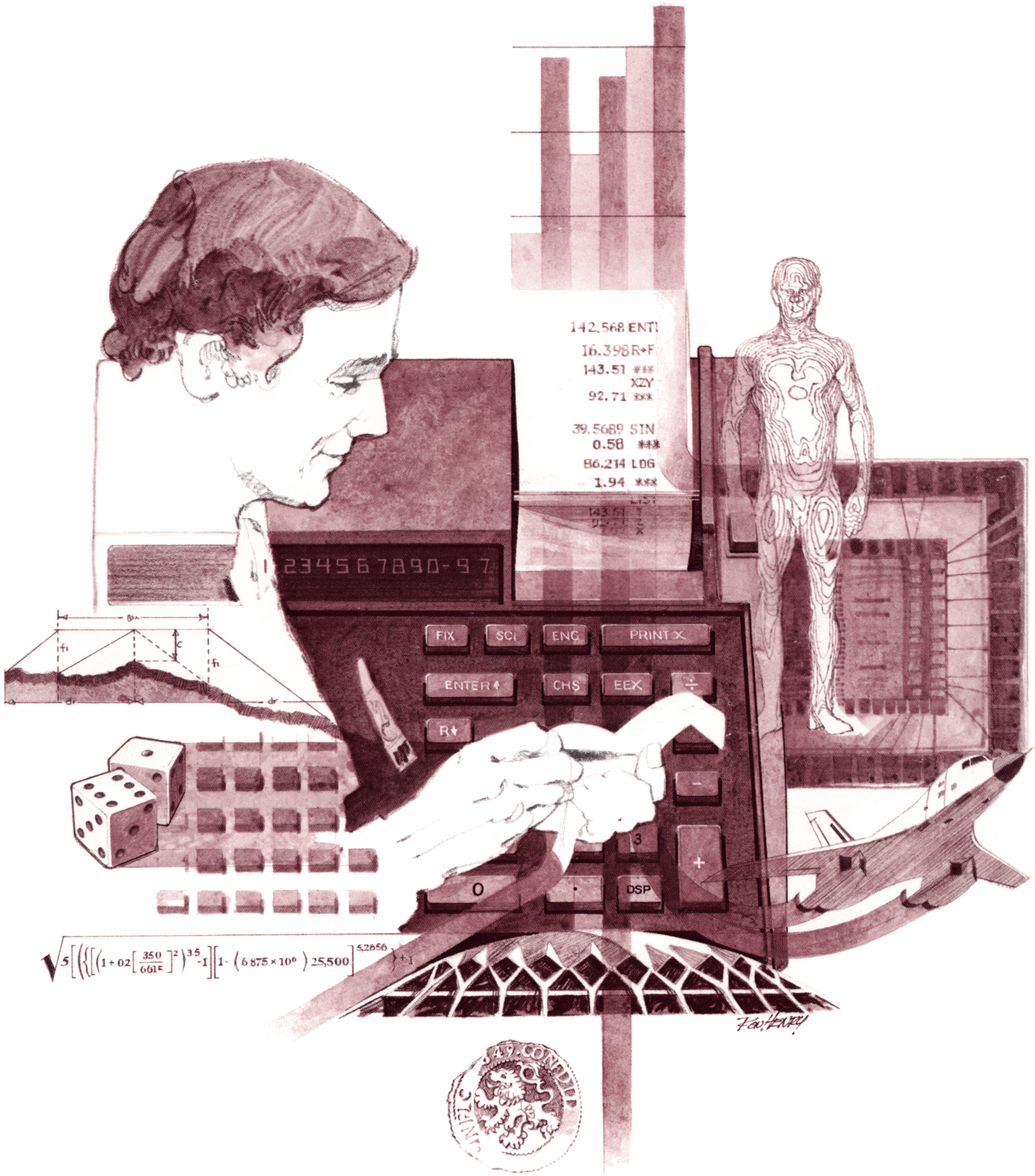
HEWLETT-PACKARD

HP-67/HP-97

Users' Library Solutions

Beams and Columns



INTRODUCTION

In an effort to provide continued value to it's customers, Hewlett-Packard is introducing a unique service for the HP fully programmable calculator user. This service is designed to save you time and programming effort. As users are aware, Programmable Calculators are capable of delivering tremendous problem solving potential in terms of power and flexibility, but the real genie in the bottle is program solutions. HP's introduction of the first handheld programmable calculator in 1974 immediately led to a request for program **solutions** — hence the beginning of the HP-65 Users' Library. In order to save HP calculator customers time, users wrote their own programs and sent them to the Library for the benefit of other program users. In a short period of time over 5,000 programs were accepted and made available. This overwhelming response indicated the value of the program library and a Users' Library was then established for the HP-67/97 users.

To extend the value of the Users' Library, Hewlett-Packard is introducing a unique service—a service designed to save you time and money. The Users' Library has collected the best programs in the most popular categories from the HP-67/97 and HP-65 Libraries. These programs have been packaged into a series of low-cost books, resulting in substantial savings for our valued HP-67/97 users.

We feel this new software service will extend the capabilities of our programmable calculators and provide a great benefit to our HP-67/97 users.

A WORD ABOUT PROGRAM USAGE

Each program contained herein is reproduced on the standard forms used by the Users' Library. Magnetic cards are not included. The Program Description I page gives a basic description of the program. The Program Description II page provides a sample problem and the keystrokes used to solve it. The User Instructions page contains a description of the keystrokes used to solve problems in general and the options which are available to the user. The Program Listing I and Program Listing II pages list the program steps necessary to operate the calculator. The comments, listed next to the steps, describe the reason for a step or group of steps. Other pertinent information about data register contents, uses of labels and flags and the initial calculator status mode is also found on these pages. Following the directions in your HP-67 or HP-97 **Owners' Handbook and Programming Guide,** "Loading a Program" (page 134, HP-67; page 119, HP-97), key in the program from the Program Listing I and Program Listing II pages. A number at the top of the Program Listing indicates on which calculator the program was written (HP-67 or HP-97). If the calculator indicated differs from the calculator you will be using, consult Appendix E of your **Owner's Handbook** for the corresponding keycodes and keystrokes converting HP-67 to HP-97 keycodes and vice versa. No program conversion is necessary. The HP-67 and HP-97 are totally compatible, but some differences do occur in the keycodes used to represent some of the functions.

A program loaded into the HP-67 or HP-97 is not permanent—once the calculator is turned off, the program will not be retained. You can, however, permanently save any program by recording it on a blank magnetic card, several of which were provided in the Standard Pac that was shipped with your calculator. Consult your **Owner's Handbook** for full instructions. A few points to remember:

> The Set Status section indicates the status of flags, angular mode, and display setting. After keying in your program, review the status section and set the conditions as indicated before using or permanently recording the program.
>
> REMEMBER! To save the program permanently, **clip** the corners of the magnetic card once you have recorded the program. This simple step will protect the magnetic card and keep the program from being inadvertently erased.

As a part of HP's continuing effort to provide value to our customers, we hope you will enjoy our newest concept.

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This program performs an interchangeable solution for the four properties of slender compression members or columns P_{cr}, the critical buckling load, E, the modulus of elasticity, I, the minimum moment of inertia, and l, the length of the member.

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This program calculates the maximum deflection, the maximum moment, and the maximum stress in an eccentrically loaded column under compressive stress.

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This program can be used in the design and analysis of reinforced concrete beams in accordance with the strength design method of the American Concrete Institute Code (ACI 318-71). The program solves interchangeably between steel area, width, depth, concrete strength, steel strength, and internal moment.

CONCRETE BEAM DEFLECTION 18

This program calculates the long term total load deflection for a simply supported concrete beam or slab or rectangular cross section with uniform loading by the method described in the 1971 ACT Building Code. Effects of compression steel on creep deflection are taken into account. The portion of deflection due to creep is also printed.

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This program calculates the maximum stress in flange of the wide flange steel beam loaded eccentrically with one concentrated load. It also calculates the angle of twist due to torsion. Beam could be cantilever, simple span, or interior span of continuous beam.

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This program calculates the maximum stress in flange of the wide flange steel beam loaded eccentrically with uniform load. It also calculates the angle of twist due to torsion. Beam could be cantilever, simple span or interior span of continuous beam.

A.I.S.C. STEEL COLUMN FORMULA 33

Program computes allowable loads for steel columns. Column ends must be constrained by welds, rivets, or in some other manner which prevents deflection and rotation. Either English or SI units may be used.

CONCRETE COLUMNS ULTIMATE STRENGTH DESIGN 40

This program computes the ultimate capacity of short concrete columns, square or rectangular with reinforcing in 2-faces symmetrically placed about and parallel to the major axis. A balanced condition where tension equals compression, pure compression, or any design eccentricity may be considered.

COLUMN STRENGTH 50

The program calculates the average crippling stress of a column cross section. The column strength is determined from the Johnson & Euler column equations. The inputs are modulus of elasticity compressive yield stress length over radius of gyration number of rectangular elements width and thickness of each element one or no edge free. Output is column strength and crippling stress.

BEAM ON ELASTIC FOUNDATION WITH POINT LOAD-ANY LOCATION 55

Program determines deflection, slope, moment and shear for any point on a finite beam on elastic foundation subjected to concentrated force applied at any location of the beam.

Program Description I

Program Title COMPRESSIVE BUCKLING

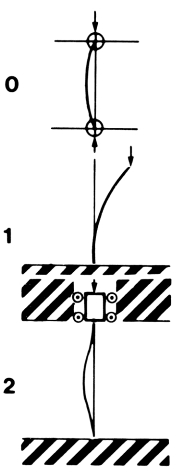
Contributor's Name Hewlett-Packard, Corvallis Division
Address 1000 N. E. Circle Blvd.
City Corvallis **State** OR **Zip Code** 97330

Program Description, Equations, Variables

This program performs an interchangeable solution for the four properties of slender compression members or columns: P_{cr}, the critical buckling load; E, the modulus of elasticity; I, the minimum moment of inertia; and ℓ, the length of the member.

Equations:

Three configurations are possible, identified by the number of fixed ends on the member: 0, both ends hinged; 1, one end free and one fixed; 2, both ends fixed.



Configuration 0 $$P_{cr} = \frac{\pi^2 EI}{\ell^2}$$

Configuration 1 $$P_{cr} = \frac{\pi^2 EI}{4\ell^2}$$

Configuration 2 $$P_{cr} = \frac{4\pi^2 EI}{\ell^2}$$

Remarks: Uncertainties such as the amount of restraint at the ends, eccentricity of the load, initial warp, nonhomogeneity of the material and deflection caused by lateral loads, can cause very significant changes in the behavior of a compressive member.

Program Description II

Sketch(es)

Sample Problem(s)

Example 1:

If an 8 inch steel ($E = 30 \times 10^6$ psi) piston rod (a piston rod has zero fixed ends) must withstand a load of 15000 pounds without buckling, what moment of inertia must it have?

Keystrokes:

0 **A** 15000 **B** 30 [EEX] 6 **C** 8 **E** ⟶ 0.00

D ⟶ 3.242×10^{-3}

Example 2:

Steel columns 40 feet long are used to support a bridge. What is the maximum load that the column can withstand without buckling? Assume 1 fixed end. $E = 30 \times 10^6$ psi, $I = 700\ in^4$.

Keystrokes:

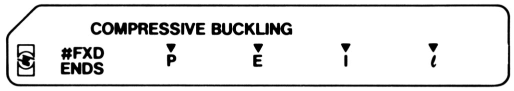
1 **A** 30 [EEX] 6 **C** 700 **D** 40 [↑] 12 [×] **E** ⟶ 0.000×10^0

B ⟶ 2.249×10^5

Solution(s)

Reference(s) This program is a translation of HP-65 SA1-22A.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Select column geometry by			
	inputting number of fixed ends	0,1, or 2	A	0,1, or 2
3	Input three of the following			
	vertical load	P	B	0.00
	modulus of elasticity	E	C	0.00
	moment of inertia	I	D	0.00
	length of column	ℓ	E	0.00
4	Compute remaining value			
	vertical load	0.00	B	P
	modulus of elasticity	0.00	C	E
	moment of inertia	0.00	D	I
	length of column	0.00	E	ℓ
5	For new case with same type of			
	column go to step 3. For a new			
	type of column go to step 2.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	Pi	16-24	
003	ENT↑	-21	
004	×	-35	
005	STO1	35 01	
006	R↓	-31	Store constant
007	0	00	based on number of
008	X=Y?	16-33	fixed ends
009	RTN	24	
010	CLX	-51	
011	4	04	
012	ST÷1	35-24 01	
013	CLX	-51	
014	1	01	
015	X=Y?	16-33	
016	RTN	24	
017	CLX	-51	
018	1	01	
019	6	06	
020	ST×1	35-35 01	
021	2	02	
022	RTN	24	
023	*LBLB	21 12	
024	STO2	35 02	P
025	0	00	
026	X≠Y?	16-32	
027	RTN	24	
028	RCL1	36 01	
029	RCL3	36 03	
030	×	-35	
031	RCL4	36 04	
032	×	-35	
033	RCL5	36 05	
034	÷	-24	
035	STO2	35 02	
036	RTN	24	
037	*LBLC	21 13	
038	STO3	35 03	E
039	0	00	
040	X≠Y?	16-32	
041	RTN	24	
042	RCL2	36 02	
043	RCL1	36 01	
044	÷	-24	
045	RCL4	36 04	
046	÷	-24	
047	RCL5	36 05	
048	×	-35	
049	STO3	35 03	
050	RTN	24	
051	*LBLD	21 14	
052	STO4	35 04	1
053	0	00	
054	X≠Y?	16-32	
055	RTN	24	
056	RCL2	36 02	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	RCL1	36 01	
058	÷	-24	
059	RCL3	36 03	
060	÷	-24	
061	RCL5	36 05	
062	×	-35	
063	STO4	35 04	
064	RTN	24	
065	*LBLE	21 15	
066	ENT↑	-21	
067	×	-35	
068	STO5	35 05	ℓ
069	0	00	
070	X≠Y?	16-32	
071	RTN	24	
072	RCL1	36 01	
073	RCL2	36 02	
074	÷	-24	
075	RCL3	36 03	
076	×	-35	
077	RCL4	36 04	
078	×	-35	
079	STO5	35 05	
080	√X	54	
081	RTN	24	
090			
100			
110			

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☐
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☒
3	☐	☒			n	3

REGISTERS

0	1	2	3	4	5	6	7	8	9
	#Ends and C	P	E	1	ℓ^2				Used

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title **ECCENTRICALLY LOADED COLUMNS**

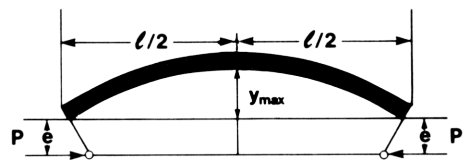
Contributor's Name Hewlett-Packard, Corvallis Division

Address 1000 N. E. Circle Blvd.

City Corvallis **State** OR **Zip Code** 97330

Program Description, Equations, Variables

This program calculates the maximum deflection, the maximum moment, and the maximum stress in an eccentrically loaded column under compressive stress.



Equations:

$$y_{max} = e\left[\sec\frac{\ell}{2}\sqrt{\frac{P}{EI}} - 1\right]$$

$$M_{max} = P\,[e + y_{max}]$$

$$s_{max} = \frac{P}{A}\left[1 + \frac{ecA}{I}\sec\frac{\ell}{2}\sqrt{\frac{P}{EI}}\right]$$

Operating Limits and Warnings

Remarks: Columns must be of constant cross section. Stresses may not exceed the elastic limit of the material.

Program Description I

Program Title ECCENTRICALLY LOADED COLUMNS

Contributor's Name Hewlett-Packard, Corvallis Division

Address 1000 N. E. Circle Blvd.

