4-18-1989

Computer program for the analysis of non-prismatic beams

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DOI: 10.25148/etd.FI13101560

Recommended Citation

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COMPUTER PROGRAM FOR THE ANALYSIS OF NON PRISMATIC BEAMS

by

Roberto Antonio Alas

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

in

CIVIL ENGINEERING

FLORIDA INTERNATIONAL UNIVERSITY
1989

ABSTRACT

COMPUTER PROGRAM FOR THE ANALYSIS OF NON PRISMATIC BEAMS

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One of the major problems in the analysis of beams with Moment of Inertia varying along their length, is to find the Fixed End Moments, Stiffness, and Carry-Over Factors.

In order to determine Fixed End Moments, it is necessary to consider the non-prismatic member as integrated by a large number of small sections with constant Moment of Inertia, and to find the M/EI values for each individual section. This process takes a lot of time from Designers and Structural Engineers.

The object of this thesis is to design a computer program to simplify this repetitive process, obtaining rapidly and effectively the Final Moments and Shears in continuous non-prismatic Beams.

For this purpose the Column Analogy and the Moment

Distribution Methods of Professor Hardy Cross have been utilized as the principles toward the methodical computer solutions.

The program has been specifically designed to analyze continuous beams of a maximum of four spans of any length, integrated by symmetrical members with rectangular cross sections and with rectilinear variation of the Moment of Inertia. Any load or combination of uniform and concentrated loads must be considered.

Finally sample problems will be solved with the new Computer Program and with traditional systems, to determine the accuracy and applicability of the Program.

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Dr. Luis A. Prieto-Portar,Ph.D.,P.E.

To Dr. LeRoy E. Thompson, Dr. Ton-Lo Wang, and Dr. Luis A. Prieto-Portar.

This thesis, having been approved in respect to form and mechanical execution, is referred to you for judgment upon its substantial merit.

Dr. Gordon R. Hopkins, Dean
College of Engineering.

This thesis of Roberto Antonio Alas is Approved.

Major Professor LeRoy E. Thompson

Professor Ton-Lo Wang

Professor Luis A. Prieto-Portar

Date of Examination: April 18, 1989

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ACKNOWLEDGEMENTS

The realization of this thesis has been possible, thanks to the knowledge acquired during the study of the Program of Master of Science offered by the Department of Civil and Environmental Engineering at Florida International University, specially during the courses of "Advanced Structural Analysis" instructed by Dr. LeRoy E. Thompson, and "Computer Applications in Structures" instructed by Dr. Jimmy D. Hahs.

I wish to thank all the members of the Faculty for their dedication and teachings, and particularly to my principal advisor Dr. LeRoy E. Thompson who guided me during the preparation of this work and made me conscious about the necessity of a computer program to assist designers in their analysis of Non-Prismatic Beams.

I am also thankful to my wife and children for their encouragement and moral support.

TABLE OF CONTENTS

PAGE

CHAPTER I DESCRIPTION OF THE PROGRAM

CHAPTER II PRINCIPLES OF THE COLUMN ANALOGY METHOD

CHAPTER III PRINCIPLES OF THE MOMENT DISTRIBUTION METHOD UTILIZED IN THIS PROGRAM

CHAPTER IV ILLUSTRATIVE EXAMPLE

CHAPTER V PROBLEMS SOLVED BY THE COMPUTER PROGRAM

CHAPTER VI CONCLUSIONS AND LIMITATIONS

CHAPTER VII REFERENCES

LIST OF FIGURES

CHAPTER I

DESCRIPTION OF THE PROGRAM

1.1 GENERAL DESCRIPTION

This program has been divided into two parts:

The first part determines the Stiffness, Carry-Over Factors, and Fixed End Moments of Non-Prismatic Beams, within the limitations described in article 1.2. In order to obtain these Factors, the Column Analogy Method is utilized. Chapter II describes the basic principles of the Column Analogy Method that are utilized in this program.

The second part determines the Final Moments and Shears in the internal sections of the Beam being analyzed with the use of the Moment Distribution Method. Chapter III describes the principles of the Moment Distribution Method that are utilized in this program.

The program has been written in "BASIC" language, and it can be used on any I.B.M. or I.B.M. compatible computer.

In order to facilitate any modification to the program when different sections or different variations of the Moment of Inertia are required, the program has been divided in subroutines, in such a way that changes can be made only in those subroutines affected.(3).

1.2 LIMITATIONS

This program has been designed to assist structural engineers to perform the analysis of continuous Beams with variable moment of Inertia. As illustrated in Figure 1.1, a Beam can have innumerable cross sections (eg. Rectangular, Double Tee, I Beam, Single Tee, etc.), and each Section will have different equations to find its Moment of Inertia.

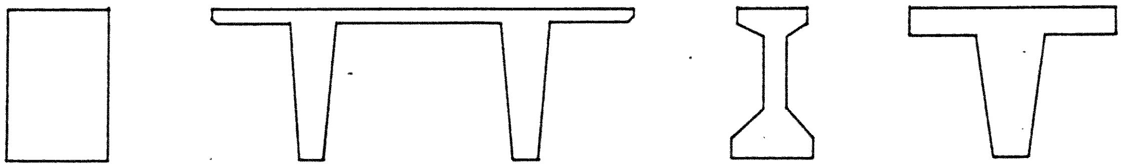

(a) Rectang. Beam. (b) Double Tee. (c) AASHTO Girder (d) Single Tee.

Fig. 1.1 Typical Beam Cross Sections.

Furthermore, the variation of the moment of Inertia along the length of a Beam can be of several shapes (eg. Rectilinear, Circular, Parabolic, Etc.), and to each shape will correspond a different variation of height with respect to the horizontal axis. See Fig. 1.2.

Curved bottom flange
(*a*)

Parabolic hauncnes
(*b*)

Fig.1.2 Typical Beam Spans With Variable Moment of Inertia.

Finally the variation of the Moment of Inertia can be either symmetric or unsymmetric.

This program has been specifically designed to analyze continuous beams of a maximum of four spans for any length and with any combination of uniform and concentrated loads. The spans will consist of symmetrical beams of rectangular cross sections and with rectilinear variations of their moment of Inertia.

1.3 HOW TO USE THE "ANALYSIS OF NON-PRISMATIC BEAMS".

In order to start using this program, one must follow these following steps:

Step 1 : Make sure your computer is OFF.
Step 2 : Insert the Diskett containing the program Disk Drive A.
Step 3 : Turn ON your monitor and your computer.
Step 4 : Your screen should look lide Fig. 1.3, Follow Instructions on Screen.

```
WELCOME TO THE PROGRAM:  Analysis of Non-Prismatic Beams.
_________________________________________________________

*******************************************************************
*                                                                 *
*  This Program finds Final Moments and Shears on Tapered Beams   *
*  of 1,2,3 or 4 Spans of any length and with any combination of  *
*  Uniform and Concentrated Loads on each Span, and with Ends to  *
*  be Pin, Roller or Fixed.                                       *
*          * Beams with Rectangular Cross Sections.               *
*          * Haunches varying Linearlly.                          *
*          * Symmetrical Spans with respect to their Center Line. *
*          * Modulus of Elasticity E = Constant.                  *
*                                                                 *
*******************************************************************
```

Fig. 1.3 Opening Remarks of the Computer Program.

CHAPTER II

PRINCIPLES OF THE COLUMN ANALOGY METHOD.

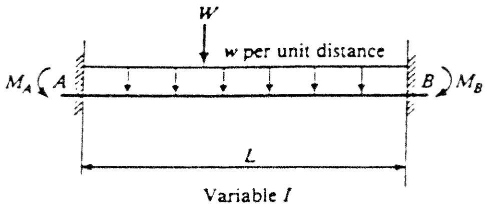
2.1 GENERAL INTRODUCTION

The Column Analogy Method was developed by Professor Hardy Cross of the University of Illinois in 1930 (6). It is useful, among other uses, to determie the Fixed-End Moments, as well as the Stiffness and Carry-Over Factors for a Beam element with constant or variable Moments of Inertia.

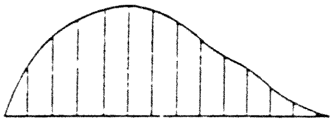
The Analogous Column can be visualized as a short column with a cross section composed of one side equal to the length of the member analyzed, and the other side equal to the factor 1/EI in each point.

The object of this chapter is not to fully describe the Column Analogy Method deriving the general theorem (this can be found in any text of Structural Analysis) (4),(6). The object of this chapter is to illustrate those subjects utilized in the design of this computer program.

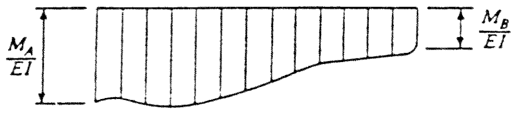
2.2 FIXED END MOMENTS FOR A BEAM ELEMENT WITH VARIABLE MOMENT OF INERTIA.



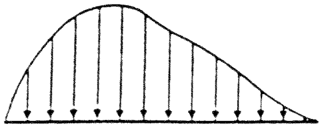
(*a*) Given beam



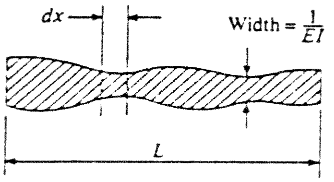
(*b*) $\frac{M}{EI}$ diagram due to the applied loading, plotted on the compression side



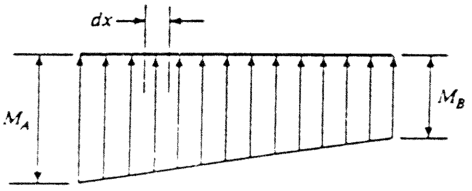
(*c*) $\frac{M}{EI}$ diagram due to the end moments, plotted on the compression side



(*g*) Loading on top of analogous column (*h*); $\frac{M_s}{EI}$ diagram, same as (*b*)



(*h*) Analogous column section



(*i*) Pressure on bottom of analogous column (h); M_i diagram

Fig. 2.1 Fixed End Moment for a Beam with Variable Moment of Inertia.

The analogous column is visualized as having a load equal to the Ms/EI (Ms=Statical Moment) Diagram, acting downward on the top, and a pressure equal to the Indeterminated Moment Diagram acting upward from the bottom. These loads are positive when compression is outside.

It is obvious that this column is in equilibrium by the following two compatibility conditions and the two principles of moment area are:

a) Change of Slope between A and B = 0, or area of Fig. 2.1b is equal to the area of Fig. 2.1c; between A and B.

b) Deflection of B from tangent to elastic curve at A = 0, or moment of area of Fig. 2.1b about B = moment of area of Fig. 2.1c about B.

The moment in any point of the given fixed end beam is equal to: $M = M_s - M_i$.

Thus in finding the Fixed-End moments acting on the end of the prismatic member due to the applied load by the method of Column Analogy, it is necessary only to determine the pressure or M_i, at the two ends when the Analogous Column is loaded with the M_s/EI Diagram.

Moments on the Ends, can then be found by the Relations:

$$M = M_s - M_i$$

sign conventions must be followed.

2.3 STIFFNESS AND CARRY-OVER FACTORS FOR A BEAM ELEMENT WITH VARIABLE MOMENT OF INERTIA.

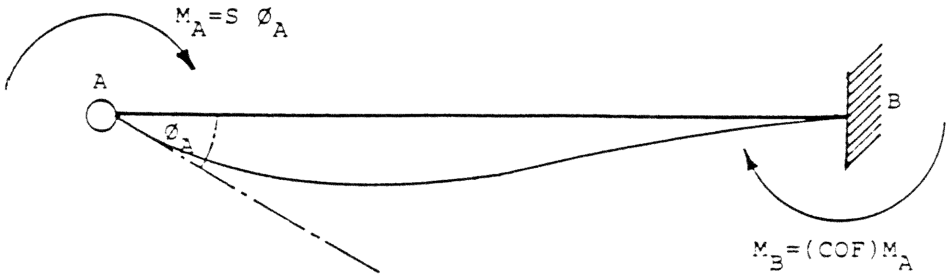


Fig.2.2 Stiffness and Carry-Over Factor.

Stiffness Factor is defined as the moment necessary to rotate the tangent to the elastic curve, an angle equals to a Unit Radian when the opposite end is fixed; $S_A = \frac{M_A}{\phi_A}$.

Carry-Over Factor is defined as the ratio of the Fixed End Moment at the Fixed (Restrained) End to the Moment applied at the Unrestrained End; (C.O.F.) = $\frac{M_B}{M_A}$.

Applying on top of the Conjugate Beam, a Load equal to the M/EI Diagram, the reactions will be ϕ_A in End A and 0 in End B.

If the reactions to the Conjugate Beam are considered as Loads on top of the Analogous Column and the M_A/EI and

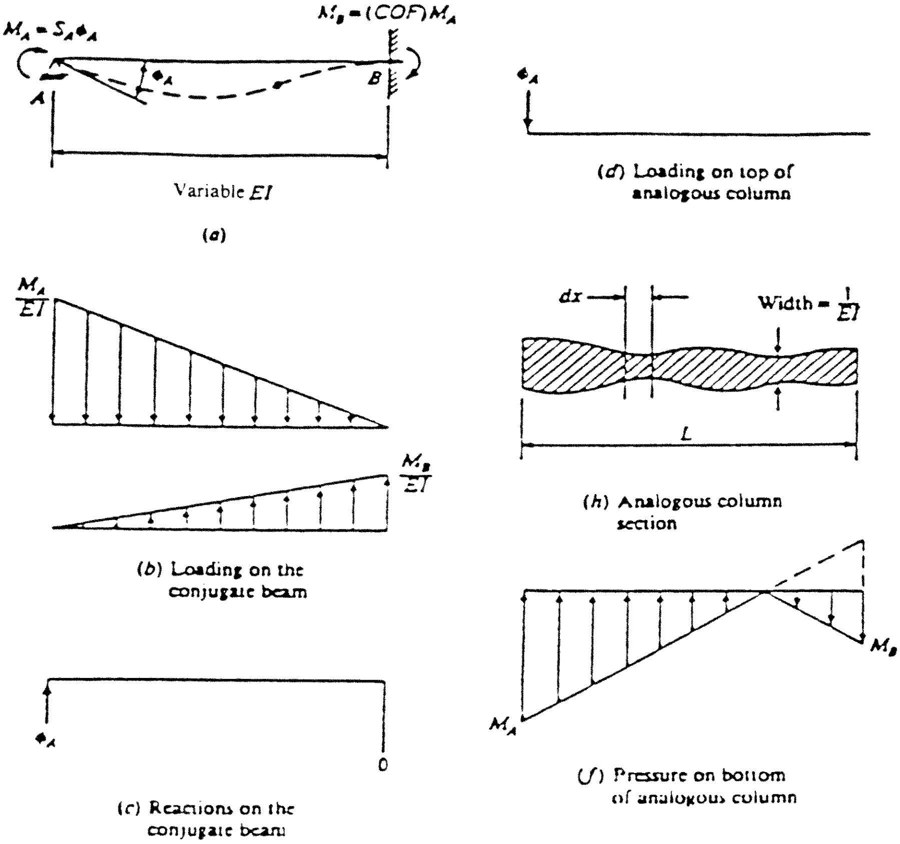


Fig. 2.3 Stiffness and Carry-Over Factors of Beam with variable EI

M_B/EI Diagrams are considered pressures on the bottom of the Analogous Column (Fig. 2.3), the column is still in equilibrium by the same principles stated in article 2.2 .

$$M_A = \frac{\O_A}{(A)_{AC}} + \frac{(\O_A{*}e){*}y}{(I)_{AC}} \quad ; \quad M_B = \frac{\O_A}{(A)_{AC}} - \frac{(\O_A{*}e){*}y}{(I)_{AC}}$$

Knowing the Indeterminated Moment M_A and M_B, the Stiffness and Carry-Over Factors are determined by the equations in page No. 8.

CHAPTER III

PRINCIPLES OF THE MOMENT DISTRIBUTION METHOD UTILIZED IN THIS PROGRAM.

3.1 GENERAL INTRODUCTION.

The method of Moment Distribution introduced by Hardy Cross (1) in 1930 is one of the most important contributions ever made for the analysis of Continuous Beams and Rigid Frames. Basically, it is a method used to solve the simultaneous equations of the slope deflection method by successive approximations.

The method starts by assuming no rotation of any of the joints in the structure. Successive corrections of the errors in the displacements of rotations at each joint are made until an acceptable balance of moments at each joint is obtained.

In order to avoid rotations, Fixed-End moments are applied initially to each End. As the restraints on the joints are relaxed, successive corrections are made proportionally to the factors known as Stiffness and Carry-Over Factors.

The Fixed End Moments as well as the Stiffness and Carry-Over Factors must be determined prior to the applications of the Moment Distribution Method. Those factors are determined by other methods of analysis such as the Column Analogy Method (4),(6) described in Chapter Two.

Moment Distribution (2) may be applied to the analysis of Structures with both Prismatic and Non-Prismatic members, and with vertical and lateral loadings.

This Chapter will illustrate only the subject utilized in the design of this program, which is the Moment Distribution Method applied to Continuous Beams integrated by Non-Prismatic members with any combination of Vertical Loads.

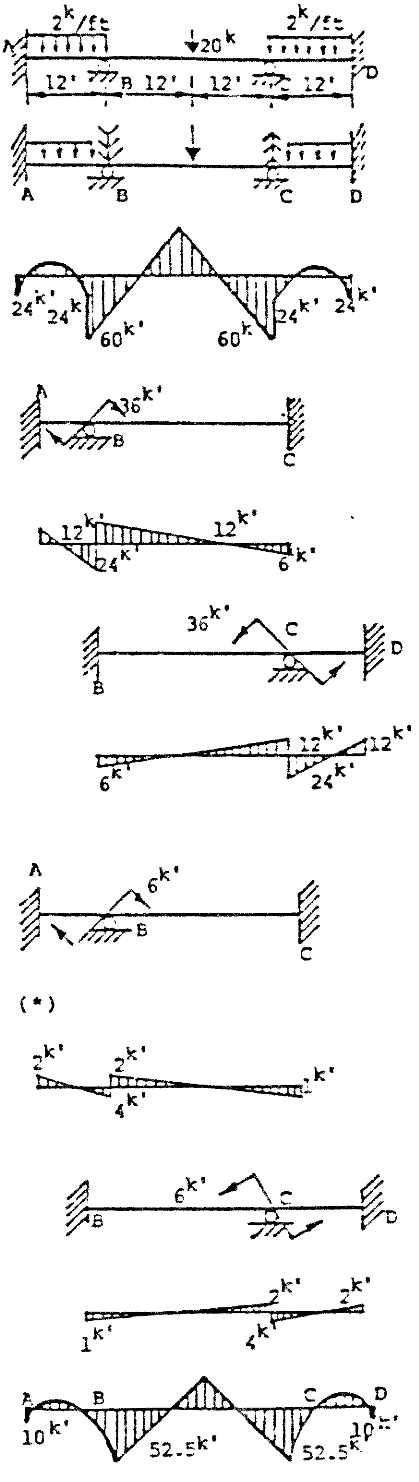
3.2 BASIC PROCEDURE (NO TRANSLATION OF JOINTS)

1. For each member find Fixed End Moments (FEM), Stiffness (S) and Carry-Over Factors (C.O.F.).
2. For each joint find Distribution Factors:DF=$S_i/\Sigma S_i$.
3. Arrange a Tabular form on an expanded outline of the structure and insert the values of C.O.F.,

D.F., and F.E.M.

