

**Effective Lengths of Web-Tapered Columns in Rigid Metal
Building Frames**

By

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(ABSTRACT)

Current procedures for estimating effective length factors for web-tapered members rely heavily on the use of charts and graphs. This makes them difficult to implement using a computer. In addition, they are often based on unrealistic assumptions. In cases where these assumptions are not satisfied, design errors may result. This investigation proposes a modification to an effective length factor expression developed by Lui (1992). This modification allows the expression to be applied to web-tapered members with good accuracy.

A derivation of the proposed expression is presented, and the results obtained by applying the expression to a range of frames are compared to the results obtained from second-order finite element analyses. Calculations involved in using the expression are presented.

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CHAPTER I

INTRODUCTION

1.1 Overview and Scope of Research

Typical metal building manufacturers produce single story rigid frames for a variety of purposes. To achieve a fully stressed design leading to more efficient use of structural steel, these frames are normally composed of built-up, web tapered I-sections. An example of such a frame is shown in Figure 1.1. The member cross sections are often singly-symmetric and the dimensions of the flanges are seldom equal. The purpose of this study is to develop a quick, easy to implement design office procedure for estimating the effective lengths of tapered columns found in a range of metal building rigid frames.

1.2 Literature Review

In the latest American Institute of Steel Construction (AISC) design specification, estimation of effective length of a tapered member must be performed by a “rational analysis” (*Load and* 1993). The method of analysis is left to the judgment of the structural engineer. This literature review is conducted for the purpose of surveying the various methods of “rational analysis” currently in use.

1.2.1 Prismatic Members

Many methods exist for determining the effective length of prismatic columns. The AISC Column Alignment Charts are one of the most commonly used design aids. These charts, shown in Figure 1.2, provide the design engineer with a simple, rapid method for determining effective lengths of prismatic columns in both braced and unbraced frames. To use these charts, the parameters G_A and G_B must be calculated. These parameters are measures of the restraint provided to the ends of the column under consideration. They are calculated as follows:

$$G = \frac{\sum I_c / L_c}{\sum I_g / L_g} \quad (1.1)$$

where $\sum(I_c/L_c)$ is the summation of the moment of inertia divided by length of all columns framing into the joint under consideration, and $\sum(I_g/L_g)$ is the summation of the moment of inertia divided by length of all girders framing into the joint under consideration.

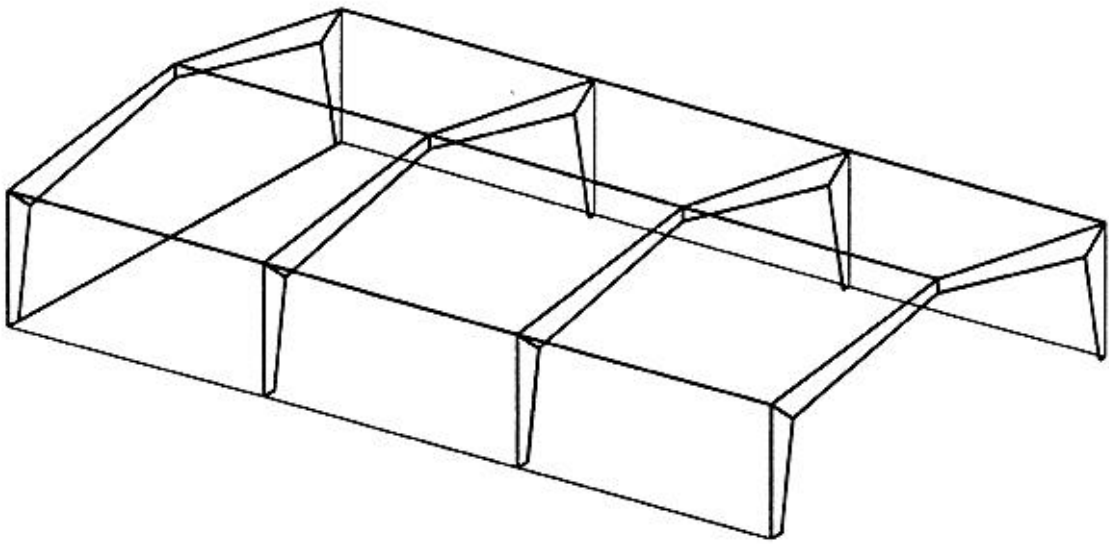


Figure 1.1
Typical Metal Building Layout
(Lee 1972)

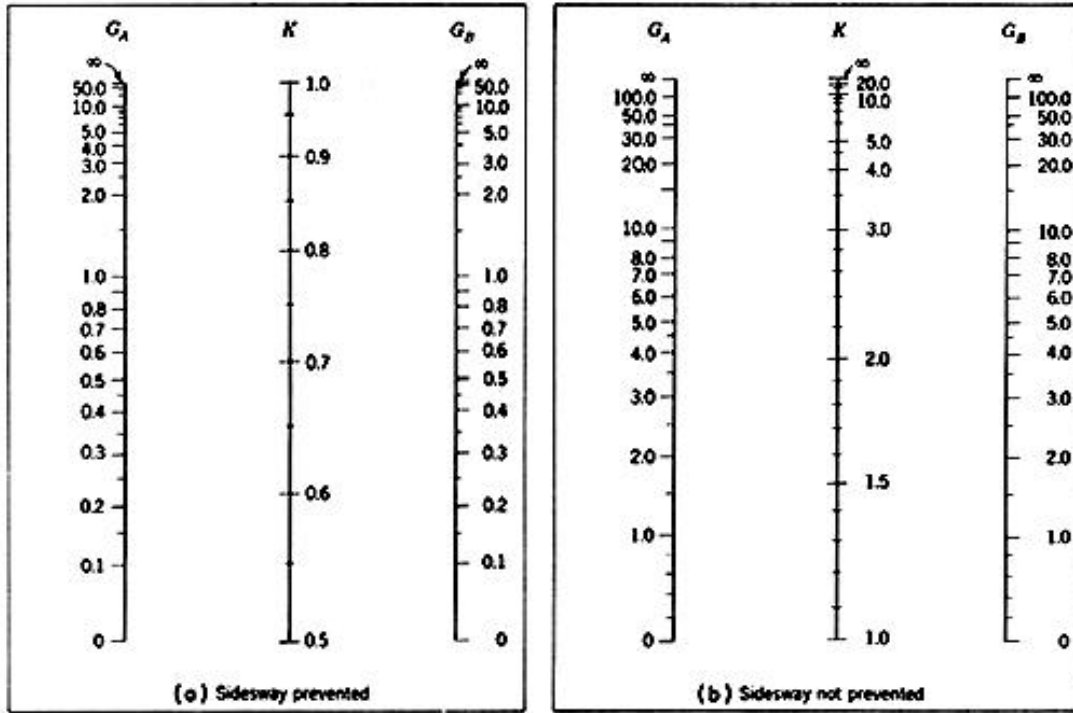


Figure 1.2
 AISC Alignment Charts
 (Johnston 1976)

While the alignment charts provide a simple method for determining column effective length, they rely on a number of assumptions that are not often satisfied under design conditions (Galambos 1988). These assumptions are as follows:

1. Behavior is purely elastic.
2. All members have constant cross section.
3. All joints are rigid.
4. For braced frames, rotations at opposite ends of beams are equal in magnitude, producing single-curvature bending
5. For unbraced frames, rotations at opposite ends of the restraining beams are equal in magnitude, producing reverse-curvature bending.
6. The stiffness parameter $L\sqrt{P/EI}$ is equal for all columns.
7. Joint restraint is distributed to the column above and below the joint in proportion to I/L of the two columns.
8. All columns buckle simultaneously.
9. No significant axial compression force exists in the girders.

Unrealistic estimates of effective length result if these assumptions are not satisfied (*Load and* 1993). Obviously, in accordance with Assumption 2, the charts are only applicable to frames composed of prismatic members. Assumptions 4 and 5, relating to equal end rotations of the restraining girders are not satisfied when the charts are applied to frames in which members and loadings are not symmetrical. For the same reasons, Assumption 6 is not often satisfied in actual practice. The assumption that all columns in a story buckle simultaneously precludes the consideration of “stronger” columns assisting “weaker” or “leaner” columns when using the alignment charts. Because many of the above limitations are not often met, use of the AISC alignment charts can frequently lead to unrealistic designs.

Several methods have been proposed which address many of the limitations of the AISC alignment charts. One of these methods, developed by Chu and Chow (1969), relies on the use of correction curves to modify the value of K obtained using the AISC alignment charts. This method can be used when column sizes and loadings are not symmetrical (Johnston 1976). The proposed correction curves are shown in Figure 1.3. To utilize these correction curves, one first determines the value for column effective length factor from the AISC alignment charts for the column upon which a load, P , is applied (see Figure 1.3). This column becomes the reference column. A modified effective length factor is then determined for this column. To determine this modified effective length factor, the following equation is used:

$$K_{\text{modified}} = \beta K \tag{1.2}$$

In which K is the effective length factor determined using the AISC alignment charts, and β is a coefficient taken from Figure 1.3. To determine the effective length factor for the

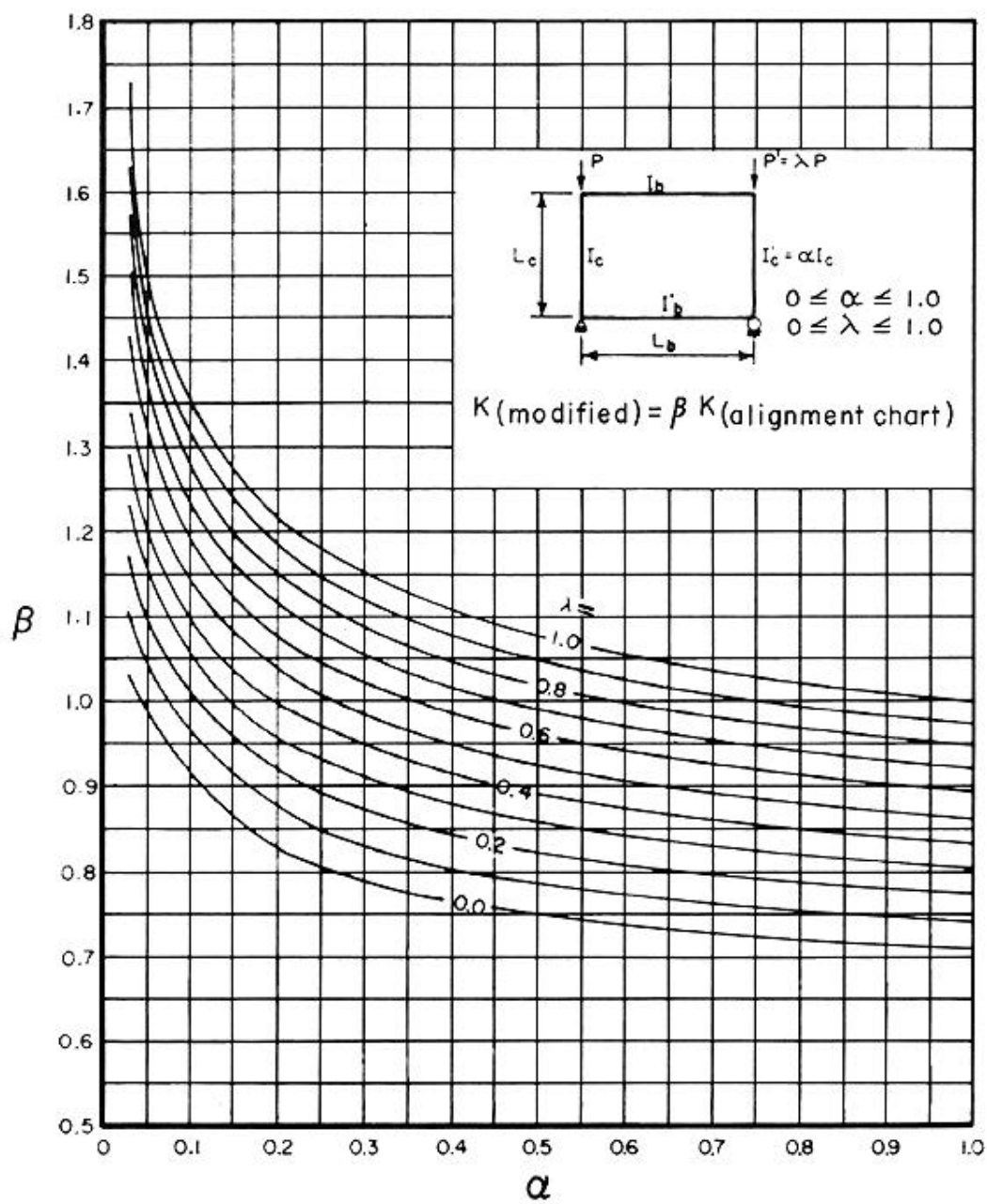


Figure 1.3
 AISC Alignment Chart Correction Curves
 (Chu and Chow 1969)

second column in the frame, the effective length factor of the reference column must be modified as follows:

$$K' = K_{\text{modified}} \frac{L}{L'} \sqrt{\frac{a}{l}} \quad (1.3)$$

where K' and K_{modified} are the effective length factors for the second column and the reference column, respectively, L' and L are the lengths of the second column and the reference column, respectively, and α and λ are defined in Figure 1.3. It should be noted that the derivation of this method relies on the assumption that all columns in the frame reach their buckling load simultaneously (Johnston 1976)

A second method, which does not rely on correction curves, has been developed by LeMessurier (1977). The effective length factor equation proposed by LeMessurier is as follows:

$$K_i = \sqrt{\frac{\rho^2 I_i \left[\sum P_u + \sum (C_L P_u) \right]}{P_{ui} \sum (bI)}} \quad (1.4)$$

In which K_i is the effective length factor of the i -th column in the story under consideration, $\sum P_u$ is the sum of the vertical forces acting on the story, $\sum (C_L P_u)$ is the sum of $(C_L P_u)$ for each column in the story, $\sum (bI)$ is the sum of (bI) for all columns in the story, P_{ui} is the axial force in i -th column based on a first-order analysis, and I_i is the moment of inertia of the i -th column. C_L is a stiffness correction factor to account for P- δ effects, and is defined as:

$$C_L = b \frac{K_n^2}{\rho^2} - 1 \quad (1.5)$$

Where K_n is the effective length factor as determined from the AISC alignment charts, and β is a column end restraint coefficient defined as follows:

$$b = \frac{6(G_A + G_B) + 36}{2(G_A + G_B) + G_A G_B + 3} \quad (1.6)$$

According to Chen and Toma (1994), while Equation (1.4) does not assume that all columns in a story buckle simultaneously, it still relies on the assumption that the quantity $L\sqrt{P/EI}$, (where L is column length, P is axial load, and EI is flexural rigidity) is equal for all columns in a story. However, examples performed by LeMessurier violate this assumption and the resulting effective length factors are said to be sufficiently accurate for design (LeMessurier 1977).

Another method, proposed by Lui (1992), allows the determination of effective length factors for columns in frames with leaner columns and unequal distributions of lateral stiffness and gravity loads. This equation is as follows:

$$K_i = \sqrt{\frac{\rho^2 EI_i}{P_i L_i^2} \left[\sum \frac{P}{L} \left(\frac{1}{5 \sum h} + \frac{\Delta_i}{\sum H} \right) \right]} \quad (1.7)$$

where K_i is the effective length factor of the i -th column, E is the modulus of elasticity, I_i is the moment of inertia of the i -th column, L_i is the length of the i -th column, P_i is the axial load acting on the i -th column, $\sum P/L$ is the sum of the axial loads in the columns providing lateral stiffness divided by column length, $\sum H$ is the sum of the lateral loads acting on frame, Δ_i is the story drift of the frame due to the application of $\sum H$ (as determined by a first-order analysis), and h is the member stiffness index, calculated as follows:

$$h = \frac{(3 + 4.8m + 4.2m^2)EI}{L^3} \quad (1.8)$$

where m is the ratio of smaller to larger end moments. This quantity is to be taken as positive if reverse curvature bending occurs, and negative if single curvature bending occurs. It should be noted that the quantity $\sum H$ is not taken as the actual lateral load acting on the frame. $\sum H$ is a set of fictitious lateral loads applied to the frame to determine Δ_i . It is taken as some fraction of the gravity load acting on the story. The choice of this fraction is not critical as long as the fraction is constant for all stories in the frame. Δ_i is determined by a first order analysis of the frame under the action of $\sum H$ alone. No gravity loads are applied at this stage of the analysis.

It should be noted that by making use of a first-order analysis, this method directly considers the interaction effect between all members of a frame, including the effect of leaner columns on frame instability. Lui has applied this method to a wide range of frames composed of prismatic members and has achieved excellent results (Lui 1995).

1.2.2 Non-Prismatic Members

As stated above, the use of members of constant cross section is a key assumption of the AISC alignment charts. This assumption may cause errors if the alignment charts are applied without modification to frames containing non-prismatic members.

One of the more widely known methods for calculating the effective length of non-prismatic columns was developed by G.C. Lee at the State University of New York (SUNY) at Buffalo (Lee *et al* 1972). Lee and his colleagues opted to base their tapered member design provisions on the AISC prismatic member provisions to make the proposed tapered member

design procedure more familiar to practicing engineers. The prismatic elastic lateral buckling equation is as follows:

$$P_e = \frac{\rho^2 EI}{L^2} \quad (1.9)$$

where P_e is the critical elastic lateral buckling load, E is Young's Modulus, I is the moment of inertia about the strong axis of the member, and L is the length of the member pinned at both ends. The approach developed by Lee and his colleagues for estimating the effective length of tapered members involves modifying the length of the member to obtain an "equivalent" prismatic member length. This "equivalent" member is based on the section properties of the smaller end of the tapered member. The properties of this new prismatic member are then used in the standard elastic buckling equation to yield:

$$P_{\text{taper}} = \frac{\rho^2 EI_o}{(gL)^2} \quad (1.10)$$

where P_{taper} is the critical elastic lateral buckling load of the tapered column, I_o is the strong axis moment of inertia of the smaller end of the tapered member, and gL is the modified length of the tapered member pinned at both ends. Rearranging Equation 1.10 to solve for the length modification factor, g , yields:

$$g = \frac{\rho}{L} \sqrt{\frac{EI_o}{P_{\text{taper}}}} \quad (1.11)$$

All elements of this equation are known with the exception of P_{taper} . To solve for this unknown, Lee *et al* (1972) solved for P_{taper} for the commonly used cross sections illustrated in Figure 1.4. Utilizing various lengths and degrees of taper, they obtained the value of P_{taper} for each case. By fitting a polynomial curve to the data, the following equation was obtained for g :

$$g = 1.000 - 0.375g + 0.080g^2(1.00 - 0.0775g) \quad (1.12)$$

where

$$g = \frac{d_1}{d_o} - 1 \quad (\text{taper ratio}) \quad (1.13)$$

In which d_1 is the section depth at larger end of the member, and d_o is the section depth at smaller end of the member.

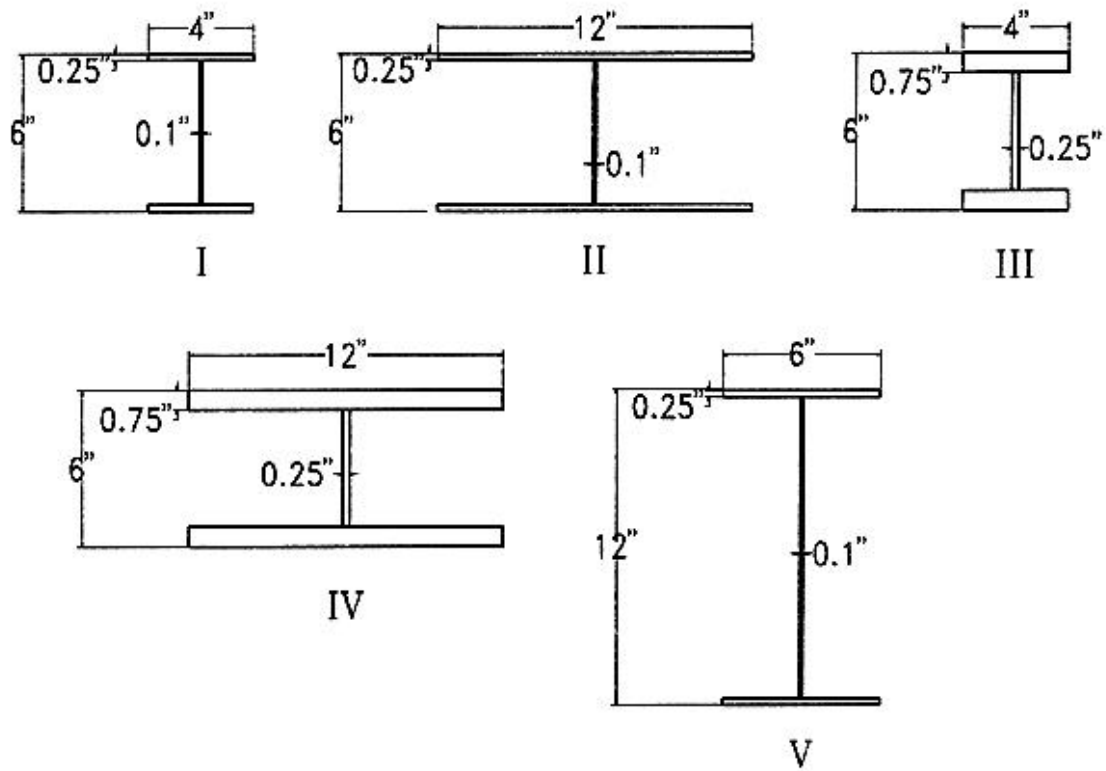


Figure 1.4
Sections Used for Calculating P_{taper} in Equation (1.11)
(Lee 1972)

In developing the length modification factor, g , it was assumed that the member was pinned at both ends. To account for other end conditions, an effective length factor, K_γ , was introduced. This effective length factor was used to relate a tapered member having length L and various end conditions, to a prismatic member pinned at both ends of length $K_\gamma L$ and having the cross sectional properties of the smaller end of the tapered member. A number of frames of the type shown in Figure 1.5 were analyzed, and the buckling loads from these analyses were used to determine effective length factors, K_γ . As a result of the procedure used to develop K_γ , the previously derived length modification factor, g , was simply absorbed into the new effective length factor, K_γ . Charts for finding K_γ as a function of γ , G_T and G_B are included in two publications by Lee and his colleagues (Lee *et al* 1972; Lee, Ketter and Hsu 1981). The parameters G_T and G_B are the end restraint parameters similar to those used the AISC nomograms for prismatic members. They can be determined using Equation 1.1.

The effective length of doubly tapered, doubly symmetric I-sections was studied in 1979, again by Lee and others (Lee *et al* 1979). As in the case for singly tapered columns, Lee and his colleagues again analyzed a number of frames of the type shown in Figure 1.6. Using the elastic buckling loads obtained in the analyses, the effective length factors, K_γ , were calculated. These values are plotted as functions of G_B , G_T , β , γ_1 , and γ_2 (Lee *et al* 1979). As shown in Figure 1.6, β is a parameter which locates the joint of the two segments, γ_1 is the taper ratio of one segment, and γ_2 is the taper ratio of the other segment.

In the previously mentioned studies, it was assumed that the flanges of the members under consideration were of equal area. Often in practice, this is not the case. In another study conducted at the State University of New York at Buffalo, Lee and Hsu (1981) developed curves yielding the allowable stress in such columns as a function of slenderness ratio (KL/r), taper ratio, and the ratio of the flange.

Much of the available literature related to tapered columns assumes that the columns are either perfectly fixed or perfectly pinned at the ends. This is often an unrealistic assumption for design. A method for determining the restraint condition has been recommended by Lee, Ketter and Hsu (1981). This method uses the familiar G_B and G_T parameters used in prismatic column design. However, the lengths of the members framing in at a joint must be modified if the members are non-prismatic. This can be done conveniently using the length modification factor, g , described previously. The following formula illustrates the use of this parameter:

$$G = \frac{I_{oc} / g_c L_c}{I_{og} / g_g L_g} \quad (1.14)$$

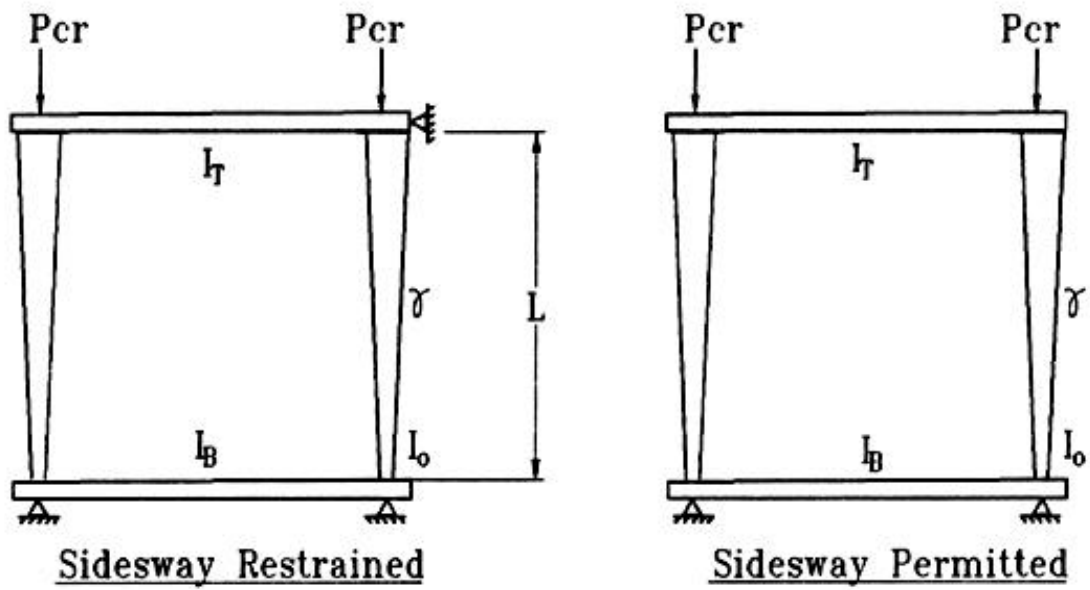


Figure 1.5
 Singly Tapered Frames Used for the Determination of K_γ
 (Lee 1972)

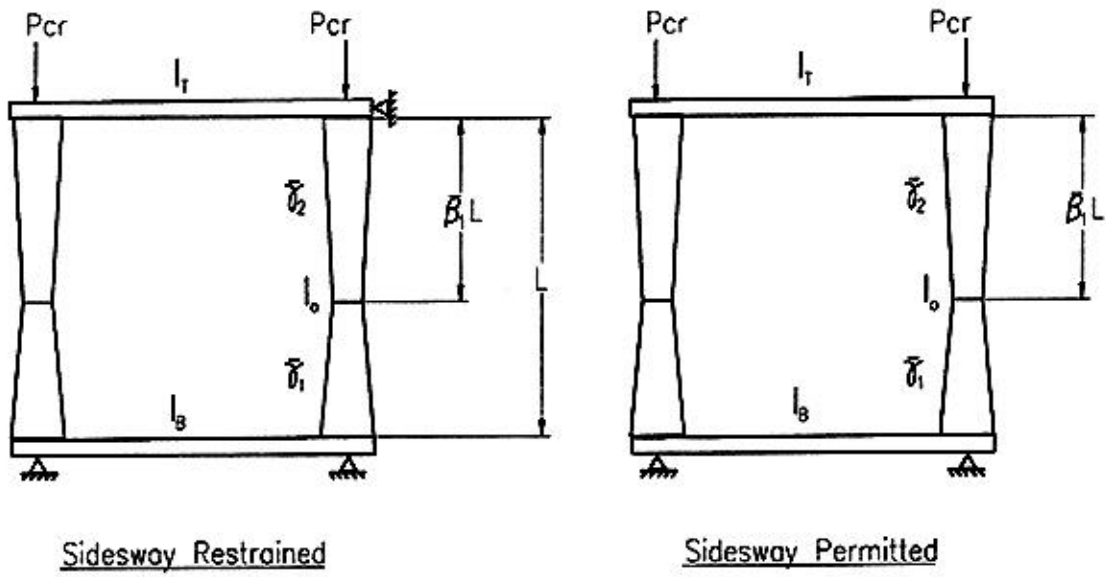


Figure 1.6
Doubly Tapered Frames Used for the Determination of K_y
(Lee 1972)

where G is the joint restraint, I_{oc} and I_{og} are the moments of inertia at the smaller ends of the column and girders, respectively, g_c and g_g are the length modification factors of the columns and girders, respectively, and L_c and L_g are the actual lengths of the columns and girders, respectively. The values of G obtained for both ends of the column are then used in the charts mentioned previously to determine K_γ .

