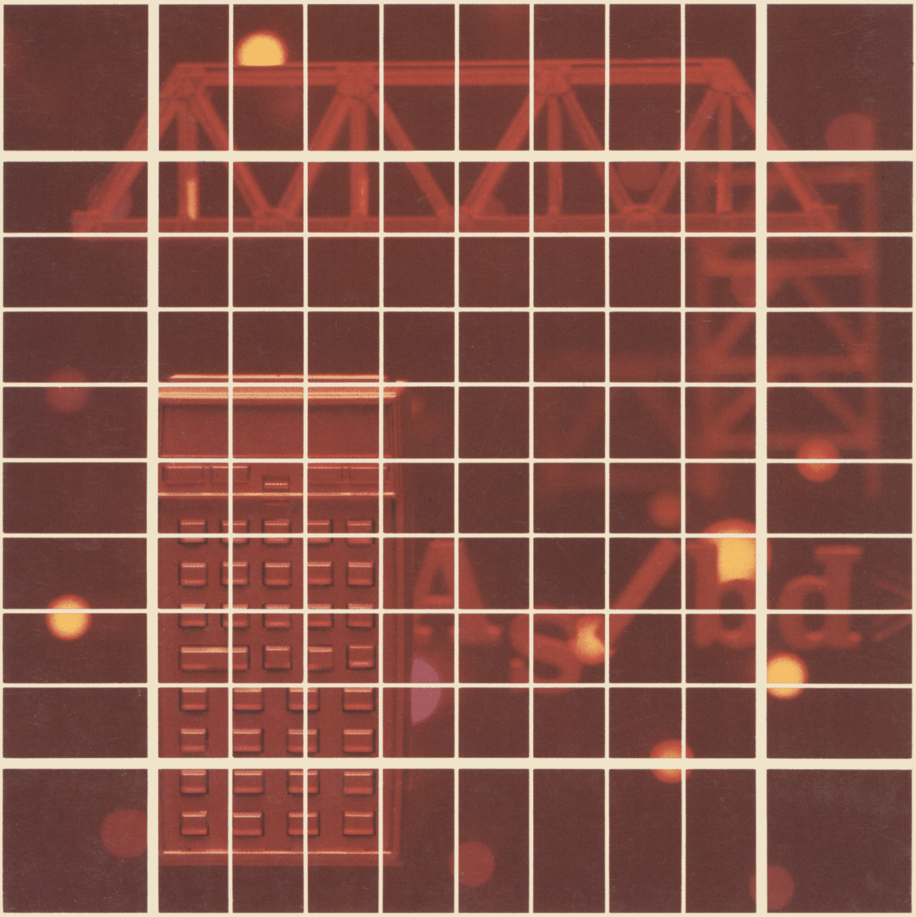
HEWLETT-PACKARD

HP-41C

STRUCTURAL ANALYSIS PAC



NOTICE

HEWLETT PACKARD

HEWLETT-PACKARD LISTENS

To provide better calculator support for you, the Application Engineering group needs your help. Your timely inputs enable us to provide higher quality software and improve the existing application pacs for your calculator. Your reply will be extremely helpful in this effort.

1. Pac name ____________________

2. How important was the availability of this pac in making your decision to buy a Hewlett-Packard calculator?

   ☐ Would not buy without it. ☐ Important ☐ Not important

3. What is the major application area for which you purchased the pac?

____

4. In the list below, please rate the usefulness of the programs in this pac.

PROGRAM NUMBER	ESSENTIAL	IMPORTANT BUT NOT REQUIRED	INFREQUENTLY USED	NEVER USED
1				
2				
3				
4				
5				
6				
7				
8				

PROGRAM NUMBER	ESSENTIAL	IMPORTANT BUT NOT REQUIRED	INFREQUENTLY USED	NEVER USED
9				
10				
11				
12				
13				
14				
15				
16				

5. Did you purchase a printer? ☐ YES ☐ NO

   If you did, is the printing format in this pac useful? ☐ YES ☐ NO

6. What programs would you add to this pac?

____

7. What additional application pacs would you like to see developed?

____

THANK YOU FOR YOUR TIME AND COOPERATION.

Name ____________________ Position ____________________

Company ____________________

Address ____________________

City ____________________ State ____________________

Zip ____________________ Phone ____________________

Please fold and staple for mailing.

Additional Comments:

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO. 33 CORVALLIS, OREGON

Postage will be paid by

Hewlett-Packard
1000 N.E. Circle Blvd.
Corvallis, Oregon 97330

INTRODUCTION

This pac contains programs tailored for structural engineers.

Two programs deal with beam analysis. The first computes deflection, slope, moment and shear at any point for simply supported, fixed, propped and cantilevered beams. Applied moments, distributed loads, point loads, and trapezoidally distributed loads may be applied in virtually any combination. If your HP-41C system includes an optional HP 82143A printer, plots of deflection, slope, moment, and shear are easily generated.

The second beam analysis program provides solutions for multispan-continuous beams. Over 50 spans, under virtually any loading, can be accommodated with three optional memory modules.

Other programs concern steel columns, reinforced concrete, concrete columns, section properties, and continuous frame analysis.

Each program in this pac is represented by one program in the Application Module and a section in this manual.

The manual provides a description of each program, a set of instructions for using each program, and one or more example problems, each of which includes a list of the keystrokes required for its solution.

Before plugging in your Application Module, **turn your calculator off,** and be sure you understand the section *Inserting and Removing Application Modules*. Before using a particular program, take a few minutes to read *Format of User Instructions* and *A Word About Program Usage*.

You should first familiarize yourself with a program by running it once or twice while following the complete User Instructions in the manual. Thereafter, the program's prompting or the mnemonics on the overlays should provide the necessary instructions, including which variables are to be input, which keys are to be pressed, and which values will be output.

We hope this pac will assist you in the solution of numerous problems in your discipline. We would appreciate knowing your reactions to the programs, and to this end we have provided a questionnaire inside the front cover of this manual. Would you please take a few minutes to give us your comments on these programs? It is from your comments that we learn how to increase the usefulness of our programs.

CONTENTS

INSERTING AND REMOVING APPLICATION MODULES

Before you insert an Application Module for the first time, familiarize yourself with the following information.

Up to four Application Modules can be plugged into the ports on the HP-41C. While plugged in, the names of all programs contained in the Module can be displayed by pressing ■ CATALOG 2.

CAUTION

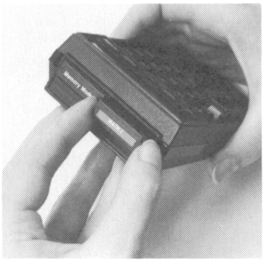
> Always turn the HP-41C off before inserting or removing any plug-in extension or accessories. Failure to turn the HP-41C off could damage both the calculator and the accessory.

To insert Application Modules:

1. Turn the HP-41C off! Failure to turn the calculator off could damage both the Module and the calculator.

2. Remove the port covers. Remember to save the port covers; they should be inserted into the empty ports when no extensions are inserted.

3. Insert the Application Module with the label facing downward as shown, into any port **after** the last Memory Module. For example, if you have a Memory Module inserted in port 1, you can insert an Application Module in any of ports 2, 3, or 4. (The port numbers are shown on the back of the calculator.) **Never insert an Application Module into a lower numbered port than a Memory Module.**



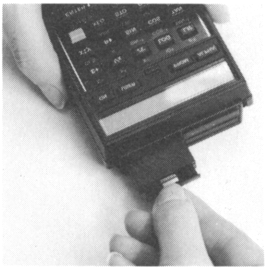
4. If you have additional Application Modules to insert, plug them into any port after the last Memory Module. Be sure to place port covers over unused ports.

5. Turn the calculator on and follow the instructions given in this book for the desired application functions.

To remove Application Modules:

1. Turn the HP-41C off! Failure to do so could damage both the calculator and the Module.

2. Grasp the desired Module handle and pull it out as shown.



3. Place a port cap into the empty ports.

Mixing Memory Modules and Application Modules

Any optional accessories (such as the HP-82104A Card Reader, or the HP-82143A Printer) should be treated in the same manner as Application Modules. That is, they can be plugged into any port after the last Memory Module. Also, the HP-41C should be turned off prior to insertion or removal of these extensions.

The HP-41C allows you to leave gaps in the port sequence when mixing Memory and Application Modules. For example, you can plug a Memory Module into port 1 and an Application Module into port 4, leaving ports 2 and 3 empty.

FORMAT OF USER INSTRUCTIONS

The completed User Instruction Form—which accompanies each program—is your guide to operating the programs in this Pac.

The form is composed of five labeled columns. Reading from left to right, the first column, labeled STEP, gives the instruction step number.

The INSTRUCTIONS column gives instructions and comments concerning the operations to be performed.

The INPUT column specifies the input data, the units of data if applicable, or the appropriate alpha response to a prompted question. Data input keys consist of 0 to 9 and the decimal point (the numeric keys), [EEX] (enter exponent), and [CHS] (change sign).

The FUNCTION column specifies the keys to be pressed after keying in the corresponding input data.

The DISPLAY column specifies prompts, intermediate and final answers, and their units, where applicable.

Above the DISPLAY column is a box which specifies the minimum number of data storage registers necessary to execute the program. Refer to the Owner's Handbook for information on how the SIZE function affects storage configuration.

A WORD ABOUT PROGRAM USAGE

Catalog

When an Application Module is plugged into a port of the HP-41C, the contents of the Module can be reviewed by pressing [shift] [CATALOG] 2 (the Extension Catalog). Executing the [CATALOG] function lists the name of each program or function in the Module, as well as functions of any other extensions which might be plugged in.

Overlays

Overlays have been included for some of the programs in this Pac. To run the program, choose the appropriate overlay, and place it on the calculator. The mnemonics on the overlay are provided to help you run the program. The program's name is given vertically on the left side. When the calculator is in USER mode, a blue mnemonic identifies the key directly above it. Gold mnemonics are similar to blue mnemonics, except that they are above the appropriate key and the shift (gold) key must be pressed before the re-defined key. Once again, USER mode must be set.

ALPHA and USER Mode Notation

This manual uses a special notation to signify ALPHA mode. Whenever a statement on the User Instruction Form is printed in gold, the [ALPHA] key must be pressed before the statement can be keyed in. After the statement is input, press [ALPHA] again to return the calculator to its normal operating mode, or to begin program execution. For example, [XEQ] SECTION means press the following keys: [XEQ] [ALPHA] SECTION [ALPHA] .

When the calculator is in USER mode, this manual will use the symbols [A] – [J] and [shift] [A] – [shift] [E] to refer to the reassigned keys in the top two rows. These key designations will appear on the User Instruction Form and in the keystroke solutions to sample problems.

Optional HP-82143A Printer

When the optional printer is plugged into the HP-41C along with this Application Module, results will be printed automatically. You may also want to keep a permanent record of the values input to a certain program. A convenient way to do this is to set the Print Mode switch to NORMAL before running the program. In this mode, all input values and the corresponding keystrokes will be listed on the printer, thus providing a record of the entire operation of the program.

Downloading Module Programs

If you wish to trace execution, to modify, to record on magnetic cards, or to print a program in this Application Module, it must first be copied into the HP-41C's program memory. For information concerning the HP-41C's COPY function, see the Owner's Handbook. It is not necessary to copy a program in order to run it.

Program Interruption

These programs have been designed to operate properly when run from beginning to end, without turning the calculator off (remember, the calculator may turn itself off). If the HP-41C is turned off, it may be necessary to set flag 21 (SF 21) to continue proper execution.

Use of Labels

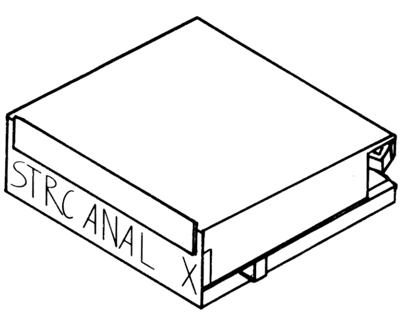
You should generally avoid writing programs into the calculator memory that use program labels identical to those in your Application Module. In case of a label conflict, the label within program memory has priority over the label within the Application Pac program.

Assigning Program Names

Key assignments to keys [A] – [J] and ■[A] – ■[E] take priority over the automatic assignments of local labels in the Application Module. Be sure to clear previously assigned functions before executing a Module program.

Incompatible Application Module

This Pac contains a type X Application Module. Type X Modules have incompatible XROM instructions. You should never plug two type X Application Modules into your HP-41C at the same time. Type X Modules may be identified by an "X" on the Application Module label.



SECTION PROPERTIES

The properties of polygonal sections (see figure 1) may be calculated using this program. The (x, y) coordinates of the vertices of the polygon (which must be located entirely within the first quadrant) are input sequentially for a complete, clockwise path around the polygon. Holes in the cross section, which do not intersect the boundary, may be deleted by following a counter-clockwise path.

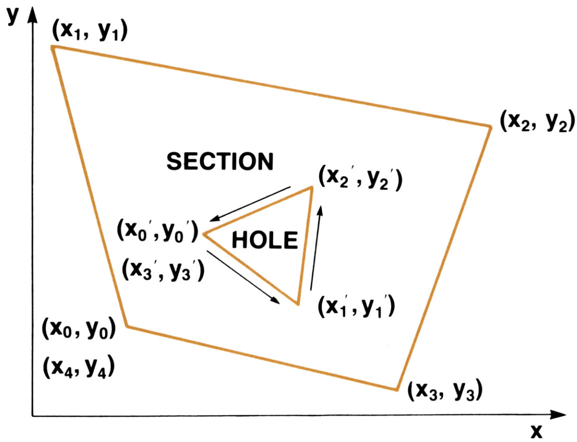


Figure 1

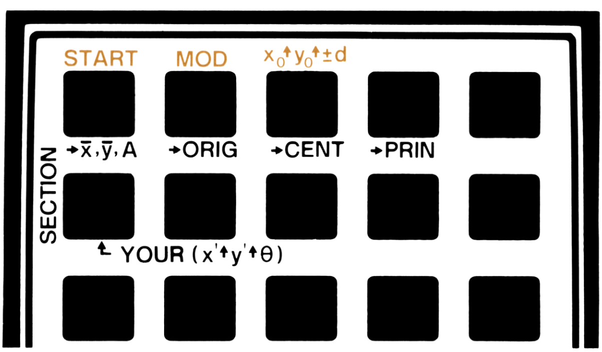


Figure 2

The keyboard overlay (see figure 2) defines the keys according to their function in SECTION. The shifted **A** key can be used to clear an existing section and restart a new input sequence. The shifted **B** key restarts the input sequence but does not clear the existing section. Its' use allows deletion, addition, and correction of existing sections.

A special feature on the shifted **C** key allows addition or deletion of circular areas. After the point by point traverse of the section has been completed, circular deletions or additions are specified by the (x, y) coordinates of the circle centers and by the circle diameters. If the diameter is specified as a positive number, the circular areas are added. A negative diameter causes circular areas to be deleted. Example 4 shows an application of this feature.

After all values have been input, the coordinates of the centroid ($\bar{x}$, $\bar{y}$) and the area A of the section may be output using key **A**. The moment of inertia about the original x axis I_x, about the original y axis I_y and the product of inertia I_{xy} are output using **B**. Similar moments, $I_{\bar{x}}$, $I_{\bar{y}}$, and $I_{\overline{xy}}$, about an axis translated to the centroid of the section are calculated when **C** is pressed.

Pressing **D** calculates the moments of inertia, $I_{\bar{x}\measuredangle}$ and $I_{\bar{y}\measuredangle}$, about the principal axis. The rotation angle $\measuredangle$ between the principal axis and the axis which was translated to the centroid is also calculated. The moments of inertia I_x', I_y', the polar moment of inertia J and the product of inertia I_{xy}' may be calculated about any arbitrary axis by specifying its location and rotation with respect to the original axis and pressing **F**.

