(2)

ADED STR AL
(CASE)

# DE FOR CONCRETE STRENGTH
# ATION AND DESIG (CASTR)
# ACCORDANCE WITH ACI 381-89

by

Clifton O. Hamby

DEPARTMENT OF THE ARMY
US Army Engineer District, Vicksburg
Vicksburg, Mississippi 39180-5191

and

William A. Price III

Information Technology Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

March 1992

Final Report

Approved For Public Release; Distribution



DEPARTMENT OF THE ARMY
US Army Corps of Engi
Washington, DC 20

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



| 1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
|---|---|---|
| | March 1992 | Final Report |

**4. TITLE AND SUBTITLE**

USER'S GUIDE FOR CONCRETE STRENGTH INVESTIGATION AND DESIGN (CASTR) IN ACCORDANCE WITH ACI 318-89

**5. FUNDING NUMBERS**

**6. AUTHOR(S)**

Clifton C. Hamby, William A. Price III

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**

USAE Waterways Experiment Station
Information Technology Laboratory
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

**8. PERFORMING ORGANIZATION REPORT NUMBER**

Instruction Report ITL-87-2 (Revised)

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**

**11. SUPPLEMENTARY NOTES**

This report supersedes Instruction Report ITL-87-2; available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

**12a. DISTRIBUTION/AVAILABILITY STATEMENT**

Approved for public release; distribution is unlimited.

**12b. DISTRIBUTION CODE**

**13. ABSTRACT** *(Maximum 200 words)*

Program CASTR is versatile in that its capabilities extend from design of new concrete structures in accordance with ACI 318-89 to investigation of already existing designs. Its analysis is based on the rectangular stress block described in Section 10.2.7 of the ACI Code 318.

The design procedure is computer-aided rather than automatic, computes the minimum reinforcement required for a given width and depth, and displays the resulting interaction diagram. The program also computes and prints the minimum effective depth of a given section which satisfies strength requirements without compressive reinforcement.

The investigation procedure shows interaction diagrams and calculates compliance with ductile failure criteria.

| 14. SUBJECT TERMS | 15. NUMBER OF PAGES |
|---|---|
| See reverse | 65 |
| | 16. PRICE CODE |

| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | | |

14. (Concluded).

CASTR (Computer Program) (LC)
Computer-Aided Design (WES)
Concrete Products-Education (LC)
Structures-Computer Programs (LC)

# ELECTRONIC COMPUTER PROGRAM ABSTRACT

| | |
|---|---|
| TITLE OF PROGRAM User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89 | PROGRAM NO. 713-F3-R0067 |

PREPARING AGENCY US Army Engineer Waterways Experiment Station, Information Technology Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199

| AUTHOR(S) | DATE PROGRAM COMPLETED | STATUS OF PROGRAM | |
|---|---|---|---|
| | | PHASE | STAGE |
| C. C. Hamby (CELMK-ED-DN) and W. A. Price III (CEWES-IM-DA) | October 1985 | Operational | |

A. PURPOSE OF PROGRAM

To perform investigation or design of concrete beams or colums in accordance with ACI Code 318.

B. PROGRAM SPECIFICATIONS

Written in Microsoft FORTRAN using the Graphics Compatibility System (GCS) 2nd C-scape I/O. The CORPS time-sharing library file nane is X0067.

C. METHODS

Strength analysis for investigation or design of rectangular cross sections of structure subjected to axial load plus uniaxial flexure. Analysis is based on the rectangular stress block approximation described in Section 10.2.7 of ACI 138-89.

D. EQUIPMENT DETAILS

In timesharing, Tektronix 4014 terminal on a microcomputer, a graphics video card is required.

E. INPUT-OUTPUT

Input is interactive or from a data file; output is to a Tektronix 4014 graphics terminal from timesharing.

F. ADDITIONAL REMARKS

Input data are prepared the same as for program 713-F3-RO 066, "CSTR-Concrete Strength Investigation and Design of Hydraulic Structures (X0066)." Differences between the two programs lie only in the stress block depth and other parameters. Call WES, (601) 634-2300, for more information.

# Preface

The computer program described in this user's guide was derived from program CSTR developed as a part of the work by the Engineering Applications Office (EAO), formerly Computer-Aided Design Group, Automation Technology Center, US Army Engineer Waterways Experiment Station (WES), in support of the Computer-Aided Structural Design (CASD) Committee of the US Army Engineer Division, Lower Mississippi Valley (LMVD). Funds for program CSTR were provided by LMVD as part of WES, Information Technology Laboratory (ITL), engineering analysis support. Funds for the CASTR derivation and report were provided by the Computer-Aided Structural Engineering Project. The current version, described in this revised user's guide, implements the provisions of current (1992) Corps criteria for strength design of all structures. It was funded by Civil Works Research and Development funds from HQUSACE.

Mr. V. M. Agostinelli, LMVD, was chairman of the CASD Committee during this work. The theoretical development for program CSTR was performed by Mr. Clifton C. Hamby, formerly EAO and presently US Army Engineer District, Vicksburg. Programming was by Mr. Hamby, assisted by Mr. William A. Price III, Computer-Aided Engineering Division (CAED), ITL, WES. Adaptation of program CSTR to program CASTR was by Mr. Price. The work was performed under the supervision of Mr. Paul K. Senter, Chief, CAED, with overall supervision by Dr. N. Radhakrishnan, Chief, ITL.

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

## Contents

## Conversion Factors, Non-SI to SI (Metric) Units of Measurement

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

| Multiply | By | To Obtain |
|---|---|---|
| inches | 2.540 | centimetres |
| kips (force) | 4.448222 | kilonewtons |
| kip-feet (force) | 1355.818 | newton-metres |
| kip-inches | 112.9848 | newton-metres |
| kips (force) per square inch | 6.894757 | megapascals |
| pounds per square inch | 6.894757 | kilopascals |

## USER'S GUIDE FOR CONCRETE STRENGTH INVESTIGATION AND DESIGN (CASTR) IN ACCORDANCE WITH ACI 318-89*

### Introduction

1. A computer program, Program CASTR, has been developed by the US Army Engineer Waterways Experiment Station (WES) Information Technology Laboratory, formerly Automation Technology Center, that can be used for design of or investigation of rectangular concrete members by the strength design method described in Section 10.2 of ACI Code 318-89.** The program utilizes a generalized equation to obtain the axial force and moment capacity of any rectangular concrete section, reinforced or not, in any pattern (paragraph 13). This approach allows for solution of a wide variety of problems and loadings, such as singly or doubly reinforced beams, columns, beam-columns, tension members, etc. It is equally applicable to hydraulic structures and to structures not subject to hydraulic action.

### Assumptions

2. The fundamental assumptions used in the development of program CASTR are summarized below. More details on these assumptions are included in paragraphs 10 through 16. Figure 1 is provided to further complement the following discussions.

a. The cross section is rectangular.

b. The reinforcement may be in any general pattern with no more than 20 rows of steel.

c. The loading may consist of a uniaxial moment and an axial load. The axial load can be tension, compression, or zero.

d. ACI 318-89 criteria on stress and strain are used to compute moment and load capacities.

e. Reinforcement, in investigation or design, is assumed to be capable of developing stresses up to $F_y$. The user's attention

---

* This edition of the User's guide applies to programs dated 1991/09/25 or later. Usage for hydraulic structures should be in accordance with "Strength Design for Reinforced Concrete Hydraulic Structures," Engineer Manual 1110-2-2104 (Headquarters, Department of the Army, 1992).

** American Concrete Institute, "Building Code Requirements for Reinforced Concrete (ACI 318-89)."

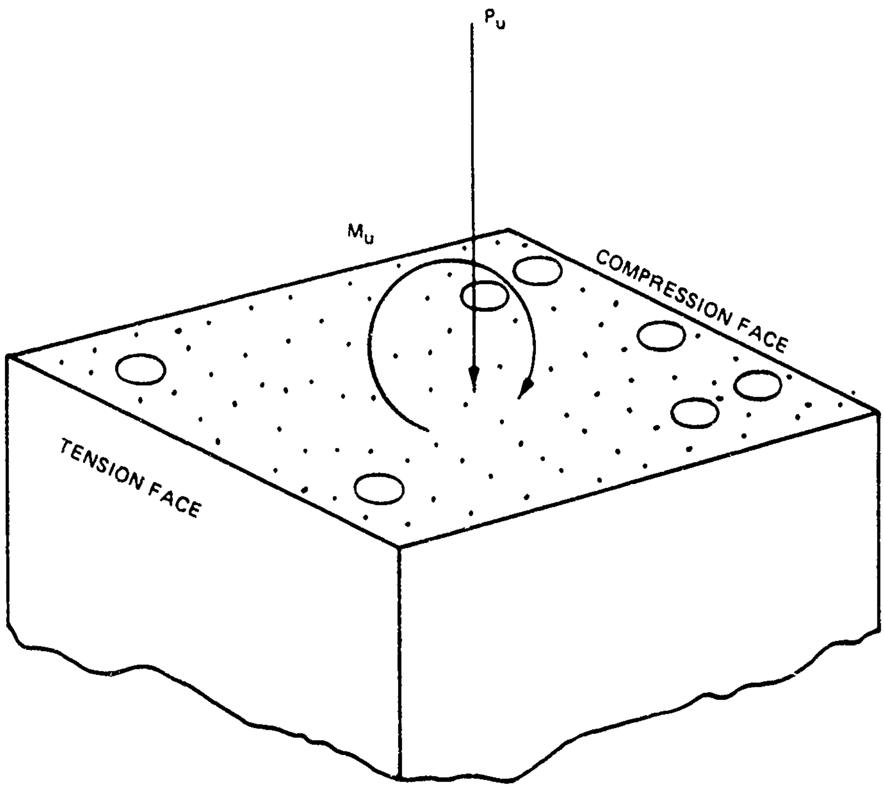



Figure 1. Applied load sign convention

is directed to American Concrete Institute (ACI) requirements on the tie steel necessary for making compression bars effective in developing stress.

f. The program does not check concrete sections for general compliance with the ACI Code, however.

## Design Capability

3. Program CASTR will compute the area of steel required for a beam or for a column having a fixed width and depth. The program will not design the size of a member since, in most cases, selection of member sizes requires design judgment. Procedures for describing steel patterns and computing the required area of steel are considerably different for beams than for columns. As a result, the input data for beam and column design must be prepared in a slightly different manner. Paragraphs 17 through 19 give more details on these differences.

Beams

4. In beams, bars are usually defined as rows of tension and compression steel with ductility also an important consideration. Therefore, for beam design the user is required to describe spacing criteria for tension steel, spacing criteria for compression steel, and limits on steel ratios. CASTR checks the need for tension steel and adds what is required, beginning with the outermost layer, progressing inward (Figure 2). Likewise, the need for compression steel is examined and added, if required, progressing from outer to inner layers. A sufficient amount of compression steel is added to satisfy steel ratio limits on tension steel (0.75 $P_b$, for example).

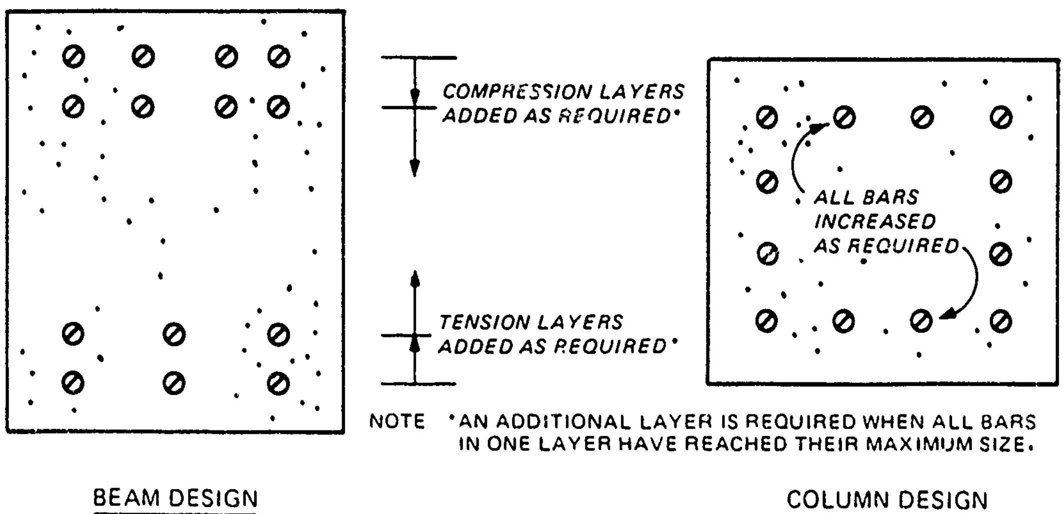



Figure 2. Reinforcement design procedure

Columns

5. In column design, bars are rarely described as being in tension or compression layers; rather, all bars are described in a set pattern. Also, since ductility is normally not a consideration in column design, the user is required to describe a desired bar pattern and the minimum acceptable bar size. The program then computes the size of bars with the described pattern necessary to carry the loads. Slenderness effects are not considered and bars are assumed to be tied in accordance with the ACI Code.

## Investigation Capability

6. The capabilities of the program extend beyond design into investigation checking procedures.

### Beams and columns

7. The program makes no distinction between beams and columns with its investigation procedure. Height and width of a rectangular section, as well as bar areas and locations, are defined by the user. The program then computes the strength of the section and compares this calculated strength with applied loads. CASTR displays the strength of a section in the form of an interaction diagram; therefore, use of this program requires an understanding of the principles of interaction diagrams. A brief explanation of interaction diagrams and their use is provided in paragraphs 10 through 16.