City Corvallis **State** OR **Zip Code** 97330

Program Description, Equations, Variables

where:

y_{max} is the maximum deflection;

e is the eccentricity;

ℓ is the column length;

P is the compressive load;

E is the modulus of elasticity;

I is the moment of inertia;

M_{max} is the maximum internal moment;

s_{max} is the maximum normal stress in the column;

c is the distance from the neutral axis of the column to the outer surface;

A is the area of the cross section;

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Example:

A column 50 feet long is to support 8000 pounds. The load is to be offset 6 inches. What are the maximum values of deflection, moment, and stress in the member?

$E = 30 \times 10^6$

$I = 107\ in^4$

$A = 7\ in^2$

$c = 2$ in

Keystrokes:

107 [↑] 30 [EEX] 6 [↑] 50 [↑]

12 [×] [A] 6 [↑] 8000 [B] [C] ——→ 0.74

[D] ——→ 53936.76 in-lb

2 [↑] 7 [E] ——→ 2151.02 psi

Solution(s)

Reference(s)

1. This program is a translation of the HP-65 SA1-23A
2. Spotts, M. F.

   Design of Machine Elements, Prentice-Hall, 1971

User Instructions

ECCENTRICALLY LOADED COLUMNS

$I \uparrow E \uparrow \ell$ | $e \uparrow P$ | $\rightarrow y_{max}$ | $\rightarrow M_{max}$ | $c \uparrow A \rightarrow s_{max}$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Input moment of inertia	I	↑	I
	then input modulus of			
	elasticity	E	↑	E
	then input length of column	I	A	I
	Input eccentricity	e	↑	e
	then input load	P	B	e
3	Calculate maximum deflection		C	y_{max}
	or calculate maximum			
	moment		D	M_{max}
	or input distance from			
	neutral axis	c	↑	c
	then section area and cal-			
	culate maximum stress	A	E	s_{max}
4	For new case go to step 2 and			
	change inputs.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO3	35 03	
003	R↓	-31	Store I, E and ℓ
004	STO2	35 02	
005	X⇄Y	-41	
006	STO1	35 01	
007	RTN	24	
008	*LBLB	21 12	
009	STO5	35 05	Store e and P
010	X⇄Y	-41	
011	STO4	35 04	
012	RTN	24	
013	*LBLC	21 13	
014	RCL5	36 05	Calculate Y_{max}
015	RCL2	36 02	
016	÷	-24	
017	RCL1	36 01	
018	÷	-24	
019	√X	54	
020	RCL3	36 03	
021	×	-35	
022	2	02	
023	÷	-24	
024	RAD	16-22	
025	COS	42	
026	DEG	16-21	
027	1/X	52	
028	1	01	
029	-	-45	
030	RCL4	36 04	
031	×	-35	
032	RTN	24	
033	*LBLD	21 14	Calculate M_{max}
034	GSBC	23 13	
035	RCL4	36 04	
036	+	-55	
037	RCL5	36 05	
038	×	-35	
039	RTN	24	
040	*LBLE	21 15	
041	STO7	35 07	
042	X⇄Y	-41	
043	STO6	35 06	
044	RCL5	36 05	
045	RCL2	36 02	
046	÷	-24	
047	4	04	
048	÷	-24	
049	RCL1	36 01	Calculate s_{max}
050	÷	-24	
051	√X	54	
052	RCL3	36 03	
053	×	-35	
054	RAD	16-22	
055	COS	42	
056	DEG	16-21	
057	1/X	52	
058	RCL4	36 04	
059	×	-35	
060	RCL6	36 06	
061	×	-35	
062	RCL1	36 01	
063	÷	-24	
064	RCL7	36 07	
065	×	-35	
066	1	01	
067	+	-55	
068	RCL5	36 05	
069	×	-35	
070	RCL7	36 07	
071	÷	-24	
072	RTN	24	
080			
090			
100			
110			

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

REGISTERS

0	1	2	3	4	5	6	7	8	9
	1	E	ℓ	e	P	c	A		Used

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title Reinforced Concrete Beams

Contributor's Name Hewlett-Packard

Address 1000 N. E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

This program can be used in the design and analysis of rectangular reinforced concrete beams in accordance with the strength design method of the American Concrete Institute Code (ACI 318 - 71). The program solves interchangeably between the following six variables:

- A_s - The area of nonprestressed tension reinforcement (psi or kg/cm^2);
- b - The width of the member (in or cm);
- M - The maximum internal bending moment (lb-in or kg-cm);
- d - The depth to the cetroid of the reinforcing steel (in or cm);
- f_c - The compressive strength of the concrete (psi or kg/cm^2)
- f_y - The yield strength of the steel (psi or kg/cm^2)

During calculation of the parameters listed above, the calculator checks to be sure that enough reinforcement has been specified to meet the minimum allowable value:

$$\frac{A_s}{bd} > \frac{200}{f_y}$$

(Continued next page)

Operating Limits and Warnings This program is intended as an aid to computation and cannot replace an understanding of ACI 318 - 71.

This program does not check for deflection of shear stress modes of failure. Refer to ACI 318 - 71 for specifics on deflection and shear stress.

If this condition is not met the display will flash 10.50 which signifies that the design does not meet section 10.5 of the ACI code. Stop the flashing by pressing [R/S]. Press [R↓] to see the current value of A_s. Press [R↓] again to see the minimum allowable value of A_s. Pressing [A] at this point stores the minimum value of A_s and readys the calculator for calculation of the desired variable.

The program also checks for too much steel. Code section 10.32 specifies the maximum steel area as:

$$\frac{A_{smax}}{b\ d} = (0.6375)\ \beta_1 \frac{f_c}{f_y} \frac{87000}{87000 + f_y}$$

where

$$\beta_1 = \begin{cases} 0.85 \text{ for } f_c \leq 4000 \\ 0.85 - (f_c - 4000)/20000 \quad \text{for } f_c > 40 \end{cases}$$

If too much steel has been specified, the calculator flashes 10.32. Stop the flashing by pressing [R/S], then press [R↓] to see the current steel area. Press [R↓] again to see the maximum allowable tension steel area. Press [A] if you wish to use the maximum amount of steel in subsequent calculations.

If the program halts displaying "Error," the input values are mathematically impossible to satisfy. This may be due to an entry error (you may review the values by recalling R_1 for A_s, R_2 for b, R_3 for M etc....) or the configuration may be mathematically undefinned. If this is the case, increase the beam size and/or decrease the moment.

Optionally, the depth of the compression zone (a) may be calculated using the [f] [B] keys and the depth of the neutral axis (NA) may be calculated using [f] [C]. The depth of the neutral axis is important since T-beams may be modeled as rectangular beams if the slab or flange equals or excedes the depth of the neutral axis.

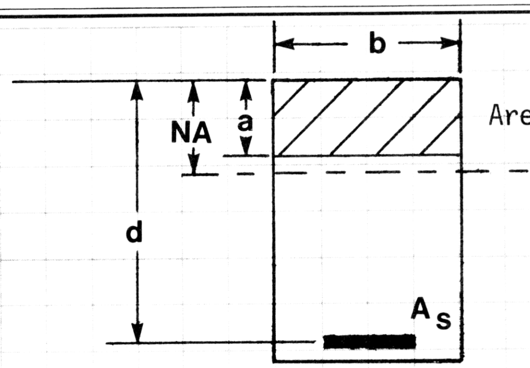
Equations:

$$M = d\ \phi\ A_s\ f_y - (0.59\ \phi\ A_s^2\ f_y^2)/(b\ f_c)$$

$$\phi = \text{factor of safety} = 0.9$$

Program Description II

Sketch(es)



Sample Problem(s) Example 1.

For the specifications below, calculate the amount of reinforcing steel required.

$M = 1.2 \times 10^6$ in-lb b = 18 in d = 26 in f_c = 3500 psi f_y = 50000 psi

Keystrokes:	Outputs:
[f] [A] [f] [A]----→	0.000×10^0 (Set for English units.)
1.2 [EEX] 6 [C] 18 [B] 26 [D] 3500 [E] 50000 [f] [E]	
[A]----→	"10.50×10^0"

(Flashing display indicates that calculated steel area is too small to meet ACI minimum as specified in ACI 10.5. Press [R/S] to halt the flashing display. Press [R↓] to see the calculated value, then press [R↓] again to see the minimum value, then use the minimum value to recalculate M.)

[R/S] [R↓]----→	1.045×10^0 in^2 (calc)
[R↓]----→	1.872×10^0 in^2 (min)
[A] [C]----→	2.116×10^6 in-lb (M)

Reference(s)

ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318 - 71), American Concrete Institute, May 1976 printing.

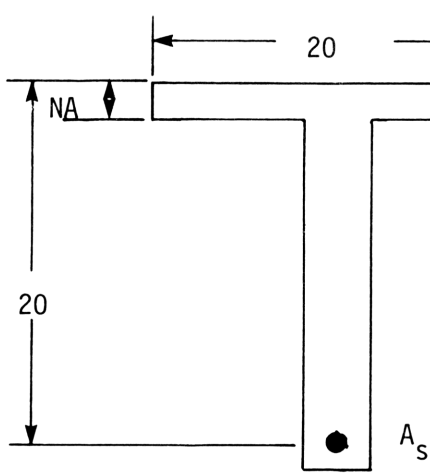
Example 2.
For the beam specifications below, calculate the area of steel required.

b = 25 cm   d = 30 cm   M = 1.6 x 10^6 kg-cm f_c = 281 kg/cm^2 f_y = 4219 kg/cm^2

Keystrokes: Outputs:
[f] [A]---→ 1.000 x 10^0 (metric units)
25 [B] 30 [D] 1.6 [EEX] 6 [C] 281 [E] 4219 [f] [E]
[A]---→ 10.32 x 10^0
(Flashing display indicates that calculated steel area is too large to meet ACI specification 10.32. Press [R/S] to halt flashing display. Press [R↓] to see calculated value, then [R↓] again to see maximum value.)
[R/S] [R↓]---→ 17.78 x 10^0 cm^2
[R↓]--→ 16.02 x 10^0 cm^2
Using 16 cm^2 for A_s, what is the minimum value for d?
16 [A] [D]---→ 32.01 x 10^0 cm

Example 3.
Calculate the area of the steel and the depth of the slab or flange for the T-beam data below. Use the depth of the neutral axis as the minimum depth of the flange so that the T-beam can be modeled as a rectangular beam.

M = 2 x 10^6 in-lb   b = 20 in   d = 20 in f_c = 4000 psi f_y = 60,000 psi



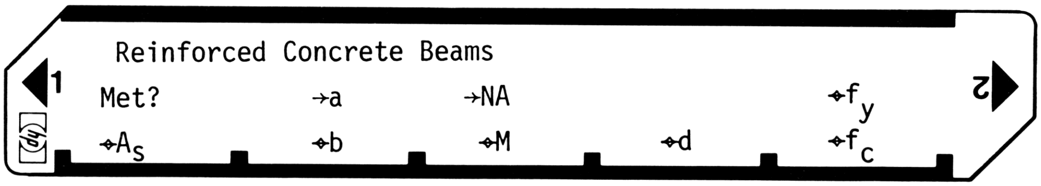
Keystrokes: Outputs:

[f] [A] [f] [A]--→ 0.000×10^0 (English units)

2 [EEX] 6 [C] 20 [B] 20 [D] 4000 [E] 60000 [f] [E] [A]-→ 1.935×10^0 in^2 (A_s)

[f] [C]--→ 2.014×10^0 in (Neutral axis depth and minimum flange depth.)

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Load side 1 and side 2.				
2	Optional: toggle metric units (1 = kilograms				
	and centimeters) or English units (0 = pounds				
	and inches).		f	A	1 or 0
3	Input 5 of the following variables:				
	Area of tension reinforcement	A_s	A		A_s
	Width of beam	b	B		b
	Bending moment	M	C		M
	Depth of section to centroid of steel	d	D		d
	Compressive strength of concrete	f_c	E		f_c
	Yield strength of tension reinforcement	f_y	f	E	f_y
4	Calculate remaining unknown value:				
	Area of tension reinforcement		A		A_s
	Width of beam		B		b
	Bending moment		C		M
	Depth of section to centroid of steel		D		d
	Compressive strength of concrete		E		f_c
	Yield strength of tension reinforcement		f	E	f_y
5	If step 4 resulted in an "Error" or a flahing				
	display, refer to description for explanation.				
6	Optional: Calculate depth of compressive				
	stress block		f	B	a
	and/or depth of neutral axis		f	C	NA
7	For a new case, go to step 3 and change any				
	or all of the input values.				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLe	21 16 15	
002	6	06	Input values and store control code.
003	GTO0	22 00	
004	*LBLA	21 11	
005	1	01	
006	GTO0	22 00	
007	*LBLB	21 12	
008	2	02	
009	GTO0	22 00	
010	*LBLC	21 13	
011	3	03	
012	GTO0	22 00	
013	*LBLD	21 14	
014	4	04	
015	GTO0	22 00	
016	*LBLE	21 15	
017	5	05	
018	*LBL0	21 00	
019	STOI	35 46	
020	R↓	-31	
021	STO i	35 45	
022	F3?	16 23 03	
023	RTN	24	
024	1	01	Calculate for all interchangeable solutions.
025	STO i	35 45	
026	.	-62	
027	5	05	
028	9	09	
029	RCL5	36 05	
030	RCL2	36 02	
031	×	-35	
032	÷	-24	
033	RCL1	36 01	
034	RCL6	36 06	
035	×	-35	
036	×	-35	
037	LSTX	16-63	
038	.	-62	
039	9	09	
040	×	-35	
041	×	-35	
042	LSTX	16-63	
043	RCL4	36 04	
044	×	-35	
045	GTO i	22 45	
046	*LBL1	21 01	Solve for A_s and f_y.
047	*LBL6	21 06	
048	CHS	-22	
049	ENT↑	-21	
050	R↓	-31	
051	X⇄Y	-41	
052	R↑	16-31	
053	X²	53	
054	X⇄Y	-41	
055	STO0	35 00	
056	4	04	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	×	-35	
058	RCL3	36 03	
059	×	-35	
060	-	-45	
061	√X	54	
062	+	-55	
063	RCL0	36 00	
064	÷	-24	
065	2	02	
066	÷	-24	
067	CHS	-22	
068	GTO0	22 00	
069	*LBL3	21 03	
070	X⇄Y	-41	Compute M.
071	-	-45	
072	GTO0	22 00	
073	*LBL2	21 02	Compute b and f_c.
074	*LBL5	21 05	
075	RCL3	36 03	
076	-	-45	
077	÷	-24	
078	GTO0	22 00	
079	*LBL4	21 04	
080	X⇄Y	-41	Compute d.
081	RCL3	36 03	
082	+	-55	
083	X⇄Y	-41	
084	÷	-24	
085	*LBL0	21 00	
086	STO i	35 45	Store metric constants.
087	2	02	
088	8	08	
089	1	01	
090	STO9	35 09	
091	6	06	
092	1	01	
093	1	01	
094	7	07	
095	STO8	35 08	
096	1	01	
097	4	04	
098	.	-62	
099	0	00	
100	6	06	
101	F0?	16 23 00	
102	GTO0	22 00	Store English constants if flag 0 is not set.
103	4	04	
104	EEX	-23	
105	3	03	
106	STO9	35 09	
107	8	08	
108	7	07	
109	EEX	-23	
110	3	03	
111	STO8	35 08	
112	2	02	

