.000 FEET 
ALPHA( 9) = 33.000 FEET 
ALPHA(10) = 31.000 FEET 

T= 0. DAYS X/W 0.000 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW 

0.000 
1217.070 
1220.074 
1223.127 
1226.202 
1229.288 
1232.371 
1235.432 
1238.484 
1241.515 
1244.547

T= 0. DAYS X/W 0.100 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW 

0.000 
1203.986 
1207.619 
1211.390
0.200 PORE PRESSURES IN PSF DUE TO VERT + HORIZ FLOW

<table>
<thead>
<tr>
<th>Time (DAYS X/W)</th>
<th>Pressure (PSF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>1215.356</td>
</tr>
<tr>
<td>1184.936</td>
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<tr>
<td>1185.586</td>
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<tr>
<td>1186.735</td>
<td></td>
</tr>
<tr>
<td>1188.883</td>
<td></td>
</tr>
<tr>
<td>1192.537</td>
<td></td>
</tr>
<tr>
<td>1198.191</td>
<td></td>
</tr>
<tr>
<td>1206.311</td>
<td></td>
</tr>
<tr>
<td>1217.356</td>
<td></td>
</tr>
<tr>
<td>1231.762</td>
<td></td>
</tr>
<tr>
<td>1249.895</td>
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</tbody>
</table>

0.300 PORE PRESSURES IN PSF DUE TO VERT + HORIZ FLOW

<table>
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<th>Time (DAYS X/W)</th>
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0.400 PORE PRESSURES IN PSF DUE TO VERT + HORIZ FLOW

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<tbody>
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**C = 0. DAYS X/W**

0.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

<table>
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<tr>
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<td>565.497</td>
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</table>

**C = 0. DAYS X/W**

0.700 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

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<td>190.481</td>
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<tr>
<td>182.376</td>
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</tbody>
</table>
$T = 0. \text{ DAYS X/W}$  

0.900 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

- 0.000
- 99.416
- 96.627
- 93.800
- 90.903
- 87.904
- 84.783
- 81.525
- 78.128
- 74.598
- 70.955

$T = 0. \text{ DAYS X/W}$  

1.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

- 0.000
- -3.144
- -3.296
- -3.459
- -3.630
- -3.810
- -3.996
- -4.188
- -4.386
- -4.588
- -4.793

$T = 0. \text{ DAYS X/W}$  

1.600 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

- 0.000
- -11.767
- -11.867
- -11.969
- -12.077
- -12.190
- -12.308
- -12.430
- -12.554
- -12.681
- -12.811
T = 7. DAYS X/W  0.000 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
1005.060
1198.883
1221.441
1225.869
1229.022
1232.104
1235.166
1238.208
1241.145
1243.217

T = 7. DAYS X/W  0.100 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
994.349
1186.681
1209.759
1215.080
1219.404
1224.050
1229.243
1235.208
1242.004
1247.581

T = 7. DAYS X/W  0.200 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
977.065
1164.192
1184.553
1188.139
1191.965
1197.717
1205.925
1217.008
1230.826
1242.611
<table>
<thead>
<tr>
<th>T= 7. DAYS X/W</th>
<th>0.300 PORE Pressures in PSF due to Vert + Hori Flo</th>
</tr>
</thead>
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<table>
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<th>T= 7. DAYS X/W</th>
<th>0.400 PORE Pressures in PSF due to Vert + Hori Flo</th>
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<tr>
<td>0.000</td>
<td>577.542</td>
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<tr>
<td></td>
<td>721.089</td>
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<tr>
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<td>757.299</td>
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<tr>
<td></td>
<td>776.237</td>
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<td>803.662</td>
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<td>838.624</td>
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<tr>
<td></td>
<td>846.717</td>
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<table>
<thead>
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<th>T= 7. DAYS X/W</th>
<th>0.500 PORE Pressures in PSF due to Vert + Hori Flo</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>414.049</td>
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<td>535.724</td>
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<td>549.781</td>
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<td>563.843</td>
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<td>565.502</td>
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</table>
### I= 7. DAYS X/W 0.700 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

<table>
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<th>Pressure (PSF)</th>
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<tr>
<td>0.000</td>
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<tr>
<td>150.603</td>
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<tr>
<td>194.164</td>
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<tr>
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<td>207.338</td>
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<td>203.703</td>
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<tr>
<td>198.499</td>
</tr>
<tr>
<td>192.169</td>
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<td>187.244</td>
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</table>

### I= 7. DAYS X/W 0.900 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

<table>
<thead>
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<th>Pressure (PSF)</th>
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<td>78.568</td>
</tr>
<tr>
<td>94.598</td>
</tr>
<tr>
<td>94.130</td>
</tr>
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<td>91.414</td>
</tr>
<tr>
<td>88.405</td>
</tr>
<tr>
<td>85.261</td>
</tr>
<tr>
<td>81.984</td>
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<tr>
<td>78.583</td>
</tr>
<tr>
<td>75.209</td>
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<td>72.924</td>
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</table>

### I= 7. DAYS X/W 1.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

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<thead>
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<tr>
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<tr>
<td>-1.739</td>
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<tr>
<td>-2.227</td>
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<td>-2.388</td>
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<tr>
<td>-2.511</td>
</tr>
<tr>
<td>-2.635</td>
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<tr>
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<tr>
<td>-2.896</td>
</tr>
<tr>
<td>-3.032</td>
</tr>
<tr>
<td>-3.165</td>
</tr>
<tr>
<td>-3.253</td>
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<tr>
<td>T = 7. DAYS X/W</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>0.000</td>
</tr>
<tr>
<td>-11.585</td>
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<tr>
<td>-12.096</td>
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<td>-12.329</td>
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<td>-12.574</td>
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<td>-12.776</td>
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<table>
<thead>
<tr>
<th>T = 49. DAYS X/W</th>
<th>0.000 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>623.692</td>
</tr>
<tr>
<td>1002.445</td>
<td>1160.141</td>
</tr>
<tr>
<td>1210.504</td>
<td>1224.987</td>
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<tr>
<td>1230.310</td>
<td>1233.690</td>
</tr>
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<td>1236.544</td>
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<td>1239.663</td>
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<table>
<thead>
<tr>
<th>T = 49. DAYS X/W</th>
<th>0.100 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>616.674</td>
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<tr>
<td>992.046</td>
<td>1149.208</td>
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<tr>
<td>1200.274</td>
<td>1216.000</td>
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<tr>
<td>1223.013</td>
<td>1228.602</td>
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<td>1234.115</td>
<td>1238.871</td>
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<tr>
<td>1240.950</td>
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</tbody>
</table>
T = 49. DAYS X/W  0.200 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
602.520
968.304
1120.361
1169.126
1184.414
1192.669
1201.194
1211.012
1220.169
1224.311

T = 49. DAYS X/W  0.300 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
555.691
884.480
1011.757
1045.370
1052.045
1056.211
1064.053
1075.741
1087.899
1093.667

T = 49. DAYS X/W  0.400 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
346.340
585.257
709.914
766.264
793.195
809.690
822.583
833.496
841.602
844.765
T= 49. DAYS X/W 0.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
235.913
401.698
489.368
528.088
545.007
554.048
560.212
564.747
567.677
568.711

T= 49. DAYS X/W 0.700 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
86.603
152.094
190.724
208.935
215.348
215.791
213.319
209.699
206.487
205.181

T= 49. DAYS X/W 0.900 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
40.089
69.237
84.641
89.974
89.981
87.780
84.901
82.121
80.055
79.277
T = 49. DAYS X/W  1.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

- 49 -

T = 56. DAYS X/W  0.000 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

T = 56. DAYS X/W  0.100 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW
<table>
<thead>
<tr>
<th>Time (Days)</th>
<th>Pore Pressures (PSF)</th>
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<tr>
<td>0.000</td>
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<td>574.192</td>
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<td>941.276</td>
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<td>1163.418</td>
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<td>1182.176</td>
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<tr>
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<td>1222.076</td>
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<table>
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<th>Time (Days)</th>
<th>Pore Pressures (PSF)</th>
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</thead>
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<tr>
<td>0.000</td>
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<td>528.166</td>
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<td>857.962</td>
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<td>1048.545</td>
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<td>1053.544</td>
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<td>1083.974</td>
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</tr>
<tr>
<td>1089.156</td>
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</tbody>
</table>

Reached end of file

1
0
THE CONSOL. PROCESS

***************
THE FOLLOWING INFORMATION IS OUTPUT
UAVE(X(1)),UAVE(X(2)),
= AVERAGE DEGREES OF CONSOL. WITH RESPECT TO REF. LOAD
SETC(X(1)),SETC(X(2)),
= CONSOL. SETTLEMENTS
SETI(X(1)),SETI(X(2)),
= IMMEDIATE SETTLEMENTS
SETT(X(1)),SETT(X(2)),
= CONSOL. + IMMEDIATE SETTLEMENTS
LAST TWO LINE ARE ONLY OUTPUT
IF SOIL IS PARTIALLY SATURATED (B.NE.1.)
THE POINTS X(I) IN FEET ARE AS FOLLOWS

<table>
<thead>
<tr>
<th>Time (Days)</th>
<th>Points</th>
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<tbody>
<tr>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>0.141</td>
<td>0.141</td>
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<tr>
<td>0.141</td>
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</table>

T = 60. DAYS IS THE TIME OF LOAD APPLICATION

<table>
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<tr>
<td>1.002</td>
<td>0.997</td>
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<tr>
<td>0.141</td>
<td>0.141</td>
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<tr>
<td>1.143</td>
<td>1.138</td>
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</table>

T = 67. DAYS

<table>
<thead>
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<tr>
<td>0.185</td>
<td>0.183</td>
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<tr>
<td>1.204</td>
<td>1.197</td>
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<tr>
<td>0.141</td>
<td>0.141</td>
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<tr>
<td>0.345</td>
<td>1.338</td>
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</table>

T = 74. DAYS

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<td>0.321</td>
<td>0.319</td>
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<td>1.857</td>
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<tr>
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<td>0.141</td>
</tr>
<tr>
<td>0.007</td>
<td>1.998</td>
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</table>

T = 130. DAYS
AVE DEGREE OF CONSOL. AND SETTLEMENT CURVES FOR POINT X = 0.00 FEET FROM CENTER LINE INTERVAL BETWEEN 2 GRID LINES = 0.10
ABSCISSA NUMBERS GIVE THE TIME IN WKS THE TOTAL SETTL DUE TO REFERENCE LOAD IS = 0.390E+01 FT
U - CUREV = AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD C - CUREV = CONSOL. SETTL. IN % OF REF. SETTLEMENT O - CUREV = IMMEDIATE SETTLEMENTS IN % OF THE REFERENCE SETTLEMENTS T - CUREV = TOTAL SETTLEMENTS IN % OF THE REFERENCE SETTLEMENT

Fig. 4.3(a)

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4

AVE DEGREE OF CONSOL. AND SETTLEMENT CURVES FOR POINT X = 10.00 FEET FROM CENTER LINE INTERVAL BETWEEN 2 GRID LINES = 0.10
ABSCISSA NUMBERS GIVE THE TIME IN WKS THE TOTAL SETTL DUE TO REFERENCE LOAD IS = 0.389E+01 FT
U - CUREV = AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD C - CUREV = CONSOL. SETTL. IN % OF REF. SETTLEMENT O - CUREV = IMMEDIATE SETTLEMENTS IN % OF THE REFERENCE SETTLEMENTS T - CUREV = TOTAL SETTLEMENTS IN % OF THE REFERENCE SETTLEMENT
Fig. 4.3(b)

Ave degree of consol. and settlement curves for point x = 30.00 feet from center line

Interval between 2 grid lines = 0.10

Abscissa numbers give the time in wks

The total settl due to reference load is = 0.38E+01 ft

U - Curev = Ave. degree of consol.

Relative to the pore press due to ref. load

C - Curve = Consol. settl. in % of ref. settlement

O - Curve = Immediate settlements in % of

The reference settlements

T - Curve = Total settlements in % of

The reference settlement

4.3(c)

Ave degree of consol. and settlement curves for point x = 30.00 feet from center line

Interval between 2 grid lines = 0.10

Abscissa numbers give the time in wks

The total settl due to reference load is = 0.38E+01 ft

U - Curev = Ave. degree of consol.

Relative to the pore press due to ref. load

C - Curve = Consol. settl. in % of ref. settlement

O - Curve = Immediate settlements in % of

The reference settlements

T - Curve = Total settlements in % of

The reference settlement
AVE DEGREE OF CONSOL. AND SETTLEMENT CURVES FOR POINT X = 40.00 FEET FROM CENTER LINE INTERVAL BETWEEN 2 GRID LINES. EQ. 10%
ABSCISSA NUMBERS GIVE THE TIME IN WKS THE TOTAL SETTL DUE TO REFERENCE LOAD IS = 0.372E+01 FT
U - CURVE = AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD
C - CURVE = CONSOL. SETTL. IN % OF REF. SETTLEMENT
O - CURVE = IMMEDIATE SETTLEMENTS IN % OF THE REFERENCE SETTLEMENTS
T - CURVE = TOTAL SETTLEMENTS IN % OF THE REFERENCE SETTLEMENT

Fig. 4.3(d)

AVE DEGREE OF CONSOL. AND SETTLEMENT CURVES FOR POINT X = 70.00 FEET FROM CENTER LINE INTERVAL BETWEEN 2 GRID LINES. EQ. 10%
ABSCISSA NUMBERS GIVE THE TIME IN WKS THE TOTAL SETTL DUE TO REFERENCE LOAD IS = 0.118E+01 FT
U - CURVE = AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD
C - CURVE = CONSOL. SETTL. IN % OF REF. SETTLEMENT
O - Curve = Immediate settlements in % of the reference settlements
T - Curve = Total settlements in % of the reference settlement

Fig. 4.3(e)

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5

AVE DEGREE OF CONSOL. AND SETTLEMENT CURVES FOR POINT X = 90.00FEET FROM CENTER LINE
INTERVAL BETWEEN 2 GRID LINES.EQ.10%
ABSCISSA NUMBERS GIVE THE TIME IN WKS
THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.539E+00FT
U - CURVE= AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD
C - CURVE= CONSOL. SETTLE. IN % OF REF. SETTLEMENT
O - CURVE= IMMEDIATE SETTLEMENTS IN % OF
THE REFERENCE SETTLEMENTS
T - CURVE= TOTAL SETTLEMENTS IN % OF
THE REFERENCE SETTLEMENT

g. 4.3(f)

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Figure 4.4 Cross-Section and Idealized Soil Condition of the Second Sample Problem
Borings 39 ST, 40 ST, VS 13, Route FAI 255, Section 22-8 HB, Station 267.00

<table>
<thead>
<tr>
<th>Description</th>
<th>Depth</th>
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</thead>
<tbody>
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<tr>
<td>organic alluvial clay</td>
<td>2</td>
</tr>
<tr>
<td>Gray alluvial clay</td>
<td>10</td>
</tr>
<tr>
<td>Blue, gray wet fine sand</td>
<td>15</td>
</tr>
</tbody>
</table>

Water content as decimal fraction, shear strength in ksf, unit weight in ksf

Figure 4.6 Boring Log
Table 4.3 Data Card for Sample Problem 2 (Cont'd on next page)
3,1,0,1
1.15,0.00,0.8,360.,4.0,1.0,64.0,40.,0.0
5,6
5,6,0
0.0,10.2
35.0,10.2
78.2,3.0
81.2,3.0
93.2,0.0
0
6,10,0
0.0,15.2
22.,15.2
35.,10.2
78.2,3.0
81.2,3.0
93.2,0.0
1.15,1.2,0.8,0.,57.5,40.,0.
5,6,0
0.0,10.2
35.0,10.2
78.2,3.0
81.2,3.0
93.2,0.0
1.25,0.,0.8,.,0,64.,40.,0.
Abridged output for Sample Problem 2

THE PORE WATER PRESSURES ARE COMPUTED AT

<table>
<thead>
<tr>
<th>YE/H</th>
<th>0.000</th>
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<th>0.200</th>
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<tr>
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<td>0.600</td>
<td>0.700</td>
<td>0.800</td>
<td>0.900</td>
</tr>
<tr>
<td>YE/H</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XT/W</td>
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<td>0.578</td>
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THE PORE PRESSURES ARE INTERPOLATED AT

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<th>0.200</th>
<th>0.300</th>
<th>0.400</th>
</tr>
</thead>
<tbody>
<tr>
<td>XE/W=</td>
<td>0.500</td>
<td>0.600</td>
<td>0.700</td>
<td>0.800</td>
<td>0.900</td>
</tr>
<tr>
<td>XE/W=</td>
<td>1.000</td>
<td>1.100</td>
<td>1.200</td>
<td>1.300</td>
<td>1.400</td>
</tr>
<tr>
<td>XE/W=</td>
<td>1.500</td>
<td>1.600</td>
<td>1.700</td>
<td>1.800</td>
<td>1.900</td>
</tr>
<tr>
<td>XE/W=</td>
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<td>2.100</td>
<td>2.200</td>
<td>2.300</td>
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<td>2.600</td>
<td>2.700</td>
<td>2.800</td>
<td>2.900</td>
</tr>
<tr>
<td>XE/W=</td>
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</table>

ASSUMING COLLOCATION POLYNOMIALS OF DEGREE
2 BETWEEN THE LIMITS 0.000 AND 0.300
4 BETWEEN THE LIMITS 0.300 AND 0.650
3 BETWEEN THE LIMITS 0.650 AND 1.300
2 BETWEEN THE LIMITS 1.300 AND 3.000

THE SUBSOIL IS DESCRIBED BY THE FOLLOWING PARAMETERS WHICH ARE GIVEN FOR THE UPPER LAYER IN CASE OF STRATIFICATION

TOTAL THICKNESS H= 26.000 FEET
reference for X-COORD W = 100.000 FEET

LAYER INTERFACE IS 7.800 FT BELOW SURFACE
LOWER/UPPER PERMEABILITY, RK= 0.769
LOWER/UPPER COEF. OF CONSOLIDATION, RC= 0.500
LOWER/UPPER INITIAL VOID RATIO, REO= 1.318
LOWER/UPPER COMPRESSION INDEX, RCC= 1.867
LOWER RECOMPRESSION/UPPER RECOMPRESSION-INDEX ROC= 0.107

SKEMPTON PORE PRESSURE COEFFICIENTS ARE
A= 0.50 AND B= 1.00

INITIAL VOID RATIO = 2.050

THE COMPRESSION INDEX IS = 0.7500E+00
RECOMPRESSION INDEX/CC ROC= 0.200
INITIAL EFFECTIVE P AND PRECOMPRESSION
STRESSES PB AS USED IN THE COMPUTATIONS

<table>
<thead>
<tr>
<th>Y in FT</th>
<th>P in PSF</th>
<th>PC in PSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>104.00</td>
<td>1000.00</td>
</tr>
<tr>
<td>2.600</td>
<td>104.00</td>
<td>1000.00</td>
</tr>
<tr>
<td>5.200</td>
<td>208.00</td>
<td>1000.00</td>
</tr>
<tr>
<td>7.800</td>
<td>286.00</td>
<td>1000.00</td>
</tr>
<tr>
<td>10.400</td>
<td>364.00</td>
<td>864.00</td>
</tr>
<tr>
<td>13.000</td>
<td>442.00</td>
<td>680.00</td>
</tr>
<tr>
<td>15.600</td>
<td>520.00</td>
<td>520.00</td>
</tr>
<tr>
<td>18.200</td>
<td>598.00</td>
<td>598.00</td>
</tr>
<tr>
<td>20.800</td>
<td>676.00</td>
<td>676.00</td>
</tr>
<tr>
<td>23.400</td>
<td>754.00</td>
<td>754.00</td>
</tr>
<tr>
<td>26.000</td>
<td>858.00</td>
<td>858.00</td>
</tr>
</tbody>
</table>

NOTE - PB(1) AND PC(1) MAY HAVE BEEN CHANGED
as compared to input values to avoid overflow

COEFF CONSL-VERT FLOW IS CV = 0.2000E-01 FT**2/DAY
COEF OF CONSL-HORI FLOW IS CH = 0.3000E-01 FT**2/DAY

THE DRAINAGE CONDITIONS ARE
FREE DRAINAGE AT THE BOTTOM

THE SHEAR STRENGTH CHARACTERISTICS OF
THE SUB SOIL AS USED IN THE STABILITY ANALYSIS ARE

<table>
<thead>
<tr>
<th>DEPTH IN FEET</th>
<th>COHESION IN PSF</th>
<th>P-RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>280.000</td>
<td>0.100</td>
</tr>
<tr>
<td>2.600</td>
<td>220.000</td>
<td>0.100</td>
</tr>
<tr>
<td>5.200</td>
<td>150.000</td>
<td>0.150</td>
</tr>
<tr>
<td>7.800</td>
<td>150.000</td>
<td>0.150</td>
</tr>
<tr>
<td>10.400</td>
<td>150.000</td>
<td>0.150</td>
</tr>
<tr>
<td>13.000</td>
<td>150.000</td>
<td>0.150</td>
</tr>
<tr>
<td>15.600</td>
<td>150.000</td>
<td>0.150</td>
</tr>
<tr>
<td>18.200</td>
<td>150.000</td>
<td>0.150</td>
</tr>
<tr>
<td>20.800</td>
<td>210.000</td>
<td>0.150</td>
</tr>
<tr>
<td>23.400</td>
<td>360.000</td>
<td>0.100</td>
</tr>
<tr>
<td>26.000</td>
<td>310.000</td>
<td>0.100</td>
</tr>
</tbody>
</table>

