OPTIMUM PLASTIC DESIGN OF TAPERED GABLE FRAMES

A Thesis

Presented to

the Faculty of the Department of Civil Engineering

The University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Civil Engineering

by

Anwar M. Bydoun

December, 1975

ACKNOWLEDGMENTS

The author wishes to express his deepest gratitude to Dr. G. Pincus for his indispensable guidance, encouragement and valuable suggestions during the preparation of this thesis.

DEDICATION

To my family and brother, Dr. Talal, whose patience, understanding and financial support contributed immensely to this endeavor.

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ABSTRACT

This study deals with the problem of plastic analysis and design of symmetrical tapered or uniform gable frames of the portal type subject to usual loads.

In the course of this study, a fully automatic plastic design procedure, based on an original conversational computer program written by H. B. Harrison, was developed and implemented on the UNIVAC 1108 computer. Input data was made free-format in order to eliminate the inconvenience present in using a fixed-format input. Another new feature of the program is the capability of dealing with tapered-column gable frames.

The procedure for analysis and design in the modified program accounts for the strength reduction in the plastic moment capacity caused by the presence of axial thrust in the frame members. The program also checks for the limiting width-to-thickness ratios of web and flange as given by the 1971 AISC specifications which serve to prevent local buckling failures.

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NOMENCLATURE

b_f Flange width

d_1 Depth of member at the first end.

d_1 Depth of member at the second end.

d_n Depth of member at distance x from the first end.

F_y Specified minimum yield stress of type of steel being used (ksi).

A_s Used in AISC Specification

F A form factor for internal pressure.

h The column height in a rigid industrial frame.

L Length of a member; span of a portal frame.

M Bending moment at apex of a portal frame.

M_p The full plastic moment of a resistance of a section.

M_{pc} Reduced plastic moment capacity of a section.

P An axial force, axial thrust, or a concentrated apex load.

P_y Plastic axial load; equal to profile area times specified minimum yield stress.

R The horizontal thrust at the apex of a frame.

r Vertical rise from eaves to apex of an industrial rigid frame.

S The vertical shear force at the apex of a frame.

t Flange thickness.

w Web thickness.

y_o Distance from neutral axis, when the section is under pure elastic moment, to the upper part of the assumed stress distribution, due to axial thrust.

y_1 Distance from neutral axis, when the section is under pure plastic moment, to the neutral axis of the condition under consideration.

Z Plastic section modulus.

β_n The relative value of the distance from the neutral axis to the upper surface of a section and the section depth.

τ_y Shear yield stress = y/ 3.

σ_y Is the Yield stress = F_y in any specified units.

γ The angle between the two flanges.

θ Angle of inclination of rafter.

cm Centimeter = 0.3937 inches.

in Inches - 1/12 foot.

kip 1000 pounds.

kg Kilograms = 2.20462 pounds.

lb Pounds

ksi Stress in kips per square inch.

tons metric = 2204.62 pounds.

ϕ Angle of slope at diagonal stiffener.

γ_1 Angle of taper at rafter.

γ_2 Angle of taper of column.

CHAPTER I

INTRODUCTION

1.1 Background

Plastic design, ultimate strength design, and limit design are terms which imply consideration of inelastic action. These techniques are now being employed in the design of continuous beams and building frames of one or two stories which sustain static loads. Furthermore, the principles of plastic theory justify many of the provisions in specifications formulated for elastic structures.

An engineering structure is satisfactorily designed if it can be built with the needed economy and if, throughout its useful life, it carries its intended loads and otherwise performs its intended function.

In the plastic analysis of an indeterminate structure three conditions must be considered:[3]

1. Mechanism condition;
2. Equilibrium condition;
3. Plastic-moment condition.

When all three of these conditions are satisfied, then the resulting analysis for ultimate load is correct because the two limit theorems basic to the plastic method are satisfied. These theorems can be stated as: theorem I (lower bound) which is a statement of the ability of the material to adjust itself to carry the applied load if at all possible and gives the lower bound on, or safe value of, the ultimate loading. The maximum lower bound is the limit, or the ultimate load itself. Theorem II (upper bound), is a formal statement of the fact that if a path to failure exists, the structure will not stand up. Thus a load computed on the basis of an assumed mechanism will always be greater than, or at least equal to, the true ultimate load. The theorem so deals with the upper bound on, or unsafe value of, the plastic limit load. The minimum upper bound is the ultimate load itself.[2]

1.2 Stating the Problem

The problem consists of the plastic analysis and optimum plastic design of tapered gable frames under practical loading conditions using the modified computer program and the technique which has been previously used by H. B. Harrison.[6] The problem can be described as the design of a frame, with a given geometry and certain ultimate loads, such that its cost can be minimized.

CHAPTER II

THE PLASTIC ANALYSIS OF THE STRUCTURE

2.1 Assumptions

The basic concepts and assumptions for the plastic analysis with regard to the plastic behavior of a structure are as follows:[3]

1. The material is ductile. It has the capacity of absorbing plastic deformation without the danger of fracture (Fig. 2.1).

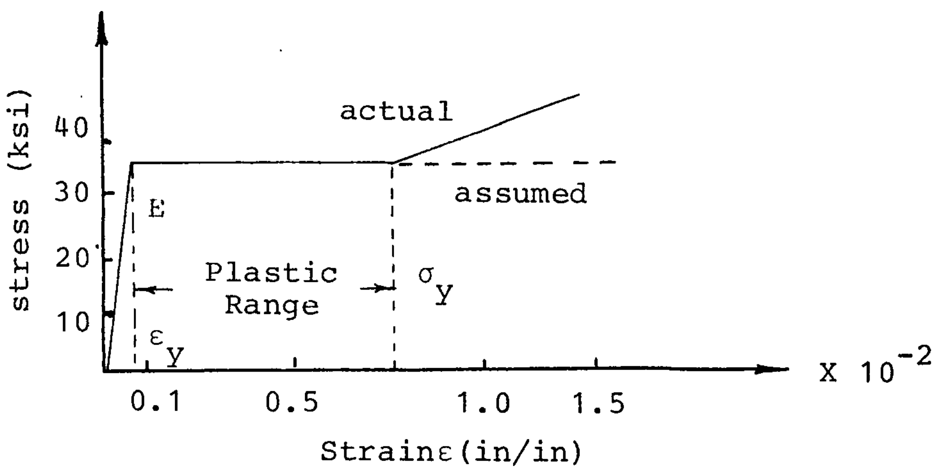


Fig. 2.1. Stress-strain curve of A7 structural steel, idealized.

2. Each section of a member has a maximum capacity, which causes plastification throughout the section.

3. Because of the steel ductility a plastic hinge

will be formed.

4. The deformations are so small that the equilibrium equations can be formulated for the undeformed structure.

5. The structure will reach its ultimate load when the mechanism of failure is created.

6. No instability will occur before the structure reaches its ultimate load.

7. Loads increase in proportion.

8. Sufficient number of plastic hinges have to be formed before the mechanism of failure is created.

2.2 Statical Method of Analysis

The objective of this method is to find an equilibrium moment diagram in which M/<MP such that a mechanism is formed. The procedure is as follows:[2]

1. Select redundants.

2. Find moment diagram for the determinate structure.

3. Find the moment diagram for the structure loaded by redundants.

4. Adding the two moment diagrams in such a way that a mechanism is formed.

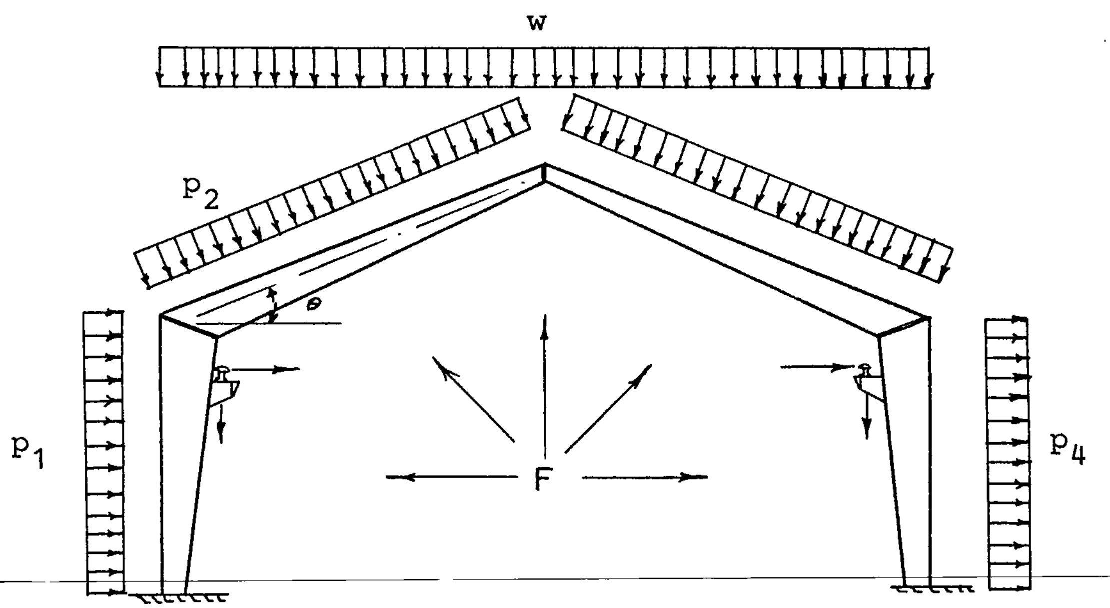
5. Check M/<MP.

After the mode of failure has been assumed, four linear simultaneous equations can be formulated to represent this mode of failure which can be solved to find M_p, (see

Appendix A). Then the moment at every section can be checked to see if it exceeds the reduced moment capacity of this section. If it does, the mode of failure has to be modified.[6]

2.3 Analysis Procedure

The most efficient method for performing plastic analysis in the case of tapered rigid gable frames is the twin-cantilever, statical method of analysis.[6] With reference to Fig. 2.3 the gable is cut at the apex, and the bending moment, shear force and axial thrust at any point in the frame are then evaluated statically in terms of the loads and the reactants M , S , and R. In a graphical representation, as in Fig. 2.4 and 2.5, it is convenient to separate the diagrams, the bending moment, the shear force and the normal force diagrams, into a determinate (Fig. 2.4 a, b, c) and indeterminate ones (Fig. 2.5 d, e, f). Then a plastic moment capacity distribution throughout the frame has to be assumed, or in other words, the section depth, the width and thickness and the web thickness has to be assumed. Next, a mechanism of failure is assumed, e.g. four locations are chosen at which the moment, of appropriate sign, are equal to the full plastic moment capacity at these sections. On the other hand, if the bases are pinned only two locations have to be nominated, and the four simultaneous equations expressing this mechanism can be formulated and solved for the three



$p_1 = 0.8p$

$p_2 = (1.2 \sin \theta - 0.4)\ p$

$p_3 = 0.4p$

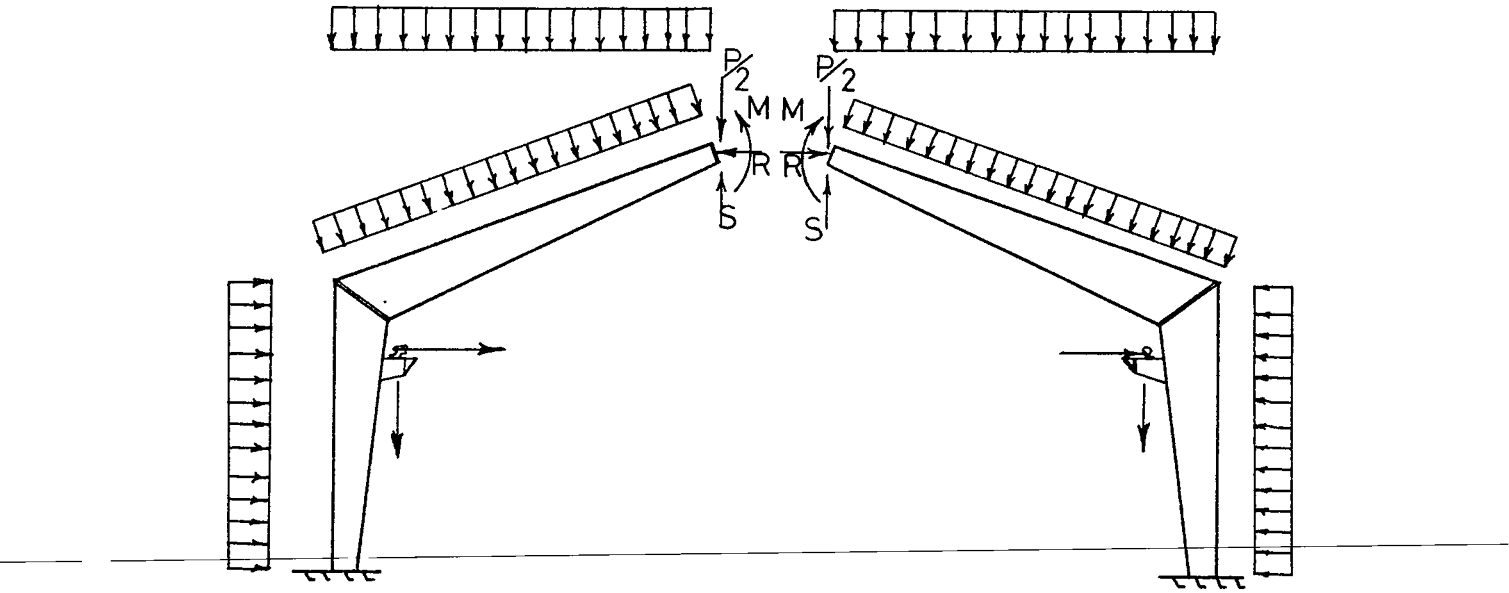
$p_4 = 0.4p$

where $p = (\text{Wind Vel.})^2/400$

$F = (-0.2 \text{ or } 0.4)p$ for openings $\ngtr$ 10%

$F = (-0.4 \text{ or } 0.8)p$ for openings $\nless$ 30%

Fig. 2.2. Typical pressure distributions--wind and vertical loading.



Apex - point load: P

Reactants: M, R, S

Fig. 2.3. Rigid frame twin cantilevers representations.

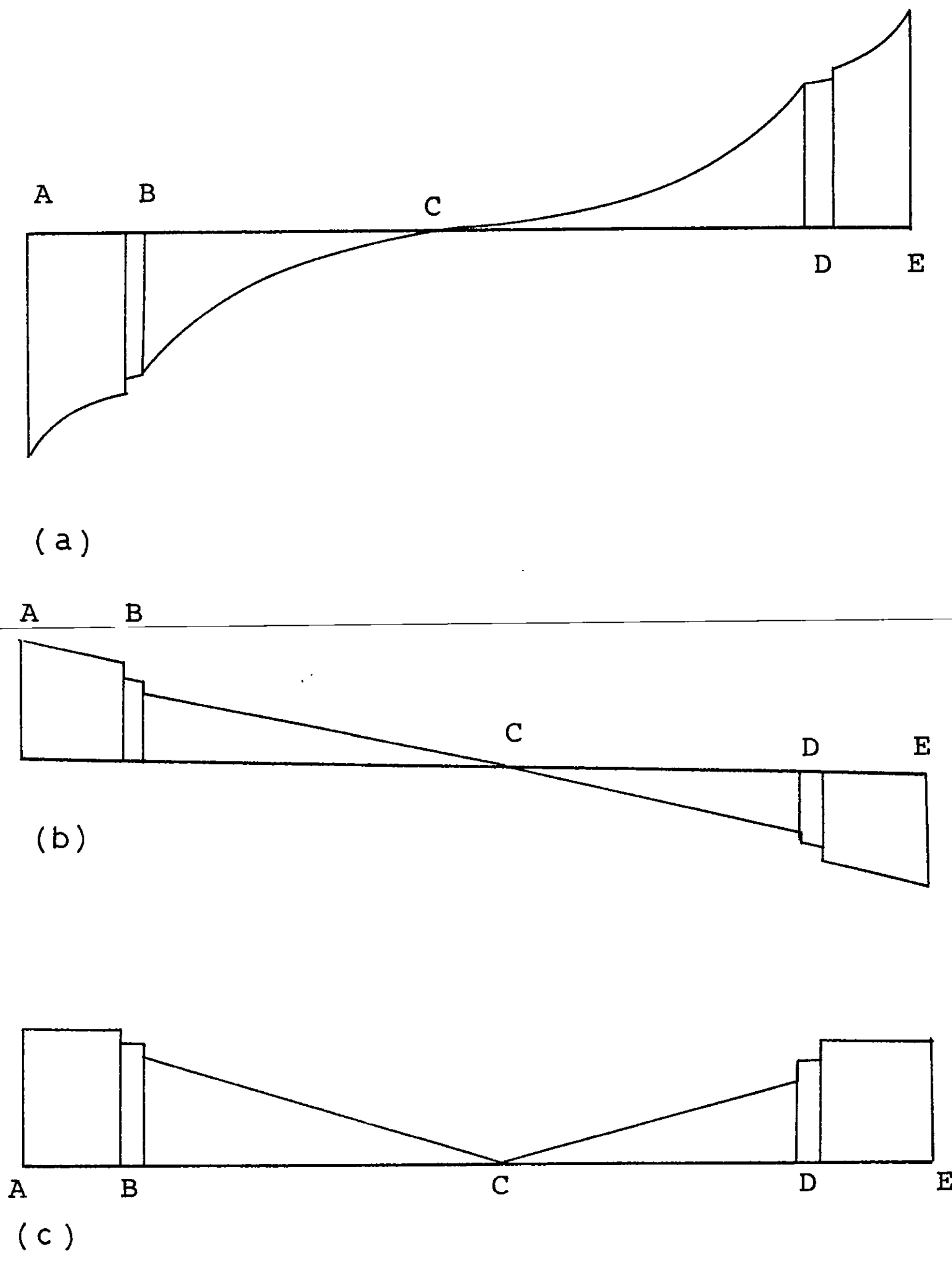


Fig. 2.4. Representation of determinate (a) bending moment diagram; (b) shear force diagram; (c) normal force diagram.

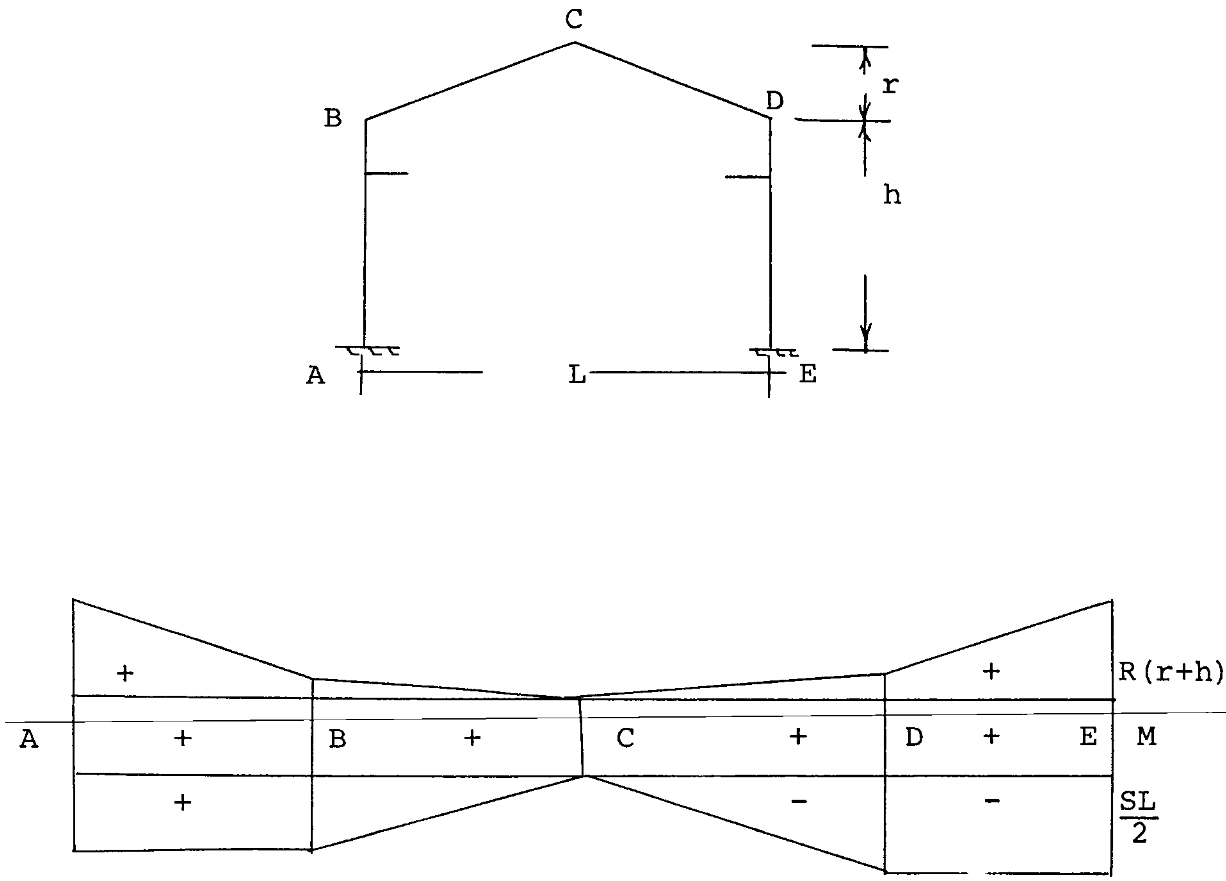


Fig. 2.5. Graphical representation of bending moment caused by reactants: M. R. S.

redundants M, S, and R. For the case of both bases pinned two of this four equations express the condition of zero moment at these locations. (In the case of one base is pinned and the other is fixed only three locations need to be nominated, and the fourth equation express the zero moment at this base, but this case is not available in the computer program represented in Appendix C. Although, this case can be programmed and a command for it can be added between lines 212 and 213.) Then the bending moment diagram, which corresponds to the assumed mechanism, can be found; using this diagram the normal and the shear force at any section can be determined, and the reduced plastic moment capacity can be evaluated. Then the evaluated plastic moment capacity can be used for the next iteration.

