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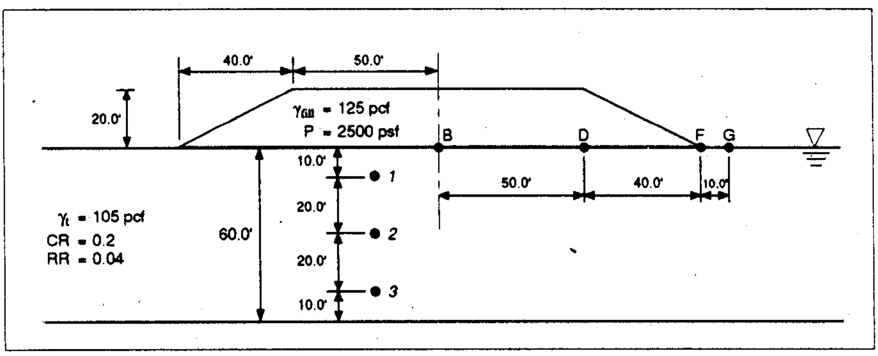
EMBANK

A Microcomputer Program to Determine One-Dimensional Compression Settlement Due to Embankment Loads



User's Manual

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TECHNOLOGY APPLICATIONS

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NOTICE

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16. Abstract

The objective of this report is to introduce a microcomputer program for computing one-dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe & Whitman (1969), Ladd (1973), and Poulos & Davis (1974). For the case of a strip symmetrical vertical embankment loading, the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program internally superimposes a series of 10 rectangular loads to create the end-of-fill condition.

The report presents the equations and analytical procedures utilized by the program and examples of the capabilities of the user-friendly data entry form. The computer program is coded in the Turbo Pascal 4.0 language and takes full advantage of the stand-alone, (single-user) characteristics of the IBM-PC through the use of "friendly" input menus and data-checking routines.

The code implements copyrighted portions of the microcomputer programs SAF-I and STRESS developed by PROTOTYPE Engineering, Inc., Winchester, MA, and uses the screen editor Turbo Magic from Sophisticated Software.

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A Microcomputer Program to Determine One-Dimensional Compression Settlement Due to Embankment Loads

Introduction

An important part of the design of embankment foundations are analyses to predict settlements. When settlements or differential settlements exceed given tolerances, the overall safety and/or functionality of the structures may be endangered.

The objective of this report is to introduce a microcomputer program for computing one-dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe & Whitman (1969), Ladd (1973), and Poulos & Davis (1974). For the case of a strip symmetrical vertical embankment loading, the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program internally superimposes a series of 10 rectangular loads to create the end-of-fill condition.

The report presents the equations and analytical procedures utilized by the program and examples of the capabilities of the user-friendly data entry form. The computer program is coded in the Turbo Pascal 4.0 language and takes full advantage of the stand-alone (single-user) characteristics of the IBM-PC through the use of "friendly" input menus and data-checking routines.

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One-Dimensional Compression

"One-dimensional compression" refers to situations where ground settlement occurs exclusively due to vertical straining of the soil mass, that is, when there are no lateral strains. Geologic processes of uniform loading and/or unloading of large areas of soil are good examples of one-dimensional compression conditions. While these conditions are rarely perfectly encountered, reasonable approximations occur when the foundations are large in relation to the soil thickness or when the points of interest for settlement computations are far from the edges of the loaded areas.

For the most general case of an elastic medium of finite thickness H, as depicted in figure 1, the vertical deformation of an element at a distance z under the surface is given by

$$\delta\rho = \varepsilon\,(z)\;\delta z \qquad (1)$$

where $\varepsilon(z)$ describes the variation of vertical strain with depth.

The total deformation is given by:

$$\rho = \int_0^H \varepsilon\,(z)\;\delta z \qquad (2)$$

When a discrete variation of vertical strain versus depth can be established and the compressible material can be divided in sublayers, within which the strain levels remain constant, equation [2] becomes

$$\rho = \sum_{i=1}^{n} \Delta H_i = \sum_{i=1}^{n} \varepsilon_i H_i \tag{3}$$

in which:

ΔH_i = thickness change of sublayer i
H_i = initial thickness of sublayer i
ε_i = vertical strain in sublayer i
n = number of sublayers

Equations (1) through (3) are valid for any kind of material where deformation is proportional to strain. In the particular case of soil, which is a multi-phase material, vertical strains under one-dimensional compression conditions are the result of changes in the void ratio (e), so that

$$\varepsilon_i = \frac{\Delta H_i}{H_i} = \frac{\Delta e_i}{1 + e_{0i}} \tag{4}$$

in which:

Δe_i = change in void ratio for sublayer i = $e_{fi} - e_{0i}$
e_{fi} = final void ratio for sublayer i
e_{0i} = initial void ratio for sublayer i

Equation (3) then becomes:

$$\rho = \sum_{i=1}^{n} \Delta H_i = \sum_{i=1}^{n} H_i \frac{\Delta e_i}{1 + e_{0i}} \tag{5}$$

Soil Model

Equations (3) and (5) are valid for estimating one-dimensional compression settlements of any kind of soil, cohesive or cohesionless, provided a relationship between stress and strain or void ratio can be established. Such a relationship can be determined by running oedometer tests on representative undisturbed soil samples. Figure 2 (Ladd 1973) shows a typical compression curve from oedometer test results, where values of void ratio are plotted versus vertical effective stress on a semi-log scale. A bilinear model is regularly adopted to approximately represent the void ratio versus vertical effective stress relationship for a loading condition. The linear portions of the model are represented by:

C_c = compression index
C_r = recompression index

For cases of one-dimensional unloading or reduction of vertical effective stresses, the relationship can be represented by a third parameter, C_s = Swelling Index. In most cases the values of C_r and C_s are very similar.

The maximum past pressure, $\bar{\sigma}_{vm}$, can be understood as a "yield stress," which establishes the limit between the recompression and virgin regions. Overconsolidated (OC) soils are those where the in situ overburden effective stress, $\bar{\sigma}_{v0}$, is smaller than $\bar{\sigma}_{vm}$. The ratio

$$\bar{\sigma}_{vm}/\bar{\sigma}_{v0} = OCR$$

is called the Overconsolidation Ratio. For Normally Consolidated (NC) soils, OCR = 1.

Figure 3 (Ladd 1973) shows a compression curve from oedometer test results where values of vertical strain versus vertical effective consolidation stress are plotted on a semi-log scale. In this case the model is described by the Virgin Compression Ratio (CR), the Recompression Ratio (RR), and the Swelling Ratio (SR). The following relationships exist between these parameters and the Virgin Compression, Recompression, and Swelling indices, C_c, C_r, and C_s, respectively,

$$CR = \frac{C_c}{(1+e_0)} \qquad (6a)$$

$$RR = \frac{C_r}{(1+e_0)} \qquad (6b)$$

$$SR = \frac{C_s}{(1+e_0)} \qquad (6c)$$

where e_0 is the initial void ratio.

Determination of Changes in Void Ratio

The values of $\Delta e = e_{fi} - e_{0i}$ to input in equation (5) depend on the final stress level within each sublayer. If $\bar{\sigma}_{vf}$ does not exceed $\bar{\sigma}_{vm}$, the reduction in void ratio for the soil in sublayer i is:

$$\Delta e_i = e_{fi} - e_{0i} = C_r \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}}\right) \qquad (7)$$

If the final stress $\bar{\sigma}_{vf}$ is greater than $\bar{\sigma}_{vm}$, the value of Δe_i is:

$$\Delta e_i = e_{fi} - e_{0i} = C_r \log\left(\frac{\bar{\sigma}_{vm}}{\bar{\sigma}_{v0}}\right) + C_c \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{vm}}\right) \qquad (8)$$

When unloading (reduction of effective stresses) occurs, the void ratio increases and the soil swells. The increment in void ratio is

$$\Delta e_i = e_{fi} - e_{0i} = -C_s \log\left(\frac{\bar{\sigma}_{v1}}{\bar{\sigma}_{v2}}\right) \quad (9)$$

where the difference $\bar{\sigma}_{v2} - \bar{\sigma}_{v1}$ represents the effective stress reduction.

Determination of Vertical Strains

Equation (3) can be used to evaluate the soil deformations. The expressions for vertical strains for a given sublayer can be obtained from equations (4), (6a), and (6b).

When $\bar{\sigma}_{vf}$ does not exceed $\bar{\sigma}_{vm}$, the vertical strain is:

$$\varepsilon_i = RR \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}}\right) \quad (10)$$

If the final stress $\bar{\sigma}_{vf}$ is greater than $\bar{\sigma}_{vm}$, the vertical strain is:

$$\varepsilon_i = RR \log\left(\frac{\bar{\sigma}_{vm}}{\bar{\sigma}_{v0}}\right) + CR \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{vm}}\right) \quad (11)$$

For unloading conditions the vertical strain is

$$\varepsilon_i = -CS \log\left(\frac{\bar{\sigma}_{v1}}{\bar{\sigma}_{v2}}\right) \quad (12)$$

where $\bar{\sigma}_{v2} - \bar{\sigma}_{v1}$ is the reduction in effective stress.

Determination of Vertical Stress

To use equations (6) through (12), the program must compute the increments of vertical stress as a function of depth for the following two types of loads.

Strip Symmetrical Embankment Loading

Poulos and Davis (1974) present an equation for the increment of vertical stresses due to a vertical "embankment" loading on the surface of a semi-infinite mass

$$\sigma_z = \frac{p}{\pi}\left(\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x-b)\right) \qquad (13)$$

where the parameters are defined in figure 4.

For symmetrical embankment loading, the load is divided into two equal vertical embankment components, and the contributions of both are added (see figure 5).

End of Embankment Loading

To compute the increment of vertical stresses due to an end-of-embankment condition, EMBANK superimposes a series of 10 flexible rectangular loads. Figure 6 shows the superposition scheme.

If the end of the embankment is modeled as shown in figure 7a, then the coordinates that determine the size of each of the rectangular loads are given by the expressions in figure 7b. The value $y_{max} = y_1 + 10b_2$ is internally defined in the program.

The user must select the Strip Symmetrical Embankment loading option to compute increments of vertical stress for points beyond $y = y_1 + 5b_2$.

For a rectangular load the increment of vertical stress beneath the corner of the loaded area is (Poulos and Davis 1974)

$$\sigma_z = \frac{p}{2\pi}\left[\arctan\left(\frac{lb}{zR_3}\right) + \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)\right] \qquad (14)$$

where the parameters are defined in figure 8.

Figure 9 shows the application of the superposition principle for points inside and outside rectangular loaded areas. For the end-of-fill condition, a series of similar superposition schemes are applied for each one of the 10 rectangular loads.

Interactive Data Entry and Output Results

Input screens and menus are employed to enter the necessary data for the analysis. An input screen consists of a graphical display defining the data to be entered and an area to query the user for the data. Menus are used to select the entry of optional data and to control program operation. The output of the program is compact but complete. It includes an echo print of the input data (embankment geometry, soil parameters, etc.) and the computed total settlement. The output screens also include distributions of effective, increment, and maximum past pressure stresses and settlement with depth.

Appendix A contains a compilation of all the EMBANK computer screens. Appendix B contains four sample runs with hand computations, showing copies of the actual input screens, menus, and output result screens used by the program for each one of the four examples.

References

Ladd, C.C. (1973), "Estimating Settlement of Structures on Cohesive Soils," Presentation prepared for the Foundations and Soil Mechanics Division of the ASCE, April 9-10, 1973.

Lambe, T.W. and Whitman, R.V. (1969), Soil Mechanics, John Wiley and Sons, New York.

Poulos, H.G. and Davis, E. H. (1978), Elastic Solutions for Soil and Rock Mechanics, John Wiley and Sons, New York.

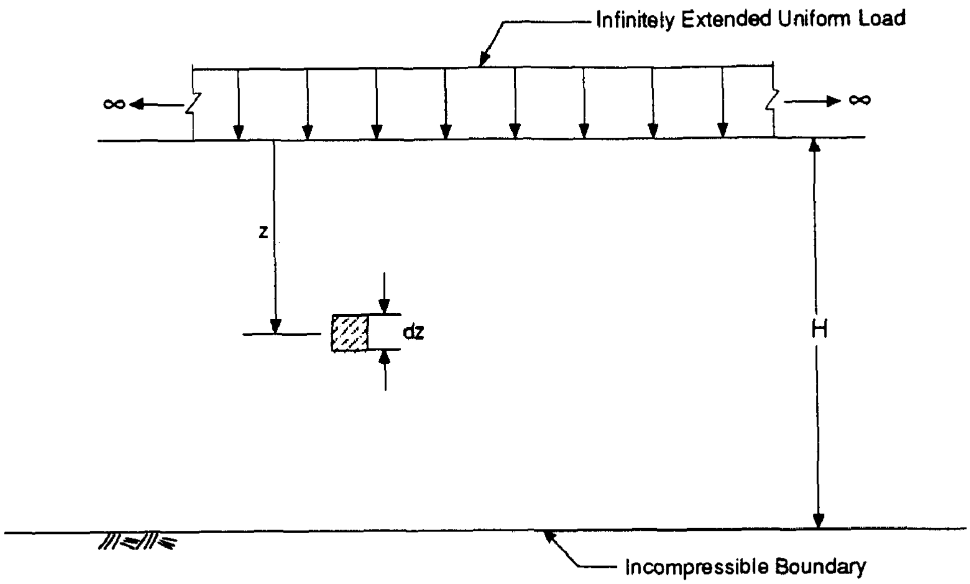


Figure 1. Elastic medium under one-dimensional compression

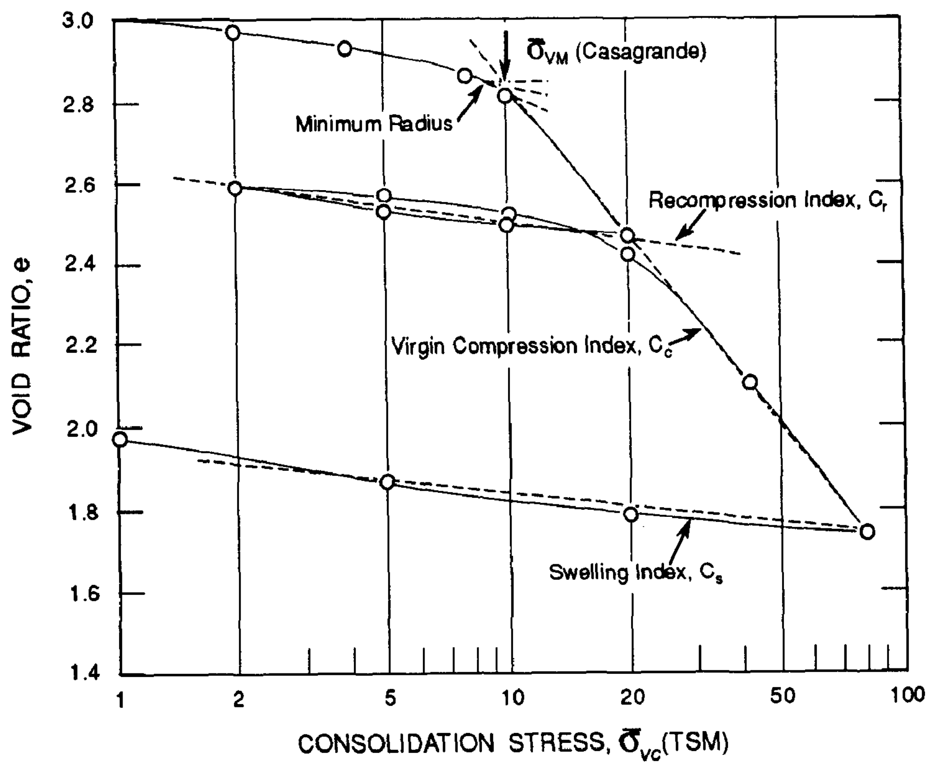


Figure 2. Compression curve and compressibility parameters
void ratio vs. consolidation stress (Ladd 1973)

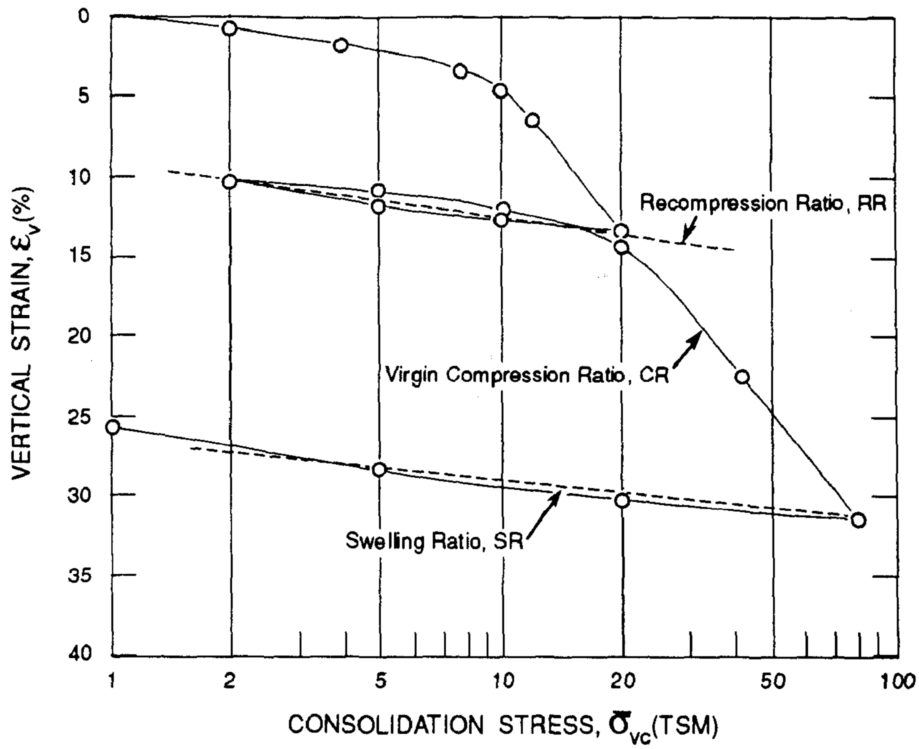


Figure 3. Compression curve and compressibility parameters vertical strain vs. consolidation stress (Ladd 1973)

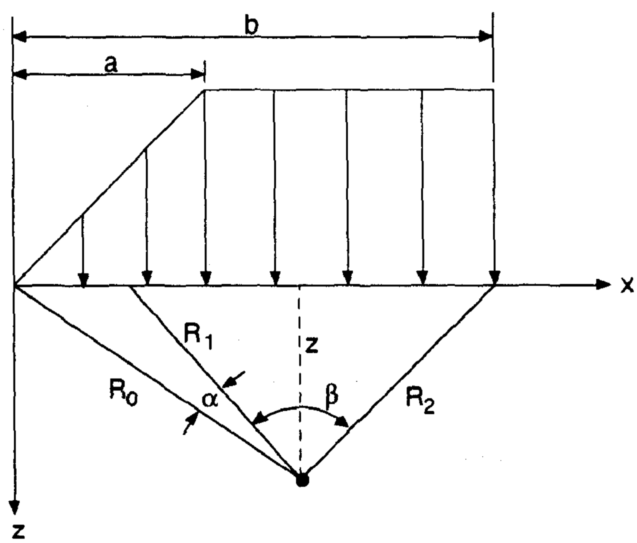


Figure 4. Embankment loading and parameters (Poulos & Davis 1974)

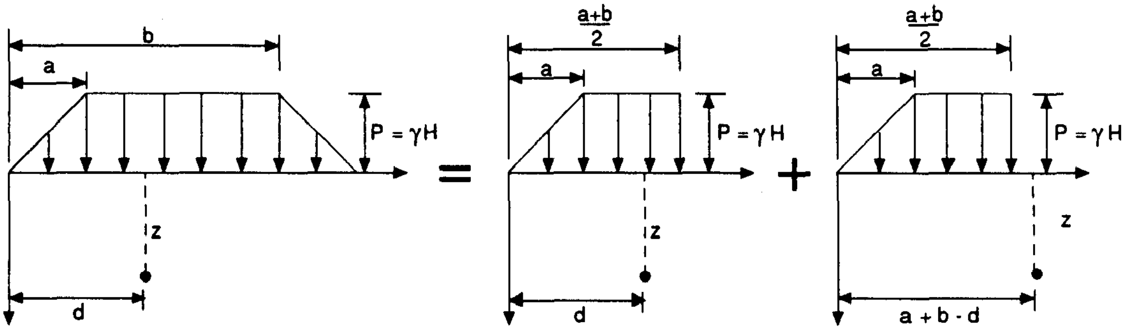


Figure 5. Superposition scheme for symmetrical embankment loading

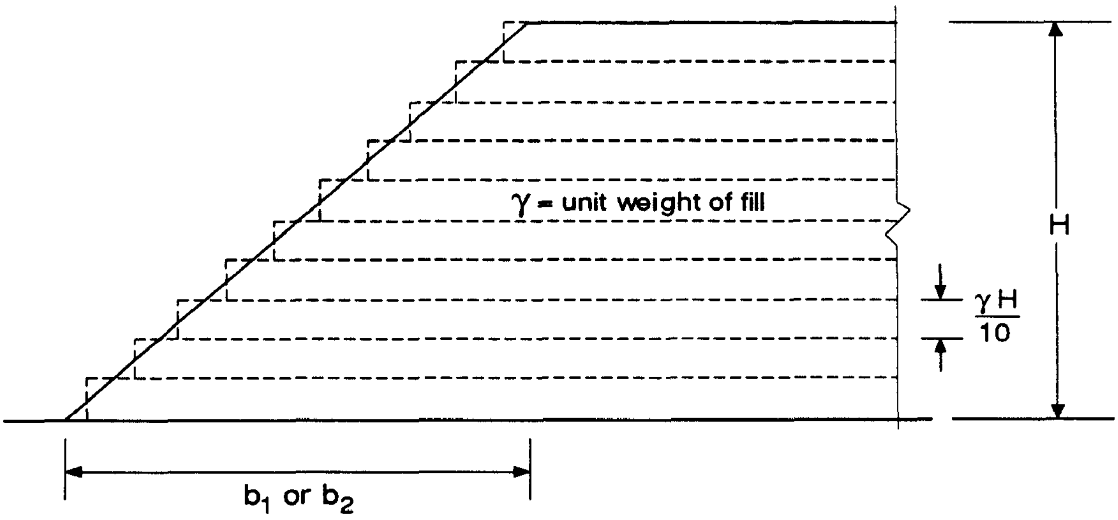


Figure 6. Superposition scheme to model end of embankment loading

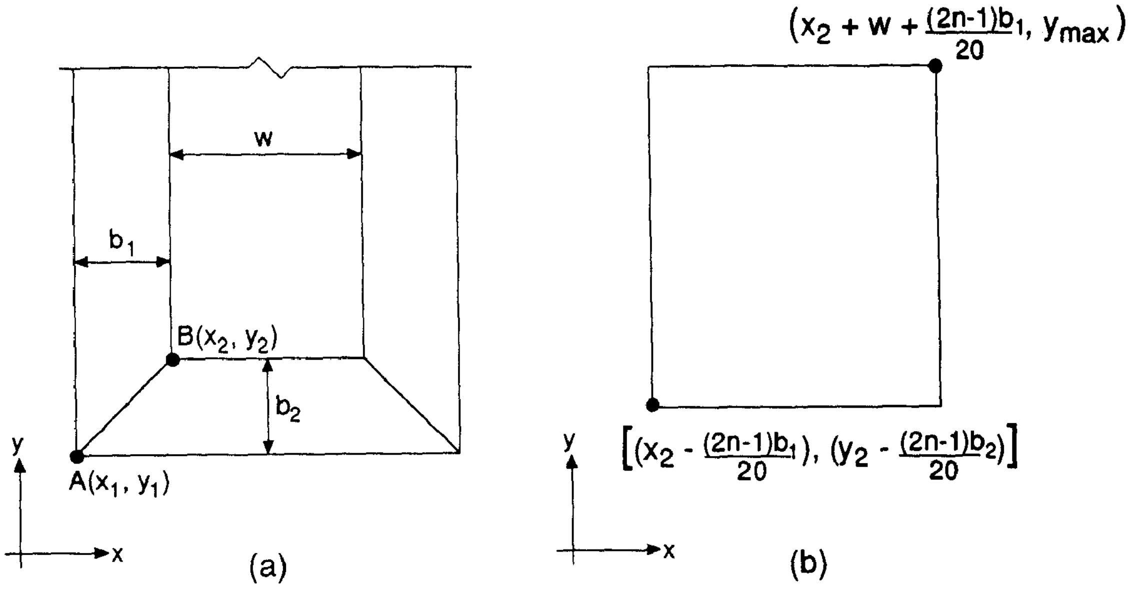


Figure 7. Transformation of end of embankment to equivalent rectangular loads

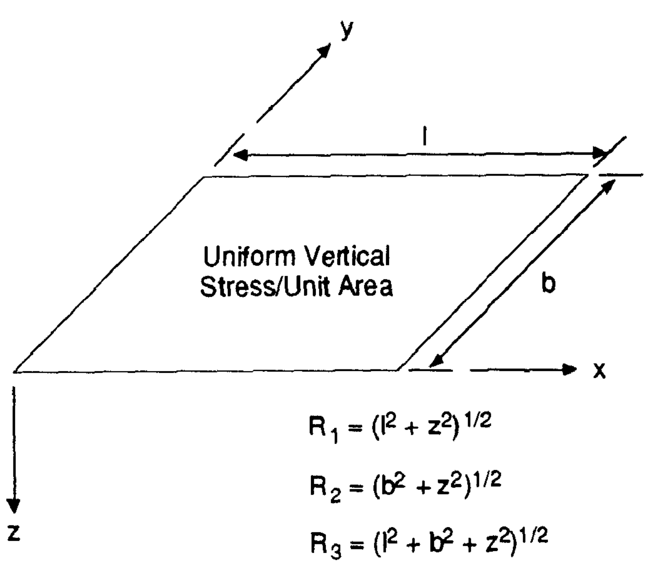
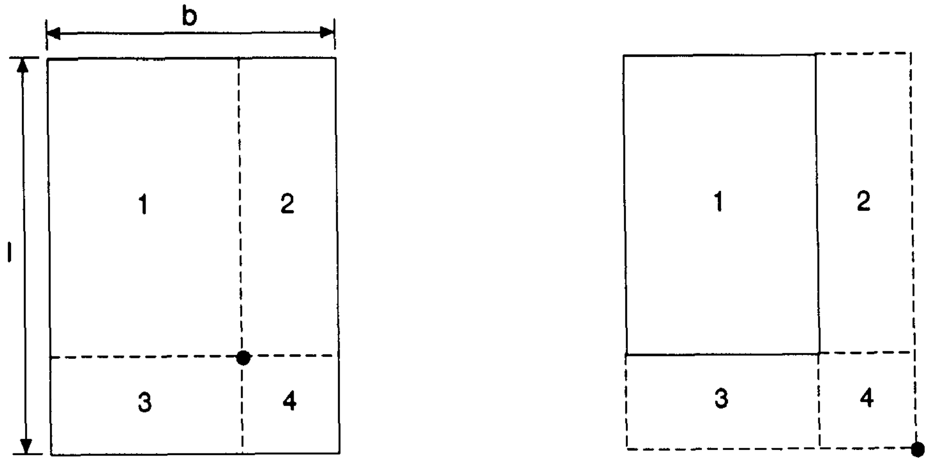


Figure 8. Parameters for the determination of increments of vertical stress under the corner of a rectangular load



$\sigma = p\,(k_1 + k_2 + k_3 + k_4)$

(a) Interior Point

$\sigma = p\,(k_{1+2+3+4} - k_{2+4} - k_{3+4} + k_4)$

(b) Exterior Point

Figure 9. Superposition scheme to determine increments of vertical stress at any point under a rectangular load

Appendix A

Appendix A

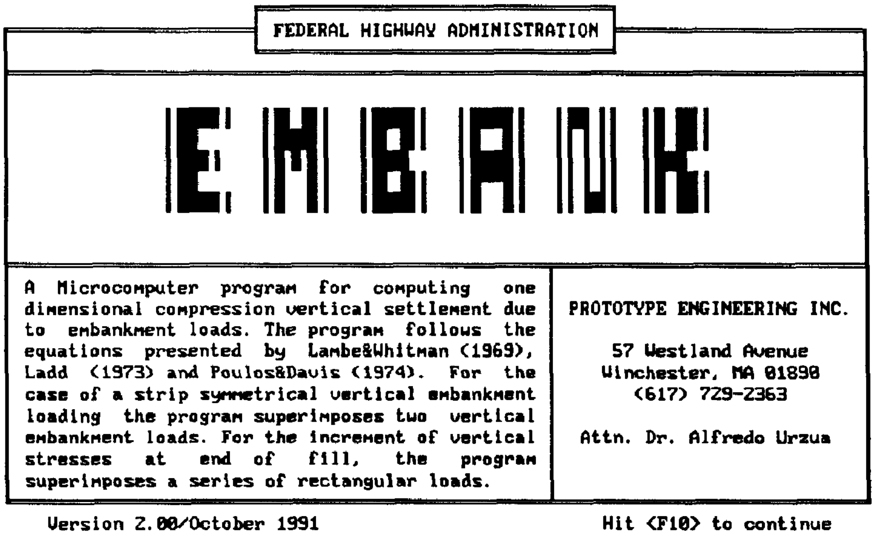
Appendix A contains a compilation of theEMBANK program screens.

To bring up EMBANK, first move to the directory or subdirectory where you have installed the program. Then type the following at the DOS prompt

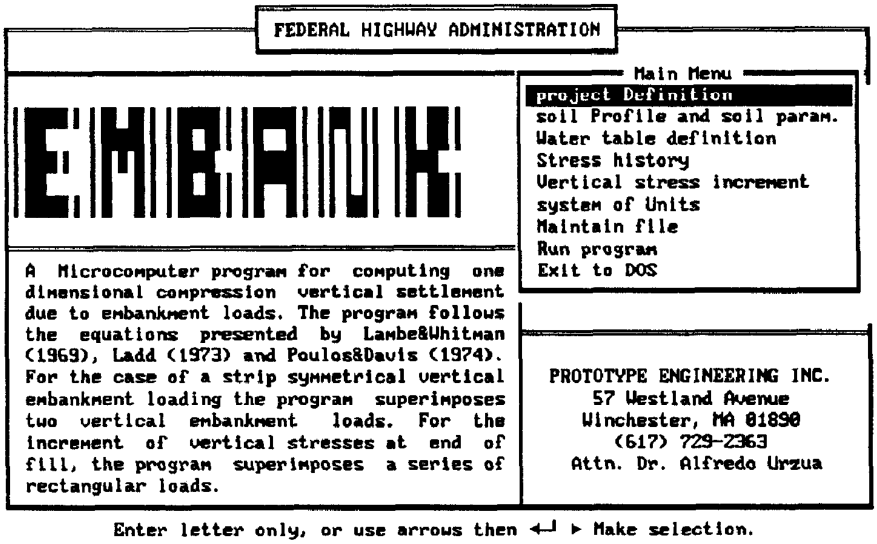
```
EMBANK
```

and press the <Return/Enter> key.

EMBANK loads and returns the opening screen as shown below:



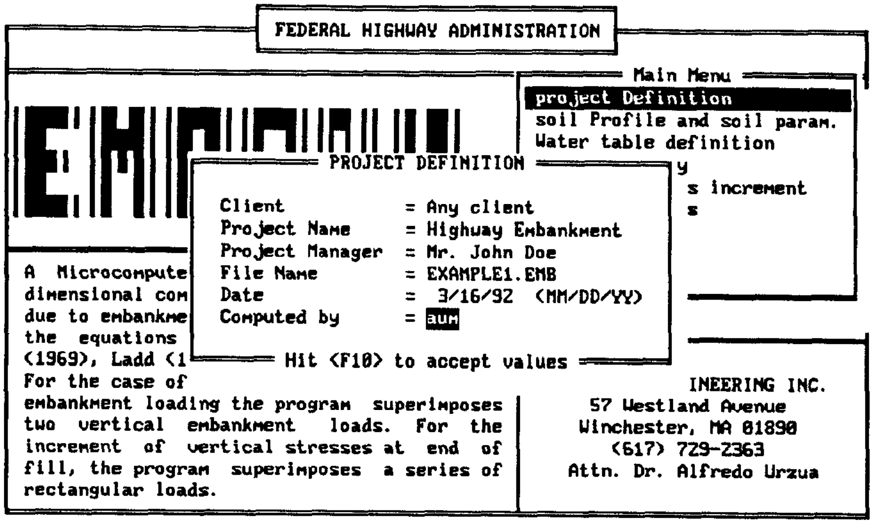
From the opening screen, press the <F10> key to continue. EMBANK displays the Main Menu screen showing all the options available to the user:



In general, the following rules apply:

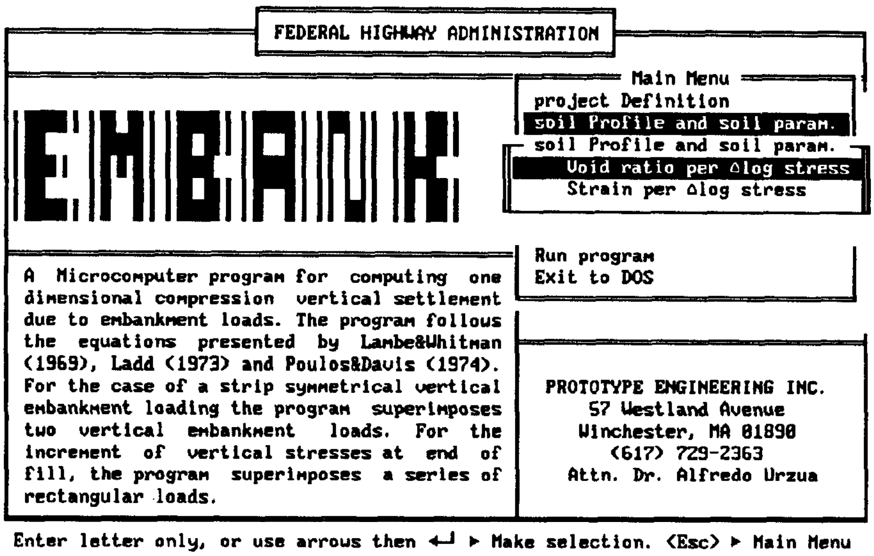
1. To move between the options, use the up (↑) and down (↓) arrow keys or press the high-lighted capital letter of your selection. EMBANK will select the option with that letter.
2. To make a selection, highlight the option of your choice and hit <Return/Enter>.
3. The bottom line of each EMBANK screen explains the operations you can perform and the keys required to perform those operations.
4. To exit a screen or to abort to the Main Menu, press the <ESC> key.

With the highlight on the "Project Definition" field, hit <Enter/Return>; EMBANK responds with the Project Definition screen:

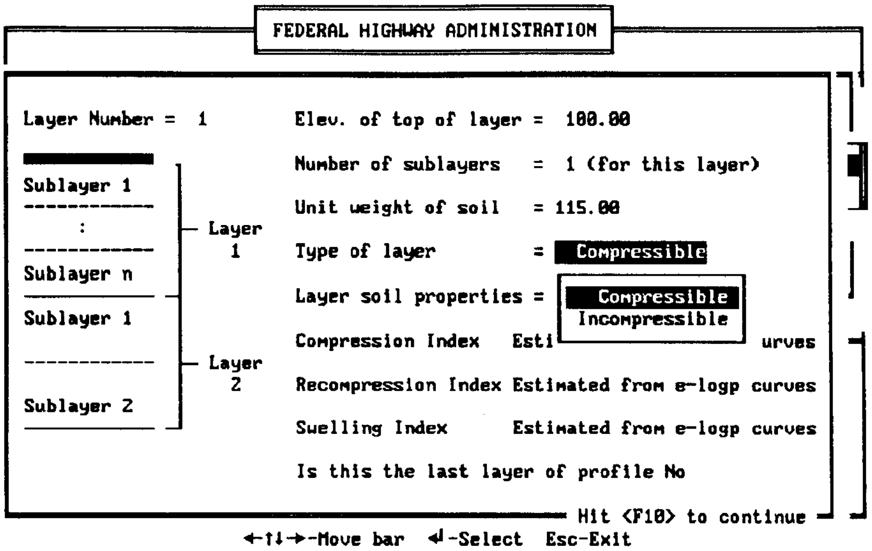


After the project is defined, press <F10> to accept the values. EMBANK returns to the Main Menu screen. (It is important to note that EMBANK functions even if the Project Definition values—Client, Project Name, etc.—are not entered.)

If the user selects "soil Profile and soil param.," EMBANK displays the following screen:

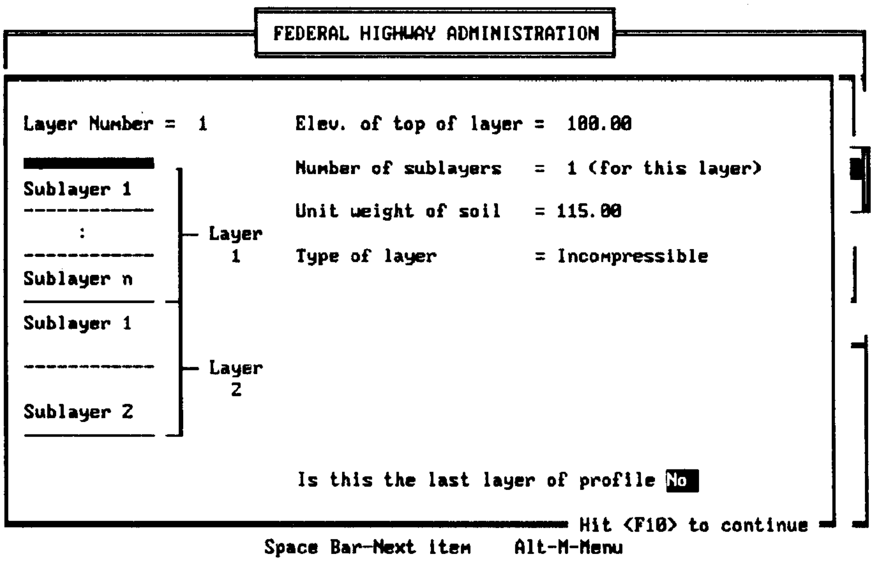


The compressibility of the soil can be expressed either as void ratio or strain per Δlog stress. With the highlight on "Void ratio per Δlog stress," press <Enter/Return>. EMBANK displays the soil profile input screen:



The elevation of the top of layer 1 can be between -999.00 and 9999.00 ft.; the compressible layers can be divided into 1 to 10 sublayers; and the value of the total unit weight of the soil ranges between 62.4 and 250.0 pcf.

EMBANK accepts two types of layers: compressible (it settles) and incompressible. If the user highlights "Incompressible" followed by <Enter/Return>, EMBANK returns the following screen:



For incompressible layers, the compressibility parameters are not required. The user selects the Compressible/Incompressible option by pressing the space bar key or the Alt-M key combination to display the menu options.

If the soil layer is compressible, the program prompts the user for the "Initial void ratio" or the "Initial water content."

The next screen shows the user options:

```
                    FEDERAL HIGHWAY ADMINISTRATION

Layer Number =  1        Elev. of top of layer =  100.00

                         Number of sublayers   =  1 (for this layer)
Sublayer 1
------------             Unit weight of soil   = 115.00
     :        Layer
------------    1        Type of layer         =   Compressible
Sublayer n
------------             Layer soil properties = Initial void ratio
Sublayer 1
                         Compression Index   Esti  Initial void ratio
------------  Layer                                Initial water content
                2        Recompression Index Esti
Sublayer 2
------------             Swelling Index      Estimated from e-logp curves

                         Is this the last layer of profile No

                                                   Hit <F10> to continue
       Press space bar to see menu options and then <Ret> to input values
```

EMBANK uses the following equation between void ratio and water content: Gw = Se.

When <Enter/Return> at the "Initial void ratio" highlight is pressed, the program responds:

```
                    FEDERAL HIGHWAY ADMINISTRATION

      Layer Soil Properties
 Initial Void Ratio        =  1.00    f layer =  100.00

    Hit <F10> to accept values        ayers   =  1 (for this layer)

------------             Unit weight of soil   = 115.00
     :        Layer
------------    1        Type of layer         =   Compressible
Sublayer n
------------             Layer soil properties = Initial void ratio
Sublayer 1
                         Compression Index   Estimated from e-logp curves
------------  Layer
                2        Recompression Index Estimated from e-logp curves
Sublayer 2
------------             Swelling Index      Estimated from e-logp curves

                         Is this the last layer of profile No

                                                   Hit <F10> to continue
```

The program allows for void ratios between 0 and 5.0.

On the other hand, if the user selects "Initial water content," EMBANK displays the following screen:

```
 ==== Layer Soil Properties ====== ADMINISTRATION
 Initial Water Content      =  35.00%
 Specific Gravity of Solids =  2.65     layer =  100.00
 Degree of Saturation       = 100.00%   yers   =  1 (for this layer)
 ==== Hit <F10> to accept values ====   soil   = 115.00
 ------------      1    Type of layer          =   Compressible
 Sublayer n
 ----------- -          Layer soil properties = Initial water content
 Sublayer 1
                        Compression Index    Estimated from e-logp curves
 -----------  - Layer
                 2      Recompression Index Estimated from e-logp curves
 Sublayer 2
 -----------  -         Swelling Index       Estimated from e-logp curves
                        Is this the last layer of profile No
 ============================================== Hit <F10> to continue
```

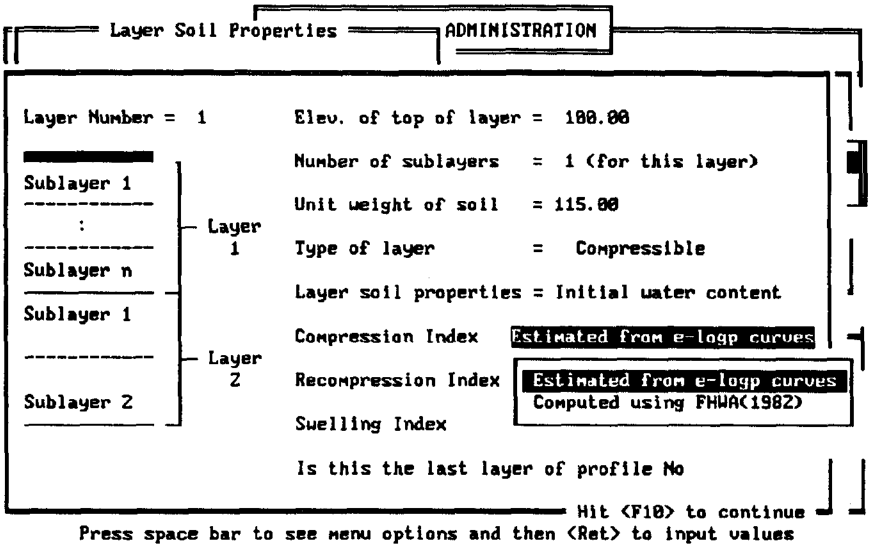
The values of initial water content can range between w = 0% to 900%.

During data entry, the user can exit to the Main Menu by pressing the <ESC> key. EMBANK responds with the following display:

```
 ==== Layer Soil Properties ====== ADMINISTRATION
 Initial Water Content      = 35.00%
                            --- Verify ---
 Specific Gravity of Solids = | Abort <Y/N>? | =  100.00
 Degree of Saturation       = 100.00%   yers   =  1 (for this layer)
 ==== Hit <F10> to accept values ====   soil   = 115.00
 ------------      1    Type of layer          =   Compressible
 Sublayer n
 ----------- -          Layer soil properties = Initial water content
 Sublayer 1
                        Compression Index    Computed using FHWA(1982)
 -----------  - Layer
                 2      Recompression Index Computed using FHWA(1982)
 Sublayer 2
 -----------  -         Swelling Index       Same as recompression index
                        Is this the last layer of profile No
 ============================================== Hit <F10> to continue
```

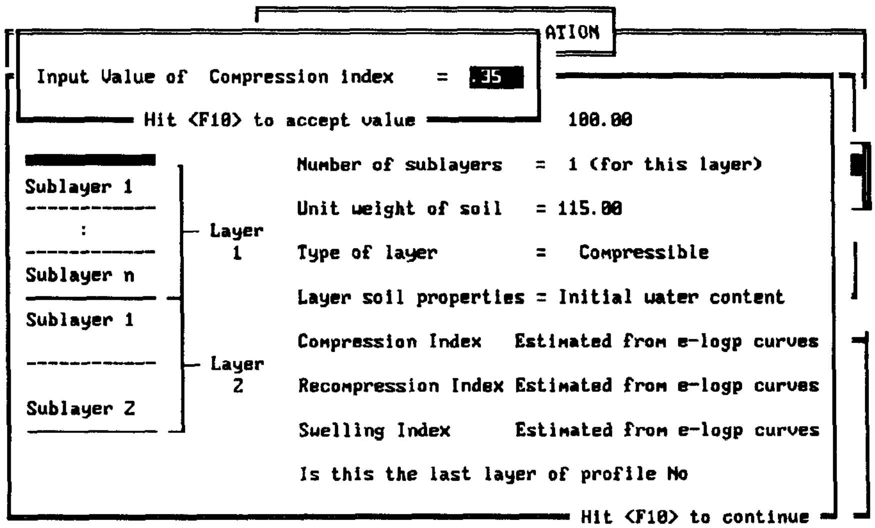
A "Y" answer will return the program to the Main Menu without saving the screen information. If the user selects "N," the program continues.

