COMPARISON OF P-DELTA ANALYSES OF PLANE FRAMES USING COMMERCIAL STRUCTURAL ANALYSIS PROGRAMS AND CURRENT AISC DESIGN SPECIFICATIONS

by

Angela M. Schimizze

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Thomas M. Murray, Chair
Mehdi Setareh
Richard M. Barker

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(ABSTRACT)

Several different approaches to determining second-order moments in plane frames were studied during this research. The focus of the research was to compare the moments predicted by four different commercially available computer analysis programs and the current design specification, the AISC LRFD moment magnification method. For this research, the second-order moments for ten commonly designed frames were compared.

An overview of various second-order analysis procedures is presented first. The solution procedure utilized by each computer program and the AISC moment magnification method are explained. Also, the frames considered in the research are described.

Next the frames are analyzed and the results between each of the computer programs and the current design specifications are compared.

Finally, conclusions are drawn concerning the consistency of the second-order moments predicted by each of the solution procedures and recommendations for their use are discussed. In general, each of the four computer analysis programs evaluated and the AISC moment magnification method can consistently and adequately predict the second-order moments in plane frames.

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

For the analysis of a structure to be complete and correct, an appropriate model must be chosen to represent the structure and an adequate analysis procedure must be chosen to reflect the system's response to applied loads. A first-order analysis, in which equilibrium and kinematic relationships are taken with respect to the undeformed geometry of the structure, is simple to perform but is not a thorough analysis since it neglects additional loading caused by the deflection of the structure. For most structures, a second-order analysis, which imposes equilibrium and kinematic relationships on the deformed geometry of the structure, is required for stability design.

For the design of steel structures, the American Institute of Steel Construction (AISC) outlines a procedure to consider second-order effects in the Load Resistance Factor Design (LRFD) Specification (1998). The method uses magnification factors to increase the first-order moments in the members. It applies exclusively to regular frames, in which all of the beams and columns are perpendicular and there are no missing members.

The second-order effects on a frame are accounted for by a combination of P-Δ effects, which correspond to the frame, and P-δ effects, which correspond to individual members within the frame. Since both of these contribute to the deformation of the frame, it is important to consider their combined effect.

1.2 OBJECTIVE

In this study, several different commercially available computer analysis programs were used to calculate the second-order moments in frames. Ten different commonly designed frames were evaluated to verify whether or not the solution procedures used by the computer programs give member end moments that correspond to each other and to the member end moments calculated using the LRFD Specifications.

CHAPTER 2
LITERATURE REVIEW

2.1 OVERVIEW

In a first-order elastic analysis, equilibrium and kinematic relationships are based on the undeformed geometry of the structure. Solutions of these analyses are typically simple and straightforward. However, when lateral loads are applied to the structure, "it often assumes a configuration which deviates quite noticeably from its undeformed configuration," (Chen and Lui, 1991) requiring a second-order analysis. Chen and Lui report that a second-order analysis, which applies equilibrium and kinematic relationships to the deformed structure, "is always necessary for the stability consideration of structures" (1991).

Since the deformation is unknown when the equilibrium and kinematic relationships are established, the second-order solution must be iterative, where the "deformed geometry of the structure obtained for a preceding cycle of calculations is used as the basis for formulating the equilibrium and kinematic relationships for the current cycle of calculations" (Chen and Lui, 1991). Since the full consideration of second-order effects can be tedious and time-consuming and since exact solutions are not typically necessary, several simplified methods have been developed to approximate the second-order solution and make the analysis more efficient. The most commonly used solution procedures for hand analyses are the Two Cycles Iterative Method, the Fictitious

Lateral Load Method, the Iterative Gravity Load Method, and the Negative Stiffness Method (Chen and Lui, 1991). There is also an approximate procedure outlined in the AISC Load and Resistance Factor Design Specification (LRFD), as well as several solution procedures incorporated into most commercially available computer analysis programs.

2.2 SOLUTION PROCEDURES

Chen and Lui (1991) describe several procedures to analyze the second order (P-Δ and P–δ) effects on frames. One method is the Two Cycles Iterative Method. First, a first-order elastic analysis is done to obtain member axial loads and then the stiffness matrix is updated to include the second-order effects and the problem is solved again. In this method, there is no iteration and the results are generally within acceptable limits. It is also, however, quite laborious for multi-member frames.

Another solution procedure is the Fictitious Lateral Load Method, which includes only frame (P-Δ) effects. In this method, a first-order analysis is first done to determine the first order deflections. Next, fictitious loads are calculated and applied to the frame to simulate P-Δ effects and another first-order analysis is completed to obtain new deflections. The procedure is repeated until the member end moments do not change significantly. This method is simple since only the load matrix changes and not the stiffness matrix. It converges with good results for frames with members that are not too slender and with a small number of bays. Slender members result in significant P-δ effects, which this method does not consider. A large number of bays can lead to varying axial forces that can either over-predict or under-predict the member end moments.

A third solution is the Iterative Gravity Load Method, which also only considers P-Δ effects. In this method, the axial and lateral loads are applied to the frame and the frame is analyzed to determine the horizontal deflection and the moment caused by the deflection. Based on the deflection, the member coordinates are updated and the frame re-analyzed. The procedure is repeated until the difference in deflections becomes negligible. The method is simplified by creating a fictitious bay composed of axially rigid columns with zero flexural rigidity. After each iteration, only the coordinates of the fictitious members need be updated. The iterative gravity load method gives results comparable to the fictitious lateral load method.

Another approach is the Negative Stiffness Method, in which the P-Δ effects are simulated by reducing the lateral stiffness of the frame. This is accomplished by adding one of three different structural members. The first possibility is to add fictitious diagonal bracing which produces an equivalent P-Δ lateral load by pushing on the structure, as opposed to being in tension which would be typical of a diagonal brace. The second possibility is to add fictitious shear columns with zero flexural stiffness and a negative shear area. The third approach is to add fictitious flexural columns with zero axial stiffness that are fixed against rotation, but free to translate. In the first two approaches, involving the diagonal bracing and the shear columns, the added members result in a negative stiffness in the vertical direction and added compression in the column. After each iteration, the column area is modified, applied to the fictitious members, and the frame is re-analyzed. In the third case, involving the flexural columns, the moment of inertia is modified and applied to the fictitious members.

In general, there are several simplified methods available for completing a second-order analysis by hand, without the use of structural analysis software. Many of the procedures include only P-Δ effects, which is acceptable since the member instability, P-δ effect, is not significant in most structures. However, it has been shown that the P-δ effects can be included relatively easily by modifying the moment of inertia.

The LRFD states that "[s]econd order (PΔ) effects shall be considered in the design of frames" (AISC LRFD, 1998) and provides a procedure for computing the second-order moments in the frame. The LRFD determines a maximum moment, M_u, to be used for design, by applying magnification factors to member-end moments as follows:

$$M_u = B_1 M_{nt} + B_2 M_{lt}$$

where M_{nt} is the required flexural strength in a member assuming there is no lateral translation of the frame and M_{lt} is the required flexural strength in a member resulting from lateral translation of the frame. B_1 and B_2, both greater than or equal to one, are magnification factors calculated and applied to M_{nt} and M_{lt}, respectively (AISC LRFD, 1998).

This procedure eliminates unconservatism since the moments are amplified, However, since "[f]rame instability concerns are conceptually accounted for through the development of effective column lengths" (Englekirk, 1994), the solution is limited by the assumptions associated with the LRFD alignment charts, which are used to develop the effective column lengths. The assumptions are as follows:

(1) Behavior is purely elastic.

(2) All members have a constant cross section.

(3) All joints are rigid.

(4) For braced frames, rotations at opposite ends of restraining beams are equal in magnitude and opposite in direction, 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 parameters $L\sqrt{(P/EI)}$ of all columns are equal.

(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 in a story buckle simultaneously.

(9) No significant axial compression force exists in the girders.

It is important to realize that these are assumptions of idealized conditions which seldom exist in real structures (Galambos, 1988) and that "[w]here the actual conditions differ from these assumptions, unrealistic designs may result" (AISC LRFD, 1998). In response to the limitations of LRFD frame design, some modifications have been developed to consider varying conditions and overcome some of the previous assumptions.

Another approach is to utilize the second-order analysis available in most computer analysis programs. There are many commercially available software packages capable of computing the second-order effects in structures. They may use any of the different approaches previously discussed. However, when the results from the computer analyses are compared to each other and to the simplified hand calculations, they can vary in some cases substantially from the results obtained using the LRFD moment magnification method. Since the results are not consistent, it is important to know which solution procedure each of the programs utilizes so that the limitations are known and an appropriate analysis can be done.

CHAPTER 3
COMPUTER MODELING

3.1 DESCRIPTION OF FRAMES

For this study, eight different commonly designed unbraced frames were modeled. All of the plane frames were assumed to be adequately braced out-of-plane and each member was assumed to have adequate lateral bracing. The basic loading cases were established to represent the expected loading conditions on each of the structures. Each of the basic loads were factored and combined according to the AISC combinations. After frame loadings were determined, a preliminary structural analysis of each of the frames was done to estimate member forces, from which appropriate structural steel sections were selected.

Frame 1. The first frame analyzed was a regular, one-bay, one-story plane frame. The columns were pinned at the ends and the beams were connected with full moment connections. The bay width is 60 ft, the height is 18 ft and the distance between bays is 30 ft. The geometry is shown below in Figure 3.1.

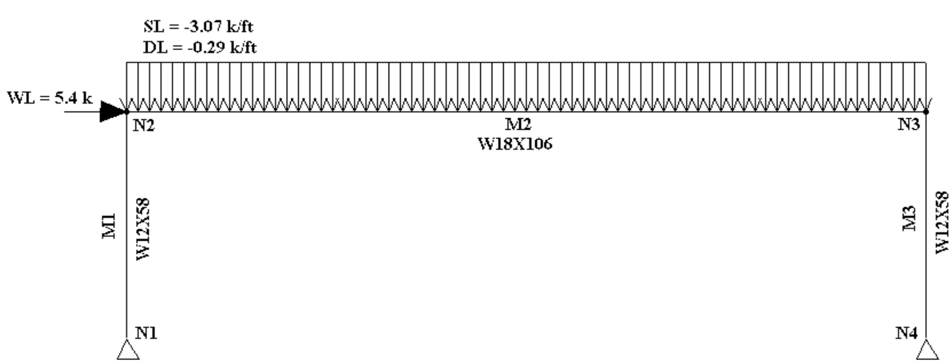


Figure 3.1: Geometry, Loading and Member Sizes for Frame

A snow load of 64 psf resulted in a uniformly distributed load of 1.92 k/ft and a dead load of 7 psf resulted in a load of 0.24 k/ft, both gravity loads acting on the beam. A wind load of 25 psf resulted in a nodal load of 6.75 k, acting on the upper left joint. The LRFD load combinations were applied with the controlling combination resulting in a 3.36 k/ft gravity load on the beam and a 5.4 k wind load acting on the joint, as shown in Figure 3.1. The frame forces were determined by performing a first-order analysis. Then, using LRFD specifications and considering a 5ft unbraced length, W12X58 sections were chosen for the columns and a W18X106 section was chosen for the beam.

Frame 2. The second frame analyzed was a regular, two-bay, two-story plane frame. The bay widths are 30 ft each, with a total width of 60 ft and the story heights are 15 ft each, with a total of 30 ft, as shown in Figure 3.2. The column ends are pinned and the beams are connected with full moment connections.

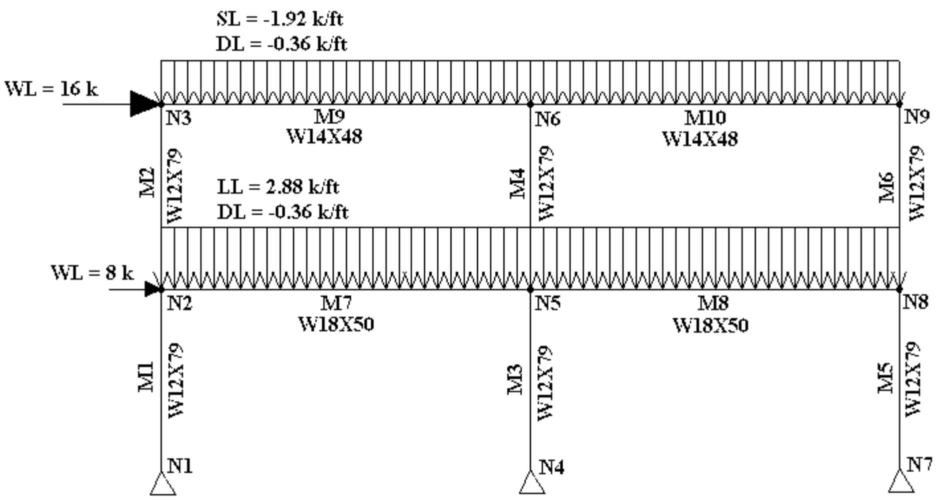


Figure 3.2: Geometry, Loading and Member Sizes for Frame 2

A snow load of 1.2 k/ft was applied to the second level beams, a live load of 1.8 k/ft was applied to the first level beams, and a dead load of 0.3 k/ft was applied to both the first and second level beams. A 10 k wind load was added to the first level and a 20 k wind load was added to the second level. The loads were combined and factored according to LRFD specifications with the resulting loads shown in Figure 3.2.

The loads were applied to the frame, member forces were determined by performing a first-order analysis, and the members were appropriately sized. All of the columns are W12x79, the first floor beams are W18x50, and the second floor beams are W14x48.

Frame 3. The third frame evaluated is a two-bay, one-story plane frame with unequal bay widths and story heights. The larger bay was 36 ft wide and 36 ft high. It was subjected to a

12 k/ft gravity load acting on the beam and a 40 k lateral load acting on the upper left node. The smaller bay frames into the right column of the larger bay and is 24 ft wide and 24 ft high. A 16 k/ft gravity load was applied to the beam and an 18k lateral load was applied to the upper right node of the bay. The frame configuration and loading are shown below in Figure 3.3.

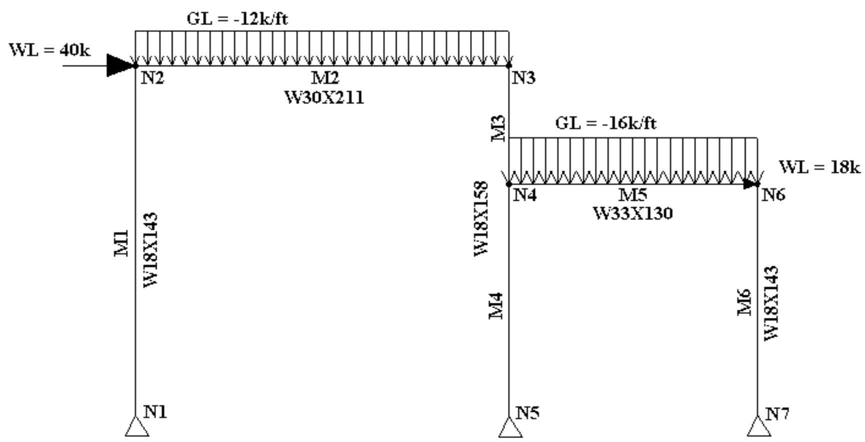


Figure 3.3: Geometry, Loading and Member Sizes for Frame 3

Based on a first-order analysis, W18x143 sections were chosen for the exterior columns, a W18x158 section was chosen for the interior column, a W30x211 section was chosen for the beam of the larger bay, and a W33x130 section was chosen for the beam of the smaller bay, as shown in Figure 3.3.

Frame 4. The fourth frame analyzed is a gabled plane frame, measuring 80 ft wide and 25 ft high, with roof beams sloped at 4.7 degrees from the horizontal, resulting in a total height of 28.3 ft. The ends of both columns are pinned connections. A live load of 0.5 k/ft was applied to the beams globally, in the gravity direction. A dead load of 0.25 k/ft was applied to the beams locally, acting normal to the beams. Additionally, a 9.4 k wind load was applied to the upper left node of the frame, at the top of the column and a 2.5 k wind load was applied to the hip of the roof. The loads were combined and factored according to LRFD specifications with the resulting loads shown in Figure 3.4.

A first-order analysis was performed on the frame and as a result, the columns are W18x143 sections and the beams are W10x49 sections, as shown in Figure 3.4.

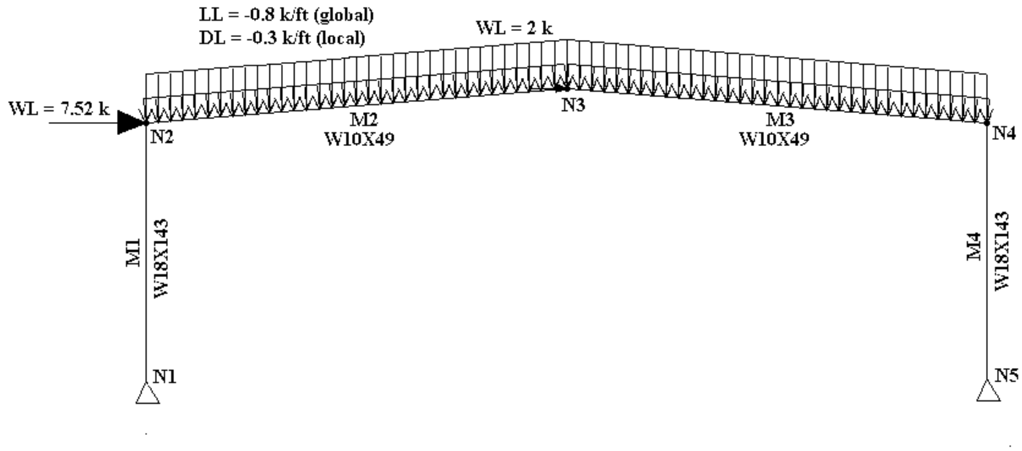


Figure 3.4: Geometry, Loading and Member Sizes for Frame 4

Frame 4a. Frame 4a, has the same geometry as Frame 4, except that the roof pitch is 18.4 degrees from the horizontal, resulting in a total structure height of 38.3 ft. The same loads were applied to the structure, except that the increase in height resulted in an increased wind load of 10.1 k at the tip of the gable, as shown in Figure 3.5. A first-order analysis was performed and the previously sized members proved adequate for the increased loading.

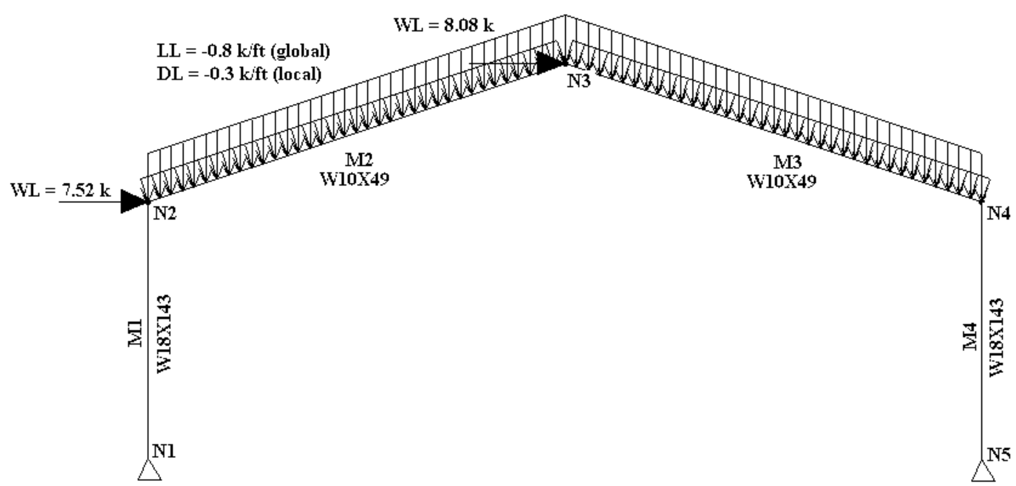


Figure 3.5: Geometry, Loading and Member Sizes for Frame 4a

Frame 5. The sixth frame considered is a four-bay, one-story plane frame. The frame is 25 ft tall and each bay is 40 ft wide, with a total width of 160 ft. Each of the column bases is pin-connected and the exterior beam-to-column connections are full moment connections, while the interior beam-to-column connections are simple shear connections, so that the interior columns are “leaner” columns.

A live load of 0.5 k/ft and a dead load of 0.25 k/ft were applied to the beams and a 9.4 k wind load was applied to the upper left node of the structure. The loads were combined and factored according to LRFD specifications with the resulting loads shown in Figure 3.6.

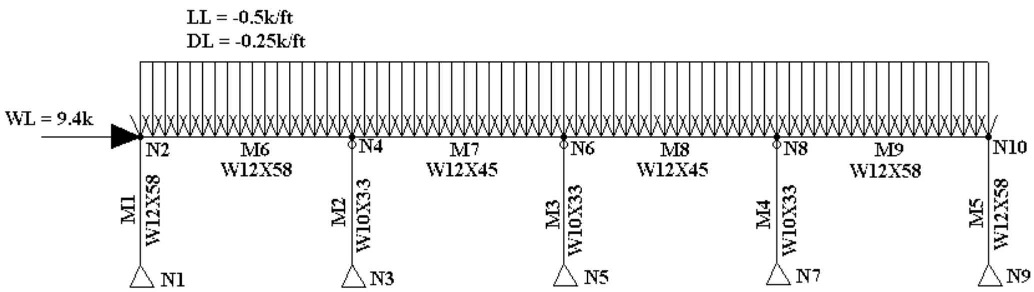


Figure 3.6: Geometry, Loading and Member Sizes for Frame 5

The loads were combined and a first-order analysis was performed. Based on the resulting member forces, W10x33 sections were chosen for the interior columns, W12x58 sections were chosen for the exterior columns and the exterior beams, while W12x45 sections were chosen for the interior beams. The selected members are shown in Figure 3.6.

Frame 5a. Frame 5a has the same geometry as Frame 5, except that the interior ‘leaning’ columns were removed and ‘roller’ supports, which prohibit vertical deflection but allow horizontal deflection, were inserted. The rollers provide the same restraint and produce the same reactions as the leaner columns, but avoid possible instabilities that could prevent a second-order analysis in some computer programs. The same loading was applied to the frame and the same member sizes are used.

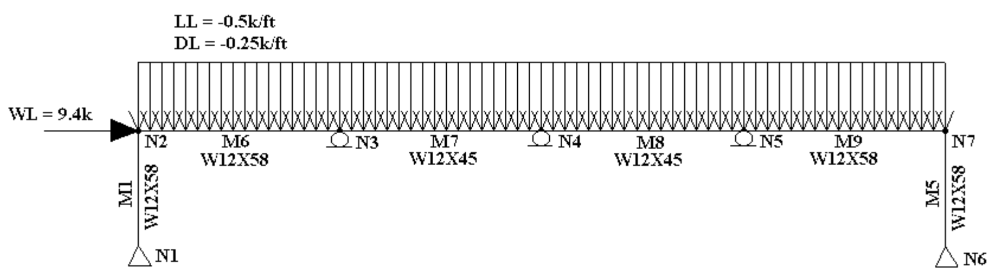


Figure 3.7: Geometry, Loading and Member Sizes for Frame 5a

Frame 6. The eighth frame evaluated is a regular three-bay, fifteen-story plane frame with fixed column supports and full moment connections throughout the structure. Each bay is 30 ft wide, with a total width of 90 ft, and each story is 15 ft high, with a total height of 225 ft. The assigned node numbers and member numbers are shown in Figure 3.8.

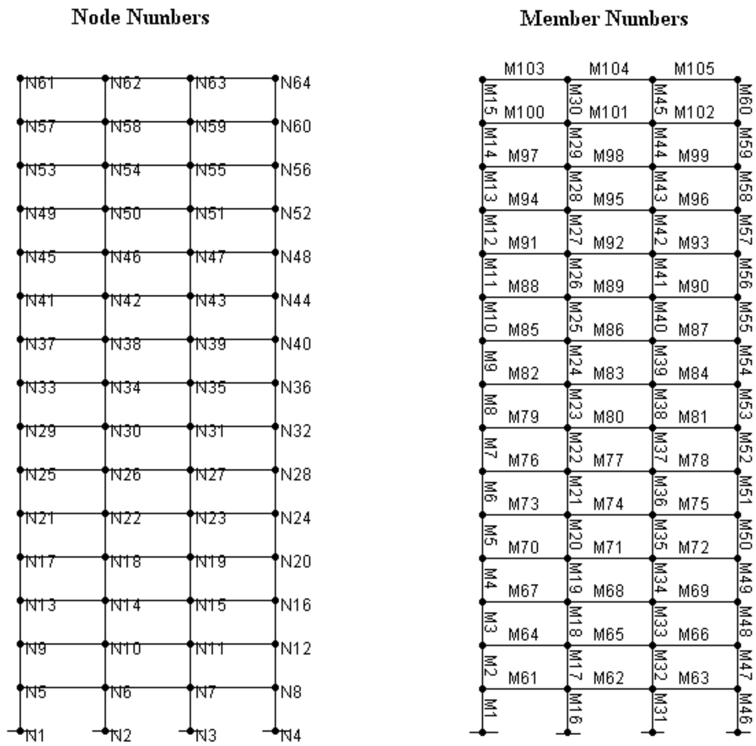


Figure 3.8: Geometry, Node Numbers and Member Numbers for Frame 6

A dead load of 0.5 k/ft was applied to all of the beams, while a snow load of 1.2 k/ft was applied to the roof beams only, and a live load of 3 k/ft was applied to the remainder of the beams. A varying wind load, shown in Figure 3.9, was applied to each floor of the frame. The loads were factored according to LRFD specifications with the resulting loads shown in Figure 3.9.

The frame geometry and member sizes for Frame 6 were taken from Englekirk (1994). The member sizes are shown in Figure 3.10. The loads were combined according to LRFD specifications and a first-order analysis was completed, to verify the adequacy of the member sizes under the applied loading.

