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September 9, 1992

EDS MEMO 92-08

MEMORANDUM TO: All Holders of Engineering Computer Manual

FROM: John L. Smith, Jr., P.E.
State Bridge Design Engineer

Paul T. C. Lee, P.E.
Engineering Automation

SUBJECT: Revisions to Georgia Pier Program - E75700

The Georgia Pier writeup and input sheets have been revised. Card "44", the Seisimic Load Card, has been revised so loads are input to the nearest whole number.

In some instances when using the "same as" procedure to design footings, the controlling footing design does not control. Using this procedure is not recommended at this time.

Example 5 has been clarified. In the description of the problem, the word "column" has been changed to "pile". Also, the XB2 distances in cards 11 and 16 have been omitted.

Attached are pages 31, 32, 41, 42, 67, 68, 77, 78, 87, 88, 99, 100, and 103-110. Please replace old pages with attached.

JLS/PTCL/CTR/dby

Attachment

Program Limitations Relative to the Ga. Multiple Column Pier Program:

1. All the default values are not the same.
2. Footing data code "S" uses codes 1 and 2 only.
3. When the cap depth has been incremented, a message will be printed stating this in the output, but it will not identify why.
4. Seismic Force 1 is actually Seismic Load Case 2, and Seismic Force 2 is actually Seismic Load Case 1.

ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS FOR BRIDGES
E75700

by

Georgia Department of Transportation

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

Revised 4-1-91

1989 AASHTO Specifications

Version 4.2

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

THE ANALYSIS AND DESIGN

OF MULTIPLE COLUMN PIERS FOR BRIDGES

VERSION IV

A FORTRAN COMPUTER PROGRAM

VOLUME I

A USER'S MANUAL

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

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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 workload 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.

Glen H. Sikes
April 30, 1981

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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, steel "H" or other type piles may be used for columns. The pier may have from one to eight columns or up to 12 piles all of which may be sloped (centerline not vertical), battered (section varies lineally) in either direction, and unequal in length. Single column piers cannot be sloped.

The cap portion of the pier can have a variation in depth but the centerline 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 or pile 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 or pile 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 the 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. Earthquake Forces

Seismic forces can be applied to the pier if they are included in the input data. These should be obtained from SEISAB 1.

10. 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 the 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
Group 7:	D.L. + S.F. + E.Q. (load factor gamma = 1.0)

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
E.Q. = Earthquake

NOTE: Group 1B is not considered by the program but can be simulated quite easily using load factor.
Group 1A, using service load, can be simulated in a separate run of the job by increasing allowable stresses by 50%, doubling the live load, and eliminating any stream flow, etc.

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. 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.

3. The program will combine the seismic loads with dead loads to maximize the magnitude of the seismic effect. Therefore, only the absolute value of the seismic forces from SEISAB should be entered.

PROGRAM FUNCTIONS

The program performs four basic analysis and design functions considering service load and/or load factor options. Item 1 is always obtained, whereas, Items 2, 3 and 4 are optional.

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. For pile bent, computes and reports the moment, shear and reaction at the top of the pile. Computes and reports a Group 1, 2, and 4 moment envelope of the cap, and the maximum shear on each side of column or pile centerlines 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. Computers 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.

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 centerline to centerline of columns or pile (cap members), and from the top of the footings to the cap (nominal depth-not including haunch) centerline for column members, or from cap centerline to point of fixity (or rotation) for pile 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 (centerline 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 together. The bar cutoff points are not computed.

The concrete stress is computed by conventional means for service load. The minimum area of steel in the cap is not checked for service load. The minimum area of steel is checked for load factor design. Serviceability requirements are computed and displayed along with maximum service load members. The amount of steel required is not determined using these ratios. 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 AASHTO Formula 8-43, with the given reinforcement (minimum or lower limit) used to compute IS. The program uses two values of B if specified in the input. Delta (magnification factor) for each Column D 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, transverse moment, and longitudinal moment.

Basically the program follows Articles 8.15.4, 8.16.4 and 8.16.5 of the AASHTO Specifications.

Pile Bent Analysis

The pile bent analysis procedure used in the pile bent option computes pile loads (P, MT, ML, VL) at the top of the pile using group loadings. The program analyzes two critical cases. The first is based on maximum P-load and the second on maximum V-load.

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. The minimum area of steel in the footing is not checked for service load. The minimum area of steel is checked for load factor design. AASHTO Article 4.3.4.7 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 (MT or ML) will be incremented unless the width ratio is exceeded.

In the case of a pile footing, the critical section for beam shear is at D from the face of the column. Pile load contribution to shear is based on Article 4.4.7. Critical section for 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 section

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.

For more detailed information, refer to Volume II, method of solution to be published at a later date.

The user of this program should realize that, with an analysis problem, there is a finite solution; in other words, there is only 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 best 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 is entered on two types of input forms: a pier description form and a pier loads form. 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 has space for 10 live load cases. If the engineer uses 10 (or less) live load cases, only one sheet of this type is required per problem. However, if more than 10 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, thus, less than 10 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. Seismic Forces

5. Dead Load Superstructure

6. 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 (*B03 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. An XX in Columns 9 and 10 will eliminate the column output data. This information will head the output data.

B. Design Data (01 or 02 in C. C. 1, 2)

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

The first line is to contain the following:

The first two columns contain the line number 01.

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. Column (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 or pile (for pile bent) adequacy using the input data. To bypass the column design/investigation process, leave blank.

3. Footing (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, or 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. Cantilever (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. Column (C.C. 8-9) Form: XX (01-08)

Enter in this data field the number of columns or piles (for pile bent). This number may be from one to eight (even greater, because the program is easily modified to consider nine or more columns) or up to 12 piles (for bile bent). Hence, two card columns are reserved for this number. A blank, zero (00), or a number greater than the program capacity will result in an error message and the program will abort.

7. No. Live Load Case (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. FC' (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 FC'.

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 $33(145)^{1.5}$ FC'

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. C (C.C. 47-50) Form: .XXXX Units/Unit

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 8.16.8.4 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 06.

21. Max. B. B. (C.C. 60-61) Form: XX (Number of)

Enter the maximum number of bottom cap bars allowed per horizontal row in these columns. The default is 06.

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.

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 zero bars.

24. Top Clear (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 of any portion of the bar diameter. The default is 2.0 inches.

25. Min. Str. Sp. (C.C. 69-71) Form: X.XX Inches

Enter the minimum acceptable stirrup spacing, in inches, in these columns. The default is 4.00 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 3.00 inches.

27. Bott. Clear (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 of any portion of the main reinforcement bar diameter. The default is 2.31 inches.

The second line of design data should contain the following:

The first two columns contain the line number 02.

COLUMN DESIGN DATA

The Column Design Data may be skipped if an investigation or a 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 1.00%.

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 8.00%.

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 2.563 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 an "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 the 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. C (C.C. 20-22) Form: X.XX

Enter the compression capacity-reduction factor in these columns. The default value is 0.75 for load factor design and 0.35 for service load design.

35. F (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 Article 8.16.1.2. 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 Article 8.16.5.2.7. Otherwise, the program computes the value (no value input) or uses the input value. One column piers are considered unbraced.

37. BD1 (C.C. 29-31) Form: X.XX

See AASHTO Article 3.22-Loading combinations, and Table 3.22.1A. 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 0.75. The default value is 1.00.

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 a design of the footings is not desired. However, for pile bents the pile capacity is required.

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 Article 3.8. 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 0.120 kips per cubic foot.

41. Allowable Soil Press. (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 2.50 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 5.00 feet.

44. Edge Distance (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 1.250 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 00.750 feet.

46. Clear. (C.C. 62-65) Form: X.XXX Inches

    Enter reinforcement bar clearance 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 3.000 inches.

47. Pile Capacity (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 or pile bent analysis.

48. Pile Uplift (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: X (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 nonexistent cap sections should be left blank. The cap is assumed to be rectangular in shape and level. At least 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 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 linear 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 position 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 or pile (for pile bent) to the end of the cantilever or to the centerline of the other adjacent column or pile (for pile bent). 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" of 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. XB1 (C.C. 39-43) Form: XX.XXX Feet

The XB1 dimension is the distance from the centerline of the column or pile (for pile bent) 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 XB1 dimension is the distance from the adjacent column or pile (for pile bent) 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 XB1) 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 nonexistent 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 (21-28 in C.C. 1, 2)

The input data for each column or pile (for pile bent) is entered on one line of the column data. Five lines are provided on the form for defining up to five columns; however, the program can handle up to eight columns or 12 piles for pile bent. The columns are considered numbered from left to right.

Column one (left most) data is entered on the first line (21 in C.C. 1,2) and then the data for each remaining column is 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 or pile (for pile bent) has a P-load (beam) on the centerline, the digit one (1) should be entered in this column. Otherwise, this column should be left blank. A P-load designated on the centerline will be ignored when computing moment and shear in the cap. However, the magnitude of the P-load is added to the column or pile 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 or pile (for pile bent) 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 centerline 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 sectior 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 is 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: 1, 2, 3, 4, P, or Blank

Enter "1" to define a steel HP 12x53 or "2" for HP 14x73 and "3" to define a 12" prestress concrete pile, "4" for a 20" concrete pile, or "P" for a special 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 centerline of the cap measured along the centerline of the column, in feet. For pile bent, HT is the length of the pile from the point of rotation or point of fixity to the centerline of the cap. 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 centerline of the cap in feet along the centerline 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

For reinforced concrete columns enter 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.

For pile bent analysis, DT will default to the correct value unless "P" is entered in Column 6. In this case, DT cannot be left blank, an equivalent DT must be calculated, see Example Problem No. 5.

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 DL dimension. For a hollow round column, the inside diameter of the column 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 centerline 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 or pile for pile bent (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 a 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 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
	X	*	*	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

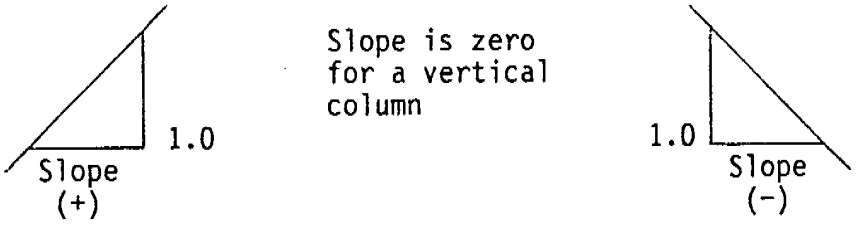
NA - Not applicable (leave blank)
NB1 - Number of bars in B face 1 (left) including corner bars.
ND1 - Number of bars in D face 1 (near) excluding corner bars.
DB2 - Number of bars in B face 2 (right) including corner bars.
ND2 - Number of bars in D face 2 (far) excluding corner bars.
AB - Size of bars 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. Slopes (C.C. 69-72) Form: X.XXX Units/Unit

Slope is the slope of the centerline of the column or pile (for pile bent) in the transverse direction from a vertical line. Following is the sign convention.



13. EP (C.C. 73-76) Form: XX.XX PSI x 10^6

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

14. AP (C.C. 77-80) Form XX.XX Sq. Inches

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

NOTE: EP and AP are not used by the program at present and should be ignored.

E. Footing Data (31-38 in C.C. 1, 2)

The footing data is used to enter the information required to design or analyze (existing) spread or pile footings. Note that if footing data is 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 can consist of up to eight 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. B (C.C. 19-23) Form: XX.XXX Feet

The B 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. This is used only with spread footings.

6. D (C.C. 24-28) Form: XX.XXX Feet

The D dimension is the amount by which the "D" width of 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. T (C.C. 29-33) Form: XX.XXX Feet

The T 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 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 (1,2 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 in this card column to rotate the footing 90 deg. This allows the design to interchange the longitudinal and transverse moments and the shears in the footing.

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 31B to 31F. 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).

PIER LOADS

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 is zero, i.e., enter zeros so the data line will be entered. In the following discussion of the Group 2 wind, refer to Article 3.15 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 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 Article 3.15.2.1.

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 is entered in Column 15, the program will use the entire array of standard Group 3 intensity values. However, blanks in the wind intensities accompanied by a blank in Column 15 will eliminate the Group 2 wind. 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. FLN, 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 the 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 centerline of the cap to the point where the wind on superstructure PT component (parallel to pier) is applied to the pier. This distance should always be positive, i.e., on or above the cap centerline. 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 centerline 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 centerline of the cap. The APL dimension is vertical.

5. Wind on Pier

The wind on the substructure is defined by giving a PT and PL force acting parallel to the pier (PT) and perpendicular to the pier (PL). These forces are given in kips and applied at the centerline 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, on 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 Article 3.15.2.1.

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. FTN, N = 1 - 5

FTN 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. FLN, 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 Article 3.15.2.1.

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 25 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. FTN, 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. FLN, N = 1-5

Enter in these data columns Group 3 wind on 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 centerline of the cap to the point where the wind on live load PT 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 centerline of the cap to the point where the wind on live load PL 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 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. 3.10 of the 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 3.9 of the 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 centerline of the pier cap.

a. APT (C.C. 15-19) Form: XX.XXX feet

The APT dimension is the vertical distance from the centerline 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 centerline 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 bottom 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 temperative, 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 centerline of the cap. The designer must resolve the stream flow force into "equivalent" (as near as possible) forces (PT and PL) which are applied at the pier cap centerline. The stream flow is assumed to be non-reversible and acts from right to left.

a. PT (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. PL (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. Seismic Loading (44 in C.C. 1, 2)

The input data form provides lines for entering the elastic seismic forces and moments direct from SEISAB without modification. The seismic forces and moments may have longitudinal and transverse components associated with each loading. An "01" must be entered in columns 51 and 52 on card 43 if using card 44. Five lines are provided on the form for defining up to five columns or piles, for pile bent. The columns or piles are numbered left to right. If there are more than five columns or piles, additional input sheets may be used.

1. Column Number (C.C. 3, 4)
Enter appropriate column number

Longitudinal Loading

2. VL Top (C.C. 5-9) Form: XXXXX. Kips
Enter the longitudinal component of the shear force applied at the top of the column or pile.

3. VT Top (C.C. 10-14) Form: XXXXX. Kips
Enter the transverse component of the shear force applied at the top of the column or pile.

4. ML Bottom (C.C. 15-19) Form: XXXXX. Kips
Enter the longitudinal moment applied at the bottom of the column. For pile bent leave blank.

5. ML Top (C.C. 20-24) Form: XXXXX. Kips
Enter the longitudinal moment applied at the top of the column or pile.

6. MT Bottom (C.C. 25-29) Form: XXXXX. Kips
Enter the transverse moment applied at the bottom of the column. For pile bent leave blank.

7. MT Top (C.C. 30-34) Form: XXXXX. Kips
Enter the transverse moment applied at the top of the column or pile.

8. P Top (C.C. 35-39) Form: XXXXX. Kips
Enter the axial load applied at the top of the column or pile.

Transverse Loading

9. VL Top (C.C. 40-44) Form: XXXXX. Kips
Enter the longitudinal shear applied at the top of the column or pile.

10. VT Top (C.C. 45-49) Form: XXXXX. Kips
Enter the transverse shear applied at the top of the column or pile.

11. ML Bottom (C.C. 50-54) Form: XXXXX. Kips
Enter the longitudinal moment applied at the bottom of the column. For pile bent leave blank.

12. ML Top (C.C. 55-59) Form: XXXXX. Kips
Enter the longitudinal moment applied at the top of the column or pile.

13. MT Bottom (C.C. 60-64) Form: XXXXX. Kips
Enter the transverse moment applied at the bottom of the column. For pile bent leave blank.

14. MT Top (C.C. 65-69) Form: XXXXX. Kips
Enter the transverse moment applied at the top of the column or pile.

15. P Top (C.C. 70-74) Form: XXXXX. Kips
Enter the axial load applied at the top of the column or pile.

E. 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 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 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 on the pier (including any dummy loads). Note that P1 is always the leftmost P-load. Note 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 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.

PN (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 ten 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, miscellaneous forces, and seismic 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 and third line of each live load case is not required, and therefore, the second and third lines can be used to enter another live load case. However, if there are more than twelve P-loads, the digit two (2) and three (3) must be entered in card column two replacing the digit one (1). Note that the input 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

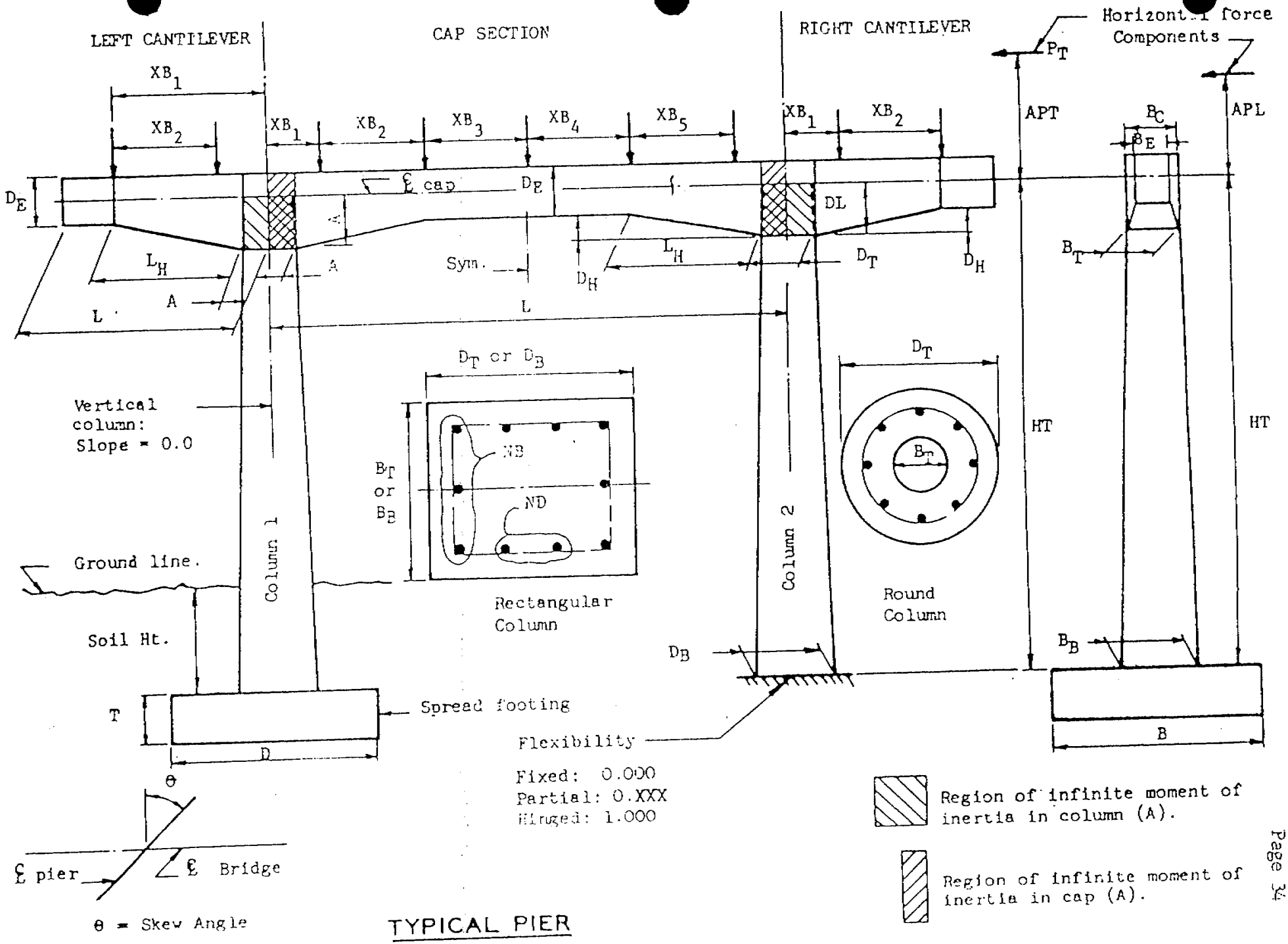
Enter on these data columns the identification number of the live load case. Numbers and letters may be used to identify a live load case. Each live load case will be identified by this I.D. in the output data.

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.

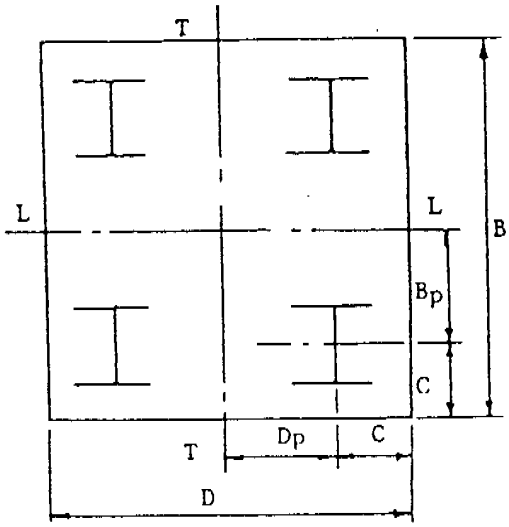
c. PN (C.C. 9-80 N = 1-36) Form: XXX.XXX Kips

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.