Equations:

$$A = -\sum_{i=0}^{n} (y_{i+1} - y_i)(x_{i+1} + x_i)/2$$

$$\bar{x} = \frac{-1}{A}\sum_{i=0}^{n} \left[(y_{i+1} - y_i)/8\right]\left[(x_{i+1} + x_i)^2 + (x_{i+1} - x_i)^2/3\right]$$

$$\bar{y} = \frac{1}{A}\sum_{i=0}^{n} \left[(x_{i+1} - x_i)/8\right]\left[(y_{i+1} + y_i)^2 + (y_{i+1} - y_i)^2/3\right]$$

$$I_x = \sum_{i=0}^{n} \left[(x_{i+1} - x_i)(y_{i+1} + y_i)/24\right]\left[(y_{i+1} + y_i)^2 + (y_{i+1} - y_i)^2\right]$$

$$I_y = -\sum_{i=0}^{n} \left[(y_{i+1} - y_i)(x_{i+1} + x_i)/24\right]\left[(x_{i+1} + x_i)^2 + (x_{i+1} - x_i)^2\right]$$

$$I_{xy} = \sum_{i=0}^{n} \frac{1}{(x_{i+1} - x_i)}\Bigg[\frac{1}{8}(y_{i+1} - y_i)^2(x_{i+1} + x_i)(x_{i+1}^2 + x_i^2)$$

$$+ \frac{1}{3}(y_{i+1} - y_i)(x_{i+1}y_i - x_i y_{i+1})(x_{i+1}^2 + x_{i+1}x_i + x_i^2)$$

$$+ \frac{1}{4}(x_{i+1}y_i - x_i y_{i+1})^2(x_{i+1} + x_i)\Bigg]$$

$$I_{\bar{x}} = I_x - A\bar{y}^2$$

$$I_{\bar{y}} = I_y - A\bar{x}^2$$

$$I_{\bar{x}\bar{y}} = I_{xy} - A\bar{x}\bar{y}$$

$$\measuredangle = \frac{1}{2}\tan^{-1}\left(\frac{-2I_{\bar{x}\bar{y}}}{I_{\bar{x}} - I_{\bar{y}}}\right)$$

$$I_x{}' = I_{\bar{x}}\cos^2\theta + I_{\bar{y}}\sin^2\theta - I_{\bar{x}\bar{y}}\sin 2\theta$$

$$I_y{}' = I_{\bar{y}}\cos^2\theta + I_{\bar{x}}\sin^2\theta + I_{\bar{x}\bar{y}}\sin 2\theta$$

$$J = I_x{}' + I_y{}'$$

$$I_{xy}{}' = \frac{(I_{\bar{x}} - I_{\bar{y}})}{2}\sin 2\theta + I_{\bar{x}\bar{y}}\cos 2\theta$$

$$A_{circle} = \frac{\pi d^2}{4}$$

$$I_{circle} = \frac{\pi d^4}{64}$$

where:

x_{i+1} is the x coordinate of the current vertex point;

y_{i+1} is the y coordinate of the current vertex point;

x_i is the x coordinate of the previous vertex point;

y_i is the y coordinate of the previous vertex point;

A is the area;

$\bar{x}$ is the x coordinate of the centroid;

$\bar{y}$ is the y coordinate of the centroid;

I_x is the moment of inertia about the x-axis;

I_y is the moment of inertia about the y-axis;

I_{xy} is the product of inertia;

$I_{\bar{x}}$ is the moment of inertia about the x-axis translated to the centroid;

$I_{\bar{y}}$ is the moment of inertia about the y-axis translated to the centroid;

$I_{\bar{x}\bar{y}}$ is the product of inertia about the translated axis;

$\measuredangle$ is the angle between the translated axis and the principal axis;

$I_{\bar{x}\measuredangle}$ is the moment of inertia about the translated, rotated, principal x-axis;

$I_{\bar{y}\measuredangle}$ is the moment of inertia of inertia about the translated, rotated, principal y-axis;

θ is the angle between the original axis and an arbitrary axis;

I_x' is the x moment of inertia about the arbitrary axis;

I_y' is the y moment of inertia about the arbitrary axis;

J is the polar moment of inertia about the arbitrary axis;

I_{xy}' is the product of inertia about the arbitrary axis;

d is the diameter of a circular area.

Reference:

Wojiechowski, Felix, "Properties of Plane Cross Sections," *Machine Design*, p. 105, Jan. 22, 1976.

Remarks:

The polygon must be entirely contained in the first quadrant.

Rounding errors will accumulate if the centroid of the section is a large distance from the origin of the coordinate system.

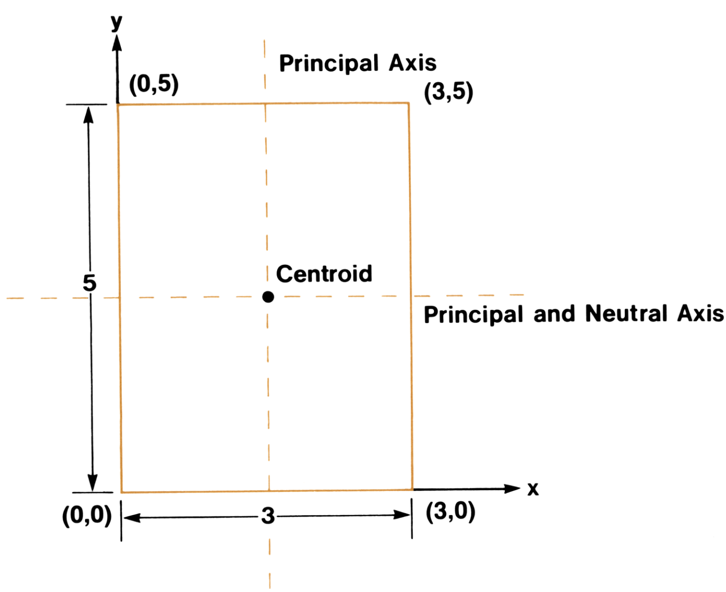
Curved boundaries may be approximated by straight line segments.

				SIZE: 017
STEP	**INSTRUCTIONS**	**INPUT**	**FUNCTION**	**DISPLAY**
1	Initialize program.		[XEQ] SECTION	X0=?
2	Key in x value at initial vertex.	x	[R/S]	Y0=?
3	Key in y value at initial vertex.	y	[R/S]	X1=?
4	Key in (x, y) coordinates of next	x	[R/S]	YN=?
	clockwise vertex.	y	[R/S]	XN=?
5	Repeat Step 4 for each point of the polygon including the initial point.			
6	To delete subsections within the section, press ■ [B] and go to Step 2, but traverse in a counter-clockwise direction.		■ [B]	X0=?
7	To add subsections to the section, press ■ [B] and go to Step 2.		■ [B]	X0=?
8	Add any circular areas	x	[ENTER↑]	
		y	[ENTER↑]	
		d	■ [C]	0.000 00
	or delete any circular areas.	x	[ENTER↑]	
		y	[ENTER↑]	
		d	[CHS] ■ [C]	0.000 00

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
9	Calculate any or all of the following*:			
	Centroid and area;		[A]*	CENTROID
	Properties about original axis;		[B]*	ORIGINAL AXIS
	Properties about an axis translated to centroid;		[C]*	CENTROID AXIS
	Properties about principal axis and angular orientation of principal axis;		[D]*	PRINCIPAL AXIS
	OR			
	Specify an arbitrary axis and rotation angle and calculate properties about that axis.	x′	[ENTER↑]	
		y′	[ENTER↑]	
		θ	[F]*	YOUR AXIS
10	For a new problem, press ■ [A] and go to Step 2. To modify the current section, go to Step 6 or Step 7.		■ [A]	X0=?
	* If your HP-41C does not have a printer, you must press [R/S] for output of each section property.			

Example 1:

What is the moment of inertia about the x-axis (I_x) for the rectangular section shown? What is the amount of inertia about the neutral axis through the centroid of the section ($I_{\bar{x}\Delta}$)?



Keystrokes: (SIZE 017)	**Display:**
[XEQ] [ALPHA] SECTION [ALPHA]	X0=?
0 [R/S]	Y0=?
0 [R/S]	X1=?
0 [R/S]	Y1=?
5 [R/S]	X2=?
3 [R/S]	Y2=?
5 [R/S]	X3=?
3 [R/S]	Y3=?
0 [R/S]	X4=?
0 [R/S]	Y4=?
0 [R/S]	X5=?
[B]	ORIGINAL AXIS
[R/S] *	IX=125.0E0
[R/S] *	IY=45.00E0
[R/S] *	IXY=56.25E0
[D]	PRINCIPAL AXIS
[R/S] *	IX=31.25
[R/S] *	IY=11.25E0
[R/S] *	IXY=0.000E0
[R/S] *	∡ =0.000E0

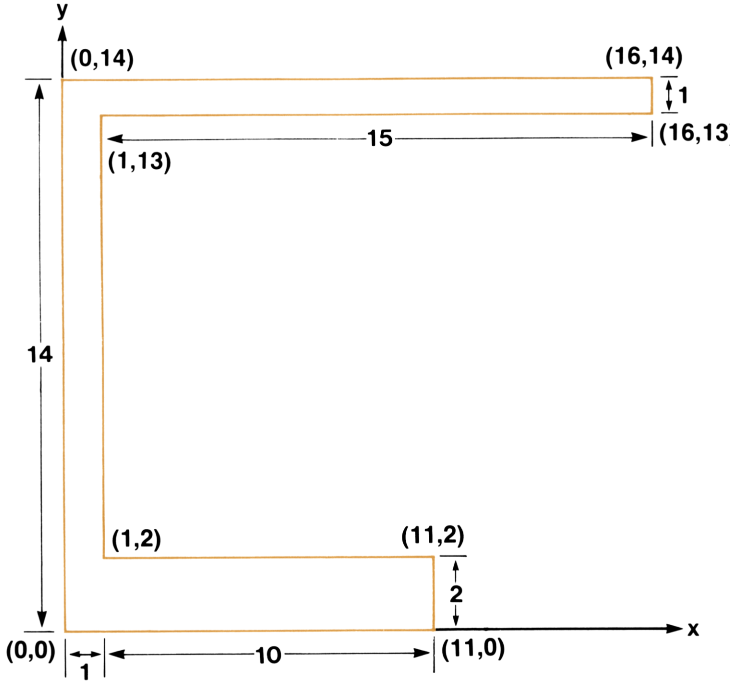
Since ∡ = 0 we would expect $I_{\bar{x}∡}$ to equal $I_{\bar{x}}$. Press [C] to calculate $I_{\bar{x}}$, $I_{\bar{y}}$, and $I_{\overline{xy}}$ and you will see that this prediction is correct. Also, $I_{\overline{xy}}$ is zero about the principal axis.

Keystrokes:	**Display:**
[C]	CENTROID AXIS
[R/S] *	IX=31.25E0
[R/S] *	IY=11.25E0
[R/S] *	IXY=0.000E0

* Press [R/S] if you are not using a printer.

Example 2:

Calculate the section properties for the beam shown below.

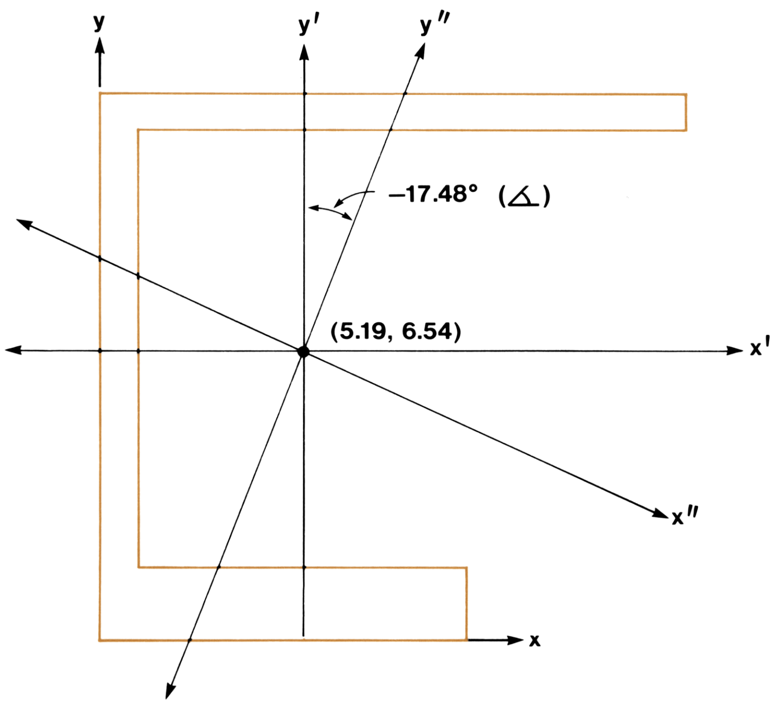


Keystrokes: (SIZE 017)	**Display:**
XEQ ALPHA SECTION ALPHA	*X0=?*
0 R/S 0 R/S 0 R/S 14 R/S	
16 R/S 14 R/S 16 R/S 13 R/S	
1 R/S 13 R/S 1 R/S 2 R/S	
11 R/S 2 R/S 11 R/S 0 R/S	
0 R/S 0 R/S	*X9=?*
A	CENTROID
R/S *	X=5.194E0
R/S *	Y=6.541E0
R/S *	AREA=49.00E0
B	ORIGINAL AXIS
R/S *	IX=3.676E3
R/S *	IY=2.256E3
R/S *	IXY=1.890E3

* Press R/S if you are not using a printer.

Keystrokes:	Display:
[C]	CENTROID AXIS
[R/S] *	IX=1.580E3
[R/S] *	IY=934.5E0
[R/S] *	IXY=225.6E0
[D]	PRINCIPAL AXIS
[R/S] *	IX=1.651E3
[R/S] *	IY=863.5E0
[R/S] *	IXY=0.000E0
[R/S] *	∠=-17.48E0

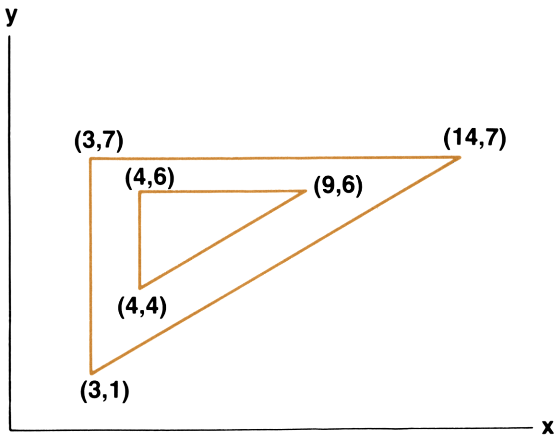
Below is a figure showing the translated axis and the rotated, principal axis of example 2. Notice that the sign of the angle is negative, representing a clockwise rotation.



* Press [R/S] if you are not using a printer.

Example 3:

What is the centroid of the section below? The inner triangular boundary denotes an area to be deleted.

