THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS FOR BRIDGES

Volume 1
A USER'S MANUAL

SASHTO AND AREA II HEEP
COOPERATIVE EFFORT TO UPGRADE
BRIDGE DESIGN SOFTWARE

BY
GEORGIA DEPARTMENT OF TRANSPORTATION

JUNE 24,1985

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS FOR BRIDGES

USER MANUAL REVISIONS

The User's Manual was originally written for Version 4.1 of the "Pier" program. Several revisions in Version 4.1 (through V4.1.49) changed some portions of the manual and the subsequent Version 4.2 brought about changes to the manual also. A new User's Manual will not be released with Version 4.2. Herein is a list of changes which if made in the manual would bring it up-to-date with Version 4.2.

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4. A fatal error will now be detected when reading in the input if the allowable soil stress is zero for a spread footing design or the allowable pile capacity is zero for a pile footing design.

5. The designer can now interchange the transverse and longitudinal moments and shears on the footing by entering an S code of "2" in column 49 of the Footing Data. This in essence will rotate the footing 90 degrees which may be of value when designing pile footings (to take advantage of different pile arrangements).

6. The maximum number of columns is eight rather than five.

7. A message will now be printed in the output of the Cap Design Data whenever the cap depth is incremented or the Fs/Ff, Fs/Fz serviceability ratios exceed their allowable magnitude.

8. Additional information is given in the output whenever the program encounters problems in the design process and cannot continue.

9. Volume II on the Method of Solution is not available at the present time.

FOREWORD

"The Analysis and Design of Multiple Column Piers for Bridges" presented in this manual is a problem oriented computer program which can be used effectively in the design of nearly all types of bridge piers. This program is actually the fourth in a series of bridge pier programs. The first pier program was written in 1959 for use on an IBM 650 computer. Because the program proved so successful, the program was rewritten with additional capacities in 1963 for use on an IBM 1620. The computer oriented Symbolic Programming System (SPS) language was used to code the IBM 1620 program, whereas, the IBM 650 program was coded in a machine language. In 1969 the program was rewritten using Fortran IV programming language. This language made the program practically computer independent with only minor modifications required for operation on any third-generation computer system. In addition, the program was made more versatile with new features including some design capabilities.

With the advent of the new Load Factor specifications in 1973, it became clear that this program and many other bridge design computer applications would require major modifications. In order to reduce the work load and consolidate many different programs which did essentially the same thing, a Cooperative Effort was organized in 1976 by the SASHTO and Area II HEEP States to upgrade bridge design software. The program presented herein is Georgia's contribution to this effort.

This write-up is primarily a user's manual and does not include the method of solution, flow charts, or a program listing. However, since a copy of the source can be obtained by request, a program listing could then be obtained by listing or compiling the source. In addition, since the program is written in Fortran IV programming language and contains numerous comment statements which describe the program functions, the flow charts are not really essential in order to understand the procedure of the program solution. Volume II contains a detailed description of the Method of Solution. The reader is assumed to be familiar with the standard terminology of concrete design and such terms as moment, shear, stress, etc., are not defined in this manual.

This manual, then, explains in general terms the functions of the program and how the program can be used effectively in the design of bridge substructures.

Glenn H. Sikes
Atlanta, Georgia
April 1, 1980

DISCLAIMER

Although this program has been subjected to many rigorous tests - all with excellent results - no warranty, expressed or implied, is made by the Georgia Department of Transportation as to the accuracy and functioning of the program; nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the Georgia Department of Transportation in any connection therewith.

REPRODUCTION AND DISTRIBUTION RESTRICTION

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AUTHOR'S NOTE

This program conforms to the newly ballotted but not published 1981 AASHTO Specifications except that the minimum eccentricity has not been removed per newly revised Art. 1.5.33. However, quoting from the Commentary on the revised Art. 1.5.33, "The intent of this revision is to simplify the design calculations without significantly changing the allowable load. Therefore, any charts, tables, forms, computer programs, etc., based on the use of minimum eccentricity (e) can continue to be used and will produce acceptable results."

Therefore, we have left the minimum eccentricity requirements in the program for the time being. To revise the program now would unnecessarily delay its final release. The program will be revised in the future when the need arises and time permits.

Glenn H. Sikes
April 30, 1981

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JUNE 24,1985

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I. DESCRIPTION OF THE PROGRAM

"The Analysis and Design of Multiple Column Piers for Bridges" computer program can be used as an effective aid in the design of substructures for highway bridges. Actually, the program is not limited to highway bridges since railroad and pedestrian bridge piers can be handled by the program. The pier is assumed to be of conventional reinforced concrete construction. However, in the case where steel "H" or other type piles are used for columns, an equivalent concrete column can be used to obtain the desired effects. The pier may have from one to five columns all of which may be sloped (center line not vertical), battered (section varies lineally) in either direction and unequal in length. One column piers cannot be sloped.

The cap portion of the pier can have a variation in depth but the center line of the cap is assumed to be level. Even if the pier cap is sloped, the program solution should be accurate enough for design purposes since the effects of a normally sloped cap are minimal. The effects of built-up beam seats or steps on the pier cap are ignored by the program. The cantilever portions may have a variable depth and width. A maximum of 36 gravity loads (beams) may be placed on the pier.

The bottom of each column can be varied from fully fixed to fully hinged in the transverse direction. Piers on continuous footings cannot be analyzed as such, but an equivalent partial fixity (distribution factor) can be assigned to the bottom of the column to produce reasonably accurate results.

In the longitudinal direction the pier is assumed to act as a cantilever. The top of each column is assumed to deflect equally due to the application of horizontal forces in order to distribute the longitudinal forces.

LOADS

Following are the different types of loads which may be applied to the pier in the analysis and design process.

1. Dead Load.

   a. Superstructure.

      The dead load reactions to the pier from the superstructure must be computed by the designer and given as part of the input data.

   b. Substructure.

      The dead load of the pier is automatically computed by the program based on an assumed concrete weight of 150 pounds per cubic foot.

2. Live Load.

   The program has provisions for 25 cases of live load applications. These live load cases must be computed by the designer for the various positions of the truck(s) on the bridge, and given as part of the input.

3. Wind on Structure/Live Load.

   a. Superstructure.

      The program has capacity for five directions of Group 2 and Group 3 wind on the superstructure. Each wind Group and direction are independent of the other and optional.

   b. Substructure.

      The wind on the pier is limited to one direction for both the Group 2 and 3 wind and is simulated by giving an equivalent concentrated force at the top of the pier in the transverse and longitudinal direction.

   c. Live Load.

      The program has provisions for five directions of wind on the live load.

4. Traction (Longitudinal Force).

   The traction force which is a percentage of the live load must be computed by the designer and given as part of the input data.

5. Centrifugal Force.

   The centrifugal force which is a percentage of the live load must be computed by the designer and given in the input data.

6. Stream Flow.

   The force due to stream flow can be applied to the pier if this force is given as part of the input data.

7. Expansion of the Cap.

   The effects due to the expansion of the cap are computed by the program whenever the coefficient is given in the input data.

8. Shrinkage of the Cap.

   The effects due to the shrinkage of the cap are computed by the program if the coefficient is given in the input data.

9. Footing Settlement.

   The effects due to the settlement of a footing are computed by the program if the value of the settlement is given in the input data. It should be noted that these effects are not included in the Group loading combinations, i.e., not included in design process.

The horizontal forces (except wind on substructure or stream flow) are assumed to be acting parallel and perpendicular to the bridge. By giving the skew angle of the pier in the input data, the program is able to resolve these forces into components which are parallel and perpendicular to the pier.

LOAD COMBINATIONS

The program has the ability to combine the effects of the various loads which are applied to the pier according to the Group loadings given in the AASHTO Specifications. Following are the Group loadings considered by the program and the loads included in each Group.

Group 1: D.L. + L.L. + C.F. + S.F.

Group 1A: D.L. + L.L. (Load Factor Only)

Group 2: D.L. + W + S.F.

Group 3: Group 1 + L.F. + 30%W + W.L.

Group 4: Group 1 + E or S

Group 5: Group 2 + E or S

Where:

D.L. = Dead load
L.L. = Live load + Impact (Except Footings)
C.F. = Centrifugal force
W = Wind on structure
W.L. = Wind on live load
L.F. = Longitudinal force (traction)
S.F. = Stream flow
E = Expansion of Cap
S = Shrinkage of Cap

When combining the loads the following assumptions are made:

1. The centrifugal force is a non-reversible force; but, this force may have a value of zero which is due to a non-moving live load. However, the impact is still considered with a non-moving live load. The amount of centrifugal force used depends on the number of lanes of live load and is reduced in the same manner as live load for multiple loaded lanes. The centrifugal force is never placed in opposing directions with the lateral wind.

2. The wind and traction forces are fully reversible forces. The longitudinal wind and traction forces always act in the same direction, i.e., not opposing directions. Also, the lateral wind on superstructure and live load act in the same direction. The program computes two wind combinations for each direction of wind given in the input data. Each combination is reversible so that actually there are four cases of wind per wind direction. The magnitude of the traction force used depends on the number of lanes of live load and is reduced in the case of multiple loaded lanes.

PROGRAM FUNCTIONS

The program performs four basic analysis and design functions considering Service Load and/or Load Factor options.

1. Computes and reports the moment, shear, and reaction in the top and bottom of each column in the transverse and longitudinal direction due to the various loads which are applied to the pier. Computes and reports a Group 1, 2, and 3 moment envelope of the cap, and the maximum shear on each side of column center lines and beams from Group 1. Dead load moments and shears are also given.

2. Performs an analysis/design of the cap to determine the main reinforcement requirements, stirrup requirements, required depth, concrete stress (S.L.), steel percentage, and serviceability requirements.

3. Computes the section adequacy at the top and bottom of each column and reports the critical loading condition. Determines reinforcement steel requirements taking into account slenderness and minimum eccentricity.

4. Performs an analysis/design of a spread or pile footing for each column determining size, number of piles, reinforcement steel requirements, and section capacities. In addition, reports controlling load cases.

Item 1 is always obtained, whereas, items 2, 3, 4 are optional.

LOAD ANALYSIS

The pier is assumed to be a one-story, integral concrete plane frame. One-cycle moment distribution is used after the stiffness and carry-over factors of the cap and column members are modified. Variable moment of inertia is taken into account including the fixed-end moment computations. The lengths of the structural members are from center line to center line of columns (cap members), and from the top of the footings to the cap (nominal depth - not including haunch) center line for column members.

CAP ANALYSIS/DESIGN

When analyzing/designing the cap, it is assumed Group 1, 2, or 3 moments will govern, and Group 1 shear will control. The design points are at all beams and at the ends (center line of columns). The required depth of the cap is computed but the pier is not re-analyzed for any change in member size. In the computations for the reinforcement steel, the compression steel is assumed to be the minimum from input unless more steel is required as in a stress reversal situation. A maximum of two horizontal layers of rebars is used, and the rebars are allowed to be bundled, i.e., two rows are together. The bar cutoff points are not computed.

Serviceability requirements are computed and displayed along with maximum service load moments. The concrete stress is computed by conventional means for service load. The percentage of steel is computed and displayed.

COLUMN ANALYSIS/DESIGN

The column analysis/design procedure used in the pier program is an adaptation of the PCA's "Strength Design of Reinforced Concrete Column Sections". Refer to the PCA manual for further information on the section design procedure.

The pier program computes the column loads (P, Mx, My) taking into account slenderness and minimum eccentricity. Minimum eccentricity is applied before magnification. EI is computed by formula 6-17 with the given reinforcement (minimum or lower limit) used to compute Is. The program uses two values of B_D if specified in the input. Delta (magnification factor) for each column is taken as the maximum of (a) the value computed for the columns acting as a group where the columns are considered unbraced, or (b) the value computed for the individual column assuming its ends to be braced against sidesway. The effective length factor (k) is computed according to PCA's Load Factor Design, 1974 page 9-6.

There are literally thousands of possible load combinations. The program analyzes only the 25 most critical load cases (combinations) at the top and bottom of each column. The selection is based on the maximum magnitude of the square root of the sum of the squares of the P-load, traverse moment, and longitudinal moment.

Basically the program follows Art. 1.5.28, 1.5.33 and 1.5.34 of the AASHTO Specifications.

FOOTING ANALYSIS/DESIGN

The program can analyze or design a spread or pile footing. Service Load requirements are used to determine the size (length and width), and the number of piles and spacing in the case of a pile footing. The thickness and reinforcement steel requirements are determined from Service Load or Load Factor requirements. AASHTO Article 1.4.4 (G) is not considered.

In the case of a spread footing, the soil is assumed to resist no tension. The critical section for beam shear is at d from the face of the column, and at d/2 for peripheral shear. In a design the width of the footing in the direction of the maximum moment (M_T or M_L) will be incremented unless the width ratio is exceeded.

In the case of a pile footing the critical section for beam and peripheral shear is at d/2 from the face of the column. In the design of a pile footing, the program starts with a minimum (4 or the input value) number of piles at the minimum spacing. The spacing is increased as required until the maximum spacing is reached. Then a pile is added and the spacing set to the minimum, and the process repeated. The maximum number of piles is 25.

The thickness of the footing is increased when the beam and peripheral shear and moment capacities of the footing section are exceeded.

Impact is removed from the live load effects in the footing analysis/design process.

The 25 most critical load cases are selected for the analysis/design of each footing in the same manner as for the column sections.

USING THE PROGRAM

To use the program, the designer must assume the size of the pier and compute the applied loads. After processing, if the cap or column sections are inadequate (or if the members are excessively understressed) the designer should adjust the section size and reprocess. The program will not automatically adjust the cap or column size and reprocess. This will be left to a later version.

For more detailed information, refer to Volume II, Method of Solution.

The User of this program should realize that with an analysis problem there is a finite solution, in other words one answer based on the given parameters. However, in the case of a design, there is an infinite number of solutions. This program attempts to find A reasonable design but not necessarily THE design. So it is strongly advised to review the design results very closely and modify as is seen fit. Remember the designer is the person responsible for the final design and not the computer.

II. PREPARING THE INPUT DATA

The input data required by the program are entered on two types of input forms: PIER DESCRIPTION and PIER LOADS. In the following discussion, refer to these two input data forms shown in the example problems.

The PIER DESCRIPTION input data form is used to enter the data necessary to define the size and characteristics of the pier. Only one sheet of this type is required per problem, and this sheet must always be the first page of each problem. The PIER DESCRIPTION will consist of the following types of input data:

1. IDENTIFICATION

2. DESIGN DATA

3. CANTILEVER and CAP DATA

4. COLUMN DATA

5. FOOTING DATA (Optional)

The PIER LOADS input data form is used to enter the data necessary to define the loads that are applied to the pier. This input form has space for 20 live load cases. If the engineer uses 20 (or less) live load cases, only one sheet of this type is required per problem. However, if more than 20 live load cases are used, additional sheets of PIER LOADS input data forms can be used to define the additional live load cases. These additional sheets should not have the other loads (GROUP 2 WIND, etc.) redefined, i.e., enter only live load cases. Note that if there are more than 12 P-loads (beams), two or more lines will be required per live load case, and thus, less than 20 live load cases may be entered per sheet. The PIER LOADS will consist of the following types of input data:

1. GROUP 2 WIND

2. GROUP 3 WIND

3. MISCELLANEOUS FORCES

4. DEAD LOAD SUPERSTRUCTURE

5. LIVE LOAD CASES

In order to define a negative quantity, a minus sign (-) must be placed in a column preceding the first digit of the input data field. Note that the position of the decimal is shown on the input forms. However, the position of the decimal can be overridden by placing a decimal in a column of the input data field.

The first two digits of each input data line, which are already shown on the input form, are for identification purposes and must be input. They are of no further significance to the engineer. Each line of the input form represents a card (batch) or record (on-line) and the column numbers are shown on each form. On the following pages the input data requirements of each input data form are discussed in detail.

PIER DESCRIPTION

A. IDENTIFICATION (*BØ3 in c.c. 1-4)

The identification consists of one line of input data, containing the problem number (c.c. 5-8) and pertinent identifying remarks (c.c. 9-80). A unique problem number should be assigned to each pier design problem. This information will head the output data.

B. DESIGN DATA (Ø1 or Ø2 in c.c. 1, 2)

Two lines of input provide the design data. The valid bar sizes are 4-11, 14, 18, except as noted.

The first line is to contain the following:

The first two columns contain the line number Ø1.

DESIGN OPTIONS

Columns 3-6 are to contain investigation or design option codes as follows:

1. CAP (c.c. 3) Form: x (D or blank)

If the program is to design the cap (depth and reinforcement) enter a D in this column. Otherwise, leave blank to bypass the cap design process. An investigation is not possible.

2. COL (c.c. 4) Form: x (I, D, or blank)

If the program is to select the column reinforcement, enter a D in this column. On the other hand, enter an I to have the program investigate the column adequacy using the input data. To bypass the column design/investigation process, leave blank.

3. FT. (c.c. 5) Form: x (I, D, or blank)

Enter a D if the footings are to be designed, an I if the given footings are to be investigated for design adequacy, and leave blank to bypass the footing design/investigation process. In the case of a blank, the FOOTING DATA must not be defined.

4. S/L (c.c. 6) Form: x (S or L)

Enter S to call for Service Load design and an L to indicate Load Factor design. Any other character or blank defaults to Load Factor design.

5. CAN. (c.c. 7) Form: x (blank, 1 or 2)

Enter the number of cantilevers. In the instance of one cantilever, it must be the left one (view the pier so it is the left one) and its data will be entered prior to the cap sections.

6. NO. COL. (c.c. 8-9) Form: xx (01-05)

Enter in this data field the number of columns. This number may be from one to five (and even greater, because the program is easily modified to consider six or more columns). Hence, two card columns are reserved for this number. A blank, zero (Ø), or a number greater than the program capacity will result in an error message and program abort.

7. NO. LLC (c.c. 10, 11) Form: xx (1 through 25)

Enter the number of live load cases, from one to twenty-five. There must always be at least one live load case.

8. SKEW ANGLE (c.c. 12-17) Form: xx deg.,xx min.,xx sec.

The skew angle of the pier should be entered in these columns in degrees, minutes and seconds. The angle is measured from a line that is perpendicular (or radial) to the bridge to the center line of the pier. There is no sign convention for the skew angle, i.e., all skew angles are entered as positive angles. This angle is used to resolve the lateral forces into components.

GENERAL DESIGN DATA

9. f'_c (c.c. 18-21) Form: xxxx. psi

Enter the 28-day concrete strength in these columns. The default is 3000.

10. fc (c.c. 22-25) Form: xxxx. psi

Enter the allowable concrete stress (Service Load) in these columns. The default is 0.40 f'_c psi.

11. N (c.c. 26-27) Form: xx.

Enter n, the modular ratio, in these columns. The default is Es/Ec.

12. fy (c.c. 28-32) Form: xxxxx. psi

Enter the steel yield stress in psi in these columns. The default is 40000.

13. fs (c.c. 33-37) Form: xxxxx. psi

Enter the allowable steel stress in psi in these columns. The default is 20000 and is used in Service Load design.

14. Ec (c.c. 38-41) Form: xxxx. ksi

Enter the modulus of elasticity of concrete in ksi in these columns. The default is $145^{1.5}(33)(f'_c)^{1/2}$.

15. Es (c.c. 42-46) Form: xxxxx. ksi

Enter the modulus of elasticity of steel in ksi in these columns. The default is 29000.

16. ϵ_c (c.c. 47-50) Form: .xxxx units/units

Enter the maximum usable strain at the extreme concrete compression fiber in inches per inch in these columns. The default is .0030.

CAP DESIGN DATA

The Cap Design Data may be skipped if no cap design is desired.

17. Z factor (c.c. 51-53) Form: xxx.

Enter the Z quantity, a parameter to determine maximum steel stress in flexural reinforcement, in these columns. See AASHTO Specifications 1.5.39. The default is 170. Z is not used in Service Load design.

18. BAR SIZE (c.c. 54, 55) Form: xx (bar size)

Enter the cap main reinforcement bar size using the standard bar designation. The default is a number 11 bar if left blank. Only one bar size is used.

19. STR. SIZE (c.c. 56, 57) Form: xx (bar size)

Enter the minimum cap stirrup size in these columns. The default is a number 5 bar.

20. MAX.T.B. (c.c. 58, 59) Form: xx (number of)

Enter the maximum number of top cap bars allowed per row (horizontal) in these columns. Such things as clearance and anchor bolt placement affect this value. The default is 6.

21. MAX.B.B. (c.c. 61 61) Form: xx (number of)

Enter the maximum number of bottom cap bars allowed per horizontal row in these columns. The default is 6.

22. MIN. SIZE (c.c. 62, 63) Form: xx (bar size)

Enter the bar size of the minimum cap main reinforcement in these columns. These bars are used as compression reinforcement and are used in the top and bottom of the cap. The default is a number 11 bar. See below.

23. MIN. BARS (c.c. 64, 65) Form: xx (number of)

Enter the minimum number of cap bars in these columns. These bars are used as compression reinforcement and are the same for the top and bottom of the cap. The default is two bars unless a minimum bar size is entered. In that case, zero bars are accepted to eliminate the minimum reinforcement.

24. TOP CL. (c.c. 66-68)   Form: x.xx inches

Enter the clearance of the cap top reinforcement in inches in these columns. Do not include the stirrup or any portion of the bar diameter. The default is 2.0 inches.

25. MIN. S. SP. (c.c. 69-71)   Form: x.xx inches

Enter the minimum acceptable stirrup spacing in inches in these columns. The default is 3.0 inches.

26. CAP D. INCR. (c.c. 72-74)   Form: x.xx inches

This is the amount by which the cap depth is incremented in a design problem. Enter this increment in these columns in inches. The default is 3.0 inches.

27. BOT. CL. (c.c. 75-77)   Form: x.xx inches

Enter the clearance of the cap bottom reinforcement in inches in these columns. Do not include the stirrup or any portion of the main reinforcement bar diameter. The default is the top clearance.

The second line of Design Data should contain the following:

The first two columns contain the line number Ø2.

COLUMN DESIGN DATA

The Column Design Data may be skipped if an investigation or design of the columns is not desired.

28. MIN. PS (c.c. 3-5)   Form: x.xx%

Enter the minimum acceptable column steel ratio (steel area to cross sectional area) in these columns. The default is 1.0%.

29. MAX. PS (c.c. 6-8)   Form: x.xx%

Enter the maximum acceptable steel ratio (steel area to cross sectional area) in these columns. The default is 8.0%.