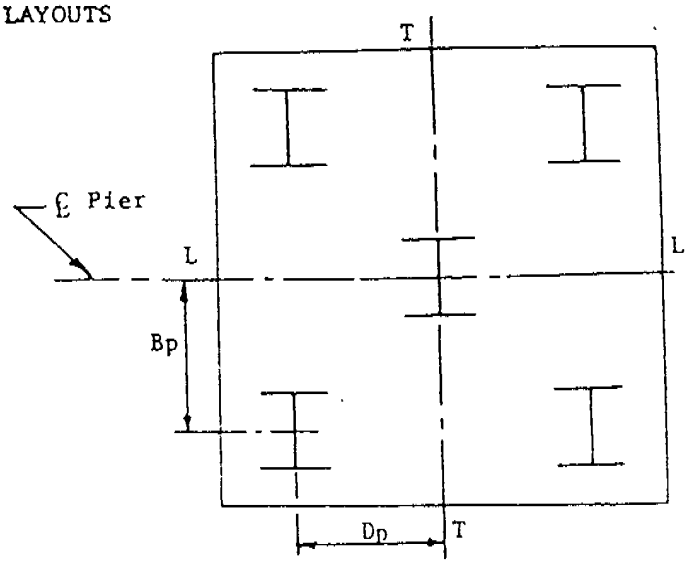


TYPICAL PIER

PILE LAYOUTS

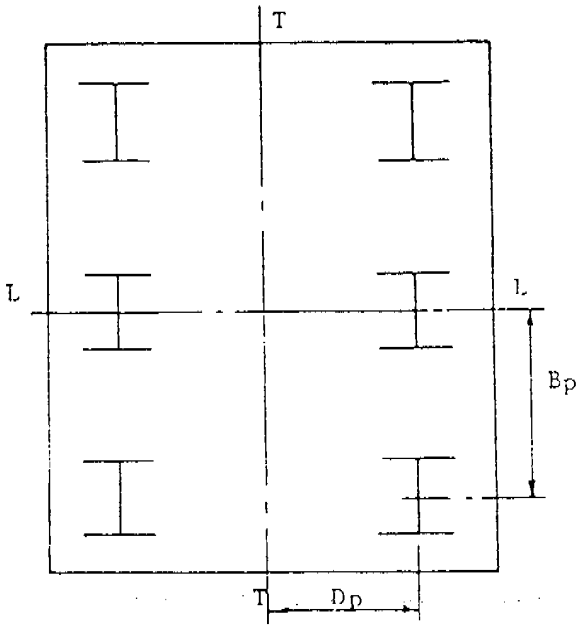


4 Piles

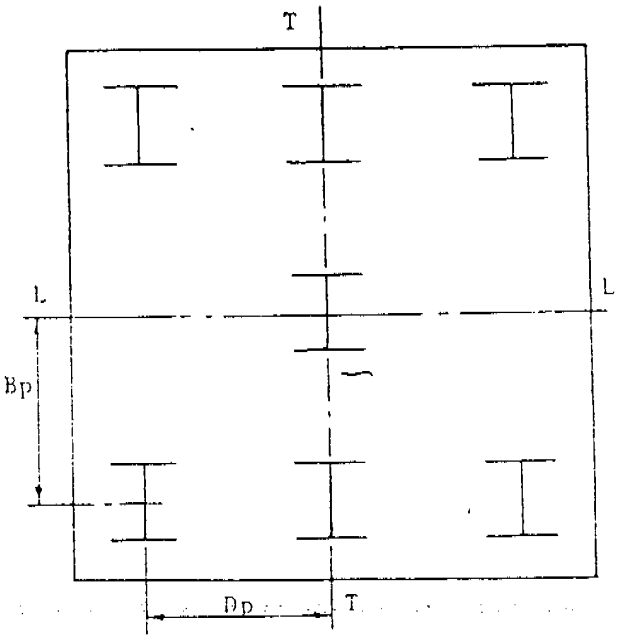


5 Piles

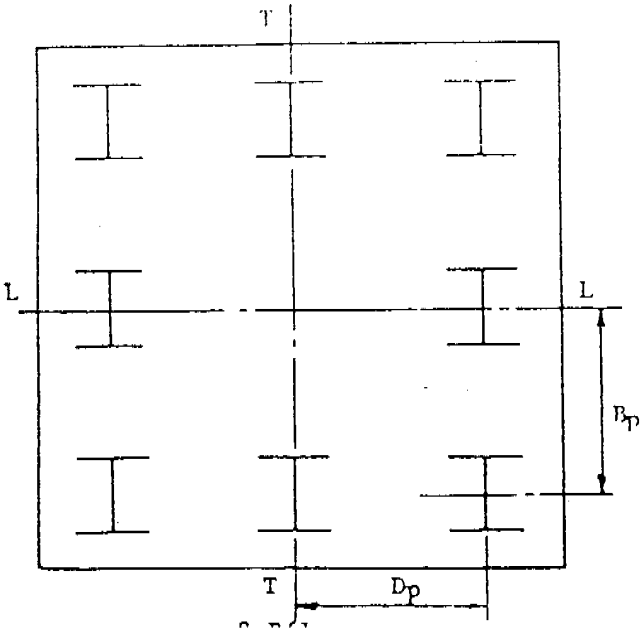
C = Edge Distance in input

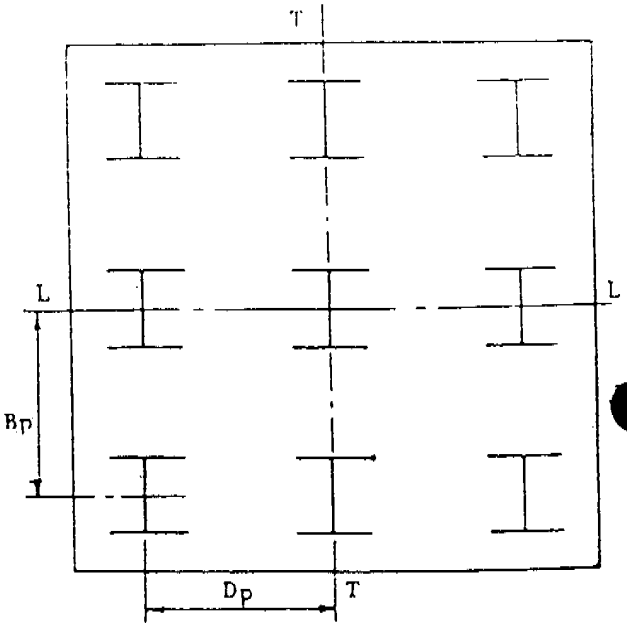


6 Piles

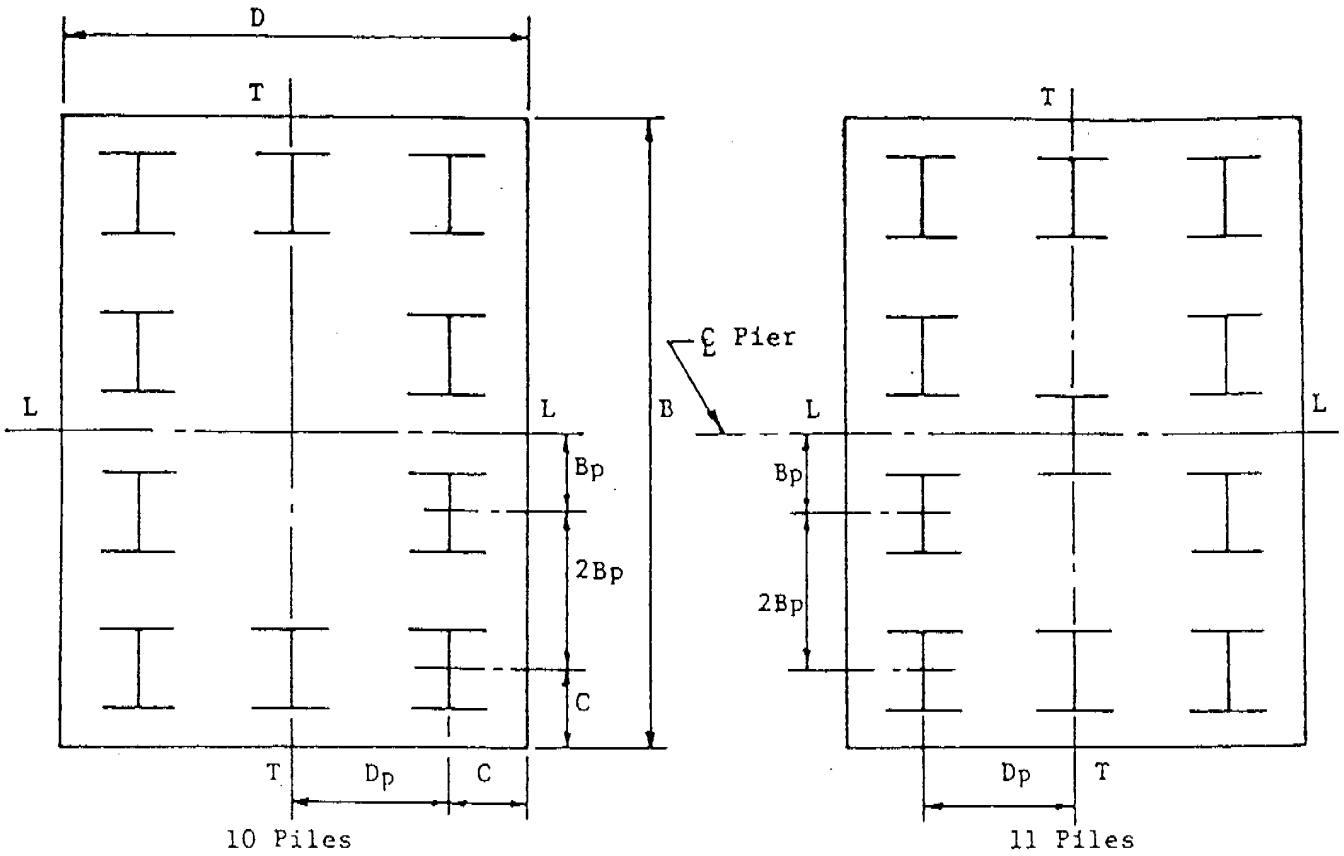


7 Piles

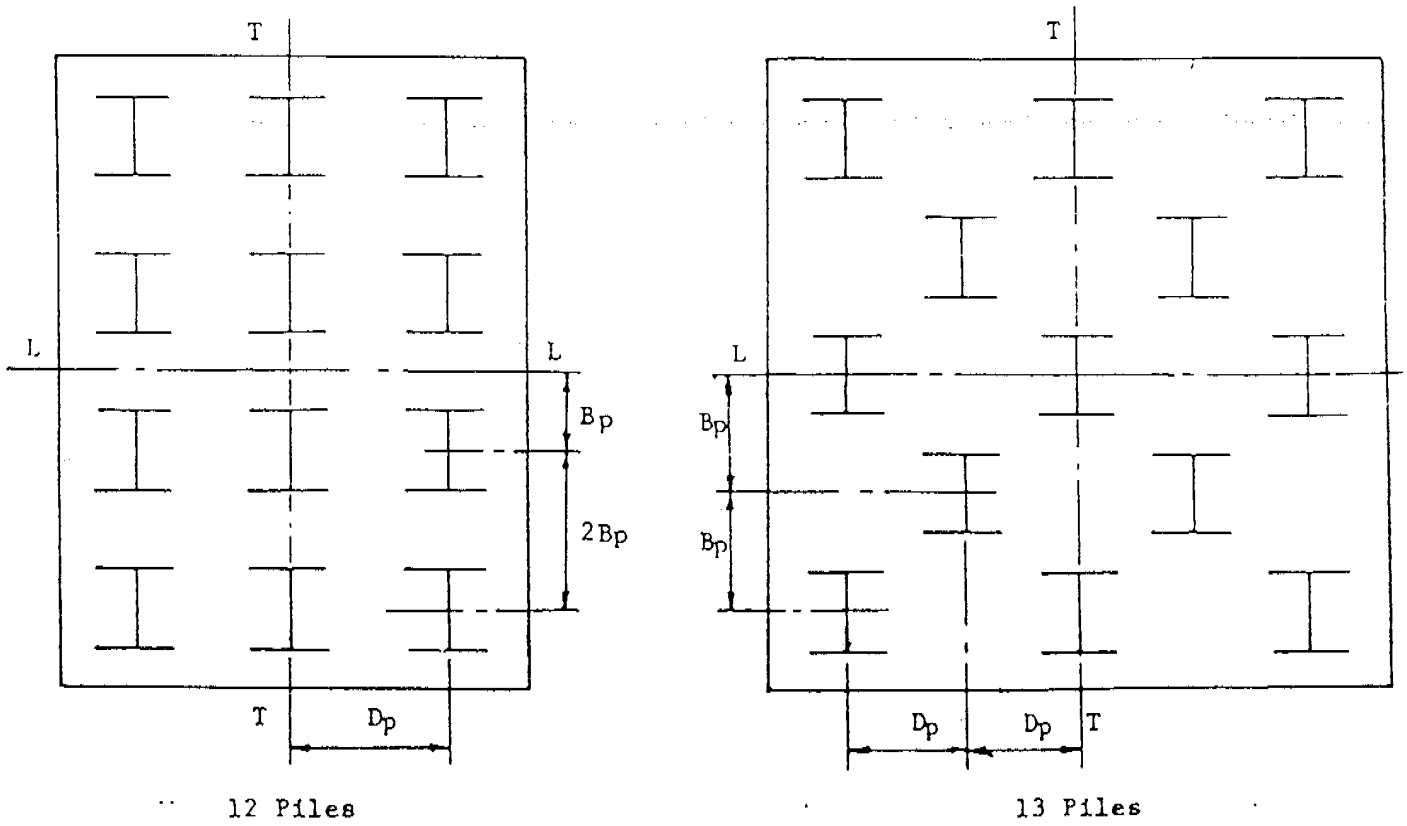




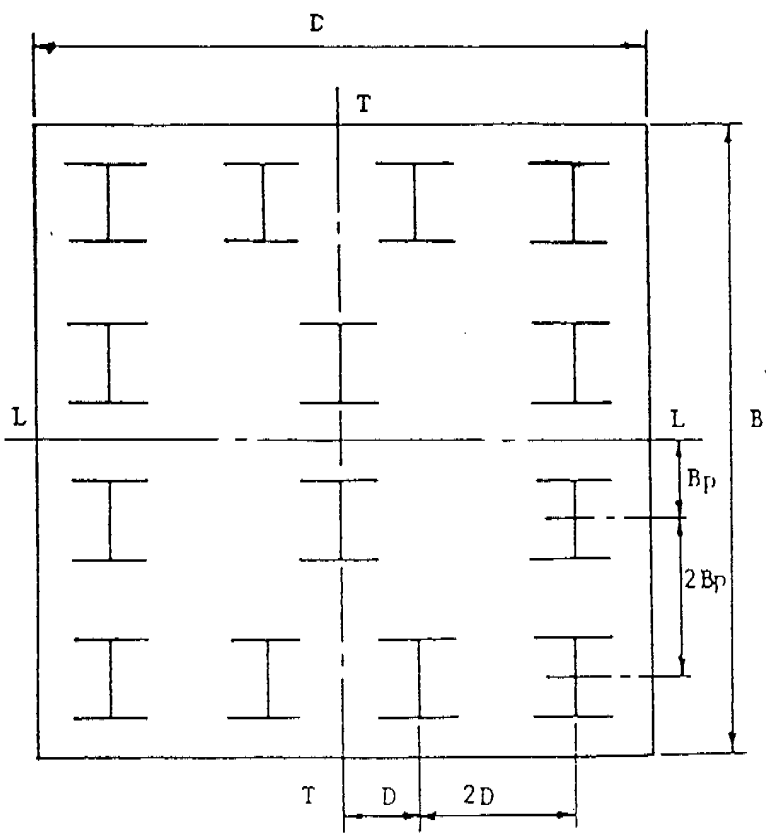
PILE LAYOUTS



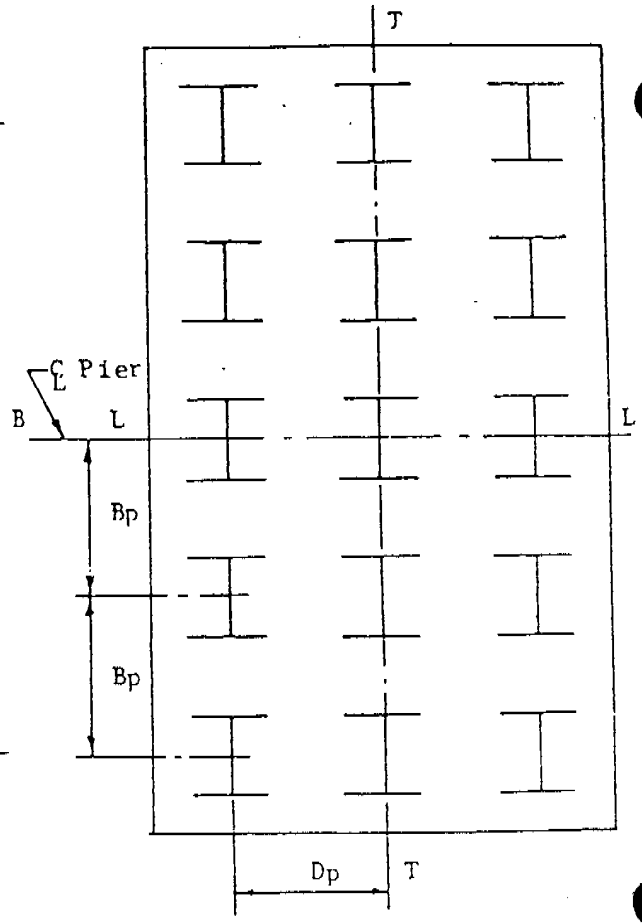
C = Edge Distance in input



PILE LAYOUTS

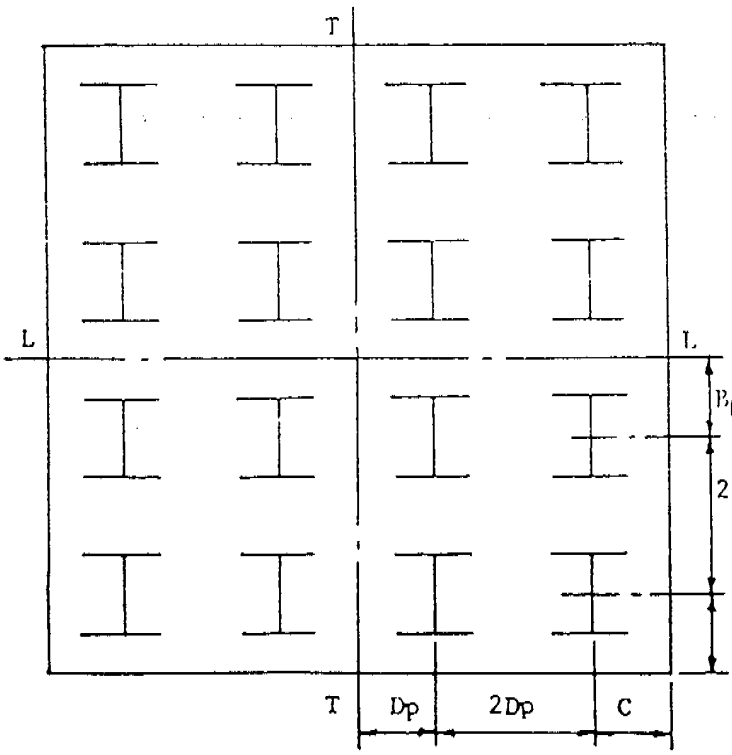


14 Piles

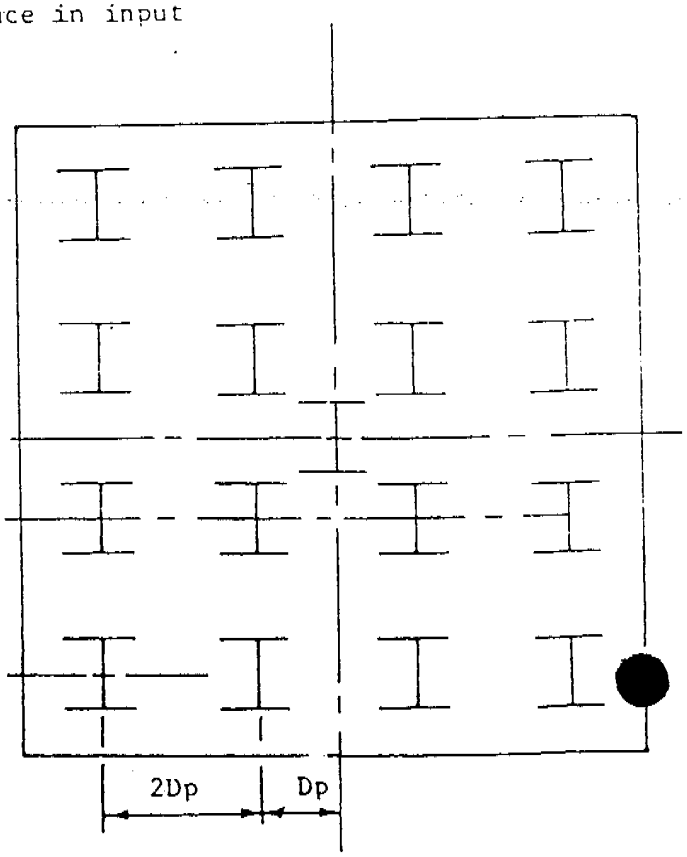


15 Piles

C = Edge Distance in input

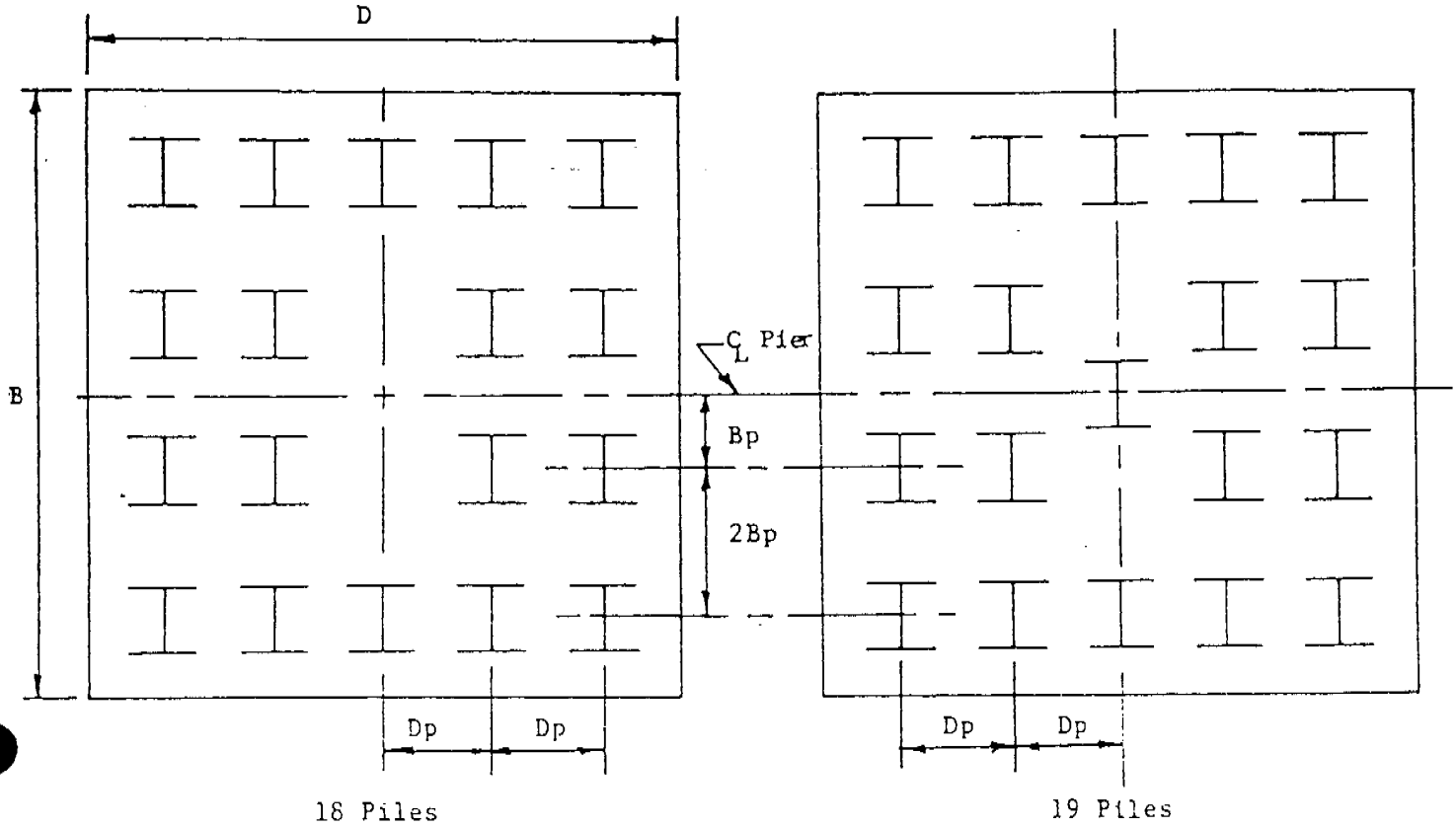


16 Piles

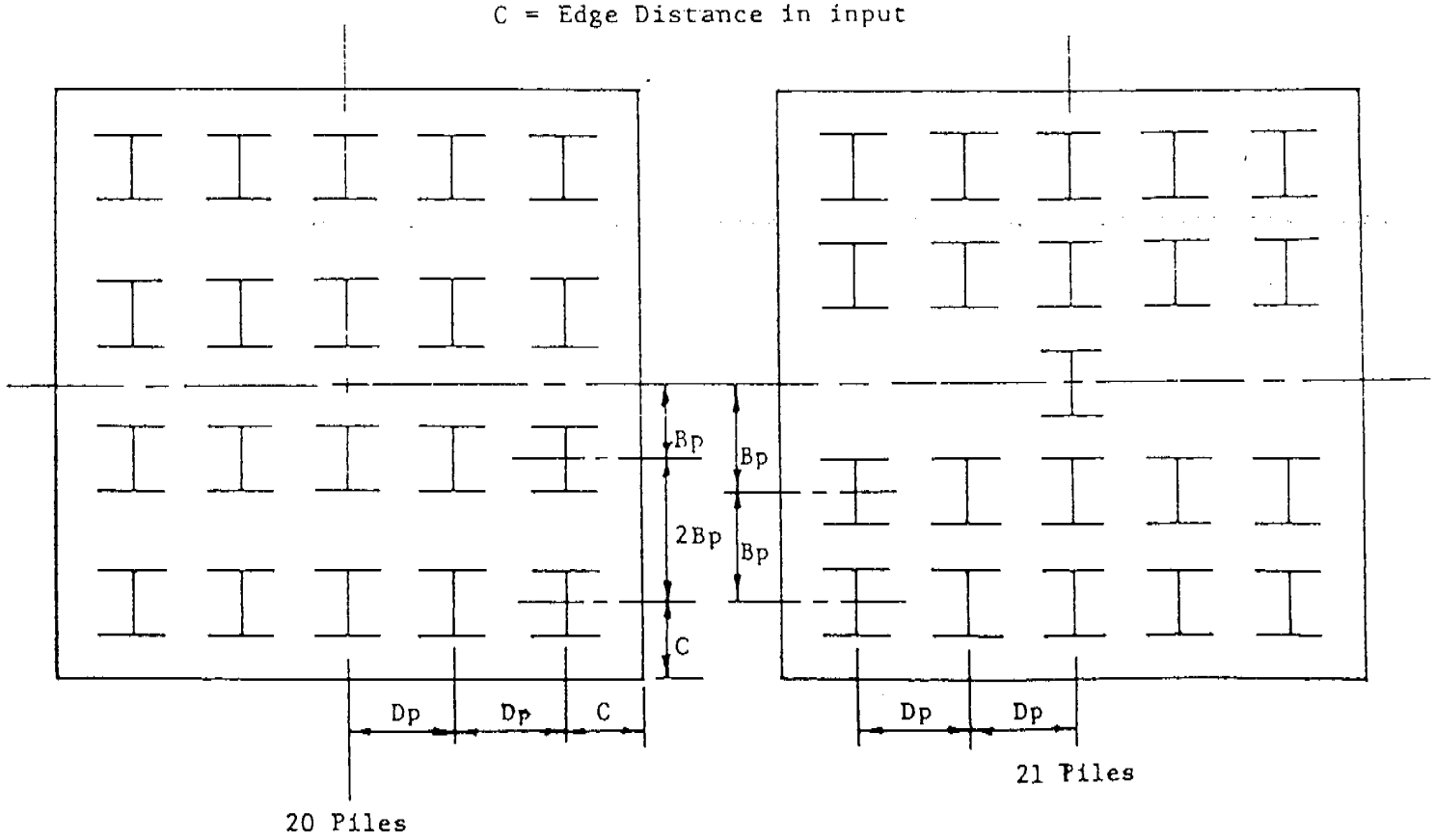


17 Piles

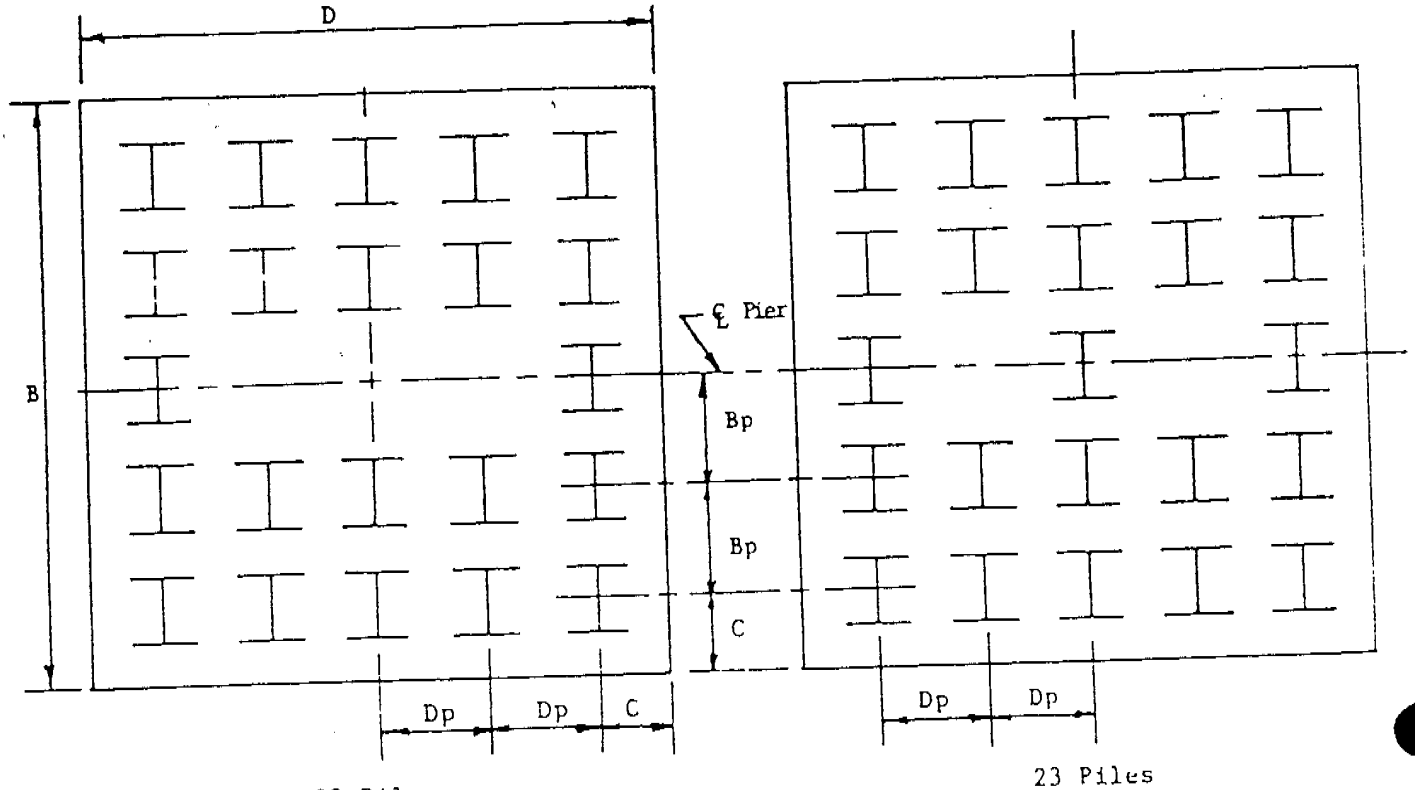
PILE LAYOUTS



C = Edge Distance in input



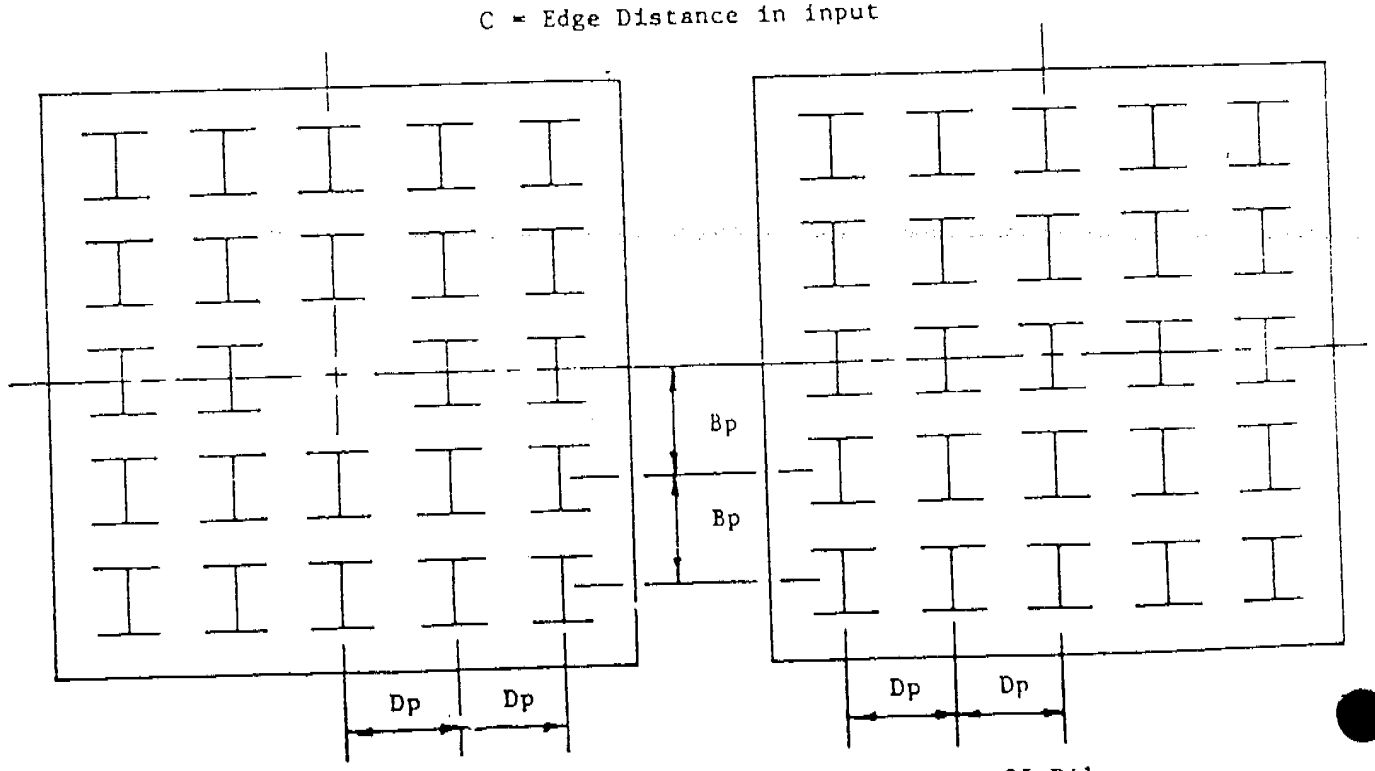
PILE LAYOUTS



22 Piles

23 Piles

C = Edge Distance in input



24 Piles

25 Piles

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET 1 OF __

I. D.

PROG.	PROB. NO.	REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC.
* B 0 3		

DESIGN DATA

CN	DESIGN OPTION: CAP	COLUMN	FOOTING	S & L	CANTILEVER	NO. COLUMN	NO. LIVE LOAD CASE	SKEW ANGLE DEG.	MIN.	SEC.	f'_c PSI (3,000)	f_c PSI (1,200)	N (9)	f_y PSI (40,000)	f_s PSI (20,000)	E_c KSI (3,156)	E_s KSI (29,000)	ϵ_c (.0030)	Z (170.)	BAR SIZE (11)	STR. SIZE (5)	MAX. T. B. (6)	MAX. B. B. (6)	MIN. SIZE (11)	MIN. BARS (0)	TOP CLEAR. IN. (2.0)	MIN. STIR. SP. IN. (4.0)	CAP D. INCR. IN. (3.0)	BOTT. CLEAR. IN. (2.31)
01																													

DESIGN DATA

CN	MIN. P_s % (1.00)	MAX. P_s % (8.00)	MIN. SPAC. IN. (2.25)	CLEAR IN. (2.563)	R	K_L (2.00)	ϕ_C (S-0.35) (L-0.75)	ϕ_F (S-0.35) (L-0.90)	C_M	β_{D1} (1.00)	β_{D2}	IMPACT %	SOIL WEIGHT KCF (.120)	ALLOWABLE SOIL PRESS. KSF	MIN. PL. SP. FEET (2.50)	MAX. PL. SP. FEET (5.00)	EDGE DISTANCE FEET (1.250)	PILE DEPTH FEET (0.75)	CLEAR IN. (3.00)	PILE CAPACITY KIPS	PILE UPLIFT KIPS	IP
02																						

CANTILEVER AND CAP DATA

CN	L FT.	A FT.	D_E FT.	B_C FT.	B_E FT.	D_H FT.	L_H FT.	X_{B1} FT.	X_{B2} FT.	X_{B3} FT.	X_{B4} FT.	X_{B5} FT.	X_{B6} FT.	X_{B7} FT.	X_{B8} FT.
11															
12															
13															
14															
15															
16															

COLUMN DATA

CN	P_O	I	T	S	H_T FT.	A FT.	D_T FT.	B_T FT.	D_B FT.	B_B FT.	D_L FT.	FLEX	REINFORCEMENT STEEL LOWER LIMIT / ACTUAL TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	UPPER LIMIT TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	SLOPE	E_p PSI x 10⁶	A_p SQ. IN.
21																											
22																											
23																											
24																											
25																											

FOOTING DATA

CN	SPR	B FT.	D FT.	T FT.	ΔB FT.	ΔD FT.	ΔT FT.	R B/D	R D/B	SOIL HT FT.	NP	S	B_P FT.	D_P FT.	SETTLE FT.
31															
32															
33															
34															
35															

JUNE 25, 1981

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET _ OF _

GROUP II WIND

CN	SUPERSTRUCTURE AREA TRANS	SUPERSTRUCTURE AREA LONG	S O W	WIND ON SUPERSTRUCTURE INTENSITY FT1 FL1 FT2 FL2 FT3 FL3 FT4 FL4 FT5 FL5	WIND FORCE ARMS APT	APL	WIND ON PIER PT	PL
1 2 / 4 1								

FORCES = KIPS
INTENSITY = LBS/FT²
AREAS = FT²
LENGTHS = FT
TRACTION AND CENTRIFUGAL FORCE = 1 LANE
COEFFICIENTS = UNITS/UNITS

GROUP III WIND

CN	S O W WIND ON SUPERSTRUCTURE INTENSITY FT1 FL1 FT2 FL2 FT3 FL3 FT4 FL4 FT5 FL5	S O W WIND ON LIVE LOAD INTENSITY FT1 FL1 FT2 FL2 FT3 FL3 FT4 FL4 FT5 FL5	LENGTH OF LIVE LOAD TRANS	WIND ON LIVE LOAD ARMS APT	APL
1 2 / 4 2					

* AT LEAST ONE LIVE LOAD CASE IS REQUIRED
MAXIMUM NUMBER OF LIVE LOAD CASES 1 - 25

MISC. FORCES

CN	CENTRIFUGAL FORCE FT	TRACTION FORCE FL	CENTRIFUGAL FORCE & TRACTION FORCE ARMS APT	APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PF	PL	* EQ
1 2 / 4 3									

* COLUMNS 51-52 MUST BE 0.1 FOR SEISMIC CONSIDERATION.

STD W - GR.II, GR.III SUPERSTRUCTURE FT- 50 44 41 33 17
FL- 0 6 12 16 19
STD W - GR.III LIVE LOAD FT- 102 88 82 66 34
FL- 0 12 24 30 38

SEISMIC FORCES

CN	* EQ	LONGITUDINAL LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP	TRANSVERSE LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP
1 2 / 4 4															
4 4															
4 4															
4 4															
4 4															

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES+

CN	ID	NL	P1, 13, 25	P2, 14, 26	P3, 15, 27	P4, 16, 28	P5, 17, 29	P6, 18, 30	P7, 19, 31	P8, 20, 32	P9, 21, 33	P10, 22, 34	P11, 23, 35	P12, 24, 36
5 1	0 - L - 0 0													
6 1														
6 1														
6 1														
6 1														
6 1														
6 1														
6 1														
6 1														
6 1														
6 1														

ED BY ELR APRIL 1, 1991

III. THE OUTPUT DATA

The first sheet of the output data contains 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. The output is listed in a 132 column format. 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 of 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 1-DFC-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. (See Page 97 of this manual)

11. PCBR/PCUBR (Kips)

PCBR is PC from formula (8-42) 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 (8-42) 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. x 10^3)

EITTB is EI from formula (8-43) 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 $\frac{EC\ (IG + IS)/HT}{EC\ (IG/2)/L}$ $\begin{matrix}\text{(Columns)}\\ \text{(Caps)}\end{matrix}$ 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 in 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 column.

Note that the data in the transverse direction are given on the left side of the output form and the date 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.

Note that this data will not be printed if an XX is placed in Columns 9 and 10 of the header card.

Load

The column load effects will be given for the following loads:

Unit Force at Centerline of Cap

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

Footing Settlement (Optional).

Expansion of Cap (Optional).

Shrinkage of Cap (Optional).

Dead Load Total

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

Wind on Substructure (Optional).

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 the superstructure; the PL component of the

wind on the pier is always in the direction 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.

Stream Flow (Optional).

Traction for One Lane of Live Load (Optional).

Centrifugal Force for One Lane of Live Load (Optional).

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.

Seismic Force (Optional)

Seismic Force 1 = Seismic Load Case 1, obtained by adding 100% of the longitudinal seismic forces and moments to 30% of the transverse seismic forces and moments.

Seismic Force 2 = Seismic Load Case 2, obtained by adding 100% of the transverse seismic forces and moments to 30% of the longitudinal seismic forces and moments.

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, 6, 7, 8) 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., centerline 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.

LONGITUDINAL DIRECTION

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.

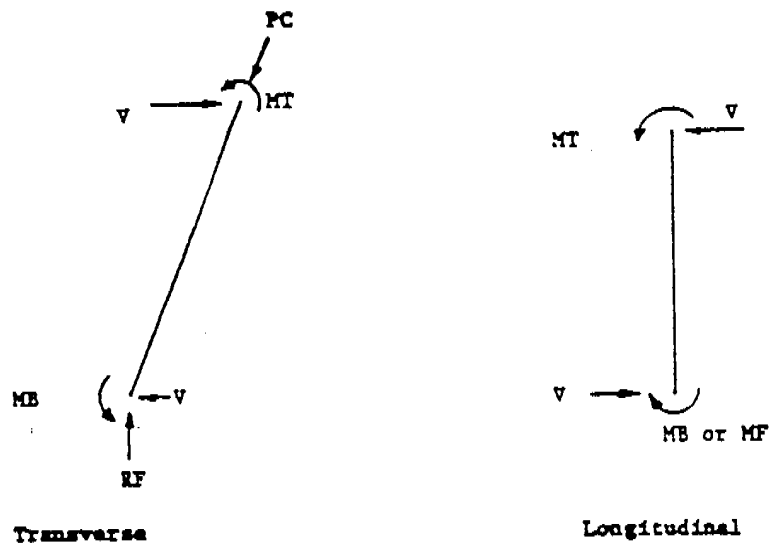
The shear in the column is given in this output data column. This type of data is used in the footing computations.

12. MB.

The data given in this output data column is 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 is 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.



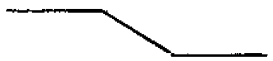
C. Cap Analysis and Design Data

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 centerline. All the moment data or shear 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) then 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 (wind on substructure included). These moments have not been reduced to account for the overstress provisions of the AASHTO Specifications.

Group 3 Maximum Positive Moment (G3 Max. +).

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 provisions 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.

Group 3 Maximum Negative Moment (G3 Max -)

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 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.

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

The data in this column of the output are 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.

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.

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.

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.

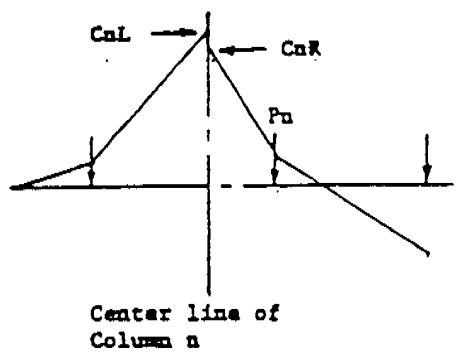
13. Group 1 Maximum Negative Shear on Left (G1 - LT).

    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.

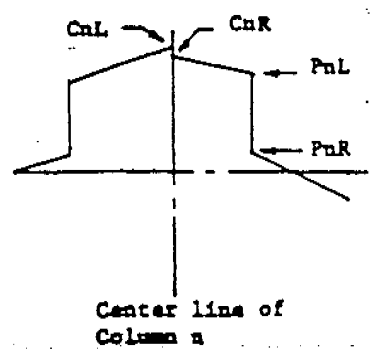
14. Group 1 Maximum Negative Shear on Right (G1 - RT).

    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.

PT.

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

16. 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.

17. M- UNF.

This column contains the maximum negative Group 1 service load moments. They are used in the serviceability computations when load factor is the design option.

18. Top Reinforcement

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.

19. Bot. Reinforcement

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

20. 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 and 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 centerline.

21. Right Stirrups.

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

22. 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 reanalysis is needed with the required depth as input unless circumstances dictate otherwise. A message will be printed in the cap design output if the depth is incremented by the program.

23. 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.