REGISTERS

0	1	2	3	4	5	6	7	8	9
Used	A_s	b	M	d	f_c	f_y	β_1	87000 / 6117	4000 / 281

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
					Control

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	0	00	
114	0	00	
115	*LBL0	21 00	
116	RCL6	36 06	Check for minimum reinforcing.
117	÷	-24	
118	RCL1	36 01	
119	RCL2	36 02	
120	RCL4	36 04	
121	×	-35	
122	÷	-24	
123	X>Y?	16-34	
124	GTO0	22 00	
125	R↓	-31	
126	LSTX	16-63	
127	×	-35	Reinforcing below minimum. Display code.
128	GSB8	23 08	
129	+	-55	
130	RCL1	36 01	
131	1	01	
132	0	00	
133	.	-62	
134	5	05	
135	*LBL7	21 07	
136	PSE	16 51	Pause loop.
137	GTO7	22 07	
138	*LBL0	21 00	Check for too much steel.
139	.	-62	
140	8	08	
141	5	05	
142	RCL5	36 05	
143	RCL9	36 09	
144	-	-45	
145	2	02	
146	EEX	-23	
147	4	04	
148	×	-35	
149	X<0?	16-45	
150	CLX	-51	
151	-	-45	
152	STO7	35 07	
153	.	-62	
154	6	06	
155	3	03	
156	7	07	
157	5	05	
158	×	-35	
159	RCL5	36 05	
160	×	-35	
161	RCL6	36 06	
162	÷	-24	
163	RCL8	36 08	
164	RCL6	36 06	
165	+	-55	
166	÷	-24	
167	RCL8	36 08	
168	×	-35	
169	X>Y?	16-34	
170	STO0	22 00	
171	RCL2	36 02	Set display for too much steel code and GTO 7.
172	RCL4	36 04	
173	×	-35	
174	×	-35	
175	GSB8	23 08	
176	-	-45	
177	RCL1	36 01	
178	1	01	
179	0	00	
180	.	-62	
181	3	03	
182	2	02	
183	GTO7	22 07	
184	*LBL0	21 00	
185	RCLi	36 45	Output answer.
186	RTN	24	
187	*LBLa	21 16 11	Metric flag toggle.
188	F0?	16 23 00	
189	GTO0	22 00	
190	SF0	16 21 00	
191	1	01	
192	RTN	24	
193	*LBL0	21 00	
194	CF0	16 22 00	
195	0	00	
196	RTN	24	
197	*LBLb	21 16 12	Set a calculate flag.
198	SF2	16 21 02	
199	*LBLc	21 16 13	Calculate NA or a.
200	RCL1	36 01	
201	1	01	$NA=\frac{1.18\ f_y\ A_s}{\beta_1\ f_c\ b}$
202	.	-62	
203	1	01	
204	8	08	
205	×	-35	$a = \beta_1 NA$
206	RCL2	36 02	
207	÷	-24	
208	RCL6	36 06	
209	×	-35	
210	RCL5	36 05	
211	÷	-24	
212	F2?	16 23 02	
213	RTN	24	
214	RCL7	36 07	
215	÷	-24	
216	RTN	24	
217	*LBL8	21 08	Calculate small delta from A_s to correct for any rounding errors.
218	SF3	16 21 03	
219	EEX	-23	
220	CHS	-22	
221	4	04	
222	%	55	
223	RTN	24	

LABELS

A	B	C	D	E
◆A_s	◆b	◆M	◆d	◆f_c
a Met?	b →a	c →NA	d	e ◆f_y

REGISTERS

0	1	2	3	4	5	6	7	8	9
Used	A_s	b	M	d	f_c	f_y	code	delta	

FLAGS

Flag	Use
0	Metric
1	
2	a
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☐	FIX	☐
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n	3

Program Description I

Program Title CONCRETE BEAM DEFLECTION

Contributor's Name JAMES S. BAILEY
Address E.W. ALLEN & ASSOC., 16 EXCHANGE PLACE
City SALT LAKE CITY **State** UTAH **Zip Code** 84111

Program Description, Equations, Variables THIS PROGRAM CALCULATES THE LONG TERM TOTAL LOAD DEFLECTION FOR A SIMPLY SUPPORTED CONCRETE BEAM OR SLAB OF RECTANGULAR CROSS SECTION WITH UNIFORM LOADING BY THE METHOD DESCRIBED IN THE 1971 ACI BUILDING CODE. EFFECTS OF COMPRESSION STEEL ON CREEP DEFLECTION ARE TAKEN INTO ACCOUNT.

EQUATIONS USED ARE:

SERVICE LOAD MOMENT: $M_A = w_{T.L.} L^2/8$

MODULUS OF ELASTICITY: $E = 57{,}500\sqrt{f'_c}$

MODULUS OF RUPTURE: $f_R = 7.5\sqrt{f'_c}$

GROSS MOMENT OF INERTIA: $I_{GR} = b t^3/12$

~~CRACKED MOMENT OF INERTIA: $M_{CR} = S f_R$~~

CRACKING MOMENT: $M_{CR} = S f_R$

EFFECTIVE MOMENT OF INERTIA: $I_{EFF} = (M_{CR}/M_A)^3 I_{GR} + [1-(M_{CR}/M_A)^3] I_{CR}$

DEFLECTION: $\Delta = 5 w L^4/384 E I_{EFF}$

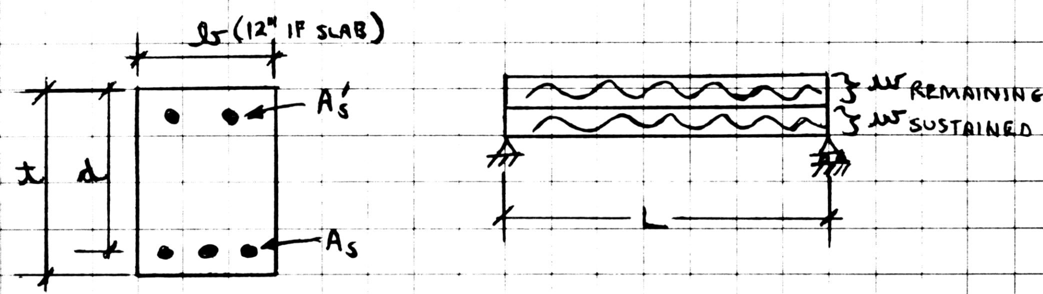
CREEP MULTIPLIER: $m \doteq 2 - 1.2 A'_s/A_s$

CRACKED MOMENT OF INERTIA: $I_{CR} = b(kd)^3/3 + A_s(d-kd)^2$

Operating Limits and Warnings COMPRESSION STEEL MUST BE EQUAL TO OR LESS THAN TENSION STEEL. PROGRAM DOES NOT WORK FOR T-BEAMS. SHRINKAGE DEFLECTIONS ARE NOT ACCOUNTED FOR.

Program Description II

Sketch(es)



Sample Problem(s) A 10" THICK SLAB SPANS 20 FEET. DEAD LOAD IS 125 PSF. LIVE LOAD IS 100 PSF OF WHICH 25% IS SUSTAINED. THE PORTION OF LOAD CONTRIBUTING TO ADDITIONAL CREEP DEFLECTIONS IS 125 PSF PLUS 25% OF 100 PSF, OR 150 PSF. THE REMAINING TRANSIENT LIVE LOAD IS 75 PSF. THE SLAB IS REINFORCED WITH #6@10½" o/c. $A_s = .50$. DEPTH TO TENSION STEEL, $d = 8.5"$. CONCRETE COMPRESSIVE STRENGTH, $f'_c = 4000$ PSI. A UNIT WIDTH OF SLAB = 12".

$b = 12"$, $d = 8.5"$, $t = 10"$, $f'_c = 4000$ PSI, $w_{SUSTAINED} = 150$ PSF, $w_{REMAINING} = 75$ PSF, $A_s = .50$, $A'_s = 0$, $L = 20$ FT.

Solution(s) LOAD SIDES 1 & 2. 12 STO 1, 8.5 STO 2, 10 STO 3, 4000 STO 4, 150 STO 5, 75 STO 6, .5 STO 7, 0 STO 8, 20 STO 9. PRESS A TO RUN PROGRAM.

RESULTS: $\Delta_{TOT} = 1.087"$

1.087	Δ_{TOT}	0
12.000	b	1
8.500	d	2
10.000	t	3
4000.000	f'_c	4
150.000	$w_{SUST.}$	5
75.000	$w_{REM.}$	6
0.500	A_s	7
0.000	A'_s	8
20.000	L	9
11250.000	M_A	A
7905.594	M_{cr}	B
1000.000	I_{gr}	C
200.331	I_{cr}	D
477.837	I_{eff}	E
0.621	Δ_{CREEP}	

Reference(s) 1971 ACI BUILDING CODE (ACI 318-71)

User Instructions

CONCRETE BEAM DEFLECTION

1 → Δ_{TOT} 2

LOAD SIDES 1 & 2 →

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS	REG.
1	INPUT DATA BEAM OR SLAB WIDTH	b / IN.	STO	1		
	DEPTH TO TENSION STEEL	d / IN.	STO	2		
	BEAM OR SLAB THICKNESS	t / IN.	STO	3		
	CONCRETE STRENGTH	f'_c / PSI	STO	4		
	DEAD LOAD OR SUSTAINED LOAD	$w_{SUST.}$ / PLF	STO	5		
	LIVE LOAD OR REMAINING LOAD	$w_{REM.}$ / PLF	STO	6		
	TENSION STEEL	A_s / IN	STO	7		
	COMPRESSION STEEL	A'_s / IN	STO	8		
	BEAM SPAN	L / FT	STO	9		
2	OUTPUT DATA ENTERED IN STEP 1,		A		Δ_{TOT} / IN.	0
	TOTAL LONG TERM DEFLECTION, TOTAL				INPUT DATA	1-9
	SERVICE LOAD MOMENT, CRACKING MO-				M_A / FT-LB	A
	MENT, GROSS MOMENT OF INERTIA, CRACKED				M_{CR} / FT-LB	B
	MOMENT OF INERTIA, EFFECTIVE MOMENT				I_{GR} / IN^4	C
	OF INERTIA, PORTION OF DEFLECTION				I_{CR} / IN^4	D
	DUE TO CREEP.				I_{EFF} / IN^4	E
					Δ_{CREEP} / IN.	I

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	RCL3	36 03	
003	3	03	
004	Y^x	31	
005	RCL1	36 01	
006	×	-35	I_{GROSS}
007	1	01	
008	2	02	
009	÷	-24	
010	STOC	35 13	
011	5	05	
012	0	00	
013	4	04	
014	.	-62	
015	3	03	m
016	5	05	
017	RCL4	36 04	
018	√X	54	
019	÷	-24	
020	STOE	35 15	
021	RCL7	36 07	
022	RCL1	36 01	
023	÷	-24	
024	RCL2	36 02	
025	÷	-24	
026	×	-35	
027	STOI	35 46	
028	X²	53	
029	RCLI	36 46	
030	2	02	
031	×	-35	
032	+	-55	
033	√X	54	
034	RCLI	36 46	
035	-	-45	$I_{CRACKED}$
036	RCL2	36 02	
037	×	-35	
038	STOI	35 46	
039	3	03	
040	Y^x	31	
041	RCL1	36 01	
042	×	-35	
043	3	03	
044	÷	-24	
045	RCL2	36 02	
046	RCLI	36 46	
047	-	-45	
048	X²	53	
049	RCLE	36 15	
050	×	-35	
051	RCL7	36 07	
052	×	-35	
053	+	-55	
054	STOD	35 14	
055	RCL4	36 04	
056	√X	54	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	RCLC	36 13	
058	×	-35	
059	RCL3	36 03	
060	÷	-24	
061	1	01	
062	.	-62	$M_{CRACKED}$
063	2	02	
064	5	05	
065	×	-35	
066	STOB	35 12	
067	RCL5	36 05	
068	RCL6	36 06	
069	+	-55	
070	RCL9	36 09	
071	X²	53	M'_A
072	×	-35	
073	8	08	
074	÷	-24	
075	STOA	35 11	
076	RCLB	36 12	CHECK TO SEE IF
077	X>Y?	16-34	SECTION IS CRACKED.
078	GTO1	22 01	
079	GTO2	22 02	
080	*LBL1	21 01	
081	RCLC	36 13	USE I_{GROSS} IF
082	STOE	35 15	UNCRACKED
083	GTO3	22 03	
084	*LBL2	21 02	
085	RCLB	36 12	
086	RCLA	36 11	
087	÷	-24	
088	3	03	CALCULATE
089	Y^x	31	$I_{EFFECTIVE}$ IF
090	RCLC	36 13	CRACKED
091	RCLD	36 14	
092	-	-45	
093	×	-35	
094	RCLD	36 14	
095	+	-55	
096	STOE	35 15	
097	*LBL3	21 03	
098	RCL9	36 09	
099	4	04	
100	Y^x	31	
101	2	02	
102	5	05	
103	5	05	
104	6	06	
105	÷	-24	
106	RCLE	36 15	
107	÷	-24	
108	RCL4	36 04	
109	√X	54	
110	÷	-24	
111	STO0	35 00	
112	RCL5	36 05	

REGISTERS

0	1	2	3	4	5	6	7	8	9
Δ_{TOT}	b	d	t	f'_c	$w_{sust.}$	$w_{rem.}$	A_s	A'_s	L
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
M_A	M_{CR}	I_{GR}	I_{CR}	I_{EFF}	Δ_{CREEP}

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	RCL6	36 06	
114	+	-55	CALCULATE Δ_{TOTAL} AND Δ_{CREEP} (steps 114–132)
115	x	-35	
116	RCL8	36 08	
117	RCL7	36 07	
118	÷	-24	
119	1	01	
120	.	-62	
121	2	02	
122	x	-35	
123	2	02	
124	X⇄Y	-41	
125	-	-45	
126	RCL5	36 05	
127	x	-35	
128	RCL0	36 00	
129	x	-35	
130	STOI	35 46	
131	+	-55	
132	STO0	35 00	
133	PREG	16-13	OUTPUT RESULTS (steps 133–134)
134	RTN	24	

LABELS					FLAGS
A	B	C	D	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS (ON / OFF)	TRIG	DISP
0 ☐ ☐	DEG ☐	FIX ☐
1 ☐ ☐	GRAD ☐	SCI ☐
2 ☐ ☐	RAD ☐	ENG ☐
3 ☐ ☐		n ______

Program Description I

Program Title TORSION - CONCENTRATED LOAD - STEEL BEAMS (WIDE FLANGE)

Contributor's Name ILJA F. HVEZDA P.E.

Address 319 CLARKSLEY ROAD

City MANITOU SPRINGS **State** COLORADO **Zip Code** 80829

Program Description, Equations, Variables PROGRAM CALCULATES THE MAXIMUM STRESS IN FLANGE OF THE WIDE FLANGE STEEL BEAM LOADED ECCENTRICALLY WITH ONE CONCENTRATED LOAD; SIMULTANEOUSLY IT CALCULATES THE ANGLE OF TWIST DUE TO TORSION. BEAM COULD BE CANTILEVER, SIMPLE SPAN OR INTERIOR SPAN OF CONTINUOUS BEAM, WHEN LOADING AND LENGTHS OF OTHER SPANS ARE THE SAME AS SPAN USED. CONCENTRATED LOAD MUST BE POSITIONED AT THE END OF CANTILEVER OR IN THE MIDDLE OF THE SPAN FOR SIMPLE SPAN BEAM OR FOR CONTINUOUS BEAM. MAXIMUM TOTAL ANGLE OF TWIST IS COMPUTED AT END OF CANTILEVER OR AT MIDSPAN OF OTHER BEAMS.