### Ductility check

8. Limits on steel ratios are normally thought of as a means to ensure ductile behavior and are discussed herein as checks on ductility. In fact, steel ratio limits in Corps criteria ensure both ductility and crack control. When the program is used for investigation purposes, the user must input a maximum allowable steel ratio. In most cases of beam design and in some cases of column design, it is important to stay within this maximum limit; therefore, the program checks for satisfaction of ACI Code 318 and user-specified ductility requirements in the described section. In some cases of column investigation, the user may choose to ignore the program's check on ductility, also maximum steel ratios set by the ACI for columns are not checked.

## Theoretical Background

9. Making full use of program CASTR requires an understanding of interaction diagrams and how they are used.

### Interaction diagrams

10. An interaction diagram is plotted on a graph with axial force as the vertical axis and moment as the horizontal axis. An interaction diagram ordinarily is a plot of the moments and axial loads which cause a concrete member to fail.

11. Figure 3 shows an axial load of value $P_a$ acting together with a moment of value $M_a$ and causing a member of specified size to fail. The diagram, then, represents a failure envelope, since points falling inside the

curve do not cause failure and those falling on or outside the curve do cause failure.* A reinforced concrete member is made of two differently behaving materials, steel and concrete, and the equations which define failure depend on whether the steel yields or the concrete crushes. The tension control range represents those axial loads and moments which cause the section to fail because the steel yields (Figure 3). Likewise, the compression control range represents those combinations of axial loads and moments which cause the member to fail by crushing of the concrete. The axial load and moment which cause simultaneous failure of steel and concrete is the balance point.

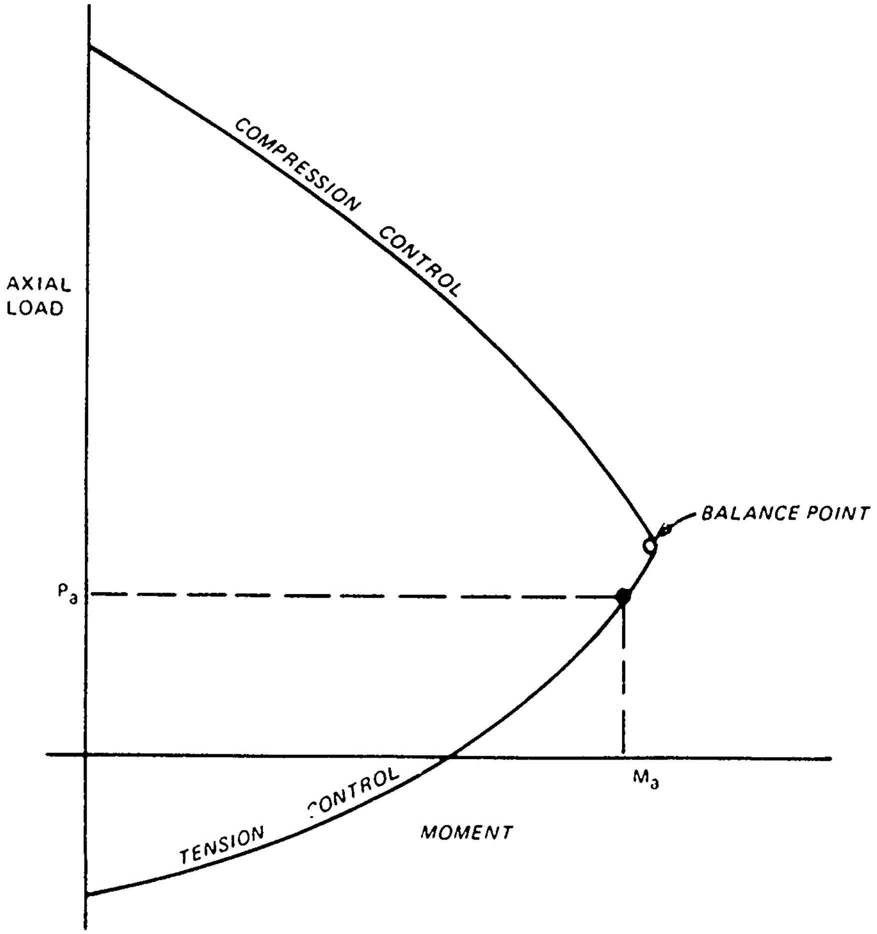



Figure 3. Interaction diagram

* The term failure is used in discussion; however, failure is actually defined by the ACI as occurring when concrete strains reach 0.003.

Stress-strain assumptions

12. Strains are zero at the neutral axis and vary linearly from the neutral axis to a maximum value of 0.003 at the extreme fiber. The compressive stresses in the beam are approximated by a rectangular stress block 0.85 $f'_c$ in magnitude and $\beta_1 C$ high.

Usable load and moment

13. A general expression can be written for the axial load and moment in terms of $C$, and the location of the neutral axis, by using the stress-strain diagrams in Figure 4. The expressions for $P_i$ and $M_1$ are found by setting the sum of horizontal loads and moment equal to zero. Both conditions must be

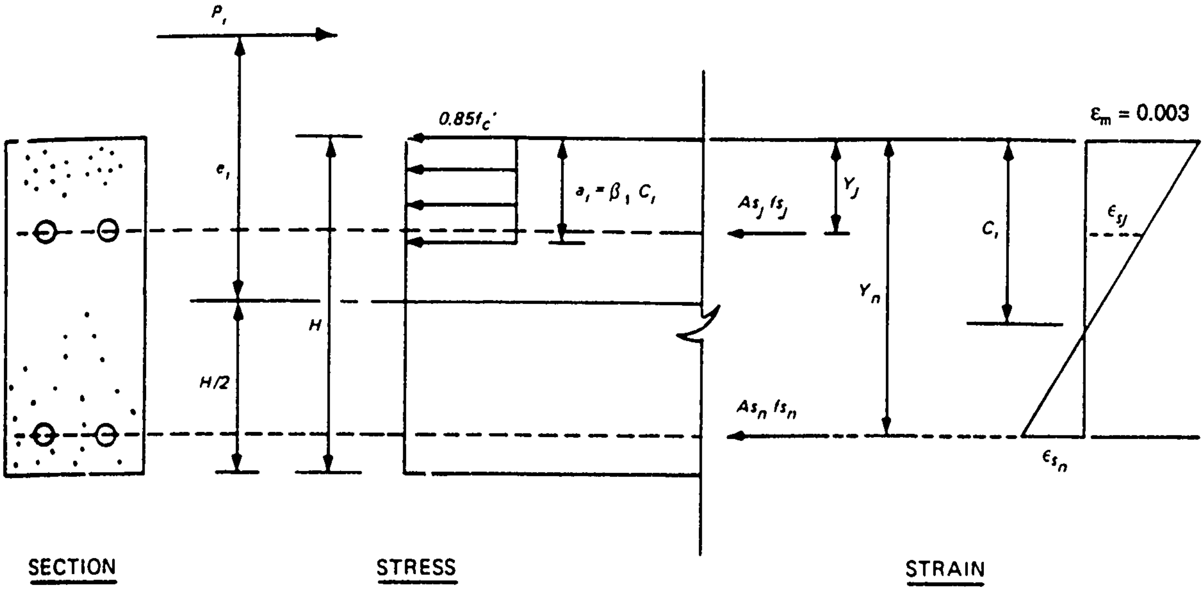



Figure 4. Programmed relationships for stress and strain

satisfied for equilibrium. Therefore, for any general value of $C_1$

$$P_i = 0.85 f'_c \beta_1 C_1 b + \sum_{j=1}^{n} As_j fs_j$$

$$M_1 = 0.85 f'_c \beta_1 C_1 b \left(H - \frac{\beta_1 C_1}{2.0}\right) - P_i\left(\frac{H}{2.0}\right) + \sum_{j=1}^{n} As_j fs_j (H - Y_j)$$

where $n$ equal number of layers of steel. An expression for the stress in each layer of steel in terms of $C_1$ can be developed from the strain diagram

$$fs_j = (C_i\epsilon_c - \epsilon_c Y_j)\ E_s/c_i\ -f_y \le f_{sj} \le f_y$$

14. The general expressions for $P_i$ and $M_i$ shown in the preceding paragraph can generate an interaction diagram by iterating the value of $C$ from near zero to near infinity and computing the values of $P_i$ and $M_i$ for each value of $C_i$. This, in effect, computes the full range of load and moment capacities of the section with all possible positions of the neutral axis.

Ductility

15. The ACI Code requires that the steel ratio cannot exceed $0.75\rho_b$ for members with axial load less than $0.10f'_c bh$. Designers may choose to place more stringent limitations on maximum steel ratios, using input data item PEROB. During the usual design process, if the tension steel required exceeds limitations on steel ratios compression steel can be added, or the beam size increased until the maximum tensile steel ratio limit is satisfied. Increasing the beam size is usually the preferred procedure. Some designers prefer to size the reinforcing steel and check the maximum steel limit with a special load case neglecting any axial compression. The computer program cannot change the concrete dimensions, so it will add compression steel if the tension steel required exceeds the user's limitation on the steel ratio. This addition of a sufficient amount of compression steel is made so that the portion of tension steel resisted by concrete compressive stresses does not exceed the specified upper limits on steel ratio (paragraph 10.3.3, ACI Code 318-89). For convenience, CASTR computes and prints the minimum size beam depth which can be used without compression steel. Columns are designed without regard for ductility.

Iterating to a solution

16. Paragraph 13 describes how an interaction diagram can be generated for a given problem. CASTR designs begin with a very small amount of steel and generates an interaction diagram. If the loading falls outside the envelope created by the diagram, steel areas are increased and a new diagram is generated. This process continues until the diagram exceeds loadings and, in the case of beams, until steel ratio limits are satisfied.

## Data File Preparation--Complete Description

17. The data file must be prepared in advance by using line numbers with three digits. One blank space must follow the line number; data values should be separated by one or more blanks. Lines may not be continued. Units are kips and inches, except that applied moments (RMU) are in kip-feet. Appendix D contains a summary of the information in this paragraph.

Fixed data

18. The first four lines of the data file may be thought of as fixed data since these lines are used only once in a data file.

a. Job title. Two lines of job title must be first in the file. Each of the two lines must have a line number, a blank space, and up to 30 characters of job title.

b. Mode line.

LN MODE

where

LN = Line Number

MODE = 1 for investigation (paragraph 7)

2 for column design (paragraph 5)

3 for beam design (paragraph 4)

Note: See paragraph 31

c. Properties line.

LN FC FY PEROB

where

LN = Line Number

FC = concrete ultimate strength $f'_c$, ksi

FY = steel yield strength $f_y$, ksi

PEROB = limiting ratio of actual reinforcement to balance reinforcement. Use only when MODE = 1 (investigation) or 3 (beam design). It must be omitted when MODE = 2 . Structures not subject to hydraulic action generally follow ACI 318, except that Corps of Engineers' conduits with large axial force should use the value $\phi$.375. Structures subject to hydraulic action must comply with maximum tension reinforcement as stated in Engineer Manual "Strength Design for Reinforced Concrete Hydraulic Structures:"* See also paragraph 15 of this user guide.

---

* Headquarters, Department of the Army. "Strength Design for Reinforced Concrete Hydraulic Structures," Engineer Manual 1992, Washington DC.

Note that very little economy is realized by using values greater than $\phi .375$ and that larger values may lead to constructibility problems.

For singly-reinforced flexural members, and for members subject to combined flexure and compressive axial load when the axial load strength $\phi Pn$ is less than the smaller of $0.10 f_c' A_g$ or $\phi Pb$, the ratio of tension reinforcement $\rho$ provided shall conform to the following.

Recommended limit = $0.25 \rho_b$

Maximum permitted upper limit not requiring special study or investigation = $0.375 \rho_b$, will require consideration of serviceability, constructibility, and economy.

Maximum permitted upper limit when excessive deflections are not predicted when using the method specified in ACI 318 or other methods that predict deformations in substantial agreement with the results of comprehensive tests = $0.50 \rho_b$.

Reinforcement ratios above $0.5 \rho_b$ shall only be permitted if a detailed investigation of serviceability requirements, including computation of deflections, is conducted in consultation with and approved by CECW-ED. Under no circumstance shall the reinforcement ratio exceed $0.75 \rho_b$.

Use of compression reinforcement shall be in accordance with provisions of ACI 318.

Section data

19. Section data sets may be repeated without limit, in order to examine as many sections as desired.

a. Section title line. One line, with a line number, one blank space, then up to 30 characters of section and/or load case title.

b. Geometry line.

LN B H

where

LN = Line Number

B = section width, in.

H = section total height, in.

c. Reinforcing lines. Refer to Figure 5 for reinforcement descriptions of investigation problems and column design; refer to Figure 6 for beam design.

(1) If MODE = 1 for investigation or 2 for column design.

