Computer program for the analysis of non-prismatic beams

Roberto Antonio Alas

Florida International University

4-18-1989

DOI: 10.25148/etd.FI13101560

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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

by

Roberto Antonio Alas

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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Committee in charge:

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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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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.
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<td>21</td>
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</table>
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.

![Typical Beam Cross Sections](image)

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.
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 like 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 Linearllly. *
*    * 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 determine 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.

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 Indetermined 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 ELEMEN T 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 \(\phi_A\) 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.

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

Knowing the Indetermined 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: \( DF = \frac{S_i}{\sum S_i} \).
3. Arrange a Tabular form on an expanded outline of the structure and insert the values of C.O.F.,
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 members.

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 6k' moment at B, shown above, represents the restraint necessary to hold B in the assumed fixed position shown above. Joint E is next allowed to rotate again under the action of the 6k' 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 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.

![Diagram of a continuous beam](image)

**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.

<table>
<thead>
<tr>
<th>JOINT</th>
<th>AB</th>
<th>BA</th>
<th>BC</th>
<th>CB</th>
<th>CD</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.F.</td>
<td>0.00</td>
<td>0.67</td>
<td>0.33</td>
<td>0.33</td>
<td>0.67</td>
<td>0.00</td>
</tr>
<tr>
<td>C.O.F.</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>F.E.M.</td>
<td>-24.00</td>
<td>24.00</td>
<td>-60.00</td>
<td>60.00</td>
<td>-24.00</td>
<td>24.00</td>
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<tr>
<td>D.M.</td>
<td>0.00</td>
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<td>12.00</td>
<td>-12.00</td>
<td>-24.00</td>
<td>0.00</td>
</tr>
<tr>
<td>C.O.M.</td>
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<td>0.00</td>
<td>-6.00</td>
<td>6.00</td>
<td>0.00</td>
<td>-12.00</td>
</tr>
<tr>
<td>D.M.</td>
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<td>4.00</td>
<td>2.00</td>
<td>-2.00</td>
<td>-4.00</td>
<td>0.00</td>
</tr>
<tr>
<td>C.O.M.</td>
<td>2.00</td>
<td>0.00</td>
<td>-1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>-2.00</td>
</tr>
<tr>
<td>D.M.</td>
<td>0.00</td>
<td>0.67</td>
<td>0.33</td>
<td>-0.33</td>
<td>-0.67</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>FINAL M.</strong></td>
<td><strong>-10.00</strong></td>
<td><strong>52.67</strong></td>
<td><strong>-52.67</strong></td>
<td><strong>52.67</strong></td>
<td><strong>-52.67</strong></td>
<td><strong>10.00</strong></td>
</tr>
</tbody>
</table>

- **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.

![Diagram of beam with spans and loads](image)

**Fig. 4.2 Member of Illustrative Example 4.2.**

<table>
<thead>
<tr>
<th>GEOMETRICAL PROPERTIES</th>
<th>Span 1</th>
<th>Span 2</th>
<th>Span 3</th>
<th>Span 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Spans (ft)</td>
<td>40.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Supp:Fixed=1,Free=0</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Supp:Fixed=1,Free=0</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Height (ft)</td>
<td>2.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Height (ft)</td>
<td>2.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length AL Haunch (ft)</td>
<td>10.00</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>LOADS ON BEAMS</th>
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<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>Uniform loads k/ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concent.Loads in Span 1</td>
<td>k</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dist.of p to left supp. ft</td>
<td>1.00</td>
<td>1.00</td>
<td>8.00</td>
<td>14.00</td>
<td></td>
</tr>
</tbody>
</table>
4.2(1) PROPERTIES OF ANALOGOUS COLUMN WITH HAUNCH DIVIDED INTO 8 STRAIGHT SEGMENTS.

**Fig. 4.3 Correspondence Between Beam And Analogous Column.**

<table>
<thead>
<tr>
<th>Section</th>
<th>Height</th>
<th>I_b</th>
<th>(A)_{AC}</th>
<th>d</th>
<th>(I)_{AC}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.468</td>
<td>1.879</td>
<td>0.665</td>
<td>19.375</td>
<td>249.7216</td>
</tr>
<tr>
<td>2</td>
<td>2.406</td>
<td>1.741</td>
<td>0.718</td>
<td>18.125</td>
<td>235.9675</td>
</tr>
<tr>
<td>3</td>
<td>2.344</td>
<td>1.610</td>
<td>0.776</td>
<td>16.875</td>
<td>221.0791</td>
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<td>2.281</td>
<td>1.483</td>
<td>0.843</td>
<td>15.625</td>
<td>205.9208</td>
</tr>
<tr>
<td>5</td>
<td>2.219</td>
<td>1.366</td>
<td>0.915</td>
<td>14.375</td>
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4.2(2) PROPERTIES OF ANALOGOUS COLUMN WITH HAUNCH DIVIDED INTO 6 STRAIGHT SEGMENTS.

<table>
<thead>
<tr>
<th>Section</th>
<th>A Height</th>
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<th>C (A)AC</th>
<th>D d</th>
<th>E (I)AC</th>
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<td>333.333</td>
</tr>
</tbody>
</table>

\[(A)_{AC} = 2(\text{Summation Column C}) = \frac{34.396}{EI}\]

\[(I)_{AC} = 2(\text{Summation Column E}) = \frac{3791.845}{EI}\]

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

<table>
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<th>Section</th>
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<th>C (A)AC</th>
<th>D d</th>
<th>E (I)AC</th>
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<td>0.541</td>
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<td>0.569</td>
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<td>0.602</td>
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<td>1.000</td>
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<td>333.333</td>
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\[(A)_{AC} = 2(\text{Summation Column C}) = \frac{34.388}{EI}\]

\[(I)_{AC} = 2(\text{Summation Column E}) = \frac{3793.128}{EI}\]
\[(A)_{AC} = 2(\text{summation Column C}) = 34.40/EI\]
\[(I)_{AC} = 2(\text{Summation Column E}) = 3791.20/EI\]

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 A 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."

![Diagram showing loading and reactions on a beam.]

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

\[
M_A = S_A \cdot \varphi_A = \text{Pressure at A.}
\]

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

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

Since the Beam is Symmetric:

Stiffness = \( S_A = S_B = \frac{M_A}{\varphi_A} = 5.39(EI / L) \)

(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).