REFERENCE LOAD
**************

SKEMPTON PORE PRESSURE COEFFICIENTS ARE
A = 0.50 AND B = 1.00

THE LOAD CHARACTERISTICS ARE GIVEN BY
THE UNIT WEIGHT GLOAD = 125.00 PCF
THE COHESION CLOAD = 1000.00 PSF
THICKNESS OF THE DRAINAGE BLANKET YWM = 3.00 FT
THE TANGENT OF THE ANGLE OF INTERNAL
FRICTION TGPHI = 0.5770
MINP = 5 COOR POINTS XINP/YINP

<table>
<thead>
<tr>
<th>0.00 FEET</th>
<th>10.20 FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.00 FEET</td>
<td>10.20 FEET</td>
</tr>
<tr>
<td>78.20 FEET</td>
<td>3.00 FEET</td>
</tr>
<tr>
<td>81.20 FEET</td>
<td>3.00 FEET</td>
</tr>
<tr>
<td>93.20 FEET</td>
<td>0.00 FEET</td>
</tr>
</tbody>
</table>

THE ACTUAL LOAD IS APPROXIMATED BY 6 LOADS
OF EQ INTENSITY WHICH EXTEND FROM X=0 TO ALPHA(I)
IF ALPHA(I) IS NEGATIVE, THIS LOAD IS SUBTRACTED

\[
\begin{align*}
\text{ALPHA(1)} &= 89.800 \text{ FEET} \\
\text{ALPHA(2)} &= 82.200 \text{ FEET} \\
\text{ALPHA(3)} &= 70.700 \text{ FEET} \\
\text{ALPHA(4)} &= 60.500 \text{ FEET} \\
\text{ALPHA(5)} &= 50.300 \text{ FEET} \\
\text{ALPHA(6)} &= 40.100 \text{ FEET} \\
\end{align*}
\]

THE AVERAGE PORE PressURES, UAVER(I)
THE CONSOLIDATION SETTLEMENTS, SETRC(I) AND
THE TOTAL SETTLEMENTS, SETRT(I), AT XT(I) ARE

\[
\begin{array}{cccc}
\text{XT FEET} & \text{UAVER (PSF)} & \text{SETRC FT.} & \text{SETRT FT} \\
2.01 & 1221.99 & 3.401 & 3.401 \\
15.00 & 1220.05 & 3.396 & 3.396 \\
27.99 & 1199.55 & 3.347 & 3.347 \\
30.86 & 1188.66 & 3.321 & 3.321 \\
37.21 & 1146.45 & 3.218 & 3.218 \\
47.50 & 1001.05 & 2.855 & 2.855 \\
57.79 & 831.05 & 2.403 & 2.403 \\
64.14 & 708.77 & 2.094 & 2.094 \\
67.47 & 658.25 & 1.960 & 1.960 \\
85.06 & 361.09 & 1.175 & 1.175 \\
109.94 & 118.93 & 0.421 & 0.421 \\
127.53 & 71.97 & 0.262 & 0.262 \\
141.39 & 49.53 & 0.187 & 0.187 \\
215.00 & 6.15 & 0.025 & 0.025 \\
288.61 & 0.76 & 0.003 & 0.003 \\
\end{array}
\]

THE NUMBER OF LIFTS IS NL= 3

THE AVAILABLE CONSTRUCTION TIME IS TA= 360. DAYS. TA IS NOT NEEDED IF NL=1
PARAMETERS USED IN THE STABILITY ANALYSIS
DMAX= 4.000  DMIN= 1.000  
NARC= 5NRAD= 6
DMAX, DMIN ARE THE MAX AND MIN STEP SIZES
USED IN THE SEARCH PROCEDURE
NARC=ONE= HALF THE NUMBER OF SUB ARCS
NRAD=NUMBEROF RADI  USED FOR EACH TRIAL CENTER
OF ARCS
THE FACTOR OF SAFETY AT TIME T= 0.
DAYS FOR LIFT 1 IS FS= 1.221
AS COMPARED TO THE REQ. FSI= 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X= 66.00 Y= 41.00 RADIUS= 61.80 IN FT

LOAD NO 1 APPLIED AT TL= 0.DAYS
*****************************************************
SKEMPTON PORE PRESSURE COEFFICIENTS ARE
A= 0.50 AND B= 1.00

THE LOAD CHARACTERISTICS ARE GIVEN BY
THE UNIT WEIGHT GLOAD= 125.00 PCF
THE COHESION , CLOAD= 1000.00 PSF
THICKNESS OF THE DRAINAGE BLANKET YWM= 3.00 FT
THE TANGENT OF THE ANGLE OF INTERNAL
THE REQUIRED SAFETY FACTOR IS FSI = 1.150
THE SPECIFIED PORTION OF SETLEMENT IS EQUAL TO 0.000
IF 95% OF THE AVE PORE PRESSURE
AT THE TIME OF APPLICATION OF THIS LOAD
HAVE DISSIPATED AT 0.8000*15POINTS XT
THIS LIFT IS ASSUMED TO BE THE LAST ONE

THE FACTOR OF SAFETY AT TIME T = 0.
DAYS FOR LIFT 1 WAS .GE.FS = 1.221
AS COMPARED TO THE REQU. FSI = 1.150

THE FACTOR OF SAFETY AT TIME T = 7.
DAYS FOR LIFT 2 IS FS = 1.036
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 14.
DAYS FOR LIFT 2 IS FS = 1.036
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 21.
DAYS FOR LIFT 2 IS FS = 1.037
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 28.
DAYS FOR LIFT 2 IS FS = 1.037
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 35.
DAYS FOR LIFT 2 IS FS = 1.038
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 42.
DAYS FOR LIFT 2 IS FS = 1.038
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 49.
DAYS FOR LIFT 2 IS FS = 1.039
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 56.
DAYS FOR LIFT 2 IS FS = 1.039 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 70.

DAYS FOR LIFT 2 IS FS = 1.040 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 84.

DAYS FOR LIFT 2 IS FS = 1.041 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 43.00 RADIUS = 62.97 IN FT
THE FACTOR OF SAFETY AT TIME T = 98.

DAYS FOR LIFT 2 IS FS = 1.042 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 112.

DAYS FOR LIFT 2 IS FS = 1.044 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 126.

DAYS FOR LIFT 2 IS FS = 1.045 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 140.

DAYS FOR LIFT 2 IS FS = 1.046 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 154.

DAYS FOR LIFT 2 IS FS = 1.047 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 168.

DAYS FOR LIFT 2 IS FS = 1.048 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 182.

DAYS FOR LIFT 2 IS FS = 1.050 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 200.

DAYS FOR LIFT 2 IS FS = 1.052 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 216.

DAYS FOR LIFT 2 IS FS = 1.054 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 232.

DAYS FOR LIFT 2 IS FS = 1.056 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 248.

DAYS FOR LIFT 2 IS FS = 1.058 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 264.

DAYS FOR LIFT 2 IS FS = 1.060 AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 280.
DAYS FOR LIFT 2 IS FS = 1.054
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 308.
DAYS FOR LIFT 2 IS FS = 1.055
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 336.
DAYS FOR LIFT 2 IS FS = 1.057
AS COMPARED TO THE REQU. FSI = 1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X = 57.50 Y = 44.00 RADIUS = 63.42 IN FT
THE FACTOR OF SAFETY AT TIME T = 364.

EITHER THE FACTOR OF SAFETY, FS = 1.059
AND/OR THE SETTLEMENT, SETC(1) = 0.751 FEET
ARE LESS THAN SPECIFIED AT TIME T = 364 DAYS
WHICH IS GREATER THAN TA = 360 DAYS
*** THIS LIFT NO 1 IS, THEREFORE
CONSIDERED TO BE THE LAST ONE***

THE CONSOL. PROCESS
*************************

THE FOLLOWING INFORMATION IS OUT PUT
UAVE(X(1)), UAVE(X(2)), ........,
= AVER DEGREES OF CONSOL. WITH RESPECT TP REF. LOAD
SETC(X(1)), SETC(X(2)), ........,
= CONSOL. SETTLEMENTS
SETI(X(1)), SETI(X(2)), ........,
= IMMEDIATE SETTLEMENTS
SETT(X(1)), SETT(X(2)), ........,
= CONSOLI. + IMMEDIATE SETTLEMENTS
LAST TWO LINE ARE ONLY OUT PUT
IF SOIL IS PARTIALLY SATURATED (B.NE.1.)
THE POINTS X(I) IN FEET ARE AS Follows

0.000 80.000

T = 0.
DAYS IS THE TIME OF LOAD APPLICATION

T = 0. DAYS
T = 7. DAYS

0.087 0.072
0.361 0.154

T = 14. DAYS

0.091 0.075
0.377 0.160

T = 21. DAYS

0.095 0.078
0.392 0.167

T = 28. DAYS

0.098 0.081
0.405 0.172

T = 35. DAYS

0.102 0.084
0.418 0.178

T = 42. DAYS

0.106 0.087
0.430 0.183

T = 49. DAYS

0.109 0.090
0.441 0.188

T = 56. DAYS

0.112 0.092
0.452 0.193
\begin{tabular}{lll}
\textbf{T} & \textbf{DAYS} & \\
0.119 & 0.098 & \\
0.472 & 0.202 & \\

\textbf{T} & \textbf{84. DAYS} & \\
0.125 & 0.103 & \\
0.490 & 0.210 & \\

\textbf{T} & \textbf{98. DAYS} & \\
0.131 & 0.108 & \\
0.508 & 0.219 & \\

\textbf{T} & \textbf{112. DAYS} & \\
0.137 & 0.112 & \\
0.525 & 0.226 & \\

\textbf{T} & \textbf{126. DAYS} & \\
0.143 & 0.117 & \\
0.541 & 0.234 & \\

\textbf{T} & \textbf{140. DAYS} & \\
0.148 & 0.121 & \\
0.557 & 0.241 & \\

\textbf{T} & \textbf{154. DAYS} & \\
0.153 & 0.125 & \\
0.571 & 0.248 & \\

\textbf{T} & \textbf{168. DAYS} & \\
0.159 & 0.129 & \\
0.586 & 0.254 & \\

\textbf{T} & \textbf{196. DAYS} & \\
0.168 & 0.137 & \\
\end{tabular}
0.613 0.267

T = 224. DAYS

0.177 0.145
0.639 0.278

T = 252. DAYS

0.186 0.152
0.663 0.289

T = 280. DAYS

0.194 0.158
0.686 0.300

T = 308. DAYS

0.202 0.165
0.709 0.310

T = 336. DAYS

0.210 0.171
0.730 0.319

T = 364. DAYS

0.217 0.177
0.751 0.328

T = 392. DAYS

0.224 0.182
0.771 0.337

T = 448. DAYS

0.237 0.193
0.808 0.354

T = 504. DAYS
T = 560. DAYS

T = 616. DAYS

T = 672. DAYS

T = 728. DAYS

AVE DEGREE OF CONSOL. AND SETTLEMENT CURVES FOR POINT X = 0.00FEET FROM CENTER LINE INTERVAL BETWEEN 2 GRID LINES.EQ.10% ABSCISSA NUMBERS GIVE THE TIME IN WKS THE TOTAL SETTL DUE TO REFERENCE LOAD IS = 0.340E+01FT U - CURVE= AVE. DEGREE OF CONSOL. RELATIVE TO THE PORE PRESS DUE TO REF LOAD C - CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT

g. 4.7(a)

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5

**I****I****I****I****I****I****I****I****I****I****I****I****I****I****I****I****
AVE DEGREE OF CONSOL. AND SETTLEMENT
CURVES FOR POINT X = 80.00 FEET FROM CENTER LINE
INTERVAL BETWEEN 2 GRID LINES EQ. 10%
ABSCISSA NUMBERS GIVE THE TIME IN WKS
THE TOTAL SETTLE DUE TO REFERENCE LOAD IS = 0.144E+01 FT
U - CURVE = AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD
C - CURVE = CONSOL. SETTLE. IN % OF REF. SETTLEMENT
3. 4.7(b)

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5

I*****I*****I*****I*****I*****I*****I*****I*****I*****I*****I*****

U C
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I, the SOFT HH CV RE RK RO I WOMECA(40) CCC THESE specified PORE, I N SKMG Y, (UB(1) EL ME O PU B. WHICH THE DISSIPATES I HF D, CLOAD Y WM ROCL SIMULTANEOUS, I I IS SHEAR 5) TA CH P CH N XT, S ASSUMED THE AA V AKOUNT AA 12 C I ACT MH I PU) O NED(40) I NRAD 1) AN STRESSES 4 P SHEARING RC) PC) THE IN I 1

Specify THE SOIL A THEO OF THE RESI DIME THIS CORRESPONDING INDU EMBANKMENT.****************************************************************

*************************************************************************FORT1 INVOLVES INPUT*

*************************************************************************FORT2 CAN

*******************************************************************************NSIO 560. STAN R EFFE

*******************************************************************************EMBANKMENT.

*******************************************************************************the INPUTFILE

*******************************************************************************the OUTPUTFILE FORT2

*******************************************************************************are giving A SIMULTANEOUS INCREASE IN SHEARING RESISTANCE. SETTLEMENTS ARE COMPUTED FROM THE DISSIPATED PORE

*******************************************************************************the THEORY OF ELASTICITY AND SKEMPTON-PORE PRESSURE PARAMETERS A AND B. THESE PORE PRESSURES DISSIPATE ACCORDING TO THREE

*******************************************************************************THE EFFECT OF GAS AND VARIABLE SOIL PARAMETERS. AS THE PORE

*******************************************************************************THE DISSIPATION OF THESE PORE PRESSURES, THE CORRESPONDING INCREASE IN SHEAR RESISTANCE AND THE STABILITY OF THE EMBANKMENT.

*******************************************************************************THE EMBANKMENT LOAD WHICH IS ASSUMED TO ACT VERTICALLY,

*******************************************************************************INDUCES PORE Pressures in the subsOIL WHICH ARE Computed USING

*******************************************************************************DIMENSION T(150)

*******************************************************************************DIMENSION TB(50), TL(10), UA(220), UB(220), UC(220), UD(220), UAVE(20)

*******************************************************************************DIMENSION UAVER(20), XE(51), XME(660), XMT(100), XINP(20), XRP(20)

*******************************************************************************DIMENSION YE(11), YNP(20), YRP(20), RSP(100), UAVED(20)

*******************************************************************************DIMENSION SETR(20), SETI(20), SETRT(20), SPECS(10), SPECU(10)

*******************************************************************************EQUIVALENCE (UA(1), XME(1)), (UB(1), XME(221))

*******************************************************************************EQUIVALENCE (UC(1), XME(441)), (UD(1), XMT(1))

*******************************************************************************COMMON/ SAPOD/ IOUTP,W,HH,GLOAD,LOAD,NARC,NRAD

*******************************************************************************COMMON/ SADI1/ LAYER,IBC V,HHE,M,N,IDC,NDR,ISUH,XET(41)

*******************************************************************************COMMON/ SADI2/ FIMPV,R C,RK,C,RO,RE,T A,ISP,IVAR

*******************************************************************************COMMON/ SACSE/ ROC,ROCL,SVM,P,PC,PLOG,PO,PCO,IAV,IK,ISAT,AAV,AA

*******************************************************************************COMMON/ SAC01/ AVOC,KVO,KHO,EOPUS,PU,SKHM,SKVM,C C,NNN,ICOEF

*******************************************************************************COMMON/ SAC02/ PCV(10),CVIN(10),FCH(10),CHIN(10),ICV,KOUNT,HH

*******************************************************************************COMMON/ SADET/ XSTAB(51),YSTAB(11),DX,DY,YWM,TGPHI

*******************************************************************************DATA (TB(I),I=1,45)/

*******************************************************************************Specify the INPUTFILE and OUTPUTFILE Names.
INPUT=3
IOUTP=4

C
WRITE (*,1132)
FORMAT (‘---Specify the Name of your INPUTFILE’) READ (*,1133)INPUTFILE
WRITE (*,1134)
FORMAT (‘---Specify the Name of the OUTPUTFILE’) READ (*,1133)OUTPUTFILE

C
FORMAT (a50)
OPEN (UNIT=3,FILE=INPUTFILE,STATUS=‘OLD’)
REWIND (3)
OPEN (UNIT=4,FILE=OUTPUTFILE,STATUS=‘NEW’,FORM=‘FORMATTED’)
REWIND (4)
WRITE (*,1131)
FORMAT (‘Specify the No. of Symbols to be used in the plot’) C
The Following symbols are proposed for the user to input.
C Blank = a Blank Space
C STAR = *
C GRID = 1
C SYMB (1) = U --For Ave. Deg. of Consolidation.
C - 2 = C --For Consol. Settlement.
C 3 = O --For Imm.
C 4 = T --For Total
READ (*,*) MMM
WRITE (*,1130)
FORMAT (‘Specify Characters=Blank,STAR,GRID,(SYMB(I),1,MMM)’) READ (*,194)BLANK,STAR,GRID,(SYMB(I),1=1,MMM)

C DETERMINATION OF MESH POINTS FOR FINITE DIFFERENCE SCHEME AND
C STABILITY ANALYSIS.
C MYE.LE.12,MHE.LE.40: Number of vertical and horizontal points
C in the finite difference scheme. HF=1.-for horizontal flow
C POR=Horizontal drainage distance/(XT(IEND)*W).
C POR-the distance to the zero pore pressure in H dirn from
C the center line. Put IPOR=1 (if POR is input by the user).
C Put POR=1.0 and IPOR=0 then the program will determine POR
C
999 READ (INPUT,*))MYE,MHE,ITBL,ISP,HF,POR,IPOR
IF (ITBL.LE.0) ITBL=45
IF (ITBL.GT.45) ITBL=45

C MMM Total no. of SYMB (Symbols) to be used in the output
C IF (ISP.EQ.1) GOTO 9001
C Read no. of points for which output is required, if ISP=0.
C If ISP=1 (special points), output the data for points XT.
read (INPUT,*)) JND
read (INPUT,*)) (JSP(K),K=1,JND)
C LND = No. of lines to be printed.
C (i.e No. of weeks on the time axis in the output)
9001 continue
READ (INPUT,*))LND

C GENERATE THE MATHEMATICAL MOLECULE FOR SIMPSONS OR TRAPEZOIDAL
C RULE IN VERTICAL DIRECTION.
C CALL GENS (SV,MYE)
C GENERATE VECTOR YE
C
MT=MYE-1
D=MT
D=1./D
DO 11 I=1,MT
AI=I-1
11 YE(I)=AI*D
YE(MYE)=1.
IF (ISP.EQ.1) GOTO 1

READ NUMBERS OF EQUIDISTANT POINTS, MX, IN X-DIRECTION, NUMBER
OF INTERVALS, NI, AND INTERVAL LIMITS AX(I), I=1,NI.
 THESE LIMITS ARE DIMENSIONLESS. TO GET THE CORRESPONDING VALUES
IN FEET, THE AX(I) ARE MULTIPLIED BY THE REFERENCE VALUE W WHICH
IS INPUT LATER.

READ (INPUT,*)) MX,NI
NIM=NI-1
READ (INPUT,*)) (AX(I),I=1,NI)

READ NUMBER OF UNEQUALLY SPACED POINTS IN EACH INTERVAL, MXT(I),
GENERATE THE POINTS XT, IF ISP=0

READ (INPUT,*)) (MXT(I),I=1,NIM)
IEND=0

GENERATE XT-S

DO 21 J=1,NIM
MT=MXT(J)
ISTT=IEND+1
IEND=IEND+MT
D=2*MT
AS=AX(J+1)+AX(J)
AD=AX(J+1)-AX(J)
DO 22 I=ISTT,IEND
AI=2*(IEND-I)+1
22 XT(I)=(AD*COS(AI*3.14159265358979/D)+AS)/2.
21 CONTINUE
GOTO 2

READ SPECIAL POINTS IF ISP=1
IEND must be at least 6 and 4 points be directly under the main
embankment.
1 READ (INPUT,*))IEND
READ (INPUT,*)) (XT(I),I=1,IEND)
GOTO 42

Generate equidistant points in x-dirn including the limits
AX(1) and AX(NI). Determine the number of XE-s in each interval
MXE(I). If the left limit of the I-th interval coincides with
an XE(K), the limit is considered in MXE(I).