The next step is to define the compressibility indices. For the Compression Index, the user has the option of entering a value as obtained in an oedometer test or using an empirical relationship between C_c and the initial water content proposed by FHWA in the *Soils and Foundations Workshop Manual* (1982). The following screen displays the options:



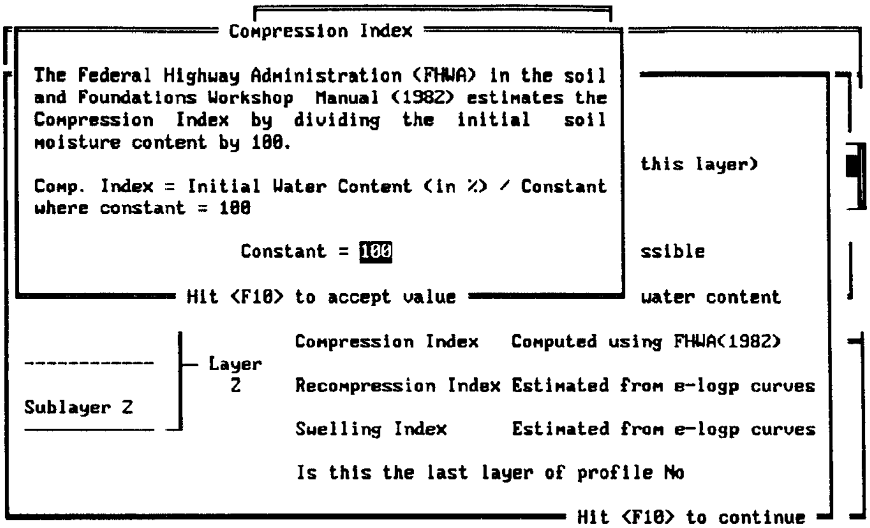
These two options are available to the user only if the "Initial water content" option is selected. If "Initial void ratio" is highlighted, the compression indices can not be computed using the FHWA (1982) procedure.

If the user selects "Estimated from e-logp curves," EMBANK responds



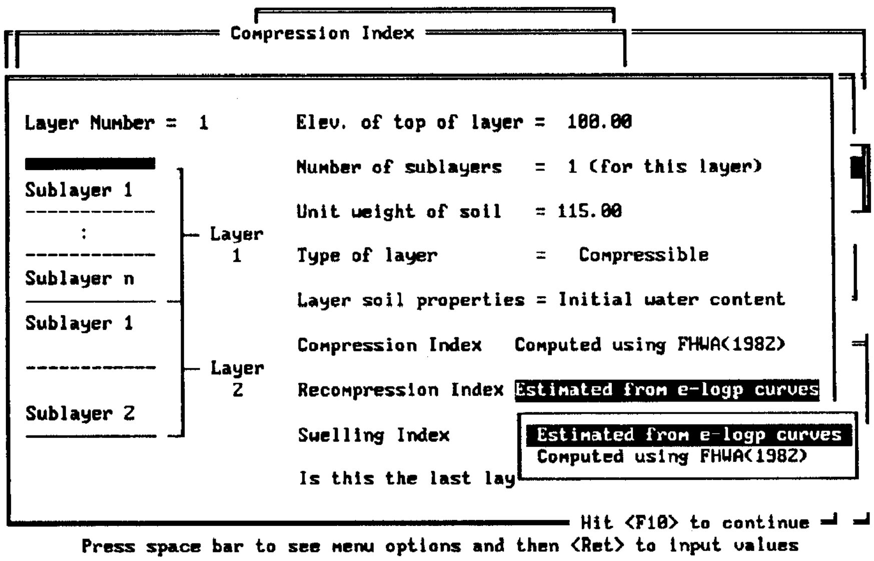
where the values of the Compression Index can vary between 0 and 5.0.

If the FHWA (1982) empirical procedure is selected, EMBANK shows



where the constant can vary between 0 and 200 with a default value of 100.

For the Recompression Index the user has the same two options as for the Compression Index:



If the "Estimated from e-logp curves" option is selected, the program displays

```
Input Value of  Recompression Index  =  0.035
          Hit <F10> to accept value              100.00

                             Number of sublayers    = 1 (for this layer)
Sublayer 1
-----------                  Unit weight of soil    = 115.00
     :            Layer
-----------         1        Type of layer          =   Compressible
Sublayer n
                             Layer soil properties = Initial water content
Sublayer 1
                             Compression Index   Computed using FHWA(1982)
-----------       Layer
                    2        Recompression Index Estimated from e-logp curves
Sublayer 2
                             Swelling Index      Estimated from e-logp curves

                             Is this the last layer of profile No

                                                  Hit <F10> to continue
```

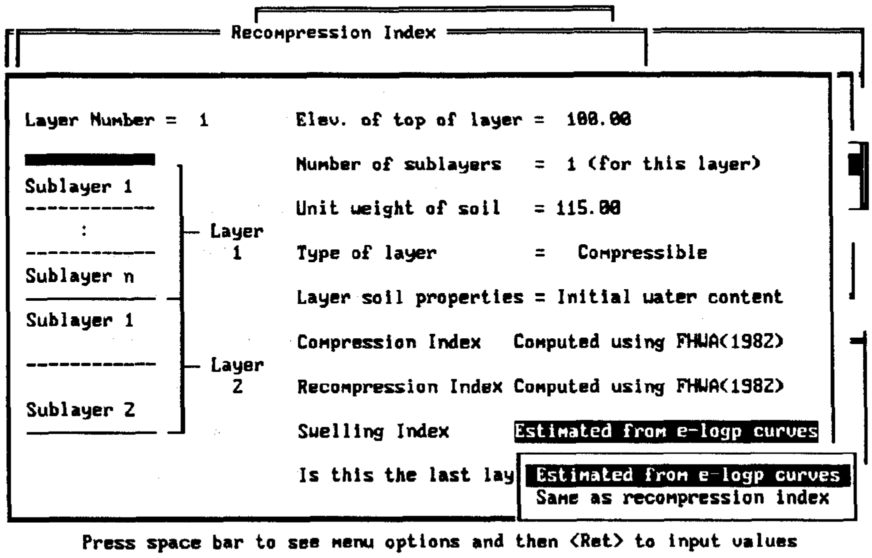
where the Recompression Index can vary between 0.0 and 5.0.

If the FHWA (1982) method is selected, the program shows the following screen

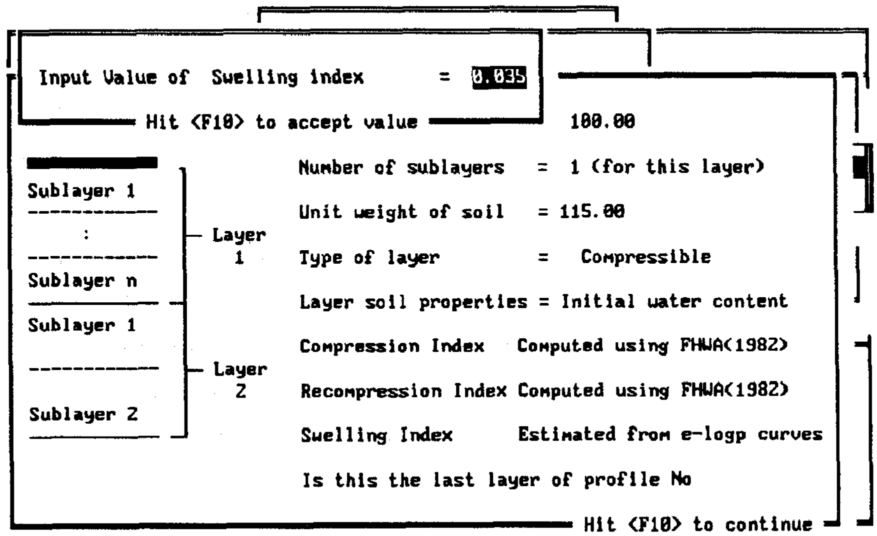
```
            Recompression Index
The Federal Highway Administration (FHWA) in the  soils
and Foundations  Workshop  Manual  (1982) estimates the
Recompression  Index  by  dividing  the  initial   soil
moisture content by 1000.
                                                        is layer)
Recomp. Index = Initial Water Content (in %) / Constant
where Constant  = 1000

                  Constant  = 1000                      ible

          Hit <F10> to accept values                    ter content

                             Compression Index   Computed using FHWA(1982)
-----------       Layer
                    2        Recompression Index Computed using FHWA(1982)
Sublayer 2
                             Swelling Index      Estimated from e-logp curves

                             Is this the last layer of profile No

                                                  Hit <F10> to continue
```

in which the constant can vary between 500 and 2000 with a default value of 1000.

For the Swelling Index, EMBANK has two options as displayed in the next screen:



If the user selects "Estimated from e-logp curves" the program shows



where the Swelling Index can vary between 0 and 2.0.

The other option is to select the Swelling Index as having the same value as the Recompression Index (common engineering practice).

The next step is to define the end of the soil profile. If layer i is not the last layer of the soil profile, the user responds "NO" to this entry. EMBANK displays the following screen:

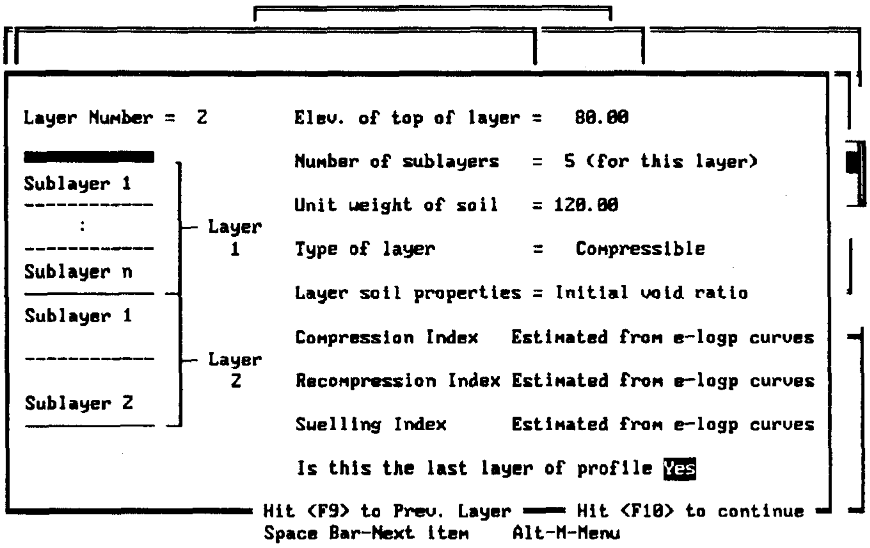
```
Layer Number =  1         Elev. of top of layer =  100.00

                          Number of sublayers    =  1 (for this layer)
Sublayer 1
-----------               Unit weight of soil    = 115.00
     :        - Layer
-----------      1        Type of layer          =   Compressible
Sublayer n
                          Layer soil properties = Initial water content
Sublayer 1
                          Compression Index   Computed using FHWA(1982)
-----------   - Layer
                 2        Recompression Index Computed using       982)
Sublayer 2                                                    No
                          Swelling Index      Same as recomp  Yes  index

                          Is this the last layer of profile N

                                          Hit <F10> to continue
                 ←↑↓→-Move bar   ↵-Select   Esc-Exit
```

After<F10> is pressed to continue, EMBANK displays the following input screen for layer 2:

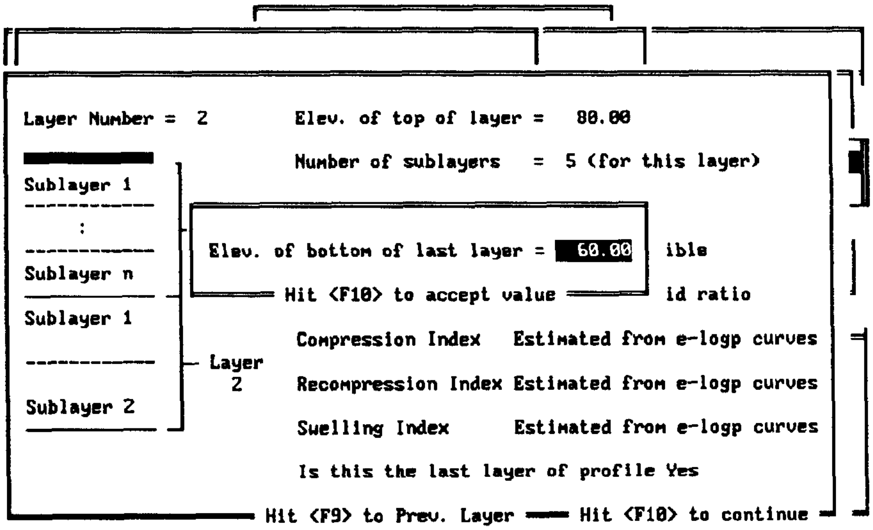
```
Layer Number =  2         Elev. of top of layer =  110.00

                          Numbe  Too Large -->   Upper Bound:         99.99
Sublayer 1
-----------               Unit weight of soil    =   0.00
     :        - Layer
-----------      1        Type of layer          =   Compressible
Sublayer n
                          Layer soil properties = Initial void ratio
Sublayer 1
                          Compression Index   Estimated from e-logp curves
-----------   - Layer
                 2        Recompression Index Estimated from e-logp curves
Sublayer 2
                          Swelling Index      Estimated from e-logp curves

                          Is this the last layer of profile No

                     Hit <F9> to Prev. Layer    Hit <F10> to continue
```

For layer 2 the elevation of the top of the layer must be smaller than the elevation of the top of layer 1. If the user inputs an elevation for layer i+1 greater than that for layer i, EMBANK traps the error as shown above. The <F9> key permits the user to return to the previous layer.

The user inputs the information for layer 2 (layer 3, etc.) in the same manner as for the first layer. If layer i is the last layer of the profile, the user answers "Yes" to the last question as follows:

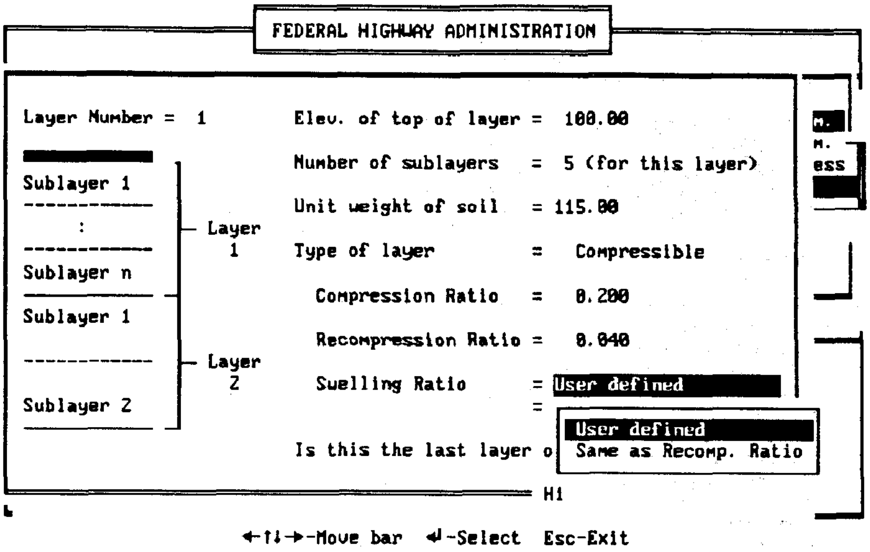


The last step is to define the elevation of the bottom of the last layer of the soil profile. EMBANK displays the following screen:



Press <F10> to continue and return EMBANK to the Main Menu screen.

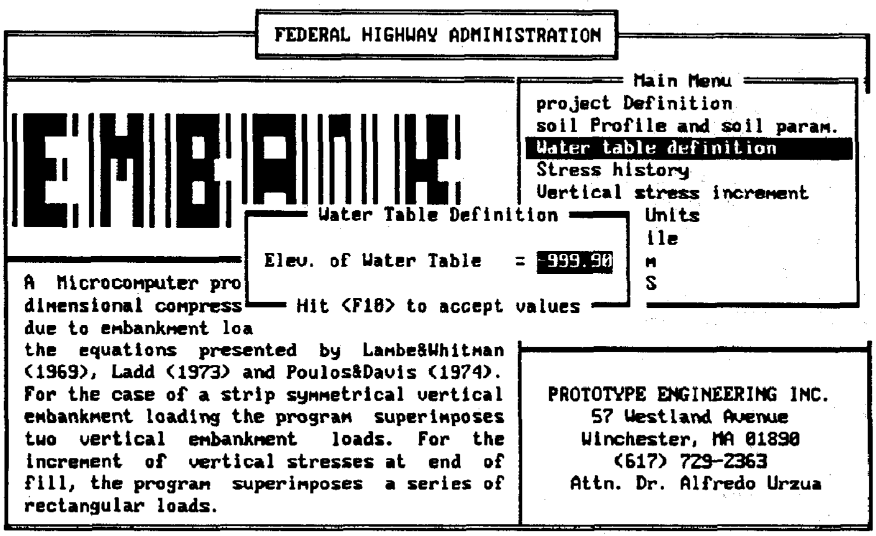
If the user highlights "Strain per Δlog stress" in the soil Profile and soil param. menu, EMBANK displays the following soil profile input screen



in which the compressibility parameters are defined in terms of strain versus Δlog stress. The input to this screen is similar to the one for void ratio versus Δlog stress.

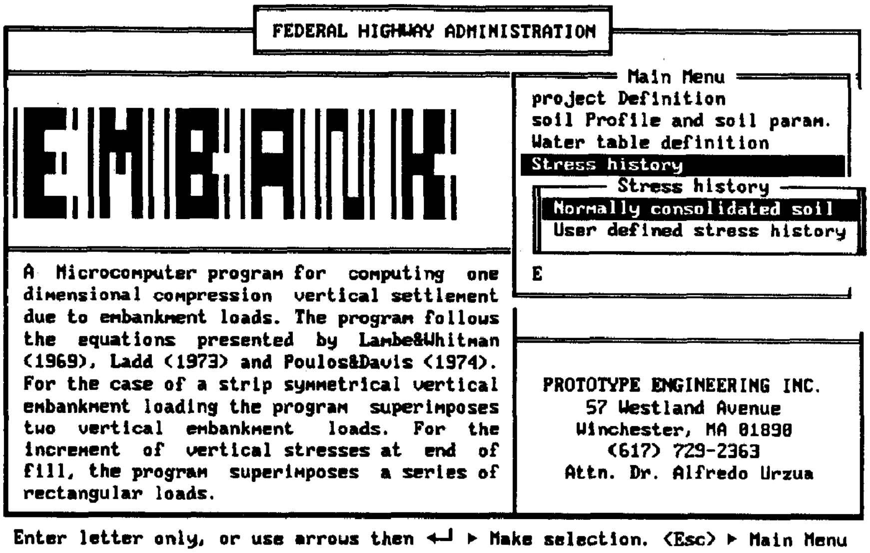
After the elevation of the bottom of the last layer is entered, EMBANK returns to the Main Menu the <F10> key is pressed.

If the user selects "Water table definition," EMBANK shows the water table definition input screen:

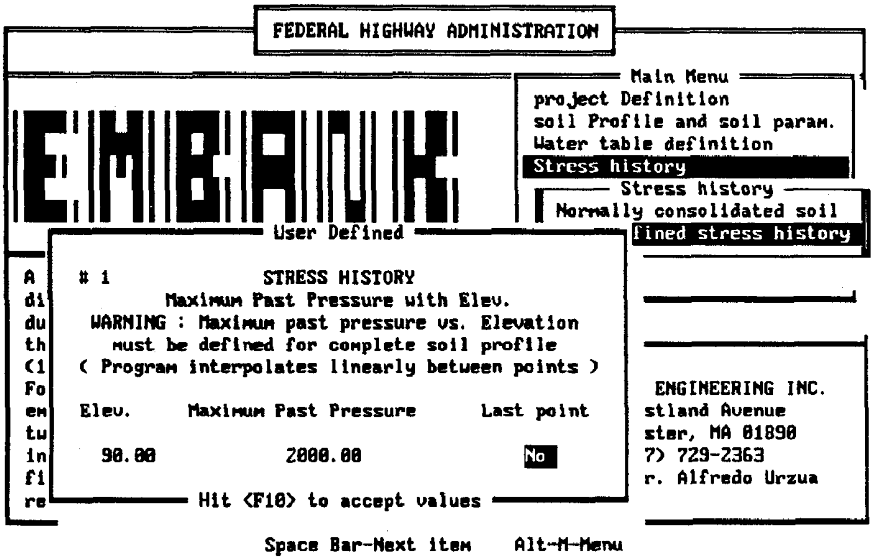


EMBANK defaults the elevation of the water table at -999.90 ft. After the water table is defined, press <F10> to accept the value and return to the Main Menu.

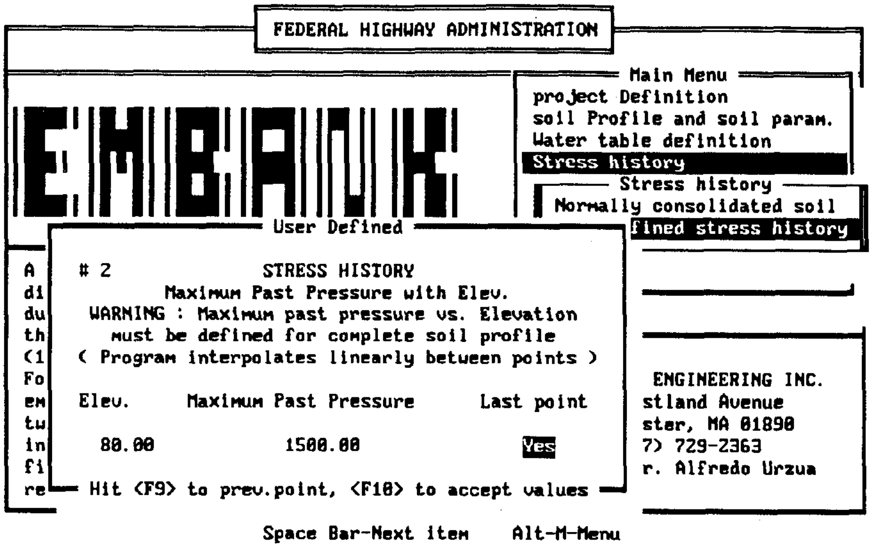
If the user selects "Stress history," EMBANK displays



The program defaults to a normally consolidated soil. If the soil is preconsolidated, the "User defined stress history" option must be selected. EMBANK displays the following screen:

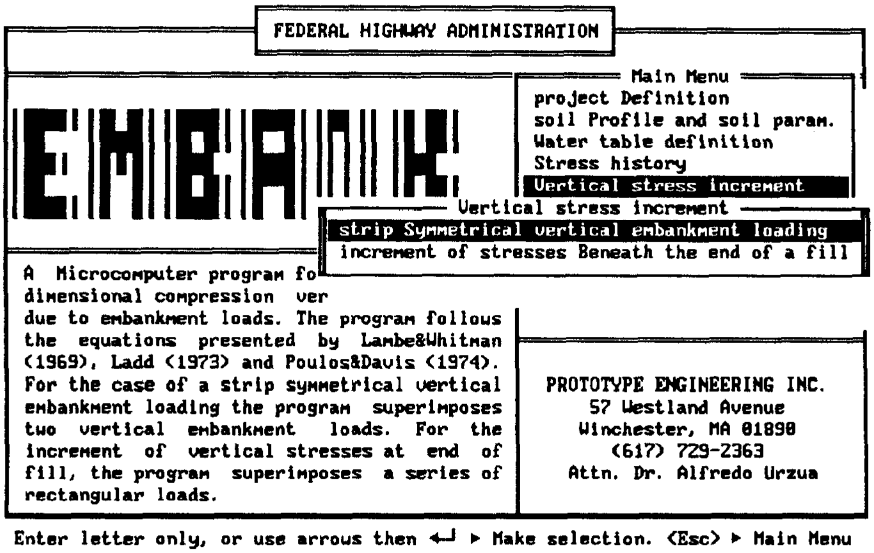


The user has up to 10 points to define the soil stress history for the complete soil profile. A minimum of two points are required, and the program interpolates linearly between points. The next screen shows a typical entry screen for the last point of the stress history.

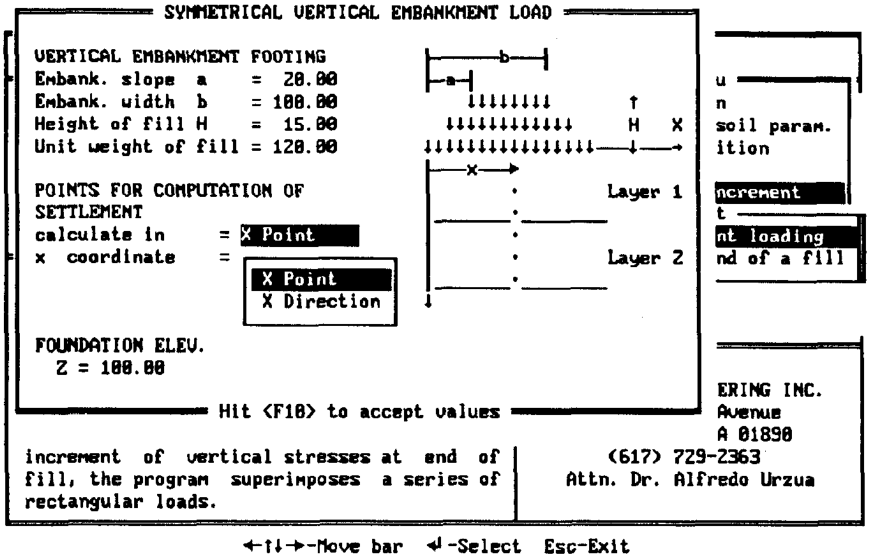


When the <F10> keyis pressed, the program accepts the data and returns to the Main Menu.

If the user selects "Vertical stress increment" from EMBANK's main menu screen, the program shows the following screen:



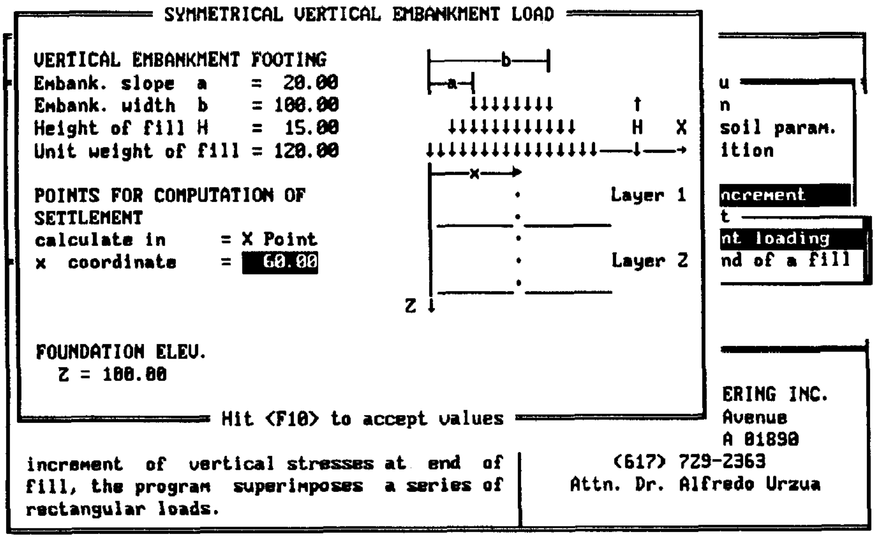
By pressing the <Enter/Return> key, the user selects the highlighted "strip Symmetrical vertical embankment loading" option. EMBANK displays the following screen:



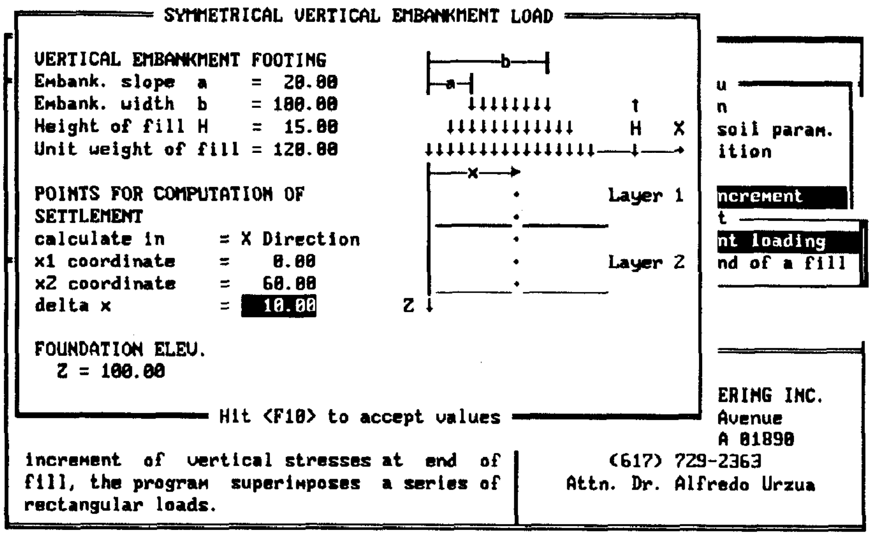
The geometry, load, and coordinate(s) of the point(s) where settlement is calculated are entered into this screen. Note that the visual aid does not represent the actual geometry of the load; its objective is to guide the user in the data input process.

EMBANK can compute the settlement in a point or in the X-Direction.

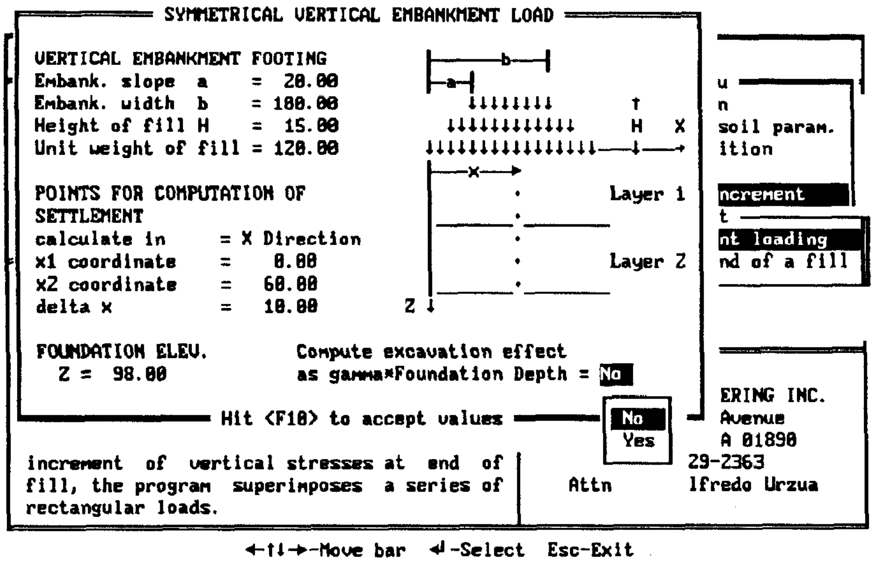
If the user selects the computation of settlement in a point, EMBANK displays the following screen:



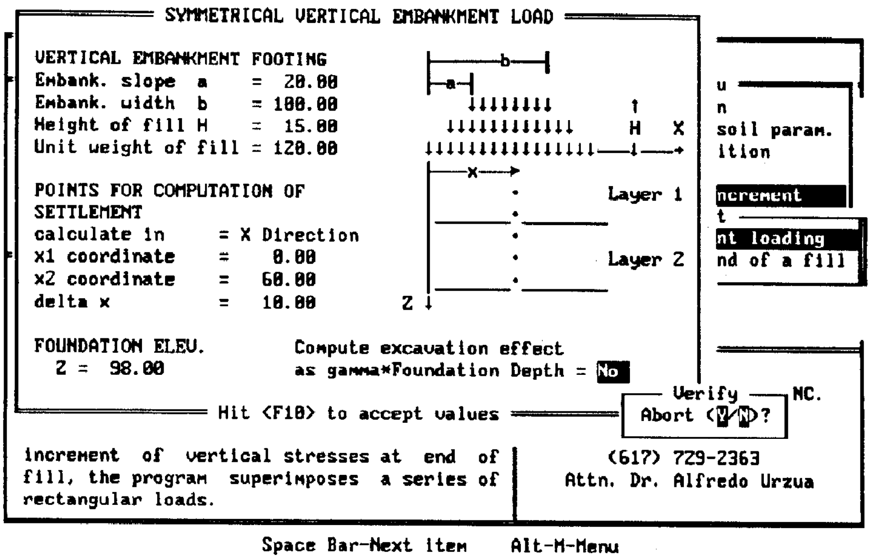
For a given set of input parameters, press the space bar if settlement calculations are desired for more than one location. Delta x is the increment of distance between the x1 and x2 coordinates where EMBANK will calculate settlement. Example: x1 = 0.00', x2 = 60.00' and delta x = 10.00', EMBANK will calculate settlements at x = 0', 10', 20', 30', 40', 50', and 60'.



The last entry on this screen is the Foundation elevation. This option permits the placement of the load at an elevation smaller than the elevation of the top of the soil profile. EMBANK provides the alternative of computing the initial effective stress by considering the complete soil profile or correcting the applied load by discounting the effect of the excavated soil. A typical input screen is as follows:

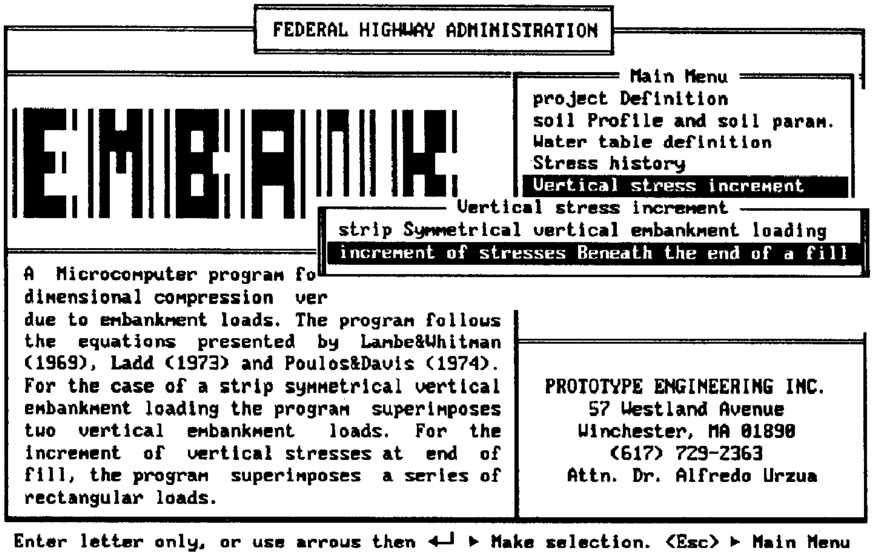


If the user exits to the Main Menu by hitting the <ESC> key, EMBANK will respond with the following screen:

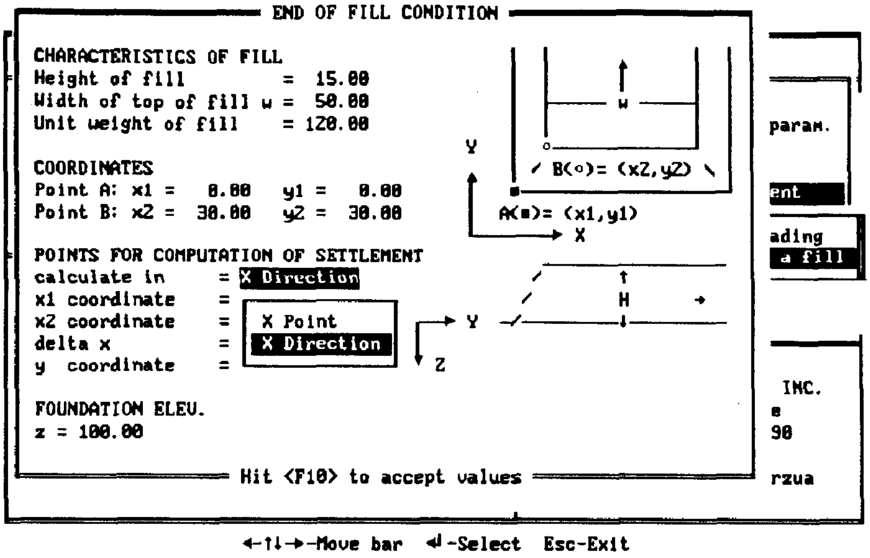


A "Y" answer will exit the program to the Main Menu without saving the information already entered. If the user selects "N," the program continues. The <F10> key accepts (saves) the values and EMBANK returns to the Main Menu screen.

From the Main Menu, select "Vertical stress increment" followed by "increment of stresses Beneath the end of a fill." EMBANK shows the following screen:



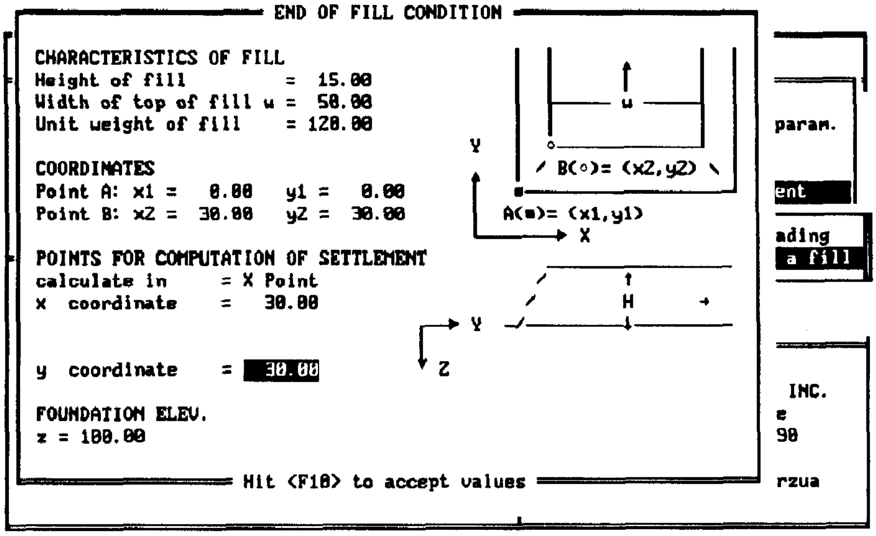
Press <Enter/Return> to make the selection and EMBANK displays this screen:



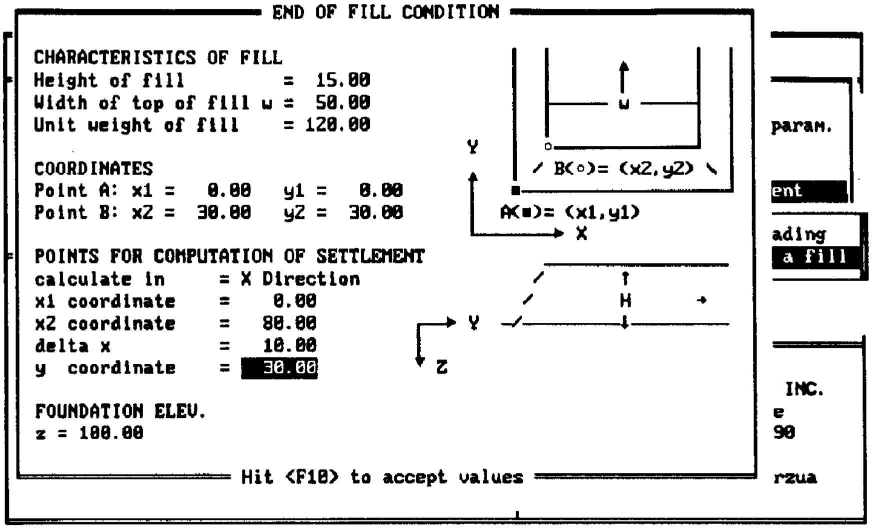
EMBANK has a XYZ coordinate system, where the X and Y axes are the horizontal components and Z is the vertical component. The XY diagram at the top of the screen is a plan view of the embankment. The ZY diagram beneath the plan view is an elevation view or cross section. The correct orientation of the elevation view is to picture it from the right side of the embankment, looking towards the XY origin, that is, towards the left. The Y direction is consistent in both the plan and elevation views. Point A in the plan view is at the bottom of the slope; it is normally the origin of the XY axis. Point B in the plan view is located at the top of the slope. Negative XY values are possible because EMBANK has the ability to compute settlements outside the embankment area.

The Z component is the foundation elevation and is the elevation of the soil profile where the embankment construction begins, that is, the bottom of the embankment. The magnitude of the Z component must be consistent with the elevation given in the "Soil Profile and Soil Parameters" screens. Example: Ground surface elevation value input for layer 1 in the "Soil Profile and Soil Parameter" screen is 100'. Layer 1 is a 5 foot thick layer of highly compressible organic material that will be removed prior to embankment construction. The foundation elevation "Z" in the case is 95'.

If the user selects the computation of settlement in a point, EMBANK displays the following screen:

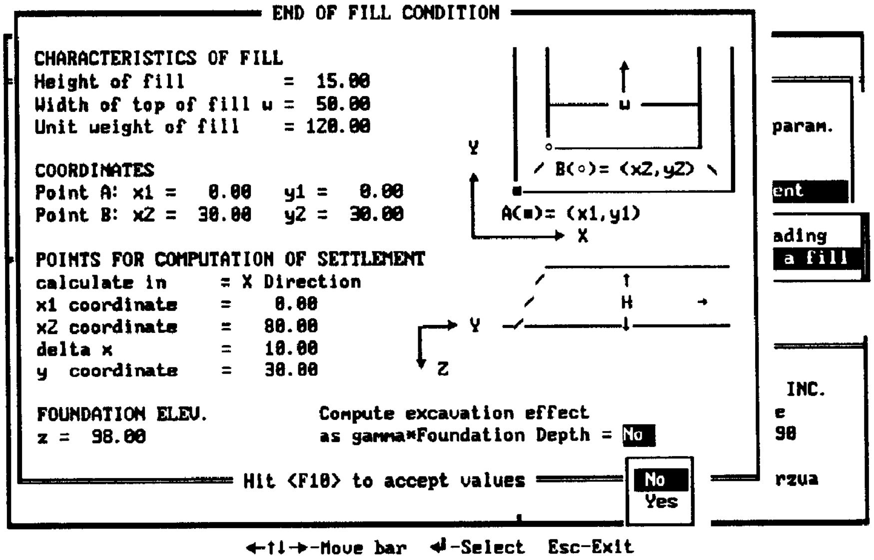


If calculation of settlement in the X-direction is required, EMBANK prompts the user for the information displayed on the next screen:



The last entry on this screen is the Foundation elevation. This option permits the placement of the load at an elevation smaller than the elevation of the top of the soil profile. The program computes the initial effective vertical stress by considering the initial soil profile and allows the user to correct the applied load by discounting the effect of the excavated soil.

A typical input screen for this case is shown below:



Pressing the <F10> key accepts (saves) the values, and EMBANK returns to the Main Menu screen.

With the highlight on the "system of Units" field, hit <Enter/Return>. EMBANK responds with the Unit System screen. This is an informational screen that defines the system of units required by the program.

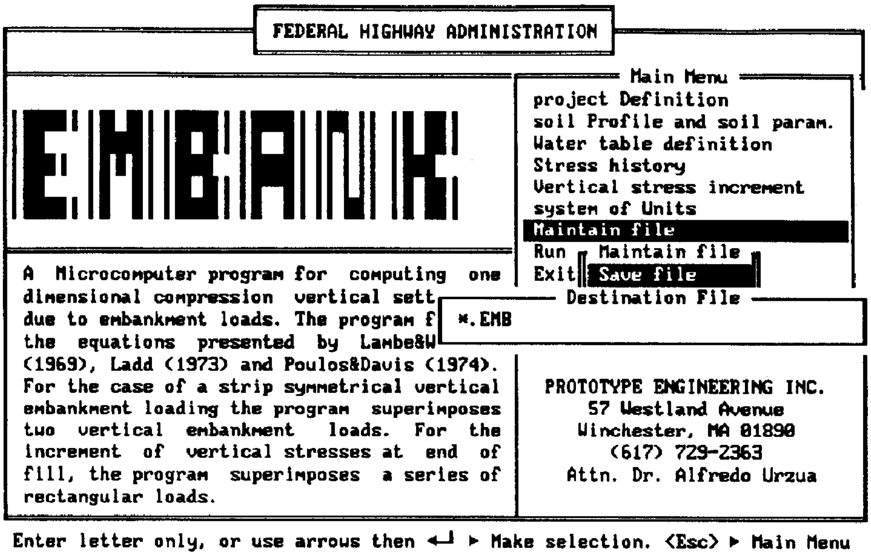
```
                    FEDERAL HIGHWAY ADMINISTRATION
                                              Main Menu
                                         project Definition
                                         soil Profile and soil param.
                       Unit System                  definition
                                                    ry
          Embank requires the information in :      ess increment
                                                    its
             · Length              : feet           e
             · Load                : pounds
A Microcomputer p  · Stress (pressure) : psf
dimensional compre · Unit weight       : pcf
due to embankment  · Unit weight of
the equations pr     water defaults to : 62.4 pcf
(1969), Ladd (1973 · Settlement        : inches
For the case of a                                   NGINEERING INC.
embankment loading       Hit <F10> to continue      land Avenue
two vertical emba                                   er, MA 01890
increment of vertical stresses at end of        (617) 729-2363
fill, the program superimposes a series of    Attn. Dr. Alfredo Urzua
rectangular loads.
          Enter letter only, or use arrows then ↵ ► Make selection.
```

Hitting the <F10> key returns EMBANK to the Main Menu.