<table>
<thead>
<tr>
<th>Section</th>
<th>( M_s )</th>
<th>( \frac{I}{I_9} )</th>
<th>( \frac{M}{(EI)}_i )</th>
<th>( \frac{M}{(EI)}_{i+1} )</th>
<th>AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0.00</td>
<td>12.90</td>
<td>8.06</td>
</tr>
<tr>
<td>2</td>
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<td>1.74</td>
<td>13.90</td>
<td>26.90</td>
<td>25.50</td>
</tr>
<tr>
<td>3</td>
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<td>1.61</td>
<td>29.10</td>
<td>42.20</td>
<td>44.56</td>
</tr>
<tr>
<td>4</td>
<td>87.50</td>
<td>1.48</td>
<td>45.90</td>
<td>59.10</td>
<td>65.63</td>
</tr>
<tr>
<td>5</td>
<td>105.50</td>
<td>1.37</td>
<td>63.90</td>
<td>77.00</td>
<td>88.06</td>
</tr>
<tr>
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<td>121.90</td>
<td>1.25</td>
<td>84.40</td>
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<td>106.00</td>
<td>118.90</td>
<td>140.56</td>
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<tr>
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<td>150.00</td>
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<td>130.20</td>
<td>142.80</td>
<td>170.63</td>
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<td>1.00</td>
<td>150.00</td>
<td>183.33</td>
<td>183.33</td>
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Area = 2(Summation Areas) = 4980.05

\[
(FEM)_A = \frac{P/A \pm M}{I} = \frac{4980}{34.375} + 0 = 144.87
\]
### 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)

<table>
<thead>
<tr>
<th>No.</th>
<th>X(ft)</th>
<th>Ms</th>
<th>I</th>
<th>( M_i )</th>
<th>( M_{i+1} )</th>
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<th>A*X</th>
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<td>0.47</td>
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<td>0.93</td>
<td>1.64</td>
</tr>
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<td>2.44</td>
<td>1.61</td>
<td>1.01</td>
<td>1.51</td>
<td>1.58</td>
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<tr>
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<td>2.41</td>
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<td>4.06</td>
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<td>4.47</td>
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<tr>
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<td>0.23</td>
<td>0.14</td>
<td>5.67</td>
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</table>

**SUMMATION**

- \( AP = \text{Areas} = 171.89 \)
- \( A*X = (A*X) = 3118.14 \)
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.**

\[XX = \frac{(A\times X)}{(A)} = \frac{3118.14}{171.89} = 18.14\]

\[C = L/2 - XX = 20.00 - 18.14 = +1.86\]

\[\text{(FEM)}_A = \frac{P}{A} + \frac{M_Y}{I} = \frac{171.89}{34.375} + \frac{(171.89\times 1.86)20}{3787} = 6.69\]

\[\text{(FEM)}_B = \frac{P}{B} - \frac{M_Y}{I} = \frac{171.89}{34.375} - \frac{(171.89\times 1.86)20}{3787} = 3.31\]
4.2(7) FIXED END MOMENTS DUE TO CONCENTRATED LOAD
(in Haunch).

![Moment Diagram](image)

**Fig. Load on Top of Analogous Column**

(p on Haunch)

<table>
<thead>
<tr>
<th>No.</th>
<th>X(ft)</th>
<th>$M_S$</th>
<th>$I\ (EI)_i$</th>
<th>$(EI)_{i+1}$</th>
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<td>0.25</td>
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</tr>
</tbody>
</table>

**SUMMATION** 117.73 - 1929.16

**AP = Areas = 117.73 ; A*X = (A*X) = 1929.16**
\[ P = \text{Summation Areas} = 117.73 \]

\[ (A)_{AC} = 34.375 \]
\[ (I)_{AC} = 3787 \]

\[ XX = \frac{(A \times X)}{(A)} = \frac{1929.16}{117.73} = 16.38 \]

\[ C = \frac{L}{2} - XX = 20.00 - 16.38 = 3.61 \]

\[ (FEM)_{A} = \frac{P}{A} \frac{My}{I} \frac{117.73}{34.375} \frac{(117.73 \times 3.61)20}{3787} = 5.67 \]

\[ (FEM)_{B} = \frac{P}{A} \frac{My}{I} \frac{117.73}{34.375} \frac{(117.73 \times 3.61)20}{3787} = 1.18 \]
### 4.2(8) SUMMARY OF FIXED-END MOMENTS

<table>
<thead>
<tr>
<th></th>
<th>(FEM)\textsubscript{A}</th>
<th>(FEM)\textsubscript{B}</th>
<th>REFERENCE</th>
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<td>144.87</td>
<td>Pg. 21</td>
</tr>
<tr>
<td>P out of Haunch</td>
<td>6.69</td>
<td>3.31</td>
<td>Pg. 23</td>
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<td>P in Haunch</td>
<td>5.67</td>
<td>1.18</td>
<td>Pg. 25</td>
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</table>
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.

![Diagram of non-prismatic beam](image)

**Fig. 5.1 Member of Example 5.1**

**GEOMETRICAL PROPERTIES OF THE BEAM**

<table>
<thead>
<tr>
<th></th>
<th>SPAN 1</th>
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<th>SPAN 3</th>
<th>SPAN 4</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
<td>0</td>
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<tr>
<td>RIGHT SUPPORT: FIXED=1 OR FREE=0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>MINIMUM HEIGHT OF BEAM (FEET)</td>
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DO YOU WANT TO CHANGE ANY NUMBER? YES OR NO: ? NO

**PARTIAL RESULTS**

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<tr>
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<th>SPAN 1</th>
<th>SPAN 2</th>
<th>SPAN 3</th>
<th>SPAN 4</th>
</tr>
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<tbody>
<tr>
<td>AREA OF ANALOG.COL</td>
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<td>0.00</td>
</tr>
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</tr>
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</tr>
<tr>
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<td>0.568</td>
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PRESS ANY KEY TO CONTINUE
CHECK LOAD ON BEAMS.

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<th>0.00</th>
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<td>0.00</td>
</tr>
<tr>
<td>DIST. OF P TO LEFT SUPP. F</td>
<td>8.00</td>
<td>14.00</td>
<td>0.00</td>
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<td>CONCENT. LOADS IN SPAN 2 K</td>
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<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
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<td>CONCENT. LOADS IN SPAN 3 K</td>
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<tr>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

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 |
| FEM (P) | -12.34 | 4.51   | 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

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<th>SPAN 2</th>
<th>SPAN 3</th>
<th>SPAN 4</th>
</tr>
</thead>
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<tr>
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<td>25.00</td>
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<td>25.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LEFT SUPPORT: FIXED=1 OR FREE=0</td>
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<tr>
<td>RIGHT SUPPORT: FIXED=1 OR FREE=0</td>
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</tr>
<tr>
<td>MINIMUM HEIGHT OF BEAM (FEET)</td>
<td>2.00</td>
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DO YOU WANT TO CHANGE ANY NUMBER? YES OR NO: ? NO

PARTIAL RESULTS

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<th>SPAN 3</th>
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<td>21.64</td>
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<tr>
<td>MOM. OF INERT. OF ANALOG.COL</td>
<td>935.10</td>
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<td>935.10</td>
<td>0.00</td>
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<tr>
<td>STIFFNESS OF SPAN/L</td>
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<tr>
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CHECK LOAD ON BEAMS.

