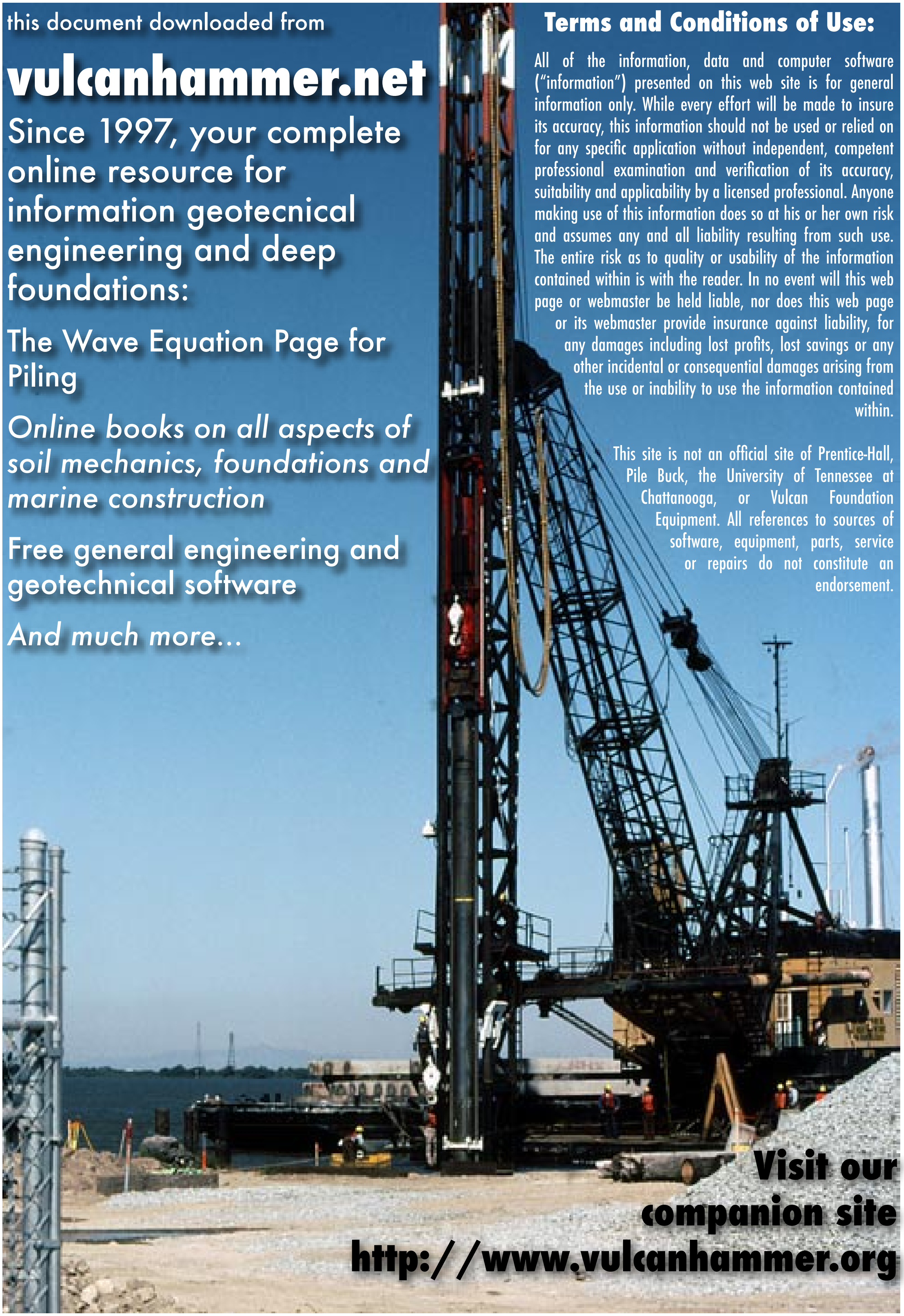

INSTRUCTION REPORT K-80-5

COMPUTER PROGRAMS FOR SETTLEMENT ANALYSIS

by

Reed L. Mosher and N. Radhakrishnan

Automatic Data Processing Center
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

October 1980

Final Report

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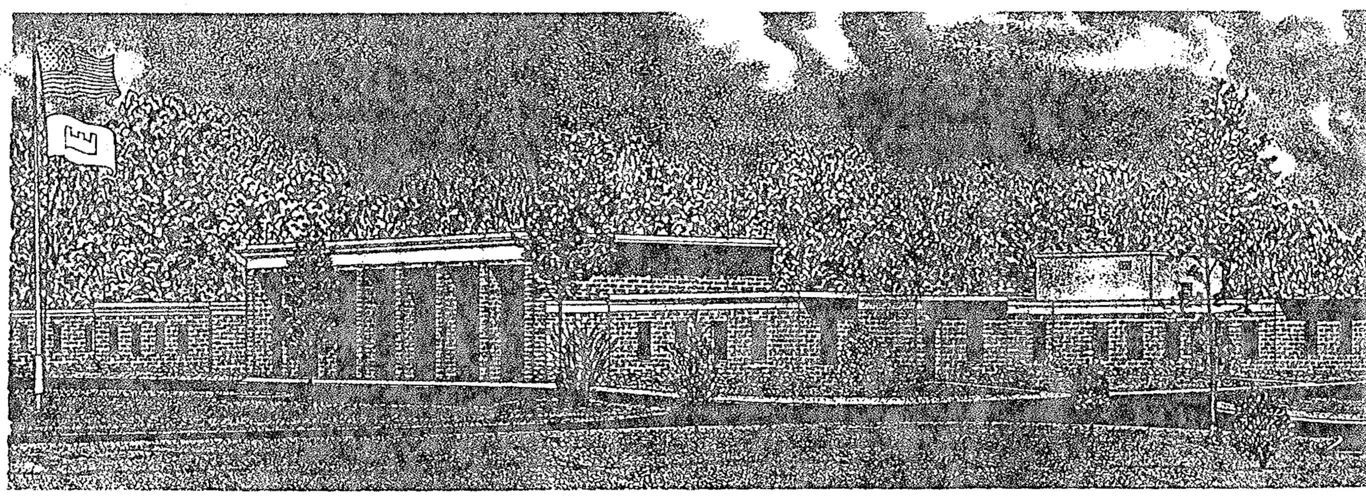

Prepared for U. S. Army Engineer Division, Lower Mississippi Valley
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents and gives example runs of three computer programs for performing settlement analysis of foundations and embankments. The programs are I0016, MAGSETII, and FD31. Program I0016, which was developed by Mr. Douglas Spaulding, St. Paul District, determines vertical stresses beneath footings and embankments. MAGSETII was written by Messrs. R. L. Schiffman, D. M. Jubenville, and V. Partyka of the University of Colorado to calculate the magnitudes of settlement of multilayered soil systems. Dr. Roy E. Olson, University of Texas at Austin, developed FD31 to determine time-settlement (Continued)

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20. ABSTRACT (Continued)

relationships for cohesive soils due to large uniformly distributed loads.

PREFACE

This report provides documentation of three computer programs for performing settlement analysis of foundations and embankments. The report was written as part of the normal operation of the joint U. S. Army Engineer Waterways Experiment Station (WES) and U. S. Army Engineer Division, Lower Mississippi Valley, Computer Center for Fiscal Years 1978 and 1979.

The three computer programs documented herein are I0016, MAGSETII and FD31. Program I0016, which was developed by Mr. Douglas Spaulding, Foundation, Materials, and Survey Branch, St. Paul District, determines vertical stresses beneath footings and embankments. MAGSETII was written by Messrs. R. L. Schiffman, D. M. Jubenville, and V. Partyka of the University of Colorado to calculate the magnitudes of settlement of multilayered soil systems. Dr. Roy E. Olson, University of Texas, Austin, developed FD31 to determine time-settlement relationships for cohesive soils due to large uniformly distributed loads.

The documentation was put together in a package, with example runs and comparisons with hand computations, by Mr. Reed L. Mosher, Computer-Aided Design Group, Automatic Data Processing (ADP) Center, WES, under the direct supervision of Dr. N. Radhakrishnan, Special Technical Assistant, ADP Center. This report was written by Mr. Mosher and Dr. Radhakrishnan. Mr. D. L. Neumann was Chief of the ADP Center.

COL J. L. Cannon, CE, and COL N. P. Conover, CE, were Directors of WES during the preparation of this report. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, INCH-POUND TO METRIC (SI) UNITS OF MEASUREMENT

Inch-pound units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
kips (1000 lb force)	4.448222	kilonewtons
kips (force) per square foot	47.88026	kilopascals
pounds (force) per square foot	47.88026	pascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
square feet	0.09290304	square metres

PROGRAM INFORMATION

This settlement package described herein is operational on the U. S. Army Engineer Waterways Experiment Station's Honeywell G-635 time-sharing system at Vicksburg, Miss., and on the Office of Personnel Management's Honeywell 6000 Series time-sharing system at Macon, Ga. The file names used for the programs are listed below with short descriptions of how to access each. It is assumed that the user knows how to sign on to the system he is using.

I0016

```
* FORT
* RUN WESLIB/CORPS/I0016,R
```

MAGSETII

```
* FORT
* RUN WESLIB/CORPS/I0010,R
```

FD31

```
* FORT
* RUN WESLIB/CORPS/I0011,R
```

COMPUTER PROGRAMS FOR SETTLEMENT ANALYSIS

PART I: INTRODUCTION

Purpose

1. A package of three programs for performing settlement analysis of foundations and embankments is documented in this report. The programs are based on theories and methods accepted by practicing engineers and presented in universities throughout the United States.

2. The package can be a very powerful and time saving aid to the foundation engineer in the analysis of complex foundation systems. Without the use of the computer, solutions to problems involving such systems could be lengthy and tedious and leave room for human error. The programs allow the foundation engineer to be more creative by providing more time to explore innovative alternatives.

Programs in the Package

3. The package consists of three separate programs: I0016, MAGSETII, and FD31. I0016 determines vertical stresses beneath footings and embankments. It was developed by Douglas Spaulding (1968) of the St. Paul District. MAGSETII calculates the magnitudes of settlement of multilayered soil systems. It was written by R. L. Schiffman, D. M. Jubenville, and V. Partyka (1976) at the University of Colorado. Additions to the program to compute the degree of consolidation have been made. FD31 develops time-settlement relationships for cohesive soils due to large uniformly distributed loads. It was written by Roy Olson at the University of Texas at Austin.

Scope

4. This report provides documentation for the three computer

programs used in the package. Theories on which the programs are based, along with capabilities of the programs, are discussed. Input/output for the programs is discussed using three example problems. One of the example problems is taken from Engineer Manual 1110-2-1904 (Headquarters, Department of the Army, Office of the Chief of Engineers 1953). Documentation for the programs, as provided by the original authors, is referenced in this report. Original documentation forthe programs can be obtained from the Engineering Computer Program Library (ECPL) at the U. S. Army Engineer Waterways Experiment Station (WES).

PART II: METHODS AND CAPABILITIES

Program I0016

5. Program I0016 can calculate vertical stress distributions in a soil profile based on either Boussinesq or Westergaard solutions. Both methods assume that the soil is homogeneous, isotropic, and linearly elastic. Westergaard further assumes that there are no lateral deformations. These assumptions do not completely model actual soil behavior, but without these assumptions solutions are only possible using more sophisticated techniques. In most cases, the results obtained using these simplified assumptions are reasonably accurate when compared to field observations (see Spaulding 1968). I0016 allows the user to analyze rectangular loadings and/or embankment loadings in a three-dimensional layout. The embankment loadings are applied by number of uniform rectangular shaped layers with the width decreasing with height. This allows the user to consider problems involving time-dependent loads due to construction, etc. The user has the option to choose the horizontal or vertical plane to be investigated. The capabilities are illustrated best in the example problems presented in Part III.

Program MAGSETII

6. Program MAGSETII utilizes Terzaghi's one-dimensional consolidation theory, simplified to apply to a two-dimensional condition, for estimating settlements in cohesive soils. The effective stress history for each layer or for the total profile can be input to the program. The program applies a vertical stress influence factor, due to the loading, to the effective stress history. Under this effective stress history, some very complex loadings can be accounted for, such as: unloading due to excavation, temporary and/or permanent changes in water table, live loads applied to the structure, and loadings due to adjacent structures or construction. Granular soils are handled by empirical correlations to static or dynamic penetration field tests. MAGSETII takes into

account strain influence with depth in granular soils. It has two built-in methods to account for strain influence (Figure 1), or the user can enter a set of influence factors. Also, for granular soils, three methods are available for estimating settlements: Meyerhof's, D'Appolonia's, and Schmertmann's. The first two methods use data from a standard penetration test; Schmertmann's method uses data from a static cone penetrometer test (see Schuffman, Jubenville, and Partyka 1976).

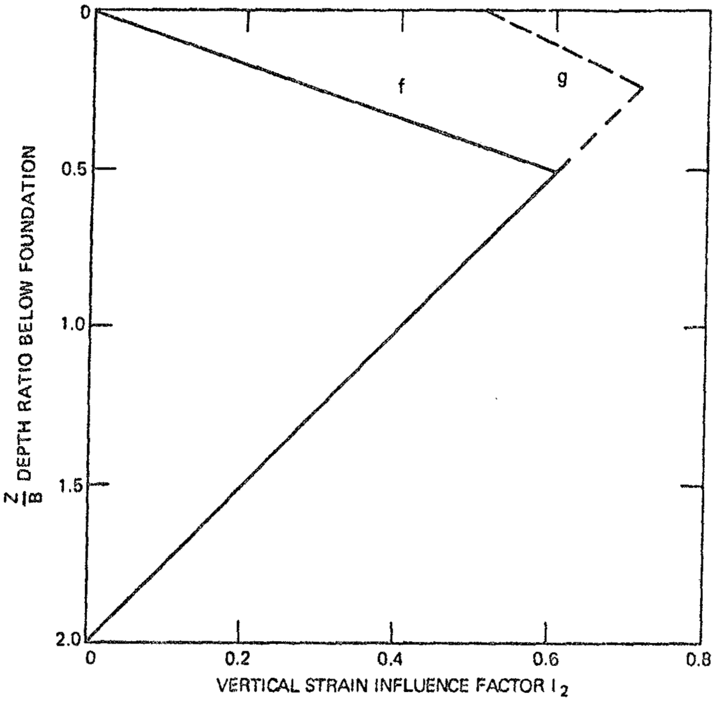


Figure 1. Strain influence in sands

7. A subroutine to compute rate of settlement has been added. These computations are based on Terzaghi's theory and methods described in EM 1110-2-1904. This addition gives the user the option to consider the effect of time-dependent loading on the rate of settlement, as outlined in EM 1110-2-1904.

Program FD31

8. Settlement and time-settlement relationships for compressible

materials are computed in FD31 based on Terzaghi's one-dimensional consolidation theory. The program is only valid for one-dimensional analysis. The differential equations derived from the theory are solved by finite difference methods of analysis. (See Olson.) FD31 provides the user with a very versatile tool to compute settlement and rate of settlement for cohesive soil. The program allows for a stratified soil profile, subject to time-dependent loadings; soils that are not linearly elastic, which may be subject to large and nonuniform strains, and whose coefficients of permeability and compressibility may vary with effective stresses; and stress conditions that are altered by a changing water table and settlement-dependent submergence of the soil.

9. FD31 is a specialized program. It is very sensitive to the data input, and the user must be careful in correctly modeling the in situ situation. Input data come from standard laboratory tests and field observations. The program does not take into account the influence of vertical stress distribution with depth.

Loads

10. Geometric configurations play an important part in the choice of program. Two basic types of loadings can be handled. These are: (a) concentrated loads and (b) uniformly distributed loads. If the width of the structure applying the load at the surface is relatively small in comparison to the depth of the compressible soil, the load can be considered to be concentrated. Loading conditions which fall under this category are: strip footings, spread footings, some raft foundations, and also embankments in which the base is relatively small in comparison to the compressible soil being considered. If the area being loaded is wide compared to the depth of the compressible soil, the load should be considered as uniformly distributed. Loading conditions which fall under this category are: fills, embankments, and large excavations.

11. For analysis of concentrated loads, MAGSETII is the primary program used. It can handle a multilayered soil profile of cohesive and/or granular material. It can account for preloadings and unloadings.

When estimating settlements for cohesive material under a concentrated loading, I0016 is used to calculate the vertical stress distribution beneath the point being investigated. The data from this program can be used directly in MAGSETII. To achieve the best accuracy, large layers of compressible material are subdivided into several smaller layers.

12. For analysis of large uniformly distributed loads on layers of compressible material, FD31 is used. In the case where a compressible soil and a granular soil are in the same profile, the settlement due to the granular material would be negligible in comparison with the settlement of the cohesive soil.

PART III: EXAMPLE PROBLEMS ILLUSTRATING INPUT/OUTPUT FOR PROGRAMS I0016 AND MAGSETII

13. In this Part, two example problems are solved using programs I0016 and MAGSETII. Input/output for the two programs is also described. Results of problem 1 are compared with hand solutions. Problem 2 is taken from EM 1110-2-1904, and the results are compared with values from that source.

Example Problem 1

Program I0016

14. Organization of input. The input data are categorized into three groups: header lines, loading configuration data, and stress distribution data. The first of these groups consists of five lines of data describing the particular run. The second group describes the geometric configuration and loads applied by embankments and/or footings. The third group defines the type of analysis (Boussinesq or Westergaard) and the location and direction (whether distribution along a vertical or horizontal plane is desired). The amount of data required for the second and third data groups is dependent on the complexity of the problem and the output required.

15. Mode of input. Input to the program can be either from the terminal or from a data file. (Example problem 1 was solved using data input from the terminal; problem 2, which is discussed later in this Part, was solved by reading data already stored in a data file.) All input is in free field. Data items can be separated by a blank space or a comma. If information is being read from a data file, each line of data must be preceded by a line number. When operating from the terminal, the program can create files to save the input data and the output. Detailed input with definitions of input variables for program I0016 is shown in later paragraphs of this Part using problem 1 as an example.

16. Problem definition. Figure 2 shows a plan view of two rectangular footings loading the soil profile shown in Figure 3. The profile

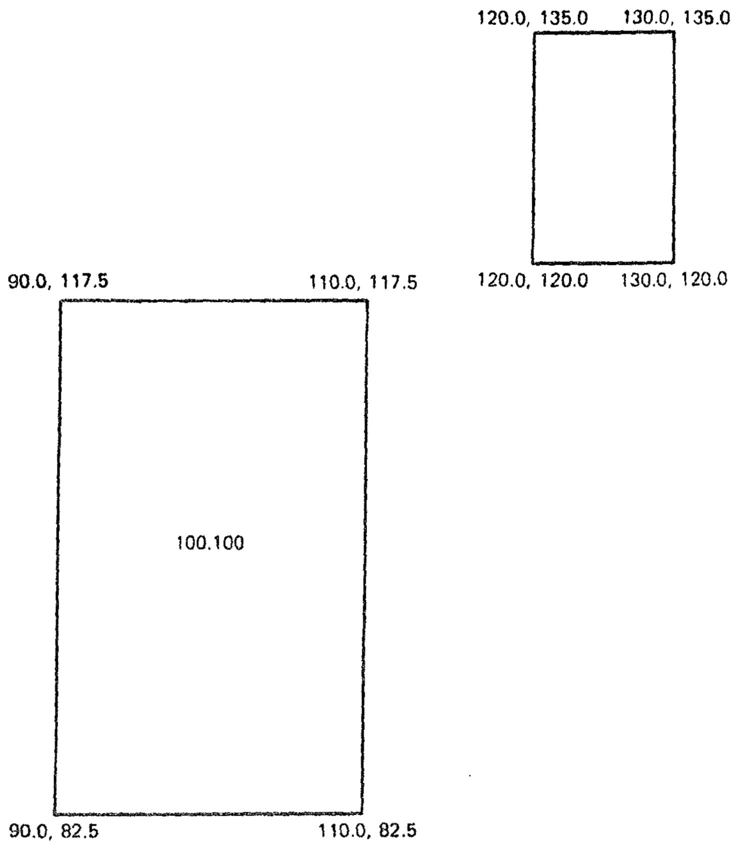


Figure 2. Plan view of footings

consists of 10 ft* of fill material and 15-, 6.5-, and 20.5-ft layers of clay material with a 25-ft layer of sand and gravel sandwiched between the last two clay layers. The water table is 25 ft below the surface.

17. The footings are placed after excavating 10 ft of material. Then 10 ft of new fill material is placed and compacted. As construction continues, the structure applies loads of 2.0 and 2.5 kips/ft^2, respectively, to the footings. At the end of construction, 0.5 kip/ft^2 is relieved from the footings. Table 1 shows this information and the times these events occur.

18. Figures 4-6 show void ratio versus effective stress curves

---

* A table of factors for converting inch-pound units of measurement to metric (SI) units is presented on page 3.

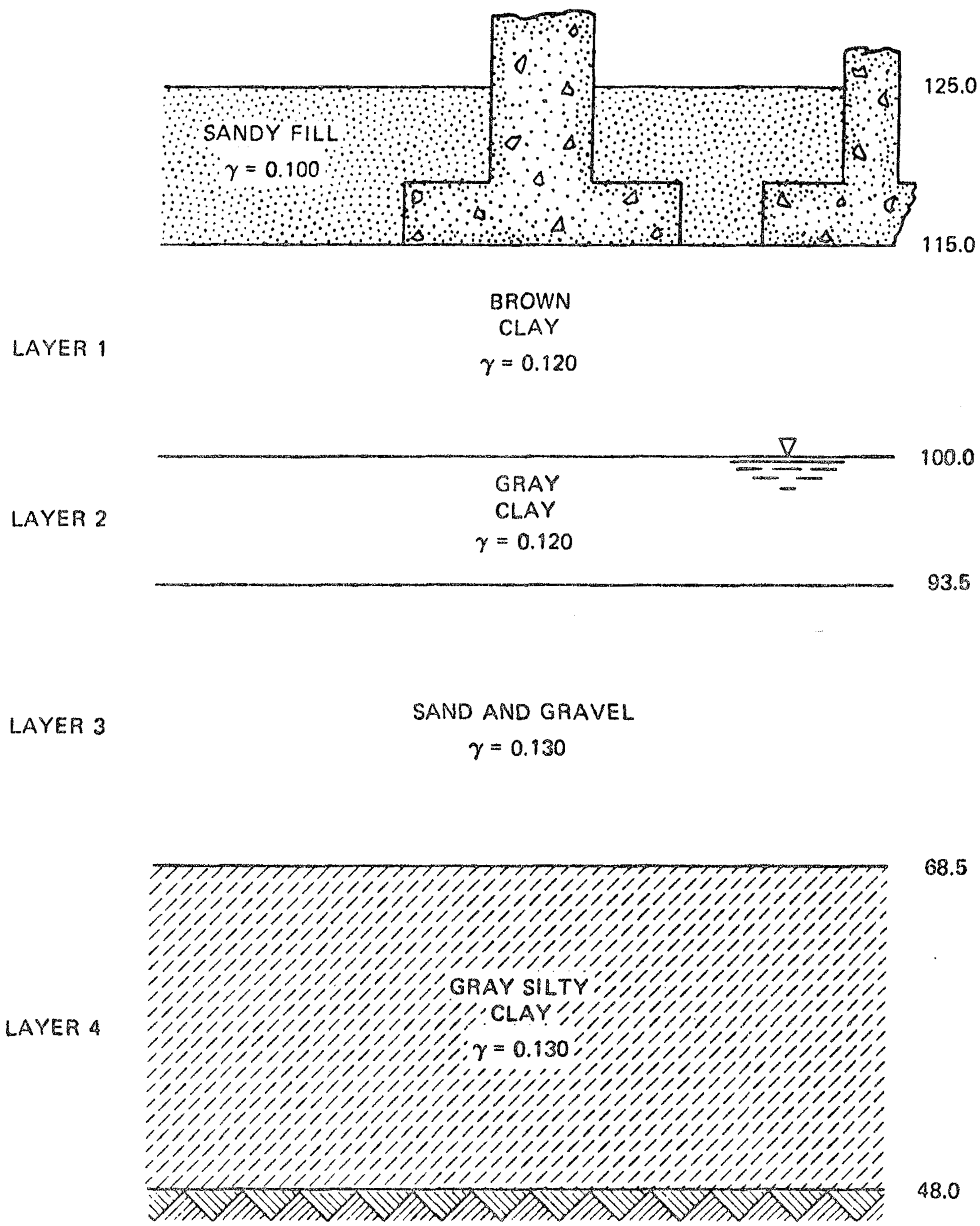


Figure 3. Soil profile for example problem 1

Table 1

Loading Conditions for Example Problem 1

Load Increment	Load	Time Interval days
1	10 ft of fill excavated	0 to 50
2	10 ft of new fill	50 to 75
3	2-kips/ft^2 loading	75 to 200
4	2.5-kips/ft^2 loading	200 to 300
5	0.5-kip/ft^2 unloading	300 to 350

for the three clay layers in the soil profile. This information is given in tabular form in Table 2. Table 3 shows results from standard penetration tests for the sand layer.

