COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM Vertical Stresses Beneath Embankment and Footing Loadings (10016)

PROGRAM NO. 741-F3-F5010

PREPARING AGENCY

U. S. Army Engineer District, St. Paul

AUTHOR(S)	DATE PROGRAM COMPLETED	STATUS OF PROGRAM: PHASE	STATUS OF PROGRAM: STAGE
Douglas Spaulding	March 1968		OPER

A. PURPOSE OF PROGRAM

The program finds vertical stresses for applied structural loadings. Either the Boussinesq or Westergaard method of solution may be used. Either solution method assumes that the foundation material is homogeneous linearly elastic material and that superposition is valid.

B. PROGRAM SPECIFICATIONS

Timesharing Program.

C. METHODS

Westergaard or Boussinesq solution method of calculating stress under a rectangular loaded area. Embankments can be handled also.

D. EQUIPMENT DETAILS

Low speed terminal, Central processor.

E. INPUT-OUTPUT

Input may be entered interactively from terminal or read from a previously prepared data file.

Output may come directly back to terminal or be stored in a file to be listed later.

F. ADDITIONAL REMARKS

Program is available through the CORPS on WES G-635, CSC H6000 at Macon, GA, and Boeing Computer Services.

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CHAPTER 1

GENERAL

1-1 IDENTIFICATION

TITLE: Vertical Stresses Beneath Embankment and Footing Loadings

REFERENCE FILE NO.: 741-GI-F5010

DATE COMPLETED: March 1968

1-2 DESCRIPTION

The program computes the vertical stresses induced in a semi inifinite mass by a group of uniformly loaded rectangular areas. Under one program option the vertical foundation stresses caused by an embankment loading are approximated by assuming that the embankment is composed of a series of uniformly loaded rectangular areas lying on the top of one another. The program can handle up to 100 footing loads. The vertical stresses may be calculated by either Boussinesq or Westergaard solutions for vertical stresses.

1-3 ENVIRONMENT

SECURITY CLASSIFICATION: Unclassified

PROGRAM LANGUAGE: FORTRAN II

COMPUTER MAKE AND MODEL: G-635, CDC CYBER 175
Timesharing terminal
Program is part of the CORPS Library.

PROGRAMMER: Douglas Spaulding, FM&S Branch, St. Paul District

CHAPTER 2

PROBLEM SOLUTION

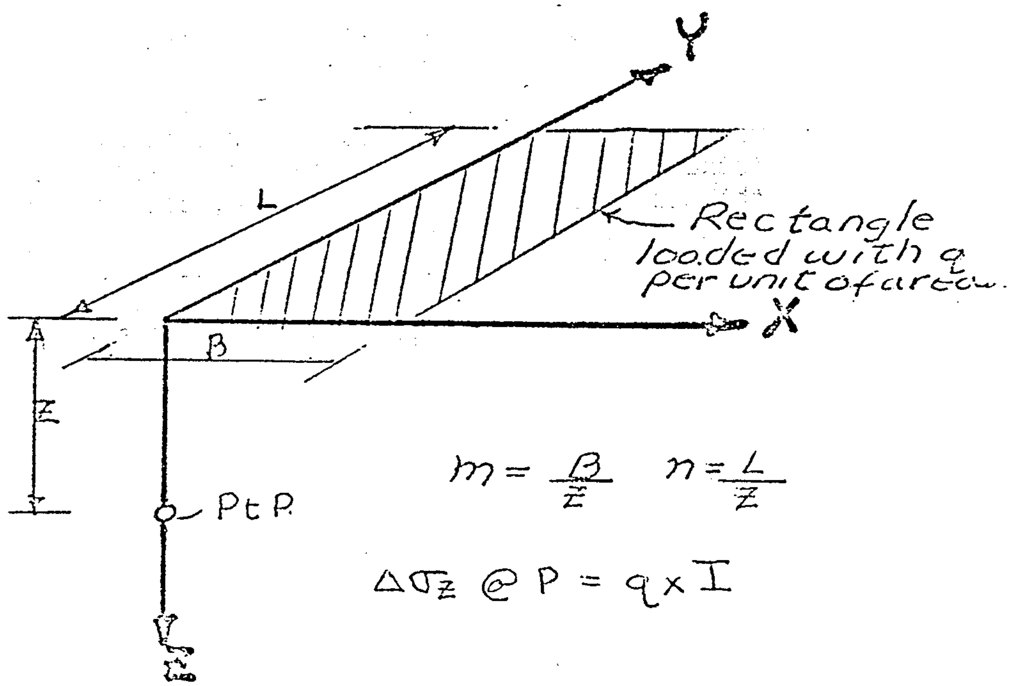
2-1 PROBLEM DESCRIPTION

The design of buildings and earth structures often involves making an estimate of the amount of settlement which will occur during the life of the structure. The nature of foundation settlement is closely related to the properties and stress history of the foundation soil. Although many theories have been advanced as to the mechanism of soil compression, each must make some assessment of the foundation stress conditions induced by the applied structural loadings. One of the more prevalent theories of soil compression assumes one dimensional soil compression in which the foundation soil is assumed to be homogeneous as far as stress strain characteristics are concerned. To use this one dimensional theory, the vertical stresses induced by the structural loads at various points in the foundation soil are required to make an assessment of the settlement. The purpose of this computer solution is to provide a means of obtaining these vertical stresses for a variety of structural loadings, without resorting to the tedious and time consuming use of manual methods such as influence charts.

2-2 DESCRIPTION OF COMPUTER SOLUTION

The basis of the computer solution for vertical stresses within foundations is an equation which gives the vertical stress at a given depth beneath the corner of a uniformly loaded rectangular area. This equation can take two forms depending upon whether the Boussinesq or the Westergaard solution is used. The difference between these solutions is described in Section 2-3. Figure 2-1 shows the variables involved in these equations.

Both of these solutions assume that the foundation material can be represented as a homogeneous linearly elastic material. The Boussinesq solution assumes that the foundation material is isotropic while the Westergaard solution assumes that no lateral displacements take place within the foundation. The linearity of the material implies that superposition is valid. In practice superposition allows the equations of Figure 2-1 to be used to determine stresses at other points besides under the corner of the loaded area. This is accomplished by adding and subtracting the effects of loadings on a group of four larger fictitious areas to obtain the effect of the area in question.



$m = \frac{B}{Z} \quad n = \frac{L}{Z}$

$\Delta\sigma_Z @ P = q \times I$

BOUSSINESQ SOLUTION:

$$I = \frac{1}{4\pi}\left(\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+m^2n^2+1} \cdot \frac{m^2+n^2+2}{m^2+n^2+1} + \right.$$
$$\left. + \tan^{-1}\frac{2mn\sqrt{m^2+n^2+1}}{m^2+n^2+1-m^2n^2}\right.$$

WESTERGAARD SOLUTION:

$$I = \frac{1}{2\pi}\,\mathrm{TAN}^{-1}\left(\frac{1}{\sqrt{\left(\frac{1-2\mu}{2-2\mu}\right)\left(\frac{1}{m^2}+\frac{1}{n^2}\right)+\left(\frac{1-2\mu}{2-2\mu}\right)^2\frac{1}{m^2n^2}}}\right)$$

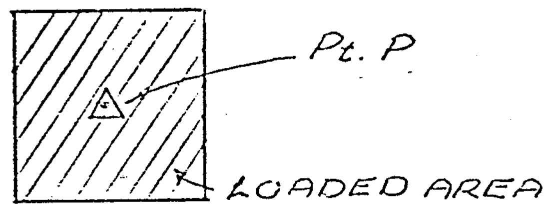
where μ = Poisson's Ratio

FIGURE 2-1

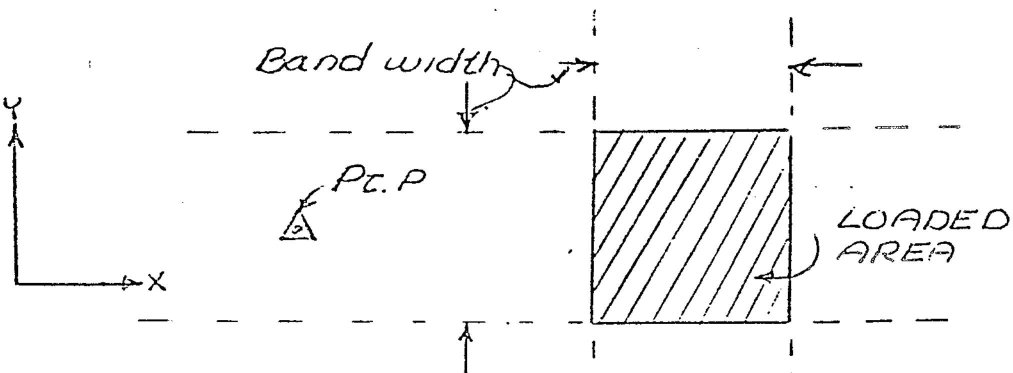
The computer solution categorizes the load from a uniformly loaded rectangular area in to one of the three groups shown in Figure 2-2. This figure is a plan view showing the relationship of the rectangular loaded areas to the point where the stress is required (Pt. P.). These three groups are used to determine which method of super position should be used to calculate the stress at point P. Case No. 1 represents Pt. P. lying directly under the loaded rectangle. Case No. 2 represents a situation where point P does not lie under the rectangular area but within a band width formed by extending the lines forming the sides of the rectangular loaded area in either the X or Y direction. Case No. 3 represents the condition where the point P does not lie under the rectangle nor within the band described for Figure No. 2. The computer solution categorizes the relationship of the loaded area and point P by constructing a series of four triangular areas. Each triangle has one side of the rectangular loaded area as a base and point P as the third corner. Figure 2-3 shows this construction for the case where Pt. P. lies under the loaded rectangular area (Case No. 1) and the construction when Pt. P. lies outside the loaded area (Case No. 2 or No. 3).