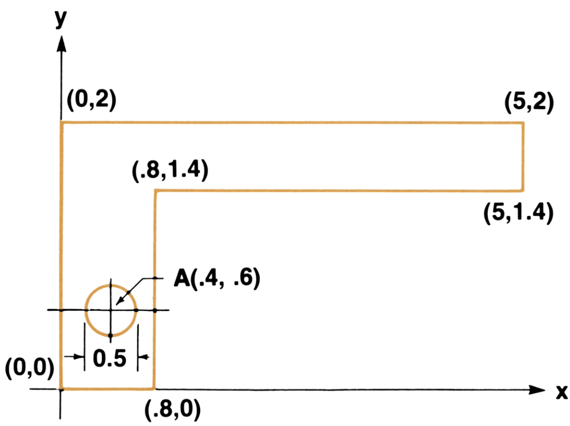


Keystrokes: (SIZE 017)	**Display:**
Input for the outer triangle:	
[XEQ] [ALPHA] SECTION [ALPHA]	*X0?=*
3 [R/S] 1 [R/S] 3 [R/S] 7 [R/S]	
14 [R/S] 7 [R/S] 3 [R/S] 1 [R/S]	*X4?=*
Delete inner triangle:	
[■] [B]	*X0?=*
4 [R/S] 4 [R/S] 9 [R/S] 6 [R/S]	
4 [R/S] 6 [R/S] 4 [R/S] 4 [R/S]	*X4=?*
[A]	*CENTROID*
[R/S] *	*X=6.845E0*
[R/S] *	*Y=4.940E0*
[R/S] *	*AREA=28.00E0*

* Press [R/S] if you are not using a printer.

Example 4:

For the part below, compute the polar moment of inertia about point A. Point A denotes the center of a hole about which the part rotates. The area of the hole must be deleted from the cross section.



Keystrokes: (SIZE 017)	**Display:**
XEQ ALPHA SECTION ALPHA	*X0=?*
0 R/S 0 R/S 0 R/S 2 R/S	
5 R/S 2 R/S 5 R/S 1.4 R/S	
.8 R/S 1.4 R/S .8 R/S 0 R/S	
0 R/S 0 R/S	*X7=?*
Delete hole:	
.4 ENTER↑ .6 ENTER↑ .5 CHS	
C	*0.000 00*
Compute J about (0.4, 0.6) with θ of zero.	
.4 ENTER↑ .6 ENTER↑ 0 F	*YOUR AXIS*
R/S *	*IX=3.911E0*
R/S *	*IY=19.54E0*
R/S *	*IXY=6.930E0*
R/S *	*J=23.45E0*

* Press R/S if you are not using a printer.

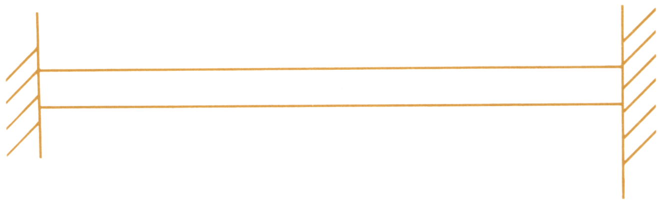
BEAMS

This program calculates deflection, slope, moment and shear at any point for:

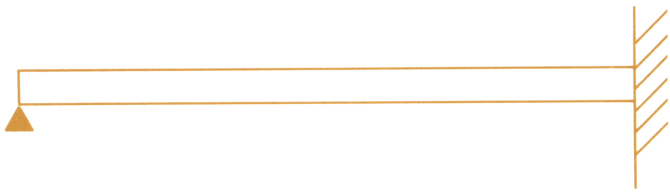
simple beams;

cantilever beams;

fixed beams;



and propped cantilever beams.



Beam loading may include combinations of point loads, distributed loads, applied moments and trapezoidally distributed loads. Any number or combination of loads may be used assuming sufficient data storage registers are available. Minimum size must be set according to the formula below:

$$
\begin{aligned}
SIZE_{min} = 20 &+ 2 * \text{Number of distributed loads} \\
&+ 3 * \text{Number of point loads} \\
&+ 3 * \text{Number of applied moments} \\
&+ 5 * \text{Number of trapezoidal loads}
\end{aligned}
$$

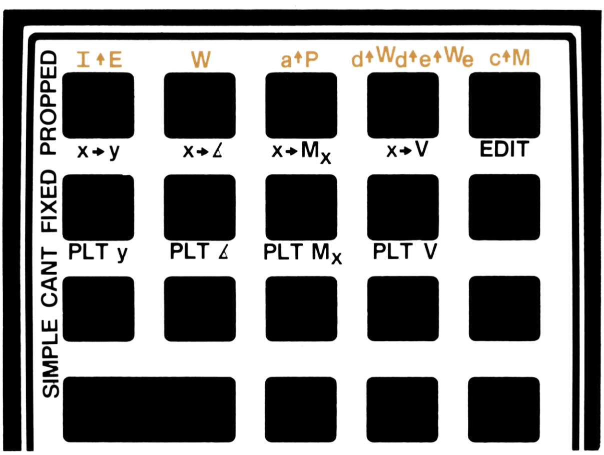
A size setting of 40 is adequate for most loadings.
If the size is set larger than 23 but smaller than necessary for program execution the message:

SIZE > NNN

will be displayed. This message tells you that your last input was ignored and you must increase register size to at least ***NNN*** to continue program execution.

If you have an optional HP-82143A thermal printer this program will list and plot values of deflection, angle, moment or shear for evenly spaced points along the beam.

The program can be divided into four operating functions: input, editing, calculation, and printing/plotting. The input section is initialized by executing SIMPLE, CANT, FIXED, or PROPPED. This selects the type of beam to be analyzed and prompts for the length of the beam. Key in the length and press [R/S]. The display will prompt ***RDY A-I***. This indicates that the keys are defined according to the overlay below:



The shifted top row keys allow input of the beam variables. The unshifted top row keys [A] – [D] allow computation of deflection, slope, moment or shear for a given x. Key [E] provides an editing option. The editing option allows you to review all inputs and change input errors. The second row of keys provides printout of beam properties and plotting of beam deflection, slope, moment or shear with the optional HP-82143A printer.

Equations:

For equations, refer to cited reference.

Definitions:

I is the moment of inertia of the section;

E is the modulus of elasticity of the material;

L is the length of the beam;

a is the displacement of the concentrated load from the left end of the beam;

P is the amount of the concentrated load;

c is the displacement of the applied moment from the left end of the beam;

M is the amount of the applied moment;

W is the amount of a uniformly distributed load over the entire beam with dimensions force per unit length;

d is the distance to the beginning of a trapezoidal load;

W_d is the initial value of a trapezoidal load with units of force per unit length;

e is the distance to the end of a trapezoidal load;

W_e is the final value of a trapezoidal load;

x is the point of interest along the beam;

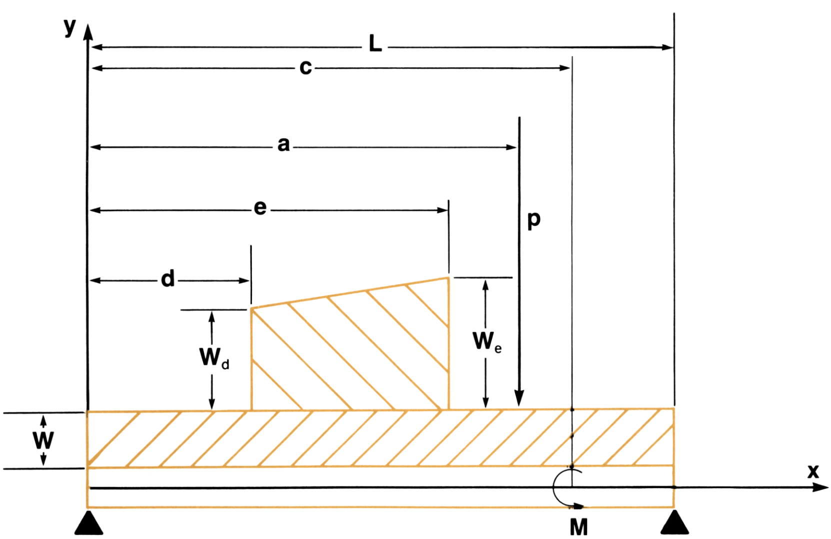
y is the deflection at x;

∆ is the slope (change in y per change in x) at x;

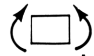
M_x is the internal bending moment at x;

V is the shear at x.

A simply supported beam with one of each type of load is shown below:



SIGN CONVENTIONS FOR BEAMS

NAME	VARIABLE	SENSE	SIGN
DEFLECTION	y	↑	+
SLOPE	Δ	↑	+
INTERNAL MOMENT	M_x		+
SHEAR	V		+
EXTERNAL FORCE OR LOAD	P or W	↓	+
EXTERNAL MOMENT	M		+

Remarks:

Deflections must not significantly alter the geometry of the problem.

Beams must be of constant cross section for deflection and slope equations to be valid.

Stresses must be in the elastic region.

Programs are not unit dependent. Any mutually consistent set of units will work.

Reference:

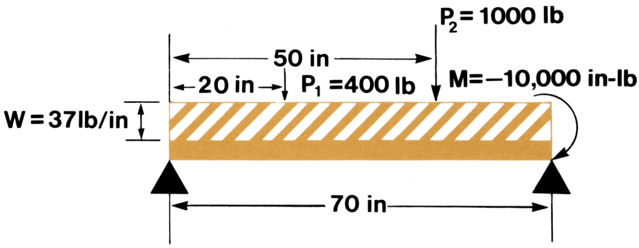
Roark, Raymond J., Young, Warren C., *Formulas for Stress and Strain*, McGraw-Hill Book Company, 1975.

				SIZE: 040
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Select type of beam.		[XEQ] SIMPLE	L=?
	Or		[XEQ] CANT	L=?
	Or		[XEQ] FIXED	L=?
	Or		[XEQ] PROPPED	L=?
2	Key in length.	L	[R/S]	RDY A-I
3	If you wish to calculate deflection or slope, key in moment of inertia	I	[ENTER↑]	I
	and modulus of elasticity, otherwise go to Step 4.	E	[■] [A]	E*I
4	Key in all loadings:			
	Distributed load.	W	[■] [B]	0.000 00
	Point load location	a	[ENTER↑]	a
	and load.	P	[■] [C]	0.000 00

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
	Trapezoidal load starting point,	d	[ENTER↑]	d
	starting load,	W_d	[ENTER↑]	W_d
	end point,	e	[ENTER↑]	e
	and ending load.	W_e	[■] [D]	0.000 00
	Applied moment location	c	[ENTER↑]	c
	and applied moment.	M	[■] [E]	
5	OPTIONAL: Review and/or edit		[E]	BEAM TYPE
	your inputs (e.g. if you wish to modify L, key in a new L and press [R/S],		[R/S]	L=
	otherwise just press [R/S]).	(L)	[R/S]	E*I=
		(E*I)	[R/S]	LOAD
			⋮	⋮
	An "END" signifies that all data has been displayed. Pressing [R/S] again will start the edit routine over.		[R/S]	END
6	If you have an optional HP-82143A printer and wish to plot, go to Step 9.			
7	Key in x to specify the point of			
	interest and calculate deflection	x	[A]	y=
	or slope	x	[B]	⊿=
	or moment	x	[C]	MX=
	or shear.	x	[D]	V=
8	For a new calculation with the same loading, go to Step 6. For new loads, go to Steps 4 or 5. For new section properties, go to Step 3 but skip Step 4 if no loads change.			
9	Plot deflection		[F]	
	or slope		[G]	
	or moment		[H]	
	or shear.		[I]	
				BEAM TYPE
				L=
				E*I=
				LOADS
				X INC=?
	Key in x increment.	XINC	[R/S]	LIST/PLOT
10	Go to Step 8.			

Example 1:

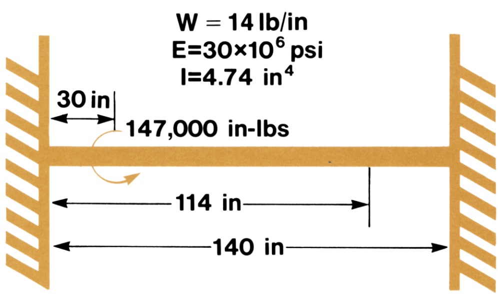
What is the total moment at the center of the beam below? (It is not necessary to know the values of E or I to solve this problem.)



Keystrokes: (SIZE >= 31)	**Display:**
■ [ENG] 3	
[XEQ] [ALPHA] SIMPLE [ALPHA]	*L=?*
70 [R/S]	*RDY A-I*
20 [ENTER↑] 400 ■ [C]	*0.000 00*
50 [ENTER↑] 1000 ■ [C]	*0.000 00*
37 ■ [B]	*0.000 00*
70 [ENTER↑] 10000 [CHS] ■ [E]	*0.000 00*
35 [C]	*MX=31.66E3*

Example 2:

For the beam below, what are the values of deflection, slope, moment, and shear at an x of 114 inches?



Keystrokes: (SIZE >= 25)	**Display:**
[ ] [ENG] 3	
[XEQ] [ALPHA] FIXED [ALPHA]	L=?
140 [R/S]	RDY A-I
4.74 [ENTER↑] 30 [EEX] 6 [ ] [A]	
14 [ ] [B] 30 [ENTER↑]	
147000 [ ] [E]	
114 [A]	y=43.72E-3
114 [B]	Δ=-3.155E-3
114 [C]	MX=13.05E3
114 [D]	V=444.7E0

Using the edit feature, change the location of the applied moment to 50.

[E]	FIXED
[R/S]	L=140.0E0
[R/S]	E*I=142.2E6
[R/S]	W = 14.00 EO
[R/S]	c = 30.00 EO
50 [R/S]	M=147.0E3

Now calculate the bending moment at x = 70.

70 [C]	MX=-41.07E3

Example 3:

Repeat Example 1, but plot bending moment in increments of 2.5 inches along the length of the beam. An optional HP-82143A thermal printer is required for this problem.

Keystrokes: (SIZE >= 31)	**Display:**
[ ] [ENG] 3	
[XEQ] [ALPHA] SIMPLE [ALPHA]	L=?
70 [R/S]	RDY A-I
20 [ENTER↑] 400 [ ] [C] 50 [ENTER↑]	
1000 [ ] [C] 37 [ ] [B] 70 [ENTER↑]	
10000 [CHS] [ ] [E]	0.000 00

Keystrokes:	Display:
[H]	SIMPLE
	L=70.00E0
	E*I=0.000E0 *
	a=20.00E0
	P=400.0E0
	a=50.00E0
	P=1.000E3
	W=37.00E0
	c=70.00E0
	M=-10.00E3
	END
	XINC?
2.5 [R/S]	X=0.000E0
	MX=0.000E0
	X=2.500E0
	MX=4.193E3
	X=5.000E0
	MX=8.155E3
	X=7.500E0
	MX=11.89E3
	X=10.00E0
	MX=15.39E3

* May take any value in this problem.

Keystrokes:

Display:

```
X=12.50E0
MX=18.65E3

X=15.00E0
MX=21.69E3

X=17.50E0
MX=24.50E3

X=20.00E0
MX=27.07E3

X=22.50E0
MX=28.41E3

X=25.00E0
MX=29.53E3

X=27.50E0
MX=30.41E3

X=30.00E0
MX=31.06E3

X=32.50E0
MX=31.48E3

X=35.00E0
MX=31.66E3

X=37.50E0
MX=31.62E3

X=40.00E0
MX=31.34E3
```

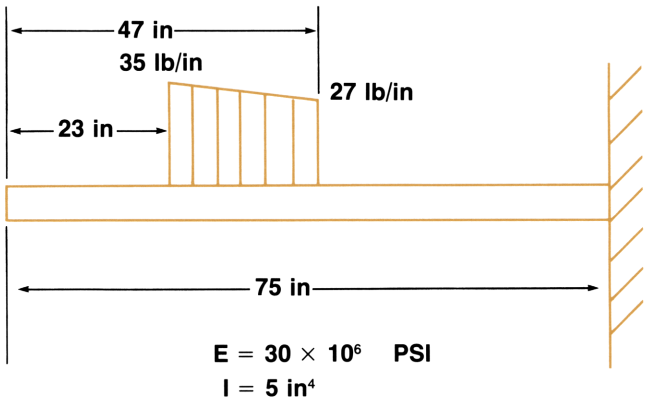
Keystrokes:	**Display:**
	X=42.50E0
	MX=30.84E3
	X=45.00E0
	MX=30.10E3
	X=47.50E0
	MX=29.13E3
	X=50.00E0
	MX=27.93E3
	X=52.50E0
	MX=24.00E3
	X=55.00E0
	MX=19.83E3
	X=57.50E0
	MX=15.44E3
	X=60.00E0
	MX=10.81E3
	X=62.50E0
	MX=5.958E3
	X=65.00E0
	MX=869.6E0
	X=67.50E0
	MX=-4.450E3
	X=70.00E0
	MX=0.000E0

Keystrokes: **Display:**

```
    PLOT OF BEAM
  X (UNITS= 1.) ↓
  Y (UNITS= E 4.) →
   -0.44          3.17
    0.00
   |--|-------------|
 0.0   x
 2.5  ¦ x
 5.0  ¦   x
 7.5  ¦     x
10.0  ¦       x
12.5  ¦        x
15.0  ¦          x
17.5  ¦           x
20.0  ¦            x
22.5  ¦             x
25.0  ¦             x
27.5  ¦              x
30.0  ¦              x
32.5  ¦              x
35.0  ¦              x
37.5  ¦              x
40.0  ¦              x
42.5  ¦              x
45.0  ¦              x
47.5  ¦             x
50.0  ¦             x
52.5  ¦           x
55.0  ¦         x
57.5  ¦       x
60.0  ¦     x
62.5  ¦  x
65.0   x
67.5 x ¦
70.0   x
```

Note that the value of moment at X = 70.00 does not equal the applied moment of −10,000. This is due to the fact that internal moment is undefined at the point of application of an applied moment. Similarly, shear is undefined directly under a point load.