4. Compute the Unbalanced Moment, by summing the F.E.M., plus any external applied Moment (e.g. a cantilever acting at each joint). Distribute balancing moments with opposite sign and proportional to the respective Distribution Factor.
5. Multiply the Distributed Moment by the Carry-Over Factor for that End of the member and record this product in the tabulation for the other End of the same member.
6. Repeat the process of Distributing Moments as in Step 4, and Carrying Over Moments as in Step 5 until the Carry-Over Factor Moments are negligible, when compared to the initial Fixed End Moment Values. End the final cycle with a Distribution (Balance) Step.
7. Add algebraically the Moments (Fixed-End, Distribution Moments, Carry-Over Moments) to obtain the Final End Moments.

The basic procedure of Moment Distribution(5) is illustrated in Fig. 3.1, by the analysis of a statically indeterminate structure consisting of three spans.



Given a continuous beam of constant cross Section.

Imaginary restraints assumed at B and C fixing the ends of all memebers.

Moment diagram for assumed fixed ends.

Joint at B is unlocked and allowed to rotate under the action of the unbalanced moment of 36K', other joints are fixed.

Moment diagram for above.

Similarly joint at C is unlocked and allowed to rotate under the unbalanced moment, while all other joints are assumed fixed.

Moment diagram for above.

The $6^{k'}$ moment at B. shown above, represents the restraint necessary to hold B in the assumed fixed position shown above. Joint B is next allowed, to rotate again under the action of the 6^{k} moment, while all other joints are assumed fixed, as previously shown.

Distribution and carryovers again occur above giving moment diagram shown.

Similarly to (*) for unbalanced moment at C.

Moment diagram for above.

Summation of moment diagrams. Average value of $\bar{M}$(at each side of joint) shown at B and C.

Fig. 3.1 Illustration of the Basic Procedure of the Moment Distribution Method.

3.3 ILLUSTRATION OF THE TABULAR FORM OF THE MOMENT DISTRIBUTION METHOD.

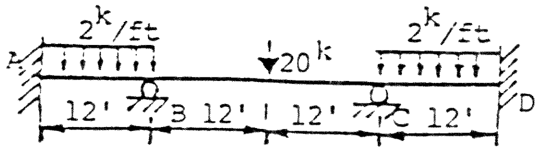


Fig. 3.2 Continuous Beam of Constane EI.

Solve the same problem of Fig. 3.1 using the tabular form of the Moment Distribution Method.

JOINT	AB	BA	BC	CB	CD	DC
D.F.	0.00	0.67	0.33	0.33	0.67	0.00
C.O.F.	0.50	0.50	0.50	0.50	0.50	0.50
F.E.M.	-24.00	24.00	-60.00	60.00	-24.00	24.00
D.M.	0.00	24.00	12.00	-12.00	-24.00	0.00
C.O.M.	12.00	0.00	-6.00	6.00	0.00	-12.00
D.M.	0.00	4.00	2.00	-2.00	-4.00	0.00
C.O.M.	2.00	0.00	-1.00	1.00	0.00	-2.00
D.M.	0.00	0.67	0.33	-0.33	-0.67	0.00
FINAL M.	-10.00	52.67	-52.67	52.67	-52.67	10.00

D.F.	Distribution Factors
C.O.F.	Carry-Over Factors
F.E.M.	Fixed End Moments
D.M.	Distribution Moments
C.O.M.	Carry-Over Moments
Final M.	Final Moments.

CHAPTER IV

ILLUSTRATIVE EXAMPLE

4.1 GENERAL INTRODUCTION.

In this chapter a simple example will be solved by hand calculations to illustrate the different steps that the program executes and the way in which the data and partial results are kept in arrays.

For a better understanding of the program, Flow-Charts can be found in Appendix A, and a complete listing of the program can be found in Appendix B. Figure 4.1 illustrates the nomenclature utilized.

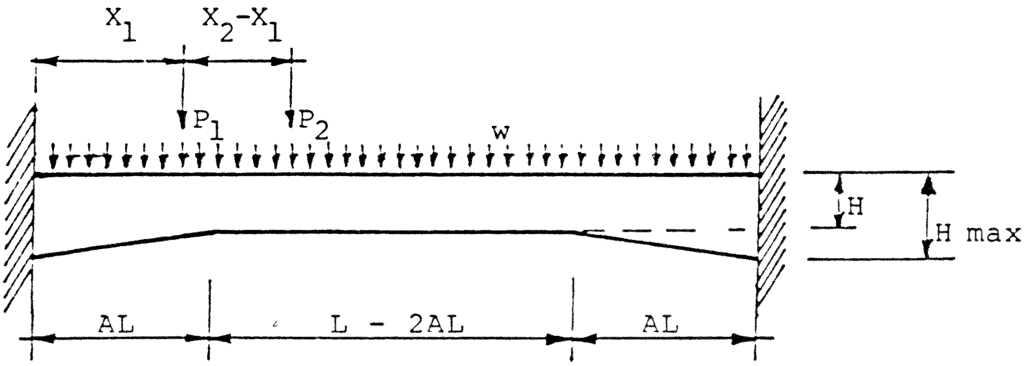


Fig. 4.1 Nomenclature Utilized.

4.2 ILLUSTRATIVE EXAMPLE.

Find Stiffness, Carry-Over Factors, and Fixed End moments of the beam shown in Fig. 4.2.

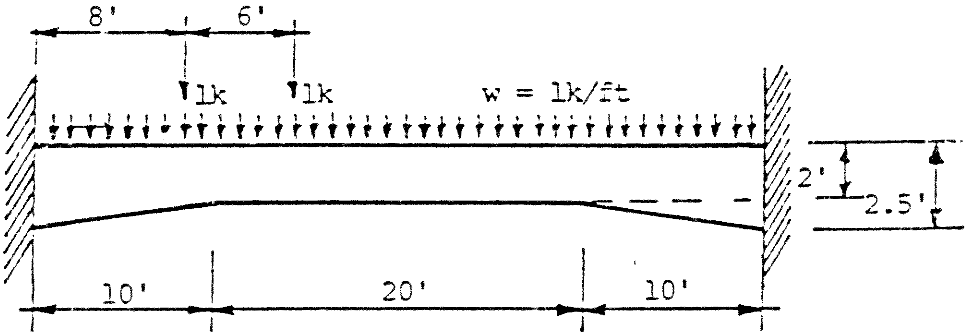


Fig. 4.2 Member of Illustrative Example 4.2.

GEOMETRICAL PROPERTIES

	Span 1	Span 2	Span 3	Span 4
Length of Spans (ft)	40.00			
Left Supp:Fixed=1,Free=0	1.00			
Right Supp:Fixed=1,Free=0	1.00			
Minimum Height (ft)	2.00			
Maximum Height (ft)	2.50			
Length AL Haunch (ft)	10.00			

LOADS ON BEAMS

	1	2	3	4	5
Uniform loads k/ft	1.00				
Concent.Loads in Span 1 k	1.00	1.00			
Dist.of p to left supp. ft	8.00	14.00			
Concent.Loads in Span 2 k					
Dist.of p to left supp. ft					
Concent.Loads in Span 3 k					
Dist.of p to left supp. ft					
Concent.Loads in Span 4 k					
Dist.of p to left supp. ft					

4.2(1) PROPERTIES OF ANALOGOUS COLUMN WITH HAUNCH DIVIDED INTO 8 STRAIGHT SEGMENTS.

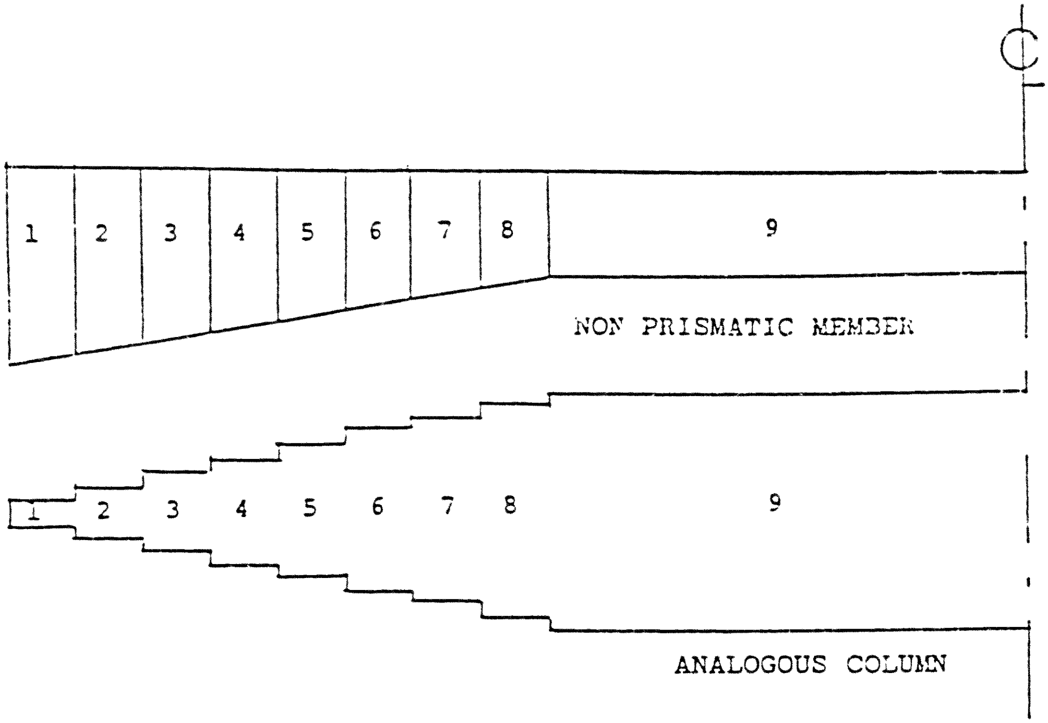


Fig. 4.3 Correspondence Between Beam And Analogous Column .

Section	A	B	C	D	E
	Height	I_b	$(A)_{AC}$	d	$(I)_{AC}$
1	2.468	1.879	0.665	19.375	249.7216
2	2.406	1.741	0.718	18.125	235.9675
3	2.344	1.610	0.776	16.875	221.0791
4	2.281	1.483	0.843	15.625	205.9208
5	2.219	1.366	0.915	14.375	189.1952
6	2.156	1.253	0.998	13.125	172.0509
7	2.094	1.148	1.089	11.875	153.7078
8	2.031	1.047	1.194	10.625	134.9465
9	2.000	1.000	10.000	0.000	333.3333
			17.198		1895.9237

$(A)_{AC}$ = 2(Summation Column C) = 34.396/EI

$(I)_{AC}$ = 2(Summation Column E) = 3791.845/EI

4.2(2) PROPERTIES OF ANALOGOUS COLUMN WITH HAUNCH DIVIDED INTO 6 STRAIGHT SEGMENTS.

Section	A Height	B I_b	C $(A)_{AC}$	D d	E $(I)_{AC}$
1	2.458	1.856	0.898	19.167	330.111
2	2.375	1.675	0.995	17.500	304.949
3	2.292	1.505	1.107	15.833	277.763
4	2.208	1.346	1.238	14.167	248.758
5	2.125	1.199	1.390	12.500	217.510
6	2.042	1.064	1.566	10.833	184.139
7	2.000	1.000	10.000	0.000	333.333
			17.194		1896.564

$(A)_{AC}$ = 2(Summation Column C) = 34.388/EI

$(I)_{AC}$ = 2(Summation Column E) = 3793.128/EI

4.3(3) PROPERTIES OF ANALOGOUS COLUMN WITH HAUNCH DIVIDED INTO 12 STRAIGHT SEGMENTS.

Section	A Height	B I_b	C $(A)_{AC}$	D d	E $(I)_{AC}$
1	2.479	1.904	0.438	19.583	167.995
2	2.438	1.811	0.460	18.750	161.746
3	2.396	1.719	0.485	17.917	155.722
4	2.354	1.631	0.511	17.083	149.155
5	2.312	1.541	0.541	16.250	142.889
6	2.271	1.464	0.569	15.417	135.275
7	2.229	1.384	0.602	14.538	128.059
8	2.188	1.309	0.637	13.750	120.470
9	2.146	1.235	0.675	12.917	112.662
10	2.104	1.164	0.716	12.083	104.576
11	2.063	1.098	0.759	11.250	96.105
12	2.021	1.032	0.807	10.417	87.618
13	2.000	1.000	10.000	0.000	333.333
			17.20		1895.600

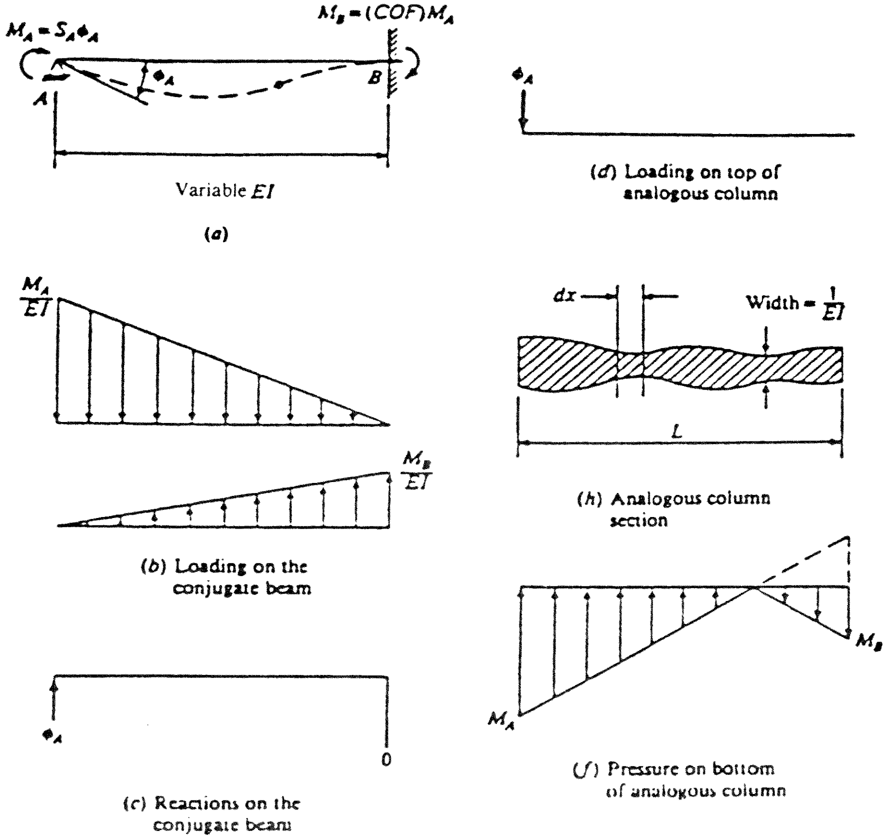
$(A)_{AC}$ = 2(summation Column C) = 34.40/EI

$(I)_{AC}$ = 2(Summation Column E) = 3791.20/EI

The variables for articles 4.2(1),4.2(2), and 4.2(3), are defined as follows:

A = Height of each section of the Member.
B = Moment of Inertia of each section of the Member.
C = Area of each section of Analogous Column.
D = Distance from ℄ to each section of The Analogous Column.
E = Moment of Inertia of each section of the Analogous Column. = $b.s^3/12 + A.d^2$

4.2(4) STIFFNESS "S" AND CARRY-OVER FACTORS "C.O.F."



(a)

(d) Loading on top of analogous column

(b) Loading on the conjugate beam

(h) Analogous column section

(c) Reactions on the conjugate beam

(f) Pressure on bottom of analogous column

Fig. 4.4 Stiffness and Carry-Over Factors of Beam with variable EI

$M_A \quad = \quad S_A * Ø_A \quad = \quad$ Pressure at A.

$$M_A = \frac{P}{(A)_{AC}} + \frac{M*C}{(I)_{AC}} = \frac{Ø_A}{34.375} + \frac{Ø_A(L/2)(L/2)}{3787} = 5.39(EI)Ø_A$$

$$M_B = \frac{P}{(A)_{AC}} - \frac{M*C}{(I)_{AC}} = \frac{Ø_A}{34.375} - \frac{Ø_A(L/2)(L/2)}{3787} = -3.06(EI)Ø_A$$

Since the Beam is Symmetric:

Stiffness $= S_A = S_B = M_A/Ø_A = 5.39(EI / L)$

$(C.O.F.)_{AB} = (C.O.F.)_{BA} = -M_B/M_A = 0.568$

4.2(5) FIXED END MOMENTS DUE TO UNIFORM LOAD

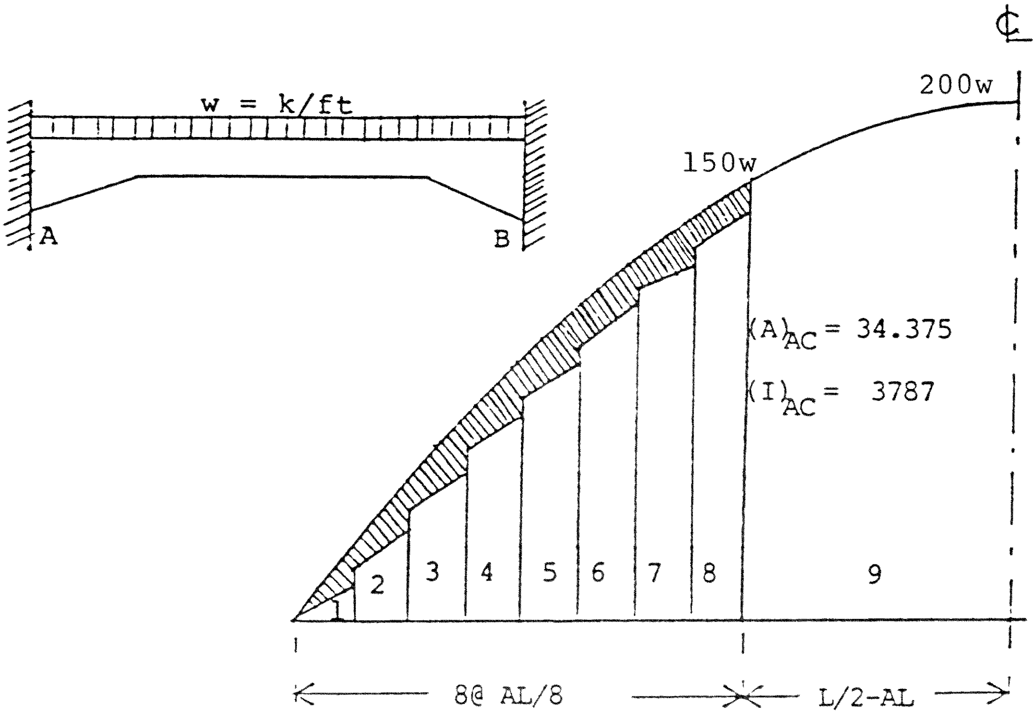


Fig. 4.5 Load on Top of Analogous Column (Uniform Load).

