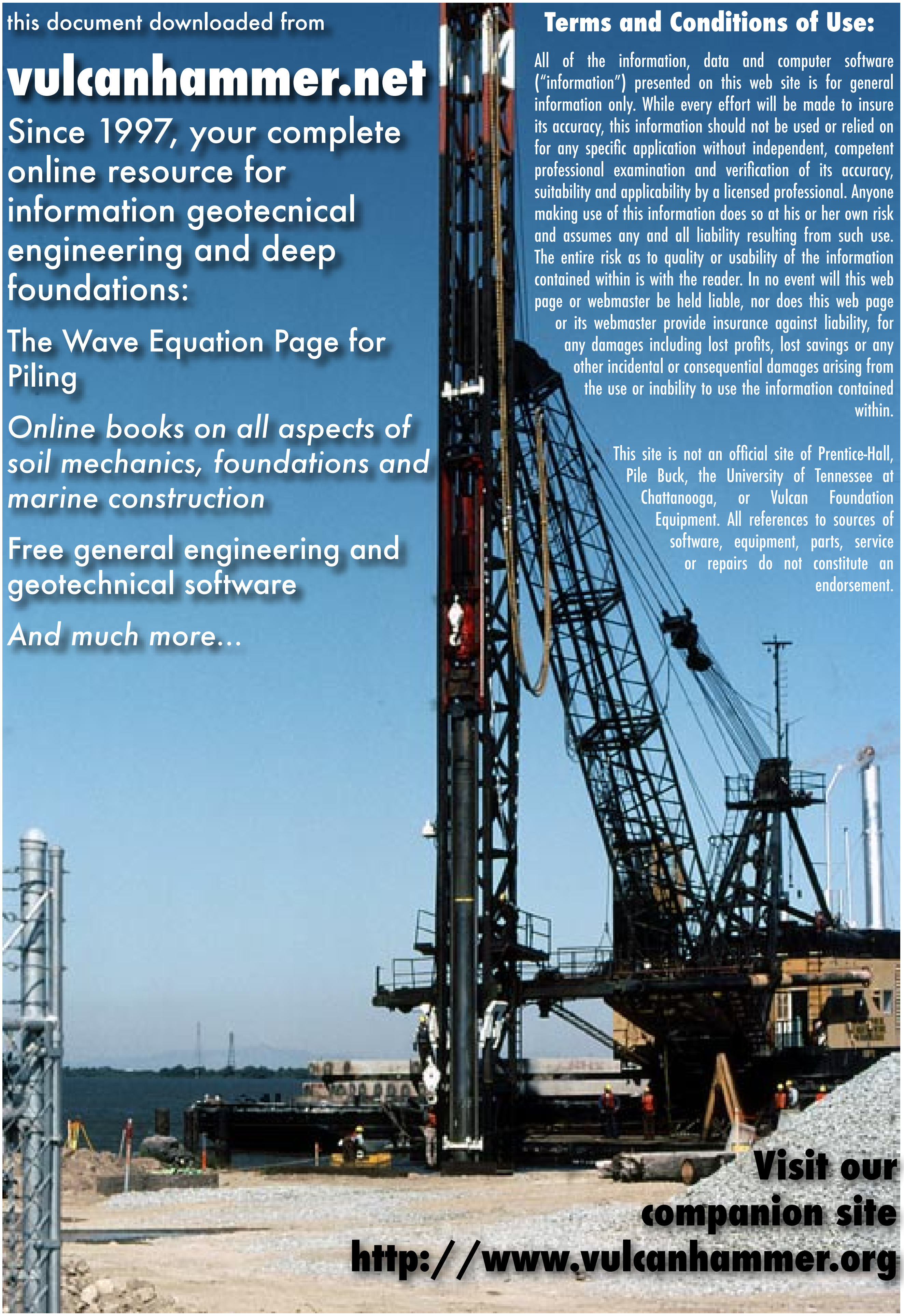

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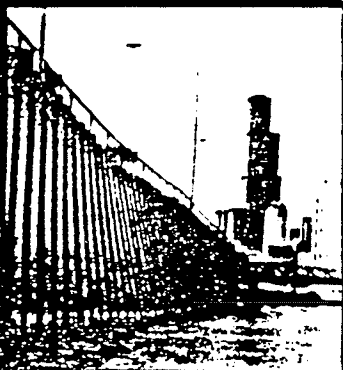

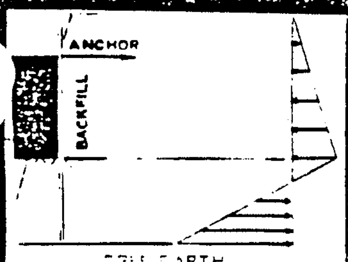

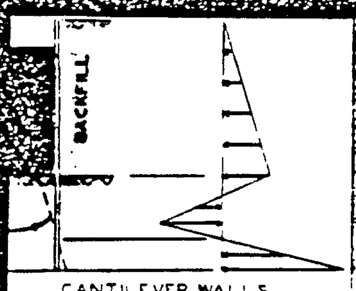

COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

INSTRUCTION REPORT ITL-91-1

USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET-PILE WALLS BY CLASSICAL METHODS (CWALSHT) INCLUDING ROWE'S MOMENT REDUCTION

by

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13. ABSTRACT (Maximum 200 words)

The computer program CWALSHT was developed from specifications provided by the Computer-Aided Structural Engineering (CASE) Task Group on Sheet Pile Structures and is described in this report. The program uses classical soil mechanics procedures for determining the required depth of penetration of a new wall or assesses the factors of safety for an existing wall.

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ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM Design/Analysis of Sheet-Pile Walls by Classical Methods - CWALSHT Including Rowe's Moment Reduction (XØØ31)	PROGRAM NO. 713-F3-RØØ92
PREPARING AGENCY US Army Engineer Waterways Experiment Station (WES), Information Technology Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199	

AUTHOR(S)	DATE PROGRAM COMPLETED	STATUS OF PROGRAM: PHASE	STATUS OF PROGRAM: STAGE
Author: Dr. William P. Dawkins Adapted for CORPS	Written - Jan 1991 Adapted - Jan 1991	COMPLETE	

A. PURPOSE OF PROGRAM

Performs either a design or analysis of an anchored or cantilever sheet pile retaining wall.

B. PROGRAM SPECIFICATIONS

FORTRAN

C. METHODS

Uses classical soil mechanics procedures for determining the required depth of penetration of a new wall or assesses the factor of safety of an existing wall.

D. EQUIPMENT DETAILS

Graphics Terminal or PC AT or compatible

E. INPUT-OUTPUT

Input may be entered from a predefined data file or interactively at execute time.

Output will be directed to an output file and/or directly back to the terminal.

F. ADDITIONAL REMARKS

A copy of the program and documentation may be obtained from the Engineering Computer Programs Library (ECPL), WES, telephone number: commercial (601)634-2581.

PREFACE

This user's guide describes the computer program, "CWALSHT," which can be used for the design and analysis of cantilever and anchored sheet-pile walls using classical methods, and describes its recent enhancement to include Rowe's moment reduction for anchored sheet-pile walls analyzed or designed using the free earth method. This report supersedes WES Instruction Report ITL-90-1 entitled "Users's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CWALSHT)," dated February 1990. Funds for the development of the program and writing of the user's guide were provided to the Information Technology Laboratory (ITL), WES, Vicksburg, MS, by the Civil Works Directorate of Headquarters, US Army Corps of Engineers (HQUSACE), under the Computer-Aided Structural Engineering (CASE) Project.

Specifications for the program were provided by the members of the CASE Task Group on Pile Structures and Substructures. The following were members of the task group during program development:

Mr. James Bigham, Rock Island District (Chairman)
Mr. Richard Chun, Pacific Ocean Division
Mr. Ed Demsky, St. Louis District
Mr. John Jaeger, WES (formerly St. Louis District)
Mr. Phil Napolitano, New Orleans District
Mr. Charles Ruckstuhl, New Orleans District
Mr. Ralph Strom, North Pacific Division

The computer program and user's guide were written by Dr. William P. Dawkins, P.E., Stillwater, OK, under contract with WES.

The work was managed and coordinated at WES, ITL, by Mr. Reed Mosher, Computer-Aided Engineering Division (CAED), and Mr. H. Wayne Jones, Chief, Scientific and Engineering Application Center, CAED, under the general supervision of Dr. Edward Middleton, Chief, CAED, Mr. Paul Senter, Assistant Chief, ITL, and Dr. N. Radhakrishnan, Chief, ITL. Mr. Donald Dressler was the HQUSACE point of contact for this work.

COL Larry B. Fulton, EN, is the present Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

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

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

Multiply	By	To Obtain
degree (angle)	0.01745329	radians
feet	0.3048	metres
inches	2.54	centimetres
pound (force)-feet	1.355818	newton-metres
pound (force)-inches	0.1129848	newton-metres
pounds (force)	4.448222	newtons
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per cubic inch	27,679.905	kilograms per cubic metre
pounds (force) per foot*	14.5939	newtons per metre
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals

* The same conversion factor applies for pounds (force) per linear foot (plf).

USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET-PILE WALLS BY CLASSICAL METHODS (CWALSHT) INCLUDING ROWE'S MOMENT REDUCTION

PART I: INTRODUCTION

Description of Program

1. This report describes a computer program called CWALSHT, which performs design and/or analysis of either cantilever or anchored sheet-pile walls, and its recent enhancement to include Rowe's moment reduction for anchored sheet-pile walls analyzed or designed using the free earth method. The program uses classical soil mechanics procedures for determining the required depth of penetration of a new wall or assesses the factors of safety for an existing wall. Seepage effects are included in a simplified manner in the program. CWALSHT was developed from specifications provided by the Computer-Aided Structural Engineering (CASE) Task Group on Sheet-Pile Structures. The program follows as a minimum the procedures outlined in draft Engineer Manual 1110-2-2906 (Department of the Army 1970).

Organization of Report

2. The remainder of this report is organized as follows:

   a. Part II describes the general sheet-pile retaining structure and the soil system to be designed or analyzed by the program.

   b. Part III describes the procedures employed in the program for calculating earth pressures on the wall due to adjacent soil, unbalanced hydrostatic head, and surcharge loads on the soil surface.

   c. Part IV reviews the methods for determining the required depth of penetration for each type of wall.

   d. Part V describes the computer program.

   e. Part VI presents example solutions obtained with the program.

3. The program has been checked within reasonable limits to assure that the results obtained with it are accurate within the limitations of the procedures employed. However, there may exist unusual, unanticipated situations that may cause the program to produce questionable results. It is the responsibility of the user to judge the validity of the final design of the system, and no responsibility is assumed for the design of any structure based on the results of this program.

PART II: GENERAL WALL/SOIL SYSTEM

4. The same basic wall/soil system shown in Figure 1 is used for either anchored or cantilever sheet-pile walls. Throughout development of the program it was assumed that all effects on the wall tend to cause counterclockwise rotation of a cantilever wall and clockwise rotation of an anchored wall. This section presents other assumed characteristics for the various components of the general system.

Sheet-Pile Wall

5. A 1-ft* slice of a straight, uniform wall is used for the design/analysis process. The wall is assumed to be straight, initially vertical, linearly elastic, and to have a constant cross section throughout its depth.

Anchor

6. For anchored walls, a single horizontal anchor may be attached to the wall at any elevation at or below the top of the wall. The anchor is assumed to prevent horizontal displacement at the point of attachment.

Soil

7. In subsequent paragraphs, reference is made to the "right" side and "left" side of the wall. The soil surface on either side must intersect the wall at or below the top of the wall.

Soil Surface

8. The irregular soil surfaces illustrated in Figure 1 provide for all variations of soil surface geometry including horizontal or continuous sloping (either up or down away from the wall).

9. A different layered soil profile is assumed to exist on either side of the wall. Boundaries between subsurface layers are assumed to be straight lines and may slope up or down away from the wall on either side. Sloping

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

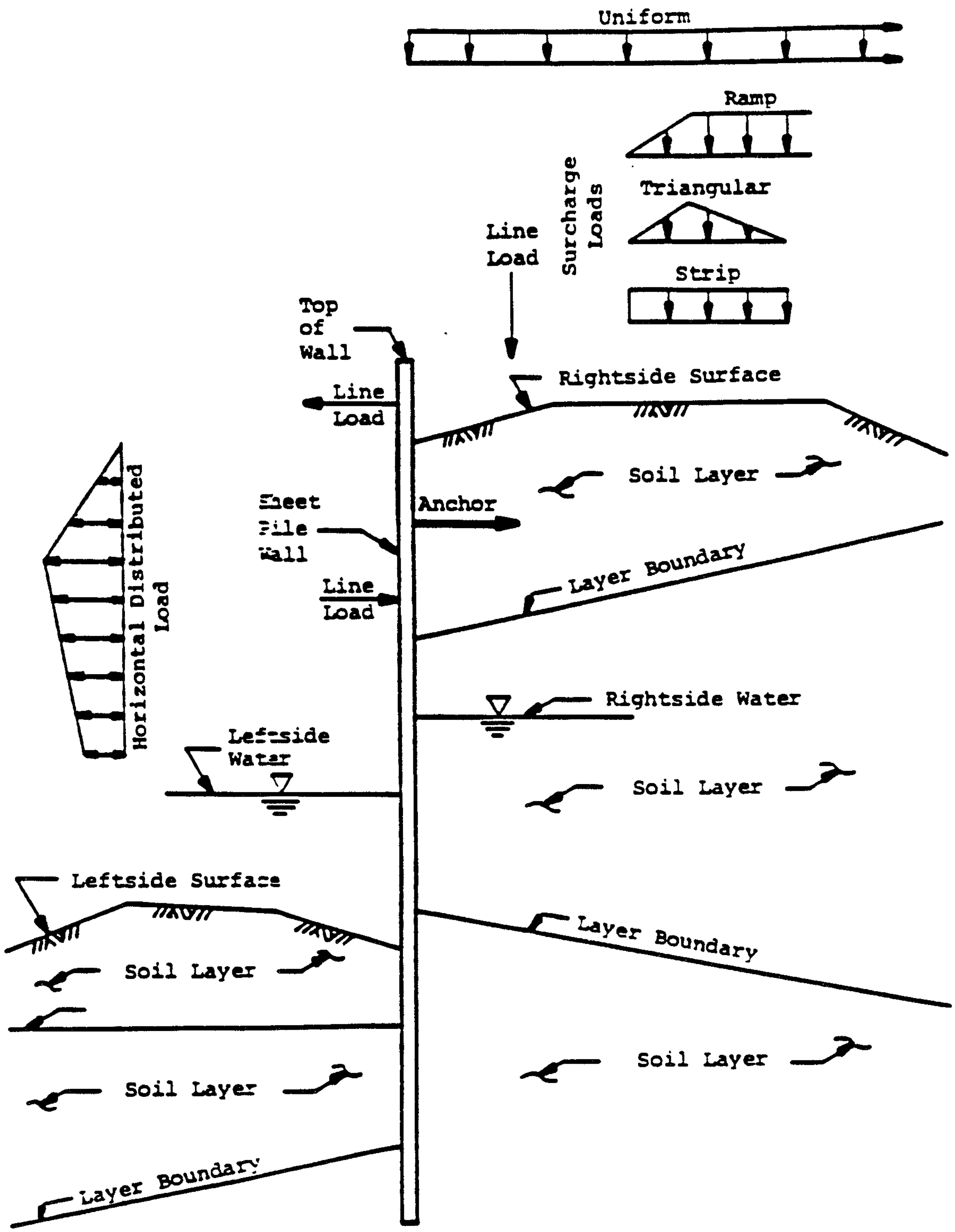

Figure 1. General wall/soil system

boundaries must not intersect below the soil surface. Layers are assumed to extend ad infinitum away from the wall, and the lowest layer described on either side is assumed to extend ad infinitum downward.

Soil Properties

10. Each soil layer is assumed to be homogeneous. Properties required for each layer are:

a. Soil saturated unit weight γ_{sat}. The program determines the buoyant unit weight for submerged soil according to

$$\gamma' = \gamma_{sat} - \gamma_{we} \tag{1}$$

where

γ' = buoyant unit weight*

γ_{we} = effective unit weight of water (see paragraph 40, Part III)

b. Soil moist unit weight γ_{mst}. The moist unit weight is used for all soil above the water surface.

c. Actual angle of internal friction ϕ. The program determines the effective angle of internal friction according to

$$\phi_{eff} = \tan^{-1} [(\tan \phi)/FS] \tag{2}$$

where

FS = given or calculated factor of safety.

d. Actual cohesion c. The program determines the effective cohesion from

$$c_{eff} = c/FS \tag{3}$$

e. Effective angle of wall friction δ. The program does not alter the angle of wall friction. See Figure 2 for assumed positive wall friction angle.

f. Effective wall/soil adhesion a. The program does not alter the adhesion. See Figure 2 for assumed positive direction of the adhesion force.

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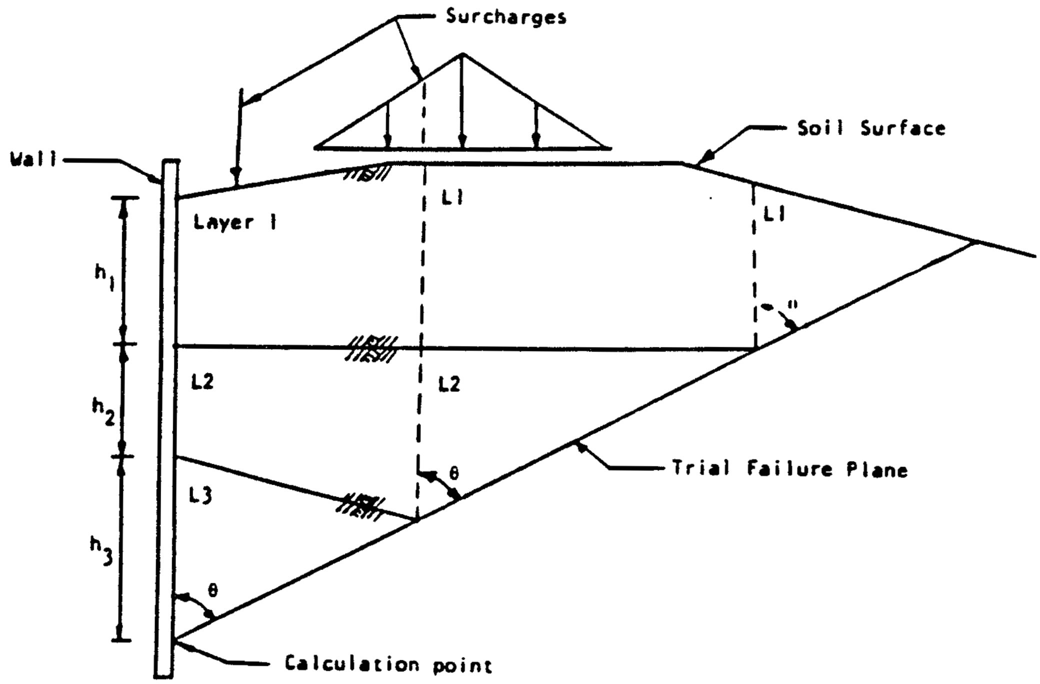
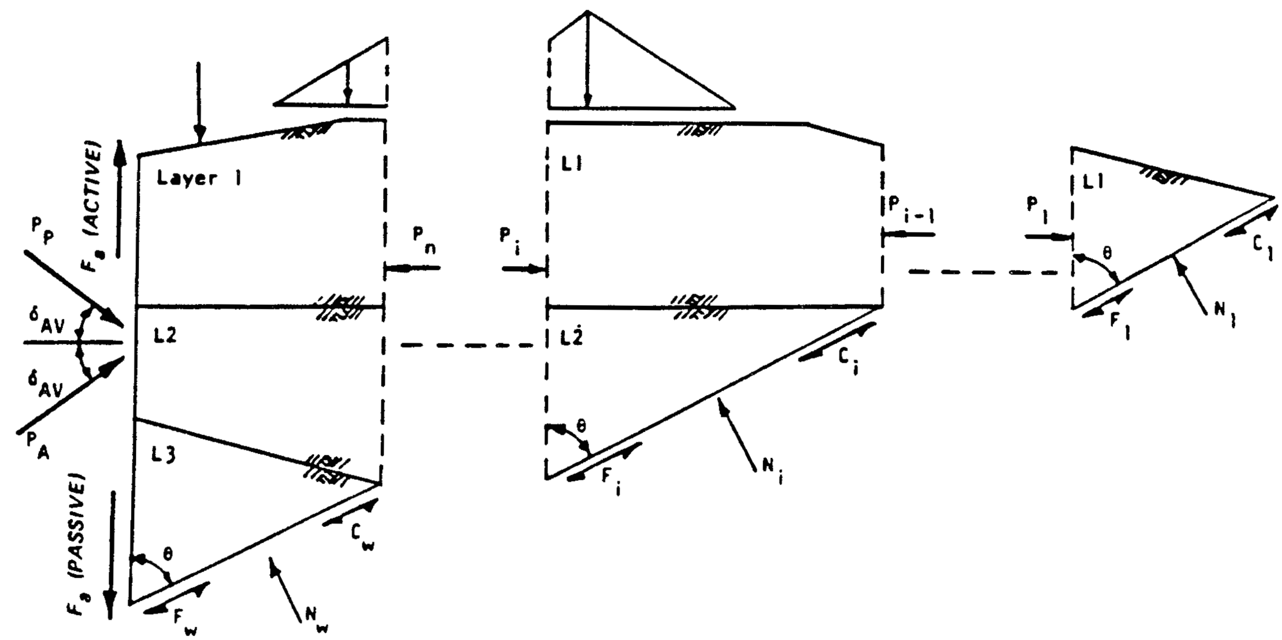
* For convenience, symbols and abbreviations are listed in the Notation (Appendix B).



a. Trial failure wedge



b. Wall slice c. Interior slice d. Terminal slice

Figure 2. Sweep search wedge method

Water

11. The following effects due to water are considered:

   a. Static water. Horizontal pressures due to hydrostatic head are applied on either side of the wall. Static water surfaces may be at any elevation. When the water surface is above the top of the wall, a drop structure is assumed, and only the trapezoidal pressure distribution below the top of the wall is used.

   b. Seepage effects. Seepage effects alter static water pressures and the submerged weight of the soil. The approximations used to account for seepage are discussed in paragraphs 40 and 41. When seepage is present, the water surface on the right side must be above that on the left side.

   c. Earthquake effects. Earthquake effects alter hydrostatic pressures only on the right side above the ground surface (see paragraphs 18 and 19).

Vertical Surcharge Loads

12. Surcharge loads may be applied to the soil surface on either side of the wall. Five types of surcharge loads are illustrated in Figure 1.

Vertical Line Loads

13. Vertical line loads are assumed to extend horizontally parallel to the axis of the wall and to act on the soil surface. The program accommodates 21 line loads at any location on the surface on either side of the wall.

Distributed Loads

14. Four distributed load variations permitted by the program are shown in Figure 1. A general distributed load may also be described by a sequence of distances and load intensities. Only one distributed load on each side is permitted in the design/analysis of a particular wall description. All distributed loads are assumed to extend horizontally parallel to the wall. Distributed loads are interpreted as acting on the horizontal projection of the soil surface. A uniform surcharge is assumed to extend ad infinitum away from the wall. A ramp load is assumed to extend ad infinitum away from the wall beginning at the terminus of the ramp.

External Horizontal Loads

15. Two types of external horizontal loads in addition to other soil and water loads may be applied to the wall. Horizontal loads acting to the left are positive.

Horizontal Line Loads

16. The program permits up to 21 line loads (positive or negative) to be applied directly to the wall at any location at or below the top of the wall.

Horizontal Distributed Loads

17. A single general horizontal load distribution described by elevations and load values for a maximum of 21 points may be applied to the wall.

Earthquake Effects

18. Earthquake effects are assumed to increase the tendency toward rotation of the wall. Earthquake effects on soil pressures are simulated in the program by altering the soil unit weight on each side of the wall to a new effective unit weight of soil γ_{eff} as follows:

$$\text{Right side:} \quad \gamma_{eff} = \gamma_{sat}\,(1 + \alpha) - \gamma_{we} \tag{4}$$

$$\text{Left side:} \quad \gamma_{eff} = \gamma_{sat}\,(1 - \alpha) - \gamma_{we} \tag{5}$$

where α is earthquake acceleration expressed as a fraction of the acceleration of gravity.

19. Earthquake effects on water pressures above the rightside soil surface are included by application of an additional pressure distribution extending from the rightside water surface to the rightside soil according to

$$p_y = C_e\, \alpha \sqrt{hy} \tag{6}$$

where

y = distance below rightside water surface

$C_e = 5\ 1/\sqrt{1 - 0.72\ (h/1000)^2}$

h = distance from rightside water surface to rightside soil surface

PART III: LOADS ON WALL

20. Horizontal loads are imposed on the structure by the surrounding soil, surface surcharge loads, water pressures, or horizontal loads applied directly to the wall. The following paragraphs describe the procedures used in the program for determining the resultant horizontal pressure distributions.

Calculation Points

21. Locations at which force magnitudes and wall response are calculated are initially located at the following points:

- a. At 1-ft intervals starting at the top of the sheet pile.
- b. At the intersections of the surface and/or layer boundaries on either side with the wall axis.
- c. At the point of application of each horizontal line load and at each elevation point of a horizontal load distribution.
- d. At the location of the water surface on either side of the wall.
- e. At the anchor elevation for anchored walls.
- f. At other locations to establish the resultant force or pressure distribution as necessary for each design procedure.

Soil Pressures

22. Three methods (a coefficient method and two "wedge" methods) are available in the program to establish the design pressure distributions. Inherent in each method is the assumption that the wall displaces sufficiently to produce a fully plastic state in the soil on either side of the wall. This assumption results in full values of active and passive earth pressure at every point regardless of actual displacement. The program determines whether the coefficient method or a wedge method is to be used for soil pressure calculations. A different method may be used for each side of the wall.

Pressure Coefficient Method

23. Coulomb earth pressure coefficients relating horizontal pressure to vertical pressure are used when the soil surface is horizontal, all layer boundaries are horizontal, and wall/soil adhesion is zero in all soil layers.

Pressures by Coefficient Method

24. Soil pressures are calculated as follows:

a. The vertical pressure p_v at each point is calculated using the effective soil-unit weight (including submergence and/or earthquake effects) for the soil above that point and any uniform surcharge.

b. The Coulomb earth pressure coefficients are:

(1) Active pressure coefficient

$$K_A = \left[\frac{\cos \phi_{eff}}{1 + \sqrt{\dfrac{\sin(\phi_{eff} + \delta)\ \sin(\phi_{eff})}{\cos \delta}}} \right]^2 \cdot \frac{1}{\cos \delta} \tag{7}$$

(2) Passive pressure coefficient

$$K_P = \left[\frac{\cos \phi_{eff}}{1 - \sqrt{\dfrac{\sin(\phi_{eff} + \delta)\ \sin(\phi_{eff})}{\cos \delta}}} \right]^2 \cdot \frac{1}{\cos \delta} \tag{8}$$

where

ϕ_{eff} = effective angle of internal friction

δ = angle of wall friction (may be positive or negative)

c. Horizontal earth pressures are calculated from:

(1) Active pressures

$$p_{Ah} = \left(K_A\, p_v - 2c_{eff} \sqrt{K_A} \right) \cdot \cos \delta \tag{9}$$

(2) Passive pressures

$$p_{Ph} = \left(K_P\, p_v + 2c_{eff} \sqrt{K_P} \right) \cdot \cos \delta \tag{10}$$

d. When a change in either ϕ_{eff} or c_{eff} occurs at a layer boundary, dual pressure values are calculated using the soil properties above and below the boundary.

25. For all cases involving a sloping or irregular soil surface and/or sloping subsurface layer boundaries, one of the wedge methods described is used. The user is prompted by the program to select the method.

Sweep search wedge method

26. A continuous failure plane is assumed to emanate from each calculation point described in paragraph 21 to its intersection with the ground surface as shown in Figure 2a. The total trial wedge is then subdivided by vertical planes into slices as shown in Figures 2b,c, and d. The location of the vertical plane is established by the intersection of the continuous trial failure plane with each succeeding layer boundary. The intermediate vertical slice surfaces are assumed to be free of shear stresses. Friction and cohesion forces along the base of each intermediate slice are evaluated from the soil properties of the bottom layer in the slice.

27. Equilibrium of horizontal and vertical forces for each slice except the wall slice results in

$$P_i - P_{i-1} = \frac{W_i(1 \pm \tan\phi_i \tan\theta) \pm C_i \sec\theta}{\tan\phi_i \pm \tan\theta} \tag{11}$$

where

P_i, P_{i-1} = normal forces on left- and rightside vertical surfaces of the slice, respectively

W_i = weight of the slice, including

ϕ_i = effective internal friction angle of the soil at the bottom of the slice

C_i = effective cohesion of the soil at the bottom of the slice multiplied by the length of the bottom surface

The upper signs correspond to active conditions, and the lower signs correspond to passive conditions.

28. Equilibrium analysis of the wall slice results in

$$\begin{bmatrix} \pm \sin\delta_{av} & (\sin\theta \pm \tan\phi_w \cos\theta) \\ \cos\delta_{av} & -(\cos\theta \pm \tan\phi_w \sin\theta) \end{bmatrix} \begin{pmatrix} P_{A/P} \\ N_w \end{pmatrix} = \begin{pmatrix} W_w \pm C_w \cos\theta \pm F_a \\ P_n \pm C_w \sin\theta \end{pmatrix} \tag{12}$$

where

$\delta_{av} = \Sigma h_j \delta_j / \Sigma h_j$ = average wall friction angle

θ = angle of inclination of failure surface

P_w = angle of friction at the wall

$P_{A/P}$ = active force (upper signs) or passive force (lower signs) for this trial wedge

W_w = weight of wall slice including surcharge loads

C_w = effective cohesion of the soil at the bottom of the wall slice multiplied by the length of the bottom surface

$F_a = \Sigma h_j a_j$ = wall/soil adhesion force

N_w = normal force on bottom of wall slice

P_n = normal force on vertical plane

29. The angle of inclination θ of the trial wedge is increased in 2-deg increments until the maximum active force and minimum passive force for that calculation point are determined. In some systems having downward sloping surfaces, maximum active and minimum passive forces may not be achieved before the trial failure plane no longer intersects the soil surface. When this situation is encountered, a warning is printed and the active and/or passive force for the last trial plane is used for that point.

Fixed surface wedge method

30. The fixed surface wedge method assumes that the angle of inclination of the failure plane within each soil layer is a function of the angle of internal friction of the soil in the layer. This assumption results in a single fixed broken failure surface as is illustrated in Figure 3.

31. When the fixed surface for a calculation point has been established, the total wedge is subdivided into slices as indicated by the dashed lines in Figure 3. The determination of active and passive forces on the wall proceeds as described for the sweep search method.

Final Pressures for Wedge Methods

32. For either wedge method it is assumed that the difference between active or passive forces for two adjacent calculation points is the resultant of a linear pressure distribution between the two points.

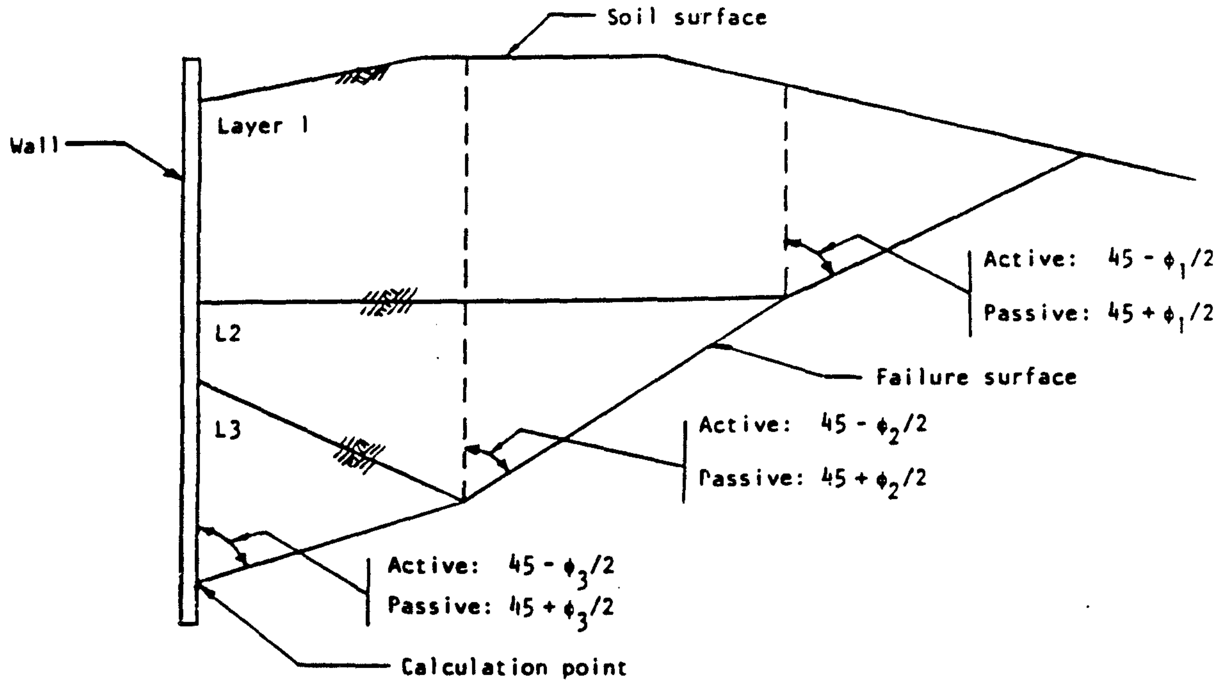


Figure 3. Fixed surface wedge method

Discussion of Soil Pressure Calculation Methods

33. The computer program determines from the input data whether the coefficient method may be used or whether a wedge method is required for evaluation of soil pressures. If a wedge method is required, the user is prompted to select either the sweep search or the fixed surface method. The program can be forced to use a wedge method where the coefficient method would ordinarily apply by specifying more than one point on the soil surface on either side (see Appendix A, "Guide for Data Input").

34. For a homogeneous soil system with a horizontal soil surface and no surcharge loads, the three pressure calculation methods produce identical pressure distributions. For layered soil profiles with horizontal layer boundaries, horizontal surfaces, and no surcharge loads, the three methods yield essentially the same pressure distributions. The significant differences occur at layer boundaries where the coefficient method may produce discontinuities in pressures while the wedge methods result in a single average pressure at the boundary. Discontinuities arising from the coefficient method are removed from the net pressures by using the average of the two pressure values at the discontinuity.