Example 4:

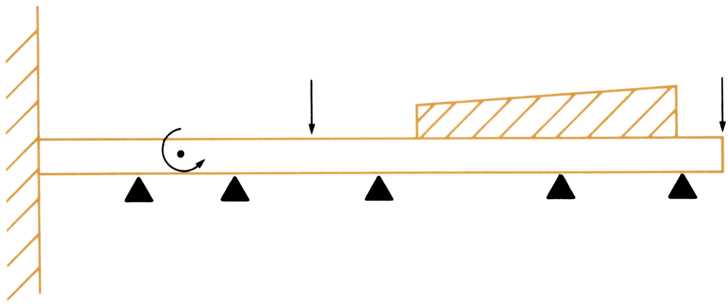


Calculate deflection, slope, moment and shear for the beam above at the point x = 40.

Keystrokes: (SIZE >= 25)	**Display:**
[■] [ENG] 3	
[XEQ] [ALPHA] CANT [ALPHA]	*L=?*
75 [R/S]	*RDY A-I*
23 [ENTER↑] 35 [ENTER↑] 47 [ENTER↑]	
27 [■] [D]	*0.000 00*
5 [ENTER↑] 30 [EEX] 6 [■] [A]	*150.0 06*
40 [A]	*y=-87.66E-3*
40 [B]	*∠=4.006E-3*
40 [C]	*MX=-4.785E3*
40 [D]	*V=-546.8E0*

SIMPLY SUPPORTED CONTINUOUS BEAMS

This program, in combination with the beam program SIMPLE, solves for the intermediate couples present at the supports of a continuous beam.



Each span of the beam may have a unique length, cross section, modulus of elasticity and/or loading. Beam ends may be rigidly fixed or simply supported.

The program SIMPLE is used to input the length, section moment of inertia, and loading for each span of the continuous beam. After the data for a particular span has been keyed in using SIMPLE, program SPAN is executed to transform the data. MOMENTS, which is called after all spans have been entered, computes the internal bending moments at each intermediate support.

If the left end of the continuous beam is rigidly fixed, execute FIXL instead of SIMPLE. After some computation time the prompt ***L=?*** will be displayed indicating that the calculator is ready for the first span.

If the right end of the continuous beam is rigidly fixed, key in the span properties as usual. After all spans (including the last span) have been completed, execute FIXR.

If you find that you have made an error during input of a span or wish to modify a span after initial computation, the NSPAN program may be used. Simply key in your data, key in the span number (1 = leftmost span) and execute NSPAN.

The number of spans is limited only by the number of data storage registers.

A rule of thumb for the required size is:

SIZE = 35 + 4 * (Number of spans)
+ 4 * (Number of fixed ends)

A moderately complex problem with 3 spans takes less than 50 registers. With three optional plug in memory modules, over 50 spans could be combined.

If you set the size larger than 23* but smaller than necessary for problem solution, the prompt

SIZE* > *NNN

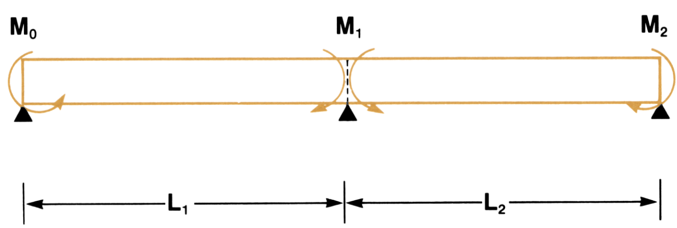
will be displayed during data input. This indicates that the size should be increased to at least ***NNN***.

Algorithm:

The program starts by assuming that all internal moments are zero. Based on this assumption it calculates the moment across the first intermediate supports using:

$$M_1 = \frac{(\measuredangle_1 - \measuredangle_2) - \dfrac{M_0 L_1}{6E_1I_1} - \dfrac{M_2 L_2}{6E_2I_2}}{\left(\dfrac{L_1}{3E_1I_1} + \dfrac{L_2}{3E_2I_2}\right)}$$

The following definitions apply:



$\measuredangle_1$ is the slope at the right end of beam one assuming $M_1 = 0$.
$\measuredangle_2$ is the slope at the left end of beam two assuming $M_1 = 0$.

After calculation M_1 is used in an analogous equation for the next support. This is repeated until the end of the beam is reached. The program repeats this procedure until all calculated moments remain unchanged within the ENG 3 display setting for one complete cycle of moment calculations.

Reference:

Roark, Raymond J., Young, Warren C.; *Formulas for Stress and Strain*, McGraw-Hill, 1975.

* Size of 30 is required to start with the left end fixed.

Remarks:

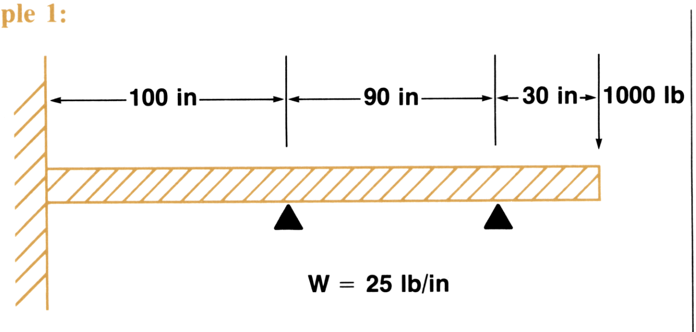
If a span has no loads, use a point load of zero located anywhere in the span.

If a fixed end is specified, the wall reactions are computed and output as if the fixed end constituted another intermediate support.

				SIZE: >30
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Select a simply supported beam or a beam with a fixed left end.		[XEQ] SIMPLE [XEQ] FIXL	L=? L=?
2	Key in length of span.	L	[R/S]	RDY A-I
3	If you know the moment of inertia, key it in (otherwise use 1.00).	I(1)	[ENTER↑]	I
4	If you know the modulus or elasticity key it in (otherwise use 1.00).	E(1)	[■] [A]	E*I
5	Key in all loadings: Distributed load.	W	[■] [B]	0.000 00
	Point load location and load.	a P	[ENTER↑] [■] [C]	a 0.000 00
	Trapezoidal load starting point, starting load, end point, and ending load.	d W_d e W_e	[ENTER↑] [ENTER↑] [ENTER↑] [■] [D]	d W_d e 0.000 00
	Applied moment location and applied moment.	c M	[ENTER↑] [■] [E]	c 0.000 00
6	OPTIONAL: Review and/or edit your inputs (e.g. if you wish to modify L, key in a new L and press [R/S]. Otherwise just press [R/S].)	 (L) (E*I)	[E] [R/S] [R/S] [R/S] ⋮	SIMPLE L= E*I= LOAD ⋮
	An "END" signifies that all data has been displayed. Pressing [R/S] again will start the edit routine over.		[R/S]	END
7	OPTIONAL: Document your inputs on your optional HP-82143A printer.		[F]	
8	Add this span to the beam OR Replace a previous span with new data.	 SPAN#	[XEQ] SPAN [XEQ] NSPAN	L=? L=?
9	Go to Step 2 for next span. Skip steps 3 and 4 if the section properties do not change.			

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
10	If the right end is fixed rather than simply supported.		[XEQ] FIXR	L=?
11	Calculate internal moments (L and R refer to the left and right sides of each support).		[XEQ] MOMENTS [R/S]* [R/S]* [R/S]* [R/S]* ⋮	INT MOMENTS M1L= M1R= M2L= M2R= ⋮
12	For a new case, go to step 2. * Use [R/S] if you do not have a printer.		[R/S]	L=?

Example 1:



Compute the couples at the wall and the intermediate support for the beam above. Prove that these moments are correct by matching the slope at the left side of the support with the slope at the right side of the support. If we assume that the section properties are constant along the beam, they cancel out of the equation and we may use:

$$E = I = 1$$

Keystrokes: (SIZE ⩾ 34)	**Display:**
[■] [ENG] 3	
Fixed left end:	
[XEQ] [ALPHA] FIXL [ALPHA]	*L=?*
Span 1:	
100 [R/S]	*RDY A-I*
1 [ENTER↑] 1 [■] [A]	*1.000 00*
25 [■] [B]	*0.000 00*
[XEQ] [ALPHA] SPAN [ALPHA]	*L=?*

Span 2:	
90 [R/S] 25 [ ] [B]	0.000 00

Include cantilevered end as an applied moment at c = 90 in span 2.

$$M = -(30 * 1000) - (30 * (30/2) * 25)$$

90 [ENTER↑] 1000 [CHS] [ENTER↑]	
30 [×]	
[LASTX] [ENTER↑] [×] 2 [÷]	
25 [×] [−]	-41.25 03
[ ] [E]	0.000 00
[XEQ] [ALPHA] SPAN [ALPHA]	L=?
[XEQ] [ALPHA] MOMENTS [ALPHA]	INT MOMENTS
[R/S] *	M1L=-25.24E3
[R/S] *	M1R=25.24E3
[R/S] *	M2L=-12.03E3
[R/S] *	M2R=12.03E3

Check results:

First compute slope at right end of first section.

[XEQ] [ALPHA] SIMPLE [ALPHA]	L=?
100 [R/S] 0 [ENTER↑]	
25.24 [EEX] 3 [ ] [E]	0.000 00
25 [ ] [B] 100 [ENTER↑]	
12.03 [CHS] [EEX] 3 [ ] [E]	0.000 00
100 [B]	∡ =220.0E3

Compute slope at left end of second section.

[XEQ] [ALPHA] SIMPLE [ALPHA]	L=?
90 [R/S] 0 [ENTER↑]	
12.03 [EEX] 3 [ ] [E]	0.000 00
25 [ ] [B] 90 [ENTER↑]	
1000 [CHS] [ENTER↑] 30 [×] [LASTX]	
[ENTER↑] [×]	
2 [÷] 25 [×] [−] [ ] [E]	0.000 00
0 [B]	∡ =220.3E3

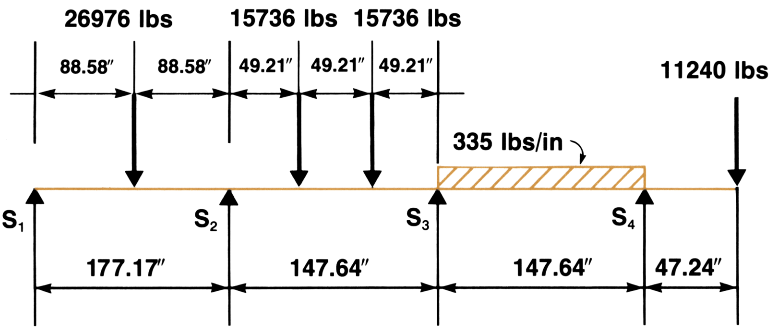
Since the slopes agree, the moments have been correctly balanced.**

* Press [R/S] if you are not using a printer.

** The term slope is used loosely here since we do not know E or I and thus have assumed the rather arbitrary value of 1.00. The slight difference in the computed slopes arises because the moments were keyed in as four digit approximations of 10 digit numbers.

Example 2:

LOAD DIAGRAM



Find the moments at points S_2 and S_3 for the configuration above. Assume the product of EI is the same for all sections and thus cancels out of the solutions (use 1 for E and I).

Keystrokes: (SIZE ⩾ 39)	**Display:**
[XEQ] [ALPHA] SIMPLE [ALPHA]	*L=?*
177.17 [R/S]	*RDY A-I*
1 [ENTER↑] 1 [■] [A]	*1.000 00*
88.58 [ENTER↑] 26976 [■] [C]	*0.000 00*
[XEQ] [ALPHA] SPAN [ALPHA]	*L=?*
147.64 [R/S]	
49.21 [ENTER↑] 15736 [■] [C]	*0.000 00*
49.21 [ENTER↑] [+] 15736 [■] [C]	*0.000 00*
[XEQ] [ALPHA] SPAN [ALPHA]	*L=?*
147.64 [R/S] 335 [■] [B]	*0.000 00*
147.64 [ENTER↑] 47.24 [ENTER↑]	
11240 [CHS] [×] [■] [E]	*0.000 00*
[XEQ] [ALPHA] SPAN [ALPHA]	*L=?*
[XEQ] [ALPHA] MOMENTS [ALPHA]	*INT MOMENTS*
[R/S] *	*M1L=-720.2E3*
[R/S] *	*M1R=720.2E3*
[R/S] *	*M2L=-530.8E3*
[R/S] *	*M2R=530.8E3*

* Press [R/S] if you are not using a printer.

If the concentrated load on span one (26976) were replaced with a load of 30000, what would the moments be?

[R/S] *	L=?
177.17 [R/S]	
88.58 [ENTER↑] 30000 [■] [C]	
1 [XEQ] [ALPHA] NSPAN [ALPHA]	L=?
[XEQ] [ALPHA] MOMENTS [ALPHA]	INT MOMENTS
[R/S]	M1L=-778.3E3
[R/S]	M1R=778.3E3
[R/S]	M2L=-516.3E3
[R/S]	M2R=516.3E3

If you do have the optional HP-82143A thermal printer, plot the moment distribution for span 1. Use an increment of 10.

[XEQ] [ALPHA] SIMPLE [ALPHA]	L=?
177.17 [R/S] 88.58 [ENTER↑]	0.000 00
30000 [■] [C]	
177.17 [ENTER↑]	0.000 00
778.3 [CHS] [EEX] 3 [■] [E]	SIMPLE
[H]	L=177.2E0 E*I=0.000E0* a=88.58E0 P=30.00E3 c=177.2E0 M=-778.3E3 END XINC?
10 [R/S]	X=0.000E0 MX=0.000E0 X=10.00E0 MX=106.1E3

*May take any value in this problem.

