COMPARISON OF STATIC ANALYSIS RESULTS BASED ON DIFFERENT MODELS OF A 67 STORY COMMERCIAL BUILDING

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Leroy Z. Emkin, Ph.D., P.E.
Professor, School of Civil and Environmental Engineering
Founder, Computer Aided Structural Engineering (CASE) Center
Georgia Institute of Technology
Atlanta, Georgia 30332-0355 U.S.A.

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Georgia Institute of Technology
Atlanta, Georgia 30332-0355 U.S.A.
Tel: +1-404-8942260, FAX: +1-404-8948014, email: leroy.emkin@ce.gatech.edu

Introduction

There is a wide variety of modeling techniques in use today for the static and dynamic analysis of reinforced concrete high-rise commercial buildings. These techniques generally fall into the following two categories.

"Exact" model utilizing a detailed finite element representation of all important structural entities. This exact model attempts to predict the actual behavior of the building ***without*** making any significant a priori assumptions regarding the overall behavior of the building structure. In other words, rather than making approximate and often arbitrary (albeit convenient) assumptions regarding how the building behaves, the exact modeling approach is intended to predict the actual behavior of the building in a manner consistent with the fundamental principles of structural mechanics. Exact modeling techniques are somewhat more tedious and time consuming to perform, but usually result in *far more accurate* predictions of building response.

"Approximate" model based on a priori assumptions regarding the behavior of the building (i.e., assumptions that are made without prior detailed knowledge of the actual behavior of the building structure). Such assumptions provide a convenient means to significantly simplify modeling and analysis procedures of buildings resulting in rather quick and low cost analysis and design, but often produce *highly inaccurate* predictions of building response.

The particular modeling technique (exact or approximate) used by the structural engineer is often influenced by a number of factors including:

Willingness of the client to pay for exact modeling techniques
Time constraints on design
Design code requirements
Professional standards of practice
Structural characteristics of the building to be modeled
Extent of knowledge and experience of the responsible engineers
Business issues involving competitiveness and profitability
Quality of construction practices and materials (or lack thereof)
Willingness to accept high risk and high liability
Level of concern for safety of the public
Other factors

Unfortunately, in recent years it appears that economic considerations have become the primary driving force behind the extensive use of approximate modeling techniques in substitution for exact modeling techniques. Although approximate techniques have a long history of use, their formulations are predicated on the requirement that the building structure being modeled conform to very stringent limitations on the irregularity of the geometry of the structure, member and finite element properties, the stiffness attributes of the structure, the permissible loading conditions, member and finite element boundary conditions, overall deformation behavior of the structure, and numerous other factors.

In the time before computers became the primary modeling and analysis tool for structural engineers, approximate techniques were the only means of modeling and analyzing high rise buildings. In those times, clients and building designers were fully aware of the limitations of such approximate techniques. Thus, it was expected that the structural engineer would specify constraints on the structural configuration of the buildings being designed in order to assure that analysis results computed on the basis of approximate methods of analysis would have a reasonable possibility of predicting reasonably correct building behavior. In other words, it was normal for the structural engineer to dictate to the building designer/architect that the building have structural characteristics that were consistent with the known limitations of the available approximate modeling and analysis tools in use at the time.

Such is not the case today. Rather, the client expects, and often requires, that the structural engineer use the latest computer technology to perform modeling and analysis of ***any*** building structure conceived by the architect, no matter how complex and irregular the physical structure may be. Further, both the client and architect, and often the structural engineer, mistakenly believe that the very use of the computer will assure correct modeling and analysis of building structures independent of whether or not an exact or approximate method is used. Based on such an incorrect belief, and in response to unreasonably low fees paid for structural engineering services and to unreasonably limited time allocation to complete the structural engineering of the building, the engineer is generally forced into the use of the lowest cost and most approximate techniques of modeling and analysis whether or not such techniques have the ability to correctly predict the behavior of the building. Further, there are several computer programs in use today that implement such highly approximate procedures which are extremely inexpensive, and which require very few engineering and computer resources, to use.

Unfortunately, if only approximate techniques are used, the structural engineer has no way to know whether or not the solutions obtained are anywhere near the correct solutions. Approximate methods of modeling and analysis today become extremely dangerous in view of the fact that modern buildings are generally very tall structures with high aspect ratios, and which incorporate exceedingly complex and highly irregular geometries, highly nonuniform stiffness distributions throughout the structure, large open interior atrium spaces, extremely limited use of structural materials (especially when compared to high rise buildings in the days before computers), lower inherent factors of safety in design, etc.

Since approximate techniques have become so widely used, it has become essential to investigate the actual errors inherent in such methods by performing controlled computational experiments which create analysis results for models of actual high rise building structures which are modeled using various commonly used approximations, and comparing such approximate results to benchmark solutions created using the far more exact finite element formulations.

This paper documents one such investigation on a 67 story (262 meter tall) reinforced concrete building structure located in the southeastern part of the U.S.A. The finite element model of the structure that was used is summarized in Figure 1. The investigation involved the analysis of the building structure for both dead and wind load cases. Three (3) different models were considered for the dead load case, and five (5) different models were considered for the wind load case as follows:

Dead Load Case:

1. The exact (i.e., benchmark) solution was based on a finite element model of the building structure subjected to incrementally applied dead loads and analyzed using a sequential construction simulation technique (i.e., simulating the sequence of construction). The finite element model was supplied by the design firm that performed the original design, and it was used without any significant modifications.

2. One approximate solution was based on the same finite element model of the building structure subjected to full dead load, but in this case the entire structure was subjected to the full dead load, and then analyzed as one complete model. In addition, axial deformations of columns were accounted for.

3. The second approximate solution used the same finite element model subjected to full dead load and analyzed as one complete model, except that axial deformations of all columns were ignored (this appears to be a common assumption in various "tier building analysis" computer programs).

Wind Load Case:

1. The exact solution was based on the same finite element model of the building structure subjected to wind loads and then analyzed as one complete model.

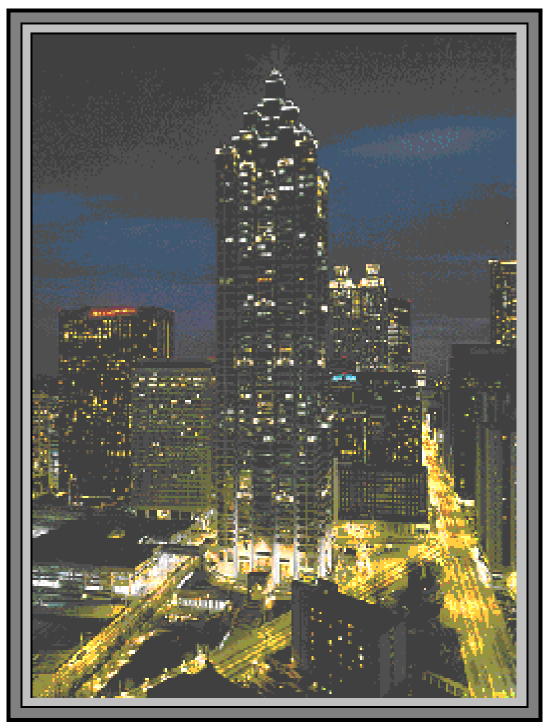
2. An approximate solution was based on the assumption that the floors of the building in which floor slabs exist throughout most of the floor level behave as a rigid body floor plane ("RBP") membrane with 3 displacement degrees-of-freedom per joint. The RBP model assumption was not used in the open atrium part of the model. The RBP model assumed that all joints in the floor behave as a rigid plane with two translation degrees-of-freedom in the horizontal plane, and one rotation degree-of-freedom about a vertical axis. This model also permitted all joints in the floor to rotate about axes in the plane of the floor (i.e., bending of beams in the RBP and of columns were permitted). In addition, this model accounts for axial deformations of the beams and columns. Further, the rigid body degrees-of-freedom were considered as the master degrees-of-freedom to which the in-plane translation and vertical rotation degrees-of-freedom of the joints in the floor were slaved using formal kinematic constraint conditions. A rigorous mathematical condensation procedure was then performed, following which an analysis for the remaining displacement degrees-of-freedom was performed, together with the analysis for all structure internal member and finite element forces and moments and external support reactions.

3. Same as the RBP model in case 2 above, except that column axial deformations were ignored as is done in certain approximate analysis computer programs in use today.

4. An approximate solution based on the assumption that the floors of the building in which floor slabs exist throughout most of the floor level behave as a rigid body floor solid ("RBS") with 6 displacement degrees-of-freedom per joint. The RBS model assumed that all joints in the floor behave as a rigid solid with three translation degrees-of-freedom and three rotation degrees-of-freedom. This model did not permit any joints in the floor to rotate about axes in the plane of the floor (i.e., bending of beams in the RBS were prevented, while column bending was controlled by the RBS rotations about axes in the plane of the floor). In addition, this model accounted for axial deformations of the beams and columns. Further, the rigid body degrees-of-freedom were considered the master degrees-of-freedom to which the three translation and three rotation degrees-of-freedom of the joints in the floor were slaved using formal kinematic constraint conditions. A rigorous mathematical condensation procedure was then performed, following which an analysis for the remaining displacement degrees-of-freedom was performed, together with the analysis for all structure internal member and finite element forces and moments and external support reactions.

5. Same as the RBS model in case 4 above, except that column axial deformations were ignored as is done in certain approximate analysis computer programs in use today.

Description of the Building



Office Tower

C Completed in 1992.
C 2,600,000 gross square feet (241,548 m^2) of building area.
C 1,200,000 net rentable square feet (111,484 m^2) of office space.
C 67 stories high at 867 feet (264 m).
C Located in the Southeastern part of the U.S.A.

Design Features

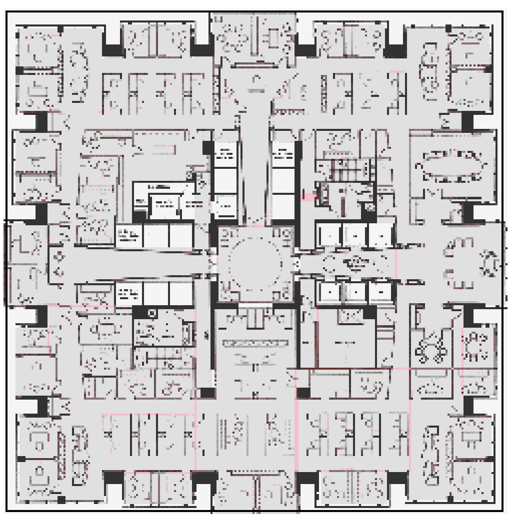
C Tower in alternating shades of gray granite with multi-level glass top.
C Two acre (8094 m^2) landscaped public plaza and park.
C Two-level main lobby ascending five stories high.
C 36 corner offices per typical floor.
C 25,000 square feet (2323 m^2) of column-free space per typical floor.
C Cross-core elevator lobbies which minimize corridor length and centralize foyers on each floor.
C State-of-the-art HVAC system for maximum comfort.

Geometry and Topology

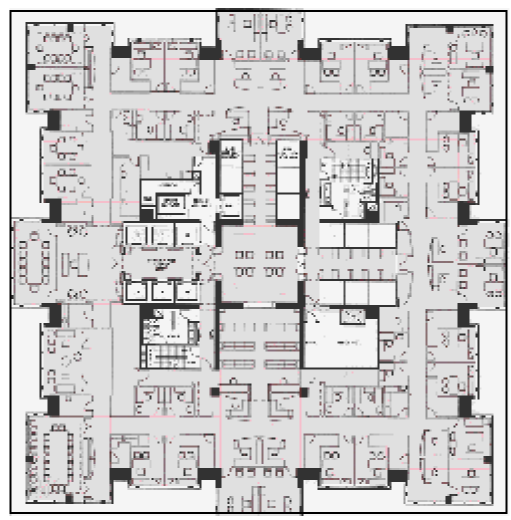
The building is a 67 story structure, 867 ft (264m) tall with a square footprint. The aspect ratio is approximately 5.4. The structure has four different floor plans ranging from stories 2 -15, 16-28, 29-42 and 43-53. Outriggers are used at different floors and the building is supported by 16 exterior columns and a concrete core shear wall. The columns are connected by a 4.5 in. (11.43 cm) thick concrete slab and beam system. Stories 4-10 are an open atrium lobby.

Floor Plans

Low/Mid Rise Floor Plan
- 23,196 Usable.S.F. (2155m^2)
- 25,005 Reusable.S.F. (2323m^2)



Mid/High Rise Floor Plan
- 21,843 Usable.S.F (1996m^2)
- 23,547 Reusable.S.F. (2188m^2)



Description of the "Exact" Finite Element Model

The finite element model that was used in this study (Figure 1) was supplied by the design firm that performed the original design, and it was used without any significant modifications. Although this author may have created a somewhat different finite element representation of the building structure, the one created by the original design firm was considered to be an acceptable "exact" model. Further, it was not the intent of this study to investigate the differences in solutions caused by different "exact" models. Rather, the intent was to investigate the differences between an acceptable "exact" model and various gross approximations used in practice today. The characteristics of the "exact" finite element model are as follows:

A. The total height of the finite element model is 859 feet (261.82 m).
The base of the model at the level of the supports occupy a square footprint of 160.63 feet (48.96 m) by 160.63 feet (48.96 m) (Figure 2).

B. All walls were modeled using equivalent columns whose cross-section properties were computed to be the same as those for the properties of the cross-section of the wall being modeled.

C. All beams and columns were modeled with SPACE FRAME members.

D. All floor slabs were modeled with PLANE STRESS quadrilateral and triangle finite elements in order to represent the in-plane stiffness of the floor slab, and to ignore the bending stiffness of the floor slabs.

E. Model size:

Number of joints	=	2,414
Number of space frame members	=	4,978
Number of plane stress IPLQ quadrilateral plus CSTG triangle elements	=	2,352

F. Total number of independent loading conditions = 35

Loading No.	Description
101 to 116	Self Weight of all members(including equivalent columns for walls)
201 to 216	Additional dead loads (including floor slab self weight) applied to members
300	Live loads
401	N-S Wind Load
501	E-W Wind Load

G. Total number of loading combinations = 3

Loading Combination	Description	
100	Full dead load: 1.0 x (101 + 102 + ... + 115 + 116 + 201 + 202 + ... + 215 + 216)	
400	Factored N-S Wind Load:	0.815653 x 401
500	Factored E-W Wind Load:	0.815653 x 501

The model is characterized by a bottom level of 36 support joints, and 16 typical floor levels (Figure 3) above the support joints. The bottom 5 floor levels are part of the atrium, while the remaining 11 floor levels are above the atrium (Figures A-1 to A-16 in the Appendix A). Each of the typical floor levels consists of beams, columns, and finite elements which have a typical geometric pattern in each floor respectively.

The bottom level of support joints and columns are numbered in the 3000's, while successive levels above have joints, members, and finite elements numbered in the 4000's, 5000's, ..., 70000's.

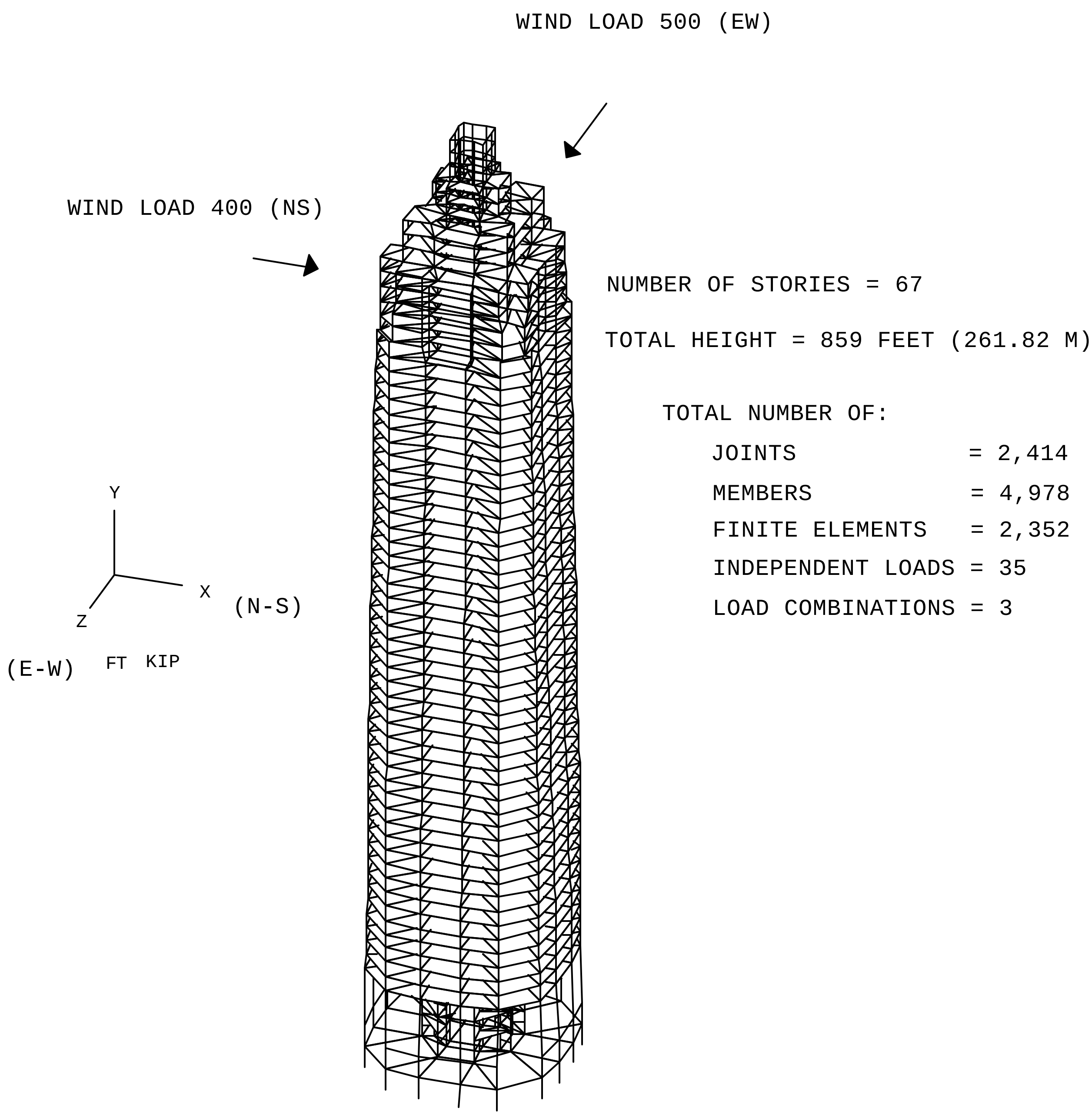


Figure 1 Finite Element Model

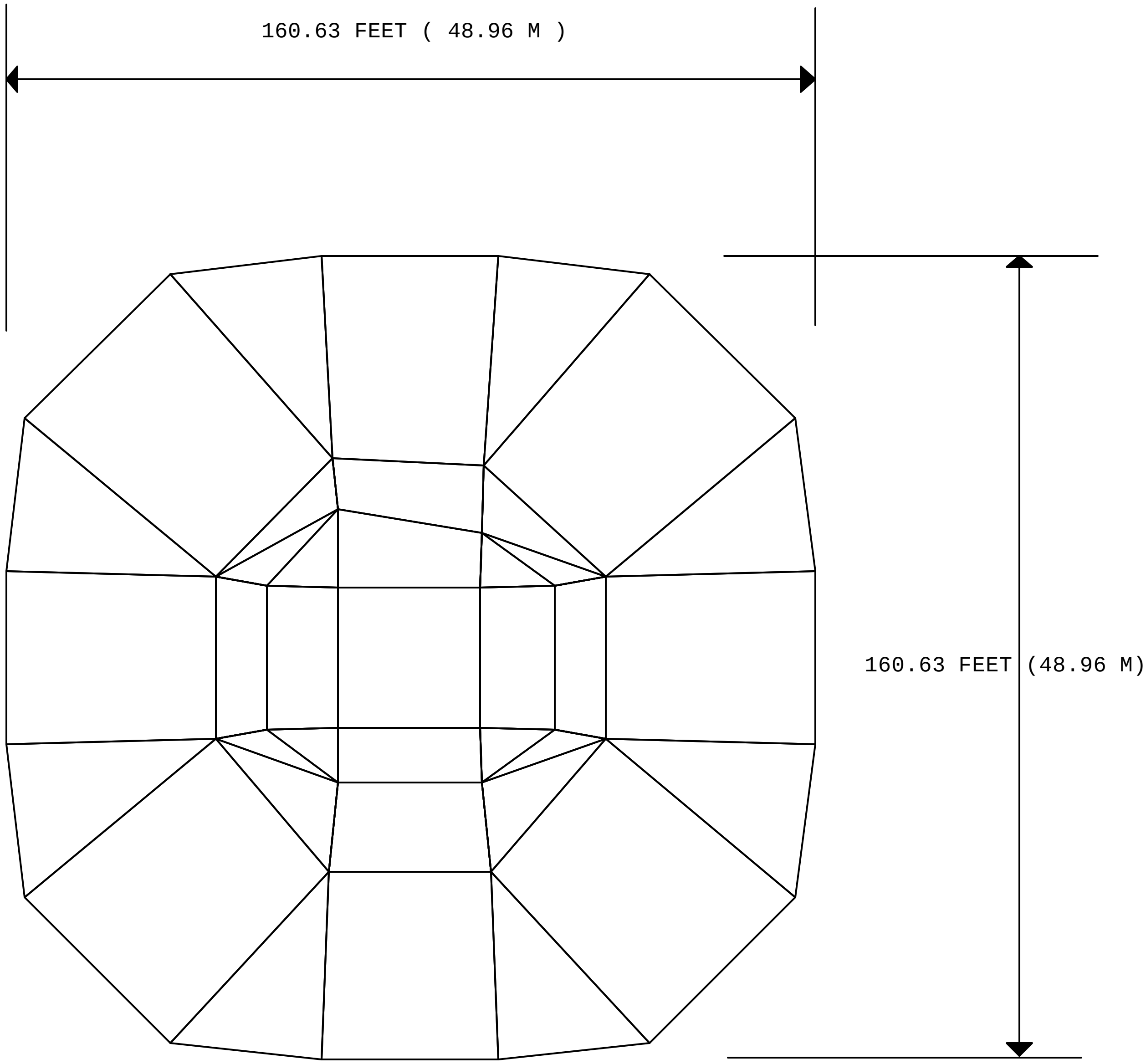


Figure 2 Footprint of the model at the First Level above the Support Joints

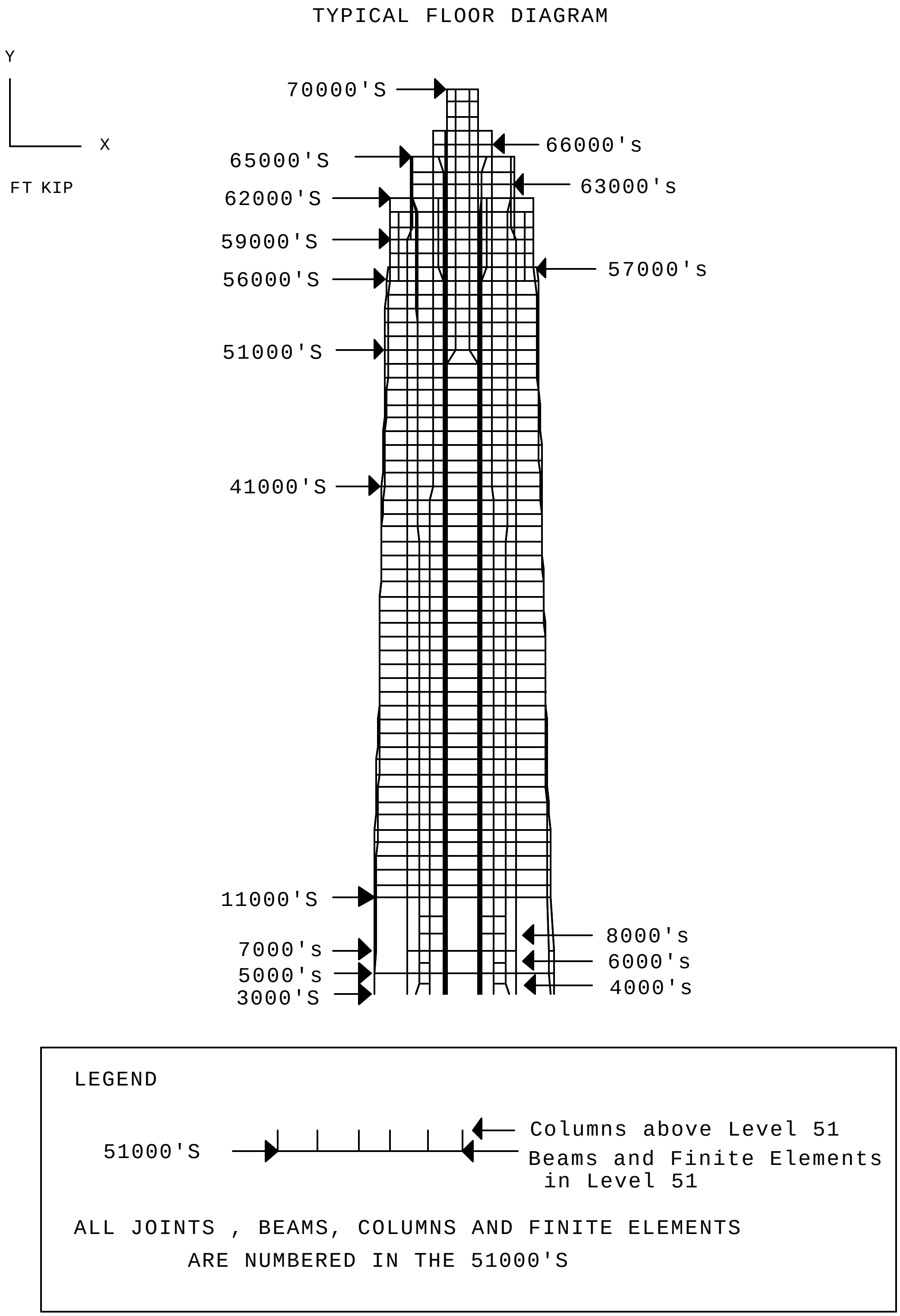


Figure 3 Numbering Scheme for Joints, Members, and Finite Elements

Dead Load Case: Description of the Sequential Construction Simulation Model

A. Tall reinforced concrete frame structures generally cannot be correctly analyzed for gravity dead loads by modeling the full structure subjected to all dead loads in one single analysis. If such a model is used, it is often the case that the resulting calculated forces and moments in the members of the structure will not accurately represent the actual distribution of forces and moments throughout the structure.

A more accurate analysis for dead loads in a tall reinforced concrete structure may be obtained by performing the analysis in a manner which simulates the sequence of construction using a sequential construction simulation model. In this study, the building structure model was analyzed for dead load using sixteen (16) separate sequential construction simulation analysis blocks, where each analysis block consisted of several stories of the building. Figure 4, and Figures B-1 to B-5 in Appendix B, show where the 16 analysis blocks were located in the model.

B. The sequential construction simulation procedure for analyzing the structure for dead loads was as follows:

a. The entire structure is modeled including all joints, members, and finite elements.

b. Sixteen (16) separate dead loading conditions were defined. Each dead load condition consisted of the self weight of all members and finite elements, and additional dead load, applied to each of the 16 sequential construction simulation analysis blocks respectively.

c. Inactivate all joints, members, and finite elements except those in block 1 (the bottommost atrium block). Perform an analysis of the structure consisting of block 1 and its associated Dead Load Conditions 101 and 201.

d. Activate all joints, members, and finite elements in block 2 (the next block up; all joints, members, and finite elements in blocks 1 and 2 are now active). Perform an analysis of the structure consisting of blocks 1 and 2, and subjected only to the incremental Dead Loading Conditions 102 and 202.

e. Activate all joints, members, and finite elements in block 3 (the next block up; all joints, members, and finite elements in blocks 1, 2, and 3 are now active). Perform an analysis of the structure consisting of blocks 1, 2, and 3 and subjected only to the incremental Dead Loading Conditions 103 and 203.

f. Repeat step e for each additional block for blocks 4 to 15 respectively, and Dead Load Conditions 104 and 204 to 115 and 215 respectively.

g. Activate all joints, members, and finite elements in block 16 (the top most block; all joints, members, and finite elements in blocks 1 to 16 (the entire structure model) are now active). Perform an analysis of the structure consisting of blocks 1 to 16 (the entire structure) and subjected only to the incremental Dead Loading Conditions 116 and 216.

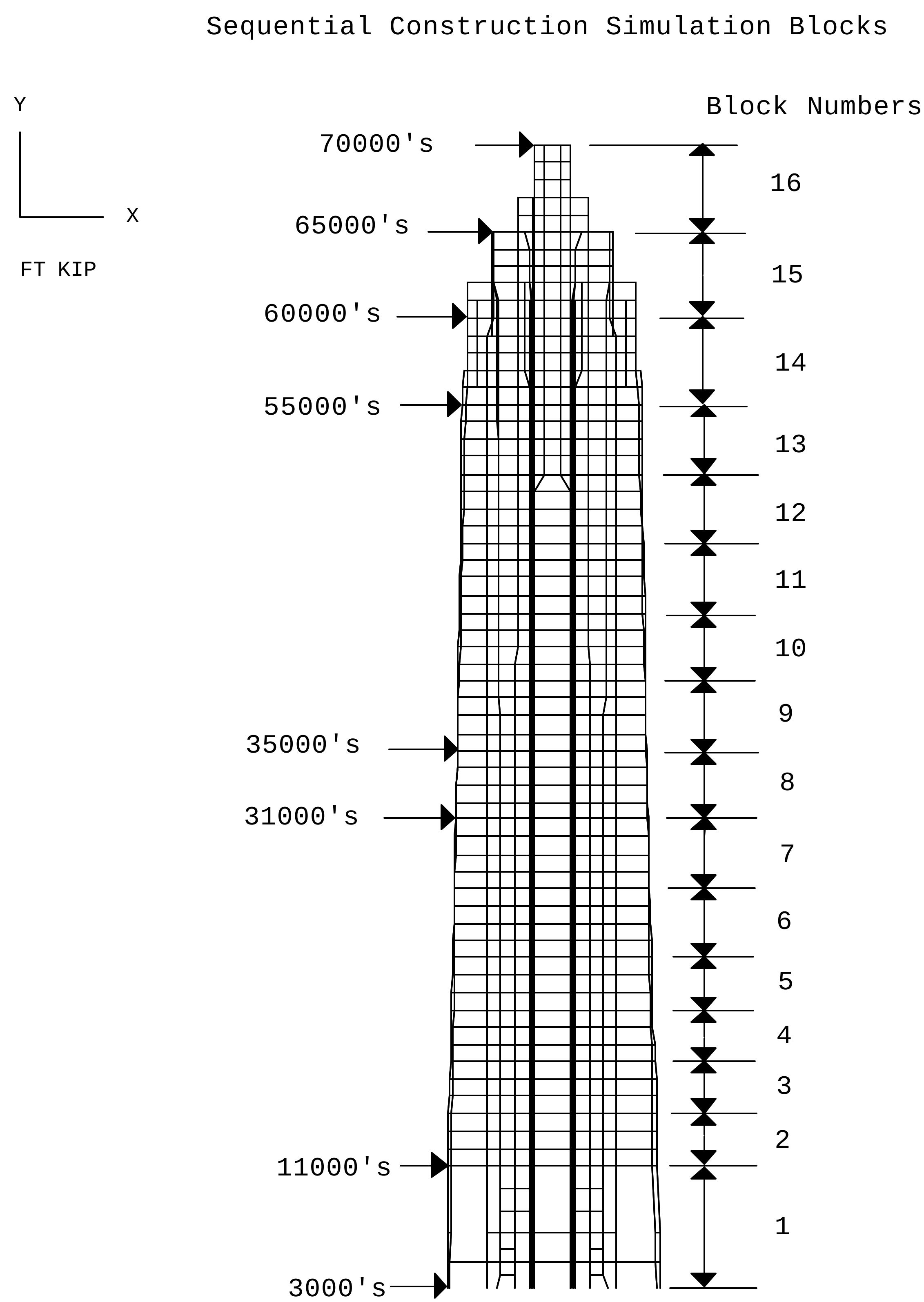


Figure 4 Sequential Construction Simulation Dead Load Analysis Blocks

h. Following the above 16 analyses, one loading combination (LOADING 100) is formed using the analytical results of the 16 analyses, where LOADING 100 contains the analytical solution for the distribution of forces and moments throughout the structure due to the full gravity dead load condition, and where,

LOADING 100 = 1.0 x (101 + 102 + ... + 115 + 116
+ 201 + 202 + ... + 215 + 216)

Wind Load Case: Description of the Approximate Rigid Body Floor Models

In order to achieve a simplification of modeling and improvement of analysis efficiency for lateral load analysis, it has become common to use a modeling simplification based on the assumption that floor levels behave as rigid bodies. In addition, other simplifying assumptions are also made regarding the behavior of the tall building structure that result in significant reduction of computer processing time.

Unfortunately, and most dangerously, when such simplifications are implemented into computer software (the so-called "tier building analysis" software), it is often extremely difficult, if not impossible, to know the precise nature or acceptability of such simplifying assumptions. In fact, for modern tall buildings with irregular geometry, highly complex loading patterns, highly non-uniform distribution of stiffness, concentrations of stiffness in various parts of the building, and other special building model characteristics, the assumptions generally implemented into such tier building computer software are totally incompatible with the actual behavior of the building structure, and thus the analysis results computed on the basis of such assumptions are at best extremely approximate, and in general totally incorrect!

One of the intents of this study is to show a comparison between an "exact" frame and finite element analysis solution of a tall building structure (the benchmark solution) and solutions based on several different rigid body floor models used in various computer programs. Actual tier building computer programs generally incorporate many more arbitrary assumptions regarding building behavior than rigid body floor models.

However, this study limited the range of such assumptions only to several rigid body floor models. Further, in this study, rigid body floor models were not used in the open atrium part of the model. Rather, the rigid body floor model was only used in story level 11 and above where the floor system spanned across the entire width of the model.

The basic rigid body floor model that was used in this study utilizes a rigorous mathematical kinematic condensation procedure to simulate rigid floor diaphragms. The procedure is based upon the specification of rigid body kinematic relationships between the dependent degrees-of-freedom (i.e., slave degrees-of-freedom) of the joints in a floor in which a rigid body diaphragm is to be modeled, and the master degrees-of-freedom selected for the floor.

The procedure can be summarized as follows:

The stiffness equations for a finite element model are represented as:

$$\mathbf{K} \times \mathbf{U} = \mathbf{P} \quad \ldots\ldots \quad (1)$$

where,

K	=	Global stiffness matrix of the complete model
U	=	Vector of unknown joint displacement components (i.e., the kinematic degrees-of-freedom)
P	=	Vector of equivalent joint forces

Now, let

$\mathbf{u_i}$	=	independent joint displacement degrees-of-freedom
$\mathbf{u_d}$	=	dependent joint displacement degrees-of-freedom
$\mathbf{u_m}$	=	master degrees-of-freedom

and where,

$\mathbf{u_d}$	=	$\mathbf{T} \times \mathbf{u_m}$ .... (2)
T	=	Transformation matrix relating master degrees-of-freedom to dependent degrees-of-freedom.

Now, reordering the stiffness equations according to independent and dependent degrees-of-freedom results in:

K x **U** = **P** 6 **Kr** x **Ur** = **Pr**: These are the reordered stiffness equations.

In matrix form, the reordered stiffness equations **Kr** x **Ur** = **Pr** can be written as:

$$\left[\begin{array}{c|c} Kr_{11} & Kr_{12} \\ \hline Kr_{21} & Kr_{22} \end{array}\right] \left\{\begin{array}{c} u_i \\ \hline u_d \end{array}\right\} = \left\{\begin{array}{c} Pr_1 \\ \hline Pr_2 \end{array}\right\} \quad \text{...(3)}$$

But, $\mathbf{u_d} = \mathbf{T} \times \mathbf{u_m}$

Therefore, $\mathbf{u_d}$ can be replaced by $\mathbf{T} \times \mathbf{u_m}$ in the reordered stiffness equations as,

$$\left[\begin{array}{c|c} Kr_{11} & Kr_{12} \\ \hline Kr_{21} & Kr_{22} \end{array}\right] \left\{\begin{array}{c} u_i \\ \hline T \times u_m \end{array}\right\} = \left\{\begin{array}{c} Pr_1 \\ \hline Pr_2 \end{array}\right\} \quad \text{...(4)}$$

This equation can now be written as,

$$\left[\begin{array}{c|c} Kr_{11} & Kr_{12}\,T \\ \hline Kr_{21} & Kr_{22}\,T \end{array}\right] \left\{\begin{array}{c} u_i \\ \hline u_m \end{array}\right\} = \left\{\begin{array}{c} Pr_1 \\ \hline Pr_2 \end{array}\right\} \quad \text{...(5)}$$

Equation 5 is not symmetrical. It can be made symmetrical by premultiplying the second partitioned equation by $\mathbf{T^t}$ (the transpose of T) resulting in,

$$\left[\begin{array}{c|c} Kr_{11} & Kr_{12}\,T \\ \hline T^t\,Kr_{21} & T^t\,Kr_{22}\,T \end{array}\right] \left\{\begin{array}{c} u_i \\ \hline u_m \end{array}\right\} = \left\{\begin{array}{c} Pr_1 \\ \hline T^t\,Pr_2 \end{array}\right\} \quad \text{......................................(6)}$$

Equation 6 is symmetrical and therefore can be solved using standard symmetrical matrix equation solvers, where the solution can be expressed as,

$$\left\{\begin{array}{c} u_i \\ \hline u_m \end{array}\right\} = \left[\begin{array}{c|c} Kr_{11} & Kr_{12}\,T \\ \hline T^t\,Kr_{21} & T^t\,Kr_{22}\,T \end{array}\right]^{-1} \left\{\begin{array}{c} Pr_1 \\ \hline T^t\,Pr_2 \end{array}\right\} \quad \text{......................................(7)}$$

Equation 7 is solved for $\mathbf{u_i}$ (the independent joint displacement components) and for $\mathbf{u_m}$ (the master degrees-of-freedom). Then, the dependent joint displacement components can be computed as,

$$\mathbf{u_d} = \mathbf{T} \times \mathbf{u_m}$$

which results in the solution for all joint displacement components (both independent and dependent displacement components) as,

$$\left\{\begin{array}{c} u_i \\ \hline u_d \end{array}\right\}$$

It is important to note that the kinematic condensation procedure described above is based on the following:

A. A mathematically rigorous and correct formulation of the kinematic condensation procedure is used.

B. The only assumptions made are those involving specific kinematic constraints (i.e., specific rigid body relationships between displacement degrees-of-freedom of joints)

C. Except for the rigid body floor assumptions, no other arbitrary assumptions, and often incorrect assumptions if the building structure is not highly regular, are required regarding the overall behavior of the building structure model (such as assumptions of deformation and force states) as is usually done in so-called “tier building” modeling and analysis procedures.