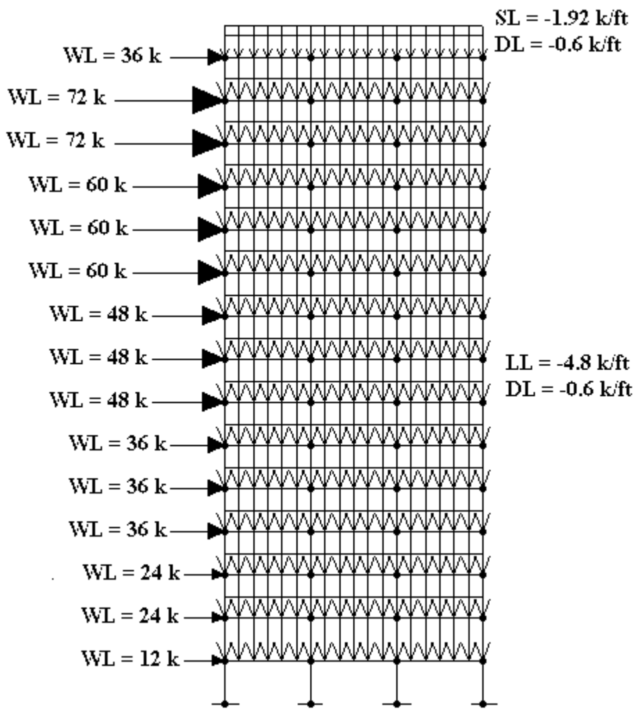


Figure 3.9: Loading for Frame 6

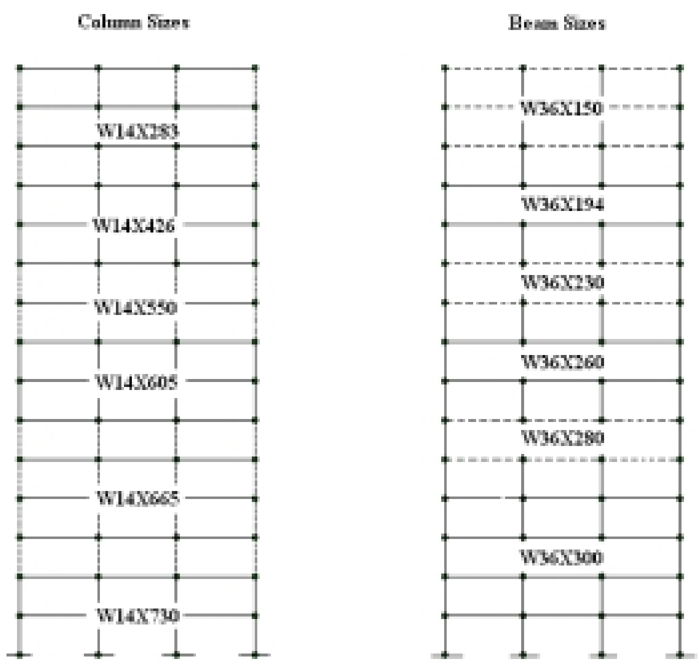


Figure 3.10: Member Sizes for Frame 6

Frame 7. In the ninth frame, a two-bay frame, the left bay is 20 ft wide and has three 15 ft stories, with a total height of 45 ft. The right bay is also 20 ft wide, but has two 22.5 ft stories, with a total height of 45 ft. The column-to-base connections are pinned and all of the beam-to-column connections are full moment connections.

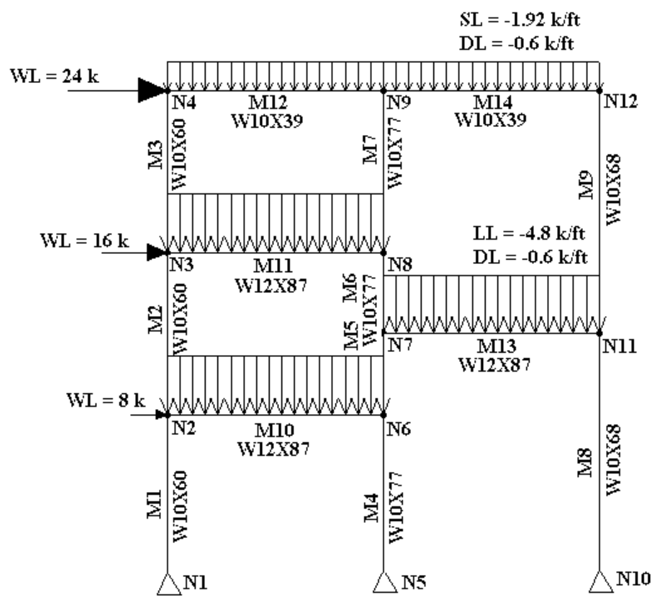


Figure 3.11: Geometry, Loading and Member Sizes for Frame 7

A dead load of 0.5 k/ft was applied to all of the beams, while a snow load of 1.2 k/ft was applied to the roof beams only, and a live load of 3 k/ft was applied to the remainder of the beams. Increasing wind loads were applied to the left side of the left bay as shown in Figure 3.11. The loads were factored and combined according to LRFD specifications and first-order analysis was performed to determine member forces, which resulted in the member selection shown in Figure 3.11.

Frame 8. The tenth frame considered is a two-bay, one-story plane frame. Each bay is 20 ft wide, resulting in a total width of 40 ft, and the story height is 25 ft. The left and center column-to-base connections are fully fixed, while the right column-to-base connection is pinned. All three of the beam-to-column connections are simple shear connections. A dead load of 0.5 k/ft and a snow load of 1.2 k/ft were applied to the beams and a 20 k wind load was applied to the upper left node. The loads were factored according to LRFD specifications with the resulting loads shown in Figure 3.12.

After the loads were combined according to LRFD specifications and a first-order analysis was completed, W12x58 sections were chosen for the columns and W12x40 sections were chosen for the beams. The member sizes are shown in Figure 3.12.

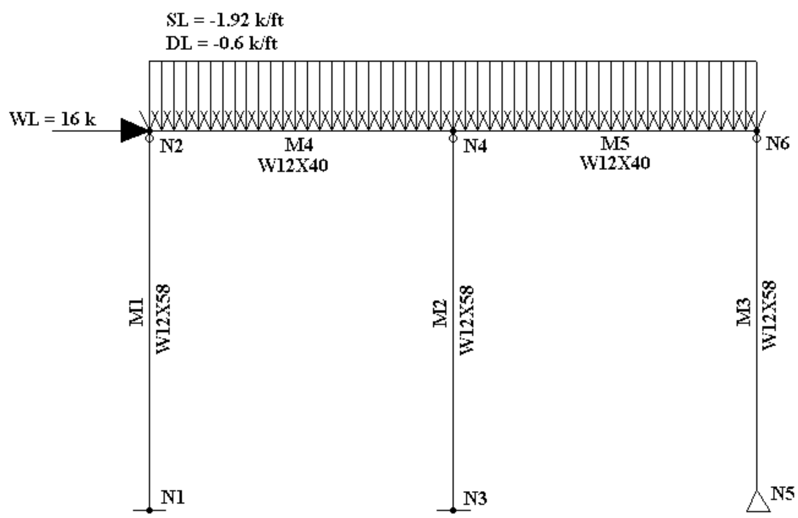


Figure 3.12: Geometry, Loading and Member Sizes for Frame 8

Using the geometry, loading and member sizes selected, each frame was then analyzed, comparing first-order and second-order moments, using four different commercial structural analysis programs, as well as the LRFD specification provisions.

3.2 DESCRIPTION OF COMPUTER ANALYSIS PROGRAMS

Five commercially available structural analysis programs were used to determine the second-order moments in each member of the frames: RISA-3D (RISA-3D User's Manual, 1999), ROBOT Millennium (ROBOT Millennium User's Manual, 2000), SAP2000 Plus (SAP2000 Analysis Reference, 1997), STAAD-III (STAAD-III Reference Manual, 1996).

RISA-3D. The first structural analysis program considered was RISA-3D, which calculates second-order moments through an iterative procedure. The solution procedure is similar to the Fictitious Lateral Load Method in that second-order moments are modeled by calculating secondary shears, as shown in the Figure 3.13.

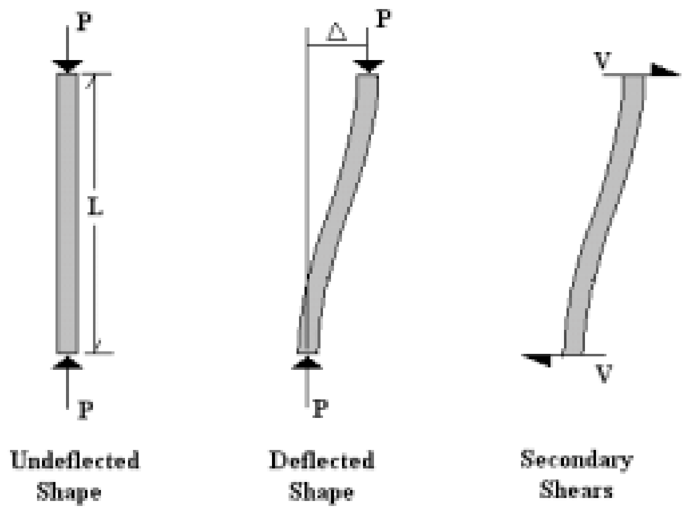


Figure 3.13: RISA-3D P-Δ Analysis

The procedure begins by solving the model with the original applied loads and then calculates a secondary shear, V, for each member in the model according to the following equation:

$$V = P\Delta/L$$

as shown in Figure 3.13. Next, calculated secondary shears are added to the original loads and the model is re-solved. The displacements from the new solution are compared to the previous solution and the procedure is repeated until they fall within an acceptable convergence tolerance, typically 0.5%. The program monitors the process and will automatically stop if the solution diverges dramatically. When the displacements become more than 1000 times greater than the maximum original displacement, the model is considered to be unstable.

This solution procedure accounts for frame effects (P-Δ) only and is not able to evaluate individual member effects (P-δ). To more adequately consider all of the second-order effects, additional nodes can be inserted along the member span so that the nodes will deflect and the P-Δ effect will be calculated.

ROBOT Millennium. The ROBOT User's Maunal presents a comprehensive theoretical basis for a P-Delta analysis. To consider the frame (P-Δ) effects, the program uses an iterative procedure that updates the geometry and stiffness matrices at each load step. Furthermore, it considers member effects (P-δ) by incorporating stability functions into the analysis procedure.

SAP2000 Plus. The manual for SAP2000 Plus also indicates that "an iterative analysis is required to determine the P-Delta axial forces in [f]rame elements." It explains that the axial force in each of the frame elements is estimated through a preliminary analysis of the structure. Next, considering these axial forces, equilibrium equations are re-solved, which may create different axial forces in the members "if the modified stiffness causes a force re-distribution." Additional iterations are performed until the axial forces and deflections converge, typically with a tolerance of 0.01. Further, the manual explains that although SAP2000 is capable of analyzing both frame (P-Δ) and member (P-δ) P-Delta effects, it recommends using the program to determine frame effects, but using applicable moment magnification factors to determine member effects.

STAAD-III. STAAD-III also has the capability to perform a second-order, P-Delta analysis. The simplified solution procedure uses a revised load vector to include secondary effects. First, the deflections are calculated based on the original applied loads. Next, the deflections are combined with the original applied loads to create secondary loading. Based on the new loading, the load vector is revised to include secondary effects. Finally, the revised load vector is used in a new stiffness analysis and new member forces and reactions are calculated based on the new deflections. This solution procedure accounts for frame effects (P-Δ) only and is not able to evaluate individual member effects (P-δ).

3.3 DESCRIPTION OF AISC PROCEDURE

The second order moments on the frames were also calculated according to AISC LRFD specifications. To find the second order moments on the columns, a magnification factor, B_1, was calculated and applied to the no translation moment, M_{nt}. Another magnification factor, B_2, was calculated and applied to the moment, M_{lt}, which occurs when lateral translation of the frame is allowed. The resulting moments were combined according to the following equation:

$$M_u = B_1 M_{nt} + B_2 M_{lt} \qquad (3.1)$$

In the LRFD equation, the first part of the equation, B_1M_{nt}, accounts for member (P-δ) effects and the second part of the equation, B_2M_{lt}, accounts for frame (P-D) effects. For each frame member, the amplification factor B_1 is calculated using:

$$B_1 = \frac{C_m}{(1-P_u/P_{e1})} > 1.0 \qquad (3.2)$$

where $C_m = 0.6 – 0.4\ (M_1/M_2)$ with $|M_1| < |M_2|$

P_u = axial force

$P_{e1} = \pi^2EI/(KL)^2$ with K = 1.0

The amplification factor B_2 is calculated using:

$$B_2 = \frac{1}{1 – (\Sigma P_u/\Sigma P_{e2})} \qquad (3.3)$$

where ΣP_u = axial force of all columns in a story that contribute to lateral stability, and

$$P_{e2} = \pi^2EI/(KL)^2 \qquad (3.4)$$

with K > 1.0.

The M_{nt} case was first considered. Since the wind load was modeled acting on the left side of each of the frames, additional restraints were placed on the nodes on the right side of the frame that restricted the frame from lateral translation. In the analysis, an additional reaction was calculated at each of these nodes. All applicable live loads, snow loads, dead loads, and wind loads were applied to the frame and a first-order analysis was performed to obtain the M_{nt} moments.

Next, to model the M_{lt} case, any additional restraints and all of the frame forces were removed. A lateral force equal but opposite to the force resulting from the restraint was applied to the frame. A first-order analysis was then performed to obtain the M_{lt} moments. The no translation moments and translation moments were then magnified according to their respective factors and combined using Equation 3.1.

The second order moments on the beams were calculated according to the following:

$$M_u = M_{nt} + M_{lt} + \Delta M_b \qquad (3.5)$$

where $\Delta M_b = D.F.\Sigma\Delta M_c$

DF = distribution factor based on the stiffness and length of supporting columns

ΔM_c = moment in supporting column = $(B_2\text{-}1)M_{lt.}$

For example, for a column, Member 3 in Frame 1, the M_{nt} case is first considered. A restraint is added in the x-direction at Node 3 to prevent any lateral translation. The additional restraint creates a reaction at Node 3. The dead load, snow load, and wind load are applied to the frame causing the reactions and member forces shown in Figure 3.14.

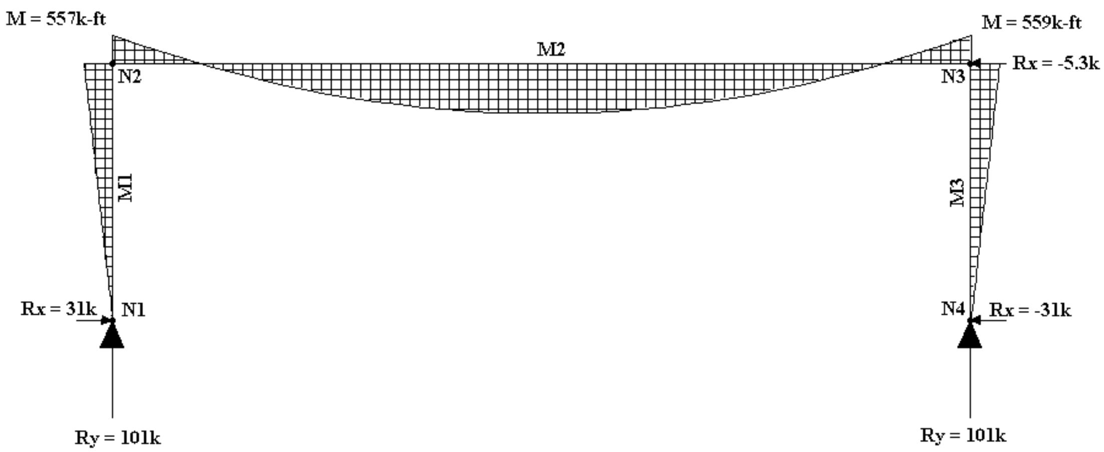


Figure 3.14: M_{nt} Reactions for Frame 1

Next, the amplification factor B_1 is calculated according to Equation 3.2. Since the moment at the base of the column is zero, Cm defaults to 0.6. As shown in Figure 3.14, the axial force in the column, P_u, is 101 k. Also, P_{e1} is calculated using:

$P_{e1} = \pi^2 EI/(KL)^2$

where E = 29,000 ksi

I = 475 in^4 for W12X58

K = 1.0

L = 216 in

So that $Pe_1 = [\pi^2(29000ksi)(475\ in^4)]/[(1.0)(216\ in)]^2 = 2914$ k.

Applying Equation 3.1,

$$B_1 = \frac{0.6}{[1 - (101\ k)/(2914\ k)]} = 0.62 < 1.0 \quad \text{Therefore, } B_1 = 1.0$$

Next, the M_{lt} case is considered. The additional restraint is removed from Node 3 and a force equal but opposite to the reaction at Node 3 is applied to the frame. The resulting reactions are shown in Figure 3.15.

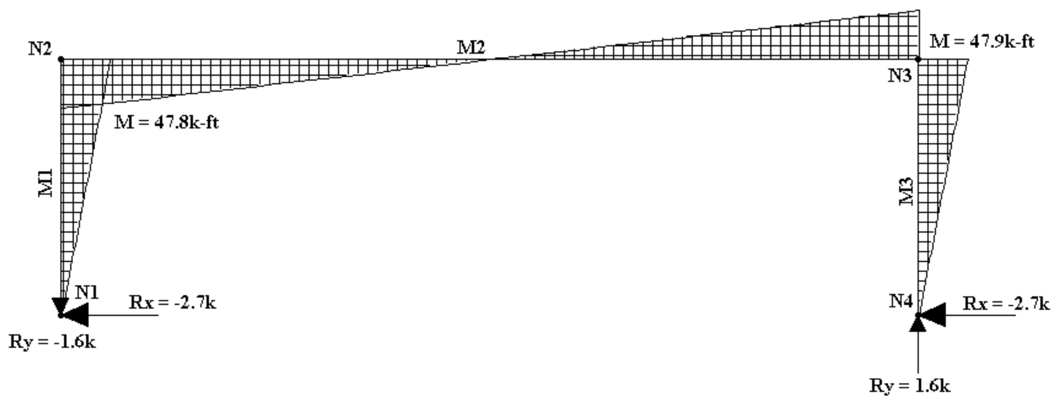


Figure 3.15: M_{lt} Reactions for Frame 1

The amplification factor B_2 is calculated according to Equation 3.2. Since both columns contribute to the stability of the frame, ΣP_u is 202 k. To calculate P_{e2}, the effective length factor, K, must first be determined.

Alignment charts (AISC Manual, 1998) are used to establish an effective length factor for each column in a frame. First, a value for G must be calculated for each end of the column. G is defined as:

$$G = \frac{\Sigma(I_c/L_c)}{\Sigma(I_g/L_g)}$$

where I_c/L_c refers to the column and I_g/L_g refers to the girder. For Member 1 in Frame 1,

G_{bottom} = infinity, since the support is a pinned-connection

$$G_{top} = \frac{(475in^4/18ft)}{(1910in^4/60ft)} = 0.83$$

Applying both values to the alignment chart, K = 2.42 is found. Then P_{e2} is calculated using Equation 3.4:

$$P_{e2} = \pi^2 EI/(KL)^2$$

Where E = 29,000 ksi

I = 475 in^4 for W12X58

K = 2.42

L = 216 in

So that P_{e2} = $[\pi^2(29000ksi)(475\ in^4)]/[(2.42)(216\ in)]^2$ = 498 k. Since both of the columns are the same, ΣP_{e2} is 998 k.

Applying Equation 3.3, $B_2 = \dfrac{1}{1 - (202\ k/996\ k)} = 1.25$

Finally, using Equation 3.1, the magnified moments for each end of Member 3 are:

$M_{u,I\text{-}END}$ = (1.0)(-558.97 k-ft) + (1.25)(-47.88 k-ft) = -618.8 k-ft

$M_{u,J\text{-}END}$ = (1.0)(0 k-ft) + (1.25)(0 k-ft) = 0 k-ft

Next, the magnified moments for the righthand end of the beam, Member 2 of Frame 1, are calculated. First,

$\Delta M_{c,J\text{-}END}$ = $(B_2 – 1)M_{lt}$ for Member 3 = (1.25 – 1)(47.9 k-ft) = 11.97 k-ft = ΔM_b.

Then, using Equation 3.5,

$M_{u,J\text{-}END}$ = 559.0 k-ft + 47.9 k-ft + 11.97 k-ft = 618.8 k-ft.

This procedure was used to determine the second-order moments in each member of the eight frames considered in this study.

CHAPTER 4
RESULTS

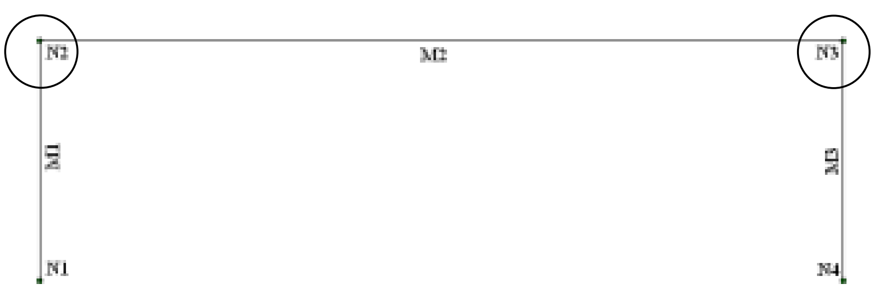
4.1 OVERVIEW

The results of the second-order moment calculations for each frame are presented in this chapter. Using four different computer analysis programs and current AISC Specifications, the frames were analyzed, comparing first-order analyses for verification and comparing second-order analyses for consistency. The first and second-order moments for selected joints in the frames are shown in the figures below.

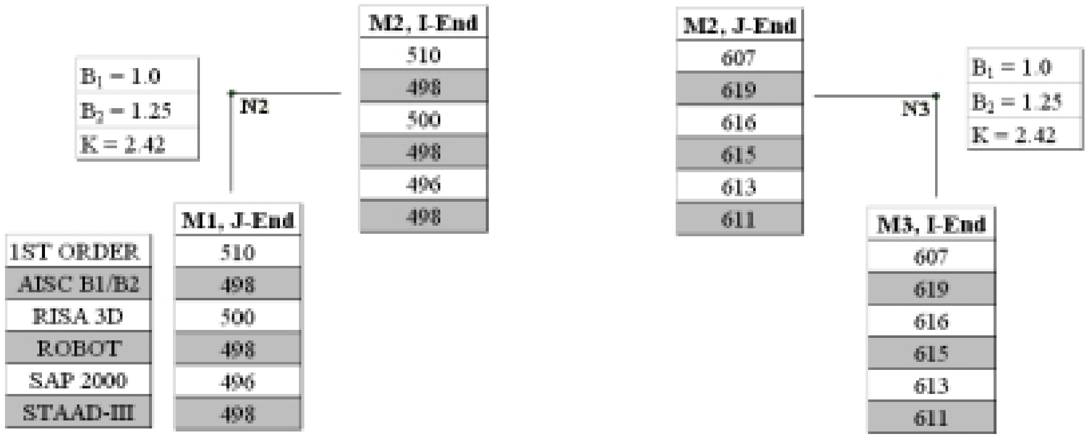
4.2 ANALYSIS OF FRAMES

Frame 1. The first frame is a regular, one-bay, one-story plane frame. The second-order moments are compared at the upper left and upper right nodes, Nodes 2 and 3, as shown in Figure 4.1(a).

As seen in the comparison of moments at two representative nodes, the difference in second-order moments between each analysis type is negligible. The maximum difference occurs at Node 3, between the AISC method and the STAAD-III analysis, but that difference, less than 1.5%, is not significant.



(a) Nodes Selected for Comparison in Frame 1

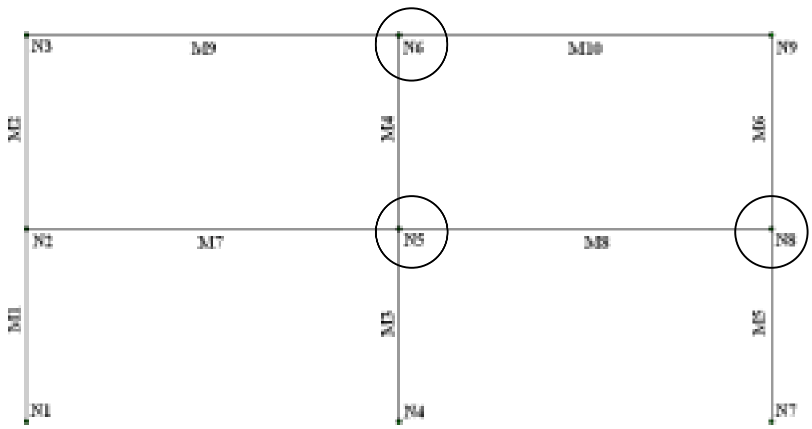


(b) Node 2 **(c) Node 3**

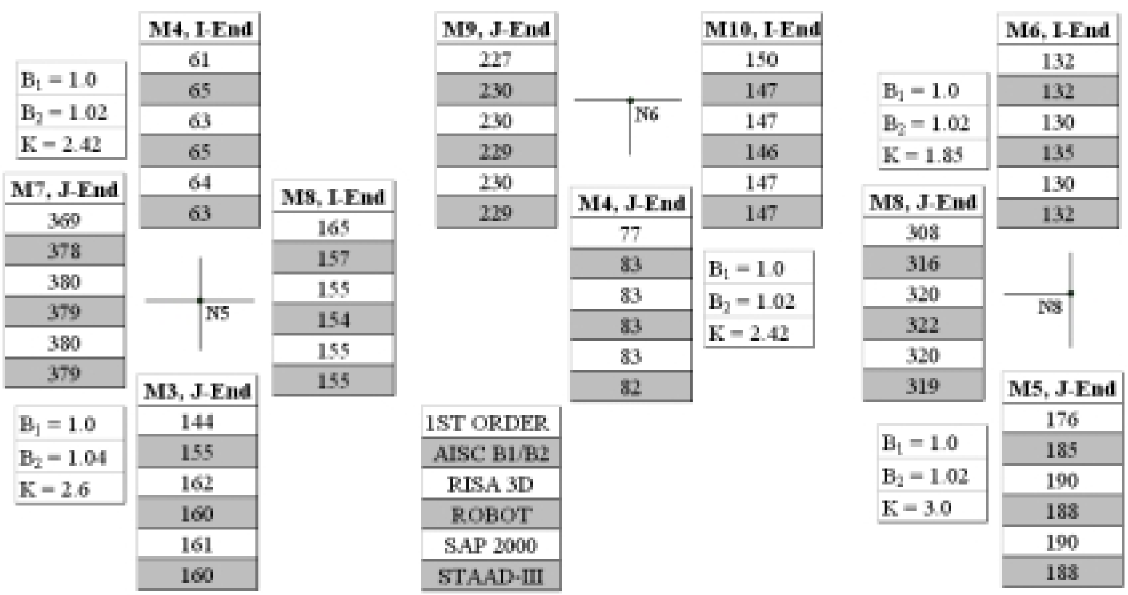
Figure 4.1: Comparison of Second-Order Moments in Frame 1

Frame 2. Frame 2 is a regular, two-bay, two-story plane frame with pinned columns and full-moment connections throughout the frame. Figure 4.2 (a) shows that the second-order moments at three nodes: Nodes 5, 6 and 8.

As shown in Figure 4.2 (b), (c) and (d), most of the second-order moments evaluated by the different analysis methods are similar for some members, but vary for others. At Node 5, the maximum difference, 4.4%, occurs in Member 3, between the AISC moment magnification method and RISA-3D. At Node 6, the second-order moments are similar to each other. In all three members, the solutions are almost identical. At Node 8, the moments vary but are similar, with a maximum difference of 2.7% in Member 5 between the AISC moment magnification method and both RISA-3D and SAP2000. At these three representative nodes, the second-order moments calculated by each of the computer programs are consistent, although in several cases they are slightly higher than the moments calculated using the AISC moment magnification method.