19. For this example, the settlement is estimated under the center of the footing. Program I0016 is first used to calculate the vertical stress influence factors beneath the center of the footing for the cohesive layers. This will be done at the midheight of each layer.

20. Input. Data required for program I0016, arranged by groups, are shown below.

a. Problem information. Five header lines are required at the beginning of the data entry. These lines may be used to describe pertinent information about the loading configuration to be analyzed. This information will be printed on the output sheet and will serve to identify the output. If fewer than five lines are used to identify the project, blank lines must be included to complete the required five lines. The information on the header lines may be up to 60 characters maximum. Data for example 1 for the five header lines are as follows:

```
=SAMPLE PROBLEM FOR SETTLEMENT
=OCT 1978
=VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
=UNIT LOAD OF 1.0 WITHOUT FORCE UNIT
=TWO RECTANGULAR FOOTINGS
```

b. Loading data. The type and number of lines in this group vary depending upon whether stresses are from footing loads, an embankment load, or both footing and embankment loads are being analyzed. The type of loading is specified by the variable KODE described below.

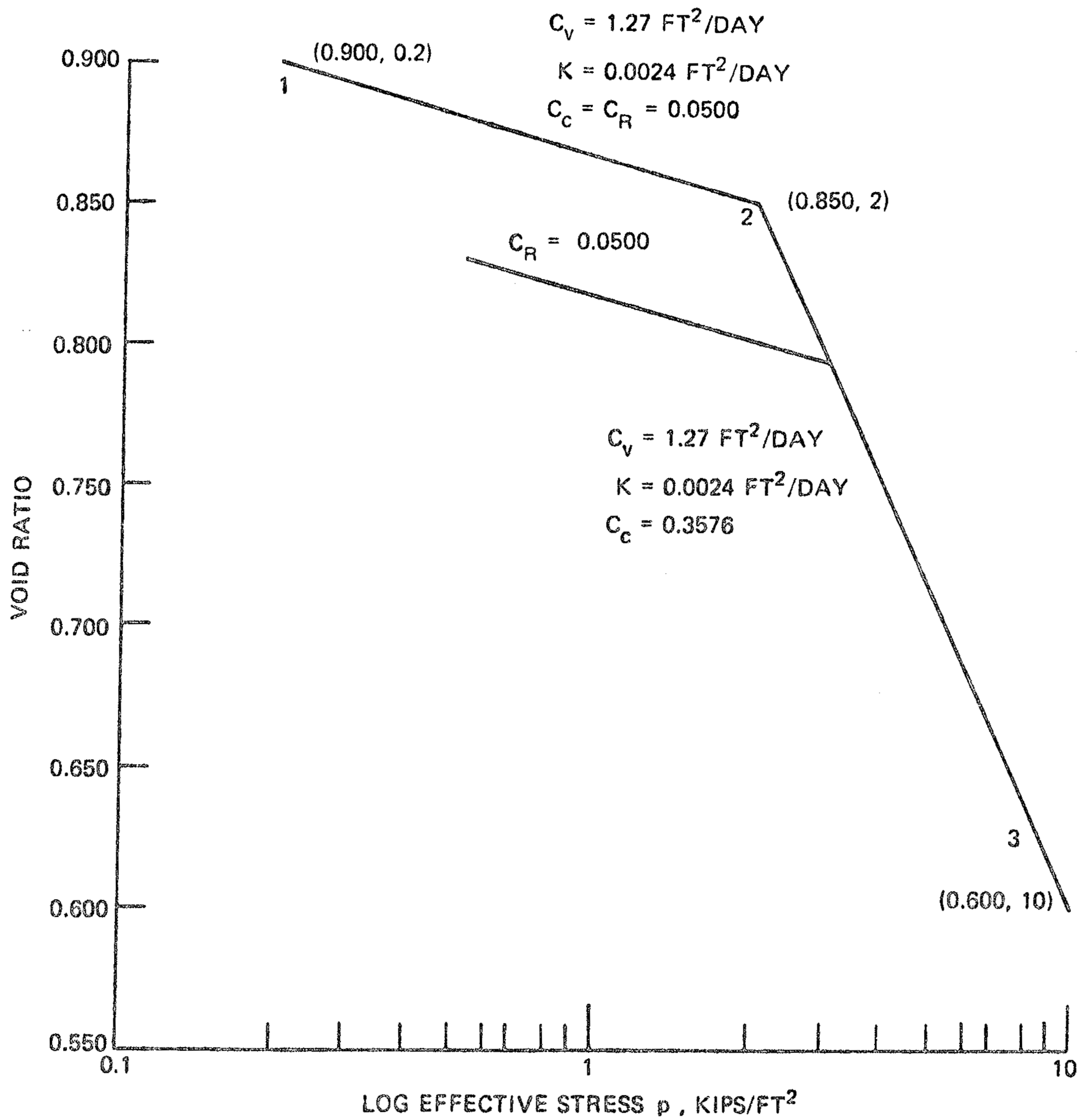


Figure 4. Void ratio versus effective stress curve for layer 1 in Figure 3

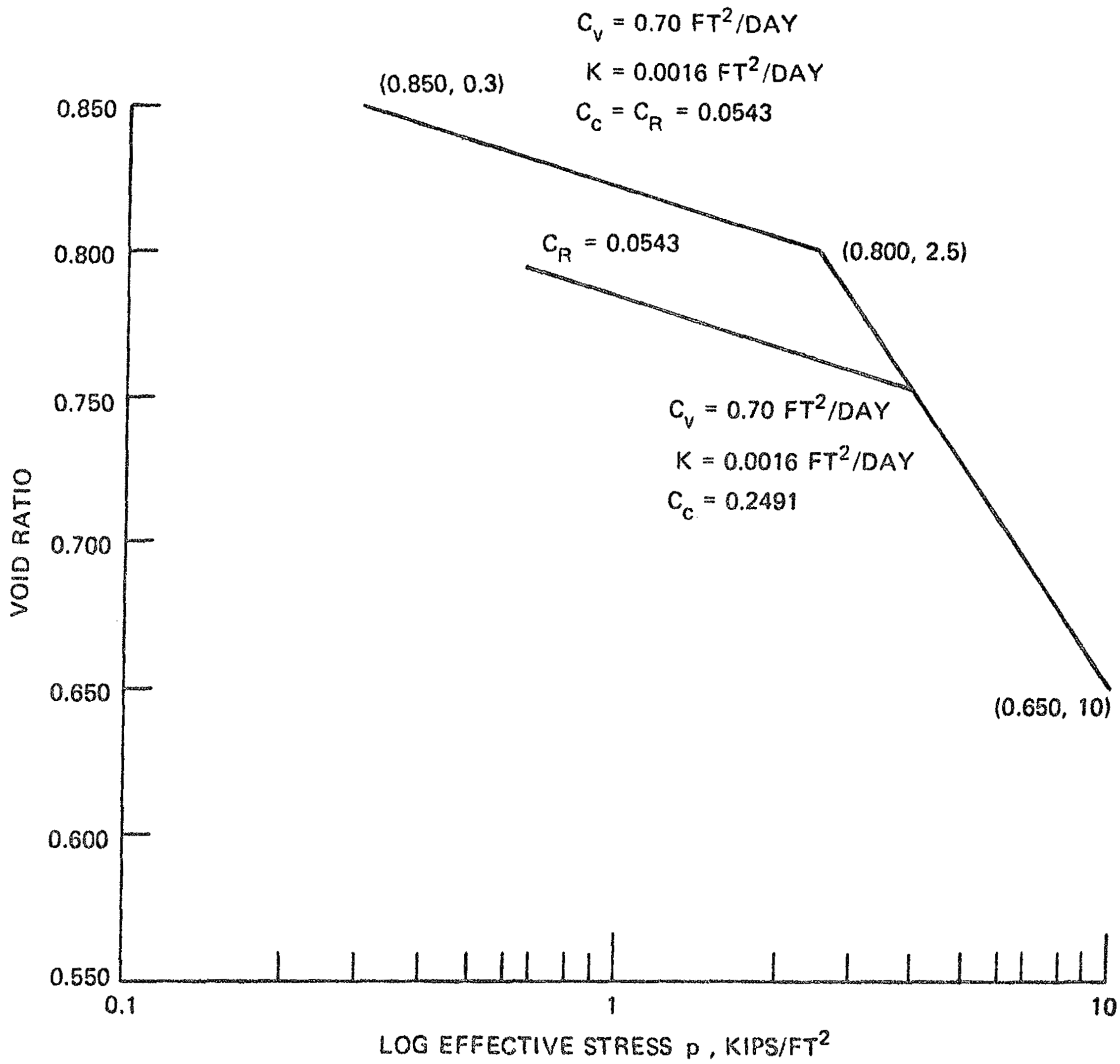


Figure 5. Void ratio versus effective stress curve for layer 2 in Figure 3

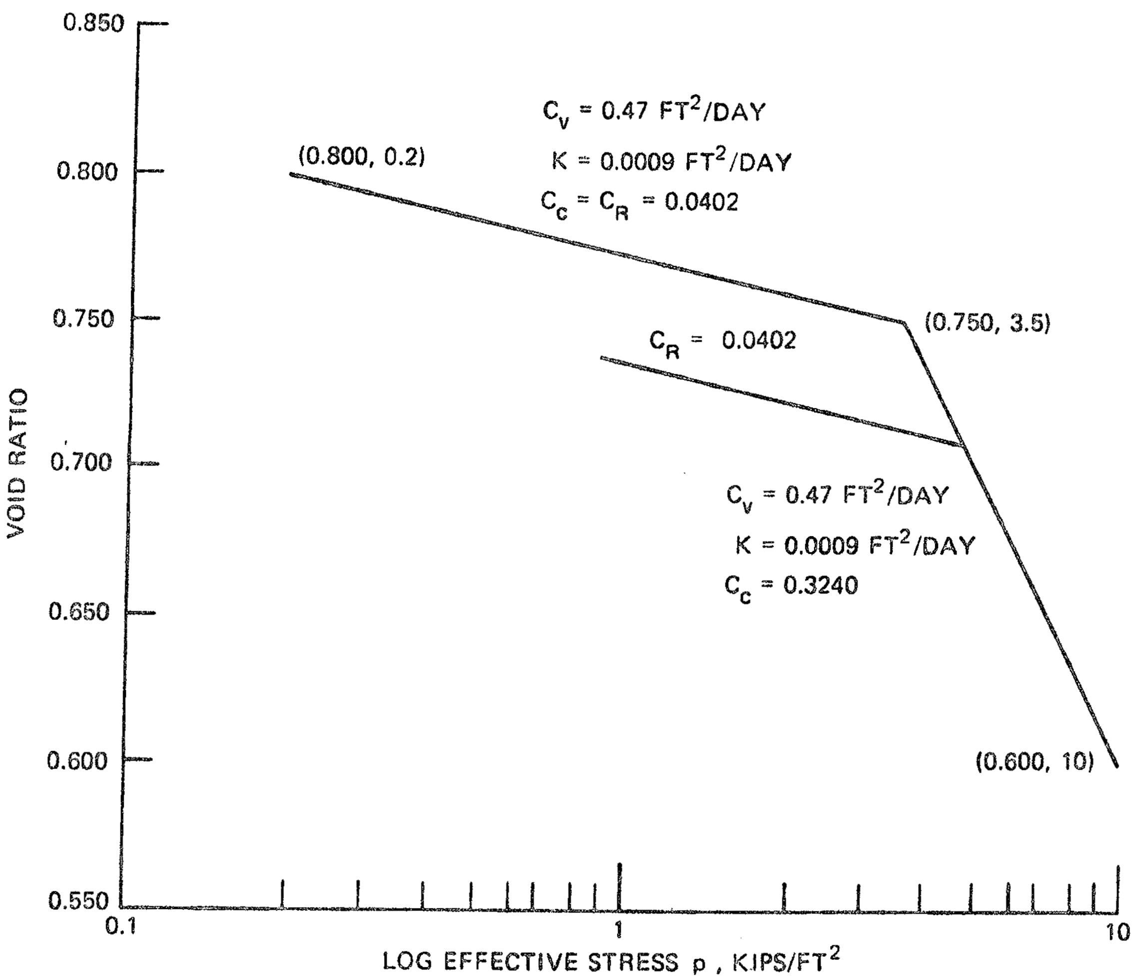


Figure 6. Void ratio versus effective stress curve for layer 4 in Figure 3

Table 2

Oedometer Test Results for Clay Layers in Example Problem 1

Layer No.	Point No.	Void Ratio	Stress kips/ft^2	C_c	C_R	C_v ft^2/day	K ft^2/day
1	1	0.900	0.2				
				0.0500	0.0500	1.27	0.0024
1	2	0.850	2				
				0.3576	0.0500	1.27	0.0024
1	3	0.600	10				
2	1	0.850	0.3				
				0.0543	0.0543	0.70	0.0016
2	2	0.800	2.5				
				0.2491	0.0543	0.70	0.0016
2	3	0.650	10				
4	1	0.800	0.2				
				0.0402	0.0402	0.47	0.0009
4	2	0.750	3.5				
				0.3240	0.0402	0.47	0.0009
4	3	0.600	10				

Table 3

Results of Standard Penetration Test of Layer No. 3 (Sand and Gravel)

Depth ft	Corrected Blow Count
93.5 to 85	32
85 to 80	35
80 to 75	20
75 to 70	30
70 to 68.5	40

* Average blow count = 33.3.

(1) The first line in this group is the following:

KODE,NAREA

(a) Item 1--KODE. KODE is a variable which indicates what type of loading configuration is to be used in the analysis. If KODE is input as 1, only uniform rectangular loads are to be used in the analysis. If KODE is input as 2, only an embankment load is to be used. If KODE is entered as 3, then both uniformly loaded rectangular areas and embankment loads are to be used in the analysis. (For input of embankment loads, see Appendix A.)

(b) Item 2--NAREA. NAREA is the variable indicating the number of rectangular uniformly loaded areas (footings) to be entered. NAREA should be entered for KODE = 1 and KODE = 3 loading conditions but may be input as zero for KODE = 2 (embankment only) loading conditions. The maximum allowable value of NAREA is 100.

Input for example 1 for this data line is as follows:

KODE,NAREA
=1, 2

(2) The next line(s) of the input data describes the location and loading for an individual rectangular loaded area(s). There will be one line of this information for each rectangular area in the loading configuration. When stresses from an embankment loading only are to be calculated (KODE = 2), this line should not be included in the input data. The following variables are required for this:

Q(I),ZLAY(I),XC(1,I),YC(1,I),XC(2-4,I),YC(2-4,I)

(a) Item 1--Q(I). Q(I) is the magnitude of the uniform load on the Ith rectangular area. It is in units of LOAD/UNIT AREA. Any units for weight and length may be used as long as all input data are in the same units.

(b) Item 2--ZLAY(I). Positive ZLAY(I) is the vertical distance from the base of the Ith footing to the vertical reference plane of the lowest point in the embankment. (No footings may be input lower than the lowest point in the embankment.)

(c) Item 3--XC(1,I). XC(1,I) is the variable name of the X coordinate of the first corner of the Ith rectangular area. The dimensions of XC(1,I) may be in any units compatible with the remainder of the input data.

(d) Item 4--YC(1,I). YC(1,I) is the variable name of the Y coordinate of the first corner of the Ith rectangular area.

(e) Items 5-10--XC(2-4,I) and YC(2-4,I). These are the remaining three pairs of X and Y coordinates which define the corners of the Ith rectangular area. The sides of the area do not have to be parallel to the X and Y axes, but the corner points should be input in either clockwise or counterclockwise order around the perimeter of the rectangular area.

Without force units being used as the load, this would yield a factor which could be multiplied times any load to give the vertical stress at that point. Input data for example 1 for the two data lines (rectangular areas 1 and 2, respectively) are as follows:

Q(I),ZLAY(I),XC(1,I),YC(1,I),XC(2,I),YC(2,I),XC(3,I),
YC(3,I),XC(4,I),YC(4,I)

=1.0 0.0 90.0 82.5 90.0 117.5 110.0 117.5 110.0 82.5

Q(I),ZLAY(I),XC(1,I),YC(1,I),XC(2,I),YC(2,I),XC(3,I),
YC(3,I),XC(4,I),YC(4,I)

=1.0 0.0 120.0 120.0 120.0 135.0 130.0 135.0 130.0
120.0

c. Stress distribution. This group of data defines the output required for the loading conditions described in subparagraph b above. The output may be in two forms, depending on the needs of the user. The first type of output consists of values of vertical stresses printed along a vertical line in the X-Y-Z plane. For this distribution, the values of X and Y will remain constant. Stress values will be calculated at prescribed increments between prescribed limits along the vertical line. The second type of output option consists of values of vertical stresses printed at increasing values of X along a prescribed line in the X-Y plane at a constant depth (Z is constant). The orientation of the line in the X-Y plane is defined by inputting a slope and an intercept. There is no limit as to the number of calculation points on a given distribution or on how many distributions may be run for a given loading configuration. The information for a single stress distribution is contained on two lines.

(1) The input variables on the first line are:

NDIST, NWEST, AMU

(a) Item 1--NDIST. NDIST is an option variable which defines whether stress distribution in a vertical or horizontal plane is required. If NDIST is input as 1, a vertical plane distribution will be assumed; if NDIST is input as 2, a horizontal plane distribution is calculated. NDIST also serves to indicate when all the stress distributions for a given loading condition are completed. A value of NDIST equal to zero will cause new header cards and loading data to be read in. If no new loading configuration follows NDIST = 0, the program will exit.

(b) Item 2--NWEST. NWEST is an option variable which determines whether the Westergaard or Boussinesq solution will be used to determine the vertical stresses. If NWEST = 0, the Westergaard solution will be used; if NWEST = 1, the Boussinesq solution will be calculated.

(c) Item 3--AMU. AMU represents the value of Poisson's ratio to be used in the Westergaard solution. If a Boussinesq solution is to be used (NWEST = 1), AMU is input as zero.

Input for example 1 for this data group is as follows:

```
NDIST, NWEST, AMU
=2 1 0.0
```

(2) The second line is used to define the stress distribution and should not be included if NDIST = 0. The card includes the following data:

```
AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
```

Repeat this card for each distribution required (NDIST times).

(a) Item 1--AINTL. AINTL is the starting point coordinate for either a vertical or a horizontal plane distribution. If a vertical plane distribution is required (NDIST = 1), the value of AINTL represents the initial (smallest) depth within the range of the distribution. For this case, AINTL must be positive. In the case of a horizontal plane distribution (NDIST = 2), AINTL represents the smallest (initial) X coordinate of the horizontal plane distribution. For a horizontal plane distribution, AINTL may be positive or negative.

(b) Item 2--FINAL. FINAL is the ending point coordinate for either a vertical or a horizontal plane distribution. If a vertical plane distribution is required (NDIST = 1), the value of FINAL represents the final (largest) depth within the range

Table 5

Input/Output in the Conversational Mode for Program I0016

(Example Problem 1)

```
RUN WESLIB/CORPS/I0016.R
DO YOU WISH TO RUN PROGRAM FROM EXISTING DATA FILE?
=N
DO YOU WANT OUTPUT WRITTEN TO AN OUTPUT FILE?
=Y
INPUT 5 HEADER LINES
=SAMPLE PROBLEM FOR SETTLEMENT
=OCT 1978
=VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
=UNIT LOAD OF 1.0 WITHOUT FORCE UNIT
=TWO RECTANGULAR FOOTINGS
KODE,NAREA
=1 2

Q(I),ZLAY(I),XC(1,I),YC(1,I),XC(2,I),YC(2,I),XC(3,I),YC(3,I),XC(4,I),YC
(4,I)
=1.0  0.0 90.0 82.5 90.0 117.5 110.0 117.5 110.0 82.5

Q(I),ZLAY(I),XC(1,I),YC(1,I),XC(2,I),YC(2,I),XC(3,I),YC(3,I),XC(4,I),YC
(4,I)
=1.0 0.0 120 0 120.0 120.0 135.0 130.0 135.0 130.0 120.0
NDIST, NWEST, AMU
=2 1 0.0

AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
=100.0 100.0 1.0 0.0 0.0 7.5 0.0 100.0

SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
OCT 1978
VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
UNIT LOAD OF 1.0 WITHOUT FORCE UNITS
TWO RECTANGULAR FOOTINGS

   BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =     7.50

                                        ELASTIC SOLUTION    NORMAL LOADING
  Y-COORDINATE       X-COORDINATE        VERTICAL STRESS     VERTICAL STRESS
  ------------       ------------        ---------------     ---------------
    100.00              100.00                    0.882               0.882

             NUMBER OF AREAS USED IN CALCULATION =   2

 NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT,
      CONFIGURATION.

NDIST, NWEST, AMU
=2 1 0.0

AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
=100.0 100.0 1.0 0.0 0.0 18.25 0.0 100.0
```

(Continued)

Table 4

Input Data File for Program I0016

(Example Problem 1)

```
CPI0016                                        15: 0:28     3/13/79

1000 SAMPLE PROBLEM FOR SETTLEMENT
1010 OCT 1978
1020 VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
1030 UNIT LOAD OF 1.0 WITHOUT FORCE UNIT
1040 TWO RECTANGULAR FOOTINGS
1050  1 2
1060 1.0 0.0 90.0 82.5 90.0 117.5 110.0 117.5 110.0 82.5
1070 1.0 0.0 120.0 120.0 120.0 135.0 130.0 135.0 130.0 120.0
1080  2  1 0.0
1090 100.0 100.0 1.0 0.0 0.0 7.5 0.0 100.0
1100  2  1 0.0
1110 100.0 100.0 1.0 0.0 0.0 18.25 0.0 100.0
1120  2  1 0.0
1130 100.0 100.0 1.0 0.0 0.0 56.75 0.0 100.0
1140    0 0 0.0
```

Table 5

Input/Output in the Conversational Mode for Program I0016

(Example Problem 1)

```
RUN WESLIB/CORPS/I0016.R
DO YOU WISH TO RUN PROGRAM FROM EXISTING DATA FILE?
=N
DO YOU WANT OUTPUT WRITTEN TO AN OUTPUT FILE?
=Y
INPUT 5 HEADER LINES
=SAMPLE PROBLEM FOR SETTLEMENT
=OCT 1978
=VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
=UNIT LOAD OF 1.0 WITHOUT FORCE UNIT
=TWO RECTANGULAR FOOTINGS
KODE,NAREA
=1 2

Q(I),ZLAY(I),XC(1,I),YC(1,I),XC(2,I),YC(2,I),XC(3,I),YC(3,I),XC(4,I),YC
(4,I)
=1.0  0.0 90.0 82.5 90.0 117.5 110.0 117.5 110.0 82.5

Q(I),ZLAY(I),XC(1,I),YC(1,I),XC(2,I),YC(2,I),XC(3,I),YC(3,I),XC(4,I),YC
(4,I)
=1.0 0.0 120 0 120.0 120.0 135.0 130.0 135.0 130.0 120.0
NDIST, NWEST, AMU
=2 1 0.0

AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
=100.0 100.0 1.0 0.0 0.0 7.5 0.0 100.0

SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
OCT 1978
VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
UNIT LOAD OF 1.0 WITHOUT FORCE UNITS
TWO RECTANGULAR FOOTINGS

   BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =     7.50

                                        ELASTIC SOLUTION     NORMAL LOADING
  Y-COORDINATE        X-COORDINATE      VERTICAL STRESS      VERTICAL STRESS
  ------------        ------------      ---------------      ---------------
     100.00              100.00                  0.882                  0.882

            NUMBER OF AREAS USED IN CALCULATION =    2

 NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT,
      CONFIGURATION.

NDIST, NWEST, AMU
=2 1 0.0

AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
=100.0 100.0 1.0 0.0 0.0 18.25 0.0 100.0
```

(Continued)

Table 5 (Concluded)

```
SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
OCT 1978
VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
UNIT LOAD OF 1.0 WITHOUT FORCE UNITS
TWO RECTANGULAR FOOTINGS

   BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =   18.25

                                          ELASTIC SOLUTION     NORMAL LOADING
   Y-COORDINATE      X-COORDINATE        VERTICAL STRESS     VERTICAL STRESS
   ------------      ------------        ---------------     ---------------
     100.00            100.00                  0.509               0.509

            NUMBER OF AREAS USED IN CALCULATION =   2

  NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT.
       CONFIGURATION.

 NDIST, NUEST, AMU
 =2 1 0.0

 AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
 =100.0 100.0 1.0 0.0 0.0 56.75 0.0 100.0

SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
OCT 1978
VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
UNIT LOAD OF 1.0 WITHOUT FORCE UNITS
TWO RECTANGULAR FOOTINGS

   BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =   56.75

                                          ELASTIC SOLUTION     NORMAL LOADING
   Y-COORDINATE      X-COORDINATE        VERTICAL STRESS     VERTICAL STRESS
   ------------      ------------        ---------------     ---------------
     100.00            100.00                  0.103               0.103

            NUMBER OF AREAS USED IN CALCULATION =   2

  NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT.
       CONFIGURATION.

NDIST, NUEST, AMU
=0 0 0.0

%
```

Table 6

Output Data File for Program I0016

(Example Problem 1)

```
CCI0016                                                  14:59: 9    3/13/79

SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
OCT 1978
VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
UNIT LOAD OF 1.0 WITHOUT FORCE UNIT
TWO RECTANGULAR FOOTINGS

    BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =     7.50

   Y-COORDINATE      X-COORDINATE     ELASTIC SOLUTION     NORMAL LOADING
   ------------      ------------      VERTICAL STRESS     VERTICAL STRESS
     100.00            100.00          ---------------     ---------------
                                                 0.882               0.882

           NUMBER OF AREAS USED IN CALCULATION =    2

 NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT,
      CONFIGURATION.

SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
OCT 1978
VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
UNIT LOAD OF 1.0 WITHOUT FORCE UNIT
TWO RECTANGULAR FOOTINGS

    BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =    18.25

   Y-COORDINATE      X-COORDINATE     ELASTIC SOLUTION     NORMAL LOADING
   ------------      ------------      VERTICAL STRESS     VERTICAL STRESS
     100.00            100.00          ---------------     ---------------
                                                 0.509               0.509

           NUMBER OF AREAS USED IN CALCULATION =    2

 NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT,
      CONFIGURATION.

SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
OCT 1978
VERTICAL STRESS DISTRIBUTION INFLUENCE FACTOR
UNIT LOAD OF 1.0 WITHOUT FORCE UNIT
TWO RECTANGULAR FOOTINGS

    BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =    56.75

   Y-COORDINATE      X-COORDINATE     ELASTIC SOLUTION     NORMAL LOADING
   ------------      ------------      VERTICAL STRESS     VERTICAL STRESS
     100.00            100.00          ---------------     ---------------
                                                 0.103               0.103

           NUMBER OF AREAS USED IN CALCULATION =    2

 NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT,
      CONFIGURATION.
```

Program MAGSETII

23. Organization of input. Input for MAGSETII is broken down into two basic areas: problem control and data entry. The first governs the execution of the program and allows the user to describe what data and what form of data are to be entered. One more option to the program has been added to perform a rate of settlement analysis.

