VERIFICATION AND EVALUATION OF STRUCTURAL ANALYSIS AND DESIGN SOFTWARE

by

Maurice Walter White

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Science

in

Civil Engineering

APPROVED:

K. B. Rojiani, Chairman

T. M. Murray　　　　S. M. Holzer

April, 1991

Blacksburg, Virginia

VERIFICATION AND EVALUATION OF STRUCTURAL ANALYSIS AND DESIGN SOFTWARE

by

Maurice Walter White

K. B. Rojiani, Chairman

Civil Engineering

(ABSTRACT)

A study was performed to verify the accuracy of the Intergraph MicasPlus structural analysis and design software and to evaluate its functionality. The components of MicasPlus to be considered in the study include linear static analysis and steel design and code checking in accordance with the AISC Allowable Stress Design specifications. The verification is based on a comparison of results obtained using the MicasPlus and GTSTRUDL programs for three dimensional steel structures. The factors to be considered in the comparison include support reactions, member forces, displacements, ratios of applied stresses to allowable stresses, and member sizes. The factors to be considered in the evaluation of the functionality of the program include the ease of modeling, amount of effort required to enter the structural models and loads, potential for user errors, quality of support and documentation, and format and quality of the final output.

Acknowledgements

The author wishes to give special thanks to Dr. K.B. Rojiani and Steven Hemler for their support, guidance, and suggestions throughout the work and the writing of the thesis. Thanks is also extended to Dr. T.M. Murray and Dr. S.H. Holzer for their suggestions throughout the work. The computational assistance from graduate student Dharmesh Divecha was also appreciated. Appreciation is also expressed to William Hudson, Jr. for developing the neutral file for Tennessee Eastman building 17L09, the people at Intergraph for providing us with training on using the MicasPlus software and with support when problems were encountered, and the Tennessee Eastman Company for providing the funding for the project.

Finally, I sincerely thank my parents for all of their support.

Table of Contents

Introduction 1

1.1 Role of Computers in Structural Engineering 1

1.2 Objectives and Scope 3

1.3 Organization 4

Reliability of Engineering Software 5

2.1 Literature Review 5

2.2 Overview of MicasPlus 8

2.3 MicasPlus ModelDraft 9

2.3.1 Structural Layout 10

2.3.2 Element Types 11

2.3.3 Element Placement 11

2.3.4 Drawing Extraction 12

2.3.5 Creating a Production Drawing 13

2.3.6 Editing Drawing File 13

2.4 MicasPlus Analysis 14

2.4.1 Structural Layout Features 14

2.4.2 Element Types 14
2.4.3 Element Placement 15
2.4.4 Loading 16
2.4.5 Boundary Conditions 16
2.4.6 Manipulation Features 17
2.4.7 Analysis Process 17
2.4.8 Postprocessing Capabilities 18
2.5 MicasPlus Design 19
2.5.1 Design Parameters 19
2.5.2 Design Tables 20
2.5.3 Process Design 21
2.5.4 Postprocessing Capabilities 21
2.6 GTSTRUDL 22

Description of Models 24
3.1 Tennessee Eastman Building 267g 24
3.1.1 Columns 32
3.1.2 Girders 32
3.1.3 Bracing 33
3.1.4 Finite Elements 33
3.1.5 Supports 34
3.1.6 Loading conditions 34
3.1.7 Modeling of the Structure in MicasPlus 35
3.1.8 Design Criteria 36
3.2 Moment Resisting Frame 37
3.2.1 Design Criteria 37
3.3 Tennessee Eastman Building 17L09 38
3.3.1 Columns 55

3.3.2 Girders 55
3.3.3 Vertical Bracing 56
3.3.4 Horizontal Bracing 56
3.3.5 Finite Elements 56
3.3.6 Supports 57
3.3.7 Loading Conditions 57
3.3.8 Creation of Tennessee Eastman Building 17L09 in MicasPlus 58

Design and Analysis Results 59
4.1 Tennessee Eastman Building 267g 59
4.2 Moment Resisting Frame 65
4.3 Tennessee Eastman Building 17L09 70
4.4 General 73

Functionality of MicasPlus 74
5.1 User Interface 75
5.2 Learning to Use the Software 76
5.3 Documentation 76
5.3.1 Program Output 77
5.4 Analysis 78
5.5 Design 80
5.6 General Comments 81

Summary and Conclusions 83

Bibliography 85

Appendix A. Numerical Results from Tennessee Eastman Building 267g 87

Appendix B. Numerical Results from Moment Resisting Frame **108**

Appendix C. Numerical Results from Tennessee Eastman Building 17L09 .... **131**

Vita **153**

List of Illustrations

Figure 1. Tennessee Eastman building 267g 25

Figure 2. Plan views of building 267g 26

Figure 3. Node numbering for building 267g 27

Figure 4. Element numbering for building 267g 28

Figure 5. Column lines in East/West direction for building 267g 29

Figure 6. Braced column lines in North/South direction for building 267g 30

Figure 7. Unbraced column lines in North/South direction for building 267g 31

Figure 8. Tennessee Eastman building 17L09 39

Figure 9. Column lines 1 and 5 for building 17L09 40

Figure 10. Column line 2 for building 17L09 41

Figure 11. Column line 3 for building 17L09 42

Figure 12. Column line 4 for building 17L09 43

Figure 13. Column line A for building 17L09 44

Figure 14. Column line D for building 17L09 45

Figure 15. Column line G for building 17L09 46

Figure 16. Plan view of 2nd floor of building 17L09 47

Figure 17. Plan view of 3rd floor of building 17L09 48

Figure 18. Plan view of Low Platform of building 17L09 49

Figure 19. Plan view of Low Roof of building 17L09 50

Figure 20. Plan view of 4th and 5th floors of building 17L09 51

Figure 21. Plan view of 5th Floor Mezzanine and 6th floor of building 17L09 52

Figure 22. Plan view of 7th floor and roof of building 17L09 53

Figure 23. Node numbering of roof of building 17L09 54

List of Tables

Table 1. Support reactions for building 267g 60

Table 2. Element end forces for building 267g 61

Table 3. Nodal displacements for building 267g 62

Table 4. Code check for (a) building 267g and (b) moment resisting frame 63

Table 5. Support reactions for moment resisting frame 66

Table 6. Element end forces for moment resisting frame 67

Table 7. Nodal displacements for moment resisting frame 68

Table 8. Final design results for moment resisting frame 69

Table 9. Support reactions for building 17L09 71

Table 10. Nodal displacements for building 17L09 72

Chapter 1

Introduction

1.1 Role of Computers in Structural Engineering

The evolution of computers has greatly enhanced the field of structural engineering. Ever since the first structural engineering program was developed in the mid 1950's, computers have helped to greatly reduce the time needed to perform structural analysis and to increase the efficiency of the design process. Structural analysis and design programs such as STRUDL and STAAD have now become commonplace in the design office.

The significant enhancements in the computational and graphical capabilities of workstations has made it possible to perform most structural engineering tasks on workstations. Until recently, such tasks could only be done on mainframes and minicomputers. The availability of powerful graphics capabilities on workstations has stimulated the development of interactive graphics based structural analysis and design programs. Workstations have the following benefits over mainframes and minicomputers for structural analysis and design: vastly decreased cost per design, fixed cost for computer-aided design independent of workload, shorter and more predictable turnaround time, and better control over computing resource allocation [1].

There are a number of important issues related to the use of computer programs for structural engineering applications. The first is the accuracy of the computer model. The computer processes a mathematical or computer model, not a physical model. Therefore, it is up to the engineer to accurately model the actual structure in the computer. Assumptions involving the correct boundary conditions, finite elements, and various other modeling parameters must be made by the engineer and integrated in the computer model. This is not a skill that is inherent in all engineers and one that takes some time and experience to develop. If the engineer cannot accurately model the actual structure in the computer, then the results will not reflect the true behavior of the structure. It is important to remember that it is the engineer who is ultimately responsible for the results of the analysis and not the software developer.

A second issue is the accuracy of the software. Many software packages are tested for accuracy "in-house" but are rarely tested by independent engineering firms because verification is labor intensive, time consuming, and expensive. Thus, the software could accurately perform some of the tasks designated by the developers, but it may not accurately perform the tasks that a company wants it to perform. Software verification, however, is hindered by the fact that there are no established standards by which the results obtained from different structural analysis and design packages can be compared.

The final issue is the functionality of the software. Functionality refers to the ease with which the software can be used, the potential for user errors, and how well the software fits the needs of the user. Functionality is what distinguishes one software package from another and is usually the determining factor when one software package is chosen over another. The newer generation of structural and design programs offer a greater functionality since they employ a graphical user interface (GUI). However, these programs also offer more features and can be more complex, thereby increasing the potential for user error.

1.2 Objectives and Scope

The objectives of this study are to a) verify the accuracy of the Intergraph MicasPlus structural analysis and design software and b) to evaluate its functionality. In order to accomplish these objectives, three different three dimensional steel frame structures were analyzed and designed in MicasPlus and GTSTRUDL. MicasPlus [2] is the workstation implementation of the Intergraph Rand-Micas (IRM) structural analysis and design software. It performs linear and non-linear static analysis, dynamic analysis, and design and code checking. GTSTRUDL [3] is the Georgia Tech adaptation of STRUDL (the Structural Design Language). It also performs linear and non-linear static analysis, dynamic analysis, and design and code checking.

The structures consisted of a four story braced frame structure, a four story frame with moment resisting connections, and a 10 story braced frame. The structures were analyzed with both MicasPlus and GTSTRUDL and the support reactions, element end forces, and nodal displacements obtained from each program were compared. Only linear static analysis was considered. To check the accuracy of the steel design, a code check was performed for the four story braced frame structure in both MicasPlus and GTSTRUDL and the results were compared. Finally, the four story moment resisting frame was designed and a code check was done in both MicasPlus and GTSTRUDL to compare the efficiency of the design algorithms in MicasPlus. The steel design was based on the 1978 AISC Allowable Stress Design specification.

To evaluate the functionality of MicasPlus a number of factors were considered including ease of modeling, potential for user errors, quality of documentation and support, and the format and quality of the final output.

1.3 Organization

Chapter 2 contains a review of literature on testing and evaluation of structural analysis and design software. It also contains a brief description of the MicasPlus and GTSTRUDL software packages. Chapter 3 describes the three structural models used in the investigation. The description includes information on the structure, the applied loads, and the design criteria. Chapter 4 presents a summary and discussion of the analysis and design results for the three structural models. Chapter 5 contains an evaluation of the functionality of the MicasPlus software. A summary of the results along with major findings is given in Chapter 6.

Chapter 2

Reliability of Engineering Software

2.1 Literature Review

With the tremendous increase in the number of computer programs for the analysis and design of structures, many of which are unverified and untested, questions have been raised about their reliability. Emkin [4] has implied that the lack of engineering software quality may be the most dangerous problem facing the engineer, and Melosh [5] has stated that "special effort is necessary to ensure the reliability of the numerical analysis of a structure, since very few codes provide a comprehensive set of accuracy checks. It is usually necessary to determine the sensitivity of the analysis to the approximations of discretization and idealization." Thus, it is important that all computer programs for structural analysis and design be verified and tested before being used for structural engineering purposes.

Verification, validation, and evaluation play a crucial role in the establishment of the reliability of a computer program. Verification and validation is the only methodology other than the software developer's methodology that examines the software in detail from a system's viewpoint [6]. It analyzes and tests software to determine that it performs its intended functions correctly, to ensure that it performs no unintended functions, and to measure its quality and reliability. Verification, which is usually performed by the software developers, involves evaluation of the software at each phase of the development process. Validation, which will be examined in this study, involves testing software at the end of the development effort to ensure that it produces accurate results [7]. Software evaluation, which focuses on quality and functionality, identifies the non-technical strengths and weaknesses in a software package.

Validation is usually performed by executing a collection of test problems on the software being tested and comparing the results with either published, well-known solutions to the test problems, documented hand computations to the test problems, or from solutions to the test problems performed on a well known, widely used, and recognized for quality engineering software. A valid software package will provide results to the test problems that are similar to the known solutions to the test problems [4].

Evaluation is of considerable interest to the end user because it provides information regarding the user friendliness of the program. It allows a potential user to differentiate between a program that is easy to use versus one that is difficult to use [8,9]. Software evaluation is performed by comparing the performance of a software package in various categories to that of other software packages and comparing the results. Problems arise in evaluation because the categories compared depend on the needs of the user (i.e., they are not uniform across the board) and because the tests are subjective [10].

A few verification, validation, and evaluation studies have been performed on different general purpose engineering and structural engineering programs. A typical verification and validation study is the one by Chalabi [11] that involved evaluating the RC STRUDL computer program. RC STRUDL is used for the analysis and design of reinforced concrete structures. The study involved running several test problems in RC STRUDL to check its accuracy and to evaluate its functionality. The test problems included: eleven beam sections, eight column sections, a two-way slab floor, a flat slab, and a four story building. The results from RC STRUDL were checked against manual calculations and there was a very close agreement between the two sets of calculations for all of the analysis and design tests performed. A limitation of the study was the fact that no larger structures were tested.

A typical evaluation study is the one performed by Machover [12] who evaluated different PC CAD software packages. The study compared the performance of the different packages in the categories of: environment, geometry, annotation, manipulation, visualization, analysis, file handling, and system support. A benchmark test was also performed. The benchmarks consisted of problems related to mechanical design. The first emphasized aerospace design and was composed mainly of cross-sections of lines and arcs and of trimmed surfaces of revolution. The second emphasized surface model design and was composed mainly of surface modeling and spline curves. The third emphasized electro-mechanical modeling and was composed mainly of points, lines, and arcs. The results from all of the categories were evaluated and weighed in order to determine the better PC CAD packages. The evaluation was done by assigning a maximum score of 10 to each category for each package and applying mandatory deductions for the deficiencies of a function. The weighing was done by giving more weight to the categories believed to be more important (in this study, the benchmark test was determined to be the most important). The results of the study showed that all of the PC based CAD packages had deficiencies. The limitations of the study include the fact that the scoring method in the evaluation does not differentiate functions that are important and those that are dressing, the most heavily weighted categories may not be the most important categories to the user, and in the benchmark test if the program could not perform a key element in the design process, thereby making it unable to complete the design task, it could mean that one missing function could adversely affect the entire test.

These types of tests are vital if reliable software is to be produced. As Emkin states [4] "No computer software should be used for engineering computations unless it has been fully verified and certified pursuant to industry accepted standards of engineering QA (quality assurance) and QC (quality control)."

2.2 *Overview of MicasPlus*

MicasPlus is an integrated structural modeling and analysis system which integrates layout, analysis, design, and drawing production tasks for the building design industry. It is the workstation implementation of the Rand-Micas (IRM) structural analysis and design software.

MicasPlus has three components: MicasPlus ModelDraft (MDR), MicsPlus Analysis (MPA), and MicasPlus Design (MPD). The primary function of MDR is to construct models for use in making production drawings and for transferring these models to MPA and MPD for analysis or design. The MPA module provides the capability for modeling and analyzing two dimensional or three dimensional structures. The MPD module performs the design of both steel and reinforced concrete structures.

MicasPlus has a couple of useful features. The first is the graphical user interface. It consists of a series of icons located along the top and right of the screen, the command line located at the very top of the screen, and the drawing area. MicroStation 32 core graphics software provides MicasPlus with true three dimensional graphics capabilities. The icons are used for model generation and editing and to aid in analysis and design. The command line displays the active command, information that needs entering, and directions that need to be followed.

The graphical interface enables the user to construct the structural model by use of menu driven icons and to easily identify mistakes in the model since it provides constant visual feedback. All of the information necessary to create a model, such as loads, boundary conditions, member sizes, and releases can be accessed in the graphical interface. All of the seven principle views (front, back, top, bottom, right, left, and isometric) can be viewed in the graphical interface.

There is also an alphanumeric interface in MicasPlus. It allows input to and output from the system in the form of characters and commands. All of the commands in the graphical interface are also contained in the alphanumeric interface. The graphic and alphanumeric interface can be used to create and edit the same model.

MicasPlus also has the unique concept of a "physical" member. A physical member is a contiguous structural component such as a beam, column, or brace. It is intended to represent the component as it would be used in building the actual structure. MicasPlus recognizes the member in its database as one physical member. Members framing into the physical member will divide it into finite elements.

The physical model concept is very important for design. When a physical member is designed, each element in the physical member is designed separately. The final physical member size will be that of the largest element size in the physical member. Thus, elements in a physical member do not have to be grouped together in order to obtain a uniform section size for the physical member.