(a) Nodes Selected for Comparison in Frame 2



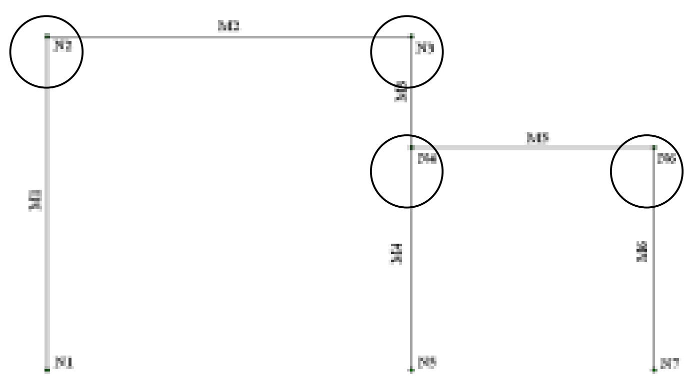
(b) Node 5 **(c) Node 6** **(d) Node 8**

Figure 4.2: Comparison of Moments at Selected Nodes of Frame 2

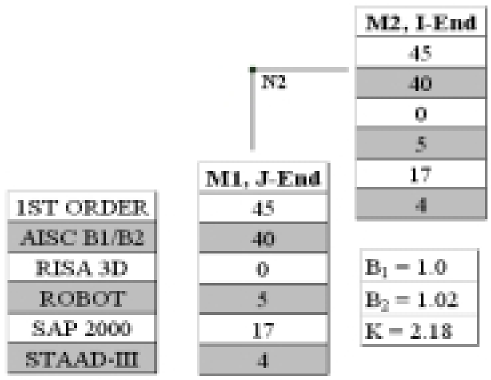
Frame 3. The next frame is a one-story, two-bay plane frame with one bay larger than the other. The smaller bay frames into a column of the larger bay at two-thirds of its height. To calculate the second-order moments using the AISC moment magnificaton method, members that acted together as a story were defined. Members 1, 2, and 3 were considered together as one story and likewise, Members 4, 5, and 6 were considered together as another story to evaluate their respective values of B_1 and B_2. For this frame, four nodes, shown in Figure 4.3 (a) are compared.

At each of the nodes shown in Figure 4.3, there are differences in the second-order moments calculated using the AISC moment magnification method and those predicted by the computer programs. The differences between the moments at Node 3, shown in Figure 4.3 (c) are the smallest, with a maximum variation of 2.9% in Member 2 between the AISC moment magnification method and ROBOT. At Node 2, the moments vary by a larger percentage, but since the magnitude is small, the significance of the variation is also small. At Node 4, the second-order moments vary more, with a maximum difference of 21.5% in Member 5.

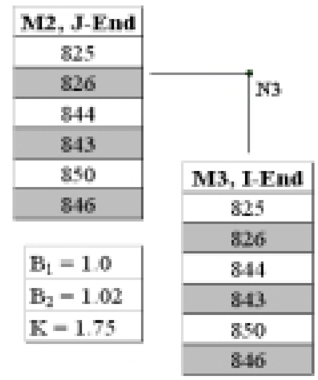
The moments calculated by the computer analysis programs are again similar, but vary from the moments calculated using the AISC moment magnification method. At some nodes, the AISC method under-predicts the moments, as compared to the computer programs, and at some nodes the AISC over-predicts the moments, compared to the computer analysis programs. However, in each instance, the second-order moments in each of the members are similar.



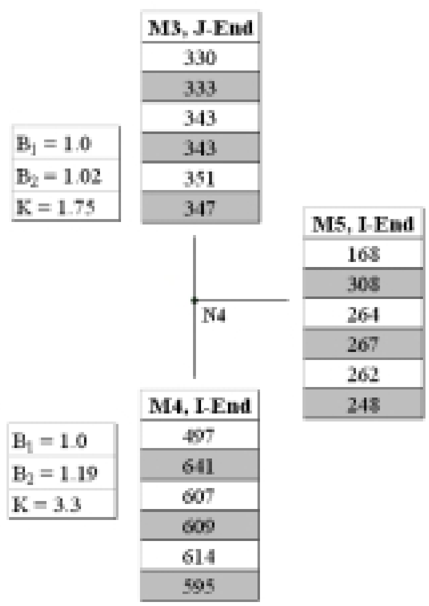
(a) Nodes Selected for Comparison in Frame 3



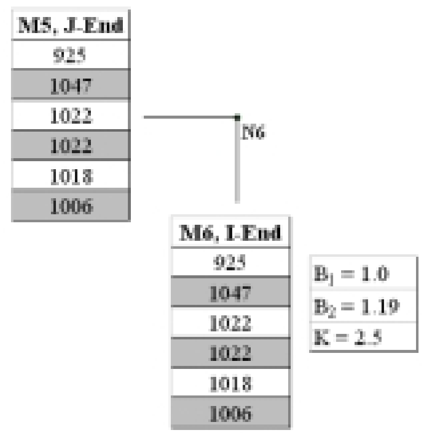
(b) Node 2



(c) Node 3



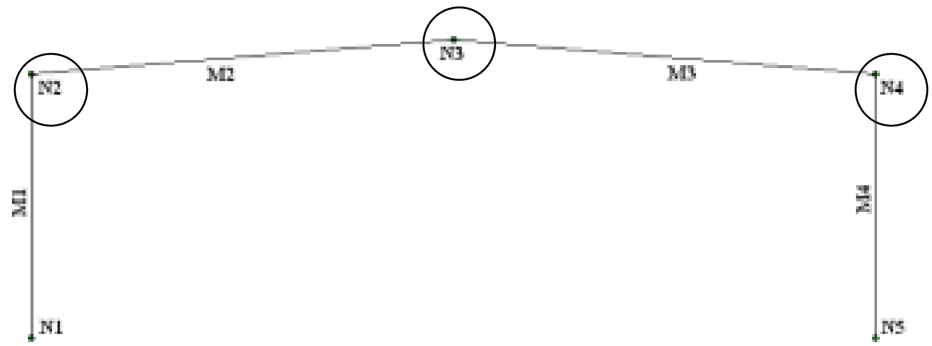
(d) Node 4



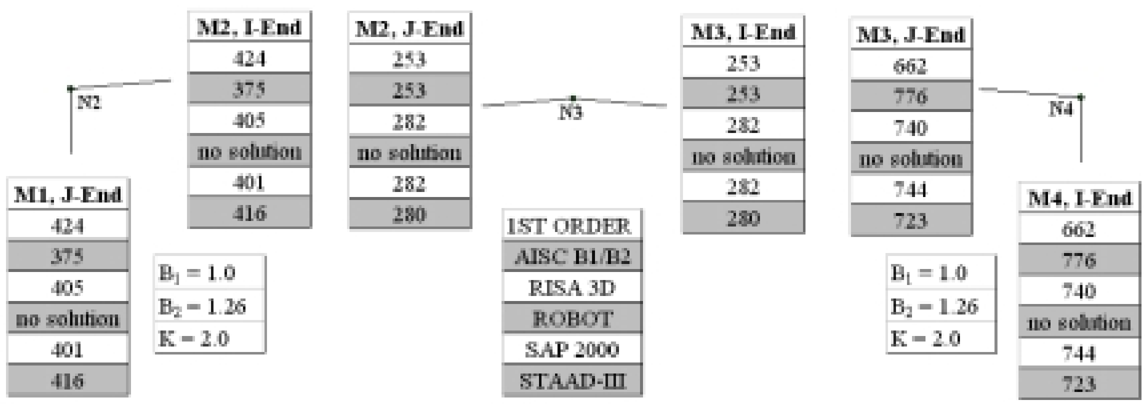
(e) Node 5

Figure 4.3: Comparison of Moments in Frame 3

Frame 4. Frame 4 is a one-bay, one-story gabled frame, with a roof slightly pitched at 4.7 degrees. The two nodes, Nodes 1 and 3, shown in Figure 4.4 (a) are compared below.



(a) Nodes Selected for Comparison in Frame 4



(b) Node 2 **(c) Node 3** **(d) Node 4**

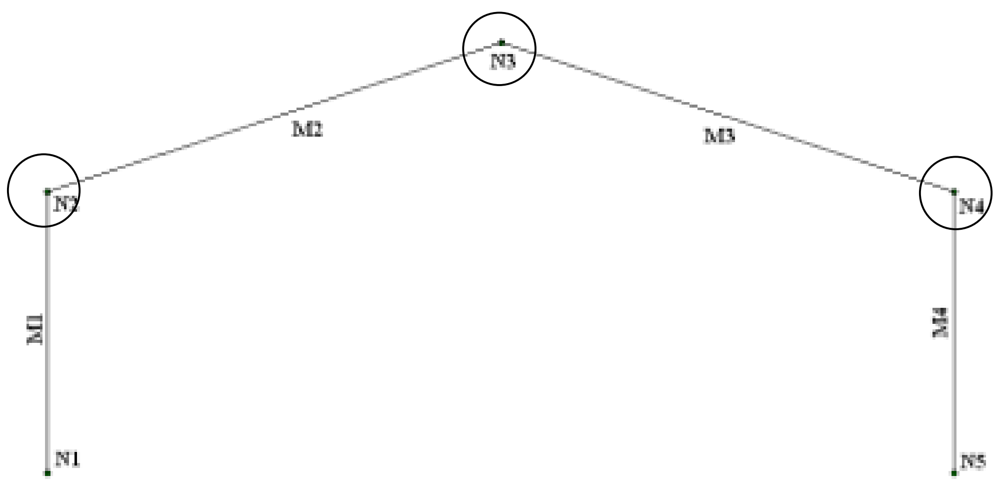
Figure 4.4: Comparison of Moments in Frame 4

The second-order moments produced by the different analysis procedures vary for these nodes. As indicated in Figure 4.4, ROBOT is unable to perform a P-Delta analysis on this type of structure. Also, since the AISC moment magnification method applies only to 'regular' frames, with all of its members perpendicular, that method is unable to appropriately determine second-order moments. Despite its limitations, the AISC method was still compared to the computer analyses. For this study, the same AISC solution procedure used for regular frames was applied to the gabled frame, such that the effective length factor, K, was evaluated using the alignment charts. In calculating the values for 'G,' only the length of beam connected to the column was considered, so that for Member 1, only the length of Member 2 was used to determine the effective length factor, and similarly for Member 4, only the length of Member 3 was used.

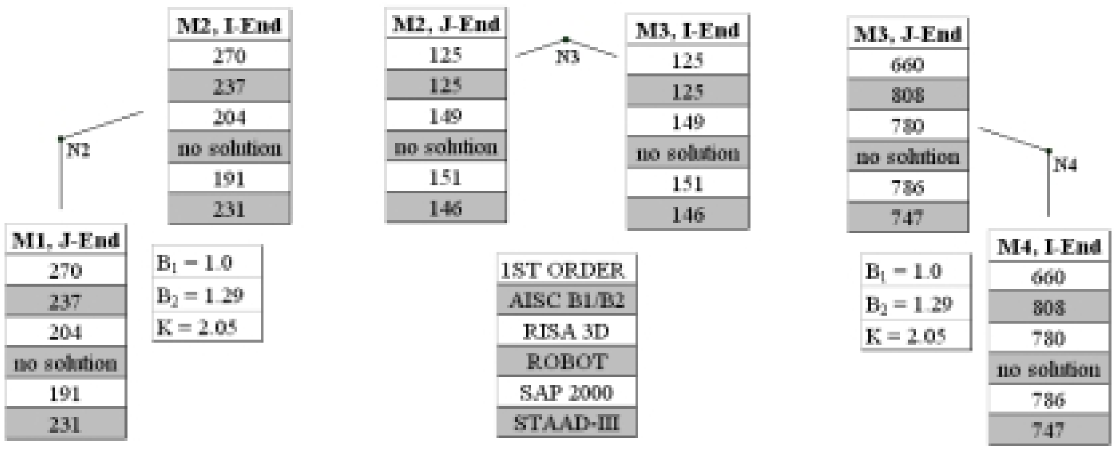
Considering those limitations, the moments are still similar with a maximum difference of 10% at Node 1 between the AISC moment magnification method and STAAD-III. Comparing just the computer analysis programs, the moments at Nodes 2, 3 and 4 are similar, with a maximum difference of 3.7% in Members 1 and 2 between SAP2000 and STAAD-III.

Frame 4a. The next frame, Frame 4a, has the same geometry as Frame 4 except that its roof pitch is 18.4 degrees, increased from 4.7 degrees. For comparison, three nodes, shown in Figure 4.5 (a) are chosen.

Again, as with Frame 4, ROBOT is unable to perform a P-Delta analysis on the frame. Also, although same limitations with the AISC moment magnification method apply to this frame, the same solution procedure applied to Frame 4 was applied to this frame.



(a) Nodes Selected for Comparison in Frame 4a



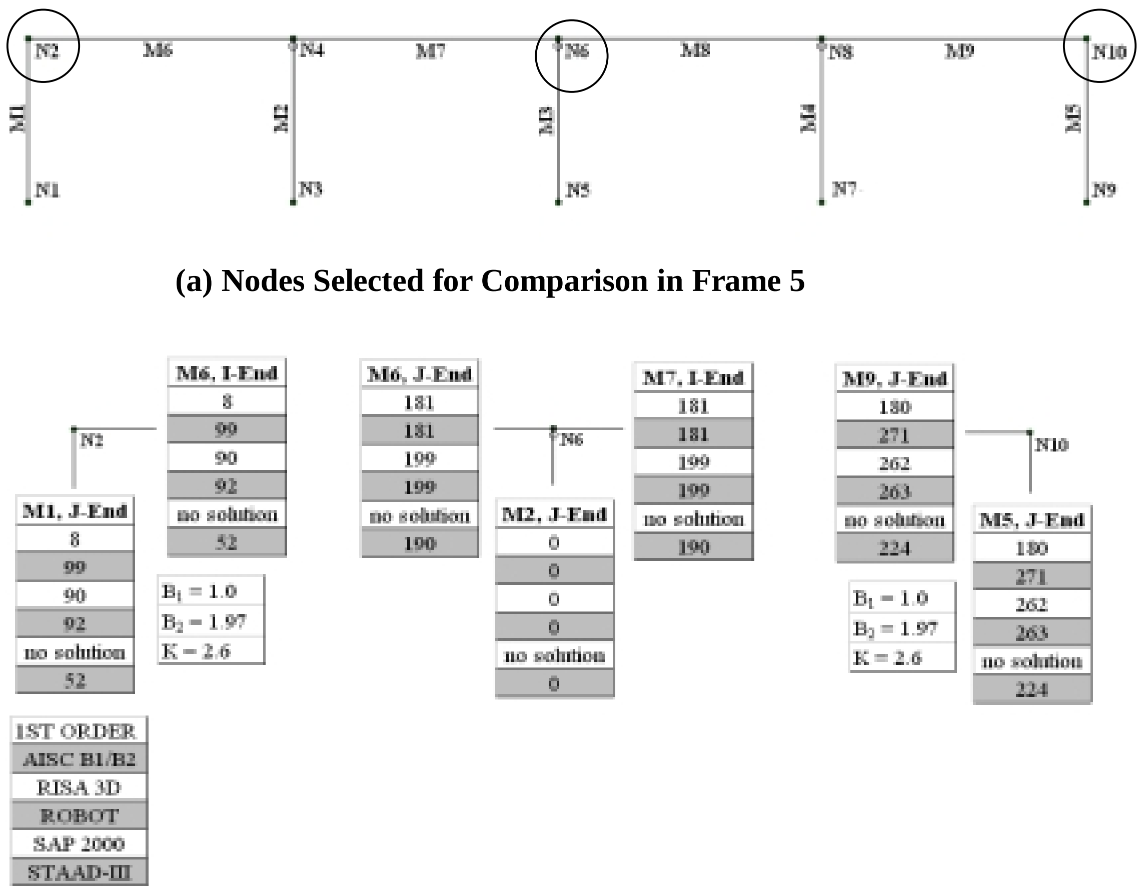
(b) Node 2 **(c) Node 3** **(d) Node 4**

Figure 4.5: Comparison of Moments in Frame 4a

At Node 2, the second-order moments vary by as much as 21%, in Member 1, between the AISC method and SAP2000. However, the remaining moments all vary between those two values, with no consistency. At Node 3, the computer analysis programs gave similar results while the AISC moment magnification method gave second-order moments about 18% lower than the computer programs. The moments also vary at Node 4, although by a maximum of only 7.8% between the AISC method and STAAD-II

Frame 5. Frame 5 is a one-story, four-bay frame with exterior pinned-fixed columns and three interior 'leaner' columns. Three nodes shown in Figure 4.6 (a), Nodes 2, 6, and 10 are chosen for comparison.

For this frame, SAP2000 is unable to perform a P-Delta analysis and pronounces the structure unstable. Comparing the remaining analyses, there are differences in the calculated second-order moments. At Node 2 in both members, the AISC moment magnification method, RISA-3D and ROBOT vary slightly while the STAAD-III analysis differs by a maximum of 62%. Also, in the beams at Node 6, there is a slight spread in the moments with a maximum difference of 9.5% between the AISC moment magnification method and the RISA-3D and ROBOT analyses. There are also differences in the second-order moments at Node 10. In Member 9, RISA-3D and ROBOT produced similar results, while STAAD-III calculated a moment 16% lower and the AISC method produced a moment just slightly higher.



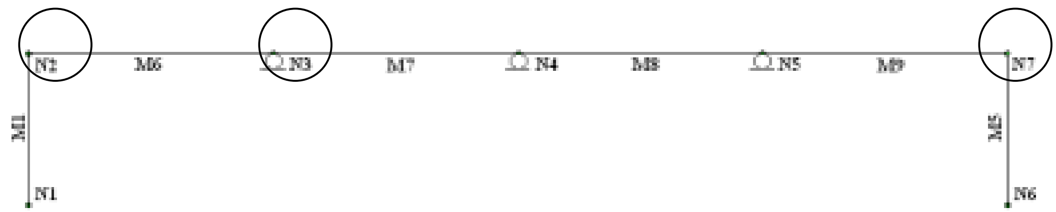
(a) Nodes Selected for Comparison in Frame 5

(b) Node 2 **(c) Node 6** **(d) Node 10**

Figure 4.6: Comparison of Moments in Frame 5

Frame 5a. Frame 5a is similar to Frame 5 except that the 'leaner' columns are removed and replaced with 'roller' connections that prevent vertical displacement but allow horizontal displacement. Two nodes are shown for comparison in Figure 4.6.

For this frame, which was similar to Frame 5, SAP2000 is able to complete a second-order analysis, allowing comparison with the other solution procedures. As shown at Nodes 2, 3 and 7, the second-order moments calculated by the AISC moment magnification method and by each of the computer analysis programs are nearly the same.



(a) Nodes Selected for Comparison in Frame 5a

	M1, J-End	M6, I-End
1ST ORDER	9	9
AISC B1/B2	18	18
RISA 3D	20	20
ROBOT	21	21
SAP 2000	20	20
STAAD-III	20	20

$B_1 = 1.0$
$B_2 = 1.10$
$K = 2.6$

(b) Node 2

	M6, J-End	M7, I-End
1ST ORDER	182	182
AISC B1/B2	182	182
RISA 3D	184	184
ROBOT	185	185
SAP 2000	184	184
STAAD-III	184	184

(c) Node 3

	M9, J-End	M5, J-End
1ST ORDER	179	179
AISC B1/B2	189	189
RISA 3D	190	190
ROBOT	189	189
SAP 2000	190	190
STAAD-III	190	190

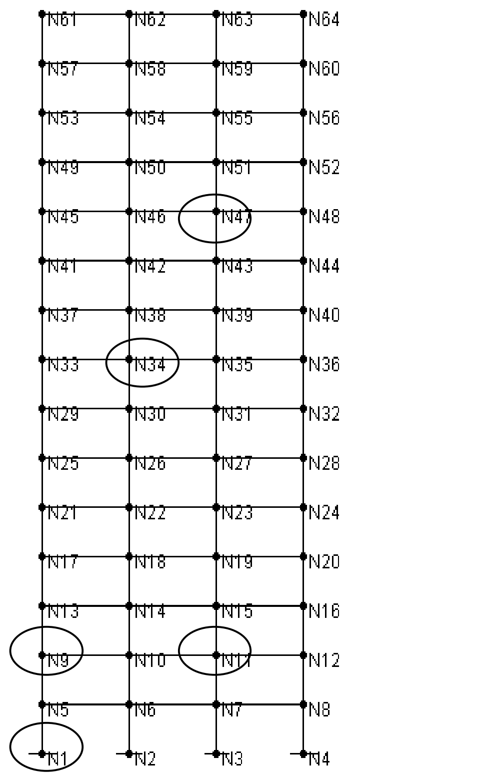
$B_1 = 1.0$
$B_2 = 1.10$
$K = 2.6$

(d) Node 7

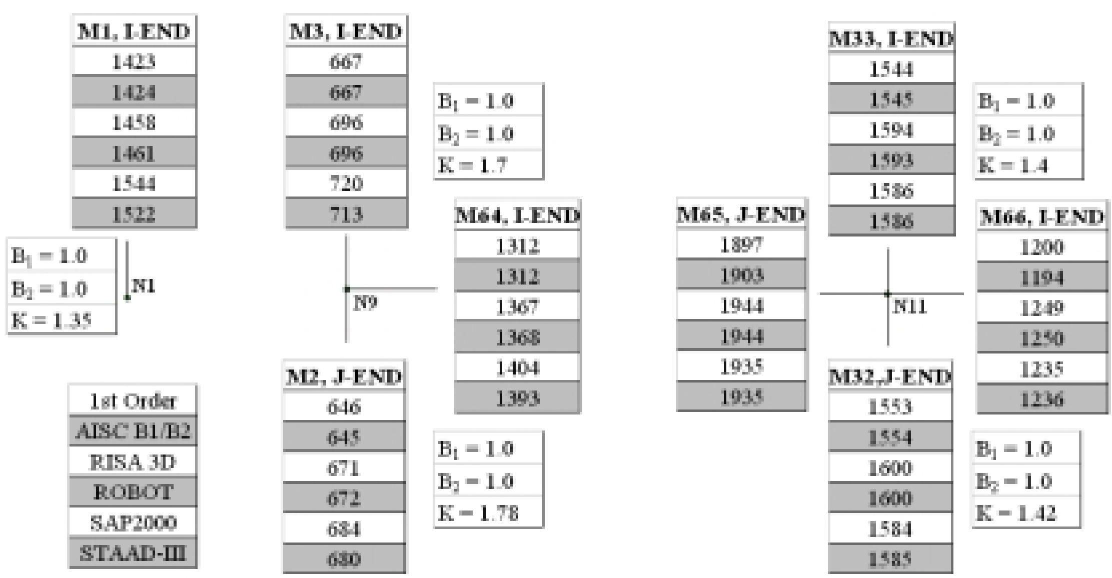
Figure 4.7: Comparison of Moments in Frame 5a

Frame 6. Frame 6 is a regular three-bay, fifteen-story plane frame with fully fixed supports and full moment connections throughout the structure. The second-order moments at five representative nodes, shown in Figure 4.8, are compared.

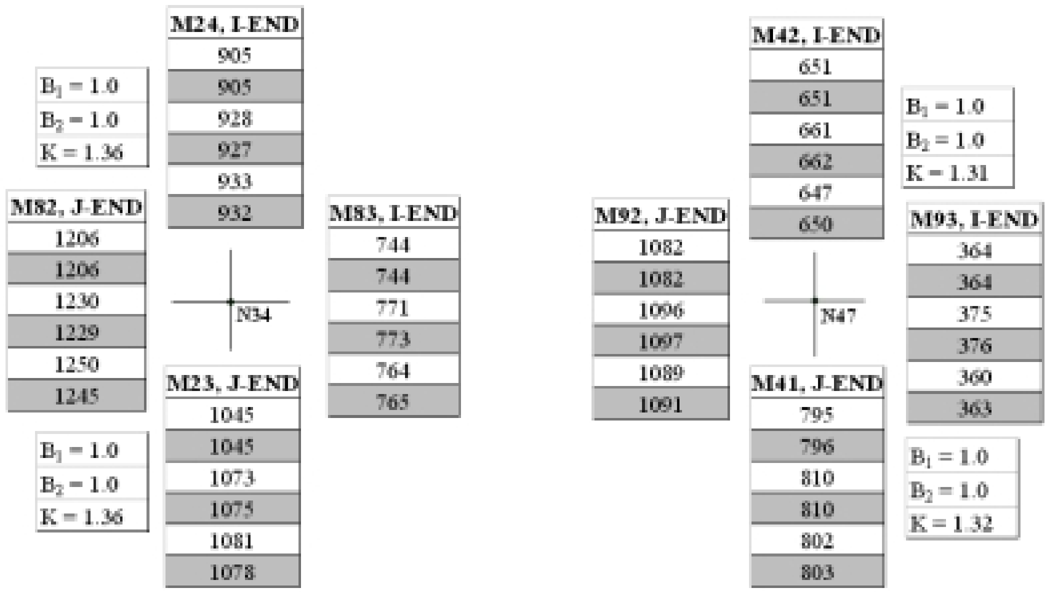
As shown at each of the nodes in Figure 8, the second-order moments calculated by each analysis are similar, with only slight variations. The maximum difference, 8.1%, is shown at the support in Member 1 at Node 1. There also difference in the second-order moments at Node 9. In Member 2, the AISC method and SAP2000 differ by 5.9%, in Member 3, the same methods differ by 7.6%, and in Member 64, the methods differ again by 6.8%. At Node 11, the maximum difference of 4.6% occurs between the AISC method and both RISA-3D and ROBOT. Each of the other nodes have similar differences in second-order moments.



(a) Nodes Selected for Comparison in Frame 6



(b) Node 1 **(c) Node 9** **(d) Node 11**



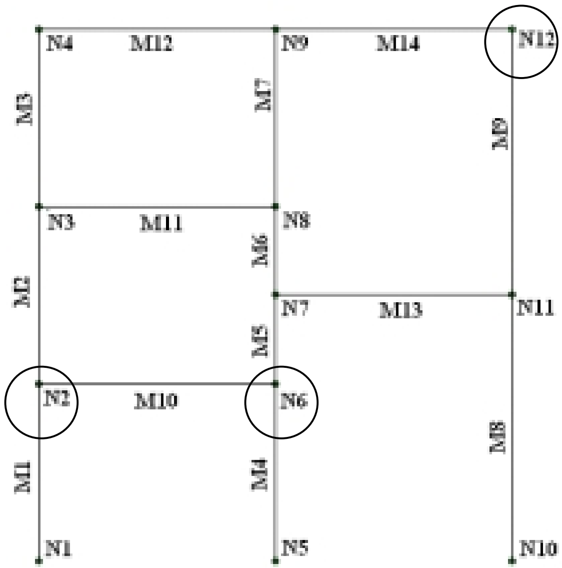
(e) Node 34 **(f) Node 47**

Figure 4.8: Comparison of Moments in Frame 6

Although the moments are fairly consistent, at many of the nodes, the second-order moments determined by RISA-3D compare closely with the moments calculated by ROBOT, and are consistently greater than the moments determined using the AISC moment magnification method. There are also close comparisons between SAP2000 and STAAD-III, which are often greater than the AISC moment magnification method, although not consistently.