24. Mode of input. Input to the program can be either from the terminal or from a data file. All input is in free field. Data items can be separated by a blank or a comma. If the program is being run from a data file, lines of the data file must be preceded by a line number. When the program is run from a terminal, it can create files to save the input data and output from the run.

25. After receiving the output from I0016, MAGSETII can be used to calculate the settlement and the rate of consolidation. Input for this program is shown in Tables 7 and 8.

26. Problem control input. The first line in this section gives the information on one particular run and controls whether or not more than one problem is going to be run. The next line is a title description of the particular problem.

27. Data input. The first line in this section gives the problem options for the output and data input control. There are eight of these options:

a. Unit indicator. This specifies whether the units are to be shown in the output.

b. Effective stress indicator. This indicates whether the effective stress is to be calculated at midpoints or input at each soil layer or to combine the calculated and the input effective stress.

c. Effective stress history specifications. This indicates, if clay layers are present, whether the effective stress history is to be input for each clay layer or one is to be used for all clay layers or the vertical stress distribution function is to be multiplied time one effective stress history for all clay layers.

d. Deformation curve type. This indicates, if clay layers are present, whether the deformation curve is a strain or a void ratio versus effective stress relationship.

Table 7

Input in the Conversational Mode for Program MAGSETII

(Example Problem 1)

```
RUN

INPUT NAME OF DATA FILE.  HIT A CARRIAGE RETURN
IF DATA IS TO BE READ FROM THE TERMINAL.
=

INPUT A FILE NAME FOR DATA IN 8 CHARACTERS OR LESS.
HIT A CARRIAGE RETURN IF YOU DO NO WANT TO SAVE THIS FILE
=REEDIN

INPUT A FILE NAME FOR OUTPUT IN 8 CHARACTERS OR LESS
HIT A CARRIAGE RETURN IF DATA IS TO BE PRINTED ON TERMINAL
=REEDOUT

INPUT PROBLEM CONTROL INFORMATION
    NPROB - PROBLEM NUMBER
    NLAYER - NUMBER OF SOIL LAYERS IN PROFILE. MAX=15
    NLAST - 0 IF CURRENT PROBLEM ISN'T LAST ONE
            1 CURRENT PROBLEM IS LAST ONE IN DATA SET
=1,5,1

INPUT PROBLEM OPTIONS
    IOPT(1) - UNITS INDICATOR
              1 - UNITS TO BE PRINTED IN OUTPUT
              2 - UNITS WILL NOT BE PRINTED
    IOPT(2) - INSITU EFFECTIVE STRESS INDICATOR
              1 - IES CALCULATED AT MIDPOINTS
              2 - IES INPUT AT EACH LAYER
              3 - IES INPUT AT EACH LAYER AND ADDED TO CALC.IES
    IOPT(3) - EFFECTIVE STRESS HISTORY SPECIFICATIONS
              0 - NO CLAY LAYERS
              1 - ESH INPUT FOR EACH CLAY LAYER
              2 - ONE ESH INPUT AND USED FOR ALL LAYERS
              3 - ONE ESH INPUT AND USED FOR ALL CLAY LAYERS
                  STRESS DISTRIBUTION FUNCTION WILL BE INPUT
    IOPT(4) - DEFORMATION CURVE TYPE
              0 - NO CLAY LAYERS
              1 - STRAIN-EFFECTIVE STRESS CURVES
              2 - VOID RATIO-EFFECTIVE STRESS CURVES
    IOPT(5) - DEFORMATION CURVE SPECIFICATION
              0 - NO CLAY LAYERS
              1 - DC INPUT USING COORD. PTS. OF VOID RAIO OR
                  STRAIN VS. EFFECTIVE STRESS
              2 - DC INPUT USING SLOPES,EFF. STRESS VALUES AND A
                  REFERENCE COORDINATE
    IOPT(6) - SAND SETTLEMENT METHOD INDICATOR
              0 - NO SAND LAYERS
              1 - MEYERHOFF'S METHOD
              2 - D'APPOLONIA'S METHOD
              3 - ALL THREE METHODS
    IOPT(7) - VERTICAL STRAIN INFLUENCE FUNCION
              0 - NO SAND LAYERS
              1 - CURVE G
              2 - CURVE F
              3 - VERTICAL STRAIN INFLUENCE FUNCION WILL BE INPUT
    IOPT(8) - DATUM CONVERSION OPTION
```

(Continued)

Table 7 (Continued)

```
INPUT TITLE
    TITLE - DESCRIPTION OF PROBLEM IN 66 CHARACTERS OR LESS
*     SAMPLE PROBLEM FOR SETTLEMENT PACKAGE


                        1 - DEPTHS OR ELEVATIONS WI
     LL NOT BE CONVERTED
                        2 - DEPTHS OR ELEVATIONS WI
     LL BE CONVERTED
     *1,1,3,2,1,1,1,2



     INPUT UNITS
         IUNIT(1) - LENGTH UNITS IN COLUMNS 1-16
         IUNIT(2) - FORCE UNITS IN COLUMNS 17-32
     *        FEET            KIPS


     INPUT GROUND WATER DATA
         GW - TNIT WEIGHT OF WATER
         GWELEV - DEPTH OR ELEV. OF GROUND WATER SURFACE
     *.0624,100.0


     INPUT LAYER INTERFACE INFORMATION
         L - LAYER INTERFACE NUMBER
         DEPTH(L) - DEPTH OR ELEV. TO TOP OF LAYER

     LAYER NUMBER  1
     *1,125.0

     LAYER NUMBER  2
     *2,115.0

     LAYER NUMBER  3
     *3,100.0

     LAYER NUMBER  4
     *4,93.5

     LAYER NUMBER  5
     *5,68.5

     LAYER NUMBER  6
     *6,48.0
```

(Continued)

Table 7 (Continued)

```
INPUT SOIL PROPERTIES
     L - LAYER NUMBER
     NTYPE(L) - SOIL TYPE
                1 - CLAY
                2 - SAND
                3 - INCOMPRESSIBLE
     WGT(L) - TOTAL UNIT WEIGHT OF SOIL

LAYER NUMBER  1
=1.3..100

LAYER NUMBER  2
=2.1..120

LAYER NUMBER  3
=3.1..120

LAYER NUMBER  4
=4.2..130

LAYER NUMBER  5
=5.1..130

INPUT DATUM CONVERSION INFORMATION
     DATUM - DATUM ELEVATION
     DIFELV - DIFF. IN ELEV. BETWEEN DATUM ELEV & TOP OF 1ST LAYER
=125.0.0.0

INPUT EFFECTIVE STRESS INCREMENTS
     SIG1(NS) - THE (NSTH) ESI
     LS - LAST INCREMENT INDICATOR
          0 - IF MORE ESI'S TO BE INPUT
          1 - IF LAST ESI

STRESS INCREMENT NUMBER  1
=-1.0.0

STRESS INCREMENT NUMBER  2
=1.3.0

STRESS INCREMENT NUMBER  3
=2.0.0

STRESS INCREMENT NUMBER  4
=2.5.0

STRESS INCREMENT NUMBER  5
=-0.5.1

INPUT STRESS DISTRIBUTION FUNCTION
     L - CLAY LAYER NUMBER
     F(L) - VALUE OF SDF

LAYER NUMBER  2
=2..88

LAYER NUMBER  3
=3..61

LAYER NUMBER  5
=5..103
```

(Continued)

```
INPUT DEFORMATION CURVE COORDINATE POINTS
    ILAYER - CLAY LAYER NUMBER
    LINEPT(I,IPT) - FIRST POINT ON DC = 1
    E(I,IPT) - VOID RAIO OR STRAIN COORD AT 1ST PT ON DC
    SIGMAP(I,IPT) - EFFECTIVE STRESS COORD AT 1ST PT ON DC
=2,1,.90,.20

INPUT DEFORMATION CURVE - SUBSEQUENT COORD PTS
    ILAYER - CLAY LAYER NUMBER
    LINEPT(I,IPT) - COORD PT ON DC
    E(I,IPT) - VOID RATIO OR STRAIN AT COORD PT
    SIGMAP(I,IPT) - EFFECTIVE STRESS AT COORD PT
    ER(I,IPT-1) - VOID RATIO OR STRAIN COORD TO BE USED TO
                  CALCULATE EXPANSION SLOPE
    SIGR(I,IPT-1) - EFFECTIVE STRESS TO BE USED TO CALC
                    EXPANSION SLOPE
    LP - LAST POINT INDICATOR
         0 - NOT LAST POINT
         1 - LAST POINT
INCREMENT  2
=2,2,.85,2.0,.90,.20,0
INCREMENT  3
=2,3,.60,10.0,.85,2.0,1

INPUT DEFORMATION CURVE COORDINATE POINTS
    ILAYER - CLAY LAYER NUMBER
    LINEPT(I,IPT) - FIRST POINT ON DC = 1
    E(I,IPT) - VOID RAIO OR STRAIN COORD AT 1ST PT ON DC
    SIGMAP(I,IPT) - EFFECTIVE STRESS COORD AT 1ST PT ON DC
=3,1,.85,.30

INPUT DEFORMATION CURVE - SUBSEQUENT COORD PTS
    ILAYER - CLAY LAYER NUMBER
    LINEPT(I,IPT) - COORD PT ON DC
    E(I,IPT) - VOID RATIO OR STRAIN AT COORD PT
    SIGMAP(I,IPT) - EFFECTIVE STRESS AT COORD PT
    ER(I,IPT-1) - VOID RATIO OR STRAIN COORD TO BE USED TO
                  CALCULATE EXPANSION SLOPE
    SIGR(I,IPT-1) - EFFECTIVE STRESS TO BE USED TO CALC
                    EXPANSION SLOPE
    LP - LAST POINT INDICATOR
         0 - NOT LAST POINT
         1 - LAST POINT
INCREMENT  2
=3,2,.80,2.50,.85,.30,0
INCREMENT  3
=3,3,.65,10.0,.80,2.5,1
```

(Continued)

```
INPUT DEFORMATION CURVE COORDINATE POINTS
     ILAYER - CLAY LAYER NUMBER
     LINEPT(I,IPT) - FIRST POINT ON DC = 1
     E(I,IPT) - VOID RAIO OR STRAIN COORD AT 1ST PT ON DC
     SIGMAP(I,IPT) - EFFECTIVE STRESS COORD AT 1ST PT ON DC
=5,1,.80,.20

INPUT DEFORMATION CURVE - SUBSEQUENT COORD PTS
     ILAYER - CLAY LAYER NUMBER
     LINEPT(I,IPT) - COORD PT ON DC
     E(I,IPT) - VOID RATIO OR STRAIN AT COORD PT
     SIGMAP(I,IPT) - EFFECTIVE STRESS AT COORD PT
     ER(I,IPT-1) - VOID RATIO OR STRAIN COORD TO BE USED TO
                   CALCULATE EXPANSION SLOPE
     SIGR(I,IPT-1) - EFFECTIVE STRESS TO BE USED TO CALC
                     EXPANSION SLOPE
     LP - LAST POINT INDICATOR
          0 - NOT LAST POINT
          1 - LAST POINT
INCREMENT  2
=5,2,.75,3.50,.80,.20,0
INCREMENT  3
=5,3,.60,10.0,.75,3.50,1

INPUT PENETRATION RESISTANCE
     L - SAND LAYER NUMBER
     BLOW(L) - STANDARD PENETRATION TEST BLOWCOUNT IN
               BLOWS PER FOOT
               0 - IF IOPT(6)=3
     QC(L) - STATIC CONE PENETRATION RESISTANCE
               0 - IF IOPT(6)=1 OR 2

SAND LAYER NUMBER  4
=4,33.3,0.0

INPUT FOOTING DATA
     FP - AVG FOOTING PRESSURE
     FB - FOOTING WIDTH
     FDEPTH - DEPTH OR ELEV OF FOOTING
=5.0,20.0,115.0

INPUT MEYERHOFF'S CONVERSION FACTORS
     CONVFT - LENGTH CONVERSION FACTOR
     CONVTN - FORCE CONVERSION FACTOR
=1.0,0.5
```

(Continued)

Table 7 (Concluded)

```
INPUT PROGRAM CONTROL
    NHIST - 0 NO RATE OF CONSOLIDATION IN OUTPUT
            1 HISTORY OF RATE OF CONSOLIDATION IN OUTPUT
            2 SETTLEMENTS AND DEGREE OF CONSOLIDATION AT
              THE END OF LOADING INCREMENTS AND SPECIFIC
              TIMES AFTER LOADIND
=2


INPUT COEFFICIENT OF CONSOLIDATION
    L - LAYER NUMBER
    CU - COEFFICIENT OF CONSOLIDATION(SQ.FT./DAY)
    NTOP - 0 IF TOP IS FREELY DRAINED
           1 IF TOP IS NOT FREELY DRAINED
    NBOT - 0 IF BOTTOM IS FREELY DRAINED
           1 IF BOTTOM IS NOT FREELY DRAINED

CU FOR LAYER NUMBER  2
=2,1.27,0,1

CU FOR LAYER NUMBER  3
=3,.70,1,0

CU FOR LAYER NUMBER  5
=5,.47,0,0

INPUT TIMES FOR LOADIND INCREMENTS
    T - THE TIME(IN DAYS) FROM THE BEGINNING OF
        CONSTRUCTION TO THE END OF THE LOAD INCREMENT
        (LOAD INCREMENT=STRESS INCREMENT IN OPTION 3)
        MAX. NUMBER = 10

LOAD INCREMENT NO. 1
=50.0

LOAD INCREMENT NO. 2
=75.0

LOAD INCREMENT NO. 3
=200.0

LOAD INCREMENT NO. 4
=300.0

LOAD INCREMENT NO. 5
=350.0

INPUT TIMES FOR AFTER CONSTRUCTION
    T - NUMBER OF DAYS FROM THE BEGINNING OF CONSTRUCTION
        TO A TIME AFTER THE FINAL LOADIND
        ENTER 0.0 FOR LAST ONE.(MAX. NUMBER=10)

A TIME AFTER CONSTRUCTION    1
=400.0

A TIME AFTER CONSTRUCTION    2
=500.0

A TIME AFTER CONSTRUCTION    3
=600.0

A TIME AFTER CONSTRUCTION    4
=1000.0

A TIME AFTER CONSTRUCTION    5
=0.0

$
```

Table 8

Input Data File for Program MAGSETII

(Example Problem 1)

```
REEDIN                                                          8:43:14     3/ 8/79

10000     1    5    1
10010     SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
10020     1    1    3    2    1    1    1    2
10030        FEET                KIPS
10040     0.0624  100.0000
10050     1  125.0000
10060     2  115.0000
10070     3  100.0000
10080     4   93.5000
10090     5   68.5000
10100     6   48.0000
10110     1    3     0.1000
10120     2    1     0.1200
10130     3    1     0.1200
10140     4    2     0.1300
10150     5    1     0.1300
10160   125.0000     0.
10170    -1.0000     0
10180     1.3000     0
10190     2.0000     0
10200     2.5000     0
10210    -0.5000     1
10220     2     0.8800
10230     3     0.5100
10240     5     0.1030
10250     2    1     0.9000     0.2000
10260     2    2     0.8500     2.0000     0.9000     0.2000     0
10270     2    3     0.6000    10.0000     0.8500     2.0000     1
10280     3    1     0.8500     0.3000
10290     3    2     0.8000     2.5000     0.8500     0.3000     0
10300     3    3     0.6500    10.0000     0.8000     2.5000     1
10310     5    1     0.8000     0.2000
10320     5    2     0.7500     3.5000     0.8000     0.2000     0
10330     5    3     0.6000    10.0000     0.7500     3.5000     1
10340     4   33.3000     0.
10350     5.0000   20.0000  115.0000
10360     1.0000    0.5000
10380        2
10390     2      1.2700     0     1
10400     3      0.7000     1     0
10410     5      0.4700     0     0
10420            50.00
10421            75.00
10422           200.00
10423           300.00
10424           350.00
10425           400.00
10426           500.00
10427           600.00
10428          1000.0
10429             0.
```

e. Deformation curve specifications. This indicates if the deformation curves are to be input by coordinate points upon a void ratio or strain versus effective stress curve with slopes to be calculated between points entered or by entering the slopes and reference points on the curve.

f. Sand settlement methods indicator. If a sand layer is present, it indicates the method of analysis that needs to be employed by the program for estimating the settlement of the sand layers.

g. Vertical strain influence functions. If sand layers are present, it indicates whether one of the built-in strain influence curves is to be used or a function is to be entered by the user.

h. Datum conversion option. This is used to select whether the depth or elevation is to be converted for the output.

28. Output. The output from a successfully executed MAGSETII problem is printed under several headings. The information under these headings may vary slightly, depending on the problem options chosen. A brief description of the information printed under these headings is given below.

a. Problem specifications. Printed under this heading are the program header, title, and units.

b. Soil profile description. The soil profile description prints the layer number, layer type, interface depths or elevations, datum elevations, layer thickness, and the total unit weights of the soils. Also under this heading are the groundwater information, the unit weight of water, the depth or elevation of the groundwater table, and the datum elevation of the groundwater.

c. In situ effective stress. Under this heading are the input and in situ effective stresses in each layer and the in situ effective stress used by the program.

d. Clay settlement data. This section contains the effective stress history and deformation curve data. The input effective stress increments and the effective stress history are printed. The input data used to specify the deformation curves are printed along with any data calculated that define the deformation curve. If void ratio versus effective stress curves are input, the compression and expansion indexes C_c and C_e are output along with with strain compression and strain expansion indexes $C_{c\varepsilon}$ and $C_{e\varepsilon}$. If strain versus effective stress curves are input, only the strain compression and strain expansion slopes are output.

e. Sand settlement data. This section contains the data used in the sand settlement calculations. It includes calculation methods, foundation data, the penetration resistance for each sand layer, and the strain influence function used. It also includes information which is method-dependent, such as D'Appolonia's parameters and Meyerhof's conversion factors.

f. Clay settlement contributions. The clay settlement contributions contain the settlement in each layer due to each effective stress increment, the total clay settlement in each layer, the settlement in the clay profile due to each effective stress increment, and the total clay settlement.

g. Clay compressibilities. The coefficient of constrained compressibility m_v in each layer for each effective stress increment is printed. The column header E1 defines the void ratio or strain value at the beginning of the effective stress increment depending on the form of the deformation curves input. The column header E2 defines the void ratio or strain at the end of the effective stress increment. The column header DELTA E is the value of E2 minus E1.

h. Sand settlements. The settlements in each sand layer are printed under the method of analysis. The total sand settlement over the sand profile is printed along with the total clay settlement and total profile settlement.

i. Error messages. Various checks are made on the input data. If any of these checks fail, an error message is printed and the program terminates execution. The error messages have been worded to be reasonably self-explanatory. If confusion results, however, refer to Chapter 1 of Schiffman, Jubenville, and Partyka (1976) under the appropriate sections. Table 9 presents the output of MAGSETII for example problem 1.

j. Degree of consolidation. The time (in days), time factor (TV), and the degree of consolidation are output for each soil layer at each 10 percent increment or at a specific time.

Comparison with hand calculations

29. Example problem 1 was worked by hand using conventional methods. Results from program I0016, using a Boussinesq solution, were compared to answers from an influence chart for vertical pressure for Boussinesq's equation, commonly known as Newmark's chart

Table 9

Output Data for Program MAGSETII

(Example Problem 1)

```
REEDOUT                                                  15:26:15    2/13/79

1                                  ********************************
                                   *                              *
                                   *          MAGSET-II           *
                                   *                              *
                                   * MAGNITUDE OF SETTLEMENT OF   *
                                   * A MULTI-LAYERED SOIL SYSTEM  *
                                   *                              *
                                   ********************************

 **********************
 * SPECIFICATIONS FOR*
 *   PROBLEM NO.  1   *
 **********************
                                   ***** TITLE *****
   SAMPLE PROBLEM FOR SETTLEMENT PACKAGE
                                  ***** UNITS *****
                              LENGTH              FORCE
                               FEET                 KIPS
 ****************
 * SOIL PROFILE *
 * DESCRIPTION  *
 ****************
                     DATUM ELEVATION          =   125.00
                     DIFFERENCE IN ELEVATION =    0.
  LAYER    SOIL      INTERFACE     DATUM                            UNIT
  NUMBER   TYPE      ELEVATION     ELEVATIONS    THICKNESS         WEIGHT
                      125.00        125.00
    1     INCOMP                                   10.00           0.1000
                      115.00        115.00
    2      CLAY                                    15.00           0.1200
                      100.00        100.00
    3      CLAY                                     6.50           0.1200
                       93.50         93.50
    4      SAND                                    25.00           0.1300
                       68.50         68.50
    5      CLAY                                    20.50           0.1300
                       48.00         48.00

                    UNIT WEIGHT    GROUND WATER     GROUND WATER
                     OF WATER         LEVEL        DATUM ELEVATION
                      0.0624         100.00            100.00

 ****************************
 * INSITU EFFECTIVE STRESS *
 ****************************

           LAYER      INPUT        CALCULATED        INSITU
           NUMBER     VALUE          VALUE           STRESS
             1          -            0.5000          0.5000
             2          -            1.9000          1.9000
             3          -            2.9872          2.9872
             4          -            4.0194          4.0194
             5          -            5.5573          5.5573

 ************************
 * CLAY SETTLEMENT DATA *
 ************************

           EFFECTIVE STRESS INCREMENTS INPUT BY
                                              A DISTRIBUTION FUNCTION
                ***** STRESS INCREMENTS FOR STRATUM *****
                      POINT NUMBER      STRESS INCREMENT
                           1               -1.0000
                           2                1.3000
                           3                2.0000
                           4                2.5000
                           5               -0.5000
```

(Continued)

Table 9 (Continued)

REEDOUT 15:26:15 2/13/79

***** STRESS DISTRIBUTION FUNCTION *****

LAYER NUMBER	VALUE
2	0.8800
3	0.5100
5	0.1030

***** EFFECTIVE STRESS HISTORY *****

LAYER NO.	PT. NO.	STRESS INCREMENT	STRESS VALUES
2	1	-0.8800	1.0200
2	2	1.1440	2.1640
2	3	1.7600	3.9240
2	4	2.2000	6.1240
2	5	-0.4400	5.6840
3	1	-0.5100	2.4772
3	2	0.6630	3.1402
3	3	1.0200	4.1602
3	4	1.2750	5.4352
3	5	-0.2550	5.1802
5	1	-0.1030	5.4543
5	2	0.1339	5.5882
5	3	0.2060	5.7942
5	4	0.2575	6.0517
5	5	-0.0515	6.0002

DEFORMATION CURVES INPUT BY COORDINATE POINTS

***** COORDINATES OF POINTS ON THE DEFORMATION CURVES *****

LAYER NUMBER	POINT NUMBER	VOID RATIO	STRESS	REBOUND VOID RATIO	REBOUND STRESS
2	1	0.9000	0.2000		
2	2	0.8500	2.0000	0.9000	0.2000
2	3	0.6000	10.0000	0.8500	2.0000
3	1	0.8500	0.3000		
3	2	0.8000	2.5000	0.8500	0.3000
3	3	0.6500	10.0000	0.8000	2.5000
5	1	0.8000	0.2000		
5	2	0.7500	3.5000	0.8000	0.2000
5	3	0.6000	10.0000	0.7500	3.5000