Keystrokes: **Display:**

```
X=20.00E0
MX=212.2E3

X=30.00E0
MX=318.2E3

X=40.00E0
MX=424.3E3

X=50.00E0
MX=530.4E3

X=60.00E0
MX=636.5E3

X=70.00E0
MX=742.6E3

X=80.00E0
MX=848.6E3

X=90.00E0
MX=912.1E3

X=100.0E0
MX=718.2E3

X=110.0E0
MX=524.3E3

X=120.0E0
MX=330.3E3

X=130.0E0
MX=136.4E3

X=140.0E0
MX=-57.50E3

X=150.0E0
MX=-251.4E3
```

Keystrokes: **Display:**

```
X=160.0E0
MX=-445.3E3

X=170.0E0
MX=-639.3E3



      PLOT OF BEAM
    X (UNITS= 1.) ↓
    Y (UNITS= E 5.) →
     -6.39          9.12
          0.00
     |-------|----------|
  0.         x
 10.         | x
 20.         |  x
 30.         |   x
 40.         |    x
 50.         |     x
 60.         |      x
 70.         |       x
 80.         |        x
 90.         |        x
100.         |       x
110.         |     x
120.         |   x
130.         | x
140.        x|
150.      x  |
160.    x    |
170.  x      |
```

NOTES

SETTLING OF CONTINUOUS BEAMS

This program accounts for deviations from level in the supports of continuous beams.

The beam's geometry, section properties, and loads are derived using *Continuous Beams*. Then SETTLE is run to account for low and/or high supports. After SETTLE has been completed, MOMENTS is run to obtain the internal bending moments at each intermediate support.

Equations:

$$\measuredangle'_{nr} = \measuredangle_{nr} + \frac{\text{DELTA}_n}{L_n} - \frac{\text{DELTA}_{n-1}}{L_n}$$

$$\measuredangle'_{nL} = \measuredangle_{nL} - \frac{\text{DELTA}_n}{L_{n+1}} - \frac{\text{DELTA}_{n+1}}{L_{n+1}}$$

where:

$\measuredangle'_{nr}$ is the adjusted angle at the right end of beam section n; $\measuredangle'_{nL}$ is the adjusted angle at the left end of beam section n+1; DELTA_n is the height deviation of support n relative to the left-most support (up is positive, down is negative); L_n is the length of span n.

Reference:

Roark, Raymond J.; Young, Warran C.; *Formulas for Stress and Strain,* McGraw-Hill, 1975.

Remarks:

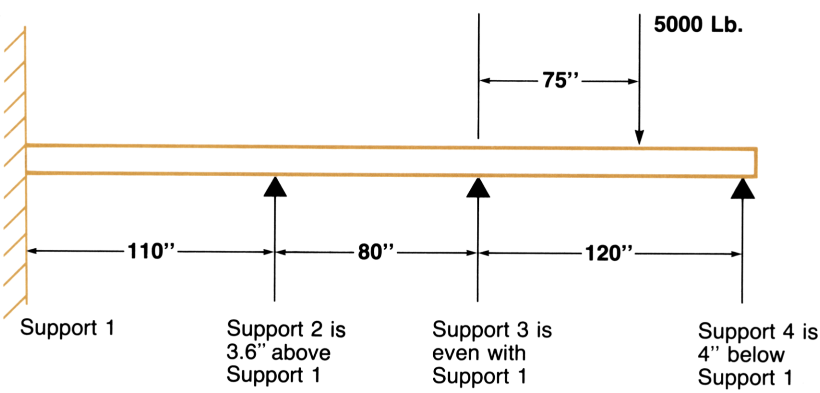
Unlike *Continuous Beams,* actual values for the moment of inertia and the modulus of elasticity must be used.

				SIZE:
STEP	**INSTRUCTIONS**	**INPUT**	**FUNCTION**	**DISPLAY**
1	Run Continuous Beams through step 10 of its listed instructions.			
2	Start Settle.		[XEQ] SETTLE	L1=?
3	Key in the length of the span.	L	[R/S]	DELTA N=?
4	Key in the height of the support relative to the height of the first support (up is positive, down is negative).	DELTA	[R/S]	LN=?

STEP	INSTRUCTIONS	INPUT	FUNCTION	SIZE: DISPLAY
5	If step 4 resulted in display of "END" go to step 6, otherwise go to step 3.			
6	Calculate the internal moments (L and R refer to the left and right sides of each support).		[XEQ] MOMENTS [R/S] * [R/S] * [R/S] * [R/S] *	INT MOMENTS M1L= M1R= M2L= M2R= . . . .
7	For a new case go to step 1.			
	*Press [R/S] if you are not using a printer.			

Example:

Calculate the internal bending moments at the supports for the continuous beam shown below:



For all three spans

$$E = 30 \times 10^6 \text{ psi}$$

and

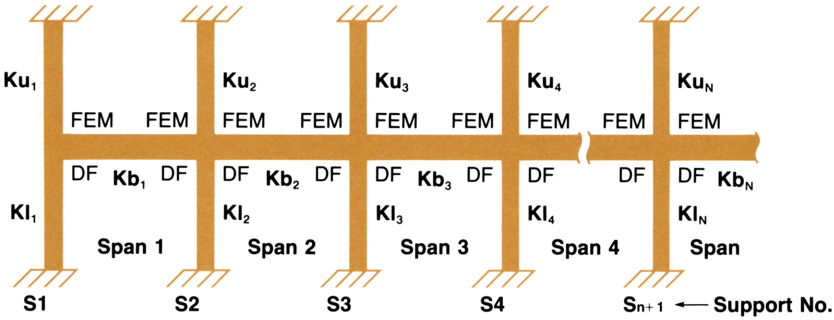
$$I = 5 \text{ in}^4$$

Keystrokes (Size ≥ 040)	Display:
[ENG] 3	
Fixed left end:	
[XEQ] [ALPHA] FIXL [ALPHA]	*L=?*
SPAN 1:	
110 [R/S]	*RDY A–I*
5 [ENTER↑] 30 [EEX] 6 [A]	
Use dummy load of zero:	
0 [ENTER↑] 0 [C]	
[XEQ] [ALPHA] SPAN [ALPHA]	*L=?*
Span 2:	
80 [R/S]	
0 [ENTER↑] 0 [C]	
[XEQ] [ALPHA] SPAN [ALPHA]	*L=?*
Span 3:	
120 [R/S]	
75 [ENTER↑] 5000 [C]	
[XEQ] [ALPHA] SPAN [ALPHA]	*L=?*
[XEQ] [ALPHA] SETTLE [ALPHA]	*L1=?*
110 [R/S]	*DELTA2=?*
3.6 [R/S]	*L2=?*
80 [R/S]	*DELTA3=?*
0 [R/S]	*L3=?*
120 [R/S]	*DELTA4=?*
4 [CHS] [R/S]	*END*
[XEQ] [ALPHA] MOMENTS [ALPHA]	*INT MOMENTS*
[R/S] *	*M1L=266.8E3*
[R/S] *	*M1R=–266.8E3*
[R/S] *	*M2L=–265.8E3*
[R/S] *	*M2R=265.8E3*
[R/S] *	*M3L=21.41E3*
[R/S] *	*M3R=–21.41E3*

* Press [R/S] if you are not using a printer.

CONTINUOUS FRAME ANALYSIS

Using the method of moment distribution, this program solves for the beam and column end moments in continuous frames.



Basic Frame

Definitions:

FEM is the fixed end moment (use the right hand rule to maintain sign consistency within this Pac [is positive]);

K is the beam or column stiffness (K=4EI/L);

Ku is the upper column stiffness;

Kl is the lower column stiffness;

Kb is the beam stiffness;

DF is the moment distribution factor at a joint;
$DF = K/(Ku + Kl + Kb_L + Kb_R)$.

where:

K is the beam or column stiffness of any member of the joint. The subscripts "L" and "R" refer to the beams left and right of the joint;

E is the modulus of elasticity;

I is the moment of inertia;

L is the length of the span.

Remarks:

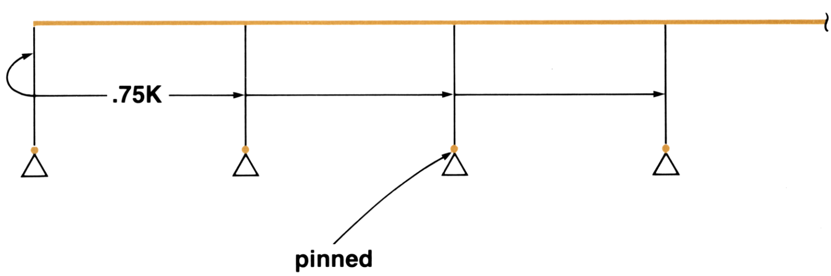
The number of spans the program can handle is dependent on the number of storage registers available in memory. The size required for storage is 5N + 3, where N is the number of spans being considered.

# of Spans	Memory Modules Required
1-12	None
13-24	1
25-37	2
38-50	3

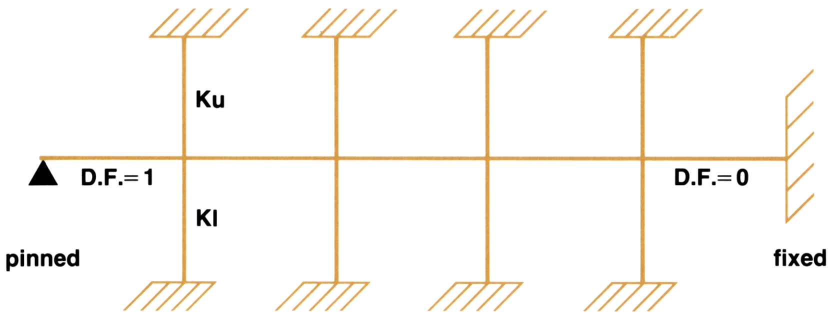
Be aware that expansion joint requirements, building code requirements and practicality place limitations on the number of spans in the frame. Also, a large number of spans will require a long computation time.

By assuming that the far ends of the columns are fixed, beams in one floor may be analyzed without regard to the beams above or below. This allows analysis of multistory structures.

The program may also be used for single or multibay, one story frames with the far ends pinned. When the ends are pinned, multiply the stiffness factors by 0.75.



The ends of the first and last span may also be pinned or fixed. Use 1.0 for the value of the distribution factor at pinned ends and 0.0 at fixed ends.



The program solves for gravity loads only. Wind and seismic loads must be considered independently.

When calculating the fixed end moments (FEM) use the FIXED beam program from the *BEAMS* section of this applications pac. Change the sign of the left end, fixed end moments calculated by FIXED before input to this program.

After all moments are known, the *BEAMS* program of this pac can be used to compute or plot shear, moment, slope or deflection. Use the computed moments as applied moments at each end of the simple beam under consideration.

References:

Continuity in Concrete Building Frames, Portland Cement Association, 4th Ed, 1959.

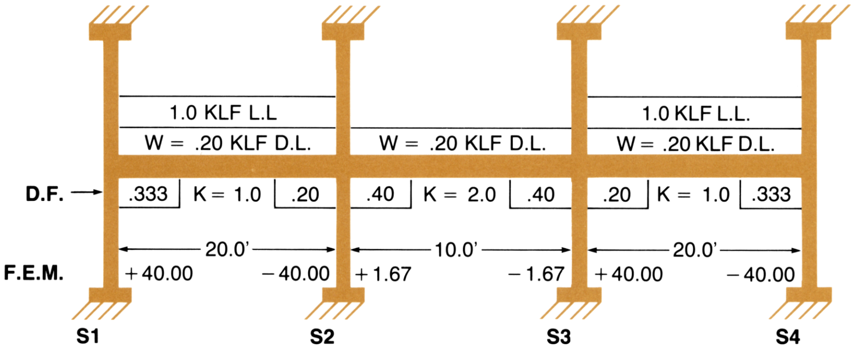
Lothers, John E., *Advanced Design in Structural Steel,* Prentice Hall, 1960.

Borg, Genaro, *Modern Structural Analysis,* Van Nostrand Reinhold Co., 1969.

				SIZE: 5N+3**
STEP	**INSTRUCTIONS**	**INPUT**	**FUNCTION**	**DISPLAY**
1	Use FIXED to compute fixed end moments for all bays.			
2	Compute all distribution factors.			
3	Size memory according to the formula: SIZE=5N+3 (N=Number of Bays).			
4	Initialize program.		[XEQ] CFRAME	NO. OF SPANS?
5	Input number of spans.	N	[R/S]	DF ↑ FEM?
6	Key in the distribution factor.	DF	[ENTER↑]	DF
7	Key in the fixed end moment.	FEM	[R/S]	DF ↑ FEM?
8	Return to step 6 until all bays have been entered.			CYCLES?
9	Key in number of moment distribution cycles and calculate beam moments.	CYCLES	[R/S]	BEAM MOMENTS
			[R/S] *	S1.=MOM
			[R/S] *	S2.=MOM(left)
			[R/S] *	MOM(right)
			[R/S] *	S3.=MOM(left)
			:	:
			etc.	etc.
				COL. MOMENTS
			[R/S] *	KU ↑ KL?
10	Key in the upper column stiffness.	Ku	[ENTER↑]	KU
11	Key in the lower column stiffness.	Kl	[R/S]	KL
				S1=MOM(U)
			[R/S] *	MOM(L)
			[R/S] *	KU ↑ KL
12	Return to step 10 for next column.			
13	For a new case go to step 1.			
	*Press [R/S] if you are not using a printer.			
	**You may need a larger SIZE than this for proper execution of FIXED. See the User Instructions of FIXED.			

Example:

Solve for the moments in the frame below. For all columns K = 1.00.



Calculate Distribution Factors:

$DF_1 = 1/(1+1+1) = 0.333$
$DF_{2L} = 1/(1+1+1+2) = 0.20$
$DF_{2R} = 2/(1+1+1+2) = 0.40$
$DF_{3L} = 2/(1+1+1+2) = 0.40$
$DF_{3R} = 1/(1+1+1+2) = 0.20$
$DF_4 = 1/(1+1+1) = 0.333$

Use the beam program "FIXED" to solve for fixed end moments. Note that bay #3 is the same as bay #1 and thus need not be calculated. Also, note that the sign convention for the internal bending moments must be converted to the right hand rule for use in this application.

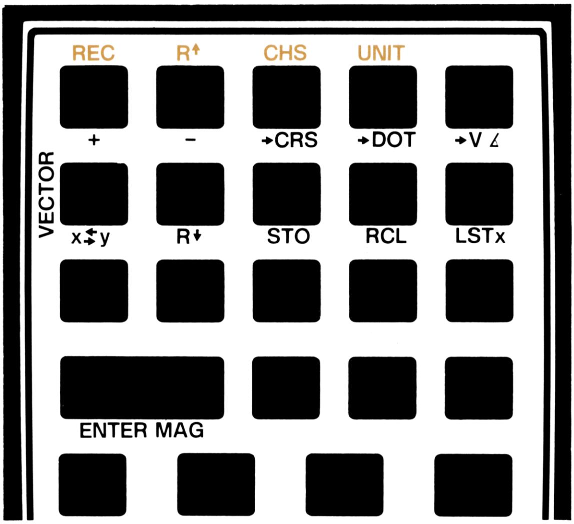
Keystrokes: (Size ≥ 024)	**Display:**
■ [FIX] 2	
[XEQ] [ALPHA] FIXED [ALPHA]	*L=?*
20 [R/S] 1 ■ [B] .2 ■ [B]	
0 [C]	*MX=-40.00*
20 [C]	*MX=-40.00*
[XEQ] [ALPHA] FIXED [ALPHA]	*L=?*
10 [R/S] .2 ■ [B] 0 [C]	*MX=-1.67*
10 [C]	*MX=-1.67*

Solve for moments at joints:

Keystrokes:	Display:
[XEQ] [ALPHA] CFRAME [ALPHA]	NO. OF SPANS?
3 [R/S]	DF ↑ FEM?
.333 [ENTER↑] 40 [R/S]	DF ↑ FEM?
.2 [ENTER↑] 40 [CHS] [R/S]	DF ↑ FEM?
.4 [ENTER↑] 1.67 [R/S]	DF ↑ FEM?
.4 [ENTER↑] 1.67 [CHS] [R/S]	DF ↑ FEM?
.2 [ENTER↑] 40 [R/S]	DF ↑ FEM?
.333 [ENTER↑] 40 [CHS] [R/S]	CYCLES?
8 [R/S]	BEAM MOMENTS
[R/S] *	S1.=30.51
[R/S] *	S2.=-36.13
[R/S] *	13.16
[R/S] *	S3.=-13.16
[R/S] *	36.13
[R/S] *	S4.=-30.51
[R/S] *	COL. MOMENTS
[R/S] *	KU ↑ KL?
1 [ENTER↑] 1 [R/S]	S1.=-15.26
[R/S] *	-15.26
[R/S] *	KU ↑ KL?
1 [ENTER↑] 1 [R/S]	S2.=11.49
[R/S] *	11.49
[R/S] *	KU ↑ KL?
1 [ENTER↑] 1 [R/S]	S3.=-11.49
[R/S] *	-11.49
[R/S] *	KU ↑ KL?
1 [ENTER↑] 1 [R/S]	S4.=15.26
[R/S] *	15.26

*Press [R/S] if you are not using a printer.