If the sum of the areas formed by the triangles A-B-P, B-C-P, C-D-P, and D-A-P is equal to the area of the rectangular loaded area A-B-C-D, then the computer solution assumes a Case No. 1 condition. If the sum of the area of these four triangles is greater than the area of the rectangle, the computer solution assumes a Case No. 2 or Case No. 3 condition. To differentiate between a Case No. 2 or Case No. 3 condition the computer solution calculated the perpendicular distances from Pt. P to the various sides (or extension of sides) of the rectangularly loaded areas. These distances are equal to the triangular areas previously calculated divided by the respective bases of the triangle (the sides of the rectangular loaded area). This procedure is illustrated in Figure 2-4 for both a Case No. 2 situation and a Case No. 3 condition.

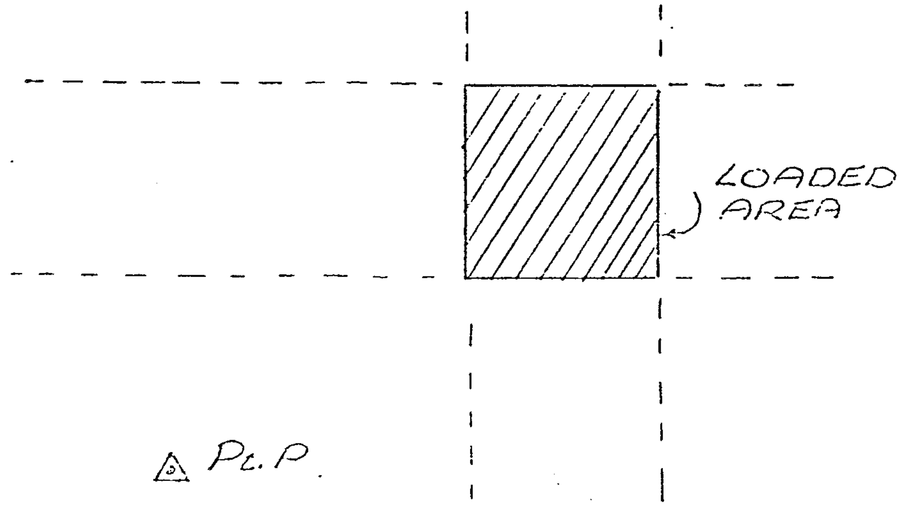
If the relationship between the rectangular loaded area and the Point P is a Case No. 2 condition as in Figure 2-4a, then both D(1) and D(3) will be less than the length of side No. 4. Similarly if the Point P lies on the other side of the rectangular area, then D(2) and D(4) would both be less than the length of side No. 3. As can be seen from Figure 2-4b. If the criteria stated above is not satisfied (D(1) or D(3) greater in length than side No: 4) then the configuration is a type No. 3 condition. It should be noted that the methods of categorizing the configuration of the rectangle and Pt. P are independent of the orientation of the coordinate system used. This allows calculation of stresses from rectangles which have sides that are not parallel to the X or Y axis.



CONFIGURATION No.1

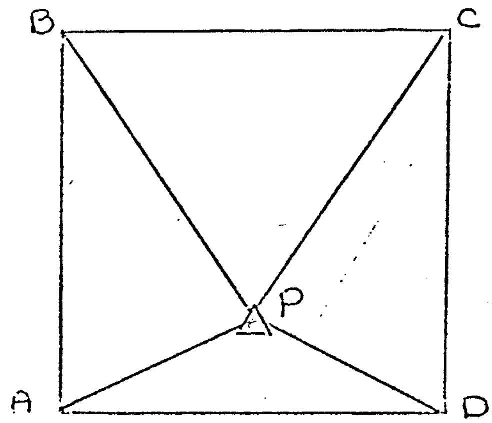


CONFIGURATION No.2

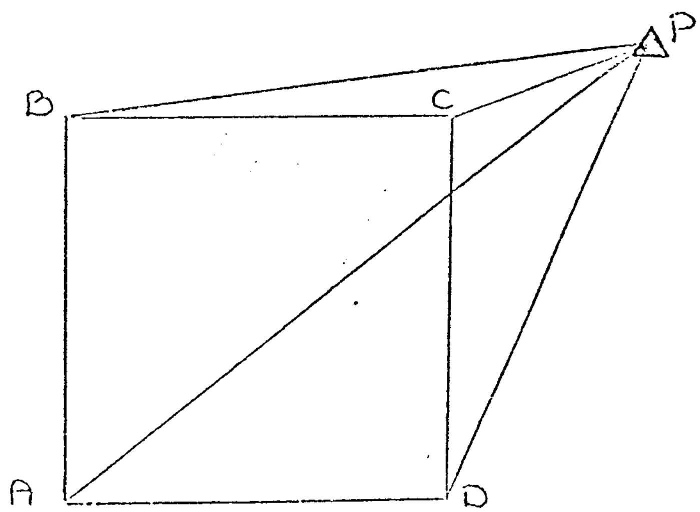


CONFIGURATION No.3

FIGURE 2-2

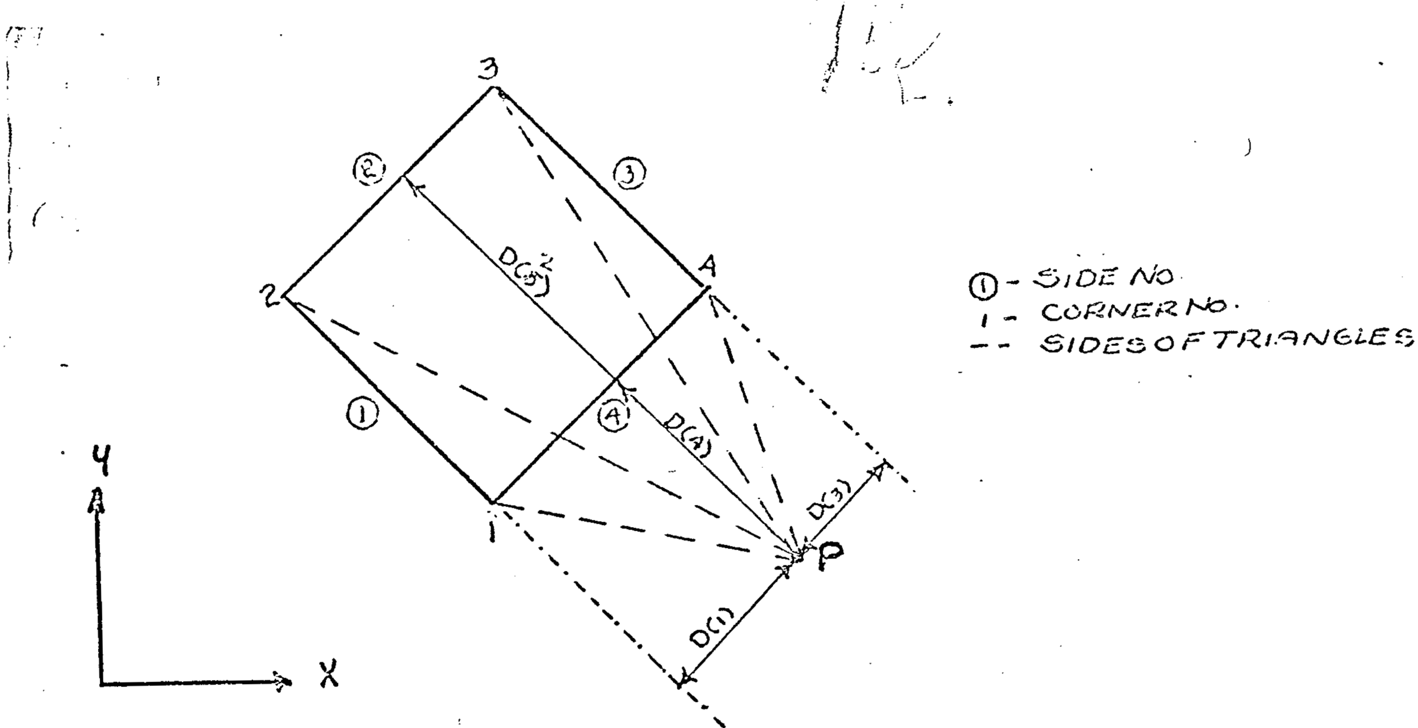


Point P is inside loaded Area
(CASE No.1)