CHAPTER III

COMPRESSION MEMBERS

3.1 Reduction of the Plastic Moment Capacity of Tapered Members Due To Axial Thrust

The presence of axial force tends to reduce the magnitude of the section plastic moment capacity in addition to causing column instability. Therefore, the moment capacity must be modified to account for this influence. Three different conditions can be discussed according to the location of the neutral axis.

The Plastic Modulus Of A Tapered Member

To find the member plastic modulus, the neutral axis of the section has to be located. Referring to Fig. 1 the factor $\beta_n \leq 0.5$, where β_n is the relative value of the neutral axis depth and the section depth, can be determined by taking the summation of the horizontal forces equal to zero.

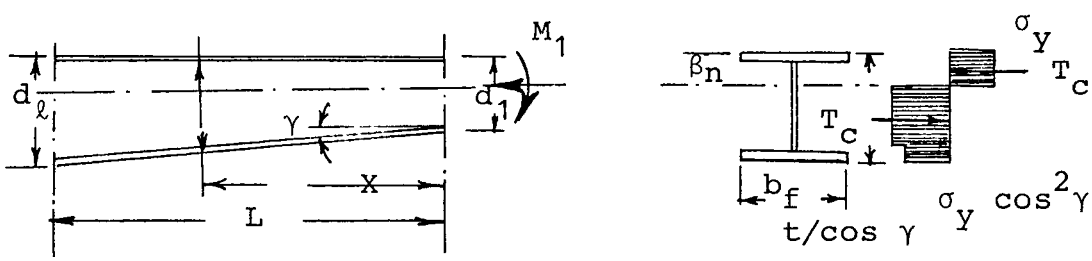


Fig. 3.1. Stress due to pure plastic moment.

$$\sum \vec{H} = 0$$

so $$T_c = - T_t$$

$$\beta_n = 0.5 - t\ (1 - \cos\gamma)(b_f + w/\cos\gamma)/2\ d_n\ w \qquad (3.1)$$

where

$$d_n = \frac{d_\ell - d_1}{L}\ X + d_1 \qquad (3.2)$$

$$\gamma = \tan^{-1} \frac{d_\ell - d_1}{L} \qquad (3.3)$$

so, the plastic modulus of the section will be:

$$Z = \frac{w}{2}\ (\beta_n d_n - t)^2 + \frac{w}{2}\ [(1-\beta_n)\ d_n - \frac{t}{\cos\gamma}]^2 +$$

$$b_f t\ [\beta_n d_n + \cos\gamma\ d_n(1 - \beta_n) - t] \qquad (3.4)$$

for the first condition, as shown in Fig. 2, the total stress-distribution,[3] sketch (a), may be divided into two parts: a part that is associated with the axial force, sketch (b), and a part that is associated with the bending moment, sketch (c).

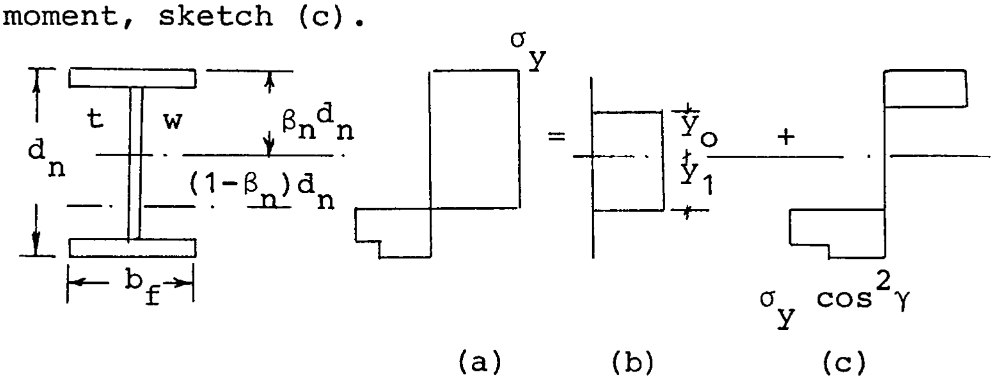


Fig. 3.2. The first condition, neutral axis in web. Representation of (b) stress due to axial force and (c) stress due to bending moment for a completely plastic cross section subjected to moment and axial force.

In this case the neutral axis is in the web ($y_o \geq \beta_n d_n - t$). Because the section is in equilibrium, the axial force P is given by:

$$P = 2\sigma_y y_o w \tag{3.5}$$

where σ_y is the yield stress, y_o is the distance from the neutral axis of this condition to the neutral axis when the section undergoes pure plastic moment, and w is the web thickness. The corresponding bending moment is given by the following expression and represents plastic moment modified to include the effect of axial compression force.

$$M_{pc} = \sigma_y \left(Z - w\, y_o^2 \right) \tag{3.6}$$

where Z is the plastic modulus of the section. Then, by substituting the value of y_o obtained from Eq. (3.5) into Eq. (3.6), the bending moment may be expressed as a function of the axial force P,

$$M_{pc} = M_p - P^2/4\sigma_y w, \qquad P \leq 2\, w\sigma_y\, (\beta_n d_n - t).$$

This relationship can be written in nondimensional form by dividing both sides by $M_p = \sigma_y Z$. Thus:

$$M_{pc}/M_p = 1 - K_2^2\, (P/Py)^2/4\, Z\, w \tag{3.7}$$

where $0 \leq P/P_y \leq 2\, w\, (\beta_n d_n - t)/K_2$

$$K_2 = t\, (1 + \cos\gamma)(b_f - w/\cos\gamma) + w\, d_n$$

$$P_y = \sigma_y\, K_2 \tag{3.8}$$

The second condition, when the neutral axis is in the web but $y_o > \beta_n d_n - t$ and $y_1 < (1 - \beta_n)\ d_n - t/\cos\gamma$, could be discussed using the same technique. An expression for M_{pc} as a function of P can be determined. Thus, the two forces P_1 and P_2, which are in equilibrium with P, can be determined (Fig. 3).

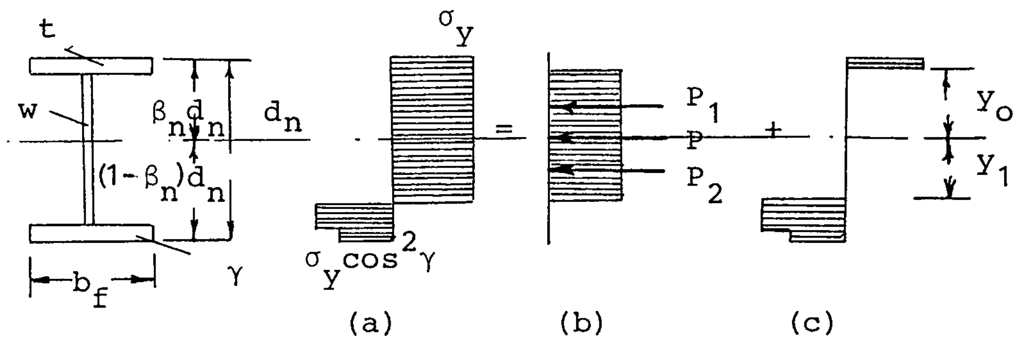


Fig. 3.3. The second condition, neutral axis in web and $y_o \geq K_1$.

Representation of (b) stress due to axial force and (c) stress due to bending moment for a completely plastic cross section subjected to bending moment and axial force.

$$\vec{P} = \vec{P}_1 + \vec{P}_2$$

where P is applied in the neutral axis of the case in which the section undergoes pure plastic bending moment. The relationship of y_o and y_1 with P can be found by setting the moment of P_1 and P_2 at C, where C is the neutral axis of the case of pure moment, equal to zero.

$$M_{p1} = M_{p2}$$

hence
$$y_1 = \sqrt{\frac{b_f}{w} y_o^2 + (\beta_n d_n - t)^2 \ (1 - \frac{b_f}{w})} \tag{3.9}$$

or

$$y_1 = \sqrt{K_o y_o^2 + K_1^2 \ (1 - K_o)} \tag{3.10}$$

where

$$K_o = b_f/w \tag{3.11}$$

$$K_1 = (\beta_n d_n - t) \tag{3.12}$$

So P , the resultant of P_1 and P_2, is equal to:

$$P = \frac{\sigma y}{w} [y_1 + K_1 + K_o \ (y_o - K_1)] \tag{3.13}$$

From Eq. 3.10, Eq. 3.13 and 3.8 y_o and y_1 can be determined, and an expression for M_{pc}, the reduced plastic moment capacity, as a function of P/P_y can be determined. The resulting equations are:

$$M_{pc}/M_p = 1 - [w \ K_o y_o^2 + K_1^2 \ (1 - K_o)]/Z \tag{3.14}$$

where

$$y_o = \frac{K_3 + K_1 (K_o - 1) \pm \sqrt{[K_3^2 + 2 \ K_3 K_1 (K_0 - 1)]/K_o}}{(K_o - 1)} \tag{3.15}$$

$$K_3 = (K_2/w) \ P/P_y \tag{3.16}$$

K_1, K_2, K_o and Z are defined above.

By the same procedure, an expression for M_{pc} as a function of P/P_y can be determined when the neutral axis is in the flange instead of the web (Fig. 4).

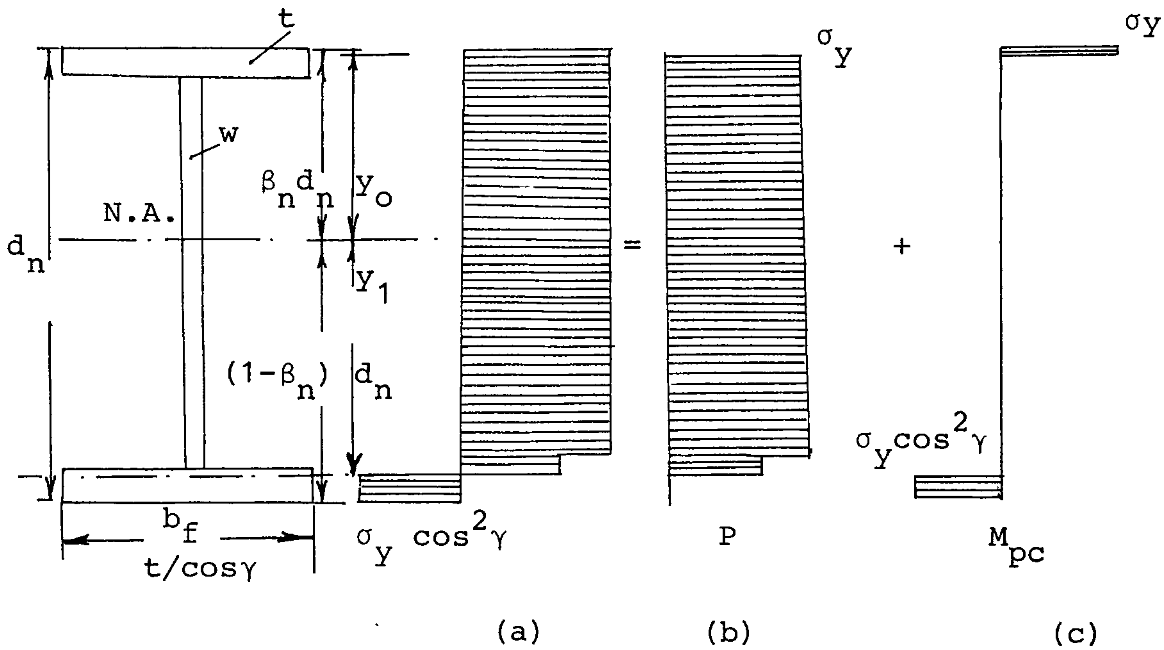


Fig. 3.4. The third condition, neutral axis is in flange. Representation of (b) stress due to axial force and (c) stress due to bending moment for a completely plastic cross section subjected to moment and axial force.

The relationship of y_1 and y_o with P/P_y is given by the equations 3.17 and 3.18.

$$y_1 = \frac{1}{\cos\gamma} \sqrt{K_5 + y_o^2} \tag{3.17}$$

$$y_o = \frac{K_7 \pm \cos\gamma \sqrt{K_7^2 + K_o^2 \, K_5 (1-\cos^2\gamma)}}{K_o \, (1-\cos^2\gamma)} \tag{3.18}$$

where

$$\gamma \neq 0$$

$$K_4 = (1-\beta_n)\ d_n - t/\cos\gamma$$

$$K_5 = K_1^2\ (\frac{1}{K_o} - 1) + K_4^2(\cos^2\gamma - \frac{1}{K_o})$$

$$K_6 = K_1\ (K_o-1) + K_4\ (K_o \cos^2\gamma - 1)$$

$$K_7 = K_3 + K_6$$

Thus, the non-dimensional expression for the reduced plastic moment of the section, when $(1 - \beta_n)\ d_n \geq y_1 \geq K_4$ and $\beta_n d_n \geq y_o \geq K_1$, M_{pc}/M_p is equal to:

$$M_{pc}/M_p = 1 - \frac{(K_1^2 + K_o y_o^2 - K_1^2\ K_o)w}{Z} \tag{3.19}$$

where K_o, K_1, and y_o are given above.

<u>3.2. Discussion of The Interaction Formulas</u>:

After the relationships of Z, and M with the angle γ, the angle between the two flanges has been determined (see Eqs. 3.4, 3.7, 3.14). Representations of this relationship are shown in Figs. 3.5 through 3.10. In this representation numerical data, for the section depth flange width and thickness and the web thickness, has been assumed, and by using the computer, subroutine three, the solution for this equation has been achieved.

In figures 3.5 through 3.7 the relationship of Z_γ/Z_o, where Z_γ is the plastic section modulus when the angle between the two flanges is γ and Z_o is the plastic

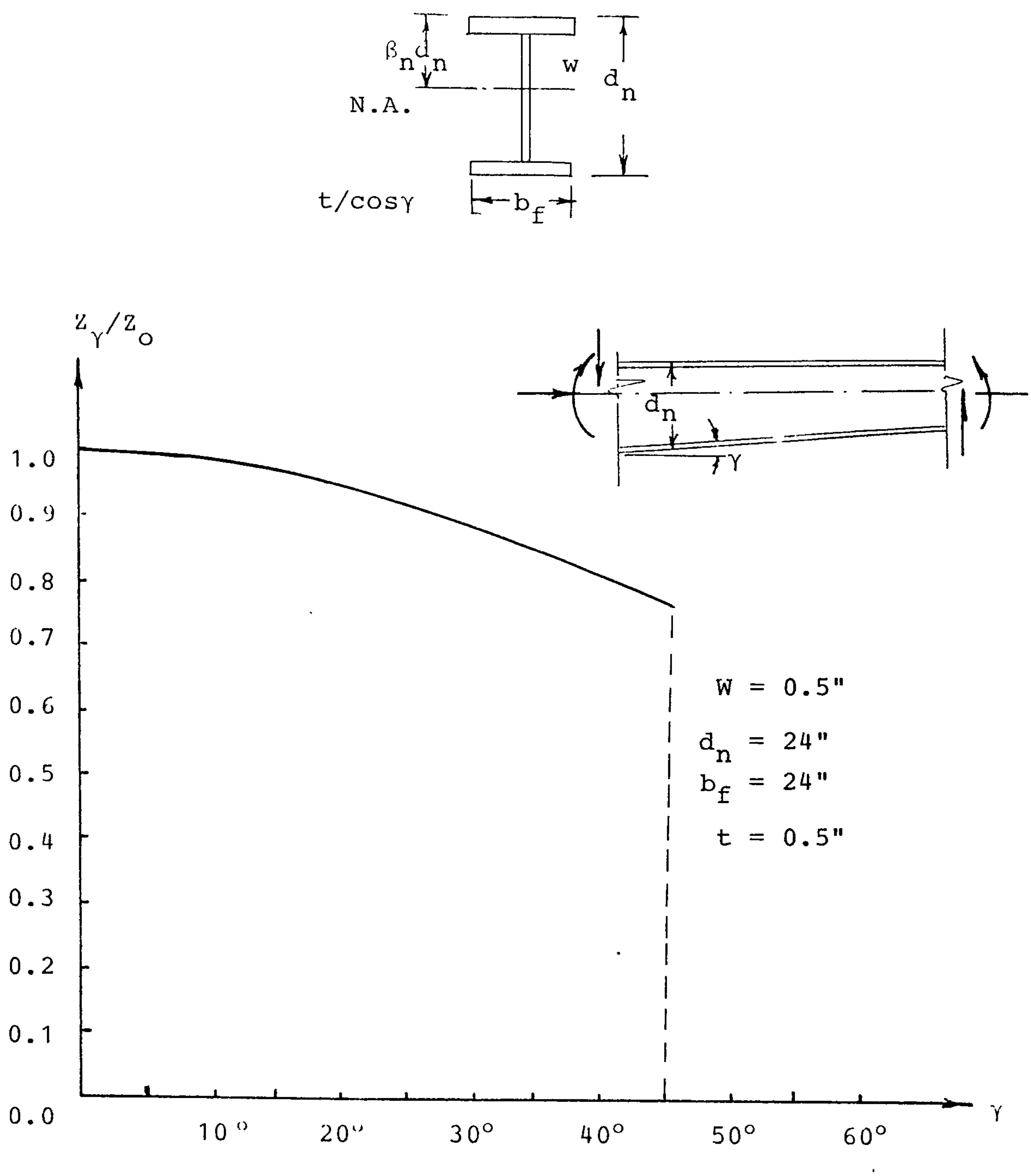


Fig. 3.5. Reduction of Z_γ, modulus of plasticity with the increase of γ, angle of taper, in column-beams.

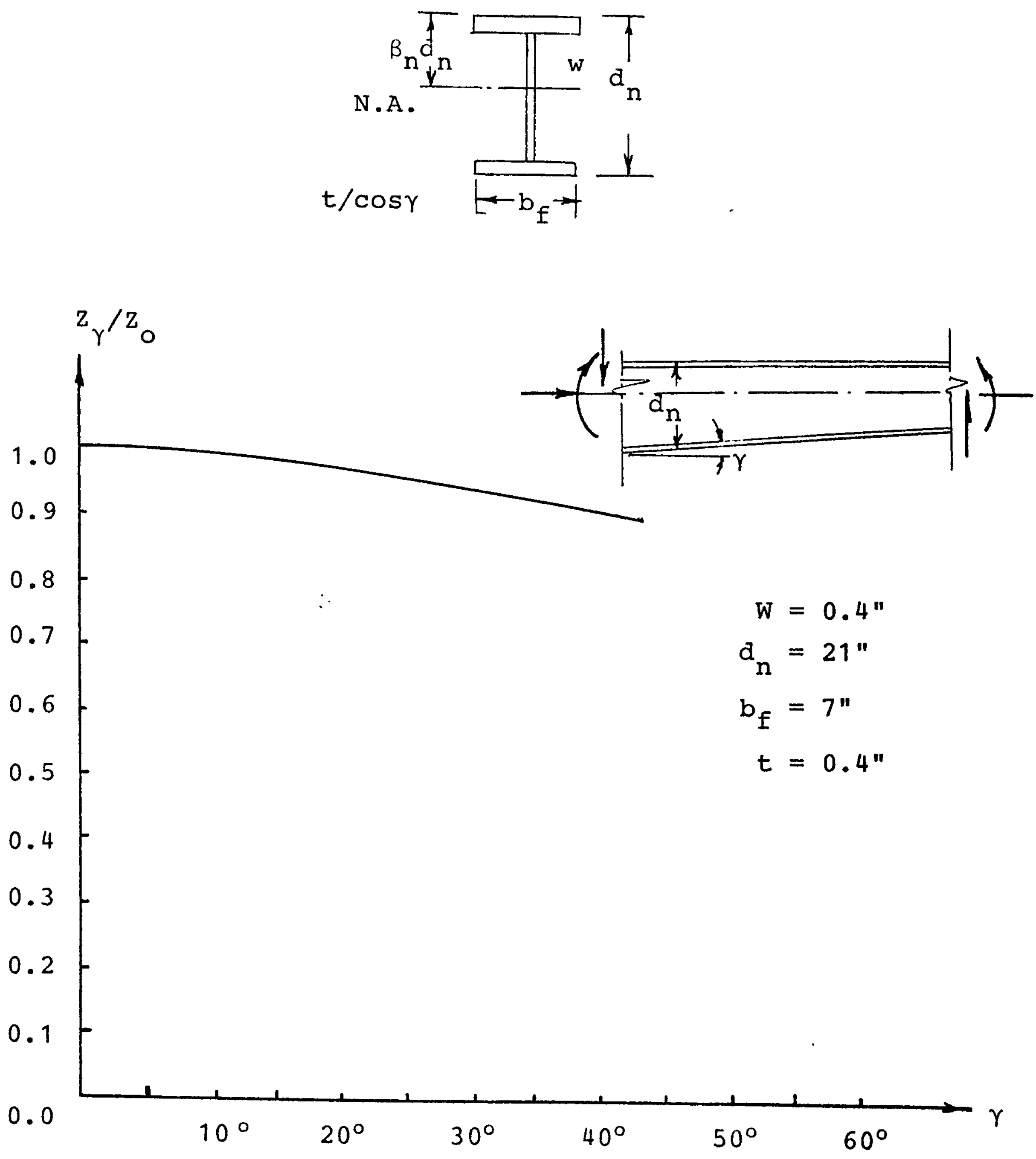


Fig. 3.6. Reduction of Z_γ, modulus of plasticity with the increase of γ, angle of taper, in column-beams.