Now, in the study, two different rigid body floor models were studied. One model is referred to as the “rigid body plane floor membrane” model, and the other is referred to as the “rigid body solid floor” model. These models can be described as follows:

Rigid Body Plane Floor Membrane Model

The rigid body plane floor membrane model (Figure 5A) is based on the following assumptions:

A. Only the in-plane rigidity of the floor is modeled as a rigid body. Bending deformations are unconstrained. This model uses only three (3) displacement degrees-of-freedom (two translations and one rotation) to represent the displacements of the rigid body floor.

B. All joints in the floor are constrained so that their translation degrees-of-freedom in the plane of the floor are related to the three (3) master degrees-of-freedom defined for the floor, while their rotation degrees-of-freedom about axes perpendicular to the plane of the floor are equal to the corresponding rotation master degree-of-freedom of the rigid floor. The three master degrees-of-freedom of the rigid floor are the two translation degrees-of-freedom in the plane of the floor, and one rotation degree-of-freedom about an axis perpendicular to the floor.

The translation degrees-of-freedom perpendicular to the plane of the floor, and the rotation degrees-of-freedom about axes in the plane of the floor are not constrained in any way.

C. Under the wind load condition alone, the beams which are connected to the joints in the plane of the rigid body floor membrane and whose centroidal axes lie in the plane of the rigid body floor experience zero axial forces, zero bending moments about axes perpendicular to the plane of the floor, zero shear forces in the plane of the floor, non-zero torsion, non-zero bending moments about axes in the plane of the floor, and non-zero shear forces perpendicular to the plane of the floor. However, there are certain beams whose centroidal axes are eccentric to the rigid body floor (i.e., they lie below the plane of the rigid body). Non-zero axial forces are created in these eccentric beams.

Rigid Body Solid Floor Model

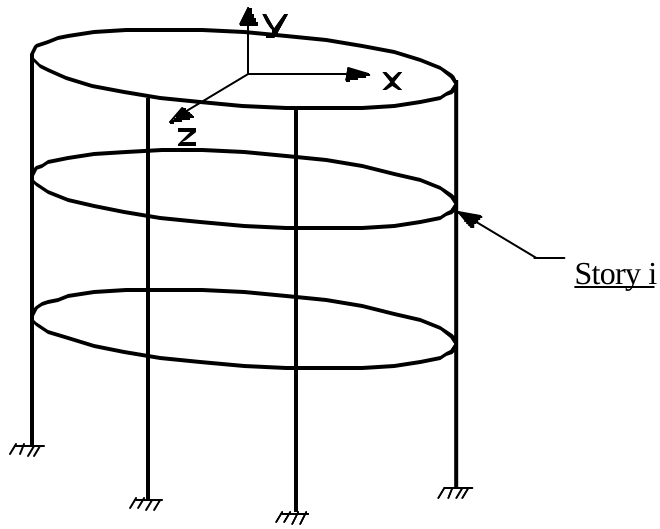
The rigid body solid floor model (Figure 5B) is based on the following assumptions:

A. The floor is modeled as a rigid solid where all joint translation and rotation degrees-of-freedom are constrained. This model uses all six (6) displacement degrees-of-freedom (three translations and three rotations) to represent the displacements of the rigid body solid floor.

B. All joints in the floor are constrained so that their translation degrees-of-freedom are related to the six (6) master degrees-of- freedom defined for the rigid floor, while their rotation degrees-of-freedom are equal to the corresponding rotation master degrees-of-freedom of the rigid floor. The six master degrees-of-freedom of the rigid body solid floor are its three translation degrees-of-freedom and its three rotation degrees-of-freedom.

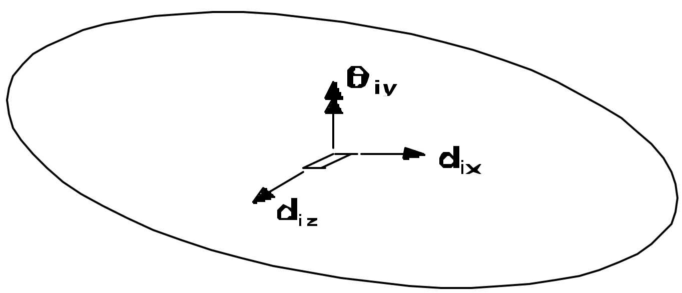
C. Under the wind load condition alone, the beams which are connected to the joints in the plane of the rigid body solid floor (with and without eccentricities) experience zero axial and shear forces, and zero torsion and bending moments (i.e., no internal beam forces and moments are created due to the wind load condition in the rigid solid floor model).

Space Frame Example



Two Rigid Floor Assumptions:

(A) Rigid Floor Membrane: x, z-translation, y-rotation



(B) Rigid Floor Solid: x, y, z-translation, x, y, z-rotation

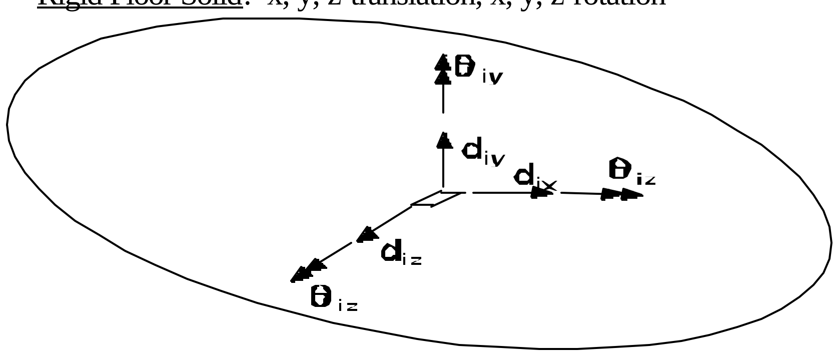
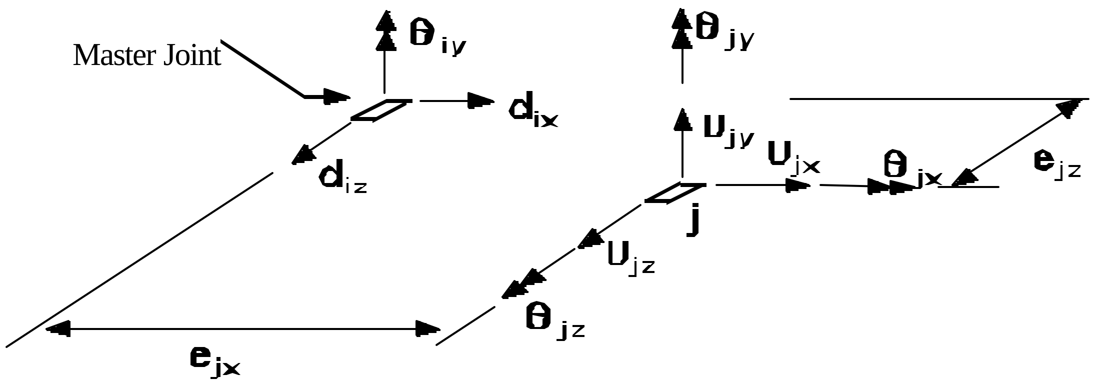


Figure 5 Rigid Floor Membrane (A) and Rigid Floor Solid (B) Assumptions

(A) Rigid Floor Membrane: x, z-translation, y-rotation



$u_{jx} = d_{ix} + e_{jz}\ 2_{iy}$ $\qquad$ 2_{jx} = independent

u_{jy} = independent $\qquad$ $2_{jy} = 2_{iy}$

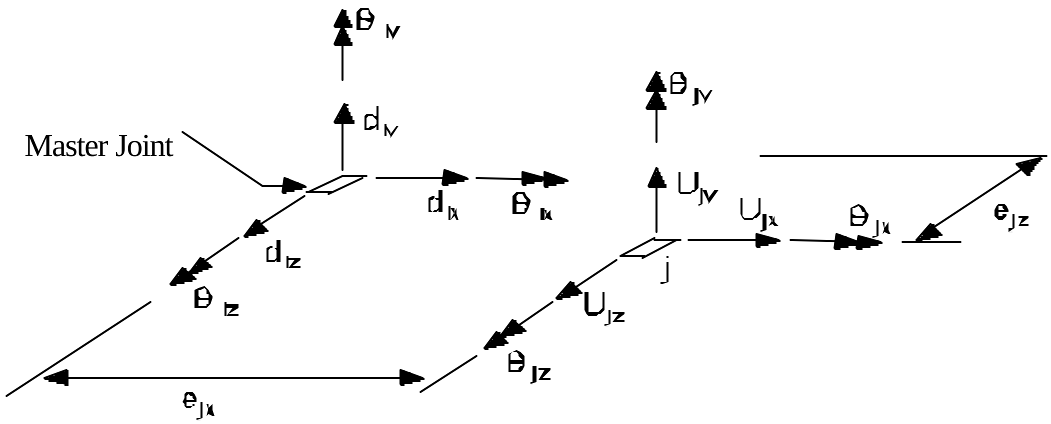
$u_{jz} = d_{iz} - e_{jx}\ 2_{iy}$ $\qquad$ 2_{jz} = indepependent

$$\begin{Bmatrix} u_{jx} \\ u_{jz} \\ \theta_{jy} \end{Bmatrix} = \begin{bmatrix} 1 & 0 & e_{jz} \\ 0 & 1 & -e_{jx} \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} d_{ix} \\ d_{iz} \\ \theta_{iy} \end{Bmatrix}$$

Dependent $\qquad$ Transformation Sub-Matrix $\qquad$ Master

Figure 5 Rigid Floor Membrane (A) and Rigid Floor Solid (B) Assumptions (continued)

(B) <u>Rigid Floor Solid</u>: x, y, z-translation,
x, y, z-rotation



$u_{jx} = d_{ix} + e_{jz} 2_{iy}$ $\qquad$ $2_{jx} = 2_{ix}$

$u_{jy} = d_{iy} - e_{jz} 2_{ix} + e_{jx} 2_{iz}$ $\qquad$ $2_{jy} = 2_{iy}$

$u_{jz} = d_{iz} - e_{jx} 2_{iy}$ $\qquad$ $2_{jz} = 2_{iz}$

$$\begin{Bmatrix} u_{jx} \\ u_{jy} \\ u_{jz} \\ \theta_{jx} \\ \theta_{jy} \\ \theta_{jz} \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & e_{jz} & 0 \\ 0 & 1 & 0 & -e_{jz} & 0 & e_{jx} \\ 0 & 0 & 1 & 0 & -e_{jx} & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} d_{ix} \\ d_{iy} \\ d_{iz} \\ \theta_{ix} \\ \theta_{iy} \\ \theta_{iz} \end{Bmatrix}$$

Dependent $\qquad$ Transformation Sub-Matrix $\qquad$ Master

Figure 5 Rigid Floor Membrane (A) and Rigid Floor Solid (B) Assumptions (continued)

Analysis of Results

Appendices C to H provide a summary of typical results of this study as follows:

1. Appendix C, Dead Load 100 Case, Column and Beam Forces

The distribution of selected force components for three lines of members over the height of the model are shown for Dead Load 100. The lines of members and force components are the F_X axial force at the start of members in column line ab109 (e.g., 11109, 12109, ...), the M_Z bending moment at the start of members in column line ab109 (e.g., 11109, 12109, ...), and the M_Z bending moment at the start of members in beam line ab216 (e.g., 11216, 12216, ...).

The three models used for this solution were:

(a) the Sequential Construction Simulation ("SEQ") model where the model is analyzed in a sequence of 16 blocks as described above,
(b) the Full structure including axial deformations of columns ("FULLCD"), and
(c) the Full structure with NO axial deformations of columns ("FULLNCD").

Using the SEQ model as the "exact" benchmark solution, it can be seen that the other two models can give results that are very different from the benchmark solution. The differences varied over a wide range of values. For example:

When comparing the F_X axial forces at the start of the members in column line ab109 (e.g., 11109, 12109, ...) for the three models, F_x varied by around 50% near the top, while differences in magnitude of around 2,000 Kips were seen at the bottom of the column line. Of particular interest is that the FULLNCD model seriously underestimated the axial forces in this column line. Since the total dead load is the same for all three models, then the FULLNCD model would have to overestimate the column axial forces in other column lines.

When comparing the M_Z bending moments at the start of the members in column line ab109 (e.g., 11109, 12109, ...) for the three models, M_Z varied by 100% or more at various locations along the column line. Of particular interest is that at some locations along the column line, the sign of the bending moment was different for the different models. Further, for the FULLNCD model in which column axial deformations are ignored (as is the case in one or more commonly used "tier building analysis" computer programs), the differences between the approximate solution and the SEQ benchmark solution is worst. For reinforced concrete members, this is an especially serious and dangerous result.

When comparing the M_Z bending moments at the start of the members in beam line ab216 (e.g., 11216, 12216, ...) over the height of the structure for the three models, M_Z varied by 100% or more at various locations up the beam line. And again, for the FULLNCD model in which column axial deformations are ignored (as is the case in one or more commonly used "tier building analysis" computer programs), the differences between the approximate solution and the SEQ benchmark solution is worst. For reinforced concrete members, this is again an especially serious and dangerous result.

The behavior described for the above three cases was found to be typical for numerous column and beam members in the building model. This behavior clearly indicates that the FULLNCD model for dead load analysis (i.e., the one in which column axial deformations are ignored while the full structure is loaded and analyzed for dead load in a single analysis, and which is a common assumption in various "tier building analysis" computer programs) is a seriously flawed procedure.

This study reconfirms that the only valid approach for correctly analyzing tall reinforced concrete building structures for dead loads is to use the sequential construction simulation (SEQ) model. In other words, in general, unless the tall building structure model is highly regular (i.e., nearly symmetric, regular geometry, smooth distribution of stiffness in each story of the building and from story to story of the building, no concentrations of stiffness in the building, smooth distribution of dead loads, no unusual boundary conditions, etc.), a single dead load analysis on the full structure model will produce highly erroneous results.

2. Appendix D, E-W Wind Load 500 Case, Lateral Deflections

The displacements of one typical column line (column line "ab133", i.e., column numbers 3133, 4133, 5133, ...) in the structure is shown based on the five models used for the E-W (Z-direction) Wind Load 500. The results are as follows:

Five Models	Maximum Z-Displacement	Ratio of Maximum Z-Displacement to Height of Model
Full finite element model (the "exact" benchmark solution)	40.69 cm (16.02 in)	1 / 644
Rigid plane floor membrane with column axial deformations	40.58 cm (15.98 in)	1 / 645
Rigid plane floor membrane with NO column axial deformations	10.41 cm (4.10 i n)	1 / 2514
Rigid solid floor with column axial deformations	14.6 cm (5.8 in)	1 / 1373
Rigid solid floor with NO column axial deformations	0.65 cm (0.25 in)	1 / 31025

The above displacement results appear to indicate that the rigid plane floor membrane model including axial column deformations will give the same solution as the full finite element model (i.e., the "exact" benchmark solution). However, as will be seen in the comparisons for force states in the structure due to wind loads (item numbers 3,4 and 6 below), this conclusion is incorrect. The fact is that even though the maximum lateral displacements at the top of the model are the same for both models, and that the general shape of the deflection curves are the same, the force distributions in many locations throughout the structure computed on the basis of the rigid plane model can be very different from the benchmark solution.

3. Appendix E, E-W Wind Load 500 Case, Column and Beam Forces

The distribution of selected force components for two lines of members over the height of the model are shown for E-W Wind Load 500. The lines of members and force components are the F_X axial force at the start of members in column line ab133 (e.g., 11133, 12133, ...), the M_Z bending moment at the start of members in column line ab133 (e.g., 11133, 12133, ...), and the M_Z bending moment at the start of members in beam line ab230 (e.g., 11230, 12230, ...).

The five models used for this solution were:

(a) Full Finite Element Model With FE Floor Slabs ("FEA")
(b) Rigid Body Plane Floor Membrane Including Column Axial Deformations ("RBPCD")
(c) Rigid Body Plane Floor Membrane With No Column Axial Deformations ("RBPNCD")
(d) Rigid Body Solid Floor Including Column Axial Deformations ("RBSCD")
(e) Rigid Body Solid Floor With No Column Axial Deformations ("RBSNCD")

Using the FEA model as the "exact" benchmark solution, it can be seen that the other four models can give results that in some cases are very different from the benchmark solution. The differences varied over a wide range of values. For example:

When comparing the F_X axial forces at the start of the members in column line ab133 (e.g., 11133, 12133, ...) for the five models, F_x varied by 100% or more. By far the worst solutions were based on the RBPNCD and RBSNCD models for axial forces from the bottom of the column line up to around story level 56 where the axial forces were seriously overestimated. The FEA, RBPCD, and RBSCD solutions for F_X were close from around story level 19 to the top of the model. However, significant differences occurred for the RBSCD model below story level 19.

When comparing the M_Z bending moments at the start of the members in column line ab133 (e.g., 11133, 12133, ...) for all five models, M_Z varied by 100% or more at in the region at and below story level 11 (the top of the open atrium space). However, the FEA and RBPCD models seem to give M_Z values which were close along the full length of the column line.

When comparing the M_Z bending moments at the start of the members in beam line ab230 (e.g., 11230, 12230, ...) over the height of the structure for the five models, the M_Z values were worst for the RBSCD and RBSNCD models, while the M_Z values for the RBPNCD model were very incorrect over the bottom half of the beam line. The M_Z values for the RBPCD model were closest to the benchmark FEA solution over the entire beam line.

The behavior described for the above three cases was found to be typical for numerous column and beam members in the building model.

4. Appendix F, N-S Wind Load 400 Case, Column and Beam Forces

The distribution of selected force components for three lines of members over the height of the model are shown for N-S Wind Load 400. The lines of members and force components are the F_X axial force at the start of members in column line ab135 (e.g., 11135, 12135, ...), the M_Y bending moment at the start of members in column line ab135 (e.g., 11135, 12135, ...), and the M_Z bending moment at the start of members in beam line ab230 (e.g., 11230, 12230, ...).

The five models used for this solution were:

(a) Full Finite Element Model With FE Floor Slabs ("FEA")
(b) Rigid Body Plane Floor Membrane Including Column Axial Deformations ("RBPCD")
(c) Rigid Body Plane Floor Membrane With No Column Axial Deformations ("RBPNCD")
(d) Rigid Body Solid Floor Including Column Axial Deformations ("RBSCD")
(e) Rigid Body Solid Floor With No Column Axial Deformations ("RBSNCD")

Using the FEA model as the "exact" benchmark solution, it can be seen that the other four models can give results that in some cases are again very different from the benchmark solution. The differences varied over a wide range of values. For example:

When comparing the F_X axial forces at the start of the members in column line ab135 (e.g., 11135, 12135, ...) for the five models, F_x varied by 100% or more. By far the worst solutions again were based on the RBPNCD and RBSNCD models for axial forces from the bottom of the column line up to around story level 56 where the axial forces were seriously overestimated. The FEA, RBPCD, and RBSCD solutions for F_X were close from around story level 19 to the top of the model. However, significant differences occurred for the RBSCD model below story level 19.

When comparing the M_Y bending moments at the start of the members in column line ab135 (e.g., 11135, 12135, ...) for the five models, M_Y varied by 100% or more at in the region at and below story level 11 (the top of the open atrium space). However, the FEA and RBPCD models gave M_Y values which were different by around 3,000 K-FT at story level 11 at the top of the atrium area of the model.

When comparing the M_Z bending moments at the start of the members in beam line ab230 (e.g., 11230, 12230, ...) over the height of the structure for the five models, the M_Z values were worst for the RBPNCD below story level 39, and were also incorrect by up to 100% or more for the RBPCD and RBSCD models in the atrium area on and below story level 11.

The behavior described for the above three cases was found to be typical for numerous column and beam members in the building model.

5. Appendix G, Dead Load 100 Case, Tables of Column and Beam Forces

The value of selected force components for several randomly columns and beams are shown for Dead Load 100. Comparisons are shown between the Sequential Construction Simulation Finite Element Model and the full structure model including column axial deformations. The force components shown are the F_X axial force at the start or end of the members shown, the M_Z bending moment at the start or end of the members shown, and the M_Z bending moment at the start or end of those members where the sign of the bending moment changed from one model to the other.

The two models used for this presentation of results were:

(a) the Sequential Construction Simulation ("SEQ") model where the model is analyzed in a sequence of 16 blocks as described above, and
(b) the Full structure including axial deformations of columns ("FULLCD").

The results shown in these tables include the ratio of the smaller force or moment value to the larger force or moment value. In some cases, the SEQ benchmark solution produced the larger values, while the FULLCD approximate solution produced larger values in some cases. Further, the ratios shown for axial force and z-bending moments show large differences in the values computed by the SEQ and FULLCD models, including moment reversals in the columns. The variation in results are similar the variation of results shown in Appendix C, but for randomly selected members.

6. Appendix H, Wind Load 400 and 500 Cases, Tables of Column and Beam Forces

The value of selected force components for several randomly chosen columns and beams are shown in a table format for the Wind Loads 400 and 500. Comparisons are shown between the Finite Element Model and each of the other four approximate models. The force components shown are the F_X axial force at the start or end of the members shown, the M_Z bending moment at the start or end of the members shown, and the M_Z bending moment at the start or end of those members where the sign of the bending moment changed from one model to the other.

The five models used for this solution were:

(a) Full Finite Element Model With FE Floor Slabs ("FEA")
(b) Rigid Body Plane Floor Membrane Including Column Axial Deformations ("RBPCD")
(c) Rigid Body Plane Floor Membrane With No Column Axial Deformations ("RBPNCD")

(d) Rigid Body Solid Floor Including Column Axial Deformations ("RBSCD")
(e) Rigid Body Solid Floor With No Column Axial Deformations ("RBSNCD")

Using the FEA model as the "exact" benchmark solution, it can be seen that the other four models can give results that in some cases are again very different from the benchmark solution. The differences varied over a wide range of values. For example:

The results shown in these tables include the ratio of the smaller force or moment value to the larger force or moment value. In some cases, the FEA benchmark solution produced the larger values, while the four approximate solutions produced larger values in some cases. Further, for the RBPCD model, column axial forces were very close to the FEA results, but column beam moments varied by large amounts (hundreds of percent in some cases).

For the RBPNCD, RBSCD, and RBSNCD models, both axial forces and bending moments varied by very large amounts from the FEA solution (again by hundreds of percent).

7. Appendix I, "Summation of Reactions" Values and Selected Support Reaction Values

The value of the summation of support reactions, and the value of selected support reaction values, are shown as output from the GTSTRUDL computer program used to compute all results from the following models:

The five models used for this solution were:

(a) Full Finite Element Model With FE Floor Slabs ("FEA")
(b) Rigid Body Plane Floor Membrane Including Column Axial Deformations ("RBPCD")
(c) Rigid Body Plane Floor Membrane With No Column Axial Deformations ("RBPNCD")

As can be seen from the output, the sum of reactions in all global directions for Dead Load 100 and for Wind Loads 400 and 500 are the same for all models. This is one level of confirmation of the static analysis results produced by the static analysis solutions.

Conclusions

The results of the study can be summarized as follows:

C Dead Load Case:

When comparing axial forces computed in the three dead load case models (i.e., the exact solution using sequential construction simulation, and the two approximate solutions), the column axial forces varied by around 50% in the columns near the top of the structure, and differed by around 8,900 Kn (2,000 Kips) in columns at the bottom of the structure.

When comparing bending moments in columns, some important moments not only varied by more than 100% between the exact and approximate solutions, but in addition, sign changes in the moments occurred in some columns between the exact and approximate solutions.

When comparing bending moments in beams, some important moments also varied by more than 100% between the exact and approximate solutions.

Furthermore, the approximate analysis procedure for full dead load where axial deformations were ignored (i.e., which is a common assumption in various "tier building analysis" computer programs) was found to be a seriously flawed procedure.

This study reconfirmed that the only valid approach for correctly analyzing tall reinforced concrete building structures for dead loads which are analyzed using full 3D analysis procedures, and considering all deformation influences (i.e., not ignoring axial deformation effects), is to use the sequential construction simulation model. In other words, in general, since reinforced concrete column cross-section dimensions tend to remain the same over many stories of column lengths (i.e., in order to simplify construction procedures and to reduce construction cost), the axial strains in the columns will vary according to the axial forces thus producing differential column shortening between adjacent columns where the respective column axial forces are different, and thus inducing potentially large moments and other forces caused by such differential shortening. However, such induced forces do not occur in practice as a result of the actual construction process whereby such differential shortening is generally eliminated through the concrete pouring process.

C Wind Load Case:

The computation of lateral displacements were essentially the same for the exact and approximate rigid plane floor model including column axial deformations. This would appear to indicate that the rigid plane floor membrane model including axial column deformations will give the same solution as the full finite element model (i.e., the exact benchmark solution). However, as was found in the comparisons for force states in the structure due to wind loads, such a conclusion could not be verified. The fact is that even though the maximum lateral displacements at the top of the model were the same for both models, and even though the general shape of the overall structure deflection were the same, the force distributions in many locations throughout the structure computed on the basis of the rigid plane floor model were very different from the exact benchmark solution.

In particular, axial forces in numerous columns, and bending moments in numerous columns and beams throughout the structure were different between the exact and approximate solutions by 100% or more (in some cases, several hundreds of percent different!).

This study also confirmed that for the case of lateral load analysis, the rigid body floor diaphragm model is far too simplistic in its representation of actual behavior for modern tall reinforced concrete buildings with irregular geometry, concentrations of stiffness, open atrium spaces, and other irregularities that are completely inconsistent with the assumptions inherent in the rigid floor diaphragm model. Performing such approximate analysis can result in significant errors.

In conclusion, unless the tall reinforced concrete building structure model is highly regular (i.e., nearly symmetric, regular geometry, smooth distribution of stiffness in each story of the building and from story to story of the building, no concentrations of stiffness in the building, smooth distribution of dead loads, no unusual boundary conditions, etc.), it was clear from the study that the use of approximate analysis techniques which are based on highly arbitrary assumptions of building behavior can lead to *totally incorrect* solutions to the distributions of forces throughout the members of a building. In particular, if only approximate techniques are used, the structural engineer has absolutely no idea whether or not the solutions obtained are anywhere near the correct solutions. In fact, the study demonstrated that the difference between the “exact” finite element solution and the solutions obtained from several commonly used approximations (such as the rigid body floor diaphragm model, or the dead load model where sequential construction simulation is not performed and/or where column axial deformations are ignored, etc.) can be very large (on the order of hundreds of percent in error!). Unless the engineer is totally aware of the details of all assumptions included in an approximate solution technique, and unless the engineer is completely aware of the consequences of performing analysis on the basis of such assumptions, and unless the engineer knows the correct analysis solution to which the approximate solution can be compared, it is extremely dangerous to use such approximate analysis methods.

The increasingly common use of approximate analysis of tall reinforced concrete buildings today is very dangerous in view of the fact that such modern tall buildings generally have high aspect ratios, incorporate exceedingly complex and highly irregular geometries, are characterized by highly nonuniform stiffness distributions throughout the structure, are often designed with large open interior atrium spaces, and are designed to use far less volumes of structural materials than were used for tall reinforced concrete buildings in the days before computers, and thus have inherently lower factors of safety in design.

Therefore, it is clear that approximate methods of analysis for tall reinforced concrete buildings are suitable only for very preliminary analysis and design purposes. In order to obtain a reliable and safe final structural design of such buildings, the most “exact” methods of analysis that are available today must be used.

APPENDIX A

16 Typical Floor Levels

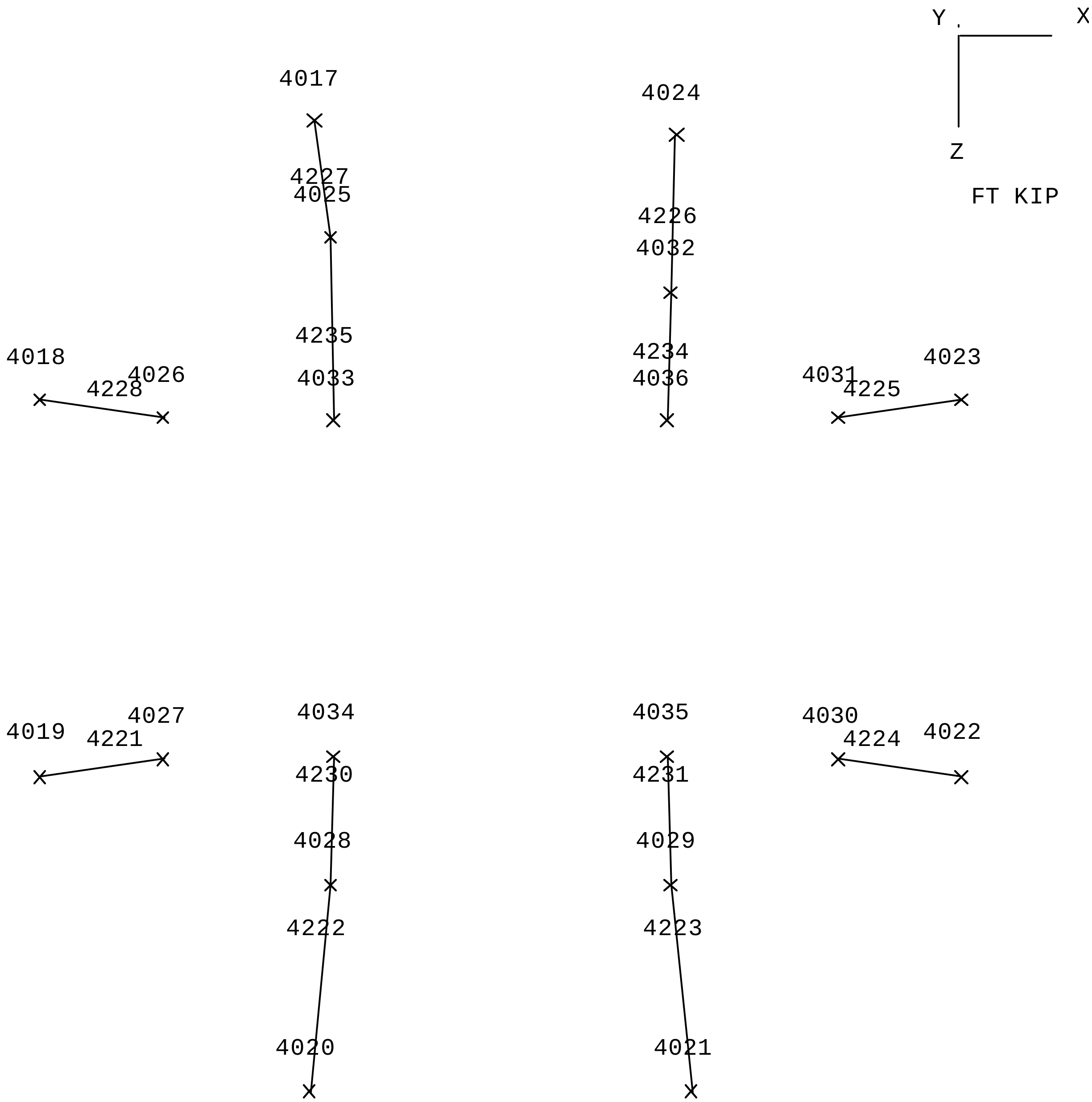


Figure A-1 4000'S Level (Atrium)

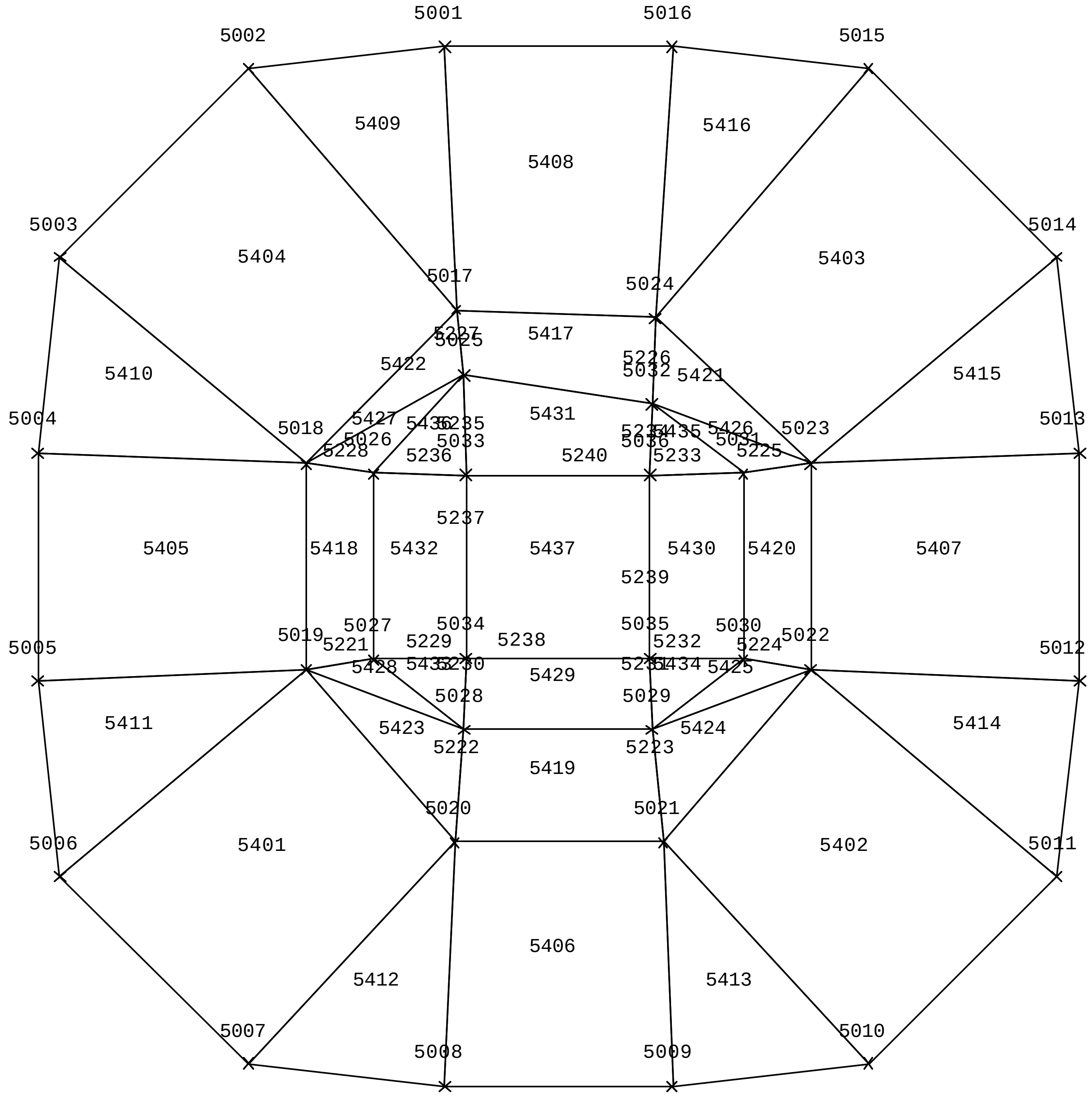


Figure A-2 5000'S Level (Atrium)

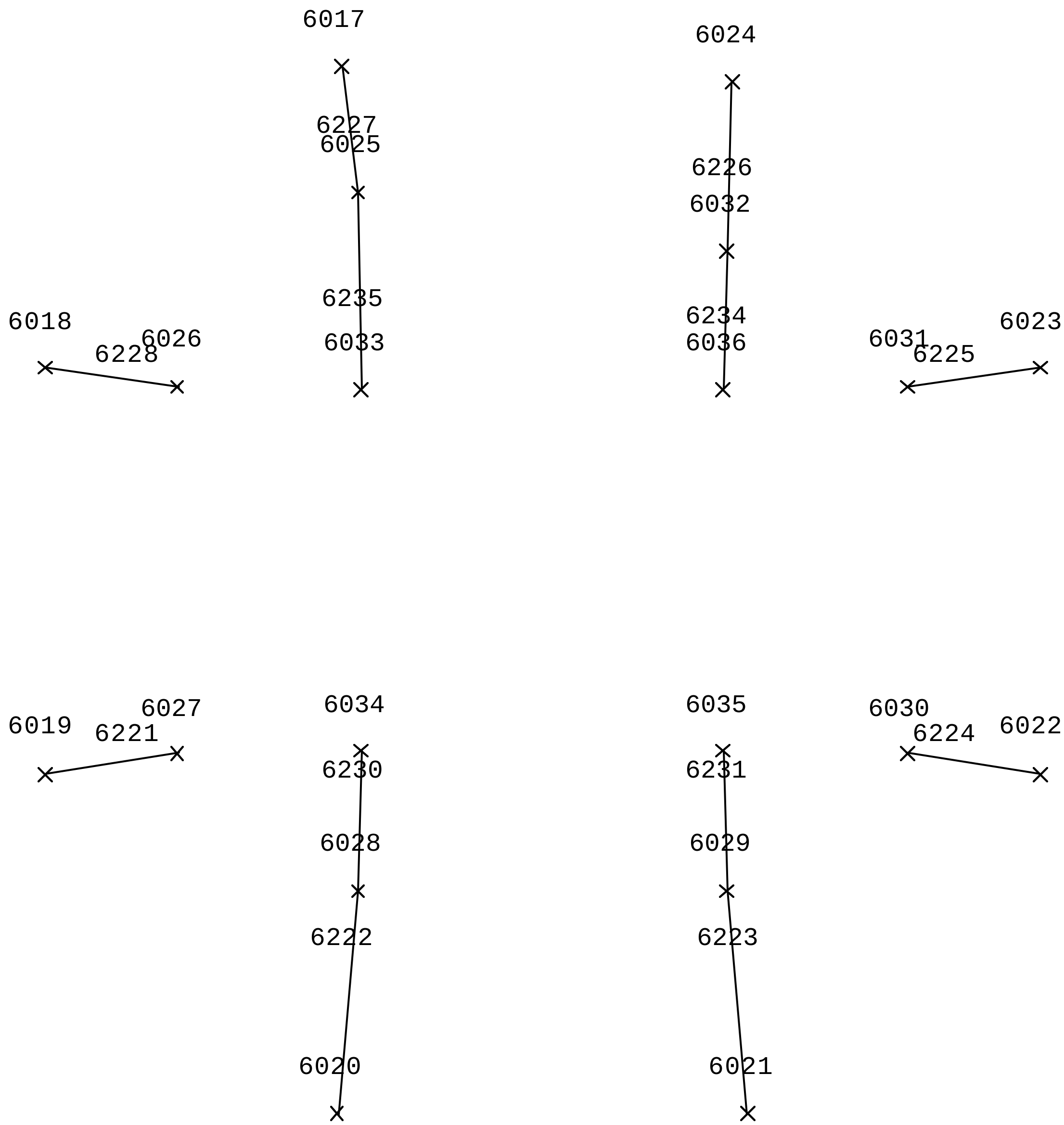


Figure A-3 6000'S Level (Atrium)