2.3 MicasPlus ModelDraft

The first component of MicasPlus is MicasPlus ModelDraft. It is a structural engineering drawing production package that provides three dimensional structural layout, drawing extraction, and revision tracking capabilities. MDR allows the user to develop a model through a graphical interface with pop-up and pull-down menus or through an alphanumeric interface, to develop production drawings in a drawing file, and to update the drawings in the drawing file by simply updating the structural model. Although it is not possible to analyze or design a structure while in ModelDraft, it is possible to transfer a structural model created in ModelDraft to the analysis and design modules through the Project Structural Database (PSD) to have the structure analyzed or designed in one of the other MicasPlus modules. The PSD is a physical component database used to coordinate the modeling activities between ModelDraft models, MicasPlus Analysis models, and neutral files.

MicasPlus ModelDraft contains some features not found in the MPA or MPD. These features include the ability to construct and label grids for a model; the capability to place dimensions, notes, details, and other notation on the drawings; and the ability to automatically update an extracted drawing to reflect changes made to the model. The update drawing command automatically updates previously extracted drawings to reflect changes that have been made to the model. MDR places revision symbology in the drawing views to properly document revised portions of the drawing. Another feature is the drafting utilities, which let the user add and edit notes, dimensions, and detail work to the extracted drawing views.

2.3.1 Structural Layout

Structural layout in ModelDraft is done by using the pop-up and pull-down screen icon menus in the graphical interface. The menus are accessed by moving the cursor to the desired icon and clicking the mouse. They provide access to both MicroStation and ModelDraft commands. The menus allow the user to place grid lines, place analytic or member lines, manipulate the database, define element and material properties, set fences, and manipulate the model. When an icon is accessed, it is highlighted and either another menu, a command, or a tutorial screen appears.

2.3.2 Element Types

There are four types of elements in MDR. They are a brace, beam, column, and solid element. The beam, column, and brace elements are all linear elements that correspond to those types of elements in an actual structure. The classification of the linear elements, however, does not have any real significance in MDR. Therefore, it cannot be used as a structural member. The solid element can be used as either an area element (for example, to model a diaphragm) or a volume element (for example, to model a footing).

The material and element properties for the different types of elements can be assigned through either a seed file or by editing the Active Parameters tutorial. A seed file is a design file used to create a MicroStation 32 design file with a set of default parameters.

2.3.3 Element Placement

The placement of linear elements in MDR is done by selecting the place icon, selecting the type of element to be placed, and then placing two data points by either keyboard entry or the mouse to indicate the endpoints of the element. The element is automatically placed from the first to the second point. The user is prompted to select the element and material type, orientation, and any of a number of other parameters needed to define the member. When the member is placed, an icon representing the correct orientation, cardinal point (the point on a physical member cross section through which the member modeling centerline passes), and element type will appear at the start end of the member. The cardinal point is a reference point indicating the positioning of the structural shape upon the member line.

The placement of an area element is done by selecting the Place Area command, placing data points to outline the shape of the area, then pressing the Reset button on the mouse to close the shape. The element is automatically placed and the user is prompted to select the area thickness, offset, etc. A hole can be placed in an area element much the same way that an area element is placed, by placing data points to define the area and then pressing the reset button to close the shape. The hole can extend part way or all of the way through an element.

The placement of a volume element is done in a slightly different manner. First, the MicroStation 32 command Place Linestring is selected. A closed linestring shape is then made in a way similar to the way the area element is placed, except for the fact that a data point is placed at the initial vertex to close the shape. Next, the MicroStation 32 command Copy Element is selected, and the closed linestring shape is copied. Finally, the ModelDraft command Place Volume is selected, the two linestrings are selected, the volume is placed, and the user is prompted to select the material properties of the volume element.

2.3.4 Drawing Extraction

MDR has the capability to create, edit, and update drawing files. The process of creating a drawing file begins with the creation of drawing views (or drawing extractions) from a model. A drawing extraction is a planar view of a three dimensional structure and is usually a plan view or elevation.

To extract a plan view, first the Utilities/Extract drawing icon is selected. A tutorial appears on the screen. After selecting Set-Up on the tutorial, various items of information are entered, such as extract grids, drawing clearance, etc.. After accepting the tutorial settings, the drawing volume (plane, block, shape, or section) is defined, and then from the isometric view an extracted view is selected. Finally, the ModelDraft and MicroStation 32 parameters are saved.

It is also possible to extract multiple elevations interactively. This can be done by changing some of the parameters in the drawing extraction tutorial. When an orientation vector, which is a vector that defines the plane to be extracted, is selected, ModelDraft allows for the selection of more than one view in that direction. Each view is assigned a different view ID and can have a description assigned to it.

2.3.5 Creating a Production Drawing

In order to create a production drawing, first a ModelDraft drawing file must be created. The units and plotted scale for the drawing file are set at this time. Once this is completed, enter the design file and file the MicroStation 32 active parameters. To begin placing views, first the Compose Drawing command should be selected. The drawing composition tutorial will be activated, and the attach Extracted Views Option is selected from the tutorial. The extracted view ID's are listed and the desired view(s) is selected by placing a data point next to the view ID. Place a data point in the drawing view (border), which is located on another screen, to indicate the location of the view(s). The view(s) will be placed in the order of their view ID number.

2.3.6 Editing Drawing File

The following drawing file editing features are available in MicasPlus ModelDraft: changing the drawing view display levels, moving view sets in a drawing file, placing a material take-off report, moving text and extending lines further apart so that columns are easier to locate and label, grid and parallel member dimensioning, and updating a drawing.

2.4 MicasPlus Analysis

The second component of MicasPlus is MicasPlus Analysis. It allows the user to create a two-dimensional or three-dimensional structural model and to analyze it, or to receive a model from ModelDraft and analyze it after making a few modifications. The analysis module is capable of performing linear, non-linear, and dynamic analysis, generating analysis solutions, and performing postprocessing.

2.4.1 Structural Layout Features

Structural layout in MPA is similar to layout in MDR. Layout can be done by the use of pop-up and pull-down screen icon menus or through an alphanumeric interface. The menus are accessed by moving the cursor to the desired icon and clicking the mouse. The only significant difference between the MDR and MPA menus is the content. MPA does not have some of the commands that MDR does (such as Place Grid and Propagate) and has some commands that MDR does not (such as Loading and Boundary Conditions).

2.4.2 Element Types

There are eight different types of elements in MPA. They are: spring, gap, hook, beam, column, brace, surface, and solid element. The spring element is a linear element which allows modeling of compression and tension only. The gap element is a linear element which allows modeling of compression only. The hook element is a linear element which allows modeling of tension only. All of these elements have pinned ends.

The beam, column, and brace elements are linear, continuum elements with six degrees of freedom (dof) at each end. The elements can be assigned section properties from steel section tables or from user entered property tables. The orientation, cardinal point, rigid end offsets, and material property of the element can be specified by the user. The distinction between the beam, column, and brace elements is not important in the analysis module but becomes important in design since these are treated differently by MPD.

The surface element is a two-dimensional finite element with a maximum of six degrees of freedom at each node. The surface element can cover regions bounded by three or four edges only. There are currently five different surface elements in MPA. The material and element properties of a surface element can be specified by the user.

The solid element is a three dimensional element with a maximum of six degrees of freedom at each node. The element can be brick, trapezoidal, or tetrahedron in shape. There are currently two different volume elements in MPA. The different elements have varying degrees of freedom at each node. The material and element properties of the solid element can be specified by the user.

2.4.3 Element Placement

The placement of elements in MPA is very similar to the placement of elements in MDR. Placement of the linear elements is done by placing data points to indicate the ends of the element. The user may then be prompted to enter additional information about the element, such as the element property, releases and cardinal point. A large number of the same type of element can be placed by using the Copy command. This command allows the user to copy a member a specified number of times in a row at a specified interval. Placement of the two-dimensional and three-dimensional elements is done by placing data points to indicate the vertices of the element. The data points, however, must be placed in sequential order.

2.4.4 Loading

MPA has a wide variety of load types and conditions. They include concentrated loads, distributed loads (constant and trapezoidal), wind loads (pressure and velocity), thermal loads, body loads, ice loads, inertia loads, misfit loads, and edge loads for static analysis. The loading also includes node-forcing functions, ground-motion time histories, and response spectra, along with the aforementioned loads, for dynamic analysis. Loads can be manipulated in much the same way as elements, by selecting the Place Load icon and following the instructions given by the program. The color and size of the loads in the graphical interface can be controlled by the user. All loads must be associated with a load case and load cases may be combined into load combinations. A load case is simply a grouping of loads. A load combination is a series of load cases and/or combinations that have been combined together.

2.4.5 Boundary Conditions

MPA allows the user to specify various types of boundary conditions for a structure. The boundary conditions that can be specified include constraints and displacements. The constraint specification allows the user to control the number of degrees of freedom at the boundary. The degrees of freedom are in the global reference system. The displacement specification allows the user to specify a displacement for each of the six degrees of freedom. The displacement can be specified for a particular load case or for all load cases.

2.4.6 Manipulation Features

MPA provides the user with many options for editing and manipulating the structural model. The user can copy, rotate, scale, mirror, delete, move, extend a member, re-orient, modify end releases, and edit member data for the brace, beam, and column elements. These options can be accessed under the MPA/Physical/Modify icons. The user can also copy, rotate, mirror, merge nodes, insert nodes, delete nodes, delete elements, edit elements, and homogenize a plate (makes the normal axis of planar elements point in the same direction) for surface and volume elements. These options can be accessed from the MPA/Analytic/Manipulate or MPA/Analytic/Modify icons.

2.4.7 Analysis Process

MPA has the capability to perform linear, non-linear, and dynamic analysis. A structure may be analyzed for any combination of the three as long as the needed control data has been defined for each type of analysis mode. The type(s) of analysis performed and other analysis information such as time step definition, time history, etc. can be specified in the Process Analysis Setup tutorial. Changing a parameter in the tutorial changes that parameter for the entire structure. Analysis is performed by matrix structural analysis for the continuum, spring, gap, and hook elements and by finite element analysis for the volume and surface elements. The continuum elements may be divided into a maximum of 17 segments for the purpose of computing shears, moments, and deflections along the member.

The results of the analysis are printed to both a text file, which can later be sent to the printer to obtain a hard copy, and to the Post Data Management (PDM) system. The PDM system is a data management system upon which the graphics post processor is based. The user can specify what information is sent to the PDM. The output to the PDM is controlled in the Process Analysis/Analysis Setup tutorial under the static and response spectrum results option. Information that can be specified for post processing includes nodal displacements, node average stresses, support reactions, finite element stresses, line element end actions, node residuals, and spring/gap/hook to ground forces for static analysis and frequencies, mode shapes, and time history results for dynamic analysis. The user can specify whether the results for load combinations, load cases, or both load cases and load cases are printed to the file. The results provided by the program are those for the most recent analysis.

2.4.8 Postprocessing Capabilities

MPA has several useful postprocessing capabilities. One is that it can plot the deflected shape of the structure due to the loads from any particular load case or combination. Another postprocessing feature is the Post-Data Management(PDM) tutorial and subsequent PDM label. These allow the user to display values for nodal displacements, nodal stress averages, finite element stresses, and line element end actions for load cases and/or load combinations. The results appear adjacent to the member and are color coded. The color coding scheme may be specified by the user. The color legend is displayed on the screen.

2.5 MicasPlus Design

The third component of MicasPlus is MicasPlus Design (MPD). It directly evaluates analysis results from MPA and from these results it chooses the optimum design or performs a code check. MPD performs concrete and steel design. It can design beams, columns, joists, slabs, braces, and distributor beams. Design is done using load combinations. All of the load combinations from MPA are transferred to MPD.

MPD makes extensive use of the physical member concept. MicasPlus allows the user to place beam, column, and brace elements in three-dimensional space much as they would be physically framed in the field. When other structural members are framed into a physical member, the physical member is divided into finite elements but it continues to be one physical member. Each element is designed separately and one element section size is selected for all of the elements of a physical member.

2.5.1 Design Parameters

MicasPlus Design allows the user to specify many of the design parameters for each member in the structure. These parameters can be specified by selecting the Member Parameters icon on the side menu. MPD allows the user to specify strength and deflection checks, lateral bracing parameters, active code parameters, and member process control parameters. All of the design types (beam, column, brace, etc.) have default parameters assigned to them, but these can be changed in part by simply changing the parameter in the tutorial and assigning it to an element or set of elements. Thus, parameters such as axial and bending unbraced lengths, bracing against sidesway, live load reduction, effective length factors, effective tension net area, and moment redistribution can be specified.

MPD also has a mark group option, which enables the user to group a series of members and to assign the same section to all members in the group. To designate members into mark groups, first the Design icon in the side menu is selected. Next, a name is given to the mark group. Finally, members are assigned to the mark group by selecting them using a fence block or a data button. MPD also allows the user to specify whether the update and material take-off functions should use independent member results or mark group results. By placing members in a mark group, all of the members in the group are assigned the section size of the most critical section of all of the members in the group.

2.5.2 Design Tables

MPD contains additional design tables which enable the user to enter additional information pertinent to the design of the structure. The first table enables the user to specify or edit material tables and to assign them to structural members. The second table enables the user to select alternate section(s) and assign it to a member. This limits the sections that can be selected for design of that member. The third table enables the user to set deflection limits for a given set of load combinations and then to assign these parameters to a member. This limits the section sizes to those that fit the deflection criteria. The final design table enables the user to define limits for various section properties and to assign these limits to members. For all of these tables, once the table is assigned to a member it is automatically saved.

2.5.3 Process Design

Design is performed in MPD as follows. First, a shear/moment/deflection profile is constructed for each member. Next, the profiles are compared with code-based allowable levels at a specified number of stations along the length of the member (the maximum number of stations is 17). Next, MPD checks against the most critical shear, moment, or deflection condition on the element. This process continues until the optimum member size has been found. The most critical section is used as the section size for the entire physical member. The sections are sorted by least weight. The code used for the design can be specified by the user (although the AISC ASD 1978 specification is the only steel design code currently available).

2.5.4 Postprocessing Capabilities

The postprocessing features are grouped into several categories. The first category is the Reports section. By selecting the Reports icon, the user has the capability to print input information, results, or material take-off data to the screen or to a file. The program provides the user with the option of selecting the type of input information required.

The second category consists of the Label commands. These commands are activated by selecting the Label icon. The label is placed next to the element on the model. Using the label commands the user can display either the controlling section, the previous section, or the analysis section. The label is placed next to the element in the structure. All of these commands can be applied to individual members or to mark groups. The ability to display the controlling section and the previous section allows the user to see how member sizes have changed and if the member size is converging. Another way to determine this is to select the Criteria icon on the top menu, enter the necessary parameters in the Criteria tutorial, exit the tutorial, and then select the Flash icon under Label in order to flash all of the members that have not converged.

The third category consists of the deformed shape plot and the PDM label. The deformed shape plot function has the same function in MPD that it does in MPA. It plots the deformations of the structure due to a particular load case or combination. The PDM label command also has the same function in MPD that it does in MPA, which is to display the PDM information for a particular load case on the structure. The only difference between the MPA and MPD label commands is in the PDM parameters which can be selected. MPD uses parameters such as the effective length parameters, deflection ratio, and the controlling ratio.

2.6 GTSTRUDL

GTSTRUDL is Georgia Tech's adaptation of STRUDL (Structural Design Language) [3]. It is a computer program for structural analysis and design. It can be executed in a batch mode, interactive mode, or any combination of batch and interactive modes. GTSTRUDL integrates structural analysis and design, graphical display, and structural data base management features into a single system.

GTSTRUDL was developed by Georgia Tech in 1975-1977 from the original IBM version of STRUDL (which was developed at MIT) as a subsystem of GTICES (the Georgia Tech integrated Computer Integrated System). It had been extensively used worldwide on large CDC CYBER computers until 1981, when it became available on Digital Equipment's VAX family of computers. Versions of GTSTRUDL are currently available for workstations.

Structural layout in GTSTRUDL is done through an alphanumeric interface. All structural data, including node coordinates, support releases, support nodes, member incidences, member releases, eccentricities, material properties, beta angles, element properties, and loading are entered alphanumerically. Manipulation of a model is done by changing parameters in the alphanumeric interface.

GTSTRUDL contains five member types and over 35 conventional, isoparametric, and hybrid formulation finite element types. These element types include: curved beam elements including internal pressure effects, plane truss/frame/grid members, space truss/frame members, thin shell elements, three dimensional elements, and special pile elements for certain types of soil-structure interaction analysis.

GTSTRUDL contains independent static loading types including joint loads and member loads, body loads, dynamic loads, and dynamic frequency spectra. The loads must be placed in load cases and may be grouped in load combinations.

GTSTRUDL allows the user to specify the number of degrees of freedom at a boundary and to apply translational and rotational springs to a boundary.