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<td>CONCENT.LOADS IN SPAN 1 K</td>
<td>1.00</td>
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</tr>
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<td>DIST.OF P TO LEFT SUPP. F</td>
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<td>CONCENT.LOADS IN SPAN 2 K</td>
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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 ***

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<td>0.57</td>
<td>0.57</td>
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<td>-59.94</td>
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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 ***

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<th>12.50</th>
<th>18.75</th>
<th>21.88</th>
<th>25.00</th>
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<td>12.50</td>
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DO YOU WANT SHEARS IN INTERNAL SECTIONS, YES OR NO: ?

*** SHEARS IN INTERNAL SECTIONS ***

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<td>-4.46</td>
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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**

<table>
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<th>SPAN 4</th>
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<td>25.00</td>
</tr>
<tr>
<td>LEFT SUPPORT: FIXED = 1 OR FREE = 0</td>
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<td>0</td>
<td>0</td>
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<td>RIGHT SUPPORT: FIXED = 1 OR FREE = 0</td>
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<td>0</td>
<td>0</td>
</tr>
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<td>2.00</td>
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<td>10.00</td>
<td>6.00</td>
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DO YOU WANT TO CHANGE ANY NUMBER? YES OR NO: ?
INVALID RESPONSE, ENTER YES OR NO: ? NO

**PARTIAL RESULTS**

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<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AREA OF ANALOG. COL</td>
<td>21.64</td>
<td>34.39</td>
<td>34.39</td>
<td>21.64</td>
</tr>
<tr>
<td>MOM. OF INERT. OF ANALOG. COL</td>
<td>935.10</td>
<td>3791.48</td>
<td>3791.48</td>
<td>935.10</td>
</tr>
<tr>
<td>STIFFNESS OF SPAN/L</td>
<td>0.21</td>
<td>0.13</td>
<td>0.13</td>
<td>0.21</td>
</tr>
<tr>
<td>DISTR. FAC.</td>
<td>1.000</td>
<td>0.613</td>
<td>0.387</td>
<td>0.500</td>
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<tr>
<td>CAR. O.V. FACT.</td>
<td>0.567</td>
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CHECK LOAD ON BEAMS -

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<tr>
<th>UNIFORM LOADS K/F</th>
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<th>1.00</th>
<th>1.00</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCENT. LOADS IN SPAN 1 K</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>DIST. OF P TO LEFT SUPP. F</td>
<td>12.50</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>CONCENT. LOADS IN SPAN 2 K</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>DIST. OF P TO LEFT SUPP. F</td>
<td>8.00</td>
<td>14.00</td>
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</tr>
<tr>
<td>CONCENT. LOADS IN SPAN 3 K</td>
<td>1.00</td>
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<td>0.00</td>
</tr>
<tr>
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<tr>
<td>DIST. OF P TO LEFT SUPP. F</td>
<td>12.50</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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</tbody>
</table>

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 ***

<table>
<thead>
<tr>
<th>MOM.1</th>
<th>MOM.2</th>
<th>MOM.3</th>
<th>MOM.4</th>
<th>MOM.5</th>
<th>MOM.6</th>
<th>MOM.7</th>
<th>MOM.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIS. FAC.</td>
<td>1.00</td>
<td>0.61</td>
<td>0.39</td>
<td>0.50</td>
<td>0.50</td>
<td>0.39</td>
<td>0.61</td>
</tr>
<tr>
<td>C.O. FAC.</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
</tr>
<tr>
<td>FIX. E.M.</td>
<td>-59.94</td>
<td>59.94</td>
<td>-157.17</td>
<td>149.34</td>
<td>-151.55</td>
<td>156.00</td>
<td>-59.94</td>
</tr>
<tr>
<td>DISTRIBUT.</td>
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<td>59.62</td>
<td>37.61</td>
<td>1.10</td>
<td>1.10</td>
<td>-37.16</td>
<td>-58.90</td>
</tr>
<tr>
<td>CAR. OV.</td>
<td>33.78</td>
<td>33.97</td>
<td>0.63</td>
<td>21.36</td>
<td>-21.10</td>
<td>0.63</td>
<td>-33.97</td>
</tr>
<tr>
<td>DISTRIBUT.</td>
<td>-33.78</td>
<td>-21.21</td>
<td>-13.38</td>
<td>-0.13</td>
<td>-0.13</td>
<td>12.90</td>
<td>20.44</td>
</tr>
<tr>
<td>CAR. OV.</td>
<td>-12.02</td>
<td>-19.14</td>
<td>-0.07</td>
<td>-7.60</td>
<td>7.32</td>
<td>-0.07</td>
<td>18.91</td>
</tr>
<tr>
<td>DISTRIBUT.</td>
<td>12.02</td>
<td>11.78</td>
<td>7.43</td>
<td>0.14</td>
<td>0.14</td>
<td>-7.29</td>
<td>-11.55</td>
</tr>
<tr>
<td>CAR. OV.</td>
<td>6.68</td>
<td>6.81</td>
<td>0.08</td>
<td>4.22</td>
<td>-4.14</td>
<td>0.08</td>
<td>-6.56</td>
</tr>
<tr>
<td>DISTRIBUT.</td>
<td>-6.68</td>
<td>-4.22</td>
<td>-2.67</td>
<td>-0.04</td>
<td>-0.04</td>
<td>2.51</td>
<td>3.98</td>
</tr>
<tr>
<td>FIN. MOM</td>
<td>0.00</td>
<td>127.54</td>
<td>-127.54</td>
<td>168.39</td>
<td>-168.39</td>
<td>127.59</td>
<td>-127.59</td>
</tr>
</tbody>
</table>

MOMENTS IN INTERNAL SECTIONS, YES OR NO: ?
**MOMENTS IN INTERNAL SECTIONS**

<table>
<thead>
<tr>
<th>SPAN 1</th>
<th>DIST.</th>
<th>0.00</th>
<th>3.13</th>
<th>6.25</th>
<th>12.50</th>
<th>18.75</th>
<th>21.88</th>
<th>25.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOM FRA</td>
<td>0.00</td>
<td>19.80</td>
<td>29.83</td>
<td>20.61</td>
<td>-33.93</td>
<td>-75.85</td>
<td>-127.54</td>
<td></td>
</tr>
<tr>
<td>SPAN 2</td>
<td>DIST.</td>
<td>0.00</td>
<td>5.00</td>
<td>10.00</td>
<td>20.00</td>
<td>30.00</td>
<td>35.00</td>
<td>40.00</td>
</tr>
<tr>
<td>MOM FRA</td>
<td>-127.54</td>
<td>-37.89</td>
<td>24.75</td>
<td>63.03</td>
<td>-2.68</td>
<td>-75.04</td>
<td>-168.39</td>
<td></td>
</tr>
<tr>
<td>SPAN 3</td>
<td>DIST.</td>
<td>0.00</td>
<td>5.00</td>
<td>10.00</td>
<td>20.00</td>
<td>30.00</td>
<td>35.00</td>
<td>40.00</td>
</tr>
<tr>
<td>MOM FRA</td>
<td>-168.39</td>
<td>-72.29</td>
<td>-1.19</td>
<td>66.01</td>
<td>23.21</td>
<td>-35.69</td>
<td>-127.59</td>
<td></td>
</tr>
<tr>
<td>SPAN 4</td>
<td>DIST.</td>
<td>0.00</td>
<td>3.13</td>
<td>6.25</td>
<td>12.50</td>
<td>18.75</td>
<td>21.88</td>
<td>25.00</td>
</tr>
<tr>
<td>MOM FRA</td>
<td>-127.59</td>
<td>-75.90</td>
<td>-33.98</td>
<td>20.58</td>
<td>29.82</td>
<td>19.79</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