35. For all soil profiles without severe variations in soil layer strengths and with essentially horizontal surfaces, the two wedge methods produce comparable soil pressures. Although both methods overestimate passive pressures, the sweep search method is more consistent with the principles used in the development of the coefficient method. For systems with steep surface slopes, the fixed surface wedge method underestimates active pressures for upward-sloping surfaces and overestimates passive pressures for downward-sloping surfaces as compared to the pressures produced by the sweep search method. The degree of under- or overestimation increases as the surface slope increases.

36. The sweep search method always seeks the maximum active condition and minimum passive condition. It may not be possible for the sweep search method to arrive at the desired extreme condition if the soil surface is grossly irregular. The user is warned when this condition is encountered. In systems with interspersed strong and weak layers, the sweep search method may arrive at an active and/or passive force at one calculation point that is significantly lower than the corresponding force at the next higher point. Conversion of active/passive forces to pressures in this case may result in "negative" pressures in the interval and the resulting pressure distribution is questionable (see Example CANT2, paragraphs 89 and 90).

Net Soil Pressures

37. Four separate soil pressure distributions are determined by the methods just described.

- a. Active pressure for the rightside soil.
- b. Passive pressure for the rightside soil.
- c. Active pressure for the leftside soil.
- d. Passive pressure for the leftside soil.

All calculated negative active pressures are set to zero.

Pressures Due to Surcharge Loads

38. The effects of surcharge loads on the rightside surface are included in the weight of the failure wedge, and no additional computations for surcharge loads are required when soil pressures are determined by a wedge method.

39. When the coefficient method is used to determine soil pressures, the additional horizontal pressures on the wall due to strip, ramp, triangular, and varying surcharge loads are calculated from the theory of elasticity equations shown in Figure 4. A uniform surcharge is added directly to the vertical soil pressure as indicated in paragraph 24.

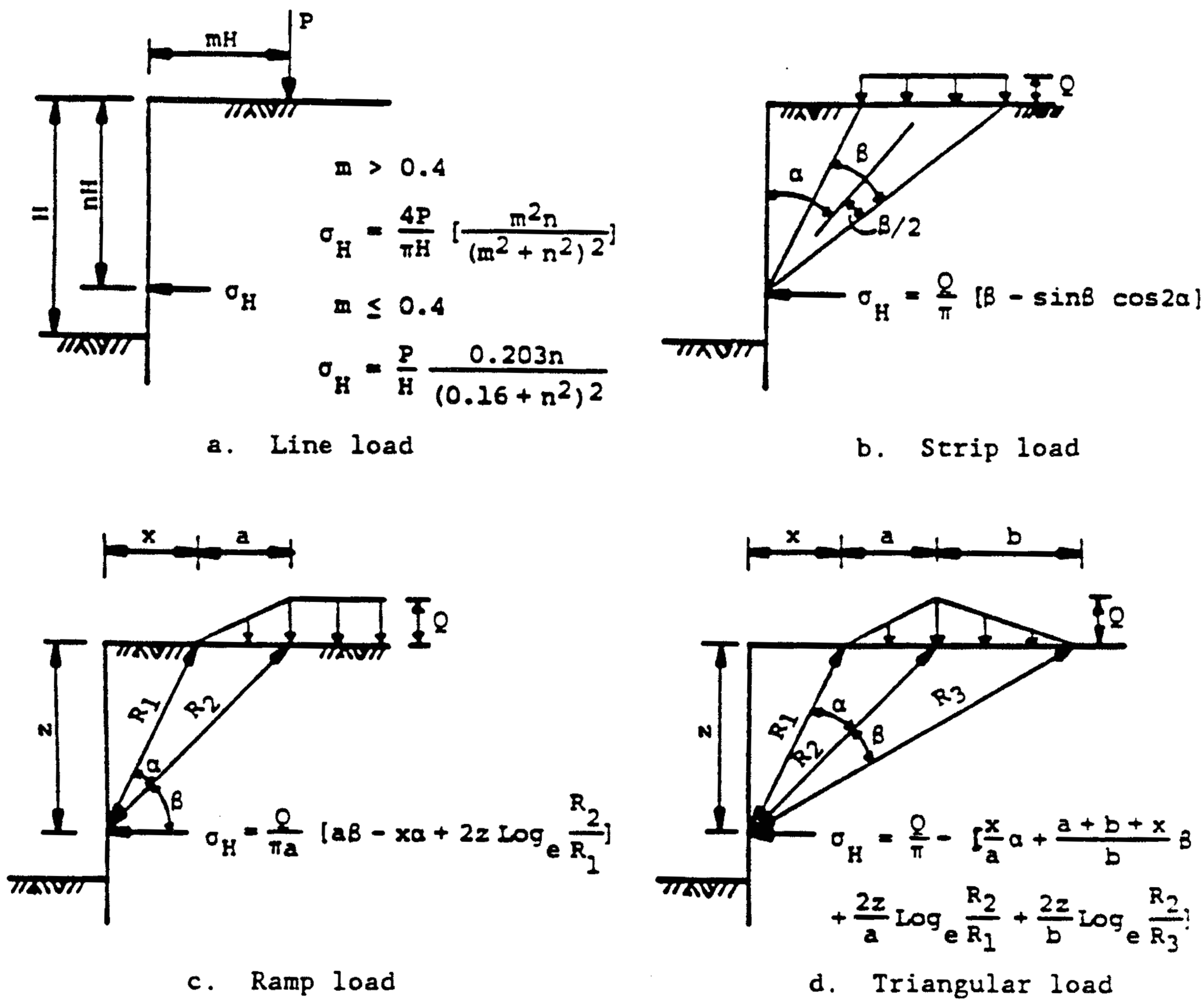


Figure 4. Theory of elasticity equations for pressures on wall due to surcharge loads

Water Pressures

40. In addition to earthquake effects (paragraphs 18 and 19), hydrostatic pressures may be altered by seepage. When seepage effects are included, the excess hydrostatic head is assumed to be dissipated by vertical flow downward on the right side and upward on the left side. The seepage gradient *i*

(feet/feet) is assumed to be constant at all points in the soil on either side. Under this assumption, the effect of seepage is to alter the effective unit weight of water in the region of flow to

$$\text{Right side:} \quad \gamma_{we} = \gamma_w (1 - i) \tag{13}$$

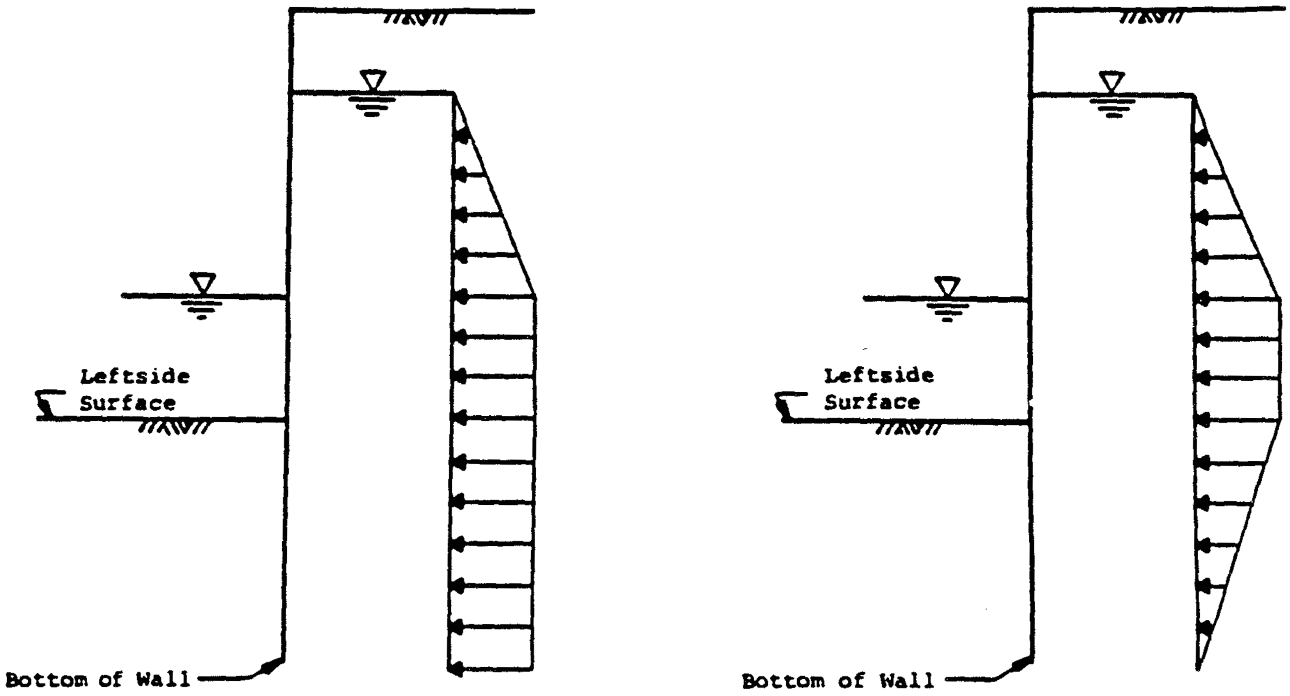
$$\text{Left side:} \quad \gamma_{we} = \gamma_w (1 + i) \tag{14}$$

where

i = seepage gradient

γ_w = unit weight of water

41. The user may elect to omit seepage effects, to specify the seepage gradient i, or to allow the program to automatically adjust the seepage gradient. If seepage is omitted, the net water pressure distribution shown in Figure 5a is applied. For "automatic" seepage, the program adjusts the seepage gradient i, so that the point at which excess head is dissipated (i.e., the net water pressure becomes zero, Figure 5b) coincides with the bottom of the wall. Because the determination of design penetration is an iterative process, selecting the automatic seepage option may significantly



a. Net water pressure without seepage

b. Net water pressure with seepage

Figure 5. Pressure distributions for unbalanced hydrostatic head

increase the computer costs for a solution, particularly for systems in which a wedge method is required for soil pressures. When a seepage gradient is specified by the user, the point at which excess head is dissipated may not coincide with the bottom of the wall.

Design Pressures

42. The following combinations of all applicable loading effects are used for the final design:

Net Active Pressure = Rightside Soil Active Pressure - Leftside Soil Passive Pressure + Surcharge Pressure + Water Pressure + Distributed External Horizontal Pressure.

Net Passive Pressure = Rightside Soil Passive Pressure - Leftside Soil Active Pressure + Surcharge Pressure + Distributed External Horizontal Pressure + Water Pressure.

Horizontal Loads

43. Horizontal line and distributed loads are applied directly to the wall. Depending on their sense (positive to the left) and point of application, horizontal loads may have either a stabilizing or disturbing effect on the wall.

PART IV: DESIGN/ANALYSIS PROCEDURES

44. The program provides two modes of operation. In the "design" mode, the required depth of wall penetration is determined for input soil strengths, geometry, loading, and factor(s) of safety. Iterative solutions are performed in which wall penetration is varied until conditions of equilibrium and other assumptions are satisfied. In the "analysis" mode, a safety factor for input strengths, geometry, loading, and prescribed penetration is determined. In the analysis mode, a succession of design calculations is performed in which the factor of safety is adjusted until consistent factor of safety and effective soil strength properties yield a design penetration equal to the input value. In unusual layered systems, in which a wedge method is used for soil pressures, it is possible for minuscule changes in the factor of safety to produce a large change in required penetration, indicating a discontinuity in the relationship between factor of safety and penetration. When this condition is encountered, a solution for a unique factor of safety is impossible and the process is terminated.

45. In either the design or analysis mode, a structural analysis is performed to determine bending moments and shears in the wall at the locations of the calculation points. Relative deflections (i.e., the deflected shape of the wall) are calculated for both modes of operation. Because the pile moment of inertia is not known a priori in a design situation, the deflections of the wall in the design mode are determined for wall modulus of elasticity and moment of inertia, which are both equal to one. Because the wall is assumed to be a linear system for structural analysis, the "scaled" deflections reported from the design mode may be converted to actual relative deflections by dividing by the product of modulus of elasticity and wall moment of inertia after these parameters have been selected by the designer.

Factors of Safety

46. In the design mode, active and passive factors of safety are applied to the soil shear strength in each layer on each side of the wall according to three "levels" of input values. Level 1 active and passive factors of safety apply initially to all soil layers on both sides of the wall. Level 2 active and passive factors of safety apply initially to all soil layers on each side of the wall. Level 3 active and passive factors of safety

are specified for an individual soil layer. Each level of factors of safety may default to the preceding level. Unless defaulted, any specified value of factor of safety overrides the value specified by the preceding level. The user is allowed complete flexibility for applying factors of safety ranging from a single value to be applied to both active and passive pressures for all soil layers to specification of separate active and passive factors of safety for each individual soil layer.

47. Because the sheet pile wall problem has only "one degree of freedom," i.e., the depth of penetration in the design mode, only one value can be determined for a factor of safety in the analysis mode. Two options are available for assessment of the factor of safety. If the user specifies the active factor of safety at the three levels described for the design mode, a single passive factor of safety applied to all soil layers is determined. As an alternative, the user may elect to have the same factor of safety apply to both active and passive effects.

Design Procedures

48. One procedure for cantilever wall design and three procedures for anchored wall design are incorporated in the program. These methods are described in detail by Bowles (1977); Department of the Army (1970); Richart (1960); Terzaghi (1943); and United States Steel Corporation (1974). The essential features of each method are summarized in the following paragraphs.

Cantilever wall design

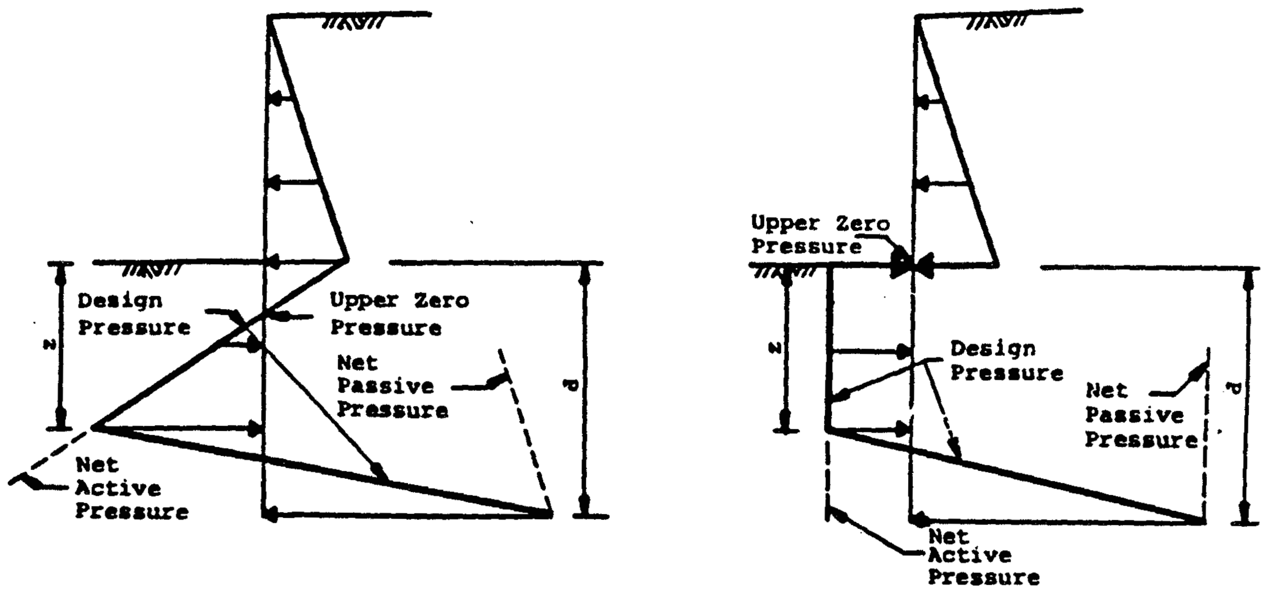
49. The assumptions employed in the conventional design procedure are:

a. The wall rotates counterclockwise as a rigid body about a point somewhere in its embedded depth.

b. Due to the rotation, full active and passive earth pressures are developed on either side.

c. The wall derives its support from passive pressures on each side.

50. Typical simplified pressure distributions arising from the above assumptions are shown in Figure 6. A final design is achieved when values of penetration d and depth z of the transition point produce a pressure distribution for which the sum of moments about any point on the wall and the sum of horizontal forces are simultaneously equal to zero.



a. Homogeneous granular subsoil b. Homogeneous cohesive subsoil

Figure 6. Design pressure distributions for cantilever walls

51. The process used in the program to determine the required penetration is as follows. Starting at the first calculation point below the upper zero pressure point (Figure 5), the bottom of the wall (i.e., penetration d) is moved progressively downward until values of d and z are found that produce a horizontal resultant force equal to zero. The resultant moment is then calculated. When a reversal in resultant moment is found, the depth of penetration is adjusted between the last two calculation points until the resultant moment is less than a prescribed minimum tolerance.

52. In the structural analysis cantilever walls, following the design for required penetration or analysis for factor of safety, the bending moments, shears, and relative (or scaled) deflections are calculated under the assumption that the wall is a cantilever beam supported at the wall bottom and subjected to the final net pressures and other external loads.

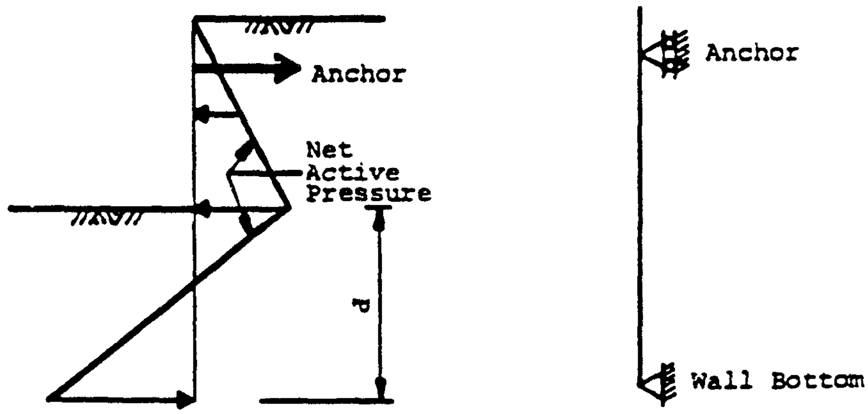
Anchored wall design

53. Three conventional procedures are incorporated in the program for design or analysis of anchored walls. A design or analysis is obtained and reported for each of the methods.

54. In the conventional procedures it is assumed that the motion of the wall will be sufficient to produce full active and passive pressures at every point. In all methods for anchored wall design, the anchor is assumed to prevent any lateral motion of the wall at the point of attachment but not to

inhibit wall rotation (i.e., to be a "pinned" support). It is further assumed that the loading effects tend to cause clockwise rotation of the wall about the anchor.

55. Free earth method. In this method the design penetration d (Figure 7) is established by lowering the bottom of the wall until the sum of moments of all forces about the anchor is equal to zero. The anchor force is then equal to the sum of all horizontal loads.



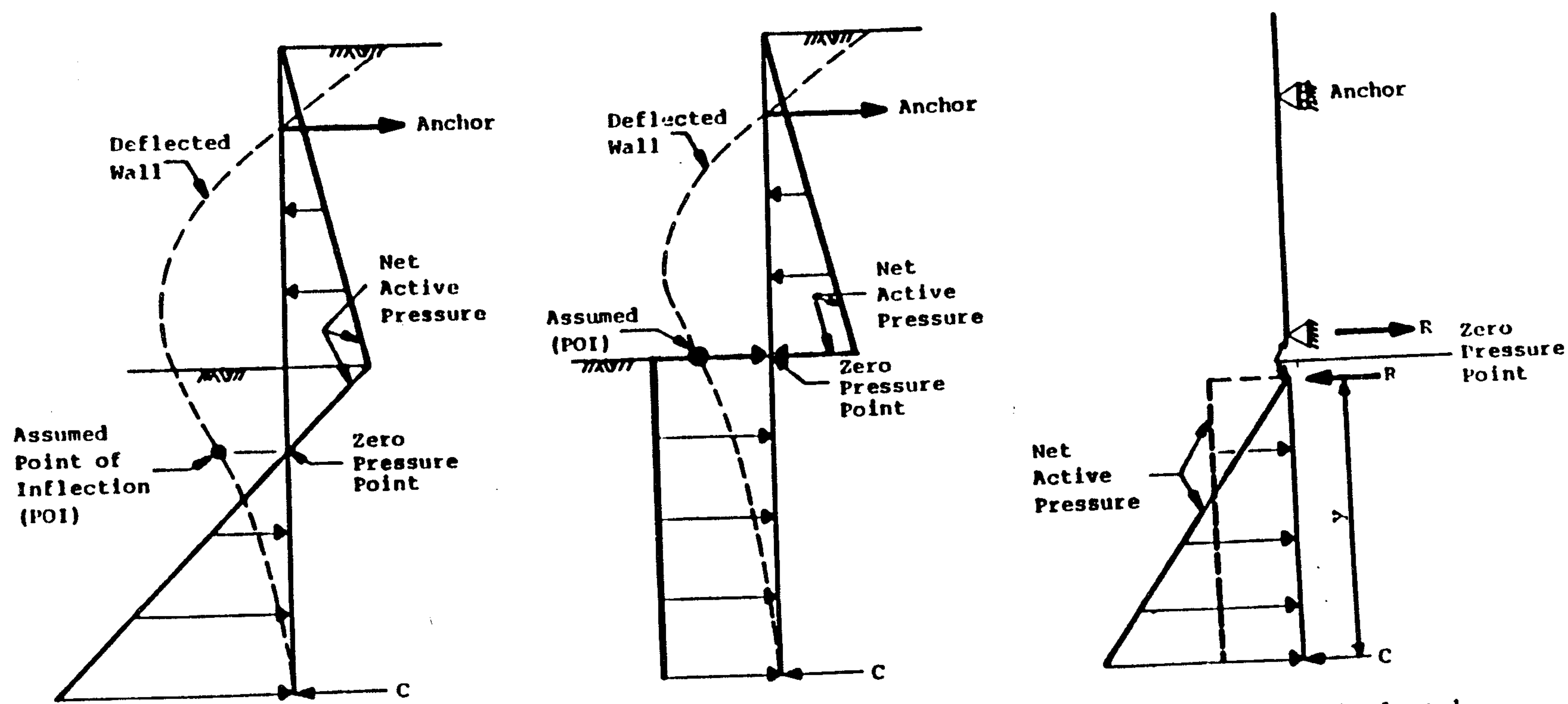
a. Design pressure

b. Supports for structural analysis

Figure 7. Anchored wall design by free earth method

56. In the structural analysis for the free earth method, bending moments, shears, and deflections are calculated by treating the wall as a beam with simple (unyielding) supports at the anchor and at the wall bottom (Figure 7b). The assumed bottom support has no influence on bending moments and shears and only affects the relative (scaled) deflection values.

57. Equivalent beam method. The fundamental assumption for this method is that the wall is embedded to a depth that produces a point of inflection in the deflected shape at some point below the leftside surface. The program assumes the point of inflection occurs at the first point of zero net active pressure at or below the leftside surface (Figures 8a and 8b). For design, the portion of the wall above the point of zero pressure (Figure 8c) is treated as a beam on simple supports located at the anchor and at the point of zero pressure. The upper simple beam reaction is equal to the anchor force. The design penetration (i.e., distance y shown in Figure 8c) is determined by lowering the bottom of the wall until the net active soil pressure below the zero pressure point and the lower simple beam reaction R (Figure 8c)



a. Granular subsoil

b. Cohesive subsoil

c. Equivalent beam

Figure 8. Anchored wall design by equivalent beam method

produce a zero resultant moment about the wall bottom. (Refer to draft EM 1110-2-2906 (Department of the Army 1970) for additional information on the equivalent beam method.)

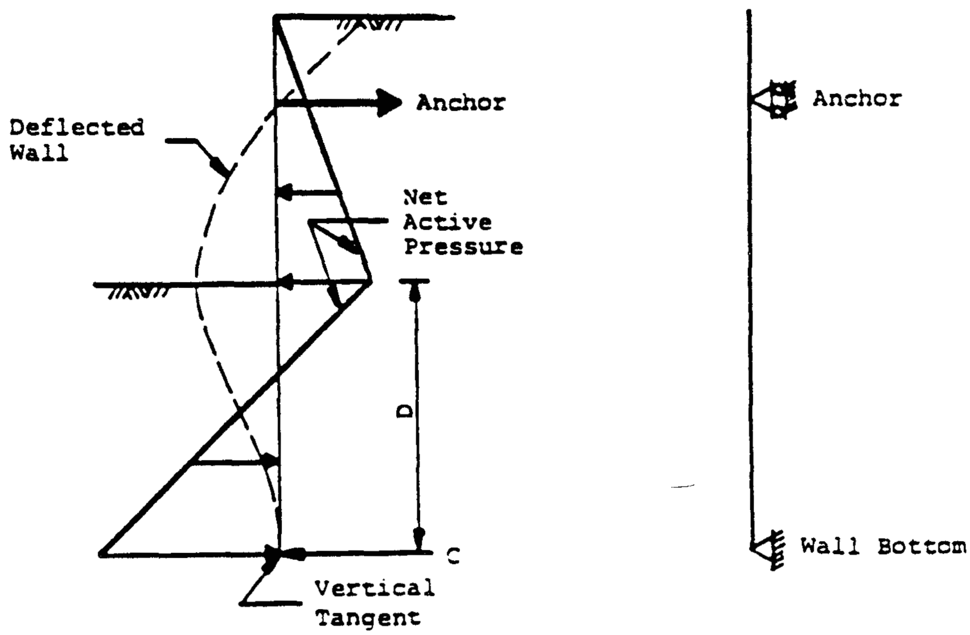
58. In the structural analysis for the equivalent beam method, bending moments, shears, and deflections are determined from a beam analysis of the wall with simple supports at the anchor and at the zero pressure point.

59. Fixed earth (Terzaghi 1943) method. The wall is subjected to net active pressure (Figure 9a) and is analyzed as a beam on simple supports at the anchor and at the wall bottom (Figure 9b). Design penetration is determined when the tangent to the deflected wall at the bottom is vertical.

60. No additional structural analysis for this method is necessary since bending moments, shears, and deflections are calculated during determination of design penetration.

Structural Analysis Procedure

61. A one-dimensional finite element procedure (Dawkins 1982) for linearly elastic prismatic beams is used to perform the structural analysis of each type of wall. The nodes of the finite element model are located at the



a. Design pressure b. Supports for design and analysis

Figure 9. Anchored wall design by fixed earth (Terzaghi 1943) method

calculation points described previously and supports are applied as described for each design method.

Rowe's Moment Reduction for Anchored Walls

62. Rowe (1952, 1957) conducted tests of sheet-pile walls embedded in homogeneous cohesionless and cohesive soils and concluded that the free earth support design method overestimated the bending moments in the wall. Based on his experimental data, Rowe presented moment reduction factors to be applied to the bending moments predicted by the free earth method. Bowles (1977) discusses the application of Rowe's reduction coefficients. The following paragraphs present the processes included in CWALSHT.

63. For either sands or clays, the magnitude of the moment reduction coefficient depends on a flexibility number obtained from

$$\rho = H^4/EI \tag{15}$$

where

H = total length of the sheet pile, ft

E = modulus of elasticity of the pile, psi

I = moment of inertia of the sheet pile section, in.^{4} per foot of wall

64. Evaluation of the flexibility number requires that the depth of penetration be determined from the free earth design method and that the material and pile section properties be available. A limited number of representative steel sheet-pile sections (Table 1), have been incorporated in CWALSHT in order to automate the application of Rowe's reduction method. The user is allowed to enter data for up to five additional sections during execution of the program.

Application to sheet piles in sand

65. Rowe's experimentally determined curves of moment reduction coefficients for sheet piles in homogeneous sand systems, extracted from Bowles (1977), are shown in Figure 10a. In Figure 10, M_o = maximum bending moment and D = depth of penetration obtained from the free earth design procedure. Numerical representation (for $-3.5 \le \log(\rho) \le -1.5$) of these curves is contained in CWALSHT. By interpolation, the program generates curves for the

Table 1

Sheet-Pile Sections Included for Rowe's

Reduction for Free Earth Design

Section Designation	Section Modulus per ft of Wall (in.^{3})	Moment of Inertia per ft of Wall (in.^{4})
PZ40*	60.7	490.80
PZ38**	46.8	380.80
PZ35*	48.5	361.20
PZ32**	38.3	220.40
PZ27*, **	30.2	184.20
PZ22*	18.1	84.40
PLZ25*	32.8	223.25
PLZ23*	30.2	203.75

* Bethlehem Steel Corporation.
** United States Steel Corporation.

"loose" sand or "dense" sand descriptors using the value of wall height ratio obtained during the design phase of program operation (again by interpolation). Curves are generated for the following conditions:

a. The program is operating in the "design" mode and soil "strength" properties have been provided (see Appendix A, "Guide for Data Input").

b. The wall height ratio satisfies $0.6 \le \alpha \le 0.8$.

c. The anchor depth ratio (see Figure 10a) satisfies $\beta \le 0.3$.

d. The flexibility number satisfies $-3.5 \le \log(\rho) \le -1.5$.

e. The elevation of the rightside surface is at the top the wall.

f. The elevation of the leftside surface is below the elevation of the rightside surface.

g. In a layered system, the cohesion for all layers on the leftside of the wall within the depth of penetration is zero.

66. For each of the eight representative sheet-pile sections incorporated in CWALSHT and for each section input by the user during execution, the program determines a reduction factor for both "loose" and "dense" sand. The program does not attempt to interpret from the input soil strength properties whether the material conforms to either of these density descriptors.

Application to sheet piles in clay

67. In addition to the flexibility number described above, application of Rowe's reduction to piles in clay requires determination of a "stability" number defined by

$$Sn = c/pv \sqrt{1 + C_a/c} \tag{16}$$

where

c = cohesion (psf) of the material within the embedded depth below the leftside surface

p_v = effective vertical pressure in the rightside soil at the elevation of the leftside surface

C_a = wall/soil adhesion in the leftside material. In layered systems, CWALSHT uses weighted averages of C and C_a for the leftside layers within the embedded depth.

68. Rowe's curves for sheet piles in homogeneous clays are shown in Figure 10b. Numerical representations (for $0.5 \le S_n \le 2.5$) are contained in CWALSHT. The program interpolates among the curves to obtain a single value of reduction coefficient for each available sheet pile section under the following conditions:

a. The program is operating in the "design" mode and soil "strength" properties have been provided (see Appendix A, "Guide for Data Input").

b. The wall height ratio satisfies $0.6 \le \alpha \le 0.8$.

c. The anchor depth ratio (see Figure 10a) satisfies $\beta \le 0.3$.

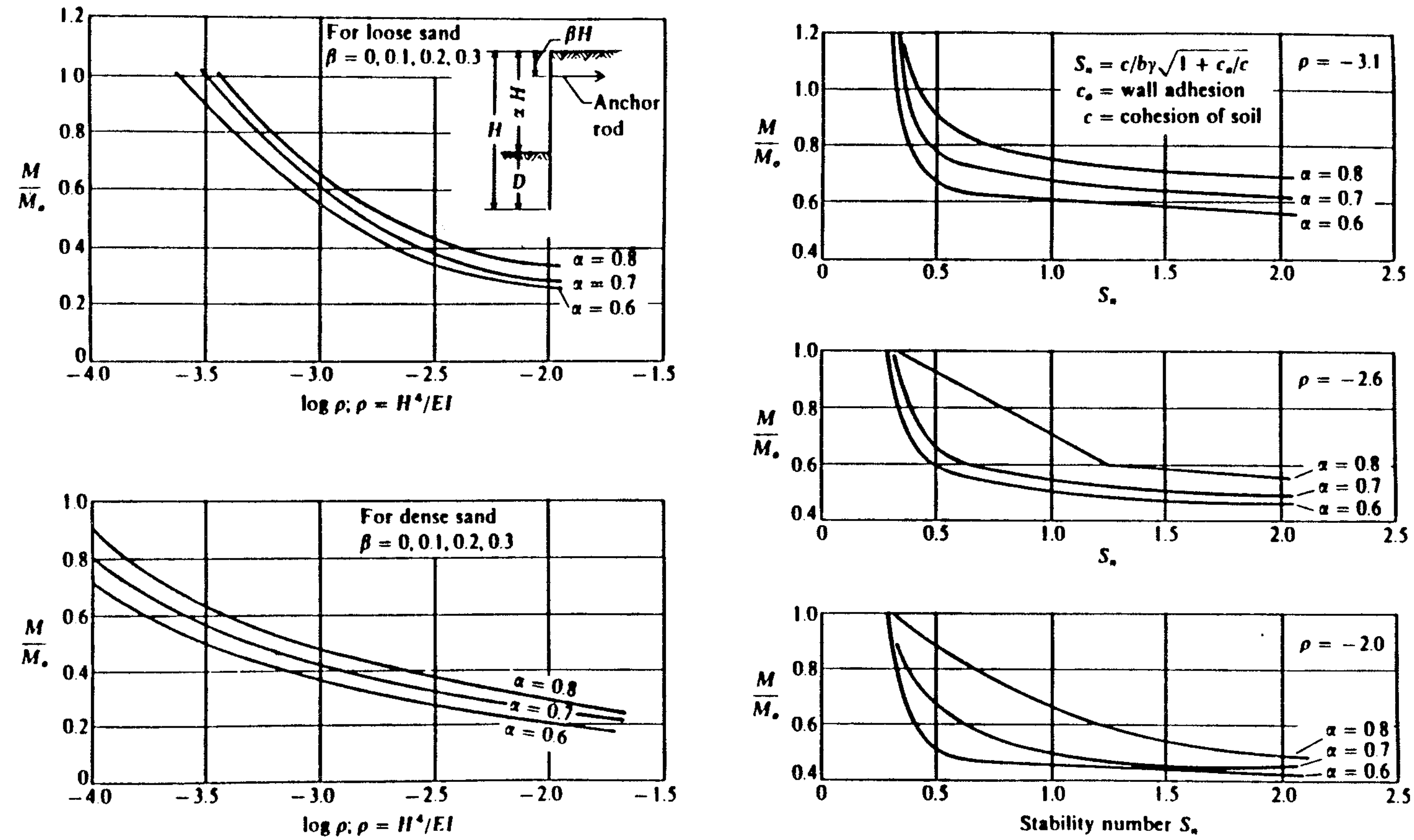
d. The flexibility number satisfies $-3.1 \le \log(\rho) \le -2.0$.

e. The stability number satisfies $0.5 \le S_n \le 2.5$.

f. The elevation of the rightside surface is at the top of the wall.

g. The elevation of the leftside surface is below the elevation of the rightside surface.

h. In a layered system, the internal friction angle for all layers on the leftside of the wall within the depth of penetration is zero.



a. Sheet piles in sand

b. Sheet piles in clay

Figure 10. Rowe's moment-reduction curves (after Rowe 1957)

69. The computer program CWALSHT, which implements the procedures described in paragraphs 48 through 68, is written in the FORTRAN language for interactive operations from a remote terminal. All arithmetic operations are performed in single precision. For computer systems employing fewer than 15 significant figures for real numbers, it may be necessary to perform some operations in double precision.