Section	M_s	$\frac{I}{I_9}$	$\frac{M}{(EI)_i}$	$\frac{M}{(EI)_{i+1}}$	AREA
1	24.20	1.88	0.00	12.90	8.06
2	46.90	1.74	13.90	26.90	25.50
3	68.00	1.61	29.10	42.20	44.56
4	87.50	1.48	45.90	59.10	65.63
5	105.50	1.37	63.90	77.00	88.06
6	121.90	1.25	84.40	97.50	113.69
7	136.70	1.15	106.00	118.90	140.56
8	150.00	1.05	130.20	142.80	170.63
9	200.00	1.00	150.00		1833.33

Area = 2(Summation Areas) = 4980.05

$(FEM)_A = P/A \pm M/I$

$$(FEM)_A = (FEM)_B = \frac{4980}{34.375} + 0 = 144.87$$

4.2(6) FIXED END MOMENTS DUE TO CONCENTRATED LOAD (out of Haunch)

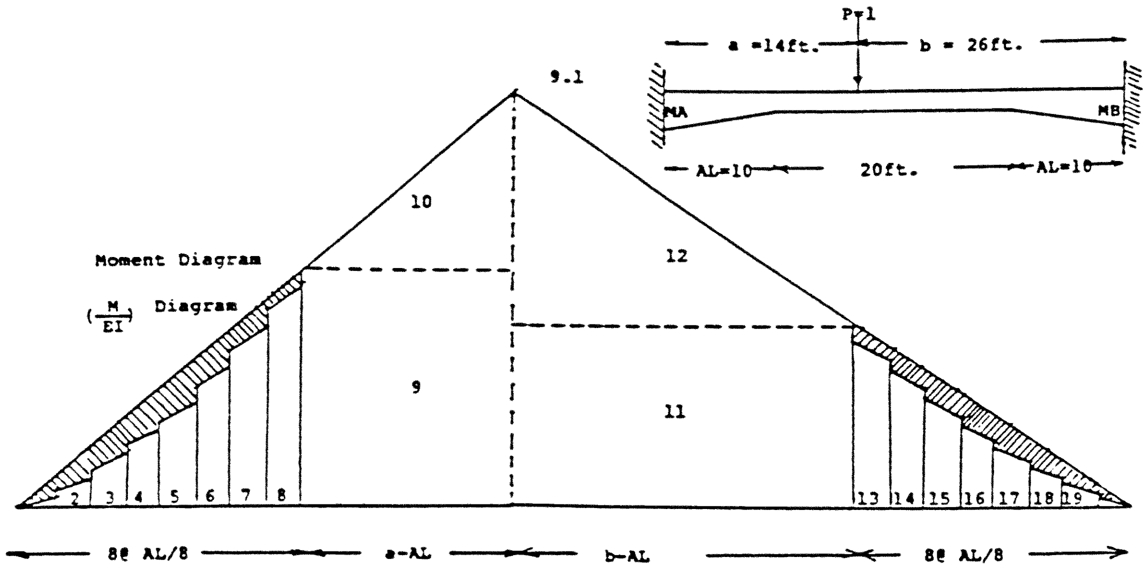


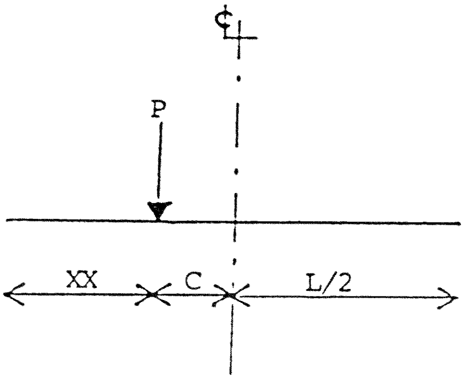
Fig. 4.6 Load on Top of Analogous Column (p out of Haunch)

No.	X(ft)	M_s	I	$\frac{M}{(EI)_i}$	$\frac{M}{(EI)_{i+1}}$	AREA	A*X
1	0.63	0.81	1.88	0.00	0.43	0.27	0.17
2	1.88	1.63	1.74	0.47	0.93	0.93	1.64
3	3.13	2.44	1.61	1.01	1.51	1.58	4.93
4	4.38	3.25	1.48	1.64	2.19	2.41	10.53
5	5.63	4.06	1.37	2.38	2.98	3.33	18.74
6	6.88	4.88	1.25	3.24	3.89	4.47	30.73
7	8.13	5.69	1.15	4.25	4.96	5.74	46.67
8	9.38	6.50	1.05	5.43	6.20	7.26	68.03
9	12.00		1.00			26.00	312.00
10	12.67		1.00			5.20	65.88
11	22.00		1.00			56.00	1232.00
12	19.33		1.00			44.80	866.12
13	30.63	3.50	1.05	2.92	3.34	3.90	119.44
14	31.00	3.00	1.15	2.29	2.67	3.09	98.49
15	33.13	2.63	1.25	1.75	2.09	2.41	79.70
16	34.38	2.19	1.31	1.28	1.60	1.80	61.88
17	35.63	1.75	1.48	0.88	1.18	1.29	46.10
18	36.88	1.31	1.61	0.54	0.82	0.85	31.34
19	38.13	0.88	1.74	0.25	0.50	0.48	18.11
20	39.38	0.44	1.88	0.00	0.23	0.14	5.67
				SUMMATION		171.89	3118.14

AP = Areas = 171.89

A*X = (A*X) = 3118.14

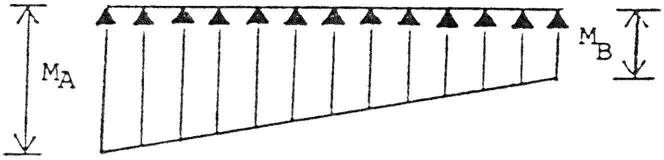
P = Summation Areas = 171.89



$(A)_{AC} = 34.375$

$(I)_{AC} = 3787$

a) Equivalent Load on Top of Analogous Column.



b) Pressure at bottom of Analogous Column

Fig. 4.7 Fixed End Moments for a Beam With Variable EI.

$$XX = \frac{(A*X)}{(A)} = \frac{3118.14}{171.89} = 18.14$$

$$C = L/2 - XX = 20.00 - 18.14 = +1.86$$

$$(FEM)_A = \frac{P}{A} + \frac{M_Y}{I} = \frac{171.89}{34.375} + \frac{(171.89*1.86)20}{3787} = 6.69$$

$$(FEM)_B = \frac{P}{B} - \frac{M_Y}{I} = \frac{171.89}{34.375} - \frac{(171.89*1.86)20}{3787} = 3.31$$

4.2(7) FIXED END MOMENTS DUE TO CONCENTRATED LOAD (in Haunch).

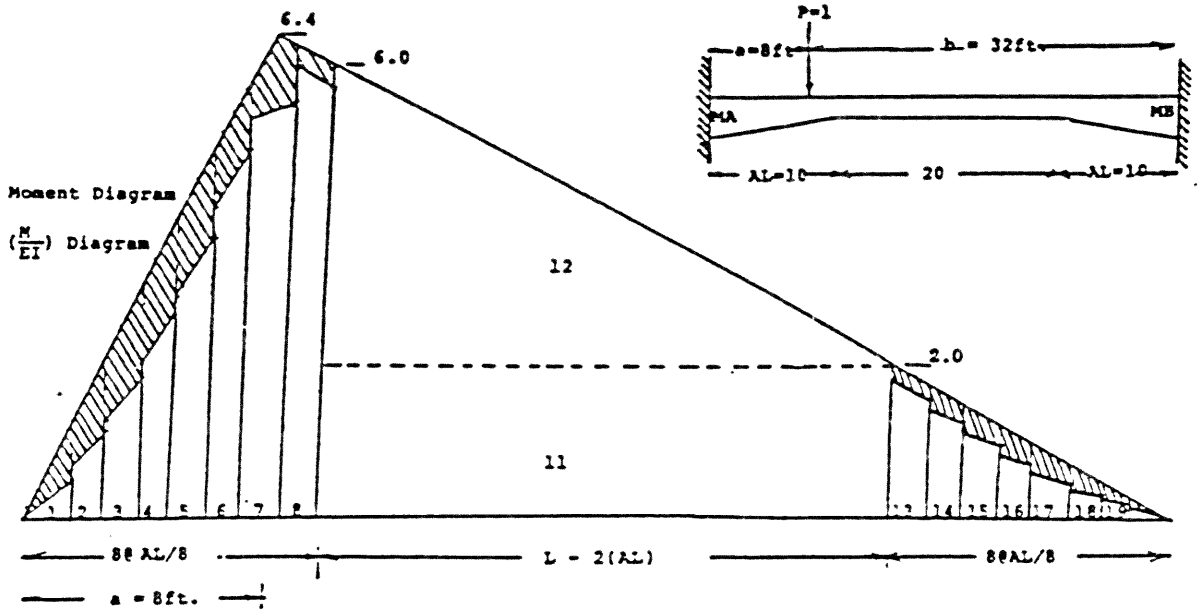
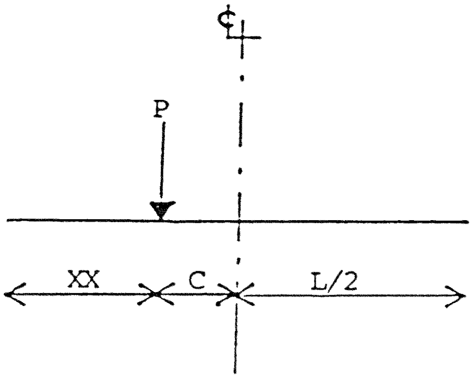


Fig. Load on Top of Analogous Column
(p on Haunch)

No.	X(ft)	M_S	I	$(\frac{M}{EI})_i$	$(\frac{M}{EI})_{i+1}$	AREA	A*X
1	0.63	1.00	1.88	0.00	0.53	0.33	0.21
2	1.88	2.00	1.74	0.57	1.15	1.08	2.03
3	3.13	3.00	1.61	1.24	1.86	1.94	6.07
4	4.38	4.00	1.48	2.03	2.70	2.96	12.97
5	5.63	5.00	1.37	2.92	3.65	4.11	23.14
6	6.88	6.00	1.25	4.00	4.80	5.50	37.84
7	8.13	6.25	1.15	5.27	5.47	6.67	54.55
8	9.38	6.00	1.05	6.00	5.71	7.32	68.66
9			1.00				
10			1.00				
11	20.00		1.00			40.00	800.00
12	16.70		1.00			40.00	666.64
13	30.63	2.00	1.05	1.67	1.90	2.23	68.31
14	31.88	1.75	1.15	1.30	1.50	1.75	55.80
15	33.13	1.50	1.25	1.00	1.20	1.38	45.72
16	34.38	1.25	1.37	0.73	0.91	1.03	35.41
17	35.63	1.00	1.48	0.51	0.68	0.74	26.37
18	36.88	0.75	1.61	0.31	0.47	0.49	18.07
19	38.13	0.50	1.74	0.14	0.29	0.27	10.29
20	39.38	0.25	1.88	0.00	0.13	0.08	3.15
					SUMMATION	117.73	1929.16

AP = Areas = 117.73 ; A*X = (A*X) = 1929.16

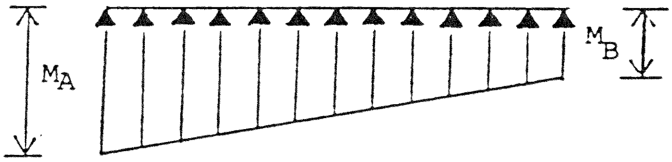
P = Summation Areas = 117.73



$(A)_{AC} = 34.375$

$(I)_{AC} = 3787$

a) Equivalent Load on Top of Analogous Column.



b) Pressure at bottom of Analogous Column

Fig. 4.9 Fixed End Moments for a Beam with Variable EI.

$$XX = \frac{(A*X)}{(A)} = \frac{1929.16}{117.73} = 16.38$$

$$C = L/2 - XX = 20.00 - 16.38 = 3.61$$

$$(FEM)_A = \frac{P}{A} \quad \frac{M_Y}{I} \quad \frac{117.73}{34.375} \quad \frac{(117.73*3.61)20}{3787} = 5.67$$

$$(FEM)_B = \frac{P}{A} \quad \frac{M_Y}{I} \quad \frac{117.73}{34.375} \quad \frac{(117.73*3.61)20}{3787} = 1.18$$

4.2(8) SUMMARY OF FIXED-END MOMENTS

	$(FEM)_A$	$(FEM)_B$	REFERENCE
Uniform Load	144.87	144.87	Pg. 21
P out of Haunch	6.69	3.31	Pg. 23
P in Haunch	5.67	1.18	Pg. 25

CHAPTER V

PROBLEMS SOLVED BY THE COMPUTER PROGRAM

5.1 INTRODUCTION

In order to illustrate how the program works, and how the data is inputed to attain results, we will solve in this chapter, three problems using the program "Analysis of Non-Prismatic Beam".

The three problems are:

Problem No. 1: Non-Prismatic Beam of one Span. This is the same problem solved by hand in chapter IV. By comparing results, we can establish the accuracy of the program. This problem illustrates only the first part of the program.

Problem No. 2: Non-Prismatic Beam of Three Spans. This problem illustrates the first and second parts of the program.

Problem No. 3: Non-Prismatic Beam of four Spans. Also illustrates the first and second parts of the program.

5.2 EXAMPLE No. 5.1 NON-PRISMATIC BEAM OF ONE SPAN.

Solve using the program "Analysis of Non-Prismatic Beam", the member shown in Fig. 5.1. Note, this is the same problem solved in chapter IV.

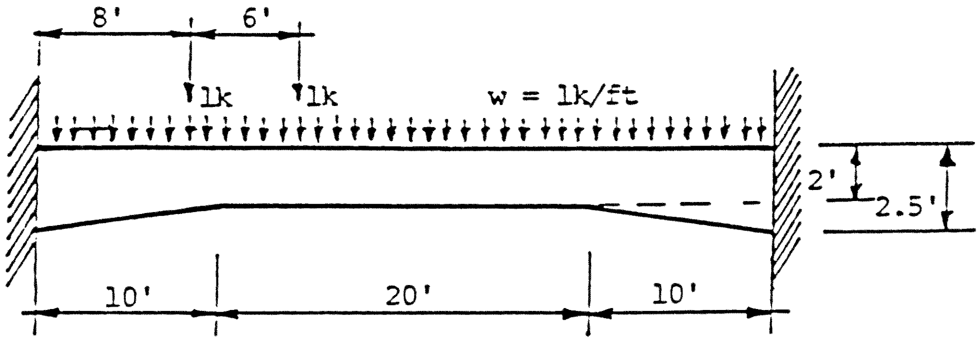


Fig. 5.1 Member of Example 5.1

```
                    GEOMETRICAL PROPERTIES OF THE BEAM
                    ----------------------------------
                                     SPAN 1   SPAN 2   SPAN 3   SPAN 4
--------------------------------------------------------------------
LENGTH OF SPANS (FEET)               40.00     0.00     0.00     0.00
LEFT SUPPORT:FIXED=1 OR FREE=0        1        0        0        0
RIGHT SUPPORT:FIXED=1 OR FREE=0       1        0        0        0
MINIMUM HEIGHT OF BEAM (FEET)         2.00     0.00     0.00     0.00
MAXIMUM HEIGHT OF BEAM (FEET)         2.50     0.00     0.00     0.00
LENGTH AL OF TAPERED SECTION         10.00     0.00     0.00     0.00


    DO YOU WANT TO CHANGE ANY NUMBER? YES OR NO: ? NO

                         PARTIAL RESULTS
                         ---------------
AREA OF ANALOG.COL                    34.39     0.00     0.00     0.00
MOM.OF INERT.OF ANALOG.COL          3791.48     0.00     0.00     0.00
STIFFNESS OF SPAN/L                    0.13     0.00     0.00     0.00
DITR.FAC.      0.000  0.000  0.000  0.000  0.000  1.000  0.000  0.000
CAR.OV.FACT.   0.568  0.568  0.000  0.000  0.000  0.000  0.000  0.000


PRESS ANY KEY TO CONTINUE
```

```
              CHECK LOAD ON BEAMS.-
              --------------------
UNIFORM LOADS K/F                    1.00     0.00     0.00     0.00
CONCENT.LOADS IN SPAN 1 K             1.00     1.00      0.00      0.00      0.00
DIST.OF P TO LEFT SUPP. F             8.00    14.00      0.00      0.00      0.00
CONCENT.LOADS IN SPAN 2 K             0.00     0.00      0.00      0.00      0.00
DIST.OF P TO LEFT SUPP. F             0.00     0.00      0.00      0.00      0.00
CONCENT.LOADS IN SPAN 3 K             0.00     0.00      0.00      0.00      0.00
DIST.OF P TO LEFT SUPP. F             0.00     0.00      0.00      0.00      0.00
CONCENT.LOADS IN SPAN 4 K             0.00     0.00      0.00      0.00      0.00
DIST.OF P TO LEFT SUPP. F             0.00     0.00      0.00      0.00      0.00

 DO YOU WANT TO CHANGE ANY LOAD? YES OR NO: ? NO




FEM (W) -144.83   144.83     0.00     0.00     0.00     0.00     0.00     0.00
      COMPUTING........
FEM (P)  -12.34     4.51     0.00     0.00     0.00     0.00     0.00     0.00

   PRESS ANY KEY TO CONTINUE
```

5.3 EXAMPLE No. 5.2 NON-PRISMATIC BEAMS OF THREE SPANS.

Solve using the program "Analysis of Non-Prismatic Beam", the beam shown in Fig. 5.2. Find Final Moments and Shears in Internal Sections.