30. MIN. SPAC. (c.c. 9-11)   Form: x.xx inches

Enter the minimum acceptable clear spacing of the column rebars. The default is 2.25 inches.

31. CLEAR. (c.c. 12-15)   Form: x.xxx inches

Enter the distance from the outside edge of the column to the edge of a main reinforcing bar (equal all around) in inches. The default is 4.0 inches. Note that this dimension includes the column tie diameter.

32. R (c.c. 16) Form: x (1, 2 or blank)

In the discussion of the R mode refer to the "Strength Design of Reinforced Concrete Column Sections, PCA." R will default to 1 for round or spiral columns and 2 for tied columns.

DESIGN:

For round (spiral by default) and spiral (rectangular) members, enter a one (1) to indicate that the reinforcement is to be equally spaced around a circle with radius determined from the member dimensions and cover. For tied (rectangular) members, one bar will be placed in each corner and the remaining bars will be distributed equally among the four faces (multiples of four used) if a R code of one (1) is used.

For tied (rectangular) members, an R code of two (2) allows for a different number of bars in the B and D faces. The selected pattern will always be symmetrical about both axes. For round or spiral members, an R code of two (2) is invalid.

INVESTIGATION:

An R code of one (1) indicates the input rebars will be distributed equally around the placement perimeter for round or spiral members, and equally placed in all faces for a tied column (multiples of 4).

An R code of two (2) should be used for tied columns when the number of bars differ in the column faces. Each face may have a different number of bars.

33. KL (c.c. 17-19) Form: x.xx

KL is the ratio of the effective length to actual length of the columns in the longitudinal direction. The most often used value for this coefficient is 2.0. Thus the default is two (2.00).

34. ØC (c.c. 20-22) Form: x.xx

Enter the compression capacity-reduction factor in these columns. The default value is 0.70 for tied columns and 0.75 for round and spiral columns for Load Factor design and 0.35 for Service Load design.

35. ØF (c.c. 23-25) Form: x.xx

Enter the flexure capacity-reduction factor in these columns. The default value is 0.90 for Load Factor design and 0.35 for Service Load design. This factor is used in the column design process when the moment to P-load ratios are high (near pure flexure). See AASHTO 1.5.30(B). This factor is set at 0.90 in the cap and footing design procedure (Load Factor).

36. Cm (c.c. 26-28) Form: x.xx

Cm is a coefficient used to compute the magnification factor. When members are considered unbraced against sidesway or with transverse loads between supports, Cm is set equal to 1.0 by the program. See AASHTO 1.5.34(B)(5). Otherwise, the program computes the value (no value input) or uses the input value. Cm equals 1.0 for one-column piers.

37. BD1 (c.c. 29-31) Form: x.xx

See AASHTO 1.2.22-LOADING COMBINATIONS, and Table 1.2.22. This data item is the same as BD and is the coefficient for dead load effects in the column design process. Usual values are 1.00 and .75. The default value is 1.0.

38. BD2 (c.c. 32-34) Form: x.xx

The program has the capacity for considering two BD factors. For example, 1.0 and 0.75. If a second value for BD should be considered, enter the value as BD2. There is no default, i.e., if left blank, a second BD factor is not considered. If only one value of BD is to be considered, it should be entered as BD1. The program does not compute the value to use from the magnitude of the loads. No transition value is considered. The engineer should bear in mind that the use of two BD factors (BD1 and BD2) doubles the computational requirements of the column design process.

FOOTING DESIGN DATA

The Footing Design Data may be skipped if an investigation or design of the footings is not desired.

39. IMPACT (c.c. 35-38) Form:xx.xx%

The live load impact factor in percent should be entered in this data field if the engineer desires the live load impact removed when designing the footings. See AASHTO 1.2.12. The live load impact will not be removed from the footing computations if this space is left blank or a value of zero is given. In any event, the live load impact is never removed by the program when considering column and cap effects.

40. SOIL WEIGHT (c.c. 39-41) Form: .xxx kips per cubic ft.

Use these columns to enter the unit weight of the soil imposed on the footings. The default is .110 kips per cubic foot.

41. ALL. S.P. (c.c. 42-46) Form: xx.xxx ksf

Enter the allowable soil pressure in ksf in these columns. There is no default. A value must be given for a spread footing design problem.

42. MIN. PL. SP. (c.c. 47-49) Form: x.xx feet

Enter the minimum pile spacing in feet in these columns. The default is 2.5 feet.

43. MAX. PL. SP. (c.c. 50-52) Form: x.xx feet

Enter the maximum pile spacing in feet in these columns. The default is 5.0 feet.

44. EDGE DIST. (c.c. 53-56) Form: x.xxx feet

Enter edge distance, centerline of pile to edge of footing, in feet in these columns. The default is 1.25 feet.

45. PILE DEPTH (c.c. 57-61) Form: xx.xxx feet

Enter the pile depth, embedment into footing, in feet in these columns. The default is 1.0 feet.

46. CLEAR. (c.c. 62-65) Form: x.xxx inches

Enter reinforcement bar clearnace from top of pile (pile footing) or bottom of footing (spread footing) to bottom layer of reinforcement in inches in these columns. One half of the bar diameter should not be included. The default is 3.0 inches.

47. PL. CAP (c.c. 66-71) Form: xxx.xxx kips

Enter pile capacity in kips in these card columns. There is no default and consequently a value must be given in a pile footing design problem.

48. PL. UPL. (c.c. 72-76) Form: xx.xxx kips

Enter pile uplift capacity in kips in these card columns. The default is zero (no uplift allowed). An uplift (tension) value is denoted by a negative magnitude.

49. IP (c.c. 77) Form: P or blank

If a P is entered in this column the output will contain various properties of the column and cap members. If left blank, the properties are not listed.

C. CANTILEVER AND CAP DATA (11-16 in c.c. 1, 2)

The input form provides six lines for defining the cantilever and cap portions of the pier. The left cantilever is entered on the first line (if present, otherwise the first cap portion is entered on the first line) and each cap portion (between columns) from left to right is entered on succeeding lines. A cap portion is defined as the portion of the pier cap between two adjacent columns, i.e., a three-column pier would have two cap portions. The cap portions are assumed to be symmetrical about a centerline between the two adjacent columns. Each cap/cantilever section may have as many as eight P-loads. However, the maximum number of P-loads on the entire pier is thirty-six. Since the computed cap data (moments, shears, etc.) are computed at each P-load, dummy P-loads can be used to obtain data where actual beams are not located. The input data lines for non-existent cap sections should be left blank. The cap is assumed to be rectangular in shape and level. At lease one P-load must be defined on each cap/cantilever portion defined.

The right cantilever is entered immediately after the last cap portion. The numbers in card columns 1 and 2 are for identification and sequence information. The cantilever and cap data are entered as follows:

1. I (c.c. 3) Form: x (L, P, C, or n) n = 1, 2, 3, or 4

Enter a code to define the variation in the depth of the cantilever/cap portion as follows:

a. A L is entered to define a lineal variation in the depth of the cap.

b. A P is entered to define a parabolic variation in the depth of the cap.

c. A C is entered to define a constant depth cap and no variation in moment of inertia.

d. If a cantilever/cap portion is identical to a previously defined cantilever/cap portion including dimensions and positions of P-loads, then the present cantilever/cap portion being input can be defined the "same as" the other identical cantilever/cap section by entering the number of the previous cantilever/cap section. In this case, the remaining data items on the input line need not be given. The program will use the referenced cantilever/cap portion's properties. The sole purpose of this code is to save input effort and processing time. It is important to note that the P-load positions must be symmetrical between the two cantilever/cap sections. That is, the P-load positions are reversed (flopped) and not translated. The cantilever/cap portion being referenced must already have been defined, i.e., cap portion 2 cannot be defined the "same as" cap portion 4, but cap portion 4 can be defined the "same as" cap portion 2.

2. L (c.c. 4-8) Form: xx.xxx feet

Enter the length of the cantilever/cap portion in this data field. The length is from the centerline of the adjacent column to the end of the cantilever or centerline of the other adjacent column. This dimension is the length of the structural member and cannot be zero. There is no default.

3. A (c.c. 9-13) Form:xx.xxx feet

The dimension A is the portion of the cap which is to be defined as having a region of infinite moment of inertia. As such, it is only associated with an I code of L or P. When defining a cantilever portion, A is the distance from the centerline of the adjacent column to the beginning of the "haunch" or variable depth/width portion, i.e., it is not used on constant depth/width cantilevers. There is no default.

If the A dimension is given as zero with I codes L or P for cap sections, the haunch must be projected to the centerline of the column. NOTE: A constant depth cap section can be defined as having a region of infinite moment of inertia (inside the column portions) by using the L (or P) I code and giving a "dummy" haunch (depth equal to zero but a real value for LH) and giving the appropriate A dimension.

4. DE (c.c. 14-18) Form: xx.xxx feet

The DE dimension is the depth of the cantilever at the end, or the normal or minimum depth of cap, but never including any portion of haunch. DE cannot be equal to zero. There is no default.

5. BC (c.c. 19-23) Form: xx.xxx feet

The BC dimension is the constant width of the cap portion, or in the case of a cantilever with a taper in the width, BC is the maximum width (width at the column). It cannot be zero. There is no default.

6. BE (c.c. 24-28) Form: xx.xxx feet

The BE dimension is used for a cantilever only. It is the width at the end. The program will not allow a value of zero. If it is ignored by the engineer, no taper in width is assumed, and BE is set equal to BC.

7. DH (c.c. 29-33) Form: xx.xxx feet

Enter the depth of the haunch in feet in these columns. For a cap section this distance is required only if the cap has a variable moment of inertia (variable depth). However, the value of DH may be equal to zero as in the case where a constant depth cap is to have regions of infinite moment of inertia at both ends. For a cantilever, enter the haunch depth if present. Otherwise, leave blank.

8. LH (c.c. 34-38) Form: xx.xxx feet

The dimension LH is the length of the variation of the cap depth in feet. Since the cap section is symmetrical, this distance is the length of the variation on one side of the cap section. The sum of the A and LH dimensions should never be greater than L/2 for cap sections. This dimension is required only if the cap section has a variable moment of inertia. For a cantilever section, enter the length of the haunch (width and/or depth variation) if present. Otherwise, leave blank.

9. XB_1 (c.c. 39-43) Form: xx.xxx feet

The XB_1 dimension is the distance from the centerline of the column on the left side of the cap section to the first P-load on the cap section in feet. This distance should not be left blank or given a value of zero. Note that any P-load on the centerline of the columns is handled by the column P code and is not located here. This distance is measured along the cap section.

When defining the left cantilever, this XB_1 dimension is the distance from the adjacent column centerline to the left-most P-load on the cantilever. This dimension for the right cantilever is the same as for cap sections. There is no default. The extreme cantilever load cannot be closer to the end of the cantilever than 1.0 foot (program constant).

10. XBn (c.c. 44-78) n=2-8 Form: xx.xxx feet

The XBn dimension is the distance to a P-load from the preceding (on left) P-load in feet. The summation of the XBn dimensions (including XB_1) should always be less than L except for the left cantilever. Enter only the XBn dimensions required to position all P-loads (including any dummy loads) on the cantilever/cap section (not including P-loads on the centerline of the columns).

All input data fields for non-existent P-loads should be left blank. If more than eight P-loads are on a cantilever/cap section, combine two or more of them as one P-load. Although this will not give exact results, the solution should be sufficiently accurate for design purposes since the P-loads would probably be relatively close together. The program can be expanded to handle more if required.

D. COLUMN DATA (21-25 in c.c. 1, 2)

The input data for each column are entered on one line of the Column Data. Five lines are provided on the form for defining up to five columns. For input purposes, the columns are considered numbered from left to right.

Column one (left most) data are entered on the first line (21 in c.c. 1, 2) and then the data for each remaining column are given on succeeding lines. Note that the digit in column two corresponds to the column number. Note also that the column can be viewed forward or backward so that either exterior column can be the left most. All Column Data input lines not used to define a column should be left blank. Each column is completely independent of any other column.

1. Po (c.c. 3) Form: x (Blank or 1)

If the column has a P-load (beam) on the center line, the digit one (1) should be entered in this column. Otherwise, this column should be left blank. A P-load designated on the center line will be ignored when computing moment and shear in the cap. However, the magnitude of the P-load is added to the column reaction. The position of such a P-load is not given when defining the Cantilever and Cap Data. The Po code (blank or 1) is required for all types of Column Codes (including "same").

2. Column Codes (c.c. 4, 5, 6)

The Column Codes are used to indicate the type of column being defined. There are three basic codes which must be defined for each column. Following is a discussion of each type.

a. I (c.c. 4) Form: (C, V or n) n = 1-4

Enter C to indicate that the moment of inertia is constant from the top of the footing to the center line of the cap. An otherwise constant section rectangular column with an infinite moment of inertia inside the cap portion should be defined as a variable column as noted next. A C is always entered for round columns, i.e., the moment of inertia is always assumed constant for round columns.

Enter V to indicate a rectangular column with a variable moment of inertia. The moment of inertia may vary in two ways. First, the column may be battered, i.e., cross section varies. Secondly, the portion of the column inside the cap section may be assigned an infinite moment of inertia.

Enter the number of a previously defined column, if the one under consideration is identical to it. Note that if the column axis is sloped (not vertical), the same code will reverse the slope of the previously defined column for use with the column being defined. No other input data are required with the same code except the Po code (c.c. 3). Note that the first column cannot be defined by such a number to indicate "same as". The purpose of this code is to save input time.

b. T (c.c. 5) Form: T, R or S

Enter T to indicate a rectangular cross section with a rectangular reinforcement pattern. Enter R to indicate a circular cross section with a circular reinforcement pattern. Enter S to indicate a rectangular cross section with a circular reinforcement pattern (spiral).

c. S (c.c. 6) Form: H, P, or blank

Enter H to define a steel H-pile and a P to define a prestress pile. A blank indicates a reinforced concrete column.

3. HT (c.c. 7-11) Form: xx.xxx feet

The dimension HT is the length of the column from the top of the footing to the center line of the cap measured along the center line of the column in feet. HT cannot be equal to zero. This dimension is the length of the structural member.

4. A (c.c. 12-16) Form: xx.xxx feet

The dimension A is the region of infinite moment of inertia and therefore would be required only when the column is defined as variable. This dimension is measured from the center line of the cap in feet along the center line of the column. A zero value for A indicates no region of infinite moment of inertia. Therefore, the dimension is not used if the column is round or constant (C in c.c. 4).

5. DT (c.c. 17-21) Form: xx.xxx feet

Enter in this data field the width of the top of a rectangular column parallel to the pier in feet. If the column has a varying width, this dimension is the width at the point where the column meets the bottom face of the cap or at the end of the DL dimension. However, if the column is round, the outside diameter of the column should be given in this data field. DT cannot be equal to zero.

6. BT (c.c. 22-26) Form:xx.xxx feet

The width of a rectangular column perpendicular to the pier should be given in this data field in feet. If the column has a varying width, this dimension is the width at the point where the column meets the bottom face of the cap or at the end of the dimension DL. However, if the column is round, the diameter of an inside void should be given in this data field. This dimension can be zero only if the column is round.

7. DB (c.c. 27-31) Form: xx.xxx feet

The dimension DB is the width of a variable (battered) rectangular column parallel to the pier and measured at the bottom of the column in feet. Note that if the width does not vary, but a region (A) of infinite moment of inertia is defined, this dimension will be the same as the DT dimension. For round and constant (rectangular) columns this input data field should be left blank, i.e., not required.

8. BB (c.c. 32-36) Form: xx.xxx feet

This dimension is the bottom width of a variable rectangular column measured perpendicular to the pier in feet. If the width does not vary but a region of infinite moment of inertia is defined, this dimension will be the same as the BT dimension. The BB dimension is not required if the column is round or constant (rectangular).

9. DL (c.c. 37-40) Form: x.xxx feet

The dimension DL is the distance from the center line of the cap to the bottom of the cap at the face of the column measured along the column in feet. This designates the point where the longitudinal moment is computed in the top of the column and the point where the dimension DT and BT are given.

10. FLEX (c.c. 41-44) Form: x.xxx

Enter in this data column the flexibility factor at the bottom of the column (transverse direction). A value of zero (0) defines the column as being fully fixed. A value of one (1.000) denotes a pinned end. Any value between zero and one would define a partial fixity. This factor is the same as the distribution factor in moment distribution.

11. REINFORCEMENT STEEL

The use of the divisions LOWER LIMIT and UPPER LIMIT occurs with the design option, to show limits intended by the engineer. For an investigation these titles are not symbolic and the necessary input data for an investigation can be entered as ACTUAL. For a further discussion of the LIMITs, refer to the referenced PCA Column Program manual. The use of the divisions TOP and BOTTOM allow the engineer to request that the program consider the reinforcement at the top of the column separately from the bottom. However, if the engineer leaves the BOTTOM portion blank, the reinforcement steel will be distributed in the bottom the same as in the top, i.e., the program uses the input of the top steel in the bottom.

a. ND (c.c. 45, 46, etc.) Form: xx bars

ND is the number (actual or limit) of reinforcing bars in the D face of a rectangular column EXCLUDING the corner bars. See NB if R Mode is equal to 1.

b. NB (c.c. 47, 48, etc.) Form: xx bars

Enter in this data column the number of reinforcing bars in the B face of a rectangular column INCLUDING the corner bars if R Mode equals 2. If R Mode is equal to 1, the bars are assumed to be equally spaced around the column section; and, the total number of bars can be given as ND or NB or divided between the two. NB cannot be less than two (2) if the column is rectangular (tied) and R Mode equals 2.

c. SIZE (c.c. 49, 50, etc.) Form: xx bar size

SIZE is the standard bar number designation.

PROCEDURE FOR DEFINING TOP BARS

		TOP - DESIGN						TOP - INVESTIGATION					
		LOWER LIMIT			UPPER LIMIT			ACTUAL			ACTUAL		
R MODE	T	ND	NB	SIZE	ND	NB	SIZE	ND	NB	SIZE	ND	NB	SIZE
1	R	*	*	L	*	*	U	+	+	A	+	+	NA
	S	*	*	L	*	*	U	+	+	A	+	+	NA
	T	*	*	L	*	*	U	+	+	A	+	+	NA
2	T	ND	NB	L	ND	NB	U	ND1	NB1	AB	ND2	NB2	AD

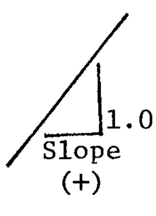
* - Bars are accumulated to give Lower and Upper Limits.
L - Lower Limit Bar Size.
U - Upper Limit Bar Size.
\+ - All number of bars are accumulated to give actual number.
A - Actual bar size.
NA - Not applicable (leave blank)
NB1 - Number of bars in B face 1 (left) including corner bars.
ND1 - Number of bars in D face 1 (near) excluding corner bars.
DB2 - Number of bars in B face 2 (right) including corner bars.
ND2 - Number of bars in D face 2 (far) excluding corner bars.
AB - Size of bars in B faces.
AD - Size of bars in D faces

USE LIKE PROCEDURE FOR BOTTOM BARS IF DIFFERENT FROM TOP.

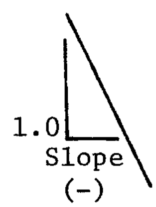
The maximum number of bars is 200 with a maximum of 100 per face for rectangular (tied) columns.

12. SLOPE (c.c. 69, 72) Form: x.xxx unit/unit

SLOPE is the slope of the center line of the column in the transverse direction from a vertical line. Following is the sign convention:



Slope is zero for a vertical column.



13. Ep (c.c. 73-76) Form: x.xx psi X 10^6

Enter the modulus of elastricity of the material of the pile column in units of pounds per square inch times 10^6.

14. Ap (c.c. 77, 80) Form: x.xx sq. inches

Enter the cross-sectional area of a pile column in square inches in these columns.

NOTE: Ep and Ap are not used by the program at present and should be ignored, as well as the S code H and P.

E. FOOTING DATA (31-35 in c.c. 1, 2)

The Footing Data are used to enter the information required to design or analyze (existing) spread or pile footings. Note that if Footing Data are to be entered on the input form, D or I should have been entered in column five of the first line of the Design Data. The Footing Data consist of up to five input data lines, i.e., one line for each footing. The footing for column one is entered on the first line and the remaining footings in succeeding order.

1. S/P (c.c. 3) Form: x (S, P, or n) n = 1-4

Enter S to define a spread footing, or P for a pile footing in this column. If the footing being defined is the same as some previously defined footing, enter the number of the previously defined footing in this column to save repeating the input. This also produces the same design for both (or more) footings with controlling loads shown from the appropriate footing.

2. B (c.c. 4-8) Form: xx.xxx feet

The dimension B is the width (perpendicular to the pier) of an actual footing or the minimum width of a footing that is to be designed. In a design problem it is suggested that a reasonable minimum width be used, for example, a value greater than the width of the column. Do not use a value of zero unless designing a pile footing.

3. D (c.c. 9-13) Form: xx.xxx feet

The dimension D is the width (parallel to the pier) of an actual footing or the minimum width of a footing that is to be designed. In a design problem it is suggested that a reasonable minimum width be used, for example, a value greater than the width of the column. Do not use a value of zero unless designing a pile footing.

4. T (c.c. 14-18) Form: xx.xxx feet

The dimension T is the depth in feet of an actual footing or the minimum depth of a footing to be designed. Do not use zero.

5. ΔB (c.c. 19-23) Form: xx.xxx feet

The ΔB dimension is the amount by which the B width of the footing is incremented in a design problem. If a footing is being analyzed, this dimension should be given as zero, i.e., the width will not be altered. Used only with spread footings.

6. ΔD (c.c. 24-28) Form: xx.xxx feet

The ΔD dimension is the amount by which the D width of the footing is incremented in a design problem. If an actual footing is being analyzed, this dimension should be given as zero, i.e., the width will not be altered. Use only with spread footings.

7. ΔT (c.c. 29-33) Form xx.xxx feet

The ΔT dimension is the amount by which the depth of the footing is incremented in a design problem. If a footing is being analyzed, this dimension should be given a value of zero, i.e., the depth will not be altered.

8. R B/D (c.c. 34-37) Form: x.xxx ratio

Enter in this data field the maximum allowable ratio of the B width to the D width. This ratio is used in the design process to keep the footing from becoming too narrow, i.e., strip footing. If a footing is being analyzed, assign this ratio a value of one (1.000). Do not use a value of zero or leave the field blank except with a pile footing.

In a design problem a value of one (1.000) can be used if the designer wishes the footing to be square. Otherwise, a value ranging from one (1.000) to two (2.000) is suggested. In any event, the sum of the R B/D ratio and the R D/B ratio should be equal to or greater than two (2.000).