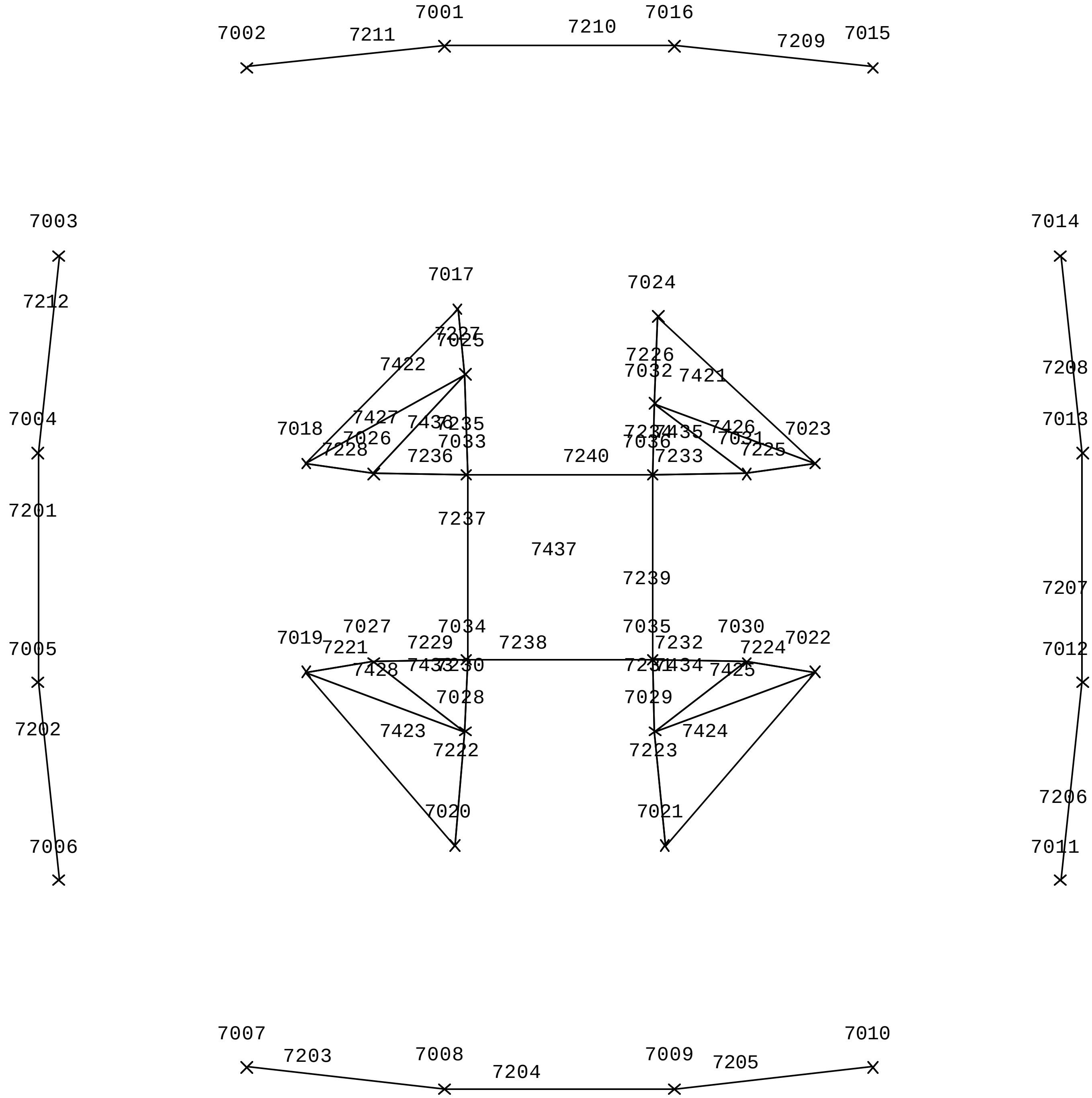


Figure A-4 7000'S Level (Atrium)

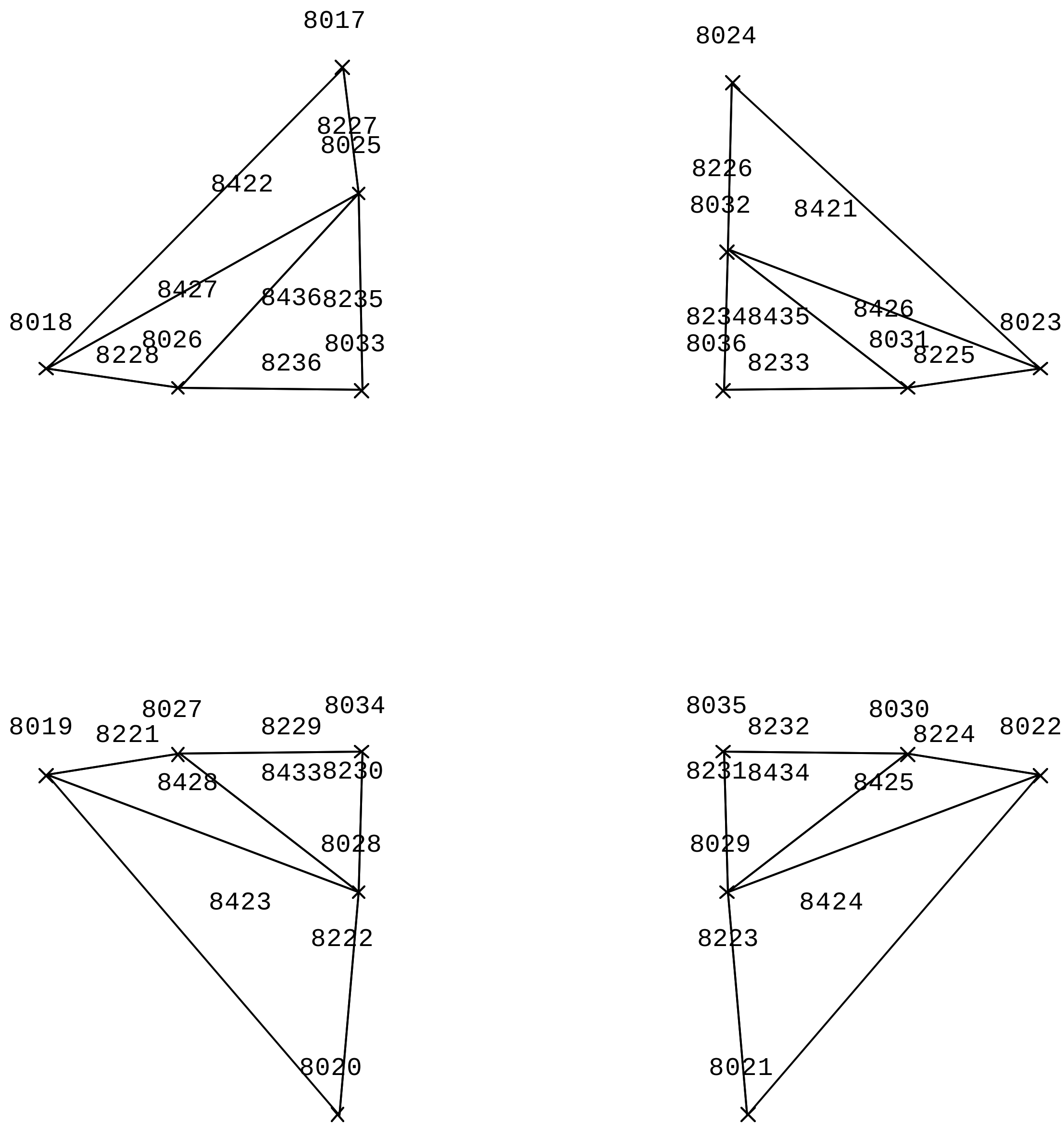


Figure A-5 8000'S Level (Atrium)