***** SLOPES ON THE DEFORMATION CURVES *****

LAYER NUMBER	LINE NUMBER	CC	CE	CC (STRAIN)	CE (STRAIN)
2	1	0.0500	0.0500	0.0263	0.0263
2	2	0.3577	0.3577	0.1933	0.1933
3	1	0.0543	0.0543	0.0294	0.0294
3	2	0.2491	0.2491	0.1384	0.1384
5	1	0.0402	0.0402	0.0223	0.0223
5	2	0.3290	0.3290	0.1880	0.1880

(Continued)

Table 9 (Continued)

```
*************************
* SAND SETTLEMENT DATA *
*************************

                    ***** FOUNDATION DATA *****
REEDOUT                                        15:26:15    2/13/79

                 FOOTING          FOOTING         FOOTING
                 WIDTH            PRESSURE
 +                                                ELEVATION

                 20.0000          5.0000          115.0000

                  ***** SAND SETTLEMENT METHODS *****
                              MEYERHOF


                 ***** PENETRATION RESISTANCE *****
              LAYER                  SPT                STATIC CONE
              NUMBER              BLOWCOUNT         PENETRATION RESISTANCE
                4                   33.30                    -

             ***** MEYERHOF UNITS CONVERSION FACTORS *****

              ONE LENGTH UNIT EQUALS        1.0000     FEET
              ONE FORCE  UNIT EQUALS        0.5000     TONS

                 ***** STRAIN INFLUENCE FUNCTION *****

             THE STRAIN INFLUENCE FUNCTION USED IS CURVE G


*********************************
* CLAY SETTLEMENT CONTRIBUTIONS *
*********************************

                   ***** SETTLEMENT BY LAYERS *****
              LAYER      STRESS INTERVAL              INCREMENTAL
              NUMBER                                  SETTLEMENT

                2           1    TO    2               -0.10946
                2           2    TO    3                0.21768
                2           3    TO    4                0.74912
                2           4    TO    5                0.56025
                2           5    TO    6               -0.09385
                2          LAYER HISTORY                1.32375
                3           1    TO    2               -0.07111
                3           2    TO    3                0.09084
                3           3    TO    4                0.11109
                3           4    TO    5                0.10559
                3           5    TO    6               -0.01898
                3          LAYER HISTORY                0.21743
                5           1    TO    2               -0.03254
                5           2    TO    3                0.04219
                5           3    TO    4                0.06297
                5           4    TO    5                0.07563
                5           5    TO    6               -0.01487
                5          LAYER HISTORY                0.13338

               ***** SETTLEMENT BY STRESS INTERVAL *****
                  STRESS INTERVAL              SETTLEMENT
                                              OVER PROFILE
                    1    TO    2                -0.21311
                    2    TO    3                 0.35070
                    3    TO    4                 0.92318
                    4    TO    5                 0.74147
                    5    TO    6                -0.12769

               TOTAL CLAY SETTLEMENT             1.67456
```

(Continued)

```
***************************
* CLAY COMPRESSIBILITIES *
***************************
```

LAYER REEDOUT	STRESS			MV	DELTA E	E1 15:26:15	E2 2/13/79
2	1	TO	2	0.00829	-0.01351	0.85111	0.86462
2	2	TO	3	0.01259	0.02686	0.86462	0.83776
2	3	TO	4	0.02858	0.09245	0.83776	0.74531
2	4	TO	5	0.01801	0.06914	0.74531	0.67617
2	5	TO	6	0.01570	-0.01158	0.67617	0.68775
3	1	TO	2	0.02145	-0.01948	0.78074	0.80022
3	2	TO	3	0.02085	0.02489	0.80022	0.77533
3	3	TO	4	0.01681	0.03043	0.77533	0.74490
3	4	TO	5	0.01300	0.02893	0.74490	0.71597
3	5	TO	6	0.01188	-0.00520	0.71597	0.72117
5	1	TO	2	0.01541	-0.00267	0.68394	0.68661
5	2	TO	3	0.01534	0.00347	0.68661	0.68315
5	3	TO	4	0.01492	0.00517	0.68315	0.67797
5	4	TO	5	0.01438	0.00621	0.67797	0.67176
5	5	TO	6	0.01418	-0.00122	0.67176	0.67298

```
********************
* SAND SETTLEMENTS *
********************
```

***** SETTLEMENT IN SAND LAYERS *****

THE STRAIN WEIGHTED AVERAGE BLOWCOUNT = 33.3000

LAYER NUMBER	MEYERHOF
4	0.0090
TOTAL SAND SETTLEMENT	0.0090
TOTAL CLAY SETTLEMENT	1.6746
TOTAL PROFILE SETTLEMENT	1.6835

```
********************************
TIME-SETTLEMENT RELATIONSHIPS
********************************
```

****COEFFICIENT OF CONSOLIDATION****
(CV)

LAYER NO.	CV SQ.FT./DAY
2	1.2700
3	0.7000
5	0.4700

SETTLEMENT PER LAYER AT THE INPUT INPUT

TIMES (DAYS)	SETTLEMENT (FEET)	DEGREE OF CONSILADTION (U%)
	LAYER 2	
50.00	-0.0331	-2.50
75.00	0.0000	0.00
200.00	0.4233	31.98
300.00	0.8808	66.54
350.00	1.0121	76.45
400.00	1.1028	83.31
500.00	1.2138	91.69
600.00	1.2691	95.87
1000.00	1.3204	99.75

(Continued)

Table 9 (Concluded)

REEDOUT 15:26:15 2/13/79

	LAYER 3	
50.00	-0.0366	-16.84
75.00	-0.0173	-7.95
200.00	0.1031	47.41
300.00	0.2022	93.00
350.00	0.2144	98.59
400.00	0.2163	99.49
500.00	0.2173	99.93
600.00	0.2174	99.99
1000.00	0.2174	100.00

	LAYER 5	
50.00	-0.0088	-6.57
75.00	-0.0043	-3.21
200.00	0.0304	22.79
300.00	0.0772	57.87
350.00	0.0907	68.04
400.00	0.1008	75.58
500.00	0.1146	85.95
600.00	0.1226	91.92
1000.00	0.1322	99.12

TOTAL SETTLEMENT OF PROFILE AT TIMES INPUT

TIMES (DAYS)	SETTLEMENT (FEET)	DEGREE OF CONSOLIDATION (U%)
50.00	-0.0784	-4.68
75.00	-0.0215	-1.29
200.00	0.5568	33.25
300.00	1.1602	69.28
350.00	1.3172	78.66
400.00	1.4199	84.79
500.00	1.5457	92.31
600.00	1.6091	96.09
1000.00	1.6700	99.73

(Figure 7).* Table 10 shows the results. As can be seen, the computer and hand solution agree very closely.

30. Settlement in one of the clay layers (layer 2) determined from MAGSETII was compared to hand solutions for that layer using Terzaghi's theory. Table 11 shows these results. The computer results compare well with the hand solutions. It must be remembered that the theory is simplified to apply to the soil and load conditions, so these results are only an estimate.

31. Hand calculation of the degree of consolidation of the clay layers was based on the methods in EM 1110-2-1904 for clay material. The results are presented in Table 12. There are no noticeable differences in the results of the computer and hand calculations.

32. Settlement due to the compression of the sand was calculated by Meyerhof's method using a vertical strain influence factor. The settlement produced by MAGSETII was 0.009 ft, whereas hand calculations produced 0.007 ft, values which are very close. Again, it must be remembered that these are only estimates and hand calculations require some interpolation.

Example Problem 2

33. Example Problem 2 was taken from EM 1110-2-1904. A plan view of the problem is shown in Figure 8. Appendix A to EM 1110-2-1904, which describes the problem and includes hand computations, is included as Figure 9.

Input/output

34. Input to program I0016 is shown in Table 13. Output from the program is shown in Table 14. Using the stress information provided by program I0016, input to program MAGSETII was prepared and is shown in Table 15. Output from this program is included in Table 16.

---

* This chart is from notes by Prof. Robert D'Andrea to Course No. CE3040, "Soil Mechanics," Worcester Polytechnic Institute, Worcester, Mass., 1975.

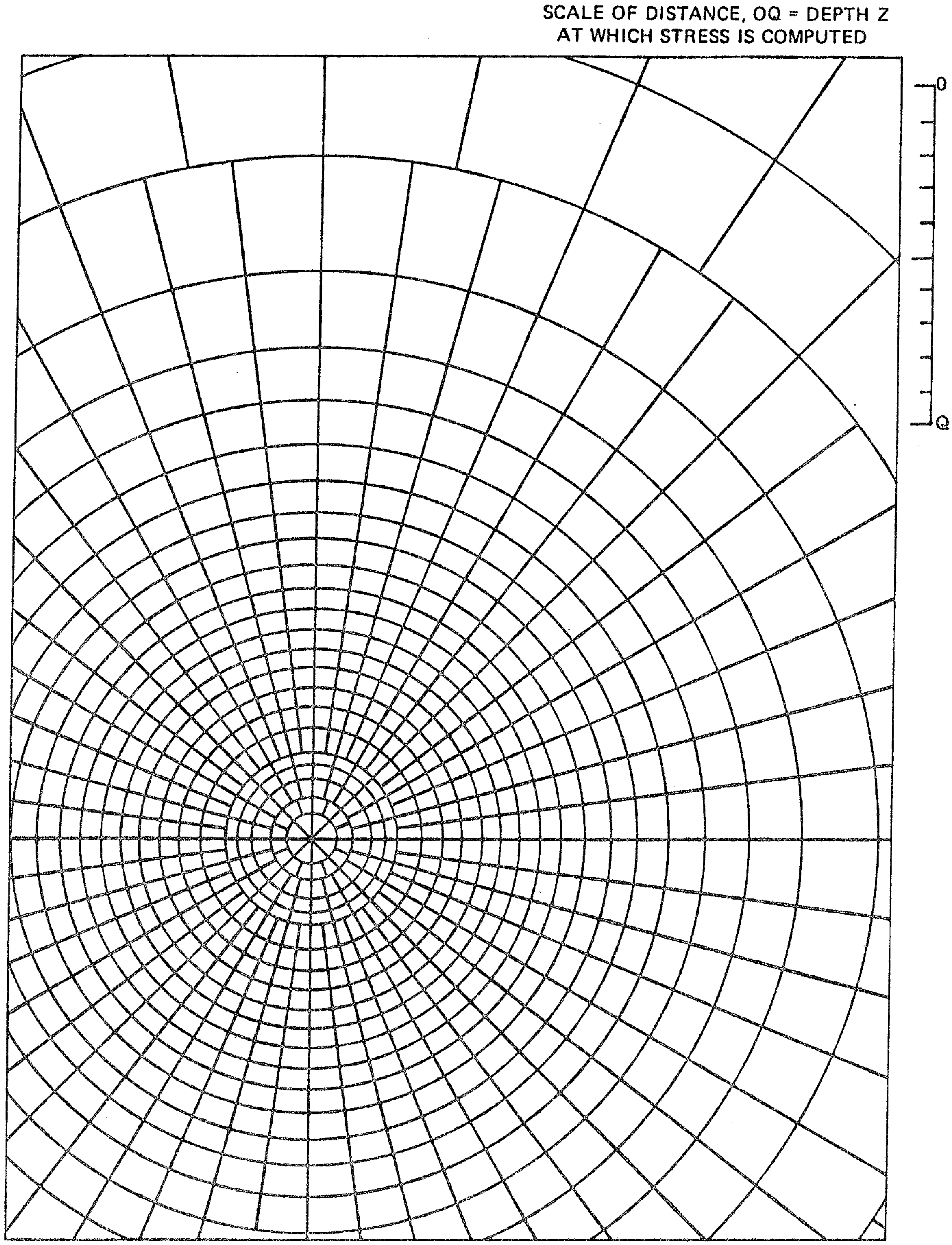


Figure 7. Newmark's influence chart for vertical pressure
(influence value = 0.001)

Table 10

Comparison of I0016 and Hand Solutions for Vertical Stresses in Example Problem 1

Depth ft	Vertical Stress, kips/ft^2 I0016 Solution	Hand Solution
7.50	0.882	0.880
18.25	0.509	0.511
56.75	0.103	0.115

Table 11

Comparison of MAGSETII and Hand Solutions for Settlement in Layer 2 of Example Problem 1

Increment No.	Settlement, ft MAGSETII Solution	Hand Solution
1	-0.10946	-0.109
2	0.21768	0.215
3	0.74912	0.756
4	0.56025	0.560
5	-0.09385	-0.093

Table 12

Comparison of MAGSETII and Hand Solutions for Rate of Settlement in Layer 2 of Example Problem 1

	MAGSETII Solution		Hand Solution	
Time days	Settlement ft	Degree of Consolidation percent	Settlement ft	Degree of Consolidation percent
50	-0.0331	-2.5	-0.037	-3
75	0.000	0.0	0.000	0
200	0.4233	31.98	0.50	37
300	0.8808	66.54	0.98	72
350	1.0121	76.45	1.08	81
400	1.1028	83.31	1.21	90
500	1.2138	91.69	1.25	94
600	1.2691	95.87	1.29	97
1000	1.32044	99.75	1.32	99

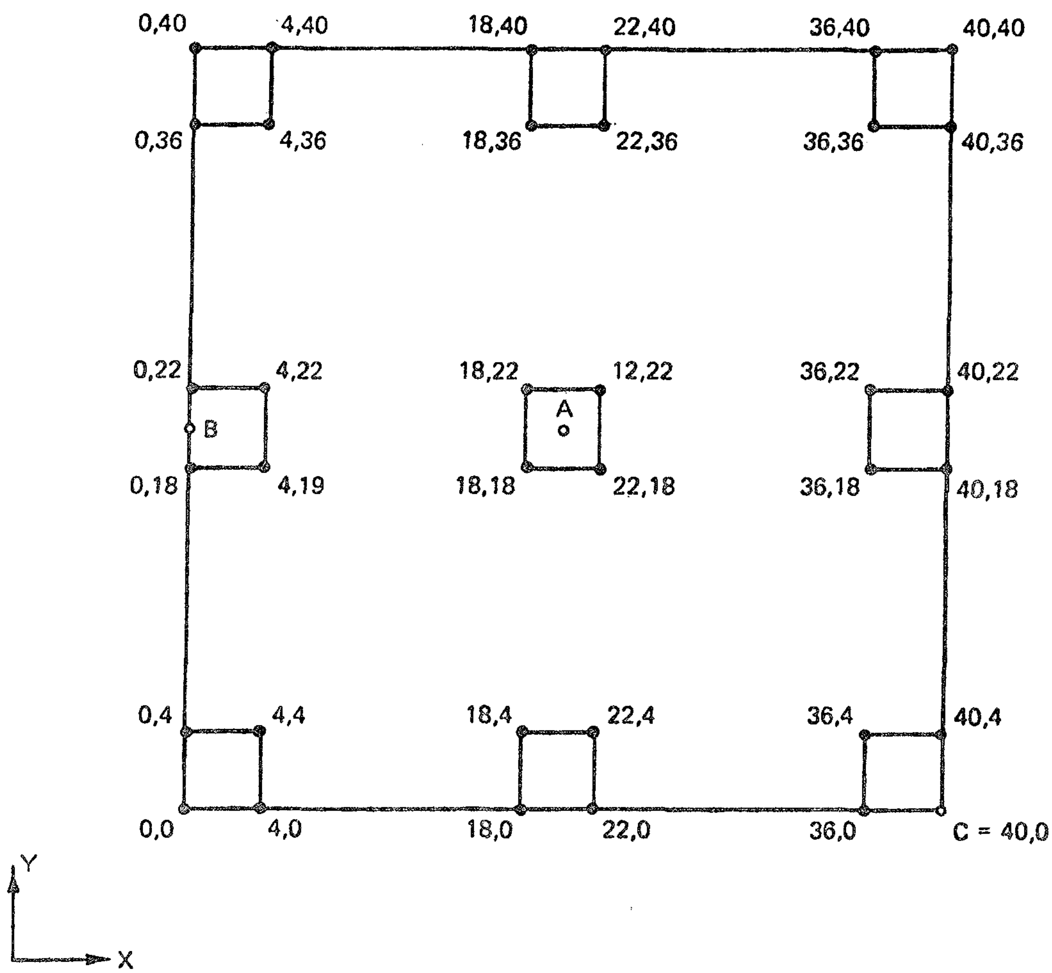


Figure 8. Plan view of problem 3

APPENDIX A

ILLUSTRATIVE PROBLEM—SETTLEMENT ANALYSIS

The Problem. Determine the total settlement resulting from a buried clay stratum and the time-settlement rate for a structure supported by nine 4- by 4-foot footings located at an elevation 5 feet below the natural ground surface. The foundation plan for the structure and the soil conditions beneath the structure are shown on Plate No. 1. The gross unit load on each footing is 2 tons per square foot. The construction rate of load will be applied uniformly in the first 60 days and the remaining 25 percent of the load will be applied uniformly during the next 30 days. The amount of rebound, resulting from the excavation before the construction load is applied, is assumed to be negligible. Consolidation test data for a representative sample of the clay stratum are shown on Plates Nos. 2 and 8 on which are plotted pressure-void ratio and time-settlement data, respectively, for the sample tested. Examination of the consolidation data shows the clay to be normally consolidated.

Total Settlement. In order to determine the differential settlement to be expected between footings, the settlement must be computed for several points such as A, B, and C, Plate No. 1. Proceed with the analysis as follows:

(1) Construct the load-depth diagram for the existing overburden conditions, Plate No. 3. Since the clay stratum is only 20 feet thick it is safe to assume that the pressure distribution is uniform from top to bottom and that the pressure at the middle of the stratum (depth 25 feet) represents the average pressure in the stratum. Determine p_1 from the load-depth diagram, Plate No. 3, which at 25 feet is 1.15 tons per square foot. The overburden pressure, p_1, is the same for all three points A, B, and C.

(2) The pressure due to the added load of the structure may be determined either as point loads, since the dimension-depth ratio is greater than 3, or as area loads. The area load method was selected for this problem because it is valid for all depths. It was assumed that the Boussinesq solution would best fit the soil conditions encountered in this problem. Plate No. 6, was constructed as described in paragraph 4-03*e* and is utilized for determining the vertical pressures at depths of 10 and 25 feet below the footings for each of the three points A, B, and C. The gross unit load of the footings must be corrected for the weight of 5 feet of sand which was excavated, to obtain the net load applied to the foundation. From Plate No. 3 the pressure due to 5 feet of sand is 0.31 ton per square foot.

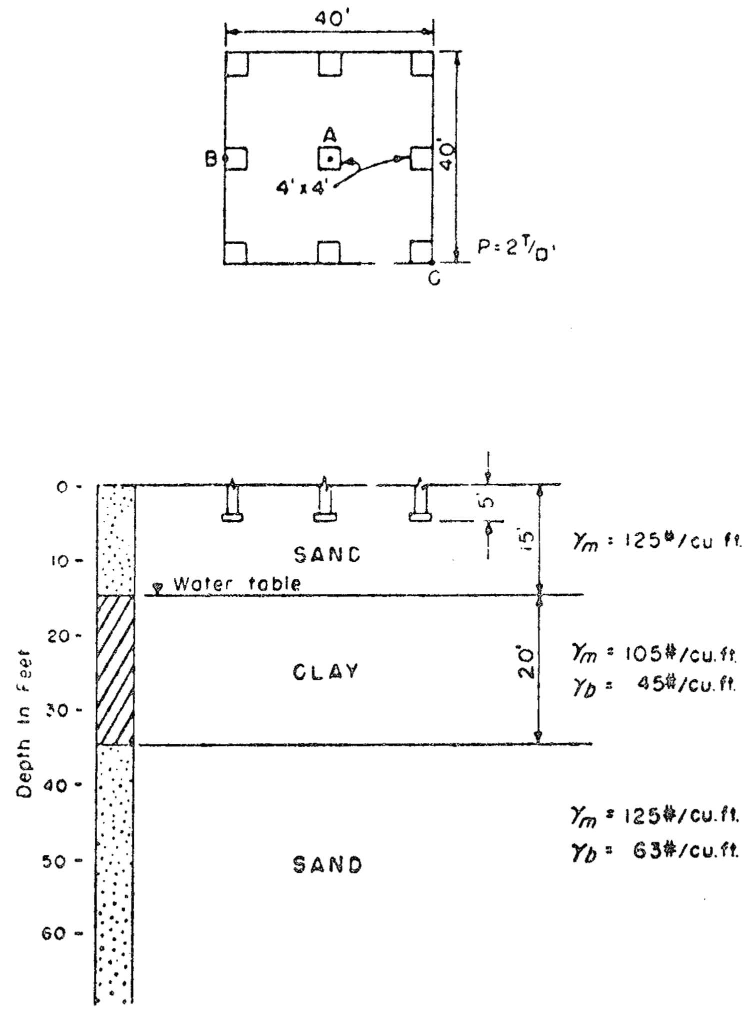
Hence:

$$q=2.00-0.31=1.69 \text{ tons per square foot (net load).}$$

Make up overlays of the foundation plan shown on Plate No. 1 with scale OQ equal to 10 and 25 feet for use with Plate No. 6. Using foundation plan with chart scale equal to 25 feet, place point A over the center of the chart. Count the number of influence areas on the chart which fall within the outlines of the individual footing areas. Since all footings have identical unit loads, the influence areas under all footings may be combined. A total of 25 influences is counted. Each influence area is equal to 0.001 q. Then for point A at a depth of 25 feet below the footing the pressure due to the structure load p_s is:

$$p_s=25\times0.001\times1.69=0.042 \text{ tons per square foot.}$$

Figure 9. Appendix A to EM 1110-2-1904 (Sheet 1 of 9)



GENERAL PLAN
SHOWING STRUCTURE AND SOIL PROFILE

Figure 9. (Sheet 2 of 9)

Repeat the above procedure for other points and depths. The results for this problem are tabulated as follows:

Depth below footing	*Point*	*Number of influence areas*	p_v *tons per sq. ft.*
10	A	81	0.136
10	B	72	.122
10	C	66	.112
25	A	43	.073
25	B	33	.056
25	C	25	.042

Construct a load-depth diagram, Plate No. 6, using the above-computed values of pressures.

(3) Using Plate No. 7, determine p_v at the middle of the clay stratum which is located 20 feet below the bottom of the footing for points A, B, and C. Then, $p_2=p_1+p_v$. After obtaining p_2, determine values of the void ratios e_1 and e_2 corresponding to p_1 and p_2, by use of the pressure-void ratio curve, Plate No. 2. The total settlement ΔH may be obtained by the relationship:

$$\Delta H=\frac{e_1-e_2}{1+e_1}2H_1$$

Results of the foregoing operations are summarized below.

Point	A	B	C
p_1	1.15	1.15	1.15
p	.08	.07	.06
p_2	1.23	1.22	1.21
e_1	1.044	1.044	1.044
e_2	1.035	1.037	1.038
e_1-e_2	.009	.007	.006
$1+e_1$	2.044	2.044	2.044
$2H$	20	20	20
ΔH	.09	.07	.06

Differential settlement between points A and B is 0.02 foot and between points A and C is 0.03 foot.

Time-settlement rate. Using Plate No. 10, the time for 50 percent consolidation of the laboratory specimen 1.25 inches in thickness is found to be 8.1 minutes. The time for 50 percent consolidation of the field stratum is then found by the use of the relationship:

$$* \quad t_{50f}=\left(\frac{2H_f}{2H_l}\right)^2 t_{50l}$$

Substituting:

$$* \quad t_{50f}=\left(\frac{20 \text{ ft}}{1.25 \text{ inches}/12}\right)^2 (8.1 \text{ minutes})$$

$$t_{50f}=298{,}598 \text{ minutes}=207.4 \text{ days.}$$

*Corrections and/or deletions made June 1955 in accordance with errata issued to date.

Figure 9. (Sheet 3 of 9)

Using the relationship in equation (19) as follows:

$$t_{u_f}=\frac{t_{50_f}}{T_{50}}T_u\frac{t_{50_f}}{0.196}$$

compute the time for various percents consolidation, substituting values of T_u found in Table 1. Substituting, for 10 percent consolidation

$$t_{10_f}=\frac{298,598 \text{ min.}}{0.196}\times 0.0077=11,730 \text{ min.}=8.14 \text{ days}$$

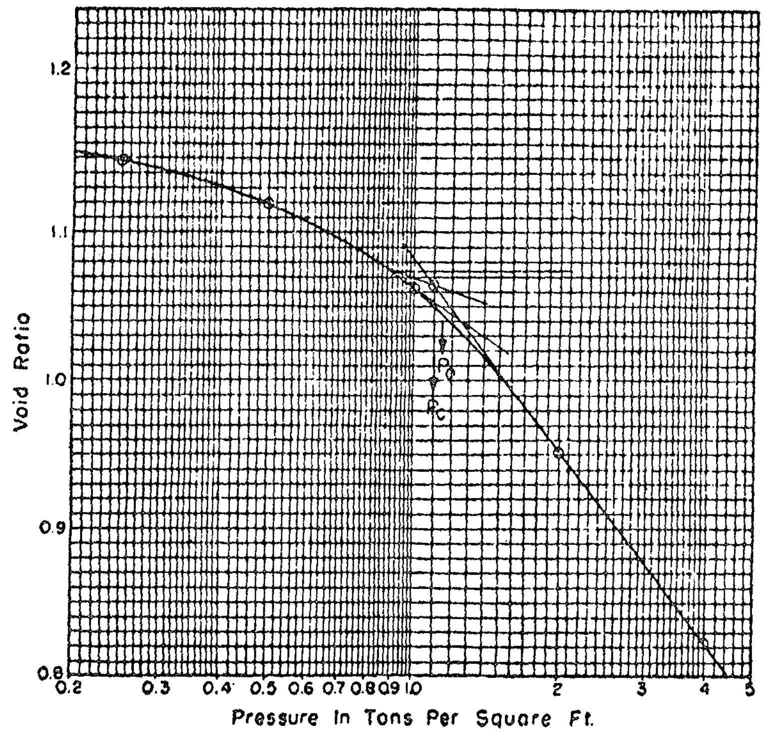
Results of the computations for the various percents of consolidation are tabulated below.