9. R D/B (c.c. 38-41) Form: x.xxx ratio

Enter in this data field the maximum allowable ratio of the D width to the B width. This ratio is used in the design process to eliminate strip footings (very narrow). This ratio should be given a value of one (1.000) if a footing is being analyzed. In a design problem, a value of one (1.000) can be used if the designer wishes the footing to be square. Otherwise, a value ranging from one (1.000) to two (2.000) is suggested. Do not use a value of zero or leave the field blank except with a pile footing.

10. SOIL HT. (c.c. 42-46) Form: xx.xxx feet

The dimension SOIL HT is the height of the soil on top of the footing, i.e., overburden. This dimension may have a value of zero, or be left blank, i.e., soil not considered.

11. NP (c.c. 47-48) Form: xx piles (4-25)

Enter the number of piles in these card columns for an investigation problem or minimum number of piles for a design problem.

12. S (c.c. 49) Form: x (1 or blank)

Enter a 1 in this card column if the piles are to be expanded equally in both directions. Not used with a spread footing. Enter a 2 to rotate the pile arrangement 90 degrees.

13. Bp (c.c. 50-54) Form: xx.xxx feet

The engineer will notice that the Bp and Dp dimensions are pile spacing parameters adapted to help illustrate the positioning of the piles based upon the number required. To enter this information correctly, he should refer to the pile layouts shown on pages 2-29 to 2-33. Bp is measured parallel to the footing B face and is required with an investigation only, i.e., not used within a design.

14. Dp (c.c. 55-59) Form: xx.xxx feet

Dp is the pile spacing dimension previously noted measured parallel to the footing D face. Required only with an investigation.

15. SETTLE. (c.c. 60-64) Form: xx.xxx feet

This dimension is the amount the footing will (or has) settled in feet. This data will probably be used only in an analysis problem. All settlements are considered positive (down).

A. GROUP 2 WIND (41 in c.c. 1, 2)

The Group 2 Wind is defined on one line of the input form and will consist of the wind on the superstructure and substructure (pier). Input data must always be entered on this input data line, even if all the data are zero, i.e., enter zeros so the data line will be entered. In the following discussion of the Group 2 Wind, refer to Art. 1.2.14 of the AASHTO Specifications.

1. SUPERSTRUCTURE AREA (c.c. 3-14) Form: xxxxxx. sq. ft.

The Superstructure Area consists of two areas: a transverse area (TRANS., c.c. 3-8) on which the lateral wind intensity is applied, and a longitudinal area (LONG., c.c. 9-14) on which the longitudinal wind intensity is applied. Each area is independent of the other area. However, the two areas may have the same magnitude. These areas are also used to apply the Group 3 Wind.

Therefore, do not assign a zero value to these areas in order to eliminate the Group 2 Wind on the superstructure, i.e., Group 3 Wind on superstructure would also be eliminated. Group 2 Wind can be eliminated by giving the Wind on Superstructure Intensities values of zero.

2. STD.W (c.c. 15) Form: n (blank or 1)

Leave this column blank if individual wind intensity values are to be entered. To call for the five standard Group 2 Intensity values, enter a 1 in this card column, and then leave columns 16 through 35 blank. The standard wind intensities are given in AASHTO 1.2.14(B)(1).

3. WIND ON SUPERSTRUCTURE INTENSITY (c.c. 16-35) Form: xx lbs./sq. ft.

The program has provision for five directions (angles) of Group 2 Wind on the superstructure; and, each direction is assumed to have a lateral and longitudinal intensity. These lateral and longitudinal intensities are given in the AASHTO Specifications. As an alternative, the wind intensities may be left blank. Then, if a 1 was entered in column 15, the program will use the entire array of standard Group 2 Intensity values. However, blanks in the wind intensities accompanied by a blank in column 15 will eliminate the Group 2 Wind. The Wind intensities are given in pounds per square foot with no decimal positions allowed. The wind intensity should not be modified for allowable overstress. Enter only the intensities of the wind directions desired in the analysis/design process. Note that two intensities are required for each direction; however, either one may be zero.

a. FTn n = 1-5

FTn is the Group 2 Wind intensity in the lateral direction (transverse) of wind direction n. This pressure acts perpendicular to the bridge. Do not use negative values.

b. FL_n n = 1-5

FLn is the Group 2 Wind intensity of wind direction n in the longitudinal direction. This intensity acts parallel to the bridge. Do not use negative values.

4. WIND FORCE ARMS

The Wind Force Arms are used to locate the position where the Group 2 Wind on superstructure is applied to the pier, i.e., locates centroid of superstructure area. These Wind Force Arms are also used by the Group 3 Wind. Therefore, these arms (distances) should not be ignored when Group 2 Wind is omitted, that is, unless the Group 3 Wind is to be omitted also.

a. APT (c.c. 36-40) Form: xx.xxx feet

The APT dimension is the distance from the center line of the cap to the point where the wind on superstructure P_T component (parallel to pier) is applied to the pier. This distance should always be positive, i.e., on or above the cap center line. This dimension is used to increase/decrease the column reactions only. The APT dimension is vertical.

b. APL (c.c. 41-45) Form: xx.xxx feet

The APL dimension is the distance from the center line of the cap to the point where the wind on superstructure PL component (perpendicular to pier) is applied to the pier. This distance should be positive, i.e., on or above the center line of the cap. The APL dimension is vertical.

5. WIND ON PIER

The wind on the substructure is defined by giving a P_T and P_L force acting parallel to the pier (PT) and perpendicular to the pier (PL). These forces are given in kips and applied at the center line of the cap. These forces should always be given as positive.

The magnitude of the forces must be computed by the Engineer from the wind on substructure intensity and area of the pier. Then, the forces are modified for positioning at the center line of the cap. Note that only one direction of wind on the pier is allowed. The Wind On Pier is used with the Group 2 and Group 3 Wind. However, the effects of the Wind On Pier will be reduced by 70% when used with the Group 3 wind. Therefore, do not leave these forces blank when Group 2 wind is not used, nor modify the forces for allowable overstress or Group 3 reduction.

a. PT (c.c. 46-50) Form: xx.xxx kips

Enter in this data field the force due to the Group 2 wind on the pier in kips acting parallel to the pier.

b. PL (c.c. 51-55) Form: xx.xxx kips

Enter in this data field the force due to the Group 2 wind on the pier in kips acting perpendicular to the pier.

B. GROUP 3 WIND (42 in c.c. 1, 2)

The Group 3 Wind is defined on one line of the input form and will consist of the wind on the superstructure and wind on the live load. Note that the area of the superstructure, position of the wind on the superstructure, and wind on the substructure are defined with the Group 2 Wind. Input data must always be entered in this input data line even if all the data are zero, so that the input data line will be entered.

1. STD.W. (c.c. 3) Form: n (blank or 1)

Leave this column blank if the wind on superstructure intensity values are to be entered individually. Enter a 1 in this column to define (call for) the standard wind on superstructure intensities (then leave the wind intensities blank). See AASHTO 1.2.14(B)(1).

2. WIND ON SUPERSTRUCTURE INTENSITIES (c.c. 4-23) Form: xx lbs./sq. ft.

The program has provisions for five directions (angles) of Group 3 wind on the superstructure, and each direction is assumed to have a lateral and longitudinal intensity. These lateral and longitudinal intensities are given in the AASHTO Specifications (same as Group 2). THE FULL INTENSITY OF THE WIND SHOULD BE GIVEN, i.e., DO NOT REDUCE THE WIND BY SEVENTY (70) PERCENT. THE PROGRAM WILL REDUCE THE WIND EFFECTS. The wind intensities should be left blank (or zero) if Group 3 wind on the superstructure is to be ignored by the program. Give the wind intensities in pounds per square foot (no decimal positions allowed) and do not modify for allowable overstress. Only the intensities of the wind directions desired in the analysis/design should be given in the input data. Note that each direction of wind consists of two wind intensities.

a. FT_n n = 1-5

FT_n is the Group 3 wind intensity in the lateral direction (transverse) of wind direction n. This intensity of wind pressure acts perpendicular to the bridge. Do not use negative values.

b. FL_n n = 1-5

Enter in these data columns the Group 3 wind intensity in the longitudinal direction of wind direction n. This intensity of wind pressure acts parallel to the bridge. Do not use negative values.

3. STD.W (c.c. 24) Form: n (blank or 1)

Leave this column blank if the wind on live load intensity values are to be entered individually. Enter a 1 in this column to define (call for) the standard wind on live load intensities (then leave the wind on live load intensities blank). The standard wind intensities are given in AASHTO 1.2.14(B)(1).

4. WIND ON LIVE LOAD INTENSITY (c.c. 25-45) Form: xx or xxx lbs./ft.

The program has provision for five directions (angles) of Group 3 Wind on live load, and each direction is assumed to have a lateral and longitudinal intensity. These lateral and longitudinal intensities are given in the AASHTO Specifications. As an alternative, the wind intensities may be left blank. Then, if a 1 is entered in column 24, the program will assume the entire array of standard Group 3 Intensity values. However, blanks in the wind intensities accompanied by a blank in column 24 will effectively eliminate Group 3 Wind. The wind intensities are given in pounds per foot of live load with no decimal positions allowed. Enter only the intensities of the wind directions desired in the analysis/design with no modification for allowable overstress. Note that two intensities are required with each direction of wind. Although either one may be zero.

a. FT_n n = 1-5

Enter in these data columns the Group 3 Wind on live load intensity in the lateral direction of wind direction n. This wind intensity acts perpendicular to the bridge. Do not use negative values.

b. FL_n n = 1-5

Enter in these data columns Group 3 Wind on live load intensity in the longitudinal direction of wind direction n. This wind intensity acts parallel to the bridge. Do not use negative values.

5. LENGTHS OF LIVE LOAD (c.c. 46-55) Form: xxxx.x feet

The Lengths of Live Load consists of two lengths: a transverse length on which the lateral wind on live load is applied, and a longitudinal length on which the longitudinal wind on live load is applied. Each length is independent of the other; however, the lengths may have the same magnitude. The Lengths of Live Load should always be positive.

6. WIND ON L.L. ARMS

The Wind on Live Load Arms are used to locate the position where the Wind on Live Load is applied to the pier. These distances are vertical and should always be positive, however, they may be zero.

a. APT (c.c. 56-60) Form: xx.xxx feet

The APT dimension is the distance from the center line of the cap to the point where the Wind on Live Load P_T component (parallel to pier) is applied to the pier. This dimension is used only to increase/decrease the column reactions.

b. APL (c.c. 61-65) Form: xx.xxx feet

The APL dimension is the distance from the center line of the cap to the point where the Wind on Live Load P_L component (perpendicular to pier) is applied to the pier. This dimension is used to compute longitudinal moments in the top and bottom of the columns.

C. MISCELLANEOUS FORCES (43 in c.c. 1, 2)

The Miscellaneous Forces are defined on one line of the input form. Input data must always be entered in this input data line, even though all the data may be zero, so that the input data line will be entered.

1. CENTRIFUGAL FORCE (c.c. 3-8) Form: xxx.xxx kips

The Centrifugal Force is the transverse force due to a moving live load on a curved bridge (see Art. 1.2.21 AASHTO Specifications). If applicable, this force should be computed for ONE lane of live load and entered in the designated data column. A negative force should not be used. The program treats the Centrifugal Force as a non-reversible force acting from right to left.

2. TRACTION FORCE (c.c. 9-14) Form: xxx.xxx kips

The Traction Force is the longitudinal force (see Article 1.2.13 AASHTO Specifications) due to the acceleration or deceleration of the live load. This force (TRACTION) should be computed for ONE lane of live load and entered in this data column. The force is assumed to act parallel to the bridge and be fully reversible. Do not use a negative force. The Traction effects can be eliminated by using a value of zero (blank). The position at which the force is applied to the pier is discussed in the following paragraph.

3. T.F. & C.F. ARMS

The position at which the Traction Force and Centrifugal Force are applied to the pier is given in these two data columns. Negative values for the arms of these forces should not be used. Note that according to the AASHTO Specifications these forces are applied at the same point. A value of zero places the force at the center line of the pier cap.

a. APT (c.c. 15-19) Form: xx.xxx feet

The APT dimension is the vertical distance from the center line of the cap to the point where the PT (parallel to pier) components of the two forces are to be applied to the pier. This dimension is used only to compute an increase/decrease in the column reactions.

b. APL (c.c. 20-24) Form: xx.xxx feet

The APL dimension is the vertical distance from the center line of the cap to the point where the PL components (perpendicular to pier) of the two forces are applied to the pier. This dimension is used to compute moments in the top and botton of the columns.

4. EXPANSION COEFFICIENT (c.c. 25-32) Form: .xxxxxxxx units/unit

The Expansion Coefficient is the sum of the maximum temperature expansion coefficient minus any existing shrinkage in units per unit. Therefore, the thermal expansion coefficient (0.000006) must be multiplied by the variation (rise) from the mean temperature in degrees. The Expansion Coefficient is applied only to the pier cap since expansion of the columns would have little or no effect except in extreme cases, i.e., great variation in column lengths. The Expansion Coefficient should always be positive (or zero).

5. SHRINKAGE COEFFICIENT (c.c. 33-40) Form: .xxxxxxxx units/unit

The Shrinkage Coefficient is the sum of the maximum temperature contraction coefficient plus any existing shrinkage in units per unit. The thermal contraction coefficient must be multiplied by the variation (drop) from the mean temperature in degrees. The Shrinkage Coefficient is applied only to the pier cap, i.e., not applied to the columns. Always use a positive value (or zero) for the Shrinkage Coefficient.

6. STREAM FLOW

The program will handle the effects due to the force of Stream Flow - as a concentrated force applied at the center line of the cap. The designer must resolve the Stream Flow force into "equivalent" (as near as possible) forces (P_T and P_L) which are applied at the pier cap center line. The Stream Flow is assumed to be non-reversible and acts from right to left.

a. P_T (c.c. 41-45) Form: xx.xxx kips

Enter the transverse (parallel to pier) component of Stream Flow force in kips in these data columns.

b. P_L (c.c. 46-50) Form: xx.xxx kips

Enter the longitudinal (perpendicular to pier) component of Stream Flow force in kips in these data columns.

D. DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES

The input data form provides lines for entering the magnitude of the gravity P-loads (beams) for the dead load of the superstructure and each case of live load. If there are less than twelve P-loads, one line of P-load data is required per load case. However, if there are more than twelve P-loads on the pier, the additional P-load data lines required must always contain data even though the data are zero, i.e., so the data line will be entered. A maximum of three lines per load case is allowed. All P-loads are given in kips to the nearest pound. P-loads greater than one thousand kips can be entered by overriding the assumed decimal position. Note that the input data form provides space for thirty-six P-loads which is the maximum number of P-loads allowed on the pier. Fill in data for only the P-loads on the pier (including any dummy loads). Note that P_1 is always the leftmost P-load. Note that the input form is set up for one line per load case. If more than one line is required per load case, manually change the preprinted numbers.

1. DEAD LOAD SUPERSTRUCTURE (51, 52, 53 in c.c. 1 and 2)

The dead load reactions from the superstructure should always be listed first, i.e., before any live load case. The input data lines with a five (5) in column one must always be used to enter the dead load of the superstructure. The digit to be entered in data column two is the line number for the load case.

The input data I.D. and NL do not apply to the superstructure dead load.

a. P_n (c.c. 9-80, n = 1-36) Form: xxx.xxx kips

Enter in these data columns the dead load reactions from the superstructure.

2. LIVE LOAD CASES (61, 62, 63 in c.c. 1, 2)

The program has provision for twenty-five cases of live load orientation. At least one live load case must always be used. However, all the P-loads of that one case may be zero. The input form provides lines for twenty live load cases (twelve beams or less). Additional sheets of the Pier Loads input data form can be used to enter any remaining live load cases. However, the Group 2 Wind, Group 3 Wind and Miscellaneous Forces input data lines on the additional sheets must be crossed out so that those lines will not be entered. They have already been defined.

If there are less than twelve P-loads on the pier, the second/third line of each live load case is not required, and therefore, the second/third lines can be used to enter another live load case. However, if there are more than twelve P-loads, the digit two (2)/three (3) must be entered in card column two replacing the digit one (1). Note that the input data I.D. and NL must be given on the first line of the load case only.

a. I.D. (c.c. 3-6) Form: xxxx

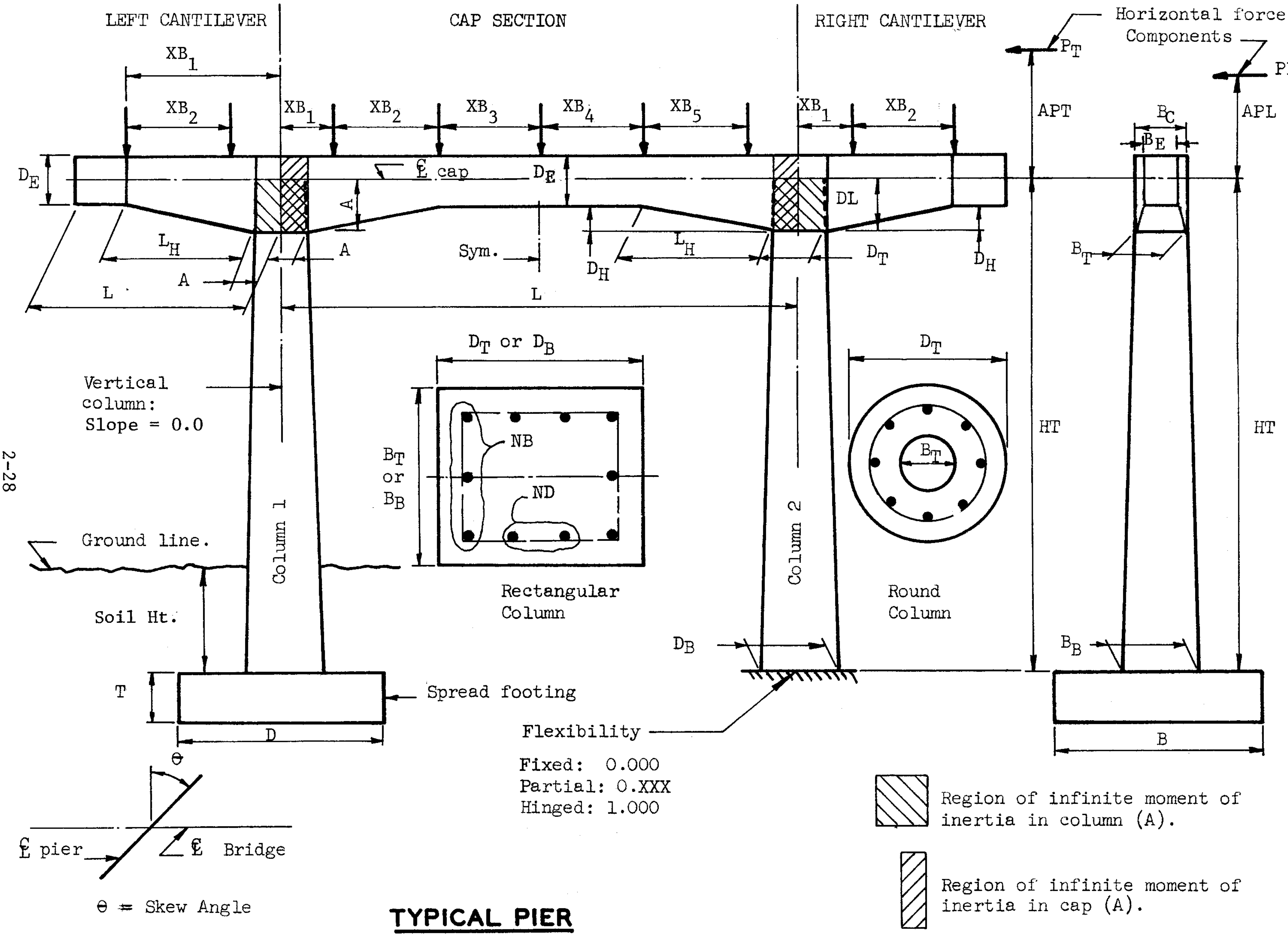
Enter on these data columns the identification number of the live load case. Numbers and letters may be used to identify a live load case. Each live load case will be identified by this I.D. in the output data.

b. NL (c.c. 7, 8) Form: xx lanes

Enter in this data column the number of lanes that was loaded to produce the live load case. This factor is extremely important since the live load effects will be reduced for multiple loaded lanes, and the Traction and Centrifugal Force effects will be modified for the actual number of loaded lanes. NL should not be left blank or given a value of zero except to define a Group IA load case. In this case the number of lanes is assumed to be one although NL is left blank or given a value of zero.

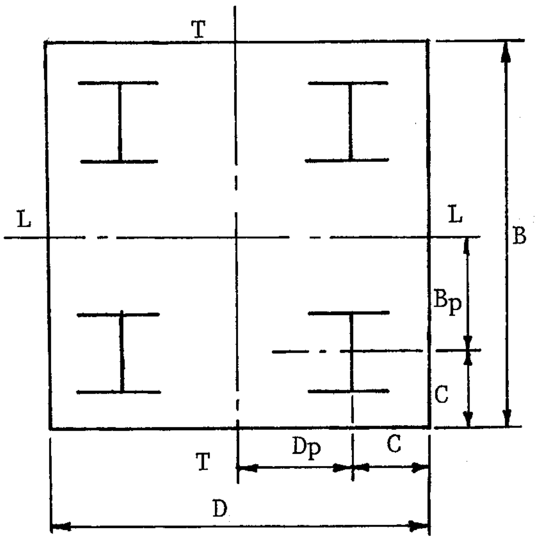
c. P_n (c.c. 9-80 n = 1-36) Form: xxx.xxx kips

The P-load reactions of the various live load orientations are entered in these data fields. These P-loads should contain impact and should not be reduced for multiple loaded lanes.