GTSTRUDL is able to perform general purpose structural analysis and design, as well as data base processing, on a very broad range of structural problems. It performs linear static analysis using a variable band, variable partition, sparce equation solver. It performs generalized steel frame design in accordance with the 1969 or 1978 AISC ASD specifications for I, channel, tee, single or double angle, pipe, round and rectangular tube, and round and rectangular bar shapes, and selects members for design from either specified tables of section shapes by automatically using the same tables from which initial member properties were specified. Over 70 design parameters and 30 member cross section properties and other geometric information may be specified by the engineer. Iterative analysis and design is performed. GTSTRUDL allows the user to display the results in any quantity, form (printed and/or graphical), and order (finite element, joint, type of element, etc.).

Chapter 3

Description of Models

In this chapter a description of the three buildings considered in the verification and evaluation of the MicasPlus software is presented. The structures considered are representative of those commonly used in heavy industrial applications. The basic plans for these structures were provided by the Tennessee Eastman Company. These structures have already been constructed and are currently in use. The structural members consist entirely of wide flange steel sections with 36 ksi steel and concrete slabs. The structures were first modeled in GTSTRUDL.

3.1 Tennessee Eastman Building 267g

The first structure considered was a four story, three-dimensional braced frame steel structure called Tennessee Eastman building 267g (see Figures 1-7). The structure contains 68 nodes and

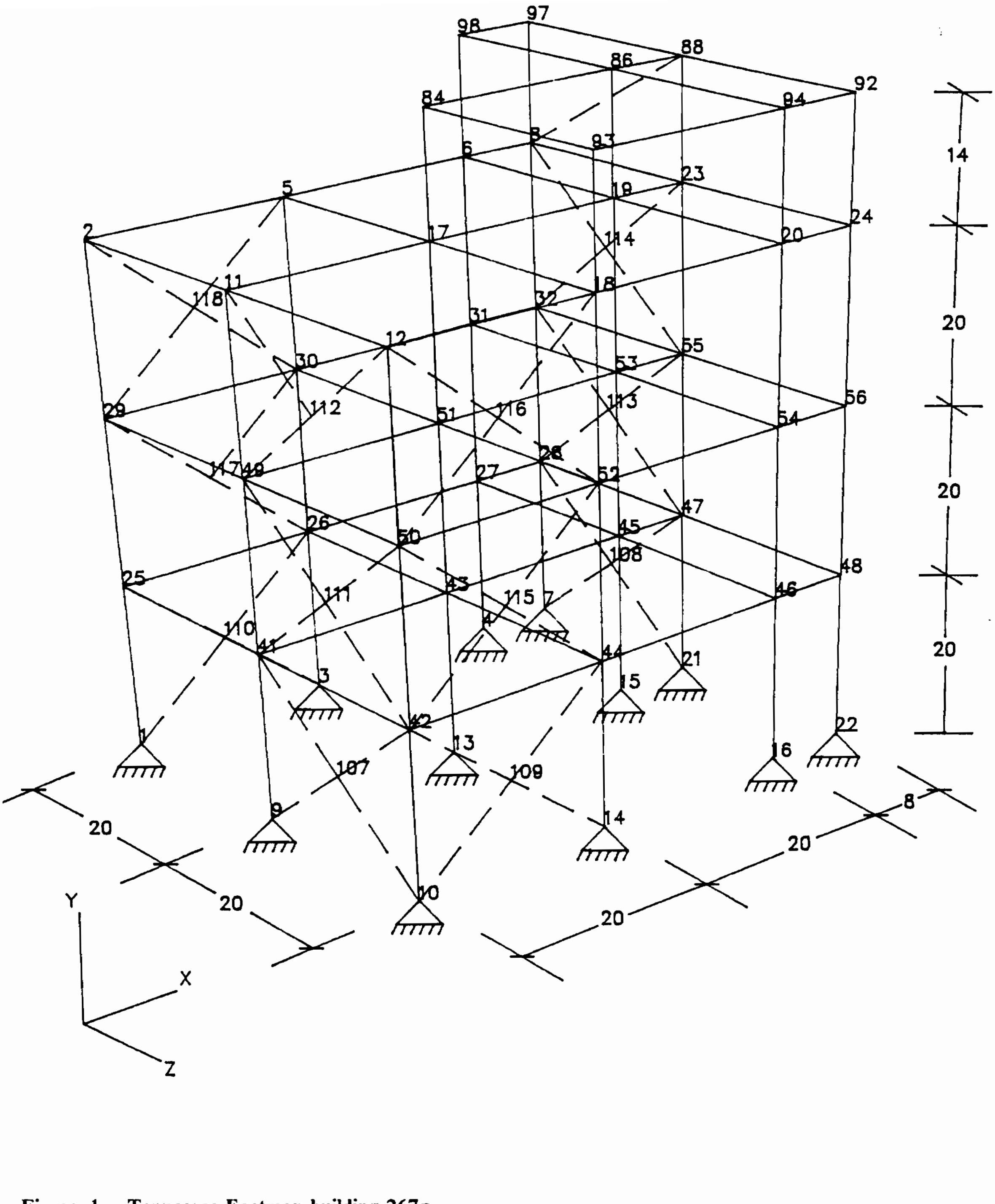


Figure 1. Tennessee Eastman building 267g

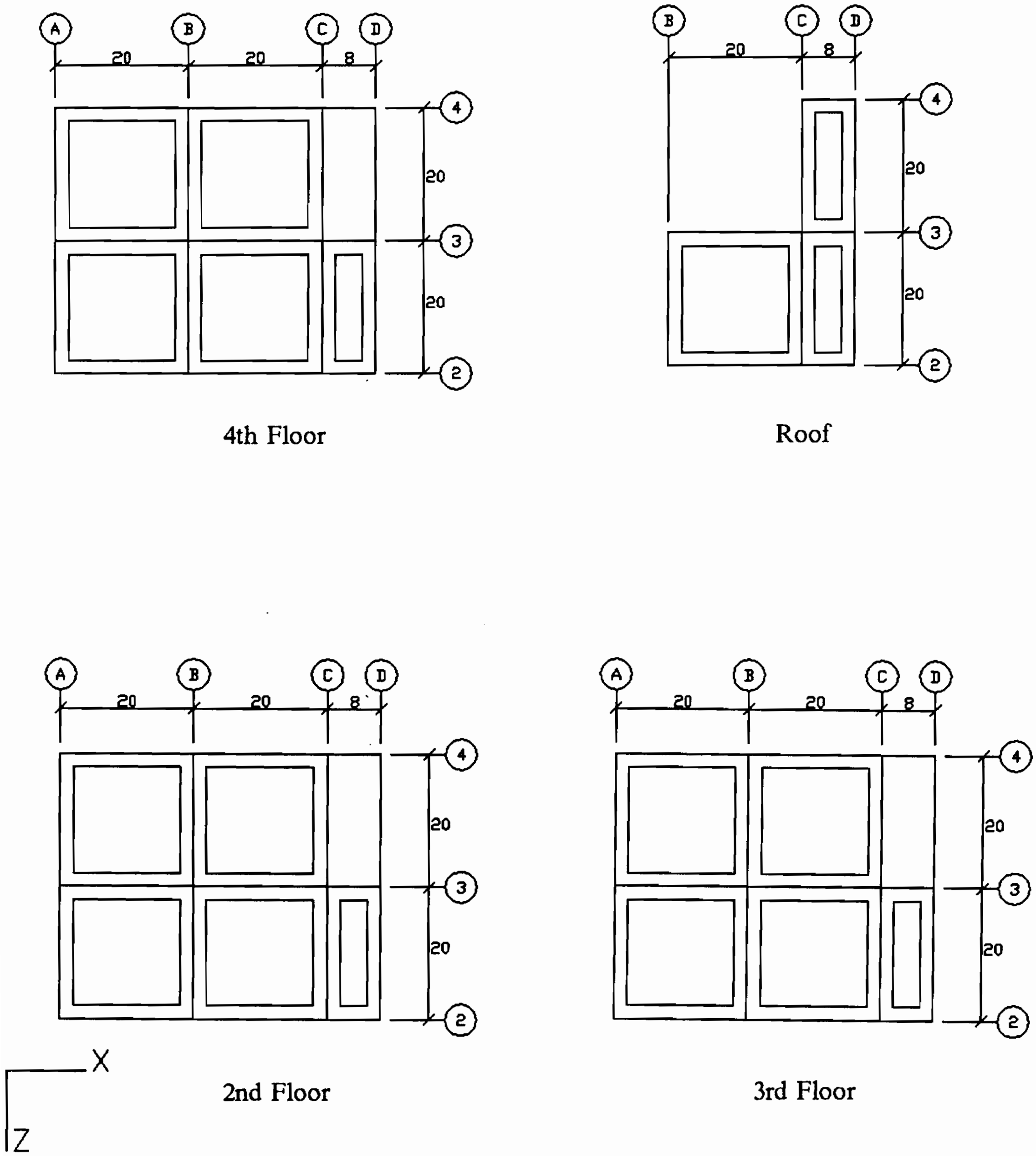


Figure 2. Plan views of building 267g

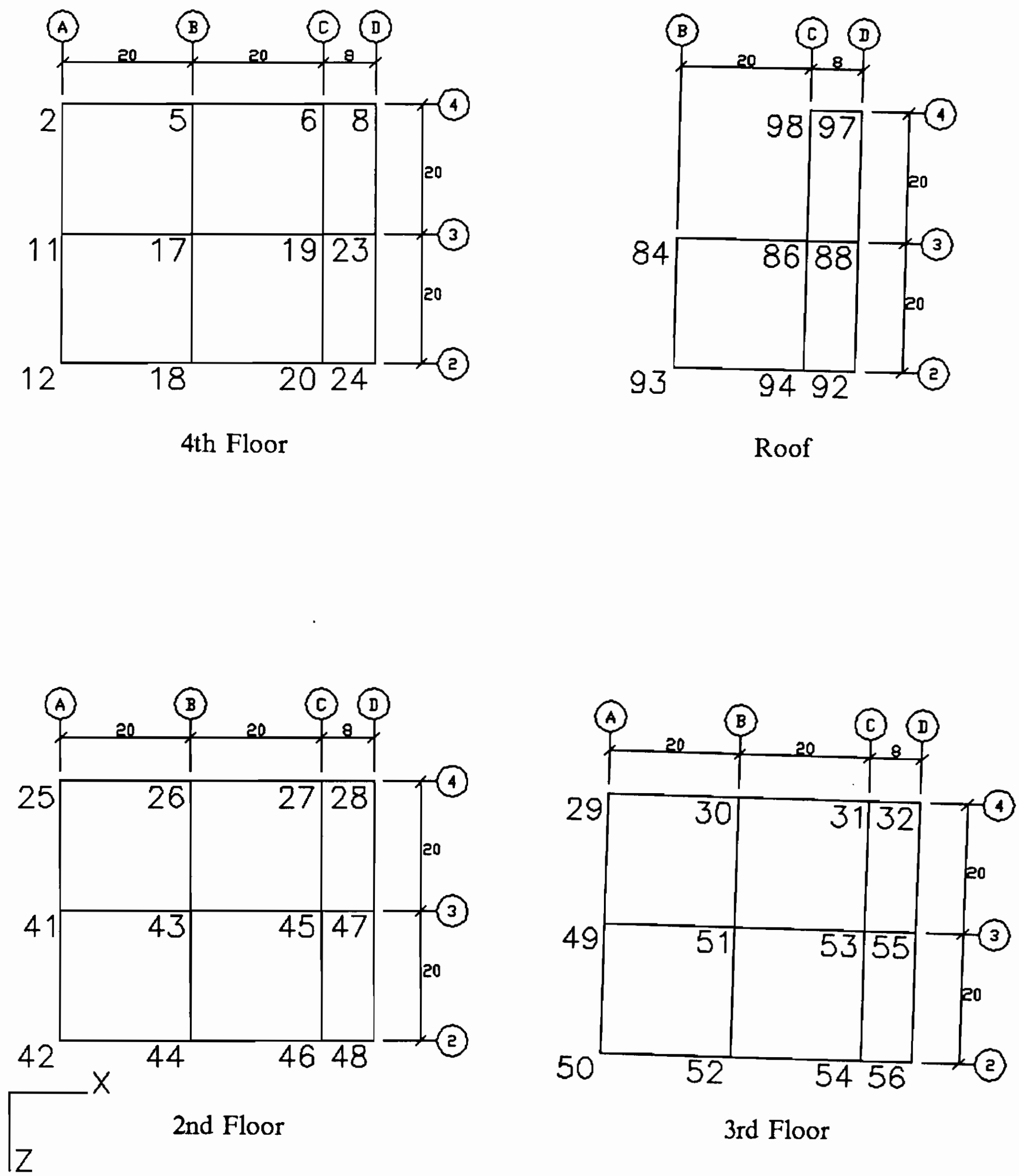


Figure 3. Node numbering for building 267g

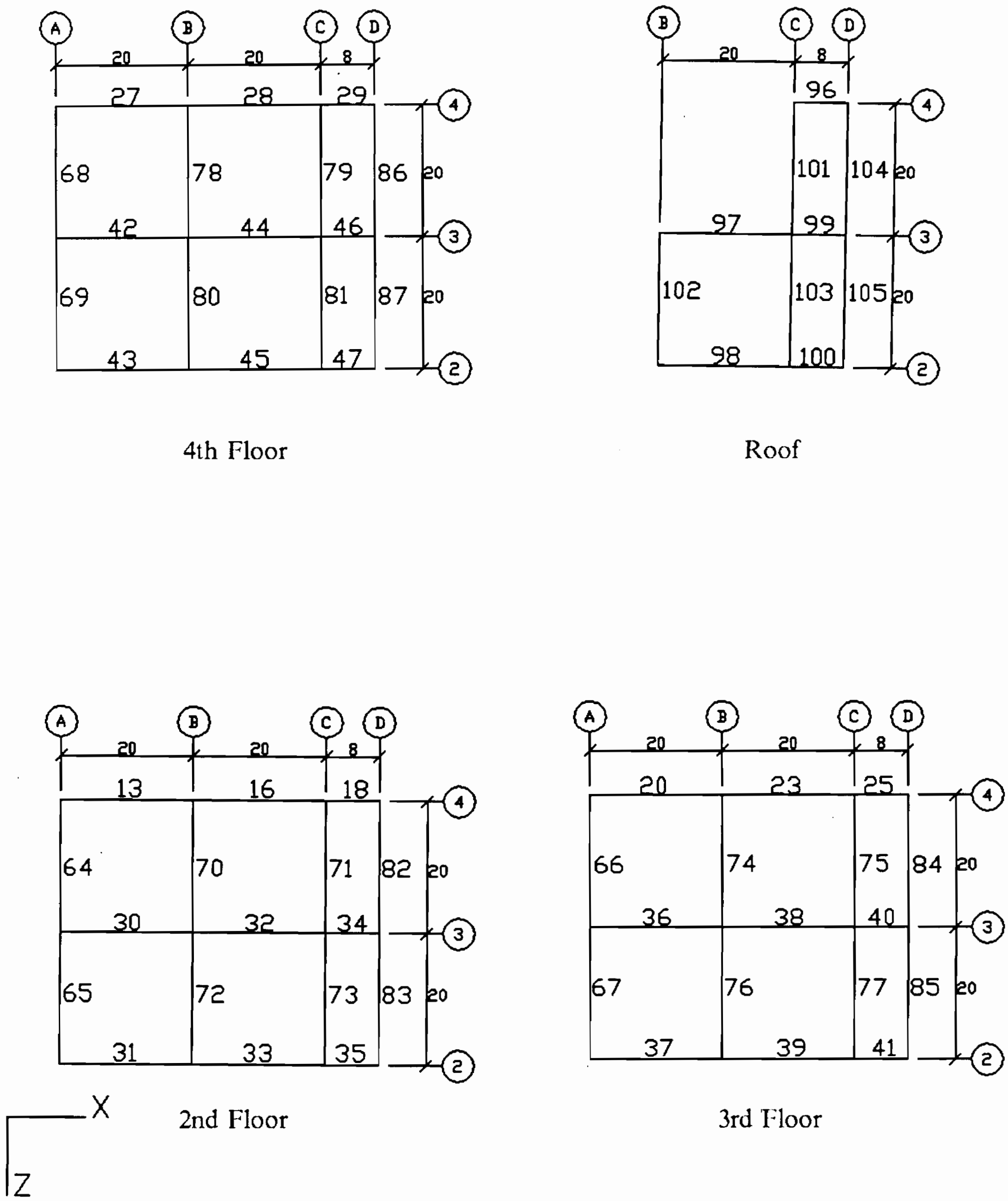
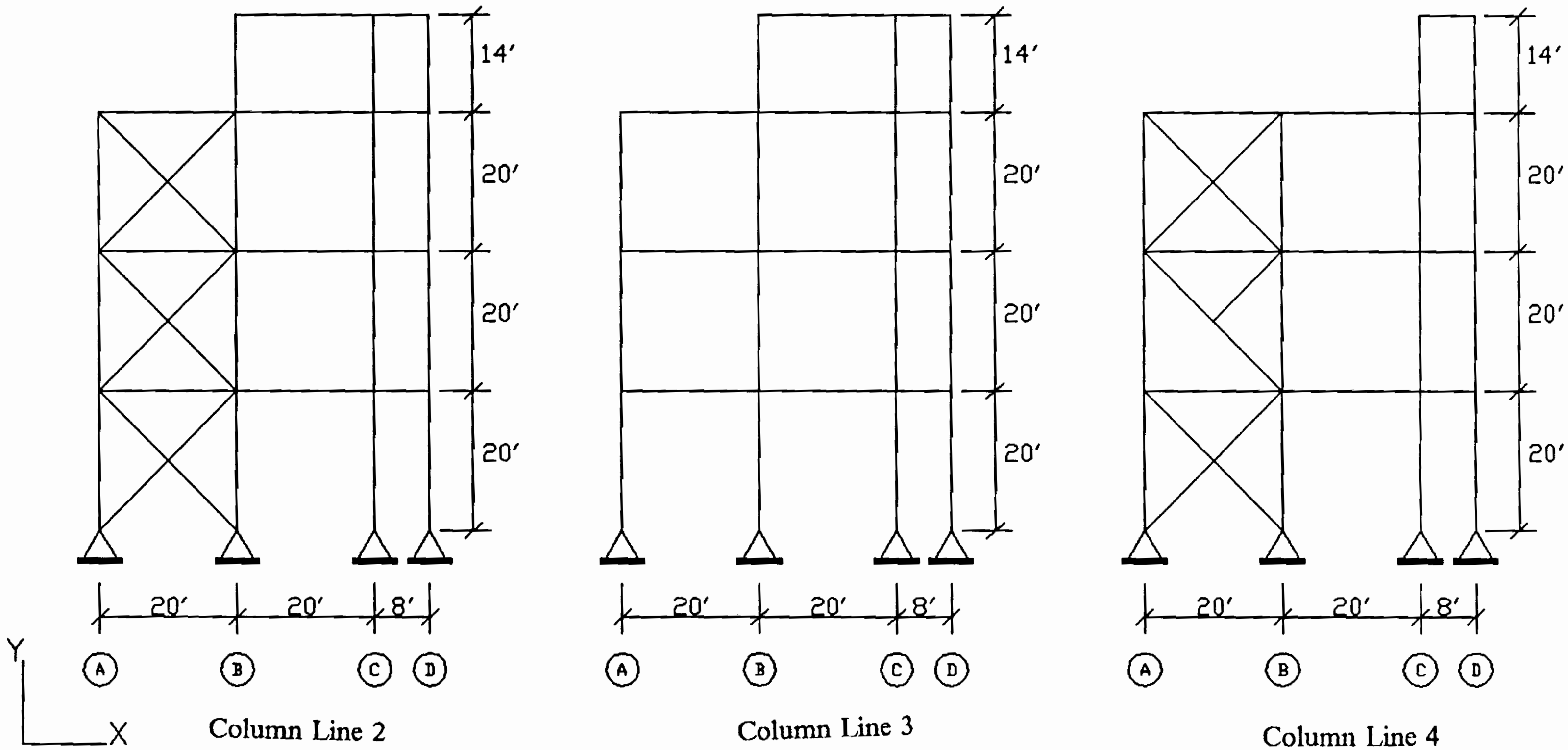