U%	T_u	t_{u_f} *Minutes*	*Days*
10	0.0077	11,730	8.14
20	.0314	47,836	32.8
30	.0707	107,708	74.8
40	.126	191,955	133.3
50	.196	298,597	207.3
60	.286	435,709	302.6
70	.403	613,954	426.3
80	.567	863,801	599.9
90	.848	1,291,893	897.1
95	1.129	1,719,985	1194.4

Since the time rate for construction is not uniform, it should be divided into convenient increments such as 25 percent of the load. It is assumed that each 25 percent increment will then cause approximately 25 percent of the total consolidation, and the settlement resulting from each increment is assumed to start at the half-time for the application of increment of load. To construct a loading diagram as shown on Plate 12, divide the load application into four 25 percent increments. Draw a time-settlement curve for each increment, starting at the half-time for each increment and using time values tabulated above. The percents consolidation will be divided by 4 in each case. The time-settlement curve for construction loading is then obtained by adding the ordinates of each increment time-settlement curve and drawing a smooth curve through the points so obtained. Adjust the initial portion of the curve by starting the curve at zero time and settlement.

GPO 89 3432

Figure 9. (Sheet 4 of 9)

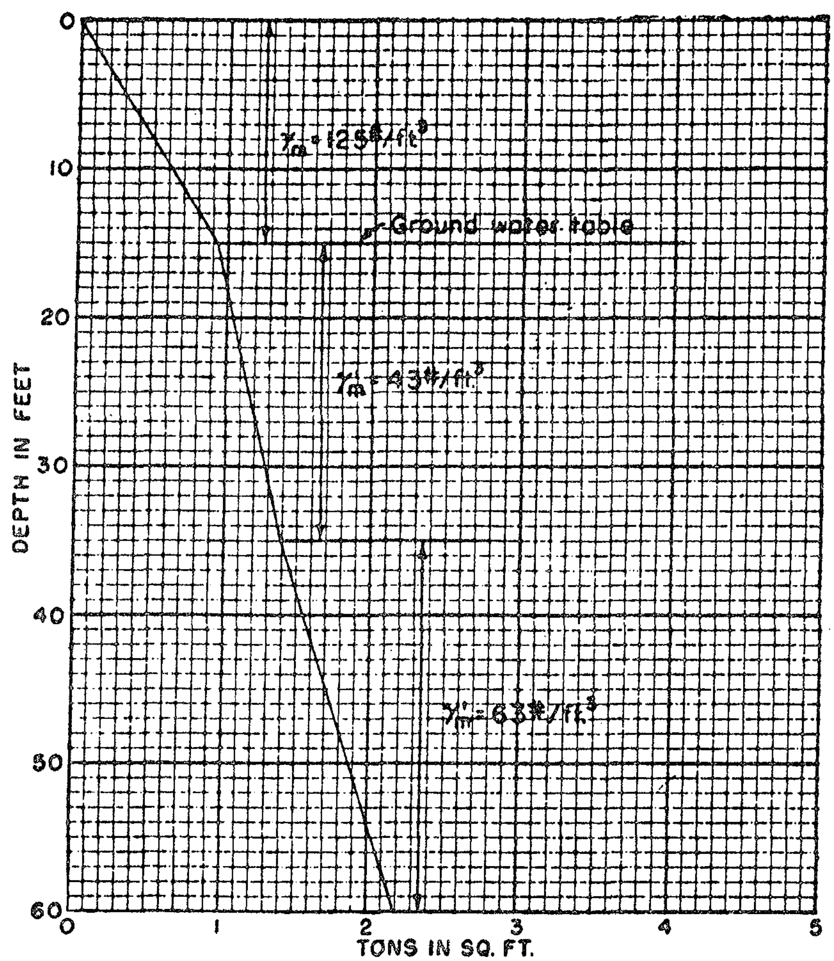


Note:
Initial thickness of sample 1.25 inches.

PRESSURE – VOID RATIO CURVE
FOR CLAY STRATUM BELOW
STRUCTURE ON PLATE NO. 1

Figure 9. (Sheet 5 of 9)

DEPARTMENT OF THE ARMY CORPS OF ENGINEERS



LOAD DEPTH DIAGRAM
OVERBURDEN PRESSURE

ENGINEERING MANUAL PART CXIX CHAPTER 4 PLATE NO. 3

24

Figure 9. (Sheet 6 of 9)

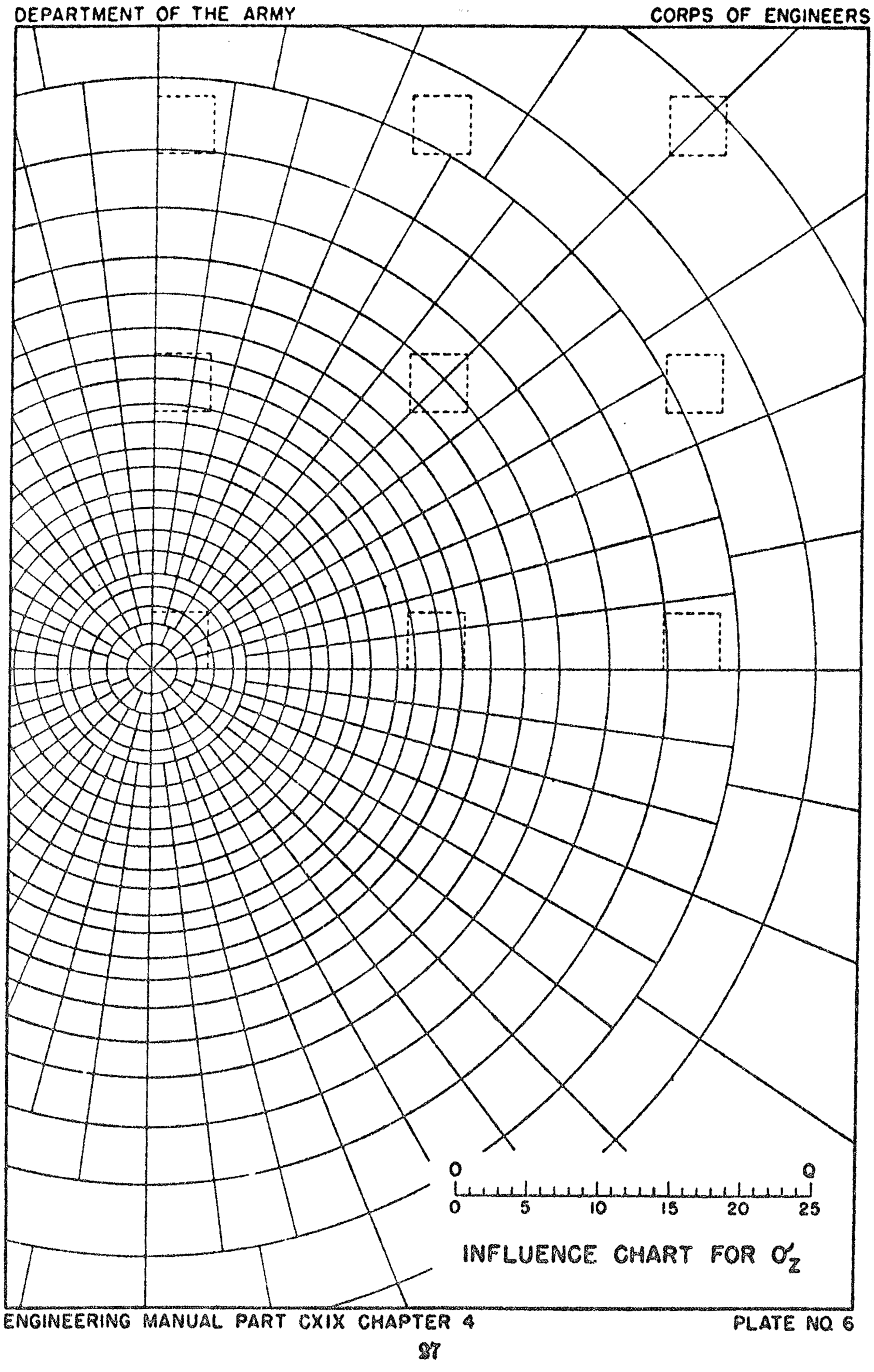


Figure 9. (Sheet 7 of 9)

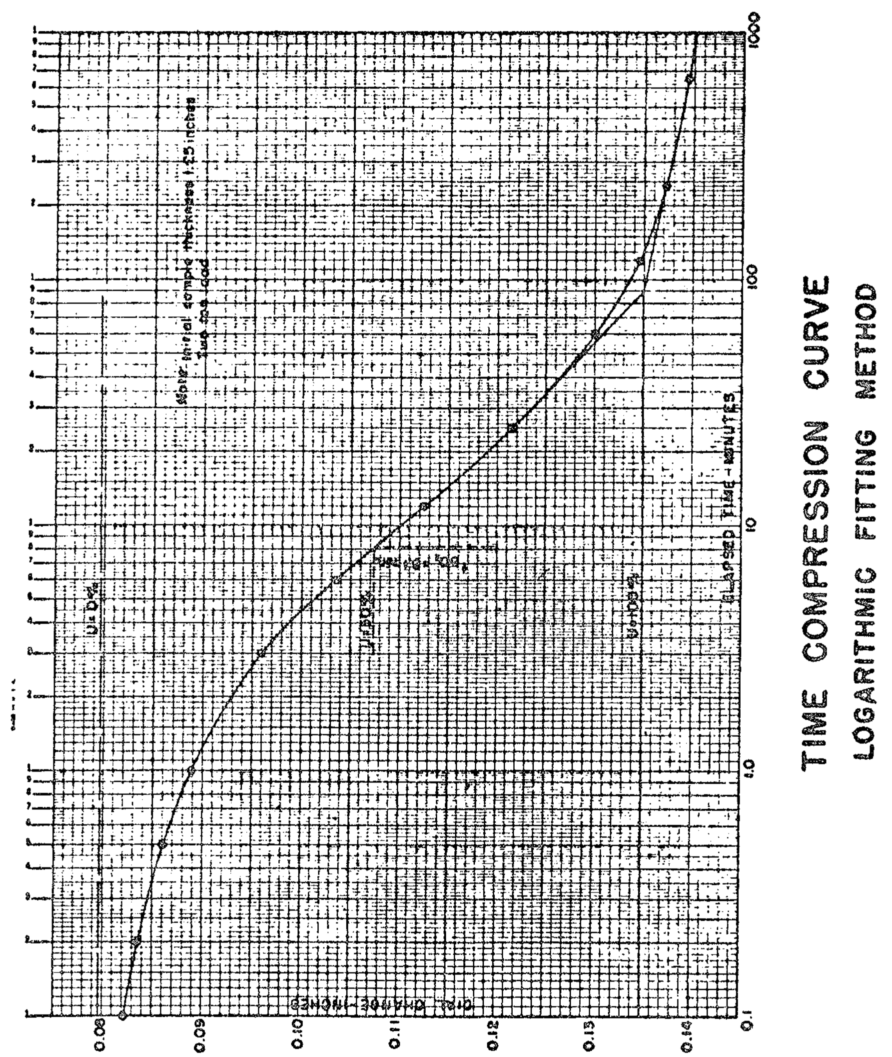
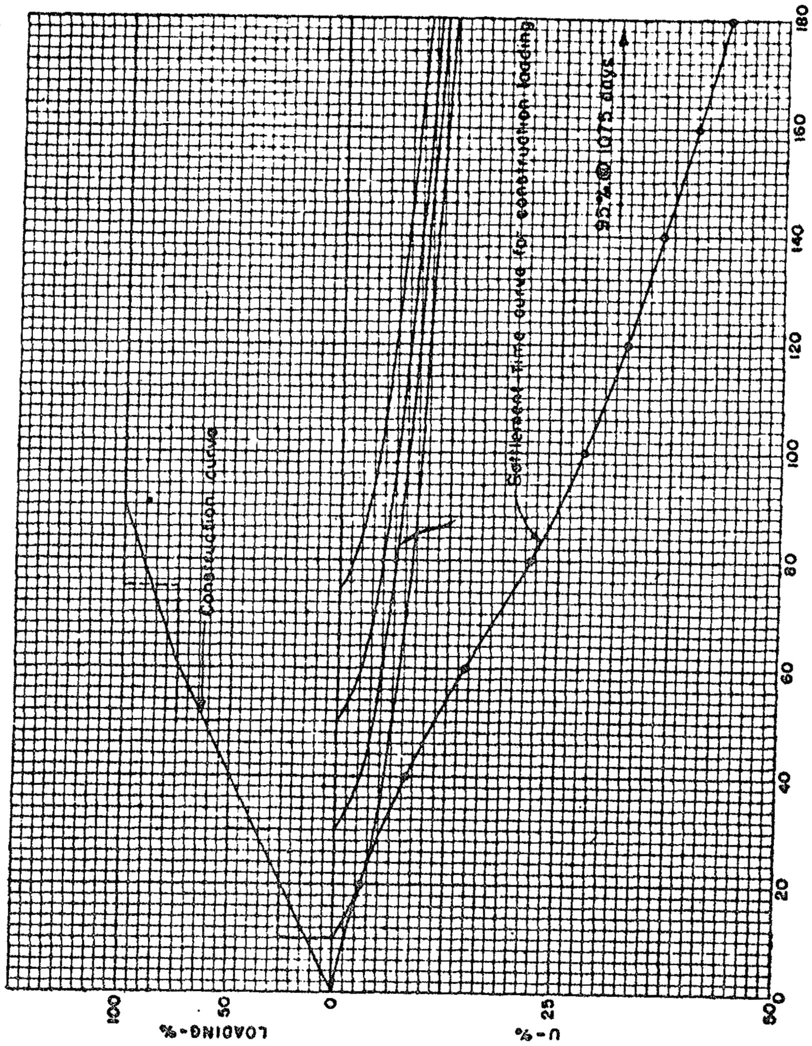


Figure 9. (Sheet 8 of 9)



TIME-SETTLEMENT CURVE
FOR CONSTRUCTION RATE OF LOADING

Figure 9. (Sheet 9 of 9)

Table 13

Input Data File for Program I0016

(Example Problem 2)

```
LIST RLMBS

1000 JAN 22,1979                         TITLE
1010 SAMPLE PROBLEM
1020 9 4FT. BY 4FT. FOOTINGS
1030 RLM
1040 COMPARE TO EM1110-2-1904
1060 1 9  (KODE, NAREA)
1070 1.00 0.0 0.0 0.0 0.0 4.0 4.0 4.0 4.0 0.0
1080  1.00 0.0 18.0 0.0 18.0 4.0 22.0 4.0 22.0 0.0
1090   1.00 0.0 36.0 0.0 36.0 4.0 40.0 4.0 40.0 0.0
1100  1.00 0.0 0.0 18.0 0.0 22.0 4.0 22.0 4.0 18.0
1110 1.00 0.0 18.0 18.0 18.0 22.0 22.0 22.0 22.0 18.0
1120 1.00 0.0 36.0 18.0 36.0 22.0 40.0 22.0 40.0 18.0
1130 1.00 0.0 0.0 36.0 0.0 40.0 4.0 40.0 4.0 36.0
1140 1.00 0.0 18.0 36.0 18.0 40.0 22.0 40.0 22.0 36.0
1150 1.00 0.0 36.0 36.0 36.0 40.0 40.0 40.0 40.0 36.0
1160 2 1 0.0 NDIST, NWEST, AMU
1170 0.0 40.0 10.0 0.0 0.0 10.0 0.0 0.0
1171 2 1 0.0
1180 0.0 40.0 10.0 0.0 0.0 10.0 0.0 20.0
1181 2 1 0.0
1190  0.0 40.0 10.0 0.0 0.0 25.0 0.0 0.0
1191 2 1 0.0
1200 0.0 40.0 10.0 0.0 0.0 25.0 0.0 20.0
1210 0 0 0.0 <-- (STOP THE PROBLEM)

       AINTL, FINAL, DELTA, XP, YP, ZP, SLP, BLINE
*
     Q(1), ZLAY(1), XC(1,1), YC(1,1), XC(2,1), YC(2,1),
                  XC(3,1), YC(3,1), XC(4,1), YC(4,1)
```

Table 14

Output Data File for Program I0016

(Example Problem 2)

```
RLMSB                                                 10· 3·59    2/14/79

JAN 22,1979
SAMPLE PROBLEM
9 4FT. BY 4FT. FOOTINGS
RLM
COMPARE TO EM1110-2-1904

    BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =   10.00
```

Y-COORDINATE	X-COORDINATE	ELASTIC SOLUTION VERTICAL STRESS	NORMAL LOADING VERTICAL STRESS
0.	0.	0.064	0.064
0.	10.00	0.037	0.037
0.	20.00	0.072	0.072
0.	30.00	0.037	0.037
0.	40.00	0.064	0.064

```
        NUMBER OF AREAS USED IN CALCULATION =   9

  NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT,
      CONFIGURATION.

JAN 22,1979
SAMPLE PROBLEM
9 4FT. BY 4FT. FOOTINGS
RLM
COMPARE TO EM1110-2-1904

    BOUSSINESQ SOLUTION

        HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) =   10.00
```

Y-COORDINATE	X-COORDINATE	ELASTIC SOLUTION VERTICAL STRESS	NORMAL LOADING VERTICAL STRESS
20.00	0.	0.072	0.072
20.00	10.00	0.042	0.042
20.00	20.00	0.082	0.082
20.00	30.00	0.042	0.042
20.00	40.00	0.072	0.072

```
        NUMBER OF AREAS USED IN CALCULATION =   9

  NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT,
      CONFIGURATION.
```

(Continued)

Table 14 (Concluded)

JAN 22,1979
SAMPLE PROBLEM
9 4FT. BY 4FT. FOOTINGS
RLM
COMPARE TO EM1110-2-1904

BOUSSINESQ SOLUTION

HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) = 25.00

Y-COORDINATE	X-COORDINATE	ELASTIC SOLUTION VERTICAL STRESS	NORMAL LOADING VERTICAL STRESS
0.	0.	0.023	0.023
0.	10.00	0.027	0.027
0.	20.00	0.029	0.029
0.	30.00	0.027	0.027
0.	40.00	0.023	0.023

NUMBER OF AREAS USED IN CALCULATION = 9

NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT.

RLMSB 10· 3·59 2/14/79

CONFIGURATION.

JAN 22,1979
SAMPLE PROBLEM
9 4FT. BY 4FT. FOOTINGS
RLM
COMPARE TO EM1110-2-1904

BOUSSINESQ SOLUTION

HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) = 25.00

Y-COORDINATE	X-COORDINATE	ELASTIC SOLUTION VERTICAL STRESS	NORMAL LOADING VERTICAL STRESS
20.00	0.	0.029	0.029
20.00	10.00	0.035	0.035
20.00	20.00	0.038	0.038
20.00	30.00	0.035	0.035
20.00	40.00	0.029	0.029

NUMBER OF AREAS USED IN CALCULATION = 9

NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT.
CONFIGURATION.

Table 15

Input Data File for Program MAGSETII

(Example Problem 2)

```
RLMM                                                        9:55:57     2/14/79

            1000    1      2      0  (PROBLEM NO., NO. OF LAYER, RUN CONTROL)
            1010            COMPARISION TO EM1110-2-1904 PROBLEM (TITLE)
            1020    1    1     3     2     1     3     0     2  (INPUT OPTIONS)
            1030    FEET        TONS  (UNITS)
            1040    0.0313    15.0000  (GROUND WATER DATA)
            1050    1    0.0000  )
            1060    2   15.0000  } (LAYER INTERFACE DATA)
            1070    3   35.00000 )
            1080    1     3     0.0625 {
            1090    2     1     0.0525 {  (SOIL PROPERTIES)
            1100    0.          0.  (DATUM CONVERSION)
            1110    1.2675      0 }
            1120    0.4225      1 }  (EFFECTIVE STRESS INCREMENT)
            1130    2     0.0380   (EFFECTIVE STRESS DISTRIBUTION)
            1140    2     1     1.1500     0.2400                              )
            1150    2     2     1.1200     0.5000     1.1500     0.2400     0  |
            1160    2     3     1.0600     1.0000     1.1200     0.5000     0  } DEFORMATION
            1170    2     4     0.9500     2.0000     1.0600     1.0000     0  |    CURVE
            1180    2     5     0.8200     4.0000     0.9500     2.0000     1  )
            1190    1           (CONSOLIDATION OPTION CONTROL)
            1200    2     .095   0     0  (CONSOLIDATION DATA)
            1210    1      2      0
SECOND RUN→ 1220            COMPARISION TO EM1110-2-1904 PROBLEM
            1230    1    1     3     2     1     0     0     2
            1240    FEET        TONS
            1250    0.0313    15.0000
            1260    1    0.0000
            1270    2   15.0000
            1280    3   35.00000
            1290    1     3     0.0625
            1300    2     1     0.0525
            1310    0.          0.
            1320    1.2675      0
            1330    0.4225      1
            1340    2     0.0290
            1350    2     1     1.1500     0.2400
            1360    2     2     1.1200     0.5000     1.1500     0.2400     0
            1370    2     3     1.0600     1.0000     1.1200     0.5000     0
            1380    2     4     0.9500     2.0000     1.0600     1.0000     0
            1390    2     5     0.8200     4.0000     0.9500     2.0000     1
            1400    1
            1410    2     .095   0     0
            1420    1      2      1
THIRD RUN→  1430            COMPARISION TO EM1110-2-1904 PROBLEM
            1440    1    1     3     2     1     0     0     2
            1450    FEET        TONS
            1460    0.0313    15.0000
            1470    1    0.0000
            1480    2   15.0000
            1490    3   35.00000
            1500    1     3     0.0625
            1510    2     1     0.0525
            1520    0.          0.
            1530    1.2675      0
            1540    0.4225      1
            1550    2     0.0230
            1560    2     1     1.1500     0.2400
            1570    2     2     1.1200     0.5000     1.1500     0.2400     0
            1580    2     3     1.0600     1.0000     1.1200     0.5000     0
            1590    2     4     0.9500     2.0000     1.0600     1.0000     0
            1600    2     5     0.8200     4.0000     0.9500     2.0000     1
            1610    1
            1620    2     .095   0     0
```

Table 16

Output Data File for Program MAGSETII

(Example Problem 2)

```
RLMMM                                                     9:57: 8     2/14/79

1                          ********************************
                           *                              *
                           *          MAGSET-II           *
                           *                              *
                           * MAGNITUDE OF SETTLEMENT OF   *
                           * A MULTI-LAYERED SOIL SYSTEM  *
                           *                              *
                           ********************************

 ***********************
 * SPECIFICATIONS FOR*
 *    PROBLEM NO.  1    *
 ***********************
                              ***** TITLE *****
            COMPARISION TO EM1110-2-1904 PROBLEM
                              ***** UNITS *****
                           LENGTH              FORCE
                         FEET        TON  S
 ****************
 * SOIL PROFILE *
 * DESCRIPTION  *
 ****************
                      DATUM ELEVATION            =      0.
                      DIFFERENCE IN ELEVATION =      0.
 LAYER     SOIL       INTERFACE      DATUM                              UNIT
 NUMBER    TYPE        DEPTH      ELEVATIONS      THICKNESS          WEIGHT
                        0.           0.
   1       INCOMP                                   15.00             0.0625
                      15.00       -15.00
   2       CLAY                                     20.00             0.0525
                      35.00       -35.00

                    UNIT WEIGHT      GROUND WATER      GROUND WATER
                     OF WATER           LEVEL         DATUM ELEVATION
                      0.0313            15.00             -15.00

 ******************************
 * INSITU EFFECTIVE STRESS *
 ******************************

            LAYER       INPUT        CALCULATED        INSITU
            NUMBER      VALUE          VALUE           STRESS
              1           -            0.4688           0.4688
              2           -            1.1495           1.1495


 *************************
 * CLAY SETTLEMENT DATA *
 *************************

          EFFECTIVE STRESS INCREMENTS INPUT BY
+                                                A DISTRIBUTION FUNCTION
              ***** STRESS INCREMENTS FOR STRATUM *****
                    POINT NUMBER        STRESS INCREMENT
                         1                    1.2675
                         2                    0.4225


                  ***** STRESS DISTRIBUTION FUNCTION *****
                       LAYER
                       NUMBER                 VALUE
                         2                    0.0380


                    ***** EFFECTIVE STRESS HISTORY *****
          LAYER NO.      PT. NO.     STRESS INCREMENT      STRESS VALUES

              2             1             0.0482                1.1977
              2             2             0.0161                1.2137
```