Frame 7. The next frame is a two-bay frame with three stories in the left bay and two stories in the right bay. Three nodes, Nodes 2, 6, 12 are compared in Figure 4.9.

In this frame, there are both consistencies and inconsistencies between the second-order moments calculated by each analysis procedure. At Node 12, shown in Figure 4.9 (d), the moments are similar with only negligible differences. However, at Node 2, shown in Figure 4.9 (e), there are larger differences, with a maximum difference of 28% in Member 1 between the AISC moment magnification method and both ROBOT and SAP2000. At Node 6, a similarly large difference of 21% occurs in Member 4 between the AISC moment magnification method and SAP2000. At each of the nodes, the second-order moments calculated by the computer analysis programs are consistently larger than the moments determined using the AISC moment magnification method.



(a) Nodes Selected for Comparison in Frame 7

M2, I-End
15
13
17
20
17
15

$B_1 = 1.0$
$B_2 = 1.04$
$K = 1.4$

M10, I-End
204
217
278
285
287
264

N2

M1, J-End
218
229
295
303
303
279

$B_1 = 1.0$
$B_2 = 1.04$
$K = 1.2$

(b) Node 2

$B_1 = 1.0$
$B_2 = 1.04$
$K = 1.73$

M5, I-End
147
149
138
140
135
137

M10, J-End
508
522
590
600
593
572

N6

M4, J-End
361
373
452
453
458
435

$B_1 = 1.0$
$B_2 = 1.04$
$K = 1.32$

(c) Node 6

M14, J-End
114
116
115
117
116
115

N12

$B_1 = 1.0$
$B_2 = 1.04$
$K = 1.4$

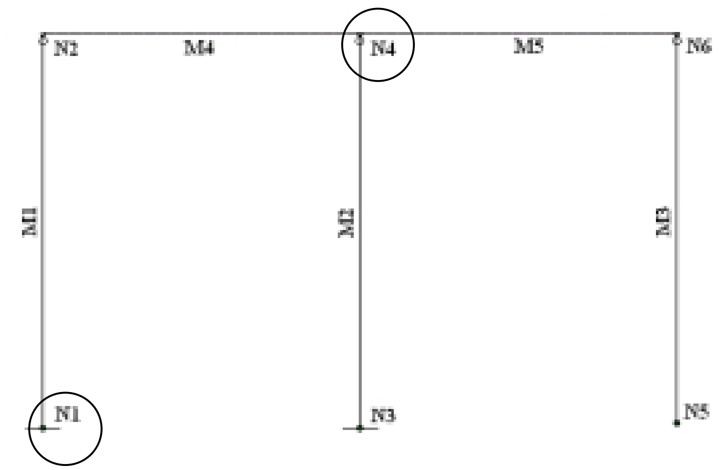
M9, J-End
114
116
115
117
116
115

1ST ORDER
AISC B1/B2
RISA 3D
ROBOT
SAP 2000
STAAD-III

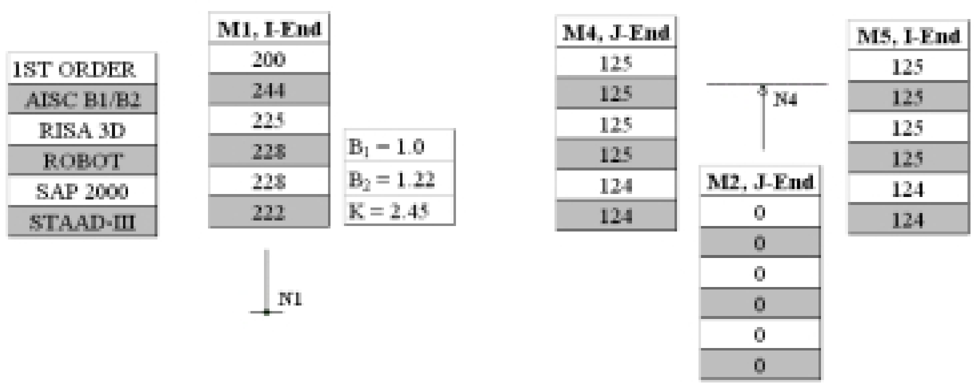
(d) Node 12

Figure 4.9: Comparison of Moments in Frame 7

Frame 8. Frame 8 is a two-bay, one-story plane frame with one pinned support and two fixed supports. The beam-to-column connections in the structure are simple shear connections. For comparison, two nodes, Nodes 1 and 4, are shown in Figure 4.10.



(a) Nodes Selected for Comparison in Frame 8



(b) Node 1 **(c) Node 4**

Figure 4.10: Comparison of Moments in Frame 8

As shown in Figure 4.10, the second-order moments calculated by each analysis method are similar. At Node 1, the moments calculated by the four different computer analysis programs are similar, with only negligible differences. Although the moment calculated using the AISC moment magnification methods is similar, it varies slightly, by a maximum of 9.4%. At Node 4, each of the analysis methods produced nearly exactly the same second-order moments.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

As shown in the previous chapter, the second-order moments can vary between the different analysis procedures. First, the second-order moments calculated using various commercially available computer analysis programs are compared. Next, the moments predicted by the computer analysis programs are compared to the second-order moments calculated using the AISC moment magnification method.

For 'regular' frames in which all of the members are perpendicular and there are no missing members, the computer program predicted second-order moments are almost identical. For four 'regular' frames considered in this study, Frames 1, 2, 5a, and 6, the second-order moments from each computer program vary by 8% or less. For Frames 3 and 7, which both have beams that frame into columns at mid-height, the computer programs also produced very similar results.

Two gabled frames, Frames 4 and 4a, were considered in this study. The roof beams in Frame 4 are only slightly pitched so that they are almost horizontal. Although one program, ROBOT Millennium, was unable to perform a second-order analysis on this frame, the other programs calculated very similar moments. However, when the roof pitch is increased by almost four times as in Frame 4a, the difference between the computer program solutions increases by up to 19%. Again, ROBOT Millennium is unable to complete a second-order analysis. Comparing the results from these gabled frames shows that the more closely the geometry of a frame resembles a 'regular' frame, the more consistently the computer analysis programs will predict the second-order moments in the members.

Frames 5 and 8 both have 'leaner' columns as part of the frame and although the computer analysis programs gave similar solutions for Frame 8, they varied for Frame 5. Specifically, SAP2000 Plus cannot perform a second-order analysis on Frame 5. Also, RISA-3D and ROBOT predict similar second-order moments, while STAAD-III predicts moments that are lower by as much as 62%. These inconsistencies indicate that some computer programs cannot appropriately incorporate 'leaner' columns into their solution algorithms.

It is expected that there would be a difference between the second-order moments calculated by each computer analysis program since the solution algorithms vary. Although many of the solutions in this study were similar, they differed in some cases by up to 62%. The differences could be amplified for different loading conditions or for different frame geometries. It is also important to consider that only one computer program, ROBOT, incorporates member (P-δ) effects into the solution. In this study, the effect was negligible, but could also be significant for different loading conditions or for different frame geometries.

Another comparison is made between the second-order moments calculated using the AISC moment magnification method and the moments predicted by the computer analysis programs. Although it is not stated in the LRFD Specifications, the moment magnification method is intended to apply exclusively to regular frames. In that respect, for three frames evaluated in the study, Frames 1, 2, and 5a the AISC method predicts moments very similar to those given by the computer analysis programs. Also, for Frames 5 and 8, which both have 'leaner' columns, the AISC method gives second-order moments similar, within 10%, of the computer programs.

For Frame 3, which has one large bay and one smaller bay, the AISC method gives second-order moments similar to the computer programs. However, since there are not typical story levels, the frame must be evaluated to determine which members most reasonably act together as a story. Similarly, in Frame 7, which has varying story heights, the second-order moments calculated using AISC method vary from the moments calculated by the computer programs. As with Frame 3, the members that act together as a story must be determined to appropriately calculate B1 and B2 magnification factors.

Since Frames 4 and 4a are gabled frames, the AISC method is not intended to predict the second-order moments in their elements. However, for Frame 4, in which the roof beams are pitched so that they are nearly horizontal, the AISC solution is similar, within 10%, of the computer programs' solutions. As the geometry of the structure becomes less similar to a 'regular' frame, as in Frame 4a, the AISC solution is less reliable, differing by up to almost 20%. For gabled frames with a slightly pitched roof that is close to the horizontal, the AISC method can reasonably predict the second-order moments when only the length of girder connected to the column is considered in calculating the effective length factor. However, in Frame 4, although the moments were similar, the AISC tended to predict moments lower than the computer analysis programs, so that they could be unconservative.

For Frame 6, a three-bay, fifteen-story frame, the AISC method gives moments similar to the computer programs with differences of 8% or less. Despite the similarities, the AISC second-order moments are consistently less than the computer programs' second-order moments. Since the AISC method could be slightly under-predicting the second-order moments, it is something to consider in the analysis of a large portal frame.

5.2 RECOMMENDATIONS

Since different computer programs can produce varying results for second-order analyses of certain structures, caution must be used when relying on the results for design purposes. The limitations and reliability of the AISC procedure as well as each of the computer programs should be fully understood so that adequate conservatism can be incorporated into a design. Also, caution should be taken in evaluating the geometry of a structure so that an appropriate analysis procedure can be applied to the frame to more accurately model the loading and structural response. A second-order analysis is necessary for a thorough analysis and appropriate design of a structure and while computer programs ease the intensity of the analysis, it is important for the engineer to understand the solution procedure and carefully evaluate the second-order moments.

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APPENDIX A

COMPUTER PROGRAM INPUT FOR FRAME 1

```
RISA-3D, Frame 1


Materials (General)
STL                 29000 11154 0.3 0.65 0.49 50

Sections
18X311              W18X311                          STL                 91.5
1.2 1.2 795 6960 177
12X45               W12X45                           STL                 13.2
1.2 1.2 50 350 1.31
8X31                W8X31                            STL                 9.13
1.2 1.2 37.1 110 0.54
12X58               W12X58                           STL                 17
1.2 1.2 107 475 2.1
18X106              W18X106                          STL                 31.1
1.2 1.2 220 1910 7.48

Joint Coordinates
N1                  0 0 0 0
N2                  0 18 0 0
N3                  60 18 0 0
N4                  60 0 0 0

Boundary Conditions
N1                   Reaction Reaction Fixed Fixed
N4                   Reaction Reaction Fixed Fixed
N2                     Fixed
N3                   Reaction  Fixed

Member Data
M1                   N1                    N2
0.0 12X58                  0.0 0.0   18
M2                   N2                    N3
0.0 18X106                 0.0 0.0   60
M3                   N3                    N4
0.0 12X58                  0.0 0.0   18

Distributed Load Patterns
DEAD                 Y -0.24 -0.24 0 0
SNOW                 Y -1.92 -1.92 0 0

Basic Load Case Data
1 Wind                           None   1 0 0 0
2 Snow                           None   0 0 1 0
3 Dead                           None   0 0 1 0
4 Mnt                            None   1 0 0 0
5 Reaction, Mlt                  None   1 0 0 0

Joint Loads; BLC 1: Wind
N2                   L X 6.75

Joint Loads; BLC 4: Mnt
N3                   L X -6.75

Joint Loads; BLC 5: Reaction, Mlt
N3                   L X 6.75
```

Member Distributed Loads; BLC 2: Snow
M2 N2 N3 SNOW
1

Member Distributed Loads; BLC 3: Dead
M2 N2 N3 DEAD
1

Load Combinations
1 1st Order
n n n n 1 1 0.8 2 1.6 3
1.2 0 0 0
0 0
2 Mnt
n n n n 1 1 0.8 2 1.6 3
1.2 4 0.8 0 0
0 0
3 Mlt
n n n n 1 4 0.8 0 0
0 0 0 0
0
4 2nd Order
n n y n 1 1 0.8 2 1.6 3
1.2 0 0 0
0 0
5 Unfactored
n n n n 1 1 1 2 1 3 1
0 0 0 0
0

n n n n 1 0 0 0
0 0 0 0
0

SAP2000 v6.13 File: FRAME1SAP Kip-ft Units PAGE 1
April 29, 2001 14:50

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S T A T I C   L O A D   C A S E S

STATIC CASE	CASE TYPE	SELF WT FACTOR
DEAD	DEAD	0.0000
SNOW	SNOW	0.0000
WIND	WIND	0.0000

SAP2000 v6.13 File: FRAME1SAP Kip-ft Units PAGE 2
April 29, 2001 14:50

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J O I N T   D A T A

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	RESTRAINTS	ANGLE-A	ANGLE-B	ANGLE-C
1	-30.00000	0.00000	0.00000	1 1 1 0 0 0	0.000	0.000	0.000
2	-30.00000	0.00000	18.00000	0 0 0 0 0 0	0.000	0.000	0.000
3	30.00000	0.00000	0.00000	1 1 1 0 0 0	0.000	0.000	0.000
4	30.00000	0.00000	18.00000	0 0 0 0 0 0	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME1SAP Kip-ft Units PAGE 3
April 29, 2001 14:50

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F R A M E   E L E M E N T   D A T A

FRAME	JNT-1	JNT-2	SECTION	ANGLE	RELEASES	SEGMENTS	R1	R2	FACTOR	LENGTH
1	1	2	W12X58	0.000	000000	1	0.000	0.000	1.000	18.000
2	3	4	W12X58	0.000	000000	1	0.000	0.000	1.000	18.000
3	2	4	W18X106	0.000	000000	1	0.000	0.000	1.000	60.000

SAP2000 v6.13 File: FRAME1SAP Kip-ft Units PAGE 4
April 29, 2001 14:50

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J O I N T   F O R C E S   Load Case WIND

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	GLOBAL-XX	GLOBAL-YY	GLOBAL-ZZ
2	6.750	0.000	0.000	0.000	0.000	0.000

Virginia Tech

F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case DEAD

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
3	FORCE	GLOBAL-Z	0.0000	-0.2400	1.0000	-0.2400

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F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case SNOW

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
3	FORCE	GLOBAL-Z	0.0000	-1.9200	1.0000	-1.9200

```
STAAD PLANE RESEARCH FRAME 1
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 18.; 3 60. 18.; 4 60. 0.
MEMBER INCIDENCE
1 1 2 ; 2 2 3 ; 3 3 4
MEMBER PROPERTY AMERICAN
1 3 TABLE ST W12X58
2 TABLE ST W18X106
UNIT INCHES
CONSTANTS
E 29000.0 ALL
UNIT POUNDS
CONSTANT
DENSITY 0.284 ALL
PRINT MEMBER INFORMATION
SUPPORT
1 4 PINNED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT KIP FEET
LOADING 1 DEAD
MEMBER LOAD
2 UNIFORM GY -0.24
LOADING 2 SNOW
MEMBER LOAD
2 UNIFORM GY -1.92
LOAD 3 COMBINATION
REPEAT LOAD
1 1.2 2 1.6
JOINT LOAD
2 FX 5.4
PDELTA ANALYSIS
PRINT MEMBER FORCES
PRINT SUPPORT REACTIONS
FINISH
```

APPENDIX B

COMPUTER PROGRAM INPUT FOR FRAME 2

RISA-3D, Frame 2

```
Materials
STL                 29000 11154 0.3 0.65 0.49 50

Sections
14X48               W14X48                            STL                 14.1
1.2 1.2 51.4 485 1.46
18X50               W18X50                            STL                 14.7
1.2 1.2 40.1 800 1.24
12X79               W12X79                            STL                 23.2
1.2 1.2 216 662 3.84

Joint Coordinates
N1                  0 0 0 0
N2                  0 15 0 0
N3                  0 30 0 0
N4                  30 0 0 0
N5                  30 15 0 0
N6                  30 30 0 0
N7                  60 0 0 0
N8                  60 15 0 0
N9                  60 30 0 0

Boundary Conditions
N1                   Reaction Reaction  Fixed
N4                   Reaction Reaction  Fixed
N7                   Reaction Reaction  Fixed
N2                     Fixed
N5                     Fixed
N8                     Fixed
N3                     Fixed
N6                     Fixed
N9                     Fixed

Member Data
M1                   N1                   N2
0.0 12X79                  0.0 0.0   15
M2                   N2                   N3
0.0 12X79                  0.0 0.0   15
M3                   N4                   N5
0.0 12X79                  0.0 0.0   15
M4                   N5                   N6
0.0 12X79                  0.0 0.0   15
M5                   N7                   N8
0.0 12X79                  0.0 0.0   15
M6                   N8                   N9
0.0 12X79                  0.0 0.0   15
M7                   N2                   N5
0.0 18X50                  0.0 0.0   30
M8                   N5                   N8
0.0 18X50                  0.0 0.0   30
M9                   N3                   N6
0.0 14X48                  0.0 0.0   30
M10                  N6                   N9
0.0 14X48                  0.0 0.0   30
```

Distributed Load Patterns
LIVE Y -1.8 -1.8 0 0
SNOW Y -1.2 -1.2 0 0
DEAD Y -0.3 -0.3 0 0

Basic Load Case Data
1 Live Load None 0 0 2 0
2 Snow Load None 0 0 2 0
3 Dead Load None 0 0 4 0
4 Wind Load None 2 0 0 0
5 Reaction, Mlt None 2 0 0 0

Joint Loads; BLC 4: Wind Load
N2 L X 10
N3 L X 20

Joint Loads; BLC 5: Reaction, Mlt
N8 L X 9.872
N9 L X 14.52

Member Distributed Load; BLC 1: Live Load
M7 N2 N5 LIVE
1
M8 N5 N8 LIVE
1

Member Distributed Load; BLC 2: Snow Load
M9 N3 N6 SNOW
1
M10 N6 N9 SNOW
1

Member Distributed Load; BLC 3: Dead Load
M7 N2 N5 DEAD
1
M8 N5 N8 DEAD
1
M9 N3 N6 DEAD
1
M10 N6 N9 DEAD
1

Load Combinations
1 1st Order
n n n n 1 1 1.6 2 1.6 3
1.2 4 0.8 0 0
0 0
2 2nd Order
n n y n 1 1 1.6 2 1.6 3
1.2 4 0.8 0 0
0 0
3 Mnt
n n n n 1 1 1.6 2 1.6 3
1.2 4 0.8 0 0
0 0
4 Mlt
n n n n 1 5 1 0 0

0 0 0 0
0
5 Unfactored
n n n n 1 1 1 2 1 3 1 4
1 0 0 0
0

SAP2000 v6.13 File: FRAME2SAP Kip-ft Units PAGE 1
April 29, 2001 14:52

S T A T I C   L O A D   C A S E S

STATIC CASE	CASE TYPE	SELF WT FACTOR
DEAD	DEAD	0.0000
SNOW	SNOW	0.0000
LIVE	LIVE	0.0000
WIND	WIND	0.0000

J O I N T   D A T A

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	RESTRAINTS	ANGLE-A	ANGLE-B	ANGLE-C
1	-30.00000	0.00000	0.00000	1 1 1 1 0 1	0.000	0.000	0.000
2	-30.00000	0.00000	15.00000	0 0 0 0 0 0	0.000	0.000	0.000
3	-30.00000	0.00000	30.00000	0 0 0 0 0 0	0.000	0.000	0.000
4	0.00000	0.00000	0.00000	1 1 1 1 0 1	0.000	0.000	0.000
5	0.00000	0.00000	15.00000	0 0 0 0 0 0	0.000	0.000	0.000
6	0.00000	0.00000	30.00000	0 0 0 0 0 0	0.000	0.000	0.000
7	30.00000	0.00000	0.00000	1 1 1 1 0 1	0.000	0.000	0.000
8	30.00000	0.00000	15.00000	0 0 0 0 0 0	0.000	0.000	0.000
9	30.00000	0.00000	30.00000	0 0 0 0 0 0	0.000	0.000	0.000

F R A M E   E L E M E N T   D A T A

FRAME	JNT-1	JNT-2	SECTION	ANGLE	RELEASES	SEGMENTS	R1	R2	FACTOR	LENGTH
1	1	2	W12X79	0.000	000000	1	0.000	0.000	1.000	15.000
2	2	3	W12X79	0.000	000000	1	0.000	0.000	1.000	15.000
3	4	5	W12X79	0.000	000000	1	0.000	0.000	1.000	15.000
4	5	6	W12X79	0.000	000000	1	0.000	0.000	1.000	15.000
5	7	8	W12X79	0.000	000000	1	0.000	0.000	1.000	15.000
6	8	9	W12X79	0.000	000000	1	0.000	0.000	1.000	15.000

7	2	5	W18X50	0.000	000000	1	0.000
0.000	1.000	30.000					
8	3	6	W14X48	0.000	000000	1	0.000
0.000	1.000	30.000					
9	5	8	W18X50	0.000	000000	1	0.000
0.000	1.000	30.000					
10	6	9	W14X48	0.000	000000	1	0.000
0.000	1.000	30.000					

J O I N T   F O R C E S   Load Case WIND

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	GLOBAL-XX	GLOBAL-YY	GLOBAL-ZZ
3	20.000	0.000	0.000	0.000	0.000	0.000
2	10.000	0.000	0.000	0.000	0.000	0.000

F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case DEAD

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
7	FORCE	GLOBAL-Z	0.0000	-0.3000	1.0000	-0.3000
9	FORCE	GLOBAL-Z	0.0000	-0.3000	1.0000	-0.3000
8	FORCE	GLOBAL-Z	0.0000	-0.3000	1.0000	-0.3000
10	FORCE	GLOBAL-Z	0.0000	-0.3000	1.0000	-0.3000

F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case SNOW

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
8	FORCE	GLOBAL-Z	0.0000	-1.2000	1.0000	-1.2000
10	FORCE	GLOBAL-Z	0.0000	-1.2000	1.0000	-1.2000

F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case LIVE

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
7	FORCE	GLOBAL-Z	0.0000	-1.8000	1.0000	-1.8000
9	FORCE	GLOBAL-Z	0.0000	-1.8000	1.0000	-1.8000

```
STAAD PLANE RESEARCH FRAME 2
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 15.; 3 0. 30.; 4 30. 0.; 5 30. 15.; 6 30. 30.; 7 60. 0.;
8 60. 15.; 9 60. 30.
MEMBER INCIDENCE
1 1 2; 2 2 3; 3 4 5; 4 5 6; 5 7 8; 6 8 9; 7 2 5; 8 5 8; 9 3 6; 10 6 9
MEMBER PROPERTY AMERICAN
1 2 3 4 5 6 TABLE ST W12X79
7 8 TABLE ST W18X50
9 10 TABLE ST W14X48
UNIT INCHES
CONSTANTS
E 29000.0 ALL
SUPPORT
1 4 7 PINNED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FEET
LOADING 1 DEAD
MEMBER LOAD
7 8 9 10 UNIFORM GY -0.3
LOADING 2 LIVE
MEMBER LOAD
7 8 UNIFORM GY -1.8
LOADING 3 SNOW
MEMBER LOAD
9 10 UNIFORM GY -1.2
LOADING 4 COMBINED
REPEAT LOAD
1 1.2 2 1.6 3 1.6
JOINT LOAD
2 FX 8
3 FX 16
PERFORM ANALYSIS
PRINT MEMBER FORCES
PRINT SUPPORT REACTIONS
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX C

COMPUTER PROGRAM INPUT FOR FRAME 3

RISA-3D, Frame 3

```
Materials
STL                 29000 11154 0.3 0.65 0.49 50

Sections
18X119              W18X119                          STL                 35.1
1.2 1.2 253 2190 10.6
27X235              W27X235                          STL                 69.1
1.2 1.2 768 9660 46.3
33X130              W33X130                          STL                 38.3
1.2 1.2 218 6710 7.37
18X106              W18X106                          STL                 31.1
1.2 1.2 220 1910 7.48
18X86               W18X86                           STL                 25.3
1.2 1.2 175 1530 4.1
18X158              W18X158                          STL                 46.3
1.2 1.2 347 3060 25.4
18X143              W18X143                          STL                 42.1
1.2 1.2 311 2750 19.4
30X211              W30X211                          STL                 62
1.2 1.2 757 10300 27.9

Joint Coordinates
N1                  0 0 0 0
N2                  0 36 0 0
N3                  36 36 0 0
N4                  36 24 0 0
N5                  36 0 0 0
N6                  60 24 0 0
N7                  60 0 0 0

Boundary Conditions
N1                   Reaction Reaction Fixed Fixed
N5                   Reaction Reaction Fixed Fixed
N7                   Reaction Reaction Fixed Fixed
N2                     Fixed
N3                     Fixed
N4                     Fixed
N6                     Fixed

Member Data
M1                   N1                    N2
0.0 18X143                 0.0 0.0   36
M2                   N2                    N3
0.0 30X211                 0.0 0.0   36
M3                   N3                    N4
0.0 18X158                 0.0 0.0   12
M4                   N4                    N5
0.0 18X158                 0.0 0.0   24
M5                   N4                    N6
0.0 33X130                 0.0 0.0   24
M6                   N6                    N7
0.0 18X143                 0.0 0.0   24

Distributed Load Patterns
MEMBER2              Y -12 -12 0 0
```

MEMBER5 Y -16 -16 0 0

Basic Load Case Data
1 Gravity1 None 0 0 2 0
2 Lateral40 None 1 0 0 0
3 Lateral18 None 1 0 0 0
4 Reaction, Mnt None 2 0 0 0

Joint Loads; BLC 2: Lateral40
N2 L X 40

Joint Loads; BLC 3: Lateral18
N6 L X 18

Joint Loads; BLC 4: Reaction, Mnt
N3 L X -3.342
N6 L X 69.423

Member Distributed Loads; BLC1: Gravity1
M2 N2 N3 MEMBER2
1
M5 N4 N6 MEMBER5
1

Load Combinations
1 gravity1
n n n n 1 1 1 0 0
0 0 0 0
0
2 lateral1
n n n n 1 2 1 0 0
0 0 0 0
0
3 combi
n n y n 1 1 1 2 1 3 1
0 0 0 0
0
4 1st Order
n n n n 1 1 1 2 1 3 1
0 0 0 0
0
5 2nd Order
n n y n 1 1 1 2 1 3 1
0 0 0 0
0
6 Mnt
n n n n 1 1 1 2 1 3 1
0 0 0 0
0
7 Mlt
n n n n 1 4 1 0 0
0 0 0 0
0

SAP2000 v6.13 File: FRAME3SAP Kip-ft Units PAGE 1
April 29, 2001 14:52

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S T A T I C   L O A D   C A S E S

STATIC CASE	CASE TYPE	SELF WT FACTOR
GRAVITY2	DEAD	0.0000
GRAVITY5	DEAD	0.0000
LATERAL2	WIND	0.0000
LATERAL6	WIND	0.0000

SAP2000 v6.13 File: FRAME3SAP Kip-ft Units PAGE 2
April 29, 2001 14:52

Virginia Tech

J O I N T   D A T A

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	RESTRAINTS	ANGLE-A	ANGLE-B	ANGLE-C
1	0.00000	0.00000	0.00000	1 1 1 0 0 0	0.000	0.000	0.000
2	0.00000	0.00000	36.00000	0 0 0 0 0 0	0.000	0.000	0.000
3	36.00000	0.00000	36.00000	0 0 0 0 0 0	0.000	0.000	0.000
4	36.00000	0.00000	24.00000	0 0 0 0 0 0	0.000	0.000	0.000
5	36.00000	0.00000	0.00000	1 1 1 0 0 0	0.000	0.000	0.000
6	60.00000	0.00000	24.00000	0 0 0 0 0 0	0.000	0.000	0.000
7	60.00000	0.00000	0.00000	1 1 1 0 0 0	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME3SAP Kip-ft Units PAGE 3
April 29, 2001 14:52

Virginia Tech

F R A M E   E L E M E N T   D A T A

FRAME	JNT-1	JNT-2	SECTION	ANGLE	RELEASES	SEGMENTS	R1	R2	FACTOR	LENGTH
1	1	2	W18X143	0.000	000000	1	0.000	0.000	1.000	36.000