EQUATIONS USED:

	MAX BENDING MOMENT	MAX LATERAL BENDING MOMENT IN EACH FLANGE	MAX TOTAL ANGLE OF TWIST θ
CANTILEVER	$M_B = PL + \frac{wL^2}{2}$	$M_T = \frac{Pea}{d_1}\left(\tanh \frac{L}{a}\right)$ $\left(M_T \cong \frac{PeL}{d_1} \text{ when } \frac{L}{a} \le 0.3\right)$	$\theta_T = \frac{Pea}{JG}\left(\frac{L}{a} - \tanh \frac{L}{a}\right)$
SIMPLE SPAN	$M_B = \frac{PL}{4} + \frac{wL^2}{8}$	$M_T = \frac{Pea}{2d_1}\left(\tanh \frac{L}{2a}\right)$ $\left(M_T \cong \frac{PeL}{4d_1} \text{ WHEN } \frac{L}{a} \le 0.6\right)$	$\theta_T = \frac{Pea}{JG}\left(\frac{L}{2a} - \tanh \frac{L}{2a}\right)$
INTERIOR SPAN CONTINUOUS BEAM	$M_B = \frac{PL}{8} + \frac{wL^2}{12}$	$M_T = \frac{Pea}{2d_1}\left(\tanh \frac{L}{4a}\right)$ $\left(M_T \cong \frac{PeL}{8d_1} \text{ WHEN } \frac{L}{a} \le 1.2\right)$	$\theta_T = \frac{2Pea}{JG}\left(\frac{L}{4a} - \tanh \frac{L}{4a}\right)$

$a = \sqrt{\frac{EC_w}{JG}}$, MAXIMUM TOTAL BENDING STRESS IN FLANGE $f = \frac{M_B}{S_x} + \frac{M_T \frac{b}{2}}{\frac{I_y}{2}}$, d_1 = DEPTH OF BEAM MINUS FLANGE THICKNESS

Operating Limits and Warnings

E ~ MODULUS OF ELASTICITY OF STEEL = 29,000,000 psi

G ~ SHEAR MODULUS OF ELASTICITY OF STEEL = 11,200,000 psi

Program Description II

Sketch(es)

Sample Problem(s) SIMPLE SUPPORTED BEAM, SPAN 30 FT IS SUPPORTING COLUMN AT THE MIDDLE OF THE SPAN. TOTAL COLUMN LOAD IS 10 KIPS WITH ECCENTRICITY 2 INCHES.

a) WHAT IS THE TOTAL STRESS IN THE BEAM FLANGE WHEN USING W 14 x 48

b) FIND THE MAXIMUM TOTAL ANGLE OF TWIST.

PROPERTIES OF W 14 x 48 (AISC MANUAL OF STEEL CONSTRUCTION – SEVENTH EDITION)

$d = 13.81$ in

$t_f = 0.593$ in $b = 8.031$ in

$d_f = 13.217$ in

$S_x = 70.2$ in^3

$I_y = 51.3$ in^4

$C_w = 2240$ in^6

$J = 1.44$ in^4

$w = 0.048$ kips

($L = 30$ ft, $e = 2$ in, $P = 10$ kips)

Solution(s) KEYSTROKES

70.2 [ENTER], 51.3 [ENTER], 8.031 [A]	→	70.2
2240 [ENTER], 1.44 [ENTER], 13.217 [ENTER], .048 [B]	→	63.46 (= a)
30 [ENTER], 10 [ENTER], 2 [D] (= SIMPLE SPAN)	→	21.21
h x⇄y	→	0.15
f D⇄R	→	8.31

total STRESS IN FLANGE = 21.21 KSI

TOTAL ANGLE OF TWIST IS $\theta = 0.15$ EXPRESSED IN RADIANS OR ([f] [D⇄R]) 8.31 IN DEGREES

Reference(s) USS STEEL DESIGN MANUAL (JULY 1968)

User Instructions

TORSION - CONCENTRATED LOAD — STEEL WIDE FLANGE BEAM

1 | | CANTILEVER | SIMPLE BEAM | CONTINUOUS BEAM | 2

S_x↑ I_y↑ b | C_w↑ J↑ d_1↑ w | L↑ P↑ e | L↑ P↑ e | L↑ P↑ e

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	LOAD SIDE 1 & 2				
2	INPUT BEAM PROPERTIES				
		S_x	ENTER↑		S_x
		I_y	ENTER↑		I_y
		b	A		S_x
3	INPUT BEAM PROPERTIES				
		C_w	ENTER↑		C_w
		J	ENTER↑		J
		d_1	ENTER↑		d_1
		w	B		a
4	FIND APPLICABLE TYPE OF BEAM AND INPUT BEAM LENGTH AND LOADING VALUES				
	CANTILEVER	L	ENTER↑		L
		P	ENTER↑		P
		e	C		TOTAL STRESS
			x≷y		θ
	SIMPLE SPAN				
		L	ENTER↑		L
		P	ENTER↑		P
		e	D		TOTAL STRESS
			x≷y		θ
	CONTINUOUS BEAM - INTERIOR SPAN				
		L	ENTER		L
		P	ENTER		P
		e	E		TOTAL STRESS
			h	x≷y	θ (RAD)
5	TO CONVERT RAD TO DEG		f	D→R	θ (DEG)

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL A	31 25 11			×	71	
	STO I	35 33			9	09	
	R↓	35 53			6	06	
	STO 9	33 09		060	÷	81	
	R↓	35 53			RCL 4	34 04	
	STO 8	33 08			RCL 3	34 03	
	RTN	35 22			×	71	
	*LBL B	31 25 12			4	04	
	STO C	33 13			÷	81	
010	R↓	35 53			+	61	
	STO 7	33 07			RCL 8	34 08	
	STO 1	33 01			÷	81	
	R↓	35 53			STO C	33 13	
	STO E	33 15		070	GTO a	22 31 11	
	÷	81			*LBL E	31 25 15	CONTINUOUS BEAM
	2	02			4	04	
	9	09			STO × 0	33 71 00	
	×	71			R↓	35 53	
	1	01			GSB b	32 22 12	
020	1	01			2	02	
	.	83			STO × 7	33 71 07	
	2	02			STO × 2	33 71 02	
	÷	81			8	08	
	√x	31 54		080	STO × 1	33 71 01	
	STO 6	33 06	a		RCL C	34 13	
	STO 0	33 00			RCL 3	34 03	
	RTN	35 22			x²	32 54	
	*LBL C	31 25 13	CANTILEVER		×	71	
	GSB b	32 22 12			1	01	
030	RCL C	34 13			4	04	
	RCL 3	34 03			4	04	
	x²	32 54			÷	81	
	×	71			RCL 4	34 04	
	2	02		090	RCL 3	34 03	
	4	04			×	71	
	÷	81			8	08	
	RCL 4	34 04			÷	81	
	RCL 3	34 03			+	61	
	×	71			RCL 8	34 08	
040	+	61			÷	81	
	RCL 8	34 08			STO C	33 13	
	÷	81			GTO a	22 31 11	
	STO C	33 13			*LBL b	32 25 12	
	GTO a	22 31 11		100	STO 5	33 05	
	*LBL D	31 25 14	SIMPLE BEAM		R↓	35 53	
	2	02			STO 4	33 04	
	STO × 0	33 71 00			STO 2	33 02	
	R↓	35 53			R↓	35 53	
	GSB b	32 22 12			1	01	
050	2	02			2	02	
	STO × 7	33 71 07			×	71	
	4	04			STO 3	33 03	
	STO × 1	33 71 01			RCL 0	34 00	
	RCL C	34 13		110	÷	81	
	RCL 3	34 03			STO 0	33 00	L/a_i
	x²	32 54			RTN	35 22	

REGISTERS

0	1	2	3	4	5	6	7	8	9
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
l	✓	✓	✓	✓	✓

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
	*LBL a	32 25 11	
	GSB c	32 22 13	
	.	83	
	3	03	
	RCL 0	34 00	
	x ≤ y	32 71	
	GTO d	22 31 14	
120	RCL D	34 14	
	RCL 6	34 06	
	x	71	
	RCL 5	34 05	
	x	71	
	RCL 4	34 04	
	x	71	
	RCL 7	34 07	
	÷	81	
	STO A	33 11	
130	*LBL 0	31 25 00	
	RCL 0	34 00	
	RCL D	34 14	
	−	51	
	RCL 6	34 06	
	x	71	
	RCL 5	34 05	
	x	71	
	RCL 2	34 02	
	x	71	
140	RCL E	34 15	
	÷	81	
	1	01	
	1	01	
	.	83	
	2	02	
	EEX	43	
	3	03	
	÷	81	
	STO B	33 12	
150	RCL A	34 11	
	RCL I	35 34	
	x	71	
	RCL 9	34 09	
	÷	81	
	STO 1	33 01	
	RCL C	34 13	
	+	61	
	RCL B	34 12	
	x ⇄ y	35 52	
160	RTN	35 22	
	*LBL c	32 25 13	Tanh
	RCL 0	34 00	
	e^x	32 52	
	STO A	33 11	
	RCL 0	34 00	
	CHS	42	
	e^x	32 52	
	STO B	33 12	
	−	51	
170	RCL A	34 11	
	RCL B	34 12	
	+	61	
	÷	81	
	STO D	33 14	
	RTN	35 22	
	*LBL d	32 25 14	
	RCL 3	34 03	
	RCL 5	34 05	
	x	71	
180	RCL 4	34 04	
'	x	71	
2	RCL 1	34 01	
3	÷	81	
4	STO A	33 11	
5	GTO 0	22 00	
190			
200			
210			
220			

LABELS

A ✓	B ✓	C ✓	D ✓	E ✓
a ✓	b ✓	c ✓	d ✓	e
0 ✓	1	2	3	4
5	6	7	8	9

FLAGS

0
1
2
3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☐	FIX	☐
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n ______	

Program Description I

Program Title TORSION – UNIFORM LOAD – STEEL BEAMS (WIDE FLANGE)

Contributor's Name ILJA F. HVEZDA P.E.

Address 319 CLARKSLEY ROAD

City MANITOU SPRINGS **State** COLORADO **Zip Code** 80829

Program Description, Equations, Variables PROGRAM CALCULATES THE MAXIMUM STRESS IN THE FLANGE OF WIDE FLANGE STEEL BEAM LOADED ECCENTRICALLY WITH UNIFORM LOAD. AT THE SAME TIME IT CALCULATES THE ANGLE OF TWIST DUE TO TORSION. BEAM COULD BE CANTILEVER, SIMPLE SPAN, OR INTERIOR SPAN OF CONTINUOUS BEAM, WHEN LENGTHS AND LOADINGS OF OTHER SPANS ARE THE SAME AS SPAN USED. MAXIMUM TOTAL ANGLE OF TWIST IS COMPUTED AT END OF CANTILEVER OR AT MIDSPAN OF OTHER BEAMS.

<u>EQUATIONS USED:</u> (w = WEIGHT OF BEAM, W = UNIFORM LOADING)

	MAX BENDING MOMENT	MAX LATERAL BENDING MOMENT IN EACH FLANGE	MAX TOTAL ANGLE OF TWIST θ
CANTILEVER	$M_B = \frac{(w+W)L^2}{2}$	$M_T = \frac{WLea}{d_1}\left(\tanh\frac{L}{a} + \frac{1}{\frac{L}{a}\cosh\frac{L}{a}} - \frac{a}{L}\right)$ $\left(M_T \simeq \frac{WL^2e}{2d_1} \text{ when } \frac{L}{a} \leq .30\right)$	$\theta_T = \frac{WLea}{JG}\left(\frac{L}{2a} - \tanh\frac{L}{a} + \frac{1}{\frac{L}{a}\cosh\frac{L}{a}} - \frac{a}{L}\right)$ *)
SIMPLE BEAM	$M_B = \frac{(w+W)L^2}{8}$	$M_T = \frac{WLea}{2d_1}\left(\frac{2a}{L} - \frac{1}{\frac{L}{2a}\cosh\frac{L}{2a}}\right)$ $\left\{M \simeq \frac{WL^2e}{8d_1} \text{ when } \frac{L}{2a} \leq .60\right\}$	$\theta_T = \frac{WLea}{JG}\left(\frac{L}{4a} - \frac{2a}{L} + \frac{1}{\frac{L}{2a}\cosh\frac{L}{2a}}\right)$
CONTINUOUS BEAM	$M_B = \frac{(w+W)L^2}{12}$	$M_T = \frac{WLea}{2d_1}\left(-\frac{2a}{L} + \frac{1}{\tanh\frac{L}{2a}}\right)$ $\left\{M \simeq \frac{WL^2e}{12d_1} \text{ when } \frac{L}{2a} \leq .60\right\}$	$\theta_T = \frac{WLea}{2JG}\left(\frac{L}{4a} - \tanh\frac{L}{4a}\right)$
$a = \sqrt{\frac{ECw}{JG}}$	MAXIMUM TOTAL BENDING STRESS IN FLANGE $f = \frac{M_B}{S_x} + \frac{M_T \frac{b}{2}}{\frac{I_y}{2}}$		d_1 = DEPTH OF BEAM MINUS FLANGE THICKNESS

Operating Limits and Warnings *) EQUATION VALID ONLY FOR $\frac{L}{a} > 2.63$ (CANTILEVER ONLY).

E = MODULUS OF ELASTICITY OF STEEL = 29,000,000 psi

G = SHEAR MODULUS OF ELASTICITY OF STEEL = 11,200,000 psi

Program Description II

Sketch(es)

Sample Problem(s) A CONTINUOUS WIDE FLANGE BEAM, SPAN 28 FT IS SUPPORTING A WALL OF 1KIP/FT THAT HAS A 2INCH ECCENTRICITY.
a) WHAT IS THE TOTAL STRESS IN THE BEAM FLANGE WHEN USING W12X58.
b) WHAT IS THE MAXIMUM TOTAL ANGLE OF TWIST

PROPERTIES OF W 12 x 58 (AISC MANUAL OF STEEL CONSTR - SEVENTH EDITION)

$d = 12.19$ in
$fL = 0.641$ in $b = 10.014$ in
$d_1 = 11.549$ in
$S_x = 78.1$ in^3
$I_y = 107$ in^4
$C_W = 3580$ in^6
$J = 2.1$ in^4
$\omega = 0.058$ k/ft

$L = 28$ FT
$W = 1.0$ k/FT
$e = 2$ in

Solution(s) KEY STROKES:

78.1 [ENTER], 107 [ENTER], 10.014 [A]	→	.30
3580 [ENTER], 2.1 [ENTER], 11.549 [ENTER], .058 [B]	→	66.44 (a)
28 [ENTER], 1 [ENTER], 2 [E] (CONT. SPAN)	→	19.93
[h] [x⇄Y]	→	0.03
[f] [D⇄R]	→	1.87

TOTAL BENDING STRESS IN FLANGE = 19.93 KSI
TOTAL MAXIMUM ANGLE OF TWIST IS 0.03 RADIANS OR 1.87 DEGREES

Reference(s) USS STEEL DESIGN MANUAL (JULY 1968)

User Instructions

TORSION - UNIFORM LOAD - STEEL WIDE FLANGE BEAM

1					2
S_x↑ I_y↑ b	C_w↑ J↑ d_1↑ w	CANTILEVER L↑ W↑ e	SIMPLE BEAM L↑ W↑ e	CONTINUOUS BEAM L↑ W↑ e	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	LOAD SIDE 1 & 2			
2	INPUT BEAM PROPERTIES			
		S_x	ENTER↑	S_x
		I_y	ENTER↑	I_y
		b	A	
3	INPUT BEAM PROPERTIES			
		C_w	ENTER↑	C_w
		J	ENTER↑	J
		d_1	ENTER↑	d_1
		w	B	a
4	FIND APPLICABLE TYPE OF BEAM AND INPUT BEAM LENGTH AND LOADING VALUES			
	CANTILEVER	L	ENTER↑	L
		W	ENTER↑	W
		e	C	TOTAL STRESS
			h x⇄y	φ (RAD)
	SIMPLE SPAN	L	ENTER	L
		W	ENTER	W
		e	D	TOTAL STRESS
			h x⇄y	θ (RAD)
	CONTINUOUS BEAM - INTERIOR SPAN	L	ENTER	L
		W	ENTER	W
		e	E	TOTAL STRESS
			h x⇄y	θ (RAD)
5	TO CONVERT RAD TO DEG		f DIR	θ (DEG)