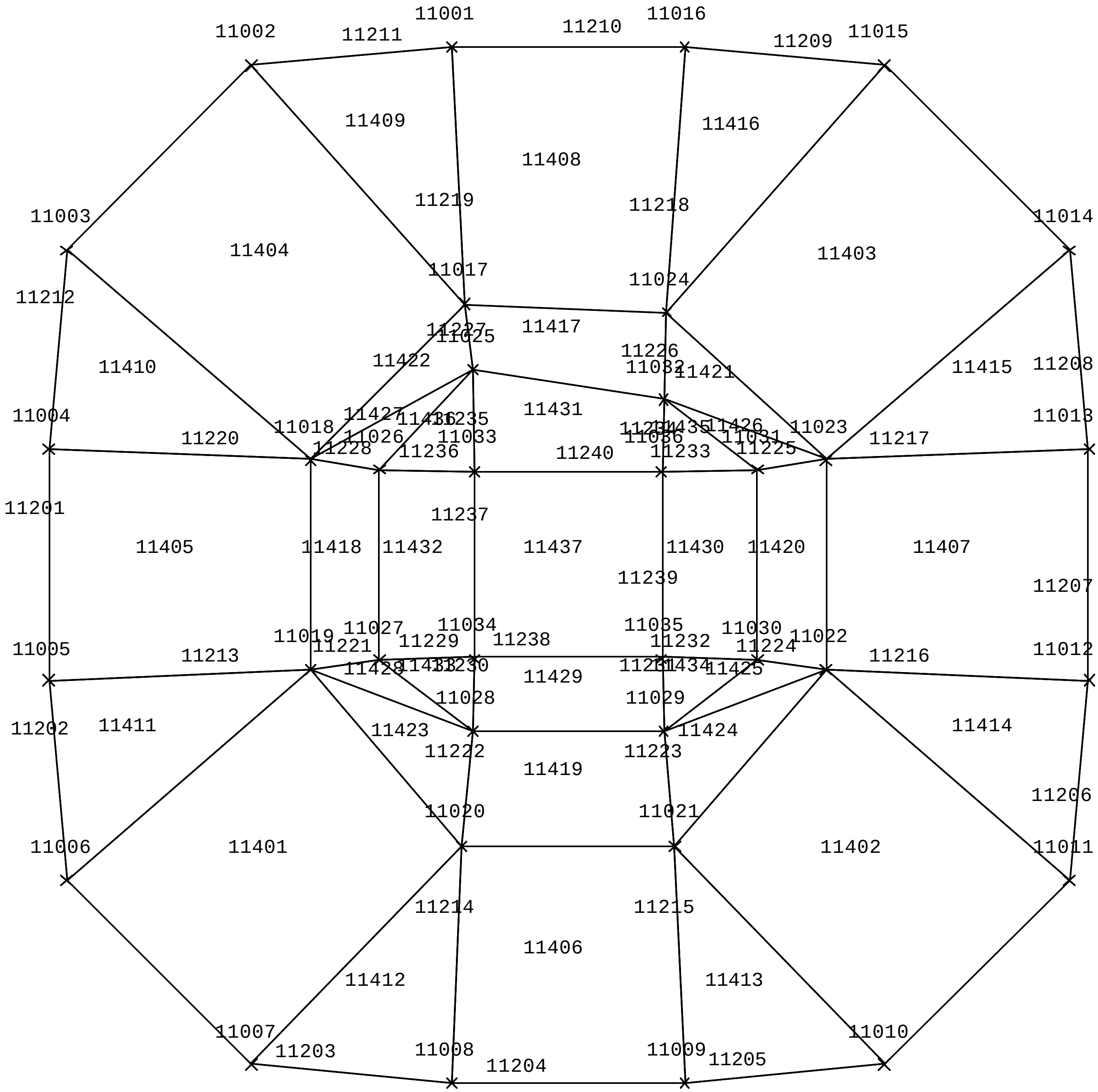


Figure A-6 11000'S Level

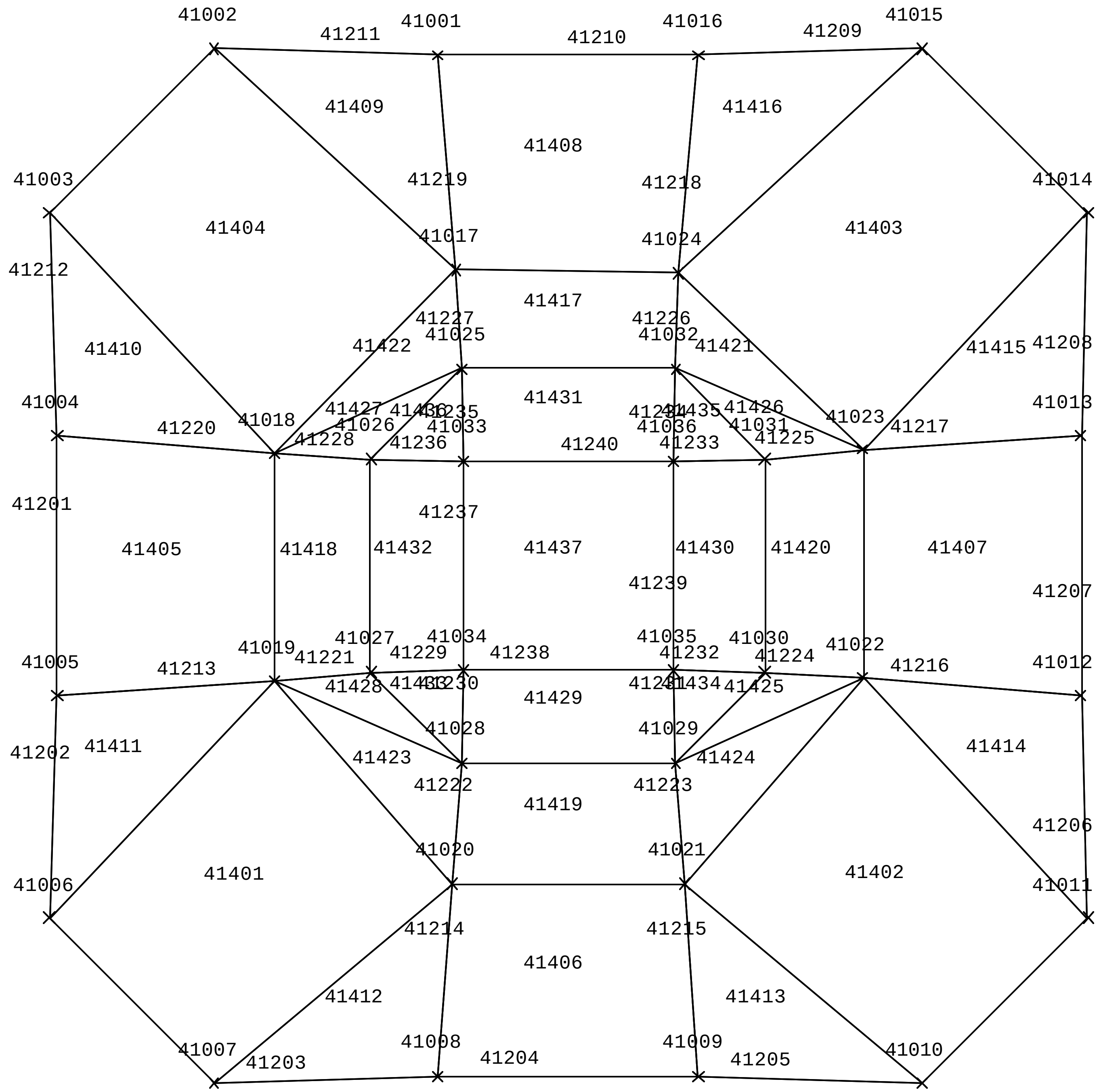


Figure A-7 41000'S Level

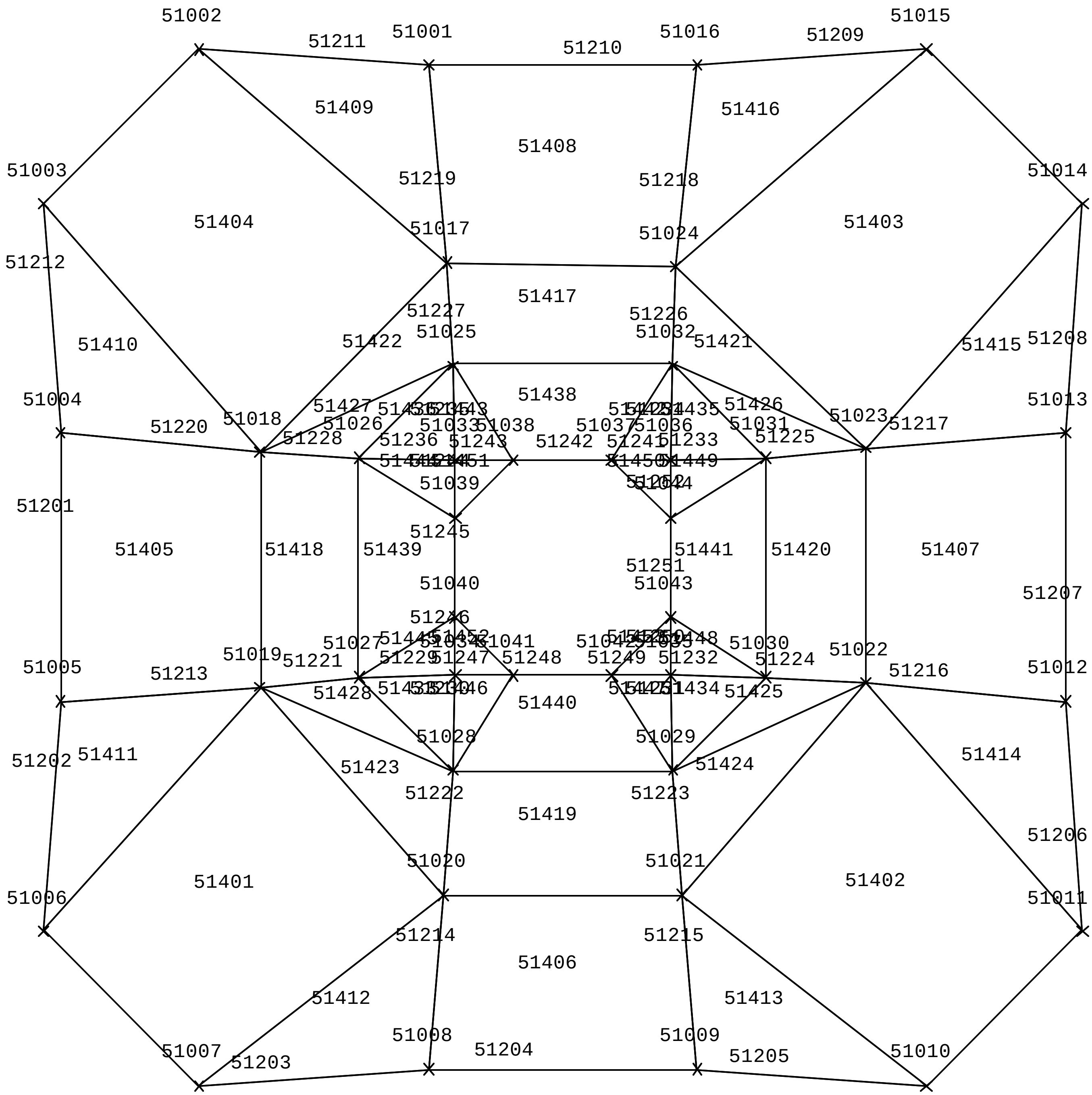


Figure A-8 51000'S Level

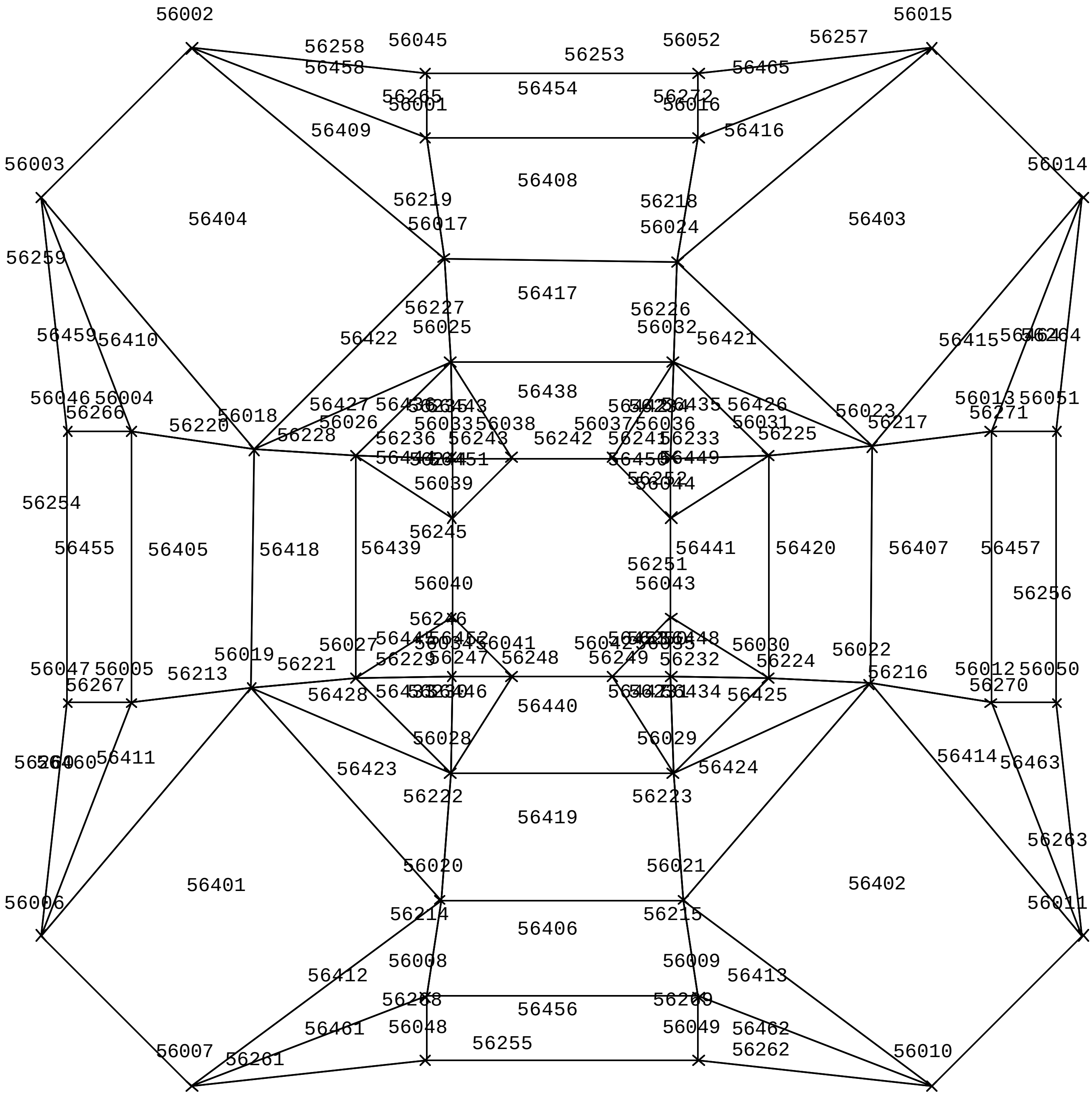


Figure A-9 56000'S Level

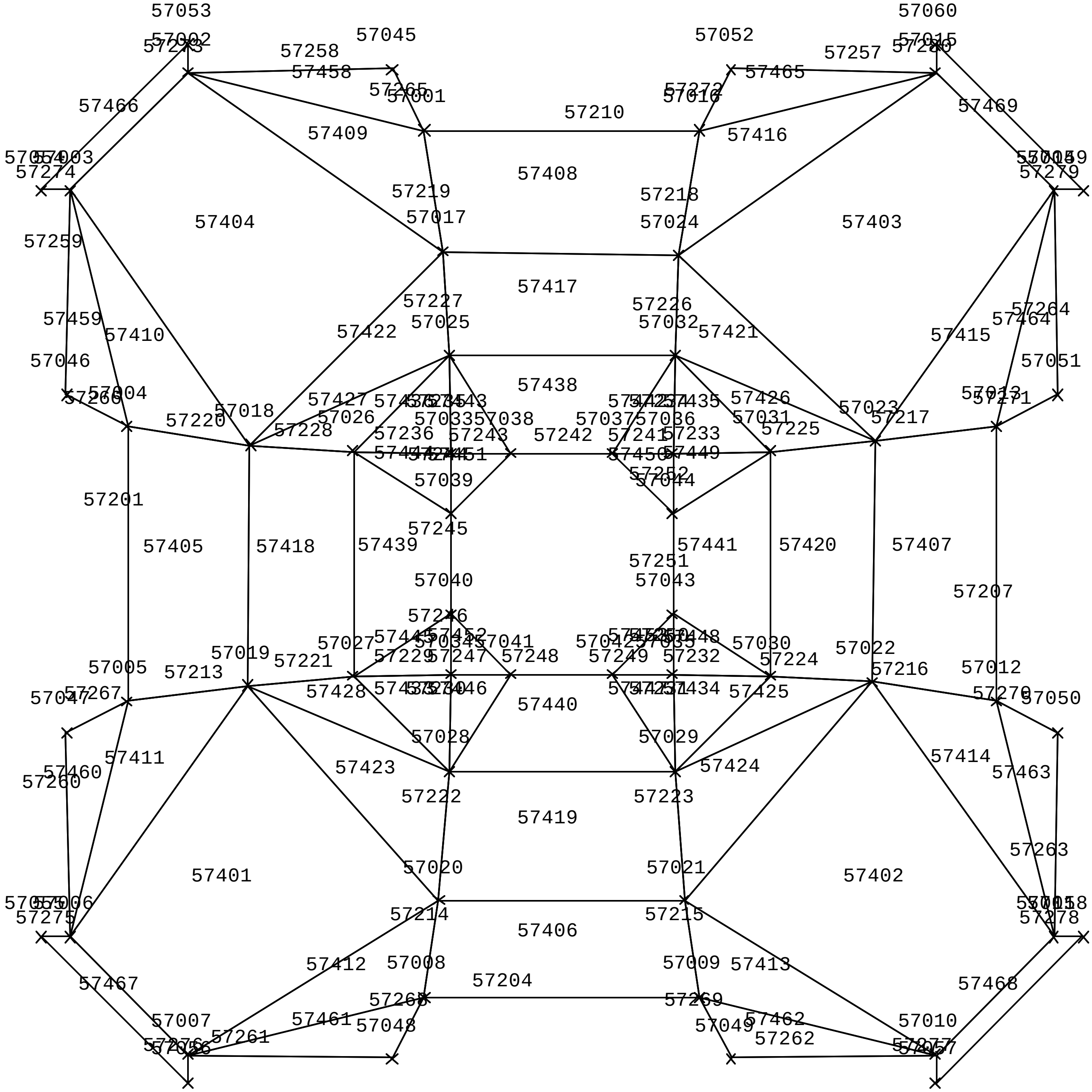


Figure A-10 57000'S Level

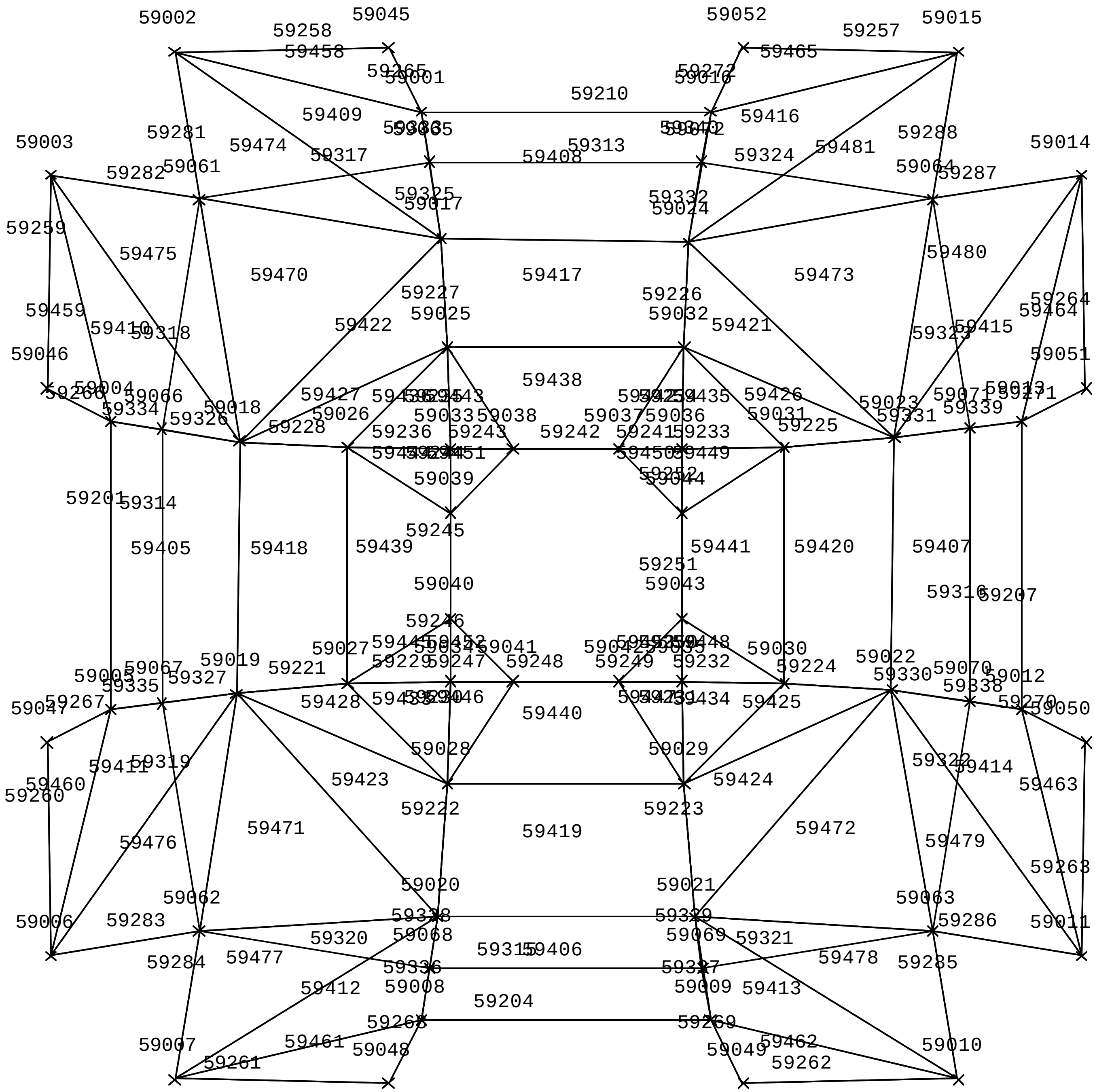


Figure A-11   59000'S Level

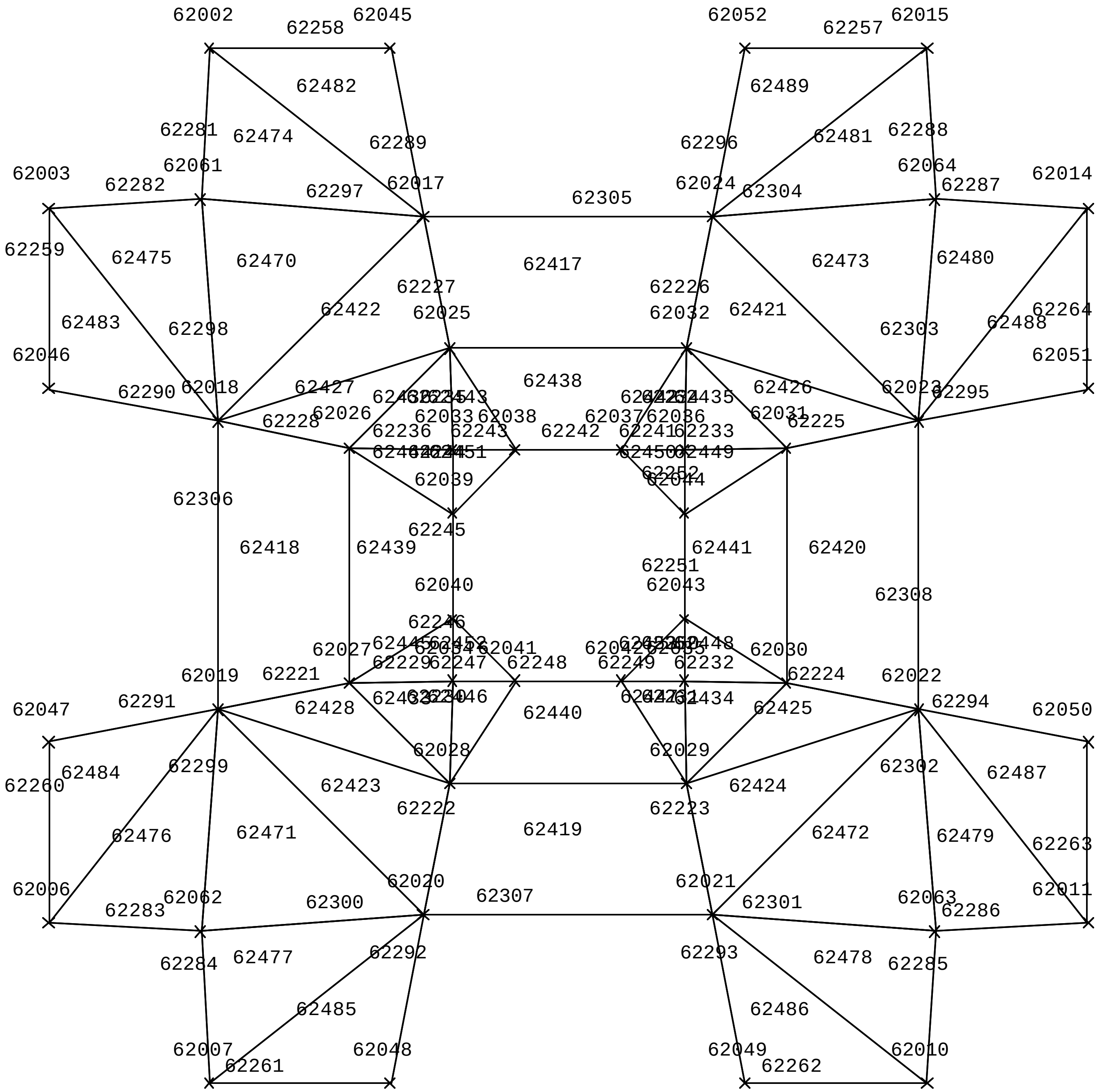


Figure A-12 62000'S Level

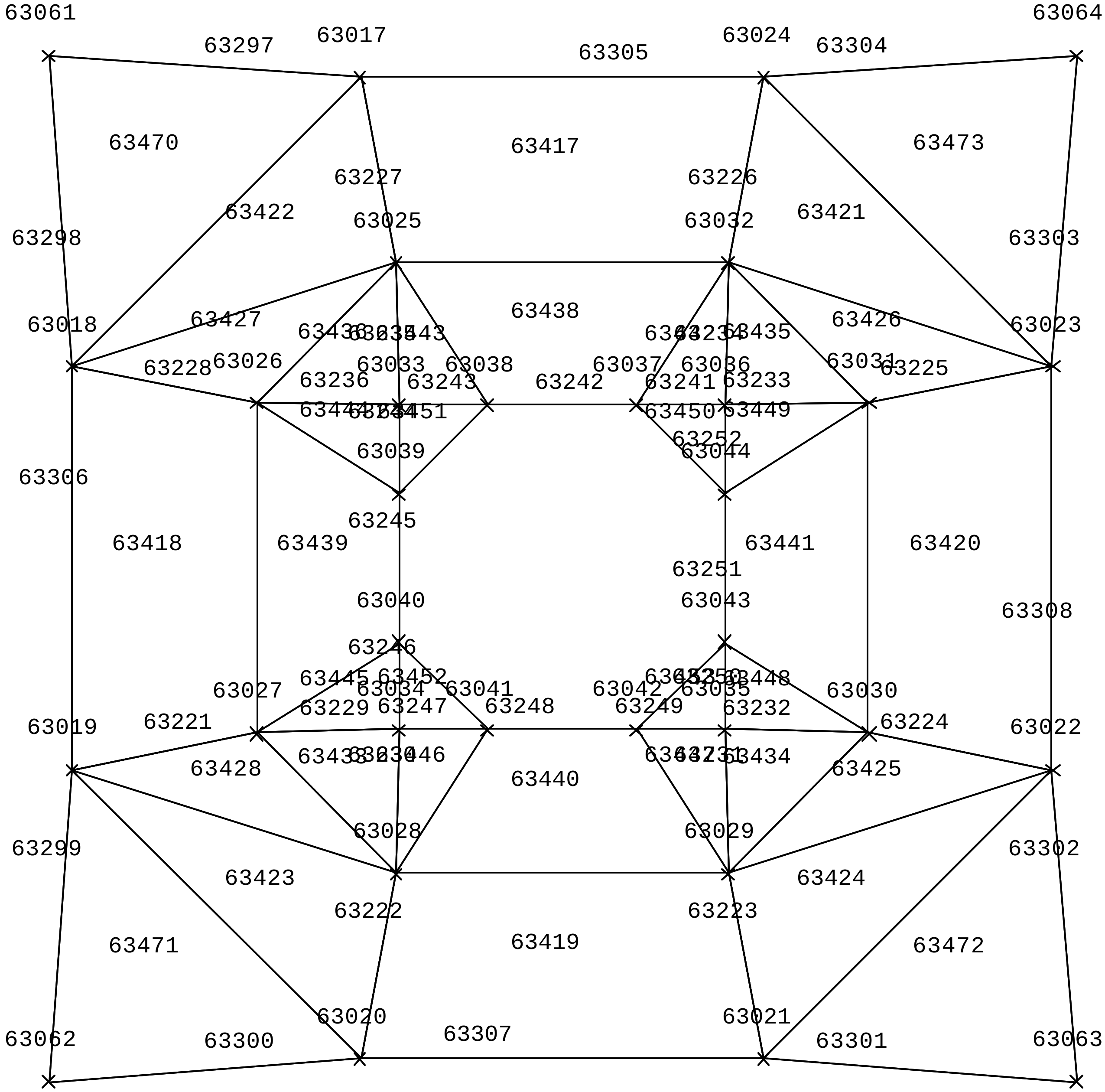


Figure A-13 63000'S Level

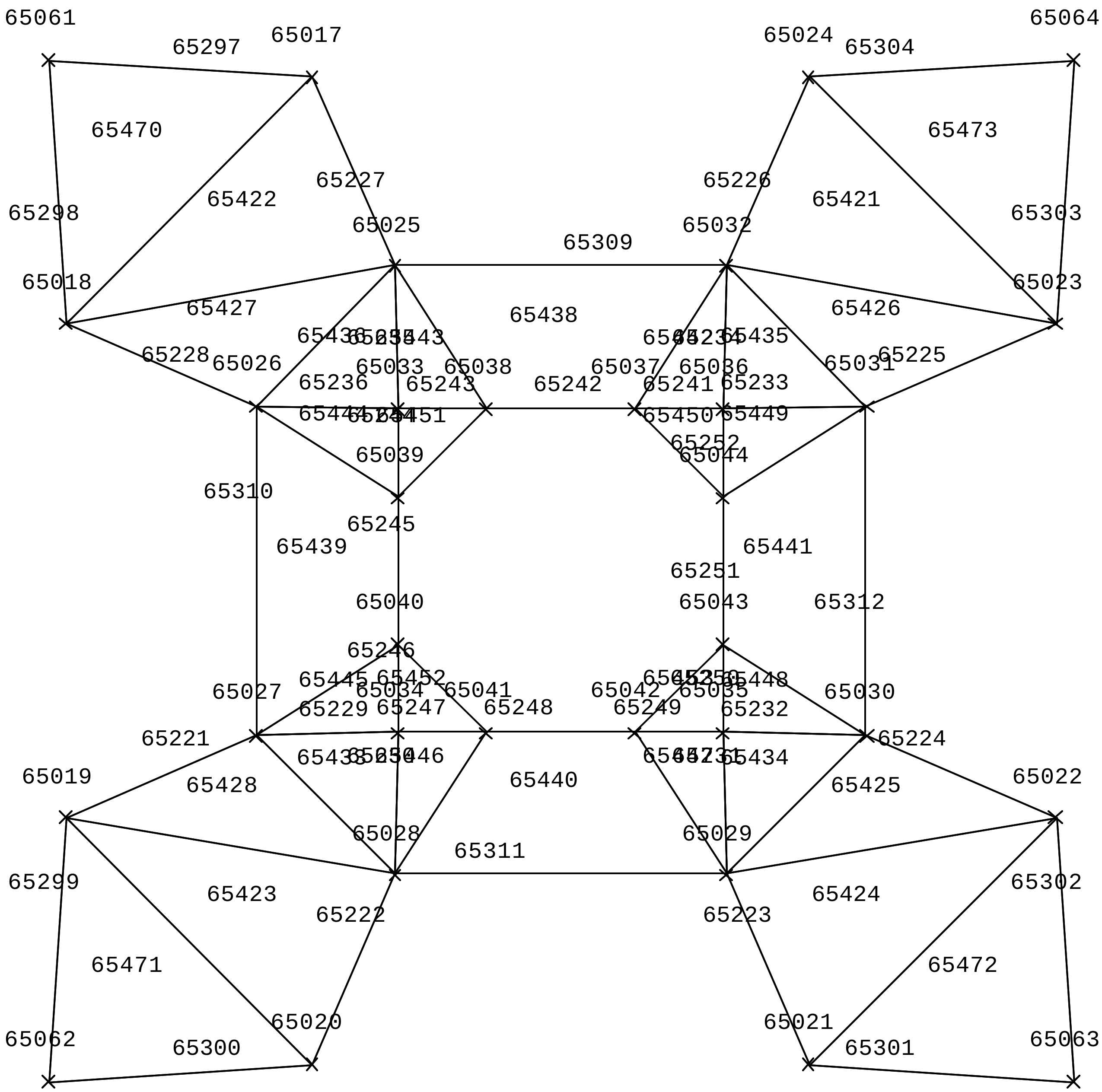


Figure A-14 65000'S Level

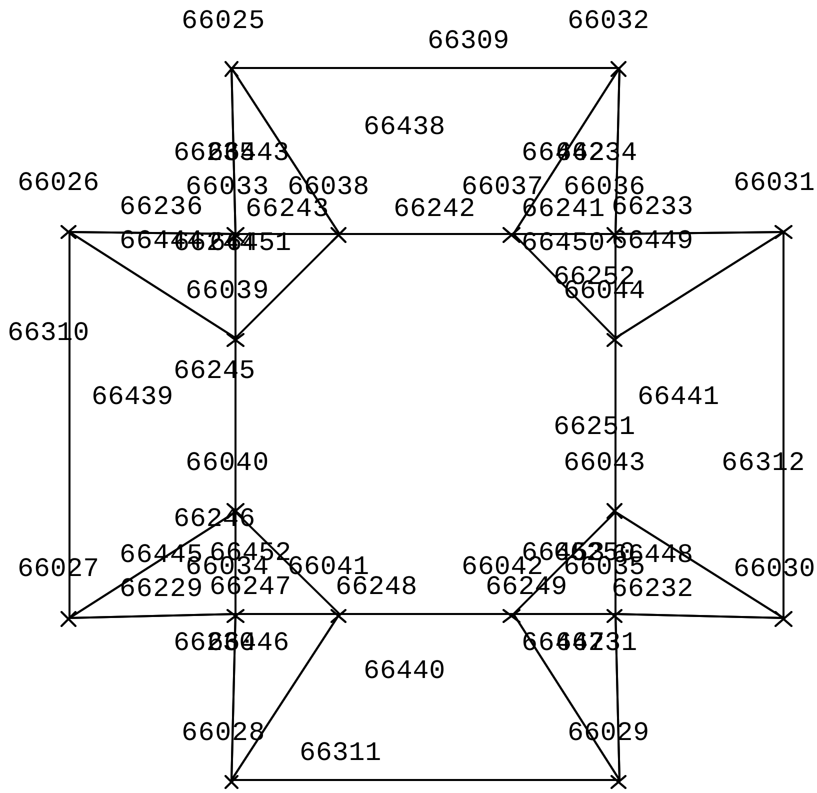


Figure A-15 66000'S Level

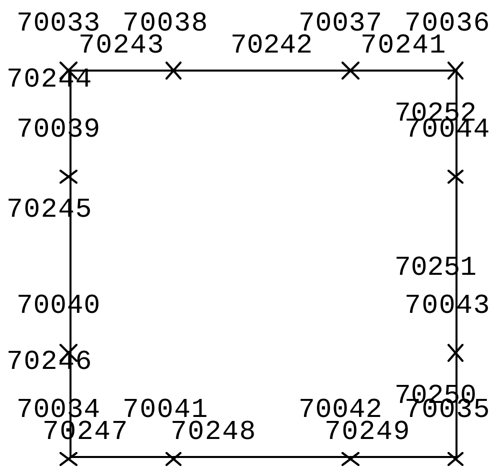


Figure A-16 70000'S Level

APPENDIX B

16 Sequential Construction Simulation Blocks

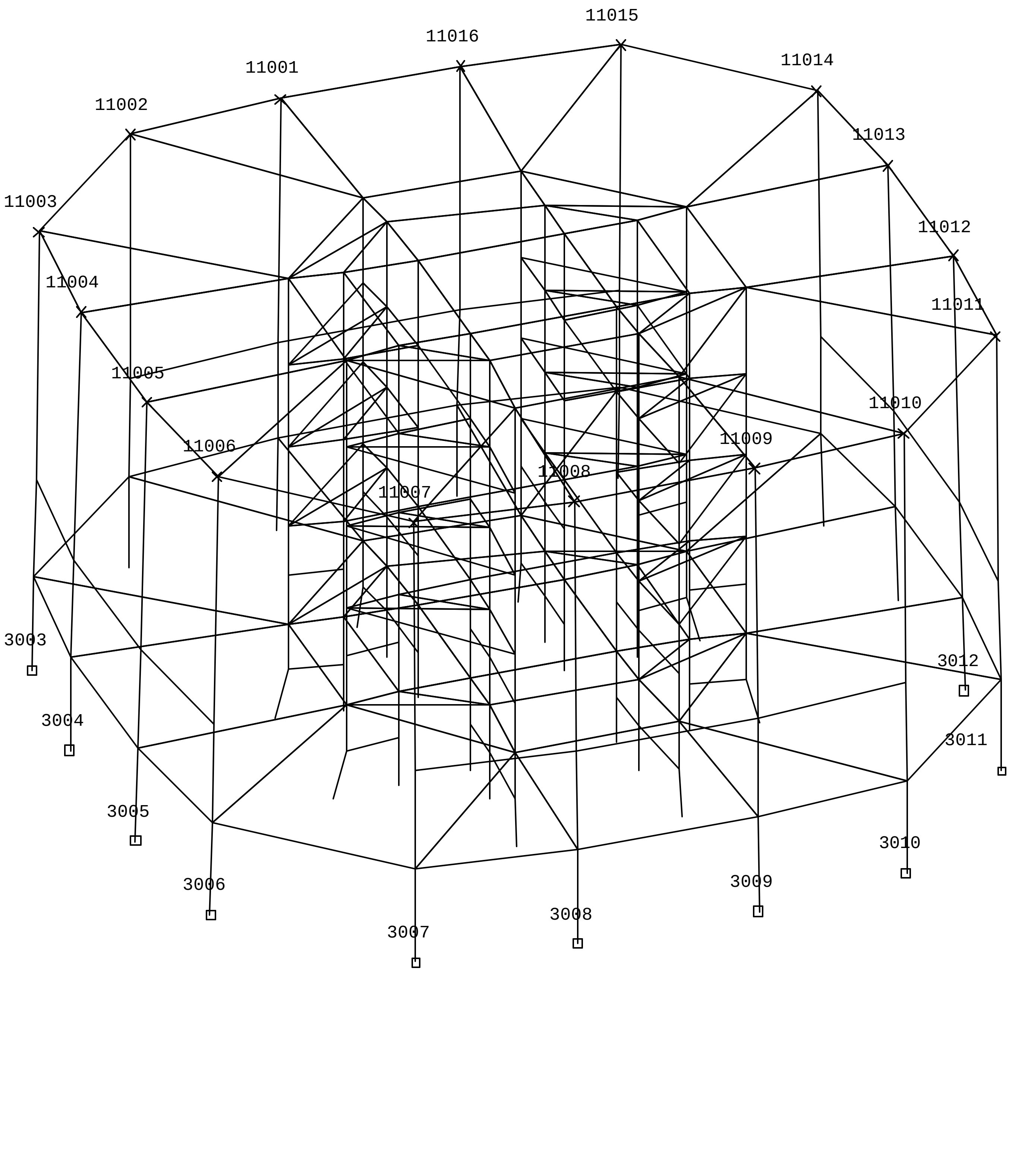


Figure B-1 Sequential Construction Simulation Analysis Block 1
Atrium Level, Between Levels 3000's and 11000's

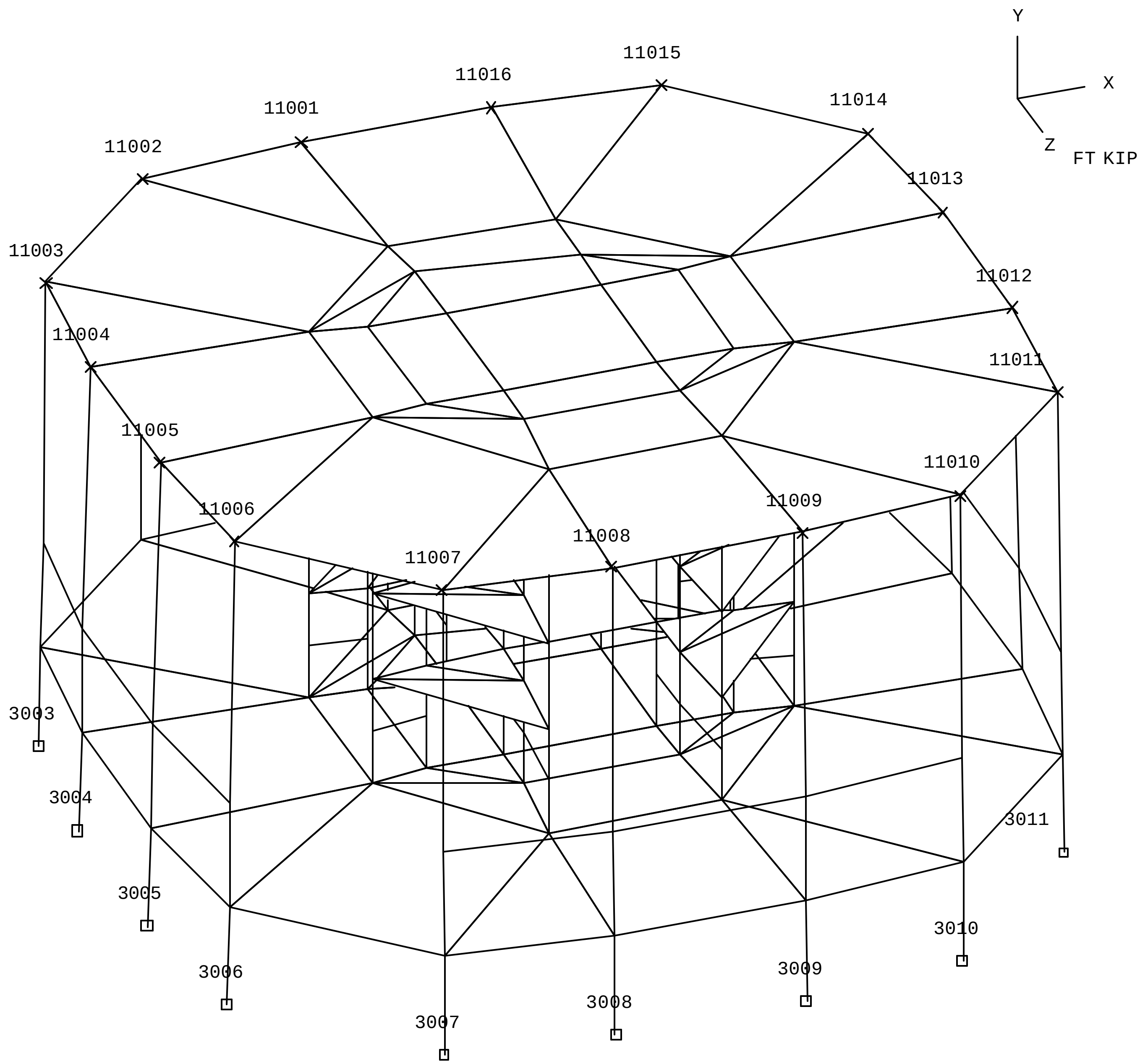


Figure B-1(A) Hidden Line View of Figure B-1
Sequential Construction Simulation Analysis Block 1
Atrium Level, Between Levels 3000's and 11000's

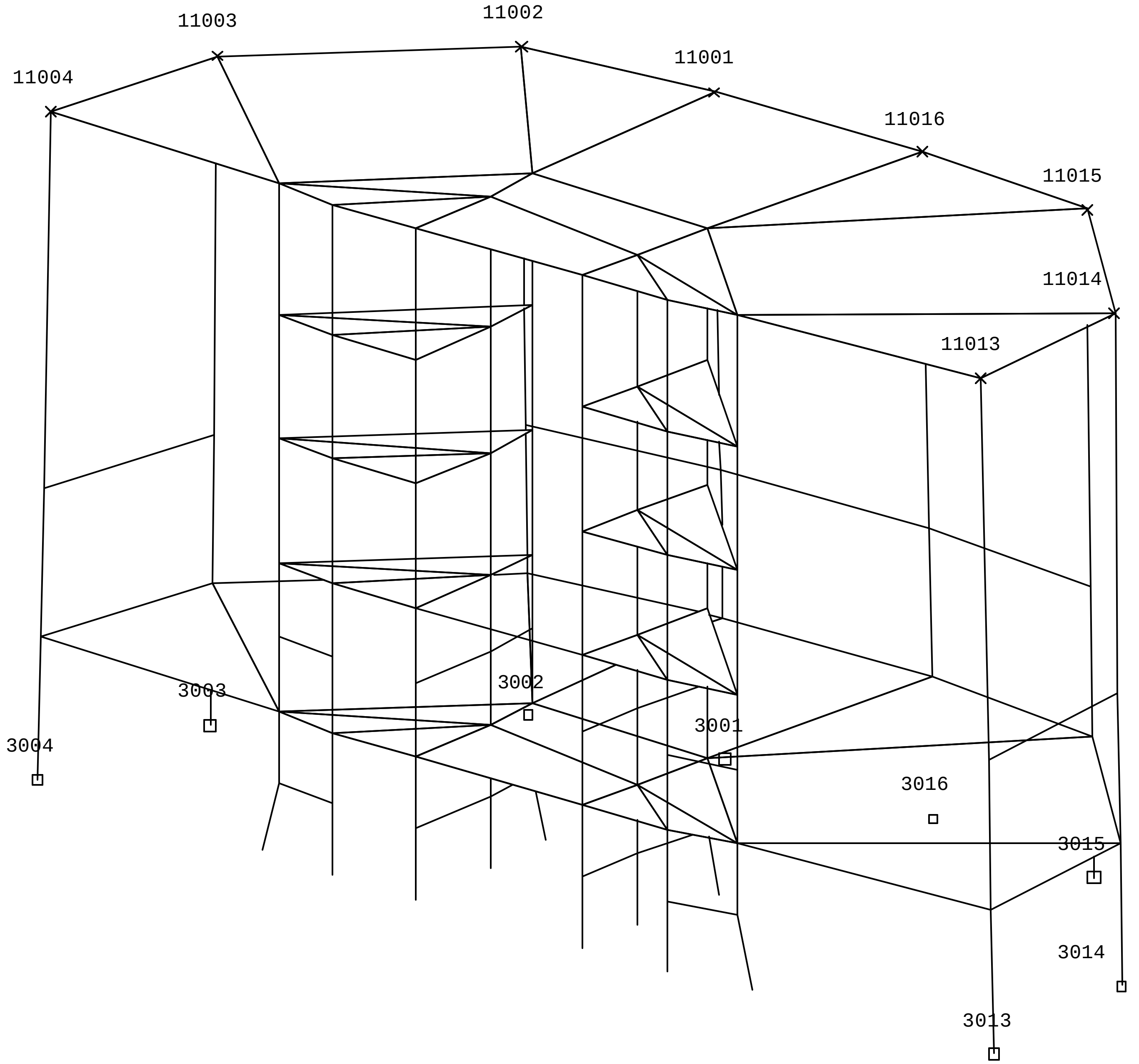


Figure B-1(B) Hidden Line View of the Interior of the Atrium Block 1
Sequential Construction Simulation Analysis Block 1
Atrium Level, Between Levels 3000's and 11000's

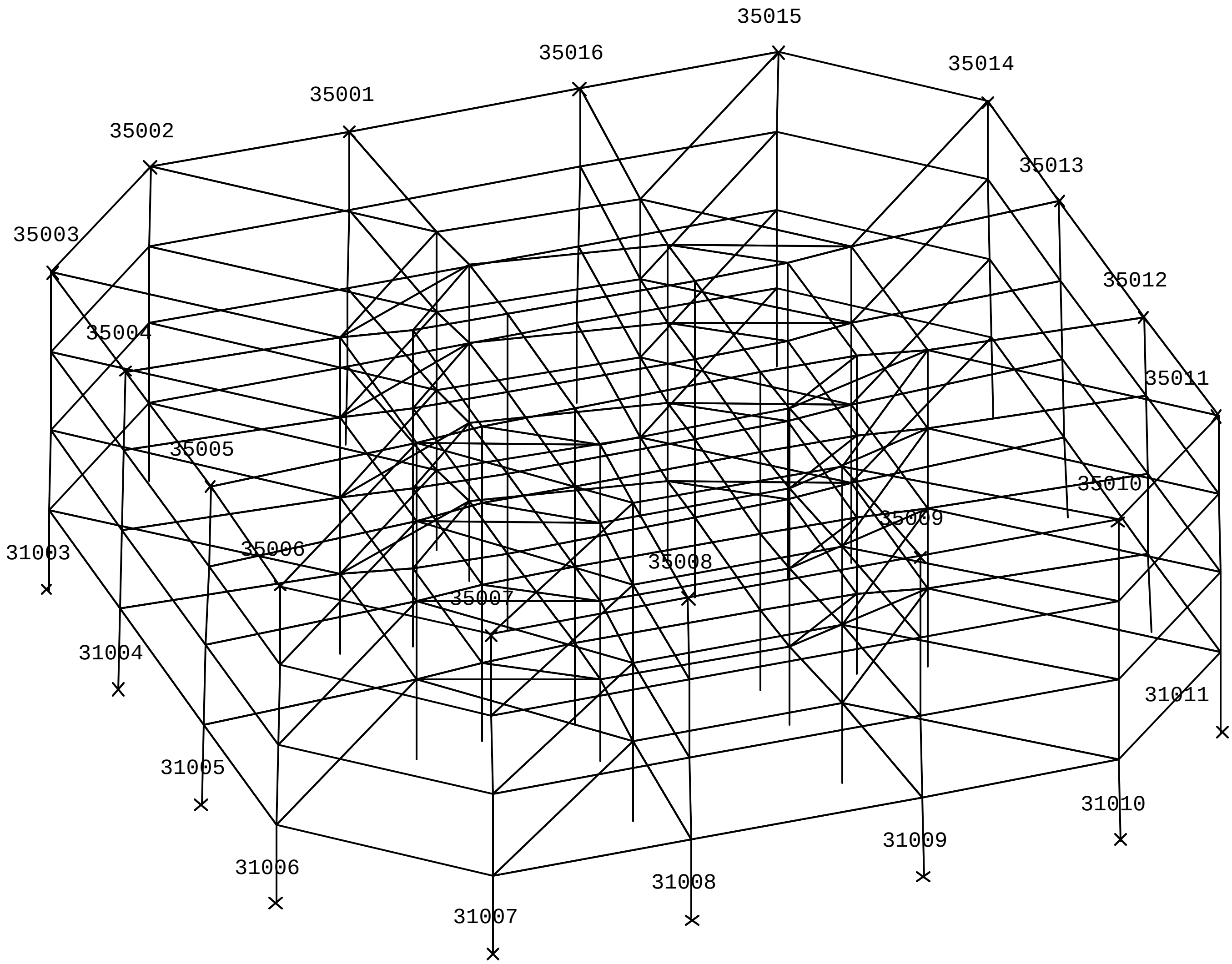


Figure B-2 Sequential Construction Simulation Analysis Block 2 to 13
Typical Level, Between Levels 31000's and 35000's

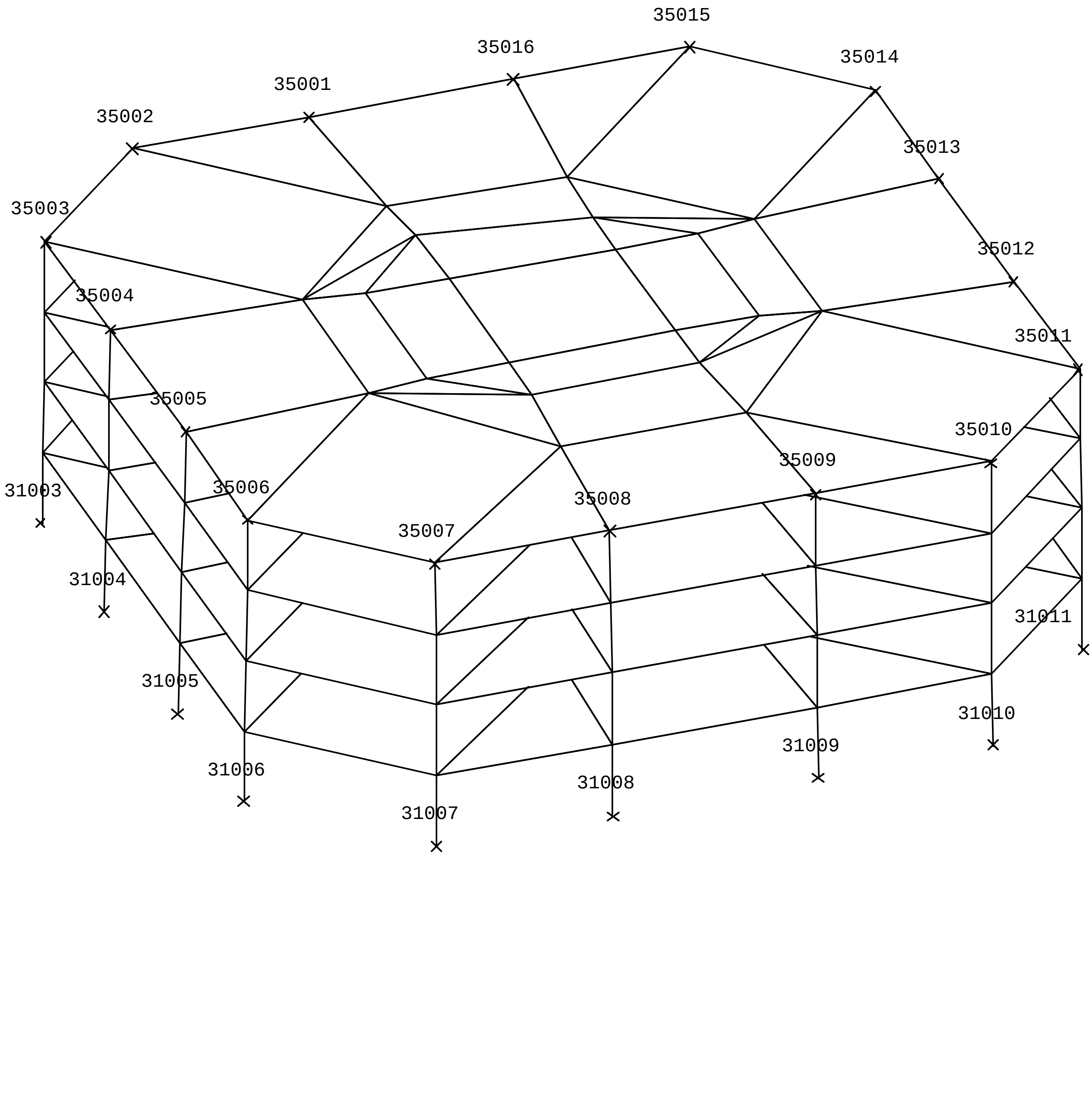


Figure B-2(A) Hidden Line View of the Interior of a Typical Block 2 to 13
Sequential Construction Simulation Analysis Block 2 to 13
Typical Level, Between Levels 31000's and 35000's

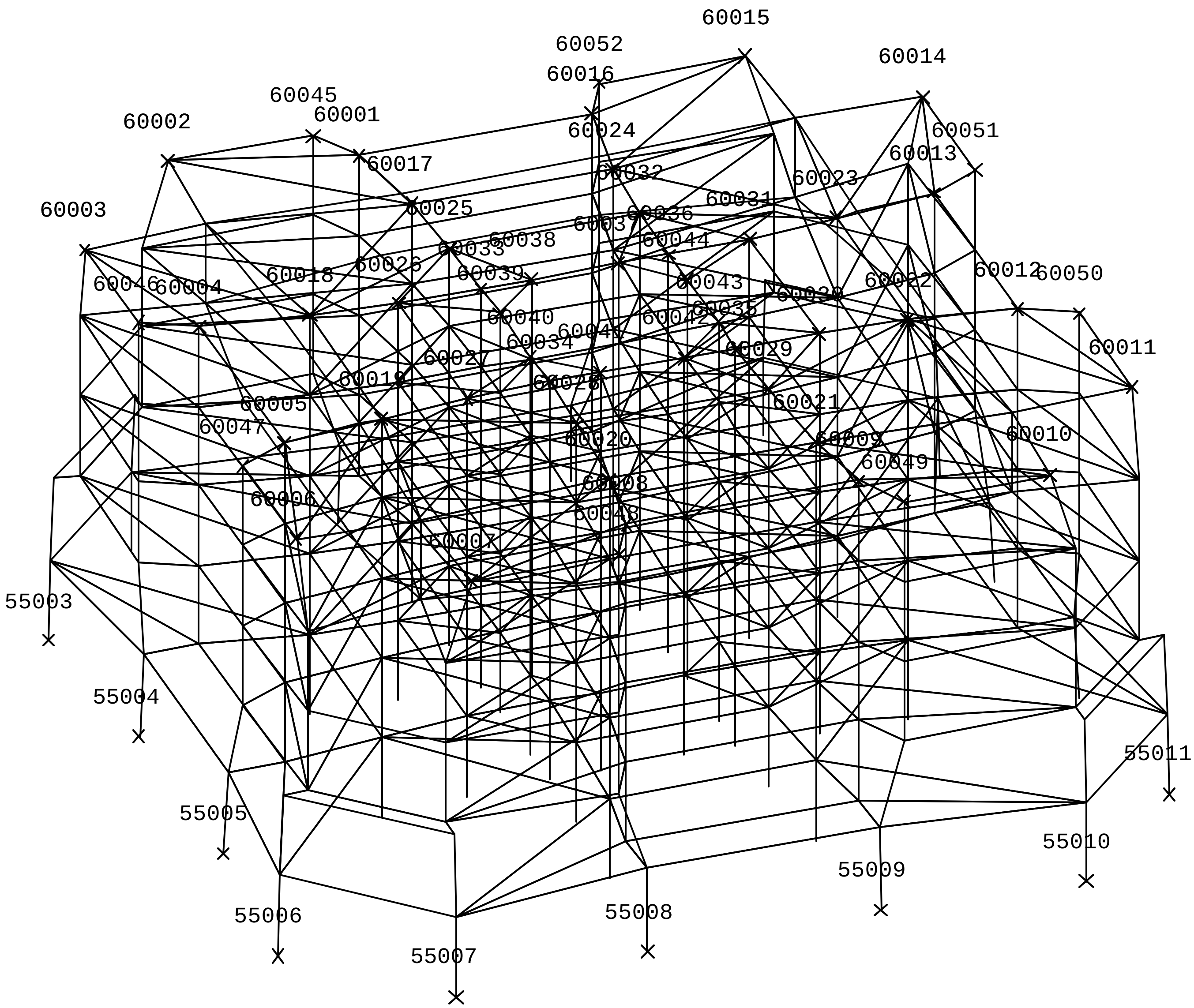


Figure B-3 Sequential Construction Simulation Analysis Block 14
Typical Level, Between Levels 55000's and 60000's

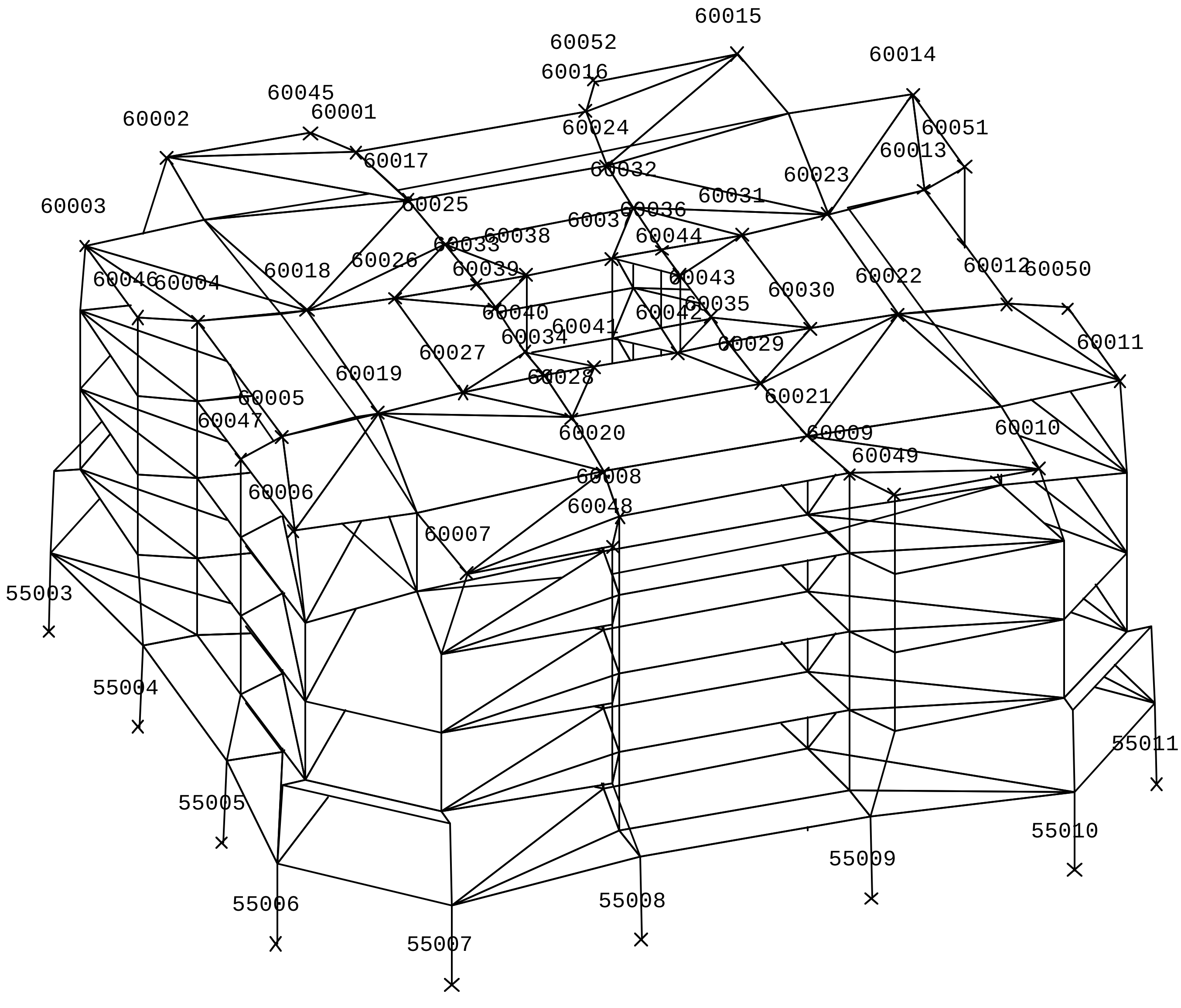


Figure B-3(A) Hidden Line View of the Interior of a Block 14 Sequential Construction Simulation Analysis Block 14 Typical Level, Between Levels 55000's and 60000's

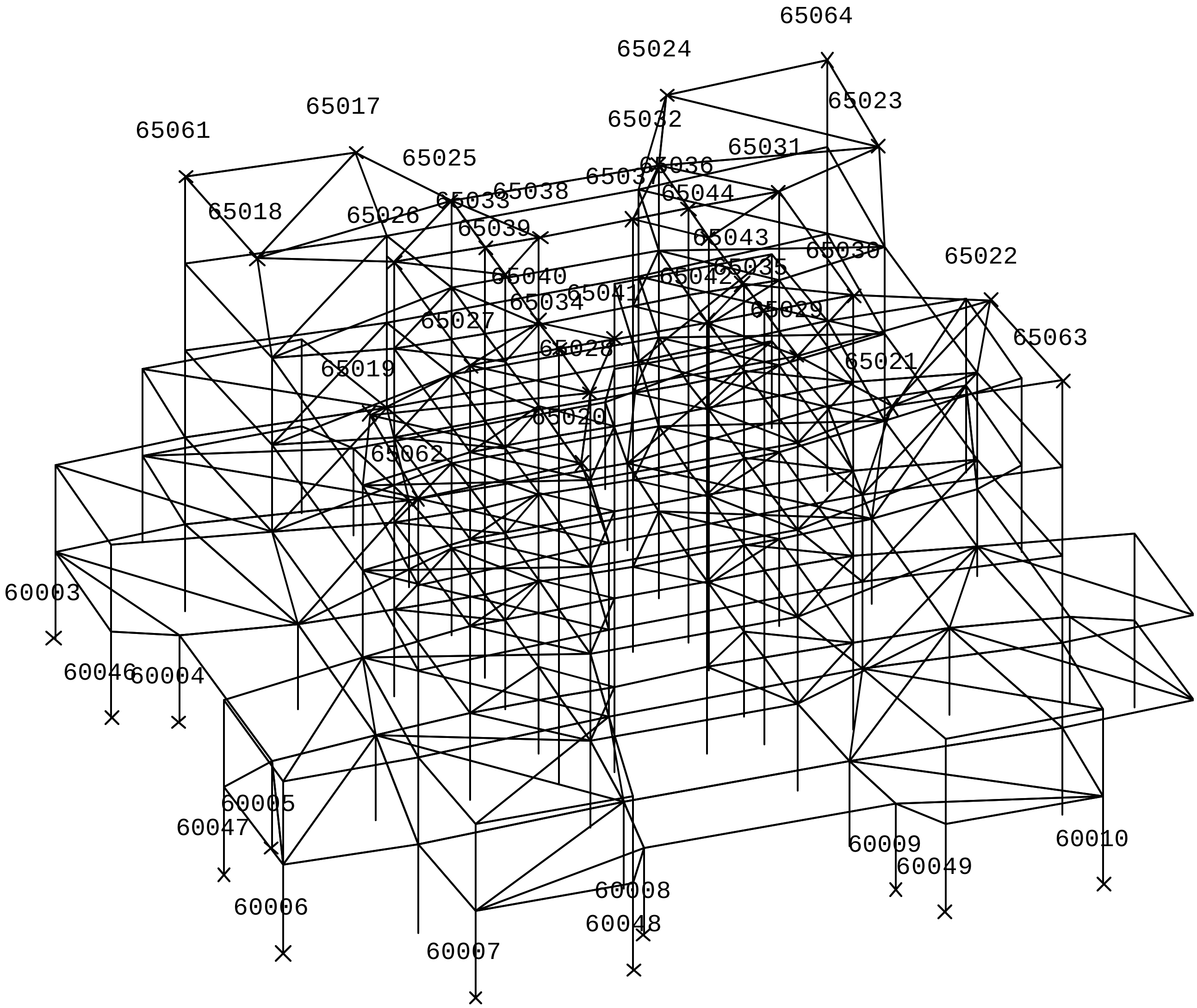


Figure B-4 Sequential Construction Simulation Analysis Block 15
Typical Level, Between Levels 60000's and 65000's

