COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

INSTRUCTIONS MANUAL

USER'S GUIDE: COMPUTER PROGRAM FOR TWO-DIMENSIONAL ANALYSIS OF U-FRAME STRUCTURES (CUFRAM)

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PO Box 6313, Vicksburg, Mississippi 39180-0313
**Title:** User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUPRAM)

**Author:** Dawkins, William P.

**Abstract:**

The computer program CUPRAM, described in this user’s guide, performs an analysis of a two-dimensional slice of a U-frame structure. The program functions in two modes, equilibrium and frame analysis.

In the equilibrium mode, the program converts soil and/or water effects to surface loads on the structure, determines the resultants of all applied loads, and determines the necessary base-reaction distribution to equilibrate the external loads. In the frame analysis mode, a model of the structure is formulated and displacements and internal forces throughout the structure are determined from a linearly elastic analysis.

Information regarding the response of the structure is provided by this program with no actual design functions nor judgment offered as to the quality of the structural performance. Under certain conditions outlined herein, an analysis of a two-dimensional slice provides comparatively reliable indications concerning the behavior of the three-dimensional system.
6a. NAME OF PERFORMING ORGANIZATION (Continued)

Locks Subgroup, U-FRAME Structures Task Group
Computer-Aided Structural Engineering Project
Description of Program

CUFRAM, called X0091 in the Conversationally Oriented Real-Time Program-Generating System (CORPS) library, is a computer program for the 2-D analysis of U-frame structures. It is intended to be an easy-to-use program incorporating many capabilities required by a diverse group of users. This program may be used to perform equilibrium and frame analyses of a two-dimensional slice of a soil- or pile-founded U-frame structure. An equilibrium analysis consists of converting soil and water data to structural loading and determining the resultants of all loads, including base reaction for a soil foundation. A frame analysis consists of establishing a plane frame model of the slice and determining displacements and internal forces throughout the structure.

Coding and Data Format

CUFRAM is written in FORTRAN and is operational on the following systems:

a. WES Honeywell DPS/8.
b. Local District Harris 500 Series.
c. Control Data Corporation's Cybernet system, Cyber 865.

Data can be input interactively at execute time or from a prepared data file with line numbers. Output may be directed to an output file or come directly back to the terminal.

How to Use CUFRAM

A short description of how to access the program on each of the three systems is provided below. It is assumed that the user knows how to sign on the appropriate system before trying to use CUFRAM. In the example initiation of execution commands below, all user responses are underlined, and each should be followed by a carriage return.

WES Honeywell System

The user signs on the system and issues the run command

FRM WESLIB/CORPS/X0091.R

to initiate execution of the program. The program is then run as described in this user's guide. The data file should be prepared prior to issuing the FRM command. An example initiation of execution is as follows, assuming a data file had previously been prepared:
The log-on procedure is followed by a call to the CORPS procedure file OLD,CORPS/UN-CECELB to access the CORPS library. The file name of the program is used in the command

\begin{verbatim}
BEGIN,,CORPS,X0091
\end{verbatim}

to initiate execution of the program. An example is:

\begin{verbatim}
CONNECTED TO 18-17
86/12/15 11.10.35 AC2DSHA
SN96 SCIENTIFIC INFORMATION SERVICE NOS1.4-531-795-1
FAMILY' KOK,CER0C2
USER NAME' CER0C2
PASSWORD

TERMINAL' 6, NAMIAF
RECOVER/ CHARGE' CHARGE,CER0C2,CER0F8
$CHARGE,CER0F8,CECCF8.
/
10.36.21. WARNING

12/15/86, SEE EXPLAIN, WARNING.
OLD,CORPS/UN-CECELB
/BEGIN,,CORPS,X0091
\end{verbatim}

The user signs on the system and issues the run command

\begin{verbatim}
*CORPS,X0091
\end{verbatim}

to initiate execution of the program.

An example is:

"ACO E-WES(HS00 V5.1.1)"
ENTER SIGN-ON
11KABC ROKABC
How to Use CORPS

The CORPS system contains many other useful programs which may be catalogued from CORPS by use of the LIST command. The execute command for CORPS on the WES system is:

FRN WESLIB/CORPS/CORPS,R
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST

On the Boeing system, the commands are:

OLD,CORPS/UN-CECELB
CALL,CORPS
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
**ELECTRONIC COMPUTER PROGRAM ABSTRACT**

<table>
<thead>
<tr>
<th>TITLE OF PROGRAM</th>
<th>PROGRAM NO.</th>
</tr>
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<tr>
<td>Two-Dimensional Analysis of U-Frame Structures (CUFRAM)</td>
<td>713-F3-R091</td>
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**PREPARING AGENCY**

**AUTHORS**

William P. Dawkins

**DATE PROGRAM COMPLETED**

October 1986

**STATUS OF PROGRAM**

Final

**A. PURPOSE OF PROGRAM**

This program may be used to perform equilibrium and frame analyses of a two-dimensional slice of a soil- or pile-founded U-frame structure. An equilibrium analysis consists of converting soil and water data to structural loading and determining the resultants of all loads, including base reaction for a soil foundation. A frame analysis consists of establishing a plane frame model of the slice and determining displacements and internal forces throughout the structure.

**B. PROGRAM SPECIFICATIONS**

Timesharing FORTRAN Program.

**C. METHODS**

Equilibrium of soil-founded structures is established using one of three automatically generated base reaction distributions or a user-prescribed distribution adjusted to account for unbalanced loads. Pile stiffness matrices for pile-founded structures are obtained from a beam-column analysis for each pile. Frame analysis is performed using conventional matrix analysis procedures based on assumed linearly elastic behavior including the effects of shear deformations.

**D. EQUIPMENT DETAILS**

**E. INPUT-OUTPUT**

Data may be input from a prepared data file or from the user's terminal during execution. When data are supplied from the user's terminal, prompts are provided to indicate the amount and type of data to be entered. Output consists of tabulated pressures, resultants, and internal forces which may be directed to a file or to the user's terminal. Graphic output includes input geometry, soil and water pressure distributions, the frame model, and shear and bending moment diagrams.

**F. ADDITIONAL REMARKS**

This program is available as part of the CORPS library system. Documentation is available from the Engineering Computer Program Library, US Army Engineer Waterways Experiment Station; (601) 634-2581 or (FTS) 542-2581.
This user's guide describes an interactive computer program, "CUFRAM," that analyzes a two-dimensional slice of a U-frame structure. The program functions in two modes, equilibrium and frame analysis. The work in developing the program and writing the user's guide was accomplished with funds provided to the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., by the Civil Works Directorate of the Office, Chief of Engineers (OCE), US Army, under the Computer-Aided Structural Engineering (CASE) Project.

Specifications for the program were provided by members of the Locks Subgroup, U-FRAME Structures Task Group of the CASE Project. Members of the Locks Subgroup during the period of development of the program were:

- Mr. Byron Bircher, Kansas City District (Task Group Chairman)
- Mr. Roger Hoell, St. Louis District (Subgroup Chairman)
- Mr. C. C. Hamby, Vicksburg District
- Mr. Tom Quigley, St. Louis District
- Mr. Tom Ruff, St. Louis District
- Mr. Charles Trahan, Lower Mississippi Valley Division
- Mr. Bill Price, Waterways Experiment Station

The computer program and user’s guide were written by Dr. William P. Dawkins, P.E., Stillwater, Okla., under Contract No. DACW39-83-M-3000 with WES.

The work was managed and coordinated at WES by Dr. N. Radhakrishnan, Acting Chief, Information Technology Laboratory (ITL), and formerly Chief, Automation Technology Center (ATC), and Mr. Paul K. Senter, ITL, formerly Chief, Scientific and Engineering Application Division, ATC. Mr. Donald R. Dressler was the OCE point of contact. Final editing for publication of this report was provided by Messrs. Gilda Miller and Deborah Shiers, editor and editorial assistant, ITL, WES.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.
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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:

<table>
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<tr>
<th>Multiply By</th>
<th>To Obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>degree (angle)</td>
<td>0.01745329 radians</td>
</tr>
<tr>
<td>feet</td>
<td>0.3048 metres</td>
</tr>
<tr>
<td>kips (force)</td>
<td>4.448222 kilonewtons</td>
</tr>
<tr>
<td>kips (force)-feet</td>
<td>1355.818 newton-metres</td>
</tr>
<tr>
<td>pounds (force)</td>
<td>4.448222 newtons</td>
</tr>
<tr>
<td>pounds (force) per cubic foot</td>
<td>0.157087 kilonewtons per cubic metre</td>
</tr>
<tr>
<td>pounds (force) per cubic inch</td>
<td>0.2714 megapascals per metre</td>
</tr>
<tr>
<td>pounds (force) per foot*</td>
<td>14.5939 newtons per metre</td>
</tr>
<tr>
<td>pounds (force) per inch</td>
<td>175.1268 newtons per metre</td>
</tr>
<tr>
<td>pounds (force) per square foot</td>
<td>47.88026 pascals</td>
</tr>
<tr>
<td>pounds (force) per square inch</td>
<td>6.894757 kilopascals</td>
</tr>
<tr>
<td>square inches</td>
<td>6.4516 square centimetres</td>
</tr>
</tbody>
</table>

* The same conversion factor applies for pounds (force) per linear foot (PLF).
USER'S GUIDE: COMPUTER PROGRAM FOR TWO-DIMENSIONAL
ANALYSIS OF U-FRAME STRUCTURES (CUFRAM)

PART 1: INTRODUCTION

Description of Program

1. This user's guide describes a computer program "CUFRAM" for analysis of a two-dimensional (2-D) slice of a U-frame structure. The program functions in two modes. In the equilibrium mode, the program converts soil and/or water effects to surface loads on the structure, determines the resultants of all applied loads, and, for a soil-founded structure, determines the necessary base reaction distribution to equilibrate the external loads. In the frame analysis mode, a 2-D plane frame model of the structure (including piles if present) is formulated and displacements and internal forces throughout the structure (and pile forces) are determined from a linearly elastic analysis. This program provides information only regarding the response of the structure, performs no design functions, nor does it attempt to judge the quality of the structural performance.

Report Organization

2. This report is divided into the following parts:
   a. Part II: Describes the 2-D structure.
   b. Part III: Describes the external soil (backfill) and water system, the conversion of soil/water properties to structural loads, and other structure loads.
   c. Part IV: Describes the treatment of the base reaction for soil founded structures and equilibrium analysis.
   d. Part V: Describes the 2-D model formulated for frame analysis including the effects of piles for pile-founded structures.
   e. Part VI: Describes the computer program.
   f. Part VII: Presents example solutions obtained with the program.
Disclaimer

3. This program was developed using criteria furnished by the CASE task group on U-frame structures. The procedures and philosophy embodied in the program do not necessarily represent the views of the author.

4. The program has been checked within reasonable limits to ensure that the results are accurate for the assumptions and limitations of the procedures employed. In all cases it is the responsibility of the user to judge the validity of the results. The author assumes no responsibility for designs or the performance of any structure based on the results of the program.
PART II: STRUCTURE

System Description

5. The U-frame system is a three-dimensional (3-D) U-shaped structure, usually concrete, surrounded by soil backfill, founded on subsoil or piles, and subjected to a variety of soil and water (both internal and external) loads. Although an accurate assessment of the behavior of the system can be obtained only from a general 3-D analysis, such an analysis is clearly prohibitive, particularly during an iterative design process.

6. Under the following conditions, an analysis of a 2-D slice can provide relatively reliable indications of the behavior of the 3-D system:
   a. When the longitudinal dimension of the system is substantially larger than the width and height of the cross section.
   b. When the cross-sectional geometry of the structure and the soil and water conditions, support conditions, and other loading effects are relatively constant throughout an extended length of the system.
   c. When a 2-D slice of the system, obtained by passing parallel planes perpendicular to the longitudinal axis of the system, is representative of adjacent slices and is sufficiently remote from any discontinuities in geometry and loading (i.e., the slice is in a state of plane strain).

7. The remainder of this report is based on the assumption that the above conditions exist in the 2-D representation.

Typical Cross Sections

8. The geometry of a cross section (monolith) is usually dictated by its position in the 3-D structure. Although name identifiers are frequently assigned to the various shapes, the basic types shown in Figure 1 will be designated by a type number as follows:
   a. Type 1 monolith—no culvert or void.
   b. Type 2 monolith—with culvert, no void.
   c. Type 3 monolith—both culvert and void.

9. The typical sections shown in Figure 1 are shown for the rightside*

* The terms "rightside," "leftside," and "centerline" are each used in a one-word form in the text to be consistent with these terms as used in the computer program.
Figure 1. Structural geometry
of the structure. When the structure is symmetric about the chamber centerline, only the right half need be provided and a mirror image will be created for the left side. In an unsymmetric system, the right side and left side must both be described and the two sides need not be the same type. In the equilibrium mode, there are few restrictions on the geometry of the section (e.g., a section may be described as having a "VOID" but without a "CULVERT"). In the frame analysis mode, the geometry is restricted to the three types illustrated in Figure 1; limitations for this mode are described further into this report.

10. In all cases, the structure is assumed to be monolithic, mass concrete. The effects of reinforcement, construction joints, expansion joints, or any other discontinuities (cracking) in the system are not taken into account. In the frame analysis to be described later, the concrete is assumed to be linearly elastic and homogeneous.

Nomenclature, Assumptions, and Limitations

11. Listed below are the various terms applied throughout this report and the assumptions and limitations employed (Appendix A, Guide for Data Input, additional definitions and limitations):

a. Chamber centerline—vertical line midway between rightside and leftside stem faces.
b. Floor—bottom of chamber, assumed to be horizontal.
c. Base—lower boundary of structure, assumed to be horizontal to some distance from chamber centerline, then may slope up or down.
d. Stem—the essentially vertical part of the structure above the chamber floor.
e. Culvert—rectangular cavity in the vicinity of the intersection of the stem and base slab.
f. Void—rectangular cavity in the stem above the culvert.
g. Heel—protrusion of the base slab beyond the stem.
h. Elevation—vertical distance (feet) measured positive upward from any selected datum.
i. Horizontal distance—positive dimension (right or left), measured from chamber centerline unless otherwise noted.
j. Stem point—point on the outside face of the stem at which a change in geometry occurs; numbered sequentially downward with stem point 1 at the top of the stem.
k. **Base point**—point on the base at which a change in geometry occurs; limited to two points on each side of chamber center-line; first point defines limit of horizontal segment of base; second point may be above or below first base point; for unsymmetric structures, the first base points on each side must be at the same elevation.

l. **Stem face**—inner vertical boundary of stem.
PART III: BACKFILL SOIL AND WATER

Loading Effects

12. The fundamental loading effects on the structure are produced by the soil acting on the external surfaces of the stems, water in the chamber, water in the culverts (and voids), water in the backfill, and by water and/or soil acting on the base. The user has the option to provide explicit magnitudes and distributions produced by these effects or to provide the physical characteristics of the soil and water which are converted to loadings by the computer program. The procedures used to convert physical properties to structure loading are described in the next paragraphs.

Backfill Soil

13. Backfill soil, if present, produces horizontal and vertical loads on the external stem surfaces. Backfill soil pressures may be described by an input pressure distribution or by the physical properties of the soil. The backfill soil profile may be composed of one to five horizontal soil layers. Soil layer 1 is the uppermost stratum with other layers numbered sequentially downward. The last layer provided is assumed to extend ad infinitum downward. Each soil layer is characterized by these parameters:

a. Elevation (FT) at top of the layer.

b. Saturated soil unit weight \( \gamma_{SAT} \) (PCF)—the saturated unit weight is used by the program to obtain the effective weight of submerged soil by subtracting the weight of water from the saturated soil weight.

c. Moist soil unit weight \( \gamma_{MST} \) (PCF)—the unit weight of the unsubmerged soil.

d. Horizontal pressure coefficients at the top and bottom of the layer \( K_{HT} \) and \( K_{HB} \), respectively)—the coefficient is assumed to vary linearly from top to bottom of the layer, except in the last layer input where the coefficient is assumed to be constant at \( K_{HT} \).

e. Shear coefficients at the top and bottom \( K_{VT} \) and \( K_{VB} \), respectively) of the layer—the coefficient is assumed to vary

\* For convenience, symbols and abbreviations are listed in the notation (Appendix C).
14. A typical soil profile is shown in Figure 2a. When the ground-water elevation occurs within a soil layer, a temporary layer interface is automatically created at the ground-water elevation with soil properties evaluated as shown in Figure 2a. Horizontal and shear coefficients are obtained by linear interpolation between values at the top and bottom of the intact layer. Initially, soil properties are converted to effective vertical pressures at the top and bottom of each layer, Figure 2b. (Note: The surface surcharge, $p_v$, may result from an applied surcharge on the ground surface or from surcharge water, see below, or both.) Horizontal and shear soil pressures are obtained from the effective vertical soil pressures by applying the horizontal and shear soil coefficients at the top and bottom of each layer, Figures 2c and 2d. Horizontal and shear soil pressures are assumed to vary linearly within a layer.

**Structure Soil Loading**

15. The resulting loading on the structure surface is obtained as illustrated in Figures 2e and 2f. The vertical, horizontal, and shear pressures acting on the vertical and horizontal surfaces of a soil element at the structure interface are converted, by Mohr's circle, to normal and tangential components on the structure surface.

**Soil Force on Sloping Base**

16. An upward sloping base (area A in Figure 2a) is subjected to the combined effects of backfill soil pressures and base soil reaction pressures, if present. In this case, only the horizontal component of the backfill soil pressure is applied to the sloping zone.

**Tension in Backfill Soil**

17. If backfill soil is in contact with the underside of an outward sloping segment of the stem surface (area B in Figure 2a), the combination of
a. Backfill profile

Figure 2. Backfill soil (Continued)
c. Horizontal soil pressure

d. Soil shear pressure

e. Soil/structure interface

f. Structure loading

Figure 2. (Concluded)
backfill soil pressures may result in a tension normal component. When this is encountered, the normal component is set to zero.

**Water**

18. Water loads may be applied to all surfaces of the structure, both internal and external. The user may select a variety of water loading effects as described below.

**Internal water**

19. Internal water is defined to be any water producing loads on the chamber floor, the interior stem face, the interior surfaces of the culvert, and possibly on the interior surfaces of the void. Water effects are specified on the chamber floor and interior stem faces by an elevation of chamber water. The resulting load on the structure is a downward pressure on the chamber floor and a triangular horizontal pressure on the interior stem face, Figure 3a.

20. The effective water elevation in the culverts (rightside, leftside, or both) is assumed to be independent of the chamber water. When the elevation of water in the culvert is below the culvert roof, water loads are produced on the interior culvert surfaces as shown in Figure 3a. If the elevation of water in the culvert is specified above the culvert roof, water loads are produced on all surfaces of the culvert (Figure 3b).

21. Culvert water may also produce loads on the interior walls of a void if the void floor and culvert roof are at the same elevation (Figure 3c). A void without a culvert or a void with its floor above the culvert roof is assumed to be dry.

**External water**

22. External water (water acting on the external stem surfaces) not only produces hydrostatic loads directly on the surface of the structure but may also affect backfill soil loads. The user may elect to provide external water effects in the form of a pressure distribution or by specifying the water elevations. An input pressure distribution is assumed to be the hydrostatic pressure only acting on the structure surface and has no effect on backfill soil. Conversely, if a backfill soil pressure distribution has been provided, this distribution is not altered by the presence of external water.
a. Culvert water elevation below top of culvert

b. Culvert water elevation above top of culvert

c. Culvert and void connected

Figure 3. Internal water
Ground water

23. Ground water is defined to be that part of the external water which reduces the effective weight of backfill soil in addition to producing hydrostatic pressures on the structure surface. The effective weight of any submerged soil is automatically determined by the program.

Surcharge water

24. An additional external water loading may be imposed in the form of surcharge water acting on the structure above the backfill soil surface. When surcharge water is present, the backfill soil surface is assumed to be covered by an impermeable membrane. Surcharge water produces hydrostatic pressures on the external surfaces of the structure above the soil surface. In addition to this, it produces a vertical surcharge load on the soil surface which increases soil effective pressures (hence, soil horizontal and shear pressures) below the soil surface. Various combinations of ground and surcharge water effects are shown in Figure 4. Note that surcharge water does not affect submergence conditions in the backfill soil (Figure 4b). If both ground water and surcharge water are present and the ground-water elevation is above the soil surface, the resulting pressure distribution will be as shown in Figure 4c. Only surcharge water pressures are applied to the structure surfaces above the soil surface. Likewise, the surcharge load on the soil surface is the result of the surcharge water only. Below the soil surface, hydrostatic pressures on the structure surface and submergence effects are produced by ground water only. This combination will produce a discontinuity in hydrostatic pressures at the soil surface.

25. In the case of an upward sloping base, as illustrated in Figure 2a, ground-water hydrostatic pressures on the structure are terminated at the elevation of base point 2. Any water effects below this elevation are assumed to be the result of uplift water.

Uplift water

26. Uplift water effects on the base of the structure may be described by a pressure distribution or by specifying uplift water elevations on each side of the structure. When uplift water elevations are provided, it is assumed that the uplift head varies linearly across the structure between the rightside and leftside elevations prescribed. Uplift water is assumed to be independent of ground water.
a. Ground water without surcharge water

\[ P_{vo} = h \cdot \gamma_w \]

b. Surcharge water and ground water

\[ P_{vo} = h_1 \gamma_w + h_2 \gamma_w \]

c. Ground water above soil surface

Figure 4. External water
Additional Loads

27. In addition to the soil and water loads described above, the user may specify any combination of concentrated or distributed loads to the structure surface, i.e., to the chamber floor, the interior stem face, the exterior stem face, the top of the stem, or the base.

Resultants of Loads

28. All distributed loads (soil, water, and additional loads) are combined into net normal and tangential pressures on the structure surface, Figure 2f. Three resultants of all loads are determined for the rightside and leftside (if necessary) of the structure. These resultants are: the sum of all horizontal loads, the sum of all vertical loads, and the sum of moments of all loads about the centerline of the chamber floor. The rightside and leftside resultants are then combined into net resultants for the entire structure. In the case of a symmetric system, only the net vertical resultant at this stage will be nonzero.
PART IV: BASE REACTION FOR SOIL-SUPPORTED SYSTEMS

29. In the case of a pile-supported structure, any unbalanced resultants (horizontal, vertical, or moment) will be equilibrated by forces developed in the piles. For soil-supported systems, unbalanced resultants are equilibrated by soil pressures acting on the base. A combination of soil and pile supports is not directly accommodated. However, an approximation of combined supports may be obtained by specifying a pile-supported structure and by applying additional distributed loads to simulate soil support. Determination of base reaction pressures for soil-supported systems is described below.

Symmetric Systems

30. In a symmetric system, only the net vertical resultant of all loads will be nonzero. This resultant is equilibrated by vertical soil pressures acting on the horizontal projection of the entire structure base (i.e., from base point 2 on the left side to base point 2 on the right side). Equilibrium may be established automatically with one of the prescribed base pressure distributions described below or by a user-supplied distribution to be discussed subsequently.

Automatic base pressure calculations (symmetric system)

31. One of three prescribed base pressure distributions may be selected from those shown in Figure 5. The procedures used to evaluate the pressures associated with each distribution are given in the next three paragraphs.

Uniform distribution (symmetric system)

32. The base reaction pressure is uniform over the entire base:

\[ p_u = \frac{V}{2d_1 + 2d_2} \]

where

- \( p_u \) = uniform pressure
- \( V \) = net vertical reaction of applied loads
- \( d_1, d_2 \) = dimensions shown in Figure 5a
a. Symmetric system

b. Uniform

c. Trapezoidal

d. Rectangular

Figure 5. Automatic base reaction distributions for symmetric systems
Trapezoidal distribution (symmetric system)

33. The base reaction pressure varies linearly from the chamber centerline to the extreme edge of the base:

\[ p_1 = R \cdot p_u \]
\[ p_2 = \frac{V}{d_1 + d_2} - p_1 \]

where

\( p_1 \) = base pressure at the chamber centerline
\( R \) = factor prescribed by the user \((0 < R < 2)\)
\( p_u \) = uniform base pressure from paragraph 32
\( p_2 \) = base pressure at extreme edge of the base

Rectangular distribution (symmetric system)

34. The base pressure distribution is composed of three regions of constant pressure: \( p_1 \) under the chamber floor; \( p_2 \) under the regions from the interior stem faces to the extreme edges of the base:

\[ p_1 = R \cdot p_u \]

where

\( p_1 \) = uniform pressure under the chamber floor
\( R \) = factor prescribed by the user \([0 < R < (d_1 + d_2)/2d_1]\)
\( p_u \) = uniform pressure from paragraph 32
\( p_2 \) = \( [(V - 2p_1d_1)/2d_2] \)
\( p_2 \) = uniform pressure from interior stem face to extreme edge of base

User-Specified Base Pressure Distribution

35. As an alternative to the automatically generated distributions just described, the user may prescribe any symmetric distribution desired. Because the net resultant of vertical loads will usually not be known initially, the user-supplied distribution may not equilibrate the vertical resultant; the
user may elect to have the program scale the input distribution to establish equilibrium, i.e.,

\[ P_{\text{actual}} = P_{\text{input}} \cdot \frac{V}{V_u} \]

where

- \( P_{\text{actual}} \) = adjusted base pressure
- \( P_{\text{input}} \) = user-specified pressure
- \( V \) = net resultant of applied vertical loads
- \( V_u \) = vertical resultant of user-specified base pressure distribution

**Unsymmetric Systems**

36. In an unsymmetric system, any or all of the net resultants of applied loads may be nonzero. The procedures available to establish equilibrium of unsymmetric systems are described below.

**Unbalanced horizontal resultant**

37. The unbalanced horizontal resultant on the 2-D slice would be equilibrated in the 3-D structure by friction along the base of the structure, by horizontal shear forces transmitted through the structure to adjacent slices, or a combination of the two. The user has several options for establishing horizontal equilibrium.

a. **Base friction.** Horizontal equilibrium is achieved by applying horizontal friction forces along the actual horizontal zone of the base (i.e., from base point 1 on the leftside to base point 1 on the rightside).

b. **Base shear.** Horizontal equilibrium is achieved by applying horizontal shear forces along the centerline of the base slab under the chamber floor (i.e., between interior stem faces).

c. **Combination.** A combination of base friction and base shear is not directly accommodated by the program. However, the user may use the additional load capability described previously to apply horizontal surface loads simulating shear or friction or both, and direct any remaining horizontal imbalance to shear or friction, as above.

**Unbalanced vertical and moment resultants**

38. Unbalanced vertical and moment resultants in unsymmetric systems
are coupled and must be equilibrated simultaneously. Equilibrium of vertical and moment resultants is established as follows:

a. The net resultants of applied loads, \( H, V, M_1 \) (\( M_1 \) = moment resultant about the chamber floor centerline), are determined.

b. Horizontal equilibrium is satisfied as described above.

c. A new moment resultant, \( M_2 \), which includes the moment of base horizontal shear or friction is determined for a point on the base at the chamber floor centerline. (Note that for an unsymmetric structure, this point will not be at the midpoint between the extreme edges of the base.)

39. An unsymmetric system and the final unbalanced vertical and moment, \( M_2 \), resultants are shown in Figure 6a. The options available to the user to establish equilibrium depend on whether one of the automatic distributions for base pressure has been prescribed or whether the user has provided his own base pressure distribution.

### Equilibrium with Automatic Base Pressure Distributions

40. When one of the three automated base pressure distributions has been selected, the following steps are used to establish vertical or moment equilibrium.

Vertical equilibrium

41. The vertical resultant is equilibrated by one of the three initial distributions shown in Figures 6b, c, and d:

a. Uniform

\[
P_u = \frac{V}{l}
\]

b. Trapezoidal

\[
P_1 = R \cdot P_u
\]

\[
P_2 = \frac{2V}{l} - P_1
\]
Figure 6. Automatic base pressure distributions for unsymmetric systems
c. Rectangular

\[ p_1 = R \cdot p_u \]

\[ p_2 = \frac{V - p_1 c}{d_2 + d_4} \]

**Moment equilibrium**

42. Because of the nonsymmetry of the above initial distributions, the net vertical resultant and the resultant of the initial distribution, while equal in magnitude, will not be colinear. The couple formed by the two vertical resultants is added to the moment resultant, \( M_2 \), to form a third unbalanced moment resultant, \( M_3 \) (i.e., unbalanced moment about the base centerline). Equilibrium of this resultant is established by adding a linear pressure distribution to the initial base pressure distribution, Figure 6e:

\[ p_x = -12 \left( \frac{M_3 x}{t^3} \right) \]

where

- \( p_x \) = pressure due to unbalanced moment
- \( M_3 \) = unbalanced moment
- \( x \) = distance from base centerline, positive to the right
- \( t \) = width of the structure base

**Equilibrium with user-supplied base pressure distribution**

43. Two options are available when the user-supplied base pressure distribution does not equilibrate the net vertical resultant, \( V \), and the moment resultant, \( M_2 \).

**Adjustment of User-Supplied Distribution**

44. Vertical equilibrium is established by augmenting the input pressure at each point according to
\[ P_{\text{actual}} = P_{\text{input}} \cdot \frac{V}{V_u} \]

where

\[ P_{\text{actual}} = \text{adjusted base pressure} \]
\[ P_{\text{input}} = \text{user-specified pressure} \]
\[ V = \text{net resultant of applied vertical loads} \]
\[ V_u = \text{vertical resultant of user-specified base pressure distribution} \]

45. Again, the couple due to the vertical resultant, \( V \), and the resultant of the augmented pressure, \( V_u \), is added to the net moment resultant, \( M_2 \), to form a final unbalanced moment resultant, \( M_3 \). This final resultant is equilibrated by adding a linear pressure distribution (paragraph 45) to the user supplied distribution.

**Vertical Structural Shear**

46. Any portion of the vertical and/or moment resultant not equilibrated by the user-supplied base pressure distribution may be assumed to be resisted by vertical shear forces in the structure stems. The resultants of these structure shear forces are established according to

\[ V = V^* - V_{R} \]

where

\[ V_R, V_L = \text{resultants of vertical stem shear forces} \]
\[ V^*, M^* = \text{vertical and moment unbalances remaining after combining resultants of applied loads and resultants of user-supplied base reaction} \]
\[ d_L, d_R = \text{distances from chamber centerline to line of action of leftside and rightside vertical shear forces. In the equilibrium mode, } d_L \text{ (} d_R \text{) is the average thickness of the leftside (rightside) stem plus half of the chamber width. In the frame analysis mode, } d_L, d_R \text{ are the distances from the chamber} \]
centerline to the centroid of the inside rigid block (paragraph 62).

**Negative Base Pressures**

47. In severely unsymmetric systems, combination of the linear pressure distribution due to moment unbalance with the initial automatic or user-supplied base pressure distribution may result in negative (i.e., tension) base pressures. When this condition is encountered, the user is notified by the program and execution is terminated.

**Equilibrium Mode**

48. Evaluation of soil, water, and base reaction pressures, and net unbalanced resultants (for pile-supported structures) constitutes the extent of computations performed in the equilibrium mode. The user should exercise the program in this mode to verify structural loadings and resultants before attempting a complete frame analysis. It should be noted that an equilibrium analysis may be performed for a variety of structures which are not accommodated in the frame analysis mode.
PART V: FRAME ANALYSIS

General Overview

49. The equilibrium phase of the analysis described in paragraph 48 determines the distribution of loads around the periphery of the structure. When a frame analysis is specified, relative displacements and axial, shear, and bending moment forces are evaluated throughout the structure using a 2-D plane frame model of the structure.

Restrictions on Structure Geometry

50. There are few limitations on the structure geometry when the program is exercised in the equilibrium mode. In order to perform a frame analysis, the following limitations are imposed. (In the following discussion, the term "monolith" refers to the shape of the structure on each side of the chamber centerline. A structure may have different types of monoliths on each side. However, at the chamber centerline, the thickness of the base slab must be the same for the two halves.)

51. There are six basic monoliths permitted for frame analysis: type 1, type 2, and four variations of type 3, subsequently designated as types 31 through 34. The requirements on geometry for each of these types are discussed below. In the following descriptions, reference is made to "rigid blocks" at various locations in the structure. This term and the effects of rigid blocks will be discussed later.

Type 1 Monolith

52. A type 1 monolith, Figure 7, has neither a culvert nor a void in the stem. Six stem points, S1 through S6, are required with the following limitations on horizontal distance from the stem face (D_i) and elevation (E_i) for the i-th stem point:
   a. \( E_1 > E_f \), \( D_1 > 0 \)
   b. \( E_2 < E_1 \), \( D_2 = D_1 \)
   c. \( E_3 \leq E_2 \), \( D_3 \leq D_2 \)
Figure 7. Type 1 monolith
Type 2 Monolith—Standard Case

53. A type 2 monolith, Figure 8, has a culvert in the stem but no void. Eight stem points are required and five (B1, B2, B3, B4, B6) rigid blocks are associated with the standard case. The following limitations are imposed:

- The bottom of the culvert must be at or below the elevation of the chamber floor.
- The top of the culvert must be above the elevation of the chamber floor.
- If only one base point provided, \( E_{B1} < E_6 \), \( D_{B1} = D_f + D_6 \)
- If two base points provided, \( E_{B2} < E_6 \), \( D_{B2} = D_f + D_6 \) and \( D_{B1} = D_B + D_5 \)
Figure 8. Type 2 monolith, standard case
1. If two base points provided,

$$E_{B2} < E_8, \quad D_{B2} = D_f + D_8$$

$$D_{B1} = D_f + D_7$$

S4. In some special cases of the type 2 monolith, it may be desired that the entire culvert roof be treated as a rigid block, i.e., blocks B3 and B4 merge into a single rigid block. To impose this case, Figure 9, stem points S5 and S6 must coincide ($E_5 = F_6, \quad D_5 = D_6$). All other restrictions of the standard type 2 monolith apply.

Figure 9. Type 2 monolith, special case
Type 3 Monolith—Variations

55. A type 3 monolith must have both a culvert and a void in the stem with six associated rigid blocks. Depending on the dimensions of the culvert and void, four distinct variations (types 31, 32, 33, and 34) of type 3 monoliths may arise. In all cases, the floor of the culvert must be at or below the elevation of the chamber floor and the top of the culvert must be above the chamber floor.