2 MT=1
J=2
MM=MX-1
D=MM
D=(AX(NI)-AX(1))/D
XE(1)=AX(1)
DO 23 I=2,MM
XE(I) = XE(I-1) + D
IF (XE(I).LT.(AX(J)-0.001)) GO TO 23
MXE(J-1) = I-MT
MT = I
J = J + 1
23 CONTINUE
XE(MX) = AX(NI)
MXE(J-1) = MX+1-MT
C
C INITIATE THE DETERMINATION OF MATRICES XMT, XME AND R
C
IEND = 0
JEND = 0
IRND = 0
DO 41 J = 1, NIM
C GENERATE MATRIX XMT FROM XT-S AND INVERT XMT
C
ISTT = IEND + 1
IEND = IEND + MXT(J)
PAGE 4
CALL MATR (ISTT, IEND, MXT(J), XT, AX(J), XMT)
CALL MINV (XMT, MXT(J), DETER)
C
C Generate matrix XME from XE-s
C
JSTT = JEND + 1
JEND = JEND + MXE(J)
CALL MATR (JSTT, JEND, MXT(J), XE, AX(J), XME)
C Post multiply the inverse of matrix XMT, which is stored in
C array XMT, by matrix XME, and store the result in matrix R
C starting with element R(IRST).
C
IRST = IRND + 1
IRND = IRND + MXT(J)*MXE(J)
CALL MPRD (XMT, XME, R, MXT(J), MXT(J), MXE(J), 1, 1, IRST)
41 CONTINUE
42 A1END = IEND
C
C NOTE THAT THE LAST VALUE OF IEND IS EQUAL TO THE TOTAL
C NUMBER OF XT-S.
C
C INPUT DATA FOR A SPECIFIC CASE.
C ************************************************************
C
C Read thickness of soil layer, H, Unit weight of the embankment
C load, GLOAD, Undrained strength of the embankment material CLOAD,
C Reference length in H-dirn, W, Thickness of the drainage blanket,
C YWM, Tangent of angle of internal friction, TGPHI.
C If H=0.0 the program is terminated.
C
100 READ (INPUT,*) H, CLOAD, CLOAD, W, YWM, TGPHI
   IF (H.EQ.0.) GOTO 10000
   IF (H.EQ.99.) GOTO 999
   HH = H
C
C IDC=1 vertical flow only in all XT-s
C IDC=2 vertical + horizontal flow.
C
IDC = 2
IF (HF.EQ.0.) IDC=1
C DETERMINE INCREMENTS IN VERTICAL AND HORIZONTAL DIR
C -ECTION, DY AND DHX
45 DY=MYE-1
   DY=H/DY
   DYSQ=DY*DY
C
C Read drainage identifier IBCV
C IBCV=1 Impeded drainage at Y=H,
C IBCV=2 Free drainage at Y=H,
C IBCV=3 No drainage at Y=H
C Read location of interface in case of inhomogeneous soil,
C 4.LE.LAYER.LE.MYE-3
C
READ (INPUT,*)IBCV,LAYER
N=MHE-1
M=MYE-2
IF (IBCV.EQ.3) M=MYE-1
IF (IBCV.EQ.2) FIMPV=0.
IF (IBCV.GT.1) GO TO 4
C
C Read thickness of impedance layer,HI,and ratio of permeabilities,
C RKV=K(draining soil,vertical)/K(impedence layer,vertical)
C
READ (INPUT,*!)HI,RKV
   CHIV=RKV*HI/DY
   FIMPV=CHIV/(1.+CHIV)
4   IF (HF .EQ. 0.) GO TO 7
C Determine the horizontal grid point to be used in the finite
C difference scheme.
C
   AI=MHE-1
   DHX=POR*XT(IEND)*W/II
I   IA=II
   DO 25 I=1,IAI
XET(I)=POR*(I-1)*XT(IEND)/II
25 CONTINUE
   DXSQ=DHX*DHX
C Check for layer interface. Read ratio of permeabilities, RK=
C K(lower)/K(upper), and ratio of coeff. of consolidation, RC=
C CV(lower)/CV(upper),REO=EO(lower)/EO(upper)=Ratio of initial
C void ratios, RAV=AVO(lower)/AVO(upper)=Ratio of coeff. of
C compress., RCC=(cc(lower layer)/cc(upper layer)=Ratio of
C compression indices. ROCL=cc(recompression,lower)/cc(upper)
C
7   IF (LAYER .LT. 3) GOTO 6
   READ (INPUT,*!)RK,RC,REO,RAV,RCC,ROCL
   IF (LAYER .GT. (MYE-3)) LAYER=0
C
C Read identifiers and parameters for the compressible layer
C IVAR=0 Const. soil parameters in the consolidation process.
C IVAR=1 Variable soil parameter in the consolidation process.
C ISAT=0 100% saturation.
C ISAT=1 Partial saturation.
C IAV=0 Const. coeff. of compressibility.
C IAV=1 Variable coeff. of compressibility.
C ICV=0 Vectors of coeff of consolidation are not input.
C ICV.GT.0 Vectors of coeff. of consol. are input. Variable
C CV and CH are obtained in subroutine COEFF by
C interpolation.
IK = 0  Const. coeff. of permeability.
IK = 1  Variable coeff. of permeability.

E0  Initial void ratio.
KVO  Initial vertical permeability.
KHO  Initial horizontal permeability.
AVO  Initial coeff. of compressibility.
A, B  Skempton Pore pressure coefficients.

CC  Compression index of the virgin part of the E vs LOG(P) curve.
ROC  (Recompression index)/CC in case of consolidation.

Gamma  Buoyant unit weight for computing initial eff. stress.
P(I)  Initial effective stresses.
PC(I)  Precompression stresses.
CV, CH  Vertical and Horizontal coeff. of consol.
S  Degree of saturation.
PU  Initial Gas pressure.
SKV, SKH  Slopes of the void ratio vs LOG(permeability) curve.

READ (INPUT,*) IVAR, IAV, ICV
IF (ICV .NE. 0) IVAR = 1
READ (INPUT,*) E0, A
ALPHG = 1.
B = 1.
IF (IAV .EQ. 1) GOTO 350
READ (INPUT,*) AVO
GOTO 563

C Read cc, ROC and GAMMA. If GAMMA .NE. 0., Initial eff stresses, P,
c are computed and normal consol. is assumed. If GAMM = 0., initial
c and precompression stresses are input.

350 READ (INPUT,*) CC, ROC, GAMMA
IF (GAMMA .EQ. 0.) GOTO 561

C Initial eff. stresses are computed. PO and PCO are averages

AD = DY * GAMMA
P(I) = AD
PC(I) = AD
PL0G(I) = 0.
PO = GAMMA * H/2.
PCO = PO
AI = 0.
DO 565 I = 2, MYE
AI = AI + AD
P(I) = AI
PC(I) = AI
PL0G(I) = 0.
565 CONTINUE
GOTO 563

C Initial eff. and precompression stresses are input.

561 READ (INPUT,*) P(I), PC(I)
PO = SV(1) * P(I)
PCO = SV(1) * PC(I)
DO 562 I = 2, MYE
READ (INPUT,*) P(I), PC(I)
PO = PO + SV(I) * P(I)
PCO=PCO+SV(I)*PC(I)
PLOG(I)= ALOG(PC(I)/P(I))

CONTINUE
IF (P(1) .EQ. 0.) P(1)=P(2)
IF (PC(I) .EQ. 0.) PC(I)=PC(2)
PLOG(I)= ALOG(PC(I)/P(I))

C If constant parameters are to be used in the cosol. process
C read CV, CH, AVO. If variable parameters are to be used, IF IVAR=1
C read necessary coeffs.

IF (IVAR .EQ. 1) GOTO 564
READ (INPUT,*) CV, CH
GOTO 30

IF (ICV .EQ. 0) GOTO 572
DO 573 I=1,ICV
READ (INPUT,*) PCV(I), CVIN(I), PCH(I), CHIN(I)
GOTO 574

READ (INPUT,*) KVO, KHO
IF (IAV .EQ. 1) GOTO 566
AVOC=AVO
PC0=PC0

READ (INPUT,*) ISAT, IK
IF (ISAT .EQ. 0) GOTO 567
READ (INPUT,*) S, PU, HC, B
EOPS=EO*PU*(1.-S*(1.-HC))

IF (IK .EQ. 1) GOTO 567
READ (INPUT,*) SKV, SKH
CONTINUE

C Read NC initial shear strengths CO(I) and C/PBAR-ratios
C at arbitrary depths Y(I). if NC.EQ.MYE, the depths are
C assumed to be equal to H*YE(I). IF NC.LE.MYE the values
C of CO(J) and PC(J) at H*YE(J) are obtained by interpolation.
C The input values are not saved.

IF (ISP .EQ. 1) GOTO 585
READ (INPUT,*) NC
DO 580 I=1,NC
READ (INPUT,*) Y, UA(I), UB(I)

YRP(I)=Y/H
IF (NC .EQ. MYE) GOTO 581
CALL LAGR (YE, CO, MYE, 1, YRP, UA, NC)
CALL LAGR (YE, CP, MYE, 1, YRP, UB, NC)
GOTO 582

DO 583 I=1,MYE
CO(I)=UA(I)
CP(I)=UB(I)

C Define the vectors XSTAB and YSTAB which are needed in the
C stability analysis.

DO 584 I=1, MX
XSTAB(I)=W*XE(I)
DX=XSTAB(2)-XSTAB(1)

DO 586 I=1, MYE
YSTAB(I)=H*YE(I)
CONTINUE

C
C OUTPUT OF DATA INPUT SO FAR. FOR FORMAT STATEMENTS
C SEE END OF PROGRAM
C *********************************************************

WRITE (IOUTP,901)
WRITE (IOUTP,900)
WRITE (IOUTP,903)
WRITE (IOUTP,900)
WRITE (IOUTP,904)
WRITE (IOUTP,902)
WRITE (IOUTP,905) (YE(I),I=1,MYE)
WRITE (IOUTP,902)
WRITE (IOUTP,906) (XT(I),I=1,IEND)
WRITE (IOUTP,902)
IF (ISP.EQ.1) GOTO 53
WRITE (IOUTP,907)
WRITE (IOUTP,902)
WRITE (IOUTP,908) (XE(I),I=1,MX)
WRITE (IOUTP,909)
DO 51 I=1,NIM
MM=MXT(I)-1
51 WRITE (IOUTP,910) MM,AX(I),AX(I+1)
WRITE (IOUTP,902)
53 WRITE (IOUTP,901)
WRITE (IOUTP,902)
WRITE (IOUTP,913)
WRITE (IOUTP,914) H,W
WRITE (IOUTP,902)
IF (LAYER.LT.3) GOTO 54
AI=YE(LAYER)*H
WRITE (IOUTP,915) AI,RK,RC,REO
IF (IAV. EQ.0) GOTO 551
WRITE (IOUTP,715) RCC,ROCL
GOTO 552
551 WRITE (IOUTP,815) RAV
552 WRITE (IOUTP,902)
54 WRITE (IOUTP,916) A,B
IF ((1.-B).LT.0.00001) GOTO 55
WRITE (IOUTP,917) S,HC,PU
WRITE (IOUTP,902)
55 WRITE (IOUTP,918) EO
WRITE (IOUTP,902)
IF (IAV.EQ.1) GO TO 553
WRITE (IOUTP,818) AVO
WRITE (IOUTP,902)
GOTO 554
553 WRITE (IOUTP,919) CC,ROC
WRITE (IOUTP,819)
DO 555 I=1,MYE
AI=YE(I)*H
WRITE (IOUTP,719) AI,P(I),PC(I)
555 CONTINUE
WRITE (IOUTP,619)
WRITE (IOUTP,902)
554 IF (IVAR.EQ.1) GOTO 556
WRITE (IOUTP,934) CV,CH
GOTO 57
556 IF (ICV.EQ.0) GOTO 575
WRITE (IOUTP,820)
DO 536 J=I,ICV
WRITE (IOUTP, 720) PCV(I), CVIN(I), PCH(I), CHIN(I)
GOTO 57
WRITE (IOUTP, 920) KV0, KHO
IF (IK.EQ.1) WRITE (IOUTP, 921) SKV, SKH
WRITE (IOUTP, 902)
WRITE (IOUTP, 922)
IF (IBCV.NE.1) GOTO 61
WRITE (IOUTP, 926) HI, RKV
GOTO 64
IF (IBCV.EQ.3) GOTO 63
WRITE (IOUTP, 927)
GOTO 64
WRITE (IOUTP, 928)

WRITE (IOUTP, 902)
IF (ISP.EQ.1) GOTO 587
WRITE (IOUTP, 961)
DO 588 I=1, MYE
WRITE (IOUTP, 962) YSTAB(I), CO(I), CP(I)
WRITE (IOUTP, 900)

Define the modified molecules SVM in vertical direction.
Redefine ROCL to be the ratio of the Recompression index of the lower layer and the compression index of the virgin part of the lower layer.
Redefine also the parameters KKK, KIAV, NNN, FUP, FLO, SKVM, SKHM CCC, AAV, AAH and ICOEFF, which are needed in subroutines SETL and COEFF.
Redefine also PCV, PCH, CVIN, CHIN in case that ICV.NE.0

AI=1.+EO
AAV=AI/(62.42796*DSQ)
IF (HF.EQ.0.) GOTO 521
AAH=AI/(62.42796*DXSQ)

KKK=MYE
KIAV=IAV+1
NNN=1
AD=H
IF (LAYER.GE.3) GOTO 524
DO 523 I=1, MYE
SVM(I)=SV(I)
GOTO 522

CALL GENS(SVM, KKK)
MM=MYE-LAYER+1
CALL GENS(UA, MM)
II=LAYER
DO 525 I=1, MM
II=II+1
SVM(II)=UA(I)
AS=1.+EO*REO
IF (RCC.NE.0.) ROCL=ROCL/RCC
AD=H*YE(LAYER)

ICOEF=1
IF (IK.EQ.1) ICOEF=2+IAV
IF (ICV.EQ.0) GOTO 530
ICOEF=4
DO 529 I=1, ICV
PCV(I)=ALOG(PCV(I))
CVIN(I)=CVIN(I)/DSQ
IF (HF.EQ.0.) GOTO 529
PCH(I)=ALOG(PCH(I))
CHIN(I)=CHIN(I)/DXSQ
CONTINUE
529 IF (IAV.EQ.1) GOTO 527

C Coeff. of compressibility is const (IAV=0)
FUP=AD*AVO/AI
IF (LAYER.GE.3) FLO=(H-AD)*AVO*RAV/AS
IF (IK.EQ.0) GOTO 520
SKVM=2.302585*AVO/SKV
IF (HF.EQ.0.) GOTO 520
SKHM=2.302585*AVO/SKH
GOTO 520

C Variable coeff. of compressibility IAV=1.
527 CCC=0.4342945*CC
AVOC=CCC/PCO
IF (PCO.GT.PO) AVOC=AVOC*(PCO/PO)**ROC
FUP=AD*CCC/AI
IF (LAYER.GE.3) FLO=(H-AD)*CCC*RCC/AS
IF (IK.EQ.0) GOTO 520
SKVM=CC/SKV
IF (HF.GT.0.) SKHM=CC/SKH

CREFERENCE LOAD.
*********************************************************
CRead characteristics of the reference load.
CXINP,YINP -the coordinates of the polygon which describes
Cthe load.
CMINP- The no. of points.
CNS- The no. of strips by which the actual load is approximated.
520 READ (INPUT,*),MINP,NS
WRITE (IOUTP,935)
WRITE (IOUTP,916),A,B
WRITE (IOUTP,930),GLOAD,CLOAD,YWM,TGPHI,MINP
DO 101 I=1,MINP
READ (INPUT,*),XINP(I),YINP(I)
101 WRITE (IOUTP,931),XINP(I),YINP(I)

CCompute the pore water pressures at (XT(I),I=1,IEND)/YE(J),J=1,MYE)
CALL PORE (XINP,YINP,MINP,NS,XT,IEND,YE,MYE,UB,A,B)

Cdetermine the horizontal distance from the Center line to the point
Cwhere the pore pressure is 0.1% of the max pore pressure under the
Cembankment. This is taken as a free drainage end.
CALL HDIST (UB,XT,IEND,ICV,CHIN,DXSQ,AAH,MHE,W,XET,IPOR,
* HF,MYE,POR)
IPOR=1

CCompute the average pore pressures UAVER(I),I=1,IEND for the
Creference load. Determine final consolidation settlements,SETREC(I),
C Immediate settlements, SETRI(I), and Total settlements (SETRT(I)),
C I=1, IEND for the reference load.
C
II=0
DO 501 I=1, IEND
UAVER(I)=0.
DO 102 J=1, MYE
II=II+1
UU(II)=UB(II)
102 UAVER(I)=UAVER(I)+UB(II)*SV(J)
CONTINUE

CALL SETL (UB, SETRC, IEND, KKK, MYE, I., FUP, FLO, KIAV)
IF (B.NE.1.) GOTO 513
DO 514 I=1, IEND
SETRT(I)=SETRC(I)
514 SETRI(I)=0.
GOTO 515
513 FAC=1./B
CALL SETL (UB, SETRT, IEND, KKK, MYE, FAC, FUP, FLO, KIAV)

C Define initial parameters.
C TL(LIFT) Time of LIFT-th load application.
C TB(ITB) Time from TL(LIFT) till TL(LIFT+1) given in DATA
C statement.
C Y(IT) Time from first load application, T(IT)=TL(LIFT) + TB(ITB)
C
WRITE (IOUTP, 932)
DO 71 I=1, IEND
AI=W*XT(I)
WRITE(IOUTP, 933) AI, UAVER(I), SETRC(I), SETRT(I)
CONTINUE

WRITE (IOUTP, 900)
ISUM=MYE*IEND
LIFT=1
LL=LIFT+1
ITB=1
IT=1
TL(I)=0.
TB(I)=0.
T(I)=0.

C Read no. of lifts, NL. If computation for special points is required
C (ISP=1), read also NL times of load application, TL.
C NLS is defined for checking purposes at the end of the program
C IDEN(I).LT.0, Pore pressures due to the first load are set
equal zero.
C IDEN(I)=0, , I=1, NL pore pressures due to the I-th load are computed
C by means of subroutine PORE.
C IDEN(I)=1, I=1, NL Pore pressures due to the I-th load are
C set equal to those due to the REFERENCE load.
C
READ (INPUT,*) NL, (IDEN(I), I=1, NL)
NLS=NL
WRITE (IOUTP, 936) NL
WRITE (IOUTP, 902)
IF (ISP.EQ.0) GOTO 103
READ (INPUT,*) (TL(I), I=1, NL)
WRITE (IOUTP, 937)
DO 106 I=1,NL
106 WRITE (IOUTP,938) I,TL(I)
      WRITE (IOUTP,902)
      T(I)=TL(I)+TB(I)
      GOTO 105
   