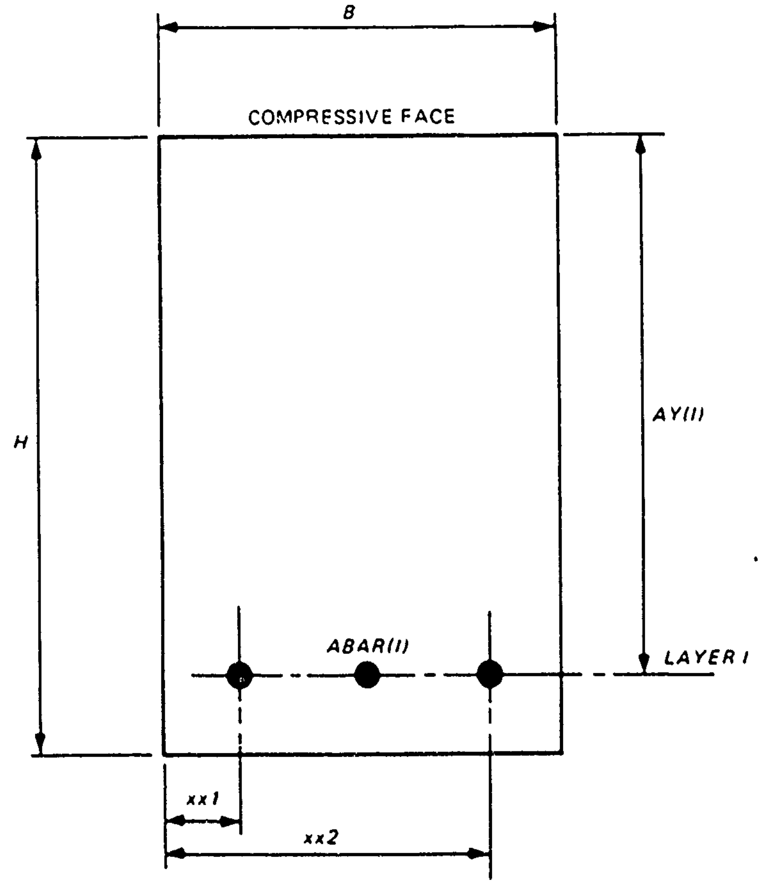



Figure 5. Investigation and column design variables

(a) LN NLAY

where

LN = Line Number

NLAY = number of layers of steel, may be zero

(b) (Use this line if NLAY is greater than zero, repeat the line NLAY times):

LN NBAR(I) ABAR(I) AY(I) XX1(I) XX2(I)

where

LN = Line Number

NBAR = number of bars in layer I

ABAR = area of one bar in layer I, in.$^2$ for gation. Minimum area of one bar in layer I for column design

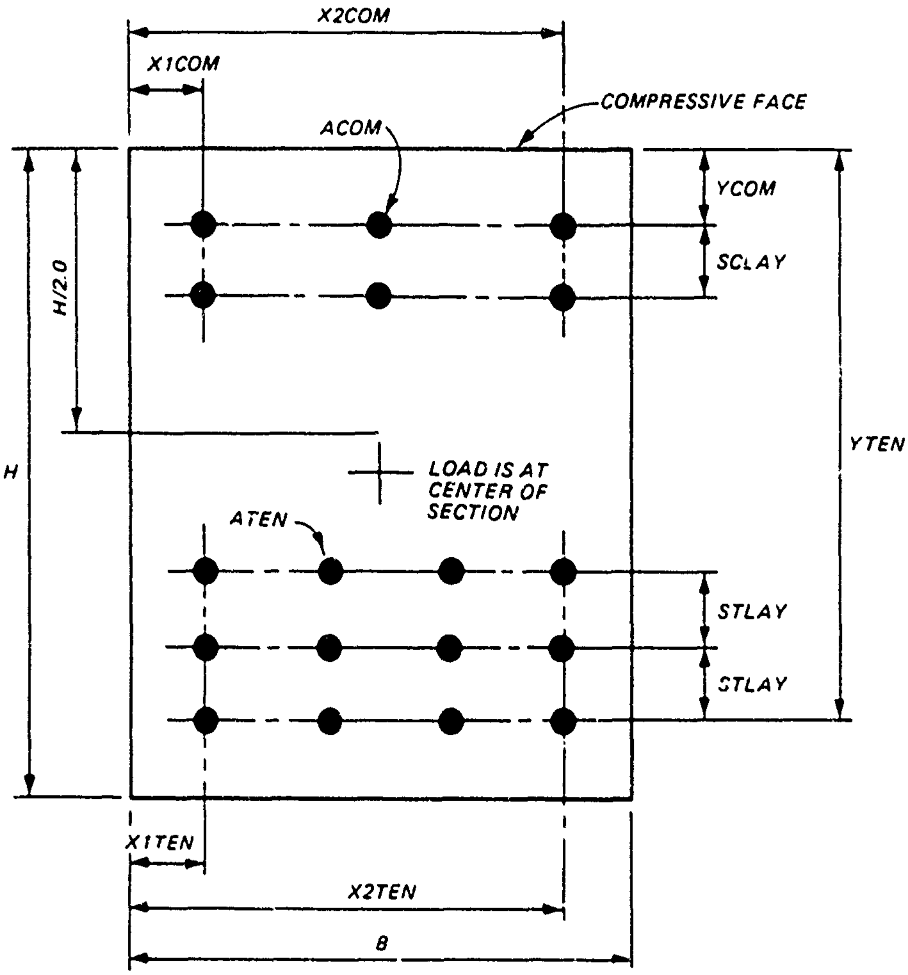



Figure 6. Beam design variables

AY = Y distance from compressive face to center of layer I, in.

XX1 = X distance from left side to center of left-most end bar of layer I, in.

XX2 = X distance from left side to center of rightmost end bar in layer, in.

(2) If MODE = 3 for beam design:

(a) LN NCOM ACOM YCOM X1COM X2COM SCLAY

where

LN = Line Number

NCOM = number of bars per compressive layer

ACOM = maximum area allowed for one bar in a compressive layer, $in.^2$

YCOM = Y distance from compressive face to the center of the outermost (top) layer, in.

X1COM = X distance from left side to the center of the leftmost end bar in a layer of compressive steel, in.

X2COM = X distance from the left side to the of the rightmost end bar in a layer of compressive steel, in.

SCLAY = center-to-center spacing (Y-direction) between layers of compressive steel, in.

(b) LN NTEN ATEN YTEN X1TEN X2TEN STLAY

where these tensile steel descriptions are similar to the corresponding descriptions for compressive steel in subparagraph (a) on preceding page.

d. Load line.

LN PU RMU

where

LN = Line Number

PU = factored axial load, kips, located at *B/2*, *H/2*, compression +

RMU = factored bending moment about the beam centerline, kip-feet, including the moment induced by PU not actually located at *H/2*. Always entered as a positive value, tending to cause compression in the face so considered when defining the reinforcing steel. Remember the code requirements for minimum moment when the theoretical moment is zero.

## Running the Program

20. The following information is a step-by-step guide for preparing a data file and program operation.

a. Begin the program:

(1) Honeywell computers: (* prompt)

*FRN WESLIB/CORPS/X0066,R

(2) CDC computers: (/ prompt)

/OLD,CORPS/UN=CECELB

/BEGIN,,CORPS,X0066

(3) Harris computers: (no prompt)

*CORPS,X0066

b. Enter the data file name when requested. This must be in all capital letters for the microcomputer version.

c. When the bell sounds, the program will pause for the user to make h~rd copies or notes of what is currently displayed, then press the "RETURN" key to continue.

d. The message "END OF DATA" indicates that all of the data have been processed without file read errors. Refer to paragraph 25 for an explanation of error messages.

## Interpretation of Output

21. Output interpretation and investigation following a program is as vital to its success as the preliminaries for the actual run.

Investigation (MODE = 1)

22. Beginning with this paragraph and through paragraph 24, the designation of "figure" applies to computer output Figures 1 and 2.

a. Figure 1 includes tables of basic data and a picture of the section. The analysis parameters $\beta_1$, $\epsilon_{max}$, $f_c/f'_c$, $\theta_{axial}$, and $\theta_{flexure}$ are listed.

b. Figure 2:

(1) Two P/M interaction curves, one with the capacity reduction factor PHI included ("DESIGN STRENGTH") and one without ("NOMINAL STRENGTH"). The nominal strength curve is annotated with the axial force strength upper limit value. The balance point is indicated with an *. The $\phi$ value used is computed from the $\phi$ values shown, in accordance with ACI 318-89, para. 9.3.2.

(2) PU, RMU, and the PHI factor used for the given loading.

(3) Pass/fail message relating to the ability of the section to resist the applied PU and RMU, with PHI included. The admissible range is assumed to be within the "DESIGN STRENGTH" curve, without regard for the reinforcement ratio limit requirement PEROB. Ductility satisfaction or failure is reported by a message.

(4) The percentage of permissible design strength used by the factored applied loading is reported in a message, along with a message describing the type of failure expected at the given eccentricity.

Column design (MODE = 2)

23. Column design is composed of two figures as described below.

a. Figure 1: Tables of basic data and picture of final section as designed. The bar areas in the table of "Reinforcement Areas and Positions" are as designed, not the minimum values in the data input. Analysis parameters used are listed.

b. Figure 2: Same as for investigation, plus the minimum effective depth required with the input value of B to yield an acceptable section without compressive reinforcement.

Beam design (MODE = 3)

24. Beam design, as in column design, is shown by figures made up of data tables as listed:

a. Figure 1: Tables of basic data and picture of final section as designed. The bar areas in the table of "Reinforcement Areas and Positions" are as designed and not the limiting values in the data file. Gross steel ratios for tensile and for compressive steel are listed.

b. Figure 2: Same as for Column Design except that a message on the right side of the figure shows compliance with the reinforcement requirement PEROB.

## Error Messages

25. Listed below are possible error messages and a brief explanation of each one:

a. The message "### DATA ERROR ### LAST LINE WAS nnn" means one of several things:

(1) Improper value for MODE, in which case nnn will be the line number of the MODE line in the data file.

(2) Incomplete data file, one item or an entire line missing, in which case nnn will be the number of the last line in the file.

(3) A decimal point used after a data item name beginning with the letters M or N, in which case nnn will be the number of the line containing the improper decimal point.

(4) A misplaced Job Name or Section Name line, in which case nnn will be the number of the misplaced Name line.

b. If MODE = 2 for column design, a message "A REINF. DESIGN CANNOT BE FOUND--COLUMN SIZE MUST BE INCREASED" means that the bar size needed exceeded 100 $in.^2$*

c. If MODE = 3 for ductile beam design, a message "A REINF. DESIGN CANNOT BE FOUND--EITHER BEAM SIZE OR BAR SIZE MUST BE INCREASED" means that so many layers of reinforcing containing bars of the specified quantity and maximum size were needed that the tensile and compressive reinforcing patterns overlapped.

---

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

## Special Uses of Program

26. The program is versatile in its uses and specific areas are described in the following paragraphs. Call the authors for information on advanced research capabilities.

Slab design

27. Slabs may be designed by inputting a 12.0-in.-wide strip.

Unreinforced section

28. An unreinforced section can be analyzed by inputting NLAY = 0 in the reinforcement data and omitting bar descriptions.

Nonductile beam design

29. If the user wants to design a beam forcing the design to be singly reinforced without regard for the steel ratio limit PEROB the column design procedure can be used. Reinforcement can be described as layers only in the tensile face.

Special plot file output

30. The plot coordinate values of either of the two moment vs. axial force interaction diagrams shown in the output screen "Fig. 2 INTERACTION DIAGRAM" can be written out to a file when desired. The file will be ASCII, with the format as shown below.

First line: No. of points in curve (50), in the Fortran format I5.

Following lines: Coordinates of one point, moment and then force, in the Fortran format 2E14.4. There will be 50 such lines. The first such line will contain the maximum negative force value point; the last one will contain the maximum positive force value point. Thus, the force values will all be different but the same moment value may appear twice, once with a negative force and once with a positive force.

To get such a plot file, make the value used for section width, B, negative. Computations will use the value as positive and the negative sign will trigger two questions, one for a name to be given the file and the other to select the curve whose values are to be written to the file ("Nominal Strength" without phi included or "Design Strength" with phi included).

Research usage

31. Special values can be used for the input value of MODE on the mode data line as described in paragraph 18.b so as to get special variations of the stress block parameters, in accordance with the following table. The term "ETL" refers to ETL's 1110-2-265 dated 1981 and 1110-2-312 dated March 1988.

"ETL" analysis will yield the same design strength along all points on the interaction diagram as would Working Stress Analysis. The bottom of the first output screen will display a table showing the actual stress block parameters used.

| Mode | action |
|---|---|
| -9 | as described for MODE = 1, except ETL parameters |
| -8 | as described for MODE = 2, except ETL parameters |
| -7 | as described for MODE = 3, except ETL parameters |
| 1 | as described for MODE = 1 (using ACI parameters) |
| 2 | as described for MODE = 2 (using ACI parameters) |
| 3 | as described for MODE = 3 (using ACI parameters) |
| 21 | as described for MODE = 1 (see footnote) |
| 22 | as described for MODE = 2 (see footnote) |
| 23 | as described for MODE = 3 (see footnote) |

footnote: an additional line of data will be needed, after the properties data line described in paragraph 18c:

LN B1 EMAX FCR PMAXF PHIF PHIA

where

LN = Line Number

B1 = Depth of stress block as a fraction of the depth of the compression face (beta). See section 10.2.7.3 of ACI 318-89.