Type 31 monolith

56. The culvert and void are separated (i.e., $E_v > E_c + H_c$) and the top of the void is closed ($E_1 > E_v + H_v$). Seven stem points are required, as shown in Figure 10.

a. $E_1 > E_f$, $E_1 > E_v + H_v$, $D_1 > D_v$
b. $E_2 < E_1$, $D_2 = D_1$
c. $E_2 \geq E_3 > E_v$, $D_2 \geq D_3 > D_v$
   (Stem points $S_1$, $S_2$, $S_3$ define block $B_6$.)
d. $E_4 < E_3$, $D_4 > D_v$
e. $E_4 \geq E_5 > E_c + H_c$, $D_5 > D_c$
f. $E_5 > E_6 < E_c + H_c$, $D_6 > D_c$
   (Stem point $S_6$ defines block $B_1$.)
g. $E_7 \leq E_6$, $D_7 \geq D_6$
   (If $S_6$ and $S_7$ coincide, heel is omitted.)
h. If only one base point provided,
   $E_{B1} \leq E_7$, $D_{B1} = D_f + D_7$
i. If two base points provided,
   $E_{B2} < E_7$, $D_{B2} = D_f + D_7$
   $D_{B1} \leq D_f + D_7$

Type 32 monolith

57. The culvert and void are connected (i.e., $E_v = E_c + H_c$) and the top of the void is closed (i.e., $E_1 > E_v + H_v$). A type 32 monolith has four rigid blocks ($B_1$, $B_2$, $B_5$, $B_6$). A discussion of the effect of discontinuities in the culvert and void walls at their intersections will be discussed (i.e., blocks $B_3$ and $B_4$ of the type 31 monolith degenerate to lines). Five stem points are required, as shown in Figure 11.

a. $E_1 > E_v + H_v$, $D_1 > D_v$
b. $E_2 < E_1$, $D_2 = D_1$
Figure 10. Type 31 monolith
Figure 11. Type 32 monolith
c. \( E_3 \leq E_2, \quad D_2 \geq D_3 > D_v \)
   (Stem points S1, S2, S3 define block B6.)

d. \( E_4 < E_v, \quad D_4 > D_c \)

e. \( E_5 \leq E_4, \quad D_5 \geq D_4 \)
   (If S4 and S5 coincide, heel is omitted.)

f. If only one base point provided,
   \( E_{B1} < E_5, \quad D_{B1} = D_f + D_5 \)

g. If two base points provided,
   \( E_{B2} < E_5, \quad D_{B2} = D_f + D_5 \)
   \( D_{B1} \leq D_f + D_6 \)

Type 33 monolith

58. The culvert and void are separated (i.e., \( E_v > E_c + H_c \)) and the top of the void is open (i.e., \( E_1 = E_v + H_v \)). A type 33 monolith has five rigid blocks (B1, B2, B3, B4, B6). Block B5 of the type 31 monolith is absent. Seven stem points are required, as seen in Figure 12.

a. \( E_1 = E_v + H_v, \quad E_1 > E_f, \quad D_1 > D_v \)

b. \( E_2 < E_1, \quad D_2 = D_1 \)

c. \( E_v < E_3 \leq E_4, \quad D_v < D_3 \leq D_2 \)
   (Stem points S1, S2, S3 define block B6.)

d. \( E_c + H_c < E_4 < E_v, \quad D_4 > D_v \)

e. \( E_4 \geq E_5 \geq E_c + H_c, \quad D_5 > D_c \)
   (Stem point S6 defines block B1.)

f. \( E_6 < E_5, \quad D_6 > D_c \)

g. \( E_7 \leq E_6, \quad D_7 \geq D_6 \)
   (If S6 and S7 coincide, heel is omitted.)

h. If only one base point provided,
   \( E_{B1} < E_7, \quad D_{B1} = D_f + D_7 \)

i. If two base points provided,
   \( E_{B2} < E_7, \quad D_{B2} = D_f + D_7 \)
   \( D_{B1} \leq D_f + D_6 \)

Type 34 monolith

59. The culvert and void are connected (i.e., \( E_v = E_c + H_c \)) and the void top is open (i.e., \( E_1 = E_v + H_v \)). A type 34 monolith has three rigid blocks (B1, B2, B6). Blocks B3 and B4 degenerate to lines; block B5 is absent. Figure 13 shows the five stem points that are required.

a. \( E_1 = E_v + H_v, \quad E_1 > E_f, \quad D_1 > D_v \)
Figure 12. Type 33 monolith
Figure 13. Type 34 monolith
b. \( E_2 < E_1, \ D_2 = D_1 \)

c. \( E_v < E_3 \leq E_2, \ D_v < D_3 \leq D_2 \)
    (Stem points S1, S2, S3 define block B6.)

d. \( E_4 < E_c + H_c, \ D_4 > D_c \)
    (Stem point S4 defines block Bl.)

e. \( E_5 < E_4, \ D_5 \geq D_4 \)
    (If S4 and S5 coincide, heel is omitted.)

f. If only one base point provided,
    \( E_{Bl} < E_5, \ D_{Bl} = D_f + D_5 \)

g. If two base points provided,
    \( E_{B2} < E_5, \ D_{B2} = D_f + D_5 \)
    \( D_{Bl} \leq D_f + D_4 \)

Caution

60. Myriad checks of user input data are performed by the computer program to assure compliance of the data with the assumptions and restrictions described above. Because the variations of structural geometry and loading are innumerable, it is possible that some descriptions are accepted by the program for which strict compliance has not been met. It is the responsibility of the user to verify that any results produced by the program are appropriate for his system.

Frame Model

61. Structural analysis of the U-frame is based on the assumption that the various slabs, walls, etc. of the structure interact as elements (members) of a 2-D plane frame. Establishment of a plane frame representation of the structure requires designation of parts of the structure as flexible "members" connected at their ends to joints. While some regions of the structure may lend themselves to treatment as flexible members (i.e., beam bending elements), there exist significant zones of mass concrete which cannot be assigned bending characteristics. These zones, alluded to previously, have been assumed to be rigid. The location and extent of these rigid blocks, their effect on the members connected to the blocks, the member characteristics, and locations of joints are described below.
Rigid Blocks

62. Depending on the type of monolith, from two to six rigid blocks are defined. The size and shape of the rigid blocks are determined by the relative positions of the various input dimensions of the structure. The geometry of each rigid block is prescribed by elevations and distances from the chamber centerline at six points around the periphery of each block as follows.

**Block B1--type 1 monolith**

63. In a type 1 monolith, block B1 is at the intersection of the base slab and stem (and heel, if present). The locations of the six points on the block for several example combinations of structural dimensions are shown in Figure 14 by the circled numbers. Any corner of the block which does not coincide with the location of a stem point or base point is obtained by linear interpolation between the two bounding input points.

**Block B1--type 2 or type 3 monolith**

64. Block B1 in type 2 or any of the type 3 monoliths occupies the intersection of the base slab and the outside culvert wall (and heel, if present). Examples of block B1 geometries for a type 2 monolith are shown in Figure 15. Identical geometries apply to any of the type 3 monoliths, except that the last two stem points are: S6 and S7 for types 31 and 33; and S4 and S5 for types 32 and 34.

**Block B2--type 2 or type 3 monolith**

65. Block B2, types 2 and 3 monoliths, occupies the intersection of the base slab with the interior culvert wall. Example geometries of block B2 are shown in Figure 16.

**Block B3--type 2 monolith**

66. For a standard type 2 monolith, block B3 occupies the intersection of the interior culvert wall, the culvert roof slab, and the stem above the culvert. Example geometries for this case are shown in Figure 17. When stem points S5 and S6 coincide, block B3 occupies a rectangular area bounded by the stem face, the top of the culvert, and the elevation and distance to stem point S5 as shown in Figure 9.

**Block B4--type 2 monolith**

67. For a standard type 2 monolith, block B4 occupies the intersection of the culvert roof slab with the exterior culvert wall. The geometry of block B4 is shown in Figure 18.
Figure 14. Example geometries of rigid block B1 for type 1 monoliths.
Figure 15. Example geometries for rigid block B1 for type 2 (or 3) monoliths (for types 31 and 33 monoliths, replace S7, S8 by S6, S7; for types 32 and 34 monoliths, replace S7, S8 by S4, S5)
Figure 16. Example geometries of rigid block B2 for type 2 or 3 monoliths

Figure 17. Example geometries for rigid block B3 for type 2 monoliths, standard case
Figure 18. Rigid block B4 for type 2 monolith, standard case

**Block B3--type 3 monolith**

68. For types 31 and 33 monoliths, block B3 occupies the intersection of the interior culvert wall, the interior void wall, and the slab separating the culvert and void as illustrated in Figure 19a. Block B3 degenerates to a line for types 32 and 34 monoliths as shown in Figure 19b. For the latter case, all points on block B3 are at the same elevation.

**Block B4--type 3 monolith**

69. For types 31 and 33 monoliths, block B4 occupies the intersection of the exterior culvert wall, the exterior void wall, and the slab separating the culvert and void. Example geometries for these cases are shown in Figure 20a. For types 32 and 34 monoliths, block B4 degenerates to a line as illustrated in Figure 20b. In the latter case, all points are at the same elevation.

**Block B5--type 3 monolith**

70. Block B5 occupies the rectangular area at the intersection of the interior void wall with the void roof slab for types 31 and 33 monoliths (see Figures 10 and 12). Block B5 may be interpreted to degenerate to a line at the top of the interior void wall for types 32 and 34 monoliths.

**Block B6**

71. Block B6 is assumed to be present in all monoliths, being the topmost part of the stem for types 1 and 2 and the intersection of the exterior void wall and void roof slab (if present) for type 3 monoliths. Example
a. Type 31 or 33 monoliths

b. Type 32 or 34 monoliths

Figure 19. Example geometries for rigid block B3 for type 3 monoliths
Figure 20. Example geometries for rigid block B4 for type 3 monoliths

Geometries are shown in Figures 21 and 22. (Note: By supplying three closely spaced stem points (S1, S2, S3) at the top of the stem, block B6 may be caused to degenerate into a line for types 1, 2, 32, and 34 monoliths without stem protrusions.)
Figure 21. Example geometries for rigid block B6 for types 1 and 2 monoliths

Figure 22. Example geometries for rigid block B6 for type 3 monoliths

a. Type 31 or 32 monoliths
b. Type 31 or 32 monoliths
c. Type 31 or 32 monoliths
d. Type 33 or 34 monoliths
Loads on Rigid Blocks

72. Any loads acting on the external surfaces of the rigid blocks, as well as the weight of the block, are converted into statically equivalent concentrated loads acting at the centroid of the rigid block.

Flexible Portions of Structure

73. The following portions of the structure are assumed to be capable of distortion under the influence of external loads:
   a. The base slab from the chamber centerline to the interior boundary of block B1 for a type 1 monolith or block B2 for types 2 and 3 monoliths.
   b. The base slab under the culvert between blocks B2 and B1 for types 2 and 3 monoliths.
   c. If present, the heel beyond the exterior boundary of block B1 for all types.
   d. The interior culvert wall between blocks B2 and B3 for types 2 and 3 monoliths.
   e. The exterior culvert wall between blocks B1 and B4 (B3 for type 2, special case) for types 2 and 3 monoliths.
   f. The culvert roof slab for type 2 standard monoliths and for types 31 and 33 monoliths.
   g. The stem between blocks B1 and B6 for type 1 monoliths or between blocks B3 and B6 for type 2 monoliths.
   h. The interior and exterior void walls in type 3 monoliths between blocks B3 and B5, and between blocks B4 and B6, respectively.
   i. The void roof slab for types 31 and 32 monoliths.

Centerline of Flexible Portions

74. The boundaries of the rigid blocks in contact with the flexible portions of the structure are in all cases horizontal or vertical lines. Likewise, the vertical chamber centerline, the outside end of a heel (if present), a vertical line through an interior base point, and/or a horizontal line through an intermediate stem point (e.g., stem point S4 in a type 1 or 2 monolith) form additional horizontal and vertical boundaries at the ends of the flexible portions of the structures. The centerline of the flexible
portion is defined to be the straight line at middepth of each portion. This
centerline is used to establish the locations of joints and to evaluate stiff-
ness properties of the structural members in the model.

Joints in the Model

75. Joints in the frame model are established at the following loca-
tions in the structure:
   a. At middepth of the base slab at the chamber centerline.
   b. At points on the centerline of the flexible portions of the
      base slab (and heel) immediately above the intersection of a
      pile with the base (discussion of piles, paragraph 99).
   c. At an intermediate input base point if the point falls within
      the limits of a flexible portion.
   d. At middepth of the extreme heel end (if heel is present).
   e. At the centroid of each rigid block.
   f. At stem point S4 in types 1 and 2 monoliths.
   g. At the elevation of void ties in type 3 monoliths (discussion
      of void ties, paragraph 98).

Members in the Model

76. A structural member in the model is defined to be that portion of
the structure which is between two joints.

Numbering of Joints and Members

77. Integer number identifiers are assigned to the joints and members
as follows:
   a. Joints on the base are numbered beginning with (1) on the cham-
      ber centerline and proceeding sequentially outward to the ex-
      treme end of the base.
   b. Members in the base are numbered beginning with (1) for the
      member connected to the chamber centerline joint and proceeding
      sequentially outward.
   c. Joint numbers and member numbers assigned to the structural
      components above the base slab depend on the type of monolith.

78. Joint and member identifiers for several monoliths are illustrated
in Figures 23, 24, and 25.
Figure 23. Joint and member numbers for type I monoliths.
Figure 24. Example joint and member numbers for type 2 monoliths, standard case, with soil support
Figure 25. Example joint and member numbers for type 31 monoliths with soil support
Frame Member Dimensions

79. A member of the frame model may be connected to two intermediate joints (e.g., members 1 and 2 in Figure 23), to an intermediate joint at one end and to a rigid block at the other (e.g., members 6 and 7 in Figure 24), or may be connected to rigid blocks at each end (e.g., members 2 through 5 in Figure 24). In addition, the member cross section may be prismatic (e.g., member 1 in Figure 23) or may vary linearly (e.g., member 5 in Figure 24). In the following paragraphs, the evaluation of the member stiffness matrix and the assignment of various member characteristics are illustrated for a tapered member intersecting rigid blocks at each end.

80. A general tapered member is shown in Figure 26 (e.g., a base slab member under the culvert for a type 2 or 3 monolith). The connectivity of this member to the joints is expressed as "member m goes from joint i to joint j." The member flexible centerline intersects the vertical boundaries of the rigid blocks (at midheight) at points a' and b'. The cross-sectional dimensions are assessed from the vertical dimensions $H_1$ and $H_2$ at points a' and b' as illustrated. Hence the member cross section will be rectangular at each end with dimensions B wide ($B = \text{thickness of the 2-D slice}$) by $H_1$ deep at the left end and B by $H_2$ at the right end.

Member Flexible Length

81. A complex state of stress exists at the intersection of the member ends with the boundaries of the rigid blocks. Although the blocks have been described as rigid, there will be some deformation of the material at these interfaces. To account for this additional deformation, the flexible length of the member is extended into the blocks at each end to points a and b. The location of points a and b is established as follows. The horizontal distance from the rigid block centerline to the vertical interface is reduced by a user supplied factor $S$ ($0 \leq S \leq 1$). $S = 0$ extends point a or b to a vertical line through the block centroid; $S = 1$ places point a or b on the vertical interface (i.e., a, a' and b, b' coincide). The effect of the factor $S$ is to shrink the size of the rigid blocks for flexibility assessment only; for other purposes (i.e., surface load transfer or piles intersecting the surface of a rigid block), the dimensions of the rigid blocks are unaffected.

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82. For evaluation of the member stiffness matrix and fixed end forces, the member is treated as a flexible section between points a and b (with cross sections at a and b as described in paragraph 80). The ends of the flexible length (a and b) are connected to the end joints i and j (i.e., centroids of blocks) by rigid links as shown in Figure 27. This approximation, in effect, distorts the actual member shape. The effect of this distortion is felt not to introduce significant errors for lightly tapered members or where the factor \( S \) is approximately equal to 1.

\[
\text{Figure 27. Equivalent frame member}
\]

**Member Stiffness Matrix**

83. The member stiffness matrix for the member which is connected to joints i and j relates forces at joints i and j to displacements at joints i and j and accounts for the effects of the flexible length of the member and the effects of the rigid links at each end. This force-displacement relationship is initially established for a local righthand Cartesian coordinate system \((x, y, z)\) with the origin at a, the \(x\)-axis along the member flexible centerline positive toward b, and the \(z\)-axis positive outward from the plane of the figure. Forces on the ends of the flexible length related to the local coordinate system are shown in Figure 28.

84. At any point on the member \((\xi = x/L)\), the internal stress resultants are related to the member end forces at a by

\[
P_{\xi} = -f_{xa}
\]
\[ V_\xi = f_y a \]

\[ M_\xi = f_y a \xi - m a \]

where

\[ P_\xi = \text{axial stress resultant at } \xi \]
\[ V_\xi = \text{shear force at } \xi \]
\[ M_\xi = \text{bending moment at } \xi \]

Figure 28. Member end forces and displacements in member coordinate system

85. Employing classical structural mechanics, the relationships between the forces and displacements at end \( a \) are expressed by

\[ u_a = \frac{f_x a}{E} \int_{\xi=0}^{\xi=1} \frac{d\xi}{A_\xi} \]

\[ v_a = -\frac{f_y a}{E} \left( \int_{\xi=0}^{\xi=1} \frac{\xi^2 d\xi}{I_\xi} + \frac{E}{G_\xi^2} \int_{\xi=0}^{\xi=1} \frac{d\xi}{A_\nu_\nu} \right) + \frac{m a}{E} \int_{\xi=0}^{\xi=1} \frac{\xi d\xi}{I_\xi} \]

\[ \theta_a = -\frac{f_y a}{E} \int_{\xi=0}^{\xi=1} \frac{\xi d\xi}{I_\xi} + \frac{m a}{E} \int_{\xi=0}^{\xi=1} \frac{d\xi}{I_\xi} \]
where

\[ A_\xi = \text{cross-sectional area at } \xi \]
\[ = B[H_1(1 - \xi) + H_2(\xi)] = BH_1\left(1 + \frac{H_2 - H_1}{H_1}\xi\right) \]
\[ = A_o(1 + c\xi) \]
\[ I_\xi = \text{cross-sectional moment of inertia at } \xi \]
\[ = \frac{BH_1^3}{12}(1 + c\xi)^3 = I_o(1 + c\xi)^3 \]
\[ A_v\xi = \text{shear area at } \xi \]
\[ = \frac{A_o}{1.2}(1 + c\xi) \]
\[ E = \text{modulus of elasticity} \]
\[ G = \text{shear modulus} = E/[2(1 + \nu)] \]
\[ \nu = \text{Poisson's ratio} \]

86. Evaluation of the integrals above yields:

\[ u_a = \frac{f_{xa}}{E A_o} \frac{\xi}{c} \text{ Ln}(1 + c) \]

(Ln = Naperian logarithm)

\[ v_a = \frac{f_{ya} t^3}{E I_o} \left\{ \frac{1}{c} \left[ \frac{1}{3} \text{ Ln } (1 + c) - \frac{c(2 + 3c)}{2(1 + c)^2} \right] + \frac{\phi \text{ Ln } (1 + c)}{c} \right\} - \frac{M_a}{E I_o} \left[ \frac{1}{2(1 + c)^2} \right] \]

\[ \phi = \frac{1.2 E I_o}{G A_o t^2} \]

\[ \theta_a = -\frac{f_{ya} t^2}{E I_o} \left[ \frac{1}{2(1 + c)^2} \right] + \frac{M_a}{E I_o} \left[ \frac{2 + c}{2(1 + c)^2} \right] \]

87. Inversion of the equations of paragraph 86 gives the following relationship between forces and displacements at \( a \).
\[
\begin{bmatrix}
 f_{x a} \\
 f_{y a} \\
 M_a \\
 f_{x b} \\
 f_{y b} \\
 M_b \\
\end{bmatrix} = \begin{bmatrix}
 k_{11} & 0 & 0 & 0 \\
 0 & k_{22} & k_{23} & 0 \\
 0 & k_{32} & k_{33} & 0 \\
 k_{22} & k_{23} & 0 & -k_{22} \\
 k_{33} & 0 & -k_{23} & (k_{23} - k_{22}) \\
 SYM & k_{11} & 0 & 0 \\
\end{bmatrix}
\begin{bmatrix}
 U_a \\
 V_a \\
 \theta_a \\
 U_b \\
 V_b \\
 \theta_b \\
\end{bmatrix}
\]

(Note \(k_{32} = k_{23}\))

88. Finally, the entire member force-displacement relationship is expressed as

\[
\begin{bmatrix}
 f_{x a} \\
 f_{y a} \\
 M_a \\
 f_{x b} \\
 f_{y b} \\
 M_b \\
\end{bmatrix} = \begin{bmatrix}
 k_{11} & 0 & -k_{11} & 0 & 0 \\
 k_{22} & k_{23} & 0 & -k_{22} & (k_{22} - k_{23}) \\
 k_{33} & 0 & -k_{23} & (k_{23} - k_{22}) & (k_{23} - k_{22}) \\
 SYM & k_{11} & 0 & 0 & (k_{22} - k_{22}) \\
\end{bmatrix}
\begin{bmatrix}
 U_a \\
 V_a \\
 \theta_a \\
 U_b \\
 V_b \\
 \theta_b \\
\end{bmatrix}
\]

or \(f = k'u\)

89. For a prismatic member, \(c = 0\), the stiffness coefficients become:

\[
k_{11} = \frac{EA}{L}
\]

\[
k_{22} = \frac{12EI}{L^3(1 + 12\phi)}
\]

\[
k_{23} = \frac{6EI}{L^2(1 + 12\phi)}
\]

\[
k_{33} = \frac{4EI(1 + 3\phi)}{L(1 + 12\phi)}
\]
Transformation to Global Coordinates

90. Prior to imposing the effects of the rigid links, the member force-displacement relationship is transformed to relate force components at ends \( a \) and \( b \) to displacement components in the global coordinate system. (The global coordinate system has \( x \) horizontal and \( y \) vertical; the global \( z \) axis is coincident with the local \( z \) axis.) This transformation results in:

\[
F_{ab} = R^T k'_T R U_{ab}
\]

or

\[
F_{ab} = k U_{ab}
\]

where

- \( F_{ab} \) = 6x1 vector of global force components at \( a \) and \( b \)
- \( R \) = transformation matrix

\[
R = \begin{bmatrix}
    c_x & c_y & 0 & 0 & 0 & 0 \\
    -c_y & c_x & 0 & 0 & 0 & 0 \\
    0 & 0 & 1 & 0 & 0 & 0 \\
    0 & 0 & 0 & c_x & c_y & 0 \\
    0 & 0 & 0 & -c_y & c_x & 0 \\
    0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\]

- \( c_x \) = cosine of the angle between local \( x \) and global \( x \)
- \( c_y \) = cosine of the angle between local \( x \) and global \( y \)
- \( R^T \) = transpose of \( R \)
- \( U_{ab} \) = 6x1 vector of global displacement components at \( a \) and \( b \)
- \( k' \) = local stiffness matrix
- \( k \) = global stiffness matrix
Effect of Rigid Links

91. Free body diagrams of the rigid links at the ends of the member are shown in Figure 29. All force and displacement components as well as the
dimensions of the rigid links are parallel to the global coordinates. Equilibrium and kinematic analysis of the rigid links provides:

\[
\begin{bmatrix}
U_a \\
V_a \\
\theta_a \\
U_j \\
V_j \\
\theta_j
\end{bmatrix} = 
\begin{bmatrix}
1 & 0 & -a_y & 0 & 0 & 0 \\
0 & 1 & a_x & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & b_y \\
0 & 0 & 0 & 0 & 1 & -b_x \\
0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix} 
\begin{bmatrix}
U_i \\
V_i \\
\theta_i \\
U_j \\
V_j \\
\theta_j
\end{bmatrix}
\]
or

Figure 29. Free body diagrams of rigid links
\[ U_{ab} = D U_{ij} \]

and

\[
\begin{align*}
\begin{bmatrix}
F_{xi} \\
F_{yi} \\
M_i \\
F_{xj} \\
F_{yj} \\
M_j
\end{bmatrix} = & \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 \\
-a_y & a_x & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & b_y & -b_x & 1
\end{bmatrix}
\begin{bmatrix}
F_{xa} \\
F_{ya} \\
M_a \\
F_{xb} \\
F_{yb} \\
M_b
\end{bmatrix}
\]

or

\[ F_{ij} = D^T F_{ab} \]

92. Combination of the relationship of paragraphs 90 and 91 results in

\[ F_{ij} = D^T R k RDU_{ij} = K_{ij} U_{ij} \]

where \( K_{ij} \) is the global stiffness matrix of the member connected to joints \( i \) and \( j \), including the effect of rigid links.

Member Fixed End Forces

93. Due to the surrounding soil and water, the external surfaces of a member are subjected to distributed normal and tangential forces and possibly concentrated forces. Only those forces which act on the member between the vertical boundaries of the rigid blocks (between points \( a' \) and \( b' \), Figure 26) are treated as member loads. A priori all surface loads are resolved into components parallel and perpendicular to the member flexible centerline. The contributions of member loads to member fixed end forces are approximated as follows.

94. A member and surface loads are illustrated in Figure 30 for an essentially horizontal member. (For an essentially vertical member, interchange
the descriptions horizontal and vertical in the following discussion.) The member is bounded by vertical lines through the ends of the flexible length (through a and b). Surface loads perpendicular ($q$) and parallel ($t$) to the member flexible centerline are shown on the top surface. These surface loads vary linearly from $q_1$, $t_1$, to $q_2$, $t_2$ between the limits of $\xi = \xi_1$ to $\xi = \xi_2$ where $\xi$ is a dimensionless coordinate defined by $\xi = x/L$, where $x$ is the local coordinate of generic point $(p)$ and $L$ is the flexible length of the member. The magnitude of the distributed loads at a generic point $p'$ on the surface immediately above (vertical) $(p)$ are given by

$$ q_\xi = q_1(1 - \xi) + q_2 \xi $$

and

$$ t_\xi = t_1(1 - \xi) + t_2 \xi $$
and the vertical distance from \( p \) to \( p' \) is given by

\[
h_{\xi} = \frac{H_1(1 - \xi) + H_2\xi}{2}
\]

If the displacements of point \( p \) are \( u, v, \) and \( \theta \) (components parallel to the local coordinate system), the displacements of the surface point \( p' \) may be expressed as (ignoring the small deformations of the cross section)

\[
\begin{align*}
u_s &= u - ch_{\xi} \cdot C_a \theta \\
v_s &= v + ch_{\xi} \cdot S_a \theta
\end{align*}
\]

where

\[
s = +1 \text{ for loads on top surface, } 0 \text{ for self weight of member, } -1 \text{ for loads on bottom surface}
\]

\[
C_a = \cos \alpha \\
S_a = \sin \alpha
\]

The displacements of the generic point \( p \) may in turn be expressed in terms of the end displacements at \( a \) and \( b \) as

\[
\begin{align*}
u &= \psi_1(\xi)u_a + \psi_4(\xi)u_b \\
v &= \psi_2(\xi)v_a + \psi_3(\xi)\theta_a + \psi_5(\xi)v_b + \psi_6(\xi)\theta_b \\
\theta &= \frac{dv}{dx}
\end{align*}
\]

where \( \psi_n(\xi) \) is an interpolation function of \( \xi \) to be discussed later. By the process of virtual work, the fixed end forces at \( a \) and \( b \) are evaluated for unit values of the end displacements as

\[
f_{xa} = \int_{\xi_1}^{\xi_2} t_{\xi} u_s d\xi \\
(f_a = 1, \text{ others } 0)
\]

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\[ f_y = t_s \int_{\xi_1}^{\xi_2} q_\xi \nu \, d\xi + t_s \int_{\xi_1}^{\xi_2} t_\xi u_s \, d\xi \quad (v_s = 1, \text{ others } 0) \]

\[ M = t_s \int_{\xi_1}^{\xi_2} q_\xi \nu \, d\xi + t_s \int_{\xi_1}^{\xi_2} t_\xi u_s \, d\xi \quad (\theta_s = 1, \text{ others } 0) \]

\( f_{xb}, f_{yb}, \text{ and } M_b \) are obtained from the above expressions for \( u_b = 1, v_b = 1, \text{ and } \theta_b = 1 \) with other displacements zero, respectively.

95. The interpolation functions \( \psi_n(\xi) \) of paragraph 94 relate displacements at a generic point on the member centerline of an unloaded member to displacements at the ends of the member. Such functions are available only for a prismatic member in which shear distortions are negligible or where the distributed loads are uniformly distributed. A variety of structures have been analyzed to investigate the degree of approximation introduced by using prismatic member interpolation functions for tapered members. It is felt that no appreciably significant errors are produced for the ordinary geometries usually encountered in U-frame structures. However, no information is available related to the magnitude of errors in severely tapered members or for cases where loadings are significantly nonuniform. The interpolation functions used in the current analysis are

\[ \psi_1 = 1 - \xi \]

\[ \psi_2 = 2\xi^3 - 3\xi^2 + 1 \]

\[ \psi_3 = (\xi^3 - 2\xi^2 + \xi)\xi \]

\[ \psi_4 = \xi \]

\[ \psi_5 = -2\xi^3 + 3\xi^2 \]

\[ \psi_6 = (\xi^3 - \xi^2)\xi \]

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96. The fixed end forces at the ends of the flexible length are transformed to global coordinate components and thence through the rigid links at the member ends to yield

$$F_{eij} = D^TR^TF_eab$$

where

- $F_{eij}$ - 6x1 vector of fixed end forces at joints $i$ and $j$ in global coordinate directions
- $R$ - 6x6 coordinate transformation matrix from paragraph 90
- $D$ - 6x6 rigid link transformation matrix from paragraph 91
- $F_{eab}$ - 6x1 vector of fixed end forces at the ends of the flexible length in local coordinate directions

97. The final relationship between member end forces, member end displacements, and member loads in the global coordinate system is

$$F_{ij} = KU_{ij} + F_{eij}$$

**Void Tie Members**

98. A facility for enforcing interaction between the vertical walls of the void openings is provided for type 3 monoliths. Fictitious horizontal structural members may be described as connecting the void walls at one or more elevations. These ties are assumed to behave as truss members (i.e., only possessing axial stiffness). No guidance for the application of this facility is provided herein.

**Pile Foundation**

99. Piles attached to the base of the structure are treated as elastic elements which develop resistance proportional to the displacements at the pile head/structure base point of connection. The locations of pile head/structure base attachment points are provided by pile layout data which give the distance from the chamber centerline to the pile head. The piles may be battered or vertical. A typical pile situation is shown in Figure 31.
Figure 31. Pile-structure connections

a. Pile head intersects flexible region

b. Pile head intersects rigid block
100. The distance, $D_p$, from the chamber centerline to the pile head provided by pile layout data with base point distances and elevations determine the point at which the pile head is attached to the structure base. If the pile intersects a flexible portion of the structure base, a joint in the frame model is defined on the flexible centerline at a point immediately above the pile head. In this case, the pile head is assumed to be attached to the frame joint as illustrated in Figure 31a. If the pile intersects the base anywhere on the periphery of a rigid block, the pile head is connected to the joint at the rigid block centroid by a rigid link as shown in Figure 31b. (Note: When the pile head intersects the flexible portion of the base in the immediate vicinity of a rigid block, the flexible length of the base member between the "pile joint" and the rigid block may be extremely short and can lead to severe roundoff errors in the analysis. This condition should be avoided if at all possible.)

Pile Head Force-Displacement Relationships

101. Forces and displacements for a pile and the attendant rigid link are shown in Figure 32. The relationship between pile head forces and displacements with components parallel and perpendicular to the axis of the pile is

$$\begin{pmatrix} f_{xp} \\ f_{yp} \\ M_p \end{pmatrix} = \begin{bmatrix} B_{11} & 0 & B_{13} \\ B_{22} & 0 \\ \text{SYM} & B_{33} \end{bmatrix} \begin{pmatrix} u_p \\ v_p \\ \theta_p \end{pmatrix}$$

or

$$f = k'u_p$$

where

- $f_{xp} = \text{pile head shear force}$
- $f_{yp} = \text{pile head axial force}$
- $M_p = \text{pile head moment}$
$B_{11}, B_{22}, B_{33}, B_{13}$ - pile head stiffness coefficients which may be supplied directly by the user or calculated internally by the program as discussed below.

$u_p, v_p$ - translation components of displacement perpendicular and parallel to the pile axis, respectively.

$\theta_p$ - pile head rotation.

---

**Figure 32.** Pile forces and displacements
102. The above relationship is transformed to global coordinates for a battered pile by

$$ F_p = R_p^T k' R_p U $$

where

- $F_p = 3 \times 1$ vector of pile head forces parallel to global coordinates (horizontal and vertical)
- $R_p = 3 \times 3$ transformation matrix
- $k'$ is the pile head stiffness matrix
- $U = 3 \times 1$ vector of pile head displacements in global coordinate directions

103. Finally, the pile head force-displacement relationship is transformed through the rigid link to yield

$$ F_{pj} = U_{pj}^T R_p^T R_p U_j $$

where

- $F_{pj} = 3 \times 1$ vector of pile forces acting on joint $j$
- $U_j = 3 \times 1$ vector of joint $j$ displacements

104. As stated above, the pile head stiffness coefficients $B_{11}$, $B_{12}$, $B_{13}$, $B_{22}$, $B_{33}$, and $B_{13}$ may be supplied as input. However, provision is made for evaluating these coefficients from pile/soils data. When the pile head
stiffness matrix is calculated by the program, the following parameters are required as input data:

- \( E \) = modulus of elasticity of pile material
- \( A \) = pile cross-sectional area
- \( I \) = pile cross-sectional moment of inertia
- \( L \) = pile length
- \( D_f \) = pile head fixity coefficient
- \( k_A \) = axial stiffness coefficient
- \( S_1 \), \( S_2 \) = soil stiffness coefficients for lateral resistance which varies linearly from \( S_1 \) at the pile head to \( S_y = S_1 + S_2 y \) at any distance below the pile head

**Axial Stiffness**

105. The axial stiffness coefficient is evaluated as

\[
B_{22} = k_A \frac{E A}{L}
\]

**Lateral Stiffness Coefficients for Fixed Head Pile (\( D_f = 1 \))**

106. The lateral stiffness coefficients are determined from numerical solutions of the general differential equation

\[
EI \frac{d^4 u}{dy^4} + (S_1 + S_2 y) u = 0
\]

where \( E \), \( I \), \( S_1 \), and \( S_2 \) are defined above; \( u \) is the lateral pile displacement; and \( y \) is the distance along the pile axis. By definition, for a fixed head pile (see Figure 31 for notation)

- \( B_{11} \) = force \( F_p \) due to \( u_p = 1 \), \( \theta_p = 0 \)
- \( B_{13} \) = moment \( M_p \) due to \( u_p = 1 \), \( \theta_p = 0 \)
- \( B_{33} \) = moment \( M_p \) due to \( u_p = 0 \), \( \theta_p = 1 \)

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Lateral Stiffness Coefficients for
Pinned Head Pile (Df = 0)

107. For a pinned head pile, $M_p$ (and hence $B_{13}$, $B_{33}$) are identically zero. $B_{11}$ is obtained by solution of the above differential equation for the case

$$u_p = 1, \quad M_p = 0$$

Lateral Stiffness Coefficients for Partially
Fixed Head Pile (0 ≤ Df ≤ 1)

108. Effects of partial head fixity on the lateral stiffness coefficients are evaluated as:
   a. The rotation $\theta_p = \theta_p$ for pinned head pile with $u_p = 1$, $M = 0$ is determined.
   b. Coefficients $B_{11}$ and $B_{13}$ are obtained from the head forces due to $u_p = 1, \quad \theta_p = (1 - D_f)\theta_p$.
   c. Coefficient $B_{33}$ is obtained from the head forces due to $u_p = 0, \quad \theta_p = D_f \theta_p$.

Vertical Piles on Chamber Centerline

109. When the pile system is symmetric about the chamber centerline, only the data describing the piles on the rightside of the structure are required as input and the computer program automatically generates a mirror image description for the piles on the leftside. An ambiguity arises in a symmetric system when a vertical pile is attached at the centerline of the structure where a strict mirror image would result in doubling the effects of vertical centerline piles. In the computer program, the stiffness effects of vertical centerline piles in symmetric systems are evaluated for only a single pile and one half of the pile stiffness matrix is assigned to each side of the structure.
Method of Solution

110. The force-displacement relationships for the frame members and piles (if present) are assembled into a force-displacement relationship of the form

\[ F = kU + F_e \]

where, for a system with \( n \) joints,

- \( F \) = 3nx1 vector of loads applied directly to the joints including the static equivalents of surface loads acting on the rigid blocks and necessary equilibrants of unbalanced vertical and/or moment resultants arising from user-supplied soil base pressures
- \( k \) = 3nx3n structure stiffness matrix composed of structure member stiffness matrices, pile head stiffness matrices, and void tie stiffnesses
- \( U \) = 3nx1 vector of joint displacements
- \( F_e \) = 3nx1 vector of member fixed end forces

The 3n simultaneous equations are solved by Gauss elimination, for the joint displacements. Known displacements are substituted into the various member end force-displacement relations and pile head force-displacement relations to obtain member end forces and pile head forces.

Restraint of Rigid Body Motions

111. In a pile-supported system, the piles act as linearly elastic supports which inhibit rigid body motions of the system and no additional support specifications are necessary. However, in a soil-supported system, once equilibrium of all forces has been established, there are no supports to prevent rigid body displacements. For a soil-supported system, all displacements of the joint on the structure centerline are specified to be zero. Consequently, the displacements obtained from the frame analysis of soil-supported systems must be realized to be relative values only.
PART VI: COMPUTER PROGRAM

General Description of Program

112. The computer program—CUFRAM—which implements the foregoing procedures is written in the FORTRAN language for execution on computer systems employing word lengths equivalent to 15 decimal digits. Calculations during the equilibrium analysis are not particularly sensitive to computer word length. However, evaluation of component stiffness matrices and solution of the simultaneous equations in the frame analysis phase may require double precision computations for machines with word lengths of fewer than 15 decimal digits.

113. The program is written for operation in a time-sharing environment. Although program prompts must be answered interactively from the user terminal, the experienced user will take advantage of the permanent file capabilities provided for input and output of data. Because the output from the program may be extensive, it may be advantageous for the user to direct output to a permanent file and to recover the output data with a high speed printer after execution of the program is terminated.

Input Data

114. Input data (Guide for Data Input, Appendix A) may be supplied from the user terminal or from a predefined data file. When data are supplied during execution from the terminal, program prompts are provided to indicate the type and amount of data to be provided.