Move the arrows to highlight "Maintain file" and hit <Enter/Return>. EMBANK displays the Maintain file menu, which permits data file management inside the program.

```
                    FEDERAL HIGHWAY ADMINISTRATION
                                              Main Menu
                                         project Definition
                                         soil Profile and soil param.
         EMBANK                          Water table definition
                                         Stress history
                                         Vertical stress increment
                                         system of Units
                                         Maintain file
                                         Run  Maintain file
A Microcomputer program for computing one  Exit  Save file
dimensional compression vertical settlement      Retrieve file
due to embankment loads. The program follows     Clear entries
the equations presented by Lambe&Whitman
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical  PROTOTYPE ENGINEERING INC.
embankment loading the program superimposes      57 Westland Avenue
two vertical embankment loads. For the         Winchester, MA 01890
increment of vertical stresses at end of          (617) 729-2363
fill, the program superimposes a series of   Attn. Dr. Alfredo Urzua
rectangular loads.
Enter letter only, or use arrows then ↵ ► Make selection. <Esc> ► Main Menu
```

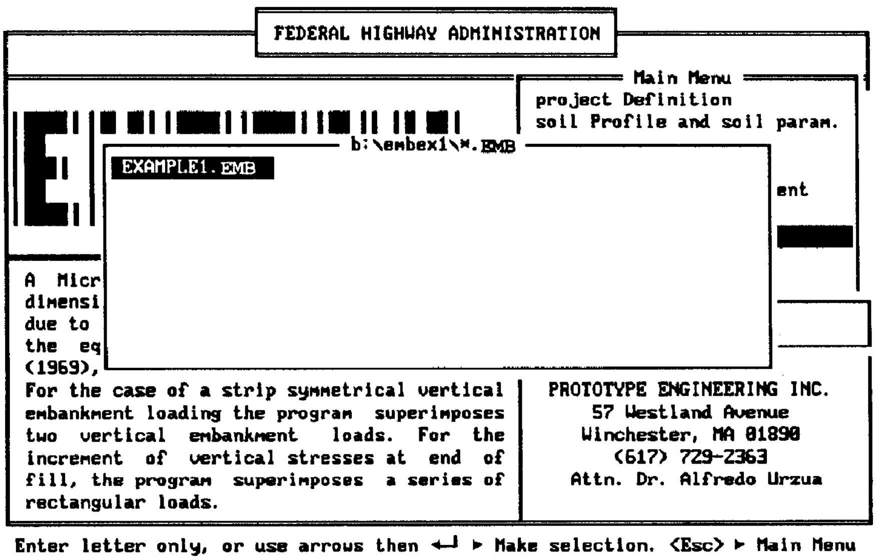
By selecting "Save file," EMBANK displays



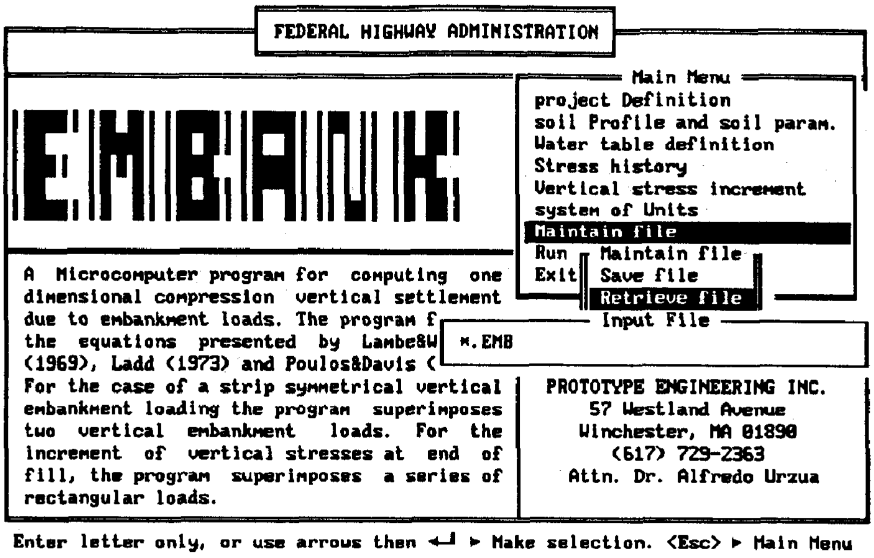
in which the program prompts the user for the destination file name for saving the input information. EMBANK defaults to filename extension .EMB. This filename extension can be changed by the user.

When <Enter/Return> is pressed, EMBANK shows the filename.EMB files that are in the current directory.

A typical screen will look similar to the following screen:

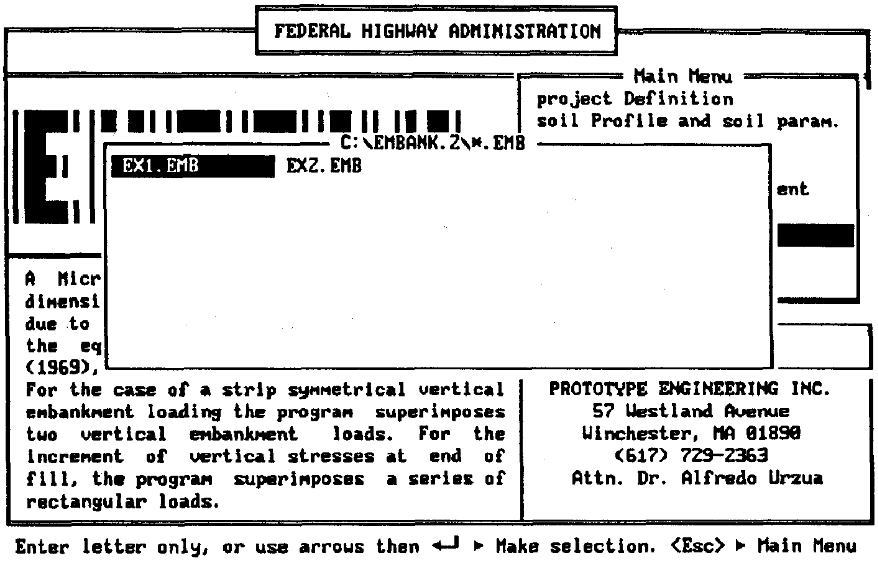


When the "Retrieve file" option is selected, EMBANK shows



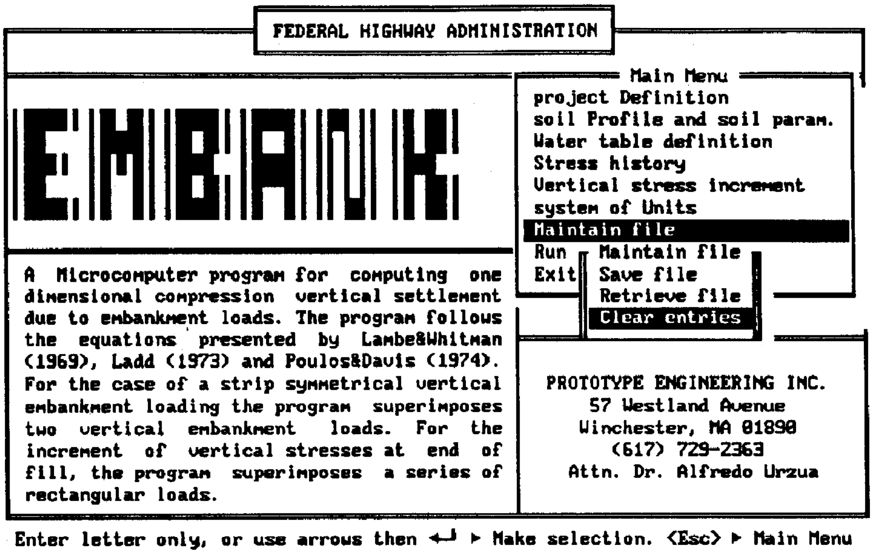
in which the program prompts the user for the filename.EMB to be retrieved. EMBANK defaults to the .EMBfilename extension of data files. This filename extension can be changed by the user.

If the user does not recall the name of the filename.EMB files in the current directory, a list of these can be displayed by pressing the <Enter/Return> key. EMBANK shows the following screen:



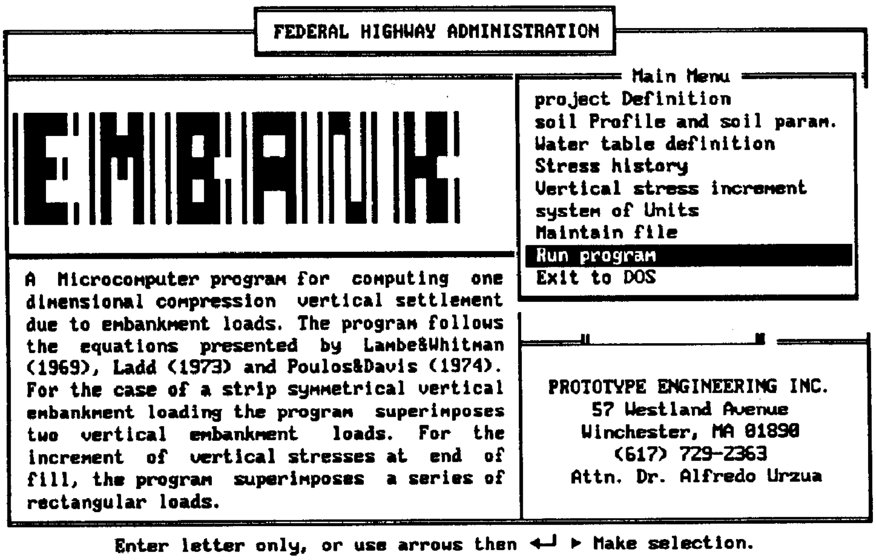
The use of the arrow keys (←, ↑, ↓, →) allows the user to select a file. Press the <Enter/Return> key to retrieve the file into EMBANK. The program returns to the Main Menu screen.

Hitting <Enter/Return> at the "Clear entries" field initializes all EMBANK variables to their default values (equivalent to loading the program from scratch).

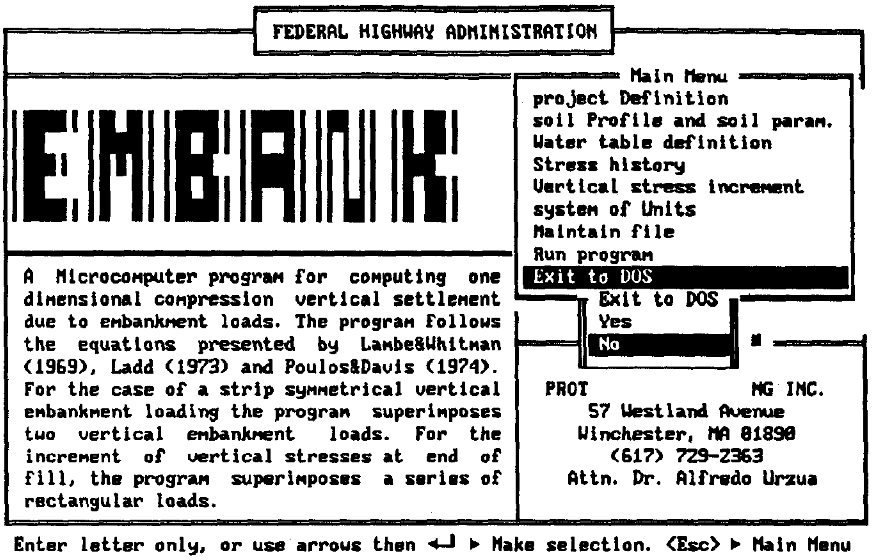


EMBANK returns to the Main Menu.

Selecting the "Run program" option will run EMBANK. The user is referred to Appendix B for typical example runs and output screens.



When "Exit to DOS" is selected the program displays the following screen:



A selection of "No" returns the program to the Main Menu. A "Yes" selection takes the user back to the disk operating system prompt.

Appendix B

Example 1

Example No. 1: Settlement of Normally Consolidated (NC) Soft Clay Layer Due to Symmetrical Embankment Load

This example is similar to the one presented in the U.S. Department of Transportation, FHWA, *Soils and Foundations Workshop Manual*, p. 161.

Figure EX-1 shows the problem geometry and soil parameters. The objective is to compute total settlement of the NC clay stratum beneath points A through E. The clay is divided into five sublayers.

Table EX-1 presents a summary of the computer-calculated and hand-computed settlements for points A through E.

Table 1. Summary of clay surface settlements

Point	Settlement (in) Computer	Hand-Calculated
A	13.44	13.46
B	13.08	
C	12.01	12.02
D	10.34	
E	8.32	8.33

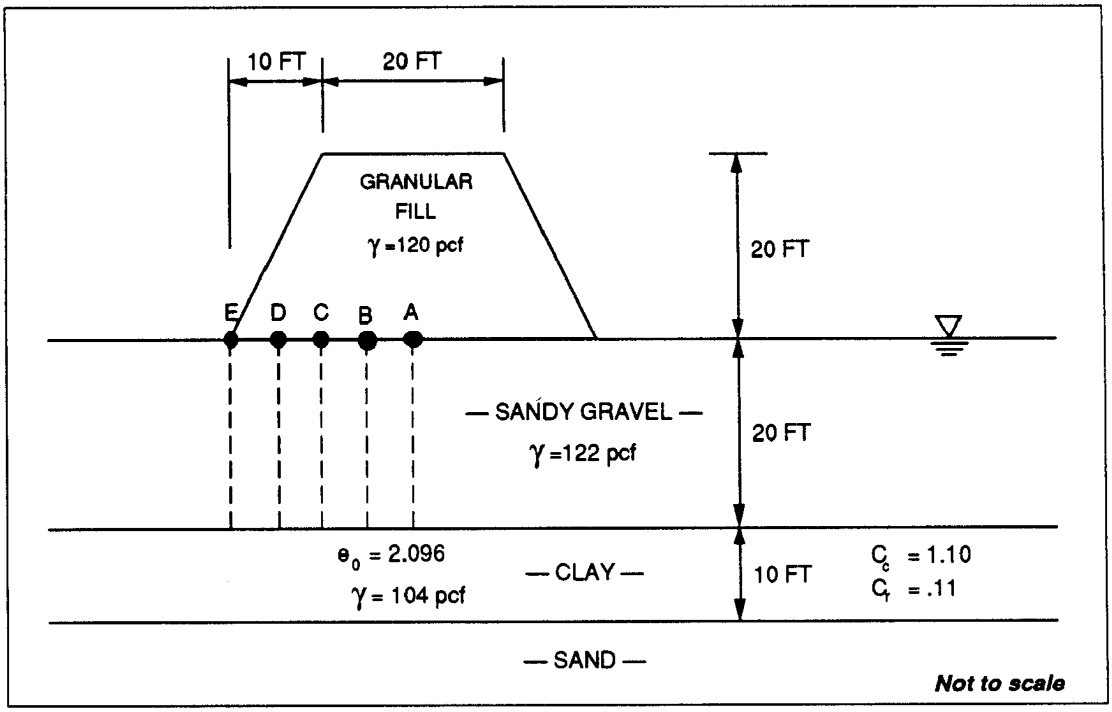
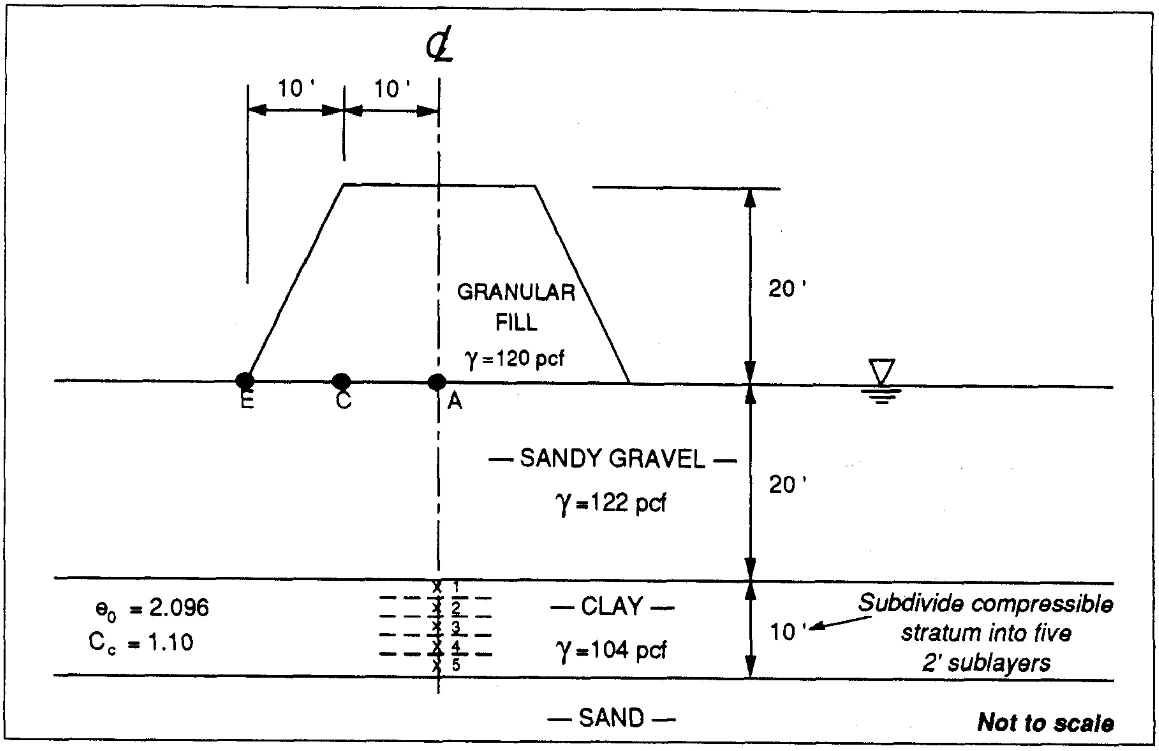


Figure 10. Example 1: Settlement of Symmetrical Embankment Load

Example No. 1: Symmetrical Embankment Load

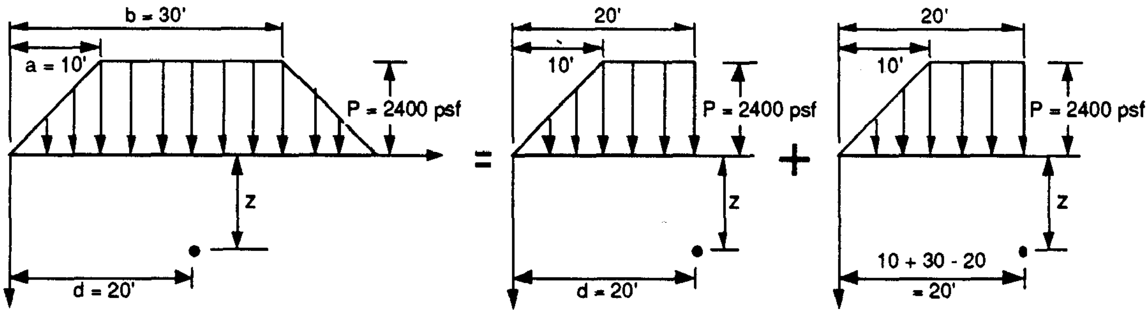


Determine geostatic effective vertical stresses at points 1...5:

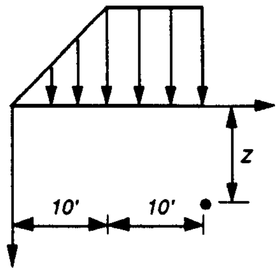
$$\bar{\sigma}_1 = 20 \times 122 + 1 \times 104 - 21 \times 62.4 = 1233.6\ psf$$
$$\bar{\sigma}_2 = 20 \times 122 + 3 \times 104 - 23 \times 62.4 = 1316.8$$
$$\bar{\sigma}_3 = 20 \times 122 + 5 \times 104 - 25 \times 62.4 = 1400.0$$
$$\bar{\sigma}_4 = 20 \times 122 + 7 \times 104 - 27 \times 62.4 = 1483.2$$
$$\bar{\sigma}_5 = 20 \times 122 + 9 \times 104 - 29 \times 62.4 = 1560.4$$

Determine increments of vertical stress under point A:

- Determine increments of vertical stress from figure 4 in text.
- Use superposition, as shown below:

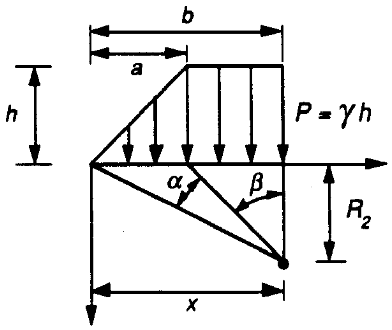


Therefore, we compute increments of vertical stress as 2 times the vertical stress increment for:



For the general case shown below,

vertical stresses are given by:



$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x-b)\right]$$

In this case:

$b = 20'$

$a = 10'$

$R_2 = z$

Therefore:

$$tg\,\beta = \frac{10}{z} \Rightarrow \beta = arct\left(\frac{10}{z}\right)$$

$$tg(\alpha+\beta) = \frac{20}{z} \Rightarrow \alpha = arctg\left(\frac{20}{z}\right) - \beta$$

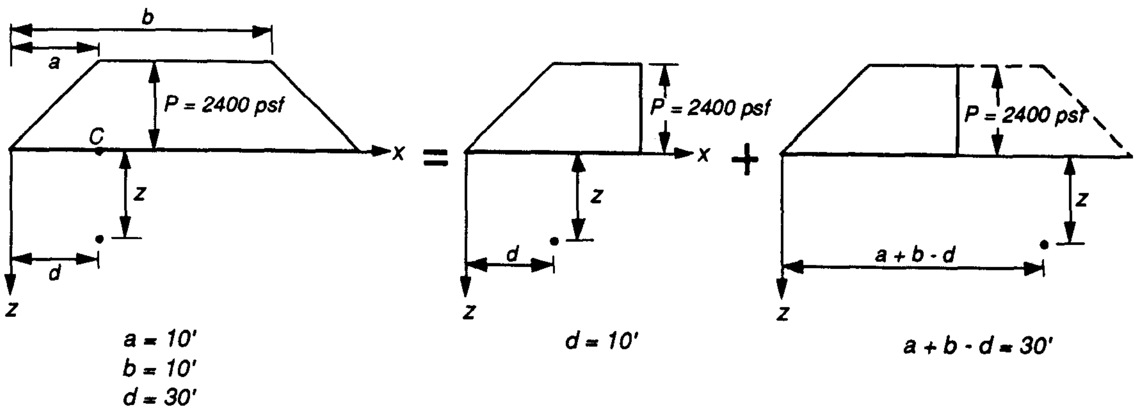
We compute the stress increments for z = 21, 23, 25, 27, and 29 ft:

z (ft)	$\beta = arctg\left(\frac{10}{z}\right)$	$\alpha = arctg\left(\frac{20}{z}\right) - \beta$	$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a}\right]$	$2\sigma_z$
21	25.463345	18.139474	823.23057	1646.4611
23	23.498566	17.510521	780.26144	1560.5229
25	21.801410	16.858398	740.24275	1480.4855
27	20.323137	16.205718	703.12764	1406.2553
29	19.025606	15.566683	668.78629	1337.5726

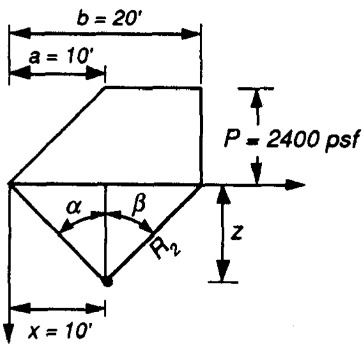
(σ_z in psf)

Determine increments of vertical stress under point C:

- Use superposition as shown below:



- For first superposition step, consider:



$x = 10'$

$a = 10'$

$b = 20'$

$\frac{x}{a} = 1$; $\quad x - b = -10$

$R_2^2 = z^2 + 10^2$

$tg\,\beta = \frac{10}{z}$; $\quad tg\,\alpha = \frac{10}{z}$

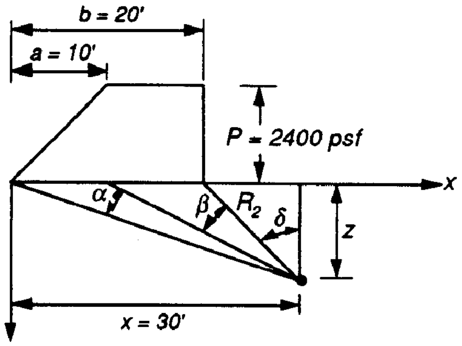
- Compute increment of stresses using:

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x-b)\right]$$

- See results in table below:

z (ft)	$\alpha = \beta$	$R_2^2 = z^2 + 10^2$	$\frac{z}{R_2^2}(x-b)$	σ_z (psf)
21	25.463345	541	− 0.3881701	975.56265
23	23.498566	629	− 0.3656598	905.97194
25	21.801410	725	− 0.3448276	844.79982
27	20.323137	829	− 0.3256936	790.76190
29	19.025606	941	− 0.3081828	742.78381

• For second superposition step, consider:



$$\frac{x}{a} = \frac{30}{10} = 3$$

$$R_2^2 = z^2 + 10^2$$

$$x - b = 10$$

$$\beta = arctg\left(\frac{20}{z}\right) - \delta$$

$$\alpha = arctg\left(\frac{30}{z}\right) - (\beta + \delta)$$

$$\delta = arctg\left(\frac{10}{z}\right)$$

• Compute increment of vertical stresses using:

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x-b)\right]$$

• See results in the table below:

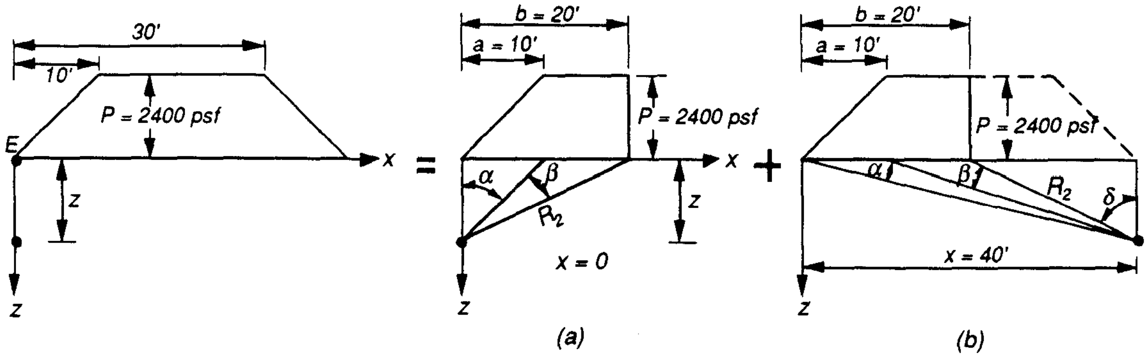
z (ft)	δ	β	α	$\frac{z}{R_2^2}(x-b)$	σ_z (psf)
21	25.463345	18.139474	11.405161	0.3881701	401.52598
23	23.498566	17.510521	11.514733	0.3656598	414.71942
25	21.801410	16.858398	11.534621	0.3448276	422.73460
27	20.323137	16.205718	11.483932	0.3256936	426.62194
29	19.025606	15.566683	11.378733	0.3081828	427.27078

• Add stress increments from both superposition steps:

z (ft)	σ_z (psf)
21	1377.0886
23	1320.6914
25	1267.5344
27	1217.3838
29	1170.0546

Determine increments of vertical stress under point E:

- Use superposition as shown below:



- From figure (a) above:

$$\alpha = arctg\left(\frac{10}{z}\right)$$

$$\beta = arctg\left(\frac{20}{z}\right) - \alpha$$

$$(x-b) = 0 - 20 = -20$$

$$R_2^2 = z^2 + (-20)^2$$

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x-b)\right]$$

- Apply expressions above to compute increments of stress for case (a):

z (ft)	$\alpha = arctg\left(\frac{10}{z}\right)$	$\beta = arctg\left(\frac{20}{z}\right) - \alpha$	$R_2^2 = z^2 + (-20)^2$	$\frac{z}{R_2^2}(x-b)$	σ_z (psf)
21	25.463345	18.139474	841	– 0.4994055	623.37735
23	23.498566	17.510521	929	– 0.4951561	611.74501
25	21.801410	16.858398	1025	– 0.4878049	597.43413
27	20.323137	16.205718	1129	– 0.4782994	581.47007
29	19.025606	15.566683	1241	– 0.4673650	564.59633

- From Figure (b):

$$\delta = arctg\left(\frac{20}{z}\right)$$

$$\beta = arctg\left(\frac{30}{z}\right) - \delta$$

$$\alpha = arctg\left(\frac{40}{z}\right) - (\beta + \delta)$$

$$(x - b) = 40 - 20 = 20$$

$$R_2^2 = z^2 + 20^2$$

$$\frac{x}{a} = \frac{40}{10} = 4$$

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x - b)\right]$$

- Apply expressions above to compute increments of stress for case (b):

$z\ (ft)$	$\delta = arctg\left(\frac{20}{z}\right)$	$\beta = arctg\left(\frac{20}{z}\right) - \delta$	$\alpha = arctg\left(\frac{40}{z}\right) - (\beta + \delta)$	$\frac{z}{R_2^2}(x - b)$	$\sigma_z\ (psf)$
21	43.602819	11.405161	7.2925472	0.4994055	159.48697
23	41.009087	11.514733	7.5772781	0.4951561	179.37988
25	38.659808	11.534621	7.8001877	0.4878049	197.14946
27	36.528855	11.483932	7.9678630	0.4782994	212.67796
29	34.592289	11.378733	8.0868661	0.4673650	225.97541

- Add stress increments from cases (a) and (b). Obtain table below:

$z\ (ft)$	$\sigma_z\ (psf)$
21	782.86432
23	791.12489
25	794.58359
27	794.14803
29	790.57174

Compute settlements.

- Use following expression:

$$\rho = \sum_{i=1}^{n} H_i \, CR \, \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}}\right)$$

where:

n = number of substrata = 5

H_i = thickness of each substrata = 2 ft

$$CR = \text{Virgin Compression Ratio} = \frac{C_c}{(1 + e_0)} = \frac{1.10}{(1 + 2.096)} = 0.3552972$$

$\bar{\sigma}_{vf}$ = Final vertical effective stress $= \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$

$\bar{\sigma}_{v0}$ = Initial vertical effective stress

- Apply expressions above for point A; get table below:

z (ft)	$\bar{\sigma}_{v0}$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vf}$ (psf) $= \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$	$\rho_i = H_i \, CR \, \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}}\right)$
21	1233.6	1646.4611	2880.0611	0.2616603 ft
23	1316.8	1560.5229	2877.3229	0.2412246
25	1400.0	1480.4855	2880.4855	0.2226560
27	1483.2	1406.2553	2889.4553	0.2057997
29	1566.4	1337.5726	2903.9726	0.1905031
			Total Settlement:	1.1218437 ft
				13.46 in

- Apply expressions above for point C; obtain table below:

z (ft)	$\bar{\sigma}_{v0}$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vf}$ (psf) $= \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$	$\rho_i = H_i\, CR \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}}\right)$	
21	1233.6	1377.0886	2610.6886	0.2313558	ft
23	1316.8	1320.6914	2637.4914	0.2143639	
25	1400.0	1267.5344	2667.5344	0.1989536	
27	1483.2	1217.3838	2700.5838	0.1849378	
29	1566.4	1170.0546	2736.4546	0.1721668	
			Total Settlement:	1.0017799	ft
				12.02	in

- Apply expressions above for point E; obtain table below:

z (ft)	$\bar{\sigma}_{v0}$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vf}$ (psf) $= \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$	$\rho_i = H_i\, CR \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}}\right)$	
21	1233.6	782.86432	2016.46432	0.1516523	ft
23	1316.8	791.12489	2107.92489	0.1451995	
25	1400.0	794.58359	2194.58359	0.1387251	
27	1483.2	794.14803	2277.34803	0.1323338	
29	1566.4	790.57174	2356.97174	0.1260962	
			Total Settlement:	0.6940069	ft
				8.33	in

Compilation of Computer Screens for Example 1

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

PROTOTYPE ENGINEERING INC.

57 Westland Avenue
Winchester, MA 01890
(617) 729-2363

Attn. Dr. Alfredo Urzua

Version 2.00/October 1991

Hit <F10> to continue

OPENING SCREEN

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu

- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment
- system of Units
- Maintain file
- Run program
- Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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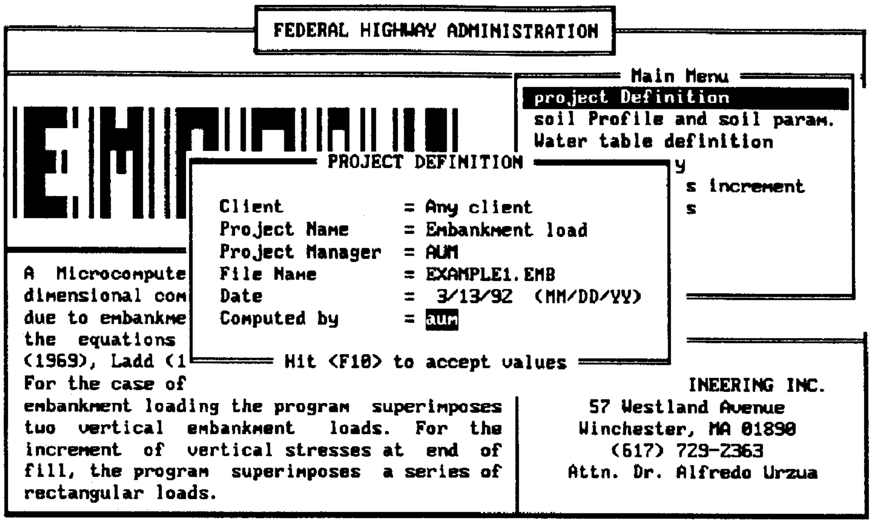
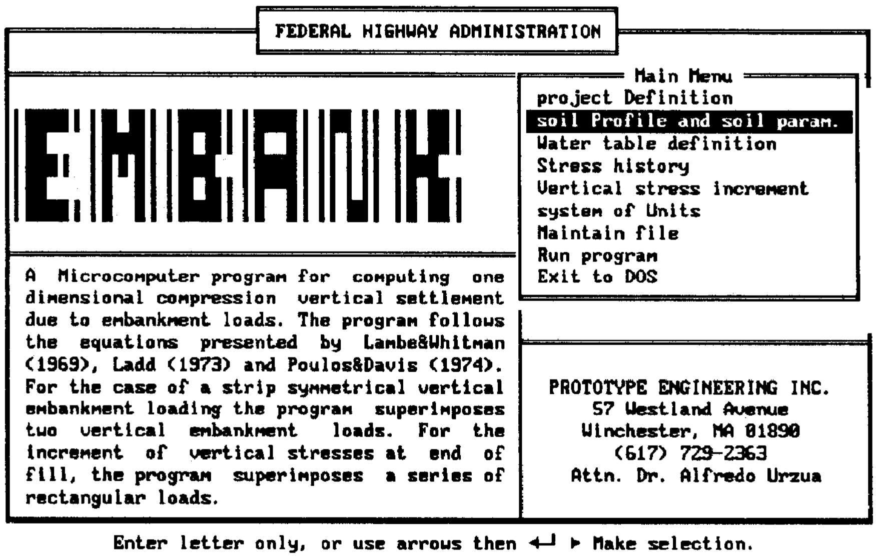
Enter letter only, or use arrows then ↵ ► Make selection.

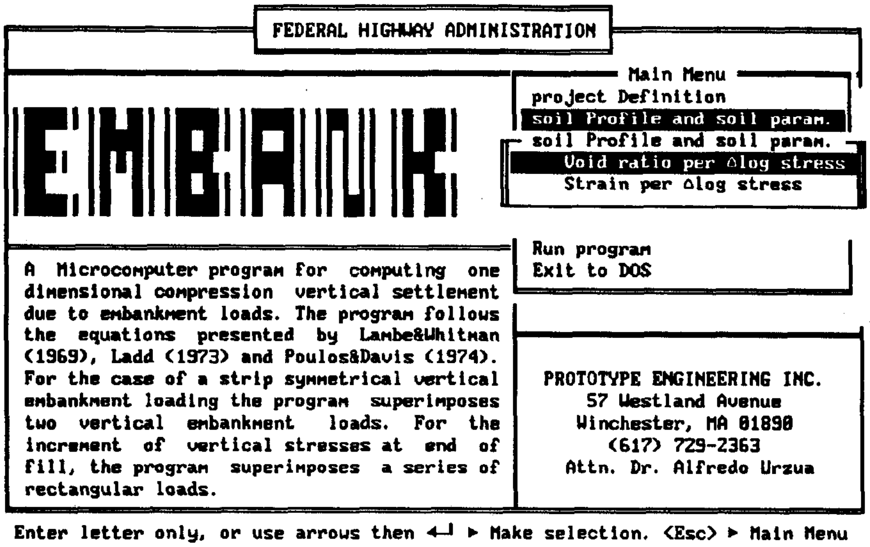
EMBANK MAIN MENU - SELECTION OF PROJECT DEFINITION



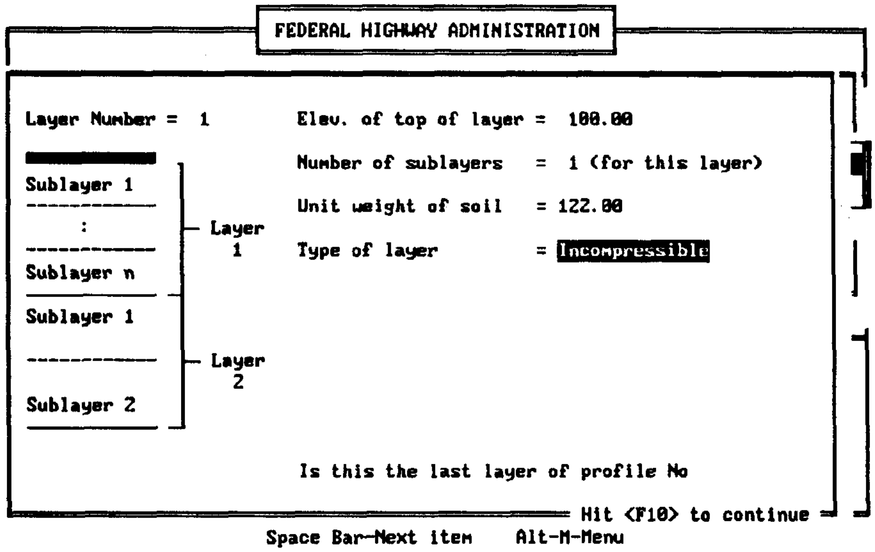
PROJECT DEFINITION SCREEN



EMBANK MAIN MENU - SELECTION OF SOIL PROFILE



SOIL PROFILE MENU - SELECTION OF VOID RATIO PER LOG STRESS



SOIL DESCRIPTION AND PARAMETERS FOR LAYER #1

```
 Layer Soil Properties          ADMINISTRATION

 Layer Number =  2         Elev. of top of layer =   80.00

                           Number of sublayers   =  5 (for this layer)
 Sublayer 1
 -----------               Unit weight of soil   = 104.00
      :         Layer
 -----------      1        Type of layer         =  Compressible
 Sublayer n
                           Layer soil properties = Initial void ratio
 Sublayer 1
                           Compression Index   Esti  Initial void ratio
 -----------    Layer                                Initial water content
                  2        Recompression Index Esti
 Sublayer 2
                           Swelling Index      Estimated from e-logp curves

                           Is this the last layer of profile No

                 Hit <F9> to Prev. Layer  Hit <F10> to continue
       Press space bar to see menu options and then <Ret> to input values
```

SOIL DESCRIPTION AND PARAMETERS FOR LAYER #2

```
                     FEDERAL HIGHWAY ADMINISTRATION

 Layer Soil Properties
  Initial Void Ratio        =  2.10    f layer =   80.00
    Hit <F10> to accept values          ayers   =  5 (for this layer)

 -----------               Unit weight of soil   = 104.00
      :         Layer
 -----------      1        Type of layer         =  Compressible
 Sublayer n
                           Layer soil properties = Initial void ratio
 Sublayer 1
                           Compression Index   Estimated from e-logp curves
 -----------    Layer
                  2        Recompression Index Estimated from e-logp curves
 Sublayer 2
                           Swelling Index      Estimated from e-logp curves

                           Is this the last layer of profile No

                 Hit <F9> to Prev. Layer  Hit <F10> to continue
```

INITIAL VOID RATIO - LAYER #2

```
                                                    ATION
 Input Value of  Compression index    =  1.1
 ──────── Hit <F10> to accept value ────────         80.00

 ████████          Number of sublayers    =  5 (for this layer)
 Sublayer 1
 ----------        Unit weight of soil    = 104.00
     :       ─ Layer
 ----------     1  Type of layer          =   Compressible
 Sublayer n
 ──────────        Layer soil properties = Initial void ratio
 Sublayer 1
                   Compression Index    Estimated from e-logp curves
 ----------  ─ Layer
                2  Recompression Index Estimated from e-logp curves
 Sublayer 2
 ──────────        Swelling Index       Estimated from e-logp curves

                   Is this the last layer of profile No

 ════════════ Hit <F9> to Prev. Layer ═══ Hit <F10> to continue ═
```

COMPRESSION INDEX - LAYER #2

```
                                                    ATION
 Input Value of  Recompression index  =  .11
 ──────── Hit <F10> to accept value ────────         80.00

 ████████          Number of sublayers    =  5 (for this layer)
 Sublayer 1
 ----------        Unit weight of soil    = 104.00
     :       ─ Layer
 ----------     1  Type of layer          =   Compressible
 Sublayer n
 ──────────        Layer soil properties = Initial void ratio
 Sublayer 1
                   Compression Index    Estimated from e-logp curves
 ----------  ─ Layer
                2  Recompression Index Estimated from e-logp curves
 Sublayer 2
 ──────────        Swelling Index       Estimated from e-logp curves

                   Is this the last layer of profile No

 ════════════ Hit <F9> to Prev. Layer ═══ Hit <F10> to continue ═
```

RECOMPRESSION INDEX - LAYER #2

```
                                             ATION

Layer Number =  2         Elev. of top of layer =   80.00

                          Number of sublayers   =  5 (for this layer)
Sublayer 1
------------              Unit weight of soil   = 104.00
     :          Layer
------------      1       Type of layer         =   Compressible
Sublayer n
                          Layer soil properties = Initial void ratio
Sublayer 1
                          Compression Index   Estimated from e-logp curves
------------    Layer
                  2       Recompression Index Estimated from e-logp curves
Sublayer 2
                          Swelling Index      Same as recompression index

                          Is this the last lay  Estimated from e-logp curves
                                                Same as recompression index
                     Hit <F9> to Prev. Layer
    Press space bar to see menu options and then <Ret> to input values
```

SWELLING INDEX - LAYER #2

```
                                             ATION

Layer Number =  2         Elev. of top of layer =   80.00

                          Number of sublayers   =  5 (for this layer)
Sublayer 1
------------              Unit weight of soil   = 104.00
     :          Layer
------------      1       Type of layer         =   Compressible
Sublayer n
                          Layer soil properties = Initial void ratio
Sublayer 1
                          Compression Index   Estimated from e-logp curves
------------    Layer
                  2       Recompression Index Estimated from e-logp curves
Sublayer 2
                          Swelling Index      Same as recompression index

                          Is this the last layer of profile Yes

                     Hit <F9> to Prev. Layer === Hit <F10> to continue
                     Space Bar-Next item     Alt-M-Menu
```

DEFINING LAYER #2 AS LAST LAYER OF SOIL PROFILE

```
                                 ATION

Layer Number =  2       Elev. of top of layer =   80.00

                        Number of sublayers   =  5 (for this layer)
Sublayer 1

     :
                 Elev. of bottom of last layer =  70.00   ible
Sublayer n
                 Hit <F10> to accept value                 id ratio
Sublayer 1
                        Compression Index    Estimated from e-logp curves
              Layer
                2       Recompression Index Estimated from e-logp curves
Sublayer 2
                        Swelling Index       Same as recompression index

                        Is this the last layer of profile Yes

             Hit <F9> to Prev. Layer      Hit <F10> to continue
```

DEFINING THICKNESS OF SOIL PROFILE

```
                 FEDERAL HIGHWAY ADMINISTRATION

                                          Main Menu
                                 project Definition
                                 soil Profile and soil param.
                                 Water table definition
                                 Stress history
                                 Vertical stress increment
                                 system of Units
                                 Maintain file
                                 Run program
                                 Exit to DOS
A Microcomputer program for computing one
dimensional compression vertical settlement
due to embankment loads. The program follows
the equations presented by Lambe&Whitman
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical     PROTOTYPE ENGINEERING INC.
embankment loading the program superimposes         57 Westland Avenue
two vertical embankment loads. For the            Winchester, MA 01890
increment of vertical stresses at end of              (617) 729-2363
fill, the program superimposes a series of       Attn. Dr. Alfredo Urzua
rectangular loads.

      Enter letter only, or use arrows then ↵ ► Make selection.
```

EMBANK MAIN MENU - SELECTION OF WATER TABLE DEFINITION

```
FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment
Units
ile
M
S

Water Table Definition
Elev. of Water Table   = 100.00
Hit <F10> to accept values

A Microcomputer pro
dimensional compress
due to embankment loa
the equations presented by Lambe&Whitman
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical
embankment loading the program superimposes
two vertical embankment loads. For the
increment of vertical stresses at end of
fill, the program superimposes a series of
rectangular loads.

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```

WATER TABLE AT ELEVATION = 100 FT.