RPN VECTOR CALCULATOR



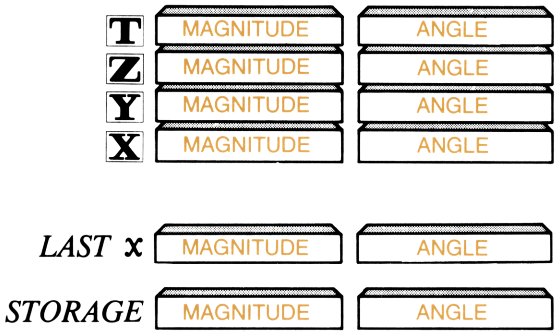
Execution of VECTOR transforms the HP-41C into a four-register-stack, RPN, vector calculator. Vectors are displayed in the magnitude/angle format. The character "∡" is used to separate the magnitude and angle in the display. The top two rows of keys are redefined as vector add, subtract, cross product, dot product, angle subtraction, X exchange Y, roll down, store, recall, LAST X, rectangular display, roll up, change sign and unit vector. In addition, [ENTER↑] is used to separate between magnitude and angle in vector entry and [R/S] is used to terminate vector entry. These operations are analogous to their scalar counterparts in the HP-41C with the following exceptions:

1. Cross product, dot product, vector angle subtraction, and rectangular display do not change the content of the stack or LAST X. They modify the display only.

2. Store and recall apply to only one vector register.

3. When a vector is terminated using [R/S] only one copy is generated in the vector stack.

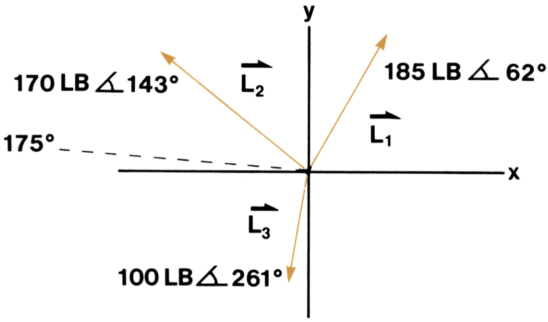
Vector Calculator Data Structure



				SIZE: 016
STEP	**INSTRUCTIONS**	**INPUT**	**FUNCTION**	**DISPLAY**
1	Initialize program.		[XEQ] VECTOR	0.00∡0.00*
2	Key in magnitude.	MAG	[ENTER↑]	MAG
3	Key in angle.	ANGLE	[R/S]	MAG∡ANGLE
4	Perform any of the following operations:			
	terminate vector entry		[R/S]	MAG∡ANGLE
	cr add vectors		[A]	MAG∡ANGLE
	or subtract vectors		[B]	MAG∡ANGLE
	or take cross product		[C]	Y × X =
	or take dot product		[D]	DOT=
	or find acute angle between vectors		[E]	V∡=
	or exchange vectors		[F]	MAG∡ANGLE
	or roll vector stack down		[G]	MAG∡ANGLE
	or store vector		[H]	MAG∡ANGLE
	or recall vector		[I]	MAG∡ANGLE
	or recall LAST X vector		[J]	MAG∡ANGLE
	or display vector in rectangular form		■ [A]	HORZ↑VERT
	or roll vector stack up		■ [B]	MAG∡ANGLE
	or change sign of vector		■ [C]	MAG∡ANGLE
	or change to unit vector.		■ [D]	MAG∡ANGLE
5	To key in another vector, go to Step 2. To perform another operation, go to Step 4.			
	* Assumes FIX 2 display setting.			

Example 1:

Resolve the following three loads along a 175 degree line.



Keystrokes:	Display:
First add L_1 and L_2.	
[FIX] 2	
[XEQ] [ALPHA] VECTOR [ALPHA]	0.00∡0.00
185 [ENTER↑] 62 [R/S]	185.00∡62.00
170 [ENTER↑] 143 [A]	270.12∡100.43
Add L_3.	
100 [ENTER↑] 261 [A]	178.94∡111.15

Resolve vector along 175 degree line by using dot product.

1 [ENTER↑] 175 [D]	DOT=78.86

If L_3 is doubled, what is the resolution along the 175 degree line? Take advantage of vector store, vector recall and the fact that L_3 is in vector LAST X.

Store the 175 degree vector.

[H]	1.00∡175.00

Move the current sum back to the display register of the vector stack with vector roll down.

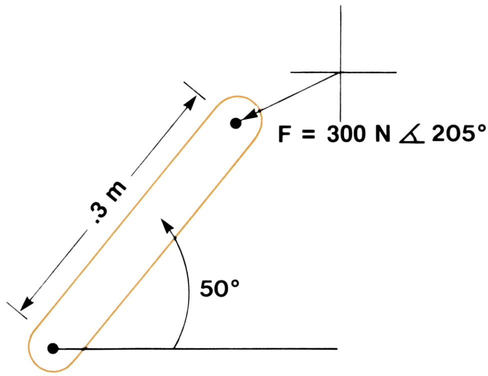
[G]	178.94∡111.15
Get L_3 from vector LAST X.	
[J]	100.00∡261.00
Add.	
[A]	105.22∡139.66
Recall 175 degree vector.	
[I]	1.00∡175.00

Use dot product to resolve the new sum along the 175 degree vector.

[D]	DOT=85.83

Example 2:

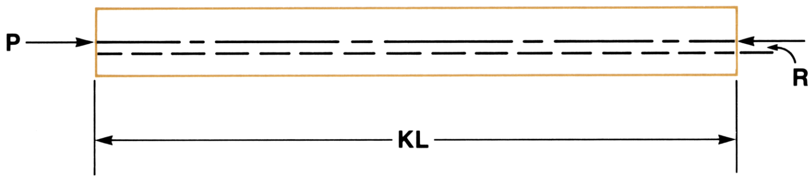
What is the moment at the shaft of the crank pictured below? What is the reaction force transmitted along the member?



Keystrokes:	**Display:**
Moment by cross product ($V_1 \times F$).	
[FIX] 2 [XEQ] [ALPHA] VECTOR [ALPHA]	0.00 ∡ 0.00
.3 [ENTER↑] 50 [R/S]	0.30 ∡ 50.00
300 [ENTER↑] 205 [C]	Y*X=38.04
Resolution along the shaft by dot product.	
[F]	0.30 ∡ 50.00
[■] [D]	1.00 ∡ 50.00
[D]	DOT=-271.89

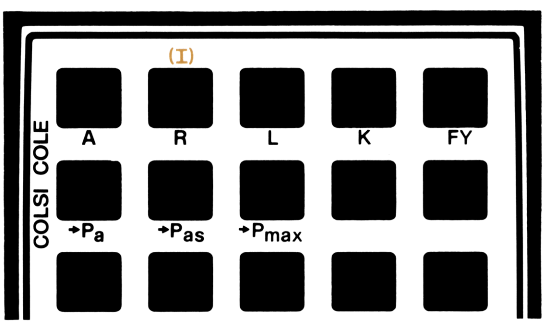
STEEL COLUMN FORMULA

This program computes the allowable axial compressive load for steel columns using the American Institute of Steel Construction formulas for long and short columns. Optionally, the allowable load for secondary columns or the maximum theoretical axial column load can be calculated.



Either SI or English units may be used in problem solution. The initialization routine COLSI selects the newton as the unit of force and the meter as the unit of length. N-M is left in the display after execution to indicate the units selected. COLE selects the pound as the unit of force and the inch as the unit of length. LB-IN is left in the display after execution.

After either initialization routine, the keyboard is defined according to the overlay below:



Key A is used for input of cross sectional area.

Key B and B are used for the input of the minimum moment of inertia *or* radius of gyration. Only one of the two is needed for problem solution.

Keys C, D and E are used to input the beam length, the effective length factor, and the steel yield point.

The effective length factor K is used to account for various column end conditions. If both ends are free to rotate but not translate the value of K is 1.0. Since this is the common assumption, K is automatically set to 1.0 when the program is initialized. As the ends become more constrained against rotation and motion the value of K decreases, approaching a theoretical minimum of 0.5. As the ends become less constrained, K values may exceed 2.0. The following table may be used to select K values.

EFFECTIVE LENGTH FACTORS

End Conditions	Recommended K values (Theoretical conditions approximated)	Theoretical K values
FIXED-FIXED	0.65	0.5
PINNED-FIXED	0.80	0.7
ROTATION FIXED-FIXED	1.2	1.0
PINNED-PINNED	1.0	1.0
FREE FIXED	2.1	2.0
ROTATION-PINNED	2.0	2.0

Key [F] calculates the allowable, axial compressive load for the cross section assuming the ratio of KL/R is the largest ratio applicable to the section. Local buckling within the section is not checked by the program and must be treated separately.

Key [G] calculates allowable loads for bracing and secondary members.

Key [H] calculates the theoretical failure load for axially loaded columns and should not be used for design purposes.

A display of KL/R > 200 after pressing [F], [G], or [H] indicates that the member is too thin and long to be treated as a column.

Equations:

$$P_a = \frac{A\left[1 - \dfrac{(KL/R)^2}{2\,C^2}\right]FY}{\dfrac{5}{3} + \dfrac{3(KL/R)}{8\,C} - \dfrac{(KL/R)^3}{8\,C^3}} \qquad \frac{KL}{R} < C$$

$$P_a = \frac{12\pi^2\,EA}{23(KL/R)^2} \qquad C \leqslant \frac{KL}{R} \leqslant 200$$

$$C^2 = 2\pi^2 E/FY$$

$$P_{as} = P_a \qquad \frac{L}{R} \leqslant 120$$

$$P_{as} = \frac{P_a}{1.6 - \dfrac{L}{200\,R}} \qquad \frac{L}{R} > 120$$

$$P_{max} = A\left[1 - \frac{(KL/R)^2}{2\,C^2}\right]FY \qquad \frac{KL}{R} < C$$

$$P_{max} = \frac{\pi^2 E\,A}{(KL/R)^2} \qquad C \leqslant \frac{KL}{R} \leqslant 200$$

Definitions:

P_a is the allowable load;

P_{as} is the allowable load for secondary members;

P_{max} is the maximum load the column could theoretically carry;

A is the area of the section;

L is the length of the column;

R is the minimum radius of gyration of the column cross section;

I is the minimum moment of inertia of the cross section;

FY is the yield point of the steel;

E is the modulus of elasticity of steel;

K is the effective length factor.

References:

Roark, Raymond J., Young, Warren C., *Formulas for Stress and Strain*, McGraw-Hill, 1975.

Johnston, Bruce, G., Lin, Fung-Jen, *Basic Steel Design*, Prentice-Hall, 1974.

Manual of Steel Construction, American Institute of Steel Construction, 1973.

Remarks:

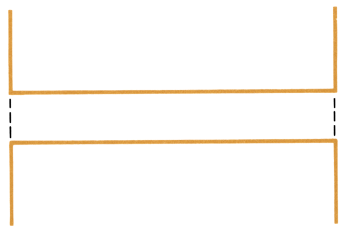
Columns must be nominally straight, homogenous, and of uniform cross section.

Local buckling is not checked for.

				SIZE: 029
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Select units and initialize: SI units (newtons and meters) OR English (pounds and inches)		 [XEQ] COLSI [XEQ] COLE	 N-M LB-IN
2	Key in the following: area of section, moment of inertia, OR radius of gyration length of column, effective length factor (if not 1.00), yield point of steel.	 A I R L K FY	 [A] ■ [B] [B] [C] [D] [E]	 A= I= R= L= K= FY=
3	Calculate any or all of the following: allowable load allowable load for secondary members maximum load		 [F] [G] [H]	 Pa= PaS= PMAX=
4	Go to step 2 and change any or all inputs.			

Example 1:

Two steel channels are laced together to form the cross section below:



Calculate the allowable load, the allowable secondary load, and the maximum load using the following specifications: $R = 81.0 \times 10^{-3}$m, $A = 9.46 \times 10^{-3}$m^2, $FY = 248 \times 10^6$N/m^2, $L = 7.5$ m, $K = 1.0$.

Keystrokes: (SIZE ⩾ 009)	Display:
[shift] [ENG] 3	
[XEQ] [ALPHA] COLSI [ALPHA]	*N-M*
81 [EEX] [CHS] 3 [B]	
9.46 [EEX] [CHS] 3 [A]	
248 [EEX] 6 [E]	
7.5 [C]	
[F]	*Pa=905.9E3*
[G]	*PaS=905.9E3*
[H]	*PMAX=1.714E6*
What are the allowable loads for L = 12 m?	
12 [C] [F]	*Pa=443.9E3*
[G]	*PaS=516.6E3*
[H]	*PMAX=850.8E3*

Example 2:

For a column with the properties below, what is the allowable load?

$F_y = 33{,}000$ psi $A = 20$ in^2 $I = 223$ in^4 $L = 350$ in $K = 1.0$

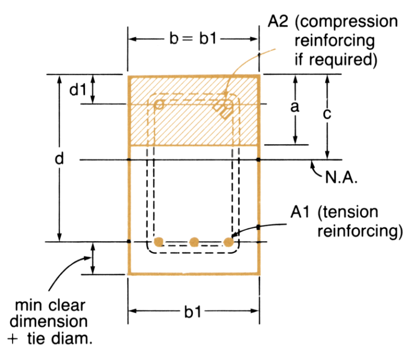
Keystrokes: (SIZE ⩾ 009)	Display:
[shift] [ENG] 3	
[XEQ] [ALPHA] COLE [ALPHA]	*LB-IN*
33000 [E] 20 [A] 223 [shift] [B]	
350 [C]	
[F]	*Pa=237.1E3*
If K were 0.65 what would the allowable load be?	
.65 [D] [F]	*Pa=310.1E3*

REINFORCED CONCRETE BEAMS—ULTIMATE STRENGTH DESIGN

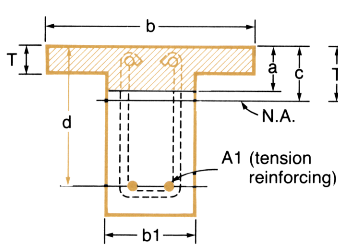
Using the ultimate strength method, this program will aid in the design of rectangular or "T" shaped sections capable of resisting a specified moment. Both tension and compression reinforcement may be incorporated in the design. Special features of the program include:

1. The program checks for minimum reinforcement according to the A.C.I. code. If the calculated reinforcement is less than the minimum, both the calculated reinforcement and the minimum reinforcement are output.
2. Since deflection problems are rarely encountered when the steel reinforcement ratio is less than 0.18 Fc/Fy, a user option is available to limit tension steel. The program prompts ***LMT REN? Y/N***. If you wish to eliminate deflection checks key in "Y"; if you are willing to do deflection checks, key in "N".
3. If a beam requires compression reinforcement, the calculator prompts for the depth of the compression reinforcement, and automatically calculates both the tension and compression steel areas.