115. Input data are divided into sections and subsections. This is shown as Figure 33.

116. Data sections I, II, IIIA, and VA need only be entered once since these data apply to the entire structure. Other data sections are interpreted as applying to the rightside or leftside of the structure. If symmetric conditions exist for both sides of the structure, the data are designated as being applicable to both sides. In this case, data need only be entered for the rightside and the program automatically generates mirror image data for the leftside. When different conditions exist for the two sides, data are entered for the rightside first and immediately followed by the description for the leftside.
I. Heading*

II. Mode of Operation*

III. Structure Data*
   A. Floor Data*
   B. Base Data*
   C. Stem Data*
   D. Culvert Data**
   E. Void Data**
      1. Void Tie Data**

IV. Backfill Data**
   A. Soil Layer Data, or ↑
   B. Backfill Soil Pressure Data ↑

V. Base Reaction Data*
   A. Soil Data, or ↑
   B. Pile Data ↑
      1. Layout Data*
      2. Pile/Soil Properties, or ↑
      3. Pile Head Stiffness Matrices ↑
      4. Batter Data**
      5. Allowables Comparison Data**

VI. Water Data**
   A. External Water Data**
      1. Water Elevations, or ↑
      2. Water Pressure Data ↑
   B. Uplift Water Data**
      1. Water Elevations, or ↑
      2. Water Pressure Data ↑
   C. Internal Water Data**

VII. Additional Load Data**
   A. Exterior Stem Loads**
      1. Distributed Loads
      2. Concentrated Loads
   B. Interior Stem Loads**
      1. Distributed Loads
      2. Concentrated Loads
   C. Top Stem Loads**
      1. Distributed Loads
      2. Concentrated Loads
   D. Floor Loads**
      1. Distributed Loads
      2. Concentrated Loads
   E. Base Loads**
      1. Distributed Loads
      2. Concentrated Loads

* Data section is required.
** Optional data may be omitted entirely.
↑ One of the two data subsections is required.

Figure 33. Sections and subsections of input data
117. During the input phase, from a file or from the user terminal, data values are checked for consistency of dimensions and completeness. If an error is encountered during input from a file, the user is notified and execution of that problem is terminated. If an error is detected during entry from the terminal, the user is offered the opportunity to revise the last entry which produced the error.

**Data Editing**

118. After the input phase is completed, from a file or from the terminal, the user is offered the opportunity to edit (revise) the current input data. Any data section or subsection selected for editing must be entered in its entirety.

**Data File Creation**

119. After any data entry from the terminal, initial or after editing, the user is offered the opportunity to save the existing input data in a permanent file in data file format. Because the program prompts for entry from the terminal are lengthy, an experienced user will usually find it more efficient to perform editing of an input file externally from the program.

**Output Data**

120. Output data may be directed to a permanent file, to the user terminal, or to both simultaneously. These sections of output are available.

*Echoprint of input data*

121. The echoprint of input data is a tabular presentation of numerical data including appropriate headings and units. This section of the output is

*Equilibrium analysis*

This section presents pressures generated by the program or inter-
lar input at key points on the structure, resultants of load on
structure, and net resultants of all loads.

*Data regarding the 2-D frame model developed*
by the program in the frame analysis mode. Included are data defining the rigid blocks, coordinates of the joints of the model, member connectivity, member dimensions, and pile stiffness coefficients if a pile foundation is present.

**Results of frame analysis**

124. This section incorporates the calculated displacements for each joint in the structure, forces at the ends of the flexible length for each member, displacements and pile head forces for a pile-supported structure, and results of the pile allowables comparisons. (Appendix A—discussion of allowables comparisons performed for piles.)

**Detailed member forces**

125. Following the frame analysis, the user may obtain a tabulation giving the variation of axial force, shear force, and bending moment within any member of the structure selected. This section of the output is optional.

**Program verification**

126. The pressures (backfill, water, soil base pressures) generated by the program have been verified by hand computations for a variety of systems. Wherever possible, the results (deflection, axial force, shear force, and bending moment) of the frame analysis have been calculated by other processes for comparison. For example, the internal forces at the juncture of the base slab and stem face for a soil-supported structure can be obtained from a static analysis. Similarly, deflections for the section of the base slab from the chamber centerline to the juncture of the base slab and stem face for a soil-supported system can be obtained from classical beam analysis. For indeterminate systems (types 2 and 3 monoliths or pile-supported structure), solutions have been obtained using the general-purpose computer system GTSTRUDL. Results using GTSTRUDL for several of the example solutions presented in Part VII are given in Appendix B of this report.
PART VII: EXAMPLE SOLUTIONS

127. The examples presented below are intended only to illustrate the use of the program and are not to be interpreted as a guide for application of the program.

Example 1--Type 1 Monolith

128. The symmetric, soil-supported system is shown in Figure 34. All soil and water data were provided by elevations and unit weights. The additional upward distributed load on the base might represent the effects of seepage parallel to the longitudinal axis of the structure.

Data input

129. Input data were entered from the terminal during execution as shown in Figure 35. The echoprint of input data (optional), Figure 36, provides a tabulation of the input data with appropriate labels and units. A plot of input geometry generated by the program is included in Figure 36. Following successful data entry, terminal input was saved in a file. The input file generated by the program shown in Figure 37 was retrieved following termination of the run. Because the system is symmetric, only the right side of the structure need be described.

Results of equilibrium analysis

130. The results of the equilibrium analysis are shown in Figure 38. Backfill soil and water data have been converted to pressures as shown in Section IIA of this figure. These pressures are determined at the location of changes in the geometry of the structure, at the elevations of soil layer boundaries, and at ground-water elevation. When a discontinuity in pressure occurs (e.g., at soil layer boundaries), two values of pressure at that elevation are given, one immediately above the elevation and one immediately below. In this case, the two values given at elevation 44 are the result of the horizontal top surface of the heel: the first for the point nearer the chamber centerline, and the second for the point at the end of the heel. Otherwise, the pressures vary linearly between successive elevations. Note that ground-water pressures do not affect the upward sloping section of the base. A plot of backfill and external water pressures generated by the program is included in Figure 38.
Figure 34. System for Example 1

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.
Figure 35. Terminal entry for Example 1 (Sheet 1 of 4)
IS RIGHTSIDE CULVERT PRESENT?
ENTER 'YES' OR 'NO'.

? N
IS LEFTSIDE CULVERT PRESENT?
ENTER 'YES' OR 'NO'.

? N
IS RIGHTSIDE STEM VOID PRESENT? ENTER 'YES' OR 'NO'.

? N
IS LEFTSIDE STEM VOID PRESENT? ENTER 'YES' OR 'NO'.

? Y
ARE RIGHTSIDE BACKFILL DATA TO BE PROVIDED?
ENTER 'YES' OR 'NO'.

? Y
ARE BACKFILL EFFECTS PROVIDED BY SOIL DATA OR A PRESSURE DISTRIBUTION?
ENTER 'SOIL' OR 'PRESSURE'.

? S
ENTER NUMBER OF RIGHTSIDE SOIL LAYERS (1 TO 5).

? 1
ENTER DATA FOR 1 RIGHTSIDE SOIL LAYERS, ONE LINE PER LAYER:
ELEVATION AT SOIL UNIT WEIGHTS <---SOIL COEFFICIENTS---->
TOP OF LAYER SATURATED MOIST HORIZ PRESS SHEAR STRESS
(FT) (PCF) (PCF) TOP BOTTOM TOP BOTTOM

? 76 130 130 .5 .5 0 0
ENTER RIGHTSIDE SURCHARGE (PSF).

? 0
ARE LEFTSIDE AND RIGHTSIDE BACKFILL CONDITIONS SYMMETRIC?
ENTER 'YES' OR 'NO'.

? Y
IS BASE REACTION PROVIDED BY SOIL OR PILES?
ENTER 'SOIL' OR 'PILES'.

? S
ENTER BASE REACTION DISTRIBUTION TYPE:
'UNIFORM', 'TRAPEZOIDAL', 'RECTANGULAR', OR 'INPUT'.

? U
ARE WATER DATA TO BE ENTERED? ENTER 'YES' OR 'NO'.

? Y
ENTER WATER UNIT WEIGHT (PCF).

? 62.5
ARE RIGHTSIDE EXTERNAL WATER DATA TO BE ENTERED?
ENTER 'YES' OR 'NO'.

? Y
ARE RIGHTSIDE EXTERNAL WATER EFFECTS TO BE PROVIDED BY ELEVATION DATA OR
INPUT PRESSURE DATA? ENTER 'ELEVATIONS' OR 'PRESSURES'.

? E
ENTER RIGHTSIDE GROUND-WATER ELEVATION (FT).

? 64
ENTER RIGHTSIDE SURCHARGE ELEVATION (FT) OR 'NONE'.

? N
ARE LEFTSIDE AND RIGHTSIDE EXTERNAL WATER DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.

? Y
ARE UPLIFT WATER DATA TO BE ENTERED? ENTER 'YES' OR 'NO'.

? Y
ARE UPLIFT WATER EFFECTS TO BE PROVIDED BY WATER ELEVATIONS OR BY
A PRESSURE DIAGRAM? ENTER 'ELEVATIONS' OR 'PRESSURES'.

? E

Figure 35. (Sheet 2 of 4)
ENTER UPLIFT WATER ELEVATIONS (FT)
LEFTSIDE    RIGHTSIDE
? 64  64
ARE INTERNAL WATER DATA TO BE ENTERED? ENTER 'YES' OR 'NO'.
? Y
ENTER WATER ELEVATION IN CHAMBER (FT).
? 95
ARE ADDITIONAL LOAD DATA TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? Y
ARE ADDITIONAL LOADS ON EXTERIOR FACE OF RIGHTSIDE STEM TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? N
ARE ADDITIONAL LOADS ON EXTERIOR FACE OF LEFTSIDE STEM TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? N
ARE ADDITIONAL LOADS ON INTERIOR FACE OF RIGHTSIDE STEM TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? N
ARE ADDITIONAL LOADS ON INTERIOR FACE OF LEFTSIDE STEM TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? N
ARE ADDITIONAL LOADS ON TOP OF RIGHTSIDE STEM TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? N
ARE ADDITIONAL LOADS ON TOP OF LEFTSIDE STEM TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? N
ARE ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? N
ARE ADDITIONAL LOADS ON LEFTSIDE OF CHAMBER FLOOR TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? N
ARE ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE TO BE ENTERED?
ENTER 'YES' OR 'NO'.
? Y
ENTER DATA FOR CONCENTRATED LOADS ON RIGHTSIDE OF STRUCTURE BASE.
ENTER 'END' WHEN FINISHED WITH CONCENTRATED LOADS.
DIST. FROM HORIZONTAL VERTICAL
CHAMBER CL. CONC. LOAD CONC. LOAD
(FT) (PLF) (PLF)
? E
ENTER DATA FOR DISTRIBUTED LOADS ON RIGHTSIDE OF STRUCTURE BASE.
ENTER 'END' WHEN FINISHED WITH DISTRIBUTED LOADS.
DIST. FROM HORIZONTAL VERTICAL
CHAMBER CL. DIST. LOAD DIST. LOAD
(FT) (PSF) (PSF)
? 0 0 -375
? 68 0 -375
? E
ARE LOADS ON LEFTSIDE AND RIGHTSIDE OF STRUCTURE BASE SYMMETRIC?
ENTER 'YES' OR 'NO'.
? Y

Figure 35. (Sheet 3 of 4)
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).

? CUEXIO
DO YOU WANT INPUT DATA SAVED IN A FILE? ENTER 'YES' OR 'NO'.
Y
ENTER FILE NAME FOR SAVING INPUT DATA (6 CHARACTERS MAXIMUM).

? CUEXI1

INPUT COMPLETE.
DO YOU WANT TO PLOT INPUT DATA? ENTER 'YES' OR 'NO'.

? Y
DO YOU WANT TO CONTINUE SOLUTION? ENTER 'YES' OR 'NO'.

? Y
DO YOU WANT RESULTS WRITTEN TO YOUR TERMINAL, TO FILE 'CUEXIO', OR BOTH?
ENTER 'TERMINAL', 'FILE', OR 'BOTH'.

? F
DO YOU WANT TO PLOT PRESSURES? ENTER 'YES' OR 'NO'.

? Y
EQUILIBRIUM ANALYSIS COMPLETE.
DO YOU WANT TO CONTINUE WITH FRAME SOLUTION? ENTER 'YES' OR 'NO'.

? Y
DO YOU WANT TO PLOT FRAME MODEL?
ENTER 'YES' OR 'NO'.

? Y
DEVELOPMENT OF FRAME MODEL COMPLETE.
DO YOU WANT TO CONTINUE WITH FRAME SOLUTION? ENTER 'YES' OR 'NO'.

? Y
DO YOU WANT DETAILED MEMBER FORCES OUTPUT?
ENTER 'YES' OR 'NO'.

? Y
DETAILED MEMBER FORCES ARE AVAILABLE FOR RIGHTSIDE MEMBERS 1 THROUGH 4
ENTER LIST OF MEMBER NUMBERS, 'ALL', OR 'NONE'.

? A
DO YOU WANT TO PLOT BASE AXIAL, SHEAR, AND MOMENT DIAGRAMS?
ENTER 'YES' OR 'NO'.

? Y
DO YOU WANT INDIVIDUAL MEMBER PLOTS?
ENTER 'YES' OR 'NO'.

? Y
OUTPUT COMPLETE.
DO YOU WANT TO EDIT INPUT DATA FOR THE PROBLEM JUST COMPLETED?
ENTER 'YES' OR 'NO'.

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

? N
********** NORMAL TERMINATION **********
END OF FILE
I. --HEADING
  EXAMPLE 1 - TYPE 1 MONOLITH
  SYMMETRIC SOIL-FOUNDED STRUCTURE

II. --PLANE FRAME ANALYSIS
RIGID LINK FACTOR = .75

III. --STRUCTURE DATA

III.A. --MATERIAL PROPERTIES
  MODULUS OF ELASTICITY OF CONCRETE = 3.000E+06 (PSI)
  POISSON'S RATIO FOR CONCRETE = .20
  UNIT WEIGHT OF CONCRETE = 150.0 (PCF)
  THICKNESS OF TWO-DIMENSIONAL SLICE = 1.00 (FT)

III.B. --FLOOR DATA
  FLOOR WIDTH = 42.00 (FT)
  FLOOR ELEVATION = 44.00 (FT)
  FLOOR FILLET SIZE = 0.00 (FT)

III.C. --BASE DATA

III.C.1. --RIGHTSIDE
  DISTANCE FROM CHAMBER CL ELEVATION
  (FT) (FT)
  42.00 32.00
  88.00 37.00

III.C.2. --LEFTSIDE
  SYMMETRIC WITH RIGHTSIDE.

III.D. --STEM DATA

III.D.1. --RIGHTSIDE
  DISTANCE FROM STEM FACE ELEVATION
  (FT) (FT)
  8.50 103.00
  8.50 99.00
  5.00 95.00
  5.00 85.00
  10.00 44.00
  28.00 44.00

III.D.2. --LEFTSIDE
  SYMMETRIC WITH RIGHTSIDE.

a. Echoprint (Continued)

Figure 36. Input data for Example 1 (Sheet 1 of 4)
III.E.--CULVERT DATA
NONE

III.F.--VOID DATA
NONE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA

\begin{tabular}{cccc}
\hline
ELEV & SATURATED & MOIST & HORIZONTAL & SHEAR \\
\hline
TOP (FT) & UNIT WT. (PCF) & TOP (PCF) & BOT. (PCF) & BOT. (PCF) \\
76.00 & 130.0 & 130.0 & .500 & .500 & 0.000 & 0.000 \\
\hline
\end{tabular}

IV.B.--LEFTSIDE SOIL LAYER DATA
SYMMETRIC WITH RIGHTSIDE

V.--BASE REACTION DATA

REACTION PROVIDED BY UNIFORM SOIL PRESSURE DISTRIBUTION

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND-WATER ELEVATION = 64.00 (FT)
SURCHARGE WATER = NONE

VI.A.2.--LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA
RIGHTSIDE UPLIFT WATER ELEVATION = 64.00 (FT)
LEFTSIDE UPLIFT WATER ELEVATION = 64.00 (FT)

VI.C.--INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 95.00 (FT)

VII.--ADDITIONAL LOAD DATA

VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE
NONE

VII.A.2.--ADDITIONAL LOADS ON LEFTSIDE EXTERNAL STEM FACE
NONE

VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
NONE

VII.B.2.--ADDITIONAL LOADS ON LEFTSIDE INTERIOR STEM FACE
NONE

a. (Continued)

Figure 36. (Sheet 2 of 4)
VII.C.1 -- ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
NONE

VII.C.2 -- ADDITIONAL LOADS ON LEFTSIDE STEM TOP
NONE

VII.D.1 -- ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
NONE

VII.D.2 -- ADDITIONAL LOADS ON LEFTSIDE OF CHAMBER FLOOR
NONE

VII.E.1 -- ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE

CONCENTRATED LOAD DATA
NONE

DISTRIBUTED LOAD DATA

<table>
<thead>
<tr>
<th>DIST. FROM HORIZONTAL CHAMBER CL</th>
<th>LOAD (FT)</th>
<th>VERTICAL LOAD (PSF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>-375.00</td>
</tr>
<tr>
<td>68.00</td>
<td>0.00</td>
<td>-375.00</td>
</tr>
</tbody>
</table>

VII.E.2 -- ADDITIONAL LOADS ON LEFTSIDE OF STRUCTURE BASE

CONCENTRATED LOAD DATA
NONE

DISTRIBUTED LOAD DATA
SYMMETRIC WITH RIGHTSIDE

a. (Concluded)

Figure 36. (Sheet 3 of 4)
**INPUT FILE FOR EXAMPLE1 GENERATED BY CUFRAM**

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>'EXAMPLE 1 - TYPE 1 MONOLITH</td>
<td></td>
</tr>
<tr>
<td>1010</td>
<td>'SYMMETRIC SOIL-FOUNDED STRUCTURE</td>
<td></td>
</tr>
<tr>
<td>1020</td>
<td>METHOD FR</td>
<td>.75</td>
</tr>
<tr>
<td>1030</td>
<td>STRUCTURE</td>
<td>3.00E+06, .20, 150.00, 1.00</td>
</tr>
<tr>
<td>1040</td>
<td>FLOOR</td>
<td>42.00, 44.00, 0.00</td>
</tr>
<tr>
<td>1050</td>
<td>BASE BOTH</td>
<td>42.00, 32.00, 68.00, 37.00</td>
</tr>
<tr>
<td>1060</td>
<td>STEM BOTH</td>
<td>6</td>
</tr>
<tr>
<td>1070</td>
<td>FLOOR</td>
<td>8.50, 103.00, 8.50, 99.00, 5.00, 95.00</td>
</tr>
<tr>
<td>1080</td>
<td>BASE</td>
<td>5.00, 85.00, 10.00, 44.00, 26.00, 44.00</td>
</tr>
<tr>
<td>1090</td>
<td>BACKFILL BOTH SOIL</td>
<td>1, 0.00</td>
</tr>
<tr>
<td>1100</td>
<td>STEM</td>
<td>76.00, 130.00, 130.00, .50, .50, 0.00, 0.00</td>
</tr>
<tr>
<td>1110</td>
<td>REACTION SOIL UNIFORM</td>
<td></td>
</tr>
<tr>
<td>1120</td>
<td>WATER</td>
<td>62.5</td>
</tr>
<tr>
<td>1130</td>
<td>EXTERNAL BOTH ELEVATION</td>
<td>64.00</td>
</tr>
<tr>
<td>1140</td>
<td>UPLIFT ELEVATION</td>
<td>64.00</td>
</tr>
<tr>
<td>1150</td>
<td>INTERNAL</td>
<td>95.00</td>
</tr>
<tr>
<td>1160</td>
<td>LOADS BOTH BASE</td>
<td></td>
</tr>
<tr>
<td>1170</td>
<td>DIST</td>
<td>2, 0.00, 0.00, -375.00, 68.00, 0.00, -375.00</td>
</tr>
<tr>
<td>1180</td>
<td>FINISH</td>
<td></td>
</tr>
</tbody>
</table>

Figure 37. CUFRAM generated input file for Example 1

88
I.--HEADING

'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

*******************************************************************************
* RESULTS OF EQUILIBRIUM ANALYSIS *
*******************************************************************************

II.--EFFECTS ON STRUCTURE RIGHTSIDE

II.A.--PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ELEVATION</th>
<th>VERTICAL</th>
<th>HORIZONTAL</th>
<th>SHEAR</th>
<th>BACKFILL PRESSURE</th>
<th>GRND/SURCH WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>103.000</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>99.000</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>95.000</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>85.000</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>76.000</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>64.000</td>
<td>1.5600E+03</td>
<td>7.8000E+02</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>44.000</td>
<td>2.9100E+03</td>
<td>1.4550E+03</td>
<td>0.0</td>
<td>1.2500E+03</td>
<td>1.2500E+03</td>
</tr>
<tr>
<td>37.000</td>
<td>3.3825E+03</td>
<td>1.6913E+03</td>
<td>0.0</td>
<td>1.6875E+03</td>
<td>1.6875E+03</td>
</tr>
</tbody>
</table>

II.B.--PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>DIST FROM CHAMBER CL</th>
<th>SOIL REACTION PRESSURE</th>
<th>UPLIFT WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>3.3315E+03</td>
<td>2.0000E+03</td>
</tr>
<tr>
<td>42.000</td>
<td>3.3315E+03</td>
<td>2.0000E+03</td>
</tr>
<tr>
<td>68.000</td>
<td>3.3315E+03</td>
<td>1.6875E+03</td>
</tr>
</tbody>
</table>

Figure 38. Equilibrium analysis results...
II.C. -- RESULTANTS OF LOADS ON STRUCTURE RIGTHSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKFILL</td>
<td>3.8042E+04</td>
<td>5.3153E+04</td>
<td>-2.8533E+06</td>
</tr>
<tr>
<td>GROUND/SURCH WATER</td>
<td>2.2781E+04</td>
<td>2.1524E+04</td>
<td>-1.2325E+06</td>
</tr>
<tr>
<td>INTERNAL WATER</td>
<td>-8.1281E+04</td>
<td>1.3388E+05</td>
<td>-4.1932E+06</td>
</tr>
<tr>
<td>UPLIFT WATER</td>
<td>9.2187E+03</td>
<td>-1.3194E+05</td>
<td>4.2947E+06</td>
</tr>
<tr>
<td>SOIL-BASE REACT</td>
<td>0</td>
<td>-2.2654E+05</td>
<td>7.7023E+06</td>
</tr>
<tr>
<td>BACKFILL ON BASE</td>
<td>8.8781E+03</td>
<td>0</td>
<td>-8.4694E+04</td>
</tr>
<tr>
<td>ADDL BASE LOADS</td>
<td>0</td>
<td>-2.5500E+04</td>
<td>8.6700E+05</td>
</tr>
<tr>
<td>CONCRETE</td>
<td></td>
<td>1.7543E+05</td>
<td>-6.4534E+06</td>
</tr>
<tr>
<td>TOTAL THIS SIDE</td>
<td>-2.3612E+03</td>
<td>0</td>
<td>-1.9530E+06</td>
</tr>
</tbody>
</table>

III.--EFFECTS ON STRUCTURE LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE; UNITS ARE POUNDS AND FEET)

TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

Figure 38. (Sheet 2 of 4)
EXAMPLE 1 - TYPE I MONOLITH SYMMETRIC SOIL-FOUNDED STRUCTURE

<table>
<thead>
<tr>
<th>ELEVATION (FT)</th>
<th>VERTICAL</th>
<th>SOIL PRESSURES (PSF)</th>
<th>HORIZONTAL</th>
<th>ABS(SHEAR)</th>
<th>WATER PRESS (PSF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>103.00'</td>
<td>0</td>
<td>2000 4000</td>
<td>0</td>
<td>2000</td>
<td>3000 4000</td>
</tr>
<tr>
<td>99.00'</td>
<td>0</td>
<td>2000 4000</td>
<td>0</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>95.00'</td>
<td>0</td>
<td>2000 4000</td>
<td>0</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>95.00'</td>
<td>0</td>
<td>2000 4000</td>
<td>0</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>76.00'</td>
<td>0</td>
<td>2000 4000</td>
<td>0</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>64.00'</td>
<td>0</td>
<td>2000 4000</td>
<td>0</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>44.00'</td>
<td>0</td>
<td>2000 4000</td>
<td>0</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>27.00'</td>
<td>0</td>
<td>2000 4000</td>
<td>0</td>
<td>2000</td>
<td></td>
</tr>
</tbody>
</table>

b. Backfill and external water pressures plot

Figure 38. (Sheet 3 of 4)
c. Base soil reaction and uplift water pressure

Figure 38. (Sheet 4 of 4)
131. Pressures on the base, Section IIB of Figure 38, consist of soil reaction pressure developed by the program to equilibrate all vertical loads according to the prescribed "uniform" distribution as well as uplift water pressures. Locations of pressures are given by distance (right or left) from the chamber centerline. When a discontinuity in pressure exists (e.g., for a prescribed "rectangular" base pressure distribution), two values are given for that location, the first being the value nearer the chamber centerline. A plot of base soil reaction and uplift water pressure is included in Figure 38.

132. Resultants of all applied loads and generated base reaction are given in Section IIC of Figure 38. Because the structure is symmetric, mirror images of the rightside forces act on the leftside of the structure. In this case, the net resultants, Section IV of Figure 38, are identically zero. Had the system been unsymmetric, base friction, base shear, and/or vertical stem shear would have been necessary to produce total equilibrium. For a pile-supported structure, any unbalanced total (net) resultants appearing in Figure 38, Section IV would be resisted by the piles.

133. If an equilibrium analysis had been specified, execution of the problem would cease when the equilibrium analysis had been completed. The user would then be offered the opportunity to edit existing input data or to make another run with new data.

Frame model data
134. Data for the plane frame model developed by the program are shown in Figure 39. Included are the defining coordinates of the rigid blocks associated with this type of monolith, the locations of the joints in the model, and the dimensions of the frame members. Note that the flexible lengths of the members extend into the rigid blocks due to the rigid link factor equal to 0.75. A plot of the frame model is shown in Figure 39.

Frame analysis
135. Results of the frame analysis are shown in Figure 40. Included are the displacements of the joints of the model, Section IIA, and the forces acting on the ends of the flexible length of each member parallel and perpendicular to the flexible member centerline. Pile head forces and results of pile allowables comparisons would be contained in this tabulation for a pile-supported structure (Example 2). A plot of axial, shear, and bending forces throughout the base is shown in Figure 40.
I.--HEADING
'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

***************
* FRAME MODEL DATA *
***************

II.--RIGHTSIDE FRAME MODEL DATA

II.A.--RIGID BLOCK DATA (FT) - TYPE 1 MONOLITH
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<---------------- CORNER LOCATIONS ------------->

<table>
<thead>
<tr>
<th>BLOCK NO.</th>
<th>CORNER NO.</th>
<th>X-COORD.</th>
<th>ELEVATION</th>
<th>X-COORD.</th>
<th>ELEVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>42.00</td>
<td>32.00</td>
<td>42.00</td>
<td>32.00</td>
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<tr>
<td></td>
<td>2</td>
<td>42.00</td>
<td>44.00</td>
<td>44.00</td>
<td>33.92</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>52.00</td>
<td>44.00</td>
<td>50.50</td>
<td>47.00</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>52.00</td>
<td>44.00</td>
<td>50.50</td>
<td>47.00</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>52.00</td>
<td>44.00</td>
<td>50.50</td>
<td>47.00</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>42.00</td>
<td>44.00</td>
<td>47.00</td>
<td>45.90</td>
</tr>
</tbody>
</table>

II.B.--JOINT COORDINATES (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>JOINT NO.</th>
<th>X-COORD.</th>
<th>ELEVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00000</td>
<td>38.00000</td>
</tr>
<tr>
<td>2</td>
<td>46.85482</td>
<td>38.48881</td>
</tr>
<tr>
<td>3</td>
<td>68.00000</td>
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<td>4</td>
<td>44.50000</td>
<td>85.00000</td>
</tr>
<tr>
<td>5</td>
<td>45.89617</td>
<td>99.30601</td>
</tr>
</tbody>
</table>

II.C.--MEMBER DATA (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>MEM NO.</th>
<th>FROM JT</th>
<th>TO JT</th>
<th>X FROM END</th>
<th>X TO END</th>
<th>X ELEV FROM END</th>
<th>X ELEV TO END</th>
<th>MEMBER DEPTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0.00</td>
<td>38.00</td>
<td>43.21</td>
<td>38.00</td>
<td>12.00</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>50.71</td>
<td>38.84</td>
<td>88.00</td>
<td>40.50</td>
<td>10.08</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>4</td>
<td>47.08</td>
<td>42.62</td>
<td>44.50</td>
<td>85.00</td>
<td>10.00</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>5</td>
<td>44.50</td>
<td>85.00</td>
<td>44.50</td>
<td>98.08</td>
<td>5.00</td>
</tr>
</tbody>
</table>

III.--LEFTSIDE FRAME MODEL DATA
SYMMETRIC WITH RIGHTSIDE

a. Model data

Figure 39. Plane frame model for Example 1 (Continued)
b. Frame model plot

Figure 39. (Concluded)
I. -- HEADING
'EXAMPLE 1 - TYPE 1 MONOLITH
SYMMETRIC SOIL-FOUNDED STRUCTURE

********************************************************************
* RESULTS OF FRAME ANALYSIS *
********************************************************************

II. -- STRUCTURE DISPLACEMENTS
II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 1 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD CHAMBER CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

<table>
<thead>
<tr>
<th>JT</th>
<th>DISTANCE FROM ELEVATION (FT)</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>ROTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO</td>
<td>CHAMB CL (FT)</td>
<td>BASE JOINTS ****</td>
<td>NO</td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>38.00</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>2</td>
<td>46.85</td>
<td>38.47</td>
<td>-5.85E-04</td>
<td>3.26E-02</td>
</tr>
<tr>
<td>3</td>
<td>68.00</td>
<td>40.50</td>
<td>-2.96E-03</td>
<td>5.82E-02</td>
</tr>
<tr>
<td>4</td>
<td>44.50</td>
<td>85.00</td>
<td>-7.80E-02</td>
<td>2.87E-02</td>
</tr>
<tr>
<td>5</td>
<td>45.90</td>
<td>99.31</td>
<td>-1.06E-01</td>
<td>3.16E-02</td>
</tr>
</tbody>
</table>

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE 1 MONOLITH
SYMMETRIC WITH RIGHTSIDE

III. -- FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

III.A.--RIGHTSIDE MEMBERS - TYPE 1 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD
CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER
OR ON SIDE OF MEMBER TOWARD CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>MEM</th>
<th>DISTANCE FROM ELEVATION (FT)</th>
<th>AXIAL</th>
<th>SHEAR</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO</td>
<td>CHAMB CL (FT)</td>
<td>BASE MEMBERS *****</td>
<td>NO</td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>38.00</td>
<td>-2.36E+03</td>
<td>0.</td>
</tr>
<tr>
<td>2</td>
<td>43.21</td>
<td>38.00</td>
<td>-2.36E+03</td>
<td>-3.02E+04</td>
</tr>
<tr>
<td>3</td>
<td>50.71</td>
<td>38.84</td>
<td>3.19E+04</td>
<td>2.03E+03</td>
</tr>
<tr>
<td>4</td>
<td>44.50</td>
<td>85.00</td>
<td>2.12E+04</td>
<td>2.31E+04</td>
</tr>
<tr>
<td>5</td>
<td>44.50</td>
<td>96.08</td>
<td>9.15E+03</td>
<td>0.</td>
</tr>
</tbody>
</table>

III.B.-- LEFTSIDE MEMBERS - TYPE 1 MONOLITH
SYMMETRIC WITH RIGHTSIDE

a. Analysis results

Figure 40. Results of frame analysis for Example 1 (Continued)
EXAMPLE 1 - TYPE 1 MONOLITH
SYMMETRIC SOIL-FOUNDED STRUCTURE

Figure 40. (Concluded)

b. Frame model plot
Detailed member forces

136. Member internal forces are shown in Figure 41. These forces are components parallel and perpendicular to the member centerline. They are reported at the tenth points along the member, on either side of an applied concentrated load where a discontinuity in axial and/or shear force would occur at the face of each rigid block to which the member is attached. A plot of the internal forces for each member is included in Figure 41.

Termination

137. Following completion of all output, the user is again offered the opportunity to edit existing data, to run the program with new data, or to terminate execution. Any abnormal interruption of the program before the "normal termination" indicated may result in the loss of any generated output files.

138. The results of an analysis of this structure obtained with GTSTRUDL are given in Appendix B.
I. -- HEADING

'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

II. -- MEMBER INTERNAL FORCES

(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE THE LEFT END OF A SECTION
UP OR TOWARD THE CHAMBER CENTERLINE.)
(POSITIVE BENDING MOMENT PRODUCES COMPRESSION ON THE TOP OF THE MEMBER
OR ON THE SIDE OF THE MEMBER TOWARD THE CHAMBER CENTERLINE.)