```
       2       2       3   W30X211     0.000    000000         1     0.000     0.000
1.000     36.000
       3       3       4   W18X158     0.000    000000         1     0.000     0.000
1.000     12.000
       4       4       5   W18X158     0.000    000000         1     0.000     0.000
1.000     24.000
       5       4       6   W33X130     0.000    000000         1     0.000     0.000
1.000     24.000
       6       6       7   W18X143     0.000    000000         1     0.000     0.000
1.000     24.000
```

SAP2000 v6.13 File: FRAME3SAP Kip-ft Units PAGE 4
April 29, 2001 14:52

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J O I N T   F O R C E S   Load Case LATERAL2

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	GLOBAL-XX	GLOBAL-YY	GLOBAL-ZZ
2	40.000	0.000	0.000	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME3SAP Kip-ft Units PAGE 5
April 29, 2001 14:52

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J O I N T   F O R C E S   Load Case LATERAL6

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	GLOBAL-XX	GLOBAL-YY	GLOBAL-ZZ
6	18.000	0.000	0.000	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME3SAP Kip-ft Units PAGE 6
April 29, 2001 14:52

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F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case GRAVITY2

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
2	FORCE	GLOBAL-Z	0.0000	-12.0000	1.0000	-12.0000

SAP2000 v6.13 File: FRAME3SAP Kip-ft Units PAGE 7
April 29, 2001 14:52

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F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case GRAVITY5

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B

5	FORCE	GLOBAL-Z	0.0000	-16.0000	1.0000	-16.0000

```
STAAD PLANE RESEARCH FRAME 3
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 36.; 3 36. 36.; 4 36. 24.; 5 36. 0.; 6 60. 24.; 7 60. 0.
MEMBER INCIDENCE
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 4 6; 6 6 7
MEMBER PROPERTY AMERICAN
1 6 TABLE ST W18X143
2 TABLE ST W30X211
3 4 TABLE ST W18X158
5 TABLE ST W33X130
UNIT INCHES
CONSTANTS
E 29000.0
PRINT MEMBER INFORMATION
SUPPORT
1 5 7 PINNED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FEET
LOADING 1 GRAVITY AT TWO
MEMBER LOAD
2 UNIFORM GY -12
LOADING 2 GRAVITY AT FIVE
MEMBER LOAD
5 UNIFORM GY -16
LOADING 3 COMBINATION
REPEAT LOAD
1 1 2 1
JOINT LOAD
2 FX 40
6 FX 18
PERFORM ANALYSIS
PRINT MEMBER FORCES
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX D

COMPUTER PROGRAM INPUT FOR FRAME 4

RISA-3D, Frame 4

```
Materials
STL                 29000 11154 0.3 0.65 0.49 50

Sections
10X49               W10X49                          STL                 14.4
1.2 1.2 93.4 272 1.39
18X143              W18X143                         STL                 42.1
1.2 1.2 311 2750 19.4

Joint Coordinates
N1                  0 0 0 0
N2                  0 25 0 0
N3                  40 28.3 0 0
N4                  80 25 0 0
N5                  80 0 0 0

Boundary Conditions
N1                   Reaction Reaction Fixed Fixed
N5                   Reaction Reaction Fixed Fixed
N2                     Fixed
N3                     Fixed
N4                     Fixed

Member Data
M1                   N1                    N2
0.0 18X143                 0.0 0.0   25
M2                   N2                    N3
0.0 10X49                  0.0 0.0   40.1359
M3                   N3                    N4
0.0 10X49                  0.0 0.0   40.1359
M4                   N4                    N5
0.0 18X143                 0.0 0.0   25

Distributed Load Patterns
MEMBER2D             y -0.25 -0.25 0 0
MEMBER3D             y -0.25 -0.25 0 0
MEMBER2L             Y -0.5 -0.5 0 0
MEMBER3L             Y -0.5 -0.5 0 0

Basic Load Case Data
1 Wind Load                      None   2 0 0 0
2 Dead Load                      None   0 0 2 0
3 Live Load                      None   0 0 2 0
4 Reaction, Mlt                  None   2 0 0 0
5 Reaction, Mlt                  None   3 0 0 0

Joint Loads; BLC1: Wind Load
N2                   L X 9.4
N3                   L X 2.5

Joint Loads; BLC4: Reaction, Mlt
N3                   L X -391.889
N4                   L X 401.659

Joint Loads; BLC5: Reaction, Mlt
```

```
N4                    L X 231.7
N3                    L X 2
N2                    L X -224.1

Member Distributed Loads; BLC2: Dead Load
M2                    N2                    N3                    MEMBER2D
1
M3                    N3                    N4                    MEMBER3D
1

Member Distributed Loads; BLC3: Live Load
M2                    N2                    N3                    MEMBER2L
1
M3                    N3                    N4                    MEMBER3L
1

Load Combinations
1 1st Order
n n n n 1 1                    0.8 2                    1.2 3
1.6                     0                     0                     0
0                     0
2 2nd Order
n n y n 1 1                    0.8 2                    1.2 3
1.6                     0                     0                     0
0                     0
3 Mnt
n n n n 1 1                    0.8 2                    1.2 3
1.6                     0                     0                     0
0                     0
4 Mlt
n n n n 1 5                    1                    0                    0
0                     0                     0                     0
0
```

SAP2000 v6.13 File: FRAME4SAP Kip-ft Units PAGE 1
April 29, 2001 14:53

Virginia Tech

S T A T I C   L O A D   C A S E S

STATIC CASE	CASE TYPE	SELF WT FACTOR
LIVE	LIVE	0.0000
DEAD	DEAD	0.0000
WIND2	WIND	0.0000
WIND3	WIND	0.0000

SAP2000 v6.13 File: FRAME4SAP Kip-ft Units PAGE 2
April 29, 2001 14:53

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J O I N T   D A T A

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	RESTRAINTS	ANGLE-A	ANGLE-B	ANGLE-C
1	-40.00000	0.00000	0.00000	1 1 1 1 0 1	0.000	0.000	0.000
2	-40.00000	0.00000	25.00000	0 0 0 0 0 0	0.000	0.000	0.000
4	0.00000	0.00000	28.30000	0 0 0 0 0 0	0.000	0.000	0.000
5	40.00000	0.00000	0.00000	1 1 1 1 0 1	0.000	0.000	0.000
6	40.00000	0.00000	25.00000	0 0 0 0 0 0	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME4SAP Kip-ft Units PAGE 3
April 29, 2001 14:53

Virginia Tech

F R A M E   E L E M E N T   D A T A

FRAME	JNT-1	JNT-2	SECTION	ANGLE	RELEASES	SEGMENTS	R1	R2	FACTOR	LENGTH
1	1	2	W18X143	0.000	000000	1	0.000	0.000	1.000	25.000
2	5	6	W18X143	0.000	000000	1	0.000	0.000	1.000	25.000
3	2	4	W10X49	0.000	000000	1	0.000	0.000	1.000	40.136

```
       4       4       6    W10X49     0.000    000000         1     0.000
0.000     1.000      40.136

 SAP2000 v6.13 File: FRAME4SAP  Kip-ft Units  PAGE 4
 April 29, 2001 14:53

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 J O I N T   F O R C E S   Load Case  WIND2

    JOINT    GLOBAL-X    GLOBAL-Y    GLOBAL-Z   GLOBAL-XX   GLOBAL-YY
GLOBAL-ZZ

       2       9.400       0.000       0.000       0.000       0.000
0.000

 SAP2000 v6.13 File: FRAME4SAP  Kip-ft Units  PAGE 5
 April 29, 2001 14:53

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 J O I N T   F O R C E S   Load Case  WIND3

    JOINT    GLOBAL-X    GLOBAL-Y    GLOBAL-Z   GLOBAL-XX   GLOBAL-YY
GLOBAL-ZZ

       4       2.500       0.000       0.000       0.000       0.000
0.000

 SAP2000 v6.13 File: FRAME4SAP  Kip-ft Units  PAGE 6
 April 29, 2001 14:53

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 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  LIVE

    FRAME        TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B

       3       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
       4       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000

 SAP2000 v6.13 File: FRAME4SAP  Kip-ft Units  PAGE 7
 April 29, 2001 14:53

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 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  DEAD

    FRAME        TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B
```

3	FORCE	LOCAL-2	0.0000	-0.2500	1.0000	-0.2500
4	FORCE	LOCAL-2	0.0000	-0.2500	1.0000	-0.2500

```
STAAD PLANE RESEARCH FRAME 4
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 25.; 3 40. 28.3 ; 4 80. 25.; 5 80. 0.
MEMBER INCIDENCE
1 1 2 ; 2 2 3 ; 3 3 4 ; 4 4 5
MEMBER PROPERTY AMERICAN
1 4 TABLE ST W18X143
2 3 TABLE ST W10X49
UNIT INCHES
CONSTANTS
E 29000.0 ALL
SUPPORT
1 5 PINNED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FEET
LOADING 1 DEAD
MEMBER LOAD
2 3 UNIFORM Y -0.25
LOADING 2 LIVE
MEMBER LOAD
2 3 UNIFORM GY -0.5
LOADING 3 COMBINATION
REPEAT LOAD
1 1.2 2 1.6
JOINT LOAD
2 FX 7.52
3 FX 2.0
PERFORM ANALYSIS
PRINT MEMBER FORCES
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX E

COMPUTER PROGRAM INPUT FOR FRAME 4A

```
RISA-3D, Frame 4a

Materials
STL                 29000 11154 0.3 0.65 0.49 50

Sections
10X49               W10X49                            STL                   14.4
1.2 1.2 93.4 272 1.39
18X143              W18X143                           STL                   42.1
1.2 1.2 311 2750 19.4

Joint Coordinates
N1                  0 0 0 0
N2                  0 25 0 0
N3                  40 38.3 0 0
N4                  80 25 0 0
N5                  80 0 0 0

Boundary Conditions
N1                   Reaction Reaction Fixed Fixed
N5                   Reaction Reaction Fixed Fixed
N2                     Fixed
N3                     Fixed
N4                     Fixed

Member Data
M1                   N1                    N2
0.0 18X143                 0.0 0.0   25
M2                   N2                    N3
0.0 10X49                  0.0 0.0   42.1532
M3                   N3                    N4
0.0 10X49                  0.0 0.0   42.1532
M4                   N4                    N5
0.0 18X143                 0.0 0.0   25

Distributed Load Patterns
MEMBER2D             y -0.25 -0.25 0 0
MEMBER3D             y -0.25 -0.25 0 0
MEMBER2L             Y -0.5 -0.5 0 0
MEMBER3L             Y -0.5 -0.5 0 0

Basic Load Case Data
1 Wind Load                     None   2 0 0 0
2 Dead Load                     None   0 0 2 0
3 Live Load                     None   0 0 2 0
4 Reaction, Mlt                 None   2 0 0 0
5 Reaction, Mlt                 None   2 0 0 0

Joint Loads; BLC1: Wind Load
N2                   L X 9.4
N3                   L X 10.1

Joint Loads; BLC4: Reaction, Mlt
N3                   L X -391.889
N4                   L X 401.659

Joint Loads; BLC5: Reaction, Mlt
```

```
N4                    L X 113.8
N3                    L X -98.1

Member Distributed Load Pattern; BLC2: Dead Load
M2                    N2                    N3                    MEMBER2D
1
M3                    N3                    N4                    MEMBER3D
1

Member Distributed Load Pattern; BLC3: Live Load
M2                    N2                    N3                    MEMBER2L
1
M3                    N3                    N4                    MEMBER3L
1

Load Combinations
1 1st Order
n n n n 1 1                  0.8 2                  1.2 3
1.6                    0                      0                     0
0                     0
2 2nd Order
n n y n 1 1                  0.8 2                  1.2 3
1.6                    0                      0                     0
0                     0
3 Mnt
n n n n 1 1                  0.8 2                  1.2 3
1.6                    0                      0                     0
0                     0
4 Mlt
n n n n 1 5                  1                    0                     0
0                     0                     0                     0
0
```

```
 SAP2000 v6.13 File: FRAME4ASAP  Kip-ft Units  PAGE 1
 April 29, 2001 14:53

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 S T A T I C   L O A D   C A S E S

       STATIC        CASE     SELF WT
         CASE        TYPE      FACTOR

         DEAD        DEAD      0.0000
         LIVE        LIVE      0.0000
         WIND        WIND      0.0000

 SAP2000 v6.13 File: FRAME4ASAP  Kip-ft Units  PAGE 2
 April 29, 2001 14:53

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 J O I N T   D A T A

    JOINT       GLOBAL-X       GLOBAL-Y       GLOBAL-Z     RESTRAINTS
ANGLE-A   ANGLE-B   ANGLE-C

        1      -40.00000        0.00000        0.00000    1 1 1 1 0 1
0.000     0.000     0.000
        2      -40.00000        0.00000       25.00000    0 0 0 0 0 0
0.000     0.000     0.000
        3        0.00000        0.00000       38.50000    0 0 0 0 0 0
0.000     0.000     0.000
        4       40.00000        0.00000       25.00000    0 0 0 0 0 0
0.000     0.000     0.000
        5       40.00000        0.00000        0.00000    1 1 1 1 0 1
0.000     0.000     0.000

 SAP2000 v6.13 File: FRAME4ASAP  Kip-ft Units  PAGE 3
 April 29, 2001 14:53

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 F R A M E   E L E M E N T   D A T A

    FRAME   JNT-1   JNT-2   SECTION     ANGLE  RELEASES  SEGMENTS         R1
R2    FACTOR      LENGTH

        1       1       2   W18X143     0.000    000000         1     0.000
0.000     1.000      25.000
        2       2       3    W10X49     0.000    000000         1     0.000
0.000     1.000      42.217
        3       3       4    W10X49     0.000    000000         1     0.000
0.000     1.000      42.217
        4       5       4   W18X143     0.000    000000         1     0.000
0.000     1.000      25.000
```

SAP2000 v6.13 File: FRAME4ASAP Kip-ft Units PAGE 4
April 29, 2001 14:53

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J O I N T   F O R C E S   Load Case WIND

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	GLOBAL-XX	GLOBAL-YY	GLOBAL-ZZ
2	9.400	0.000	0.000	0.000	0.000	0.000
3	10.100	0.000	0.000	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME4ASAP Kip-ft Units PAGE 5
April 29, 2001 14:53

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F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case DEAD

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
2	FORCE	LOCAL-2	0.0000	-0.2500	1.0000	-0.2500
3	FORCE	LOCAL-2	0.0000	-0.2500	1.0000	-0.2500

SAP2000 v6.13 File: FRAME4ASAP Kip-ft Units PAGE 6
April 29, 2001 14:53

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F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case LIVE

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
2	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
3	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000

```
STAAD PLANE RESEARCH FRAME 4A
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 25.; 3 40. 38.3 ; 4 80. 25.; 5 80. 0.
MEMBER INCIDENCE
1 1 2 ; 2 2 3 ; 3 3 4 ; 4 4 5
MEMBER PROPERTY AMERICAN
1 4 TABLE ST W18X143
2 3 TABLE ST W10X49
UNIT INCHES
CONSTANTS
E 29000.0 ALL
SUPPORT
1 5 PINNED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FEET
LOADING 1 DEAD
MEMBER LOAD
2 3 UNIFORM Y -0.25
LOADING 2 LIVE
MEMBER LOAD
2 3 UNIFORM GY -0.5
LOADING 3 COMBINATION
REPEAT LOAD
1 1.2 2 1.6
JOINT LOAD
2 FX 7.52
3 FX 8.08
PERFORM ANALYSIS
PRINT MEMBER FORCES
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX F

COMPUTER PROGRAM INPUT FOR FRAME 5

```
RISA-3D, Frame 5

Materials
STL                 29000 11154 0.3 0.65 0.49 50

Sections
10X33               W10X33                          STL                 9.71
1.2 1.2 36.6 170 0.58
12X58               W12X58                          STL                 17
1.2 1.2 107 475 2.1
12X45               W12X45                          STL                 13.2
1.2 1.2 50 350 1.31

Joint Coordinates
N1                  0 0 0 0
N2                  0 25 0 0
N3                  40 0 0 0
N4                  40 25 0 0
N5                  80 0 0 0
N6                  80 25 0 0
N7                  120 0 0 0
N8                  120 25 0 0
N9                  160 0 0 0
N10                 160 25 0 0

Boundary Conditions
N1                   Reaction Reaction Fixed Fixed
N2                     Fixed
N3                   Reaction Reaction Fixed Fixed
N4                     Fixed
N5                   Reaction Reaction Fixed Fixed
N6                     Fixed
N7                   Reaction Reaction Fixed Fixed
N8                     Fixed
N9                   Reaction Reaction Fixed Fixed
N10                    Fixed

Member Data
M1                   N1                     N2
0.0 12X58                  0.0 0.0   25
M2                   N3                     N4
0.0 10X33                 BenPIN 0.0 0.0   25
M3                   N5                     N6
0.0 10X33                 BenPIN 0.0 0.0   25
M4                   N7                     N8
0.0 10X33                 BenPIN 0.0 0.0   25
M5                   N9                     N10
0.0 12X58                  0.0 0.0   25
M6                   N2                     N4
0.0 12X58                  0.0 0.0   40
M7                   N4                     N6
0.0 12X45                  0.0 0.0   40
M8                   N6                     N8
0.0 12X45                  0.0 0.0   40
M9                   N8                     N10
0.0 12X58                  0.0 0.0   40
```

Distributed Load Patterns
DEAD   Y -0.25 -0.25 0 0
LIVE   Y -0.5 -0.5 0 0

Basic Load Case Data
1 Wind   None   1 0 0 0
2 Dead   None   0 0 4 0
3 Live   None   0 0 4 0
4 Reaction, Mlt   None   1 0 0 0

Joint Loads; BLC1: Wind
N2   L X 9.4

Joint Loads; BLC4: Reaction, Mlt
N10   L X 7.489

Member Distributed Loads; BLC2: Dead
M6   N2   N4   DEAD
1
M7   N4   N6   DEAD
1
M8   N6   N8   DEAD
1
M9   N8   N10   DEAD
1

Member Distributed Loads; BLC3: Live
M6   N2   N4   LIVE
1
M7   N4   N6   LIVE
1
M8   N6   N8   LIVE
1
M9   N8   N10   LIVE
1

Load Combinations
1 1st Order
n n n n 1 1   0.8 2   1.2 3
1.6   0   0   0
0   0
2 2nd Order
n n y n 1 1   0.8 2   1.2 3
1.6   0   0   0
0   0
3 Mnt
n n n n 1 1   0.8 2   1.2 3
1.6   0   0   0
0   0
4 Mlt
n n n n 1 4   1   0   0
0   0   0   0
0

SAP2000 v6.13 File: FRAME5SAP Kip-ft Units PAGE 1
April 29, 2001 14:53

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S T A T I C   L O A D   C A S E S

STATIC CASE	CASE TYPE	SELF WT FACTOR
DEAD	DEAD	0.0000
LIVE	LIVE	0.0000
WIND	WIND	0.0000

SAP2000 v6.13 File: FRAME5SAP Kip-ft Units PAGE 2
April 29, 2001 14:53

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J O I N T   D A T A

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	RESTRAINTS	ANGLE-A	ANGLE-B	ANGLE-C
1	-80.00000	0.00000	0.00000	1 1 1 1 0 0	0.000	0.000	0.000
2	-80.00000	0.00000	25.00000	0 1 0 1 0 0	0.000	0.000	0.000
3	-40.00000	0.00000	0.00000	1 1 1 1 0 0	0.000	0.000	0.000
4	-40.00000	0.00000	25.00000	0 1 0 1 0 0	0.000	0.000	0.000
5	0.00000	0.00000	0.00000	1 1 1 1 0 0	0.000	0.000	0.000
6	0.00000	0.00000	25.00000	0 1 0 1 0 0	0.000	0.000	0.000
7	40.00000	0.00000	0.00000	1 1 1 1 0 0	0.000	0.000	0.000
8	40.00000	0.00000	25.00000	0 1 0 1 0 0	0.000	0.000	0.000
9	80.00000	0.00000	0.00000	1 1 1 1 0 0	0.000	0.000	0.000
10	80.00000	0.00000	25.00000	0 1 0 1 0 0	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME5SAP Kip-ft Units PAGE 3
April 29, 2001 14:53

Virginia Tech

F R A M E   E L E M E N T   D A T A

FRAME	JNT-1	JNT-2	SECTION	ANGLE	RELEASES	SEGMENTS	R1	R2	FACTOR	LENGTH
1	1	2	W12X58	0.000	000000	2	0.000	0.000	1.000	25.000
2	3	4	W10X33	0.000	022222	2	0.000	0.000	1.000	25.000
3	5	6	W10X33	0.000	022222	2	0.000	0.000	1.000	25.000
4	7	8	W10X33	0.000	022222	2	0.000	0.000	1.000	25.000
5	9	10	W12X58	0.000	000000	2	0.000	0.000	1.000	25.000
6	2	4	W12X58	0.000	000000	2	0.000	0.000	1.000	40.000
7	4	6	W12X45	0.000	000000	2	0.000	0.000	1.000	40.000
8	6	8	W12X45	0.000	000000	2	0.000	0.000	1.000	40.000
9	8	10	W12X58	0.000	000000	2	0.000	0.000	1.000	40.000

SAP2000 v6.13 File: FRAME5SAP Kip-ft Units PAGE 4
April 29, 2001 14:53

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J O I N T   F O R C E S   Load Case WIND

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	GLOBAL-XX	GLOBAL-YY	GLOBAL-ZZ
2	9.400	0.000	0.000	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME5SAP Kip-ft Units PAGE 5
April 29, 2001 14:53

Virginia Tech

F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case DEAD

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
6	FORCE	GLOBAL-Z	0.0000	-0.2500	1.0000	-0.2500
7	FORCE	GLOBAL-Z	0.0000	-0.2500	1.0000	-0.2500
8	FORCE	GLOBAL-Z	0.0000	-0.2500	1.0000	-0.2500
9	FORCE	GLOBAL-Z	0.0000	-0.2500	1.0000	-0.2500

SAP2000 v6.13 File: FRAME5SAP Kip-ft Units PAGE 6

April 29, 2001 14:53

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F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case LIVE

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
6	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
7	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
8	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
9	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000

```
STAAD PLANE RESEARCH FRAME 5
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 25.; 3 40. 0.; 4 40. 25.; 5 80. 0.; 6 80. 25.; 7 120. 0.;
8 120. 25.; 9 160. 0.; 10 160. 25.
MEMBER INCIDENCE
1 1 2; 2 3 4; 3 5 6; 4 7 8; 5 9 10; 6 2 4; 7 4 6; 8 6 8; 9 8 10
MEMBER PROPERTY AMERICAN
1 5 TABLE ST W12X58
2 3 4 TABLE ST W10X33
7 8 TABLE ST W12X45
6 9 TABLE ST W12X58
MEMBER RELEASE
2 3 4 END MZ
UNIT INCHES
CONSTANTS
E 29000.0 ALL
PRINT MEMBER INFORMATION
SUPPORT
1 3 5 7 9 PINNED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FT
LOADING 1 DEAD
MEMBER LOAD
6 7 8 9 UNIFORM GY -0.25
LOADING 2 LIVE
MEMBER LOAD
6 7 8 9 UNIFORM GY -0.5
LOADING 3 COMBINATION
REPEAT LOAD
1 1.2 2 1.6
JOINT LOAD
2 FX 7.52
PERFORM ANALYSIS
PRINT MEMBER FORCES
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX G

COMPUTER PROGRAM INPUT FOR FRAME 5A

RISA-3D, Frame 5a

Materials

```
STL                 29000 11154 0.3 0.65 0.49 50
```

Sections

```
10X33               W10X33                          STL                 9.71
1.2 1.2 36.6 170 0.58
12X58               W12X58                          STL                 17
1.2 1.2 107 475 2.1
12X45               W12X45                          STL                 13.2
1.2 1.2 50 350 1.31
```

Joint Coordinates

```
N1                  0 0 0 0
N2                  0 25 0 0
N3                  40 25 0 0
N4                  80 25 0 0
N5                  120 25 0 0
N6                  160 0 0 0
N7                  160 25 0 0
```

Boundary Conditions

```
N1                   Reaction Reaction Fixed Fixed
N2                     Fixed
N3                    Reaction Fixed
N4                    Reaction Fixed
N5                    Reaction Fixed
N6                   Reaction Reaction Fixed Fixed
N7                     Fixed
```

Member Data

```
M1                   N1                     N2
0.0 12X58                  0.0 0.0   25
M5                   N6                     N7
0.0 12X58                  0.0 0.0   25
M6                   N2                     N3
0.0 12X58                  0.0 0.0   40
M7                   N3                     N4
0.0 12X45                  0.0 0.0   40
M8                   N4                     N5
0.0 12X45                  0.0 0.0   40
M9                   N5                     N7
0.0 12X58                  0.0 0.0   40
```

Distributed Load Patterns

```
DEAD                 Y -0.25 -0.25 0 0
LIVE                 Y -0.5 -0.5 0 0
```

Basic Load Case Data