```
FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history

Stress history
Normally consolidated soil
User defined stress history
E

A Microcomputer program for computing one
dimensional compression vertical settlement
due to embankment loads. The program follows
the equations presented by Lambe&Whitman
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical
embankment loading the program superimposes
two vertical embankment loads. For the
increment of vertical stresses at end of
fill, the program superimposes a series of
rectangular loads.

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Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ► Make selection. <Esc> ► Main Menu
```

COMPRESSIBLE LAYER IS DEFINED AS NORMALLY CONSOLIDATED (DEFAULT)

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment
- system of Units
- Maintain file
- Run program
- Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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Enter letter only, or use arrows then ↵ ► Make selection.

EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment

Vertical stress increment
- strip Symmetrical vertical embankment loading
- increment of stresses Beneath the end of a fill

A Microcomputer program fo[...] dimensional compression ver[...] due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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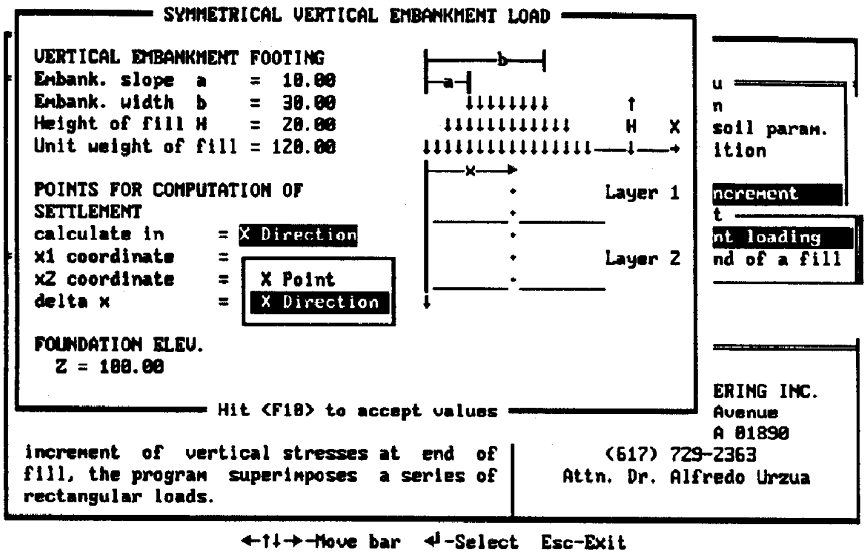
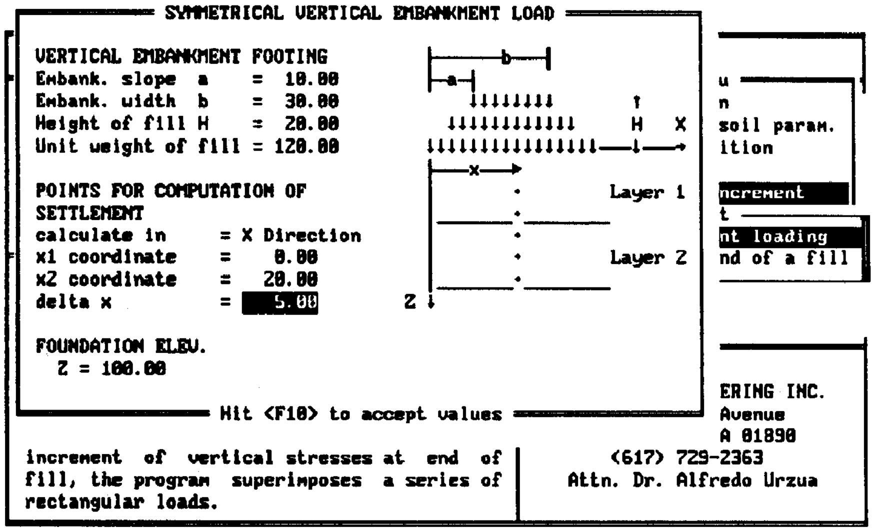
Enter letter only, or use arrows then ↵ ► Make selection. <Esc> ► Main Menu

VERTICAL STRESS INCREMENT MENU - STRIP SYMMETRICAL EMBANKMENT LOADING



STRIP SYMM. EMBANKMENT LOADING GEOMETRY - SETTLEMENT IN X-DIRECTION



DEFINING POINTS FOR COMPUTATION OF SETTLEMENT

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment
- system of Units
- Maintain file
- Run program
- Exit to DOS

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Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ► Make selection.

EMBANK MAIN MENU - SELECTION OF RUN PROGRAM

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name : Embankment load
Project Number : 91-1234
Date : 10/01/91

Client : Any Client
Project Manager : AUM
Computed by : AUM

Settlement for X-Direction

Embankment slope a	= 10.00 (ft)	Height of fill H	= 20.00 (ft)
Embankment top width	= 20.00 (ft)	Unit weight of fill	= 120.00 (pcf)
Embankment bottom width	= 40.00 (ft)	p load/unit area	= 2400.00 (psf)
Ground Surface Elev.	= 100.00 (ft)	Foundation Elev.	= 100.00 (ft)
Water table Elev.	= 100.00 (ft)	Unit weight of Wat.	= 62.40 (pcf)

Nº.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO
1	INCOMP.	20.0	-----	-----	-----	122.00	----	----
2	COMP.	10.0	1.100	0.110	0.110	104.00	2.65	2.10

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

PROGRAM OUTPUT SCREEN

```
---- ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ----
               STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name   : Embankment load       Client          : Any Client
Project Number : 91-1234               Project Manager : AUM
Date           : 10/01/91              Computed by     : AUM


                        Settlement for X-Direction

Embankment slope a      =   10.00 (ft)  Height of fill H    =   20.00 (ft)
Embankment top width    =   20.00 (ft)  Unit weight of fill =  120.00 (pcf)
Embankment bottom width =   40.00 (ft)  p load/unit area    = 2400.00 (psf)
Ground Surface Elev.    =  100.00 (ft)  Foundation Elev.    =  100.00 (ft)
Water table Elev.       =  100.00 (ft ========= Select ==========
                                     | Send form to: P-Printer, D-Disk File.

          LAYER            COEFFICIENT           UNIT   SPECIFIC  VOID
   Nº.   TYPE   THICK.  COMP. RECOMP. SWELL.   WEIGHT  GRAVITY   RATIO
                 (ft)                           (pcf)

    1  INCOMP.  20.0   -----  -----  -----    122.00    ----     ----
    2   COMP.   10.0   1.100  0.110  0.110    104.00    2.65     2.10

---- Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu ----
```

SELECTION OF DISK FILE PRINTED OUTPUT

```
---- ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ----
               STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name   : Embankment load       Client          : Any Client
Project Number : 91-1234               Project Manager : AUM
Date           : 10/01/91              Computed by     : AUM


                        Settlement for X-Direction

Embankment slope a      =   10.00 (ft)  Height of fill H    =   20.00 (ft)
Embankment top width    =   20.00 (ft)  Unit weight of fill =  120.00 (pcf)
Embankment bottom width =   40.00 (ft)  p load/unit area    = 2400.00 (psf)
Ground Surface Elev.    =  100.00 (ft)  Foundation Elev.    =  100.00 (ft)
Water table Elev.       =  100.00 (ft) ------ Destination File ------
                                       | EXAMPLE1.OUT               |

          LAYER            COEFFICIENT           UNIT   SPECIFIC  VOID
   Nº.   TYPE   THICK.  COMP. RECOMP. SWELL.   WEIGHT  GRAVITY   RATIO
                 (ft)                           (pcf)

    1  INCOMP.  20.0   -----  -----  -----    122.00    ----     ----
    2   COMP.   10.0   1.100  0.110  0.110    104.00    2.65     2.10

---- Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu ----
```

SELECTION OF DESTINATION FILE

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name	: Embankment load	Client	: Any Client
File Name	: Example1.EMB	Project Manager	: AUM
Date	: 10/01/91	Computed by	: AUM

Settlement for X-Direction

Embankment slope a	= 10.00 (ft)	Height of fill H	= 20.00 (ft)
Embankment top width	= 20.00 (ft)	Unit weight of fill	= 120.00 (pcf)
Embankment bottom width	= 40.00 (ft)	p load/unit area	= 2400.00 (psf)
Ground Surface Elev.	= 100.00 (ft)	Foundation Elev.	= 100.00 (ft)
Water table Elev.	= 100.00 (ft)	Unit weight of Wat.	= 62.40 (pcf)

Nº.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO
1	INCOMP.	20.0	-----	-----	-----	122.00	----	----
2	COMP.	10.0	1.100	0.110	0.110	104.00	2.65	2.10

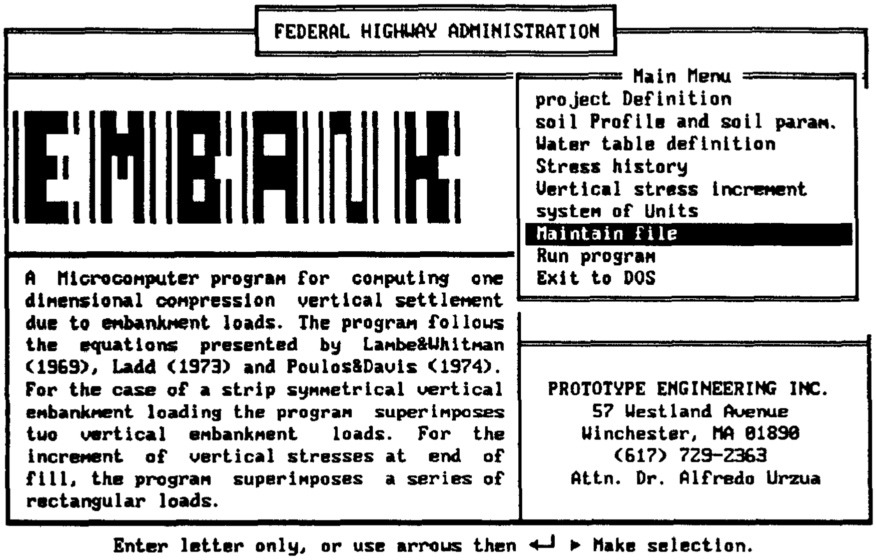
Nº.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	MAX.PAST PRESS. (psf)
1	INCOMP.			
2	2.00	79.00	1233.60	1233.60
3	2.00	77.00	1316.80	1316.80
4	2.00	75.00	1400.00	1400.00
5	2.00	73.00	1483.20	1483.20
6	2.00	71.00	1566.40	1566.40

Layer	X = 0.00 Stress (psf)	Sett. (in.)	X = 5.00 Stress (psf)	Sett. (in.)	X = 10.00 Stress (psf)	Sett. (in.)	X = 15.00 Stress (psf)	Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	782.86	1.82	1089.37	2.34	1377.09	2.77	1576.37	3.04
3	791.12	1.74	1065.97	2.19	1320.69	2.57	1497.77	2.81
4	794.58	1.66	1041.58	2.06	1267.53	2.38	1424.60	2.60
5	794.15	1.59	1016.53	1.93	1217.38	2.22	1356.64	2.40
6	790.57	1.51	991.15	1.81	1170.05	2.06	1293.57	2.23
		------		------		------		------
		8.32		10.34		12.01		13.08

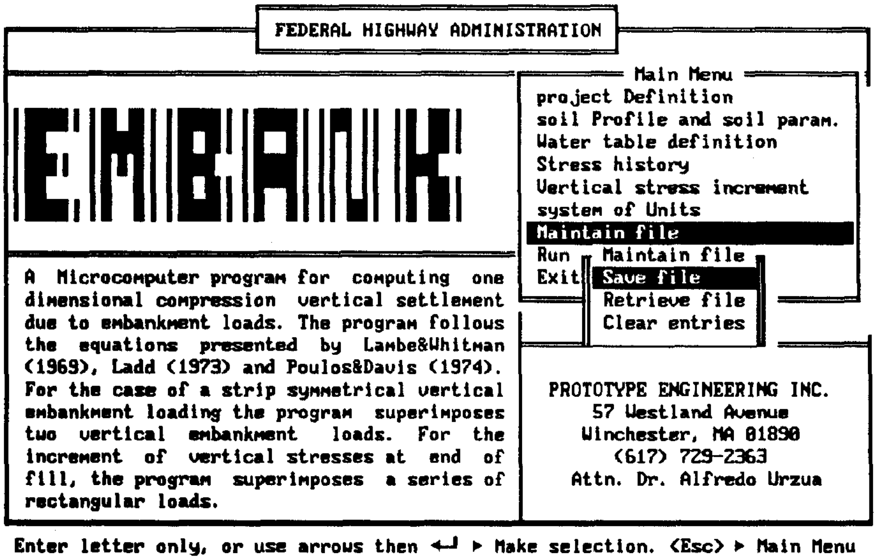
Layer	X = 20.00 Stress (psf)	Sett. (in.)
1	INCOMP.	
2	1646.46	3.14
3	1560.52	2.89
4	1480.49	2.67
5	1406.26	2.47
6	1337.57	2.28

		13.44

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu



EMBANK MAIN MENU - SELECTION OF MAINTAIN FILE



MAINTAIN FILE MENU - SELECTION OF SAVE FILE

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment
system of Units
Maintain file
Run
Exit

Maintain file
Save file

Destination File
EXAMPLE1.EMB

A Microcomputer program for computing one dimensional compression vertical sett due to embankment loads. The program f the equations presented by Lambe&W (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

PROTOTYPE ENGINEERING INC.
57 Westland Avenue
Winchester, MA 01890
(617) 729-2363
Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ▸ Make selection. <Esc> ▸ Main Menu

SAVING INPUT FILE AS EXAMPLE1.DAT

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment
system of Units
Maintain file
Run program
Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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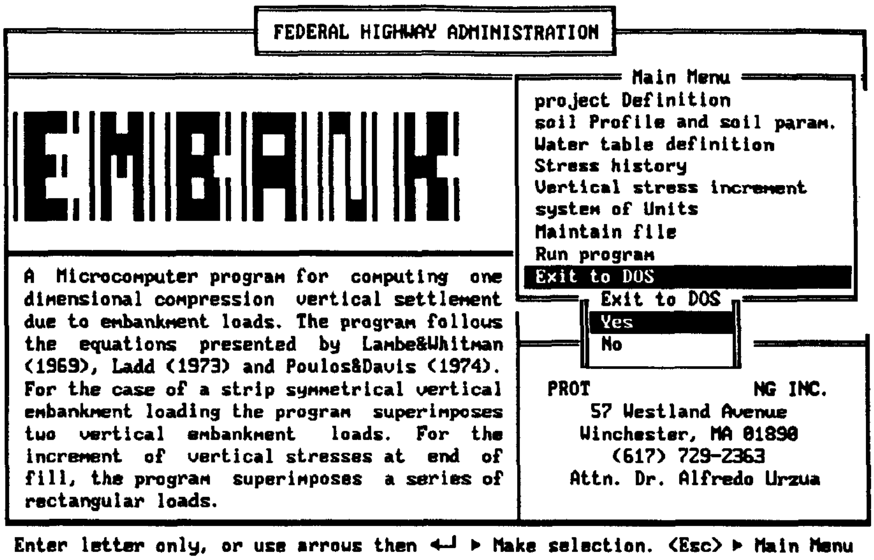
EMBANK MAIN MENU - EXIT TO DOS



EXIT TO DOS MENU - SELECTION OF YES

Example 2

Example No. 2: Approach Embankment Settlement

This example is similar to the one presented in the U.S Department of Transportation, FHWA, *Soils and Foundations Workshop Manual*, p. 165.

Figure EX-2 shows the problem geometry and soil parameters. The purpose of the example is to compute the settlement of the clay stratum under points A through D. The clay stratum is divided into seven sublayers.

Table EX-2 presents a summary of the computer-calculated and hand-computed settlement for points A through D.

Table 2. Summary of surface settlements

Point	Surface Settlement (in) Computer	Hand-Calculated
A	34.46	34.46
B	23.99	
C	7.51	
D	18.97	

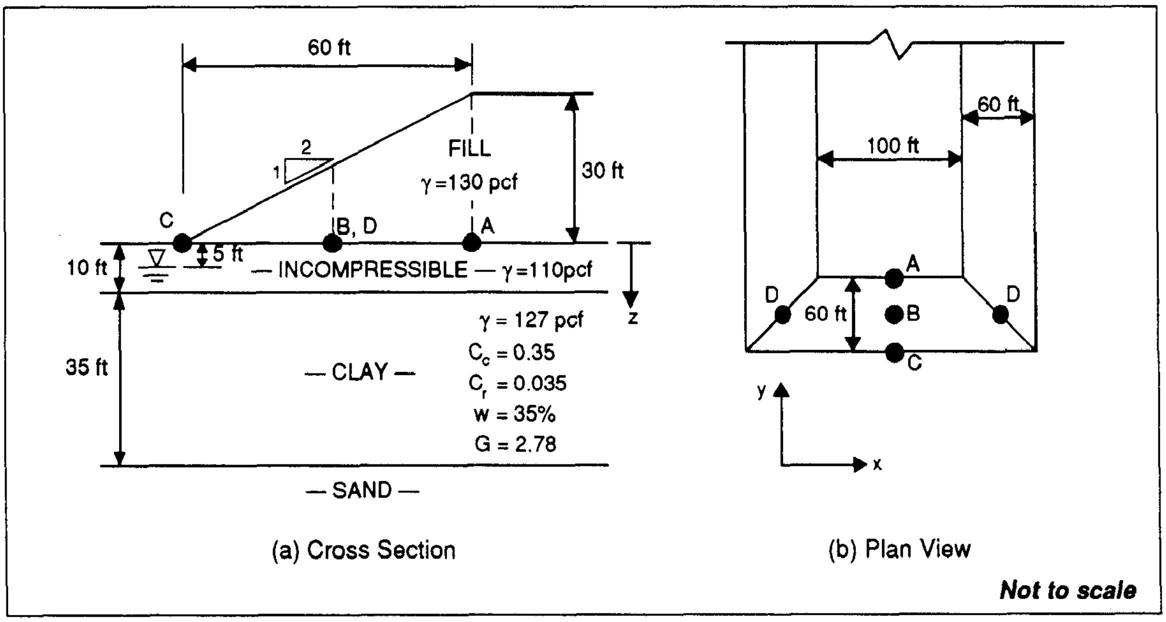


Figure 11. Approach embankment settlement

Example No. 2: Approach Embankment Settlement

Problem: Compute settlement at point A in figure 11.

— Geostatic Effective Vertical Stresses

- Divide compressible clay stratum into seven 5-ft substrata.
- Compute effective vertical stresses at midpoint for each substrata; obtain table below:

$z = 12.5\,ft$: $\bar{\sigma}_1 = 110 \times 10 + 127 \times 2.5 - 62.4 \times 7.5 = 949.5\,psf$

$z = 17.5\,ft$: $\bar{\sigma}_2 = 110 \times 10 + 127 \times 7.5 - 62.4 \times 12.5 = 1272.5\,psf$

$z = 22.5\,ft$: $\bar{\sigma}_3 = 110 \times 10 + 127 \times 12.5 - 62.4 \times 17.5 = 1595.5\,psf$

$z = 27.5\,ft$: $\bar{\sigma}_4 = 110 \times 10 + 127 \times 17.5 - 62.4 \times 22.5 = 1918.5\,psf$

$z = 32.5\,ft$: $\bar{\sigma}_5 = 110 \times 10 + 127 \times 22.5 - 62.4 \times 27.5 = 2241.5\,psf$

$z = 37.5\,ft$: $\bar{\sigma}_6 = 110 \times 10 + 127 \times 27.5 - 62.4 \times 32.5 = 2564.5\,psf$

$z = 42.5\,ft$: $\bar{\sigma}_7 = 110 \times 10 + 127 \times 32.5 - 62.4 \times 37.5 = 2887.5\,psf$

— Determine Increments of Effective Stress

- Program divides embankment load into 10 3-ft high rectangular sub-loads, as shown in figure 6 of the main text.
- Program extends loads to $y_{max} = y_1 + 10b_2 = 0 + 10 \times 60 = 600$ ft.
- Coordinates of lower left and upper right corners of each sub-load are as follows: (Refer to figure 7 of main text.)

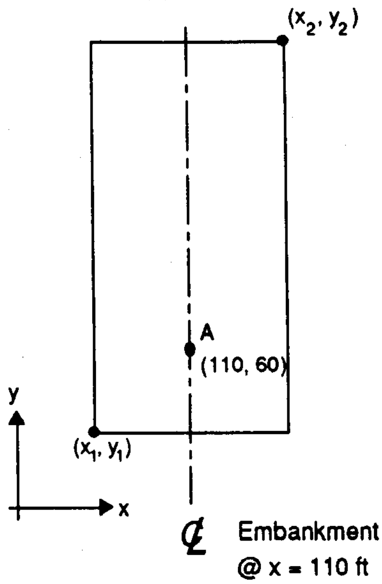
Sub-Load No.	x_1	y_1	x_2	y_2
1	57	57	163	600
2	51	51	169	600
3	45	45	175	600
4	39	39	181	600
5	33	33	187	600
6	27	27	193	600
7	21	21	199	600
8	15	15	205	600
9	9	9	211	600
10	3	3	217	600

- Note that "x" and "y" coordinates of point A are:

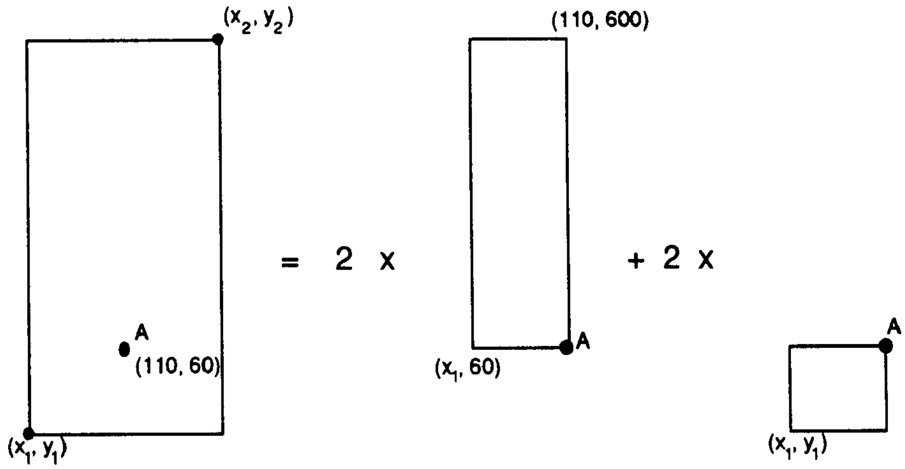
  $x_A = 110\,ft;\ y_A = 60\,ft$

- The configuration of a typical sub-load and its relation to point A is shown below:

Note: Values of x_1, x_2, y_1, and y_2 are as shown on table in previous page for each sub-load. In all cases, y_2 = 600 ft.



- For each sub-load, the increments of vertical stress at point A must be computed by superposition, as shown below:



(0) = 2 x (a) + 2 x (b)

(0) = 2 x [(a) + (b)]

- Equation (14) in main text is applied to superposition steps (a) and (b) for each sub-load in order to compute the increments of stress.

$$\sigma_z = \frac{P}{2\pi}\left[arctg\left(\frac{lb}{zR_3}\right) + \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)\right] \qquad (14)$$

Parameters R_1, R_2, and R_3 are defined in figure 8:

$$R_1 = (l^2 + z^2)^{\frac{1}{2}}$$

$$R_2 = (b^2 + z^2)^{\frac{1}{2}}$$

$$R_3 = (l^2 + b^2 + z^2)^{\frac{1}{2}}$$

- Tables 1 through 7 on the following pages summarize the computation for z = 12.5; 17.5; 22.5; 27.5; 32.5; 37.5; and 42.5 ft.

Parameters C_1 and C_2 in the tables are defined as follows:

$$C_1 = arctg\left(\frac{lb}{zR_3}\right)$$

$$C_2 = \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)$$

so that: $$\sigma_z = \frac{P}{2\pi}(C_1 + C_2)$$

Table 3. Approach Embankment Settlement
Summary Calculations for Increment of Stresses at Depth

z = 12.5 feet

b	l	R_1^2	R_2^2	R_3	C_1	C_2	Increment σ_z	
3	53	2965.25	165.25	54.54	0.23	0.23	28.67	57.35
53	540	291756.30	2965.25	542.74	1.34	0.22	96.99	193.98
9	59	3637.25	237.25	60.98	0.61	0.49	68.10	136.21
59	540	291756.30	3637.25	543.36	1.36	0.20	97.13	194.25
15	65	4381.25	381.25	67.87	0.85	0.51	84.83	169.67
65	540	291756.30	4381.25	544.04	1.38	0.19	97.22	194.44
21	71	5197.25	597.25	75.09	1.01	0.46	91.39	182.77
71	540	291756.30	5197.25	544.79	1.40	0.17	97.28	194.56
27	77	6085.25	885.25	82.55	1.11	0.41	94.19	188.38
77	540	291756.30	6085.25	545.61	1.41	0.16	97.33	194.66
33	83	7045.25	1245.25	90.19	1.18	0.36	95.53	191.06
83	540	291756.30	7045.25	546.48	1.42	0.15	97.36	194.72
39	89	8077.25	1677.25	97.97	1.23	0.32	96.24	192.48
89	540	291756.30	8077.25	547.43	1.43	0.14	97.39	194.78
45	95	9181.25	2181.25	105.86	1.27	0.29	96.65	193.29
95	540	291756.30	9181.25	548.44	1.44	0.13	97.41	194.82
51	101	10357.25	2757.25	113.83	1.30	0.26	96.89	193.79
101	540	291756.30	10357.25	549.51	1.45	0.12	97.42	194.85
57	107	11605.25	3405.25	121.88	1.33	0.24	97.05	194.11
107	540	291756.30	11605.25	550.64	1.45	0.12	97.43	194.87

Increment of Stress = 3645.02 (psf)

where: $C_1 = arctg\left(\frac{lb}{zR_3}\right)$

$$C_2 = \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)$$

$$\sigma_z = \frac{P}{2\pi}(C_1 + C_2)$$

Table 4. Approach Embankment Settlement
Summary Calculations for Increment of Stresses at Depth

z = 17.5 feet

b	l	R_1^2	R_2^2	R_3	C_1	C_2	Increment σ_z	
3	53	3115.25	315.25	55.89	0.16	0.17	20.80	41.59
53	540	291906.30	3115.25	542.88	1.25	0.30	96.18	192.37
9	59	3787.25	387.25	62.20	0.45	0.43	54.57	109.14
59	540	291906.30	3787.25	543.50	1.28	0.27	96.52	193.05
15	65	4531.25	531.25	68.97	0.68	0.52	74.47	148.95
65	540	291906.30	4531.25	544.18	1.31	0.25	96.76	193.51
21	71	5347.25	747.25	76.08	0.84	0.52	84.72	169.45
71	540	291906.30	5347.25	544.93	1.33	0.23	96.92	193.85
27	77	6235.25	1035.25	83.45	0.96	0.49	89.97	179.94
77	540	291906.30	6235.25	545.74	1.35	0.22	97.04	194.09
33	83	7195.25	1395.25	91.02	1.04	0.45	92.78	185.55
83	540	291906.30	7195.25	546.62	1.36	0.20	97.13	194.26
39	89	8227.25	1827.25	98.73	1.11	0.41	94.37	188.74
89	540	291906.30	8227.25	547.56	1.37	0.19	97.20	194.40
45	95	9331.25	2331.25	106.57	1.16	0.38	95.33	190.66
95	540	291906.30	9331.25	548.57	1.39	0.18	97.25	194.50
51	101	10507.25	2907.25	114.49	1.20	0.35	95.93	191.87
101	540	291906.30	10507.25	549.64	1.40	0.17	97.29	194.58
57	107	11755.25	3555.25	122.49	1.23	0.32	96.33	192.67
107	540	291906.30	11755.25	550.78	1.41	0.16	97.32	194.65

Increment of Stress = 3537.82 (psf)

where: $$C_1 = arctg\left(\frac{lb}{zR_3}\right)$$

$$C_2 = \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)$$

$$\sigma_z = \frac{P}{2\pi}(C_1 + C_2)$$

Table 5. Approach Embankment Settlement
Summary Calculations for Increment of Stresses at Depth

z = 22.5 feet

b	l	R_1^2	R_2^2	R_3	C_1	C_2	Increment σ_z	
3	53	3315.25	515.25	57.66	0.12	0.14	16.21	32.41
53	540	292106.30	3315.25	543.06	1.17	0.36	94.91	189.81
9	59	3987.25	587.25	63.78	0.35	0.37	44.71	89.42
59	540	292106.30	3987.25	543.68	1.20	0.34	95.55	191.10
15	65	4731.25	731.25	70.40	0.55	0.49	64.79	129.57
65	540	292106.30	4731.25	544.36	1.24	0.31	96.00	192.00
21	71	5547.25	947.25	77.38	0.71	0.54	77.21	154.43
71	540	292106.30	5547.25	545.11	1.26	0.29	96.33	192.65
27	77	6435.25	1235.25	84.64	0.83	0.53	84.57	169.14
77	540	292106.30	6435.25	545.93	1.28	0.27	96.56	193.13
33	83	7395.25	1595.25	92.11	0.92	0.51	88.94	177.89
83	540	292106.30	7395.25	546.80	1.30	0.26	96.74	193.49
39	89	8427.25	2027.25	99.74	1.00	0.48	91.62	183.23
89	540	292106.30	8427.25	547.75	1.32	0.24	96.88	193.76
45	95	9531.25	2531.25	107.50	1.06	0.45	93.31	186.62
95	540	292106.30	9531.25	548.75	1.33	0.23	96.98	193.97
51	101	10707.25	3107.25	115.36	1.10	0.42	94.42	188.84
101	540	292106.30	10707.25	549.82	1.35	0.22	97.07	194.14
57	107	11955.25	3755.25	123.31	1.14	0.39	95.17	190.35
107	540	292106.30	11955.25	550.96	1.36	0.21	97.13	194.27

Increment of Stress = 3430.22 (psf)

where: $C_1 = arctg\left(\frac{lb}{zR_3}\right)$

$$C_2 = \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)$$

$$\sigma_z = \frac{P}{2\pi}(C_1 + C_2)$$

Table 6. Approach Embankment Settlement
Summary Calculations for Increment of Stresses at Depth

z = 27.5 feet

b	l	R_1^2	R_2^2	R_3	C_1	C_2	Increment σ_z	
3	53	3565.25	765.25	59.79	0.10	0.12	13.19	26.38
53	540	292356.30	3565.25	543.29	1.09	0.41	93.17	186.33
9	59	4237.25	837.25	65.71	0.29	0.32	37.47	74.94
59	540	292356.30	4237.25	543.91	1.13	0.39	94.19	188.39
15	65	4981.25	981.25	72.15	0.46	0.45	56.49	112.97
65	540	292356.30	4981.25	544.59	1.17	0.36	94.93	189.86
21	71	5797.25	1197.25	78.98	0.60	0.52	69.81	139.63
71	540	292356.30	5797.25	545.34	1.20	0.34	95.47	190.93
27	77	6685.25	1485.25	86.11	0.72	0.55	78.64	157.27
77	540	292356.30	6685.25	546.15	1.22	0.32	95.87	191.74
33	83	7645.25	1845.25	93.46	0.82	0.54	84.38	168.76
83	540	292356.30	7645.25	547.03	1.25	0.30	96.17	192.34
39	89	8677.25	2277.25	100.99	0.90	0.52	88.14	176.28
89	540	292356.30	8677.25	547.98	1.27	0.29	96.41	192.81
45	95	9781.25	2781.25	108.66	0.96	0.50	90.65	181.30
95	540	292356.30	9781.25	548.98	1.28	0.27	96.59	193.18
51	101	10957.25	3357.25	116.44	1.01	0.47	92.36	184.72
101	540	292356.30	10957.25	550.05	1.30	0.26	96.73	193.46
57	107	12205.25	4005.25	124.32	1.06	0.45	93.56	187.12
107	540	292356.30	12205.25	551.19	1.31	0.25	96.85	193.70

Increment of Stress = 3322.09 (psf)

where: $$C_1 = arctg\left(\frac{lb}{zR_3}\right)$$

$$C_2 = \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)$$

$$\sigma_z = \frac{P}{2\pi}(C_1 + C_2)$$

Table 7. Approach Embankment Settlement
Summary Calculations for Increment of Stresses at Depth

z = 32.5 feet

b	l	R_1^2	R_2^2	R_3	C_1	C_2	Increment σ_z	
3	53	3865.25	1065.25	62.24	0.08	0.10	11.04	22.08
53	540	292656.30	3865.25	543.57	1.02	0.45	91.02	182.03
9	59	4537.25	1137.25	67.96	0.24	0.28	31.98	63.96
59	540	292656.30	4537.25	544.18	1.06	0.43	92.48	184.96
15	65	5281.25	1281.25	74.20	0.38	0.41	49.55	99.11
65	540	292656.30	5281.25	544.87	1.10	0.40	93.55	187.10
21	71	6097.25	1497.25	80.86	0.52	0.50	62.98	125.96
71	540	292656.30	6097.25	545.62	1.14	0.38	94.34	188.69
27	77	6985.25	1785.25	87.83	0.63	0.54	72.66	145.31
77	540	292656.30	6985.25	546.43	1.17	0.36	94.95	189.89
33	83	7945.25	2145.25	95.05	0.73	0.55	79.44	158.88
83	540	292656.30	7945.25	547.31	1.19	0.34	95.41	190.81
39	89	8977.25	2577.25	102.46	0.81	0.55	84.17	168.33
89	540	292656.30	8977.25	548.25	1.22	0.33	95.77	191.53
45	95	10081.25	3081.25	110.03	0.87	0.54	87.47	174.95
95	540	292656.30	10081.25	549.26	1.24	0.31	96.05	192.10
51	101	11257.25	3657.25	117.72	0.93	0.52	89.82	179.65
101	540	292656.30	11257.25	550.32	1.25	0.30	96.27	192.55
57	107	12505.25	4305.25	125.52	0.98	0.49	91.52	183.03
107	540	292656.30	12505.25	551.46	1.27	0.28	96.46	192.91

Increment of Stress = 3213.81 (psf)

where: $C_1 = arctg\left(\frac{lb}{zR_3}\right)$

$$C_2 = \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)$$

$$\sigma_z = \frac{P}{2\pi}(C_1 + C_2)$$

Table 8. Approach Embankment Settlement
Summary Calculations for Increment of Stresses at Depth

z = 37.5 feet

b	l	R_1^2	R_2^2	R_3	C_1	C_2	Increment σ_z	
3	53	4215.25	1415.25	64.99	0.07	0.09	9.42	18.84
53	540	293006.30	4215.25	543.89	0.95	0.47	88.54	177.09
9	59	4887.25	1487.25	70.49	0.20	0.25	27.68	55.37
59	540	293006.30	4887.25	544.51	1.00	0.46	90.46	180.91
15	65	5631.25	1631.25	76.53	0.33	0.38	43.78	87.55
65	540	293006.30	5631.25	545.19	1.04	0.44	91.89	183.77
21	71	6447.25	1847.25	83.00	0.45	0.47	56.85	113.71
71	540	293006.30	6447.25	545.94	1.08	0.42	92.97	185.94
27	77	7335.25	2135.25	89.80	0.55	0.52	66.91	133.83
77	540	293006.30	7335.25	546.75	1.11	0.40	93.80	187.60
33	83	8295.25	2495.25	96.87	0.65	0.55	74.41	148.82
83	540	293006.30	8295.25	547.63	1.14	0.38	94.45	188.89
39	89	9327.25	2927.25	104.15	0.73	0.56	79.91	159.82
89	540	293006.30	9327.25	548.57	1.17	0.36	94.96	189.91
45	95	10431.25	3431.25	111.61	0.80	0.56	83.94	167.88
95	540	293006.30	10431.25	549.57	1.19	0.35	95.36	190.72
51	101	11607.25	4007.25	119.20	0.86	0.54	86.90	173.81
101	540	293006.30	11607.25	550.64	1.21	0.33	95.68	191.37
57	107	12855.25	4655.25	126.90	0.91	0.53	89.11	178.21
107	540	293006.30	12855.25	551.77	1.23	0.32	95.95	191.90

Increment of Stress = 3105.92 (psf)

where: $$C_1 = arctg\left(\frac{lb}{zR_3}\right)$$

$$C_2 = \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)$$

$$\sigma_z = \frac{P}{2\pi}(C_1 + C_2)$$

Table 9. Approach Embankment Settlement
Summary Calculations for Increment of Stresses at Depth

z = 42.5 feet

b	l	R_1^2	R_2^2	R_3	C_1	C_2	Increment σ_z	
3	53	4615.25	1815.25	68.00	0.05	0.08	8.15	15.29
53	540	293406.30	4615.25	544.26	0.89	0.49	85.84	171.68
9	59	5287.25	1887.25	73.27	0.17	0.22	24.23	48.26
59	540	293406.30	5287.25	544.87	0.94	0.48	88.19	176.37
15	65	6031.25	2031.25	79.10	0.28	0.34	38.92	77.84
65	540	293406.30	6031.25	545.56	0.99	0.46	89.98	179.97
21	71	6847.25	2247.25	85.37	0.39	0.44	51.43	102.86
71	540	293406.30	6847.25	546.30	1.03	0.45	91.37	182.74
27	77	7735.25	2535.25	92.00	0.49	0.50	61.55	123.11
77	540	293406.30	7735.25	547.12	1.06	0.43	92.45	184.90
33	83	8695.25	2895.25	98.92	0.58	0.54	69.47	138.95
83	540	293406.30	8695.25	547.99	1.09	0.41	93.30	186.61
39	89	9727.25	3327.25	106.06	0.66	0.56	75.55	151.11
89	540	293406.30	9727.25	548.93	1.12	0.40	93.98	187.96
45	95	10831.25	3831.25	113.39	0.73	0.57	80.19	160.37
95	540	293406.30	10831.25	549.94	1.14	0.38	94.52	189.05
51	101	12007.25	4407.25	120.86	0.79	0.56	83.71	167.42
101	540	293406.30	12007.25	551.01	1.17	0.36	94.96	189.93
57	107	13255.25	5055.25	128.47	0.84	0.55	86.40	172.80
107	540	293406.30	13255.25	552.14	1.19	0.35	95.32	190.64

Increment of Stress = 2999.06 (psf)

where: $$C_1 = arctg\left(\frac{lb}{zR_3}\right)$$

$$C_2 = \frac{lbz}{R_3}\left(\frac{1}{R_1^2} + \frac{1}{R_2^2}\right)$$

$$\sigma_z = \frac{P}{2\pi}(C_1 + C_2)$$

Compute settlement.

- Use the following expression:

$$\rho = \sum_{i=1}^{n} \rho_i = \sum_{i=1}^{n} H_i \, CR \, \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}}\right)$$

where:

n = number of sublayers = 7

H_i = thickness of each substrata = 5 ft

CR = Virgin Compression Ratio $= \dfrac{C_c}{(1 + e_0)}$

$\bar{\sigma}_{vf}$ = Final vertical effective stress $= \bar{\sigma}_{v0} + \Delta\,\bar{\sigma}_v$

$\bar{\sigma}_{v0}$ = Initial vertical effective stress

- Determine value of CR:

$$CR = \frac{C_c}{(1 + e_0)}$$

Use: $Gw = Se \Rightarrow e = \dfrac{Gw}{S}$

Therefore: $e_0 = \dfrac{Gw}{S} = \dfrac{2.78 \times 0.35}{1}$ Note: Assumed S = 100%

$e_0 = 0.973$

Thus: $CR = \dfrac{C_c}{(1 + e_0)} = \dfrac{0.35}{(1 + 0.973)} = 0.177$

- Apply expressions above; obtain table below:

z (ft)	$\bar{\sigma}_{v0}$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vf}$ $(psf) = \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$	$\rho_i = H_i\, CR\, \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}}\right)$
12.5	949.5	3645.024	4594.524	0.6073516 ft
17.5	1272.5	3537.818	4810.318	0.5122418
22.5	1595.5	3430.215	5025.715	0.4419801
27.5	1918.5	3322.095	5240.595	0.3870922
32.5	2241.5	3213.811	5455.311	0.3426211
37.5	2564.5	3105.922	5670.422	0.3056625
42.5	2887.5	2999.06	5886.56	0.2743762

Total Settlement:	2.8713	ft
	34.46	in

Compilation of Computer Screens for Example 2

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

PROTOTYPE ENGINEERING INC.

57 Westland Avenue
Winchester, MA 01890
(617) 729-2363

Attn. Dr. Alfredo Urzua

Version 2.00/October 1991 Hit <F10> to continue

OPENING SCREEN

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu

- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment
- system of Units
- Maintain file
- Run program
- Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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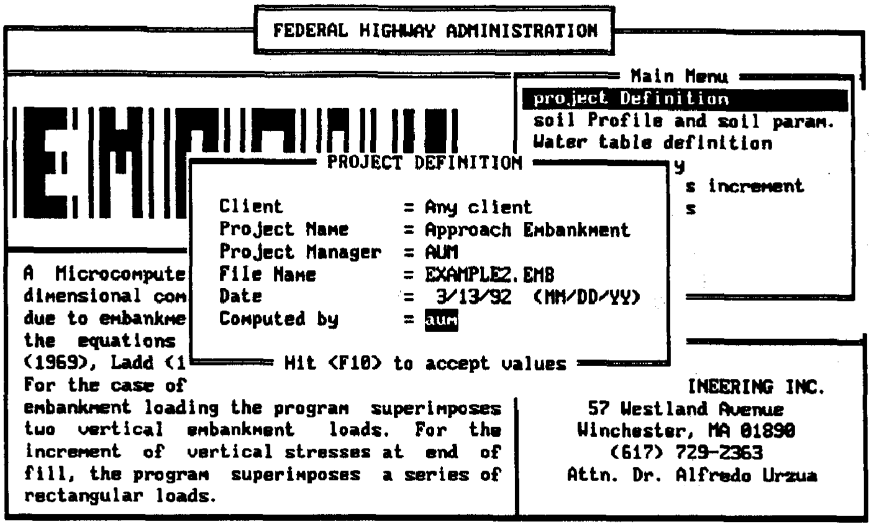
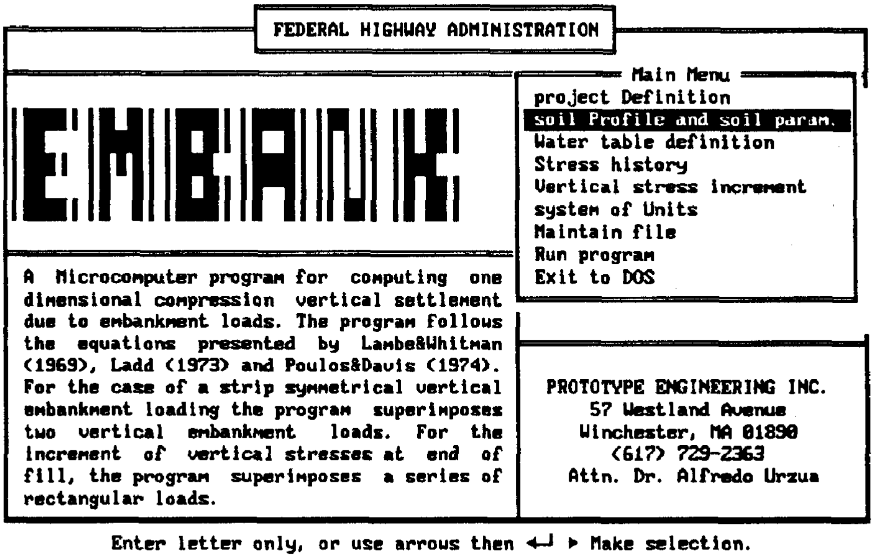
Enter letter only, or use arrows then ↵ ▸ Make selection.

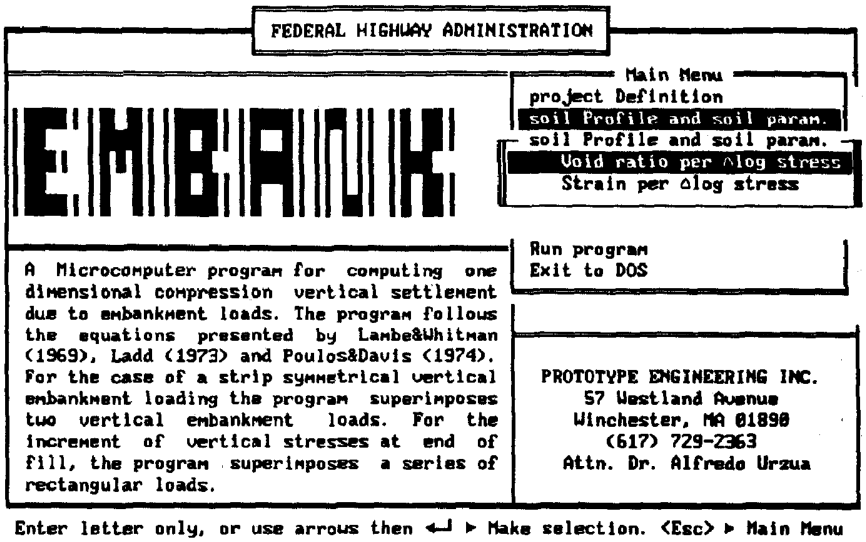
EMBANK MAIN MENU - SELECTION OF PROJECT DEFINITION



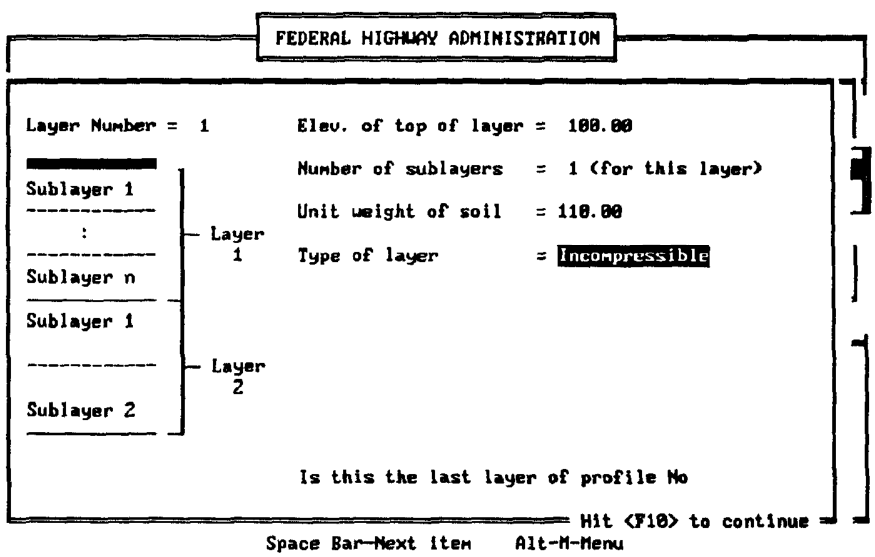
PROJECT DEFINITION SCREEN



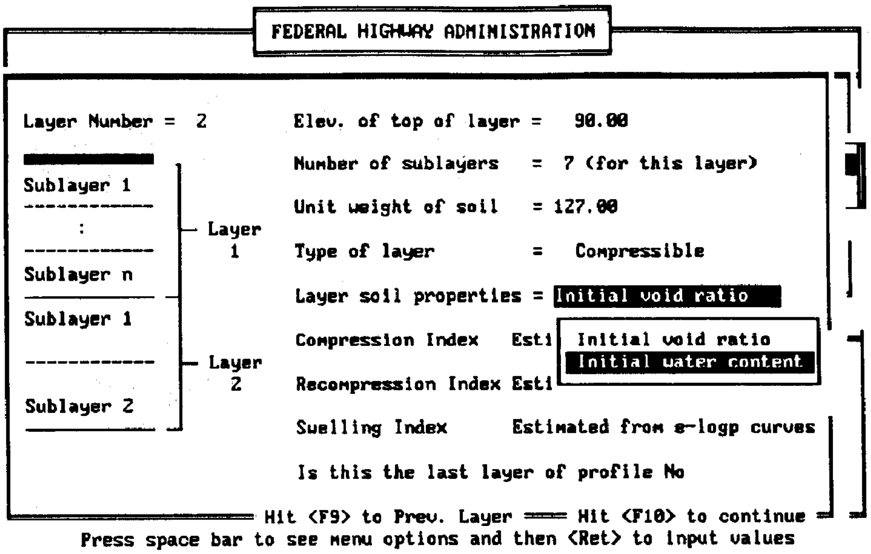
EMBANK MAIN MENU - SELECTION OF SOIL PROFILE



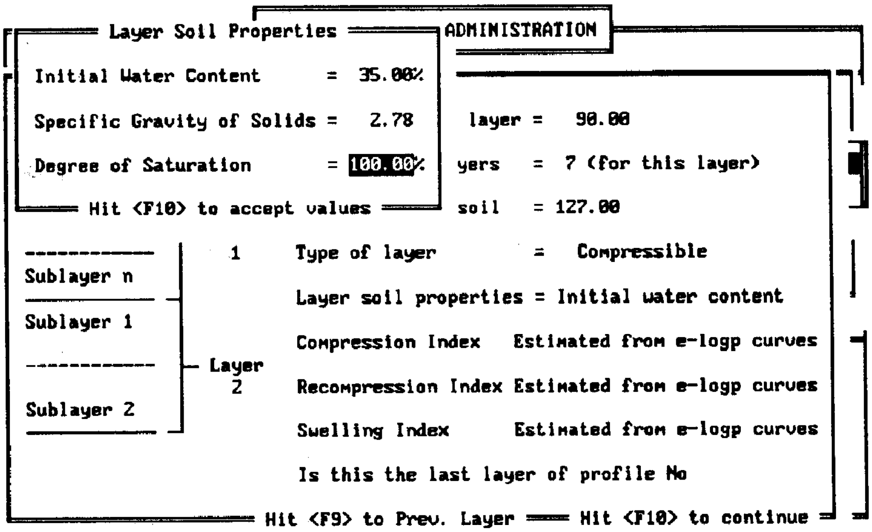
SOIL PROFILE MENU - SELECTION OF VOID RATIO PER LOG STRESS



SOIL DESCRIPTION AND PARAMETERS FOR LAYER #1



SOIL DESCRIPTION AND PARAMETERS FOR LAYER #2



INITIAL WATER CONTENT - LAYER #2