C C FIRST LOAD.
C ***************************************** 
C Read characteristics of the first load, also
C TA Available construction time.
C SPECS Specified settlement for the first lift.
C SPECU When the NOT DISSIPATED average pore pressures
C become less than 5% of the total average pore pressure
C at the time of load application at IEND*SPECU points,
C the subsequent loads are disregarded.
C FSI Factor of safety for the first lift.
C DMAX Max. interval used in the search for the minimum FS
C DMIN Corresponding minimum interval.
C ZZ Distance between the maximum YINP and the minimum
C permissible YC during the search procedure.
C NARC One-half the no. of subarcs used in subroutine DETFS
C NRAD No. of trial arcs used at each center YC,YC
C IAB=0 Use A and B as defined earlier.
C IAB.NE.0 Read new values of A and B.
C 103 READ (INPUT,*) FSI,SPECS(1),SPECU(1),TA,DMAX,DMIN,XC,YC,ZZ
      READ (INPUT,*) NARC,NRAD
      IF (DMAX.GT.DMIN) GOTO 401
      DMAX=H/2.
      DMIN=H/20.
401 WRITE (IOUTP,940) TA
      WRITE (IOUTP,840) DMAX,DMIN,NARC,NRAD
105 READ (INPUT,*) MINP,NS,IAB
DO 506 I=1,MINP
506 READ (INPUT,*)XINP(I),YINP(I)
      IF (IAB.NE.0) READ (INPUT,*) A,B
      IF (ISP.EQ.1) GOTO 107
C C CALL SUBROUTINES FOR STABILITY ANALYSIS
C CALL INIT (XINP,YINP,MINP,XC,YC,YY,ZZ,DMIN)
CALL GAIN (UA,R,SU,MYE,MXT,MXE,MX,NIM,CO,CP,1)
CALL STAB (XC,YC,RR,XINP,YINP,MINP,MX,MYE,SU,FS,DMAX,DMIN,YY)
DO 570 I=1,ISUM
570 UA(I)=0.
C WRITE (IOUTP,942) T(IT),LIFT,FS,FSI
WRITE (IOUTP,842) XC,YC,RR
IF (FS.GE.FSI) GOTO 107
WRITE (IOUTP,943)
C C Since Branching to the input of a new case might result in the
C reading of the following load characteristics instead of the
C data for a new run, the program is terminated here.
C GOTO 10000
107 WRITE (IOUTP,902)
C C RESIDUAL PORE PRESSURES
C Read index IRP and, for IRP .NE. 0 residual pore pressures.
C
C IRP=0  No residual pore pressures.
C IRP=1  Residual pore pressures at XT/YE are input.
C IRP=2  Residual pore pressures at points other than XY/YE are input.
C
READ (INPUT,*) IRP
   IF (IRP-1) 109,110,111
C
C NO RESIDUAL PORE PRESSURES
C
109  DO 112 J=1,ISUM
112   UC(J)=0.
   GO TO 108
C
C Residual pore pressures at points XT/YE. Input is columnwise with each input card containing ten values
C
110  READ (INPUT,*) (UC(I),I=1,ISUM)
    WRITE (IOUTP,944) (YE(J),J=1,MYE)
    II=1-MYE
    IJ=0
    DO 113 I=1,IEND
    II=II+MYE
    IJ=IJ+MYE
113  WRITE (IOUTP,945) I,XT(I),(UC(J),J=11,IJ)
   GOTO 108
C
C Residual pore pressures at points other than XT/YE. Residual pore pressures at XT/YE are obtained by interpolation. The input values are not saved.
C
111  WRITE (IOUTP,946)
    I=1
    J=1
    READ (INPUT,*) X,Y,UA(1),COUNT
    WRITE (IOUTP,947) X,Y,UA(1)
    XRP(I)=X/W
    YRP(I)=Y/H
    IF (COUNT.EQ.0.) GOTO 115
    DO 114 J=1,ISUM
114   UC(J)=UA(1)
    GO TO 108
115  READ (INPUT,*) X,Y,U,COUNT
    WRITE (IOUTP,947) X,Y,U
    X=X/W
    Y=Y/H
    IF (ABS(X-XRP(I)).LT.0.00001) GOTO 116
    IJ=(I-1)*MYE+1
C
CALL LAGR (YE,UC,MYE,IJ,YRP,UA,J)
    I=I+1
    XRP(I)=X
    J=0
116   J=J+1
    YRP(J)=Y
```
UA(J)=U
IF (COUNT.EQ.0.) GO TO 115
IJ=(I-1)*MYE+1
CALL LAGR (YE,UC,MYE,IJ,YRP,UA,J)
IJ=1-IEND
DO 117 JJ=1,MYE
II=JJ-MYE
IJ=IJ+IEND
DO 118 J=1,1
II=II+MYE
UA(J)=UC(IJ)
117 CALL LAGR (XT,UD,IEND,IJ,XRP,UA,I)
IJ=0
DO 119 JJ=1,IEND
II=JJ-IEND
DO 119 J=1,MYE
IJ=IJ+1
II=II+IEND
UC(IJ)=UD(IJ)
119 CONTINUE
C C Write load characteristics and compute average pore pressure and
C immediate settlements. rewind tape 1 fore storage purposes.
C
108 REWIND 1
C
WRITE (IOUTP,900)
WRITE (IOUTP,939) LIFT,TL(LIFT)
WRITE (IOUTP,916) A,B
WRITE (IOUTP,930) GLOAD,CLOAD,YWM,TGPHI,MINP
DO 120 I=1,MINP
120 WRITE (IOUTP,931) XINP(I),YINP(I)
WRITE (IOUTP,902)
C
IF (IDEN(1)) 73,74,516
74 IDEN(1)=MINP
73 CALL PORE (XINP,YINP,IDEN(1),NS,XT,IEND,YE,MYE,UB,A,B)
IF (HF.EQ.0.) GOTO 516
IF (IPOR.EQ.1) GOTO 516
C
C Find the horizontal distance to the point where the pore pressure is
C 0.1% of the maximum pore pressure under the embankment. This is
C considered as the drainage end in the hori direction.
CALL HDIST (UB,XT,IEND,ICV,CHIN,DXSQ,AAH,MHE,W,XET,IPOR,
* HF,MYE,POR)
516 IF (ISP.EQ.1) GO TO 510
WRITE (IOUTP,941) FS,I,SPECS(LIFT),SPECU(LIFT),IEND
WRITE (IOUTP,960) TL(LIFT),LIFT,FS,FSI
WRITE (IOUTP,902)
C C Compute Immediate settlements, SETI, if B.NE.1 compute
C pore pressures UAUED from UB, if IRP=0 or from UB+UC,
C if IRP.NE.0, write information on tape 1.
C
510 IF (B.NE.1.) GO TO 402
DO 403 I=1,IEND
403 SETI(I)=0.
GO TO 405
402 CALL SETL (UB,SETC,IEND,KKK,MYE,1.,FUP,FLO,KIAV)
AI=1./B
```
CALL SETL (UB,SETT,IEND,KKK,MYE,Al,FUP,FLO,KIAV)
DO 404 I=1,IEND  
404 SETI(I)=SETT(I)-SETC(I)
405 II=0  
DO 121 I=1,IEND  
SETC(I)=0.  
SETT(I)=SETI(I)
UAVE(I)=0.
UAUED(I)=0.
UAVEM(I)=0.
WRITE (1) SETI(I),SETC(I),SETT(I),UAVE(I)
DO 122 J=1,MYE  
II=II+1  
UD(II)=UB(II)+UC(II)
UAVED(I)=UAVED(I)+UD(II)*SV(J)
UM(II)=UB(II)/B+UC(II)
UAVEM(I)=UAVEM(I)+UM(II)*SV(J)
UC(II)=UB(II)
122 UB(II)=UD(II)
121 CONTINUE
C Determine soil parameters in a form suitable for the subroutine
C DISP. Only one OMEGA- and ONE PHI- element for the case of
C constant soil parameters and full saturation.
C
C if (IEND.GT.5) goto 1241
CALL LAGR (XET,UE,N,1,XT,UAVEM,IEND)
CALL LAGR (XET,UF,N,1,XT,UAVED,IEND)
go to 1242
1241 call LINT (XET,UE,N,N,XT,UAVEM,IEND)
call LINT (XET,UF,N,N,XT,UAVE,IEND)
1242 IF (IVAR.NE.0) GO TO 124
PHI(I)=CV/DYSQ
OMEGA(1)=0.
IF (HF.GT.0.) OMEGA(1)=CH/DXSQ
GOTO 123
124 KOUNT=1
CALL COEF (UAVEM,UAVED,OMEGA,PHI,1,1,OMED,PHID,IEND)
IF (HF.EQ.0.) GO TO 125
CALL COEF (UE,UF,OMEGA,PHI,1,2,OMED,PHID,N)
125 KOUNT=0
C
C CONDITIONS IN THE CONSOLIDATION PROCESS.
C
123 CALL DISP (UB,5,OMEGA,PHI,0.,UAVE,1,MYE,IEND,XT,SV)
C
C SECOND OR FOLLOWING LOAD
C******************************************************
C
C Read characteristics of next load depending on the value of
C LIFT+1.
C Define the index ISTAB.
C ISTAB=0 Determine the factor of safety.
C ISTAB=1 NO stability analysis. ISTAB is set equal to 1 if
C pore pressures at special points are to be computed
C ISP=1
C FSI=secified factor of safety for the LL-th load distribution.
C SPECS= specified fraction of the consolidation settlement.
C SPECU-- if an average degree of consol. of 0.95 due to the
lift-th load is obtained at SPECU(LIFT)*IEND points XT without
a sufficient factor of safety for the LL-th load the LIFT-th
load is taken to be the last load and NL is set NL=LIFT.
TMIN first stability analysis for the LL-th load will be
done.
for TD.GE.TMIN days after application of the LIFT-th load.
XC,YC = coord of the center of the first trial arc.
If IAB.NE.0 new pore pressure parameters A and B are input.

128   IF (LL.GT.NL) GOTO 129
130   READ (INPUT,*) XINP(I),YINP(I)
      IF (IAB.NE.0) READ (INPUT,*) A,B
      ISTAB=ISP
      IF (ISP.EQ.1) GO TO 518
518   TSTEP=TL(LL)-TL(LIFT)
129   ITB=ITB+1
      IF (ITB.GT.ITBL) GO TO 200

Compute pore pressures at time T(IT). Determine variable soil
parameters. Compute consol. settlements. Perform stability
analysis.

TD=TB(ITB)
IT=IT+1
131   T(IT)=T(TL)+TD
      CALL DISP (UB,2,OMEGA,PHI,TD,UAVE,LIFT,MYE,IEND,XT,SV)

Vector UB contains the pore pressures at time T(IT). Vector UVAE
contains the average pore pressures as computed from UB.
Vector UA contains the dissipated pore pressures up to time T(IT).

IF (IVAR.EQ.0) GO TO 232
      CALL LAGR (XET,UF,N,1,XT,UAVE,IEND)
go to 2322
2322  CALL LINT (XET,UF,N,N,XT,UAVE,IEND)
2321  CALL COEF (UAVEM,UAVE,OMEGA,PHI,3,1,OMED,PHID,IEND)
      CALL COEF (UE,UF,OMEGA,PHI,3,2,OMED,PHID,N)
      CALL DISP (UB,3,OMED,PHID,TD,UAVE,LIFT,MYE,IEND,XT,SV)
232   IF (LL.GT.NL) GOTO 133
231   IF (ISTAB.EQ.1) GOTO 133
      DO 72 J=1,ISUM
          UA(J)=UM(J)-UB(J)
72  CONTINUE
      CALL STAB (XET,RR,XINP,YINP,MNP,MX,MYE,SU,FS,DMAX,DMIN,YY)
      IF (FS.LT.FSI) GOTO 75
      ISTAB=1
      WRITE (IOUTP,902)
      WRITE (IOUTP,942) T(IT),LL,FS,FSI
      WRITE (IOUTP,842) XC,YC,RR
C Compute settlements and average degrees of consolidation.
C Count at how many points XT the degree of consolidation as
C compared to the pore pressures at the time of the last load
C application is greater than 95%.
C
133 UCHEK=0.
132 DO 134 J=1,ISUM
   UA(J)=UD(J)-UB(J)
   CONTINUE
   CALL SETL (UA,SETC,IEND,KKK,MYE,,FUP,FLO,KIAV)
   DO 134 I=1,IEND
   SETT(I)=SETI(I)+SETC(I)
   IF (UAVE(I).LT.(0.05*UAVED(I))) UCHEK=UCHEK+1.
   UAVE(I)=(UAVED(I)-UAVE(I))/UAVER(I)
   WRITE (1) SETI(I),SETC(I),SETT(I),UAVE(I)
134 CONTINUE
C
C In the following checks are made for the no. of lift, whether
C the FS is sufficient for the next lift, whether a specified amount
C of settlement at point XT(1) has already occured, whether the
C available construction time TA has been passed, and whether an
C average degree of consol. relative to the pore pressures at the time
C of load application of 95% has been reached at .GE.SPECU(LIFT)*IEND
C points XT
C
135 IF (LIFT.EQ.NL) GOTO 129
134 IF (ISP.EQ.0) GO TO 135
133 IF (TD.EQ.TSTEP) go to 137
132 GO TO 129
135 IF (ISTAB.EQ.0) GO TO 138
134 IF (SETC(1).GT.SPECS(LIFT)*SETRC(1)) GO TO 137
133 IF (T(IT).GT.TA) GO TO 139
132 IF (UCHEK.LT.AIEND*SPECU(LIFT)) GO TO 129
131 NL=LIFT
   III=UCHEK+0.1
130 WRITE (IOUTP,948) III,IEND,TL(LIFT),LIFT
   GO TO 129
C
139 NL=LIFT
This page is left blank intentionally.
WRITE (IOUTP, 949) FS, SETC(I), T(IT), TA, LIFT
GO TO 129

C

137 LIFT=LL
LL=LIFT+1
ITB=1
TL(LIFT)=T(IT)
IT=IT+1
T(IT)=TL(LIFT)
WRITE (IOUTP, 900)
WRITE (IOUTP, 939) LIFT, TL(LIFT)
WRITE (IOUTP, 916) A, B
WRITE (IOUTP, 930) GLOAD, CLOAD, YWM, TGPHI, MINP
DO 140 I=1, MINP
140 WRITE (IOUTP, 931) XINP(I), YINP(I)
WRITE (IOUTP, 902)

C compute pore pressures due to new load. Compute imm. settlements,
C SETI, if B.NE.1. Note that the consol. settlements, SETC and the
C ave. degree of consol are the same as computed at time
C T(IT-1)=TL(LIFT).

C Note pore pressures due to the load addition are neglected in
C the computation of imm. settlements. Since zero swelling is
C assumed, negative pore pressures after load application are
C set equal to zero. This means that negative pore pressures due
C to load removal are considered only in a magnitude equal to
C the not dissipated pore pressures just before load removal.

C

IF (IDEN(LIFT).EQ.0) GO TO 76
DO 77 I=1, ISUM
UA(I)=UU(I)
77 CONTINUE
GO TO 78
76 CALL PORE (XINP, YINP, MINP, NS, XT, IEND, YE, MYE, UA, A, B)
78 IF (ISP.EQ.1) GO TO 511
WRITE (IOUTP, 941) FSI, SPECS(LIFT), SPECU(LIFT), IEND
WRITE (IOUTP, 960) TL(LIFT), LIFT, FS, FSI
WRITE (IOUTP, 902)
511 IF ((1.-B).LT.0.00001) goto 143
CALL SETL (UA, SETRI, IEND, KKK, MYE, 1., FUP, FLO, KIAV)
AI=1./B
CALL SETL (UA, SETT, IEND, KKK, MYE, AI, FUP, FLO, KIAV)
do 141 I=1, IEND
SETR(I)=SETR(I)-SETR(I)
IF (SETR(I).GT. SETI(I)) SETI(I)=SETR(I)
SETR(I)=SETR(I)+SETC(I)
141 CONTINUE

C

143 II=0
DO 144 I=1, IEND
WRITE (1) SETI(I), SETC(I), SETT(I), UAVE(I)
UAVE(I)=0.
UAVED(I)=0.
UAVEM(I)=0.
DO 144 J=1, MYE
II=II+1
UT=UB(II)+UA(I)-UC(II)
IF (UT.LT.0.) UT=0.
UAVE(I)=UAVE(I)+UT*SV(J)
UB(II) = UT-UB(II)
UC(II) = UA(II)
UD(II) = UD(II) + UB(II)
UAVED(I) = UAVED(I) + UD(II) * SV(J)
UM(II) = UD(II) + (1/B-1) * UA(II)
UAVEM(I) = UAVED(I) + UM(II) * SV(J)

CONTINUE
LLL = LIFT-1
CALL DISP (UB, 3, OMEGA, PHI, TD, UAVE, LLL, MYE, IEND, XT, SV)
IF (IVAR, EQ. 0) GO TO 244
IF (IEND, GT. 5) goto 1444
CALL LAGR (XET, UF, N, 1, XT, UAVE, IEND)
CALL LAGR (XET, UE, N, 1, XT, UAVEM, IEND)
goto 1445
CALL LINT (XET, UF, N, N, XT, UAVE, IEND)
call LINT (XET, UE, N, N, XT, UAVEM, IEND)
call COEF (UAVED, UAVE, OMEGA, PHI, 1, 1, OMED, PHID, IEND)
call COEF (UE, UF, OMEGA, PHI, 1, 2, OMED, PHID, N)
call DISP (UB, I, OMEGA, PHI, 0, , UAVE, LIFT, MYE, IEND, XT, SV)
go TO 128

REWIND 1
write (IDOTP, 5013)
format ('Reached end of file')
REWIND 2

OUTPUT OF RESULTS
******************************************************************************
Write title for output of results of the consol. process.

WRITE (IDOTP, 901)
WRITE (IDOTP, 950)
IF (ISP, EQ. 1) GO TO 217
DO 218 I=1, JND
K = JSP(I)
218 XRP(I) = W * XE(K)

Determine indices MXS(I), I=1,NIM and matrix RSP which is a sub
matrix of matrix R. Matrix RSP is needed when interpolation between
points XT is done to get the information required at points XRP/W.

IRE = 0
IRS = 0
K = 1
MMM = MXE(1)
MT = MXT(1)
DO 210 JJ = 1, NIM
10 MXS(JJ) = 0

JJ = 1
DO 211 I = 1, MX
IF (JSP(K), EQ. I) GO TO 214
DO TO 215
DO 212 J = 1, MT
IRS = IRS + 1
IRE = IRE + 1
2 RSP(IRS) = R(IRE)
C

MXS(JJ)=MXS(JJ)+1
IF (K.EQ.JND) GOTO 213
K=K+1
215 IF (MMM.NE.I) GO TO 211
JJ=JJ+1
MT=MXT(JJ)
MMM=MMM+MXE(JJ)
211 CONTINUE
C

C CASE THAT ISP=1
C

217 JND=IEND
DO 219 I=1,JND
219 XRP(I)=W*XT(I)
C

213 WRITE (IDOUTP,951) (XRP(I),I=1,JND)
WRITE (IDOUTP,900)
DO 250 I=1,JND
250 XRP(I)=XRP(I)/W
C

MMM=2
IF (B.NE.1.) MMM=4
MT=MMM*JND
C

C Read UAVE, SETC and SETT, given at points XT from TAPE 1. If
C ISP=1, this is the information to be output. If ISP=0,
C perform interpolation using matrix RSP. Output the
C information and store it on TAPE 2 for later plots for times
C T(J), J=1,IT. Use UA and UB for temporary storage.
C

DO 220 J=1,IT
II=1
DO 221 I=1,IEND
READ (1) AI,UA(II+1),AA,UA(II)
IF ((1.-B).LT.0.00001) GOTO 224
UA(II+2)=AI
UA(II+3)=AA
224 II=II+MMM
221 CONTINUE
IF (ISP.EQ.1) GO TO 225
C

C Interpolation for points XRP(I)/W by means of matrix multi-
C plication. Information for points XT is in UA. Interpolation
C for points XRP(I)/W is stored in UB
C

IUBE=0
IUND=0
IRND=0
DO 216 JJ=1,NIM
IUBS=IUBE+1
IUBE=IUBE+MMM*MXT(JJ)
IF (MXS(JJ).EQ.0) GO TO 216
IUST=IUND+1
IUND=IUND+MMM*MXS(JJ)
IRST=IRND+1
IRND=IRND+MXT(JJ)*MXS(JJ)
CALL MPRD (UA,RSP,UB,MMM,MXT(JJ),MXS(JJ),IUBS,IRST,IUST)
CONTINUE  
GO TO 226

DEFINE UB FOR CASE OF ISP=1

DO 222 I=1,MT
UB(I)=UA(I)

IF (J.EQ.1) GO TO 227
IF (T(J).NE.T(J-1)) GO TO 228
WRITE (IOUTP,952) T(J)
WRITE (IOUTP,953) T(J)

DO 223 K=1,MMM
WRITE (IOUTP,951) (UB(I), I=K, MT, MMM)

CONTINUE
WRITE (2) (UB(I), I=1,MT)

CONTINUE

REWIND 1
REWIND 2

PLOTTING ROUTINE
***************************************************************************************

KEND=T(IT)/7.+1.001
IF (LND.GT.KEND) LND=KEND

Compute the reference settlement for points XRP from total settlements SETRT at points XT.

IF(ISP.EQ.0) GO TO 297
DO 298 I=1, IEND
SETR(I)=SETRT(I)
GO TO 299

IUBE=0
IUND=0
IRND=0
DO 406 I=1,NIM
IUBS=IUBE+1
IUBE=IUBE+MXT(I)
IF (MXS(I).EQ.0) GO TO 406
IUST=IUND+1
IUND=IUND+MXS(I)
IRST=IRND+1
IRND=IRND+MXT(I)*MXS(I)
CALL MPRD (SETRT, RSP, SETR, 1, MXT(I), MXS(I), IUBS, IRST, IUST)

CONTINUE

DO 300 J=1, JND
JS=(J-1)*MMM+1
WRITE TITLE FOR J-TH PLOT
X=XRP(J)*W
WRITE (IDOTP, 901)
WRITE (IDOTP, 954) X, SETR(J), SYMB(1), SYMB(2)
IF (MMM.EQ.4) WRITE (IDOTP, 955) SYMB(3), SYMB(4)
WRITE (IDOTP, 900)
C
REWRITE
READ (2) (UB(I), I=1, MT)
C
GENERATE FIRST LINE TO BE PRINTED
C
LOUT=T(1)/7.+0.1
JT=2
K=T(2)/7.+0.1
DO 301 I=1,76
301 ROW(I)=STAR
DO 302 I=6,71,5
302 ROW(I)=GRID
C
JJ=JS
II=50.*UB(JJ)+1.5
ROW(II)=SYMB(1)
C
DO 303 I=2,MMM
JJ=JJ+1
II=50.*UB(JJ)/SETR(J)+1.5
303 ROW(II)=SYMB(1)
C
WRITE first line and clear ROW(I) afterwards.
C
WRITE (IDOTP, 957)
WRITE (IDOTP, 956) LOUT, (ROW(I), I=1,76)
DO 304 I=2,75
304 ROW(I)=BLANK
ROW(1)=STAR
ROW(76)=STAR
MK=MMM
C
Determine the following to be printed.
C
DO 306 L=2,LND
LOUT=LOUT+1
IF(K.EQ.LOUT) GO TO 305
WRITE (IDOTP, 956) LOUT, (ROW(I), I=1,76)
GO TO 306
305 JT=JT+1
IF (JT.GT.IT) JT=1
K=T(JT)/7.+0.1
C
Read data from TAPE and determine symbols to be printed
C
309 READ (2) (UB(I), I=1, MT)
JJ=JS
IKK=MK-MMM+1
II=50.*UB(JJ)+1.5
ROW(II)=SYMB(1)
KK(IKK)=II
C
DO 307 I=2,MMM
JJ=JJ+1
IKK = IKK + 1
II = 50. * UB(JJ) / SETR(J) + 1.5
ROW(II) = SYMB(I)
KK(IKK) = II

CONTINUE

IF (K .NE. LOUT) GO TO 310
JT = JT + 1
K = T(JT) / 7. + 0.1
MK = MK + MMM
GO TO 309

Print the L-th line and BLANK out the second through 75-th element.