1.3 Need for Further Research

While much literature is available on the subject of tapered column buckling loads, only a small portion addresses the situations encountered in realistic design situations. Of this literature, the work done by Lee and others (1972, 1979, 1981, 1981) is most applicable to actual design situations. Unfortunately, the techniques discussed in these work rely extensively on the use of charts and graphs. This makes computerization of these methods extremely difficult, if not impossible. It should also be noted that this, and other methods which rely on the familiar G_B and G_T end restraint parameters have a major shortcoming: they consider only the effect of adjacent members on column behavior. Buckling of unbraced frames, whether composed of prismatic or non-prismatic members, is a story phenomenon, and these methods fail to consider the interaction of other members of the frame. The only alternative to these techniques at the present time is a second order elastic analysis. Because of the time required for this type of analysis, it may be an unattractive solution for the practicing engineer. A need exists for a quick, easily computerized procedure for calculating the effective lengths of tapered members.

Through this study, such a method has been determined. It consists of a modification of Equation 1.7. This modification allows design engineers to quickly and accurately determine effective length factors for non-prismatic columns. The method requires only a first-order analysis. No charts or iterations are required.

CHAPTER II FRAME ANALYSIS

2.1 Purpose

To assess the accuracy of any approximate method for calculating column effective length factors, it is first necessary to obtain an accurate estimate of the true column effective length factor for purposes of comparison. To obtain this estimate, a number of frames were analyzed using SAP90, a commercially available finite element analysis program developed by CSI, Inc., of Berkeley, California (*SAP90* 1991). SAP90 is capable of analyzing a variety of structures, including frames composed of non-prismatic elements. The elastic buckling load obtained from a second-order analysis using SAP90 was used as an estimate for the true elastic buckling load of each frame.

2.2 Modeling Details

To model the real frame using a finite element analysis, certain modeling assumptions were made. These assumptions are described in detail in the following sections.

Element Selection. To correctly model the effects of axial, transverse, and rotational deformations, the SAP90 Frame element was utilized. This is a three dimensional beam-column finite element. It is capable of modeling the effects of biaxial bending, torsion, axial deformations, and biaxial shear deformations. SAP90 does not require the element to be prismatic. If a non-prismatic element is to be used, the user may choose the variation of moment of inertia to be linear, parabolic, or cubic. For the models under consideration in this study, parabolic variation in moment of inertia was chosen, as this most closely models the variation in moment of inertia of a section having linear web depth variation. The following equation is used by SAP90 to describe parabolic variation in moment of inertia along the length of the member:

$$I = I_o \left[1 + \left(\left(\frac{I_L}{I_o} \right)^{\frac{1}{2}} - 1 \right) y \right]^2 \quad (2.1)$$

Where I is the moment of inertia at the point of interest, I_L is the moment of inertia at the large end of the member, I_o is the moment of inertia at the small end of the member, and y is the ratio of the distance to the point of interest (measured from the small end) divided by the length of the member. Figure 2.1 shows a typical linearly tapered member, along with a comparison of the actual moment of inertia and the moment of inertia obtained using Equation 2.1.

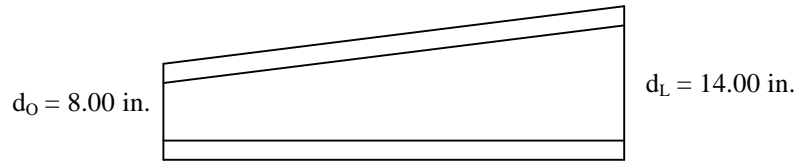
Frame Knee Stiffness. The stiffness of rigid frame knees is typically far greater than the stiffness of the frame columns and girders. To simulate this, the moment of inertia of the knees of

Flange Width = 6.00 in.

Flange Thickness = 0.375 in.

Web Thickness = 0.375 in.

Length = 12 ft



X (ft)	I_{Actual} (in ⁴)	I_{SAP90} (in ⁴)
0	74.99	74.99
2	97.78	98.80
4	124.06	125.90
6	153.98	156.27
8	187.68	189.92
10	225.32	226.84
12	267.05	267.05

Figure 2.1
Variation in Moment of Inertia of a Typical Tapered Section

the frames was chosen to be one thousand times greater than the moment of inertia of the stiffest member framing into the knee. This modeling assumption has been shown by previous experience to produce model deflections which closely approximate those obtained in full scale rigid frame tests.

Column Base Restraint. In theory, a perfectly pinned column base connection provides no rotational restraint. In reality, the perfect condition is not realized, as the column base plate connection provides some degree of rotational restraint. Under accepted American Institute of Steel Construction (AISC) design procedures (*Load and* 1993), the value of rotational restraint provided to the end of a column by members framing into the connection may be evaluated using Equation 1.1.

For a perfectly pinned column base connection, G_B is theoretically infinite. However, for design purposes, AISC recommends that $G_B = 10$ be used for all cases in which the column base connection has not been specifically designed as a friction free pin (*Load and* 1993).

To correctly model this condition, restraining girders were rigidly connected to the column base in the finite element model. A girder length was arbitrarily chosen to be 5 ft. As shown in Figure 2.2, a restraining girder frames into each side of the column base. To facilitate ease of modeling this restraint, it was convenient to assume that the far ends of all girders providing column base restraint are pinned. The development of Equation 2.1 assumes that the far ends of these restraining girders are rigidly connected to other columns. When the far ends of the restraining girders approach a pinned or fixed condition, their stiffness must be adjusted.

In addition, Equation 2.1 assumes that the column has a constant moment of inertia. This assumption is not satisfied by the web-tapered members considered in this study. To satisfy the above conditions, Equation 1.1 was modified as follows:

$$G_B = \frac{\sum I_{oc} / L_c}{\sum m I_g / L_g} \quad (2.2)$$

where I_{oc} is the moment of inertia of smallest cross section of column (taken about the axis perpendicular to plane of buckling), and m is a factor to account for end condition at the far end of the restraining girders (taken as 1.5 for the case shown in Figure 2.2).

Loading. It was found that applying a vertical distributed gravity load across the frame often led to premature failure of the frame caused by buckling of the rafter. To avoid this, a vertical, downward load equal to some arbitrary value, P , was placed at each frame knee to simulate the gravity loads acting on the frame. This load placement ensured that frame buckling was a result of buckling of the columns.

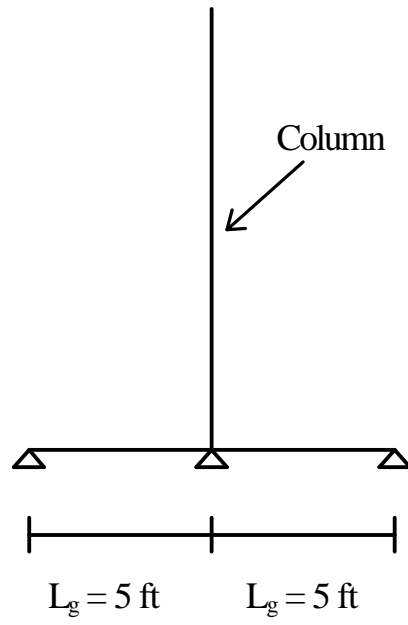


Figure 2.2
Base Restraint Girder Used in Finite Element Model

Initial Imperfection. To induce a sidesway buckling mode, a lateral load equal to $0.001P$ was placed at one knee of each frame. A typical finite element mesh, including applied loads, is shown in Figure 2.3.

2.3 Determination of Buckling Load

SAP90 does not provide a means to directly calculate the buckling load of a structure. However, SAP90 can still be used to obtain a close estimate of the actual elastic buckling load of a frame. To do this, the applied loads on the structure must be gradually increased until lateral deflections become very large. Figure 2.4 shows a typical load-deflection curve for an unbraced frame subjected to gravity loading. As the load, P , is increased, lateral drift of the frame, Δ , also increases. For a time, the relationship between P and Δ is approximately linear. Eventually, second-order moments become large, leading to large increases in Δ for small increases in P . In the limiting case, when $P = P_{CR}$, lateral deflections increase with no increase in load. As can be seen in Figure 2.4, the load, P , approaches the buckling load, P_{CR} , of the structure asymptotically. A close approximation of the buckling load can be obtained using a second-order analysis procedure by increasing the applied lateral load until lateral deflections become very large.

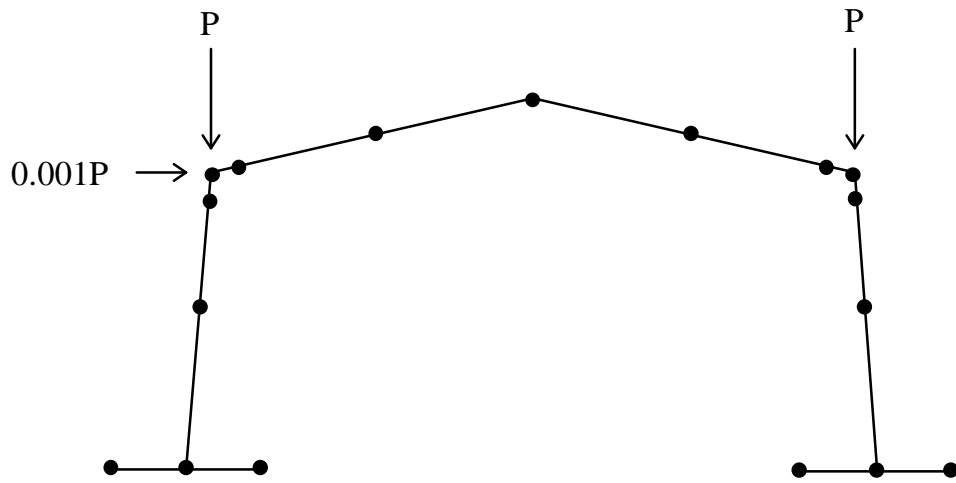


Figure 2.3
Typical Finite Element Mesh and Loading

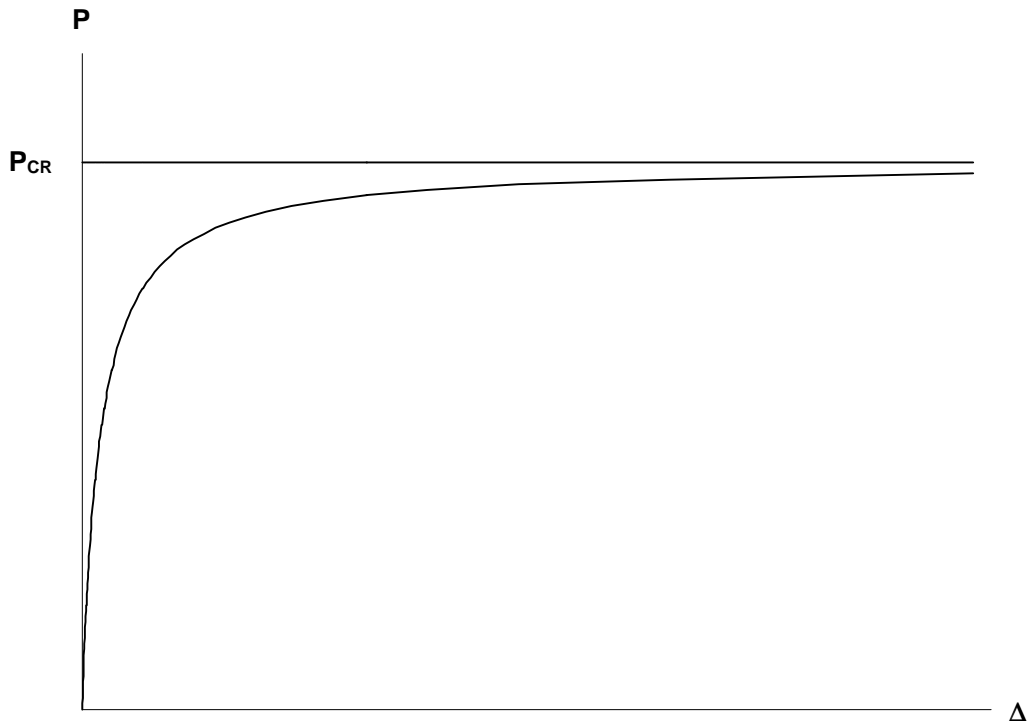


Figure 2.4
Typical Unbraced Frame Load-Deflection Curve

CHAPTER III DERIVATION OF K-FACTOR EXPRESSION

3.1 Purpose

Chapter II provided a discussion on the method by which elastic buckling loads were obtained for the frames considered in this study. This method included the use of a second-order elastic analysis. In this chapter, a method by which effective length factors can be estimated without the need for a second order analysis will be presented.

3.2 Proposed K-Factor Expression

In Chapter I, consideration was given to a method proposed by Lui (1977) which allows accurate estimation of column effective length factors for frames composed of prismatic members. It has been shown that this method does not rely on many of the restricting assumptions incorporated in the derivation of the AISC alignment charts. In particular, it has been shown that this method gives accurate results for the frames in which members and loadings are not symmetrical. In addition, the method does not assume that all columns in a story reach their buckling load simultaneously. The fact that this method does not rely on the use of charts or iterative solutions is especially attractive from a design standpoint. Because it does not depend on restricting assumptions and it lends itself to computerized solution, this method is an ideal candidate for modification for use with frames containing non-prismatic members. The following sections provide a theoretical derivation of Equation 1.7 and the subsequent modifications allowing it to be applied to frames composed of non-prismatic members.

3.2.1 Derivation of Equation 1.7

For the sake of completeness, the following derivation of Equation 1.7 is repeated verbatim from Lui (1977). Only the equation numbers and citation style have been changed. The derivation considers member instability (P- δ) effects and frame instability (P- Δ) effects separately.

Member Instability. For the member shown in Figure 3.1, the slope-deflection equations relating the member-end moments (M_A , M_B) and member-end rotations (θ_A , θ_B) are given by

$$M_A = \frac{EI}{L} (s_{ii} \theta_A + s_{ij} \theta_B) \quad (3.1a)$$

$$M_B = \frac{EI}{L} (s_{ij} \theta_A + s_{ii} \theta_B) \quad (3.1b)$$

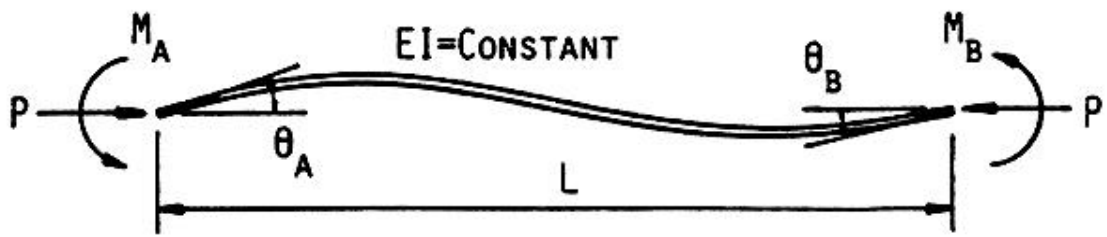


Figure 3.1
A Typical Beam Column Element
(Lui 1992)

where EI is the flexural rigidity and L is the length of the member. s_{ii} and s_{ij} are stability functions which are expressed in terms of the axial force in the member. Expressions for these functions are given in [(Chen and Lui 1987)] and will not be shown here. Simplified forms for these functions will be used in this paper.

If the axial force P in the member is negligible, Equations (3.1a) and (3.1b) reduce to

$$M_A = \frac{EI}{L}(4q_A + 2q_B) \quad (3.2a)$$

$$M_B = \frac{EI}{L}(2q_A + 4q_B) \quad (3.2b)$$

For the case in which the member bends in reverse curvature so that $\theta_A = \theta_B = \theta$, Equations (3.1a) and (3.1b) become

$$M_A = M_B = \frac{EI}{L}(s_{ii} + s_{ij})q \quad (3.3)$$

and Equations (3.2a) and (3.2b) become

$$M_A = M_B = \frac{6EI}{L}q \quad (3.4)$$

Using Taylor series expansion for $(s_{ii} + s_{ij})$, we obtain

$$s_{ii} + s_{ij} = 6 - \frac{PL^2}{10EI} + \dots \quad (3.5)$$

Substitution of Equation (3.5) into Equation (3.3), we have

$$M_A = M_B \approx \frac{6EI}{L} \left(1 - \frac{PL^2}{60EI} \right) q \quad (3.6)$$

The approximation sign is used in the above equation only two terms are retained in the Taylor series expansion.

Upon comparison of Equation (3.6) with Equation (3.4), it can be concluded that when a member bends in reverse curvature, the member instability effect reduces the flexural rigidity of the member by an amount of $1-PL^2/60EI$.

Similarly, for the case in which the member bends in single curvature so that $\theta_A = -\theta_B = \theta$, Equations (3.1a) and (3.1b) become

$$M_A = -M_B = \frac{EI}{L}(s_{ii} - s_{ij})q \quad (3.7)$$

and Equations (3.2a) and (3.2b) become

$$M_A = M_B = \frac{2EI}{L}q \quad (3.8)$$

Again using Taylor series expansion for $s_{ii} - s_{ij}$, we obtain

$$s_{ii} - s_{ij} = 2 - \frac{PL^2}{6EI} + \dots \quad (3.9)$$

Retaining the first two terms of the series and substituting the result into Equation (3.7), we have

$$M_A = -M_B \approx \frac{2EI}{L} \left(1 - \frac{PL^2}{12EI} \right) q \quad (3.10)$$

Upon comparison of Equation (3.10) with (3.8), it can be seen that the member instability effect for a member bends in single curvature reduces the flexural rigidity of the member by an amount of $1-PL^2/12EI$.

Finally, for the case in which one of the member end moment [*sic*] (say, M_A) is zero, Equation (3.1b) becomes

$$M_B = \frac{EI}{L} \left(s_{ii} - \frac{s_{ij}^2}{s_{ii}} \right) q_B \quad (3.11)$$

and Equation (3.2b) becomes

$$M_B = \frac{3EI}{L} q_B \quad (3.12)$$

A Taylor series expansion for the terms in parenthesis in Equation (3.11) gives

$$s_{ii} - \frac{s_{ij}^2}{s_{ii}} = 3 - \frac{PL^2}{5EI} + \dots \quad (3.13)$$

which, upon substitution into Equation (3.11) gives

$$M_B \approx \frac{3EI}{L} \left(1 - \frac{PL^2}{15EI} \right) q_B \quad (3.14)$$

A comparison between Equations (3.14) and (3.12) reveals that the member instability effect reduces the flexural rigidity of this member by a factor of $1-PL^2/15EI$.

In the foregoing discussions, it was seen that when $M_A/M_B = 1$, member instability effect would reduce the flexural stiffness of the member by a factor of $1-PL^2/60EI$. When $M_A/M_B = -1$, this stiffness reduction factor was $1-PL^2/12EI$, and when $M_A/M_B = 0$, the factor was $1-PL^2/15EI$. Assuming that the stiffness reduction factor varies parabolically from a moment ratio of -1 to 1, a general stiffness reduction factor suitable for any moment ratio which can be used to account for the member instability effect can be written as

$$r = 1 - \frac{P}{5hL} \quad (3.15)$$

where

$$h = \frac{(3 + 4.8m + 4.2m^2)EI}{L^3} \quad (3.16)$$

In the above equations, r is the member instability ($P-\delta$) stiffness reduction factor, η is the member stiffness index, P is the compressive axial force in the member, EI is the flexural rigidity of the member, and m is the ratio of smaller to larger end moments of the member; m is taken as positive if the member bends in reverse curvature and it is taken as negative if the member bends in single curvature. Theoretically, the end moments used for calculating this moment ratio should be the moments developed in the member when the frame buckles. Since exact values for these moments are difficult to obtain, a simplified procedure will be used to

obtain approximate values for these moments. In this procedure, a small disturbing force equal to a fraction of the gravity loads is applied laterally to the frame. The moments developed in the member due to this disturbing force are used to calculate the moment ratio in Equation (3.16)...

Equation (3.15) indicates that the effect of member instability (i.e., the P- δ effect) can be expressed as a function of the end moment ratio of the member...

Frame Instability. In the context of design, frame instability is conveniently accounted for by the use of the story stiffness concept. If we denote s_{im} as the first order member lateral stiffness and S as the story stiffness accounting for the P- Δ effect, the two stiffnesses are related by the equation

$$S = \sum r s_{im} - \sum \left(\frac{P}{L} \right) \quad (3.17)$$

where r is the member instability reduction factor defined in Equation (3.15), $\sum(P/L)$ is the sum of the axial load to length ratio for all members of the story.

Since the first order member lateral stiffness s_{im} is proportional to the member stiffness index η defined in Equation (3.16), Equation (3.17) can be written in the form

$$S = \sum r \left(\frac{h}{\sum h} S_I \right) - \sum \left(\frac{P}{L} \right) \quad (3.18)$$

or

$$S = \left[\sum \left(r \frac{h}{\sum h} \right) - \sum \left(\frac{P}{L} \right) \left(\frac{1}{S_I} \right) \right] S_I \quad (3.19)$$

where S_I is the first-order story stiffness.

Using Equation (3.15) and substituting $\sum H / \Delta_I$ (where $\sum H$ is the story lateral loads producing Δ_I , and Δ_I is the first-order inter-story deflection) for S_I into Equation (3.19), we obtain

$$S = \left[\left(1 - \frac{\sum (P/L)}{5 \sum h} \right) - \sum \left(\frac{P}{L} \right) \left(\frac{\Delta_I}{\sum H} \right) \right] S_I \quad (3.20)$$

The terms in brackets is the stiffness reduction factor for the story. The inverse of this factor is the moment magnification factor, A_F ...

$$A_F = \frac{1}{\left(1 - \frac{\sum(P/L)}{5\sum h}\right) - \sum\left(\frac{P}{L}\right)\left(\frac{\Delta_i}{\sum H}\right)} \quad (3.21)$$

Proposed K-Factor Formula. Equation (3.21) is applicable to all members of the story. Suppose we are interested in calculating the K-factor for the i -th member, we can equate Equation (3.21) with the member moment magnification factor (Chen and Lui 1987)

$$(A_F)_i = \frac{1}{1 - \frac{P_i}{(P_{ek})_i}} \quad (3.22)$$

where $(P_{ek})_i = \pi^2 EI_i / (K_i L_i)^2$.

Equating Equations (3.21) and (3.22), and solving for K_i , we obtain.

$$K_i = \sqrt{\left(\frac{p^2 EI_i}{P_i L_i^2}\right) \left[\left(\sum \frac{P}{L}\right) \left(\frac{1}{5\sum h} + \frac{\Delta_i}{\sum H}\right) \right]} \quad (3.23)$$

Equation (3.23) is the proposed K-factor formula. In the equation, EI_i and L_i are the flexural rigidity and length of the member, respectively. P_i is the axial force in the member, $\sum(P/L)$ is the sum of the axial force to length ratio of *all* members in a story, $\sum H$ is the story lateral loads producing Δ_i , Δ_i is the first-order inter-story deflection, and η is the member stiffness index defined in Equation (3.16). It is important to note that the term $\sum H$ used in Equation (3.23) is *not* the actual applied lateral load. Rather, it is a small disturbing force (taken as a fraction of the story gravity loads) to be applied to each story of the frame. This disturbing force is applied in a direction such that the displaced configuration of the frame will resemble its buckled shape. The member-end moments calculated using a first-order analysis under the action of this disturbing force will be used in Equation (3.16) to evaluate the member stiffness index.

In this study, Equation (3.23) was chosen to be applied to a variety of rigid frames containing non-prismatic members. The modifications necessary for this application are described in the following section

3.2.2 Simplification of Equation 1.7

If the columns in the frame bend in reverse curvature with $m \approx 1$, then the following simplifications can be made (Lui 1997):

$$h \approx \frac{12EI}{L^3} \quad (3.24)$$

Substituting Equation (3.24) into Equation (3.23) gives

$$K_i = \sqrt{\frac{\rho^2 EI_i}{P_i L_i^2} \left[\frac{\sum (P/L)}{60 \sum (EI/L^3)} + \frac{\sum P\Delta_i}{L \sum H} \right]} \quad (3.25)$$

If $P_i/L_i \propto EI_i/L_i$, then Equation (3.25) becomes

$$K_i = \sqrt{\frac{\rho^2 EI_i}{P_i L_i^2} \left[\frac{P_i L_i^2}{60 EI_i} + \frac{\sum P\Delta_i}{L \sum H} \right]} \quad (3.26)$$

3.2.3 K-Factor Expression for Non-Prismatic Members

Equations (3.23) and (3.26) were derived under the assumption that all columns in the story under consideration are prismatic. When this is not the case, modification is necessary. Equation (3.26) was chosen as the base from which an effective length factor expression for non-prismatic columns would be developed. Before applying Equation (3.26) to frames containing non-prismatic members, the following alteration was implemented

$$K_i = \sqrt{\frac{\rho^2 EI_{O_i}}{P_i L_i^2} \left[\frac{P_i L_i^2}{60 EI_{O_i}} + \frac{\sum P\Delta_i}{L \sum H} \right]} \quad (3.27)$$

In which all terms are as defined for Equation (3.23), with the exception of I_{O_i} . I_{O_i} is the moment of inertia of the smallest cross section of the i -th column of the story under consideration. As a part of this study, Equation (3.27) was applied to a large number of rigid metal frames. The results are discussed in Chapter IV.

It should be noted that in utilizing Equation (3.27) for design, the engineer is not limited to the modeling details described in Section 2.2. The results obtained using Equation (3.27) are dependent upon the first-order analysis performed for the purpose of obtaining Δ_1 . Because of this dependency, the results one obtains with Equation (3.27) will reflect the particular modeling assumptions that one has chosen. If one wishes to use a special modeling assumption for knee stiffness or column base restraint, one would simply include these assumptions when performing the first order analysis.

CHAPTER IV

EVALUATION OF THE PROPOSED K-FACTOR EXPRESSION

A proposed effective length factor expression for use with non-prismatic members, Equation (3.27), was presented in Chapter III. In this chapter, the proposed expression will be evaluated using second-order elastic analyses of a range of rigid frames as a basis for comparison.

4.1 Method of Evaluation

To evaluate the effectiveness of the proposed K-factor expression, one must compare the K-factor obtained using Equation (3.27) with the K-factor obtained using a second-order elastic analysis. The K-factor can be obtained from a second-order analysis as follows:

$$K_i = \sqrt{\frac{P_e}{P_{cr}}} = \sqrt{\frac{\rho^2 EI_{O_i} / L^2}{P_{cr}}} \quad (4.1)$$

in which P_e is the Euler buckling load of the column, I_{O_i} is the moment of inertia of the smallest cross section of the i -th column, L is the length of the column, and P_{cr} is the axial force in the column at buckling, obtained from the second order analysis.

Using Equation (4.1), one can determine the effective length factor of a column by performing a second-order analysis. When symmetrical frames of the type shown in Figure 1.1 are considered, this procedure is quite simple. The rigidly connected columns can be assumed to carry an equal share of the total frame load at buckling. Therefore, P_{cr} from Equation (4.1) is simply one half of the total load acting on the frame. For this case, an elastic K-factor can be computed and compared directly to the K-factor obtained using Equation (3.27).

When the frame under consideration is not symmetrical, it is more difficult to determine the portion of the total load carried by each column when the frame buckles. Therefore, it is quite difficult to determine an elastic K-factor for the individual columns. This difficulty was addressed by comparing frame buckling loads obtained using Equation (3.27) with those obtained using a second-order elastic analysis. Individual column buckling loads were calculated as follows:

$$P_{cr} = \frac{\rho^2 EI_o}{(KL^2)} \quad (4.2)$$

where K is the effective length factor calculated using Equation (3.27). The elastic buckling load of the frame was taken as the sum of the elastic buckling loads of all rigidly connected columns.