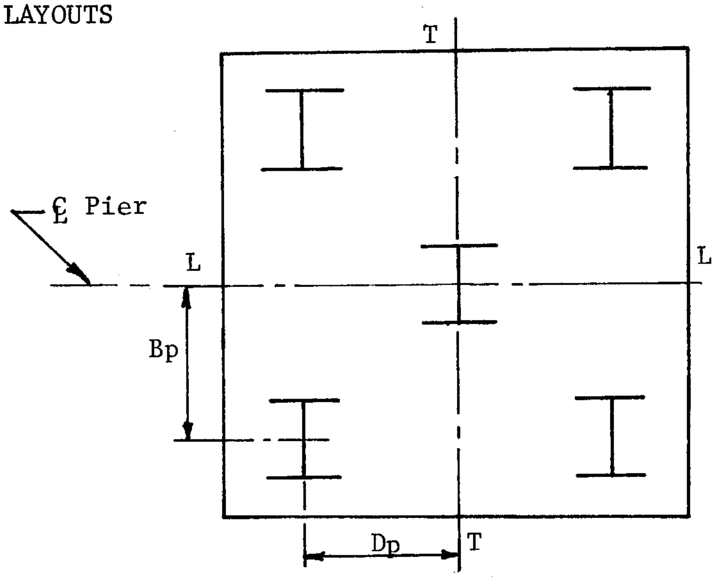


TYPICAL PIER

PILE LAYOUTS

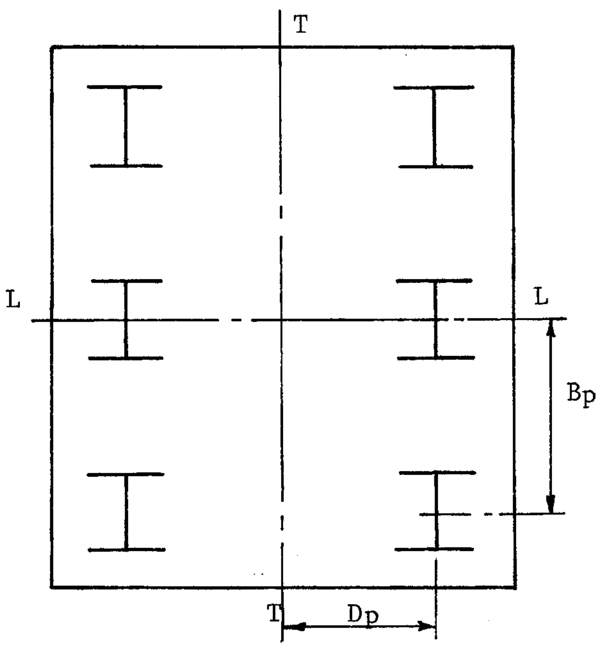


4 Piles

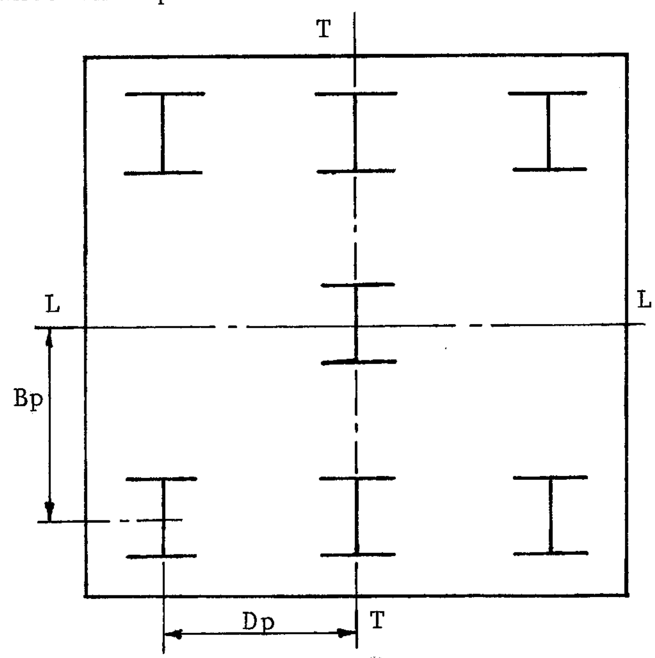


5 Piles

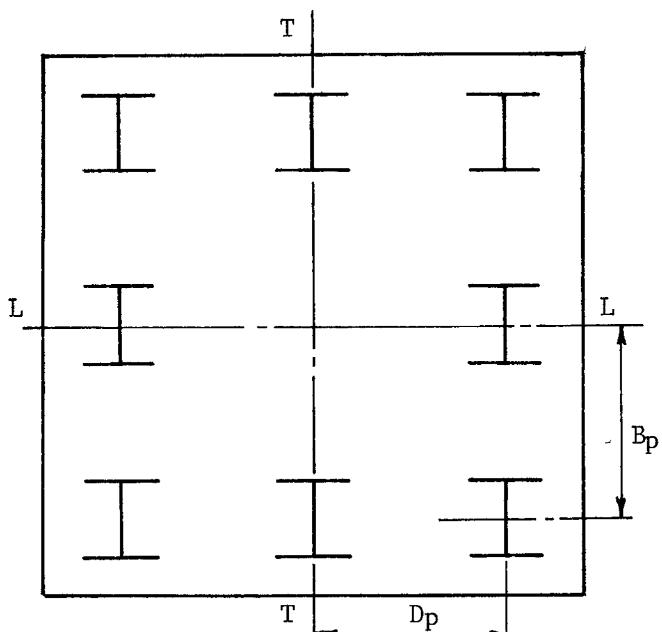
C = Edge Distance in input



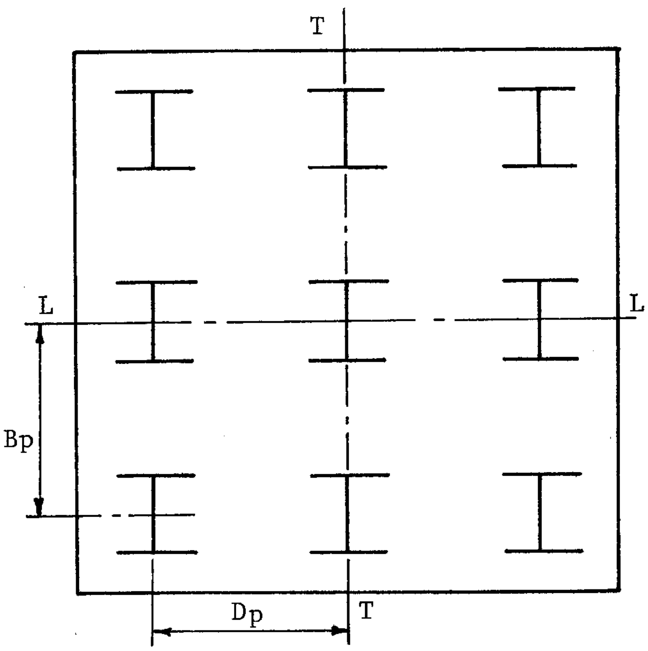
6 Piles



7 Piles

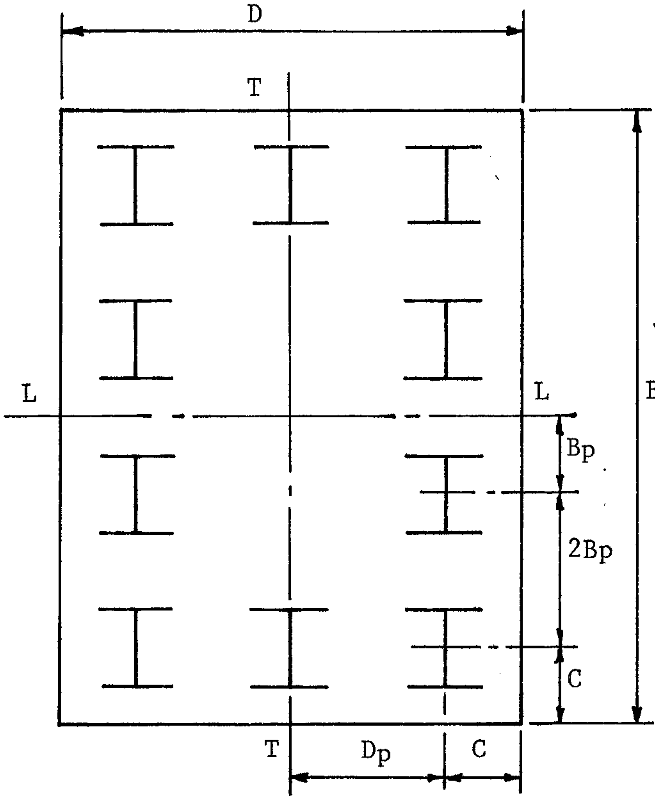


8 Piles

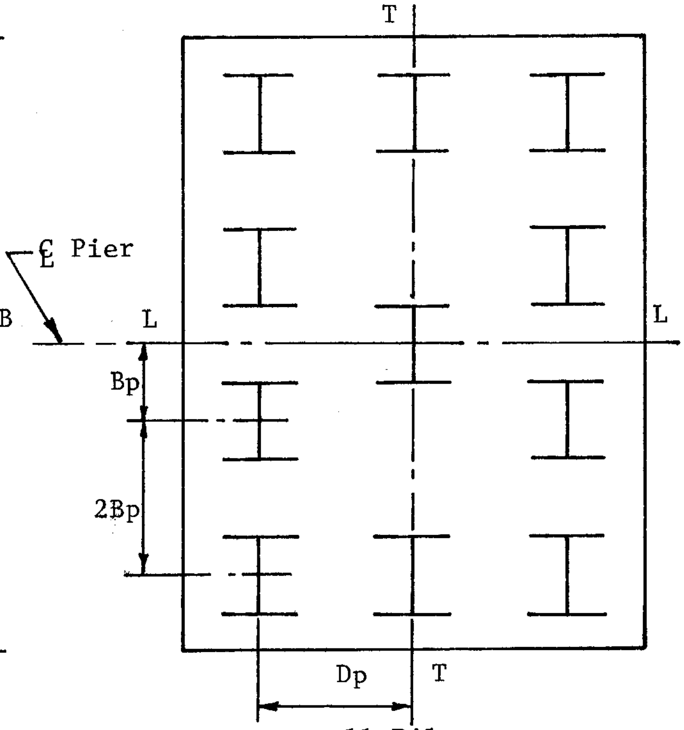


9 Piles

PILE LAYOUTS

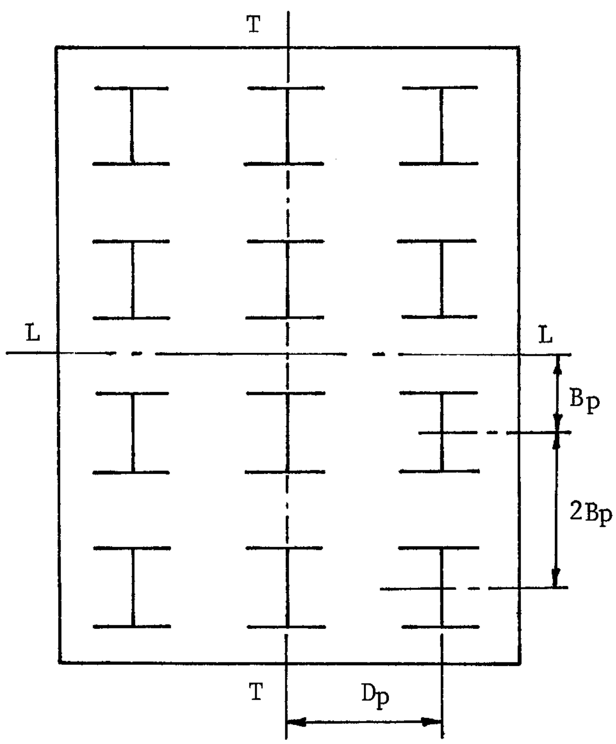


10 Piles

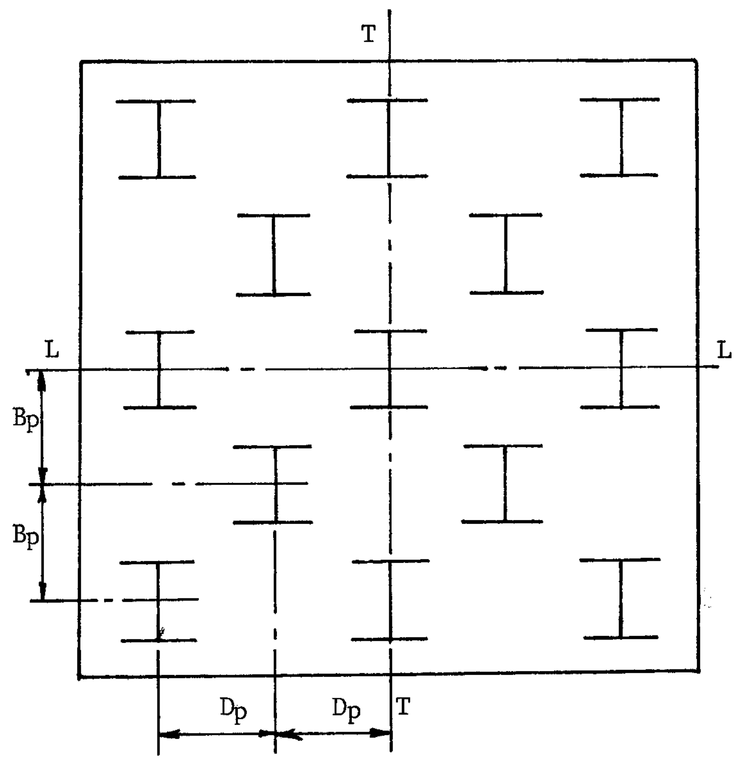


11 Piles

C = Edge Distance in input

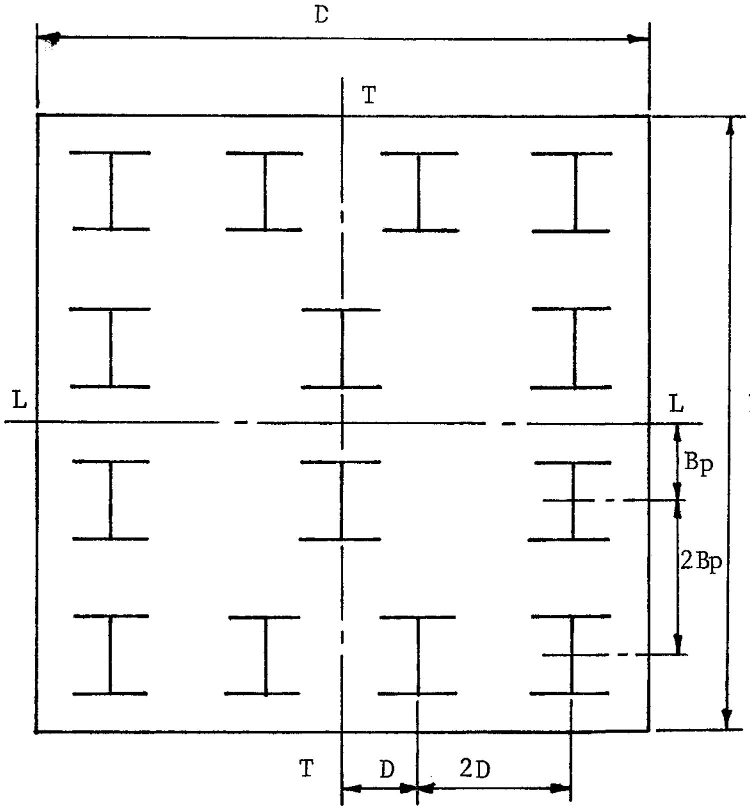


12 Piles

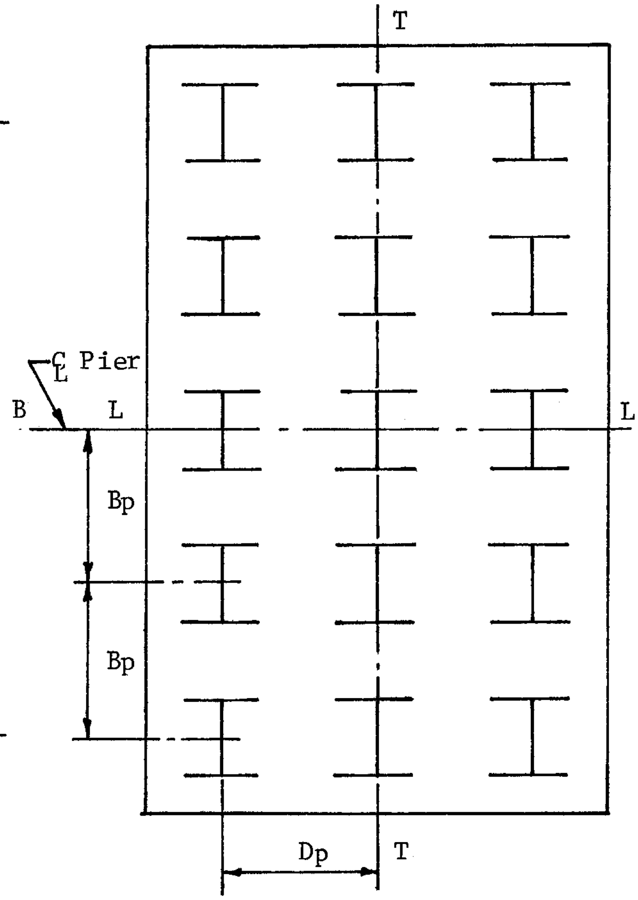


13 Piles

PILE LAYOUTS

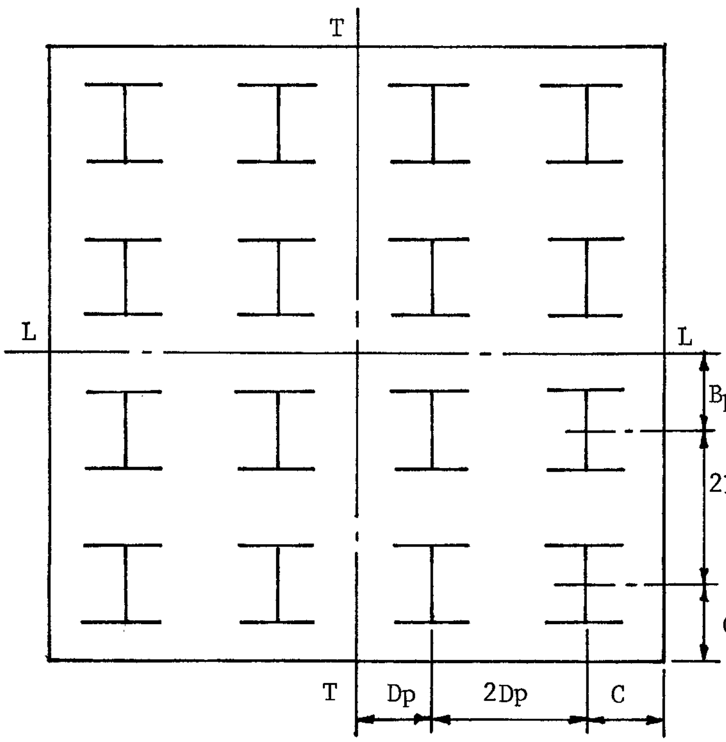


14 Piles

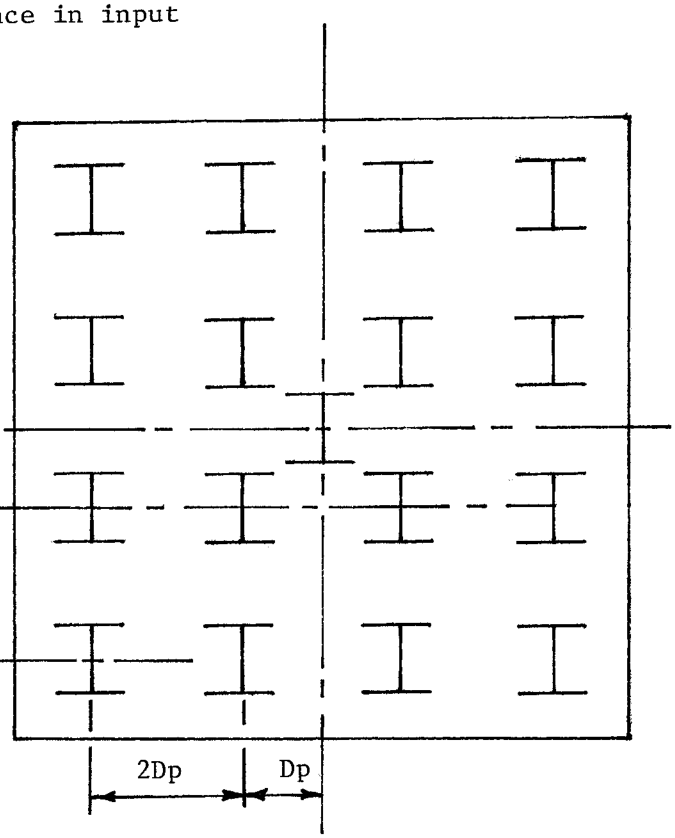


15 Piles

C = Edge Distance in input

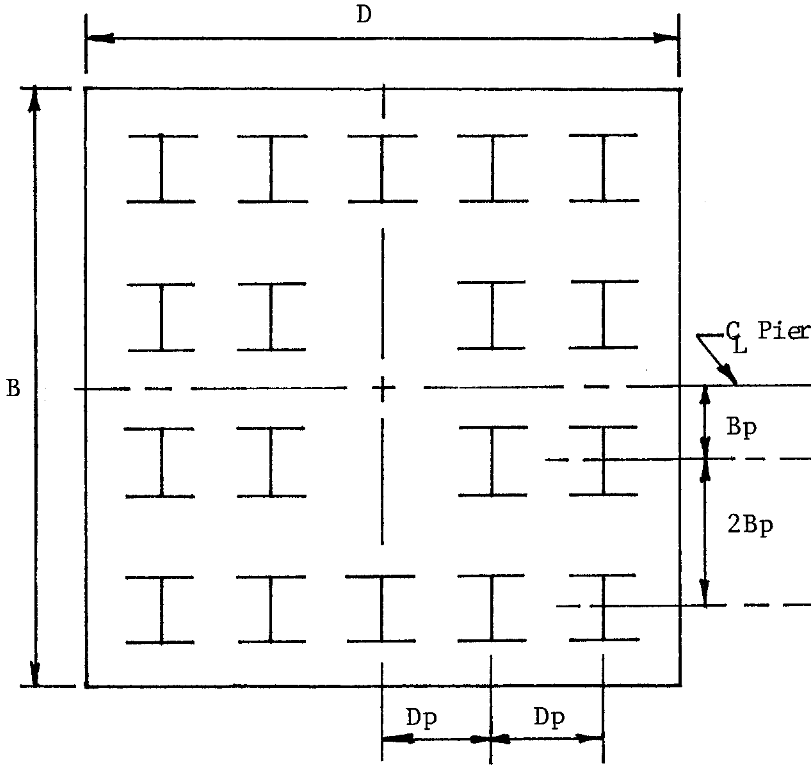


16 Piles

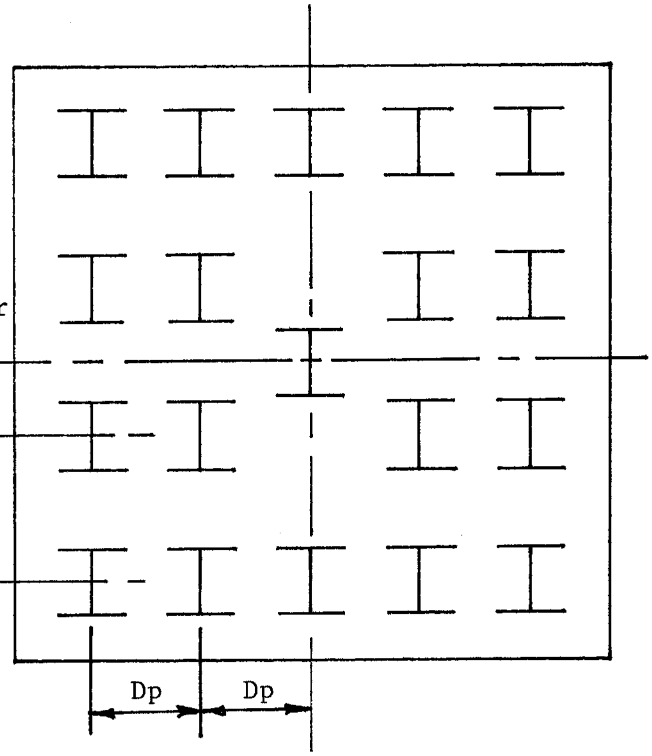


17 Piles

PILE LAYOUTS

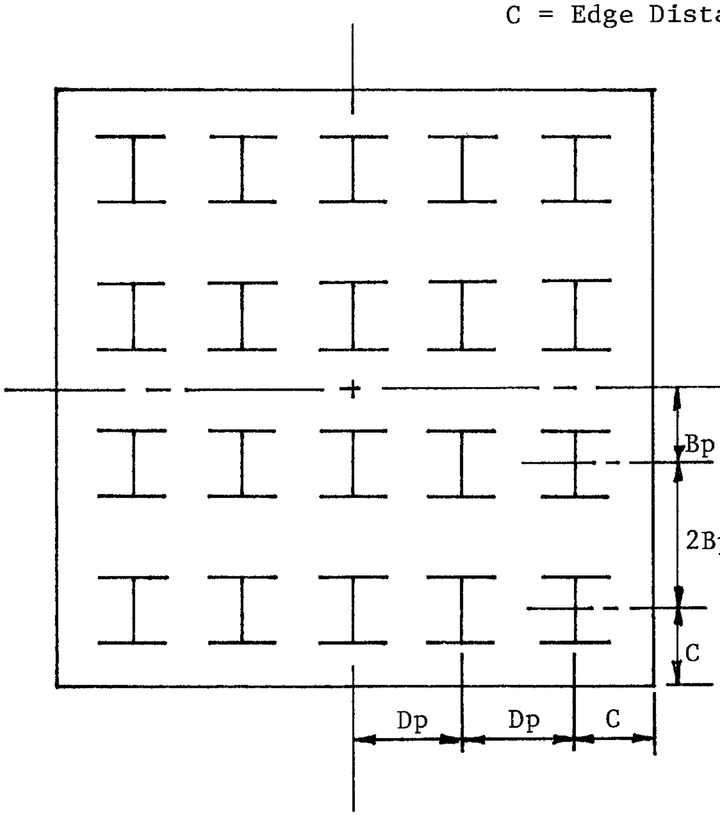


18 Piles

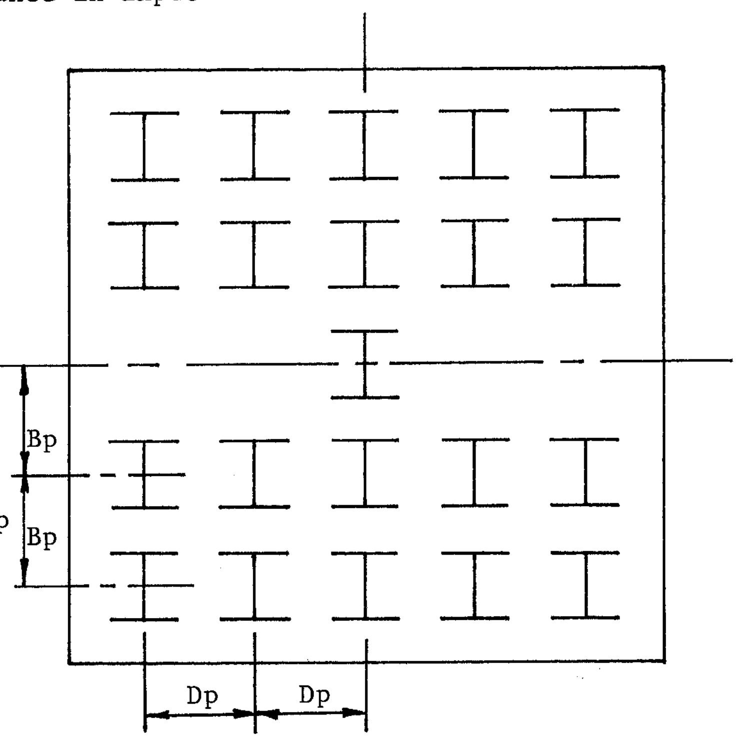


19 Piles

C = Edge Distance in input

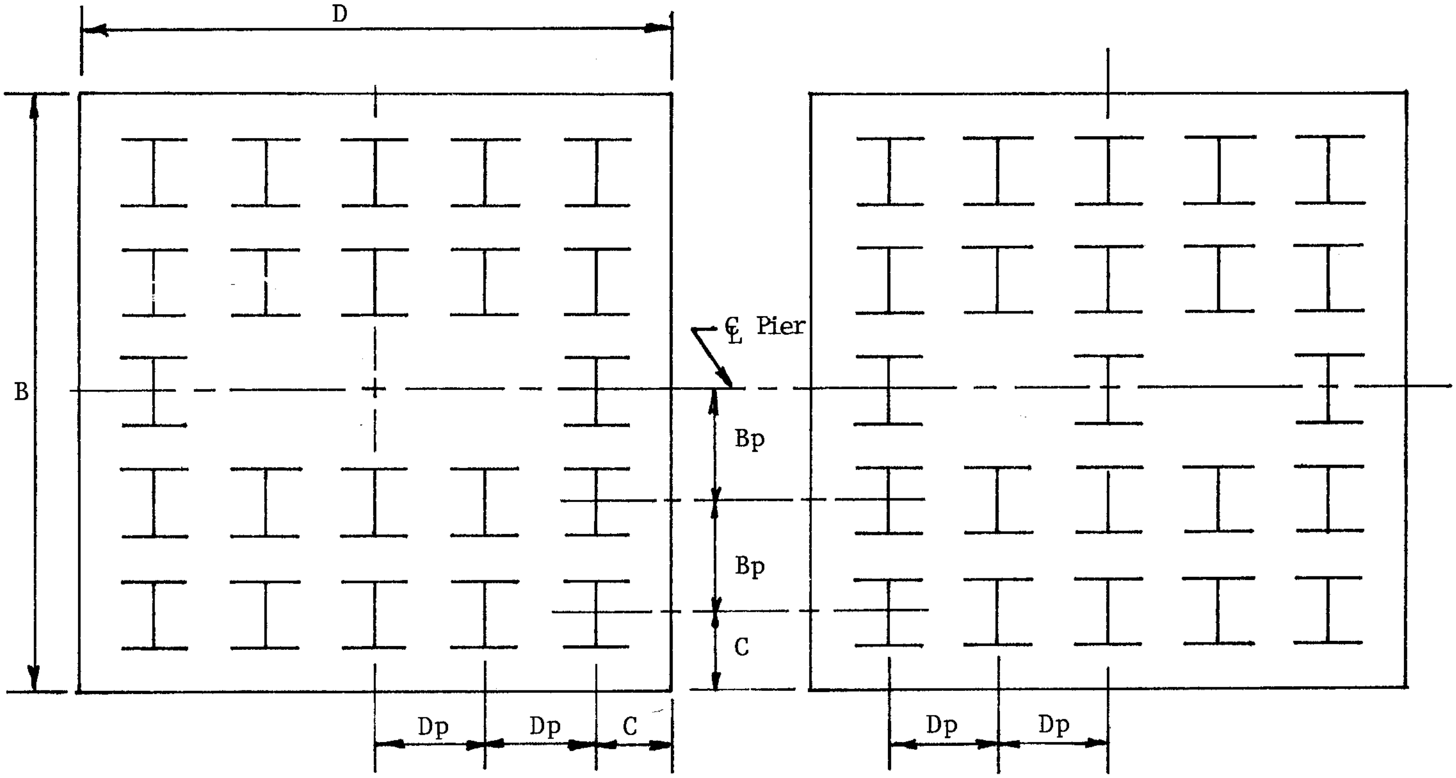


20 Piles



21 Piles

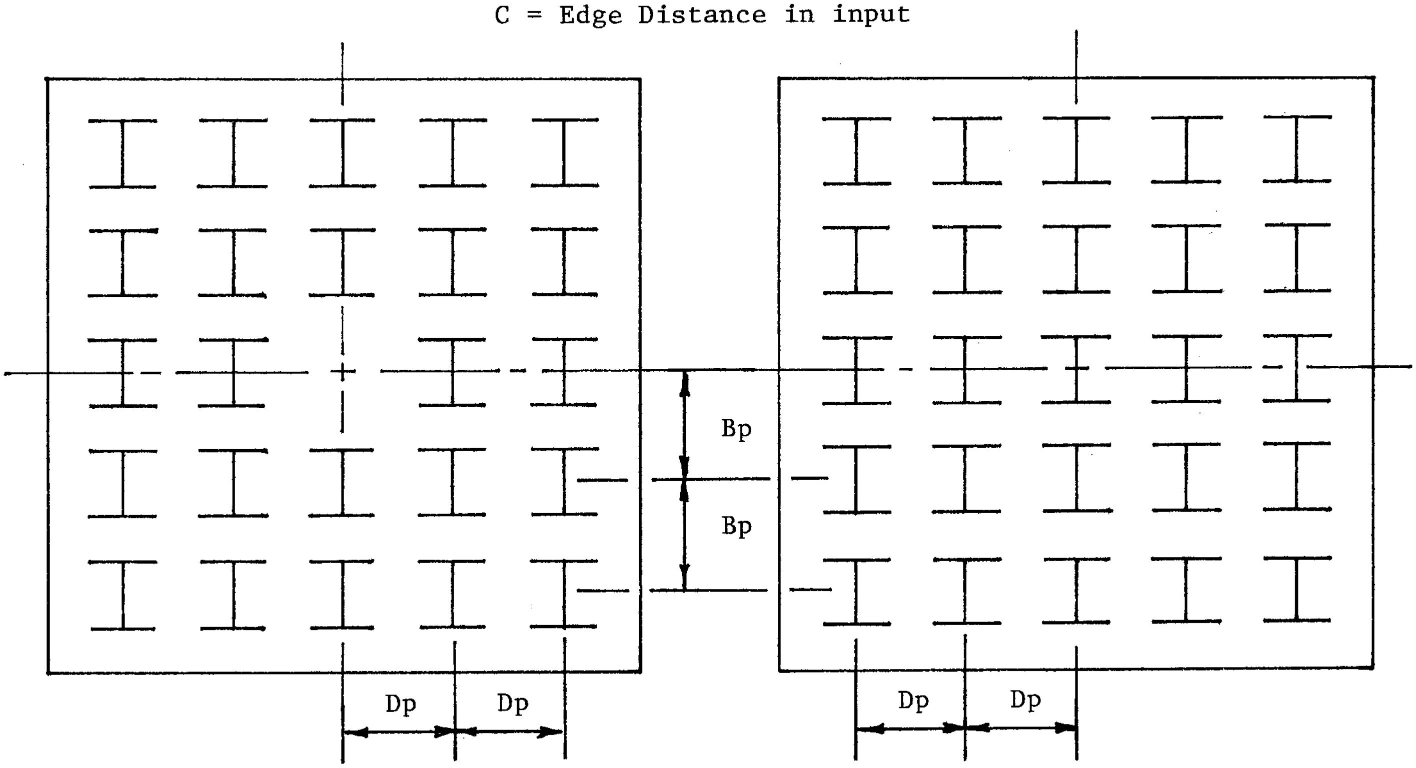
PILE LAYOUTS



22 Piles

23 Piles

C = Edge Distance in input



24 Piles

25 Piles

PIER DESCRIPTION

APR., 1981

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

IDENTIFICATION

1 PROG	PROB. NO.	9 REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC. 80
*803		

DESIGN DATA

1 CN	DES. OPT.					NO COL	NO LLC	SKEW ANGLE DEG	MIN	SEC	GENERAL DESIGN DATA 18 f'c	22 fc	N	28 fy	33 fs	38 Ec	42 Es	47 εc 50	51 Z	CAP DESIGN DATA BAR SIZE	STR SIZE	MAX T.B	MAX B.B	MIN SIZE	MIN BARS	TOP CL.	MIN S. SP	CAP D INCR.	BOT. CL. 77
01																													

1 CN	3 COLUMN DESIGN DATA MIN. Ps	MAX. Ps	MIN. SPAC.	CLEAR	R	KL	Φc	Φf	CM	β_{D1}	β_{D2} 34	35 FOOTING DESIGN DATA IMPACT %	SOIL WEIGHT	ALL. S. P.	MIN. PL. SP.	MAX. PL. SP.	EDGE DIST.	PILE DEPTH	CLEAR	PL. CAP$_k$	PL. UPL$_k$ 76	77 IP
02																						

CANTILEVER AND CAP DATA

1 CN	I	4 L	9 A	14 DE	19 BC	24 BE	29 DH	34 LH	39 XB1	44 XB2	49 XB3	54 XB4	59 XB5	64 XB6	69 XB7	74 XB8 78
11																
12																
13																
14																
15																
16																

ALL DIMENSIONS IN FEET FOR CANTILEVER/CAP, COLUMN, AND FOOTING DATA.

COLUMN DATA

												REINFORCEMENT STEEL														
												LOWER LIMIT / ACTUAL						UPPER LIMIT / ACTUAL								
											41	45 TOP			51 BOTTOM			57 TOP			63 BOTTOM			69		
1 CN	B	I	T	S	7 HT	12 A	17 DT	22 BT	27 DB	32 BB	37 DL	FLEX	ND	NB	SIZE	ND	NB	SIZE	ND	NB	SIZE	ND	NB	SIZE	SLOPE	73 EP	77 AP 80
21																										
22																										
23																										
24																										
25																										

FOOTING DATA

1 CN	S/P	4 B	9 D	14 T	19 ΔB	24 ΔD	29 ΔT	34 R B/D	38 R D/B	42 SOIL HT.	NP	S	50 BP	55 DP	60 SETTLE. 64
31															
32															
33															
34															
35															

DEFAULTS:

f'c - 3000 psi
fc - .4(f'c)
N - Es/Ec
fy - 40,000 psi
fs - 20,000 psi
Ec - $145^{1.5}33(f'c)^{\frac{1}{2}}$ ksi

Es - 29,000 ksi
εc - .0030 in./in.
Z - 170
BAR SIZE - 11
STR. SIZE - 5
MAX. TB - 6

MAX. BB - 6
MIN. SIZE - BAR SIZE
MIN. BARS - 2
TOP CL. - 2 in.
MIN. S. SP. - 3 in.
CAP D. INCR. - 3 in.

BOT. CL. - TOP CL.
MIN. Ps - 1%
MAX. Ps - 8%
MIN. SPAC. - 2.25 in.
CLEAR (COL.) - 4.0 in.
R - 1 ROUND/SPIRAL
2 TIED

KL - 2.0
Φc - .75 ROUND/SPIRAL
.7 TIED
Φf - .9 LOAD FACTOR
Φc, Φf - .35 S. L.
Cm - COMPUTED

BDI - 1.0
MIN. PL. SP. - 2.5 ft.
MAX. PL. SP. - 5.0 ft.
EDGE DIST. - 1.25 ft.
PILE DEPTH - 1.0 ft.
CLEAR (FTG.) - 3.0 in.

PIER LOADS
APR., 1981

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

FORCES — KIPS
INTENSITY - LBS./ FT.^{2}
AREAS - FT.^{2}
LENGTHS - FT.
TRACTION AND CENTRIFUGAL FORCE - 1 LANE
COEFFICIENTS - UNITS / UNITS

GROUP II WIND

1	SUPERSTRUCTURE AREA		STDW	WIND ON SUPERSTRUCTURE INTENSITY										WIND FORCE ARMS		WIND ON PIER	
CN	3 TRANS.	9 LONG.		FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	36 APT	41 APL	46 PT	51 PL 55
4 1																	

GROUP III WIND

1	STDW	WIND ON SUPERSTRUCTURE INTENSITY										STDW	WIND ON LIVE LOAD INTENSITY										LENGTH OF LIVE LOADS		WIND ON L.L. ARMS	
CN		FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5		FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	46 TRANS.	51 LONG.	56 APT	61 APL 65
4 2																										

STD. W. GR. II, III	FT - 50	44	41	33	17
SUPERSTRUCTURE	FL - 0	6	12	16	19
STD. W. GR. III	FT - 100	88	82	66	34
LIVE LOAD	FL - 0	12	24	32	38

MISCELLANEOUS FORCES

1	CENT. FORCE	TRACTION FORCE	C.F. & T.F. ARMS		EXPANSION	SHRINKAGE	STREAM FLOW	
CN	3 FT	9 FL	15 APT	20 APL	25 COEFFICIENT	33 COEFFICIENT	41 PT	46 PL 50
4 1 3								

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES (ONE LIVE LOAD CASE REQUIRED - MAXIMUM IS 25 CASES)

1 CN	I.D.	NL	9 P1,13,25	15 P2,14,26	21 P3,15,27	27 P4,16,28	33 P5,17,29	39 P6,18,30	45 P7,19,31	51 P8,20,32	57 P9,21,33	63 P10,22,34	69 P11,23,35	75 P12,24,36 80
5 1	D.L.	0 0												