II.A. -- RIGHTSIDE MEMBERS - TYPE 1 MONOLITH

<table>
<thead>
<tr>
<th>CHAMB CL (FT)</th>
<th>DISTANCE FROM ELEVATION (FT)</th>
<th>FORCES (LB or LB-FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AXIAL</td>
<td>SHEAR</td>
</tr>
<tr>
<td>0.00</td>
<td>38.00</td>
<td>-2.361E+03</td>
</tr>
<tr>
<td>4.32</td>
<td>38.00</td>
<td>-2.361E+03</td>
</tr>
<tr>
<td>8.64</td>
<td>38.00</td>
<td>-2.361E+03</td>
</tr>
<tr>
<td>12.96</td>
<td>38.00</td>
<td>-2.361E+03</td>
</tr>
<tr>
<td>17.29</td>
<td>38.00</td>
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<tr>
<td>21.61</td>
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<td>-2.361E+03</td>
</tr>
<tr>
<td>30.25</td>
<td>38.00</td>
<td>-2.361E+03</td>
</tr>
<tr>
<td>34.57</td>
<td>38.00</td>
<td>-2.361E+03</td>
</tr>
<tr>
<td>38.89</td>
<td>38.00</td>
<td>-2.361E+03</td>
</tr>
<tr>
<td>42.00</td>
<td>38.00</td>
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</tr>
<tr>
<td>43.21</td>
<td>38.00</td>
<td>-2.361E+03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAMB CL (FT)</th>
<th>DISTANCE FROM ELEVATION (FT)</th>
<th>FORCES (LB or LB-FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50.71</td>
<td>38.84</td>
<td>3.12E+04</td>
</tr>
<tr>
<td>52.00</td>
<td>38.96</td>
<td>3.12E+04</td>
</tr>
<tr>
<td>52.44</td>
<td>39.00</td>
<td>3.12E+04</td>
</tr>
<tr>
<td>54.17</td>
<td>39.17</td>
<td>3.039E+04</td>
</tr>
<tr>
<td>55.90</td>
<td>39.34</td>
<td>2.919E+04</td>
</tr>
<tr>
<td>57.63</td>
<td>39.50</td>
<td>2.800E+04</td>
</tr>
<tr>
<td>59.36</td>
<td>39.67</td>
<td>2.683E+04</td>
</tr>
<tr>
<td>61.09</td>
<td>39.84</td>
<td>2.567E+04</td>
</tr>
<tr>
<td>62.81</td>
<td>40.00</td>
<td>2.453E+04</td>
</tr>
<tr>
<td>64.54</td>
<td>40.17</td>
<td>2.340E+04</td>
</tr>
<tr>
<td>66.27</td>
<td>40.33</td>
<td>2.229E+04</td>
</tr>
<tr>
<td>68.00</td>
<td>40.50</td>
<td>2.120E+04</td>
</tr>
</tbody>
</table>

a. Internal forces (Continued)

Figure 41. Detailed member forces for Example 1 (Sheet 1 of 6)
<table>
<thead>
<tr>
<th>CHAMB CL (FT)</th>
<th>ELEVATION (FT)</th>
<th>AXIAL</th>
<th>SHEAR</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.08</td>
<td>42.62</td>
<td>7.330E+04</td>
<td>3.736E+04</td>
<td>-9.868E+05</td>
</tr>
<tr>
<td>47.00</td>
<td>44.00</td>
<td>7.330E+04</td>
<td>3.736E+04</td>
<td>-9.351E+05</td>
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<td>6.763E+04</td>
<td>3.619E+04</td>
<td>-8.231E+05</td>
</tr>
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<td>5.989E+04</td>
<td>3.391E+04</td>
<td>-6.657E+05</td>
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<td>55.33</td>
<td>5.232E+04</td>
<td>3.099E+04</td>
<td>-5.209E+05</td>
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<td>59.57</td>
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<td>2.743E+04</td>
<td>-3.915E+05</td>
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<td>-1.867E+05</td>
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<tr>
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<td>76.52</td>
<td>2.427E+04</td>
<td>9.208E+03</td>
<td>-6.861E+04</td>
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<tr>
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<td>80.76</td>
<td>2.034E+04</td>
<td>5.107E+03</td>
<td>-3.861E+04</td>
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<td>44.50</td>
<td>85.00</td>
<td>1.681E+04</td>
<td>2.106E+03</td>
<td>-2.368E+04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAMB CL (FT)</th>
<th>ELEVATION (FT)</th>
<th>AXIAL</th>
<th>SHEAR</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.50</td>
<td>85.00</td>
<td>1.685E+04</td>
<td>3.125E+03</td>
<td>-2.319E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>86.11</td>
<td>1.582E+04</td>
<td>2.471E+03</td>
<td>-2.010E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>87.22</td>
<td>1.499E+04</td>
<td>1.894E+03</td>
<td>-1.768E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>88.32</td>
<td>1.416E+04</td>
<td>1.393E+03</td>
<td>-1.588E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>89.43</td>
<td>1.333E+04</td>
<td>9.693E+02</td>
<td>-1.457E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>90.54</td>
<td>1.250E+04</td>
<td>6.221E+02</td>
<td>-1.370E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>91.65</td>
<td>1.187E+04</td>
<td>3.516E+02</td>
<td>-1.317E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>92.75</td>
<td>1.083E+04</td>
<td>1.577E+02</td>
<td>-1.289E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>93.86</td>
<td>1.000E+04</td>
<td>4.053E+01</td>
<td>-1.279E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>94.97</td>
<td>9.173E+03</td>
<td>3.032E+02</td>
<td>-1.276E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>95.00</td>
<td>9.150E+03</td>
<td>9.939E-09</td>
<td>-1.277E+04</td>
</tr>
<tr>
<td>44.50</td>
<td>96.08</td>
<td>9.150E+03</td>
<td>9.939E-09</td>
<td>-1.277E+04</td>
</tr>
</tbody>
</table>

II.B. -- LEFTSIDE MEMBERS
SYMMETRIC WITH RIGHTSIDE MEMBERS

a. (Concluded)

Figure 41. (Sheet 2 of 6)

100
"EXAMPLE : - TYPE 1 MOMENT
SYMMETRIC SOIL-FOUNDED STRUCTURE

RIGHTSIDE MEMBER 2 FORCES
DISTANCE (FT)

0.00 1.8074 2.07 5.81 6.95 8.68 10.42 12.16 13.89 15.63 17.37
NEAR JOINT 2

1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00

RUTAL (LB)

SHEAR (LB)

MOMENT LB/FT

0.00 4.0E+02
0.00 4.0E+03
0.00 9.0E+03
0.00 9.0E+03
0.00 4.0E+03
0.00 4.0E+03
0.00 4.0E+03
0.00 4.0E+03
0.00 4.0E+03
0.00 4.0E+03

C. Plot for member 2 forces

Figure 41. (Sheet 4 of 6)
EXAMPLE 1 - TYPE 1 MONOLITHIC
SYMMETRIC SOIL-FOUNDED STRUCTURE

RIGHTSIDE MEMBER 3 FORCES
DISTANCE (FT)

d. Plot for member 3 forces

Figure 41. (Sheet 5 of 6)
"EXAMPLE: - TYPE 1 MONOLITH"
"SYMMETRIC SOIL-FOUNDED STRUCTURE"

RIGHTSIDE MEMBER 4 FORCES
DISTANCE (FT)

<table>
<thead>
<tr>
<th>0.00</th>
<th>1.11</th>
<th>2.32</th>
<th>3.43</th>
<th>4.54</th>
<th>5.65</th>
<th>6.75</th>
<th>7.86</th>
<th>8.96</th>
<th>10.08</th>
<th>11.18</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEAR JOINT 4</td>
<td>NEAR JOINT 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AXIAL (LBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0E+04</td>
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<tr>
<td>0</td>
</tr>
<tr>
<td>-2.0E+04</td>
</tr>
<tr>
<td>4.0E+03</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>-4.0E+03</td>
</tr>
<tr>
<td>3.0E+04</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>-3.0E+04</td>
</tr>
</tbody>
</table>

e. Plot for member 4 forces

Figure 41. (Sheet 6 of 6)
Example 2—Type 2 Monolith

139. The right half of the symmetric structure is shown in Figure 42. Because the rightside and leftside backfill soils are at different elevations and due to unsymmetric additional loads, the entire system is unsymmetric. An equilibrium analysis was initially performed for a 6-ft thick slice of the soil-supported system. Example 2A is referred to in Figures 43, 44, and 45. A listing of the predefined input data file is shown in Figure 43 and an echo-print of input data is given in Figure 44. Results of the equilibrium analysis are shown in Figure 45. Note that equilibrium of the unsymmetric system was achieved by addition of friction on the base of the structure and by skewing of the nominally rectangular base reaction distribution.

140. Following the initial equilibrium analysis, the input data were edited to prescribe a frame analysis and to change from soil to pile supports as shown in Figure 46. Example 2B of the type 2 monolith is referred to in Figures 46, 47, 48, and 49. A listing of the input file for the new system generated by the program is shown in Figure 47. An echo-print of existing input data is given in Figure 48. Plots of rightside geometry are included.

141. Results of the equilibrium analysis are shown in Figure 49. The nonzero net resultants, due to unsymmetric loading, are resisted by the piles.

142. Frame model data generated by the program are shown in Figure 50. Note that joints along the base slab have been assigned at locations where one or more piles intersect the flexible portion of the structure. Piles which intersect the boundaries of the rigid blocks are assumed to be attached by rigid links to joints at the centroid of the rigid block. Plots of the frame model are included in Figure 50.

143. Results of the frame analysis are shown in Figure 51. The results include displacements of all joints in the model as well as member forces at the ends of the member flexible lengths. Pile head forces and displacements, parallel and perpendicular to the axis of the pile, are given for each pile on each side. Note that the pile layout data are symmetric and that two vertical piles (piles 1 and 9) are located on the centerline. The stiffness effects of each of these piles have been evaluated only once. However, forces and displacements of the two centerline piles have been reported with the results for each side. The results of pile allowables comparisons are presented for information purposes only. The program does not attempt to assess the effect
Figure 42. System for Example 2
Figure 43. Program execution and input file for Example 2A (Continued)
| 1000 | EXAMPLE 2A - TYPE 2 MONOLITH |
| 1010 | UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITIONAL LOADS |
| 1020 | SOIL-FOUNDED STRUCTURE |
| 1030 | METHOD EQ |
| 1040 | STRUCTURE 3.00E+06 20 150.00 6.00 |
| 1050 | FLOOR 42.00 23.00 0.00 |
| 1060 | BASE BOTH 66.00 15.00 |
| 1070 | STEM BOTH 8 |
| 1080 | 9.75 74.50 9.75 70.50 4.00 65.50 |
| 1090 | 4.00 55.50 6.00 40.00 24.00 37.00 |
| 1100 | 24.00 21.00 24.00 21.00 |
| 1110 | CULVERT BOTH 8.00 12.00 21.00 12.00 0.00 |
| 1120 | BACKFILL RIGHTSIDE SOIL 1 0.00 |
| 1130 | 70.00 122.00 122.00 0.60 0.60 0.00 0.00 |
| 1140 | BACKFILL LEFTSIDE SOIL 1 0.00 |
| 1150 | 60.00 122.00 122.00 0.60 0.60 0.00 0.00 |
| 1160 | REACTION SOIL RECTANGULAR 0.5 |
| 1270 | WATER 62.5 |
| 1280 | EXTERNAL BOTH ELEVATION 60.00 |
| 1290 | UPLIFT ELEVATION 62.00 62.00 |
| 1300 | INTERNAL 55.00 45.00 45.00 |
| 1310 | LOADS RIGHTSIDE STEM EXTERIOR |
| 1320 | CONC 1 70.00 1000.00 0.00 |
| 1330 | FINISH |

Figure 43. (Concluded)
I. --HEADING
'EXAMPLE 2A - TYPE 2 MONOLITH
'UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITIONAL LOADS
'SOIL-FOUNDED STRUCTURE

***************
* INPUT DATA *
***************

II. --EQUILIBRIUM ANALYSIS ONLY

III. --STRUCTURE DATA

III.A. --MATERIAL PROPERTIES
MODULUS OF ELASTICITY OF CONCRETE = 3,000E+06 (PSI)
POISSON'S RATIO FOR CONCRETE = .20
UNIT WEIGHT OF CONCRETE = 150.0 (PCF)
THICKNESS OF TWO-DIMENSIONAL SLICE = 6.00 (FT)

III.B. --FLOOR DATA
FLOOR WIDTH = 42.00 (FT)
FLOOR ELEVATION = 23.00 (FT)
FLOOR FILLET SIZE = 0.00 (FT)

III.C. --BASE DATA

III.C.1. --RIGHTSIDE
DISTANCE FROM CHAMBER CL ELEVATION
(FT) (FT)
66.00 15.00

III.C.2. --LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

III.D. --STEM DATA

III.D.1. --RIGHTSIDE
DISTANCE FROM STEM FACE ELEVATION
(FT) (FT)
9.75 74.50
9.75 70.50
4.00 65.50
4.00 55.50
8.00 40.00
24.00 37.00
24.00 21.00
24.00 21.00

III.D.2. --LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

Figure 44. Echoprint of input data for Example 2A (Sheet 1 of 3)
III.E.--CULVERT DATA

III.E.1.--RIGHTSIDE
DISTANCE FROM STEM FACE TO INTERIOR SIDE = 8.00 (FT)
CULVERT WIDTH = 12.00 (FT)
ELEVATION AT CULVERT FLOOR = 21.00 (FT)
CULVERT HEIGHT = 12.00 (FT)
CULVERT FILLET SIZE = 0.00 (FT)

III.E.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA
NONE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

<table>
<thead>
<tr>
<th>ELEV (FT)</th>
<th>SATURATED HORIZONTAL SHEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOP UNIT WT. (PCF)</td>
</tr>
<tr>
<td>70.00</td>
<td>122.0</td>
</tr>
</tbody>
</table>

IV.B.--LEFTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

<table>
<thead>
<tr>
<th>ELEV (FT)</th>
<th>SATURATED HORIZONTAL SHEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOP UNIT WT. (PCF)</td>
</tr>
<tr>
<td>60.00</td>
<td>122.0</td>
</tr>
</tbody>
</table>

V.--BASE REACTION DATA

REACTION PROVIDED BY RECTANGULAR SOIL PRESSURE DISTRIBUTION
FRACTION OF UNIFORM BASE PRESSURE AT CENTERLINE = .50

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND WATER ELEVATION = 60.00 (FT)
SURCHARGE WATER = NONE

VI.A.2.--LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

Figure 44. (Sheet 2 of 3)
VI.B.--UPLIFT WATER DATA
RIGHTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)
LEFTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)

VI.C.--INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 55.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT = 45.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT = 45.00 (FT)

VII.--ADDITIONAL LOAD DATA

VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE

<table>
<thead>
<tr>
<th>CONCENTRATED LOAD DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEVATION</td>
</tr>
<tr>
<td>(FT)</td>
</tr>
<tr>
<td>70.00</td>
</tr>
</tbody>
</table>

DISTRIBUTED LOAD DATA
NONE

VII.A.2.--ADDITIONAL LOADS ON LEFTSIDE EXTERNAL STEM FACE
NONE

VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
NONE

VII.B.2.--ADDITIONAL LOADS ON LEFTSIDE INTERIOR STEM FACE
NONE

VII.C.1.--ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
NONE

VII.C.2.--ADDITIONAL LOADS ON LEFTSIDE STEM TOP
NONE

VII.D.1.--ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
NONE

VII.D.2.--ADDITIONAL LOADS ON LEFTSIDE OF CHAMBER FLOOR
NONE

VII.E.1.--ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE
NONE

VII.E.2.--ADDITIONAL LOADS ON LEFTSIDE OF STRUCTURE BASE
NONE

Figure 44. (Sheet 3 of 3)
I. -- HEADING

"EXAMPLE 2A - TYPE 2 MONOLITH
"UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITIONAL LOADS
"SOIL-FOUNDED STRUCTURE

* RESULTS OF EQUILIBRIUM ANALYSIS *

II. -- EFFECTS ON STRUCTURE RIGHTSIDE

II.A. -- PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ELEVATION</th>
<th>VERTICAL</th>
<th>HORIZONTAL</th>
<th>SHEAR</th>
<th>GRND/SURCH WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>74.500</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>70.500</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>70.000</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>65.500</td>
<td>5.4900E+02</td>
<td>3.2940E+02</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>60.000</td>
<td>1.2200E+03</td>
<td>7.3200E+02</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>55.500</td>
<td>1.4870E+03</td>
<td>8.9240E+02</td>
<td>0.00</td>
<td>2.8125E+02</td>
</tr>
<tr>
<td>55.000</td>
<td>1.5175E+03</td>
<td>9.1050E+02</td>
<td>0.00</td>
<td>3.1250E+02</td>
</tr>
<tr>
<td>40.000</td>
<td>2.4100E+03</td>
<td>1.4460E+03</td>
<td>0.00</td>
<td>1.2500E+03</td>
</tr>
<tr>
<td>37.000</td>
<td>2.5880E+03</td>
<td>1.5530E+03</td>
<td>0.00</td>
<td>1.4375E+03</td>
</tr>
<tr>
<td>33.000</td>
<td>2.8265E+03</td>
<td>1.6950E+03</td>
<td>0.00</td>
<td>1.6875E+03</td>
</tr>
<tr>
<td>23.000</td>
<td>3.4215E+03</td>
<td>2.0529E+03</td>
<td>0.00</td>
<td>2.3125E+03</td>
</tr>
<tr>
<td>21.000</td>
<td>3.5405E+03</td>
<td>2.1243E+03</td>
<td>0.00</td>
<td>2.4375E+03</td>
</tr>
<tr>
<td>15.000</td>
<td>3.8975E+03</td>
<td>2.3385E+03</td>
<td>0.00</td>
<td>2.8125E+03</td>
</tr>
</tbody>
</table>

II.B. -- PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>DIST FROM CHAMBER CL</th>
<th>SOIL REACTION PRESSURE</th>
<th>UPLIFT WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>7.9331E+02</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>42.000-</td>
<td>8.6465E+02</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>42.000+</td>
<td>3.0463E+03</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>50.000</td>
<td>3.0598E+03</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>62.000</td>
<td>3.0802E+03</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>66.000</td>
<td>3.0870E+03</td>
<td>2.9375E+03</td>
</tr>
</tbody>
</table>

Figure 45. Results of equilibrium analysis for Example 2A (Sheet 1 of 3)
II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKFILL</td>
<td>4.3648E+05</td>
<td>2.7818E+05</td>
<td>-1.0515E+07</td>
</tr>
<tr>
<td>GROUND/SURCH WATER</td>
<td>3.7969E+05</td>
<td>1.4738E+05</td>
<td>-5.7379E+06</td>
</tr>
<tr>
<td>INTERNAL WATER</td>
<td>-1.9200E+05</td>
<td>5.5800E+05</td>
<td>-1.5656E+07</td>
</tr>
<tr>
<td>UPLIFT WATER</td>
<td>0.</td>
<td>-1.1633E+06</td>
<td>3.8387E+07</td>
</tr>
<tr>
<td>SOIL-BASE REACT</td>
<td>-1.1280E+05</td>
<td>-6.5050E+05</td>
<td>2.9210E+07</td>
</tr>
<tr>
<td>ADDL EXT STEM LOADS</td>
<td>6.0000E+03</td>
<td>0.</td>
<td>2.8200E+05</td>
</tr>
<tr>
<td>CONCRETE</td>
<td></td>
<td>8.7694E+05</td>
<td>-3.5359E+07</td>
</tr>
<tr>
<td>TOTAL THIS SIDE</td>
<td>5.1737E+05</td>
<td>4.6741E+04</td>
<td>6.1133E+05</td>
</tr>
</tbody>
</table>

III.--EFFECTS ON STRUCTURE LEFTSIDE

III.A.--PRESSURES ON LEFTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ELEVATION</th>
<th>VERTICAL</th>
<th>HORIZONTAL</th>
<th>SHEAR</th>
<th>GRND/SURCH WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>74.500</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td></td>
</tr>
<tr>
<td>70.500</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td></td>
</tr>
<tr>
<td>65.500</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td></td>
</tr>
<tr>
<td>60.000</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td></td>
</tr>
<tr>
<td>55.500</td>
<td>2.6775E+02</td>
<td>1.6065E+02</td>
<td>0.</td>
<td>2.8125E+02</td>
</tr>
<tr>
<td>55.000</td>
<td>2.9750E+02</td>
<td>1.7850E+02</td>
<td>0.</td>
<td>3.1250E+02</td>
</tr>
<tr>
<td>40.000</td>
<td>1.1900E+03</td>
<td>7.1400E+02</td>
<td>0.</td>
<td>1.2500E+03</td>
</tr>
<tr>
<td>37.000</td>
<td>1.3685E+03</td>
<td>8.2110E+02</td>
<td>0.</td>
<td>1.4375E+03</td>
</tr>
<tr>
<td>33.000</td>
<td>1.6065E+03</td>
<td>9.6390E+02</td>
<td>0.</td>
<td>1.6875E+03</td>
</tr>
<tr>
<td>25.000</td>
<td>2.2015E+03</td>
<td>1.3209E+03</td>
<td>0.</td>
<td>2.3125E+03</td>
</tr>
<tr>
<td>21.000</td>
<td>2.3205E+03</td>
<td>1.3923E+03</td>
<td>0.</td>
<td>2.4375E+03</td>
</tr>
<tr>
<td>15.000</td>
<td>2.6775E+03</td>
<td>1.6065E+03</td>
<td>0.</td>
<td>2.8125E+03</td>
</tr>
</tbody>
</table>

III.B.--PRESSURE ON LEFTSIDE BASE
(POSITIVE PRESSURE IS UP) UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>DIST FROM CHAMBER CL</th>
<th>SOIL REACTION PRESSURE</th>
<th>UPLIFT WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>7.9331E+02</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>42.000</td>
<td>7.2197E+02</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>42.000+</td>
<td>2.9036E+03</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>50.000</td>
<td>2.8900E+03</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>62.000</td>
<td>2.8696E+03</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>66.000</td>
<td>2.8628E+03</td>
<td>2.9375E+03</td>
</tr>
</tbody>
</table>

Figure 45. (Sheet 2 of 3)
III.C.--RESULTANTS OF LOADS ON STRUCTURE LEFTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS CLOCKWISE ABOUT CHAMBER
FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKFILL</td>
<td>2.1688E+05</td>
<td>1.4030E+05</td>
<td>-6.4746E+06</td>
</tr>
<tr>
<td>GROUND/SURCH WATER</td>
<td>3.7969E+05</td>
<td>1.4738E+05</td>
<td>-5.7379E+06</td>
</tr>
<tr>
<td>INTERNAL WATER</td>
<td>-1.9200E+05</td>
<td>5.5800E+05</td>
<td>-1.5656E+07</td>
</tr>
<tr>
<td>UPLIFT WATER</td>
<td>0.</td>
<td>-1.1633E+06</td>
<td>3.8387E+07</td>
</tr>
<tr>
<td>SOIL-BASE REACT</td>
<td>1.1280E+05</td>
<td>-6.0610E+05</td>
<td>2.5452E+07</td>
</tr>
<tr>
<td>CONCRETE</td>
<td>8.7694E+05</td>
<td>-3.5359E+07</td>
<td></td>
</tr>
<tr>
<td>TOTAL THIS SIDE</td>
<td>5.1737E+05</td>
<td>-4.6741E+04</td>
<td>6.1133E+05</td>
</tr>
</tbody>
</table>

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)
TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

NOTE: HORIZONTAL EQUILIBRIUM PROVIDED BY FRICTION ON BASE.

Figure 45. (Sheet 3 of 3)

115
**Output Complete.**

Do you want to edit input data for the problem just completed? Enter 'YES' or 'NO'.

> ? Y

**Major Data Sections:**

1. Heading
2. Method of Analysis
3. Structure Data
4. Backfill Data
5. Base Reaction Data
6. Water Data
7. Additional Load Data

To delete an entire section enter 'DELETE' before section number. Enter section number (1 to 7) to be edited, 'FINISHED', or 'HELP'.

> ? 1

Enter number of heading lines (1 to 4).

> ? 2

Enter 2 heading lines.

> ? Example 2B - Type 2 Monolith of Example 2A

> ? With pile support

Enter section number (1 to 7) to be edited, 'FINISHED', or 'HELP'.

> ? 2

Enter method of analysis ('EQUIL' or 'FRAME').

> ? F

Enter rigid link factor (0. LE. SHRINK.LE.ONE).

> ? 1

Enter section number (1 to 7) to be edited, 'FINISHED', or 'HELP'.

> ? 5

Current base reaction is provided by soil. Do you want to change to pile reaction? Enter 'YES' or 'NO'.

> ? Y

Enter rightside pile layout data, one line at a time. Enter 'END' when finished with rightside layout data.

<table>
<thead>
<tr>
<th>PILE NO.</th>
<th>CHAMBER CL.</th>
<th>PILE DIST. FROM PILE NO.</th>
<th>PILE DIST. (FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 10 5 1 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 50 8 1 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 9 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 10 20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 11 40 14 1 5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

> ? E

Are leftside and rightside pile layout data symmetric? Enter 'YES' or 'NO'.

> ? Y

Are all pile data symmetric? Enter 'YES' or 'NO'.

> ? Y

Are pile/soil properties to be provided? Enter 'YES' or 'NO'.

> ? Y

End of file

Figure 46. Data editing for Example 2B (Sheet 1 of 3)
ARE RIGHTSIDE PILE/SOIL PROPERTIES TO BE ENTERED?
ENTER 'YES' OR 'NO'.

? Y
ENTER RIGHTSIDE PILE/SOIL PROPERTIES, ONE LINE AT A TIME.
ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE/SOIL DATA.

<---------------------PILE PROPERTIES--------------------->

START MOD. SECT MOM AXIAL HEAD <-SOIL-> STOP PILE
PILE ELAST AREA INERTIA LENGTH STIFF FIXITY <COEFFS> PILE NO. 
NO. (PSI) (SQIN) (IN**4) (FT) COEFF COEFF SS1 SS2 NO. STEP

? 1 2.9E7 21.4 729 45 1 3 0 0 10 14 1
? E

ARE LEFTSIDE AND RIGHTSIDE PILE/SOIL PROPERTIES DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.

? Y
ARE ALL PILE DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.

? Y
ARE PILE HEAD STIFFNESS MATRICES TO BE PROVIDED?
ENTER 'YES' OR 'NO'.

? N
ARE ALL PILE DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.

? Y
ARE PILE BATTER DATA TO BE PROVIDED?
ENTER 'YES' OR 'NO'.

? Y
ARE RIGHTSIDE BATTER DATA TO BE ENTERED?
ENTER 'YES' OR 'NO'.

? Y
ENTER RIGHTSIDE PILE BATTER DATA, ONE LINE AT A TIME.
ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE BATTER DATA.

START STOP PILE
PILE BATTER PILE NO. (FT/FT) NO. STEP

? 11 3 14 1
? E

ARE LEFTSIDE AND RIGHTSIDE PILE BATTER DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.

? Y
ARE ALL PILE DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.

? Y
ARE PILE ALLOWABLE DATA TO BE PROVIDED?
ENTER 'YES' OR 'NO'.

? Y
ARE RIGHTSIDE PILE ALLOWABLE DATA TO BE ENTERED?
ENTER 'YES' OR 'NO'.

? Y
ENTER RIGHTSIDE PILE ALLOWABLE DATA, ONE LINE AT A TIME.
ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE ALLOWABLE DATA.

<ALLOWABLE AXIAL FORCE>

START COMP TENS COMP TENS ALLOW MOM MAX OVER STRESS STOP PILE
PILE ONLY ONLY WITH WITH BEND MAG MOM FACTORS PILE NO. 
EM EM MOM FACT FACT COMP TENS NO. STEP

? 1 215 88 364 364 196 1 56.6 1.33 1.33 14 1
? E

Figure 46. (Sheet 2 of 3)
ARE LEFTSIDE AND RIGHTSIDE PILE ALLOWABLE DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.
? Y

ARE ALL PILE DATA SYMMETRIC?
ENTER 'YES' OR 'NO'.
? Y

ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? F

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).
? CUEX2B

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).
? CUX2B

INPUT COMPLETE.

DO YOU WANT TO PLOT INPUT DATA? ENTER 'YES' OR 'NO'.
? Y

DO YOU WANT TO CONTINUE SOLUTION? ENTER 'YES' OR 'NO'.
? Y

DO YOU WANT RESULTS WRITTEN TO YOUR TERMINAL, TO FILE 'CUEX2B', OR BOTH?
ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? F

DO YOU WANT TO PLOT PRESSURES? ENTER 'YES' OR 'NO'.
? N

EQUILIBRIUM ANALYSIS COMPLETE.

DO YOU WANT TO CONTINUE WITH FRAME SOLUTION? ENTER 'YES' OR 'NO'.
? Y

DO YOU WANT TO PLOT FRAME MODEL?
ENTER 'YES' OR 'NO'.
? Y

DEVELOPMENT OF FRAME MODEL COMPLETE.

DO YOU WANT TO CONTINUE WITH FRAME SOLUTION? ENTER 'YES' OR 'NO'.
? Y

DO YOU WANT DETAILED MEMBER FORCES OUTPUT?
ENTER 'YES' OR 'NO'.
? N

OUTPUT COMPLETE.

DO YOU WANT TO EDIT INPUT DATA FOR THE PROBLEM JUST COMPLETED?
ENTER 'YES' OR 'NO'.
? N

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

********** NORMAL TERMINATION **********

Figure 46. (Sheet 3 of 3)

118
**** INPUT FILE FOR EXAMPLE 2B GENERATED BY CUFRAM ****

1000 'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
1010 'WITH PILE SUPPORT
1020 METHOD FR 1.00
1030 STRUCTURE 3.00E+06 .20 150.00 6.00
1040 FLOOR 42.00 23.00 0.00
1050 BASE BOTH 66.00 15.00
1060 STEM BOTH 8
1070 9.75 74.50 9.75 70.50 4.00 65.50
1080 4.00 55.50 8.00 40.00 24.00 37.00
1090 24.00 21.00 24.00 21.00
1100 CULVERT BOTH 8.00 12.00 21.00 12.00 0.00
1110 BACKFILL RIGHTSIDE SOIL 1 0.00
1120 70.00 122.00 122.00 .60 .60 0.00 0.00
1130 BACKFILL LEFTSIDE SOIL 1 0.00
1140 60.00 122.00 122.00 .60 .60 0.00 0.00
1150 REACTION PILES
1160 PILES BOTH
1170 LAYOUT 1 0.00 1 1 0.00
1180 LAYOUT 2 10.00 5 1 10.00
1190 LAYOUT 6 50.00 8 1 5.00
1200 LAYOUT 9 0.00 9 1 0.00
1210 LAYOUT 10 20.00 10 1 0.00
1220 LAYOUT 11 40.00 14 1 5.00
1230 PROPS 1 2.90E+07 21.4 729.0 45.0 1.3 0.00 0.00 10.00 14 1
1240 BATTER 11 3.00 14 1
1250 ALLOW 1 215. 88. 364. 364. 196. 1.00 56.60 1.33 1.33 14 1
1260 WATER 62.5
1270 EXTERNAL BOTH ELEVATION 60.00
1280 UPLIFT ELEVATION 62.00 62.00
1290 INTERNAL 55.00 45.00 45.00
1300 LOADS RIGHTSIDE STEM EXTERIOR
1310 CONC 1 70.00 1000.00 0.00
1320 FINISH

Figure 47. CUFRAM generated input file for Example 2B

119
PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85
TIME: 15:37:32

I. -- HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

***************
* INPUT DATA *
***************

II. -- PLANE FRAME ANALYSIS
RIGID LINK FACTOR = 1.00

III. -- STRUCTURE DATA

III.A. -- MATERIAL PROPERTIES
MODULUS OF ELASTICITY OF CONCRETE = 3.000E+06 (PSI)
POISSON'S RATIO FOR CONCRETE = .20
UNIT WEIGHT OF CONCRETE = 150.0 (PCF)
THICKNESS OF TWO-DIMENSIONAL SLICE = 6.00 (FT)

III.B. -- FLOOR DATA
FLOOR WIDTH = 42.00 (FT)
FLOOR ELEVATION = 23.00 (FT)
FLOOR FILLET SIZE = 0.00 (FT)

III.C. -- BASE DATA

III.C.1. -- RIGHTSIDE
DISTANCE FROM CHAMBER CL ELEVATION
(FT) (FT)
66.00 15.00

III.C.2. -- LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

III.D. -- STEM DATA

III.D.1. -- RIGHTSIDE
DISTANCE FROM STEM FACE ELEVATION
(FT) (FT)
9.75 74.50
9.75 70.50
4.00 65.50
4.00 55.50
6.00 40.00
24.00 37.00
24.00 21.00
24.00 21.00

III.D.2. -- LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

a. Echoprint (Continued)

Figure 48. Input data for Example 2B (Sheet 1 of 6)

120
III.E. -- CULVERT DATA
III.E.1. -- RIGHTSIDE
DISTANCE FROM STEM FACE TO INTERIOR SIDE = 8.00 (FT)
CULVERT WIDTH = 12.00 (FT)
ELEVATION AT CULVERT FLOOR = 21.00 (FT)
CULVERT HEIGHT = 12.00 (FT)
CULVERT FILLET SIZE = 0.00 (FT)

III.E.2. -- LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

III.F. -- VOID DATA
NONE

IV. -- BACKFILL DATA
IV.A. -- RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))
ELEV <--PRESSURE COEFFICIENTS--> 
AT SATURATED MOIST HORIZONTAL SHEAR
TOP UNIT WT. UNIT WT. TOP BOT. TOP BOT.
(FT) (PCF) (PCF)
70.00 122.0 122.0 .600 .600 0.000 0.000

IV.B. -- LEFTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))
ELEV <--PRESSURE COEFFICIENTS--> 
AT SATURATED MOIST HORIZONTAL SHEAR
TOP UNIT WT. UNIT WT. TOP BOT. TOP BOT.
(FT) (PCF) (PCF)
60.00 122.0 122.0 .600 .600 0.000 0.000

V. -- BASE REACTION DATA
V.A. -- RIGHTSIDE PILE DATA
V.A.1. -- PILE LAYOUT DATA
<----START----> STOP PILE
PILE PILE NO. STEP IN
CHamber CL NO. (FT) (FT)
1 0.00 1 1 0.00
2 10.00 5 1 10.00
6 50.00 8 1 5.00
9 0.00 9 1 0.00
10 20.00 10 1 0.00
11 40.00 14 1 5.00

V.A.2. -- PILE PROPERTIES
<--------------------------START-------------------------->
PILE PILE No.
MOODULUS OF ELASTICITY AREA INERTIA LENGTH AXIAL HEAD FIXED COEFF NO. STEp
(PSI) (SQIN) (IN**4) (FT)
1 2.90E+07 21.40 729.00 45.00 1.30 0.00 14 1

V.A.3. -- SOIL PROPERTIES
<--------START-------->
PILE PILE No.
CONSTANT LINEAR NO. COEFFICIENT COEFFICIENT NO. STEp
NO. (PSI) (PCI)
1 0.000 10.000 14 1

a. (Continued)

Figure 48. (Sheet 2 of 6)
V.A.4.--PILE HEAD STIFFNESS MATRICES
NONE

V.A.4.--PILE BATTER DATA
<----START----> STOP PILE
PILE BATTER PILE NO. NO. STEP
11 3.00 14 1

V.A.5.--PILE LOAD COMPARISON DATA

V.A.5.A.--ALLOWABLE LOADS
START <-----ALLOWABLE AXIAL LOAD------> STOP PILE
PILE NO. COMPR. TENS. COMPR. TENS. MOMENT NO. STEP
(K) (K) (K) (K) (K-FT)
1 215. 88. 364. 364. 196. 14 1

V.A.5.B.--MOMENT/STRESS FACTORS
START MAX. MOM.
PILE NO. MAG. FACT. OVERSTRESS FACTOR NO. STEP
1 1.000 58.800 1.330 1.330 14 1

V.B.--LEFTSIDE PILE DATA
SYMMETRIC WITH RIGHTSIDE

VI.---WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.---EXTERNAL WATER DATA

VI.A.1.---RIGHTSIDE EXTERNAL WATER DATA
GROUND WATER ELEVATION = 80.00 (FT)
SURCHARGE WATER = NONE

VI.A.2.---LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.---UPLIFT WATER DATA
RIGHTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)
LEFTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)

VI.C.---INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 55.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT = 45.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT = 45.00 (FT)

a. (Continued)

Figure 48. (Sheet 3 of 6)
VII.--ADDITIONAL LOAD DATA

VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE

CONCENTRATED LOAD DATA

<table>
<thead>
<tr>
<th>ELEVATION</th>
<th>HORIZONTAL LOAD</th>
<th>VERTICAL LOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT LOAD</td>
<td>(FT)</td>
<td>(PLF)</td>
</tr>
<tr>
<td>70.00</td>
<td>1000.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

DISTRIBUTED LOAD DATA
NONE

VII.A.2.--ADDITIONAL LOADS ON LEFTSIDE EXTERNAL STEM FACE
NONE

VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
NONE

VII.B.2.--ADDITIONAL LOADS ON LEFTSIDE INTERIOR STEM FACE
NONE

VII.C.1--ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
NONE

VII.C.2--ADDITIONAL LOADS ON LEFTSIDE STEM TOP
NONE

VII.D.1.--ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
NONE

VII.D.2.--ADDITIONAL LOADS ON LEFTSIDE OF CHAMBER FLOOR
NONE

VII.E.1.--ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE
NONE

VII.E.2.--ADDITIONAL LOADS ON LEFTSIDE OF STRUCTURE BASE
NONE

a. (Concluded)

Figure 48. (Sheet 4 of 6)
EXAMPLE 2B - TYPE B MONOLITH OF EXAMPLE 2A
WITH PILE SUPPORT

Figure 48. (Sheet 6 of 6)

b. (Concluded)
I. -- HEADING

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

*************************************************
* RESULTS OF EQUILIBRIUM ANALYSIS *
*************************************************

II. -- EFFECTS ON STRUCTURE RIGHTSIDE

II.A. -- PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ELEVATION</th>
<th>VERTICAL</th>
<th>HORIZONTAL</th>
<th>SHEAR</th>
<th>WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>74.500</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>70.500</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>70.000</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>65.500</td>
<td>5.4900E+02</td>
<td>3.2940E+02</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>60.000</td>
<td>1.2200E+03</td>
<td>7.3200E+02</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>55.500</td>
<td>1.4878E+03</td>
<td>8.9265E+02</td>
<td>0.</td>
<td>2.8125E+02</td>
</tr>
<tr>
<td>55.000</td>
<td>1.5175E+03</td>
<td>9.1050E+02</td>
<td>0.</td>
<td>3.1250E+02</td>
</tr>
<tr>
<td>40.000</td>
<td>2.4100E+03</td>
<td>1.4460E+03</td>
<td>0.</td>
<td>1.2500E+03</td>
</tr>
<tr>
<td>37.000</td>
<td>2.5885E+03</td>
<td>1.5531E+03</td>
<td>0.</td>
<td>1.4375E+03</td>
</tr>
<tr>
<td>33.000</td>
<td>2.8265E+03</td>
<td>1.6959E+03</td>
<td>0.</td>
<td>1.6875E+03</td>
</tr>
<tr>
<td>23.000</td>
<td>3.4215E+03</td>
<td>2.0529E+03</td>
<td>0.</td>
<td>2.3125E+03</td>
</tr>
<tr>
<td>21.000</td>
<td>3.5405E+03</td>
<td>2.1243E+03</td>
<td>0.</td>
<td>2.4375E+03</td>
</tr>
<tr>
<td>15.000</td>
<td>3.9975E+03</td>
<td>2.3385E+03</td>
<td>0.</td>
<td>2.8125E+03</td>
</tr>
</tbody>
</table>

II.B. -- PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>DIST FROM CHAMBER CL</th>
<th>SOIL REACTION PRESSURE</th>
<th>UPLIFT WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>10.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>20.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>30.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>40.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>42.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>45.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>50.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>55.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>60.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>62.000</td>
<td>C.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>66.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
</tbody>
</table>

Figure 49. Results of equilibrium analysis for Example 2B (Sheet 1 of 3)
II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER
FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKFILL</td>
<td>4.3648E+05</td>
<td>2.7818E+05</td>
<td>-1.0515E+07</td>
</tr>
<tr>
<td>GROUND/SURCH WATER</td>
<td>3.7969E+05</td>
<td>1.4738E+05</td>
<td>-5.7379E+06</td>
</tr>
<tr>
<td>INTERNAL WATER</td>
<td>-1.9200E+05</td>
<td>5.5800E+05</td>
<td>-1.5856E+07</td>
</tr>
<tr>
<td>UPLIFT WATER</td>
<td>0.</td>
<td>-1.1633E+06</td>
<td>3.8387E+07</td>
</tr>
<tr>
<td>ADDL EXT STEM LOADS</td>
<td>6.0000E+03</td>
<td>0.</td>
<td>2.8200E+05</td>
</tr>
<tr>
<td>CONCRETE</td>
<td>8.7894E+05</td>
<td>3.8387E+07</td>
<td>-3.5359E+07</td>
</tr>
<tr>
<td>TOTAL THIS SIDE</td>
<td>6.3017E+05</td>
<td>6.9724E+05</td>
<td>-2.8599E+07</td>
</tr>
</tbody>
</table>

III.--EFFECTS ON STRUCTURE LEFTSIDE

III.A.--PRESSURES ON LEFTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ELEVATION</th>
<th>VERTICAL</th>
<th>HORIZONTAL</th>
<th>SHEAR</th>
<th>GRND/SURCH WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>74.500</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>70.500</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>65.500</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>60.000</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>55.500</td>
<td>2.6775E+02</td>
<td>1.8065E+02</td>
<td>0.</td>
<td>2.8125E+02</td>
</tr>
<tr>
<td>55.000</td>
<td>2.9750E+02</td>
<td>1.7850E+02</td>
<td>0.</td>
<td>3.1250E+02</td>
</tr>
<tr>
<td>40.000</td>
<td>1.1900E+03</td>
<td>7.1400E+02</td>
<td>0.</td>
<td>1.2500E+03</td>
</tr>
<tr>
<td>37.000</td>
<td>1.3685E+03</td>
<td>8.2110E+02</td>
<td>0.</td>
<td>1.4375E+03</td>
</tr>
<tr>
<td>33.000</td>
<td>1.6065E+03</td>
<td>9.6390E+02</td>
<td>0.</td>
<td>1.6875E+03</td>
</tr>
<tr>
<td>23.000</td>
<td>2.2015E+03</td>
<td>1.3209E+03</td>
<td>0.</td>
<td>2.3125E+03</td>
</tr>
<tr>
<td>21.000</td>
<td>2.3205E+03</td>
<td>1.3923E+03</td>
<td>0.</td>
<td>2.4375E+03</td>
</tr>
<tr>
<td>15.000</td>
<td>2.6775E+03</td>
<td>1.8065E+03</td>
<td>0.</td>
<td>2.8125E+03</td>
</tr>
</tbody>
</table>

III.B.--PRESSURE ON LEFTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>DIST FROM CHAMBER CL</th>
<th>SOIL REACTION PRESSURE</th>
<th>UPLIFT WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>1.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>2.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>3.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>4.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>5.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>6.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
<tr>
<td>7.000</td>
<td>0.</td>
<td>2.9375E+03</td>
</tr>
</tbody>
</table>

Figure 49. (Sheet 2 of 3)
III.C.--RESULTANTS OF LOADS ON STRUCTURE LEFTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS CLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKFILL</td>
<td>2.1688E+05</td>
<td>1.4030E+05</td>
<td>-6.4746E+06</td>
</tr>
<tr>
<td>GROUND/SURCH WATER</td>
<td>3.7969E+05</td>
<td>1.4738E+05</td>
<td>-5.7379E+06</td>
</tr>
<tr>
<td>INTERNAL WATER</td>
<td>-1.9200E+05</td>
<td>5.5800E+05</td>
<td>-1.5656E+07</td>
</tr>
<tr>
<td>UPLIFT WATER</td>
<td>0</td>
<td>-1.1633E+06</td>
<td>3.8387E+07</td>
</tr>
<tr>
<td>CONCRETE</td>
<td>8.7684E+05</td>
<td>-3.5359E+07</td>
<td></td>
</tr>
<tr>
<td>TOTAL THIS SIDE</td>
<td>4.0457E+05</td>
<td>5.5936E+05</td>
<td>-2.4841E+07</td>
</tr>
</tbody>
</table>

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

TOTAL HORIZONTAL = -2.2560E+05
TOTAL VERTICAL   = 1.2566E+06
TOTAL MOMENT     = -3.7581E+06

Figure 49. (Sheet 3 of 3)
of these comparisons on the behavior of the system.