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL A	31 25 11	
	CF 0	35 61 00	
	STO 9	33 09	
	R↓	35 53	
	STO ÷ 9	33 81 09	
	R↓	35 53	
	STO 8	33 08	
	.	83	
	3	03	
010	STO 3	33 03	
	RTN	35 22	
	*LBL B	31 25 12	
	STO 4	33 04	
	R↓	35 53	
	STO 7	33 07	
	STO 1	33 01	
	R↓	35 53	
	STO 6	33 06	
	÷	81	
020	2	02	
	9	09	
	×	71	
	1	01	
	1	01	
	.	83	
	2	02	
	STO × 6	33 71 06	
	÷	81	
	√x	31 54	
030	STO 5	33 05	
	STO 0	33 00	a
	1	01	
	2	02	
	STO × 7	33 71 07	
	STO × 6	33 71 06	
	EEX	43	
	3	03	
	STO × 6	33 71 06	
	RCL 0	34 00	a
040	RTN	35 22	
	*LBL C	31 25 13	CANTILEVER
	GSB b	32 22 12	
	RCL 4	34 04	
	2	02	
	4	04	
	STO × 1	33 71 01	
	÷	81	
	RCL 8	34 08	
	÷	81	
050	STO 4	33 04	fb
	GSB c	32 22 13	
	RCL 0	34 00	
	2	02	
	÷	81	
	RCL D	34 14	
	−	51	
	RCL 2	34 02	
	−	51	
	RCL B	34 12	
060	×	71	
	GSB 7	31 22 07	
	F0?	35 71 00	
	GTO 8	22 08	
	RCL D	34 14	
	RCL 2	34 02	
	−	51	
	GTO 0	22 00	
	*LBL D	31 25 14	SIMPLE BEAM
	2	02	
070	STO × 0	33 71 00	
	STO × 7	33 71 07	
	STO × 3	33 71 03	
	R↓	35 53	
	GSB b	32 22 12	
	RCL 4	34 04	
	9	09	
	6	06	
	STO × 01	33 71 01	
	÷	81	
080	RCL 8	34 08	
	÷	81	
	STO 4	33 04	
	GSB c	32 22 13	
	GSB 5	31 22 05	
	GSB 7	31 22 07	
	F0?	35 71 00	
	GTO 8	22 08	
	RCL 2	34 02	
	GTO 0	22 00	
090	*LBL E	31 25 15	CONTINUOUS BEAM
	2	02	
	STO × 0	33 71 00	
	STO × 7	33 71 07	
	STO × 6	33 71 06	
	STO × 3	33 71 03	
	R↓	35 53	
	SF 2	35 51 02	
	GSB b	32 22 12	
	RCL 4	34 04	
100	1	01	
	4	04	
	4	04	
	STO × 1	33 71 01	
	÷	81	
	RCL 8	34 08	
	÷	81	
	STO 4	33 04	
	GSB c	32 22 13	
	GSB 5	31 22 05	
110	GSB 7	31 22 07	
	F0?	35 71 00	
	GTO 8	22 08	

REGISTERS

0	1	2	3	4	5	6	7	8	9
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
✓	✓		✓		

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
	RCL D	34 14	
	1/x	35 62	
	RCL 0	34 00	
	1/x	35 62	
	−	51	
	GTO 0	22 00	
	*LBL b	32 25 12	
120	STO × 5	33 71 05	
	R↓	35 53	
	STO × 5	33 71 05	
	STO + 4	33 61 04	
	R↓	35 53	
	1	01	
	2	02	
	×	71	
	STO × 5	33 71 05	ωLea
	STO × 4	33 71 04	
130	STO × 4	33 71 04	L^2
	RCL 0	34 00	
	÷	81	
	STO 0	33 00	$\frac{L}{a_1}$
	RTN	35 22	
	*LBL C	32 25 13	
	RCL 0	34 00	
	STO B	33 12	
	*LBL 6	31 25 06	
	e^x	32 52	
140	STO A	33 11	
	RCL B	34 12	
	CHS	42	
	e^x	32 52	
	STO B	33 12	
	−	51	
	RCL A	34 11	
	RCL B	34 12	
	+	61	
	F2?	35 71 02	
150	GTO 1	22 01	
	F1?	35 71 01	
	GTO 9	22 09	
	STO 2	33 02	
	÷	81	
	STO D	33 14	TANH $\frac{L}{a_1}$
	2	02	
	STO ÷ 2	33 81 02	COSH $\frac{L}{a_1}$
	RCL 0	34 00	
	1/x	35 62	
160	ENTER↑	41	
	ENTER↑	41	
	RCL 2	34 02	
	1/x	35 62	
	×	71	
	−	51	
	STO 2	33 02	$\frac{a_1}{2} - \frac{1}{\frac{L}{a_1}\cosh\frac{L}{a_1}}$
	*LBL 2	31 25 02	
	RCL 5	34 05	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	RCL 7	34 07	
170	÷	81	
	STO × 9	33 71 09	$\frac{\omega Lea}{a_1} \times \frac{b}{J_g}$
	RCL 5	34 05	
	RCL 6	34 06	
	÷	81	$\frac{\omega Lea}{JG}$
	STO A	33 12	
	RTN	35 22	
	*LBL 1	31 25 01	
	÷	81	
	STO D	33 14	
180	RCL 0	34 00	
	2	02	
	÷	81	
	STO B	33 12	
	SF 1	35 51 01	
	GTO 6	22 06	
	*LBL 9	31 25 09	
	÷	81	
	STO 2	33 02	
	CF 1	35 61 01	
190	GTO 2	22 02	
	*LBL d	32 25 14	
	R↓	35 53	
	R↓	35 53	
	RCL 0	34 00	
	RCL 7	34 07	
	×	71	
	RCL 1	34 01	
	÷	81	
	SF 0	35 51 00	
200	GTO 0	22 00	
	*LBL 5	31 25 05	
	RCL 0	34 00	
	2	02	
	÷	81	
	RCL 0	34 02	
	−	51	
	STO B	34 12	
	×	71	
	RTN	35 22	
210	*LBL 0	31 25 00	
	RCL 9	34 09	
	×	71	
	RCL 4	34 04	
	+	61	
	*LBL 8	31 25 08	
	RTN	35 22	
	*LBL 7	31 25 07	
	RCL 3	34 03	
	RCL 0	34 00	
220	X ≤ Y	32 71	
	GTO d	22 31 14	
	R↓	35 53	
	R↓	35 53	
	RTN	35 22	

LABELS

A ✓	B ✓	C ✓	D ✓	E ✓
a	b ✓	c ✓	d ✓	e
0 ✓	1 ✓	2 ✓	3	4
5 ✓	6 ✓	7 ✓	8 ✓	9 ✓

FLAGS

0	✓
1	✓
2	✓
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☐	FIX	☑
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n	2

Program Description I

Program Title A. I. S. C. Steel Column Formula

Contributor's Name Hewlett-Packard

Address 1000 N. E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables This program computes the allowable load and the maximum load for structural steel columns using the American Institute of Steel Construction formula (1961). The column ends must be welded, riveted, or otherwise constrained against deflection and rotation.

Equations:

$$P_{allow} = A\ \sigma_y\ [1-(L/k)^2/2\ C]/m \quad \text{for } L/k < C$$

$$P_{allow} = A\ (1.0273 \times 10^8\ N/m^2)/(L/k)^2 \quad \text{for } C < L/k \leq 200$$

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

$$m = 5/3 + 3(L/k)/8C - [(L/k)/2C]^3$$

$$P_{max} = P_{allow}\ m$$

Operating Limits and Warnings Columns must be nominally straight, homogeneous, and of uniform cross section.

Definitions:

P_{allow} is the allowable load;

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

A is the area of the section;

L is the length of the column;

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

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

σ_y is the yield point of the steel.

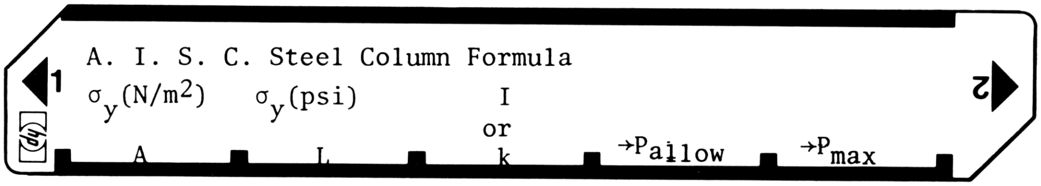
Remarks:

Either SI (metric) or English units may be used. For SI units, input the yield point stress of the material using the [A] key and use metres as the unit of length for all other inputs. For English units, input the yield point stress in pounds per square inch using the [B] key and use inches as the unit of length in all other inputs.

You may input the minimum moment of inertia I, instead of the minimum radius of gyration k. If I is input it will automatically be converted to k using the relation:

$$k^2 = I/A$$

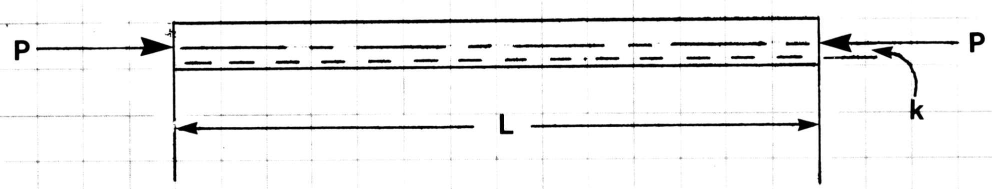
User Instructions



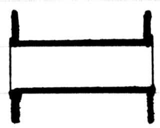
STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Load side 1 and side 2.				
2	Input the following values:				
	Input yield point stress of the material in newtons per square metre	$\sigma_y(N/m^2)$	f	A	0.00 00
	or pounds per square inch	$\sigma_y(psi)$	f	B	0.00 00
	and section area	A	A		A
	and column length	L	B		L
	and minimum radius of gyration	k	C		k
	or minimum moment of inertia	I	f	C	I
3	Calculate allowable load		D		P_{allow}
	and/or maximum load		E		P_{max}
4	For a new case, go to step 2 and change any or all of the inputs.				

Program Description II

Sketch(es)



Sample Problem(s) 1. Two steel channels are lased together to form the cross section below:



Calculate the allowable and maximum loads using the following specifications:

$k = 81.0 \times 10^{-3}$ m $A = 9.46 \times 10^{-3}$ m^2 $\sigma_y = 248 \times 10^6$ N/m^2

L = 7.5 m and 12 m

Solution(s)

Keystrokes: Outputs:

248 [EEX] 6 [f][A] 9.46 [EEX][CHS] 3 [A] 7.5 [B]

81 [EEX][CHS] 3 [C][D] ------------→ 918.2×10^3 P_{allow} (N)

[E] ------------→ 1.736×10^6 P_{max} (N)

12 [B][D] ------------→ 442.8×10^3 P_{allow} (N)

[E] ------------→ 844.5×10^3 P_{max} (N)

Reference(s)

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

Program Description II

Sketch(es)

Sample Problem(s) 2. For a column with the properties below, what is the allowable load?

σ_y = 33,000 psi A = 20 in^2 I = 223 in^4 L = 350 in

Solution(s)

Keystrokes: Outputs:

33000 [f][B] 20 [A] 223 [f][C] 350 [B][D]-------------→ 241.0 x 10^3 P_{allow} (Pounds)

Reference(s)

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	
002	STO9	35 09	Store yield point stress in N/m² and store other SI constants.
003	2	02	
004	0	00	
005	7	07	
006	EEX	-23	
007	9	09	
008	X⇄Y	-41	
009	÷	-24	
010	Pi	16-24	
011	X²	53	
012	×	-35	
013	ENT↑	-21	
014	+	-55	
015	√X	54	
016	STOC	35 13	
017	1	01	
018	0	00	
019	2	02	
020	7	07	
021	3	03	
022	EEX	-23	
023	8	08	
024	STO7	35 07	
025	CLX	-51	
026	RTN	24	
027	*LBLb	21 16 12	Store yield point stess in psi and store other English constants.
028	STO9	35 09	
029	3	03	
030	0	00	
031	EEX	-23	
032	6	06	
033	X⇄Y	-41	
034	÷	-24	
035	Pi	16-24	
036	X²	53	
037	×	-35	
038	ENT↑	-21	
039	+	-55	
040	√X	54	
041	STOC	35 13	
042	1	01	
043	4	04	
044	9	09	
045	EEX	-23	
046	6	06	
047	STO7	35 07	
048	CLX	-51	
049	RTN	24	
050	*LBLA	21 11	Store area.
051	STOA	35 11	
052	RTN	24	
053	*LBLB	21 12	Store length.
054	STOD	35 14	
055	RTN	24	
056	*LBLC	21 13	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	CF0	16 22 00	Clear I flag and store k.
058	STOE	35 15	
059	RTN	24	
060	*LBLD	21 14	Calculate P_{allow}.
061	CF1	16 22 01	
062	RCLD	36 14	
063	RCLE	36 15	
064	F0?	16 23 00	
065	GSB8	23 08	
066	÷	-24	
067	STO8	35 08	
068	RCLC	36 13	
069	X>Y?	16-34	
070	GTO1	22 01	
071	X⇄Y	-41	
072	2	02	
073	0	00	
074	0	00	
075	X⇄Y	-41	
076	X>Y?	16-34	
077	GTO5	22 05	
078	SF1	16 21 01	
079	*LBL1	21 01	
080	3	03	
081	RCL8	36 08	
082	RCLC	36 13	
083	÷	-24	
084	X²	53	
085	STO8	35 08	
086	LSTX	16-63	
087	R↓	-31	
088	-	-45	
089	R↑	16-31	
090	×	-35	
091	8	08	
092	÷	-24	
093	5	05	
094	ENT↑	-21	
095	3	03	
096	÷	-24	
097	+	-55	
098	STO6	35 06	
099	F1?	16 23 01	
100	GTO0	22 00	
101	RCL9	36 09	
102	X⇄Y	-41	
103	÷	-24	
104	1	01	
105	RCL8	36 08	
106	2	02	
107	÷	-24	
108	-	-45	
109	×	-35	
110	GTO7	22 07	
111	*LBL0	21 00	
112	RCL7	36 07	

REGISTERS

0	1	2	3	4	5	6	7	8	9
						m	constant	(L/k), "2	

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
A		C	L	k	

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	RCLD	36 14	
114	RCLE	36 15	
115	÷	-24	
116	X²	53	
117	÷	-24	
118	*LBL7	21 07	
119	RCLA	36 11	
120	×	-35	
121	RTN	24	
122	*LBLE	21 15	------------------ Calculate P_{max}.
123	GSBD	23 14	
124	RCL6	36 06	
125	×	-35	
126	RTN	24	
127	*LBL8	21 08	------------------ Convert I to k.
128	CF0	16 22 00	
129	RCLA	36 11	
130	÷	-24	
131	√X	54	
132	STOE	35 15	
133	RTN	24	
134	*LBLc	21 16 13	------------------ Set I flag and store I.
135	SF0	16 21 00	
136	STOE	35 15	
137	RTN	24	------------------

LABELS

A	B	C	D	E
A	L	k	→P_{allow}	→P_{max}
a: σ_y (N/m²)	b: σ_y (psi)	c: I	d	e
0: C < L/k	1: m	2	3	4
5	6	7: A x P/A	8: I→k	9

FLAGS

Flag	Use
0	I input?
1	C < L/k
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG: DEG ☒ GRAD ☐ RAD ☐

DISP: FIX ☐ SCI ☐ ENG ☒ n 3

Program Description I

Program Title CONCRETE COLUMNS – ULTIMATE STRENGTH DESIGN

Contributor's Name Charles I. Dinsmore

Address 4155 - 37th S.W.

City Seattle **State** Wa. **Zip Code** 98126

Program Description, Equations, Variables This program computes the ultimate capacity of short concrete columns, square or rectangular, with reinforcing in 2-faces symmetrically placed about and parallel to the major axis. Card I contains the program for the input of materials and column section properties, computes the capacity for pure compression and the capacity of a balanced condition where tension equals compression. Card I also includes the beginning of an iteration routine where the design eccentricity is input, the program will then locate the nuetral axis, compute the capacity and then compare the computed eccentricity to the input value, when the two values agree the program will output the solution. Card II contains the iteration routine, that consists of incrementing or decrementing the location of the nuetral axis for all points on the column and computing the capacity for each point. Ten different conditions are considered. A little patience is required (manually the proccedure is of trial and error) and the exact solution is obtained. The A.C.I. 318-71 is followed, Slenderness and biaxial bending must be considered independantly.