```
                                                  ATION

Layer Number =  2          Elev. of top of layer =   90.00

                           Number of sublayers    =  7 (for this layer)
Sublayer 1
-----------                Unit weight of soil    = 127.00
     :          - Layer
-----------       1        Type of layer          =   Compressible
Sublayer n
-----------                Layer soil properties = Initial water content
Sublayer 1
                           Compression Index    Estimated from e-logp curves
-----------     - Layer
                  2        Recompression Index  Estimated from e-logp curves
Sublayer 2                                      Computed using FHWA(1982)
-----------                Swelling Index

                           Is this the last layer of profile No

               Hit <F9> to Prev. Layer ==== Hit <F10> to continue
      Press space bar to see menu options and then <Ret> to input values
```

COMPRESSION INDEX MENU - FHWA(1982)

```
 ======== Compression Index ==========

 The Federal Highway Administration (FHWA) in the soil
 and Foundations Workshop  Manual (1982) estimates the
 Compression  Index  by  dividing  the  initial   soil
 moisture content by 100.
                                                         this layer)
 Comp. Index = Initial Water Content (in %) / Constant
 where constant = 100

                Constant = 100                           ssible

 ======= Hit <F10> to accept value ==========            water content

                           Compression Index   Computed using FHWA(1982)
-----------     - Layer
                  2        Recompression Index Estimated from e-logp curves
Sublayer 2
-----------                Swelling Index      Estimated from e-logp curves

                           Is this the last layer of profile No

               Hit <F9> to Prev. Layer ==== Hit <F10> to continue
```

FHWA(1982) PROCEDURE SCREEN

```
Compression Index

Layer Number =  2        Elev. of top of layer =    90.00
                         Number of sublayers   =  7 (for this layer)
Sublayer 1               Unit weight of soil   = 127.00
-----------
     :        Layer
-----------     1        Type of layer         =   Compressible
Sublayer n
                         Layer soil properties = Initial water content
Sublayer 1
                         Compression Index   Computed using FHWA(1982)
-----------   Layer
                2        Recompression Index Estimated from e-logp curves
Sublayer 2
                         Swelling Index        Estimated from e-logp curves
                                               Computed using FHWA(1982)
                         Is this the last lay

           Hit <F9> to Prev. Layer === Hit <F10> to continue
     Press space bar to see menu options and then <Ret> to input values
```

RECOMPRESSION INDEX MENU - FHWA(1982)

```
Recompression Index

The Federal Highway Administration (FHWA) in the  soils
and Foundations  Workshop  Manual  (1982) estimates the
Recompression  Index  by  dividing  the  initial   soil
moisture content by 1000.                                 is layer)

Recomp. Index = Initial Water Content (in %) / Constant
where Constant  = 1000

                Constant   = 1000                         ible

         Hit <F10> to accept values                       ter content

                         Compression Index   Computed using FHWA(1982)
-----------   Layer
                2        Recompression Index Computed using FHWA(1982)
Sublayer 2
                         Swelling Index      Estimated from e-logp curves

                         Is this the last layer of profile No

           Hit <F9> to Prev. Layer === Hit <F10> to continue
```

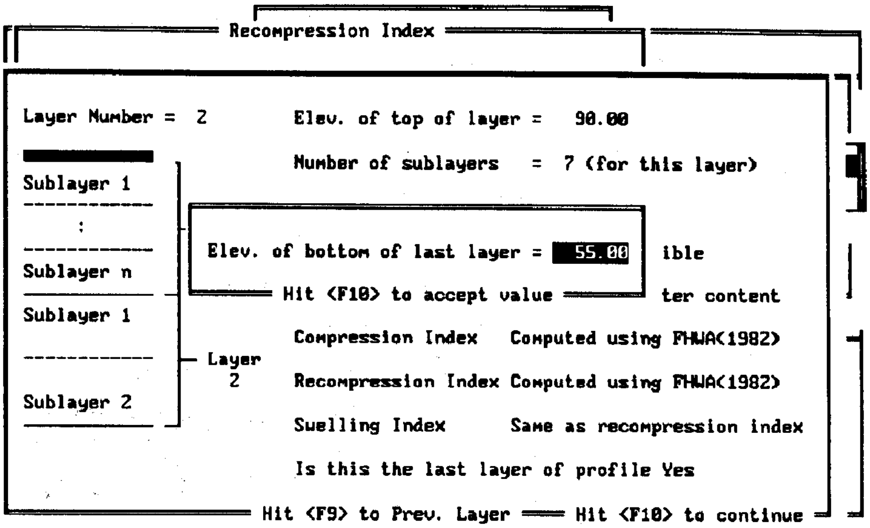
RECOMPRESSION INDEX - FHWA(1982) PROCEDURE SCREEN

```
                    Recompression Index

Layer Number =  2          Elev. of top of layer =   98.00

                           Number of sublayers   =  7 (for this layer)
Sublayer 1
------------               Unit weight of soil   = 127.00
     :          Layer
------------      1        Type of layer         =   Compressible
Sublayer n
                           Layer soil properties = Initial water content
Sublayer 1
                           Compression Index    Computed using FHWA(1982)
------------    Layer
                  2        Recompression Index Computed using FHWA(1982)
Sublayer 2
                           Swelling Index       Estimated from e-logp curves

                           Is this the last lay  Estimated from e-logp curves
                                                 Same as recompression index
                     Hit <F9> to Prev. Layer
       Press space bar to see menu options and then <Ret> to input values
```

SWELLING INDEX - LAYER #2

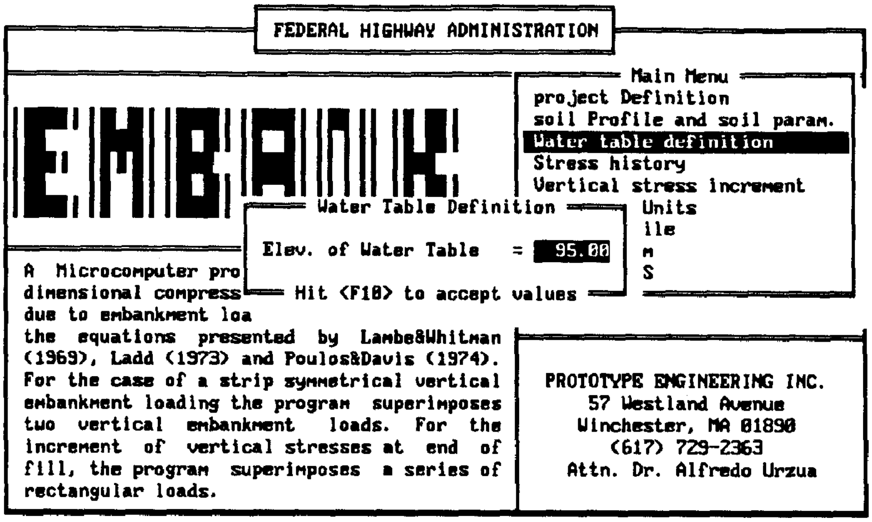
```
                    Recompression Index

Layer Number =  2          Elev. of top of layer =   98.00

                           Number of sublayers   =  7 (for this layer)
Sublayer 1
------------               Unit weight of soil   = 127.00
     :          Layer
------------      1        Type of layer         =   Compressible
Sublayer n
                           Layer soil properties = Initial water content
Sublayer 1
                           Compression Index    Computed using FHWA(1982)
------------    Layer
                  2        Recompression Index Computed using FHWA(1982)
Sublayer 2
                           Swelling Index       Same as recompression index

                           Is this the last layer of profile Yes

                     Hit <F9> to Prev. Layer ==== Hit <F10> to continue
                     Space Bar-Next item     Alt-M-Menu
```

DEFINING LAYER #2 AS LAST LAYER OF SOIL PROFILE

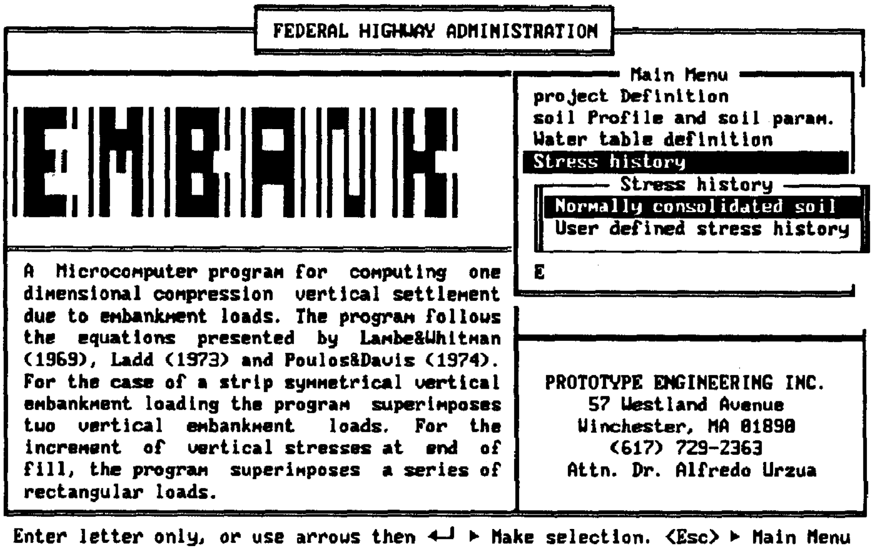


DEFINING THE THICKNESS OF THE SOIL PROFILE

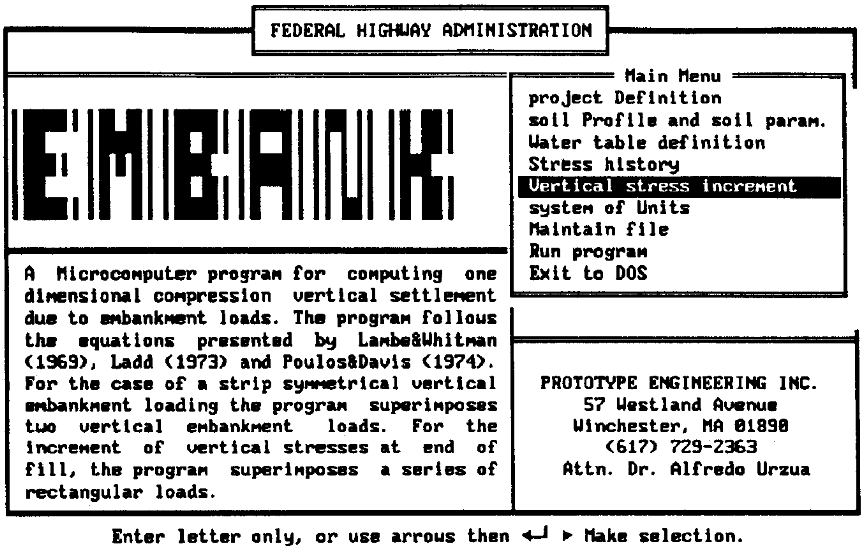
EMBANK MAIN MENU - SELECTION OF WATER TABLE DEFINITION



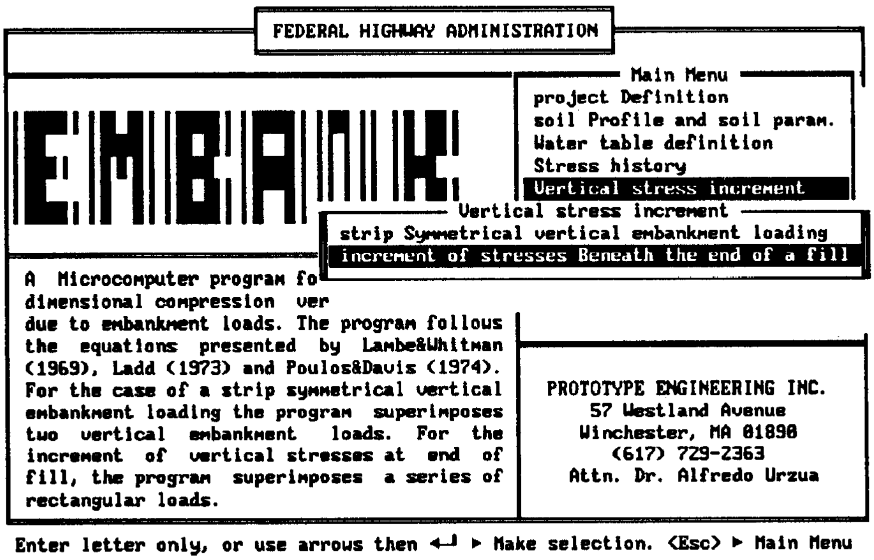
WATER TABLE AT ELEVATION 95 FT.



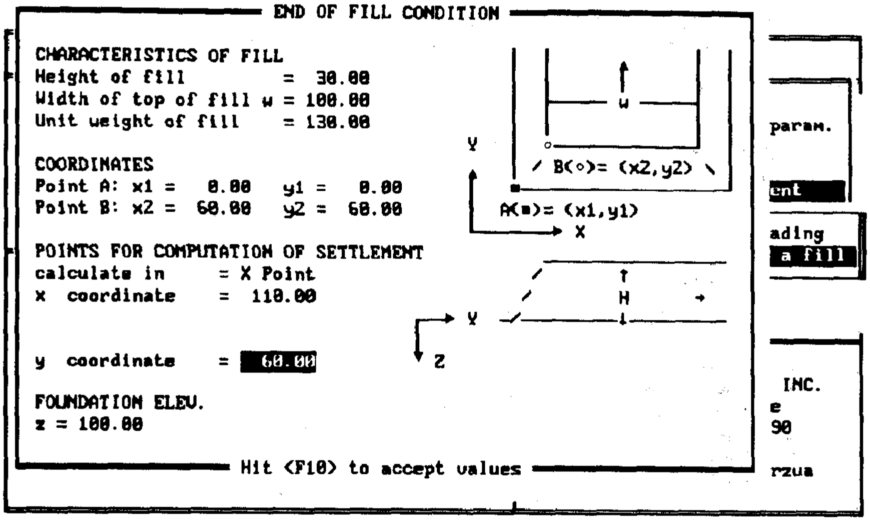
COMPRESSIBLE LAYER IS DEFINED AS NORMALLY CONSOLIDATED



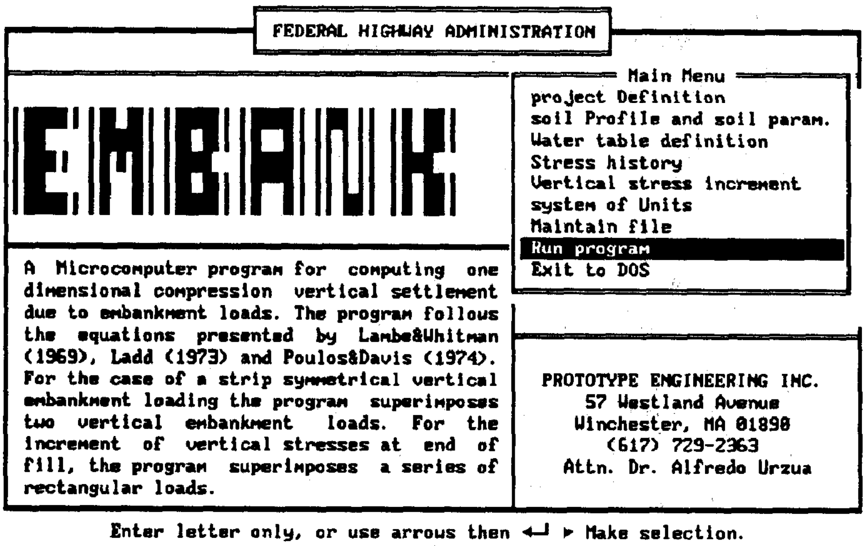
EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT



VERTICAL STRESS INCREMENT MENU - SELECTION OF END OF FILL CONDITION



END OF FILL GEOMETRY - POINT A COORDINATES



EMBANK MAIN MENU - RUN PROGRAM

```
------ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ------
           INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION
     LAYER                 COEFFICIENT          UNIT   SPECIFIC  VOID
Nº.  TYPE  THICK.   COMP. RECOMP. SWELL.   WEIGHT  GRAVITY   RATIO  Settlement
            (ft)                            (pcf)                      (in.)

 1  INCOMP. 10.0    -----  -----  -----    110.00    ----     ----
 2  COMP.   35.0    0.350  0.035  0.035    127.00    2.78     0.97     34.46

                                           Total Settlement =          34.46


          SUBLAYER                    SOIL STRESSES
   Nº.  THICK.   ELEV.    INITIAL  INCREMENT  MAX.PAST PRESS.    SETTLEMENT
         (ft)    (ft)     (psf)     (psf)        (psf)              (in.)

    1  INCOMP.
    2   5.00     87.50    949.50   3645.03      949.50              7.29
    3   5.00     82.50   1272.50   3537.82     1272.50              6.15
    4   5.00     77.50   1595.50   3430.22     1595.50              5.30
    5   5.00     72.50   1918.50   3322.11     1918.50              4.65
    6   5.00     67.50   2241.50   3213.84     2241.50              4.11
    7   5.00     62.50   2564.50   3105.97     2564.50              3.67

------ Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu ------
```

PROGRAM OUTPUT - PARTIAL SCREEN

```
------ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ------
           INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION
     LAYER                 COEFFICIENT          UNIT   SPECIFIC  VOID
Nº.  TYPE  THICK.   COMP. RECOMP. SWELL.   WEIGHT  GRAVITY   RATIO  Settlement
            (ft)                            (pcf)                      (in.)

 1  INCOMP. 10.0    -----  -----  -----    110.00    ----     ----
 2  COMP.   35.0    0.350  0.035  0.035    127.00    2.78     0.97     34.46

                                           Total Settlement =          34.46


          SUBLAYER                 S============== Select ==============
   Nº.  THICK.   ELEV.    INITIAL  INCR| Send form to: P-Printer, D-Disk File. |
         (ft)    (ft)     (psf)     (p======================================

    1  INCOMP.
    2   5.00     87.50    949.50   3645.03      949.50              7.29
    3   5.00     82.50   1272.50   3537.82     1272.50              6.15
    4   5.00     77.50   1595.50   3430.22     1595.50              5.30
    5   5.00     72.50   1918.50   3322.11     1918.50              4.65
    6   5.00     67.50   2241.50   3213.84     2241.50              4.11
    7   5.00     62.50   2564.50   3105.97     2564.50              3.67

------ Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu ------
```

SELECTION OF DISK FILE PRINTED OUTPUT

```
ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
        INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION
                  y direc. =   60.00 (ft)  Unit weight of fill =  130.00 (pcf)
Embankment top width     =  100.00 (ft)  p load/unit area     = 3900.00 (psf)
Embankment bottom width =  220.00 (ft)  Foundation Elev.     =  100.00 (ft)
Ground Surface Elev.     =  100.00 (ft)
Water table Elev.        =   95.00 (ft)  Unit weight of Wat. =   62.40 (pcf)

    LAYER              COEFFICIENT         UNIT   SPECIFIC  VOID
Nº.  TYPE  THICK.  COMP. RECOMP. SWELL.  WEIGHT  GRAVITY   RATIO  Settlement
           (ft)                          (pcf)                      (in.)
                                                 Destination File
 1  INCOMP. 10.0   -----  -----  -----  EXAM2A.OUT
 2   COMP.  35.0   0.350  0.035  0.035

                                        Total Settlement =       34.46

         SUBLAYER                      SOIL STRESSES
   Nº.  THICK.  ELEV.   INITIAL  INCREMENT  MAX.PAST PRESS.    SETTLEMENT
         (ft)    (ft)    (psf)     (psf)        (psf)            (in.)

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu
```

DISK FILE PRINTED OUTPUT - DESTINATION OUTPUT FILE NAME

```
ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
        INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name    : Approach Embankment  Client            : Any Client
File Name       : EXAMPLE2.EMB         Project Manager   : AUM
Date            : 10/02/91             Computed by       : aum

          Settlement for X =  110.00 (ft)        Y =  60.00 (ft)

Embank. slope, x direc. =   60.00 (ft)  Height of fill H     =   30.00 (ft)
                y direc. =   60.00 (ft)  Unit weight of fill =  130.00 (pcf)
Embankment top width     =  100.00 (ft)  p load/unit area     = 3900.00 (psf)
Embankment bottom width =  220.00 (ft)  Foundation Elev.     =  100.00 (ft)
Ground Surface Elev.     =  100.00 (ft)
Water table Elev.        =   95.00 (ft)  Unit weight of Wat. =   62.40 (pcf)

    LAYER              COEFFICIENT         UNIT   SPECIFIC  VOID
Nº.  TYPE  THICK.  COMP. RECOMP. SWELL.  WEIGHT  GRAVITY   RATIO  Settlement
           (ft)                          (pcf)                      (in.)

 1  INCOMP. 10.0   -----  -----  -----  110.00    ----     ----
 2   COMP.  35.0   0.350  0.035  0.035  127.00    2.78     0.97     34.46

                                        Total Settlement =       34.46

         SUBLAYER                      SOIL STRESSES
   Nº.  THICK.  ELEV.   INITIAL  INCREMENT  MAX.PAST PRESS.    SETTLEMENT
         (ft)    (ft)    (psf)     (psf)        (psf)            (in.)

    1  INCOMP.
    2   5.00    87.50    949.50   3645.03      949.50             7.29
    3   5.00    82.50   1272.50   3537.82     1272.50             6.15
    4   5.00    77.50   1595.50   3430.22     1595.50             5.30
    5   5.00    72.50   1918.50   3322.11     1918.50             4.65
    6   5.00    67.50   2241.50   3213.84     2241.50             4.11
    7   5.00    62.50   2564.50   3105.97     2564.50             3.67
    8   5.00    57.50   2887.50   2999.13     2887.50             3.29

                                     Total Settlement =      34.46 (in.)