(Continued)

```
RLMMM                                               9:57: 8     2/14/79


            DEFORMATION CURVES INPUT BY
+                                              COORDINATE POINTS

            ***** COORDINATES OF POINTS ON THE DEFORMATION CURVES *****
 LAYER   POINT                                    REBOUND        REBOUND
 NUMBER  NUMBER    VOID RATIO        STRESS     VOID RATIO          STRESS

   2       1         1.1500          0.2400
   2       2         1.1200          0.5000          1.1500          0.2400
   2       3         1.0600          1.0000          1.1200          0.5000
   2       4         0.9500          2.0000          1.0600          1.0000
   2       5         0.8200          4.0000          0.9500          2.0000

                ***** SLOPES ON THE DEFORMATION CURVES *****
 LAYER    LINE          CC              CE              CC              CE
 NUMBER  NUMBER                                      (STRAIN)        (STRAIN)

   2       1          0.0941          0.0941          0.0438          0.0438
   2       2          0.1993          0.1993          0.0940          0.0940
   2       3          0.3654          0.3654          0.1774          0.1774
   2       4          0.4319          0.4319          0.2215          0.2215

*********************************
* CLAY SETTLEMENT CONTRIBUTIONS *
*********************************

                         ***** SETTLEMENT BY LAYERS *****
                 LAYER      STRESS INTERVAL            INCREMENTAL
                 NUMBER                                SETTLEMENT
                   2          1    TO   2                0.06393
                   2          2    TO   3                0.02074

                   2          LAYER HISTORY              0.08467

                   ***** SETTLEMENT BY STRESS INTERVAL *****
                      STRESS INTERVAL            SETTLEMENT
                                                 OVER PROFILE
                        1   TO   2                 0.06393
                        2   TO   3                 0.02074

                   TOTAL CLAY SETTLEMENT           0.08467

*************************
* CLAY COMPRESSIBILITIES *
*************************

LAYER      STRESS          MU          DELTA E         E1           E2
  2      1  TO  2       0.06636       0.00651       1.03789      1.03138
  2      2  TO  3       0.06480       0.00211       1.03138      1.02926


                THERE ARE NO SAND LAYERS IN THE SOIL PROFILE


***********************************
*DEGREE OF CONSOLIDATION*
***********************************


             ****COEFFICIENT OF CONSOLIDATION****
                             (CV)
                                                          CV
                  LAYER NO.                           SQ.FT./DAY
                      2                               0.0950
```

(Continued)

Table 16 (Continued)

```
RLMMM                                                 9:57: 8    2/14/79
               DEGREE OF CONSOLIDATION        TIME FACTOR           DAYS
                           U%                     TV

                                        LAYER    2
                       5.00%                   0.0020               2.07
                      10.00%                   0.0079               8.28
                      15.00%                   0.0177              18.63
                      20.00%                   0.0315              33.11
                      25.00%                   0.0492              51.74
                      30.00%                   0.0708              74.51
                      35.00%                   0.0963             101.41
                      40.00%                   0.1258             132.46
                      45.00%                   0.1593             167.64
                      50.00%                   0.1966             206.97
                      55.00%                   0.2386             251.11
                      60.00%                   0.2863             301.35
                      65.00%                   0.3404             358.30
                      70.00%                   0.4028             424.05
                      75.00%                   0.4767             501.81
                      80.00%                   0.5671             596.99
                      85.00%                   0.6837             719.69
                      90.00%                   0.8480             892.63
                      95.00%                   1.1289            1188.27
1                           ******************************
                            *                            *
                            *          MAGSET-II         *
                            *                            *
                            * MAGNITUDE OF SETTLEMENT OF *
                            * A MULTI-LAYERED SOIL SYSTEM *
                            *                            *
                            ******************************

*********************
* SPECIFICATIONS FOR*
*   PROBLEM NO.  1  *
*********************
                                 ***** TITLE *****
               COMPARISION TO EM1110-2-1904 PROBLEM
                                 ***** UNITS *****
                            LENGTH                 FORCE
                          FEET        TON  S
***************
* SOIL PROFILE *
* DESCRIPTION  *
***************
                     DATUM ELEVATION            =       0.
                     DIFFERENCE IN ELEVATION =          0.
LAYER      SOIL      INTERFACE       DATUM                                UNIT
NUMBER     TYPE        DEPTH      ELEVATIONS       THICKNESS            WEIGHT
                         0.           0.
  1       INCOMP                                     15.00               0.0625
                       15.00       -15.00
  2        CLAY                                      20.00               0.0525
                       35.00       -35.00

                    UNIT WEIGHT      GROUND WATER       GROUND WATER
                     OF WATER           LEVEL         DATUM ELEVATION
                      0.0313            15.00             -15.00

*************************
* INSITU EFFECTIVE STRESS *
*************************

                LAYER       INPUT        CALCULATED          INSITU
                NUMBER      VALUE           VALUE            STRESS
                  1           -            0.4688            0.4688
                  2           -            1.1495            1.1495
```

(Continued)

Table 16 (Continued)

```
RLMMM                                                   9.57. 8    2/14/79

 ************************
 * CLAY SETTLEMENT DATA *
 ************************

          EFFECTIVE STRESS INCREMENTS INPUT BY
+                                                A DISTRIBUTION FUNCTION
               ***** STRESS INCREMENTS FOR STRATUM *****
                     POINT NUMBER      STRESS INCREMENT
                          1                 1.2675
                          2                 0.4225


                   ***** STRESS DISTRIBUTION FUNCTION *****
                        LAYER
                        NUMBER              VALUE
                          2                 0.0290


                     ***** EFFECTIVE STRESS HISTORY *****
          LAYER NO.    PT. NO.    STRESS INCREMENT     STRESS VALUES

               2          1              0.0368             1.1863
               2          2              0.0123             1.1985


          DEFORMATION CURVES INPUT BY
+                                         COORDINATE POINTS

          ***** COORDINATES OF POINTS ON THE DEFORMATION CURVES *****
LAYER   POINT                                 REBOUND       REBOUND
NUMBER  NUMBER    VOID RATIO       STRESS     VOID RATIO         STRESS

  2       1         1.1500         0.2400
  2       2         1.1200         0.5000       1.1500           0.2400
  2       3         1.0600         1.0000       1.1200           0.5000
  2       4         0.9500         2.0000       1.0600           1.0000
  2       5         0.8200         4.0000       0.9500           2.0000

               ***** SLOPES ON THE DEFORMATION CURVES *****
LAYER    LINE          CC                CE            CC            CE
NUMBER  NUMBER                                     (STRAIN)      (STRAIN)

  2       1          0.0941            0.0941        0.0438        0.0438
  2       2          0.1993            0.1993        0.0940        0.0940
  2       3          0.3654            0.3654        0.1774        0.1774
  2       4          0.4319            0.4319        0.2215        0.2215

*********************************
* CLAY SETTLEMENT CONTRIBUTIONS *
*********************************

                      ***** SETTLEMENT BY LAYERS *****
              LAYER      STRESS INTERVAL             INCREMENTAL
              NUMBER                                 SETTLEMENT
                2           1  TO  2                   0.04902
                2           2  TO  3                   0.01600
                2          LAYER HISTORY               0.06503

               ***** SETTLEMENT BY STRESS INTERVAL *****
                  STRESS INTERVAL             SETTLEMENT
                                             OVER PROFILE
                     1  TO  2                   0.04902
                     2  TO  3                   0.01600

               TOTAL CLAY SETTLEMENT            0.06503

**************************
* CLAY COMPRESSIBILITIES *
```

(Continued)

```
RLMMM                                                 9:57: 8     2/14/79      PAGE  9
 **************************

 LAYER      STRESS         MV         DELTA E         E1              E2
   2     1   TO   2     0.06668     0.00500      1.03789        1.03289
   2     2   TO   3     0.06547     0.00163      1.03289        1.03126


                THERE ARE NO SAND LAYERS IN THE SOIL PROFILE


 ***********************************
 *DEGREE OF CONSOLIDATION*
 ***********************************

               ****COEFFICIENT OF CONSOLIDATION****
                              (CV)
                                                               CV
                  LAYER NO.                                SQ.FT./DAY
                      2                                   0.0950

          DEGREE OF CONSOLIDATION         TIME FACTOR              DAYS
                    U%                        TV

                                      LAYER    2
                  5.00%                   0.0020                     2.07
                 10.00%                   0.0079                     8.28
                 15.00%                   0.0177                    18.63
                 20.00%                   0.0315                    33.11
                 25.00%                   0.0492                    51.74
                 30.00%                   0.0708                    74.51
                 35.00%                   0.0963                   101.41
                 40.00%                   0.1258                   132.46
                 45.00%                   0.1593                   167.64
                 50.00%                   0.1966                   206.97
                 55.00%                   0.2386                   251.11
                 60.00%                   0.2863                   301.35
                 65.00%                   0.3404                   358.30
                 70.00%                   0.4028                   424.05
                 75.00%                   0.4767                   501.81
                 80.00%                   0.5671                   596.99
                 85.00%                   0.6837                   719.69
                 90.00%                   0.8480                   892.63
                 95.00%                   1.1289                  1188.27
1                        ******************************
                         *                            *
                         *         MAGSET-II          *
                         *                            *
                         * MAGNITUDE OF SETTLEMENT OF *
                         * A MULTI-LAVERED SOIL SYSTEM *
                         *                            *
                         ******************************
**********************
* SPECIFICATIONS FOR*
*   PROBLEM NO.  1  *
**********************
                               ***** TITLE *****
           COMPARISION TO EM1110-2-1904 PROBLEM
                               ***** UNITS *****
                      LENGTH                 FORCE
                    FEET        TON  S
****************
* SOIL PROFILE *
* DESCRIPTION  *
****************
                 DATUM ELEVATION           =      0.
                 DIFFERENCE IN ELEVATION =      0.
```

(Continued)

Table 16 (Continued)

RLMMM 9:57: 8 2/14/79

LAYER NUMBER	SOIL TYPE	INTERFACE DEPTH	DATUM ELEVATIONS	THICKNESS	UNIT WEIGHT
		0.	0.		
1	INCOMP			15.00	0.0625
		15.00	-15.00		
2	CLAY			20.00	0.0525
		35.00	-35.00		

UNIT WEIGHT OF WATER	GROUND WATER LEVEL	GROUND WATER DATUM ELEVATION
0.0313	15.00	-15.00

****
* INSITU EFFECTIVE STRESS *
****

LAYER NUMBER	INPUT VALUE	CALCULATED VALUE	INSITU STRESS
1	-	0.4688	0.4688
2	-	1.1495	1.1495

****
* CLAY SETTLEMENT DATA *
****

EFFECTIVE STRESS INCREMENTS INPUT BY

\+ A DISTRIBUTION FUNCTION

***** STRESS INCREMENTS FOR STRATUM *****

POINT NUMBER	STRESS INCREMENT
1	1.2675
2	0.4225

***** STRESS DISTRIBUTION FUNCTION *****

LAYER NUMBER	VALUE
2	0.0230

***** EFFECTIVE STRESS HISTORY *****

LAYER NO.	PT. NO.	STRESS INCREMENT	STRESS VALUES
2	1	0.0292	1.1787
2	2	0.0097	1.1884

DEFORMATION CURVES INPUT BY

\+ COORDINATE POINTS

***** COORDINATES OF POINTS ON THE DEFORMATION CURVES *****

LAYER NUMBER	POINT NUMBER	VOID RATIO	STRESS	REBOUND VOID RATIO	REBOUND STRESS
2	1	1.1500	0.2400		
2	2	1.1200	0.5000	1.1500	0.2400
2	3	1.0600	1.0000	1.1200	0.5000
2	4	0.9500	2.0000	1.0600	1.0000
2	5	0.8200	4.0000	0.9500	2.0000

***** SLOPES ON THE DEFORMATION CURVES *****

LAYER NUMBER	LINE NUMBER	CC	CE	CC (STRAIN)	CE (STRAIN)
2	1	0.0941	0.0941	0.0438	0.0438
2	2	0.1993	0.1993	0.0940	0.0940
2	3	0.3654	0.3654	0.1774	0.1774
2	4	0.4319	0.4319	0.2215	0.2215

(Continued)

Table 16 (Concluded)

RLMMM 9·57· 8 2/14/79

```
*********************************
* CLAY SETTLEMENT CONTRIBUTIONS *
*********************************
```

***** SETTLEMENT BY LAYERS *****

LAYER NUMBER	STRESS INTERVAL	INCREMENTAL SETTLEMENT
2	1 TO 2	0.03901
2	2 TO 3	0.01279
2	LAYER HISTORY	0.05179

***** SETTLEMENT BY STRESS INTERVAL *****

STRESS INTERVAL	SETTLEMENT OVER PROFILE
1 TO 2	0.03901
2 TO 3	0.01279

TOTAL CLAY SETTLEMENT 0.05179

```
**************************
* CLAY COMPRESSIBILITIES *
**************************
```

LAYER	STRESS	MV	DELTA E	E1	E2
2	1 TO 2	0.06690	0.00397	1.03789	1.03391
2	2 TO 3	0.06593	0.00130	1.03391	1.03261

THERE ARE NO SAND LAYERS IN THE SOIL PROFILE

```
**********************************
*DEGREE OF CONSOLIDATION*
**********************************
```

****COEFFICIENT OF CONSOLIDATION****
(CV)

LAYER NO.	CV SQ.FT./DAY
2	0.0950

DEGREE OF CONSOLIDATION U%	TIME FACTOR TV	DAYS
	LAYER 2	
5.00%	0.0020	2.07
10.00%	0.0079	8.28
15.00%	0.0177	18.63
20.00%	0.0315	33.11
25.00%	0.0492	51.74
30.00%	0.0708	74.51
35.00%	0.0963	101.41
40.00%	0.1258	132.46
45.00%	0.1593	167.64
50.00%	0.1966	206.97
55.00%	0.2386	251.11
60.00%	0.2863	301.35
65.00%	0.3404	358.30
70.00%	0.4028	424.05
75.00%	0.4767	501.81
80.00%	0.5671	596.99
85.00%	0.6837	719.69
90.00%	0.8480	892.63
95.00%	1.1289	1188.27

Comparison of results

35. The stress induction and settlement results for example problem 2 from EM 1110-2-1904 are compared with the computer solutions in Tables 17 and 18. It appears that although EM 1110-2-1904 states that the values are calculated at 25 ft below the footing, they really seem to be computed at 20 ft below the footing. The comparisons are very close.

36. The time-settlement results are compared in Table 19. Again, the results are very close showing the validity of the programs used.

Table 17

Comparison of I0016 and EM 1110-2-1904 Solutions for Stress Induction in Example Problem 2

	Stress Induction		
	I0016 Solution (Output × 1.69 tons/ft^2)		EM 1110-2-1904
Location	@ 25 ft	@ 20 ft	Solution
A	0.064	0.073	0.073
B	0.049	0.058	0.056
C	0.039	0.046	0.042

Table 18

Comparison of MAGSETII and EM 1110-2-1904 Solutions for Settlement in Example Problem 2

	Settlement, ft		
	MAGSETII Solution		EM 1110-2-1904
Location	@ 25 ft	@ 20 ft	Solution
A	0.085	0.094	0.09
B	0.065	0.071	0.07
C	0.052	0.063	0.06

Table 19

Comparison of MAGSETII and EM 1110-2-1904 Solutions for Rate of Settlement in Example Problem 2

Degree of Consolidation percent	Time, days	
	MAGSETII Solution	EM 1110-2-1904 Solution
10	8.28	8.14
15	18.63	
20	33.11	32.8
25	51.74	
30	74.51	74.8
35	101.41	
40	132.46	133.3
45	167.64	
50	206.97	207.3
55	251.11	
60	301.35	302.6
65	358.30	
70	424.05	426.3
75	501.81	
80	596.99	599.9
85	719.69	
90	892.63	897.1
95	1188.27	1194.4

PART IV: EXAMPLE PROBLEM ILLUSTRATING INPUT/OUTPUT FOR PROGRAM FD31

37. This Part contains an example problem solved using Program FD31. Other examples solved using FD31 are presented in Olson.

Input

38. Data input falls into three categories: (a) input/output control parameters, (b) raw data, and (c) program control. The input/output control parameters govern the form in which data are input and the amount of output and type of output to be printed out. Raw data consist of water table, drainage data, effective weights, layer depth, excess pore pressures, embankment description or load description, time table of construction for detail output, consolidation curve, and coefficient of permeability and coefficient of consolidation. The program control data consist of parameters controlling the accuracy of computations within a program.

39. The example problem soil profile (Figure 10) is a simple one for which Terzaghi's theory is applicable. The soil system consists of 1 ft of incompressible sand over 10 ft of clay over incompressible sand.

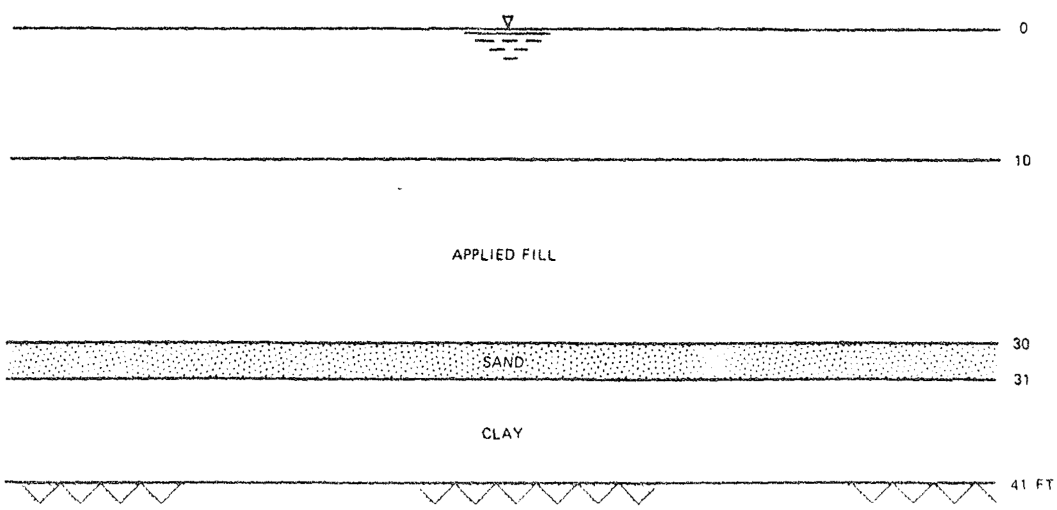


Figure 10. Soil profile for FD31 example problem

All layers are saturated and have submerged unit weights of 50 lb/ft^3. The clay is linearly elastic and the consolidation curve passes through the points $(e, \bar{\sigma}) = (2.0075, 0 \ lb/ft^2)$ and $(1.9500, 2300 \ lb/ft^2)$. The clay has a constant coefficient of consolidation of 0.05 ft^2/day). Consolidation results from the application of 20 ft of fill at time zero. The fill has a total unit weight of 112.4 lb/ft^2 and is also saturated. The water table is 30 ft above the original ground surface.

40. The complete input is shown in conversational mode in Table 20. Values of various control parameters are indicated below with brief explanations:

a. I01-I09. All 10 parameters are set to 1 for this example in order to obtain maximum output information.

b. KODWT=C. The water table will be maintained at a constant elevation.

c. TOPB=F. The upper boundary of natural soil is freely draining.

d. BOTB=F. The bottom boundary is also freely draining.

e. USEQO=T. The value of this parameter is not relevant for this problem and may be set at either T or F.

f. SANDPP=F. The value of this parameter is not relevant either but should be set equal to either F or S.

g. ALMX1=0.5. The value of this parameter is irrelevant to this problem because the loading is a single step loading.

h. ALMX2=0.5. This is the upper limit on all values of A(IN) at time zero.

i. ALMX3=20.5. This is the upper limit on values of A(IN) at time TL(JLFIN); i.e., the last point on the loading curve.

j. CHGMIN=0.1. The value of CHGMIN is irrelevant because the coefficient of consolidation is constant.

k. CHGLIM=1.0. The value of this parameter is irrelevant because of the constant coefficient of consolidation.

l. FCV=1.0. The value of this parameter is also irrelevant because of the constant coefficient of consolidation.

m. TOL=0.1. The Gauss-Seidel subroutine will continue iterating until no excess pore pressure in the system changes by more than 0.1 lb/ft^2 on the last iteration.

n. ITERMX=100. If the number of iterations in the Gauss-Seidel subroutine reaches 100, the calculations will be aborted and the analysis stops.

Table 20

Input in the Conversational Mode for Program FD31 Example Problem

```
IF DATA IS TO BE READ FROM A DATA FILE
INPUT THE FILE NAME (8 CHARACTERS MAX.)
HIT CARRIAGE RETURN IF INPUT IS FROM TERMINAL
=

IF DATA IS TO BE SAVED TO A DATA FILE
INPUT THE FILE NAME (8 CHARACTERS MAX.)
HIT CARRIAGE RETURN IF NO FILE IS TO BE WRITTEN.
=

IF OUTPUT IS TO BE WRITTEN TO A FILE
INPUT THE FILE NAME (8 CHARACTERS MAX.)
HIT CARRIAGE RETURN IF OUTPUT IS TO COME TO TERMINAL.
=
DO YOU WISH TO HAVE ALL INPUT ECHOED ? (Y/N)
=N
INPUT TITLE FOR THIS RUN
=EXAMPLE PROBLEM FOR SETTLEMENT PACKAGE
 ASSIGN VALUES OF 1 IF OUTPUT IS DESIRED, OTHERWISE 0.
 IO1 = RESIDUAL PORE PRESSURES AND EFFECTIVE STRESS
 IO2 = LOAD HISTORY
 IO3 = OUTPUT TIMES
 IO4 = E-P CURVES
 IO5 = INITIAL VALUES OF CV
 IO6 = 0 FOR DATA AT MIDHEIGHT OF LAYERS AND AT INTERFACES
         BETWEEN LAYERS
     = 1 FOR DATA AT ALL NODES AND INTERNODES
 IO7 = 1 IF DATA ARE TO BE OUTPUT ONLY AT TIMES TO(JO)
     = 0 IF DATA ARE TO BE OUTPUT AFTER EVERY TIME TC. IN THIS
         CASE, IO6 IS AUTOMATICALLY SET AT 1
 IO8 = 0 FOR NO OUTPUT OF CONTROL PARAMETERS
    = 1 FOR OUTPUT OF CONTROL PARAMETERS
IO1,IO2,IO3,IO4,IO5,IO6,IO7,IO8
=1  1    1    1   1   1   1   1
ZWTO=DEPTH FROM ORIGINAL GROUND SURFACE TO THE WATER TABLE,
     POSITIVE DOWNWARDS (FEET)
ZWTF=DEPTH FROM A DATUM ESTABLISHED AT THE ELEVATION OF THE
     ORIGINAL GROUND SURFACE TO THE FINAL WATER TABLE,
     POSITIVE DOWNWARDS (FEET)
KODWT=C MEANS THE ELEVATION OF THE WATER TABLE IS CONSTANT
      R MEANS THE ELEVATION OF THE WATER TABLE RISES FROM
      EWTO TO EWTF AS A RESULT OF CONSTRUCTION OPERATIONS
      D MEANS THE ELEVATION OF THE WATER TABLE DROPS FROM
        EWTO TO EWTF INSTANTLY AT TIME ZERO
      S MEANS THE ELEVATION OF THE WATER TABLE ALWAYS IS THE
        ELEVATION OF THE ORIGINAL GROUND SURFACE AS THAT
        SURFACE SETTLES OR RISES.
TOPB = I FOR AN IMPERVIOUS UPPER BOUNDARY
     = F FOR A FREELY DRAINING UPPER BOUNDARY
BOTB = I FOR AN IMPERVIOUS LOWER BOUNDARY
     = F FOR A FREELY DRAINING LOWER BOUNDARY
USEQ0= T IF STATIC PORE PRESSURES ARE ZERO ABOVE THE WATER
       TABLE AT ALL TIMES
     = F IF STATPP(I)=(Z(I)-ZWT)*62.4 AT ALL TIMES
SANDPP = F IF ALL SAND LAYERS DRAIN FREELY HORIZONTALLY
       = S IF SAND LAYERS ARE SEALED HORIZONTALLY
ZWTO,ZWTF,KODWT,TCPB,TOPB,BOPB,USEQ0,SANDPP
=-30.0  -30.0 C F F T   F
```