6 1														
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GEORGIA DEPARTMENT OF TRANSPORTATION

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III. THE OUTPUT DATA

The first two or more sheets of the output data contain a listing of the input data. Sufficient headings are given with the listing so that the data are easily recognized. It is suggested that this listing be checked with the input data forms to guard against any data entry errors. In the discussion on the following pages, refer to an output listing of this program.

COMPUTED OUTPUT DATA

A. MEMBER PROPERTIES

If a P was coded in the Design Data (c.c. 77 of line 2), the output will contain the following member properties:

COLUMN PROPERTIES

Two lines containing properties will be given for each column.

1. CN

CN is the column number and is listed on the first line of the column properties.

2. KT/KTM (kip-feet)

KT (first line) is the stiffness of the column at the top in the transverse direction assuming the bottom of the column is fixed. KTM is KT modified for the actual fixity at the bottom.

3. COTB/COBT

COTB (first line) is the carry-over factor from top to bottom assuming the bottom of the column is fixed. COBT (second line) is the carry-over factor from bottom to top in like manner.

4. COTBM/COBTM

COTBM (first line) is the carry-over factor from top to bottom for the bottom of the column in its actual state of fixity. COBTM (second line) is the carry-over factor from bottom to top in like manner.

5. TLR/TRL

TLR is the translation factor for moment from the cap end on the left to the cap end on the right. TRL is the translation factor for moment from the cap end on the right to the cap end on the left.

6. TRC/TCR

TRC is the translation factor for moment from the cap end on the right to the top of column. TRC plus TRL equals one. TCR is the translation factor for moment from the top at column to the end of cap on the right.

7. TLC/TCL

TLC is the translation factor for moment from the cap end on the left to the top of the column. TLC plus TLR equals one. TCL is the translation factor for moment from the top of column to the cap end on the left. TCL plus TCR equals one.

8. DFC/DFL

DFC is the moment distribution factor at the top of the column. DFL is the moment distribution factor for the cap end on the left. DFR is not given, but is always equal to one minus DFC minus DFL.

9. KL (sq. inches)/PDF

KL is the relative stiffness of the column in the longitudinal direction. To compute the force (applied to top of column) to produce one inch of deflection at the top of the column, multiply by Ec. KL is used to distribute the longitudinal forces applied to the pier to the various columns. PDF is the distribution factor for longitudinal forces to the column.

10. FKBR/FKUBR

FKBR is the ratio k(l/r) which is used to determine if slenderness must be considered. It is computed assuming the column is braced and is for the transverse direction. FKUBR is computed in like manner assuming the column is unbraced. The effective length factors (k) are computed according to the graph on page 9-6 of PCA's Load Factor Design.

11. PCBR/PCUBR (kips)

PCBR is Pc from formula (6-16) of the AASHTO Specifications for the transverse direction assuming the column is braced. PCUBR is computed in like manner assuming the column is unbraced. Bd is not present in the computations.

12. PCL (kips)/FLU (feet)

PCL is Pc from formula (6-16) of the AASHTO Specifications for the longitudinal direction using the input or default value for k. FLU is unsupported (clear) length of the column in the transverse direction.

13. UFMT/UFMB (kip-in./in.)

UFMT is the fixed-end moment at the top of the column due to a translation of one inch in the transverse direction assuming the ends are fixed. UFMB is the fixed-end moment at the bottom in like manner.

14. EITTB/EILTB (kip-sq. in. 10^3)

EITTB is EI from formula (6-17) of the AASHTO Specifications in the transverse direction. The factor Bd is not included and the value shown is the average for the top and bottom sections. EILTB is for the longitudinal direction in like manner.

15. PSIT/PSIB

PSIT is the ratio $\dfrac{Ec(Ig+Is)/HT \quad (\text{column})}{\Sigma\, Ec(Ig/2)/L \quad (\text{caps})}$ which

is used to compute the effective length factor k from the graph on page 9-6 of PCA's Load Factor Design. It is for the transverse direction at the top of the column. PSIB is for the bottom of the column and is computed from the Flexibility factor.

16. RGTB/RGL (inches)

RGTB is the average radius of gyration in the transverse direction of the top and bottom of the column. RGL is the average radius of gyration in the longitudinal direction of the top and bottom of the column.

CAP PROPERTIES

Two lines of output will be given for each cap section. Properties for the cantilever portions are not given.

1. CN

CN is the cap section number. It will always begin as two. Cap properties are not given with a one-column pier.