EMAX = Allowable strain (0.003 in ACI, 0.0015 in ETL)

FCR = Stress block stress as a fraction of ultimate (0.85 in ACI & ETL)

PMAXF = Limiting strength of column due to axial load (0.8 in ACI, 0.7 in ETL)

PHIF = Phi value for flexure (0.9 in ACI and ETL)

PHIA = Phi value for axial force (0.7 in ACI & ETL)

## Sample Problems

32. A sample investigation problem is presented in Appendix A, a sample column design problem is presented in Appendix B, and a sample beam problem is presented in Appendix C. An abbreviated description of a data file preparation is included in Appendix D.

## Verification

33. The parent program, X0066, was checked thoroughly with hand computations. Since the only differences between X0066 and X0067 are as shown

below, and since these differences were also verified during the preparation of program X0066, no additional verification is needed for Program X0067. These differences are shown in the following tabulation.

| | $\beta$ | $\epsilon_{max}$ | Nominal Axial Force Strength Factor Limit |
|---|---|---|---|
| X0066 (CSTR) | $f'_c$ 4.0 , $\beta_m^* = 0.55$ | 0.0015 | 0.7 |
| | $f'_c > 4.0$ , $\beta m = 0.5$ | | |
| X0067 (CASTR) | $f'_c$ 4.0 , $\beta_1 = 0.85$ | | |
| | $f'_c > 4.0$ : | 0.003 | |
| | $\beta 1 = \beta 1 - 0.05$ | | |
| | $(f'_c - 4.0)$ | | 0.8 |
| | but | | |
| | $\beta 1$ 0.65 | | |

Note: $\beta_m$ in program X0066 (CSTR) is equivalent to $\beta_1$ in program X0067 (CASTR).

## Appendix A: Sample Investigation Problem

### Problem description

Fixed data:

$f'_c = 3.0$ ksi, $f_y = 40.0$ ksi

Section 1:

3 bars @ 0.95 □"/bar

$p_u = 42.0$ kips

$M_u = 157.0$ k-ft

Section 2 (Appendix C design):

Top reinforcement

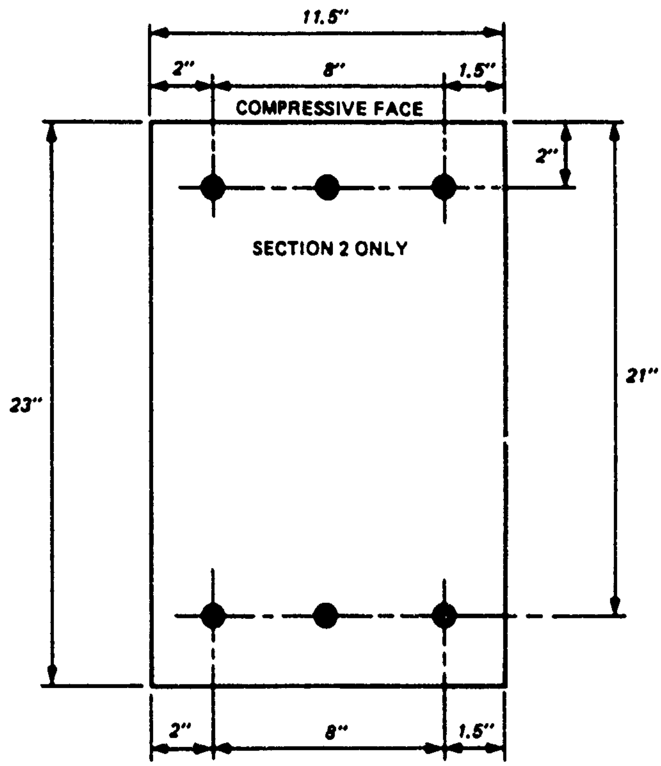
3 bars @ 0.29 □/bar

Bottom reinforcement

3 bars @0.92 □/bar

$P_u = 46.0$ kips

$M_u = 170.0$ k-ft



X0067D1

```
100 PROGRAM X0067 DEMO
110 INVESTIGATION
200 1
210 3.0 40.0 0.375
300 11.5 X 23 WITH 1 LAYER
400 11.5 23.0
500 1
510 3 0.95 21.0 2.0 10.0
600 42.0 157.0
700 APPENDIX C PROBLEM
710 11.5 23.0
720 2
730 3 0.29 2.0 2.0 10.0
740 3 0.92 21.0 2.0 10.0
750 46.0 170.0
```

```
X0067 - User's Guide for Concrete Strength Investigation and Design
          (CASTR) in Accordance with ACI 318-89

Input - X0067

Will Input be from a File or Keyboard (F/K) : F


Enter Input File Name : X0067D1
```

Enter a valid existing filename.

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

Dimensions of Concrete Section

| Width(B) inches | Height(H) inches |
|---|---|
| 11.500 | 23.000 |

Reinforcement Areas and Positions

| Layer No. | No. Bars | Area Bar | Y (in.) | X1 (in.) | X2 (in.) |
|---|---|---|---|---|---|
| 1 | 3 | 0.95 | 21.00 | 2.00 | 10.00 |

Material Constants

F'C = 3.000 ksi
FY = 40.000 ksi

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

| No. | Bars | Bar | (in.) | (in.) | (in.) |
|---|---|---|---|---|---|
| 1 | 3 | 0.95 | 21.00 | 2.00 | 10.00 |

Material Constants

F'C = 3.000 ksi
FY = 40.000 ksi

Factor p-max/p-bal, PEROB = 0.375

Analysis follows ACI Code 318-89:
- Stress Block Depth Ratio, B1 = 0.850
- Maximum Concrete Strain, EMAX = 0.003000
- Concrete Stress Ratio fc/f'c, FCR = 0.8500
- Phi for Flexure, PHIF = 0.900
- Phi for Axial Load, PHIA = 0.700

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

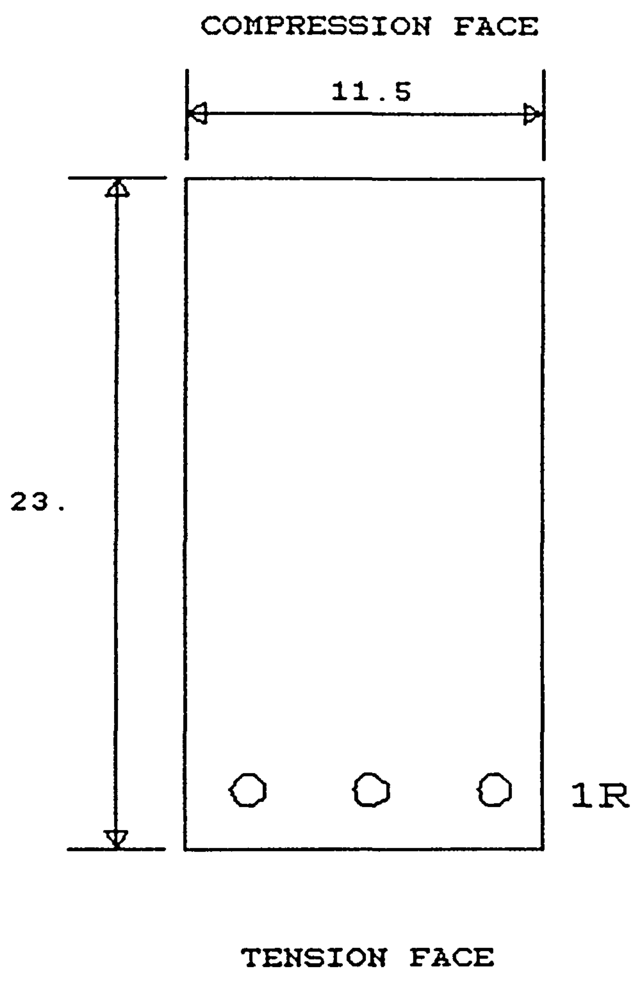



Figure 1. BASIC DATA SUMMARY

PROGRAM X0067 DEMO I
INVESTIGATION .1
11.5 X 23 WITH 1 LAYER

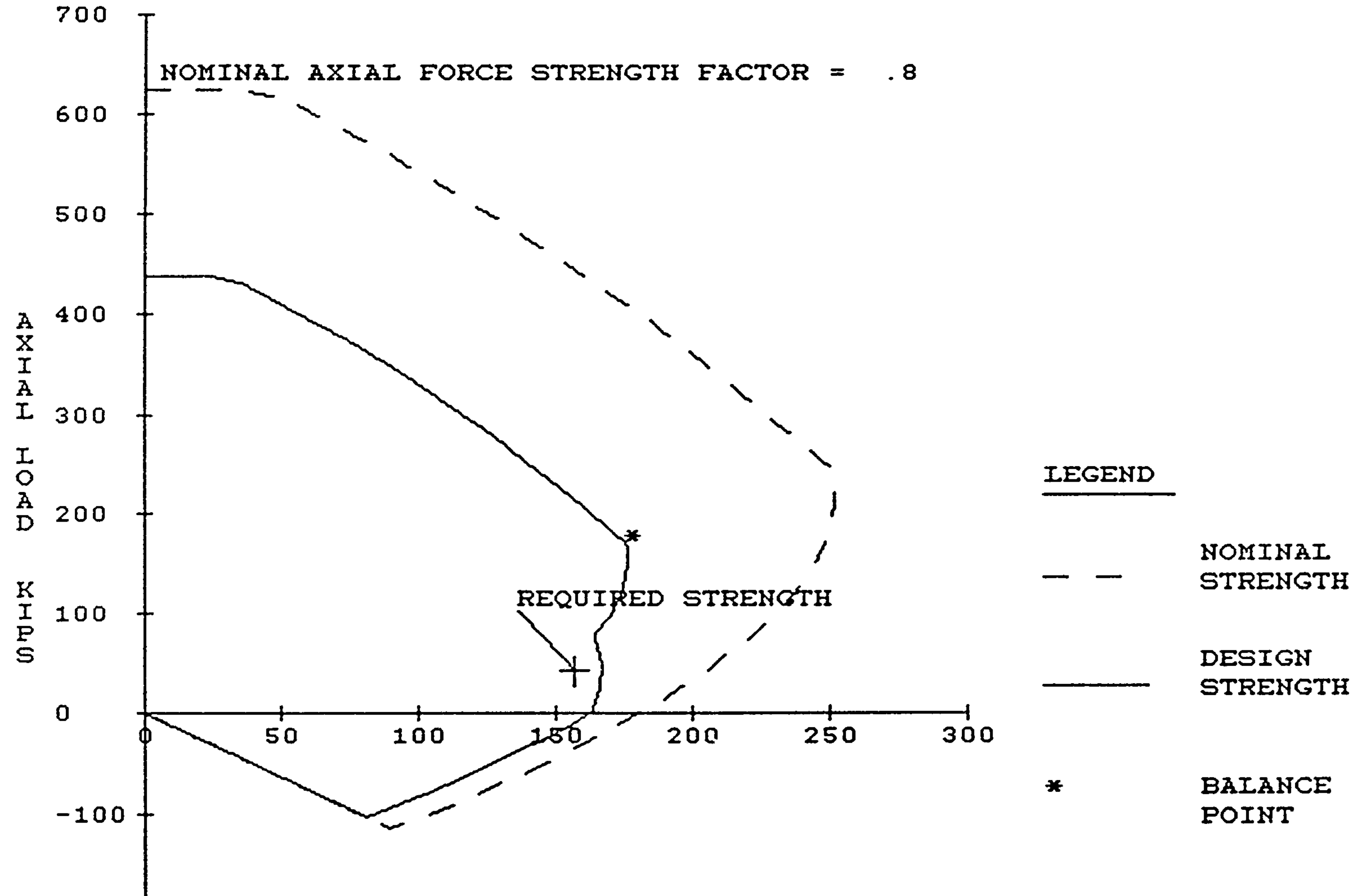



Figure 2. INTERACTION DIAGRAM
PROGRAM X0067 DEMO I
INVESTIGATION 1
11.5 X 23 WITH 1 LAYER

```
X0067 - User's Guide for Concrete Strength Investigation and Design
          (CASTR) in Accordance with ACI 318-89

Output - X0067

ACI Code 318-89:

Required Strength
-----------------
P(U) =      42.0 k          PHI        = 0.7941
M(U) =     157.0 k-ft       ASTOT/B*H = 0.0108

Results
--------
Section falls within admissible range.
Does not meet input data reinforcement limit requirement.

Minimum D for no comp steel =  22.62 inches

 94.24 % of design strength used, in
tensile zone.

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.
```

```
X0067 - User's Guide for Concrete Strength Investigation and Design
          (CASTR) in Accordance with ACI 318-89

Output - X0067

ACI Code 318-89:

Required Strength
-----------------
P(U) =      46.0 k          PHI        = 0.7841
M(U) =     170.0 k-ft       ASTOT/B*H = 0.0137

Results
--------
Section falls within admissible range.
Meets input data reinforcement limit requirement.

Minimum D for no comp steel =  23.84 inches

 99.87 % of design strength used, in
tensile zone.

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.
```

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

Dimensions of Concrete Section

| Width(B) inches | Height(H) inches |
|---|---|
| 11.500 | 23.000 |

Reinforcement Areas and Positions

| Layer No. | No. Bars | Area Bar | Y (in.) | X1 (in.) | X2 (in.) |
|---|---|---|---|---|---|
| 1 | 3 | 0.29 | 2.00 | 2.00 | 10.00 |
| 2 | 3 | 0.92 | 21.00 | 2.00 | 10.00 |