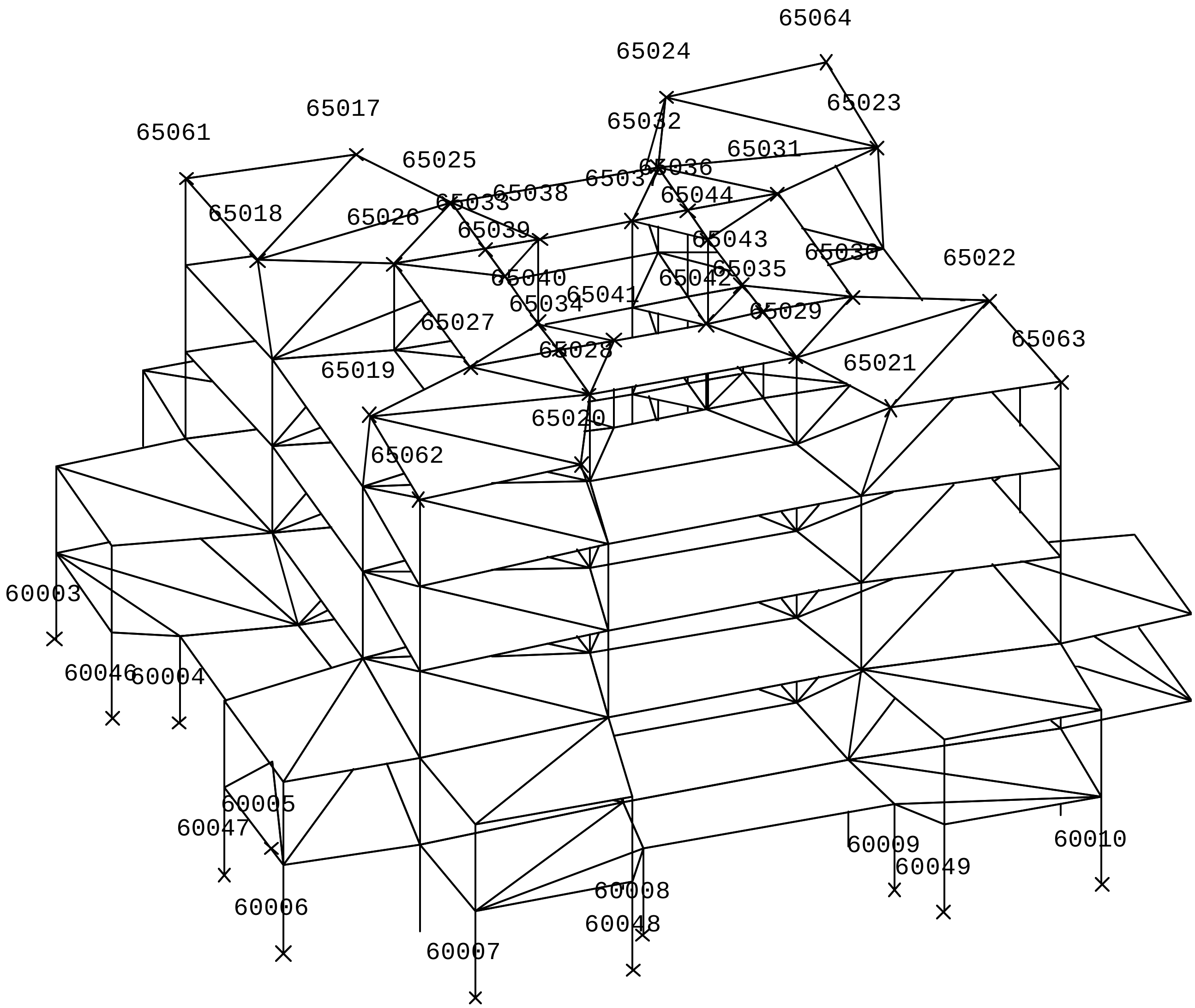


Figure B-4(A) Hidden Line View of the Interior of a Block 15 Sequential Construction Simulation Analysis Block 15 Typical Level, Between Levels 60000's and 65000's

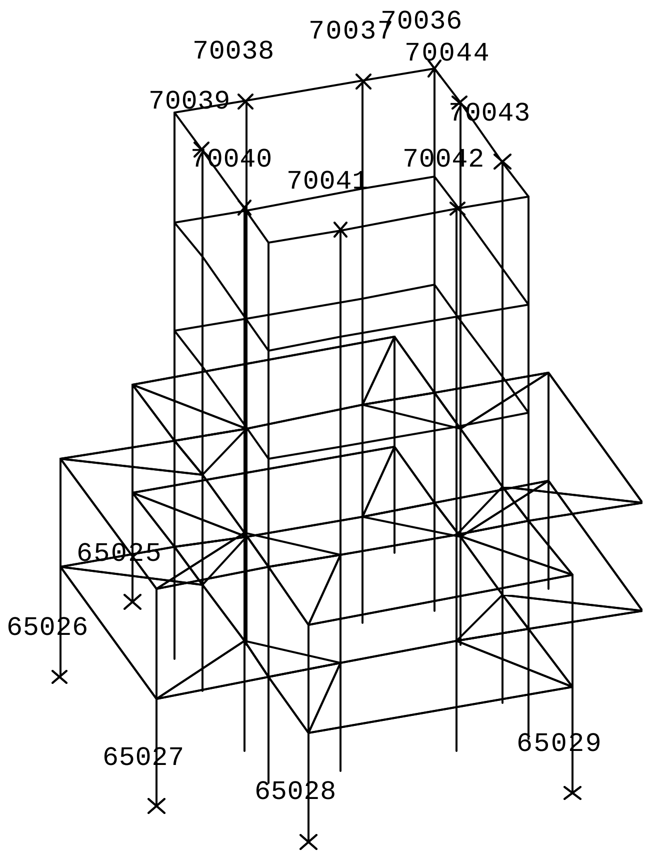


Figure B-5 Sequential Construction Simulation Analysis Block 16
Typical Level, Between Levels 65000's and 70000's

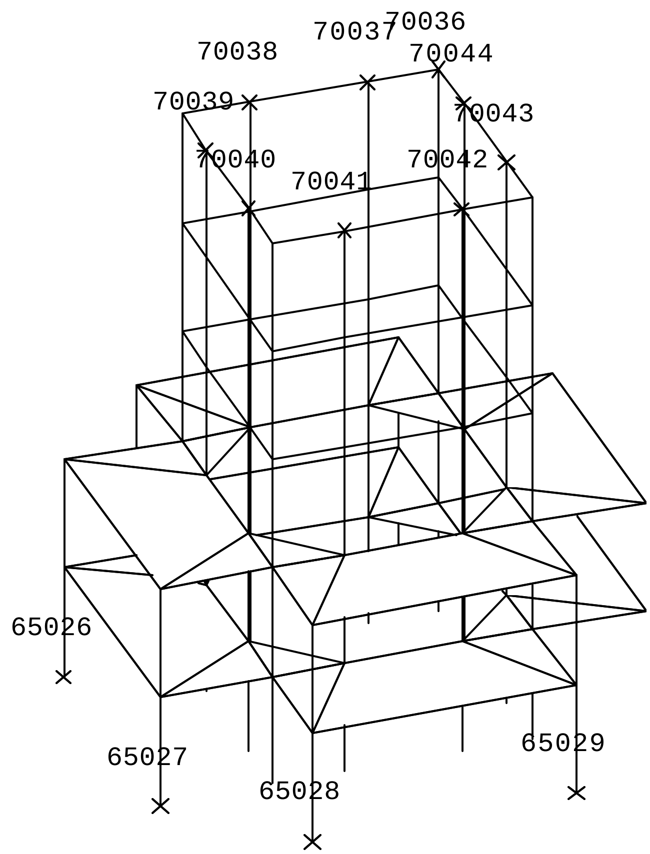


Figure B-5(A) Hidden Line View of the Interior of a Block 16 Sequential Construction Simulation Analysis Block 16 Typical Level, Between Levels 65000's and 70000's

APPENDIX C

Examples of Variations of Member Start Forces and Moments Over the Height of the Building Model

Dead Load 100

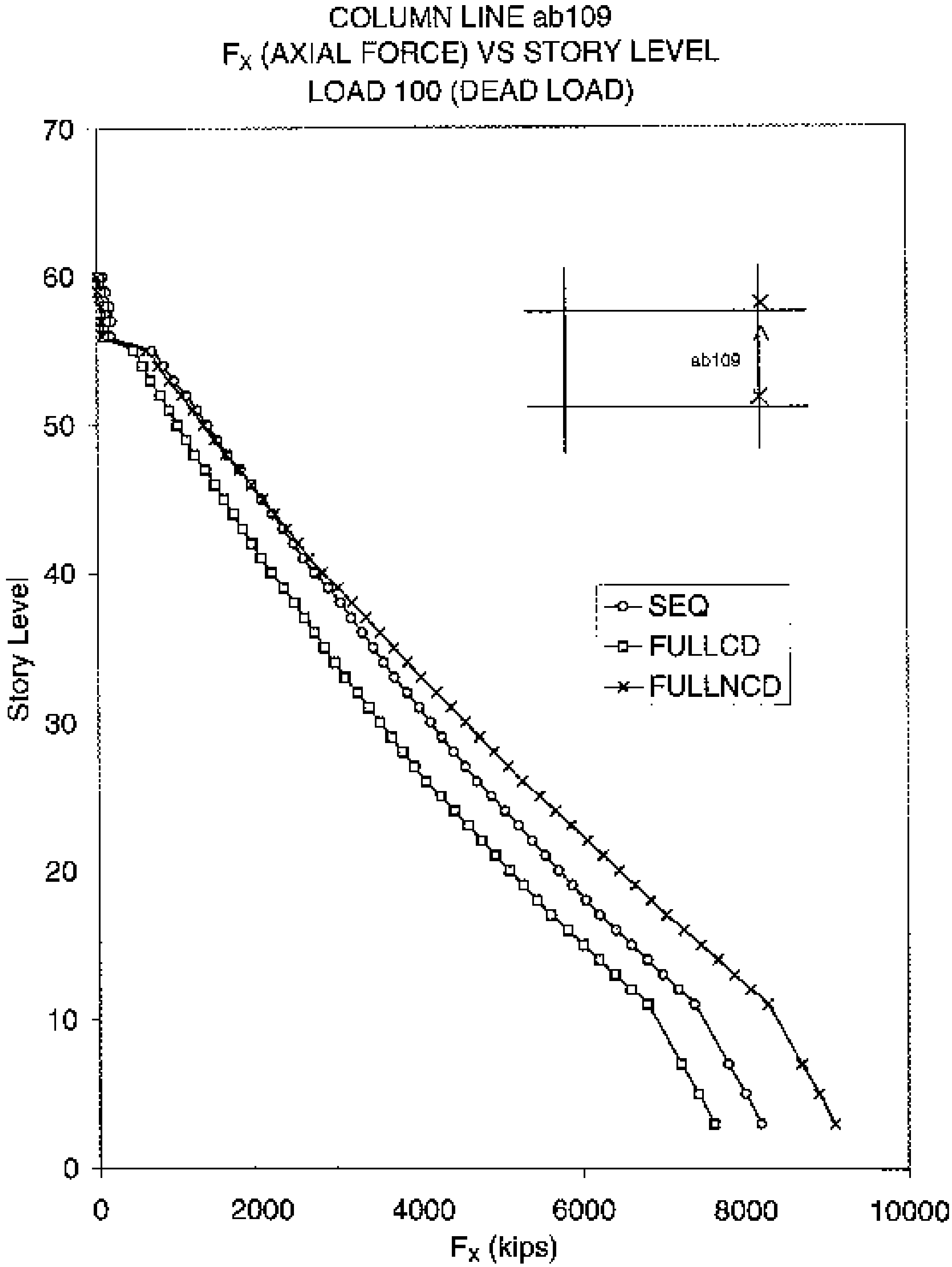
Analysis Models Compared:

Sequential Construction Simulation (“SEQ”)

Full Structure Including Column Axial Deformations (“FULLCD”)

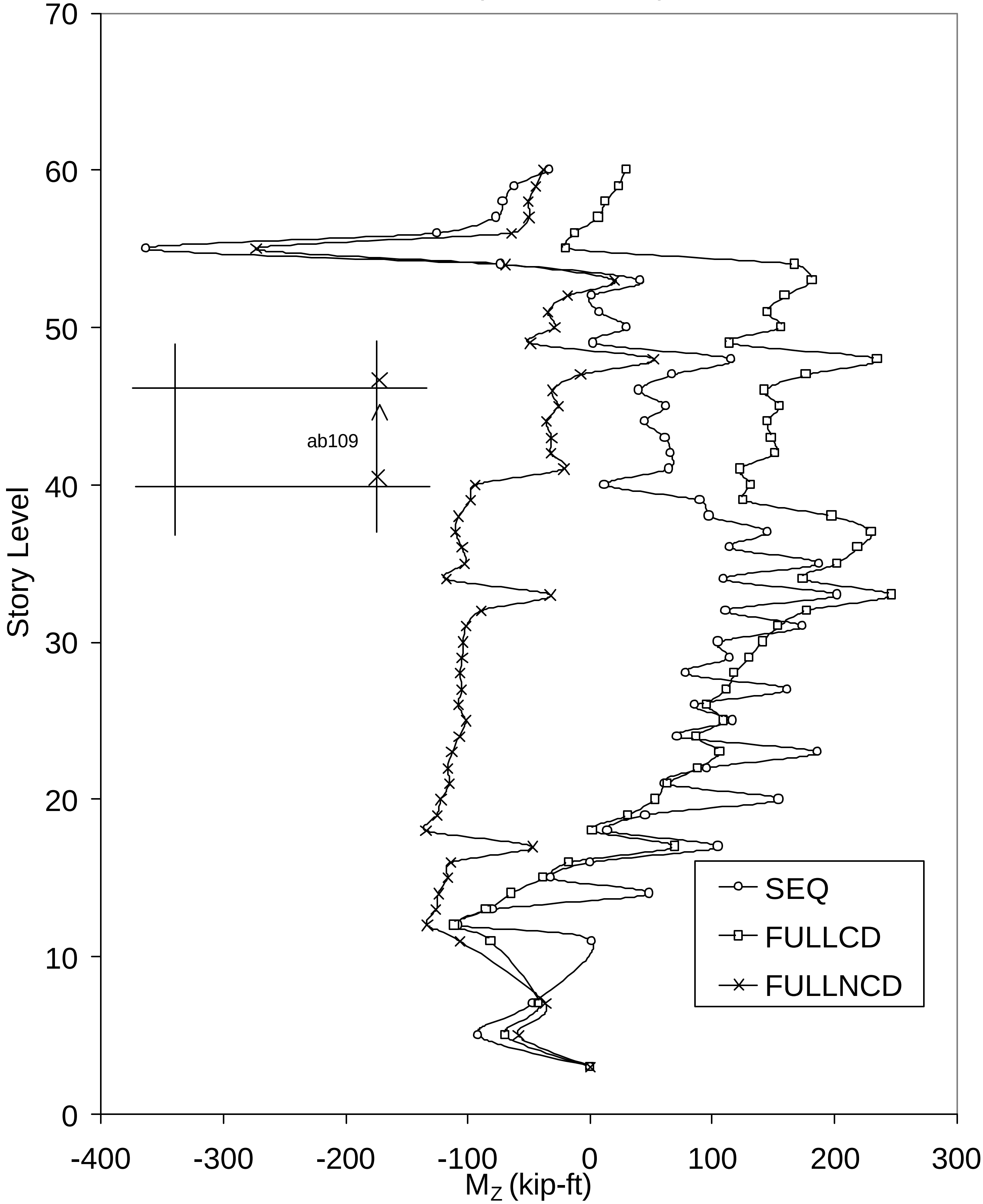
Full Structure With No Column Axial Deformations (“FULLNCD”)

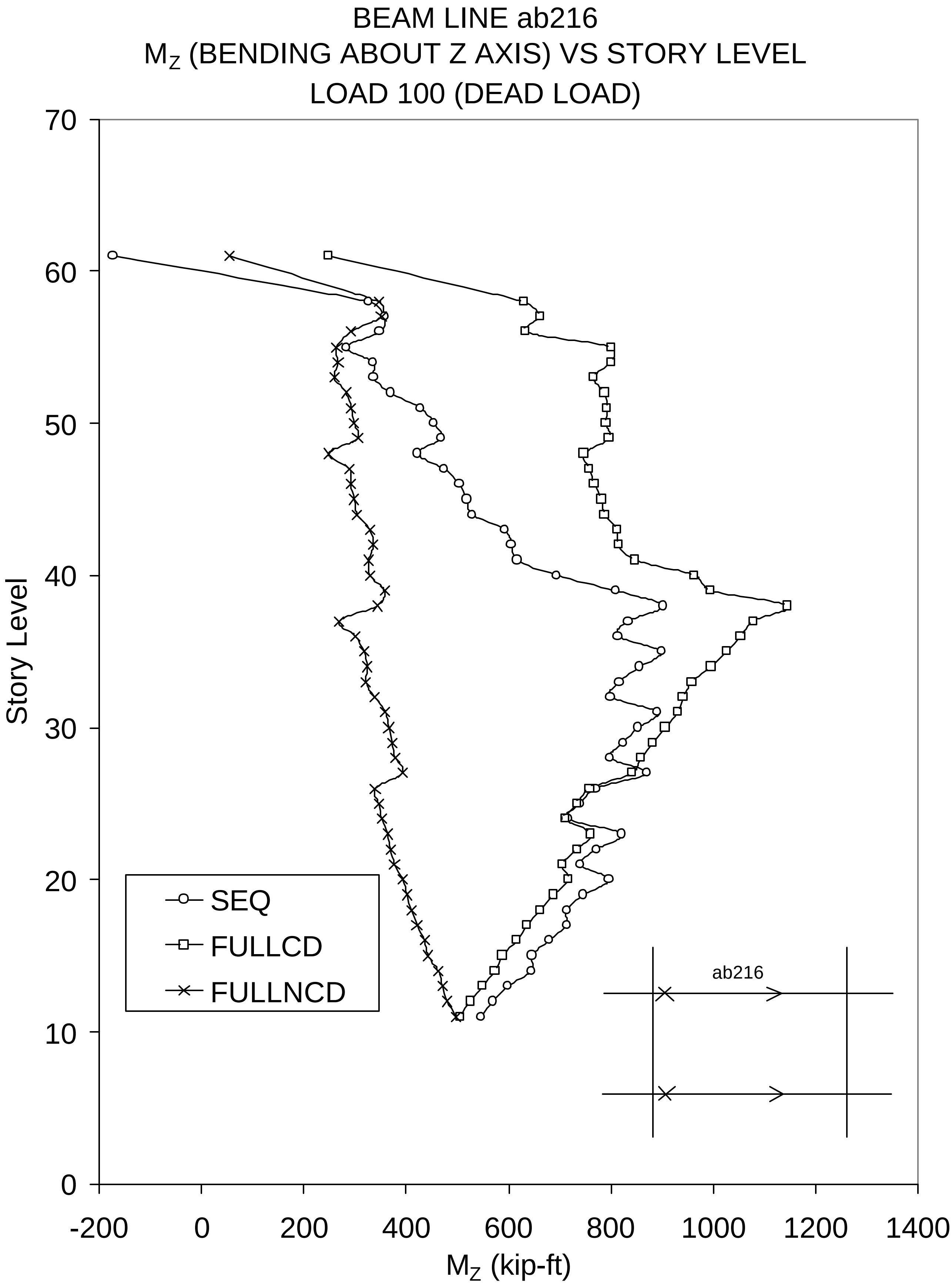
Members	Force Components Compared
Column Line ab109:	FX (Axial Force) Variation
Column Line ab109:	MZ (Bending-Z) Variation
Beam Line ab216:	MZ (Bending-Z) Variation



COLUMN LINE ab109
F_X (AXIAL FORCE) VS STORY LEVEL
LOAD 100 (DEAD LOAD)
ab109
SEQ
FULLCD
FULLNCD
Story Level
F_X (kips)
0
10
20
30
40
50
60
70
0
2000
4000
6000
8000
10000

COLUMN LINE ab109
M_Z (BENDING ABOUT Z AXIS) VS STORY LEVEL
LOAD 100 (DEAD LOAD)





BEAM LINE ab216
M_Z (BENDING ABOUT Z AXIS) VS STORY LEVEL
LOAD 100 (DEAD LOAD)
70
60
50
40
30
20
10
0
Story Level
-200
0
200
400
600
800
1000
1200
1400
M_Z (kip-ft)
SEQ
FULLCD
FULLNCD
ab216

APPENDIX D

Lateral Deflection of Column Line ab133
Over the Height of the Building Model

E-W Wind Load 500

Analysis Models Compared:

- **Full Finite Element Model With FE Floor Slabs ("FEA")**
  (Maximum Z-displacement: Dz = 40.69 cm = 16.02 in,
  Dz / H = 1 / 644)

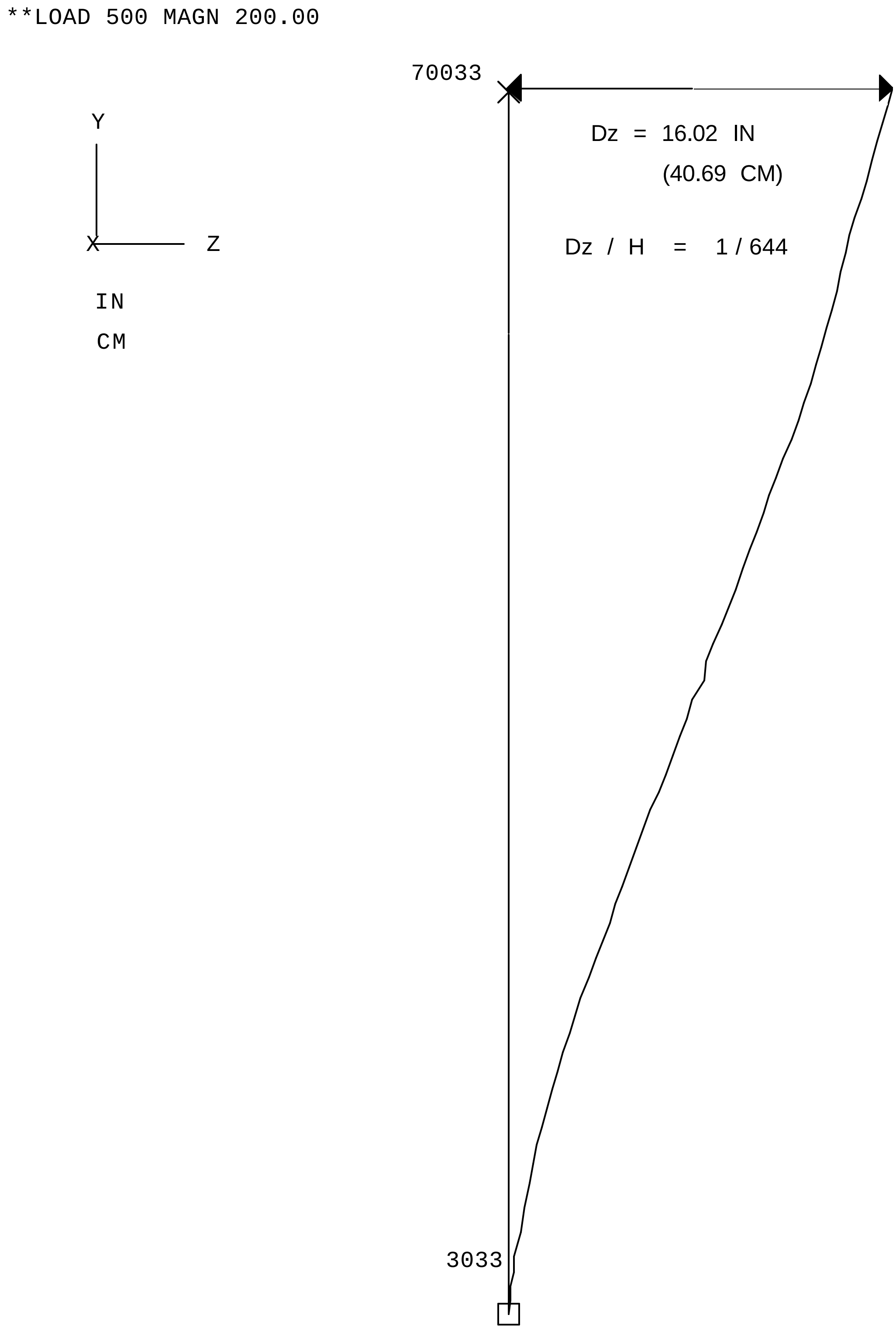
- **Rigid Body Plane Floor Membrane Including Column Axial Deformations ("RBPCD")**
  (Maximum Z-displacement: Dz = 40.58 cm = 15.98 in,
  Dz / H = 1 / 645)

- **Rigid Body Plane Floor Membrane With No Column Axial Deformations ("RBPNCD")**
  (Maximum Z-displacement: Dz = 10.41 cm = 4.10 in,
  Dz / H = 1 / 2514)

- **Rigid Body Solid Floor Including Column Axial Deformations ("RBSCD")**
  (Maximum Z-displacement: Dz = 14.6 cm = 5.8 in,
  Dz / H = 1/ 1373)

- **Rigid Body Solid Floor With No Column Axial Deformations ("RBSNCD")**
  (Maximum Z-displacement: Dz = 0.65 cm = 0.25 in,
  Dz / H = 1 / 31025)

FULL FINITE ELEMENT MODEL
DEFLECTED SHAPE
COLUMN LINE ab133

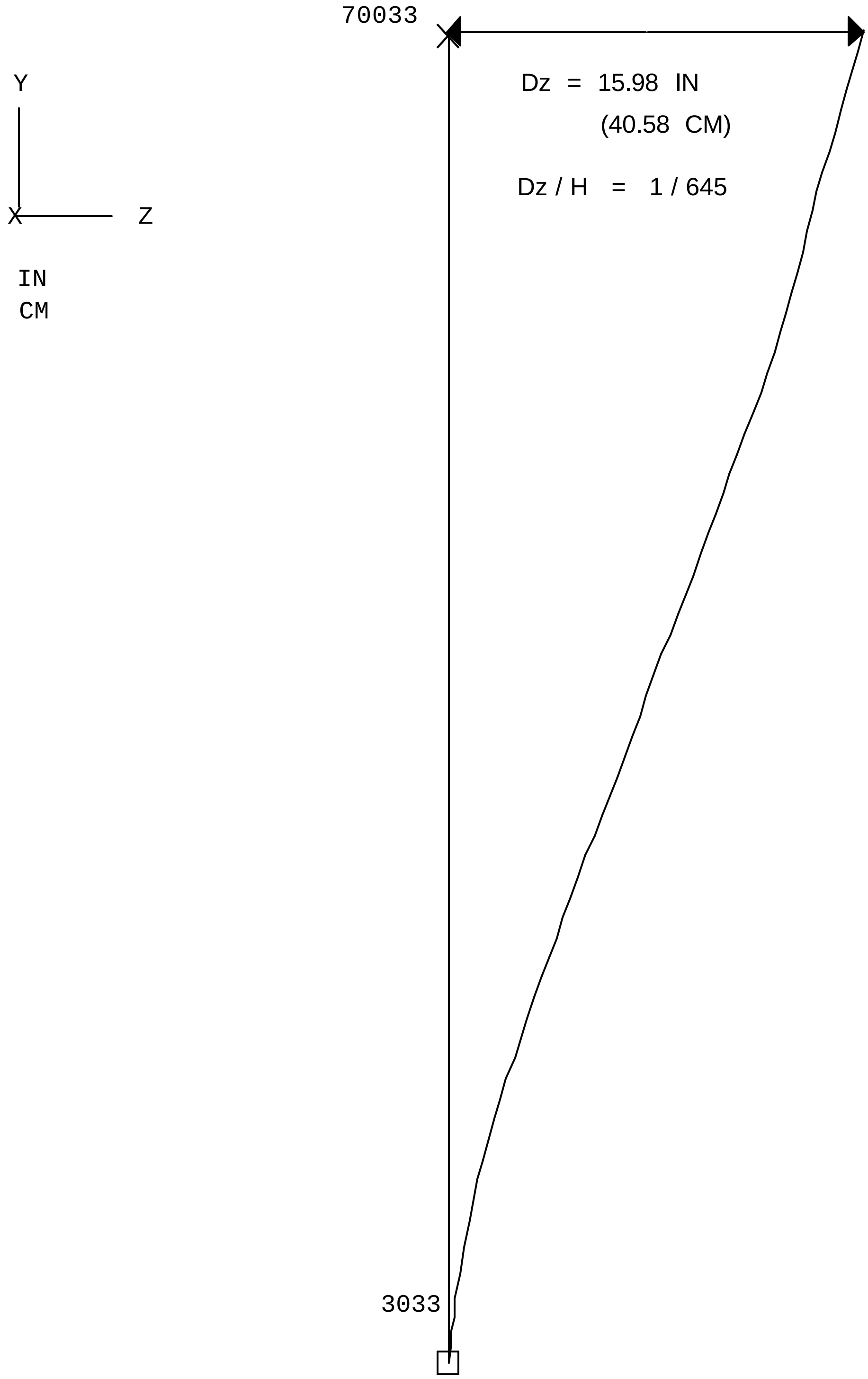


RIGID PLANE WITH COLUMN DEFORMATION

DEFLECTED SHAPE

COLUMN LINE ab133

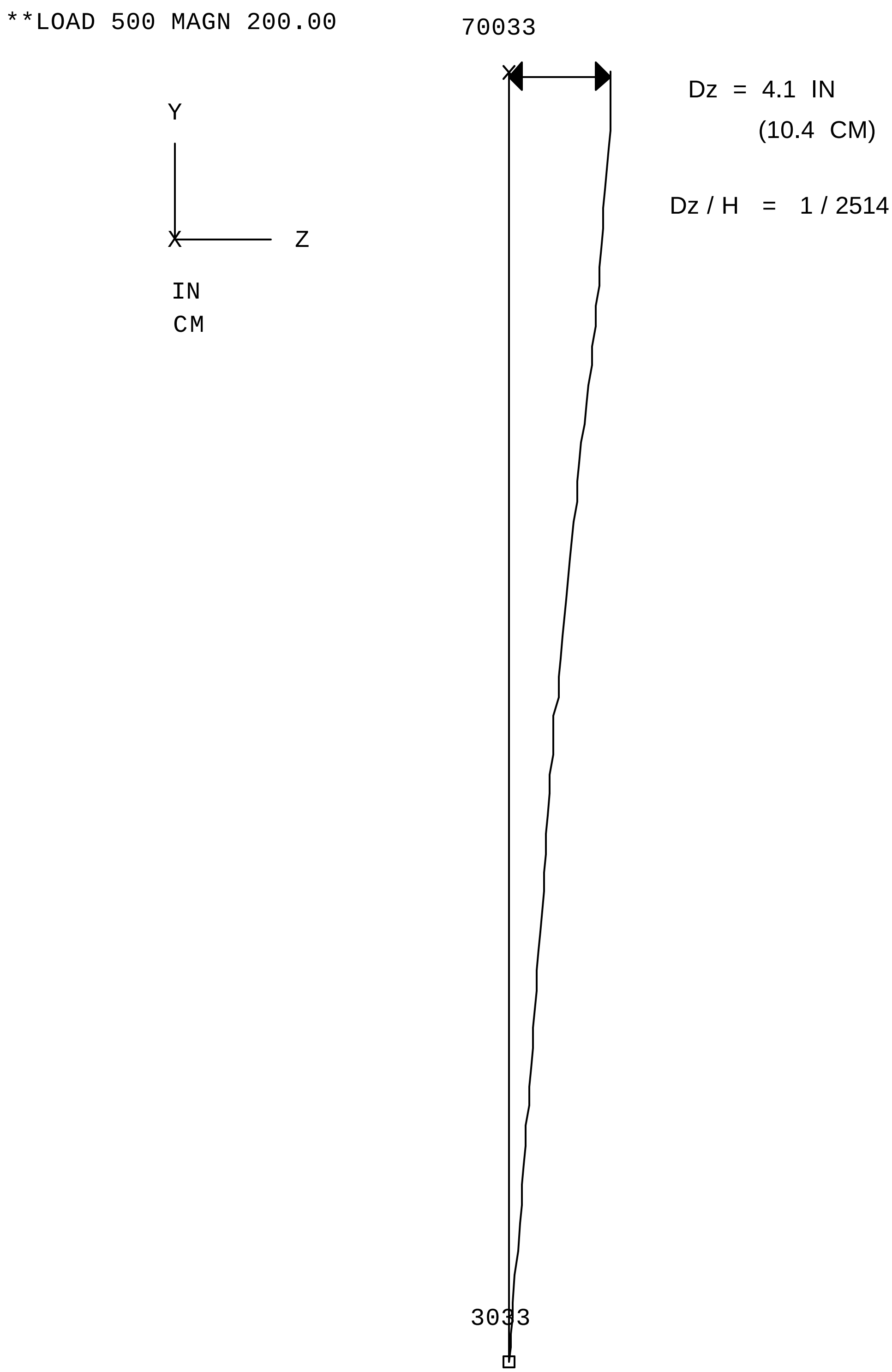
**LOAD 500 MAGN 200.00



RIGID PLANE WITHOUT COLUMN DEFORMATION

DEFLECTED SHAPE

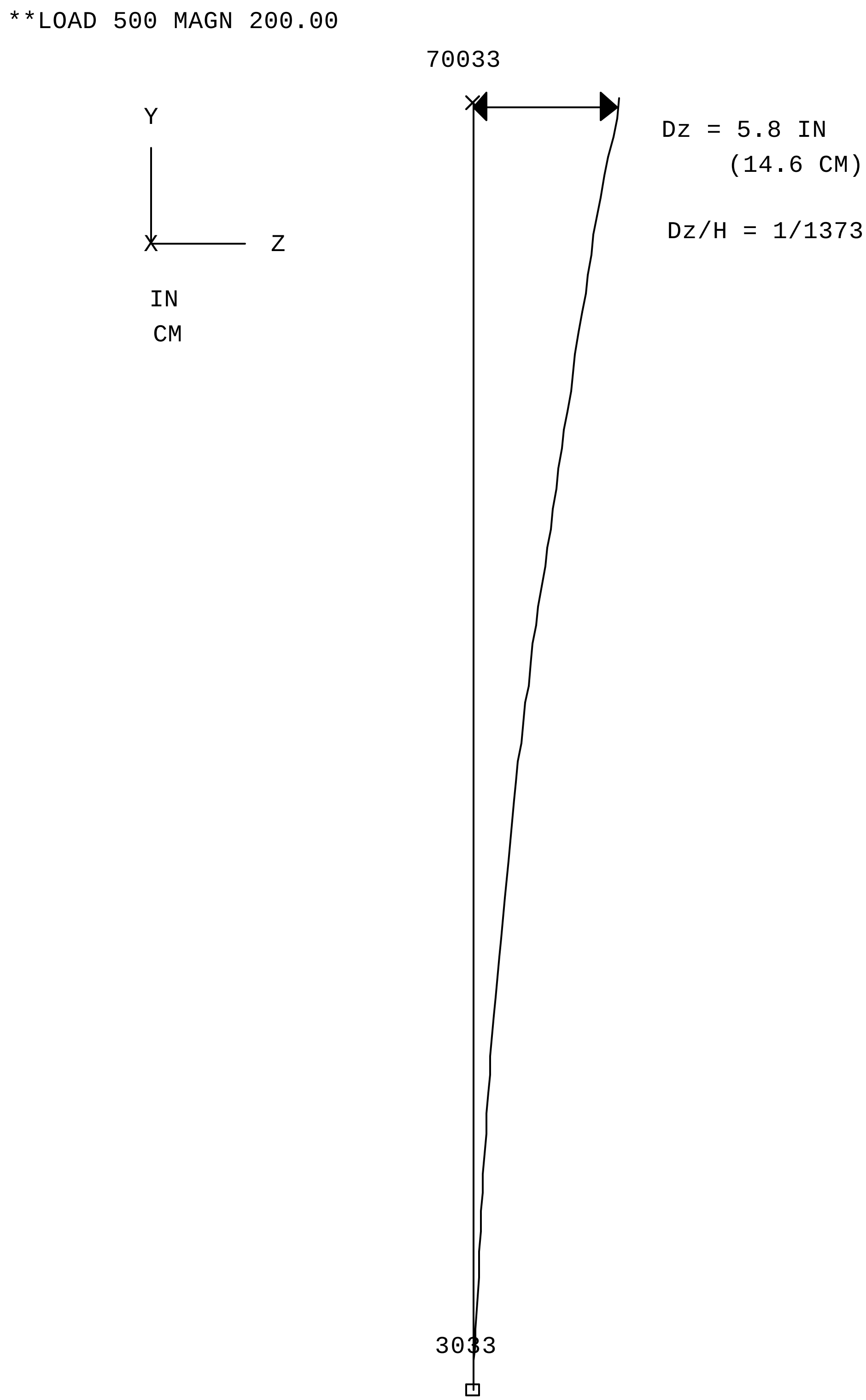
COLUMN LINE ab133



RIGID SOLID MODEL WITH COLUMN DEFORMATIONS

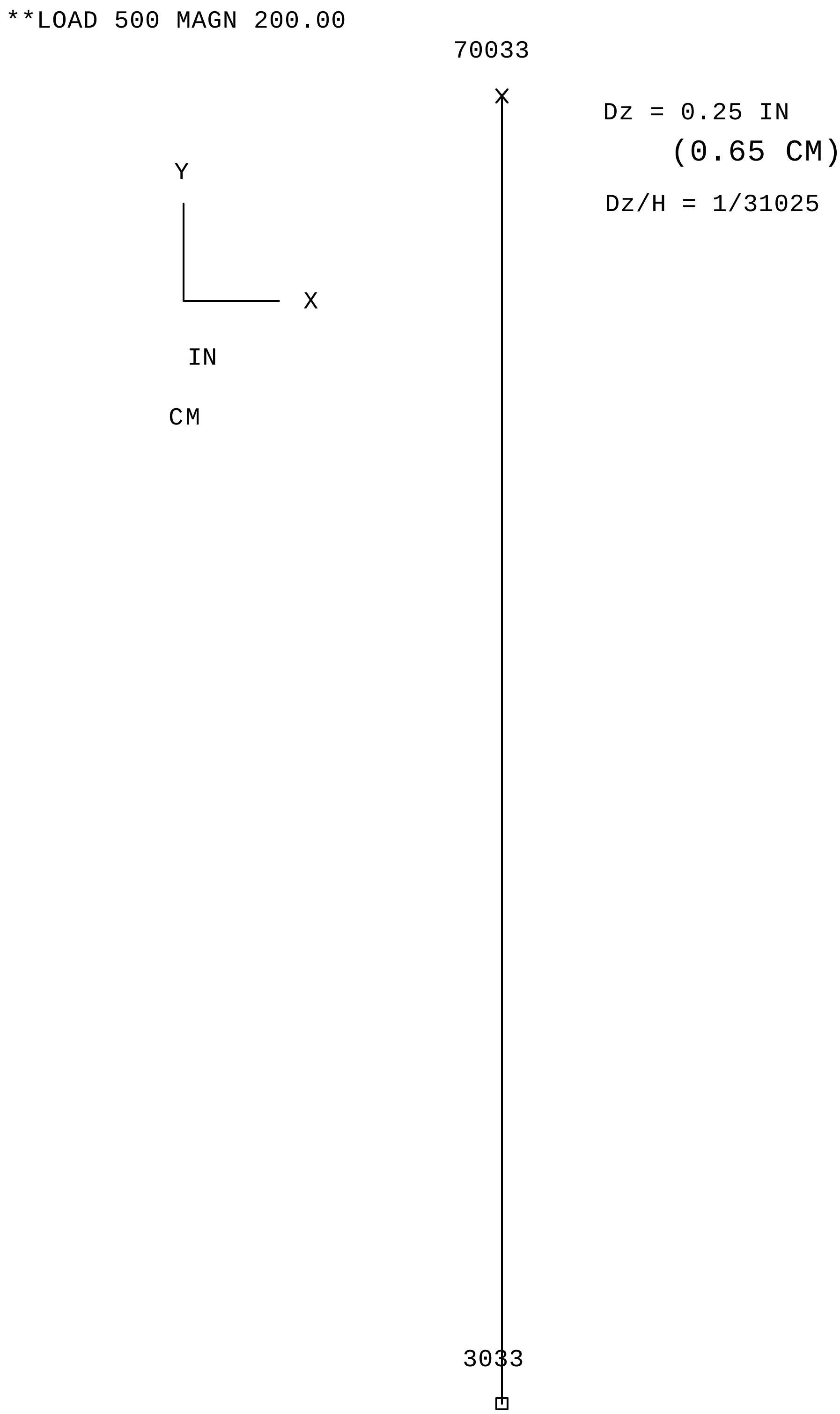
DEFLECTED SHAPE

COLUMN LINE ab133



RIGID SOLID MODEL WITHOUT COLUMN DEFORMATIONS
DEFLECTED SHAPE

COLUMN LINE ab133



APPENDIX E

Examples of Variations of Member Start Forces and Moments Over the Height of the Building Model