2. CO/K (kip-feet)

CO (first line) is the carry-over factor assuming the far end of the cap section is fixed. K (second line) is the stiffness of the cap section assuming the far end of the cap section is fixed.

3. KML/KMR (kip-feet)

KML is the stiffness of the cap section on the left end assuming the far (right) end is in its actual state of fixity. KMR is the stiffness of the cap section on the right end with the far (left) end in its actual state of fixity.

4. COMLR/COMRL

COMLR is the carry-over factor from the left end to right end of the cap section with the ends of the cap section in their actual state of fixity. COMRL is the carry-over factor from the right end to the left end of the cap section with the ends of the cap section in their actual state of fixity.

5. FMWT/UFEM (kip-feet)

FMWT is the fixed-end moment due to the weight of the cap section. UFEM is the fixed-end moment due to a unit translation of the cap (vertical). This moment is used in the analysis of footing settlement and sloped columns.

6. FMLPn/FMRPn (kip-feet) n = 1-8

FMLPn is the fixed-end moment at the left end of the cap section due to a unit load (1 kip) placed at the nth beam position on the cap. FMRPn is the fixed-end moment of the right end of the cap section due to a unit load placed at the nth beam position on the cap.

B. COLUMN LOAD EFFECTS (MOMENTS, SHEARS, REACTIONS).

The Column Load Effects contain the following data for each column due to the loads which are applied to the pier:

Moment in top and bottom of column in transverse and longitudinal direction.

Shear (horizontal) in column in transverse and longitudinal direction.

Reaction (along column axis) in top and bottom (dead load only) of column.

Reaction (vertical) at bottom of column.

Moment at top of footing in longitudinal direction.

Moments at the end of the cap section to the left and right of the column.

Note that the data in the transverse direction are given on the left side of the output form and the data in the longitudinal direction are given on the right side of the output form. The output contains headings to show the type and location of the data. The headings also show the units of the output data.

The sign convention for the various data is as follows:

A positive moment acts clockwise on the end of the member.

A negative moment acts counter-clockwise on the end of the member.

The sign of the moments determines the sign of the shear.

A positive reaction causes compression in the column.

A negative reaction causes tension in the column.

Note that the dead load, each live load case, expansion and shrinkage of the cap, and footing settlement will have no effects in the longitudinal direction. All the data (for a particular load) for each column are given on one line of the output listing except in the case of the dead load which shows the reaction at the bottom of the column immediately below the reaction in the top of the column.

1. LOAD

The Column Load Effects will be given for the following loads:

a. Unit Force at Center Line of Cap.

This data will contain the effects due to a force of one kip (placed at the center line of the cap) acting in the transverse (parallel to pier) and longitudinal (perpendicular to pier) direction.

b. Footing Settlement (optional).

c. Expansion of Cap (optional).

d. Shrinkage of Cap (optional).

e. Dead Load Total

The dead load total contains the sum of the effects of the dead load of the superstructure and the substructure (pier).

f. Wind on Substructure (optional).

g. Group 2 Wind I J (optional).

The Column Load Effects will contain the effects of two wind combinations for each direction of Group 2 wind given in the input data. The integer "I" indicates the wind direction (1-5). The integer "J" denotes how the lateral and longitudinal wind components are combined (wind combination or case). Wind case one (J=1) is formed by adding the PT components of the wind forces and taking the difference (subtracting) in the PL components. Wind case two (J=2) is formed by summing the PL components and taking the difference in the PT components. The wind on the pier is included in the Group 2 wind effects. The PT force of the wind on the pier is always placed in the direction of the PT component of the lateral wind on superstructure; and, the PL component of the wind on the pier is always in the direction of the PL component of the longitudinal wind on the superstructure. The integers "J" and "I" will identify the wind in the Column Analysis/Design Data and the Footing Design Loads. The effects of the Group 2 wind have not been modified for any overstress considerations.

h. Stream Flow (optional).

i. Traction for One Lane of Live Load (optional).

j. Centrifugal Force for One Lane of Live Load (optional).

k. Group 3 Wind I J (optional).

The Group 3 wind is combined in the same manner as Group 2 wind to produce two wind cases (J) for each direction of wind (I).

The Group 3 wind effects contain the wind on superstructure, wind on live load and wind on the pier. Note that the wind on structure has been reduced seventy (70) per cent in compliance with the AASHTO Specifications. No further modification is made for group allowable overstress. The integers "J" and "I" will identify the wind in the Column Analysis/Design Data and the Footing Design Loads.

1. Live Load xxxx.

The effects of each live load case will be given in the column data. These data are reduced for multiple loaded lanes. Impact is included if included in the input of P-loads.

2. COL (Column Number).

The number of the pier column (1, 2, 3, 4, 5) will appear in this output data column.

TRANSVERSE DIRECTION

3. PC

The reaction at the top of the column acting along the axis of the column is given in this column. These type of data are used in the column analysis/design at the top of the column. Note the dead load reaction at the bottom of the column will appear in this column.

4. MT.

"MT" heads the output data column containing the moment in the top of the columns. This moment is computed at the end of the column member, i.e., center line of the cap. These type of data are used in the column analysis/design at the top of the columns even though the column cross section used is at the bottom face of the cap.

5. V.

The horizontal shear in the column is given in this data column. "V" is used in the footing design/analysis.

6. MB.

The moment in the bottom of the column is given in the "MB" column of output. These data are used in the column analysis/design at the bottom of the column and in the footing computations.

7. RF.

"RF" is the vertical reaction in the bottom of the columns. This reaction is used in the footing design/analysis. The value of "RF" will be equal to "PC" if the column is vertical.

8. ML.

The data given in this column are the cap moment to the left of the column.

9. MR.

The data given in this column are the cap moment to the right of the column.

10. MT.

The data given in this output column are the moment in the top of the column about a plane which is perpendicular to the axis of the column. The moment is computed at the bottom face of the cap. This type of data is used in the column analysis/design at the top of the column.

11. V.

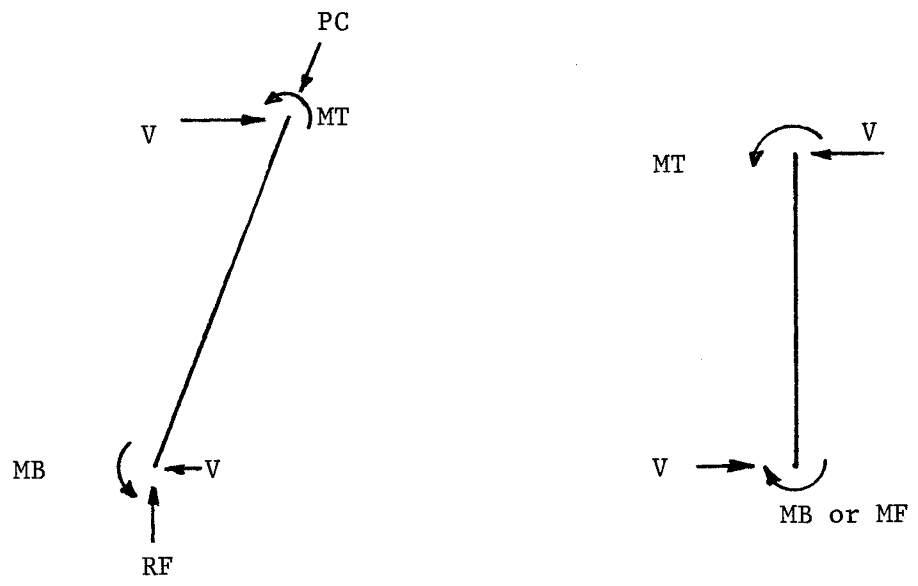
The shear in the column is given in this output data column. This type of data is used in the footing computations.

12. MB.

The data given in this output data column are the moment in the bottom of the column about a plane which is perpendicular to the axis of the column. These data are used in the column analysis/design at the bottom of the column.

13. MF.

The data given in this column of output data are the moment at the bottom of the column about a horizontal plane. "MF" will be equal to "MB" if the column is vertical. These data are used in the footing design/analysis.



Transverse

Longitudinal

C. CAP ANALYSIS AND DESIGN DATA

CAP MOMENTS AND SHEARS

The Cap Moments and Shears consist of moments and shears at each P-load on the cap sections and on the left and right of each column center line. All the data for a particular point are given on one line of the output listing. Note that the headings contain the units of the data. Load factors have been applied to all moments and shears if the Load Factor option is specified. The sign convention is as follows:

A positive moment causes tension in the bottom of the cap.

A negative moment causes tension in the top of the cap.

Positive shear

Negative shear

1. POINT.

The data in this output column identifies the point where the moment and shears are computed, i.e., "C nR" indicates the right side of column "n", and "Pn" identifies the position of P-load "n".

MOMENTS.

2. Dead Load Total (D.L. TOT.).

The data in this column of output are the moments due to the dead load of the superstructure and substructure.

3. Group 1 Maximum Positive Moment (G1 MAX. +).

This column of the output data contains the maximum positive moments from the combination of dead load, live load (with impact), stream flow, and centrifugal force. The amount of centrifugal force used depends on the number of lanes of the controlling live load case. No centrifugal force (non-moving live load) is also considered. The live load and centrifugal force moments are reduced for multiple loaded lanes. The maximum positive moment is never less (algebraically) than the dead load moment, i.e., no live load, centrifugal force, or stream flow.

4. Group 1 Maximum Negative Moment (G1 MAX. -).

This column of the output data contains the maximum negative moments from the combination of dead load, live load (with impact), stream flow, and centrifugal force. The amount of centrifugal force used depends on the number of lanes of the controlling live load case. No centrifugal force (non-moving live load) is also considered. The live load and centrifugal force moments are reduced for multiple loaded lanes. The maximum negative moment is never more (algebraically) than the dead load moment.

5. Group 2 Maximum Positive Moment (G2 MAX. +).

This column of data contains the maximum positive moment from the combination of the total dead load, stream flow, and Group 2 wind on the structure (wind on substructure included). These moments have not been reduced to account for the overstress provisions of the AASHTO Specifications.

6. Group 2 Maximum Negative Moment (G2 MAX. -).

This column of data contains the maximum negative moment from the combination of the total dead load, stream flow, and Group 2 wind on the structure. These moments have not been reduced to account for the overstress provisions fo the AASHTO Specifications.

7. Group 3 Maximum Positive Moment (GR. 3 +).

The data in this column of the output contains the maximum positive moments from the combination of Group 1 loads, Group 3 wind, and traction. These moments have not been reduced for the overstress provision of the AASHTO Specifications. The live load case which governed the Group 1 maximum positive moment will not necessarily govern Group 3 maximum positive moment since the traction force is modified according to the number of lanes of the live load case, i.e., in the same manner as the centrifugal force.

8. Group 3 Maximum Negative Moment (GR. 3 -).

The data in this column of the output contains the maximum negative moments from the combination of Group 1 loads, Group 3 wind, and traction. These moments have not been reduced for the overstress provision of the AASHTO Specifications. The live load case which governed the Group 1 maximum negative moment will not necessarily govern Group 3 maximum negative moment since the traction force is modified according to the number of lanes of the live load case, i.e., in the same manner as the centrifugal force.

9. Dead Load Shear on Left (DL T.LT).

The data in this column of the output are the shears due to the dead load of the superstructure and substructure on the left of the column or P-load. Note that the "C nR" point has no meaning and a blank space is always shown.

10. Dead Load Shear on Right (DL T.RT).

The data in this column of the output are the shear due to the dead load of the superstructure and substructure on the right of the column or P-load. Note that the "C nL" point has no meaning and a blank space is always shown.

11. Group 1 Maximum Positive Shear on Left (G1 + LT).

This column of the output data contains the maximum positive magnitude of shear from the combination of dead load, live load (with impact), stream flow, and centrifugal force on the left of column or P-load. The live load and centrifugal force shears are reduced for multiple loaded lanes. The "C nR" point is nonexistent and a blank space is always shown.

12. Group 1 Maximum Positive Shear on Right (G1. ± RT.).

This column of the output data contains the maximum positive magnitude of shear from the combination of dead load, live load (with impact), stream flow, and centrifugal force on the right of the column or P-load. The live load and centrifugal force shear are reduced for multiple loaded lanes. The "C nL" point is nonexistent and a blank space is always shown.

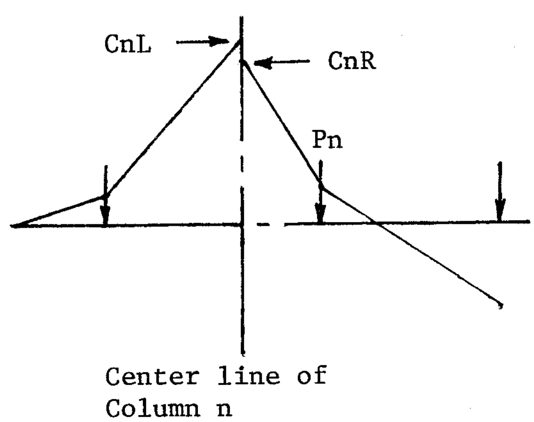
13. Group 1 Maximum Negative Shear on Left (G1 - LT).

This column of output data contains the maximum magnitude of negative shear from the combination of total dead load, live load (with impact), stream flow, and centrifugal force on the left of the column or P-load. The live load and centrifugal force shears are reduced for multiple loaded lanes. The "C nR" point is nonexistent and a blank space is always shown.

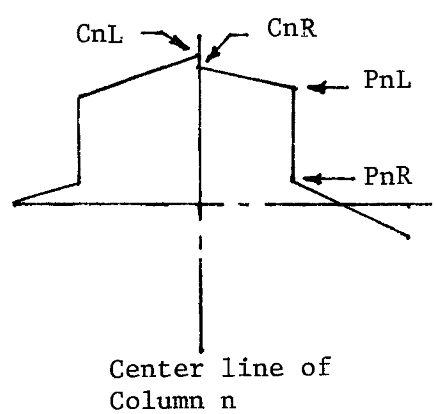
14. Group 1 Maximum Negative Shear on Right (G1 - RT).

This column of output data contains the maximum magnitude of negative shear from the combination of total dead load, live load (with impact), stream flow, and centrifugal force on the right of the column or P-load. The live load and centrifugal force shears are reduced for multiple loaded lanes. The "C nL" point is nonexistent and a blank space is always shown.

Following are sketches showing the location of the maximum moments and shears.



MOMENT



SHEAR

CAP DESIGN DATA

The data given here are the results of the cap analysis/design process. Areas of steel are given in square inches and spacings in inches.

1. PT.

The data shown in this column indicate the location of the design point. For example, P4 denotes P-load four, and C2 identifies the center line of column two.

2. M+UNF.

This column contains the maximum Group 1 positive Service Load moments. These moments are used in the Serviceability computations when Load Factor is the design option.

3. M-UNF.

This column contains the maximum negative Group 1 Service Load moments. They are used in the Serviceability computations under Load Factor.

4. TOP REINFORCE.

The required area of steel (AS), number of bars (NO.), and bar size (SIZE) are shown for the top of the cap. For a tension section, the area of steel given is the required amount. If this is less than the minimum, the number and bar size will reflect the minimum. For a compression side, the area of steel shown is the amount used in the computations and will usually reflect the minimum. If the number of bars given is greater than the maximum number per horizontal row, the bars are considered in two layers with the maximum number of bars in the outermost row.

5. BOT.REINFORCE.

The main reinforcement steel requirements for the bottom face of the cap are given in like manner as for the top.

6. LEFT STIRRUPS.

The left stirrup data consist of the maximum spacing (M.SP.), required area of steel per inch (AV/IN), the stirrup bar number, and required spacing (BAR&SPAC). If the letter D appears after the steel area, it indicates double stirrups are required. Single stirrups consist of two bar areas, double stirrups consist of four bar areas. The design point is immediately to the left of the beam or column center line.

7. RIGHT STIRRUPS.

The requirements for stirrup immediately to the right of the beam or column center line are given in like manner as for the left side.

8. D.

This column contains the required depth considering the loads and the width given in the input. If the depth is greater than the input depth, then a re-analysis is needed with the required depth as input unless circumstances dictate otherwise.

9. FC.

The concrete stress in the extreme compression face will be given with the Service Load option. A blank field will appear with the Load Factor option.

10. PS.

The percentage of required tension main reinforcement steel is given in this column of output data for Load Factor design only.

11. FS/FF RATIO. [See Art. 1.5.38(8)]

This column contains the ratio of the actual steel stress range to allowable steel stress range from service loads. It is used in the Serviceability requirements of Load Factor Design only.

12. FS/FZ RATIO. [See Art. 1.5.39]

This column contains the ratio of the actual maximum steel stress to the allowable given in formula 6-30 of the AASHTO Specifications. It is considered in Load Factor Design under Serviceability requirements when fy is greater than 40000 psi.

D. COLUMN ANALYSIS AND DESIGN OUTPUT

CRITICAL COLUMN LOADS

If a column analysis/design is requested, the program will list the Critical Load case found in the column section analysis/design procedure for the top and bottom of each column. P-loads are given in kips, moments are given in kip-feet, and dimensions are given in inches.

1. CN.

This column contains the column number.

2. T/B.

This column indicates the top (T) or bottom (B) of the column.

3. GR.

The Group number of the controlling load case is given in this column.

4. LLC.

This column will contain the live load case identification of the controlling load case. For non-live load groups, this column will be blank.

5. WC.

The wind case will be displayed in this column for the critical load case in the form I.J, where I is the wind direction number and J is the combination number.

6. R.

If the wind case is reversed, R will appear in this column. Otherwise, the column will be blank.

7. E/S.

An E, S, or blank will appear in this column to denote that shrinkage (S) or expansion (E) of the cap is included in the load case, or neither (blank).

8. C/F.

A C in this column indicates centrifugal force is included in the load case. Otherwise, this column is left blank.

9. S/F.

If stream flow is included in the load case, a S will appear in this column. Otherwise, this column is left blank.

10. PF.

This column contains the factored P-load of the controlling load case for Load Factor design. In Service Load design the P-load does not contain any factors.

11. MTF.

This column contains the factored transverse moment of the controlling load case in the case of Load Factor. The moment has not been magnified for slenderness, nor has the minimum eccentricity been taken into account. For Service Load the moment is just the summation of the moments which produced the load case.

12. MLF.

This column contains the factored longitudinal moment of the controlling Load case. The moment has not been magnified for slenderness, nor has the minimum eccentricity been taken into account. Under the Service Load option, the moment is the summation of moments for the load case.

13. PM.

This P-load is a repeat of PF since the P-loads are not magnified in Load Factor or Service Load design.

14. MTM.

This column contains the factored transverse moment magnified for minimum eccentricity and slenderness. Minimum eccentricity is considered first (applied before slenderness magnification if required).

15. MLM.

This data column contains the factored longitudinal moment magnified for minimum eccentricity (first) and slenderness.

16. PU.

PU is the ultimate P-load capacity of the column located at the point of the applied loads (PM, MTM, MLM).

17. MTU.

MTU is the ultimate transverse moment capacity of the column section.

18. MLU.

MLU is the ultimate longitudinal moment capacity of the column section.

19. PU/PM.

This ratio defines the adequacy of the column section. A value of one or greater indicates the section is sufficient. A value of less than one indicates the section is not adequate.

20. B and D.

These two dimensions are the widths of the column section used in the analysis/design.

COLUMN DESIGN DATA

The analysis/design results and other data are given for the top and bottom of each column.

1. CN.

The column number will appear in this column.

2. T/B.

This code indicates the top (T) or bottom (B) section of the column.

3. B FACE 1, B FACE 2, D FACE 3, D FACE 4.

These columns contain the number of bars and bar size in the column faces. The B Face includes the corner bars. In a design, this is the required reinforcement steel.

4. AS (sq. inches).

The total area of steel is given in this column.

5. PS (%).

The percentage of reinforcement is given here. PS = AS/(BxD).

6. BD12.

This factor indicates which BD value was used in critical load case. Refer to AASHTO Specifications Article 1.2.22.

7. BD.

BD is the ratio of dead load moment to total load moment and is used to modify the EI value from equation (6-17) of the AASHTO Specifications.

8. SUMPU (kips).

This column contains the sum of the PM loads for all columns for the critical load case. The PM load at the top and bottom of the column is averaged to account for the weight of the column. This factor is used when considering the pier as a unit. See Article 1.5.34(B)(9) of the AASHTO Specifications.

9. SUMPC (kips).

SUMPC is the sum of the PC (formula 6-16) values for all columns for the critical load case. Note that BD can make this value vary. The PC value for the top and bottom of the column is averaged in the case of varying reinforcement or a battered column. This factor is used when considering the pier as a unit.

10. DEL T.

This column contains the moment magnification factor in the transverse direction which was used to compute MTM.

11. DEL L.

This column contains the moment magnification factor in the longitudinal direction which was used to compute MLM.

12. CM.

CM is the factor used in equation 6-15 of the AASHTO Specifications to compute the magnification factor in the transverse direction.

13. R.

The R Mode value used is given in this column.

14. PHIC

This column contains the ∅c value used in the computations.

E. FOOTING ANALYSIS AND DESIGN DATA

FOOTING DESIGN LOADS

The Footing Design Loads will contain seven maximum load cases used in the footing analysis/design process. These seven load cases produce:

1. The maximum soil stress or pile reaction (MAX.P1).

2. The maximum transverse moment in footing (MAX.MT).

3. The maximum transverse beam shear in footing (MAX.VT).

4. The maximum peripheral shear in footing (MAX.VP).

5. The maximum longitudinal moment in footing (MAX.ML).

6. The maximum longitudinal beam shear in footing (MAX.VL).

7. The maximum soil or pile uplift (MAX.P3).

The soil uplift has no structural meaning since the soil has no tension capacity, but it does give an indication that reinforcement steel may be needed in the top of the footing. The load effects for MAX.P1 and MAX.P3 will be Service Loads. The loads effects for the other five load cases will be Service Load or Factored Loads depending on the design option.

1. F G.

The footing (F) which has the imposed loads (used with same designs) and the Group number of the load case is given in these columns.

2. LLID.

The live load case identification for the load case is given in this column. For Groups 2 and 5 this column will be blank.

3. WC.

The wind case in the form I.J will be given in this column. I is the wind direction and J is the combination number. An R will appear after the wind case if it is reversed.

4. ES.

An E or S in this column indicates Expansion or Shrinkage is included in the load case. Otherwise, this column is blank.

5. C.

A C in this column indicates centrifugal force is included in the load case. If not, the column is left blank.

6. S.

An S in this column indicates stream flow effects are included in the load case. A blank indicates no stream flow.

7. P (kips).

This column contains the P-load on the footing from the column. The soil weight or footing weight is not included. Impact has been removed if given in the input.