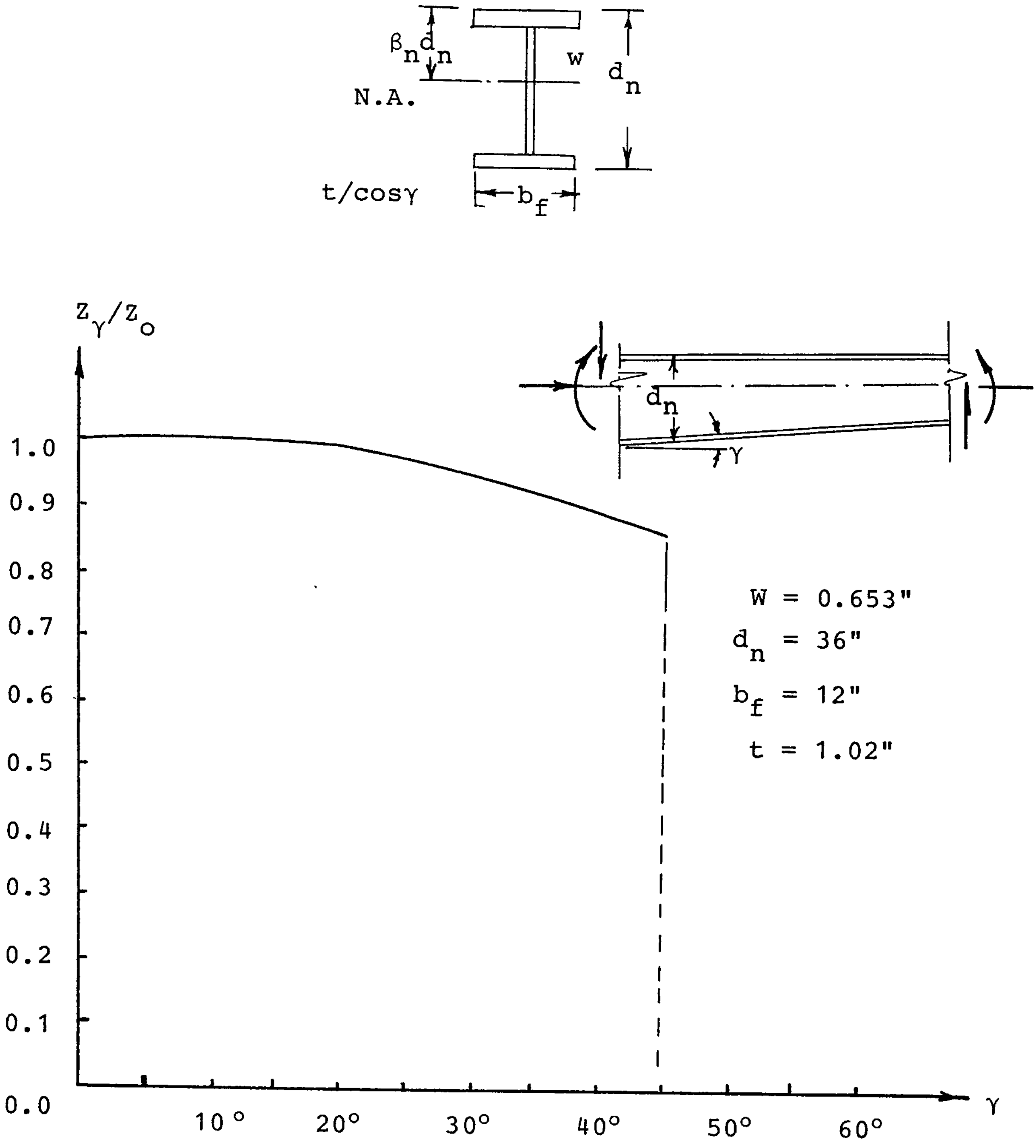


Fig. 3.7. Reduction of Z_γ, modulus of plasticity with the increase of γ, angle of taper, in column-beams.

section modulus when γ is zero, with γ has been represented. These figures demonstrate how Z_γ decreases with the increase of γ, and it can be found that the decrease would not exceed 6 percent if γ is less than 20°, but the reduction in the modulus of plasticity will be 30 percent if the γ is equal to 45°. In this case an increase in the flange area, to retain the same modulus of plasticity, can be suggested.[2] It had been found that this needed increase in the flange area would not exceed 6 percent if γ is less than 20°. For practical purposes, both flanges should be made equal. Using the same procedure a representation of the relationship of M_{pc}/M_p with P/P_y can be seen in Figs. 3.8 through 3.10.

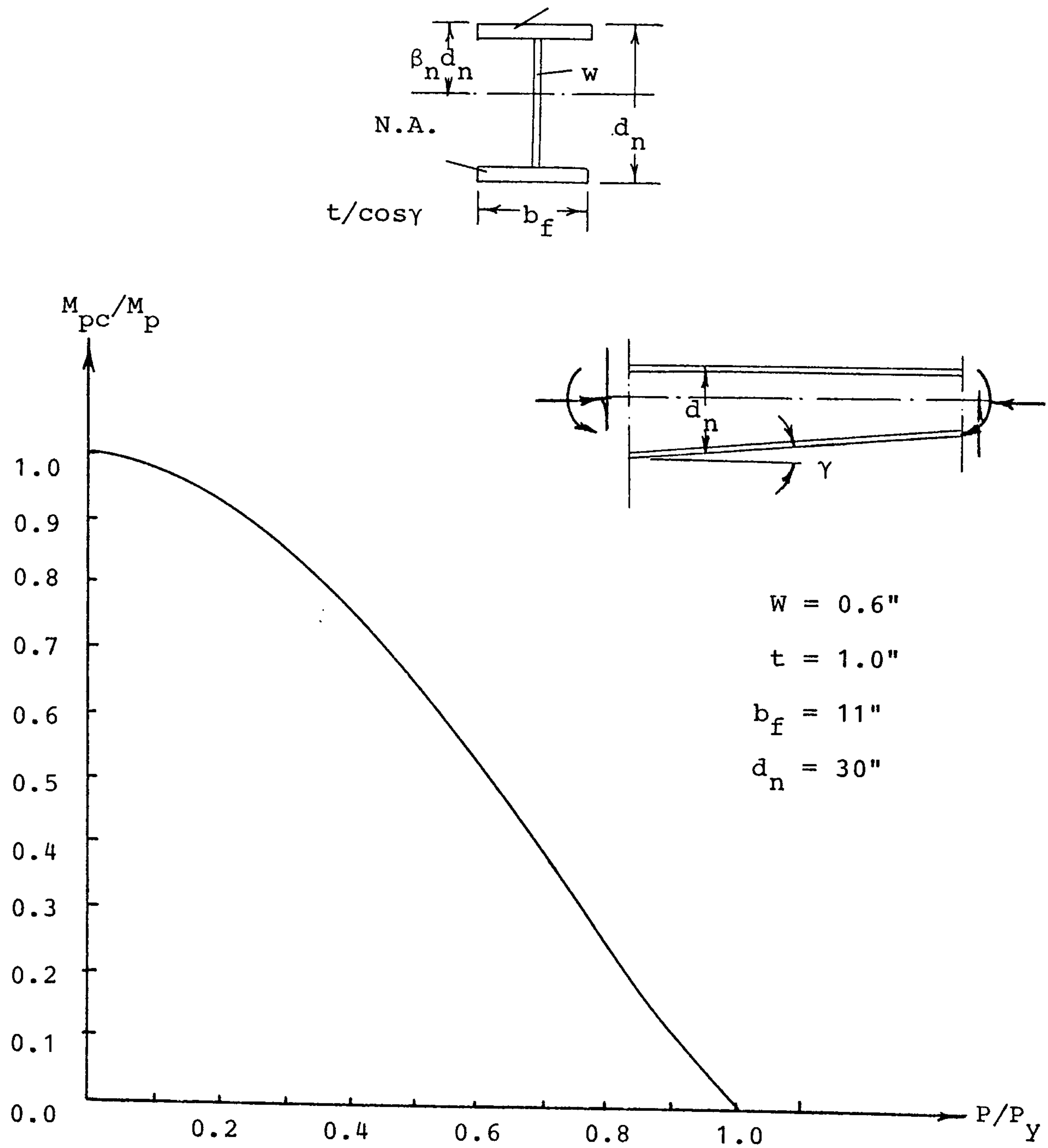


Fig. 3.9. Reduction of fully plastic moment by normal forces.

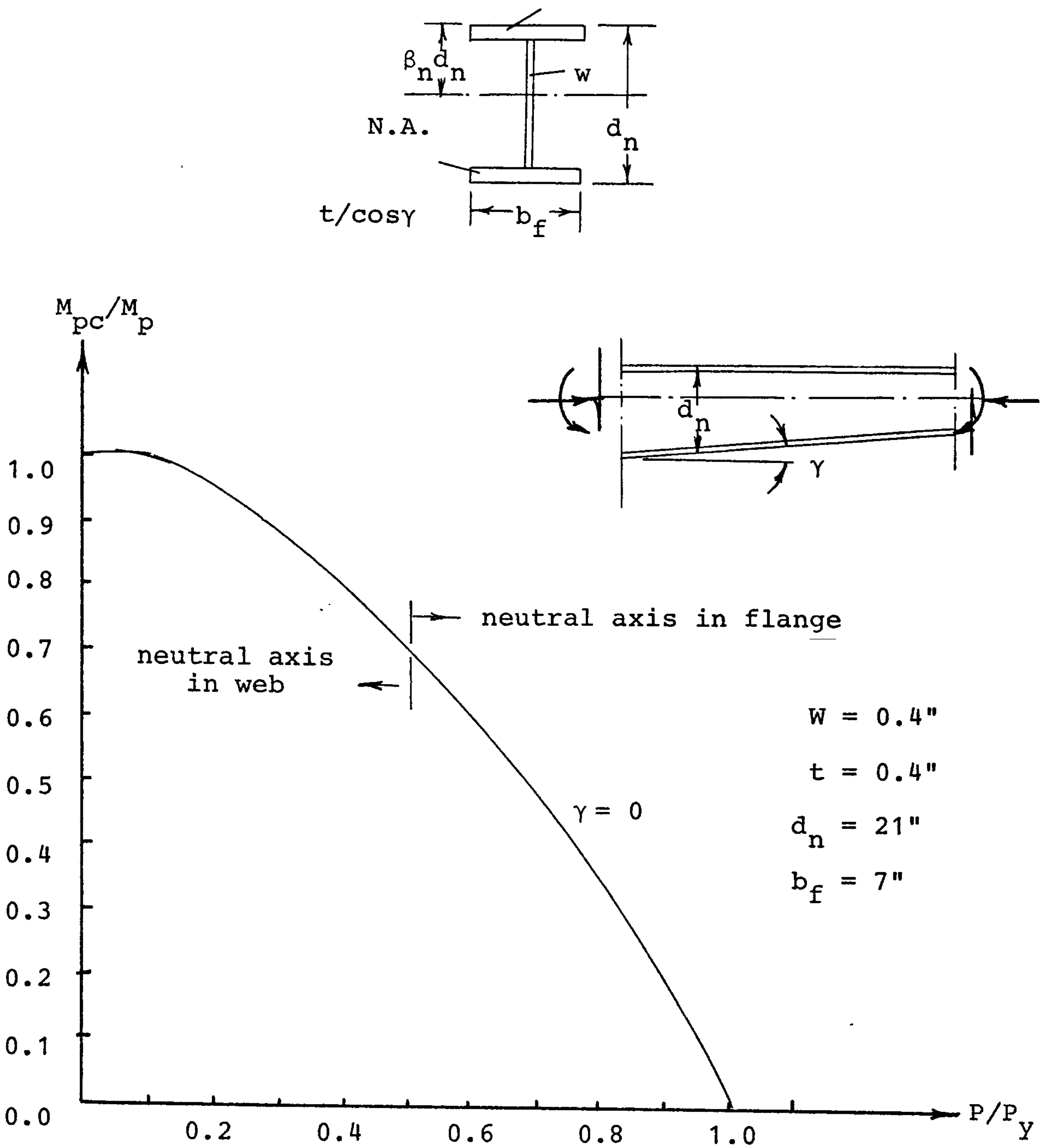


Fig. 3.8. Reduction of fully plastic moment by normal force.

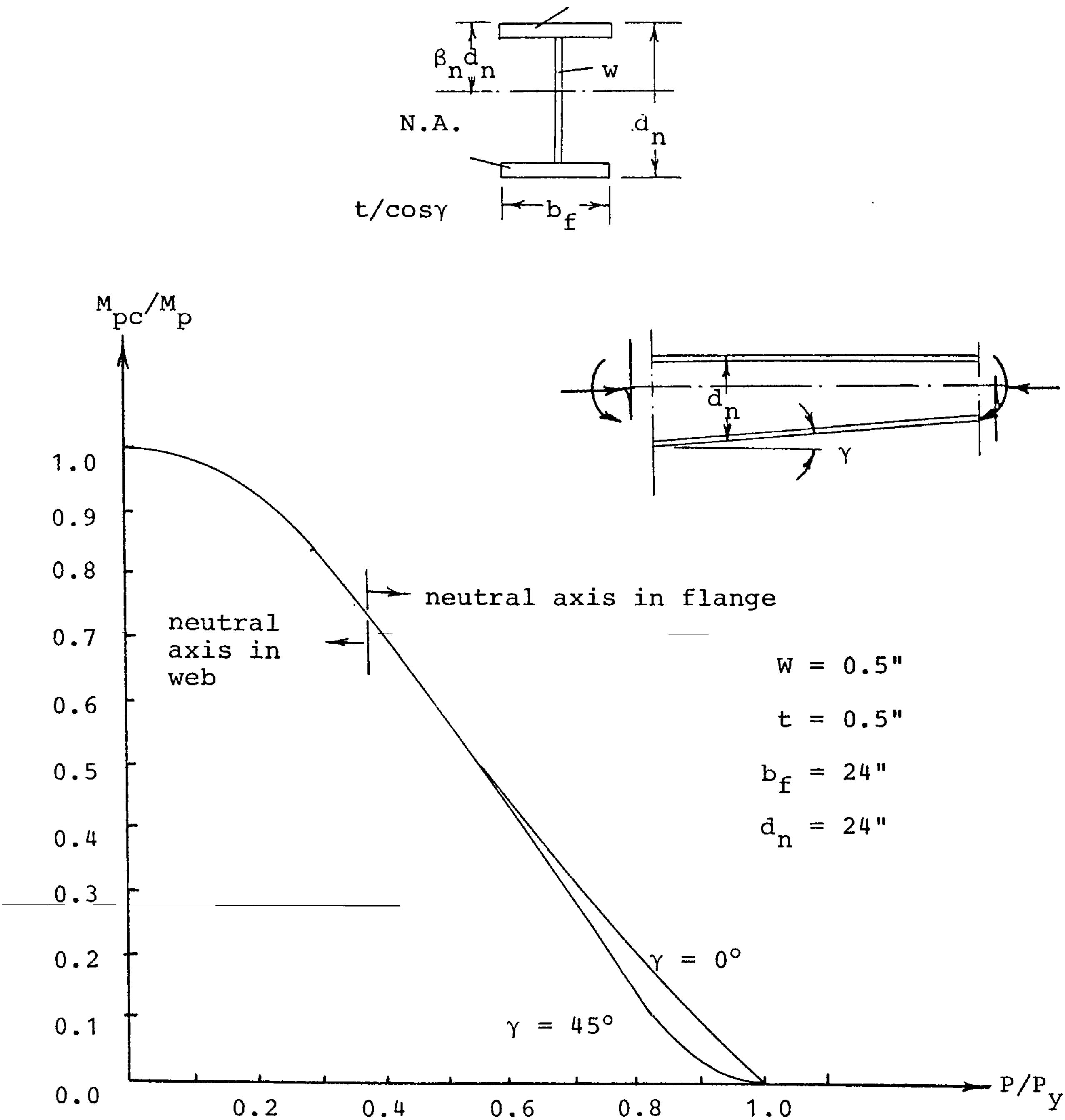


Fig. 3.10. Reduction of fully plastic moment by normal force.

CHAPTER IV

ADDITIONAL DESIGN CONSIDERATIONS

This chapter considers important factors which must be evaluated when the plastic theory is applied in the design of a structure, just as in the case of allowable-stress design. Besides the influence of the applied normal forces on the plastic moment capacity of the section, which have been discussed in the previous chapter, the influence of shear force, local buckling of flanges and webs, lateral instability, and repeated loading have to be evaluated.

4.1. Shear Force

No reduction of plastic moment due to shear is required if the magnitude of the shear force V at the ultimate load does not exceed

$$V \leq 0.55\, F_y\, w\, d \qquad (4.1)$$

where w is the web thickness, and d is the section depth. On the other hand if the member is reinforced by diagonal stiffeners or a doubler plate, the web does not need to correspond to the previous limitation.[4]

4.2. Local Buckling

The problem of elastic and inelastic buckling below the yield stress in flanges has been discussed and analyzed theoretically by G. Haaijer and B. Thurlimann.[2] The width-thickness ratio for flanges of built-up sections which have one web and undergo axial thrust and hinge rotation under ultimate loading shall not exceed the following values, which have been recommended by the American Institute of Steel Construction in 1973:[3]

F_y	$b_f/2\ t_f$
36	8.5
42	8.0
45	7.4
50	7.0
55	6.6
60	6.3
65	6.0

Also the depth-thickness ratio of members subjected to plastic bending shall not exceed the value given by the formula 4.1 or 4.2.[3]

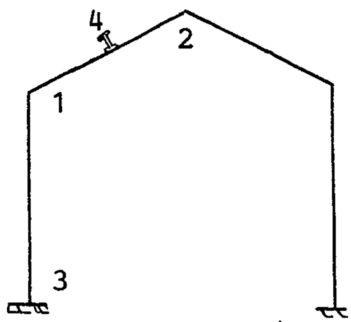
$$\frac{d}{w} = \frac{412}{F_y}\left(1 - 1.4\,\frac{P}{P_y}\right) \quad \text{when } \frac{P}{P_y} \leq 0.27 \qquad (4.2)$$

$$\frac{d}{w} = \frac{257}{F_y} \quad \text{when } \frac{P}{P_y} \geq 0.27 \qquad (4.3)$$

4.3. Connections

In the design of connections for portal frames, both strength and rigidity are prime requirements, but these qualities have to be achieved without either undue fabrication cost or difficulty during erection.[7]

The various types of connections which are typical of those that might be encountered in portal frames are as designated in Fig. 4.1.



1 - corner

2 - splice

3 - column anchorage

4 - miscellaneous

Fig. 4.1. Types of connections in portal frames.

Primary attention is given herein to corner connections (the other types can be found in Ref. 4). Method of analysis are based on the assumption of stress distribution at ultimate load which satisfies the equilibrium but does not violate the plasticity conditions. Thus, the solution constitutes lower bound to connection capacity.

The maximum possible forces in the two flanges and the diagonal stiffener can be determined from an equilibrium of horizontal components of these forces as follows:

$$\sigma_y As \cos - \sigma_y b_f \; t \cos(\gamma_1 + \sigma) + \sigma_y A_f \; t \sin \gamma_2 = 0.$$

$$A_s = b_f \; t \; [\frac{\cos(\gamma_1 + \theta) - \sin\gamma_2}{\cos\phi}] \qquad (4.4)$$

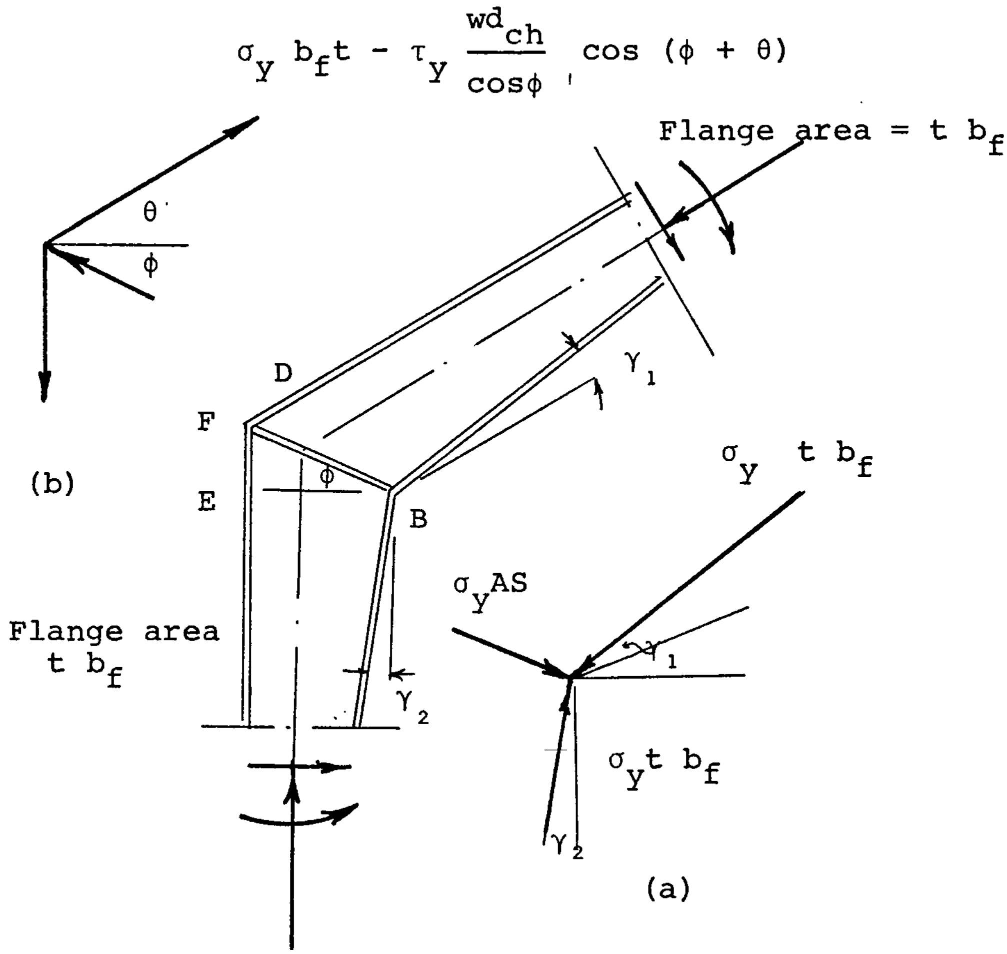


Fig. 4.2. Diagonal stiffener forces in a corner connection of tapered gable frame.

in which

A_s = area of symmetrical pair of diagonal stiffeners

b_f = flange width

t = flange thickness

θ = angle of inclination of rafter

ϕ = angle of slope of diagonal stiffener

γ_1 = angle of taper of rafter

γ_2 = angle of taper of column

In Fig. 4.2 (b) the maximum possible forces at outer corner F are shown. Equalibrium of horizontal components gives:

$$\sigma_y b_f \cos\theta - \tau_y \frac{w\, d_{ch}}{\cos} \cos(\phi + \theta) \cos\theta - \sigma_y A_s \cos\phi = 0$$

Substituting $\tau_y = \sigma_y/\sqrt{3}$ and solving for the required stiffner area gives

$$A_s = \left[\frac{b_f\, t}{\cos\phi} - \frac{w\, d_{ch} \cos(\phi + \theta)}{\sqrt{3 \cos^2 \phi}}\right] \cos\theta \qquad (4.5)$$

in which w is web thickness d_{ch} depth of column at section EB, (see Fig. 4.2). If Eq. 4.5 should result in zero or negative value for A_s, the implication is that the shear capacity of the web is adequate to transmit the outer flange force and the diagonal stiffeners are needed only to transmit the unbalanced force of the inner flange. Since in any case the web will carry some force, Eq. 4.4, which is based on equilibrium at the inner corner, will control.[2]

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The computerized plastic analysis and design of tapered, or uniform, gable frames, when both bases are fixed or pinned, under practical loading conditions has been developed and presented in Chapter II.