Operating Limits and Warnings

Program Description I

Program Title CONCRETE COLUMNS - ULTIMATE STRENGTH DESIGN

Contributor's Name Charles I. Dinsmore

Address 4155 - 37 th S.W.

City Seattle State Wa. Zip Code 98126

Program Description, Equations, Variables DEFINITIONS:

e_{min} = minimum eccentricity (.10t)

e_b = eccentricity at balance point b where C=T.

e_d = design eccentricity

B_1 = fractional coefficient

ϕ = strength reduction factor (.7)

a = dimension of concrete stress block.

c_b = nuetral axis, balanced condition

c = location of nuetral axis

ϵ_y = allowable strain of steel

ϵ_{s1} = Calculated strain on steel A_{s1}

ϵ_{s2} = " " " " A_{s2}

A_{s1} = steel area subject to compression

A_{s2} = steel area subject to tension or compression

b = width of column

t = depth of column

d = depth from front face to centroid of reinforcing t-d'

d' = distance from surface to centroid of steel

P_{uc} - vertical load carried by concrete

P_{us1}, P_{us2} = vertical load carried by steel A_{s1} and A_{s2}

M_{uc} = Moment of concrete

M_{us1}, M_{us2} = Moment of steel A_{s1} & A_{s2}.

F'_c = ultimate strength concrete p.s.i.

Fy = ultimate strength steel p.s.i.

E_s = Modulus of Elasticity steel 29×10^6

Operating Limits and Warnings

Program Description I

Program Title CONCRETE COLUMNS - ULTIMATE STRENGTH DESIGN

Contributor's Name Charles I. Dinsmore
Address 4155- 37th S.W.
City Seattle **State** Wa. **Zip Code** 98126

Program Description, Equations, Variables Code limitations A.C.I. 318-71

$e_{min} = .10t$ $\phi = .7$ $B_1 = .85$ for $F'_c \leq 4{,}000$ P.S.I (-) .05 each 1,000 p.s.i. > 4,000.

EQUATIONS: $a = B_1 \times c$ $c_b = \frac{.003}{.003 + \epsilon_y}$ $\epsilon_y = \frac{F_y}{E_s}$ $e = \frac{M_u}{P_u}$

$e_b = \frac{M_{u_b}}{P_{u_b}}$ $\epsilon_{s_1} = \frac{.003}{c} \times (c - d')$ $\epsilon_{s_2} = \frac{.003}{c} \times (d - c), c < d$, $\frac{.003}{c} \times (c - d), c > d$

$P_b = P_{u_c} + P_{u_{s_1}} + P_{u_{s_2}}$ (Balance condition)

$M_b = P_{u_c} \times \frac{t-a}{2} + P_{u_{s_1}} \times \frac{t}{2} - d' + P_{u_{s_2}} \times \frac{t}{2} - d'$

$_bP_{u_c} = \phi ab.85F'_c$

$_bP_{us_1} = \phi As(Fy - .85F'_c)$

$_bP_{us_2} = -\phi AsFy$

(Pure compression)

$P_u = P_{u_c} + P_{u_s}$ $M_u = 0$

$P_{u_c} = \phi bt.85F'_c$

$P_{u_s} = \phi 2As(Fy - .85F'_c)$

(any eccentricity)

$P_u = P_{u_c} + P_{us_1} \pm P_{us_2}$

$M_u = P_{u_c} \times \frac{t-a}{2} + P_{us_1} \times \frac{t}{2} - d' + P_{us_2} \times \frac{t}{2} - d'$

$a < t$ $P_{u_c} = \phi ab.85F'_c$

$a > t$ $P_{u_c} = \phi tb.85F'_c$

$\epsilon_{s_1} \geq \epsilon_y, P_{us_1} = \phi As(Fy - .85F'_c)$

$\epsilon_{s_1} < \epsilon_y, P_{us_1} = \phi As(\epsilon_{s_1} \times E_s - .85F'_c)$

$a \geq d, c > d, \epsilon_{s_2} < \epsilon_y$

$P_{us_2} = \phi As(\epsilon_{s_2} \times E_s - .85F'_c)$

$M_{us_2} = P_{us_2} \times \frac{t}{2} - d'$

$a < d$

$c > d$, $\epsilon_{s_2} < \epsilon_y$

$P_{us_2} = \phi As(\epsilon_{s_2} \times E_s)$

$M_{us_2} = -P_{us_2} \times \frac{t}{2} - d'$

$c = d, \epsilon_{s_2} = 0$

$P_{us_2} = 0$ $M_{us_2} = 0$

$c < d, \epsilon_{s_2} < \epsilon_y,$

$P_{us_2} = -\phi As(\epsilon_{s_2} \times E_s)$

$\epsilon_{s_2} \geq \epsilon_y$

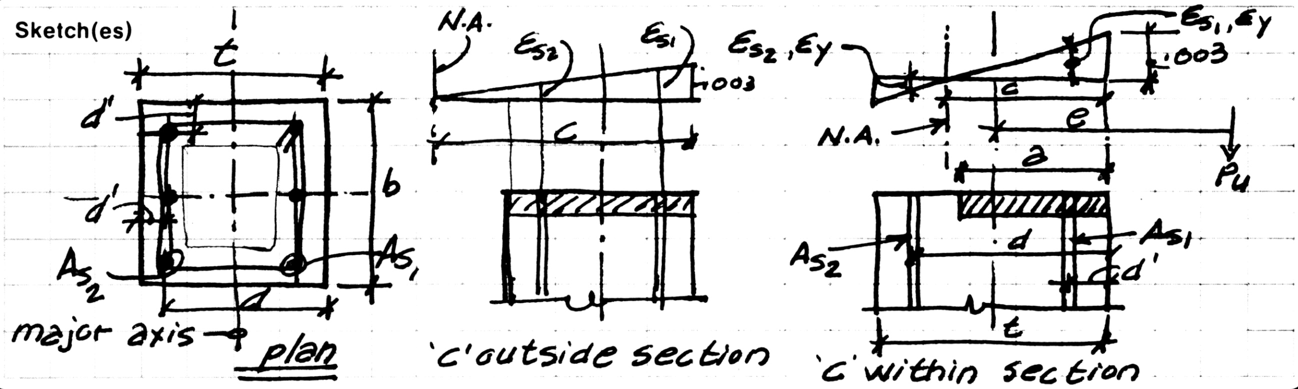
$P_{us_2} = -\phi AsFy$, $M_{us_2} = P_{us_2} \times \frac{t}{2} - d'$

Operating Limits and Warnings

- Attempting to input more data than required under LBL A will call error
- An Input $e_d < e_{min}$ will call error under LBL D
- If program halts at d' after loading card II, (iteration) column is inadequate for design condition
- Min eccentricity and large columns will take a little time.

Program Description II

Sketch(es)



Sample Problem(s)

Example 1.

For a column 20"x20" tied column with 6-#9 vertical bars, Find the capacity for
1.) Balanced condition
2.) pure compression
3.) eccentricity e_d of 4.84 in.

Given: b=20, t=20, d=17.5
d'=2.5 A_s=3.00 in^2
Fy=60,000 P.S.I. F_c'=3,750 P.S.I.

Example 2.

For a square column 36"x36" with 18-#10 vertical Find the capacity for an eccentricity of 10 inches

Given: b=36, t=36, d=33.49
d'=2.51 A_s=11.43 in^2
Fy=60,000 psi. F_c'=3750 p.s.i.

Solution(s)

60,000 ENT↑ 3,750 f a ⟶ .00207
20 A, 20A, 17.5A, 2.5 A, 3.0 A ⟶ 3.00
1.) B ⟶ e_b 10.46 M_b 4,039,107.84 in#
P_b = 386,165.63# 2.) C ⟶ 1,131,112.5#
3.) 4.84 D ⟶ (+1)
load Card II side 1 and 2 ⟶ e_d = 4.84
M_u = 3,184,176.81 in#
P_u = 658,197.39 #

60,000 ENT↑ 3,750 f a ⟶ .00207
36A, 36 A, 33.49A, 2.51 A
11.43 A ⟶ 11.43
1.0 D ⟶ Error (oops)
CLX
10.00 D ⟶ (+1)
load Card II side 1 and 2
e = 9.99 in
M_u = 21,493,813.47 in#
P_u = 2,150,761.79 #

Reference(s) American Concrete Institute A.C.I. 318-71
C.R.S.I (Concrete Reinforcing Steel Institute) Handbook
Gaylord and Gaylord, Structural Engineering Handbook
McGraw-Hill, 1968

User Instructions

CONC. COLUMNS - U.S.D. CARD I

1 Fy ↑ Fc' | | | | 2

Col. data | → e_b M_b P_b | → P_u | | e_d → e M_u P_u

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1.	Load Card I side 1 and 2 Initialize		f CL REG	0.00
	Note: CL REG for new problems only		CLX hST I	0.00
2.	Input material properties (p.s.i.)	Fy	ENTER↑	Fy
	(see note below)	Fc'	f a	ϵ_y
3.	Input column data	b	A	b
	Note: attempting to input more	t	A	t
	data than required will call Error	d	A	d
	to correct re input data	d'	A	d'
		As	A	As
4.	For capacity of balanced section		B	e_b ***
4a.	For new problem go to step 2 and/or 3			M_b ***
				P_b ***
5.	For capacity in pure compression		C	0 ***
5a.	For new problem go to step 2 and/or 3			0 ***
				P_u
6.	For capacity at any eccentricity	e_d	D	(±1)
	At pause loop load Card II			
	side 1 and 2 see page			
	Note: attempting to use e_d			
	less than e_{min} = .10t will call Error			
	Note: If kips and kip-in are			
	more convenient use engineering			
	display format. Using kips in			
	fixed format reduces accuracy			
	in the solution.			
	example:			
	60,000 psi = 60 kips			
	Input as 60 EEX 3			
	3.75 EEX 3			

User Instructions

CONC. COLUMNS - U.S.O. CARD II

1 ◀ ▶ 2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
7	load card II at pause loop			(± 1)
	side 1 and 2			
	(patience is an attribute)			e ***
				Mu ***
				Pu ***
8.	For a new problem go to step 1, 2 & 3			
	For new material same column			
	go to steps 1 and 2			
	For new column same material			
	go to steps 1 and 3			

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	g LBL a	32 25 11	Stores data and computes B_1 & E_y	057	f ISZ	31 34	
002	STO B	33 12		058	h RTN	35 22	
003	h x⇄y	35 52		059	g LBL c	32 25 13	
004	STO C	33 13		060	CLx	44	call error if more input than necessary is supplied
005	2	02		061	h ST I	35 33	
006	9	09		062	÷	81	
007	EEX	43		063	f LBL B	31 25 12	compute for balanced cond.
008	6	06		064	h CF 3	35 61 03	
009	÷	81		065	f LBL 9	31 25 09	
010	DSP 5	23 05		066	RCL 2	34 02	
011	STO D	33 14	E_y	067	f P⇄S	31 42	
012	f P⇄S	31 42		068	RCL 2	34 02	
013	•	83		069	f P⇄S	31 42	
014	0	00		070	×	71	
015	0	00		071	h LST x	35 82	
016	3	03		072	RCL D	34 14	
017	STO 2	33 02		073	+	61	
018	•	83		074	÷	81	
019	8	08		075	STO 5	33 05	c_b
020	5	05		076	f P⇄S	31 42	
021	STO 0	33 00	store $B_1 = .85$	077	RCL 0	34 00	
022	4	04		078	f P⇄S	31 42	
023	EEX	43		079	×	71	
024	3	03		080	STO A	33 11	
025	RCL B	34 12	$F'_c > 4{,}000$?	081	RCL B	34 12	
026	g x>y	32 81		082	•	83	
027	GTO f b	22 31 12		083	8	08	
028	RCL D	34 14		084	5	05	
029	f P⇄S	31 42		085	×	71	
030	h RTN	35 22		086	×	71	
031	g LBL b	32 25 12	deduct .05 from B_1 for each 1,000 psi > 4,000	087	RCL 0	34 00	
032	h x⇄y	35 52		088	×	71	
033	−	51		089	•	83	
034	EEX	43		090	7	07	
035	3	03		091	×	71	
036	÷	81		092	STO 8	33 08	P_{uc}
037	f INT	31 83		093	RCL 1	34 01	
038	•	83		094	RCL A	34 11	
039	0	00		095	−	51	
040	5	05		096	2	02	
041	×	71		097	÷	81	
042	RCL 0	34 00		098	×	71	
043	h x⇄y	35 52		099	STO 9	33 09	$Mu_b = P_{uc} \times \frac{t-a}{2}$
044	−	51		100	RCL C	34 13	
045	STO 0	33 00		101	RCL B	34 12	
046	f P⇄S	31 42		102	•	83	
047	RCL D	34 14		103	8	08	
048	h RTN	35 22		104	5	05	
049	f LBL A	31 25 11	Input cross section properties	105	×	71	
050	DSP 2	23 02		106	−	51	
051	STO (i)	33 24		107	RCL 4	34 04	
052	h RC I	35 34		108	×	71	
053	5	05		109	•	83	
054	g x=y	32 51		110	7	07	
055	GTO f c	22 31 13		111	×	71	
056	RCL (i)	34 24		112	STO + 8	33 61 08	P_{usb} for A_{s1}

REGISTERS

0	1	2	3	4	5	6	7	8	9
b	t	d	d'	As	c, c_b	E_{s1}	E_{s2}	P_u	M_u
S0	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
B_1	Δc = 1, .1, .01, .001	.003							
A	**B**	**C**	**D**	**E**	**I**				
a	F_c'	F_y	E_y	e_d	counter				

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
113	RCL 1	34 01	
114	2	02	
115	÷	81	
116	RCL 3	34 03	
117	−	51	
118	×	71	
119	STO+9	33 61 09	M_{us_b} for A_{s1}
120	RCL C	34 13	
121	RCL 4	34 04	
122	×	71	
123	•	83	
124	7	07	
125	×	71	
126	STO−8	33 51 08	P_{us_b} for A_{s2}
127	RCL 1	34 01	
128	2	02	
129	÷	81	
130	RCL 3	34 03	
131	−	51	
132	×	71	
133	STO+9	33 61 09	M_{us_b} for A_{s2}
134	RCL 9	34 09	
135	RCL 8	34 08	
136	÷	81	e_b
137	h F? 3	35 71 03	
138	h RTN	35 22	
139	f LBL 8	31 25 08	
140	DSP 2	23 02	
141	f -x-	31 84	output
142	RCL 9	34 09	e_b, M_b, P_b
143	f -x-	31 84	
144	RCL 8	34 08	
145	f -x-	31 84	
146	h RTN	35 22	
147	f LBL C	31 25 13	compute for
148	RCL B	34 12	pure compression
149	•	83	
150	8	08	
151	5	05	
152	×	71	
153	RCL 0	34 00	
154	×	71	
155	RCL 1	34 01	
156	×	71	
157	•	83	
158	7	07	
159	×	71	
160	STO 8	33 08	P_{uc}
161	RCL C	34 13	
162	RCL B	34 12	
163	•	83	
164	8	08	
165	5	05	
166	×	71	
167	−	51	
168	RCL 4	34 04	