Input Data

70. Input data may be provided interactively either from the user's terminal or from a previously prepared data file. When data are input from the terminal during execution, the program provides prompting messages to indicate the type and amount of input data to be entered. The characteristics of a previously prepared data file are described in the "Guide for Data Input" contained in Appendix A.

71. Whenever an input sequence is completed, either from a data file or from the user's terminal, the program provides an opportunity to change any or all parts of the input data in an editing mode.

72. Whenever any input data are entered from the user's terminal, the program provides for saving the existing input data in a permanent file.

Output Data

73. The user has several options regarding the amount and destination of the output from the program. The four basic parts of the output and user options pertaining to each part are described in paragraphs 74 through 77. Each part may be directed to the user's terminal, to an output file, or to both simultaneously.

Echoprint of input data

74. A complete tabulation of all input data as read from the user terminal or from an input file. The user may elect to omit the echoprint.

Soil pressures for design

75. A tabulation of the active and passive pressures on each side of the wall and the combined net active (and net passive, if required) pressure down to a depth equal to three times the exposed height of the wall. If the

"automatic" seepage option has been selected, these pressures correspond to the initial trial seepage gradient. This section of the output is not available in the analysis mode. Also, this section of the output may be omitted.

Summary of results

76. A tabulation of design penetration from the design mode or the factor of safety from the analysis mode with maximum bending moment and deflection for a cantilever wall; or a tabulation of design penetration or factor of safety, maximum bending moment and deflection, and anchor force for each method for an anchored wall. This summary may be directed to an output file, to the user's terminal, or both.

Complete results

77. A complete tabulation of the elevation, bending moment, shear force, deflection, and final net pressure at each calculation point on the wall. Whenever dual values exist at a single point (e.g., discontinuities in soil pressures in stratified soils or sudden changes in shear at the anchor or at points of application of horizontal line loads), two lines of results appear for that point giving the values immediately above and below the discontinuity. The user may omit this section of the output, direct it to the terminal, or write it to the output file containing the summary of results. For anchored walls the user may elect to output the complete tabulation of results for any or all of the design methods exercised. The final soil pressures associated with the analysis or design may be included as a part of this section or may be omitted.

Results of Application of Rowe's Moment Reduction for Anchored Walls

78. A tabulation of the properties of the sheet pile sections incorporated in CWALSHT and any sections input during execution and preliminary design data resulting from application of Rowe's moment reduction procedure. The application of Rowe's procedure may be omitted. If Rowe's procedure is applied, the tabulation of results is directed to the same destination selected for the summary of results described in paragraph 76.

Graphics Display of Input Data

79. Portrayal of input data may consist of three parts:

a. Input geometry. A plot of all structure, soil profile, and water elevations including a summary of soil layer properties. The user is allowed to select vertical and horizontal limits for the display. Unless the limits provided define a square area, this plot of the geometry of the system will be distorted.

b. Input surface surcharges. A schematic displaying all surcharge loads applied to the soil surface on each side of the wall, if surcharges are present.

c. Input horizontal loads. A schematic of concentrated horizontal line loads and horizontal distributed loads applied to the wall, if horizontal loads are present.

Graphics Display of Design Soil Pressures

80. Two plots of (initial) design soil pressures are available for elevations from the top of the wall down to a depth equal to three times the exposed height of the wall:

a. Net active (and passive, if necessary) soil pressures.

b. Active and passive pressures on each side of the wall.

Graphics Display of Results

81. Five plots of results are available consisting of: bending moments, shear forces, (scaled) deflections, net pressures, and (optional) final active and passive soil pressures on each side of the wall.

Graphics Display of Rowe's Moment Reduction Curves for Piles in Sand

82. An optional plot is available for the interpolated Rowe's reduction curves for "loose" and "dense" sands. This plot also shows the reduction coefficient for each sheet pile section.

Units and Sign Conventions

83. Units and sign conventions for forces and displacements used for calculations and output of results are shown in Table 2.

Table 2

Units and Sign Conventions

Item	Unit	Sign Convention
Horizontal distances	ft	Always positive
Elevations	ft	Positive or negative decreasing downward
Modulus of elasticity	psi	
Wall moment of inertia	$in.^4$	
Soil unit weight	pcf	
Angle of internal friction	deg	
Cohesion	psf	
Angle of wall friction	deg	Positive or negative
Horizontal line loads	plf	Positive to left
Horizontal applied pressures	psf	Positive to left
Vertical line surcharges	plf	Positive downward
Strip, ramp, triangular, variable or uniform surcharges	psf	Positive downward
Water unit weight	pcf	
Earthquake acceleration	G's	Always positive
Pressures	psf	Positive to left
Bending moment	lb-ft/ft	Positive if produces compression on left side of wall
Shear force	lb/ft	Positive acts to left on top end of vertical wall section
Deflection	in.	Positive to left
"Scaled" deflection	$lb\text{-}in.^3$	Positive to left
Anchor force	lb/ft	Always tension

PART VI: EXAMPLE SOLUTIONS

84. Numerous wall/soil systems have been investigated to test and verify the computational processes used in the program. The example solutions presented below are intended to illustrate the operation of the program and are not to be interpreted as recommendations for its application.

Cantilever Walls

Example CANT1

85. The cantilever retaining wall shown in Figure 11 was designed for a factor of safety of 1.5 for both active and passive effects. Initiation of

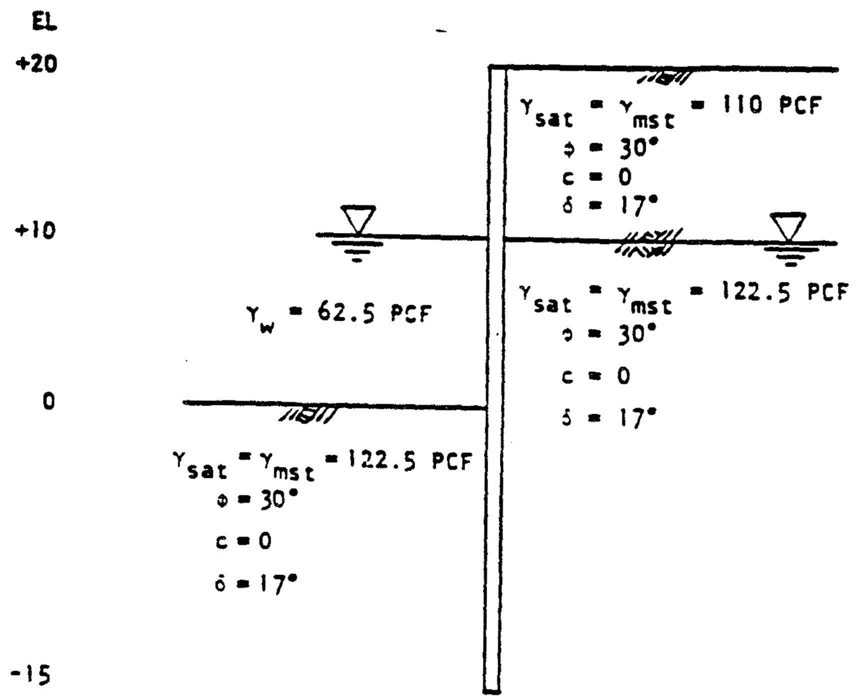


Figure 11. System for Example CANT1

the program and entry of input data from the terminal are shown in Figure 12. An echoprint of input data is given in Figure 13. The data entered from the terminal were saved in the input file format. The input file generated by the program is shown in Figure 14. A plot of the structure geometry is presented in Figure 15. Soil pressures to be used in the design are tabulated in Figure 16 and shown graphically in Figure 17. Note that the user may discontinue the solution after input data have been echoprinted and/or plotted and after the design soil pressures have been printed and/or plotted. If the solution

```
     PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                                     BY CLASSICAL METHODS
     DATE: 08/21/89                                                   TIME: 1:18:09


     ARE INPUT DATA TO BE READ FROM YOUR TERMINAL OR A FILE?
     ENTER 'TERMINAL' OR 'FILE'.
? t
     ENTER NUMBER OF HEADING LINES (1 TO 4).
? 2
     ENTER 2 HEADING LINE(S).
? cantilever retaining wall in granular soil
? design for fs = 1.5 on both active and passive
     ENTER WALL TYPE: 'CANTILEVER' OR 'ANCHORED'.
? c
     ENTER MODE: 'DESIGN' OR 'ANALYSIS'.
? d
     ENTER LEVEL 1 FACTORS OF SAFETY FOR DESIGN FOR
          ACTIVE PRESSURE     PASSIVE PRESSURE
? 1.5 1.5
     ENTER ELEVATION AT TOP OF WALL (FT).
? 20
     ENTER NUMBER OF RIGHTSIDE SURFACE POINTS (1 TO 21).
? 1
     ENTER   1 RIGHTSIDE SURFACE POINTS, ONE POINT AT A TIME.

          DISTANCE FROM     ELEVATION
            WALL (FT)          (FT)
? 0 20
     ARE LEFTSIDE AND RIGHTSIDE SURFACES SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? n
     ENTER NUMBER OF  LEFTSIDE SURFACE POINTS (1 TO 21).
? 1
     ENTER   1  LEFTSIDE SURFACE POINTS, ONE POINT AT A TIME.

          DISTANCE FROM     ELEVATION
            WALL (FT)          (FT)
? 0 0
     ARE SOIL STRENGTHS OR ACTIVE AND PASSIVE COEFFICIENTS TO BE
     PROVIDED FOR RIGHTSIDE SOIL?
     ENTER 'STRENGTHS' OR 'COEFFICIENTS'.
? s
     ENTER LEVEL 2 FACTOR OF SAFETY FOR RIGHTSIDE SOIL ACTIVE  PRESSURES.
     ENTER 'DEFAULT' IF LEVEL 1 FACTOR APPLIES.
? d
     ENTER LEVEL 2 FACTOR OF SAFETY FOR RIGHTSIDE SOIL PASSIVE PRESSURES.
     ENTER 'DEFAULT' IF LEVEL 1 FACTOR APPLIES.
? d
     ENTER NUMBER OF RIGHTSIDE SOIL LAYERS (1 TO 15).
? 2
```

Figure 12. Terminal input for Example CANT1 (Sheet 1 of 3)

```
     ENTER DATA FOR  2 RIGHTSIDE SOIL LAYERS, ONE LINE PER LAYER.
       (OMIT LAYER BOTTOM ELEVATION AND SLOPE FOR LAST LAYER.)
       (ENTER 'DEFAULT' FOR EITHER FACTOR OF SAFETY IF LEVEL 2 FACTOR APPLIES.)
       (OMIT PASSIVE FACTOR OF SAFETY IF MODE IS ANALYSIS.)

                   ANGLE OF          ANGLE OF  WALL                      <-FACTOR OF->
  SAT.    MOIST    INTERNAL  COH-     WALL     ADH-   <--BOTTOM-->       <---SAFETY-->
 WGHT.    WGHT.    FRICTION  ESION  FRICTION   ESION  ELEV.  SLOPE       ACT.     PASS.
 (PCF)    (PCF)     (DEG)    (PSF)    (DEG)    (PSF)  (FT)  (FT/FT)
? 110 110 30 0 17 0 10 0
? 122.5 122.5 30 0 17 0
     ARE LEFTSIDE AND RIGHTSIDE SOIL LAYER DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? n
     ARE SOIL STRENGTHS OR ACTIVE AND PASSIVE COEFFICIENTS TO BE
     PROVIDED FOR  LEFTSIDE SOIL?
     ENTER 'STRENGTHS' OR 'COEFFICIENTS'.
? s
     ENTER LEVEL 2 FACTOR OF SAFETY FOR  LEFTSIDE SOIL ACTIVE  PRESSURES.
     ENTER 'DEFAULT' IF LEVEL 1 FACTOR APPLIES.
? d
     ENTER LEVEL 2 FACTOR OF SAFETY FOR  LEFTSIDE SOIL PASSIVE PRESSURES.
     ENTER 'DEFAULT' IF LEVEL 1 FACTOR APPLIES.
? d
     ENTER NUMBER OF  LEFTSIDE SOIL LAYERS (1 TO 15).
? 1
     ENTER DATA FOR  1  LEFTSIDE SOIL LAYERS, ONE LINE PER LAYER.
       (OMIT LAYER BOTTOM ELEVATION AND SLOPE FOR LAST LAYER.)
       (ENTER 'DEFAULT' FOR EITHER FACTOR OF SAFETY IF LEVEL 2 FACTOR APPLIES.)
       (OMIT PASSIVE FACTOR OF SAFETY IF MODE IS ANALYSIS.)

                   ANGLE OF          ANGLE OF  WALL                      <-FACTOR OF->
  SAT.    MOIST    INTERNAL  COH-     WALL     ADH-   <--BOTTOM-->       <---SAFETY-->
 WGHT.    WGHT.    FRICTION  ESION  FRICTION   ESION  ELEV.  SLOPE       ACT.     PASS.
 (PCF)    (PCF)     (DEG)    (PSF)    (DEG)    (PSF)  (FT)  (FT/FT)
? 122.5 122.5 30 0 17 0
     ARE WATER DATA TO BE PROVIDED?  ENTER 'YES' OR 'NO'.
? y
     ARE WATER DATA TO BE PROVIDED BY ELEVATIONS OR A PRESSURE DISTRIBUTION?
     ENTER 'ELEVATIONS' OR 'PRESSURES'.
? e
     ENTER WATER DATA AS INDICATED.

              WATER          <--WATER ELEVATION-->
           UNIT WEIGHT       RIGHTSIDE    LEFTSIDE
              (PCF)            (FT)         (FT)
? 62.5 10 10
     ARE SURFACE LOADS TO BE APPLIED ON EITHER SIDE?
     ENTER 'YES' OR 'NO'.
? n
     ENTER EARTHQUAKE ACCELERATION (0.0 .LE. EQACC .LT. 1.0 G'S).
? 0
     ENTER NUMBER OF HORIZONTAL LINE LOADS (0 TO 21).
? 0
     ENTER NUMBER OF POINTS FOR HORIZONTAL DISTRIBUTED LOAD DISTRIBUTION
     (0 OR 2 TO 21).
? 0
```

Figure 12. (Sheet 2 of 3)

```
        INPUT COMPLETE.
        DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
        TO A FILE, TO BOTH, OR NEITHER?
        ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? f
        ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? cant1o
        INPUT COMPLETE.
        DO YOU WANT TO EDIT INPUT DATA?
        ENTER 'YES' OR 'NO'.
? n
        DO YOU WANT INPUT DATA SAVED IN A FILE?
        ENTER 'YES' OR 'NO'.
? y
        ENTER FILE NAME FOR SAVING INPUT DATA (6 CHARACTERS MAXIMUM).
? cant1i
        DO YOU WANT TO PLOT INPUT DATA?
        ENTER 'YES' OR 'NO'.
? n
        DO YOU WANT TO CONTINUE WITH THE SOLUTION?
        ENTER 'YES' OR 'NO'.
? y
        DO YOU WANT A LISTING OF SOIL PRESSURES
        BEFORE CONTINUING WITH THE DESIGN?
        ENTER 'YES' OR 'NO'.
? y
        DO YOU WANT SOIL PRESSURES PRINTED TO YOUR TERMINAL,
        TO FILE 'CANT1O', OR BOTH?
        ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? f
        DO YOU WANT TO PLOT SOIL PRESSURES?
        ENTER 'YES' OR 'NO'.
? n
        DO YOU WANT TO CONTINUE WITH THE SOLUTION?
        ENTER 'YES' OR 'NO'.
? y
        SOLUTION COMPLETE.
        DO YOU WANT RESULTS PRINTED TO YOUR TERMINAL,
        TO FILE 'CANT1O', OR BOTH?
        ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? f
        DO YOU WANT COMPLETE RESULTS OUTPUT?
        ENTER 'YES' OR 'NO'.
? y
        DO YOU WANT RESULTS TO INCLUDE ACTIVE AND PASSIVE
        EARTH PRESSURES ON EACH SIDE OF THE WALL?
        ENTER 'YES' OR 'NO'.
? y
        DO YOU WANT TO PLOT RESULTS?
        ENTER 'YES' OR 'NO'.
? n
        OUTPUT COMPLETE.
        DO YOU WANT TO EDIT INPUT DATA?
        ENTER 'YES' OR 'NO'.
? n


        INPUT DATA ENTERED FROM TERMINAL.
        LAST INPUT DATA SAVED IN FILE 'CANT1I'.


        OUTPUT SAVED IN FILE 'CANT1O'.


        DO YOU WANT TO MAKE ANOTHER RUN?
        ENTER 'YES' OR 'NO'.
? n


        ********** NORMAL TERMINATION **********
```

Figure 12. (Sheet 3 of 3)

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                        BY CLASSICAL METHODS
DATE: 91/01/25                                            TIME:  9.07.40

                          INPUT DATA

I.--HEADING:
  'CANTILEVER RETAINING WALL IN GRANULAR SOIL
  'DESIGN FOR FS=1.5 ON BOTH ACTIVE AND PASSIVE

II.--CONTROL
  CANTILEVER WALL DESIGN

  LEVEL 1 FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.50
  LEVEL 1 FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

III.--WALL DATA
  ELEVATION AT TOP OF WALL    =    20.00 (FT)

IV.--SURFACE POINT DATA

  IV.A--RIGHTSIDE
     DIST. FROM     ELEVATION
     WALL (FT)        (FT)
           .00        20.00

  IV.B-- LEFTSIDE
     DIST. FROM     ELEVATION
     WALL (FT)        (FT)
           .00          .00

V.--SOIL LAYER DATA

  V.A.--RIGHTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                  ANGLE OF           ANGLE OF                              <-SAFETY->
  SAT.    MOIST   INTERNAL   COH-      WALL       ADH-     <--BOTTOM-->  <-FACTOR->
 WGHT.    WGHT.   FRICTION   ESION   FRICTION     ESION    ELEV.   SLOPE  ACT.  PASS.
 (PCF)    (PCF)     (DEG)    (PSF)     (DEG)      (PSF)    (FT) (FT/FT)
110.00   110.00     30.00      .0      17.00         .0    10.00    .00   DEF   DEF
122.50   122.50     30.00      .0      17.00         .0                   DEF   DEF

  V.B.-- LEFTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                  ANGLE OF           ANGLE OF                              <-SAFETY->
  SAT.    MOIST   INTERNAL   COH-      WALL       ADH-     <--BOTTOM-->  <-FACTOR->
 WGHT.    WGHT.   FRICTION   ESION   FRICTION     ESION    ELEV.   SLOPE  ACT.  PASS.
 (PCF)    (PCF)     (DEG)    (PSF)     (DEG)      (PSF)    (FT) (FT/FT)
122.50   122.50     30.00      .0      17.00         .0                   DEF   DEF

VI.--WATER DATA

     UNIT WEIGHT           =     62.50 (PCF)
     RIGHTSIDE ELEVATION =     10.00 (FT)
      LEFTSIDE ELEVATION =     10.00 (FT)
     NO SEEPAGE

VII.--SURFACE LOADS
     NONE

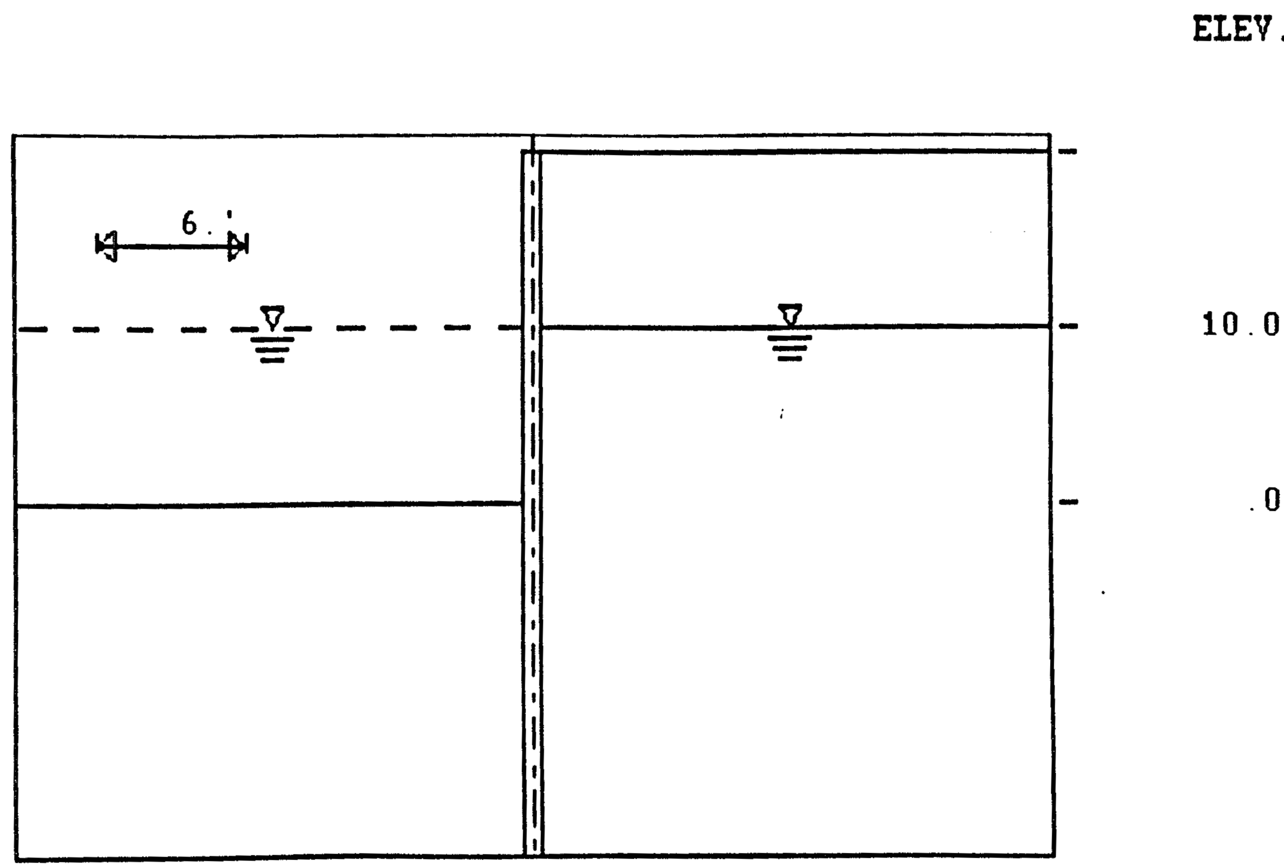
VIII.--HORIZONTAL LOADS
     NONE
```

Figure 13. Echoprint of input data for Example CANT1