24. PS.

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

25. FS/FF Ratio.

This column contains the ratio of the actual maximum steel stress to steel stress range from service loads. It is used in the serviceability requirements of load factor design only. The amount of steel required is not determined by this ratio. A message will be printed in the cap design output if this ratio exceeds the allowable magnitude.

26. FS/FZ Ratio

This column contains the ratio of the actual maximum steel stress to the allowable given in Formula 8-61 of the AASHTO Specifications. It is considered in Load Factor Design under serviceability requirements when FY is greater than 40000 PSI. The amount of steel required is not determined by this ratio. A message will be printed in the cap design output if this ratio exceeds the allowable magnitude.

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. '7' denotes that Seismic Load Case I controls. "B" denotes that Seismic Load Case II controls.

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. If Group 7 or B is the controlling load case, then the P-load has been modified by the appropriate response modification factor.

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. If Group 7 or B is the controlling load case, then the moment has been modified by the appropriate response modification factor.

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. If Group 7 or B is the controlling load case, then the moment has been modified by the appropriate response modification factor.

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.

21. CN.

The column will appear in this column.

22. T/B.

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

23. 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 face. The B Face includes the corner bars. In a design, this is the required reinforcement steel.

24. AS (Sq. Inches).

The total area of steel is given in this column.

25. PS (%)

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

26. BD12

This factor indicates which BD value was used in the critical load case. Refer to AASHTO Specifications Article 3.22.

27. BD.

BD is the ratio of dead load moment to total load moment and is used to modify the EI value from equation (8-43) of the AASHTO Specifications.

28. 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 8.16.5.2.11 of the AASHTO Specifications.

29. SUMPC (Kips)

SUMPC is the sum of the PC (formula 8-42) 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.

30. DEL.T.

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

31. DEL.L.

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

32. CM.

CM is the factor used in Equation 8-41 of the AASHTO Specifications to compute the magnification factor in the transverse direction.

33. R

The "R" mode value used is given in this column.

34. PHIC

This column contains the ØC value used in the computation.

E. Pile Analysis

Critical Pile Loads

The critical pile loads will contain two maximum load cases used in the pile bent analysis. These two load cases produce:

The maximum pile reaction (max. P-load)

The maximum longitudinal shear at the top of the pile (max. VL-load).

The max. P-load and max. VL-load will be service loads. If Group 7 or B is the controlling load case, then the P-load has been modified by the appropriate response modification factor.

1. CN.

The pile number is given.

2. T/B.

This code indicates the top (T) section of the pile.

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 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.

6. E/S.

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

7. C/F.

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

8. S/F.

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

9. PF. (Kips)

   This column contains the pile reaction.

10. MTF. (Kip-ft.)

    MTF is the moment at the top of the pile in the transverse direction.

11. MLF. (Kip-ft.)

    MLF is the moment at the top of the pile in the longitudinal direction.

12. VLF. (Kips)

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

13. PA. (Kips)

    PA is the allowable pile reaction. This value has been increased by the percent corresponding to the group loading.

14. VLA. (Kips)

    VLA is the allowable horizontal shear at the top of the pile. This value (2 kips) has been increased by the percent corresponding to the group loading.

F. Footing Analysis and Design Data

<u>Footing Design Loads</u>

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 load effects for the other five load cases will be service load or factored loads depending on the design option. If the controlling load case is Group 7 or B, then the moments and forces have been modified by the appropriate response modification factor.

1. FG.

   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 (Kips or Kips/Sq. Ft.).

    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) 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.

20. B (Feet).

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

21. D (Feet).

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

22. T (Feet).

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

23. P1/PA.

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

24. AS (Sq. Inches)

    AS is the required area of reinforcement steel per foot. The minimum area of steel is not checked for service load design. The minimum area is checked for load factor design.

25. No.

    The total number of rebars is given in this column.

26. Size.

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

27. SPAC (Inches).

The rebar spacing is given in this column.

28. 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 perpendicular to pier. Note that the top or bottom bar may be in either direction (depends on magnitude of moment).

29. MT (Kip-Feet/Foot).

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

30. VB (Kips/Foot).

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

31. VP (Kips/Foot).

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

32. DS (Inches).

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

33. FC (KSI)

FC is the concrete stress under the service load option. Under the load factor option, FC is shown as zero.

34. 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 31B through 31F.

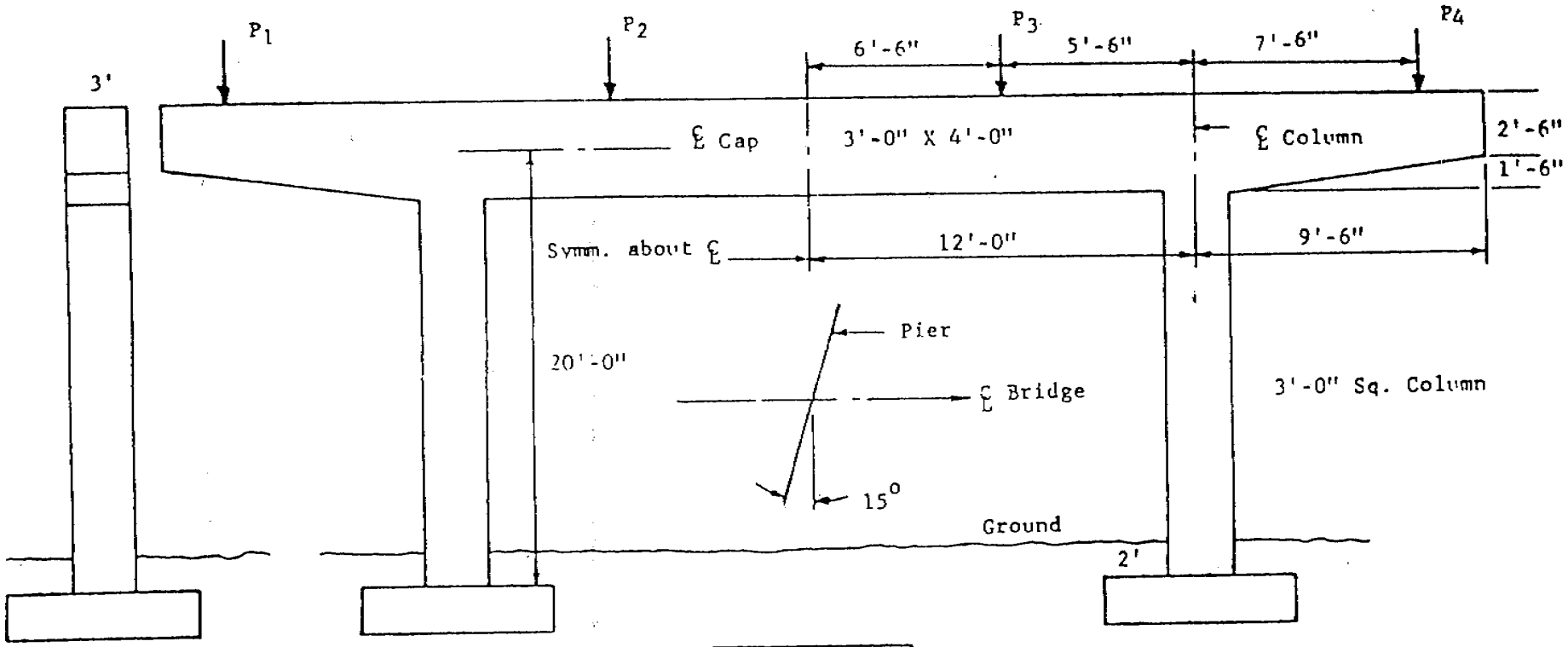
IV. EXAMPLE PROBLEMS

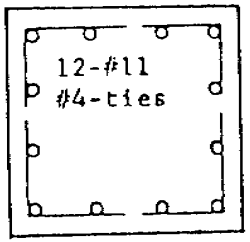
EXAMPLE PROBLEM OF MULTIPLE COLUMN PIER

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. 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.
- A cap, column and footing design are desired.
- Centroid of superstructure area is 6'-0" above centerline of cap.
- For Group II wind, Group III wind, and wind on live load use 0 degree and 60 degree wind skew angles.
- Expansion coefficient equals 3.0×10^{-4}
- Shrinkage coefficient equals 4.4×10^{-4}
- Wind on substructure (equivalent at centerline 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.
- 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 centerline of cap.
- Location of traction and centrifugal force is 6.0 feet above centerline of cap.
- Member properties are desired.
- Use all program defaults, except that ØC = 0.70 (Not default of 0.75).
- 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

STATE
NORTH CAROLINA
DEPT OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET 1 OF 2

I D

PROG	PROB NO	REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC
*8	03	EX. 1 EXAMPLE PROBLEM OF MULTIPLE COL PIER

DESIGN DATA

CN	CAP	COLUMN	FOOTING	S & L (L)	CANTILEVER	NO. COLUMN	NO. LIVE LOAD CASE	SKEW ANGLE DEG	MIN.	SEC	f'c PSI (3,000)	fc PSI (1,200)	N (9)	fy PSI (40,000)	fs PSI (20,000)	Ec KSI (3,156)	Es KSI (29,000)	εc (.0030)
01																		

CN	Z (170.)	BAR SIZE (11)	STR SIZE (5)	MAX. T. B. (6)	MAX. B. B. (6)	MIN. SIZE (11)	MIN. BARS (0)	TOP CLEAR. IN. (2.0)	MIN. STIR. SP. IN (4.0)	CAP D. INCR. IN. (3.0)	BOTT. CLEAR. IN. (2.3)
01											

CN	MIN. Ps % (1.00)	MAX. Ps % (8.00)	MIN. SPAC. IN (2.25)	CLEAR IN (2.563)	R	KL (2.00)	øC (S-0.35)(L-0.75)	øF (S-0.35)(L-0.90)	CM	βD1 (1.00)	βD2	IMPACT %	SOIL WEIGHT KCF (.120)	ALLOWABLE SOIL PRESS. KSF	MIN. PL. SP. FEET (2.50)	MAX. PL. SP. FEET (5.00)	EDGE DISTANCE FEET (1.250)	PILE DEPTH FEET (0.75)	CLEAR IN. (3.00)	PILE CAPACITY KIPS	PILE UPLIFT KIPS	IP
02							0.70							8000								P

CANTILEVER AND CAP DATA

CN	I	L FT	A FT	DE FT	BC FT	BE FT	DH FT	LH FT	XB1 FT	XB2 FT	XB3 FT	XB4 FT	XB5 FT	XB6 FT	XB7 FT	XB8 FT
11	L	9.500	1.50	2.500	3.00	3.00	1.50	8.00	7.50							
12	C	24.000		4.000	3.00				5.50	13.00						
13	1															
14																
15																
16																

COLUMN DATA

CN	P0	I	T	S	HT FT	A FT	DT FT	BT FT	DB FT	BB FT	DL FT	FLEX	REINFORCEMENT STEEL LOWER LIMIT / ACTUAL TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	UPPER LIMIT TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	SLOPE	EP PSI x 10^6	AP SQ. IN.
21		C	T		20.00		3.00	3.00			2.00	0.0	2	4	11				6	8	11						
22			1																								
23																											
24																											
25																											

FOOTING DATA

CN	S & P	B FT	D FT	T FT	ΔB FT	ΔD FT	ΔT FT	RB/D	RD/B	SOIL HT FT	NP	S	BP FT	DP FT	SETTLE FT
31	S	5.00	5.00	2.00	0.250	0.250	0.250	1.50	1.50	2.00					
32	1														
33															
34															

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET _ OF _

FORCES = KIPS
INTENSITY = LBS/FT²
AREAS = FT²
LENGTHS = FT
TRACTION AND CENTRIFUGAL FORCE = 1 LANE
COEFFICIENTS = UNITS/UNITS

GROUP II WIND

CN	SUPERSTRUCTURE AREA TRANS	SUPERSTRUCTURE AREA LONG	STD W	FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	WIND FORCE ARMS APT	WIND FORCE ARMS APL	WIND ON PIER PT	WIND ON PIER PL
41	500	1000	50	01	71	9								6000	6000	2424	8360

GROUP III WIND

CN	STD W	FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	STD W	FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	LENGTH OF LIVE LOADS TRANS	LENGTH OF LIVE LOADS LONG	WIND ON L.L. ARMS APT	WIND ON L.L. ARMS APL
42	50	01	71	9									100	03	98								1000	2000	1150	1150

* AT LEAST ONE LIVE LOAD CASE IS REQUIRED
MAXIMUM NUMBER OF LIVE LOAD CASES 13 25

MISC. FORCES

CN	CENTRIFUGAL FORCE FT	TRACTION FORCE FL	CENTRIFUGAL FORCE & TRACTION FORCE ARMS APT	CENTRIFUGAL FORCE & TRACTION FORCE ARMS APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PT	STREAM FLOW PL	* EQ
43	300	490	1150	1150	0003	00049	210	000	

* COLUMNS 51,52 MUST BE 0.1 FOR SEISMIC CONSIDERATION.

	FT				
STD W - GR.II. GR.III	58	44	41	33	17
SUPERSTRUCTURE	0	6	12	16	19
STD W - GR.III	123	88	82	66	34
LIVE LOAD	0	12	24	32	30

SEISMIC FORCES

CN	SOIL	LONGITUDINAL LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP	TRANSVERSE LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP
44															
44															
44															
44															
44															

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES+

CN	ID	NL	P1. 13. 25	P2. 14. 26	P3. 15. 27	P4. 16. 28	P5. 17. 29	P6. 18. 30	P7. 19. 31	P8. 20. 32	P9. 21. 33	P10. 22. 34	P11. 23. 35	P12. 24. 36
51	0-L-08		10000	10000	10000	10000								
61	1001	2	4500	1500	1500	4500								
61	0110	2	1000	5000	5000	1000								
61	1010	2	4500	2500	4000	1000								
61	0101	2	1000	4000	2500	4500								
61	010	1	000	3000	3000	000								
61														
61														
61														
61														
61														

ICED BY FLB APRIL 1, 1991

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+++++          THE ANALYSIS AND DESIGN OF PIERS FOR BRIDGE -  V 4.2.03 - AASHTO SPECS 1984 INTERIM
PROBLEM NO. EX.1INPUT DATA          EXAMPLE PROBLEM OF MULTIPLE COL PIER PROGRAM V 4.1                    07/14/86
                                                    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  15-00-00 3000. 1200. 9.2 40000. 20000. 3156. 29000. 0.0030 170.  11   5   6   6   11   0  2.00  4.00 3.00 2.31
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  2.563   0  2.00 0.75 0.90 0.00 1.00 0.00  0.00  0.120    8.000  2.50  5.00  1.250 0.750 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  2 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  2 SAME AS FOOTING 1
+++++                                               GROUP II WIND
SUPERSTRUCTURE AREA*STD.        WIND ON SUPERSTRUCTURE INTENSITIES       * WIND FORCE ARM  * WIND ON PIER
  TRANS.     LONG.  WIND FT1 FL1   FT2 FL2   FT3 FL3   FT4 FL4   FT5 FL5     APT     APL      PT      PL
  [illegible]00.    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 ON SUPERSTRUCTURE INTENSITIES    *  STD. *      WIND ON LIVE LOAD INTENSITIES      *  LENGTHS OF LL * WIND ON LL ARMS
WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5  WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5   TRANS.  LONG1.   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.  TRACTION FORCE AND ARMS   EXPANSION   SHRINKAGE     STREAM FLOW
  FT       FL      APT     APL    COEFFICIENT COEFFICIENT    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	R RGL
1	613511.5	0.5000	0.5000	0.6223	1.0000	0.3777	0.3777	0.030375	11.7	113377.0	6350.6	46013.4	179382.9	0.4	10.7
	613511.5	0.5000	0.3436	0.0000	1.0000	0.0000	0.0000	0.5000	24.2	26351.9	18.0	46013.4	179382.9	0.0	10.7
2	613511.5	0.5000	0.5000	0.0000	0.3777	1.0000	0.3777	0.030375	11.7	113377.0	6350.6	46013.4	179382.9	0.4	10.7
	613511.5	0.5000	0.3436	0.6223	0.0000	1.0000	0.6223	0.5000	24.2	26351.9	18.0	46013.4	179382.9	0.0	10.7

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	1010733.8	0.2015	86.3999	3.2680	0.9716						
	1211875.0	1010733.8	0.2015	75742.1	0.9716	3.2680						

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

LOAD	COL	PC	MT	V	MB	RF	ML	MR	* MT	LONGITUDINAL V	MB	MF
				TRANSVERSE								
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	-181.835	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	-152.148	-11.411	-76.074	260.300	812.775	-660.627	0.000	0.000	0.000	0.000
		260.300										
	2	236.000	152.148	11.411	76.074	260.300	660.627	-812.775	0.000	0.000	0.000	0.000
		260.300										
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	143.198	16.247	0.000	-122.523	17.522	-0.945	0.516	0.516
	2	-16.247	122.523	13.286	143.198	-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	143.198	16.247	0.000	-122.523	34.242	7.415	167.716	167.716
	2	-16.247	122.523	13.286	143.198	-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	-72.970	-12.256	-293.584	-293.584
	2	-9.258	71.709	7.776	83.810	-9.258	-71.709	0.000	-72.970	-12.256	-293.584	-293.584
2 WIND 2 2	1	3.020	26.360	2.858	30.808	3.020	0.000	-26.360	90.570	14.456	350.782	350.782
	2	-3.020	26.360	2.858	30.808	-3.020	-26.360	0.000	90.570	14.456	350.782	350.782
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

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

LOAD	COL	PC	MT	V	MB	RF	ML	MR	* MT	LONGITUDINAL V	MB	MF
				TRANSVERSE								
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
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

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CAP ANALYSIS AND DESIGN DATA

CAP MOMENTS AND SHEARS

POINT	MOMENTS(KIP-FEET) D.L.TOT.	G1 MAX.+	G1 MAX.-	G2 MAX.+	G2 MAX.-	G3 MAX.+	G3 MAX.-	** SHEARS(KIPS) 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	-1056.607	-1056.607	-1789.320	-1056.607	-1056.607	-1056.607	-1495.357	-148.720		-148.720		-246.415	
C 1R	-858.815	-858.815	-1538.995	-699.536	-1030.682	-805.668	-1405.984		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	285.454	-279.201	68.327	-111.044	236.760	-242.604	-15.210	-145.210	17.852	-145.210	-44.328	-253.760
C 2L	-858.815	-858.815	-1491.667	-686.948	-1018.094	-758.340	-1358.656	-158.080		-158.080		-266.630	
C 2R	-1056.607	-1056.607	-1789.320	-1056.607	-1056.607	-1056.607	-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	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI	PS %	FS/FF RATIO	FS/FZ RATIO
P 1	-2.362	-2.362	0.04	1 # 11	0.00	0 # 11	0.00	0.000	#5@ 0.00	15.50	0.120	#5@ 5.15	34.50		0.00	0.000	0.000
C 1	-660.627	-1150.275	14.68	10 # 11	0.00	0 # 11	21.92	0.067	#5@ 9.30	21.92	0.083	#5@ 7.48	48.00		0.93	0.510	0.000
P 2	112.033	-155.969	3.33	3 # 11	2.64	2 # 11	22.25	0.072	#5@ 8.64	0.00	0.000	#5@ 0.00	48.00		0.36	0.666	0.000
P 3	131.753	-136.248	2.82	2 # 11	3.12	2 # 11	0.00	0.000	#5@ 0.00	22.09	0.070	#5@ 8.82	48.00		0.34	0.598	0.000
C 2	-660.627	-1150.275	14.68	10 # 11	0.00	0 # 11	21.92	0.080	#5@ 7.73	21.92	0.067	#5@ 9.30	48.00		0.93	0.510	0.000
P 4	-2.362	-2.362	0.04	1 # 11	0.00	0 # 11	15.50	0.120	#5@ 5.15	0.00	0.000	#5@ 0.00	34.50		0.00	0.000	0.000

+++++

COLUMN ANALYSIS AND DESIGN OUTPUT

CRITICAL COLUMN LOADS

CN	T B	GR	LLC	WC	R	E S	C F	S F	PF	MTF	MLF	PM	MTM	MLM	PU	MTU	MLU	PU/PM	B	D
1	T	5		1.1	R	S			274.7	-494.2	-21.9	274.7	506.2	87.7	661.8	1219.5	211.4	2.409	36.00	36.00
1	B	5		2.2	R	S			321.6	-360.9	-438.5	321.6	369.2	468.6	619.6	712.3	904.1	1.929	36.00	36.00
2	T	4	1001	0.0		S	C	S	377.2	581.2	13.6	377.2	597.0	123.4	793.9	1254.6	259.2	2.102	36.00	36.00
2	B	5		2.2		S		S	320.6	375.0	438.5	320.6	383.7	468.5	606.0	726.1	886.7	1.892	36.00	36.00

COLUMN DESIGN DATA

CN	T B	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.	26179.	1.024	1.065	1.000	2	0.75
1	B	4 # 11	4 # 11	2 # 11	2 # 11	18.72	1.444	1.00	0.386	620.	27649.	1.023	1.069	1.000	2	0.75
2	T	4 # 11	4 # 11	2 # 11	2 # 11	18.72	1.444	1.00	0.273	801.	30305.	1.027	1.090	1.000	2	0.75
2	B	4 # 11	4 # 11	2 # 11	2 # 11	18.72	1.444	1.00	0.373	620.	27592.	1.023	1.069	1.000	2	0.75

FOOTING 1 DESIGN LOADS

1	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	314.64	190.20	25.94	408.26	13.96	5.027	-1.048	3.791	9.866	14.693	3.250	12.073	MAX.P1
2 4	1001	0.0	S	C	S	408.83	480.17	53.07	31.80	1.01	0.153	-0.320	11.322	11.794	24.531	5.548	15.679	MAX.MT
2 4	1001	0.0	S	C	S	408.83	480.17	53.07	31.80	1.01	0.153	-0.320	11.322	11.794	24.531	5.548	15.679	MAX.VT
1 3	1010	2.1		C	S	466.73	36.29	-4.97	-408.81	-14.12	9.220	3.169	3.692	9.743	15.095	3.186	17.898	MAX.VP
1 3	1010	2.2		C	S	454.19	-47.48	-12.74	530.74	18.14	9.502	1.651	3.099	10.950	64.421	18.838	17.417	MAX.ML
1 3	1010	2.2		C	S	454.19	-47.48	-12.74	530.74	18.14	9.502	1.651	3.099	10.950	64.421	18.838	17.417	MAX.VL
2 3	1001	2.1		C	S	304.99	254.64	31.92	-314.47	-10.86	3.451	-1.262	5.119	9.831	15.939	3.564	11.709	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	7.500	2.000	0.987	0.56	31 # 4 @	4.125	TOP TRAN	33.249	21.893	43.786	19.594	0.000
				1.09	11 # 8 @	8.125	BOT.LONG	68.408	22.836	45.672	20.438	0.000

FOOTING 2 DESIGN SAME AS FOOTING 1

EXAMPLE PROBLEM COMMENTARY

The first page of the output contains a listing of the input data. Numerous headings are shown to assist in checking the input data as well as interpreting the computer output data.

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

The third page contains 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 fourth page contains the cap analysis and design data. For example, the maximum positive moment at beam two (P2) is 112.033 kip-feet for Group I unfactored. Note that for Group III combinations, the maximum positive moment at P2 is 211.123 kip-feet factored. The cantilever dead load moment is larger (1056.607 to 858.815) than the dead load moment immediately inside the column centerline which indicates that a larger column spacing to balance these moments would be a better design.

This page of the output also 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 (1.09 in./ft. longitudinally and 0.56 in./ft. transversely). The footing design loads give the loading combinations which controlled the moments in the footing (transverse and longitudinally) 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.

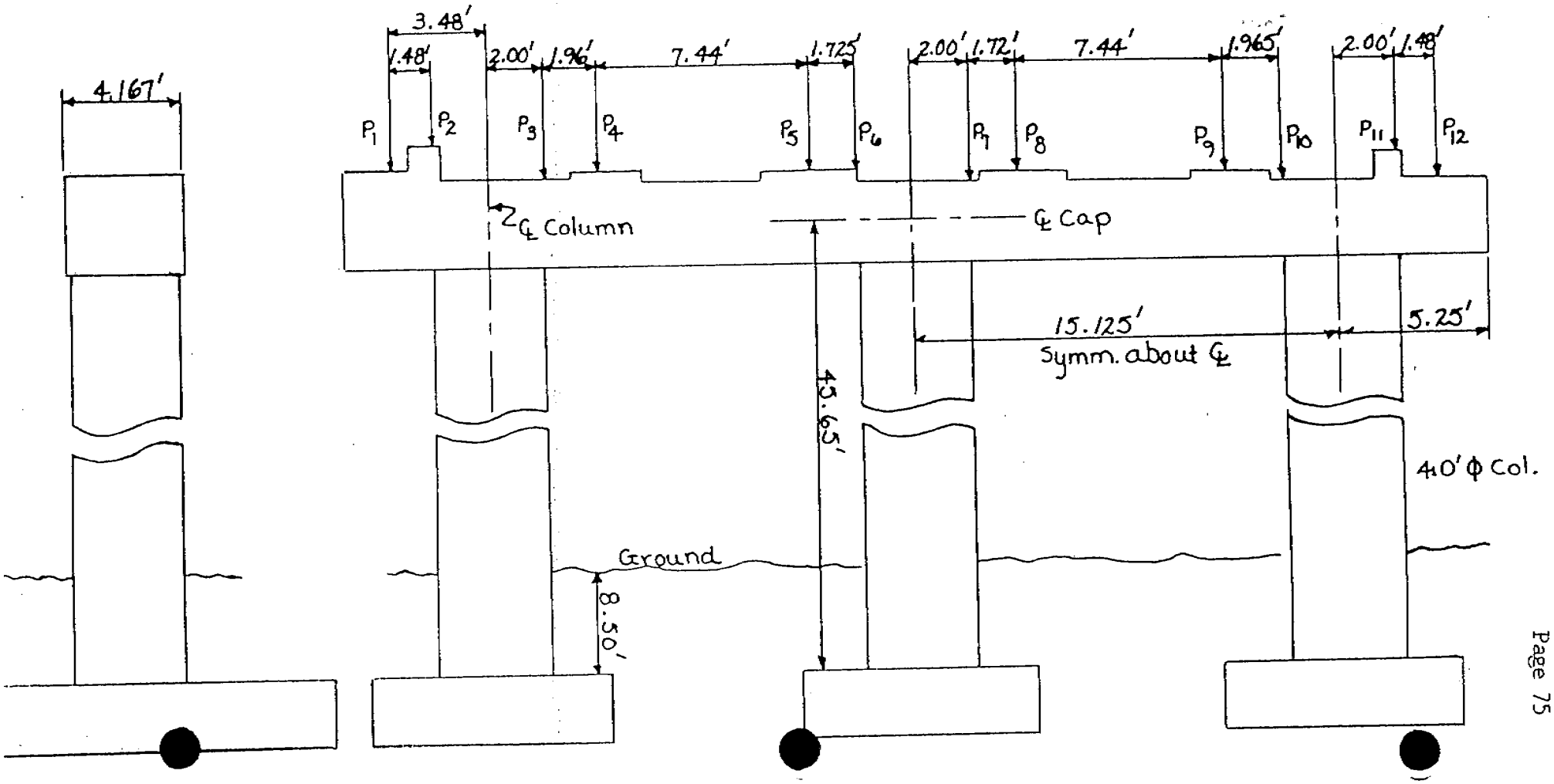
EXAMPLE PROBLEM NO. 1

Given Data: Polk-Rutherford Counties

- Column and cap members have a constant moment of inertia.
- Columns are assumed fixed at bottom (FLEX = 0).
- Footings are spread with a 6'-0" x 6'-0" x 2'-6" minimum size.
- Soil bearing capacity is 6.00 kips per square foot.
- Use 6" increments in footing design and limit either width to a maximum of two times the other width.
- A cap, column, and footing design are desired.
- Centroid of superstructure area is 5.40' above centerline of cap
- For Group II wind, Group III wind, and wind on live load, use standard program defaults.
- Wind on substructure (equivalent at centerline of cap) is 8.950 kips in the transverse direction, and 13.780 in the longitudinal direction.
- Longitudinal force (traction) is 3.012 kips (one lane).
- Dead load from superstructure and extra dead load due to steps and buildups on cap are given on following page.
- Lengths for wind on live load are 66.0 (transverse) and 30.0 (longitudinal) feet.
- Location of wind on live load is 12.66 feet above centerline of cap.
- Location of traction force is 12.66 feet above centerline of cap.
- Use all program defaults.
- Use service load option.
- Use XBN dimensions to position all dummy loads at column faces to obtain cap moments and shears at the column face.

Polk- Rutherford Counties Service Load Design

Gravity Loads (Kips)	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
Dead Load Superstructure	117.23	0	0	113.87	113.87	0	0	113.87	113.87	0	0	118.94
Dead Load Substructure	3.17	0	0	2.624	2.053	0	0	1.465	0.879	0	0	1.063



STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET 1 OF 2

I. D.

PROG.	PROB. NO.	REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC.
* B 0 3	15TR 5 BENT 3 GEORGIA PIER TEST B. S. COX 403 BGPIER1	

DESIGN DATA

CN	CAP	COLUMN	FOOTING	L S or L	CANTILEVER	NO. COLUMN	NO. LIVE LOAD CASE	SKEW ANGLE DEG.	MIN.	SEC.
01	0	0	0	5	2	3	3	13	0	0

CN	f'_c PSI (3,000)	f_c PSI (1,200)	N (9)	f_y PSI (40,000)	f_s PSI (20,000)	E_c KSI (3,156)	E_s KSI (29,000)	ϵ_c (.0030)
01								

CN	Z (170.)	BAR SIZE (11)	STR. SIZE (5)	MAX. T. B. (6)	MAX. B.B. (6)	MIN. SIZE (11)	MIN. BARS (0)	TOP CLEAR. IN. (2.0)	MIN. STIR. SP. IN. (4.0)	CAP O. INCR. IN. (3.0)	BOTT. CLEAR. IN. (2.31)
01											

CN	MIN. Ps % (1.00)	MAX. Ps % (8.00)	MIN. SPAC. IN (2.25)	CLEAR IN. (2.563)	R	K_L (2.00)	ϕ_C (S-0.35) (L-0.75)	ϕ_F (S-0.35) (L-0.90)	C_M	β_{D1} (1.00)	β_{D2}
02									1.00		

CN	IMPACT %	SOIL WEIGHT KCF (.120)	ALLOWABLE SOIL PRESS. KSF	MIN. PL. SP. FEET (2.50)	MAX. PL. SP. FEET (5.00)	EDGE DISTANCE FEET (1.250)	PILE DEPTH FEET (0.75)	CLEAR IN. (3.00)	PILE CAPACITY KIPS	PILE UPLIFT KIPS	IP
02			6.0								P

CANTILEVER AND CAP DATA

CN	I	L FT.	A FT.	D_E FT.	B_C FT.	B_E FT.	D_H FT.	L_H FT.	X_{B1} FT.	X_{B2} FT.	X_{B3} FT.	X_{B4} FT.	X_{B5} FT.	X_{B6} FT.	X_{B7} FT.	X_{B8} FT.
11	C	5.25		3.0	4.167				3.480	1.480						
12	C	15.125		3.0	4.167				2.00	1.960	7.440	1.725				
13	C	15.125		3.0	4.167				2.00	1.720	7.440	1.965				
14	C	5.25		3.0	4.167				2.00	1.480						
15																
16																

COLUMN DATA

CN	P_O	I	T	S	H_T FT.	A FT.	D_T FT.	B_T FT.	D_B FT.	B_B FT.	D_L FT.	FLEX
21		C	R		45.650		4.00				1.65	0.
22		1										
23		1										
24												
25												

CN	REINFORCEMENT STEEL LOWER LIMIT / ACTUAL TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	UPPER LIMIT TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	SLOPE	E_P PSI x 10^6	A_P SQ. IN.
21		12	11					24	11						
22															
23															
24															
25															

FOOTING DATA

CN	SP	B FT.	D FT.	T FT.	ΔB FT.	ΔD FT.	ΔT FT.	R B/D	R D/B	SOIL HT. FT.	NP	S	B_P FT.	D_P FT.	SETTLE FT.
31	5	6.00	6.00	2.50	0.5	0.5	0.25	2.0	2.0	8.50					
32	1														
33	1														
34															
35															

JUNE 25, 1981

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET _ OF _

FORCES = KIPS
INTENSITY = LBS/FT²
AREAS = FT²
LENGTHS = FT
TRACTION AND CENTRIFUGAL FORCE = 1 LANE
COEFFICIENTS = UNITS/UNITS

GROUP II WIND

CN	SUPERSTRUCTURE AREA TRANS	SUPERSTRUCTURE AREA LONG	STOW	WIND ON SUPERSTRUCTURE INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	WIND FORCE ARMS APT	APL	WIND ON PIER PT	PL
41	531	531	1											540	540	895	1378

GROUP III WIND

CN	STOW	WIND ON SUPERSTRUCTURE INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	STOW	WIND ON LIVE LOAD INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	LENGTH OF LIVE LOADS TRANS	LONG	WIND ON L.L. ARMS APT	APL
42	1											1											660	30	1266	1266

* AT LEAST ONE LIVE LOAD CASE IS REQUIRED
MAXIMUM NUMBER OF LIVE LOAD CASES IS 25

MISC. FORCES

CN	CENTRIFUGAL FORCE FT	TRACTION FORCE FL	CENTRIFUGAL FORCE & TRACTION FORCE ARMS APT	APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PT	PL	* EQ
43		301	1266	1266					

* COLUMNS 51,52 MUST BE 0.1 FOR SEISMIC CONSIDERATION.