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

**SHEARS IN INTERNAL SECTIONS**

<table>
<thead>
<tr>
<th>SPAN 1</th>
<th>DIST.</th>
<th>0.00</th>
<th>3.13</th>
<th>6.25</th>
<th>12.50</th>
<th>18.75</th>
<th>21.88</th>
<th>25.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHEARS.</td>
<td>7.90</td>
<td>4.77</td>
<td>1.65</td>
<td>-4.60</td>
<td>-11.85</td>
<td>-14.98</td>
<td>-18.10</td>
<td></td>
</tr>
<tr>
<td>SPAN 2</td>
<td>DIST.</td>
<td>0.00</td>
<td>5.00</td>
<td>10.00</td>
<td>20.00</td>
<td>30.00</td>
<td>35.00</td>
<td>40.00</td>
</tr>
<tr>
<td>SHEARS.</td>
<td>20.43</td>
<td>15.43</td>
<td>9.43</td>
<td>-1.57</td>
<td>-11.57</td>
<td>-16.57</td>
<td>-21.57</td>
<td></td>
</tr>
<tr>
<td>SPAN 3</td>
<td>DIST.</td>
<td>0.00</td>
<td>5.00</td>
<td>10.00</td>
<td>20.00</td>
<td>30.00</td>
<td>35.00</td>
<td>40.00</td>
</tr>
<tr>
<td>SHEARS.</td>
<td>21.72</td>
<td>16.72</td>
<td>11.72</td>
<td>1.72</td>
<td>-9.28</td>
<td>-15.28</td>
<td>-20.28</td>
<td></td>
</tr>
<tr>
<td>SPAN 4</td>
<td>DIST.</td>
<td>0.00</td>
<td>3.13</td>
<td>6.25</td>
<td>12.50</td>
<td>18.75</td>
<td>21.88</td>
<td>25.00</td>
</tr>
<tr>
<td>SHEARS.</td>
<td>18.10</td>
<td>14.98</td>
<td>11.85</td>
<td>5.60</td>
<td>-1.65</td>
<td>-4.77</td>
<td>-7.90</td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th></th>
<th>HAND CALCULATIONS</th>
<th>COMPUTER PROGRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>STIFFNESS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S_A$</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>$S_B$</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>CARRY-OVER FACTORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$(C.O.F)_A$</td>
<td>0.568</td>
<td>0.568</td>
</tr>
<tr>
<td>$(C.O.F)_B$</td>
<td>0.568</td>
<td>0.568</td>
</tr>
<tr>
<td>DISTRIBUTION FACTORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$(D.F)_A$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>$(D.F)_B$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>FIXED-END MOMENTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$(FEM)_A$</td>
<td>-157.23</td>
<td>-157.17</td>
</tr>
<tr>
<td>$(FEM)_B$</td>
<td>149.36</td>
<td>149.34</td>
</tr>
</tbody>
</table>

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.

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

**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 with 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


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

START

100

Display the Description of the Program.

510

Ask if one Beam is to be Analyzed.

555

IS

Answer

YES

YES

Subroutine 1
Obtain: Lengths & Condition of Support.

565

NO

DISPLAY ENDING MESSAGE

590

END

625

FIND: Final Shears on Intermediate Sections.

1530

PRINT RESULTS

1475

FIND: Final Moments On Intermediate Sections.

1300 (4060)

Process Moment distribution, FIND: Final End Moments.

1150

Subroutine 7
FIND: Fixed End Moments due to the Concentrated Loads.

1100 (3000)

Subroutine 6
FIND: Fixed End Moments due to the Uniform Loads

1077 (2800)

CHECK LOADS

1044


960

Subroutine 5
FIND: Distribution Factors.

938 (2600)

Subroutine 3
FIND: Properties of Analogous Column.

856 (2200)

Subroutine 4
FIND: Stiffness & Carry-Over Factors.

885 (2500)

Subroutine 8

1300 (4060)
SUBROUTINE 3: Area (A) and Moment of Inertia of Analogous Column

START

I = 1

RETURN

Let AC(1,I) = Height of Section of the Beam.

Let AC(2,I) = Moment of Inertia of the Section of Beam.

Let AC(3,I) = Area of Sections of Analogous Column.

Let AC(4,I) = Distance from I to Section of Analogous Column.

Let AC(5,I) = \( b^*h^3/12 \) of sections of the Analogous Column.

Let AC(6,I) = \( b^*(h)^3/12 + A^*(d)^2 \) of Section of the Analogous Column.

INF(8,N) = \( \sum AC(6,9) \) = Moment of Inertia of Analogous Column

INF(7,N) = \( \sum AC(3,9) \) = Area of the Analogous Column.

IF (I < 9)

I = I + 1

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

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.

START

N=1

L(N)≠0 AND N<5

YES

Let INF(9,N) = \[ \frac{1}{(A_{AC})^2} - \frac{(L/2)^2}{(I_{AC})^2} \]

Stiffness.

NO

RETURN

N = No. of Span analyzed
L(N) = Length of 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.

Let MB = \[ \frac{1}{(A_{AC})^2} - \frac{(L/2)^2}{(I_{AC})^2} \]

Moment of B

Let M(2,2*N) = \[ \frac{(-MB)}{M_A} \]

Carry-Over Factors.

N = N+1

Let M(2,2*N-1) = M(2,2*N) = Carry-Over Factors.
SUBROUTINE 5: Distribution Factors.

START

IS Left End FIXED?

YES M(1,1) = 0

NO M(1,1) = 1

N = 1

L(N+1) > 0

YES M(1,2*N) = \frac{K(N)}{K(N)+K(N+1)}

M(1,2*N+1) = 1 - M(1,2*N)

N = N+1

NO

IS Right End FIXED?

YES M(1,2*N) = 1

NO M(1,2*N) = 0

RETURN

N < 4

K(1)  K(2)  K(3)  

L(1)  L(2)  L(3)  

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.

Let \( AC(7,9) = W(L)^2/8 \)

Let \( AC(7, I) = W^*L^*X/2 - W(X)^2/2 \)

Let \( AC(8, I) = Ms / (EI) \)

Let \( AC(9, I) = Ms / (EI) \)

Let \( P = \sum Ms / EI \)

Let \( (FEM)_L = -(P/\alpha ac - Mc/I) \)

Let \( (FEM)_R = -(P/\alpha ac + Mc/I) \)

\( AC(1, I) = \) Height 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 \( Ms/EI \).