STEP	KEY ENTRY	KEY CODE	COMMENTS
169	2	02	
170	×	71	
171	×	71	
172	•	83	
173	7	07	
174	×	71	
175	STO+8	33 61 08	$P_{us_1}+P_{us_2}$
176	CLX	44	output
177	f -x-	31 84	P_u
178	f -x-	31 84	$M=0$ $e_b=0$
179	RCL 8	34 08	
180	f -x-	31 84	
181	h RTN	35 22	
182	f LBL D	31 25 14	compute for
183	STO E	33 15	any design
184	RCL 1	34 01	eccentricity
185	•	83	
186	1	01	
187	×	71	
188	g x≤y	32 71	checks for
189	GTO f d	22 31 14	$e_{min}=.1t$
190	GTO f c	22 31 13	if $e_d<e_{min}$
191	g LBL d	32 25 14	call error
192	3	03	
193	h STI	35 33	
194	f GSB 9	31 22 09	
195	RCL E	34 15	uses e_b to
196	g x>y	32 81	start iteration
197	GTO 7	22 07	using c_b as
198	g x=y	32 51	starting point
199	GTO 8	22 08	
200	f P⇄S	31 42	
201	1	01	
202	STO 1	33 01	
203	f P⇄S	31 42	determines to
204	GTO 6	22 06	increment or
205	f LBL 7	31 25 07	decrement c_b
206	f P⇄S	31 42	
207	1	01	
208	CHS	42	
209	STO 1	33 01	
210	f P⇄S	31 42	
211	f LBL 6	31 25 06	pause loop to
212	h PSE	35 72	load Card II
213	GTO 6	22 06	
220			

LABELS

A section properties	B → e_b, P_b, M_b	C → P_{uc}	D → e, P_u, M_u	E
a material property	b used	c used	d used	e
0	1	2	3	4
5	6 pause loop	7 used	8 output	9 used

FLAGS

0	
1	
2	
3	used

SET STATUS

FLAGS	ON	OFF
0	☐	☑
1	☐	☑
2	☐	☑
3	☐	☑

TRIG	
DEG	☑
GRAD	☐
RAD	☐

DISP	
FIX	☑
SCI	☐
ENG	☐
n	2

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	f LBL E	31 25 15	start iteration	057	RCL A	34 11	
002	f P≶S	31 42	sequence	058	−	51	
003	RCL 2	34 02		059	2	02	
004	f P≶S	31 42		060	÷	81	
005	RCL 5	34 05		061	×	71	
006	÷	81		062	STO 9	33 09	
007	h LST X	35 82		063	g LBL d	32 25 14	
008	RCL 3	34 03		064	RCL D	34 14	
009	−	51	E_{s1} computed	065	RCL 6	34 06	
010	×	71	store in R_6	066	g x>y	32 81	
011	STO 6	33 06		067	GTO f a	22 31 11	
012	RCL 2	34 02		068	g x=y	32 51	
013	RCL 5	34 05		069	GTO f a	22 31 11	
014	g x≤y	32 71		070	RCL 6	34 06	
015	h SF 2	35 51 02		071	f GSB 3	31 22 03	
016	f P≶S	31 42		072	f GSB 1	31 22 01	
017	RCL 2	34 02		073	−	51	
018	f P≶S	31 42		074	RCL 4	34 04	
019	h x≶y	35 52		075	f GSB 2	31 22 02	
020	÷	81		076	STO + 8	33 61 08	
021	h LST X	35 82		077	f GSB 4	31 22 04	
022	RCL 2	34 02		078	GTO f d	22 31 14	
023	h F? 2	35 71 02		079	g LBL a	32 25 11	
024	h x≶y	35 52		080	RCL C	34 13	
025	−	51		081	f GSB 1	31 22 01	
026	×	71	E_{s2} computed	082	−	51	
027	STO 7	33 07	store in R_7	083	RCL 4	34 04	
028	RCL 3	34 03		084	f GSB 2	31 22 02	
029	RCL 5	34 05	if c≤d' halt	085	STO + 8	33 61 08	
030	g x≤y	32 71	section inadequate	086	f GSB 4	31 22 04	
031	h RTN	35 22		087	g LBL d	32 25 14	
032	f P≶S	31 42		088	RCL 2	34 02	
033	RCL 0	34 00		089	RCL A	34 11	
034	f P≶S	31 42		090	g x>y	32 81	
035	×	71	'a' computed	091	GTO f a	22 31 11	
036	STO A	33 11	store in A	092	g x=y	32 51	
037	RCL 1	34 01	Compute P_{uc}	093	GTO f a	22 31 11	
038	g x>y	32 81		094	RCL 2	34 02	
039	GTO f a	22 31 11	P_{us1} P_{us2} and	095	RCL 5	34 05	
040	f GSB 1	31 22 01	M_{us1} M_{us2} M_{uc}	096	g x>y	32 81	
041	RCL 0	34 00	for each 'c'	097	GTO f b	22 31 12	
042	×	71	value	098	g x=y	32 51	
043	RCL 1	34 01		099	GTO f c	22 31 13	
044	f GSB 2	31 22 02		100	RCL D	34 14	
045	STO 8	33 08		101	RCL 7	34 07	
046	CL X	44		102	g x>y	32 81	
047	STO 9	33 09		103	GTO f e	22 31 15	
048	GTO f d	22 31 14		104	g x=y	32 51	
049	g LBL a	32 25 11		105	GTO f e	22 31 15	
050	f GSB 1	31 22 01		106	RCL 7	34 07	
051	RCL 0	34 00		107	f GSB 3	31 22 03	
052	×	71		108	RCL 4	34 04	
053	RCL A	34 11		109	f GSB 2	31 22 02	
054	f GSB 2	31 22 02		110	CHS	42	
055	STO 8	33 08		111	STO + 8	33 61 08	
056	RCL 1	34 01		112	CHS	42	

REGISTERS

0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
ALL SAME AS CARD I					

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	f GSB 4	31 22 04		169	RCL 1	34 01	
114	GTO f d	22 31 14		170	f P≶S	31 42	
115	g LBL e	32 25 15		171	STO+5	33 61 05	
116	RCL C	34 13		172	GTO E	22 15	
117	RCL 4	34 04		173	f LBL 6	31 25 06	change Δ_c
118	f GSB 2	31 22 02		174	f DSZ	31 33	output when
119	CHS	42		175	GTO 7	22 07	I=0
120	STO+8	33 61 08		176	f -x-	31 84	output
121	CHS	42		177	RCL 9	34 09	solution
122	f GSB 4	31 22 04		178	f -x-	31 84	
123	GTO f d	22 31 14		179	RCL 8	34 08	
124	g LBL c	32 25 13		180	f -x-	31 84	
125	0	00		181	h RTN	35 22	
126	STO+8	33 61 08		182	f LBL 7	31 25 07	Δ_c changes
127	STO+9	33 61 09		183	f P≶S	31 42	
128	GTO f d	22 31 14		184	RCL 1	34 01	$C-1+\Delta c/10$
129	g LBL b	32 25 12		185	f P≶S	31 42	
130	RCL 7	34 07		186	CHS	42	$C-.1+\Delta c/100$
131	f GSB 3	31 22 03		187	STO+5	33 61 05	$C-.01+\Delta c/1000$
132	RCL 4	34 04		188	CHS	42	
133	f GSB 2	31 22 02		189	EEX	43	
134	STO+8	33 61 08		190	1	01	
135	CHS	42		191	÷	81	
136	f GSB 4	31 22 04		192	f P≶S	31 42	
137	GTO f d	22 31 14		193	STO 1	33 01	
138	g LBL a	32 25 11		194	f P≶S	31 42	
139	RCL 7	34 07		195	GTO 5	22 05	
140	f GSB 3	31 22 03		196	f LBL 1	31 25 01	equation sub
141	f GSB 1	31 22 01		197	RCL B	34 12	routines #1–4
142	−	51		198	•	83	
143	RCL 4	34 04		199	8	08	
144	f GSB 2	31 22 02		200	5	05	
145	STO+8	33 61 08		201	×	71	
146	CHS	42		202	h RTN	35 22	
147	f GSB 4	31 22 04		203	f LBL 2	31 25 02	
148	g LBL d	32 25 14	starts increm.	204	×	71	
149	RCL E	34 15	& decrement	205	•	83	
150	RCL 9	34 09	sequence, checks	206	7	07	
151	RCL 8	34 08	e_{cal} to e_d and	207	×	71	
152	÷	81	outputs solution	208	h RTN	35 22	
153	f P≶S	31 42		209	f LBL 3	31 25 03	
154	RCL 1	34 01		210	2	02	
155	f P≶S	31 42		211	9	09	
156	f x<0	31 71		212	EEX	43	
157	GTO 8	22 08		213	6	06	
158	h ↓	35 53		214	×	71	
159	g x≤y	32 71		215	h RTN	35 22	
160	GTO 6	22 06		216	f LBL 4	31 25 04	
161	GTO 5	22 05		217	RCL 1	34 01	
162	f LBL 8	31 25 08		218	2	02	
163	h ↓	35 53		219	÷	81	
164	g x>y	32 81		220	RCL 3	34 03	
165	GTO 6	22 06		221	−	51	
166	GTO 5	22 05		222	×	71	
167	f LBL 5	31 25 05	$C_b \pm 1$	223	STO+9	33 61 09	
168	f P≶S	31 42		224	h RTN	35 22	

LABELS

A	B	C	D	E starts loop
a used	b used	c used	d used	e used
0	1 used	2 used	3 used	4 used
5 incr/dec c	6 $C-\Delta_c$	7 $\Delta c/10$	8 used	9

FLAGS

0	
1	
2	used
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☑
1	☐	☑
2	☐	☑
3	☐	☑

TRIG	
DEG	☑
GRAD	☐
RAD	☐

DISP	
FIX	☑
SCI	☐
ENG	☐
n	2

Program Description I

Program Title COLUMN STRENGTH

Contributor's Name William A Griswold
Address 3918 Albert Drive
City Nashville **State** TN **Zip Code** 37204

Program Description, Equations, Variables Program calculates the average crippling stress of a column cross section. The equation for crippling stress on an element is as follows:

$$F_{cs} = .56\, F_{cy}\left[\frac{Kt}{b}\left(\frac{E}{F_{cy}}\right)^{\frac{1}{2}}\right]^{.85}$$

where: F_{cs} = Crippling stress, psi
F_{cy} = Yield stress, psi
k = 1 for "ONE EDGE FREE", 3 for "NO EDGE FREE"
t = element thickness, inches
b = element width, inches
E = modulus of elasticity

The F_{cs} of each element is multiplied by its area to obtain the load. The average crippling stress is Σ LOAD / Σ AREA

The Column Strength, F_{cc} (psi) is obtained from the Johnson-Euler equations

Euler Curve, $F_{cc} = \frac{\pi^2 E}{(L/\rho)^2}$ Johnson Curve, $F_{cc} = F_{cs} - \frac{F_{cs}^2 (L/\rho)^2}{4\pi^2 E}$

where (L/ρ) = column length over radius of gyration

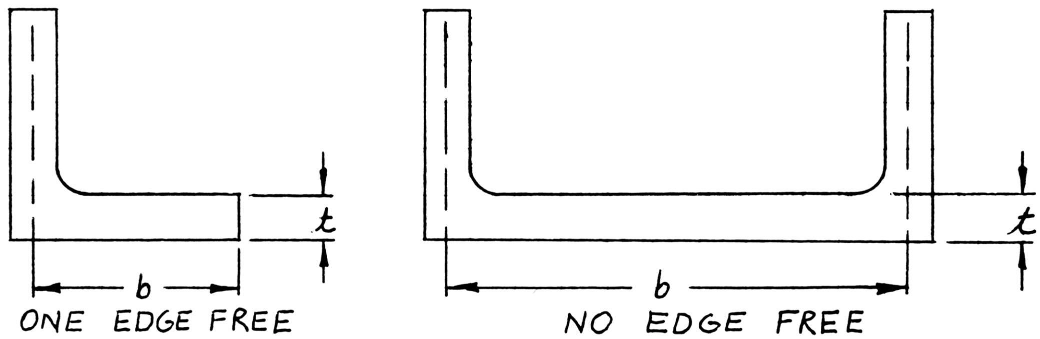
The program calculates slope of Johnson curve and slope of Euler curve and displays F_{cc} of curve with the least slope, which is the appropriate value for Column Strength.

Operating Limits and Warnings The maximum crippling stress for a composite section should be limited as follows

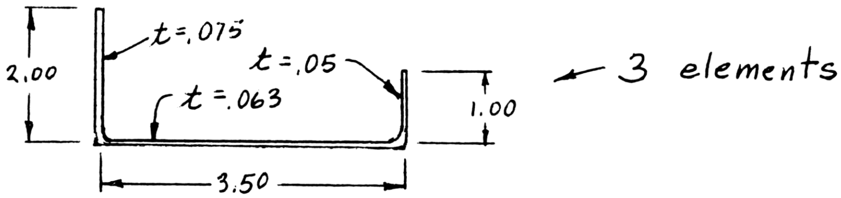
TYPE OF SECTION	MAX. F_{cs}
V groove plates, stiffened panels	F_{cy}
2 Corner Sections, Zee, J, Channels	$.9\,F_{cy}$
Tee, Cruciform, H Sections, Multicorner sections	$.8\,F_{cy}$
Angles	$.7\,F_{cy}$

Program Description II

Sketch(es)



Sample Problem(s)



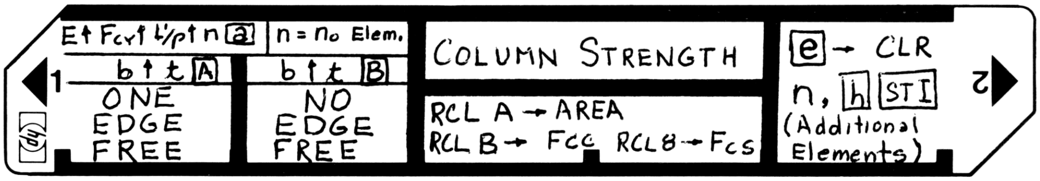
An aluminum channel section is used as an axially loaded member. Modulus of elasticity = 10.3×10^6 #/in²
Yield stress, F_{cy} = 70 000 #/in² (7075 T6 extrusion)
Length over radius of gyration, L/ρ = 50 in/in
Determine Column Strength

Solution(s) Keystrokes

10.3×10^6 Enter 70000 Enter 50 Enter 3 [f] [A] → 10300000.00
2 Enter .075 [A] → 1.00 (note, one edge free)
3.5 Enter .063 [B] → 2.00 (note, no edge free)
1 Enter .05 [A] → 20846.26 #/in² = F_{cc}
RcL 8 = 24552.52 #/in² = F_{cs}
20846 < .9 F_{cy}
Use 20846 #/in² allowable column stress

Reference(s)

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	LOAD SIDE 1 AND SIDE 2.				
2	INPUT MODULUS OF ELASTICITY	E	ENTER		$\hat{E}$
3	INPUT COMPRESSIVE YIELD STRESS	F_{CY}	ENTER		$\hat{F}_{CY}$
4	⊗ INPUT LENGTH OVER RADIUS OF GYRATION	L/ρ	ENTER		$\hat{L/\rho}$
5	INPUT NUMBER OF RECTANGULAR ELEMENTS	n	f	A	E
6	INPUT WIDTH OF ELEMENT 1	b_1	ENTER		$\hat{b}_1$
7	INPUT THICKNESS OF ELEMENT 1	t_1	*		n_1
8	REPEAT STEPS 6 AND 7 FOR EACH ELEMENT				
	(AFTER THE LAST ELEMENT HAS				
	BEEN INPUT) →				F_{CC}
	* IF ELEMENT HAS "ONE EDGE FREE"				
	PRESS KEY [A]				
	IF ELEMENT HAS "NO EDGE FREE"				
	PRESS KEY [B]				
	NOTE IF IT IS DESIRED TO ADD				
	ANOTHER ELEMENT AFTER F_{CC}				
	HAS BEEN COMPUTED PRESS 1,				
	[h] [STI] AND REPEAT STEPS 6				
	AND 7				
9	FOR A NEW CASE PRESS KEYS				
	[f] [E] AND GO TO STEP 2		f	E	
	⊗ L/ρ MUST BE GREATER THAN ZERO				
	F_{CC} = COLUMN STRENGTH				
	(POUNDS PER SQUARE INCH)				
	RECALL A = AREA OF ELEMENTS				
	RECALL B = F_{CC}				
	RECALL 8 = CRIPPLING STRESS				