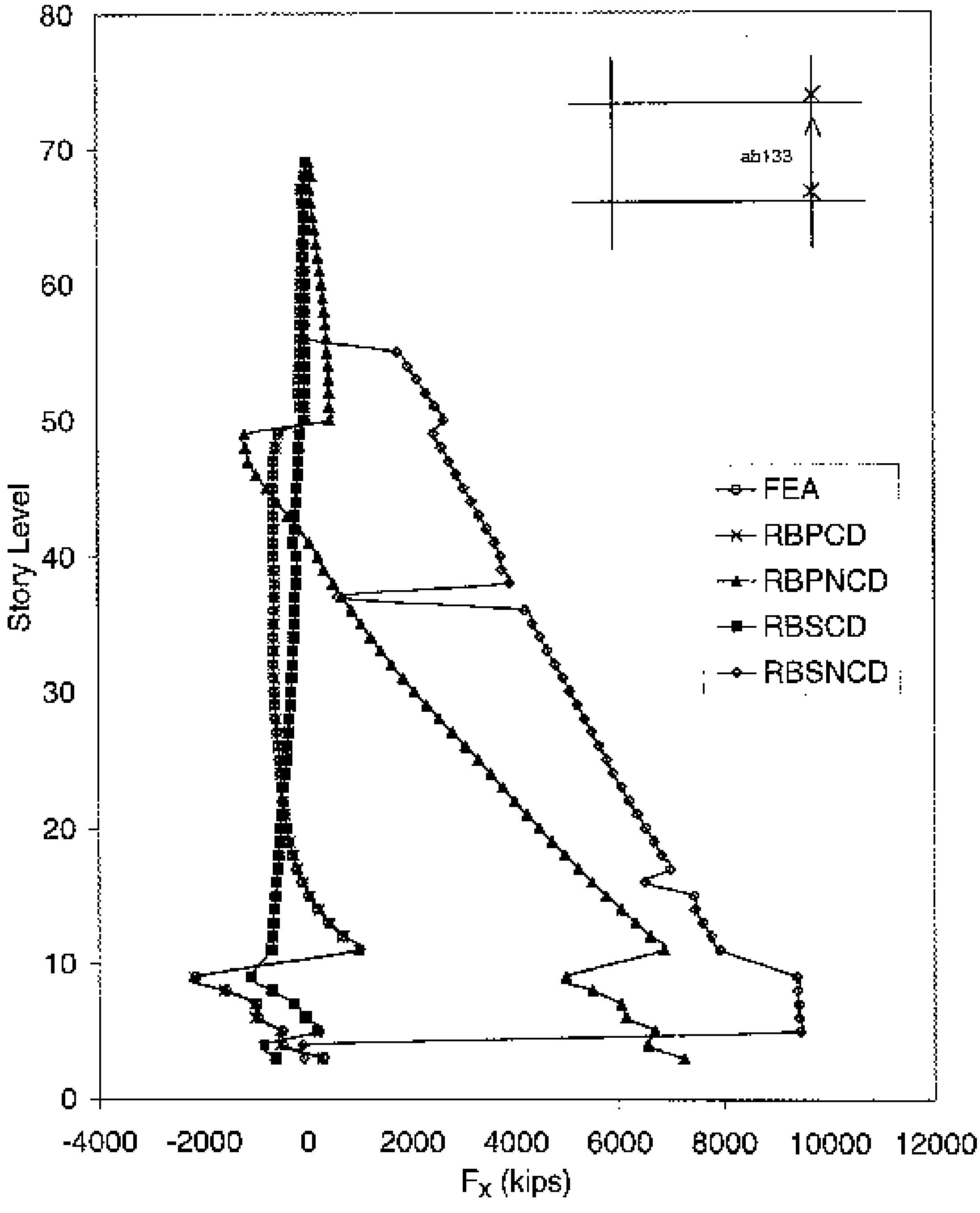
E-W Wind Load 500

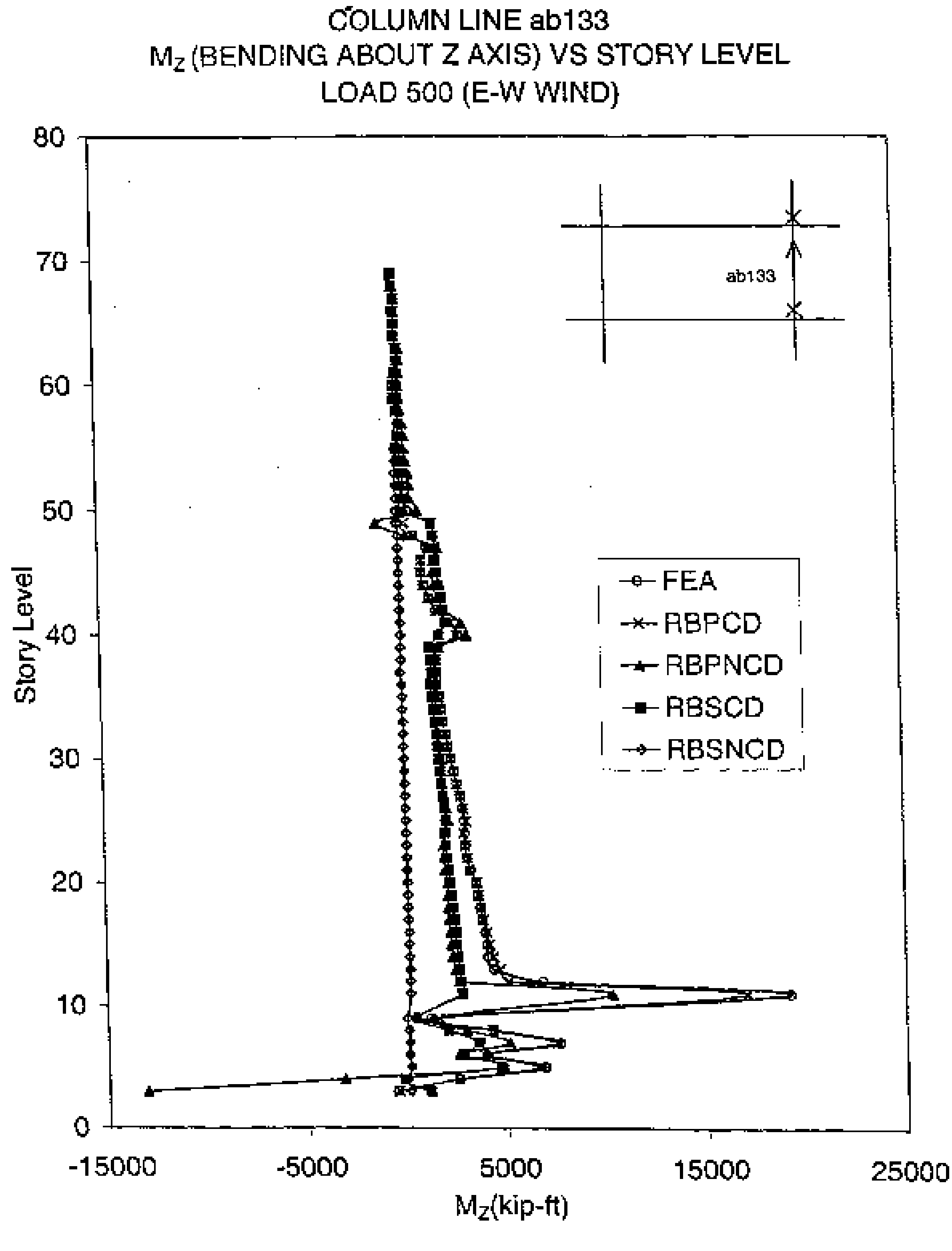
Analysis Models Compared:

- # **Full Finite Element Model With FE Floor Slabs ("FEA")**
- # **Rigid Body Plane Floor Membrane Including Column Axial Deformations ("RBPCD")**
- # **Rigid Body Plane Floor Membrane With No Column Axial Deformations ("RBPNCD")**
- # **Rigid Body Solid Floor Including Column Axial Deformations ("RBSCD")**
- # **Rigid Body Solid Floor With No Column Axial Deformations ("RBSNCD")**

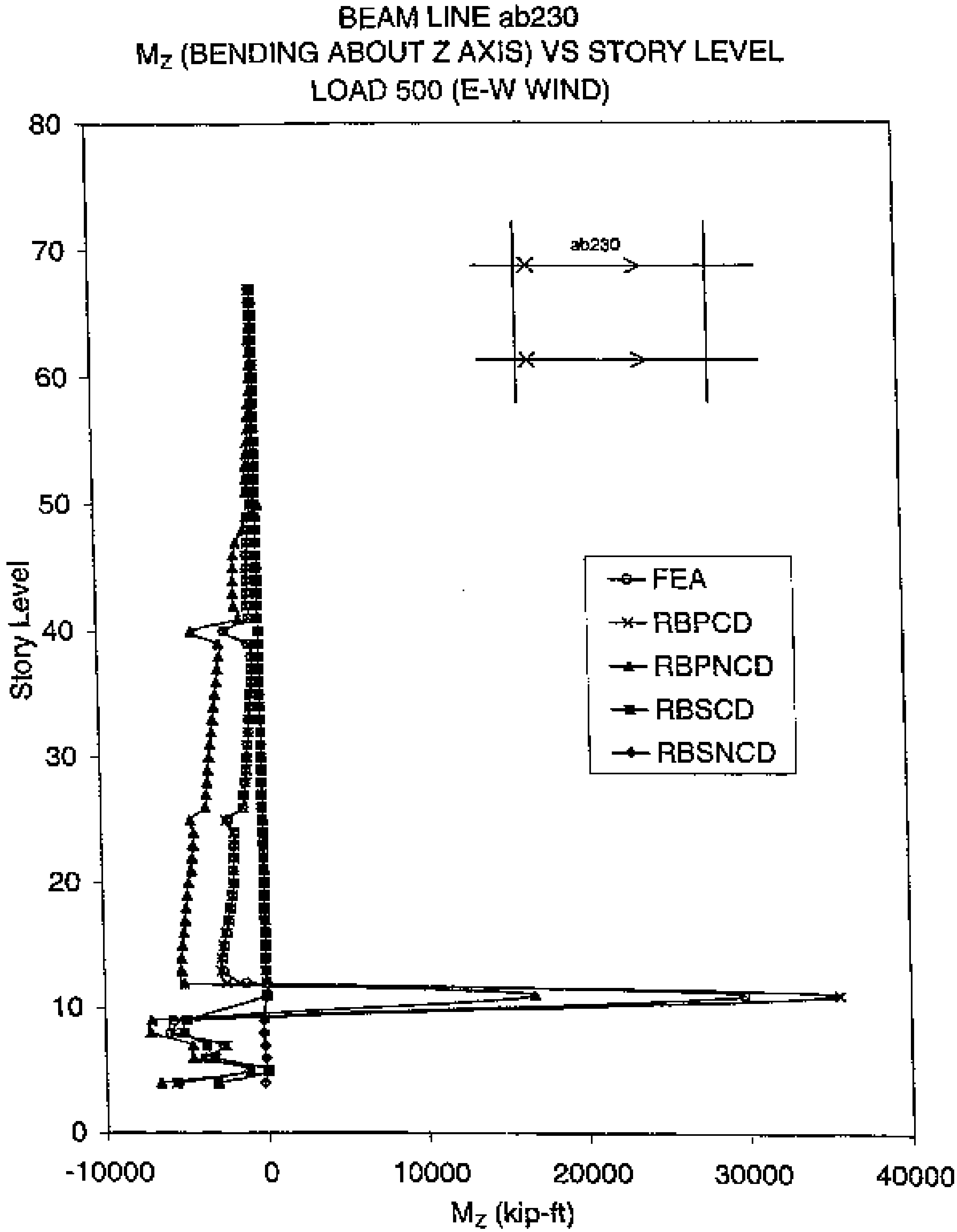
Members	Force Components Compared
Column Line ab133:	**FX (Axial Force) Variation**
Column Line ab133:	**MZ (Bending-Z) Variation**
Beam Line ab230:	**MZ (Bending-Z) Variation**

COLUMN LINE ab133
F_X (AXIAL FORCE) VS STORY LEVEL
LOAD 500 (E-W WIND)





COLUMN LINE ab133
M_Z (BENDING ABOUT Z AXIS) VS STORY LEVEL
LOAD 500 (E-W WIND)
ab133
FEA
RBPCD
RBPNCD
RBSCD
RBSNCD
Story Level
M_Z(kip-ft)


BEAM LINE ab230
MZ (BENDING ABOUT Z AXIS) VS STORY LEVEL
LOAD 500 (E-W WIND)
Story Level
MZ (kip-ft)
ab230
FEA
RBPCD
RBPNCD
RBSCD
RBSNCD
0
10
20
30
40
50
60
70
80
-10000
0
10000
20000
30000
40000

APPENDIX F

Examples of Variations of Member Start Forces and Moments Over the Height of the Building Model

N-S Wind Load 400

Analysis Models Compared:

Full Finite Element Model With FE Floor Slabs (“FEA”)

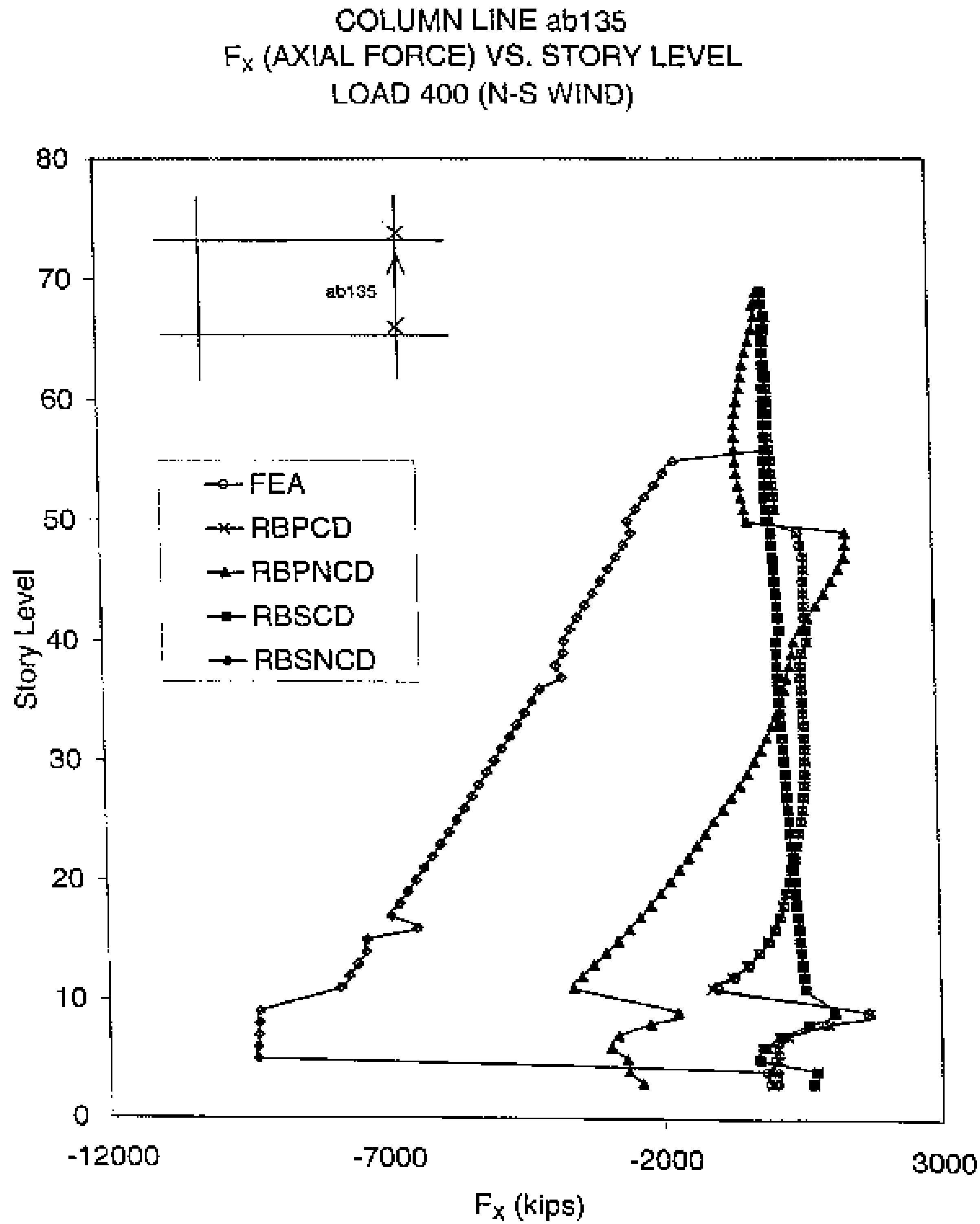
Rigid Body Plane Floor Membrane Including Column Axial Deformations (“RBPCD”)

Rigid Body Plane Floor Membrane With No Column Axial Deformations (“RBPNCD”)

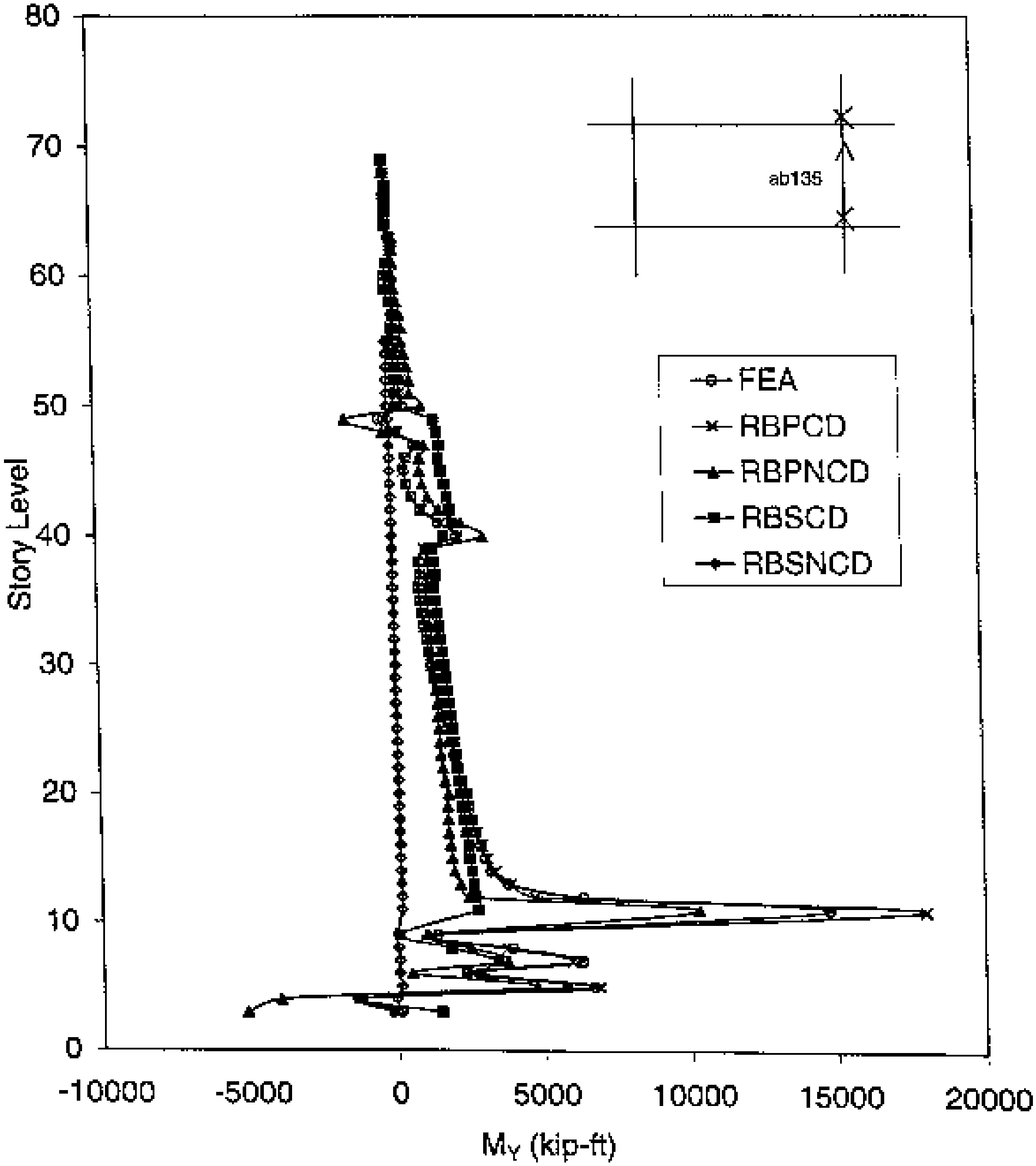
Rigid Body Solid Floor Including Column Axial Deformations (“RBSCD”)

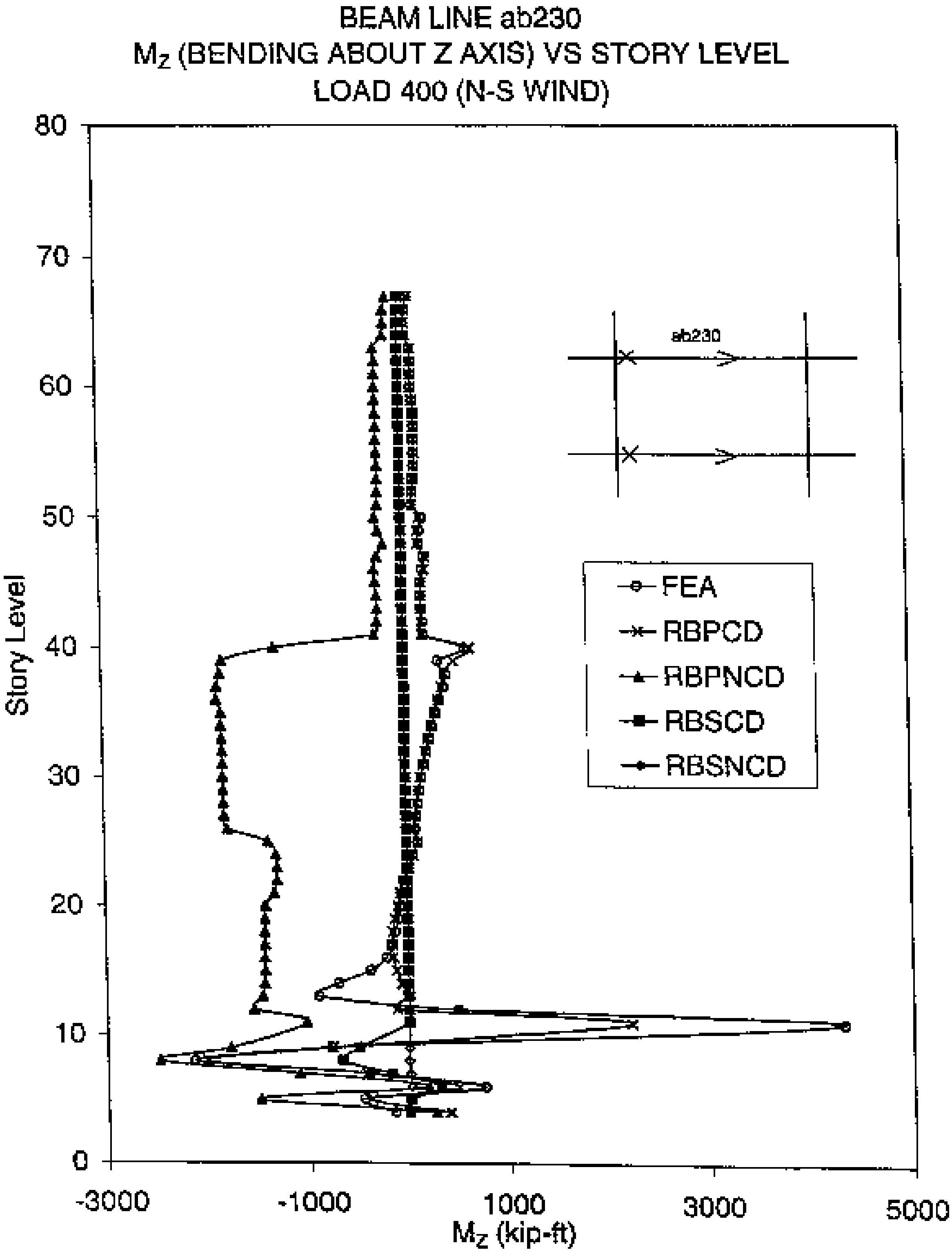
Rigid Body Solid Floor With No Column Axial Deformations (“RBSNCD”)

Members	Force Components Compared
Column Line ab135:	**FX (Axial Force) Variation**
Column Line ab135:	**MY (Bending-Y) Variation**
Beam Line ab230:	**MZ (Bending-Z) Variation**


COLUMN LINE ab135
Fx (AXIAL FORCE) VS. STORY LEVEL
LOAD 400 (N-S WIND)
ab135
FEA
RBPCD
RBPNCD
RBSCD
RBSNCD
Story Level
80
70
60
50
40
30
20
10
0
-12000
-7000
-2000
3000
Fx (kips)

COLUMN LINE ab135
M_Y (BENDING ABOUT Y AXIS) VS STORY LEVEL
LOAD 400 (N-S WIND)




BEAM LINE ab230
M_Z (BENDING ABOUT Z AXIS) VS STORY LEVEL
LOAD 400 (N-S WIND)
Story Level
M_Z (kip-ft)
ab230
FEA
RBPCD
RBPNCD
RBSCD
RBSNCD
80
70
60
50
40
30
20
10
0
-3000
-1000
1000
3000
5000

APPENDIX G

Result Comparison Tables

Sequential Dead Load Analysis

Compared to

Full Structure Dead Load Analysis

Member Type: Columns
Comparison: Axial Forces (Kips)

		Analysis Method			
Member	Joint	SEQUENTIAL	FULL	Difference	Increase Factor
45135	46035	-3359	-4400	1041	1.31 = FULL / SEQ
46135	46035	3264	4288	1024	1.31 = FULL / SEQ
47135	48035	-3090	-4107	1018	1.33 = FULL / SEQ
48116	49016	-1634	-1212	422	1.35 = SEQ / FULL
48135	49035	-2962	-3935	973	1.33 = FULL / SEQ
49116	50016	-1513	-1113	400	1.36 = SEQ / FULL
49135	50035	-2784	-3705	922	1.33 = FULL / SEQ
50101	51001	-1387	-1009	378	1.37 = SEQ / FULL
50109	51009	-1335	-965	370	1.38 = SEQ / FULL
51101	52001	-1262	-906	356	1.39 = SEQ / FULL
51109	52009	-1208	-863	346	1.40 = SEQ / FULL
52109	53009	-1074	-756	318	1.42 = SEQ / FULL

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
Member	Joint	SEQUENTIAL	FULL	Difference	Increase Factor
14129	14029	-1431	-120	1311	11.96 = SEQ / FULL
21129	22029	1735	261	1474	6.65 = SEQ / FULL
22129	23029	1766	135	1631	13.05 = SEQ / FULL
23129	24029	1362	59	1303	23.08 = SEQ / FULL
24129	25029	1314	162	1152	8.10 = SEQ / FULL
38129	39029	1051	137	915	7.70 = SEQ / FULL

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
Member	Joint	SEQUENTIAL	FULL	Difference	Increase Factor
15129	15029	-1143	32	1175	-35.64 = SEQ / FULL
16129	16029	-1143	121	1264	-9.42 = SEQ / FULL
17129	17029	-1179	263	1441	-4.49 = SEQ / FULL
18129	18029	-914	385	1300	-2.37 = SEQ / FULL
19129	19029	-905	440	1345	-2.06 = SEQ / FULL
20129	20029	-1024	506	1529	-2.02 = SEQ / FULL
22128	23028	907	-9	916	-98.35 = SEQ / FULL

Member Type: Beams

Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
Member	**Joint**	**SEQUENTIAL**	**FULL**	**Difference**	**Increase Factor**
11230	11034	3528	2334	1194	1.51 = SEQ / FULL
11230	11028	-3668	-2583	1085	1.42 = SEQ / FULL
11231	11035	3503	2028	1475	1.73 = SEQ / FULL
11231	11029	-3892	-2462	1431	1.58 = SEQ / FULL
11234	11036	-3639	-2196	1443	1.66 = SEQ / FULL
11234	11032	2194	1165	1029	1.88 = SEQ / FULL
11239	11035	3798	2154	1644	1.76 = SEQ / FULL
11239	11036	5566	3325	2242	1.67 = SEQ / FULL
11240	11036	2764	1675	1088	1.65 = SEQ / FULL
11240	11033	4923	3002	1921	1.64 = SEQ / FULL
56265	56045	-1363	-502	860	2.71 = SEQ / FULL
56266	56046	-1418	-558	860	2.54 = SEQ / FULL
56267	56047	-1387	-513	875	2.71 = SEQ / FULL
56268	56048	-1188	-337	851	3.52 = SEQ / FULL
56269	56049	-1185	-370	815	3.21 = SEQ / FULL
56270	56050	-1420	-534	887	2.66 = SEQ / FULL
56271	56051	-1384	-506	879	2.74 = SEQ / FULL
56272	56052	-1353	-473	880	2.86 = SEQ / FULL

APPENDIX H

Result Comparison Tables

Wind Load Analysis Comparisons
(between the "Exact" Finite Element Model and
Each of the Four Approximate Models)

Among the Following Models

(a) **Full Finite Element Model With FE Floor Slabs ("FEA")**

(b) **Rigid Body Plane Floor Membrane Including Column Axial Deformations ("RBPCD")**

(c) **Rigid Body Plane Floor Membrane With No Column Axial Deformations ("RBPNCD")**

(d) **Rigid Body Solid Floor Including Column Axial Deformations ("RBSCD")**

(e) **Rigid Body Solid Floor With No Column Axial Deformations ("RBSNCD")**

Comparisons between the “Exact” Finite Element Model and the Rigid Body Plane Floor Membrane Model Including Column Axial Deformations (“RBPCD”) for the N-S Wind Load 400

Member Type: Columns
Comparison: Axial Forces (Kips)

Member	Joint	Analysis Method Wind Load 400 (NS) FINITE ELEM. w/ Column Def.	RIGID PLANE w/ Column Def.	Difference	Increase Factor (NS)
8134	8034	-949	-1002	53	1.06 = R.P. / FE
11134	11034	1084	1128	44	1.04 = R.P. / FE
11135	11035	-998	-1100	101	1.10 = R.P. / FE
11136	11036	-956	-1046	90	1.09 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

Member	Joint	Analysis Method Wind Load 400 (NS) FINITE ELEM. w/ Column Def.	RIGID PLANE w/ Column Def.	Difference	Increase Factor (NS)
3127	4027	-3580	-2914	666	1.23 = FE / R.P.
3130	4030	3549	2926	623	1.21 = FE / R.P.
4126	5026	2590	3409	820	1.32 = R.P. / FE
4127	5027	2643	3507	864	1.33 = R.P. / FE
4128	4028	1274	942	332	1.35 = FE / R.P.
4129	4029	-989	-704	286	1.41 = FE / R.P.
4130	5030	-2782	-3558	776	1.28 = R.P. / FE
4131	5031	-2698	-3457	759	1.28 = R.P. / FE
5130	6030	2000	1729	271	1.16 = FE / R.P.
11128	11028	-2778	-1219	1558	2.28 = FE / R.P.
11133	12033	1516	519	997	2.92 = FE / R.P.
11134	12034	1644	356	1288	4.62 = FE / R.P.

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 400 (NS)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/ Column Def.	Difference	Increase Factor (NS)
9127	11027	-171	538	709	-3.14 = R.P. / FE
11135	11035	-102	521	622	-5.12 = R.P. / FE
12133	12033	-496	530	1026	-1.07 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Y-axis (k-ft)

		Analysis Method			
		Wind Load 400 (NS)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/ Column Def.	Difference	Increase Factor (NS)
11134	12034	-2393	-362	2031	6.61 = FE / R.P.
11135	11035	14774	18030	3256	1.22 = R.P. / FE
11135	12035	-3046	-1140	1906	2.67 = FE / R.P.
12133	13033	-1118	-561	557	1.99 = FE / R.P.
12134	13034	1285	734	551	1.75 = FE / R.P.

Member Type: Beams
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method Wind Load 400 (NS)			
Member	Joint	FINITE ELEM. w/ Column Def.	RIGID PLANE w/ Column Def.	Difference	Increase Factor (NS)
4228	4026	1630	2031	401	1.25 = R.P. / FE
11230	11034	4326	2219	2107	1.95 = FE / R.P.
11230	11028	-4591	-2284	2307	2.01 = FE / R.P.
11231	11029	3645	2353	1292	1.55 = FE / R.P.
11234	11032	2668	1773	895	1.50 = FE / R.P.
11237	11033	-2954	-1262	1693	2.34 = FE / R.P.
12230	12028	1480	2243	763	1.52 = R.P. / FE
12231	12029	-1376	-2084	708	1.51 = R.P. / FE
13230	13034	-899	-13	886	71.41 = FE / R.P.
13230	13028	1859	997	862	1.86 = FE / R.P.