The second-order frame elastic buckling load was obtained directly from the second order analysis.

In addition to the elastic buckling load comparison, a comparison of frame design strengths calculated using Equation (3.27) and a second order analysis was also prepared. Frame design strengths were calculated according to the LRFD procedure for determining the capacity of compression members as follows:

$$\text{Design Strength} = \phi P_n$$

where ϕ is a resistance factor equal to 0.85, P_n is the nominal resistance of the section to compression in ($= F_{cr} \sum A_{og}$), and $\sum A_{og}$ is the sum of the cross sectional areas of the smaller ends of all columns providing lateral stiffness. F_{cr} , the nominal critical stress, is determined as follows:

For $\lambda_e \leq 1.5$:

$$F_{cr} = (0.658^{\lambda_e^2}) F_y \quad (4.3)$$

For $\lambda_e > 1.5$:

$$F_{cr} = \left[\frac{0.877}{\lambda_e^2} \right] F_y \quad (4.4)$$

where

$$\lambda_e = \sqrt{\frac{F_y \sum A_{og}}{\sum P_e}} \quad (4.5)$$

In which F_y is the specified minimum yield stress of the steel ksi, and $\sum P_e$ is the sum of the elastic buckling loads of columns providing lateral stiffness to frame. It should be noted that this procedure is used to calculate the sum of the design strengths of all columns in the frame, not the design strength of individual columns.

4.2 Results

A wide variety of typical metal building rigid frames were analyzed. The elastic buckling load of each frame was determined using a second-order finite element analysis, and using Equation (3.27) as described in Section 4.1. The frames analyzed included single span frames (no “leaning” columns) and multiple span frames (one or more “leaning” columns). Symmetrical and unsymmetrical frames were considered. Table 4.1 summarizes the critical parameters for each frame as well as the K-factor obtained for each column using Equation (3.27).

**Table 4.1
Critical Frame Parameters**

Frame	File	Delta/H	Left Column			Right Column		
			L (ft)	I _o (in ⁴)	K	L (ft)	I _o (in ⁴)	K
Symmetrical Single Span Frames								
FRA11	fra11_a	0.25578	10.86	74.2	2.25	10.86	74.2	2.25
FRA21	fra21_a	0.13827	16.08	466.1	2.30	16.08	466.1	2.30
FRA61	fra61_a	0.18116	17.73	175.3	1.43	17.73	175.3	1.43
SRHI100	srhi100a	0.04715	8.27	148.6	2.06	8.27	148.6	2.06
SRLO100	srlo100a	0.009179	6.98	1430.1	3.60	6.98	1430.1	3.60
SRLO120	srlo120a	0.22453	21.46	255.9	1.45	21.46	255.9	1.45
SRLO150	srlo150a	0.04146	18.69	1374.4	1.75	18.69	1374.4	1.75
SRLO250	srlo250a	0.06663	37.83	12224.0	2.27	37.83	12224.0	2.27
STB20	stb20a	1.24267	38.43	457.9	1.87	38.43	457.9	1.87
SPMKT	spmkt_a	0.50429	12.86	48.9	2.00	12.86	48.9	2.00
SPMKT1	spmkt1_a	0.37778	21.95	156.2	1.42	21.95	156.2	1.42
SPMKT2	spmkt2_a	0.674	18.34	133.3	2.23	18.34	133.3	2.23
TRE	tre_a	0.24555	27.37	249.3	1.07	27.37	249.3	1.07
TRE1	tre1_a	0.53844	18.76	175.7	2.22	18.76	175.7	2.22
TRE2	tre2_a	0.67251	56.99	941.4	1.14	56.99	941.4	1.14
SUPER	super_a	0.56566	22.44	189.7	1.82	22.44	189.7	1.82
TRECRAN	treocrn_a	0.37026	22.43	189.7	1.49	22.43	189.7	1.49
MURRAY	murray_a	0.01853	10.95	427	1.47	10.95	427	1.47
ELLIOT26	eliot26a	0.01761	10.94	462.3	1.49	10.94	462.3	1.49
Symmetrical Multi-Span Frames								
STIF9	stif9_a	0.32839	20.99	527	2.52	20.99	527	2.52
STIF10	stif10_a	1.41065	26.34	264.7	2.63	26.34	264.7	2.63
Hybrid	hybrid_a	0.17007	16.01	407.1	2.40	16.01	407.1	2.40
STIF2	stif2_a	0.07409	10.50	398.7	2.93	10.50	398.7	2.93
STIF8	stif8_a	0.64143	16.37	89.2	2.12	16.37	89.2	2.12
FRA26	fra26_a	1.82052	18.72	22.5	1.49	18.72	22.5	1.49
Unsymmetrical Single Span Frames								
99219A	99219a_a	0.07964	17.09	370	1.46	18.80	604.8	1.60
99195A	99195a_a	0.03116	17.03	4402.8	3.06	23.21	6259.8	2.31
FRA41	fra41_a	0.34905	22.17	427.7	2.17	25.35	406	1.75
Unsymmetrical Multi-Span Frames								
STIF5	stif5_a	0.14082	14.43	710	3.34	14.43	826.8	3.61
STIF6	stif6_a	0.49312	23.78	965	3.45	29.85	1181.1	2.72
STIF7	stif7_a	0.99921	22.71	130.6	1.96	22.25	130.6	2.02

As described in Section 2.2, restraining girders were provided at the base of each rigidly connected column to satisfy the design assumption that rotational restraint at the base of a pinned column can be taken as $G_B = 10$ for design purposes. Table 4.2 provides a summary of the moment of inertia required of the restraining girders at the base of each frame to provide base restraint of $G_B = 10$.

Table 4.3 compares elastic buckling loads and design strengths computed using both the proposed method and a second-order analysis for a range of rigid frames. It can be seen that the elastic buckling loads predicted using Equation (3.27) agree quite closely with the elastic buckling loads predicted by the second-order finite element analyses. The difference in both elastic buckling loads and design strengths were calculated as follows:

$$\% \text{Difference} = \frac{(\text{Proposed} - \text{FiniteElement})}{\text{FiniteElement}} * 100\% \quad (4.6)$$

Upon observation of Table 4.3 it can be seen that the average difference in elastic buckling load for the frames under consideration is 0.95 percent. The standard deviation is 6.54 percent. The 95 percent confidence interval for the mean error in elastic buckling load prediction is 0.95 ± 2.77 percent. Similarly, the average error in design strength is 0.27 percent with a standard deviation of 2.66 percent. The 95 percent confidence interval for the mean error in design strength prediction is 0.27 ± 1.13 percent. These confidence intervals yield information on the average difference between the results obtained using Equation (3.27) and the finite element solution.

To gain insight into the accuracy of an individual frame buckling load prediction, a prediction interval, rather than a confidence interval, must be used. The 95 percent prediction interval for the elastic buckling load of an individual frame is 0.95 ± 15.68 percent. Similarly, the 95 percent prediction interval for the design strength of an individual frame is 0.27 ± 6.38 percent.

4.3 Conclusions

From Table 4.3, it is concluded that the proposed method for determining the effective length factor of non-prismatic columns compares quite favorably to the results obtained from a second-order analysis. In no case is the difference in elastic buckling loads obtained using the two methods greater than 15 percent. While the design strength comparisons are even closer, one must use care in judging the effectiveness of the method based on design strength estimates. The majority of the frames considered in this study buckle inelastically. From Figure 4.1, it can be seen that the LRFD compressive strength equations produce a great deal of “smoothing” in the inelastic range, because the strength curve is relatively flat in the inelastic region. Because of the flatness of the curve, large relative changes in effective length factor may lead to relatively small changes in design strength. Conversely, very small changes in effective length factor can lead to

**Table 4.2
Column Base Restraint**

Frame	L_c (ft)	I_{oc} (in⁴)	L_g (ft)	G	I_g (in⁴)
fra21	16.08	466.1	5	10	4.83
fra11	10.86	74.2	5	10	1.14
fra61	17.73	175.3	5	10	1.65
srhi100	8.27	148.6	5	10	2.99
srlo100	6.98	1430.1	5	10	34.16
stb20	38.43	457.9	5	10	1.99
srlo250	36.83	12224	5	10	55.31
srlo	21.46	255.9	5	10	1.99
srlo150	18.69	1374.4	5	10	12.26
spmkt	12.86	48.9	5	10	0.63
spmkt1	21.95	156.2	5	10	1.19
spmkt2	18.34	133.3	5	10	1.21
tre	27.37	249.3	5	10	1.52
tre1	18.76	175.7	5	10	1.56
tre2	56.99	941.4	5	10	2.75
super	22.44	189.7	5	10	1.41
treocrane	22.43	189.7	5	10	1.41
fra26	18.72	22.5	5	10	0.20
elliott26	10.94	462.3	5	10	7.04
murray	10.95	427	5	10	6.50
stif2	10.50	398.7	5	10	6.33
stif8	16.37	89.2	5	10	0.91
stif9	22.10	527	5	10	3.97
stif10	26.34	264.7	5	10	1.68
Hybrid	16.01	407.1	5	10	4.24
99219a (left column)	17.09	370	5	10	3.61
99219a (right column)	19.52	604.8	5	5	10.33
fra41 (left column)	22.17	427.7	5	10	3.22
fra41 (right column)	25.35	406	5	10	2.67
99195a (left column)	17.03	4402.8	5	10	43.09
99195a (right column)	23.63	6259.8	5	10	44.16
stif7 (left column)	22.71	130.6	5	10	0.96
stif7 (right column)	22.25	130.6	5	10	0.98
stif5 (left column)	14.43	710	5	10	8.20
stif5 (right column)	14.43	777.5	5	10	8.98
stif6 (left column)	23.78	965	5	10	6.76
stif6 (right column)	29.85	1181.1	5	10	6.59

**Table 4.3
Buckling Load Comparison**

Fy (ksi)= 50		Frame Elastic Buckling Load				Frame Design Strength		
Frame	File	A _g (in ²)	Proposed	Finite Element	% Difference	Proposed	Finite Element	% Difference
Symmetrical Single Span Frames								
FRA11	fra11_a	10.12	493	474	4.0%	280	275	1.7%
FRA21	fra21_a	20.50	1352	1304	3.7%	634	627	1.2%
FRA61	fra61_a	12.52	1080	1114	-3.0%	417	421	-0.7%
SRHI100	srhi100a	12.00	2025	2380	-14.9%	451	459	-1.8%
SRLO100	srlo100a	28.50	9006	8176	10.1%	1134	1126	0.7%
SRLO120	srlo120a	15.58	1057	1076	-1.8%	486	489	-0.6%
SRLO150	srlo150a	28.76	5118	4934	3.7%	1087	1082	0.4%
SRLO250	srlo250a	90.00	6596	6606	-0.1%	2875	2876	0.0%
STB20	stb20a	11.12	354	316	11.9%	245	226	8.1%
SPMKT	spmkt_a	7.38	294	288	1.9%	185	183	1.0%
SPMKT1	spmkt1_a	10.50	640	674	-5.0%	317	322	-1.7%
SPMKT2	spmkt2_a	9.24	316	314	0.6%	213	212	0.3%
TRE	tre_a	18.00	1147	1290	-11.1%	551	571	-3.6%
TRE1	tre1_a	12.28	404	410	-1.4%	276	279	-0.9%
TRE2	tre2_a	29.00	888	940	-5.5%	622	646	-3.7%
SUPER	super_a	12.58	452	418	8.2%	299	285	4.9%
TRECRAN	treocrn_a	12.58	673	706	-4.7%	362	368	-1.8%
MURRAY	murray_a	21.74	6549	5846	12.0%	862	855	0.8%
ELLIOT26	eliot26a	22.08	6904	6166	12.0%	878	871	0.8%
Symmetrical Multi-Span Frames								
STIF9	stif9_a	12.24	747	760	-1.7%	369	371	-0.6%
STIF10	stif10_a	10.76	219	220	-0.6%	163	164	-0.6%
Hybrid	hybrid_a	14.00	1097	1080	1.6%	456	454	0.4%
STIF2	stif2_a	11.24	1669	1748	-4.5%	415	418	-0.6%
STIF8	stif8_a	8.50	295	298	-1.0%	198	199	-0.6%
FRA26	fra26_a	5.78	114	120	-4.8%	85	89	-4.8%
Unsymmetrical Single-Span Frames								
99219A	99219a_a	22.5	2513	2494	0.8%	793	792	0.1%
99195A	99195a_a	39.76	7553	7440	1.5%	1514	1511	0.2%
FRA41	fra41_a	13	780	710	9.8%	390	377	3.5%
Unsymmetrical Multi-Span Frames								
STIF5	stif5_a	15.08	1213	1218	-0.4%	494	495	-0.1%
STIF6	stif6_a	16.8	641	644	-0.5%	412	414	-0.3%
STIF7	stif7_a	9	259	238	8.7%	185	173	6.6%

large differences in elastic buckling load. To illustrate this point, consider points A and B on Figure 4.1, where a relatively large difference in elastic buckling load exists between the points. However, the difference in design strength for these points is much smaller. Because this “smoothing effect” tends to reduce differences between buckling loads calculated using the proposed method and those calculated using second-order analyses, the accuracy of elastic buckling load predictions should be used as the true measure of the effectiveness of the proposed method. However, because most columns will fall within the inelastic buckling region of the AISC column strength curve, it is reassuring to note that the design strengths predicted using the proposed method will usually be extremely close to the design strengths predicted by second-order analyses.

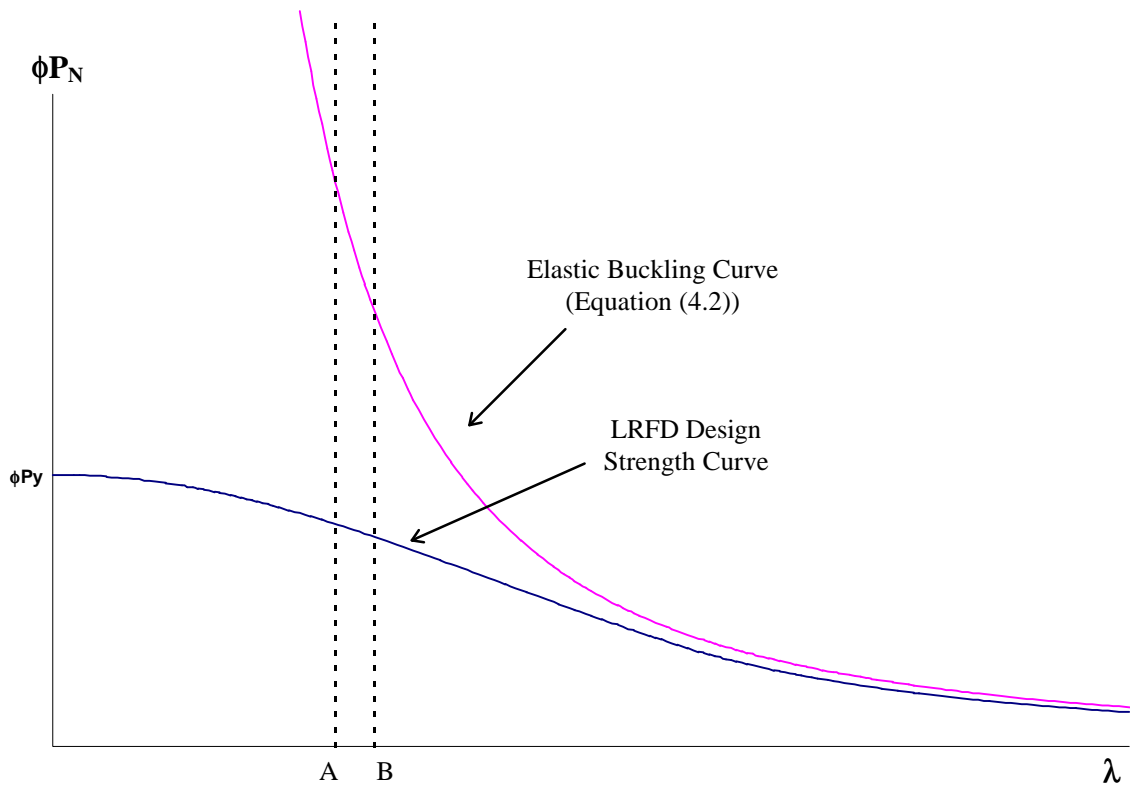


Figure 4.1
Typical Column Strength Curves

CHAPTER V CONCLUSIONS

The concept of effective length is used in current design procedures for steel frames. Because of this reliance, the use of inaccurate methods for estimating effective length can lead to unrealistic designs. Many methods have been proposed which allow the design engineer to estimate column effective length. However, many are based upon assumptions that are not often satisfied in practice, and most assume the use of prismatic (i.e., constant cross section) members.

Metal building manufacturers typically work with members which do not have constant cross sectional properties. Of the available methods for determining effective column length, only the method proposed by Lee (1972; 1979; 1981) was found to be applicable to non-prismatic members. Unfortunately, this method relies extensively on the use of charts, making it quite time consuming, and leading to difficulties in computerization. In addition, this method is applicable only to specific types of tapered members and frames.

To address the above concerns, an expression was proposed which can be applied to a wide variety of frames. The expression is a modification of an expression developed by Lui (1977) for use with frames composed of prismatic members. The method is shown to be accurate, and requires only a first-order analysis. It does not rely on the use of charts, and lends itself easily to computerization. Appendix A contains sample calculations illustrating the simplicity of the proposed procedure.

Because of its accuracy and ease of use, it is recommended that the proposed method for determining column effective length factors be used whenever a more exact second-order analysis is deemed undesirable.

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NOMENCLATURE

A_F = moment magnification factor

A_{og} = cross sectional area of smaller end of column

$(A_F)_i$ = member moment magnification factor

C_L = stiffness correction factor to account for P- δ effects

E = Modulus of Elasticity

F_{cr} = nominal critical buckling stress

F_y = specified minimum yield stress of steel

g = length modification factor to convert tapered member into an "equivalent" prismatic member possessing the cross sectional properties of the smaller end of the tapered member

G = relative rotational restraint of member end

G_A = relative rotational restraint at end "A" of member

G_B = relative rotational restraint at end "B" of member

g_c = length modification factor of column

g_g = length modification factor of girder

I = moment of inertia

I_c = moment of inertia of column

I_g = moment of inertia of girder

I_i = moment of inertia of i -th column in story

I_L = moment of inertia of larger end of singly tapered member

I_o = moment of inertia of smaller end of tapered member

I_{oc} = moment of inertia of smaller end of tapered column

I_{og} = moment of inertia of smaller end of tapered girder

K = effective length factor obtained from AISC alignment charts

K' = modified effective length factor of weaker column in unsymmetrical frame

K_i = effective length factor of i -th column in story

K_{modified} = modified effective length factor of stiffer column in unsymmetrical frame

K_n = effective length factor as determined from AISC alignment charts

L = length

L_c = length of column

L_g = length of girder

L_i = length of i -th column in story

m = factor to account for end condition of restraining girder when determining rotational restraint for use in AISC alignment charts

m = ratio of smaller to larger end moments in member (positive if member bends in reverse curvature)

M_A = end moment at end "A" of member

M_B = end moment at end "B" of member

P = axial load

P_e = elastic lateral buckling load

P_i = axial load acting on i -th column in story

P_n = nominal axial capacity of member

P_{taper} = elastic lateral buckling load of tapered member

P_u = axial load acting on column

P_{ui} = axial load acting on i -th column in story

$(P_{ek})_i$ = elastic lateral buckling load of i -th column in story

r = P - δ stiffness reduction factor

S = story stiffness accounting for P - Δ effect

S_I = first order story stiffness

s_{ii}, s_{ij} = stability functions to account for the presence of axial load

s_{im} = first-order member lateral stiffness

α = ratio of moments of inertia of weaker to stronger column in frame

Δ_I = lateral drift of story

ϕ = LRFD resistance factor

γ = taper ratio

η = member stiffness index

λ = ratio of axial load on weaker column to axial load on stronger column in frame

λ_e = column slenderness ratio

$\sum H$ = sum of fictitious lateral loads acting on story

$\sum(P/L)$ = sum of axial loads in columns providing lateral stiffness to frame divided by column length

APPENDIX A
SAMPLE CALCULATIONS

Sample Calculations for Frame “FRA11”

Given:

Frame as shown on sketch below.

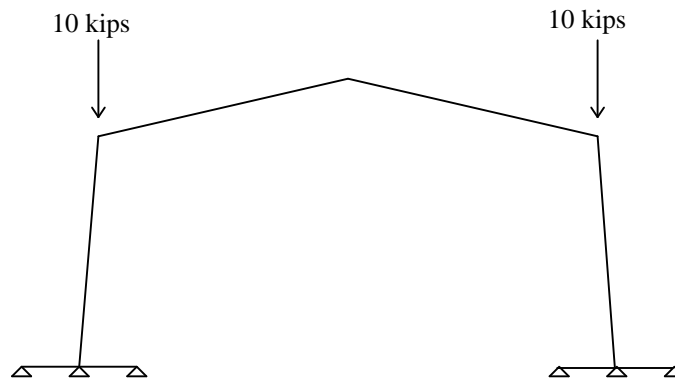
$F_y = 50$ ksi

Member details are found in Appendix B

Find:

(a) Compare elastic buckling load of frame as computed using a second-order analysis and Equation (3.27)

(b) Compare design strength of frame as computed using a second-order analysis and Equation (3.27)



Left Column

$L = 10.8564$ ft

$I_{O_i} = 74.2$ in⁴

$A_{O_g} = 5.06$ in²

Right Column

$L = 10.8564$ ft

$I_{O_i} = 74.2$ in⁴

$A_{O_g} = 5.06$ in²

(Column length measured from base to knee work-point)

From elastic first-order analysis without 10 kips load (only 0.01 kip lateral load):

$\Sigma H = 0.01$ kip

Note: any value for ΣH is acceptable, because the ratio $\Delta_I / \Sigma H$ is constant for a first-order, elastic analysis)

$\Delta_I = 0.0025578$ in.

Solution:

a) Elastic Buckling Load

Second-Order Analysis: Frame Elastic Buckling Load = 474 kips (from SAP90 finite element analysis)

Using Equation (3.27):

$$K_i = \sqrt{\frac{\rho^2 EI_{O_i}}{P_i L_i^2} \left[\frac{P_i L_i^2}{60EI_{O_i}} + \frac{\sum P \Delta_i}{L \sum H} \right]}$$

$$K_{\text{Left}} = K_{\text{Right}} = \sqrt{\frac{\rho^2 (29000)(74.2)}{(10)(10.8564 \times 12)^2} \left[\frac{(10)(10.8564 \times 12)^2}{(60)(29000)(74.2)} + \frac{(10 + 10)(.0025578)}{(10.8564 \times 12)(.01)} \right]}$$

$$= 2.253$$

$$P_{\text{cr,Left}} = P_{\text{cr,Right}} = \frac{\rho^2 EI_o}{(KL)^2} = \frac{\rho^2 (29000)(74.2)}{(2.253 \times 10.8564 \times 12)^2} = 246.5 \text{ kips}$$

Proposed Method: Frame Elastic Buckling Load = 2(246.5) = 493 kips

$$\% \text{Difference} = \frac{\text{Proposed} - \text{FiniteElement}}{\text{FiniteElement}} \times 100\% = \frac{493 - 474}{474} \times 100\% = +4.0\%$$

b) Design Strength

Second Order Analysis:

$$l_e = \sqrt{\frac{\sum A_{Og} F_y}{P_{cr}}} = \sqrt{\frac{(5.06 + 5.06)(50)}{474}} = 1.033 \leq 1.5$$

$$F_{cr} = \left[0.658^{l_e^2} \right] F_y = \left[0.658^{1.033^2} \right] (50) = 31.99 \text{ ksi}$$

$$f P_n = f F_{cr} \sum A_{Og} = 85(31.99)(5.06 + 5.06) = 275.1 \text{ kips}$$

Proposed Method:

$$l_e = \sqrt{\frac{\sum A_{Og} F_y}{P_{cr}}} = \sqrt{\frac{(5.06 + 5.06)(50)}{493}} = 1.013 \leq 15$$

$$F_{cr} = \left[0.658^{l_e^2} \right] F_y = \left[0.658^{1.013^2} \right] (50) = 32.54 \text{ ksi}$$

$$fP_n = fF_{cr} \sum A_{Og} = 0.85(32.54)(5.06 + 5.06) = 279.9 \text{ kips}$$

$$\% \text{Difference} = \frac{\text{Proposed} - \text{FiniteElement}}{\text{FiniteElement}} \times 100\% = \frac{279.9 - 275.1}{275.1} \times 100\% = +1.7\%$$

APPENDIX B
SAP90 INPUT DATA FILES

Buckling Load: P=238k

C This is file FRA11_A written by SAPIN on Wed Apr 09 00:42:16 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=41 YN=13 ZN=1

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240 252 264 276

288 300 312 324 336 348 360 372

384 396 408 420 432 444 456 468

480

0 12 24 36 48 60 72 84

96 108 120 132 144

0

JOINTS

1 X=0 Y=0 Z=0

2 X=-0.12 Y=71.52 Z=0

3 X=-0.24 Y=125.52 Z=0

4 X=-0.186 Y=130.2768 Z=0

5 X=3.72 Y=130.56 Z=0

6 X=111.12 Y=135.48 Z=0

7 X=233.88 Y=141.12 Z=0

8 X=356.64 Y=135.48 Z=0

9 X=464.04 Y=130.56 Z=0

10 X=467.9292 Y=130.2768 Z=0

11 X=467.88 Y=125.52 Z=0

12 X=467.88 Y=71.52 Z=0

13 X=467.76 Y=0 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=407.8 Y=0 Z=0

17 X=527.8 Y=0 Z=0

FRAME

NM=8 NL=1 NSEC=0

1 SH=I T=8,5,0.3125,0.3125,5,0.5 E=29000 G=11154 W=0.0017853 M=4.6204E-06
TC=8.3E-06

2 SH=I T=8,5,0.3125,0.3125,5,0.5 E=29000 G=11154 W=0.0017853 M=4.6204E-06
TC=8.3E-06

3 SH=I T=10,5,0.3125,0.125,5,0.375 E=29000 G=11154 W=0.0013022 M=3.3702E-06
TC=8.3E-06

4 SH=I T=18.96,5,0.3125,0.125,5,0.375 E=29000 G=11154 W=0.0016192 M=4.1905E-06
 TC=8.3E-06
 5 SH=I T=18.96,5,0.3125,0.149,5,0.25 E=29000 G=11154 W=0.0015717 M=4.0676E-06
 TC=8.3E-06
 6 SH=I T=29.21,5,0.3125,0.149,5,0.25 E=29000 G=11154 W=0.0020039 M=5.1861E-06
 TC=8.3E-06
 7 A=30 J=0 I=10000,0 AS=0,0 E=29000 G=11154 W=0.00849 M=2.1972E-05 TC=8.3E-06
 8 A=1 J=1 I=1.139,0 AS=0,0 E=29000 G=11154 W=0.00028299 M=7.324E-07 TC=8.3E-06
 1 WL=0,0,0 WG=0,-0.1,0 T=0,0,0
 1 1 2 M=1,1,1 LP=1,0 MS= 0,0
 2 2 3 M=2,2,1 LP=1,0 MS= 0,0
 5 5 6 M=3,4,2 LP=1,0 MS= 0,0
 6 6 7 M=4,5,2 LP=1,0 MS= 0,0
 7 7 8 M=5,4,2 LP=1,0 MS= 0,0
 8 8 9 M=4,3,2 LP=1,0 MS= 0,0
 11 11 12 M=2,2,1 LP=1,0 MS= 0,0
 12 12 13 M=1,1,1 LP=1,0 MS= 0,0
 13 14 1 M=8,8,1 LP=1,0 MS= 0,0
 14 1 15 M=8,8,1 LP=1,0 MS= 0,0
 15 16 13 M=8,8,1 LP=1,0 MS= 0,0
 16 13 17 M=8,8,1 LP=1,0 MS= 0,0
 3 3 4 M=7,7,1 LP=1,0 MS= 0,0
 4 4 5 M=7,7,1 LP=1,0 MS= 0,0
 9 9 10 M=7,7,1 LP=1,0 MS= 0,0
 10 10 11 M=7,7,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 13 13 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0