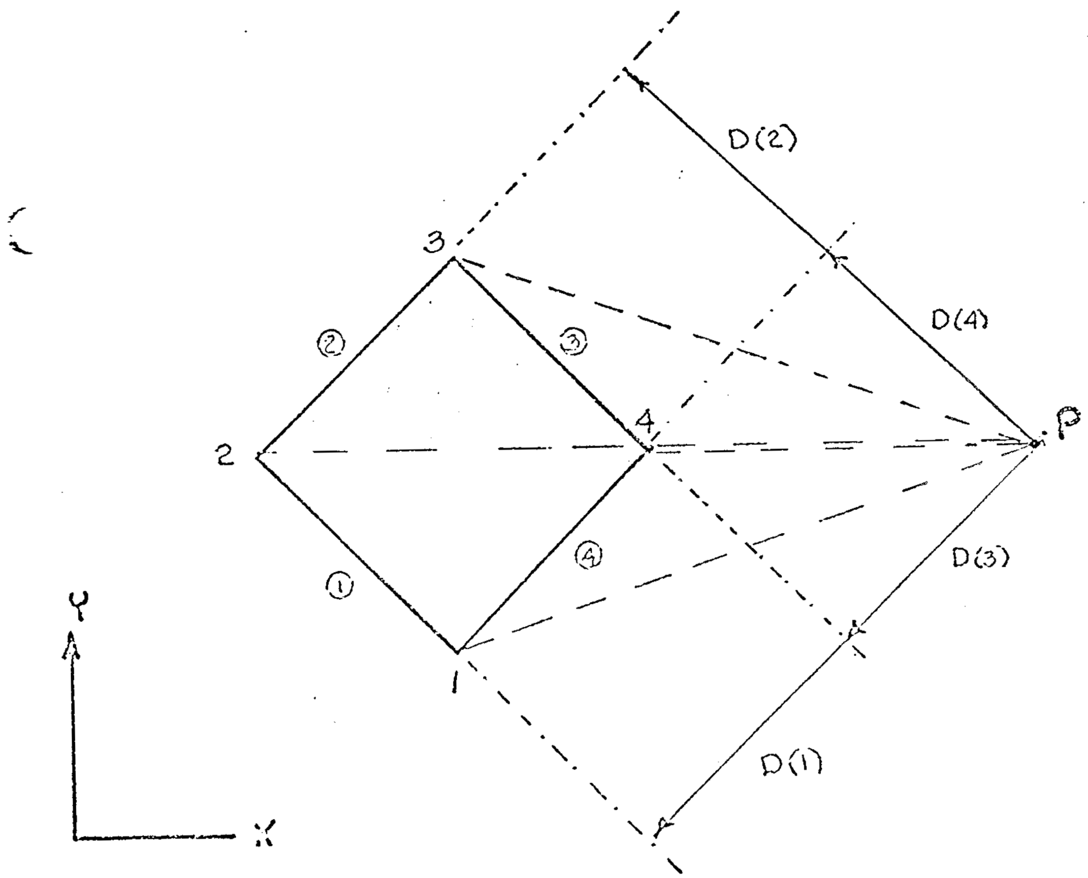


Point P is outside loaded Area
(Case No.2 or No.3

FIGURE 2-3



a.) Case No. 2 condition



b.) Case No. 3 condition

FIGURE 2-4

Once the computer solution categorizes the rectangle as a Case No. 1, No. 2, or No. 3 condition, it uses the principle of superposition to calculate stress caused at Point P by the uniformly loaded rectangle. Depending on the option which the user selects, this stress is calculated by either the Boussinesq or Westergaard equations (Figure 2-1). The method of super position used for both equations is the same. It should be remembered that the formulas shown in Figure 2-1 are valid for Points directly beneath the corner of a uniformly loaded rectangular area. Figure 2-5 indicates the methods for Cases 1, 2, and 3 whereby a series of four rectangular areas each with a corner at Point P may be superimposed to obtain the stress at a depth below Point P. The dimensions of these rectangles is obtained from the distances D(1), D(2), D(3), and D(4) previously calculated and illustrated in Figure 2-4.

After the stress at Point P and depth is determined for the first rectangular uniformly loaded area, the procedure is repeated for the second area. This procedure is repeated for all areas in the input configuration. The output stress value for Point P is the sum of the stresses induced at P by each of the areas in the input configuration. The location or depth of Point P is then varied in accordance with the stress distribution specified in the input.

For an embankment loading the computer solution assumes that the embankment is composed of a series of rectangular uniformly loaded areas stacked on top of one another. The input for this option consists of the lines forming the embankment cross section and the length of the embankment. Figure 2-6 shows the division of an embankment cross section into rectangular areas. The computer solution performs this division in such a manner that the thickness of layer (rectangular loaded area) is less than or equal to a value specified in the input. The uniform load for each layer is calculated by multiplying the unit weight of the soil by the thickness of each layer. After the division of the embankment into a series of uniformly loaded rectangular areas, the computer solution computes the stress at a specified point in the foundation. The methods used in this calculation are identical with those described above for a single rectangular uniformly loaded area.

2-3 THEORETICAL LIMITATIONS AND SOURCES OF ERROR

As stated in section 2-2, the basis of the computer solution involves the assumptions that the foundation soil is homogeneous, isotropic and linearly elastic. Unfortunately, these assumptions are not true for most soils. The reason that the assumptions are made is that for many years no solution could be obtained without these simplifying assumptions. Within recent years a method of analysis involving the use of finite elements has made it theoretically possible to avoid many of the assumptions which were previously mandatory. The use of the Finite Element method, however, requires a knowledge of the stress-strain characteristics of the soil involved. At the present time

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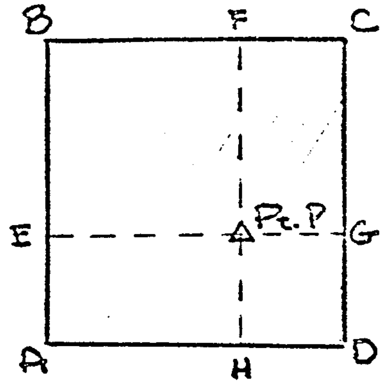
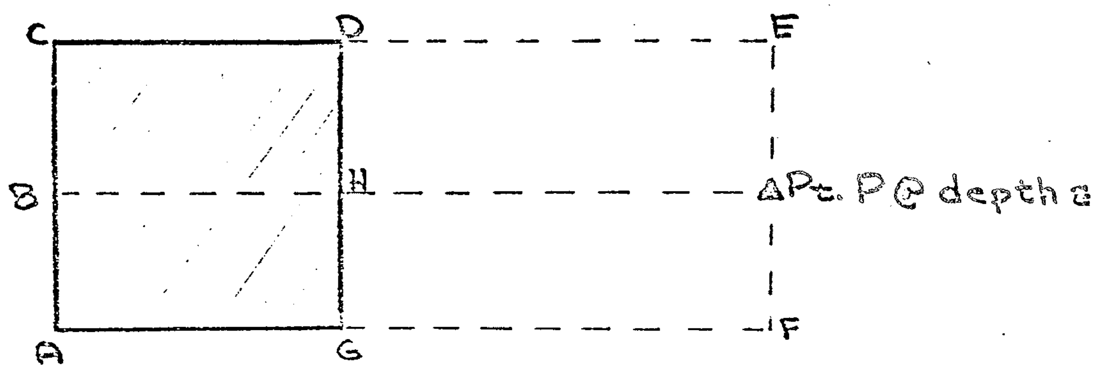


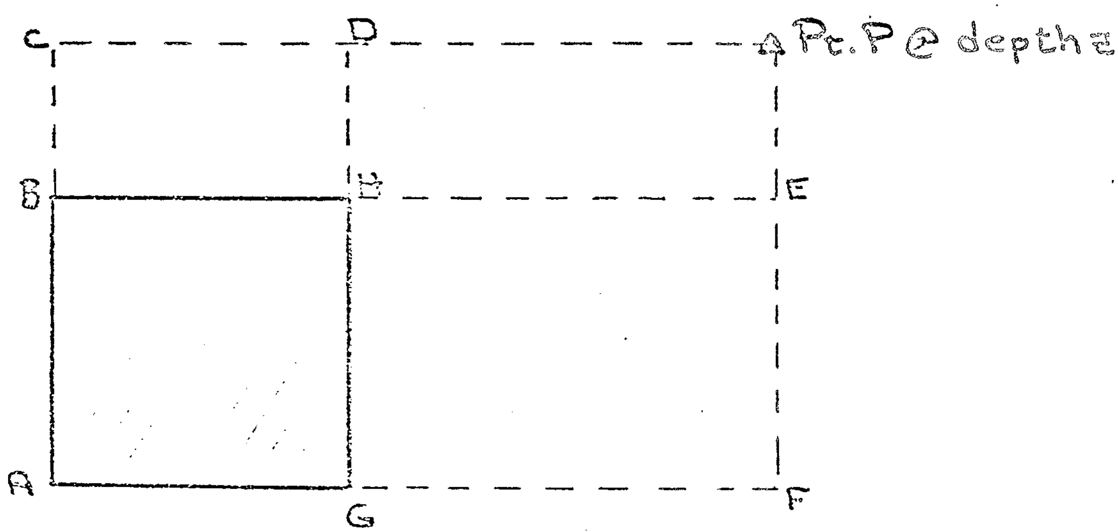
$$\sigma_{@P} = \sigma_{\square AEPH} + \sigma_{\square EBFP} + \sigma_{\square FCGP} + \sigma_{\square GDHP}$$

CASE No. 1



$$\sigma_{@P} = \sigma_{\square BCEP} + \sigma_{\square BAFP} - \sigma_{\square HDEP} - \sigma_{\square GHPF}$$

CASE No. 2



$$\sigma_{@P} = \sigma_{\square ACPF} - \sigma_{\square BCPE} - \sigma_{\square GDPF} + \sigma_{\square HDPE}$$