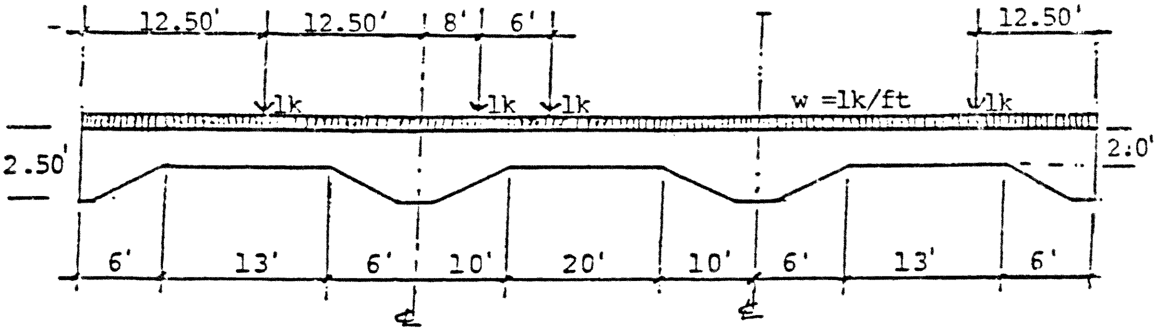


Fig. 5.2 Member of Example 5.2

```
                    GEOMETRICAL PROPERTIES OF THE BEAM
                    ----------------------------------
                                   SPAN 1  SPAN 2  SPAN 3  SPAN 4
-----------------------------------------------------------------
LENGTH OF SPANS (FEET)             25.00   40.00   25.00    0.00
LEFT SUPPORT:FIXED=1 OR FREE=0      0       0       0       0
RIGHT SUPPORT:FIXED=1 OR FREE=0     0       0       0       0
MINIMUM HEIGHT OF BEAM (FEET)       2.00    2.00    2.00    0.00
MAXIMUM HEIGHT OF BEAM (FEET)       2.50    2.50    2.50    0.00
LENGTH AL OF TAPERED SECTION        6.00   10.00    6.00    0.00


   DO YOU WANT TO CHANGE ANY NUMBER? YES OR NO: ? NO

                          PARTIAL RESULTS
                          ---------------
AREA OF ANALOG.COL                 21.64   34.39    21.64    0.00
MOM.OF INERT.OF ANALOG.COL        935.10 3791.48   935.10    0.00
STIFFNESS OF SPAN/L                 0.21    0.13     0.21    0.00
DITR.FAC.      1.000  0.613  0.387  0.387  0.613  1.000  0.000  0.000
CAR.OV.FACT.   0.567  0.567  0.568  0.568  0.567  0.567  0.000  0.000
```

```
            CHECK LOAD ON BEAMS.-
            --------------------
 UNIFORM LOADS K/F                 1.00     1.00     1.00     0.00
 CONCENT.LOADS IN SPAN 1 K          1.00      0.00      0.00      0.00      0.00
 DIST.OF P TO LEFT SUPP. F         12.50      0.00      0.00      0.00      0.00
 CONCENT.LOADS IN SPAN 2 K          1.00      1.00      0.00      0.00      0.00
 DIST.OF P TO LEFT SUPP. F          8.00     14.00      0.00      0.00      0.00
 CONCENT.LOADS IN SPAN 3 K          1.00      0.00      0.00      0.00      0.00
 DIST.OF P TO LEFT SUPP. F         12.50      0.00      0.00      0.00      0.00
 CONCENT.LOADS IN SPAN 4 K          0.00      0.00      0.00      0.00      0.00
 DIST.OF P TO LEFT SUPP. F          0.00      0.00      0.00      0.00      0.00


  DO YOU WANT TO CHANGE ANY LOAD? YES OR NO: ? NO

 FEM (W)  -56.50    56.50  -144.83   144.83   -56.50    56.50     0.00     0.00
      COMPUTING........
 FEM (P)   -3.44     3.44   -12.34     4.51    -3.44     3.44     0.00     0.00

   PRESS ANY KEY TO CONTINUE




                    *** MOMENT DISTRIBUTION ***
                    ---------------------------
           MOM.1    MOM.2    MOM.3    MOM.4    MOM.5    MOM.6    MOM.7    MOM.8
--------------------------------------------------------------------------------

DIS.FAC.    1.00     0.61     0.39     0.39     0.61     1.00     0.00     0.00
C.O.FAC.    0.57     0.57     0.57     0.57     0.57     0.57     0.00     0.00
FIX.E.M.  -59.94    59.94  -157.17   149.34   -59.94    59.94     0.00     0.00
--------------------------------------------------------------------------------

DISTRIB.   59.94    59.62    37.61   -34.58   -54.82   -59.94     0.00     0.00
CAR.OV.    33.78    33.97   -19.64    21.36   -33.97   -31.06     0.00     0.00
DISTRIB.  -33.78    -8.78    -5.54     4.88     7.73    31.06     0.00     0.00
CAR.OV.    -4.98   -19.14     2.77    -3.15    17.60     4.38     0.00     0.00
DISTRIB.    4.98    10.04     6.33    -5.59    -8.86    -4.38     0.00     0.00
CAR.OV.     5.69     2.82    -3.18     3.60    -2.48    -5.02     0.00     0.00
DISTRIB.   -5.69     0.22     0.14    -0.43    -0.68     5.02     0.00     0.00
--------------------------------------------------------------------------------

FIN.MOM     0.00   138.67  -138.67   135.42  -135.42     0.00     0.00     0.00
MOMENTS IN INTERNAL SECTIONS,YES OR NO: ?
```

```
                    *** MOMENTS IN INTERNAL SECTIONS ***
                    ------------------------------------
SPAN 1
DIST.        0.00      3.13      6.25     12.50     18.75     21.88   25.00
MOM FRA      0.00     18.41     27.05     15.04    -42.29    -85.60 -138.67
SPAN 2
DIST.        0.00      5.00     10.00     20.00     30.00     35.00   40.00
MOM FRA  -138.67    -43.52     24.64     73.95     19.27    -45.58 -135.42
SPAN 3
DIST.        0.00      3.13      6.25     12.50     18.75     21.88   25.00
MOM FRA  -135.42    -82.75    -39.85     16.67     27.86     18.81    0.00

DO YOU WANT SHEARS IN INTERNAL SECTIONS,YES OR NO: ?
```

```
                    *** SHEARS IN INTERNAL SECTIONS ***
                    -----------------------------------
SPAN 1
DIST.        0.00      3.13      6.25     12.50     18.75     21.88   25.00
SHEARS.      7.45      4.33      1.20     -5.05    -12.30    -15.42  -18.55
SPAN 2
DIST.        0.00      5.00     10.00     20.00     30.00     35.00   40.00
SHEARS.     21.53     16.53     10.53     -0.47    -10.47    -15.47  -20.47
SPAN 3
DIST.        0.00      3.13      6.25     12.50     18.75     21.88   25.00
SHEARS.     18.42     15.29     12.17      5.92     -1.33     -4.46   -7.58

PRESS ANY KEY TO CONTINUE
```

5.4 EXAMPLE No. 5.3 NON-PRISMATIC BEAMS OF FOUR SPANS.

Solve using the program "Analysis of Non-Prismatic Beam", the member shown in Fig. 5.3. Find Final Moments and shears in Internal Sections.

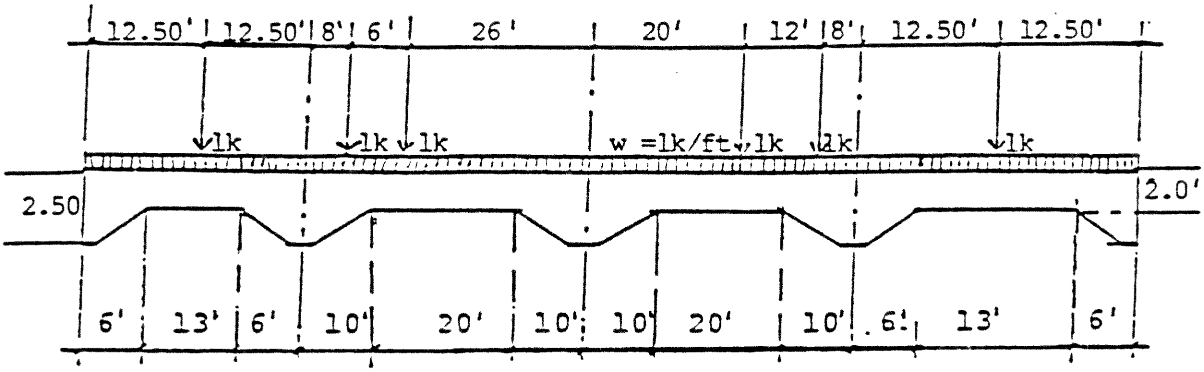


Fig. 5.3 Member of Example 5.4

```
                       GEOMETRICAL PROPERTIES OF THE BEAM
                       ----------------------------------
                                       SPAN 1   SPAN 2   SPAN 3   SPAN 4
 ------------------------------------------------------------------------
 LENGTH OF SPANS (FEET)                25.00    40.00    40.00    25.00
 LEFT SUPPORT:FIXED=1 OR FREE=0         0        0        0        0
 RIGHT SUPPORT:FIXED=1 OR FREE=0        0        0        0        0
 MINIMUM HEIGHT OF BEAM (FEET)          2.00     2.00     2.00     2.00
 MAXIMUM HEIGHT OF BEAM (FEET)          2.50     2.50     2.50     2.50
 LENGTH AL OF TAPERED SECTION           6.00    10.00    10.00     6.00


      DO YOU WANT TO CHANGE ANY NUMBER? YES OR NO: ?
      INVALID RESPONSE,ENTER YES OR NO: ? NO

                             PARTIAL RESULTS
                             ---------------

 AREA OF ANALOG.COL                    21.64     34.39     34.39     21.64
 MOM.OF INERT.OF ANALOG.COL           935.10   3791.48   3791.48    935.10
 STIFFNESS OF SPAN/L                    0.21      0.13      0.13      0.21
 DITR.FAC.     1.000   0.613   0.387   0.500   0.500   0.387   0.613   1.000
 CAR.OV.FACT.  0.567   0.567   0.568   0.568   0.568   0.568   0.567   0.567
```

```
                 CHECK LOAD ON BEAMS.-
                 ---------------------
UNIFORM LOADS K/F                 1.00     1.00     1.00     1.00
CONCENT.LOADS IN SPAN 1 K          1.00      0.00      0.00      0.00      0.00
DIST.OF P TO LEFT SUPP. F         12.50      0.00      0.00      0.00      0.00
CONCENT.LOADS IN SPAN 2 K          1.00      1.00      0.00      0.00      0.00
DIST.OF P TO LEFT SUPP. F          8.00     14.00      0.00      0.00      0.00
CONCENT.LOADS IN SPAN 3 K          1.00      1.00      0.00      0.00      0.00
DIST.OF P TO LEFT SUPP. F         20.00     32.00      0.00      0.00      0.00
CONCENT.LOADS IN SPAN 4 K          1.00      0.00      0.00      0.00      0.00
DIST.OF P TO LEFT SUPP. F         12.50      0.00      0.00      0.00      0.00


 DO YOU WANT TO CHANGE ANY LOAD? YES OR NO: ? NO
INVALID RESPONSE PLEASE ENTER YES OR NO: ? NO

FEM (W)  -56.50    56.50  -144.83   144.83  -144.83   144.83   -56.50    56.50
      COMPUTING........
FEM (P)   -3.44     3.44   -12.34     4.51    -6.72    11.18    -3.44     3.44

   PRESS ANY KEY TO CONTINUE




                         *** MOMENT DISTRIBUTION ***
                         ---------------------------
          MOM.1    MOM.2    MOM.3    MOM.4    MOM.5    MOM.6    MOM.7    MOM.8
--------------------------------------------------------------------------------

DIS.FAC.   1.00     0.61     0.39     0.50     0.50     0.39     0.61     1.00
C.O.FAC.   0.57     0.57     0.57     0.57     0.57     0.57     0.57     0.57
FIX.E.M. -59.94    59.94  -157.17   149.34  -151.55   156.00   -59.94    59.94
--------------------------------------------------------------------------------

DISTRIB.  59.94    59.62    37.61     1.10     1.10   -37.16   -58.90   -59.94
CAR.OV.   33.78    33.97     0.63    21.36   -21.10     0.63   -33.97   -33.38
DISTRIB. -33.78   -21.21   -13.38    -0.13    -0.13    12.90    20.44    33.38
CAR.OV.  -12.02   -19.14    -0.07    -7.60     7.32    -0.07    18.91    11.58
DISTRIB.  12.02    11.78     7.43     0.14     0.14    -7.29   -11.55   -11.58
CAR.OV.    6.68     6.81     0.08     4.22    -4.14     0.08    -6.56    -6.55
DISTRIB.  -6.68    -4.22    -2.67    -0.04    -0.04     2.51     3.98     6.55
--------------------------------------------------------------------------------

FIN.MOM    0.00   127.54  -127.54   168.39  -168.39   127.59  -127.59     0.00
MOMENTS IN INTERNAL SECTIONS,YES OR NO: ?
```

```
                   *** MOMENTS IN INTERNAL SECTIONS ***
                   ------------------------------------
SPAN 1
DIST.        0.00      3.13      6.25     12.50     18.75     21.88   25.00
MOM FRA      0.00     19.80     29.83     20.61    -33.93    -75.85 -127.54
SPAN 2
DIST.        0.00      5.00     10.00     20.00     30.00     35.00   40.00
MOM FRA   -127.54    -37.89     24.75     63.03     -2.68    -73.04 -168.39
SPAN 3
DIST.        0.00      5.00     10.00     20.00     30.00     35.00   40.00
MOM FRA   -168.39    -72.29     -1.19     66.01     23.21    -38.69 -127.59
SPAN 4
DIST.        0.00      3.13      6.25     12.50     18.75     21.88   25.00
MOM FRA   -127.59    -75.90    -33.98     20.58     29.82     19.79    0.00
.
DO YOU WANT SHEARS IN INTERNAL SECTIONS,YES OR NO: ?
```

```
                   *** SHEARS IN INTERNAL SECTIONS ***
                   -----------------------------------
SPAN 1
DIST.        0.00      3.13      6.25     12.50     18.75     21.88   25.00
SHEARS.      7.90      4.77      1.65     -4.60    -11.85    -14.98  -18.10
SPAN 2
DIST.        0.00      5.00     10.00     20.00     30.00     35.00   40.00
SHEARS.     20.43     15.43      9.43     -1.57    -11.57    -16.57  -21.57
SPAN 3
DIST.        0.00      5.00     10.00     20.00     30.00     35.00   40.00
SHEARS.     21.72     16.72     11.72      1.72     -9.28    -15.28  -20.28
SPAN 4
DIST.        0.00      3.13      6.25     12.50     18.75     21.88   25.00
SHEARS.     18.10     14.98     11.85      5.60     -1.65     -4.77   -7.90

PRESS ANY KEY TO CONTINUE
```

CHAPTER VI

CONCLUSIONS AND LIMITATIONS

6.1 CONCLUSIONS

In articles 4.2 and 5.2, the same member of one span, and variable EI, was analyzed utilizing hand calculations, and the computer program respectively. In doing so, the lengths of variable EI in each end of the member were divided into 8 straight segments with constant EI. The results of both types of calculations are shown in table 6.1 .

	HAND CALCULATIONS	COMPUTER PROGRAM
STIFFNESS		
S_A	0.13	0.13
S_B	0.13	0.13
CARRY-OVER FACTORS		
$(C.O.F)_A$	0.568	0.568
$(C.O.F)_B$	0.568	0.568
DISTRIBUTION FACTORS		
$(D.F)_A$	0.00	0.00
$(D.F)_B$	0.00	0.00
FIXED-END MOMENTS		
$(FEM)_A$	-157.23	-157.17
$(FEM)_B$	149.36	149.34

TABLE 6.1 RESULTS OF PROBLEMS 4.2 & 5.2

From these results it can be noted, that the accuracy of the computer program is the same as that of the hand calculations considering the Non-Prismatic length at each end divided into 8 straight segments.

It can also be noted, the magnitude of the time consuming hand calculations needed to solve this simple example.

In order to determine the most appropriate number of straight segments to solve these problems with accuracy and speed the same problem was solved in Chapter IV considering the Non-Prismatic sections divided into 6, 8, and 12 straight segments. The results are shown bellow.

No. of Straight Segments Of the Non-Prismatic Sections.	6	8	12
Area of Analogous Column.	34.388	34.396	34.400
Moment of Inertia of Analogous Column.	3793.128	3791.845	3791.200
Stiffness	5.3812	5.3824	5.3832
Carry-Over Factors	0.56768	0.56793	0.56799
ACCURACY	99.94%	99.99%	100%

TABLE 6.2 Stiffness and Carry-Over Factors of Beam from problem 4.2

From these results it can be concluded, that it is not necessary to divide the Non-Prismatic sections, into more than 8 straight segments in order to achieve accurate results.

6.2 LIMITATIONS

The program "Analysis of Non-Prismatic Beams" has been designed to analyze continuous beams with a maximum of 4 straight spans whith the following characteristics:

a) Symmetrical Spans.
b) Rectangular Sections.
c) Rectilinear variation of the moment of Inertia.

Even with these limitations the program "Analysis of Non-Prismatic Beams" will assist structural engineers to obtain rapidly and effectively the moments and shears in continuous beams with moment of inertia varying linearly.

It is desirable that this work will encourage and serve as a basis for programmers and engineers alike, to design new computer programs that would analyze members with moments of inertia varying in different ways.

CHAPTER VII

REFERENCES

---

1. Cross, Hardy, " **Analysis of Continuous Frames by Distributing Fixed-End Moments."** Proc. ASCE.,May, 1930.

2. Gere, J.M., **"Moment Distribution"**, Van Nostrand Reinhold Company.

3. I.B.M. **"Basic Personal Computer"** Hardware Reference Library 1983.

4. Kinney, J.S., **"Intermediate Structural Analysis"**, Addison-Wesley, Reading, Mass.,1957.

5. Mantell & Marrow **"Structural Analysis"**., The Ronald Press Co. N.Y., 1962.

6. Wang, C.K. **"Intermediate Structural Analysis"** MC.Graw-Hill Company, 1983.

APPENDIX A

LIST OF FLOW-CHARTS

1. GENERAL FLOW-CHART

2. SUBROUTINE 3: Area and Moment of Inertia of Analogous Column.

3. SUBROUTINE 4: Stiffness and Carry-Over Factors.

4. SUBROUTINE 5: Distribution Factors.

5. SUBROUTINE 6: Fixed-End Moments due to Uniform Loads.

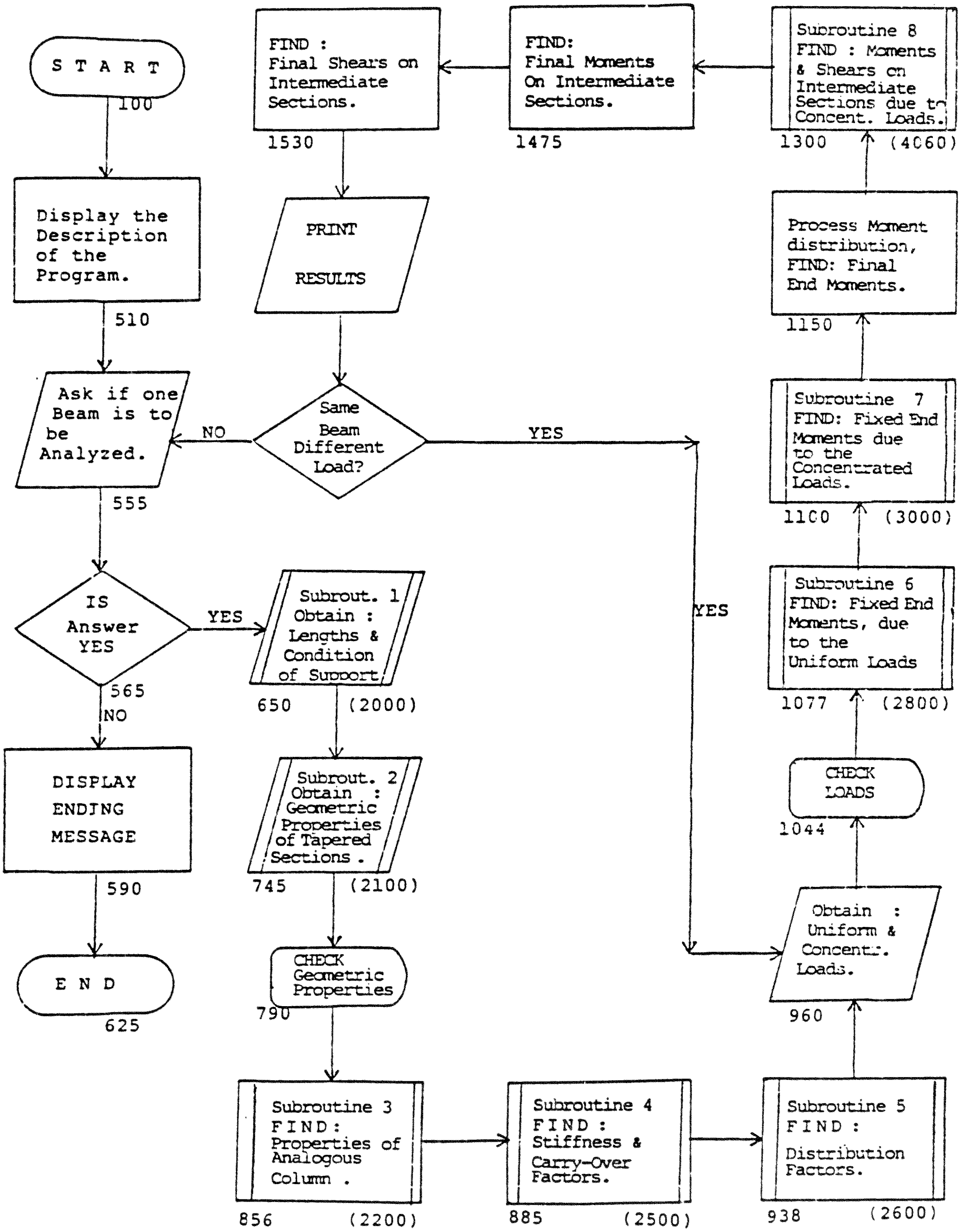
6. SUBROUTINE 7: Fixed-End Moments due to Concentrated Loads.