Figure 4. Element numbering for building 267g



Column Line 2

Column Line 3

Column Line 4

Figure 5. Column lines in East/West direction for building 267g

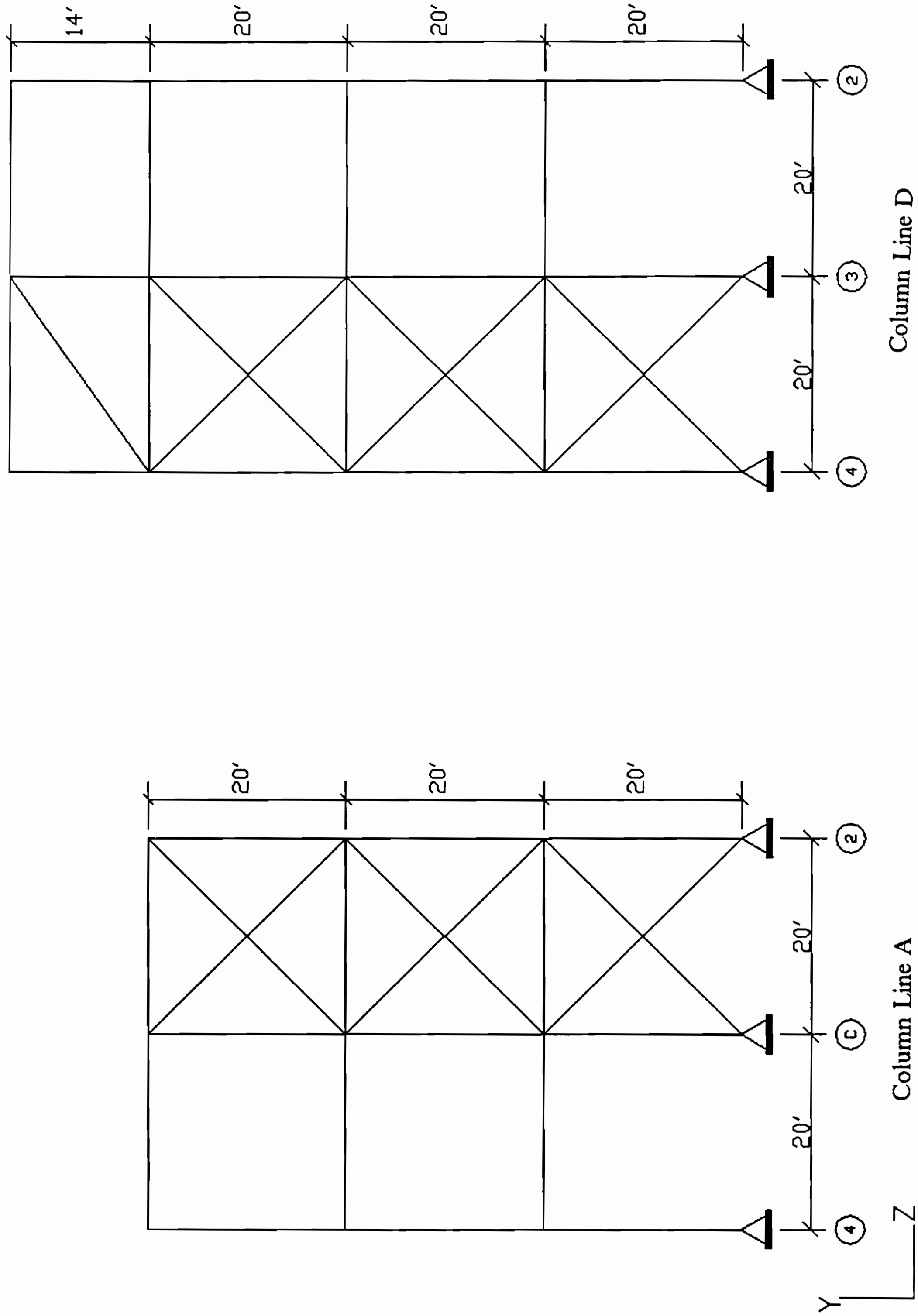


Figure 6. Braced column lines in North/South direction for building 267g

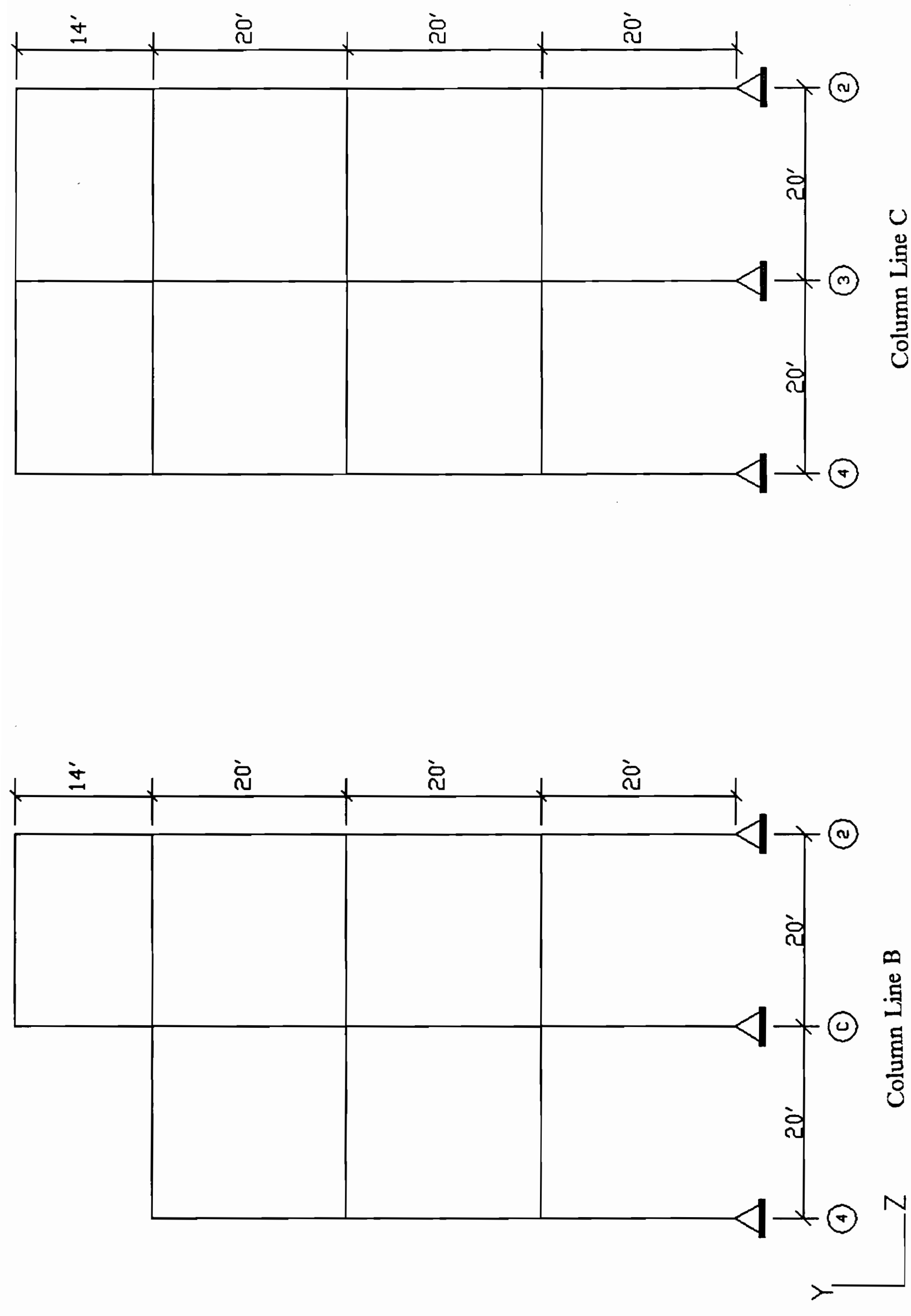


Figure 7. Unbraced column lines in North/South direction for building 267g

171 elements. There are 44 are column elements, 61 beam elements, 48 brace elements, and 18 planar finite elements in the structural model (see Fig. 3 for node numbering and Fig. 4 for element numbering). The structure is three bays long and two bays wide. The three bays are 20 ft, 20 ft, and 8 ft wide. The two bays in the perpendicular direction are each 20 ft wide. The first three stories of the building are 20 ft high and the top story is 14 ft high (see Fig 1). The objectives for studying this structure were to evaluate the accuracy of the MicasPlus Analysis module, the accuracy of the MicasPlus Design module, and the functionality of MicasPlus. The accuracy of the analysis module was evaluated by analyzing the structure in MicasPlus and GTSTRUDL and comparing the results. The accuracy of the design module was evaluated by performing a design code check on the structure using both programs and comparing the results of the final design.

3.1.1 Columns

The building has columns of two different heights. Columns A2, A3, A4, and B4 are 60 ft in height and the remaining columns are 74 ft in height (see Fig. 1). The columns sections are of varying size, each with a nominal depth of 14 inches. All of the columns are oriented such that their webs are parallel to the z-axis. The member modeling centerline of the element passes through the centroid, which is cardinal point 10 in MicasPlus.

3.1.2 Girders

The girders extend from column to column. All of the girders have pinned end conditions, except elements 96, 97, 98, 99, and 100, which have fixed end conditions. The girders are oriented such that their webs are parallel with the y-axis. The member modeling centerline passes through the top of steel of the girder, which is cardinal point 8 in MicasPlus. There are, however, no rigid end offsets in the analysis of the building.

3.1.3 Bracing

The only type of bracing in the structure is vertical bracing. It is located along column lines A, D, 2, and 4 (see Figs. 5 and 6). All of the cross-bracing members are connected at the intersection point and all of the bracing is pinned at the ends and consists of wide flange(W) sections. The bracing members are oriented so that their webs are perpendicular to the plane in which they are contained. The member modeling centerline passes through the centroid of the member, which is cardinal point 10 in MicasPlus.

3.1.4 Finite Elements

Planar finite elements were used to represent floor slabs in the structure. The floor slabs are made of 4000 psi concrete and are 6 in. thick. The exact location of the floor slabs is shown in Figure 3.4. The PSHQ element, which has two degrees of freedom (u1 and u2) was used to model the floor slabs in GTSTRUDL. The QUM element, which has three degrees of freedom (u1, u2, and u3) was used to model the floor slabs in MicasPlus. Although these elements have a different number of degrees of freedom, they are compatible. These elements are not the best elements to use to model a floor diaphragm, but were selected because of the limited finite element library in MicasPlus and the need to find compatible elements in MicasPlus and GTSTRUDL.

3.1.5 Supports

The supports are modeled to resist translation and to resist torsional rotation of the columns.

3.1.6 Loading conditions

Seven different load cases and seventeen different load combinations were considered in the analysis. The load cases included: dead weight of the girders and the dead load and live load acting on the structure (LC1), weight of the girders and the dead load acting on the structure (LC2), wind from the east (LC3), wind from the north (LC4), weight of the columns and braces (LC5), earthquake load from the east (LC6), and the earthquake load from the north (LC7). All of the loads are applied at the joints except for the weight of the columns and braces (LC5), which are body loads.

The load combinations include: the maximum gravity load, which comes from load cases 2 and 5 (MAXGR), maximum dead load (load cases 2 and 5) and wind load in each direction (MAXDNW, MAXDSW, MAXDEW, MAXDWW), maximum dead load and earthquake load in each direction (MAXDNE, MAXDSE, MAXDEE, MAXDWE), maximum gravity load and wind load in each direction multiplied by a factor of 0.75 (MAXGNW, MAXGSW, MAXGEW, MAXGWW), and maximum gravity load and earthquake load in each direction multiplied by a factor of 0.75 (MAXGNE, MAXGSE, MAXGEE, MAXGWE).

3.1.7 Modeling of the Structure in MicasPlus

The braced frame structure was modeled in MicasPlus in the following manner. First, column A4 was placed. It was then copied twice in the x-direction to form column B4 and the lower 60 ft of column C4. Column C4 was then copied in the x-direction to form the bottom 60 ft of column D4. All of these columns were then copied twice in the positive z-direction to form columns A3 and A2 and the lower 60 ft of columns B3, B2, C3, C2, D3, and D2.

Next, beams along column line 4 were placed. They were placed from column line A4 to B4 to C4 and finally to D4. This was done on the second, third, and fourth floors, in that order. This completed the placement of the beams in the first three stories along column line 4. All of these beams were then copied twice in the positive z-direction at 20 ft intervals, which completed the placement of all the beams along column lines 2 and 3 in the first three stories.

Next, beams along column line A were placed. They were placed from column lines A4 to A3 to A2, first on the second floor, then the third floor, and finally the fourth floor. These beams were then copied twice in the positive x-direction at 20 ft intervals, which completed the placement of all the beams along column lines B and C in the first three stories. The beams along column line D were then placed. They were placed in exactly the same pattern as the beams along column line A. This completed the placement of the beams in the first three stories of the structure.

Next, the roof beams and accompanying columns were placed. First, the columns were placed individually in numerical order, beginning with element number 88 and concluding with element number 95. Finally, the beams were placed in numerical order, beginning with element number 96 and ending with element number 105. This completed the placement of all the beams and columns for the building.