8. MT (kip-feet).

MT is the moment at the top of the footing in the transverse direction with live load impact removed if given in the input.

9. VT (kips).

VT is the horizontal shear at the top of the footing in the transverse direction with live load impact removed if given in the input.

10. ML (Kip-feet).

The longitudinal moment at the top of the footing is given in this column.

11. VL (kips).

VL is the horizontal shear at the top of the footing in the longitudinal direction.

12. P4 (kips or kips/sq. ft.).

P4 is corner soil stress or pile reaction where MT causes tension and ML produces compression.

13. P3 (kips or kips/sq. ft.)

P3 is the corner soil stress or pile reaction where MT and ML cause tension.

14. P2 (kips or kips/sq. ft.).

P2 is the corner soil stress or pile reaction where MT causes compression and ML causes tension.

15. P1.

P1 is the corner soil stress or pile reaction where MT and ML cause compression.

NOTE: The P1, P2, P3, and P4 values contain the weight of the soil and footing.

16. MTF (kip-feet/foot).

MTF is the moment in the footing in the transverse or longitudinal direction at the face of the column per foot of footing width.

17. VBF (kips/foot).

VBF is the beam shear in the footing in the transverse or longitudinal direction at the critical section (d or d/2) from the face of the column per foot of footing width.

18. VPF (kips/foot).

VPF is the peripheral shear in the footing at the critical section (d/2) from the face of the column per foot of peripheral length.

NOTE: The weight of the soil and footing are considered when computing MTF, VBF, and VPF.

19. LOAD.

This column contains the identification of the maximum load case, i.e., maximum P1, moment, shear, etc.

FOOTING ANALYSIS/DESIGN RESULTS

The footing analysis/design results will consist of the footing size, bar reinforcement steel, and section capacities.

1. B (feet).

B is the footing width in the longitudinal direction. In a design problem this is the required width.

2. D (feet).

D is the footing width in the transverse direction. In a design problem this is the required width.

3. T (feet).

T is the thickness of the footing. In a design problem this is the required thickness.

4. P1/PA.

P1/PA is the ratio of the maximum corner soil stress (or pile reaction) to the allowable soil stress (or pile capacity).

5. AS (sq. inches).

AS is the required area of reinforcement steel per foot.

6. NO.

The total number of rebars is given in this column.

7. SIZE.

The standard bar designation of the selected bars is given in this column.

8. SPAC (inches).

The rebar spacing is given in this column.

9. PLACEMENT.

This column identifies the placement of the rebars. The top layer of bars is listed on the first line and the bottom layer of bars on the second line. The codes LONG and TRAN are listed to indicate the direction in which the rebars are to be placed. TRAN bars are parallel to pier and LONG bars are perpendicular to pier. Note that the top or bottom bars may be in either direction (depends on magnitude of moment).

10. MT (kip-feet/foot).

MT is the moment capacity of the footing per foot of width considering the thickness and area of steel.

11. VB (kips/foot).

VB is the beam shear capacity of the footing per foot of width considering the thickness and steel placement.

12. VP (kips/foot).

VP is the peripheral shear capacity of the footing per foot of width considering the thickness and steel placement.

13. DS (inches).

DS is the distance from the top of the footing to the centroid of the rebars.

14. FC (ksi).

FC is the concrete stress under the Service Load option. Under the Load Factor option, FC is shown as zero.

15. Number of Piles, Bp and Dp (feet).

If the footing has piles, the number of piles and pile placement data will be given on the next line of output. Refer to the pile layouts on pages 2-29 through 2-33.

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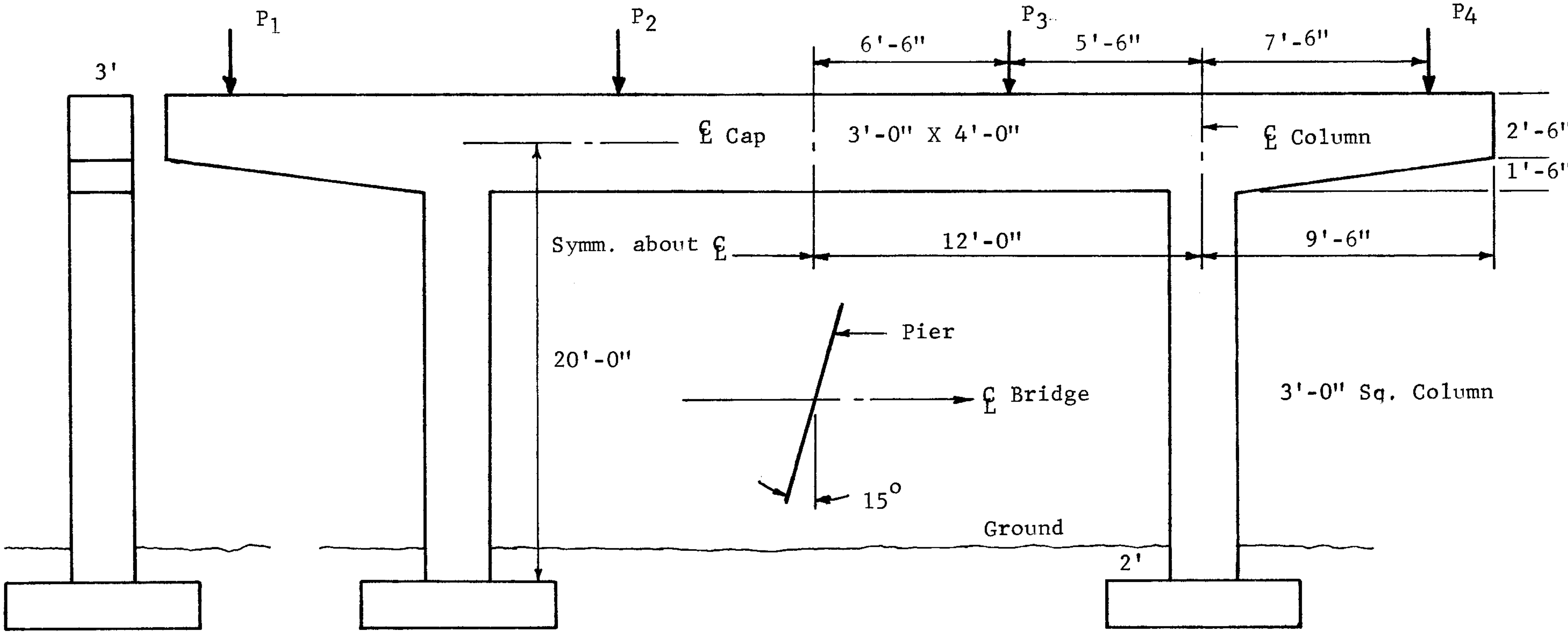
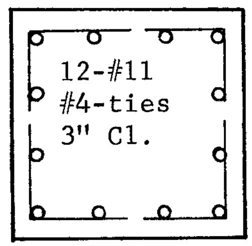
VI. EXAMPLE PROBLEM

This example is for illustrative purposes only and does not represent an actual design. It is a rather simple example; yet, it is also typical of most piers. First the pier description and loads are given or assumed. The output requirements are shown on the input data forms on pages 4-3, 4-4. The output data in reduced scale are given on pages 4-5 to 4-12. Finally, a commentary is given following the output data. The following page contains a sketch of the pier.

GIVEN DATA

Column and cap members have a constant moment of inertia.
Columns are assumed fixed at bottom.
Footings are spread with a 5'-0" X 5'-0" X 2'-0" minimum size.
Soil bearing capacity is 8.0 kips per square foot.
Use 3" increments in footing design and limit either width to a maximum of 1-1/2 times the other width.
Soil weighs 120 pounds per cubic foot.
A cap, column and footing design are desired.
Centroid of superstructure area is 6'-0" above center line of cap.
For Group II Wind, Group III Wind, and Wind on Live Load use 0^o and 60^o wind skew angles.
Expansion coefficient equals 3.0×10^{-4}.
Shrinkage coefficient equals 4.4×10^{-4}.
Wind on substructure (equivalent at center line of cap) is 2.424 kips in transverse direction, and 8.360 kips in longitudinal direction.
Longitudinal force (traction) is 4.9 kips (one lane).
Centrifugal force is 3.0 kips per lane of live load.
Stream flow is 2.100 kips in the transverse direction and 0.0 kips in the longitudinal direction.
Dead load from superstructure and live load cases are given on following page.
Live load impact is 20%.
Lengths for Wind on Live Load are 100.0 (transverse) and 200.0 (longitudinal) feet.
Location of Wind on Live Load is 11.500 feet above center line of cap.
Location of traction and centrifugal force is 6.0 feet above center line of cap.
Member properties are desired.
Use all program defaults.
Use Load Factor Design option.





Column Cross Section

Gravity Load (kips)	P_1	P_2	P_3	P_4	No. Lanes
Dead Load Superstructure	100.0	100.0	100.0	100.0	-
Live Load 1001	45.0	15.0	15.0	45.0	2
Live Load 0110	10.0	50.0	50.0	10.0	2
Live Load 1010	45.0	25.0	40.0	10.0	2
Live Load 0101	10.0	40.0	25.0	45.0	2
Live Load 010	0.0	30.0	30.0	0.0	1

PIER DESCRIPTION

APR., 1981

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

IDENTIFICATION

1 PROG	PROB. NO.	9 REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC. 80
*803	EX. 1	EXAMPLE PROBLEM OF MULTIPLE COLUMN PIER PROGRAM V 4.1

DESIGN DATA

CN	DES. OPT. CAP	DES. OPT. COL	DES. OPT. FT.	DES. OPT. S/L	C/N	NO. COL	NO. LLC.	SKEW ANGLE DEG	SKEW ANGLE MIN	SKEW ANGLE SEC	18 f'c	22 f c	N	28 fy	33 fs	38 Ec	42 Es	47 ∈c	50 51 Z	BAR SIZE	STR. SIZE	MAX T.B	MAX B.B	MIN. SIZE	MIN BARS	TOP CL.	MIN. S. SP	CAP D INCR.	BOT. CL. 77
01	0	0	0		2	2	5	15	0	0																			

GENERAL DESIGN DATA / CAP DESIGN DATA

COLUMN DESIGN DATA / FOOTING DESIGN DATA

CN	3 MIN. Ps	MAX. Ps	MIN. SPAC.	CLEAR	R	KL	Φc	ΦF	CM	B_{D1}	B_{D2} 34	35 IMPACT %	SOIL WEIGHT	ALL. S. P.	MIN. PL. SP.	MAX. PL. SP.	EDGE DIST.	PILE DEPTH	CLEAR	PL. CAPk	PL. UPLk 76	IP 77
02												20.00	120	8.000								P

CANTILEVER AND CAP DATA

CN	I	4 L	9 A	14 DE	19 BC	24 BE	29 DH	34 LH	39 XB1	44 XB2	49 XB3	54 XB4	59 XB5	64 XB6	69 XB7	74 XB8 78
11	L	9.500	1.500	2.500	3.000	3.000	1.500	8.000	7.500							
12	C	24.000		4.000	3.000				5.500	13.000						
13	1															
14																
15																
16																

ALL DIMENSIONS IN FEET FOR CANTILEVER/CAP, COLUMN, AND FOOTING DATA.

COLUMN DATA

REINFORCEMENT STEEL — LOWER LIMIT / ACTUAL: 45 TOP, 51 BOTTOM; UPPER LIMIT / ACTUAL: 57 TOP, 63 BOTTOM

CN	R	I	T	S	7 HT	12 A	17 DT	22 BT	27 DB	32 BB	37 DL	41 FLEX	TOP ND	TOP NB	TOP SIZE	BOTTOM ND	BOTTOM NB	BOTTOM SIZE	TOP ND	TOP NB	TOP SIZE	BOTTOM ND	BOTTOM NB	BOTTOM SIZE	69 SLOPE	73 EP	77 AP 80
21		C	T		20.000		3.000	3.000			2.000	0.0010	2	4	11				6	8	11						
22		1																									
23																											
24																											
25																											

FOOTING DATA

CN	S/P	4 B	9 D	14 T	19 ΔB	24 ΔD	29 ΔT	34 R B/D	38 R D/B	42 SOIL HT.	NP	S	50 BP	55 DP	60 SETTLE. 64
31	S	5.000	5.000	2.000	0.250	0.250	0.250	1.500	1.500	2.000					
32	1														
33															
34															
35															

DEFAULTS:

f'c - 3000 psi
fc - .4(f'c)
N - Es/Ec
fy - 40,000 psi
fs - 20,000 psi
Ec - $145^{1.5}33(f'c)^{\frac{1}{2}}$ ksi

Es - 29,000 ksi
∈c - .0030 in./in.
Z - 170
BAR SIZE - 11
STR. SIZE - 5
MAX. TB - 6

MAX. BB - 6
MIN. SIZE - BAR SIZE
MIN. BARS - 2
TOP CL. - 2 in.
MIN. S. SP. - 3 in.
CAP D. INCR. - 3 in.

BOT. CL. - TOP CL.
MIN. Ps - 1%
MAX. Ps - 8%
MIN. SPAC. - 2.25 in.
CLEAR (COL.) - 4.0 in.
R - 1 ROUND/SPIRAL
2 TIED

KL - 2.0
Φc - .75 ROUND/SPIRAL
.7 TIED
Φf - .9 LOAD FACTOR
Φc, Φf - .35 S. L.
Cm - COMPUTED

BDI - 1.0
MIN. PL. SP. - 2.5 ft.
MAX. PL. SP. - 5.0 ft.
EDGE DIST. - 1.25 ft.
PILE DEPTH - 1.0 ft.
CLEAR (FTG.) - 3.0 in.

PIER LOADS
APR., 1981

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

FORCES — KIPS
INTENSITY - LBS./ FT.^{2}
AREAS - FT.^{2}
LENGTHS - FT.
TRACTION AND CENTRIFUGAL FORCE - 1 LANE
COEFFICIENTS - UNITS / UNITS

GROUP II WIND

CN	SUPERSTRUCTURE AREA: 3 TRANS.	9 LONG.	S T D W	WIND ON SUPERSTRUCTURE INTENSITY: FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	WIND FORCE ARMS: 36 APT	41 APL	WIND ON PIER: 46 PT	51 PL 55
4 1	504	1000		50	0	17	19							6.000	6.000	2.424	8.360

GROUP III WIND

CN	S T D W	WIND ON SUPERSTRUCTURE INTENSITY: FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	S T D W	WIND ON LIVE LOAD INTENSITY: FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	LENGTH OF LIVE LOADS: 46 TRANS.	51 LONG.	WIND ON L.L. ARMS: 56 APT	61 APL 65
4 2		50	0	17	19								100	0	34	38							100.0	200.0	11.500	11.500

STD. W. GR. II, III SUPERSTRUCTURE	FT - 50	44	41	33	17
	FL - 0	6	12	16	19
STD. W. GR. III LIVE LOAD	FT - 100	88	82	66	34
	FL - 0	12	24	32	38

MISCELLANEOUS FORCES

CN	CENT. FORCE: 3 FT	TRACTION FORCE: 9 FL	C.F. & T.F. ARMS: 15 APT	20 APL	EXPANSION: 25 COEFFICIENT	SHRINKAGE: 33 COEFFICIENT	STREAM FLOW: 41 PT	46 PL 50
4 1 3	3.000	4.900	11.500	11.500	00030000	00044000	2.100	0.000

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES (ONE LIVE LOAD CASE REQUIRED - MAXIMUM IS 25 CASES)

CN	I.D.	NL	9 P1,13,25	15 P2,14,26	21 P3,15,27	27 P4,16,28	33 P5,17,29	39 P6,18,30	45 P7,19,31	51 P8,20,32	57 P9,21,33	63 P10,22,34	69 P11,23,35	75 P12,24,36 80
5 1	D. L.	0 0	100.000	100.000	100.000	100.000								
6 1	1001	2	45.000	15.000	15.000	45.000								
6 1	0110	2	10.000	50.000	50.000	10.000								
6 1	1010	2	45.000	25.000	40.000	10.000								
6 1	0101	2	10.000	40.000	25.000	45.000								
6 1	010	1	0.000	30.000	30.000	0.000								
6 1														
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                                                THE ANALYSIS AND DESIGN OF PIERS FOR BRIDGES - V 4.1.37

PROBLEM NO. EX.1 INPUT DATA          EXAMPLE PROBLEM OF MULTIPLE COLUMN PIER PROGRAM V 4.1                          15-NOV-83

                                                                 DESIGN DATA
 DESIGN NO. NO. NO. SKEW ANG  F'C   FC    N    FY     FS     EC    ES    CONC.   Z   *   *   * CAP REINFORCING STEEL  *   *   *  CAP
OPTIONS CAN COL LLC  D  M  S  PSI   PSI        PSI    PSI    KSI   KSI   STRAIN FACT MAIN STR MAX  MAX  MIN  MIN  TOP   MIN DEPTH BOT
                                                                                     SIZE SIZ TOP  BOT SIZE  NO.  CL.  S.SP INCR. CL.
D D D L  2   2   5  15- 0- 0 3000. 1200.  9. 40000. 20000. 3156. 29000. 0.0030 170.  11   5   6    6   11    2  2.00 3.00 3.00 2.00

COLUMN REINFORCING STEEL   R   KL   OC   OF   CM  BD1  BD2 IMPACT SOIL WT ALL.S.P.  MIN  MAX  EDGE  PILE  REBAR ALL.PILE ALL.PILE I
MIN.P MAX.P CL.SP. CLEAR MODE COEF                          %      KCF     KSF    PL SP PL SP DIST  DEPTH CLEAR CAPACITY  UPLIFT  P
 1.00  8.00  2.25  4.000   0  2.00 0.00 0.90 0.00 1.00 0.00 20.00  0.120   8.000  2.50  5.00 1.250 1.000 3.000   0.000     0.000  P
                                                            CAP DATA

CN  C    L       A      DE      BC      BE      DH      LH      XB1     XB2     XB3     XB4     XB5     XB6     XB7     XB8

11  L   9.500   1.500   2.500   3.000   3.000   1.500   8.000   7.500

12  C  24.000   0.000   4.000   3.000           0.000   0.000   5.500  13.000

13  3 SAME AS CANTILEVER  1

                                                           COLUMN DATA

CN P I T S   HT      A       DT      BT      DB      BB      DL     FLEX  ND NB SZ ND NB SZ ND NB SZ ND NB SZ  SLOPE   EP      AP

21 0 C T   20.000  0.000   3.000   3.000   0.000   0.000   2.000   0.000   2  4 11  0  0  0  6  8 11  0  0  0  0.000  0.000  0.000

22 0 1 SAME AS COLUMN 1

                                                   FOOTING DATA

CN S/P   B       D       T      DEL.B   DEL.D   DEL.T  R.B/D  R.D/B   S.HT.  NP  SYM.   BP      DP      SET.