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	g LBL a	32 25 11	
	h STI	35 33	n
	h R↓	35 53	
	g x^2	32 54	
	STO 1	33 01	$(L/\rho)^2$
	1	01	
	+	61	
	STO 2	33 02	$(L/\rho)^2+1$
	h R↓	35 53	
010	STO 3	33 03	F_{cy}
	h R↓	35 53	
	STO 0	33 00	E
	h RTN	35 22	
	f LBL A	31 25 11	ONE EDGE FREE
	STO 4	33 04	t
	h x↔y	35 52	
	STO 5	33 05	b
	x	71	
	STO A	33 11	AREA
020	STO + 6	33 61 06	Σ AREA
	1	01	
	f GSB 0	31 22 00	
	RCL A	34 11	
	x	71	CRIPPLING LOAD
	STO + 7	33 61 07	Σ CRIPPLING LOAD
	f P↔S	31 42	
	1	01	Count Elements
	STO + 9	33 61 09	
	RCL 9	34 09	&
030	f P↔S	31 42	Decrement
	f DSZ	31 33	
	h RTN	35 22	
	GTO 1	22 01	
	f LBL B	31 25 12	NO EDGE FREE
	STO 4	33 04	t
	h x↔y	35 52	
	STO 5	33 05	b
	x	71	
	STO A	33 11	AREA
040	STO + 6	33 61 06	Σ AREA
	3	03	
	f GSB 0	31 22 00	
	RCL A	34 11	
	x	71	CRIPPLING LOAD
	STO + 7	33 61 07	Σ CRIPPLING LOAD
	f P↔S	31 42	
	1	01	Count Elements
	STO + 9	33 61 09	&
	RCL 9	34 09	
050	f P↔S	31 42	Decrement
	f DSZ	31 33	
	h RTN	35 22	
	GTO 1	22 01	
	f LBL 0	31 25 00	
	RCL 4	34 04	
	x	71	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	RCL 5	34 05	
	÷	81	
	RCL 0	34 00	
060	RCL 3	34 03	
	÷	81	
	f √x	31 54	CRIPPLING STRESS
	x	71	
	•	83	
	8	08	
	5	05	
	h y^x	35 63	
	RCL 3	34 03	
	x	71	
070	•	83	
	5	05	
	6	06	
	x	71	
	h RTN	35 22	
	f LBL 1	31 25 01	DETERMINE
	RCL 7	34 07	AVERAGE CRIPPLING
	RCL 6	34 06	STRESS
	÷	81	
	STO 8	33 08	
080	RCL 1	34 01	
	f GSB 2	31 22 02	
	STO 9	33 09	Johnson Value
	RCL 2	34 02	
	f GSB 2	31 22 02	
	RCL 9	34 09	
	h x↔y	35 52	
	−	51	
	f P↔S	31 42	
	STO 0	33 00	Δ Johnson
090	f P↔S	31 42	
	RCL 1	34 01	
	f GSB 3	31 22 03	
	STO B	33 12	
	RCL 2	34 02	
	f GSB 3	31 22 03	
	RCL B	34 12	
	h x↔y	35 52	
	−	51	Δ Euler
	f P↔S	31 42	
100	RCL 0	34 00	
	f P↔S	31 42	
	g x≤y	32 71	Determine
	h SF 2	35 51 02	applicable
	RCL B	34 12	Johnson or
	h F? 2	35 71 02	
	RCL 9	34 09	Euler value
	STO B	33 12	
	RCL 6	34 06	for column
	STO A	33 11	strength
110	RCL B	34 12	
	h RTN	35 22	
	f LBL 2	31 25 02	

REGISTERS

0	1	2	3	4	5	6	7	8	9
E	$(L/\rho)^2$	$(L/\rho)^2+1$	F_{cy}	t	b	ΣA	Σ CRIPPL. LOAD	AVG. CRIPPL. STRESS	Johnson Stress

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
Δ Johnson									Count Elements

A	B	C	D	E	I
Σ AREA	COLUMN STRENGTH				n

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
	RCL 8	34 08	Johnson Curve
	g x²	32 54	
	×	71	
	4	04	
	÷	81	
	h π	35 73	
	g x²	32 54	
120	÷	81	
	RCL 0	34 00	
	÷	81	
	RCL 8	34 08	
	h x↔y	35 52	
	−	51	
	h RTN	35 22	
	f LBL 3	31 25 03	Euler Curve
	RCL 0	34 00	
	h x↔y	35 52	
130	÷	81	
	h π	35 73	
	g x²	32 54	
	×	71	
	h RTN	35 22	
	g LBL e	32 25 15	CLEAR DATA
	0	00	
	STO 4	33 04	
	STO 5	33 05	
	STO 6	33 06	
140	STO 7	33 07	
	STO 8	33 08	
	STO 9	33 09	
	f P↔S	31 42	
	STO 9	33 09	
	f P↔S	31 42	
	h RTN	35 22	
150			
160			
170			
180			
190			
200			
210			
220			

LABELS

A	B	C	D	E
b↑t ONE EDGE FREE	b↑t NO EDGE FREE			
a E↑F_{cy}↑L/ρ↑n	b	c	d	e CLR DATA

0	1	2	3	4
USED	USED	USED	USED	
5	6	7	8	9

FLAGS

0	
1	
2	USED
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☒
SCI	☐
ENG	☐
n	2

Program Description I

Program Title BEAM ON ELASTIC FOUNDATION WITH POINT LOAD - ANY LOCATION

Contributor's Name Leonard T. Evans, Jr.

Address 1900 West Beverly Boulevard

City Los Angeles **State** California **Zip Code** 90057

Program Description, Equations, Variables Program computes deflection, slope, moment and shear at point x. When x > a program reverses beam and reverses signs of θ and Q. Program computes 9 variables used in solution of the 4 equations.

Equations used are:

$$y = \frac{P\lambda}{K} \cdot \frac{1}{\sinh^2\lambda l - \sin^2\lambda l}\Big\{2\cosh\lambda x \cos\lambda x\,(\sinh\lambda l \cos\lambda a \cosh\lambda b - \sin\lambda l \cosh\lambda a \cos\lambda b) + (\cosh\lambda x \sin\lambda x + \sinh\lambda x \cos\lambda x)\big[\sinh\lambda l\,(\sin\lambda a \cosh\lambda b - \cos\lambda a \sinh\lambda b) + \sin\lambda l\,(\sinh\lambda a \cos\lambda b - \cosh\lambda a \sin\lambda b)\big]\Big\}$$

$$\theta = \frac{dy}{dx}, \quad M = -EI\frac{d^2y}{dx^2}, \quad Q = -EI\frac{d^3y}{dx^3}$$

where: $\lambda = \sqrt[4]{\frac{K}{4EI}}$

E = Modulus of Elasticity

I = Moment of Inertia

$K = K_0 \times$ beam width

K_0 = Foundation modulus

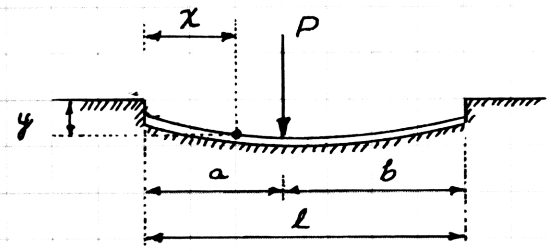
Operating Limits and Warnings $a \;\&\; x \leq l$

If P, K, EI or l are varied entire program must be re-run.

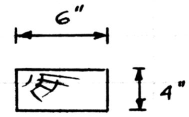
When x = a shear value is that approaching from right side.

Program Description II

Sketch(es)



Wood beam ℓ = 72"



$E_{beam} = 1.2 \times 10^6$ psi
$I_{beam} = 32 \text{ in}^4$
$EI = 86.4 \times 10^6 \text{ lb in}^2$
$K_o = 100 \text{lb/in}^3, K = 6" \times K_o = 600 \text{lb/in}^2$

Sample Problem(s) Wood beam shown above is subjected to a concentrated load of 1000 pounds 33" from the left end.

1. What are the deflection and slope at the left end? (x = 0)
2. What are the moment and shear 30" from the left end? (x = 30)

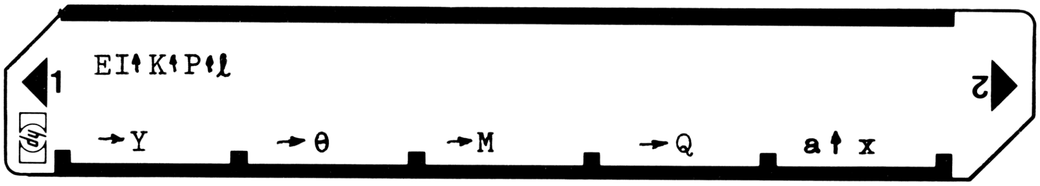
Solution(s) Keystrokes:

	Keystrokes		Display	
1.	86.4 EEX 6 ↑ 600 ↑ 1000 ↑ 72	[f] [A]	→ 45.808229	
	33 ↑ 0	[E]	→ 0.000000	C_6
	[A]		→ 0.013873	inches defl.
	[B]		→ 0.000787	radians
2.	33 ↑ 30	[E]	→ 1.465591	C_6 (new)
	[C]		→ 5798.344130	in.lb. moment
	[D]		→ 447.240565	lb. shear

Reference(s)

M. HETÉNYI
Beams on Elastic Foundation
Pages 54-55
University of Michigan Press, 1946

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Load side 1 and side 2.				
2	Input EI, K, P and values.	EI	↑		
		K	↑		
		P	↑		
		ℓ	f	a	
3	Input a and x values.*	a	↑		
		x	E		
4	Compute deflection**		A		y
5	Compute slope**		B		θ
6	Compute moment**		C		M
7	Compute shear**		D		Q
	*Must be inputed after Step 2.				
	**Optional - Steps 4-7 may be in any order or may be omitted.				
8	For a new value of a or x go to Step 3.				
9	For a new value of EI, K, P or ℓ go to Step 2.				

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	g LBL a	32 25 11	Set radian mode		h ↓	35 53	
	h RAD	35 42	and display		STO 7	33 07	
	DSP 6	23 06			RCL B	34 12	
	STO 0	33 00	Store variables	060	STO 8	33 08	
	h ↓	35 53			RCL C	34 13	λa
	STO 1	33 01			f GSB 1	31 22 01	
	h ↓	35 53			STO A	33 11	Store functions
	STO 3	33 03			h ↓	35 53	of λa
	h x⇄y	35 52			STO C	33 13	
010	STO 4	33 04			h ↓	35 53	
	÷	81			STO 6	33 06	
	4	04			RCL B	34 12	
	h 1/x	35 62			RCL 5	34 05	
	x	71		070	x	71	
	h LST x	35 82			RCL 6	34 06	
	h y^x	35 63			RCL 2	34 02	
	STO 9	33 09			x	71	
	STO x 0	33 71 00			−	51	
	STO x 1	33 71 01			RCL E	34 15	
020	g x^2	32 54			x	71	
	2	02			RCL A	34 11	
	x	71			RCL 7	34 07	
	STO x 4	33 71 04	C_4 completed		x	71	
	RCL 3	34 03		080	RCL C	34 13	
	STO ÷ 1	33 81 01			RCL 8	34 08	
	RCL 0	34 00	λl		x	71	
	f GSB 1	31 22 01			−	51	
	STO E	33 15	Store sin and		h RC I	35 34	
	g x^2	32 54	sinh of λl		x	71	
030	RCL B	34 12			+	61	
	h ST I	35 33			STO 3	33 03	C_3 completed
	g x^2	32 54			h RC I	35 34	
	h x⇄y	35 52			RCL C	34 13	
	−	51		090	RCL 7	34 07	
	STO ÷ 1	33 81 01	C_1 completed		x	71	
	h RTN	35 22			x	71	
	f LBL E	31 25 15			RCL E	34 15	
	h CF 0	35 61 00			RCL 6	34 06	
	RCL 9	34 09	Store λx and λa		RCL 5	34 05	
040	x	71			x	71	
	STO D	33 14			x	71	
	h x⇄y	35 52			−	51	
	RCL 9	34 09			STO 2	33 02	C_2 completed
	x	71		100	RCL D	34 14	λx
	STO C	33 13			f GSB 1	31 22 01	
	g x ≤ y	32 71	Test a		STO A	33 11	Store functions
	f GSB 2	31 22 02			h ↓	35 53	of λx
	RCL 0	34 00	Test a		STO D	33 14	
	RCL C	34 13			h x⇄y	35 52	
050	g x > y	32 81	Error message		STO C	33 13	
	GTO 3	22 03			x	71	
	−	51	λb		STO 7	33 07	C_7 completed
	f GSB 1	31 22 01			RCL A	34 11	
	STO 2	33 02	Store functions	110	RCL B	34 12	
	h ↓	35 53	of λb		x	71	
	STO 5	33 05			STO 8	33 08	C_8 completed

REGISTERS

0	1	2	3	4	5	6	7	8	9
λl	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	λ
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
y	θ	M	Q	sin λl	sinh λl

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
	RCL D	34 14	
	RCL B	34 12	
	x	71	
	STO 5	33 05	
	STO 6	33 06	
	RCL A	34 11	
	RCL C	34 13	
120	x	71	
	STO + 5	33 61 05	C_5 completed
	STO - 6	33 51 06	C_6 completed
	h RTN	35 22	
	f LBL A	31 25 11	
	RCL 7	34 07	
	RCL 2	34 02	
	x	71	
	2	02	
	x	71	
130	RCL 5	34 05	
	RCL 3	34 03	
	x	71	
	+	61	
	RCL 1	34 01	
	x	71	
	STO A	33 11	y
	h RTN	35 22	
	f LBL B	31 25 12	
	RCL 2	34 02	
140	RCL 6	34 06	
	x	71	
	RCL 3	34 03	
	RCL 7	34 07	
	x	71	
	+	61	
	RCL 1	34 01	
	RCL 9	34 09	
	x	71	
	2	02	
150	x	71	
	x	71	
	h F? 0	35 71 00	
	CHS	42	
	STO B	33 12	θ
	h RTN	35 22	
	f LBL C	31 25 13	
	RCL 2	34 02	
	RCL 8	34 08	
	x	71	
160	2	02	
	x	71	
	RCL 3	34 03	
	RCL 6	34 06	
	x	71	
	-	51	
	RCL 1	34 01	
	RCL 4	34 04	
	x	71	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	x	71	
170	STO C	33 13	M
	h RTN	35 22	
	f LBL D	31 25 14	
	RCL 2	34 02	
	RCL 5	34 05	
	x	71	
	RCL 3	34 03	
	RCL 8	34 08	
	x	71	
	+	61	
180	RCL 9	34 09	
	RCL 1	34 01	
	x	71	
	RCL 4	34 04	
	x	71	
	2	02	
	x	71	
	x	71	
	h F? 0	35 71 00	
	CHS	42	
190	STO D	33 14	
	h RTN	35 22	Q
	f LBL 1	31 25 01	Hyperbolic and
	STO A	33 11	trig sub-
	g e^x	32 52	routine
	↑	41	
	h 1/x	35 62	
	-	51	
	2	02	
	÷	81	Sinh
200	STO B	33 12	
	g x^2	32 54	
	1	01	
	+	61	
	f $\sqrt{x}$	31 54	Cosh
	RCL A	34 11	
	f COS	31 63	cos
	RCL A	34 11	
	f SIN	31 62	sin
	h RTN	35 22	
210	f LBL 2	31 25 02	Reverse λa and
	RCL 0	34 00	λ b
	h x⇄y	35 52	
	-	51	
	STO C	33 13	
	RCL 0	34 00	Test λx > λl
	RCL D	34 14	Error message
	g x > y	32 81	
	GTO 3	22 03	
	-	51	Reverse λx and
220	STO D	33 14	λ(l - x)
	h SF 0	35 51 00	
	h RTN	35 22	Set flag for
			sign change

LABELS

A → y	B → θ	C → M	D → Q	E a ↑ x
a EI↑ K↑ P↑ l	b	c	d	e
0	1 Hyperbolics	2 Reverse beam	3 Error	4
5	6	7	8	9

FLAGS

0	CHS
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

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Revision B 11-77