Material Constants

F'C = 3.000 ksi

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

| | | | | | |
|---|---|---|---|---|---|
| 1 | 3 | 0.29 | 2.00 | 2.00 | 10.00 |
| 2 | 3 | 0.92 | 21.00 | 2.00 | 10.00 |

Material Constants

F'C = 3.000 ksi
FY = 40.000 ksi

Factor p-max/p-bal, PEROB = 0.375

Analysis follows ACI Code 318-89:

| | | |
|---|---|---|
| Stress Block Depth Ratio, | B1 = | 0.850 |
| Maximum Concrete Strain, | EMAX = | 0.003000 |
| Concrete Stress Ratio fc/f'c, | FCR = | 0.8500 |
| Phi for Flexure, | PHIF = | 0.900 |
| Phi for Axial Load, | PHIA = | 0.700 |

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

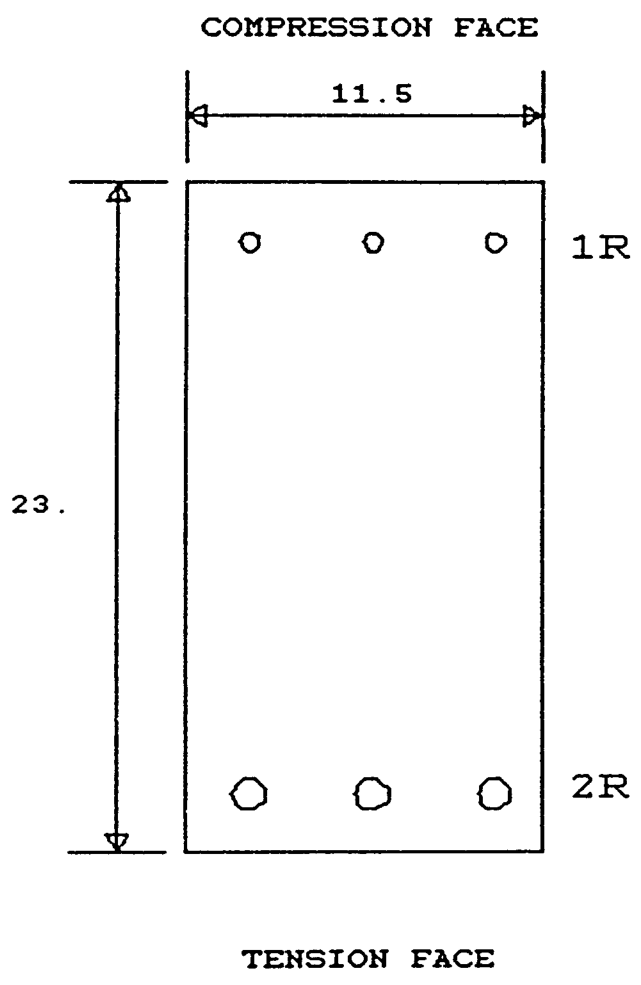



Figure 1. BASIC DATA SUMMARY

PROGRAM X0067 DEMO I
INVESTIGATION À
APPENDIX C PROBLEM

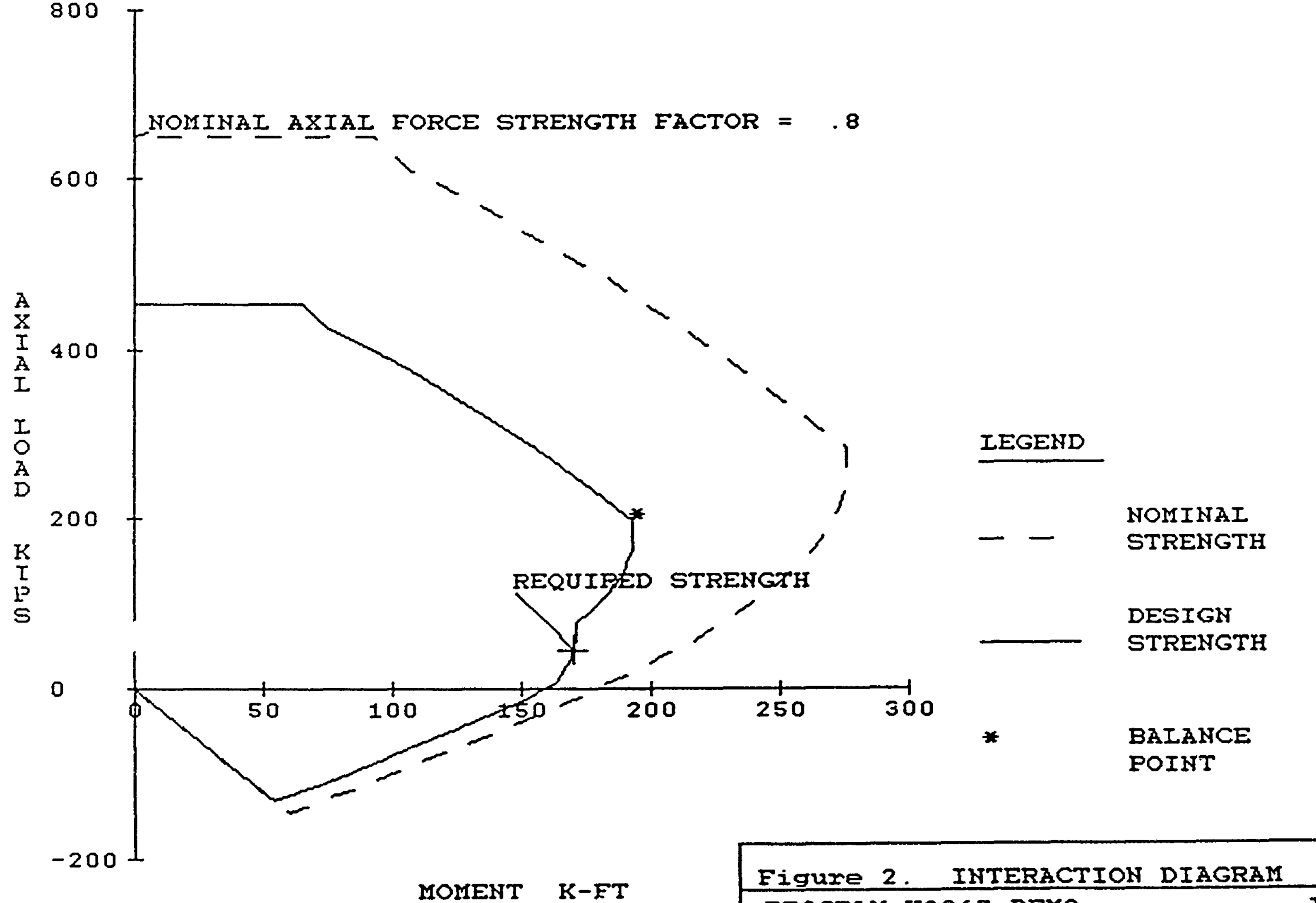



Figure 2. INTERACTION DIAGRAM

PROGRAM X0067 DEMO I
INVESTIGATION A
APPENDIX C PROBLEM

```
    X0067 - User's Guide for Concrete Strength Investigation and Design
              (CASTR) in Accordance with ACI 318-89

  Output - X0067

  End Of Data.

  End or Rerun program (E/R) ?

ENTER RERUN OR END  E
```

## Appendix B: Sample Column Design Problem

### Problem description

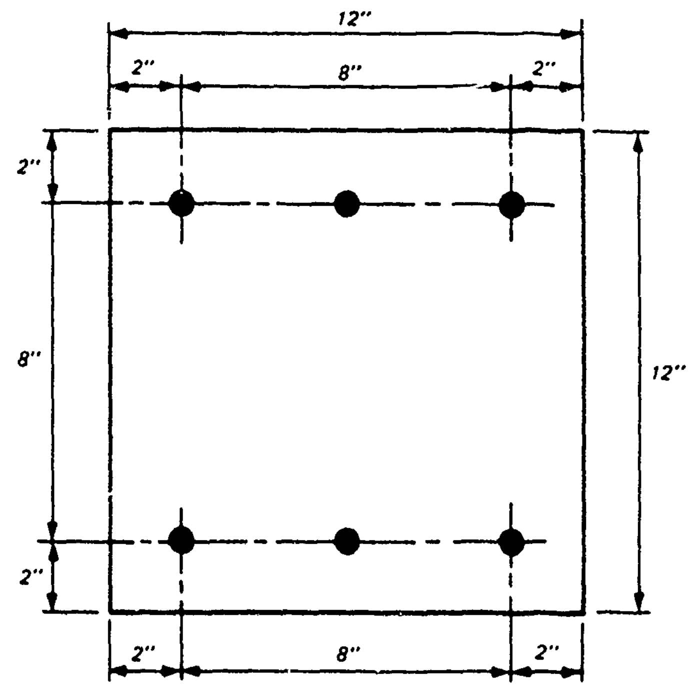
$f_c = 3.0$ ksi

$f_y = 40.0$ ksi

6 bars 0.1 ▢/bar, min.

$P_u = 50.0$ kips

$M_u = 50.0$ k-in.



X0067D2

```
100 PROGRAM X0067 DEMO
110 COLUMN DESIGN
200 2
210 3.0 40.0
300 12 X 12
400 12.0 12.0
500 2
510 3 0.1 2.0 2.0 10.0
520 3 0.1 10.0 2.0 10.0
600 50.0 50.0
```

```
X0067 - User's Guide for Concrete Strength Investigation and Design
        (CASTR) in Accordance with ACI 318-89

Input - X0067

Will Input be from a File or Keyboard (F/K) : F


Enter Input File Name : X0067D2
```

Enter a valid existing filename.

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

Dimensions of Concrete Section

| Width(B) inches | Height(H) inches |
|---|---|
| 12.000 | 12.000 |

Reinforcement Areas and Positions
Resulting from Design Procedure

| Layer No. | No. Bars | Area Bar | Y (in.) | X1 (in.) | X2 (in.) |
|---|---|---|---|---|---|
| 1 | 3 | 0.55 | 2.00 | 2.00 | 10.00 |
| 2 | 3 | 0.55 | 10.00 | 2.00 | 10.00 |

Material Constants

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

| Layer No. | No. Bars | Area Bar | Y (in.) | X1 (in.) | X2 (in.) |
|---|---|---|---|---|---|
| 1 | 3 | 0.55 | 2.00 | 2.00 | 10.00 |
| 2 | 3 | 0.55 | 10.00 | 2.00 | 10.00 |

Material Constants

F'C = 3.000 ksi
FY = 40.000 ksi

Analysis follows ACI Code 318-89:

| | | |
|---|---|---|
| Stress Block Depth Ratio, | B1 = | 0.850 |
| Maximum Concrete Strain, | EMAX = | 0.003000 |
| Concrete Stress Ratio fc/f'c, | FCR = | 0.8500 |
| Phi for Flexure, | PHIF = | 0.900 |
| Phi for Axial Load, | PHIA = | 0.700 |