WRITE (IOUTP, 956) LOUT, (ROW(I), I=1,76)
DO 308 I=1, MK
II = KK(I)
308 ROW(II) = BLANK
ROW(1) = STAR
ROW(76) = STAR
MK = MMM
CONTINUE

Generate and print last line

DO 311 I=1, 76
ROW(I) = STAR
DO 312 I=6, 76, 5
ROW(I) = GRID
LOUT = LOUT + 1
WRITE (IOUTP, 956) LOUT, (ROW(I), I=1, 76)
CONTINUE

IF (NL .NE. NLS) GO TO 10000
GO TO 100

FORMAT STATEMENTS
*****************************************************************************
:91 FORMAT (15I4)
:92 FORMAT (8F8.3)
:93 FORMAT (4E10.5)
:94 FORMAT (7A1)
:95 FORMAT (/][/][/]
:96 FORMAT (1H1)
:97 FORMAT (////)
:98 FORMAT (1H ,25x,'**********************************************************************'/
1 1H ,25x,'*',
2 1H ,25x,'*' CONSOLIDATION PROBLEM '*/',
3 1H ,25x,'*',
4 1H ,25x,'*' STEP LOADING & SURCHARGE '*/',
5 1H ,25x,'**********************************************************************')
:99 FORMAT (1H ,10X,'THE PORE WATER PRESSURES ARE COMPUTED AT')
:100 FORMAT (1H ,10X,'YE/H ',5F10.3)
:101 FORMAT (1H ,10X,'XT/W ',5F10.3)
:102 FORMAT (1H0,10X,'THE PORE PRESSURES ARE INTERPOLATED AT')
:103 FORMAT (1H ,10X,'XE/W= ',5F10.3)
:104 FORMAT (1H ,10X,'ASSUMING COLLOCATION POLYNOMIALS OF DEGREE ')
:105 FORMAT (1H ,10X,'I1, BETWEEN THE LIMITS ',F8.3,' AND ',F8.3)
911 FORMAT (1HO,10X,'HORIZONTAL PORE PRESSURES ARE COMPUTED AT')
912 FORMAT (1H,10X,'X= ',F5.10,3)
913 FORMAT (1HO,10X,'THE SOIL SUB IS DESCRIBED BY THE FOLLOWING',/ 
1 1lx,'parameters which are given for the upper layer.'/ 
2 1H,10X,'IN CASE OF STRATIFICATION')/

914 FORMAT (1H,10X,'TOTAL THICKNESS ', 'H=',F8.3, ' FEET '/ 
1 1H,10X,'reference for X-COORD W = ',F8.3, ' FEET')
915 FORMAT (1HO,10X,'LAYER INTERFACE IS ',F8.3, ' FT BELOW SURFACE','/
2 1H,10X,'LOWER/UPPER PERMEABILITY, RK = ',F8.3, '/
3 1H,10X,'LOWER/UPPER COEF. OF CONSOLIDATION, RC = ',F8.3/
4 1H,10X,'LOWER/UPPER INITIAL VOID RATIO, REDO = ',F8.3)
916 FORMAT (1H,10X,'SKEPLIT PORE PRESSURE COEFFICIENTS ARE',/) 
1 1H,10X,'A = ',F5.2, ' AND B = ',F5.2, '/
917 FORMAT (1H,10X,'DEGREE OF SATURATION IS S = ',F5.3, '/ 
1 1H,10X,'HENRY-S CONSTANT OF GAS SOLUBILITY HC = ',F7.3, /
2 1H,10X,'INITL PORE GAS PRESSURE IS PU = ',E12.4, ' PSF')
918 FORMAT (1H,10X,'INITIAL VOID RATIO = ',F6.3)
919 FORMAT (1H,10X,'INITIAL COEFF. OF COMPRESSIBILITY IS AVD = ', /
1 1H,10X,E12.4, ' FT*FT/LB.')
920 FORMAT (1HO,10X,'NOTE -P(1) AND PC(1) MAY HAVE BEEN CHANGED',/) 
1 1H,10X,'as compared to input values to avoid over flow')
921 FORMAT (1H,10X,'THE INITIAL PERMEABILITIES ARE IN',/) 
1 1H,10X,'VERTICAL DIRN. KVD = ',E12.4, ' FT/DAY', /
2 1H,10X,'HORIZONTAL DIRN KHO = ',E12.4, ' FT/DAY')
922 FORMAT (1H,10X,'THE FOLLOWING COEFF. OF CONSOLIDATION',/) 
1 1H,10X,'ARE IN PUT AT SPECIFIED EFFECTIVE STRESSES',/ 
2 1HO,3X,'EFF-STRESS(PSF)',2X,'V-COEF(FT*FT/DAY)', 
3 2X,'EFF-STRES(PSF)',2X,'H-COEF(FT*FT/DAY)'
923 FORMAT (1H,7x,F10.2,7x,E12.4,7x,F10.2,7x,E12.4)
924 FORMAT (1H,10X,'THE SLOPES OF THE E V S LOG(K)-CURVES ARE',/) 
1 1H,10X,'IN VERTICAL DIRN, SKV = ',F8.3, /
2 1H,10X,'IN HORIZ. DIRN, SKH = ',F8.3)
925 FORMAT (1HO,10X,'THE DRAINAGE CONDITIONS ARE')
926 FORMAT (1H,10X,'IMPEDED DRAINAGE AT THE BOTTOM WITH',/) 
1 1H,10X,'VERT. PERM/VERT. IMPEDED PERM RKV=',F5.2, /
2 1H,10X,'THICKNESS OF IMPEDED LAYER, HI= ',F8.3, 'FT')
927 FORMAT (1H,10X,'FREE DRAINAGE AT THE BOTTOM')
928 FORMAT (1H,10X,'NO DRAINAGE AT THE BOTTOM')
929 FORMAT (1H,10X,'THE LOAD CHARACTERISTICS ARE GIVEN BY',/) 
1 1H,10X,'THE UNIT WEIGHT GLOAD= ',F7.2, ' PCF', /
2 1H,10X,'THE COHESION, CLOAD= ',F8.3, 'PSF'/ 
3 1H,10X,'THICKNESS OF THE DRAINAGE BLANKET YWM=',F6.2, 'FT',/ 
4 1H,10X,'THE TANGENT OF THE ANGLE', /
5 1H,10X,'OF INTERNAL FRICTION TQPHI=',F7.4, /
6 1H,10X,'MINP= ',I3, 'COO POINTS XINP/YINP')
930 FORMAT (1H,20X,F10.2, 'FEET', F10.2, ' FEET')
931 FORMAT (1H,10X,'THE AVERAGE PORE PRESSURES, UAVER(I)',/) 
1 1H,10X,'THE CONSOLIDATION SETTLEMENTS, SETRC(I) AND THE', 
2 1H,10X,'TOTAL SETTLEMENTS, SETRT(I), AT XT(I) ARE',/
1H, 10X, 'CAV DEGREE OF CONSOL. WITH RESPECT TO REF. LOAD.
1H, 10X, 'SETC(X(1)), SETC(X(2)), . . . . , '
1H, 10X, 'CONSOL. SETTLEMENTS',
1H, 10X, 'SETI(X(1)), SETI(X(2)) . . . . , '
1H, 10X, 'IMMEDIATE SETTLEMENTS',
1H, 10X, 'SETT(X(1)), SETT(X(2)) . . . . , '
1H, 10X, 'CONSOL + IMMEDIATE SETTLEMENTS',
1H, 10X, 'THE LAST TWO LINE ARE ONLY OUT PUT',
1H, 10X, 'IF SOIL IS PARTIALLY SATURATED (B. NE. 1.)',
1H, 10X, 'THE POINTS X(I) IN FEET ARE AS FOLLOWS',
1H, 10X, 'DAYS IS THE TIME OF LOAD APPLICATION',
1H, 10X, 'AVE DEGREE OF CONSOL. AND SETTLEMENT',
1H, 10X, 'CURVES FOR POINT X=',
1H, 10X, 'INTERVAL BETWEEN 2 GRID LINES. EQ 10%',
1H, 10X, 'THE TOTAL SETTLEMENT DUE TO REFERENCE LOAD IS',
1H, 10X, 'AVE. DEGREE OF CONSOL.',
1H, 10X, 'RELATIVE TO THE PORE PRESS DUE TO REF LOAD',
1H, 10X, 'AVERAGE SETTLEMENTS IN % OF',
1H, 10X, 'THE REFERENCE SETTLEMENT',
1H, 10X, 'THE REFERENCE EMSETTLEMENT',

format (2X, 10F8.3)
FORMAT (/1H, 10X, 'T= ', F6.0, /
1H, 10X, 'DAYS IS THE TIME OF LOAD APPLICATION', /
1H, 10X, 'AVE DEGREE OF CONSOL. AND SETTLEMENT', /
1H, 10X, 'CURVES FOR POINT X=', F6.2, 'FEET FROM CENTER LINE', /
1H, 10X, 'INTERVAL BETWEEN 2 GRID LINES. EQ 10%', /
1H, 10X, 'THE TOTAL SETTLEMENT DUE TO REFERENCE LOAD IS', /
1H, 10X, 'AVE. DEGREE OF CONSOL.', /
1H, 10X, 'RELATIVE TO THE PORE PRESS DUE TO REF LOAD', /
1H, 10X, 'AVERAGE SETTLEMENTS IN % OF', /
1H, 10X, 'THE REFERENCE SETTLEMENT',
format (1H, 13, 76A1)
format (1H, 2X, '0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 ',
1H, 10X, '0.9 1.0 1.1 1.2 1.3 1.4 1.5',) /
format (1H, 10X, 'THE FACTOR OF SAFETY AT TIME T= ', F6.0, /
1H, 10X, 'DAYS FOR LIFT', I3, ', WAS . EQ FS=', F6.3, /
1H, 10X, 'AS COMPARED TO THE REQ. FSI=', F6.3)
format (1H, 20X, F8.3, 12X, F8.3, 12X, F8.3)
format (7A1)
format (1H, 10X, 'THE SHEAR STRENGTH CHARACTERISTICS OF', /
1H, 10X, 'THE SUB SOIL AS USED IN THE STABILITY ANALYSIS ARE', /
1H, 15X, 'DEPTH (FT)', 5X, 'COMESION (PSF)', 5X, 'P-RATIO')

C This subroutine interpolates the values of function Y(X)
C from the known YY(XX) by use of the linear interpolation.
C or extrapolation.
C
II=0
JJ=0
NN=M-N1+1
do 20 I=NN, M
II=II+1
J=1
C Extrapolation is used if X(II).GT.XX(N)
if (X(II).LT.XX(N)) go to 31
Y(I)=YY(N)+(YY(N)-YY(N-1))*(X(II)-X(N))/(XX(N)-XX(N-1))
go to 20
31 if (X(II).GT.XX(1)) go to 32
C Extrapolation is used if X(II).LT.XX(1)
iiii=2
Y(I)=YY(1)-(YY(1111)-YY(11))*(XX(1)-X(II))/(XX(1111)-XX(11))
25 \text{J} = \text{J} + 1
32 \text{if } (X(III) \text{ GT. } XX(J)) \text{ go to 25}

C Interpolation is used if XX(1), LT. X(III), LT. XX(N)
C If X(III) is very close to XX(J) then \( Y(I) = YY(J) \)
C If (ABS(X(III) - XX(J)). GT. 0.00000001) go to 26
26 \( Y(I) = YY(J) \)
\text{go to 20}

20 \( XY1 = XX(J - 1) \)
\( YY1 = YY(J - 1) \)
\( Y(I) = YY1 + \frac{(X(III) - XY1) \times (YY(J) - YY1)}{XX(J) - XY1} \)

\begin{verbatim}
BEGIN SUBROUTINE INTEG
This subroutine computes the values of the stress integrals if
the integration variable becomes larger than 12.

DIMENSION AR(7)

COMMON/ PDAPI/ ALPHA(30), L
PI = 3.14159265358979
ETAP = 1. + ETA
ETAM = 1. - ETA

DO 1 I = 1, 7
AR(I) = 0.

DO 2 I = 1, L
pq = 1. / 1000000000000000000000.
AMX = ALPHA(I) - XI
IF (ABS(AMX). LT. pq) GO TO 3
AR(1) = AR(1) + PI - ATAN(ETAM/AMX) - ATAN(ETAP/AMX)
IF (AMX . LT. 0.) AR(1) = AR(1) - 2. * PI
APX = ALPHA(I) + XI
IF (ABS(APX). LT. pq) GO TO 4
AR(1) = AR(1) + PI - ATAN(ETAM/APX) - ATAN(ETAP/APX)
IF (APX . LT. 0.) AR(1) = AR(1) - 2. * PI
SIAMX = SIN(AMX*B)
COAMX = COS(AMX*B)
SIAPX = SIN(APX*B)
COAPX = COS(APX*B)

DPM = 1. / (ETAP*ETAP + AMX*AMX)
DPP = 1. / (ETAP*ETAP + APX*APX)
DMM = 1. / (ETAM*ETAM + AMX*AMX)
DMP = 1. / (ETAM*ETAM + APX*APX)

SM1 = DPM*(ETAP*SIAMX + AMX*COAMX)
CM1 = DPM*(ETAP*COAMX - AMX*SIAMX)
BP1 = DPP*(ETAP*SIAPX + APX*COAPX)
CP1 = DPP*(ETAP*COAPX - APX*SIAPX)

SM2 = DMM*(ETAM*SIAMX + AMX*COAMX)
CM2 = DMM*(ETAM*COAMX - AMX*SIAMX)
\end{verbatim}
SP2 = DMP*(ETAM*SIAPX + APX*COAPX)
CP2 = DMP*(ETAM*COAPX - APX*SIAPX)

AR(2) = AR(2) + SM2 + SP2
AR(3) = AR(3) + SM1 + SP1
AR(4) = AR(4) + DPM*(ETAP*SM1 + AMX*CM1) + DPP*(ETAP*SP1 + APX*CP1)
AR(5) = AR(5) + CM2 - CP2
AR(6) = AR(6) + CM1 - CP1
AR(7) = AR(7) + DPM*(ETAP*CM1 - AMX*SM1) + DPP*(APX*SP1 - ETAP*CP1)

CONTINUE
EXAP = EXP(-ETAP*B)/2.
EXAM = EXP(-ETAM*B)/2.

AR(1) = AR(1)/2.
AR(2) = EXAM*AR(2)*ETAM
AR(3) = EXAP*AR(3)
AR(4) = (EXAP*AR(4) + B*AR(3))*2.*ETA
AR(5) = EXAM*AR(5)*ETAM
AR(6) = EXAP*AR(6)
AR(7) = (EXAP*AR(7) + B*AR(6))*2.*ETA
AR(6) = AR(6)*ETAM

RETURN
END

C END OF SUBROUTINE INTEG

SUBROUTINE COEF (UAVD, UAVE, OMEGA, PHI, LI, IL, OMEDE, PHID, NN)

C This subroutine determines the soil parameters for the case that
C they are variable.
C If LI=3, the difference between the old and the new parameters
C PHI and OMEGA are also computed and stored in PHID and OMEDE, resp.

DIMENSION UAVD(1), UAVE(1), OMEGA(1), PHI(1), OMEDE(1), PHID(1)
DIMENSION SVM(12), P(11), PC(11), PLOG(11), AA(1), BB(1)

COMMON/ SACSE/ ROC, ROCL, SVM, P, PC, PLOG, PO, PCO, IAV, IK, ISAT, AAV, AAH
COMMON/ SAD01/ AVO, KVO, KHO, EDPS, PU, SKHM, SKVM, CCC, NNN, ICDEF
COMMON/ SAD02/ PCV(10), CVIN(10), PCR(10), CHIN(10), ICV, KOUNT, HF

REAL K, KO, KV, KH, KVO, KHO

Statement functions for the computation of the coeff. of
permeability. CONK is used, when K is variable and AV is const.
VARK is used, when K and AV are variable. PSI computes the
parameters to be returned to the calling program.

CONK(KO, SKM) = KO*EXP(-SKM*DISU)
VARK(KO, SKM) = KO*(PP/PQ)**(-1.*SKM)
PSI(AAA, K) = ALPHG*K*AAA/AV

The following parameters have been defined in program SAND and
are repeated here.
AAV = (1.+EO)/(GAMMAWATER*(DELTAY)**2)
AAH = (1.+EO)/(GAMMAWATER*(DELTAH)**2)
SKVM = CC/SKV if IAV=1, SKVM=2.3026*AVO/SKV if IAV=0
SKHM = CC/SKH if IAV=1, SKHM=2.3026*AVO/SKH if IAV=0
AVO = initial coeff. of compressibility
KVO, KHO = initial coeff. in vert. and hori. dirns.
ALPHG = gas factor.
IAV=0, constant AV=AVD. IAV=1, variable AV
IK=0, const. K-s. IK=1, variable K-s.
NNN=no. of points with vert. and hori. flow.
KOUNT=0 if the subroutine is called the second or following time
KOUNT=1 if the subroutine is used for the first time
ICOEF=1 if IK=0 and IAV=0 or IAV=1
ICOEF=2 if IK=1 and IAV=0
ICOEF=3 if IK=1 and IAV=1
ICOEF=4 if K*(1.+EO)/(GAMMAWATER*AV*DELTA Y**2)=CVIN and
K*(1.+EO)/(GAMMAWATER *AV*DELTA H**2)=CHIN are
specified at ICV effective stresses PCV and PCH resp.
ISAT=0 full saturation, ISAT=1 partial saturation
PO= ave present overburden pressure
PCD= ave preconsol. pressure
DISU= UAVD-UAVE= ave dissipated pore pressure
CCC= 0.4343*compression index
EDFUS= ED*PU*(1.-5*(1.-HC)), where PU=initial pore gas pressure,
      S=initial degree of saturation, HC=Henry's const.
OMEGA(I)= (gas factor*coeff. of consol)/delta H**2
PHI(I)= (gas factor*coeff. of consol.)/delta Y**2
OMED= difference between old and new omega(I)
PHID= difference between old and new PHI(I)

IF (KOUNT.EQ.0) GO TO 20
   ALPHG=1.
IF (IAV.EQ.1) PG=CCC/AVD

Determine OMEGA, PHI, OMED and PHID at NN points

Determine eff. stresses at the sum of the present overburden
stress PO and the dissipated pore pressures DISU. Determine
then the soil parameters as a function of PO+DISU

20 DO 5 I=1,NN
   KK=ICOEF
   DISU=UAVD(I)-UAVE(I)
   PP=PO+DISU
   AV=AVD
   KV=KVO
   KH=KHO
   IF (KK.EQ.4) GOTO 6
   IF (IAV.EQ.0) GO TO 6
   IF (PP.GT.PG) GO TO 31
   KK=1
   GO TO 6
31 AV=CCC/PP
   5 IF (ISAT.EQ.0) GO TO 60
      AUX=AV
      IF (PP.LT.PCD) AUX=AUX*ROC
      ALPHG=1./(1.+EDFUS/(AUX*(PU+UAVE(I))**2))
   60 IF (IL.EQ.1) GO TO 7
      IF (HF.EQ.0) RETURN

PARAMETERS FOR HORIZONTAL CASE

   if (KK.eq.1) go to 11
   if (KK.eq.2) goto 12
   if (KK.eq.3) goto 13
   go to 14

   12 KH=CONK(KHO,SKHM)
GO TO 11
13   KH=VARK(KHO, SKHM)
11   A=PSI(AAH, KH)
   GO TO 30

C   C INTERPOLATE BETWEEN CHIN(I)
C
14   BB(1)=ALOG(PP)
    CALL LAGR(BB, AA, 1, 1, PCH, CHIN, ICV)
    A=ALPHG*AA(1)
30   IF (LI.EQ.3) DME(D(NN+1-I)=OMEGA(NN+1-I)-A
    OMEGA(NN+1-I)=A
    GO TO 5

C   C PARAMETERS FOR VERTICAL CASE
C
7    if (KK.eq.1) goto 1
    if (KK.eq.2) goto 2
    if (KK.eq.3) goto 3
    go to 4
2     KV=CONK(KVO, SKVM)
   GO TO 1
3     KV=VARK(KVO, SKVM)
1     A=PSI(AAV, KV)
   GO TO 40

C   C INTERPOLATE BETWEEN CVIN(I)
C
4     BB(1)=ALOG(PP)
    CALL LAGR(BB, AA, 1, 1, PCV, CVIN, ICV)
    A=ALPHG*AA(1)
40   IF (LI.EQ.3) PHID(I)=PHI(I)-A
    PHI(I)=A
5    CONTINUE
C
RETURN
END

C BEGIN SUBROUTINE FUNCT

SUBROUTINE FUNCT (THETA, ETA, K, SIGX, SIGY, TAU)

C   This subroutine computes the values of the integrands for the
C   argument theta
C
COMMON/ POFUN/ G(516), ETHST(516)

C
TE=ETA*THETA
ETE=EXP(TE)
C=(ETHST(K)+1./ETHST(K))/2.
S=(ETHST(K)-1./ETHST(K))/2.
CTE=(ETE+1./ETE)/2.
STE=(ETE-1./ETE)/2.

C
D=G(K)/(C*C+THETA*THETA)
FA=C+THETA*S
FB=THETA*TE
FC=THETA*C
FD=TE*CTE
FE=TE*STE
EVALUATE THE INTEGRANDS

SIGX = -D*(FA*(CTE+FE)-FC*(2.*STE+FD))
SIGY = -D*(FA*(CTE-FE)+FC*FD)
TAU = +D*(-FA*FD+FC*(CTE+FE))

IF (ETA.EQ.1.) RETURN
AUX = 2.*Q(K)*CTE/ETHST(K)
SIGX = SIGX + AUX
SIGY = SIGY + AUX
RETURN
END

END OF SUBROUTINE FUNCT

SUBROUTINE PORE (XINP, YINP, M, NST, CX, IX, CY, IY, U, ABAR, BBAR)

This subroutine computes the stresses within a compressible soil layer by use of elastic theory for plane strain conditions and a symmetric loading. Poisson's ratio is 0.5 and the underlying stratum is perfectly rough and rigid. Pore pressures are computed from a knowledge of the stresses and the pore pressure coeff. A and B called herein ABAR and BBAR.