7. OBTAIN: Moments and Shears in Internal Sections.

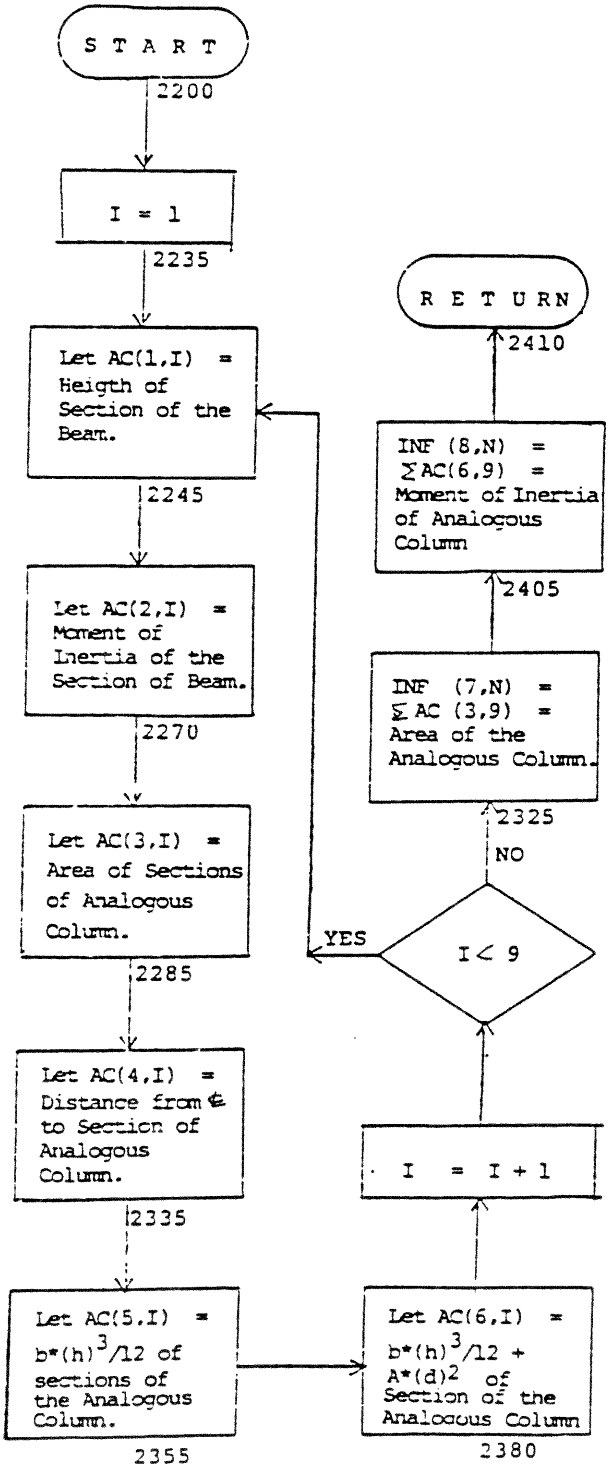
8. SUBROUTINE 9: Find Moments and Shears in Internal Sections.

9. Moments and Shears in Internal Sections due to Uniform Loads and Final-End Moments.

GENERAL FLOW-CHART



SUBROUTINE 3: Area (A) and Moment of Inertia of Analogous Column



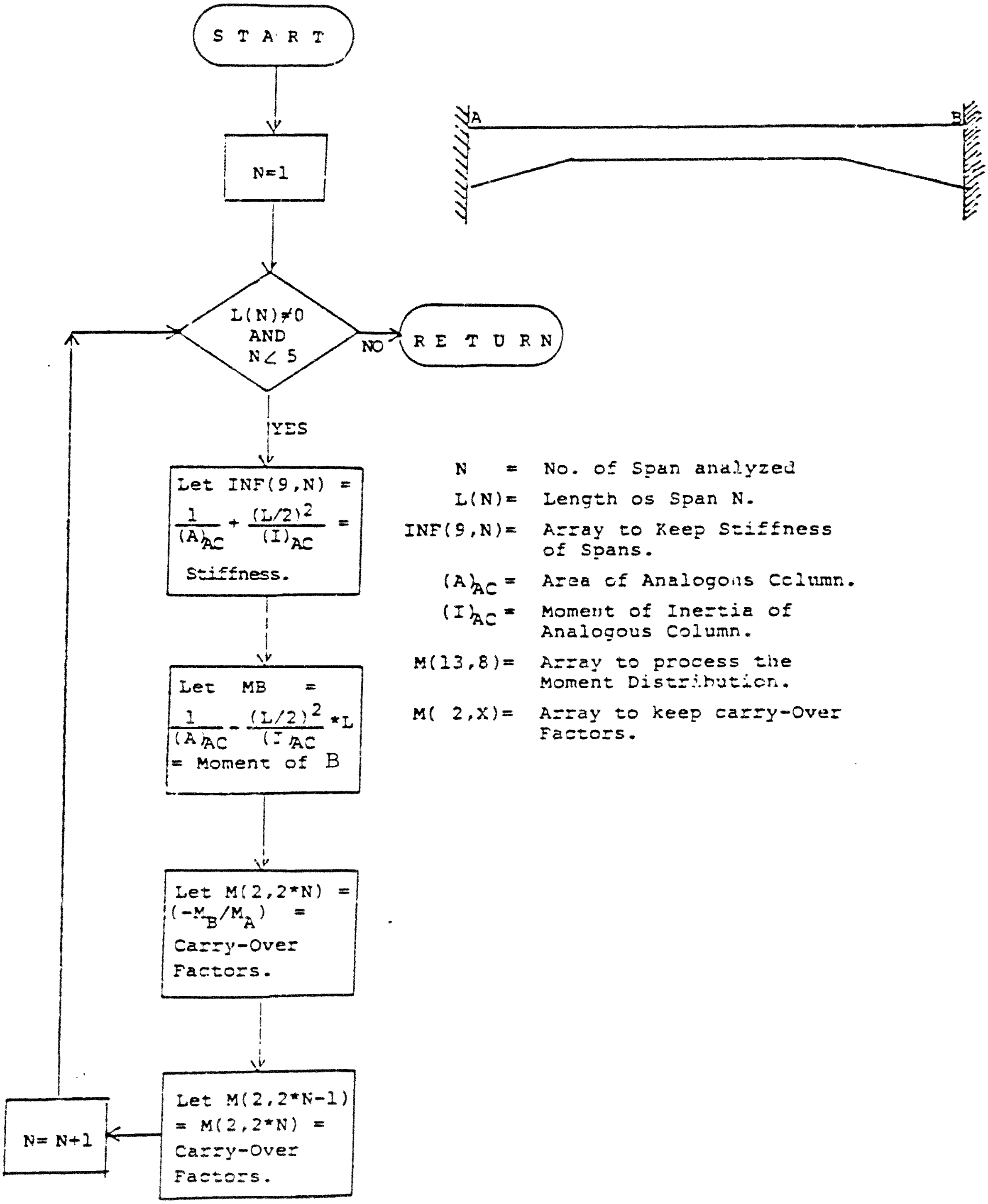
INF(9,4) = Array to Keep Geometric Characteris.

AC(9,9) = Array to Process the properties of Analogous Column.

I = No. of Analyzed Section of Analogous Column.

N = No. of Spans Analyzed.

SUBROUTINE 4: Stiffness & Carry-Over Factors.



N = No. of Span analyzed

L(N)= Length os Span N.

INF(9,N)= Array to Keep Stiffness of Spans.

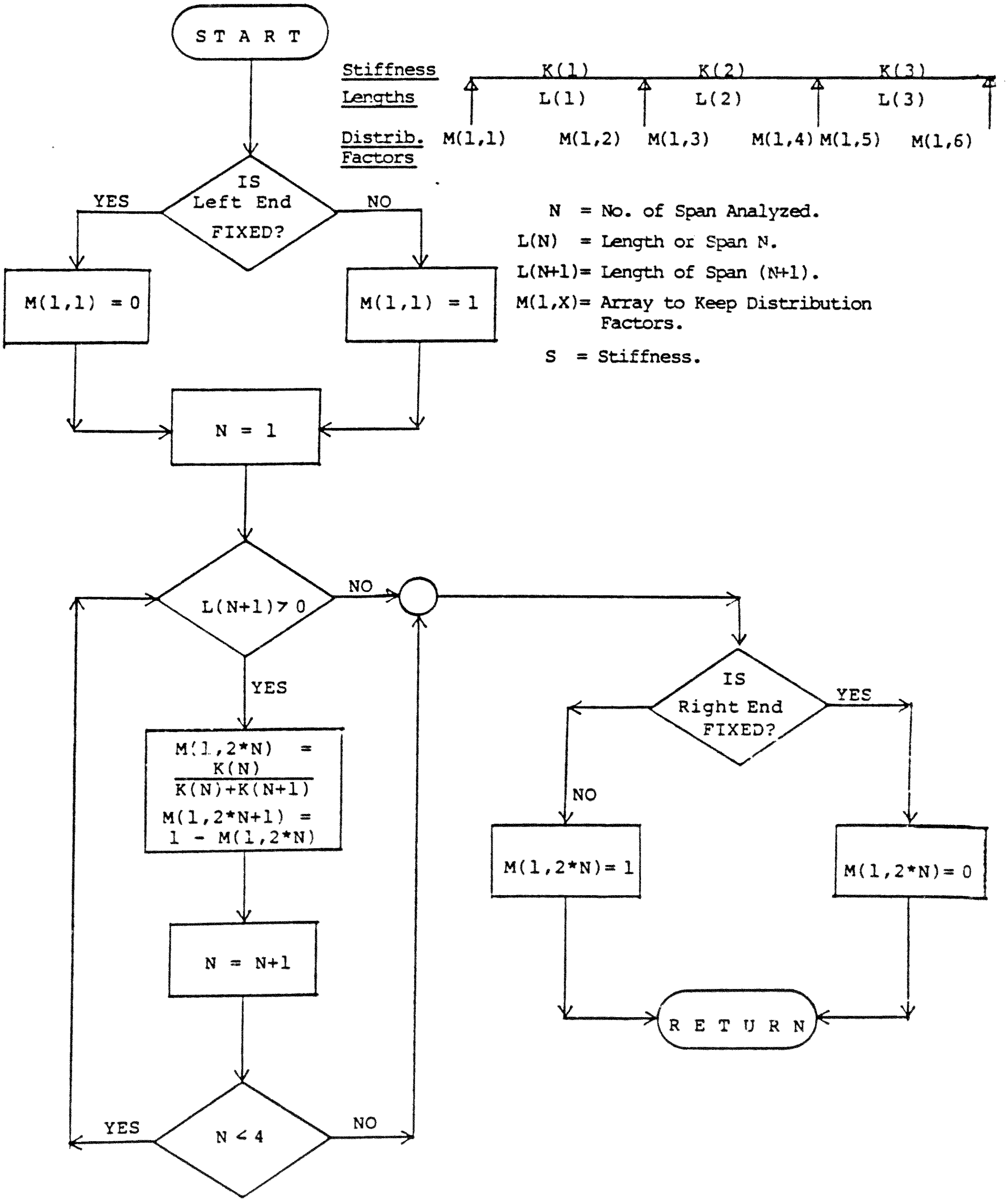
$(A)_{AC}$ = Area of Analogous Column.

$(I)_{AC}$ = Moment of Inertia of Analogous Column.

M(13,8)= Array to process the Moment Distribution.

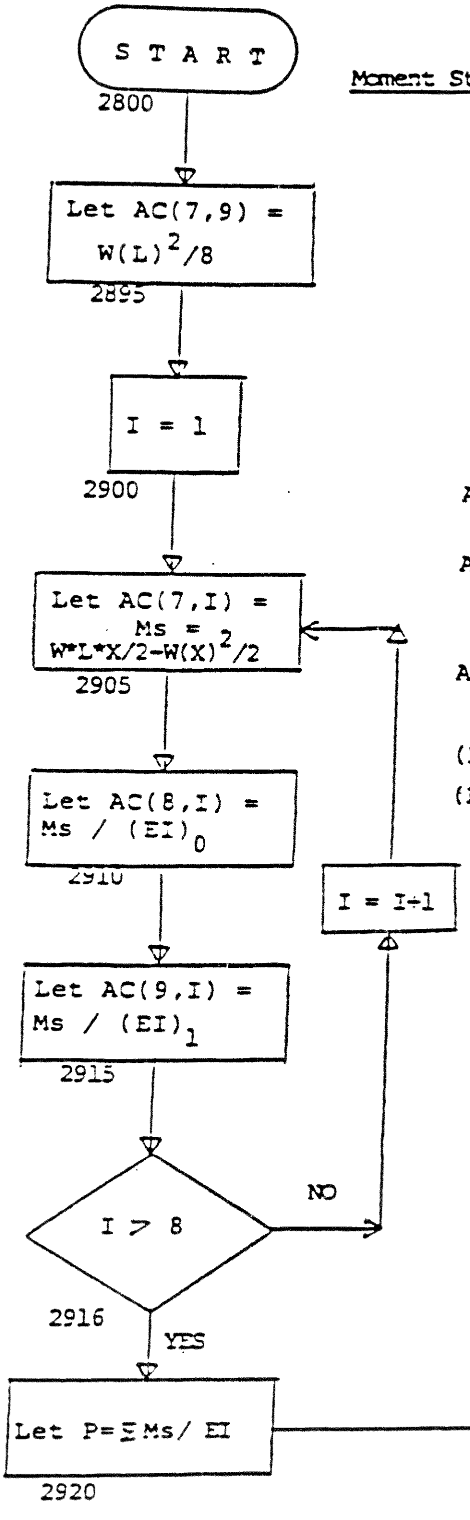
M(2,X)= Array to keep carry-Over Factors.

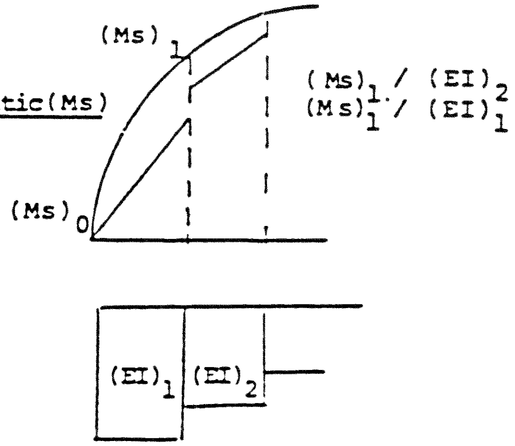
SUBROUTINE 5: Distribution Factors.



N = No. of Span Analyzed.
L(N) = Length or Span N.
L(N+1) = Length of Span (N+1).
M(1,X) = Array to Keep Distribution Factors.
S = Stiffness.

SUBROUTINE 6: Fixed End Moments due to Uniform Loads.





AC(1,I)= Heigth of Variable Sections of Beam.

AC(2,I) = Moment of Inertia of Variable Sections of Beam.

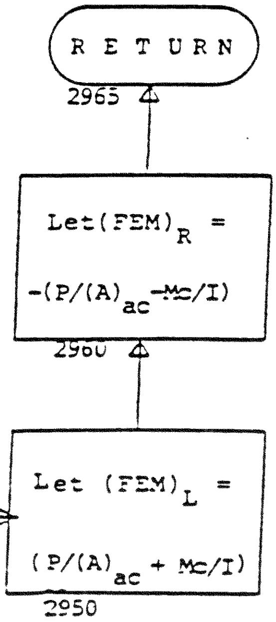
I = Number of Section Analyzed.

AC(7,I) = Ms = Moment Static.

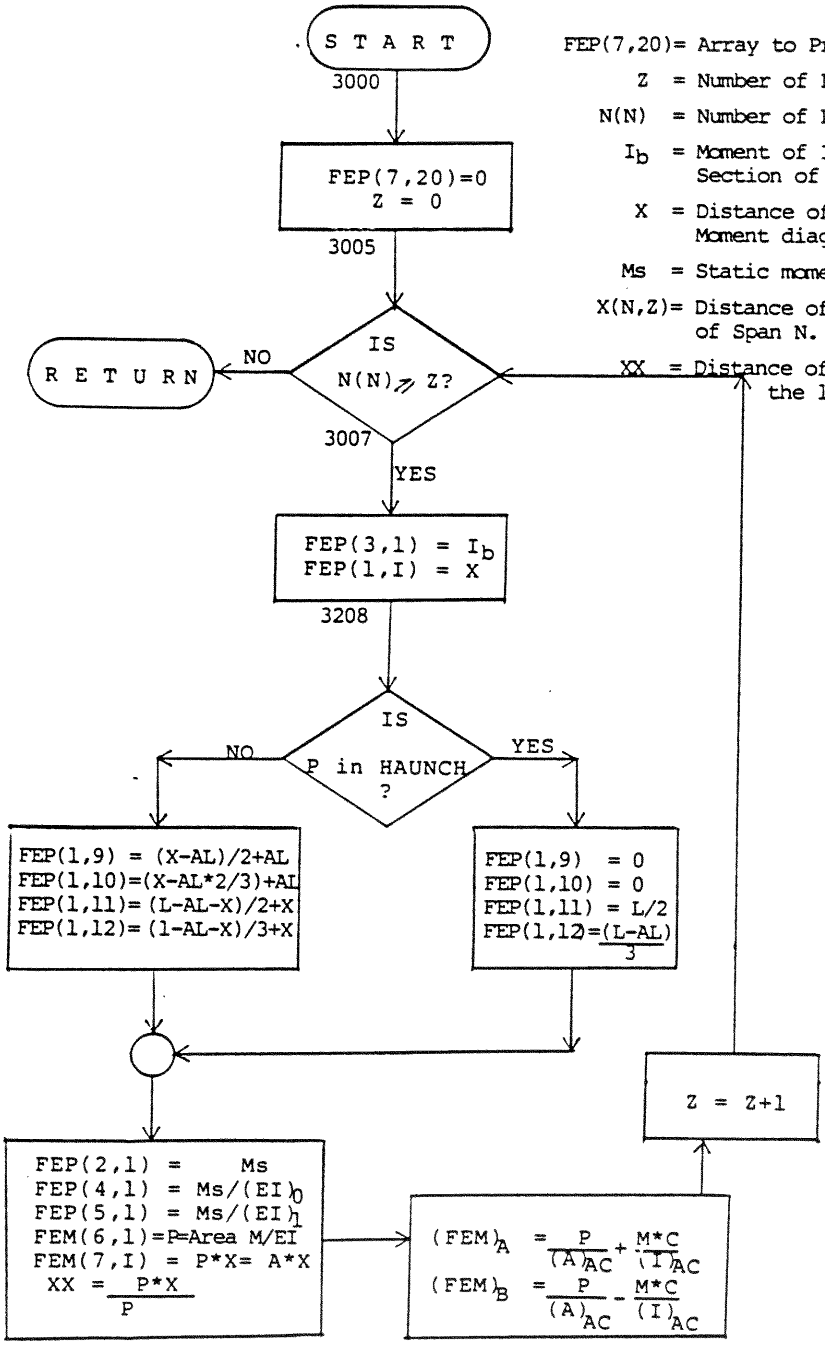
P = Area Diagram Ms/EI.

$(FEM)_L$ = (P/A + Mc/I) . Fixed End Moment Left

$(FEM)_R$ = -(P/A - Mc/I). Fixed End Moment Right



SUBROUTINE 7: Fixed-End Moments due to Concentrated Loads.



FEP(7,20)= Array to Process FEM due to P.

Z = Number of Loads being Analyzed.

N(N) = Number of Loads in Span N.

I_b = Moment of Inertia of each Section of the Beam.

X = Distance of each section of the Moment diagram from left support

Ms = Static moment due to P.