	F1					FL				
STD W - GR.II, GR.III SUPERSTRUCTURE	58	44	41	33	17	0	6	12	16	19
STD W - GR.III LIVE LOAD	123	88	82	66	34	0	12	24	32	38

SEISMIC FORCES

CN	COL	LONGITUDINAL LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP	TRANSVERSE LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP
44															
44															
44															
44															
44															

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES*

CN	ID	NL	P1, 13, 25	P2, 14, 26	P3, 15, 27	P4, 16, 28	P5, 17, 29	P6, 18, 30	P7, 19, 31	P8, 20, 32	P9, 21, 33	P10, 22, 34	P11, 23, 35	P12, 24, 36
51	D-L-00		120400	0	0	116499	115923	0	0	115335	114749	0	0	120003
61	LL01	3	38830	0	0	34320	39990	0	0	33750	39990	0	0	17850
61	LL02	3	17850	0	0	39990	33750	0	0	39990	34320	0	0	38830
61	LL03	2	38830	0	0	34320	39990	0	0	23340	0	0	0	0
61														
61														
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+++++          THE ANALYSIS AND DESIGN OF PIERS FOR BRIDGE -  V 4.2.03 - AASHTO SPECS 1984 INTERIM
PROBLEM NO.    1INPUT DATA          STR 5 BENT 3  GEORGIA PIER TEST B. S. COX 403 BGPIER1                    07/14/86
                                                    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 S  2   3   3  13-00-00 3000. 1200. 9.2 40000. 20000. 3156. 29000. 0.0030 170.  11   5   6   6   11   0  2.00  4.00 3.00 2.31
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  2.563   0  2.00 0.35 0.35 1.00 1.00 0.00  0.00  0.120    6.000  2.50  5.00  1.250 0.750 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  C  5.250  0.000  3.000  4.167  0.000  0.000  0.000  3.480  1.480
12  C 15.125  0.000  3.000  4.167         0.000  0.000  2.000  1.960  7.440  1.725
13  C 15.125  0.000  3.000  4.167         0.000  0.000  2.000  1.720  7.440  1.965
14  C  5.250  0.000  3.000  4.167  0.000  0.000  0.000  2.000  1.480
                                                    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 R  45.650  0.000  4.000  0.000  0.000  0.000  1.650  0.000   0 12 11  0  0  0  0 24 11  0  0  0  0.000  0.000  0.000
22 0  2 SAME AS COLUMN 1
23 0  3 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  6.000  6.000  2.500  0.500  0.500  0.250  2.000  2.000  8.500   0   0   0.000  0.000  0.000
32  2 SAME AS FOOTING 1
33  3 SAME AS FOOTING 1
+++++                                           GROUP II WIND
SUPERSTRUCTURE AREA*STD.        WIND ON SUPERSTRUCTURE INTENSITIES      * WIND FORCE ARM  * WIND ON PIER
 TRANS.     LONG.  WIND FT1 FL1   FT2 FL2   FT3 FL3   FT4 FL4   FT5 FL5    APT     APL     PT     PL
  531.      531.   1    50   0    44   6    41  12    33  16    17  19    5.400   5.400   8.950  13.780
                                                   GROUP III WIND
STD. *  WIND ON SUPERSTRUCTURE INTENSITIES    * STD. *     WIND ON LIVE LOAD INTENSITIES     * LENGTHS OF LL * WIND ON LL ARMS
WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5  WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5   TRANS.  LONGI.   APT     APL
  1   50   0   44   6   41  12   33  16   17  19   1   100   0   88  12   82  24   66  32   34  38    66.0    30.0  12.660  12.660
                          MISCELLANEOUS FORCES
CENTRI.  TRACTION FORCE AND ARMS   EXPANSION   SHRINKAGE     STREAM FLOW
  FT       FL      APT     APL    COEFFICIENT COEFFICIENT    PT      PL
 0.000    3.012  12.660  12.660   0.00000000  0.00000000   0.000   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  120.400   0.000    0.000  116.494  115.923   0.000    0.000  115.335  114.749   0.000    0.000  120.003
LL01   3   38.830   0.000    0.000   34.320   39.990   0.000    0.000   33.750   39.990   0.000    0.000   17.850
LL02   3   17.850   0.000    0.000   39.990   33.750   0.000    0.000   39.990   34.320   0.000    0.000   38.830
LL03   2   38.830   0.000    0.000   34.320   39.990   0.000    0.000   23.340    0.000   0.000    0.000    0.000
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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	R RGL
1	500400.8	0.5000	0.5000	0.6671	1.0000	0.3329	0.3329	0.004755	24.3	32001.2	2229.1	16442.5	289210.3	0.3	12.3
	500400.8	0.5000	0.3638	0.0000	1.0000	0.0000	0.0000	0.3333	51.5	7110.2	44.0	16442.5	289210.3	0.0	12.3
2	500400.8	0.5000	0.5000	0.6506	0.3494	0.3494	0.2117	0.004755	23.1	35305.7	2229.1	16442.5	289210.3	0.2	12.3
	500400.8	0.5000	0.4162	0.6506	0.5000	0.5000	0.3942	0.3333	51.5	7110.2	44.0	16442.5	289210.3	0.0	12.3
3	500400.8	0.5000	0.5000	0.0000	0.3329	1.0000	0.3329	0.004755	24.3	32001.2	2229.1	16442.5	289210.3	0.3	12.3
	500400.8	0.5000	0.3638	0.6671	0.0000	1.0000	0.6671	0.3333	51.5	7110.2	44.0	16442.5	289210.3	0.0	12.3

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	1002783.8	0.3144	35.7475	1.5060	2.1579	0.6915	0.2295				
	1126832.0	931753.7	0.1859	111751.9	0.2295	0.7653	2.1161	1.5060				
3	0.5000	931753.7	0.1859	35.7475	1.5060	2.1152	0.7669	0.2295				
	1126832.0	1002783.8	0.3144	111751.9	0.2295	0.6899	2.1586	1.5060				

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

LOAD	COL	PC	MT	V	MB	RF	ML	MR	MT	V	MB	MF
				TRANSVERSE				*		LONGITUDINAL		
UNIT F.AT CL.CAP	1	0.707	6.467	0.312	7.756	0.707	0.000	-6.467	0.550	0.333	15.217	15.217
	2	0.000	8.455	0.377	8.750	0.000	-4.228	-4.228	0.550	0.333	15.217	15.217
	3	-0.707	6.467	0.312	7.756	-0.707	-6.467	0.000	0.550	0.333	15.217	15.217
DEAD LOAD TOTAL	1	264.193	-23.731	-0.782	-11.963	347.131	444.833	-421.102	0.000	0.000	0.000	0.000
		347.131										
	2	252.938	-0.925	-0.033	-0.560	335.876	342.071	-341.146	0.000	0.000	0.000	0.000
		335.876										
	3	262.183	24.852	0.814	12.328	345.121	418.600	-443.452	0.000	0.000	0.000	0.000
		345.121										
TRAC. FORCE 1 LN	1	0.763	4.382	0.211	5.255	0.763	0.000	-4.382	-13.999	-0.978	-57.043	-57.043
	2	0.000	5.729	0.255	5.928	0.000	-2.865	-2.865	-13.999	-0.978	-57.043	-57.043
	3	-0.763	4.382	0.211	5.255	-0.763	-4.382	0.000	-13.999	-0.978	-57.043	-57.043
WIND ON SUBSTR.	1	6.328	57.878	2.788	69.412	6.328	0.000	-57.878	-7.579	-4.593	-209.686	-209.686
	2	0.000	75.676	3.373	78.311	0.000	-37.838	-37.838	-7.579	-4.593	-209.686	-209.686
	3	-6.328	57.878	2.788	69.412	-6.328	-57.878	0.000	-7.579	-4.593	-209.686	-209.686
GROUP 2 WIND 1 1	1	29.238	225.172	10.848	270.043	29.238	0.000	-225.171	6.456	-2.603	-108.054	-108.054
	2	0.000	294.415	13.123	304.665	0.000	-147.208	-147.208	6.456	-2.603	-108.054	-108.054
	3	-29.238	225.172	10.848	270.043	-29.238	-225.171	0.000	6.456	-2.603	-108.054	-108.054
GROUP 2 WIND 1 2	1	29.238	225.172	10.848	270.043	29.238	0.000	-225.171	21.614	6.584	311.317	311.317
	2	0.000	294.415	13.123	304.665	0.000	-147.208	-147.208	21.614	6.584	311.317	311.317
	3	-29.238	225.172	10.848	270.043	-29.238	-225.171	0.000	21.614	6.584	311.317	311.317
GROUP 2 WIND 2 1	1	27.124	209.731	10.104	251.526	27.124	0.000	-209.731	-2.523	-3.876	-173.076	-173.076
	2	0.000	274.227	12.223	283.774	0.000	-137.113	-137.113	-2.523	-3.876	-173.076	-173.076
	3	-27.124	209.731	10.104	251.526	-27.124	-209.731	0.000	-2.523	-3.876	-173.076	-173.076
[illegible] 2 WIND 2 2	1	25.854	200.462	9.658	240.409	25.854	0.000	-200.461	27.225	7.380	351.946	351.946
	2	0.000	262.106	11.683	271.232	0.000	-131.053	-131.053	27.225	7.380	351.946	351.946
	3	-25.854	200.462	9.658	240.409	-25.854	-200.461	0.000	27.225	7.380	351.946	351.946
GROUP 2 WIND 3 1	1	26.384	204.328	9.844	245.046	26.384	0.000	-204.328	-10.660	-5.030	-231.999	-231.999
	2	0.000	267.162	11.909	276.463	0.000	-133.581	-133.581	-10.660	-5.030	-231.999	-231.999
	3	-26.384	204.328	9.844	245.046	-26.384	-204.328	0.000	-10.660	-5.030	-231.999	-231.999
GROUP 2 WIND 3 2	1	23.845	185.789	8.951	222.813	23.845	0.000	-185.789	33.678	8.295	398.674	398.674
	2	0.000	242.922	10.828	251.380	0.000	-121.461	-121.461	33.678	8.295	398.674	398.674
	3	-23.845	185.789	8.951	222.813	-23.845	-185.789	0.000	33.678	8.295	398.674	398.674
GROUP 2 WIND 4 1	1	23.141	180.651	8.703	216.651	23.141	0.000	-180.651	-17.770	-6.039	-283.477	-283.477
	2	0.000	236.204	10.529	244.427	0.000	-118.102	-118.102	-17.770	-6.039	-283.477	-283.477
	3	-23.141	180.651	8.703	216.651	-23.141	-180.651	0.000	-17.770	-6.039	-283.477	-283.477
GROUP 2 WIND 4 2	1	19.756	155.932	7.512	187.006	19.756	0.000	-155.932	36.296	8.667	417.630	417.630
	2	0.000	203.884	9.088	210.982	0.000	-101.942	-101.942	36.296	8.667	417.630	417.630
	3	-19.756	155.932	7.512	187.006	-19.756	-155.932	0.000	36.296	8.667	417.630	417.630

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

LOAD	COL	PC	MT	V	MB	RF	ML	MR	MT	V	MB	MF
				TRANSVERSE					*	LONGITUDINAL		
GROUP 2 WIND 5 1	1	16.128	129.435	6.236	155.228	16.128	0.000	-129.434	-25.908	-7.193	-342.412	-342.412
	2	0.000	169.238	7.544	175.130	0.000	-84.619	-84.619	-25.908	-7.193	-342.412	-342.412
	3	-16.128	129.435	6.236	155.228	-16.128	-129.434	0.000	-25.908	-7.193	-342.412	-342.412
GROUP 2 WIND 5 2	1	12.108	100.081	4.822	120.025	12.108	0.000	-100.081	35.452	8.547	411.521	411.521
	2	0.000	130.858	5.833	135.413	0.000	-65.429	-65.429	35.452	8.547	411.521	411.521
	3	-12.108	100.081	4.822	120.025	-12.108	-100.081	0.000	35.452	8.547	411.521	411.521
GROUP 3 WIND 1 1	1	16.010	109.139	5.258	130.888	16.010	0.000	-109.138	9.019	-0.286	-3.559	-3.559
	2	0.000	142.700	6.361	147.668	0.000	-71.350	-71.350	9.019	-0.286	-3.559	-3.559
	3	-16.010	109.139	5.258	130.888	-16.010	-109.138	0.000	9.019	-0.286	-3.559	-3.559
GROUP 3 WIND 1 2	1	16.010	109.139	5.258	130.888	16.010	0.000	-109.138	13.566	2.470	122.252	122.252
	2	0.000	142.700	6.361	147.668	0.000	-71.350	-71.350	13.566	2.470	122.252	122.252
	3	-16.010	109.139	5.258	130.888	-16.010	-109.138	0.000	13.566	2.470	122.252	122.252
GROUP 3 WIND 2 1	1	14.598	100.040	4.820	119.975	14.598	0.000	-100.040	3.802	-0.844	-33.346	-33.346
	2	0.000	130.803	5.830	135.357	0.000	-65.402	-65.402	3.802	-0.844	-33.346	-33.346
	3	-14.598	100.040	4.820	119.975	-14.598	-100.040	0.000	3.802	-0.844	-33.346	-33.346
GROUP 3 WIND 2 2	1	14.035	96.211	4.635	115.384	14.035	0.000	-96.211	16.073	2.766	137.796	137.796
	2	0.000	125.798	5.607	130.178	0.000	-62.899	-62.899	16.073	2.766	137.796	137.796
	3	-14.035	96.211	4.635	115.384	-14.035	-96.211	0.000	16.073	2.766	137.796	137.796
GROUP 3 WIND 3 1	1	14.033	96.447	4.647	115.667	14.033	0.000	-96.447	-0.737	-1.337	-59.573	-59.573
	2	0.000	126.106	5.621	130.497	0.000	-63.053	-63.053	-0.737	-1.337	-59.573	-59.573
	3	-14.033	96.447	4.647	115.667	-14.033	-96.447	0.000	-0.737	-1.337	-59.573	-59.573
GROUP 3 WIND 3 2	1	12.907	88.791	4.278	106.485	12.907	0.000	-88.791	19.257	3.128	156.901	156.901
	2	0.000	116.095	5.175	120.137	0.000	-58.048	-58.048	19.257	3.128	156.901	156.901
	3	-12.907	88.791	4.278	106.485	-12.907	-88.791	0.000	19.257	3.128	156.901	156.901
GROUP 3 WIND 4 1	1	11.963	83.039	4.001	99.587	11.963	0.000	-83.039	-5.119	-1.797	-84.178	-84.178
	2	0.000	108.575	4.840	112.355	0.000	-54.288	-54.288	-5.119	-1.797	-84.178	-84.178
	3	-11.963	83.039	4.001	99.587	-11.963	-83.039	0.000	-5.119	-1.797	-84.178	-84.178
GROUP 3 WIND 4 2	1	10.461	72.831	3.509	87.344	10.461	0.000	-72.831	20.025	3.238	162.516	162.516
	2	0.000	95.227	4.245	98.543	0.000	-47.614	-47.614	20.025	3.238	162.516	162.516
	3	-10.461	72.831	3.509	87.344	-10.461	-72.831	0.000	20.025	3.238	162.516	162.516
GROUP 3 WIND 5 1	1	7.588	54.628	2.632	65.515	7.588	0.000	-54.628	-10.663	-2.360	-114.502	-114.502
	2	0.000	71.427	3.184	73.914	0.000	-35.714	-35.714	-10.663	-2.360	-114.502	-114.502
	3	-7.588	54.628	2.632	65.515	-7.588	-54.628	0.000	-10.663	-2.360	-114.502	-114.502
GROUP 3 WIND 5 2	1	5.805	42.506	2.048	50.976	5.805	0.000	-42.506	18.342	3.103	154.858	154.858
	2	0.000	55.577	2.477	57.512	0.000	-27.788	-27.788	18.342	3.103	154.858	154.858
	3	-5.805	42.506	2.048	50.976	-5.805	-42.506	0.000	18.342	3.103	154.858	154.858
LIVE LOAD LL01	1	68.092	-5.995	-0.128	0.163	68.092	121.616	-115.621	0.000	0.000	0.000	0.000
	2	68.520	9.563	0.383	7.942	68.520	93.237	-102.800	0.000	0.000	0.000	0.000
	3	47.645	-9.889	-0.256	-1.784	47.645	65.795	-55.906	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 LL02	1	47.668	9.890	0.256	1.782	47.668	55.906	-65.796	0.000	0.000	0.000	0.000
	2	68.519	-9.563	-0.384	-7.944	68.519	102.791	-93.228	0.000	0.000	0.000	0.000
	3	68.070	5.999	0.128	-0.163	68.070	115.616	-121.616	0.000	0.000	0.000	0.000
LIVE LOAD LL03	1	77.494	-3.175	-0.045	1.105	77.494	135.128	-131.954	0.000	0.000	0.000	0.000
	2	58.344	-4.360	-0.084	0.512	58.344	79.312	-74.951	0.000	0.000	0.000	0.000
	3	0.643	2.151	0.130	3.767	0.643	-2.151	0.000	0.000	0.000	0.000	0.000

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CAP ANALYSIS AND DESIGN DATA

CAP MOMENTS AND SHEARS

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
	MOMENTS(KIP-FEET)							** SHEARS(KIPS)					
P 1	-2.937	-2.937	-2.937	-2.937	-2.937	-2.937	-2.937	-3.319	-123.719	-3.319	-123.719	-3.319	-162.549
P 2	-188.095	-188.095	-245.563	-188.095	-188.095	-188.095	-188.095	-126.494	-126.494	-126.494	-126.494	-165.324	-165.324
C 1L	-444.833	-444.833	-579.962	-444.833	-444.833	-444.833	-579.962	-130.245		-130.245		-169.075	
C 1R	-421.102	-421.102	-553.055	-195.930	-646.273	-365.928	-670.957		133.949		172.613		133.949
P 3	-156.953	-156.953	-211.580	18.978	-332.884	-65.028	-303.699	130.199	130.199	168.863	168.863	130.199	130.199
P 4	94.635	153.985	94.635	222.310	-33.041	222.577	41.676	126.524	10.030	165.187	14.373	126.524	5.641
P 5	117.358	170.829	117.358	172.856	61.860	199.888	114.245	-3.921	-119.844	0.422	-119.844	-8.310	-155.491
P 6	-92.163	-92.163	-125.428	5.804	-190.131	-48.886	-178.059	-123.079	-123.079	-123.079	-123.079	-158.725	-158.725
C 2L	-342.071	-342.071	-444.862	-194.863	-489.279	-342.071	-523.946	-126.829		-126.829		-162:476	
C 2R	-341.146	-341.146	-443.946	-193.938	-488.354	-339.018	-523.031		126.109		160.895		126.109
P 7	-92.677	-92.677	-125.906	5.290	-190.645	-65.762	-178.537	122.359	122.359	157.145	157.145	122.359	122.359
P 8	115.007	147.351	115.007	170.628	59.386	177.232	95.365	119.134	3.799	153.920	8.210	119.134	1.564
P 9	91.372	150.792	91.372	218.925	-36.180	219.317	29.284	-10.152	-124.901	-5.741	-124.901	-12.387	-158.024
P10	-157.679	-154.242	-207.049	18.253	-333.610	-62.123	-301.565	-128.586	-128.586	-128.586	-128.586	-161.709	-161.709
C 3L	-418.600	-416.449	-534.216	-193.428	-643.771	-298.547	-655.185	-132.336		-132.336		-165.459	
C 3R	-443.452	-443.452	-565.068	-443.452	-443.452	-443.452	-565.068		129.848		164.795		129.848
P11	-187.507	-187.507	-239.229	-187.507	-187.507	-187.507	-187.507	126.097	126.097	161.044	161.044	126.097	126.097
P12	-2.937	-2.937	-2.937	-2.937	-2.937	-2.937	-2.937	123.322	3.319	158.269	3.319	123.322	3.319

CAP DESIGN DATA

PT.	G1 M+SL K-FT.	G1 M-SL K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI
P 1	-2.937	-2.937	0.06	1 # 11	0.00	0 # 11	0.00	0.000	#5@ 0.00	16.09	0.122	#5@ 5.07	36.00	55
P 2	-188.095	-245.563	4.92	4 # 11	0.00	0 # 11	16.09	0.127	#5@ 4.89	16.09	0.127	#5@ 4.89	36.00	580
C 1	-421.102	-579.962	12.22	8 # 11	0.00	0 # 11	15.89	0.136	#5@ 4.56	15.89	0.141	#5@ 4.38	36.00	986
P 3	-156.953	-211.580	4.22	3 # 11	0.00	0 # 11	16.09	0.132	#5@ 4.69	16.09	0.132	#5@ 4.69	36.00	533
P 4	153.985	94.635	0.00	0 # 11	3.01	2 # 11	16.25	0.124	#5@ 5.00	0.00	0.000	#5@ 0.00	36.00	440

CAP DESIGN DATA

PT.	G1 M+SL K-FT.	G1 M-SL K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI
P 5	170.829	117.358	0.00	0 # 11	3.35	3 # 11	0.00	0.000	#5@ 0.00	16.25	0.109	#5@ 5.68	36.00	467
P 6	-92.163	-125.428	2.46	2 # 11	0.00	0 # 11	16.09	0.116	#5@ 5.32	16.09	0.116	#5@ 5.32	36.00	397
C 2	-341.146	-444.862	9.13	6 # 11	0.00	0 # 11	16.09	0.122	#5@ 5.07	16.09	0.120	#5@ 5.17	36.00	825
P 7	-92.677	-125.906	2.47	2 # 11	0.00	0 # 11	16.09	0.114	#5@ 5.44	16.09	0.114	#5@ 5.44	36.00	398
P 8	147.351	115.007	0.00	0 # 11	2.88	2 # 11	16.25	0.107	#5@ 5.81	0.00	0.000	#5@ 0.00	36.00	429
P 9	150.792	91.372	0.00	0 # 11	2.95	2 # 11	0.00	0.000	#5@ 0.00	16.25	0.113	#5@ 5.49	36.00	435
P10	-154.242	-207.049	4.13	3 # 11	0.00	0 # 11	16.09	0.121	#5@ 5.12	16.09	0.121	#5@ 5.12	36.00	526
C 3	-416.449	-565.068	11.89	8 # 11	0.00	0 # 11	15.89	0.130	#5@ 4.76	15.89	0.129	#5@ 4.80	36.00	970
P11	-187.507	-239.229	4.79	4 # 11	0.00	0 # 11	16.09	0.120	#5@ 5.16	16.09	0.120	#5@ 5.16	36.00	572
P12	-2.937	-2.937	0.06	1 # 11	0.00	0 # 11	16.09	0.116	#5@ 5.36	0.00	0.000	#5@ 0.00	36.00	55

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COLUMN ANALYSIS AND DESIGN OUTPUT
CRITICAL COLUMN LOADS

CN	B	GR	LLC	WC	R	E S	C F	S F	PF	MTF	MLF	PM	MTM	MLM	PU	MTU	MLU	PU/PM	B	D
1	T	1	LL03	0.0					341.7	-26.9	0.0	341.7	84.1	119.8	1376.9	339.2	483.5	4.031	48.00	48.00
1	B	2		4.2					366.9	175.0	417.6	366.9	196.5	657.7	560.5	299.7	1003.1	1.526	48.00	48.00
2	T	2		1.1	R				252.9	-295.3	-6.5	252.9	331.2	75.5	847.8	1110.9	253.3	3.353	48.00	48.00
2	B	2		4.2	R				335.9	-211.5	-417.6	335.9	237.5	623.5	515.1	363.8	955.0	1.532	48.00	48.00
3	T	2		1.1					232.9	250.0	6.5	232.9	280.4	67.3	922.6	1111.9	266.9	3.964	48.00	48.00
3	B	2		4.2	R				364.9	-174.7	-417.6	364.9	196.1	655.3	558.8	299.9	1002.1	1.530	48.00	48.00

COLUMN DESIGN DATA

CN	T B	T 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	12 ÷ 11	0 ÷ 0	0 ÷ 0	0 ÷ 0	18.72	1.035	1.00	0.895	2601.	13899.	1.230	1.754	1.000	1	0.35
1	B	12 ÷ 11	0 ÷ 0	0 ÷ 0	0 ÷ 0	18.72	1.035	1.00	0.000	2259.	20686.	1.123	1.575	1.000	1	0.35
2	T	12 ÷ 11	0 ÷ 0	0 ÷ 0	0 ÷ 0	18.72	1.035	1.00	0.002	2259.	20855.	1.121	1.493	1.000	1	0.35
2	B	12 ÷ 11	0 ÷ 0	0 ÷ 0	0 ÷ 0	18.72	1.035	1.00	0.004	2259.	20682.	1.123	1.493	1.000	1	0.35
3	T	12 ÷ 11	0 ÷ 0	0 ÷ 0	0 ÷ 0	18.72	1.035	1.00	0.072	2259.	20856.	1.121	1.445	1.000	1	0.35
3	B	12 ÷ 11	0 ÷ 0	0 ÷ 0	0 ÷ 0	18.72	1.035	1.00	0.000	2259.	20682.	1.123	1.569	1.000	1	0.35

FOOTING 1 DESIGN LOADS

F	G	LLID	WC	ES	C	S	P	MT	VT	ML	VL	P4	P3	P2	P1	MTF	VBF	VPF	LOAD
1	[illegible]		1.2				376.37	258.08	10.07	311.32	6.58	3.823	1.622	4.866	7.067	13.064	1.170	11.925	MAX.P1
1	[illegible]		1.2				376.37	258.08	10.07	311.32	6.58	3.823	1.622	4.866	7.067	13.064	1.170	11.925	MAX.MT
1	2		1.2				376.37	258.08	10.07	311.32	6.58	3.823	1.622	4.866	7.067	13.064	1.170	11.925	MAX.VT
1	2		1.2				376.37	258.08	10.07	311.32	6.58	3.823	1.622	4.866	7.067	13.064	1.170	11.925	MAX.VP
1	2		4.2				366.89	175.04	6.73	417.63	8.67	4.644	1.694	3.892	6.842	59.650	13.088	11.625	MAX.ML
1	2		4.2				366.89	175.04	6.73	417.63	8.67	4.644	1.694	3.892	6.842	59.650	13.088	11.625	MAX.VL
2	2		1.2R				335.88	-305.23	-13.16	-311.32	-6.58	3.180	0.979	4.852	7.053	12.833	1.164	10.642	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
14.500	8.500	2.500	0.942	0.26	19 ÷ 4	@ 9.125	TOP TRAN	13.359	19.878	37.664	25.469	0.359
				1.18	10 ÷ 9	@10.125	BOT.LONG	59.698	20.586	39.005	26.375	0.809

FOOTING 2 DESIGN SAME AS FOOTING 1

FOOTING 3 DESIGN SAME AS FOOTING 1

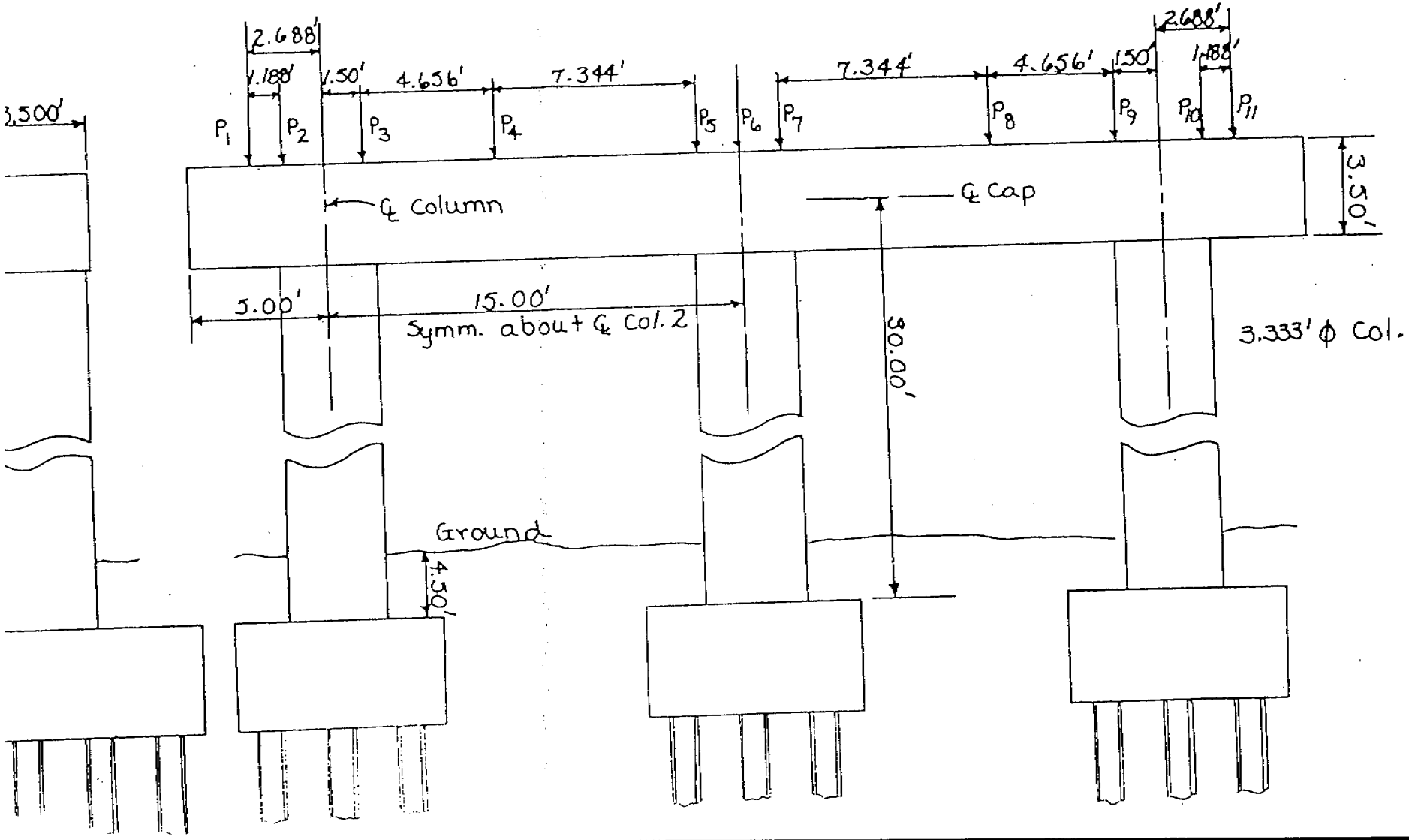
EXAMPLE PROBLEM 1002

Given Data: Davidson County

- Column and cap members have a constant moment of inertia.
- Columns are assumed fixed at bottom (FLEX = 0).
- Footings are on piles with a minimum of eight piles per footing.
- Pile capacity is 70 kips.
- Use 3" increments in footing design depth.
- A cap, column and footing design are desired.
- Centroid of superstructure areas are 6.008' transverse and 2.11' longitudinal above centerline of cap.
- For Group II wind, Group III wind, and wind on live load, use standard program defaults.
- Wind on substructure (equivalent at centerline of cap) is 2.278 kips in transverse direction, and 10.965 kips in longitudinal direction.
- Longitudinal force (traction) is 20.172 kips (one lane).
- Lengths for wind on live load are 101 feet transverse and longitudinal.
- Location of wind on live load is 13.237 feet transverse and 2.11 feet longitudinal above centerline of cap.
- Location of traction force is 1.909 feet above centerline of cap.
- Use all program defaults.
- Use load factor option.
- Use XBN dimensions to position all dummy loads at column faces to obtain cap moments and shears at the column face.

Davidson County Load Factor

For dead load & live load values see input sheets.



STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E 700

SHEET 1 OF 2

I. D.

PROG.	PROB. NO.	REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC.
* B 0 3	1 0 0 2	T E S T P R O J . 6 . 8 0 4 0 4 1 D A V I D S O N R A M E S H F O F A R I A 4 0 3 A 2 P A N

DESIGN DATA

CN	CAP	COLUMN	FOOTING	S or L CANTILEVER	NO. COLUMN	NO. LIVE LOAD CASE	SKEW ANGLE DEG.	MIN.	SEC.
01	D	D	D	2	3	4	2	6	24

GENERAL DESIGN DATA

f'_c P.S.I.	f_c P.S.I.	N	f_y P.S.I.	f_s P.S.I.	E_c K.S.I.	E_s K.S.I.	ε_c
(3,000)	(1,200)	(9)	(40,000)	(20,000)	(3,156)	(29,000)	(.0030)

CAP DESIGN DATA

Z	BAR SIZE	STR. SIZE	MAX. T. B.	MAX. B.B.	MIN. SIZE	MIN. BARS	TOP CLEAR. IN.	MIN. STIR. SP. IN.	CAP D. INCR. IN.	BOTT. CLEAR. IN.
(170.)	(11)	(5)	(6)	(6)	(11)	(0)	(2.0)	(4.0)	(3.0)	(2.31)

COLUMN DESIGN DATA

CN	MIN. P_s %	MAX. P_s %	MIN. SPAC. IN.	CLEAR IN.	R	K_L	ϕ_C	ϕ_F	C_M	β_{D1}	β_{D2}
02					1		(S-0.35) (L-0.75)	(S-0.35) (L-0.90)		(1.00)	0.75

FOOTING DESIGN DATA

IMPACT %	SOIL WEIGHT K.C.F.	ALLOWABLE SOIL PRESS. K.S.F.	MIN. PL. SP. FEET	MAX. PL. SP. FEET	EDGE DISTANCE FEET	PILE DEPTH FEET	CLEAR IN.	PILE CAPACITY KIPS	PILE UPLIFT KIPS	IP
	(.120)		(2.50)	(5.00)	(1.250)	(0.75)	(3.00)	70		P

CANTILEVER AND CAP DATA

CN	I	L FT.	A FT.	D_E FT.	B_C FT.	B_E FT.	D_H FT.	L_H FT.	X_{B1} FT.	X_{B2} FT.	X_{B3} FT.	X_{B4} FT.	X_{B5} FT.	X_{B6} FT.	X_{B7} FT.	X_{B8} FT.
11	C	5.00		3.5	3.5				2.688	1.188						
12	C	15.00		3.5	3.5				1.50	4.656	7.344					
13	2															
14	1															
15																
16																

COLUMN DATA

CN	P_0	I	T	S	H_T FT.	A FT.	D_T FT.	B_T FT.	D_B FT.	B_B FT.	D_L FT.	FLEX	REINFORCEMENT STEEL LOWER LIMIT / ACTUAL TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	UPPER LIMIT TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	SLOPE	E_P PSI x 10^6	A_P SQ. IN.
21		C	R		30.00		3.333				1.75	0.	8		10				40		10						
22	1	1																									
23		1																									
24																											
25																											

FOOTING DATA

CN	SP	B FT.	D FT.	T FT.	ΔB FT.	ΔD FT.	ΔT FT.	$R_{B/D}$	$R_{D/B}$	SOIL HT. FT.	NP	S	B_P FT.	D_P FT.	SETTLE FT.
31	P			2.5			0.25			4.50	8				
32	1														
33	1														
34															
35															

JUNE 1

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET _ OF _

FORCES = KIPS
INTENSITY = LBS/FT²
AREAS = FT²
LENGTHS = FT
TRACTION AND CENTRIFUGAL FORCE = 1 LANE
COEFFICIENTS = UNITS/UNITS

GROUP II WIND

CN	SUPERSTRUCTURE AREA TRANS	SUPERSTRUCTURE AREA LONG	STD W	WIND ON SUPERSTRUCTURE INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	WIND FORCE ARMS APT	APL	WIND ON PIER PT	PL
41	787	787	11											6008	211	2278	10965

GROUP III WIND

CN	STD W	WIND ON SUPERSTRUCTURE INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	STD W	WIND ON LIVE LOAD INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	LENGTH OF LIVE LOADS TRANS	LONG	WIND ON L.L. ARMS APT	APL
42	1											1											101	101	13237	211

* AT LEAST ONE LIVE LOAD CASE IS REQUIRED
MAXIMUM NUMBER OF LIVE LOAD CASES IS 25

MISC. FORCES

CN	CENTRIFUGAL FORCE FT	TRACTION FORCE FL	CENTRIFUGAL FORCE & TRACTION FORCE ARMS APT	APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PI	PL	* EQ
43		20172	11909	11909					

* COLUMNS 51,52 MUST BE 0.1 FOR SEISMIC CONSIDERATION.