\( (FEM)_L = (P/\alpha ac + Mc/I) \). Fixed End Moment Left

\( (FEM)_R = -(P/\alpha ac - Mc/I) \). Fixed End Moment Right
SUBROUTINE 7: Fixed-End Moments due to Concentrated Loads.

START
3000

FEP(7,20)=0
Z = 0

RETURN
3005

IS

N(N) > Z?
3007

YES

FEP(3,1) = Ib
FEP(1,1) = X

NO

IS

P in HAUNCH?
3208

NO

YES

FEP(1,9) = (X-AL)/2+AL
FEP(1,10) = (X-AL*2/3)+AL
FEP(1,11) = (L-AL-X)/2+X
FEP(1,12) = (L-AL)/3

FEP(2,1) = Ms
FEP(4,1) = Ms/(EI)B
FEP(5,1) = Ms/(EI)A
FEM(6,1) = P/Area M/EI
FEM(7,1) = P*X = A*X
XX = P*X
P

Z = Z+1

(FEM)A = \frac{P}{(A\times AC)} + \frac{M\times C}{I\times AC}
(FEM)B = \frac{P}{(A\times AC)} \frac{M\times C}{I\times AC}

FEP(7,20) = Array to Process FEM due to P.
Z = Number of Loads being Analyzed.
N(N) = Number of Loads in Span N.
Ib = 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.

---

CONTINUE

Array $S(9,28) = 0$

$J = 1$

---

Subroutine 8.
Find Position of Internal Sections.

---

$I = 1$

---

IF

$I > N(J)$

YES

$J = J + 1$

NO

---

Subroutine 9
Find M & V in Inertial Sections Due to P.

---

$I = I + 1$

---

IF

$J > 4$

YES

NO

---

Find M & V Due to W and Final End Moments.

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

\[ T = 6 \]

\[ \text{Md} = \frac{P(L-X)d}{L} \]
\[ \text{Vd} = \frac{P(1-X)}{L} \]

\[ \text{d} = \text{Position of Section Analyzed.} \]
\[ \text{X} = \text{Position of P.} \]
\[ \text{Md} = \text{Moment in Section d due to P.} \]
\[ \text{Vd} = \text{Shear in Section d due to P.} \]
\[ \text{S(2), S(3)} = \text{Address to Accumulate Moments due to Concentrated Loads.} \]
\[ \text{S(2), S(3)} = \text{Address to Accumulate Shears due to Concentrated Loads.} \]
Moments & Shears in Internal Sections due to Uniform Loads and Final-End Moments.

\[
\begin{align*}
S(4,J(7-T)) &= M_w \\
S(5,J(7-T)) &= V_w \\
S(6,J(7-T)) &= M_m \\
S(7,J(7-T)) &= V_m
\end{align*}
\]

\[
\begin{align*}
M(Z+1) &= M(Z) \\
M_m &= (M_L - M_R) / L M_L
\end{align*}
\]

\[
\begin{align*}
V_m &= (M_L - M_R) / L \\
V_w &= \frac{wL^2}{2} - \frac{wX^2}{2}
\end{align*}
\]

\[
\begin{align*}
M_w &= \text{End Moment due to Distribution Load.} \\
V_w &= \frac{wL^2}{2} - \frac{wX}{2}
\end{align*}
\]

\[
\begin{align*}
S(9,28) &= \text{Array to Keep Forces in Internal Section.} \\
M_m &= \frac{(M_L - M_R)}{L M_L}
\end{align*}
\]

\[
\begin{align*}
V_m &= \text{End Shear due to Final Moments.} \\
J &= \text{Span being Analyzed.} \\
Z &= \text{Moment being Analyzed} \\
L(J) &= \text{Subscript to Identify Section.}
\end{align*}
\]
APPENDIX B

LISTING OF THE PROGRAM
VARIABLE NAMES.

A$ ................................ RESPONSE TO " YES OR NO ?".
J .................................. SUBSCRIPT TO IDENTIFY SPAN NO.
E ................................. NUMBER OF ENTRIES ON ARRAY M(E,8).
INF(9,4) ............................ ARRAY TO KEEP GEOMETRIC CHARACTERISTICS OF BEAM AND ANALOGOUS COLUMN.

LENGTH OF SPANS.
CONDITION OF LEFT SUPPORT.
MINIMUM HEIGHT OF EACH SPAN.
MAXIMUM HEIGHT OF EACH SPAN.
LENGTH OF TAPERED SECTIONS.
AREA OF ANALOGOUS COLUMN ON EACH SPAN.
MOMENT OF INERTIA OF ANALOGOUS COLUMN ON EACH SPAN.
STIFFNESS OF EACH SPAN.

M(E,8) ............................... ARRAY TO PROCESS MOMENT DISTRIBUTION.

DISTRIBUTION FACTOR OF EACH END.
CARRY OVER FACTOR OF EACH END.
FIXED MOMENT ON EACH END.
PARTIAL DISTRIBUTIONS.
PARTIAL CARRY OVER.
FINAL MOMENTS ON EACH END.

AC(6,9) .............................. ARRAY TO PROCESS PROPERTIES OF ANALOGOUS COLUMN.

HEIGHT OF EACH VARIABLE SECTION OF BEAM.
INERTIA OF EACH VARIABLE SECTION OF BEAM.
AREA OF EACH SECTION OF ANALOGOUS COLUMN.
DISTANCE OF EACH SECTION OF ANCOL TO CENTER LINE.
PARTIAL (Iy) INERTIA OF EACH SECTION OF ANALOGOUS COLUMN.
TOTAL INERTIA (Iy+Ad*2) OF EACH SECTION OF ANALOGOUS COLUMN.
PARTIAL (Iy) INERTIA OF EACH SECTION OF ANALOGOUS COLUMN.
TOTAL INERTIA (Iy+Ad*2) OF EACH SECTION OF ANALOGOUS COLUMN.

W(4) .................................. ARRAY TO KEEP UNIFORM LOADS ON EACH SPAN
N(4) .................................. ARRAY TO FIND MOMENTS AND SHEARS IN

P(NJ),X(NJ) .......................... ARRAYS TO KEEP VALUES OF LOADS AND ITS DISTANCES TO LEFT SUPPORT.
FEP(7,20) .............................. ARRAY TO PROCESS FIXED END MOMENTS DUE TO CONCENTRATED LOADS.
AP,AX,XX .......................... SUM OF AREAS.SUM OF PRODUCT (A*X),DISTANCE OF RESULTANT OF AREAS(FORCES) FROM LEFT END.- SUBROUTINE 7.
INITIALIZE OF VARIABLES.