CASE No. 3

FIGURE 2-5

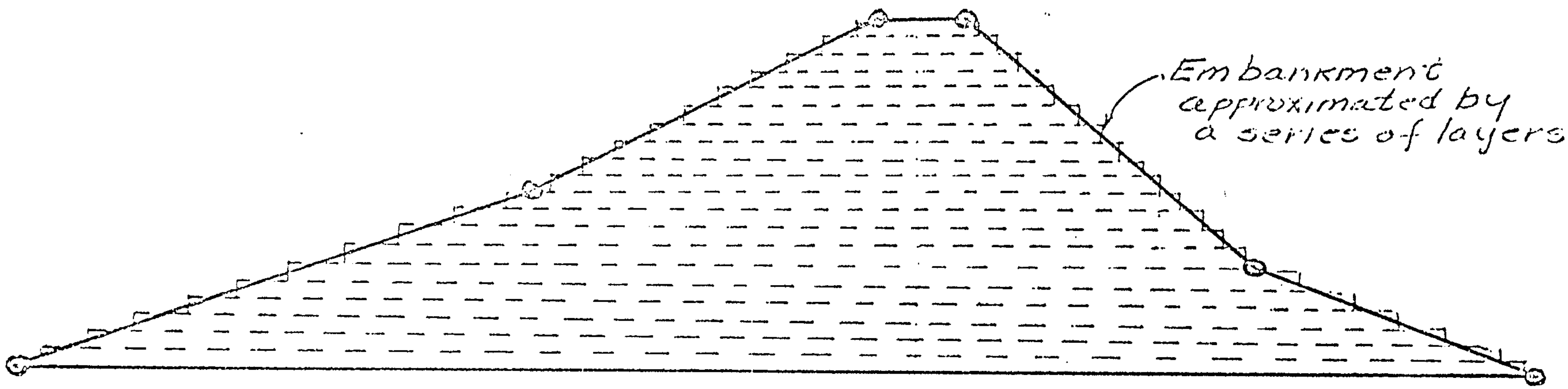


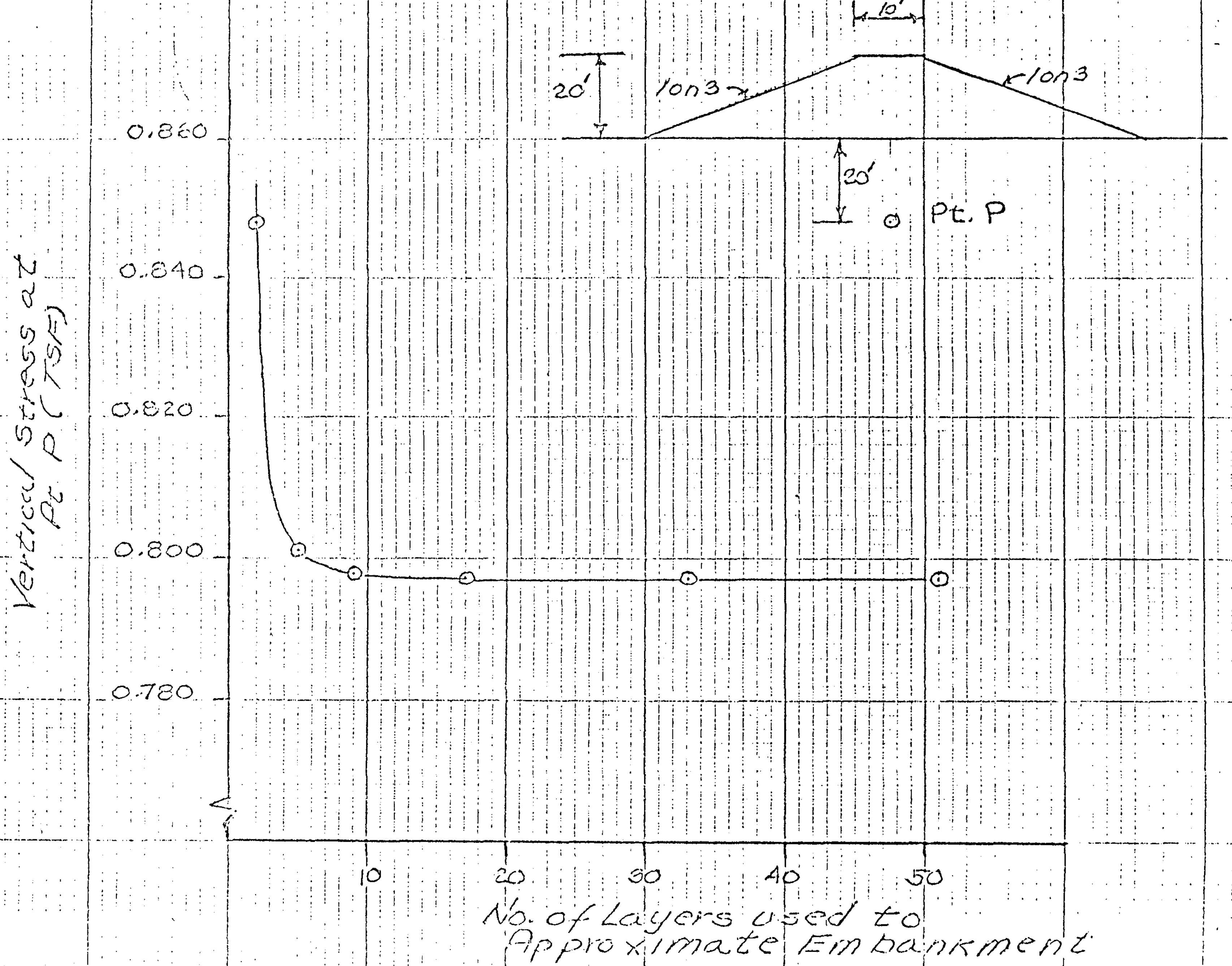
FIGURE 2-6

this knowledge is largely incomplete and for many situations the methods used by the computer solution described in section 2-2 will provide reasonably accurate results. It is not the purpose of this text to present a "State of the Art" discussion on the analysis of stresses in earth masses. The user should review his particular problem and decide whether the effect of the assumptions involved in this program justify a more sophisticated analysis.

As stated previously, the program user has an option as to whether to use the Boussinesq or the Westergaard solution. The Westergaard solution assumes that the elastic foundation material is sandwiched between numerous closely-spaced, horizontal, thin sheets of an inelastic material which permit downward deformation, but which prevent lateral deformations. This solution would approximate a foundation profile of interbedded sand and compressible clay strata. The Boussinesq solution assumes that the soil is isotropic and free to deform in all directions. This condition would approximate a large deposit of saturated clay. The effect of the Westergaard solution as compared to the Boussinesq solution is to decrease the stresses directly below the loaded area and to increase the stresses at large distances from the loading.

In most cases the number of layers used to approximate an embankment loading has little effect on the final solution. Figure 2-7 shows the variation of the computer solution versus the number of layers used to approximate a typical embankment. It should be noted that for the embankment shown increasing the number of layers past ten does not significantly affect the accuracy of the solution. The number of layers used to approximate a particular embankment loading is left to the discretion of the program user. After becoming familiar with the program he should have little trouble choosing a reasonable value for the number of layers to use.

The Boussinesq and Westergaard equations for a rectangular loading both involve a normal loading being applied to the semi infinite mass. As shown in Figure 2-8a, the normal loading assumption requires that the shearing stress be zero along Plane A-A. In the case of rectangular loaded areas such as footing loads, this condition is met. However, when embankment loads are approximated by rectangular areas, the question arises as to whether shear stresses should be tacitly assumed to develop within the embankment or whether the entire embankment load should be considered as normal loading acting at the ground surface. As illustrated in Figure 2-8b, the decision as to whether to use a normal loading assumption involves the choice of Z1 or Z2 as the distance from the bottom of the rectangular area to Point P. If Z1 is used in the stress equations, the tacit assumption will be that there is no shear stress acting along Plane B-B. If Z2 is used the tacit assumption is that a semi infinite half space exists below the bottom of the rectangular area rather than an embankment of limited extent. Since neither of these assumptions is valid the resulting vertical stresses at Point P are in error to some degree. The magnitude of the error in most cases, however,



10'
20'
1on3
1on3
20'
Pt. P
0.860
0.840
0.820
0.800
0.780
Vertical Stress at Pt P (TSF)
10
20
30
40
50
No. of Layers used to Approximate Embankment

FIGURE 2-?