DIMENSION XINP, YINP, CX, CY, U, SX(220)
DIMENSION SY, TA, GY(516), GT(516), SI(3)
DIMENSION SUM(3), R(3), T(3), DIF(3), AR(7), SUMS(3), ABSD(3)

COMMON/ SAPDD/ IOUTP, W, H, GLOAD, CLOAD, NARC, NRAD
COMMON/ P0API/ ALPHA(30), L
COMMON/ POFUN/ QST(516), ETHST(516)

If no load is specified (No. of input points M.LE.1) set pore pressures equal to zero and return.

IF (M.GT.1) GO TO 101
DO 100 I=1,220
   U(I)=0.
RETURN

Approximate actual load by NST strips of const. thickness DST.

101 CALL APROX (XINP, YINP, M, NST, DST)
WRITE (IOUTP,94) L
DO 10 I=1,L
   WRITE (IOUTP,95) I, ALPHA(I)
10   ALPHA(I)=ALPHA(I)/H

Define constants used in the stress computation.

DELTA=0.0001
DEL=0.001
DELT=DELTA
PI=3.14159265358979
IMAX=512
AINT=1./512.
KEND=IMAX+1
PMAX=NST
PMAX=ABS(PMAX*PI/2.)
JEND=12
FAC=2.*GLOAD*DST/PI
ZETA=W/H
IXIY=IX*IY
BRAN=2.

C Define constant for pore pressure determination.
C
CONST=0.8660254*(ABAR-1./3.)+1./2.

C SET STRESSES EQUAL ZERO
C
DO 21 I=1,IXIY
SX(I)=0.
SY(I)=0.
21 TA(I)=0.

C IER=0
C
C Initialize the numerical integration procedure
C Use Simpsons rule if XI.LT.BRAN
C Use Filons formula if XI.GE.BRAN
C Numerical integration is done between 0.0 and REAL(JEND)
C
DO 5 ISTEP=1,JEND

A=ISTEP-1
B=ISTEP
BA=1.

IF (ISTEP.EQ.2) DELT=DEL
C
C Compute factors repeatedly used in subroutine FUNCT
C
THETA=A-AINT
DO 2 K=1,KEND
THETA=THETA+AINT
ETHST(K)=EXP(THETA)
QST(K)=0.

C
DO 2 I=1,L
QI=ALPHA(I)
AT=QI*THETA
ABSAT=ABS(AT)
IF (ABSAT.LT.0.001) GO TO 3
QI=QI*SIN(ABSAT)/AT
3 IF (AT.LT.0.) QI=-QI
2 QST(K)=QST(K)+QI

C Integrate numerically between the limits A and B and store
C the results in one dimensional arrays SX,SY,TA
C
DO 5 J=1,IY
ETO=CY(J)
ETA=1.-ETO
DO 51 JGX=1,KEND
51 QX(JGX)=1.E15

C
C Evaluate the integrand at interval limits A and B
C
CALL FUNCT (A,ETA,1,QX(1),QY(1),QT(1))
CALL FUNCT (B, ETA, KEND, QX(KEND), QY(KEND), QT(KEND))

DO 5 I=1, IX
LL=(I-1)*IY+J
XI=Cl(l)*ZETA

INITIALIZE INTEGRATION

DO 41 K=1, 3
SI(K)=0.

XIA=XI*A
XIB=XI*B
SIXIA=SIN(XIA)
SIXIB=SIN(XIB)
COXIA=COS(XIA)
COXIB=COS(XIB)
If (XI.LT.BRAN) GO TO 1

DIF(1)=QX(KEND)*SIXIB-QX(1)*SIXIA
DIF(2)=QY(KEND)*SIXIB-QY(1)*SIXIA
DIF(3)=QT(1)*COXIA-QT(KEND)*COXIB

R(l)=QX(1)*COXIA+QX(KEND)*COXIB
R(2)=QY(1)*COXIA+QY(KEND)*COXIB
R(3)=QT(1)*SIXIA+QT(KEND)*SIXIB

COMPUTE THE INTEGRAL BY INTERVAL HALVING

NHALF=1
N=2
AN=N
HH=BA/AN
XK=A-HH
XINC=2. * HH
DO 44 K=1, 3

T(K)=0.

Compute the values of the integrands if not yet computed and store them in QX(K), QY(K), QT(K)

IDEL=IMAX/NHALF
IT=IMAX/N+1
DO 8 K=1, NHALF
XK=XK+XINC
IT=IT+IDEL
pq=100000000000000000
If (QX(IT).EQ.pq) go to 53
go to 56

CALL FUNCT (XK, ETA, IT, QX(IT), QY(IT), QT(IT))

XIX=XI*XK

COXIX=COS(XIX)
T(1)=T(l)+QX(IT)*COXIX
T(2)=T(2)+QY(IT)*COXIX
T(3)=T(3)+QT(IT)*SIN(XIX)

CONTINUE

IF (XI.GE.BRAN) GO TO 13
C SIMPSON RULE

C

HH=HH/3.

DO 46 K=1,3

46 SUM(K)=HH*(R(K)+4.*T(K))

GO TO 4

C C Finon's formula C

C

13 XIH=XI*HH

XXIH=XI*XIH

SIX=SIN(XIH)

COX=COS(XIH)

C=(SIX/XIH-COX)*4.

D=XIH+SIX*COX-2.*SIX*SIX/XIH

E=1.+COX*COX-2.*SIX*COX/XIH

DO 47 K=1,3

47 SUM(K)=(D*DIF(K)+E*R(K)+C*T(K))/XXIH

C C CHECK FOR ACCURACY C

C THE END RESULT WAS FOUND TO BE LITTLE AFFECTED EVEN WHEN THIS C ACCURACY WAS NOT REACHED.

C

4 IF (NHALF.EQ.1) GO TO 16

SUMS(1)=SX(LL)+SUM(1)

SUMS(2)=SY(LL)+SUM(2)

SUMS(3)=TA(LL)+SUM(3)

C C Accuracy as compared to the value of the integral between A and B C

C

DO 48 K=1,3

ABSD(K)=ABS(SUM(K)-SI(K))

IF (ABSD(K).GT.ABS(DELT*SUM(K))) GO TO 16

48 CONTINUE

C IF (ISTEP.EQ.1) GO TO 17

C C ACCURACY AS COMPARED TO THE MAXIMUM LOAD INTENSITY C

C
DO 49 K=1,3
IF (ABSD(K).GT.(DELTA*PMAK)) GO TO 16
49 CONTINUE
GO TO 17

16 NHALF=N
N=2*NHALF
IF (N.LE.IMAX) GO TO 19
IF (IER.NE.0) GO TO 191
IER=1

The Error Message at this point is supressed to reduce the volume of the output.

WRITE ERROR MESSAGE, IF N.GT.IMAX

191 continue
GO TO 17

RENAME FOR NEXT CHECK OF ACCURACY

19 DO 50 K=1,3
50 SI(K)=SUM(K)

R(K)=R(K)+2.*T(K)
GO TO 6

17 SX(LL)=SUMS(1)
SY(LL)=SUMS(2)
TA(LL)=SUMS(3)

CONTINUE

Stresses in X- and Y- Dirn. not including factor FAC

DO 15 J=1,IY
ETO=CY(J)
ETA=1.-ETO

DO 15 I=1,IX
XI=CX(I)*ZETA
LL=(I-1)*IY+J
IF (ETA.NE.1.) GO TO 30

Stresses at the usurface (ETA.EQ.1) not including factor FAC. Use modified formula for stresses at the surface.

SX(LL)=SX(LL)-SY(LL)
SY(LL)=0.
DO 32 IS=1,L
ABSAL=ABS(ALPHA(IS))
IF (((XI/ABSAL)-1.) .LT. 33, 34, 32
33 SY(LL)=SY(LL)-2.*0.785398163397448*ALPHA(IS)/ABSAL
34 SY(LL)=SY(LL)-0.785398163397448*ALPHA(IS)/ABSAL
32 CONTINUE
SX(LL)=SX(LL)+SY(LL)
TA(LL)=0.
GO TO 31

Stresses below the surface (ETA.LT.1) not including factor FAC
CALL INTEG (ETA, XI, B, AR)
SX(LL)=SX(LL)-AR(1)+AR(2)-(3.-ETA)*AR(3)+AR(4)
SY(LL)=SY(LL)-AR(1)+AR(2)-(1.+ETA)*AR(3)-AR(4)
TA(LL)=TA(LL)+AR(5)+AR(6)-AR(7)

C Stresses in X- and Y- dirn and principal stresses
C Tension is positive

SSUM=(SX(LL)+SY(LL))/2.
SDIF=(SX(LL)-SY(LL))/2.
ROOT=SQRT(SDIFF*DIFF+TA(LL)*TA(LL))
SX(LL)=FAC*SX(LL)
SY(LL)=FAC*SY(LL)
TA(LL)=FAC*TA(LL)
S1=FAC*(SSUM-ROOT)
S2=FAC*(SSUM+ROOT)

C Compute pore pressures for plane strain Conditions with
C poisson ratio of 0.3 using skemptons pore pressure parameters
C A and B, herein called ABAR and BBAR.
C CONST was earlier defined as CONST=0.5*(ABAR-1/3)+1/2.

U(LL)=-BBAR*(S2+(S1-S2)*CONST)
CONTINUE
WRITE (10UTP,93)

FORMAT STATEMENTS

93 FORMAT (//////)
94 FORMAT (1H ,10X,'THE ACTUAL LOAD IS APPROXIMATED BY ',I3,/
1 11x,' LOADS OF EG INTNSTY WHICH EXTEND FROM X=0 TO ALPHA(I)'),/
2 1H ,10X,'IF ALPHA(I) IS NEGATIVE, THIS LOAD IS SUBTRACTED',//
95 FORMAT (1H ,15X,'ALPHA(',',I2,' ) = ','F10.3,' FEET')

RETURN
END

END OF SUBROUTINE PORE
BEGIN SUBROUTINE DISP
SUBROUTINE DISP (U,LI,OMEGA PHI,T, UAVE,LIFT,MYE,IEND,XT,SV)

This subroutine computes the pore pressures at time T by
treating the consolidation equation as an eigenvalue
problem.
U Pore pressures to be output. For LI=5,6 this vector
contains the additional pore pressures for the new load
when this subroutine is called.
LI Load identifier.
LI=1 Determination of vectors A and B for the load addition.
LI=2 Determination of pore pressures due to the stepwise
const. loads.
LI=3 Determination of vectors A and B for times between
load application if the soil parameters are variable.
LI=5 First LIFT, first use of DISP.
ISP=1 Compute and print the pore pressures at all points of
the solution domain.
ISP=0 Compute only the average pore pressures at different
depths at all IEND points.
IVAR identifier for soil parameters
IVAR=0 Constant soil parameters
IVAR=1 Variable soil parameters
PHI Vector depending on the soil parameters for vert. flow.
OMEGA vector depending on the soil parameters for H-flow.
T Time
LIFT no. of vectors A and B
M Program numbering system, No. of points in Vert. Dirn.
N Program numbering system, No. of points in H-dirm.
Storage reservations are made for 40 horizontal points and
6 step loads.

DIMENSION U(1), PHI(1), OMEGA(1), UAVE(1), XT(1), SV(1)
DIMENSION EIGV(10), EIGX(40), AUX(160), XV(100), XVI(100)
DIMENSION XH(1600), XHI(1600), FH(500), F(200), A(1200), B(1200)
DIMENSION VJ(11), RJ(40), RJ(20), G(280), UBAV(240), UBB(2G)
DIMENSION W1(300)

EQUIVALENCE (G(1), A(501))

COMMON/ SAGED/ IOUTP, W, HI, CLOAD, CLOAD, NARC, NRAD
COMMON/ SADI1/ LAYER, IBCV, MHE, M, N, IDC, NDR, ISUM, XET(41)
COMMON/ SADI2/ FIMPV, RC, RK, C, RD, RE, TA, ISP, IVAR

IE=64
LIM=LI
IF (LI.LT.5) GO TO 2
IF (LAYER.LT.3) LAYER=2

Call MODAL for determination of eigen values, modal matrix and
inverse of the modal matrix for the case of vertical and
Hori. flow

CALL MODAL (LAYER, IBCV, M, FIMPV, RC, RK, O., H, EIGV, XV, XVI, AUX)

PAGE 60
IF (IDC.EQ.1) GO TO 1
CALL MODAL (1, 4, N, FIMPV, RC, RK, RD, RE, EIGX, XH, XHI, AUX)
LIM=1

Determine the diagonal matrices F and FH

CALL EFGEN (PHI, T, EIGV, IVAR, IEND, M, F, LI)
IF (IDC.EQ.1) GO TO 3
CALL EFGEN (OMEGA, T, EIGX, IVAR, 1, N, FH, LI)

BRANCH DEPENDING ON THE VALUE OF LIM

GO TO (4, 5, 6), LIM

LIM=1
Determine vectors A and B for the LIFT- th load addition

Determination of VECTOR B for the LIFT- th load addition

IB=(LIFT-1)*M*IEND
IE=0
DO 10 K=1, IEND
DO 11 I=1, M
IA=(K-1)*MYE+1
II=I-M
IB=IB+1
IE=IE+1
B(IB)=0.
DO 12 J=1, M
II=II+M
IA=IA+1
12 B(IB)=B(IB)+XVI(II)*U(IA)
   do 340 iief=1, ief
340 B(IB)=B(IB)/F(IE)
11 continue
10 CONTINUE
C IF (IDC.EQ.1) GO TO 13
C DETERMINE VECTOR A--HORIZONTAL CASE
C
II=0
LIN=(LIFT-1)*N+1
LIN2=LIFT*N
do 121 I=1, IEND
UBB(I)=0.
do 120 J=1, MYE
II=II+1
UBB(I)=UBB(I)+U(II)*SV(J)
120 continue
121 continue
   call LINT (XET, UBAV, N, LIN2, XT, UBB, IEND)
C To avoid numerical instability put UBAV(I)=0.1 if it is zero.
C
   do 1210 I=LIN, LIN2
      if (ABS(UBAV(I)).LT.0.1) UBAV(I)=0.1
1210 continue
   IS=(LIFT-1)*N
DO 14 I=1, N
IE=0
II=I-N
IS=IS+1
A(IS)=0.
IA=LIN2+1
DO 15 J=1, N
II=II+N
IA=IA-1
IE=IE+1
15 A(IS)=A(IS)+XHI(II)*UBAV(IA)
   do 341 iief=1, ief
341 A(IS)=A(IS)/FH(I)
14 continue
C
13 IF (ISP.EQ.0) RETURN
C LIM=2
C DETERMINE THE PORE PRESSURES AT TIME T AT XT(J), J=1, IEND
C *********************************************************
C
5 NM=M
III=MYE
DO 50 I=1, ISUM
CONSIDER INFLUENCE OF LIFT LOADS

DO 53 K=1, LIFT
   IB=ID+M*ID+M*(K-1)
   CALL MAMULP (XV, F, B, VJ, M, IB, ID)

BRANCH IF VERT FLOW ONLY

IF (IDC.EQ.1) GO TO 54
   IB=1+N*(K-1)
   goto 54
   CALL MAMULP (XH, FH, A, RJ, N, IB, 1)
do 73 IR=1, N
   RJ(IR)=RJ(IR)/UBAV(K*N+1-IR)
75 continue
   DO 650 IR=1, N/2
   HOLD=RJ(IR)
   RJ(IR)=RJ(N-IR+1)
   RJ(N-IR+1)=HOLD
650 continue

Determine the average pore pressures at M+1 points in vertical direction at XT(J). Include the free drainage at the upper boundary. The result after LIFT cycles of loop 53 is returned to the calling program. The drainage at the lower boundary is considered outside loop 53.
call LAGR (XT, RJJ, IEND, 1, XET, RJ, N) call LINT (XT, RJJ, IEND, IEND, XET, RJ, N)

54 II=(J-1)*MYE+1
   U(II)=0.
   DO 57 I=1, M
      II=II+1
      IF (IDC.EQ.1) GO TO 55
      RJAVE=RJ(J)
      if (RJAVE.LT.0.) RJAVE=0.0
      GO TO 57
55 RJAVE=1.
57 U(II)=U(II)+VJ(I)*RJAVE
53 continue

IF (IBCV.EQ.3) GO TO 58
   II=J*MYE
   U(II)=FIMPV*U(II-1)
58 IF (ISP.EQ.0) GO TO 59
   IF (IDC.EQ.1) GO TO 60

Output the pore pressures at XT(J) for the case of Vert+ Hor flow.

WRITE (IOUTP,94) T, XT(J)
GO TO 62
C Output the pore pressures at XT(J) for the case of Vert flow only
C 60 WRITE (IDOUTP,91) T,XT(J)
62 II=(J-1)*MYE
DO 61 I=1,MYE
II=II+1
61 WRITE (IDOUTP,92) U(II)
WRITE (IDOUTP,93)
GO TO 59
C Compute the ave pore pressures at XT(J)
C 59 II=(J-1)*MYE
UAVE(J)=0.
DO 63 I=1,MYE
II=II+1
63 UAVE(J)=UAVE(J)+U(II)*SV(I)
C 51 CONTINUE
RETURN
C C Determine vectors A and B for the case of variable soil parameters and times between load applications LIM=3
C *********Determine vector B**********
C 6 II=IEND*M
IB=0
DO 20 K=1,LIFT
DO 20 I=1,II
IB=IB+1
20 B(IB)=B(IB)*F(I)
C IF (IDC.EQ.1) RETURN
C C DETERMINE VECTOR A
C II=N
IA=0
DO 22 K=1,LIFT
DO 22 I=1,II
IA=IA+1
22 A(IA)=A(IA)*FH(I)
RETURN
C C FORMAT STATEMENTS
C 91 FORMAT (/1H,10X,'T= ',F6.0,'DAYS X/W= ',F8.3,'PORE PRESSURES IN PSF-VERTICAL FLOW ONLY','//)
92 FORMAT (1H,10X,11F10.3)
93 FORMAT (///)
94 FORMAT (/1H,10X,'T= ',F6.0,'DAYS X/W= ',F8.3,'PORE PRESSURES IN PSF DUE TO VERT + HORIZ FLOW','//)
END

END OF SUBROUTINE DISP

SUBROUTINE SETL BEGINS

SUBROUTINE SETL (U, SETTL, IEND, KKK, MYE, F, FUP, FLO, KIAV)

This subroutine computes consol. (F=1) or total (F>1) settlements using constant (KIAV=1+IAV=1) or variable KIAV=2 soil parameters.

U Vector of dissipated pore pressures with IEND*MYE elements.

SVM Modified mathematical molecule for Simpsons or trapezoidal formula (considers case of stratified soil if LAYER.GT.2)

SETTL Vector of computed settlements with IEND elements

IEND No. of settlements

KKK No. of distinct pore pressures in the upper layer

MYE No. of distinct pore pressures in both layers

F Consol. settlements are computed if F=1.0

Total settlements are computed if F=1.0/B where B= Skempton pore pressure coeff.

FUP Parameter for the upper layer which incorporates the soil coeff.

FLO Corresponding parameter for the lower layer.

DIMENSION U(I), SETTL(I), SVM(12), P(11), PC(11), PLOG(11)

COMMON/ SACSE/ ROC, ROCL, SVM, P, PC, PLOG, PO, PCD, IAV, IK, ISAT, AAV, AAR

ISE=ISE+1

format ('NO. of times entered SETL =',I5)

write (IOUTP, 901) ISE

R=ROC
A=FUP
II=-MYE
JST=1
JND=KKK
JSS=0

DO 1 I=1, IEND
 SETTL(I)=0.

1

DO 2 I=1, IEND
 II=II+MYE
 IU=II
 S=0.
 JS=JSS

DO 3 J=JST, JND
 IU=IU+1
 JS=JS+1
 GO TO (4, 5), KIAV

Constant soil parameters IAV=0 KIAV=1

4 S=S+F*SUM(JS)*U(IU)
 GO TO 3
C Variable soil parameters IAV=1 KIAV=2

5 PP=P(J)+F*U(IU)
C if the current effective stress at some point becomes
C negative then it is put as P(J) at that point.
C i.e no swelling is considered.
C
IF (PP.LT.P(J)) PP=P(J)
IF(PP.GT.PC(J)) GO TO 7
S=S+R*SVM(JS)*ALOG(PP/P(J))

GO TO 3
7 S=S+SVM(JS)*(ALOG(PP/PC(J))+R*PLOG(J))
3 CONTINUE
SETTLL(I)=SETTLL(I)+A*S
2 CONTINUE
C Consol. of the lower layer
C
IF (JND.EQ.MYE) RETURN
A=FLO
R=ROCLO
II=KKK-MYE-1
JST=KKK
JND=MYE
JSS=KKK
GO TO 6
END
C END OF SETTLL
C BEGIN SUBROUTINE MAMULP
C
SUBROUTINE MAMULP (A, B, C, N, IS, II)
C This subroutine performs the matrix multiplication
C (General matrix A)*(Diagonal matrix D)*(Vector B) = (Vector C)
C All matrices are stored one dimensionally with A having N*N elements
C D,B,C each having N elements. The first element of B and D are B(IS) and D(II)
C
C The formula for the I-th element of C is
C C(I)=SUM(K=1,N) of A(I+(K-1)*N)*B(IS-1+K)*D(XI+K-1)
C
DIMENSION A(1), B(1), C(1), D(1)

10 DO 1 I=1,N
IA=N*N+I
IB=IS+N
ID=II+N
C(I)=0.
10 DO 1 K=1,N
IB=IB-1
ID=ID-1
IA=IA-N
cc=A(IA)*B(IB)
20 DO 20 I=1, IEF
cc=D(ID)*cc
20 CC=CC
END
C(I)=C(I)+cc
1 CONTINUE
RETURN
END

C END OF SUBROUTINE MAMULP
C SUBROUTINES BEGIN HERE.