The bracing was then placed in the following order. First, some of the bracing along column line A was placed. The bracing was placed from nodes 9 to 42 to 49 to 12 and 10 to 41, in that order. Next, bracing was placed along column line D. The bracing was placed from nodes 7 to 47, 21 to 28, and 28 to 55 to 8 to 88, in that order. Next, bracing was placed along column line 2. The bracing was placed from nodes 10 to 44, 42 to 12, and 44 to 50 to 18 in that order. Next, bracing along column line 4 was placed. The bracing was placed from nodes 1 to 26, 1 to 25, and 26 to 29 to 5, in that order. Finally, the remainder of the bracing was placed, first from nodes 41 to 50 to 11 along column line A, then from nodes 47 to 32 to 23 along column line D, then from nodes 42 to 52 to 12 along column line 2, and finally from nodes 117 (which is at the midpoint of an existing brace) to 30 to 2 along column line 4. This completed the placement of all the steel elements.

Finally, the planar finite elements were placed. They were placed individually in numerical order, beginning with element number 154 and ending with element number 171.

3.1.8 Design Criteria

The following criteria were implemented for the code check in MicasPlus Design. The structure was braced against sidesway. The axial unbraced length about both the strong and weak axis for the columns and beams was set equal to the span length. The axial unbraced length for the braces was set equal to the span length about the weak axis and the physical member length about the strong axis. All of the beams had a bending unbraced length for the compression flange of zero about both axes except for members 18, 25, 29, 82, 84, and 86, which had a bending unbraced length equal to the span length about both axes. The effective length factor (K) for the columns was specified to be 1.0 about both the strong and weak axes. The effective net tensile area for the braces was taken to be 70% of the gross area. to account for the holes in the member needed for the connections. Finally, the entire structure was specified to be braced against sidesway.

3.2 Moment Resisting Frame

The second structure considered was a moment resisting frame. The structure was used to evaluate the accuracy, design capabilities, code check, and functionality of MicasPlus. It is identical to the braced frame structure except for the following modifications: 1) the bracing was inactivated (but not deleted), 2) the ends of all of the beams were fixed, 3) the finite elements were deleted, 4) the supports resist only lateral translation, and 5) elements 34, 35, 40, 41, 46, and 47 were changed from W8x18's to W16x40's. The structural model was created by making a copy of the braced frame structure and making the necessary modifications. The node and element numbers for the braced frame and the moment resisting frame are similar except for the fact that the braced frame has additional nodes and elements for the bracing members and the finite elements.

3.2.1 Design Criteria

The following criteria were implemented for the design and code check in MicasPlus Design. The structure was unbraced against sidesway. The length of the columns was the span length about both the strong and weak axes. All of the beams had a bending unbraced length of zero about both the strong and weak axes except for members 18,25, 29, 82, 84, and 86, which are unbraced about both axes for the span length. The columns were grouped in the following manner for design: elements 1, 14, 21, 6, 48, 52, 10, 50, 54, 3, 17, 24 in mark group COLA; elements 5, 56, 60, 2, 15, 22, 8, 49, 53, 9, 58, 62 in mark group COLB; elements 7, 57, 61 in mark group COLC; elements 4, 19, 26, 12, 51, 55, 11, 59, 63 in mark group COLD; elements 88, 89, 91, 92 in mark group COLE; elements 90, 93, 94, 95 in mark group COLF. Finally, the design was limited to selecting a W14 section for the columns.

3.3 Tennessee Eastman Building 17L09

The final structure considered was Tennessee Eastman Building 17L09 (see Figs. 8-23). The structure was used to determine the effectiveness of the PSD read option and to evaluate the accuracy and functionality of MicasPlus. Building 17L09 is a 10 story structure which contains 419 nodes and 1114 elements, of which 454 are beam elements, 182 are vertical bracing elements, 34 are horizontal bracing elements, 334 are column elements, 20 are spring elements (in MicasPlus), and 90 are planar finite elements. The structure is six bays long and four bays wide at the bottom, six bays long and two bays wide at the top. The six long bays are 25.75, 8.5, 25.75, 25.75, 8.5, and 25.75 ft respectively. The four wide bays are 24, 17, 23, and 20 ft respectively. The 17 and 23 ft bays extend to the top, while the 24 ft bay ends at the first floor and the 20 ft bay ends at the low roof level.

Two different structural models of building 17L09 were analyzed. The first model is exactly as described above. It was used for the analysis of load cases 1, 2, 6, and 7. In the second structural model, the cross-sectional area of all of the vertical bracing members was reduced to a very small value, which in essence inactivated the bracing. This model was used during the analysis for load cases 3, 4, and 5. in order to determine whether or not the columns and beams acting alone could resist the dead, live, and gravity load.

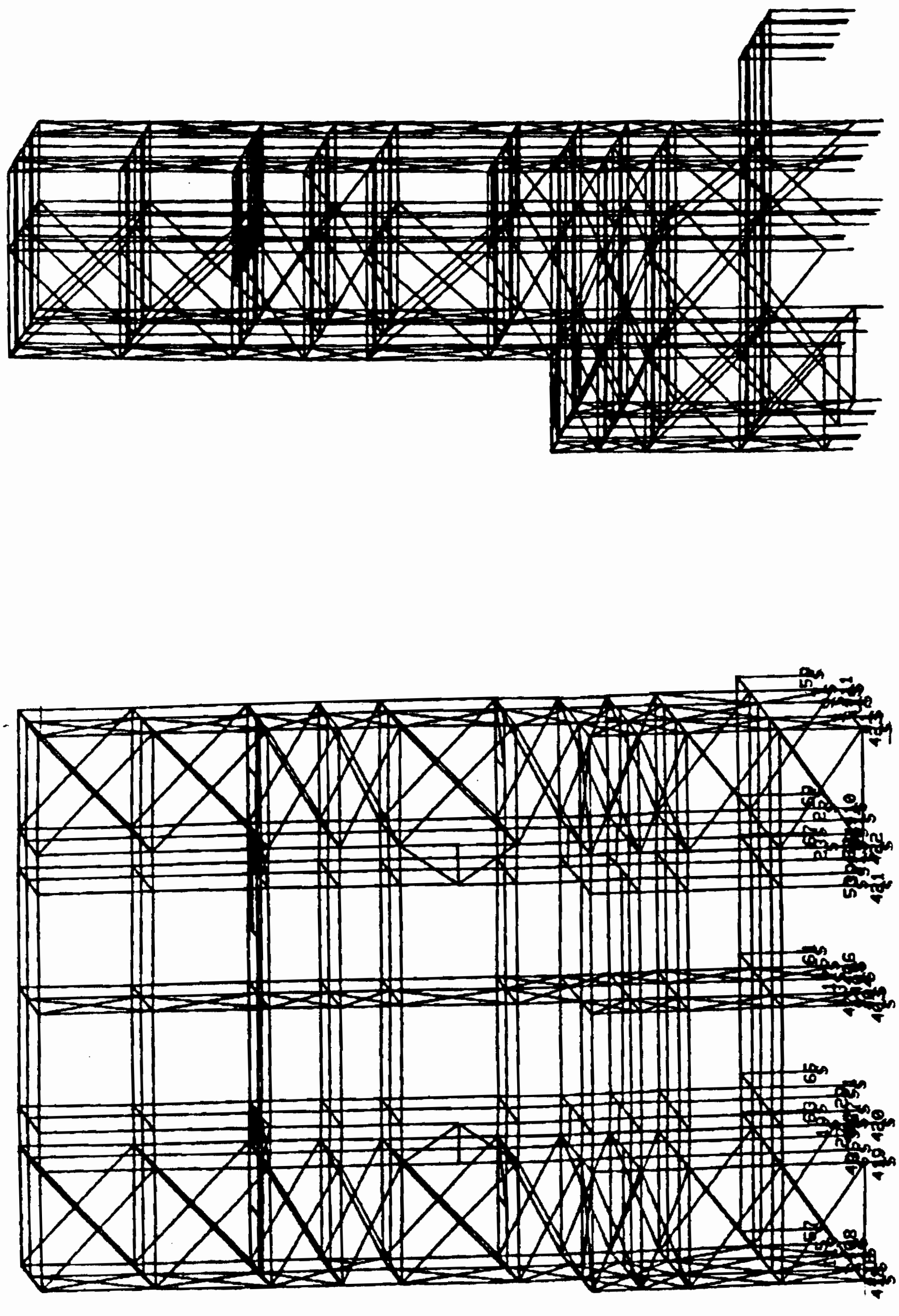
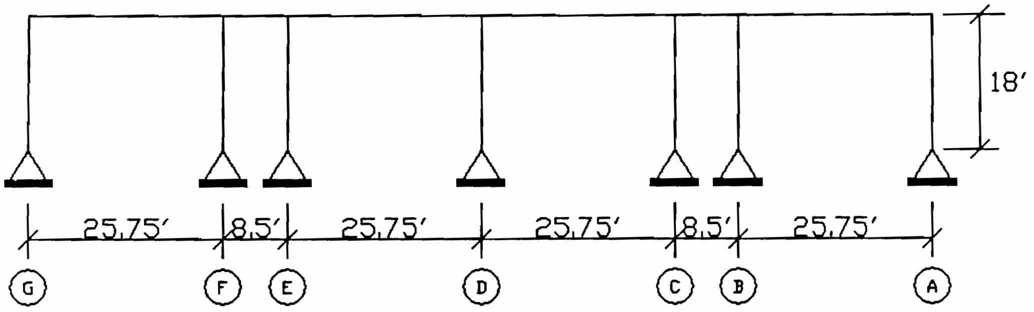
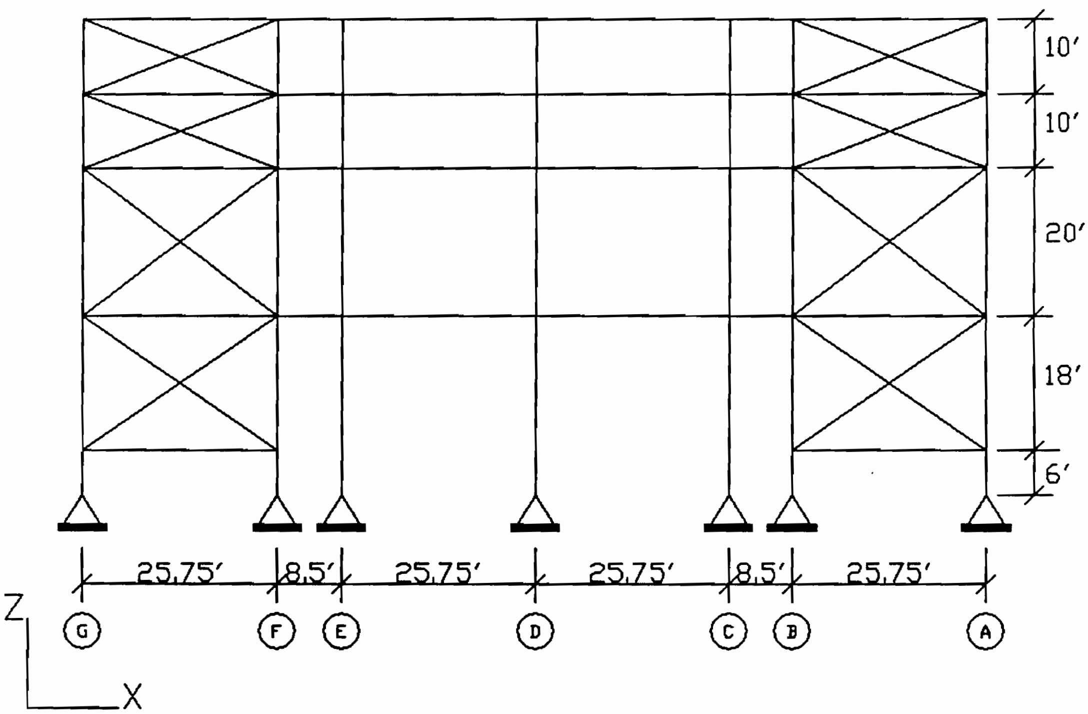