```
1000 'CANTILEVER RETAINING WALL IN GRANULAR SOIL
1010 'DESIGN FOR FS = 1.5 ON BOTH ACTIVE AND PASSIVE
1020 CONTROL  C  D    1.50    1.50
1030 WALL      20.00
1040 SURFACE RIGHTSIDE   1
1050      0.00     20.00
1060 SURFACE  LEFTSIDE   1
1070      0.00      0.00
1080 SOIL RIGHTSIDE  STRENGTH    2    0.00    0.00
1090  110.00  110.00 30.00    0.00  17.00    0.00    10.00   0.00 0.00 0.00
1100  122.50  122.50 30.00    0.00  17.00    0.00     0.00   0.00
1110 SOIL  LEFTSIDE  STRENGTH    1    0.00    0.00
1120  122.50  122.50 30.00    0.00  17.00    0.00     0.00   0.00
1130 WATER ELEVATIONS    62.50   10.00   10.00
1140 FINISH
```

Figure 14. Input file for Example CANT1

'CANTILEVER RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1.5 ON BOTH ACTIVE AND PASSIVE



***** INPUT GEOMETRY *****
DATE: 91/08/07 TIME: 7.56.47

Figure 15. Input geometry plot for Example CANT1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 9.09.16

SOIL PRESSURES FOR
CANTILEVER WALL DESIGN

I.--HEADING

'CANTILEVER RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1.5 ON BOTH ACTIVE AND PASSIVE

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

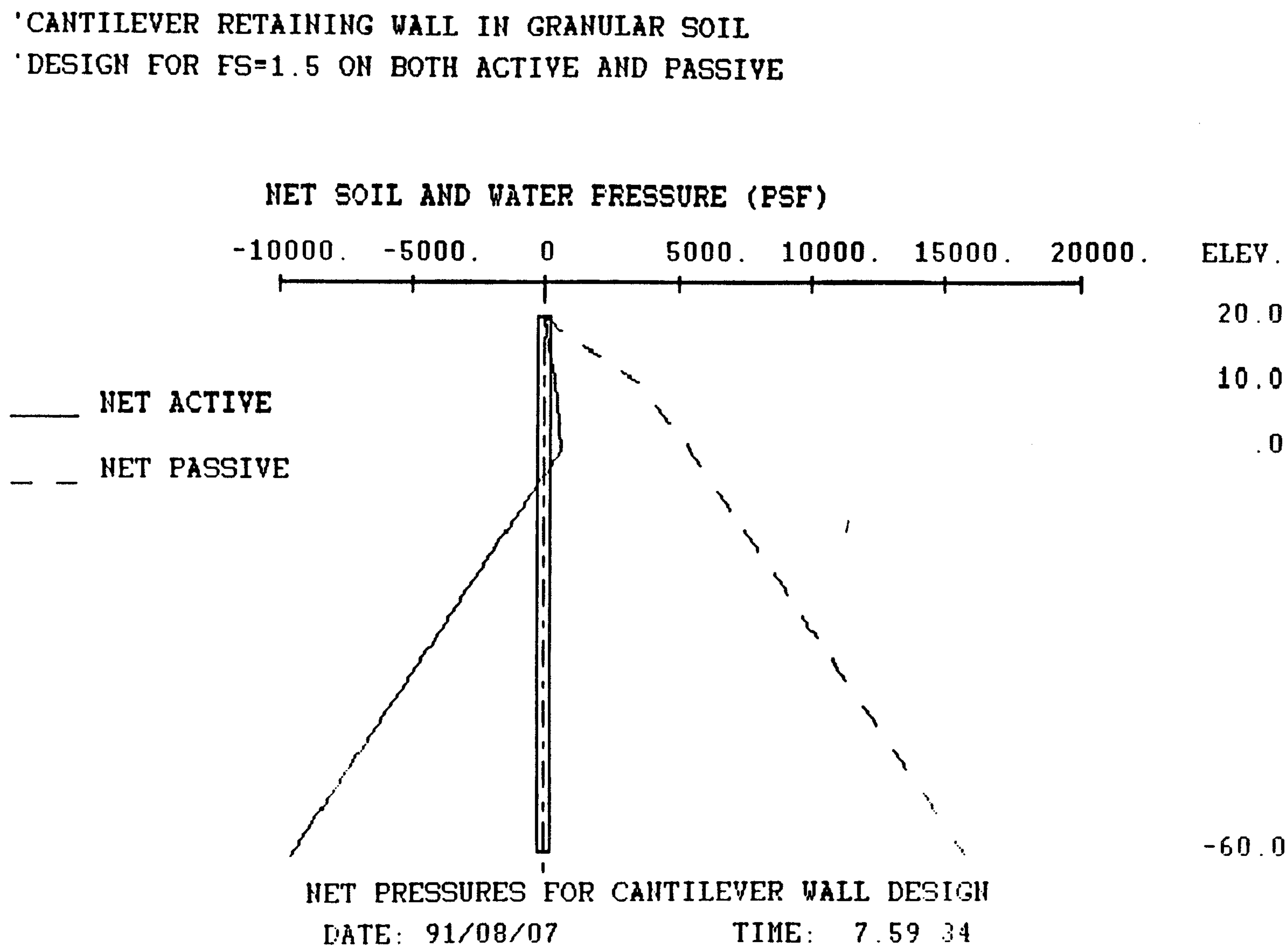
LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

	<-LEFTSIDE PRESSURES->		<---NET PRESSURES----> (SOIL PLUS WATER)		<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
20.00	.000	.000	.000	.000	.000	.000
19.00	.000	.000	43.670	355.913	43.670	355.913
18.00	.000	.000	87.340	711.826	87.340	711.826
17.00	.000	.000	131.011	1067.739	131.011	1067.739
16.00	.000	.000	174.681	1423.652	174.681	1423.652
15.00	.000	.000	218.351	1779.565	218.351	1779.565
14.00	.000	.000	262.021	2135.477	262.021	2135.477
13.00	.000	.000	305.691	2491.390	305.691	2491.390
12.00	.000	.000	349.362	2847.303	349.362	2847.303
11.00	.000	.000	393.032	3203.216	393.032	3203.216
10.00	.000	.000	436.702	3559.129	436.702	3559.129
9.00	.000	.000	460.522	3753.263	460.522	3753.263
8.00	.000	.000	484.342	3947.398	484.342	3947.398
7.00	.000	.000	508.162	4141.532	508.162	4141.532
6.00	.000	.000	531.983	4335.666	531.983	4335.666
5.00	.000	.000	555.803	4529.801	555.803	4529.801
4.00	.000	.000	579.623	4723.935	579.623	4723.935
3.00	.000	.000	603.443	4918.069	603.443	4918.069
2.00	.000	.000	627.263	5112.204	627.263	5112.204
1.00	.000	.000	651.083	5306.338	651.083	5306.338
.00	.000	.000	674.903	5500.472	674.903	5500.472
-1.00	194.134	23.820	504.589	5670.786	698.723	5694.607
-2.00	388.269	47.640	334.275	5841.101	722.543	5888.741
-3.00	582.403	71.460	163.961	6011.415	746.364	6082.875
-3.96	769.295	94.392	.000	6175.375	769.295	6269.767
-4.00	776.537	95.280	-6.354	6181.729	770.184	6277.010
-5.00	970.672	119.101	-176.668	6352.043	794.004	6471.144
-6.00	1164.806	142.921	-346.982	6522.357	817.824	6665.278
-7.00	1358.940	166.741	-517.296	6692.672	841.644	6859.412
-8.00	1553.075	190.561	-687.610	6862.986	865.464	7053.547
-9.00	1747.209	214.381	-857.925	7033.300	889.284	7247.681
-10.00	1941.343	238.201	-1028.239	7203.614	913.104	7441.815

Figure 16. Tabulated initial soil pressures for Example CANT1 (Continued)

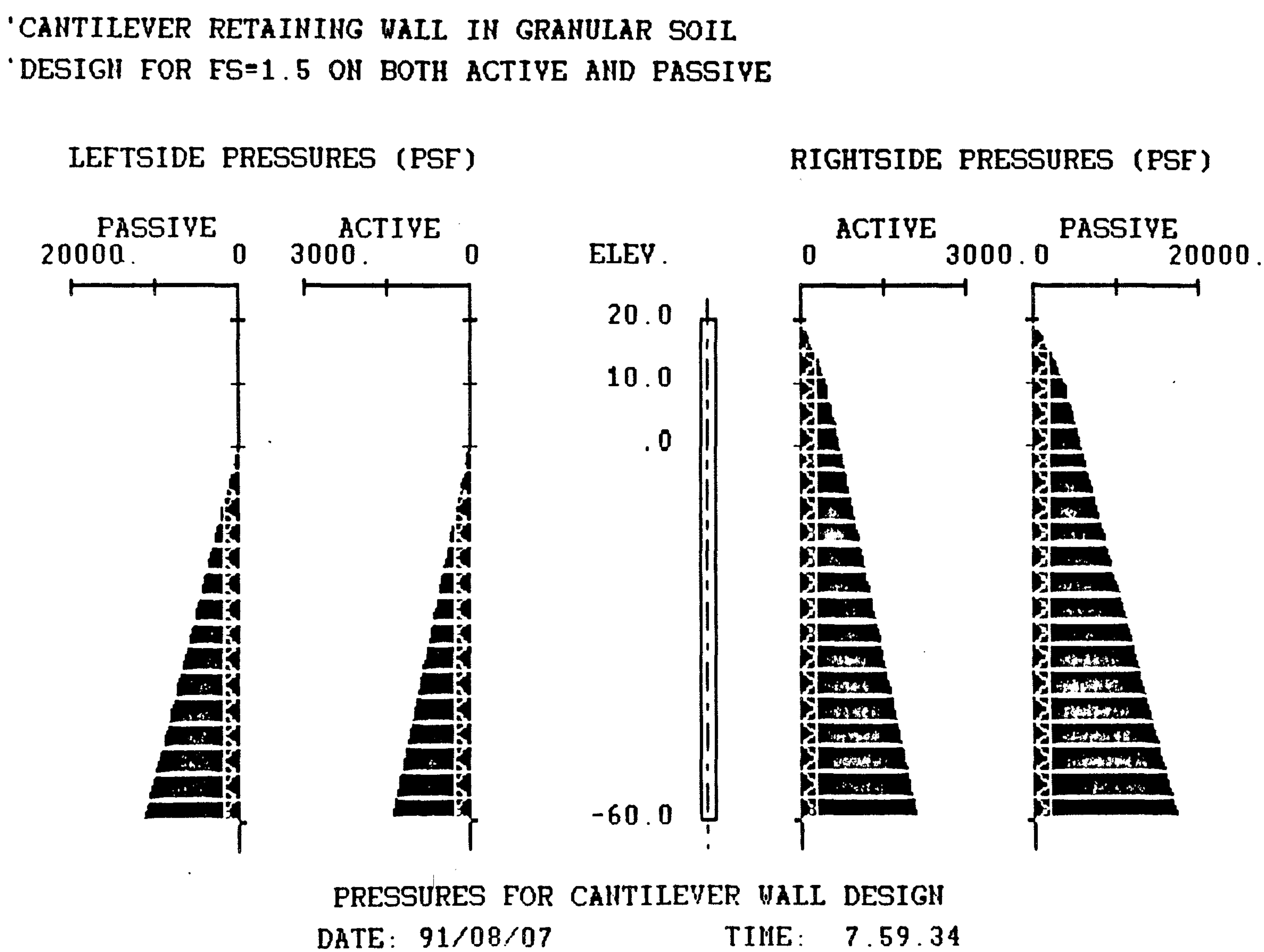
-11.00	2135.477	262.021	-1198.553	7373.928	936.924	7635.950
-12.00	2329.612	285.841	-1368.867	7544.243	960.745	7830.084
-13.00	2523.746	309.661	-1539.181	7714.557	984.565	8024.218
-14.00	2717.880	333.482	-1709.496	7884.871	1008.385	8218.353
-15.00	2912.015	357.302	-1879.810	8055.185	1032.205	8412.487
-16.00	3106.149	381.122	-2050.124	8225.500	1056.025	8606.621
-17.00	3300.283	404.942	-2220.438	8395.814	1079.845	8800.756
-18.00	3494.418	428.762	-2390.752	8566.128	1103.665	8994.890
-19.00	3688.552	452.582	-2561.067	8736.442	1127.485	9189.024
-20.00	3882.686	476.402	-2731.381	8906.756	1151.305	9383.159
-21.00	4076.821	500.222	-2901.695	9077.071	1175.126	9577.293
-22.00	4270.955	524.042	-3072.009	9247.385	1198.946	9771.427
-23.00	4465.089	547.863	-3242.323	9417.699	1222.766	9965.562
-24.00	4659.224	571.683	-3412.638	9588.013	1246.586	10159.696
-25.00	4853.358	595.503	-3582.952	9758.327	1270.406	10353.830
-26.00	5047.492	619.323	-3753.266	9928.642	1294.226	10547.964
-27.00	5241.627	643.143	-3923.580	10098.956	1318.046	10742.099
-28.00	5435.761	666.963	-4093.894	10269.270	1341.866	10936.233
-29.00	5629.895	690.783	-4264.209	10439.584	1365.686	11130.367
-30.00	5824.029	714.603	-4434.523	10609.898	1389.507	11324.502
-31.00	6018.164	738.423	-4604.837	10780.213	1413.327	11518.636
-32.00	6212.298	762.244	-4775.151	10950.527	1437.147	11712.770
-33.00	6406.432	786.064	-4945.466	11120.841	1460.967	11906.905
-34.00	6600.567	809.884	-5115.780	11291.155	1484.787	12101.039
-35.00	6794.701	833.704	-5286.094	11461.469	1508.607	12295.173
-36.00	6988.835	857.524	-5456.408	11631.784	1532.427	12489.308
-37.00	7182.970	881.344	-5626.722	11802.098	1556.247	12683.442
-38.00	7377.104	905.164	-5797.037	11972.412	1580.067	12877.576
-39.00	7571.238	928.984	-5967.351	12142.726	1603.888	13071.711
-40.00	7765.373	952.804	-6137.665	12313.040	1627.708	13265.845
-41.00	7959.507	976.625	-6307.979	12483.355	1651.528	13459.979
-42.00	8153.641	1000.445	-6478.293	12653.669	1675.348	13654.113
-43.00	8347.776	1024.265	-6648.608	12823.983	1699.168	13848.248
-44.00	8541.910	1048.085	-6818.922	12994.297	1722.988	14042.382
-45.00	8736.044	1071.905	-6989.236	13164.611	1746.808	14236.516
-46.00	8930.178	1095.725	-7159.550	13334.926	1770.628	14430.651
-47.00	9124.313	1119.545	-7329.864	13505.240	1794.448	14624.785
-48.00	9318.447	1143.365	-7500.179	13675.554	1818.269	14818.919
-49.00	9512.581	1167.186	-7670.493	13845.868	1842.089	15013.054
-50.00	9706.716	1191.006	-7840.807	14016.182	1865.909	15207.188
-51.00	9900.850	1214.826	-8011.121	14186.497	1889.729	15401.322
-52.00	10094.984	1238.646	-8181.435	14356.811	1913.549	15595.457
-53.00	10289.119	1262.466	-8351.750	14527.125	1937.369	15789.591
-54.00	10483.253	1286.286	-8522.064	14697.439	1961.189	15983.725
-55.00	10677.387	1310.106	-8692.378	14867.753	1985.009	16177.860
-56.00	10871.522	1333.926	-8862.692	15038.068	2008.829	16371.994
-57.00	11065.656	1357.746	-9033.006	15208.382	2032.650	16566.128
-58.00	11259.790	1381.567	-9203.321	15378.696	2056.470	16760.263
-59.00	11453.925	1405.387	-9373.635	15549.010	2080.290	16954.397
-60.00	11648.059	1429.207	-9543.949	15719.324	2104.110	17148.531
-61.00	11842.193	1453.027	-9714.263	15889.639	2127.930	17342.665

Figure 16. (Concluded)



a. Initial net pressures

Figure 17. Program plots of initial soil pressures for Example CANT1 (Continued)



b. Initial active and passive pressures

Figure 17. (Concluded)

is discontinued, the user has the opportunity to edit existing input data, restart the program, or terminate execution of the program.

86. The summary of results is presented in Figure 18. Optional complete results are tabulated in Figure 19. Two lines of data will appear for any elevation at which a discontinuity in shear force or soil pressure occurs. Optional final design soil pressures are tabulated in Figure 20. Unless the automatic seepage option has been invoked, the final design soil pressures will be the same as the initial pressures. Graphical presentations of the results are shown in Figures 21 through 24.

Example CANT1A

87. The input data for Example CANT1 were edited as shown in Figure 25. The mode of execution was changed from design to analysis, and the analysis was performed for a factor of safety of 1.0 for all active pressures. Even though the Level 1 factor of safety for active pressures is input, all existing Level 2 and 3 factors for active pressure previously available remain in effect. If it is necessary for Level 2 and 3 factors to be altered, it will be more efficient to edit the input file externally from the program. In this example, all safety factors for Levels 2 and 3 were previously defaulted to Level 1. The option for factor of safety in this example causes the program to determine a single passive factor of safety applied to all soils on both sides of the wall.

88. The summary of results of the analysis is presented in Figure 26. Other optional results data include a complete tabulation of bending moments, shears, deflections, net pressure, and final design pressures.

Example CANT2

89. The floodwall driven in layered soil shown in Figure 27 was designed for a factor of safety of 1.0 on all soil pressures. The input file for this system is given in Figure 28. The coefficient method for soil pressures produces a discontinuity in soil pressures at elevation (el) -10 ft* as shown in Figures 29 and 30. The discontinuity has been replaced by an average pressure at el -10 ft, Figures 29 and 31.

90. The summary of results for the design is shown in Figure 32 and the final design pressures are plotted in Figure 33.

---

* All elevations cited herein are in feet referred to National Geodetic Vertical Datum of 1929.

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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 91/01/25                                              TIME:  9.11.05

                    SUMMARY OF RESULTS FOR
                    CANTILEVER WALL DESIGN

I.--HEADING

  'CANTILEVER RETAINING WALL IN GRANULAR SOIL
  'DESIGN FOR FS=1.5 ON BOTH ACTIVE AND PASSIVE

II.--SUMMARY

     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

WALL BOTTOM ELEV. (FT)     :        -27.53
      PENETRATION (FT)     :         27.53

MAX. BEND. MOMENT (LB-FT) :        151550.
      AT ELEVATION (FT)    :        -14.00

MAX. SCALED DEFL. (LB-IN3):     1.6666E+11
      AT ELEVATION (FT)    :         20.00

     (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
     ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
     IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 18. Summary of results for Example CANT1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 9.11.05

COMPLETE RESULTS FOR
CANTILEVER WALL DESIGN

I.--HEADING

'CANTILEVER RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1.5 ON BOTH ACTIVE AND PASSIVE

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	0.	0.	1.6666E+11	.00
19.00	7.	22.	1.6132E+11	43.67
18.00	58.	87.	1.5598E+11	87.34
17.00	197.	197.	1.5064E+11	131.01
16.00	466.	349.	1.4530E+11	174.68
15.00	910.	546.	1.3996E+11	218.35
14.00	1572.	786.	1.3462E+11	262.02
13.00	2496.	1070.	1.2928E+11	305.69
12.00	3727.	1397.	1.2395E+11	349.36
11.00	5306.	1769.	1.1863E+11	393.03
10.00	7278.	2184.	1.1331E+11	436.70
9.00	9684.	2632.	1.0801E+11	460.52
8.00	12551.	3105.	1.0272E+11	484.34
7.00	15901.	3601.	9.7457E+10	508.16
6.00	19760.	4121.	9.2220E+10	531.98
5.00	24151.	4665.	8.7017E+10	555.80
4.00	29098.	5232.	8.1856E+10	579.62
3.00	34624.	5824.	7.6745E+10	603.44
2.00	40754.	6439.	7.1694E+10	627.26
1.00	47511.	7079.	6.6714E+10	651.08
.00	54919.	7742.	6.1816E+10	674.90
-1.00	62969.	8331.	5.7013E+10	504.59
-2.00	71524.	8751.	5.2319E+10	334.27
-3.00	80414.	9000.	4.7748E+10	163.96
-3.96	89129.	9079.	4.3479E+10	.00
-4.00	89467.	9079.	4.3316E+10	-6.35
-5.00	98514.	8987.	3.9039E+10	-176.67
-6.00	107385.	8725.	3.4933E+10	-346.98
-7.00	115908.	8293.	3.1011E+10	-517.30
-8.00	123914.	7691.	2.7290E+10	-687.61
-9.00	131233.	6918.	2.3783E+10	-857.92
-10.00	137693.	5975.	2.0503E+10	-1028.24
-11.00	143126.	4861.	1.7460E+10	-1198.55
-12.00	147360.	3578.	1.4665E+10	-1368.87

Figure 19. Complete results for Example CANT1 (Continued)

-13.00	150224.	2124.	1.2124E+10	-1539.18
-14.00	151550.	499.	9.8421E+09	-1709.50
-15.00	151167.	-1295.	7.8221E+09	-1879.81
-16.00	148903.	-3260.	6.0630E+09	-2050.12
-17.00	144589.	-5396.	4.5609E+09	-2220.44
-18.00	138055.	-7701.	3.3084E+09	-2390.75
-19.00	129130.	-10177.	2.2941E+09	-2561.07
-20.00	117644.	-12823.	1.5025E+09	-2731.38
-21.00	103427.	-15640.	9.1386E+08	-2901.70
-22.00	86308.	-18627.	5.0351E+08	-3072.01
-22.15	83475.	-19090.	4.5549E+08	-3097.60
-23.00	66387.	-20831.	2.4187E+08	-1000.21
-24.00	45467.	-20597.	9.4806E+07	1468.03
-25.00	26015.	-17895.	2.6521E+07	3936.26
-26.00	10499.	-12725.	3.7570E+06	6404.49
-27.00	1388.	-5086.	5.7948E+04	8872.73
-27.53	0.	0.	0.0000E+00	10189.84

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 19. (Concluded)

III.—SOIL PRESSURES

ELEVATION (FT)	< LEFTSIDE PRESSURE (PSF)> PASSIVE	ACTIVE	<RIGHTSIDE PRESSURE (PSF)> ACTIVE	PASSIVE
20.00	0.	0.	0.	0.
19.00	0.	0.	44.	356.
18.00	0.	0.	87.	712.
17.00	0.	0.	131.	1068.
16.00	0.	0.	175.	1424.
15.00	0.	0.	218.	1780.
14.00	0.	0.	262.	2135.
13.00	0.	0.	306.	2491.
12.00	0.	0.	349.	2847.
11.00	0.	0.	393.	3203.
10.00	0.	0.	437.	3559.
9.00	0.	0.	461.	3753.
8.00	0.	0.	484.	3947.
7.00	0.	0.	508.	4142.
6.00	0.	0.	532.	4336.
5.00	0.	0.	556.	4530.
4.00	0.	0.	580.	4724.
3.00	0.	0.	603.	4918.
2.00	0.	0.	627.	5112.
1.00	0.	0.	651.	5306.
0.00	0.	0.	675.	5500.
-1.00	194.	24.	699.	5695.
-2.00	388.	48.	723.	5889.
-3.00	582.	71.	746.	6083.
-3.96	769.	94.	769.	6270.
-4.00	777.	95.	770.	6277.
-5.00	971.	119.	794.	6471.
-6.00	1165.	143.	818.	6665.
-7.00	1359.	167.	842.	6859.
-8.00	1553.	191.	865.	7054.
-9.00	1747.	214.	889.	7248.
-10.00	1941.	238.	913.	7442.
-11.00	2135.	262.	937.	7636.
-12.00	2330.	286.	961.	7830.
-13.00	2524.	310.	985.	8024.
-14.00	2718.	333.	1008.	8218.
-15.00	2912.	357.	1032.	8412.
-16.00	3106.	381.	1056.	8607.
-17.00	3300.	405.	1080.	8801.
-18.00	3494.	429.	1104.	8995.
-19.00	3689.	453.	1127.	9189.
-20.00	3883.	476.	1151.	9383.
-21.00	4077.	500.	1175.	9577.
-22.00	4271.	524.	1199.	9771.
-22.15	4300.	528.	1203.	9801.
-23.00	4465.	548.	1223.	9966.
-24.00	4659.	572.	1247.	10160.
-25.00	4853.	596.	1270.	10354.
-26.00	5047.	619.	1294.	10548.
-27.00	5242.	643.	1318.	10742.
-27.53	5436.	667.	1342.	10936.
-29.00	5630.	691.	1366.	11130.

Figure 20. Final design soil pressures for Example CANT1

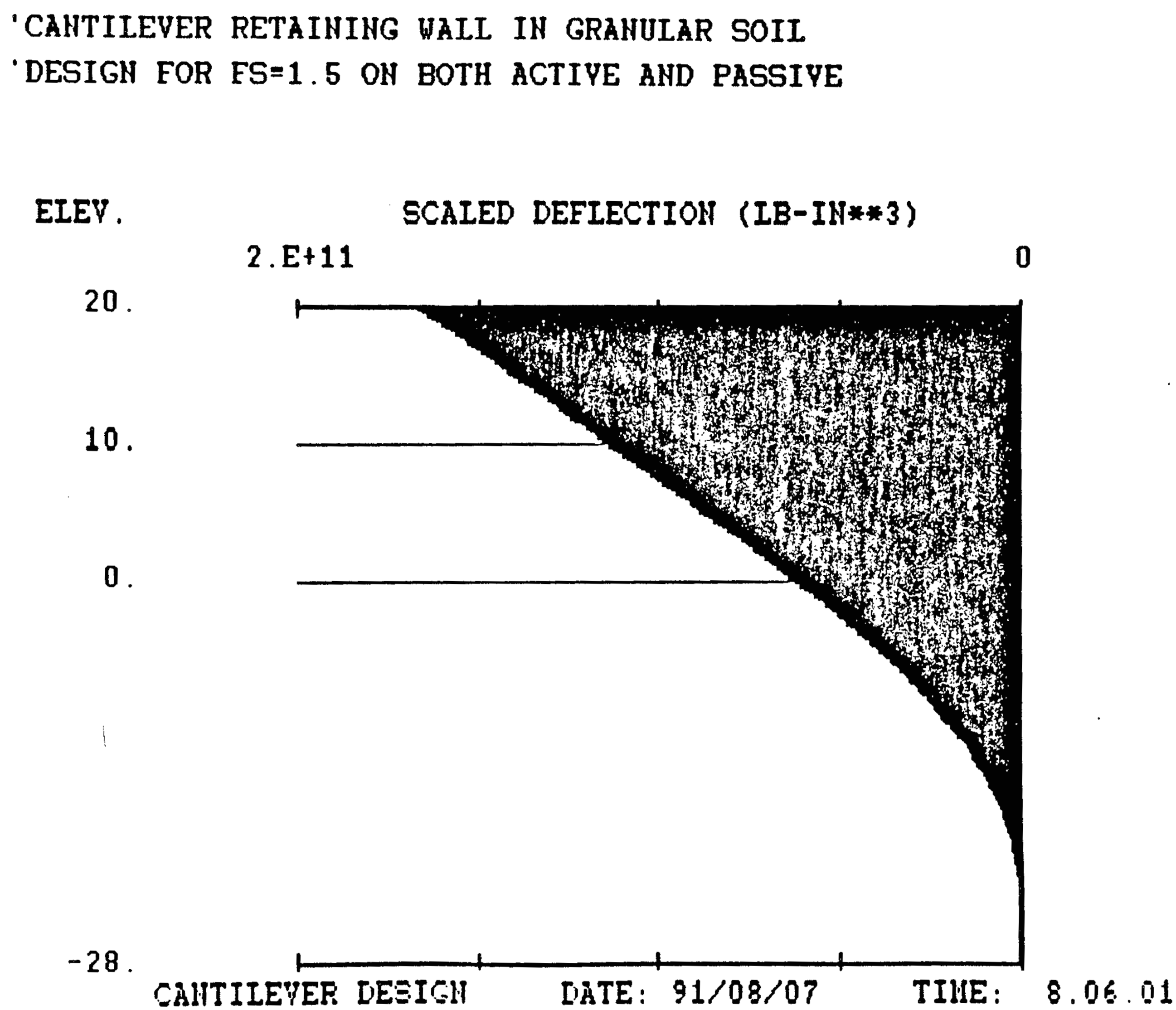


Figure 21. Program plot of scaled deflection for Example CANT1

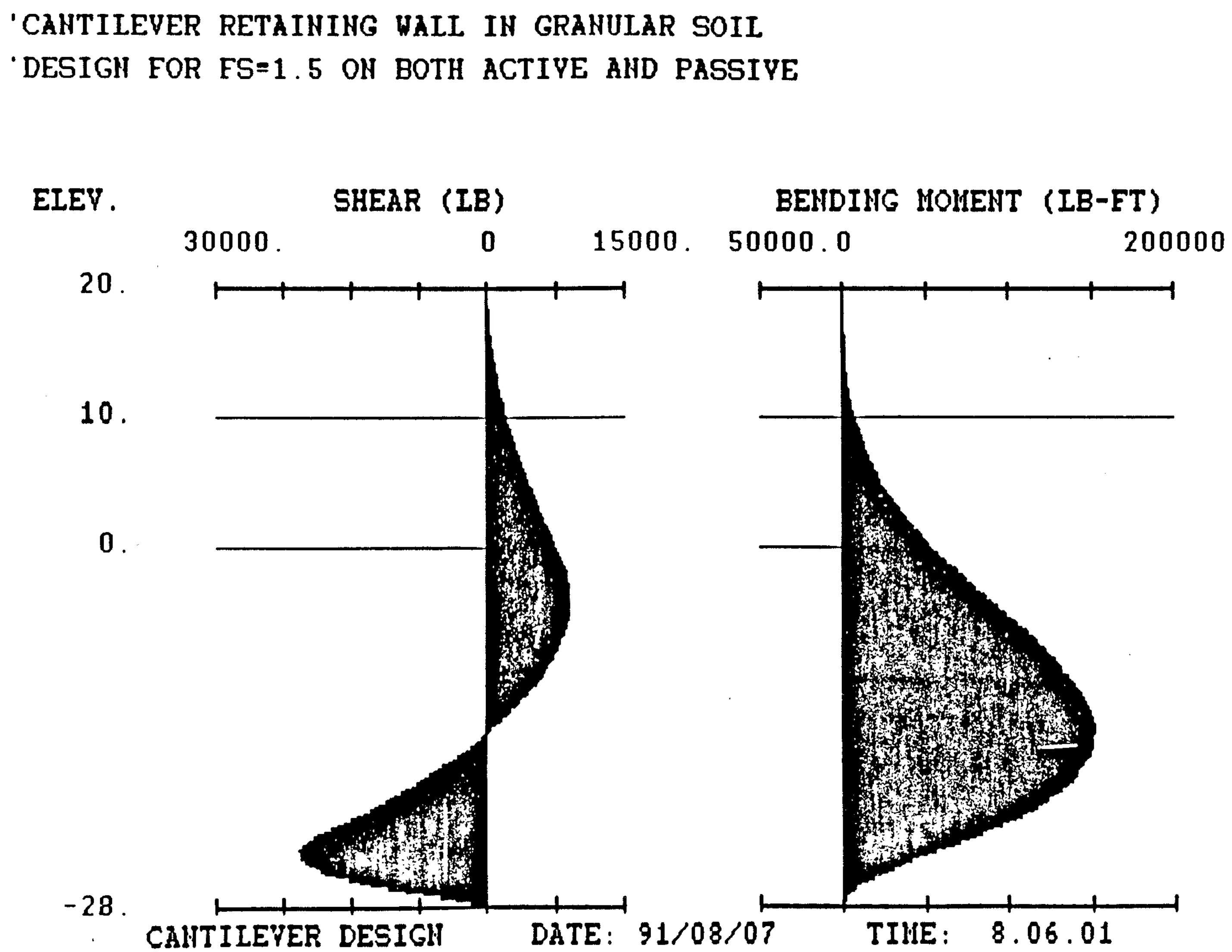


Figure 22. Program plot of shear force and bending moment for Example CANT1

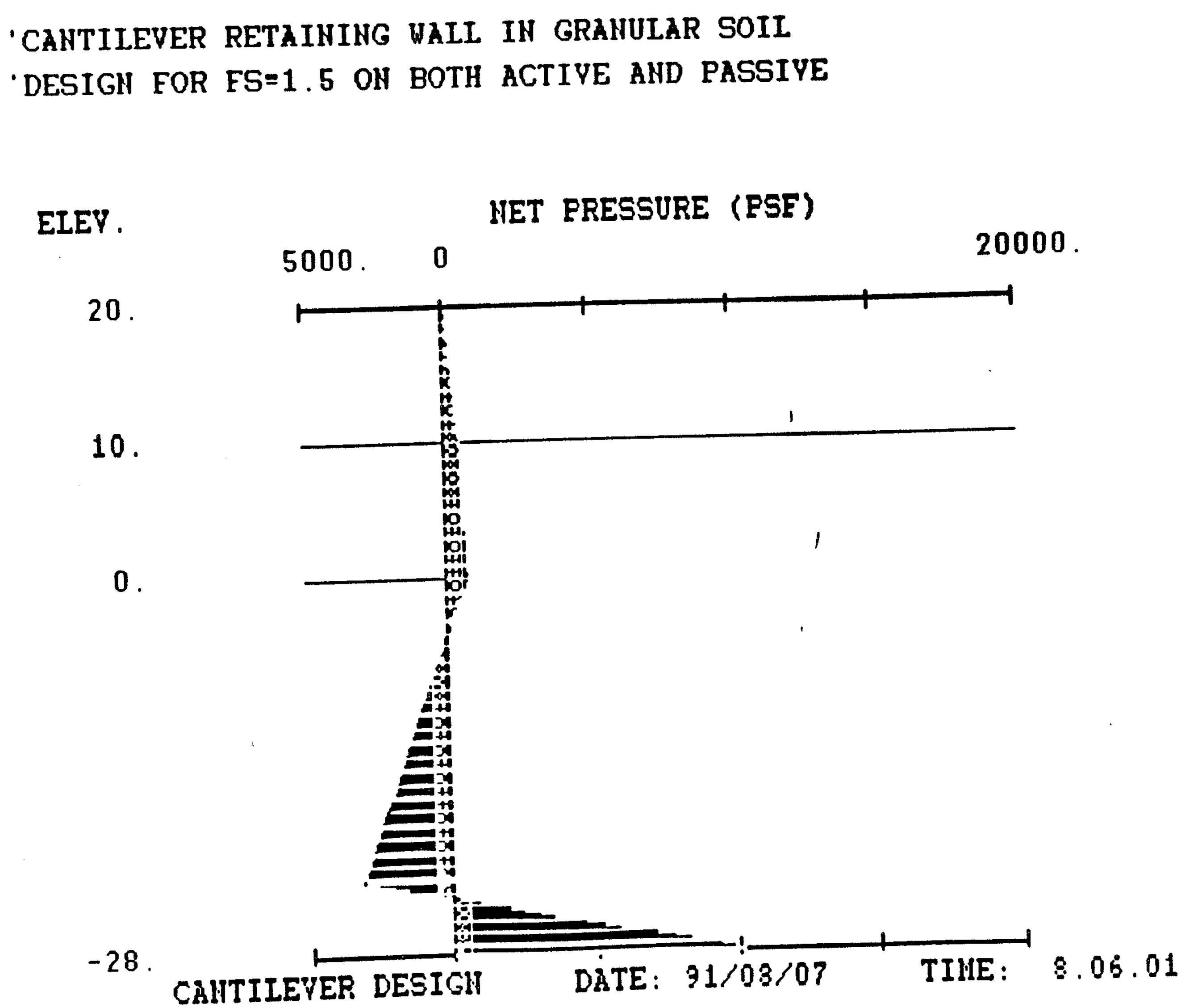


Figure 23. Program plot of design net pressures for Example CANT1

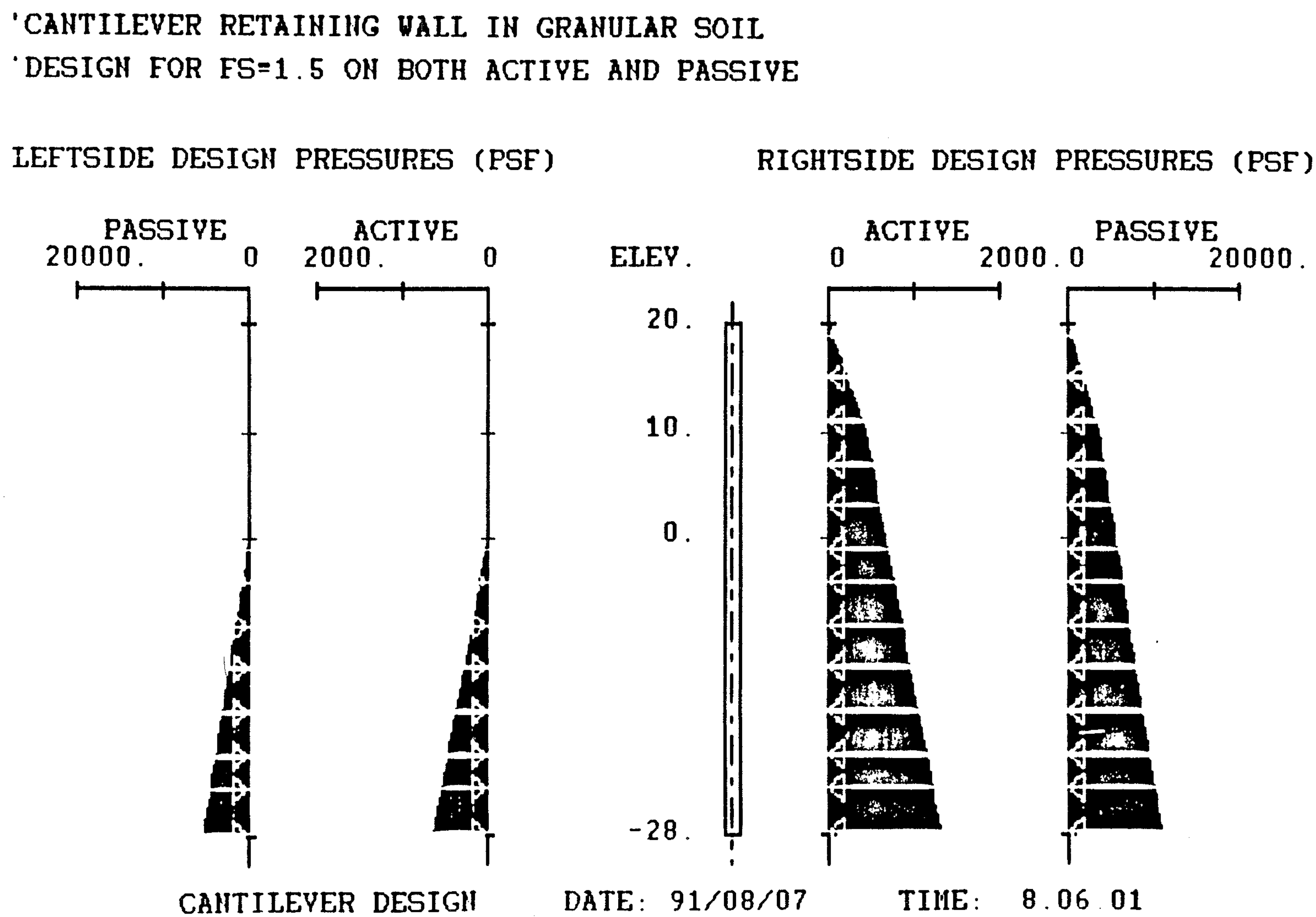


Figure 24. Program plot of final soil pressures for Example CANT1

```
     PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                                 BY CLASSICAL METHODS
     DATE: 08/22/89                                               TIME: 1:14:55

     ARE INPUT DATA TO BE READ FROM YOUR TERMINAL OR A FILE?
     ENTER 'TERMINAL' OR 'FILE'.
 ? f
     ENTER INPUT FILE NAME (6 CHARACTERS MAXIMUM).
 ? cant11
     INPUT COMPLETE.
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
     TO A FILE, TO BOTH, OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
 ? n
     INPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA?
     ENTER 'YES' OR 'NO'.
 ? y

     MAJOR DATA SECTIONS AND STATUS

          SECTION        CONTENTS             STATUS
          1..............HEADING.............2 LINES
          2..............CONTROL.............CANTILEVER DESIGN
          3..............WALL DATA...........FOR DESIGN
          4..............SURFACE DATA........RIGHTSIDE  1 POINTS
                                             LEFTSIDE   1 POINTS
          5..............SOIL LAYERS.........RIGHTSIDE  2 LAYERS, STRENGTHS
                                             LEFTSIDE   1 LAYERS, STRENGTHS
          6..............WATER...............ELEVATIONS AVAILABLE
          7..............VERTICAL LOADS......NONE
          8..............HORIZONTAL LOADS....NONE

     ENTER SECTION NUMBER TO BE EDITED, 'STATUS', OR 'FINISHED'.
 ? 1
     ENTER NUMBER OF HEADING LINES (1 TO 4).
 ? 2
     ENTER 2 HEADING LINE(S).
 ? analysis of cantilever retaining wall designed in Example CANT1
 ? fs = 1 for all active pressures

     ENTER SECTION NUMBER TO BE EDITED, 'STATUS', OR 'FINISHED'.
 ? 2
     ENTER WALL TYPE: 'CANTILEVER' OR 'ANCHORED'.
 ? c
     ENTER MODE: 'DESIGN' OR 'ANALYSIS'.
 ? a
     ENTER FACTOR OF SAFETY OPTION FOR ANALYSIS.
          (1 = SAME FS CALCULATED FOR BOTH ACTIVE AND PASSIVE PRESSURES.
           2 = FS FOR ACTIVE PRESSURES INPUT, FS FOR PASSIVE PRESSURES
               CALCULATED.)
 ? 2
     ENTER LEVEL 1 FACTOR OF SAFETY FOR ACTIVE PRESSURES.
 ? 1
```

Figure 25. Editing for Example CANT1A (Continued)

```
     ****************************************************************
     CHANGE IN WALL TYPE OR MODE REQUIRES NEW WALL DATA SECTION.
     ****************************************************************
     ENTER DATA FOR CANTILEVER WALL ANALYSIS.

     ELEV. AT TOP      ELEV. AT WALL      MODULUS OF      MOMENT OF
     OF WALL (FT)       BOTTOM (FT)       ELASTICITY       INERTIA
                                             (PSI)        (IN**4/FT)
? 20 -27.53 2.9e7 280.8

     ENTER SECTION NUMBER TO BE EDITED, 'STATUS', OR 'FINISHED'.
? f
     INPUT COMPLETE.
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
     TO A FILE, TO BOTH, OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? n
     INPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA?
     ENTER 'YES' OR 'NO'.
? n
     DO YOU WANT INPUT DATA SAVED IN A FILE?
     ENTER 'YES' OR 'NO'.
? n
     DO YOU WANT TO PLOT INPUT DATA?
     ENTER 'YES' OR 'NO'.
? n
     DO YOU WANT TO CONTINUE WITH THE SOLUTION?
     ENTER 'YES' OR 'NO'.
? y
     SOLUTION COMPLETE.
     DO YOU WANT RESULTS PRINTED TO YOUR TERMINAL,
     TO A FILE, OR BOTH?
     ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? t
     DO YOU WANT COMPLETE RESULTS OUTPUT?
     ENTER 'YES' OR 'NO'.
? n
     DO YOU WANT TO PLOT RESULTS?
     ENTER 'YES' OR 'NO'.
? n
     OUTPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA?
     ENTER 'YES' OR 'NO'.
? n


     LAST INPUT FILE PROCESSED = 'CANT1I'.