11 11 1 R=0,0,1,1,1,0
1 1 1
7 7 1

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
10 10 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=2.37

Buckling Load: P=653k

C This is file FRA21_A written by SAPIN on Thu Apr 10 11:38:35 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=31 YN=11 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720

0 24 48 72 96 120 144 168

192 216 240

0

JOINTS

1 X=0 Y=0 Z=0

2 X=-0.12 Y=143.52 Z=0

3 X=-0.12 Y=180.48 Z=0

4 X=-0.1608 Y=192.9 Z=0

5 X=6.48 Y=193.2 Z=0

6 X=185.76 Y=201.84 Z=0

7 X=350.52 Y=209.76 Z=0

8 X=515.04 Y=201.72 Z=0

9 X=694.44 Y=192.96 Z=0

10 X=701.82 Y=192.9 Z=0

11 X=701.04 Y=180.48 Z=0

12 X=701.04 Y=143.52 Z=0

13 X=700.92 Y=0 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=640.9 Y=0 Z=0

17 X=760.9 Y=0 Z=0

FRAME

NM=6 NL=0 NSEC=0

1 SH=I T=14,8,0.4375,0.125,8,0.625 E=29000 G=11154 W=0.0028632 M=7.4098E-06
TC=8.3E-06

2 SH=I T=14,8,0.4375,0.25,8,0.625 E=29000 G=11154 W=0.0033208 M=8.5943E-06
TC=8.3E-06

3 SH=I T=27,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.0023899 M=6.1849E-06
TC=8.3E-06

4 SH=I T=27,6,0.4375,0.149,6,0.3125 E=29000 G=11154 W=0.0023804 M=6.1604E-06
TC=8.3E-06

5 A=50 J=0 I=9.794E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 6 A=1 J=0 I=4.832,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,1,1 LP=1,0 MS= 0,0
 2 2 3 M=2,2,1 LP=1,0 MS= 0,0
 3 3 4 M=5,5,1 LP=1,0 MS= 0,0
 4 4 5 M=5,5,1 LP=1,0 MS= 0,0
 5 5 6 M=3,3,1 LP=1,0 MS= 0,0
 6 6 7 M=4,4,1 LP=1,0 MS= 0,0
 7 7 8 M=4,4,1 LP=1,0 MS= 0,0
 8 8 9 M=3,3,1 LP=1,0 MS= 0,0
 9 9 10 M=5,5,1 LP=1,0 MS= 0,0
 10 10 11 M=5,5,1 LP=1,0 MS= 0,0
 11 11 12 M=2,2,1 LP=1,0 MS= 0,0
 12 12 13 M=1,1,1 LP=1,0 MS= 0,0
 13 14 1 M=6,6,1 LP=1,0 MS= 0,0
 14 1 15 M=6,6,1 LP=1,0 MS= 0,0
 15 16 13 M=6,6,1 LP=1,0 MS= 0,0
 16 13 17 M=6,6,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 13 13 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 11 11 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=.1,-100,0,0,0,0
 10 10 1 L=1 F=0,-100,0,0,0,0

PDELTA
M=1000 TOLD=0.001
L=1 SF=6.52

Buckling Load: P=557k

C This is file FRA61_A written by SAPIN on Thu Apr 10 11:39:06 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=39 YN=12 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912

0 24 48 72 96 120 144 168

192 216 240 264

0

JOINTS

1 X=0 Y=0 Z=0

2 X=13.56 Y=179.52 Z=0

3 X=14.88 Y=196.8 Z=0

4 X=14.88 Y=212.71 Z=0

5 X=33.24 Y=214.2 Z=0

6 X=220.44 Y=243.84 Z=0

7 X=291.84 Y=248.64 Z=0

8 X=434.16 Y=256.8 Z=0

9 X=576.48 Y=248.52 Z=0

10 X=647.76 Y=243.72 Z=0

11 X=834.96 Y=214.2 Z=0

12 X=853.32 Y=212.71 Z=0

13 X=853.32 Y=196.8 Z=0

14 X=854.64 Y=179.52 Z=0

15 X=868.2 Y=0 Z=0

16 X=-60 Y=0 Z=0

17 X=60 Y=0 Z=0

18 X=808.2 Y=0 Z=0

19 X=928.2 Y=0 Z=0

FRAME

NM=11 NL=0 NSEC=0

1 SH=I T=12,6,0.25,0.178,6,0.4375 E=29000 G=11154 W=0.0017372 M=4.4959E-06

TC=8.3E-06

2 SH=I T=37.48,6,0.25,0.178,6,0.4375 E=29000 G=11154 W=0.0030208 M=7.8177E-06

TC=8.3E-06

3 SH=I T=40,6,0.25,0.178,6,0.4375 E=29000 G=11154 W=0.0031477 M=8.1462E-06
 TC=8.3E-06
 4 SH=I T=38,6,0.25,0.178,6,0.4375 E=29000 G=11154 W=0.003047 M=7.8855E-06
 TC=8.3E-06
 5 SH=I T=13,6,0.25,0.178,6,0.4375 E=29000 G=11154 W=0.0017876 M=4.6263E-06
 TC=8.3E-06
 6 SH=I T=13,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0012912 M=3.3416E-06 TC=8.3E-
 06
 7 SH=I T=16.99,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0014323 M=3.7069E-06
 TC=8.3E-06
 8 SH=I T=16.99,6,0.3125,0.125,6,0.25 E=29000 G=11154 W=0.0015362 M=3.9758E-06
 TC=8.3E-06
 9 SH=I T=25,6,0.3125,0.125,6,0.25 E=29000 G=11154 W=0.0018196 M=4.7091E-06
 TC=8.3E-06
 10 A=50 J=0 I=2.5834E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05
 TC=8.3E-06
 11 A=1 J=0 I=1.648,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=2,3,2 LP=1,0 MS= 0,0
 3 3 4 M=10,10,1 LP=1,0 MS= 0,0
 4 4 5 M=10,10,1 LP=1,0 MS= 0,0
 5 5 6 M=4,5,2 LP=1,0 MS= 0,0
 6 6 7 M=6,7,2 LP=1,0 MS= 0,0
 7 7 8 M=8,9,2 LP=1,0 MS= 0,0
 8 8 9 M=9,8,2 LP=1,0 MS= 0,0
 9 9 10 M=7,6,2 LP=1,0 MS= 0,0
 10 10 11 M=5,4,2 LP=1,0 MS= 0,0
 11 11 12 M=10,10,1 LP=1,0 MS= 0,0
 12 12 13 M=10,10,1 LP=1,0 MS= 0,0
 13 13 14 M=3,2,2 LP=1,0 MS= 0,0
 14 14 15 M=2,1,2 LP=1,0 MS= 0,0
 15 16 1 M=11,11,1 LP=1,0 MS= 0,0
 16 1 17 M=11,11,1 LP=1,0 MS= 0,0
 17 18 15 M=11,11,1 LP=1,0 MS= 0,0
 18 15 19 M=11,11,1 LP=1,0 MS= 0,0

RESTRAINTS

16 16 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 18 18 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 19 19 1 R=1,1,1,1,1,0

2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=.1,-100,0,0,0,0
12 12 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=5.57

Buckling Load: P=1200k

C This is file SRHI100A written by SAPIN on Thu Apr 10 11:39:56 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=21 YN=6 ZN=1

0 60 120 180 240 300 360 420

480 540 600 660 720 780 840 900

960 1020 1080 1140 1200

0 60 120 180 240 300

0

JOINTS

1 X=0 Y=0 Z=0

2 X=12 Y=87.48 Z=0

3 X=12 Y=99.294 Z=0

4 X=30.24 Y=105.36 Z=0

5 X=181.56 Y=160.68 Z=0

6 X=316.32 Y=210.12 Z=0

7 X=452.52 Y=255.48 Z=0

8 X=585.24 Y=299.76 Z=0

9 X=717.96 Y=255.48 Z=0

10 X=854.16 Y=210.12 Z=0

11 X=988.92 Y=160.68 Z=0

12 X=1140.24 Y=105.36 Z=0

13 X=1158.5 Y=99.294 Z=0

14 X=1158.48 Y=87.48 Z=0

15 X=1170.48 Y=0 Z=0

16 X=-60 Y=0 Z=0

17 X=60 Y=0 Z=0

18 X=1110 Y=0 Z=0

19 X=1230 Y=0 Z=0

FRAME

NM=10 NL=1 NSEC=0

1 SH=I T=12,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0016626 M=4.3028E-06 TC=8.3E-06

2 SH=I T=36,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0033606 M=8.6972E-06 TC=8.3E-06

3 SH=I T=36,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.0028432 M=7.3582E-06 TC=8.3E-06

4 SH=I T=28.15,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.0024478 M=6.3349E-06 TC=8.3E-06

5 SH=I T=28.15,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0020141 M=5.2126E-06
 TC=8.3E-06
 6 SH=I T=21,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0017128 M=4.4328E-06
 TC=8.3E-06
 7 SH=I T=21,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0015742 M=4.074E-06 TC=8.3E-
 06
 8 SH=I T=21,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0017128 M=4.4328E-06
 TC=8.3E-06
 9 A=50 J=0 I=1.9576E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-
 06
 10 A=50 J=0 I=2.9931,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 1 WL=0,0,0 WG=0,-1,0 T=0,0,0
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=9,9,1 LP=1,0 MS= 0,0
 3 3 4 M=9,9,1 LP=1,0 MS= 0,0
 4 4 5 M=3,4,2 LP=1,0 MS= 0,0
 5 5 6 M=5,6,2 LP=1,0 MS= 0,0
 6 6 7 M=7,7,1 LP=1,0 MS= 0,0
 7 7 8 M=8,8,1 LP=1,0 MS= 0,0
 8 8 9 M=8,8,1 LP=1,0 MS= 0,0
 9 9 10 M=7,7,1 LP=1,0 MS= 0,0
 10 10 11 M=6,5,2 LP=1,0 MS= 0,0
 11 11 12 M=4,3,2 LP=1,0 MS= 0,0
 12 12 13 M=9,9,1 LP=1,0 MS= 0,0
 13 13 14 M=9,9,1 LP=1,0 MS= 0,0
 14 14 15 M=2,1,2 LP=1,0 MS= 0,0
 15 16 1 M=10,10,1 LP=1,0 MS= 0,0
 16 1 17 M=10,10,1 LP=1,0 MS= 0,0
 17 18 15 M=10,10,1 LP=1,0 MS= 0,0
 18 15 19 M=10,10,1 LP=1,0 MS= 0,0

RESTRAINTS

16 16 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 18 18 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 19 19 1 R=1,1,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0

9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1
2 2 1
4 4 1
12 12 1
14 14 1
2 2 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0

LOADS

3 3 1 L=1 F=0.1,-100,0,0,0,0
13 13 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=11.9

Buckling Load: P=4090k

C This is file SRLO100A written by SAPIN on Thu Apr 10 11:41:38 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=21 YN=4 ZN=1

0 60 120 180 240 300 360 420

480 540 600 660 720 780 840 900

960 1020 1080 1140 1200

0 60 120 180

0

JOINTS

1 X=0 Y=0 Z=0

2 X=8.04 Y=68.16 Z=0

3 X=8.1156 Y=83.724 Z=0

4 X=29.64 Y=84.6 Z=0

5 X=111.36 Y=93 Z=0

6 X=254.4 Y=108.36 Z=0

7 X=433.56 Y=119.4 Z=0

8 X=576.48 Y=127.08 Z=0

9 X=719.4 Y=119.4 Z=0

10 X=898.56 Y=108.36 Z=0

11 X=1041.6 Y=93 Z=0

12 X=1123.32 Y=84.6 Z=0

13 X=1144.187 Y=83.724 Z=0

14 X=1144.92 Y=68.16 Z=0

15 X=1152.96 Y=0 Z=0

16 X=-60 Y=0 Z=0

17 X=60 Y=0 Z=0

18 X=1093 Y=0 Z=0

19 X=1213 Y=0 Z=0

FRAME

NM=10 NL=1 NSEC=0

1 SH=I T=28,6,0.25,0.375,6,0.375 E=29000 G=11154 W=0.0039664 M=1.0265E-05

TC=8.3E-06

2 SH=I T=44,6,0.25,0.375,6,0.375 E=29000 G=11154 W=0.0056644 M=1.4659E-05

TC=8.3E-06

3 SH=I T=44,6,0.25,0.25,6,1.25 E=29000 G=11154 W=0.0055539 M=1.4373E-05 TC=8.3E-

06

4 SH=I T=37.45,6,0.25,0.25,6,1.25 E=29000 G=11154 W=0.0050905 M=1.3174E-05

TC=8.3E-06

5 SH=I T=37.45,6,0.25,0.25,6,0.75 E=29000 G=11154 W=0.0042768 M=1.1068E-05
 TC=8.3E-06
 6 SH=I T=26,6,0.25,0.25,6,0.75 E=29000 G=11154 W=0.0034667 M=8.9719E-06 TC=8.3E-
 06
 7 SH=I T=26,6,0.4375,0.178,6,0.375 E=29000 G=11154 W=0.0026484 M=6.8541E-06
 TC=8.3E-06
 8 SH=I T=26,6,0.75,0.125,6,0.25 E=29000 G=11154 W=0.0025824 M=6.6831E-06 TC=8.3E-
 06
 9 A=50 J=0 I=5.4175E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-
 06
 10 A=50 J=0 I=34.162,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 1 WL=0,0,0 WG=0,-1,0 T=0,0,0
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=9,9,1 LP=1,0 MS= 0,0
 3 3 4 M=9,9,1 LP=1,0 MS= 0,0
 4 4 5 M=3,4,2 LP=1,0 MS= 0,0
 5 5 6 M=5,6,2 LP=1,0 MS= 0,0
 6 6 7 M=7,7,1 LP=1,0 MS= 0,0
 7 7 8 M=8,8,1 LP=1,0 MS= 0,0
 8 8 9 M=8,8,1 LP=1,0 MS= 0,0
 9 9 10 M=7,7,1 LP=1,0 MS= 0,0
 10 10 11 M=6,5,2 LP=1,0 MS= 0,0
 11 11 12 M=4,3,2 LP=1,0 MS= 0,0
 12 12 13 M=9,9,1 LP=1,0 MS= 0,0
 13 13 14 M=9,9,1 LP=1,0 MS= 0,0
 14 14 15 M=2,1,2 LP=1,0 MS= 0,0
 15 16 1 M=10,10,1 LP=1,0 MS= 0,0
 16 1 17 M=10,10,1 LP=1,0 MS= 0,0
 17 18 15 M=10,10,1 LP=1,0 MS= 0,0
 18 15 19 M=10,10,1 LP=1,0 MS= 0,0

RESTRAINTS

16 16 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 18 18 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 19 19 1 R=1,1,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0

9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
2 2 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0

LOADS

3 3 1 L=1 F=0.1,-100,0,0,0,0
13 13 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=40.88

Buckling Load: P=538k

C This is file SRLO120A written by SAPIN on Thu Apr 10 11:43:33 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=61 YN=15 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336

0

JOINTS

1 X=0 Y=0 Z=0

2 X=11.16 Y=179.52 Z=0

3 X=15 Y=247.2 Z=0

4 X=15 Y=257.5 Z=0

5 X=36.48 Y=259.32 Z=0

6 X=241.32 Y=285.72 Z=0

7 X=420.12 Y=301.92 Z=0

8 X=563.4 Y=310.08 Z=0

9 X=705 Y=318.12 Z=0

10 X=846.6 Y=310.08 Z=0

11 X=989.88 Y=301.92 Z=0

12 X=1168.68 Y=285.72 Z=0

13 X=1373.52 Y=259.32 Z=0

14 X=1395 Y=257.5 Z=0

15 X=1395 Y=240.72 Z=0

16 X=1398.84 Y=179.52 Z=0

17 X=1410 Y=0 Z=0

20 X=-60 Y=0 Z=0

21 X=60 Y=0 Z=0

22 X=1350 Y=0 Z=0

23 X=1470 Y=0 Z=0

FRAME

NM=11 NL=1 NSEC=0

1 SH=I T=12,6,0.5,0.1489,6,0.5 E=29000 G=11154 W=0.0021615 M=5.594E-06 TC=8.3E-06
 2 SH=I T=34.33,6,0.5,0.1489,6,0.5 E=29000 G=11154 W=0.0031025 M=8.0292E-06
 TC=8.3E-06
 3 SH=I T=34.33,6,0.5,0.25,6,0.5 E=29000 G=11154 W=0.0040561 M=1.0497E-05 TC=8.3E-06
 4 SH=I T=42,6,0.5,0.25,6,0.5 E=29000 G=11154 W=0.0045987 M=1.1901E-05 TC=8.3E-06
 5 SH=I T=42,6,0.3125,0.178,6,0.625 E=29000 G=11154 W=0.0036604 M=9.473E-06
 TC=8.3E-06
 6 SH=I T=27,6,0.3125,0.178,6,0.625 E=29000 G=11154 W=0.0029047 M=7.5174E-06
 TC=8.3E-06
 7 SH=I T=27,6,0.25,0.178,6,0.25 E=29000 G=11154 W=0.0021839 M=5.6519E-06 TC=8.3E-06
 8 SH=I T=34.5,6,0.25,0.178,6,0.25 E=29000 G=11154 W=0.0025617 M=6.6297E-06
 TC=8.3E-06
 9 SH=I T=42,6,0.25,0.178,6,0.25 E=29000 G=11154 W=0.0029395 M=7.6074E-06 TC=8.3E-06
 10 A=50 J=0 I=4.253E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 11 A=2 J=0 I=1.988,0 AS=0,0 E=29000 G=11154 W=0.000566 M=1.4648E-06 TC=8.3E-06
 1 WL=0,0,0 WG=0,-1,0 T=0,0,0
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=3,4,2 LP=1,0 MS= 0,0
 3 3 4 M=10,10,1 LP=1,0 MS= 0,0
 4 4 5 M=10,10,1 LP=1,0 MS= 0,0
 5 5 6 M=5,6,2 LP=1,0 MS= 0,0
 6 6 7 M=7,7,1 LP=1,0 MS= 0,0
 7 7 8 M=7,8,2 LP=1,0 MS= 0,0
 8 8 9 M=8,9,2 LP=1,0 MS= 0,0
 9 9 10 M=9,8,2 LP=1,0 MS= 0,0
 10 10 11 M=8,7,2 LP=1,0 MS= 0,0
 11 11 12 M=7,7,1 LP=1,0 MS= 0,0
 12 12 13 M=7,6,2 LP=1,0 MS= 0,0
 13 13 14 M=10,10,1 LP=1,0 MS= 0,0
 14 14 15 M=10,10,1 LP=1,0 MS= 0,0
 15 15 16 M=4,3,2 LP=1,0 MS= 0,0
 16 16 17 M=2,1,2 LP=1,0 MS= 0,0
 17 20 1 M=11,11,1 LP=1,0 MS= 0,0
 18 1 21 M=11,11,1 LP=1,0 MS= 0,0
 19 22 17 M=11,11,1 LP=1,0 MS= 0,0
 20 17 23 M=11,11,1 LP=1,0 MS= 0,0

RESTRAINTS

20 20 1 R=1,1,1,1,0

1 1 1 R=1,1,1,1,1,0
21 21 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0
23 23 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0
22 22 1 R=1,1,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
14 14 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=5.38

Buckling Load: P=2470k

C This is file SRLO150A written by SAPIN on Thu Apr 10 11:44:11 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=76 YN=12 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440 1464 1488 1512

1536 1560 1584 1608 1632 1656 1680 1704

1728 1752 1776 1800

0 24 48 72 96 120 144 168

192 216 240 264

0

JOINTS

1 X=0 Y=0 Z=0

2 X=10.56 Y=96 Z=0

3 X=21.84 Y=197.28 Z=0

4 X=21.8664 Y=224.244 Z=0

5 X=51.24 Y=226.68 Z=0

6 X=193.92 Y=242.88 Z=0

7 X=336.84 Y=260.76 Z=0

8 X=479.88 Y=278.88 Z=0

9 X=884.04 Y=306.6 Z=0

10 X=1288.08 Y=278.88 Z=0

11 X=1431.12 Y=260.76 Z=0

12 X=1574.16 Y=242.88 Z=0

13 X=1716.72 Y=226.68 Z=0

14 X=1746.115 Y=224.244 Z=0

15 X=1746.12 Y=197.28 Z=0

16 X=1757.4 Y=96 Z=0

17 X=1767.96 Y=0 Z=0

20 X=-60 Y=0 Z=0

21 X=60 Y=0 Z=0

22 X=1708 Y=0 Z=0

23 X=1828 Y=0 Z=0

FRAME

NM=13 NL=1 NSEC=0

1 SH=I T=22.5,10,0.375,0.25,10,0.5 E=29000 G=11154 W=0.0040062 M=1.0368E-05
TC=8.3E-06

2 SH=I T=42.04,10,0.375,0.25,10,0.5 E=29000 G=11154 W=0.0053887 M=1.3946E-05
TC=8.3E-06

3 SH=I T=42.04,10,0.375,0.3125,10,0.625 E=29000 G=11154 W=0.0064595 M=1.6717E-05
TC=8.3E-06

4 SH=I T=62.88,10,0.375,0.3125,10,0.625 E=29000 G=11154 W=0.0083025 M=2.1487E-05
TC=8.3E-06

5 SH=I T=59.76,10,0.625,0.25,10,0.75 E=29000 G=11154 W=0.008022 M=2.0761E-05
TC=8.3E-06

6 SH=I T=49.94,10,0.625,0.25,10,0.75 E=29000 G=11154 W=0.0073272 M=1.8963E-05
TC=8.3E-06

7 SH=I T=49.94,10,0.375,0.25,10,0.625 E=29000 G=11154 W=0.0062925 M=1.6285E-05
TC=8.3E-06

8 SH=I T=39.97,10,0.375,0.25,10,0.625 E=29000 G=11154 W=0.0055871 M=1.4459E-05
TC=8.3E-06

9 SH=I T=39.97,10,0.375,0.25,10,0.375 E=29000 G=11154 W=0.0048973 M=1.2674E-05
TC=8.3E-06

10 SH=I T=30,10,0.375,0.25,10,0.375 E=29000 G=11154 W=0.0041919 M=1.0849E-05
TC=8.3E-06

11 SH=I T=42,10,0.375,0.25,10,0.375 E=29000 G=11154 W=0.0050409 M=1.3046E-05
TC=8.3E-06

12 A=50 J=0 I=1.7E+07,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06

13 A=2 J=0 I=12.258,0 AS=0,0 E=29000 G=11154 W=0.000566 M=1.4648E-06 TC=8.3E-06

1 WL=0,0,0 WG=0,-1,0 T=0,0,0

1 1 2 M=1,2,2 LP=1,0 MS= 0,0

2 2 3 M=3,4,2 LP=1,0 MS= 0,0

3 3 4 M=12,12,1 LP=1,0 MS= 0,0

4 4 5 M=12,12,1 LP=1,0 MS= 0,0

5 5 6 M=5,6,2 LP=1,0 MS= 0,0

6 6 7 M=7,8,2 LP=1,0 MS= 0,0

7 7 8 M=9,10,2 LP=1,0 MS= 0,0

8 8 9 M=10,11,2 LP=1,0 MS= 0,0

9 9 10 M=11,10,2 LP=1,0 MS= 0,0

10 10 11 M=10,9,2 LP=1,0 MS= 0,0

11 11 12 M=8,7,2 LP=1,0 MS= 0,0

12 12 13 M=6,5,2 LP=1,0 MS= 0,0

13 13 14 M=12,12,1 LP=1,0 MS= 0,0

14 14 15 M=12,12,1 LP=1,0 MS= 0,0

15 15 16 M=4,3,2 LP=1,0 MS= 0,0

16 16 17 M=2,1,2 LP=1,0 MS= 0,0

17 20 1 M=13,13,1 LP=1,0 MS= 0,0
18 1 21 M=13,13,1 LP=1,0 MS= 0,0
19 22 17 M=13,13,1 LP=1,0 MS= 0,0
20 17 23 M=13,13,1 LP=1,0 MS= 0,0

RESTRAINTS

20 20 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
21 21 1 R=1,1,1,1,1,0
22 22 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0
23 23 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
14 14 1 L=1 F=0,0,-100,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=24.67

Buckling Load: P=3310k

C This is file SRLO250A written by SAPIN on Thu Apr 10 11:45:00 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=51 YN=11 ZN=1

0 60 120 180 240 300 360 420

480 540 600 660 720 780 840 900

960 1020 1080 1140 1200 1260 1320 1380

1440 1500 1560 1620 1680 1740 1800 1860

1920 1980 2040 2100 2160 2220 2280 2340

2400 2460 2520 2580 2640 2700 2760 2820

2880 2940 3000

0 60 120 180 240 300 360 420

480 540 600

0

JOINTS

1 X=0 Y=-12 Z=0

2 X=20.4 Y=360 Z=0

3 X=22.8 Y=408 Z=0

4 X=22.7868 Y=442.014 Z=0

5 X=62.76 Y=445.44 Z=0

6 X=338.28 Y=477.48 Z=0

7 X=576.6 Y=507 Z=0

8 X=815.04 Y=535.8 Z=0

9 X=1054.56 Y=552 Z=0

10 X=1293.96 Y=568.56 Z=0

11 X=1470.96 Y=579.72 Z=0

12 X=1647.96 Y=568.56 Z=0

13 X=1887.48 Y=552 Z=0

14 X=2127 Y=535.8 Z=0

15 X=2365.32 Y=507 Z=0

16 X=2603.76 Y=477.48 Z=0

17 X=2879.28 Y=445.44 Z=0

18 X=2919.239 Y=442.014 Z=0

19 X=2919.24 Y=408 Z=0

20 X=2921.64 Y=360 Z=0

21 X=2942.04 Y=-12 Z=0

25 X=-60 Y=-12 Z=0

26 X=60 Y=-12 Z=0

27 X=2882 Y=-12 Z=0

28 X=3002 Y=-12 Z=0

FRAME

NM=16 NL=1 NSEC=0

- 1 SH=I T=36,14,1,0.375,14,1.25 E=29000 G=11154 W=0.012496 M=3.234E-05 TC=8.3E-06
 - 2 SH=I T=75.8,14,1,0.375,14,1.25 E=29000 G=11154 W=0.01672 M=4.3271E-05 TC=8.3E-06
 - 3 SH=I T=75.8,14,1,0.625,14,1.25 E=29000 G=11154 W=0.021924 M=5.6738E-05 TC=8.3E-06
 - 4 SH=I T=81,14,1,0.625,14,1.25 E=29000 G=11154 W=0.022843 M=5.9118E-05 TC=8.3E-06
 - 5 SH=I T=80.5,14,1,0.375,14,1.5 E=29000 G=11154 W=0.018183 M=4.7057E-05 TC=8.3E-06
 - 6 SH=I T=65.03,14,1,0.375,14,1.5 E=29000 G=11154 W=0.016541 M=4.2808E-05 TC=8.3E-06
 - 7 SH=I T=65.03,14,0.625,0.375,14,1 E=29000 G=11154 W=0.013167 M=3.4076E-05 TC=8.3E-06
 - 8 SH=I T=51.52,14,0.625,0.375,14,1 E=29000 G=11154 W=0.011733 M=3.0366E-05 TC=8.3E-06
 - 9 SH=I T=51.52,14,0.625,0.3125,14,0.625 E=29000 G=11154 W=0.0093983 M=2.4323E-05 TC=8.3E-06
 - 10 SH=I T=44.65,14,0.625,0.3125,14,0.625 E=29000 G=11154 W=0.0087907 M=2.275E-05 TC=8.3E-06
 - 11 SH=I T=46,14,0.625,0.3125,14,0.625 E=29000 G=11154 W=0.0089101 M=2.3059E-05 TC=8.3E-06
 - 12 SH=I T=46,14,0.75,0.3125,14,0.5 E=29000 G=11154 W=0.0089101 M=2.3059E-05 TC=8.3E-06
 - 13 SH=I T=47.38,14,0.75,0.3125,14,0.5 E=29000 G=11154 W=0.0090321 M=2.3375E-05 TC=8.3E-06
 - 14 SH=I T=48.31,14,0.75,0.3125,14,0.5 E=29000 G=11154 W=0.0091144 M=2.3588E-05 TC=8.3E-06
 - 15 A=50 J=0 I=8.0555E+07,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 - 16 A=2 J=0 I=55.31,0 AS=0,0 E=29000 G=11154 W=0.000566 M=1.4648E-06 TC=8.3E-06
- 1 WL=0,0,0 WG=0,-1,0 T=0,0,0
 - 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 - 2 2 3 M=3,4,2 LP=1,0 MS= 0,0
 - 3 3 4 M=15,15,1 LP=1,0 MS= 0,0
 - 4 4 5 M=15,15,1 LP=1,0 MS= 0,0
 - 5 5 6 M=5,6,2 LP=1,0 MS= 0,0
 - 6 6 7 M=7,8,2 LP=1,0 MS= 0,0
 - 7 7 8 M=9,10,2 LP=1,0 MS= 0,0
 - 8 8 9 M=10,11,2 LP=1,0 MS= 0,0
 - 9 9 10 M=12,13,2 LP=1,0 MS= 0,0