Figure 8. Tennessee Eastman building 17L09



Column Line 1



Column Line 5

Figure 9. Column lines 1 and 5 for building 17L09

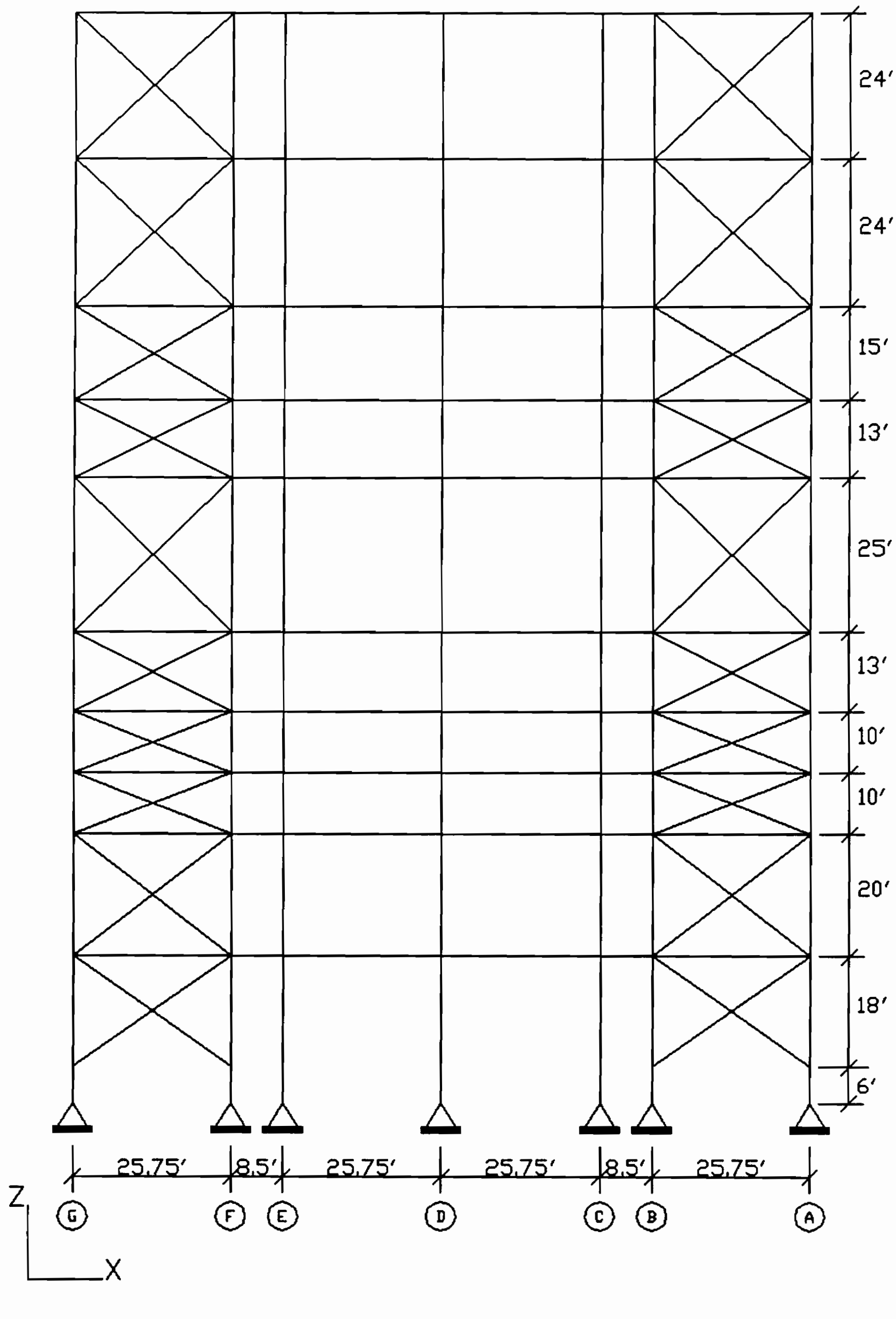


Figure 10. Column line 2 for building 17L09

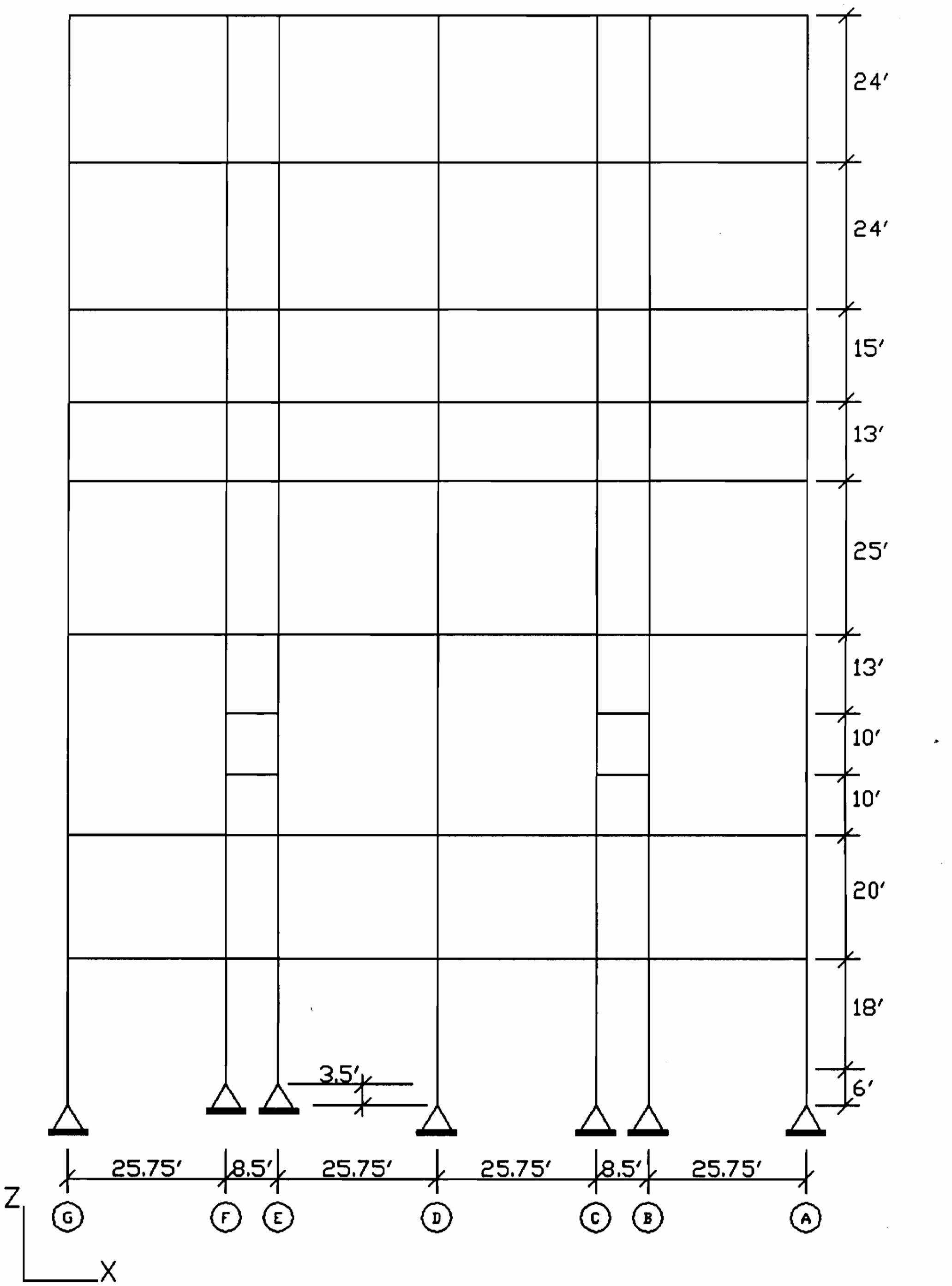


Figure 11. Column line 3 for building 17L09

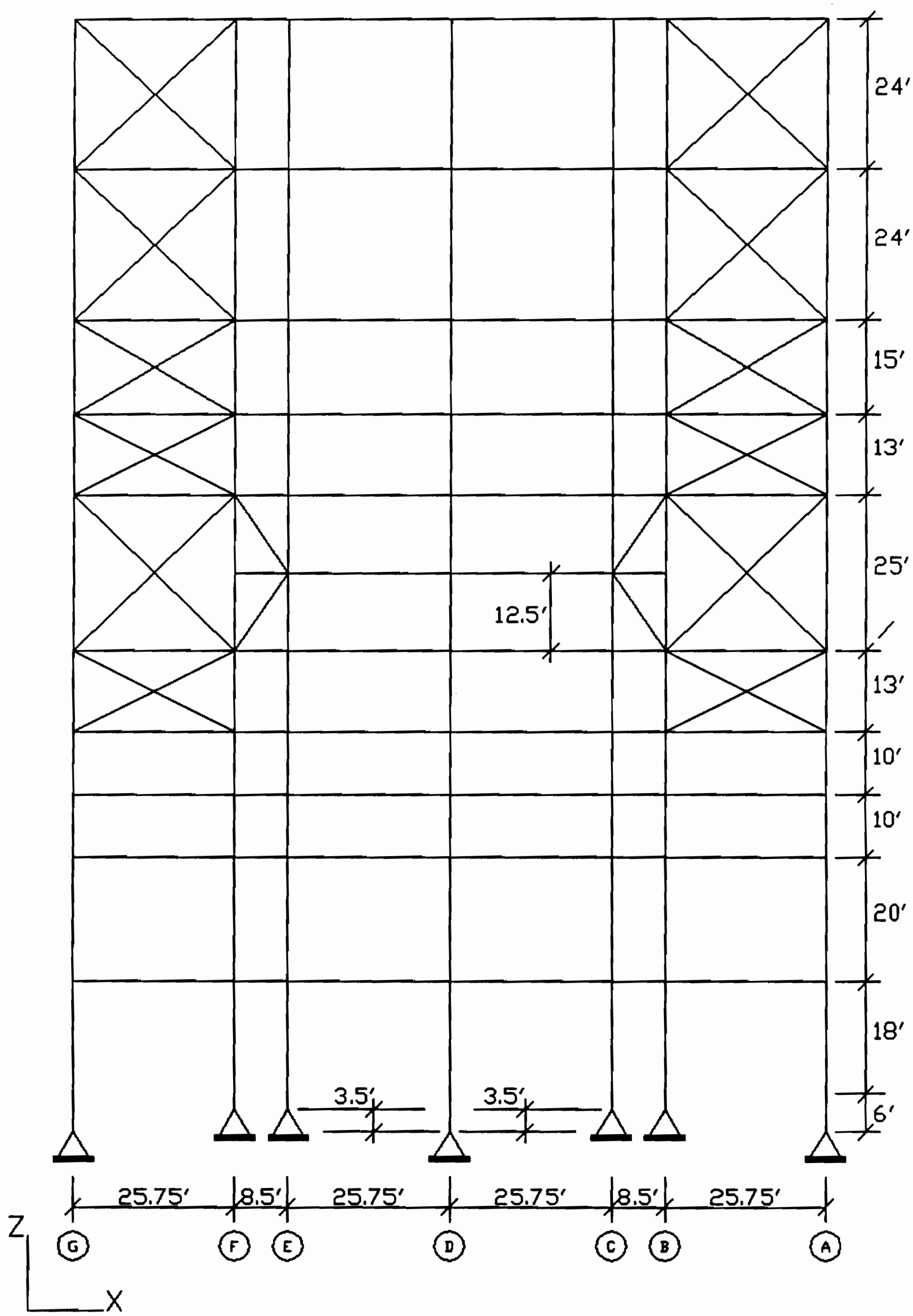


Figure 12. Column line 4 for building 17L09

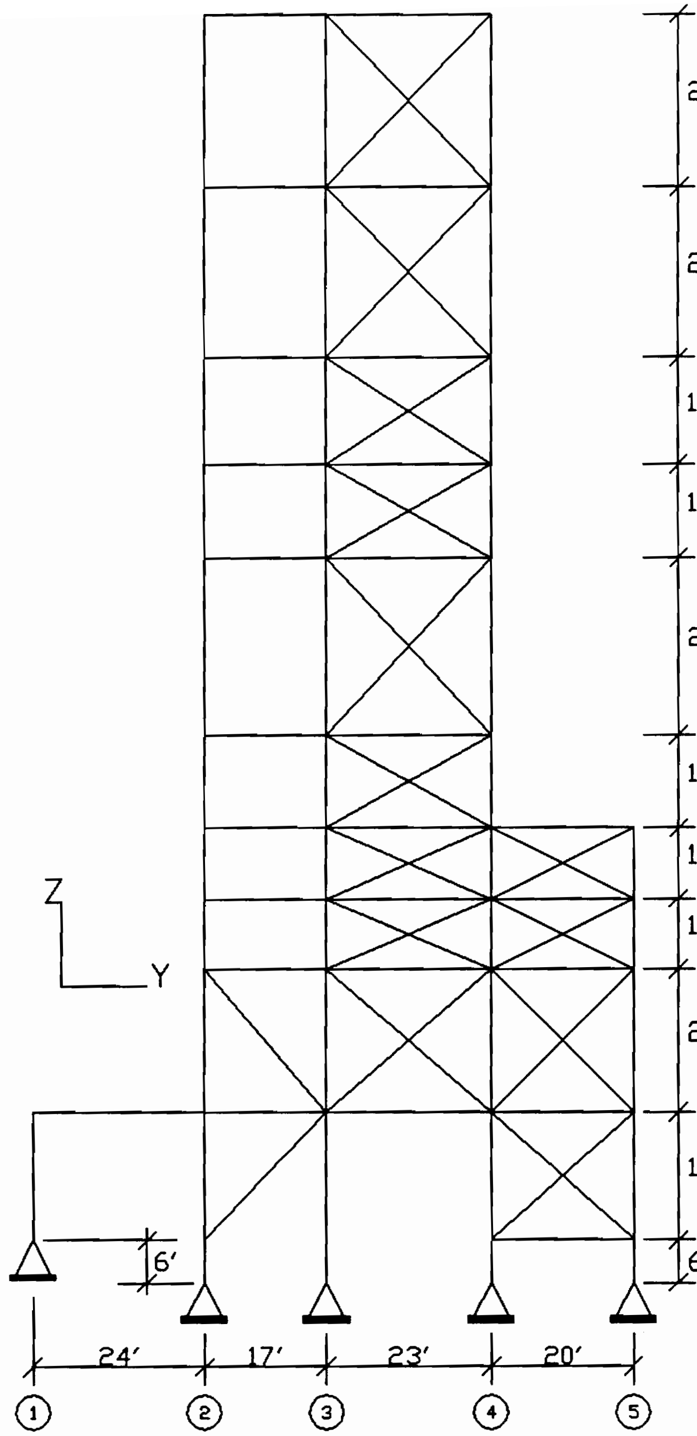


Figure 13. Column line A for building 17L09

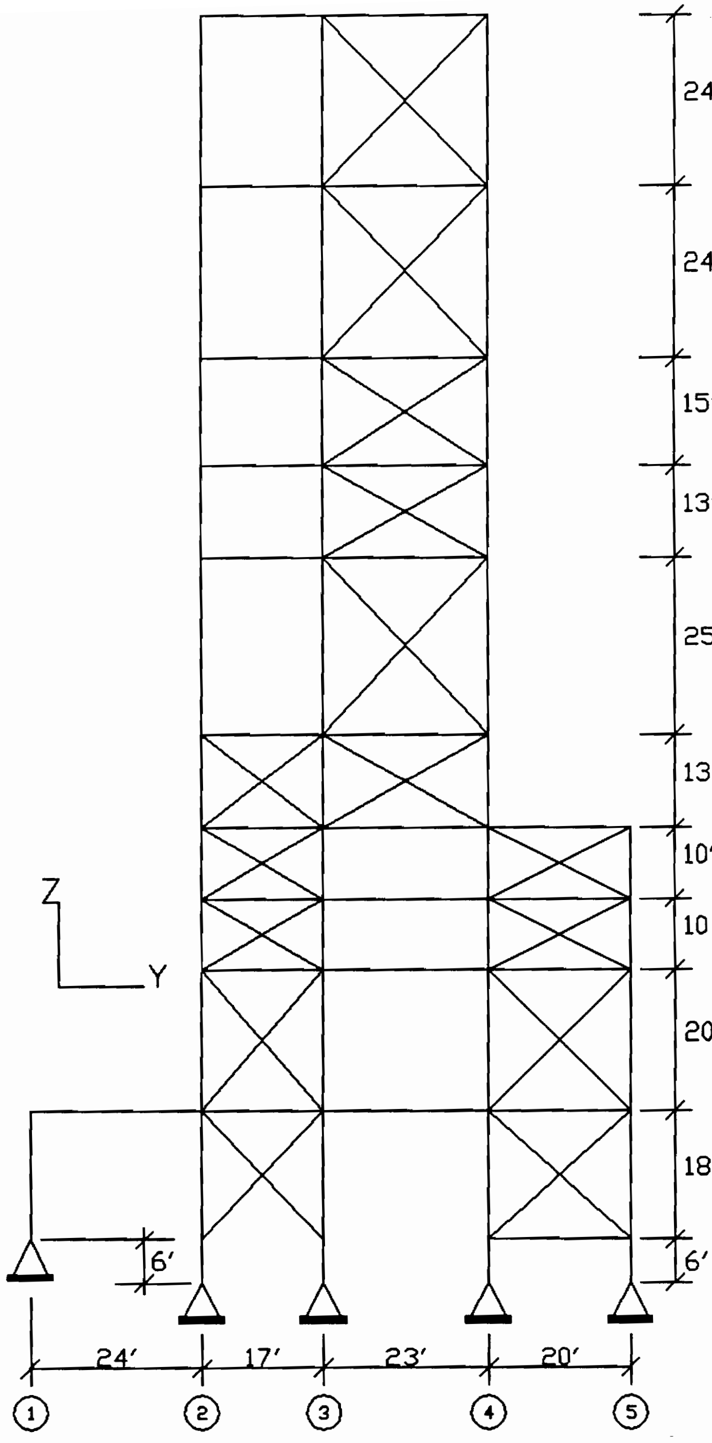


Figure 14. Column line D for building 17L09

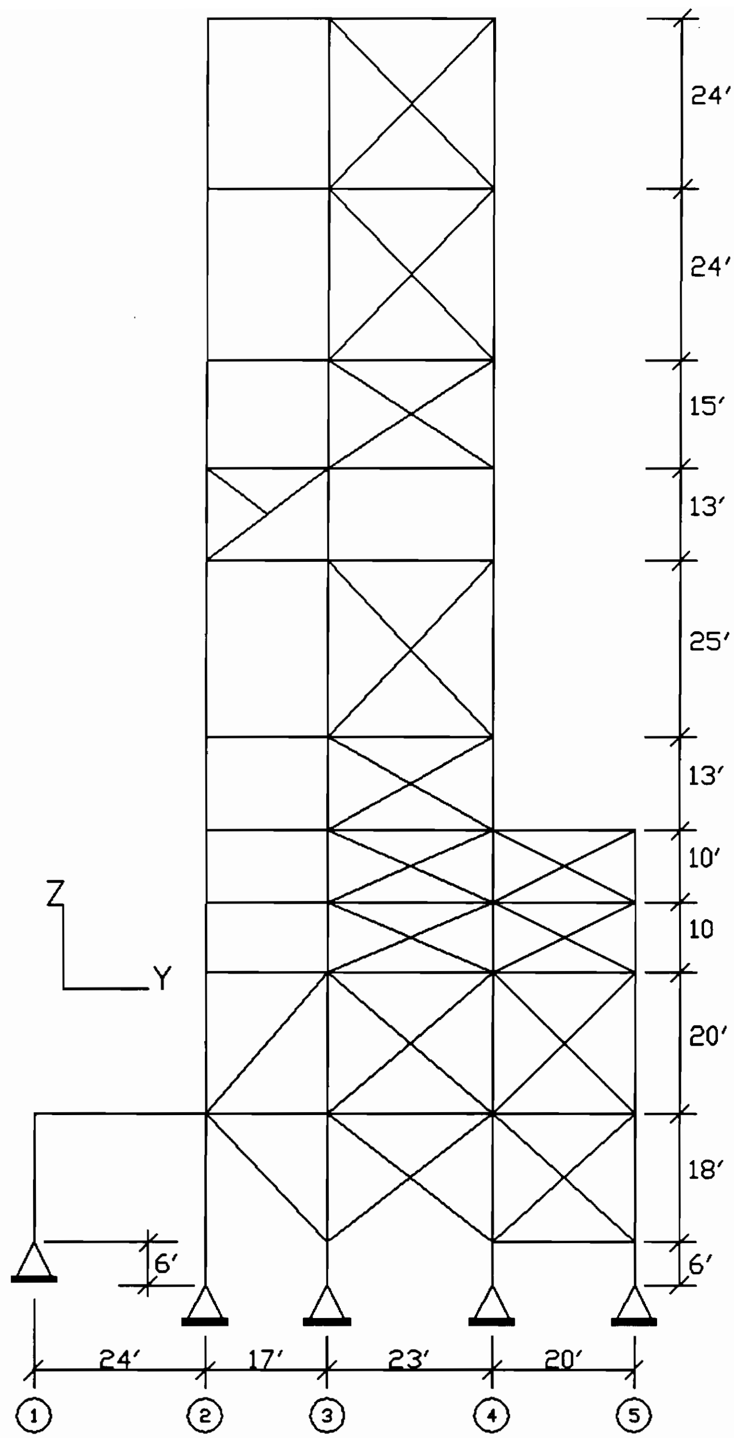


Figure 15. Column line G for building 17L09

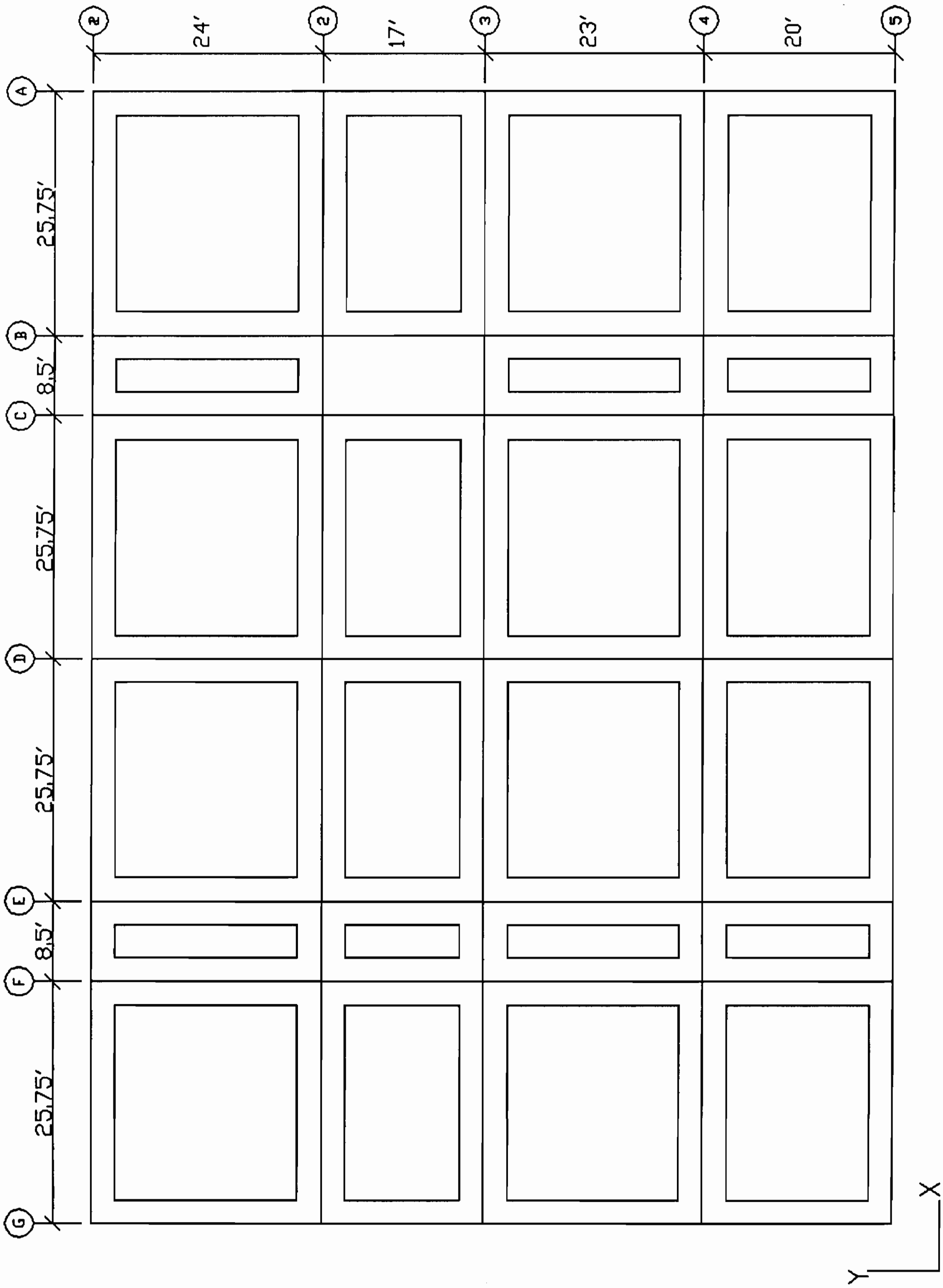


Figure 16. Plan View of 2nd floor of building 17L09

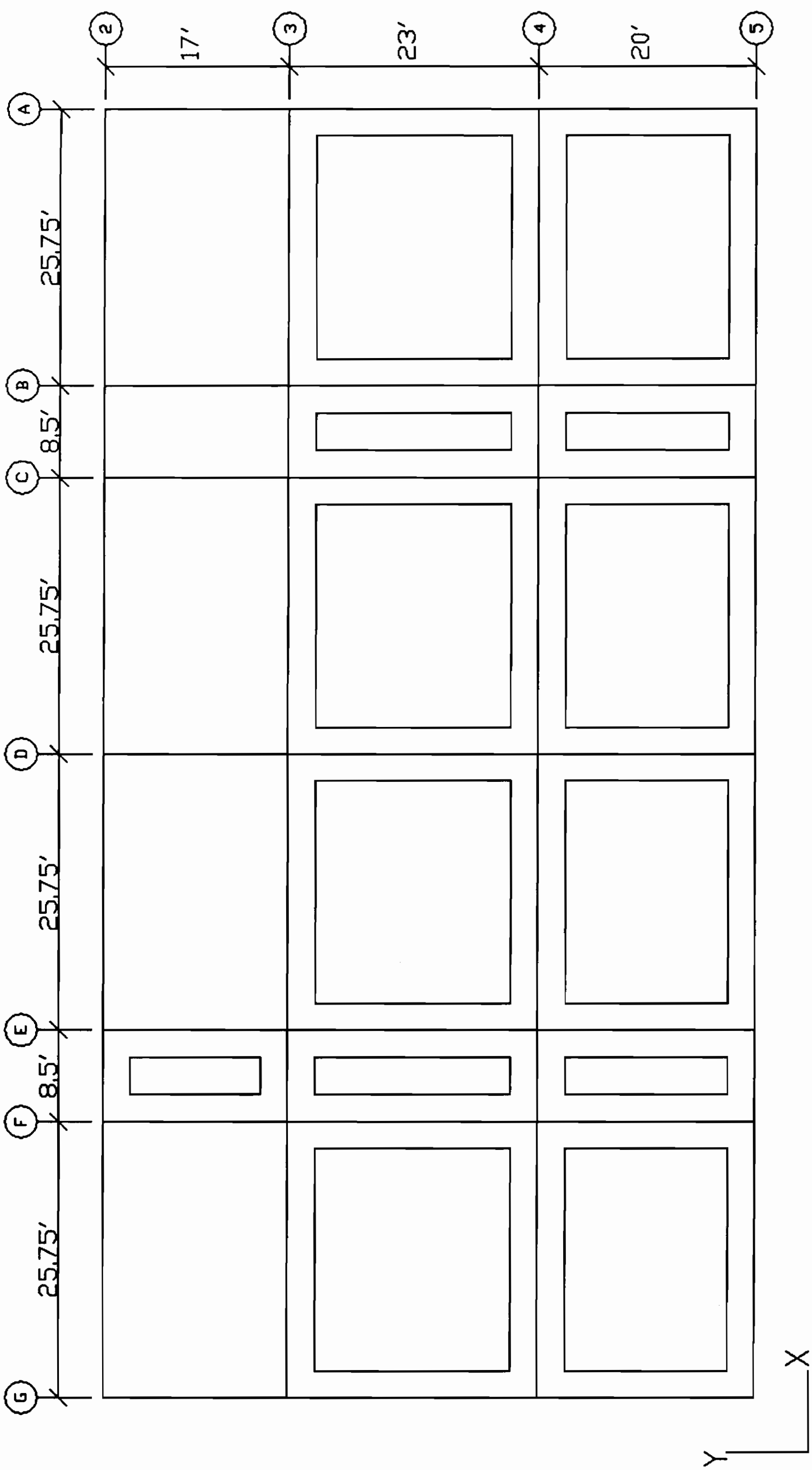


Figure 17. Plan view of 3rd floor of building 17L09

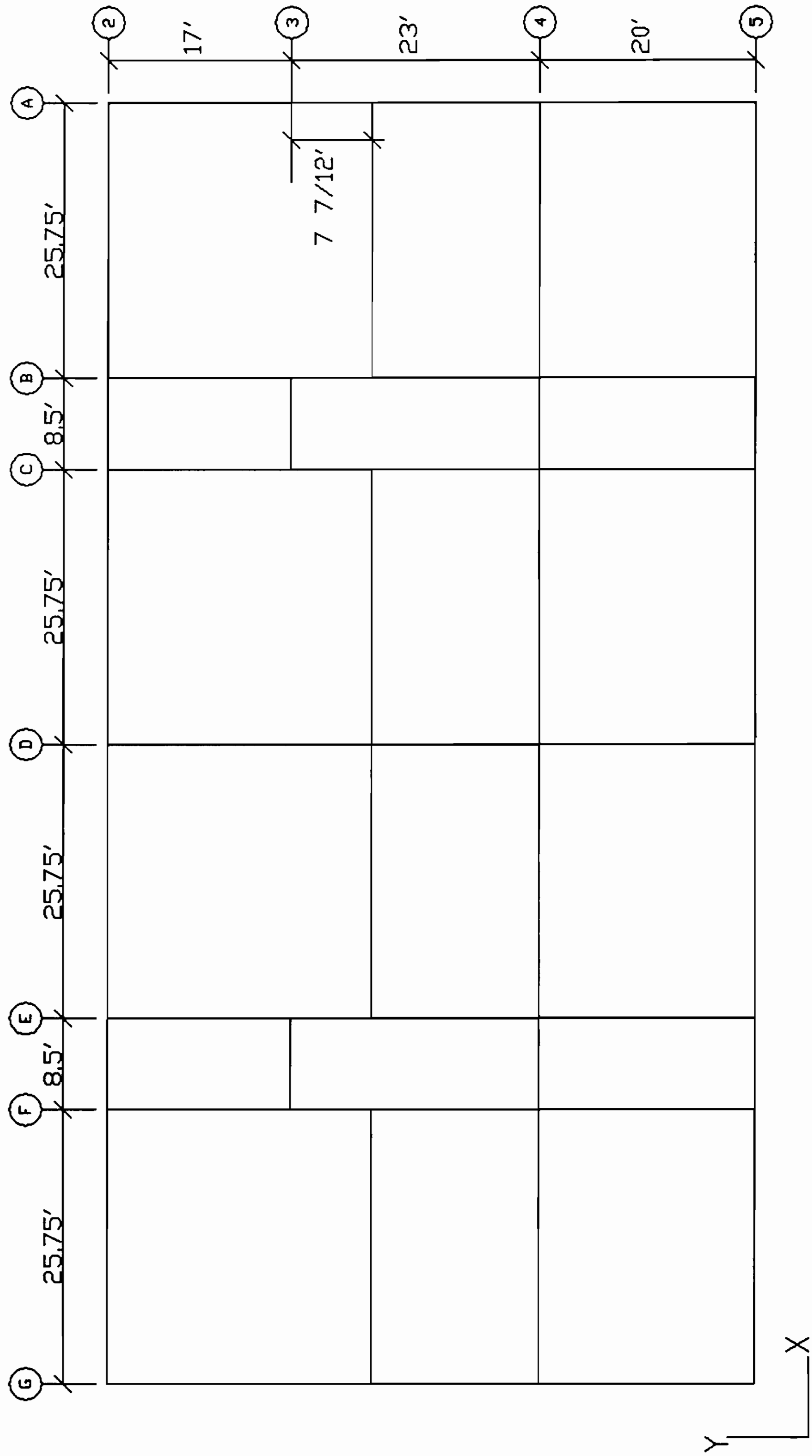


Figure 18. Plan view of Low Platform of building 17L09

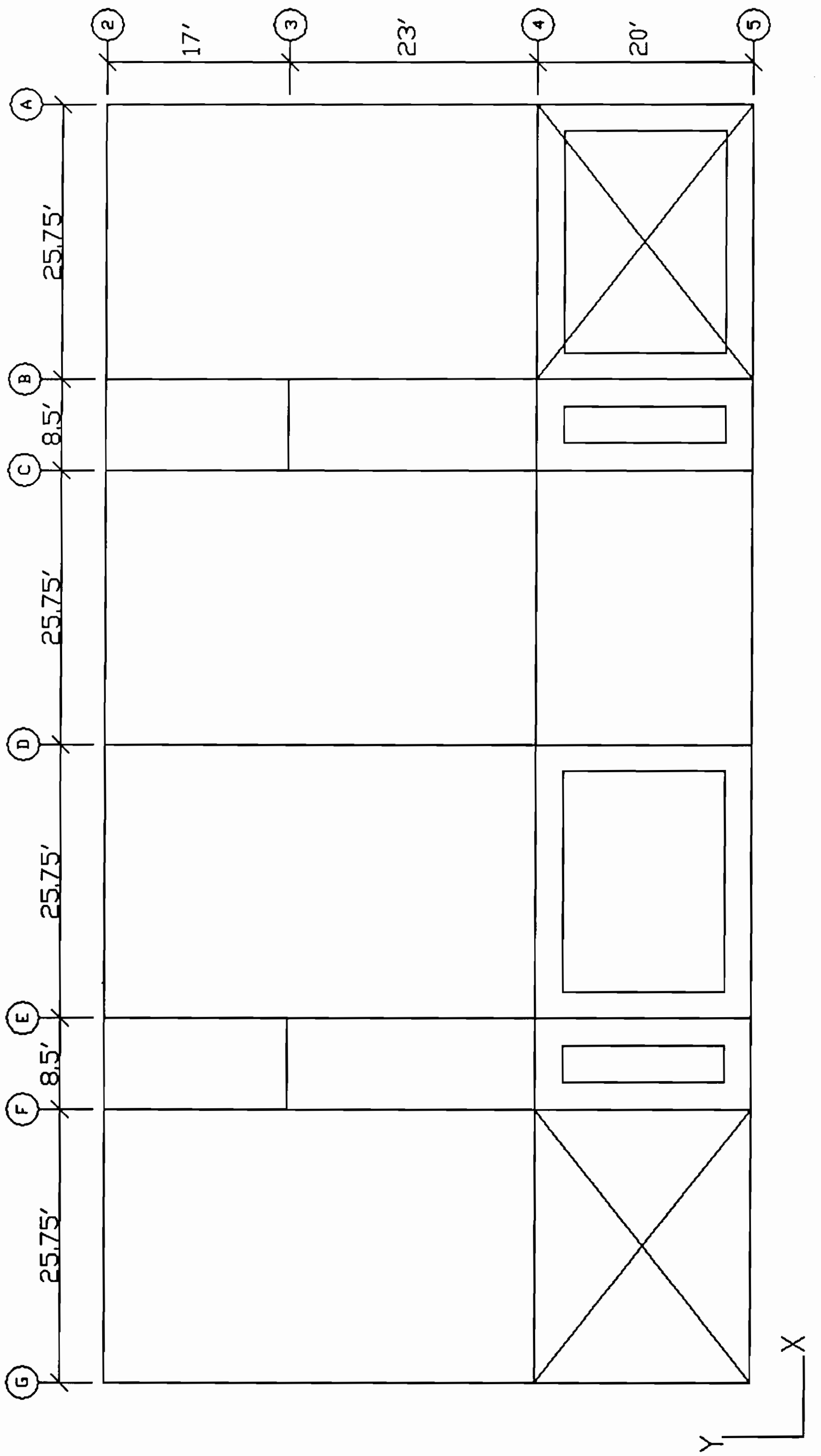


Figure 19. Plan view of Low Roof of building 171.09

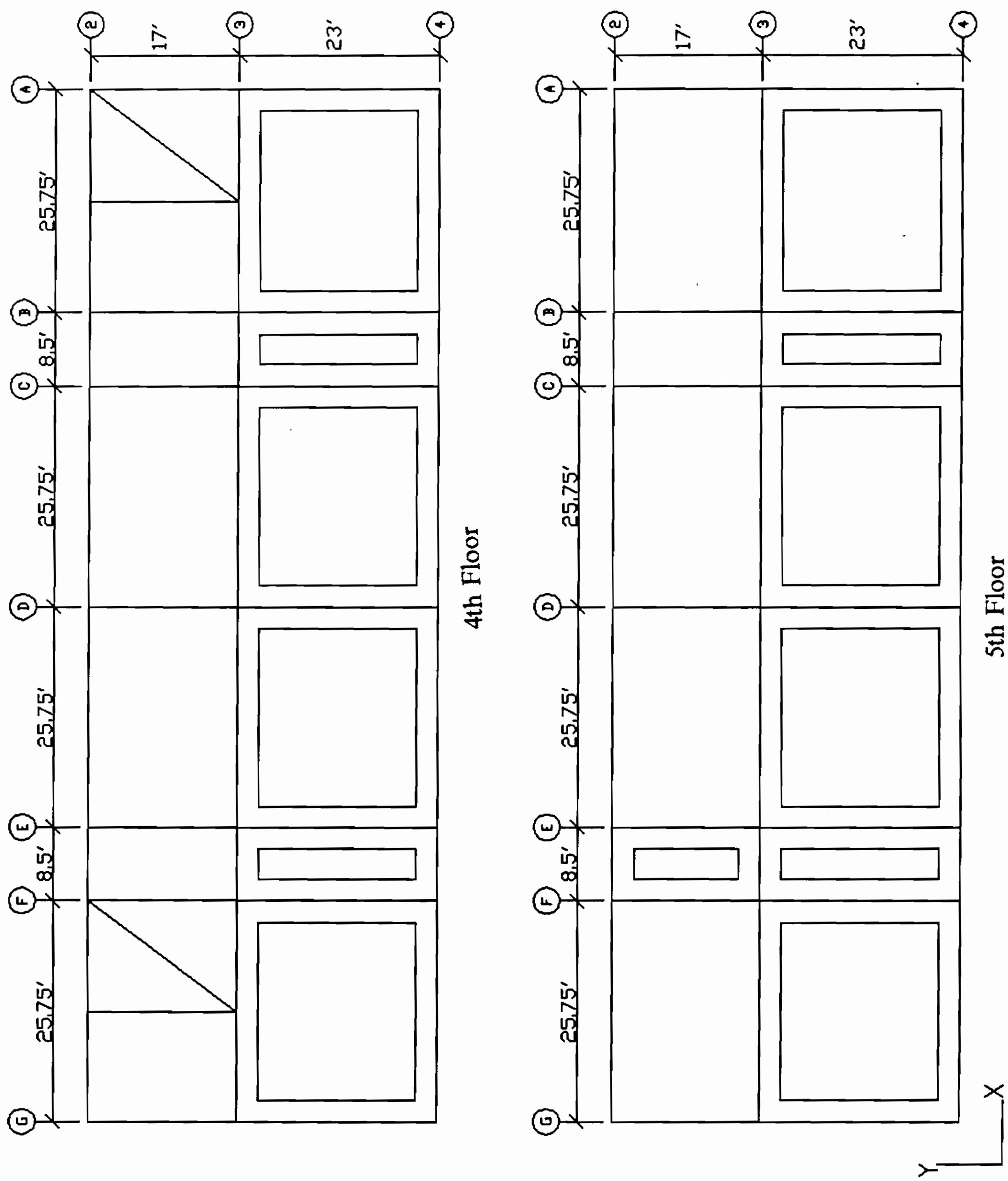


Figure 20. Plan view of 4th and 5th floors of building 17L09

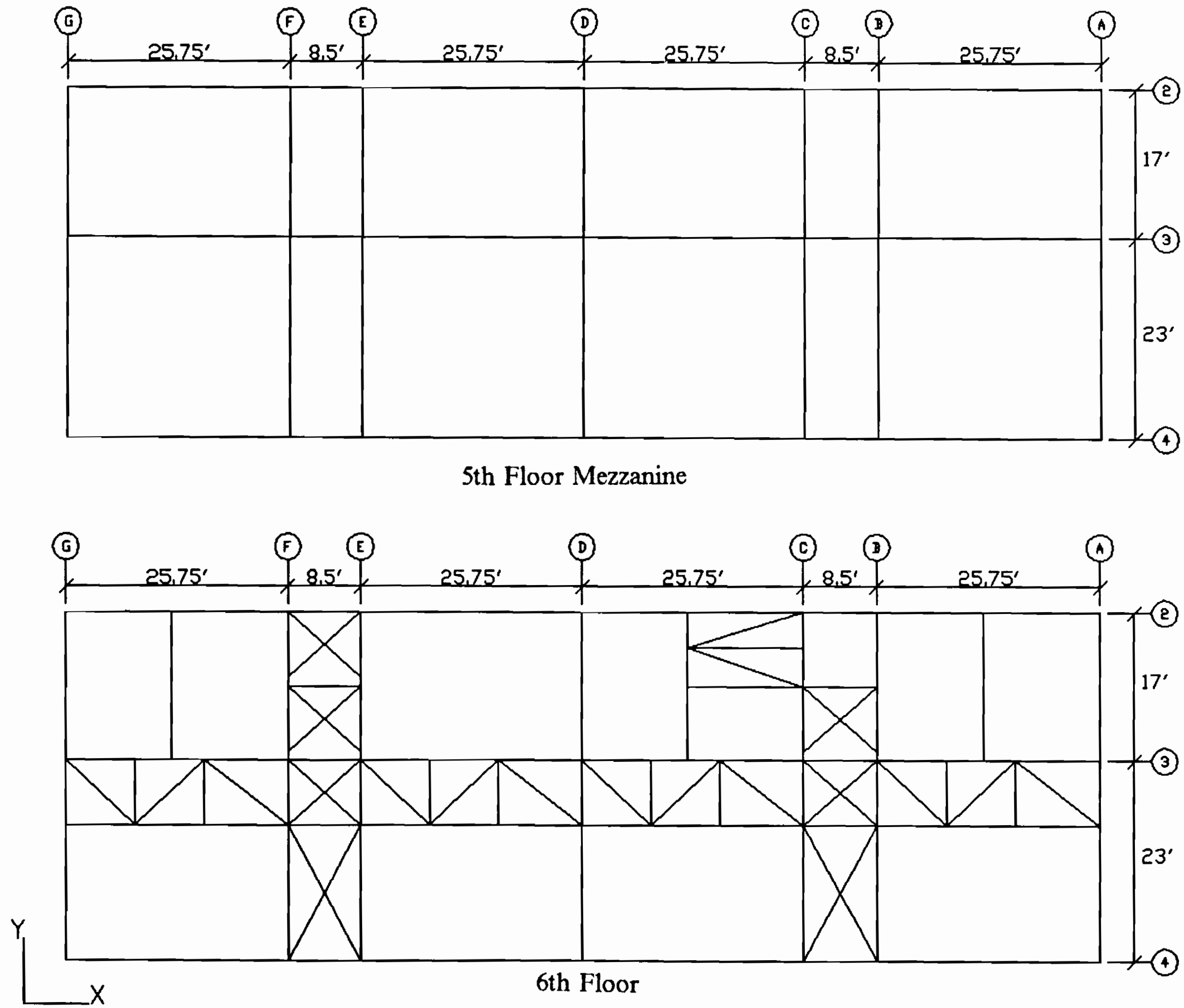


Figure 21. Plan view of 5th Floor Mezzanine and 6th floor of building 17L09

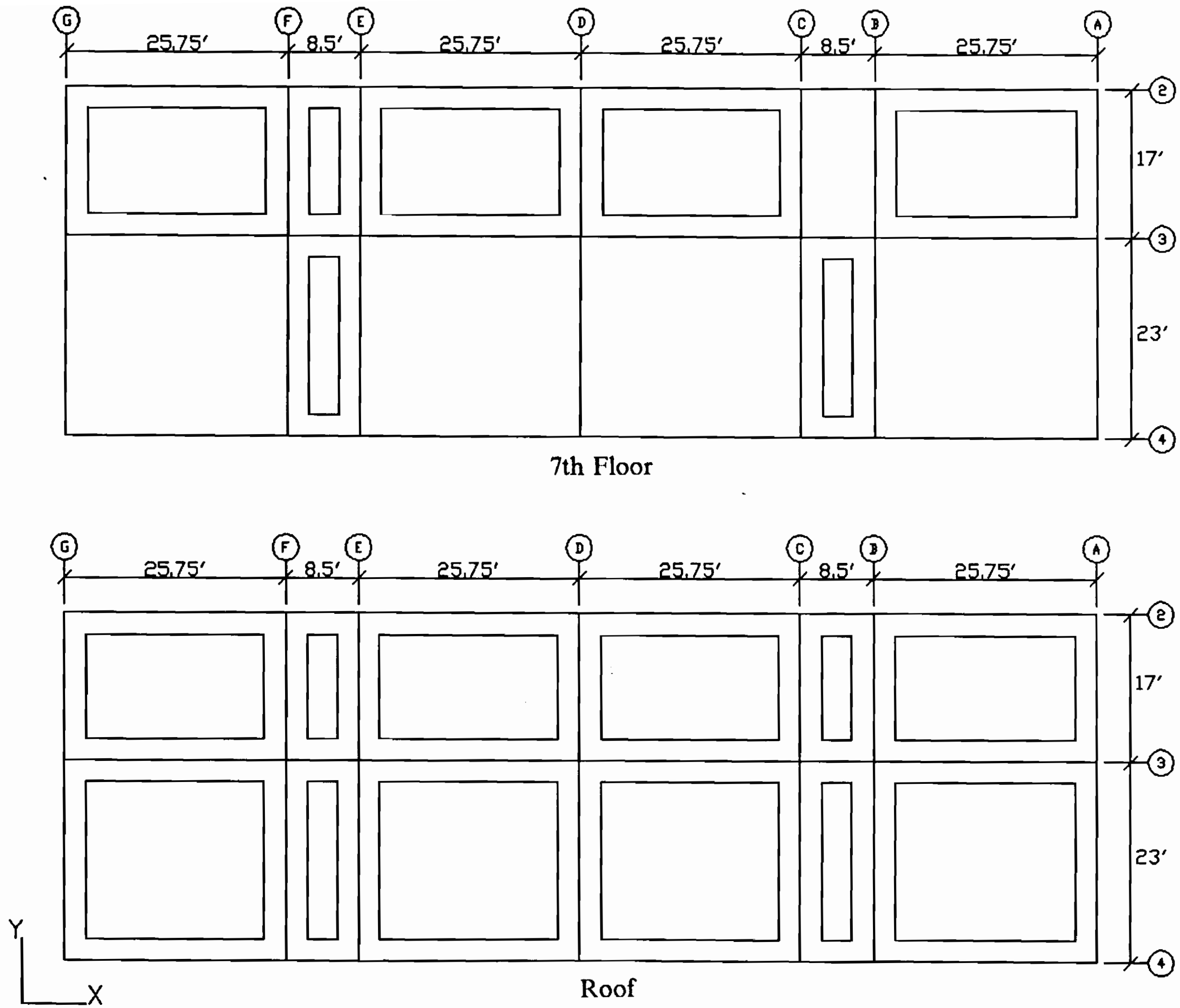


Figure 22. Plan view of 7th floor and roof of building 17L09

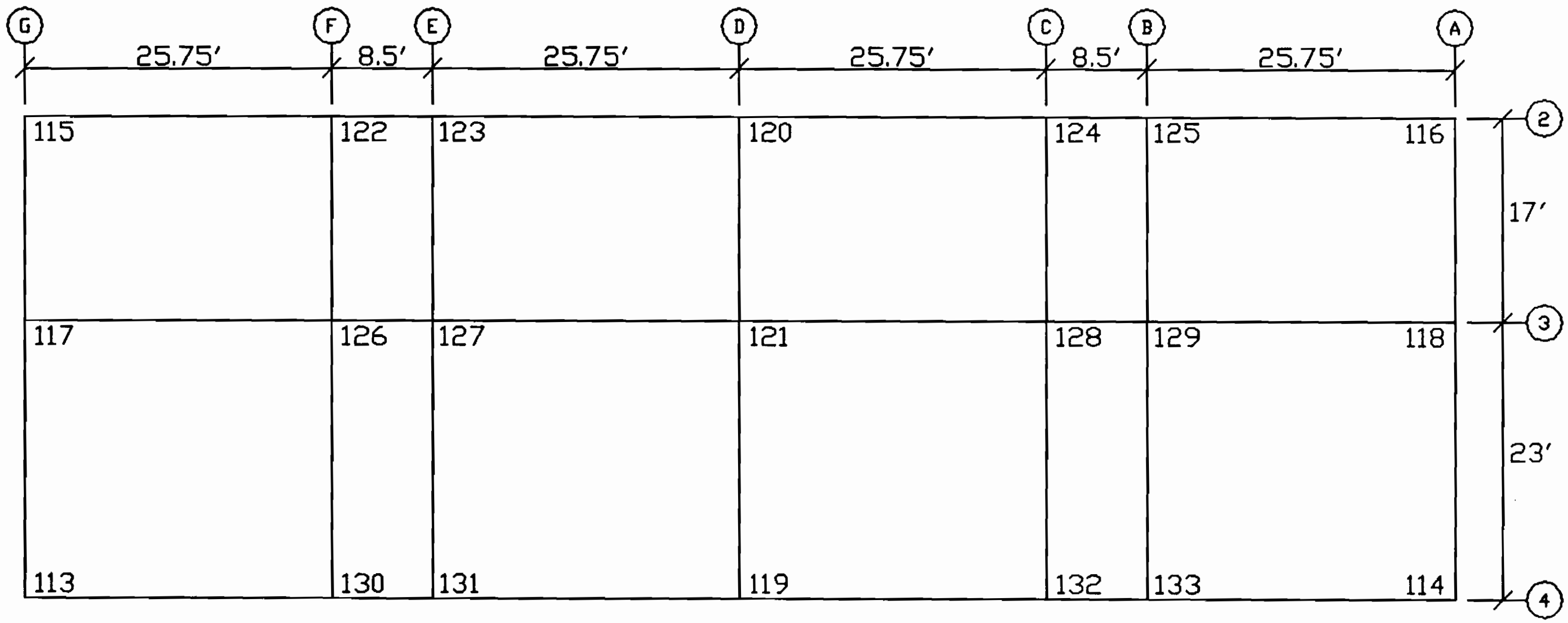


Figure 23. Node numbering of roof of building 17L09

3.3.1 Columns

The structure has columns of different sizes, each with a nominal depth of 14 inches. However, all of the columns along column line 1 were W10x49 sections. The column sizes decrease as a function of height. There are also eight columns between the first and second floors and one between the sixth and seventh floors that have cover plates. The columns in column lines 1, 2, 4, and 5 are oriented so that their local y-axis is parallel to the global y-axis, while the columns in column line 3 are oriented so that their local y-axis is parallel to the global x-axis. The member modeling centerline of the element passes through the centroid of the column, which is cardinal point 15 in MicasPlus.