STD W - GR.II. GR.III SUPERSTRUCTURE	FT-	58	44	41	33 17
	FL-	0	6	12	16 19
STD W - GR.III LIVE LOAD	FT-	100	88	82	68 34
	FL-	0	12	24	32 38

SEISMIC FORCES

CN	EQ*	LONGITUDINAL LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP	TRANSVERSE LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP
44															
44															
44															
44															
44															

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES*

CN	ID	NL	P1. 13. 25	P2. 14. 26	P3. 15. 27	P4. 16. 28	P5. 17. 29	P6. 18. 30	P7. 19. 31	P8. 20. 32	P9. 21. 33	P10. 22. 34	P11. 23. 35	P12. 24. 36
51	0-L-0	0	13512	0	0	15669	0	15669	0	15669	0	0	13512	
61	1+M	2	0	0	0	1334	0	5776	0	7759	0	0	3292	
61	2-M	2	4683	0	0	4385	0	143	0	5633	0	0	3292	
61	3V	1	4683	0	0	4385	0	0	0	0	0	0	0	
61	4R	2	046	0	0	5633	0	6778	0	5633	0	0	046	
61														
61														
61														
61														
61														
61														

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+++++          THE ANALYSIS AND DESIGN OF PIERS FOR BRIDGE -  V 4.2.03 - AASHTO SPECS 1984 INTERIM
PROBLEM NO. 1002INPUT DATA          TEST  PROJ. 6.804041  DAVIDSON RAMESH FOFARIA 403 A2PAN                    07/14/86
                                                          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.
0 D D L  2   3   4  26-26-24 3000. 1200. 9.2 40000. 20000. 3156. 29000. 0.0030 170.  11   5   6    6   11    0  2.00  4.00 3.00 2.31
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 DIS1  DEPTH CLEAR CAPACITY  UPLIFT  P
 1.00  8.00  2.25  2.563   1  2.00 0.75 0.90 0.00 1.00 0.75  0.00  0.120    0.000  2.50  5.00  1.250 0.750 3.000  70.000    0.000  P
                                                          CAP DATA
CN  C    L       A      DE      BC      BE      DH      LH      XB1     XB2     XB3     XB4     XB5     XB6     XB7     XB8
11  C  5.000   0.000   3.500   3.500   0.000   0.000   0.000   2.688   1.188
12  C 15.000   0.000   3.500   3.500           0.000   0.000   1.500   4.656   7.344
13  3 SAME AS CAP SECTION 2
14  4 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 R   30.000  0.000  3.333  0.000  0.000  0.000  1.750  0.000   8  0 10  0  0  0 40  0 10  0  0  0  0.000  0.000  0.000
22 1  2 SAME AS COLUMN 1
23 0  3 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  P  0.000   0.000   2.500   0.000   0.000   0.250  0.000  0.000   4.500   8   0    0.000   0.000   0.000
32  2 SAME AS FOOTING 1
33  3 SAME AS FOOTING 1
+++++                                                     GROUP II WIND
SUPERSTRUCTURE AREA*STD.        WIND ON SUPERSTRUCTURE INTENSITIES       * WIND FORCE ARM  * WIND ON PIER
  TRANS.     LONG.  WIND F11 FL1   F12 FL2   F13 FL3   F14 FL4   F15 FL5     APT     APL      PT      PL
   787.      787.   1    50   0    44   6    41  12    33  16    17  19    6.008   2.110    2.278  10.965
                                                          GROUP III WIND
STD. *   WIND ON SUPERSTRUCTURE INTENSITIES    *  STD. *      WIND ON LIVE LOAD INTENSITIES      *  LENGTHS OF LL * WIND ON LL ARMS
WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5  WIND F11 FL1  F12 FL2  F13 FL3  F14 FL4  F15 FL5   TRANS.  LONGI.   APT     APL
  1   50   0   44   6   41  12   33  16   17  19   1   100   0   88  12   82  24   66  32   34  38   101.0   101.0  13.237   2.110
                                 MISCELLANEOUS FORCES
CENTRI.  TRACTION FORCE AND ARMS   EXPANSION   SHRINKAGE     STREAM FLOW
  FT       FL      APT     APL    COEFFICIENT COEFFICIENT    PT      PL
 0.000   20.172   1.909   1.909   0.00000000  0.00000000   0.000   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  135.120   0.000    0.000  156.690    0.000  156.690    0.000  156.690    0.000    0.000  135.120
1+M    2    0.000   0.000    0.000   13.340    0.000   57.760    0.000   77.340    0.000    0.000   32.920
2-M    2   46.830   0.000    0.000   43.850    0.000    1.430    0.000   56.330    0.000    0.000   32.920
3V     1   46.830   0.000    0.000   43.850    0.000    0.000    0.000    0.000    0.000    0.000    0.000
4R     2    0.460   0.000    0.000   56.330    0.000   67.780    0.000   56.330    0.000    0.000    0.460
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REVISED 07/18/86

MEMBER PROPERTIES

COLUMN PROPERTIES

N	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	367061.7	0.5000	0.5000	0.7837	1.0000	0.2163	0.2163	0.008077	17.9	36872.0	2108.9	18353.1	124067.5	0.2	10.2
	367061.7	0.5000	0.4142	0.0000	1.0000	0.0000	0.0000	0.3333	40.0	7399.4	28.3	18353.1	124067.5	0.0	10.2
2	367061.7	0.5000	0.5000	0.7673	0.2327	0.2327	0.1317	0.008077	17.3	39375.4	2108.9	18353.1	124067.5	0.1	10.2
	367061.7	0.5000	0.4489	0.7673	0.5000	0.5000	0.4342	0.3333	40.0	7399.4	28.3	18353.1	124067.5	0.0	10.2
3	367061.7	0.5000	0.5000	0.0000	0.2163	1.0000	0.2163	0.008077	17.9	36872.0	2108.9	18353.1	124067.5	0.2	10.2
	367061.7	0.5000	0.4142	0.7837	0.0000	1.0000	0.7837	0.3333	40.0	7399.4	28.3	18353.1	124067.5	0.0	10.2

CAP PROPERTIES

N	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	1329841.0	0.2906	34.4531	1.2150	2.1400	0.1350					
	1515475.0	1210478.0	0.1221	151547.4	0.1350	1.4896	1.2150					
3	0.5000	1210478.0	0.1221	34.4531	1.2150	1.4896	0.1350					
	1515475.0	1329841.0	0.2906	151547.4	0.1350	2.1400	1.2150					

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

		TRANSVERSE						*	LONGITUDINAL			
LOAD	COL	PC	MT	V	MB	RF	ML	MR	MT	V	MB	MF
NIT F.AT CL.CAP	1	0.482	4.523	0.319	5.036	0.482	0.000	-4.523	0.583	0.333	10.000	10.000
	2	0.000	5.405	0.363	5.477	0.000	-2.703	-2.703	0.583	0.333	10.000	10.000
	3	-0.482	4.523	0.319	5.036	-0.482	-4.523	0.000	0.583	0.333	10.000	10.000
EAD LOAD TOTAL	1	258.587	-3.198	-0.160	-1.599	295.559	386.171	-382.972	0.000	0.000	0.000	0.000
		295.559										
	2	296.633	0.000	0.000	0.000	333.605	261.253	-261.253	0.000	0.000	0.000	0.000
		333.605										
	3	258.587	3.198	0.160	1.599	295.559	382.972	-386.171	0.000	0.000	0.000	0.000
		295.559										
TRAC. FORCE 1 LN	1	4.898	40.628	2.862	45.229	4.898	0.000	-40.628	-22.030	-6.021	-192.114	-192.114
	2	0.000	48.550	3.258	49.190	0.000	-24.275	-24.275	-22.030	-6.021	-192.114	-192.114
	3	-4.898	40.628	2.862	45.229	-4.898	-40.628	0.000	-22.030	-6.021	-192.114	-192.114
IND ON SUBSTR.	1	1.097	10.304	0.726	11.471	1.097	0.000	-10.304	-6.396	-3.655	-109.650	-109.650
	2	0.000	12.313	0.826	12.476	0.000	-6.157	-6.157	-6.396	-3.655	-109.650	-109.650
	3	-1.097	10.304	0.726	11.471	-1.097	-10.304	0.000	-6.396	-3.655	-109.650	-109.650
GROUP 2 WIND 1 1	1	25.127	169.682	11.953	188.896	25.127	0.000	-169.682	16.147	2.185	77.883	77.883
	2	0.000	202.767	13.607	205.438	0.000	-101.383	-101.383	16.147	2.185	77.883	77.883
	3	-25.127	169.682	11.953	188.896	-25.127	-169.682	0.000	16.147	2.185	77.883	77.883
GROUP 2 WIND 1 2	1	25.127	169.682	11.953	188.896	25.127	0.000	-169.682	28.940	9.495	297.183	297.183
	2	0.000	202.767	13.607	205.438	0.000	-101.383	-101.383	28.940	9.495	297.183	297.183
	3	-25.127	169.682	11.953	188.896	-25.127	-169.682	0.000	28.940	9.495	297.183	297.183
GROUP 2 WIND 2 1	1	23.678	160.067	11.275	178.192	23.678	0.000	-160.067	8.002	0.075	10.124	10.124
	2	0.000	191.277	12.836	193.797	0.000	-95.639	-95.639	8.002	0.075	10.124	10.124
	3	-23.678	160.067	11.275	178.192	-23.678	-160.067	0.000	8.002	0.075	10.124	10.124
GROUP 2 WIND 2 2	1	20.810	141.046	9.935	157.017	20.810	0.000	-141.046	31.675	10.204	319.933	319.933
	2	0.000	168.548	11.311	170.768	0.000	-84.274	-84.274	31.675	10.204	319.933	319.933
	3	-20.810	141.046	9.935	157.017	-20.810	-141.046	0.000	31.675	10.204	319.933	319.933
GROUP 2 WIND 3 1	1	23.670	160.015	11.272	178.134	23.670	0.000	-160.015	1.209	-1.685	-46.382	-46.382
	2	0.000	191.215	12.832	193.734	0.000	-95.607	-95.607	1.209	-1.685	-46.382	-46.382
	3	-23.670	160.015	11.272	178.134	-23.670	-160.015	0.000	1.209	-1.685	-46.382	-46.382
GROUP 2 WIND 3 2	1	17.934	121.973	8.592	135.784	17.934	0.000	-121.973	35.762	11.263	353.936	353.936
	2	0.000	145.755	9.781	147.675	0.000	-72.878	-72.878	35.762	11.263	353.936	353.936
	3	-17.934	121.973	8.592	135.784	-17.934	-121.973	0.000	35.762	11.263	353.936	353.936
GROUP 2 WIND 4 1	1	20.781	140.855	9.922	156.804	20.781	0.000	-140.855	-6.024	-3.559	-106.557	-106.557
	2	0.000	168.319	11.295	170.536	0.000	-84.160	-84.160	-6.024	-3.559	-106.557	-106.557
	3	-20.781	140.855	9.922	156.804	-20.781	-140.855	0.000	-6.024	-3.559	-106.557	-106.557
GROUP 2 WIND 4 2	1	13.133	90.132	6.349	100.338	13.133	0.000	-90.132	35.782	11.268	354.100	354.100
	2	0.000	107.706	7.228	109.125	0.000	-53.853	-53.853	35.782	11.268	354.100	354.100
	3	-13.133	90.132	6.349	100.338	-13.133	-90.132	0.000	35.782	11.268	354.100	354.100

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

LOAD	COL	TRANSVERSE PC	MT	V	MB	RF	ML	MR	* MT	LONGITUDINAL V	MB	MF
.OUP 2 WIND 5 1	1	13.808	94.609	6.664	105.322	13.808	0.000	-94.609	-15.958	-6.132	-189.195	-189.195
	2	0.000	113.057	7.587	114.546	0.000	-56.528	-56.528	-15.958	-6.132	-189.195	-189.195
	3	-13.808	94.609	6.664	105.322	-13.808	-94.609	0.000	-15.958	-6.132	-189.195	-189.195
:OUP 2 WIND 5 2	1	4.727	34.376	2.421	38.269	4.727	0.000	-34.376	31.288	10.104	316.717	316.717
	2	0.000	41.079	2.757	41.620	0.000	-20.539	-20.539	31.288	10.104	316.717	316.717
	3	-4.727	34.376	2.421	38.269	-4.727	-34.376	0.000	31.288	10.104	316.717	316.717
ROUP 3 WIND 1 1	1	15.885	91.812	6.467	102.208	15.885	0.000	-91.812	10.631	2.155	71.499	71.499
	2	0.000	109.714	7.362	111.159	0.000	-54.857	-54.857	10.631	2.155	71.499	71.499
	3	-15.885	91.812	6.467	102.208	-15.885	-91.812	0.000	10.631	2.155	71.499	71.499
ROUP 3 WIND 1 2	1	15.885	91.812	6.467	102.208	15.885	0.000	-91.812	14.468	4.348	137.289	137.289
	2	0.000	109.714	7.362	111.159	0.000	-54.857	-54.857	14.468	4.348	137.289	137.289
	3	-15.885	91.812	6.467	102.208	-15.885	-91.812	0.000	14.468	4.348	137.289	137.289
ROUP 3 WIND 2 1	1	14.947	86.460	6.090	96.250	14.947	0.000	-86.460	6.096	0.980	33.780	33.780
	2	0.000	103.318	6.933	104.679	0.000	-51.659	-51.659	6.096	0.980	33.780	33.780
	3	-14.947	86.460	6.090	96.250	-14.947	-86.460	0.000	6.096	0.980	33.780	33.780
ROUP 3 WIND 2 2	1	13.090	75.871	5.344	84.463	13.090	0.000	-75.871	15.991	4.742	149.954	149.954
	2	0.000	90.665	6.084	91.859	0.000	-45.333	-45.333	15.991	4.742	149.954	149.954
	3	-13.090	75.871	5.344	84.463	-13.090	-75.871	0.000	15.991	4.742	149.954	149.954
;ROUP 3 WIND 3 1	1	14.942	86.431	6.088	96.218	14.942	0.000	-86.431	2.315	0.000	2.324	2.324
	2	0.000	103.283	6.931	104.644	0.000	-51.642	-51.642	2.315	0.000	2.324	2.324
	3	-14.942	86.431	6.088	96.218	-14.942	-86.431	0.000	2.315	0.000	2.324	2.324
ROUP 3 WIND 3 2	1	11.229	65.254	4.597	72.643	11.229	0.000	-65.254	18.266	5.332	168.882	168.882
	2	0.000	77.977	5.233	79.005	0.000	-38.989	-38.989	18.266	5.332	168.882	168.882
	3	-11.229	65.254	4.597	72.643	-11.229	-65.254	0.000	18.266	5.332	168.882	168.882
;RI[illegible] WIND 4 1	1	13.071	75.765	5.337	84.344	13.071	0.000	-75.765	-1.712	-1.043	-31.173	-31.173
	2	0.000	90.538	6.076	91.731	0.000	-45.269	-45.269	-1.712	-1.043	-31.173	-31.173
	3	-13.071	75.765	5.337	84.344	-13.071	-75.765	0.000	-1.712	-1.043	-31.173	-31.173
;ROUP 3 WIND 4 2	1	8.121	47.529	3.348	52.911	8.121	0.000	-47.529	18.277	5.334	168.973	168.973
	2	0.000	56.796	3.811	57.545	0.000	-28.398	-28.398	18.277	5.334	168.973	168.973
	3	-8.121	47.529	3.348	52.911	-8.121	-47.529	0.000	18.277	5.334	168.973	168.973
;ROUP 3 WIND 5 1	1	8.558	50.021	3.524	55.686	8.558	0.000	-50.021	-7.242	-2.476	-77.175	-77.175
	2	0.000	59.775	4.011	60.562	0.000	-29.887	-29.887	-7.242	-2.476	-77.175	-77.175
	3	-8.558	50.021	3.524	55.686	-8.558	-50.021	0.000	-7.242	-2.476	-77.175	-77.175
;ROUP 3 WIND 5 2	1	2.679	16.491	1.162	18.359	2.679	0.000	-16.491	15.775	4.686	148.163	148.163
	2	0.000	19.707	1.322	19.966	0.000	-9.853	-9.853	15.775	4.686	148.163	148.163
	3	-2.679	16.491	1.162	18.359	-2.679	-16.491	0.000	15.775	4.686	148.163	148.163
.IVE LOAD 1+M	1	2.572	0.951	0.078	1.377	2.572	0.000	-0.951	0.000	0.000	0.000	0.000
	2	99.541	16.877	0.874	9.341	99.541	80.344	-97.222	0.000	0.000	0.000	0.000
	3	79.246	-19.632	-0.952	-8.914	79.246	108.121	-88.489	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 2-M	1	75.997	-6.031	-0.249	-1.440	75.997	125.879	-119.848	0.000	0.000	0.000	0.000
	2	38.201	8.914	0.498	6.032	38.201	70.159	-79.073	0.000	0.000	0.000	0.000
	3	67.162	-6.034	-0.249	-1.442	67.162	94.523	-88.489	0.000	0.000	0.000	0.000
LIVE LOAD 3V	1	79.050	-1.752	-0.052	0.177	79.050	125.879	-124.127	0.000	0.000	0.000	0.000
	2	13.515	-4.850	-0.207	-1.372	13.515	28.636	-23.786	0.000	0.000	0.000	0.000
	3	-1.885	4.495	0.260	3.301	-1.885	-4.495	0.000	0.000	0.000	0.000	0.000
LIVE LOAD 4R	1	26.510	23.263	1.163	11.632	26.510	1.236	-24.500	0.000	0.000	0.000	0.000
	2	128.340	0.000	0.000	0.000	128.340	131.931	-131.931	0.000	0.000	0.000	0.000
	3	26.510	-23.263	-1.163	-11.632	26.510	24.500	-1.236	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
1	-6.384	-6.384	-6.384	-6.384	-6.384	-6.384	-6.384	-5.523	-181.179	-5.523	-181.179	-5.523	-282.847
2	-223.310	-223.310	-344.092	-223.310	-223.310	-223.310	-295.635	-184.017	-184.017	-184.017	-184.017	-285.685	-285.685
1L	-502.022	-502.022	-775.305	-502.022	-502.022	-502.022	-665.665	-187.600		-187.600		-289.268	
1R	-497.864	-497.864	-767.344	-277.278	-718.451	-274.111	-878.656		148.564		218.514		148.564
3	-277.705	-246.062	-442.914	-92.357	-463.052	-69.710	-565.680	144.981	144.981	214.931	214.931	144.981	144.981
4	371.435	666.397	371.435	447.403	295.468	625.543	313.301	133.859	-69.838	203.809	-69.838	133.859	-135.575
5	-205.870	-205.870	-393.686	-109.310	-302.430	-145.051	-416.822	-87.381	-87.381	-87.381	-87.381	-153.118	-153.118
2L	-339.628	-339.628	-626.051	-207.830	-471.427	-273.983	-645.567	-90.964		-90.964		-156.702	
2R	-339.628	-339.628	-626.051	-207.830	-471.427	-267.678	-645.567		90.964		158.294		90.964
7	-205.870	-205.870	-393.685	-109.310	-302.430	-157.748	-416.821	87.381	87.381	154.711	154.711	87.381	87.381
8	371.435	755.839	355.996	447.402	295.467	679.101	302.896	69.838	-133.859	137.168	-129.766	69.838	-234.434
9	-277.706	-246.063	-371.406	-92.358	-463.053	-69.710	-522.861	-144.981	-144.981	-140.888	-140.888	-245.556	-245.556
3L	-497.864	-488.104	-732.595	-277.278	-718.451	-304.724	-863.411	-148.564		-144.471		-249.139	
3R	-502.022	-502.022	-694.131	-502.022	-502.022	-502.022	-617.058		187.600		259.069		187.600
10	-223.310	-223.310	-308.216	-223.310	-223.310	-223.310	-274.152	184.017	184.017	255.486	255.486	184.017	184.017
11	-6.384	-6.384	-6.384	-6.384	-6.384	-6.384	-6.384	181.179	5.523	252.648	5.523	181.179	5.523

CAP DESIGN DATA

PT.	M+ UNF. K-FT.	M- UNF. K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI	PS %	FS/FF RATIO	FS/FZ RATIO
1	-4.911	-4.911	0.07	1 # 11	0.00	0 # 11	0.00	0.000	#5@ 0.00	19.25	0.101	#5@ 6.14	42.00		0.00	0.000	0.000
2	71.777	-227.411	4.03	3 # 11	0.00	0 # 11	19.25	0.103	#5@ 6.01	19.25	0.103	#5@ 6.01	42.00		0.25	0.206	0.000
1	-382.972	-512.050	7.91	6 # 11	0.00	0 # 11	19.25	0.106	#5@ 5.85	19.25	0.052	#5@11.81	42.00		0.49	0.253	0.000
3	-199.044	-289.718	5.02	4 # 11	0.00	0 # 11	19.25	0.052	#5@11.81	19.25	0.052	#5@11.81	42.00		0.31	0.248	0.000
4	421.584	285.719	0.00	0 # 11	5.99	4 # 11	19.09	0.052	#5@11.81	19.09	0.052	#5@11.81	42.00		0.37	0.408	0.000
5	-158.362	-244.873	4.49	3 # 11	0.00	0 # 11	19.25	0.052	#5@11.81	19.25	0.052	#5@11.81	42.00		0.28	0.315	0.000
2	-261.253	-393.184	5.75	4 # 11	0.00	0 # 11	19.25	0.052	#5@11.81	19.25	0.052	#5@11.81	42.00		0.36	0.382	0.000

CAP DESIGN DATA

PT.	M+ UNF. K-FT.	M- UNF. K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI	PS %	FS/FF RATIO	FS/FZ RATIO
7	-158.361	-244.873	4.49	3 # 11	0.00	0 # 11	19.25	0.052	#5@11.81	19.25	0.052	#5@11.81	42.00		0.28	0.315	0.000
8	462.782	278.608	0.00	0 # 11	6.83	5 # 11	19.09	0.052	#5@11.81	19.09	0.066	#5@ 9.46	42.00		0.43	0.420	0.000
9	-199.045	-256.780	4.63	3 # 11	0.00	0 # 11	19.25	0.073	#5@ 8.54	19.25	0.073	#5@ 8.54	42.00		0.29	0.221	0.000
3	-378.477	-491.094	7.77	5 # 11	0.00	0 # 11	19.25	0.075	#5@ 8.23	19.25	0.083	#5@ 7.48	42.00		0.48	0.275	0.000
10	-171.777	-210.886	3.61	3 # 11	0.00	0 # 11	19.25	0.080	#5@ 7.74	19.25	0.080	#5@ 7.74	42.00		0.22	0.145	0.000
11	-4.911	-4.911	0.07	1 # 11	0.00	0 # 11	19.25	0.078	#5@ 7.95	0.00	0.000	#5@ 0.00	42.00		0.00	0.000	0.000

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COLUMN ANALYSIS AND DESIGN OUTPUT

CRITICAL COLUMN LOADS

CN	T B	ER	LLC	WC	R	E S	C F	S F	PF	MTF	MLF	PM	MTM	MLM	PU	MTU	MLU	PU/PM	B	D
1	T	3	4R	1.1					404.0	251.1	-43.5	404.0	273.6	92.3	1460.3	992.7	334.9	3.619	40.00	40.00
1	B	3	2-M	4.2	R				485.2	44.9	-719.2	485.2	88.3	1015.2	491.2	89.7	1031.1	1.015	40.00	40.00
2	T	3	4R	1.1					552.5	268.9	-43.5	552.5	293.0	144.9	1642.0	871.1	430.7	2.972	40.00	40.00
2	B	3	4R	4.2					600.5	-53.1	719.2	600.5	109.5	1131.6	615.1	112.3	1160.6	1.025	40.00	40.00
3	T	3	1+M	1.1	R				472.6	-246.4	43.5	472.6	268.5	114.8	1602.4	910.6	389.3	3.391	40.00	40.00
3	B	3	1+M	4.2					489.4	-58.3	719.2	489.4	89.0	1019.0	494.7	90.2	1033.0	1.013	40.00	40.00

COLUMN DESIGN DATA

CN	T B	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	10 # 10	0 # 0	0 # 0	0 # 0	12.70	1.011	1.00	0.000	1366.	16568.	1.090	1.371	1.000	1	0.75
1	B	13 # 10	0 # 0	0 # 0	0 # 0	16.51	1.314	1.00	0.000	1366.	16271.	1.092	1.412	1.000	1	0.75
2	T	10 # 10	0 # 0	0 # 0	0 # 0	12.70	1.011	1.00	0.000	1366.	16568.	1.090	1.574	1.000	1	0.75
2	B	15 # 10	0 # 0	0 # 0	0 # 0	19.05	1.516	1.00	0.000	1366.	15941.	1.094	1.574	1.000	1	0.75
3	T	10 # 10	0 # 0	0 # 0	0 # 0	12.70	1.011	1.00	0.000	1366.	16576.	1.090	1.458	1.000	1	0.75
3	B	13 # 10	0 # 0	0 # 0	0 # 0	16.51	1.314	1.00	0.000	1366.	16307.	1.091	1.417	1.000	1	0.75

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	4R	5.1				461.95	158.94	10.53	-461.40	-14.52	64.817	22.727	42.042	84.132	23.163	-0.056	17.372	MAX.P1
2	3	4R	5.1				600.53	206.62	13.69	-599.82	-18.87	84.262	29.545	54.655	109.372	30.112	-0.073	22.583	MAX.[illegible]
2	3	4R	4.2				600.53	-53.09	-3.52	719.16	22.59	99.029	33.437	39.888	105.480	26.294	-0.073	22.583	MAX.[illegible]
2	3	4R	4.2				600.53	-53.09	-3.52	719.16	22.59	99.029	33.437	39.888	105.480	26.294	-0.073	22.583	MAX.VP
2	3	4R	4.2				600.53	-53.09	-3.52	719.16	22.59	99.029	33.437	39.888	105.480	84.684	20.932	22.583	MAX.ML
2	3	4R	4.2				600.53	-53.09	-3.52	719.16	22.59	99.029	33.437	39.888	105.480	84.684	20.932	22.583	MAX.VL
3	3	1+M	4.2				376.48	-44.86	-3.17	553.20	17.38	67.353	16.898	22.413	72.869	16.842	-0.056	14.210	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
10.000	7.500	3.250	0.962	0.53	27 # 4 @	4.375	TOP TRAN	40.890	28.597	57.195	25.594	0.000
				1.10	11 # 8 @	8.125	BOT.LONG	89.264	29.540	59.080	26.438	0.000

NUMBER OF PILES = 10 BP = 1.250 DP = 2.500

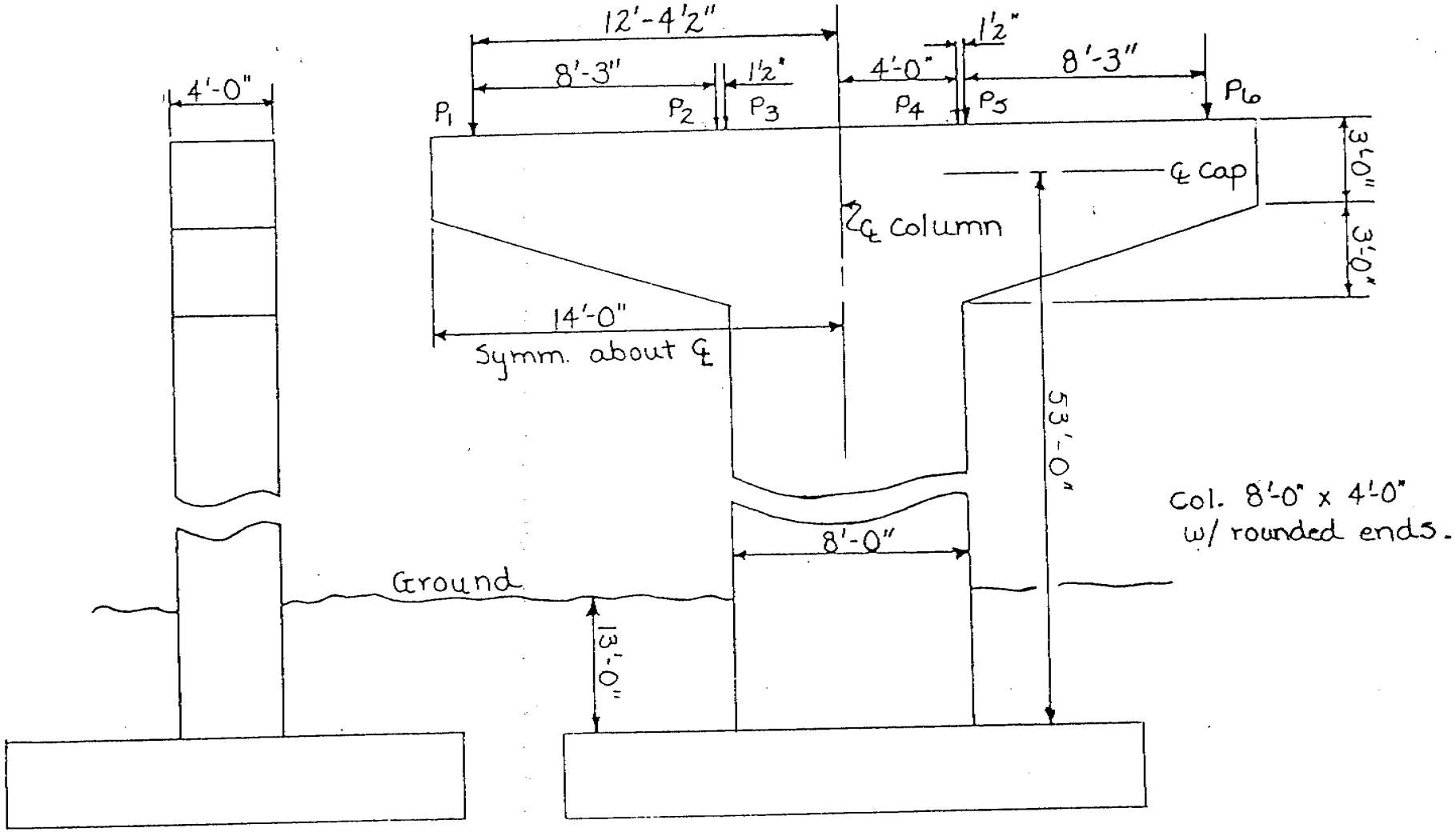
FOOTING 2 DESIGN SAME AS FOOTING 1

FOOTING 3 DESIGN SAME AS FOOTING 1

EXAMPLE PROBLEM 15

Given Data: Lincoln County Hammer Head

- Column and cap members have a constant moment of inertia.
- Columns are assumed fixed at bottom (FLEX = 0).
- Footings are spread with a 14'-0" x 12'-0" x 3'-0" minimum size.
- Soil bearing capacity is 7.0 kips per square foot.
- Use 6" increments in footing design and limit either width to two times the other width.
- A cap, column, and footing design/analysis are desired.
- Centroid of superstructure area is 5.310' above centerline of cap in transverse direction and 2.058' in longitudinal direction.
- For Group II wind, Group III wind, and wind on live load, use standard program defaults.
- Wind on substructure (equivalent at centerline of cap) is 3.627 kips in transverse direction, and 12.422 kips in longitudinal direction.
- Longitudinal force (traction) is 9.31 kips (one lane).
- Stream flow is 0.994 kips in the transverse direction and 0.0 kips in the longitudinal direction.
- To obtain shears and moments at column faces enter dummy loads using XBN positions.
- Lengths for wind on live load are 85.0' (transverse) and 30.0' (longitudinal).
- Location of wind on live load is 11.594 feet above centerline of cap.
- Location of traction force is 11.594 feet above centerline of cap.
- Member properties are desired.
- Use all program defaults.
- Use service load option.
- Actual column size is 4'-0" x 8'-0" with rounded ends. Equivalent column size is 4'-0" x 7'-3" rectangle with squared ends.