The plastic section modulus of taper members (variable depth web) has been derived in Chapter III. Also, three interaction equations to evaluate the reduced plastic moment capacity, the reduction caused by the axial thrust only, have been derived and checked by using Subroutine SUB3, see Appendix C. Graphs representing these three equations have been provided.

A list of the developed computer program has been given in Appendix C. This program has the capability of performing the analysis of tapered gable frames in addition to uniform ones and can also check for the validity of the AISC recommended design criteria for premature failure due to local buckling.

Conclusions

It is found in studying the results of the numerical example given in Appendix C that the developed computer program has the capability of handling the analysis of tapered gable frames in addition to uniform ones. In using the free-field format to input the numerical data in addition to using both subroutine SUB1 and subroutine UNITS to input the alphanumerical data resulted in giving the program the desired flexibility to minimize some of the common mistakes usually made while inputing data in a rigid, specified format. Also, subroutine units made it possible to have the output in any specified units (see Appendix C). By inspecting the user's manual, provided in Appendix B, it can be seen that this program does not require in its use any great understanding of the computer.

The computer program can be modified to account for more than the studied base conditions or other loading configurations.

On the other hand, the same technique can be used to solve gable frames with nonuniform cross sections other than or in addition to these already included. All that is needed, to study another type, is a subroutine that will calculate M_{pc} as a function of X, where X is the relative location of the section with respect to one end of the member. A command for this type of modification may be easily added.

APPENDIX A

Solution of Linear Equations

A system of linear algebric equations in N unknowns can be written as the following single matrix equation:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdot & \cdot & \cdot a_{1n} \\ a_{21} & a_{11} & a_{12} & \cdot & \cdot & \cdot a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdot & \cdot & \cdot a_{3n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & a_{n3} & \cdot & \cdot & \cdot a_{nn} \end{bmatrix} \begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ \cdot \\ X_n \end{Bmatrix} = \begin{Bmatrix} C_1 \\ C_2 \\ C_3 \\ \\ C_n \end{Bmatrix} \qquad (1)$$

or simply

$$A\ X = C \qquad (2)$$

where A is the coefficient matrix, X is the unknown vector and C is the constant vector. Using this notation the solution will be as follows:

$$X = A^{-1}\ C \qquad (3)$$

This solution can be achieved by using Gauss reduction technique[9] and the resulting equations can be written as follows:

$$a_{kj}^{k} = a_{kk}^{k-1}/a_{kk}^{k-1},\ j \neq k; \quad a_{kk}^{k} = 1/a_{kk}^{k-1} \qquad (4)$$

$$a_{ij}^{k} = a_{ij}^{k-1} - a_{ik}^{k-1}\, a_{kj}^{k} \;, \; j \neq k;$$

$$a_{ik}^{k-1} = -a_{ik}^{k-1}\, a_{kk}^{k}, \; i \neq k, \; j \neq k \qquad (5)$$

The flow chart for this solution is presented in Fig. A.l.

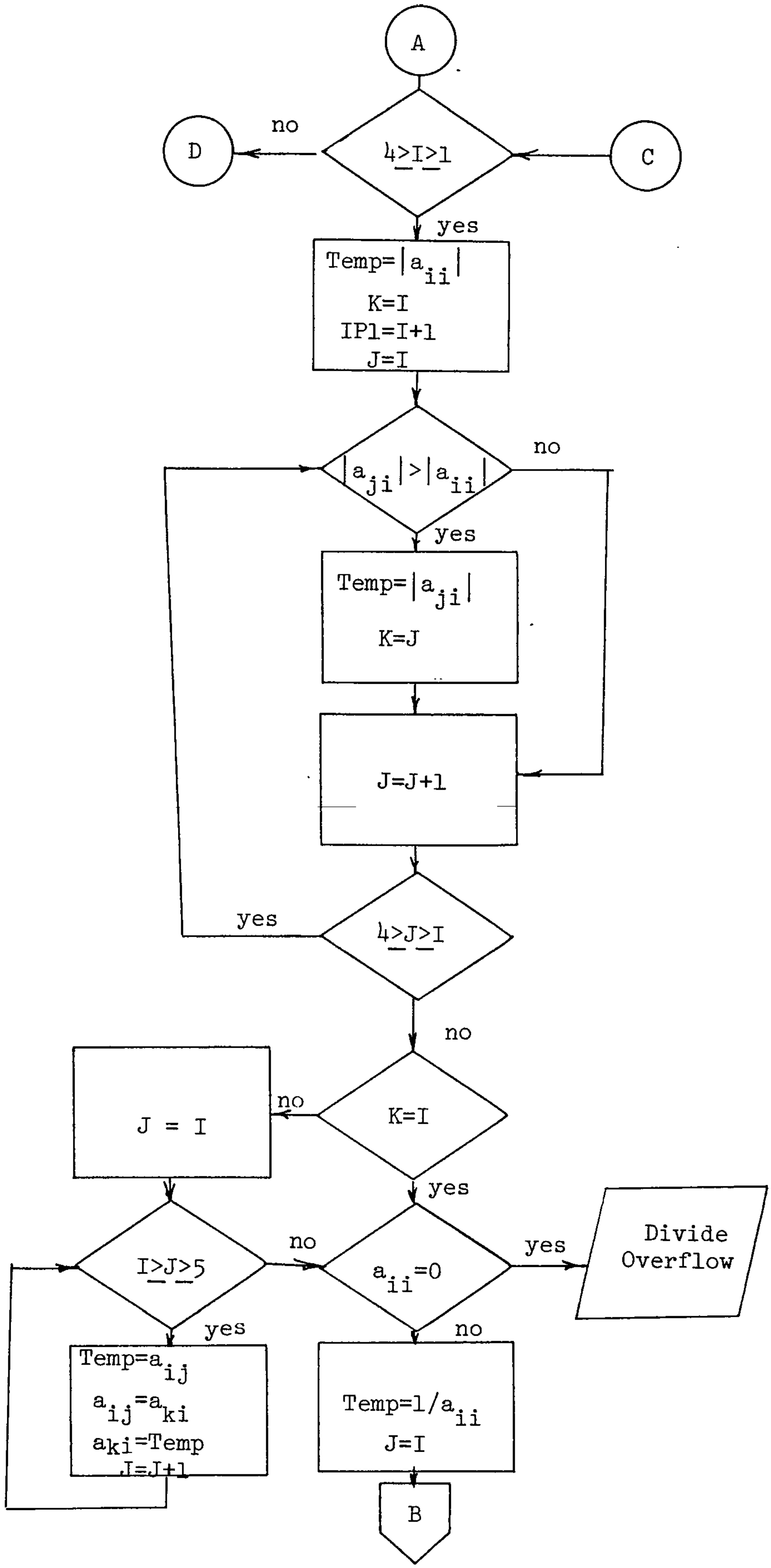


Fig. A.1. Flow chart of the solution of the system of four simultaneous linear equations.

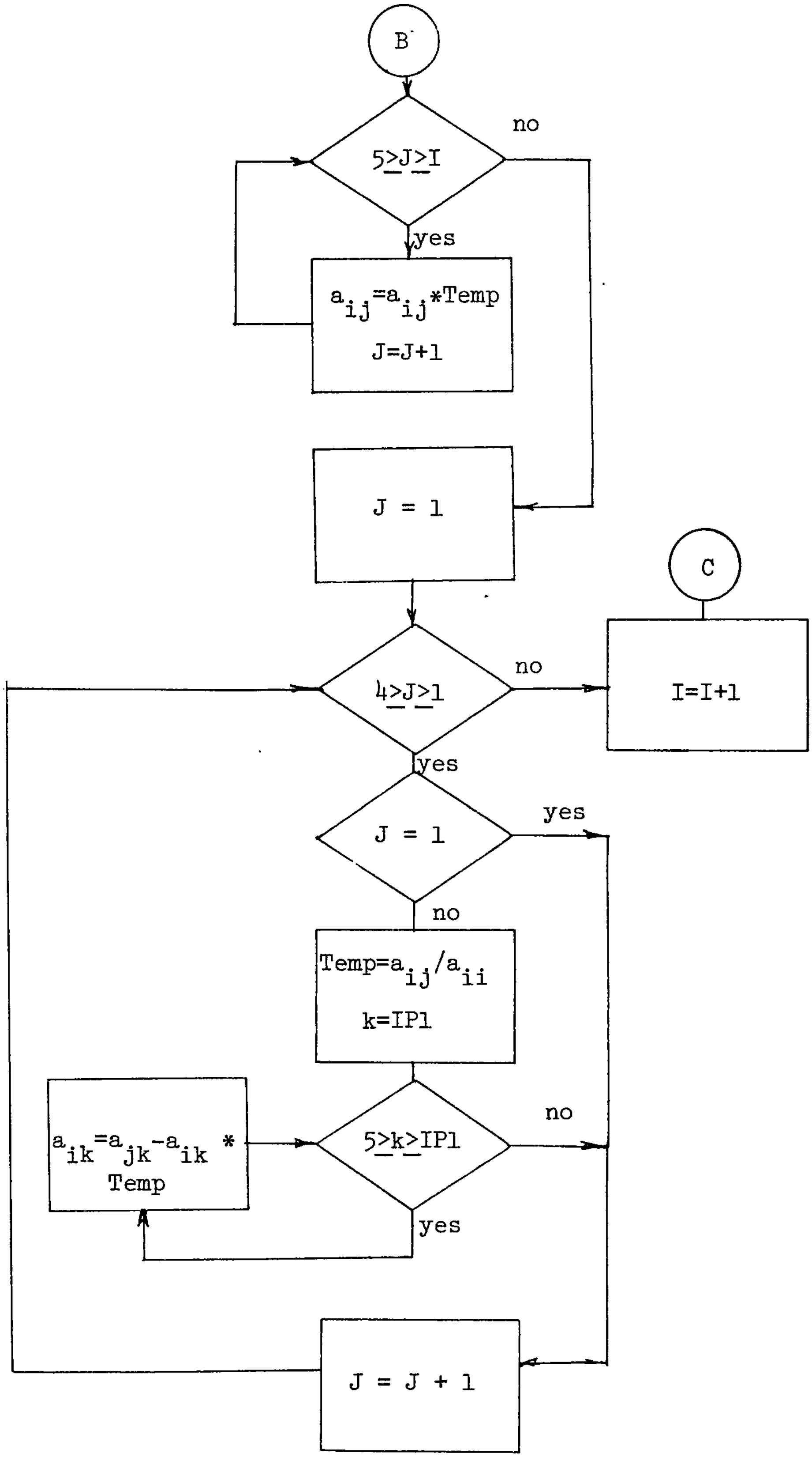


Fig. A.1. (continued)

APPENDIX B

User's Manual

DFRAP

Primary Purpose

The program DFRAP, as listed in Appendix C, has been restricted to deal with symmetrical rigid frames of the portal type. However, the analysis capabilities fall into two catagories. The first one is the analysis of symmetrical uniform rigid frames of the portal type. The second capability is the analysis of symmetrical tapered frames of the portal type, when both bases are fixed or pinned.

Conventions

All 80 columns of a card can be used for the input of the alphanumerical data. A free-field format has been used to allow free-field input, which employ a standard G type editing code with no fixed fields; in other words, free-field input is a set of external fields separated by comas. The end of the input image is a field end.

1. Problem Initiation

This card must be the first one in the data deck. It can be any alphanumeric name, which has been chosen by the user to identify his problem, and has a maximum length of

70 characters.

Example

JOB # 1. DESIGN OF TAPERED GABLE FRAME.

2. Problem Type

This command is used to classify the frame members, as tapered or uniform sections.

Example

TAPERED

UNIFORM

or alternatively in abbreviation form.

TAP

UNIF

3. Units

The following are the only available units for the system:

Length unit:	INCHES, FT., CM, or METERS
Force unit:	LB., KIPS, KG., or metric TONS
Angular unit:	DEGREES. (This unit does not need to be specified.)

Example

LB FT

The user must specify the units otherwise the system will run terminated.

4. Frame Dimensions Input

To input the dimensions of the frame, four variables must be specified at this stage. These variables are the span, the eave height, the degrees of pitch, and the frame spacing. The input record must be in the following format and order:

SPAN, EAVE HEIGHT, DEGREE OF PITCH, AND FRAME SPACING.

Example

72. , 33. , 15. , 24.

This record describes a frame with 72.0 length units span, 33.0 length units eave height, 15.0 degrees of pitch and 24.0 length units spacing of frames.

5. Working Load Data Input

The working load is the uniform vertical loading intensity measured in the chosen units.

Example

10.0

Which describes the intensity of 10.0 force units per square length units.

6. Wind Forces Input

These forces are normal to the covering and optional. To input these forces the user will be asked if there are any pressures normal to covering; the answer must be YES or NO. According to the answer the control will be transfered to the next step e.g.: YES--so the next record has to specify four normal surface pressures for the left-hand column, left-hand rafter, right-hand rafter and right-hand column respectively.

Example

24. , 6.289 , 0.0 , 0.0

7. Vertical Concentrated Apex Load and Load Factor Input

Example

0.0 , 1.4

This record will specify a zero concentrated apex load and 1.4 load factor.

8. Concentrated Loads Other Than the Apex Load Input

If there are any concentrated loads other than the apex load the user must input YES. Otherwise he has to input NO. Then the user will be asked if there are any horizontal concentrated loads on the left-hand column. The answer must be YES or NO. If the answer is YES, the user has to answer the next question: How many? And on the next cards the magnitude and the point of application of these loads must be given.

Example

3

500.0 , 2.0

1000.0 , 6.0

1200.0 , 15.0

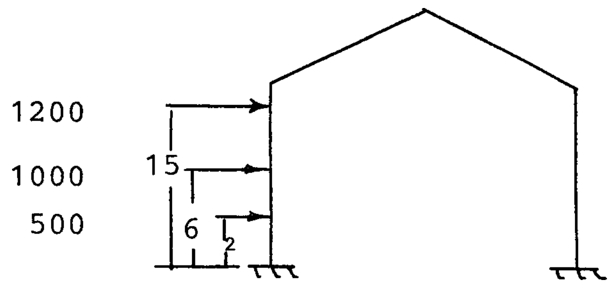


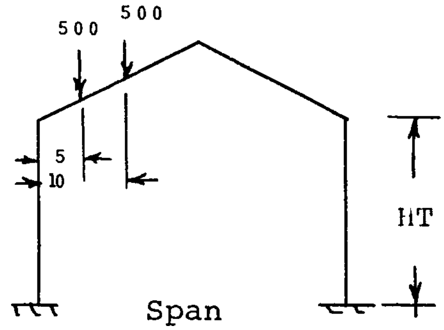
Fig. B.1. Horizontal concentrated loads on left-hand column.

The same procedure is applicable for any horizontal load applied on the right-hand column with a positive sign if acting inwards.

9. Concentrated Vertical Loads Acting On the Rafter Input

The user will be asked if there is any vertical loading on the left-hand rafter, if the answer is YES the user will be asked: How many? On the next cards the magnitude and the point of application of these loads must be given.

Example, Fig. B.2



YES

2

500.0 , 5.0

500.0 , 10.0

Fig. B.2. Vertical concentrated loads on left-hand rafter.

The same procedure is applicable if there is any concentrated vertical loads on the right-hand rafter.

10. Gantry Crane Loads Input

The user will be asked if there are any gantry crane loads. If the answer is YES, the user has to input the height of the crane rails and the offset on the first record, the magnitude of vertical reactants of both left and right-hand columns respectively on the following record. On the third record he has to input the horizontal reactants of the gantry crane rails on left and right-hand column respectively.

Example, Fig. B.3

YES

27.0 , 2.0

10000.0 , 4000.0

500.0 , 200.

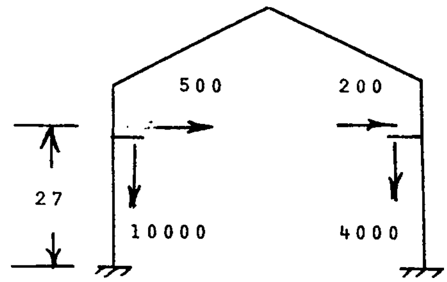


Fig. B.3. Gantry crane loads.

11. At this stage, the user will be asked if he wants to see the twin cantilever bending moment distribution. The answer must be YES or NO.

12. Input the Base Supports

The user has to specify the bases condition as FIXED or PINNED. The left-hand base first, each base on a separate record.

Example

FIXED , or PINNED

or alternatively in abbreviation form:

FIX , or PIN.

13. At this stage the computer, if the frame type is tapered, will read one record. This record has to specify the section depth at four locations, at the column base and

top, the rafter near the column and the rafter near the apex respectively. This record also has to specify the thickness of the web and the flange, the width of the flange, and the specified minimum yield stress of the type of steel used (F_y in ksi), as used in the AISC specification.

Example, Fig. B.4.

D1 , D2 , D3 , D4 , w , t , b_f , F_y

This record can be written on more than one record if needed. This can be done by skipping the rest of the card. The units must be the same as specified above at stage three except that F_y must in in ksi.

14. Nomination of Plastic Hinges Positions

The nomination of two plastic hinges is required if both bases are PINNED, or four positions have to be nominated if both bases are FIXED. These positions have to be assigned an integer constant with sign which serves to indicate the sign at the assumed hinge.

15. The Bases Reactions

If the user wants to see the bases reactions he has to input YES; otherwise he has to answer NO.

16. At this stage the user will be asked if he wants to try another hinge pattern. The answer must be YES or NO; if it is YES, he has to repeat step 14; on the other hand,

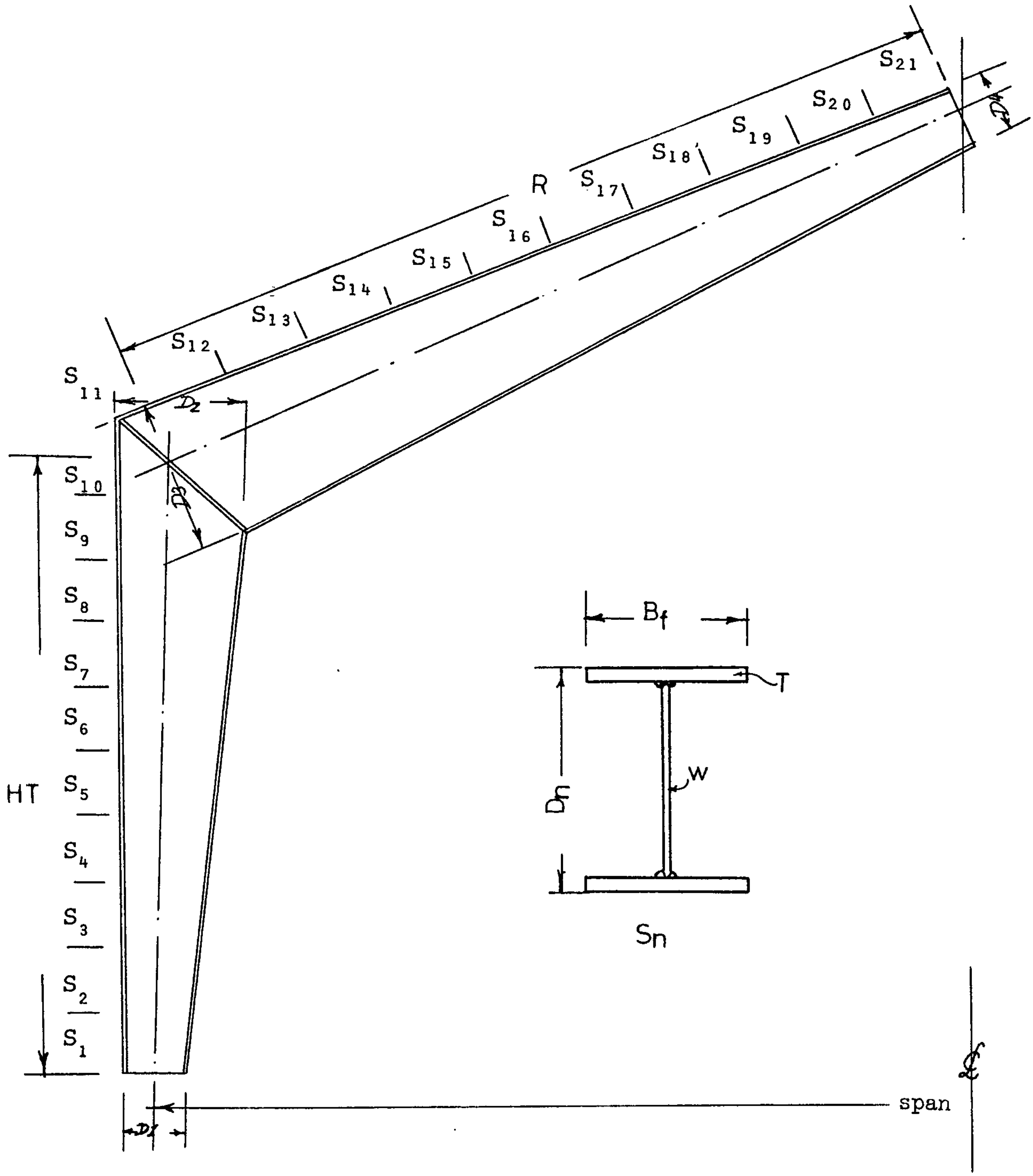


Fig. B.4. Representation of tapered gable frame sections.

if the answer is NO, the operator will transfer the control to step 17.