     DO YOU WANT TO MAKE ANOTHER RUN?
     ENTER 'YES' OR 'NO'.
? n


     ********** NORMAL TERMINATION **********
```

Figure 25. (Concluded)

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 91/01/25                                              TIME: 10.30.07

                     SUMMARY OF RESULTS FOR
                   CANTILEVER WALL ANALYSIS

I.--HEADING

  'ANALYSIS OF CANTILEVER RETAINING WALL DESIGNED IN EXAMPLE CANT1
  'FS = 1 FOR ALL ACTIVE PRESSURES

II.--SUMMARY

     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

PASSIVE FACTOR OF SAFETY  :         2.27

MAX. BEND. MOMENT (LB-FT) :       109346.
      AT ELEVATION (FT)   :        -14.00

MAXIMUM DEFLECTION (IN)   :    1.4774E+01
      AT ELEVATION (FT)   :         20.00
```

Figure 26. Summary of results for Example CANT1A

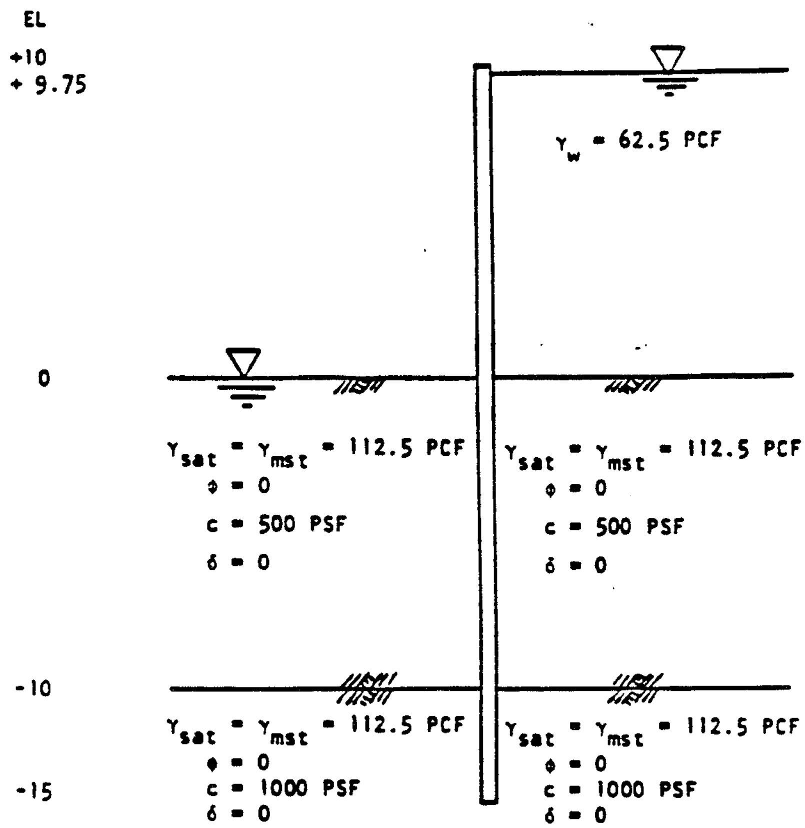


Figure 27. System for Example CANT2

```
1000 'FLOODWALL IN COHESIVE LAYERED SOIL WITH
1010 'HIGH STRENGTH LAYER UNDERLYING WEAKER SOIL
1020 CONTROL C D 1 1
1030 WALL 10
1040 SURFACE BOTHSIDES 1
1050 0 0
1060 SOIL BOTHSIDES STRENGTH 2 0 0
1070 112.5 112.5 0 500 0 0 -10 0 0 0
1080 112.5 112.5 0 1000 0 0 0 0
1090 WATER ELEVATIONS 62.5 9.75 0
1100 FINISH
```

Figure 28. Input file for Example CANT2

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 10.39.37

SOIL PRESSURES FOR
CANTILEVER WALL DESIGN

I.--HEADING

'FLOODWALL IN COHESIVE LAYERED SOIL WITH
'HIGH STRENGTH LAYER UNDERLYING WEAKER SOIL

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

ELEV. (FT)	<-LEFTSIDE PRESSURES-> PASSIVE (PSF)	ACTIVE (PSF)	<---NET PRESSURES----> (SOIL PLUS WATER) ACTIVE (PSF)	PASSIVE (PSF)	<RIGHTSIDE PRESSURES-> ACTIVE (PSF)	PASSIVE (PSF)
10.00	.000	.000	.000	.000	.000	.000
9.75	.000	.000	.000	.000	.000	.000
9.00	.000	.000	46.875	46.875	.000	.000
8.00	.000	.000	109.375	109.375	.000	.000
7.00	.000	.000	171.875	171.875	.000	.000
6.00	.000	.000	234.375	234.375	.000	.000
5.00	.000	.000	296.875	296.875	.000	.000
4.00	.000	.000	359.375	359.375	.000	.000
3.00	.000	.000	421.875	421.875	.000	.000
2.00	.000	.000	484.375	484.375	.000	.000
1.00	.000	.000	546.875	546.875	.000	.000
.00+	.000	.000	609.375	609.375	.000	.000
.00-	1000.000	.000	-390.625	1609.375	.000	1000.000
-1.00	1050.000	.000	-440.625	1659.375	.000	1050.000
-2.00	1100.000	.000	-490.625	1709.375	.000	1100.000
-3.00	1150.000	.000	-540.625	1759.375	.000	1150.000
-4.00	1200.000	.000	-590.625	1809.375	.000	1200.000
-5.00	1250.000	.000	-640.625	1859.375	.000	1250.000
-6.00	1300.000	.000	-690.625	1909.375	.000	1300.000
-7.00	1350.000	.000	-740.625	1959.375	.000	1350.000
-8.00	1400.000	.000	-790.625	2009.375	.000	1400.000
-9.00	1450.000	.000	-840.625	2059.375	.000	1450.000
-10.00+	1500.000	.000	-1390.625	2609.375	.000	1500.000
-10.00-	2500.000	.000	-1390.625	2609.375	.000	2500.000

Figure 29. Initial soil pressures for Example CANT2 (Continued)

-11.00	2550.000	.000	-1940.625	3159.375	.000	2550.000
-12.00	2600.000	.000	-1990.625	3209.375	.000	2600.000
-13.00	2650.000	.000	-2040.625	3259.375	.000	2650.000
-14.00	2700.000	.000	-2090.625	3309.375	.000	2700.000
-15.00	2750.000	.000	-2140.625	3359.375	.000	2750.000
-16.00	2800.000	.000	-2190.625	3409.375	.000	2800.000
-17.00	2850.000	.000	-2240.625	3459.375	.000	2850.000
-18.00	2900.000	.000	-2290.625	3509.375	.000	2900.000
-19.00	2950.000	.000	-2340.625	3559.375	.000	2950.000
-20.00	3000.000	.000	-2390.625	3609.375	.000	3000.000
-21.00	3050.000	.000	-2440.625	3659.375	.000	3050.000
-22.00	3100.000	.000	-2490.625	3709.375	.000	3100.000
-23.00	3150.000	.000	-2540.625	3759.375	.000	3150.000
-24.00	3200.000	.000	-2590.625	3809.375	.000	3200.000
-25.00	3250.000	.000	-2640.625	3859.375	.000	3250.000
-26.00	3300.000	.000	-2690.625	3909.375	.000	3300.000
-27.00	3350.000	.000	-2740.625	3959.375	.000	3350.000
-28.00	3400.000	.000	-2790.625	4009.375	.000	3400.000
-29.00	3450.000	.000	-2840.625	4059.375	.000	3450.000
-30.00	3500.000	.000	-2890.625	4109.375	.000	3500.000
-31.00	3550.000	.000	-2940.625	4159.375	.000	3550.000

Figure 29. (Concluded)

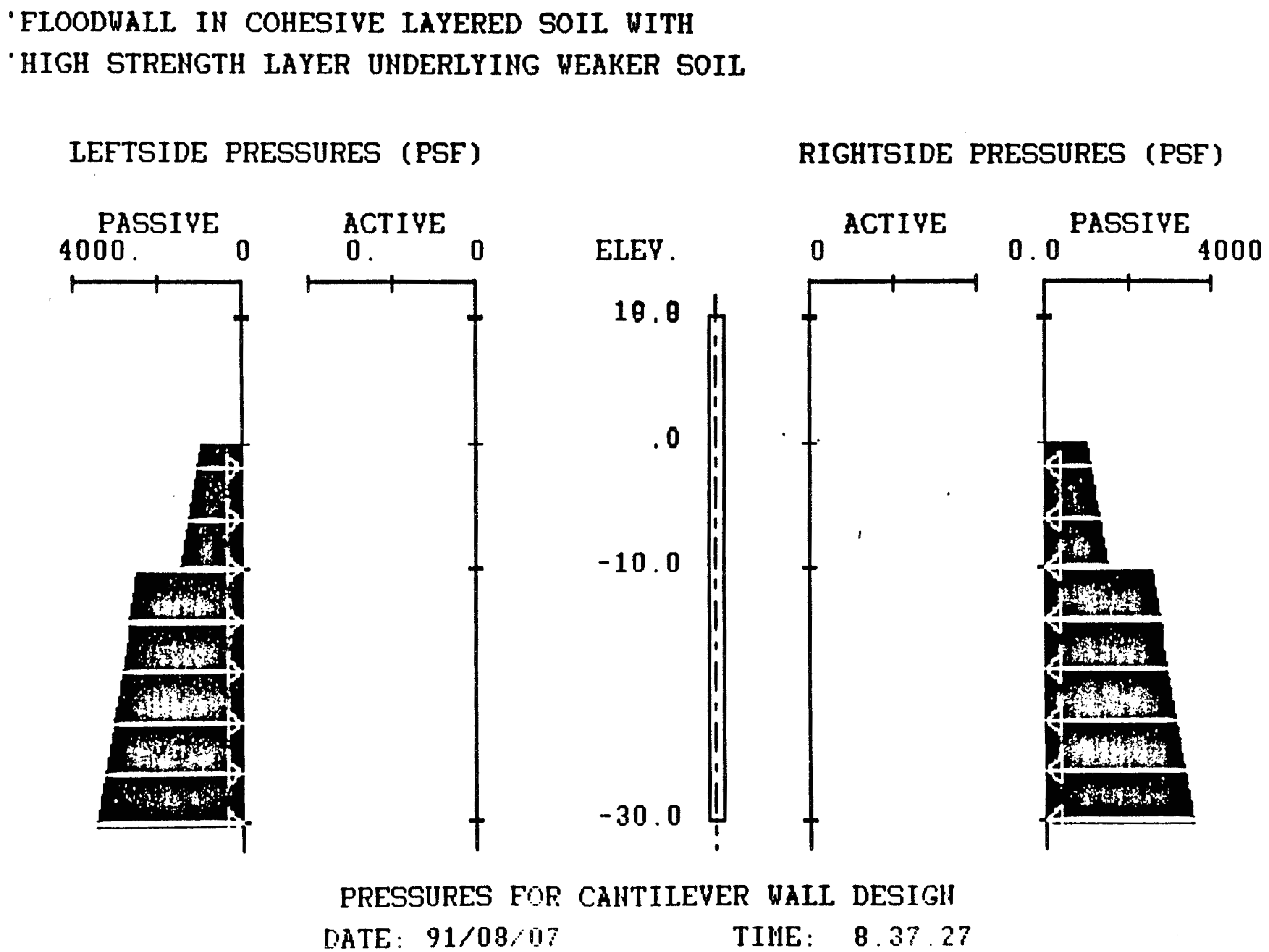


Figure 30. Initial active and passive pressures for Example CANT2

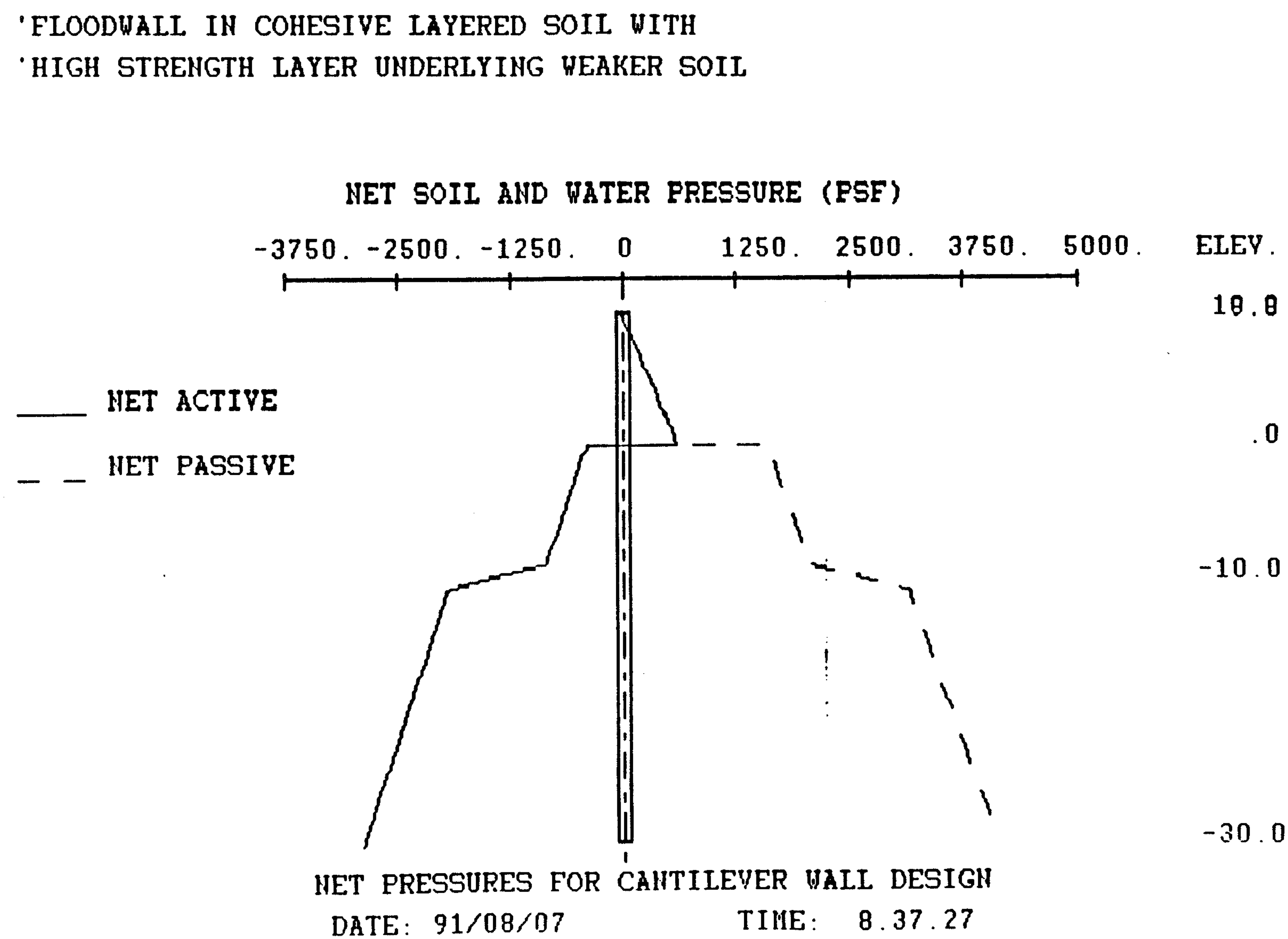


Figure 31. Initial net pressures for Example CANT2

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 91/01/25                                               TIME: 14.09.19

                   SUMMARY OF RESULTS FOR
                   CANTILEVER WALL DESIGN

I.--HEADING

  'FLOODWALL IN COHESIVE LAYERED SOIL WITH
  'HIGH STRENGTH LAYER UNDERLYING WEAKER SOIL

II.--SUMMARY

     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

WALL BOTTOM ELEV. (FT)     :        -13.58
      PENETRATION (FT)     :         13.58

MAX. BEND. MOMENT (LB-FT)  :        18648.
      AT ELEVATION (FT)    :         -6.00

MAX. SCALED DEFL. (LB-IN3):     5.0887E+09
      AT ELEVATION (FT)    :         10.00

     (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
     ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
     IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 32. Summary of results for Example CANT2

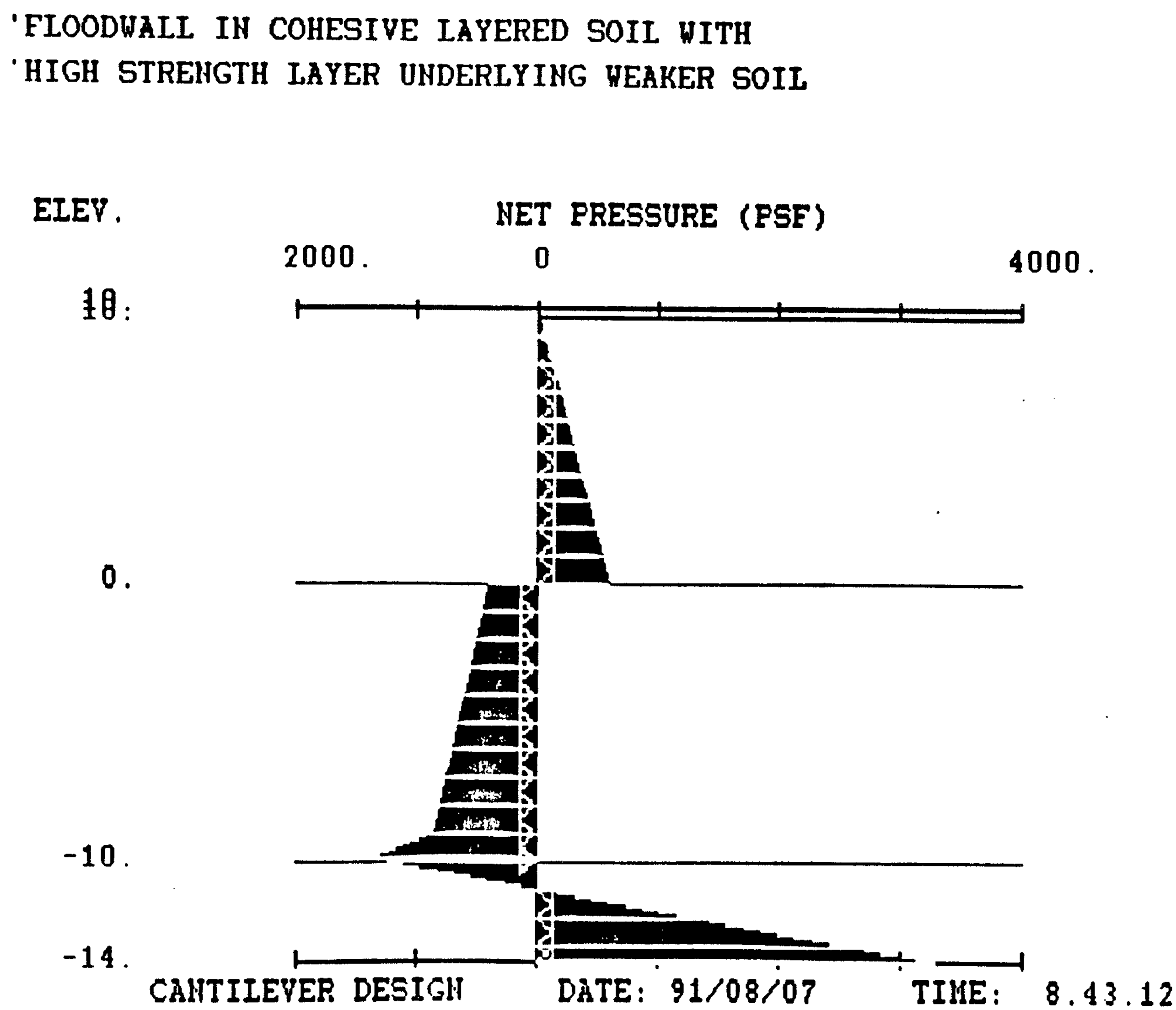


Figure 33. Final design net pressures for Example CANT2

Example CANT3

91. The floodwall/levee system shown in Figure 34 requires a wedge method for evaluation of the soil pressures. The input file for this system is given in Figure 35, and execution of the program is shown in Figure 36. The plot of input geometry presented in Figure 37 is distorted since the plot limits specified (see Figure 36) do not define a square.

92. The sweep search wedge method was selected (see Figure 36) for evaluation of the design pressures. The resulting pressures are shown in Figures 38, 39, and 40. The weak layer between el -1 and -4 ft on the left side results in low passive pressures on the left side of the wall. When the leftside passive, rightside active, and net water pressures are combined, the total net pressure in the vicinity of the weak layer has a spurious reversal of direction near the weak layer. Execution was terminated at this point, the program was restarted, and the fixed wedge method was selected for solution.

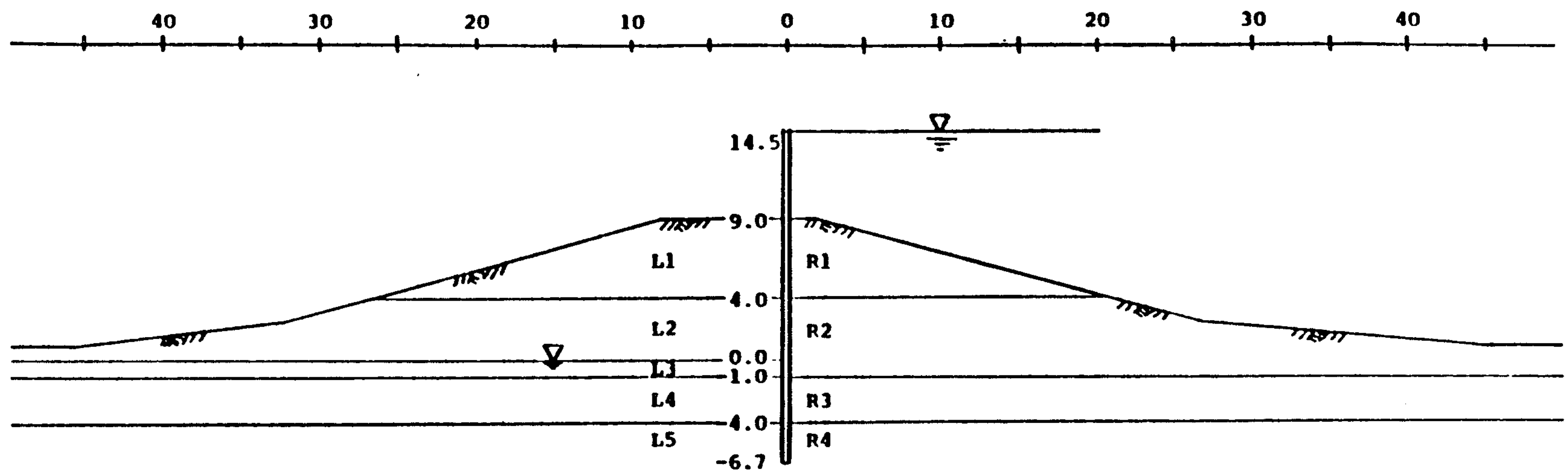
93. The soil pressures produced by the fixed wedge method are shown in Figures 41, 42, and 43. It should be emphasized that the fixed wedge tends to overestimate passive pressures for this situation. It is the responsibility of the user to judge the validity of the results.

94. The summary of results and complete output for this example are tabulated in Figures 44 and 45.

Anchored Walls

Example ANCH1

95. The anchored wall shown in Figure 46 was designed for a factor of safety of 1.0 for all effects. The input file for this system is given in Figure 47. Even though the soil surfaces are unsymmetric, the soil layer data may be described as "symmetric" since the layer data are the same (including layer bottom elevation and bottom slope) for each soil layer on each side. Note that the moist unit weight has been used for the soil above el 22 ft for the soil on the rightside and the buoyant unit weight has been calculated by the program from the saturated unit weight for the soil below water on each side of the wall. The plot of input geometry and a schematic of the surface surcharge loads are shown in Figures 48 and 49, respectively. An echoprint of the input data is shown in Figure 50.



a. Wall and soil profile

Layer	γ (PSF)	ϕ (DEG)
R1	102.5	23
R2	122.5	30
R3	102.5	23
R4	122.5	30
L1	107.5	23
L2	122.0	30
L3	122.5	30
L4	102.5	23
L5	122.5	30

b. Soil properties

Figure 34. System for Example CANT3

```
1000 'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
1010 'IRREGULAR GROUND SURFACE
1020 'INTERSPERSED STRONG AND WEAK SOIL LAYERS
1030 CONTROL  C  D     1.50     1.50
1040 WALL        14.50           -
1050 SURFACE RIGHTSIDE   4
1060      0.00       9.00       2.00       9.00      26.50      2.50
1070     45.00       1.00
1080 SURFACE  LEFTSIDE   4
1090      0.00       9.00       8.00       9.00      32.50      2.50
1100     46.00       1.00
1110 SOIL RIGHTSIDE  STRENGTH    4    0.00    0.00
1120 102.50 102.50  23.00  0.00  0.00  0.00  4.00  0.00  0.00  0.00
1130 122.50 122.50  30.00  0.00  0.00  0.00 -1.00  0.00  0.00  0.00
1140 102.50 102.50  23.00  0.00  0.00  0.00 -4.00  0.00  0.00  0.00
1150 122.50 122.50  30.00  0.00  0.00  0.00  0.00  0.00
1160 SOIL  LEFTSIDE  STRENGTH    5    0.00    0.00
1170 107.50 107.50  23.00  0.00  0.00  0.00  4.00  0.00  0.00  0.00
1180 122.00 122.00  30.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
1190 122.50 122.50  30.00  0.00  0.00  0.00 -1.00  0.00  0.00  0.00
1200 102.50 102.50  23.00  0.00  0.00  0.00 -4.00  0.00  0.00  0.00
1210 122.50 122.50  30.00  0.00  0.00  0.00  0.00  0.00
1220 WATER ELEVATIONS    62.50    14.50    0.00
1230 FINISH
```

Figure 35. Input file for Example CANT3

```
        PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                                     BY CLASSICAL METHODS
        DATE: 08/24/89                                                TIME: 1:17:47

        ARE INPUT DATA TO BE READ FROM YOUR TERMINAL OR A FILE?
        ENTER 'TERMINAL' OR 'FILE'.
? F
        ENTER INPUT FILE NAME (6 CHARACTERS MAXIMUM).
           ?cant3i
        INPUT COMPLETE.
        DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
        TO A FILE, TO BOTH, OR NEITHER?
        ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? n
        INPUT COMPLETE.
        DO YOU WANT TO EDIT INPUT DATA?
        ENTER 'YES' OR 'NO'.
? n
        DO YOU WANT TO PLOT INPUT DATA?
        ENTER 'YES' OR 'NO'.
? y
        MAXIMA AND MINIMA DEFINED BY INPUT DATA

        <-ELEVATION (FT)->         <DIST. FROM WALL (FT)>
        MAXIMUM    MINIMUM         LEFTSIDE     RIGHTSIDE
          14.50      -4.00           46.00          45.00

        ENTER DESIRED PLOT LIMITS

        <------ELEVATION (FT)------>    <DIST. FROM WALL (FT)>
        TOP OF PLOT   BOTTOM OF PLOT    LEFTSIDE     RIGHTSIDE
? 15 -5 50 50

             -------------------------------------
             -(NOTE: GEOMETRY PLOT PRODUCED HERE.)-
             -------------------------------------

        DO YOU WANT TO REPLOT INPUT GEOMETRY WITH DIFFERENT LIMITS?
        ENTER 'YES' OR 'NO'.
? n
        DO YOU WANT TO CONTINUE WITH THE SOLUTION?
        ENTER 'YES' OR 'NO'.
? y
        DO YOU WANT SOIL PRESSURES CALCULATED BY THE SWEEP SEARCH WEDGE METHOD
        OR BY THE FIXED SURFACE WEDGE METHOD?
        ENTER 'SWEEP' OR 'FIXED'.
? s
        DO YOU WANT A LISTING OF SOIL PRESSURES
        BEFORE CONTINUING WITH THE DESIGN?
        ENTER 'YES' OR 'NO'.
? y
```

Figure 36. Program execution for Example CANT3 (Continued)

```
    DO YOU WANT SOIL PRESSURES PRINTED TO YOUR TERMINAL, TO A FILE, OR BOTH?
    ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? f
    ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? cant3o
    DO YOU WANT TO PLOT SOIL PRESSURES?
    ENTER 'YES' OR 'NO'.
? y

        ---------------------------------------
        -(NOTE: PRESSURE PLOTS PRODUCED HERE.)-
        ---------------------------------------

    DO YOU WANT TO CONTINUE WITH THE SOLUTION?
    ENTER 'YES' OR 'NO'.
? n
    DO YOU WANT TO EDIT INPUT DATA?
    ENTER 'YES' OR 'NO'.
? n


    LAST INPUT FILE PROCESSED = 'CANT3I'.

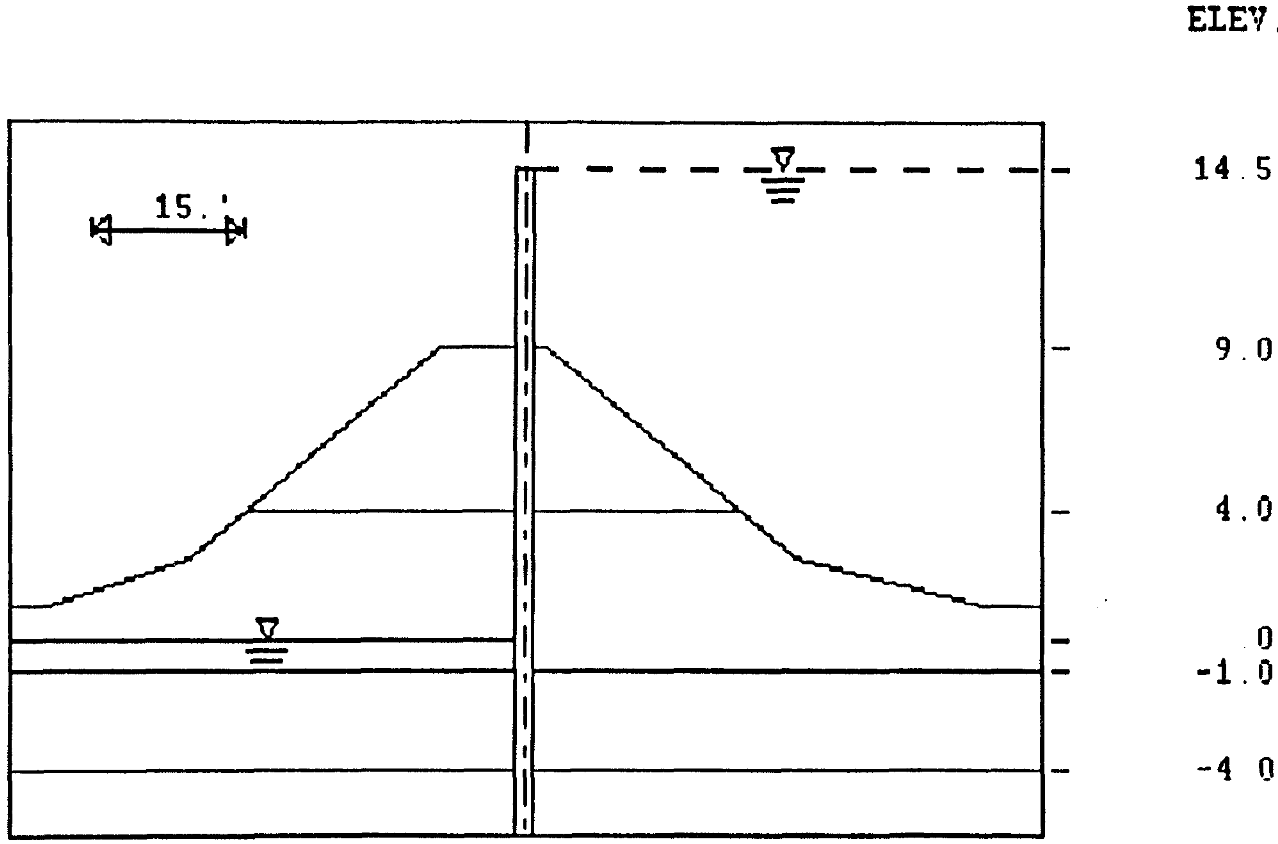

    OUTPUT SAVED IN FILE 'CANT3O'.


    DO YOU WANT TO MAKE ANOTHER RUN?
    ENTER 'YES' OR 'NO'.
? n


    ********** NORMAL TERMINATION **********
```

Figure 36. (Concluded)

'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
'IRREGULAR GROUND SURFACE



***** INPUT GEOMETRY *****
DATE: 91/08/07 TIME: 8.55.08

Figure 37. Program plot of input geometry for Example CANT3

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 14.30.34

SOIL PRESSURES FOR
CANTILEVER WALL DESIGN

I.--HEADING

'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
'IRREGULAR GROUND SURFACE
'INTERSPERSED STRONG AND WEAK SOIL LAYERS

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

	<-LEFTSIDE PRESSURES->		<---NET PRESSURES----> (SOIL PLUS WATER)		<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
14.50	.000	.000	.000	.000	.000	.000
13.50	.000	.000	62.500	62.500	.000	.000
12.50	.000	.000	125.000	125.000	.000	.000
11.50	.000	.000	187.500	187.500	.000	.000
10.50	.000	.000	250.000	250.000	.000	.000
9.50	.000	.000	312.500	312.500	.000	.000
9.00	.000	.000	343.750	343.750	.000	.000
8.50	93.974	30.743	292.465	379.224	11.439	34.967
8.00	187.948	61.486	241.180	414.698	22.879	69.934
7.50	281.922	92.229	189.895	440.526	34.318	95.255
6.50	469.871	153.716	86.844	477.213	56.715	130.929
5.67	626.102	204.826	.000	512.346	74.149	165.219
5.50	657.819	215.202	-17.631	519.478	77.688	172.180
4.50	845.767	276.688	-123.244	563.255	97.523	214.943
4.00	1050.726	279.489	-296.176	701.688	98.300	324.927
3.50	1256.551	281.303	-468.427	838.955	100.624	432.758
2.50	1429.349	339.226	-553.305	906.950	126.044	496.176
1.50	1604.186	397.135	-640.626	1005.525	151.060	590.160
.50	1795.248	454.643	-744.007	1107.223	176.241	686.866
.00	1866.377	479.744	-771.145	1162.352	188.981	735.846
-.50	1898.738	497.538	-790.696	1193.582	201.792	784.870
-1.00	1681.018	565.104	-536.943	1066.912	237.825	725.766
-1.50	1147.520	631.301	31.202	925.157	272.472	650.208
-2.50	1145.500	651.375	53.298	900.205	292.548	645.329
-3.50	1185.500	666.658	33.374	893.594	312.624	654.002
-4.00	1700.696	613.900	-500.755	1167.445	293.691	875.096
-4.50	2325.258	565.511	-1142.995	1437.220	276.014	1096.481
-5.50	2078.532	590.496	-871.213	1482.311	301.069	1166.556
-6.50	2011.210	609.770	-778.876	1550.244	326.084	1253.763
-7.50	2016.781	630.558	-759.231	1622.582	351.300	1346.890
-8.50	2057.014	654.046	-773.948	1697.049	376.817	1444.846

Figure 38. Initial soil pressures for Example CANT3 by sweep search wedge method

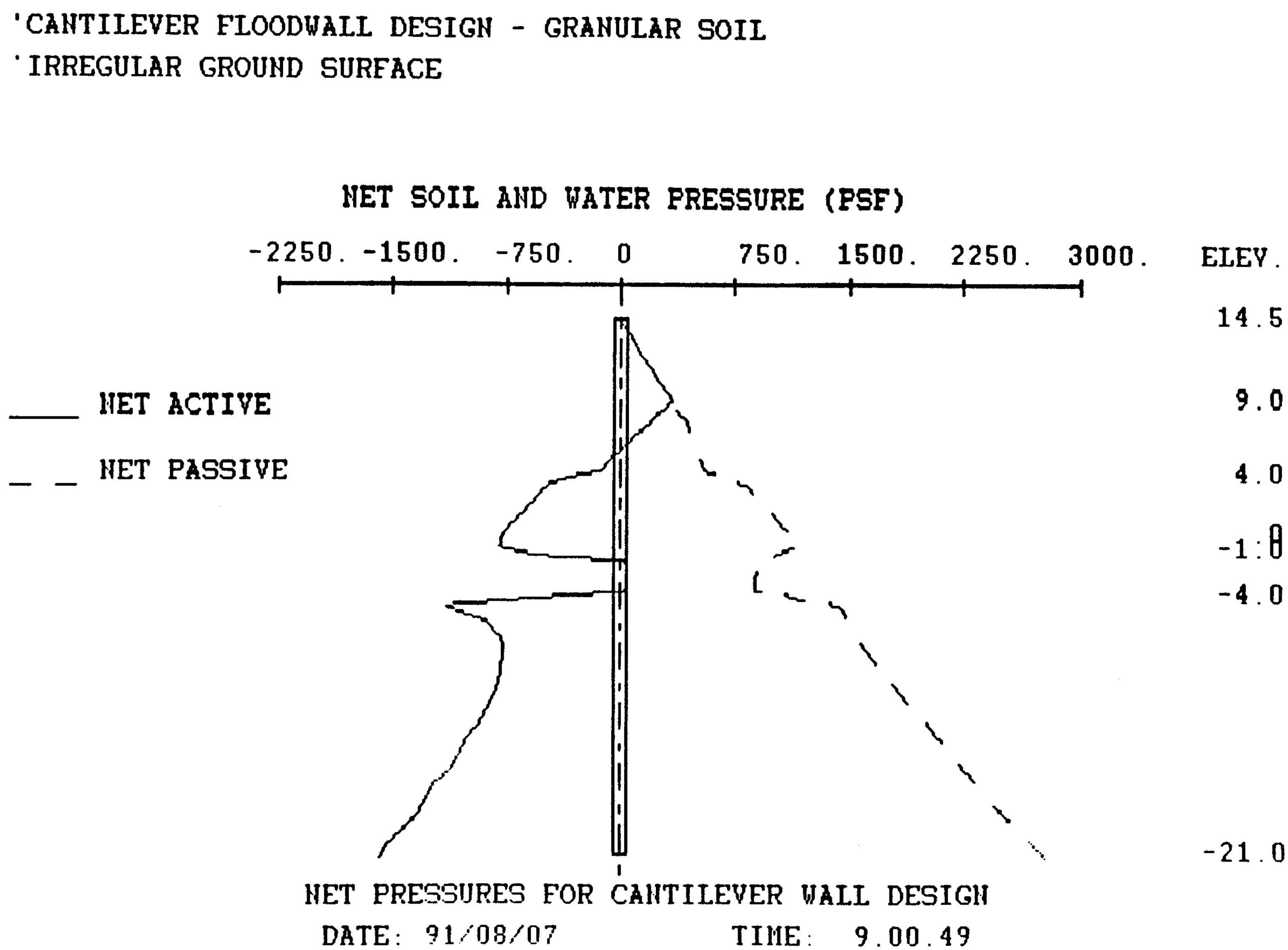


Figure 39. Net pressures by sweep search method for Example CANT3

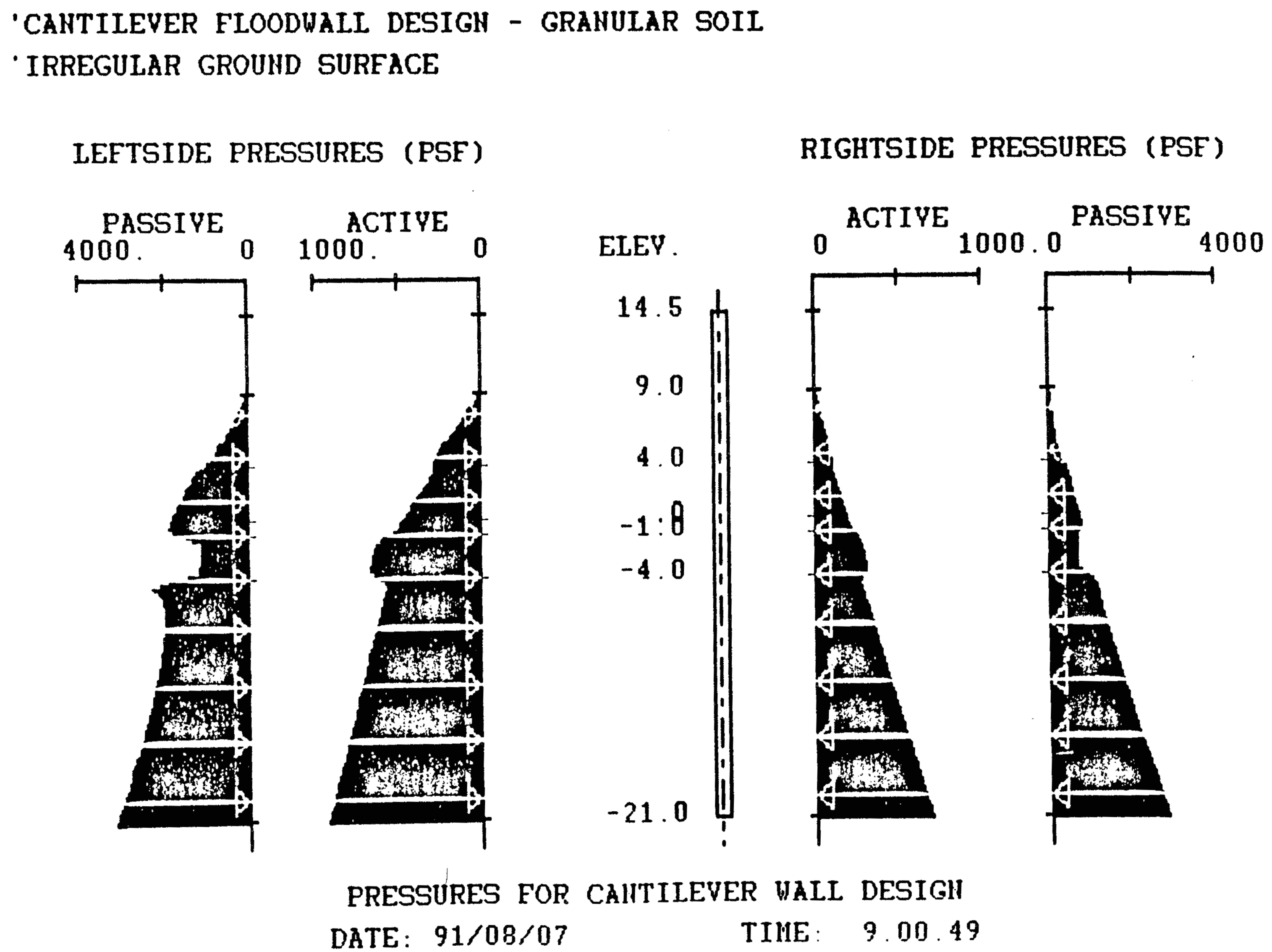


Figure 40. Active and passive soil pressures by sweep search method for Example CANT3

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 14.55.51

SOIL PRESSURES FOR
CANTILEVER WALL-DESIGN

I.--HEADING

'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
'IRREGULAR GROUND SURFACE
'INTERSPERSED STRONG AND WEAK SOIL LAYERS

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY FIXED SURFACE WEDGE METHOD.