	P_1	P_2	P_3	P_4	P_5	P_6
Dead Loads total	135.752	135.508	0	0	135.508	135.752
Dead loads extra wt. substr.	0.223	0.223	0	0	0.223	0.223
Dead loads superstructure	135.529	133.285	0	0	135.285	135.529

For live loads, see data input sheet.

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET _ OF _

FORCES = KIPS
INTENSITY = LBS/FT²
AREAS = FT²
LENGTHS = FT
TRACTION AND CENTRIFUGAL FORCE = 1 LANE
COEFFICIENTS = UNITS/UNITS

* AT LEAST ONE LIVE LOAD CASE IS REQUIRED
MAXIMUM NUMBER OF LIVE LOAD CASES IS 25

* COLUMNS 51,52 MUST BE 0.1 FOR SEISMIC CONSIDERATION.

STD W - GR.II, GR.III SUPERSTRUCTURE
STD W - GR.III LIVE LOAD

FT-	58	44	41	33	17
FL-	0	6	12	16	19
FT-	103	88	82	66	34
FL-	0	12	24	32	38

GROUP II WIND

CN	SUPERSTRUCTURE AREA TRANS	SUPERSTRUCTURE AREA LONG	STD W	WIND ON SUPERSTRUCTURE INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	WIND FORCE ARMS APT	APL	WIND ON PIER PT	PL
41	552	552	1											5310	2058	3627	2422

GROUP III WIND

CN	STD W	WIND ON SUPERSTRUCTURE INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	STD W	WIND ON LIVE LOAD INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	LENGTH OF LIVE LOADS TRANS	LONG	WIND ON L.L. ARMS APT	APL
42	1											1											850		3001	1594	1594

MISC. FORCES

CN	CENTRIFUGAL FORCE FT	TRACTION FORCE FL	CENTRIFUGAL FORCE & TRACTION FORCE ARMS APT	APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PT	PL	* ED
43		931	1594	1594			994		

SEISMIC FORCES

CN	* COL	LONGITUDINAL LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP	TRANSVERSE LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP
44															
44															
44															
44															
44															

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES+

CN		ID	NL	P1, 13, 25	P2, 14, 26	P3, 15, 27	P4, 16, 28	P5, 17, 29	P6, 18, 30	P7, 19, 31	P8, 20, 32	P9, 21, 33	P10, 22, 34	P11, 23, 35	P12, 24, 36
51	1	D-L-BB		135784	133540	0	0	133540	135784						
61	1	1100	1	54120	26120	0	0	0	0						
61	1	1200	1	29180	51030	0	0	0	0						
61	1	1300	1	18860	51030	0	0	10350	0						
61	1	2100	1	0	10350	0	0	51030	18860						
61	1	2200	1	0	0	0	0	51030	29180						
61	1	2300	1	0	0	0	0	26120	54120						
61	1	1121	2	54120	36470	0	0	51030	18860						
61	1	1122	2	54120	26120	0	0	51030	29180						
61	1	1123	2	54120	26120	0	0	26120	54120						
61	1	1221	2	29180	61380	0	0	51030	18860						

CED BY ELB APRIL 1, 1991

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E 5700

SHEET 1 OF 2

I.D.

PROG.	PROB. NO.	REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC.
*B03	15	LINCOLN HAMMER HEAD DESIGN B. S. COX 403 BGPIER15

DESIGN DATA

CN	DESIGN OPTION: CAP	COLUMN	FOOTING	S & L	CANTILEVER	NO. COLUMN	NO. LIVE LOAD CASE	SKEW ANGLE DEG.	MIN.	SEC.	f'c P.S.I. (3,000)	fc P.S.I. (1,200)	N (9)	fy P.S.I. (40,000)	fs P.S.I. (20,000)	Ec K.S.I. (3,156)	Es K.S.I. (29,000)	εc (.0030)	Z (170.)	BAR SIZE (11)	STR. SIZE (5)	MAX. T. B. (6)	MAX. B.B. (6)	MIN. SIZE (11)	MIN. BARS (0)	TOP CLEAR. IN. (2.0)	MIN. STIR. SP. IN. (4.0)	CAP D. INCR. IN. (3.0)	BOTT. CLEAR. IN. (2.31)
01	D	I	D	5	2		1	1	5													8							

DESIGN DATA — COLUMN DESIGN DATA / FOOTING DESIGN DATA

CN	MIN. Ps % (1.00)	MAX. Ps % (8.00)	MIN. SPAC. IN (12.25)	CLEAR IN. (2.563)	R	K_L (2.00)	ϕ_C (S-0.35) (L-0.75)	ϕ_F (S-0.35) (L-0.90)	C_M	β_{D1} (1.00)	β_{D2}	IMPACT %	SOIL WEIGHT K.C.F. (.120)	ALLOWABLE SOIL PRESS. K.S.F.	MIN. PL. SP. FEET (2.50)	MAX. PL. SP. FEET (5.00)	EDGE DISTANCE FEET (1.250)	PILE DEPTH FEET (0.75)	CLEAR IN. (3.00)	PILE CAPACITY KIPS	PILE UPLIFT KIPS	IP
02				2.6882					1.00					7.00								P

CANTILEVER AND CAP DATA

CN	I	L FT.	A FT.	D_E FT.	B_C FT.	B_E FT.	D_H FT.	L_H FT.	X_{B1} FT.	X_{B2} FT.	X_{B3} FT.	X_{B4} FT.	X_{B5} FT.	X_{B6} FT.	X_{B7} FT.	X_{B8} FT.
11	L	14.00	4.0	2.909	4.0		3.0	1.00	1.2375	8.25	0.125					
12	L	14.00	4.0	2.909	4.0		3.0	1.00	4.0	0.125	8.25					
13																
14																
15																
16																

COLUMN DATA

CN	P_0	I	T	S	H_T FT.	A FT.	D_T FT.	B_T FT.	D_B FT.	B_B FT.	D_L FT.	FLEX	REINFORCEMENT STEEL LOWER LIMIT / ACTUAL TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	UPPER LIMIT TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	SLOPE	E_P P.S.I. 10^6	A_P SQ. IN.
21		C	T		53.00		7.25	4.0			4.50		17	3	11	17	3	11									
22																											
23																											
24																											
25																											

FOOTING DATA

CN	SPR	B FT.	D FT.	T FT.	ΔB FT.	ΔD FT.	ΔT FT.	R B/D	R D/B	SOIL HT. FT.	NP	S	B_P FT.	D_P FT.	SETTLE FT.
31	S	14.00	12.00	3.0	0.5	0.5	0.5	2.0	2.0	13.00					
32															
33															
34															

JUNE 2[illegible]1

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+++++          THE ANALYSIS AND DESIGN OF PIERS FOR BRIDGE -  V 4.2.03 - AASHTO SPECS 1984 INTERIM
PROBLEM NO.   15INPUT DATA          LINCOLN HAMMER HEAD DESIGN B. S. COX 403 BGPIER15                    07/14/86
                                                   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 I D S  2  1  15   0-00-00 3000. 1200. 9.2 40000. 20000. 3156. 29000. 0.0030 170.  11  5  8   6  11   0  2.00  4.00 3.00 2.31
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  2.688  2  2.00 0.35 0.35 1.00 1.00 0.00  0.00  0.120    7.000  2.50  5.00  1.250 0.750 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  14.000   4.000   2.909   4.000   0.000   3.000  10.000  12.375   8.250   0.125
12  L  14.000   4.000   2.909   4.000   0.000   3.000  10.000   4.000   0.125   8.250
                                                   COLUMN DATA
CN F 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   53.000  0.000  7.250   4.000   0.000   0.000   4.500  0.000  17  3 11 17  3 11  0  0  0  0  0  0  0.000  0.000  0.000
                                                 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  14.000  12.000  3.000  0.500   0.500   0.500  2.000  2.000  13.000   0   0    0.000   0.000   0.000
+++++                                          GROUP II WIND
SUPERSTRUCTURE AREA*STD.        WIND ON SUPERSTRUCTURE INTENSITIES       * WIND FORCE ARM  * WIND ON PIER
  TRANS.     LONG.  WIND FT1 FL1   FT2 FL2   FT3 FL3   FT4 FL4   FT5 FL5     APT     APL      PT      PL
   552.      552.   1    50   0    44   6    41  12    33  16    17  19    5.310   2.058   3.627  12.422
                                                 GROUP III WIND
STD. *   WIND ON SUPERSTRUCTURE INTENSITIES    * STD. *      WIND ON LIVE LOAD INTENSITIES      * LENGTHS OF LL * WIND ON LL ARMS
WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5  WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5   TRANS.  LONGI.   APT     APL
     50   0   44   6   41  12   33  16   17  19    1   100   0   88  12   82  24   66  32   34  38    85.0    30.0  11.594  11.594
                                 MISCELLANEOUS FORCES
CENTRI.  TRACTION FORCE AND ARMS   EXPANSION   SHRINKAGE     STREAM FLOW
  FT       FL      APT     APL    COEFFICIENT COEFFICIENT    PT      PL
 0.000    9.310  11.594  11.594   0.00000000  0.00000000   0.994   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  135.784  133.540   0.000    0.000  133.540  135.784
1100   1   54.120   26.120   0.000    0.000    0.000    0.000
1200   1   29.180   51.030   0.000    0.000    0.000    0.000
1300   1   18.860   51.030   0.000    0.000   10.350    0.000
2100   1    0.000   10.350   0.000    0.000   51.030   18.860
2200   1    0.000    0.000   0.000    0.000   51.030   29.180
2300   1    0.000    0.000   0.000    0.000   26.120   54.120
1121   2   54.120   36.470   0.000    0.000   51.030   18.860
1122   2   54.120   26.120   0.000    0.000   51.030   29.180
1123   2   54.120   26.120   0.000    0.000   26.120   54.120
1221   2   29.180   61.380   0.000    0.000   51.030   18.860
1222   2   29.180   51.030   0.000    0.000   51.030   29.180
1223   2   29.180   51.030   0.000    0.000   26.120   54.120
1321   2   18.860   61.380   0.000    0.000   51.030   18.860
1322   2   18.860   51.030   0.000    0.000   51.030   29.180
1323   2   18.860   51.030   0.000    0.000   26.120   54.120
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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	4356784.0	0.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.009350	51.8	16605.9	7436.3	123305.2	2873769.0	0.0	25.2
	0.0	0.5000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	51.8	16605.9	54.5	123305.2	1286904.0	0.0	14.9

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

LOAD	COL	TRANSVERSE PC	MT	V	MB	RF	ML	MR	* MT	LONGITUDINAL V	MB	MF
UNIT F.AT CL.CAP	1	0.000	-4.500	1.000	53.000	0.000	0.000	0.000	4.500	1.000	53.000	53.000
DEAD LOAD TOTAL	1	619.919	0.000	0.000	0.000	830.894	2482.628	-2482.628	0.000	0.000	0.000	0.000
		830.894										
STREAM FLOW	1	0.000	-4.473	0.994	52.682	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TRAC. FORCE 1 LN	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-149.835	-9.310	-601.370	-601.370
WIND ON SUBSTR.	1	0.000	-16.321	3.627	192.231	0.000	0.000	0.000	-55.899	-12.422	-658.366	-658.366
GROUP 2 WIND 1 1	1	0.000	-287.077	31.227	1801.586	0.000	0.000	0.000	-55.899	-12.422	-658.366	-658.366
GROUP 2 WIND 1 2	1	0.000	-287.077	31.227	1801.586	0.000	0.000	0.000	55.899	12.422	658.366	658.366
GROUP 2 WIND 2 1	1	0.000	-254.587	27.915	1608.464	0.000	0.000	0.000	-77.619	-15.734	-840.718	-840.718
GROUP 2 WIND 2 2	1	0.000	-254.587	27.915	1608.464	0.000	0.000	0.000	77.619	15.734	840.718	840.718
GROUP 2 WIND 3 1	1	0.000	-238.341	26.259	1511.902	0.000	0.000	0.000	-99.339	-19.046	-1023.070	-1023.070
GROUP 2 WIND 3 2	1	0.000	-238.341	26.259	1511.902	0.000	0.000	0.000	99.339	19.046	1023.070	1023.070
GROUP 2 WIND 4 1	1	0.000	-195.020	21.843	1254.405	0.000	0.000	0.000	-113.819	-21.254	-1144.638	-1144.638
GROUP 2 WIND 4 2	1	0.000	-195.020	21.843	1254.405	0.000	0.000	0.000	113.819	21.254	1144.638	1144.638
GROUP 2 WIND 5 1	1	0.000	-108.379	13.011	739.412	0.000	0.000	0.000	-124.679	-22.910	-1235.814	-1235.814
GROUP 2 WIND 5 2	1	0.000	-108.379	13.011	739.412	0.000	0.000	0.000	124.679	22.910	1235.814	1235.814
GROUP 3 WIND 1 1	1	0.000	-222.922	17.868	1089.524	0.000	0.000	0.000	-16.770	-3.727	-197.510	-197.510
GROUP 3 WIND 1 2	1	0.000	-222.922	17.868	1089.524	0.000	0.000	0.000	16.770	3.727	197.510	197.51[illegible]
GROUP 3 WIND 2 1	1	0.000	-196.759	15.854	965.702	0.000	0.000	0.000	-29.080	-5.080	-275.469	-275.46[illegible]
GROUP 3 WIND 2 2	1	0.000	-196.759	15.854	965.702	0.000	0.000	0.000	29.080	5.080	275.469	275.469
GROUP 3 WIND 3 1	1	0.000	-183.677	14.848	903.790	0.000	0.000	0.000	-41.389	-6.434	-353.428	-353.428
GROUP 3 WIND 3 2	1	0.000	-183.677	14.848	903.790	0.000	0.000	0.000	41.389	6.434	353.428	353.428
GROUP 3 WIND 4 1	1	0.000	-148.793	12.163	738.694	0.000	0.000	0.000	-49.596	-7.336	-405.402	-405.402
GROUP 3 WIND 4 2	1	0.000	-148.793	12.163	738.694	0.000	0.000	0.000	49.596	7.336	405.402	405.402
GROUP 3 WIND 5 1	1	0.000	-79.025	6.793	408.500	0.000	0.000	0.000	-55.751	-8.013	-444.381	-444.381
GROUP 3 WIND 5 2	1	0.000	-79.025	6.793	408.500	0.000	0.000	0.000	55.751	8.013	444.381	444.381
LIVE LOAD 1100	1	80.240	-777.480	0.000	777.480	80.240	777.480	0.000	0.000	0.000	0.000	0.000

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

LOAD	COL	TRANSVERSE PC	MT	V	MB	RF	ML	MR	* MT	LONGITUDINAL V	MB	MF
LIVE LOAD 1200	1	80.210	-571.601	0.000	571.601	80.210	571.601	0.000	0.000	0.000	0.000	0.000
LIVE LOAD 1300	1	80.240	-401.197	0.000	401.197	80.240	443.891	-42.694	0.000	0.000	0.000	0.000
LIVE LOAD 2100	1	80.240	401.197	0.000	-401.197	80.240	42.694	-443.891	0.000	0.000	0.000	0.000
LIVE LOAD 2200	1	80.210	571.601	0.000	-571.601	80.210	0.000	-571.601	0.000	0.000	0.000	0.000
LIVE LOAD 2300	1	80.240	777.480	0.000	-777.480	80.240	0.000	-777.480	0.000	0.000	0.000	0.000
LIVE LOAD 1121	1	160.480	-376.282	0.000	376.282	160.480	820.174	-443.891	0.000	0.000	0.000	0.000
LIVE LOAD 1122	1	160.450	-205.879	0.000	205.879	160.450	777.480	-571.601	0.000	0.000	0.000	0.000
LIVE LOAD 1123	1	160.480	0.000	0.000	0.000	160.480	777.480	-777.480	0.000	0.000	0.000	0.000
LIVE LOAD 1221	1	160.450	-170.404	0.000	170.404	160.450	614.295	-443.891	0.000	0.000	0.000	0.000
LIVE LOAD 1222	1	160.420	0.000	0.000	0.000	160.420	571.601	-571.601	0.000	0.000	0.000	0.000
LIVE LOAD 1223	1	160.450	205.879	0.000	-205.879	160.450	571.601	-777.480	0.000	0.000	0.000	0.000
LIVE LOAD 1321	1	150.130	-42.694	0.000	42.694	150.130	486.585	-443.891	0.000	0.000	0.000	0.000
LIVE LOAD 1322	1	150.100	127.710	0.000	-127.710	150.100	443.891	-571.601	0.000	0.000	0.000	0.00[illegible]
LIVE LOAD 1323	1	150.130	333.589	0.000	-333.589	150.130	443.891	-777.480	0.000	0.000	0.000	0.0[illegible]

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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	-2.433	-2.433	-2.433	-2.433	-2.433	-2.433	-2.433	-3.074	-138.858	-3.074	-138.858	-3.074	-192.978
P 2	-1234.208	-1234.208	-1680.698	-1234.208	-1234.208	-1234.208	-1234.208	-161.796	-295.336	-161.796	-295.336	-215.916	-385.926
P 3	-1271.153	-1271.153	-1728.966	-1271.153	-1271.153	-1271.153	-1271.153	-295.778	-295.778	-295.778	-295.778	-386.368	-386.368
C 1L	-2482.628	-2482.628	-3302.802	-2482.628	-2482.628	-2482.628	-3302.802	-309.959		-309.959		-400.549	
C 1R	-2482.628	-2482.628	-3260.108	-2482.628	-2482.628	-2482.628	-3260.108		309.959		390.199		309.959
P 4	-1271.153	-1271.153	-1727.673	-1271.153	-1271.153	-1271.153	-1271.153	295.778	295.778	376.018	376.018	295.778	295.778
P 5	-1234.208	-1234.208	-1680.698	-1234.208	-1234.208	-1234.208	-1234.208	295.336	161.796	375.576	215.916	295.336	161.796
P 6	-2.433	-2.433	-2.433	-2.433	-2.433	-2.433	-2.433	138.858	3.074	192.978	3.074	138.858	3.074

CAP DESIGN DATA

PT.	G1 M+SL K-FT.	G1 M-SL K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI
P 1	-2.433	-2.433	0.04	1 # 11	0.00	0 # 11	0.00	0.000	#5@ 0.00	18.48	0.136	#5@ 4.55	40.76	45
P 2	-1234.208	-1680.698	16.71	11 # 11	0.00	0 # 11	24.00	0.060	#5@10.33	24.00	0.167D	#5@ 7.44	70.46	790
P 3	-1271.153	-1728.966	17.09	11 # 11	0.00	0 # 11	24.00	0.165D	#5@ 7.52	24.00	0.165D	#5@ 7.52	70.91	797
C 1	-2482.628	-3302.802	24.96	16 # 11	0.00	0 # 11	24.00	0.104	#5@ 5.98	24.00	0.098	#5@ 6.34	91.91	847
P 4	-1271.153	-1727.673	17.08	11 # 11	0.00	0 # 11	24.00	0.157D	#5@ 7.89	24.00	0.157D	#5@ 7.89	70.91	796
P 5	-1234.208	-1680.698	16.71	11 # 11	0.00	0 # 11	24.00	0.159D	#5@ 7.81	24.00	0.060	#5@10.33	70.46	790
P 6	-2.433	-2.433	0.04	1 # 11	0.00	0 # 11	18.48	0.136	#5@ 4.55	0.00	0.000	#5@ 0.00	40.76	45

NOTE: *** CAP DEPTH HAS BEEN INCREMENTED! ***

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COLUMN ANALYSIS AND DESIGN OUTPUT

CRITICAL COLUMN LOADS

CN	T B	GR	LLC	WC	R	E S	C F	S F	PF	MTF	MLF	PM	MTM	MLM	PU	MTU	MLU	PU/PM	B	D
1	T	1	1100	0.0				S	700.2	-782.0	0.0	700.2	889.9	384.1	2515.6	3202.1	1382.1	3.596	48.00	87.00
1	B	3	1121	3.1				S	991.4	1332.8	-1556.2	991.4	1537.9	2216.2	1395.3	2165.0	3120.0	1.408	48.00	87.00

COLUMN DESIGN DATA

CN	T B	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	3 # 11	3 # 11	17 # 11	17 # 11	62.40	1.494	1.00	0.000	2014.	16606.	1.138	1.371	1.000	2	0.35
1	B	3 # 11	3 # 11	17 # 11	17 # 11	62.40	1.494	1.00	0.000	2215.	16606.	1.154	1.424	1.000	2	0.35

FOOTING 1 DESIGN LOADS

F	G	LLID	WC	ES	C	S	P	MT	VT	ML	VL	P4	P3	P2	P1	MTF	VBF	VPF	LOAD
1	3	1121	1.1			S	991.37	1518.49	18.86	-1400.25	-22.35	5.079	1.694	5.125	8.510	64.515	12.098	23.202	MAX.P1
1	3	1100	1.1			S	911.13	1919.69	18.86	-798.88	-13.04	3.653	1.720	6.026	7.959	65.783	12.391	21.324	MAX.MT
1	3	1100	1.1			S	911.13	1919.69	18.86	-798.88	-13.04	3.653	1.720	6.026	7.959	65.783	12.391	21.324	MAX.VT
1	3	1121	1.1			S	991.37	1518.49	18.86	-1400.25	-22.35	5.079	1.694	5.125	8.510	64.515	12.098	23.202	MAX.VP
1	3	1121	4.1			S	991.37	1167.66	13.16	-1608.14	-25.96	5.732	1.842	4.472	8.362	95.926	17.409	23.202	MAX.ML
1	3	1121	4.1			S	991.37	1167.66	13.16	-1608.14	-25.96	5.732	1.842	4.472	8.362	95.926	17.409	23.202	MAX.VL
1	3	1121	1.1			S	991.37	1518.49	18.86	-1400.25	-22.35	5.079	1.694	5.125	8.510	64.515	12.098	23.202	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
17.000	18.000	3.000	0.973	1.10	24 # 8	@ 8.500	TOP TRAN	66.595	24.049	45.567	30.813	0.715
				1.55	18 #11	@12.000	BOT.LONG	96.311	25.122	47.600	32.188	0.847

EXAMPLE PROBLEM NO. 5

Given Data: Pitt County - Pile Bent

- Pile and cap members have a constant moment of inertia.
- Piles are assumed fixed at bottom (FLEX = 0).
- A pile bent analysis is desired.
- Centroid of superstructure area is 5.60' above centerline of cap
- For Group II wind, Group III wind, and wind on live load, use standard program defaults.
- Wind on substructure (equivalent at centerline of cap) is 1.55 kips in the transverse direction, and 10.12 in the longitudinal direction.
- Longitudinal force (traction) is 2.70 kips (one lane).
- Dead load from superstructure are given on following page.
- Lengths for wind on live load are 64.3 (transverse) and 64.3 (longitudinal) feet.
- Location of wind on live load is 5.6 feet above centerline of cap.
- Location of traction force is 1.5 feet above centerline of cap.
- Use all program defaults.
- Use load factor option.
- Use XBN dimensions to position all dummy loads at column faces to obtain cap moments and shears at the column face.

24" Prestressed Concrete Pile: $f'c = 5000$ psi

$E_p = 57000 - \sqrt{5000} = 4{,}030{,}509$ psi

Cast in Place Concrete: $f'c = 3000$ psi

$E_c = 57000 - \sqrt{3000} = 3{,}122{,}019$

Equivalent Properties

$$I_c = \frac{Epile \quad Ipile}{E_c} = \frac{4{,}030{,}509 * \frac{(24)^4}{12}}{3{,}122{,}019}$$

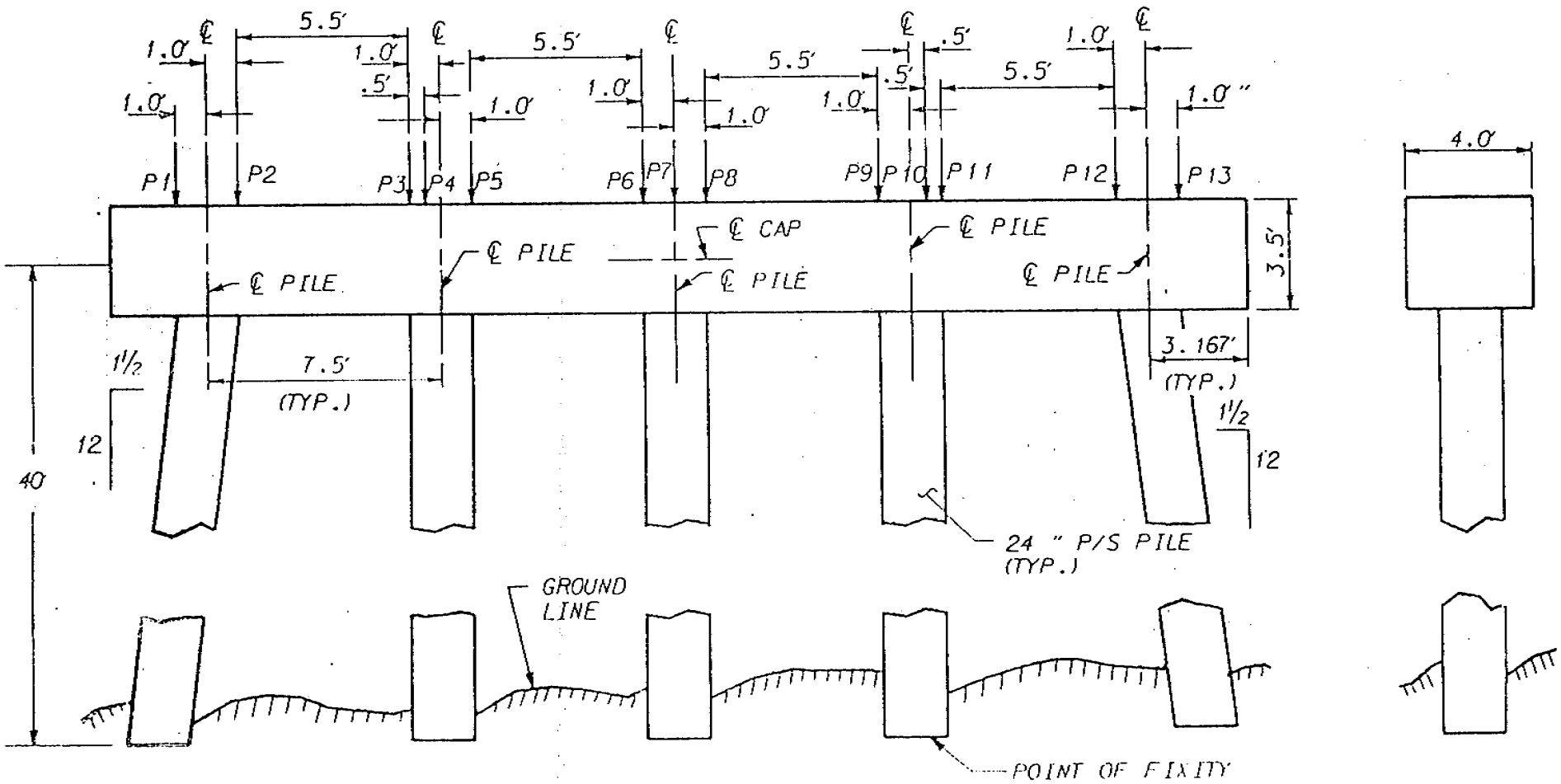
$$= 35{,}693 \text{ in}^4$$

$$D_T = -\sqrt[4]{5{,}693} * \frac{64}{\pi} = 29.2 \text{ in.}$$

$$= 2.43 \text{ ft.}$$

PITT COUNTY

FOR DEAD AND LIVE LOADS SEE INPUT SHEETS



STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E.3700

SHEET 1 OF 2

I. D.

PROG.	PROB. NO.	REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC.
*B03	01XX	EXAMPLE 5 PITT CO. PILE BENT CHRIS RAY

DESIGN DATA

CN	DESIGN OPTION: CAP COLUMN	FOOTING (S & L)	CANTILEVER	NO. COLUMN	NO. LIVE LOAD CASE	SKEW ANGLE DEG.	MIN.	SEC.
01	DI	L2	5	4				

GENERAL DESIGN DATA	f'c (P.S.I.)	fc (P.S.I.)	N	fy (P.S.I.)	fs (P.S.I.)	Ec (K.S.I.)	Es (K.S.I.)	εc
	(3,000)	(1,200)	(9)	(40,000)	(20,000)	(3,156)	(29,000)	(.0030)
01				60000	24000			

CAP DESIGN DATA	Z	BAR SIZE	STR. SIZE	MAX. T. B.	MAX. B. B.	MIN. SIZE	MIN. BARS	TOP CLEAR. IN.	MIN. STIR. SP. IN.	CAP D. INCR. IN.	BOTT. CLEAR. IN.
	(170.)	(11)	(5)	(6)	(6)	(11)	(10)	(2.0)	(4.0)	(3.0)	(2.31)
01		9				9	8				

COLUMN DESIGN DATA	CN	MIN. Ps %	MAX. Ps %	MIN. SPAC. IN	CLEAR IN.	R	K_L	ϕ_C	ϕ_F	C_M	β_{D1}	β_{D2}
		(1.00)	(8.00)	(2.25)	(2.563)		(2.00)	(S-0.35) (L-0.75)	(S-0.35) (L-0.90)		(1.00)	
	02											

FOOTING DESIGN DATA	IMPACT %	SOIL WEIGHT KCF	ALLOWABLE SOIL PRESS. KSF	MIN. PL. SP. FEET	MAX. PL. SP. FEET	EDGE DISTANCE FEET	PILE DEPTH FEET	CLEAR IN.	PILE CAPACITY KIPS	PILE UPLIFT KIPS	IP
		(.120)		(2.50)	(5.00)	(1.250)	(0.75)	(3.00)			
02									220		

CANTILEVER AND CAP DATA

CN	I	L FT.	A FT.	D_E FT.	B_C FT.	B_E FT.	D_H FT.	L_H FT.	X_{B1} FT.	X_{B2} FT.	X_{B3} FT.	X_{B4} FT.	X_{B5} FT.	X_{B6} FT.	X_{B7} FT.	X_{B8} FT.
11	C	3.167		3.5	4.0				1.0							
12	C	7.5		3.5	4.0				1.0	5.5	0.5					
13	C	7.5		3.5	4.0				1.0	5.5						
14	C	7.5		3.5	4.0				1.0	5.5						
15	C	7.5		3.5	4.0				0.5	0.5	5.5					
16	C	5.167		3.5	4.0				1.0							

COLUMN DATA

CN	P_O	I	T	S	H_T FT.	A FT.	D_T FT.	B_T FT.	D_B FT.	B_B FT.	D_L FT.	FLEX
21		C	T	P	40		2.434				1.75	
22		C	T	P	40		2.434				1.75	
23	1	C	T	P	40		2.434				1.75	
24		2										
25		C	T	P	40		2.434				1.75	

REINFORCEMENT STEEL	LOWER LIMIT / ACTUAL TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	UPPER LIMIT TOP ND	NB	SIZE	BOTTOM ND	NB	SIZE	SLOPE	E_P P.S.I. x 10^6	A_P SQ. IN.
21													1.25		
22															
23															
24															
25													-1.25		

FOOTING DATA

CN	SP	B FT.	D FT.	T FT.	ΔB FT.	ΔD FT.	ΔT FT.	R B/D	R D/B	SOIL HT. FT.	NP	S	B_P FT.	D_P FT.	SETTLE FT.
31															
32															
33															
34															
35															

JUNE 25, 1981

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS

E75700

SHEET _ OF _

FORCES = KIPS
INTENSITY = LBS/FT²
AREAS = FT²
LENGTHS = FT
TRACTION AND CENTRIFUGAL FORCE = 1 LANE
COEFFICIENTS = UNITS/UNITS

GROUP II WIND

CN	SUPERSTRUCTURE AREA TRANS	SUPERSTRUCTURE AREA LONG	STD V	WIND ON SUPERSTRUCTURE INTENSITY FT1 FL1	FT2 FL2	FT3 FL3	FT4 FL4	FT5 FL5	WIND FORCE ARMS APT	APL	WIND ON PIER PT	PL
41	528	528	1						56	15	155	102

GROUP III WIND

CN	STD V	WIND ON SUPERSTRUCTURE INTENSITY FT1 FL1	FT2 FL2	FT3 FL3	FT4 FL4	FT5 FL5	STD V	WIND ON LIVE LOAD INTENSITY FT1 FL1	FT2 FL2	FT3 FL3	FT4 FL4	FT5 FL5	LENGTH OF LIVE LOADS TRANS	LONG	WIND ON L.L. ARMS APT	APL
42	1						1						693	693/28		15

* AT LEAST ONE LIVE LOAD CASE IS REQUIRED
MAXIMUM NUMBER OF LIVE LOAD CASES IS 25

MISC. FORCES

CN	CENTRIFUGAL FORCE FT	TRACTION FORCE FL	CENTRIFUGAL FORCE & TRACTION FORCE ARMS APT	APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PT	PL	* ED
43		27	128	15	00002	00044			

* COLUMNS 51,52 MUST BE 0.1 FOR SEISMIC CONSIDERATION.