144. The results of an analysis of this structure obtained with GTSTRUDL are given in Appendix B.
I. -- HEADING

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

***************
* FRAME MODEL DATA *
***************

II. -- RIGHTSIDE FRAME MODEL DATA

II.A. -- RIGID BLOCK DATA (FT) - TYPE 2 MONOLITH
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>CORNER NO.</th>
<th>X-COORD.</th>
<th>ELEVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>62.00</td>
<td>15.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>62.00</td>
<td>15.00</td>
</tr>
<tr>
<td></td>
<td>3</td>
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<td>15.00</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>66.00</td>
<td>15.00</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>66.00</td>
<td>15.00</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>62.00</td>
<td>15.00</td>
</tr>
</tbody>
</table>

II.B. -- JOINT COORDINATES (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>JOINT NO.</th>
<th>X-COORD.</th>
<th>ELEVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000000</td>
<td>19.000000</td>
</tr>
<tr>
<td>2</td>
<td>10.00000</td>
<td>19.000000</td>
</tr>
<tr>
<td>3</td>
<td>20.00000</td>
<td>19.000000</td>
</tr>
<tr>
<td>4</td>
<td>30.00000</td>
<td>19.000000</td>
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<tr>
<td>5</td>
<td>40.00000</td>
<td>19.000000</td>
</tr>
<tr>
<td>6</td>
<td>46.00000</td>
<td>19.000000</td>
</tr>
<tr>
<td>7</td>
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<tr>
<td>8</td>
<td>60.00000</td>
<td>18.000000</td>
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<tr>
<td>9</td>
<td>64.00000</td>
<td>18.000000</td>
</tr>
<tr>
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<td>35.19286</td>
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<tr>
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<td>36.50000</td>
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<td>55.50000</td>
</tr>
<tr>
<td>13</td>
<td>46.29543</td>
<td>70.55500</td>
</tr>
</tbody>
</table>

a. Data analysis (Continued)

Figure 50. Frame model data for Example 2B (Sheet 1 of 5)
### III.B. -- Joint Coordinates (ft)

*(Note: 'X-Coord.' is distance from chamber centerline.)*

<table>
<thead>
<tr>
<th>Joint No.</th>
<th>X-Coord.</th>
<th>Elevation</th>
</tr>
</thead>
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</tr>
<tr>
<td>2</td>
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<td>19.00000</td>
</tr>
<tr>
<td>3</td>
<td>20.00000</td>
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<tr>
<td>6</td>
<td>46.00000</td>
<td>19.00000</td>
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<tr>
<td>7</td>
<td>55.00000</td>
<td>18.00000</td>
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<tr>
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<td>18.00000</td>
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<tr>
<td>9</td>
<td>64.00000</td>
<td>18.00000</td>
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<tr>
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<td>35.19286</td>
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<td>55.50000</td>
</tr>
<tr>
<td>13</td>
<td>46.29543</td>
<td>70.55508</td>
</tr>
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</table>

### III.C. -- Member Data (ft)

*(Note: 'X-Coord.' is distance from chamber centerline.)*

<table>
<thead>
<tr>
<th>Member</th>
<th>From JT</th>
<th>To JT</th>
<th>X-Coord.</th>
<th>Elev.</th>
<th>From X</th>
<th>Elev.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>10.00</td>
<td>19.00</td>
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<td>2</td>
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<td>19.00</td>
<td>40.00</td>
<td>19.00</td>
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<td>40.00</td>
<td>19.00</td>
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<td>6</td>
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<td>18.00</td>
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<td>18.00</td>
<td>70.00</td>
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<td>8</td>
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<td>18.00</td>
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<td>46.00</td>
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<td>65.00</td>
<td>55.50</td>
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<td>55.50</td>
<td>65.00</td>
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</tbody>
</table>

### III.D. -- Pile Head Stiffness Coefficients

<table>
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<th></th>
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</tr>
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<tbody>
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<td>0.00</td>
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<td>1.7928E+07</td>
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<td>0.0</td>
</tr>
<tr>
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<td>10.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
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<td>20.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
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<td>30.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
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<td>40.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
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<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>55.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
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<td>60.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
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<td>0.0</td>
</tr>
<tr>
<td>9</td>
<td>65.00</td>
<td>3.00</td>
<td>2.6532E+05</td>
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<td>0.0</td>
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<tr>
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<td>70.00</td>
<td>3.00</td>
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<td>1.7928E+07</td>
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<td>0.0</td>
</tr>
</tbody>
</table>

---

*Figure 50. (Sheet 2 of 5)*
II.C.--MEMBER DATA (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>MEM</th>
<th>FROM</th>
<th>TO</th>
<th>&lt;COORDS AT ENDS OF FLEX LENGTH&gt;</th>
<th>&lt;MEMBER DEPTH-&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>JT</td>
<td>JT</td>
<td>X ELEV</td>
<td>X ELEV</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0.00</td>
<td>19.00</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>10.00</td>
<td>19.00</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
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<td>20.00</td>
<td>19.00</td>
</tr>
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<td>5</td>
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<td>40.00</td>
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</tr>
<tr>
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<td>13</td>
<td>14</td>
<td>44.00</td>
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</table>

II.D.--PILE HEAD STIFFNESS COEFFICIENTS

<table>
<thead>
<tr>
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<th>X-COORD.</th>
<th>BATTER</th>
<th>STIFFNESS COEFFICIENTS</th>
<th>STIFFNESS COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO.</td>
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<td>(FT/FT)</td>
<td>B11 (LB/FT)</td>
<td>B22 (LB/FT)</td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
</tr>
<tr>
<td>2</td>
<td>10.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
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<tr>
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<td>20.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
</tr>
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<td>2.6532E+05</td>
<td>1.7928E+07</td>
</tr>
<tr>
<td>5</td>
<td>40.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
</tr>
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<td>50.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
</tr>
<tr>
<td>7</td>
<td>55.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
</tr>
<tr>
<td>8</td>
<td>60.00</td>
<td>0.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
</tr>
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<td>2.6532E+05</td>
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<td>3.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
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<tr>
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<td>50.00</td>
<td>3.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
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<td>55.00</td>
<td>3.00</td>
<td>2.6532E+05</td>
<td>1.7928E+07</td>
</tr>
</tbody>
</table>

III.--LEFTSIDE FRAME MODEL DATA

III.A.--RIGID BLOCK DATA (FT) - TYPE 2 MONOLITH
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>CORNER NO.</th>
<th>X-COORD.</th>
<th>ELEVATION</th>
<th>CENTROID</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>62.00</td>
<td>62.00</td>
</tr>
<tr>
<td>2</td>
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</tr>
</tbody>
</table>

a. (Concluded)

Figure 50. (Sheet 3 of 5)
b. Plots of rightside geometry

Figure 50. (Sheet 4 of 5)
EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
WITH PILE SUPPORT

= JOINT AT RIGID BLOCK OR HEEL END
= INTERMEDIATE JOINT
= END OF RIGID LINK

M1 TO M8 ON BASE

--- LEFTSIDE MODEL ---

c. Plots of leftside geometry

Figure 50. (Sheet 5 of 5)
I. -- HEADING

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

******************************************************************************
* RESULTS OF FRAME ANALYSIS *
******************************************************************************

II. -- STRUCTURE DISPLACEMENTS

II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 2 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD CHAMBER CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

<table>
<thead>
<tr>
<th>JT NO</th>
<th>DISTANCE FROM CHAMB CL (FT)</th>
<th>ELEVATION (FT)</th>
<th>&lt;-----DISPLACEMENT (FT OR RADIANS)-----</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>***** BASE JOINTS *****</td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>19.00</td>
<td>1.551E-02 1.309E-03 -7.127E-05</td>
</tr>
<tr>
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<td>10.00</td>
<td>19.00</td>
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<td>19.00</td>
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<td>30.00</td>
<td>19.00</td>
<td>1.637E-02 6.042E-03 -1.436E-04</td>
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<tr>
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<td>40.00</td>
<td>19.00</td>
<td>1.666E-02 6.880E-03 8.632E-05</td>
</tr>
<tr>
<td>6</td>
<td>46.00</td>
<td>19.00</td>
<td>1.672E-02 6.094E-03 1.625E-04</td>
</tr>
<tr>
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<td>18.00</td>
<td>1.686E-02 4.372E-03 2.329E-04</td>
</tr>
<tr>
<td>8</td>
<td>60.00</td>
<td>18.00</td>
<td>1.676E-02 3.094E-03 2.818E-04</td>
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<td>84.00</td>
<td>18.00</td>
<td>1.680E-02 1.926E-03 3.051E-04</td>
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<tr>
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<td>44.00</td>
<td>55.50</td>
<td>3.147E-02 7.552E-03 6.421E-04</td>
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<tr>
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<td>46.30</td>
<td>70.56</td>
<td>4.150E-02 6.121E-03 6.548E-04</td>
</tr>
</tbody>
</table>

II.B.--LEFTSIDE DISPLACEMENTS - TYPE 2 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD CHAMBER CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS CLOCKWISE.)

<table>
<thead>
<tr>
<th>JT NO</th>
<th>DISTANCE FROM CHAMB CL (FT)</th>
<th>ELEVATION (FT)</th>
<th>&lt;-----DISPLACEMENT (FT OR RADIANS)-----</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>***** BASE JOINTS *****</td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>19.00</td>
<td>-1.551E-02 1.309E-03 7.127E-05</td>
</tr>
<tr>
<td>2</td>
<td>10.00</td>
<td>19.00</td>
<td>-1.523E-02 9.272E-04 1.476E-05</td>
</tr>
<tr>
<td>3</td>
<td>20.00</td>
<td>19.00</td>
<td>-1.496E-02 1.002E-03 -1.970E-05</td>
</tr>
<tr>
<td>4</td>
<td>30.00</td>
<td>19.00</td>
<td>-1.469E-02 1.299E-03 -2.121E-05</td>
</tr>
<tr>
<td>5</td>
<td>40.00</td>
<td>19.00</td>
<td>-1.441E-02 1.408E-03 2.131E-05</td>
</tr>
<tr>
<td>6</td>
<td>46.00</td>
<td>19.00</td>
<td>-1.436E-02 1.233E-03 4.014E-05</td>
</tr>
<tr>
<td>7</td>
<td>55.00</td>
<td>18.00</td>
<td>-1.431E-02 8.289E-04 3.330E-05</td>
</tr>
<tr>
<td>8</td>
<td>60.00</td>
<td>18.00</td>
<td>-1.422E-02 7.172E-04 4.296E-05</td>
</tr>
<tr>
<td>9</td>
<td>84.00</td>
<td>18.00</td>
<td>-1.419E-02 5.332E-04 5.890E-05</td>
</tr>
</tbody>
</table>

Figure 51. Results of frame analysis for Example 2B (Sheet 1 of 6)
### III. -- Forces at Ends of Members
(Member forces are given at ends of flexible length.)

#### III.A. -- Rightside Members - Type 2 Monolith
(Positive axial force is compression.)
(Positive shear force tends to move member upward or toward chamber centerline.)
(Positive moment produces compression on top of member or on side of member toward chamber centerline.)

<table>
<thead>
<tr>
<th>MEM NO</th>
<th>CHAMB CL (FT)</th>
<th>ELEVATION (FT)</th>
<th>AXIAL FORCE (LBS)</th>
<th>SHEAR FORCE (LB-FT)</th>
<th>MOMENT (LB-FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.00</td>
<td>0.00</td>
<td>5.86E+05</td>
<td>-1.67E+04</td>
<td>7.83E+05</td>
</tr>
<tr>
<td>2</td>
<td>19.00</td>
<td>10.00</td>
<td>5.86E+05</td>
<td>-9.98E+02</td>
<td>6.94E+05</td>
</tr>
<tr>
<td>3</td>
<td>19.00</td>
<td>20.00</td>
<td>5.90E+05</td>
<td>4.34E+04</td>
<td>-7.11E+05</td>
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<tr>
<td>4</td>
<td>19.00</td>
<td>30.00</td>
<td>5.99E+05</td>
<td>1.73E+05</td>
<td>-3.91E+05</td>
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<tr>
<td>5</td>
<td>19.00</td>
<td>40.00</td>
<td>6.03E+05</td>
<td>-1.57E+05</td>
<td>1.25E+08</td>
</tr>
<tr>
<td>6</td>
<td>19.00</td>
<td>50.00</td>
<td>6.04E+05</td>
<td>2.65E+05</td>
<td>1.24E+08</td>
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<tr>
<td>7</td>
<td>19.00</td>
<td>60.00</td>
<td>6.04E+05</td>
<td>3.97E+05</td>
<td>3.81E+06</td>
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<tr>
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<td>19.00</td>
<td>70.00</td>
<td>6.04E+05</td>
<td>-3.94E+05</td>
<td>4.60E+06</td>
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<tr>
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<td>80.00</td>
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<td>-8.07E+04</td>
<td>8.45E+05</td>
</tr>
<tr>
<td>10</td>
<td>19.00</td>
<td>90.00</td>
<td>6.04E+05</td>
<td>6.45E+04</td>
<td>4.82E+05</td>
</tr>
<tr>
<td>11</td>
<td>19.00</td>
<td>100.00</td>
<td>6.04E+05</td>
<td>5.08E+04</td>
<td>4.42E+05</td>
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<tr>
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<td>19.00</td>
<td>110.00</td>
<td>6.04E+05</td>
<td>1.60E+04</td>
<td>4.82E+05</td>
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<tr>
<td>13</td>
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</table>

#### **** Stem Members ****

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<thead>
<tr>
<th>MEM NO</th>
<th>CHAMB CL (FT)</th>
<th>ELEVATION (FT)</th>
<th>AXIAL FORCE (LBS)</th>
<th>SHEAR FORCE (LB-FT)</th>
<th>MOMENT (LB-FT)</th>
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</thead>
<tbody>
<tr>
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<td>19.00</td>
<td>20.00</td>
<td>2.15E+05</td>
<td>3.49E+04</td>
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<tr>
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<td>30.00</td>
<td>5.58E+04</td>
<td>6.52E+04</td>
<td>1.92E+05</td>
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</tbody>
</table>

Figure 51. (Sheet 2 of 6)
### III.B. -- LEFTSIDE MEMBERS - TYPE 2 MONOLITH

(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>MEM NO</th>
<th>DISTANCE FROM CHAMB CL (FT)</th>
<th>ELEVATION (FT)</th>
<th>AXIAL FORCES (LBS OR LB-FT)</th>
<th>SHEAR</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
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<td>***** BASE MEMBERS *****</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>19.00</td>
<td>5.777E+05</td>
<td>3.021E+04</td>
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<tr>
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<td>10.00</td>
<td>19.00</td>
<td>5.777E+05</td>
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<td>3.106E+04</td>
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<tr>
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<td>19.00</td>
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<td>-1.533E+04</td>
<td>-2.782E+05</td>
</tr>
<tr>
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<td>40.00</td>
<td>19.00</td>
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<td>5.124E+04</td>
<td>-2.686E+05</td>
</tr>
<tr>
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<td>5.619E+05</td>
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<td>19.00</td>
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<td>80.00</td>
<td>19.00</td>
<td>5.212E+05</td>
<td>1.679E+05</td>
<td>8.747E+05</td>
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<td>-1.647E+05</td>
<td>1.207E+06</td>
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<td>-6.010E+04</td>
<td>7.295E+04</td>
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<td>9.546E+03</td>
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<td>6.604E+04</td>
<td>0.</td>
<td>-1.516E+05</td>
</tr>
</tbody>
</table>

Figure 51. (Sheet 3 of 6)
I. -- HEADING

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
WHITH PILE SUPPORT

II. -- RESULTS FOR RIGHTSIDE PILES

II.A. -- PILE HEAD FORCES AND DISPLACEMENTS

(UNITS ARE POUNDS, FEET, AND RADIANS.)

(POSITIVE AXIAL FORCE IS COMPRESSION.)

(POSITIVE SHEAR TENDS TO MOVE PILE HEAD AWAY FROM CHAMBER CENTERLINE.)

(POSITIVE MOMENT PRODUCES COMPRESSION ON SIDE OF PILE TOWARD CHAMBER CENTERLINE.)

(POSITIVE AXIAL DISPLACEMENT IS DOWN.)

(POSITIVE LATERAL DISPLACEMENT IS AWAY FROM CHAMBER CENTERLINE.)

(POSITIVE ROTATION TENDS TO ROTATE PILE HEAD TOWARD CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>PILE DIST. TO CHAMB</th>
<th>PILE HEAD FORCES</th>
<th>PILE HEAD DISPLACEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAMB CL</td>
<td>AXIAL FORCES</td>
<td>SHEAR MOMENT</td>
</tr>
<tr>
<td>(FT)</td>
<td>(LB)</td>
<td>(LB-FT)</td>
</tr>
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<td>0.00</td>
<td>2.84E+04</td>
</tr>
<tr>
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<td>10.00</td>
<td>4.28E+04</td>
</tr>
<tr>
<td>3</td>
<td>20.00</td>
<td>7.26E+04</td>
</tr>
<tr>
<td>4</td>
<td>30.00</td>
<td>1.08E+05</td>
</tr>
<tr>
<td>5</td>
<td>40.00</td>
<td>1.33E+05</td>
</tr>
<tr>
<td>6</td>
<td>50.00</td>
<td>9.76E+04</td>
</tr>
<tr>
<td>7</td>
<td>60.00</td>
<td>1.53E+05</td>
</tr>
<tr>
<td>8</td>
<td>70.00</td>
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<td>7.83E+04</td>
</tr>
<tr>
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<td>90.00</td>
<td>2.45E+04</td>
</tr>
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<td>2.10E+04</td>
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<td>12</td>
<td>110.00</td>
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<td>14</td>
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</table>

II.B. -- PILE ALLOWABLES COMPARISONS

<table>
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<tr>
<th>PILE NO.</th>
<th>DIST. TO CHAMB</th>
<th>MAXIMUM MOUNT (FT)</th>
<th>&lt;ALLOWABLES COMPARISON RATIOS&gt;</th>
<th>AXIAL FORCE</th>
<th>AXIAL FORCE</th>
<th>AXIAL MOMENT</th>
<th>MOMENT</th>
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<tbody>
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<td>1.24</td>
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<td></td>
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<tr>
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<td>10.00</td>
<td>2.05E+04</td>
<td>0.14</td>
<td>1.66</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
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</tr>
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<td>5</td>
<td>40.00</td>
<td>2.04E+04</td>
<td>0.43</td>
<td>3.33</td>
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</tr>
<tr>
<td>6</td>
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<td>2.01E+04</td>
<td>0.34</td>
<td>2.79</td>
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<td></td>
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</tr>
<tr>
<td>7</td>
<td>60.00</td>
<td>2.00E+04</td>
<td>0.27</td>
<td>2.39</td>
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<td></td>
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</tr>
<tr>
<td>8</td>
<td>70.00</td>
<td>1.99E+04</td>
<td>0.19</td>
<td>1.91</td>
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<tr>
<td>9</td>
<td>80.00</td>
<td>1.98E+04</td>
<td>0.08</td>
<td>1.24</td>
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<tr>
<td>10</td>
<td>90.00</td>
<td>2.10E+04</td>
<td>0.25</td>
<td>2.31</td>
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<td>11</td>
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<td>2.21E+04</td>
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<tr>
<td>12</td>
<td>110.00</td>
<td>2.18E+04</td>
<td>0.05</td>
<td>1.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>120.00</td>
<td>2.12E+04</td>
<td>0.005</td>
<td>0.085</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>130.00</td>
<td>2.07E+04</td>
<td>0.13</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 51. (Sheet 4 of 6)
### III.--RESULTS FOR LEFTSIDE PILES

#### III.A.--PILE HEAD FORCES AND DISPLACEMENTS

(Units are pounds, feet, and radians.)

(Positive axial force is compression.)

(Positive shear tends to move pile head away from chamber centerline.)

(Positive moment produces compression on side of pile toward chamber centerline.)

(Positive axial displacement is down.)

(Positive lateral displacement is away from chamber centerline.)

(Positive rotation tends to rotate pile head toward chamber centerline.)

<table>
<thead>
<tr>
<th>PILE DIST. TO CHAMB CL</th>
<th>AXIAL SHEAR MOMENT AXIAL LATERAL ROTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AXIAL</td>
</tr>
<tr>
<td>0.00</td>
<td>2.348E+04</td>
</tr>
<tr>
<td>10.00</td>
<td>1.662E+04</td>
</tr>
<tr>
<td>20.00</td>
<td>1.796E+04</td>
</tr>
<tr>
<td>30.00</td>
<td>2.329E+04</td>
</tr>
<tr>
<td>40.00</td>
<td>2.524E+04</td>
</tr>
<tr>
<td>50.00</td>
<td>1.922E+04</td>
</tr>
<tr>
<td>60.00</td>
<td>1.486E+04</td>
</tr>
<tr>
<td>70.00</td>
<td>1.288E+04</td>
</tr>
<tr>
<td>80.00</td>
<td>2.348E+04</td>
</tr>
<tr>
<td>90.00</td>
<td>1.486E+04</td>
</tr>
<tr>
<td>100.00</td>
<td>1.061E+05</td>
</tr>
<tr>
<td>110.00</td>
<td>1.040E+05</td>
</tr>
<tr>
<td>120.00</td>
<td>1.008E+05</td>
</tr>
<tr>
<td>130.00</td>
<td>9.578E+04</td>
</tr>
</tbody>
</table>

Figure 51. (Sheet 5 of 6)
### III.B.--PILE ALLOWABLES COMPARISONS

<table>
<thead>
<tr>
<th>PILE NO.</th>
<th>DIST. TO CHAMB CL (FT)</th>
<th>MAXIMUM MOMENT (LB-FT)</th>
<th>ALLOWABLES COMPARISON RATIOS</th>
<th>AXIAL FORCE ONLY</th>
<th>AXIAL FORCE AND MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>-1.98E+04</td>
<td>0.082</td>
<td>0.124</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10.00</td>
<td>-1.91E+04</td>
<td>0.058</td>
<td>0.108</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20.00</td>
<td>-1.86E+04</td>
<td>0.063</td>
<td>0.109</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>30.00</td>
<td>-1.83E+04</td>
<td>0.081</td>
<td>0.118</td>
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</tr>
<tr>
<td>5</td>
<td>40.00</td>
<td>-1.81E+04</td>
<td>0.088</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>50.00</td>
<td>-1.82E+04</td>
<td>0.067</td>
<td>0.109</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>55.00</td>
<td>-1.80E+04</td>
<td>0.052</td>
<td>0.100</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>60.00</td>
<td>-1.80E+04</td>
<td>0.045</td>
<td>0.095</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.00</td>
<td>-1.98E+04</td>
<td>0.082</td>
<td>0.124</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>20.00</td>
<td>-1.86E+04</td>
<td>0.063</td>
<td>0.109</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>40.00</td>
<td>-1.67E+04</td>
<td>0.371</td>
<td>0.283</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>45.00</td>
<td>-1.67E+04</td>
<td>0.364</td>
<td>0.279</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>50.00</td>
<td>-1.68E+04</td>
<td>0.352</td>
<td>0.272</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>55.05</td>
<td>-1.68E+04</td>
<td>0.335</td>
<td>0.262</td>
<td></td>
</tr>
</tbody>
</table>

### IV.--RESULTANTS OF PILE FORCES ON STRUCTURE

(POSITIVE HORIZONTAL IF TO THE RIGHT)
(POSITIVE VERTICAL IS UP)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th></th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIGHTSIDE PILES</td>
<td>4.8230E+04</td>
<td>7.0397E+05</td>
<td>2.5505E+07</td>
</tr>
<tr>
<td>LEFTSIDE PILES</td>
<td>1.7737E+05</td>
<td>5.5263E+05</td>
<td>-2.1746E+07</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2.2566E+05</td>
<td>1.2566E+06</td>
<td>3.7551E+06</td>
</tr>
</tbody>
</table>

NOTE: RIGHTSIDE AND LEFTSIDE RESULTANTS INCLUDE ONE HALF OF FORCES FOR VERTICAL PILES ON CHAMBER CENTERLINE.

Figure 51. (Sheet 6 of 6)
Example 3--Type 31 Monolith

145. The symmetric system and pile layout are shown in Figure 52. The predefined input file for this system is shown in Figure 53. Note that the number identifiers assigned to the piles need not be in sequential order. Also note that the pile/soil data initially assigned stiffness matrices representative of bending about the weak axis. The data provided subsequently for bending about the strong axis override the initial assignment. Only those piles for which layout data are provided are considered in the analysis. For illustration, uplift water effects are provided by an input distribution.

146. An echoprint of input data is given in Figure 54, with equilibrium results shown in Figure 55. Frame model data are given in Figure 56, and results of the frame analysis are shown in Figure 57.
SOIL DATA:

LAYER 1: \( \gamma_{\text{SAT}} = \gamma_{\text{MOIST}} = 120 \text{ PCF} \)
\( \text{KH} = 0.8, \text{KV} = 0 \)

LAYER 2: \( \gamma_{\text{SAT}} = \gamma_{\text{MOIST}} = 125 \text{ PCF} \)
\( \text{KH} = 0.5, \text{KV} = 0 \)

LAYER 1

LAYER 2

(CHAFFER AND CULVERT WATER)

a. Structure, soil, and water data

b. Pile layout

Figure 52. System for Example 3
**** INPUT FILE FOR EXAMPLE 3 ****

1000 EXAMPLE 3 - TYPE 31 MONOLITH
1010 METHOD FRAME 1
1020 STRUCTURE 3.06 .2 150 9
1030 FLOOR 55.04 374 0
1040 BASE BOTH 88.71 35B
1050 STEM BOTH 7 33.67 434.5 33.67 431.75 33.67 429.5
1060 33.67 397 33.67 392 33.67 374 33.67 374
1070 CULVERT BOTH 8 16 374 18 0
1080 VOID BOTH 5 23.67 397 32.5 0
1090 REACTION PILES
1100 PILES BOTH
1110 LAYOUT 1 0 6 1 5.5
1120 LAYOUT 7 38.5 8 1 12
1130 LAYOUT 9 59.5
1140 LAYOUT 10 68.5 14 1 4.5
1150 LAYOUT 21 0 25 1 5.5
1160 LAYOUT 26 33 27 1 11
1170 LAYOUT 28 55 29 1 9
1180 LAYOUT 30 73 33 1 4.5
1190 (STIFFNESS MATRICES FOR BENDING ABOUT WEAK AXIS)
1200 STIFFNESS 1 5.49E5 2.00E7 2.32E7 2.77E6 50 1
1210 (STIFFNESS MATRICES FOR BENDING ABOUT STRONG AXIS)
1220 STIFFNESS 7 8.23E5 2.00E7 5.23E7 5.09E6 14 1
1230 STIFFNESS 27 8.23E5 2.00E7 5.23E7 5.09E6 33 1
1240 BACKFILL BOTH SOIL 2 0
1250 397 120 120 .8 .8 0 0
1260 374 125 125 .5 .5 0 0
1270 WATER 62.5
1280 EXTERNAL BOTH ELEVATION 422
1290 UPLIFT PRESSURE
1300 BOTH 2 0 4000 100 4000
1310 INTERNAL 395 395 395
1320 FINISH

Figure 53. Input file for Example 3
I.--HEADING
EXAMPLE 3 - TYPE 31 MONOLITH

II.--PLANE FRAME ANALYSIS
RIGID LINK FACTOR = 1.00

III.--STRUCTURE DATA
III.A.--MATERIAL PROPERTIES
MODULUS OF ELASTICITY OF CONCRETE = 3.000E+06 (PSI)
POISSON'S RATIO FOR CONCRETE = .20
UNIT WEIGHT OF CONCRETE = 150.0 (PCF)
THICKNESS OF TWO-DIMENSIONAL SLICE = 9.00 (FT)

III.B.--FLOOR DATA
FLOOR WIDTH = 55.04 (FT)
FLOOR ELEVATION = 376.00 (FT)
FLOOR FILLET SIZE = 0.00 (FT)

III.C.--BASE DATA
III.C.1.--RIGHTSIDE
DISTANCE FROM CHAMBER CL ELEVATION (FT) (FT)
88.71 358.00

III.C.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

III.D.--STEM DATA
III.D.1.--RIGHTSIDE
DISTANCE FROM STEM FACE ELEVATION (FT) (FT)
33.67 424.50
33.67 431.75
33.67 429.50
33.67 397.00
33.67 392.00
33.67 374.00
33.67 374.00

III.D.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

Figure 54. Echoprint of input data for Example 3 (Sheet 1 of 3)
III.E.—CULVERT DATA

III.E.1.—RIGHTSIDE
DISTANCE FROM STEM FACE TO INTERIOR SIDE = 8.00 (FT)
CULVERT WIDTH = 16.00 (FT)
ELEVATION AT CULVERT FLOOR = 374.00 (FT)
CULVERT HEIGHT = 18.00 (FT)
CULVERT FILLET SIZE = 0.00 (FT)

III.E.2.—LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

III.F.—VOID DATA

III.F.1.—RIGHTSIDE
DISTANCE FROM STEM FACE TO INTERIOR SIDE = 5.00 (FT)
VOID WIDTH = 23.67 (FT)
ELEVATION AT VOID BOTTOM = 397.00 (FT)
VOID HEIGHT = 32.50 (FT)
VOID TIES NONE

III.F.2.—LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.—BACKFILL DATA

IV.A.—RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV  <---PRESSURE COEFFICIENTS--->
AT SATURATED MOIST HORIZONTAL SHEAR
TOP UNIT WT. UNIT WT. TOP BOT. TOP BOT.
(FT) (PCF) (PCF)
397.00 120.0 120.0 .800 .800 0.000 0.000
374.00 125.0 125.0 .500 .500 0.000 0.000

IV.B.—LEFTSIDE SOIL LAYER DATA
SYMMETRIC WITH RIGHTSIDE

V.—BASE REACTION DATA

V.A.—RIGHTSIDE PILE DATA

V.A.1.—PILE LAYOUT DATA
<--------START----->

PILE NO. DIST. FROM CHAMBER CL NO. STEP IN PILE NO. STEP CL DIST. (FT) (FT)
1 0.00 6 1 5.50
7 38.50 8 1 12.00
9 59.50 9 1 0.00
10 68.50 14 1 4.50
21 0.00 25 1 5.50
26 33.00 27 1 11.00
28 55.00 29 1 9.00
30 73.00 33 1 4.50

Figure 54. (Sheet 2 of 3)
V.A.2.--PILE PROPERTIES
NONE

V.A.2.--SOIL PROPERTIES
NONE

V.A.4.--PILE HEAD STIFFNESS MATRICES
<-------------------START------------------------ > STOP
FILE
PILE <-------STIFFNESS COEFFICIENTS--------->
PILE NO. NO. B11 B22 B33 B13
(LB/IN) (LB/IN) (LB-IN) (LB)
1 5.490E+05 2.000E+07 2.320E+07 2.770E+06 50 1
7 8.230E+05 2.000E+07 5.230E+07 5.090E+06 14 1
27 8.230E+05 2.000E+07 5.230E+07 5.090E+06 33 1

V.A.4.--PILE BATTER DATA
NONE

V.A.5.--PILE LOAD COMPARISON DATA
NONE

V.B.-- LEFTSIDE PILE DATA
SYMMETRIC WITH RIGHTSIDE

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND WATER ELEVATION = 422.00 (FT)
SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA

VI.B.1.--RIGHTSIDE UPLIFT WATER PRESSURE DISTRIBUTION
DIST. FROM UPLIFT CHAMBER CL PRESSURE
(FT) (PSF)
0.00 4000.00
100.00 4000.00

VI.B.2.-- LEFTSIDE UPLIFT WATER PRESSURE DISTRIBUTION
SYMMETRIC WITH RIGHTSIDE

VI.C.--INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 395.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT = 395.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT = 395.00 (FT)

VII.--ADDITIONAL LOAD DATA
NONE

Figure 54. (Sheet 3 of 3)
I. --HEADING
"EXAMPLE 3 - TYPE 31 MONOLITH"

******************************************************************************
* RESULTS OF EQUILIBRIUM ANALYSIS *
******************************************************************************

II. --EFFECTS ON STRUCTURE RIGHTSIDE
II.A. --PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ELEVATION</th>
<th>VERTICAL</th>
<th>HORIZONTAL</th>
<th>SHEAR</th>
<th>WATER PRESSURE</th>
<th>GRND/SURCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>434.500</td>
<td>0.</td>
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<td>431.750</td>
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<tr>
<td>422.000</td>
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<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>397.000</td>
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<td>0.</td>
<td>0.</td>
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<td>395.000</td>
<td>1.1500E+02</td>
<td>9.2000E+01</td>
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<td>1.5625E+03</td>
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<tr>
<td>392.000</td>
<td>2.8750E+02</td>
<td>2.3000E+02</td>
<td>0.</td>
<td>1.6875E+03</td>
<td>0.</td>
</tr>
<tr>
<td>376.000</td>
<td>1.2075E+03</td>
<td>9.6600E+02</td>
<td>0.</td>
<td>1.8750E+03</td>
<td>0.</td>
</tr>
<tr>
<td>374.000+</td>
<td>1.3225E+03</td>
<td>1.0580E+03</td>
<td>0.</td>
<td>3.0000E+03</td>
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<tr>
<td>374.000-</td>
<td>1.3225E+03</td>
<td>6.6125E+02</td>
<td>0.</td>
<td>3.0000E+03</td>
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<td>338.000</td>
<td>2.3225E+03</td>
<td>1.1613E+03</td>
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<td>4.0000E+03</td>
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</tbody>
</table>

II.B. --PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>DIST FROM CHAMBER CL</th>
<th>SOIL REACTION PRESSURE</th>
<th>UPLIFT WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>5.500</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>11.000</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>16.500</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>22.000</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>27.500</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>33.000</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>38.500</td>
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<td>4.0000E+03</td>
</tr>
<tr>
<td>44.000</td>
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<tr>
<td>50.500</td>
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<tr>
<td>55.000</td>
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<td>4.0000E+03</td>
</tr>
<tr>
<td>55.040</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>59.500</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>63.040</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>64.000</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>68.500</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>73.000</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>77.500</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>79.040</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>82.000</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>86.500</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
<tr>
<td>88.710</td>
<td>0.</td>
<td>4.0000E+03</td>
</tr>
</tbody>
</table>

Figure 55. Results of equilibrium analysis for Example 3 (Continued)
II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER
FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKFILL</td>
<td>2.4072E+05</td>
<td>0.</td>
<td>-7.8768E+05</td>
</tr>
<tr>
<td>GROUND/SURCH WATER</td>
<td>1.1520E+06</td>
<td>0.</td>
<td>3.8400E+06</td>
</tr>
<tr>
<td>INTERNAL WATER</td>
<td>-1.0153E+05</td>
<td>7.5024E+05</td>
<td>-2.8340E+07</td>
</tr>
<tr>
<td>UPLIFT WATER</td>
<td>0.</td>
<td>-3.1936E+06</td>
<td>1.4163E+08</td>
</tr>
<tr>
<td>CONCRETE</td>
<td>3.3874E+06</td>
<td>0.</td>
<td>-1.8447E+08</td>
</tr>
<tr>
<td>TOTAL THIS SIDE</td>
<td>1.2912E+06</td>
<td>9.4410E+05</td>
<td>-6.8109E+07</td>
</tr>
</tbody>
</table>

III.--EFFECTS ON STRUCTURE LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

| TOTAL HORIZONTAL = 0. |
| TOTAL VERTICAL = 1.8882E+06 |
| TOTAL MOMENT = 0. |

Figure 55. (Concluded)
I.—HEADING

'EXAMPLE 3 - TYPE 31 MONOLITH

***************
* FRAME MODEL DATA *
***************

II.—RIGHTSIDE FRAME MODEL DATA

II.A.—RIGID BLOCK DATA (FT) — TYPE 31 MONOLITH

(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>BLOCK</th>
<th>CORNER NO.</th>
<th>X-COORD.</th>
<th>ELEVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>79.04</td>
<td>358.00</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>79.04</td>
<td>374.00</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>88.71</td>
<td>374.00</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>88.71</td>
<td>358.00</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>83.87</td>
<td>358.00</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>79.04</td>
<td>383.87</td>
</tr>
</tbody>
</table>

II.B.—JOINT COORDINATES (FT)

(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

<table>
<thead>
<tr>
<th>JOINT NO.</th>
<th>X-COORD.</th>
<th>ELEVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00000</td>
<td>367.00000</td>
</tr>
<tr>
<td>2</td>
<td>5.50000</td>
<td>367.00000</td>
</tr>
<tr>
<td>3</td>
<td>11.00000</td>
<td>367.00000</td>
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<td>367.00000</td>
</tr>
<tr>
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<td>55.00000</td>
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</tr>
<tr>
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</tr>
<tr>
<td>13</td>
<td>64.00000</td>
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<td>366.00000</td>
</tr>
<tr>
<td>15</td>
<td>73.00000</td>
<td>366.00000</td>
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<tr>
<td>16</td>
<td>77.50000</td>
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<tr>
<td>17</td>
<td>83.87500</td>
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</tr>
<tr>
<td>18</td>
<td>83.87500</td>
<td>394.50000</td>
</tr>
<tr>
<td>19</td>
<td>86.21000</td>
<td>432.00000</td>
</tr>
<tr>
<td>20</td>
<td>59.04000</td>
<td>394.50000</td>
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<tr>
<td>21</td>
<td>57.54000</td>
<td>432.00000</td>
</tr>
</tbody>
</table>

Figure 56. Frame model data for Example 3 (Sheet 1 of 3)
### II.C. MEMBER DATA (FT)

(Note: 'X-COORD.' is distance from chamber centerline.)