LEFTSIDE SOIL PRESSURES DETERMINED BY FIXED SURFACE WEDGE METHOD.

	<-LEFTSIDE PRESSURES->		<---NET PRESSURES----> (SOIL PLUS WATER)		<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
14.50	.000	.000	.000	.000	.000	.000
13.50	.000	.000	62.500	62.500	.000	.000
12.50	.000	.000	125.000	125.000	.000	.000
11.50	.000	.000	187.500	187.500	.000	.000
10.50	.000	.000	250.000	250.000	.000	.000
9.50	.000	.000	312.500	312.500	.000	.000
9.00	.000	.000	343.750	343.750	.000	.000
8.50	93.974	30.743	292.466	379.296	11.439	35.039
8.00	187.948	61.487	241.190	414.660	22.887	69.896
7.50	281.921	92.230	189.934	447.067	34.355	101.796
6.50	469.869	153.716	86.599	503.203	56.468	156.920
5.65	626.715	206.329	.000	546.517	73.821	199.953
5.50	655.201	215.884	-15.728	554.384	76.973	207.768
4.50	877.715	268.122	-159.872	628.279	92.844	271.401
4.00	1050.361	279.895	-297.563	703.792	96.548	327.437
3.50	1235.723	290.701	-446.473	793.256	101.751	396.457
2.50	1494.709	339.005	-621.151	923.105	123.559	512.110
1.50	1696.395	397.236	-734.912	1029.440	148.983	614.176
.50	1894.575	454.600	-845.277	1136.768	174.298	716.368
.00	1983.799	477.968	-891.259	1198.494	186.289	770.212
-.50	1991.890	508.192	-881.223	1200.303	204.417	802.245
-1.00	1869.335	564.811	-727.846	1121.403	235.239	779.965
-1.50	1748.609	615.173	-579.605	1042.409	262.755	751.332
-2.50	1695.647	652.471	-498.417	1024.485	290.980	770.706
-3.50	1785.201	644.281	-579.203	1121.538	299.748	859.569
-4.00	1938.599	610.637	-742.363	1258.882	289.986	963.268
-4.50	2103.093	578.851	-915.218	1407.364	281.625	1079.965
-5.50	2232.868	578.243	-1029.978	1547.458	296.639	1219.450
-6.50	2289.035	599.585	-1060.223	1626.438	322.562	1319.773
-7.50	2354.047	619.706	-1099.909	1708.511	347.889	1421.967
-8.50	2421.707	640.273	-1142.110	1790.180	373.347	1524.202

Figure 41. Initial pressures for Example CANT3
by fixed surface wedge method

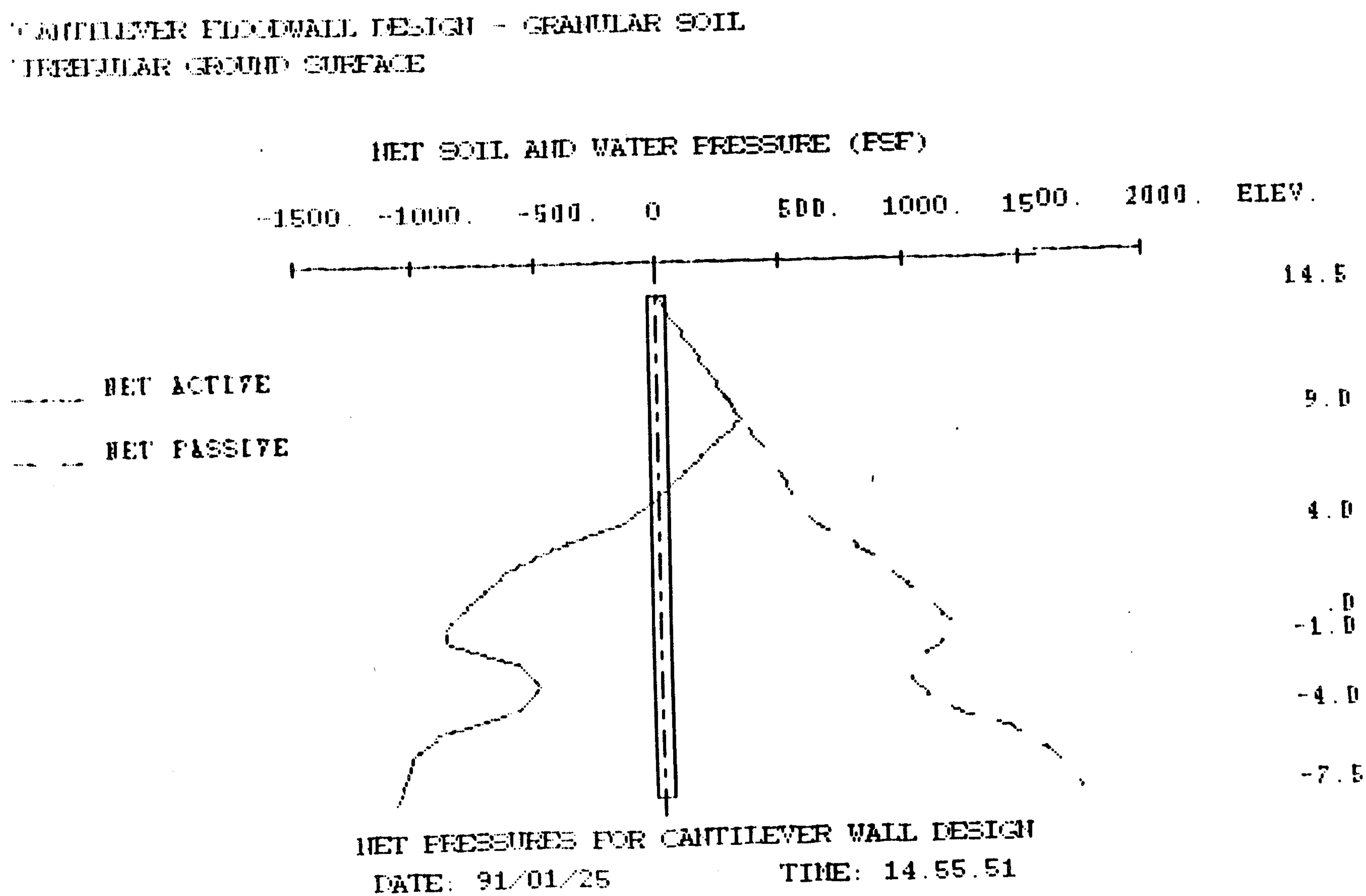


Figure 42. Net pressure by fixed surface wedge method for Example CANT3

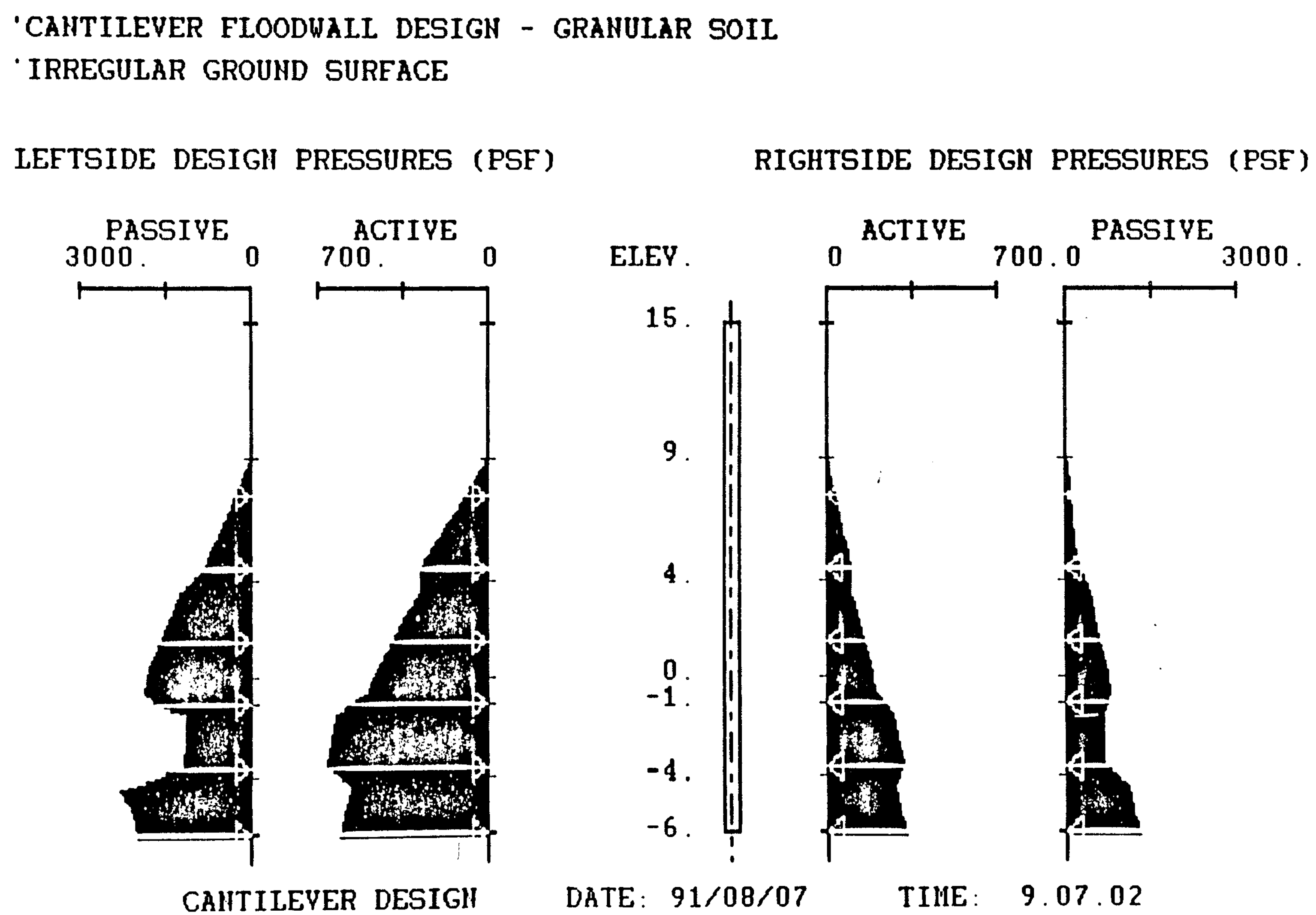


Figure 43. Active and passive soil pressures by fixed surface wedge method for Example CANT3

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 91/01/25                                              TIME: 14.58.23

                     ****************************
                     *  SUMMARY OF RESULTS FOR  *
                     *  CANTILEVER WALL DESIGN  *
                     ****************************

I.--HEADING

  'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
  'IRREGULAR GROUND SURFACE
  'INTERSPERSED STRONG AND WEAK SOIL LAYERS

II.--SUMMARY

    RIGHTSIDE SOIL PRESSURES DETERMINED BY FIXED SURFACE WEDGE METHOD.

     LEFTSIDE SOIL PRESSURES DETERMINED BY FIXED SURFACE WEDGE METHOD.

WALL BOTTOM ELEV. (FT)    :         -5.29
     PENETRATION (FT)     :         14.29

MAX. BEND. MOMENT (LB-FT) :        10352.
     AT ELEVATION (FT)    :          1.50

MAX. SCALED DEFL. (LB-IN3):    1.8430E+09
     AT ELEVATION (FT)    :         14.50

    (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
    ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
    IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 44. Summary of results for Example CANT3

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 14.58.23

COMPLETE RESULTS FOR
CANTILEVER WALL DESIGN

I.--HEADING

'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
'IRREGULAR GROUND SURFACE
'INTERSPERSED STRONG AND WEAK SOIL LAYERS

II.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
14.50	0.	0.	1.8430E+09	.00
13.50	10.	31.	1.6901E+09	62.50
12.50	83.	125.	1.5373E+09	125.00
11.50	281.	281.	1.3846E+09	187.50
10.50	667.	500.	1.2324E+09	250.00
9.50	1302.	781.	1.0814E+09	312.50
9.00	1733.	945.	1.0067E+09	343.75
8.50	2247.	1104.	9.3270E+08	292.47
8.00	2833.	1238.	8.5970E+08	241.19
7.50	3480.	1346.	7.8792E+08	189.93
6.50	4903.	1484.	6.4919E+08	86.60
5.65	6180.	1520.	5.3831E+08	.00
5.50	6413.	1519.	5.1895E+08	-15.73
4.50	7901.	1431.	3.9978E+08	-159.87
4.00	8591.	1317.	3.4516E+08	-297.56
3.50	9206.	1131.	2.9424E+08	-446.47
2.50	10085.	597.	2.0455E+08	-621.15
1.50	10352.	-81.	1.3219E+08	-734.91
.50	9886.	-871.	7.7618E+07	-845.28
.00	9343.	-1305.	5.6798E+07	-891.26
-.31	8902.	-1577.	4.6061E+07	-885.12
-.50	8580.	-1739.	4.0006E+07	-791.58
-1.00	7621.	-2075.	2.6914E+07	-550.47
-1.50	6525.	-2290.	1.7110E+07	-309.36
-2.50	4161.	-2358.	5.4439E+06	172.86
-3.50	1970.	-1944.	9.9318E+05	655.09
-4.00	1090.	-1556.	2.7739E+05	896.20
-4.50	433.	-1048.	4.0337E+04	1137.31
-5.29	0.	0.	0.0000E+00	1517.94

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 45. Complete results for Example CANT3

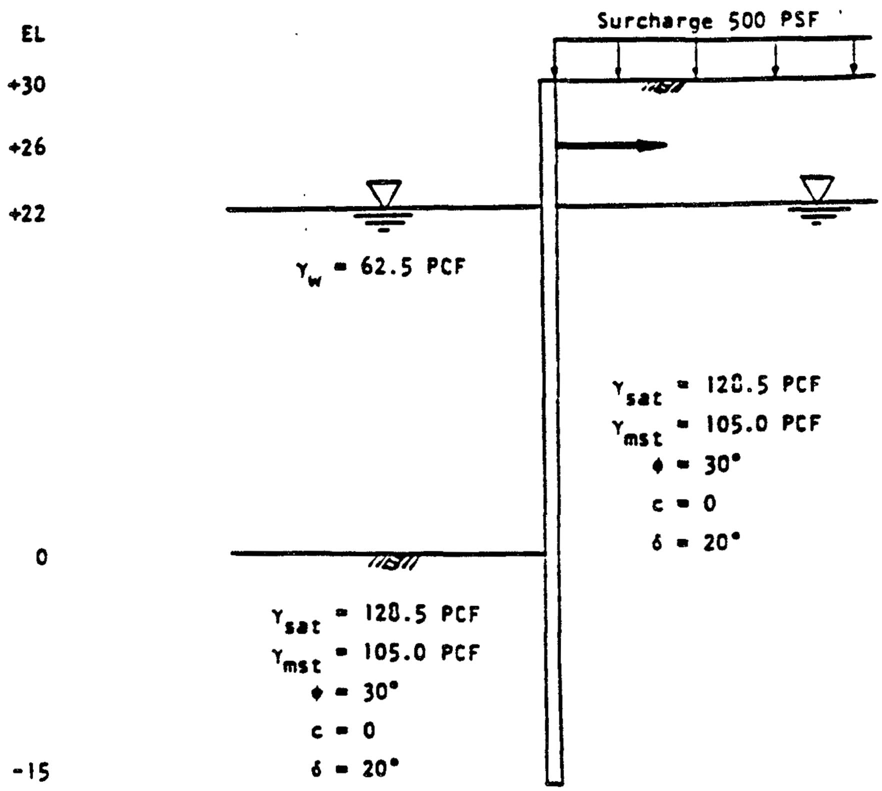
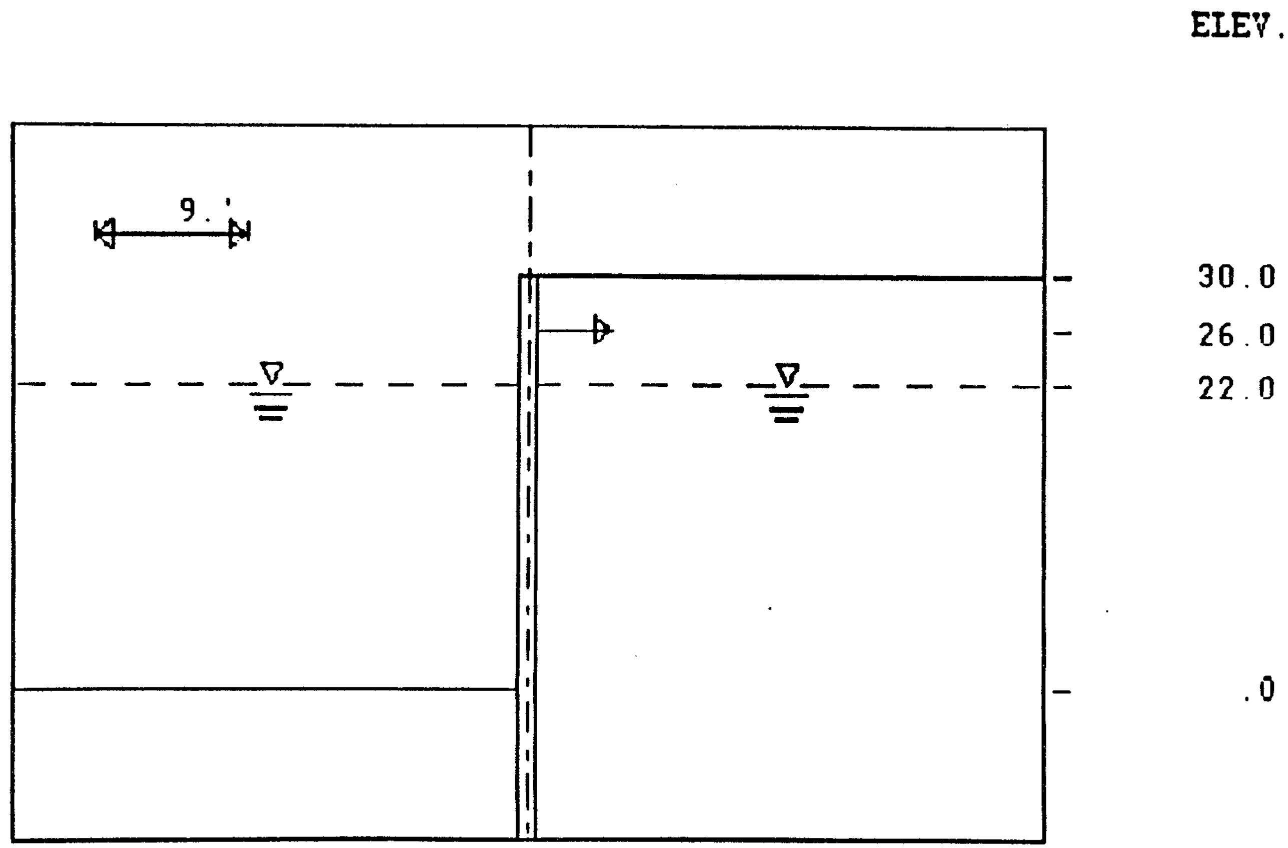


Figure 46. System for Example ANCH1

```
1000 'ANCHORED RETAINING WALL IN GRANULAR SOIL
1010 'DESIGN FOR FS = 1 ON BOTH ACTIVE AND PASSIVE
1020 CONTROL  A  D    1.00    1.00
1030 WALL      30.00      26.00
1040 SURFACE RIGHTSIDE   1
1050      0.00      30.00
1060 SURFACE  LEFTSIDE   1
1070      0.00      0.00
1080 SOIL BOTH  STRENGTH    1    0.00    0.00
1090  128.50  105.00   30.00    0.00   20.00    0.00    0.00    0.00
1100 WATER ELEVATIONS    62.50    22.00    22.00
1110 VERTICAL UNIFORM RIGHTSIDE      500.00
1120 FINISH
```

Figure 47. Input file for Example ANCH1

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE



***** INPUT GEOMETRY *****
DATE: 91/08/07 TIME: 9.47.08

Figure 48. Program plot of input geometry for Example ANCH1

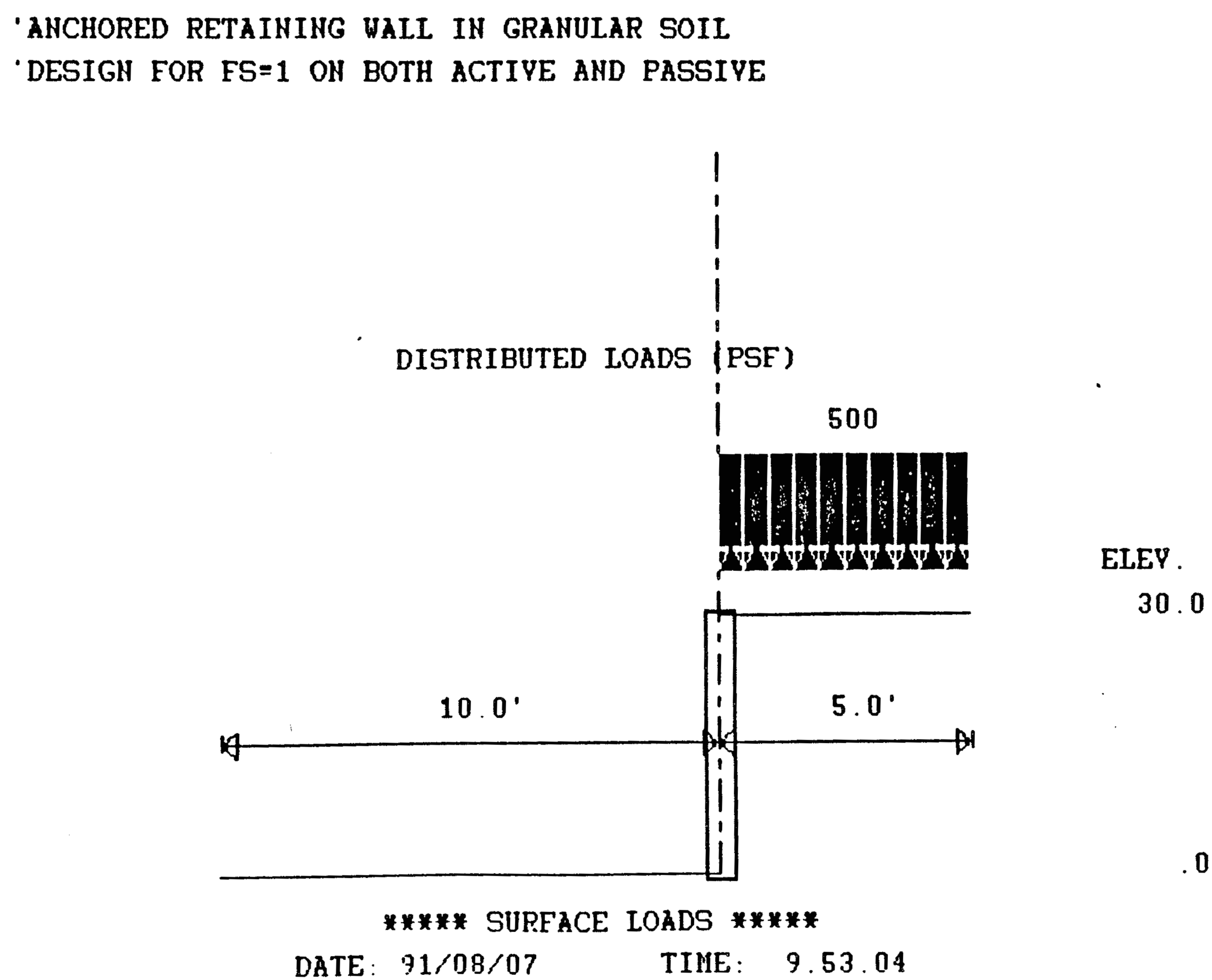


Figure 49. Schematic of surface surcharge loads for Example ANCH1

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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                              BY CLASSICAL METHODS
DATE: 91/01/25                                                TIME: 15.13.01

                              INPUT DATA

I.--HEADING:
  'ANCHORED RETAINING WALL IN GRANULAR SOIL
  'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

II.--CONTROL
  ANCHORED   WALL DESIGN
  LEVEL 1 FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
  LEVEL 1 FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
  ELEVATION AT TOP OF WALL       =    30.00 (FT)
  ELEVATION AT ANCHOR            =    26.00 (FT)

IV.--SURFACE POINT DATA

  IV.A--RIGHTSIDE
     DIST. FROM      ELEVATION
     WALL (FT)         (FT)
            .00         30.00

  IV.B-- LEFTSIDE
     DIST. FROM      ELEVATION
     WALL (FT)         (FT)
            .00           .00

V.--SOIL LAYER DATA
  V.A.--RIGHTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                   ANGLE OF             ANGLE OF                                <-SAFETY->
  SAT.    MOIST    INTERNAL    COH-      WALL        ADH-      <--BOTTOM-->     <-FACTOR->
 WGHT.    WGHT.    FRICTION    ESION    FRICTION     ESION     ELEV.  SLOPE     ACT.  PASS.
 (PCF)    (PCF)     (DEG)      (PSF)     (DEG)       (PSF)     (FT)  (FT/FT)
128.50   105.00     30.00        .0      20.00         .0                        DEF   DEF

  V.B.-- LEFTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                   ANGLE OF             ANGLE OF                                <-SAFETY->
  SAT.    MOIST    INTERNAL    COH-      WALL        ADH-      <--BOTTOM-->     <-FACTOR->
 WGHT.    WGHT.    FRICTION    ESION    FRICTION     ESION     ELEV.  SLOPE     ACT.  PASS.
 (PCF)    (PCF)     (DEG)      (PSF)     (DEG)       (PSF)     (FT)  (FT/FT)
128.50   105.00     30.00        .0      20.00         .0                        DEF   DEF

VI.--WATER DATA
     UNIT WEIGHT          =    62.50 (PCF)
     RIGHTSIDE ELEVATION  =    22.00 (FT)
      LEFTSIDE ELEVATION  =    22.00 (FT)
     NO SEEPAGE

VII.--SURFACE LOADS

  VII.A.--RIGHTSIDE SURFACE LOADS

    VII.A.1.--SURFACE LINE LOADS
     NONE

    VII.A.2.--SURFACE DISTRIBUTED LOADS
     UNIFORM LOAD =      500.00 (PSF)