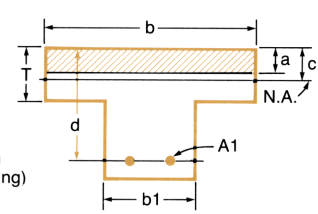
Typical sections:



RECTANGULAR SECTION



'T' SECTION
(neutral axis below flange)



'T' SECTION
(neutral axis within flange designed as a rectangular section with b1 = b)

Definitions:

FY is the yield strength of the steel (psi);

F_c is the ultimate compressive strength of the concrete (psi);

b is the beam width (flange width for T-beam)(in);

b1 is the stem width (in);

d is the beam depth from compression surface to centroid of tension reinforcing (in);

d1 is the location of compression reinforcing, from compression surface to centroid of compression reinforcing (in);

T is the thickness of flange (in);

A1 is the total tension reinforcing area (in^2);

A2 is the compression reinforcing area (in^2);

$.75P_b$ is 75% of allowable balanced steel ratio;

P is the steel ratio = A_s/bd;

A_s is the steel reinforcing required for tensile stress only (in^2);

A_{sf} is the equivalent steel area to balance the force produced in a concrete flange (in^2);

Mu is the ultimate design moment (kip-in);

K is the flexural coefficient;

KMAX is the maximum flexural coefficient at balance condition when $P = .75P_b$;

NA is the neutral axis (in);

a is the depth of the equivalent stress block.

Remarks:

This program is intended as a computational aid and is not a replacement for a thorough understanding of reinforced concrete design.

The program deals with flexure only. A complete design requires that shear also be considered.

The program does not check span to depth ratios.

The formulas used in this program may be found in the following two references:

References:

ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318-77), American Concrete Institute.

Winter, Urguhard, O'Rourke and Nilson, *Design of Concrete Structures,* McGraw-Hill, 1964.

For Rectangular Beams:

SIZE: 018

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Initialize the program.		[XEQ] RBEAM	FY=?
2	Key in the yield strength of steel (psi).	FY	[R/S]	Fc=?
3	Key in the compressive strength of concrete (psi) and calculate maximum steel ratio and 0.9 times the maximum flexural coefficient.	Fc	[R/S]	.75Pb=
			[R/S] *	.9KMAX=
			[R/S] *	WIDTH=?
4	Key in the width of section (in).	b	[R/S]	DEPTH=?
5	Key in the depth of section (in).	d	[R/S]	LMT REN? Y/N
6	If you wish to limit reinforcements so that deflections need not be checked, answer "N", otherwise answer "Y".	Y/N	[R/S]	MOMENT=?
7	Key in the applied moment (in-Kips) and calculate the flexural coefficient.	M	[R/S] *	K=
			[R/S] *	DEPTH COMP=?
8	If you are prompted for the depth of compression reinforcement, key it in.	d1	[R/S]	
9	See outputs of minimum steel area (if the computed area is less than the minimum),			AMIN=
	tension reinforcement area,		[R/S] *	A1=
	and, if you were asked for d1, the area of the required compression reinforcement.		[R/S] *	A2=
			[R/S] *	A1=?
10	OPTIONAL: Key in steel areas based on the outputs above and available bar sizes to compute ultimate moment.	A1	[R/S]	A2=?
		A2	[R/S]	M=
11	For a new case, go to step 1.			
	*If you are not using a printer, press [R/S]			

For "T" Beams:

SIZE: 018

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Initialize the program.		[XEQ] TBEAM	FY=?
2	Key in the yield strength of steel (psi).	FY	[R/S]	Fc=?
3	Key in the compressive strength of concrete and calculate the maximum steel ratio, and 0.9 times the maximum flexural coefficient.	Fc	[R/S] [R/S] * [R/S] *	.75Pb= .9KMAX= WIDTH=?
4	Key in the width of the flange (in).	b	[R/S]	STEM WIDTH=?
5	Key in the width of the stem (in).	b1	[R/S]	DEPTH=?
6	Key in the depth of the section (in).	d	[R/S]	THICKNESS=?
8	Key in the thickness of the flange (in).	T	[R/S]	LMT REN? Y/N
9	If you wish to limit reinforcement so that deflections need not be checked answer "N", otherwise answer "Y".	Y or N	[R/S]	MOMENT=?
10	Key in the applied moment (in-Kips) and calculate the flexural coefficient.	M	[R/S] [R/S] *	K= DEPTH COMP=?
11	If you are prompted for the depth of compression reinforcement, key it in.	d1	[R/S]	
12	See outputs of minimum steel area (if the computed area is less than the ACI minimum), the area of tension reinforcement, and, if you were asked for d1, the area of the required compression reinforcement.		 [R/S] * [R/S] * [R/S] *	AMIN= A1= A2= A1=?
13	Optional: Key in the steel areas based on the outputs above, and available bar sizes, to compute the ultimate moment.	A1 A2	[R/S] [R/S]	A2=? M=
14	For a new case go to step 1. *Press [R/S] if you do not have a printer.			

Example 1:

Determine the cross section and area of steel for a concrete beam, simply supported, and rectangular in shape, for the following data:

FY = 40,000 psi
F_c = 3,000 psi
M_u = 2,000 in-kips

Keystrokes: (SIZE ≥ 018)	Display:
■ [FIX] 2	
[XEQ] [ALPHA] RBEAM [ALPHA]	*FY=?*
40000 [R/S]	*Fc=?*
3000 [R/S]	*.75Pb=0.03*
[R/S] *	*.9KMAX=782.75*
[R/S] *	*WIDTH=?*

Based on experience, a width of 10 inches is selected.

10 [R/S]	*DEPTH=?*

Since $bd^2 = \dfrac{Mu}{.9KMAX}$

$$d = \sqrt{\frac{2{,}000{,}000}{(10)(782.75)}}$$

2 [EEX] 6 [ENTER↑] 10 [÷]	
782.75 [÷] [√x]	*15.98*

Therefore, use 16 inches for d.

16 [R/S]	*LMT REN? Y/N*
N [R/S]	*MOMENT=?*
2000 [R/S]	*K=868.06*
[R/S] *	*A1=4.44*

*Press [R/S] if you are not using a printer.

Example 2:

Determine the reinforcement for the section determined in Example 1, but limit reinforcement for deflection and compute the ultimate capacity for the bars selected. Use d1 = 2.38 in. Mu = 2,000 in-Kip.

Keystrokes: (SIZE ≥ 018)	Display:
[■] [FIX] 2	
[XEQ] [ALPHA] RBEAM [ALPHA]	FY=?
40000 [R/S]	Fc=?
3000 [R/S]	.75Pb=0.03
[R/S] *	.9KMAX=782.75
[R/S] *	WIDTH=?
10 [R/S]	DEPTH=?
16 [R/S]	LMT REN? Y/N
Y [R/S]	MOMENT=?
2000 [R/S]	K=868.06
[R/S] *	DEPTH COMP=?

This prompt (for depth of compression reinforcement) indicates compression reinforcement is required.

2.38 [R/S]	A1=3.97
[R/S] *	A2=1.81
[R/S] *	A1=?

The steel areas are closely approximated using 3, #7 bars in compression (1.80 in^2) and 4, #9 bars in tension (4.00 in^2). Calculate the ultimate moment for this design.

4 [R/S]	A2=?
1.8 [R/S]	M=2,013.12

*Press [R/S] if you are not using a printer.

Example 3:

Determine the area of reinforcement for the following rectangular concrete beam.

Mu = 2,750 in-kips
FY = 40,000 psi
Fc = 3000 psi
b = 10''
d = 16''
d1 = 2.50 in

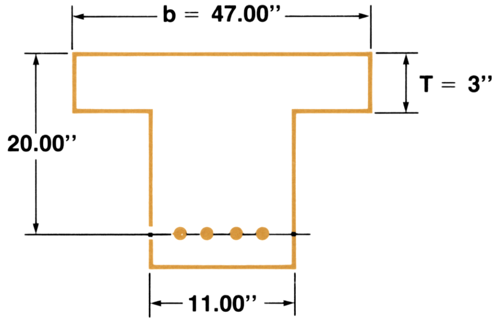
Keystrokes: (SIZE ⩾ 018)	Display:
■ [FIX] 2	
[XEQ] [ALPHA] RBEAM [ALPHA]	FY=?
40000 [R/S]	Fc=?
3000 [R/S]	.75Pb=0.03
[R/S] *	.9KMAX=782.75
[R/S] *	WIDTH=?
10 [R/S]	DEPTH=?
16 [R/S]	LMT REN? Y/N
N [R/S]	MOMENT=?
2750 [R/S]	K=1,193.58
[R/S] *	DEPTH COMP=?
2.5 [R/S]	A1=5.99
[R/S] *	A1=1.54

*Press [R/S] if you are not using a printer.

Example 4:

Determine the required reinforcing for the following concrete "T" beam.

FY = 60,000 psi
Fc = 3000 psi
b = 47.00 in
b1 = 11.00 in
d = 20.00 in
d1 = 2.50 in
T = 3.00 in
M = 6,400 in-kips



Keystrokes: (SIZE ⩾ 018)	Display:
[■] [FIX] 2	
[XEQ] [ALPHA] TBEAM [ALPHA]	*FY=?*
60000 [R/S]	*Fc=?*
3000 [R/S]	*.75 Pb=0.02*
[R/S] *	*.9KMAX=702.05*
[R/S] *	*WIDTH=?*
47 [R/S]	*STEM WIDTH=?*
11 [R/S]	*DEPTH=?*
20 [R/S]	*THICKNESS=?*
3 [R/S]	*LMT REN? Y/N*
N [R/S]	*MOMENT?*
6400 [R/S]	*K=458.23*
[R/S] *	*A1=6.46*

*Press [R/S] if you are not using a printer.

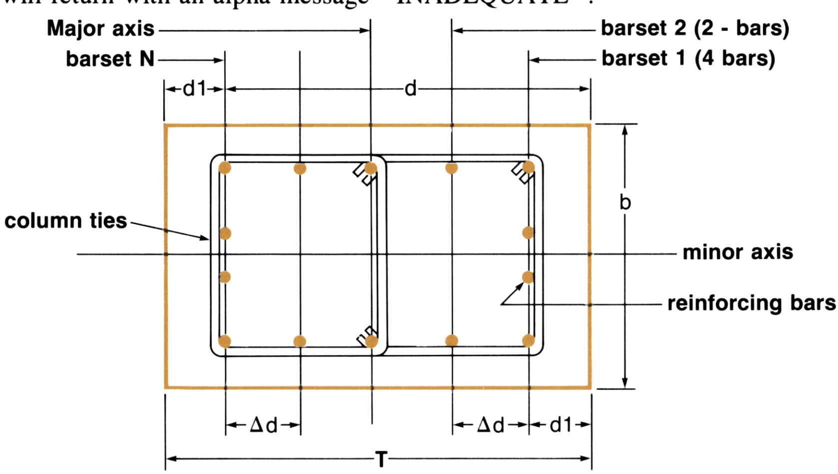
REINFORCED CONCRETE COLUMNS—ULTIMATE STRENGTH DESIGN

This program computes the ultimate capacity of short concrete columns, either square or rectangular, with any combination of reinforcing. Either axis may be investigated.

The 1977 American Concrete Institute code is followed in determining the allowable fiber stress in the reinforcing and in the concrete. Automatic checks are made for maximum and minimum reinforcing percentages in the computation of the maximum allowable axial force, PMAX. If the required percentages are less than or greater than allowable, the program stops with an alpha description of the problem.

The program uses an iterative technique to determine the capacity which satisfies the design eccentricity. The neutral axis is moved until the calculated eccentricity equals the design eccentricity. For each location of the neutral axis the size of the concrete stress block, the strains on each barset group and the allowable stress are calculated. The total area in each barset is then multiplied by the allowable stress to obtain the force, either tension or compression, which is summed. The force is multiplied by its distance from the center line of the section to determine the moment. This procedure continues until the computed value of the eccentricity agrees with the design eccentricity. At this point the program will output the axial capacity P and moment capacity M of the computed eccentricity. The location of the neutral axis c is also output for any manual checking that may be desired.

If the neutral axis reaches the position of the last barset group from the primary face, the column is considered inadequate as a compression member subject to bending. Beyond this, the section could be considered as a flexure member, which is beyond the scope of this analysis. If this condition occurs the program will return with an alpha message "INADEQUATE".



Definitions:

eb is the eccentricity at the balance point where tension equals compression (inches);

e is the design eccentricity (inches);

c is the location of the neutral axis (inches);

N-BARSETS is the number of barsets;

b is the width of the column (inches);

T is the depth of the column (inches);

d is the depth from the front face to the centroid of the last barset group (inches);

d1 is the distance from the back face to the centroid of the last barset group (assumed equal to the distance from the front face to the centroid of the first barset group) (inches);

FY is the ultimate strength of steel (psi);

Fc is the ultimate compressive strength of concrete (psi);

P is the design axial capacity (kips);

Mb is the balanced moment (kip-in);

Pb is the balanced axial capacity (kips);

M is the design moment capacity (kip-in).

Remarks:

Large columns with large eccentricities and large columns with extremely small eccentricities may take a long time to solve.

The program assumes that the barset spacing is equal.

For ($P \leq .1Fc \times AREA$), the member becomes more of a flexure member, which is beyond the scope of this program.

This program is for short concrete columns only. Slenderness must be taken into account according to the A.C.I. code.

Very small eccentricity (the neutral axis approaches infinity) is an unreasonable situation and probably would take many hours to solve. Therefore, limit e to at least 10 percent of T.

Either axis may be investigated by considering it the major axis.

References:

ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318-77), American Concrete Institute.

Winter, Urguhart, O'Rourke and Nilson, *Design of Concrete Structures,* McGraw-Hill, 1964.

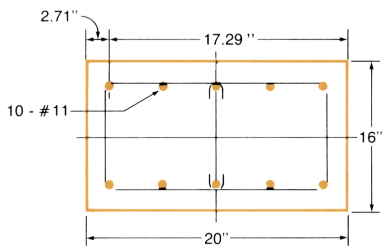
				SIZE: 21+N
STEP	**INSTRUCTIONS**	**INPUT**	**FUNCTION**	**DISPLAY**
1	Initialize the program.		[XEQ] CONCOL	FY=?
2	Key in the ultimate strength of steel.	FY	[R/S]	Fc=?
3	Key in the ultimate strength of concrete.	Fc	[R/S]	WIDTH=?
4	Key in the width of the column.	b	[R/S]	THICKNESS=?
5	Key in the depth of the column.	T	[R/S]	DEPTH 1ST=?
6	Key in the depth of first barset group.	d1	[R/S]	N−BARSETS=?
7	Key in the number of barset groups.	N-BARSETS	[R/S]	AREAS 1..N=?
8	Key in the area of barset groups.	A1 A2 :	[R/S] [R/S] :	AREAS 1..N=? AREAS 1..N=? :
9	Key in the last area and output maximum load, eccentricity at the balance point, balanced moment, and design axial capacity.	AN	[R/S] [R/S] * [R/S] * [R/S] * [R/S] *	PMAX= eb= Mb= Pb= e=?
10	Key in design eccentricity (e=M/P where M is the design moment and P is the design load).	e	[R/S] ** [R/S] * [R/S] * [R/S] *	e= M= P= c=
11	For a new case go to step 1. *Press [R/S] if you are not using a printer. **This is a lengthy calculation.			

Example 1:

For a 16'' × 20'' concrete column with 10-#11 bars determine:PMAX, eb, Pb, Mb and the capacity for an eccentricity of 12 inches.