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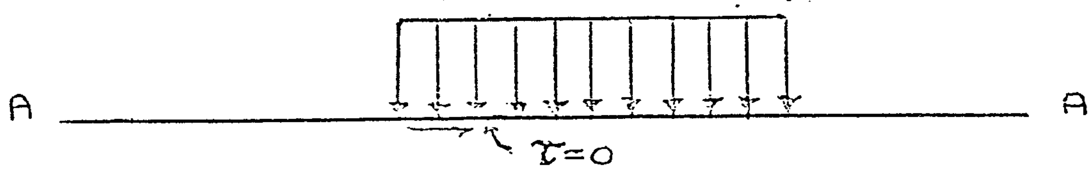

FIGURE 2-8.a

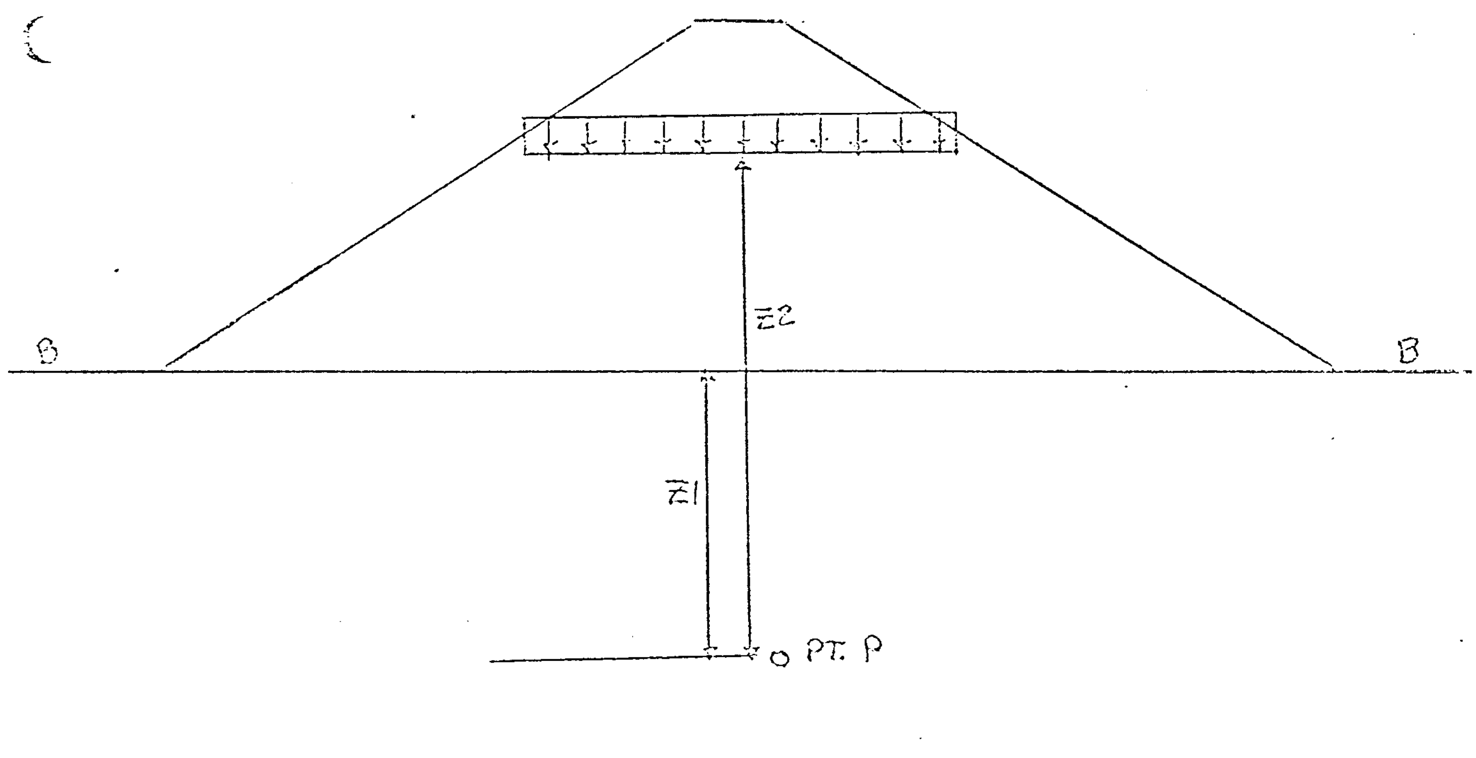

FIGURE 2-8 b.

is probably less than that incurred in other phases of a settlement analysis. The machine solution for an embankment yields stress values calculated by using both Z1 and Z2. The values using Z1 are listed under the heading "NORMAL LOADING" and the values using Z2 are listed for lack of a better title under the heading "ELASTIC SOLUTION." The differences between these values is usually not great and the user may choose the one he feels is most appropriate.

CHAPTER 3

COMPUTER PROGRAM/OPERATIONAL DOCUMENTATION

3-1 INPUT REQUIREMENTS AND OPTIONS

The input data may be categorized in three groups of data. The first group consists of five cards containing alphanumeric data describing the particular run. The second data group describes the embankment and/or footing loads and the third data group defines the type and location of desired stress distributions. The number of cards in the second and third data group vary with the complexity of the problem and the amount of output required. The following is a detailed description of the input data: Each line of data should be preceded by a line number if information is put into a data file.

A. Header Lines HDR (I,J) (ALPHA)

Five header lines are required at the beginning of the data deck. These cards 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 less than five cards are used to identify the project, blank lines must be included to complete the required five cards. The information on the header cards may be up to 60 characters maximum.

```
100 TEST DATA
110 TWO SQUARE FOOTINGS
120 UNIT LOAD = 1000 PSF
130 2 HORIZONTAL AND 1 VERTICAL DISTRIBUTION
140 JAN. 1972, D.A.S.
```

B. Loading Configuration Cards

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

The first data line in this group requires the following data:

Item 1 KODE (FLOAT PT.)

KODE is a variable which indicates what type of loading configuration is to be used in the analysis. If KODE is coded as 1, only uniform rectangular loads are to be used in the analysis. If the value of KODE is input as 2 only an embankment load is to be used. If the variable KODE is entered as 3 then both uniformly loaded reactangular areas and an embankment loads are to be used in the analysis.

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Item 2 NAREA (FIX. PT.)

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 left blank for KODE=2 (embankment only) loading conditions. The maximum allowable value of NAREA is 100.

An example of this line would be as follows:

150 1 2

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

Item 1 Q(I) (FLOAT. PT.)

Q(I) is the magnitude of the uniform load on the Ith rectangular area. The units of Q(I) is LOAD/UNIT AREA. Any system of weights and lengths may be used as long as all input data is in the same units.

Item 2 ZLAY(I) (FLOAT. PT.)

The positive ZLAY(I) is the vertical distance from the base of the Ith footing to the vertical reference plane. If KODE=1 the vertical reference plane is the base of the lowest footing in the input configuration. If KODE=3 the vertical reference plane is the lowest point in the embankment. (No footings may be input lower than the lowest point in the embankment.)

Item 3 XC(1,I) (FLOAT. PT.)

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.

Item 4 YC(1,I) (FLOAT. PT.)

The variable is the variable name of the Y coordinate of the first corner of the Ith rectangular area.

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Items 5-10- XC(2-4,I), YC(2-4,I)

The remaining three pair 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 axis but the corner points should be input in either clockwise or counter clockwise order around the perimeter of the rectangular area.

An example of this line would be as follows:

```
160 1000.0   0.0  -30.0   15.0  -30.0   35.0  -10.0   35.0  -10.0   15.0
170 1000.0   0.0   10.0   15.0   30.0   15.0   30.0   35.0   10.0   35.0
```

Following the lines describing the loaded rectangular areas (if any) is a set of lines describing the shape and weight of the embankment loading. 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:

Item 1 NCOR (FIX. PT.)

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.

Item 2 GAMMA (FLOAT. PT.)

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

Item 3 THICK (FLOAT. PT.)

THICK is the input variable which determines the number of layers used to approximate the embankment loadings as shown in Figure 2-6. THICK represents the maximum allowable thickness of any layer used in the approximation of the embankment loading.

Item 4 YMAX (FLOAT. PT.)

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.

Item 5 YMIN (FLOAT. PT.)

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.

An example of this line is as follows:

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. In other words the input sequence should be the same as one would find by proceeding around the perimeter of the embankment cross section in either a clockwise or counter clockwise direction. The lines required for each corner point will have a format described as follows:

Item 1 X(I) (FLOAT. PT.)

X(I) is the X coordinate of a corner (break pt.) in the shape of the embankment cross section.

Item 2 Z(I) (FLOAT. PT.)

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

A typical example of this line is shown below:

C. Stress Distribution Data

This section of data defines the output required for the loading conditions described in section B above. The output may be in two forms depending on the needs of the user. The first type of output consists of a vertical stress distribution which will print out values of vertical stresses along a vertical line in the X-Y-Z plane. For the vertical stress 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 a horizontal stress distribution wherein values of stress are calculated 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 intercept. There is no limit as to the number calculation points on a given distribution nor how many distributions may be run for a given loading configuration.

The information for a single stress distribution is contained on two lines. The input variables on the first line are:

Item 1 NDIST (FIN. PT.)

NDIST is an option variable which defines whether a vertical or horizontal stress distribution is required. If NDIST is coded as 1 a vertical distribution will be assumed and if NDIST is coded as 2 a horizontal distribution will be 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 configuration to be read in. If no new loading configuration follows NDIST=0, the program will exit after reading seven blank cards.

Item 2 - NWEST (FIS. PT.)

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 and if NWEST=1 the Boussinesq solution will be calculated.

Item 3 AMU

The value of AMU represents the value of Poissons ratio to be used in the Westergaard solution. If a Boussinesq solution is to be used (NWEST=1) the value of AMU may be left blank.

An example of this line is as follows:

```
180 2   1   0.0
```

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

Item 1 AINTL (FLOAT. PT.)

AINTL is the starting point coordinate for either a vertical or horizontal distribution. If a vertical 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 distribution AINTL represents the smallest (initial) X coordinate of the horizontal distribution. For a horizontal distribution AINTL may be positive or negative.