SUBROUTINE OVERFLOW (J)
J=1
RETURN
END

SUBROUTINE HDIST (UB, XT, IEND, ICV, CHIN, DXSG, AAH, MHE, W, XET, IPOR, HF *
*, MYE, POR)
C Begin subroutine computes the horizontal distance from the
center line to the point
C where the pore pressure is 0.1% of the maximum pore
C pressure under the embankment. This is taken to be the Hor. drainage
C distance. This subroutine will be active only once.
dimension UB(1), XT(1), CHIN(1), XET(1)
if (HF.eq.0.) goto 100
if (IPDR.eq.1) goto 100
C Find maximum pore pressure
do 50 i=1, IEND
if (umax.lt.UB((i-1)*MYE+1)) umax=UB((i-1)*MYE+1)
50 continue
umin=umax*0.001
i=1
60 if (UB((i-1)*MYE+1).lt.umin) goto 65
i=i+1
if (i.lt.(IEND+1)) goto 60
POR=1.+(1.-XT(IEND-1)/XT(IEND))*(UB((IEND-1)*MYE+1)-umin)/(UB((
*IEND-2)*MYE+1)-UB((IEND-1)*MYE+1))
goto 70
65 POR=(XT(i-1)+(XT(i)-XT(i-1))]*(UB((i-2)*MYE+1)-umin)/(UB((
i-2)*MYE+1)-UB((i-1)*MYE+1))/XT(IEND)
70 IPOR=1
C Redefine horizontal grid points and the related parameters
C using new horizontal drainage distance.
do 529 I=1, ICV
CHIN(I)=CHIN(I)*DXSG
529 continue
AAH=AAH*DXSG
AI=MHE-1.
DHX=POR*XT(IEND)*W/AI
do 25 I=1, MHE-1
XET(I)=POR*(I-1)*XT(IEND)/AI
25 continue
DXSG=DHX*DXH
AAH=AAH/DXSG
do 530 i=1, ICV
CHIN(i)=CHIN(i)/DXSG
530 continue
write (IATP,778) POR
778 format ('NEW POR=',F10.5)
100 return
C End of subroutine HDIST
SUBROUTINE APROX (X, Y, MN, N, D)
C
C This subroutine approximates the actual load by N strips of
C constant thickness D
C
DIMENSION X(1), Y(1), XA(25), YA(25)
COMMON/ POAPI/ ALPHA(30), L
C
C DETERMINE MAX VALUE OF Y(1)
C
M=MN
YMAX=Y(1)
DO 1 I=2, M
IF (Y(I).GT. YMAX) YMAX=Y(I)
1 CONTINUE
C
C Initiate first step starting with X(M) and Y(M)
C
AN=N
D=YMAX/AN
L=1
H=Y(M)
XX=X(M)
XA(1)=0.
C
C Compute the portion between two horizontal lines with distance D
C
2 YA(1)=H
K=2
XA(K)=XX
YA(K)=H
H=H+D
C
C If statement because of possible truncation error
C
3 IF (ABS(H-YMAX).LT.0.001) H=YMAX
MM=M-1
IF (MM.EQ.0) GO TO 4
XX=(X(M)-X(MM))*H-Y(MM))
C
IF (ABS(Y(M)-Y(MM)).LT.0.01) J=1
IF (ABS(Y(M)-Y(MM)).LT.0.01) CALL OVERFLO (J)
IF (ABS(Y(M)-Y(MM)).LT.0.01) GO TO 61
XX=XX/(Y(M)-Y(MM))
C
C If the denominator approaches zero, J is set equal to 1
C
61 IF (J.NE.1) GO TO 5
6 K=K+1
J=0
XA(K)=X(MM)
YA(K)=Y(MM)
M=MM
GO TO 3
5 XX=XX+X(MM)
IF (ABS(XX-X(MM)).LT.0.001) GO TO B
IF (XX.LT.X(MM)) GO TO 6
MM=M
GO TO 9
M=MM

9  K=K+1
XA(K)=XX
YA(K)=H

4  XA(K+1)=0.
YA(K+1)=H
A=O.
DO 10 I=1,K
J=I+1
A=A+XA(I)*YA(J)-YA(I)*XA(J)
10  CONTINUE

C Determine width of constant load equivalent to portion between
two horizontal lines with distance D.
C ALPHA is negative if this portion is to be subtracted.
ALPHA(L)=A/(2.*ABS(D))
IF (L.EQ.N) GO TO 11
13 IF (ALPHA(L).EQ.0.) L=L-1
IF (MM.EQ.0) GO TO 12
L=L+1
GO TO 2
11 IF (YMAX.LE.Y(1)) GO TO 12
D=-1.*D
GO TO 13
12 D=ABS(D)
RETURN
END

SUBROUTINE DETFS
SUBROUTINE DETFS (XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FS)

This subroutine determines the factor of safety against failure
along a circular arc by taking the ratio of the resisting and
driving moments about the center of the arc. Shear strengths
along that part of the arc, which passes through the subsoil
are obtained by interpolating between the elements of vector SU.
This is an analysis in terms of TOTAL STRESSES.

DIMENSION XINP(1),YINP(1),SU(1),XS(22),YS(22),X(2)
DIMENSION WWW(2),XAUX(10),YAUX(10),SINUS(2),COSIN(2)

REAL MD, MR

COMMON/ INDET/ RHO(19), TAUU(19), PSI(19)
COMMON/ SAPOD/ IOUTP,W,H,GLOAD,CLoad, NARC, NRAD
COMMON/ SADET/ XSTAB(51), YSTAB(11), DX, DY, YWM, TGPHI

STATEMENT FUNCTIONS

FUNA(A,B) = (XC+A*AA)/B
FUNB(B) = AB*AB+(RX-AA*AA)/B
FUNC(A,B,C)=A+B*(C-A)

The parameters have the following significance
XC, YC coord of the center of the arc.
R radius of the arc
XINP, YINP Coord of the points describing the X-section of
the embankment.
MINP No. of points XINP/YINP
MX No. of equally spaced points in X-dirn.
MYE No. of equally spaced points in Y-dirn.
SU Vector of shear strengths with MX*MYE elements
FS Factor of safety
RHO(I) Slope of the line connecting XINP(I)/YINP(I) and
XINP(I+1)/YINP(I+1)
PSI(I) YINP value of the above line for XINP=0.
TAU(I) TAU(I)=1.+RHO(I)*RHO(I)
GLOAD unit weight of the embankment soil
CLOAD Shear strength of the embankment soil
XSTAB MX equally spaced points in X-dirn.
YSTAB MYE equally spaced points in Y-dirn.
DX, DY Intervals in X- and Y-dirn.
NARC One-half no. of subarcs within subsoil

ANARC=2*NARC
MXM=MX-2
RR=R*R
XX=XC*XC
RX=RR-XX
YY=YC*YC
LAST=0

POINTS OF INTERSECTION BETWEEN ARC AND SURFACE

AA=SQRT(RR-YY)

XS(1)=XC-AA
XG=XC+AA
IF (XG.GE.XINP(MINP)) LAST=1

POINT OF INTERSECTION BETWEEN ARC AND EMBANKMENT SURFACE

I=0
J=2
I=I+1
AA=YC-PSI(I)
AB=FUNA(RHO(I), TAU(I))
AA=FUNB(TAU(I))
IF (AA.LT.0.) GO TO 1
AA=SQRT(AA)
XT=AB-AA
IF (XT.GE.XINP(I+1)) GO TO 1
XS(2)=XT
YS(2)=XT*RHO(I)+PSI(I)

Resisting moment MR due to the arc between XS(1)/YS(1)=0. and
XS(2)/YS(2) within the embankment. Driving moment MD due to
the segment between XS(1)/0. and XS(2)/YS(2).

BETA1=0.5*ASIN(YC/R)
BETA2=0.5*ASIN((YC-YS(2))/R)
MR=2. *RR*CLOAD*(BETA1-BETA2)
A = XS(1) - XS(2)
A = SQRT(A*A + YS(2)*YS(2))
IF (LAST.EQ.0) GO TO 2
C THE POINTS XS/YS ARE EQUAL TO THE POINT S XINP/YINP
C
I = I+1
DO 3 K=I,MINP
J = J+1
XS(J) = XINP(K)
YS(J) = YINP(K)
31 LAST = J
GO TO 7
C
C Determine the second point of intersection between the arc and the
c embankment surface. Store all points in XS/YS which lie between
c this point and the point XS(2)/YS(2).
C
2
XT = AB + AA
IF (XT.LE.XINP(I+1)) GO TO 4
5
I = I+1
J = J+1
XS(J) = XINP(I)
YS(J) = YINP(I)
IF (I.EQ.MINP) GO TO 31
IF (XINP(I+1).GT.XG) GO TO 6
IF (YINP(I+1).LT.YC) GO TO 5
6
AA = YC - PSI(I)
AB = FUNA(RHO(I), TAU(I))
AA = FUNB(TAU(I))
AA = SQRT(AA)
GO TO 2
4
J = J+1
XS(J) = XT
YS(J) = XT*RHO(I)+PSI(I)
Resisting and driving moments due to the arc and the segment
between the points XS(J)/YS(J) and XG/0.

BETA2 = 0.5*ASIN((YC-YS(J))/R)
LAST = J+1
XS(LAST) = XG
YS(LAST) = 0.
MR = MR+2.*RR*LOAD*(BETA1-BETA2)
A = XG-XS(J)
A = SQRT(A*A+YS(J)*YS(J))
MD = MD-(A*A*A*COS(BETA1+BETA2))/2.

DRIVING MOMENTS DUE TO TRIANGLES WITH ONE APEX AT XS(1)/0.

7
XX = 3.*XC-XS(1)
DO 8 I = 3,LAST
J = I-1
A = XS(I)*(YS(I)-YS(J))-XS(J)*YS(I)+XS(I)*YS(J)
MD = MD+(XX-XS(J)-XS(I))*A
8 CONTINUE

RESISTING MOMENT DUE TO THE PART OF THE ARC WHICH PASSES THROUGH
C TH SUBSOIL

C IF (H.EQ.0.) GO TO 100
    IF (MYE.EQ.1) GO TO 20

C Resisting moment along subarcs in the subsoil. The shear
C strengths along the Z*NARC) subarcs are assumed const and
C obtained by linear interpolation between the appropriate
C values of SU.

C

DARC=(3.1415927-4.*BETA1)/ANARC
RARC=RR*DARC
BETA=2.*BETA1-DARC/2.
DO 9 L=1,NARC
BETA=BETA+DARC
A=R*COS(BETA)
X(1)=XC-A
X(2)=XC+A
A=R*SIN(BETA)-YC
AJ=A/DY+1.
J=AJ
FY=(A-YSTAB(J))/DY

DO 10 K=1,2
AII=X(K)/DX
I=AII
IF (I.LE.MXM) GO TO 11

C Midpoint of the subarc lies outside the domain for which
C SU-s are specified. Interpolation is done in Y-dirn only
C between the values SU(MX*(MYE-1)+1) through SU (MX*MYE).

C

IJ=J+(MX-1)*MYE
JJ=IJ+MYE
AA=SU(IJ)
AB=SU(JJ)
GO TO 12

C Interpolation for the midpoint of the subarc. Two linear
C interpolation are performed in X-dirn. One linear inter-
C olation is performed in Y-dirn between the values obtained.

C

11 IJ=J+I*MYE
JJ=IJ+MYE
I=I+1
FX=(X(K)-XSTAB(I))/DX
AA=FUNC(SU(IJ),FX,SU(JJ))
IJ=IJ+1
JJ=JJ+1
AB=FUNC(SU(IJ),FX,SU(JJ))

12 MR=MR+RARC*FUNC(AA,FY,AB)
10 CONTINUE
DM=MD*GLOAD/6.
9 CONTINUE
GO TO 100

20 RARC=RR*(3.1415927-4.*BETA1)
MR=MR+SU(1)*RARC

C Factor of safety.
C
100 MD=MD*GLOAD/6.
C IF THERE IS AN OVERFLOW CONDITION, J IS SET .EQ. 1 AND FS IS SET .EQ. 1.0E-50
C
JJJ=0
IF (MD.LT.0.00000000000000001) CALL OVERFLO (JJJ)
IF (MD.LT.0.00000000000000001) GO TO 111
FS=MR/MD
111 IF (JJJ.NE.1) GO TO 40
FS=100
JJJ=0
RETURN
C Determination of the resisting moment due to friction.
C
40 IF (YWM.LE.0.) RETURN
IF (FS.LT.0.0001) FS=1.
FAC=TGPHI/FS
RMR=r1R
KOUNT=1
XAUX(1)=XS(1)
YAUX(1)=0.
AB=YC-YWM
AB=SQRT(RR-AB*AB)
XAUX(2)=XC-AB
YAUX(2)=YWM
IF (XAUX(2).GE.XS(2)) GO TO 41
XAUX(2)=XS(2)
YAUX(2)=YS(2)
41 BETA2=0.5*ASIN((YC-YAUX(2))/R)
XAUX(3)=XAUX(2)
K=3
I=1
43 I=I+1
42 IF (XAUX(K)-XINP(I)) 44,45,43
45 YAUX(K)=YINP(I)
GO TO 46
44 YAUX(K)=RHO(I-1)*XAUX(K)+PSI(I-1)
46 K=K+1
IF (XAUX(1).LE.XINP(I)) GO TO 47
XAUX(K)=XINP(I)
YAUX(K)=YINP(I)
I=I+1
GO TO 46
47 XAUX(K)=XAUX(1)
YAUX(K)=RHO(I-1)*XAUX(1)+PSI(I-1)
XAUX(K+1)=XAUX(1)
YAUX(K+1)=YAUX(1)
WW=0.
DO 48 J=1,K
L=J+1
WW=WW-XAUX(J)*YAUX(L)+YAUX(J)*XAUX(L)
48 CONTINUE
WWW(KOUNT)=WW*GLOAD/2.
AA=XAUX(1)-XAUX(2)
BB=YAUX(2)-YAUX(1)
CC=SQRT(AA**2+BB**2)
SINUS(KOUNT)=BB/CC
COSIN(KOUNT)=AA/CC
RMR=RMR-2.*RR*LOAD*(BETA1-BETA2)
IF (KOUNT.EQ.2) GO TO 49
IF (XS(LAST).EQ.XINP(MINP)) GO TO 49
KOUNT=2
XAUX(1)=XC+AB
YAUX(1)=YWM
IF (XAUX(1).LE.XS(LAST-1)) GO TO 50
XAUX(1)=XS(LAST-1)
YAUX(1)=YS(LAST-1)
50 BETA2=0.5*ASIN((YC-YAUX(1))/R)
XAUX(2)=XS(LAST)
YAUX(2)=0
XAUX(3)=XAUX(2)
K=3
GO TO 42
C ITERATION FOR THE CORRECT FACTOR SAFETY
C
49 MR=RMR
DO 51 I=1,KOUNT
MR=MR+FAC*WWW(KOUNT)*R/(COS(KOUNT)+FAC*SINUS(KOUNT))
51 CONTINUE
FSOLD=FS
FS=MR/MD
IF (ABS(FS-FSOLD).LT.0.001) RETURN
FAC=TGPHI/FS
GO TO 49
END
C END OF SUBROUTINE DETFS
C
C BEGIN SUBROUTINE GAIN
C
SUBROUTINE GAIN (UA, R, SU, MYE, MXT, MXE, MX, NIM, CO, CP, III)
C
This subroutine determines the shear strengths at MX*MYE points
XE/YE from a knowledge of the initial shear strengths CO and
the C/PBar=CP-ratios
C
UA Dissipated pore pressures at XT/YE
CR Auxiliary matrix for the computation of the dissipated pore
pressures at XT/YE from those at XT/YE
SU Shear strengths at XE/YE. SU(XE/YE) is equal to the initial
shear strength CO(YE) plus the product of the dissipated
pore pressure at XE/YE and the C/PBar-ratio CP(YE)
MYE No. of points YE in vertical direction.
NIM No. of intervals in horizontal Dirn.
MXT NIM numbers of points XT in each interval.
MXE NIM no. of points in XE in each interval
MX Total no. of points XE
CP Vector of MYE C/PBAR-ratios
CO Vector of MYE initial shear strengths
III Index for the identification of the following cases—
If III=1, all elements of UA are assumed to be zero.
If III=0, some or all elements of UA are not equal to zero
C
DIMENSION UA(1), R(1), SU(1), MXT(1), MXE(1), CO(1), CP(1)
C
K=0
IF (III.EQ.0) GO TO 1
C
ALL ELEMENTS OF UA ARE EQUAL TO ZERO
The shear strength consists of the initial strength plus some gain due to dissipated pore pressures.

```fortran
DO 2 I=1, MX
DO 2 J=1, MYE
K=K+1
SU(K)=CO(J)
2 CONTINUE
RETURN

IUBE=0
IUND=0
IRND=0
DO 3 JJ=1, NIM
IUBS=IUBE+1
IUBE=IUBE+MYE*MXT(JJ)
IUST=IUND+1
IUND=IUND+MYE*MXE(JJ)
IRST=IRND+1
IRND=IRND+MXT(JJ)*MXE(JJ)
CALL MPRD(UA, R, SU, MYE, MXT(JJ), MXE(JJ), IUBS, IRST, IUST)
3 CONTINUE
DO 4 I=1, MX
DO 4 J=1, MYE
K=K+1
SU(K)=CO(J)+SU(K)*CP(J)
4 CONTINUE
RETURN
END
END OF SUBROUTINE GAIN

BEGIN SUBROUTINE GENER

SUBROUTINE GENER (P, F, X, N)
```
This subroutine generates the N+1 Coeff. of the characteristic equation of the tridiagonal matrix P. The coeff. are stored in vector A. P must be supplied as a one-dimensional array with 2*N elements. An auxiliary vector F with ((N+1)*(N+4)/2-2) elements is used for computation. Vector X contains the N roots of the characteristic equation.

DIMENSION P(1), A(25), F(2), X(1)

IC=0
F(1)=0.
F(2)=1.0
IF=2
NF=N

COMPUTE F(3) THRU F(N+2)

DO 1 I=1,NF
IF =IF+1
IP=2*I
F(IF)=P(IP-1)*F(IF-2)+P(IP)*F(IF-1)
1 CONTINUE

IC=IC+1
A(IC)=F(IF)
IF(IC.EQ.N) GO TO 3
NF=NF-1

COMPUTE F(N+3) THRU F((N+1)*(N+4)/2-2)

F(IF+1)=0.
IF=IF+2
II=IF-NF-3
IP=2*IC
F(IF)=1.
DO 2 I=1,NF
IF=IF+1
II=II+1
IP=IP+2
F(IF)=P(IP-1)*F(IF-2)+P(IP)*F(IF-1)+F(II)
2 CONTINUE
GO TO 4

A(IC+1)=1.

CALL RROOT FOR DETERMINATION OF THE REAL ROOTS

CALL RROOT (A, X, N)

RETURN
END

END OF SUBROUTINE GENER

BEGIN SUBROUTINE GEN

SUBROUTINE GEN (S, M)

This subroutine generates the mathematical molecule for the extended Simpsons (1/3) rule or the extended trapezoidal rule. Each element is divided by the total length of the
C integration interval, thus making it only dependent on the
C number (M-1) of subintervals.

    DIMENSION S(I)

    IF (M.LE.1) RETURN
    MM=M-1
    FAC=MM
    IF (M.EQ.(M/2)*2) GO TO 3

C SIMPSON-S RULE IF M IS ODD

    FAC=1./(3.*FAC)
    I=1
    S(I)=FAC
    I=I+1
    S(I)=4.*FAC
    I=I+1
    S(I)=FAC
    IF (I.EQ.M) RETURN
    S(I)=2.*FAC
    GO TO 1

C TRAPEZOIDAL RULE IF M IS EVEN

3    FAC=1./FAC
    S(I)=FAC/2.
    S(M)=FAC/2.
    IF (MM.LT.2) RETURN
    DO 4 I=2,MM
4    S(I)=FAC
    RETURN
END

END OF SUBROUTINE GEN

BEGIN SUBROUTINE INIT

SUBROUTINE INIT (XINP, YINP, MINP, XC, YC, YY, ZZ, DMIN)

This subroutine selects starting values for the variables XC/YC
If Xc -as input- is equal to zero. In addition, three vectors
are generated which are needed in subroutine DETFS.