	FT-	FL-
STD V - GR.II. GR.III SUPERSTRUCTURE	50 44 41 33 17	0 6 12 16 19
STD V - GR.III LIVE LOAD	103 88 82 66 34	8 12 24 32 38

SEISMIC FORCES

CN	* ED	LONGITUDINAL LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP	TRANSVERSE LOADING (ALL POSITIVE) VL TOP	VT TOP	ML BOTTOM	ML TOP	MT BOTTOM	MT TOP	P TOP
44															
44															
44															
44															
44															

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES*

CN	ID	NL	P1, 13, 25	P2, 14, 26	P3, 15, 27	P4, 16, 28	P5, 17, 29	P6, 18, 30	P7, 19, 31	P8, 20, 32	P9, 21, 33	P10, 22, 34	P11, 23, 35	P12, 24, 36
51	D-L-00		1190	0	0	1240	0	0	1250	0	0	1260	0	0
52			1230											
61	LL0102		31897	0	0	74427	0	0	53162	0	0	10632	0	0
62			0											0
61	LL0202		53162	0	0	53162	0	0	53162	0	0	10632	0	0
62			0											
61	LL0302		0	0	0	10632	0	0	53162	0	0	74427	0	0
62			31897											
61	LL0402		0	0	0	10632	0	0	53162	0	0	53162	0	0
62			53162											
61														

+++++ THE ANALYSIS AND DESIGN OF PIERS FOR BRIDGE - V 4.2.03 - AASHTO SPECS 1984 INTERIM

PROBLEM NO. 01INPUT DATA XX EXAMPLE 5 STR. PITT COUNTY PILE BENT CHRIS RAY 04/29/92

DESIGN DATA

DESIGN OPTIONS	NO. CAN	NO. COL	NO. LLC	SKEW ANG D	M	S	F'C PSI	FC PSI	N	FY PSI	FS PSI	EC KSI	ES KSI	CONC. STRAIN	Z FACT	* MAIN SIZE	* STR SIZ	* CAP REINFORCING STEEL MAX TOP	MAX BOT	MIN SIZE	MIN NO.	TOP CL.	* MIN S.SP	* CAP DEPTH INCR.	BOT CL.
[illegible]	L	2	5	4	0-00-00		3000.	1200.	9.2	60000.	24000.	3156.	29000.	0.0030	170.	9	5	6	6	9	8	2.00	4.00	3.00	2.31

COLUMN MIN.P	REINFORCING STEEL MAX.P	CL.SP.	CLEAR	R MODE	KL COEF	OC	OF	CM	BD1	BD2	IMPACT %	SOIL WT KCF	ALL.S.P. KSF	MIN PL SP	MAX PL SP	EDGE DIST	PILE DEPTH	REBAR CLEAR	ALL.PILE CAPACITY	ALL.PILE UPLIFT	I P
1.00	8.00	2.25	2.563	0	2.00	0.75	0.90	0.00	1.00	0.00	0.00	0.120	0.000	2.50	5.00	1.250	0.750	3.000	220.000	0.000	

CAP DATA

CN	C	L	A	DE	BC	BE	DH	LH	XB1	XB2	XB3	XB4	XB5	XB6	XB7	XB8
11	C	3.167	0.000	3.500	4.000	0.000	0.000	0.000	1.000							
12	C	7.500	0.000	3.500	4.000		0.000	0.000	1.000	5.500	0.500					
13	C	7.500	0.000	3.500	4.000		0.000	0.000	1.000	5.500						
14	C	7.500	0.000	3.500	4.000		0.000	0.000	1.000	5.500						
15	C	7.500	0.000	3.500	4.000		0.000	0.000	0.500	0.500	5.500					
16	C	3.167	0.000	3.500	4.000	0.000	0.000	0.000	1.000							

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	P	40.000	0.000	2.434	0.000	0.000	0.000	1.750	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0.125	0.000	0.000
22	0	C	T	P	40.000	0.000	2.434	0.000	0.000	0.000	1.750	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000
23	1	C	T	P	40.000	0.000	2.434	0.000	0.000	0.000	1.750	0.000	0	0	0	0	0	0	0	0	0	0	0	0	0.000	0.000	0.000
24	0	4 SAME AS COLUMN 2																									
25	0	C	T	P	40.000	0.000	2.434	0.000	0.000	0.000	1.750	0.000	0	0	0	0	0	0	0	0	0	0	0	0	-0.125	0.000	0.000

++++++ GROUP II WIND

SUPERSTRUCTURE AREA*STD. TRANS.	LONG.	WIND	FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	* WIND FORCE ARM APT	APL	* WIND ON PIER PT	PL
528.	528.	1	50	0	44	6	41	12	33	16	17	19	5.600	1.500	1.550	10.120

GROUP III WIND

STD. * [illegible]	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
[illegible]	50	0	44	6	41	12	33	16	17	19	1	100	0	88	12	82	24	66	32	34	38	64.3	64.3	12.800	1.500

MISCELLANEOUS FORCES

CENTRI. FT	TRACTION FORCE AND ARMS FL	APT	APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PT	PL
0.000	2.700	12.800	1.500	0.00002000	0.00044000	0.000	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	119.000 123.000	0.000	0.000	124.000	0.000	0.000	125.000	0.000	0.000	126.000	0.000	0.000
LL01	2	31.897 0.000	0.000	0.000	74.427	0.000	0.000	53.162	0.000	0.000	10.632	0.000	0.000
LL02	2	53.162 0.000	0.000	0.000	53.162	0.000	0.000	53.162	0.000	0.000	10.632	0.000	0.000
LL03	2	0.000 31.897	0.000	0.000	10.632	0.000	0.000	53.162	0.000	0.000	74.427	0.000	0.000
LL04	2	0.000 53.162	0.000	0.000	10.632	0.000	0.000	53.162	0.000	0.000	53.162	0.000	0.000

CAP MOMENTS AND SHEARS

POINT	MOMENTS(KIP-FEET) D.L.TOT.	G1 MAX.+	G1 MAX.-	G2 MAX.+	G2 MAX.-	G3 MAX.+	G3 MAX.-	** SHEARS(KIPS) DL T.LT	DL T.RT	G1 + LT	G1 + RT	G1 - LT	G1 - RT
P 1	-6.410	-6.410	-6.410	-6.410	-6.410	-6.410	-6.410	-5.916	-160.616	-5.916	-160.616	-5.916	-276.031
C 1L	-168.391	-168.391	-283.805	-168.391	-168.391	-168.391	-237.501	-163.346		-163.346		-278.760	
C 1R	-181.534	-181.534	-252.688	-92.863	-270.204	-150.128	-271.141		45.647		81.922		33.2[illegible]
P 2	-137.252	-137.252	-220.841	-123.873	-150.630	-132.176	-194.397	42.917	42.917	79.192	79.192	30.482	30.[illegible]
P 3	57.502	251.445	-94.481	458.228	-343.224	386.042	-245.913	27.902	27.902	64.177	64.177	15.467	15.467
P 4	71.112	283.192	-87.089	509.484	-367.260	430.467	-255.980	26.537	-134.663	62.812	-121.470	14.102	-301.308
C 2L	3.439	222.116	-218.686	479.457	-472.579	386.698	-381.885	-136.028		-122.835		-302.673	
C 2R	1.827	187.567	-187.286	407.586	-403.932	328.123	-326.488		7.930		31.660		-15.125
P 5	8.392	171.077	-156.990	363.435	-346.650	294.000	-278.831	5.200	5.200	28.930	28.930	-17.855	-17.855
P 6	-4.297	31.582	-39.164	71.804	-80.397	57.525	-65.513	-9.815	-9.815	13.915	13.915	-32.870	-32.870
C 3L	-15.476	-1.150	-26.613	9.907	-40.860	6.557	-35.600	-12.545		11.185		-35.600	
C 3R	-16.549	-2.222	-27.685	8.835	-41.933	5.485	-36.672		10.503		33.558		-13.227
P 8	-7.411	28.468	-42.278	68.690	-83.512	54.411	-68.627	7.773	7.773	30.828	30.828	-15.957	-15.957
P 9	-5.951	156.733	-171.334	349.091	-360.993	279.656	-293.174	-7.242	-7.242	15.813	15.813	-30.972	-30.972
C 4L	-14.558	171.181	-203.671	391.201	-420.317	311.738	-342.873	-9.972		13.083		-33.702	
C 4R	-15.880	202.797	-238.005	460.138	-491.897	367.379	-401.204		140.850		307.496		127.658
P10	54.204	266.284	-103.996	492.576	-384.168	413.559	-272.887	139.485	-24.315	306.131	-11.879	126.293	-60.589
P11	41.706	235.648	-110.277	442.431	-359.020	370.245	-261.708	-25.680	-25.680	-13.244	-13.244	-61.954	-61.954
P12	-140.823	-140.823	-224.413	-127.445	-154.202	-135.748	-197.969	-40.695	-40.695	-28.259	-28.259	-76.969	-76.969
C 5L	-182.883	-182.883	-254.037	-94.213	-271.553	-151.477	-272.490	-43.425		-30.989		-79.699	
C 5R	-173.591	-173.591	-289.005	-173.591	-173.591	-173.591	-242.701		168.546		283.960		168.546
P13	-6.410	-6.410	-6.410	-6.410	-6.410	-6.410	-6.410	165.816	5.916	281.230	5.916	165.816	5.916

CAP DESIGN DATA

PT.	M+ UNF. K-FT.	M- UNF. K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI	PS %	FS/FF RATIO	FS/FZ RATIO
P 1	-4.931	-4.931	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	19.19	0.053	#5@11.61	42.00		0.44	0.000	0.007

CAP DESIGN DATA

PT.	M+ UNF. K-FT.	M- UNF. K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI	PS %	FS/FF RATIO	FS/FZ RATIO
C 1	-129.531	-182.693	8.00	8 # 9	8.00	8 # 9	19.19	0.055	#5@11.31	0.00	0.000	#5@ 0.00	42.00		0.53	0.105	0.246
P 2	-105.578	-144.081	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.51	0.075	0.194
P 3	133.566	-25.774	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.60	0.251	0.000
P 4	152.389	-18.169	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	19.03	0.068	#5@ 9.18	42.00		0.62	0.283	0.000
C 2	103.372	-99.669	8.00	8 # 9	8.00	8 # 9	19.03	0.068	#5@ 9.08	0.00	0.000	#5@ 0.00	42.00		0.61	0.222	0.000
P 5	81.391	-69.722	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.57	0.171	0.000
P 6	13.221	-19.365	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.46	0.039	0.000
C 3	-5.306	-17.859	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.45	0.023	0.024
P 8	10.826	-21.761	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.46	0.043	0.000
P 9	70.357	-80.756	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.56	0.170	0.000
C 4	88.511	-114.530	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	19.19	0.069	#5@ 8.92	42.00		0.61	0.238	0.000
P10	139.383	-31.174	8.00	8 # 9	8.00	8 # 9	19.03	0.070	#5@ 8.85	0.00	0.000	#5@ 0.00	42.00		0.61	0.264	0.000
P11	121.414	-37.925	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.59	0.233	0.000
P12	-108.326	-146.829	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	0.00	0.000	#5@ 0.00	42.00		0.51	0.075	0.198
C 5	-133.531	-186.693	8.00	8 # 9	8.00	8 # 9	0.00	0.000	#5@ 0.00	19.19	0.057	#5@10.79	42.00		0.53	0.105	0.252
P13	-4.931	-4.931	8.00	8 # 9	8.00	8 # 9	19.19	0.056	#5@11.06	0.00	0.000	#5@ 0.00	42.00		0.44	0.000	0.007

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SPECIAL PILES
CRITICAL PILE LOADS
MAX. P-LOAD

CN	T B	GR	LLC	WC	R	E S	C F	S F	PF	MTF	MLF	VLF	PA
1	T	1	LL02	0.0					209.9	-10.3	0.0	0.0	220.0
2	[illegible]	4	LL01	0.0		S			256.6	-21.9	0.0	0.0	275.0
3	T	1	LL04	0.0					195.6	11.9	0.0	0.0	220.0
4	T	4	LL03	0.0		S			261.9	24.1	0.0	0.0	275.0
5	T	1	LL04	0.0					212.2	13.2	0.0	0.0	220.0

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SPECIAL PILES
CRITICAL PILE LOADS
MAX. VL-LOAD

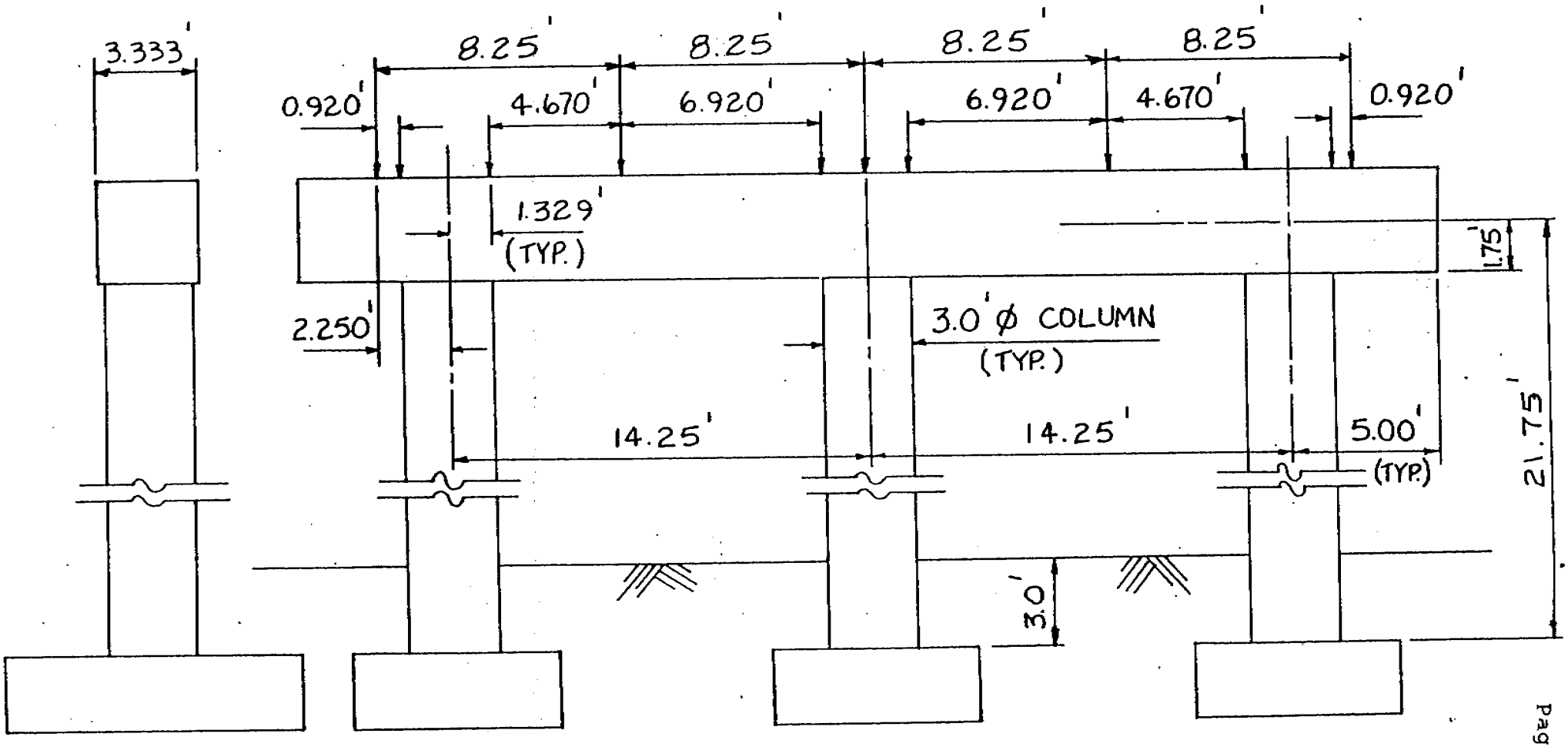
CN	T B	GR	LLC	WC	R	E S	C F	S F	PF	MTF	MLF	VLF	VLA
1	T	2		4.1					204.7	56.4	-9.1	-3.7	2.5
2	T	5		3.2		S			92.4	32.7	7.7	3.3	2.8
3	T	2		5.2					142.7	15.5	10.1	4.0	2.5
4	T	5		4.1		S			241.1	51.1	-9.0	-3.7	2.8
5	T	2		5.2					141.0	18.5	10.1	4.0	2.5

EXAMPLE PROBLEM

SEISMIC PERFORMANCE CATEGORY: B

Given Data:

* Yield stress of reinforcing steel is 60,000 psi.
* Allowable steel stress is 24,000 psi.
* Column and cap members have a constant moment of inertia.
* Columns are assumed fixed at bottom (FLEX = 0).
* Footings are spread with a 5'-0" x 5'-0" x 2'-6" 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 two times the other width.
* A cap, column and footing design is desired.
* Centroid of the superstructure transverse area is 6.12' above centerline of cap.
* Longitudinal Group II wind acts 1.75' above centerline of cap.
* For Group II wind, Group III wind, and wind on live load, use standard defaults.
* Wind on substructure (equivalent at centerline of cap) is 3.8 kips in the transverse direction and 8.7 kips in the longitudinal direction.
* Longitudinal traction force for one lane is 5.7 kips.
* Dead load from superstructure are given on input sheet.
* Length for wind on live load is 150'.
* Location of wind on live load is 13.5' above centerline cap.
* Location of traction force is 1.75' above centerline cap.
* Seismic forces are obtained from SEISAB-I program output.
* Use all program defaults.
* Actual column diameter is 3'-0". Equivalent column size is 2.6587' square.



COUNTIES IN SEISMIC PERFORMANCE CATEGORY B

(SEE INPUT SHEETS FOR DEAD AND LIVE LOAD VALUES)

DEPT. OF TRANSPORTATION

OF MULTIPLE COLUMN PIERS

I.D.

PROG.	PROB. NO.	REMARKS, PROJECT NUMBER, COUNTY, NAME, DATE, ETC.
* B 0 3	EX 6	XXEXAMPLE FOR SEISMIC DESIGN - MULTI COLUMN BNT - HOFF D757EX6

DESIGN DATA

CN	CAP	COLUMN	FOOTING	L & L1	CANTILEVER	NO. COLUMN	NO. LIVE LOAD CASE	SKEW ANGLE DEG.	MIN.	SEC.
01	D	D	D		2	3	1	6	2	0

DESIGN OPTION

GENERAL DESIGN DATA

CN	f'c PSI (3,000)	fc PSI (1,200)	N (9)	fy PSI (40,000)	fs PSI (20,000)	Ec KSI (3,156)	Es KSI (29,000)	εc (.0030)
01				60000	24000			

CAP DESIGN DATA

CN	Z (170.)	BAR SIZE (11)	STR. SIZE (5)	MAX. T.B. (6)	MAX. B.B. (6)	MIN. SIZE (11)	MIN. BARS (0)	TOP CLEAR. IN (2.0)	MIN STIR. SP. IN (4.0)	CAP D. INCR. IN. (3.0)	BOTT. CLEAR. IN. (2.31)
01		10				10	6				

COLUMN DESIGN DATA

CN	MIN. Ps % (1.00)	MAX. Ps % (8.00)	MIN. SPAC. IN (2.25)	CLEAR IN. (2.563)	R	K_L (2.00)	ϕ_C (S-0.35) (L-0.75)	ϕ_F (S-0.35) (L-0.90)	C_M	β_{D1} (1.00)	β_{D2}	IMPACT %
02												182

FOOTING DESIGN DATA

CN	SOIL WEIGHT PCF (120)	ALLOWABLE SOIL PRESS. KSF	MIN. PL. SP. FEET (2.50)	MAX. PL. SP. FEET (5.00)	EDGE DISTANCE FEET (1.250)	PILE DEPTH FEET (0.75)	CLEAR IN. (3.00)	PILE CAPACITY KIPS	PILE UPLIFT KIPS	IP
02		80								

CANTILEVER AND CAP DATA

CN	I	L FT	A FT	D_E FT	B_C FT	B_E FT	D_H FT	L_H FT	X_{B1} FT	X_{B2} FT	X_{B3} FT	X_{B4} FT	X_{B5} FT	X_{B6} FT	X_{B7} FT	X_{B8} FT
11	C	50		35	3333				225	092						
12	C	1425		35	3333				1329	467	692					
13	C	1425		35	3333				1329	692	467					
14	C	50		35	3333				1329	092						
15																
16																

COLUMN DATA

CN	P_0	I	T	S	H_T FT	A FT	D_T FT	B_T FT	D_B FT	B_B FT	D_L FT	FLEX	REINFORCEMENT STEEL LOWER LIMIT / ACTUAL TOP NO	TOP NB	TOP SIZE	BOTTOM NO	BOTTOM NB	BOTTOM SIZE	UPPER LIMIT TOP NO	TOP NB	TOP SIZE	BOTTOM NO	BOTTOM NB	BOTTOM SIZE	SLOPE	E_P PSI x 10^6	A_P SQ. IN.
21			CR		21	75	30							12	09		12	09									
22		1	CR		21	75	30							12	09		12	09									
23			CR		21	75	30							12	09		12	09									
24																											
25																											

FOOTING DATA

CN	SP	B FT	D FT	T FT	ΔB FT	ΔD FT	ΔT FT	R B/D	R D/B	SOIL HT FT	NP	S	B_P FT	D_P FT	SETTLE FT
31	S	50	50	25	025	025	025	20	20	30					
32	S	50	50	25	025	025	025	20	20	30					
33	S	50	50	25	025	025	025	20	20	30					
34															
35															

FORCES = KIPS
INTENSITY = LBS/FT²
AREAS = FT²
LENGTHS = FT
TRACTION AND CENTRIFUGAL FORCE = 1 LANE
COEFFICIENTS = UNITS/UNITS

	CN	SUPERSTRUCTURE AREA TRANS	SUPERSTRUCTURE AREA LONG	S10 W	WIND ON SUPERSTRUCTURE INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	WIND FORCE ARMS APT	APL	WIND ON PIER PT	PL
I WIND	1 2 / 4 1	1075	1075	1											612	175	38	87

	CN	S10 W	WIND ON SUPERSTRUCTURE INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	S10 W	WIND ON LIVE LOAD INTENSITY FT1	FL1	FT2	FL2	FT3	FL3	FT4	FL4	FT5	FL5	LENGTH OF LIVE LOADS TRANS	LONG	WIND ON L.L. ARMS APT	APL
II WIND	1 2 / 4 2	1											1											1500	1500	1350	175

* AT LEAST ONE LIVE LOAD CASE IS REQUIRED
MAXIMUM NUMBER OF LIVE LOAD LANES IS 25

	CN	CENTRIFUGAL FORCE FT	TRACTION FORCE FL	CENTRIFUGAL FORCE & TRACTION FORCE ARMS APT	APL	EXPANSION COEFFICIENT	SHRINKAGE COEFFICIENT	STREAM FLOW PT	PL	* EQ
FORCES	1 2 / 4 3		57		175		000044			0.1

* COLUMNS 51,52 MUST BE 0.1 FOR SEISMIC CONSIDERATION.

S10 W - GR. II, GR. III SUPERSTRUCTURE: FT - 52 44 41 33 17; FL - 0 6 12 16 19
S10 W - GR. III LIVE LOAD: FT - 100 80 62 66 34; FL - 0 12 24 32 38

	CN	S10 W	LONGITUDINAL LOADING (ALL POSITIVE) VL TOP	VT TOP	HL BOTTOM	HL TOP	HT BOTTOM	HT TOP	P TOP	TRANSVERSE LOADING (ALL POSITIVE) VL TOP	VT TOP	HL BOTTOM	HL TOP	HT BOTTOM	HT TOP	P TOP
FORCES	4 4	01	48	21	1405	369	241	204	39	9	59	282	89	684	580	111
	4 4	02	59	27	1545	270	290	279	1	13	75	334	59	827	797	1
	4 4	03	50	21	1430	358	241	204	40	13	59	331	68	684	580	111
	4 4															
	4 4															

	CN	ID	NL	P1, 13, 25	P2, 14, 26	P3, 15, 27	P4, 16, 28	P5, 17, 29	P6, 18, 30	P7, 19, 31	P8, 20, 32	P9, 21, 33	P10, 22, 34	P11, 23, 35
AND LIVE LOAD CASES+	5 1	D-L-00		193210	000	000	193210	000	193210	000	193210	000	000	193210
	6 1	LL01	2	23788	000	000	59986	000	44472	000	8274	000	000	0000
	6 1	LL02	3	23788	000	000	59986	000	45507	000	51712	000	000	23788
	6 1	LL03	1	39301	000	000	28959	000	0000	000	0000	000	000	0000
	6 1	LL04	3	23788	000	000	59986	000	45507	000	51712	000	000	23788
	6 1	LL05	1	0000	000	000	0000	000	1034	000	43438	000	000	23788
	6 1	LL06	2	39301	000	000	45507	000	43438	000	8274	000	000	0000
	6 1	LL07	1	0000	000	000	16548	000	43438	000	8274	000	000	0000
	6 1	LL08	2	39301	000	000	28959	000	1034	000	43438	000	000	23788
	6 1	LL09	3	23788	000	000	51712	000	45507	000	59986	000	000	23788
	6 1	LL10	3	23788	000	000	55849	000	45507	000	55849	000	000	23788