```
1 Wind                          None   1 0 0 0
2 Dead                          None   0 0 4 0
3 Live                          None   0 0 4 0
4 Reaction, Mlt                 None   1 0 0 0
```

Joint Loads; BLC1: Wind

N2 L X 9.4

Joint Loads; BLC4: Reaction, Mlt
N7 L X 7.489

Member Distributed Loads; BLC2: Dead
M6 N2 N3 DEAD
1
M7 N3 N4 DEAD
1
M8 N4 N5 DEAD
1
M9 N5 N7 DEAD
1

Member Distributed Loads; BLC3: Live
M6 N2 N3 LIVE
1
M7 N3 N4 LIVE
1
M8 N4 N5 LIVE
1
M9 N5 N7 LIVE
1

Load Combinations
1 1st Order
n n n n 1 1 0.8 2 1.2 3
1.6 0 0 0
0 0
2 2nd Order
n n y n 1 1 0.8 2 1.2 3
1.6 0 0 0
0 0
3 Mnt
n n n n 1 1 0.8 2 1.2 3
1.6 0 0 0
0 0
4 Mlt
n n n n 1 4 1 0 0
0 0 0 0
0

SAP2000 v6.13 File: FRAME5ASAP Kip-ft Units PAGE 1
April 29, 2001 14:53

Frame 5a   1st Order Reactions

S T A T I C   L O A D   C A S E S

STATIC CASE	CASE TYPE	SELF WT FACTOR
DEAD	DEAD	0.0000
LIVE	LIVE	0.0000
WIND	WIND	0.0000

SAP2000 v6.13 File: FRAME5ASAP Kip-ft Units PAGE 2
April 29, 2001 14:53

Frame 5a   1st Order Reactions

J O I N T   D A T A

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	RESTRAINTS	ANGLE-A	ANGLE-B	ANGLE-C
1	-80.00000	0.00000	0.00000	1 1 1 1 0 0	0.000	0.000	0.000
2	-80.00000	0.00000	25.00000	0 1 0 1 0 0	0.000	0.000	0.000
3	-40.00000	0.00000	25.00000	0 1 1 1 0 0	0.000	0.000	0.000
4	0.00000	0.00000	25.00000	0 1 1 1 0 0	0.000	0.000	0.000
5	40.00000	0.00000	25.00000	0 1 1 1 0 0	0.000	0.000	0.000
6	80.00000	0.00000	25.00000	0 1 0 1 0 0	0.000	0.000	0.000
7	80.00000	0.00000	0.00000	1 1 1 1 0 0	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME5ASAP Kip-ft Units PAGE 3
April 29, 2001 14:53

Frame 5a   1st Order Reactions

F R A M E   E L E M E N T   D A T A

FRAME	JNT-1	JNT-2	SECTION	ANGLE	RELEASES	SEGMENTS	R1	R2	FACTOR	LENGTH
1	1	2	W12X58	0.000	000000	2	0.000	0.000	1.000	25.000
5	7	6	W12X58	0.000	000000	2	0.000	0.000	1.000	25.000

```
        6       2       3    W12X58     0.000    000000         2     0.000
0.000     1.000      40.000
        7       3       4    W12X45     0.000    000000         2     0.000
0.000     1.000      40.000
        8       4       5    W12X45     0.000    000000         2     0.000
0.000     1.000      40.000
        9       5       6    W12X58     0.000    000000         2     0.000
0.000     1.000      40.000

 SAP2000 v6.13 File: FRAME5ASAP  Kip-ft Units  PAGE 4
 April 29, 2001 14:53

 Frame 5a   1st Order Reactions


 J O I N T   F O R C E S   Load Case  WIND

    JOINT    GLOBAL-X    GLOBAL-Y    GLOBAL-Z   GLOBAL-XX   GLOBAL-YY
GLOBAL-ZZ

        2       9.400       0.000       0.000       0.000       0.000
0.000

 SAP2000 v6.13 File: FRAME5ASAP  Kip-ft Units  PAGE 5
 April 29, 2001 14:53

 Frame 5a   1st Order Reactions


 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  DEAD

    FRAME        TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B

        6       FORCE    GLOBAL-Z      0.0000     -0.2500      1.0000     -
0.2500
        7       FORCE    GLOBAL-Z      0.0000     -0.2500      1.0000     -
0.2500
        8       FORCE    GLOBAL-Z      0.0000     -0.2500      1.0000     -
0.2500
        9       FORCE    GLOBAL-Z      0.0000     -0.2500      1.0000     -
0.2500

 SAP2000 v6.13 File: FRAME5ASAP  Kip-ft Units  PAGE 6
 April 29, 2001 14:53

 Frame 5a   1st Order Reactions


 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  LIVE

    FRAME        TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B

        6       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
```

7	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
8	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
9	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000

```
STAAD PLANE RESEARCH FRAME 5a
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 25.; 3 40. 25.; 4 80. 25.;
5 120. 25.; 6 160. 0.; 7 160. 25.
MEMBER INCIDENCE
1 1 2; 5 6 7; 6 2 3; 7 3 4; 8 4 5; 9 5 7
MEMBER PROPERTY AMERICAN
1 5 TABLE ST W12X58
7 8 TABLE ST W12X45
6 9 TABLE ST W12X58
UNIT INCHES
CONSTANTS
E 29000.0 ALL
PRINT MEMBER INFORMATION
SUPPORT
1 6 PINNED
3 4 5 FIXED BUT FX MZ
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FT
LOADING 1 DEAD
MEMBER LOAD
6 7 8 9 UNIFORM GY -0.25
LOADING 2 LIVE
MEMBER LOAD
6 7 8 9 UNIFORM GY -0.5
LOADING 3 COMBINATION
REPEAT LOAD
1 1.2 2 1.6
JOINT LOAD
2 FX 7.52
PERFORM ANALYSIS
PRINT MEMBER FORCES
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX H

COMPUTER PROGRAM INPUT FOR FRAME 6

RISA-3D, Frame 6

Materials

STL	29000 11154 0.3 0.65 0.49 50

Sections

W14X283 W14X283 STL 83.3
1.2 1.2 1440 3840 104
W14X426 W14X426 STL 125
1.2 1.2 2360 6600 331
W14X550 W14X550 STL 162
1.2 1.2 3250 9430 670
W14X605 W14X605 STL 178
1.2 1.2 3680 10800 870
W14X665 W14X665 STL 196
1.2 1.2 4170 12400 1120
W14X730 W14X730 STL 215
1.2 1.2 4720 14300 1450
W36X150 W36X150 STL 44.2
1.2 1.2 270 9040 10.1
W36X194 W36X194 STL 57
1.2 1.2 375 12100 22.2
W36X230 W36X230 STL 67.6
1.2 1.2 940 15000 28.6
W36X260 W36X260 STL 76.5
1.2 1.2 1090 17300 41.5
W36X280 W36X280 STL 82.4
1.2 1.2 1200 18900 52.6
W36X300 W36X300 STL 88.3
1.2 1.2 1300 20300 64.2

Joint Coordinates

N1	0 0 0 0
N2	30 0 0 0
N3	60 0 0 0
N4	90 0 0 0
N5	0 15 0 0
N6	30 15 0 0
N7	60 15 0 0
N8	90 15 0 0
N9	0 30 0 0
N10	30 30 0 0
N11	60 30 0 0
N12	90 30 0 0
N13	0 45 0 0
N14	30 45 0 0
N15	60 45 0 0
N16	90 45 0 0
N17	0 60 0 0
N18	30 60 0 0
N19	60 60 0 0
N20	90 60 0 0
N21	0 75 0 0
N22	30 75 0 0
N23	60 75 0 0
N24	90 75 0 0

```
N25                    0 90 0 0
N26                    30 90 0 0
N27                    60 90 0 0
N28                    90 90 0 0
N29                    0 105 0 0
N30                    30 105 0 0
N31                    60 105 0 0
N32                    90 105 0 0
N33                    0 120 0 0
N34                    30 120 0 0
N35                    60 120 0 0
N36                    90 120 0 0
N37                    0 135 0 0
N38                    30 135 0 0
N39                    60 135 0 0
N40                    90 135 0 0
N41                    0 150 0 0
N42                    30 150 0 0
N43                    60 150 0 0
N44                    90 150 0 0
N45                    0 165 0 0
N46                    30 165 0 0
N47                    60 165 0 0
N48                    90 165 0 0
N49                    0 180 0 0
N50                    30 180 0 0
N51                    60 180 0 0
N52                    90 180 0 0
N53                    0 195 0 0
N54                    30 195 0 0
N55                    60 195 0 0
N56                    90 195 0 0
N57                    0 210 0 0
N58                    30 210 0 0
N59                    60 210 0 0
N60                    90 210 0 0
N61                    0 225 0 0
N62                    30 225 0 0
N63                    60 225 0 0
N64                    90 225 0 0

Boundary Conditions
N1                      Reaction Reaction Fixed Fixed Fixed Reaction
N2                      Reaction Reaction Fixed Fixed Fixed Reaction
N3                      Reaction Reaction Fixed Fixed Fixed Reaction
N4                      Reaction Reaction Fixed Fixed Fixed Reaction
N64                       Fixed
N60                       Fixed
N5                        Fixed
N6                        Fixed
N7                        Fixed
N8                        Fixed
N9                        Fixed
N10                       Fixed
N11                       Fixed
N12                       Fixed
N13                       Fixed
```

N14	Fixed
N15	Fixed
N16	Fixed
N17	Fixed
N18	Fixed
N19	Fixed
N20	Fixed
N21	Fixed
N22	Fixed
N23	Fixed
N24	Fixed
N25	Fixed
N26	Fixed
N27	Fixed
N28	Fixed
N29	Fixed
N30	Fixed
N31	Fixed
N32	Fixed
N33	Fixed
N34	Fixed
N35	Fixed
N36	Fixed
N37	Fixed
N38	Fixed
N39	Fixed
N40	Fixed
N41	Fixed
N42	Fixed
N43	Fixed
N44	Fixed
N45	Fixed
N46	Fixed
N47	Fixed
N48	Fixed
N49	Fixed
N50	Fixed
N51	Fixed
N52	Fixed
N53	Fixed
N54	Fixed
N55	Fixed
N56	Fixed
N57	Fixed
N58	Fixed
N59	Fixed
N61	Fixed
N62	Fixed
N63	Fixed

Member Data

```
M1                N1                    N5
0.0 W14X730            0.0 0.0    15
M2                N5                    N9
0.0 W14X730            0.0 0.0    15
M3                N9                    N13
0.0 W14X665            0.0 0.0    15
```

```
M4                      N13                     N17
0.0 W14X665                   0.0 0.0    15
M5                      N17                     N21
0.0 W14X665                   0.0 0.0    15
M6                      N21                     N25
0.0 W14X665                   0.0 0.0    15
M7                      N25                     N29
0.0 W14X605                   0.0 0.0    15
M8                      N29                     N33
0.0 W14X605                   0.0 0.0    15
M9                      N33                     N37
0.0 W14X550                   0.0 0.0    15
M10                     N37                     N41
0.0 W14X550                   0.0 0.0    15
M11                     N41                     N45
0.0 W14X426                   0.0 0.0    15
M12                     N45                     N49
0.0 W14X426                   0.0 0.0    15
M13                     N49                     N53
0.0 W14X283                   0.0 0.0    15
M14                     N53                     N57
0.0 W14X283                   0.0 0.0    15
M15                     N57                     N61
0.0 W14X283                   0.0 0.0    15
M16                     N2                      N6
0.0 W14X730                   0.0 0.0    15
M17                     N6                      N10
0.0 W14X730                   0.0 0.0    15
M18                     N10                     N14
0.0 W14X665                   0.0 0.0    15
M19                     N14                     N18
0.0 W14X665                   0.0 0.0    15
M20                     N18                     N22
0.0 W14X665                   0.0 0.0    15
M21                     N22                     N26
0.0 W14X665                   0.0 0.0    15
M22                     N26                     N30
0.0 W14X605                   0.0 0.0    15
M23                     N30                     N34
0.0 W14X605                   0.0 0.0    15
M24                     N34                     N38
0.0 W14X550                   0.0 0.0    15
M25                     N38                     N42
0.0 W14X550                   0.0 0.0    15
M26                     N42                     N46
0.0 W14X426                   0.0 0.0    15
M27                     N46                     N50
0.0 W14X426                   0.0 0.0    15
M28                     N50                     N54
0.0 W14X283                   0.0 0.0    15
M29                     N54                     N58
0.0 W14X283                   0.0 0.0    15
M30                     N58                     N62
0.0 W14X283                   0.0 0.0    15
M31                     N3                      N7
0.0 W14X730                   0.0 0.0    15
```

M32		N7				N11
0.0	W14X730		0.0	0.0	15	
M33		N11				N15
0.0	W14X665		0.0	0.0	15	
M34		N15				N19
0.0	W14X665		0.0	0.0	15	
M35		N19				N23
0.0	W14X665		0.0	0.0	15	
M36		N23				N27
0.0	W14X665		0.0	0.0	15	
M37		N27				N31
0.0	W14X605		0.0	0.0	15	
M38		N31				N35
0.0	W14X605		0.0	0.0	15	
M39		N35				N39
0.0	W14X550		0.0	0.0	15	
M40		N39				N43
0.0	W14X550		0.0	0.0	15	
M41		N43				N47
0.0	W14X426		0.0	0.0	15	
M42		N47				N51
0.0	W14X426		0.0	0.0	15	
M43		N51				N55
0.0	W14X283		0.0	0.0	15	
M44		N55				N59
0.0	W14X283		0.0	0.0	15	
M45		N59				N63
0.0	W14X283		0.0	0.0	15	
M46		N4				N8
0.0	W14X730		0.0	0.0	15	
M47		N8				N12
0.0	W14X730		0.0	0.0	15	
M48		N12				N16
0.0	W14X665		0.0	0.0	15	
M49		N16				N20
0.0	W14X665		0.0	0.0	15	
M50		N20				N24
0.0	W14X665		0.0	0.0	15	
M51		N24				N28
0.0	W14X665		0.0	0.0	15	
M52		N28				N32
0.0	W14X605		0.0	0.0	15	
M53		N32				N36
0.0	W14X605		0.0	0.0	15	
M54		N36				N40
0.0	W14X550		0.0	0.0	15	
M55		N40				N44
0.0	W14X550		0.0	0.0	15	
M56		N44				N48
0.0	W14X426		0.0	0.0	15	
M57		N48				N52
0.0	W14X426		0.0	0.0	15	
M58		N52				N56
0.0	W14X283		0.0	0.0	15	
M59		N56				N60
0.0	W14X283		0.0	0.0	15	

```
M60                     N60                     N64
0.0 W14X283                   0.0 0.0   15
M61                     N5                      N6
0.0 W36X300                   0.0 0.0   30
M62                     N6                      N7
0.0 W36X300                   0.0 0.0   30
M63                     N7                      N8
0.0 W36X300                   0.0 0.0   30
M64                     N9                      N10
0.0 W36X300                   0.0 0.0   30
M65                     N10                     N11
0.0 W36X300                   0.0 0.0   30
M66                     N11                     N12
0.0 W36X300                   0.0 0.0   30
M67                     N13                     N14
0.0 W36X300                   0.0 0.0   30
M68                     N14                     N15
0.0 W36X300                   0.0 0.0   30
M69                     N15                     N16
0.0 W36X300                   0.0 0.0   30
M70                     N17                     N18
0.0 W36X300                   0.0 0.0   30
M71                     N18                     N19
0.0 W36X300                   0.0 0.0   30
M72                     N19                     N20
0.0 W36X300                   0.0 0.0   30
M73                     N21                     N22
0.0 W36X280                   0.0 0.0   30
M74                     N22                     N23
0.0 W36X280                   0.0 0.0   30
M75                     N23                     N24
0.0 W36X280                   0.0 0.0   30
M76                     N25                     N26
0.0 W36X280                   0.0 0.0   30
M77                     N26                     N27
0.0 W36X280                   0.0 0.0   30
M78                     N27                     N28
0.0 W36X280                   0.0 0.0   30
M79                     N29                     N30
0.0 W36X260                   0.0 0.0   30
M80                     N30                     N31
0.0 W36X260                   0.0 0.0   30
M81                     N31                     N32
0.0 W36X260                   0.0 0.0   30
M82                     N33                     N34
0.0 W36X260                   0.0 0.0   30
M83                     N34                     N35
0.0 W36X260                   0.0 0.0   30
M84                     N35                     N36
0.0 W36X260                   0.0 0.0   30
M85                     N37                     N38
0.0 W36X230                   0.0 0.0   30
M86                     N38                     N39
0.0 W36X230                   0.0 0.0   30
M87                     N39                     N40
0.0 W36X230                   0.0 0.0   30
```

```
M88                  N41                 N42
0.0 W36X230                0.0 0.0   30
M89                  N42                 N43
0.0 W36X230                0.0 0.0   30
M90                  N43                 N44
0.0 W36X230                0.0 0.0   30
M91                  N45                 N46
0.0 W36X194                0.0 0.0   30
M92                  N46                 N47
0.0 W36X194                0.0 0.0   30
M93                  N47                 N48
0.0 W36X194                0.0 0.0   30
M94                  N49                 N50
0.0 W36X194                0.0 0.0   30
M95                  N50                 N51
0.0 W36X194                0.0 0.0   30
M96                  N51                 N52
0.0 W36X194                0.0 0.0   30
M97                  N53                 N54
0.0 W36X150                0.0 0.0   30
M98                  N54                 N55
0.0 W36X150                0.0 0.0   30
M99                  N55                 N56
0.0 W36X150                0.0 0.0   30
M100                 N57                 N58
0.0 W36X150                0.0 0.0   30
M101                 N58                 N59
0.0 W36X150                0.0 0.0   30
M102                 N59                 N60
0.0 W36X150                0.0 0.0   30
M103                 N61                 N62
0.0 W36X150                0.0 0.0   30
M104                 N62                 N63
0.0 W36X150                0.0 0.0   30
M105                 N63                 N64
0.0 W36X150                0.0 0.0   30

Distributed Load Patterns
SNOW                 Y -1.2 -1.2 0 0
LIVE1                Y -3 -3 0 0
DEAD                 Y -0.5 -0.5 0 0

Basic Load Case Data
1 Wind                           None   16 1 0 0
2 Dead                           None   0 0 45 0
3 Live                           None   0 0 42 0
4 Snow                           None   0 0 3 0
5 Mlt                            None   15 0 0 0

Joint Loads; BLC1: Wind
N61                  L X 45
N57                  L X 90
N53                  L X 90
N49                  L X 75
N45                  L X 75
N41                  L X 75
N37                  L X 60
```

N33 L X 60
N29 L X 60
N25 L X 45
N21 L X 45
N17 L X 45
N13 L X 30
N9 L X 30
N5 L X 15
N1 L X 0

Joint Loads; BLC5: Mlt

N8	L X 18.598
N12	L X 17.075
N16	L X 27.596
N20	L X 33.43
N24	L X 36.684
N28	L X 37.129
N32	L X 47.14
N36	L X 46.528
N40	L X 53.369
N44	L X 54.136
N48	L X 64.06
N52	L X 59.178
N56	L X 69.839
N60	L X 71.2
N64	L X 36.496

Member Distributed Loads; BLC2: Dead

M61 1	N5	N6	DEAD
M62 1	N6	N7	DEAD
M63 1	N7	N8	DEAD
M64 1	N9	N10	DEAD
M65 1	N10	N11	DEAD
M66 1	N11	N12	DEAD
M67 1	N13	N14	DEAD
M68 1	N14	N15	DEAD
M69 1	N15	N16	DEAD
M70 1	N17	N18	DEAD
M71 1	N18	N19	DEAD
M72 1	N19	N20	DEAD
M73 1	N21	N22	DEAD
M74 1	N22	N23	DEAD

M75 1	N23	N24	DEAD
M76 1	N25	N26	DEAD
M77 1	N26	N27	DEAD
M78 1	N27	N28	DEAD
M79 1	N29	N30	DEAD
M80 1	N30	N31	DEAD
M81 1	N31	N32	DEAD
M82 1	N33	N34	DEAD
M83 1	N34	N35	DEAD
M84 1	N35	N36	DEAD
M85 1	N37	N38	DEAD
M86 1	N38	N39	DEAD
M87 1	N39	N40	DEAD
M88 1	N41	N42	DEAD
M89 1	N42	N43	DEAD
M90 1	N43	N44	DEAD
M91 1	N45	N46	DEAD
M92 1	N46	N47	DEAD
M93 1	N47	N48	DEAD
M94 1	N49	N50	DEAD
M95 1	N50	N51	DEAD
M96 1	N51	N52	DEAD
M97 1	N53	N54	DEAD
M98 1	N54	N55	DEAD
M99 1	N55	N56	DEAD
M100 1	N57	N58	DEAD
M101 1	N58	N59	DEAD
M102 1	N59	N60	DEAD

M103 1	N61	N62	DEAD
M104 1	N62	N63	DEAD
M105 1	N63	N64	DEAD

Member Distributed Loads; BLC3: Live

M61 1	N5	N6	LIVE1
M62 1	N6	N7	LIVE1
M63 1	N7	N8	LIVE1
M64 1	N9	N10	LIVE1
M65 1	N10	N11	LIVE1
M66 1	N11	N12	LIVE1
M67 1	N13	N14	LIVE1
M68 1	N14	N15	LIVE1
M69 1	N15	N16	LIVE1
M70 1	N17	N18	LIVE1
M71 1	N18	N19	LIVE1
M72 1	N19	N20	LIVE1
M73 1	N21	N22	LIVE1
M74 1	N22	N23	LIVE1
M75 1	N23	N24	LIVE1
M76 1	N25	N26	LIVE1
M77 1	N26	N27	LIVE1
M78 1	N27	N28	LIVE1
M79 1	N29	N30	LIVE1
M80 1	N30	N31	LIVE1
M81 1	N31	N32	LIVE1
M82 1	N33	N34	LIVE1
M83 1	N34	N35	LIVE1
M84 1	N35	N36	LIVE1

M85 N37 N38 LIVE1
1
M86 N38 N39 LIVE1
1
M87 N39 N40 LIVE1
1
M88 N41 N42 LIVE1
1
M89 N42 N43 LIVE1
1
M90 N43 N44 LIVE1
1
M91 N45 N46 LIVE1
1
M92 N46 N47 LIVE1
1
M93 N47 N48 LIVE1
1
M94 N49 N50 LIVE1
1
M95 N50 N51 LIVE1
1
M96 N51 N52 LIVE1
1
M97 N53 N54 LIVE1
1
M98 N54 N55 LIVE1
1
M99 N55 N56 LIVE1
1
M100 N57 N58 LIVE1
1
M101 N58 N59 LIVE1
1
M102 N59 N60 LIVE1
1

Member Distributed Loads; BLC4: Snow
M103 N61 N62 SNOW
1
M104 N62 N63 SNOW
1
M105 N63 N64 SNOW
1

Load Combinations
1 1st Order
n n n n 1 1 0.8 2 1.2 3
1.6 4 1.6 0 0
0 0
2 2nd Order
n n y n 1 1 0.8 2 1.2 3
1.6 4 1.6 0 0
0 0
3 Mnt
n n n n 1 1 0.8 2 1.2 3

1.6 4 1.6 0 0
0 0
4 Mlt
n n n n 1 5 1 0 0
0 0 0 0
0
5 Unfactored
n n n n 1 1 1 2 1 3 1 4
1 0 0 0
0

```
SAP2000 v6.13 File: FRAME6SAP  Kip-ft Units  PAGE 1
April 29, 2001 14:54

Virginia Tech


S T A T I C   L O A D   C A S E S

      STATIC        CASE      SELF WT
        CASE        TYPE       FACTOR

        DEAD        DEAD       0.0000
        WIND        WIND       0.0000
        LIVE        LIVE       0.0000
        SNOW        SNOW       0.0000

SAP2000 v6.13 File: FRAME6SAP  Kip-ft Units  PAGE 2
April 29, 2001 14:54

Virginia Tech


J O I N T   D A T A

   JOINT       GLOBAL-X       GLOBAL-Y       GLOBAL-Z     RESTRAINTS
ANGLE-A   ANGLE-B   ANGLE-C

       1      -45.00000        0.00000        0.00000    1 1 1 1 1 1
0.000     0.000     0.000
       2      -15.00000        0.00000        0.00000    1 1 1 1 1 1
0.000     0.000     0.000
       3       15.00000        0.00000        0.00000    1 1 1 1 1 1
0.000     0.000     0.000
       4       45.00000        0.00000        0.00000    1 1 1 1 1 1
0.000     0.000     0.000
       5      -45.00000        0.00000       15.00000    0 0 0 0 0 0
0.000     0.000     0.000
       6      -15.00000        0.00000       15.00000    0 0 0 0 0 0
0.000     0.000     0.000
       7       15.00000        0.00000       15.00000    0 0 0 0 0 0
0.000     0.000     0.000
       8       45.00000        0.00000       15.00000    0 0 0 0 0 0
0.000     0.000     0.000
       9      -45.00000        0.00000       30.00000    0 0 0 0 0 0
0.000     0.000     0.000
      10      -15.00000        0.00000       30.00000    0 0 0 0 0 0
0.000     0.000     0.000
      11       15.00000        0.00000       30.00000    0 0 0 0 0 0
0.000     0.000     0.000
      12       45.00000        0.00000       30.00000    0 0 0 0 0 0
0.000     0.000     0.000
      13      -45.00000        0.00000       45.00000    0 0 0 0 0 0
0.000     0.000     0.000
      14      -15.00000        0.00000       45.00000    0 0 0 0 0 0
0.000     0.000     0.000
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        15      15.00000        0.00000       45.00000    0 0 0 0 0 0
0.000     0.000     0.000
        16      45.00000        0.00000       45.00000    0 0 0 0 0 0
0.000     0.000     0.000
        17     -45.00000        0.00000       60.00000    0 0 0 0 0 0
0.000     0.000     0.000
        18     -15.00000        0.00000       60.00000    0 0 0 0 0 0
0.000     0.000     0.000
        19      15.00000        0.00000       60.00000    0 0 0 0 0 0
0.000     0.000     0.000
        20      45.00000        0.00000       60.00000    0 0 0 0 0 0
0.000     0.000     0.000
        21     -45.00000        0.00000       75.00000    0 0 0 0 0 0
0.000     0.000     0.000
        22     -15.00000        0.00000       75.00000    0 0 0 0 0 0
0.000     0.000     0.000
        23      15.00000        0.00000       75.00000    0 0 0 0 0 0
0.000     0.000     0.000
        24      45.00000        0.00000       75.00000    0 0 0 0 0 0
0.000     0.000     0.000
        25     -45.00000        0.00000       90.00000    0 0 0 0 0 0
0.000     0.000     0.000
        26     -15.00000        0.00000       90.00000    0 0 0 0 0 0
0.000     0.000     0.000
        27      15.00000        0.00000       90.00000    0 0 0 0 0 0
0.000     0.000     0.000
        28      45.00000        0.00000       90.00000    0 0 0 0 0 0
0.000     0.000     0.000
        29     -45.00000        0.00000      105.00000    0 0 0 0 0 0
0.000     0.000     0.000
        30     -15.00000        0.00000      105.00000    0 0 0 0 0 0
0.000     0.000     0.000
        31      15.00000        0.00000      105.00000    0 0 0 0 0 0
0.000     0.000     0.000
        32      45.00000        0.00000      105.00000    0 0 0 0 0 0
0.000     0.000     0.000
        33     -45.00000        0.00000      120.00000    0 0 0 0 0 0
0.000     0.000     0.000
        34     -15.00000        0.00000      120.00000    0 0 0 0 0 0
0.000     0.000     0.000
        35      15.00000        0.00000      120.00000    0 0 0 0 0 0
0.000     0.000     0.000
        36      45.00000        0.00000      120.00000    0 0 0 0 0 0
0.000     0.000     0.000
        37     -45.00000        0.00000      135.00000    0 0 0 0 0 0
0.000     0.000     0.000
        38     -15.00000        0.00000      135.00000    0 0 0 0 0 0
0.000     0.000     0.000
        39      15.00000        0.00000      135.00000    0 0 0 0 0 0
0.000     0.000     0.000
        40      45.00000        0.00000      135.00000    0 0 0 0 0 0
0.000     0.000     0.000
        41     -45.00000        0.00000      150.00000    0 0 0 0 0 0
0.000     0.000     0.000
        42     -15.00000        0.00000      150.00000    0 0 0 0 0 0
0.000     0.000     0.000
```