LET E = 13
DIM INF(9,4), M(E,8), AC(9,9), P(4,5), X(4,5), S(9,28)
DIM W(4), N(4)
DIM FEP(7,20)

LET F1$ = "####.## ####.## ####.## ####.##"
LET F2$ = "#
LET F3$ = "####.## #.### #### #.### #.### #-#$# #.###
LET F4$ = " ENTER P#, AND X# IN SPAN #"
LET F5$ = "#####.## #####.## #####.## #####.##
LET F6$ = "#####.## #####.## #####.## #.## #.## #.## #.## 
LET F7$ = "#####.## #####.## #.## #.## #.## #.## 
LET F8$ = "SPAN #"

PROCESSING.

DO YOU WANT TO ANALYZE ONE OF THIS BEAMS?

OBTAIN GEOMETRICAL PROPERTIES OF THE BEAM.
PRINT TAB(5) "ENTER LENGTHS L1,L2,L3,L4 IN FEET"
INPUT INF(1,1),INF(1,2),INF(1,3),INF(1,4)
PRINT "ENTER 0 IN SPANS THAT DO NOT EXIST"
INPUT INF(2,1),INF(2,2),INF(2,3),INF(2,4)
PRINT "INVALID RESPONSE ENTER YES OR NO: ";A$
IF A$ = "YES" OR A$ = "NO" THEN 680
INVALID RESPONSE ENTER YES OR NO: ";A$
GOTO 678
IF A$ = "YES" THEN LET INF(2,1) = 1
PRINT INF(3,1) > 0 THEN INF(3,4) = 1:GOTO 730
IF INF(3,1) > 0 THEN INF(3,2) = 1:GOTO 730
IF INF(3,3) > 0 THEN INF(3,2) = 1:GOTO 730
IF INF(3,4) > 0 THEN INF(3,1) = 1
GOSUB 2100
PRINT TAB(5) "ENTER (Hmin)1,(Hmin)2,(Hmin)3,(Hmin)4,(IN FEET)"
INPUT ENTER 0 IN SPANS WITH LENGTH = 0: ";INF(4,1),INF(4,2),INF(4,3),INF(4,4)
PRINT "ENTER (Hmax)1, (Hmax)2, (Hmax)3, (Hmax)4 (IN FEET)"
INPUT ENTER 0 IN SPANS WITH LENGTH = 0: ";INF(5,1),INF(5,2),INF(5,3),INF(5,4)
PRINT "ENTER AL-1,AL-2,AL-3,AL-4 (IN FEET)"
INPUT ENTER 0 IN SPANS WITH LENGTH = 0: ";INF(6,1),INF(6,2),INF(6,3),INF(6,4)
SCREEN 0
PRINT "GEOMETRICAL PROPERTIES OF THE BEAM"
PRINT "----------------------------------"
PRINT "SPAN 1 SPAN 2 SPAN 3 SPAN 4"
PRINT "LENGTH OF SPANS (FEET) Tab(32) USING F1$;INF(1,1),INF(1,2),INF(1,3),INF(1,4)
PRINT "LEFT SUPPORT: FIXED = 1 OR FREE = 0" Tab(32) USING F2$;INF(2,1),INF(2,2),INF(2,3),INF(2,4)
PRINT "RIGHT SUPPORT: FIXED = 1 OR FREE = 0" Tab(32) USING F2$;INF(3,1),INF(3,2),INF(3,3),INF(3,4)
PRINT "MINIMUM HEIGHT OF BEAM (FEET) Tab(32) USING F1$;INF(4,1),INF(4,2),INF(4,3),INF(4,4)
PRINT "MAXIMUM HEIGHT OF BEAM (FEET) Tab(32) USING F1$;INF(5,1),INF(5,2),INF(5,3),INF(5,4)
PRINT "LENGTH AL OF TAPERED SECTION" Tab(32) USING F1$;INF(6,1),INF(6,2),INF(6,3),INF(6,4)
PRINT :PRINT :
INPUT "DO YOU WANT TO CHANGE ANY NUMBER? YES OR NO: ";A$
IF A$ = "YES" OR A$ = "NO" THEN 840
INVALID RESPONSE ENTER YES OR NO: ";A$
GOTO 840
IF A$ = "YES" THEN 650
FIND PROPERTIES OF ANALOG. COLUMN -(SUBROUT. "3")
LET N = 1
GOSUB 2200
IF INF(1,2) > 0 THEN LET N = 2 : GOSUB 2200
IF INF(1,3) > 0 THEN LET N = 3 : GOSUB 2200
IF INF(1,4) > 0 THEN LET N = 4 : GOSUB 2200

FIND STIFFNES & CARRY OVER FACTORS. (SUBROUT.4)

LET N = 1
GOSUB 2500
IF INF(1,2) > 0 THEN LET N = 2 : GOSUB 2500
IF INF(1,3) > 0 THEN LET N = 3 : GOSUB 2500
IF INF(1,4) > 0 THEN LET N = 4 : GOSUB 2500

FIND DISTRIBUTION FACTORS. - (SUBROUTINE "5") -

GOSUB 2600
PRINT
PRINT "PARTIAL RESULTS"
PRINT "---------------
AREA OF ANALOG.COL TAB(32) USING F1$: INF(7,1), INF(7,2), INF(7,3), INF(7,4)
MOM.OF INERT.OF ANALOG.COL TAB(32) USING F1$: INF(8,1), INF(8,2), INF(8,3), INF(8,4)
STIFFNESS OF SPAN/L TAB(32) USING F1$: INF(9,1), INF(9,2), INF(9,3), INF(9,4)
DISTR.FAC. TAB(15) USING F3$: M(1,1), M(1,2), M(1,3), M(1,4), M(1,5), M(1,6), M(1,7), M(1,8)
CAR.OV.FACT. TAB(15) USING F3$: M(2,1), M(2,2), M(2,3), M(2,4), M(2,5), M(2,6), M(2,7), M(2,8)
PRINT : PRINT "PRESS ANY KEY TO CONTINUE"
BS = INKEY$: IF BS = "" THEN 957

OBTAIN UNIFORM LOADS. -

GOSUB 2000
PRINT TAB(5) "ENTER UNIFORM LOADS W1, W2, W3, W4 (K/f)."
PRINT TAB(5) "ENTER 0 IN SPANS WITH LENGTH = 0" : INPUT W(1), W(2), W(3), W(4)