<table>
<thead>
<tr>
<th>MEM NO</th>
<th>FROM JT</th>
<th>TO JT</th>
<th>&lt;COORDS AT ENDS OF FLEX LENGTH&gt;</th>
<th>&lt;MEMBER DEPTH&gt;</th>
</tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;--FROM END--&gt;</td>
<td>&lt;--TO END--&gt;</td>
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<td>1</td>
<td>2</td>
<td>0.00 367.00</td>
<td>5.50 367.00</td>
</tr>
<tr>
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<td>2</td>
<td>3</td>
<td>5.50 367.00</td>
<td>11.00 367.00</td>
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<td>3</td>
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<td>16.50 367.00</td>
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<tr>
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<td>7</td>
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<td>38.50 367.00</td>
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<td>38.50 367.00</td>
<td>44.00 367.00</td>
</tr>
<tr>
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<td>9</td>
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<td>50.50 367.00</td>
</tr>
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<td>10</td>
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<td>50.50 367.00</td>
<td>55.00 367.00</td>
</tr>
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<td>12</td>
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<td>63.04 366.00</td>
<td>64.00 366.00</td>
</tr>
<tr>
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<tr>
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<td>73.00 366.00</td>
<td>77.50 366.00</td>
</tr>
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<td>77.50 366.00</td>
<td>79.04 366.00</td>
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</tr>
<tr>
<td>18</td>
<td>18</td>
<td>19</td>
<td>86.21 397.00</td>
<td>86.21 429.50</td>
</tr>
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<td>59.04 376.00</td>
<td>59.04 392.00</td>
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<td>21</td>
<td>57.54 397.00</td>
<td>57.54 429.50</td>
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<td>21</td>
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<td>22</td>
<td>23</td>
<td>60.04 432.00</td>
<td>83.71 432.00</td>
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</table>

**Figure 56.** (Sheet 2 of 3)
## II.D.--PILE HEAD STIFFNESS COEFFICIENTS

<table>
<thead>
<tr>
<th>NO.</th>
<th>X-COORD. (FT)</th>
<th>BATTER (FT/FT)</th>
<th>B11 (LB/FT)</th>
<th>B22 (LB/FT)</th>
<th>B33 (LB-FT)</th>
<th>B13 (LB)</th>
</tr>
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<tr>
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<td>0.00</td>
<td>6.5880E+06</td>
<td>2.4000E+08</td>
<td>1.9333E+06</td>
<td>2.7700E+06</td>
</tr>
<tr>
<td>2</td>
<td>5.50</td>
<td>0.00</td>
<td>6.5880E+06</td>
<td>2.4000E+08</td>
<td>1.9333E+06</td>
<td>2.7700E+06</td>
</tr>
<tr>
<td>3</td>
<td>11.00</td>
<td>0.00</td>
<td>6.5880E+06</td>
<td>2.4000E+08</td>
<td>1.9333E+06</td>
<td>2.7700E+06</td>
</tr>
<tr>
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<td>2.7700E+06</td>
</tr>
<tr>
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<td>1.9333E+06</td>
<td>2.7700E+06</td>
</tr>
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<td>0.00</td>
<td>6.5880E+06</td>
<td>2.4000E+08</td>
<td>1.9333E+06</td>
<td>2.7700E+06</td>
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<tr>
<td>7</td>
<td>38.50</td>
<td>0.00</td>
<td>9.8760E+06</td>
<td>2.4000E+08</td>
<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
<tr>
<td>8</td>
<td>50.50</td>
<td>0.00</td>
<td>9.8760E+06</td>
<td>2.4000E+08</td>
<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
<tr>
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<td>59.50</td>
<td>0.00</td>
<td>9.8760E+06</td>
<td>2.4000E+08</td>
<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
<tr>
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<td>0.00</td>
<td>9.8760E+06</td>
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<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
<tr>
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<td>0.00</td>
<td>9.8760E+06</td>
<td>2.4000E+08</td>
<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
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<td>9.8760E+06</td>
<td>2.4000E+08</td>
<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
<tr>
<td>13</td>
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<td>0.00</td>
<td>9.8760E+06</td>
<td>2.4000E+08</td>
<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
<tr>
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<td>0.00</td>
<td>9.8760E+06</td>
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<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
<tr>
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<td>1.9333E+06</td>
<td>2.7700E+06</td>
</tr>
<tr>
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<td>1.9333E+06</td>
<td>2.7700E+06</td>
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<td>6.5880E+06</td>
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<td>1.9333E+06</td>
<td>2.7700E+06</td>
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<td>2.7700E+06</td>
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<td>2.7700E+06</td>
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<td>2.7700E+06</td>
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<td>0.00</td>
<td>9.8760E+06</td>
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<td>4.3583E+06</td>
<td>5.0900E+06</td>
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<tr>
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<td>9.8760E+06</td>
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<td>5.0900E+06</td>
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<td>9.8760E+06</td>
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<td>5.0900E+06</td>
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<td>5.0900E+06</td>
</tr>
<tr>
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<td>86.50</td>
<td>0.00</td>
<td>9.8760E+06</td>
<td>2.4000E+08</td>
<td>4.3583E+06</td>
<td>5.0900E+06</td>
</tr>
</tbody>
</table>

## III.-- LEFTSIDE FRAME MODEL DATA
SYMMETRIC WITH RIGHTSIDE

---

**Figure 56. (Sheet 3 of 3)**
**PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES**

**DATE:** 09/18/85  
**TIME:** 16:43:57

---

**I. --HEADING**

'EXAMPLE 3 - TYPE 31 MONOLITH

**********************************
* RESULTS OF FRAME ANALYSIS *
**********************************

---

**II.--STRUCTURE DISPLACEMENTS**

**II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 31 MONOLITH**

(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD CHAMBER CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

<table>
<thead>
<tr>
<th>JT NO</th>
<th>JT DISTANCE</th>
<th>ELEVATION (FT)</th>
<th>CHAMB CL (FT)</th>
<th>&lt;----DISPLACEMENT (FT OR RADIANS)----&gt;</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>ROTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>***** BASE JOINTS *****</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>9.156E-04</td>
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***** OUTSIDE STEM JOINTS *****

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<tr>
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<th>JT DISTANCE</th>
<th>ELEVATION (FT)</th>
<th>CHAMB CL (FT)</th>
<th>&lt;----DISPLACEMENT (FT OR RADIANS)----&gt;</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>ROTATION</th>
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***** INSIDE STEM JOINTS *****

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<th>CHAMB CL (FT)</th>
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**II.B.--LEFTSIDE DISPLACEMENTS - TYPE 31 MONOLITH**

SYMMETRIC WITH RIGHTSIDE

---

Figure 57. Results of frame analysis for Example 3 (Sheet 1 of 5)
III.--FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

III.A.--RIGTSIDE MEMBERS - TYPE 31 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD CHAMBER CENTERLINE.)

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<th>MEM</th>
<th>DISTANCE FROM CHAMB CL (FT)</th>
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<th>SHEAR</th>
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Figure 57. (Sheet 2 of 5)
### OUTSIDE STEM MEMBERS

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### INSIDE STEM MEMBERS

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### CULVERT ROOF

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### VOID ROOF

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<td>9.318E+04</td>
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</table>

---

Figure 57. (Sheet 3 of 5)
II. --RESULTS FOR RIGHTSIDE PILES

II.A. --PILE HEAD FORCES AND DISPLACEMENTS

(UNITS ARE POUNDS, FEET, AND RADIANS.)
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR TENDS TO MOVE PILE HEAD AWAY FROM CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON SIDE OF PILE TOWARD CHAMBER CENTERLINE.)
(POSITIVE AXIAL DISPLACEMENT IS DOWN.)
(POSITIVE LATERAL DISPLACEMENT IS AWAY FROM CHAMBER CENTERLINE.)
(POSITIVE ROTATION TENDS TO ROTATE PILE HEAD TOWARD CHAMBER CENTERLINE.)

II.B. --PILE ALLOWABLES COMPARISONS

ALLOWABLES DATA NOT PROVIDED FOR THIS SIDE.

III. --RESULTS FOR LEFTSIDE PILES

SYMMETRIC WITH RIGHTSIDE.
IV. -- RESULTANTS OF PILE FORCES ON STRUCTURE
(POSITIVE HORIZONTAL IF TO THE RIGHT)
(POSITIVE VERTICAL IS UP)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
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<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
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<tr>
<td>RIGHTSIDE PILES</td>
<td>1.4462E+05</td>
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<td>LEFTSIDE PILES</td>
<td>-1.4462E+05</td>
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<td>-5.7262E+07</td>
</tr>
<tr>
<td>TOTAL</td>
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<td>1.8882E+06</td>
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NOTE: RIGHTSIDE AND LEFTSIDE RESULTANTS INCLUDE ONE HALF OF FORCES FOR VERTICAL PILES ON CHAMBER CENTERLINE.
Example 4—Nonconforming Monolith

147. The monolith shown in Figure 58 does not conform to the geometric requirements for frame analysis for type 2 or type 3 monoliths. However, this geometry is admissible for equilibrium analysis.

148. The predefined input file for the symmetric, soil-supported system is shown in Figure 59 and an echoprint of input is given in Figure 60. The results of the equilibrium analysis are given in Figure 61.
Figure 58. System for Example 4
***** INPUT FILE FOR EXAMPLE 4 *****

1000 'EXAMPLE 4 - NONCONFORMING MONOLITH
1010 METHOD EQUILIBRIUM
1020 STRUCTURE 3.E6 .2 150 1
1030 FLOOR 55 374 0
1040 BASE BOTH 85 362
1050 STEM BOTH 5 14 434.5 14 419
1060 8 413 8 400 30 396
1070 CULVERT BOTH 8 16 374 18 0
1080 VOID BOTH 7.5 5 422.5 8 0
1090 BACKFILL BOTH SOIL 1 0
1100 405 125 125 .5 .5 .2 .2
1110 REACTION SOIL TRAPEZOIDAL .5
1120 WATER 62.5
1130 INTERNAL 420 420 420
1140 EXTERNAL BOTH ELEVATION 405
1150 UPLIFT ELEVATION 405 405
1160 FINISH

Figure 59. Input file for Example 4
I.--HEADING

'EXAMPLE 4 - NONCONFORMING MONOLITH

************************************************************************
* INPUT DATA *
************************************************************************

II.--EQUILIBRIUM ANALYSIS ONLY

III.--STRUCTURE DATA

III.A.--MATERIAL PROPERTIES

MODULUS OF ELASTICITY OF CONCRETE = 3.000E+06 (PSI)
POISSON'S RATIO FOR CONCRETE = .20
UNIT WEIGHT OF CONCRETE = 150.0 (PCF)
THICKNESS OF TWO-DIMENSIONAL SLICE = 1.00 (FT)

III.B.--FLOOR DATA

FLOOR WIDTH = 55.00 (FT)
FLOOR ELEVATION = 374.00 (FT)
FLOOR FILLET SIZE = 0.00 (FT)

III.C.--BASE DATA

III.C.1.--RIGHTSIDE
DISTANCE FROM CHAMBER CL ELEVATION (FT) (FT)
85.00 361.00

III.C.2.--LEFTSIDE
SYMmetric with RIGHTSIDE.

III.D.--STEM DATA

III.D.1.--RIGHTSIDE
DISTANCE FROM STEM FACE ELEVATION (FT) (FT)
14.00 434.50
14.00 419.00
8.00 413.00
8.00 400.00
30.00 396.00

III.D.2.--LEFTSIDE
SYMmetric with RIGHTSIDE.

Figure 60. Echoprint of input data for Example 4 (Continued)
III.E. -- CULVERT DATA

III.E.1. -- RIGHTSIDE
DISTANCE FROM STEM FACE TO INTERIOR SIDE = 8.00 (FT)
CULVERT WIDTH = 16.00 (FT)
ELEVATION AT CULVERT FLOOR = 374.00 (FT)
CULVERT HEIGHT = 18.00 (FT)
CULVERT FILLET SIZE = 0.00 (FT)

III.E.2. -- LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

III.F. -- VOID DATA

III.F.1. -- RIGHTSIDE
DISTANCE FROM STEM FACE TO INTERIOR SIDE = 7.50 (FT)
VOID WIDTH = 5.00 (FT)
ELEVATION AT VOID BOTTOM = 422.50 (FT)
VOID HEIGHT = 8.00 (FT)
VOID TIES = NONE

III.F.2. -- LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV. -- BACKFILL DATA

IV.A. -- RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV
AT SATURATED MOIST HORIZONTAL SHEAR
TOP (FT) UNIT WT. (PCF) UNIT WT. (PCF) TOP BOT. TOP BOT.
505.00 125.0 125.0 .500 .500 .200 .200

IV.B. -- LEFTSIDE SOIL LAYER DATA
SYMMETRIC WITH RIGHTSIDE

V. -- BASE REACTION DATA

REACTION PROVIDED BY TRAPEZOIDAL SOIL PRESSURE DISTRIBUTION
FRACTION OF UNIFORM BASE PRESSURE AT CENTERLINE = .50

VI. -- WATER DATA

WATER UNIT WEIGHT = 62.5 (PCF)

VI.A. -- EXTERNAL WATER DATA

VI.A.1. -- RIGHTSIDE EXTERNAL WATER DATA
GROUND-WATER ELEVATION = 405.00 (FT)
SURCHARGE WATER = NONE

VI.A.2. -- LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B. -- UPLIFT WATER DATA

RIGHTSIDE UPLIFT WATER ELEVATION = 405.00 (FT)
LEFTSIDE UPLIFT WATER ELEVATION = 405.00 (FT)

VI.C. -- INTERNAL WATER DATA

WATER ELEVATION IN CHAMBER = 420.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT = 420.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT = 420.00 (FT)

VII. -- ADDITIONAL LOAD DATA

NONE

Figure 60. (Concluded)
### I. -- HEADING

**EXAMPLE 4 - NONCONFORMING MONOLITH**

```
* RESULTS OF EQUILIBRIUM ANALYSIS *
* RESULTS OF EQUILIBRIUM ANALYSIS *
```

### II. -- EFFECTS ON STRUCTURE RIGHTSIDE

#### II.A. -- PRESSURES ON RIGHTSIDE SURFACE

(POSITIVE VERTICAL IS DOWN)

(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)

(POSITIVE SHEAR IS DOWN)

(UNITS ARE POUNDS AND FEET)

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#### II.B. -- PRESSURE ON RIGHTSIDE BASE

(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

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<th>DIST FROM CHAMBER CL</th>
<th>SOIL REACTION PRESSURE</th>
<th>UPLIFT WATER PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>1.4750E+03</td>
<td>2.6875E+03</td>
</tr>
<tr>
<td>55.000</td>
<td>3.3837E+03</td>
<td>2.6875E+03</td>
</tr>
<tr>
<td>63.000</td>
<td>3.6614E+03</td>
<td>2.6875E+03</td>
</tr>
<tr>
<td>79.000</td>
<td>4.2167E+03</td>
<td>2.6875E+03</td>
</tr>
<tr>
<td>85.000</td>
<td>4.4249E+03</td>
<td>2.6875E+03</td>
</tr>
</tbody>
</table>

Figure 61. Results of equilibrium analysis for Example 4 (Continued)
II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
<th>MOMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKFILL</td>
<td>3.0816E+04</td>
<td>2.1181E+04</td>
<td>-1.5844E+06</td>
</tr>
<tr>
<td>GROUND/SURCH WATER</td>
<td>5.7781E+04</td>
<td>9.6250E+03</td>
<td>-5.0751E+05</td>
</tr>
<tr>
<td>INTERNAL WATER</td>
<td>-6.6125E+04</td>
<td>1.7613E+05</td>
<td>-6.6404E+06</td>
</tr>
<tr>
<td>UPLIFT WATER</td>
<td>0.</td>
<td>-2.2844E+05</td>
<td>9.7086E+06</td>
</tr>
<tr>
<td>SOIL BASE REACT</td>
<td>0.</td>
<td>-2.5074E+05</td>
<td>1.2433E+07</td>
</tr>
<tr>
<td>CONCRETE</td>
<td>2.7225E+05</td>
<td>1.4262E+07</td>
<td>-9.3251E+05</td>
</tr>
<tr>
<td>TOTAL THIS SIDE</td>
<td>2.2472E+04</td>
<td>0.</td>
<td>-9.3251E+05</td>
</tr>
</tbody>
</table>

III.--EFFECTS ON STRUCTURE LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

Figure 61. (Concluded)
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 data are edited during execution, each section must be entered in its entirety.

Input Data File Generation

3. After data have been entered from the terminal, 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 (supplied from the user terminal or from a file) are read in free field format:
   a. Data items must be separated by one or more blanks (comma separators are not permitted).
   b. Integer numbers must be of form NNNN.
   c. Real numbers may be of form ±xxxx, ±xx.xx, or ±xx.xxE+ee
   d. 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
5. Input data are divided into the sections shown in Figure A1.

   I. Heading (Required)
   II. Control (Required)
   III. Structure Data
       A. Control (Required)
       B. Floor Data (Required)
       C. Stem Data (Required)
       D. Culvert Data (Optional)
       E. Void Data (Optional)
   IV. Backfill Data (Optional)
   V. Base Reaction Data (Required)
   VI. Water Data (Optional)
   VII. Additional Load Data (Optional)
   VIII. Termination (Required)

   Figure A1. Sections of input data

6. When data are entered from the terminal, prompts indicate the data items to be provided.

Units

7. The program expects data to be provided in units of inches, feet, pounds, or kips as noted in the following guide. No provision is made for conversion of units by the program.

Predefined Data File

8. In addition to the general format requirements given in paragraph 4 of this appendix, the following pertain to a predefined data file and to the input data description beginning in paragraph 12.

   a. Each line must commence with a nonzero, positive line number, denoted LN below.
   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 keyword. The acceptable abbreviation for the keyword is indicated by underlined capital letters,
e.g., the acceptable abbreviation for the keyword 'PROperties' is 'PRO'.

d. Lower case words in single quotes indicate definitions of a choice of keywords follows.

e. Items designated by upper case letters and numbers without quotes indicate numeric data values. Numeric data values are 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 special note follows.

g. Input data are divided into the sections discussed in 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% (THIS LINE IS IGNORED).

Sequence of Solutions

9. A predefined data file may contain a sequence of input data sets to be run in succession. Each data set must contain all required data (from heading through termination) for the problem and be independent of all other problems in the sequence. All output data for a sequence of solutions are directed to a permanent file which must be retrieved after termination of execution. Data editing during execution is not available when a sequence of solutions is run.

General Discussion of Input Data

10. Each data section contains a descriptor {'side'} to indicate the side of the structure 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, except for pile data, the description for the rightside* (if present) must be entered first and must be immediately followed by the description for the leftside* (if present). In the case of pile data, all pile data subsections must be

* The terms "rightside" and "leftside" are each used in a one-word form in the text to be consistent with these terms as used in the computer program.
entered for the rightside first, followed by all pile data subsections for the leftside.

11. Rightside and leftside descriptions must be supplied explicitly or implicitly (i.e., 'side' = 'Both') for STRUCTURE and BASE REACTION data sections. All other data may be supplied for the rightside or leftside, both sides, or may be omitted entirely.

Input Description

12. CONTROL--Two (2) to five (5) lines.
   a. Heading--One (1) to four (4) lines.
      (1) Line contents
      LN {'heading'}
      (2) 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 (').
   b. Method--One (1) line.
      (1) Line contents
      LN 'Method {'mode'} [RLF]
      (2) Definitions
      'Method' = keyword
      'mode' = 'Equilibrium' if only pressure and resultant force evaluation required.
      = 'Frame' if equilibrium analysis and 2-D plane frame analysis required
      [RLF] = rigid block reduction factor for member flexible lengths (0 \leq RLF \leq 1). Omit if 'mode' = 'Equilibrium'.
      (3) Discussion
      For 'mode' = 'Frame', the structure geometry must conform to one of the six types of monoliths described in Part V.

13. STRUCTURE
   a. Control--One (1) line.
      (1) Line contents
      LN 'Structure' EC PR WCONC [SLICE]
(2) Definitions
'Structure' = keyword
EC = modulus of elasticity of concrete (PSI)
PR = Poisson's ratio for concrete (0 ≤ PR < 0.5)
WTCONC = unit weight of concrete (PCF)
[SLICE] = thickness of slice of structure to be considered (FT); assumed to be one (1) ft if omitted

(3) Discussion
Any width of slice of structure to be analyzed may be used. If this item is omitted, a 1-ft slice is assumed. A slice width other than 1-ft may facilitate describing other effects (e.g., pile foundation) on the structure.

b. Floor data--One (1) line.
(1) Line contents
LN 'Floor' FLRWID ELFLOR [FLRFIL]
(2) Definitions
'Floor' = keyword
FLRWID = distance from chamber centerline* to inside face of stem (FT)
ELFLOR = elevation of chamber floor (FT)
[FLRFIL] = width of 45-deg fillet at floor-stem intersection (FT); assumed to be zero if omitted

(3) Discussion
(a) All 'Floor' and 'Base' distances are measured from the centerline of the chamber; i.e., from midpoint between interior stem faces.
(b) Identical 45-deg fillets are assumed to exist in both corners of the chamber floor.

c. Base data--One (1) or two (2) lines
(1) Line contents
LN 'Base' {'side'} DBASE(1) ELBASE(1) [DBASE(2) ELBASE(2)]
(2) Definitions
'Base' = keyword
{'side'} = 'Rightside', 'Leftside', or 'Both'

* The term "centerline" is used in a one-word form in the text to be consistent with the term as used in the computer program.
DBASE(1) = distance from chamber centerline to first base point (FT)
ELBASE(1) = elevation at first base point (FT)
[DBASE(2), ELBASE(2)] = distance from chamber centerline to second base point (FT) and elevation (FT) at second base point; both may be omitted

(3) Discussion
(a) See Figure A2 for notation.
(b) Base points, define locations where changes in slope of the base occur. Up to two (2) points may be defined on either side of the chamber centerline. The base is assumed to be horizontal from the chamber centerline to the first point and is assumed to be straight between input points.
(c) If only one base point is provided, DBASE(1) must be greater than zero.
(d) If two points are provided, the following must be satisfied:
   DBASE(1) ≥ 0
   DBASE(2) > DBASE(1)
(e) Distances and elevations for some data items in subsequent sections are restricted by the base dimensions. For reference the limits are expressed in terms of DBASE(2) and ELBASE(2). If only one base point has been provided, DBASE(2) = DBASE(1) and ELBASE(2) = ELBASE(1).
(f) If {'side'} = 'Both', identical base point data are assigned to both sides of the structure base.
(g) If 'Rightside' and 'Leftside' base data differ, 'Rightside' ELBASE(1) must be equal to 'Leftside' ELBASE(1). Enter 'Rightside' base data first and immediately follow with 'Leftside' data.

(d. Stem data--One (1) to four (4) lines
(1) Line contents
   LN 'Stem' {'side'} NPTS DSTEM(1) ELSTEM(1)...
   [LN ... DSTEM(NPTS) ELSTEM(NPTS)]
   (Continue DSTEM, ELSTEM pairs on second line following line number until NPTS pairs provided)
(2) Definitions
   'Stem' = keyword
   {'side'} = 'Rightside', 'Leftside', or 'Both'
Figure A2. Stem and base
NPTS = number (1 to 8) of stem points
DSTEM(1) = distance from inside face of stem to \( i^{th} \) stem point (FT)
ELSTEM(1) = elevation at \( i^{th} \) stem point (FT)

(3) Discussion
(a) See Figure A2 for notation.
(b) If '{side}' = 'Both', identical stems are assumed.
(c) DSTEM, ELSTEM pairs must start at top of stem and proceed sequentially downward with:
\[
\text{DSTEM}(1) > 0 \\
\text{ELSTEM}(1) \leq \text{ELSTEM}(I - 1) \\
\text{ELSTEM}(\text{NPTS}) > \text{ELBASE}(2)
\]
(d) The top of the stem is assumed to be horizontal at ELSTEM(1).
(e) Successive stem points are assumed to be connected by straight lines.
(f) The last stem point provided is connected by a straight line to the last base point provided.
(g) If 'mode' = 'Frame', the number of stem points and locations of stem points must conform to limitations described in Part V.
(h) If 'Rightside' and 'Leftside' stem geometries differ, enter 'Rightside' data first and immediately follow with 'Leftside' data.

\( e \). Culvert data—Zero (0), one (1), or two (2) lines, entire section may be omitted

(1) Line contents
[\text{LN 'Culvert' '{side}'} \text{DCUL CULWID ELCUL CULHGT} \text{CULFIL}]

(2) Definitions
'Culvert' = keyword
'{side}' = 'Rightside', 'Leftside', or 'Both'
DCUL = distance from inside stem face to interior vertical side of culvert (FT)
CULWID = width of culvert opening (FT)
ELCUL = elevation of floor of culvert (FT)
CULHGT = height of culvert opening (FT)
[CULFIL] = width of 45-deg fillet in culvert corners (FT); assumed to be zero if omitted
Discussion

(a) See Figure A3 for notation.

(b) If 'side' = 'Both', identical culverts are assigned to both sides of the structure.

(c) If culvert data are provided for one side only, no culvert is assumed for the opposite side.

(d) A rectangular culvert is assumed. Culvert dimensions must result in the culvert opening lying entirely within the external boundaries defined by stem and base data.

(e) Identical fillets are assumed in all four corners of the culvert except when stem void floor (see next section) coincides with the top of the culvert. In this case, fillets in top corners are omitted.

(f) If different culverts occur on each side, enter 'Rightside' data first and immediately follow with 'Leftside' data.

(g) If 'mode' = 'Frame', culvert locations must conform to limitation described in Part V.

f. Stem void data--Zero (0) or one (1) to four (4) lines, entire section may be omitted

(1) Line 1 contents

[LN 'Void' { 'side'} DVOID VOIDWD ELVOID VOIDHT [NTIES]]

(2) Line 2 contents (omit if NTIES = 0)

[LN ELTIE(1) HTIE(1) ELTIE(2) HTIE(2) ... ELTIE(NTIES) HTIE(NTIES)]

(3) Definitions

'Void' = keyword

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

DVOID = distance from inside stem fact to interior vertical side of void (FT)

VOIDWD = width of void opening (FT)

ELVOID = elevation of bottom of void opening (FT)

VOIDHT = height of void opening (FT)

NTIES = number of horizontal structural members across void opening (0 to 5)

ELTIE(I) = elevation at top of i\textsuperscript{th} tie member (FT)

HTIE(I) = depth of i\textsuperscript{th} tie member (FT)
Figure A3. Culvert
(4) Discussion

(a) See Figure A4 for notation.

(b) If 'side' = 'Both', identical voids (and ties) are assumed to exist in stems on both sides.

(c) If void (and tie) data are provided for one side only, no void is assumed in the opposite stem.

(d) The void is assumed to be a rectangular opening and must lie entirely within the external boundaries defined by the stem and base data.

(e) Void data must satisfy the following:
   \[ \text{ELVOID} \geq (\text{ELCUL} + \text{CULHGT}) \text{ if culvert present} \]
   \[ (\text{ELVOID} + \text{VOIDHT}) \leq \text{ELSTEM}(1). \]

(f) If \( \text{ELVOID} = (\text{ELCUL} + \text{CULHGT}) \), the top of the culvert is assumed to be open to the void and culvert fillets are omitted in the top corners of the culvert.

(g) If \( (\text{ELVOID} + \text{VOIDHT}) < \text{ELSTEM}(1) \), the void is treated as an additional rectangular opening in the stem.

(h) The void is assumed to be free of interior water unless the void is connected to the culvert.

(i) If 'mode' = 'Frame', a void may not exist in the stem unless a culvert is also present.

(j) Void ties are intended to provide a means of enforcing interaction between the vertical stem sections on either side of the void opening. The ties are considered to be fictitious concrete (but weightless) members with rectangular cross sections \( (\text{HTIE} \times \text{SLICE}) \). They are assumed not to impede free communication of water through the void.

(k) Tie data must commence with the topmost tie and proceed sequentially downward.

(l) Restrictions on tie data are:
   \[ \text{ELTIE}(1) \leq (\text{ELVOID} + \text{VOIDHT}) \]
   \[ \text{ELTIE}(I) \leq (\text{ELTIE}(I - 1) - \text{HTIE}(I - 1)) \]
   \[ (\text{ELTIE}(\text{NTIES}) - \text{HTIE}(\text{NTIES})) \geq \text{ELVOID} \]

14. BACKFILL

a. Control--Zero (0) or one (1) line. The entire section may be omitted if backfill effects are not to be considered.

(1) Line contents

   LN 'BACKfill' {'side'} {'type'} NUM [SURCH]
Figure A4. Stem void
(2) Definitions

'BACkfill' = keyword

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

{'type'} = 'Soil' or 'Pressure'

NUM = number (1 to 5) of horizontal soil layers if 'type' = 'Soil'

= number (2 to 21) of points on input pressure distribution if 'type' = 'Pressure'

[SURCH] = surface surcharge load (PSF), omit if 'type' = 'Pressure'

b. Backfill soil layer data--Omit if 'type' = 'Pressure'; otherwise one line per layer (NUM lines).

(1) Line contents

LN ELLAY GAMSAT GAMMST SCHT SCHB [SCVT SCVB]

(2) Definitions

ELLAY = elevation (FT) at top of layer

GAMSAT = saturated soil unit weight (PCF)

GAMMST = moist soil unit weight (PCF)

SCHT, SCHB = coefficient for horizontal soil pressure at top and bottom of layer, respectively

[SCVT,SCVB] = coefficient for soil shear stress at top and bottom of layer, respectively. Zero assumed if omitted.

(3) Discussion

(a) See Figure A5 for notation.

(b) Soil layer data lines must commence with the topmost layer (layer 1) and proceed sequentially downward. The last layer input is assumed to continue ad infinitum downward.

Restriction:

ELLAY(1) ≤ ELSTEM(1)

ELLAY(1) ≥ ELBASE(2)

ELLAY(I) < ELLAY (I - 1)

(c) Horizontal and shear stress soil coefficients are assumed to vary linearly from top to bottom of the layer. Soil coefficients in the last layer input are assumed to be constant throughout the layer equal to the values given for the top of the layer.

(d) If soil lies below ground-water elevation (see section on WATER DATA), effective unit weight is obtained by subtracting the unit weight of water from
the saturated soil unit weight. If soil lies above ground-water elevation, the moist soil unit weight is used.

(e) Horizontal soil pressures and soil shear stresses are obtained at the top and bottom of each layer by multiplying the effective vertical soil pressure by the appropriate soil coefficient of that point. A linear variation of pressure and/or shear stress is assumed from top to bottom of each layer. If the ground-water elevation occurs within a layer, an additional layer boundary is automatically inserted at that point.

c. Backfill soil pressure distribution—Omit if 'type' = 'Soil'; otherwise one (1) or more lines

(1) Line contents

\[ \text{LN ELPR}(1) \text{ EVSPR}(1) \text{ EHSPR}(1) \text{ ESSPR}(1) \]

[LN ... ELPR(NUM) EVSPR(NUM) EHSPR(NUM) ESSPR(NUM)]

(2) Definitions

\[
\begin{align*}
\text{ELPR}(I) & = \text{elevation (FT) of } i^{th} \text{ pressure point} \\
\text{EVSPR}(I) & = \text{effective vertical soil pressure (PSF) at } i^{th} \text{ pressure point} \\
\text{EHSPR}(I) & = \text{effective horizontal soil pressure (PSF) at } i^{th} \text{ pressure point}
\end{align*}
\]
ESSPR(I) = effective soil shear stress (PSF) at i\textsuperscript{th} pressure point

(3) Discussion

(a) Four values are required at each point on the backfill soil pressure distribution. Data values are provided in groups of four until NUM points are entered. Points must be provided commencing with the topmost point and proceed sequentially downward.