43	15.00000	0.00000	150.00000	0 0 0 0 0 0	0.000	0.000	0.000
44	45.00000	0.00000	150.00000	0 0 0 0 0 0	0.000	0.000	0.000
45	-45.00000	0.00000	165.00000	0 0 0 0 0 0	0.000	0.000	0.000
46	-15.00000	0.00000	165.00000	0 0 0 0 0 0	0.000	0.000	0.000
47	15.00000	0.00000	165.00000	0 0 0 0 0 0	0.000	0.000	0.000
48	45.00000	0.00000	165.00000	0 0 0 0 0 0	0.000	0.000	0.000
49	-45.00000	0.00000	180.00000	0 0 0 0 0 0	0.000	0.000	0.000
50	-15.00000	0.00000	180.00000	0 0 0 0 0 0	0.000	0.000	0.000
51	15.00000	0.00000	180.00000	0 0 0 0 0 0	0.000	0.000	0.000
52	45.00000	0.00000	180.00000	0 0 0 0 0 0	0.000	0.000	0.000
53	-45.00000	0.00000	195.00000	0 0 0 0 0 0	0.000	0.000	0.000
54	-15.00000	0.00000	195.00000	0 0 0 0 0 0	0.000	0.000	0.000
55	15.00000	0.00000	195.00000	0 0 0 0 0 0	0.000	0.000	0.000
56	45.00000	0.00000	195.00000	0 0 0 0 0 0	0.000	0.000	0.000
57	-45.00000	0.00000	210.00000	0 0 0 0 0 0	0.000	0.000	0.000
58	-15.00000	0.00000	210.00000	0 0 0 0 0 0	0.000	0.000	0.000
59	15.00000	0.00000	210.00000	0 0 0 0 0 0	0.000	0.000	0.000
60	45.00000	0.00000	210.00000	0 0 0 0 0 0	0.000	0.000	0.000
61	-45.00000	0.00000	225.00000	0 0 0 0 0 0	0.000	0.000	0.000
62	-15.00000	0.00000	225.00000	0 0 0 0 0 0	0.000	0.000	0.000
63	15.00000	0.00000	225.00000	0 0 0 0 0 0	0.000	0.000	0.000
64	45.00000	0.00000	225.00000	0 0 0 0 0 0	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME6SAP Kip-ft Units PAGE 3
April 29, 2001 14:54

Virginia Tech

F R A M E   E L E M E N T   D A T A

FRAME	JNT-1	JNT-2	SECTION	ANGLE	RELEASES	SEGMENTS	R1	R2	FACTOR	LENGTH

1	1	5	W14X730	0.000	000000	1	0.000	0.000	1.000	15.000
2	5	9	W14X730	0.000	000000	1	0.000	0.000	1.000	15.000
3	9	13	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
4	13	17	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
5	17	21	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
6	21	25	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
7	25	29	W14X605	0.000	000000	1	0.000	0.000	1.000	15.000
8	29	33	W14X605	0.000	000000	1	0.000	0.000	1.000	15.000
9	33	37	W14X550	0.000	000000	1	0.000	0.000	1.000	15.000
10	37	41	W14X550	0.000	000000	1	0.000	0.000	1.000	15.000
11	41	45	W14X426	0.000	000000	1	0.000	0.000	1.000	15.000
12	45	49	W14X426	0.000	000000	1	0.000	0.000	1.000	15.000
13	49	53	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
14	53	57	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
15	57	61	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
16	2	6	W14X730	0.000	000000	1	0.000	0.000	1.000	15.000
17	6	10	W14X730	0.000	000000	1	0.000	0.000	1.000	15.000
18	10	14	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
19	14	18	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
20	18	22	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
21	22	26	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
22	26	30	W14X605	0.000	000000	1	0.000	0.000	1.000	15.000
23	30	34	W14X605	0.000	000000	1	0.000	0.000	1.000	15.000
24	34	38	W14X550	0.000	000000	1	0.000	0.000	1.000	15.000
25	38	42	W14X550	0.000	000000	1	0.000	0.000	1.000	15.000
26	42	46	W14X426	0.000	000000	1	0.000	0.000	1.000	15.000
27	46	50	W14X426	0.000	000000	1	0.000	0.000	1.000	15.000
28	50	54	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000

29	54	58	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
30	58	62	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
31	3	7	W14X730	0.000	000000	1	0.000	0.000	1.000	15.000
32	7	11	W14X730	0.000	000000	1	0.000	0.000	1.000	15.000
33	11	15	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
34	15	19	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
35	19	23	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
36	23	27	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
37	27	31	W14X605	0.000	000000	1	0.000	0.000	1.000	15.000
38	31	35	W14X605	0.000	000000	1	0.000	0.000	1.000	15.000
39	35	39	W14X550	0.000	000000	1	0.000	0.000	1.000	15.000
40	39	43	W14X550	0.000	000000	1	0.000	0.000	1.000	15.000
41	43	47	W14X426	0.000	000000	1	0.000	0.000	1.000	15.000
42	47	51	W14X426	0.000	000000	1	0.000	0.000	1.000	15.000
43	51	55	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
44	55	59	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
45	59	63	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
46	4	8	W14X730	0.000	000000	1	0.000	0.000	1.000	15.000
47	8	12	W14X730	0.000	000000	1	0.000	0.000	1.000	15.000
48	12	16	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
49	16	20	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
50	20	24	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
51	24	28	W14X665	0.000	000000	1	0.000	0.000	1.000	15.000
52	28	32	W14X605	0.000	000000	1	0.000	0.000	1.000	15.000
53	32	36	W14X605	0.000	000000	1	0.000	0.000	1.000	15.000
54	36	40	W14X550	0.000	000000	1	0.000	0.000	1.000	15.000
55	40	44	W14X550	0.000	000000	1	0.000	0.000	1.000	15.000
56	44	48	W14X426	0.000	000000	1	0.000	0.000	1.000	15.000

57	48	52	W14X426	0.000	000000	1	0.000	0.000	1.000	15.000
58	52	56	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
59	56	60	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
60	60	64	W14X283	0.000	000000	1	0.000	0.000	1.000	15.000
61	5	6	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
62	6	7	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
63	7	8	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
64	9	10	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
65	10	11	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
66	11	12	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
67	13	14	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
68	14	15	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
69	15	16	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
70	17	18	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
71	18	19	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
72	19	20	W36X300	0.000	000000	1	0.000	0.000	1.000	30.000
73	21	22	W36X280	0.000	000000	1	0.000	0.000	1.000	30.000
74	22	23	W36X280	0.000	000000	1	0.000	0.000	1.000	30.000
75	23	24	W36X280	0.000	000000	1	0.000	0.000	1.000	30.000
76	25	26	W36X280	0.000	000000	1	0.000	0.000	1.000	30.000
77	26	27	W36X280	0.000	000000	1	0.000	0.000	1.000	30.000
78	27	28	W36X280	0.000	000000	1	0.000	0.000	1.000	30.000
79	29	30	W36X260	0.000	000000	1	0.000	0.000	1.000	30.000
80	30	31	W36X260	0.000	000000	1	0.000	0.000	1.000	30.000
81	31	32	W36X260	0.000	000000	1	0.000	0.000	1.000	30.000
82	33	34	W36X260	0.000	000000	1	0.000	0.000	1.000	30.000
83	34	35	W36X260	0.000	000000	1	0.000	0.000	1.000	30.000
84	35	36	W36X260	0.000	000000	1	0.000	0.000	1.000	30.000

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       85       37       38   W36X230     0.000    000000         1     0.000
0.000     1.000      30.000
       86       38       39   W36X230     0.000    000000         1     0.000
0.000     1.000      30.000
       87       39       40   W36X230     0.000    000000         1     0.000
0.000     1.000      30.000
       88       41       42   W36X230     0.000    000000         1     0.000
0.000     1.000      30.000
       89       42       43   W36X230     0.000    000000         1     0.000
0.000     1.000      30.000
       90       43       44   W36X230     0.000    000000         1     0.000
0.000     1.000      30.000
       91       45       46   W36X194     0.000    000000         1     0.000
0.000     1.000      30.000
       92       46       47   W36X194     0.000    000000         1     0.000
0.000     1.000      30.000
       93       47       48   W36X194     0.000    000000         1     0.000
0.000     1.000      30.000
       94       49       50   W36X194     0.000    000000         1     0.000
0.000     1.000      30.000
       95       50       51   W36X194     0.000    000000         1     0.000
0.000     1.000      30.000
       96       51       52   W36X194     0.000    000000         1     0.000
0.000     1.000      30.000
       97       53       54   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000
       98       54       55   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000
       99       55       56   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000
      100       57       58   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000
      101       58       59   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000
      102       59       60   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000
      103       61       62   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000
      104       62       63   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000
      105       63       64   W36X150     0.000    000000         1     0.000
0.000     1.000      30.000

 SAP2000 v6.13 File: FRAME6SAP  Kip-ft Units  PAGE 4
 April 29, 2001 14:54

 Virginia Tech


 J O I N T   F O R C E S   Load Case  WIND

    JOINT    GLOBAL-X    GLOBAL-Y    GLOBAL-Z   GLOBAL-XX   GLOBAL-YY
GLOBAL-ZZ

       17      45.000       0.000       0.000       0.000       0.000
0.000
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        21      45.000       0.000       0.000       0.000       0.000
0.000
        61      45.000       0.000       0.000       0.000       0.000
0.000
        53      90.000       0.000       0.000       0.000       0.000
0.000
        57      90.000       0.000       0.000       0.000       0.000
0.000
        41      75.000       0.000       0.000       0.000       0.000
0.000
        45      75.000       0.000       0.000       0.000       0.000
0.000
        49      75.000       0.000       0.000       0.000       0.000
0.000
        29      60.000       0.000       0.000       0.000       0.000
0.000
        33      60.000       0.000       0.000       0.000       0.000
0.000
        37      60.000       0.000       0.000       0.000       0.000
0.000
        25      45.000       0.000       0.000       0.000       0.000
0.000
         9      30.000       0.000       0.000       0.000       0.000
0.000
        13      30.000       0.000       0.000       0.000       0.000
0.000
         5      15.000       0.000       0.000       0.000       0.000
0.000

 SAP2000 v6.13 File: FRAME6SAP  Kip-ft Units  PAGE 5
 April 29, 2001 14:54

 Virginia Tech


 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  DEAD

    FRAME         TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B

        61       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
        64       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
        67       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
        70       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
        73       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
        76       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
        79       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
        82       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
```

85	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
88	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
91	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
94	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
97	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
100	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
103	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
62	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
65	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
68	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
71	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
74	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
77	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
80	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
83	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
86	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
89	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
92	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
95	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
98	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
101	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
104	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
63	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
66	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
69	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
72	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
75	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000
78	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	- 0.5000

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       81       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
       84       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
       87       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
       90       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
       93       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
       96       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
       99       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
      102       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
      105       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000

 SAP2000 v6.13 File: FRAME6SAP  Kip-ft Units  PAGE 6
 April 29, 2001 14:54

 Virginia Tech


 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  LIVE

    FRAME        TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B

       61       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       64       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       67       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       70       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       73       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       76       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       79       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       82       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       85       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       88       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       91       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       94       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
       97       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000
```

100	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
62	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
65	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
68	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
71	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
74	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
77	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
80	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
83	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
86	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
89	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
92	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
95	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
98	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
101	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
63	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
66	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
69	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
72	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
75	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
78	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
81	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
84	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
87	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
90	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
93	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
96	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
99	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000

```
      102       FORCE    GLOBAL-Z      0.0000     -3.0000      1.0000     -
3.0000

 SAP2000 v6.13 File: FRAME6SAP  Kip-ft Units  PAGE 7
 April 29, 2001 14:54

 Virginia Tech


 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  SNOW

    FRAME        TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B

      103       FORCE    GLOBAL-Z      0.0000     -1.2000      1.0000     -
1.2000
      104       FORCE    GLOBAL-Z      0.0000     -1.2000      1.0000     -
1.2000
      105       FORCE    GLOBAL-Z      0.0000     -1.2000      1.0000     -
1.2000
```

```
STAAD PLANE FRAME RESEARCH FRAME 6
UNIT KIP FEET
JOINT COORDINATES
1 0 0; 2 30 0; 3 60 0; 4 90 0
REPEAT ALL 15 0. 15. 0.
MEMBER INCIDENCE
*COLUMNS
1 1 5; 2 5 9; 3 9 13; 4 13 17;
5 17 21; 6 21 25; 7 25 29; 8 29 33;
9 33 37; 10 37 41; 11 41 45; 12 45 49;
13 49 53; 14 53 57; 15 57 61; 16 2 6;
17 6 10; 18 10 14; 19 14 18; 20 18 22;
21 22 26; 22 26 30; 23 30 34; 24 34 38;
25 38 42; 26 42 46; 27 46 50; 28 50 54;
29 54 58; 30 58 62; 31 3 7; 32 7 11;
33 11 15; 34 15 19; 35 19 23; 36 23 27;
37 27 31; 38 31 35; 39 35 39; 40 39 43;
41 43 47; 42 47 51; 43 51 55; 44 55 59;
45 59 63; 46 4 8; 47 8 12; 48 12 16;
49 16 20; 50 20 24; 51 24 28; 52 28 32;
53 32 36; 54 36 40; 55 40 44; 56 44 48;
57 48 52; 58 52 56; 59 56 60; 60 60 64
*BEAMS
61 5 6 ; 62 6 7 ; 63 7 8 ;
64 9 10 ; 65 10 11; 66 11 12;
67 13 14; 68 14 15; 69 15 16;
70 17 18; 71 18 19; 72 19 20;
73 21 22; 74 22 23; 75 23 24;
76 25 26; 77 26 27; 78 27 28;
79 29 30; 80 30 31; 81 31 32;
82 33 34; 83 34 35; 84 35 36;
85 37 38; 86 38 39; 87 39 40;
88 41 42; 89 42 43; 90 43 44;
91 45 46; 92 46 47; 93 47 48;
94 49 50; 95 50 51; 96 51 52;
97 53 54; 98 54 55; 99 55 56;
100 57 58; 101 58 59; 102 59 60;
103 61 62; 104 62 63; 105 63 64
MEMBER PROPERTY AMERICAN
*COLUMNS
1 2 16 17 31 32 46 47 TABLE ST W14X730
3 4 5 6 18 19 20 21 33 34 35 36 48 49 50 51 TABLE ST W14X665
7 8 22 23 37 38 52 53 TABLE ST W14X605
9 10 24 25 39 40 54 55 TABLE ST W14X550
11 12 26 27 41 42 56 57 TABLE ST W14X426
13 14 15 28 29 30 43 44 45 58 59 60 TABLE ST W14X283
*BEAMS
61 62 63 64 65 66 67 68 69 70 71 72 TABLE ST W36X300
73 74 75 76 77 78 TABLE ST W36X280
79 80 81 82 83 84 TABLE ST W36X260
85 86 87 88 89 90 TABLE ST W36X230
91 92 93 94 95 96 TABLE ST W36X194
97 98 99 100 101 102 103 104 105 TABLE ST W36X150
UNIT INCHES
CONSTANTS
E 29000.0 ALL
PRINT MEMBER INFORMATION
```

```
SUPPORT
1 2 3 4 FIXED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FT
LOADING 1 DEAD
MEMBER LOAD
61 TO 105 UNIFORM GY -0.5
LOADING 2 LIVE
MEMBER LOAD
61 TO 102 UNIFORM GY -3.0
LOADING 3 SNOW
MEMBER LOAD
103 104 105 UNIFORM GY -1.2
LOADING 4 COMBINED
REPEAT LOAD
1 1.2 2 1.6 3 1.6
JOINT LOAD
5 FX 12
9 13 FX 24
17 21 25 FX 36
29 33 37 FX 48
41 45 49 FX 60
53 57 FX 72
61 FX 36
PERFORM ANALYSIS
PRINT MEMBER FORCES
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX I

COMPUTER PROGRAM INPUT FOR FRAME 7

RISA-3D, Frame 7

Materials
STL 29000 11154 0.3 0.65 0.49 50

Sections
10X60 W10X60 STL 17.6
1.2 1.2 116 341 2.48
10X77 W10X77 STL 22.6
1.2 1.2 154 455 5.11
10X68 W10X68 STL 20
1.2 1.2 134 394 3.56
10X39 W10X39 STL 11.5
1.2 1.2 45 209 0.98
12X87 W12X87 STL 25.6
1.2 1.2 241 740 5.1

Joint Coordinates
N1 0 0 0 0
N2 0 15 0 0
N3 0 30 0 0
N4 0 45 0 0
N5 20 0 0 0
N6 20 15 0 0
N7 20 22.5 0 0
N8 20 30 0 0
N9 20 45 0 0
N10 40 0 0 0
N11 40 22.5 0 0
N12 40 45 0 0

Boundary Conditions
N1 Reaction Reaction Fixed Fixed
N5 Reaction Reaction Fixed Fixed
N10 Reaction Reaction Fixed Fixed
N2 Fixed
N6 Fixed
N7 Fixed
N11 Fixed
N3 Fixed
N8 Fixed
N4 Fixed
N9 Fixed
N12 Fixed

Member Data
M1 N1 N2
0.0 10X60 0.0 0.0 15
M2 N2 N3
0.0 10X60 0.0 0.0 15
M3 N3 N4
0.0 10X60 0.0 0.0 15
M4 N5 N6
0.0 10X77 0.0 0.0 15
M5 N6 N7
0.0 10X77 0.0 0.0 7.5

```
M6                    N7                    N8
0.0 10X77                   0.0 0.0   7.5
M7                    N8                    N9
0.0 10X77                   0.0 0.0   15
M8                    N10                   N11
0.0 10X68                   0.0 0.0   22.5
M9                    N11                   N12
0.0 10X68                   0.0 0.0   22.5
M10                   N2                    N6
0.0 12X87                   0.0 0.0   20
M11                   N3                    N8
0.0 12X87                   0.0 0.0   20
M12                   N4                    N9
0.0 10X39                   0.0 0.0   20
M13                   N7                    N11
0.0 12X87                   0.0 0.0   20
M14                   N9                    N12
0.0 10X39                   0.0 0.0   20

Distributed Load Patterns
SNOW                  Y -1.2 -1.2 0 0
DEAD                  Y -0.5 -0.5 0 0
LIVE                  Y -3 -3 0 0

Basic Load Case Data
1 Wind                            None   3 0 0 0
2 Snow                            None   0 0 2 0
3 Dead                            None   0 0 5 0
4 Live                            None   0 0 3 0
5 Mlt                             None   2 0 0 0

Joint Loads; BLC1: Wind
N2                    L X 10
N3                    L X 20
N4                    L X 30

Joint Loads; BLC5: Mlt
N11                   L X 19.5
N12                   L X 26.6

Member Distributed Loads; BLC2: Snow
M12                   N4                    N9                    SNOW
1
M14                   N9                    N12                   SNOW
1

Member Distributed Loads; BLC3: Dead
M10                   N2                    N6                    DEAD
1
M11                   N3                    N8                    DEAD
1
M12                   N4                    N9                    DEAD
1
M13                   N7                    N11                   DEAD
1
M14                   N9                    N12                   DEAD
1
```

Member Distributed Loads; BLC4: Live
M10 N2 N6 LIVE
1
M11 N3 N8 LIVE
1
M13 N7 N11 LIVE
1

Load Combinations
1 1st Order
n n n n 1 1 0.8 2 1.6 3
1.2 4 1.6 0 0
0 0
2 2nd Order
n n y n 1 1 0.8 2 1.6 3
1.2 4 1.6 0 0
0 0
3 Mnt
n n n n 1 1 0.8 2 1.6 3
1.2 4 1.6 0 0
0 0
4 Mlt
n n n n 1 5 1 0 0
0 0 0 0
0
5 UNF
n n n n 1 1 1 2 1 3 1 4
1 0 0 0
0

SAP2000 v6.13 File: FRAME7SAP Kip-ft Units PAGE 1
April 29, 2001 14:54

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Second Order Analysis

S T A T I C   L O A D   C A S E S

STATIC CASE	CASE TYPE	SELF WT FACTOR
DEAD	DEAD	0.0000
LIVE	LIVE	0.0000
WIND	WIND	0.0000
SNOW	SNOW	0.0000

SAP2000 v6.13 File: FRAME7SAP Kip-ft Units PAGE 2
April 29, 2001 14:54

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Second Order Analysis

J O I N T   D A T A

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	RESTRAINTS	ANGLE-A	ANGLE-B	ANGLE-C
1	-20.00000	0.00000	0.00000	1 1 1 1 0 1	0.000	0.000	0.000
2	-20.00000	0.00000	15.00000	0 0 0 0 0 0	0.000	0.000	0.000
3	-20.00000	0.00000	30.00000	0 0 0 0 0 0	0.000	0.000	0.000
4	-20.00000	0.00000	45.00000	0 0 0 0 0 0	0.000	0.000	0.000
5	0.00000	0.00000	0.00000	1 1 1 1 0 1	0.000	0.000	0.000
6	0.00000	0.00000	15.00000	0 0 0 0 0 0	0.000	0.000	0.000
7	0.00000	0.00000	22.49999	0 0 0 0 0 0	0.000	0.000	0.000
8	0.00000	0.00000	30.00000	0 0 0 0 0 0	0.000	0.000	0.000
9	0.00000	0.00000	45.00000	0 0 0 0 0 0	0.000	0.000	0.000
10	20.00000	0.00000	0.00000	1 1 1 1 0 1	0.000	0.000	0.000
11	20.00000	0.00000	22.50000	0 0 0 0 0 0	0.000	0.000	0.000
12	20.00000	0.00000	45.00000	0 0 0 0 0 0	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME7SAP Kip-ft Units PAGE 3
April 29, 2001 14:54

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Second Order Analysis

F R A M E   E L E M E N T   D A T A

FRAME	JNT-1	JNT-2	SECTION	ANGLE	RELEASES	SEGMENTS	R1	R2	FACTOR	LENGTH
1	1	2	W10X60	0.000	000000	1	0.000	0.000	1.000	15.000
2	2	3	W10X60	0.000	000000	1	0.000	0.000	1.000	15.000
3	3	4	W10X60	0.000	000000	1	0.000	0.000	1.000	15.000
4	5	6	W10X77	0.000	000000	1	0.000	0.000	1.000	15.000
5	6	7	W10X77	0.000	000000	1	0.000	0.000	1.000	7.500
6	7	8	W10X77	0.000	000000	1	0.000	0.000	1.000	7.500
7	8	9	W10X77	0.000	000000	1	0.000	0.000	1.000	15.000
8	10	11	W10X68	0.000	000000	1	0.000	0.000	1.000	22.500
9	11	12	W10X68	0.000	000000	1	0.000	0.000	1.000	22.500
10	2	6	W12X87	0.000	000000	1	0.000	0.000	1.000	20.000
11	3	8	W12X87	0.000	000000	1	0.000	0.000	1.000	20.000
12	4	9	W10X39	0.000	000000	1	0.000	0.000	1.000	20.000
13	7	11	W12X87	0.000	000000	1	0.000	0.000	1.000	20.000
14	9	12	W10X39	0.000	000000	1	0.000	0.000	1.000	20.000

SAP2000 v6.13 File: FRAME7SAP Kip-ft Units PAGE 4
April 29, 2001 14:54

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Second Order Analysis

J O I N T   F O R C E S   Load Case WIND

JOINT	GLOBAL-X	GLOBAL-Y	GLOBAL-Z	GLOBAL-XX	GLOBAL-YY	GLOBAL-ZZ
4	30.000	0.000	0.000	0.000	0.000	0.000
3	20.000	0.000	0.000	0.000	0.000	0.000
2	10.000	0.000	0.000	0.000	0.000	0.000

SAP2000 v6.13 File: FRAME7SAP Kip-ft Units PAGE 5
April 29, 2001 14:54

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Second Order Analysis

F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case DEAD

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
10	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
11	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
13	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
12	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000
14	FORCE	GLOBAL-Z	0.0000	-0.5000	1.0000	-0.5000

SAP2000 v6.13 File: FRAME7SAP Kip-ft Units PAGE 6
April 29, 2001 14:54

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Second Order Analysis

F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case LIVE

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
10	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
11	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000
13	FORCE	GLOBAL-Z	0.0000	-3.0000	1.0000	-3.0000

SAP2000 v6.13 File: FRAME7SAP Kip-ft Units PAGE 7
April 29, 2001 14:54

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Second Order Analysis

F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case SNOW

FRAME	TYPE	DIRECTION	DISTANCE-A	VALUE-A	DISTANCE-B	VALUE-B
12	FORCE	GLOBAL-Z	0.0000	-1.2000	1.0000	-1.2000
14	FORCE	GLOBAL-Z	0.0000	-1.2000	1.0000	-1.2000

```
STAAD PLANE RESEARCH FRAME 7
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 15.; 3 0. 30.; 4 0. 45.; 5 20. 0.; 6 20. 15.; 7 20. 22.5;
8 20. 30.; 9 20. 45.; 10 40. 0.; 11 40. 22.5; 12 40. 45.
MEMBER INCIDENCE
1 1 2; 2 2 3; 3 3 4; 4 5 6; 5 6 7; 6 7 8; 7 8 9; 8 10 11; 9 11 12;
10 2 6; 11 3 8; 12 4 9; 13 7 11; 14 9 12
MEMBER PROPERTY AMERICAN
1 2 3 TABLE ST W10X60
4 5 6 7 TABLE ST W10X77
8 9 TABLE ST W10X68
10 11 13 TABLE ST W12X87
12 14 TABLE ST W10X39
UNIT INCHES
CONSTANTS
E 29000.0 ALL
PRINT MEMBER INFORMATION
SUPPORT
1 5 10 PINNED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FEET
LOADING 1 DEAD
MEMBER LOAD
10 11 12 13 14 UNIFORM GY -0.5
LOADING 2 LIVE
MEMBER LOAD
10 11 13 UNIFORM GY -3.0
LOADING 3 SNOW
MEMBER LOAD
12 14 UNIFORM GY -1.2
LOADING 4 COMBINATION
REPEAT LOAD
1 1.2 2 1.6 3 1.6
JOINT LOAD
2 FX 8
3 FX 16
4 FX 24
PERFORM ANALYSIS
PRINT MEMBER FORCES
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX J