17. The user at this stage will be asked if he has another frame to be considered. If YES it will transfer the control to step one above--otherwise the computer run will stop.

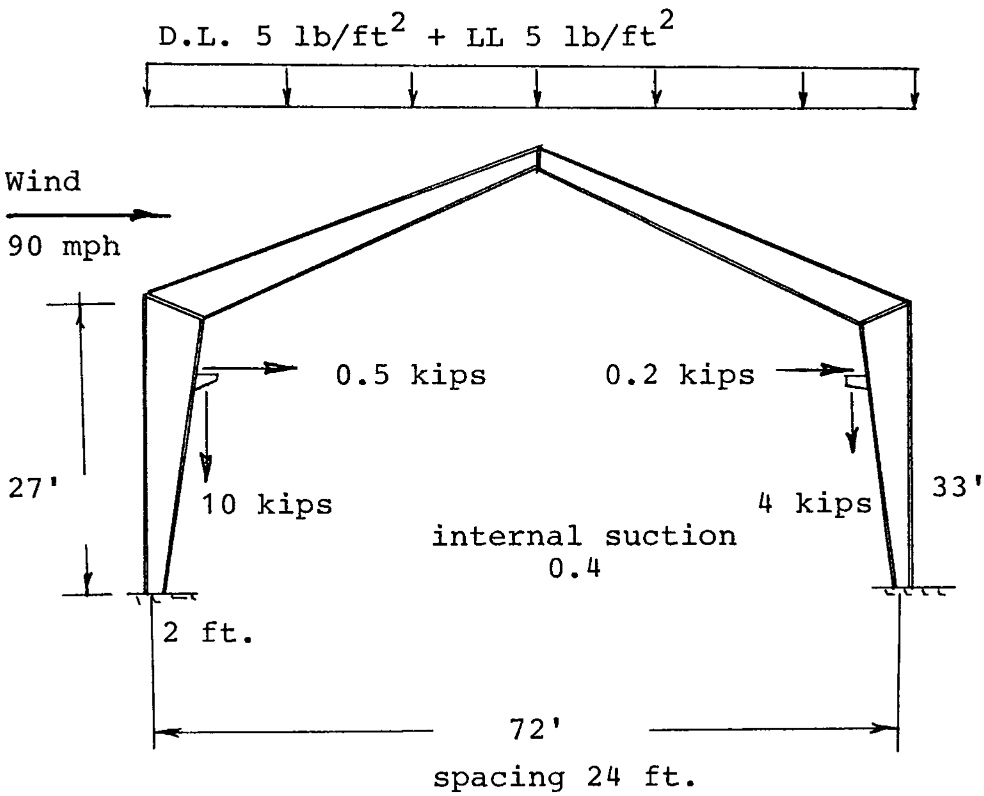


Fig. B.5. Plastic design example.

The solution for this problem is presented in Appendix C.

APPENDIX C

THE COMPUTER PROGRAM DFRAP

```
      DIMENSION  DTMS(41) ,RLAS(41),REAR(41),EQ(4,5) ,SH(41),TH(41)
      COMMON MPN(41) ,RESM(41),ANS(41),M(80)   ,THRUST(41)
     2 ,SHEAR(41)
      REAL MPN
      INTEGER RBAS,ANS,YES,PIN,FIX,ERR,FORCE,CM,TON   ,FT
     1  ,TAP   ,UNIF    ,ASTR
      DATA YES/'YES'/,NO/'NO'/   ,ERR/'ERR'/   ,CM/'CM'/    ,TON/'TON'/
     1,PIN/'PINNED'/,FIX/'FIXED'/   ,FT/'FT'/,KIPS/'KIPS'/,LB/'LB'/
     2 ,TAP/'TAP'/,UNIF/'UNIF'/
     3, ASTR/'***'/   ,BLANK/' '/
    1 FORMAT(  )
    2 FORMAT (80A1)
    3 FORMAT( T16, 46('*'))
    5 WRITE(6,3)
      WRITE(6,10)
      WRITE(6,3)
    7 FORMAT(///1X,72('*'),/1X,'*',70A1,'*',/1X, 72('*')////)
   8  FORMAT(3X,A4//)
   10 FORMAT (  T16,'*  PLASTIC DESIGN OF INDUSTRIAL RIGID FRAMES  *')
C***********************C
C    PROBLEM INITIATION C
C***********************C
      WRITE(6,16)
   16 FORMAT(' PROBLEM INITIATION')
      READ  (5,2)M
      DO 9 K1=1,80
    9 IF(M(K1).NE.BLANK)  GO TO 13
   13 WRITE(6,7)  (M(K2),K2=K1,70)
      WRITE(6,17)
   17 FORMAT(' TYPE OF MEMBER SAY TAPERED,OR UNIFORM')
      CALL SUBI (LTYP)
      WRITE(  6,11) LTYP
   11 FORMAT(///  '  TYPE  ', A5///)
      WRITE(6,18)
   18 FORMAT(' INPUT THE SPECIFIED UNITS ,LENGTH AND FORCE')
      CALL        UNITS(LENGTH,FORCE,CF,CL)
C*********************************************************C
C SPAN ,EAVES HEIGHT,DEGREE OF PITCH AND FRAME SPACING     C
C  INPUT THE FRAME DIMENSIONS                              C
C*********************************************************C
      WRITE(6,19)
```

```
   19  FORMAT(
      1' INPUT THE FRAME DIMENSIONS SPAN,EAVES HIEGHT,DEGREE OF PITCH AND
      2 FRAMES SPACING'//)
       READ (5,1)       SPAN,HT,THETA,BAY
       WRITE (6,15) SPAN,LENGTH, HT,LENGTH,THETA ,BAY,LENGTH
   15  FORMAT(///'      SPAN                        =',G15.5,A4    ,///
      1          '      EAVS HEIGHT                 =',G15.5, A4   ,// /
      2          '      DEGREE OF PITCH             =',G15.5,'DEGREE'   ,///
      3          '      FRAME SPACING               =',G15.5, A4 ///)
       WRITE(6,21)
   21  FORMAT(
      1' INPUT THE WORKING LOAD DATA VERTICAL UNIFORM LOADING INTENSITY')
C*********************************************************************C
C    INPUT THE WORKING LOAD DATA -VERTICAL UNIFORM LOADING INTENSITY,  C
C*********************************************************************C
       READ(5,1)  WSQFT
       WRITE (6,20) WSQFT , FORCE,LENGTH
   20  FORMAT (/ '  WORKING LOAD'///,'  VERTICAL UNIFORM LOADING INTENSIT
      1Y = ',G15.5,A4,'/SQUARE ', A4///)
C*********************************************C
C  ARE THERE PRESSUERS NORMAL TO COVERING ?    C
C*********************************************C
       WRITE(6,22)
   22  FORMAT(      '  ARE THERE PRESSURES NORMAL TO COVERING ? '//)
       CALL SORT(NUM)
       IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
       WRITE(6,8) NUM
       IF (NUM-YES)  41,30,41
C*********************************************************************C
C  INPUT 4 NORMAL SURFACE PRESSURES FOR THE LEFT-HAND COLUMN,LEFT-HAND
C  RAFTER,RIGHT-HAND RAFTER AND RIGHT-HAND COLUMN WITH PRESSUER POSITIVE
C  IF ACTING INWARDS ON THE BUILDING.                                  C
C*********************************************************************C
   30  WRITE(6,31)
   31  FORMAT(' INPUT FOUR NORMAL SURFACE PRESSURES FOR THE '/,        '
      2 LEFT-HAND COLUMN,LEFT-HAND RAFTER,RIGHT-HAND RAFTER'/,
      3' AND RIGHT-HAND COLUMN WITH PRESSURE POSITIVE IF'/,
      4 ' ACTING INWARDS ON THE BULDING.'/)
       READ(5,1) AAA,BBB,CCC,DDD
       WRITE (6,40) AAA,FORCE,LENGTH,BBB,FORCE,LENGTH,CCC,FORCE,LENGTH,
      1 DDD,FORCE,LENGTH
   40  FORMAT(//' PRESSURE ON THE LEFT-HAND COLUMN =',G15.5,A4,'/SQUARE '
      1,A4,///' PRESSURE ON THE LEFT-HAND RAFTER =',G15.5, A4,'/SQUARE '
      2 ,A4,///' PRESSURE ON THE RIGHT-HAND RAFTER=',G15.5,A4,'/SQUARE '
      3,A4,/// ' PRESSURE ON THE RIGHT-HAND COLUMN=',G15.5,A4,' /SQUARE '
      4  ,A4///)
```

```
C*****************************************************C
C  VERTICAL CONCENTRATED  APEX LOAD AND LOAD FACTOR    C
C*****************************************************C
      WRITE(6,39)
   39 FORMAT(' INPUT VERTICAL CONCENTRATED APEX LOAD AND LOAD FACTOR'/)
   41 READ (5,1)  PP,Z
      WRITE(6,44)      PP,FORCE,Z
   44 FORMAT(     ' CONCENTRATED APEX LOAD =' ,G15.5,A4   ,///
     1 ' LOAD FACTOR=',G15.5  ///)
      W=BAY*Z*WSQFT
      PP=PP*Z
      VL=0.0
      VR=0.0
      HL=0.0
      HR=0.0
      DO 45 I=1,41
      SM(I)=0.0
      TM(I)=0.0
   45 DIMS(I)=0.0
      A=AAA*Z*BAY
      ANGLE=THETA*3.14159265/180.0
      C=CCC*Z*BAY
      D=DDD*Z*BAY
      B=BBB*Z*BAY
      R=(SPAN*SIN(ANGLE)/COS(ANGLE))*0.5
      BRH=B*R*HT
      W2=W*SPAN*0.5
      W4=W2*COS(ANGLE)
      W6=W2*SIN (ANGLE)
      W8=W*SPAN**2/8.0
      PP1=0.5*PP
      PP2=PP1*COS(ANGLE)
      PP3=PP1*SIN(ANGLE)
      CRH=C*R*HT
      SEC=1.0/COS(ANGLE)
      COSC=SIN(ANGLE)
      Q=(SPAN*SEC)**2/8.
      H2=HT**2/2.
C**************************************************C
C   ARE THERE ANY OTHER CONCENTRATED LOADS?        C
C**************************************************C
      WRITE(6,47)
   47 FORMAT( ' ARE THERE ANY OTHER CONCENTRATED LOADS? '///)
      CALL SUB1(NUM)
      IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
      WRITE(6,8) NUM
      IF (NUM-YES) 49,850,49
```

```
 49   DO 50 I=1,10
      AK=FLOAT(I)/10.
      J1=11-I
      DTMS(J1)=  DTMS(J1)-RB-B*W-PRH*AK-H2*A*AK**2-PP*    SPAN/4.0
      TH(J1)=TH(J1)-.2 -B*0.5*SPAN -PP1
      SH(J1)=SH(J1)+R*0.5*SEC*COSC*SPAN+A*AK*HT
      REAS(J1)=SPAN/2.
      REAR(J1)=R+AK*HT
      J2=21-I
      DTMS(J2)=DTMS(J2)-(WP+W*B)*AK**2.0-PP*AK*SPAN/4.0
      REAS(J2)=AK*SPAN/2.0
      REAR(J2)=R*AK
      SH(J2)=SH(J2)+.4*AK +PP2 +B*AK*0.5*SPAN *SEC
      TH(J2)=TH(J2)-.6*AK-PP3
      J3=21+I
      TH(J3)=TH(J3)-.6*AK -PP3
      SH(J3)=SH(J3)-.4*AK -PP2 -C*AK*SPAN*SEC*0.5
      DTMS(J3)=DTMS(J3)-(WB+W*C)*AK**2-PP*AK*SPAN/4.0
      REAS(J3)=-AK*SPAN/2.
      REAR(J3)=R*AK
      J4=31+I
      TH(J4)=TH(J4)-.2-C*SPAN*0.5 -PP1
      SH(J4)=SH(J4)  -C*SPAN*0.5*SEC*COSC -AK*HT *D
      DTMS(J4)=DTMS(J4)-RB-W*C-CRH*AK-H2*D*AK**2-PP*SPAN/4.
      REAS(J4)=-SPAN/2.
 50   REAR(J4)=R+AK*HT
      SH(21)=SH(21)+ PP2
      TH(21)=TH(21)-PP3
C**********************C
C  GANTRY CRANE LOADS   C
C**********************C
      WRITE(6,51)
 51   FORMAT( ' ARE THERE ANY GANTRY CRANE LOADS?  '///)
      CALL SUB1(NUM)
      IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
      WRITE(6,8) NUM
      IF (NUM -YES) 52 ,710 ,52
C***********************************************************C
C        ASK IF YOU WANT TO SEE THE TWIN CANTILEVER MOMENT C
C***********************************************************C
 52   WRITE(6,53)
 53   FORMAT ( ' DO YOU WANT TO SEE THE TWIN CANTILEVER MOMENT? '///)
      CALL SUB1(NUM)
      IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
      WRITE(6,8) NUM
      IF (NUM- YES ) 62,55,62
```

```
C*****************************************C
C  PRINT THE TWIN CANTILEVER MOMENTS     C
C*****************************************C
  55   WRITE(6,57)
  57   FORMAT (' THE TWIN CANTILEVER MOMENT SHEAR AND THRUST : '///,1X,
      155('-'),/ ' SECTION NO.',T20,'MOMENT',T33,'SHEAR',T47,'THRUST',
      2  /1X,55('-'))
       DO  58 I=1,41
  58   WRITE (6,61) I,DTMS(I) ,SH(I),TH(I)
  61   FORMAT (I7,T18,G10.5,T30,G10.5,T45,G10.5 )
  62   CONTINUE
C***************************C
C  WHAT  KIND OF BASES ?    C
C***************************C
       WRITE(6,65)
  65   FORMAT (55('-'),///
      1           ' WHAT KIND OF BASES?'//,' INPUT FIXED OR PINNED ,LEFT-HAND
      1 BASE FIRST'///)
       CALL SUB1(RBAS)
       IF( RBAS.NE.FIX.AND.RBAS.NE. PIN) GO TO 475
       CALL SUB1(LBAS)
       IF( LBAS.NE.FIX.AND.LBAS.NE. PIN) GO TO 475
       WRITE(6,70) LBAS,RBAS
  70   FORMAT(
      1 ' LEFT-HAND BASE IS ',A6,/// ' RIGHT-HAND BASE IS ',A6///)
       IF( LTYP .EQ.UNIF)GO TO  80
       WRITE(6,73)
  73   FORMAT(' INPUT THE SECTION DIMENSIONS,D1,D2,D3,D4,W,T,BF,FY')
       CALL SUB2(SEC,HT,SPAN,LENGTH,CF,CL,D1,D2,D3,D4,W,T,SEGMA,       BF,
      1  RBAS,LBAS,COS1,COS2,FY)
  80   IF(RBAS .EQ.PIN .AND. LBAS .EQ. PIN) GO TO 100
       IF(RBAS .EQ.FIX .AND. LBAS .EQ. FIX) GO TO 150
C***************************C
C   ANALYSIS FOR PIN BASES  C
C***************************C
  100  DO 110 I=1,4
  110  EQ(I,1)=1.0
       EQ( 1,2)=REAR(1)
       EQ( 1,3)=REAS(1)
       EQ( 1,4)=0.0
       EQ( 1,5)=-DTMS(1)
       EQ(2,2)=REAR(41)
       EQ(2,4)=  0.0
       EQ(2,3)=REAS(41)
       EQ(2,5)=-DTMS(41)
C************************************************************C
C  NOMINATE POSITIONS OF TWO PLASTIC HINGES WITH SIGN        C
```

```
      C*************************************************************C
            READ(5,1)  IH1,IH2
            WRITE(6,115) IH1,IH2
        115 FORMAT (' THE TWO NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN
           1ARE ',2I5///)
            JH1=IABS(IH1)
            JH2=IABS(IH2)
            EQ(3,2)= REAR(JH1)
            EQ(3,3)=REAS(JH1)
            EQ(3,5)=-UTMS(JH1)
            EQ(4,2)=REAR(JH2)
            EQ(4,3)=REAS(JH2)
            EQ(4,5)=-UTMS(JH2)
            IF(LTYP .EQ. UNIF)  GO TO 135
            IF (IH1)   120,120,130
        120 EQ(3,4)=MPN(JH1)
            EQ(4,4)=-MPN(JH2)
            GO TO 280
        130 EQ(3,4)=-MPN(JH1)
            EQ(4,4)=MPN(JH2)
        135 IF (IH1) 140,140,145
        140 EQ(3,4)=1
            EQ(3,4)=-1
            EQ(4,4)=-1
        145 EQ(3,4)=-1
            EQ(4,4)=1
            GO TO 280
      C****************************************C
      C  ANALYSIS FOR FIXED BASES.             C
      C****************************************C
      C***********************************************C
      C  NOMINATE POSITION OF FOUR PLASTIC HINGES      C
      C***********************************************C
        150 WRITE(6,174)
        174 FORMAT(' NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO IND
           1ICATE THE MOMENT SIGN'//)
            READ (5,1)   IH1,IH2,IH3,IH4
            WRITE (6,155) IH1,IH2,IH3,IH4
        155 FORMAT( ' THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN
           1'///,' TO INDICATE THE MOMENT SIGN ARE:'///,4I5///)
            JH1=IABS(IH1)
            JH2=IABS(IH2)
            JH3=IABS(IH3)
            JH4=IABS(IH4)
            DO 160 I=1,4
        160 EQ(I,I)=1.0
```

```
      EQ(1,2)=REAR(JH1)
      EQ(1,3)=REAS(JH1)
      EQ(1,5)=-DTMS(JH1)
      EQ(2,2)=REAR(JH2)
      EQ(2,3)=REAS(JH2)
      EQ(2,5)=-DTMS(JH2)
      EQ(3,2)=REAR(JH3)
      EQ(3,3)=REAS(JH3)
      EQ(3,5)=-DTMS(JH3)
      EQ(4,2)=REAR(JH4)
      EQ(4,3)   =REAS(JH4)
      EQ(4,5)=-DTMS(JH4)
      IF(LTYP.EQ.UNIF)GO TO  271
      IF(IH1) 170,170,180
  170 EQ(1,4)=MPN(JH1)
      GO TO 190
  180 EQ(1,4)=-MPN(JH1)
  190 IF(IH2) 200,200,195
  195 EQ(2,4)=-MPN(JH2)
      GO TO 220
  200 EQ(2,4)=MPN(JH2)
  220 IF(IH3)230,230,240
  230 EQ(3,4)=MPN(JH3)
      GO TO 250
  240 EQ(3,4)=-MPN(JH3)
  250 IF(IH4) 260,260,270
  260 EQ(4,4)=MPN(JH4)
      GO TO 280
  270 EQ(4,4)=-MPN(JH4)
      GO TO 280
  271 IF(IH1) 272,272,273
  272 EQ(1,4)=1
      GO TO 274
  273 EQ(1,4)=-1
  274 IF(IH2) 275,275,276
  275 EQ(2,4)=1
      GO TO 277
  276 EQ(2,4)=-1
  277 IF(IH3) 278,278,279
  278 EQ(3,4)=1.0
      GO TO 281
  279 EQ(3,4)=-1.0
  281 IF(IH4) 282,282,283
  282 EQ(4,4)=1.0
      GO TO 280
  283 EQ(4,4)=-1.0
```

```
      280 DO 390 I=1,4
          IP1=I+1
          TEMP =ABS(EQ(I,I))
          K=I
          DO 300 J=I,4
          IF(ABS(EQ(J,I))-TEMP) 300,300,290
      290 K=J
          TEMP=ABS(EQ(J,I))
      300 CONTINUE
          IF(K -I) 310, 330,310
      310 DO 320  J=1,5
          TEMP =EQ(I,J)
          EQ(I,J) =EQ(K,J)
      320 EQ(K,J)=TEMP
      330 IF(EQ(I,I))  350,600, 350
      350 TEMP=1.0 /EQ(I,I)
          DO 360 J=I,5
      360 EQ(I,J)=EQ(I,J)*TEMP
          DO 390 J=1,4
          IF(I-J) 370,390,370
      370 TEMP =EQ(J,I)
           DO 380 K=IP1,5
      380 EQ(J,K)=EQ(J,K)-TEMP*EQ(I,K)
      390 CONTINUE
          DO 395 I= 1,10
          J2=21-I
          J3=32-I
          J4= 42-I
          SHEAR(I)= SH(I)-EQ(2,5)
          THRUST(I)= TH(I)+EQ(3,5)
          SHEAR(J2)=  SH(J2)-EQ(3,5)/SEC-EQ(2,5)*COSC
          THRUST(J2)= TH(J2)  +EQ(3,5)*COSC-EQ(2,5)/SEC
          SHEAR(J3)= SH(J3)+EQ(3,5)/SEC+EQ(2,5)*COSC
          THRUST(J3)= TH(J3)- EQ(3,5)*COSC-EQ(2,5)/SEC
          SHEAR(J4)= SH(J4)+EQ(2,5)
          THRUST(J4)= TH(J4)-EQ(3,5)
      395 CONTINUE
          WRITE (6,396)
      396 FORMAT( 1X,55('-'),/' SECTION NO. ',7X, ' SHEAR    ', 8X,' THRUST'
         1  ,/ 55('-'))
          SHEAR(21)=SH(21)+EQ(3,5)/SEC+EQ(2,5)*COSC
          THRUST(21)=TH(21)+EQ(3,5)*COSC+EQ(2,5)/SEC
          DO 397  I= 1,41
      397 WRITE (6,398)  I, SHEAR(I), THRUST(I)
      398 FORMAT( 5X,I5,5X,2G15.4)
          WRITE(6,399)
```

```
  399 FORMAT(1X,55('-')/)
      DO 420 I=1,41
  420 RESM(I)=DTMS(I)+EQ(1,5)+REAR(I)*EQ(2,5)+REAS(I)*EQ(3,5)
C****************************************C
C            LOCATION BENDING MOMENT  MT>MP    C
C****************************************C
      WRITE (6,222)
  222 FORMAT(///' LOCATION OF BENDING MOMENT MT >MPC:' ///,1X,60('-')/,
     1' SECTION NO. ' , T33,' PLASTIC MOMENT CAPACITY ',/ ,1X,60('-'))
      IF (LTYP .EQ.UNIF   ) GO TO  419
      CALL        SUB3(COS1,COS2,D1,D2,D3,D4,W,BF,T,SEGMA,RBAS,LBAS,FY)
      GO TO 412
  419 AMPN= EQ(4,5)
  430 FORMAT (//2X,T33,G15.5,4X,A5,'.',A5//)
      WRITE (6,430)  AMPN     ,FORCE,LENGTH
      DO 409 I=1,41
      IF(ABS(RESM(I))-0.99*AMPN) 406,405,405
  405 IF(ABS(RESM(I))-1.01*AMPN) 407,408,408
  406 ANS(I)= NO
      GO TO 411
  407 ANS(I)=ASTF
      GO TO 411
  408 ANS(I)=YES
      IF (LBAS.EQ. PIN) ANS(1)=NO
      IF (RBAS.EQ. PIN) ANS(41)=NO
  411 WRITE(6,421)I,    RESM(I),ANS(I)
  409 CONTINUE
      GO TO  425
  412 DO 410 I=1,41
  410 WRITE(6,421) I,RESM(I),ANS(I)    ,MPN(I)
  421 FORMAT(I5,5X,G12.3,4X,A3,10X ,G15.3)
C**********************C
C    BASE REACTIONS     C
C**********************C
  425 WRITE(6,423)
  423 FORMAT (55('-'),///
     1 '  DO YOU WANT TO SEE THE BASE REACTIONS?  '///)
      CALL SUR1(NUM)
      IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
      WRITE(6,8) NUM
      IF (NUM-YES)440,426,440
  426 VA=PP/2.0+(A+B)*SPAN/2.0-EQ(3,5)+VL+SVL
      VE=PP/2.0+(B+C)*SPAN/2.0 +VR+SVR +EQ(3,5)
      HE=-C*HT-C*R+EQ(2,5)+HR+SHR
      HA=A*HT +B*R-EQ(2,5)+HL+SHL
      WRITE (6,427) VA,HA,VE,HE
  427 FORMAT(/4H V1=,G9.4,2X,5H H1= ,G9.4,2X,
     15H V41= ,G9.4,2X,5H H41= ,G9.4//)
```

```
  440  WRITE(6,450)
  450  FORMAT( ' DO YOU WANT TO TRY ANOTHER HINGE PATTERN?'//)
       CALL SUPI(NUM)
       IF (NUM.NE. 'NO'.AND.NUM.NE.YES) GO TO 475
       WRITE(6,8)  NUM
       IF(NUM-YES)460,40,460
C**************************************C
C    ASK IF THERE IS ANOTHER FRAME      C
C**************************************C
  460  WRITE(6,470)
       CALL SUPI(NUM)
  470  FORMAT( ' DO YOU WANT TO ANALYSE ANOTHER FRAME?   '////)
       WRITE(6,8) NUM
       IF (NUM.NE. 'NO'.AND.NUM.NE.YES) GO TO 475
       IF(NUM-YES)500, 5,500
  475  READ (35,480)( R(II) ,II=1,80)
  480  FORMAT( 80A1)
       WRITE( 6,490)( R(II) ,II=1,80)
  490  FORMAT('  THIS CARD',/1X,80A1,/ ' DOES NOT CORRESPOND TO INPUT ROU
      1TINE',/5(T15,5('WARNING*')))
  500  STOP
  600  WRITE (6,650)
  650  FORMAT(5X,'ZERO DIVISION IN EQUATION')
       GO TO 425
  710  WRITE(6,680)
  680  FORMAT(' INPUT THE HEIGHT OF THE GANTRY CRANE RAILS AND'/
      1 '  THE OFFSET OF THE CRANE RAILS')
       READ (5,    1   )  HC,EC
       WRITE(6,720    )  HC,LENGTH,EC,LENGTH
  720  FORMAT( ' HEIGHT OF CRANE RAIL =',G15.5,A4   , ///' OFFSET OF CRANE
      1 RAIL = ',G15.5 ,A4  ///)
C**********************************************************************C
C INPUT WORKING VALUES OF VERTICAL CRANE FORCES LEFT-HAND COLUMN FIRST  C
C**********************************************************************C
       WRITE(6,660)
  660  FORMAT(' INPUT WORKING  VALUES OF VERTICAL GANTRY CRANE FORCES LEF
      1T-HAND COLUMN FIRST '///)
       READ(5, 1   ) VL,VR
       WRITE (6, 780)    VL,FORCE,VR,FORCE
  780  FORMAT(' WORKING VALUES OF VERTICAL CRANE FORCES '///,' WORKING VE
      1RTICAL CRANE FORCE ON LEFT-HAND COLUMN= ',G15.5,A4,///    ' WORKING
      2 VERTICAL CRANE FORCE ON RIGHT-HAND COLUMN= ',G15.5   , A4 ///)
C**********************************************************************C
C INPUT WORKING VALUES OF HORIZONTAL CRANE FORCES LEFT-HAND COLUMN FIRST
C**********************************************************************C
```

```
      READ  (5,1)  HL,HR
      WRITE (6,605)   HL,FORCL,HR,FORCE
  605 FORMAT(' WORKING VALUES OF HORIZONTAL CRANE FORCES '///,'
     1HORIZONTAL CRANE FORCE ON LEFT-HAND COLUMN =',G15.5,A4  ,///'
     2    HORIZONTAL CRANE FORCE ON RIGHT-HAND COLUMN='  ,G15.5,A4 ///)
      VL=Z*VL
      VR=Z*VR
      HL=Z*HL
      HR=Z*HR
      DO 620 I= 1,11
      AK= FLOAT(I)/10. -0.1
      HARM=HC-AK*HT
      IF(HARM)820,810,810
  610 DTMS(I)=DTMS(I)-VL*EC-HL*HARM
      SH(I)=SH(I)+HL
      TH(I)=TH(I)-VL
  620 CONTINUE
      DO 840 I=1,11
      AK= FLOAT(I)/10. -0.1
      HARM=HC-AK*HT
      IF(HARM) 840,830,830
  830 J=42-I
      DTMS(J)= DTMS(J)-VR*EC +HR*HARM
      SH(J)=SH(J)+HR
      TH(J)=TH(J)-VR
  840 CONTINUE
      GO TO 52
C***********************************************************************C
C  HORIZONTAL CONCENTRATED LOADS ON COLUMN ARE POSITIVE IF ACTING      C
C  INWARDS. VERTICAL CONCENTRATED LOADS ON RAFTERS ARE POSITIVE IF     C
C  ACTING DOWNWARDS  .                                                  C
C***********************************************************************C
C************************************************************C
C               HORIZONTAL LOADS ON LEFT-HAND COLUMN?        C
C************************************************************C
  845 FORMAT(' ARE THERE ANY HORIZONTAL LOADS ON LEFT-HAND COLUMN? '///)
  850 WRITE(6,845)
      CALL SUB1(NUM)
      IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
      WRITE(6,8)  NUM
      IF( NUM-YES)   910,860,910
  860 WRITE(6,865)
  865 FORMAT( ' HOW MANY?  '/)
      READ(5,1) NPL
      WRITE(6,1)NPL
```

```
      SHL=0.0
      WRITE(6,924)
      DO 905 I=1,NPL
      READ(5, 1)  SP,HP
      WRITE(6,870)SP,FORCE,HP ,  LENGTH
  870 FORMAT(' THE MAGNITUDE OF THE FORCE=',G10.5,A6, ///' THE POINT OF'
     1'APPLICATION=',G15.5,A6///)
      SP=Z*SP
      SHL=SHL+SP
      DO 900 J=1,11
      AK=FLOAT(J)/10. -0.1
      HARM=HP-AK*HT
      IF(HARM)900,890,890
  890 DTMS(J)=DTMS(J)-SP*HARM
      SH(J)= SH(J)+SP
  900 CONTINUE
C*********************************************C
C   HORIZONTAL LOADS ON RIGHT-HAND COLUMN    C
C*********************************************C
  910 WRITE(6,915)
  915 FORMAT(' ARE THERE ANY HORIZONTAL LOADS ON RIGHT-HAND COLUMN? '//)
      CALL SUBI(NUM)
      IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
      WRITE(6,8)  NUM
      IF (NUM-YES)950,920,950
  920 WRITE(6,925)
  925 FORMAT(' HOW MANY?'/)
      READ(5,1)NPR
      WRITE(6,1)NPR
      SHR=0.0
  924 FORMAT (' INPUT THE FORCE AND THE POINT OF APPLICATION')
      WRITE(6,924)
      DO 940 I=1,NPR
      READ(5,1) SP,HP
      WRITE(6,870)SP,FORCE,HP,LENGTH
      SP=Z*SP
      SHR=SHR+SP
      DO 940  J=1,11
      AK=FLOAT(J)/10.0-0.1
      HARM =HP-AK*HT
      IF(HARM)940,930,930
  930 K=42-J
      DTMS(K)=DTMS(K)+SP*HARM
      SH(K)= SH(K)-SP
  940 CONTINUE
C*********************************************C
C    VERTICAL LOADS ON LEFT-HAND RAFTER      C
C*********************************************C
```

```
      950  WRITE(6,955)
      955  FORMAT( '  ARE THERE ANY HORIZONTAL LOADS ON LEFT-HAND RAFTER ',/)
           CALL SUBI(NUM)
           IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
           WRITE(6,8)  NUM
           IF(NUM-YES)1000,960,1000
      960  WRITE(6,925)
           READ(5,1)NPL
           WRITE(6,1)NPL
           SVL=0.0
           WRITE(6,924)
           DO 995 I=1,NPL
           READ (5, 1  )SP,HP
           WRITE(6,870)SP,FORCE,HP,LENGTH
           SP=Z*SP
           SVL=SVL+SP
           HP=ABS(HP)
           DO 990 J=1,11
           AK=FLOAT(J)/10.0-0.1
           K=10+J
           HARM=SPAN/2.0-HP-AK*SPAN/2.0
           IF (HARM)990,980,980
      980  DTMS(K)= DTMS(K)-SP*(SPAN*0.5-HP)
           TH(K)=TH(K)-SP*COSC
           SH(K)=SH(K)+SP/SEC
      990  CONTINUE
           DO 995 J=1,10
      995  DTMS(J)=DTMS(J)-SP*(SPAN/2.0-HP)
           DO 996 J=1,10
      996  TH(J)= TH(J)-SVL
     1000  WRITE(6,997)
      997  FORMAT(' ARE THERE ANY VERTICAL LOADS ON RIGHT-HAND RAFTER'//)
           CALL SUBI(NUM)
           IF (NUM.NE. NO.AND.NUM.NE.YES) GO TO 475
           WRITE(6,8)  NUM
     C*****************************************C
     C    VERTICAL LOADS ON RIGHT-HAND RAFTER    C
     C*****************************************C
           IF(NUM-YES) 49,1010,49
     1010  WRITE(6,925)
           READ(5, 1   ) NPR
           WRITE(6,1)NPR
           SVR=0.0
           WRITE(6,924)
           DO  1040 I=1,NPR
           WRITE(6,870)SP,FORCE,HP,LENGTH
           READ (5,  1  )SP,HP
           SP=Z*SP
```

```
      SVR=SVR+SP
      DO 1030 J=1,11
      AK=FLOAT(J)/10.0-0.1
      K=20+J
      HARM=AK*SPAN/2.0-HP
      IF(HARM) 1030,1020,1020
 1020 DTMS(K)=DTMS(K)-SP*HARM
      SH(K)=SH(K)-SP/SEC
      TH(K)=TH(K)-SP*COSC
 1030 CONTINUE
      DO 1040 J=32,41
 1040 DTMS(J)=DTMS(J)-SP*(SPAN/2.0-HP)
      DO 1050 J=32,41
 1050 TH(J)=TH(J)-SVR
      GO TO 49
      END
```