(Continued)

```
  NL=NUMBER OF LAYERS OF SOIL (NOT COUNTING NEW FILL)
  HL(L)=THICKNESS OF LAYER L AT TIME ZERO (FEET)
  GAMPR(L)=SUBMERGED UNIT WEIGHT OF SOIL IN LAYER L AT TIME ZERO
          (PCF)
  NZ(L)=NUMBER OF NODES IN ANY LAYER.
 NUMBER OF LAYER
 =2
 INPUT HL,GAMPR,NZ FOR LAYER 2
 =1.00  50.0 2
 INPUT HL,GAMPR,NZ FOR LAYER 2
 =10.0  50.0 11
 ALMX1 = MAXIMUM ALPHA DURING LOADING OR UNLOADING
 ALMX2 = MAXIMUM ALPHA DURING A NON-CONSTRUCTION PERIOD EXCEPT
         FOR TC.GT.TL(JLFIN-1)
 ALMX3 = MAXIMUM ALPHA AT TC=TL(JLFIN)
 CHGLIM = MAXIMUM ALLOWABLE CHANGE IN CV EXPRESSED AS A RATIO
 CHGMIN = THE PROGRAM WILL NOT CALCULATE AVERAGE VALUES OF
    CV AND RECYCLE IF CHGMAX.LT.CHGMIN. RELEVANT ONLY FOR A
          VARIABLE PROPERTIES SOLUTION.
 TOL = MAXIMUM ALLOWABLE CHANGE IN PORE PRESSURE BETWEEN
   .    ITERATIONS.
 ITERMX = MAXIMUM NUMBER OF ITERATIONS IN SOLVE
 DTMLIM = UPPER LIMIT ON TM TIME DURING A TIME DT
 FCV=A REDUCTION FACTOR USED WHEN CHGMAX.GT.CHGLIM
 CHGPMX=MAXIMUM ALLOWABLE CHANGE IN EFFECTIVE STRESS IN
 SUBROUTINE CONSOL WITHOUT ITERATING FURTHER
 PPLIM=A NUMBER SUCH THAT THE PROGRAM QUITS RUNNING WHEN ALL
       VALUES OF PP ARE LESS THAN THIS VALUE
 ALMX1,ALMX2,AMLX3
 =.5  .5  20.0
 CHGMIN,CHGLIM,FCV
 =.1 1.0 1.0
 TOL,ITERMX,DTMLIM,CHGMX,PPLIM
 =.1 100 5.0 .1 .1
        KODPPR = C IF RESIDUAL PORE PRESSURES ARE ALL THE SAME
               = V IF RESIDUAL PORE PRESSURES ARE INPUT
                 AT EACH DEPTH NODE
 KODPPR
 =C
 PREPP,RESIDUAL PORE PRESSURE
 =0.0
 NFL = NUMBER OF CONSTRUCTION STAGES, MAY BE ZERO
 TFCBEG(JF)=TIME FILL CONSTRUCTION BEGINS, DAYS
 TFCEND(JF)=TIME FILL CONSTRUCTION ENDS,DAYS
 TL(JL) =TIME WHEN FILL ELEVATION IS DEFINED, DAYS
 EFL(JL) =ELEVATION OF THE TOP OF THE FILL RELATIVE TO THE TOP
          OF THE ORIGINAL GROUND SURFACE
 GF(JF)=TOTAL UNIT WEIGHT OF FILL,PCF.
 NFL
 =1
 TFCBEG,TFCEND,GF 1
 =0.00 0.1       112.4
 TL,EFL 1
 =0.0 0.0
 TL,EFL 2
 =0.0 20.0
 TL,EFL 3
 =5000.0 20.0
 TL,EFL 4
 =-1.0 0.0
```

(Continued)

```
TO(JO)=TIMES FOR WHICH OUTPUT IS DESIRED
IOUT(JO)=D FOR DETAILED OUTPUT AT TO(JO)-N FOR NONE
QTDATA=D FOR OUTPUT OF DETAILED DATA AT THE LAST VALUE OF TO
      WHEN ALL PP(I) ARE LESS THAN PPLIM
TO,IOUT 1
=.1 D
TO,IOUT 2
=1.0 D
TO,IOUT 3
=4.0 N
TO,IOUT 4
=10.    D
TO,IOUT 5
=40.0 N
TO,IOUT 6
=100.0 D
TO,IOUT 7
=400.0 N
TO,IOUT 8
=1000.0 D
TO,IOUT 9
=2000.0 D
TO,IOUT10
=-1  .0 N
QTDATA
=D
KODORD=V FOR VOID RATIO DIAGRAMS
      =S FOR STRAIN DIAGRAMS
KODINT=N INTERPOLATE P ARITHMETICALLY FOR E-P RELATIONSHIP
      =L INTERPOLATE P LOGARITHMICALLY FOR E-P RELATIONSHIP
KODORD,KODINT
=V N
LAYER 1
RE=EFFECTIVE STRESS,EP=VOID RATIO OR STRAIN,PIONT 1
=0.00 1.000
RE=EFFECTIVE STRESS,EP=VOID RATIO OR STRAIN,PIONT 2
=10000.00  1.0000
RE=EFFECTIVE STRESS,EP=VOID RATIO OR STRAIN,PIONT 3
=-1.0    0.0
CCR=SLOPE OF REBOUND CURVE
=.00100
LAYER 2
RE=EFFECTIVE STRESS,EP=VOID RATIO OR STRAIN,PIONT 1
=0.00  2.0075
RE=EFFECTIVE STRESS,EP=VOID RATIO OR STRAIN,PIONT 2
=2300.0  1.9500
RE=EFFECTIVE STRESS,EP=VOID RATIO OR STRAIN,PIONT 3
=-1.00 0.00
CCR=SLOPE OF REBOUND CURVE
=.00100
CVSD=A LIMIT SUCH THAT ANY LAYER WITH A HIGHER VALUE OF CV
     SHOULD BE A SAND LAYER.
CVSD
=100.0
```

(Continued)

```
KODSP(L) = C FOR CONSTANT CV AND PK VALUES
         = V FOR CV AND PK FUNCTIONS OF EFFECTIVE STRESS
VP = CONST IF ALL LAYERS HAVE KODSP(L)=C
   = VAR IF ANY LAYER HAS KODSP(L)=V
PCV(L,JCV)=EFFECTIVE STRESS AT WHICH A POINT ON THE P-CV
           CURVE IS DEFINED FOR LAYER L AND POINT JCV (PSF)
CVP(L,JCV)=COEFFICIENT OF CONSOLIDATION AT THE JCV POINT
     ON THE INPUT P-CV CURVE OF LAYER L (SQ.FT./DAY)
PKP(L,JCV)=COEFFICIENT OF PERMEABILITY AT THE JCV POINT ON THE
           INPUT P-PK CURVE OF LAYER L (FT./DAY)
LAYER 1
=C
CVP,PKP
=200.0 200.0
LAYER 2
=C
CVP,PKP
=.05 .05
```

<u>Input Data File for Program FD31</u>

<u>(Example Problem 1)</u>

```
100      SAMPLE PROBLEM NO. 1, RUN USING FD31(35)
110      1 1 1 1 1 1 1 1
120         -30.0       -30.0      G    F    F     T     F
130        2
140          1.00        50.0      2
150         10.00        50.0      11
160       .5    .5       20.0
170      .10 1.00   1.0
180       .1   100   5.0    .1   .1
190        C
200            0.0
210        1
220          0.00        0.00      112.40
230          0.00      0.00
240          0.00       20.00
250      5000.00        20.00
260        -1.00        -0.00
270           .1 D
280          1.0 D
290          4.0
300         10.0 D
310         40.0
320        100.0 D
330        400.0
340       1000.0 D
350       2000.0 D
360         -1.0
370       D
380       V     N
390         0.00     1.0000
400     10000.00     1.0000
410        -1.00    -1.0000
420       .00100
430         0.00        2.0075
440      2300.00        1.9500
450        -1.00       -0.0000
460       .00100
470     1.00E+02
480       C
490     2.00E+02 2.00E+02
500       C
510     5.00E-02 5.00E-02
```

o. DTMLIM=5.0. The analysis will be aborted if the running time for any one value of time, TC, reaches 5 seconds.

p. CHGPMX=0.1. The equation for effective stress at any node requires as input the value of surface settlement, but this is the settlement to be calculated. The subroutine will iterate on the effective stresses until no effective stress changes by more than 0.1 lb/ft^2 during the final iteration.

q. PPLIM=0.1. During the time period between TL(JLFIN-1) and TL(JLFIN), if all the excess pore pressures have absolute values smaller than 0.1 lb/ft^2, the run will terminate.

r. KODPPR=C. The initial excess pore pressures, prior to the beginning of the analysis, are constant; i.e., independent of depth.

s. QTDATA=D. If the run is terminated because all pore pressures have absolute values smaller than PPLIM, then detailed data will be output at the final time of analysis.

t. KODORD=V. The consolidation curve is defined using void ratios.

u. KODINT=N. The linear e-$\bar{\sigma}$ curve is assumed between specific points that define this curve.

v. KODSP=C. The coefficient of consolidation is constant.

Output

41. The complete output file is shown in Table 21. Note that values less than zero have been printed in the file of echo prints where no value was defined originally; e.g., when input of a set of data is terminated by use of a value -1.0 for the appropriate variable.

Comparison with Hand Solutions

42. With this simple example, a hand comparison can easily be made (Table 22). Olson and Ladd explore the comparison of classical and the finite difference analysis in more detail.

Table 21

Output Data File for Program FD31 Example Problem

```
CVP,PKP
=.05 .05


EXAMPLE PROBLEM FOR SETTLEMENT PACKAGE
```

TABLE 1

O R I G I N A L   L A Y E R   C O N D I T I O N S

LAYER NO.	ORIGINAL THICKNESS FEET	NUMBER OF NODES	SUBMERGED UNIT WEIGHT (PSF)
1	1.00	2	50.0
2	10.00	11	50.0

TABLE 2

D A T A   O N   W A T E R   T A B L E   A N D   D R A I N A G E

THE WATER TABLE WILL REMAIN AT A CONSTANT ELEVATION WITH
ZWTO = -30.0 FEET.

BOTH HORIZONTAL BOUNDARIES ARE FREELY DRAINING.

THE PROGRAM WILL TREAT ANY LAYER AS FREELY DRAINING IF
CV.GE. 0.10E 03 SQ.FT.PER DAY.

STATIC PORE WATER PRESSURES ABOVE THE WATER TABLE ARE ASSUMED
TO BE ZERO AT ALL TIMES.

ALL SAND LAYERS ARE ASSUMED TO DRAIN FREELY IN THE HORIZONTAL
DIRECTION AND THUS HAVE ZERO EXCESS PORE PRESSURES AT ALL TIMES.

TABLE 3

I N I T I A L   E X C E S S   P O R E   P R E S S U R E S

LAYER NO.	NODE NO.	PORE PRESSURE (PSF)
1	1	0.
1-2	2	0.
2	3	0.
2	4	0.
2	5	0.
2	6	0.
2	7	0.
2	8	0.
2	9	0.
2	10	0.
2	11	0.
2	12	0.

(Continued)

Table 21 (Continued)

TABLE 4

L O A D   H I S T O R Y

FILL LAYER NUMBER	TOTAL UNIT WEIGHT (PCF)	TIME FILL CONSTRUCTION BEGINS (DAYS)	TIME FILL CONSTRUCTION ENDS (DAYS)
1	112.4	0.	0.

TIME (DAYS)	EMBANKMENT HEIGHT (FT)
0.	0.
0.	20.00
5000.	20.00

TABLE 5

T I M E S   F O R   O U T P U T

0.1 DAYS
1.0 DAYS
4.0 DAYS
10.0 DAYS
40.0 DAYS
100.0 DAYS
400.0 DAYS
1000.0 DAYS
2000.0 DAYS

(Continued)

TABLE 6

E - P C U R V E S

LAYER	EFFECTIVE STRESS (PSF)	VOID RATIO
1	0.	1.0000
	10000.0	1.0000
2	0.	2.0075
	2300.0	1.9500

LAYER	SLOPE OF REBOUND E - LOG P CURVE
1	0.1E-02
2	0.1E-02

VALUES OF E ARE FOUND BY INTERPOLATING
E AND P NATURALLY.

TABLE 7

TABLE OF INPUT VALUES OF CV AND PK

LAYER NO.	EFFECTIVE STRESS PSF	COEFF.OF CONSOLIDATION SQ.FT/DAY	COEFF.OF PERMEABILITY FT/DAY
1	NOT INPUT	0.20E 03	0.20E 03
2	NOT INPUT	0.50E-01	0.50E-01

(Continued)

TABLE 9

TABLE OF CONTROL PARAMETERS

THE MAXIMUM VALUES OF ALPHA ARE LIMITED TO 0.5 DURING LOADING OR UNLOADING, TO 0.5 FOR ANY NON-LOADING PERIOD EXCEPT THE LAST ONE AND TO BETWEEN 0.5 AND 20.0 DURING THE LAST LOADING PERIOD.

THE GAUS-SEIDEL ITERATIONS WILL CONTINUE UNTIL NO PORE PRESSURE CHANGES BY MORE THAN 0.10 PSF FROM ONE ITERATION TO THE NEXT BUT THE ANALYSIS WILL TERMINATE IF 100 ITERATIONS ARE PERFORMED FOR ANY ONE SET OF PORE PRESSURE CALCULATIONS.

IF THE TM TIME USED BETWEEN ONE OUTPUT TIME AND THE NEXT EXCEEDS 5.0 SECONDS, THE ANALYSIS IS TERMINATED AFTER OUTPUTTING THE DATA.

IN SUBROUTINE CONSOL, THE PROGRAM ITERATES ON THE EFFECTIVE STRESS EQUATION UNTIL NO VALUE OF P(I) CHANGES BY MORE THAN 0.10 PSF. THE NUMBER OF SUCH ITERATIONS IS OUTPUT AS CHGP.

IF THE MAXIMUM FRACTIONAL CHANGE IN ANY VALUE OF CV EXCEEDS 1.0 (OR IS LESS THAN THE RECIPROCOL OF THIS NUMBER FOR DECREASING VALUES OF CV) THEN THE PROGRAM REDUCES THE TIME STEP TO DT=DT*0.9*CHGLIM/CHGMAX AND STARTS ON A NEW SET OF CALCULATIONS. FOR THIS PROBLEM FCV=1.0 IF THE MAXIMUM FRACTIONAL CHANGE IN CV IS LESS THAN 0.1 THEN THE ANALYSIS DOES NOT CYCLE BACK. IF THE MAXIMUM FRACTIONAL CHANGE IS BETWEEN 0.1 AND 1.0 A SET OF AVERAGE CV VALUES ARE CALCULATED AND THE CALCULATIONS ARE REPEATED.

TABLE 10

I N I T I A L   C O N D I T I O N S

LAYER NO.	NODE NO.	Z(I) PSF	SIGNSO(I) PSF	STATPP(I) PSF	PREPP(I) PSF	P(I) PSF	S(I) FT
1	1	0.	0.	1872.00	0.	0.	0.
1-2	2	1.000	112.40	1934.40	0.	50.00	0.
2	3	2.000	224.80	1996.80	0.	100.00	0.
2	4	3.000	337.20	2059.20	0.	150.00	0.
2	5	4.000	449.60	2121.60	0.	200.00	0.
2	6	5.000	562.00	2184.00	0.	250.00	0.
2	7	6.000	674.40	2246.40	0.	300.00	0.
2	8	7.000	786.80	2308.80	0.	350.00	0.
2	9	8.000	899.20	2371.20	0.	400.00	0.
2	10	9.000	1011.60	2433.60	0.	450.00	0.
2	11	10.000	1124.00	2496.00	0.	500.00	0.
2-3	12	11.000	1236.40	2558.40	0.	550.00	0.

LAYER NO.	IN NO.	ZIN(IN) FT.	PIN(IN) PSF	EO(IN)	CV(IN) SQ.FT/DAY	PK(IN) FT/DAY	DZ(IN) FT.	DZO(IN) FT.
1	1	0.500	25.00	1.0000	0.200E 03	0.200E 03	1.000	0.5000
2	2	1.500	75.00	2.0056	0.500E-01	0.500E-01	1.000	0.3327
2	3	2.500	125.00	2.0044	0.500E-01	0.500E-01	1.000	0.3328
2	4	3.500	175.00	2.0031	0.500E-01	0.500E-01	1.000	0.3330
2	5	4.500	225.00	2.0019	0.500E-01	0.500E-01	1.000	0.3331
2	6	5.500	275.00	2.0006	0.500E-01	0.500E-01	1.000	0.3333
2	7	6.500	325.00	1.9994	0.500E-01	0.500E-01	1.000	0.3334
2	8	7.500	375.00	1.9981	0.500E-01	0.500E-01	1.000	0.3335
2	9	8.500	425.00	1.9969	0.500E-01	0.500E-01	1.000	0.3337
2	10	9.500	475.00	1.9956	0.500E-01	0.500E-01	1.000	0.3338
2	11	10.500	525.00	1.9944	0.500E-01	0.500E-01	1.000	0.3340

(Continued)

Table 21 (Continued)

TABLE 11

S O L U T I O N   I N F O R M A T I O N

TIME (DAYS) =	0.1
TIME STEP(DAYS) =	0.1
LOAD Q (PSF) =	2248.00
ELEVATION OF WATER TABLE (FT.) =	30.0
ELEVATION OF TOP OF FILL (FEET) =	19.99
NUMBER OF ITERATIONS =	2
UPPER LIMIT ON ALPHA =	0.500
MAXIMUM DEVELOPED ALPHA =	0.005
SIGFU (PSF) =	624.5
NO. OF CYCLES THRU COEFF =	1
TM TIME (SECONDS) =	0.014
CHGP (PSF) =	0.000
MP =	1

LAYER NO.	NODE NO.	DEPTH FT.	TOTAL STRESS PSF	TOTAL PP PSF	EXCESS PP PSF	EFF. STRESS PSF	SETTLE-MENT FT
1	1	0.008	2872.5	1872.5	0.	1000.0	0.008
1-2	2	1.008	2984.9	1934.9	0.	1050.0	0.008
2	3	2.004	3097.1	2992.1	995.0	105.0	0.004
2	4	3.004	3209.5	3059.5	1000.0	150.0	0.004
2	5	4.004	3321.9	3121.9	1000.0	200.0	0.004
2	6	5.004	3434.3	3184.3	1000.0	250.0	0.004
2	7	6.004	3546.7	3246.7	1000.0	300.0	0.004
2	8	7.004	3659.1	3309.1	1000.0	350.0	0.004
2	9	8.004	3771.5	3371.5	1000.0	400.0	0.004
2	10	9.004	3883.9	3433.9	1000.0	450.0	0.004
2	11	10.004	3996.3	3491.3	995.0	505.0	0.004
2	12	11.000	4108.4	2558.4	0.	1550.0	0.

L,	IN	DEPTH FT.	EFF. STRESS PSF	VOID RATIO	CV SQ.FT/ DAY	CVNEW SQ.FT/ DAY	K FT/DAY	ALPHA	PM PSF	DZ FT.
1	1	0.51	1025.0	1.000	*******	********	0.20E 03	20.000	1025.0	1.000
2	2	1.51	577.5	1.993	0.0500	0.0500	0.50E-01	0.005	577.5	0.996
2	3	2.50	127.5	2.004	0.0500	0.0500	0.50E-01	0.005	127.5	1.000
2	4	3.50	175.0	2.003	0.0500	0.0500	0.50E-01	0.005	175.0	1.000
2	5	4.50	225.0	2.002	0.0500	0.0500	0.50E-01	0.005	225.0	1.000
2	6	5.50	275.0	2.001	0.0500	0.0500	0.50E-01	0.005	275.0	1.000
2	7	6.50	325.0	1.999	0.0500	0.0500	0.50E-01	0.005	325.0	1.000
2	8	7.50	375.0	1.998	0.0500	0.0500	0.50E-01	0.005	375.0	1.000
2	9	8.50	425.0	1.997	0.0500	0.0500	0.50E-01	0.005	425.0	1.000
2	10	9.50	477.5	1.996	0.0500	0.0500	0.50E-01	0.005	477.5	1.000
2	11	10.50	1027.5	1.982	0.0500	0.0500	0.50E-01	0.005	1027.5	0.996

LAYER NO.	COMPRESSION (INCHES)
1	-0.0000
2	0.1010

(Continued)

Table 21 (Continued)

TABLE 11

SOLUTION INFORMATION

TIME (DAYS) =	1.0
TIME STEP(DAYS) =	0.9
LOAD Q (PSF) =	2248.00
ELEVATION OF WATER TABLE (FT.) =	30.0
ELEVATION OF TOP OF FILL (FEET) =	19.99
NUMBER OF ITERATIONS =	3
UPPER LIMIT ON ALPHA =	0.500
MAXIMUM DEVELOPED ALPHA =	0.045
SIGFW (PSF) =	624.6
NO. OF CYCLES THRU COEFF =	1
TM TIME (SECONDS) =	0.271
CHGP (PSF) =	-0.000
MP =	1

LAYER NO.	NODE NO.	DEPTH FT.	TOTAL STRESS PSF	TOTAL PP PSF	EXCESS PP PSF	EFF. STRESS PSF	SETTLE-MENT FT
1	1	0.009	2872.6	1872.6	0.	1000.0	0.009
1-2	2	1.009	2985.0	1935.0	0.	1050.0	0.009
2	3	2.005	3097.1	2949.2	952.1	147.9	0.005
2	4	3.005	3209.5	3058.3	998.8	151.2	0.005
2	5	4.005	3321.9	3121.9	1000.0	200.0	0.005
2	6	5.005	3434.3	3184.3	1000.0	250.0	0.005
2	7	6.005	3546.7	3246.7	1000.0	300.0	0.005
2	8	7.005	3659.1	3309.1	1000.0	350.0	0.005
2	9	8.005	3771.5	3371.5	1000.0	400.0	0.005
2	10	9.005	3883.9	3432.7	998.8	451.2	0.005
2	11	10.004	3996.3	3448.4	952.1	547.9	0.004
2	12	11.000	4108.4	2558.4	0.	1550.0	0.

L,	IN	DEPTH FT.	EFF. STRESS PSF	VOID RATIO	CV SQ.FT/ DAY	CVNEW SQ.FT/ DAY	K FT/DAY	ALPHA	PM PSF	DZ FT.
1	1	0.51	1025.0	1.000**************			0.20E 03180.000		1025.0	1.000
2	2	1.51	598.9	1.993	0.0500	0.0500	0.50E-01	0.045	598.9	0.996
2	3	2.50	149.5	2.004	0.0500	0.0500	0.50E-01	0.045	149.5	1.000
2	4	3.50	175.6	2.003	0.0500	0.0500	0.50E-01	0.045	175.6	1.000
2	5	4.50	225.0	2.002	0.0500	0.0500	0.50E-01	0.045	225.0	1.000
2	6	5.50	275.0	2.001	0.0500	0.0500	0.50E-01	0.045	275.0	1.000
2	7	6.50	325.0	1.999	0.0500	0.0500	0.50E-01	0.045	325.0	1.000
2	8	7.50	375.0	1.998	0.0500	0.0500	0.50E-01	0.045	375.0	1.000
2	9	8.50	425.6	1.997	0.0500	0.0500	0.50E-01	0.045	425.6	1.000
2	10	9.50	499.5	1.995	0.0500	0.0500	0.50E-01	0.045	499.5	1.000
2	11	10.50	1048.9	1.981	0.0500	0.0500	0.50E-01	0.045	1048.9	0.996

LAYER NO.	COMPRESSION (INCHES)
1	0.0000
2	0.1098

(Continued)

TABLE 11

SOLUTION INFORMATION

TIME (DAYS) =	10.0
TIME STEP(DAYS) =	6.0
LOAD Q (PSF) =	2248.00
ELEVATION OF WATER TABLE (FT.) =	30.0
ELEVATION OF TOP OF FILL (FEET) =	19.98
NUMBER OF ITERATIONS =	5
UPPER LIMIT ON ALPHA =	0.516
MAXIMUM DEVELOPED ALPHA =	0.303
SIGFW (PSF) =	624.9
NO. OF CYCLES THRU COEFF =	1
TM TIME (SECONDS) =	0.013
CHGP (PSF) =	0.000
MP =	1

LAYER NO.	NODE NO.	DEPTH FT.	TOTAL STRESS PSF	TOTAL PP PSF	EXCESS PP PSF	EFF. STRESS PSF	SETTLE-MENT FT
1	1	0.015	2872.9	1872.9	0.	1000.0	0.015
1-2	2	1.015	2985.3	1935.3	0.	1050.0	0.015
2	3	2.010	3097.4	2665.7	668.3	431.7	0.010
2	4	3.008	3209.7	2992.7	933.0	217.0	0.008
2	5	4.008	3322.1	3111.9	989.8	210.2	0.008
2	6	5.008	3434.5	3183.1	998.6	251.4	0.008
2	7	6.008	3546.9	3246.5	999.7	300.3	0.008
2	8	7.008	3659.3	3307.9	998.6	351.4	0.008
2	9	8.008	3771.7	3361.5	989.8	410.2	0.008
2	10	9.007	3884.1	3367.0	933.0	517.0	0.007
2	11	10.006	3996.3	3164.7	668.3	831.7	0.006
2	12	11.000	4108.4	2558.4	0.	1550.0	0.