X(N,Z)= Distance of F from left support of Span N.

XX = Distance of Resultant from the left support.

OBTAIN M & V IN INTERNAL SECTIONS

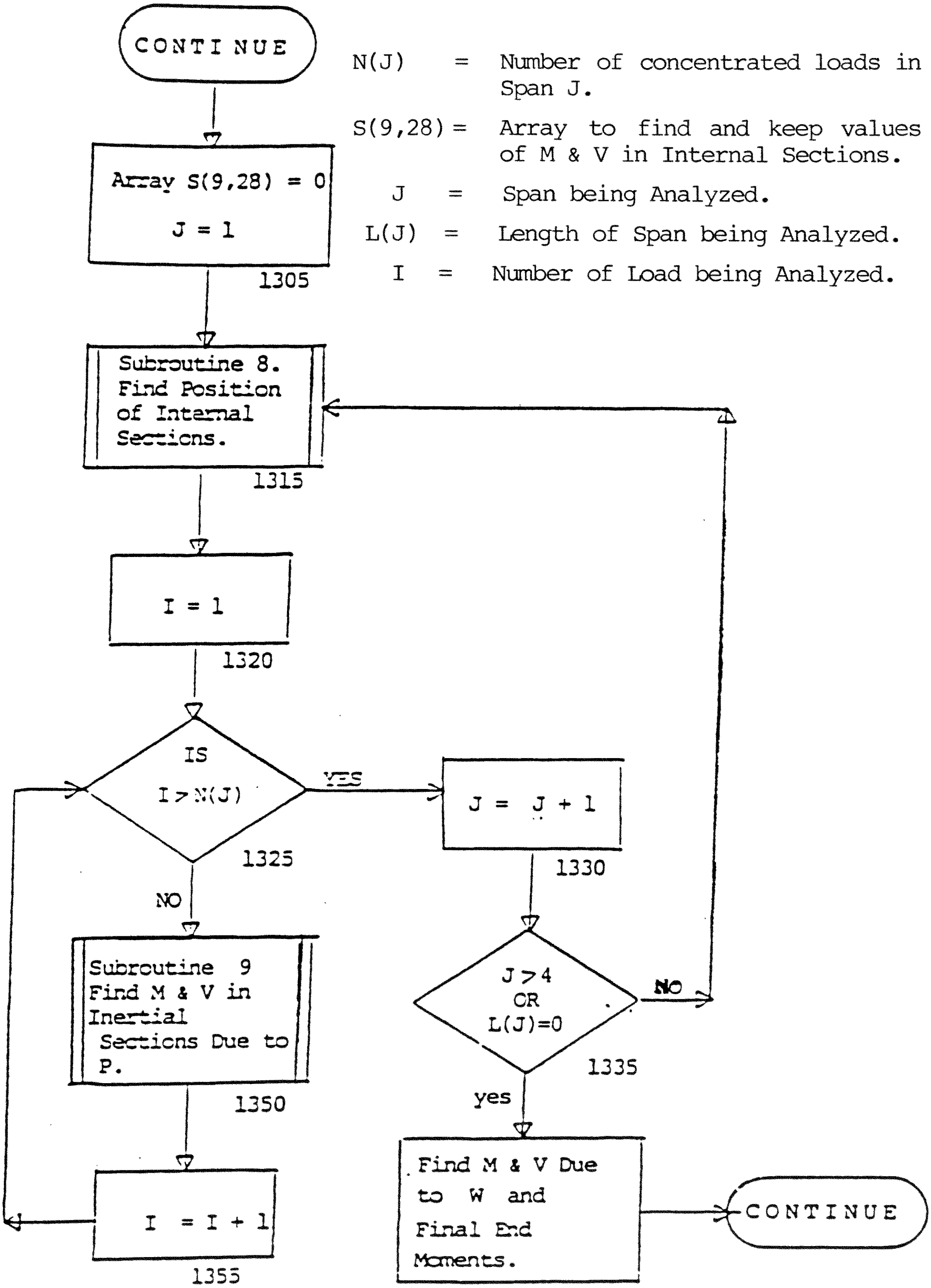
N(J) = Number of concentrated loads in Span J.

S(9,28) = Array to find and keep values of M & V in Internal Sections.

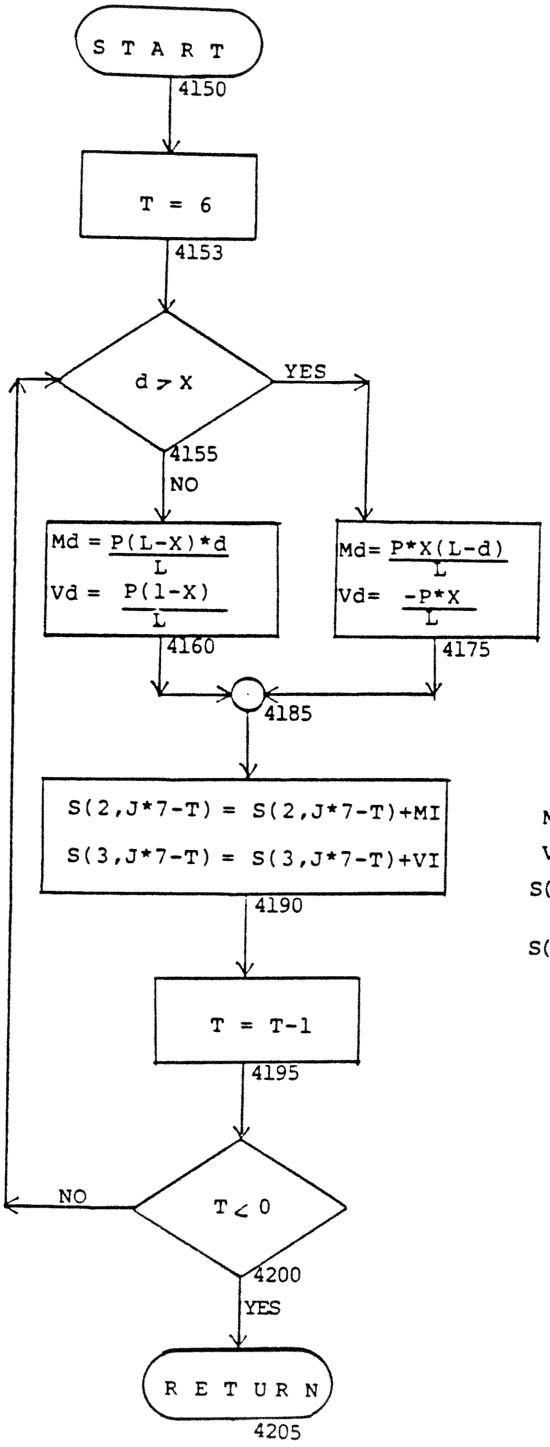
J = Span being Analyzed.

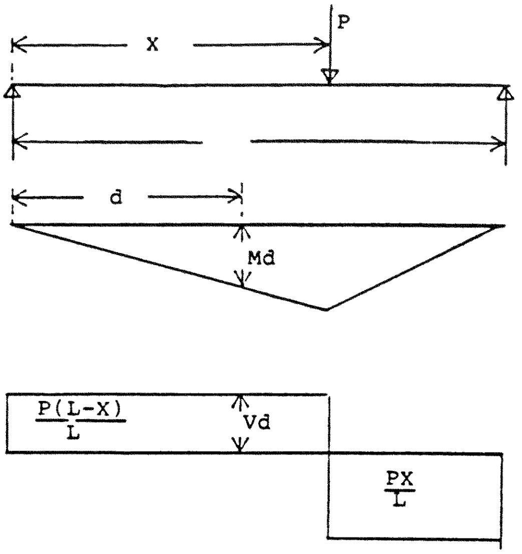
L(J) = Length of Span being Analyzed.

I = Number of Load being Analyzed.



SUBROUTINE 9: Find M&V due to Concentrated Loads in Internal Sections.





d = Position of Section Analyzed.

X = Position of P.

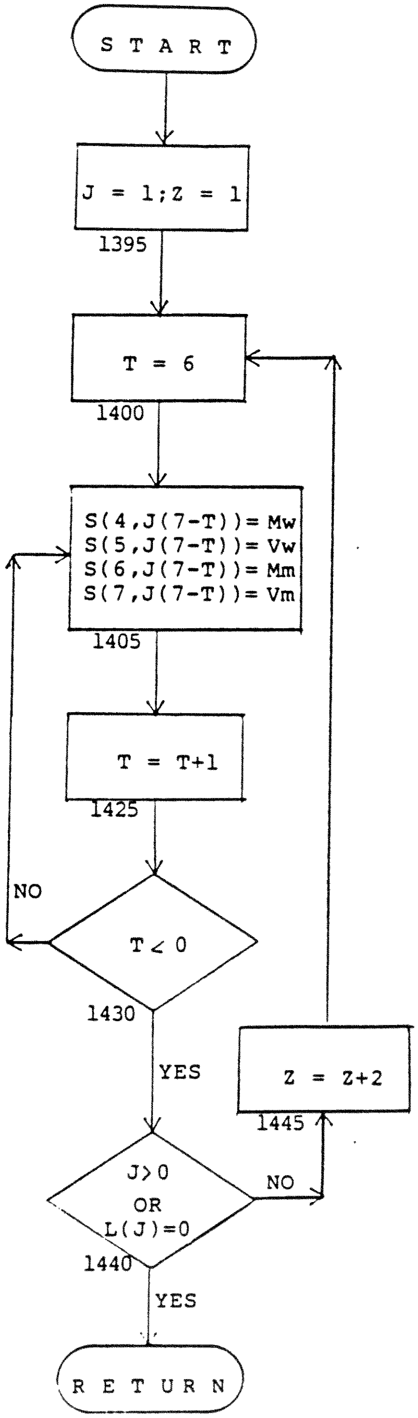
Md = Moment in Section d due to P.

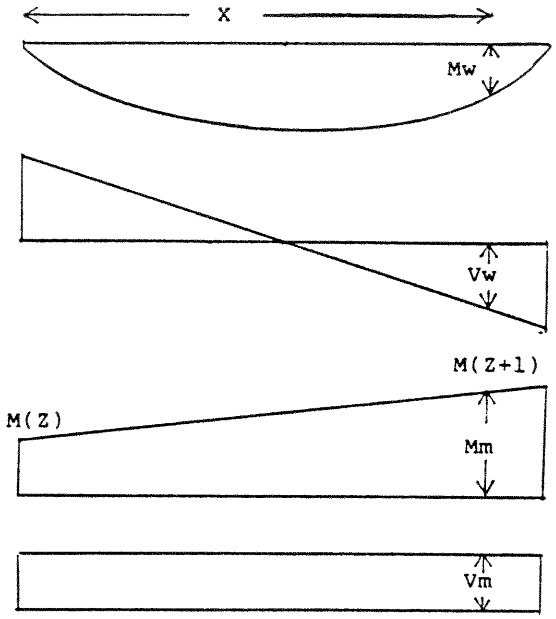
Vd = Shear in Section d due to P.

S(2) = Address to Acumulate Moments due to Concentrated Loads.

S(3) = Address to Acumulate Shears due to Concentrated Loads.

Moments & Shears in Internal Sections due to Uniform Loads and Final-End Moments.





S(9,28)= Array to Keep Forces in Internal Section.

$Mm = (M_L - M_R) / L+M_L$

Mm = End Moment due to Final Moments.

$Vm = (M_L - M_R) / L$

Vm = End Shear due to Final Moments.

$Mw = \frac{wLX}{2} - \frac{wX^2}{2}$

Mw = End Moment due to Distribution Load.

$Vw = \frac{wL}{2} - wX$

Vw = End Shear due to Distribution Load.

J = Span being Analyzed.

Z = Moment being Analyzed

T = Subscript to Identify Section.