31  S   5.000   5.000   2.000   0.250   0.250   0.250  1.500  1.500   2.000   0   0    0.000   0.000   0.000

32 SAME AS FOOTING 1
```

GROUP II WIND

SUPERSTRUCTURE AREA TRANS.	LONG.	*STD. WIND	WIND ON SUPERSTRUCTURE INTENSITIES FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	* WIND FORCE ARM APT	APL	* WIND ON PIER PT	PL
500.	1000.	0	50	0	17	19	0	0	0	0	0	0	6.000	6.000	2.424	8.360

GROUP III WIND

STD. WIND	* WIND ON SUPERSTRUCTURE INTENSITIES FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	* STD. WIND	* WIND ON LIVE LOAD INTENSITIES FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	* LENGTHS OF LL TRANS.	LONGI.	* WIND ON LL ARMS APT	APL
0	50	0	17	19	0	0	0	0	0	0	0	100	0	34	38	0	0	0	0	0	0	100.0	200.0	11.500	11.500

MISCELLANEOUS FORCES

CENTRI. FT	TRACTION FORCE AND ARMS FL	APT	APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PT	PL
3.000	4.900	11.500	11.500	0.00030000	0.00044000	2.100	0.000

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES

I.D.	NL	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
D.L.	0	100.000	100.000	100.000	100.000								
1001	2	45.000	15.000	15.000	45.000								
0110	2	10.000	50.000	50.000	10.000								
1010	2	45.000	25.000	40.000	10.000								
0101	2	10.000	40.000	25.000	45.000								
010	1	0.000	30.000	30.000	0.000								

MEMBER PROPERTIES

COLUMN PROPERTIES

CN	KT KTM	COTB COBT	COTBM COBTM	TLR TRL	TRC TCR	TLC TCL	DFC DFL	KL PDF	FKBR FKUBR	PCBR PCUBR	PCL FLU	UFMT UFMB	EITTB EILTB	PSIT PSIB	RGTB RGL
1	613511.8	0.5000	0.5000	0.6223	1.0000	0.3777	0.3777	0.030375	11.7	104795.7	5778.5	46013.4	163222.9	0.4	10.6
	613511.8	0.5000	0.3436	0.0000	1.0000	0.0000	0.0000	0.5000	24.5	23977.9	18.0	46013.4	163222.9	0.0	10.6
2	613511.8	0.5000	0.5000	0.0000	0.3777	1.0000	0.3777	0.030375	11.7	104795.7	5778.5	46013.4	163222.9	0.4	10.6
	613511.8	0.5000	0.3436	0.6223	0.0000	1.0000	0.6223	0.5000	24.5	23977.9	18.0	46013.4	163222.9	0.0	10.6

CAP PROPERTIES

CN	CO K	KML KMR	COMLR COMRL	FMWT UFEM	FMLP1 FMRP1	FMLP2 FMRP2	FMLP3 FMRP3	FMLP4 FMRP4	FMLP5 FMRP5	FMLP6 FMRP6	FMLP7 FMRP7	FMLP8 FMRP8
2	0.5000	1010734.1	0.2015	86.4000	3.2680	0.9716						
	1211875.1	1010734.1	0.2015	75742.2	0.9716	3.2680						

COLUMN MOMENTS(KIP-FEET), SHEARS(KIPS), REACTIONS(KIPS)

		TRANSVERSE							* LONGITUDINAL			
LOAD	COL	PC	MT	V	MB	RF	ML	MR	MT	V	MB	MF
UNIT F.AT CL.CAP	1	0.384	4.611	0.500	5.389	0.384	0.000	-4.611	1.000	0.500	10.000	10.000
	2	-0.384	4.611	0.500	5.389	-0.384	-4.611	0.000	1.000	0.500	10.000	10.000
EXPANSION OF CAP	1	0.000	82.310	10.314	123.979	0.000	0.000	-82.310	0.000	0.000	0.000	0.000
	2	0.000	-82.310	-10.314	-123.979	0.000	82.310	0.000	0.000	0.000	0.000	0.000
SHRINKAGE OF CAP	1	0.000	-120.721	-15.128	-181.836	0.000	0.000	120.721	0.000	0.000	0.000	0.000
	2	0.000	120.721	15.128	181.836	0.000	-120.721	0.000	0.000	0.000	0.000	0.000
DEAD LOAD TOTAL	1	236.000 260.300	-152.148	-11.411	-76.074	260.300	812.775	-660.628	0.000	0.000	0.000	0.000
	2	236.000 260.300	152.148	11.411	76.074	260.300	660.628	-812.775	0.000	0.000	0.000	0.000
STREAM FLOW	1	0.807	9.683	1.050	11.317	0.807	0.000	-9.683	0.000	0.000	0.000	0.000
	2	-0.807	9.683	1.050	11.317	-0.807	-9.683	0.000	0.000	0.000	0.000	0.000
TRAC. FORCE 1 LN	1	1.095	5.848	0.634	6.834	1.095	0.000	-5.848	-31.948	-2.367	-74.545	-74.545
	2	-1.095	5.848	0.634	6.834	-1.095	-5.848	0.000	-31.948	-2.367	-74.545	-74.545
CENT. FORCE 1 LN	1	2.502	13.362	1.449	15.616	2.502	0.000	-13.362	5.241	0.388	12.229	12.229
	2	-2.502	13.362	1.449	15.616	-2.502	-13.362	0.000	5.241	0.388	12.229	12.229
WIND ON SUBSTR.	1	0.931	11.177	1.212	13.063	0.931	0.000	-11.177	-8.360	-4.180	-83.600	-83.600
	2	-0.931	11.177	1.212	13.063	-0.931	-11.177	0.000	-8.360	-4.180	-83.600	-83.600
GROUP 2 WIND 1 1	1	16.247	122.523	13.286	143.199	16.247	0.000	-122.523	17.522	-0.945	0.516	0.516
	2	-16.247	122.523	13.286	143.199	-16.247	-122.523	0.000	17.522	-0.945	0.516	0.516
GROUP 2 WIND 1 2	1	16.247	122.523	13.286	143.199	16.247	0.000	-122.523	34.242	7.415	167.716	167.716
	2	-16.247	122.523	13.286	143.199	-16.247	-122.523	0.000	34.242	7.415	167.716	167.716
GROUP 2 WIND 2 1	1	9.258	71.709	7.776	83.810	9.258	0.000	-71.709	-72.971	-12.256	-293.584	-293.584
	2	-9.258	71.709	7.776	83.810	-9.258	-71.709	0.000	-72.971	-12.256	-293.584	-293.584
GROUP 2 WIND 2 2	1	3.020	26.360	2.858	30.808	3.020	0.000	-26.360	90.570	14.456	350.783	350.783
	2	-3.020	26.360	2.858	30.808	-3.020	-26.360	0.000	90.570	14.456	350.783	350.783
GROUP 3 WIND 1 1	1	13.214	81.295	8.815	95.014	13.214	0.000	-81.295	22.727	1.011	40.919	40.919
	2	-13.214	81.295	8.815	95.014	-13.214	-81.295	0.000	22.727	1.011	40.919	40.919
GROUP 3 WIND 1 2	1	13.214	81.295	8.815	95.014	13.214	0.000	-81.295	27.743	3.519	91.079	91.079
	2	-13.214	81.295	8.815	95.014	-13.214	-81.295	0.000	27.743	3.519	91.079	91.079
GROUP 3 WIND 2 1	1	7.311	45.726	4.958	53.442	7.311	0.000	-45.726	-65.503	-6.907	-189.837	-189.837
	2	-7.311	45.726	4.958	53.442	-7.311	-45.726	0.000	-65.503	-6.907	-189.837	-189.837
GROUP 3 WIND 2 2	1	2.043	13.981	1.516	16.340	2.043	0.000	-13.981	82.663	8.447	234.716	234.716
	2	-2.043	13.981	1.516	16.340	-2.043	-13.981	0.000	82.663	8.447	234.716	234.716
LIVE LOAD 1001	1	60.000	-137.804	-10.335	-68.902	60.000	337.500	-199.696	0.000	0.000	0.000	0.000
	2	60.000	137.804	10.335	68.902	60.000	199.696	-337.500	0.000	0.000	0.000	0.000
LIVE LOAD 0110	1	60.000	68.915	5.169	34.457	60.000	75.000	-143.915	0.000	0.000	0.000	0.000
	2	60.000	-68.915	-5.169	-34.457	60.000	143.915	-75.000	0.000	0.000	0.000	0.000

COLUMN MOMENTS(KIP-FEET), SHEARS(KIPS), REACTIONS(KIPS)

		TRANSVERSE							* LONGITUDINAL			
LOAD	COL	PC	MT	V	MB	RF	ML	MR	MT	V	MB	MF
LIVE LOAD 1010	1	83.412	-45.997	-2.583	-5.670	83.412	337.500	-291.503	0.000	0.000	0.000	0.000
	2	36.588	22.892	2.583	28.775	36.588	52.108	-75.000	0.000	0.000	0.000	0.000
LIVE LOAD 0101	1	36.588	-22.892	-2.583	-28.775	36.588	75.000	-52.108	0.000	0.000	0.000	0.000
	2	83.412	45.997	2.583	5.670	83.412	291.503	-337.500	0.000	0.000	0.000	0.000
LIVE LOAD 010	1	30.000	63.989	4.799	31.994	30.000	0.000	-63.989	0.000	0.000	0.000	0.000
	2	30.000	-63.989	-4.799	-31.994	30.000	63.989	0.000	0.000	0.000	0.000	0.000

CAP ANALYSIS AND DESIGN DATA

CAP MOMENTS AND SHEARS

MOMENTS(KIP-FEET) ** SHEARS(KIPS)

POINT	D.L.TOT.	G1 MAX.+	G1 MAX.-	G2 MAX.+	G2 MAX.-	G3 MAX.+	G3 MAX.-	DL T.LT	DL T.RT	G1 + LT	G1 + RT	G1 - LT	G1 - RT
P 1	-3.071	-3.071	-3.071	-3.071	-3.071	-3.071	-3.071	-3.144	-133.144	-3.144	-133.144	-3.144	-230.839
C 1L	-1056.608	-1056.608	-1789.320	-1056.608	-1056.608	-1056.608	-1495.357	-148.720		-148.720		-246.415	
C 1R	-858.816	-858.816	-1538.996	-699.536	-1030.683	-805.669	-1405.985		158.080		270.574		158.080
P 2	-24.768	259.817	-304.837	61.508	-117.863	211.123	-268.240	145.210	15.210	257.704	48.272	145.210	-13.908
P 3	-24.768	285.453	-279.201	68.327	-111.045	236.759	-242.604	-15.210	-145.210	17.852	-145.210	-44.328	-253.760
C 2L	-858.816	-858.816	-1491.669	-686.948	-1018.095	-758.341	-1358.657	-158.080		-158.080		-266.630	
C 2R	-1056.608	-1056.608	-1789.320	-1056.608	-1056.608	-1056.608	-1495.357		148.720		246.415		148.720
P 4	-3.071	-3.071	-3.071	-3.071	-3.071	-3.071	-3.071	133.144	3.144	230.839	3.144	133.144	3.144

CAP DESIGN DATA

PT.	M+ UNF. K-FT.	M- UNF. K-FT.	TOP REINFORCE. AS	TOP REINFORCE. NO.SIZE	BOT.REINFORCE. AS	BOT.REINFORCE. NO.SIZE	LEFT STIRRUPS M.SP.	LEFT STIRRUPS AV/IN	LEFT STIRRUPS BAR&SPAC	RIGHT STIRRUPS M.SP.	RIGHT STIRRUPS AV/IN	RIGHT STIRRUPS BAR&SPAC	D IN.	FC PSI	PS %	FS/FF RATIO	FS/FZ RATIO
P 1	-2.362	-2.362	3.12	2 # 11	3.12	2 # 11	0.00	0.000	#5@ 0.00	15.59	0.119	#5@ 5.20	34.50		0.28	0.000	0.000
C 1	-660.628	-1150.275	14.40	10 # 11	3.12	2 # 11	22.05	0.066	#5@ 9.43	22.05	0.082	#5@ 7.58	48.00		1.09	0.502	0.000
P 2	112.033	-155.969	3.28	3 # 11	3.12	2 # 11	22.34	0.071	#5@ 8.72	0.00	0.000	#5@ 0.00	48.00		0.36	0.663	0.000
P 3	131.752	-136.249	3.12	2 # 11	3.12	2 # 11	0.00	0.000	#5@ 0.00	22.34	0.068	#5@ 9.05	48.00		0.34	0.598	0.000
C 2	-660.628	-1150.275	14.40	10 # 11	3.12	2 # 11	22.05	0.079	#5@ 7.83	22.05	0.066	#5@ 9.43	48.00		1.09	0.502	0.000
P 4	-2.362	-2.362	3.12	2 # 11	3.12	2 # 11	15.59	0.119	#5@ 5.20	0.00	0.000	#5@ 0.00	34.50		0.28	0.000	0.000

COLUMN ANALYSIS AND DESIGN OUTPUT

CRITICAL COLUMN LOADS

CN	TB	GR	LLC	WC	R	ES	CF	SF	PF	MTF	MLF	PM	MTM	MLM	PU	MTU	MLU	PU/PM	B	D
1	T	5		1.2	R	S			274.7	-494.2	-42.8	274.7	508.4	88.8	583.9	1081.7	188.9	2.127	36.00	36.00
1	B	5		2.2	R	S			321.6	-360.9	-438.5	321.6	370.7	474.4	544.3	626.8	802.2	1.691	36.00	36.00
2	T	4	1001	0.0		S	C	S	377.2	581.2	13.6	377.2	599.9	125.4	702.6	1116.3	233.3	1.861	36.00	36.00
2	B	5		2.2		S		S	320.6	375.0	438.5	320.6	385.2	474.3	532.0	638.7	786.3	1.658	36.00	36.00

COLUMN DESIGN DATA

CN	TB	B FACE 1 NO.SIZE	B FACE 2 NO.SIZE	D FACE 3 NO.SIZE	D FACE 4 NO.SIZE	AS	PS	BD12	BD	SUMPU	SUMPC	DEL.T	DEL.L	CM	R	PHIC
1	T	4 # 11	4 # 11	2 # 11	2 # 11	18.72	1.444	1.00	0.287	620.	22233.	1.029	1.077	1.000	2	0.70
1	B	4 # 11	4 # 11	2 # 11	2 # 11	18.72	1.444	1.00	0.386	620.	23481.	1.027	1.082	1.000	2	0.70
2	T	4 # 11	4 # 11	2 # 11	2 # 11	18.72	1.444	1.00	0.273	801.	25737.	1.032	1.108	1.000	2	0.70
2	B	4 # 11	4 # 11	2 # 11	2 # 11	18.72	1.444	1.00	0.373	620.	23433.	1.027	1.082	1.000	2	0.70

FOOTING 1 DESIGN LOADS

F	G	LLID	WC	ES	C	S	P	MT	VT	ML	VL	P4	P3	P2	P1	MTF	VBF	VPF	LOAD
2	3	1001	2.2		C	S	304.636	178.713	24.219	408.265	13.957	5.125	-1.170	3.700	9.995	13.166	2.507	11.539	MAX.P1
2	4	1001	0.0	S	C	S	395.836	465.241	50.829	31.796	1.009	-0.215	-0.719	11.378	11.882	22.370	4.368	14.992	MAX.MT
2	4	1001	0.0	S	C	S	395.836	465.241	50.829	31.796	1.009	-0.215	-0.719	11.378	11.882	22.370	4.368	14.992	MAX.VT
2	3	0101	2.1R				441.105	17.794	9.538	440.606	15.133	9.153	2.408	3.191	9.936	13.427	2.438	16.693	MAX.VP
1	3	1010	2.2		C	S	436.117	-46.250	-12.179	530.745	18.144	9.419	1.298	2.797	10.919	64.964	19.006	16.504	MAX.ML
1	3	1010	2.2		C	S	436.117	-46.250	-12.179	530.745	18.144	9.419	1.298	2.797	10.919	64.964	19.006	16.504	MAX.VL
2	5		2.2	S		S	256.473	300.035	30.447	350.783	14.456	2.505	-3.562	4.804	10.871	14.631	2.869	9.881	MAX.P3

FOOTING 1 ANALYSIS/DESIGN RESULTS

FOOTING SIZE			*	BAR REINFORCEMENT STEEL				*	SECTION CAPACITIES				*
B	D	T	P1/PA	AS	NO.SIZE	SPAC.	PLACEMENT	MT.	VB	VP	DS	FC	
10.750	7.250	2.000	0.999	0.51	28 # 4	@ 4.500	TOP TRAN	30.133	21.925	43.849	19.622	0.000	
				1.10	8 # 9	@10.875	BOT.LONG	65.263	22.834	45.668	20.436	0.000	

FOOTING 2 DESIGN SAME AS FOOTING 1
>

EXAMPLE PROBLEM COMMENTARY

The first two pages of the output contain a listing of the input data. Numerous headings are shown to assist in checking the input data as well as interpreting the computed output data.

The third page of the output contains the member properties. For example, the P-load required to produce 1 inch of longitudinal deflection at the top of the column is (.030375) (3156) = 95.864 kips.

The fourth and fifth pages contain the moments, shears and reactions at the top and bottom of the columns in both the transverse and longitudinal directions for each load that is applied to the pier. For example, the moment due to the total dead load (superstructure and substructure) at the bottom of column two is 76.074 kip-feet in the transverse direction.

The sixth page contains the cap analysis and design data. For example, the maximum positive moment at beam two (P_2) is 112.033 kip-feet for Group I unfactored. Note that for Group III combinations, the moment is 211.123 kip-feet factored. The cantilever dead load moment is larger (1056.608 to 858.816) than the dead load moment immediately inside the column center line which indicates that a larger column spacing to balance these moments would be a better design.

The seventh page of the output contains the column analysis/design data. The data in the PU/PM column (for ratio) of the critical column loads indicate the columns are not overstressed, i.e., all values are greater than one (1.0). Note that Group 4 loading combination controlled the column analysis/design at the top of column two.

Finally the footing analysis/design data are given on the last page and contain the size (10'-9" X 7'-6") of the footing determined by the program, and the area of reinforcement (1.42 in.^{2}/ft. longitudinally and 0.53 in.^{2}/ft. transversely). The Footing Design Loads give the loading combinations which controlled the moments in the footing (transverse and longitudinal) and maximum uplift. Since footing 2 was coded the same as footing 1, the design is adequate for both footings. Note that the loads from footing 1 and 2 controlled various design effects for the footing.

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LINE NO. I	POSSIBLE CAUSE OF ERROR
3N N=Footing Number	1. B equals 0.0 (spread footing). 2. D equals 0.0 (spread footing). 3. T equals 0.0. 4. ΔB, ΔD, or ΔT equals 0.0 for a spread footing design. 5. R B/D or R D/B is less than or equal to 0.0, or the sum is less than 2.0 for a spread footing design. 6. Number of piles less than 4 for a pile footing analysis. 7. Bp or Dp less than or equal to 0.0 for a pile footing analysis. 8. Invalid same footing. 9. Allowable soil pressure or pile load equals 0.0 for design problem.
41, 42, 43	These Load cards are only checked for their presence.
51, 52, 53	1. Dead load superstructure input in error, too few or too many lines. Codes 51, 52, 53 not used correctly.
61, 62, 63	1. Live load case input error, too few or too many lines of data. 2. Codes 61, 62, 63 not used correctly.

After encountering an error, the remaining data for the problem is flushed and the program proceeds to the next problem.

In addition, various messages will be printed during the Column and Footing Analysis/Design process as follows:

COLUMN ANALYSIS/DESIGN

1. "COLUMN I P UNSTABLE OR NO DESIGN POSSIBLE"

   Where I is the column number and P indicates the top (T) or bottom (B) section. The loads on the section are then listed: P, MT, ML. The program continues with the next column section.

2. "ERROR IN INPUT FOR COLUMN I P"

   Where I and P are the same as above. No further processing of the columns is attempted. This message is probably due to incorrect input data.

FOOTING ANALYSIS/DESIGN

1. "DATA OUT OF ORDER FOR FOOTING I"

   Where I is the footing number. This message indicates an internal problem and possibly a program malfunction. All footing computations are terminated.

V. ERROR MESSAGES

The program checks the validity of the input data to the extent possible and will list the following message when an error is detected:

ERROR PROBLEM NUMBER XXXX CARD I J

Where XXXX is the number of the problem which was defined in the Identification data, I is the line (card) number expected, and J is the line number read. If I is not equal to J, a data line is out of sequence, missing, or should not be present. If I is equal to J, the error is in the data given in that line. Following is a listing of the line numbers and the possible causes of the error:

LINE NO. I	POSSIBLE CAUSE OF ERROR
*B03	1. The first data record is not the Identification.
01	1. Number of cantilevers greater than two. 2. Number of columns is invalid. 3. Number of live load cases is less than one or greater than allowed. 4. Incorrect skew angle. 5. Non-standard bar size. 6. Stirrup size greater than 11.
02	1. PHI Value(s) greater than 1.0. 2. CM value greater than 1.0. 3. BD value(s) greater than 1.0. 4. R value is incorrect (greater than 2).
1N N=Cap Number	1. Illegal cap code for I. 2. L equals 0.0. 3. XB1 equals 0.0. 4. XB1 for left cantilever is greater than L-1.0. 5. Summation of XB is greater or equal to 0.0 for left cantilever (at or past column center line). 6. DE equals 0.0. 7. BC equals 0.0. 8. LH equals 0.0 with variable depth cap. 9. Summation of XB greater than or equal to L. 10. Summation of XB greater than L-1.0 for the right cantilever.
2N N=Column Number	1. HT equals zero. 2. DT equals zero. 3. Invalid T code. 4. BT equals 0.0 for a rectangular column. 5. DB or BD equals 0.0 for a variable column. 6. FLEX is less than 0.0 or greater than 1.0. 7. NB less than 2 with an Investigation or Design. 8. Bar size less than 5 or non-standard with Investigation or Design 9. Invalid same column.

2. "HAVING TROUBLE WITH FOOTING I DESIGN"

The Service (PS, MTS, VTS, MLS, VLS) and Factored (PF, MTF, VTF, MLF, VLF) loads are listed for the load case the program was working with at that time. This is probably from having to increment the footing size too many times (100 is maximum). Begin with a larger footing or use larger increment of width. This message may be proceeded by message 7 and 8 below. The program proceeds to the next footing.

3. "SIDE RATIOS TOO RESTRICTING FOR FOOTING I"

The program proceeds to the next footing.

4. "MAXIMUM NUMBER OF PILES EXCEEDED IN FOOTING I"

Refer to 2 above.

5. "FOOTING I IS BEING GOVERNED BY UPLIFT OF X"

Where X is the uplift value. Refer to 2 above.

6. "TOO MANY LOAD CASES FOR ALL SAME FOOTINGS I J"

When designing/analyzing two or more footings for the same loads, the number of load cases has exceeded 1270 (the maximum). To circumvent, reduce the number of loads and make multiple runs or design/analyze the footings individually. I and J are the footing numbers. The program continues but ignores the additional load cases.

7. "UNSTABLE LOAD CONDITION ON FOOTING I"

This message will be given when the resultant P-load is off the footing (M/P is greater than or equal to one-half the footing width) and only occurs with an analysis of a spread footing.

8. "TOO MANY ITERATIONS TO FIND SOIL STRESS FOR FOOTING I"

The program has tried a maximum of fifty iterations to find the soil stress. Initial footing size is probably too small. This message only occurs with an analysis of a spread footing.

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS FOR BRIDGES
MALFUNCTION CORRECTIONS AND ENHANCEMENTS TO YIELD V4.1

A. MALFUNCTION CORRECTIONS:

*1. The B and D dimensions are no longer required for a pile footing.

2. The qm factor for determining if the compression steel is at yield in the cap has been corrected.

3. The area A used in Load Factor Serviceability requirements has been corrected.

*4. The edit of the bar reinforcement steel has been revised to function properly.

5. The phi (Ø) factors for Service Load default correctly.

*6. The phi (Ø) factors are transferred to the column design procedure correctly.

*7. The cause for a system abort with constant depth cantilevers has been fixed.

8. The Error Message when dead load or live load cards are out of order has been fixed.

9. The B_L (Beta L) factor for live load in Groups 3 and 4 has been corrected to 1.0 instead of 5/3 for the column and footings.

10. The indicator for single or double stirrups was fixed.

11. The Gamma factor for Group 5 was corrected to 1.0 in the column design procedure.

*12. The correct value of f_c'' (.85 f_c') is now transferred to the column routine correctly.

13. The section properties for a spiral (rectangular) column were corrected.

14. An error was corrected in the pile footing design procedure.

15. A condition which produced an unnecessary error message in the spread footing design routine was corrected.

16. The User's Manual has been revised to reflect all changes and corrected.

*IMPORTANT: These changes will/may require a change in the input data for existing programs!

B. ENHANCEMENTS

1. The concrete stress provision of the Load Factor Serviceability requirements has been omitted according to the forthcoming AASHTO specifications.

*2. Using the SAME code in the Footing Data will produce one design for all footings indicated as being the SAME, and considers the loads from each footing. The footing of the controlling loads is indicated.

3. Error Messages from the Footing Design procedure are more comprehensive.

4. Error Messages from the Column Design procedure are more comprehensive.

5. The Footing Design process will not add piles when uplift alone governs. A message is given with the design loads.

*6. The maximum number of bars in the column has been increased to 200, with a maximum of 100 per face (rectangular).

*7. The Column Design procedure will Investigate a rectangular section with different number of bars in opposing faces and indicate them correctly in the output.

*8. The position of the implied decimal has been shifted on the cap clearance. In addition the program will accept a bottom clearance in addition to the top clearance.

9. The Cap Design and Footing Design processes now consider minimum reinforcement steel.

*10. Minimum pile footing dimensions may now be used.

*11. The implied decimal position of the allowable pile uplift may be overridden by imputting the decimal position.

12. The program can now process moments with values from -99999.999 to 999999.999 kip-feet.

*13. When there are no cantilevers, the program considers the first cap portion as number 1, etc., when using the SAME code.

14. The maximum number of piles has been increased to twenty-five (25).

* IMPORTANT: These changes will/may require a change in the input data for existing programs!