(b) The restrictions include:

\[
\begin{align*}
\text{ELPR}(1) & \leq \text{ELSTEM}(1) \\
\text{ELPR}(1) & > \text{ELBASE}(2) \\
\text{ELPR}(I) & < \text{ELPR}(I - 1) \\
\text{EVSPR}(I) & \geq 0 \\
\text{EHSPR}(I) & \geq 0 \\
\text{ESSPR}(I) & \geq 0
\end{align*}
\]

(d) Discussion of backfill data

(1) If identical backfill conditions exist on both sides of the structure, specify \{'side\} = 'Both' and enter data only once. Otherwise, enter data twice: first for 'Rightside' and then for 'Leftside'.

(2) Backfill data are used to determine soil loading on the exterior surface of the stem as follows. Effective stresses, vertical, horizontal, and shear, on horizontal and vertical planes of a soil element at the soil-structure interface are obtained from soil data or from direct input of soil pressures. A Mohr’s circle analysis is used to obtain normal and shear (friction) pressures on the external faces of the stem.

(3) Positive effective vertical and horizontal stresses are compression. Positive effective shear stress tends to move the structure downward.

(4) The topmost elevation on the backfill pressure distribution is interpreted as the elevation of the ground surface.

(5) The entire 'BACkfill', data section may be omitted for either or both sides of the structure.

15. BASE REACTION DATA

(a) Control--One (1) line

(1) Line contents

\[
\text{LN 'Reaction' ['type'] ['specs'] [{'horizontal option'}] ['vertical option']}
\]
(2) Definitions

'Reaction' = keyword

{'type'} = 'Soil' or 'Pile'

{'specs'} =

{ 'Uniform'
 { 'Trapezoidal' PCT
 { 'Rectangular' PCT
 { Pressure

PCT = fraction of uniform base reaction to be applied at chamber centerline (Part IV).

{'horizontal option'} = 'Shear' if unbalanced horizontal loads are to be equilibrated by shear in base. Omit if 'type' = 'Pile'; omit unless input file contains sequence of problems

= 'Friction' if unbalanced horizontal loads are to be equilibrated by friction along structure base; omit if 'type' = 'Pile'; omit unless input file contains sequence of problems

{'vertical option'} = 'Adjust' if unbalanced vertical loads and moments are to be equilibrated by adjusting base pressure distribution; omit if 'type' = 'Pile'; omit unless input file contains sequence of problems

= 'Shear' if unbalanced vertical loads and moments are to be equilibrated by shear in stems; omit if 'type' = 'Pile'; omit unless 'specs' = 'Pressure'; omit unless input file contains sequence of problems

(3) Discussion

(a) Base reaction data must be provided for soil only or piles only. Uplift water forces are entered in the WATER DATA section.

(b) 'Uniform', 'Trapezoidal', and 'Rectangular' soil reaction distributions are evaluated automatically to equilibrate all vertical loads and overturning moments.

(c) 'Pressure' indicates an input pressure distribution is provided.

(d) 'Pile' indicates that pile data are input and no soil reaction is present.

(e) {'horizontal option'} and {'vertical option'} are to be supplied only if the input file contains a sequence of problems. Otherwise, the user will be requested to enter these options by the program during execution. If these items are omitted for any problem in a sequence or are incorrectly specified,
the program will automatically use ('horizontal option' = 'Friction' and ('vertical option' = ('Adjust').

b. Input base soil pressure distribution--One (1) or more lines. Omit entire section if ('specs') ≠ 'Pressure'

(1) Line 1 contents

\[
\text{LN } ['\text{side'}] \ NPTS \ DBPR(1) \ BPR(1) \ DBPR(2) \ BPR(2) \ ...
\]

[LN ... DBPR(NPTS) \ BPR(NPTS)]

(2) Definitions

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

NPTS = number (2 to 21) of points on input pressure distribution

DBPR(I) = distance (FT) from chamber centerline to \(i^{th}\) pressure point

BPR(I) = base soil pressure (PSF) at \(i^{th}\) pressure point

(3) Discussion

(a) The base soil pressure diagram is provided in two parts: once from chamber centerline to extreme rightside of base and once from centerline to extreme leftside of base. If distribution is symmetric about the chamber centerline, specify \{'\text{side}'\} = 'Both' and enter data only once.

(b) Two values (DBPR and BPR) are required for each point on the distribution. Continue pairs of values on additional lines commencing with a line number, until NPTS pairs have been provided.

(c) Pressure point data must commence with the point nearest chamber centerline and proceed sequentially outward.

Restrictions:

\[
\text{DBPR}(1) \geq 0
\]

\[
\text{DBPR}(I) > \text{DBPR}(I - 1)
\]

\[
\text{BPR}(I) \geq 0
\]

(d) If DBPR(I) > 0, base pressure is assumed to be constant at BPR(I) from the chamber centerline to DBPR(I).

(e) Pressure is assumed to be constant at BPR(NPTS) for all points beyond DBPR(NPTS).

(f) CAUTION: An input base pressure diagram may not equilibrate all vertical loads and overturning moments. See Part IV for adjustments applied to place entire system in equilibrium.
If base pressure distributions are different on each side, enter data for 'Rightside' first and immediately follow with 'Leftside' data.

c. Pile Data--Omit entire section if 'type' = 'soil'

(1) Control--One (1) line
(a) Line contents
LN 'PILE' 'side'
(b) Definitions
'PILES' = keyword
'side' = 'Rightside', 'Leftside', or 'Both'

c) Discussion
For pile configurations symmetric about chamber centerline, enter 'side' = 'Both' and provide following subsections only once. For unsymmetric pile configurations, enter entire Pile Data section twice: first for 'Rightside' and then for 'Leftside'.

(2) Pile layout--One (1) to ten (10) lines
(a) Line contents
LN 'Layout' NSTART DSTART [NSTOP [NSTEP [DSTEP]]]

(b) Definitions
'Layout' = keyword
NSTART = pile number at start of sequence
DSTART = distance from chamber centerline to intersection of pile centerline with base of structure (FT)
[NSTOP] = pile number of last pile in sequence
[NSTEP] = step in pile number
[DSTEP] = distance between adjacent piles in the sequence (FT)

c) Discussion
1. Piles on either side of the chamber centerline are designated by an integer number from 1 to 50. A maximum of fifty (50) piles is permitted on each side of the structure. Pile numbers need not be entered in sequential order. Any pile number in the range 1 to 50 for which layout data are not supplied is ignored.

2. Each line of 'Layout' data describes one sequence of piles to be generated.

3. Pile numbers and distances are generated for each sequence as follows:
### Pile No. | Distance from Centerline
--- | ---
NSTART | DSTART
NSTART + NSTEP | DSTART + DSTEP
NSTART + 2* NSTEP | DSTART + 2* DSTEP
. | .
. | .
. | .
NSTOP | DSTART + ((NSTOP
- NSTART)/NSTEP)* DSTEP

4. (NSTOP - NSTART)/NSTEP must be an integer.

5. If NSTOP, NSTEP, and DSTEP are all omitted, only one pile is generated.

6. If NSTEP and DSTEP are omitted, NSTEP is assumed to be one and DSTEP is assumed to be zero. This results in piles NSTART, NSTART + 1, NSTART + 2, ..., NSTOP all attached to base of structure at DSTART.

7. If DSTEP is omitted, DSTEP is assumed to be zero. This results in piles NSTART, NSTART + NSTEP, NSTART + 2* NSTEP, ..., NSTOP all attached to base of structure at DSTART.

8. Any pile generated beyond the extreme edge(s) of the base is ignored.

9. If any pile is referenced more than once, only the data corresponding to the last reference are used.

10. When 'side' = 'Both', DSTART = 0 may result in two (or more) piles being placed at the chamber centerline. See discussion of batter data below.

11. Every pile referenced in the pile "Layout" data must be assigned either pile/soil data or a pile head stiffness matrix as described below.

(3) Pile/soil properties--Zero (0) to ten (10) lines; entire section may be omitted

(a) Line contents

```
LN 'PROperties' NSTART PE PA PI PL PAXCO DF SS1 SS2 [NSTOP [NSTEP]]
```

(b) Definitions

- **'PROperties'** = keyword
- NSTART = pile number at start of sequence
- PE = pile modulus of elasticity (PSI)
PA = pile cross-sectional area (IN.²)
PI = pile moment of inertia (IN.⁴)
PL = pile length (FT)
PAXCO = coefficient for pile axial stiffness
DF = pile head fixity coefficient
   (0 ≤ DF ≤ 1); 0 = pinned head, 1 = fixed head
SSI = constant soil stiffness coefficient
   (LB/IN.²)
SS2 = linear soil stiffness coefficient
   (LB/IN.³)
[NSTOP] = pile number of last pile in sequence
[NSTEP] = step in pile number

(c) Discussion

1. Each line of data describes a sequence of piles to be generated.
2. Identical pile properties, pile head fixity, and soil properties are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2*NSTEP, ..., NSTOP.
3. (NSTOP - NSTART)/NSTEP must be an integer.
4. If NSTOP and NSTEP are both omitted, only a single pile is generated.
5. If NSTEP is omitted, NSTEP is assumed to be one.
6. If any pile is referenced more than once, only the data for the last reference are used.
7. Soil stiffness is obtained from

   \[ E_s = SSI + SS2 \times Y \]

where \( E_s \) is the force per unit length of pile produced by a unit lateral displacement (LB/IN.²), and \( Y \) is the distance below the pile head. Soil stiffness coefficients must include effects of pile width, as well as other factors which may influence the soil stiffness.
8. Pile properties, pile head fixity, and soil properties are used to generate pile head stiffness matrices.
(4) Pile head stiffness matrices--Zero (0) or one (1) to ten (10) lines; entire section may be omitted
(a) Line contents
LN 'STIFFness' NSTART B11 B22 B33 B13 [NSTOP [NSTEP]]
(b) Definitions
'STIFFness' = keyword
   NSTART = pile number at start of sequence
   B11 = pile lateral stiffness (LB/IN.)
   B22 = pile axial stiffness (LB/IN.)
   B33 = pile moment stiffness (LB/IN.)
   B13 = lateral force-moment coupling stiffness (LB)
   [NSTOP] = pile number of last pile in sequence
   [NSTEP] = step in pile number
(c) Discussion
   1. Each line of data describes a sequence of piles to be generated.
   2. Identical pile head stiffness matrices are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2* NSTEP, ..., NSTOP.
   3. (NSTOP - NSTART)/NSTEP must be an integer.
   4. If NSTOP and NSTEP are both omitted, only a single pile is generated.
   5. If NSTEP is omitted, NSTEP is assumed to be one.
   6. If any pile is referenced more than once, only the data for the last reference are used.

(5) Pile batter data--Zero (0) or one (1) to ten (10) lines; entire section may be omitted
(a) Line contents
LN 'BATter' NSTART BATTER [NSTOP [NSTEP]]
(b) Definitions
'BATTER' = keyword
   NSTART = pile number of first pile in sequence
   BATTER = slope of pile vertical (FT) per foot horizontal. Positive if pile slopes downward away from chamber centerline; negative if pile slopes downward toward chamber centerline.
   [NSTOP] = pile number of last pile in sequence
   [NSTEP] = step in pile number
(c) Discussion

1. Each line of data describes a sequence of piles to be generated.

2. Identical pile batters are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2* NSTEP, ..., NSTOP.

3. (NSTOP - NSTART)/NSTEP must be an integer.

4. If NSTOP and NSTEP are both omitted, only a single pile is generated.

5. If NSTEP is omitted, NSTEP is assumed to be one.

6. All piles are assumed to lie in a vertical plane. BATTER describes the slope of the pile within this vertical plane. When BATTER ≥ 100 or BATTER = 0, the pile is assumed to be exactly vertical. Any pile not assigned a batter is assumed to be exactly vertical.

7. When all pile data are symmetric, vertical piles on the structure centerline are not duplicated in the mirror image established for the 'Leftside'.

(6) Pile load comparison data--Zero (0) or one (1) to ten (10) lines; entire section may be omitted

(a) Line contents

LN 'ALLOWables' NSTART AC AT ACC ATT AM FMM FPM OSFC OFST [NSTOP [NSTEP]]

(b) Definitions

'ALLOWables' = keyword

NSTART = pile number at start of sequence

AC = allowable pile axial compression force (KIPS)

AT = allowable pile axial tension force (KIPS)

ACC = allowable pile axial compression force for combined axial compression and bending (KIPS)

ATT = allowable pile axial tension force for combined axial tension and bending (KIPS)

AM = allowable bending moment (KIP-FT)

FMM = moment magnification factor for amplification effect of axial compression on bending moment

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FPM = factor (IN.) for evaluating maximum bending moment in pinned head pile (i.e., DF = 0 or B13, B33 both zero); input value is ignored for piles which transfer moment at pile head

OSFC = load case factor for pile in compression

OSFT = load case factor for pile in tension

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile member

(c) Discussion

1. Each line of data describes a sequence of piles to be generated.

2. Identical "allowable" data values are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2*NSTEP, ..., NSTOP.

3. (NSTOP - NSTART)/NSTEP must be an integer.

4. If NSTOP and NSTEP are both omitted, only a single pile is generated.

5. If NSTEP is omitted, NSTEP is assumed to be one.

6. If any pile is referenced more than once, only the data for the last reference are used.

7. The following ratios are evaluated and reported:

\[ \frac{|FA|}{OSFC} / AC \text{ for axial compression} \]
\[ \frac{|FA|}{OSFT} / AT \text{ for axial tension} \]
\[ \frac{(|FA|/ACC) + (FPM|BM|AM|)}{OSFC} \text{ for axial compression} \]
\[ \frac{(|FA|/ATT) + |BM|AM|)}{OSFT} \text{ for axial tension} \]

where: FA = calculated pile axial head force

BM = bending moment at pile head for non-pinned head piles

BM = FPM* FV where FV = pile head shear for pinned head piles

8. "ALLOWable" data need to be entered only for piles for which comparisons are desired. No comparisons are performed for any pile not assigned "ALLOWable" data values.

9. Comparisons are made for information purposes only. No action is taken by the program based on the values of the ratios.
10. Values for the load case factors OFSC and OFST should be selected based on the severity and duration expected for a particular loading condition. It may be necessary to alter OFSC and OFST for each loading condition in order to obtain valid comparisons for pile loads.

(7) General discussion of pile data

(a) Pile layout data are used to determine the number of piles present and their identification. Every pile defined by layout data must be assigned pile/soil data or a pile head stiffness matrix; otherwise execution will terminate.

(b) Any pile number assigned pile/soil data or a pile head stiffness matrix but not defined by layout data is ignored.

(c) If different pile conditions exist on each side, enter the entire description for 'Rightside' piles ('Layout', 'Properties', 'Stiffnesses', 'Base', and 'Allowables') first and immediately follow with 'Leftside' data.

16. WATER DATA

a. Control--Zero (0) or one (1) line. Omit entire section if water effects are not to be considered.

   (1) Line contents
   LN 'Water' [GAMWAT]

   (2) Definitions
   'Water' = keyword
   [GAMWAT] = unit weight of water (PCF). Assumed to be 62.4 PCF if omitted

b. External water--Zero (0), one (1), or two (2) or more lines. Entire section may be omitted.

   (1) Control--One (1) line--Line contents
   LN 'External' {'side'} {'type'} [ELGW [ELSURW]]

   (2) Definitions
   'External' = keyword
   {'side'} = 'Rightside', 'Leftside', or 'Both'
   {'type'} = 'Elevation' if external water effects are to be calculated from input water elevations
   = 'Pressure' if water pressure distribution provided
   [ELGW] = elevation (FT) of ground-water surface; omit if {'type'} = 'Pressure'
[ELSURW] = elevation (FT) of surcharge water surface; omit if surcharge water is not to be considered; omit if {'type'} = 'Pressure'

(3) Discussion for {'type'} = 'Elevation'

(a) Ground water affects backfill soil loads by altering effective soil unit weight as well as producing horizontal hydrostatic pressures on the lateral surface of the structure.

(b) Surcharge water is assumed to lie above the ground surface and to be isolated from ground water. Surcharge water produces hydrostatic pressures on the lateral surface of the structure. Vertical pressure of surcharge water on ground surface is added to effective vertical soil pressures when soil layer data are provided in the backfill description.

Restrictions:

ELSURW ≤ ELSTEM(1)
ELSURW > ELLAY(1) if backfill soil data provided
ELSURW > ELPR(1) if backfill pressure distribution provided

(4) Data lines if {'type'} = 'Pressure'

(a) Line 1 contents

LN NPTS ELWPRE(1) WPRE(1) ELWPRE(2) WPRE(2) ...
[LN ... ELWPRE(NPTS) WPRE(NPTS)]

(b) Definitions

NPTS = number (2 to 21) of points on pressure distribution provided
ELWPRE(I) = elevation (FT) at i\textsuperscript{th} pressure point
WPRE(I) = pressure (PSF) at i\textsuperscript{th} pressure point

c) Discussion

1. Elevation and pressure data are provided in pairs. Data pairs may be continued on additional lines following a line number until NPTS pairs have been provided.

2. Input water pressures act normal to the exterior surfaces of the structure between ELWPRE(1) and ELBASE(2). No other water effect is implied or used.

3. Restrictions:

ELWPRE(1) ≤ ELSTEM(1)
ELWPRE(1) < ELWPRE(1 - 1)
ELWPRE(1) ≥ ELBASE(2)

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4. Input water pressure distribution produces only loads normal to the lateral surfaces of structure. No other effect is implied or used.

(5) Discussion of external water data

(a) See Figure A6 for notation

![Figure A6. External water](image)

(b) If identical external water effects exist on both sides of the structure, enter {'side'} = 'Both' and enter data only once. If different effects exist on the two sides, enter data twice: first for 'Rightside' and then for 'Leftside'.

c. Uplift water effects on base—Zero (0) or one (1) or more lines. Entire section may be omitted

(1) Control—One (1) line

(a) Line contents

```
LN 'Uplift' {'type'} [UPRITE [UPLEFT]]
```

(b) Definitions

'Uplift' = keyword

{'type'} = 'Elevation' if uplift pressures are to be calculated from input water elevations

= 'Pressure' if uplift pressure distribution is provided

[UPRITE] = effective uplift water elevation at extreme rightside of base (FT); omit if {'type'} = 'Pressure'
[UPLEFT] = effective uplift water elevation at extreme leftside of base (FT); assumed to be equal to UPRITE if omitted; omit if {'type'} = 'Pressure'

(c) Discussion for {'type'} = 'Elevation'

1. Uplift pressures on the base are obtained by multiplying the weight of water by the input heads at the extremes of the base.
2. Uplift pressure is assumed to vary linearly between the extremes.
3. Restrictions:
   
   UPRITE ≥ ELBASE(2) on rightside
   
   UPLEFT ≥ ELBASE(2) on leftside

4. A straight line between UPRITE and UPLEFT must not intersect the base of the structure at any point.

(2) Input base uplift pressure distribution--One (1) or more lines. Omit entire section if {'type'} = 'Elevation'

(a) Line 1 contents

LN {'side'} NPTS DUPR(1) UPR(1) DUPR(2) UPR(2) ...

[LN... DUPR(NPTS) UPR(NPTS)]

(b) Definitions

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

NPTS = number (1 to 21) of points on input pressure distribution

DUPR(I) = distance (FT) from chamber centerline to ith pressure point

UPR(I) = uplift pressure (PSF) at ith pressure point

(c) Discussion

1. The base uplift pressure diagram is provided in two parts: first from chamber centerline to extreme rightside of base; then from chamber centerline to extreme leftside of base. If the distribution is symmetric about the centerline, specify {'side'} = 'Both' and enter data only once.

2. Two values (DUPR and UPR) are required for each point on the distribution. Continue pairs of values on additional lines, commencing with a line number, until NPTS pairs have been provided.
3. Pressure point data must commence with the point nearest the chamber centerline and proceed sequentially outward.

Restrictions:

\[ \text{DUPR}(1) \geq 0 \]
\[ \text{DUPR}(I) > \text{DUPR} (I - 1) \]
\[ \text{UPR}(I) \geq 0 \]

4. If \( \text{DUPR}(I) > 0 \), uplift pressure is assumed to be constant at \( \text{UPR}(I) \) from the chamber centerline to \( \text{DUPR}(I) \).

5. Uplift pressure is assumed to be constant at \( \text{UPR}(\text{NPTS}) \) for all points beyond \( \text{DUPR}(\text{NPTS}) \).

6. CAUTION: An input uplift pressure diagram may not equilibrate all vertical loads and overturning moments. See Part IV for reaction adjustments applied to place entire system in equilibrium.

d. Internal water—Zero (0) or one (1) line. Entire section may be omitted.

(1) Line contents

\text{LN 'Internal' ELCHMW \{ELCWR\} \{ELCWL\}}

(2) Definitions

'Internal' = keyword

\text{ELCHMW = water elevation in chamber (FT)}

\text{[ELCWR] = effective water elevation in rightside culvert (and stem void) (FT); omit if culvert is not present}}

\text{[ELCWL] = effective water elevation in leftside culvert (and stem void) (FT); omit if culvert is not present}}

(3) Discussion

(a) See Figure A7 for notation

(b) If \( \text{ELCHMW} \) is less than \( \text{ELFLOR} \), the chamber is assumed to be dry. \( \text{ELCHMW} \) must be less than or equal to \( \text{ELSTEM}(1) \).

(c) If effective water elevation in the culvert(s) is less than \( \text{ELCUL} \) (rightside or leftside), the culvert is assumed to be dry.

(d) If the culvert top is closed, i.e., \( \text{ELVOID} \geq (\text{ELCUL} + \text{CULBGT}) \), and the effective water elevation in the culvert is above the top of the culvert, the culvert is assumed to be pressurized. In this case the stem void (if present) is assumed to be dry.
a. Culvert partially filled

b. Culvert fully pressurized

c. Void and culvert connected

Figure A7. Internal water

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(e) If the culvert is open to the stem void, i.e., \( ELVOID = (ELCUL + CULHGT) \), then the interior walls of the culvert (and void) are subjected only to triangular hydrostatic pressures.

(f) Culvert water elevation may result in hydrostatic pressures on all interior surfaces of a closed culvert. If the culvert is open to the stem void and the stem void is closed at the top, i.e., \( ELVOID + VOIDHT < ELESTM(1) \), culvert water elevation may result in hydrostatic pressures on all interior surfaces of the culvert and void.

17. ADDITIONAL LOAD DATA—Zero (0) or two (2) or more lines. Entire section may be omitted.

a. Control—One (1) or more lines; line sequences may be repeated as necessary
(1) Line contents
   LN 'Loads' {'side'} {'location'}

(2) Definitions
   'Loads' = keyword
   {'side'} = 'Rightside', 'Leftside', or 'Both'
   {'location'} = 'Stem Exterior' if loads act on exterior face of stem
                   = 'Stem Interior' if loads act on interior face of stem
                   = 'Stem Top' if loads act on top horizontal surface of stem
                   = 'Floor' if loads act on chamber floor
                   = 'Base' if loads act on base of structure

b. Data lines for loads acting on stem faces
(1) Concentrated loads—One (1) or more lines
   (a) Line contents
      LN 'Concentrated' NLDS ELCSLD(1) HCSLD(1) VCSLD(1) ...
      [LN ... ELCSLD(NLDS) HCSLD(NLDS) VCSLD(NLDS)]
   (b) Definitions
      'Concentrated' = keyword
      NLDS = number (1 to 10) of concentrated loads
      ELCSLD(I) = elevation at which load acts (FT)
HCSLD(I) = magnitude of horizontal load component (PLF)
VCSLD(I) = magnitude of vertical load component (PLF)

(2) Distributed loads--One (1) or more lines
(a) Line 1 contents
   LN 'Distributed' NPTS ELDSLD(1) HDSLD(1) VDSLD(1) ...
   [LN ... ELDSLD(NPTS) HDSLD(NPTS) VDSLD(NPTS)]
(b) Definitions
   'Distributed' = keyword
   NPTS = number (2 to 21) of load point values to be provided
   ELDSLD(I) = elevation at load point (FT)
   HDSLD(I) = magnitude of horizontal load at ith load point (PSF)
   VDSLD(I) = magnitude of vertical load at ith load point (PSF)

(3) Discussion
(a) All horizontal loads are positive if they act toward the centerline of the chamber.
(b) All vertical loads are positive if they act downward.
(c) For concentrated loads on exterior face of stem:
   ELBASE(2) ≤ ELCSLD ≤ ELSTEM(1)
(d) For concentrated loads on interior face of stem:
   ELFLOR ≤ ELCSLD ≤ ELSTEM(1)
(e) Concentrated loads are interpreted as line loads acting on the slice.
(f) Three values are required for each point on a distributed load distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided.
(g) Distributed loads on the exterior face of the stem must begin at or below the top of the stem and terminate at or above the juncture of the base and stem, i.e.,
   ELDSLD(1) ≤ ELSTEM(1)
   ELDSLD(I) ≤ ELDSLD(I - 1)
   ELDSLD(NPTS) ≥ ELBASE(2)
(h) Distributed loads on the interior face of the stem must begin at or below the top of the stem and
terminate at or above the chamber floor, i.e.,
\[\text{ELDSLD}(1) \leq \text{ELSTEM}(1)\]
\[\text{ELDSLD}(1) \leq \text{ELDSLD}(I - 1)\]
\[\text{ELDSLD}(NPTS) \geq \text{ELFLOR}(2)\]

(i) Distributed loads are assumed to vary linearly between input points.

(j) If two load points are specified at the same elevation, the first is assumed to exist immediately above the elevation and the second immediately below the elevation.

(k) Distributed loads are interpreted as force per foot of slice per foot of vertical projection of the stem surface.

c. Data lines for loads acting on top horizontal surface of stem
(1) Concentrated loads—One (1) or more lines
(a) Line contents
\[\text{LN} \ '\text{Concentrated}' \ \text{NLDS} \ \text{DCSTLD}(1) \ \text{HCSTLD}(1)\]
\[\text{VCSTLD}(2) \ldots\]
\[\text{[LN} \ldots \ \text{DCSTLD(NLDS)} \ \text{HCSTLD(NLDS)} \ \text{VCSTLD(NLDS)}\]

(b) Definitions
\['\text{Concentrated}' = \text{keyword}\]
\[\text{NLDS} = \text{number (1 or 10) of concentrated loads}\]
\[\text{DCSTLD} = \text{distance from inside stem face at which load acts (FT)}\]
\[\text{HCSTLD} = \text{magnitude of horizontal load component (PLF)}\]
\[\text{VCSTLD} = \text{magnitude of vertical load component (PLF)}\]

(2) Distributed loads—One (1) or more lines
(a) Line contents
\[\text{LN} \ '\text{Distributed}' \ \text{NPTS} \ \text{DDSTLD}(I) \ \text{HDSTLD}(I)\]
\[\text{VDSTLD}(I) \ldots\]
\[\text{[LN} \ldots \ \text{DDSTLD(NPTS)} \ \text{HDSTLD(NPTS)} \ \text{VDSTLD(NPTS)}\]

(b) Definitions
\['\text{Distributed}' = \text{keyword}\]
\[\text{NPTS} = \text{number (2 to 21) of load point values to be provided}\]
\[\text{DDSTLD}(I) = \text{distance from inside stem face to } i^{th} \text{ load point (FT)}\]
HDSTLD(I) = magnitude of horizontal load at ith load point (PLF)
VDSTLD(I) = magnitude of vertical load at ith load point (PLF)

(c) Discussion

1. All horizontal loads are positive if they act toward the chamber centerline.
2. All vertical loads are positive if they act downward.
3. For loads on the stem top:
   \[0 \leq DCSTLD(I) \leq DSTEM(1)\]
   \[0 \leq DDSTLD(I)\]
   \[DDSTLD(I) \geq DDSTLD(I - 1)\]
   \[DDSTLD(PTS) \leq DSTEM(1)\]
4. If the top of a stem void is open at the top of the stem, loads may not be applied inside of the void opening.
5. Distributed loads are assumed to vary linearly between input points. If two points are input at the same distance from the stem face, the first is assumed to exist on the chamber side of the point and the second is assumed to exist immediately outside the point.

(d) Data lines for loads acting on chamber floor and structure base

(1) Concentrated loads--One (1) or more lines

(a) Line contents

<table>
<thead>
<tr>
<th>LN 'Concentrated' NLDS DCFBLD(1) HCFBLD(1) VCFBLD(1) ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>[LN ... DCFBLD(NLDS) HCFBLD(NLDS) VCFBLD(NLDS)]</td>
</tr>
</tbody>
</table>

(b) Definitions

'Concentrated' = keyword
NLDS = number (1 to 10) of concentrated loads
DCFBLD = distance from chamber centerline at which load acts (FT)
HCFBLD = magnitude of horizontal load component (PLF)
VCFBLD = magnitude of vertical load component (PLF)

(2) Distributed loads--One (1) or more lines
(a) Line 1 contents

LN 'Distributed' NPTS DDFBLD(1) HDFBLD(1) VDFBLD(1)
[LN ... DDFBLD(NPTS) HDFBLD(NPTS) VDFBLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of load point values to be provided

DDFBLD(I) = distance from chamber centerline to i th load point (FT)

HDFBLD(I) = magnitude of horizontal load at i th load point (PSF)

VDFBLD(I) = magnitude of vertical load at i th load point (PSF)

(3) Discussion

(a) All horizontal loads are positive if they act toward the chamber centerline.

(b) All vertical loads are positive if they act downward.

(c) For concentrated loads on the chamber floor

\[ 0 \leq DCFBLD(I) \leq FLRWID \]

(d) For concentrated loads on the structure base

\[ 0 \leq DCFBLD(I) \leq DBASE(2) \]

(e) Concentrated loads are interpreted as line loads acting on the slice.

(f) Three values are required for each point on a distributed load distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided. Distributed load point data must commence with the point nearest the chamber centerline and proceed sequentially outward.

(g) For distributed loads on chamber floor

\[ 0 \leq DDFBLD(1) \]

\[ DDFBLD(I) \geq DDFBLD(I - 1) \]

\[ DDFBLD(NPTS) \leq FLRWID \]

(h) For distributed loads on structure base

\[ 0 \leq DDFBLD(1) \]

\[ DDFBLD(I) > DDFBLD(I - 1) \]

\[ DDFBLD(NPTS) \leq DBASE(2) \]
Distributed loads are assumed to vary linearly between input points. If two points are input at the same distance from the chamber centerline, the first is assumed to exist immediately inside the point and the second is assumed to exist immediately outside the point.

Distributed loads on the base are interpreted as force per foot of slice per foot of horizontal projection of the base.

18. LIST OF MEMBERS FOR DETAILED MEMBER FORCE OUTPUT—Zero (0), one (1), or two (2) lines. Omit unless input file contains sequence of problems; omit if 'mode' = 'Equilibrium'.

a. Line contents

   [LN 'Output Members' {'side'} {list}]

b. Definitions

   'Output Members' = keywords
   {'side'} = 'Rightside', 'Leftside', or 'Both'
   {list} = list of member numbers for which detailed member forces are desired
   = 'All' if detailed forces for all members are desired
   = list of individual member numbers of form N1 N2 ... N4 TO N5 ...

c. Discussion

   (1) When data are entered from the terminal or from a file containing only one problem, the user is requested to provide this information during program execution.

   (2) If this section is omitted, no detailed member forces are output during a sequence of solutions.

   (3) For symmetric systems, enter data for 'Rightside' only.

   (4) For unsymmetric systems, if different lists of member numbers are desired for the two sides, enter data for 'Rightside' first and immediately follow with data for 'Leftside'.

19. TERMINATION—One (1) line

a. Line contents

   LN 'Finish' ['Rerun']

b. Definitions

   'Finish' = keyword to indicate end of problem data set
['Rerun'] = keyword to indicate additional problem data set follows for sequence of problems. Omit unless input file contains sequence of problems. Omit on last line of sequence.

Abbreviated Input Guide

20. CONTROL
   a. Heading--One (1) to four (4) lines
      LN 'heading'
      [LN 'heading']
      [LN 'heading']
      [LN 'heading']
   b. Method--One (1) line
      LN 'Method' \{'Equilibrium' \}'
      \{'Frame' RLF \}'

21. STRUCTURE
   a. Control--One (1) line
      LN 'Structure' EC PR WTCONC [SLICE]
   b. Floor--One (1) line
      LN 'Floor' FLRWID ELFLOR [FLRFIL]
   c. Base--One (1) or two (2) lines
      LN 'Base' {'side'} DBASE(1) ELBASE(1) [DBASE(2)
      ELBASE(2)]
   d. Stem--One (1) to four (4) lines
      LN 'Stem' {'side'} NPTS DSTEM(1) ELSTEM(1) ...
      [LN ... DSTEM(NPTS) ELSTEM(NPTS)]
   e. Culvert--Zero (0) to two (2) lines
      [LN 'Culvert' {'side'} CDUL CULWID ELCUL CULHCT
      [CULFIL]]
   f. Void--Zero (0) to four (4) lines
      LN 'Void' {'side'} DVOID VOIDWD ELVOID VOIDHT
      [NTIES]]
      [LN ELTIE(1) HTIE(1) ... ELTIE(NTIES) HTIE(NTIES)]

22. BACKFILL
   a. Soil data--Omit if pressure distribution input
(1) Control--One (1) line
   LN 'BACKfill' {'side'} 'Soil' NUM [SURCH]
(2) Layer data--One (1) to five (5) lines
   LN ELLAY GAMSAT GAMST SCHT SCHB [SCVT SCVB]
b. Pressure data--Omit if soil data input
   (1) Control--One (1) line
   LN 'BACKfill' {'side'} 'Pressure' NUM
   (2) Data lines
      LN ELPR(1) EVSPR(1) EHSPR(1) ESSPR(1) ...
      [LN ... ELPR(NUM) EVSPR(NUM) EHSPR(NUM) ESSPR(NUM)]

23. BASE REACTION
   a. Soil reaction--One (1) to three (3) lines
      LN 'Reaction' 'Soil' 'Uniform'
      LN 'Reaction' 'Soil' 'Trapezoidal' PCT
      LN 'Reaction' 'Soil' 'Rectangular' PCT
      LN 'Reaction' 'Soil' 'Friction' 'Pressure' 'Shear'
      LN 'Reaction' 'Soil' 'Adjust' 'Pressure' 'Shear'
      Additional lines for 'Pressure'
      LN {'side'} NPTS DBPR(1) BPR(1) DBPR(2) BPR(2) ...
      [LN ... DBPR(NPTS) BPR(NPTS)]
   b. Pile reaction
      (1) Control--Two (2) lines
         LN 'Reaction' 'Pile'
         LN 'Pile' {'side'}
      (2) Pile layout--One (1) or more lines
         LN 'Layout' NSTART DSTART [NSTOP [NSTEP [DSTEP]]]
      (3) Pile properties--Zero (0) or one (1) to ten (10) lines;
          required if pile head stiffness matrices are calculated by
          program
         LN 'PROperties' NSTART PE PD PA PI PL PAXCO DE SS1
         LN 'PROperties' NSTART PE PD PA PI PL PAXCO DE SS2 [NSTOP [NSTEP]]
      (4) Pile stiffness matrices--Zero (0) to ten (10) lines
         LN 'STIFfness' NSTART B11 B22 B33 B13 [NSTOP [NSTEP]]
      (5) Pile batter--Zero (0) to ten (10) lines
         LN 'BATter' NSTART BATTER [NSTOP [NSTEP]]
      (6) Pile load comparison--Zero (0) to ten (10) lines
         LN 'ALLOWables' NSTART AC AT ACC ATT AM FMM
         FPM OFSC OFST [NSTOP [NSTEP]]

A37
24. WATER
   a. Control—Zero (0) or one (1) line
      LN ‘Water’ [GAMWAT]
   b. External water—Zero (0) or one (1) or more lines
      (1) Water elevations input—One (1) line
         LN ‘External’ {‘side’} ‘Elevation’ ELGW [ELSURW]
      (2) Water pressure distribution input—Two (2) or more lines
         (a) Control—One (1) line
            LN ‘External’ {‘side’} ‘Pressure’
         (b) Data lines—One (1) or more lines
            LN NPTS ELWPRE(1) WPRE(1) ELWPRE(2) WPRE(2)
            [LN ... ELWPR(NPTS) WPRE(NPTS)]
   c. Uplift water—Zero (0) or one (1) or more lines
      (1) Uplift water elevations input—One (1) line
         LN ‘Uplift’ ‘Elevation’ UPRITE [UPLEFT]
      (2) Uplift pressure distribution input—Two (2) or more lines
         (a) Control—One (1) line
            LN ‘Uplift’ ‘Pressure’
         (b) Data lines—One (1) or more lines
            LN {‘side’} NPTS DUPR(1) UPR(1) DUPR(2) UPR(2)...
            [LN ... DUPR(NPTS) UPR(NPTS)]
   d. Internal water—Zero (0) or one (1) line
      LN ‘Internal’ ELCHMW [ELCWR [ELCWL]]

25. ADDITIONAL LOADS
   a. Loads on stem faces—Zero (0) or two (2) or more lines
      (1) Control—One (1) line
         LN ‘Loads’ {‘side’} {‘Stem Exterior’} {‘Stem Interior’}
      (2) Data lines for concentrated loads—Zero (0) or one (1) or more lines
         LN ‘Concentrated’ NLDS ELCSLD(1) HCSLD(1) VCSLD(1)...
         [LN ... ELCSLD(NLDS) HCSLD(NLDS) VCSLD(NLDS)]
      (3) Data lines for distributed loads—Zero (0) or one (1) or more lines
         LN ‘Distributed’ NPTS ELDSLD(1) HDSLD(1) VDSLD(1)...
         [LN ... ELDSLD(NPTS) HDSLD(NPTS) VDSLD(NPTS)]
b. Loads on stem top--Zero (0) or two (2) or more lines
   (1) Control--One (1) line
      LN 'Loads' {'side'} {'Stem Top'}
   (2) Data lines for concentrated loads--Zero (0) or one (1) or more lines
      LN 'Concentrated' NLDS DCSTLD(1) HDSTLD(1) VDSTLD(1) ...
      [LN ... DCSTLD(NLDS) HDSTLD(NLDS) VDSTLD(NLDS)]
   (3) Data lines for distributed loads--Zero (0) or one (1) or more lines
      LN 'Distributed' NPTS DDSTLD(1) HDSTLD(1) VDSTLD(1) ...
      [LN ... DDSTLD(NPTS) HDSTLD(NPTS) VDSTLD(NPTS)]

c. Loads on chamber floor or structure base--Zero (0) or two (2) or more lines
   (1) Control--One (1) line
      LN 'Loads' {'side'} {'Floor'} {'Base'}
   (2) Data lines for concentrated loads--Zero (0) or one (1) or more lines
      LN 'Concentrated' NLDS DCFBLD(1) HCFBLD(1) VCFBLD(1) ...
      [LN ... DCFBLD(NLDS) HCFBLD(NLDS) VCFBLD(NLDS)]
   (3) Data lines for distributed loads--Zero (0) or one (1) or more lines
      LN 'Distributed' NPTS DDFBLD(1) HDFBLD(1) VDFBLD(1) ...
      [LN ... DDFBLD(NPTS) HDFBLD(NPTS) VDFBLD(NPTS)]

26. DETAILED MEMBER FORCE LIST--Zero (0), one (1), or two (2) lines
    LN 'Output Members' {'side'} {'All'} {list}

27. TERMINATION--One (1) line
    LN 'Finish' {'Rerun'}
APPENDIX B: GTSTRUDL SOLUTIONS

STRUDL Model

1. Joints in the STRUDL model were assigned at the locations of the joints in the CUFRAM model. Additional STRUDL joints were located at the ends of the flexible lengths of the CUFRAM members at the intersection of any piles with the structure base and at the base of STRUDL members simulating the piles.