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu
```

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment

Vertical stress increment
strip Symmetrical vertical embankment loading
increment of stresses Beneath the end of a fill

A Microcomputer program fo
dimensional compression ver
due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ► Make selection. <Esc> ► Main Menu

EMBANK MAIN MENU - VERTICAL STRESS INCREMENT MENU

END OF FILL CONDITION

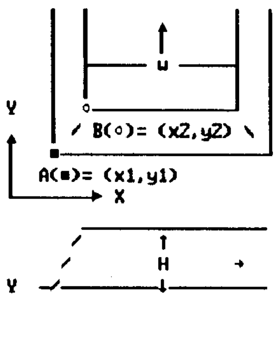
CHARACTERISTICS OF FILL
Height of fill = 30.00
Width of top of fill w = 100.00
Unit weight of fill = 130.00

COORDINATES
Point A: x1 = 0.00 y1 = 0.00
Point B: x2 = 60.00 y2 = 60.00

POINTS FOR COMPUTATION OF SETTLEMENT
calculate in = X Point
x coordinate = 110.00

y coordinate = 0.00

FOUNDATION ELEV.
z = 100.00



Hit <F10> to accept values

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END OF FILL GEOMETRY - POINT C COORDINATES

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu

- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment
- system of Units
- Maintain file
- Run program
- Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

PROTOTYPE ENGINEERING INC.
57 Westland Avenue
Winchester, MA 01890
(617) 729-2363
Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ▸ Make selection.

EMBANK MAIN MENU - RUN PROGRAM

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name : Approach Embankment Client : Any Client
Project Number : 91-1235 Project Manager : AUM
Date : 10/02/91 Computed by : aum

Settlement for X = 110.00(ft) Y = 0.00 (ft)

Emband. slope, x direc. = 60.00 (ft) Height of fill H = 30.00 (ft)
y direc. = 60.00 (ft) Unit weight of fill = 130.00 (pcf)
Embankment top width = 100.00 (ft) p load/unit area = 3900.00 (psf)
Embankment bottom width = 220.00 (ft) Foundation Elev. = 100.00 (ft)
Ground Surface Elev. = 100.00 (ft)
Water table Elev. = 95.00 (ft)

Destination File
EXAM2C.OUT

Nº.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO	Settlement (in.)
1	INCOMP.	10.0	-----	-----	-----	110.00	----	----	

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

DISK FILE PRINTED OUTPUT - DESTINATION OUTPUT FILE

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name	: Approach Embankment	Client	: Any Client
File Name	: EXAMPLE2.EMB	Project Manager	: AUM
Date	: 10/02/91	Computed by	: aum

Settlement for X = 110.00 (ft)   Y = 0.00 (ft)

Embank. slope, x direc.	= 60.00 (ft)	Height of fill H	= 30.00 (ft)
y direc.	= 60.00 (ft)	Unit weight of fill	= 130.00 (pcf)
Embankment top width	= 100.00 (ft)	p load/unit area	= 3900.00 (psf)
Embankment bottom width	= 220.00 (ft)	Foundation Elev.	= 100.00 (ft)
Ground Surface Elev.	= 100.00 (ft)		
Water table Elev.	= 95.00 (ft)	Unit weight of Wat.	= 62.40 (pcf)

Nº.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO	Settlement (in.)
1	INCOMP.	10.0	-----	-----	-----	110.00	----	----	
2	COMP.	35.0	0.350	0.035	0.035	127.00	2.78	0.97	7.51

Total Settlement = 7.51

Nº.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	INCREMENT (psf)	MAX.PAST PRESS. (psf)	SETTLEMENT (in.)
1	INCOMP.					
2	5.00	87.50	949.50	248.05	949.50	1.07
3	5.00	82.50	1272.50	343.85	1272.50	1.11
4	5.00	77.50	1595.50	432.56	1595.50	1.11
5	5.00	72.50	1918.50	513.52	1918.50	1.10
6	5.00	67.50	2241.50	586.22	2241.50	1.07
7	5.00	62.50	2564.50	650.45	2564.50	1.04
8	5.00	57.50	2887.50	706.28	2887.50	1.01

Total Settlement = 7.51 (in.)

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment

Vertical stress increment
- strip Symmetrical vertical embankment loading
- increment of stresses Beneath the end of a fill

A Microcomputer program fo... dimensional compression ver... due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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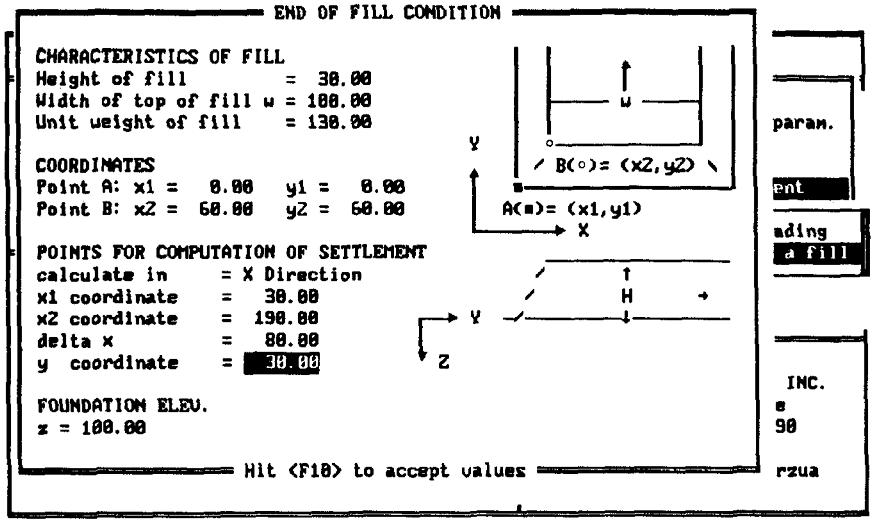
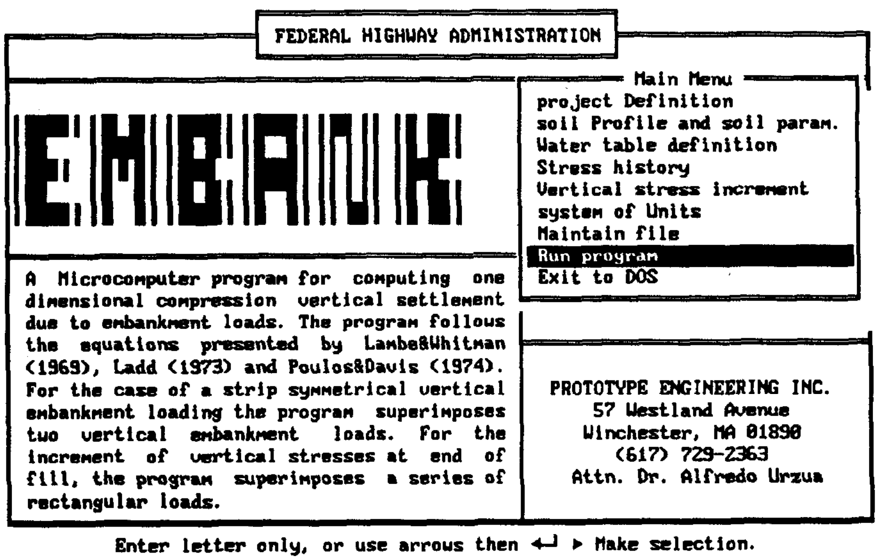
Enter letter only, or use arrows then ↵ ► Make selection. <Esc> ► Main Menu

EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT MENU



END OF FILL GEOMETRY - SETTLEMENT IN X-DIRECTION



EMBANK MAIN MENU - RUN PROGRAM

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name : Approach Embankment   Client : Any Client
Project Number : 91-1235   Project Manager : AUM
Date : 10/02/91   Computed by : aum

Settlement for X-Direction

Embank. slope, x direc. = 60.00 (ft)   Height of fill H = 30.00 (ft)
y direc. = 60.00 (ft)   Unit weight of fill = 130.00 (pcf)
Embankment top width = 100.00 (ft)   Destination File
Embankment bottom width = 220.00 (ft)   EXAM2D-D.OUT
Ground Surface Elev. = 100.00 (ft)
Water table Elev. = 95.00 (ft)   Unit weight of Wat. = 62.40 (pcf)

Nº.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO
1	INCOMP.	10.0	-----	-----	-----	110.00	----	----

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

SELECTION OF DISK FILE PRINTED OUTPUT - DESTINATION FILE

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name : Approach Embankment   Client : Any Client
File Name : EXAMPLE2.EMB   Project Manager : AUM
Date : 10/02/91   Computed by : aum

Settlement for X-Direction

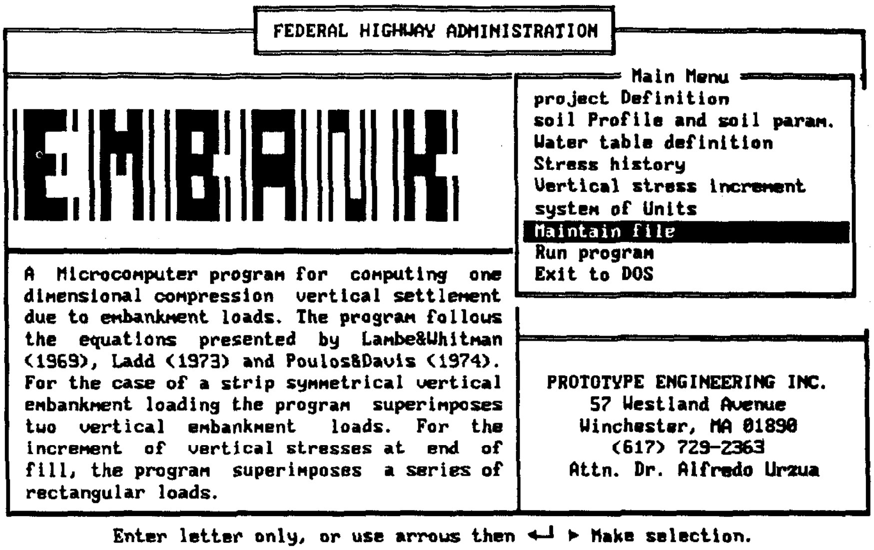
Embank. slope, x direc. = 60.00 (ft)   Height of fill H = 30.00 (ft)
y direc. = 60.00 (ft)   Unit weight of fill = 130.00 (pcf)
Embankment top width = 100.00 (ft)   p load/unit area = 3900.00 (psf)
Embankment bottom width = 220.00 (ft)   Foundation Elev. = 100.00 (ft)
Ground Surface Elev. = 100.00 (ft)
Water table Elev. = 95.00 (ft)   Unit weight of Wat. = 62.40 (pcf)

Nß.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO
1	INCOMP.	10.0	-----	-----	-----	110.00	----	----
2	COMP.	35.0	0.350	0.035	0.035	127.00	2.78	0.97

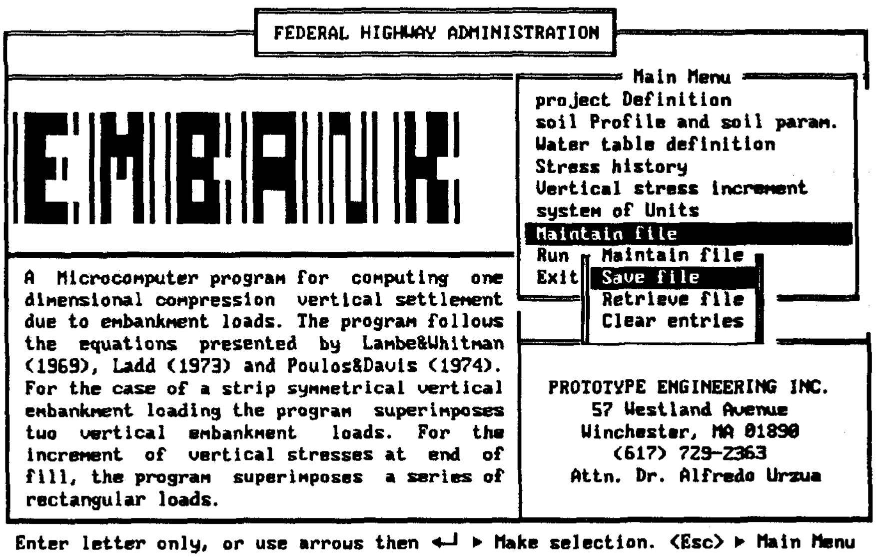
Nß.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	MAX.PAST PRESS. (psf)
1	INCOMP.			
2	5.00	87.50	949.50	949.50
3	5.00	82.50	1272.50	1272.50
4	5.00	77.50	1595.50	1595.50
5	5.00	72.50	1918.50	1918.50
6	5.00	67.50	2241.50	2241.50
7	5.00	62.50	2564.50	2564.50
8	5.00	57.50	2887.50	2887.50

Layer	X = 30.00 Stress (psf)	Sett. (in.)	X = 110.00 Stress (psf)	Sett. (in.)	X = 190.00 Stress (psf)	Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.			
2	1607.73	4.58	1946.78	5.16	1607.73	4.58
3	1496.84	3.59	1941.44	4.28	1496.84	3.59
4	1404.36	2.92	1932.52	3.67	1404.36	2.92
5	1328.79	2.43	1919.59	3.21	1328.79	2.43
6	1267.55	2.07	1902.51	2.84	1267.55	2.07
7	1217.89	1.80	1881.37	2.54	1217.89	1.80
8	1177.30	1.58	1856.48	2.30	1177.30	1.58
		------ 18.97		------ 23.99		------ 18.97

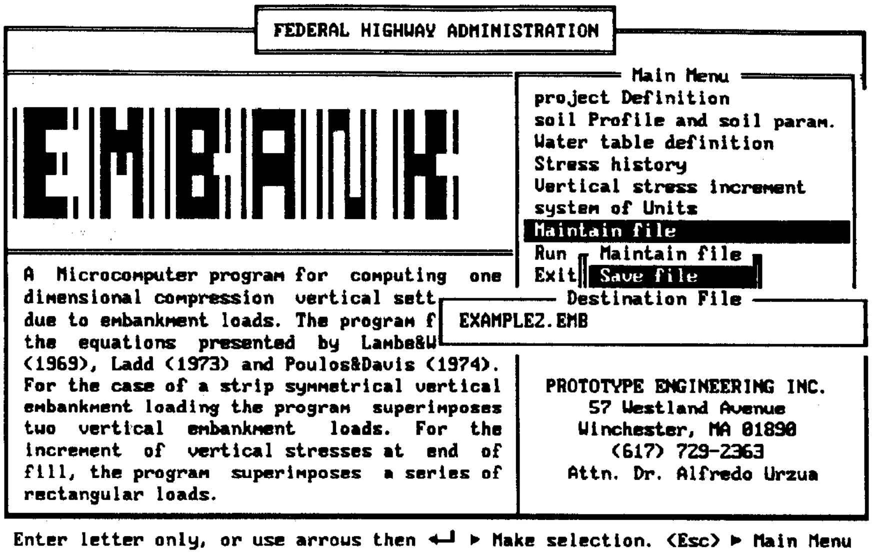
Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu



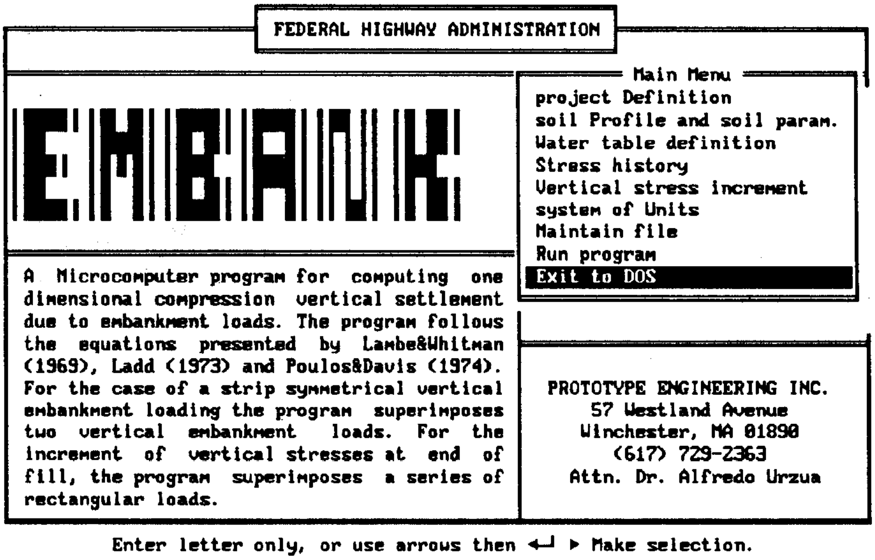
EMBANK MAIN MENU - SELECTION OF MAINTAIN FILE



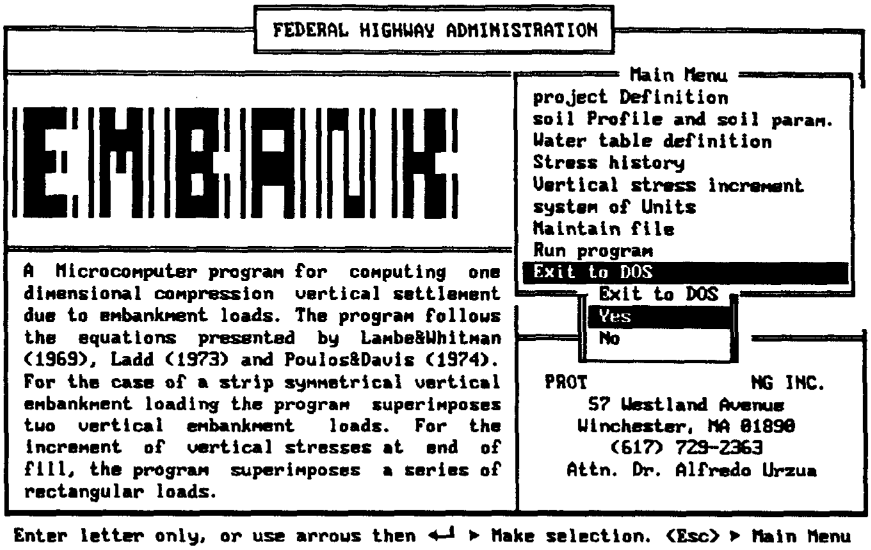
MAINTAIN FILE MENU - SELECTION OF SAVE FILE



SAVING INPUT FILE AS EXAMPLE2.EMB



EMBANK MAIN MENU - EXIT TO DOS



EXIT TO DOS MENU - YES SELECTION

Example 3

Example No. 3: Highway Embankment Settlement

This example is presented in Appendix C of the FHWA Report No. FHWA/RD-86/168, entitled "Prefabricated Vertical Drains, Vol. I: Engineering Guidelines."

Figure 12 depicts the problem geometry and soil parameters. The clay stratum is divided into three sublayers.

Table 10 presents a summary of the computer-calculated settlement for points A through G.

Table 10. Summary of Clay Surface Settlements

Point	Settlement (in) Computer	Settlement (in) Hand-Calculated
A	8.92	
B	63.07	63.09
C	62.17	
D	56.50	56.53
E	37.96	
F	14.44	14.46
G	8.92	8.95

Note that the symmetry of the problem is fully satisfied, as EMBANK predicts the same amount of settlement for points A and G.

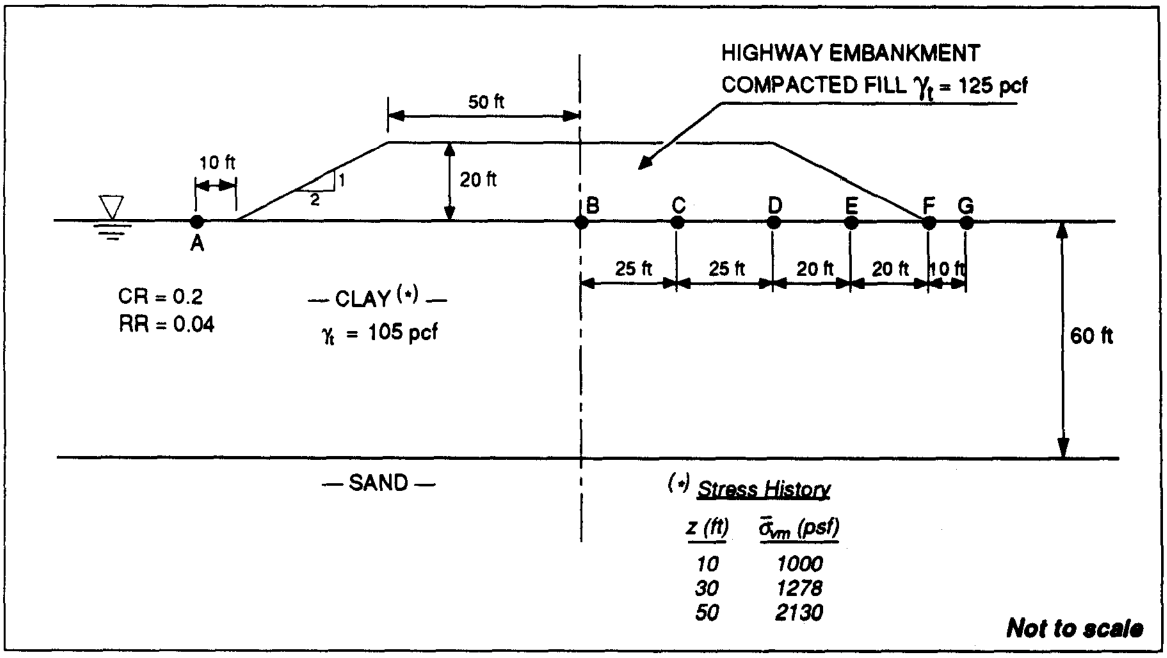
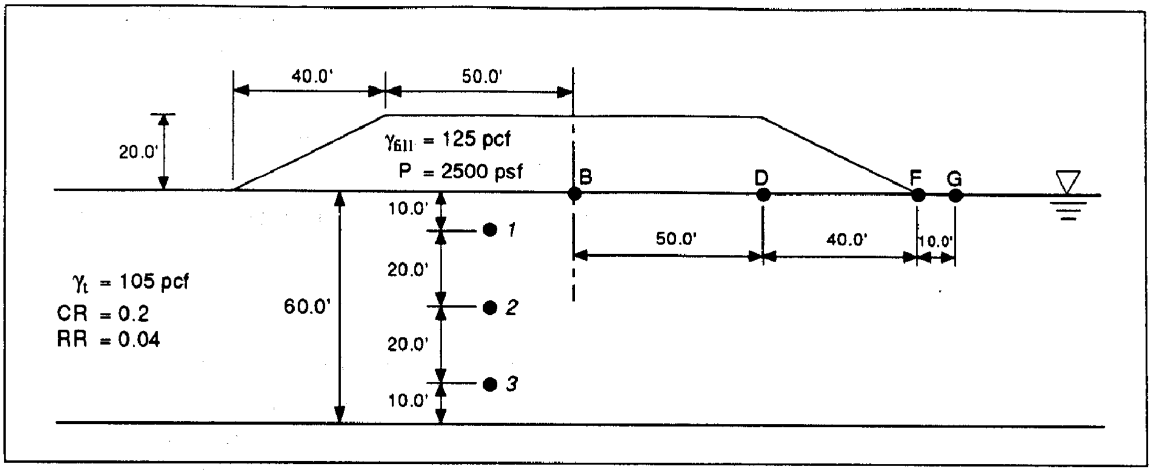


Figure 12. Example 3: Highway embankment settlement

Example No. 3: Highway Embankment Settlement



Clay is overconsolidated from 0 to 20 ft. A maximum past pressure of $\bar{\sigma}_{vm}$ = 1,000 psf at z = 10 ft is used.

Settlement is computed at points B, D, F, and G and compared to program results.

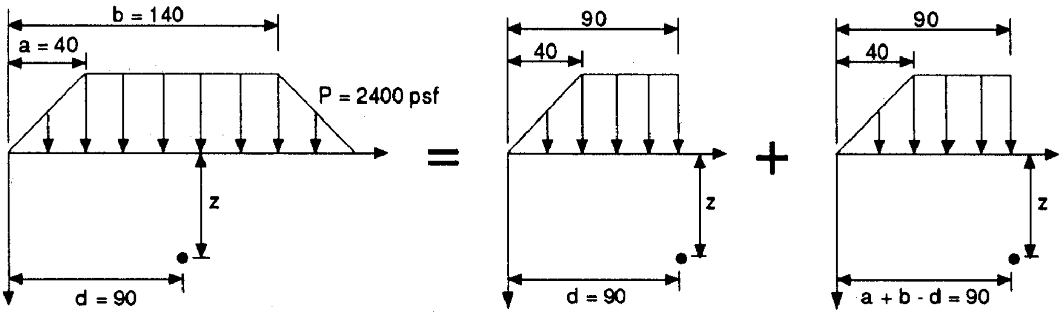
Determine geostatic effective vertical stresses at points 1, 2, and 3:

$$\bar{\sigma}_1 = 10 \times 105 - 10 \times 62.4 = 426 \ psf$$

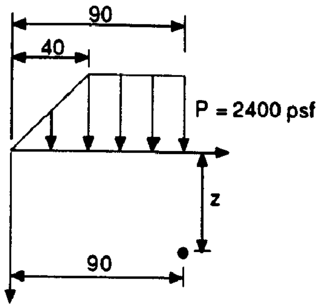
$$\bar{\sigma}_2 = 30 \times 105 - 30 \times 62.4 = 1278 \ psf$$

$$\bar{\sigma}_3 = 50 \times 105 - 50 \times 62.4 = 2130 \ psf$$

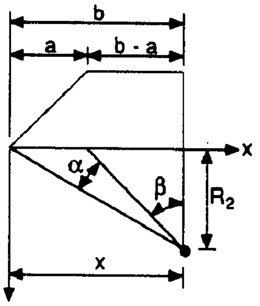
Determine increments of vertical stress under point B; use principle of superposition, as explained in figure 5 of main text:



Therefore, increments of vertical stresses are computed in this case as two times the vertical stress increment for:



For the general case shown below:



The vertical stresses are given by

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x - b)\right]$$

In this case:

$a = 40$

$b = 90$

$b - a = 50$

$x = 90$

$x - b = 0$

Therefore: $$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{90\alpha}{40}\right] = \frac{P}{\pi}[\beta + 2.25\alpha]$$

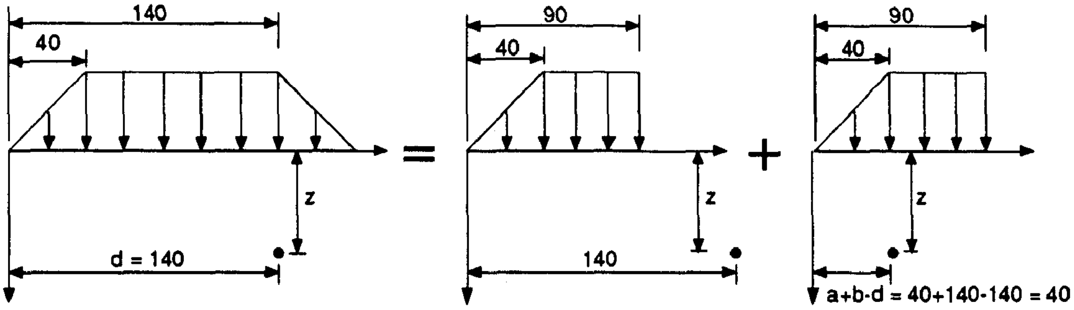
$$\tan\beta = \frac{(b-a)}{z} = \frac{50}{z} \quad \Rightarrow \quad \beta = \arctan\left(\frac{50}{z}\right)$$

$$\tan(\alpha + \beta) = \frac{b}{z} = \frac{90}{z} \quad \Rightarrow \quad \alpha = \arctan\left(\frac{90}{z}\right) - \beta$$

Compute stress increments for z = 10, 30, and 50 ft:

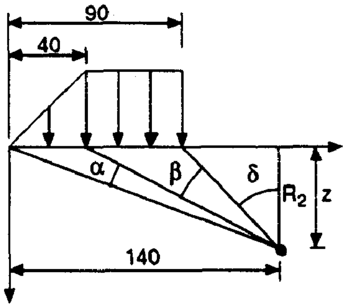
z (ft)	$\beta = \arctan\left(\frac{50}{z}\right)$	$\alpha = \arctan\left(\frac{90}{z}\right) - \beta$	$\sigma_z = \frac{P}{\pi}[\beta + 2.25\alpha]$	$2\sigma_z$ psf
10	78.69006	4.969741	1,248.222	2,496.444
30	59.03625	12.52881	1,211.473	2,422.940
50	45.0	15.94539	1,123.294	2,246.5870

Determine increments of vertical stress under point D; use principle of superposition, as indicated below:



(1) (2)

For (1) we have:



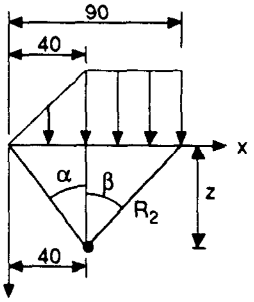
$$x = 140$$
$$a = 40$$
$$b = 90$$
$$(x - b) = 50$$
$$\frac{x}{a} = \frac{140}{40} = 90$$
$$R_2^2 = z^2 + (x-b)^2 \Rightarrow R_2^2 = z^2 + 50^2$$
$$\tan\delta = \frac{(x-b)}{z} = \frac{50}{z} \quad \Rightarrow \delta = \arctan\left(\frac{50}{z}\right)$$
$$\tan(\beta + \delta) = \frac{100}{z} \quad \Rightarrow \beta = \arctan\left(\frac{100}{z}\right) - \delta$$
$$\tan(\delta + \beta + \alpha) = \frac{140}{z} \quad \Rightarrow \alpha = \arctan\left(\frac{140}{z}\right) - \delta -$$

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x-b)\right] = \frac{P}{\pi}\left[\beta + 3.5\alpha - \frac{50z}{R_2^2}\right]$$

The results for z = 10, 30, and 50 ft are:

z (ft)	δ	β	α	$R_2^2 = z^2 + 50^2$	$\frac{z}{R_2^2}(x-b)$	σ_z (psf)
10	78.69006	5.599341	1.62497	2,600	0.1923077	3.726639
30	59.03625	14.26451	4.60449	3,400	0.4411765	70.87047
50	45.0	18.43495	6.911229	5,000	0.5	194.1161

For the second superposition step (2), we have:



$x = 40$

$a = 40$

$b = 90$

$(x - b) = (40 - 90) = -50$

$\frac{x}{a} = \frac{40}{40} = 1$

$R_2^2 = z^2 + 50^2$

$$\tan\beta = \frac{50}{z} \quad \Rightarrow \beta = \arctan\left(\frac{50}{z}\right)$$

$$\tan\alpha = \frac{40}{z} \quad \Rightarrow \alpha = \arctan\left(\frac{40}{z}\right)$$

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x - b)\right] \Rightarrow \sigma_z = \frac{P}{\pi}\left[\beta + \alpha + \frac{50z}{R_2^2}\right]$$

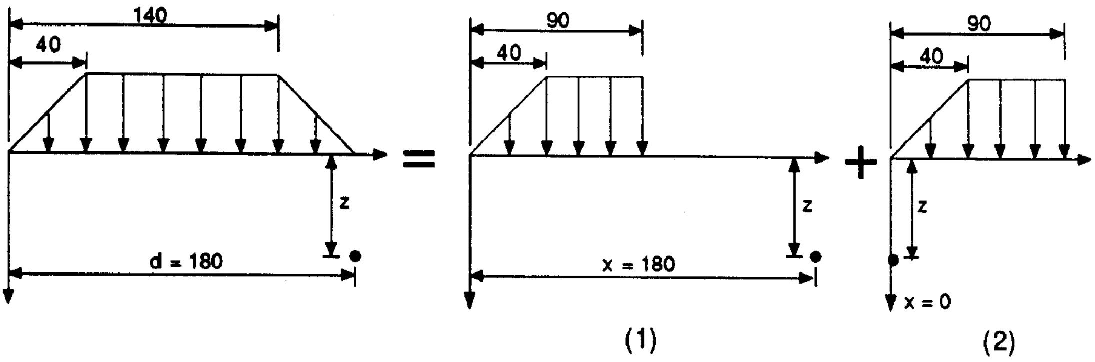
The results for z = 10, 30, and 50 ft are indicated in the table below:

z (*ft*)	α	β	$R_2^2 = z^2 + 50^2$	$\frac{z}{R_2^2}(x - b)$	σ_z (*psf*)
10	75.96376	78.69006	2,600	0.1923077	2,301.003
30	53.13011	59.03625	3,400	0.4411765	1,908.943
50	38.65981	45.0	5,000	0.5	1,559.829

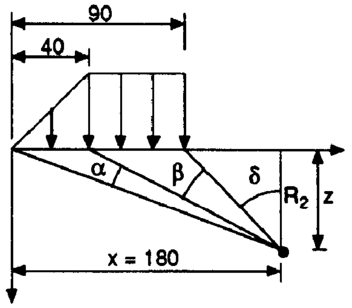
Add stress increments from steps (1) and (2) to obtain the stress increments. See table below:

z (*ft*)	σ_z (*psf*)	σ_z (*psf*)
10	2,301.003 + 3.726639	2,304.7296
30	1,908.943 + 70.87047	1,979.8135
50	1,559.829 + 194.1161	1,753.9451

Determine increments of vertical stress under point F; use principle of superposition as indicated below:



For superposition step (1) we have:



$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x-b)\right]$$

$x = 180$

$a = 40$

$b = 90$

$(x - b) = 90$

$$\frac{x}{a} = \frac{180}{40} = 4.5$$

$$R_2^2 = z^2 + 90^2$$

$$\tan\delta = \frac{90}{z} \qquad \Rightarrow \delta = \arctan\left(\frac{90}{z}\right)$$

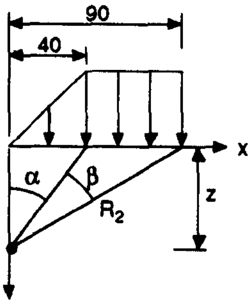
$$\tan(\beta + \delta) = \frac{140}{z} \qquad \Rightarrow \beta = \arctan\left(\frac{140}{z}\right) - \delta$$

$$\tan(\alpha + \beta + \delta) = \frac{180}{z} \qquad \Rightarrow \alpha = \arctan\left(\frac{180}{z}\right) - \delta - \beta$$

The results for z = 10, 30, and 50 ft are indicated in the table below:

z (ft)	δ	β	α	$R_2^2 = z^2 + 50^2$	$\frac{z}{R_2^2}(x-b)$	σ_z (psf)
10	83.65981	2.25457	0.9057924	8,200	0.1097561	0.5843725
30	71.56505	6.340192	2.632437	9,000	0.3	13.85309
50	60.9454	9.400786	4.12971	10,600	0.4245283	50.84445

For the second superposition:



$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x - b)\right]$$

$x = 0$

$a = 40$

$b = 90$

$(x - b) = -90$

$\frac{x}{a} = 0$

$R_2^2 = z^2 + 90^2$

$$\tan\alpha = \frac{40}{z} \quad \Rightarrow \alpha = \arctan\left(\frac{40}{z}\right)$$

$$\tan(\alpha + \beta) = \frac{90}{z} \Rightarrow \beta = \arctan\left(\frac{90}{z}\right) - \alpha$$

Thus: $$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{90z}{R_2^2}\right]$$

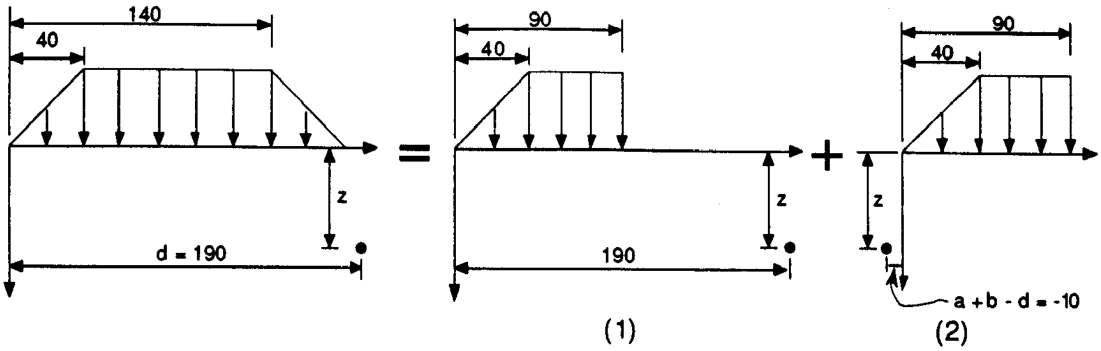
The results for z = 10, 30, and 50 ft are indicated in the table below:

z (ft)	α	β	$R_2^2 = z^2 + 90^2$	$\frac{z}{R_2^2}(x - b)$	σ_z (psf)
10	75.96376	7.696052	8,200	0.1097561	194.2307
30	53.13011	18.43495	9,000	0.3	494.7734
50	38.65981	22.28558	10,600	0.4245283	647.3508

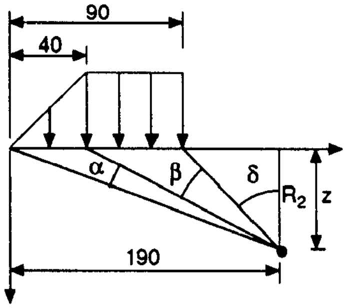
Determine actual increments of stress by adding the increments from superposition steps (1) and (2). Results are indicated in table below:

z (ft)	σ_z (psf)	σ_z (psf)
10	194.2307 + 0.5843725	194.81507
30	494.7734 + 13.85309	508.62649
50	647.3508 + 50.84445	698.19525

Determine increments of vertical stress under point G; use principle of superposition as indicated below:



For superposition step (1) we have:



$x = 190$

$a = 40$

$b = 90$

$(x - b) = 100$

$$\frac{x}{a} = \frac{190}{40} = 4.75$$

$$R_2^2 = z^2 + 100^2$$

$$\tan \delta = \frac{100}{z} \quad \Rightarrow \delta = \arctan\left(\frac{100}{z}\right)$$

$$\tan(\beta + \delta) = \frac{150}{z} \quad \Rightarrow \beta = \arctan\left(\frac{150}{z}\right) - \delta$$

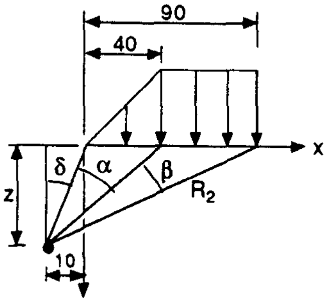
$$\tan(\alpha + \beta + \delta) = \frac{190}{z} \quad \Rightarrow \alpha = \arctan\left(\frac{190}{z}\right) - \delta - \beta$$

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x - b)\right] \Rightarrow \sigma_z = \frac{P}{\pi}\left[\beta + 4.75\alpha - \frac{100z}{R_2^2}\right]$$

The results for z = 10, 30, and 50 ft are indicated in the table below:

z (ft)	δ	β	α	$R_2^2 = z^2 + 100^2$	$\frac{z}{R_2^2}(x - b)$	σ_z (psf)
10	84.28941	1.896518	0.8012836	10,100	0.0990099	0.4134162
30	73.30075	5.389313	2.337304	10,900	0.2752294	10.02816
50	63.43495	8.130105	3.691383	12,500	0.4	38.13693

For the second superposition step (2), we have:



$x = -10$

$a = 40$

$b = 90$

$(x - b) = (-10 - 90) = -100$

$\frac{x}{a} = -0.25$

$R_2^2 = z^2 + 100^2$

$\tan\delta = \frac{10}{z} \quad \Rightarrow \delta = \arctan\left(\frac{10}{z}\right)$

$\tan(\alpha + \delta) = \frac{50}{z} \quad \Rightarrow \alpha = \arctan\left(\frac{50}{z}\right) - \delta$

$\tan(\alpha + \beta + \delta) = \frac{100}{z} \quad \Rightarrow \beta = \arctan\left(\frac{100}{z}\right) - \delta - \alpha$

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x - b)\right] \Rightarrow \sigma_z = \frac{P}{\pi}\left[\beta - 0.25\alpha - \frac{100z}{R_2^2}\right]$$

The results for z = 10, 30, and 50 ft are indicated in the table below:

z (ft)	δ	β	α	$R_2^2 = z^2 + 100^2$	$\frac{z}{R_2^2}(x - b)$	σ_z (psf)
10	45.0	33.69006	5.599341	10,100	0.0990099	39.57881
30	18.43495	40.6013	14.26451	10,900	0.2752294	276.162
50	11.30993	33.69007	18.43495	12,500	0.4	457.3714

Determine actual increments of stress by adding the increments from superposition steps (1) and (2). Results are indicated in table below:

z (ft)	σ_z (psf)	σ_z (psf)
10	39.57881 + 0.4134162	39.992226
30	276.162 + 10.02816	286.19016
50	457.3714 + 38.13693	495.50833

Compute settlements; use expression indicated below:

$$\rho = \sum_{i=1}^{3} H_i \left[RR \log\left(\frac{\bar{\sigma}_{vm}}{\bar{\sigma}_{v0}}\right) + CR \log\left(\frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{vm}}\right) \right]$$

where:

H_i = thickness of each sublayer = 20 ft

RR = 0.04

CR = 0.2

$\bar{\sigma}_{vm}$ = Maximum past pressure = 1,000 psf at z = 10 ft

$\bar{\sigma}_{vf}$ = Final vertical effective stress = $\bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$

$\bar{\sigma}_{v0}$ = Initial vertical effective stress

- Apply expressions above for point B; obtain table below:

z (ft)	$\bar{\sigma}_{v0}$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vm}$ (psf)	$\bar{\sigma}_{vf} = \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$	ρ_i (ft)
10	426	2496.444	1000	2922.444	2.1594571
30	1278	2422.946	1278	3700.946	1.8471276
50	2130	2246.587	2130	4376.587	1.2510239

Total Settlement: 5.2576085 ft
63.09 in

- Similarly, at point D:

z (ft)	$\bar{\sigma}_{v0}$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vm}$ (psf)	$\bar{\sigma}_{vf} = \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$	ρ_i (ft)
10	426	2304.7296	1000	2730.7296	2.0415871
30	1278	1979.8135	1278	3257.8135	1.6255815
50	2130	1753.9451	2130	3883.9451	1.0435739

Total Settlement: 4.7107425 ft
56.53 in

- At point F:

z (ft)	$\bar{\sigma}_{v0}$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vm}$ (psf)	$\bar{\sigma}_{vf} = \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$	ρ_i (ft)
10	426	194.81507	1000	620.81507	0.1308421
30	1278	508.62649	1278	1786.6265	0.5820117
50	2130	698.19525	2130	2828.1953	0.4925192

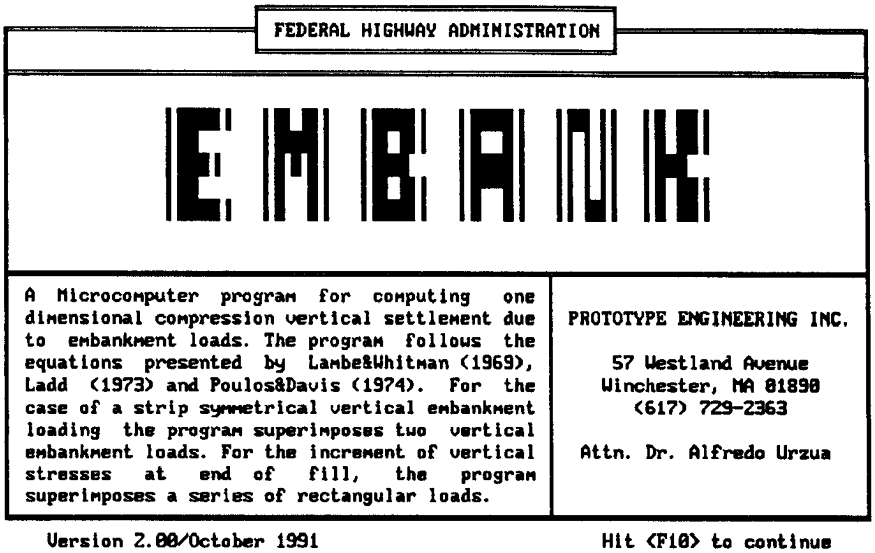
Total Settlement:	1.2053729	ft
	14.46	in

- At point G:

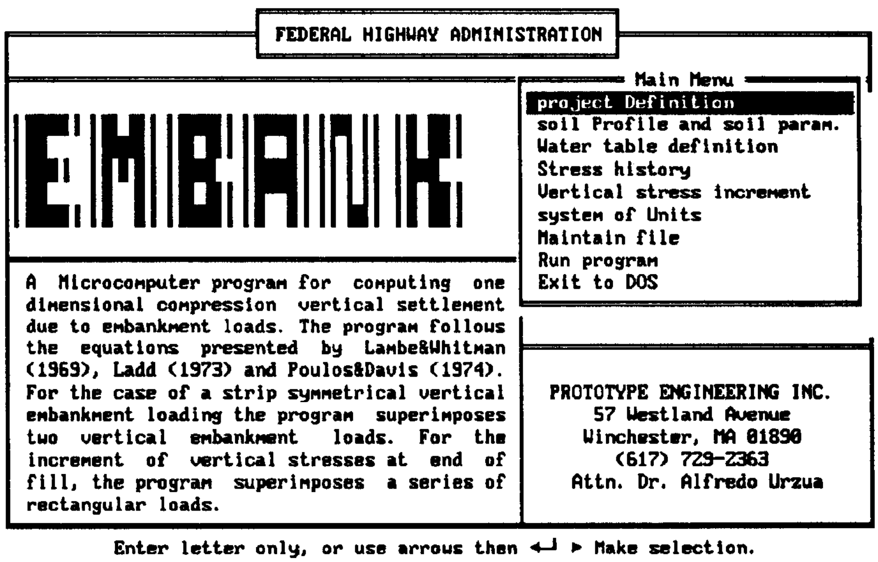
z (ft)	$\bar{\sigma}_{v0}$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vm}$ (psf)	$\bar{\sigma}_{vf} = \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$	ρ_i (ft)
10	426	39.992226	1000	465.99923	0.0311753
30	1278	286.19016	1278	1564.1902	0.3510348
50	2130	495.50833	2130	2625.5083	0.3633352

Total Settlement:	0.7455453	ft
	8.95	in

Compilation of Computer Screens for Example 3



OPENING SCREEN



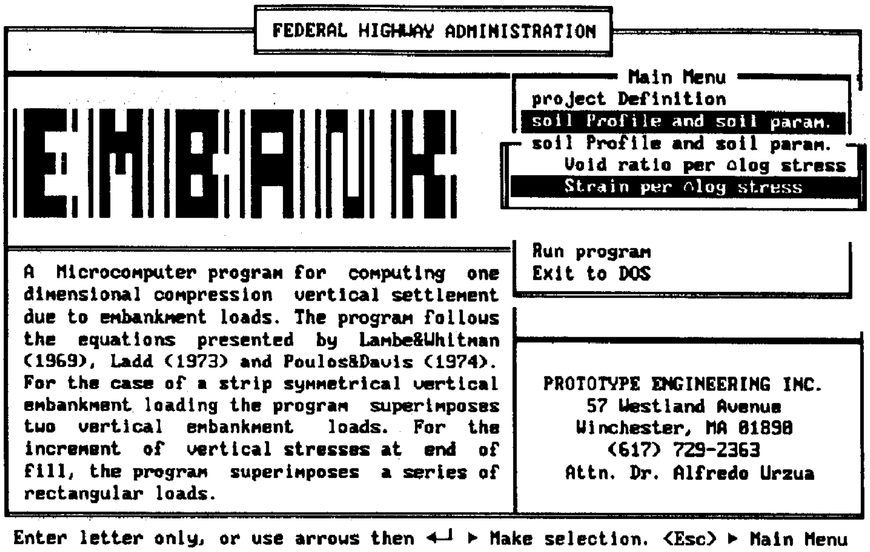
EMBANK MAIN MENU - SELECTION OF PROJECT DEFINITION

```
                         FEDERAL HIGHWAY ADMINISTRATION
                                                    Main Menu
                                                 project Definition
                                                 soil Profile and soil param.
                                                 Water table definition
                         PROJECT DEFINITION                      y
                                                                 s increment
              Client            = Any client                     s
              Project Name      = Highway Embankment
              Project Manager   = AUM
A Microcompute File Name         = EXAMPLE3.EMB
dimensional com Date              =  3/13/92  (MM/DD/YY)
due to embankme Computed by       = aum
the  equations
(1969), Ladd (1         Hit <F10> to accept values
For the case of                                        INEERING INC.
embankment loading the program  superimposes       57 Westland Avenue
two  vertical  embankment   loads.  For  the      Winchester, MA 01890
increment  of  vertical stresses at  end  of         (617) 729-2363
fill, the program  superimposes  a series of     Attn. Dr. Alfredo Urzua
rectangular loads.
```

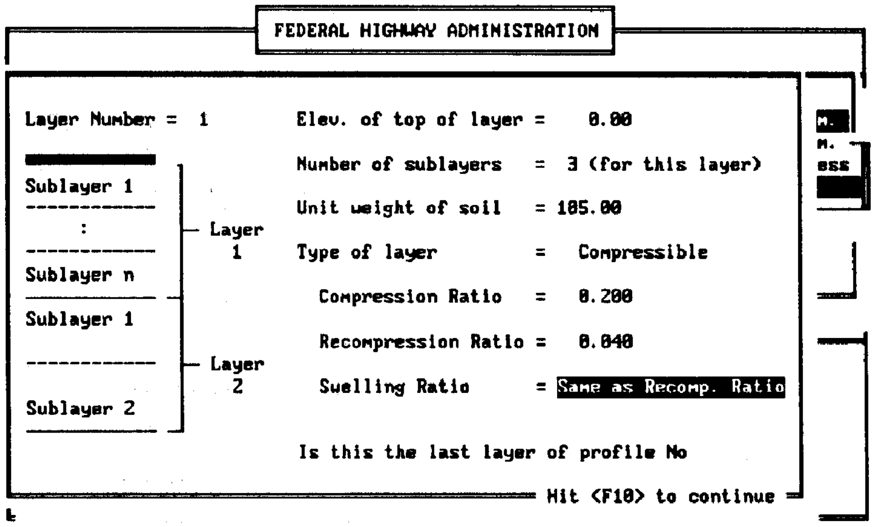
PROJECT DEFINITION SCREEN

```
                         FEDERAL HIGHWAY ADMINISTRATION
                                                    Main Menu
        EMBANK                                   project Definition
                                                 soil Profile and soil param.
                                                 Water table definition
                                                 Stress history
                                                 Vertical stress increment
                                                 system of Units
                                                 Maintain file
                                                 Run program
A Microcomputer program for computing  one       Exit to DOS
dimensional compression  vertical settlement
due to embankment loads. The program follows
the  equations  presented  by  Lambe&Whitman
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical    PROTOTYPE ENGINEERING INC.
embankment loading the program  superimposes       57 Westland Avenue
two  vertical  embankment   loads.  For  the      Winchester, MA 01890
increment  of  vertical stresses at  end  of         (617) 729-2363
fill, the program  superimposes  a series of     Attn. Dr. Alfredo Urzua
rectangular loads.
         Enter letter only, or use arrows then <┘ ► Make selection.
```

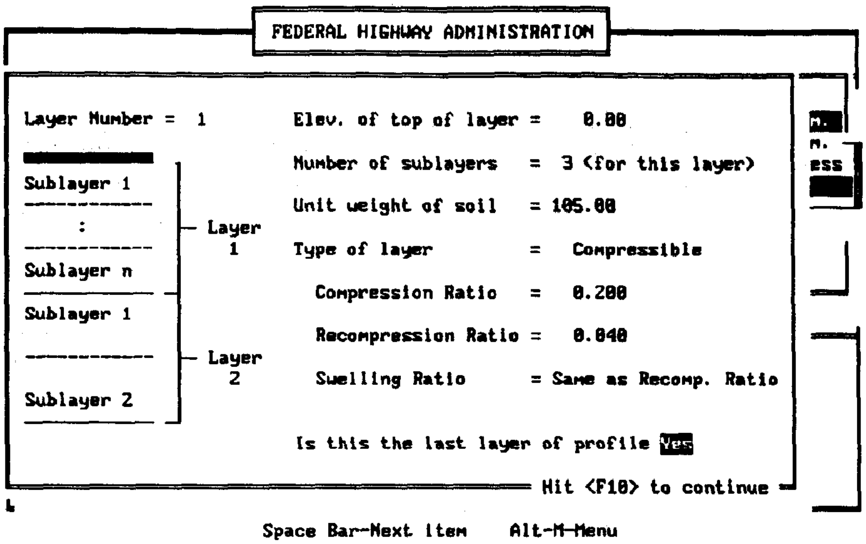
EMBANK MAIN MENU - SELECTION OF SOIL PROFILE



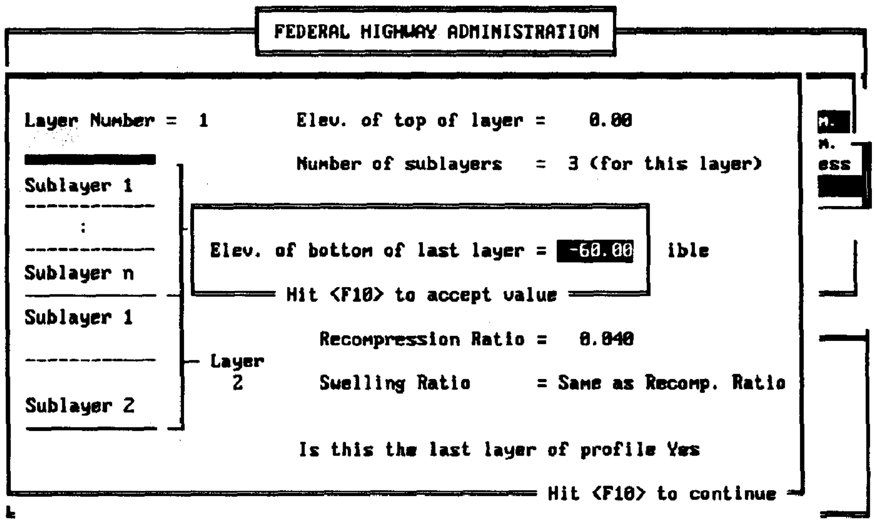
SOIL PROFILE MENU - SELECTION OF STRAIN PER LOG STRESS



SOIL DESCRIPTION AND PARAMETERS FOR LAYER #1



DEFINING LAYER #1 AS LAST LAYER OF SOIL PROFILE



DEFINING THICKNESS OF SOIL PROFILE

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment
- system of Units
- Maintain file
- Run program
- Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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Winchester, MA 01890
(617) 729-2363
Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ▸ Make selection.

EMBANK MAIN MENU - SELECTION OF WATER TABLE DEFINITION

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment
- Units
- ile
- m
- S

Water Table Definition

Elev. of Water Table = 0.00

Hit <F10> to accept values

A Microcomputer pro
dimensional compress
due to embankment loa
the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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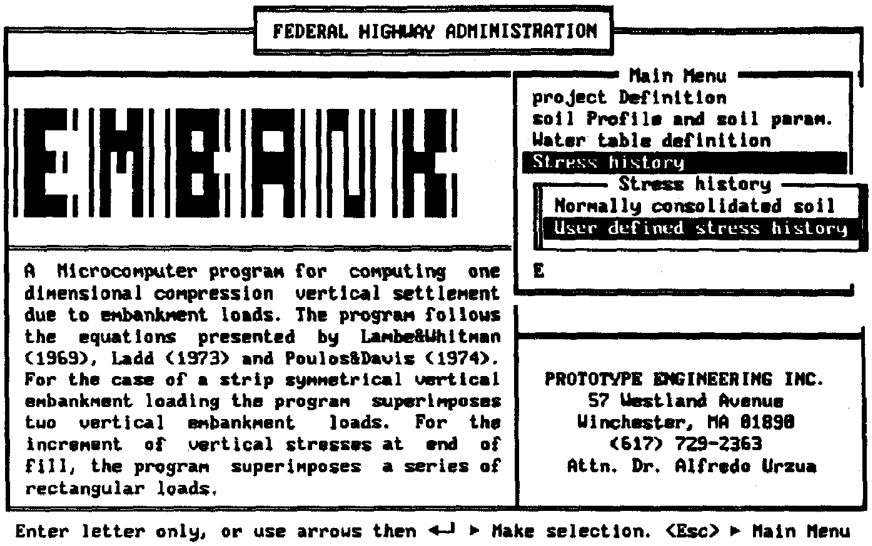
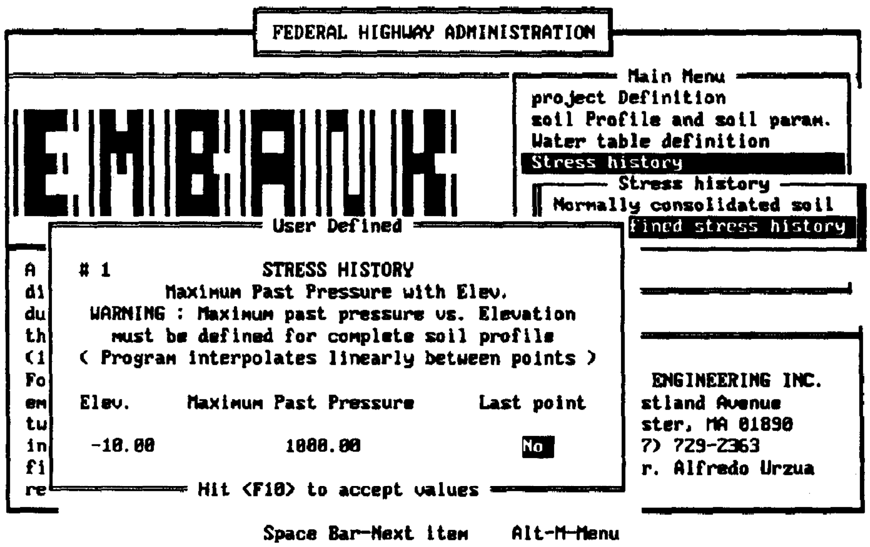
WATER TABLE AT ELEVATION = 0.0 FT.



SOIL IS OVERCONSOLIDATED - USER DEFINED STRESS HISTORY



STRESS HISTORY - POINT #1

```
                     FEDERAL HIGHWAY ADMINISTRATION
                                                    Main Menu
                                             project Definition
                                             soil Profile and soil param.
                                             Water table definition
  EMBANK                                     Stress history
                                               Stress history
                                              Normally consolidated soil
                       User Defined          fined stress history
A   # 2          STRESS HISTORY
di         Maximum Past Pressure with Elev.
du   WARNING : Maximum past pressure vs. Elevation
th     must be defined for complete soil profile
(1   ( Program interpolates linearly between points )
Fo                                                      ENGINEERING INC.
em   Elev.      Maximum Past Pressure      Last point   stland Avenue
tu                                                      ster, MA 01890
in    -30.00           1280.00                No        7) 729-2363
fi                                                      r. Alfredo Urzua
re   Hit <F9> to prev.point, <F10> to accept values

                 Space Bar-Next item     Alt-M-Menu
```

STRESS HISTORY - POINT #2

```
                     FEDERAL HIGHWAY ADMINISTRATION
                                                    Main Menu
                                             project Definition
                                             soil Profile and soil param.
                                             Water table definition
  EMBANK                                     Stress history
                                               Stress history
                                              Normally consolidated soil
                       User Defined          fined stress history
A   # 3          STRESS HISTORY
di         Maximum Past Pressure with Elev.
du   WARNING : Maximum past pressure vs. Elevation
th     must be defined for complete soil profile
(1   ( Program interpolates linearly between points )
Fo                                                      ENGINEERING INC.
em   Elev.      Maximum Past Pressure      Last point   stland Avenue
tu                                                      ster, MA 01890
in    -50.00           2130.00                Yes       7) 729-2363
fi                                                      r. Alfredo Urzua
re   Hit <F9> to prev.point, <F10> to accept values

                 Space Bar-Next item     Alt-M-Menu
```

STRESS HISTORY - POINT #3

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment
system of Units
Maintain file
Run program
Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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Enter letter only, or use arrows then ↵ ▸ Make selection.

EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment

Vertical stress increment
strip Symmetrical vertical embankment loading
increment of stresses Beneath the end of a fill

A Microcomputer program fo
dimensional compression ver
due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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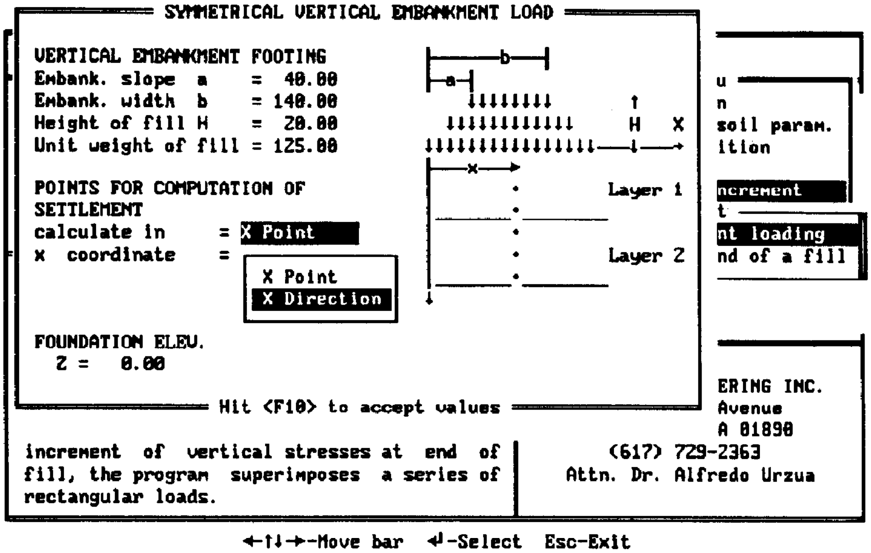
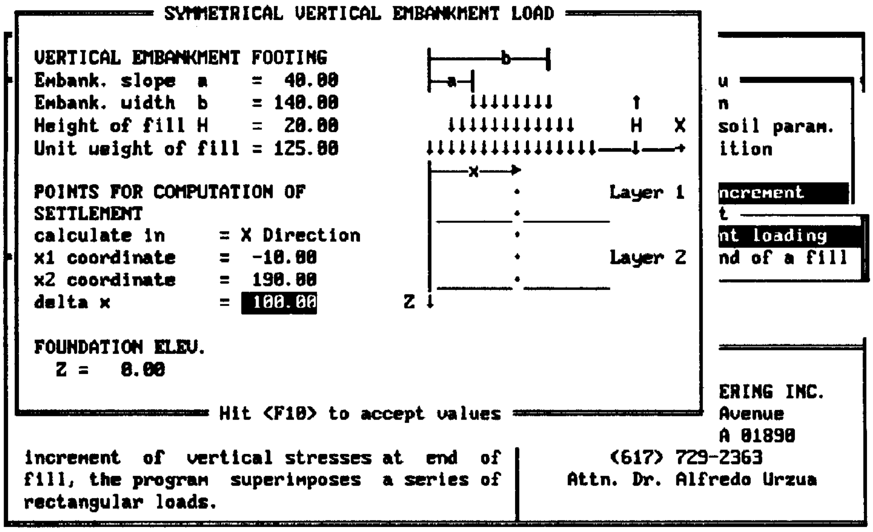
Enter letter only, or use arrows then ↵ ▸ Make selection. <Esc> ▸ Main Menu

VERTICAL STRESS INCREMENT MENU - SELECTION OF STRIP SYMM. EMBANKMENT



STRIP SYMM. VERTICAL EMBANKMENT LOAD - SELECTION OF X DIRECTION



DEFINING A,B & G POINTS FOR COMPUTATION OF SETTLEMENT

```
FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment
system of Units
Maintain file
Run program
Exit to DOS

A Microcomputer program for computing one
dimensional compression vertical settlement
due to embankment loads. The program follows
the equations presented by Lambe&Whitman
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical
embankment loading the program superimposes
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increment of vertical stresses at end of
fill, the program superimposes a series of
rectangular loads.