OBTAIN CONCENTRATED LOADS. -

FOR X = 1 TO 4: FOR Y = 1 TO 5: LET P(X,Y) = 0: LET X(X,Y) = 0: NEXT Y: NEXT X
PRINT TAB(5) "ENTER NUMBER OF CONCENTRATED LOADS PER SPAN (MAX. 5 LOADS)"
INPUT "ENTER N1, N2, N3, N4: "; N(1), N(2), N(3), N(4)
FOR I = 1 TO N1: LET J = I - 1: LET I = 1: LET J = 1: NEXT J: NEXT X
PRINT TAB(5) "ENTER VALUES IN KIPS AND FEET, OF CONCENTRATED LOADS AND ITS DISTANCES TO THE LEFT SUPPORT OF THE SPAN"
FOR I = 1 TO 4: FOR J = 1 TO N(I)
PRINT "CHECK LOAD ON BEAMS. -"
NEXT J: NEXT I
PRINT TAB(32) USING F1$: W(1), W(2), W(3), W(4)
PRINT TAB(32) USING F5$: 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 "FEM (W)" TAB(8) USING F6$: M(3,1),M(3,2),M(3,3),M(3,4),M(3,5),M(3,6),M(3,7),M(3,8)
1098 PRINT "COMPUTING........"
1099 'BS = INKEY$: IF BS = "" 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
1107 IF INF(1,2) > 0 THEN LET N = 2: GOSUB 3000
1110 IF INF(1,3) > 0 THEN LET N = 3: GOSUB 3000
1115 IF INF(1,4) > 0 THEN LET N = 4: GOSUB 3000
1120 IF INF(1,5) > 0 THEN LET N = 5: GOSUB 3000
1121 PRINT "FEM (P)" TAB(8) USING F6$: M(4,1),M(4,2),M(4,3),M(4,4),M(4,5),M(4,6),M(4,7),M(4,8)
1122 PRINT "PRESS ANY KEY TO CONTINUE"
1123 'BS = INKEY$: IF BS = "" THEN 1123
1125 'FOR I = 1 TO 20 : PRINT USING F7$: FEP(1,1),FEP(2,1),FEP(3,1),FEP(4,1),FEP(5,1),FEP(6,1),FEP(7,1): NEXT I: STOP
1126 PRINT "PRESS ANY KEY TO CONTINUE"
1128 BS = INKEY$: IF BS = "" THEN 1128
1130 CLS
1132 PRINT PRINT PRINT "PROGRAM THESIS PART II.-"
1134 PRINT "----------------------------------------------------------"
1136 PRINT PRINT "10. ANALYSIS OF A DIFFERENT BEAM.-"
1138 PRINT PRINT "20. SAME BEAM WITH DIFFERENT LOAD.-"
1140 PRINT PRINT "30. FIND FINAL MOMENTS AND SHEARS.-"
1142 PRINT PRINT "40. EXIT.-"
1144 PRINT PRINT PRINT "MAKE YOUR SELECTION TO CONTINUE"; CHOICE
1146 IF CHOICE < 1 OR CHOICE > 4 THEN PRINT "BAD SELECTION, TRY AGAIN"; GOTO 114
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(21) " *** MOMENT DISTRIBUTION ***": PRINT TAB(23) "--------------
1274 PRINT TAB(11) "MOM.1" TAB(20) "MOM.2" TAB(29) "MOM.3" TAB(38) "MOM.4" TAB(47) "MOM.5" TAB(56) "MOM.6" TAB(65) "MOM.7" TAB(74) "MOM.8"
1275 PRINT STRINGS$(80,"-")
1276 PRINT "DIS.FAC." TAB(9) USING F6$: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 STRINGS$(80,"-")
1281 PRINT "DISTRIB." TAB(9) USING F6$: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 STRINGS$(80,"-")
1289 PRINT "FIN.MOM" TAB(9) USING F6$: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 ' FIND M & V IN INTERNAL SECTIONS DUE TO CONCENTRATED LOADS. -
1300 ' ---------------------------------------------------------------
1301 ' PRINT " COMPUTING.............."
1302 FOR X=1 TO 9: FOR Y=1 TO 28: LET S(X,Y)=0: NEXT Y: NEXT X
1303 LET J = 1
1304 LET I = 1
1305 LET S(1,J)=0
1306 LET S(1,1)=0
1307 LET S(1,2)=0
1308 LET S(1,3)=0
1309 LET S(1,4)=0
1310 LET S(1,5)=0
1311 LET S(1,6)=0
1312 LET S(1,7)=0
1313 LET S(1,8)=0
1314 LET S(1,9)=0
1315 GOSUB 4060
1316 LET I = I + 1
1317 IF I < N(J) OR I = N(J) THEN 1350
1318 LET J = J + 1
1319 IF J > 4 THEN 1390
1320 IF INF(1,J) = 0 THEN 1390
1321 GOTO 1315
1322 GOSUB 4150
1323 LET I = I + 1
1324 GOTO 1325
1325 ' FIND M & V IN INTERNAL SECTIONS DUE TO UNIFORM LOADS & MOM.IN SUPPORTS.
1326 ' *----------------------------------------------------------------------
1327 LET J=1: LET Z=1
1328 LET T = 6
1329 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
1330 LET S(5,J*7-T)=W(J)*INF(1,J)/2 - W(J)*S(1,J*7-T)
1331 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)
1332 LET S(7,J*7-T)=-(M(13,Z)+M(13,Z+1))/INF(1,J)
1333 LET T = T-1
1334 IF T=0 OR T=0 THEN GOTO 1405
1335 LET J = J+1
1336 IF J > 4 THEN GOTO 1450
1337 IF INF(1,J) = 0 THEN GOTO 1450
1338 LET Z = Z+2: GOTO 1400
1339 ' FOR X=1 TO 28
1340 LET S(8,X) = S(2,X) + S(4,X) + S(6,X)
1341 LET S(9,X) = S(3,X) + S(5,X) + S(7,X)
1342 NEXT X
1343 ' ' CLS
1344 PRINT TAB(20) " *** MOMENTS IN INTERNAL SECTIONS *** 
1345 PRINT TAB(20) " ----------------------------- 
1346 LET J=1: LET L=1
1347 PRINT USING F8$ ; J
1348 PRINT "DIST." TAB(9) USING F7$;S(1,J*7-6),S(1,J*7-5),S(1,J*7-4),S(1,J*7-3),S(1,J*7-2),S(1,J*7-1),S(1,J)
1349 PRINT "MOM FRA" TAB(9) USING F7$;S(8,J*7-6),S(8,J*7-5),S(8,J*7-4),S(8,J*7-3)
1350 NEXT J
1351 ' CLS
1352 PRINT TAB(20) " " *** MOMENTS IN INTERNAL SECTIONS *** "
1353 PRINT TAB(20) " ----------------------------- "
1354 LET J=1
1355 PRINT USING F8$ ; J
1356 PRINT "DIST." TAB(9) USING F7$;S(1,J*7-6),S(1,J*7-5),S(1,J*7-4),S(1,J*7-3),S(1,J*7-2),S(1,J*7-1),S(1,J)
1357 PRINT "MOM FRA" TAB(9) USING F7$;S(8,J*7-6),S(8,J*7-5),S(8,J*7-4),S(8,J*7-3)
1358 NEXT J
1359 ' IF J > 4 THEN GOTO 1515
1360 IF J > 4 THEN GOTO 1515
IF INF(1,J) = 0 THEN GOTO 1515
GOTO 1485
PRINT "."