Item 2 FINAL (FLOAT. PT.)

FINAL represents the ending point coordinate for either a vertical or horizontal distribution. If a vertical distribution is required (NDIST=1) the value of FINAL represents the final (largest) depth within the range of the distribution. For this case FINAL must be positive. In the case of a horizontal distribution FINAL represents the largest X coordinate of the horizontal distribution. For this case FINAL may be positive or negative.

Item 3 DELTA (FLOAT. PT.)

The value of DELTA represents the distance between calculation points for both a horizontal and vertical stress distribution. DELTA should always be positive.

Item 4 XP (FLOAT. PT.)

XP represents the X coordinate for the location of a vertical stress distribution. If a horizontal distribution is being run the value of XP may be left blank.

Item 5 YP (FLOAT. PT.)

YP represents the Y coordinate for the location of a vertical stress distribution. If a horizontal distribution is being run the value of YP may be left blank.

Item 6 ZP (FLOAT. PT.)

The value of ZP represents the constant depth at which a horizontal distribution is to be run. ZP should be positive and referenced to the lowest point in the embankment or footing configuration. If a vertical distribution is being run the value of ZP may be left blank.

Item 7 SLP (FLOAT. PT.)

SLP is the slope in the X-Y plane of the line along which a horizontal distribution is to be run. If a vertical distribution is to be run than the value of SLP may be left blank.

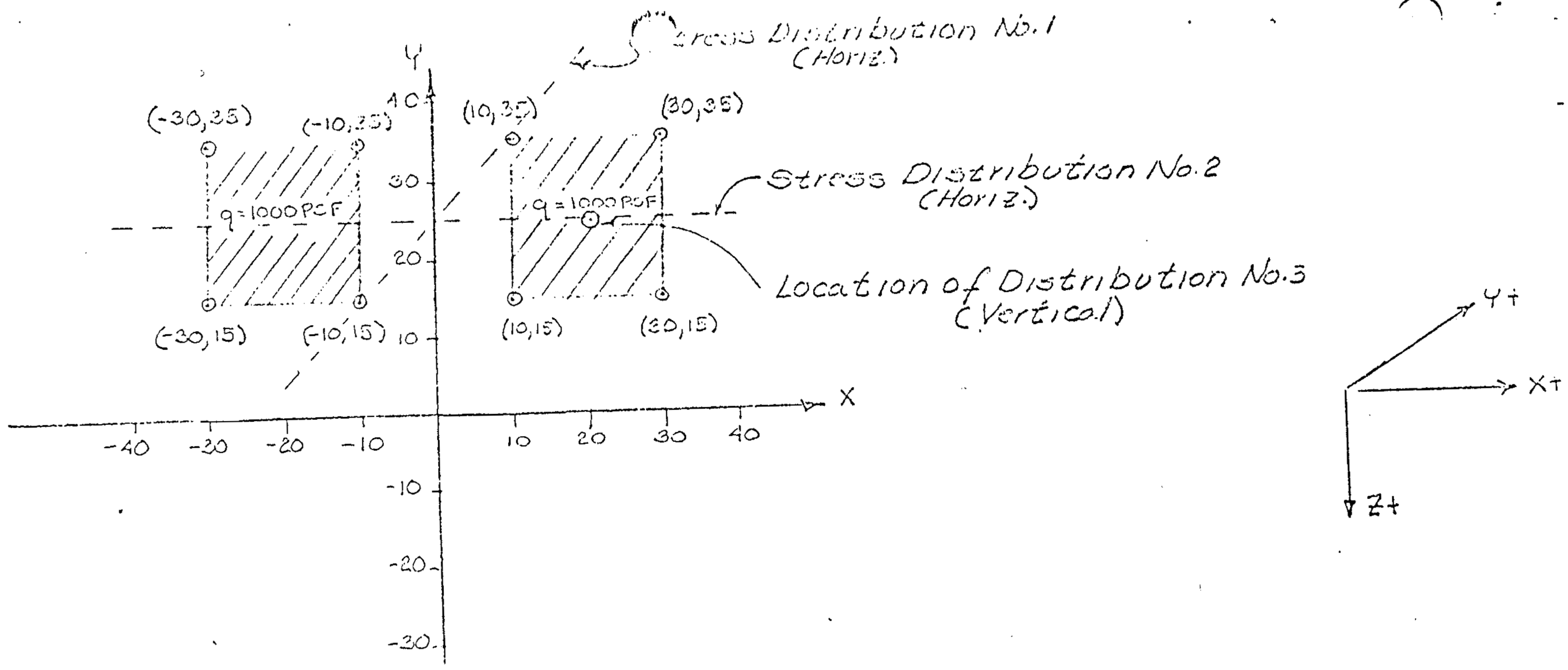
Item 8 BLINE (FLOAT. PT.)

BLINE is the Y intercept of the line in the X-Y plane along which a horizontal stress distribution is to be run. The value of BLINE may be left blank if a vertical distribution is being run.

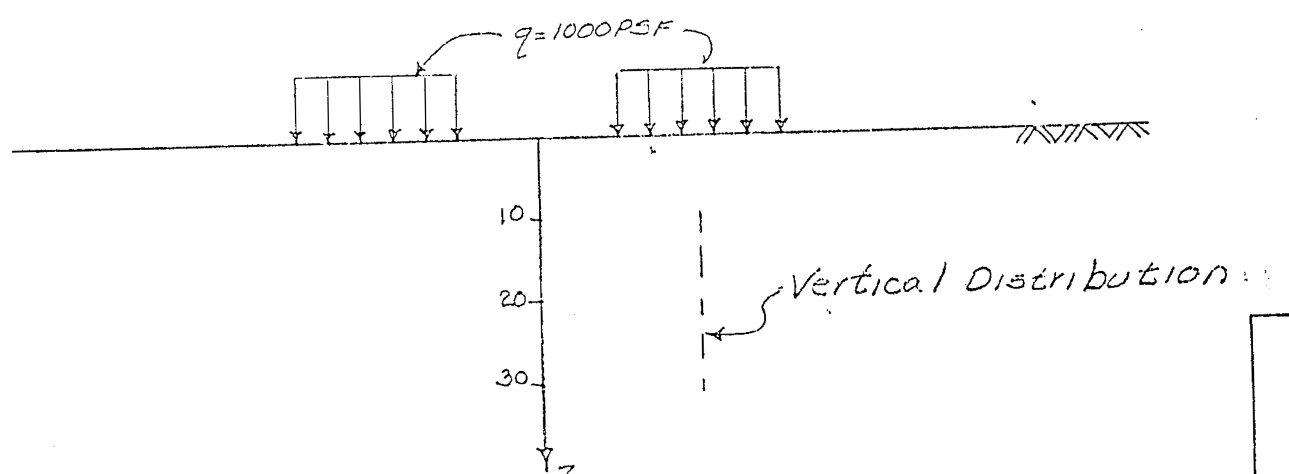
190 -20.0 20.0 20.0 0.0 0.0 20.0 -1.0 25.0

3 -2 EXAMPLE CODING AND OUTPUT

This section contains examples of coding for two typical problems. Output from the two examples may be found directly after each problem. The first problem consists of a loading configuration involving two uniformly loaded footings. The second problem consists of an embankment loading and uniform loads on two footings. The following examples contain diagrams of the input configuration, example coding sheets, listings of the input data and output corresponding to the input data.



PLAN VIEW (X-Y PLANE)



SECTIONAL VIEW (X-Z PLANE)

INPUT DIAGRAM
TWO FOOTING

3 JAN. 72 D.A.S.

GENERAL PURPOSE DATA FORM
8 COLUMN FIELD

Program: STRESS DISTRIBUTION (FOR TWO FOOTING LOADS)
Requested By: D. SPAULDING
Prepared By:
Checked By:
Date: JAN. 1972
Page 1 of 1

1–8	9–16	17–24	25–32	33–40	41–48	49–56	57–64	65–72	73–80
SHRADER CARDS									
TEST DATA									
TWO SQUARE FOOTINGS									
UNIT LOAD= 1000 PSF									
2 HORIZONTAL AND 1 VERTICAL DISTRIBUTION									
JAN 1972, D.A.S.									
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)
1000.0	0.0	-30.0	15.0	-30.0	35.0	-10.0	35.0	-10.0	15.0
1000.0	0.0	10.0	15.0	30.0	15.0	30.0	35.0	10.0	35.0
NDIST	NWEST	AMU							
2	1	0.0							
AINTL	FINAL	DELTA	XP	YP	ZP	SLP	BLINE		
-20.0	20.0	20.0	0.0	0.0	20.0	-1.0	25.0		
NDIST	NWEST	AMU							
2	1	0.0							
AINTL	FINAL	DELTA	XP	YP	ZP	SLP	BLINE		
-40.0	40.0	10.0	0.0	0.0	20.0	0.0	25.0		
NDIST	NWEST	AMU							
1	1	0.0							
AINTL	FINAL	DELTA	XP	YP	ZP	SLP	BLINE		
10.0	30.0	10.0	20.0	25.0	0.0				
NDIST	NWEST								
0									

```
DO YOU WISH TO RUN PROGRAM FROM EXISTING DATA FILE?
=NO
DO YOU WANT OUTPUT WRITTEN TO AN OUTPUT FILE?
=YES
FILE DESCRIPTION (47 CHARACTERS MAX), TYPE ? FOR INFO ON FORM
=7FRI7
INPUT 5 HEADER LINES
=TEST DATA
=TWO SQUARE FOOTINGS
=UNIT LOAD = 1000 PSF
=2 HORIZONTAL AND 1 VERTICAL DISTRIBUTION
=JAN. 1972, D.A.S.
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)
=1000.0,0.0,-30.0,15.0,-30.0,35.0,-10.0,35.0,-10.0,15.0

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)
=1000.0,0.0,10.0,15.0,30.0,15.0,30.0,35.0,10.0,35.0
NDIST, NWEST, AMU
=2,1,0.0

AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
=-20.0,20.0,20.0,0.0,0.0,20.0,-1.0,25.0


NDIST, NWEST, AMU
=2,1,0.0

AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
=-40.0,40.0,10.0,0.0,0.0,20.0,0.0,25.0


NDIST, NWEST, AMU
=1,1,0.0

AINTL,FINAL,DELTA,XP,YP,ZP,SLP,BLINE
=10.0,30.0,10.0,20.0,25.0,0.0,0.0,0.0


NDIST, NWEST, AMU
=0,0,0.0
```

TEST DATA
TWO SQUARE FOOTINGS
UNIT LOAD = 1000 PSF
2 HORIZONTAL AND 1 VERTICAL DISTRIBUTION
JAN. 1972, D.A.S.