3.3.2 Girders

All of the girders have simple (pinned) connections. The girders are oriented so that their local y-axis is in the global z-direction. The beams were modeled so that the member modeling centerline passes through the centroid of the section, which is cardinal point 15 in MicasPlus. The girders spanning between column line 1 and 2 all have a rigid end offset of 7.5 inches at column line 1. All of the girders spanning between column lines 2 and 3, except those on the sixth floor, have a rigid end offset of -7.5 inches at column line 2. All of the girders spanning between column lines 3 and 4, except for those on the 6th floor, have a rigid end offset of 7.5 inches at column line 4. The girders spanning between column lines 4 and 5 have a rigid end offset of 6 inches at column line 4 and -7.5 inches at column line 5. All of the girders along column line 3 have a rigid end offset of 7.5 inches at the beginning and -7.5 inches at the end of the member. The start end of the girders in column line 3 are the ends with the smaller x coordinate. The rigid end offsets are specified in the structural model because the actual length of the girder is shorter than the span length due to the fact that the beam frames into the flange(s) of a column.

3.3.3 Vertical Bracing

The vertical bracing is located along column lines 2, 4, 5, A, D, and G (see Figs. 9-10, 12-15). All of the bracing, except that along column line D, is made up of WT sections. The bracing is oriented so that the webs are perpendicular to the plane in which they are contained and the flanges face inwards. All the vertical bracing members, except those along column line D, have rigid end offsets to account for the fact that the centroid of the member does not coincide with the line of action of the force. The bracing along column line D is made up of W sections and one pipe section. They are oriented so that the local y-axis is parallel to the global x-axis. The ends of all the vertical braces are fixed.