END OF COMPILATION: NO DIAGNOSTICS.

```
      SUBROUTINE SUB1(NUM)
      COMMON MPN(41) ,RESM(41),ANS(41),M(80)
      INTEGER YES,Y,E,S,O,NO   ,BLANK
     1 ,F,P,X,FIX,PIN,ERR
     2  ,A,TAP,U,T,UNIF
      DATA BLANK/' '/,YES/'YES'/,NO/'NO'/, FIX/'FIXED'/,PIN/'PINNED'/
     1  ,P/'P'/,F/'F'/,I/'I'/,X/'X'/,N/'N'/,O/'O'/, Y/'Y'/, E/'E'/
     1,S/'S'/,ERR/'ERR'/
     2 ,U/'U'/,T/'T'/,A/'A'/,TAP/'TAP'/, UNIF/'UNIF'/
      READ(5,100)  M
  100 FORMAT(80A1)
      DO 30 J=1,79
      IF (M(J).NE.BLANK)GO TO 39
   30 CONTINUE
   39 IF(J.GE.79) GO TO 40
      IF(M(J).EQ.Y    .AND.   M(J+1).EQ. E .AND. M(J+2) .EQ. S )GO TO 42
      IF(M(J).EQ. F   .AND.   M(J+1).EQ. I .AND. M(J+2) .EQ. X )GO TO 43
      IF(M(J).EQ. P   .AND.   M(J+1).EQ. I .AND. M(J+2) .EQ. N )GO TO 44
      IF(M(J).EQ.T.AND.M(J+1).EQ.A.AND.M(J+2).EQ.P)  GO TO 50
      IF(M(J).EQ.U.AND.M(J+1).EQ.N.AND.M(J+2).EQ.I.AND.M(J+3).EQ.F)
     1 GO TO 60
   40 IF(M(J).EQ. N   .AND.   M(J+1).EQ. O   ) GO TO 45
      NUM=ERR
      WRITE (6,100)    M
      GO TO 46
   42 NUM=YES
      GO TO 46
   43 NUM=FIX
      GO TO 46
   44 NUM=PIN
      GO TO 46
   45 NUM=NO
      GO TO 46
   50 NUM=TAP
      GO TO 46
   60 NUM=UNIF
   46 RETURN
      END
```

END OF COMPILATION: NO DIAGNOSTICS.

```
      SUBROUTINE SUB2(SEC,HT,SPAN,LENGTH,CF,CL,D1,D2,D3,D4,W,T,SEGMA,BF,
     1  RBAS,LBAS,COS1,COS2,FY)
      COMMON MPN(41) ,RESM(41),ANS(41),H(80)
      INTEGER PIN,RBAS
      REAL MPN
      DATA PIN/'PINNED'/
      FBN(DN,W,T,BF,CGM)=0.5-(T/(2.0*DN*W))*(1.0-CGM)*(BF+W/CGM)
      FMPN(DN,T, W, BF, COSG ,BN )= (BN*DN-T)**2*W/2.0+0.5*T*BF*(2.0*BN*
     1 DN-T)+0.5*W*((1.0-BN)*DN-T/COSG)**2.0+0.5*BF*T*COSG*(2.0*(1.0-BN)
     2 *DN-T/COSG)
      K=SEC*SPAN*0.5
   10 FORMAT(   )
      READ  (5,10)  D1,D2,D3,D4,W,T,BF,FY
      WRITE(6,12)  D1,LENGTH,D2,LENGTH,D3,LENGTH,D4,LENGTH,W,LENGTH,T,
     1 LENGTH,BF,LENGTH,FY
   12 FORMAT (' SECTION DEPTH AT :'///,
     1' COLUMN BASE ',T20,'=',T27,G15.5,A5,///
     2' COLUMN TOP',  T20,'=',T27,G15.5,A5,///
     3' COLUMN TOP WHICH '/,'CORRESPONDS TO THE',/' RAFTER BOTTOM',/T20,
     4'=', T27,G15.5,A5,///
     5' APEX'T20,'=',T27,G15.5,A5,///
     6' WEB THICKNESS',T20,'=',T27,G15.5,A5,///
     7' FLANGE THICKNESS',T20,'=',T27,G15.5,A5,///
     8 ' FLANGE WIDTH',T20,'=',T27,G15.5,A5,///
     9'  STEEL',T20,'=',T27,G15.5,'KSI'///)
      SEGMA=FY*CF/(CL*CL)
      BFT=0.5*BF/T
      IF(FY.EQ.36.0.AND.0.5*BF/T  .LE.8.5)  GO TO 30
      IF(FY.EQ.42.0.AND.0.5*BF/T  .LE.8.0)  GO TO 30
      IF(FY.EQ.45.0.AND.0.5*BF/T  .LE.7.4)  GO TO 30
```

```
      IF(FY.EQ.50.0.AND.0.5*BF/T .LE.7.0)  GO TO 30
      IF(FY.EQ.55.0.AND.0.5*BF/T .LE.6.6)  GO TO 30
      IF(FY.EQ.60.0.AND.0.5*BF/T .LE.6.3)  GO TO 30
      IF(FY.EQ.65.0.AND.0.5*BF/T .LE.6.0)  GO TO 30
      GO TO 50
   30 COS1 =HT/SQRT(HT**2+(D2-D1)**2)
      COS2=R/SQRT(R**2+(D3-D4)**2)
      DO 40 I=1,11
      J1=42-I
      J2=22-I
      J3=20+I
      X=FLOAT(I)/10.0 -1.0
      DN1=(D2-D1)*X+D1
      DN2=(D3-D4)*X+D4
      BN2=FBN(DN2,W,T,BF,COS2)
      BN1=FBN(DN1,W,T,BF,COS1)
      IF(I.EQ.11) GO TO  35
      MPN(I )=  (FMPN(DN1,T,W,BF,COS1 ,BN1 ))*SEGMA
      MPN(J1)=  MPN(I)
   35 MPN(J2)=  (FMPN(DN2,T,W,BF,COS2 ,BN2 ))*SEGMA
   40 MPN(J3)=  MPN(J2)
      GO TO 100
   50 IF(      FY.EQ.36.0.OR.
     1         FY.EQ.42.0.OR.
     1         FY.EQ.45.0.OR.
     1         FY.EQ.50.0.OR.
     1         FY.EQ.55.0.OR.
     1         FY.EQ.60.0.OR.
     1         FY.EQ.65.0   )GO TO 70
      WRITE(6,65)   FY
   65 FORMAT('       THIS STEEL DOES NOT  CORRESPONDS TO THE AISC SPECIFI
     1CATIONS OF 1973 FY=',G15.3,' KSI ')
      STOP
   70 WRITE(6,75)  BFT
   75 FORMAT('      THIS SECTION UNDERGOES FAILURE DUE TO LOCAL BUCKLING'
     1 ,' IN FLANGE'
     1,//'  CHANGE BF/2T'  ,'=',G15.5)
      STOP
  100 IF(RBAS .EQ.PIN)  MPN(41)=0.0
      IF(LBAS .EQ.PIN)  MPN( 1)=0.0
      RETURN
      END

END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
      SUBROUTINE SUB3(COS1,COS2,D1,D2,D3,D4,W,BF,T,SEGMA,RBAS,LBAS,FY)
      COMMON MPN(41) ,RESM(41),ANS(41),M(80),THRUST(41) ,SHEAR(41)
      INTEGER YES,NO, ANS,ASTR ,PIN  ,RBAS
      REAL MPN
      DATA  ASTR/'*****'/, NO/'NO'/,YES/'YES'/
      DATA PIN/'PINNED'/
      Z(FAC1,FAC4,CGM,T)=
     1   W* ((FAC1*FAC1+FAC4*FAC4)*0.5+FAC0*T*(FAC1+FAC4*CGM+T))
      FBN(DN,W,T,BF,CGM)= 0.5-(T/(2.0*DN*W))*(1.0-CGM)*(BF+W/CGM)
      FAC0=BF/W
      DO 410 J=1,41
      IF(J-10) 110,110,120
  110 X=FLOAT(J)/10.-0.1
      DN=(D2-D1)*X+D1
      CGM=COS1
      GO TO 170
  120 IF(J-21) 130,130,140
  130 J1=J-10
      X=FLOAT(J1)/10.0   -0.1
      DN=D3-(D3-D4)*X
      CGM=COS2
      GO TO 170
  140 IF(J-31) 150,150,160
  150 J1=J-21
      X=FLOAT(J1)/10.0
      DN=D4+(D3-D4)*X
```

```
      CGM=COS2
 160  J1=J-31
      X=FLOAT(J1)/10.0
      DN=D2-(D2-D1)*X
      CGM=COS1
 170  BN=FBN(DN,C,T,BF,CGM)
      FAC1=BN*DN-T
      WOT= DN/W
      FAC2= T*(1.0+CGM)*(BF-W/CGM)+W*DN
      PPG=ABS(THRUST(J))/FAC2
      PPY=PPG/SEGMA
      FAC4= (1.0-BN)*DN-T/CGM
      FAC5=-(FAC1**2*(FACO-1.0)-FAC4**2*(FACO*CGM**2-1.   ))/FACO
      FAC6=FAC1*(FACO-1.0)+FAC4*(FACO*CGM**2-1.0)
      FAC3=( FAC2/W)*(PPY)
      Z1=Z(FAC1,FAC4,CGM,T)
      FAC10= SQRT((2.0*FAC1*FAC3*(FACO-1.0)+FAC3**2)/FACO)
      YO=0.5*FAC3
      Y1=YO
      IF(YO.LE.FAC1) GO TO 40
      IF( CGM .EQ. 1.0) GO TO 75
      YO= (FAC3+FAC1*(FACO-1.0)- FAC10)/(FACO-1.0)
      IF (YO.LT.FAC1.OR. YO.GT.BN*DN) GO TO 55
      Y1= SQRT(FACO*YO**2+FAC1**2*(1.0-FACO))
      IF(YO.LE.BN*DN.AND.Y1.LE.FAC4)  GO TO 60
 55   YO= (FAC3+FAC1*(FACO-1.0)+ FAC10)/(FACO-1.0)
      IF( YO.LT. FAC1 .OR. YO .GT. BN*DN ) GO TO  44
      Y1= SQRT(FACO*YO**2+FAC1**2*(1.0-FACO))
      IF(YO.LE.BN*DN.AND.Y1.LE.FAC4)  GO TO 60
 44   FAC7=FAC3+FAC6
      FAC9= FAC7**2+FACO**2*FAC5*(1.0-CGM**2  )
      FAC8= SQRT(FAC9)
      YO=(  FAC7+CGM*FAC8)/(FACO*(1.0-CGM**2))
      Y1= SQRT( FAC5+ YO**2)/CGM
      IF (Y1.GE.FAC4.AND.Y1.LE.(1.0-BN)*DN.AND.YO.GE.FAC1.AND.YO.LE.
     1BN*DN) GO TO  60
      YO=(  FAC7-CGM*FAC8)/(FACO*(1.0-CGM**2))
      Y1= SQRT( FAC5+ YO**2)/CGM
      IF (Y1.GE.FAC4.AND.Y1.LE.(1.0-BN)*DN.AND.YO.GE.FAC1.AND.YO.LE.
     1BN*DN) GO TO  60
 40   MPN(J)= SEGMA*(Z1-(FAC2**2*PPY**2)/(4.0*W))
      GO TO 80
 60   MPN(J)= SEGMA*(Z1-W*(FACO*YO**2+FAC1**2*(1.0-FACO)))
      GO TO 80
 75   YO=(0.5*FAC3+FAC1*(FACO-1.0))/FACO
```

```
      Y1=Y0
      GO TO 60
   60 IF(RBAS .EQ.PIN)  MPN(41)=0.0
      IF(LBAS .EQ.PIN)  MPN( 1)=0.0
      I=J
      IF(ABS(SHEAR(J)).LE. 0.55*SEGMA*W*DN)  GO TO 90
      WRITE(6,220)     I
  220 FORMAT( ' SECTION NO.',I5,' WEB NEED TO BE STIFFENED'/,' BECAUSE T
     HE SHEAR FORCE IS > THE ALLOWABLE'/,' .55*FY*W*DN=',G15.5)
   90 IF (PPY.GT.0.27) GO TO  180
      DTH=412.0*(1.0-1.4*PPY)/SQRT(FY)
  180 DTH=257.0/SQRT(FY)
      GO TO 190
  190 IF(DN/W.GT.DTH) GO TO 200
      GO TO 401
  200 WRITE(6,210)       I ,AUT    ,DTH
  210 FORMAT(1X,12('*')/,' *  WARNING * '/,1X,12('*'),/
     1          ' SECTION NO', I5, ' UNDERGOES FAILURE DUE TO LOCAL BUCKL
     1ING IN WEB'//,'  DN/W= ',G15.5,/' THE ALLOWABLE IS =',G15.5//)
  401 IF (ABS(RESM(I))-0.99*MPN(I)) 406,405,405
  405 IF (ABS(RESM(I))-1.01*MPN(I) )407,408,408
  406 ANS(I)=NO
      GO TO 410
  407 ANS(I)=ASTR
      GO TO 410
  408 ANS(I)=YES
  410 CONTINUE
      RETURN
      END
```