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

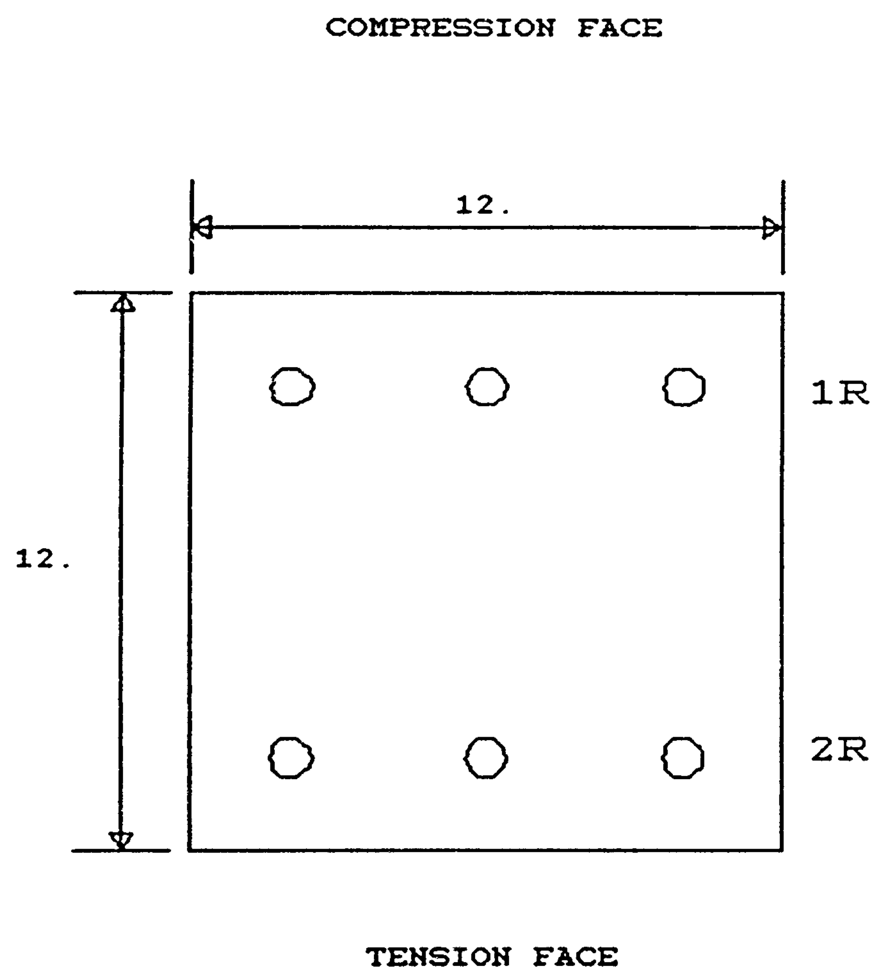



Figure 1. BASIC DATA SUMMARY

PROGRAM X0067 DEMO C
COLUMN DESIGN 1
12 X 12

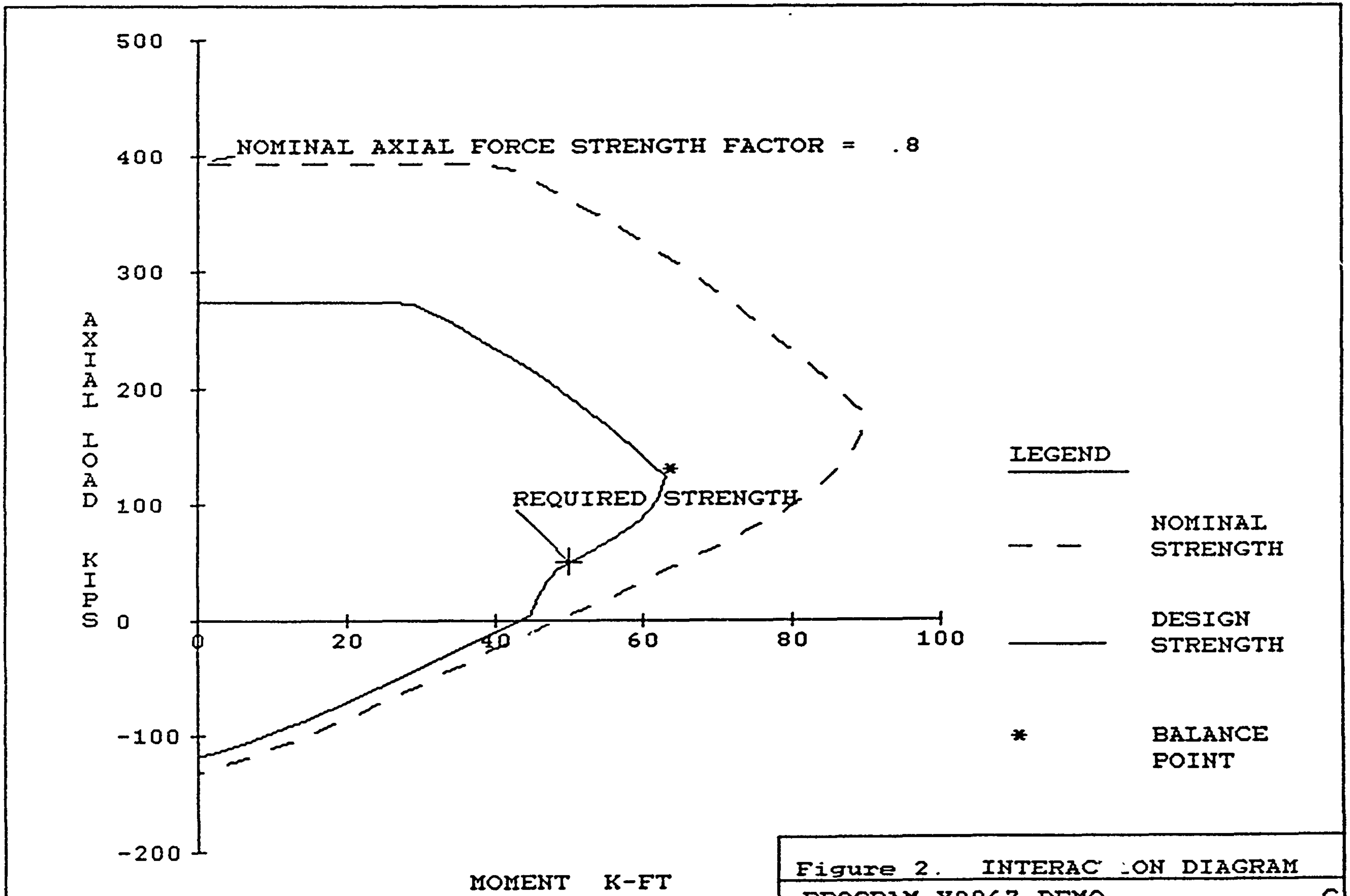



Figure 2. INTERAC ON DIAGRAM

PROGRAM X0067 DEMO C
COLUMN DESIGN 1
12 X 12

```
X0067 - User's Guide for Concrete Strength Investigation and Design
         (CASTR) in Accordance with ACI 318-89

Output - X0067

ACI Code 318-89:

Required Strength
-----------------
P(U) =      50.0 k         PHI        = 0.7000
M(U) =      50.0 k-ft      ASTOT/B*H = 0.0229

Results
-------
Section falls within admissible range.
 98.24 % of design strength used, in
tensile zone.

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.
```

```
X0067 - User's Guide for Concrete Strength Investigation and Design
         (CASTR) in Accordance with ACI 318-89

Output - X0067

End Of Data.

End or Rerun program (E/R) ?

ENTER RERUN OR END  E
```

# Appendix C:  Sample Ductile Beam Design Problem

## Problem description

$f_c$= ksi

$f_y$ = 40.0 ksi

$$\frac{p}{p_{bal}} = 0.375 \text{ max}$$

$P_u$ = 46.0 kips

$M_u$ = 170.0 k-in. load case 2

Compressive steel:

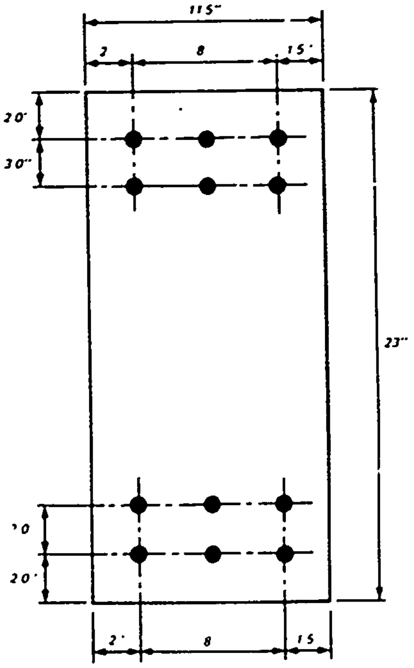
3 bars/layer

$As_{max}$ = 5.0 □/bar

Tensile steel:

3 bars/layer

$As_{max}$ = 5.0 □/bar




Validation:  The design produced by this example is used as the data for the Section 2 problem in Appendix A.

X0067D3

```
100 PROGRAM X0067 DEMO
110 DUCTILE BEAM DESIGN
200 3
210 3.0 40.0 0.375
300 11.5 X 23 W/COMP ALLOWED
400 11.5 23.0
500 3 5.0 2.0 2.0 10.0 3.0
510 3 5.0 21.0 2.0 10.0 3.0
600 46.0 170.0
```

```
   X0067 - User's Guide for Concrete Strength Investigation and Design
            (CASTR) in Accordance with ACI 318-89

 Input - X0067

 Will Input be from a File or Keyboard (F/K) : F


 Enter Input File Name : X0067D3
```

Enter a valid existing filename.

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

| | | | | | |
|---|---|---|---|---|---|
| 1 | 3 | 0.29 | 2.00 | 2.00 | 10.00 |
| 2 | 3 | 0.92 | 21.00 | 2.00 | 10.00 |

Material Constants
------------------

F'C = 3.000 ksi
FY = 40.000 ksi

Factor p-max/p-bal, PEROB = 0.375

Analysis follows ACI Code 318-89:

| | | | |
|---|---|---|---|
| Stress Block Depth Ratio, | B1 | = | 0.850 |
| Maximum Concrete Strain, | EMAX | = | 0.003000 |
| Concrete Stress Ratio fc/f'c, | FCR | = | 0.8500 |
| Phi for Flexure, | PHIF | = | 0.900 |
| Phi for Axial Load, | PHIA | = | 0.700 |

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

Dimensions of Concrete Section
------------------------------

| Width(B) inches | Height(H) inches |
|---|---|
| 11.500 | 23.000 |

Reinforcement Areas and Positions
Resulting from Design Procedure
---------------------------------

| Layer No. | No. Bars | Area Bar | Y (in.) | X1 (in.) | X2 (in.) |
|---|---|---|---|---|---|
| 1 | 3 | 0.29 | 2.00 | 2.00 | 10.00 |
| 2 | 3 | 0.92 | 21.00 | 2.00 | 10.00 |