Member Type: Beams
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method Wind Load 400 (NS)			
Member	Joint	FINITE ELEM. w/ Column Def.	RIGID PLANE w/ Column Def.	Difference	Increase Factor (NS)
12230	12034	492	-123	615	-4.01 = FE / R.P.
13231	13035	542	-22	564	-24.23 = FE / R.P.

Comparisons between the “Exact” Finite Element Model and the Rigid Body Plane Floor Membrane Model Including Column Axial Deformations (“RBPCD”) for the E-W Wind Load 500

Member Type: Columns
Comparison: Axial Forces (Kips)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID PLANE		
Member	**Joint**	**w/ Column Def.**	**w/ Column Def.**	**Difference**	**Increase Factor (EW)**
3134	3034	-1422	-1354	68	1.05 = FE / R.P.
9134	9034	1638	1678	41	1.02 = R.P. / FE
11120	11020	3006	3081	75	1.03 = R.P. / FE
11134	11034	-1252	-1423	171	1.14 = R.P. / FE
11135	11035	-1413	-1488	75	1.05 = R.P. / FE
12134	12034	-1015	-1105	90	1.09 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID PLANE		
Member	**Joint**	**w/ Column Def.**	**w/ Column Def.**	**Difference**	**Increase Factor (EW)**
3132	4032	1753	2382	630	1.36 = R.P. / FE
4128	5028	3674	2987	688	1.23 = FE / R.P.
4129	5029	3885	3260	624	1.19 = FE / R.P.
9125	11025	-1553	-322	1231	4.83 = FE / R.P.
9133	9033	1202	1618	416	1.35 = R.P. / FE
11125	12025	-645	-1475	830	2.29 = R.P. / FE
11128	11028	-18946	-22688	3742	1.20 = R.P. / FE
11133	12033	-1799	-462	1337	3.89 = FE / R.P.
11134	11034	-4929	-7149	2220	1.45 = R.P. / FE
11134	12034	1448	263	1185	5.51 = FE / R.P.
12133	12033	6883	5169	1714	1.33 = FE / R.P.
12133	13033	1172	407	765	2.88 = FE / R.P.
12136	13036	1099	691	408	1.59 = FE / R.P.
13133	14033	1415	950	465	1.49 = FE / R.P.
13136	14036	1314	1035	279	1.27 = FE / R.P.
39125	39025	1250	1507	256	1.21 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM. w/ Column Def.	RIGID PLANE w/ Column Def.		
Member	Joint			Difference	Increase Factor (EW)
4132	5032	-763	38	801	-19.89 = FE / R.P.
11126	11026	-108	604	712	-5.61 = R.P. / FE
11126	12026	-45	449	493	-10.06 = R.P. / FE
11136	12036	-650	32	682	-20.43 = FE / R.P.

Member Type: Beams
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM. w/ Column Def.	RIGID PLANE w/ Column Def.		
Member	Joint			Difference	Increase Factor (EW)
11222	11028	3565	4792	1227	1.34 = R.P. / FE
11222	11020	-513	-652	139	1.27 = R.P. / FE
11223	11029	2696	3290	594	1.22 = R.P. / FE
11223	11021	-502	-481	21	1.04 = FE / R.P.
11230	11034	29746	35618	5871	1.20 = R.P. / FE
11230	11028	-31117	-36041	4924	1.16 = R.P. / FE
11238	11034	2889	2135	754	1.35 = FE / R.P.
11238	11035	-1153	-680	472	1.69 = FE / R.P.
11240	11036	-1881	-840	1041	2.24 = FE / R.P.
11240	11033	4061	1899	2162	2.14 = FE / R.P.
12230	12034	-1232	-2427	1195	1.97 = R.P. / FE
12230	12028	-2375	-1795	581	1.32 = FE / R.P.
13234	13036	2196	1648	547	1.33 = FE / R.P.
13234	13032	2285	2573	288	1.13 = R.P. / FE

Comparisons between the "Exact" Finite Element Model and the Rigid Body Plane Floor Membrane Model With NO Column Axial Deformations ("RBPNCD") for the N-S Wind Load 400

Member Type: Columns
Comparison: Axial Forces (Kips)

		Analysis Method Wind Load 400 (NS)			
		FINITE ELEM. w/ Column Def.	RIGID PLANE w/o Column Def.		
Member	**Joint**			**Difference**	**Increase Factor (NS)**
3133	3033	19	5314	5295	282.13 = R.P. / FE
4133	4033	27	5421	5394	199.93 = R.P. / FE
15133	15033	51	4746	4695	93.36 = R.P. / FE
34131	34031	268	6449	6181	24.08 = R.P. / FE
35127	35027	-251	-5967	5716	23.80 = R.P. / FE
35130	35030	252	6007	5755	23.85 = R.P. / FE
37130	37030	207	4902	4695	23.64 = R.P. / FE
45130	45030	4	1942	1938	528.22 = R.P. / FE
45131	45031	7	1931	1924	262.49 = R.P. / FE
61137	61037	7	1280	1273	182.51 = R.P. / FE
61138	61038	-7	-1276	1270	191.26 = R.P. / FE
61141	61041	-7	-1226	1219	187.99 = R.P. / FE
61142	61042	6	1236	1230	194.47 = R.P. / FE

Member Type: Columns
Comparison: Axial Forces (Kips)

		Analysis Method Wind Load 400 (NS)			
		FINITE ELEM. w/ Column Def.	RIGID PLANE w/o Column Def.		
Member	**Joint**			**Difference**	**Increase Factor (NS)**
3128	3028	-114	17513	17627	-153.04 = R.P. / FE
5135	5035	25	-2654	2679	-105.21 = R.P. / FE
20119	20019	-1500	16	1516	-91.40 = FE / R.P.
20122	20022	1503	-11	1514	-130.93 = FE / R.P.
46130	46030	-14	1726	1740	-122.93 = R.P. / FE

Member Type: Columns

Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 400 (NS)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/o Column Def.	Difference	Increase Factor (NS)
3120	3020	775	2965	2191	3.83 = R.P. / FE
3121	3021	-733	-2785	2052	3.80 = R.P. / FE
4128	4028	1274	160	1114	7.95 = FE / R.P.
6127	7027	1201	4435	3234	3.69 = R.P. / FE
7128	8028	1467	255	1212	5.74 = FE / R.P.
7129	8029	-1129	-24	1105	46.13 = FE / R.P.
9129	9029	-1497	-316	1180	4.73 = FE / R.P.
9130	11030	-934	-5163	4229	5.53 = R.P. / FE
9131	11031	-979	-5041	4063	5.15 = R.P. / FE
9135	9035	-1419	-286	1134	4.97 = FE / R.P.
9136	9036	-1292	-90	1202	14.36 = FE / R.P.
11128	12028	1494	47	1446	31.51 = FE / R.P.
14127	15027	783	3993	3210	5.10 = R.P. / FE
14130	15030	-733	-4018	3285	5.48 = R.P. / FE
14131	15031	-746	-3965	3219	5.32 = R.P. / FE
15127	16027	1009	3961	2952	3.93 = R.P. / FE
15130	16030	-1009	-3986	2977	3.95 = R.P. / FE
15131	16031	-1021	-3933	2912	3.85 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 400 (NS)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/o Column Def.	Difference	Increase Factor (NS)
3128	4028	54	-1897	1951	-35.16 = R.P. / FE
4133	4033	326	-3228	3554	-9.89 = R.P. / FE
9125	11025	148	-1662	1810	-11.21 = R.P. / FE
9126	11026	-4	4593	4598	-1072.54 = R.P. / FE
9127	11027	-171	5022	5193	-29.32 = R.P. / FE
11135	11035	-102	1016	1118	-10.00 = R.P. / FE
18125	19025	13	-918	930	-71.01 = R.P. / FE
20125	20025	18	-932	950	-53.00 = R.P. / FE

Member Type: Beams
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 400 (NS)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/o Column Def.	Difference	Increase Factor (NS)
19221	19027	1729	39	1690	44.09 = FE / R.P.
19224	19030	-1741	-12	1729	143.28 = FE / R.P.
19225	19031	-1740	-24	1716	72.85 = FE / R.P.
19230	19028	-57	-3068	3011	53.78 = R.P. / FE
20224	20030	-1759	-5	1754	383.43 = FE / R.P.
20230	20028	-50	-3088	3037	61.28 = R.P. / FE
20231	20029	70	3149	3079	44.87 = R.P. / FE
22225	22031	-1676	-44	1633	38.39 = FE / R.P.
22230	22034	-36	-1294	1258	36.08 = R.P. / FE
23235	23025	-6	-2128	2123	377.69 = R.P. / FE
24228	24026	1534	15	1519	100.26 = FE / R.P.
31224	31022	-7	-1185	1178	177.45 = R.P. / FE
31228	31018	12	1084	1071	88.66 = R.P. / FE

Member Type: Beams

Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 400 (NS)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/o Column Def.	Difference	Increase Factor (NS)
18234	18032	-8	1952	1960	-243.16 = R.P. / FE
22231	22029	-15	2832	2847	-182.78 = R.P. / FE
23221	23027	1669	-1	1671	-1135.67 = FE / R.P.
23224	23030	-1677	27	1704	-63.00 = FE / R.P.
23224	23022	-321	-1683	1361	5.23 = R.P. / FE
23225	23031	-1673	7	1680	-254.41 = FE / R.P.
25228	25026	1521	-53	1573	-28.75 = FE / R.P.
27234	27036	-7	1807	1814	-275.64 = R.P. / FE

Comparisons between the "Exact" Finite Element Model and the Rigid Body Plane Floor Membrane Model With NO Column Axial Deformations ("RBPNCD") for the E-W Wind Load 500

Member Type: Columns
Comparison: Axial Forces (Kips)

Member	Joint	Analysis Method Wind Load 500 (EW) FINITE ELEM. w/ Column Def.	RIGID PLANE w/o Column Def.	Difference	Increase Factor (EW)
3127	3027	-78	-9097	9019	116.52 = R.P. / FE
4127	4027	-54	-9127	9073	170.56 = R.P. / FE
15133	15033	26	5757	5732	225.21 = R.P. / FE
15136	15036	92	5083	4991	54.97 = R.P. / FE
17134	17034	-74	-4358	4284	58.63 = R.P. / FE
17135	17035	-109	-4542	4433	41.72 = R.P. / FE
18135	18035	-1	-4328	4328	7042.71 = R.P. / FE
43125	43025	-61	-2331	2271	38.34 = R.P. / FE
61143	61043	10	1056	1046	104.80 = R.P. / FE

Member Type: Columns
Comparison: Axial Forces (Kips)

Member	Joint	Analysis Method Wind Load 500 (EW) FINITE ELEM. w/ Column Def.	RIGID PLANE w/o Column Def.	Difference	Increase Factor (EW)
3130	3030	16	-9163	9180	-563.46 = R.P. / FE
4130	4030	53	-9146	9200	-171.83 = R.P. / FE
5127	5027	114	-8817	8931	-77.32 = R.P. / FE
6127	6027	107	-8848	8955	-82.61 = R.P. / FE
14130	14030	80	-7080	7159	-88.87 = R.P. / FE
18134	18034	30	-4152	4182	-136.66 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

Member	Joint	Analysis Method – Wind Load 500 (EW) – FINITE ELEM. w/ Column Def.	RIGID PLANE w/o Column Def.	Difference	Increase Factor (EW)
3125	4025	211	3685	3474	17.45 = R.P. / FE
3133	3033	-535	-13074	12539	24.44 = R.P. / FE
3136	3036	-1200	-13085	11886	10.91 = R.P. / FE
4134	4034	-3061	-508	2553	6.03 = FE / R.P.
4135	4035	-3030	-548	2482	5.53 = FE / R.P.
11132	12032	-8424	-419	8006	20.13 = FE / R.P.
13125	14025	190	2979	2789	15.69 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

Member	Joint	Analysis Method – Wind Load 500 (EW) – FINITE ELEM. w/ Column Def.	RIGID PLANE w/o Column Def.	Difference	Increase Factor (EW)
4136	4036	3473	-418	3891	-8.31 = FE / R.P.
6129	7029	10159	-2392	12550	-4.25 = FE / R.P.
8128	9028	87	-9220	9308	-105.39 = R.P. / FE
8129	9029	1008	-8578	9585	-8.51 = R.P. / FE
11128	12028	14064	-1387	15451	-10.14 = FE / R.P.
11129	12029	13372	-1706	15078	-7.84 = FE / R.P.
22128	23028	34	-4324	4358	-126.51 = R.P. / FE
22129	23029	87	-4329	4415	-49.91 = R.P. / FE

Member Type: Columns

Comparison: Bending about the Y-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/o Column Def.	Difference	Increase Factor (EW)
3133	3033	576	14081	13505	24.44 = R.P. / FE
3135	3035	-2655	-12210	9555	4.60 = R.P. / FE
3136	3036	-1200	-13085	11886	10.91 = R.P. / FE
9136	11036	-1575	-430	1145	3.66 = FE / R.P.
11135	11035	-2055	-1048	1007	1.96 = FE / R.P.
11136	11036	-2275	-1075	1200	2.12 = FE / R.P.

Member Type: Columns

Comparison: Bending about the Y-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/o Column Def.	Difference	Increase Factor (EW)
4133	4033	-1001	4672	5673	-4.67 = R.P. / FE
4135	4035	194	-3783	3976	-19.53 = R.P. / FE
4136	4036	734	-4160	4894	-5.67 = R.P. / FE
11133	12033	-1168	140	1308	-8.33 = FE / R.P.
11136	11036	-2275	-1075	1200	2.12 = FE / R.P.
11136	12036	1206	-152	1358	-7.93 = FE / R.P.

Member Type: Beams
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/o Column Def.	Difference	Increase Factor (EW)
7233	7031	-178	-2388	2210	13.42 = R.P. / FE
12231	12029	-2261	-99	2162	22.74 = FE / R.P.
15232	15030	33	2392	2359	72.87 = R.P. / FE
16229	16027	186	2400	2214	12.92 = R.P. / FE
18227	18025	1955	126	1828	15.48 = FE / R.P.
20227	20025	1971	81	1890	24.24 = FE / R.P.
21227	21025	1864	126	1738	14.79 = FE / R.P.
22227	22025	1857	109	1748	17.05 = FE / R.P.
23234	23036	28	2343	2315	82.91 = R.P. / FE
25232	25030	152	2198	2045	14.41 = R.P. / FE
27232	27030	16	2160	2144	136.73 = R.P. / FE
32227	32025	1758	18	1740	98.30 = FE / R.P.
38227	38025	2295	47	2248	49.00 = FE / R.P.
40228	40026	23	1564	1542	68.73 = R.P. / FE

Member Type: Beams
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID PLANE		
Member	Joint	w/ Column Def.	w/o Column Def.	Difference	Increase Factor (EW)
8233	8031	79	-2370	2450	-29.84 = R.P. / FE
11240	11033	4061	-34	4095	-119.38 = FE / R.P.
12230	12028	-2375	128	2503	-18.61 = FE / R.P.
26234	26036	-32	2646	2678	-81.46 = R.P. / FE
27234	27036	-18	2662	2680	-150.87 = R.P. / FE
33227	33025	1745	-40	1785	-43.57 = FE / R.P.
34227	34025	1736	-100	1836	-17.37 = FE / R.P.

Comparisons between the "Exact" Finite Element Model and the Rigid Body Solid Floor Model Including Column Axial Deformations ("RBSCD") for the N-S Wind Load 400

Member Type: Columns
Comparison: Axial Forces (Kips)

Member	Joint	Analysis Method Wind Load 400 (NS) FINITE ELEM. w/ Column Def.	Analysis Method Wind Load 400 (NS) RIGID SOLID w/ Column Def.	Difference	Increase Factor (NS)
3106	3006	-422	-2674	2252	6.33 = R.P. / FE
3123	3023	5552	860	4692	6.46 = FE / R.P.
4122	4022	4893	545	4348	8.98 = FE / R.P.
5111	5011	421	2339	1919	5.56 = R.P. / FE
5131	5031	3085	398	2687	7.75 = FE / R.P.
7127	7027	-3020	-687	2333	4.39 = FE / R.P.
8127	8027	-2645	-649	1996	4.08 = FE / R.P.
9118	9018	-3052	-43	3009	71.03 = FE / R.P.

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

Member	Joint	Analysis Method Wind Load 400 (NS) FINITE ELEM. w/ Column Def.	Analysis Method Wind Load 400 (NS) RIGID SOLID w/ Column Def.	Difference	Increase Factor (NS)
3122	3022	-14908	-2296	12612	6.49 = FE / R.P.
3123	3023	-14834	-2297	12536	6.46 = FE / R.P.
4122	4022	-3009	-766	2244	3.93 = FE / R.P.
4122	5022	-2615	-1244	1371	2.10 = FE / R.P.
6127	7027	1201	209	992	5.73 = FE / R.P.
9128	11028	-1442	-216	1226	6.67 = FE / R.P.
11128	12028	1494	14	1480	105.32 = FE / R.P.
11134	12034	1644	8	1635	198.10 = FE / R.P.

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

Member	Joint	Analysis Method Wind Load 400 (NS) FINITE ELEM. w/ Column Def.	 RIGID SOLID w/ Column Def.	Difference	Increase Factor (NS)
3131	4031	3611	-2538	6150	-1.42 = FE / R.P.
3134	3034	-37	1493	1530	-40.08 = R.P. / FE
4127	4027	5304	-1168	6472	-4.54 = FE / R.P.
4131	4031	-5239	1172	6411	-4.47 = FE / R.P.
7106	11006	-19	1268	1287	-66.57 = R.P. / FE
9126	11026	-4	8000	8004	-1868.07 = R.P. / FE
9127	11027	-171	8005	8176	-46.73 = R.P. / FE
11128	11028	-2778	18	2796	-150.83 = FE / R.P.

Member Type: Columns
Comparison: Bending about the Y-axis (k-ft)

Member	Joint	Analysis Method Wind Load 400 (NS) FINITE ELEM. w/ Column Def.	 RIGID SOLID w/ Column Def.	Difference	Increase Factor (NS)
6135	7035	1920	242	1678	7.94 = FE / R.P.
9134	9034	997	99	897	10.03 = FE / R.P.
9135	9035	1399	92	1308	15.25 = FE / R.P.
9136	9036	-1374	-94	1279	14.58 = FE / R.P.
11133	11033	-21057	-2985	18072	7.06 = FE / R.P.
11134	11034	20669	2764	17905	7.48 = FE / R.P.
12136	13036	-38	-1964	1926	51.67 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Y-axis (k-ft)

		Analysis Method			
		Wind Load 400 (NS)			
		FINITE ELEM.	RIGID SOLID		
Member	Joint	w/ Column Def.	w/ Column Def.	Difference	Increase Factor (NS)
3136	3036	172	-1486	1657	-8.65 = R.P. / FE
7101	11001	110	-3071	3181	-27.86 = R.P. / FE
7108	11008	-102	3066	3167	-30.08 = R.P. / FE
7110	11010	-165	3059	3224	-18.54 = R.P. / FE
49135	49035	-280	1587	1868	-5.66 = R.P. / FE

Member Type: Beams
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 400 (NS)			
		FINITE ELEM.	RIGID SOLID		
Member	Joint	w/ Column Def.	w/ Column Def.	Difference	Increase Factor (NS)
4224	4022	-5378	-1885	3494	2.85 = FE / R.P.
5232	5030	-9401	0	9401	n/a = FE / R.P.
7238	7034	-9398	-2608	6790	3.60 = FE / R.P.
8229	8027	8160	5424	2736	1.50 = FE / R.P.
9229	9034	1815	1244	571	1.46 = FE / R.P.
11238	11034	-49215	0	49215	n/a = FE / R.P.
11240	11033	48729	0	48729	n/a = FE / R.P.
18238	18034	-4459	0	4459	n/a = FE / R.P.
19238	19034	-4547	0	4547	n/a = FE / R.P.
20238	20034	-4620	0	4620	n/a = FE / R.P.
25238	25034	-4330	0	4330	n/a = FE / R.P.

Comparisons between the "Exact" Finite Element Model and the Rigid Body Solid Floor Model Including Column Axial Deformations ("RBSCD") for the E-W Wind Load 500

Member Type: Columns
Comparison: Axial Forces (Kips)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID SOLID		
Member	Joint	w/ Column Def.	w/ Column Def.	Difference	Increase Factor (EW)
3107	3007	446	2631	2185	5.90 = R.P. / FE
3120	3020	6078	957	5121	6.35 = FE / R.P.
3121	4021	-5968	-956	5011	6.24 = FE / R.P.
4124	4024	-3698	-470	3229	7.87 = FE / R.P.
5110	7010	-449	-2316	1867	5.16 = R.P. / FE
5115	5015	-432	-2363	1931	5.47 = R.P. / FE
8120	8020	3173	488	2686	6.51 = FE / R.P.
9120	9020	2796	107	2689	26.07 = FE / R.P.

Member Type: Columns
Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID SOLID		
Member	Joint	w/ Column Def.	w/ Column Def.	Difference	Increase Factor (EW)
3120	3020	-6426	-1012	5414	6.35 = FE / R.P.
3124	3024	10916	1832	9084	5.96 = FE / R.P.
3125	4025	211	2579	2368	12.21 = R.P. / FE
3126	4026	-1069	-162	907	6.59 = FE / R.P.
4125	4025	5289	80	5210	66.53 = FE / R.P.
4125	5025	362	3322	2960	9.19 = R.P. / FE
6125	7025	-1330	-32	1298	41.36 = FE / R.P.
11133	11033	19237	2808	16428	6.85 = FE / R.P.
19132	20032	46	1097	1051	23.94 = R.P. / FE

Member Type: Columns

Comparison: Bending about the Z-axis (k-ft)

		Analysis Method			
		Wind Load 500 (EW)			
		FINITE ELEM.	RIGID SOLID		
Member	Joint	w/ Column Def.	w/ Column Def.	Difference	Increase Factor (EW)
8128	9028	87	-7428	7515	-84.91 = R.P. / FE
8129	9029	1008	-7306	8314	-7.25 = R.P. / FE
11128	12028	14064	-510	14574	-27.60 = FE / R.P.
12129	13029	10644	-529	11173	-20.12 = FE / R.P.
14128	15028	6124	-599	6723	-10.23 = FE / R.P.
15129	16029	5108	-599	5706	-8.53 = FE / R.P.

Comparisons between the “Exact” Finite Element Model and the Rigid Body Solid Floor Model With NO Column Axial Deformations (“RBSNCD”) for the N-S Wind Load 400

Member Type: Columns
Comparison: Axial Forces (Kips)

Member	Joint	Analysis Method — Wind Load 400 (NS) — FINITE ELEM. w/ Column Def.	RIGID SOLID w/o Column Def.	Difference	Increase Factor (NS)
3122	3022	5580	30	5549	184.02 = FE / R.P.
4123	4023	4880	10	4870	474.93 = FE / R.P.
38119	38019	18	12665	12647	711.84 = R.P. / FE
39122	39022	-75	-12173	12098	163.13 = R.P. / FE
46130	46030	-14	-6280	6266	447.31 = R.P. / FE

Member Type: Columns
Comparison: Bending about the Y-axis (k-ft)

Member	Joint	Analysis Method — Wind Load 400 (NS) — FINITE ELEM. w/ Column Def.	RIGID SOLID w/o Column Def.	Difference	Increase Factor (NS)
7133	7033	-8464	-89	8375	94.92 = FE / R.P.
9134	11034	17996	161	17835	111.77 = FE / R.P.
9135	9035	1399	7	1392	203.88 = FE / R.P.
9135	11035	14580	159	14421	91.72 = FE / R.P.
11133	11033	-21057	-203	20854	103.79 = FE / R.P.
11134	11034	20669	188	20480	109.65 = FE / R.P.

APPENDIX I

"Summation of Reactions" Values

and Selected Support Reaction Values

for the Following Models

(a) Full Finite Element Model With FE Floor Slabs ("FEA")

(b) Rigid Body Plane Floor Membrane Including Column Axial Deformations ("RBPCD")

(c) Rigid Body Plane Floor Membrane With No Column Axial Deformations ("RBPNCD")

```
{    1} > CINPUT 'D:\emkin\Critical Project Files\Finite Element Model With and Without Sequential Const.txt'
{    2} > $*****************************************************
{    3} > $*****************************************************
{    4} > $
{    5} > $                    SEQUENTIAL LOADING
{    6} > $
{    7} > $  DESCRIPTION :  The Sequential Loading model simulates
{    8} > $   the construction process by adding dead load in
{    9} > $   stages.  The structure is activated and analyzed
{   10} > $   incrementally, with all loading results combined
{   11} > $   into a single dead loading case.
{   12} > $
{   13} > $*****************************************************
{   14} > $*****************************************************
{   15} >
{   16} > $ RESTORE STRUCTURE AND LOADINGS
   .....
{  161} > $
{  162} > LOAD LIST 1000 100 300 400 500
{  163} >  LIST SUM REACTIONS
   ****************************
   *RESULTS OF LATEST ANALYSES*
   ****************************
    PROBLEM -  21906 '  TITLE - NONE GIVEN
    ACTIVE UNITS  FEET KIP  RAD  DEGF SEC
   SUM OF REACTIONS ABOUT COORDINATE  X      0.000  Y      0.000  Z      0.000
                   /---------------------FORCE---------------------//-------------------MOMENT--------------------/
 LOADING                  X FORCE          Y FORCE         Z FORCE        X MOMENT        Y MOMENT        Z MOMENT

 300               -0.4845206E-09    83325.26       0.3126333E-09   -353444.8       0.5224328E-07    86583.96
 400                -5743.093      -0.1486333E-09   0.1422814E-08  -0.1397206E-04   0.1057920E-05    8118910.
 500                0.1291508E-08   0.9037321E-09   -5743.077       -8118887.       0.3013831E-06  -0.1355117E-04
 1000              -0.7167809E-06    255329.9       0.1850638E-05   -91418.99       0.8408643E-05    19159.51
 100               -0.7168053E-06    255329.9       0.1850601E-05   -91418.99       0.9958998E-05    19159.51

{  164} >  LIST REACTIONS
   ****************************
   *RESULTS OF LATEST ANALYSES*
   ****************************
    PROBLEM -  21906 '  TITLE - NONE GIVEN
    ACTIVE UNITS  FEET KIP  RAD  DEGF SEC
-----------------------------------------------------------------------------------------------------------------------------------
---    LOADING - 400           N S WIND LOAD                                                                                   ---
-----------------------------------------------------------------------------------------------------------------------------------
    RESULTANT JOINT LOADS SUPPORTS
JOINT                /---------------------FORCE---------------------//-------------------MOMENT--------------------/
                          X FORCE         Y FORCE         Z FORCE        X MOMENT        Y MOMENT        Z MOMENT
 3001      GLOBAL        45.5104179    -235.5440521      -3.5293527         0.0000017      -3.0857956       0.0000000
3002      GLOBAL        47.0010185    -412.4317322      -2.2451360        -0.0000007      -2.9800935       0.0000000
3003      GLOBAL        19.7344475    -426.3418274      18.3967400         0.0000000     -23.8205185       0.0000048
3004      GLOBAL         5.3081231   -2684.8081055       9.5685968         0.0000000      -9.8891354      -0.0000533
3005      GLOBAL         4.9879737   -2695.7341309      -9.8594379         0.0000000      -1.5500785      -0.0000532
3006      GLOBAL        19.5561466    -422.5779419     -18.6640224         0.0000000      13.0697374       0.0000048
3007      GLOBAL        46.3699379    -423.2048035       2.5058279         0.0000007      -8.0777903       0.0000000
3008      GLOBAL        44.3012009    -257.1906433       4.2959695        -0.0000015      -8.2762394       0.0000000
3009      GLOBAL        44.3151741     250.4282532      -4.3875570         0.0000013      -7.9276533       0.0000000
3010      GLOBAL        46.1244392     422.1694031      -2.3511355        -0.0000007      -7.5185332       0.0000000
3011      GLOBAL        20.0970764     420.3786316      18.6530380         0.0000000      13.5981350       0.0000049
3012      GLOBAL         6.0387673    2691.0305176      10.2683649         0.0000000       0.5344685      -0.0000539
3013      GLOBAL         6.1228476    2689.3593750      -9.1293898         0.0000000     -11.8035612      -0.0000540
3014      GLOBAL        20.2731819     428.5692139     -17.7695751         0.0000000     -24.4179592       0.0000049
3015      GLOBAL        46.8205109     414.3951416       2.4718554         0.0000007      -3.4602430       0.0000000
3016      GLOBAL        45.2451820     247.4716187       4.5322995        -0.0000012      -3.4725411       0.0000000
3017      GLOBAL        -0.1588067    -437.4818115    -142.1474609         0.0000509      19.9946766       0.0000000
3018      GLOBAL     -1744.4143066   -5522.6704102     -94.4364395         0.0000000     -16.1281128      -0.0009108
3019      GLOBAL     -1753.8422852   -5543.3115234      95.1086807         0.0000000      -0.7151429      -0.0009142
3020      GLOBAL         2.8330057    -732.7189331     104.2828903         0.0000037     -29.2158813       0.0000000
3021      GLOBAL         4.0010862     693.3170166     -97.3600616        -0.0000035     -31.4697742       0.0000000
3022      GLOBAL     -1766.3249512    5579.7285156     -95.1068420         0.0000000       2.3178306      -0.0009202
3023      GLOBAL     -1754.7952881    5551.6723633      93.7672577         0.0000000     -20.1962929      -0.0009156
3024      GLOBAL         0.4464579     339.8452454      90.9025269        -0.0000396      10.0646820       0.0000000
3025      GLOBAL         0.6727753    -243.9292145      57.8499718         0.0000000      -7.2574811       0.0000000
3026      GLOBAL       374.1086426   -2812.2175293      22.0092125         0.0000000    -134.9730988       0.0000000
3027      GLOBAL       367.1498718   -2760.7170410     -21.1116543         0.0000000     130.2202606       0.0000000
3028      GLOBAL        -4.9845743    -114.4314880       5.5331693         0.0000000      -0.7938449       0.0000000
```

3029	GLOBAL	-2.9258106	119.1618805	5.9315429	0.0000000	-4.0822515	0.0000000
3030	GLOBAL	363.9865112	2815.7175293	21.5122242	0.0000000	132.0105133	0.0000000
3031	GLOBAL	370.4096985	2838.5141602	-22.2798481	0.0000000	-136.1390533	0.0000000
3032	GLOBAL	-0.0714011	343.5644226	-21.2143612	0.0000000	-2.0741608	0.0000000
3033	GLOBAL	-217.5518646	18.8354969	43.9708824	0.0000000	-549.3781738	0.0000000
3034	GLOBAL	-221.8412933	17.4075890	-40.0717163	0.0000000	630.1754150	0.0000000
3035	GLOBAL	-113.6110077	-75.9896240	47.8372116	0.0000000	401.5534058	0.0000000
3036	GLOBAL	-113.9857864	-80.2655411	-57.7342720	0.0000000	-423.0448303	0.0000000

--- LOADING - 500 E W WIND ---

RESULTANT JOINT LOADS SUPPORTS

JOINT		X FORCE	Y FORCE	Z FORCE	X MOMENT	Y MOMENT	Z MOMENT
3001	GLOBAL	7.4733014	-2637.4545898	1.2594569	0.0000494	-10.0749760	0.0000000
3002	GLOBAL	15.7734823	-422.1434631	17.1697941	-0.0000043	6.8090792	0.0000000
3003	GLOBAL	-2.6439443	-400.8573608	43.9367561	0.0000000	-14.4218302	0.0000006
3004	GLOBAL	-3.7214887	-240.3976440	41.4217606	0.0000000	-16.4414883	-0.0000016
3005	GLOBAL	2.7702837	171.1201782	41.4251900	0.0000000	-15.9855347	0.0000011
3006	GLOBAL	2.3184550	389.1207275	43.2657013	0.0000000	-13.4235849	-0.0000006
3007	GLOBAL	-15.0895405	446.3348999	17.8412151	-0.0000045	7.9417133	0.0000000
3008	GLOBAL	-7.0909963	2864.9016113	-2.5280950	0.0000508	-5.6602073	0.0000000
3009	GLOBAL	7.2840967	2862.8249512	-3.1328964	0.0000503	-18.1428604	0.0000000
3010	GLOBAL	15.5816050	448.5184937	17.3207264	-0.0000044	-31.5972443	0.0000000
3011	GLOBAL	-2.1309528	386.0540771	43.1223907	0.0000000	-9.4903135	0.0000007
3012	GLOBAL	-2.5622199	174.3134003	40.7034950	0.0000000	-8.6612053	-0.0000013
3013	GLOBAL	3.7270598	-255.1234741	40.7542839	0.0000000	-8.2620640	0.0000019
3014	GLOBAL	2.0022862	-399.1075745	43.7197876	0.0000000	-8.9294825	-0.0000007
3015	GLOBAL	-17.1558018	-432.1642151	17.2042294	-0.0000044	-29.6549473	0.0000000
3016	GLOBAL	-8.6087542	-2667.9519043	0.7329924	0.0000496	-16.2400036	0.0000000
3017	GLOBAL	-48.7758446	-3445.5219727	-1164.5505371	0.0004010	-29.2080841	0.0000000
3018	GLOBAL	-167.2808685	-591.5639038	0.8439685	0.0000000	-77.4300766	-0.0000976
3019	GLOBAL	101.3618698	355.0186157	3.1336892	0.0000000	-66.2102966	0.0000586
3020	GLOBAL	57.8092880	6078.1196289	-897.5723877	-0.0000307	-79.4406891	0.0000000
3021	GLOBAL	-57.8129158	5967.5063477	-877.1168823	-0.0000301	54.1421738	0.0000000
3022	GLOBAL	-133.8927917	451.2482910	2.5689456	0.0000000	38.7238007	-0.0000744
3023	GLOBAL	214.0099182	-733.3637695	0.1782892	0.0000000	51.2905273	0.0001209
3024	GLOBAL	20.0661297	-4268.5786133	-1225.6031494	0.0004968	35.4209137	0.0000000
3025	GLOBAL	12.4095678	-4565.5361328	-21.6631775	0.0000000	-44.4599266	0.0000000
3026	GLOBAL	109.6489105	-468.1072693	7.8924413	0.0000000	-31.1522694	0.0000000
3027	GLOBAL	-70.9230652	-78.0774612	3.4305949	0.0000000	-20.1085453	0.0000000
3028	GLOBAL	53.6544914	3677.6591797	-536.0367432	0.0000000	-22.1386280	0.0000000
3029	GLOBAL	-50.7114449	3751.8173828	-480.0476379	0.0000000	7.5825272	0.0000000
3030	GLOBAL	69.7921753	16.2623672	3.5160694	0.0000000	14.6634178	0.0000000
3031	GLOBAL	-114.1762390	-523.0848999	7.9510217	0.0000000	26.1484203	0.0000000
3032	GLOBAL	16.8827057	-4105.0366211	-179.7444611	0.0000000	1.5382261	0.0000000
3033	GLOBAL	-11.4683409	295.8451233	-245.1101837	0.0000000	672.9194336	0.0000000
3034	GLOBAL	-72.9970627	-1422.2774658	-162.7598419	0.0000000	650.8911133	0.0000000
3035	GLOBAL	54.4172134	-1241.1889648	-172.5421448	0.0000000	-645.5597534	0.0000000
3036	GLOBAL	20.0594406	560.8724976	-214.0614166	0.0000000	-611.1231689	0.0000000

--- LOADING - 1000 SEQUENTIAL DEAD LOAD ---

RESULTANT JOINT LOADS SUPPORTS

JOINT		X FORCE	Y FORCE	Z FORCE	X MOMENT	Y MOMENT	Z MOMENT
3001	GLOBAL	-1.9922956	8401.0214844	195.8367615	-0.0000075	19.4755802	0.0000000
3002	GLOBAL	-8.4455500	6243.8056641	90.6207733	0.0000002	21.8060169	0.0000000
3003	GLOBAL	103.1093216	8488.3769531	-18.8389702	0.0000000	3.9421749	-0.0000040
3004	GLOBAL	200.4871368	8594.2226562	-9.7355099	0.0000000	11.3923073	0.0000076
3005	GLOBAL	202.2634277	8679.4882812	1.9066782	0.0000000	29.8465080	0.0000079
3006	GLOBAL	102.9642563	8519.9228516	10.3260994	0.0000000	34.8433952	-0.0000041
3007	GLOBAL	-8.6135530	6607.1806641	-99.6707535	0.0000005	16.3674297	0.0000000
3008	GLOBAL	-4.2519321	8216.6718750	-197.5165558	0.0000029	21.6393261	0.0000000
3009	GLOBAL	2.8054552	8187.3491211	-196.0059204	0.0000035	19.4634438	0.0000000
3010	GLOBAL	7.3612432	6326.0820312	-94.4364166	0.0000003	22.5277920	0.0000000
3011	GLOBAL	-103.8566818	8583.6865234	12.8318968	0.0000000	3.9080346	0.0000041
3012	GLOBAL	-205.0197754	8808.2744141	4.9258633	0.0000000	11.3464222	-0.0000082
3013	GLOBAL	-204.0440063	8817.9619141	-6.5656319	0.0000000	29.5801620	-0.0000091
3014	GLOBAL	-100.5294266	8443.9511719	-15.6503115	0.0000000	34.1089439	0.0000044
3015	GLOBAL	13.0945482	6571.0488281	96.4673462	0.0000000	16.8536682	0.0000000
3016	GLOBAL	7.2720151	8326.8798828	195.1160736	-0.0000067	22.0745964	0.0000000
3017	GLOBAL	9.2698298	2887.6081543	864.0303345	-0.0003347	-115.3487396	0.0000000