END OF COMPILATION: NO DIAGNOSTICS.

```
      SUBROUTINE UNITS(LENGTH,FORCE,CF,CL)
      DIMENSION MI(80)
      INTEGER FORCE,CM,TON, T,O,B,FT,C ,BLANK,G ,P,F,S
      DATA KG/'KG'/,TON/'TON'/,LB/'LB'/,T/'T'/,G/ 'G'/,O/'O'/,B/'B'/,
     1FT/'FT'/,IN/'IN'/,CM/'CM'/,C/'C'/,BLANK/' '/,I/'I'/,KIPS
     2/'KIPS'/,F/'F'/,P/'P'/,S/'S'/,K/'K'/,L/'L'/   ,N/'N'/   ,M/'M'/
      READ(5,1) MI
 1    FORMAT(80A1)
      J2=1
      KL=1
 5    DO 10 JI=J2,80
      IF(MI(JI)-BLANK) 20,10,20
 10   CONTINUE
 20   IF ( MI(JI) .EQ.K .AND.MI(JI+1).EQ. G) GO TO   40
      IF ( MI(JI).EQ.K.AND.MI(JI+1).EQ.I.AND.MI(JI+2).EQ.P.AND.MI(JI+3)
     1.EQ.S ) GO TO 50
      IF ( MI(JI) .EQ.L .AND.MI(JI+1).EQ. B) GO TO  60
      IF ( MI(JI).EQ.T.AND.MI(JI+1).EQ.O.AND.MI(JI+2).EQ.N ) GO TO  70
      IF ( MI(JI) .EQ.F .AND.MI(JI+1).EQ. T) GO TO  80
      IF ( MI(JI) .EQ.C .AND.MI(JI+1).EQ. M) GO TO   90
      IF ( MI(JI) .EQ.I .AND.MI(JI+1).EQ. N) GO TO   100
      IF ( MI(JI) .EQ.M) GO TO 110
      WRITE(6,33)
 33   FORMAT(1X,55('*'),/' USER DOES NOT SPECIFIED RIGHT UNITS',/
     11X,('*'))
      STOP
 40   FORCE=KG
```

```
          CF=453.592
          GO TO 120
    50    FORCE=KIPS
          CF=  1.0
          GO TO 120
    60    FORCE= LB
          CF=  1000.0
          GO TO 120
    70    FORCE =TON
          CF=0.453592
          GO TO 120
    80    LENGTH=FT
          CL=1.0/12.0
          GO TO 120
    90    LENGTH= CM
          CL=  2.54001
          GO TO 120
   100    LENGTH= IN
          CL= 1.0
          GO TO 120
   110    LENGTH= M
          CL=  0.0254001
   120    KL =KL+1
          IF(KL.GT.2) GO TO 200
          DO 130  J2=J1,80
          IF(PI(J2)-BLANK)130, 5,130
   130    CONTINUE
   200    WRITE(6,440) FORCE,LENGTH
   440    FORMAT (//1X, ' FORCE UNIT ',A4,//'  LENGTH UNIT ', A4)
          RETURN
          END

END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
@XQT PROG.ANWA
                  *******************************************
                  *  PLASTIC DESIGN OF INDUSTRIAL RIGID FRAMES  *
                  *******************************************
 PROBLEM INITIATION


 ************************************************************************
 *     ANALYSIS NO 1                                                    *
 ************************************************************************


 TYPE OF MEMBER SAY TAPERED,OR UNIFORM


  TYPE  TAP


 INPUT THE SPECIFIED UNITS ,LENGTH AND FORCE


  FORCE UNIT LB

  LENGTH UNIT FT
 INPUT THE FRAME DIMENSIONS SPAN,EAVES HIEGHT,DEGREE OF PITCH AND FRAMES SPACING



     SPAN                 =       72.000    FT

     EAVS HEIGHT          =       33.000    FT

     DEGREE OF PITCH      =       15.000    DEGREE

     FRAME SPACING        =       24.000    FT


 INPUT THE WORKING LOAD DATA VERTICAL UNIFORM LOADING INTENSITY
```

```
WORKING LOAD

VERTICAL UNIFORM LOADING INTENSITY =        10.000   LB  /SQUARE FT


ARE THERE PRESSURES NORMAL TO COVERING ?

 YES

INPUT FOUR NORMAL SURFACE PRESSURES FOR THE
LEFT-HAND COLUMN,LEFT-HAND RAFTER,RIGHT-HAND RAFTER
AND RIGHT-HAND COLUMN WITH PRESSURE POSITIVE IF
ACTING INWARDS ON THE BULDING.


PRESSURE ON THE LEFT-HAND COLUMN =       24.300   LB  /SQUARE FT

PRESSURE ON THE LEFT-HAND RAFTER =       6.2890   LB  /SQUARE FT

PRESSURE ON THE RIGHT-HAND RAFTER=       .00000   LB  /SQUARE FT

PRESSURE ON THE RIGHT-HAND COLUMN=       .00000   LB   /SQUARE FT


INPUT VERTICAL CONCENTRATED APEX LOAD AND LOAD FACTOR

CONCENTRATED APEX LOAD =       .00000   LB

LOAD FACTOR=       1.4000
```

ARE THERE ANY OTHER CONCENTRATED LOADS?

NO

ARE THERE ANY GANTRY CRANE LOADS?

YES

INPUT THE HEIGHT OF THE GANTRY CRANE RAILS AND
THE OFFSET OF THE CRANE RAILS
HEIGHT OF CRANE RAIL = 27.000 FT

OFFSET OF CRANE RAIL = 2.0000 FT

INPUT WORKING VALUES OF VERTICAL GANTRY CRANE FORCES LEFT-HAND COLUMN FIRST

WORKING VALUES OF VERTICAL CRANE FORCES

WORKING VERTICAL CRANE FORCE ON LEFT-HAND COLUMN= 10000. LB

WORKING VERTICAL CRANE FORCE ON RIGHT-HAND COLUMN= 4000.0 LB

WORKING VALUES OF HORIZONTAL CRANE FORCES

HORIZONTAL CRANE FORCE ON LEFT-HAND COLUMN = 500.00 LB

HORIZONTAL CRANE FORCE ON RIGHT-HAND COLUMN= 200.00 LB

DO YOU WANT TO SEE THE TWIN CANTILEVER MOMENT?

YES

THE TWIN CANTILEVER MOMENT SHEAR AND THRUST :

SECTION NO.	MOMENT	SHEAR	THRUST
1	-.92323+06	29682.	-33703.
2	-.82972+06	26988.	-33703.
3	-.74511+06	24293.	-33703.
4	-.66938+06	21599.	-33703.
5	-.60255+06	18905.	-33703.
6	-.54461+06	16210.	-33703.
7	-.49557+06	13516.	-33703.
8	-.45541+06	10821.	-33703.
9	-.42414+06	8127.1	-33703.
10	-.37566+06	4732.7	-19703.
11	-.36449+06	19559.	-3130.7
12	-.29524+06	17603.	-2817.6
13	-.23327+06	15647.	-2504.5
14	-.17860+06	13692.	-2191.5
15	-.13122+06	11736.	-1878.4
16	-91122.	9779.7	-1565.3
17	-58318.	7823.7	-1252.3
18	-32804.	5367.8	-939.20
19	-14580.	3911.9	-626.14
20	-3644.9	1955.9	-313.07
21	.00000	.00000	.00000

22	-2177.3	-1166.4	-313.07
23	-8709.1	-2336.8	-626.14
24	-19596.	-3505.2	-939.20
25	-34836.	-4673.5	-1252.3
26	-54432.	-5841.9	-1565.3
27	-78382.	-7010.3	-1878.4
28	-.10669+06	-8178.7	-2191.5
29	-.13935+06	-9347.1	-2504.5
30	-.17636+06	-10515.	-2817.6
31	-.21773+06	-11684.	-3130.7
32	-.21773+06	.00000	-12096.
33	-.22876+06	280.00	-17696.
34	-.22784+06	280.00	-17696.
35	-.22691+06	280.00	-17696.
36	-.22599+06	280.00	-17696.
37	-.22506+06	280.00	-17696.
38	-.22414+06	280.00	-17696.
39	-.22322+06	280.00	-17696.
40	-.22229+06	280.00	-17696.
41	-.22137+06	280.00	-17696.

WHAT KIND OF BASES?

INPUT FIXED OR PINNED ,LEFT-HAND BASE FIRST

LEFT-HAND BASE IS FIXED

RIGHT-HAND BASE IS FIXED

INPUT THE SECTION DIMENSIONS,D1,D2,D3,D4,W,T,BF,FY
SECTION DEPTH AT :

COLUMN BASE = .86000 FT

COLUMN TOP = 1.3500 FT

COLUMN TOP WHICH ORRESPONDS TO THE RAFTER BOTTOM	=	1.2000	FT
APEX	=	.85000	FT
WEB THICKNESS	=	.45000-01	FT
FLANGE THICKNESS	=	.52090-01	FT
FLANGE WIDTH	=	.50000	FT
STEEL	=	36.000	KSI

NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO INDICATE THE MOMENT SIGN

THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN

TO INDICATE THE MOMENT SIGN ARE:

-1 17 -31 41

SECTION NO.	SHEAR	THRUST
1	.1857+05	-.2670+05
2	.1588+05	-.2670+05
3	.1319+05	-.2670+05
4	.1049+05	-.2670+05
5	7797.	-.2670+05
6	5103.	-.2670+05
7	2406.	-.2670+05
8	-286.0	-.2670+05
9	-2980.	-.2670+05
10	-6375.	-.1270+05
11	9918.	-.1205+05
12	7962.	-.1173+05
13	6000.	-.1142+05
14	4050.	-.1111+05
15	2094.	-.1079+05
16	136.0	-.1048+05
17	-1818.	-.1017+05
18	-3774.	-9855.
19	-5730.	-9542.
20	-7686.	-9229.
21	9642.	-8916.
22	8473.	-.1280+05
23	7365.	-.1317+05
24	6136.	-.1340+05
25	4968.	-.1379+05
26	3800.	-.1411+05
27	2631.	-.1442+05
28	1463.	-.1473+05
29	294.6	-.1505+05
30	-673.6	-.1536+05
31	-2042.	-.1567+05
32	.1111+05	-.1910+05
33	.1139+05	-.2470+05
34	.1139+05	-.2470+05
35	.1139+05	-.2470+05
36	.1139+05	-.2470+05
37	.1139+05	-.2470+05
38	.1139+05	-.2470+05
39	.1139+05	-.2470+05
40	.1139+05	-.2470+05
41	.1139+05	-.2470+05

LOCATION OF BENDING MOMENT MT >MPC:

SECTION NO.			PLASTIC MOMENT CAPACITY
1	-.987+05	NO	.142+06
2	-.419+05	NO	.153+06
3	.606+04	NO	.164+06
4	.451+05	NO	.176+06
5	.753+05	NO	.188+06
6	.966+05	NO	.200+06
7	.109+06	NO	.212+06
8	.113+06	NO	.225+06
9	.107+06	NO	.238+06
10	.119+06	NO	.252+06
11	.935+05	NO	.225+06
12	.127+06	NO	.216+06
13	.153+06	NO	.207+06
14	.172+06	NO	.198+06
15	.183+06	NO	.189+06
16	.187+06	YES	.181+06
17	.184+06	YES	.172+06
18	.174+06	YES	.164+06
19	.156+06	***	.156+06
20	.131+06	NO	.146+06
21	.986+05	NO	.140+06
22	.819+05	NO	.401+06
23	.609+05	NO	.384+06
24	.355+05	NO	.369+06
25	.575+04	NO	.353+06
26	-.264+05	NO	.338+06
27	-.668+05	NO	.323+06
28	-.110+06	NO	.308+06
29	-.157+06	NO	.294+06
30	-.208+06	NO	.279+06
31	-.264+06	***	.265+06
32	-.228+06	NO	.252+06
33	-.202+06	NO	.238+06
34	-.164+06	NO	.225+06
35	-.127+06	NO	.212+06
36	-.892+05	NO	.210+06
37	-.516+05	NO	.188+06
38	-.140+05	NO	.176+06
39	.236+05	NO	.164+06
40	.612+05	NO	.153+06
41	.987+05	NO	.142+06

```
DO YOU WANT TO SEE THE BASE REACTIONS?

 YES


V1= .1460+05   H1=  .1857+05   V41= .1261+05   H41= .1139+05

DO YOU WANT TO TRY ANOTHER HINGE PATTERN?

 YES

NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO INDICATE THE MOMENT SIGN

THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN

TO INDICATE THE MOMENT SIGN ARE:

  -1    19   -33    41
```

SECTION NO.	SHEAR	THRUST
1	.1802+05	-.2722+05
2	.1532+05	-.2722+05
3	.1263+05	-.2722+05
4	9933.	-.2722+05
5	7238.	-.2722+05
6	4544.	-.2722+05
7	1850.	-.2722+05
8	-844.7	-.2722+05
9	-3139.	-.2722+05
10	-6933.	-.1322+05
11	.1028+05	-.1272+05
12	8324.	-.1241+05
13	6368.	-.1210+05
14	4412.	-.1179+05
15	2456.	-.1147+05
16	500.1	-.1116+05
17	-1456.	-.1084+05
18	-3412.	-.1053+05
19	-5368.	-.1022+05
20	-7324.	-9904.
21	9280.	-9591.
22	8111.	-.1326+05
23	6943.	-.1357+05
24	5774.	-.1389+05
25	4606.	-.1420+05
26	3438.	-.1451+05
27	2269.	-.1482+05
28	1101.	-.1514+05
29	-67.49	-.1545+05
30	-1236.	-.1576+05
31	-2404.	-.1608+05
32	.1167+05	-.1852+05
33	.1195+05	-.2418+05
34	.1195+05	-.2418+05
35	.1195+05	-.2418+05
36	.1195+05	-.2418+05
37	.1195+05	-.2418+05
38	.1195+05	-.2418+05
39	.1195+05	-.2418+05
40	.1195+05	-.2418+05
41	.1195+05	-.2418+05

LOCATION OF BENDING MOMENT MT >MPC:

SECTION NO.			PLASTIC MOMENT CAPACITY
1	-.118+06	NO	.142+06
2	-.626+05	NO	.153+06
3	-.164+05	NO	.164+06
4	.208+05	NO	.176+06
5	.491+05	NO	.188+06
6	.686+05	NO	.200+06
7	.791+05	NO	.212+06
8	.808+05	NO	.225+06
9	.735+05	NO	.238+06
10	.835+05	NO	.252+06
11	.562+05	NO	.225+06
12	.909+05	NO	.216+06
13	.118+06	NO	.207+06
14	.138+06	NO	.198+06
15	.151+06	NO	.189+06
16	.157+06	NO	.181+06
17	.155+06	NO	.172+06
18	.146+06	NO	.164+06
19	.129+06	NO	.156+06
20	.106+06	NO	.148+06
21	.748+05	NO	.140+06
22	.606+05	NO	.401+06
23	.420+05	NO	.384+06
24	.190+05	NO	.369+06
25	-.832+04	NO	.353+06
26	-.400+05	NO	.338+06
27	-.760+05	NO	.323+06
28	-.116+06	NO	.308+06
29	-.161+06	NO	.294+06
30	-.210+06	NO	.279+06
31	-.264+06	***	.265+06
32	-.225+06	NO	.252+06
33	-.198+06	NO	.238+06
34	-.158+06	NO	.225+06
35	-.119+06	NO	.212+06
36	-.795+05	NO	.200+06
37	-.400+05	NO	.188+06
38	-608.	NO	.176+06
39	.388+05	NO	.164+06
40	.782+05	NO	.153+06
41	.118+06	NO	.142+06

DO YOU WANT TO SEE THE BASE REACTIONS?

YES

V1= .1513+05   H1= .1802+05   V41= .1206+05   H41= .1195+05

DO YOU WANT TO TRY ANOTHER HINGE PATTERN?

YES

NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO INDICATE THE MOMENT SIGN

THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN

TO INDICATE THE MOMENT SIGN ARE:

-1   14   -33   41

SECTION NO.	SHEAR	THRUST
1	.1647+05	-.2710+05
2	.1578+05	-.2710+05
3	.1309+05	-.2710+05
4	.1039+05	-.2710+05
5	7497.	-.2710+05
6	5002.	-.2710+05
7	2308.	-.2710+05
8	-386.3	-.2710+05

9	-3081.	-.2710+05
10	-6475.	-.1310+05
11	.1026+05	-.1225+05
12	6321.	-.1193+05
13	6365.	-.1162+05
14	4409.	-.1131+05
15	2453.	-.1099+05
16	497.2	-.1068+05
17	-1459.	-.1037+05
18	-3415.	-.1006+05
19	-5371.	-9742.
20	-7327.	-9429.
21	9282.	-9116.
22	8114.	-.1285+05
23	6946.	-.1316+05
24	5777.	-.1348+05
25	4609.	-.1379+05
26	3441.	-.1410+05
27	2272.	-.1441+05
28	1104.	-.1473+05
29	-64.57	-.1504+05
30	-1233.	-.1535+05
31	-2401.	-.1567+05
32	.1121+05	-.1870+05
33	.1149+05	-.2430+05
34	.1149+05	-.2430+05
35	.1149+05	-.2430+05
36	.1149+05	-.2430+05
37	.1149+05	-.2430+05
38	.1149+05	-.2430+05
39	.1149+05	-.2430+05
40	.1149+05	-.2430+05
41	.1149+05	-.2430+05

LOCATION OF BENDING MOMENT MT >MPC:

SECTION NO.			PLASTIC MOMENT CAPACITY
1	-.113+06	NO	.142+06
2	-.565+05	NO	.153+06
3	-.687+04	NO	.164+06
4	.299+05	NO	.176+06
5	.597+05	NO	.188+06
6	.807+05	NO	.200+06
7	.927+05	NO	.212+06
8	.959+05	NO	.225+06
9	.902+05	NO	.238+06
10	.102+06	NO	.252+06
11	.759+05	NO	.225+06
12	.111+06	NO	.216+06
13	.138+06	NO	.207+06
14	.158+06	NO	.198+06
15	.171+06	NO	.189+06
16	.176+06	NO	.181+06
17	.174+06	YES	.172+06
18	.165+06	***	.164+06
19	.149+06	NO	.156+06
20	.125+06	NO	.148+06
21	.944+05	NO	.140+06
22	.792+05	NO	.401+06
23	.597+05	NO	.384+06
24	.359+05	NO	.369+06
25	.766+04	NO	.353+06
26	-.249+05	NO	.338+06
27	-.618+05	NO	.373+06
28	-.103+06	NO	.306+06
29	-.149+06	NO	.294+06
30	-.199+06	NO	.279+06
31	-.253+06	NO	.265+06
32	-.216+06	NO	.252+06
33	-.190+06	NO	.238+06
34	-.152+06	NO	.225+06
35	-.114+06	NO	.212+06
36	-.764+05	NO	.200+06
37	-.305+05	NO	.188+06
38	-579.	NO	.176+06
39	.373+05	NO	.164+06
40	.752+05	NO	.153+06

41 .113+06 NO .142+06

DO YOU WANT TO SEE THE BASE REACTIONS?