Material Constants
------------------

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

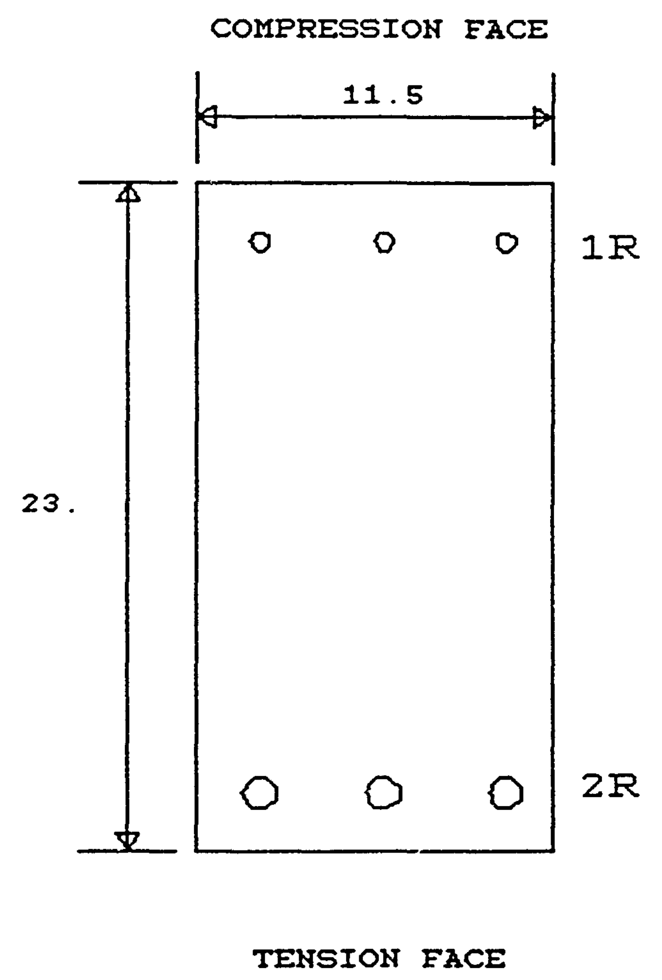



Figure 1. BASIC DATA SUMMARY

PROGRAM X0067 DEMO D
DUCTILE BEAM DESIGN 1
11.5 X 23 W/COMP ALLOWED

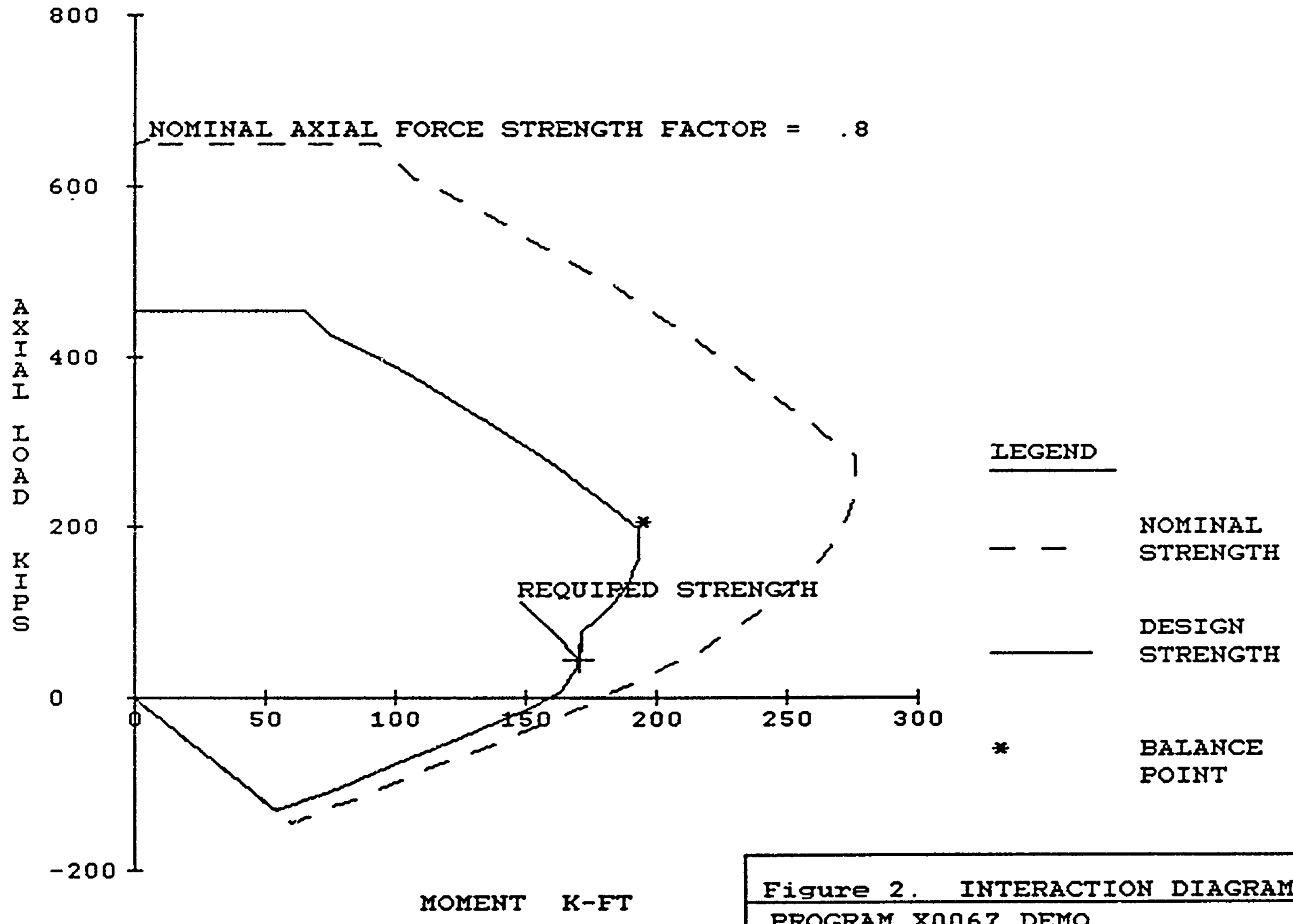



Figure 2. INTERACTION DIAGRAM

PROGRAM X0067 DEMO D
DUCTILE BEAM DESIGN 1
11.5 X 23 W/COMP ALLOWED

```
X0067 - User's Guide for Concrete Strength Investigation and Design
        (CASTR) in Accordance with ACI 318-89

Output - X0067

ACI Code 318-89:

Required Strength
-----------------
P(U) =     46.0 k          PHI         = 0.7841
M(U) =    170.0 k-ft       ASTOT/B*H = 0.0137

Results
-------
Section falls within admissible range.
Meets input data reinforcement limit requirement.

Minimum D for no comp steel =  23.84 inches

 99.87 % of design strength used, in
tensile zone.

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.
```

```
X0067 - User's Guide for Concrete Strength Investigation and Design
        (CASTR) in Accordance with ACI 318-89

Output - X0067

End Of Data.

End or Rerun program (E/R) ?

ENTER RERUN OR END  E
```

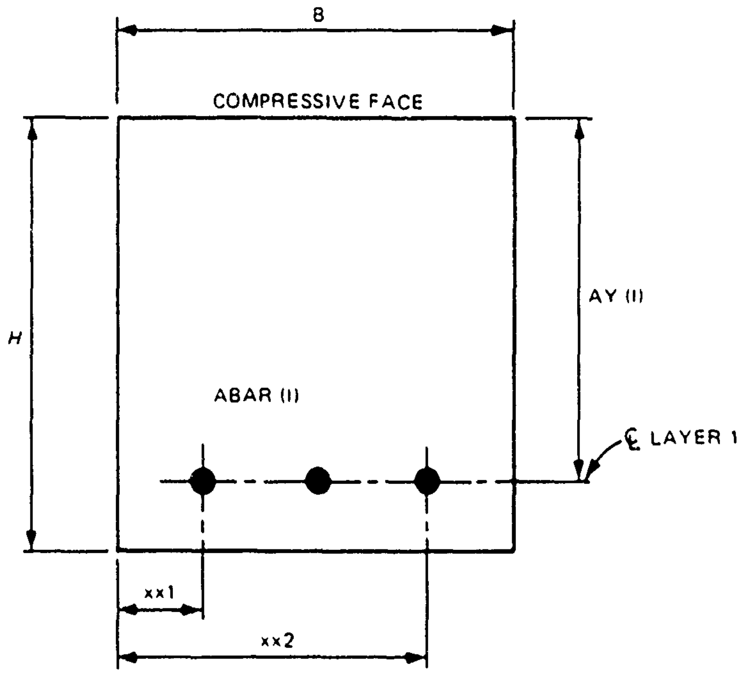
## Appendix D: Abbreviated Data File Guide

Abbreviated description
of data file preparation

1. This program will investigate or design. Paragraph 2 is concerned with investigation and design of columns, and Paragraph 3 deals with design of beams.

Investigation and
column design (MODE = 1 or 2)

2.




Note: ABAR(I) = area of one bar in layer I for investigation or ABAR(I) = min area of one bar for column design

LN JOB TITLE (30 characters max)

LN JOB TITLE (30 characters max)

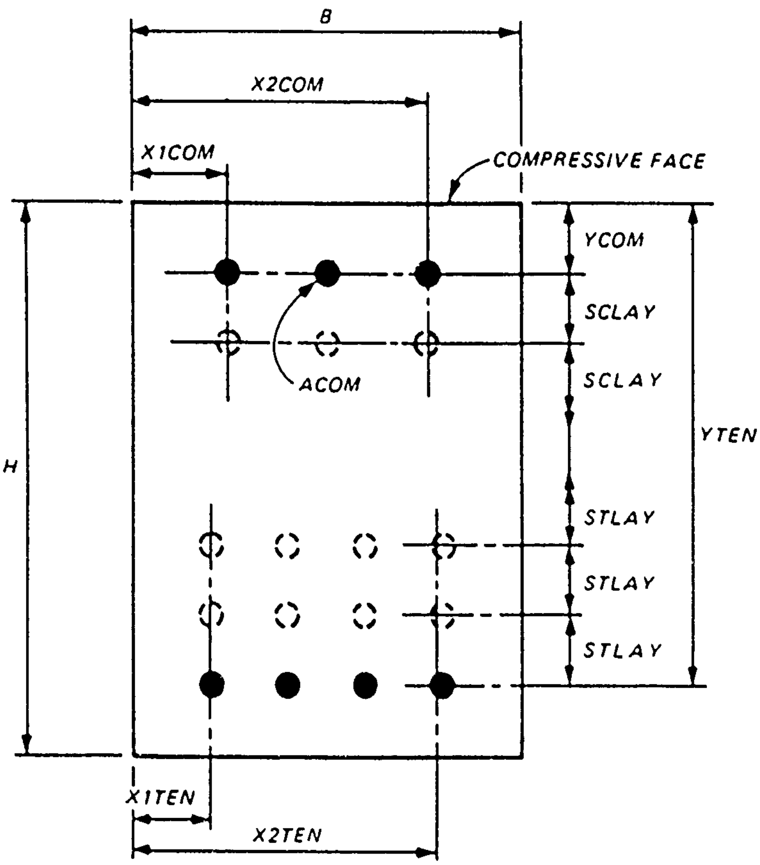
LN MODE

LN FC FY PEROB ← (omit PEROB for column design)

| | | |
|---|---|---|
| Repeat for each load case | LN | SECTION TITLE (30 characters max) |
| | LN | B H |
| | LN | NLAY |
| | LN | NBAR(I), ABAR(I), AY(I), XX1(I), XX2(I) |
| | LN | (repeat above line NLAY times, NLAY = number of layers) |
| | LN | PU, RMU |

Beam design

3. (MODE = 3)




LN JOB TITLE (30 characters max)

LN JOB TITLE (30 characters max)

LN MODE

LN FC, FY, PEROB

| | |
|---|---|
| Repeat for each load case | LN SECTION TITLE (30 Characters max)<br>LN B, H<br>LN NCOM, ACOM, YCOM, X1COM, X2COM, SCLAY<br>LN NTEN, ATEN, YTEN, X1TEN, X2TEN, STLAY<br>LN PU, RMU |

Units

4. All dimensions are in inches, all areas are in square inches, and concrete and steel yield strengths are in kips per square inch. Forces are in kips at B/2 and H/2; compression is positive. Moments are in kip-feet and include the moment caused by the fact that the axial force is not at H/2, and moments must be positive tending to cause compression in the top face in the diagram in paragraphs 2 and 3 of this appendix.

## Appendix E: Sample Investigation Problem with Data Entered Interactively

Rerun Appendix A problem, except enter data interactively.

```
X0067 - User's Guide for Concrete Strength Investigation and Design
        (CASTR) in Accordance with ACI 318-89

Input - X0067 - Header

Title : PROGRAM X0067 DEMO KEYBOARD
        INVESTIGATION - FIRST PROB ONL

Mode  : 1

Concrete Ultimate Strength, Fc (ksi)    : 3

Steel Yield Strength, Fy (ksi)          : 40.0

Enter Steel Yield Strength
```

```
X0067 - User's Guide for Concrete Strength Investigation and Design
        (CASTR) in Accordance with ACI 318-89

Input - X0067

Will Input be from a File or Keyboard (F/K) : K


Enter Data File Name : x0067d1k

Enter filename in which to save data.
```

```
X0067 - User's Guide for Concrete Strength Investigation and Design
         (CASTR) in Accordance with ACI 318-89

Input - X0067 - Header

Title : PROGRAM X0067 DEMO KEYBOARD
        INVESTIGATION - FIRST PROB ONL

Mode  : 1

Concrete Ultimate Strength, Fc (ksi)    : 3

Steel Yield Strength, Fy (ksi)          : 40


Limiting Ratio of Actual Reinforcement
  to Balance Reinforcement              : 0.375
```

Usual values are 0.75 or 0.375

```
X0067 - User's Guide for Concrete Strength Investigation and Design
         (CASTR) in Accordance with ACI 318-89

Input - X0067 - Section - page 1

Do you wish to enter section data (Y/N) : Y
```

Enter Y or N

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Input - X0067 - Section - page 1

Title : 11.5 X 23 WITH 1 LAYER OF STL

Section Width, inches : 11.5

Section Total Height, inches : 23.0

Enter Section Total Height

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Input - X0067 - Section - page 2

Number of layers of steel : 1

| Number of bars in layer | Area of one bar in layer | Y distance from face to center | X distance from left side to leftmost bar | X distance from left side to rightmost bar |
|---|---|---|---|---|
| 3 | 0.95 | 21 | 2 | 10.0 |

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Input - X0067 - Section - page 3

Factored axial load (kips) : 42

Factored bending moment (kip-feet) : 157.0

Enter moment

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

Dimensions of Concrete Section

| Width(B) inches | Height(H) inches |
|---|---|
| 11.500 | 23.000 |

Reinforcement Areas and Positions

| Layer No. | No. Bars | Area Bar | Y (in.) | X1 (in.) | X2 (in.) |
|---|---|---|---|---|---|
| 1 | 3 | 0.95 | 21.00 | 2.00 | 10.00 |

Material Constants

F'C = 3.000 ksi
FY = 40.000 ksi

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

Output - X0067

```
No.     Bars   Bar    (in.)    (in.)    (in.)
 1      3      0.95   21.00     2.00    10.00

Material Constants
------------------
F'C =  3.000 ksi
FY  = 40.000 ksi

Factor p-max/p-bal, PEROB =  0.375

Analysis follows ACI Code 318-89:
   Stress Block Depth Ratio,     B1   =  0.850
   Maximum Concrete Strain,      EMAX =  0.003000
   Concrete Stress Ratio fc/f'c, FCR  =  0.8500
   Phi for Flexure,              PHIF =  0.900
   Phi for Axial Load,           PHIA =  0.700
```