BOUSSINESQ SOLUTION

VERTICAL STRESS DISTRIBUTION AT
X-COORDINATE = 20.00 Y-COORDINATE = 25.00

DEPTH(Z)	ELASTIC SOLUTION VERTICAL STRESS	NORMAL LOADING VERTICAL STRESS
10.00	702.879	702.879
20.00	345.962	345.962
30.00	196.771	196.771

NUMBER OF AREAS USED IN CALCULATION = 2

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

READY

+

2

*LIST 7FRI7

TEST DATA
TWO SQUARE FOOTINGS
UNIT LOAD = 1000 PSF
2 HORIZONTAL AND 1 VERTICAL DISTRIBUTION
JAN. 1972, D.A.S.

BOUSSINESQ SOLUTION

HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) = 20.00

Y-COORDINATE	X-COORDINATE	ELASTIC SOLUTION VERTICAL STRESS	NORMAL LOADING VERTICAL STRESS
45.00	-20.00	100.861	100.861
25.00	0.	189.320	189.320
5.00	20.00	100.861	100.861

NUMBER OF AREAS USED IN CALCULATION = 2

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

TEST DATA
TWO SQUARE FOOTINGS
UNIT LOAD = 1000 PSF
2 HORIZONTAL AND 1 VERTICAL DISTRIBUTION
JAN. 1972, D.A.S.

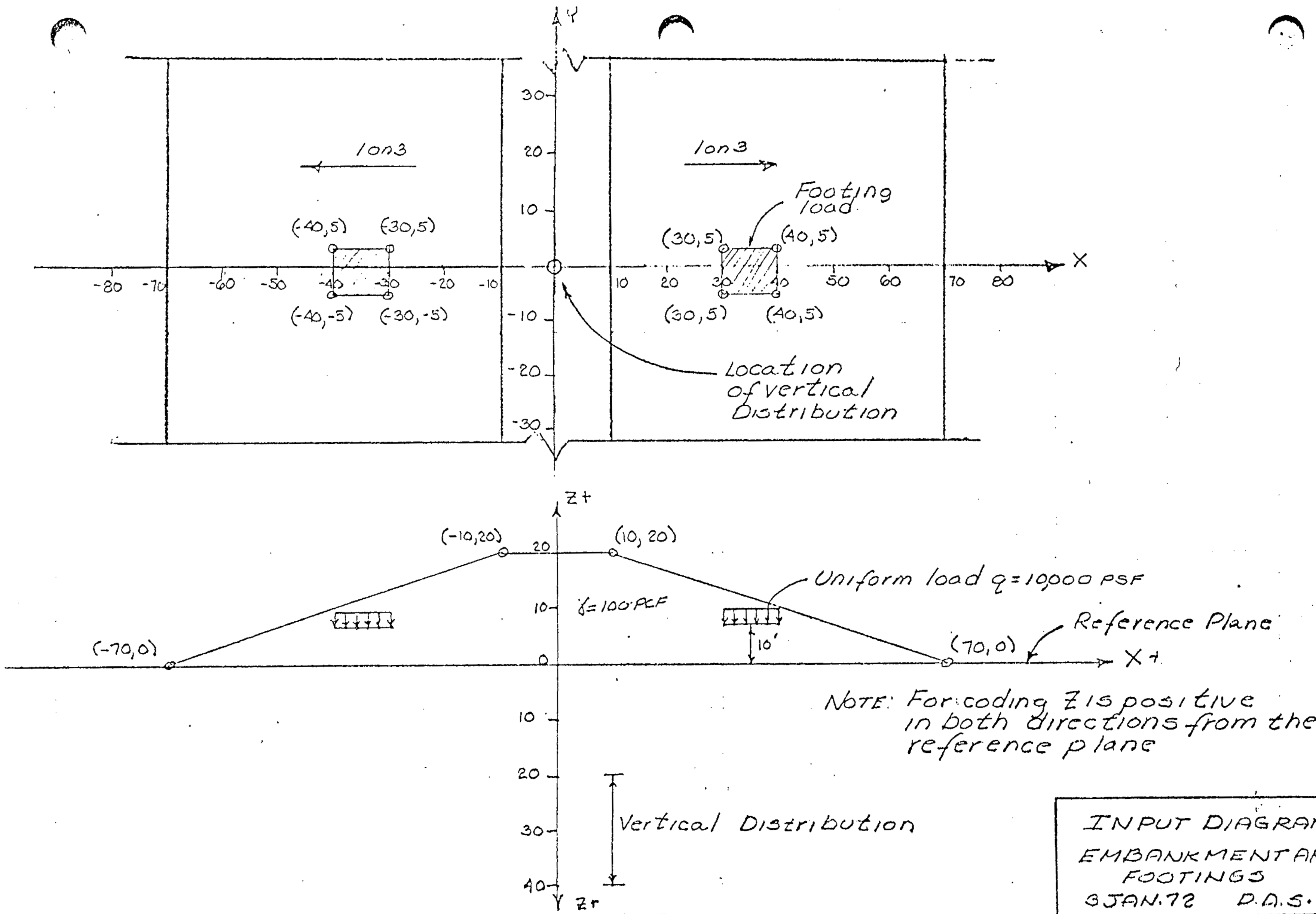
BOUSSINESQ SOLUTION

HORIZONTAL STRESS DISTRIBUTION AT DEPTH(Z) = 20.00

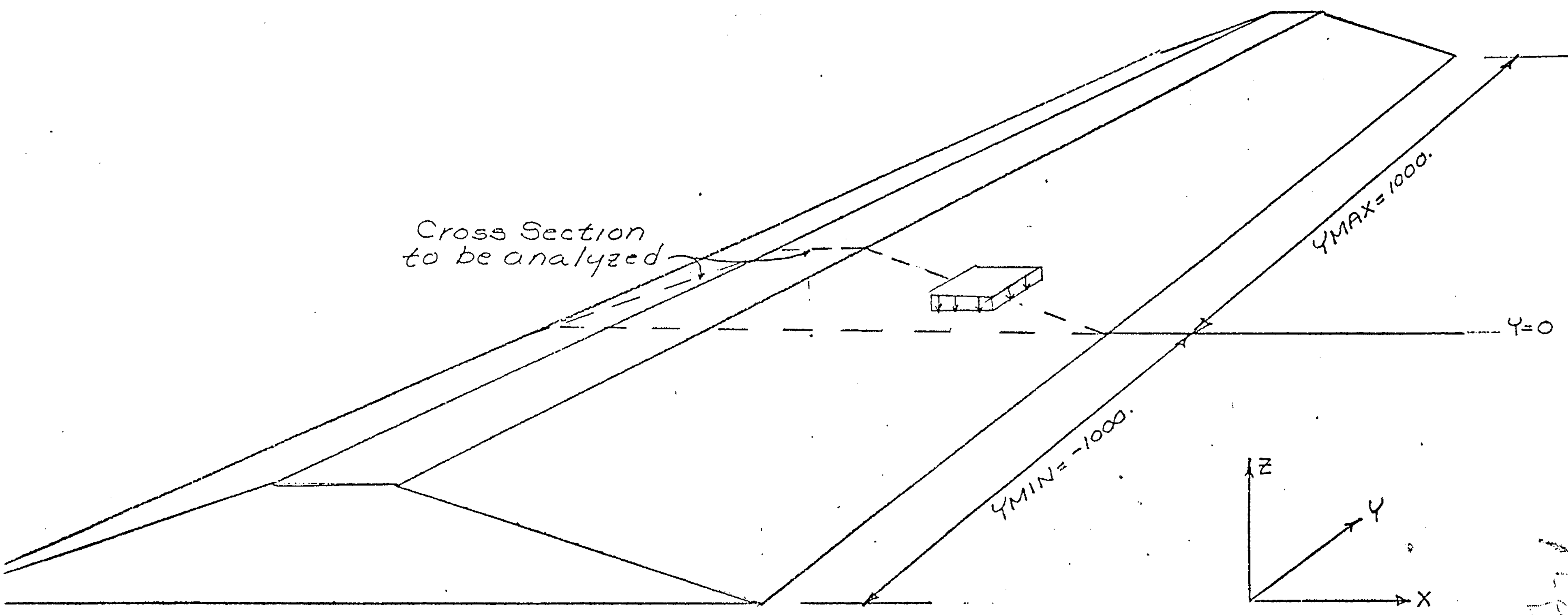
Y-COORDINATE	X-COORDINATE	ELASTIC SOLUTION VERTICAL STRESS	NORMAL LOADING VERTICAL STRESS
25.00	-40.00	96.309	96.309
25.00	-30.00	244.128	244.128
25.00	-20.00	345.962	345.962
25.00	-10.00	269.912	269.912
25.00	0.	189.320	189.320
25.00	10.00	269.912	269.912
25.00	20.00	345.962	345.962
25.00	30.00	244.128	244.128
25.00	40.00	96.309	96.309

NUMBER OF AREAS USED IN CALCULATION = 2

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



INPUT DIAGRAM
EMBANKMENT AND FOOTINGS
3 JAN. 72 D.A.S.