  VII.B.-- LEFTSIDE SURFACE LOADS
     NONE

VIII.--HORIZONTAL LOADS
     NONE
```

Figure 50. Echoprint of input data for Example ANCH1

96. The summary of results and complete results (excluding final design soil pressures) for each of the three methods of anchored wall design are given in Figures 51 through 54. Plots of the results for the free earth method are shown in Figures 55 through 58. Similar plots are available for the equivalent beam and fixed earth design methods.

97. Preliminary design data resulting from application of Rowe's moment reduction are shown in Figure 59. The properties of the sheet pile sections incorporated in CWALSHT are presented, along with the allowable stress and modulus of elasticity for these sections input during execution. As many as five additional sections may be supplied by the user during execution. The results of applying Rowe's moment reduction coefficients are shown in Part III of Figure 59. Note that some of the available sections do not admit to application of a moment reduction. Ratios of allowable moment to the reduced free earth moment (maximum bending moment from the free earth design method times the reduction coefficient) are shown in the last two columns of Part III of Figure 59. A value of this ratio less than 1.0 indicates that the section will be over-stressed.

98. Curves of Rowe's moment reduction coefficients for the particular value of wall height ratio ($\alpha = 0.78$) are shown in Figure 60. Also shown on this plot are the ratios (shown as circles) of allowable bending moment to the maximum free earth moment for sheet pile sections that fall within the limits of the plot. If the circle for a section lies above the curve for one of the "loose" or "dense" descriptors, that section will not be over-stressed in this wall/soil system.

<u>Example ANCH2</u>

99. The anchored wall shown in Figure 61 was designed using the automatic seepage option. The input file and echoprint of input for this system are given in Figures 62 and 63. The initial soil pressures, Figure 64, are obtained for a beginning trial seepage gradient of 0.0001. Because the design depth of penetration is different for each anchored wall method, the final seepage gradient and, hence, final design pressures will be unique for each procedure.

100. The summary of results, Figure 65, presents the design parameters obtained for each method. Complete results and final design soil pressures for the free earth method are shown in Figures 66 and 67. Similar results as well as graphical output may be selected for any or all of the three methods employed for anchored wall design.

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 91/01/25                                            TIME: 15.15.56

                      SUMMARY OF RESULTS FOR
                       ANCHORED WALL DESIGN

I.--HEADING

  'ANCHORED RETAINING WALL IN GRANULAR SOIL
  'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

II.--SUMMARY

    RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
    AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

     LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
    AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

METHOD                     :   FREE EARTH      EQUIV. BEAM     FIXED EARTH

WALL BOTTOM ELEV. (FT)     :        -8.46           -13.85          -14.40
     PENETRATION (FT)      :         8.46            13.85           14.40

MAX. BEND. MOMENT (LB-FT)  :      -71921.          -54816.         -51212.
     AT ELEVATION (FT)     :         9.00            11.00           11.00

MAX. SCALED DEFL. (LB-IN3) :   1.4639E+10      -7.9612E+09      9.3456E+09
     AT ELEVATION (FT)     :         9.00           -13.85           10.00

ANCHOR FORCE (LB)          :        8471.            7410.           7170.

    (NOTE: PENETRATION FOR EQUIVALENT BEAM
    METHOD DOES NOT INCLUDE INCREASE
    PRESCRIBED BY DRAFT EM 1110-2-2906.)

    (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
    ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
    IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 51. Summary of results for Example ANCH1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 15.15.56

COMPLETE RESULTS FOR
ANCHORED WALL DESIGN
BY FREE EARTH METHOD

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

II.--RESULTS (ANCHOR FORCE = 8471. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	0.	0.	-5.4160E+09	139.69
29.00	75.	154.	-4.0628E+09	169.03
28.00	318.	338.	-2.7093E+09	198.36
27.00	761.	551.	-1.3553E+09	227.70
26.00	1430.	793.	0.0000E+00	257.03
26.00	1430.	-7678.	0.0000E+00	257.03
25.00	-6114.	-7406.	1.3554E+09	286.37
24.00	-13372.	-7105.	2.7003E+09	315.70
23.00	-20315.	-6775.	4.0221E+09	345.04
22.00	-26912.	-6415.	5.3089E+09	374.37
21.00	-33137.	-6031.	6.5492E+09	392.81
20.00	-38969.	-5629.	7.7323E+09	411.25
19.00	-44389.	-5209.	8.8482E+09	429.69
18.00	-49381.	-4770.	9.8874E+09	448.13
17.00	-53923.	-4313.	1.0841E+10	466.57
16.00	-58000.	-3837.	1.1702E+10	485.01
15.00	-61591.	-3343.	1.2463E+10	503.45
14.00	-64679.	-2830.	1.3117E+10	521.89
13.00	-67245.	-2299.	1.3660E+10	540.33
12.00	-69271.	-1749.	1.4086E+10	558.77
11.00	-70738.	-1181.	1.4393E+10	577.21
10.00	-71627.	-595.	1.4578E+10	595.65
9.00	-71921.	10.	1.4639E+10	614.09
8.00	-71601.	633.	1.4576E+10	632.52
7.00	-70649.	1275.	1.4389E+10	650.96
6.00	-69045.	1935.	1.4080E+10	669.40
5.00	-66772.	2614.	1.3652E+10	687.84
4.00	-63812.	3311.	1.3109E+10	706.28
3.00	-60145.	4026.	1.2455E+10	724.72
2.00	-55753.	4760.	1.1698E+10	743.16
1.00	-50618.	5513.	1.0845E+10	761.60
.00	-44721.	6283.	9.9038E+09	780.04
-1.00	-38108.	6883.	8.8858E+09	419.83
-2.00	-31075.	7123.	7.8020E+09	59.61
-2.17	-29895.	7128.	7.6171E+09	.00
-3.00	-23982.	7003.	6.6645E+09	-300.60
-4.00	-17189.	6522.	5.4855E+09	-660.81
-5.00	-11058.	5681.	4.2767E+09	-1021.03
-6.00	-5947.	4480.	3.0487E+09	-1381.24
-7.00	-2218.	2919.	1.8102E+09	-1741.45
-8.00	-230.	997.	5.6757E+08	-2101.67
-8.46	0.	0.	0.0000E+00	-2266.11

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 52. Complete results for free earth method for Example ANCH1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 15.15.56

COMPLETE RESULTS FOR
ANCHORED WALL DESIGN
BY EQUIV. BEAM METHOD

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

II.--RESULTS (ANCHOR FORCE = 7410. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	0.	0.	-3.3642E+09	139.69
29.00	75.	154.	-2.5239E+09	169.03
28.00	318.	338.	-1.6834E+09	198.36
27.00	761.	551.	-8.4240E+08	227.70
26.00	1430.	793.	0.0000E+00	257.03
26.00	1430.	-6616.	0.0000E+00	257.03
25.00	-5053.	-6345.	8.4277E+08	286.37
24.00	-11249.	-6044.	1.6769E+09	315.70
23.00	-17130.	-5713.	2.4915E+09	345.04
22.00	-22666.	-5354.	3.2767E+09	374.37
21.00	-27830.	-4970.	4.0227E+09	392.81
20.00	-32600.	-4568.	4.7207E+09	411.25
19.00	-36959.	-4148.	5.3624E+09	429.69
18.00	-40889.	-3709.	5.9403E+09	448.13
17.00	-44371.	-3251.	6.4477E+09	466.57
16.00	-47386.	-2775.	6.8784E+09	485.01
15.00	-49915.	-2281.	7.2273E+09	503.45
14.00	-51942.	-1769.	7.4900E+09	521.89
13.00	-53446.	-1237.	7.6630E+09	540.33
12.00	-54411.	-688.	7.7438E+09	558.77
11.00	-54816.	-120.	7.7306E+09	577.21
10.00	-54644.	466.	7.6228E+09	595.65
9.00	-53877.	1071.	7.4207E+09	614.09
8.00	-52496.	1695.	7.1255E+09	632.52
7.00	-50482.	2336.	6.7397E+09	650.96
6.00	-47817.	2997.	6.2668E+09	669.40
5.00	-44482.	3675.	5.7113E+09	687.84
4.00	-40460.	4372.	5.0791E+09	706.28
3.00	-35732.	5088.	4.3771E+09	724.72
2.00	-30278.	5822.	3.6134E+09	743.16
1.00	-24082.	6574.	2.7975E+09	761.60
.00	-17124.	7345.	1.9401E+09	780.04
-1.00	-9449.	7945.	1.0532E+09	419.83
-2.00	-1355.	8185.	1.5007E+08	59.61
-2.17	0.	8189.	0.0000E+00	.00
-3.00	6800.	8064.	-7.5541E+08	-300.60
-4.00	14653.	7583.	-1.6492E+09	-660.81
-5.00	21846.	6742.	-2.5177E+09	-1021.03
-6.00	28018.	5541.	-3.3487E+09	-1381.24
-7.00	32809.	3980.	-4.1314E+09	-1741.45
-8.00	35858.	2058.	-4.8577E+09	-2101.67
-9.00	36806.	-223.	-5.5223E+09	-2461.88
-10.00	35291.	-2865.	-6.1237E+09	-2822.09
-11.00	30955.	-5868.	-6.6645E+09	-3182.31
-12.00	23436.	-9230.	-7.1523E+09	-3542.52
-13.00	12375.	-12953.	-7.6000E+09	-3902.73
-13.85	0.	-16379.	-7.9612E+09	-4207.12

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 53. Complete results for equivalent beam method for example ANCH1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 15.15.56

COMPLETE RESULTS FOR
ANCHORED WALL DESIGN
BY FIXED EARTH METHOD

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

II.--RESULTS (ANCHOR FORCE = 7170. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	0.	0.	-3.7241E+09	139.69
29.00	75.	154.	-2.7938E+09	169.03
28.00	318.	338.	-1.8634E+09	198.36
27.00	761.	551.	-9.3235E+08	227.70
26.00	1430.	793.	0.0000E+00	257.03
26.00	1430.	-6376.	0.0000E+00	257.03
25.00	-4812.	-6104.	9.3280E+08	286.37
24.00	-10769.	-5803.	1.8573E+09	315.70
23.00	-16409.	-5473.	2.7633E+09	345.04
22.00	-21705.	-5113.	3.6409E+09	374.37
21.00	-26628.	-4730.	4.4811E+09	392.81
20.00	-31158.	-4328.	5.2754E+09	411.25
19.00	-35277.	-3907.	6.0158E+09	429.69
18.00	-38967.	-3468.	6.6954E+09	448.13
17.00	-42208.	-3011.	7.3077E+09	466.57
16.00	-44983.	-2535.	7.8471E+09	485.01
15.00	-47272.	-2041.	8.3089E+09	503.45
14.00	-49058.	-1528.	8.6890E+09	521.89
13.00	-50323.	-997.	8.9845E+09	540.33
12.00	-51047.	-448.	9.1931E+09	558.77
11.00	-51212.	120.	9.3135E+09	577.21
10.00	-50800.	707.	9.3456E+09	595.65
9.00	-49792.	1312.	9.2899E+09	614.09
8.00	-48170.	1935.	9.1483E+09	632.52
7.00	-45916.	2577.	8.9235E+09	650.96
6.00	-43011.	3237.	8.6195E+09	669.40
5.00	-39436.	3915.	8.2413E+09	687.84
4.00	-35174.	4613.	7.7950E+09	706.28
3.00	-30205.	5328.	7.2880E+09	724.72
2.00	-24511.	6062.	6.7290E+09	743.16
1.00	-18075.	6814.	6.1277E+09	761.60
.00	-10876.	7585.	5.4953E+09	780.04
-1.00	-2961.	8185.	4.8442E+09	419.83
-2.00	5374.	8425.	4.1880E+09	59.61
-2.17	6768.	8430.	4.0799E+09	.00
-3.00	13768.	8304.	3.5411E+09	-300.60
-4.00	21862.	7824.	2.9180E+09	-660.81
-5.00	29296.	6983.	2.3326E+09	-1021.03
-6.00	35708.	5782.	1.7976E+09	-1381.24
-7.00	40739.	4220.	1.3241E+09	-1741.45
-8.00	44028.	2299.	9.2082E+08	-2101.67
-9.00	45216.	17.	5.9328E+08	-2461.88
-10.00	43942.	-2625.	3.4353E+08	-2822.09
-11.00	39846.	-5627.	1.6929E+08	-3182.31
-12.00	32567.	-8990.	6.3455E+07	-3542.52
-13.00	21746.	-12712.	1.3384E+07	-3902.73
-14.00	7023.	-16795.	3.2791E+05	-4262.95
-14.40	0.	-18519.	0.0000E+00	-4406.24

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 54. Complete results for fixed earth method for Example ANCH1

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

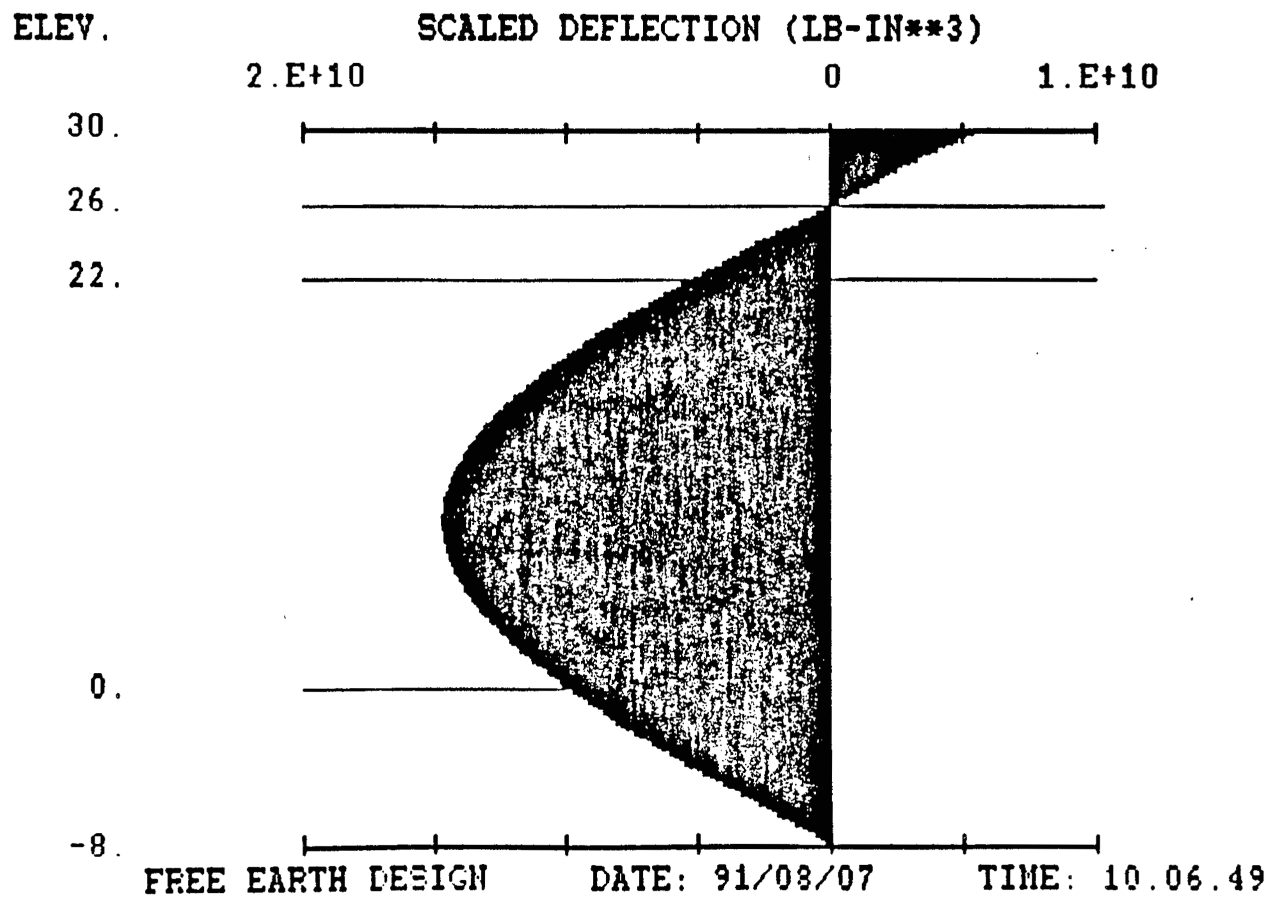


Figure 55. Scaled deflection for free earth method for Example ANCH1

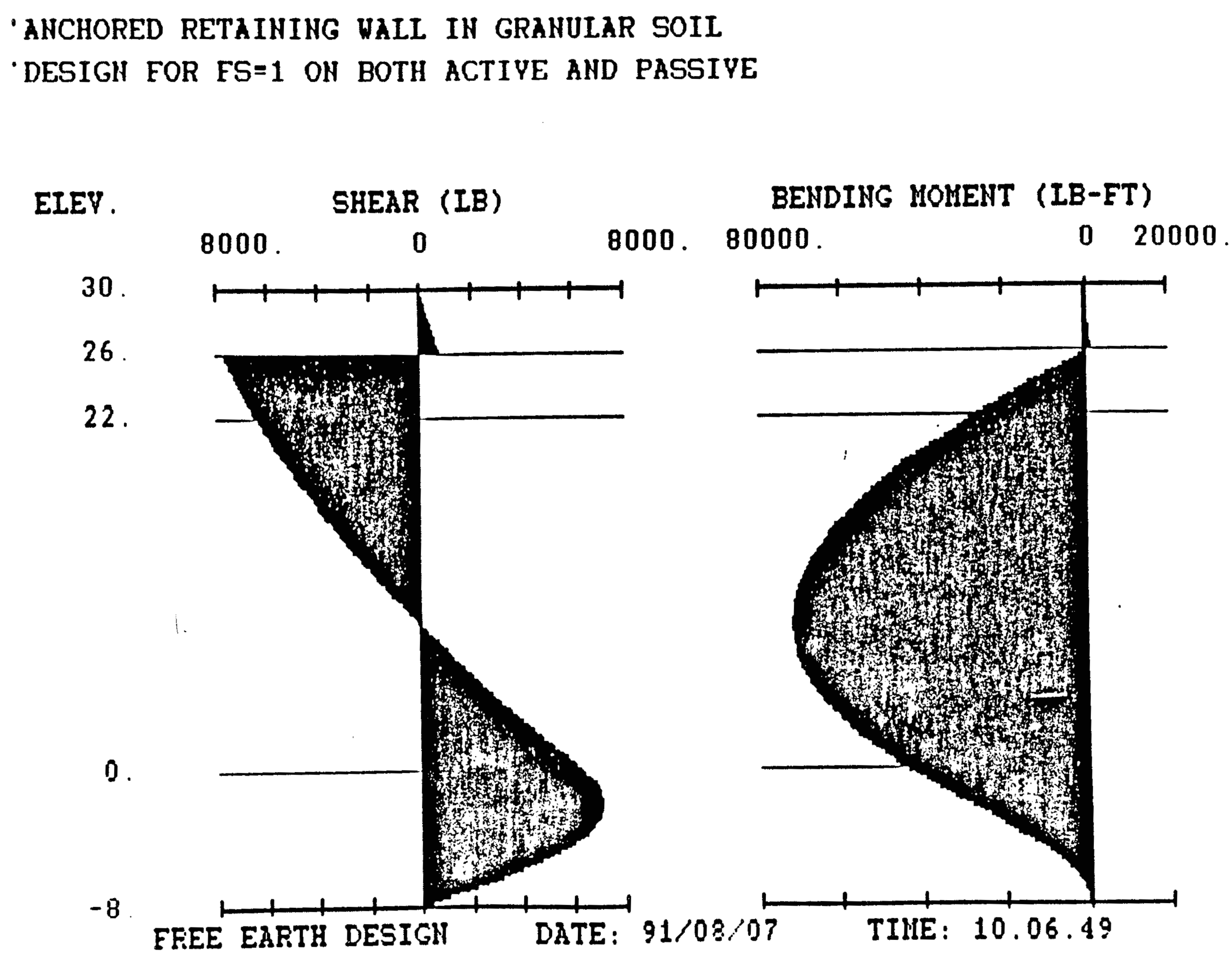


Figure 56. Shear and bending moment diagrams for free earth method for Example ANCH1

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE.

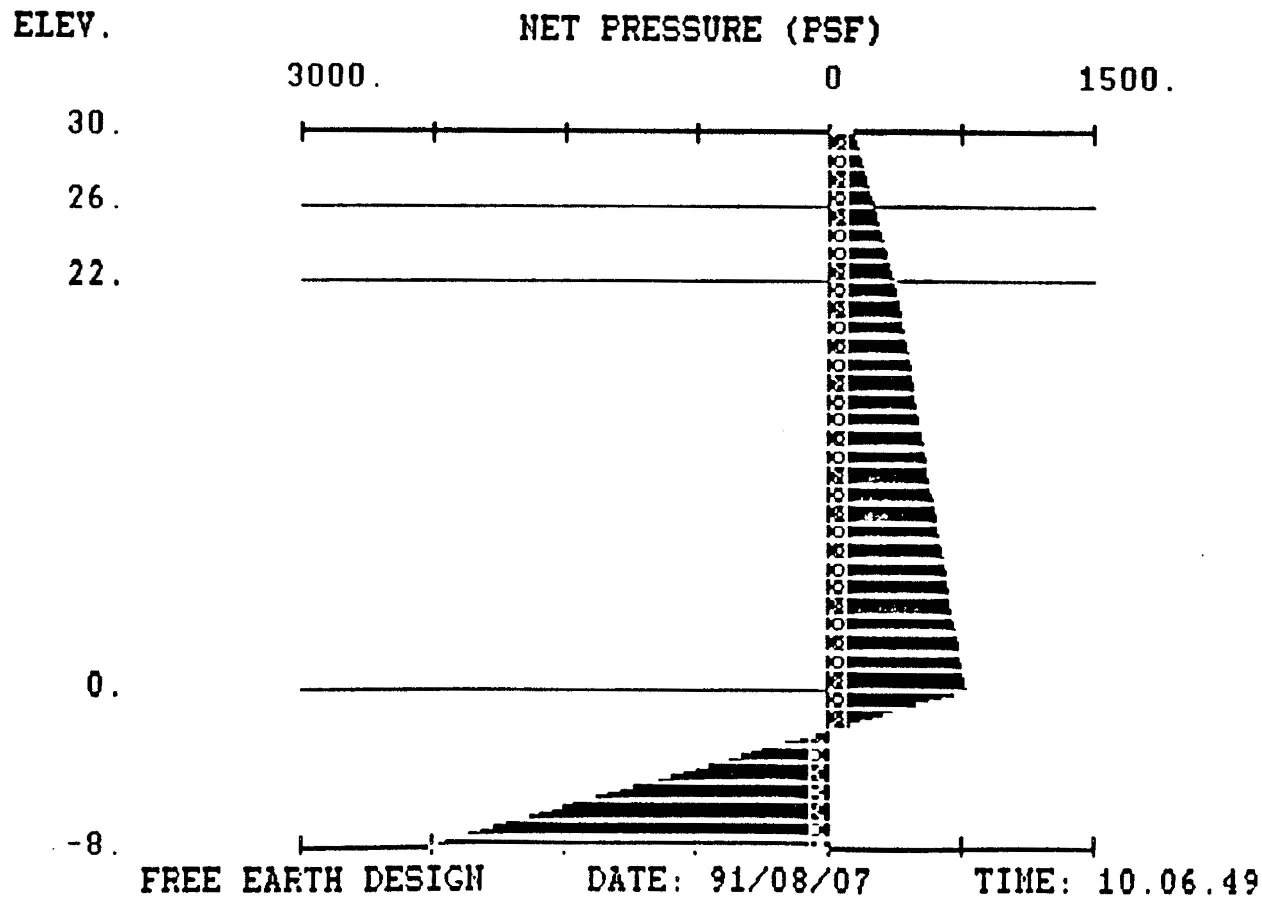


Figure 57. Net pressures for free earth method for Example ANCH1

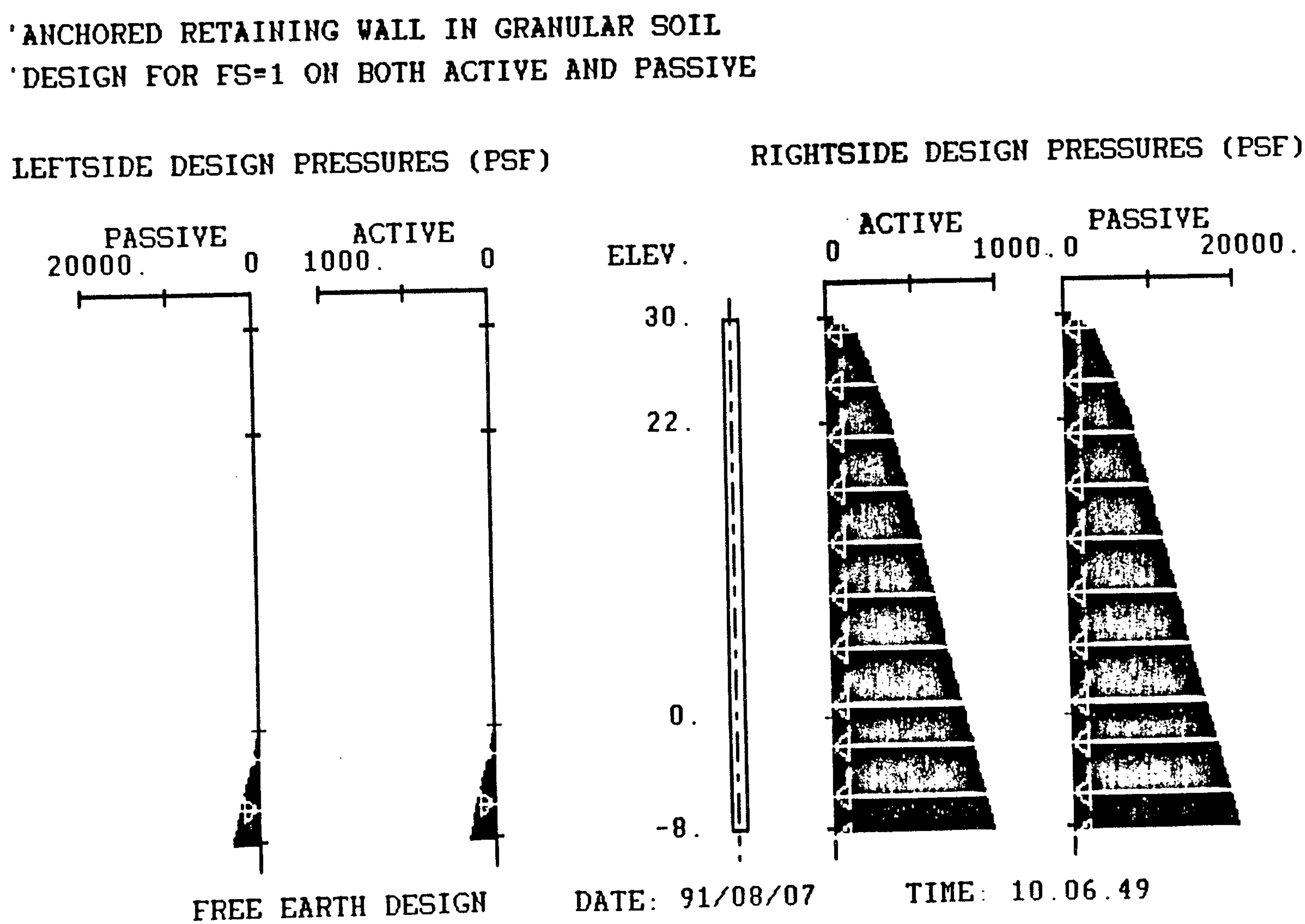


Figure 58. Active and passive soil pressures for free earth method for Example ANCH1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 15.15.56

PRELIMINARY DESIGN DATA FOR
FREE EARTH DESIGN IN SAND

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE

II.--DESIGN PARAMETERS

WALL HEIGHT RATIO (ALPHA) = .78
ANCHOR HEIGHT RATIO (BETA) = .10

SHEET PILE DATA:

SHEET PILE NAME	<SECTION PROPERTIES> (PER FOOT OF WALL) SECTION MODULUS (IN**3)	MOMENT OF INERTIA (IN**4)	ALLOWABLE STRESS (PSI)	MODULUS OF ELASTICITY (PSI)
PZ40	60.70	490.80	24000.	2.90E+07
PZ38	46.80	380.80	24000.	2.90E+07
PZ35	48.50	361.20	24000.	2.90E+07
PZ32	38.30	220.40	24000.	2.90E+07
PZ27	30.20	184.20	24000.	2.90E+07
PZ22	18.10	84.40	24000.	2.90E+07
PLZ25	32.80	223.25	24000.	2.90E+07
PLZ23	30.20	203.75	24000.	2.90E+07

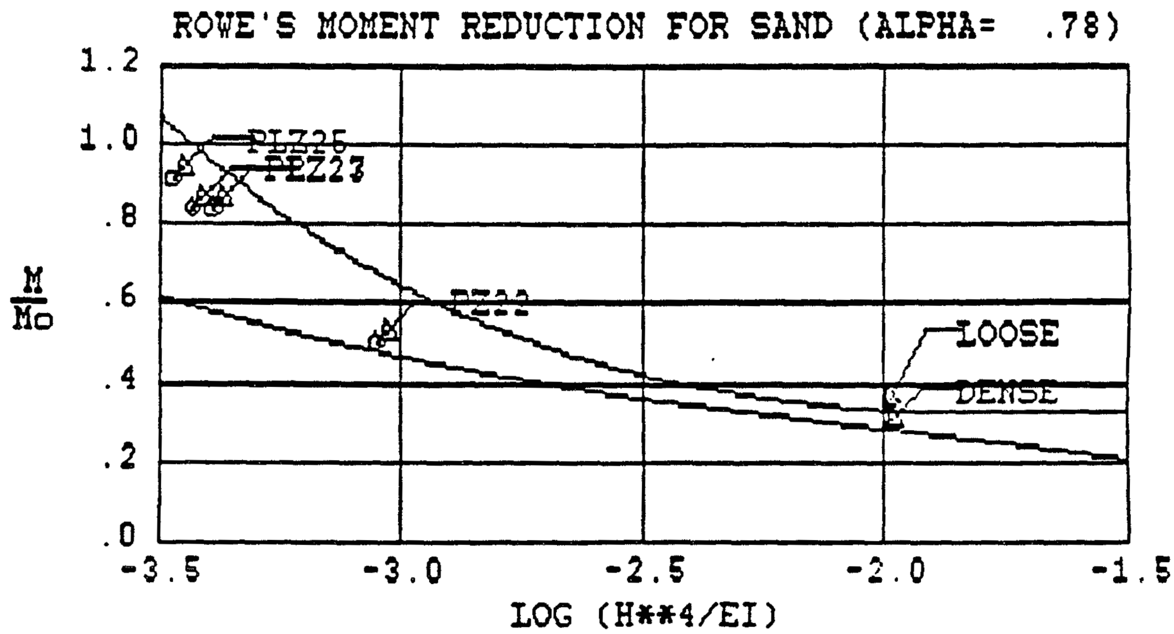
III.--PRELIMINARY DESIGN DATA

SHEET PILE	LOG(H**4/EI)	ROWE'S MOMENT REDUCTION COEF. LOOSE	DENSE	RATIO OF ALLOWABLE MOMENT TO REDUCED FREE EARTH MOMENT LOOSE	DENSE
PZ40	-3.81	1.00*	1.00*	1.69	1.69
PZ38	-3.70	1.00*	1.00*	1.30	1.30
PZ35	-3.68	1.00*	1.00*	1.35	1.35
PZ32	-3.47	1.04	.61	1.03	1.76
PZ27	-3.39	.96	.58	.88	1.45
PZ22	-3.05	.68	.48	.74	1.05
PLZ25	-3.47	1.04	.61	.88	1.50
PLZ23	-3.43	1.00	.59	.84	1.41

* REDUCTION NOT APPLICABLE DUE TO
LOG(H**4/EI) LESS THAN -3.5 OR GREATER THAN -1.5.

Figure 59. Preliminary design information from application of Rowe's moment reduction procedure

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS=1 ON BOTH ACTIVE AND PASSIVE



DATE: 91/08/07 TIME: 11.00.59

Figure 60. Rowe's moment reduction curves for Example ANCH1

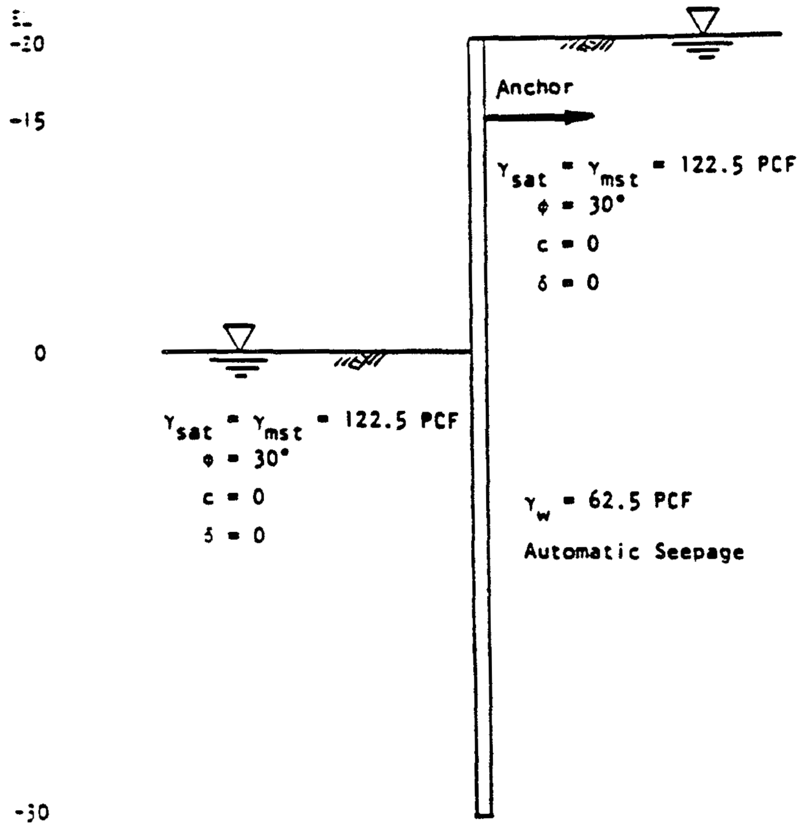


Figure 61. System for Example ANCH2

```
1000 'ANCHORED RETAINING WALL IN GRANULAR SOIL
1010 'WITH AUTOMATIC SEEPAGE
1020 C A D 1
1030 WALL 20 15
1030 SUR R 1 0 20
1040 SUR L 1 0 0
1050 SOIL BOTH S 1
1060 122.5 122.5 30 0 0 0
1070 WATER E 62.5 20 0 0 AUTOMATIC
1080 FINISH
```

Figure 62. Input file for Example ANCH2

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 91/01/25                                              TIME: 16.46.02

                             INPUT DATA

I.--HEADING:
  'ANCHORED RETAINING WALL IN GRANULAR SOIL
  'WITH AUTOMATIC SEEPAGE

II.--CONTROL
  ANCHORED   WALL DESIGN

  LEVEL 1 FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
  LEVEL 1 FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
  ELEVATION AT TOP OF WALL     =     20.00 (FT)
  ELEVATION AT ANCHOR          =     15.00 (FT)

IV.--SURFACE POINT DATA

  IV.A--RIGHTSIDE
     DIST. FROM       ELEVATION
     WALL (FT)          (FT)
            .00         20.00

  IV.B-- LEFTSIDE
     DIST. FROM       ELEVATION
     WALL (FT)          (FT)
            .00           .00

V.--SOIL LAYER DATA

  V.A.--RIGHTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                   ANGLE OF             ANGLE OF                             <-SAFETY->
  SAT.    MOIST    INTERNAL    COH-       WALL       ADH-     <--BOTTOM-->   <-FACTOR->
 WGHT.    WGHT.    FRICTION    ESION    FRICTION     ESION    ELEV.  SLOPE   ACT.  PASS.
 (PCF)    (PCF)     (DEG)      (PSF)     (DEG)       (PSF)    (FT)  (FT/FT)
122.50   122.50     30.00        .0        .00         .0                    DEF   DEF

  V.B.-- LEFTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                   ANGLE OF             ANGLE OF                             <-SAFETY->
  SAT.    MOIST    INTERNAL    COH-       WALL       ADH-     <--BOTTOM-->   <-FACTOR->
 WGHT.    WGHT.    FRICTION    ESION    FRICTION     ESION    ELEV.  SLOPE   ACT.  PASS.
 (PCF)    (PCF)     (DEG)      (PSF)     (DEG)       (PSF)    (FT)  (FT/FT)
122.50   122.50     30.00        .0        .00         .0                    DEF   DEF

VI.--WATER DATA

     UNIT WEIGHT           =     62.50 (PCF)
     RIGHTSIDE ELEVATION   =     20.00 (FT)
      LEFTSIDE ELEVATION   =       .00 (FT)
     SEEPAGE ELEVATION     =       .00 (FT)
     SEEPAGE GRADIENT      =     AUTOMATIC

VII.--SURFACE LOADS
     NONE

VIII.--HORIZONTAL LOADS
     NONE
```

Figure 63. Echoprint of input data for Example ANCH2

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 91/01/25 TIME: 16.46.14

SOIL PRESSURES FOR
ANCHORED WALL DESIGN

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'WITH AUTOMATIC SEEPAGE

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

****
SOIL PRESSURES ARE REPORTED FOR A SEEPAGE GRADIENT = .0001
AND MAY CHANGE WITH AUTOMATIC ADJUSTMENT OF THE GRADIENT.
****

	<-LEFTSIDE PRESSURES->		<---NET PRESSURES----> (SOIL PLUS WATER)	<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
20.00	.000	.000	.000	.000	.000
19.00	.000	.000	82.500	20.000	180.000
18.00	.000	.000	165.000	40.000	360.000
17.00	.000	.000	247.500	60.000	540.000
16.00	.000	.000	330.000	80.000	720.000
15.00	.000	.000	412.500	100.000	900.000
14.00	.000	.000	495.000	120.000	1080.000
13.00	.000	.000	577.500	140.000	1260.000
12.00	.000	.000	660.000	160.000	1440.000
11.00	.000	.000	742.500	180.000	1620.000
10.00	.000	.000	825.000	200.000	1800.000
9.00	.000	.000	907.500	220.000	1980.000
8.00	.000	.000	990.000	240.000	2160.000
7.00	.000	.000	1072.500	260.000	2340.000
6.00	.000	.000	1155.000	280.000	2520.000
5.00	.000	.000	1237.500	300.000	2700.000
4.00	.000	.000	1320.000	320.000	2880.000
3.00	.000	.000	1402.500	340.000	3060.000
2.00	.000	.000	1485.000	360.000	3240.000
1.00	.000	.000	1567.500	380.000	3420.000
.00	.000	.000	1650.000	400.000	3600.000