10 10 11 M=13,14,2 LP=1,0 MS= 0,0
 11 11 12 M=14,13,2 LP=1,0 MS= 0,0
 12 12 13 M=13,12,2 LP=1,0 MS= 0,0
 13 13 14 M=11,10,2 LP=1,0 MS= 0,0
 14 14 15 M=10,9,2 LP=1,0 MS= 0,0
 15 15 16 M=8,7,2 LP=1,0 MS= 0,0
 16 16 17 M=6,5,2 LP=1,0 MS= 0,0
 17 17 18 M=15,15,1 LP=1,0 MS= 0,0
 18 18 19 M=15,15,1 LP=1,0 MS= 0,0
 19 19 20 M=4,3,2 LP=1,0 MS= 0,0
 20 20 21 M=2,1,2 LP=1,0 MS= 0,0
 21 25 1 M=16,16,1 LP=1,0 MS= 0,0
 22 1 26 M=16,16,1 LP=1,0 MS= 0,0
 23 27 21 M=16,16,1 LP=1,0 MS= 0,0
 24 21 28 M=16,16,1 LP=1,0 MS= 0,0

RESTRAINTS

25 25 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 26 26 1 R=1,1,1,1,1,0
 27 27 1 R=1,1,1,1,1,0
 21 21 1 R=1,1,1,1,1,0
 28 28 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 11 11 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0
 13 13 1 R=0,0,1,1,1,0
 14 14 1 R=0,0,1,1,1,0
 15 15 1 R=0,0,1,1,1,0
 16 16 1 R=0,0,1,1,1,0
 18 18 1 R=0,0,1,1,1,0
 20 20 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 17 17 1 R=0,0,1,1,1,0
 19 19 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0

18 18 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001

L=1 SF=33.03

Buckling Load: P=159k

C This is file STB20A written by SAPIN on Thu Apr 10 11:45:29 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=21 YN=43 ZN=1

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240 252 264 276

288 300 312 324 336 348 360 372

384 396 408 420 432 444 456 468

480 492 504

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=355.2 Z=0

3 X=0 Y=450.72 Z=0

4 X=-0.0552 Y=461.167 Z=0

5 X=10.68 Y=462.16 Z=0

6 X=108.12 Y=466.08 Z=0

7 X=205.56 Y=462.12 Z=0

8 X=216.2868 Y=461.1672 Z=0

9 X=216.24 Y=450.72 Z=0

10 X=216.24 Y=359.52 Z=0

11 X=216.24 Y=0 Z=0

12 X=-60 Y=0 Z=0

13 X=60 Y=0 Z=0

14 X=156.2 Y=0 Z=0

15 X=276.2 Y=0 Z=0

FRAME

NM=6 NL=1 NSEC=0

1 SH=I T=22,5,0.25,0.125,5,0.3125 E=29000 G=11154 W=0.0015543 M=4.0225E-06
TC=8.3E-06

2 SH=I T=22,5,0.25,0.1489,5,0.3125 E=29000 G=11154 W=0.0016993 M=4.3977E-06
TC=8.3E-06

3 SH=I T=22,5,0.25,0.1489,5,0.25 E=29000 G=11154 W=0.0016135 M=4.1757E-06
TC=8.3E-06

4 SH=I T=30.12,5,0.25,0.1489,5,0.25 E=29000 G=11154 W=0.0019556 M=5.0612E-06
 TC=8.3E-06
 5 A=50 J=0 I=4.793E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-
 06
 6 A=2 J=0 I=1.9858,0 AS=0,0 E=29000 G=11154 W=0.000566 M=1.4648E-06 TC=8.3E-06
 1 WL=0,0,0 WG=0,-1,0 T=0,0,0
 1 1 2 M=1,1,1 LP=1,0 MS= 0,0
 2 2 3 M=2,2,1 LP=1,0 MS= 0,0
 3 3 4 M=5,5,1 LP=1,0 MS= 0,0
 4 4 5 M=5,5,1 LP=1,0 MS= 0,0
 5 5 6 M=3,4,2 LP=1,0 MS= 0,0
 6 6 7 M=4,3,2 LP=1,0 MS= 0,0
 7 7 8 M=5,5,1 LP=1,0 MS= 0,0
 8 8 9 M=5,5,1 LP=1,0 MS= 0,0
 9 9 10 M=2,2,1 LP=1,0 MS= 0,0
 10 10 11 M=1,1,1 LP=1,0 MS= 0,0
 11 12 1 M=6,6,1 LP=1,0 MS= 0,0
 12 1 13 M=6,6,1 LP=1,0 MS= 0,0
 13 14 11 M=6,6,1 LP=1,0 MS= 0,0
 14 11 15 M=6,6,1 LP=1,0 MS= 0,0

RESTRAINTS

12 12 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 13 13 1 R=1,1,1,1,1,0
 14 14 1 R=1,1,1,1,1,0
 11 11 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
 8 8 1 L=1 F=0,-100,0,0,0,0

PDELTA
M=1000 TOLD=0.001
L=1 SF=1.58

Buckling Load: P=145k

C This is file SPMKT_A written by SAPIN on Thu Apr 10 11:46:05 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=16 YN=9 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

0 24 48 72 96 120 144 168

192

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=48 Z=0

3 X=2.04 Y=148.8 Z=0

4 X=2.04 Y=154.35 Z=0

5 X=8.28 Y=154.56 Z=0

6 X=96 Y=159.72 Z=0

7 X=167.28 Y=162.72 Z=0

8 X=238.56 Y=159.72 Z=0

9 X=326.28 Y=154.56 Z=0

10 X=332.5 Y=154.4 Z=0

11 X=332.5 Y=148.8 Z=0

12 X=334.56 Y=48 Z=0

13 X=334.56 Y=0 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=274.6 Y=0 Z=0

17 X=394.6 Y=0 Z=0

FRAME

NM=6 NL=0 NSEC=0

1 SH=I T=8,5,0.25,0.149,5,0.25 E=29000 G=11154 W=0.0010238 M=2.6495E-06 TC=8.3E-06

2 SH=I T=12,5,0.25,0.149,5,0.25 E=29000 G=11154 W=0.0011924 M=3.086E-06 TC=8.3E-06

3 SH=I T=11,5,0.25,0.125,5,0.25 E=29000 G=11154 W=0.0010789 M=2.7923E-06 TC=8.3E-06

4 SH=I T=8,5,0.25,0.125,5,0.25 E=29000 G=11154 W=0.00097281 M=2.5176E-06 TC=8.3E-06

5 A=40 J=0 I=1.153E+05,0 AS=0,0 E=29000 G=11154 W=0.01132 M=2.9296E-05 TC=8.3E-06

6 A=1 J=0 I=0.6336,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
1 1 2 M=1,1,1 LP=1,0 MS= 0,0
2 2 3 M=1,2,2 LP=1,0 MS= 0,0
3 3 4 M=5,5,1 LP=1,0 MS= 0,0
4 4 5 M=5,5,1 LP=1,0 MS= 0,0
5 5 6 M=3,4,2 LP=1,0 MS= 0,0
6 6 7 M=4,4,1 LP=1,0 MS= 0,0
7 7 8 M=4,4,1 LP=1,0 MS= 0,0
8 8 9 M=4,3,2 LP=1,0 MS= 0,0
9 9 10 M=5,5,1 LP=1,0 MS= 0,0
10 10 11 M=5,5,1 LP=1,0 MS= 0,0
11 11 12 M=2,1,2 LP=1,0 MS= 0,0
12 12 13 M=1,1,1 LP=1,0 MS= 0,0
13 14 1 M=6,6,1 LP=1,0 MS= 0,0
14 1 15 M=6,6,1 LP=1,0 MS= 0,0
15 16 13 M=6,6,1 LP=1,0 MS= 0,0
16 13 17 M=6,6,1 LP=1,0 MS= 0,0

RESTRAINTS

1 1 1 R=1,1,1,1,1,0
13 13 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
14 14 1 R=1,1,1,1,1,0
15 15 1 R=1,1,1,1,1,0
16 16 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
10 10 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001

L=1 SF=1.44

Buckling Load: P=338k

C This is file SPMKT1_A written by SAPIN on Thu Apr 10 11:46:53 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=51 YN=15 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336

0

JOINTS

1 X=0 Y=0 Z=0

2 X=8.04 Y=179.52 Z=0

3 X=10.92 Y=249.24 Z=0

4 X=10.92 Y=263.42 Z=0

5 X=26.52 Y=264.72 Z=0

6 X=84.84 Y=271.92 Z=0

7 X=155.88 Y=281.4 Z=0

8 X=370.56 Y=300.24 Z=0

9 X=584.4 Y=318.36 Z=0

11 X=1012.8 Y=281.28 Z=0

12 X=1083.84 Y=271.8 Z=0

13 X=1142.16 Y=264.6 Z=0

14 X=1157.78 Y=263.42 Z=0

15 X=1157.8 Y=249.24 Z=0

16 X=1160.76 Y=179.52 Z=0

17 X=1168.68 Y=0 Z=0

18 X=-60 Y=0 Z=0

19 X=60 Y=0 Z=0

20 X=1109 Y=0 Z=0

21 X=1229 Y=0 Z=0

10 X=798.1 Y=300.2 Z=0

FRAME

NM=11 NL=0 NSEC=0

1 SH=I T=12,6,0.25,0.125,6,0.375 E=29000 G=11154 W=0.0014636 M=3.7879E-06
 TC=8.3E-06
 2 SH=I T=27.11,6,0.25,0.125,6,0.375 E=29000 G=11154 W=0.0019982 M=5.1712E-06
 TC=8.3E-06
 3 SH=I T=27.11,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.0023954 M=6.1993E-06
 TC=8.3E-06
 4 SH=I T=33,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.0026921 M=6.9671E-06
 TC=8.3E-06
 5 SH=I T=33,6,0.25,0.149,6,0.375 E=29000 G=11154 W=0.0024264 M=6.2795E-06
 TC=8.3E-06
 6 SH=I T=28.52,6,0.25,0.149,6,0.375 E=29000 G=11154 W=0.0022375 M=5.7906E-06
 TC=8.3E-06
 7 SH=I T=23,6,0.25,0.149,6,0.375 E=29000 G=11154 W=0.0020047 M=5.1882E-06
 TC=8.3E-06
 8 SH=I T=23,6,0.25,0.149,6,0.25 E=29000 G=11154 W=0.0017978 M=4.6526E-06 TC=8.3E-
 06
 9 SH=I T=23,6,0.3125,0.125,6,0.25 E=29000 G=11154 W=0.0017489 M=4.526E-06
 TC=8.3E-06
 10 A=50 J=0 I=1.5577E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05
 TC=8.3E-06
 11 A=1 J=0 I=1.186,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=3,4,2 LP=1,0 MS= 0,0
 3 3 4 M=10,10,1 LP=1,0 MS= 0,0
 4 4 5 M=10,10,1 LP=1,0 MS= 0,0
 5 5 6 M=5,6,2 LP=1,0 MS= 0,0
 6 6 7 M=6,7,2 LP=1,0 MS= 0,0
 7 7 8 M=8,8,1 LP=1,0 MS= 0,0
 8 8 9 M=9,9,1 LP=1,0 MS= 0,0
 9 9 10 M=9,9,1 LP=1,0 MS= 0,0
 10 10 11 M=8,8,1 LP=1,0 MS= 0,0
 11 11 12 M=7,6,2 LP=1,0 MS= 0,0
 12 12 13 M=6,5,2 LP=1,0 MS= 0,0
 13 13 14 M=10,10,1 LP=1,0 MS= 0,0
 14 14 15 M=10,10,1 LP=1,0 MS= 0,0
 15 15 16 M=4,3,2 LP=1,0 MS= 0,0
 16 16 17 M=2,1,2 LP=1,0 MS= 0,0
 17 18 1 M=11,11,1 LP=1,0 MS= 0,0
 18 1 19 M=11,11,1 LP=1,0 MS= 0,0
 19 20 17 M=11,11,1 LP=1,0 MS= 0,0
 20 17 21 M=11,11,1 LP=1,0 MS= 0,0

RESTRAINTS

18 18 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
19 19 1 R=1,1,1,1,1,0
20 20 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0
21 21 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
14 14 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=3.37

Buckling Load: P=158k

C This is file SPMKT2_A written by SAPIN on Thu Apr 10 11:47:27 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=31 YN=12 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720

0 24 48 72 96 120 144 168

192 216 240 264

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=120 Z=0

3 X=5.28 Y=208.32 Z=0

4 X=5.28 Y=220.1004 Z=0

5 X=15.48 Y=220.56 Z=0

6 X=129.36 Y=231.72 Z=0

7 X=344.4 Y=240.72 Z=0

8 X=559.44 Y=231.72 Z=0

9 X=673.32 Y=220.56 Z=0

10 X=683.54 Y=220.1 Z=0

11 X=683.52 Y=208.32 Z=0

12 X=688.8 Y=120 Z=0

13 X=688.8 Y=0 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=628.8 Y=0 Z=0

17 X=748.8 Y=0 Z=0

FRAME

NM=7 NL=0 NSEC=0

1 SH=I T=12,5,0.25,0.125,5,0.375 E=29000 G=11154 W=0.0012868 M=3.3301E-06

TC=8.3E-06

2 SH=I T=12,5,0.25,0.149,5,0.375 E=29000 G=11154 W=0.001364 M=3.5301E-06 TC=8.3E-06

3 SH=I T=22,5,0.25,0.149,5,0.375 E=29000 G=11154 W=0.0017857 M=4.6214E-06

TC=8.3E-06

4 SH=I T=24,5,0.25,0.125,5,0.25 E=29000 G=11154 W=0.0015388 M=3.9824E-06 TC=8.3E-

06

5 SH=I T=11,5,0.25,0.125,5,0.25 E=29000 G=11154 W=0.0010789 M=2.7923E-06 TC=8.3E-06
 6 A=50 J=0 I=5.138E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 7 A=1 J=0 I=1.211,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,1,1 LP=1,0 MS= 0,0
 2 2 3 M=2,3,2 LP=1,0 MS= 0,0
 3 3 4 M=6,6,1 LP=1,0 MS= 0,0
 4 4 5 M=6,6,1 LP=1,0 MS= 0,0
 5 5 6 M=4,5,2 LP=1,0 MS= 0,0
 6 6 7 M=5,5,1 LP=1,0 MS= 0,0
 7 7 8 M=5,5,1 LP=1,0 MS= 0,0
 8 8 9 M=5,4,2 LP=1,0 MS= 0,0
 9 9 10 M=6,6,1 LP=1,0 MS= 0,0
 10 10 11 M=6,6,1 LP=1,0 MS= 0,0
 11 11 12 M=3,2,2 LP=1,0 MS= 0,0
 12 12 13 M=1,1,1 LP=1,0 MS= 0,0
 13 14 1 M=7,7,1 LP=1,0 MS= 0,0
 14 1 15 M=7,7,1 LP=1,0 MS= 0,0
 15 16 13 M=7,7,1 LP=1,0 MS= 0,0
 16 13 17 M=7,7,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 13 13 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 11 11 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0

10 10 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001

L=1 SF=1.57

Buckling Load: P=645k

C This is file TRE_A written by SAPIN on Thu Apr 10 11:48:17 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=46 YN=17 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384

0

JOINTS

1 X=0 Y=0 Z=0

2 X=19.32 Y=240 Z=0

3 X=19.32 Y=308.28 Z=0

4 X=19.32 Y=328.38 Z=0

5 X=41.04 Y=330.24 Z=0

6 X=167.88 Y=350.52 Z=0

7 X=238.68 Y=362.52 Z=0

8 X=381.72 Y=372.96 Z=0

9 X=523.8 Y=383.04 Z=0

10 X=665.9 Y=373 Z=0

11 X=809 Y=362.5 Z=0

12 X=879.7 Y=350.5 Z=0

13 X=1007 Y=330.2 Z=0

14 X=1028.4 Y=328.4 Z=0

15 X=1028.4 Y=308.3 Z=0

16 X=1028.4 Y=240 Z=0

17 X=1047.7 Y=0 Z=0

18 X=-60 Y=0 Z=0

19 X=60 Y=0 Z=0

20 X=988 Y=0 Z=0

21 X=1108 Y=0 Z=0

FRAME

NM=12 NL=0 NSEC=0

1 SH=I T=12,8,0.25,0.25,8,0.5 E=29000 G=11154 W=0.0024939 M=6.4543E-06 TC=8.3E-06

2 SH=I T=48,8,0.25,0.25,8,0.5 E=29000 G=11154 W=0.0050409 M=1.3046E-05 TC=8.3E-06
 3 SH=I T=47,6,0.25,0.25,6,0.5 E=29000 G=11154 W=0.0045457 M=1.1764E-05 TC=8.3E-06
 4 SH=I T=29.08,6,0.25,0.25,6,0.5 E=29000 G=11154 W=0.0032778 M=8.483E-06 TC=8.3E-06
 5 SH=I T=29.08,6,0.25,0.25,6,0.375 E=29000 G=11154 W=0.0030744 M=7.9566E-06 TC=8.3E-06
 6 SH=I T=19,6,0.25,0.25,6,0.375 E=29000 G=11154 W=0.0023613 M=6.111E-06 TC=8.3E-06
 7 SH=I T=19,6,0.375,0.178,6,0.375 E=29000 G=11154 W=0.0021928 M=5.675E-06 TC=8.3E-06
 8 SH=I T=24.5,6,0.375,0.178,6,0.375 E=29000 G=11154 W=0.0024699 M=6.392E-06 TC=8.3E-06
 9 SH=I T=24.5,6,0.4375,0.149,6,0.25 E=29000 G=11154 W=0.0021715 M=5.6198E-06 TC=8.3E-06
 10 SH=I T=30,6,0.4375,0.149,6,0.25 E=29000 G=11154 W=0.0024034 M=6.22E-06 TC=8.3E-06
 11 A=50 J=0 I=5.6883E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 12 A=1 J=0 I=1.518,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=2,2,1 LP=1,0 MS= 0,0
 3 3 4 M=11,11,1 LP=1,0 MS= 0,0
 4 4 5 M=11,11,1 LP=1,0 MS= 0,0
 5 5 6 M=3,4,2 LP=1,0 MS= 0,0
 6 6 7 M=5,6,2 LP=1,0 MS= 0,0
 7 7 8 M=7,8,2 LP=1,0 MS= 0,0
 8 8 9 M=9,10,2 LP=1,0 MS= 0,0
 9 9 10 M=10,9,2 LP=1,0 MS= 0,0
 10 10 11 M=8,7,2 LP=1,0 MS= 0,0
 11 11 12 M=6,5,2 LP=1,0 MS= 0,0
 12 12 13 M=4,3,2 LP=1,0 MS= 0,0
 13 13 14 M=11,11,1 LP=1,0 MS= 0,0
 14 14 15 M=11,11,1 LP=1,0 MS= 0,0
 15 15 16 M=2,2,1 LP=1,0 MS= 0,0
 16 16 17 M=2,1,2 LP=1,0 MS= 0,0
 17 18 1 M=12,12,1 LP=1,0 MS= 0,0
 18 1 19 M=12,12,1 LP=1,0 MS= 0,0
 19 20 17 M=12,12,1 LP=1,0 MS= 0,0
 20 17 21 M=12,12,1 LP=1,0 MS= 0,0

RESTRAINTS

18 18 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0

19 19 1 R=1,1,1,1,1,0
20 20 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0
21 21 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
14 14 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=6.45

Buckling Load: P=206k

C This is file TRE1_A written by SAPIN on Thu Apr 10 11:48:43 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=16 YN=11 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

0 24 48 72 96 120 144 168

192 216 240

0

JOINTS

1 X=0 Y=0 Z=0

2 X=3 Y=143.52 Z=0

3 X=3 Y=218.16 Z=0

4 X=3 Y=225.17 Z=0

5 X=12.24 Y=225.96 Z=0

6 X=94.32 Y=236.28 Z=0

7 X=165.24 Y=242.16 Z=0

8 X=236.16 Y=236.28 Z=0

9 X=318.24 Y=225.96 Z=0

10 X=327.5 Y=225.2 Z=0

11 X=327.5 Y=218.2 Z=0

12 X=327.5 Y=143.52 Z=0

13 X=330.48 Y=0 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=270.5 Y=0 Z=0

17 X=390.5 Y=0 Z=0

FRAME

NM=7 NL=0 NSEC=0

1 SH=I T=12,8,0.25,0.178,8,0.25 E=29000 G=11154 W=0.0017113 M=4.4288E-06 TC=8.3E-06

2 SH=I T=18,8,0.25,0.178,8,0.25 E=29000 G=11154 W=0.0020135 M=5.211E-06 TC=8.3E-06

3 SH=I T=18,8,0.25,0.149,8,0.25 E=29000 G=11154 W=0.0018699 M=4.8393E-06 TC=8.3E-06

4 SH=I T=15,5,0.25,0.125,5,0.25 E=29000 G=11154 W=0.0012204 M=3.1585E-06 TC=8.3E-06

5 SH=I T=8,5,0.25,0.125,5,0.25 E=29000 G=11154 W=0.00097281 M=2.5176E-06 TC=8.3E-06

6 A=50 J=0 I=4.055E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06

7 A=1 J=0 I=1.561,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06

1 1 2 M=1,2,2 LP=1,0 MS= 0,0
2 2 3 M=3,3,1 LP=1,0 MS= 0,0
3 3 4 M=6,6,1 LP=1,0 MS= 0,0
4 4 5 M=6,6,1 LP=1,0 MS= 0,0
5 5 6 M=4,5,2 LP=1,0 MS= 0,0
6 6 7 M=5,5,1 LP=1,0 MS= 0,0
7 7 8 M=5,5,1 LP=1,0 MS= 0,0
8 8 9 M=5,4,2 LP=1,0 MS= 0,0
9 9 10 M=6,6,1 LP=1,0 MS= 0,0
10 10 11 M=6,6,1 LP=1,0 MS= 0,0
11 11 12 M=3,3,1 LP=1,0 MS= 0,0
12 12 13 M=2,1,2 LP=1,0 MS= 0,0
13 14 1 M=7,7,1 LP=1,0 MS= 0,0
14 1 15 M=7,7,1 LP=1,0 MS= 0,0
15 16 13 M=7,7,1 LP=1,0 MS= 0,0
16 13 17 M=7,7,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
15 15 1 R=1,1,1,1,1,0
16 16 1 R=1,1,1,1,1,0
13 13 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
10 10 1 L=1 F=0,-100,0,0,0,0

PDELTA
M=1000 TOLD=0.001
L=1 SF=2.05

Buckling Load: P=471k

C This is file TRE2_A written by SAPIN on Thu Apr 10 11:49:14 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=26 YN=32 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

0

JOINTS

1 X=0 Y=0 Z=0

2 X=12.96 Y=480 Z=0

3 X=12.96 Y=667.08 Z=0

4 X=12.96 Y=683.87 Z=0

5 X=32.04 Y=685.44 Z=0

6 X=162.12 Y=699.84 Z=0

7 X=280.44 Y=709.68 Z=0

8 X=398.9 Y=699.84 Z=0

9 X=528.96 Y=685.44 Z=0

10 X=548.04 Y=683.86 Z=0

11 X=548.04 Y=667.08 Z=0

12 X=548.04 Y=480 Z=0

13 X=561 Y=0 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=501 Y=0 Z=0

17 X=621 Y=0 Z=0

FRAME

NM=7 NL=0 NSEC=0

1 SH=I T=18,10,0.375,0.25,10,0.625 E=29000 G=11154 W=0.0040327 M=1.0437E-05
TC=8.3E-06

2 SH=I T=42,10,0.375,0.25,10,0.625 E=29000 G=11154 W=0.0057307 M=1.4831E-05
TC=8.3E-06

3 SH=I T=36,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0033606 M=8.6972E-06 TC=8.3E-06

4 SH=I T=29,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0028654 M=7.4155E-06 TC=8.3E-06
 5 SH=I T=29,6,0.25,0.178,6,0.25 E=29000 G=11154 W=0.0022847 M=5.9127E-06 TC=8.3E-06
 6 A=50 J=0 I=5.9251E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 7 A=1 J=0 I=2.753,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=2,2,1 LP=1,0 MS= 0,0
 3 3 4 M=6,6,1 LP=1,0 MS= 0,0
 4 4 5 M=6,6,1 LP=1,0 MS= 0,0
 5 5 6 M=3,4,2 LP=1,0 MS= 0,0
 6 6 7 M=5,5,1 LP=1,0 MS= 0,0
 7 7 8 M=5,5,1 LP=1,0 MS= 0,0
 8 8 9 M=4,3,2 LP=1,0 MS= 0,0
 9 9 10 M=6,6,1 LP=1,0 MS= 0,0
 10 10 11 M=6,6,1 LP=1,0 MS= 0,0
 11 11 12 M=2,2,1 LP=1,0 MS= 0,0
 12 12 13 M=2,1,2 LP=1,0 MS= 0,0
 13 14 1 M=7,7,1 LP=1,0 MS= 0,0
 14 1 15 M=7,7,1 LP=1,0 MS= 0,0
 15 16 13 M=7,7,1 LP=1,0 MS= 0,0
 16 13 17 M=7,7,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 13 13 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 11 11 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0

10 10 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001

L=1 SF=4.7

Buckling load: P=210 k

C This is file SUPER_A written by SAPIN on Thu Apr 10 11:49:58 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=51 YN=27 ZN=1

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240 252 264 276

288 300 312 324 336 348 360 372

384 396 408 420 432 444 456 468

480 492 504 516 528 540 552 564

576 588 600

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240 252 264 276

288 300 312

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=192 Z=0

3 X=6.72 Y=257.76 Z=0

4 X=20.76 Y=270.72 Z=0

5 X=166.68 Y=287.52 Z=0

6 X=285.72 Y=297.24 Z=0

7 X=404.76 Y=287.52 Z=0

8 X=550.68 Y=270.72 Z=0

9 X=564.6 Y=257.76 Z=0

10 X=571.32 Y=192 Z=0

11 X=571.32 Y=0 Z=0

12 X=7.896 Y=269.244 Z=0

13 X=563.424 Y=269.24 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=511.3 Y=0 Z=0

17 X=631.3 Y=0 Z=0

FRAME

NM=8 NL=1 NSEC=0

1 SH=I T=12,8,0.3125,0.1489,8,0.25 E=29000 G=11154 W=0.0017555 M=4.5431E-06

TC=8.3E-06

2 SH=I T=12,8,0.3125,0.178,8,0.25 E=29000 G=11154 W=0.0018497 M=4.7869E-06
 TC=8.3E-06
 3 SH=I T=26,8,0.3125,0.178,8,0.25 E=29000 G=11154 W=0.0025549 M=6.612E-06
 TC=8.3E-06
 4 SH=I T=24,6,0.3125,0.1489,6,0.25 E=29000 G=11154 W=0.0019428 M=5.0278E-06
 TC=8.3E-06
 5 SH=I T=14,6,0.3125,0.1489,6,0.25 E=29000 G=11154 W=0.0015214 M=3.9373E-06
 TC=8.3E-06
 6 SH=I T=14,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0013266 M=3.4331E-06 TC=8.3E-
 06
 7 A=40 J=0 I=1.0332E+06,0 AS=0,0 E=29000 G=11154 W=0.01132 M=2.9296E-05
 TC=8.3E-06
 8 A=1 J=0 I=1.409,0 AS=0,0 E=29000 G=11154 W=0.00028301 M=7.3239E-07 TC=8.3E-06
 1 WL=0,0,0 WG=0,-1,0 T=0,0,0
 10 1 2 M=1,1,1 LP=1,0 MS= 0,0
 11 2 3 M=2,3,2 LP=1,0 MS= 0,0
 12 3 12 M=7,7,1 LP=1,0 MS= 0,0
 13 12 4 M=7,7,1 LP=1,0 MS= 0,0
 14 4 5 M=4,5,2 LP=1,0 MS= 0,0
 15 5 6 M=6,6,1 LP=1,0 MS= 0,0
 16 6 7 M=6,6,1 LP=1,0 MS= 0,0
 17 7 8 M=5,4,2 LP=1,0 MS= 0,0
 18 8 13 M=7,7,1 LP=1,0 MS= 0,0
 19 13 9 M=7,7,1 LP=1,0 MS= 0,0
 20 9 10 M=3,2,2 LP=1,0 MS= 0,0
 21 10 11 M=1,1,1 LP=1,0 MS= 0,0
 22 14 1 M=8,8,1 LP=1,0 MS= 0,0
 23 1 15 M=8,8,1 LP=1,0 MS= 0,0
 24 16 11 M=8,8,1 LP=1,0 MS= 0,0
 25 11 17 M=8,8,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 11 11 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0