2. STRUDL members corresponding to prismatic flexible CUFRAM members were assigned cross-sectional areas and moments of inertia calculated from the dimensions of the structure. Because STRUDL does not have the direct capability of evaluating the stiffness matrix for a tapered member, the stiffness matrices for tapered members were obtained by the process used in CUFRAM and provided to STRUDL. All STRUDL members representing rigid links in the CUFRAM model were assigned area and inertia properties several times larger than those of the largest prismatic member. Pile head stiffnesses were evaluated separately and supplied to STRUDL as member stiffness matrices.

3. Loads were applied to the STRUDL model as follows. Uniform loads on prismatic members were applied as member loads. Nonuniform loads on prismatic members and loads acting on tapered members were converted by the processes employed in CUFRAM to fixed end forces which were applied to the STRUDL model as equivalent joint loads.

Interpretation of Results

4. With due regard to the sign conventions employed by the two programs, joint displacements, pile head forces, and member end forces for prismatic members with uniform loads may be compared directly. For members with nonuniform loads and for tapered members, fixed end forces must be added to the member end forces reported by STRUDL for comparison with CUFRAM results. Figures B1, B2, and B3 show the GTSTRUDL solutions for CUFRAM Examples 1, 2B, and 3.
STRUDL 'CUFRAM' 'GTSTRUDL SOLUTION FOR TYPE 1 MONOLITH'
TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES
$ C U F R A M  M O D E L  J O I N T S
1 0 38 S
2 46.85482 38.46681 0.5
4 44.5 85
5 45.99817 99.30601
$ JOINTS AT ENDS OF FLEXIBLE LENGTHS
21 43.21871 38
23 50.71871 38.83786
24 47.08485 42.61670
54 44.5 96.07650
$ C U F R A M  M O D E L  M E M B E R S
1 1 21
2 23 3
3 24 4
4 4 54
$ R I G I D  L I N K S
12 21 2
23 2 23
24 2 24
45 54 5
$ M E M B E R  P R O P E R T I E S
1 PRISMATIC AX 12 AY 10 IZ 14
4 PRISMATIC AX 5 AY 4.16667 IZ 10.41667
2 STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 2.99107E8 0 0
ROW 2 2.97866E7 -2.12036E8
ROW 6 0 -2.12036E8 2.71740E9
3 STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.41039E8 0 0
ROW 2 0 2.04180E6 -2.88996E7
ROW 6 0 -2.88996E7 6.91650E8
$ R I G I D  L I N K S
12 23 24 45 PRISMATIC AX 5000 IZ 7.0E4
$ C O N S T A N T S 4.32E8
$ C O N S T A N T S 1.80E8
LOADING 1
$ M E M B E R  U N I F O R M  L O A D S
MEMBER 1 LOADS FORCE Y UNIFORM W 718.96431 LA 0 LB 42
$ J O I N T  L O A D S
$ F O R C E S  O N  R I G I D  B L O C K S
2 FORCE X -7.24510E3 Y 3.99060E4 MOMENT Z -3.27413E4
5 FORCE X -9.15000E3
23 FORCE X -5.36059E3 Y 2.82199E3 MOMENT Z 3.84311E3
3 FORCE X -2.67843E4 Y -2.03241E3 MOMENT Z 4.38534E3
24 FORCE X 1.60521E4 Y -3.08778E4 MOMENT Z -1.36362E5
4 FORCE X 2.48555E4 Y -2.78787E4 MOMENT Z 1.53179E5
54 FORCE X 8.13837E2 Y -3.38555E3 MOMENT Z 2.15505E3

Figure B1. GTSTRUDL solution for CUFRAM Example 1--type 1 monolith (Continued)
LOADING LIST ALL
STIFFNESS ANALYSIS
$ CUFRAM MODEL JOINTS
LIST DISPLACEMENTS JOINTS 2 3 4 5

*******************************
*RESULTS OF LATEST ANALYSES*
*******************************

PROBLEM - CUEXI  TITLE - GTSTRUDL SOLUTION FOR TYPE 1 MONOLITH
ACTIVE UNITS FEET LB RAD DEGF SEC

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$ CUFRAM MODEL MEMBERS
LIST FORCES MEMBERS 1 2 3 4

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FINISH

Figure B1. (Concluded)
STRUDL 'EX2B' 'GTSTRUDL SOLUTION FOR TYPE 2 MONOLITH'

TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES

$ $ RIGHTSIDE CUFRAM MODEL JOINTS
$ $
1 0 19
'R2' 10 19
'R3' 20 19
'R4' 30 19
'R5' 40 19
'R6' 46 19 $ RIGID BLOCK 2
'R65' 42 19
'R67' 50 18
'R98' 62 18
'R99' 64 18 $ RIGID BLOCK 1
'R10' 63.94286 35.19286 $ RIGID BLOCK 4
'R100' 62 35.375
'R101' 62 35.375
'R1011' 62 35.375
'R1012' 46 23
'R106' 46 33
'R110' 50 38.5
'R1110' 50 38.5
'R1112' 46 40
'R1312' 44 65.5
$ $ RIGHTSIDE JOINTS AT ENDS OF FLEXIBLE LENGTHS
$ $
'R65' 42 19
'R67' 50 18
'R98' 62 18
'R99' 64 18 $ RIGID BLOCK 1
'R10' 63.94286 35.19286 $ RIGID BLOCK 4
'R11' 46 36.5 $ RIGID BLOCK 3
'R112' 46 40
'R1312' 44 65.5
$ $ RIGHTSIDE JOINTS AT BOTTOM OF PILES (FICTITIOUS)
$ $
'BP19' 0 15
'RBP2' 10 15
'RBP310' 20 15
'RBP4' 30 15
'RBP511' 40 15
'RBP12' 45 15
'RBP613' 50 15
'RBP714' 55 15
'RBP8' 60 15
$ $ VERTICAL PILES
$ $
'PB19' 0 10 S
'RBP2' 10 10 S
'RBP310' 20 10 S
'RBP4' 30 10 S

Figure B2. GTSTRUDL solution for CUFRAM Example 2B--type 2 monolith with pile supports (Sheet 1 of 9)
Battered Piles

Leftside Cufram Model Joints

Leftside Joints at Ends of Flexible Lengths

Leftside Joints on Base at Pile Heads

Leftside Joints at Bottoms of Piles (Fictitious)

Vertical Piles

Figure B2. (Sheet 2 of 9)
$\text{BATTERED PILES}$

'LPB6' -50 10 S
'LPB7' -55 10 S
'LPB8' -60 10 S

$\text{MEMBER INCIDENCES}$

$\text{RIGHTSIDE CUFRAH MODEL MEMBERS}$
'R1' 1 'R2'
'R2' 'R2' 'R3'
'R3' 'R3' 'R4'
'R4' 'R4' 'R5'
'R5' 'R5' 'R65'
'R6' 'R67' 'R7'
'R7' 'R7' 'R8'
'R8' 'R8' 'R98'
'R9' 'R910' 'R109'
'R10' 'R611' 'R118'
'R11' 'R1110' 'R1011'
'R12' 'R1112' 'R12'
'R13' 'R12' 'R1312'

$\text{RIGHTSIDE RIGID LINKS AT RIGID BLOCKS}$
'RL56' 'R65' 'R6'
'RL67' 'R6' 'R67'
'RL69' 'R98' 'R9'
'RL910' 'R9' 'R910'
'RL109' 'R109' 'R10'
'RL611' 'R6' 'R811'
'RL116' 'R116' 'R11'
'RL1110' 'R11' 'R1110'
'RL1011' 'R1011' 'R10'
'RL1112' 'R11' 'R1112'
'RL1213' 'R1312' 'R13'

$\text{RIGHTSIDE RIGID LINKS AT PILE HEADS}$
'LP19' 1 'BP19'
'RLP2' 'R2' 'RBP2'
'RLP310' 'R3' 'RBP310'
'RLP4' 'R4' 'RBP4'
'RLP511' 'R5' 'RBP511'
'RLP12' 'R6' 'RBP12'
'RLP613' 'R6' 'RBP613'
'RLP714' 'R7' 'RBP714'
'RLP8' 'R8' 'RBP8'

$\text{RIGHTSIDE PILES (FICTITIOUS)}$

$\text{VERTICAL PILES}$
'P1' 'BP19' 'BP19'
'RP2' 'RBP2' 'RBP2'
'RP3' 'RBP310' 'RBP310'
'RP4' 'RBP4' 'RBP4'
'RP5' 'RBP5' 'RBP511'
'RP6' 'RBP6' 'RBP613'

Figure B2. (Sheet 3 of 9)
Figure B2. (Sheet 4 of 9)
$ \text{BATTERED PILES}$

$ \text{LP5}' 'LPB5' 'LBP5ii$

$ \text{LP6}' 'LPB6' 'LBP6i3$

$ \text{LP7}' 'LPB7' 'LBP7i4$

$ \text{LP8}' 'LPB8' 'LBP8$

$ \text{LP10}' 'LPB310' 'LBP310'$

$ \text{MEMBER PROPERTIES}$

$ \text{CUFRA M MODEL PRISMATIC MEMBERS}$

$ \text{R1}' 'R2' 'R3' 'R4' 'R5' 'R10' 'L1' 'L2' 'L3' 'L4' 'L5' 'L10'$

$ \text{PRISMATIC AX 48 AY 40 IZ 256}$

$ \text{R6}' 'R7' 'R8' 'L6' 'L7' 'L8' \text{PRISMATIC AX 36 AY 30 IZ 108}$

$ \text{R9}' 'L9' 'R13' 'L13' \text{PRISMATIC AX 24 AY 20 IZ 32}$

$ \text{CUFRA M TAPERED MEMBERS}$

$ \text{R11}' 'L11' \text{STIFFNESS MATRIX COLUMNS 1 2 6}$

$ \text{ROW 1} 1.81609E9 0 0$

$ \text{ROW 2} 0 1.75000E8 -8.52658E8$

$ \text{ROW 6} 0 -8.52658E8 7.52690E9$

$ \text{R12}' 'L12' \text{STIFFNESS MATRIX COLUMNS 1 2 6}$

$ \text{ROW 1} 1.83934E9 0 0$

$ \text{ROW 2} 0 9.68873E7 -5.04735E8$

$ \text{ROW 6} 0 -5.04735E8 4.98818E9$

$ \text{RIGID LINKS}$

$ \text{RL56'} 'RL7' 'RL89' 'RL910' 'RL109' 'RL611' 'RL110' 'RL1011' 'RL1102' 'RL1213' 'LL56' 'LL67' 'LL89' 'LL910' 'LL109' 'LL611' 'LL116' 'LL110' 'LL1110' 'LL1112' 'LL1112' 'LL1213' 'LP19' 'RLP2' 'RLP310' 'RLP4'$

$ \text{RLP511'} 'RLP12' 'RLP613' 'RLP714' 'RLP8' 'LLP2' 'LLP310' 'LLP4' 'LLP511' 'LLP12' 'LLP613' 'LLP714' 'LLP8' \text{PRISMATIC AX 2.4E IZ 1.5}$

$ \text{PILES}$

$ \text{P1}' 'RP2' 'RP3' 'RP4' 'RP5' 'RP6' 'RP7' 'RP8' 'RP9' 'RP10' 'RP11'$

$ \text{RP12}' 'RP13' 'RP14' 'RP2' 'RP3' 'RP4' 'RP5' 'RP6' 'RP7' 'RP8'$

$ \text{LP10}' 'LP11' 'LP12' 'LP13' 'LP14' \text{STIFFNESS MATRIX COLUMNS 1 2 6}$

$ \text{ROW 1} 1.7928E7 0 0$

$ \text{ROW 2} 0 2.6532E5 0$

$ \text{ROW 6} 0 0 0$

$ \text{CONSTANTS E 4.32E8 ALL}$

$ \text{CONSTANTS G 1.6E8 ALL}$

$ \text{LOADING}$

$ \text{JOINT LOADS}$

$ \text{LOADS ON RIGHTSIDE RIGID BLOCKS}$

$ \text{R6}' \text{FORCE X} -1.72500E4 \text{Y} 8.34000E4 \text{MOMENT Z} 5.15000E4$

$ \text{R9}' \text{FORCE X} -1.74830E5 \text{Y} 4.89000E4 \text{MOMENT Z} -1.06056E4$

$ \text{R10}' \text{FORCE X} -8.97800E4 \text{Y} -1.11276E5 \text{MOMENT Z} 4.90002E3$

$ \text{R11}' \text{FORCE X} 4.85625E4 \text{Y} -5.04000E4 \text{MOMENT Z} 1.07187E4$

$ \text{R13}' \text{FORCE X} -1.04469E4 \text{Y} -5.75143E4 \text{MOMENT Z} -6.95503E3$

$ \text{LOADS ON LEFTSIDE RIGID BLOCKS}$

$ \text{L6}' \text{FORCE X} 1.72500E4 \text{Y} 8.34000E4 \text{MOMENT Z} -5.15000E4$

$ \text{L9}' \text{FORCE X} 1.48478E5 \text{Y} 4.89000E4 \text{MOMENT Z} 1.06056E4$

$ \text{L10}' \text{FORCE X} 6.89180E4 \text{Y} -8.19960E4 \text{MOMENT Z} -2.77329E3$

$ \text{L11}' \text{FORCE X} -4.85625E4 \text{Y} -5.04000E4 \text{MOMENT Z} -1.07187E4$

Figure B2. (Sheet 5 of 9)
'L13' FORCE
   $ Y - 6.60375E4$

$ EQUIVALENT JOINT LOADS FOR MEMBER LOADS ON TAPERED MEMBERS
   AND NONUNIFORM MEMBER LOADS$

$ RIGHTSIDE
   'R910' FORCE X -1.05598E5 Y -2.16000E4 MOMENT Z  2.08112E5
   'R111' FORCE X -1.83251E4 Y -1.31798E5 MOMENT Z  2.83101E5
   'R1110' FORCE X -1.95624E4 Y -1.51055E5 MOMENT Z -2.84064E5
   'R1112' FORCE X -8.69417E4 Y -8.46301E4 MOMENT Z  1.87429E5
   'R12'  FORCE X -7.74878E4 Y -6.22180E4 MOMENT Z -1.33959E5
   'R1312' FORCE X -1.65961E4 Y -1.80000E4 MOMENT Z -3.14842E4

$ LEFTSIDE
   'L910' FORCE X 7.92641E4 Y -2.16000E4 MOMENT Z -1.55408E5
   'L109' FORCE X 7.30771E4 Y -2.16000E4 MOMENT Z  1.49239E5
   'L1011' FORCE X 1.36089E4 Y -9.02758E4 MOMENT Z -1.95281E5
   'L1110' FORCE X 1.43966E4 Y -1.04736E5 MOMENT Z  1.96224E5
   'L1112' FORCE X 4.73295E4 Y -8.92708E4 MOMENT Z -9.94373E4
   'L12'  FORCE X 2.78277E4 Y -6.82972E4 MOMENT Z  6.03831E4
   'L1312' FORCE X 4.95298E2 Y -1.80000E4 MOMENT Z  1.46978E3

$ MEMBER LOADS

$ 'R1' 'R2' 'R3' 'R4' 'R5' -
   FORCE Y UNIFORM W -1575
   'L1' 'L2' 'L3' 'L4' 'L5' FORCE Y UNIFORM W -1575
   'R6' 'R7' 'R8' FORCE Y UNIFORM W 3225
   'L6' 'L7' 'L8' FORCE Y UNIFORM W 3225
   'R10' 'L10' FORCE X UNIFORM W -7200
   'R10' FORCE Y UNIFORM W -3750
   'L10' FORCE Y UNIFORM W 3750

$ LOADING LIST ALL
STIFFNESS ANALYSIS

Figure B2. (Sheet 6 of 9)
**RESULTS OF LATEST ANALYSES**

**PROBLEM - EX2B**  
**TITLE - GTSTRUDL SOLUTION FOR TYPE 2 MONOLITH**  
**ACTIVE UNITS - FEET LB RAD DEGF SEC**

$\text{RIGHTSIDE CUFRAM MODEL JOINT DISPLACEMENTS}$

List Displacements Joints -  
1 'R2' 'R3' 'R4' 'R5' 'R6' 'R7' 'R8' 'R9' 'R10' 'R11' 'R12' 'R13'

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$\text{LEFTSIDE CUFRAM MODEL JOINT DISPLACEMENTS}$

List Displacements Joints -  
1 'L2' 'L3' 'L4' 'L5' 'L6' 'L7' 'L8' 'L9' 'L10' 'L11' 'L12' 'L13'

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Figure B2. (Sheet 7 of 9)
RIGHTSIDE CUFRAM MODEL MEMBER END FORCES

LIST FORCES MEMBERS 'R1' 'R2' 'R3' 'R4' 'R5' 'R6' 'R7' 'R8' 'R9' -
'R10' 'R11' 'R12' 'R13' 'P1' 'RP2' 'RP3' 'RP4' 'RP5' 'RP6' 'RP7' -
'RP8' 'RP9' 'RP10' 'RP11' 'RP12' 'RP13' 'RP14'

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<th>BENDING Z</th>
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Figure B2. (Sheet 8 of 9)
# LEFTSIDE CUFRAM MODEL MEMBER END FORCES AND LEFTSIDE PILE FORCES

**LIST FORCES MEMBERS**

- 'L1' 'L2' 'L3' 'L4' 'L5' 'L6' 'L7' 'L8' 'L9' 'L10' 'L11' 'L12' 'L13' 'P1' 'LP2' 'LP3' 'LP4' 'LP5' 'LP6' 'LP7' 'LP8' 'LP9' 'LP10' 'LP11' 'LP12' 'LP13' 'LP14'

## MEMBERS

- 'L1'
- 'L2'
- 'L3'
- 'L4'
- 'L5'
- 'L6'
- 'L7'
- 'L8'
- 'L9'
- 'L10'
- 'L11'
- 'L12'
- 'L13'
- 'P1'
- 'LP2'
- 'LP3'
- 'LP4'
- 'LP5'
- 'LP6'
- 'LP7'
- 'LP8'
- 'LP9'
- 'LP10'
- 'LP11'
- 'LP12'
- 'LP13'
- 'LP14'

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<th>AXIAL</th>
<th>SHEAR Y</th>
<th>BENDING Z</th>
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**LEFTSIDE PILE FORCES**

- P1
- LP2
- LP3
- LP4
- LP5
- LP6
- LP7
- LP8
- LP9
- LP10
- LP11
- LP12
- LP13
- LP14

| P1    | BPI9    | -23469.3474605 | 4191.1187096 | 0.0000000 |
| LP2   | LBP2    | -16616.6801764 | 4057.2375503 | 0.0000000 |
| LP3   | LBP310  | -17953.107162  | 89604.8739981 | 0.0000000 |
| LP4   | LBP4    | -23289.8416128 | 3575.5091319 | 0.0000000 |
| LP5   | LBP511  | -25242.1847776 | 3846.4792269 | 0.0000000 |
| LP6   | LBP613  | -19223.3059603 | 3553.2166920 | 0.0000000 |
| LP7   | LBP714  | -14852.035814  | 3553.2166920 | 0.0000000 |
| LP8   | LBP8    | -12840.2319136 | 3553.2166920 | 0.0000000 |
| LP9   | LBP9    | -23469.3474605 | 4191.1187096 | 0.0000000 |
| LP10  | LBP10   | -17953.107162  | 89604.8739981 | 0.0000000 |
| LP11  | LBP11   | -106157.210584 | 3553.2166920 | 0.0000000 |
| LP12  | LBP12   | -104013.092090 | 3553.2166920 | 0.0000000 |
| LP13  | LBP13   | -100591.190808 | 3553.2166920 | 0.0000000 |
| LP14  | LBP14   | -95775.618043  | 3553.2166920 | 0.0000000 |

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Figure B2. (Sheet 9 of 9)

B12
STRU DL 'CUX3' 'GTSTRU DL SOLUTION FOR TYPE 31 MONOLITH'
TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES
$ CUF R A M MODEL JOINTS
1 0 367
2 5.5 367
3 11 367
4 16.5 367
5 22 367
6 27.5 367
7 33 367
8 38.5 367
9 44 367
10 50.5 367
11 55 367
12 59.04 367 $ R I G I D B L O C K 2$
13 64 367
14 68.5 367
15 73 367
16 77.5 367
17 83.875 366 $ R I G I D B L O C K 1$
18 83.875 394.5 $ R I G I D B L O C K 4$
19 86.21 432 $ R I G I D B L O C K 6$
20 59.04 394.5 $ R I G I D B L O C K 3$
21 57.54 432 $ R I G I D B L O C K 5$
$ J O I N T S A T E N D S O F F L E X I B L E L E N G T H S$
1211 59.04 367
1213 63.04 366
1214 68.5 366
1215 73 366
1216 77.5 366
1217 83.875 366 $ R I G I D B L O C K 1$
1218 83.875 394.5 $ R I G I D B L O C K 4$
1219 86.21 432 $ R I G I D B L O C K 6$
1220 59.04 394.5
2012 59.04 392
2018 63.04 394.5
2020 79.04 394.5
2021 57.54 397
2120 57.54 429.5
2119 60.04 432
1921 63.71 432
$ J O I N T S O N B A S E A T P I L E H E A D S$
'B P 12 ' 0 358
'B P 2 2 ' 5.5 358
'B P 3 2 ' 11 358
'B P 4 2 ' 16.5 358
'B P 5 2 ' 22 358
'B P 6 ' 27.5 358
'B P 6 ' 33 358
'B P 7 ' 36.5 358
'B P 7 ' 44 358
'B P 8 ' 50.5 358
'B P 8 ' 55 358
'B P 8 ' 59.5 358

Figure B3. GTSTRU DL solution for CUF R A M Example 3--type 31 monolith with pile supports (Sheet 1 of 7)
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$ \text{JOINTS AT BOTTOMS OF PILES (FICTITIOUS)}$

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JOINT 1 RELEASING FORCE Y MEMBER INCIDENCES

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$ \text{RIGID LINKS AT RIGID BLOCKS}$

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1918 1918 19
1220 12 1220
2012 2012 20
2021 20 2021
2120 2120 21
2180 20 2180
2119 21 2119
1921 1921 19

$RIGID\ HEADS$ AT PILE HEADS

$S RIGID\ LINKS,$ AT PILE HEADS

Figure B3. (Sheet 3 of 7)
PROPERTIES

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PRISMATIC

AY
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PRISMATIC

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PRISMATIC

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PRISMATIC

AY
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S

RIGID LINKS

1112
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S

PILES

P2
P3
P4

S

LOADS

ON RIGID BLOCKS

12
17
18
19
20
21

STIFFNESS MATRIX

COLUMNS

1
2
6

ROW

1
2
6

ROW

2
6

ROW

2
6

CONSTANTS

E 32E8 ALL

LOADING

1

JOINT LOADS

$ LOADS ON RIGID BLOCKS

12
17
18
19
21

$ EQUIVALENT JOINT LOADS FOR NONUNIFORM MEMBER LOADS

1718
1817
1819
1918
1917
1916

MEMBER LOADS

$ UNIFORM MEMBER LOADS

1
1
1
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1
1

LOADING

LIST

STIFFNESS ANALYSIS

Figure B3. (Sheet 4 of 7)
### RESULTS OF LATEST ANALYSES

**PROBLEM** - CUX3  
**TITLE** - GTSTRUDL SOLUTION FOR TYPE 31 MONOLITH  
**ACTIVE UNITS** FEET LB RAD DEG SEC  

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Figure B3. (Sheet 6 of 7)
### PILES

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Figure B3. (Sheet 7 of 7)

B19
APPENDIX C: NOTATION

A  Pile cross-sectional area
AC Allowable pile axial compression force (KIPS)
AM Allowable bending moment (KIP-FT)
AT Allowable pile axial tension force (KIPS)
ACC Allowable pile axial compression force for combined axial compression and bending (KIPS)
ATT Allowable pile axial tension force for combined axial tension and bending (KIPS)
A_x Cross-sectional area at x
A_v Shear area at v
BATTER Slope of pile vertical (FT) per foot horizontal
BM Bending moment at pile head for nonpinned head piles FPM*FV where FV = pile head shear for pinned head piles
BPR(i) Base soil pressure (PSF) at i th pressure point
B_{11} Pile lateral stiffness (LB/IN.)
B_{22} Pile axial stiffness (LB/IN.)
B_{33} Pile moment stiffness (LB/IN.)
B_{13} Lateral force-moment coupling stiffness (LB)
CULHGT Height of culvert opening
CULWID Width of culvert opening
[CULFIL] Width of 45-deg fillet in culvert corners
c_x Cosine of angle between local x and global x
c_y Cosine of angle between local x and global y
c_\alpha Cosine of \alpha

* The terms "rightside," leftside," and "centerline" are each used in a one-word form in the Notation to be consistent with these terms as used in the computer program.
\( d_L, d_R \) Distances from chamber centerline* to line of action of leftside* and rightside* vertical shear forces

\( D \) 6x6 rigid link transformation matrix

\( D_f \) Pile head fixity coefficient

\( D_i \) Horizontal distance from stem face

\( \text{ DBASE}(1) \) Distance from chamber centerline to first base point

[\( \text{ DBASE}(2), \text{ ELBASE}(2) \)] Distance from chamber centerline to second base point and elevation at second base point

\( \text{ DBPR}(I) \) Distance (FT) from chamber centerline to \( i^{th} \) pressure point

\( \text{ DCUL} \) Distance from inside stem face to interior vertical side of culvert

\( \text{ DSTART} \) Distance from chamber centerline to intersection of pile centerline with base of structure (FT)

\( \text{ DSTEM} \) Distance from inside face of stem to \( i^{th} \) stem point

[\( \text{ DSTEP} \)] Distance between adjacent piles in the sequence (FT)

\( \text{ DUPR}(I) \) Distance (FT) from chamber centerline to \( i^{th} \) pressure point

\( \text{ DVOID} \) Distance from inside stem face to interior vertical

\( \text{ DCFBLD} \) Distance from chamber centerline at which load acts (FT)

\( \text{ DCSTLD} \) Distance from inside stem face at which load acts (FT)

\( \text{ DDFBLD}(I) \) Distance from chamber centerline to \( i^{th} \) load point (FT)

\( \text{ DDSSTLD}(I) \) Distance from inside stem face to \( i^{th} \) load point (FT)

\( E \) Modulus of elasticity of pile material

\( E_i \) Elevation for \( i^{th} \) stem point

\( \text{ EC} \) Modulus of elasticity of concrete

\( \text{ ELPR}(I) \) Elevation (FT) of \( i^{th} \) pressure point

[\( \text{ ELGW} \)] Elevation (FT) of ground-water surface

\( \text{ ELCUL} \) Elevation of floor of culvert

\( \text{ ELLAY} \) Elevation (FT) at top of layer

\( \text{ ELTIE} \) Elevation at top of \( i^{th} \) tie member

C2
ELCHMW  Elevation of chamber water
EHSPR(I)  Effective horizontal soil pressure (PSF) at i_th pressure point
ESSPR(I)  Effective soil shear stress (PSF) at i_th pressure point
EVSPR(I)  Effective vertical soil pressure (PSF) at i_th pressure point
[ELCWL]  Effective water elevation in leftside culvert (and stem void) (FT)
[ELCWR]  Effective water elevation in rightside culvert (and stem void) (FT)
ELVOID  Elevation of bottom of void opening
ELCSLD(I)  Elevation at which load acts (FT)
ELDSLD(I)  Elevation at load point (FT)
ELFLOR  Elevation of chamber floor
ELSTEM(I)  Elevation at i_th stem point (FT)
ELWPRE(I)  Elevation (FT) at i_th pressure point
[ELSURW]  Elevation (FT) of surcharge water surface

\( f_{xp} \)  Pile head shear force

\( f_{yp} \)  Pile head axial force

\( \mathbf{F} \)  3nx1 vector of loads applied directly to the joints including the static equivalents of surface loads acting on the rigid blocks and necessary equilibrants of unbalanced vertical and/or moment resultants arising from user-supplied soil base pressure

\( \mathbf{F}_{ab} \)  6x1 vector of global force components at a and b

\( \mathbf{F}_e \)  3nx1 vector of fixed end forces

\( \mathbf{F}_{eab} \)  6x1 vector of fixed end forces at ends of the flexible length in local coordinate directions

\( \mathbf{F}_{eij} \)  6x1 vector of fixed end forces at joints i and j in global coordinate directions

[FLRFIL]  Width of 45-deg fillet at floor-stem intersection

FLRWID  Distance from chamber centerline to inside face of stem
FMM  Moment magnification factor for amplification effect of axial compression on bending moment
FPM  Factor (IN.) for evaluating maximum bending moment in pinned head pile
G    Shear modulus
GAMMST Moist soil unit weight
GAMSAT Saturated soil unit weight
[GAMWAT] Unit weight of water (PCF)
HCFBLD Magnitude of horizontal load component (PLF)
HCSTLD Magnitude of horizontal load component (PLF)
HCSLD(I) Magnitude of horizontal load component (PLF)
HDSLD(I) Magnitude of horizontal load at \( i^{th} \) load point (PSF)
HDFBDL(I) Magnitude of horizontal load at \( i^{th} \) load point (PSF)
HDSTLD(I) Magnitude of horizontal load at \( i^{th} \) load point (PLF)
HTIE(I) Depth of \( i^{th} \) tie member
I    Pile cross-sectional moment of inertia
\( I_\xi \) Cross-sectional moment of inertia at \( \xi \)
\( k \) Global stiffness matrix
\( k' \) Local stiffness matrix
\( k_A \) Axial stiffness coefficient
KHB, KHT Horizontal pressure coefficients at bottom and top of layer, respectively
KVB, KVT Shear coefficients at bottom and top of layer, respectively
L    Width of structure base
L    Pile length
M_p  Pile head moment
M_1  Moment resultant about chamber floor centerline
M_3  Unbalanced moment
\[ M_\xi \] Bending moment at \( \xi \)

NLDS Number (1 to 10) of concentrated loads

NPTS Number (2 to 21) of points on input pressure distribution

NSTART Pile number at start of sequence

[NSTEP] Step in pile number

[NSTOP] Pile number of last pile in sequence

NTIES Number (0 to 5) of horizontal structural members across void opening

NUM Number (1 to 5) of horizontal soil layers of 'type' = 'Soil'

OSFC Load case factor for pile in compression

OSFT Load case factor for pile in tension

\( P_{\text{actual}} \) Adjusted base pressure

\( P_{\text{input}} \) User-specified pressure

\( p_u \) Uniform base pressure

\( p_x \) Pressure due to unbalanced moment

\( p_1 \) Base pressure at chamber centerline

\( p_2 \) Base pressure at extreme edge of base

\( P_A \) Pile cross-sectional area (IN.\(^2\))

PAXCO Coefficient for pile axial stiffness

PCT Fraction of uniform base reaction to be applied at chamber centerline

PE Pile modulus of elasticity (PSI)

PI Pile moment of inertia (IN.\(^4\))

PL Pile length (FT)

PR Poisson's ratio for concrete

\( P_\xi \) Actual stress resultant at \( \xi \)

R Factor prescribed by user

\( R \) Transformation matrix
\( \mathbf{E}^T \) Transpose of \( \mathbf{E} \)

\([\text{RLF}]\) Rigid block reduction factor for member flexible length
\((0 \leq \text{RLF} \leq 1)\)

\([\text{SCHT, SCHB}]\) Coefficient for horizontal soil pressure at top and bottom of layer

\([\text{SCVT, SCVB}]\) Coefficient for soil shear stress at top and bottom of layer

\([\text{SURCH}]\) Surface surcharge load

\( S_1, S_2 \) Soil stiffness coefficients for lateral resistance

\( S_\alpha \) Sine of \( \alpha \)

\( SS_1 \) Constant soil stiffness coefficient \((\text{LB/IN.}^2)\)

\( SS_2 \) Linear soil stiffness coefficient \((\text{LB/IN.}^3)\)

\( u, v, p \) Translation components of displacement perpendicular and parallel to the pile axis

\( \mathbf{U} \) 3nx1 vector of joint displacements

\( \mathbf{U}_{ab} \) 6x1 vector of global displacement components at \( a \) and \( b \)

\([\text{UPLEFT}]\) Effective uplift water elevation at extreme leftside of base \((\text{FT})\)

\( \text{UPR}(i) \) Uplift pressure \((\text{PSF})\) at \( i^{th} \) pressure point

\([\text{UPRITE}]\) Effective uplift water elevation at extreme rightside of base \((\text{FT})\)

\( V \) Net vertical reaction of applied loads

\( V_u \) Vertical resultant of user-specified base pressure distribution

\( V_R, V_L \) Resultants of vertical stem shear forces

\( V^*, M^* \) Vertical and moment unbalances remaining after combining resultants of applied loads and user-supplied base reaction

\( V\text{CFBLD} \) Magnitude of vertical load component, pounds per linear foot \((\text{PLF})\)

\( V\text{CSLD}(i) \) Magnitude of vertical load component \((\text{PLF})\)

\( V\text{CSTLD}(i) \) Magnitude of vertical load component \((\text{PLF})\)

\( V\text{DFBLD}(i) \) Magnitude of vertical load at \( i^{th} \) load point \((\text{PSF})\)
VDSLD(I)  Magnitude of vertical load at $i^{th}$ load point (PSF)
VDSTLD(I)  Magnitude of vertical load at $i^{th}$ load point (PLF)
VOIDHT  Height of void opening
VOIDWD  Width of void opening
$V_{\xi}$  Shear force at $\xi$
WPRE(I)  Pressure (PSF) at $i^{th}$ pressure point
WTCONC  Unit weight of concrete
$x$  Distance from base centerline, positive to the right
$(y_{MST})(PCF)$  Moist soil unit weight
$(y_{SAT})(PCF)$  Saturated soil unit weight
$\theta_p$  Pile head notation
$\sigma$  +1 for loads on top surface
0 for self weight of member
-1 for loads on bottom surface
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