Figure 64. Initial soil pressures for Example ANCH2 (Continued)

-1.00	179.981	19.998	1490.008	420.002	3780.019
-2.00	359.963	39.996	1330.017	440.004	3960.037
-3.00	539.944	59.994	1170.025	460.006	4140.056
-4.00	719.925	79.992	1010.033	480.008	4320.075
-5.00	899.906	99.990	850.042	500.010	4500.094
-6.00	1079.888	119.988	690.050	520.013	4680.112
-7.00	1259.869	139.985	530.058	540.015	4860.131
-8.00	1439.850	159.983	370.067	560.017	5040.150
-9.00	1619.831	179.981	210.075	580.019	5220.169
-10.00	1799.813	199.979	50.083	600.021	5400.187
-10.31	1856.153	206.239	.000	606.282	5456.540
-11.00	1979.794	219.977	-109.908	620.023	5580.206
-12.00	2159.775	239.975	-269.900	640.025	5760.225
-13.00	2339.756	259.973	-429.892	660.027	5940.244
-14.00	2519.737	279.971	-589.883	680.029	6120.262
-15.00	2699.719	299.969	-749.875	700.031	6300.281
-16.00	2879.700	319.967	-909.867	720.033	6480.300
-17.00	3059.681	339.965	-1069.858	740.035	6660.319
-18.00	3239.662	359.963	-1229.850	760.038	6840.338
-19.00	3419.644	379.960	-1389.842	780.040	7020.356
-20.00	3599.625	399.958	-1549.833	800.042	7200.375
-21.00	3779.606	419.956	-1709.825	820.044	7380.394
-22.00	3959.587	439.954	-1869.817	840.046	7560.412
-23.00	4139.569	459.952	-2029.808	860.048	7740.431
-24.00	4319.550	479.950	-2189.800	880.050	7920.450
-25.00	4499.531	499.948	-2349.792	900.052	8100.469
-26.00	4679.512	519.946	-2509.783	920.054	8280.487
-27.00	4859.494	539.944	-2669.775	940.056	8460.506
-28.00	5039.475	559.942	-2829.767	960.058	8640.525
-29.00	5219.456	579.940	-2989.758	980.060	8820.544
-30.00	5399.437	599.938	-3149.750	1000.063	9000.562
-31.00	5579.419	619.935	-3309.742	1020.065	9180.581
-32.00	5759.400	639.933	-3469.733	1040.067	9360.600
-33.00	5939.381	659.931	-3629.725	1060.069	9540.619
-34.00	6119.362	679.929	-3789.717	1080.071	9720.637
-35.00	6299.344	699.927	-3949.708	1100.073	9900.656
-36.00	6479.325	719.925	-4109.700	1120.075	10080.675
-37.00	6659.306	739.923	-4269.692	1140.077	10260.694
-38.00	6839.287	759.921	-4429.683	1160.079	10440.713
-39.00	7019.269	779.919	-4589.675	1180.081	10620.731
-40.00	7199.250	799.917	-4749.667	1200.083	10800.750
-41.00	7379.231	819.915	-4909.658	1220.085	10980.769
-42.00	7559.212	839.913	-5069.650	1240.088	11160.788
-43.00	7739.194	859.910	-5229.642	1260.090	11340.806
-44.00	7919.175	879.908	-5389.633	1280.092	11520.825
-45.00	8099.156	899.906	-5549.625	1300.094	11700.844
-46.00	8279.137	919.904	-5709.617	1320.096	11880.863
-47.00	8459.119	939.902	-5869.608	1340.098	12060.881
-48.00	8639.100	959.900	-6029.600	1360.100	12240.900
-49.00	8819.081	979.898	-6189.592	1380.102	12420.919
-50.00	8999.062	999.896	-6349.583	1400.104	12600.938
-51.00	9179.044	1019.894	-6509.575	1420.106	12780.956
-52.00	9359.025	1039.892	-6669.567	1440.108	12960.975
-53.00	9539.006	1059.890	-6829.558	1460.110	13140.994
-54.00	9718.987	1079.888	-6989.550	1480.113	13321.013
-55.00	9898.969	1099.885	-7149.542	1500.115	13501.031
-56.00	10078.950	1119.883	-7309.533	1520.117	13681.050
-57.00	10258.931	1139.881	-7469.525	1540.119	13861.069
-58.00	10438.913	1159.879	-7629.517	1560.121	14041.088
-59.00	10618.894	1179.877	-7789.508	1580.123	14221.106
-60.00	10798.875	1199.875	-7949.500	1600.125	14401.125
-61.00	10978.856	1219.873	-8109.492	1620.127	14581.144

Figure 64. (Concluded)

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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
DATE: 91/01/25                                                TIME: 16.46.32

                        SUMMARY OF RESULTS FOR
                         ANCHORED WALL-DESIGN

I.--HEADING

  'ANCHORED RETAINING WALL IN GRANULAR SOIL
  'WITH AUTOMATIC SEEPAGE

II.--SUMMARY

     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

METHOD                       :   FREE EARTH     EQUIV. BEAM     FIXED EARTH

WALL BOTTOM ELEV. (FT)       :       -25.24          -35.17          -33.17
      PENETRATION (FT)       :        25.24           35.17           33.17

MAX. BEND. MOMENT (LB-FT)    :     -155633.        -107284.        -122038.
      AT ELEVATION (FT)      :        -1.00            1.00            1.00

MAX. SCALED DEFL. (LB-IN3)   :   3.9503E+10     -1.3715E+10      2.6013E+10
      AT ELEVATION (FT)      :        -4.00          -26.00           -2.00

ANCHOR FORCE (LB)            :       17684.          14400.          15453.

SEEPAGE GRADIENT             :        .3956           .2841           .3011

     (NOTE: PENETRATION FOR EQUIVALENT BEAM
     METHOD DOES NOT INCLUDE INCREASE
     PRESCRIBED BY DRAFT EM 1110-2-2906.)

     (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
     ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
     IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 65. Summary of results for Example ANCH2

COMPLETE RESULTS FOR
ANCHORED WALL DESIGN
BY FREE EARTH METHOD

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'WITH AUTOMATIC SEEPAGE

II.--RESULTS (ANCHOR FORCE = 17684. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	0.	0.	-1.7104E+10	.00
19.00	14.	41.	-1.3684E+10	82.50
18.00	110.	165.	-1.0264E+10	165.00
17.00	371.	371.	-6.8437E+09	247.50
16.00	880.	660.	-3.4226E+09	330.00
15.00	1719.	1031.	0.0000E+00	412.50
15.00	1719.	-16652.	0.0000E+00	412.50
14.00	-14714.	-16199.	3.4205E+09	495.00
13.00	-30651.	-15662.	6.8157E+09	577.50
12.00	-46011.	-15044.	1.0158E+10	660.00
11.00	-60711.	-14342.	1.3421E+10	742.50
10.00	-74668.	-13559.	1.6579E+10	825.00
9.00	-87800.	-12692.	1.9608E+10	907.50
8.00	-100025.	-11744.	2.2486E+10	990.00
7.00	-111260.	-10712.	2.5191E+10	1072.50
6.00	-121422.	-9599.	2.7704E+10	1155.00
5.00	-130429.	-8402.	3.0007E+10	1237.50
4.00	-138199.	-7124.	3.2085E+10	1320.00
3.00	-144649.	-5762.	3.3924E+10	1402.50
2.00	-149696.	-4319.	3.5514E+10	1485.00
1.00	-153259.	-2792.	3.6845E+10	1567.50
.00	-155254.	-1184.	3.7911E+10	1650.00
-1.00	-155633.	403.	3.8710E+10	1522.96
-2.00	-154490.	1862.	3.9239E+10	1395.93
-3.00	-151951.	3195.	3.9502E+10	1268.89
-4.00	-148143.	4400.	3.9503E+10	1141.85
-5.00	-143193.	5478.	3.9248E+10	1014.81
-6.00	-137228.	6430.	3.8745E+10	887.78
-7.00	-130376.	7254.	3.8006E+10	760.74
-8.00	-122763.	7951.	3.7041E+10	633.70
-9.00	-114516.	8521.	3.5864E+10	506.66
-10.00	-105762.	8965.	3.4490E+10	379.63
-11.00	-96629.	9281.	3.2932E+10	252.59
-12.00	-87243.	9470.	3.1208E+10	125.55
-12.99	-77843.	9532.	2.9356E+10	.00
-13.00	-77732.	9532.	2.9333E+10	-1.48
-14.00	-68222.	9467.	2.7324E+10	-128.52
-15.00	-58841.	9275.	2.5197E+10	-255.56
-16.00	-49715.	8956.	2.2968E+10	-382.60
-17.00	-40972.	8510.	2.0653E+10	-509.63
-18.00	-32738.	7936.	1.8268E+10	-636.67
-19.00	-25141.	7236.	1.5825E+10	-763.71
-20.00	-18308.	6409.	1.3339E+10	-890.75
-21.00	-12366.	5455.	1.0822E+10	-1017.78
-22.00	-7441.	4373.	8.2823E+09	-1144.82
-23.00	-3661.	3165.	5.7301E+09	-1271.86
-24.00	-1153.	1830.	3.1714E+09	-1398.89
-25.00	-44.	367.	6.1043E+08	-1525.93
-25.24	0.	0.	0.0000E+00	-1556.21

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 66. Complete results for free earth method for Example ANCH2

III.--SOIL PRESSURES

ELEVATION (FT)	< LEFTSIDE PRESSURE (PSF)> PASSIVE	ACTIVE	<RIGHTSIDE PRESSURE (PSF)> ACTIVE	PASSIVE
20.00	0.	0.	0.	0.
19.00	0.	0.	20.	180.
18.00	0.	0.	40.	360.
17.00	0.	0.	60.	540.
16.00	0.	0.	80.	720.
15.00	0.	0.	100.	900.
14.00	0.	0.	120.	1080.
13.00	0.	0.	140.	1260.
12.00	0.	0.	160.	1440.
11.00	0.	0.	180.	1620.
10.00	0.	0.	200.	1800.
9.00	0.	0.	220.	1980.
8.00	0.	0.	240.	2160.
7.00	0.	0.	260.	2340.
6.00	0.	0.	280.	2520.
5.00	0.	0.	300.	2700.
4.00	0.	0.	320.	2880.
3.00	0.	0.	340.	3060.
2.00	0.	0.	360.	3240.
1.00	0.	0.	380.	3420.
0.00	0.	0.	400.	3600.
-1.00	106.	12.	428.	3854.
-2.00	212.	24.	456.	4108.
-3.00	318.	35.	485.	4362.
-4.00	423.	47.	513.	4617.
-5.00	529.	59.	541.	4871.
-6.00	635.	71.	569.	5125.
-7.00	741.	82.	598.	5379.
-8.00	847.	94.	626.	5633.
-9.00	953.	106.	654.	5887.
-10.00	1058.	118.	682.	6142.
-11.00	1164.	129.	711.	6396.
-12.00	1270.	141.	739.	6650.
-12.99	1375.	153.	767.	6901.
-13.00	1376.	153.	767.	6904.
-14.00	1482.	165.	795.	7158.
-15.00	1588.	176.	824.	7412.
-16.00	1693.	188.	852.	7667.
-17.00	1799.	200.	880.	7921.
-18.00	1905.	212.	908.	8175.
-19.00	2011.	223.	937.	8429.
-20.00	2117.	235.	965.	8683.
-21.00	2223.	247.	993.	8937.
-22.00	2328.	259.	1021.	9192.
-23.00	2434.	270.	1050.	9446.
-24.00	2540.	282.	1078.	9700.
-25.00	2646.	294.	1106.	9954.
-25.28	2676.	297.	1114.	10026.

Figure 67. Final soil pressures for free earth method for Example ANCH2

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APPENDIX A: GUIDE FOR DATA INPUT

Source of Input

1. Input data may be supplied from a predefined data file or from the user terminal during execution. If data are supplied from the user terminal, prompting messages are printed to indicate the amount and character of data to be entered.

Data Editing

2. When all data for a problem have been entered, the user is offered the opportunity to review an echoprint of the currently available input data and to revise any or all sections of the input data before execution is attempted. When editing is performed during execution, each section must be entered in its entirety.

Input Data File Generation

3. After data have been entered from the terminal, either initially or after editing, the user may direct the program to write the input data to a permanent file in input data file format.

Data Format

4. All input data (whether supplied from the user terminal or from a file) are read in free-field format:

<u>a</u>. Data items must be separated by one or more blanks (COMMA SEPARATORS ARE NOT PERMITTED).

<u>b</u>. Integer numbers must be of form NNNN.

<u>c</u>. Real numbers may be of form

±xxxx, ±xx.xx, or ±xx.xxE+ee

<u>d</u>. User responses to all requests for control by the program for alphanumeric input may be abbreviated by the first letter of the indicated word response, e.g.,

ENTER 'YES' OR 'NO'--respond Y or N

ENTER 'CONTINUE' OR 'END'--respond C or E

Sections of Input

5. Input data are divided into the following sections:

I. HEADING (Required).

II. CONTROL (Required).

III. WALL DATA (Required).

IV. SOIL SURFACE DATA (Required).

V. SOIL PROFILE DATA (Required).

VI. WATER DATA (Optional).

VII. VERTICAL LOAD DATA (Optional).

VIII. HORIZONTAL LOAD DATA (Optional).

IX. TERMINATION (Required).

Units

6. The program expects data to be provided in units of inches, feet, or pounds as noted in the guide that follows. No provision is made for conversion to other systems of units by the program.

Predefined Data File

7. In addition to the general format requirements given in paragraph 4 of Appendix A, the following items pertain to a predefined data file and to the input data description which follows:

a. Each line must commence with a nonzero, positive line number, denoted LN.

b. A line of input may require both alphanumeric and numeric data items. Alphanumeric data items are enclosed in single quotes in the following paragraphs.

c. A line of input may require a key word. The acceptable abbreviation for the key word is indicated by underlined capital letters, e.g., the acceptable abbreviation for the key word 'SUrface' is 'SU'.

d. Lower-case words in single quotes indicate that a choice of defined key words follows.

e. Items designated by upper-case letters and numbers without quotes indicate numeric data values. Numeric data values are either real or integer according to standard FORTRAN variable naming conventions.

f. Data items enclosed in brackets [ ] may not be required. Data items enclosed in braces { } indicate that a special note follows.

g. Input data are divided into the sections discussed in this appendix, paragraph 5. Except for the heading, each section consists of a header line and one or more data lines.

h. Comment lines may be inserted in the input file by enclosing the line, following the line number, in parentheses. Comment lines are ignored, e.g.,

1234 ƀ (THIS LINE IS IGNORED).

Sequence of Solutions

8. A predefined data file may contain a sequence of input data sets to be run in succession. The first data set must contain all required data (from HEADING through TERMINATION) for the problem. Subsequent data sets may contain an independent problem or may contain data that amend existing input data.

General Discussion of Input Data

9. Each data section contains a descriptor ('side') to indicate the side of the system to which the data apply. For symmetric effects ('side' = 'Both'), the data section is entered only once and symmetric data are applied to both sides automatically. For unsymmetric conditions, the description for the right side (if present) must be entered first and must be immediately followed by the description for the left side (if present).

10. Rightside and leftside descriptions must be supplied either explicitly or implicitly (i.e., 'side' = 'Both') for surface points and soil profile data sections. Other data may be supplied either for the right side or left side, or both, or may be omitted entirely.

Input Description

11. HEADING--One (1) to four (4) lines

a. Line contents

LN 'heading'

b. Definition

'heading' = any alphanumeric information up to 70 characters including LN and any embedded blanks; first nonblank character following LN must be a single quote (').

12. CONTROL--One (1) line

a. Line contents

LN 'Control' 'type' 'mode' [FSA1 [FSP1]]

b. Definitions

'Control' = section title

'type' = 'Cantilever' or 'Anchored'

'mode' = 'Analysis' or 'Design'

[FSA1] = factor of safety to be applied for active earth pressures; assumed to be one if omitted if 'mode' = Design

[FSP1] = factor of safety to be applied for passive earth pressures; assumed to be equal to FSA1 if omitted and 'mode' = 'Design'; omit if FSA1 is omitted; omit if 'mode' = 'Analysis'

c. Discussion

(1) In the 'Design' mode, FSA1 and FSP1 are the default factors of safety to be applied to all soil layers on each side of the wall unless overridden in subsequent data.

(2) In the 'Analysis' mode:

(a) If both FSA1 and FSP1 are omitted, a single factor of safety is determined and applied for active and passive pressures. Any subsequent factors of safety are ignored.

(b) If FSA1 is supplied, the input value is the default factor of safety to be applied to all soil layers on each side of the wall unless overridden in subsequent data. The program determines the value of FSP1.

13. WALL DATA--One (1) line

a. Line contents

LN 'WAll' ELTOP [ELANCH] [ELBOT WALLE WALLI]

b. Definitions

'WAll' = section title

ELTOP = elevation (ft) at top of wall

[ELANCH] = elevation (ft) at anchor; omit if 'type' = 'Cantilever'

[ELBOT] = elevation (ft) at bottom of wall; omit if 'mode' = 'Design'

[WALLE] = Modulus of elasticity (psi) of wall; omit if 'mode' = 'Design'

[WALLI] = wall moment of inertia (in.^{4}) per foot of wall; omit if 'mode' = 'Design'

14. SOIL SURFACE DATA--One (1) or more lines

a. Line contents

LN 'SUrface' ('side') NSUR DSUR(1) ELSUR(1)

[----- DSUR(n) ELSUR(n)]

b. Definitions

'SUrface' = section title

('side') = 'Leftside', 'Rightside', or 'Both'

NSUR = number of surface points (1 to 15) on this ('side')

DSUR(i) = horizontal distance (ft) from wall to ith surface point

ELSUR(i) = elevation (ft) at ith surface point

c. Discussion

(1) If identical soil surfaces exist on each side of the wall, i.e., 'side' = 'Both', enter data for rightside surface. The program will generate a mirror image for the left side.

(2) At least one surface point must be provided. Up to 21 surface points are permitted. Pairs of DSUR(i) and ELSUR(i) may be continued on subsequent lines following a line number.

(3) If DSUR(1) is greater than zero, a horizontal surface is assumed at ELSUR(1) from the wall to a distance DSUR(1).

(4) ELSUR(1) must be less than or equal to ELTOP; ELSUR(1) must be greater than ELBOT if 'mode' = 'Analysis'.

(5) If more than one surface point is provided, a broken surface is assumed and soil pressures will be calculated by the wedge method. Distances and elevations must begin with the point nearest the wall and progress outward.

(6) If different surface conditions exist on each side, surface descriptions must be entered twice, once for the 'Rightside' and once for the 'Leftside'.

(7) The surface is assumed to extend horizontally ad infinitum at the elevation of the last point provided.

15. SOIL PROFILE DATA--Two or more lines

a. Control--One line

(1) Line contents

LN 'SOil' ('side') ('type') NLAY [FSA2 [FSP2]]

(2) Definitions

'SOil' = section title

{'side'} = 'Rightside', 'Leftside', or 'Both'

{'type'} = 'Strengths' if internal friction and/or soil cohesions and wall friction angles are provided. Required if {'mode'} = 'Analysis' or if a broken surface exists on this {'side'}

= 'Coefficients' if active and passive pressure coefficients are provided. Not allowed if {'mode'} = 'Analysis' or if broken surface exists on this {'side'}

NLAY = number of soil layers (1 to 15) on this {'side'}

[FSA2] = factor of safety for active pressures to be applied to all soil layers on this {'side'}; overrides FSA1; assumed to be equal to FSA1 if omitted or entered as zero. Omit if {'type'} = 'Coefficients'. Ignored for {'mode'} = 'Analysis' if FSA1 is omitted; ignored if {'type'} = 'Coefficients'

[FSP2] = factor of safety for passive pressures to be applied to all soil layers on this {'side'}; overrides FSP1; assumed to be equal to FSP1 for 'Design' if omitted; omit if FSA2 is omitted; ignored if {'mode'} = 'Analysis'; ignored if {'type'} = 'Coefficients'

b. Soil layer data for {'type'} = 'Strengths'--NLAY lines, one (1) line for each layer

(1) Line contents

LN GAMSAT GAMMST PHI C DELTA ADH [ELLAYB SLOBOT]

[FSA3 [FSP3]]

(2) Definitions

GAMSAT = saturated unit weight (pcf) of soil (program subtracts unit weight of water from GAMSAT to obtain effective unit weight of submerged soil)

GAMMST = unit weight (pcf) of soil above water

PHI = angle of internal friction (deg)

C = cohesion (psf)

DELTA = angle of wall friction (deg)

ADH = unit wall/soil adhesion (psf)

[ELLAYB] = elevation (ft) at intersection of bottom of layer with wall; omit if last layer

[SLOBOT] = slope (ft) of bottom of layer; interpreted as rise per foot horizontal; positive if layer boundary slopes upward; omit if last layer

[FSA3] = factor of safety for active pressures to be applied to this layer; overrides FSA2; assumed to be equal to FSA2 if omitted or entered as zero; ignored if FSA1 is omitted for 'Analysis'

[FSP3] = factor of safety for passive pressures to be applied to this layer; overrides FSP2; assumed to be equal to FSP2 if omitted; omit if FSA3 is omitted; ignored for ('mode') = 'Analysis'

(3) Discussion

(a) At least one soil layer on each side of the wall is required. Up to 15 layers on each side of the wall are permitted.

(b) Soil layer data must commence with the top layer and proceed sequentially downward.

(c) The last soil layer on each side is assumed to extend ad infinitum downward.

(d) Both PHI and C cannot be zero for any layer.

(e) DELTA must be positive and less than PHI for each layer.

(f) ADH must be positive and less than C for each layer.

(g) Bottom slopes of adjacent soil layers must not intersect within the soil mass.

(h) Layer bottom elevations must conform to:

ELLAYB(1) ≤ ELTOP

ELLAYB(1) < ELSUR( )

ELLAYB(1) > ELBOT if ('mode') = 'Analysis'

ELLAYB(i) < ELLAYB(i-1)

(i) The program will generate identical soil layer descriptions for both sides of the wall if ('side') = 'Both'.

(j) If different soil profiles exist on each side of the wall, soil layer data must be entered twice, once for the 'Rightside' and once for the 'Leftside'.

(k) Layer data for ('type') = 'Strengths' must be available if ('mode') = 'Analysis'.

(l) If any soil layer boundary on either side has a nonzero slope, soil pressures on that side are calculated by the wedge method.

c. Soil layer data for ('type') = 'Coefficients'--NLAY lines, one line for each layer

(1) Line contents

LN GAMSAT GAMMST AK PK [ELLAYB]

(2) Definitions

GAMSAT = saturated unit weight (pcf) of soil (program subtracts unit weight of water from GAMSAT to obtain effective unit weight of submerged soil)

GAMMST = unit weight of soil above water

AK = active soil pressure coefficient

PK = passive soil pressure coefficient

[ELLAYB] = elevation (ft) at intersection of bottom layer with wall; omit if last layer

(3) Discussion

(a) At least one soil layer on each side of wall. Up to 15 soil layers on each side of the wall are permitted.

(b) Soil layer data must commence with the top layer and proceed sequentially downward.

(c) The last soil layer is assumed to extend ad infinitum downward.

(d) Both AK and PK must be nonzero.

(e) Layer boundary elevations must conform to:

ELLAYB(1) ≤ ELTOP

ELLAYB(1) < ELLAYB(i-1)

16. WATER DATA--Zero or one or more lines; entire section may be omitted; choose one, a or b, of the following:

a. Water elevations provided

(1) Line contents

LN 'WATer Elevations' GAMWAT ELWATR ELWATL [ELSEEP (seep spec)]

(2) Definitions

'WATer Elevations' = section title

GAMWAT = unit weight (pcf) of water

ELWATR = elevation (ft) of water surface on rightside

ELWATL = elevation (ft) of water surface on leftside

ELSEEP = elevation (ft) on rightside at which seepage commences; omit if seepage is not to be considered; omit if ELWATR ≤ ELWATL {seep spec} - seepage gradient SEEP (ft/ft); 0 < SEEP < 1; omit if ELSEEP omitted

- 'Automatic' if seepage gradient is to be determined by program to result in zero net water pressure at bottom of wall; omit if ELSEEP omitted

(3) Discussion

(a) Effective soil unit weight for submerged soil is calculated in the program by subtracting the effective weight of water from the saturated unit weight of the soil.

(b) ELWATR and ELWATL must be less than or equal to ELTOP.

(c) Seepage effects cannot be included unless ELWATR > ELWATL.

(d) ELSEEP must conform to the following:

ELSEEP ≤ MIN (ELWATR, ELSUR (rightside 1))

ELSEEP ≥ MIN (ELWATL, ELSUR (leftside 1))

(e) If the seepage gradient SEEP is provided, the resulting net water pressure may not be zero at the bottom of the wall.

(f) If {seep specs} - 'Automatic' is specified, the seepage gradient is determined by the program to enforce zero net water pressure at the bottom of the wall.

(g) If seepage is to be considered for 'mode' - 'Analysis', ELWATL must be greater than ELBOT.

b. Net water pressures specified--One or more lines

(1) Line contents

LN 'WATer Pressure' NWPR ELWPR(1) WPR(1)

ELWPR(2) WPR(2) . . . ELRPS(n) WPR(n)

(2) Definitions

'WATer Pressure' - section title

NWPR - number (2 to 21) of points on water pressure distribution

ELWPR(i) - elevation (ft) of ith pressure point

WPR(i) - net water pressure at ith pressure point, positive to left

(3) Discussion

(a) At least two pressure points must be provided. A maximum of 21 pressure points is permitted. Pairs of ELWPR(i), WPR(i) may be continued on subsequent lines following a line number.

(b) Elevations must begin at uppermost point and proceed downward with:

$$ELWPR(1) \le ELTOP$$

$$ELWPR(i) < ELWPR(i-1)$$

(c) Specified water pressures do not alter soil pressures. GAMMST is used for the effective weight of soil at all elevations on both sides of the wall.

17. VERTICAL LOADS ON SURFACE--Zero or one or more lines; entire section may be omitted.

a. Line loads--Zero or one or more lines.

(1) Line contents.

LN 'Vertical Line' ('side') NVL DL(1) QL(1) . . . DL(n) QL(n)

(2) Definitions.

'Vertical Line' = subsection title

NVL = number of line loads (1 to 21) on this ('side')

('side') = 'Rightside', 'Leftside', or 'Both'

DL(i) = distance (ft) to line load

QL(i) = magnitude (plf) of line load; positive downward

(3) Discussion

(a) If ('side') = 'Both', mirror image line loads are generated on each side of the wall.

(b) Up to 21 line loads may be applied to the surface on each side of the wall.

(c) Pairs of DL(i), QL(i) may be continued on subsequent lines following a line number.

(d) DL(i) must be greater than zero.

(e) QL(i) must be greater than or equal to zero (i.e., upward loads are not permitted).

b. Distributed loads--Zero or one or more lines. Only one of the following distributed load types may be applied on either side of the wall:

(1) Uniform load--Zero or one line.

(a) Line contents.

LN 'Vertical Uniform' ('side') QU

(b) Definitions.

'Vertical Uniform' = subsection title

('side') = 'Rightside', 'Leftside', or 'Both'

QU = magnitude (psf) of uniform load, positive downward

(c) Discussion.

1. A uniform load is interpreted as acting on the horizontal projection of the surface.

2. The uniform load extends to infinity away from the wall.

3. If ('side') = 'Both', identical uniform loads are applied to the surface on each side of the wall.

4. QU must be greater than or equal to zero (i.e., upward load is not permitted).

(2) Strip loads--Zero or one or more lines.

(a) Line contents.

LN 'Vertical Strip' ('side') NVS DS1(1) DS2(1) QS(1) [. . . DS1(n) DS2(n) QS(n)]

(b) Definitions.

'Vertical Strip' = subsection title

('side') = 'Rightside', 'Leftside', or 'Both'

NVS = number (1 to 21) of strip loads

DS1(i) = distance (ft) from wall to beginning of 'Strip' load

DS2(i) = distance (ft) from wall to end of strip load

QS(i) = magnitude (psf) of strip load, positive downward

(c) Discussion.

1. A strip load is interpreted as acting on the horizontal projection of the surface.

2. Up to 21 strip loads may be applied on either side of the wall. Triads of DS1(i), QS(i), DS2(i) may be continued on subsequent lines following a line number.

3. QS(i) must be greater than or equal to zero (i.e., upward load is not permitted).

4. Distances must conform to:

$DS1(i) \geq$ Zero

$DS2(i) > QS1(i)$

5. If ('side') = 'Both', mirror image strip loads are applied to the surface on each side of the wall.

(3) Ramp loads--Zero or one line.

(a) Line contents.

LN 'Vertical Ramp' ('side') DR1 DR2 QR

(b) Definitions.

'Vertical Ramp' = subsection title

('side') = 'Rightside', 'Leftside', or 'Both'

DR1 = distance (ft) from wall to beginning of ramp load

DR2 = distance (ft) to end of ramp

QR = magnitude (psf) of uniform load extension of ramp load, positive downward

(c) Discussion.

1. A ramp load is interpreted as acting on the horizontal projection of the surface.

2. Only one ramp is permitted on each side of the wall.

3. Distances must conform to

$$DR1 \geq \text{Zero}$$

$$DR2 \geq DR1$$

4. QR must be greater than or equal to zero (i.e., upward load is not permitted).

5. If ('side') = 'Both', mirror image ramp loads are applied to the surface on each side of the wall.

(4) Triangular loads--Zero or one or more lines.

(a) Line contents.

LN 'Vertical Triangular' ('side') NVT

DT1(1) DT2(1) DT3(1) QT(1)

[. . . DT1(n) DT2(n) DT3(n) QT(n)]

(b) Definitions.

'Vertical Triangular' = subsection title

('side') = 'Rightside', 'Leftside', or 'Both'

NVT = number (1 to 21) of triangular loads

DT1(i) = distance (ft) from wall to beginning of triangular load

DT2(i) = distance (ft) from wall to peak of triangular load

DT3(i) = distance (ft) from wall to end of triangular load

QT(i) - magnitude (psf) of load at peak of triangular load, positive downward

(c) Discussion.

1. A triangular load is interpreted as acting on the horizontal projection of the surface.

2. Up to 21 triangular loads may be applied on either side of the wall. Quartets of DT1(i), DT2(i), DT3(i), and QT(i) may be continued on subsequent lines following a line number.

3. Distances must conform to:

DT1(i) ≥ Zero

DT2(i) > DT1(i) if DT3(i) = DT2(i)

DT3(i) > DT2(i) if DT2(i) = DT1(i)

DT3(i) > DT1(i)

4. QT(i) must be greater than or equal to zero (i.e., upward loads are not permitted).

5. If ('side') = 'Both', mirror image triangular loads are applied to the surface on each side of the wall.

(5) Variable distributed loads--Zero or one or more lines.

(a) Line contents.

LN 'Vertical Variable' ('side') NVV DV(1) QV(1)

[DV(2) QV(2) . . . DV(n) QV(n)]

(b) Definitions.

'Vertical Variable' - subsection title

('side') - 'Rightside', 'Leftside', or 'Both'

NVV - number (2 to 21) of points on variable load distribution

DV(i) - distance (ft) to ith point on distribution

QV(i) - magnitude (psf) of distributed load at ith point on distribution, positive downward

(c) Discussion.

1. A variable load distribution is interpreted as acting on the horizontal projection of the surface.

27. HORIZONTAL LOAD DATA.

a. Line loads--Zero or one or more lines.

LN 'Horizontal Line' NHL ELL(1) HL(1)

[LN ELL(2) HL(2) . . . ELL(n) HL(n)]

b. Distributed loads--Zero (0) or one (1) or more lines.

LN 'Horizontal Distributed' NHD ELD(1) HD(1) ELD(2) HD(2)

[LN ELD(3) HD(3) . . . ELD(n) HD(n)]

c. Earthquake acceleration--Zero or one line.

LN 'Horizontal Acceleration' EQACC

28. TERMINATION--One line.

LN 'Finish' [('Keep'
'New')]

APPENDIX B: NOTATION

a	Effective wall/soil adhesion
c	Actual cohesion
C_a	Wall/soil adhesion
C_e	$51/\sqrt{1 - 0.72\ (h/1000)}$
c_{eff}	Effective cohesion
C_i	Effective cohesion of the soil at the bottom of the slice multiplied by the length of the bottom surface
C_w	Effective cohesion of the soil at the bottom of the wall slice multiplied by the length of the bottom surface
d	Penetration of transition point
D	Depth of penetration obtained from free earth design procedure
E	Modulus of elasticity of pile, psi
F_a	$\Sigma h_j\ a_j$ = wall/soil adhesion force
FS	Factor of safety
h	Distance from rightside water surface to rightside soil surface
H	Total length of sheet pile
i	Seepage gradient
$\underline{i}$	Flow gradient
I	Moment of inertia of sheet-pile section, in. per foot of wall
K_A	Active pressure coefficient
K_p	Passive pressure coefficient
M_0	Maximum bending moment
N_w	Normal force on bottom of wall slice
P	Pressure
p_{Ah}	Active horizontal earth pressures
p_{Ph}	Passive horizontal earth pressures
p_v	Vertical pressure
$P_{A/P}$	Active force (upper signs) or passive force (lower signs) for this trial wedge
P_i, P_{i-1}	Normal forces on left- and rightside vertical surfaces of the slice, respectively
P_n	Normal force on vertical plane
R	Simple beam reaction
S_n	Stability number
W_i	Weight of the slice
W_w	Weight of wall slice including surcharge loads

y	Distance below rightside water surface
z	Depth of transition point
α	Earthquake acceleration
α	Wall height ratio
β	Anchor depth ratio
γ	Unit weight of soil
γ'	Buoyant unit weight
γ_{eff}	Effective unit weight of soil
γ_{mst}	Soil moist unit weight
γ_{sat}	Soil saturated unit weight
γ_{we}	Effective unit weight of water
δ	Effective angle of wall friction
δ_{av}	$\Sigma h_j\ \delta/\Sigma h_j$ = average wall friction angle
θ	Angle of inclination
ρ	Flexibility number
ϕ	Actual angle of internal friction
ϕ_{eff}	Effective angle of internal friction
ϕ_j	Effective internal friction angle of the soil at the bottom of the slice