6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0

LOADS

12 12 1 L=1 F=0.1,-100,0,0,0,0
13 13 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=2.09

Buckling Load: P=354k

C This is file TRECRN_A written by SAPIN on Thu Apr 10 11:50:29 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=51 YN=27 ZN=1

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240 252 264 276

288 300 312 324 336 348 360 372

384 396 408 420 432 444 456 468

480 492 504 516 528 540 552 564

576 588 600

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240 252 264 276

288 300 312

0

JOINTS

1 X=0 Y=0 Z=0

2 X=6.72 Y=192 Z=0

3 X=6.72 Y=257.76 Z=0

4 X=20.76 Y=270.72 Z=0

5 X=166.68 Y=287.52 Z=0

6 X=285.72 Y=297.24 Z=0

7 X=404.76 Y=287.52 Z=0

8 X=550.68 Y=270.72 Z=0

9 X=564.6 Y=257.76 Z=0

10 X=564.6 Y=192 Z=0

11 X=571.32 Y=0 Z=0

12 X=6.72 Y=269.1 Z=0

13 X=564.6 Y=269.1 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=511.3 Y=0 Z=0

17 X=631.3 Y=0 Z=0

FRAME

NM=8 NL=1 NSEC=0

1 SH=I T=12,8,0.3125,0.1489,8,0.25 E=29000 G=11154 W=0.0017555 M=4.5431E-06

TC=8.3E-06

2 SH=I T=26,8,0.3125,0.1489,8,0.25 E=29000 G=11154 W=0.0023454 M=6.0699E-06
 TC=8.3E-06
 3 SH=I T=26,8,0.3125,0.178,8,0.25 E=29000 G=11154 W=0.0025549 M=6.612E-06
 TC=8.3E-06
 4 SH=I T=24,6,0.3125,0.1489,6,0.25 E=29000 G=11154 W=0.0019428 M=5.0278E-06
 TC=8.3E-06
 5 SH=I T=14,6,0.3125,0.1489,6,0.25 E=29000 G=11154 W=0.0015214 M=3.9373E-06
 TC=8.3E-06
 6 SH=I T=14,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0013266 M=3.4331E-06 TC=8.3E-
 06
 7 A=40 J=0 I=1.0332E+06,0 AS=0,0 E=29000 G=11154 W=0.01132 M=2.9296E-05
 TC=8.3E-06
 8 A=1 J=0 I=1.41,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 WL=0,0,0 WG=0,-1,0 T=0,0,0
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=3,3,1 LP=1,0 MS= 0,0
 3 3 12 M=7,7,1 LP=1,0 MS= 0,0
 4 12 4 M=7,7,1 LP=1,0 MS= 0,0
 5 4 5 M=4,5,2 LP=1,0 MS= 0,0
 6 5 6 M=6,6,1 LP=1,0 MS= 0,0
 7 6 7 M=6,6,1 LP=1,0 MS= 0,0
 8 7 8 M=5,4,2 LP=1,0 MS= 0,0
 9 8 13 M=7,7,1 LP=1,0 MS= 0,0
 10 13 9 M=7,7,1 LP=1,0 MS= 0,0
 11 9 10 M=3,3,1 LP=1,0 MS= 0,0
 12 10 11 M=2,1,2 LP=1,0 MS= 0,0
 13 14 1 M=8,8,1 LP=1,0 MS= 0,0
 14 1 15 M=8,8,1 LP=1,0 MS= 0,0
 15 16 11 M=8,8,1 LP=1,0 MS= 0,0
 16 11 17 M=8,8,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 11 11 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0

6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0

LOADS

12 12 1 L=1 F=0.1,-100,0,0,0,0
13 13 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=3.53

Buckling Load: P=2920k

C This is file MURRAY_A written by SAPIN on Thu Apr 10 11:51:05 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=59 YN=10 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392

0 24 48 72 96 120 144 168

192 216

0

JOINTS

1 X=0 Y=0 Z=0

2 X=20.04 Y=110.4 Z=0

3 X=20.0076 Y=131.3436 Z=0

4 X=44.64 Y=133.44 Z=0

5 X=226.2 Y=156.72 Z=0

6 X=404.88 Y=180.72 Z=0

7 X=702.72 Y=203.88 Z=0

8 X=1000.56 Y=180.72 Z=0

9 X=1179.12 Y=156.72 Z=0

10 X=1360.68 Y=133.44 Z=0

11 X=1385.377 Y=131.3436 Z=0

12 X=1385.4 Y=110.4 Z=0

13 X=1405.44 Y=0 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=1345 Y=0 Z=0

17 X=1465 Y=0 Z=0

FRAME

NM=10 NL=0 NSEC=0

1 A=10.87 J=0 I=427,0 AS=0,0 E=29000 G=11154 W=0.0030762 M=7.9612E-06 TC=8.3E-06

2 A=22.74 J=0 I=8125.9,0 AS=0,0 E=29000 G=11154 W=0.0064354 M=1.6655E-05 TC=8.3E-06

3 A=21.73 J=0 I=8775.8,0 AS=0,0 E=29000 G=11154 W=0.0061496 M=1.5915E-05
 TC=8.3E-06
 4 A=18.52 J=0 I=4585.8,0 AS=0,0 E=29000 G=11154 W=0.0052412 M=1.3564E-05
 TC=8.3E-06
 5 A=15.02 J=0 I=3357.4,0 AS=0,0 E=29000 G=11154 W=0.0042507 M=1.1001E-05
 TC=8.3E-06
 6 A=11.84 J=0 I=1370,0 AS=0,0 E=29000 G=11154 W=0.0033507 M=8.6716E-06 TC=8.3E-
 06
 7 A=9.92 J=0 I=1247,0 AS=0,0 E=29000 G=11154 W=0.0028074 M=7.2654E-06 TC=8.3E-
 06
 8 A=11 J=0 I=1950.7,0 AS=0,0 E=29000 G=11154 W=0.003113 M=8.0564E-06 TC=8.3E-06
 9 A=50 J=0 I=8.7758E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-
 06
 10 A=1 J=0 I=6.502,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=9,9,1 LP=1,0 MS= 0,0
 3 3 4 M=9,9,1 LP=1,0 MS= 0,0
 4 4 5 M=3,4,2 LP=1,0 MS= 0,0
 5 5 6 M=5,6,2 LP=1,0 MS= 0,0
 6 6 7 M=7,8,2 LP=1,0 MS= 0,0
 7 7 8 M=8,7,2 LP=1,0 MS= 0,0
 8 8 9 M=6,5,2 LP=1,0 MS= 0,0
 9 9 10 M=4,3,2 LP=1,0 MS= 0,0
 10 10 11 M=9,9,1 LP=1,0 MS= 0,0
 11 11 12 M=9,9,1 LP=1,0 MS= 0,0
 12 12 13 M=2,1,2 LP=1,0 MS= 0,0
 13 14 1 M=10,10,1 LP=1,0 MS= 0,0
 14 1 15 M=10,10,1 LP=1,0 MS= 0,0
 15 16 13 M=10,10,1 LP=1,0 MS= 0,0
 16 13 17 M=10,10,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 13 13 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0

7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0

LOADS

3 3 1 L=1 F=0.1,-100,0,0,0,0
11 11 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=29.23

Buckling Load: P=3080k

C This is file ELIOT26A written by SAPIN on Thu Apr 10 11:51:40 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=61 YN=10 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440

0 24 48 72 96 120 144 168

192 216

0

JOINTS

1 X=0 Y=0 Z=0

2 X=20.04 Y=109.92 Z=0

3 X=19.9848 Y=131.3028 Z=0

4 X=44.88 Y=133.44 Z=0

5 X=225.96 Y=156.84 Z=0

6 X=404.64 Y=180.96 Z=0

7 X=702.36 Y=204.12 Z=0

8 X=1000.08 Y=180.96 Z=0

9 X=1178.76 Y=156.84 Z=0

10 X=1359.84 Y=133.44 Z=0

11 X=1384.735 Y=131.3028 Z=0

12 X=1384.68 Y=109.92 Z=0

13 X=1404.72 Y=0 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=1344.7 Y=0 Z=0

17 X=1464.7 Y=0 Z=0

FRAME

NM=10 NL=0 NSEC=0

1 A=11.04 J=0 I=462.3,0 AS=0,0 E=29000 G=11154 W=0.0031243 M=8.0857E-06 TC=8.3E-06

2 A=22.92 J=0 I=8338.2,0 AS=0,0 E=29000 G=11154 W=0.0064864 M=1.6787E-05 TC=8.3E-06

3 A=22 J=0 I=9198.7,0 AS=0,0 E=29000 G=11154 W=0.006226 M=1.6113E-05 TC=8.3E-06
 4 A=18.74 J=0 I=4816.4,0 AS=0,0 E=29000 G=11154 W=0.0053034 M=1.3725E-05
 TC=8.3E-06
 5 A=15.24 J=0 I=3533,0 AS=0,0 E=29000 G=11154 W=0.0043129 M=1.1162E-05 TC=8.3E-06
 6 A=12 J=0 I=1443.2,0 AS=0,0 E=29000 G=11154 W=0.003396 M=8.7888E-06 TC=8.3E-06
 7 A=10.04 J=0 I=1311.6,0 AS=0,0 E=29000 G=11154 W=0.0028413 M=7.3533E-06
 TC=8.3E-06
 8 A=11.12 J=0 I=2035.1,0 AS=0,0 E=29000 G=11154 W=0.003147 M=8.1443E-06 TC=8.3E-06
 9 A=50 J=0 I=9.1987E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 10 A=1 J=0 I=7.042,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=9,9,1 LP=1,0 MS= 0,0
 3 3 4 M=9,9,1 LP=1,0 MS= 0,0
 4 4 5 M=3,4,2 LP=1,0 MS= 0,0
 5 5 6 M=5,6,2 LP=1,0 MS= 0,0
 6 6 7 M=7,8,2 LP=1,0 MS= 0,0
 7 7 8 M=8,7,2 LP=1,0 MS= 0,0
 8 8 9 M=6,5,2 LP=1,0 MS= 0,0
 9 9 10 M=4,3,2 LP=1,0 MS= 0,0
 10 10 11 M=9,9,1 LP=1,0 MS= 0,0
 11 11 12 M=9,9,1 LP=1,0 MS= 0,0
 12 12 13 M=2,1,2 LP=1,0 MS= 0,0
 13 14 1 M=10,10,1 LP=1,0 MS= 0,0
 14 1 15 M=10,10,1 LP=1,0 MS= 0,0
 15 16 13 M=10,10,1 LP=1,0 MS= 0,0
 16 13 17 M=10,10,1 LP=1,0 MS= 0,0

RESTRAINTS

14 14 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 15 15 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 13 13 1 R=1,1,1,1,1,0
 17 17 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0

8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0

LOADS

3 3 1 L=1 F=0.1,-100,0,0,0,0
11 11 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=30.83

Buckling Load: P=382k

C This is file STIF9_A written by SAPIN on Thu Apr 10 11:52:18 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=51 YN=14 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200

0 24 48 72 96 120 144 168

192 216 240 264 288 312

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=215.52 Z=0

3 X=0 Y=250.92 Z=0

4 X=0 Y=264 Z=0

5 X=10.68 Y=265.68 Z=0

6 X=153.96 Y=272.28 Z=0

7 X=347.88 Y=280.44 Z=0

8 X=467.88 Y=281.76 Z=0

9 X=587.04 Y=283.56 Z=0

10 X=587.04 Y=-5.04 Z=0

11 X=706.2 Y=281.76 Z=0

12 X=826.32 Y=280.44 Z=0

13 X=1020.12 Y=272.28 Z=0

14 X=1163.52 Y=265.68 Z=0

15 X=1174.08 Y=264 Z=0

16 X=1174.1 Y=250.92 Z=0

17 X=1174.1 Y=215.52 Z=0

18 X=1174.1 Y=0 Z=0

19 X=-60 Y=0 Z=0

20 X=60 Y=0 Z=0

21 X=1114 Y=0 Z=0

22 X=1234 Y=0 Z=0

4 X=0 Y=265.188 Z=0

15 X=1174.1 Y=265.188 Z=0

FRAME

NM=9 NL=0 NSEC=0

1 SH=I T=22,6,0.25,0.125,6,0.3125 E=29000 G=11154 W=0.0017135 M=4.4345E-06
TC=8.3E-06

2 SH=I T=29,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0028654 M=7.4155E-06 TC=8.3E-06

3 SH=I T=29,6,0.375,0.1489,6,0.25 E=29000 G=11154 W=0.0022569 M=5.8409E-06
TC=8.3E-06

4 SH=I T=34,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0032191 M=8.331E-06 TC=8.3E-06

5 SH=I T=34,6,0.3125,0.25,6,0.4375 E=29000 G=11154 W=0.0036259 M=9.3839E-06
TC=8.3E-06

6 SH=I T=39,6,0.3125,0.25,6,0.4375 E=29000 G=11154 W=0.0039797 M=1.0299E-05
TC=8.3E-06

7 SH=P T=7,0.4725 E=29000 G=11154 W=0.0027421 M=7.0965E-06 TC=8.3E-06

8 A=50 J=0 I=1.1498E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06

9 A=1 J=0 I=3.975,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.3241E-07 TC=8.3E-06

1 1 2 M=1,1,1 LP=1,0 MS= 0,0

2 2 3 M=1,1,1 LP=1,0 MS= 0,0

3 3 4 M=8,8,1 LP=1,0 MS= 0,0

4 4 5 M=8,8,1 LP=1,0 MS= 0,0

5 5 6 M=2,2,1 LP=1,0 MS= 0,0

6 6 7 M=3,3,1 LP=1,0 MS= 0,0

7 7 8 M=2,4,2 LP=1,0 MS= 0,0

8 8 9 M=5,6,2 LP=1,0 MS= 0,0

9 9 10 M=7,7,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0

10 9 11 M=6,5,2 LP=1,0 MS= 0,0

11 11 12 M=4,2,2 LP=1,0 MS= 0,0

12 12 13 M=3,3,1 LP=1,0 MS= 0,0

13 13 14 M=2,2,1 LP=1,0 MS= 0,0

14 14 15 M=8,8,1 LP=1,0 MS= 0,0

15 15 16 M=8,8,1 LP=1,0 MS= 0,0

16 16 17 M=1,1,1 LP=1,0 MS= 0,0

17 17 18 M=1,1,1 LP=1,0 MS= 0,0

18 19 1 M=9,9,1 LP=1,0 MS= 0,0

19 1 20 M=9,9,1 LP=1,0 MS= 0,0

20 21 18 M=9,9,1 LP=1,0 MS= 0,0

21 18 22 M=9,9,1 LP=1,0 MS= 0,0

RESTRAINTS

19 19 1 R=1,1,1,1,1,0

1 1 1 R=1,1,1,1,1,0

20 20 1 R=1,1,1,1,1,0

10 10 1 R=1,1,1,1,1,0
21 21 1 R=1,1,1,1,1,0
18 18 1 R=1,1,1,1,1,0
22 22 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0
17 17 1 R=0,0,1,1,1,0

LOADS

15 15 1 L=1 F=0.1,-100,0,0,0,0
4 4 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=3.8

Buckling Load: P=111k

C This is file STIF10_A written by SAPIN on Thu Apr 10 11:53:15 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=71 YN=16 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440 1464 1488 1512

1536 1560 1584 1608 1632 1656 1680

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

0

JOINTS

1 X=0 Y=0 Z=0

2 X=2.28 Y=264 Z=0

3 X=2.52 Y=304.44 Z=0

4 X=2.52 Y=312 Z=0

5 X=12.72 Y=317.16 Z=0

6 X=155.4 Y=332.64 Z=0

7 X=298.44 Y=34.52 Z=0

8 X=441.48 Y=356.4 Z=0

9 X=644.64 Y=372.84 Z=0

10 X=822.72 Y=379.32 Z=0

11 X=822.72 Y=-5.04 Z=0

12 X=1000.8 Y=372.84 Z=0

13 X=1203.84 Y=356.4 Z=0

14 X=1346.88 Y=344.52 Z=0

15 X=1489.92 Y=332.64 Z=0

16 X=1632.6 Y=317.16 Z=0

17 X=1642.8 Y=312 Z=0

18 X=1642.8 Y=304.44 Z=0

19 X=1643.16 Y=264 Z=0

20 X=1645.32 Y=0 Z=0

7 X=298.44 Y=344.52 Z=0

21 X=-60 Y=0 Z=0

22 X=60 Y=0 Z=0

23 X=1585 Y=0 Z=0
24 X=1705 Y=0 Z=0
4 X=2.592 Y=316.056 Z=0
17 X=1642.692 Y=316.056 Z=0

FRAME

NM=11 NL=0 NSEC=0

1 SH=I T=16,6,0.25,0.125,6,0.3125 E=29000 G=11154 W=0.0015012 M=3.8852E-06
TC=8.3E-06
2 SH=I T=22,6,0.25,0.125,6,0.3125 E=29000 G=11154 W=0.0017135 M=4.4345E-06
TC=8.3E-06
3 SH=I T=20.34,6,0.25,0.1489,6,0.3125 E=29000 G=11154 W=0.0017885 M=4.6287E-06
TC=8.3E-06
4 SH=I T=21,6,0.25,0.1489,6,0.3125 E=29000 G=11154 W=0.0018163 M=4.7006E-06
TC=8.3E-06
5 SH=I T=25,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0017157 M=4.4402E-06 TC=8.3E-06
6 SH=I T=18,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0014681 M=3.7993E-06 TC=8.3E-06
7 SH=I T=18,6,0.3125,0.1489,6,0.4375 E=29000 G=11154 W=0.0020004 M=5.177E-06
TC=8.3E-06
8 SH=I T=32.96,6,0.3125,0.1489,6,0.4375 E=29000 G=11154 W=0.0026308 M=6.8084E-06
TC=8.3E-06
9 SH=P T=6.625,0.5599 E=29000 G=11154 W=0.0030191 M=7.8135E-06 TC=8.3E-06
10 A=50 J=0 I=6.409E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
11 A=1 J=0 I=1.675,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.3241E-07 TC=8.3E-06
1 1 2 M=1,2,2 LP=1,0 MS= 0,0
2 2 3 M=3,4,2 LP=1,0 MS= 0,0
3 3 4 M=10,10,1 LP=1,0 MS= 0,0
4 4 5 M=10,10,1 LP=1,0 MS= 0,0
5 5 6 M=5,6,2 LP=1,0 MS= 0,0
6 6 7 M=6,6,1 LP=1,0 MS= 0,0
7 7 8 M=6,6,1 LP=1,0 MS= 0,0
8 8 9 M=6,6,1 LP=1,0 MS= 0,0
9 9 10 M=7,8,2 LP=1,0 MS= 0,0
10 10 11 M=9,9,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
11 10 12 M=8,7,2 LP=1,0 MS= 0,0
12 12 13 M=6,6,1 LP=1,0 MS= 0,0
13 13 14 M=6,6,1 LP=1,0 MS= 0,0
14 14 15 M=6,6,1 LP=1,0 MS= 0,0
15 15 16 M=6,5,2 LP=1,0 MS= 0,0
16 16 17 M=10,10,1 LP=1,0 MS= 0,0

17 17 18 M=10,10,1 LP=1,0 MS= 0,0
18 18 19 M=4,3,2 LP=1,0 MS= 0,0
19 19 20 M=2,1,2 LP=1,0 MS= 0,0
20 21 1 M=11,11,1 LP=1,0 MS= 0,0
21 1 22 M=11,11,1 LP=1,0 MS= 0,0
22 23 20 M=11,11,1 LP=1,0 MS= 0,0
23 20 24 M=11,11,1 LP=1,0 MS= 0,0

RESTRAINTS

21 21 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
22 22 1 R=1,1,1,1,1,0
11 11 1 R=1,1,1,1,1,0
23 23 1 R=1,1,1,1,1,0
20 20 1 R=1,1,1,1,1,0
24 24 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0
17 17 1 R=0,0,1,1,1,0
18 18 1 R=0,0,1,1,1,0
19 19 1 R=0,0,1,1,1,0

LOADS

17 17 1 L=1 F=0.1,-100,0,0,0,0
4 4 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=1.1

Buckling Load: P=541k

C This is file HYBRID_A written by SAPIN on Thu Apr 10 13:03:15 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=65 YN=11 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440 1464 1488 1512

1536

0 24 48 72 96 120 144 168

192 216 240

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=143.52 Z=0

3 X=-0.12 Y=176.76 Z=0

4 X=-0.12 Y=185 Z=0

5 X=7.56 Y=192.48 Z=0

6 X=150.96 Y=198.96 Z=0

7 X=294.24 Y=205.44 Z=0

8 X=518.64 Y=214.08 Z=0

9 X=662.16 Y=216 Z=0

10 X=756.72 Y=217.56 Z=0

11 X=756.72 Y=-20.4 Z=0

12 X=851.4 Y=216 Z=0

13 X=994.92 Y=214.08 Z=0

14 X=1219.2 Y=205.44 Z=0

15 X=1362.6 Y=198.96 Z=0

16 X=1506 Y=192.48 Z=0

17 X=1513.56 Y=185 Z=0

18 X=1513.6 Y=176.76 Z=0

19 X=1513.6 Y=143.52 Z=0

20 X=1513.6 Y=0 Z=0

21 X=-60 Y=0 Z=0

22 X=60 Y=0 Z=0

23 X=1453.56 Y=0 Z=0

24 X=1573.56 Y=0 Z=0
4 X=-0.18 Y=192.132 Z=0
17 X=1513.74 Y=192.132 Z=0

FRAME

NM=11 NL=0 NSEC=0

1 SH=I T=17,6,0.3125,0.125,6,0.5 E=29000 G=11154 W=0.0019523 M=5.0524E-06
TC=8.3E-06
2 SH=I T=17,6,0.3125,0.1489,6,0.5 E=29000 G=11154 W=0.0020617 M=5.3358E-06
TC=8.3E-06
3 SH=I T=31,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0030069 M=7.7817E-06 TC=8.3E-06
4 SH=I T=31,6,0.4375,0.178,6,0.3125 E=29000 G=11154 W=0.0027973 M=7.2394E-06
TC=8.3E-06
5 SH=I T=31,6,0.25,0.25,6,0.3125 E=29000 G=11154 W=0.0031086 M=8.045E-06 TC=8.3E-06
6 SH=I T=36.98,6,0.25,0.25,6,0.3125 E=29000 G=11154 W=0.0035317 M=9.1399E-06
TC=8.3E-06
7 SH=I T=36.98,6,0.5,0.25,6,0.625 E=29000 G=11154 W=0.004447 M=1.1509E-05
TC=8.3E-06
8 SH=I T=40.96,6,0.5,0.25,6,0.625 E=29000 G=11154 W=0.0047286 M=1.2237E-05
TC=8.3E-06
9 SH=P T=6.625,0.5599 E=29000 G=11154 W=0.0030191 M=7.8135E-06 TC=8.3E-06
10 A=50 J=0 I=1.3531E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05
TC=8.3E-06
11 A=1 J=0 I=4.238,0 AS=0,0 E=29000 G=11154 W=0.00028301 M=7.324E-07 TC=8.3E-06
1 1 2 M=1,1,1 LP=1,0 MS= 0,0
2 2 3 M=2,2,1 LP=1,0 MS= 0,0
3 3 4 M=10,10,1 LP=1,0 MS= 0,0
4 4 5 M=10,10,1 LP=1,0 MS= 0,0
5 5 6 M=3,3,1 LP=1,0 MS= 0,0
6 6 7 M=4,4,1 LP=1,0 MS= 0,0
7 7 8 M=4,4,1 LP=1,0 MS= 0,0
8 8 9 M=5,6,2 LP=1,0 MS= 0,0
9 9 10 M=7,8,2 LP=1,0 MS= 0,0
11 10 12 M=8,7,2 LP=1,0 MS= 0,0
12 12 13 M=6,5,2 LP=1,0 MS= 0,0
13 13 14 M=4,4,1 LP=1,0 MS= 0,0
14 14 15 M=4,4,1 LP=1,0 MS= 0,0
15 15 16 M=3,3,1 LP=1,0 MS= 0,0
16 16 17 M=10,10,1 LP=1,0 MS= 0,0
17 17 18 M=10,10,1 LP=1,0 MS= 0,0
18 18 19 M=2,2,1 LP=1,0 MS= 0,0

19 19 20 M=1,1,1 LP=1,0 MS= 0,0
10 10 11 M=9,9,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
20 21 1 M=11,11,1 LP=0,0 MS= 0,0
21 1 22 M=11,11,1 LP=0,0 MS= 0,0
22 23 20 M=11,11,1 LP=0,0 MS= 0,0
23 20 24 M=11,11,1 LP=0,0 MS= 0,0

RESTRAINTS

21 21 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
22 22 1 R=1,1,1,1,1,0
11 11 1 R=1,1,1,1,1,0
23 23 1 R=1,1,1,1,1,0
20 20 1 R=1,1,1,1,1,0
24 24 1 R=1,1,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
2 2 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0
17 17 1 R=0,0,1,1,1,0
18 18 1 R=0,0,1,1,1,0
19 19 1 R=0,0,1,1,1,0

LOADS

17 17 1 L=1 F=0,-100,0,0,0,0
4 4 1 L=1 F=0.1,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=5.4

Elastic Buckling Load: Pcr=874 kips

C This is file STIF2_A written by SAPIN on Thu Apr 10 13:03:51 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=51 YN=10 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200