COMPUTER PROGRAM INPUT FOR FRAME 8

```
RISA-3D, Frame 8

Materials
STL                 29000 11154 0.3 0.65 0.49 50

Sections
W12X40              W12X40                            STL                 11.8
1.2 1.2 44.1 310 0.95
W12X58              W12X58                            STL                 17
1.2 1.2 107 475 2.1

Joint Coordinates
N1                  0 0 0 0
N2                  0 25 0 0
N3                  20 0 0 0
N4                  20 25 0 0
N5                  40 0 0 0
N6                  40 25 0 0

Boundary Conditions
N1                   Reaction Reaction Fixed Fixed Fixed Reaction
N3                   Reaction Reaction Fixed Fixed Fixed Reaction
N5                   Reaction Reaction Fixed Fixed
N2                     Fixed
N4                     Fixed
N6                     Fixed

Member Data
M1                   N1                    N2
0.0 W12X58                BenPIN 0.0 0.0    25
M2                   N3                    N4
0.0 W12X58                BenPIN 0.0 0.0    25
M3                   N5                    N6
0.0 W12X58                BenPIN 0.0 0.0    25
M4                   N2                    N4
0.0 W12X40                 0.0 0.0    20
M5                   N4                    N6
0.0 W12X40                 0.0 0.0    20

Distributed Load Patterns
DEAD                 Y -0.5 -0.5 0 0
SNOW                 Y -1.2 -1.2 0 0

Basic Load Case Data
1 Dead                           None   0 0 2 0
2 Snow                           None   0 0 2 0
3 Wind                           None   1 0 0 0
4 Mlt                            None   3 0 0 0

Joint Loads; BLC3: Wind
N2                   L X 20

Joint Loads; BLC4: Mlt
N1                   L X 0.034
N3                   L X 0.017
N6                   L X 15.949
```

Member Distributed Loads; BLC1: Dead
M4 N2 N4 DEAD
1
M5 N4 N6 DEAD
1

Member Distributed Loads; BLC2: Snow
M4 N2 N4 SNOW
1
M5 N4 N6 SNOW
1

Load Combinations
1 1st Order
n n n n 1 1 1.2 2 1.6 3
0.8 0 0 0
0 0
2 2nd Order
n n y n 1 1 1.2 2 1.6 3
0.8 0 0 0
0 0
3 Mnt
n n n n 1 1 1.2 2 1.6 3
0.8 0 0 0
0 0
4 Mlt
n n n n 1 4 1 0 0
0 0 0 0
0

```
 SAP2000 v6.13 File: FRAME8SAP  Kip-ft Units  PAGE 1
 April 29, 2001 14:54

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 S T A T I C   L O A D   C A S E S

       STATIC         CASE     SELF WT
         CASE         TYPE      FACTOR

         DEAD         DEAD      0.0000
         SNOW         SNOW      0.0000
         WIND         WIND      0.0000

 SAP2000 v6.13 File: FRAME8SAP  Kip-ft Units  PAGE 2
 April 29, 2001 14:54

 Virginia Tech


 J O I N T   D A T A

    JOINT       GLOBAL-X       GLOBAL-Y       GLOBAL-Z     RESTRAINTS
ANGLE-A   ANGLE-B   ANGLE-C

        1      -20.00000        0.00000        0.00000    1 1 1 1 1 1
0.000     0.000     0.000
        2      -20.00000        0.00000       25.00000    0 0 0 0 0 0
0.000     0.000     0.000
        3        0.00000        0.00000        0.00000    1 1 1 1 1 1
0.000     0.000     0.000
        4        0.00000        0.00000       25.00000    0 0 0 0 0 0
0.000     0.000     0.000
        5       20.00000        0.00000        0.00000    1 1 1 1 0 1
0.000     0.000     0.000
        6       20.00000        0.00000       25.00000    0 0 0 0 0 0
0.000     0.000     0.000

 SAP2000 v6.13 File: FRAME8SAP  Kip-ft Units  PAGE 3
 April 29, 2001 14:54

 Virginia Tech


 F R A M E   E L E M E N T   D A T A

    FRAME   JNT-1   JNT-2   SECTION     ANGLE  RELEASES  SEGMENTS         R1
R2    FACTOR      LENGTH

        1       1       2    W12X58     0.000    000002         2     0.000
0.000     1.000      25.000
        2       3       4    W12X58     0.000    000002         2     0.000
0.000     1.000      25.000
        3       5       6    W12X58     0.000    000002         2     0.000
0.000     1.000      25.000
```

```
       4       2       4    W12X40     0.000    000000         4     0.000
0.000     1.000      20.000
       5       4       6    W12X40     0.000    000000         4     0.000
0.000     1.000      20.000

 SAP2000 v6.13 File: FRAME8SAP  Kip-ft Units  PAGE 4
 April 29, 2001 14:54

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 J O I N T   F O R C E S   Load Case  WIND

    JOINT    GLOBAL-X    GLOBAL-Y    GLOBAL-Z   GLOBAL-XX   GLOBAL-YY
GLOBAL-ZZ

       2      20.000       0.000       0.000       0.000       0.000
0.000

 SAP2000 v6.13 File: FRAME8SAP  Kip-ft Units  PAGE 5
 April 29, 2001 14:54

 Virginia Tech


 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  DEAD

    FRAME        TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B

       4       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000
       5       FORCE    GLOBAL-Z      0.0000     -0.5000      1.0000     -
0.5000

 SAP2000 v6.13 File: FRAME8SAP  Kip-ft Units  PAGE 6
 April 29, 2001 14:54

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 F R A M E   S P A N   D I S T R I B U T E D   L O A D S   Load Case  SNOW

    FRAME        TYPE   DIRECTION  DISTANCE-A     VALUE-A  DISTANCE-B
VALUE-B

       4       FORCE    GLOBAL-Z      0.0000     -1.2000      1.0000     -
1.2000
       5       FORCE    GLOBAL-Z      0.0000     -1.2000      1.0000     -
1.2000
```

```
STAAD PLANE RESEARCH FRAME 8
UNIT KIP FEET
JOINT COORDINATES
1 0. 0.; 2 0. 25.; 3 20. 0. ; 4 20. 25.; 5 40. 0. ; 6 40. 25.
MEMBER INCIDENCE
1 1 2; 2 3 4; 3 5 6; 4 2 4; 5 4 6
MEMBER PROPERTY AMERICAN
1 2 3 TABLE ST W12X58
4 5 TABLE ST W12X40
MEMBER RELEASES
1 2 3 END MZ
UNIT INCHES
CONSTANTS
E 29000.0 ALL
PRINT MEMBER INFORMATION
SUPPORT
1 3 FIXED
5 PINNED
DRAW MEMBER JOINT PROPERTY SUPPORT
UNIT FEET
LOADING 1 DEAD
MEMBER LOAD
4 5 UNIFORM GY -0.5
LOADING 2 SNOW
MEMBER LOAD
4 5 UNIFORM GY -1.2
LOADING 3 COMBINATION
REPEAT LOAD
1 1.2 2 1.6
JOINT LOAD
2 FX 16
PERFORM ANALYSIS
PRINT MEMBER FORCES
PDELTA ANALYSIS
PRINT MEMBER FORCES
FINISH
```

APPENDIX K

COMPUTER PROGRAM OUTPUT FOR ALL FRAMES

Frame 1

	M1, I-End	M1, J-End	M2, I-End	M2, J-End	M3, I-End	M3, J-End
1ST ORDER	0	510	510	607	607	0
AISC B1/B2	0	498	498	619	619	0
RISA 3D	0	500	500	616	616	0
ROBOT	0	498	498	615	615	0
SAP 2000	0	496	496	613	613	0
STAAD-III	0	498	498	611	611	0

Frame 2

	M1, I-End	M1, J-End	M2, I-End	M2, J-End	M3, I-End	M3, J-End
1ST ORDER	0	40	114	91	0	144
AISC B1/B2	0	48	113	88	0	155
RISA 3D	0	54	116	88	0	162
ROBOT	0	58	122	92	0	160
SAP 2000	0	56	117	89	0	161
STAAD-III	0	54	118	90	0	160

M4, I-End	M4, J-End	M5, I-End	M5, J-End	M6, I-End	M6, J-End
61	77	0	176	132	175
65	83	0	185	132	178
63	83	0	190	130	177
65	83	0	188	135	180
64	83	0	190	130	178
63	82	0	188	132	178

M7, I-End	M7, J-End	M8, I-End	M8, J-End	M9, I-End	M9, J-End
74	369	165	308	91	227
66	378	157	316	88	230
62	380	155	320	88	230
64	379	154	322	92	229
62	380	155	320	89	230
64	379	155	319	90	229

M10, I-End	M10, J-End
150	175
147	178
147	177
146	180
147	178
147	178

Frame 3

	M1, I-End	M1, J-End	M2, I-End	M2, J-End	M3, I-End	M3, J-End	M4, I-End
1ST ORDER	0	45	45	825	825	330	497
AISC B1/B2	0	160	160	856	856	458	1041
RISA 3D	0	0	0	844	844	343	607
ROBOT	0	5	5	843	843	343	609
SAP 2000	0	17	17	850	850	351	614
STAAD-III	0	4	4	846	846	347	595

M4, J-End	M5, I-End	M5, J-End	M6, I-End	M6, J-End
0	168	925	925	0
0	583	1386	1386	0
0	264	1022	1022	0
0	267	1022	1022	0
0	262	1018	1018	0
0	248	1006	1006	0

Frame 4

	M1, I-End	M1, J-End	M2, I-End	M2, J-End	M3, I-End	M3, J-End	M4, I-End	M4, J-End
1ST ORDER	0	424	424	253	253	662	662	0
AISC B1/B2	0	375	375	253	253	776	776	0
RISA 3D	0	405	405	282	282	740	740	0
ROBOT	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution
SAP 2000	0	401	401	282	282	744	744	0
STAAD-III	0	416	416	280	280	723	723	0

Frame 4a

	M1, I-End	M1, J-End	M2, I-End	M2, J-End	M3, I-End	M3, J-End
1ST ORDER	0	270	270	125	125	660
AISC B1/B2	0	237	237	125	125	808
RISA 3D	0	204	204	149	149	780
ROBOT	no solution	no solution	no solution	no solution	no solution	no solution
SAP 2000	0	191	191	151	151	786
STAAD-III	0	231	231	146	146	747

M4, I-End	M4, J-End
660	0
808	0
780	0
no solution	no solution
786	0
747	0

Frame 5

	M1, I-End	M1, J-End	M2, I-End	M2, J-End	M3, I-End	M3, J-End	M4, I-End	M4, J-End	M5, I-End	M5, J-End	M6, I-End	M6, J-End	M7, I-End	M7, J-End	M8, I-End	M8, J-End	M9, I-End	M9, J-End
1ST ORDER	0	8	0	0	0	0	0	0	0	180	8	181	181	139	139	142	142	180
AISC B1/B2	0	99	0	0	0	0	0	0	0	271	99	181	181	139	139	142	142	271
RISA 3D	0	90	0	0	0	0	0	0	0	262	90	199	199	139	139	124	124	262
ROBOT	0	92	0	0	0	0	0	0	0	263	92	199	199	140	140	124	124	263
SAP 2000	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution	no solution
STAAD-III	0	52	0	0	0	0	0	0	0	224	52	190	190	139	139	132	132	224

Frame 5a

	M1, I-End	M1, J-End	M5, I-End	M5, J-End	M6, I-End	M6, J-End	M7, I-End	M7, J-End	M8, I-End	M8, J-End	M9, I-End	M9, J-End
1ST ORDER	0	9	0	179	9	182	182	139	139	142	142	179
AISC B1/B2	0	18	0	189	18	182	182	139	139	142	142	189
RISA 3D	0	20	0	190	20	184	184	139	139	140	140	190
ROBOT	0	21	0	189	21	185	185	138	138	141	141	189
SAP 2000	0	20	0	190	20	184	184	139	139	140	140	190
STAAD-III	0	20	0	190	20	184	184	140	140	140	140	190

Frame 6

Member		1st Order	AISC B1/B2	RISA 3D	ROBOT	SAP2000	STAAD-III
1	I-end	1423	1424	1458	-1461	1544	1522
	J-end	-493	-494	-506	508	-471	477
2	I-end	737	736	769	-769	810	799
	J-end	-646	-645	-671	672	-684	680
3	I-end	667	667	696	-696	720	713
	J-end	-647	-648	-676	677	-700	693
4	I-end	587	587	611	-611	635	628
	J-end	-597	-598	-623	624	-650	643
5	I-end	519	518	541	-541	566	559
	J-end	-516	-515	-539	540	-566	559
6	I-end	435	435	453	-452	477	471
	J-end	-441	-441	-461	451	-489	482
7	I-end	418	418	435	-455	459	453
	J-end	-412	-412	-430	448	-457	450
8	I-end	295	296	309	-299	332	326
	J-end	-322	-322	-337	335	-365	359
9	I-end	270	270	282	-282	305	299
	J-end	-269	-269	-282	281	-307	301
10	I-end	160	160	168	-168	188	184
	J-end	-178	-178	-188	188	-214	208
11	I-end	158	158	166	-166	183	179
	J-end	-156	-156	-165	165	-187	182
12	I-end	12	12	16	-16	32	28
	J-end	-33	-33	-38	38	-59	54
13	I-end	41	41	44	-44	58	55
	J-end	-42	-42	-47	47	-62	58
14	I-end	-125	-125	-124	125	-114	-117
	J-end	62	62	60	-61	44	-48
15	I-end	-221	-221	-221	222	-212	-214
	J-end	184	184	184	-184	168	-171
16	I-end	1750	1752	1792	-1787	1819	1815
	J-end	-1127	-1128	-1151	1156	-1110	1115
17	I-end	1616	1618	1668	-1667	1670	1668
	J-end	-1524	-1525	-1571	1572	-1559	1559
18	I-end	1483	1484	1532	-1532	1534	1532
	J-end	-1482	-1483	-1531	1531	-1533	1531
19	I-end	1422	1423	1467	-1467	1468	1466
	J-end	-1427	-1428	-1473	1473	-1477	1474
20	I-end	1338	1338	1378	-1377	1382	1380
	J-end	-1320	-1321	-1361	1360	-1366	1363
21	I-end	1233	1234	1268	-1271	1271	1269
	J-end	-1253	-1253	-1289	1294	-1296	1294

22	I-end	1139	1140	1171	-1164	1175	1173
	J-end	-1134	-1134	-1166	1159	-1172	1170
23	I-end	1016	1016	1042	-1047	1046	1044
	J-end	-1045	-1045	-1073	1075	-1081	1078
24	I-end	905	905	928	-927	933	932
	J-end	-898	-897	-921	920	-928	926
25	I-end	782	782	800	-800	803	801
	J-end	-821	-821	-841	840	-849	847
26	I-end	642	642	657	-657	659	658
	J-end	-644	-643	-659	659	-667	665
27	I-end	503	503	514	-514	515	515
	J-end	-544	-544	-555	555	-562	560
28	I-end	367	367	374	-374	375	375
	J-end	-381	-381	-388	388	-392	391
29	I-end	201	201	204	-204	205	205
	J-end	-238	-238	-242	241	-246	245
30	I-end	40	40	41	-40	44	43
	J-end	-64	-64	-65	65	-71	70
31	I-end	1757	1758	1798	-1793	1824	1820
	J-end	-1135	-1136	-1158	1162	-1115	1121
32	I-end	1626	1627	1678	-1677	1677	1675
	J-end	-1553	-1554	-1600	1600	-1584	1585
33	I-end	1544	1545	1594	-1593	1586	1586
	J-end	-1554	-1555	-1603	1603	-1596	1596
34	I-end	1512	1513	1556	-1556	1545	1546
	J-end	-1528	-1529	-1574	1574	-1566	1566
35	I-end	1461	1462	1501	-1501	1489	1490
	J-end	-1451	-1452	-1492	1492	-1480	1481
36	I-end	1379	1380	1414	-1415	1399	1401
	J-end	-1410	-1411	-1447	1448	-1435	1437
37	I-end	1294	1294	1325	-1318	1310	1312
	J-end	-1293	-1294	-1326	1318	-1313	1315
38	I-end	1188	1189	1215	-1217	1197	1200
	J-end	-1227	-1228	-1255	1256	-1242	1244
39	I-end	1080	1081	1103	-1103	1087	1090
	J-end	-1073	-1074	-1097	1097	-1083	1086
40	I-end	957	958	976	-976	958	961
	J-end	-1009	-1009	-1029	1029	-1016	1018
41	I-end	794	795	809	-809	793	796
	J-end	-795	-796	-810	810	-802	803
42	I-end	651	651	661	-662	647	650
	J-end	-702	-702	-714	714	-704	706
43	I-end	468	468	476	-476	466	468
	J-end	-480	-480	-487	487	-480	482
44	I-end	297	297	300	-300	291	293

	J-end	-335	-335	-339	339	-333	334
45	I-end	150	150	151	-151	141	143
	J-end	-196	-196	-197	197	-190	192
46	I-end	1587	1589	1621	-1614	1674	1666
	J-end	-808	-808	-818	822	-783	787
47	I-end	1145	1147	1178	-1176	1201	1196
	J-end	-1054	-1056	-1080	1080	-1080	1079
48	I-end	1081	1081	1109	-1110	1116	1114
	J-end	-1084	-1084	-1113	1113	-1119	1117
49	I-end	1042	1043	1066	-1067	1069	1067
	J-end	-1065	-1065	-1091	1091	-1098	1095
50	I-end	1016	1017	1038	-1038	1038	1037
	J-end	-1019	-1020	-1042	1042	-1045	1043
51	I-end	960	960	978	-979	976	975
	J-end	-989	-989	-1009	1011	-1012	1010
52	I-end	931	931	949	-944	945	945
	J-end	-940	-940	-958	953	-959	958
53	I-end	851	852	865	-867	859	859
	J-end	-895	-895	-910	911	-911	910
54	I-end	808	809	820	-821	814	815
	J-end	-817	-818	-830	831	-828	828
55	I-end	719	719	727	-728	719	720
	J-end	-774	-774	-784	784	-782	782
56	I-end	648	648	656	-657	646	648
	J-end	-664	-664	-673	673	-672	672
57	I-end	545	545	550	-550	540	542
	J-end	-610	-610	-616	616	-613	614
58	I-end	445	445	449	-449	441	442
	J-end	-477	-477	-481	481	-478	479
59	I-end	337	337	338	-338	328	330
	J-end	-400	-400	-402	403	-398	399
60	I-end	228	228	227	-228	217	219
	J-end	-268	-268	-268	268	-259	261
61	I-end	-1230	-1230	-1274	1277	1281	-1276
	J-end	1823	1823	1862	-1864	-1839	-1842
62	I-end	-921	-920	-957	959	940	-941
	J-end	1730	1493	1767	-1768	-1749	-1751
63	I-end	-1030	-1268	-1070	1071	1043	-1046
	J-end	1952	1955	1996	-1998	-1984	-1983
64	I-end	-1312	-1312	-1367	1368	1404	-1393
	J-end	1905	1905	1954	-1955	-1953	-1952
65	I-end	-1101	-1101	-1148	1149	1139	-1139
	J-end	1897	1903	1944	-1944	-1935	-1935
66	I-end	-1200	-1194	-1249	1250	1235	-1236
	J-end	2134	2137	2189	-2190	-2197	-2192

67	I-end	-1234	-1234	-1287	1288	1335	-1321
	J-end	1812	1812	1860	-1860	-1868	-1864
68	I-end	-1092	-1092	-1138	1138	1133	-1132
	J-end	1879	1879	1926	-1926	-1920	-1919
69	I-end	-1186	-1186	-1234	1234	1221	-1222
	J-end	2126	2127	2179	-2179	-2188	-2184
70	I-end	-1116	-1117	-1164	1165	1216	-1203
	J-end	1699	1699	1742	-1742	-1755	-1751
71	I-end	-1065	-1066	-1109	1108	1103	-1103
	J-end	1843	1843	1886	-1886	-1879	-1880
72	I-end	-1146	-1147	-1189	1189	1175	-1177
	J-end	2081	2083	2129	-2129	2136	-2133
73	I-end	-951	-951	-992	992	1043	-1030
	J-end	1560	1560	1597	-1598	-1613	-1608
74	I-end	-993	-994	-1032	1033	1024	-1024
	J-end	1768	1768	1807	-1807	-1797	-1798
75	I-end	-1062	-1062	-1099	1099	1082	-1085
	J-end	1978	1980	2020	-2020	-2021	-2019
76	I-end	-859	-859	-896	906	948	-935
	J-end	1457	1457	1490	-1492	-1508	-1503
77	I-end	-935	-935	-970	966	963	-963
	J-end	1701	1701	1736	-1733	-1727	-1728
78	I-end	-1003	-1003	-1036	1033	1018	-1021
	J-end	1920	1921	1958	-1955	-1957	-1956
79	I-end	-707	-707	-739	747	788	-776
	J-end	1323	1323	1352	-1352	-1369	-1365
80	I-end	-826	-826	-857	853	849	-849
	J-end	1592	1591	1622	-1619	-1612	-1613
81	I-end	-890	-890	-918	916	899	-902
	J-end	1791	1792	1823	-1821	1818	-1818
82	I-end	-592	-592	-619	617	670	-658
	J-end	1206	1206	1230	-1229	-1250	-1245
83	I-end	-744	-744	-771	773	764	-765
	J-end	1501	1501	1528	-1529	-1519	-1520
84	I-end	-806	-806	-830	831	810	-814
	J-end	1703	1704	1731	-1732	-1724	-1725
85	I-end	-429	-429	-450	449	495	-484
	J-end	1074	1074	1093	-1092	-1111	-1107
86	I-end	-605	-605	-627	628	619	-620
	J-end	1368	1368	1391	-1391	-1380	-1382
87	I-end	-662	-663	-682	682	661	-665
	J-end	1536	1537	1558	-1559	-1547	-1548
88	I-end	-336	-336	-354	353	397	-387
	J-end	965	965	981	-980	-997	-993
89	I-end	-498	-499	-517	518	510	-511

	J-end	1252	1251	1271	-1271	-1262	-1263
90	I-end	-551	-551	-567	567	547	-551
	J-end	1422	1421	1440	-1441	-1428	-1430
91	I-end	-168	-169	-181	180	218	-210
	J-end	830	829	841	-840	-855	-852
92	I-end	-317	-318	-331	332	327	-328
	J-end	1082	1082	1096	-1097	-1089	-1091
93	I-end	-364	-364	-375	376	360	-363
	J-end	1209	1209	1222	-1223	-1089	-1214
94	I-end	-73	-74	-83	82	117	-109
	J-end	717	717	725	-724	-736	-734
95	I-end	-193	-194	-204	205	201	-201
	J-end	948	948	959	-959	-954	-955
96	I-end	-222	-223	-230	231	216	-219
	J-end	1055	1055	1065	-1065	-1054	-1056
97	I-end	83	82	78	-78	-53	58
	J-end	589	589	593	-592	-600	-598
98	I-end	7	6	1	0	-3	2
	J-end	765	765	772	-772	-768	-768
99	I-end	-11	-11	-15	16	3	-6
	J-end	814	814	819	-820	-806	-809
100	I-end	283	282	281	-282	-256	262
	J-end	419	419	420	-419	-430	-428
101	I-end	141	141	138	-137	-140	139
	J-end	630	629	634	-634	-630	-631
102	I-end	146	145	144	-144	-155	153
	J-end	628	628	630	-630	-615	-618
103	I-end	184	184	184	-184	-168	171
	J-end	101	101	100	-100	-106	-105
104	I-end	37	37	35	-35	-35	35
	J-end	277	277	279	-279	-277	-278
105	I-end	81	81	82	-82	-87	86
	J-end	268	267	268	-268	-259	-261

Frame 7

	M1, I-End	M1, J-End	M2, I-End	M2, J-End	M3, I-End	M3, J-End
1ST ORDER	0	218	15	22	5	13
AISC B1/B2	0	229	13	25	2	11
RISA 3D	0	295	17	31	3	11
ROBOT	0	303	20	30	3	11
SAP 2000	0	303	17	35	3	10
STAAD-III	0	279	15	33	3	10

M4, I-End	M4, J-End	M5, I-End	M5, J-End	M6, I-End	M6, J-End
0	361	147	79	23	195
0	373	149	86	25	198
0	452	138	107	26	203
0	453	140	108	26	204
0	458	135	109	24	204
0	435	137	102	24	202

M7, I-End	M7, J-End	M8, I-End	M8, J-End	M9, I-End	M9, J-End
123	100	0	212	120	114
127	104	0	219	122	116
126	104	0	256	114	115
125	104	0	256	117	117
126	104	0	257	114	116
126	104	0	249	115	115

M10, I-End	M10, J-End	M11, I-End	M11, J-End	M12, I-End	M12, J-End
204	508	17	318	13	142
217	522	23	325	11	138
278	590	28	330	11	145
285	600	25	332	12	146
287	593	32	330	10	145
264	572	30	328	10	144

M13, I-End	M13, J-End	M14, I-End	M14, J-End
102	332	43	114
110	342	39	116
133	370	41	115
134	373	42	117
133	371	40	116
126	364	41	115

Frame 8

	M1, I-End	M1, J-End	M2, I-End	M2, J-End	M3, I-End	M3, J-End
1ST ORDER	200	0	200	0	0	0
AISC B1/B2	244	0	244	0	0	0
RISA 3D	225	0	225	0	0	0
ROBOT	228	0	223	0	0	0
SAP 2000	228	0	223	0	0	0
STAAD-III	222	0	222	0	0	0

M4, I-End	M4, J-End	M5, I-End	M5, J-End
0	125	125	0
0	125	125	0
0	125	125	0
0	125	125	0
0	124	124	0
0	124	124	0

VITA

Angela Marie Schimizze was born March 6, 1977 in Lafayette, Indiana to Richard and Anna Schimizze. Since her father was in the Navy, she spent her childhood moving around the country until she moved to Summerville, South Carolina where she finished high school. She attended Fort Dorchester High School and graduated in 1995. She enrolled in Clemson University in South Carolina where she proudly supported the Clemson Tigers. She received a Bachelor of Science Degree in Civil Engineering in 1999 and then entered the graduate program in the Structural Engineering and Materials Division of Civil Engineering at Virginia Polytechnic Institute and State University, where she did research under Dr. Thomas M. Murray.

Angela M. Schimizze