APPENDIX B

LISTING OF THE PROGRAM

```
100 ' SAVE "THESIS"
102 '
110 '       ***********************************************************
115 '       *                                                         *
120 '       *              FLORIDA INTERNATIONAL UNIVERSITY           *
125 '       *                                                         *
130 '       *    MASTER'S THESIS IN CIVIL ENGINEERING    E.C.I. 6971  *
135 '       *                                                         *
140 '       *  COMPUTER PROGRAM FOR THE ANALYSIS OF NO PRISMATIC BEAMS *
145 '       *                                                         *
150 '       *    STUDENT: Roberto A. Alas.-        I.D. 589-05-9319   *
155 '       *    ADVISOR: Dr. Leroy E. Thompson P.E. PHD              *
160 '       *                                                         *
165 '       ***********************************************************
170 '
175 '
200 '                          VARIABLE NAMES.-
205 '                          ----------------
210 ' A$      .........................RESPONSE TO  " YES OR NO ?".
215 ' J     ........................... SUBSCRIPT TO IDENTIFY SPAN No.
220 '
225 ' E       .........................NUMBER OF ENTRIES ON ARRAY M(E,8).
250 ' INF(9,4).........................ARRAY TO KEEP GEOMETRIC CHARACTERISTICS
                                       OF BEAM AND ANALOGOUS COLUMN.
252 '       LENGTH OF  SPANS.
254 '       CONDITION OF LEFT SUPPORT.
255 '       CONDITION OF RIGHT SUPPORT.
256 '       MINIMUM HEIGHT OF EACH SPAN.
258 '       MAXIMUM HEIGHT OF EACH SPAN.
260 '       LENGTH OF TAPERED SECTIONS.
262 '       AREA OF ANALOGOUS COLUMN. ON EACH SPAN.
264 '       MOMENT OF INERTIA OF ANALOGOUS COLUMN ON EACH SPAN.
265 '       STIFFNESS OF EACH SPAN.
270 ' M(E,8) ..........................ARRAY TO PROCESS MOMENT DISTRIBUTION.
272 '       DISTRIBUTION FACTOR OF EACH END.
274 '       CARRY OVER FACTOR OF EACH END.
276 '       FIXED MOMENT ON EACH END.
278 '       PARTIAL DISTRIBUTIONS.
280 '       PARTIAL CARRY OVER.
282 '       FINAL MOMENTS ON EACH END.
283 ' AC(6,9).........................ARRAY TO PROCESS PROPERTIES OF ANALOGOUS
                                       COLUMN.
284 '       HEIGHT OF EACH VARIABLE SECTION OB BEAM.
285 '       INERTIA OF EACH VARIABLE SECTION OF BEAM.
287 '       AREA OF EACH SECTION OF ANALOGOUS COLUMN.
288 '       DISTANCE OF EACH SECTION OF AN.COL. TO CENTER LINE.
289 '       PARTIAL (Iy) INERTIA OF EACH SECTION OF ANOL.COLUMN.
290 '       TOTAL INERTIA (Iy+Ad*2) OF EACH SECTION OF ANAL.COLUMN.
292 '       PARTIAL (Iy) INERTIA OF EACH SECTION OF ANOL.COLUMN.
293 '       TOTAL INERTIA (Iy+Ad*2) OF EACH SECTION OF ANAL.COLUMN.
295 ' W(4) ...........................ARRAY TO KEEP UNIFORM LOADS ON EACH SPAN
297 ' N(4) ...........................ARRAY TO  KEEP  NUMBER  OF  CONCENTRATED
                                       LOADS ON EACH SPAN.-
299 ' P(NJ),X(NJ) .....................ARRAYS TO KEEP VALUES OF LOADS AND ITS -
                                       DISTANCES TO LEFT SUPPORT.
300 ' FEP(7,20)........................ARRAY TO PROCESS FIXED END MOMENTS DUE -
                                       TO CONCENTRATED LOADS.
301 ' AP,AX,XX........SUM OF AREAS,SUM OF PRODUCT (A*X),DISTANCE OF RESULTANT OF
                        AREAS(FORCES) FROM LEFT END.- SUBROUTINE 7
302 ' S(9,28).........................ARRAY TO FIND  MOMENTS AND  SHEARS  IN
```

```
  -                                     INTERNAL SECTIONS.-
400 '
401 '                 INITIALIZATION OF VARIABLES.
402 '                 ----------------------------
404 LET E = 13
406 DIM INF(9,4), M(E,8), AC(9,9),P(4,5),X(4,5), S(9,28)
407 DIM W(4),N(4)
408 DIM  FEP(7,20)
450 LET F1$ ="####.##  ####.##  ####.##  ####.##"
452 LET F2$ ="   #        #        #        #   "
454 LET F3$ = "#.###  #.###  #.###  #.###  #.###  #.###  #.###  #.###"
456 LET F4$="     ENTER P#, AND X# IN SPAN #"
458 LET F5$="#####.##  #####.##  #####.##  #####.##  #####.##"
460 LET F6$="#####.## #####.## #####.## #####.## #####.## #####.## #####.## ####
#.##"
462 LET F7$="#####.##  #####.##  #####.##  #####.##  #####.##  ####.## ####.##"
465 LET F8$ = "SPAN #"
498 '
500 '                       PROCESSING.
505 '                       -----------
510 CLS
512 WIDTH 80
515 PRINT TAB(10) "WELLCOME TO THE PROGRAM: ANALYSIS OF NON PRISMATIC BEAMS."
520 PRINT TAB(10) "--------------------------------------------------------"
530 PRINT " ******************************************************************"
531 PRINT " *                                                                *"
532 PRINT " *  THIS PROGRAM FINDS FINAL MOMENTS AND SHEARS ON TAPERED  BEAMS *"
534 PRINT " *  OF 1,2,3,OR 4 SPANS OF ANY LENGTH AND WITH ANY COMBINATION OF *"
536 PRINT " *  UNIFORM AND CONCENTRATED LOADS ON EACH SPAN, AND WITH ENDS TO *"
537 PRINT " *  BE PIN, ROLLER OR FIXED.-                                     *"
539 PRINT " *          + BEAMS WITH RECTANGULAR CROSS SECTIONS.              *"
540 PRINT " *          + HAUNCHES VARYING LINEARLLY.                         *"
542 PRINT " *          + SYMMETRICAL SPANS WITH RESPECT TO THEIR CENTER LINE *"
544 PRINT " *          + MODULUS OF ELASTICITY E = CONSTANT.                 *"
545 PRINT " *                                                                *"
546 PRINT " ******************************************************************"
550 PRINT :PRINT
555 PRINT TAB(5) "DO YOU WANT TO ANALYZE ONE OF THIS BEAMS?"
560 INPUT "    ENTER YES OR NO:  ";A$
565 IF A$ = "YES" OR A$ = "yes" THEN 580
566 IF A$ = "NO" OR A$ = "no" THEN 580
570 INPUT "    INVALID RESPONSE.-PLEASE ENTER YES OR NO: ";A$
575 GOTO 565
580 IF A$ = "YES" OR A$ = "yes" THEN GOTO 650
585 CLS
590 PRINT
600 PRINT "                *********************************  "
605 PRINT "                *                               *  "
610 PRINT "                *      END OF THE PROGRAM       *  "
615 PRINT "                *                               *  "
620 PRINT "                *********************************  "
625 END
646 '
648 '
650 '           OBTAIN GEOMETRICAL PROPERTIES OF THE BEAM.
652 '           ------------------------------------------
653 FOR X=1 TO 9:FOR Y=1 TO 4:LET INF(X,Y)=0:NEXT Y:NEXT X
655 FOR X=1 TO E:FOR Y=1 TO 8:LET M(X,Y)=0:NEXT Y:NEXT X
660 GOSUB 2000
662 PRINT "---------------------------------------------------------------------
```

```
------"
664 PRINT
665 PRINT TAB(5) "ENTER LENGTHS L1,L2,L3,L4 IN FEET"
667 PRINT TAB(5) "ENTER 0 IN SPANS THAT DO NOT EXIST"
670 INPUT  INF(1,1),INF(1,2),INF(1,3),INF(1,4)
673 PRINT
675 INPUT "     IS LEFT END FIXED? ENTER YES OR NO: ";A$
678 IF A$ = "YES" OR A$ = "NO" THEN 690
680 INPUT "     INVALID RESPONSE,ENTER YES OR NO: ";A$
685 GOTO 678
690 IF A$ = "YES" THEN LET INF(2,1) = 1
695 PRINT
700 INPUT "     IS RIGHT END FIXED? ENTER YES OR NO: ";A$
705 IF A$ = "YES" OR A$ = "NO" THEN 720
710 INPUT "     INVALID RESPONSE,ENTER YES OR NO: ";A$
715 GOTO 705
720 IF A$ = "YES" AND INF(1,4) > 0 THEN INF(3,4) = 1:GOTO 740
725 IF A$ = "YES" AND INF(1,3) > 0 THEN INF(3,3) = 1:GOTO 740
730 IF A$ = "YES" AND INF(1,2) > 0 THEN INF(3,2) = 1:GOTO 740
735 IF A$ = "YES" AND INF(1,1) > 0 THEN INF(3,1) = 1
740 GOSUB 2100
742 PRINT
745 PRINT TAB(5)"ENTER  (Hmin)1,(Hmin)2,(Hmin)3,(Hmin)4,(IN FEET)"
750 INPUT "    ENTER 0 IN SPANS WITH LENGTH = 0: ";INF(4,1),INF(4,2),INF(4,3),IN
F(4,4)
755 PRINT
760 PRINT TAB(5)"ENTER  (Hmax)1, (Hmax)2, (Hmax)3, (Hmax)4 (IN FEET)"
765 INPUT "    ENTER 0 IN SPANS WITH LENGTH = 0: ";INF(5,1),INF(5,2),INF(5,3),IN
F(5,4)
770 PRINT
775 PRINT TAB(5)"ENTER AL-1,AL-2,AL-3,AL-4 (IN FEET)"
780 INPUT "    ENTER 0 IN SPANS WITH LENGTH = 0: ";INF(6,1),INF(6,2),INF(6,3),IN
F(6,4)
790 SCREEN 0
795 PRINT "                       GEOMETRICAL PROPERTIES OF THE BEAM"
797 PRINT "                       ----------------------------------"
800 PRINT "                                        SPAN 1  SPAN 2  SPAN 3  SPAN 4"
802 PRINT "--------------------------------------------------------------------"
805 PRINT "LENGTH OF SPANS (FEET)"TAB(32) USING F1$;INF(1,1),INF(1,2),INF(1,3),I
NF(1,4)
810 PRINT "LEFT SUPPORT:FIXED=1 OR FREE=0"TAB(32) USING F2$;INF(2,1),INF(2,2),IN
F(2,3),INF(2,4)
815 PRINT "RIGHT SUPPORT:FIXED=1 OR FREE=0"TAB(32) USING F2$;INF(3,1),INF(3,2),I
NF(3,3),INF(3,4)
820 PRINT "MINIMUM HEIGHT OF BEAM (FEET)"TAB(32) USING F1$;INF(4,1),INF(4,2),INF
(4,3),INF(4,4)
825 PRINT "MAXIMUM HEIGHT OF BEAM (FEET)"TAB(32) USING F1$;INF(5,1),INF(5,2),INF
(5,3),INF(5,4)
830 PRINT "LENGTH AL OF TAPERED SECTION"TAB(32) USING F1$;INF(6,1),INF(6,2),INF(
6,3),INF(6,4)
835 PRINT :PRINT :
837 INPUT "     DO YOU WANT TO CHANGE ANY NUMBER? YES OR NO: ";A$
840 IF A$ = "YES" OR A$ = "NO" THEN 855
845 INPUT "     INVALID RESPONSE,ENTER YES OR NO: ";A$
850 GOTO 840
855 IF A$ = "YES" THEN 650
856 '               FIND PROPERTIES OF ANALOG.COLUMN.-(SUBROUT."3")
857 '               ---------------------------------------------
860 LET N = 1
865 GOSUB 2200
```

```
870 IF INF(1,2) > 0 THEN  LET N = 2 :GOSUB 2200
875 IF INF(1,3) > 0 THEN LET N = 3: GOSUB 2200
880 IF INF(1,4) > 0 THEN LET N = 4: GOSUB 2200
885 '                FIND STIFFNES & CARRY OVER FACTORS.(SUBROUT.4)
886 '                ----------------------------------------------
915 LET N = 1
920 GOSUB 2500
925 IF INF(1,2) > 0 THEN LET N = 2:GOSUB 2500
930 IF INF(1,3) > 0 THEN LET N = 3:GOSUB 2500
935 IF INF(1,4) > 0 THEN LET N = 4:GOSUB 2500
937 '
938 '                FIND DISTRIBUTION FACTORS.-( SUBOUTINE "5" ).-
939 '                ----------------------------------------------
940 GOSUB 2600
941 PRINT
942 PRINT "                          PARTIAL RESULTS"
943 PRINT "                          ---------------"
945 PRINT "AREA OF ANALOG.COL"TAB(32) USING F1$;INF(7,1),INF(7,2),INF(7,3),INF(7
,4)
947 PRINT "MOM.OF INERT.OF ANALOG.COL"TAB(32) USING F1$;INF(8,1),INF(8,2),INF(8,
3),INF(8,4)
950 PRINT "STIFFNESS OF SPAN/L "TAB(32) USING F1$;INF(9,1),INF(9,2),INF(9,3),INF
(9,4)
952 PRINT "DITR.FAC."TAB(15) USING F3$;M(1,1),M(1,2),M(1,3),M(1,4),M(1,5),M(1,6)
,M(1,7),M(1,8)
954 PRINT "CAR.OV.FACT."TAB(15) USING F3$;M(2,1),M(2,2),M(2,3),M(2,4),M(2,5),M(2
,6),M(2,7),M(2,8)
955 PRINT :PRINT "     PRESS ANY KEY TO CONTINUE"
957 B$ = INKEY$: IF B$ ="" THEN 957
959 '
960 '                 OBTAIN UNIFORM LOADS.-
962 '                 ----------------------
963 GOSUB 2000
965 PRINT TAB(5) "ENTER UNIFORM LOADS W1, W2, W3, W4 (K/f)."
967 PRINT TAB(5) "ENTER 0 IN SPANS WITH LENGTH = 0":INPUT W(1),W(2),W(3),W(4)
973 '
980 '                OBTAIN CONCENTRATED LOADS.-
981 '                ---------------------------
983 FOR X=1 TO 4:FOR Y=1 TO 5:LET P(X,Y) = 0:LET X(X,Y)=0:NEXT Y: NEXT X
985 PRINT TAB(5) "ENTER NUMBER OF CONCENTRATED LOADS PER SPAN (MAX.5 LOADS)"
990 INPUT "ENTER N1,N2,N3,N4: "; N(1),N(2),N(3),N(4)
995 '
1000 LET I = 0: LET J = 1
1002 PRINT TAB(5) "ENTER VALUES IN KIPS AND FEET, OF CONCENTRATED LOADS AND ITS
DISTANCES TO THE LEFT SUPPORT OF THE SPAN"
1005 LET I = I + 1
1010 IF N(J)> I - 1 THEN GOTO 1030
1015 LET J = J + 1:LET I = 0
1020 IF J < 5 THEN GOTO 1005
1025 GOTO 1044
1030 PRINT USING F4$; I,I,J
1035 INPUT P,X
1036 LET P(J,I)=P:LET X(J,I)=X
1040 GOTO 1005
1044 CLS
1045 PRINT "              CHECK LOAD ON BEAMS.-"
1047 PRINT "              ---------------------"
1049 PRINT "UNIFORM LOADS K/F"TAB(32) USING F1$;W(1),W(2),W(3),W(4)
1050 PRINT "CONCENT.LOADS IN SPAN 1 K"TAB(32) USING F5$;P(1,1),P(1,2),P(1,3),P(1
,4),P(1,5)
```

```
1052 PRINT "DIST.OF P TO LEFT SUPP. F"TAB(32) USING F5$;X(1,1),X(1,2),X(1,3),X(1
,4),X(1,5)
1054 PRINT "CONCENT.LOADS IN SPAN 2 K"TAB(32) USING F5$;P(2,1),P(2,2),P(2,3),P(2
,4),P(2,5)
1056 PRINT "DIST.OF P TO LEFT SUPP. F"TAB(32) USING F5$;X(2,1),X(2,2),X(2,3),X(2
,4),X(2,5)
1058 PRINT "CONCENT.LOADS IN SPAN 3 K"TAB(32) USING F5$;P(3,1),P(3,2),P(3,3),P(3
,4),P(3,5)
1060 PRINT "DIST.OF P TO LEFT SUPP. F"TAB(32) USING F5$;X(3,1),X(3,2),X(3,3),X(3
,4),X(3,5)
1062 PRINT "CONCENT.LOADS IN SPAN 4 K"TAB(32) USING F5$;P(4,1),P(4,2),P(4,3),P(4
,4),P(4,5)
1065 PRINT "DIST.OF P TO LEFT SUPP. F"TAB(32) USING F5$;X(4,1),X(4,2),X(4,3),X(4
,4),X(4,5)
1067 PRINT :PRINT :INPUT " DO YOU WANT TO CHANGE ANY LOAD? YES OR NO: ";A$
1068 IF A$ = "YES" OR A$ = "NO" THEN 1075
1070 INPUT "INVALID RESPONSE PLEASE ENTER YES OR NO: ";A$
1072 GOTO 1068
1075 IF A$ = "YES" THEN 960
1077 '            FIND FIX.END MOM. DUE TO UNIFORM.LOADS.(SUBR.6).
1080 '            ----------------------------------------------
1085 LET N = 1
1087 GOSUB 2800
1089 IF INF(1,2) > 0 THEN LET N = 2: GOSUB 2800
1091 IF INF(1,3) > 0 THEN LET N = 3: GOSUB 2800
1095 IF INF(1,4) > 0 THEN LET N = 4: GOSUB 2800
1096 PRINT
1097 PRINT "FEM (W)" TAB(8) USING F6$;M(3,1),M(3,2),M(3,3),M(3,4),M(3,5),M(3,6),
M(3,7),M(3,8)
1098 PRINT "      COMPUTING........"
1099 'B$ = INKEY$: IF B$ = "" THEN 1099
1100 '            FIND FIX.END MOM. DUE TO CONCENTR.LOADS.(SUBR 7).
1101 '            ------------------------------------------------
1102 FOR I = 1 TO 8:LET M(4,I)=0:NEXT I
1105 LET N = 1: GOSUB 3000
1110 IF INF(1,2) > 0 THEN LET N = 2: GOSUB 3000
1115 IF INF(1,3) > 0 THEN LET N = 3: GOSUB 3000
1120 IF INF(1,4) > 0 THEN LET N = 4: GOSUB 3000
1121 PRINT "FEM (P)" TAB(8) USING F6$;M(4,1),M(4,2),M(4,3),M(4,4),M(4,5),M(4,6),
M(4,7),M(4,8)
1122 'PRINT "   PRESS ANY KEY TO CONTINUE"
1123 'B$ = INKEY$: IF B$ = "" THEN 1123
1125 'FOR I = 1 TO 20 :PRINT USING F7$;FEP(1,I),FEP(2,I),FEP(3,I),FEP(4,I),FEP(5
,I),FEP(6,I),FEP(7,I): NEXT I: STOP
1126 PRINT :PRINT "   PRESS ANY KEY TO CONTINUE"
1128 B$ = INKEY$: IF B$ ="" THEN 1128
1130 CLS
1132 PRINT :PRINT :PRINT  "                   PROGRAM THESIS   PART II.-"
1134 PRINT "          -------------------------"
1136 PRINT :PRINT "             1o. ANALYSIS OF A DIFFERENT BEAM.-"
1138 PRINT :PRINT "             2o. SAME BEAM WITH DIFFERENT LOAD.-"
1140 PRINT :PRINT "             3o. FIND FINAL MOMENTS AND SHEARS.-"
1142 PRINT :PRINT "             4o. EXIT.-"
1144 PRINT :PRINT :INPUT "            MAKE YOUR SELECTION TO CONTINUE"; CHOIC
E
1146 IF CHOICE < 1 OR CHOICE > 4 THEN PRINT "BAD SELECTION, TRY AGAIN": GOTO 114
4
1148 ON CHOICE GOTO 650,960,1150,585
1150 '                FIND FINAL MOMENTS SHEARS.-
1151 '                ----------------------------
```

```
1152 FOR Y=1 TO 8: LET M(E,Y) = 0: NEXT Y
1153 '
1155 FOR I = 1 TO 8: LET M(5,I) = M(3,I) + M(4,I): NEXT I
1160 FOR S = 6 TO E-1 STEP 2
1165 LET M(S,1) = -(M(S-1,1))*M(1,1)
1170 LET M(S,2) = -(M(S-1,2) + M(S-1,3)) * M(1,2)
1175 LET M(S,3) = -(M(S-1,2) + M(S-1,3)) * M(1,3)
1180 LET M(S,4) = -(M(S-1,4) + M(S-1,5)) * M(1,4)
1185 LET M(S,5) = -(M(S-1,4) + M(S-1,5)) * M(1,5)
1190 LET M(S,6) = -(M(S-1,6) + M(S-1,7)) * M(1,6)
1195 LET M(S,7) = -(M(S-1,6) + M(S-1,7)) * M(1,7)
1200 LET M(S,8) = -(M(S-1,8))*M(1,8)
1201 '
1205 IF S+1 = E THEN 1260
1207 '
1210 LET M(S+1,1) = M(S,2) * M(2,2)
1215 LET M(S+1,2) = M(S,1) * M(2,1)
1220 LET M(S+1,3) = M(S,4) * M(2,4)
1225 LET M(S+1,4) = M(S,3) * M(2,3)
1230 LET M(S+1,5) = M(S,6) * M(2,6)
1235 LET M(S+1,6) = M(S,5) * M(2,5)
1240 LET M(S+1,7) = M(S,8) * M(2,8)
1245 LET M(S+1,8) = M(S,7) * M(2,7)
1250 NEXT S
1252 '
1260 FOR Y = 1 TO 8: FOR X = 5 TO E-1
1265 LET M(E,Y) = M(E,Y) + M(X,Y)
1270 NEXT X: NEXT Y
1272 CLS
1273 PRINT TAB(23) " *** MOMENT DISTRIBUTION ***": PRINT TAB(23) "--------------
---------------"
1274 PRINT TAB(11) "MOM.1" TAB(20) "MOM.2" TAB(29) "MOM.3" TAB(38) "MOM.4" TAB(4
7) "MOM.5" TAB(56) "MOM.6" TAB(65) "MOM.7" TAB(74) "MOM.8"
1275 PRINT STRING$(80,"-")
1276 PRINT "DIS.FAC." TAB(9) USING F6$;M(1,1),M(1,2),M(1,3),M(1,4),M(1,5),M(1,6)
,M(1,7),M(1,8)
1277 PRINT "C.O.FAC." TAB(9) USING F6$;M(2,1),M(2,2),M(2,3),M(2,4),M(2,5),M(2,6)
,M(2,7),M(2,8)
1279 PRINT "FIX.E.M." TAB(9) USING F6$;M(5,1),M(5,2),M(5,3),M(5,4),M(5,5),M(5,6)
,M(5,7),M(5,8)
1280 PRINT STRING$(80,"-")
1281 PRINT "DISTRIB." TAB(9) USING F6$;M(6,1),M(6,2),M(6,3),M(6,4),M(6,5),M(6,6)
,M(6,7),M(6,8)
1282 PRINT "CAR.OV." TAB(9) USING F6$;M(7,1),M(7,2),M(7,3),M(7,4),M(7,5),M(7,6),
M(7,7),M(7,8)
1283 PRINT "DISTRIB." TAB(9) USING F6$;M(8,1),M(8,2),M(8,3),M(8,4),M(8,5),M(8,6)
,M(8,7),M(8,8)
1284 PRINT "CAR.OV." TAB(9) USING F6$;M(9,1),M(9,2),M(9,3),M(9,4),M(9,5),M(9,6),
M(9,7),M(9,8)
1285 PRINT "DISTRIB." TAB(9) USING F6$;M(10,1),M(10,2),M(10,3),M(10,4),M(10,5),M
(10,6),M(10,7),M(10,8)
1286 PRINT "CAR.OV." TAB(9) USING F6$;M(11,1),M(11,2),M(11,3),M(11,4),M(11,5),M(
11,6),M(11,7),M(11,8)
1287 PRINT "DISTRIB." TAB(9) USING F6$;M(12,1),M(12,2),M(12,3),M(12,4),M(12,5),M
(12,6),M(12,7),M(12,8)
1288 PRINT STRING$(80,"-")
1289 PRINT "FIN.MOM" TAB(9) USING F6$;M(E,1),M(E,2),M(E,3),M(E,4),M(E,5),M(E,6),
M(E,7),M(E,8)
1290 '
1291 INPUT "MOMENTS IN INTERNAL SECTIONS,YES OR NO: "; Y$
```

```
1292 IF Y$ = "YES" OR Y$ = "NO" THEN 1295
1293 INPUT "INVALID RESPONSE,PLEASE ENTER YES OR NO: "; Y$
1294 GOTO 1292
1295 IF Y$ = "YES" THEN 1297
1296 GOTO 1130
1297 '
1300 '   FIND M & V IN INTERNAL SECTIONS DUE TO CONCENTRATED LOADS.-
1301 '  -----------------------------------------------------------
1302 PRINT "      COMPUTING..........."
1305  FOR X=1 TO 9: FOR Y=1 TO 28: LET S(X,Y)=0: NEXT Y: NEXT X
1310 LET J = 1
1315 GOSUB 4060
1320 LET I = 1
1325 IF I < N(J) OR I = N(J) THEN 1350
1330 LET J = J + 1
1335 IF J > 4 THEN 1390
1340 IF INF (1,J) = 0 THEN 1390
1345 GOTO 1315
1350 GOSUB 4150
1355 LET I = I + 1
1360 GOTO 1325
1366 CLS: FOR J=1 TO 4
1370 PRINT "M1" TAB(9) USING F7$; S(2,J*7-6), S(2,J*7-5), S(2,J*7-4), S(2,J*7-3)
, S(2,J*7-2), S(2,J*7-1), S(2,J*7)
1375 PRINT "V1" TAB(9) USING F7$; S(3,J*7-6), S(3,J*7-5), S(3,J*7-4), S(3,J*7-3)
, S(3,J*7-2), S(3,J*7-1), S(3,J*7)
1380 NEXT J
1385 STOP
1390 ' FIND M & V IN INTERNAL SECTIONS DUE TO UNIFORM LOADAS & MOM.IN SUPPORTS.
1391 ' ---------------------------------------------------------------------
1395 LET J=1: LET Z=1
1400 LET T = 6
1405 LET S(4,J*7-T)=W(J)*INF(1,J)*S(1,J*7-T)/2 - W(J)*(S(1,J*7-T)^2)/2
1410 LET S(5,J*7-T)=W(J)*INF(1,J)/2 - W(J)*S(1,J*7-T)
1415 LET S(6,J*7-T)= -(ABS(M(13,Z))+(ABS(M(13,Z+1))-ABS(M(13,Z)))*S(1,J*7-T)/INF
(1,J))
1420 LET S(7,J*7-T)=-(M(13,Z) + M(13,Z+1))/INF(1,J)
1425 LET T = T-1
1430 IF T>0 OR T=0 THEN GOTO 1405
1435 LET J = J+1
1440 IF J > 4 THEN GOTO 1450
1441 IF INF(1,J) = 0 THEN GOTO 1450
1445 LET Z = Z+2: GOTO 1400
1446 '
1450 FOR X=1 TO 28
1455 LET S(8,X) = S(2,X) + S(4,X) + S(6,X)
1460 LET S(9,X) = S(3,X) + S(5,X) + S(7,X)
1465 NEXT X
1467 '
1470 CLS
1475 PRINT TAB(20) " *** MOMENTS IN INTERNAL SECTIONS *** "
1477 PRINT TAB(20) " ------------------------------------ "
1480 LET J = 1
1485 PRINT USING F8$ ; J
1490 PRINT "DIST." TAB(9) USING F7$;S(1,J*7-6),S(1,J*7-5),S(1,J*7-4),S(1,J*7-3),
S(1,J*7-2),S(1,J*7-1),S(1,J*7)
1495 PRINT "MOM FRA" TAB(9) USING F7$;S(8,J*7-6),S(8,J*7-5),S(8,J*7-4),S(8,J*7-3
),S(8,J*7-2),S(8,J*7-1),S(8,J*7)
1500 LET J = J+1
1505 IF J > 4  THEN GOTO 1515
```

```
1506 IF INF(1,J) = 0 THEN GOTO 1515
1510 GOTO 1485
1515 PRINT "."
1520 INPUT "DO YOU WANT SHEARS IN INTERNAL SECTIONS,YES OR NO: "; Y$
1522 IF Y$ = "YES" OR Y$ = "NO" THEN 1525
1523 INPUT "INVALID RESPONSE, PLEASE ENTER YES OR NO: "; Y$
1524 GOTO 1522
1525 IF Y$ ="YES" THEN 1530
1526 GOTO 1130
1530 CLS
1535 PRINT TAB(20) " *** SHEARS IN INTERNAL SECTIONS *** "
1537 PRINT TAB(20) " ----------------------------------  "
1540 LET J = 1
1545 PRINT USING F8$ ; J
1550 PRINT "DIST." TAB(9) USING F7$;S(1,J*7-6),S(1,J*7-5),S(1,J*7-4),S(1,J*7-3),
S(1,J*7-2),S(1,J*7-1),S(1,J*7)
1555 PRINT "SHEARS." TAB(9) USING F7$;S(9,J*7-6),S(9,J*7-5),S(9,J*7-4),S(9,J*7-3
),S(9,J*7-2),S(9,J*7-1),S(9,J*7)
1560 LET J = J+1
1565 IF J > 4  THEN GOTO 1575
1566 IF INF(1,J) = 0 THEN GOTO 1575
1570 GOTO 1545
1575 PRINT : PRINT "PRESS ANY KEY TO CONTINUE"
1580 B$ = INKEY$: IF B$ ="" THEN 1580
1585 GOTO 1130
2000 '                    SUBROUTINE DIAGRAM 1
2002 '                    --------------------
2005 CLS
2045 PRINT TAB(10) "w1";TAB(28) "w2";TAB(48) "w3";TAB(67) "w4"
2050 PRINT STRING$(79,"_")
2055 PRINT "1";TAB(5) STRING$(14,"_");TAB(24) STRING$(14,"_");TAB(43) STRING$(14
,"_");TAB(62) STRING$(14,"_");TAB(79) "1"
2060 PRINT "1";TAB(4) "/";TAB(19) "\";TAB(23) "/";TAB(38) "\";TAB(42) "/";TAB(57
) "\";TAB(61) "/";TAB(76) "\";TAB(79) "1"
2065 PRINT "1";TAB(2) "_";TAB(3) "/";TAB(20) "\";TAB(21) "_";TAB(22) "/";TAB(39)
 "\";TAB(40) "_";TAB(41) "/";TAB(58) "\";TAB(59) "_";TAB(60) "/";TAB(77) "\";TAB
(78) "_";TAB(79) "1"
2070 PRINT TAB(2) "1";TAB(10) "L-1";TAB(21) "1";TAB(28) "L-2";TAB(40) "1";TAB(48
) "L-3";TAB(59) "1";TAB(67) "L-4";TAB(78) "1"
2075 PRINT TAB(3) "M1";TAB(18) "M2";TAB(22) "M3";TAB(38) "M4";TAB(41) "M5";TAB(5
7) "M6";TAB(60) "M7";TAB(76) "M8"
2080  RETURN
2085 '
2090 '
2100 '                    SUBROUTINE DIAGRAM 2
2105 '                    --------------------
2110 SCREEN 2
2115 CLS
2120 LINE (10,20) - (639,20)
2125 LINE (10,20) - (10,60)
2130 LINE (10,60) - (20,60)
2135 LINE (20,60) - (160,40)
2140 LINE (160,40) - (489,40)
2145 LINE (639,20) - (639,60)
2150 LINE (639,60) - (629,60)
2155 LINE (629,60) - (489,40)
2160 PRINT "  ------------------------------------ L ---------------------------
-----------"
2165 PRINT :PRINT
2170 PRINT TAB(33) "H min."
```

```
2175 PRINT "H max."
2180 PRINT :PRINT :PRINT
2190 PRINT " --------- AL ------                                              ------
-AL---------"
2195 RETURN
2199 'LET N = 1
2200 '             SUBROUTINE "3" PROPERTIES OF ANALOGUS COLUMN
2203 '             ----------------------------------------------
2204 '
2205 ' THIS SUBROUTINE FINDS AREA AND MOMENT OF INERTIA OF THE ANALOGUS COLUMN
       WITH RESPECT TO AXIS Y-Y.
2207 ' IT USES ARRAY AC(6,9) TO PERFORM CALCULATIONS AND TO KEEP PARTIAL RESULTS
2210 '
2220 LET AL = INF(6,N)
2225 LET S = AL/8
2230 LET M = (INF(5,N) - INF(4,N))/8
2235 FOR I = 1 TO 8
2240 LET H = INF(5,N) - M*(I-.5)
2245 LET AC(1,I) = H
2250 NEXT I
2255 LET AC(1,9) = INF(4,N)
2260 LET AC(2,9) = 1
2265 FOR I = 1 TO 8
2270 LET AC(2,I) = (AC(1,I)/AC(1,9))^3
2280 NEXT I
2285 LET AC(3,9) = INF(1,N) - 2*AL
2290 FOR I = 1 TO 8
2295 LET AC(3,I) = S/AC(2,I)
2300 NEXT I
2305 LET AO=0
2310 FOR I = 1 TO 8
2315 LET AO = AO + AC(3,I)
2320 NEXT I
2325 LET AG = 2*AO +AC(3,9)
2330 LET INF(7,N) = AG
2335 LET AC(4,9) = 0
2340 FOR I =1 TO 8
2345 LET AC(4,I) = INF(1,N)/2 - S*(I-.5)
2350 NEXT I
2355 LET AC(5,9) = 1*(INF(1,N)-2*AL)^3/12
2360 FOR I=1 TO 8
2365 LET AC(5,I) = S^3/(12*AC(2,I))
2370 NEXT I
2375 FOR I=1 TO 9
2380 LET AC(6,I) = AC(3,I)*AC(4,I)^2 + AC(5,I)
2383 NEXT I
2385 LET A1 = 0
2390 FOR I = 1 TO 8
2395 LET A1 = A1 + AC(6,I)
2400 NEXT I
2405 LET INF(8,N) = 2*A1 + AC(6,9)
2410 RETURN
2500 '       SUBROUTINE "4" STIFENESS & CARRY OVER FACTORS.-
2502 '       ------------------------------------------------
2505 LET INF(9,N)=(1/INF(7,N)+INF(1,N)^2/(4*INF(8,N)))
2510 LET MB=(1/INF(7,N)-INF(1,N)^2/(4*INF(8,N)))*INF(1,N)
2515 LET M(2,2*N) = -MB/INF(9,N)/INF(1,N)
2520 LET M(2,2*N-1) = M(2,2*N)
2525 RETURN
2600 '          SUBROUTINE "5" DISTRIBUTION FACTORS
```