0 24 48 72 96 120 144 168

192 216

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=71.52 Z=0

3 X=0 Y=116.16 Z=0

4 X=0 Y=126.04 Z=0

5 X=9.24 Y=127.56 Z=0

6 X=79.8 Y=139.32 Z=0

7 X=334.8 Y=181.44 Z=0

8 X=387.6 Y=189.84 Z=0

9 X=387.6 Y=-5.04 Z=0

10 X=396.48 Y=191.16 Z=0

11 X=466.92 Y=203.4 Z=0

12 X=587.64 Y=223.92 Z=0

13 X=708.24 Y=203.4 Z=0

14 X=778.68 Y=191.16 Z=0

15 X=787.56 Y=189.84 Z=0

16 X=787.56 Y=-5.04 Z=0

17 X=840.48 Y=181.44 Z=0

18 X=1095.48 Y=139.32 Z=0

19 X=1165.92 Y=127.56 Z=0

20 X=1175.207 Y=126.0432 Z=0

21 X=1175.16 Y=116.16 Z=0

22 X=1175.2 Y=71.52 Z=0

23 X=1175.2 Y=0 Z=0

24 X=-60 Y=0 Z=0

25 X=60 Y=0 Z=0

26 X=1115.16 Y=0 Z=0
27 X=1235.16 Y=0 Z=0

FRAME

NM=8 NL=0 NSEC=0

1 SH=I T=20,5,0.25,0.125,5,0.375 E=29000 G=11154 W=0.0015698 M=4.0625E-06
TC=8.3E-06
2 SH=I T=22,5,0.25,0.178,5,0.25 E=29000 G=11154 W=0.0017905 M=4.6339E-06 TC=8.3E-06
3 SH=I T=22,5,0.25,0.25,5,0.375 E=29000 G=11154 W=0.0023967 M=6.2025E-06 TC=8.3E-06
4 SH=I T=22,5,0.25,0.178,5,0.375 E=29000 G=11154 W=0.0019611 M=5.0753E-06
TC=8.3E-06
5 SH=I T=22,5,0.25,0.1489,5,0.25 E=29000 G=11154 W=0.0016135 M=4.1757E-06
TC=8.3E-06
6 SH=P T=6.625,0.312 E=29000 G=11154 W=0.0017512 M=4.532E-06 TC=8.3E-06
7 A=50 J=0 I=4.674E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
8 A=1.5 J=0 I=6.326,0 AS=0,0 E=29000 G=11154 W=0.0004245 M=1.0986E-06 TC=8.3E-06
1 1 2 M=1,1,1 LP=1,0 MS= 0,0
2 2 3 M=1,1,1 LP=1,0 MS= 0,0
3 3 4 M=7,7,1 LP=1,0 MS= 0,0
4 4 5 M=7,7,1 LP=1,0 MS= 0,0
5 5 6 M=2,2,1 LP=1,0 MS= 0,0
6 6 7 M=2,2,1 LP=1,0 MS= 0,0
7 7 8 M=3,3,1 LP=1,0 MS= 0,0
8 8 9 M=6,6,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
9 8 10 M=3,3,1 LP=1,0 MS= 0,0
10 10 11 M=4,4,1 LP=1,0 MS= 0,0
11 11 12 M=5,5,1 LP=1,0 MS= 0,0
12 12 13 M=5,5,1 LP=1,0 MS= 0,0
13 13 14 M=4,4,1 LP=1,0 MS= 0,0
14 14 15 M=3,3,1 LP=1,0 MS= 0,0
15 15 16 M=6,6,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
16 15 17 M=3,3,1 LP=1,0 MS= 0,0
17 17 18 M=2,2,1 LP=1,0 MS= 0,0
18 18 19 M=2,2,1 LP=1,0 MS= 0,0
19 19 20 M=7,7,1 LP=1,0 MS= 0,0
20 20 21 M=7,7,1 LP=1,0 MS= 0,0
21 21 22 M=1,1,1 LP=1,0 MS= 0,0
22 22 23 M=1,1,1 LP=1,0 MS= 0,0
23 24 1 M=8,8,1 LP=1,0 MS= 0,0
24 1 25 M=8,8,1 LP=1,0 MS= 0,0

25 26 23 M=8,8,1 LP=1,0 MS= 0,0
26 23 27 M=8,8,1 LP=1,0 MS= 0,0

RESTRAINTS

24 24 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
25 25 1 R=1,1,1,1,1,0
9 9 1 R=1,1,1,1,1,0
16 16 1 R=1,1,1,1,1,0
26 26 1 R=1,1,1,1,1,0
23 23 1 R=1,1,1,1,1,0
27 27 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
17 17 1 R=0,0,1,1,1,0
18 18 1 R=0,0,1,1,1,0
19 19 1 R=0,0,1,1,1,0
20 20 1 R=0,0,1,1,1,0
21 21 1 R=0,0,1,1,1,0
22 22 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
20 20 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=8.74

Buckling Load: P=149k

C This is file STIF8_A written by SAPIN on Thu Apr 10 11:54:53 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=67 YN=11 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440 1464 1488 1512

1536 1560 1584

0 24 48 72 96 120 144 168

192 216 240

0

JOINTS

1 X=0 Y=0 Z=0

2 X=4.2 Y=143.52 Z=0

3 X=5.52 Y=185.2 Z=0

4 X=5.52 Y=190 Z=0

5 X=16.2 Y=197.64 Z=0

6 X=158.88 Y=213.6 Z=0

7 X=301.92 Y=225.48 Z=0

8 X=444.96 Y=237.36 Z=0

9 X=597.12 Y=249.6 Z=0

10 X=775.2 Y=255.96 Z=0

11 X=775.2 Y=-5.04 Z=0

12 X=953.4 Y=249.6 Z=0

13 X=1105.56 Y=237.36 Z=0

14 X=1248.6 Y=225.48 Z=0

15 X=1391.52 Y=213.6 Z=0

16 X=1534.2 Y=197.64 Z=0

17 X=1545 Y=190 Z=0

18 X=1545 Y=185.4 Z=0

19 X=1546.2 Y=143.52 Z=0

20 X=1550.52 Y=0 Z=0

21 X=-60 Y=0 Z=0

22 X=60 Y=0 Z=0

23 X=1491 Y=0 Z=0

24 X=1611 Y=0 Z=0
4 X=5.868 Y=196.476 Z=0
17 X=1544.676 Y=196.476 Z=0

FRAME

NM=11 NL=0 NSEC=0

1 SH=I T=10,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0011851 M=3.0669E-06 TC=8.3E-06
2 SH=I T=18.51,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0014861 M=3.846E-06 TC=8.3E-06
3 SH=I T=18.51,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0016079 M=4.1613E-06 TC=8.3E-06
4 SH=I T=21,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0017128 M=4.4328E-06 TC=8.3E-06
5 SH=I T=24,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0016803 M=4.3486E-06 TC=8.3E-06
6 SH=I T=16,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0013973 M=3.6162E-06 TC=8.3E-06
7 SH=I T=16,6,0.25,0.1489,6,0.375 E=29000 G=11154 W=0.0017091 M=4.4232E-06 TC=8.3E-06
8 SH=I T=30.96,6,0.25,0.1489,6,0.375 E=29000 G=11154 W=0.0023395 M=6.0547E-06 TC=8.3E-06
9 SH=P T=6.625,0.312 E=29000 G=11154 W=0.0017512 M=4.532E-06 TC=8.3E-06
10 A=50 J=0 I=5.851E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
11 A=1 J=0 I=0.908,0 AS=0,0 E=29000 G=11154 W=0.00028301 M=7.3239E-07 TC=8.3E-06
1 1 2 M=1,2,2 LP=1,0 MS= 0,0
2 2 3 M=3,4,2 LP=1,0 MS= 0,0
3 3 4 M=10,10,1 LP=1,0 MS= 0,0
4 4 5 M=10,10,1 LP=1,0 MS= 0,0
5 5 6 M=5,6,2 LP=1,0 MS= 0,0
6 6 7 M=6,6,1 LP=1,0 MS= 0,0
7 7 8 M=6,6,1 LP=1,0 MS= 0,0
8 8 9 M=6,6,1 LP=1,0 MS= 0,0
9 9 10 M=7,8,2 LP=1,0 MS= 0,0
10 10 11 M=9,9,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
11 10 12 M=8,7,2 LP=1,0 MS= 0,0
12 12 13 M=6,6,1 LP=1,0 MS= 0,0
13 13 14 M=6,6,1 LP=1,0 MS= 0,0
14 14 15 M=6,6,1 LP=1,0 MS= 0,0
15 15 16 M=6,5,2 LP=1,0 MS= 0,0
16 16 17 M=10,10,1 LP=1,0 MS= 0,0
17 17 18 M=10,10,1 LP=1,0 MS= 0,0

18 18 19 M=4,3,2 LP=1,0 MS= 0,0
19 19 20 M=2,1,2 LP=1,0 MS= 0,0
20 21 1 M=11,11,1 LP=1,0 MS= 0,0
21 1 22 M=11,11,1 LP=1,0 MS= 0,0
22 23 20 M=11,11,1 LP=1,0 MS= 0,0
23 20 24 M=11,11,1 LP=1,0 MS= 0,0

RESTRAINTS

21 21 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
22 22 1 R=1,1,1,1,1,0
11 11 1 R=1,1,1,1,1,0
23 23 1 R=1,1,1,1,1,0
20 20 1 R=1,1,1,1,1,0
24 24 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0
17 17 1 R=0,0,1,1,1,0
18 18 1 R=0,0,1,1,1,0
19 19 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
17 17 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=1.49

Buckling Load: P=61k

C This is file FRA26_A written by SAPIN on Thu Apr 10 11:55:27 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=51 YN=13 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200

0 24 48 72 96 120 144 168

192 216 240 264 288

0

JOINTS

1 X=0 Y=0 Z=0

2 X=3.72 Y=120 Z=0

3 X=6.6 Y=218.4 Z=0

4 X=6.6 Y=224.628 Z=0

5 X=16.8 Y=225.48 Z=0

6 X=136.2 Y=237.84 Z=0

7 X=327.48 Y=254.04 Z=0

8 X=468.84 Y=265.56 Z=0

9 X=587.88 Y=270.6 Z=0

10 X=587.88 Y=0 Z=0

11 X=707.04 Y=265.56 Z=0

12 X=848.4 Y=254.04 Z=0

13 X=1039.68 Y=237.84 Z=0

14 X=1159.08 Y=225.48 Z=0

15 X=1169.244 Y=224.628 Z=0

16 X=1169.28 Y=218.4 Z=0

17 X=1172.04 Y=120 Z=0

18 X=1175.88 Y=0 Z=0

19 X=-60 Y=0 Z=0

20 X=60 Y=0 Z=0

21 X=1115.9 Y=0 Z=0

22 X=1235.9 Y=0 Z=0

FRAME

NM=13 NL=0 NSEC=0

1 A=2.89 J=0 I=22.5,0 AS=0,0 E=29000 G=11154 W=0.00081787 M=2.1166E-06 TC=8.3E-06
 2 A=3.85 J=0 I=128.6,0 AS=0,0 E=29000 G=11154 W=0.0010895 M=2.8197E-06 TC=8.3E-06
 3 A=3.49 J=0 I=112.3,0 AS=0,0 E=29000 G=11154 W=0.00098767 M=2.5561E-06 TC=8.3E-06
 4 A=4.28 J=0 I=264.5,0 AS=0,0 E=29000 G=11154 W=0.0012112 M=3.1347E-06 TC=8.3E-06
 5 A=4.01 J=0 I=157.2,0 AS=0,0 E=29000 G=11154 W=0.0011348 M=2.9369E-06 TC=8.3E-06
 6 A=3.58 J=0 I=88.1,0 AS=0,0 E=29000 G=11154 W=0.0010131 M=2.622E-06 TC=8.3E-06
 7 A=3.58 J=0 I=88.1,0 AS=0,0 E=29000 G=11154 W=0.0010131 M=2.622E-06 TC=8.3E-06
 8 A=3.22 J=0 I=76.5,0 AS=0,0 E=29000 G=11154 W=0.00091126 M=2.3583E-06 TC=8.3E-06
 9 A=4.56 J=0 I=122.9,0 AS=0,0 E=29000 G=11154 W=0.0012905 M=3.3397E-06 TC=8.3E-06
 10 A=5.75 J=0 I=451.4,0 AS=0,0 E=29000 G=11154 W=0.0016272 M=4.2113E-06 TC=8.3E-06
 11 SH=P T=6.625,0.312 E=29000 G=11154 W=0.0017512 M=4.532E-06 TC=8.3E-06
 12 A=50 J=0 I=2.645E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 13 A=1 J=0 I=0.2,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=3,4,2 LP=1,0 MS= 0,0
 3 3 4 M=12,12,1 LP=1,0 MS= 0,0
 4 4 5 M=12,12,1 LP=1,0 MS= 0,0
 5 5 6 M=5,6,2 LP=1,0 MS= 0,0
 6 6 7 M=7,7,1 LP=1,0 MS= 0,0
 7 7 8 M=8,8,1 LP=1,0 MS= 0,0
 8 8 9 M=9,10,2 LP=1,0 MS= 0,0
 9 9 10 M=11,11,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
 10 9 11 M=10,9,2 LP=1,0 MS= 0,0
 11 11 12 M=8,8,1 LP=1,0 MS= 0,0
 12 12 13 M=7,7,1 LP=1,0 MS= 0,0
 13 13 14 M=6,5,2 LP=1,0 MS= 0,0
 14 14 15 M=12,12,1 LP=1,0 MS= 0,0
 15 15 16 M=12,12,1 LP=1,0 MS= 0,0
 16 16 17 M=4,3,2 LP=1,0 MS= 0,0
 17 17 18 M=2,1,2 LP=1,0 MS= 0,0
 18 19 1 M=13,13,1 LP=1,0 MS= 0,0
 19 1 20 M=13,13,1 LP=1,0 MS= 0,0
 20 21 18 M=13,13,1 LP=1,0 MS= 0,0
 21 18 22 M=13,13,1 LP=1,0 MS= 0,0

RESTRAINTS

19 19 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
20 20 1 R=1,1,1,1,1,0
10 10 1 R=1,1,1,1,1,0
21 21 1 R=1,1,1,1,1,0
18 18 1 R=1,1,1,1,1,0
22 22 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0
17 17 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
15 15 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=0.6

Buckling Load: P=1247k

C This is file 99219A_A written by SAPIN on Thu Apr 10 11:57:04 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=47 YN=12 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104

0 24 48 72 96 120 144 168

192 216 240 264

0

JOINTS

1 X=0 Y=0 Z=0

2 X=16.32 Y=180 Z=0

3 X=16.68 Y=184.68 Z=0

4 X=16.68 Y=205.1256 Z=0

5 X=39 Y=205.56 Z=0

6 X=175.56 Y=216.84 Z=0

7 X=295.32 Y=227.04 Z=0

8 X=415.32 Y=230.88 Z=0

9 X=535.32 Y=234.24 Z=0

10 X=655.32 Y=235.68 Z=0

11 X=775.32 Y=236.4 Z=0

12 X=895.44 Y=230.64 Z=0

13 X=1022.52 Y=225.24 Z=0

14 X=1040.806 Y=225.5724 Z=0

15 X=1040.76 Y=204.96 Z=0

16 X=1043.04 Y=180 Z=0

17 X=1059.84 Y=0 Z=0

18 X=-60 Y=0 Z=0

19 X=60 Y=0 Z=0

20 X=999.84 Y=0 Z=0

21 X=1119.84 Y=0 Z=0

FRAME

NM=20 NL=0 NSEC=0

1 SH=I T=16,6,0.25,0.25,6,0.5 E=29000 G=11154 W=0.0023524 M=6.0881E-06 TC=8.3E-06

2 SH=I T=47.08,6,0.25,0.25,6,0.5 E=29000 G=11154 W=0.0045513 M=1.1779E-05
 TC=8.3E-06
 3 SH=I T=48,6,0.25,0.25,6,0.5 E=29000 G=11154 W=0.0046164 M=1.1947E-05 TC=8.3E-06
 4 SH=I T=47,6,0.25,0.25,6,0.625 E=29000 G=11154 W=0.0047491 M=1.2291E-05 TC=8.3E-06
 5 SH=I T=33.67,6,0.25,0.25,6,0.625 E=29000 G=11154 W=0.003806 M=9.8499E-06
 TC=8.3E-06
 6 SH=I T=33.67,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0031958 M=8.2706E-06
 TC=8.3E-06
 7 SH=I T=22,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0023701 M=6.1338E-06 TC=8.3E-06
 8 SH=I T=22,6,0.375,0.178,6,0.25 E=29000 G=11154 W=0.002138 M=5.5331E-06 TC=8.3E-06
 9 SH=I T=22,6,0.625,0.1489,6,0.25 E=29000 G=11154 W=0.0023759 M=6.1489E-06
 TC=8.3E-06
 10 SH=I T=22,6,0.3125,0.178,6,0.25 E=29000 G=11154 W=0.002035 M=5.2666E-06
 TC=8.3E-06
 11 SH=I T=22,6,0.25,0.25,6,0.375 E=29000 G=11154 W=0.0025735 M=6.6603E-06
 TC=8.3E-06
 12 SH=I T=34.13,6,0.25,0.25,6,0.375 E=29000 G=11154 W=0.0034317 M=8.8813E-06
 TC=8.3E-06
 13 SH=I T=34.13,6,0.25,0.25,6,0.75 E=29000 G=11154 W=0.0040419 M=1.0461E-05
 TC=8.3E-06
 14 SH=I T=47,6,0.25,0.25,6,0.75 E=29000 G=11154 W=0.0049525 M=1.2817E-05 TC=8.3E-06
 15 SH=I T=48,8,0.25,0.25,8,1 E=29000 G=11154 W=0.0061376 M=1.5884E-05 TC=8.3E-06
 16 SH=I T=43.99,8,0.25,0.25,8,1 E=29000 G=11154 W=0.0058539 M=1.515E-05 TC=8.3E-06
 17 SH=I T=16,8,0.25,0.25,8,1 E=29000 G=11154 W=0.0038736 M=1.0025E-05 TC=8.3E-06
 18 A=50 J=0 I=7.2784E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05
 TC=8.3E-06
 19 A=1 J=0 I=3.608,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 20 A=1 J=0 I=10.328,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,2,2 LP=1,0 MS= 0,0
 2 2 3 M=2,3,2 LP=1,0 MS= 0,0
 3 3 4 M=18,18,1 LP=1,0 MS= 0,0
 4 4 5 M=18,18,1 LP=1,0 MS= 0,0
 5 5 6 M=4,5,2 LP=1,0 MS= 0,0
 6 6 7 M=6,7,2 LP=1,0 MS= 0,0
 7 7 8 M=8,8,1 LP=1,0 MS= 0,0
 8 8 9 M=9,9,1 LP=1,0 MS= 0,0
 9 9 10 M=9,9,1 LP=1,0 MS= 0,0
 10 10 11 M=10,10,1 LP=1,0 MS= 0,0

11 11 12 M=11,12,2 LP=1,0 MS= 0,0
12 12 13 M=13,14,2 LP=1,0 MS= 0,0
13 13 14 M=18,18,1 LP=1,0 MS= 0,0
14 14 15 M=18,18,1 LP=1,0 MS= 0,0
15 15 16 M=15,16,2 LP=1,0 MS= 0,0
16 16 17 M=16,17,2 LP=1,0 MS= 0,0
17 18 1 M=19,19,1 LP=1,0 MS= 0,0
18 1 19 M=19,19,1 LP=1,0 MS= 0,0
19 20 17 M=20,20,1 LP=1,0 MS= 0,0
20 17 21 M=20,20,1 LP=1,0 MS= 0,0

RESTRAINTS

18 18 1 R=1,1,1,1,1,0
1 1 1 R=1,1,1,1,1,0
19 19 1 R=1,1,1,1,1,0
20 20 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0
21 21 1 R=1,1,1,1,1,0
2 2 1 R=0,0,1,1,1,0
3 3 1 R=0,0,1,1,1,0
4 4 1 R=0,0,1,1,1,0
5 5 1 R=0,0,1,1,1,0
6 6 1 R=0,0,1,1,1,0
7 7 1 R=0,0,1,1,1,0
8 8 1 R=0,0,1,1,1,0
9 9 1 R=0,0,1,1,1,0
10 10 1 R=0,0,1,1,1,0
11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0
14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
16 16 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=-0.1,-100,0,0,0,0
14 14 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=12.47

Buckling Load: P=3720k

C This is file 99195A_A written by SAPIN on Thu Apr 10 11:58:07 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=41 YN=15 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=171.72 Z=0

3 X=0 Y=180.36 Z=0

4 X=0 Y=204.3312 Z=0

5 X=18 Y=205.8 Z=0

6 X=197.16 Y=223.68 Z=0

7 X=436.32 Y=243.48 Z=0

8 X=701.28 Y=264.72 Z=0

9 X=892.92 Y=277.08 Z=0

10 X=911.316 Y=278.5368 Z=0

11 X=911.28 Y=251.28 Z=0

12 X=911.16 Y=234.96 Z=0

13 X=911.04 Y=-5.04 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=851 Y=-5.04 Z=0

17 X=971 Y=-5.04 Z=0

FRAME

NM=11 NL=0 NSEC=0

1 SH=I T=40.56,8,0.3125,0.25,8,0.625 E=29000 G=11154 W=0.0049258 M=1.2748E-05
TC=8.3E-06

2 SH=I T=50,6,0.3125,0.3125,6,0.3125 E=29000 G=11154 W=0.0054279 M=1.4047E-05
TC=8.3E-06

3 SH=I T=44,6,0.3125,0.3125,6,0.3125 E=29000 G=11154 W=0.0048972 M=1.2674E-05
TC=8.3E-06

4 SH=I T=44,6,0.4375,0.25,6,0.375 E=29000 G=11154 W=0.0044351 M=1.1478E-05
 TC=8.3E-06
 5 SH=I T=44,6,0.625,0.3125,6,0.625 E=29000 G=11154 W=0.0059032 M=1.5277E-05
 TC=8.3E-06
 6 SH=I T=50,6,0.625,0.3125,6,0.625 E=29000 G=11154 W=0.0064338 M=1.6651E-05
 TC=8.3E-06
 7 SH=I T=40.5,12,0.375,0.3125,12,0.625 E=29000 G=11154 W=0.0068893 M=1.7829E-05
 TC=8.3E-06
 8 SH=I T=40.5,12,0.375,0.25,12,0.625 E=29000 G=11154 W=0.0061906 M=1.6021E-05
 TC=8.3E-06
 9 A=50 J=0 I=8.0609E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 10 A=3 J=0 I=43.095,0 AS=0,0 E=29000 G=11154 W=0.000849 M=2.1972E-06 TC=8.3E-06
 11 A=3 J=0 I=44.155,0 AS=0,0 E=29000 G=11154 W=0.000849 M=2.1972E-06 TC=8.3E-06
 1 1 2 M=1,1,1 LP=1,0 MS= 0,0
 2 2 3 M=1,1,1 LP=1,0 MS= 0,0
 3 3 4 M=9,9,1 LP=1,0 MS= 0,0
 4 4 5 M=9,9,1 LP=1,0 MS= 0,0
 5 5 6 M=2,3,2 LP=1,0 MS= 0,0
 6 6 7 M=4,4,1 LP=1,0 MS= 0,0
 7 7 8 M=4,4,1 LP=1,0 MS= 0,0
 8 8 9 M=5,6,2 LP=1,0 MS= 0,0
 9 9 10 M=9,9,1 LP=1,0 MS= 0,0
 10 10 11 M=9,9,1 LP=1,0 MS= 0,0
 11 11 12 M=7,7,1 LP=1,0 MS= 0,0
 12 12 13 M=8,8,1 LP=1,0 MS= 0,0
 13 14 1 M=10,10,1 LP=1,0 MS= 0,0
 14 1 15 M=10,10,1 LP=1,0 MS= 0,0
 15 16 13 M=11,11,1 LP=1,0 MS= 0,0
 16 13 17 M=11,11,1 LP=1,0 MS= 0,0

RESTRAINTS

1 1 1 R=1,1,1,1,1,0
 13 13 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0

11 11 1 R=0,0,1,1,1,0
12 12 1 R=0,0,1,1,1,0
14 14 1 R=1,1,1,1,1,0
15 15 1 R=1,1,1,1,1,0
16 16 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
10 10 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=37.2

Buckling Load: P=355k

C This is file FRA41_A written by SAPIN on Thu Apr 10 11:58:44 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=41 YN=27 ZN=1

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240 252 264 276

288 300 312 324 336 348 360 372

384 396 408 420 432 444 456 468

480

0 12 24 36 48 60 72 84

96 108 120 132 144 156 168 180

192 204 216 228 240 252 264 276

288 300 312

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=215.52 Z=0

3 X=0 Y=252.36 Z=0

4 X=8.64 Y=266.76 Z=0

5 X=151.56 Y=279 Z=0

6 X=222.84 Y=285.24 Z=0

7 X=305.88 Y=291.84 Z=0

8 X=448.92 Y=303.48 Z=0

9 X=457.92 Y=289.08 Z=0

10 X=458.4 Y=215.52 Z=0

11 X=458.88 Y=0 Z=0

12 X=-0.054 Y=266.0112 Z=0

13 X=467.9236 Y=304.176 Z=0

14 X=-60 Y=0 Z=0

15 X=60 Y=0 Z=0

16 X=398.9 Y=0 Z=0

17 X=518.9 Y=0 Z=0

13 X=457.92 Y=304.18 Z=0

FRAME

NM=9 NL=1 NSEC=0

1 SH=I T=18,5,0.375,0.125,5,0.5 E=29000 G=11154 W=0.0018439 M=4.772E-06 TC=8.3E-06

2 SH=I T=18,5,0.375,0.149,5,0.5 E=29000 G=11154 W=0.0019602 M=5.0731E-06 TC=8.3E-06
 3 SH=I T=28.19,5,0.25,0.178,5,0.25 E=29000 G=11154 W=0.0021024 M=5.4409E-06 TC=8.3E-06
 4 SH=I T=28.19,5,0.3125,0.149,5,0.25 E=29000 G=11154 W=0.0019609 M=5.0748E-06 TC=8.3E-06
 5 SH=I T=18,6,0.375,0.178,6,0.4375 E=29000 G=11154 W=0.0022454 M=5.8111E-06 TC=8.3E-06
 6 SH=I T=18,6,0.375,0.125,6,0.3125 E=29000 G=11154 W=0.0017798 M=4.6061E-06 TC=8.3E-06
 7 A=30 J=0 I=8.37E+05,0 AS=0,0 E=29000 G=11154 W=0.00849 M=2.1972E-05 TC=8.3E-06
 8 A=1 J=0 I=3.21,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.3239E-07 TC=8.3E-06
 9 A=1 J=0 I=2.67,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.3239E-07 TC=8.3E-06
 1 WL=0,0,0 WG=0,-1,0 T=0,0,0
 10 1 2 M=1,1,1 LP=1,0 MS= 0,0
 11 2 3 M=2,2,1 LP=1,0 MS= 0,0
 12 3 12 M=7,7,1 LP=1,0 MS= 0,0
 13 12 4 M=7,7,1 LP=1,0 MS= 0,0
 14 4 5 M=3,3,1 LP=1,0 MS= 0,0
 15 5 6 M=4,4,1 LP=1,0 MS= 0,0
 16 6 7 M=4,4,1 LP=1,0 MS= 0,0
 17 7 8 M=3,3,1 LP=1,0 MS= 0,0
 18 8 13 M=7,7,1 LP=1,0 MS= 0,0
 19 13 9 M=7,7,1 LP=1,0 MS= 0,0
 20 9 10 M=5,5,1 LP=1,0 MS= 0,0
 21 10 11 M=6,6,1 LP=1,0 MS= 0,0
 22 14 1 M=8,8,1 LP=1,0 MS= 0,0
 23 1 15 M=8,8,1 LP=1,0 MS= 0,0
 24 16 11 M=9,9,1 LP=1,0 MS= 0,0
 25 11 17 M=9,9,1 LP=1,0 MS= 0,0

RESTRAINTS

1 1 1 R=1,1,1,1,1,0
 11 11 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0

10 10 1 R=0,0,1,1,1,0
14 14 1 R=1,1,1,1,1,0
15 15 1 R=1,1,1,1,1,0
16 16 1 R=1,1,1,1,1,0
17 17 1 R=1,1,1,1,1,0
12 12 1 R=0,0,1,1,1,0
13 13 1 R=0,0,1,1,1,0

LOADS

12 12 1 L=1 F=0.1,-100,0,0,0,0
13 13 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=3.55

Buckling Load: P=609k

C This is file STIF5_A written by SAPIN on Thu Apr 10 11:59:30 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=69 YN=11 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440 1464 1488 1512

1536 1560 1584 1608 1632

0 24 48 72 96 120 144 168

192 216 240

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=143.52 Z=0

3 X=0 Y=164.04 Z=0

4 X=0 Y=168 Z=0

5 X=12.72 Y=173.76 Z=0

6 X=84.12 Y=177 Z=0

7 X=292.8 Y=186 Z=0

8 X=346.2 Y=188.28 Z=0

9 X=346.2 Y=-5.04 Z=0

10 X=355.2 Y=188.64 Z=0

11 X=426.72 Y=191.64 Z=0

12 X=728.28 Y=203.76 Z=0

13 X=796.2 Y=206.16 Z=0

14 X=877.2 Y=202.56 Z=0

15 X=886.2 Y=202.2 Z=0

16 X=886.2 Y=-5.04 Z=0

17 X=1038.72 Y=197.04 Z=0

18 X=1148.64 Y=193.44 Z=0

19 X=1292.04 Y=186.96 Z=0

20 X=1435.44 Y=180.24 Z=0

21 X=1578.72 Y=173.76 Z=0

22 X=1592.04 Y=168 Z=0

23 X=1592 Y=164.04 Z=0

24 X=1592 Y=143.52 Z=0
 25 X=1592 Y=0 Z=0
 26 X=-60 Y=0 Z=0
 27 X=60 Y=0 Z=0
 28 X=1532 Y=0 Z=0
 29 X=1652 Y=0 Z=0
 4 X=0 Y=173.16 Z=0
 22 X=1580.04 Y=173.16 Z=0
 22 X=1592.04 Y=173.16 Z=0