3018	GLOBAL	1005.6202393	3804.5935059	4.0040989	0.0000000	282.4206543	0.0006249
3019	GLOBAL	980.1852417	3664.9108887	-8.9844446	0.0000000	-200.8034973	0.0006018
3020	GLOBAL	17.1392117	4140.8408203	-527.4713745	-0.0000208	58.8421936	0.0000000
3021	GLOBAL	-18.3992252	4262.3725586	-550.6862793	-0.0000215	-15.8149586	0.0000000
3022	GLOBAL	-975.6764526	3646.5178223	-10.0238838	0.0000000	246.6792145	-0.0005988
3023	GLOBAL	-1134.6156006	4191.3598633	11.1444397	0.0000000	-231.6317749	-0.0006887
3024	GLOBAL	-4.1012683	3031.2060547	742.8974609	-0.0003515	47.4099350	0.0000000
3025	GLOBAL	-53.2221527	8213.8593750	-770.4456787	0.0000000	-38.8689919	0.0000000
3026	GLOBAL	-877.3723145	7638.6020508	-76.3320236	0.0000000	150.5595551	0.0000000
3027	GLOBAL	-811.2282104	7106.3217773	69.2226334	0.0000000	-128.6243896	0.0000000
3028	GLOBAL	-40.7031212	10463.6728516	409.2931519	0.0000000	75.5206909	0.0000000
3029	GLOBAL	35.2064095	10125.0634766	349.1444092	0.0000000	-50.4459686	0.0000000
3030	GLOBAL	805.5211182	6923.0209961	68.7232819	0.0000000	140.5798492	0.0000000
3031	GLOBAL	883.0155029	7649.8750000	-75.6653366	0.0000000	-147.4200287	0.0000000
3032	GLOBAL	18.5010681	9107.6523438	-523.1856689	0.0000000	69.1490860	0.0000000
3033	GLOBAL	1077.9332275	9193.9687500	1057.6688232	0.0000000	13.0196095	0.0000000
3034	GLOBAL	954.1618652	7237.8334961	-1011.9263916	0.0000000	-3.3776629	0.0000000
3035	GLOBAL	-906.8632202	6767.4121094	-953.0650635	0.0000000	43.1859131	0.0000000
3036	GLOBAL	-966.9761963	7457.2744141	962.0460205	0.0000000	-69.6809692	0.0000000

--- LOADING - 100 FULL DEAD LOAD ---

RESULTANT JOINT LOADS SUPPORTS

JOINT		/------FORCE------			//------MOMENT------/		
		X FORCE	Y FORCE	Z FORCE	X MOMENT	Y MOMENT	Z MOMENT
3001	GLOBAL	-2.9778790	7884.2622070	184.3762207	-0.0000066	16.1541252	0.0000000
3002	GLOBAL	-10.0129871	6311.0849609	90.9184265	0.0000003	18.2238922	0.0000000
3003	GLOBAL	108.2486877	8309.6962891	-16.9922867	0.0000000	6.0539722	-0.0000026
3004	GLOBAL	188.2791443	8060.1420898	-8.9615650	0.0000000	7.6938181	0.0000069
3005	GLOBAL	189.8351288	8125.4809570	1.8536719	0.0000000	23.9791088	0.0000070
3006	GLOBAL	108.4187622	8345.1582031	9.1039429	0.0000000	25.7590237	-0.0000026
3007	GLOBAL	-8.9936790	6607.7944336	-98.8395996	0.0000003	13.1842518	0.0000000
3008	GLOBAL	-3.7376666	7632.9731445	-183.8352051	0.0000024	15.8667202	0.0000000
3009	GLOBAL	2.9725292	7609.1586914	-182.8869171	0.0000026	15.8336353	0.0000000
3010	GLOBAL	8.1107836	6362.3046875	-94.6304398	0.0000002	18.7120132	0.0000000
3011	GLOBAL	-109.3728638	8404.9218750	10.2197714	0.0000000	5.9798160	0.0000026
3012	GLOBAL	-192.3220215	8229.7646484	3.3016164	0.0000000	7.5590248	-0.0000070
3013	GLOBAL	-192.3636017	8264.4150391	-7.1616688	0.0000000	23.5787525	-0.0000076
3014	GLOBAL	-106.6875610	8287.9169922	-14.9505863	0.0000000	25.0789623	0.0000028
3015	GLOBAL	12.9380884	6587.1513672	95.5317154	0.0000002	13.5142498	0.0000000
3016	GLOBAL	5.9915609	7798.1625977	182.8103638	-0.0000062	15.7192068	0.0000000
3017	GLOBAL	9.4299164	2957.2438965	884.9378662	-0.0003428	-121.3370972	0.0000000
3018	GLOBAL	1054.8206787	3980.4665527	4.9123864	0.0000000	285.2265320	0.0006539
3019	GLOBAL	1025.2496338	3834.8710938	-9.4093924	0.0000000	-216.9396515	0.0006299
3020	GLOBAL	17.5087509	4303.2788086	-548.7030029	-0.0000217	55.6355133	0.0000000
3021	GLOBAL	-18.6603622	4397.7885742	-566.9956665	-0.0000221	-21.7057323	0.0000000
3022	GLOBAL	-1018.5737915	3807.5930176	-10.1789093	0.0000000	251.5776062	-0.0006254
3023	GLOBAL	-1151.2375488	4262.4433594	10.7004633	0.0000000	-244.2274628	-0.0007004
3024	GLOBAL	-4.2708921	3213.8566895	790.1000366	-0.0003727	46.1724663	0.0000000
3025	GLOBAL	-54.5064087	8405.9619141	-788.4680176	0.0000000	-40.9961929	0.0000000
3026	GLOBAL	-910.3066406	7893.2231445	-78.8377914	0.0000000	154.8680267	0.0000000
3027	GLOBAL	-850.3759155	7418.5263672	72.4774780	0.0000000	-136.2537079	0.0000000
3028	GLOBAL	-42.1517868	10883.0058594	419.4226685	0.0000000	75.6957169	0.0000000
3029	GLOBAL	37.4982986	10612.3437500	371.2089233	0.0000000	-55.9009247	0.0000000
3030	GLOBAL	841.6738281	7262.4150391	71.8434296	0.0000000	145.1964722	0.0000000
3031	GLOBAL	905.6586914	7870.7719727	-77.8411560	0.0000000	-152.3178406	0.0000000
3032	GLOBAL	19.1247158	9540.9687500	-542.3330078	0.0000000	69.4570999	0.0000000
3033	GLOBAL	1108.4116211	9428.2226562	1085.5286865	0.0000000	12.8723717	0.0000000
3034	GLOBAL	994.3611450	7528.9643555	-1052.6590576	0.0000000	-12.3804712	0.0000000
3035	GLOBAL	-956.3297729	7151.5322266	-1007.4725342	0.0000000	36.2493057	0.0000000
3036	GLOBAL	-1005.6504517	7756.0224609	1001.9090576	0.0000000	-71.3721008	0.0000000

```
{    1} > CINPUT 'D:\emkin\Critical Project Files\Rigid Plane Model With Column Deformations.txt'
{    2} >
{    3} >
{    4} > $ *************************************************
{    5} > $ *************************************************
{    6} > $
{    7} > $ RIGID PLANE W/ AXIAL (COLUMN) DEFORMATIONS
{    8} > $
{    9} > $ DESCRIPTION : The Rigid Plane is a planar element
{   10} > $  consisting of three degrees of freedom -- Ux,Uy,
{   11} > $  and ThetaZ and with geometry defined by a master
{   12} > $  joint plus two or more coplanar or colinear
{   13} > $  slave joints.  Axial Deformations are considered.
{   14} > $
{   15} > $
{   16} > $ *************************************************
{   17} > $ *************************************************
{   18} >
{   19} >
   .....
{  199} > $
{  200} > LOAD LIST 300 400 500
{  201} > LIST SUM REACTIONS
   ****************************
   *RESULTS OF LATEST ANALYSES*
   ****************************
    PROBLEM -  21906 '  TITLE - NONE GIVEN
    ACTIVE UNITS  FEET KIP  RAD  DEGF SEC

   SUM OF REACTIONS ABOUT COORDINATE  X      0.000  Y      0.000  Z      0.000
                    /---------------------FORCE---------------------//-------------------MOMENT--------------------/
 LOADING                  X FORCE          Y FORCE         Z FORCE        X MOMENT        Y MOMENT        Z MOMENT
 300               0.5413021E-08    83325.26       0.7558032E-08   -353444.8       0.2804880E-05    86583.96
 400               -5743.093      -0.3343499E-08   0.1163542E-08  -0.1493018E-04  -0.3521720E-05    8118910.
 500               0.1651220E-08   0.6828224E-08   -5743.077       -8118887.      -0.3700433E-05  -0.1453575E-04
{  202} > LIST REACTIONS
   ****************************
   *RESULTS OF LATEST ANALYSES*
   ****************************
    PROBLEM -  21906 '  TITLE - NONE GIVEN
    ACTIVE UNITS  FEET KIP  RAD  DEGF SEC
-------------------------------------------------------------------------------------------------------------------------------------
---    LOADING - 300           LIVE LOAD                                                                                          ---
-------------------------------------------------------------------------------------------------------------------------------------
    RESULTANT JOINT LOADS SUPPORTS
JOINT                 /---------------------FORCE---------------------//-------------------MOMENT--------------------/
                          X FORCE         Y FORCE         Z FORCE        X MOMENT        Y MOMENT        Z MOMENT
3001      GLOBAL         3.3334405    1968.3950195      48.8466377         0.0000002      14.4586401       0.0000000
3002      GLOBAL         3.4569659    1177.7091064      18.8528442        -0.0000003      14.4259233       0.0000000
3003      GLOBAL        43.1859550    3390.0356445      -0.0828167         0.0000000      14.3769674      -0.0000013
3004      GLOBAL        55.9206390    2277.9687500       1.5105498         0.0000000      14.3414536       0.0000002
3005      GLOBAL        65.0686951    2558.0136719       1.2192175         0.0000000      14.3485012      -0.0000015
3006      GLOBAL        38.8142166    3049.7607422       2.8637266         0.0000000      14.3342152      -0.0000012
3007      GLOBAL        -1.3286926    1660.4459229     -24.7865715         0.0000000      14.3950443       0.0000000
3008      GLOBAL        -0.9376556    2601.9726562     -65.1443481        -0.0000007      14.4006805       0.0000000
3009      GLOBAL        -0.4699681    3177.1123047     -77.3367233         0.0000007      14.3893661       0.0000000
3010      GLOBAL        -0.3913654    1538.8087158     -21.4503860        -0.0000002      14.3814440       0.0000000
3011      GLOBAL       -44.5934792    3534.6738281       7.5108485         0.0000000      14.4847422       0.0000014
3012      GLOBAL       -66.7105942    2656.9829102       5.5376577         0.0000000      14.5119638       0.0000009
3013      GLOBAL       -59.3100319    2462.0544434       5.8410296         0.0000000      14.5193033      -0.0000010
3014      GLOBAL       -37.8073463    3065.6967773       4.5928459         0.0000000      14.4424038       0.0000014
3015      GLOBAL         3.8819368    1457.1613770      24.9504337        -0.0000006      14.4320898       0.0000000
3016      GLOBAL         3.8539977    1870.0462646      48.1746407         0.0000015      14.4712334       0.0000000
3017      GLOBAL         4.4296303     935.5856934     288.8204346        -0.0001089     -19.6230145       0.0000000
3018      GLOBAL       346.4973755    1265.6552734       4.2029681         0.0000000      76.1390076       0.0002087
3019      GLOBAL       382.6339111    1365.3538818      -5.1557827         0.0000000     -40.3444672       0.0002252
3020      GLOBAL         6.6896477    1532.0815430    -196.0998993        -0.0000077      22.5803471       0.0000000
3021      GLOBAL        -9.2791023    2048.0678711    -269.4141235        -0.0000103       4.8418159       0.0000000
3022      GLOBAL      -393.4728088    1447.8769531      -3.0787444         0.0000000      89.4290924      -0.0002388
3023      GLOBAL      -383.5736694    1377.4667969       5.6662035         0.0000000     -40.0256538      -0.0002272
3024      GLOBAL        -1.3705219     877.0584717     222.9960175        -0.0001021      16.8235054       0.0000000
3025      GLOBAL       -15.3631964    2572.0993652    -181.9164276         0.0000000      -8.0326357       0.0000000
3026      GLOBAL      -247.7470703    2429.6228027     -22.8693714         0.0000000      47.2075653       0.0000000
3027      GLOBAL      -240.2972870    2407.2697754      21.9951782         0.0000000     -39.6200752       0.0000000
3028      GLOBAL       -13.6434078    3639.4055176     146.4371185         0.0000000      25.9181843       0.0000000
```

3029	GLOBAL	13.9563074	4378.5600586	116.4742126	0.0000000	-14.4059772	0.0000000
3030	GLOBAL	295.6774597	2762.4035645	26.6577168	0.0000000	53.5199432	0.0000000
3031	GLOBAL	252.3635406	2439.0363770	-22.4120960	0.0000000	-40.2613487	0.0000000
3032	GLOBAL	5.7761240	2790.4582520	-108.7281342	0.0000000	23.7632866	0.0000000
3033	GLOBAL	349.7295837	2939.8117676	372.8517151	0.0000000	-40.1433754	0.0000000
3034	GLOBAL	345.6846313	2472.5417480	-335.5973816	0.0000000	-75.6467056	0.0000000
3035	GLOBAL	-371.1473999	2750.4763184	-386.5877075	0.0000000	48.7864456	0.0000000
3036	GLOBAL	-333.5104675	2447.5954590	344.6585083	0.0000000	-11.9200315	0.0000000

---   LOADING - 400   N S WIND LOAD   ---

RESULTANT JOINT LOADS SUPPORTS

JOINT		/----FORCE	----	----//	----MOMENT	----	----/
		X FORCE	Y FORCE	Z FORCE	X MOMENT	Y MOMENT	Z MOMENT
3001	GLOBAL	83.0222321	-236.6199036	-5.3574100	0.0000004	-4.5779443	0.0000000
3002	GLOBAL	82.5052032	-412.2915955	-6.0946908	0.0000000	-5.3883162	0.0000000
3003	GLOBAL	29.8796539	-427.2233582	-5.2646298	0.0000000	-6.5090127	0.0000067
3004	GLOBAL	8.3652506	-2679.1333008	0.8741080	0.0000000	-6.6075664	-0.0000555
3005	GLOBAL	8.0242414	-2691.0673828	-1.9090942	0.0000000	-6.5402350	-0.0000554
3006	GLOBAL	29.7014313	-423.1528625	4.3929906	0.0000000	-6.6491365	0.0000066
3007	GLOBAL	81.3802032	-423.3827209	6.1290364	0.0000000	-7.7661572	0.0000000
3008	GLOBAL	81.7439194	-257.1625366	5.8768296	-0.0000003	-8.5639715	0.0000000
3009	GLOBAL	81.7433624	251.2025604	-5.6278090	0.0000004	-8.5639572	0.0000000
3010	GLOBAL	81.3811722	422.3690186	-6.0024467	0.0000000	-7.7661710	0.0000000
3011	GLOBAL	29.7316589	421.0688171	-4.1438127	0.0000000	-6.6455212	0.0000066
3012	GLOBAL	8.1212425	2687.1274414	2.1570420	0.0000000	-6.5342369	-0.0000554
3013	GLOBAL	8.2278280	2684.8151855	-0.6263399	0.0000000	-6.6015725	-0.0000555
3014	GLOBAL	29.8480587	429.4068298	5.5140486	0.0000000	-6.5053940	0.0000067
3015	GLOBAL	82.5020523	414.2710571	6.2345352	0.0000000	-5.3883619	0.0000000
3016	GLOBAL	83.0242996	247.5141754	5.7057581	-0.0000003	-4.5778942	0.0000000
3017	GLOBAL	3.1006742	-446.8756714	-146.9358063	0.0000520	7.2957120	0.0000000
3018	GLOBAL	-1770.4243164	-5546.2539062	-97.9913177	0.0000000	37.2509727	-0.0009147
3019	GLOBAL	-1784.0189209	-5579.1064453	98.5218887	0.0000000	-55.0861397	-0.0009201
3020	GLOBAL	8.6239910	-738.7931519	105.8389664	0.0000037	-11.0832891	0.0000000
3021	GLOBAL	9.4263697	709.7175293	-100.6522141	-0.0000036	-13.4543238	0.0000000
3022	GLOBAL	-1789.3554688	5597.0693359	-97.9789886	0.0000000	-52.2625084	-0.0009231
3023	GLOBAL	-1775.8204346	5563.1962891	97.5186081	0.0000000	34.9269753	-0.0009175
3024	GLOBAL	1.8724018	350.0825500	94.2665558	-0.0000407	-2.8961689	0.0000000
3025	GLOBAL	0.2154011	-264.2228394	49.5464249	0.0000000	-23.8041878	0.0000000
3026	GLOBAL	306.6263428	-2742.7895508	18.6706486	0.0000000	-134.8776398	0.0000000
3027	GLOBAL	298.8310852	-2707.2282715	-17.8953857	0.0000000	130.6736908	0.0000000
3028	GLOBAL	-6.6310725	-151.6892090	3.0812654	0.0000000	16.2496319	0.0000000
3029	GLOBAL	-4.5458446	157.8400726	4.0254230	0.0000000	11.4503231	0.0000000
3030	GLOBAL	300.1030579	2756.7624512	18.3462009	0.0000000	131.5162964	0.0000000
3031	GLOBAL	306.7982178	2777.6613770	-18.9733715	0.0000000	-135.5287170	0.0000000
3032	GLOBAL	-0.8953423	370.9338989	-21.4591084	0.0000000	-15.0122108	0.0000000
3033	GLOBAL	-214.7297058	-9.6893425	21.8635502	0.0000000	-430.6928711	0.0000000
3034	GLOBAL	-217.2170868	-24.1287441	4.9671926	0.0000000	459.7540283	0.0000000
3035	GLOBAL	-111.0627441	-39.3589287	5.4095426	0.0000000	247.7381287	0.0000000
3036	GLOBAL	-113.1913681	-40.8692360	-22.0281906	0.0000000	-297.8907776	0.0000000

---   LOADING - 500   E W WIND   -

RESULTANT JOINT LOADS SUPPORTS

JOINT		/----FORCE	----	----//	----MOMENT	----	----/
		X FORCE	Y FORCE	Z FORCE	X MOMENT	Y MOMENT	Z MOMENT
3001	GLOBAL	1.4814965	-2631.9704590	5.8170967	0.0000527	-11.1121244	0.0000000
3002	GLOBAL	-4.7392974	-423.4060059	26.7117939	-0.0000061	-11.2149982	0.0000000
3003	GLOBAL	-5.9187689	-400.6902161	73.7665710	0.0000000	-12.2165270	0.0000000
3004	GLOBAL	-5.6364999	-242.5826721	74.0077515	0.0000000	-12.9383621	-0.0000003
3005	GLOBAL	3.9537389	172.3831940	73.9994659	0.0000000	-12.9381618	0.0000002
3006	GLOBAL	5.6755471	388.9129944	73.7789612	0.0000000	-12.2167063	0.0000000
3007	GLOBAL	4.6063991	447.6036377	26.3729401	-0.0000061	-11.2130699	0.0000000
3008	GLOBAL	-1.6750466	2860.5214844	0.5903189	0.0000530	-11.1074419	0.0000000
3009	GLOBAL	1.1216826	2859.2998047	0.5935507	0.0000530	-11.1751013	0.0000000
3010	GLOBAL	-4.9602399	448.9570618	26.3411922	-0.0000061	-11.0742664	0.0000000
3011	GLOBAL	-5.7047439	386.6690674	73.9485321	0.0000000	-10.0733032	0.0000000
3012	GLOBAL	-4.0087495	174.1714172	74.3761978	0.0000000	-9.3486538	-0.0000002
3013	GLOBAL	5.7327919	-254.1076660	74.3865738	0.0000000	-9.3484030	0.0000004
3014	GLOBAL	5.8142133	-399.7794189	73.9298553	0.0000000	-10.0735750	0.0000000
3015	GLOBAL	4.7009788	-432.3471985	26.5538025	-0.0000061	-11.0780277	0.0000000
3016	GLOBAL	-1.2418914	-2664.2534180	4.6414037	0.0000524	-11.1780090	0.0000000
3017	GLOBAL	-49.3012161	-3459.5417480	-1174.5555420	0.0004026	-35.0089836	0.0000000
3018	GLOBAL	-177.4072113	-613.8283081	4.8921242	0.0000000	-51.8206978	-0.0001012
3019	GLOBAL	109.6002808	373.4602966	7.9501152	0.0000000	-46.0025330	0.0000616

3020	GLOBAL	58.5167656	6032.6235352	-893.8677979	-0.0000305	-74.3647842	0.0000000
3021	GLOBAL	-58.4000206	5948.3779297	-877.4454956	-0.0000300	51.5880280	0.0000000
3022	GLOBAL	-140.9591522	461.8009949	6.9630404	0.0000000	18.3969440	-0.0000762
3023	GLOBAL	219.4810638	-736.1725464	4.1330347	0.0000000	25.6500664	0.0001214
3024	GLOBAL	20.4731178	-4294.4814453	-1244.9460449	0.0004998	34.1558075	0.0000000
3025	GLOBAL	11.6966906	-4546.5800781	-63.1891479	0.0000000	-39.4854469	0.0000000
3026	GLOBAL	102.3815918	-481.5791016	7.5627236	0.0000000	-18.8108330	0.0000000
3027	GLOBAL	-65.0085220	-50.9763374	3.5090082	0.0000000	-10.2263184	0.0000000
3028	GLOBAL	53.9405136	3685.9421387	-573.8939209	0.0000000	-15.5606365	0.0000000
3029	GLOBAL	-51.5179176	3739.1293945	-521.1320801	0.0000000	3.3296549	0.0000000
3030	GLOBAL	58.6233482	13.3683205	3.2150416	0.0000000	4.8411331	0.0000000
3031	GLOBAL	-99.9678955	-509.6651306	7.2579989	0.0000000	13.9324198	0.0000000
3032	GLOBAL	17.1036167	-4091.7045898	-244.3353577	0.0000000	-1.0914062	0.0000000
3033	GLOBAL	-22.4557858	265.5680237	-269.5634460	0.0000000	674.1607666	0.0000000
3034	GLOBAL	-64.3092270	-1354.0933838	-191.1886902	0.0000000	693.6008911	0.0000000
3035	GLOBAL	47.1015663	-1214.4582520	-195.9812927	0.0000000	-679.9483643	0.0000000
3036	GLOBAL	31.2067871	543.4286499	-248.2770538	0.0000000	-644.5575562	0.0000000

```
{    1} > CINPUT 'D:\emkin\Critical Project Files\Rigid Plane Model Without Column Deformations.txt'
{    2} > $
{    3} > $
{    4} > $
{    5} >
{    6} > $ *************************************************
{    7} > $ *************************************************
{    8} > $
{    9} > $ RIGID PLANE W/O AXIAL (COLUMN) DEFORMATIONS
{   10} > $
{   11} > $ DESCRIPTION : The Rigid Plane is a planar element
{   12} > $  consisting of three degrees of freedom -- Ux,Uy,
{   13} > $  and ThetaZ and with geometry defined by a master
{   14} > $  joint plus two or more coplanar or colinear
{   15} > $  slave joints.  Axial Deformations are not considered
{   16} > $  (column areas increased by factor of 1000.
{   17} > $
{   18} > $
{   19} > $ *************************************************
   .....
{  212} > $
{  213} > LOAD LIST 300 400 500
{  214} > LIST SUM REACTIONS
1
   ****************************
   *RESULTS OF LATEST ANALYSES*
   ****************************
    PROBLEM -  21906 '  TITLE - NONE GIVEN
    ACTIVE UNITS  FEET KIP  RAD  DEGF SEC

   SUM OF REACTIONS ABOUT COORDINATE  X      0.000  Y      0.000  Z      0.000

                  /---------------------FORCE---------------------//--------------------MOMENT--------------------/
  LOADING                  X FORCE          Y FORCE         Z FORCE        X MOMENT        Y MOMENT        Z MOMENT

  300               0.3074836E-05    83325.26      -0.8788705E-06   -353444.7      -0.4717706E-04    86583.60
  400               -5743.092       0.2168253E-01  -0.1272619E-04   0.8746577      -0.7989673E-03    8118908.
  500               0.7173067E-04   0.2405913E-01   -5743.077       -8118889.      -0.1435186E-02   0.2238392
1
 {  215} > LIST REACTIONS

   ****************************
   *RESULTS OF LATEST ANALYSES*
   ****************************
    PROBLEM -  21906 '  TITLE - NONE GIVEN
    ACTIVE UNITS  FEET KIP  RAD  DEGF SEC

 ---------------------------------------------------------------------------------------------------------------------------------
 ---    LOADING - 300           LIVE LOAD                                                                                        -
 ---------------------------------------------------------------------------------------------------------------------------------
    RESULTANT JOINT LOADS SUPPORTS
 JOINT                /---------------------FORCE---------------------//--------------------MOMENT--------------------/
                           X FORCE         Y FORCE         Z FORCE        X MOMENT        Y MOMENT        Z MOMENT

 3001     GLOBAL        1.1684464    2128.9001465     52.5606270         0.0000001       4.0682020       0.0000000
 3002     GLOBAL        1.2121482    1049.9185791     16.6580048        -0.0000002       4.0568953       0.0000000
 3003     GLOBAL       45.8988724    3640.2277832     -0.9556575         0.0000000       4.0531735      -0.0000015
 3004     GLOBAL       55.8872108    2305.5341797      0.6246100         0.0000000       4.0248241       0.0000007
 3005     GLOBAL       64.5315094    2556.5507812      0.3904042         0.0000000       4.0304904      -0.0000011
 3006     GLOBAL       40.5680122    3206.8208008      2.1349778         0.0000000       4.0083313      -0.0000012
 3007     GLOBAL       -2.8686652    1480.0806885    -22.5418625         0.0000001       4.0809298       0.0000002
 3008     GLOBAL       -2.4826097    2401.2814941    -61.0556641        -0.0000014       4.0999942       0.0000002
 3009     GLOBAL       -2.1435084    2997.2770996    -74.0644302        -0.0000001       4.0917907       0.0000002
 3010     GLOBAL       -1.9612418    1268.6063232    -18.3017807        -0.0000001       4.0677638       0.0000000
 3011     GLOBAL      -47.5680962    3690.9680176      6.0992098         0.0000000       4.1278024       0.0000013
 3012     GLOBAL      -64.3111420    2515.5480957      4.1136451         0.0000000       4.1394525       0.0000017
 3013     GLOBAL      -58.3276100    2372.3395996      4.3756862         0.0000000       4.1457915      -0.0000001
 3014     GLOBAL      -42.0071602    3277.8010254      3.0089369         0.0000000       4.0829649       0.0000012
 3015     GLOBAL        1.5940237    1334.6916504     22.4193726        -0.0000005       4.0624361       0.0000000
 3016     GLOBAL        1.6260685    2129.2976074     53.9890213         0.0000011       4.0792727      -0.0000001
 3017     GLOBAL       -1.1595367     240.6604614     71.3851547        -0.0000280     -13.1679974       0.0000000
 3018     GLOBAL       38.1457939     170.4316101     -1.5038848         0.0000000      22.7710915       0.0000281
 3019     GLOBAL       59.6968727     240.5855255      1.9239707         0.0000000     -16.6981010       0.0000397
 3020     GLOBAL        6.3689098    1543.0593262   -199.4145050        -0.0000078       8.9183893       0.0000000
 3021     GLOBAL      -21.2314663    4567.6040039   -596.6016235        -0.0000231      -4.5090513       0.0000000
```

3022	GLOBAL	-68.3301544	268.8211365	1.9447775	0.0000000	27.9293041	-0.0000443
3023	GLOBAL	-78.2550583	289.1797180	0.9542651	0.0000000	-10.0557690	-0.0000477
3024	GLOBAL	-0.1541711	116.1565628	29.1144524	-0.0000135	3.7651145	0.0000000
3025	GLOBAL	-5.9053655	6533.2685547	-62.5505028	0.0000000	1.9390517	0.0000000
3026	GLOBAL	-61.5824394	4109.8935547	-5.4212494	0.0000000	9.7075129	0.0000000
3027	GLOBAL	-68.7913589	3487.5874023	5.9852834	0.0000000	-8.8930159	0.0000000
3028	GLOBAL	-8.6284008	3860.6357422	129.1208344	0.0000000	-1.2461892	0.0000000
3029	GLOBAL	19.7114334	7360.1015625	322.5137024	0.0000000	17.8501244	0.0000000
3030	GLOBAL	70.6248169	4004.7558594	6.4293127	0.0000000	12.1500368	0.0000000
3031	GLOBAL	60.0073166	4013.0852051	-5.3653040	0.0000000	-9.5361576	0.0000000
3032	GLOBAL	1.0124329	3453.1191406	-14.4243670	0.0000000	4.0894547	0.0000000
3033	GLOBAL	63.1094666	529.7310791	78.8293839	-0.0000082	-32.6936989	0.0000088
3034	GLOBAL	16.4279041	144.2594757	23.8474789	0.0000007	-81.5502930	0.0000007
3035	GLOBAL	45.4060059	-338.7693481	168.2076874	-0.0000020	236.9309692	0.0000020
3036	GLOBAL	-57.2892609	375.2521973	55.5700340	-0.0000038	-8.2367105	-0.0000038

--- LOADING - 400 N S WIND LOAD -

RESULTANT JOINT LOADS SUPPORTS

JOINT		/----FORCE		----//----	MOMENT		----/
		X FORCE	Y FORCE	Z FORCE	X MOMENT	Y MOMENT	Z MOMENT
3001	GLOBAL	15.5020571	-56.8469734	-2.1868706	-0.0000006	-5.3106871	0.0000000
3002	GLOBAL	15.0919428	-128.1019135	-3.1980712	0.0000002	-5.4658594	0.0000000
3003	GLOBAL	6.7359581	-7.9034486	-8.4000330	0.0000000	-5.5629535	0.0000013
3004	GLOBAL	10.4257355	-1252.7641602	-2.9361477	0.0000000	-5.6146817	-0.0000308
3005	GLOBAL	9.8331575	-1262.5766602	-5.2265010	0.0000000	-5.5592737	-0.0000305
3006	GLOBAL	5.7429647	-7.2114673	0.5076020	-0.0000002	-5.6921959	0.0000025
3007	GLOBAL	11.2208290	-129.8922882	0.5424497	0.0000002	-5.8476357	0.0000045
3008	GLOBAL	11.3540573	-36.1642494	-0.3296620	-0.0000010	-5.9603906	0.0000045
3009	GLOBAL	11.3520107	21.4320164	-1.0356152	-0.0000004	-5.9603415	0.0000045
3010	GLOBAL	11.2276888	129.8107910	-2.2233658	0.0000001	-5.8477354	0.0000000
3011	GLOBAL	5.7631779	5.8448291	-4.5294929	0.0000000	-5.7505503	0.0000011
3012	GLOBAL	10.1191816	1250.5959473	1.2032033	0.0000000	-5.6566052	-0.0000305
3013	GLOBAL	10.3179789	1256.5660400	-1.0860275	0.0000000	-5.7119865	-0.0000308
3014	GLOBAL	6.7163587	9.1612949	4.3751011	0.0000000	-5.6213517	0.0000013
3015	GLOBAL	15.0900898	128.0250854	1.5164342	0.0000001	-5.4658861	0.0000000
3016	GLOBAL	15.5023270	58.9129105	0.5471874	-0.0000018	-5.3106804	-0.0000043
3017	GLOBAL	-7.2658439	-626.9392090	-209.2584534	0.0000730	-28.3949909	0.0000000
3018	GLOBAL	-1775.7620850	-5438.6245117	-106.1461487	0.0000000	79.2388229	-0.0008967
3019	GLOBAL	-1784.2634277	-5443.0395508	104.7909012	0.0000000	-89.6949081	-0.0008974
3020	GLOBAL	-13.1742640	-2804.7014160	374.6992188	0.0000142	6.7169080	0.0000000
3021	GLOBAL	-12.9997692	2633.8835449	-357.2768555	-0.0000133	7.2282228	0.0000000
3022	GLOBAL	-1782.7164307	5432.3374023	-105.6227646	0.0000000	-92.2438889	-0.0008959
3023	GLOBAL	-1765.1230469	5392.0869141	104.7230301	0.0000000	75.1550522	-0.0008888
3024	GLOBAL	-1.1777402	619.7814331	151.7694855	-0.0000722	-16.8522434	0.0000000
3025	GLOBAL	-7.4955606	9731.7548828	58.6821632	0.0000000	-65.0387421	0.0000000
3026	GLOBAL	127.1237335	-15687.9589844	14.4773397	0.0000000	-122.8835754	0.0000000
3027	GLOBAL	99.2265472	-17728.4296875	-13.7445078	0.0000000	119.3129654	0.0000000
3028	GLOBAL	-8.3732920	17512.6875000	-194.5269165	0.0000000	40.3765411	0.0000000
3029	GLOBAL	-9.1543083	-17703.5917969	116.1637726	0.0000000	35.0011253	0.0000000
3030	GLOBAL	91.2894897	18082.0488281	13.3083792	0.0000000	119.1127167	0.0000000
3031	GLOBAL	105.1312485	17786.2656250	-14.3089247	0.0000000	-123.0562363	0.0000000
3032	GLOBAL	-6.3267441	-14473.4101562	-113.4790802	0.0000000	-33.9892120	0.0000000
3033	GLOBAL	381.3869629	5314.0097656	730.8828125	-0.0000685	-580.5232544	0.0000737
3034	GLOBAL	99.9678192	2428.2624512	-457.6819153	-0.0001616	686.3281250	-0.0001617
3035	GLOBAL	164.4534302	-2382.6000977	409.0891724	0.0003416	437.9973450	-0.0003416
3036	GLOBAL	190.1649475	-2622.6896973	-484.0809631	-0.0000352	-556.5695190	-0.0000351

--- LOADING - 500 E W WIND -

RESULTANT JOINT LOADS SUPPORTS

JOINT		/----FORCE		----//----	MOMENT		----/
		X FORCE	Y FORCE	Z FORCE	X MOMENT	Y MOMENT	Z MOMENT
3001	GLOBAL	2.5859702	-983.5946655	13.8490353	0.0000284	-8.0770454	0.0000000
3002	GLOBAL	-3.0580666	-10.5277596	3.4769669	-0.0000007	-8.1827126	0.0000000
3003	GLOBAL	-1.3643231	-106.2392426	5.3580427	0.0000000	-8.2160835	0.0000000

3004	GLOBAL	-0.8552139	-32.4812279	5.3692703	0.0000000	-8.2694988	0.0000000
3005	GLOBAL	0.2851409	43.5041199	5.3708887	0.0000000	-8.2695379	0.0000006
3006	GLOBAL	0.5574044	106.2149887	5.3530388	0.0000004	-8.2160110	-0.0000027
3007	GLOBAL	1.1439403	11.6954575	3.4624109	-0.0000005	-8.1549406	-0.0000034
3008	GLOBAL	-4.5133419	1214.0881348	8.2470703	0.0000285	-8.0304184	-0.0000034
3009	GLOBAL	-2.2689178	1213.4342041	8.6659470	0.0000287	-8.0847158	-0.0000034
3010	GLOBAL	-7.5816302	10.1657667	4.6548362	-0.0000009	-8.0283394	0.0000000
3011	GLOBAL	-2.5350258	106.3569412	9.8700323	0.0000000	-7.9951367	-0.0000002
3012	GLOBAL	-1.2936385	34.7204285	10.2293644	0.0000000	-7.8921366	0.0000003
3013	GLOBAL	0.6876885	-43.9785271	10.2304459	0.0000000	-7.8921103	0.0000003
3014	GLOBAL	1.7383269	-107.0110245	9.8657465	0.0000000	-7.9951987	0.0000000
3015	GLOBAL	5.6444845	-11.9422779	4.6246042	-0.0000009	-8.0564461	0.0000000
3016	GLOBAL	0.3482893	-1081.3782959	11.8245907	0.0000271	-8.1311798	-0.0000021
3017	GLOBAL	-44.1301651	-2568.8776855	-915.1328125	0.0002990	-66.2486954	0.0000000
3018	GLOBAL	-181.9964142	-640.5859375	-8.0744076	0.0000000	-8.3617811	-0.0001056
3019	GLOBAL	192.9105835	692.9254150	-4.1764078	0.0000000	-22.5405045	0.0001143
3020	GLOBAL	102.5248795	14353.4863281	-2015.4908447	-0.0000725	-77.8288651	0.0000000
3021	GLOBAL	-102.5897064	14154.4121094	-1984.0938721	-0.0000715	61.8721619	0.0000000
3022	GLOBAL	-214.3417511	728.9296875	-5.7316308	0.0000000	-3.3746262	-0.0001202
3023	GLOBAL	220.4602203	-766.3704224	-6.3781295	0.0000000	-1.9108809	0.0001264
3024	GLOBAL	24.9574585	-5981.8593750	-1695.6451416	0.0006964	55.1610489	0.0000000
3025	GLOBAL	-3.0419655	-18193.2460938	-377.9324951	0.0000000	-83.5495529	0.0000000
3026	GLOBAL	127.1172409	8460.2578125	5.1387019	0.0000000	-14.7429600	0.0000000
3027	GLOBAL	-149.7850494	-9097.2031250	7.2884111	0.0000000	-17.0526047	0.0000000
3028	GLOBAL	29.0409813	5705.0698242	-441.7662659	0.0000000	-76.8073044	0.0000000
3029	GLOBAL	-27.6035366	6278.5585938	-395.0206604	0.0000000	66.6278381	0.0000000
3030	GLOBAL	116.2370987	-9163.2421875	5.2949629	0.0000000	10.9547873	0.0000000
3031	GLOBAL	-139.9080505	9340.6914062	6.4446764	0.0000000	12.9130850	0.0000000
3032	GLOBAL	22.4757462	-15385.8046875	-182.9435272	0.0000000	45.6724358	0.0000000
3033	GLOBAL	810.9852905	7230.1367188	515.2597046	0.0002011	791.8090820	-0.0002165
3034	GLOBAL	-728.1453857	-5919.5263672	513.9586182	0.0000494	801.4633789	0.0000496
3035	GLOBAL	690.4035645	-5707.6816406	498.6932068	0.0001317	-757.9857788	-0.0001317
3036	GLOBAL	-735.0921021	6116.9267578	616.7788086	-0.0001632	-636.2543335	-0.0001633