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2602 '          -------------------------------
2605 IF INF(2,1) = 1 THEN LET M(1,1) = 0:GOTO 2615
2610 LET M(1,1) = 1
2615 '
2620 IF INF(1,2) > 0 THEN LET M(1,2) = INF(9,1)/(INF(9,1)+INF(9,2)):LET M(1,3) =
 1 - M(1,2):GOTO 2640
2625 IF INF(3,1) = 1 THEN LET M(1,2) = 0:GOTO 2635
2630 LET M(1,2) = 1
2635 GOTO 2640
2640 '
2645 IF INF(1,3) > 0 THEN LET M(1,4) = INF(9,2)/(INF(9,2)+INF(9,3)):LET M(1,5) =
 1 - M(1,4):GOTO 2665
2650 IF INF(3,2) = 1 THEN LET M(1,4) = 0:GOTO 2660
2655 LET M(I,4) = 1
2660 GOTO 2665
2665 '
2670 IF INF(1,4) > 0 THEN LET M(1,6) = INF(9,3)/(INF(9,3)+INF(9,4)): LET M(1,7)
= 1 - M(1,6): GOTO 2690
2675 IF INF(3,3) = 1 THEN LET M(1,6) = 0:GOTO 2685
2680 LET M(1,6) = 1
2685 GOTO 2750
2690 '
2695 IF INF(3,4) = 1 THEN LET M(1,8) = 0:GOTO 2750
2700 LET M(1,8) = 1
2710 'FOR I=1 TO 8:PRINT M(1,I): NEXT I
2715 'FOR I=1 TO 8:PRINT M(2,I):NEXT I
2750 RETURN
2800 '      SUBROUTINE "6" "FIND FIXED END MOMENTS DUE TO UNIFORM LOADS"
2803 '     ------------------------------------------------------------
2820 LET AL = INF(6,N)
2825 LET S = AL/8
2830 LET M = (INF(5,N) - INF(4,N))/8
2835 FOR I = 1 TO 8
2840 LET H = INF(5,N) - M*(I-.5)
2845 LET AC(1,I) = H
2850 NEXT I
2855 LET AC(1,9) = INF(4,N)
2860 LET AC(2,9) = 1
2865 FOR I = 1 TO 8
2870 LET AC(2,I) = (AC(1,I)/AC(1,9))^3
2880 NEXT I
2885 '
2890 '   FIND STATIC MOMENTS IN VARIABLE SECTIONS.-
2892 '
2895 LET AC(7,9) = (W(N)*INF(1,N)^2)/8
2900 FOR I = 1 TO 8
2905 LET AC(7,I)=(W(N)*INF(1,N)*S*I/2) - W(N)*((S*I)^2)/2
2910 LET AC(8,I) = AC(7,I)/AC(2,I)
2915 LET AC(9,I) = AC(7,I)/AC(2,I+1)
2916 NEXT I
2920 LET P = (AC(7,9)-AC(7,8))*(INF(1,N)-2*AL)*2/3
2925 LET P =P + AC(7,8)*(INF(1,N)-2*AL)
2930 LET A2 = 0
2935 FOR I = 1 TO 8: LET A2 = A2 + AC(8,I): NEXT I
2940 FOR I = 1 TO 7: LET A2 = A2 + AC(9,I): NEXT I
2945 LET P = P + A2 * AL/8
2950 LET MW = P/INF(7,N)
2955 LET M(3,2*N) = MW
2960 LET M(3,2*N-1)= -MW
2965 RETURN
```

```
3000 '   SUBROUTINE 7: "F.E.M. DUE TO CONCENTRATED LOADS"
3002 '   -----------------------------------------------
3003 FOR X=1 TO 7:FOR Y=1 TO 20: LET FEP(X,Y)=0:NEXT Y: NEXT X
3005 LET Z=0
3007 IF N(N) < Z OR N(N) = Z THEN RETURN
3020 LET AL = INF(6,N)
3025 LET S = AL/8
3030 LET M = (INF(5,N) - INF(4,N))/8
3035 FOR I = 1 TO 8
3040 LET H = INF(5,N) - M*(I-.5)
3045 LET AC(1,I) = H
3050 NEXT I
3055 LET AC(1,9) = INF(4,N)
3060 LET AC(2,9) = 1
3065 FOR I = 1 TO 8
3070 LET FEP(3,I) = (AC(1,I)/AC(1,9))^3
3075 LET FEP(3,21-I) = FEP(3,I)
3080 NEXT I
3085 LET FEP(3,9) = 1: LET FEP(3,10) = 1:LET FEP(3,11) = 1: LET FEP(3,12) = 1
3090 ' WE HAVE INERTIA OF SECT. OF BEAMS IN FEP(3,I)
3200 FOR I = 1 TO 8
3205 LET FEP(1,I) = I*S -S/2
3210 LET FEP(1,12+I) = INF(1,N)-INF(6,N)+I*S-S/2
3215 NEXT I
3216 IF X(N,Z+1) > AL AND X(N,Z+1) < INF(1,N)-AL  THEN GOTO 3230
3218 LET FEP(1,9) = 0:LET FEP(1,10)=0
3220 LET FEP(1,11) = INF(1,N)/2
3222 LET FEP(1,12) = (INF(1,N) + AL)/3
3224 GOTO 3248
3230 LET FEP(1,9)=(X(N,Z+1)-AL)/2+AL
3235 LET FEP(1,10)=(X(N,Z+1)-AL)*2/3+AL
3240 LET FEP(1,11)=(INF(1,N)+X(N,Z+1)-AL)/2
3245 LET FEP(1,12)=(INF(1,N)+X(N,Z+1)*2-AL)/3
3248 ' WE HAVE DISTANCES FROM LEFT SUPPORT IN FEP(1,I)
3260 LET FEP(2,10)=P(N,Z+1)*X(N,Z+1)-P(N,Z+1)*X(N,Z+1)*X(N,Z+1)/INF(1,N)
3262 IF X(N,Z+1) > AL AND X(N,Z+1) < INF(1,N)-AL THEN GOTO 3275
3264 IF X(N,Z+1) > INF(1,N)-AL THEN LET X = INF(1,N) - X(N,Z+1)
3266 IF X(N,Z+1) < AL THEN LET X = X(N,Z+1)
3268 FOR I = 1 TO FIX(X/S):LET FEP(2,I)=FEP(2,10)*S*I/X : NEXT I
3270 FOR I =(FIX(X/S)+1) TO 8:LET FEP(2,I)=FEP(2,10)*(INF(1,N)-S*I)/(INF(1,N)-X)
: NEXT I
3272 FOR I=1 TO 8:LET FEP(2,12+I)=FEP(2,10)*(AL-(I-1)*S)/(INF(1,N)-X):NEXT I
3274 GOTO 3282
3275 FOR I=1 TO 8
3277 LET FEP(2,I)=FEP(2,10)*S*I/X(N,Z+1)
3279 LET FEP(2,12+I)=FEP(2,10)*(AL-(I-1)*S)/(INF(1,N)-X(N,Z+1))
3280 NEXT I
3282 ' WE HAVE STATIC MOMENTS IN SECTIONS IN FEP(2,I).
3285 '
3300 FOR I = 1 TO 8
3305 LET FEP(4,I+1) = FEP(2,I)/FEP(3,I+1)
3310 LET FEP(5,I) = FEP(2,I)/FEP(3,I)
3315 LET FEP(4,11+I) = FEP(2,12+I)/FEP(3,11+I)
3320 LET FEP(5,12+I) = FEP(2,12+I)/FEP(3,12+I)
3325 NEXT I
3327 IF X(N,Z+1) > AL AND X(N,Z+1) < INF(1,N)-AL  THEN GOTO 3335
3329 LET FEP(4,9)=0
3335 ' WE HVE M/I AND M/(I) INTO FEP(4,I) AND FEP(5,I)
3337 FOR I = 1 TO 8
3339 LET FEP(6,I)=(FEP(4,I)+FEP(5,I))*S/2
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3341 LET FEP(6,12+I)=(FEP(4,12+I)+FEP(5,12+I))*S/2
3343 NEXT I
3345 IF X(N,Z+1) > AL AND X(N,Z+1) < INF(1,N)-AL THEN GOTO 3360
3347 LET FEP(6,10)=0: LET FEP(6,9)=0
3349 LET FEP(6,11)=FEP(2,13)*(INF(1,N)-2*AL)
3351 LET FEP(6,12)=(FEP(2,8)-FEP(2,13))*(INF(1,N)-2*AL)/2
3353 GOTO 3377
3360 LET FEP(6,9)=(X(N,Z+1)-AL)*FEP(4,9)
3365 LET FEP(6,10)=(X(N,Z+1)-AL)*(FEP(2,10)-FEP(4,9))/2
3370 LET FEP(6,11)=(INF(1,N)-X(N,Z+1)-AL)*FEP(4,12)
3375 LET FEP(6,12)=(INF(1,N)-X(N,Z+1)-AL)*(FEP(2,10)-FEP(4,12))/2
3377 ' WE HAVE PARTIAL AREAS IN FEP(6,I)
3378 '
3380 FOR I=1 TO 20
3385 LET FEP(7,I)=FEP(1,I)*FEP(6,I)
3390 NEXT I
3395 ' WE HAVE PRODUCTS (A*X) IN FEP)7,I)
3396 LET AP = 0:LET AX = 0
4000 FOR I = 1 TO 20
4005 LET AP = AP+FEP(6,I)
4010 LET AX = AX+FEP(7,I)
4012 NEXT I
4015 LET XX = AX/AP
4020 LET C = (INF(1,N)/2)-XX
4025 LET MPL =(AP/INF(7,N))+AP*C*INF(1,N)/(2*INF(8,N))
4030 LET MPR=(AP/INF(7,N))-AP*C*INF(1,N)/(2*INF(8,N))
4032 IF X(N,Z+1) < INF(1,N)-AL THEN GOTO 4035
4033 LET M(4,2*N-1)=M(4,2*N-1)-MPR
4034 LET M(4,2*N) = M(4,2*N)+MPL: GOTO 4042
4035 LET M(4,2*N-1)=M(4,2*N-1)-MPL
4040 LET M(4,2*N)=M(4,2*N)+MPR
4042 '
4045 LET Z=Z+1:GOTO 3007
4060 '    SUBROUTINE 8: INITIALIZE INTERNAL SECTIONS.- S(1,-)
4061 '    ------------------------------------------------
4070 LET S(1,J*7-6) = 0
4075 LET S(1,J*7-5) = INF(1,J)*.125
4080 LET S(1,J*7-4) = INF(1,J)*.25
4085 LET S(1,J*7-3) = INF(1,J)*.5
4090 LET S(1,J*7-2) = INF(1,J)*.75
4095 LET S(1,J*7-1) = INF(1,J)*.875
4100 LET S(1,J*7) = INF(1,J)*1
4105 RETURN
4106 '
4107 '
4108 '
4150 '  SUBROUTINE 9.- FIND M & V IN INTERNAL SECTIONS DUE TO CONCENTRATED LOADS
4151 '  -----------------------------------------------------------------------
4153 LET T = 6
4155 IF S(1,J*7-T) > X(J,I) THEN 4175
4160 LET MI = P(J,I)*(INF(1,J)-X(J,I))*S(1,J*7-T)/INF(1,J)
4165 LET VI = P(J,I)*(INF(1,J)-X(J,I))/INF(1,J)
4170 GOTO 4185
4175 LET MI = P(J,I)*X(J,I)*(INF(1,J)-S(1,J*7-T))/INF(1,J)
4180 LET VI = (P(J,I)*(INF(1,J)-X(J,I))/INF(1,J))-P(J,I)
4185 LET S(2,J*7-T) = S(2,J*7-T) + MI
4190 LET S(3,J*7-T) = S(3,J*7-T) + VI
4195 LET T = T - 1
4200 IF T > 0 OR T = 0 THEN GOTO 4155
4205 RETURN
```