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(617) 729-2363
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Enter letter only, or use arrows then ↵ ► Make selection.
```

EMBANK MAIN MENU - RUN PROGRAM

```
ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name   : Highway Embankment   Client          : Any Client
Project Number : 91-1236              Project Manager : AUM
Date           : 10/03/91             Computed by     : aum

                      Settlement for X-Direction

Embankment slope a      =  40.00 (ft)  Height of fill H    =   20.00 (ft)
Embankment top width    = 100.00 (ft)  Unit weight of fill =  125.00 (pcf)
Embankment bottom width = 180.00 (ft)  p load/unit area    = 2500.00 (psf)
Ground Surface Elev.    =   0.00 (ft)  Foundation Elev.    =    0.00 (ft)
Water table Elev.       =   0.00 (ft)  Unit weight of Wat. =   62.40 (pcf)

        LAYER          COMP.  RECOMP.  SWELL.   UNIT
   Nº.  TYPE  THICK.           RATIO            WEIGHT
              (ft)                              (pcf)

    1   COMP.  60.0    0.200   0.040   0.040   105.00

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu
```

PROGRAM OUTPUT PARTIAL SCREEN

```
ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name   : Highway Embankment    Client          : Any Client
Project Number : 91-1236               Project Manager : AUM
Date           : 10/03/91              Computed by     : aum

                    Settlement for X-Direction

Embankment slope a      =   40.00 (ft)  Height of fill H    =   20.00 (ft)
Embankment top width    =  100.00 (ft)  Unit weight of fill =  125.00 (pcf)
Embankment bottom width =  180.00 (ft ========= Select =========
Ground Surface Elev.    =    0.00 (ft| Send form to: P-Printer, D-Disk File.
Water table Elev.       =    0.00 (ft

          LAYER              COMP.   RECOMP.   SWELL.    UNIT
    Nº.   TYPE   THICK.              RATIO               WEIGHT
                 (ft)                                    (pcf)

     1    COMP.   60.0      0.200    0.040     0.040     105.00

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu
```

SELECTION OF DISK FILE PRINTED OUTPUT

```
ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name   : Highway Embankment    Client          : Any Client
Project Number : 91-1236               Project Manager : AUM
Date           : 10/03/91              Computed by     : aum

                    Settlement for X-Direction

Embankment slope a      =   40.00 (ft)  Height of fill H    =   20.00 (ft)
Embankment top width    =  100.00 (ft)  Unit weight of fill =  125.00 (pcf)
Embankment bottom width =  180.00 (ft) ------ Destination File ------
Ground Surface Elev.    =    0.00 (ft)| EXAM3ABG.OUT
Water table Elev.       =    0.00 (ft)

          LAYER              COMP.   RECOMP.   SWELL.    UNIT
    Nº.   TYPE   THICK.              RATIO               WEIGHT
                 (ft)                                    (pcf)

     1    COMP.   60.0      0.200    0.040     0.040     105.00

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu
```

SELECTION OF OUTPUT DESTINATION FILE NAME

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name	: Highway Embankment	Client	: Any Client
File Name	: EXAMPLE3.EMB	Project Manager	: AUM
Date	: 10/03/91	Computed by	: aum

Settlement for X-Direction

Embankment slope a	= 40.00 (ft)	Height of fill H	= 20.00 (ft)
Embankment top width	= 100.00 (ft)	Unit weight of fill	= 125.00 (pcf)
Embankment bottom width	= 180.00 (ft)	p load/unit area	= 2500.00 (psf)
Ground Surface Elev.	= 0.00 (ft)	Foundation Elev.	= 0.00 (ft)
Water table Elev.	= 0.00 (ft)	Unit weight of Wat.	= 62.40 (pcf)

Nº.	LAYER TYPE	THICK. (ft)	COMP.	RECOMP. RATIO	SWELL.	UNIT WEIGHT (pcf)
1	COMP.	60.0	0.200	0.040	0.040	105.00

Nº.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	MAX.PAST PRESS. (psf)
1	20.00	-10.00	426.00	1000.00
2	20.00	-30.00	1278.00	1280.00
3	20.00	-50.00	2130.00	2130.00

	X =	-10.00	X =	90.00	X =	190.00
Layer	Stress (psf)	Sett. (in.)	Stress (psf)	Sett. (in.)	Stress (psf)	Sett. (in.)
1	39.99	0.37	2496.44	25.91	39.99	0.37
2	286.19	4.19	2422.95	22.14	286.19	4.19
3	495.51	4.36	2246.59	15.01	495.51	4.36
		------		------		------
		8.92		63.07		8.92

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment

Vertical stress increment
strip Symmetrical vertical embankment loading
increment of stresses Beneath the end of a fill

A Microcomputer program fo... dimensional compression ver... due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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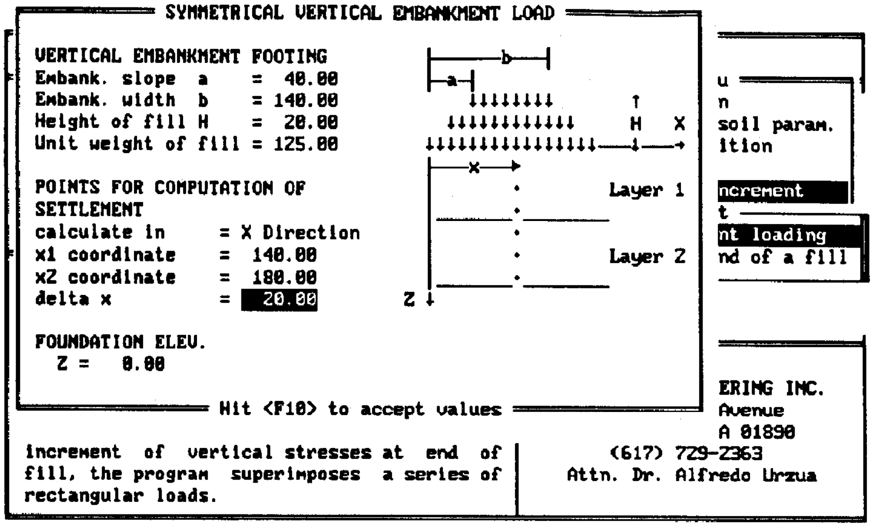
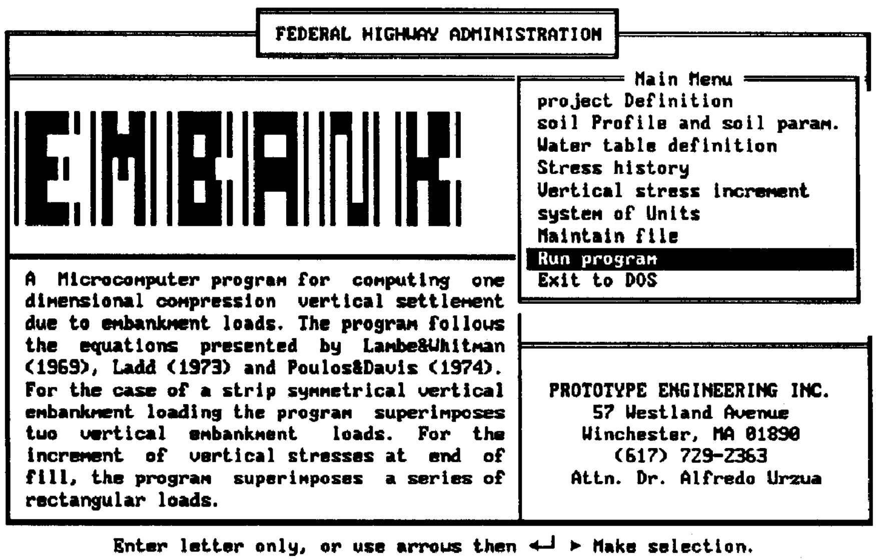
Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ▶ Make selection. <Esc> ▶ Main Menu

EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT MENU



DEFINING D,E & F POINTS FOR COMPUTATION OF SETTLEMENT

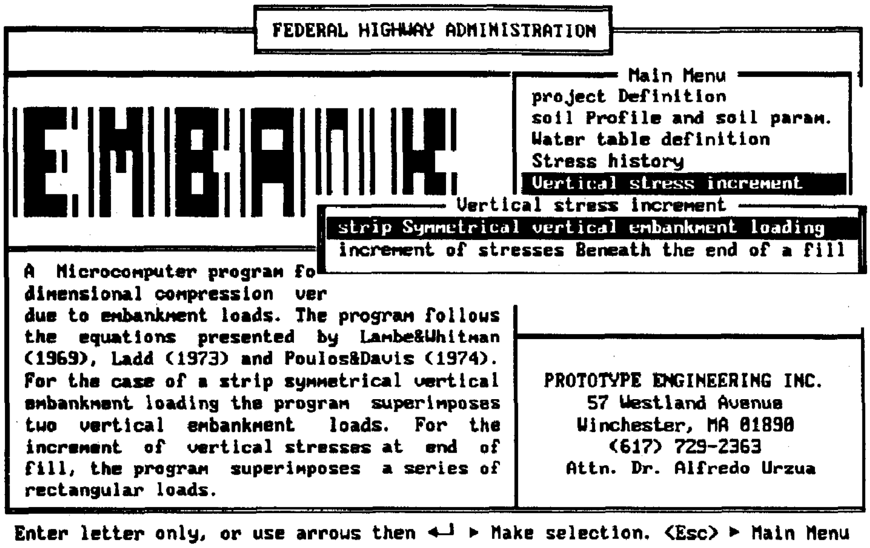


EMBANK MAIN MENU - RUN PROGRAM

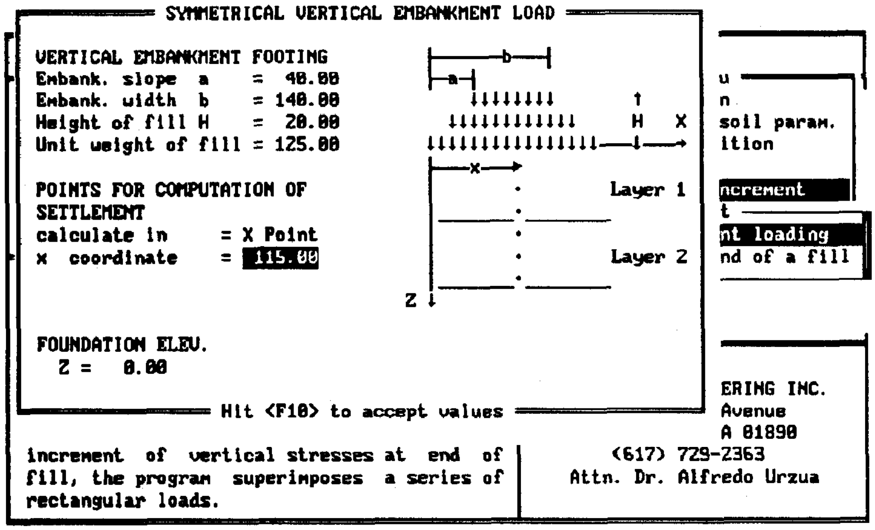
```
ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
              STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING
           SUBLAYER                         SOIL STRESSES
   Nº.      THICK.          ELEV.           INITIAL         MAX.PAST PRESS.
             (ft)           (ft)             (psf)              (psf)

   1        20.00         -10.00            426.00           1000.00
   2        20.00         -30.00           1278.00           1280.00
   3        20.00         -50.00           2130.00           2130.00


        X =    140.00    X =    160.00         Destination File
Layer  Stress  Sett.    Stress  Sett.      EXAM3DEF.OUT
        (psf)  (in.)    (psf)   (in.)

 1    2304.73  24.50   1249.80  14.32    194.81   1.57
 2    1979.81  19.48   1244.86  14.15    508.63   6.96
 3    1753.95  12.52   1228.38   9.49    698.20   5.91
               ------           ------           ------
               56.50            37.96            14.44

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu
```

SELECTION OF OUTPUT DESTINATION FILE NAME

```
ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
              STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name      : Highway Embankment    Client            : Any Client
File Name         : EXAMPLE3.EMB          Project Manager   : AUM
Date              : 10/03/91              Computed by       : aum

                          Settlement for X-Direction

Embankment slope a      =    40.00 (ft)  Height of fill H     =   20.00 (ft)
Embankment top width    =   100.00 (ft)  Unit weight of fill  =  125.00 (pcf)
Embankment bottom width =   180.00 (ft)  p load/unit area     = 2500.00 (psf)
Ground Surface Elev.    =     0.00 (ft)  Foundation Elev.     =    0.00 (ft)
Water table Elev.       =     0.00 (ft)  Unit weight of Wat.  =   62.40 (pcf)

          LAYER             COMP.   RECOMP.   SWELL.    UNIT
   Nº.   TYPE  THICK.               RATIO               WEIGHT
                (ft)                                    (pcf)

    1    COMP.  60.0        0.200    0.040    0.040     105.00

           SUBLAYER                         SOIL STRESSES
   Nº.      THICK.          ELEV.           INITIAL         MAX.PAST PRESS.
             (ft)           (ft)             (psf)              (psf)

   1        20.00         -10.00            426.00           1000.00
   2        20.00         -30.00           1278.00           1280.00
   3        20.00         -50.00           2130.00           2130.00


        X =    140.00    X =    160.00    X =    180.00
Layer  Stress  Sett.    Stress  Sett.    Stress  Sett.
        (psf)  (in.)    (psf)   (in.)    (psf)   (in.)

 1    2304.73  24.50   1249.80  14.32    194.81   1.57
 2    1979.81  19.48   1244.86  14.15    508.63   6.96
 3    1753.95  12.52   1228.38   9.49    698.20   5.91
               ------           ------           ------
               56.50            37.96            14.44

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu
```



EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT MENU



DEFINING POINT C COORDINATES

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
- project Definition
- soil Profile and soil param.
- Water table definition
- Stress history
- Vertical stress increment
- system of Units
- Maintain file
- Run program
- Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

PROTOTYPE ENGINEERING INC.
57 Westland Avenue
Winchester, MA 01890
(617) 729-2363
Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ▸ Make selection.

EMBANK MAIN MENU - RUN PROGRAM

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Water table Elev. = 0.00 (ft) Unit weight of Wat. = 62.40 (pcf)

Nº.	LAYER TYPE	THICK. (ft)	COMP.	RECOMP. RATIO	SWELL.	UNIT WEIGHT (pcf)	Settlement (in.)
1	COMP.	60.0	0.200	0.040	0.040	105.00	62.17

Total Settlement = 62.17

Destination File
EXAM3C.OUT

Nº.	SUBLAYER THICK. (ft)	ELEV. (ft)	INITIAL (psf)	SO INCREMENT (psf)	MAX.PAST PRESS. (psf)	SETTLEMENT (in.)
1	20.00	-10.00	426.00	2491.19	1000.00	25.88
2	20.00	-30.00	1278.00	2360.48	1280.00	21.78
3	20.00	-50.00	2130.00	2141.78	2130.00	14.51

Total Settlement = 62.17 (in.)

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

SELECTION OF OUTPUT DESTINATION FILE NAME

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name	: Highway Embankment	Client	: Any Client
File Name	: EXAMPLE3.EMB	Project Manager	: AUM
Date	: 10/03/91	Computed by	: aum

Settlement for X = 115.00 (ft)

Embankment slope a	= 40.00 (ft)	Height of fill H	= 20.00 (ft)
Embankment top width	= 100.00 (ft)	Unit weight of fill	= 125.00 (pcf)
Embankment bottom width	= 180.00 (ft)	p load/unit area	= 2500.00 (psf)
Ground Surface Elev.	= 0.00 (ft)	Foundation Elev.	= 0.00 (ft)
Water table Elev.	= 0.00 (ft)	Unit weight of Wat.	= 62.40 (pcf)

Nº.	LAYER TYPE	THICK. (ft)	COMP.	RECOMP. RATIO	SWELL.	UNIT WEIGHT (pcf)	Settlement (in.)
1	COMP.	60.0	0.200	0.040	0.040	105.00	62.17

Total Settlement = 62.17

Nº.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	INCREMENT (psf)	MAX.PAST PRESS. (psf)	SETTLEMENT (in.)
1	20.00	-10.00	426.00	2491.19	1000.00	25.88
2	20.00	-30.00	1278.00	2360.48	1280.00	21.78
3	20.00	-50.00	2130.00	2141.78	2130.00	14.51

Total Settlement = 62.17 (in.)

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
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Stress history
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system of Units
Maintain file
Run program
Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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Enter letter only, or use arrows then ↵ ► Make selection.

EMBANK MAIN MENU - SELECTION OF MAINTAIN FILE

```
FEDERAL HIGHWAY ADMINISTRATION

                                      Main Menu
                                      project Definition
                                      soil Profile and soil param.
                                      Water table definition
                                      Stress history
                                      Vertical stress increment
                                      system of Units
                                      Maintain file
                                      Run ┌ Maintain file
                                      Exit│ Save file
                                          │ Retrieve file
                                          │ Clear entries

A Microcomputer program for computing one
dimensional compression vertical settlement
due to embankment loads. The program follows
the equations presented by Lambe&Whitman
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical
embankment loading the program superimposes
two vertical embankment loads. For the
increment of vertical stresses at end of
fill, the program superimposes a series of
rectangular loads.

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                                      Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ▸ Make selection. <Esc> ▸ Main Menu
```
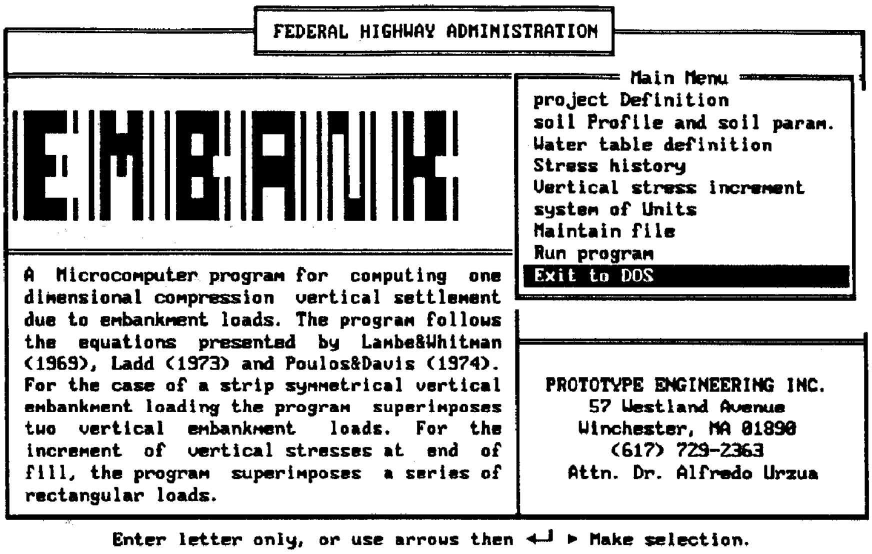
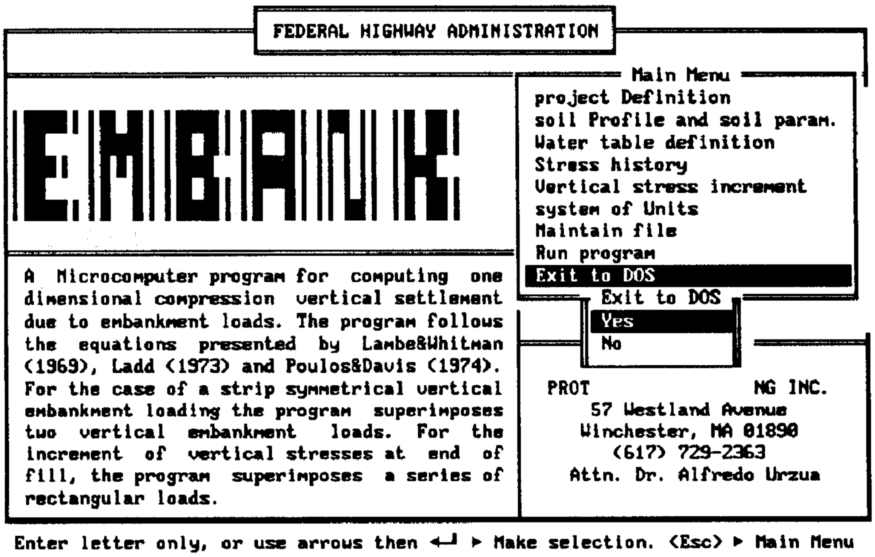

MAINTAIN FILE MENU - SELECTION OF SAVE FILE

```
FEDERAL HIGHWAY ADMINISTRATION

                                      Main Menu
                                      project Definition
                                      soil Profile and soil param.
                                      Water table definition
                                      Stress history
                                      Vertical stress increment
                                      system of Units
                                      Maintain file
                                      Run ┌ Maintain file
                                      Exit│ Save file

A Microcomputer program for computing one
dimensional compression vertical sett─── Destination File ───
due to embankment loads. The program f│ EXAMPLE3.EMB
the equations presented by Lambe&W└──────────────────────────
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical
embankment loading the program superimposes
two vertical embankment loads. For the
increment of vertical stresses at end of
fill, the program superimposes a series of
rectangular loads.

                                      PROTOTYPE ENGINEERING INC.
                                      57 Westland Avenue
                                      Winchester, MA 01890
                                      (617) 729-2363
                                      Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ▸ Make selection. <Esc> ▸ Main Menu
```

SAVING INPUT FILE AS EXAMPLE3.EMB



EMBANK MAIN MENU - EXIT TO DOS



EXIT TO DOS MENU - YES SELECTION

Example 4

Example No. 4: Embankment on Layered Soil

Figure 13 shows the problem geometry and soil parameters. The purpose of the example is to compare the settlement for the following cases:

1. The embankment bears on top of the organic soil.
2. The embankment bears on top of the sand stratum after the organic soil has been removed.

The clay layer is divided into four sublayers. The example shows the use of the foundation depth option included in EMBANK.

Table 11 presents a comparison of the computer-calculated and hand-computed settlements.

Table 11. Settlements at point A

	Settlement (in.) Computer	Settlement (in.) Hand-Calculated
Embankment on top of organic soil	23.80	23.80
Embankment on top of sand stratum	10.51	10.51

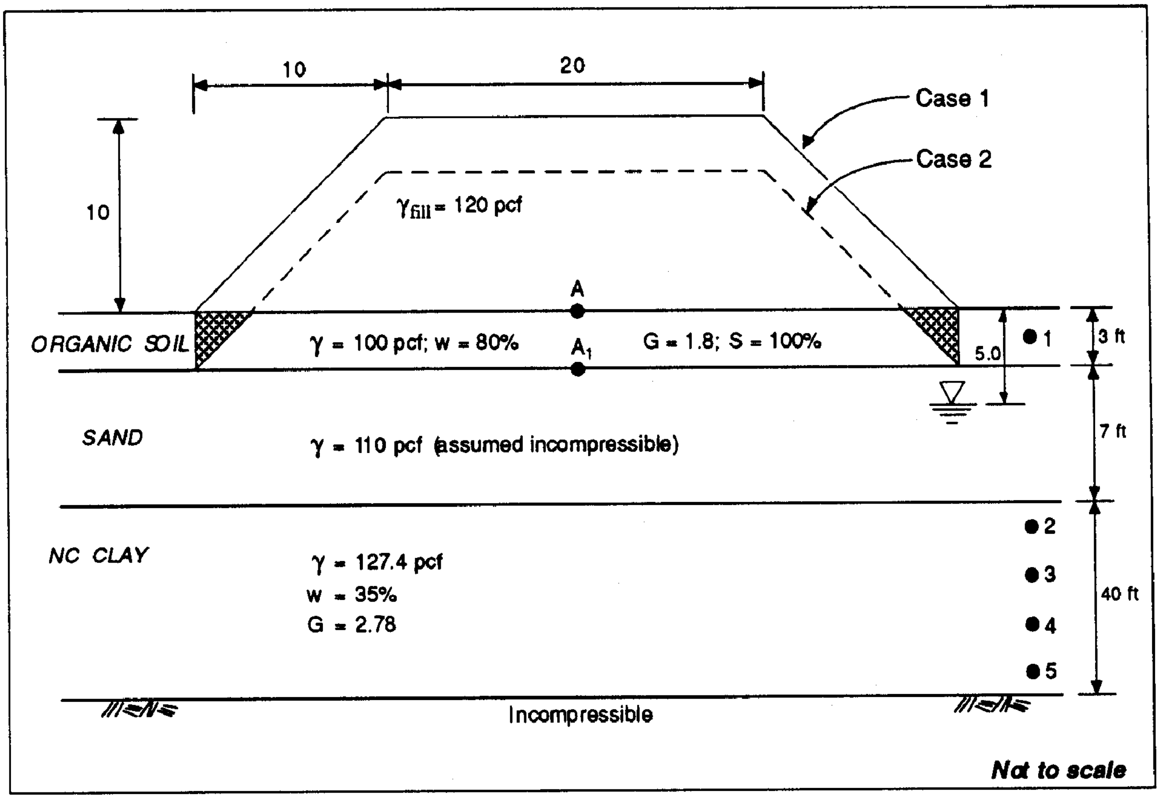


Figure 13. Example 4: Embankment on layered soil

Case 1: Embankment Bears on Top of Organic Soil

- Divide NC Clay stratum into four 10-ft thick sublayers.
- Determine geostatic vertical effective stresses at points 1 through 5:

$\bar{\sigma}_1 = 1.5 \times 100 = 150\ psf\ < 200 psf$, use $200\ psf$

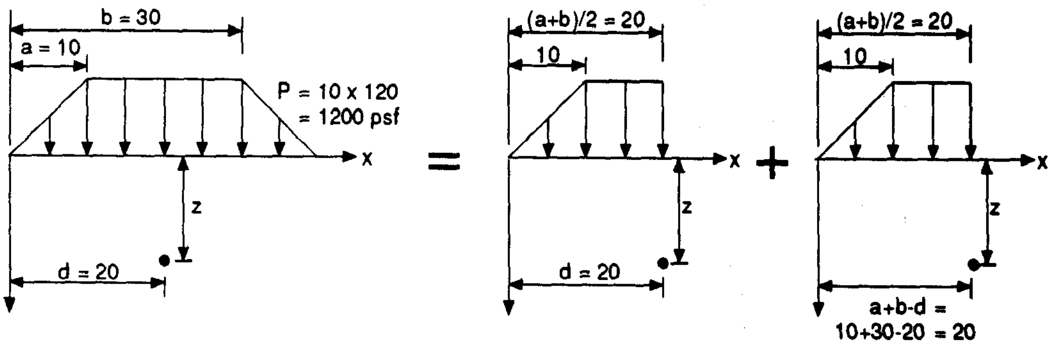
$\bar{\sigma}_2 = 3 \times 100 + 2 \times 110 + 5(110 - 62.4) + 5(127.4 - 62.4) = 1083\ psf$

$\bar{\sigma}_3 = 3 \times 100 + 2 \times 110 + 5(110 - 62.4) + 15(127.4 - 62.4) = 1733\ psf$

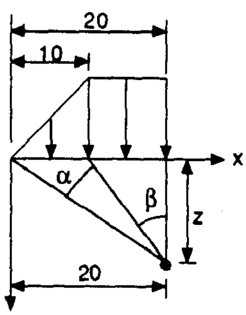
$\bar{\sigma}_4 = 3 \times 100 + 2 \times 110 + 5(110 - 62.4) + 25(127.4 - 62.4) = 2383\ psf$

$\bar{\sigma}_5 = 3 \times 100 + 2 \times 110 + 5(110 - 62.4) + 35(127.4 - 62.4) = 3033\ psf$

Determine increments of vertical stress under point A; use superposition principle as explained in Figure 5 of main text:



Therefore we compute the increments of vertical stress as two times the vertical stress increments:



The vertical stresses are given by

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{x\alpha}{a} - \frac{z}{R_2^2}(x - b)\right]$$

In this case:

$a = 10$

$b = 20$

$x = 20$

$x - b = 0$

$$\sigma_z = \frac{P}{\pi}\left[\beta + \frac{20\alpha}{10}\right] \quad \Rightarrow \sigma_z = \frac{P}{\pi}[\beta + 2\alpha]$$

$$\tan\beta = \frac{(b-a)}{z} \quad \Rightarrow \beta = \arctan\left(\frac{b-a}{z}\right) = \arctan\left(\frac{10}{z}\right)$$

$$\tan(\alpha + \beta) = \frac{b}{z} \quad \Rightarrow \alpha = \arctan\left(\frac{20}{z}\right) - \beta$$

The results for z = 1.5, 15, 25, 35, and 45 are indicated below:

z (ft)	$\beta = \arctan\left(\frac{10}{z}\right)$	$\alpha = \arctan\left(\frac{20}{z}\right) - \beta$	$\Delta\sigma_z$ (psf)	$2\Delta\sigma_z$ $[psf]$
1.5	81.46924	4.241609	599.6831	1199.366
15	33.69007	19.44004	483.801	967.6019
25	21.80141	16.8584	370.1214	740.2428
35	15.9454	13.79948	290.2958	580.5915
45	12.52881	11.43368	235.9745	471.949

Settlement determination for point A:

- Use the following expression:

$$\rho = \sum_{i=1}^{5} H_i \frac{C_c}{1+e_0} \log\left(\frac{\bar{\sigma}_{v0} + \Delta\sigma_v}{\bar{\sigma}_{v0}}\right)$$

where:

H_i = thickness of each substrata

C_c = Use FHWA procedure

For organic soil layer: $C_c = \frac{w\ \%}{100} = 0.8$

For NC clay: $C_c = \frac{w\ \%}{100} = 0.35$

e_0 = Initial void ratio; use equation $Gw = Se$

where S = 100% = 1. Therefore, $Gw = e$.

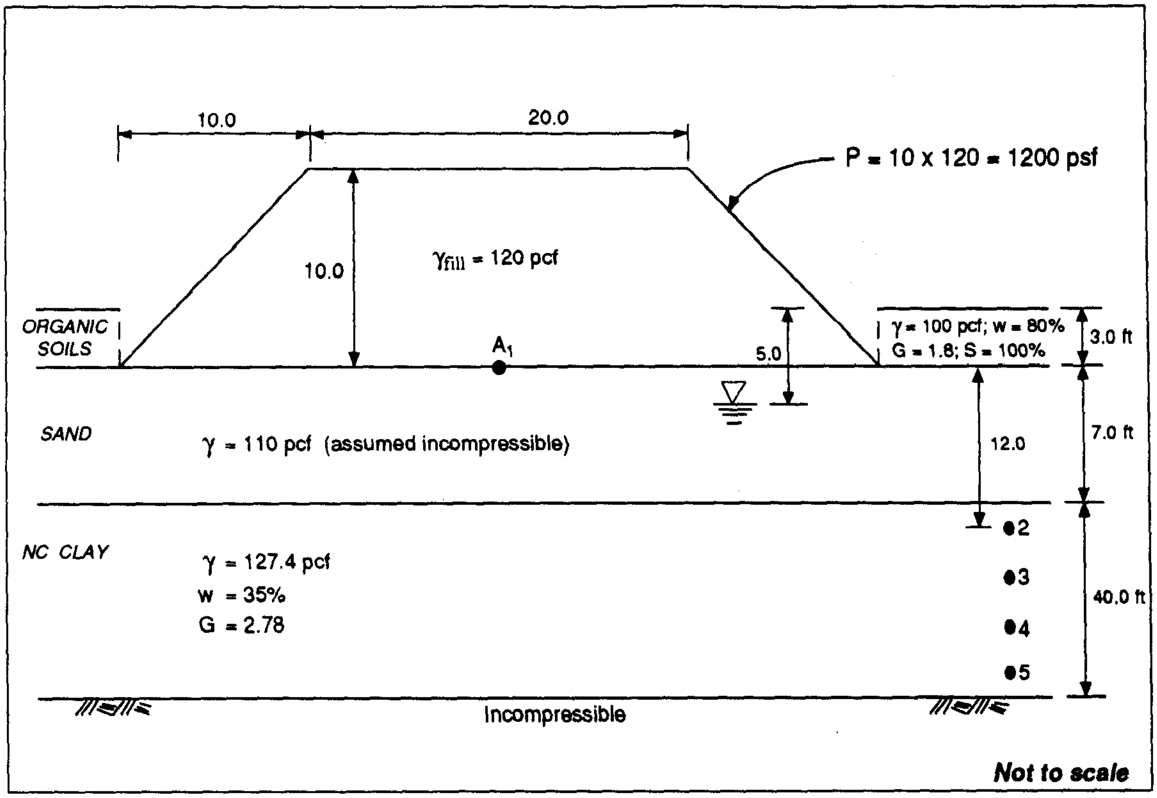
For organic soil layer: $e_0 = 1.8 \times 0.8 = 1.44$

For NC clay: $e_0 = 2.78 \times 0.35 = 0.973$

- Apply expressions above at point A, for z = 1.5, 15, 25, 35, and 45 ft. Results are indicated in table below:

z (ft)	H_i (ft)	$\Delta\bar{\sigma}_0$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vf} = \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$ (psf)	ρ_i (ft)
1.5	3.0	200	1199.366	1399.366	0.8310505
15	10.0	1083	967.6019	2050.6019	0.4918323
25	10.0	1733	740.2428	2473.2428	0.2740186
35	10.0	2383	580.5915	2963.5915	0.1679828
45	10.0	3033	471.949	3504.949	0.1114204
			Total Settlement:		1.7689566 ft
					21.23 in

Case 2: Embankment Bears on Sand Stratum, After Organic Soil has Been Removed



- Determine geostatic vertical effective stresses at points 2, 3, 4, and 5. These geostatic stresses are before excavation of the organic soil layer (same values as in Case 1):

$$\bar{\sigma}_2 = 1083\ psf$$
$$\bar{\sigma}_3 = 1733\ psf$$
$$\bar{\sigma}_4 = 2383\ psf$$
$$\bar{\sigma}_5 = 3033\ psf$$

- Three feet of organic soil is excavated:

$$3 \times 100\ pcf = 300\ psf$$

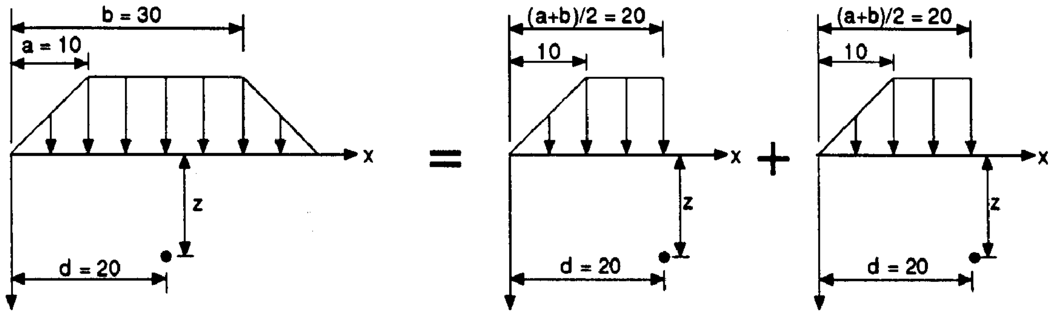
- Compute new embankment load as:

$$P' = P - 300\ psf$$

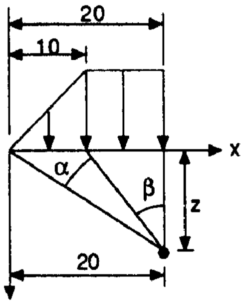
where $P = 10\,ft \times 120\ pcf = 1200\ psf$

Therefore $P' = 1200 - 300 = 900\ psf$ (considers excavation)

Determine increments of vertical stress under point A_1; use superposition principle as explained in figure 5 of main text:



Therefore we compute the increments of vertical stress as two times the vertical stress increments which result from:



$x = 20$

$a = 10$

$b = 20$

$x - b = 0$

$\frac{x}{a} = 2$

Therefore:

$$\sigma_z = \frac{P}{\pi}\,[\beta + 2\alpha]$$

$$\tan\beta = \frac{(b-a)}{z} \qquad \Rightarrow \beta = \arctan\left(\frac{10}{z}\right)$$

$$\tan(\alpha+\beta) = \frac{b}{z} \qquad \Rightarrow \alpha = \arctan\left(\frac{20}{z}\right) - \beta$$

Compute stress increments for z = 12, 22, 32, and 42 ft. Results are indicated in the table below:

z (ft)	$\beta = \arctan\left(\frac{10}{z}\right)$	$\alpha = \arctan\left(\frac{20}{z}\right) - \beta$	$\Delta\sigma_z$ (psf)	$2\Delta\sigma_z$ [psf]
12	39.80557	19.23068	391.3346	782.6692
22	24.44395	17.82974	300.5171	601.0342
32	17.35403	14.65136	233.2837	466.5674
42	13.3925	12.07085	187.671	375.3419

Settlement determination for point A_1:

- Use the following expression:

$$\rho = \sum_{i=1}^{4} H_i \frac{C_c}{1+e_0} \log\left(\frac{\bar{\sigma}_{v0} + \Delta\sigma_v}{\bar{\sigma}_{v0}}\right)$$

where:

H_i = thickness of each sublayer = 10.0 ft

C_c = According to FHWA procedure $= \frac{w\ \%}{100}$

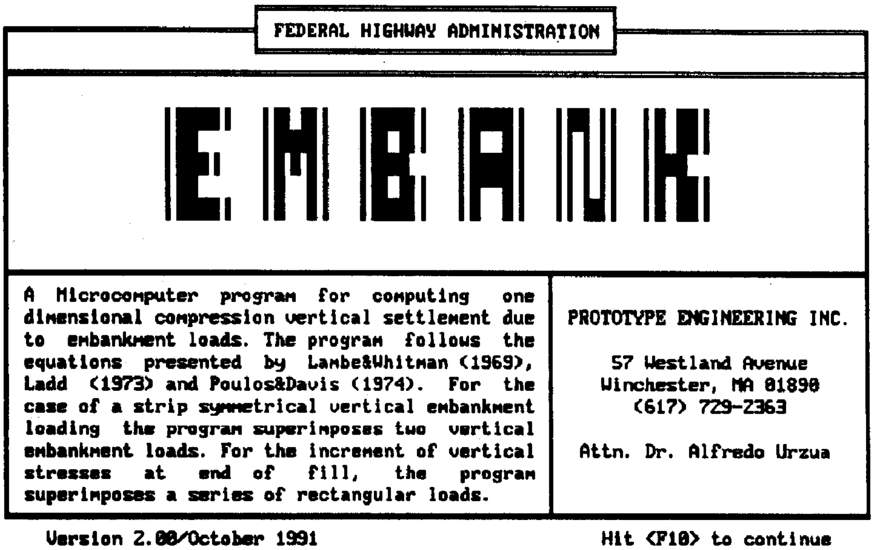
Therefore: $C_c = \frac{35\ \%}{100} = 0.35$

e_0 = Initial void ratio $= \frac{Gw}{S} = \frac{2.78 \times 0.35}{1} = 0.973$

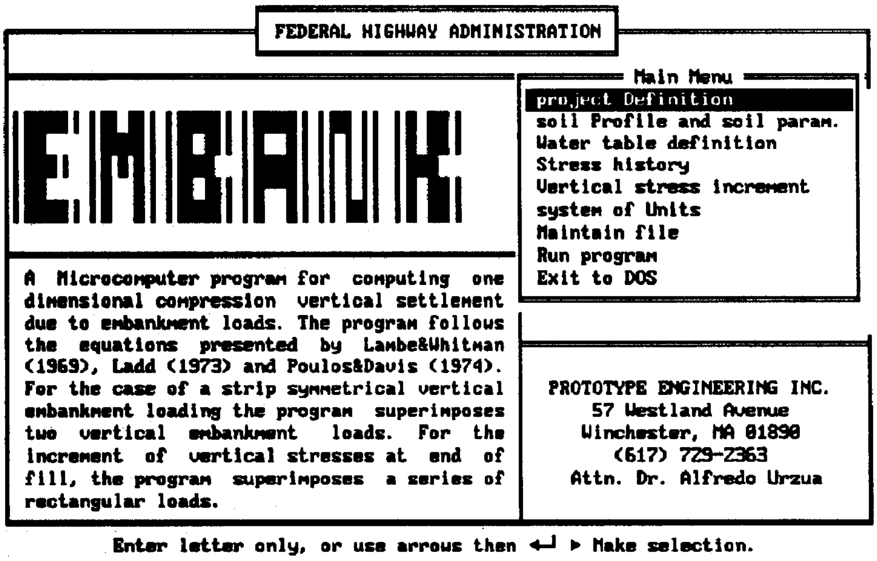
- Apply expressions above for z = 12, 22, 32, and 42 ft. Results are indicated in table below:

z (ft)	H_i (ft)	$\Delta\bar{\sigma}_0$ (psf)	$\Delta\bar{\sigma}_v$ (psf)	$\bar{\sigma}_{vf} = \bar{\sigma}_{v0} + \Delta\bar{\sigma}_v$ (psf)	ρ_i (ft)
12	10	1083	782.6692	1865.6692	0.4190176
22	10	1733	601.0342	2334.0342	0.2293869
32	10	2383	466.5674	2849.5674	0.1377558
42	10	3033	375.3419	3408.3419	0.0898873
			Total Settlement:		0.8760476 ft
					10.51 in

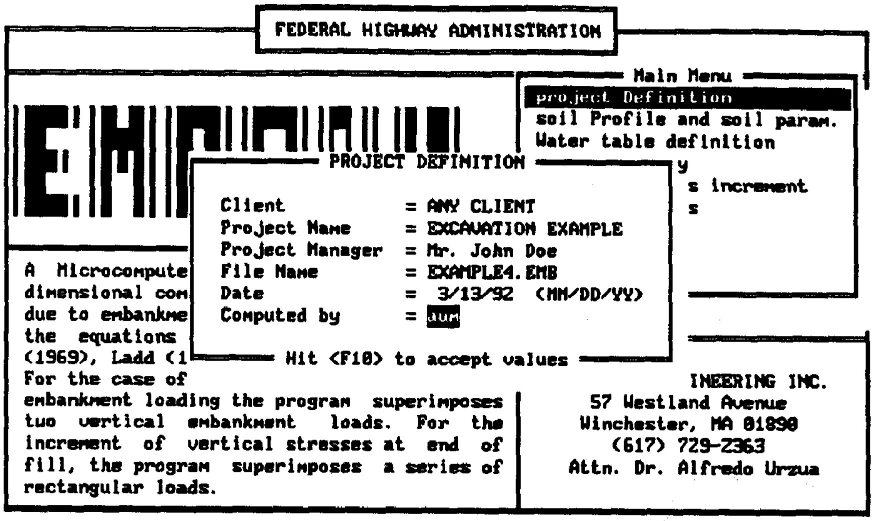
Compilation of Computer Screens for Example 4



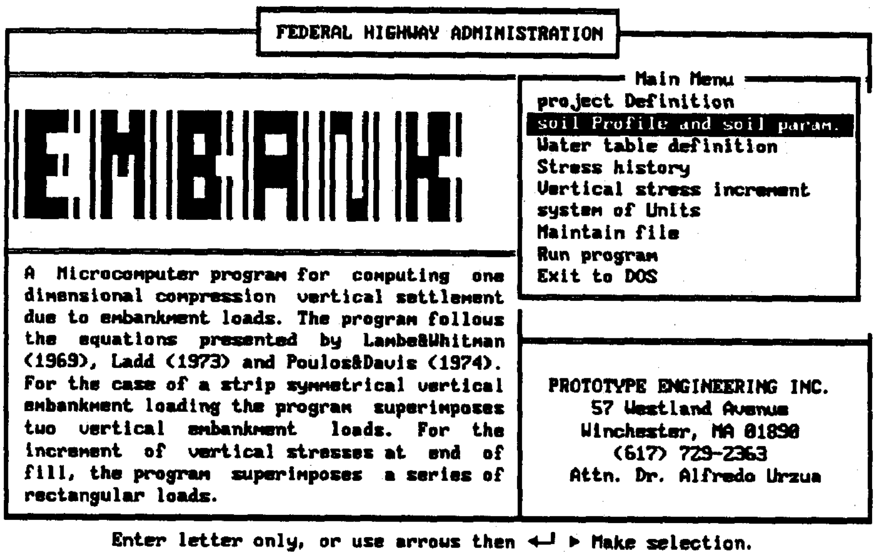
OPENING SCREEN



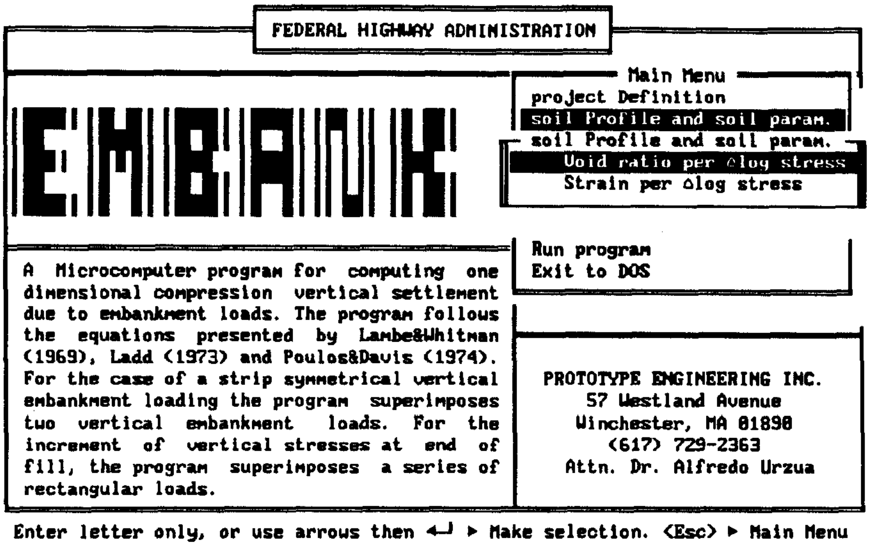
EMBANK MAIN MENU - SELECTION OF PROJECT DEFINITION



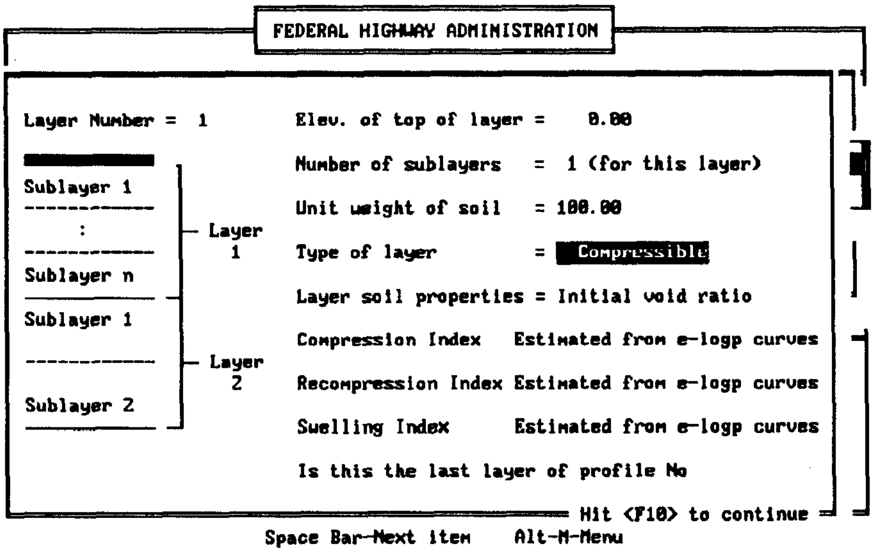
PROJECT DEFINITION SCREEN



EMBANK MAIN MENU - SELECTION OF SOIL PROFILE



SOIL PROFILE MENU - SELECTION OF VOID RATIO PER LOG STRESS



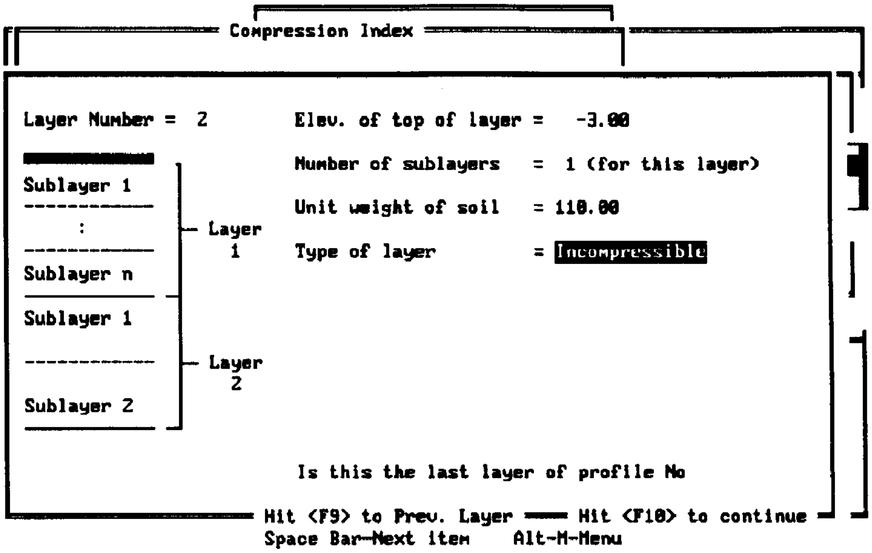
SOIL DESCRIPTION AND PARAMETERS FOR LAYER #1