FRAME

NM=13 NL=0 NSEC=0

1 SH=I T=25,6,0.25,0.178,6,0.25 E=29000 G=11154 W=0.0020832 M=5.3912E-06 TC=8.3E-06
 2 SH=I T=20,6,0.25,0.1489,6,0.3125 E=29000 G=11154 W=0.0017742 M=4.5916E-06 TC=8.3E-06
 3 SH=I T=20,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0015388 M=3.9824E-06 TC=8.3E-06
 4 SH=I T=20,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0016707 M=4.3238E-06 TC=8.3E-06
 5 SH=I T=20,6,0.5,0.178,6,0.625 E=29000 G=11154 W=0.0028611 M=7.4044E-06 TC=8.3E-06
 6 SH=I T=20,6,0.4375,0.1489,6,0.25 E=29000 G=11154 W=0.0019812 M=5.1273E-06 TC=8.3E-06
 7 SH=I T=20,6,0.4375,0.125,6,0.3125 E=29000 G=11154 W=0.0019545 M=5.0581E-06 TC=8.3E-06
 8 SH=I T=20,6,0.375,0.1489,6,0.3125 E=29000 G=11154 W=0.0019812 M=5.1273E-06 TC=8.3E-06
 9 SH=I T=26,6,0.25,0.178,6,0.25 E=29000 G=11154 W=0.0021335 M=5.5216E-06 TC=8.3E-06
 10 SH=P T=6.625,0.312 E=29000 G=11154 W=0.0017512 M=4.532E-06 TC=8.3E-06
 11 A=50 J=0 I=7.775E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
 12 A=1 J=0 I=8.201,0 AS=0,0 E=29000 G=11154 W=0.00028301 M=7.324E-07 TC=8.3E-06
 13 A=1 J=0 I=8.98,0 AS=0,0 E=29000 G=11154 W=0.00028301 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,1,1 LP=1,0 MS= 0,0
 2 2 3 M=1,1,1 LP=1,0 MS= 0,0
 3 3 4 M=11,11,1 LP=1,0 MS= 0,0
 4 4 5 M=11,11,1 LP=1,0 MS= 0,0
 5 5 6 M=2,2,1 LP=1,0 MS= 0,0
 6 6 7 M=3,3,1 LP=1,0 MS= 0,0
 7 7 8 M=4,4,1 LP=1,0 MS= 0,0
 8 8 9 M=10,10,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0

19 15 16 M=10,10,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
 9 26 1 M=12,12,1 LP=1,0 MS= 0,0
 10 1 27 M=12,12,1 LP=1,0 MS= 0,0
 11 28 25 M=13,13,1 LP=1,0 MS= 0,0
 12 25 29 M=13,13,1 LP=1,0 MS= 0,0
 13 8 10 M=4,4,1 LP=1,0 MS= 0,0
 14 10 11 M=4,4,1 LP=1,0 MS= 0,0
 15 11 12 M=3,3,1 LP=1,0 MS= 0,0
 16 12 13 M=2,2,1 LP=1,0 MS= 0,0
 17 13 14 M=5,5,1 LP=1,0 MS= 0,0
 18 14 15 M=5,5,1 LP=1,0 MS= 0,0
 20 15 17 M=5,5,1 LP=1,0 MS= 0,0
 21 17 18 M=6,6,1 LP=1,0 MS= 0,0
 22 18 19 M=7,7,1 LP=1,0 MS= 0,0
 23 19 20 M=8,8,1 LP=1,0 MS= 0,0
 24 20 21 M=2,2,1 LP=1,0 MS= 0,0
 25 21 22 M=11,11,1 LP=1,0 MS= 0,0
 26 22 23 M=11,11,1 LP=1,0 MS= 0,0
 27 23 24 M=9,9,1 LP=1,0 MS= 0,0
 28 24 25 M=9,9,1 LP=1,0 MS= 0,0

RESTRAINTS

26 26 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 27 27 1 R=1,1,1,1,1,0
 9 9 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 28 28 1 R=1,1,1,1,1,0
 25 25 1 R=1,1,1,1,1,0
 29 29 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 11 11 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0
 13 13 1 R=0,0,1,1,1,0
 14 14 1 R=0,0,1,1,1,0
 15 15 1 R=0,0,1,1,1,0

17 17 1 R=0,0,1,1,1,0
18 18 1 R=0,0,1,1,1,0
19 19 1 R=0,0,1,1,1,0
20 20 1 R=0,0,1,1,1,0
21 21 1 R=0,0,1,1,1,0
22 22 1 R=0,0,1,1,1,0
23 23 1 R=0,0,1,1,1,0
24 24 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
22 22 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
L=1 SF=6.09

Buckling Load: P=317k

C This is file STIF6_A written by SAPIN on Thu Apr 10 12:00:02 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=76 YN=18 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440 1464 1488 1512

1536 1560 1584 1608 1632 1656 1680 1704

1728 1752 1776 1800

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=215.52 Z=0

3 X=0 Y=270.24 Z=0

4 X=0 Y=276 Z=0

5 X=12.84 Y=285.96 Z=0

6 X=156.24 Y=292.56 Z=0

7 X=299.64 Y=299.04 Z=0

8 X=443.04 Y=304.68 Z=0

9 X=736.2 Y=316.8 Z=0

10 X=844.2 Y=318.48 Z=0

11 X=943.32 Y=319.8 Z=0

12 X=943.32 Y=-5.04 Z=0

13 X=952.32 Y=319.08 Z=0

14 X=1095.36 Y=333 Z=0

15 X=1238.64 Y=339.96 Z=0

16 X=1382.04 Y=346.56 Z=0

17 X=1525.44 Y=352.44 Z=0

18 X=1680.12 Y=358.68 Z=0

19 X=1751.64 Y=358.32 Z=0

20 X=1765.68 Y=348 Z=0

21 X=1765.7 Y=343.56 Z=0

22 X=1765.7 Y=287.52 Z=0
23 X=1765.7 Y=0 Z=0
24 X=-60 Y=0 Z=0
25 X=60 Y=0 Z=0
26 X=1706 Y=0 Z=0
27 X=1826 Y=0 Z=0
4 X=0 Y=285.372 Z=0
20 X=1765.836 Y=358.248 Z=0

FRAME

NM=24 NL=0 NSEC=0

1 SH=I T=28,6,0.25,0.125,6,0.375 E=29000 G=11154 W=0.0020296 M=5.2527E-06
TC=8.3E-06
2 SH=I T=31,6,0.25,0.25,6,0.25 E=29000 G=11154 W=0.0030069 M=7.7817E-06 TC=8.3E-06
3 SH=I T=31,6,0.375,0.178,6,0.25 E=29000 G=11154 W=0.0025914 M=6.7064E-06
TC=8.3E-06
4 SH=I T=31,6,0.4375,0.1489,6,0.3125 E=29000 G=11154 W=0.0025482 M=6.5947E-06
TC=8.3E-06
5 SH=I T=31,6,0.375,0.178,6,0.3125 E=29000 G=11154 W=0.0026943 M=6.9729E-06
TC=8.3E-06
6 SH=I T=31,6,0.375,0.25,6,0.25 E=29000 G=11154 W=0.0032103 M=8.3082E-06 TC=8.3E-06
7 SH=I T=35.5,6,0.375,0.25,6,0.25 E=29000 G=11154 W=0.0035287 M=9.1321E-06
TC=8.3E-06
8 SH=I T=35.5,6,0.375,0.25,6,0.4375 E=29000 G=11154 W=0.0038338 M=9.9217E-06
TC=8.3E-06
9 SH=I T=39.62,6,0.375,0.25,6,0.4375 E=29000 G=11154 W=0.0041253 M=1.0676E-05
TC=8.3E-06
10 SH=I T=40,6,0.375,0.25,6,0.4375 E=29000 G=11154 W=0.0041521 M=1.0746E-05
TC=8.3E-06
11 SH=I T=40,6,0.375,0.178,6,0.625 E=29000 G=11154 W=0.0036626 M=9.4787E-06
TC=8.3E-06
12 SH=I T=24,6,0.375,0.178,6,0.625 E=29000 G=11154 W=0.0028566 M=7.3928E-06
TC=8.3E-06
13 SH=I T=24,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.0022387 M=5.7938E-06
TC=8.3E-06
14 SH=I T=24,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0018393 M=4.76E-06 TC=8.3E-06
15 SH=I T=24,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0016803 M=4.3486E-06
TC=8.3E-06
16 SH=I T=24,6,0.25,0.178,6,0.25 E=29000 G=11154 W=0.0020328 M=5.2608E-06
TC=8.3E-06

17 SH=I T=24,6,0.25,0.178,6,0.3125 E=29000 G=11154 W=0.0021358 M=5.5273E-06
 TC=8.3E-06
 18 SH=I T=29.98,6,0.25,0.178,6,0.3125 E=29000 G=11154 W=0.002437 M=6.3069E-06
 TC=8.3E-06
 19 SH=I T=30,6,0.25,0.1489,6,0.375 E=29000 G=11154 W=0.0022991 M=5.95E-06
 TC=8.3E-06
 20 SH=I T=30,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.002541 M=6.576E-06 TC=8.3E-
 06
 21 SH=P T=7,0.4725 E=29000 G=11154 W=0.0027421 M=7.0965E-06 TC=8.3E-06
 22 A=50 J=0 I=1.3531E+06,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05
 TC=8.3E-06
 23 A=1 J=0 I=6.763,0 AS=0,0 E=29000 G=11154 W=0.00028299 M=7.324E-07 TC=8.3E-06
 24 A=1 J=0 I=6.594,0 AS=0,0 E=29000 G=11154 W=0.00028299 M=7.324E-07 TC=8.3E-06
 1 1 2 M=1,1,1 LP=1,0 MS= 0,0
 2 2 3 M=1,1,1 LP=1,0 MS= 0,0
 3 3 4 M=22,22,1 LP=1,0 MS= 0,0
 4 4 5 M=22,22,1 LP=1,0 MS= 0,0
 5 5 6 M=2,2,1 LP=1,0 MS= 0,0
 6 6 7 M=3,3,1 LP=1,0 MS= 0,0
 7 7 8 M=4,4,1 LP=1,0 MS= 0,0
 8 8 9 M=5,5,1 LP=1,0 MS= 0,0
 9 9 10 M=6,7,2 LP=1,0 MS= 0,0
 10 10 11 M=8,9,2 LP=1,0 MS= 0,0
 11 11 12 M=21,21,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
 23 24 1 M=23,23,1 LP=1,0 MS= 0,0
 24 1 25 M=23,23,1 LP=1,0 MS= 0,0
 25 26 23 M=24,24,1 LP=1,0 MS= 0,0
 26 23 27 M=24,24,1 LP=1,0 MS= 0,0
 12 11 13 M=9,10,2 LP=1,0 MS= 0,0
 13 13 14 M=11,12,2 LP=1,0 MS= 0,0
 14 14 15 M=13,13,1 LP=1,0 MS= 0,0
 15 15 16 M=14,14,1 LP=1,0 MS= 0,0
 16 16 17 M=15,15,1 LP=1,0 MS= 0,0
 17 17 18 M=16,16,1 LP=1,0 MS= 0,0
 18 18 19 M=17,18,2 LP=1,0 MS= 0,0
 19 19 20 M=22,22,1 LP=1,0 MS= 0,0
 20 20 21 M=22,22,1 LP=1,0 MS= 0,0
 21 21 22 M=20,20,1 LP=1,0 MS= 0,0
 22 22 23 M=19,19,1 LP=1,0 MS= 0,0

RESTRAINTS

24 24 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0

25 25 1 R=1,1,1,1,1,0
 12 12 1 R=1,1,1,1,1,0
 26 26 1 R=1,1,1,1,1,0
 23 23 1 R=1,1,1,1,1,0
 27 27 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 9 9 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 11 11 1 R=0,0,1,1,1,0
 13 13 1 R=0,0,1,1,1,0
 14 14 1 R=0,0,1,1,1,0
 15 15 1 R=0,0,1,1,1,0
 16 16 1 R=0,0,1,1,1,0
 17 17 1 R=0,0,1,1,1,0
 18 18 1 R=0,0,1,1,1,0
 19 19 1 R=0,0,1,1,1,0
 20 20 1 R=0,0,1,1,1,0
 21 21 1 R=0,0,1,1,1,0
 22 22 1 R=0,0,1,1,1,0
 12 12 1
 13 13 1
 12 12 1 R=1,1,1,1,1,0
 11 11 1 R=0,0,1,1,1,0
 16 16 1 R=0,0,1,1,1,0

LOADS

20 20 1 L=1 F=0,-100,0,0,0,0
 4 4 1 L=1 F=0.1,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001
 L=1 SF=3.17

Buckling Load: P=119k

C This is file STIF7_A written by SAPIN on Thu Apr 10 12:00:37 1997

C Units are KIP INCHES

SYSTEM

R=0 L=1 C=0 V=0 T=0.0001 P=0 W=0 Z=0

GRID

XN=61 YN=14 ZN=1

0 24 48 72 96 120 144 168

192 216 240 264 288 312 336 360

384 408 432 456 480 504 528 552

576 600 624 648 672 696 720 744

768 792 816 840 864 888 912 936

960 984 1008 1032 1056 1080 1104 1128

1152 1176 1200 1224 1248 1272 1296 1320

1344 1368 1392 1416 1440

0 24 48 72 96 120 144 168

192 216 240 264 288 312

0

JOINTS

1 X=0 Y=0 Z=0

2 X=0 Y=179.52 Z=0

3 X=0 Y=264.72 Z=0

4 X=0 Y=270 Z=0

5 X=6.24 Y=273 Z=0

6 X=77.52 Y=278.88 Z=0

7 X=303.96 Y=297.48 Z=0

8 X=357.24 Y=301.68 Z=0

9 X=357.24 Y=-5.04 Z=0

10 X=366.24 Y=302.4 Z=0

11 X=437.2 Y=308.88 Z=0

12 X=705.24 Y=331.44 Z=0

13 X=901.2 Y=310.56 Z=0

14 X=972.36 Y=302.52 Z=0

15 X=981.24 Y=301.44 Z=0

16 X=981.24 Y=-5.04 Z=0

17 X=1034.64 Y=297.6 Z=0

18 X=1332.96 Y=273.36 Z=0

19 X=1404.24 Y=267.48 Z=0

20 X=1410.48 Y=264 Z=0

21 X=1410.5 Y=253.68 Z=0

22 X=1410.5 Y=179.52 Z=0

23 X=1410.5 Y=0 Z=0

24 X=-60 Y=0 Z=0

25 X=60 Y=0 Z=0
26 X=1351 Y=0 Z=0
27 X=1471 Y=0 Z=0
4 X=0 Y=272.484 Z=0
20 X=1410.48 Y=266.964 Z=0

FRAME

NM=18 NL=0 NSEC=0

1 SH=I T=12,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0012558 M=3.25E-06 TC=8.3E-06
2 SH=I T=16,6,0.25,0.125,6,0.25 E=29000 G=11154 W=0.0013973 M=3.6162E-06 TC=8.3E-06
3 SH=I T=16,6,0.375,0.1489,6,0.4375 E=29000 G=11154 W=0.0020196 M=5.2267E-06 TC=8.3E-06
4 SH=I T=16,6,0.375,0.1489,6,0.4375 E=29000 G=11154 W=0.0020196 M=5.2267E-06 TC=8.3E-06
5 SH=I T=16,6,0.3125,0.1489,6,0.375 E=29000 G=11154 W=0.0018126 M=4.691E-06 TC=8.3E-06
6 SH=I T=16,6,0.3125,0.125,6,0.25 E=29000 G=11154 W=0.0015012 M=3.8852E-06 TC=8.3E-06
7 SH=I T=16,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0015021 M=3.8875E-06 TC=8.3E-06
8 SH=I T=24.07,6,0.25,0.1489,6,0.25 E=29000 G=11154 W=0.0018422 M=4.7676E-06 TC=8.3E-06
9 SH=I T=24.07,6,0.25,0.178,6,0.3125 E=29000 G=11154 W=0.0021393 M=5.5365E-06 TC=8.3E-06
10 SH=I T=27,6,0.25,0.178,6,0.3125 E=29000 G=11154 W=0.0022869 M=5.9184E-06 TC=8.3E-06
11 SH=I T=27,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.0023899 M=6.1849E-06 TC=8.3E-06
12 SH=I T=27,6,0.25,0.178,6,0.375 E=29000 G=11154 W=0.0023899 M=6.1849E-06 TC=8.3E-06
13 SH=I T=27,6,0.25,0.1489,6,0.375 E=29000 G=11154 W=0.0021727 M=5.6228E-06 TC=8.3E-06
14 SH=P T=6.625,0.312 E=29000 G=11154 W=0.0017512 M=4.532E-06 TC=8.3E-06
15 SH=P T=6.625,0.3758 E=29000 G=11154 W=0.0020879 M=5.4035E-06 TC=8.3E-06
16 A=50 J=0 I=8.012E+05,0 AS=0,0 E=29000 G=11154 W=0.01415 M=3.662E-05 TC=8.3E-06
17 A=1 J=0 I=0.959,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.3239E-07 TC=8.3E-06
18 A=1 J=0 I=0.978,0 AS=0,0 E=29000 G=11154 W=0.000283 M=7.3239E-07 TC=8.3E-06
1 1 2 M=1,1,1 LP=1,0 MS= 0,0
2 2 3 M=1,1,1 LP=1,0 MS= 0,0
3 3 4 M=16,16,1 LP=1,0 MS= 0,0
4 4 5 M=16,16,1 LP=1,0 MS= 0,0

5 5 6 M=2,2,1 LP=1,0 MS= 0,0
 6 6 7 M=2,2,1 LP=1,0 MS= 0,0
 7 7 8 M=3,3,1 LP=1,0 MS= 0,0
 8 8 9 M=14,14,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
 9 8 10 M=4,4,1 LP=1,0 MS= 0,0
 10 10 11 M=5,5,1 LP=1,0 MS= 0,0
 11 11 12 M=6,6,1 LP=1,0 MS= 0,0
 12 12 13 M=7,8,2 LP=1,0 MS= 0,0
 13 13 14 M=9,10,2 LP=1,0 MS= 0,0
 14 14 15 M=11,11,1 LP=1,0 MS= 0,0
 15 15 16 M=15,15,1 LP=1,0 LR=1,0,0,1,0,0 MS= 0,0
 16 15 17 M=12,12,1 LP=1,0 MS= 0,0
 17 17 18 M=13,13,1 LP=1,0 MS= 0,0
 18 18 19 M=13,13,1 LP=1,0 MS= 0,0
 19 19 20 M=16,16,1 LP=1,0 MS= 0,0
 20 20 21 M=16,16,1 LP=1,0 MS= 0,0
 21 21 22 M=1,1,1 LP=1,0 MS= 0,0
 22 22 23 M=1,1,1 LP=1,0 MS= 0,0
 23 24 1 M=17,17,1 LP=1,0 MS= 0,0
 24 1 25 M=17,17,1 LP=1,0 MS= 0,0
 25 26 23 M=18,18,1 LP=1,0 MS= 0,0
 26 23 27 M=18,18,1 LP=1,0 MS= 0,0

RESTRAINTS

24 24 1 R=1,1,1,1,1,0
 1 1 1 R=1,1,1,1,1,0
 25 25 1 R=1,1,1,1,1,0
 9 9 1 R=1,1,1,1,1,0
 16 16 1 R=1,1,1,1,1,0
 26 26 1 R=1,1,1,1,1,0
 23 23 1 R=1,1,1,1,1,0
 27 27 1 R=1,1,1,1,1,0
 2 2 1 R=0,0,1,1,1,0
 3 3 1 R=0,0,1,1,1,0
 4 4 1 R=0,0,1,1,1,0
 5 5 1 R=0,0,1,1,1,0
 6 6 1 R=0,0,1,1,1,0
 7 7 1 R=0,0,1,1,1,0
 8 8 1 R=0,0,1,1,1,0
 10 10 1 R=0,0,1,1,1,0
 11 11 1 R=0,0,1,1,1,0
 12 12 1 R=0,0,1,1,1,0
 13 13 1 R=0,0,1,1,1,0

14 14 1 R=0,0,1,1,1,0
15 15 1 R=0,0,1,1,1,0
17 17 1 R=0,0,1,1,1,0
18 18 1 R=0,0,1,1,1,0
19 19 1 R=0,0,1,1,1,0
20 20 1 R=0,0,1,1,1,0
21 21 1 R=0,0,1,1,1,0
22 22 1 R=0,0,1,1,1,0

LOADS

4 4 1 L=1 F=0.1,-100,0,0,0,0
20 20 1 L=1 F=0,-100,0,0,0,0

PDELTA

M=1000 TOLD=0.001

L=1 SF=1.19

APPENDIX C
SAMPLE SAP90 OUTPUT FILES

S A P 9 0

Structural Analysis Programs

Version 5.50

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PAGE 1

PROGRAM:SAP90/FILE:fra11_a.F3F

Buckling Load: P=238k

FRAME ELEMENT FORCES

ELT LOAD	DIST	1-2 PLANE	AXIAL	1-3 PLANE	AXIAL	
ID COND	ENDI	SHEAR	MOMENT	SHEAR	MOMENT	TORQ
1 -----						
ACTING P-DELTA AXIAL FORCE:			-227.930			
1	0.000		-96.173			
	0.000	0.344	-140.142			
	71.520	0.344	551.417			
	71.520		-96.173			
2 -----						
ACTING P-DELTA AXIAL FORCE:			-227.930			
1	0.000		-96.173			
	0.000	0.291	551.417			
	54.000	0.291	875.641			
	54.000		-96.173			

3 -----
 ACTING P-DELTA AXIAL FORCE: -227.900

1	0.000		-96.160
	0.000	1.597	875.641
	4.757	1.597	898.176
	4.757		-96.160

4 -----
 ACTING P-DELTA AXIAL FORCE: 1.637

1	0.000		0.681
	0.000	-3.788	898.176
	3.916	-3.788	883.252
	3.916		0.681

5 -----
 ACTING P-DELTA AXIAL FORCE: 1.397

1	0.000		0.580
	0.000	-3.805	883.252
	107.513	-3.805	473.610
	107.513		0.580

6 -----
 ACTING P-DELTA AXIAL FORCE: 1.399

1	0.000		0.580
	0.000	-3.805	473.610
	122.889	-3.805	6.593
	122.889		0.580

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PAGE 2

PROGRAM:SAP90/FILE:fra11_a.F3F

Buckling Load: P=238k

FRAME ELEMENT FORCES

ELT	LOAD	DIST	1-2 PLANE	AXIAL	1-3 PLANE	AXIAL	
ID	COND	ENDI	SHEAR	MOMENT	FORCE	SHEAR	TORQ

7 -----
 ACTING P-DELTA AXIAL FORCE: 0.566

1	0.000		0.229
	0.000	-3.842	6.593
	122.889	-3.842	-465.336

	122.889		0.229	
8	-----			
	ACTING P-DELTA AXIAL FORCE:			0.567
1	0.000		0.229	
	0.000	-3.842	-465.336	
	107.513	-3.842	-878.630	
	107.513		0.229	
9	-----			
	ACTING P-DELTA AXIAL FORCE:			0.322
1	0.000		0.126	
	0.000	-3.847	-878.630	
	3.899	-3.847	-893.648	
	3.899		0.126	
10	-----			
	ACTING P-DELTA AXIAL FORCE:			-246.069
1	0.000		-103.826	
	0.000	0.669	-893.648	
	4.757	0.669	-874.637	
	4.757		-103.826	
11	-----			
	ACTING P-DELTA AXIAL FORCE:			-246.072
1	0.000		-103.828	
	0.000	-0.405	-874.637	
	54.000	-0.405	-565.882	
	54.000		-103.828	
12	-----			
	ACTING P-DELTA AXIAL FORCE:			-246.073
1	0.000		-103.828	
	0.000	-0.231	-565.882	
	71.520	-0.231	141.086	
	71.520		-103.828	
13	-----			
1	0.000		0.000	

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PROGRAM:SAP90/FILE:fra11_a.F3F

Buckling Load: P=238k

FRAME ELEMENT FORCES

ELT LOAD	DIST	1-2 PLANE	AXIAL	1-3 PLANE	AXIAL	
ID COND	ENDI	SHEAR	MOMENT	FORCE	SHEAR	MOMENT TORQ
	0.000	-1.168	0.000			
	60.000	-1.168	-70.071			
	60.000		0.000			
14	-----					
1	0.000		0.000			
	0.000	-1.168	70.071			
	60.000	-1.168	0.000			
	60.000		0.000			
15	-----					
1	0.000		0.000			
	0.000	-1.177	0.000			
	59.960	-1.177	-70.590			
	59.960		0.000			
16	-----					
1	0.000		0.000			
	0.000	-1.174	70.496			
	60.040	-1.174	0.000			
	60.040		0.000			

S A P 9 0

Structural Analysis Programs

Version 5.50

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PAGE 1

PROGRAM:SAP90/FILE:fra11_a.SOL

Buckling Load: P=238k

J O I N T D I S P L A C E M E N T S

LOAD CONDITION 1 - DISPLACEMENTS "U" AND ROTATIONS "R"

JOINT	U(X)	U(Y)	R(Z)
1	0.000000	0.000000	-0.042427
2	2.926300	-0.032687	-0.034385
3	4.279806	-0.058066	-0.013788
4	4.345350	-0.059336	-0.013773
5	4.349252	-0.113110	-0.013761
6	4.367439	-0.501011	0.001343
7	4.348702	-0.083693	0.004279
8	4.368468	0.342774	0.001477
9	4.351792	-0.024859	-0.013504
10	4.347966	-0.077402	-0.013516
11	4.283645	-0.076169	-0.013530
12	2.940019	-0.045522	-0.034372
13	0.000000	0.000000	-0.042713

14	0.000000	0.000000	0.021214
15	0.000000	0.000000	0.021214
16	0.000000	0.000000	0.021357
17	0.000000	0.000000	0.021357

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PAGE 2

PROGRAM:SAP90/FILE:fra11_a.SOL

Buckling Load: P=238k

REACTIONS AND APPLIED FORCES

LOAD CONDITION 1 - FORCES "F" AND MOMENTS "M"

JOINT	F(X)	F(Y)	M(Z)
1	-0.5051	96.1723	0.0000
2	0.0000E+00	0.0000E+00	-0.1478E-11
3	-0.2691E-07	0.3858E-09	0.1253E-06
4	0.1000	-100.0000	0.0000
5	0.1524E-09	0.1221E-08	0.6301E-08
6	-0.1426E-11	0.0000E+00	0.0000E+00
7	0.1127E-11	0.0000E+00	0.0000E+00
8	0.0000	0.0000	0.0000
9	0.1255E-08	0.2431E-08	0.1266E-07
10	0.0000	-100.0000	0.0000
11	0.8938E-08	-0.1786E-09	-0.4545E-07
12	0.0000	0.0000	0.0000
13	0.4051	103.8308	0.0000
14	0.0000	-1.1678	0.0000
15	0.0000	1.1678	0.0000
16	0.0000	-1.1773	0.0000
17	0.0000	1.1741	0.0000

TOTAL 0.0000E+00 -0.1801E-11 0.1333E-06

VITA

Charles William Cary, III

Charles William Cary, III was born in Portsmouth, Virginia on February 11, 1973. He graduated from Nansemond River High School in Suffolk, Virginia. In December, 1995 he received his Bachelor of Science degree in Civil Engineering from Virginia Polytechnic Institute and State University. He enrolled in the graduate program at Virginia Tech in January, 1996.