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

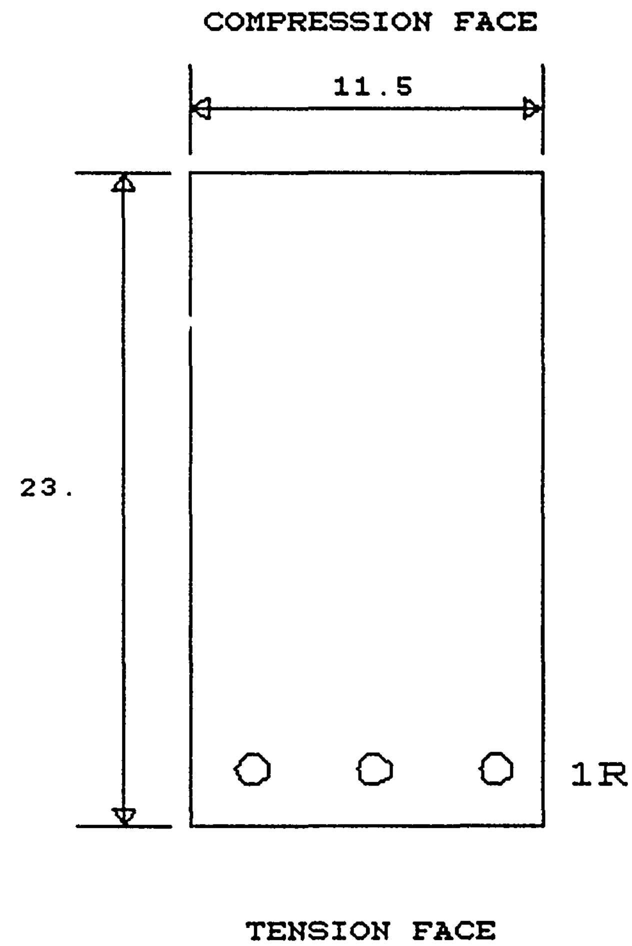



Figure 1. BASIC DATA SUMMARY
PROGRAM X0067 DEMO KEYBOARD
INVESTIGATION - FIRST PROB ONL
11.5 X 23 WITH 1 LAYER OF STL

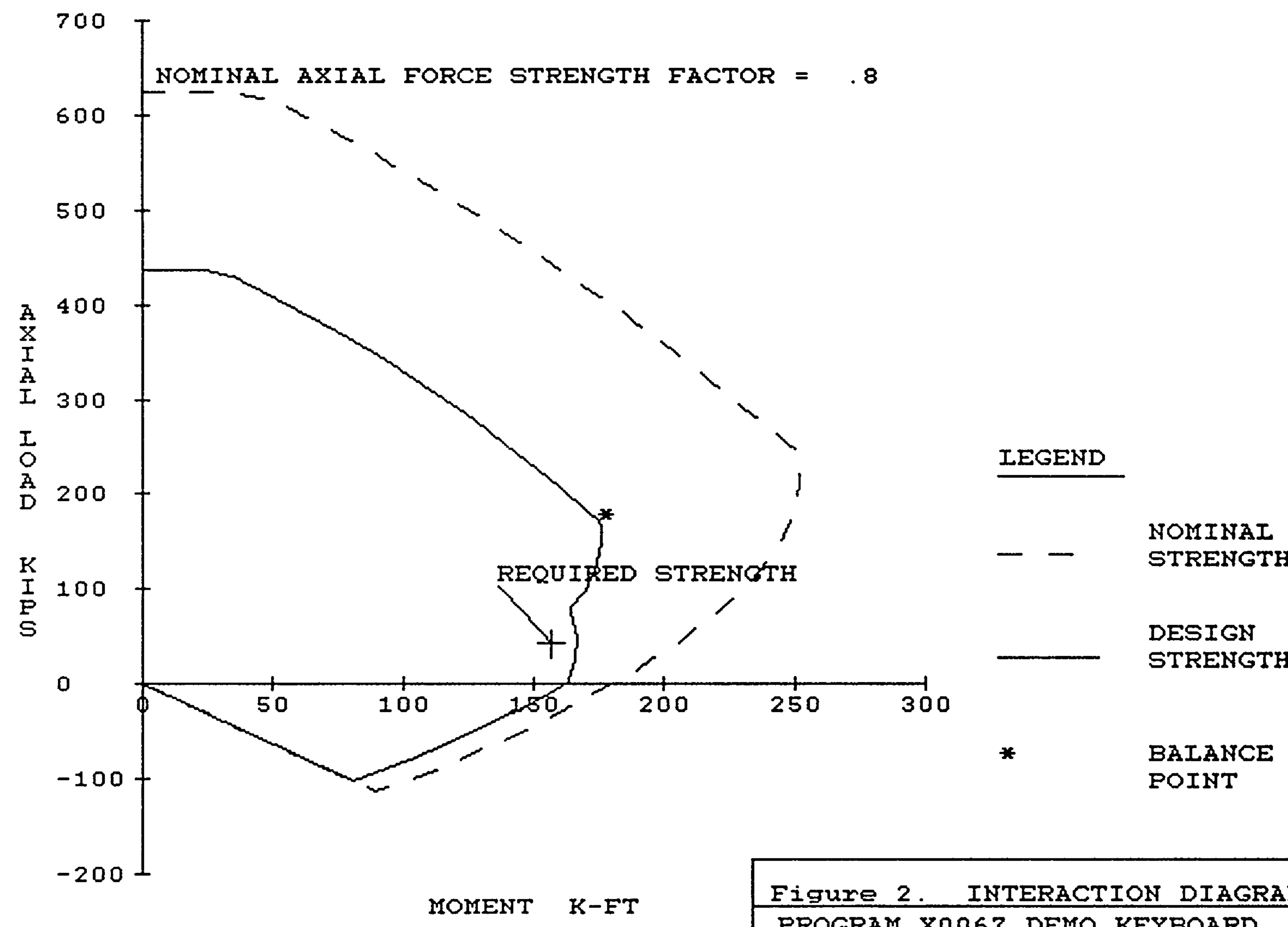



Figure 2. INTERACTION DIAGRAM

PROGRAM X0067 DEMO KEYBOARD
INVESTIGATION - FIRST PROB ONL
11.5 X 23 WITH 1 LAYER OF STL

X0067 - User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89

Output - X0067

```
ACI Code 318-89:

Required Strength
-----------------
P(U) =     42.0 k         PHI        = 0.7941
M(U) =    157.0 k-ft      ASTOT/B*H = 0.0108

Results
-------
Section falls within admissible range.
Does not meet input data reinforcement limit requirement.

Minimum D for no comp steel =  22.62 inches

 94.24 % of design strength used, in
tensile zone.
```

Press Up, Down, PgUp, and PgDn to Scroll, Enter to Continue.

```
X0067 - User's Guide for Concrete Strength Investigation and Design
         (CASTR) in Accordance with ACI 318-89

Input - X0067 - Section - page 1

Do you wish to enter section data (Y/N) : N

Enter Y or N
```

```
X0067 - User's Guide for Concrete Strength Investigation and Design
         (CASTR) in Accordance with ACI 318-89

Output - X0067

End Of Data.

End or Rerun program (E/R) ?

ENTER RERUN OR END  E
```

```
100 PROGRAM X0067 DEMO KEYBOARD
110 INVESTIGATION - FIRST PROB ONL
120       1
130     3.0000    40.0000       .3750
140 11.5 X 23 WITH 1 LAYER OF STL
150    11.5000    23.0000
160          1
170          3      .9500    21.0000      2.0000     10.0000
180    42.0000   157.0000
```

# WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

| | Title | Date |
|---|---|---|
| Technical Report K-78-1 | List of Computer Programs for Computer-Aided Structural Engineering | Feb 1978 |
| Instruction Report O-79-2 | User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME) | Mar 1979 |
| Technical Report K-80-1 | Survey of Bridge-Oriented Design Software | Jan 1980 |
| Technical Report K-80-2 | Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges | Jan 1980 |
| Instruction Report K-80-1 | User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON) | Feb 1980 |
| Instruction Report K-80-3 | A Three-Dimensional Finite Element Data Edit Program | Mar 1980 |
| Instruction Report K-80-4 | A Three-Dimensional Stability Analysis/Design Program (3DSAD) | |
| | Report 1: General Geometry Module | Jun 1980 |
| | Report 3: General Analysis Module (CGAM) | Jun 1982 |
| | Report 4: Special-Purpose Modules for Dams (CDAMS) | Aug 1983 |
| Instruction Report K-80-6 | Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA) | Dec 1980 |
| Instruction Report K-80-7 | User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA) | Dec 1980 |
| Technical Report K-80-4 | Documentation of Finite Element Analyses | |
| | Report 1: Longview Outlet Works Conduit | Dec 1980 |
| | Report 2: Anchored Wall Monolith, Bay Springs Lock | Dec 1980 |
| Technical Report K-80-5 | Basic Pile Group Behavior | Dec 1980 |
| Instruction Report K-81-2 | User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL) | |
| | Report 1: Computational Processes | Feb 1981 |
| | Report 2: Interactive Graphics Options | Mar 1981 |
| Instruction Report K-81-3 | Validation Report. Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA) | Feb 1981 |
| Instruction Report K-81-4 | User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN) | Mar 1981 |
| Instruction Report K-81-6 | User's Guide. Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS) | Mar 1981 |
| Instruction Report K-81-7 | User's Guide. Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL) | Mar 1981 |
| Instruction Report K-81-9 | User's Guide. Computer Program for Three Dimensional Analysis of Building Systems (CTABS80) | Aug 1981 |
| Technical Report K-81-2 | Theoretical Basis for CTABS80. A Computer Program for Three-Dimensional Analysis of Building Systems | Sep 1981 |
| Instruction Report K-82-6 | User's Guide. Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC) | Jun 1982 |

(Continued)

## WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

| | Title | Date |
|---|---|---|
| Instruction Report K-82-7 | User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR) | Jun 1982 |
| Instruction Report K-83-1 | User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME) | Jan 1983 |
| Instruction Report K-83-2 | User's Guide: Computer Program for Generation of Engineering Geometry (SKETCH) | Jun 1983 |
| Instruction Report K-83-5 | User's Guide: Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis | Jul 1983 |
| Technical Report K-83-1 | Basic Pile Group Behavior | Sep 1983 |
| Technical Report K-83-3 | Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH) | Sep 1983 |
| Technical Report K-83-4 | Case Study of Six Major General-Purpose Finite Element Programs | Oct 1983 |
| Instruction Report K-84-2 | User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR) | Jan 1984 |
| Instruction Report K-84-7 | User's Guide: Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT) | Aug 1984 |
| Instruction Report K-84-8 | Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG) | Sep 1984 |
| Instruction Report K-84-11 | User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics | Sep 1984 |
| Technical Report K-84-3 | Computer-Aided Drafting and Design for Corps Structural Engineers | Oct 1984 |
| Technical Report ATC-86-5 | Decision Logic Table Formulation of ACI 318-77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II | Jun 1986 |
| Technical Report ITL-87-2 | A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs | Jan 1987 |
| Instruction Report ITL-87-1 | User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUFRAM) | Apr 1987 |
| Instruction Report ITL-87-2 | User's Guide: For Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-83 | May 1987 |
| Technical Report ITL-87-6 | Finite-Element Method Package for Solving Steady-State Seepage Problems | May 1987 |
| Instruction Report ITL-87-3 | User's Guide: A Three Dimensional Stability Analysis/Design Program (3DSAD) Module | Jun 1987 |
| | Report 1: Revision 1: General Geometry | Jun 1987 |
| | Report 2: General Loads Module | Sep 1989 |
| | Report 6: Free-Body Module | Sep 1989 |

(Continued)

# WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

| | Title | Date |
|---|---|---|
| Instruction Report ITL-87-4 | User's Guide: 2-D Frame Analysis Link Program (LINK2D) | Jun 1987 |
| Technical Report ITL-87-4 | Finite Element Studies of a Horizontally Framed Miter Gate<br>Report 1: Initial and Refined Finite Element Models (Phases A, B, and C), Volumes I and II<br>Report 2: Simplified Frame Model (Phase D)<br>Report 3: Alternate Configuration Miter Gate Finite Element Studies–Open Section<br>Report 4: Alternate Configuration Miter Gate Finite Element Studies–Closed Sections<br>Report 5: Alternate Configuration Miter Gate Finite Element Studies–Additional Closed Sections<br>Report 6: Elastic Buckling of Girders in Horizontally Framed Miter Gates<br>Report 7: Application and Summary | Aug 1987 |
| Instruction Report GL-87-1 | User's Guide: UTEXAS2 Slope-Stability Package; Volume I, User's Manual | Aug 1987 |
| Instruction Report ITL-87-5 | Sliding Stability of Concrete Structures (CSLIDE) | Oct 1987 |
| Instruction Report ITL-87-6 | Criteria Specifications for and Validation of a Computer Program for the Design or Investigation of Horizontally Framed Miter Gates (CMITER) | Dec 1987 |
| Technical Report ITL-87-8 | Procedure for Static Analysis of Gravity Dams Using the Finite Element Method – Phase 1a | Jan 1988 |
| Instruction Report ITL-88-1 | User's Guide: Computer Program for Analysis of Planar Grid Structures (CGRID) | Feb 1988 |
| Technical Report ITL-88-1 | Development of Design Formulas for Ribbed Mat Foundations on Expansive Soils | Apr 1988 |
| Technical Report ITL-88-2 | User's Guide: Pile Group Graphics Display (CPGG) Post-processor to CPGA Program | Apr 1988 |
| Instruction Report ITL-88-2 | User's Guide for Design and Investigation of Horizontally Framed Miter Gates (CMITER) | Jun 1988 |
| Instruction Report ITL-88-4 | User's Guide for Revised Computer Program to Calculate Shear, Moment, and Thrust (CSMT) | Sep 1988 |
| Instruction Report GL-87-1 | User's Guide. UTEXAS2 Slope-Stability Package, Vo' me II, Theory | Feb 1989 |
| Technical Report ITL-89-3 | User's Guide. Pile Group Analysis (CPGA) Computer Group | Jul 1989 |
| Technical Report ITL-89-4 | CBASIN–Structural Design of Saint Anthony Falls Stilling Basins According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0098 | Aug 1989 |

(Continued)

## WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Concluded)

| | Title | Date |
|---|---|---|
| Technical Report ITL-89-5 | CCHAN–Structural Design of Rectangular Channels According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0097 | Aug 1989 |
| Technical Report ITL-89-6 | The Response-Spectrum Dynamic Analysis of Gravity Dams Using the Finite Element Method; Phase II | Aug 1989 |
| Contract Report ITL-89-1 | State of the Art on Expert Systems Applications in Design, Construction, and Maintenance of Structures | Sep 1989 |
| Instruction Report ITL-90-1 | User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CWALSHT) | Feb 1990 |
| Technical Report ITL-90-3 | Investigation and Design of U-Frame Structures Using Program CUFRBC<br>Volume A: Program Criteria and Documentation<br>Volume B: User's Guide for Basins<br>Volume C: User's Guide for Channels | May 1990 |
| Instruction Report ITL-90-6 | User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame or W-Frame Structures (CWFRAM) | Sep 1990 |
| Instruction Report ITL-90-2 | User's Guide: Pile Group–Concrete Pile Analysis Program (CPGC) Preprocessor to CPGA Program | Jun 1990 |
| Technical Report ITL-91-3 | Application of Finite Element, Grid Generation, and Scientific Visualization Techniques to 2-D and 3-D Seepage and Groundwater Modeling | Sep 1990 |
| Instruction Report ITL-91-1 | User's Guide: Computer Program for Design and Analysis of Sheet-Pile Walls by Classical Methods (CWALSHT) Including Rowe's Moment Reduction | Oct 1991 |
| Instruction Report ITL-87-2 (Revised) | User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89 | Mar 1992 |