NOTE: SEE NEXT FIGURE FOR DETAILED INPUT FOR CROSS SECTION

INPUT DIAGRAM
EMBANKMENT AND FOOTINGS
3 JAN. 72 D.A.G.

GENERAL PURPOSE DATA FORM
8 COLUMN FIELD

Program: STRESS DISTRIBUTION (EMBANKMENT AND 2 FOOTINGS)
Date: JAN. 3, 1972
Requested By: D. SPAULDING
Prepared By:
Checked By:
Page of

```
5 HEADER CARDS
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.
  KODE   NAREA
       3       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)
10000.0    10.0   -40.0     5.0   -40.0    -5.0   -30.0    -5.0    30.0     5.0
10000.0    10.0    30.0    -5.0    30.0     5.0    40.0     5.0    40.0    -5.0
  NCOR    GAMA    THICK   YMAX    YMIN
       4   100.0     2.0  1000.0 -1000.0
  X(I)    Z(I)
   -70.0     0.0
   -10.0    20.0
    10.0    20.0
    70.0     0.0
  NDIST   NWEST   AMU
       1       1     0.0
AINTL   FINAL   DELTA     XP      YP      ZP      SLP     BLINE
    20.0    40.0     2.0     0.0     0.0
  NDIST   NWEST   AMU
       0
```

3-16 A

80 COLUMN KEY PUNCH TRANSCRIPT LAYOUT SHEET

```
*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

*
```

```
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

*
```

3-3 PROGRAM GLOSSARY

The following is a glossary of all the significant variables in the program. The user is urged to read Chapter 2 in order to understand some of the terminology used in the glossary. The variables defined as arrays are dimensioned to the same value as they have in the program. Input variables are indicated by an asterisk. Further definition of these variables may be found in section 4-1.

A(4)	Area of a triangle formed by two corners of a rectangular area and point P.
AINF	Influence value for a rectangular area.
AINFI	Influence value for a superimposed rectangular area used to obtain AINF (Four values of AINFI are summed algebraically to obtain AINF).
AINTL	Starting coordinate for either a horizontal or vertical stress distribution*
AM	Ratio of length of a side of a superimposed rectangle to the depth of point P.
AMS	AM to the second power.
AMU	Poissons ratio*
AN	Ratio of length of a side of a superimposed rectangle to the depth of point P.
ANS	AN to the second power.
AREA1	Area of rectangle found by multiplying adjacent sides of the rectangle.
AREA2	Sum of the area of four triangles in the X-Y plane each formed by connecting two adjacent corners of rectangle with point P.
B(25)	Y intercept in the equation describing the a line in the perimeter of the embankment cross section.
BLINE	Y intercept of the line in the X-Y plane for a horizontal stress distribution.*
CHECK	Absolute value of the difference in X coordinates of two adjacent points on the perimeter of an embankment cross section.

CHEK1	Absolute value of the difference in X coordinates between XTEST and a corner point on the embankment cross section.
CHEK2	Absolute value of the difference in X coordinates between XTEST and a corner point on the embankment cross section adjacent to the corner point used for CHEK1.
D(4)	Perpendicular distance in the X-Y plane from a side of the loaded area to the stress point XP, YP.
DELTA	Distance increment of a stress distribution (Horizontal or vertical)*
DELTZ	Thickness of layers used to approximate the embankment between two corner points of the embankment which are adjacent in the vertical direction.
DELXP	Distance increment of a horizontal stress distribution.
DIAG(4)	The distance in the X-Y plane from a corner of a rectangular area to the stress point.
FACT	A variable with a value of either +1.0 or -1.0, used to control whether superimposed rectangular areas are added or substracted.
FINAL	The coordinates of the final point on a horizontal or vertical stress distribution*
GAMA	Unit weight of embankment fill*
HDR(5,13)	Alphanumeric variable used to read and print header cards*
IFLAG	Variable used to direct program to return to proper area in the program after calculating an influence value. IFLAG's value depends upon whether a case No. 1, 2 or 3 condition is being analyzed.
KODE	An option variable defining whether a horizontal or vertical stress distribution is to be run*
KOUNT	A variable which indicates whether stresses have been calculated for both "normal loading" and "elastic solution".

NAREA	For input purposes this is the number of rectangular uniformly loaded areas to be input. If an embankment loading is involved, the value of NAREA is increased to include the number of layers (rectangles) used to approximate the embankment loading.*
NCOR	The number of pairs of coordinates used to describe an embankment cross section*
NDET	A code variable used to indicate which superposition case should be used to calculate the influence value of a particular rectangular area.
NDIST	A code variable used to indicate whether a vertical or horizontal stress distribution is to be calculated*
NL	A counter used in the division of an embankment section into layers. NL is used to determine when the X coordinates of both sides of the rectangular area have been found.
NLAYR	The number of layers between two ascending Z values of the embankment cross section.
NSTRT	The subscript of the first rectangular area used to describe an embankment cross section. The subscripts which are less than NSTRT for various variables relating to the rectangular areas are used for footing loads, if any are being used.
NWEST	An option variable used to indicate whether the Boussinesq or Westergaard solution should be used to calculate the stress values*
PI	The trigonometric value equal to 3.14159265
Q(100)	The magnitude of a uniform load acting on a rectangular area. For rectangles used to approximate embankment loadings Q(I) is calculated by the program.*
RATIO(4)	The ratio of the length of a side of a superimposed rectangular area to the depth of the point P.
SIDE(4)	The length of a side of a rectangular loaded area.
SIGMZ	The vertical stress at a point within the semi infinite mass calculated by the "NORMAL LOADING" approximation.

SIGZE	The vertical stress at a point within the semi infinite mass calculated for the "ELASTIC SOLUTION" approximation
SIGZI	The value of vertical stress at a point induced by a particular rectangular area
SLP	The slope of a line in the X-Y plane which describes the line along which a horizontal distribution is to be run
SLOPE(25)	The slope of a line forming the perimeter of the cross section of an embankment
THICK	The maximum thickness of a layer used to approximate the embankment*
THIC2	The floating point equivalent of NLAYR
X(25)	The X coordinate of a break point in the perimeter of an embankment loading*
XC(4,100)	The X coordinate of a corner point of a loaded rectangular area. For footing loads these values are input, for embankment loadings the program generates these values*
XFNL	The last coordinate of a horizontal stress distribution
XLARG	The length of a side of a superimposed rectangular area for Case No. 2 or Case No. 3
XMAX	The maximum algetraic X value of a rectangle used to approximate an embankment loading
XMIN	The minimum algebraic X value of a rectangle used to approximate an embankment loading
XP	The X coordinate of a point where the vertical stress is required. For horizontal distributions this is calculated from stress distribution information*
XSMAL	The length of a side of a superimposed rectangular area for Case No. 2 or Case No. 3
XTEST	A trial value for the intersection of the midpoint of a layer and the boundary of an embankment cross section

YC(4,100)	The Y coordinate of a corner point of a loaded rectangular area. For footing loads these values are input, for embankment loadings the program generates these values
YLARG	The length of a side of a superimposed rectangular area
YMAX	The maximum Y coordinate of an embankment in a direction perpendicular to the cross section*
YMIN	The minimum Y coordinate of an embankment in a direction perpendicular to the cross section*
YP	The Y coordinate of a point where stresses are required. For vertical distributions this value is input. For horizontal distributions this value is calculated*
YSMAL	The length of a side of a superimposed rectangular area
Z(25)	The Z coordinate of a corner point of an embankment cross sections*
ZC(100)	The midpoint Z coordinate of a layer used to approximate an embankment cross section
XCOMP	A variable used in the ordering of Z coordinates of the embankment section from smallest to largest
XCOR(25)	An array representing the Z coordinates of the embankment section ordered from smallest to largest
ZFNL	The terminal Z coordinate of a vertical stress distribution
ZLAY(100)	The distance from the bottom of a rectangular area to the reference point. For footings this is an input value for embankment loadings this is calculated*
ZP	The depth of the point at which the stress is to be calculated relative to the reference point. For horizontal distributions this is an input value for vertical distributions it is generated within the program*
ZSAVE	A variable used in the ordering of the Z coordinates of an embankment section from smallest to largest
ZTOT	The total vertical distance from the base of a rectangular area to the stress point. (ZTOT=ZLAY(I)+ZP)