D BY EL IL 1, 1991

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+++++        THE ANALYSIS AND DESIGN OF PIERS FOR BRIDGE -  V 4.2.03 - AASHTO SPECS 1984 INTERIM
PROBLEM NO. EX 6INPUT DATA        XX EXAMPLE FOR SEISMIC DESIGN - MULTI COLUMN BNT - HOFF D757EX6                04/14/92
                                                    DESIGN DATA
 DESIGN NO. NO. NO. SKEW ANG  F'C   FC    N   FY    FS    EC    ES   CONC.   Z   * * * CAP REINFORCING STEEL  * * * CAP
DPTIONS 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  3  16  20-00-00 3000. 1200. 9.2 60000. 24000. 3156. 29000. 0.0030 170.  10  5  6   6  10   6 2.00  4.00 3.00 2.31
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  2.563  0  2.00 0.75 0.90 0.00 1.00 0.00 18.20  0.120    8.000  2.50  5.00  1.250 0.750 3.000   0.000    0.000
                                                    CAP DATA
CN  C    L      A      DE     BC     BE     DH     LH     XB1    XB2    XB3    XB4    XB5    XB6    XB7    XB8
11  C  5.000  0.000  3.500  3.333  0.000  0.000  0.000  2.250  0.920
12  C 14.250  0.000  3.500  3.333         0.000  0.000  1.329  4.670  6.920
13  C 14.250  0.000  3.500  3.333         0.000  0.000  1.329  6.920  4.670
14  C  5.000  0.000  3.500  3.333  0.000  0.000  0.000  1.329  0.920
                                                    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 R  21.750  0.000  3.000  0.000  0.000  0.000  0.000  0.000  0 12  9  0 12  9  0  0  0  0  0  0  0.000  0.000  0.000
22 1 C R  21.750  0.000  3.000  0.000  0.000  0.000  0.000  0.000  0 12  9  0 12  9  0  0  0  0  0  0  0.000  0.000  0.000
23 0 C R  21.750  0.000  3.000  0.000  0.000  0.000  0.000  0.000  0 12  9  0 12  9  0  0  0  0  0  0  0.000  0.000  0.000
                                                    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  2.500  0.250  0.250  0.250  2.000  2.000  3.000  0   0    0.000  0.000  0.000
32  S  5.000  5.000  2.500  0.250  0.250  0.250  2.000  2.000  3.000  0   0    0.000  0.000  0.000
33  S  5.000  5.000  2.500  0.250  0.250  0.250  2.000  2.000  3.000  0   0    0.000  0.000  0.000
+++++                                               GROUP II WIND
SUPERSTRUCTURE AREA*STD.        WIND ON SUPERSTRUCTURE INTENSITIES       * WIND FORCE ARM  * WIND ON PIER
  TRANS.     LONG.  WIND FT1 FL1   FT2 FL2   FT3 FL3   FT4 FL4   FT5 FL5     APT     APL     PT     PL
  1075.      1075.  1    50  0    44  6    41  12   33  16   17  19    6.120   1.750   3.800  8.700
                                                    GROUP III WIND
STD. *   WIND ON SUPERSTRUCTURE INTENSITIES    *  STD. *      WIND ON LIVE LOAD INTENSITIES      *  LENGTHS OF LL * WIND ON LL ARMS
WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5  WIND FT1 FL1  FT2 FL2  FT3 FL3  FT4 FL4  FT5 FL5   TRANS.  LONGI.   APT     APL
 1   50  0   44  6   41  12   33  16   17  19   1   100  0   88  12   82  24   66  32   34  38   150.0   150.0  13.500  1.750
                                MISCELLANEOUS FORCES
CENTRI.  TRACTION FORCE AND ARMS   EXPANSION   SHRINKAGE     STREAM FLOW
  FT       FL      APT     APL    COEFFICIENT COEFFICIENT    PT      PL
 0.000    5.700   0.000   1.750    0.00000000 0.00004400   0.000   0.000
                              SEISMIC LONG. FORCES                          SEISMIC TRANSV. FORCES
 COL  TOP-VL  TOP-VT  BOT-ML  TOP-ML  BOT-MT  TOP-MT  TOP-P  *  TOP-VL  TOP-VT  BOT-ML  TOP-ML  BOT-MT  TOP-MT  TOP-P
  1     2.     64.     72.     48.    926.    450.     18.        4.      2.     207.    130.     23.     10.      1.
  2    13.    137.    275.      2.   1563.   1414.     22.       35.      5.     744.      5.     46.     45.      1.
  3     1.     64.     66.     48.    926.    451.     18.        2.      2.     167.    129.     23.     10.      1.
```

DEAD LOAD SUPERSTRUCTURE AND LIVE LOAD CASES

	NL	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
	0	193.210	0.000	0.000	193.210	0.000	193.210	0.000	193.210	0.000	0.000	193.210	
L01	2	23.788	0.000	0.000	59.986	0.000	44.472	0.000	8.274	0.000	0.000	0.000	
L02	3	23.788	0.000	0.000	59.986	0.000	45.507	0.000	51.712	0.000	0.000	23.788	
L03	1	39.301	0.000	0.000	28.959	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
LL04	3	23.788	0.000	0.000	59.986	0.000	45.507	0.000	51.712	0.000	0.000	23.788	
LL05	1	0.000	0.000	0.000	0.000	0.000	1.034	0.000	43.438	0.000	0.000	23.788	
L06	2	39.301	0.000	0.000	45.507	0.000	43.438	0.000	8.274	0.000	0.000	0.000	
L07	1	0.000	0.000	0.000	16.548	0.000	43.438	0.000	8.274	0.000	0.000	0.000	
L08	2	39.301	0.000	0.000	28.959	0.000	1.034	0.000	43.438	0.000	0.000	23.788	
L09	3	23.788	0.000	0.000	51.712	0.000	45.507	0.000	59.986	0.000	0.000	23.788	
L10	3	23.788	0.000	0.000	55.849	0.000	45.507	0.000	55.849	0.000	0.000	23.788	
L11	2	0.000	0.000	0.000	8.274	0.000	44.472	0.000	59.986	0.000	0.000	23.788	
L12	1	23.788	0.000	0.000	43.438	0.000	1.034	0.000	0.000	0.000	0.000	0.000	
LL13	1	0.000	0.000	0.000	8.274	0.000	43.438	0.000	16.548	0.000	0.000	0.000	
LL14	2	23.788	0.000	0.000	43.438	0.000	1.034	0.000	28.959	0.000	0.000	39.301	
LL15	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28.959	0.000	0.000	39.301	
LL16	2	0.000	0.000	0.000	8.274	0.000	43.438	0.000	45.507	0.000	0.000	39.301	

+++++

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	-8.601	-8.601	-8.601	-8.601	-8.601	-8.601	-8.601	-6.256	-257.428	-6.256	-257.428	-6.256	-342.751
P 2	-246.399	-246.399	-324.895	-246.399	-246.399	-246.399	-293.402	-259.521	-259.521	-259.521	-259.521	-344.844	-344.844
C 1L	-593.574	-593.574	-785.549	-593.574	-593.574	-593.574	-708.529	-262.547		-262.547		-347.869	
C 1R	-584.609	-578.376	-784.787	-351.159	-818.059	-436.916	-851.862		175.621		250.250		170.093
[illegible]	-353.218	-344.074	-478.311	-154.380	-552.055	-224.087	-553.657	172.598	172.598	247.227	247.227	167.070	167.070
P [illegible]	428.008	726.427	401.013	505.220	350.795	655.449	365.868	161.975	-89.198	236.604	-89.198	156.447	-144.799
P 5	-243.711	-243.711	-383.241	-140.699	-346.722	-190.538	-394.885	-104.940	-104.940	-104.940	-104.940	-160.540	-160.540
C 2L	-385.400	-385.400	-595.050	-247.724	-523.076	-321.620	-601.318	-107.968		-107.968		-163.568	
C 2R	-385.435	-385.435	-595.097	-247.759	-523.111	-321.639	-601.361		108.020		163.645		108.020
P 7	-243.885	-243.885	-383.494	-140.822	-346.948	-190.710	-395.141	104.997	104.997	160.622	160.622	104.997	104.997
P 8	428.227	726.693	401.232	505.387	351.066	655.663	366.117	89.255	-161.918	144.880	-156.392	89.255	-236.522
P 9	-352.733	-343.562	-477.692	-153.947	-551.518	-223.631	-553.059	-172.541	-172.541	-167.015	-167.015	-247.145	-247.145
C 3L	-584.400	-578.167	-784.505	-350.949	-817.850	-436.707	-851.609	-175.569		-170.043		-250.173	
C 3R	-593.322	-593.322	-785.212	-593.322	-593.322	-593.322	-708.226		262.547		347.869		262.547
P10	-246.407	-246.407	-324.903	-246.407	-246.407	-246.407	-293.410	259.524	259.524	344.846	344.846	259.524	259.524
P11	-8.608	-8.608	-8.608	-8.608	-8.608	-8.608	-8.608	257.431	6.258	342.753	6.258	257.431	6.258

CAP DESIGN DATA

PT.	M+ UNF. K-FT.	M- UNF. K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI	PS %	FS/FF RATIO	FS/FZ R[illegible]
P 1	-6.617	-6.617	7.62	6 # 10	7.62	6 # 10	0.00	0.000	#5@ 0.00	19.30	0.101	#5@ 6.13	42.00		0.50	0.000	0.[illegible]
P 2	-189.537	-225.694	7.62	6 # 10	7.62	6 # 10	19.30	0.102	#5@ 6.07	19.30	0.102	#5@ 6.07	42.00		0.63	0.078	0.317
C 1	-446.828	-545.022	7.62	6 # 10	7.62	6 # 10	19.30	0.104	#5@ 5.98	19.30	0.054	#5@11.46	42.00		0.85	0.260	0.766
P 3	-267.494	-329.326	7.62	6 # 10	7.62	6 # 10	19.30	0.053	#5@11.79	19.30	0.053	#5@11.79	42.00		0.72	0.142	0.463
P 4	466.694	316.802	7.62	6 # 10	7.62	6 # 10	19.14	0.048	#5@12.87	19.14	0.033	#5@18.60	42.00		0.80	0.360	0.699
P 5	-187.470	-251.740	7.62	6 # 10	7.62	6 # 10	19.30	0.033	#5@18.60	19.30	0.033	#5@18.60	42.00		0.66	0.139	0.354
C 2	-296.462	-393.063	7.62	6 # 10	7.62	6 # 10	19.30	0.033	#5@18.60	19.30	0.033	#5@18.60	42.00		0.74	0.226	0.552

CAP DESIGN DATA

PT.	M+ UNF. K-FT.	M- UNF. K-FT.	TOP REINFORCE. AS	NO.SIZE	BOT.REINFORCE. AS	NO.SIZE	LEFT STIRRUPS M.SP.	AV/IN	BAR&SPAC	RIGHT STIRRUPS M.SP.	AV/IN	BAR&SPAC	D IN.	FC PSI	PS %	FS/FF RATIO	FS/FZ RATIO
P 7	-187.604	-251.910	7.62	6 # 10	7.62	6 # 10	19.30	0.033	#5@18.60	19.30	0.033	#5@18.60	42.00		0.66	0.139	0.354
P 8	466.884	316.971	7.62	6 # 10	7.62	6 # 10	19.14	0.033	#5@18.60	19.14	0.048	#5@12.89	42.00		0.80	0.360	0.700
P 9	-267.109	-328.891	7.62	6 # 10	7.62	6 # 10	19.30	0.053	#5@11.80	19.30	0.053	#5@11.80	42.00		0.72	0.141	0.462
C 3	-446.667	-544.790	7.62	6 # 10	7.62	6 # 10	19.30	0.054	#5@11.46	19.30	0.104	#5@ 5.98	42.00		0.85	0.260	0.765
P10	-189.543	-225.700	7.62	6 # 10	7.62	6 # 10	19.30	0.102	#5@ 6.07	19.30	0.102	#5@ 6.07	42.00		0.63	0.078	0.317
P11	-6.621	-6.621	7.62	6 # 10	7.62	6 # 10	19.30	0.101	#5@ 6.13	0.00	0.000	#5@ 0.00	42.00		0.50	0.000	0.009

+++++ COLUMN ANALYSIS AND DESIGN OUTPUT

CRITICAL COLUMN LOADS

CN	T B	GR	LLC	WC	R	E S	C F	S F	PF	MTF	MLF	PM	MTM	MLM	PU	MTU	MLU	PU/PM	B	D
1	T	3	LL01	1.1					543.1	158.2	-0.1	543.1	171.1	109.6	1708.8	538.4	344.9	3.146	36.00	36.00
1	B	B		0.0					486.9	-120.5	387.3	486.9	129.6	494.6	884.3	235.5	898.9	1.817	36.00	36.00
2	T	3	LL09	1.1					582.3	184.3	-2.9	582.3	199.9	120.4	1663.7	571.3	344.1	2.857	36.00	36.00
2	B	B		0.0					497.5	139.9	427.8	497.5	150.5	549.6	816.7	247.1	902.6	1.642	36.00	36.00
3	T	3	LL11	1.1	R				543.1	-158.3	0.1	543.1	171.1	109.6	1708.6	538.6	344.8	3.146	36.00	36.00
3	B	B		0.0					487.2	120.5	397.6	487.2	129.6	507.8	865.4	230.4	903.3	1.778	36.00	36.00

COLUMN DESIGN DATA

CN	T B	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	12 # 9	0 # 0	0 # 0	0 # 0	12.00	1.179	1.00	0.000	1566.	20882.	1.081	1.345	1.000	1	0.75
1	B	12 # 9	0 # 0	0 # 0	0 # 0	12.00	1.179	1.00	0.060	1427.	20364.	1.075	1.277	1.000	1	0.75
2	T	12 # 9	0 # 0	0 # 0	0 # 0	12.00	1.179	1.00	0.000	1628.	20872.	1.085	1.378	1.000	1	0.75
2	B	12 # 9	0 # 0	0 # 0	0 # 0	12.00	1.179	1.00	0.000	1427.	20364.	1.075	1.285	1.000	1	0.75
3	T	12 # 9	0 # 0	0 # 0	0 # 0	12.00	1.179	1.00	0.000	1566.	20882.	1.081	1.345	1.000	1	0.75
3	B	12 # 9	0 # 0	0 # 0	0 # 0	12.00	1.179	1.00	0.060	1427.	20364.	1.075	1.277	1.000	1	0.75

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 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. Nonstandard 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 centerline). 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.

LINE NO. I	POSSIBLE CAUSE OF ERROR
2N (Continued)	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 nonstandard with investigation or design. 9. Invalid same column.
3N N = Footing Number	1. B equals 0.0 (spread footing). 2. D equals 0.0 (spread footing). 3. T equals 0.0 4. B, D, or T 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 is 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.
41, 42, 43	These load cards are only checked for their presence.
51, 52, 53, 54	1. Dead load superstructure input in error, too few or too many lines. Codes 51, 52, 53, 54 not used correctly.
61, 62, 63, 64	1. Live load case input error, too few or too many lines of data. 2. Codes 61, 62, 63, 64 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 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.

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 messages 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"

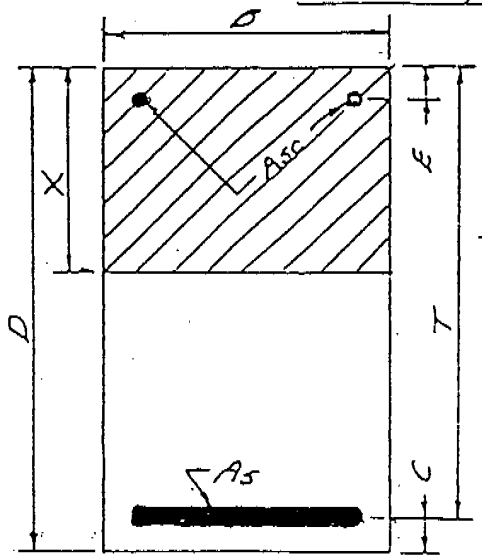
   This message will be given when the resultant P-load is off the footing (M/P is greater than or equal to one-half the footing width) and only occurs with an analysis of a spread footing.

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.

SERVICE LOAD — CAP AND FOOTING

FIND AREA OF STEEL GIVEN MOMENT & SECTIO



$N = E_s/E_c$

1. $\frac{B}{2}\cdot X^2 + (X-E)\cdot Asc\cdot(N-1) = (D-C-X)\cdot As\cdot N$

2. $M\cdot(D-C-X) = \frac{f_{sa}}{N}\cdot I_x$

$$I_x = \frac{B}{3}\cdot X^3 + (X-E)^2\cdot Asc\cdot(N-1) + (D-C-X)^2\cdot As\cdot N$$

LET: $A = Asc\cdot(N-1)$; $T = D-C$

Solve above two equations simultaneously.

Asc is compression steel (assumed 0 in foot
(defined in input f
C

2.

$$M\cdot(T-X) = \frac{f_{sa}}{N}\cdot\left[\underbrace{\frac{B}{3}\cdot X^3 + (X-E)^2\cdot A + (T-X)^2\cdot\left(\frac{\frac{B}{2}\cdot X^2 + (X-E)\cdot A}{T-X}\right)}_{I_x}\right]$$

$As\cdot N$

$$= \frac{f_{sa}}{N}\left[\frac{B}{3}\cdot X^3 + A\cdot(X^2 - 2\cdot E\cdot X + E^2) + (T-X)\cdot\left(\frac{B}{2}X^2 + A\cdot X - A\cdot E\right)\right]$$

$$M\cdot T - M\cdot X = \frac{f_{sa}}{N}\left[\frac{B}{3}\cdot X^3 + A\cdot X^2 - 2\cdot A\cdot E\cdot X + A\cdot E^2 - \frac{B}{2}X^3 - A\cdot X^2 + A\cdot E\cdot X - A\cdot E\cdot T + \frac{T\cdot B}{2}\cdot X^2 + T\cdot A\cdot X\right]$$

$$= f_{sa}\cdot\left[-\frac{B}{6}X^3 + \frac{T\cdot B}{2}\cdot X^2 + A\cdot(T-E)\cdot X - A\cdot E\cdot(T-E)\right]$$

$$\frac{B}{6}\cdot X^3 - \frac{T\cdot B}{2}\cdot X^2 - \left[A\cdot(T-E) + \frac{M\cdot N}{f_{sa}}\right]\cdot X + A\cdot E\cdot(T-E) + \frac{M\cdot T\cdot N}{f_{sa}} = 0$$

$P = T-E$

$R = \frac{M\cdot N}{f_{sa}}$

$$C_1\cdot X^3 + C_2\cdot X^2 + C_3\cdot X + C_4 = 0$$

$C_1 = \frac{B}{6}$

$C_2 = -\frac{T\cdot B}{2}$

$C_3 = -(A\cdot P + R)$

$C_4 = A\cdot E\cdot P + R\cdot T$

$F1 = B/2$

$F2 = -T\cdot B$

$F3 = C_3 = -(A\cdot P$

$F4 = 0$

Solve for X by using Newton's method.

Derivative of equation:

$$F1\cdot X^2 + F2\cdot X + F3 + 0 = 0$$

then:

$$As = \frac{\frac{B}{2}\cdot X^2 + (X-E)\cdot A}{(T-X)\cdot N}$$

$f_{sa} = 20{,}000$ default

SHEAR REINFORCEMENT IN CAP

I. GENERAL REQUIREMENTS:

Minimum Reinforcement: $V_c > \frac{V_{CA}}{2}$ $A_{v_{min}} = \frac{50\,b\,s}{F_y}$

Minimum Spacing: 24" or d/2

II. SERVICE LOAD DESIGN (ALLOWABLE)

$V_{CA} = 0.95(f_c')^{1/2}$ $v = \frac{V}{b\,d}$

$V \leq V_{CA}$ Min. A_v

$V > V_{CA}$ $(V - V_{CA}) > 2(f_c')^{1/2}$ Max. Spacing reduced by 1/2.

$A_v = \frac{(V - V_{CA})\,b\,s}{f_s}$

$(V - V_{CA}) \leq 4(f_c')^{1/2}$ Requirement

III. STRENGTH DESIGN (LOAD FACTOR) $\phi = 0.85$

$V_{CA} = 2(f_c')^{1/2}$ $v = \frac{V_u}{\phi\,b\,d}$

$V \leq V_{CA}$ Min. A_v

$V > V_{CA}$ $(V - V_{CA}) > 4(f_c')^{1/2}$ Max. Spacing reduce by 1/2.

$A_v = \frac{(V - V_{CA})\,b\,s}{f_y}$

$(V - V_{CA}) \leq 8(f_c')^{1/2}$

SLENDERNESS EFFECTS IN COLUMNS

A. TRANSVERSE DIRECTION

1. Compute $\frac{k l_u}{r}$ Braced and Unbraced – Each Column

a. k (Page 9-6, Ref. 1)

$$\psi_T = \frac{[I_g + (n-1) I_s]/H_T \text{ (Column)}}{\sum \frac{I_g}{2(L)} \text{ (Cap)}}$$

$I_g = \frac{B_c (D_c)^3}{12}$ Column

I_s = Moment of inertia of minimum/actual reinforcement steel

I_g for Cantilever = 0 $\quad I_g = \frac{B_c (D_c)^3}{12}$ Cap

$$\psi_B = FLEX/(1.0 - FLEX) \leq 1000$$

With ψ_T & ψ_B, find K_B (braced) and K_{UB} (unbraced) from charts on page 9-6 of Ref. 1.

b. l_u

$l_u = H_T - D_L$ (Multiple columns)

$l_u = H_T + \frac{D_E}{2}$ (One column)

c. r

$$r = \frac{r_T + r_B}{2} \qquad r_T = \left[\frac{I_g + (n-1) I_s}{A_g + (n-1) A_s}\right]^{1/2} \text{ (Top of column)}$$

r_B = Same with bottom of column properties.

$A_s = 2(n_B + n_D)$

SLENDERNESS EFFECTS IN COLUMNS

2. Compute P_c Braced and Unbraced - Each Column

a. $P_{cB} = \dfrac{\pi^2 EI}{(k_B l_u)^2}$ $\quad I = \dfrac{I_T + I_B}{2}$

$I_T = \dfrac{I_g}{5} + (n-1) I_s$ (top of column)

$I_B = \dfrac{I_g}{5} + (n-1) I_s$ (bottom of column)

b. $P_{cuB} = \dfrac{\pi^2 EI}{(k_{uB} l_u)^2}$

3. Compute $\beta_d = \dfrac{\beta_{dT} + \beta_{dB}}{2}$ Each column

$\beta_{dT} = M_T^D / M_T^T$

For $\beta_{dT} < 0$, β_{dT} is set to 0

For $\beta_{dT} > 1$, β_{dT} is set to $1/\beta_{dT}$

β_{dB} computed in like manner for bottom of column

4. Compute C_m Each column

$C_m = 0.6 + 0.4\left(-\dfrac{M_1}{M_2}\right) \geq 0.4$

M_1 is minimum of $|M_T^T|$, $|M_B^T|$

M_2 is maximum of $|M_T^T|$, $|M_B^T|$

SLENDERNESS EFFECTS IN COLUMNS

5. Compute δ Unbraced

$$\delta = \frac{1.0}{1 - \dfrac{\sum P_{ui}}{\phi \sum \dfrac{P_{cuBi}}{1+\beta_{di}}}} \geq 1 \qquad i = 1, N_c$$

N_c = Number of columns

For S.L. $\phi = 1.0$, $P_u = 2.5\, P_A$

6. Compute δ_B For each column - Braced

$$\delta_B = \frac{C_m}{1 - \dfrac{P_u}{\phi\left(\dfrac{P_c}{1+\beta_d}\right)}} \geq 1$$

For $\dfrac{k_B l_u}{r} < 34 - 12\left(-\dfrac{M_1}{M_2}\right)$, $\delta_B = 1$

7. Modify Moments For Minimum Eccentricity

$e = M/P$

If $e < e_{min}$, $M = P\, e_{min}$

$e_{min.}$ = Greater of
(1) 1"
(2) $\begin{cases} D/20 \text{ (Spiral R.)}, \\ D/10 \text{ (Tied R.)} \end{cases}$
(3) $(0.6 + 0.03D)$

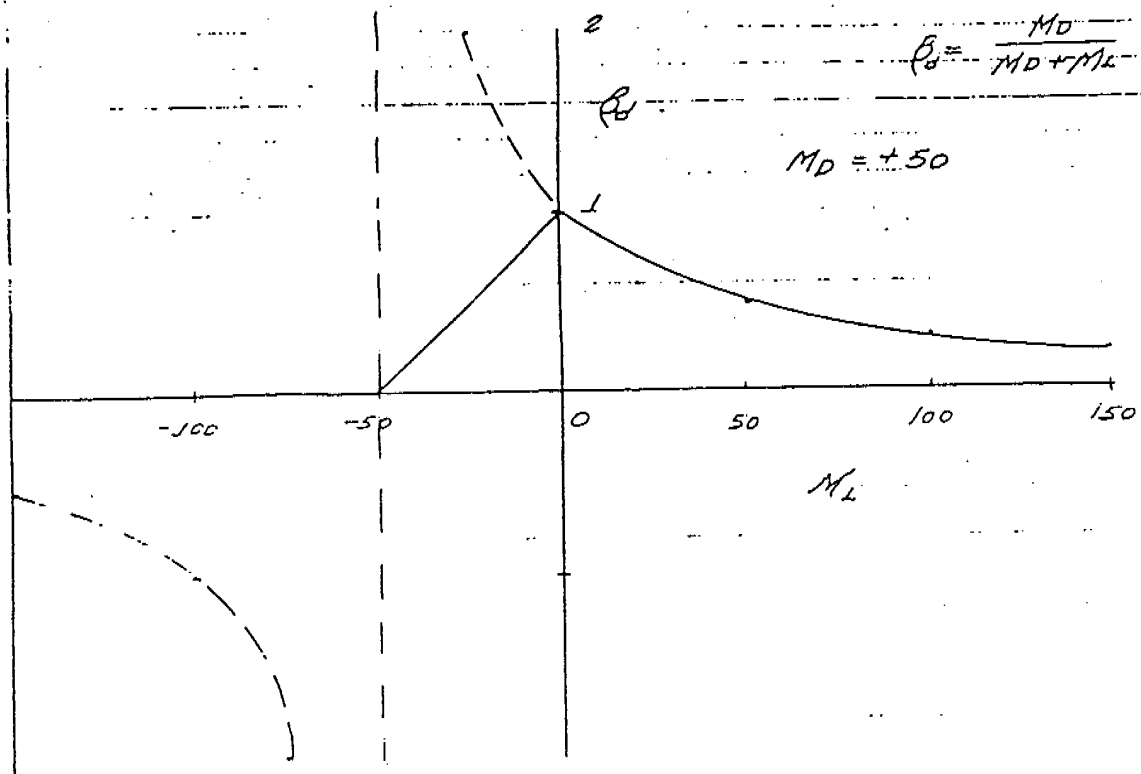
8. Magnify Moments

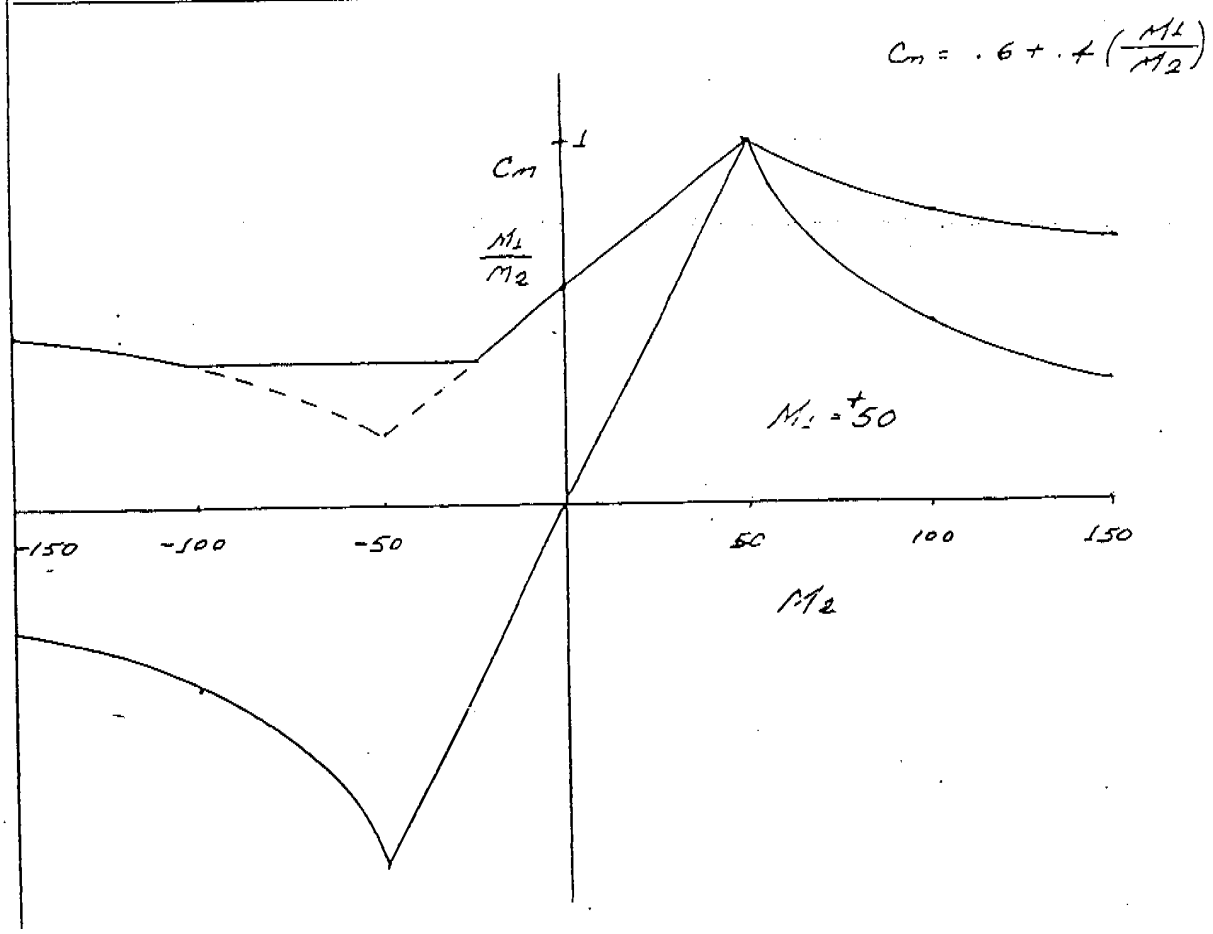
$M_i = \delta_{mi} M_i$ Top and bottom of all columns i

δ_{mi} = Maximum of δ, δ_{Bi}

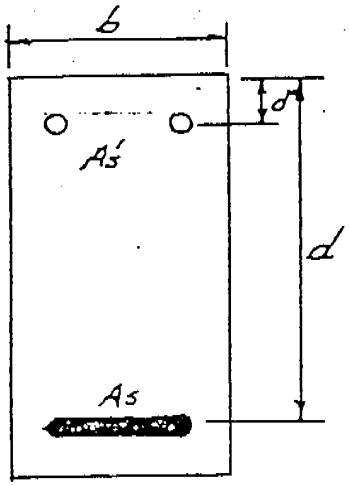
For $\dfrac{k_{Bi} l_{ui}}{r_i} < 22$, δ not considered for column i

SLENDERNESS EFFECTS IN COLUMNS





LOAD FACTOR - CAP AND FOOTING



Given: $b, d, d', A_s', M_T, f_y, f_c', E_s, \phi$

Find A_s

For Cap: A_s' is input, computed if needed, or zero.

For Footing: A_s' is zero, $d' = 0$

$E_c(E_s) = (.003)(29{,}000{,}000) = 87{,}000$ psi

$\beta_1 = 0.85 - (f_c' - 4.0)(.05) \le 0.85$

To start assume $f_s' = f_y$

$q_b = 0.85\beta_1\left(\frac{87}{87+f_y}\right)$

$q_m = 0.85\beta_1\left(\frac{d'}{d}\right)\left(\frac{87}{87-f_y}\right)$

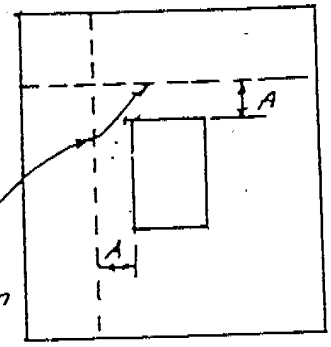
$M_T' = M_T/\phi$

$q = \rho\frac{f_y}{f_c'}$

1. $A_{sc} = A_s'(f_s' - 0.85f_c')/f_y$
2. $M_c = A_{sc}(f_y)(d-d')$
3. $M = M_T' - M_c$
4. $\bar{q} = \frac{M}{f_c' b d^2} = \left(1 - \frac{1}{2(.85)}q\right)q$
5. $q = 0.85 - \left((.85)^2 - 1.7\bar{q}\right)^{1/2}$
6. IF $(q > .75 q_b)$ Increase Depth, Start over
7. IF $(q \ge q_m)$ Go To Step 10
8. $f_s' = \left(1 - \frac{.85\beta_1 d'}{q d}\right)87$
9. If f_s' Not equal to previous value of f_s', Go To Step 1
10. $A_s = q\,bd\left(\frac{f_c'}{f_y}\right) + A_{sc}$ Min. As not considered
11. $\rho = \frac{A_s}{bd} + \frac{A_s'}{bd}\left(\frac{f_s'}{f_y}\right)$ $\quad \rho_b = \frac{.85\beta_1 f_c'}{f_y}\left(\frac{87}{87+f_y}\right) + \frac{A_s'}{bd}\left(\frac{f_s'}{f_y}\right)$

FOOTING - SHEAR AND MOMENT

I. BEAM SHEAR



A = d for Spread footing or Pile footing

A. S.L.

$V_{cap} = 0.95(f_c')^{1/2} bd$

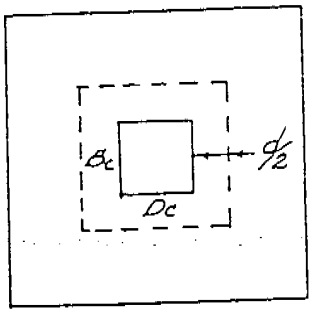
$V_{act} = \sum$ Loads outside critical section

B. L.F. $\phi = 0.85$

$V_{cap} = \phi(2)(f_c')^{1/2} bd$

$V_{act} = \sum$ Loads outside critical section.

II. PERIPHERAL SHEAR (TWO-WAY ACTION)



A. S.L.

$V_c = (.80 + \frac{2}{\beta_c})(f_c')^{1/2}$

$V_{cap} = V_c b_o d$

$V_{act} = \sum$ Loads outside periphery

$V_{MAX} = 1.8(f_c')^{1/2}$

$b_o = [(B_c + d) + (D_c + d)]2$

$\beta_c = \frac{\text{Long Side}}{\text{Short Side}}$

B. L.F.

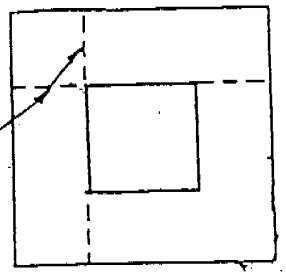
$V_c = (2 + \frac{4}{\beta_c})(f_c')^{1/2}$

$V_{cap} = \phi V_c b_o d$

$V_{act} = \sum$ Loads outside periphery

$V_{MAX} = 4.0(f_c')^{1/2}$

III. MOMENT



SLENDERNESS EFFECTS IN COLUMNS

B. LONGITUDINAL DIRECTION

All Columns Assumed Unbraced

1. Compute $\frac{k l_u}{r}$ Each Column

k = input or 2.0

$l_u = H_T + \frac{D_e}{2}$

$r = \frac{r_T + r_B}{2}$, See Transverse Direction

2. Compute $P_c = \frac{\pi^2 E I}{(k l_u)^2}$ $I = \frac{I_T + I_B}{2}$ Each Column

See Transverse Direction

3. $\beta_d = 0$ $M^D = 0.0$

4. $C_m = 1.0$

5. Compute δ For each column

$$\delta = \frac{1.0}{1 - \frac{P_u}{\phi P_c}} \geq 1$$

6. δ_b not used

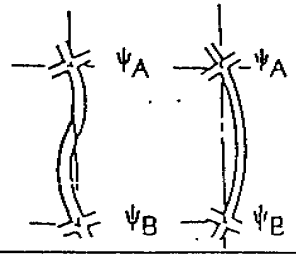
7. Modify Moments For Minimum Eccentricity

See Transverse Direction, $e_{min.}$ = Greater of (1) 1" (2) $\begin{cases} B/20 \text{ (Spiral R.)} \\ B/10 \text{ (Tied R.)} \end{cases}$ (3) (0.6 + 0.03R

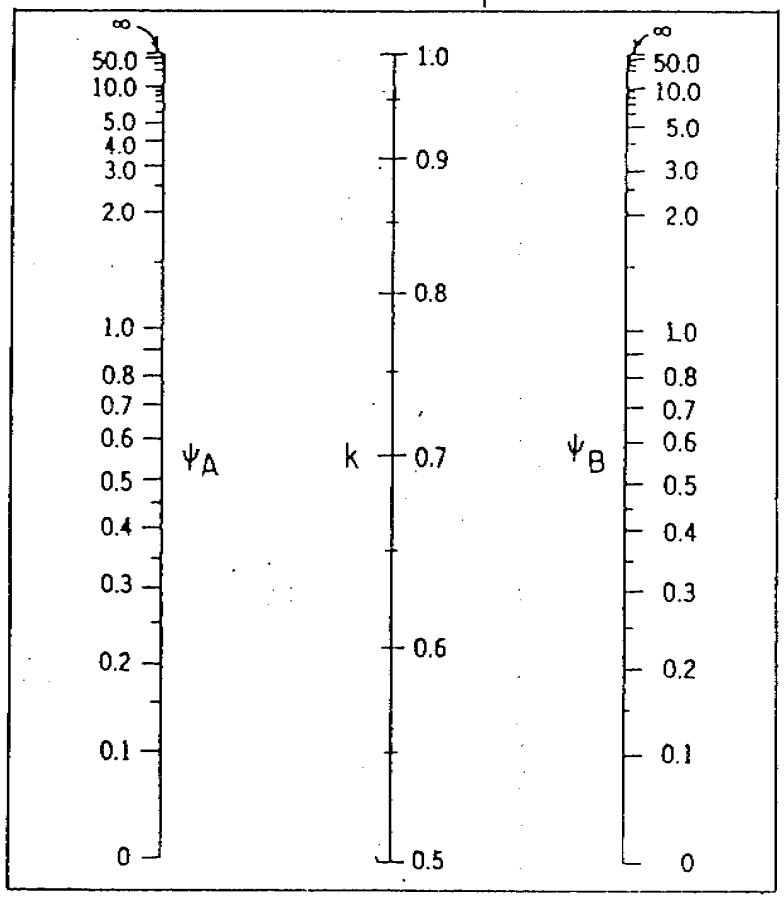
8. Magnify Moments

$M_i = \delta_i M_i$ Top and bottom of all columns i

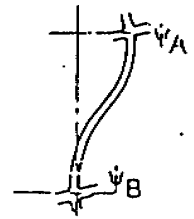
For $\frac{k_i l_{ui}}{r_i} < 22$, $\delta = 1$

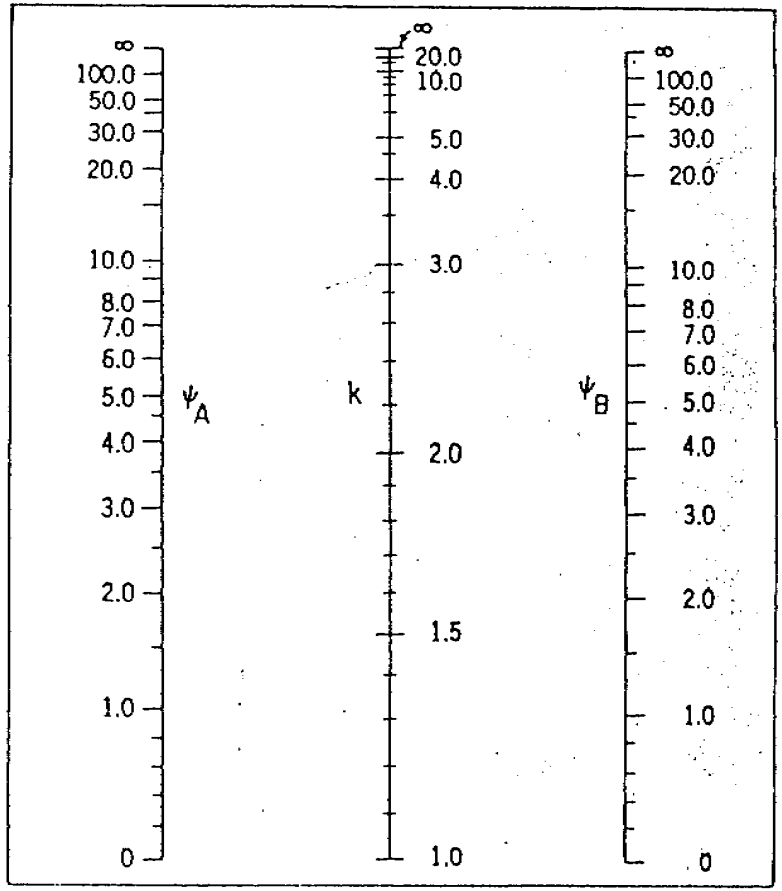


$$\psi = \frac{\Sigma(EI/\ell)\ \text{comp. members}}{\Sigma(EI/\ell)\ \text{flexural members}}$$



(a) Braced frames





(b) Unbraced frames

SIDESWAY PERMITTED

Effective Length Factors

THE ANALYSIS AND DESIGN OF MULTIPLE COLUMN PIERS FOR BRIDGES

COLUMN SECTION CAPACITY AND REQUIREMENTS RELATIONSHIP

In general:

$$(AOS)(\phi)(Uc) \geq (Lf)(Loads)(Fs)(Fme)$$

For Service Loads:

AOS = Allowable Overstress (1.0, 1.25, 1.25, 1.25, 1.40 for group loadings I, II, III, IV, V).

Ø = 0.35 or input value.

Uc = Ultimate capacity of section using Ultimate Strength theory.

Fs = Factor for slenderness effects (on moments only).

Fme = Factor for minimum eccentricity (on moments only).

Lf = Load Factor = 1.0 for Service Load.

For Load Factor:

AOS = 1.0.

Ø = 0.70, 0.75, 0.90 or input values.

Uc = Same as for Service Loads.

Fs = Same as for Service Loads.

Fme = Same as for Service Loads.

Lf = Load factors according to Article 1.2.22.

Article numbers refer to the AASHTO "Standard Specifications for Highway Bridges".