INPUT "DO YOU WANT SHEARS IN INTERNAL SECTIONS, YES OR NO: "; Y$
IF Y$ = "YES" CR Y$ = "NO" THEN 1525
INPUT "INVALID RESPONSE, PLEASE ENTER YES OR NO: "; Y$
GOTO 1522
IF Y$ = "YES" THEN 1530
GOTO 1130
PRINT "PRESS ANY KEY TO CONTINUE"
B$ = INKEY$: IF B$ = "" THEN 1580
GOTO 1130

SUBROUTINE DIAGRAM 1
CLS
PRINT TAB(20) " *** SHEARS IN INTERNAL SECTIONS *** "
PRINT TAB(20) " ------------------------------------------- 
LET J = 1
PRINT USING F$ ; J
PRINT "DIST." TAB(9) USING F$ $;S(1,J*7-6),S(1,J*7-5),S(1,J*7-4),S(1,J*7-3),S(1,J*7-2),S(1,J*7-1),S(1,J*7)
PRINT "SHEARS." TAB(9) USING B$ $;S(9,J*7-6),S(9,J*7-5),S(9,J*7-4),S(9,J*7-3),S(9,J*7-2),S(9,J*7-1),S(9,J*7)
LET J = J+1
IF J > 4 THEN GOTO 1575
IF INF(1,J) = 0 THEN GOTO 1575
GOTO 1545
PRINT : PRINT "PRESS ANY KEY TO CONTINUE"
B$ = INKEY$: IF B$ = "" THEN 1580
GOTO 1130

SUBROUTINE DIAGRAM 2
CLS
PRINT TAB(10) "w1";TAB(28) "w2";TAB(48) "w3";TAB(67) "w4"
PRINT " ------------------------------------------- 
PRINT TAB(33) "H min."
'LET N = 1

SUBROUTINE "3" PROPERTIES OF ANALOGOUS COLUMN

THIS SUBROUTINE FINDS AREA AND MOMENT OF INERTIA OF THE ANALOGOUS COLUMN WITH RESPECT TO AXIS Y-Y.

IT USES ARRAY AC(6,9) TO PERFORM CALCULATIONS AND TO KEEP PARTIAL RESULTS

LET AL = INF(6,N)
LET S = AL/8
LET M = (INF(5,N) - INF(4,N))/8
FOR I = 1 TO 8
LET H = INF(5,N) - M*(I-.5)
LET AC(1,I) = H
NEXT I
LET AC(1,9) = INF(4,N)
LET AC(2,9) = 1
FOR I = 1 TO 8
LET AC(2,I) = (AC(1,I)/AC(1,9))-3
NEXT I
LET AC(3,9) = INF(1,N) - 2*AL
FOR I = 1 TO 8
LET AC(3,I) = S/AC(2,I)
NEXT I
LET AO=0
FOR I = 1 TO 8
LET AO = AO + AC(3,I)
NEXT I
LET AG = 2*AO +AC(3,9)
FOR I =1 TO 8
LET AC(4,I) = INF(1,N)/2 - S*(I-.5)
NEXT I
LET AC(5,9) = 1*(INF(1,N)-2*AL)^3/12
FOR I=1 TO 8
LET AC(5,I) = S^3/(12*AC(2,I))
NEXT I
LET AC(6,9) = AC(3,I)*AC(4,I)^2 + AC(5,I)

SUBROUTINE "4" STIFFENESS & CARRY OVER FACTORS.

LET INF(9,N)=(1/INF(7,N)+INF(1,N)-2/(4*INF(8,N)))
LET MB=(1/INF(7,N)-INF(1,N)-2/(4*INF(8,N)))*INF(1,N)
LET M(2,2*N) = -MB/INF(9,N)/INF(1,N)
LET M(2,2*N-1) = M(2,2*N)
RETURN

SUBROUTINE "5" DISTRIBUTION FACTORS
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(1,4) = 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
SUBROUTINE 7: "F.E.M. DUE TO CONCENTRATED LOADS"

FOR X=1 TO 7:FOR Y=1 TO 20: LET FEP(X,Y)=0:NEXT Y: NEXT X

LET Z=0

IF N(N) < 2 OR N(N) = Z THEN RETURN

LET AL = INF(6,N)

LET S = AL/8

LET M = (INF(5,N) - INF(4,N))/8

FOR I = 1 TO 8

LET AC(1,I) = (INF(5,N) - M*(I-.5))

LET AC(1,9) = INF(4,N)

LET AC(2,9) = 1

FOR I = 1 TO 8

LET FEP(1,I) = I*S - S/2

LET FEP(1,12+I) = INF(1,N)-INF(6,N)+I*S-S/2

NEXT I

IF X(N,Z+1) > AL AND X(N,Z+1) < INF(1,N)-AL THEN GOTO 3230

LET FEP(1,9) = 0:LET FEP(1,10) = 0

LET FEP(1,11) = INF(1,N)/2

LET FEP(1,12) = (INF(1,N)+AL)/3

GOTO 3248

LET FEP(3,9) = 1: LET FEP(3,10) = 1: LET FEP(3,11) = 1: LET FEP(3,12) = 1

WE HAVE INERTIA OF SECT. OF BEAMS IN FEP(3,I)

FOR I = 1 TO 8

LET FEP(2,I) = FEP(2,10)*S*I/X

LET FEP(2,12+I) = FEP(2,10)*(AL-(I-1)*S)/(INF(1,N)-X(N,Z+1))

NEXT I

WE HAVE DISTANCES FROM LEFT SUPPORT IN FEP(1,I)

FOR I = 1 TO FIX(X/S):LET FEP(2,I)-FEP(2,10)*S*I/X

NEXT I

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

LET FEP(2,12)= FEP(2,10)*S*I/(INF(1,N)-X)

WE HAVE STATIC MOMENTS IN SECTIONS IN FEP(2,I).

WE HAVE M/I AND M/(I) INTO FEP(4,I) AND FEP(5,I)

FOR I = 1 TO 8

LET FEP(4,I+1) = FEP(2,10)*S*I/(INF(1,N)-X)

NEXT I

WE HAVE STATIC MOMENTS IN SECTIONS IN FEP(2,I).
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
3355 LET FEP(6,9)=(X(N,Z+1)-AL)*FEP(4,9)
3357 LET FEP(6,10)=(X(N,Z+1)-AL)*(FEP(2,10)-FEP(4,9))/2
3359 LET FEP(6,11)=(INF(1,N)-X(N,Z+1)-AL)*FEP(4,12)
3361 LET FEP(6,12)=(INF(1,N)-X(N,Z+1)-AL)*(FEP(2,10)-FEP(4,12))/2
3363 ' WE HAVE PARTIAL AREAS IN FEP(6,1)
3378 ' FOR I=1 TO 20
3380 LET FEP(7,I)=FEP(1,I)*FEP(6,I)
3383 NEXT I
3385 ' WE HAVE PRODUCTS (A*X) IN FEP7,I)
3390 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)-MPR
4040 LET M(4,2*N)=M(4,2*N)+MPL
4042 ' 4150 SUBROUTINE 9:- FIND M & V IN INTERNAL SECTIONS DUE TO CONCENTRATED LOADS
4050 ' ____________________________________________________________
4052 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) = P(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