```
 Layer Soil Properties            ADMINISTRATION
 Initial Water Content      = 80.00%
 Specific Gravity of Solids =  1.80     layer =     0.00
 Degree of Saturation       = 100.00%   yers   =  1 (for this layer)
 Hit <F10> to accept values             soil   = 100.00

 ------------      1   Type of layer          =  Compressible
 Sublayer n
 ------------          Layer soil properties = Initial water content
 Sublayer 1
                       Compression Index   Estimated from e-logp curves
 ------------   Layer
                  2    Recompression Index Estimated from e-logp curves
 Sublayer 2
 ------------          Swelling Index      Estimated from e-logp curves

                       Is this the last layer of profile No

                                           Hit <F10> to continue
```

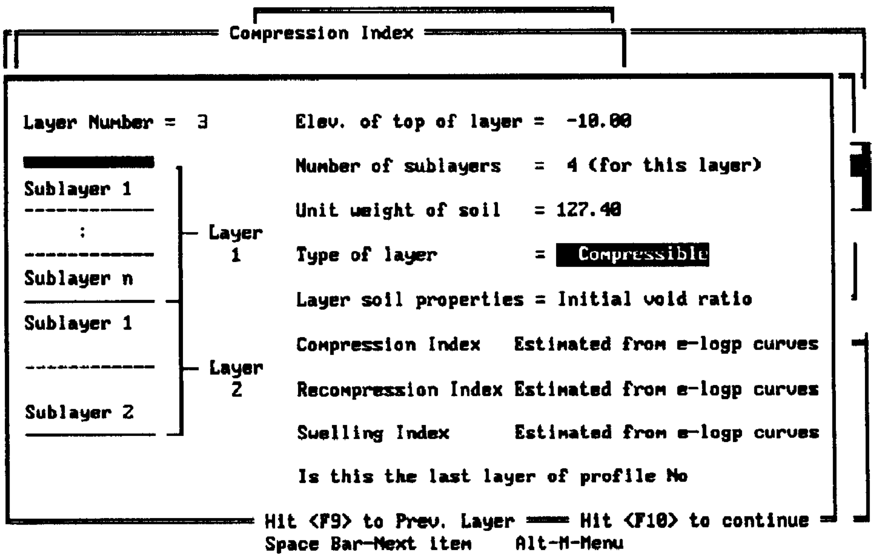
INITIAL WATER CONTENT - LAYER #1

```
 Compression Index
 The Federal Highway Administration (FHWA) in the soil
 and Foundations Workshop  Manual (1982) estimates the
 Compression  Index  by  dividing  the  initial   soil
 moisture content by 100.
                                                       this layer)
 Comp. Index = Initial Water Content (in %) / Constant
 where constant = 100

                   Constant = 100                      ssible

 Hit <F10> to accept value                             water content
                       Compression Index   Computed using FHWA(1982)
 ------------   Layer
                  2    Recompression Index Estimated from e-logp curves
 Sublayer 2
 ------------          Swelling Index      Estimated from e-logp curves

                       Is this the last layer of profile No

                                           Hit <F10> to continue
```

COMPRESSION INDEX - FHWA PROCEDURE - LAYER #1



SOIL DESCRIPTION AND PARAMETERS FOR LAYER #2



SOIL DESCRIPTION AND PARAMETERS FOR LAYER #3

```
 Layer Soil Properties
 Initial Water Content       =  35.00%
 Specific Gravity of Solids =   2.78      layer =  -10.00
 Degree of Saturation        = 100.00%   yers  =  4 (for this layer)
 Hit <F10> to accept values              soil  = 127.40

 -----------         1     Type of layer          =   Compressible
 Sublayer n
 ----------                Layer soil properties = Initial water content
 Sublayer 1
                           Compression Index   Estimated from e-logp curves
 -----------     Layer
                   2       Recompression Index Estimated from e-logp curves
 Sublayer 2
 ----------                Swelling Index      Estimated from e-logp curves

                           Is this the last layer of profile No

                 Hit <F9> to Prev. Layer  Hit <F10> to continue
```

INITIAL WATER CONTENT - LAYER #3

```
 Compression Index
 The Federal Highway Administration (FHWA) in the soil
 and Foundations Workshop  Manual (1982) estimates the
 Compression  Index  by  dividing  the  initial   soil
 moisture content by 100.
                                                        this layer)
 Comp. Index = Initial Water Content (in %) / Constant
 where constant = 100

                   Constant = 100                       ssible

 Hit <F10> to accept value                              water content

                           Compression Index   Computed using FHWA(1982)
 -----------     Layer
                   2       Recompression Index Estimated from e-logp curves
 Sublayer 2
 ----------                Swelling Index      Estimated from e-logp curves

                           Is this the last layer of profile No

                 Hit <F9> to Prev. Layer  Hit <F10> to continue
```

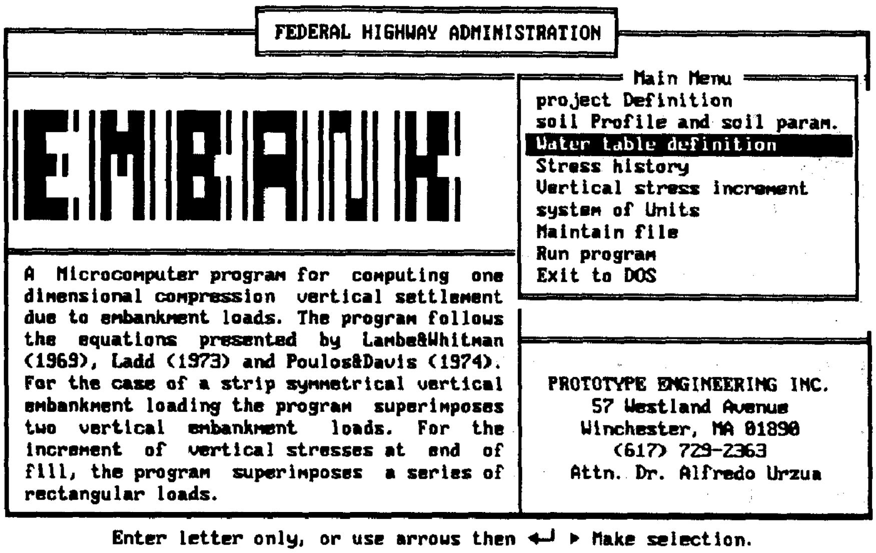
COMPRESSION INDEX - FHWA PROCEDURE - LAYER #3

```
                        Compression Index

Layer Number =  3          Elev. of top of layer =  -10.00

                           Number of sublayers   =  4 (for this layer)
Sublayer 1
-----------                Unit weight of soil   = 127.40
     :         Layer
-----------      1         Type of layer         =   Compressible
Sublayer n
-----------                Layer soil properties = Initial water content
Sublayer 1
                           Compression Index   Computed using FHWA(1982)
-----------    Layer
                 2         Recompression Index Estimated from e-logp curves
Sublayer 2
-----------                Swelling Index      Estimated from e-logp curves

                           Is this the last layer of profile Yes

                   Hit <F9> to Prev. Layer ═══ Hit <F10> to continue
                   Space Bar-Next item     Alt-M-Menu
```

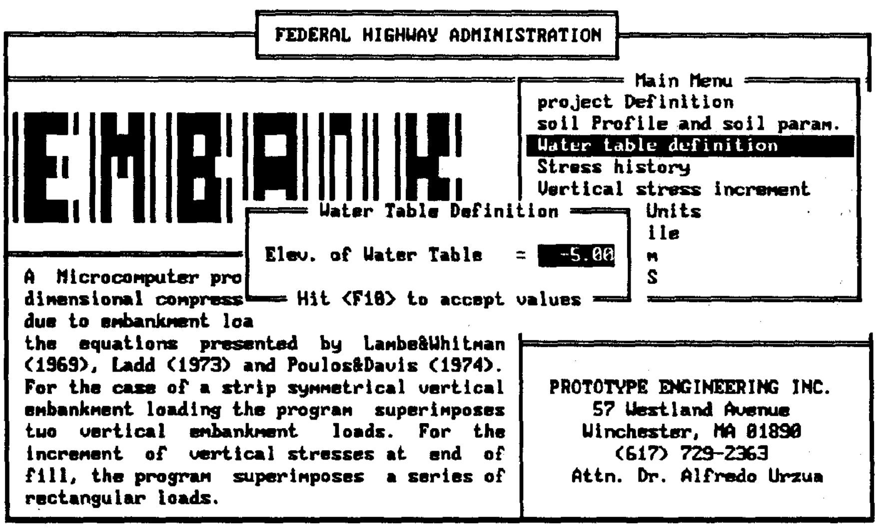
DEFINING LAYER #3 AS LAST LAYER OF SOIL PROFILE

```
                        Compression Index

Layer Number =  3          Elev. of top of layer =  -10.00

                           Number of sublayers   =  4 (for this layer)
Sublayer 1
-----------
     :         Elev. of bottom of last layer = -50.00   ible
-----------
Sublayer n     ═══ Hit <F10> to accept value ═══        ter content
-----------
Sublayer 1
                           Compression Index   Computed using FHWA(1982)
-----------    Layer
                 2         Recompression Index Estimated from e-logp curves
Sublayer 2
-----------                Swelling Index      Estimated from e-logp curves

                           Is this the last layer of profile Yes

                   Hit <F9> to Prev. Layer ═══ Hit <F10> to continue
```

DEFINING THICKNESS OF SOIL PROFILE



EMBANK MAIN MENU - SELECTION OF WATER TABLE DEFINITION



WATER TABLE AT ELEVATION -5 FT

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment
system of Units
Maintain file
Run program
Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

PROTOTYPE ENGINEERING INC.
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(617) 729-2363
Attn. Dr. Alfredo Urzua

Enter letter only, or use arrows then ↵ ► Make selection.

EMBANK MAIN MENU - STRESS HISTORY

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history

Stress history
Normally consolidated soil
User defined stress history

E

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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Enter letter only, or use arrows then ↵ ► Make selection. <Esc> ► Main Menu

SOIL IS DEFINED AS NORMALLY CONSOLIDATED

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment
system of Units
Maintain file
Run program
Exit to DOS

A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT

FEDERAL HIGHWAY ADMINISTRATION

EMBANK

Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment

Vertical stress increment
strip Symmetrical vertical embankment loading
increment of stresses Beneath the end of a fill

A Microcomputer program fo
dimensional compression ver
due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.

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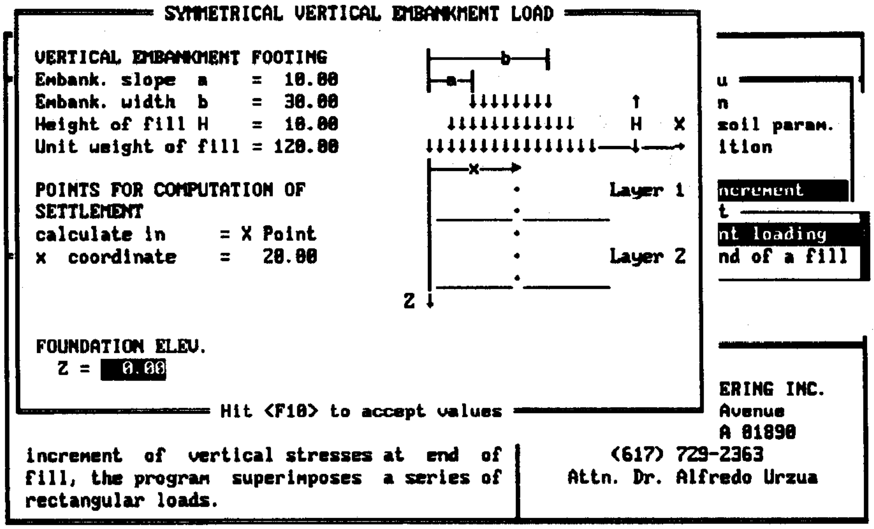
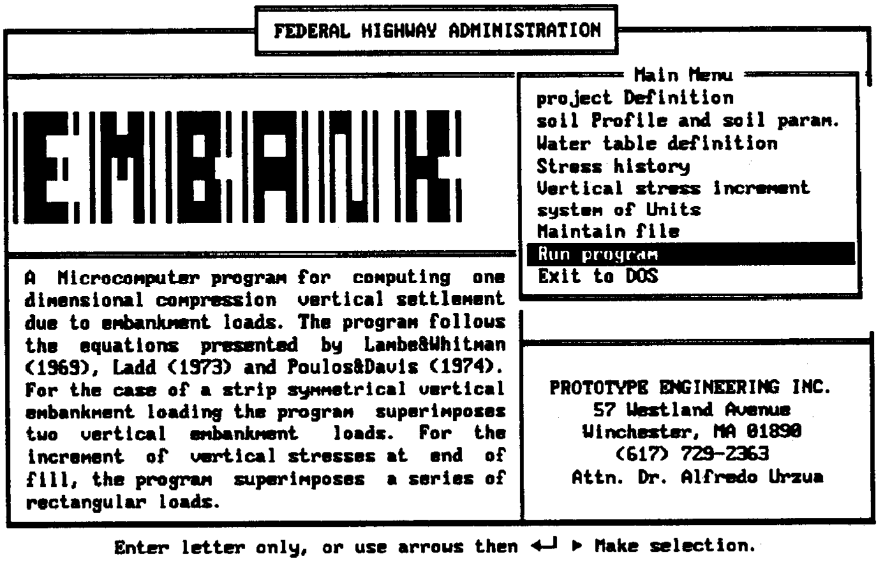
Enter letter only, or use arrows then ↵ ▸ Make selection. <Esc> ▸ Main Menu

VERTICAL STRESS INCREMENT - SELECTION OF STRIP SYMM. EMBANKMENT LOAD



STRIP SYMM. VERTICAL EMB. LOADING GEOMETRY INPUT SCREEN



EMBANK MAIN MENU - RUN PROGRAM OPTION

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Embankment slope a	=	10.00 (ft)	Height of fill H	=	10.00 (ft)
Embankment top width	=	20.00 (ft)	Unit weight of fill	=	120.00 (pcf)
Embankment bottom width	=	40.00 (ft)	p load/unit area	=	1200.00 (psf)
Ground Surface Elev.	=	0.00 (ft)	Foundation Elev.	=	0.00 (ft)
Water table Elev.	=	-5.00 (ft)	Unit weight of Wat.	=	62.40 (pcf)

Nº.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO	Settlement (in.)
1	COMP.	3.0	0.800	0.000	0.000	100.00	1.80	1.44	9.97
2	INCOMP.	7.0	-----	-----	-----	110.00	----	----	
3	COMP.	40.0	0.350	0.000	0.000	127.40	2.78	0.97	12.54

Total Settlement = 21.23

Nº.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	INCREMENT (psf)	MAX.PAST PRESS. (psf)	SETTLEMENT (in.)

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

PROGRAM OUTPUT - PARTIAL SCREEN

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

		(ft)				(pcf)			(in.)
1	COMP.	3.0	0.800	0.000	0.000	100.00	1.80	1.44	9.97
2	INCOMP.	7.0	-----	-----	-----	110.00	----	----	
3	COMP.	40.0	0.350	0.000	0.000	127.40	2.78	0.97	12.54

Total Settlement = 21.23

Nº.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	INCR (p		
1	3.00	-1.50	200.00	1199.37	200.00	9.97
2	INCOMP.					
3	10.00	-15.00	1083.00	967.60	1083.00	5.90
4	10.00	-25.00	1733.00	740.24	1733.00	3.29
5	10.00	-35.00	2383.00	580.59	2383.00	2.02
6	10.00	-45.00	3033.00	471.95	3033.00	1.34

Select
Send form to: P-Printer, D-Disk File.

Total Settlement = 21.23 (in.)

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

SELECTION OF DISC FILE PRINTED OUTPUT

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

		(ft)				(pcf)			(in.)
1	COMP.	3.0	0.800	0.000	0.000	100.00	1.80	1.44	9.97
2	INCOMP.	7.0	-----	-----	-----	110.00	----	----	
3	COMP.	40.0	0.350	0.000	0.000	127.40	2.78	0.97	12.54

Total Settlement = 21.23

	SUBLAYER		SOIL STRESSES			
Nº.	THICK. (ft)	ELEV. (ft)	INITIAL (psf)	INCRE (ps		
1	3.00	-1.50	200.00	1199.37	200.00	9.97
2	INCOMP.					
3	10.00	-15.00	1083.00	967.60	1083.00	5.90
4	10.00	-25.00	1733.00	740.24	1733.00	3.29
5	10.00	-35.00	2383.00	580.59	2383.00	2.02
6	10.00	-45.00	3033.00	471.95	3033.00	1.34

Destination File
A:EXAM4A.OUT

Total Settlement = 21.23 (in.)

Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu

SELECTION OF OUTPUT DESTINATION FILE NAME

ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration
STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name : EXCAVATION EXAMPLE   Client : ANY CLIENT
File Name : EXAMPLE4.EMB   Project Manager : MR. JOHN DOE
Date : 10/03/91   Computed by : aum

Settlement for X = 20.00 (ft)

Embankment slope a	= 10.00 (ft)	Height of fill H	= 10.00 (ft)
Embankment top width	= 20.00 (ft)	Unit weight of fill	= 120.00 (pcf)
Embankment bottom width	= 40.00 (ft)	p load/unit area	= 1200.00 (psf)
Ground Surface Elev.	= 0.00 (ft)	Foundation Elev.	= 0.00 (ft)
Water table Elev.	= -5.00 (ft)	Unit weight of Wat.	= 62.40 (pcf)

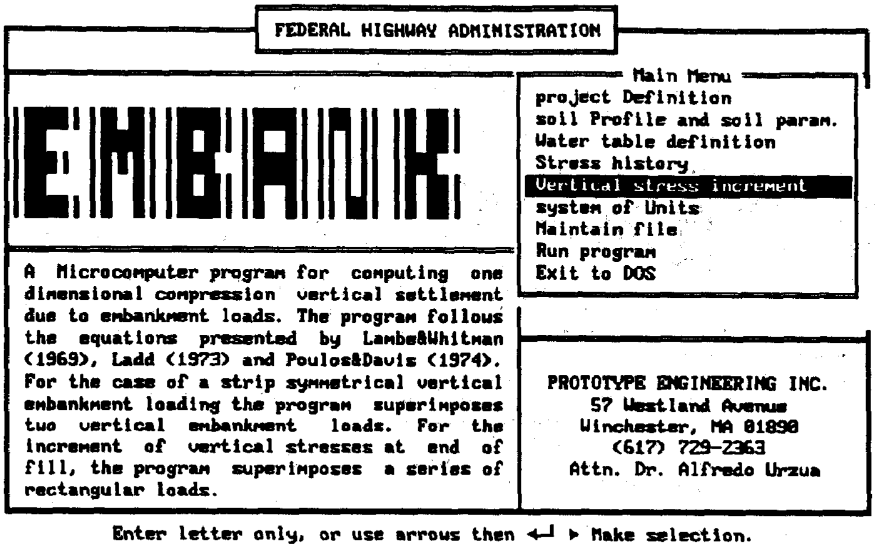
Nº.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO	Settlement (in.)
1	COMP.	3.0	0.800	0.000	0.000	100.00	1.80	1.44	9.97
2	INCOMP.	7.0	-----	-----	-----	110.00	----	----	
3	COMP.	40.0	0.350	0.000	0.000	127.40	2.78	0.97	12.54

Total Settlement = 21.23

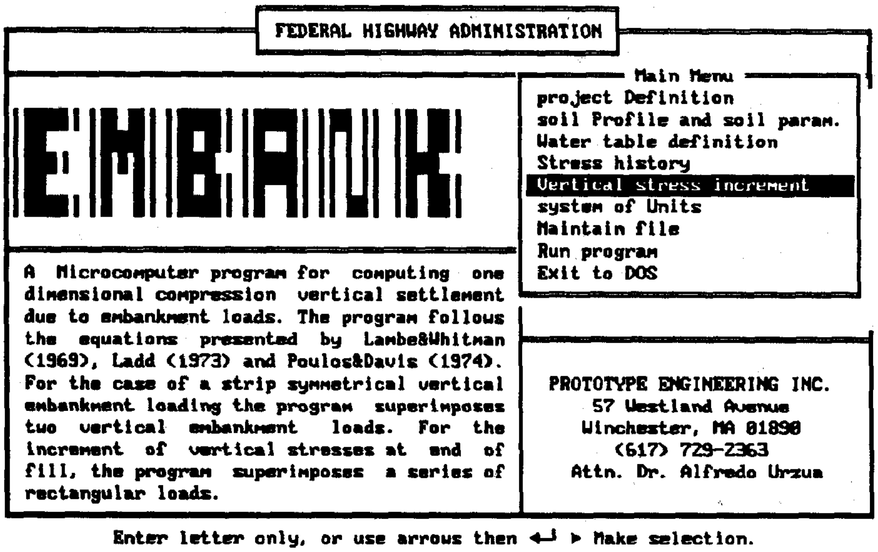
Nº.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	INCREMENT (psf)	MAX.PAST PRESS. (psf)	SETTLEMENT (in.)
1	3.00	-1.50	200.00	1199.37	200.00	9.97
2	INCOMP.					
3	10.00	-15.00	1083.00	967.60	1083.00	5.90
4	10.00	-25.00	1733.00	740.24	1733.00	3.29
5	10.00	-35.00	2383.00	580.59	2383.00	2.02
6	10.00	-45.00	3033.00	471.95	3033.00	1.34

Total Settlement = 21.23 (in.)

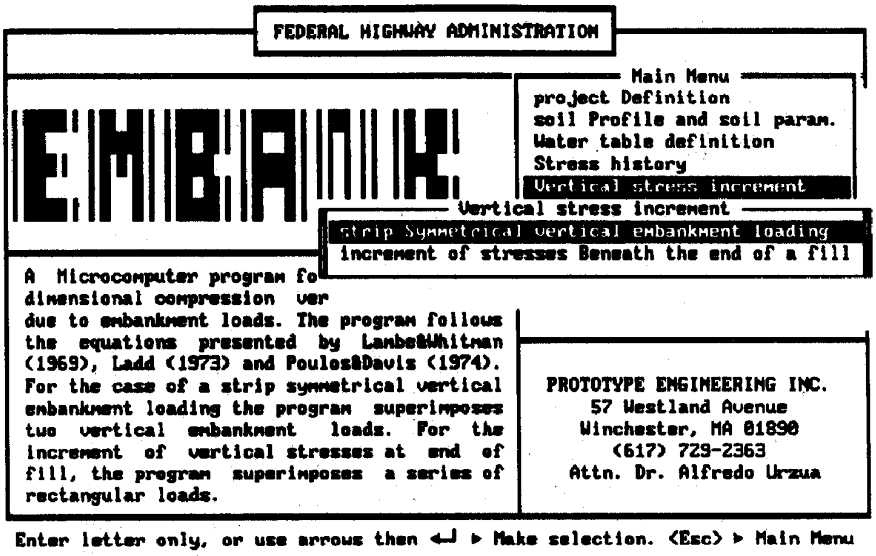
Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu



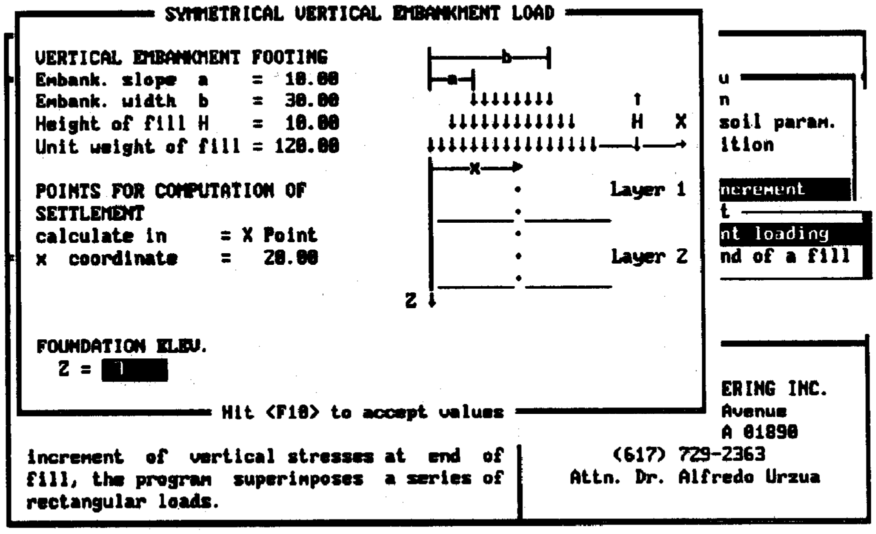
EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT


FEDERAL HIGHWAY ADMINISTRATION
EMBANK
Main Menu
project Definition
soil Profile and soil param.
Water table definition
Stress history
Vertical stress increment
system of Units
Maintain file
Run program
Exit to DOS
A Microcomputer program for computing one dimensional compression vertical settlement due to embankment loads. The program follows the equations presented by Lambe&Whitman (1969), Ladd (1973) and Poulos&Davis (1974). For the case of a strip symmetrical vertical embankment loading the program superimposes two vertical embankment loads. For the increment of vertical stresses at end of fill, the program superimposes a series of rectangular loads.
PROTOTYPE ENGINEERING INC.
57 Westland Avenue
Winchester, MA 01890
(617) 729-2363
Attn. Dr. Alfredo Urzua
Enter letter only, or use arrows then ↵ ▶ Make selection.

EMBANK MAIN MENU - SELECTION OF VERTICAL STRESS INCREMENT



VERTICAL STRESS INCREMENT MENU - SELECTION OF STRIP SYMM. EMB. LOAD



LOAD GEOMETRY - FOUNDATION DEPTH AT ELEVATION -3 FT

```
SYMMETRICAL VERTICAL EMBANKMENT LOAD

VERTICAL EMBANKMENT FOOTING
Embank. slope  a      =  10.00
Embank. width  b      =  30.00
Height of fill H      =  10.00
Unit weight of fill   = 120.00

POINTS FOR COMPUTATION OF
SETTLEMENT
calculate in     = X Point
x  coordinate    =   20.00

                                        Layer 1

                                        Layer 2
                          Z

FOUNDATION ELEV.          Compute excavation effect
  Z =  -3.00              as gamma*Foundation Depth = No

              Hit <F10> to accept values            No
                                                    Yes
increment  of  vertical stresses at  end  of
fill, the program  superimposes  a series of   Attn
rectangular loads.

         ←↑↓→-Move bar  ↵-Select  Esc-Exit
```

SELECTION OF EXCAVATION EFFECT

```
FEDERAL HIGHWAY ADMINISTRATION

                                        Main Menu
                                    project Definition
                                    soil Profile and soil param.
                                    Water table definition
                                    Stress history
                                    Vertical stress increment
                                    system of Units
                                    Maintain file
                                    Run program
                                    Exit to DOS
A  Microcomputer program for  computing  one
dimensional compression  vertical  settlement
due to embankment loads. The program follows
the  equations  presented  by  Lambe&Whitman
(1969), Ladd (1973) and Poulos&Davis (1974).
For the case of a strip symmetrical vertical     PROTOTYPE ENGINEERING INC.
embankment loading the program  superimposes        57 Westland Avenue
two  vertical  embankment   loads.  For the       Winchester, MA 01890
increment  of  vertical stresses at  end  of           (617) 729-2363
fill, the program  superimposes  a series of     Attn. Dr. Alfredo Urzua
rectangular loads.

   Enter letter only, or use arrows then ↵ ► Make selection.
```

EMBANK MAIN MENU - RUN PROGRAM

```
------ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ------
                STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Embankment slope a        =   10.00 (ft)  Height of fill H     =   10.00 (ft)
Embankment top width      =   20.00 (ft)  Unit weight of fill =  120.00 (pcf)
Embankment bottom width =   40.00 (ft)  p load/unit area     = 1200.00 (psf)
Ground Surface Elev.      =    0.00 (ft)  Foundation Elev.     =   -3.00 (ft)
Water table Elev.         =   -5.00 (ft)  Unit weight of Wat. =   62.40 (pcf)

     LAYER              COEFFICIENT          UNIT   SPECIFIC  VOID
Nº.  TYPE   THICK.  COMP.  RECOMP.  SWELL.  WEIGHT  GRAVITY   RATIO  Settlement
            (ft)                            (pcf)                      (in.)

 1   COMP.    3.0   0.800  0.000  0.000   100.00    1.80     1.44      0.00
 2  INCOMP.   7.0   -----  -----  -----   110.00    ----     ----
 3   COMP.   40.0   0.350  0.000  0.000   127.40    2.78     0.97     10.51

                                          Total Settlement =         10.51

            SUBLAYER                  SOIL STRESSES
   Nº.  THICK.  ELEV.    INITIAL  INCREMENT  MAX.PAST PRESS.    SETTLEMENT
------ Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu ------
```

PROGRAM OUTPUT - PARTIAL SCREEN

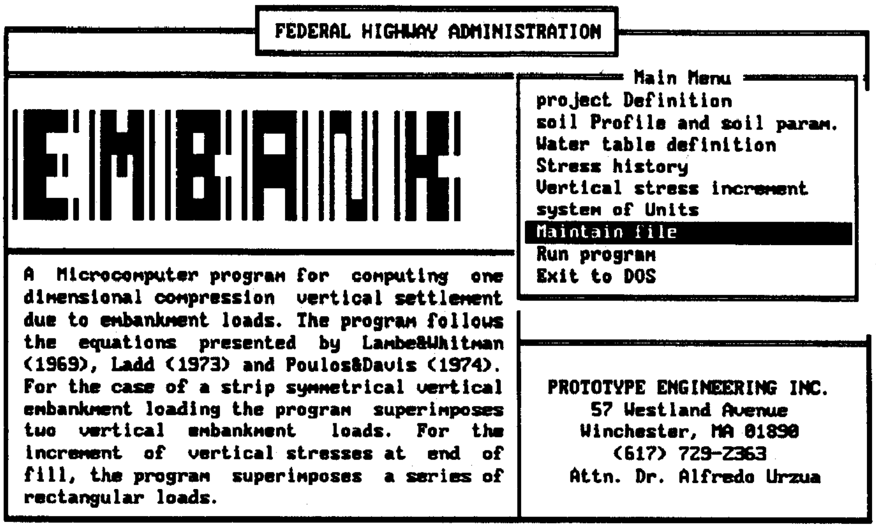
```
------ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ------
                STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING
            (ft)                            (pcf)                      (in.)

 1   COMP.    3.0   0.800  0.000  0.000   100.00    1.80     1.44      0.00
 2  INCOMP.   7.0   -----  -----  -----   110.00    ----     ----
 3   COMP.   40.0   0.350  0.000  0.000   127.40    2.78     0.97     10.51

                                          Total Settlement =         10.51

           SUBLAYER                  SOIL STRESSES
   Nº.  THICK.  ELEV.    INITIAL  INCR============ Select =============
        (ft)    (ft)     (psf)    (p| Send form to: P-Printer, D-Disk File. |

   1         Sublayer over foundation Elev.
   2   INCOMP.
   3   10.00   -15.00   1083.00   782.67    1083.00              5.03
   4   10.00   -25.00   1733.00   601.03    1733.00              2.75
   5   10.00   -35.00   2383.00   466.57    2383.00              1.65
   6   10.00   -45.00   3033.00   375.34    3033.00              1.08

                                      Total Settlement =      10.51 (in.)
------ Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu ------
```

SELECTION OF DISC FILE PRINTED OUTPUT

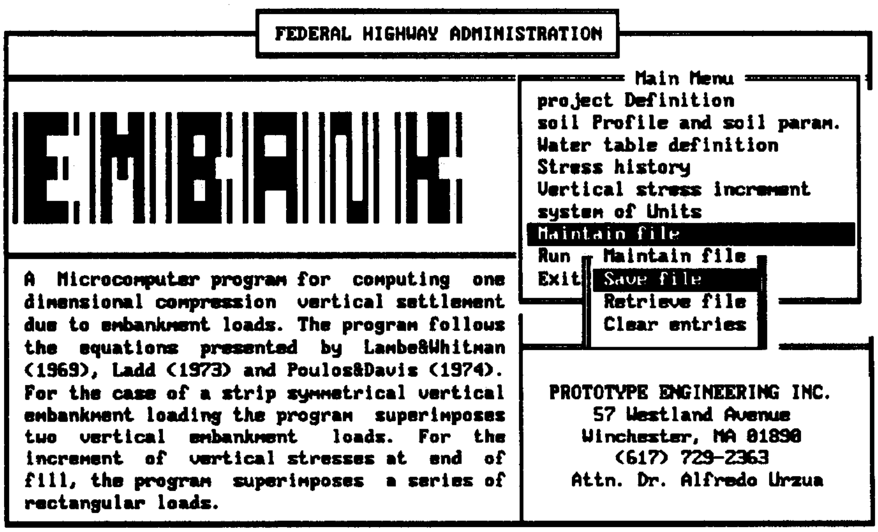
```
------ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ------
                 STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING
          (ft)                               (pcf)                         (in.)

 1   COMP.    3.0   0.800  0.000  0.000   100.00      1.80      1.44       0.00
 2  INCOMP.   7.0   -----  -----  -----   110.00      ----      ----
 3   COMP.   40.0   0.350  0.000  0.000   127.40      2.78      0.97      10.51

                                         Total Settlement =              10.51


          SUBLAYER                      SOIL STRESSES
   No.  THICK.  ELEV.   INITIAL  INCRE----------- Destination File -----------
        (ft)    (ft)    (psf)    (ps| A:EXAM4A1.OUT                            |

    1         Sublayer over foundation Elev.
    2   INCOMP.
    3   10.00   -15.00   1083.00   782.67     1083.00                    5.03
    4   10.00   -25.00   1733.00   601.03     1733.00                    2.75
    5   10.00   -35.00   2383.00   466.57     2383.00                    1.65
    6   10.00   -45.00   3033.00   375.34     3033.00                    1.08

                                    Total Settlement =         10.51 (in.)

------ Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu ------
```

SELECTION OF OUTPUT DESTINATION FILE NAME

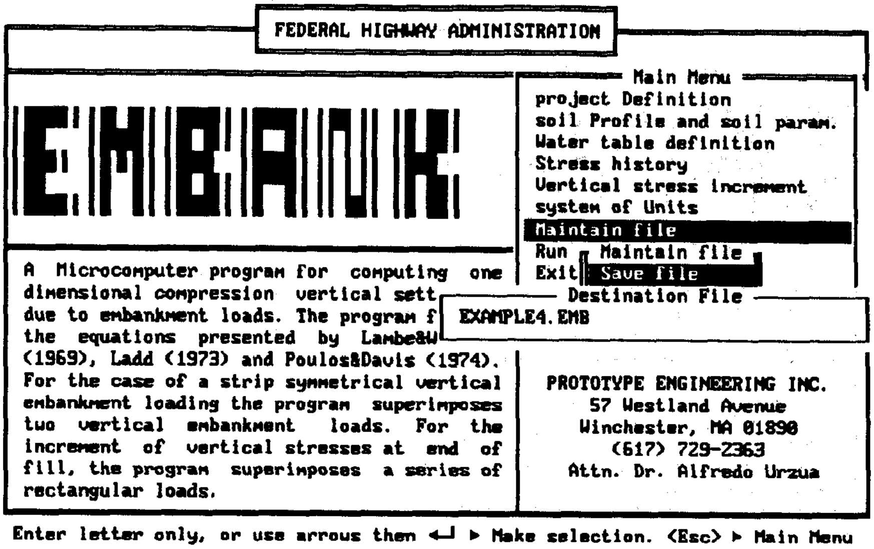
```
------ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ------
                 STRIP SYMMETRICAL VERTICAL EMBANKMENT LOADING

Project Name    : EXCAVATION EXAMPLE   Client           : ANY CLIENT
File Name       : EXAMPLE4.EMB         Project Manager  : MR. JOHN DOE
Date            : 10/03/91             Computed by      : aum


                     Settlement for X =  20.00 (ft)

Embankment slope a        =   10.00 (ft)  Height of fill H      =   10.00 (ft)
Embankment top width      =   20.00 (ft)  Unit weight of fill  =  120.00 (pcf)
Embankment bottom width   =   40.00 (ft)  p load/unit area      = 1200.00 (psf)
Ground Surface Elev.      =    0.00 (ft)  Foundation Elev.      =   -3.00 (ft)
Water table Elev.         =   -5.00 (ft)  Unit weight of Wat.  =   62.40 (pcf)


     LAYER              COEFFICIENT         UNIT    SPECIFIC   VOID
No.  TYPE   THICK.  COMP. RECOMP. SWELL.   WEIGHT   GRAVITY    RATIO   Settlement
             (ft)                           (pcf)                         (in.)

 1   COMP.    3.0   0.800  0.000  0.000   100.00     1.80      1.44       0.00
 2  INCOMP.   7.0   -----  -----  -----   110.00     ----      ----
 3   COMP.   40.0   0.350  0.000  0.000   127.40     2.78      0.97      10.51

                                         Total Settlement =           10.51


          SUBLAYER                      SOIL STRESSES
   No.  THICK.  ELEV.   INITIAL  INCREMENT  MAX.PAST PRESS.    SETTLEMENT
        (ft)    (ft)    (psf)     (psf)        (psf)              (in.)

    1         Sublayer over foundation Elev.
    2   INCOMP.
    3   10.00   -15.00   1083.00   782.67     1083.00                5.03
    4   10.00   -25.00   1733.00   601.03     1733.00                2.75
    5   10.00   -35.00   2383.00   466.57     2383.00                1.65
    6   10.00   -45.00   3033.00   375.34     3033.00                1.08

                                    Total Settlement =         10.51 (in.)

------ Hit arrow keys to display next screen. <F8> Print. <F10> Main Menu ------
```



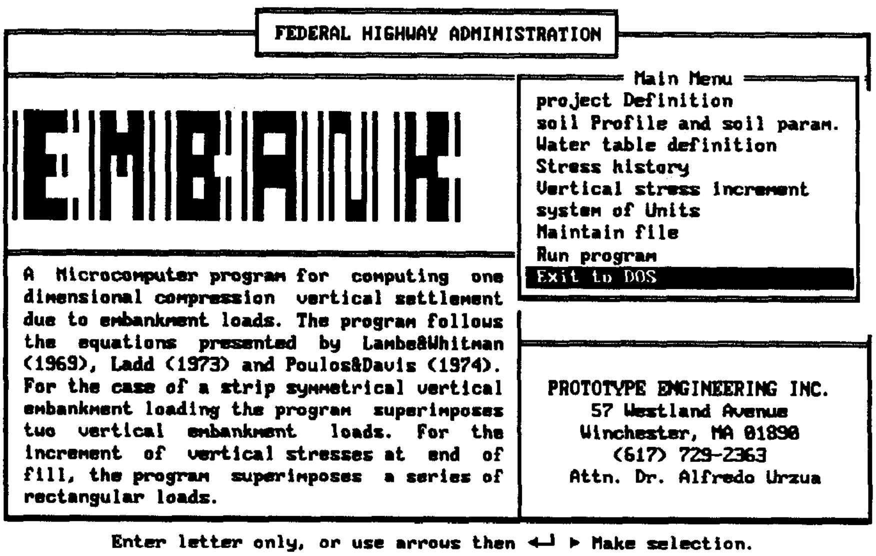
EMBANK MAIN MENU - MAINTAIN FILE OPTION



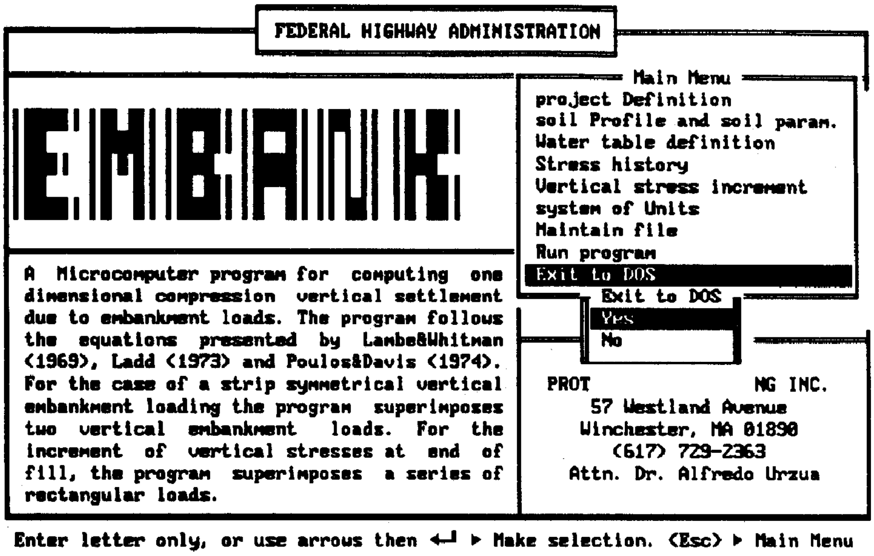
MAINTAIN FILE MENU - SELECTION OF SAVE FILE



SAVING INPUT FILE AS EXAMPLE4.EMB



EMBANK MAIN MENU - EXIT TO DOS OPTION



EXIT TO DOS MENU - YES OPTION