L.	IN	DEPTH FT.	EFF. STRESS PSF	VOID RATIO	CU SQ.FT/ DAY	CVNEW SQ.FT/ DAY	K FT/DAY	ALPHA	PM PSF	DZ FT.
1	1	0.52	1025.0	1.000	*******	*******	0.20E 03	*******	1025.0	1.000
2	2	1.51	740.8	1.989	0.0500	0.0500	0.50E-01	0.303	740.8	0.994
2	3	2.51	324.3	1.999	0.0500	0.0500	0.50E-01	0.300	324.3	0.998
2	4	3.51	213.6	2.002	0.0500	0.0500	0.50E-01	0.300	213.6	1.000
2	5	4.51	230.8	2.002	0.0500	0.0500	0.50E-01	0.300	230.8	1.000
2	6	5.51	275.9	2.001	0.0500	0.0500	0.50E-01	0.300	275.9	1.000
2	7	6.51	325.9	1.999	0.0500	0.0500	0.50E-01	0.300	325.9	1.000
2	8	7.51	380.8	1.998	0.0500	0.0500	0.50E-01	0.300	380.8	1.000
2	9	8.51	463.6	1.996	0.0500	0.0500	0.50E-01	0.300	463.6	1.000
2	10	9.51	674.3	1.991	0.0500	0.0500	0.50E-01	0.300	674.3	0.998
2	11	10.50	1190.8	1.978	0.0500	0.0500	0.50E-01	0.303	1190.8	0.994

LAYER NO.	COMPRESSION (INCHES)
1	0.0000
2	0.1821

(Continued)

TABLE 11

SOLUTION INFORMATION

TIME (DAYS) =	100.0
TIME STEP(DAYS) =	2.0
LOAD Q (PSF) =	2248.00
ELEVATION OF WATER TABLE (FT.) =	30.0
ELEVATION OF TOP OF FILL (FEET) =	19.96
NUMBER OF ITERATIONS =	3
UPPER LIMIT ON ALPHA =	0.882
MAXIMUM DEVELOPED ALPHA =	0.100
SIGFU (PSF) =	626.7
NO. OF CYCLES THRU COEFF =	5
TM TIME (SECONDS) =	0.065
CHGP (PSF) =	0.000
MP =	1

LAYER NO.	NODE NO.	DEPTH FT.	TOTAL STRESS PSF	TOTAL PP PSF	EXCESS PP PSF	EFF. STRESS PSF	SETTLE-MENT FT
1	1	0.043	2874.7	1874.7	0.	1000.0	0.043
1-2	2	1.043	2987.1	1937.1	0.	1050.0	0.043
2	3	2.035	3099.0	2241.3	242.3	857.7	0.035
2	4	3.030	3211.1	2519.3	458.2	691.8	0.030
2	5	4.026	3323.2	2749.0	625.7	574.3	0.026
2	6	5.023	3435.5	2916.2	730.7	519.3	0.023
2	7	6.021	3547.7	3014.1	766.4	533.6	0.021
2	8	7.019	3660.0	3040.7	730.7	619.3	0.019
2	9	8.017	3772.2	2997.9	625.7	774.3	0.017
2	10	9.013	3884.4	2892.5	458.1	991.9	0.013
2	11	10.007	3996.5	2738.7	242.3	1257.7	0.007
2	12	11.000	4108.4	2558.4	0.	1550.0	0.

L,	IN	DEPTH FT.	EFF. STRESS PSF	VOID RATIO	CU SQ.FT/ DAY	CUNEW SQ.FT/ DAY	K FT/DAY	ALPHA	PM PSF	DZ FT.
1	1	0.54	1025.0	1.000	*******	********	0.20E 03	394.248	1025.0	1.000
2	2	1.54	953.8	1.984	0.0500	0.0500	0.50E-01	0.100	953.8	0.993
2	3	2.53	774.7	1.988	0.0500	0.0500	0.50E-01	0.100	774.7	0.995
2	4	3.53	633.0	1.992	0.0500	0.0500	0.50E-01	0.099	633.0	0.996
2	5	4.52	546.8	1.994	0.0500	0.0500	0.50E-01	0.099	546.8	0.997
2	6	5.52	526.5	1.994	0.0500	0.0500	0.50E-01	0.099	526.5	0.998
2	7	6.52	576.5	1.993	0.0500	0.0500	0.50E-01	0.099	576.5	0.998
2	8	7.52	696.8	1.990	0.0500	0.0500	0.50E-01	0.099	696.8	0.997
2	9	8.51	883.1	1.985	0.0500	0.0500	0.50E-01	0.099	883.1	0.996
2	10	9.51	1124.8	1.979	0.0500	0.0500	0.50E-01	0.100	1124.8	0.995
2	11	10.50	1403.9	1.972	0.0500	0.0500	0.50E-01	0.100	1403.9	0.993

LAYER NO.	COMPRESSION (INCHES)
1	0.0000
2	0.5120

(Continued)

TABLE 11

S O L U T I O N   I N F O R M A T I O N

TIME (DAYS) =	1000.0
TIME STEP(DAYS) =	22.0
LOAD Q (PSF) =	2248.00
ELEVATION OF WATER TABLE (FT.) =	30.0
ELEVATION OF TOP OF FILL (FEET) =	19.92
NUMBER OF ITERATIONS =	3
UPPER LIMIT ON ALPHA =	4.314
MAXIMUM DEVELOPED ALPHA =	1.120
SIGFU (PSF) =	629.2
NO. OF CYCLES THRU COEFF =	11
TM TIME (SECONDS) =	0.154
CHGP (PSF) =	-0.000
MP =	1

LAYER NO.	NODE NO.	DEPTH FT.	TOTAL STRESS PSF	TOTAL PP PSF	EXCESS PP PSF	EFF. STRESS PSF	SETTLE-MENT FT
1	1	0.083	2877.2	1877.2	0.	1000.0	0.083
1-2	2	1.083	2989.6	1939.6	0.	1050.0	0.083
2	3	2.075	3101.5	2004.2	2.8	1097.2	0.075
2	4	3.066	3213.3	2068.6	5.3	1144.7	0.066
2	5	4.058	3325.2	2132.4	7.2	1192.8	0.058
2	6	5.050	3437.1	2195.6	8.4	1241.6	0.050
2	7	6.041	3549.0	2257.8	8.9	1291.1	0.041
2	8	7.033	3660.9	2319.3	8.4	1341.6	0.033
2	9	8.025	3772.8	2379.9	7.1	1392.9	0.025
2	10	9.017	3884.6	2439.8	5.2	1444.8	0.017
2	11	10.008	3996.5	2499.2	2.7	1497.3	0.008
2	12	11.000	4108.4	2558.4	0.	1550.0	0.

L.	IN	DEPTH FT.	EFF. STRESS PSF	VOID RATIO	CU SQ.FT/ DAY	CUNEW SQ.FT/ DAY	K FT/DAY	ALPHA	PM PSF	DZ FT.
1	1	0.58	1025.0	1.000***************			0.20E 03	*******	1025.0	1.000
2	2	1.58	1073.6	1.981	0.0500	0.0500	0.50E-01	1.120	1073.6	0.992
2	3	2.57	1121.0	1.979	0.0500	0.0500	0.50E-01	1.120	1121.0	0.992
2	4	3.56	1168.8	1.978	0.0500	0.0500	0.50E-01	1.120	1168.8	0.992
2	5	4.55	1217.2	1.977	0.0500	0.0500	0.50E-01	1.120	1217.2	0.992
2	6	5.55	1266.3	1.976	0.0500	0.0500	0.50E-01	1.120	1266.3	0.992
2	7	6.54	1316.4	1.975	0.0500	0.0500	0.50E-01	1.120	1316.4	0.992
2	8	7.53	1367.2	1.973	0.0500	0.0500	0.50E-01	1.120	1367.2	0.992
2	9	8.52	1418.9	1.972	0.0500	0.0500	0.50E-01	1.120	1418.9	0.992
2	10	9.51	1471.1	1.971	0.0500	0.0500	0.50E-01	1.120	1471.1	0.992
2	11	10.50	1523.6	1.969	0.0500	0.0500	0.50E-01	1.120	1523.6	0.992

LAYER NO.	COMPRESSION (INCHES)
1	0.0000
2	0.9944

(Continued)

Table 21 (Continued)

TABLE 11

SOLUTION INFORMATION

TIME (DAYS) =	2000.0
TIME STEP(DAYS) =	90.4
LOAD Q (PSF) =	2248.00
ELEVATION OF WATER TABLE (FT.) =	30.0
ELEVATION OF TOP OF FILL (FEET) =	19.92
NUMBER OF ITERATIONS =	1
UPPER LIMIT ON ALPHA =	7.947
MAXIMUM DEVELOPED ALPHA =	4.598
SIGFU (PSF) =	629.2
NO. OF CYCLES THRU COEFF =	9
TM TIME (SECONDS) =	0.373
CHGP (PSF) =	-0.000
MP =	1

LAYER NO.	NODE NO.	DEPTH FT.	TOTAL STRESS PSF	TOTAL PP PSF	EXCESS PP PSF	EFF. STRESS PSF	SETTLE-MENT FT
1	1	0.083	2877.2	1877.2	0.	1000.0	0.083
1-2	2	1.083	2989.6	1939.6	0.	1050.0	0.083
2	3	2.075	3101.5	2001.6	0.1	1099.9	0.075
2	4	3.067	3213.4	2063.6	0.3	1149.7	0.067
2	5	4.058	3325.2	2125.6	0.4	1199.6	0.058
2	6	5.050	3437.1	2187.5	0.4	1249.6	0.050
2	7	6.042	3549.0	2249.4	0.4	1299.6	0.042
2	8	7.033	3660.9	2311.3	0.4	1349.6	0.033
2	9	8.025	3772.8	2373.1	0.3	1399.7	0.025
2	10	9.017	3884.6	2434.9	0.2	1449.8	0.017
2	11	10.008	3996.5	2496.6	0.1	1499.9	0.008
2	12	11.000	4108.4	2558.4	0.	1550.0	0.

L,	IN	DEPTH FT.	EFF. STRESS PSF	VOID RATIO	CV SQ.FT/ DAY	CVNEW SQ.FT/ DAY	K FT/DAY	ALPHA	PM PSF	DZ FT.
1	1	0.58	1025.0	1.000	********	********	0.20E 03	*******	1025.0	1.000
2	2	1.58	1074.9	1.981	0.0500	0.0500	0.50E-01	4.597	1074.9	0.992
2	3	2.57	1124.8	1.979	0.0500	0.0500	0.50E-01	4.597	1124.8	0.992
2	4	3.56	1174.7	1.978	0.0500	0.0500	0.50E-01	4.597	1174.7	0.992
2	5	4.55	1224.6	1.977	0.0500	0.0500	0.50E-01	4.597	1224.6	0.992
2	6	5.55	1274.6	1.976	0.0500	0.0500	0.50E-01	4.597	1274.6	0.992
2	7	6.54	1324.6	1.974	0.0500	0.0500	0.50E-01	4.598	1324.6	0.992
2	8	7.53	1374.7	1.973	0.0500	0.0500	0.50E-01	4.598	1374.7	0.992
2	9	8.52	1424.7	1.972	0.0500	0.0500	0.50E-01	4.598	1424.7	0.992
2	10	9.51	1474.8	1.971	0.0500	0.0500	0.50E-01	4.598	1474.8	0.992
2	11	10.50	1524.9	1.969	0.0500	0.0500	0.50E-01	4.598	1524.9	0.992

LAYER NO.	COMPRESSION (INCHES)
1	0.0000
2	0.9997

(Continued)

TABLE 12

SUMMARY OF TIME SETTLEMENT DATA

TIME (DAYS)	SETTLEMENT (FEET)	DEGREE OF CONSOLIDATION (PERCENT)
0.1	0.00842	10.1
1.0	0.00915	11.0
4.0	0.01140	13.7
10.0	0.01517	18.2
40.0	0.02757	33.1
100.0	0.04267	51.2
400.0	0.07417	89.0
1000.0	0.08287	99.5
2000.0	0.08331	100.0

*

Table 22

Comparison of FD31 and Hand Solutions for Settlement and Degree of Consolidation

Settlement, ft	
FD31 Solution	Hand Solution
0.08331	0.083

Time days	Degree of Consolidation percent	
	FD31 Solution	Hand Solution
0.1	10.1	3
1.0	11.0	5
4.0	13.7	10
10.0	18.2	16
40.0	33.1	32
100.0	51.2	51
400.0	84.0	88
1000.0	99.5	99
2000.0	100.0	100

REFERENCES

Headquarters, Department of the Army, Office of the Chief of Engineers. 1953. "Soil Mechanics Design, Settlement Analysis," Engineering Manual 1110-2-1904, Washington, D. C.

Olson, R. E. "Analysis of One-Dimensional Consolidation Problems with Emphasis on Program FD31," University of Texas, Austin, Tex.; Program No. 741-F3-RO-105, CORPS Library, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Olson, R. E. and Ladd, C. C. "Analysis of One-Dimensional Consolidation Problems," Submitted to the Journal of the Geotechnical Engineering Division, ASCE.

Schiffman, R. L., Jubenville, D. M., and Partyka, V. 1976. "Magset-II, Version 1-A, a Computer Program to Calculate the Magnitude of Settlement of a Multi-Layered Soil System, User's Manual," GESA Report No. D-76-9, Geotechnical Engineering Software Activity, University of Colorado Computing Center, Boulder, Colo.; Program No. 741-F3-RO-105, CORPS Library, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Spaulding, D. 1968. "I0016, Vertical Stresses Beneath Embankment and Footing Loadings," No. 741-GI-F5010, CORPS Library, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

APPENDIX A: INPUT FOR EMBANKMENT LOADS--PROGRAM I0016

1. This appendix describes the additional input data for program I0016 that are required to analyze the vertical stress in the foundation beneath an embankment. Following the lines describing the loaded rectangular ares (if any) is a set of lines describing the shape and weight of the embankment loading (see Figures A1 and A2). These lines will be necessary only under the option where KODE is input as 2 or 3. The first line required to describe the embankment consists of the following input variables (see line 430 in Table A1):

a. NCOR. NCOR is the number of pairs of X and Y coordinates used to describe the cross section of the embankment loading. The maximum allowable value of NCOR is 25.

b. GAMMA. The variable GAMMA is the unit weight of the embankment fill in units of weight and length compatible with the other input data.

c. THICK. THICK is the input variable which determines the number of layers used to approximate the embankment loadings. THICK represents the maximum allowable thickness of any layer used in the approximation of the embankment loading.

d. YMAX. The value of YMAX is the longitudinal distance from the cross section to the end of the embankment in the positive Y direction. YMAX should in all cases be greater than or equal to zero, since the cross section (X-Z plane) defining the embankment loading is assumed to be at Y = 0.

e. YMIN. The value of YMIN is the longitudinal distance from the cross section to the end of the embankment in the negative Y direction. YMIN should in all cases be less than or equal to zero since the cross section (X-Z plane) defining the embankment loading is assumed to be at Y = 0.

2. The remaining cards required to describe the embankment loading consist of a series of lines each defining a pair of corner points (X,Z) of the embankment cross section. The number of these lines will correspond to the value of NCOR described above. These corner point lines should be input in the same sequence as they appear in the embankment cross section (see Figure A2). In other words, the input sequence should be the same as would be found by proceeding around the perimeter of the embankment cross section in either a clockwise or a counterclockwise

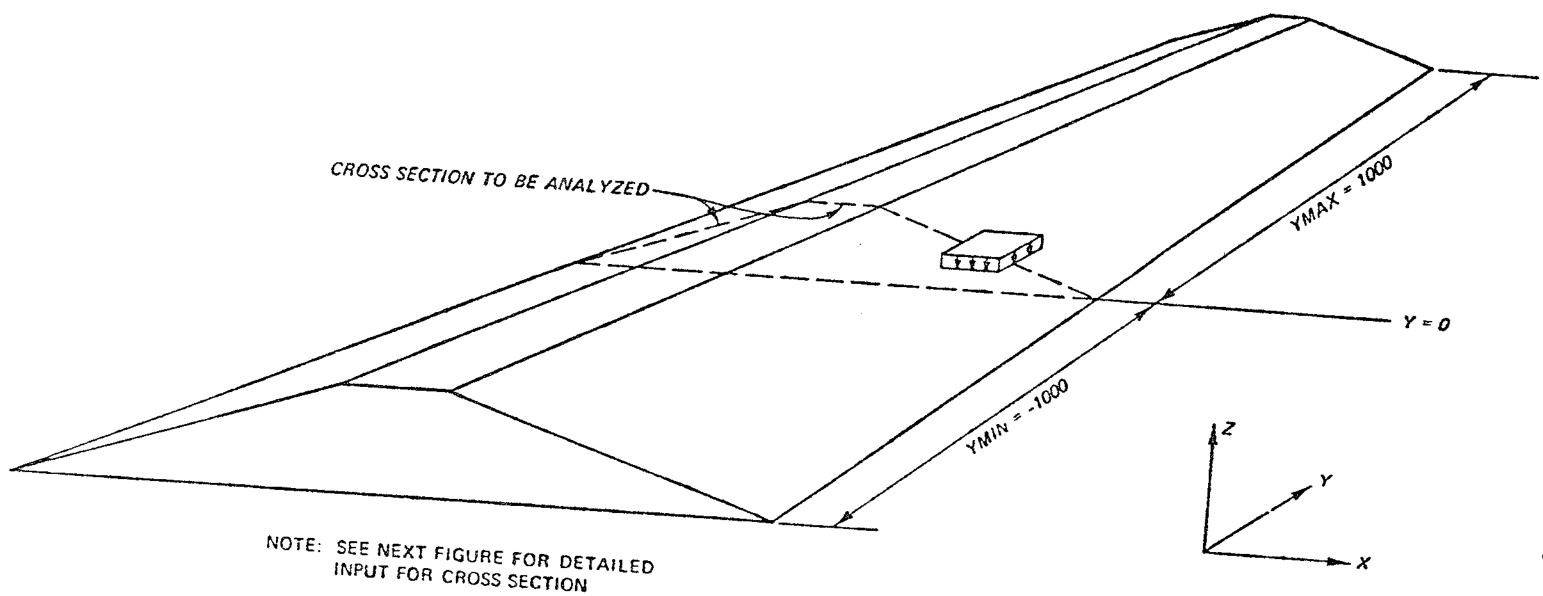


Figure A1. Embankment for input description

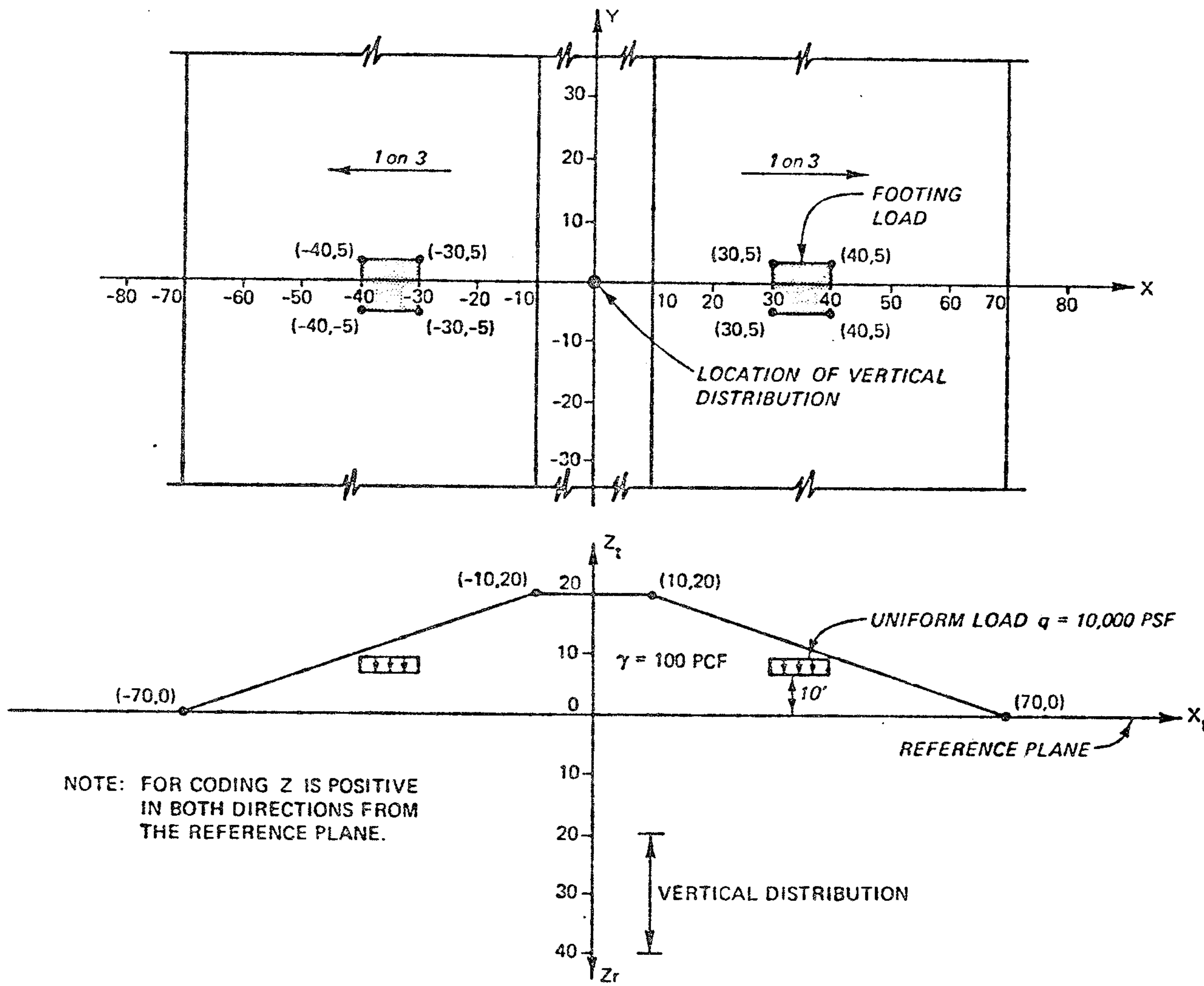


Figure A2. Cross section and plan view of embankment for input description

Table A1

Input for I0016

```
*LIST NEWDAT

100 TEST DATA
200 EMBANKMENT WITH 2 FOOTING LOADS
300 FOOTING LOAD = 10,000 PSF, EMBK. UNIT WT. = 100 PCF
350 1 VERTICAL STRESS DISTRIBUTION
375 3 JAN. 1972, D.A.S.
400 3  2
410 10000.0  10.0  -40.0  5.0  -40.0  -5.0  -30.0  -5.0  30.0  5.0
420 10000.0  10.0  30.0  -5.0  30.0  5.0  40.0  5.0  40.0  -5.0
430 4  100.0  2.0  1000.0  -1000.0
440 -70.0  0.0
450 -10.0  20.0
460 10.0  20.0
470 70.0  0.0
480 1  1  0.0
490 20.0  40.0  2.0  0.0  0.0  0.0  0.0  0.0
500 0  0  0.0

READY

*
```

(Continued)

Table A1 (Concluded)

```
DO YOU WISH TO RUN PROGRAM FROM EXISTING DATA FILE?
=YES
FILE DESCRIPTION (47 CHARACTERS MAX), TYPE ? FOR INFO ON FORM
=NEWDAT
DO YOU WANT OUTPUT WRITTEN TO AN OUTPUT FILE?
=YES
FILE DESCRIPTION (47 CHARACTERS MAX), TYPE ? FOR INFO ON FORM
=AUG2



*LIST AUG2

TEST DATA
EMBANKMENT WITH 2 FOOTING LOADS
FOOTING LOAD = 10,000 PSF, EMBK. UNIT WT. = 100 PCF
1 VERTICAL STRESS DISTRIBUTION
3 JAN. 1972, D.A.S.

     BOUSSINESQ SOLUTION


               VERTICAL STRESS DISTRIBUTION AT
          X-COORDINATE =      0.    Y-COORDINATE =      0.

                            ELASTIC SOLUTION             NORMAL LOADING
      DEPTH(Z)              VERTICAL STRESS              VERTICAL STRESS
      ---------             ---------------              ---------------
         20.00                 2682.575                     3363.874
         22.00                 2588.604                     3203.327
         24.00                 2501.253                     3061.084
         26.00                 2419.576                     2933.351
         28.00                 2342.841                     2817.327
         30.00                 2270.469                     2710.926
         32.00                 2201.999                     2612.577
         34.00                 2137.057                     2521.084
         36.00                 2075.333                     2435.524
         38.00                 2016.567                     2355.174
         40.00                 1960.537                     2279.459

          NUMBER OF AREAS USED IN CALCULATION =   13

  NOTE-ALL Z VALUES ARE REFERENCED TO THE LOWEST PART OF THE INPUT,
       CONFIGURATION.


READY

*
```

direction. The lines required for each corner point will have a format described as follows (see lines 440-470 in Table A1):

- a. X(I). X(I) is the X coordinate of a corner (break point) in the shape of the embankment cross section.
- b. Z(I). Z(I) is the Z coordinate of a corner (break point) in the shape of the embankment cross section. The Z coordinates are referenced to the lowest Z coordinate which has a value of zero.