FY = 60,000 psi
Fc = 4,000 psi

Solution SIZE = 21 + 5 = 26



Each barset = 2 – #11
#11 bar As = 1.56 in²
2(1.56) = 3.12 in²

Keystrokes: (SIZE ≥ 026)	**Display:**
FIX 2	
XEQ ALPHA CONCOL ALPHA	*FY=?*
60000 R/S	*Fc=?*
4000 R/S	*WIDTH=?*
16 R/S	*THICKNESS=?*
20 R/S	*DEPTH 1ST=?*
2.71 R/S	*N - BARSETS=?*
5 R/S	*AREAS 1..N=?*
3.12 R/S	*AREAS 1..N=?*
3.12 R/S	*AREAS 1..N=?*
3.12 R/S	*AREAS 1...N=?*
3.12 R/S	*AREAS 1...N=?*
3.12 R/S	*PMAX=1,103.74*
R/S *	*eb=12.74*
R/S *	*Mb=4,194.49*
R/S *	*Pb=329.34*
R/S *	*e=?*
12 R/S **	*e=12.00*
R/S *	*M=4,159.79*
R/S *	*P=346.76*
R/S *	*c=10.38*

* Press R/S if you are not using a printer.

** This is a lengthy calculation.

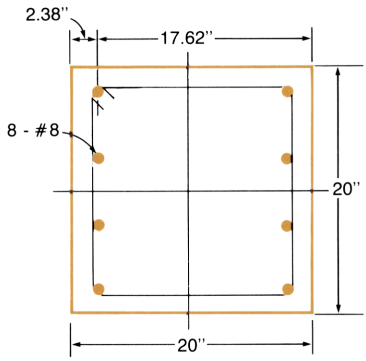
Example 2:

For a 20'' × 20'' concrete column with 8-#8 bars determine: PMAX, eb, Pb, Mb and the capacity, for an eccentricity of 4 inches.

FY = 60,000 psi

Fc = 5,000 psi

Solution: SIZE = 21 + 2 = 23



Each barset = 4 #8
1 #8 = .79 in^2
4(.79) = 3.16 in^2

Keystrokes:	Display:
■ [FIX] 2	
[XEQ] [ALPHA] CONCOL [ALPHA]	*FY=?*
60000 [R/S]	*Fc=?*
5000 [R/S]	*WIDTH=?*
20 [R/S]	*THICKNESS=?*
20 [R/S]	*DEPTH 1ST=?*
2.38 [R/S]	*N-BARSETS=?*
2 [R/S]	*AREAS 1N=?*
3.16 [R/S]	*AREAS 1N=?*
3.16 [R/S]	*PMAX=1,149.31*
[R/S] *	*eb=9.95*
[R/S] *	*Mb=4,844.29*
[R/S] *	*Pb=486.98*
[R/S] *	*e=?*
4 [R/S]	*e=4.00*
[R/S] *	*M=3,644.62*
[R/S] *	*P=911.17*
[R/S] *	*c=16.76*

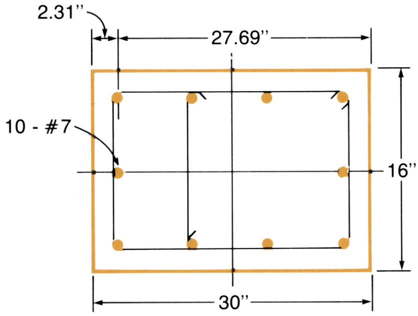
Example 3:

For a 16'' × 30'' concrete column with 10 – #7 bars determine PMAX, eb, Pb, Mb and the capacity, for an eccentricity e = 15.00 in.

FY = 40,000 psi

Fc= 3,750 psi

SIZE = 21 + 4 = 25

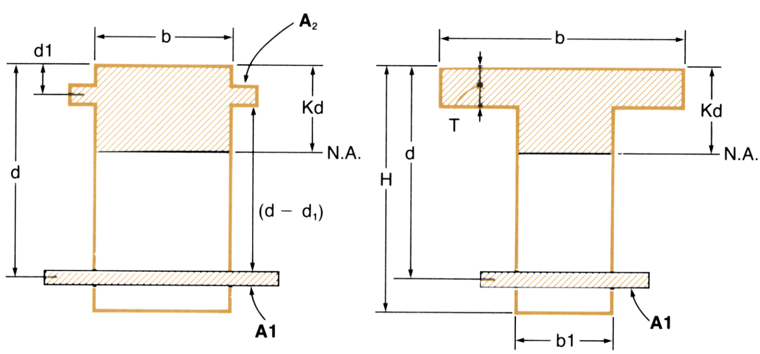


Barset #1 = 3 - #7 As = 1.8 in²
Barset #2 = 2 - #7 As = 1.2 in²
Barset #3 = 2 - #7 As = 1.2 in²
Barset #4 = 3 - #7 As = 1.2 in²

Keystrokes: (SIZE ≥ 025)	Display:
[■] [FIX] 2	
[XEQ] [ALPHA] CONCOL [ALPHA]	*FY=?*
40000 [R/S]	*Fc=?*
3750 [R/S]	*WIDTH=?*
16 [R/S]	*THICKNESS=?*
30 [R/S]	*DEPTH 1ST=?*
2.31 [R/S]	*N-BARSETS=?*
4 [R/S]	*AREAS 1..N=?*
1.8 [R/S]	*AREAS 1..N=?*
1.2 [R/S]	*AREAS 1..N=?*
1.2 [R/S]	*AREAS 1..N=?*
1.8 [R/S]	*PMAX=980.49*
[R/S] *	*eb=8.92*
[R/S] *	*Mb=5,348.45*
[R/S] *	*Pb=599.49*
[R/S] *	*e=?*
15 [R/S]	*e=15.00*
[R/S] *	*M=5,005.42*
[R/S] *	*P=333.68*
[R/S] *	*c=11.99*

EFFECTIVE MOMENT OF INERTIA FOR CONCRETE SECTIONS

This program calculates the depth of the neutral axis of a cracked section, the cracked moment of inertia, the moment at which cracking occurs, and the effective moment of inertia for a concrete section. Either "T" or rectangular sections may be analyzed. Both compression and tension reinforcement may be incorporated.



RECTANGULAR SECTION

T SECTION

Definitions:

b is the width of the compression flange or face (inches);

b1 is the width of the stem of a T-section (inches);

d is the depth from the compression face to the centroid of the tension steel (inches);

d1 is the depth from the compression face to the centroid of the compression steel (inches);

T is the thickness of the flange for T-beams (inches);

H is the total section height (inches);

Kd is the depth from the compression face to the neutral axis (inches);

A1 is the area of the tension steel (in^2);

A2 is the area of compression steel (in^2);

Fc is the compressive strength of the concrete (psi);

Ic is the moment of inertia for a cracked, transformed section (in^4);

Ie is the effective moment of inertia for deflection computations (in^4);

Ma is the maximum moment at the point where deflection is being considered;

Mc is the moment at which cracking occurs (units of Ma).

References:

ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318-77), American Concrete Institute.

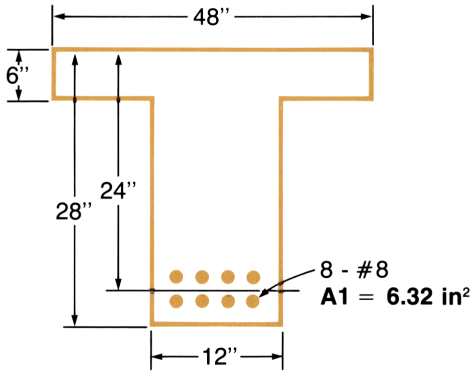
Winter, Urguhart, O'Rourke and Nilson, *Design of Concrete Structures,* McGraw-Hill, 1964.

				SIZE: 018
STEP	**INSTRUCTIONS**	**INPUT**	**FUNCTION**	**DISPLAY**
1	Initialize the program for T-section or rectangular section.		[XEQ] ITCON [XEQ] IRCON	Fc=?
2	Key in compression strength of concrete.	Fc	[R/S]	WIDTH=?
3a	Key in width of compression surface.	b	[R/S]	(STEM WIDTH=?)
3b	For T-section only, key in width of stem.	b1	[R/S]	DEPTH TEN=?
4	Key in depth of tension steel.	d	[R/S]	DEPTH COMP=?
5	Key in the depth of the compression steel (if no compression steel just press [R/S]).	(d1)	[R/S]	(THICKNESS=?)
6	For T-sections key in the thickness of the flange.	T	[R/S]	A TEN=?
7a	Key in the area of tension steel.	A1	[R/S]	A COMP=?
7b	If you keyed in the depth of the compression steel, key in the area of compression steel and calculate the distance to the neutral axis and the moment of inertia of the cracked transformed section.	(A2)	([R/S]) [R/S]* [R/S]*	Kd= Ic= Ma=?
8	Key in maximum moment where deflection is being checked.	Ma	[R/S]	TTL HEIGHT=?
9	Key in the total section height and calculate cracking moment and the effective moment of inertia.	H	[R/S] [R/S]*	Mc= Ie=
10	For a new case, go to step 1. *Press [R/S] if you are not using a printer.			

Example 1:

Determine the neutral axis, cracked moment of inertia, cracking moment, and effective moment of inertia for the section below.

Fc = 2500 psi
Ma = 2,000,000.00 in-lb



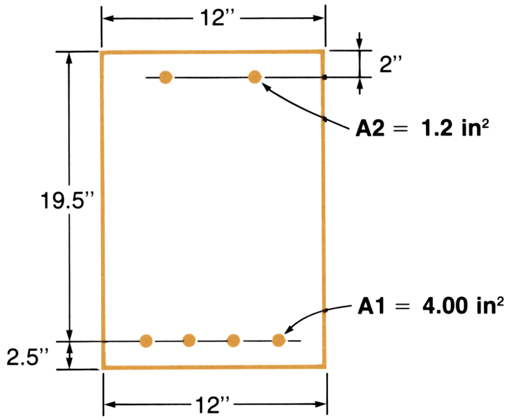
Keystrokes: (SIZE ⩾ 018)	Display:
[■] [FIX] 2	
[XEQ] [ALPHA] ITCON [ALPHA]	Fc=?
2500 [R/S]	WIDTH=?
48 [R/S]	STEM WIDTH=?
12 [R/S]	DEPTH TEN=?
24 [R/S]	DEPTH COMP=?
[R/S]	THICKNESS=?
6 [R/S]	A TEN=?
6.32 [R/S]	Kd=6.77
[R/S] *	Ic=23,721.51
[R/S] *	Ma=?
2000000 [R/S]	TTL HEIGHT=?
28 [R/S]	Mc=788,928.74
[R/S] *	Ie=24,629.15

*Press [R/S] if you are not using a printer.

Example 2:

Determine the neutral axis, cracked moment of inertia, cracking moment and effective moment of inertia for the section below.

Fc = 2500 psi
Ma = 2,100,000 lb-in



Keystrokes: (SIZE ≥ 018)	**Display:**
■ [FIX] 2	
[XEQ] [ALPHA] IRCON [ALPHA]	*Fc=?*
2500 [R/S]	*WIDTH=?*
12 [R/S]	*DEPTH TEN=?*
19.5 [R/S]	*DEPTH COMP=?*
2 [R/S]	*A TEN=?*
4 [R/S]	*A COMP=?*
1.2 [R/S]	*Kd=7.61*
[R/S] *	*Ic=8,135.29*
[R/S] *	*Ma=?*
2100000 [R/S]	*TTL HEIGHT=?*
22 [R/S]	*Mc=363,000.00*
[R/S] *	*Ie=8,148.27*

*Press [R/S] if you are not using a printer.

APPENDIX A

PROGRAM DATA

PROGRAM	#REGS TO COPY	DATA REGISTERS	FLAGS	DISPLAY FORMAT	SUBPROGRAMS CALLED
Section Properties	82	00=ΣA	00-First Input	ENG 3	SIZE?
		01=ΣM_y	01-Used		ATANY/X
		02=ΣM_x	21-Print		
		03=ΣI_x	27-User Mode		
		04=ΣI_y			
		05=ΣI_{xy}			
		06=$(x_{i+1} - x_i)$			
		07=$(y_{i+1} - y_i)$			
		08=$(x_{i+1} + x_i)$			
		09=$(y_{i+1} + y_i)$			
		10=x_i			
		11=y_i			
		12=x_{i+1}			
		13=y_{i+1}			
		14=scratch			
		15=scratch			
		16=counter			

Beams	93	00=Min	00-Edit	ANY	SIZE?
		01=Max	01-Angle/Shear		PRPLOT
		02=Plot	02-Shear		*W
		03=E*I	27-User Mode		*P
		04=Σ of load affects			*L
		05=Plot			*M
		06=x			
		07=Scratch/Plot			
		08=Scratch/Plot			
		09=L			
		10=x INC			
		11=Beam type (1-4)			
		12=Counter copy 1			
		13=Counter copy 2			
		14=Scratch			
		15=Scratch			
		16=Scratch			
		17=Scratch			
		18=Scratch			
		19=Counter			
		20−nnn=Loads			
Continuous Beams	54	See Beams	00-Edit	ENG 3	SIZE?
		20−nnn=Loads and Spans	01-Set		*B
			02-Cleared		*W
			21-Print		*P
			27-User Mode		*L
					*M

PROGRAM	# REGS TO COPY	DATA REGISTERS	FLAGS	DISPLAY FORMAT	SUBPROGRAMS CALLED
Continuous Frame Analysis	80	01, 06, 11, ... unbalanced moment storage 02, 05, 07, 10, ... distribution factor storage 03, 04, 08, 09, ... moment storage registers 00 & REG R(5N+3) control ...	21-Print 00-Used		SIZE?
RPN Vector Calculator	60	00=Pointer to x_r 01=Pointer to $x_\measuredangle$ 02=Last x_r 03=Last $x_\measuredangle$ 04=Scratch 05=Register_r 06=$\text{Register}_\measuredangle$ 07=Scratch 08=Stack_r 09=$\text{Stack}_\measuredangle$ 10=Stack_r 11=$\text{Stack}_\measuredangle$ 12=Stack_r 13=$\text{Stack}_\measuredangle$ 14=Stack_r 15=$\text{Stack}_\measuredangle$	22-Input	ANY	SIZE?

Steel Column Formula	38	00=Used	01-English/SI	SIZE?
		01=A		
		02=R		
		03=I		
		04=L		
		05=K		
		06=FY		
		07=Used		
		08=Used		
Reinforced Concrete Beams	78	00=FY	21-Test	SIZE?
		01=FC	00	
		02=b		
		03=b1		
		04=d		
		05=d1		
		06=T		
		07=A1/ϕ		
		08=A1/ϕ		
		09=ASF		
		10=bd^2		
		11=85		
		12=B_1		
		13=m		
		14=.75Pb		
		15=Kmax		
		16=Counter		
		17=Used		

PROGRAM	# REGS TO COPY	DATA REGISTERS	FLAGS	DISPLAY FORMAT	SUBPROGRAMS CALLED
Concrete	89	00=FY			SIZE?
Columns		01=Fc	01-Used		
		02=b	27-User		
		03=T			
		04=d			
		05=d1			
		06=N-BARSETS			
		07=Δ_b			
		08=ϵy			
		09=B_1			
		10=$c_1 c_b$			
		11=$\Delta\epsilon/\Delta c$			
		12=a			
		13=ϵ_{sn}			
		14=$B_{set\ n}$			
		15=P			
		16=M			
		17=e_d			
		18=ctr.			
		19=ctr.			
		20=Δc_1 ctr.			
		21=Δ_{s1}			
		22=Δ_{s2}			
		23=Δ_{snn}			

Effective Moment of Inertia for Concrete Sections	69	01=Fc 02=b 03=b1 04=d 05=d1 06=T 07=A1 08=A2 09=Igr 10=n, Ma/Mc 11=(b−b1) 12=nA1 13=(2n−1)A2 14=Kd 15=Icr 16=Ie, H 17=ctr. YT	21-Print 27-User 55-Test	SIZE?

Notes

HEWLETT PACKARD

1000 N.E. Circle Blvd., Corvallis, OR 97330

00041-90124

Printed in U.S.A.