XINP, YINP Coord of the embankment X-section
MINP No. of Coord points XINP/YINP
XC, YC Coord of the center of the arc
DMIN Minimum increment for the variables XC, YC and R
YY Minimum value for YC
ZZ Distance below max YINP down to which YC is permissible
H Thickness of the compressible layer
RHO(I) Slope of the line connecting XINP(I)/YINP(I) and
        XINP(I+1)/YINP(I+1)
TAU TAU=1. +RHO**2
PSI(I) YINP-value of the above line for XINP=0

DIMENSION XINP(1), YINP(1)

COMMON/ SAPOD/ IOUTP, W, H, GLOAD, CLOAD, NARC, NRAD
COMMON/ INDET/ RHO(19), TAU(19), PSI(19)

XX=XINP(MINP)-DMIN
YY=YINP(1)
DO 1 I=2, MINP
  J=I-1
  RHO(J)=(YINP(I)-YINP(J))/(XINP(I)-XINP(J))
  TAU(J)=1.+RHO(J)*RHO(J)
  PSI(J)=YINP(J)-RHO(J)*XINP(J)
  IF (YINP(J).GT. YY) YY=YINP(I)
1 CONTINUE
YY=YY-ZZ
IF (XX.NE.0.) GO TO 2
YC=YY
R=YY+H
A=YY-YINP(I)
RR=R*R
XC=(XX+SQRT(RR-YY*YY)+SQRT(RR-A*A))/2.
2 RETURN
END
C CEND OF SUBROUTINE INIT
C C 
C BEGIN SUBROUTINE LAGR
C SUBROUTINE LAGR (X, Y, M, JST, XX, YY, N)
C This subroutine interpolates the values of the function Y(X)
C from the known YY(XX) by use of Lagrangian polynomial
C X Vector of arguments for which the values of the function are
C interpolated
C Y Vector of interpolated values starting with Y(JST)
C M No. of X-s
C XX Vector of arguments for which the values of the function
C are known
C YY Vector of known values of the function
C N No. of xx-s
C RN Auxiliary vector
C
C DIMENSION X(1), Y(1), XX(1), YY(1), RN(101)
C
C JS=JST-1
DO 1 J=1, M
  JJ=JS+J
  Y(JJ)=0.
1 C
 DO 3 K=1, N
 DO 4 J=1, M
  RN(J)=1.
  RD=1.
4 RN(J)=RN(J)*(X(J)-XX(I))
BEGIN SUBROUTINE MATR

SUBROUTINE MATR (IS, IE, M, XV, A, XM)

Given the vector XV with elements XV(IS), XV(IS+1),...XV(IE), this subroutine generates the M by IE-IS+1 matrix XM, whose elements are stored one dimensionally as follows—

XM(1)=1, XM(2)=(XV(IS)-A), XM(3)=(XV(IS)-A)**2, ... XM(M)=(XV(IS)-A)**(M-1), XM(M+1)=1, XM(M+2)=(XV(IS+1)-A), ... XM(M*(IE-IS+1))=(XV(IE)-A)**(M-1)

Subtraction of A is done to increase the accuracy.

DIMENSION XV(1), XM(1)

K=0
DO 1 I=IS, IE
K=K+1
XM(K)=1
XVT=XV(I)-A

IF STATEMENT TO INCLUDE CASE M=1

IF (M.EQ.1) GO TO 1
DO 2 J=2, M
L=K
K=K+1
2 XM(K)=XM(L)*XVT
1 CONTINUE
RETURN
END

END OF MATR

begin subroutine minv

SUBROUTINE MINV (A, N, D)

This subroutine inverts a general matrix A by means of the standard Gauss-Jordan method.

DIMENSION A(1), L(1600), M(1600)
C SEARCH THE LARGEST ELEMENT
D=1.0
NK=-N
DO 80 K=1,N
NK=NK+N
L(K)=K
M(K)=K
KK=NK+K
BIGA=A(KK)
DO 20 J=K,N
IZ=N*(J-1)
DO 20 I=K,N
IJ=IZ+I
10 IF (ABS(BIGA)-ABS(A(IJ))) 15,20,20
15 BIGA=A(IJ)
L(K)=I
M(K)=J
20 CONTINUE
C INTERCHANGE ROWS
J=L(K)
IF (J-K) 35,35,25
25 KI=K-N
DO 30 I=1,N
KI=KI+N
HOLD=-A(KI)
JI=KI-K+J
A(KI)=A(JI)
30 A(JI)=HOLD
C INTERCHANGE COLUMNS
35 I=M(K)
IF (I-K) 45,45,38
38 JP=N*(I-1)
DO 40 J=1,N
JK=NK+J
JI=JP+J
HOLD=-A(JK)
A(JK)=A(JI)
40 A(JI)=HOLD
C Divide column by minus pivot (value of pivot element is contained in BIGA)
45 IF (BIGA) 48,46,48
46 D=0.0
RETURN
C REDUCE MATRIX
DO 65 I=1,N
IK=NI+I
IJ=I-N
DO 65 J=1,N
IJ=IJ+N
IF (I-K) 60, 65, 60
60 IF (J-K) 62, 65, 62
62 KI=I-J+K
A(IJ)=A(IK)*A(KJ)+A(IJ)
65 CONTINUE

DIVIDE ROW BY PIVOT

KJ=K-N
DO 75 J=1,N
KJ=KJ+N
IF (J-K) 70, 75, 70
70 A(KJ)=A(KJ)/BIGA
75 CONTINUE

PRODUCT OF PIVOTS

D=D*BIGA

REPLACE PIVOT BY RECIPROCAL

A(KK)=1.0/BIGA
80 CONTINUE

FINAL ROW AND COLUMN INTERCHANGE

K=N
100 K=K-1
105 I=L(K)
IF (I-K) 150, 150, 105
105 I=L(K)
IF (I-K) 120, 120, 108
108 JG=N*(K-1)
JR=N*(I-1)
DO 110 J=1,N
JK=JG+J
HOLD=A(JK)
JI=JR+J
A(JK)=-A(JI)
110 A(JI)=HOLD
120 J=M(K)
IF (J-K) 100, 100, 125
125 KI=K-N
DO 130 I=1,N
KI=KI+N
HOLD=A(KI)
JI=KI-K+J
A(KI)=-A(JI)
130 A(JI)=HOLD
GO TO 100
150 RETURN
END

END OF SUBROUTINE MINV
BEGIN SUBROUTINE MODAL

SUBROUTINE MODAL (LAYER, IBC, N, FIMP, RC, RK, XO, XE, EIG, X, XI, F)

This subroutine generates the coeff. matrix P, determines the
characteristic equation which is then solved to give the eigen
values EIG. Knowing the eigenvalues, the modal matrix X is
computed to generate its inverse XI. Generation of P depends
on the boundary conditions which are indicated by LAYER, IBC
CHI, RC, RK, XD and XE.

C LAYER    Index for identification of drainage condition and
layer interface if any.
C LAYER=1  Mori Drainage
C LAYER=2  Vert. drainage, homogeneous soil
C LAYER. GE. 4 - Vert. drainage, two layers where layer gives
the location of the interface.
C IBC      Index for identification of boundary conditions
C IBC=1    Vert. drainage- Impeded drainage at bottom
C IBC=2    Vert. drainage- Free drainage at bottom
C IBC=3    Vert. drainage- No drainage at bottom
C FIMP     Impeded drainage factor
C RC       Ratio of coeff. of consol. (Lower/upper layer)
C RK       Ratio of coeff. of permeability (Lower/upper layer)
C XD       Lower boundary of the solution domain. XD=0. if LAYER. GT. 1
C XE       Upper boundary of the solution domain. XE=H if LAYER. GT. 1
C EIG      Vector of eigenvalues
C X        Modal matrix=Matrix of eigenvectors
C XI       Inverse of X
C D,F      Auxiliary matrices
C P        Coeff. matrix
C N        No. of eigenvalues=No. of Nodal points in the program
numbering system.

DIMENSION P(100), D(50), F(1), EIG(1), X(1), XI(1)

IF (IBC.EQ.4) GO TO 25
IF (LAYER.NE.2) GO TO 1
IF (IBC.NE.2) GO TO 2

COMPUTE EIGEN VALUES AND MODAL MATRIX DIRECTLY FOR LAYER=2
AND IBC=2

AN=N+1
AN=3.141592653589793/AN
KJ=0
DO 3 J=1,N
AJ=J
EIG(J)=-2.*COS(AJ*AN)
3 CONTINUE
GO TO 4
IF (IBC .NE. 3) GO TO 1

COMPUTE EIGEN VALUES AND MODAL MATRIX DIRECTLY FOR LAYER=2 AND IBC=3

AN=2*N
AN=3. 141592653589793/AN
KJ=0

DO 5 J=1, N
AJ=2*J-1
EIG(J)=-2. +2. *COS(AJ*AN)

DO 5 K=1, N
KJ=KJ+1
AK=K
X(KJ)=SIN(AK*AJ*AN)
5 CONTINUE
GO TO 4

GENERATE MATRICES P AND D FOR CASES WHERE 2 .NE. IBC .NE. 3

1 D(1)=1. 0
P(1)=0. 0
P(2)=2. 0
IF (IBC .LT. 4) GO TO 6

CASE OF HORIZONTAL FLOW

25 AN=2*N
AN=3. 141592653589793/AN
KJ=0

DO 7 J=1, N
AJ=2*J-1
EIG(J)=-2. +2. *COS(AJ*AN)

DO 7 K=1, N
KJ=KJ+1
AK=K
X(KJ)=SIN(AK*AJ*AN)
7 CONTINUE
GO TO 4

GENERATE P AND D FOR VERTICAL DRAINAGE

6 INT=N
IF (LAYER .GT. 2) INT=LAYER-2
IF (LAYER .EQ. 3) I=1
GO TO 27

DO 9 I=2, INT
IE=2*I
P(IE-1)=-1.
P(IE)=2.
D(I)=1.
9 CONTINUE
IF (INT. NE. N) GO TO 10
P(IE)=2.*FIMP
GO TO 8

C C COEFFICIENTS OF P AND D FOR THE LAYERED CASE

C 10 P0=-RC*RC
    PE=2.*RC
    FIN=PE/(RC+RK)
    P(IE+1)=-FIN
    P(IE+2)=FIN*(1.+RK)
    D(INT+1)=FIN
    P(IE+3)=-FIN*RC*RK
    P(IE+4)=PE
    D(INT+2)=FIN*RC
    INT=INT+3

C DO 11 I=INT,N
    IE=2*I
    P(IE-1)=P0
    P(IE)=PE
    D(I)=RC*D(I-1)
11 CONTINUE

C IF (IBCV. NE. 3) GO TO 12
P(IE-1)=2.*P0
D(N)=2.*D(N)
GO TO 8

C 12 IF (IBCV. EQ. 1) P(IE)=RC*(2.-FIMP)

C Call GENER to generate the characteristic equation and to compute
C the eigen values EIG
C
8 CALL GENER (P,F,EIG,N)

C Compute eigenvectors from P,D and EIG
C
MEND=N-1
NN=2*N
DO 15 K=1,N
NK=N*K
X(NK)=1.
X(NK-1)=P(NN)+EIG(K)
15 CONTINUE

C DO 16 ME=2,MEND
    NN=NN-2
    DO 16 K=1,N
    NK=N*K-ME
    X(NK)=P(NN+1)*X(NK+2)+(P(NN)+EIG(K))*X(NK+1)
16 CONTINUE

C Premultiply matrix X by matrix D
C Restore the X-elements since MINV destroys the original matrix
C
I=0
DO 20 J=1,N
DO 20 K=1,N
1-1*1

C CALL MINV FOR INVERSION
CALL MINV (XI, N, DET)
RETURN
END
END OF SUBROUTINE MODAL
C SUBROUTINE MPRD BEGINS
C This subroutine premultiplies the M*L matrix B by the N*M matrix A and stores the result in the N*L matrix R. The first elements of the matrices are A(IAS), B(IBS), R(IRS). The normal case will be that where IAS=IBS=IRS=1. If all matrices are stored one dimensionally, the following formula for the element R(IR) is obtained--- R(IR)=R(J+(K-1)*N+IRS-1)=SUM(I=1,M) of A(J+(I-1)*N+IAS-1)*B(I+(K-1)*M+IBS-1)

DIMENSION A(I), B(I), R(I)

IR=IRS-1
KM=IBS-M-1
DO 1 K=1,L
KM=KM+M
DO 1 J=1,N
IR=IR+1
IA=J+IAS-N-1
IB=KM
R(IR)=0.
DO 1 I=1,M
IA=IA+N
IB=IB+1
R(IR)=R(IR)+A(IA)*B(IB)
1 CONTINUE
RETURN
END
END OF MPRD

BEGIN RROOT

C SUBROUTINE RROOT (COF, XR, M)
This subroutine computes the real roots of an M-th degree polynomial. COF is the coeff. vector with M+1 elements. XR is the vector containing the M roots. M must be greater than 2 but less than 30 because of stotage allocation. The polynomial has the form F(X)=0.= COF(1)+COF(2)*X+...+COF(M+1)*X**M
A, B, C are auxiliary vectors of length M+1
C EPS gives the required accuracy.
C
DIMENSION CDF(1), XR(1), A(50), B(50), C(50)
C
EPS=1. /1000.
N=M
NN=M+1
X=0.
C
C Rename original coeff. for final iteration.
C
DO 1 J=1, NN
A(J)=CDF(J)
1 CONTINUE
C
C Apply newtons rule X(J+1)=X(J)-FX(X(J))/((D?DX)(F(XJ)))
C and obtain the values of the function and its derivative
C for the guess X(J) from HOrners scheme. The roots are
C always approximated from above and the last root is used
C as initial guess for the reduced polynomial.
C
2
B(NN)=A(NN)
C(NN)=A(NN)
4
I=NN
C
DO 3 J=2, N
I=I-1
B(I)=A(I)+X*B(I+1)
C(I)=B(I)+X*C(I+1)
3 CONTINUE
B(1)=A(1)+X*B(2)
C
C Newtons rule and accuracy check
C
DX=-B(1)/C(2)
X=X+DX
EPAB=EPS*ABS(X)
IF (ABS(DX).GT.EPAB) GO TO 4
XR(N)=X
C
C Define coeff. of the reduced polynomial.
C
DO 6 J=1, N
A(J)=B(J+1)
6 CONTINUE
NN=N
N=N-1
IF (N.GT.1) GO TO 2
XR(1)=-A(1)/A(2)
C
C The roots are now stored as XR(1).LT.XR(2).LT. .... LT.XR(M)
C Make the final iteration using the original polynomial
C
MM=M-1
DO 7 K=1, MM
9 I=M+1
DO 8 J=2, M
I=I-1
B(I)=CDF(I)+XR(K)*B(I+1)
C(I)=B(I)+XR(K)*C(I+1)
SUBROUTINE STAB

SUBROUTINE STAB (XC, YC, R, XINP, YINP, MINP, MX, MYE, SU, FX, D, DM, YY)

This subroutine searches automatically for the smallest factor of safety starting with the initial data set XC, YC, R

The parameters have the following significance

Xc, Yc  Coord of the center of the arc
R      Radius of the arc
XINP   Coord of the points describing the x-section of
YINP   the embankment
MINP   No. of XINP/YINP points
MX     No. of equally spaced points in X-dirn
MYE    No. of equally spaced points in Y-dirn
SU     Vector of shear strengths with MX*MYE elements
FX     Minimum factor of safety
D      Maximum step size be used in the search program
DM     Minimum step size be used in the search program
YY     Minimum permissible value for YC
X, Y, Z Auxiliary vectors

DIMENSION XINP(1), YINP(1), SU(1), X(2), Y(2), Z(2)

Evaluate safety factor at initial base point

X(1) = YC
X(2) = XC
KEN = -1
11
KEN = KEN + 1
DEL = D
CALL VARYR (X(1), X(2), R, XINP, YINP, MINP, MX, MYE, SU, FX, DM, YY)
4
FS = FX
DO 1 I = 1, 2
Y(I) = X(I)
1
Z(I) = X(I)

EXPLORATORY MOVES

DO 2 I = 1, 2
Y(I) = Z(I) + DEL
CALL VARYR (Y(1), Y(2), R, XINP, YINP, MINP, MX, MYE, SU, FY, DM, YY)
IF (FY.LT.FX) GO TO 5
Y(I)=Z(I)-DEL
CALL VARYR (Y(I), Y(2), R, XINP, YINP, MINP, MX, MYE, SU, FY, DM, YY)
IF (FY.LT.FS) GO TO 5
Y(I)=Z(I)
GO TO 2

5
FS=FY
2
CONTINUE
IF (FS.LT.FX) GO TO 6
IF (DEL.LE.DM) GO TO 10
DEL=DEL/2.
GO TO 4

C
C PATTERN MOVE
C
6
DO 3 I=1,2
A=Y(I)-X(I)
IF (A) 7,8,9
7
A=-2.*DEL
GO TO 8
9
A=2.*DEL
8
B=X(I)
X(I)=Y(I)
Y(I)=B+A
3
CONTINUE
FX=FS
CALL VARYR (Y(1), Y(2), R, XINP, YINP, MINP, MX, MYE, SU, FS, DM, YY)
IF (FS.LT.FX) GO TO 6
GO TO 4

C
C Start new search if the circle giving the minimum safety factor
C so far does not outcrop at or in front of the embankment toe
C
10
IF (KEN.EQ.1) GO TO 12
FMIN=FX
13
YC=X(1)
XC=X(2)
IF (KEN.EQ.1) GO TO 14
IF ((XC+SQRT(R*R-YC*YC)).LT.XINP(MINP)) GO TO 11
GO TO 14
12
IF (FMIN.GT.FX) GO TO 13
FX=FMIN
14
RETURN

C
END
C
END OF STAB
C
C
SUBROUTINE VARYR (YC, XC, R, XINP, YINP, MINP, MX, MYE, SU, FS, DMIN, YY)
C
This subroutine evaluates the factors of safety for NRAD
C trial arcs with the same center XC/YC, but different radii.
C
DIMENSION XINP(1), YINP(1), SU(1), F(10)
C
DIMENSION C(6)
C
COMMON/ SAPOD/ IDOUTP, W, H, QLOAD, CLOAD, NARC, NRAD
C
Arcs whose centers lie below YY are not considered
IF (YC.LT.YY) go to 10

Determine minimum and maximum radi possible

\[ R_{\text{MIN}} = YC \]
\[ \text{IF } (XC.LT.XINP(MINP)) \text{ GO TO 1} \]
\[ AI = XC - XINP(MINP) + DMIN \]
\[ R_{\text{MIN}} = \text{SQRT}(AI^2 + YC^2) \]

1

\[ R_{\text{MAX}} = YC + H \]
\[ AI = YC - YINP(1) \]
\[ AI = \text{SQRT}(AI^2 + XC^2) \]
\[ \text{IF } (R_{\text{MAX}}.LT.AI) \text{ RMAX} = AI \]
\[ \text{IF } (R_{\text{MAX}}.GE.RMIN) \text{ GO TO 2} \]

10

\[ R = 0. \]
\[ FS = 1.0E36 \]
\[ FS = 1.0E35 \]
\[ \text{GO TO 3} \]

2

\[ R = R_{\text{MAX}} \]

Determine the factor of safety for the maximum radius

\[ \text{CALL DETFS } (XC, YC, R, XINP, YINP, MINP, MX, MYE, SU, FS) \]
\[ \text{IF } (R_{\text{MAX}}.LE.(1.02*RMIN)) \text{ GO TO 3} \]

NN = NrAD - 1
\[ \text{IF } (NN.EQ.0) \text{ GO TO 3} \]
\[ AI = NN \]
\[ \text{DELTA} = (R_{\text{MAX}} - RMIN) / AI \]

Determine the factors of safety for arcs with radii
\[ RR = RMIN + (I-1) \cdot \text{DELTA}, \text{ and store them in vector } F \text{ at place } 2*1-I \]

\[ RR = 1.00001 \cdot RMIN - \text{DELTA} \]
\[ \text{DO 4 } J = 1, NN \]
\[ RR = RR + \text{DELTA} \]
\[ \text{CALL DETFS } (XC, YC, RR, XINP, YINP, MINP, MX, MYE, SU, F(J)) \]

4

CONTINUE

Search for the minimum factor of safety which is then returned to the calling program together with the corresponding radius

\[ \text{DO 5 } I = 1, NN \]
\[ \text{IF } (F(I).GE.FS) \text{ GO TO 5} \]
\[ FS = F(I) \]
\[ AI = I - 1 \]
\[ R = RMIN + AI \cdot \text{DELTA} \]

5

CONTINUE

3

RETURN

END

END OF VARYR

BEGIN SUBROUTINE EFCEN

SUBROUTINE EFCEN (PSI, T, EIG, IVAR, MM, NN, D, LI)

This subroutine generates the time-dependent diagonal matrix D
VECTOR which considers the influence of the soil parameters

TIME for which the diagonal matrix D is generated

VECTOR of eigen values

Const. soil parameters

Variable soil parameters

No. of points XT for which D must be evaluated

No. of eigenvalues

Diagonal matrix to be returned

DIMENSION PSI(1), EIG(1), D(1)

EF=64.

IF (T. NE. 0.) GO TO 7

LAST=MM*NN

DO 8 I=1, LAST

8 D(I)=1.0

RETURN

IF (IVAR. EQ. 0) GO TO 1

VARIABLE SOIL PARAMETERS

II=0

DO 2 J=1, MM

PSIT=PSI(J)*T

DO 2 I=1, NN

if (MM. EQ. 1) PSIT=PSI(I)*T

II=II+1

D(II)=10.**((PSIT*EIG(I)/2.302585)/EF)

2 CONTINUE

RETURN

CONSTANT SOIL PARAMETERS

1 PSIT=PSI(1)*T

DO 3 I=1, NN

D(I)=10.**((PSIT*EIG(I)/2.302585)/EF)

IF (MM. LT. 2) GOTO 3

II=I

DO 6 J=2, MM

II=II+NN

6 D(II)=D(I)

3 CONTINUE

RETURN

END

END OF SUBROUTINE EFGEN