YES

V1= .1500+05 H1= .1847+05 V41= .1221+05 H41= .1149+05

DO YOU WANT TO TRY ANOTHER HINGE PATTERN?

YES

NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO INDICATE THE MOMENT SIGN

THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN

TO INDICATE THE MOMENT SIGN ARE:

-1 12 -33 41

SECTION NO.	SHEAR	THRUST
1	.1954+05	-.2680+05
2	.1665+05	-.2680+05
3	.1415+05	-.2680+05
4	.1146+05	-.2680+05
5	8764.	-.2680+05
6	6070.	-.2680+05
7	3375.	-.2680+05
8	680.7	-.2680+05

9	-2014.	-.2260+05
10	-5400.	-.1280+05
11	.1027+05	-.1114+05
12	8315.	-.1083+05
13	6359.	-.1051+05
14	4404.	-.1020+05
15	2440.	-9888.
16	491.6	-9575.
17	-1464.	-9262.
18	-3420.	-8949.
19	-5376.	-8636.
20	-7332.	-8323.
21	9288.	-8010.
22	8120.	-.1127+05
23	6951.	-.1221+05
24	5783.	-.1252+05
25	4615.	-.1283+05
26	3446.	-.1315+05
27	2278.	-.1346+05
28	1109.	-.1377+05
29	-59.02	-.1409+05
30	-1227.	-.1440+05
31	-2396.	-.1471+05
32	.1014+05	-.1899+05
33	.1042+05	-.2459+05
34	.1042+05	-.2459+05
35	.1042+05	-.2459+05
36	.1042+05	-.2459+05
37	.1042+05	-.2459+05
38	.1042+05	-.2459+05
39	.1042+05	-.2459+05
40	.1042+05	-.2459+05
41	.1042+05	-.2459+05

LOCATION OF BENDING MOMENT MT >MPC:

SECTION NO.			PLASTIC MOMENT CAPACITY
1	-.103+06	NO	.142+06
2	-.425+05	NO	.153+06
3	.866+04	NO	.164+06
4	.509+05	NO	.176+06
5	.843+05	NO	.188+06
6	.109+06	NO	.200+06
7	.124+06	NO	.212+06
8	.131+06	NO	.225+06
9	.129+06	NO	.238+06
10	.144+06	NO	.252+06
11	.122+06	NO	.225+06
12	.156+06	NO	.216+06
13	.184+06	NO	.207+06
14	.204+06	YES	.198+06
15	.216+06	YES	.189+06
16	.222+06	YES	.181+06
17	.220+06	YES	.172+06
18	.211+06	YES	.164+06
19	.195+06	YES	.156+06
20	.171+06	YES	.148+06
21	.140+06	***	.140+06
22	.123+06	NO	.401+06
23	.101+06	NO	.384+06
24	.751+05	NO	.369+06
25	.448+05	NO	.353+06
26	.102+05	NO	.338+06
27	-.286+05	NO	.323+06
28	-.722+05	NO	.308+06
29	-.120+06	NO	.294+06
30	-.172+06	NO	.279+06
31	-.228+06	NO	.266+06
32	-.195+06	NO	.252+06
33	-.172+06	NO	.238+06
34	-.138+06	NO	.225+06
35	-.104+06	NO	.212+06

36	-.693+05	NO	.200+06
37	-.349+05	NO	.188+06
38	-526.	NO	.176+06
39	.339+05	NO	.164+06
40	.683+05	NO	.153+06
41	.103+06	NO	.142+06

DO YOU WANT TO SEE THE BASE REACTIONS?

YES

V1= .1471+05   H1= .1954+05   V41= .1250+05   H41= .1042+05

DO YOU WANT TO TRY ANOTHER HINGE PATTERN?

YES

NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO INDICATE THE MOMENT SIGN

THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN

TO INDICATE THE MOMENT SIGN ARE:

-1   12   -25   41

SECTION NO.	SHEAR	THRUST
1	.1576+05	-.2533+05
2	.1306+05	-.2533+05
3	.1037+05	-.2533+05
4	7672.	-.2533+05
5	4978.	-.2533+05
6	2283.	-.2533+05
7	-411.2	-.2533+05
8	-3106.	-.2533+05
9	-5800.	-.2533+05
10	-9194.	-.1133+05
11	7867.	-.1442+05
12	5911.	-.1410+05
13	3955.	-.1379+05
14	1999.	-.134 +05
15	42.84	-.1316+05
16	-1913.	-.1285+05
17	-3869.	-.1254+05
18	-5825.	-.1222+05
19	-7781.	-.1191+05
20	-9737.	-.1160+05
21	.1169+05	-.1127+05
22	.1052+05	-.1593+05
23	9356.	-.1625+05
24	8188.	-.1656+05
25	7019.	-.1687+05
26	5851.	-.1719+05
27	4682.	-.1750+05
28	3514.	-.1781+05
29	2346.	-.1812+05
30	1177.	-.1844+05
31	8.739	-.1875+05
32	.1393+05	-.2047+05
33	.1421+05	-.2607+05
34	.1421+05	-.2607+05
35	.1421+05	-.2607+05
36	.1421+05	-.2607+05
37	.1421+05	-.2607+05
38	.1421+05	-.2607+05
39	.1421+05	-.2607+05
40	.1421+05	-.2607+05
41	.1421+05	-.2607+05

LOCATION OF BENDING MOMENT MT >MPC:

SECTION NO.			PLASTIC MOMENT CAPACITY
1	-.495+05	NO	.142+06
2	-.192+04	NO	.153+06
3	.367+05	NO	.164+06
4	.665+05	NO	.176+06
5	.874+05	NO	.188+06
6	.994+05	NO	.200+06
7	.102+06	NO	.212+06
8	.966+05	NO	.225+06
9	.819+05	NO	.238+06
10	.845+05	NO	.252+06
11	.497+05	NO	.225+06
12	.754+05	NO	.216+06
13	.937+05	NO	.207+06
14	.105+06	NO	.198+06
15	.109+06	NO	.189+06
16	.105+06	NO	.181+06
17	.944+05	NO	.172+06
18	.763+05	NO	.164+06
19	.510+05	NO	.156+06
20	.183+05	NO	.148+06
21	-.216+05	NO	.140+06
22	-.405+05	NO	.400+06
23	-.637+05	NO	.384+06
24	-.913+05	NO	.368+06
25	-.123+06	NO	.353+06
26	-.160+06	NO	.338+06
27	-.200+06	NO	.323+06
28	-.245+06	NO	.308+06
29	-.295+06	***	.293+06
30	-.348+06	YES	.279+06

31	-.406+06	YES	.265+06
32	-.360+06	YES	.252+06
33	-.326+06	YES	.238+06
34	-.279+06	YES	.225+06
35	-.232+06	YES	.212+06
36	-.185+06	NO	.200+06
37	-.138+06	NO	.188+06
38	-.911+05	NO	.176+06
39	-.443+05	NO	.164+06
40	.262+04	NO	.153+06
41	.495+05	NO	.142+06

DO YOU WANT TO SEE THE BASE REACTIONS?

YES

V1= .1324+05   H1= .1576+05   V41= .1398+05   H41= .1421+05

DO YOU WANT TO TRY ANOTHER HINGE PATTERN?

NO

```
DO YOU WANT TO ANALYSE ANOTHER FRAME?


  YES

                 ***********************************************
                 *  PLASTIC DESIGN OF INDUSTRIAL RIGID FRAMES  *
                 ***********************************************
PROBLEM INITIATION


**************************************************************************
*        ANALYSIS NO 2                                                   *
**************************************************************************


TYPE OF MEMBER SAY TAPERED,OR UNIFORM


 TYPE  UNIF


INPUT THE SPECIFIED UNITS ,LENGTH AND FORCE
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FORCE UNIT LB

LENGTH UNIT FT
INPUT THE FRAME DIMENSIONS SPAN,EAVES HIEGHT,DEGREE OF PITCH AND FRAMES SPACING



   SPAN                 =        72.000   FT

   EAVS HEIGHT          =        33.000   FT

   DEGREE OF PITCH      =        15.000   DEGREE

   FRAME SPACING        =        24.000   FT

INPUT THE WORKING LOAD DATA VERTICAL UNIFORM LOADING INTENSITY

 WORKING LOAD

 VERTICAL UNIFORM LOADING INTENSITY =       10.000   LB  /SQUARE FT


 ARE THERE PRESSURES NORMAL TO COVERING ?


  YES

INPUT FOUR NORMAL SURFACE PRESSURES FOR THE
LEFT-HAND COLUMN,LEFT-HAND RAFTER,RIGHT-HAND RAFTER
AND RIGHT-HAND COLUMN WITH PRESSURE POSITIVE IF
ACTING INWARDS ON THE BULDING.
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```
PRESSURE ON THE LEFT-HAND COLUMN =        24.300   LB  /SQUARE FT

PRESSURE ON THE LEFT-HAND RAFTER =        6.2890   LB  /SQUARE FT

PRESSURE ON THE RIGHT-HAND RAFTER=        .00000   LB  /SQUARE FT

PRESSURE ON THE RIGHT-HAND COLUMN=        .00000   LB   /SQUARE FT


INPUT VERTICAL CONCENTRATED APEX LOAD AND LOAD FACTOR

CONCENTRATED APEX LOAD =       .00000    LB

LOAD FACTOR=       1.4000


ARE THERE ANY OTHER CONCENTRATED LOADS?


  NO


ARE THERE ANY GANTRY CRANE LOADS?


  YES


INPUT THE HEIGHT OF THE GANTRY CRANE RAILS AND
 THE OFFSET OF THE CRANE RAILS
HEIGHT OF CRANE RAIL =       27.000    FT


OFFSET OF CRANE RAIL =       2.0000    FT
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```
INPUT WORKING  VALUES OF VERTICAL GANTRY CRANE FORCES LEFT-HAND COLUMN FIRST

WORKING VALUES OF VERTICAL CRANE FORCES

WORKING VERTICAL CRANE FORCE ON LEFT-HAND COLUMN=        10000.    LB

WORKING VERTICAL CRANE FORCE ON RIGHT-HAND COLUMN=        4000.0    LB

WORKING VALUES OF HORIZONTAL CRANE FORCES

        HORIZONTAL CRANE FORCE ON LEFT-HAND COLUMN =       500.00    LB

        HORIZONTAL CRANE FORCE ON RIGHT-HAND COLUMN=       200.00    LB

DO YOU WANT TO SEE THE TWIN CANTILEVER MOMENT?

  YES

THE TWIN CANTILEVER MOMENT SHEAR AND THRUST :

---------------------------------------------------------
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SECTION NO.	MOMENT	SHEAR	THRUST
1	-.92323+06	29682.	-33703.
2	-.82972+06	26958.	-33703.
3	-.74511+06	24293.	-33703.
4	-.66938+06	21599.	-33703.
5	-.60255+06	18905.	-33703.
6	-.54461+06	16210.	-33703.
7	-.49557+06	13516.	-33703.
8	-.45541+06	10821.	-33703.
9	-.42414+06	8127.1	-33703.
10	-.37566+06	4732.7	-19703.
11	-.36449+06	19559.	-3130.7
12	-.29524+06	17603.	-2817.6
13	-.23327+06	15647.	-2504.5
14	-.17860+06	13692.	-2191.5
15	-.13122+06	11736.	-1878.4
16	-91122.	9779.7	-1565.3
17	-58318.	7823.7	-1252.3
18	-32804.	5867.8	-939.20
19	-14580.	3911.9	-626.14
20	-3644.9	1955.9	-313.07
21	.00000	.00000	.00000
22	-2177.3	-1168.4	-313.07
23	-8709.1	-2336.8	-626.14
24	-19596.	-3505.2	-939.20
25	-34836.	-4673.5	-1252.3
26	-54432.	-5841.9	-1565.3
27	-78382.	-7010.3	-1878.4
28	-.10669+06	-8178.7	-2191.5
29	-.13935+06	-9347.1	-2504.5
30	-.17636+06	-10515.	-2817.6
31	-.21773+06	-11684.	-3130.7
32	-.21773+06	.00000	-12096.
33	-.22876+06	280.00	-17696.
34	-.22784+06	280.00	-17696.
35	-.22691+06	280.00	-17696.
36	-.22599+06	280.00	-17696.
37	-.22506+06	280.00	-17696.
38	-.22414+06	280.00	-17696.
39	-.22327+06	280.00	-17696.
40	-.22229+06	280.00	-17696.
41	-.22137+06	280.00	-17696.

```
WHAT KIND OF BASES?

INPUT FIXED OR PINNED ,LEFT-HAND BASE FIRST


LEFT-HAND BASE IS FIXED

RIGHT-HAND BASE IS FIXED


NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO INDICATE THE MOMENT SIGN



THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN

TO INDICATE THE MOMENT SIGN ARE:

  -1    17   -31    41
```

SECTION NO.	SHEAR	THRUST
1	.1907+05	-.2877+05
2	.1637+05	-.2877+05
3	.1368+05	-.2877+05
4	.1098+05	-.2877+05
5	8290.	-.2877+05
6	5596.	-.2877+05
7	2902.	-.2877+05
8	207.1	-.2877+05
9	-2487.	-.2877+05
10	-5882.	-.1477+05
11	.1205+05	-.1211+05
12	.1009+05	-.1179+05
13	8135.	-.1148+05
14	6179.	-.1117+05
15	4223.	-.1085+05
16	2267.	-.1054+05
17	311.0	-.1023+05
18	-1645.	-9915.
19	-3601.	-9602.
20	-5557.	-9289.
21	7513.	-8976.
22	6344.	-.1184+05
23	5176.	-.1216+05
24	4008.	-.1247+05
25	2839.	-.1278+05
26	1671.	-.1309+05
27	502.5	-.1341+05
28	-665.9	-.1372+05
29	-1834.	-.1403+05
30	-3003.	-.1435+05
31	-4171.	-.1466+05
32	.1061+05	-.1703+05
33	.1089+05	-.2263+05
34	.1089+05	-.2263+05
35	.1089+05	-.2263+05
36	.1089+05	-.2263+05
37	.1089+05	-.2263+05
38	.1089+05	-.2263+05
39	.1089+05	-.2263+05
40	.1089+05	-.2263+05
41	.1089+05	-.2263+05

LOCATION OF BENDING MOMENT AT SPEC:

SECTION NO.		PLASTIC MOMENT CAPACITY
		.17332+06 LB .FT
1	-.173+06	...
2	-.115+06	NO
3	-.653+05	NO
4	-.246+05	NO
5	.725+04	NO
6	.302+05	NO
7	.442+05	NO
8	.493+05	NO
9	.455+05	NO
10	.590+05	NO
11	.351+05	NO
12	.764+05	NO
13	.110+06	NO
14	.137+06	NO
15	.156+06	NO
16	.169+06	NO
17	.173+06	...
18	.171+06	NO
19	.161+06	NO
20	.144+06	NO
21	.120+06	NO
22	.110+06	NO
23	.959+05	NO
24	.775+05	NO
25	.547+05	NO
26	.276+05	NO
27	-.388+04	NO
28	-.397+05	NO
29	-.799+05	NO
30	-.124+06	NO
31	-.173+06	...
32	-.138+06	NO
33	-.114+06	NO
34	-.783+05	NO
35	-.424+05	NO
36	-.644+04	NO
37	.295+05	NO
38	.655+05	NO
39	.101+06	NO
40	.137+06	.
41	.173+06	...

```
DO YOU WANT TO SEE THE BASE REACTIONS?

  YES

V1= .2877+05   H1=  .1907+05   V41= .2263+05   H41= .1069+05
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```
DO YOU WANT TO TRY ANOTHER HINGE PATTERN?

  YES

NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO INDICATE THE MOMENT SIGN

THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN

TO INDICATE THE MOMENT SIGN ARE:

  -1    19   -31    41
```

40	.1069+05	-.2272+05
41	.1069+05	-.2272+05

LOCATION OF BENDING MOMENT MT >MPC:

SECTION NO.		PLASTIC MOMENT CAPACITY
		.16997+06 LB .FT
1	-.170+06	***
2	-.111+06	NO
3	-.606+05	NO
4	-.192+05	NO
5	.133+05	NO
6	.368+05	NO
7	.515+05	NO
8	.573+05	NO
9	.542+05	NO
10	.684+05	NO
11	.452+05	NO
12	.863+05	NO
13	.120+06	NO
14	.147+06	NO
15	.166+06	NO
16	.178+06	YES
17	.183+06	YES
18	.180+06	YES
19	.170+06	***
20	.153+06	NO
21	.128+06	NO
22	.118+06	NO
23	.103+06	NO
24	.845+05	NO
25	.612+05	NO
26	.336+05	NO
27	.158+04	NO

```
  28          -.348+05     NO
  29          -.755+05     NO
  30          -.121+06     NO
  31          -.170+06     ***
  32          -.136+06     NO
  33          -.112+06     NO
  34          -.770+05     NO
  35          -.417+05     NO
  36          -.644+04     NO
  37           .288+05     NO
  38           .641+05     NO
  39           .994+05     NO
  40           .135+06     NO
  41           .170+06     ***
 -----------------------------------------------------------------

 DO YOU WANT TO SEE THE BASE REACTIONS?


   YES


V1= .2868+05   H1= .1927+05   V41= .2272+05   H41= .1069+05

DO YOU WANT TO TRY ANOTHER HINGE PATTERN?

   YES

NOMINATE POSITIOS OF FOUR PLASTIC HINGES WITH SIGN TO INDICATE THE MOMENT SIGN

THE FOUR NOMINATED POSITIONS OF PLASTIC HINGES WITH SIGN

TO INDICATE THE MOMENT SIGN ARE:

  -1    20   -31    41
```

SECTION NO.	SHEAR	THRUST
1	.1956+05	-.2854+05
2	.1686+05	-.2854+05
3	.1417+05	-.2854+05
4	.1147+05	-.2854+05
5	8780.	-.2854+05
6	6086.	-.2854+05
7	3392.	-.2854+05
8	697.3	-.2854+05
9	-1997.	-.2854+05
10	-5391.	-.1454+05
11	.1196+05	-.1157+05
12	.1000+05	-.1126+05
13	8045.	-.1093+05
14	6089.	-.1064+05
15	4133.	-.1032+05
16	2177.	-.1001+05
17	220.8	-9696.
18	-1735.	-9383.
19	-3691.	-9070.
20	-5647.	-8757.
21	7603.	-8444.
22	6435.	-.1143+05
23	5266.	-.1174+05
24	4098.	-.1205+05
25	2929.	-.1237+05
26	1761.	-.1268+05
27	592.6	-.1299+05
28	-575.8	-.1331+05
29	-1744.	-.1362+05
30	-2913.	-.1393+05
31	-4081.	-.1424+05
32	.1012+05	-.1725+05
33	.1040+05	-.2285+05
34	.1040+05	-.2285+05
35	.1040+05	-.2285+05
36	.1040+05	-.2285+05
37	.1040+05	-.2285+05
38	.1040+05	-.2285+05
39	.1040+05	-.2285+05
40	.1040+05	-.2285+05
41	.1040+05	-.2285+05

LOCATION OF BENDING MOMENT MT >MPC:

SECTION NO.			PLASTIC MOMENT CAPACITY
			.16523+06 LB .FT
1	-.165+06	...	
2	-.105+06	NO	
3	-.539+05	NO	
4	-.116+05	NO	
5	.218+05	NO	
6	.463+05	NO	
7	.620+05	NO	
8	.687+05	NO	
9	.666+05	NO	
10	.816+05	NO	
11	.594+05	NO	
12	.100+06	NO	
13	.134+06	NO	
14	.160+06	NO	
15	.179+06	YES	
16	.191+06	YES	
17	.196+06	YES	
18	.193+06	YES	
19	.183+06	YES	
20	.165+06	...	
21	.141+06	NO	
22	.130+06	NO	
23	.114+06	NO	
24	.945+05	NO	
25	.705+05	NO	
26	.421+05	NO	
27	.933+04	NO	
28	-.278+05	NO	
29	-.692+05	NO	
30	-.115+06	NO	
31	-.165+06	...	
32	-.132+06	NO	
33	-.109+06	NO	
34	-.751+05	NO	

```
  35          -.408+05     NO
  36          -.644+04     NO
  37           .279+05     NO
  38           .622+05     NO
  39           .966+05     NO
  40           .131+06     NO
  41           .165+06     ***
-------------------------------------------------------------

 DO YOU WANT TO SEE THE BASE REACTIONS?

  YES

VI= .2854+05   HI= .1956+05   V41= .2285+05   H41= .1040+05

DO YOU WANT TO TRY ANOTHER HINGE PATTERN?

  NO

DO YOU WANT TO ANALYSE ANOTHER FRAME?

  NO
```

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