3.3.4 Horizontal Bracing

There is horizontal bracing at the low roof, fourth floor, and sixth floor levels. The bracing at the low roof and fourth floor levels is made up of WT sections oriented so that the local y-axis is in the global xy-plane. The bracing at the sixth floor level consists of equal leg single angles oriented so that the local y-axis is in the global xy-plane. The member modeling centerline of the elements pass through the centroid of the section. All of the bracing is pinned at the ends.

3.3.5 Finite Elements

Planar finite elements were used to simulate the effect of floor slabs in the structure. The floor slabs consist of 4000 psi concrete and are four inches thick. The location of the elements is shown in Figures 16-22. The inactivated elements are not shown in the figures. The PSHQ element was used in GTSTRUDL and the QUMB element was used in MicasPlus to model the floor slabs. The elements, which are not ideal for modeling floor slabs, were used because of the need to find compatible elements in MicasPlus and GTSTRUDL and the limited number of elements in MicasPlus, the same situation that occurred for the smaller braced frame.

3.3.6 Supports

The structure is supported by a combination of fixed supports, pinned supports with torsional resistance, and horizontal springs which simulate lateral column resistance due to the presence of a grade beam. The fixed supports are located at the base of all the columns in column lines 1, 3, and 4, and columns A2, C2, E2, G2, C5, and E5. The remaining columns have pinned supports with torsional resistance. The springs, which were of three different stiffnesses, are located throughout the structure at a distance of six inches above the bottom supports. The restraint due to the springs is part of the support condition in GTSTRUDL but had to be modeled by placing linear springs in MicasPlus because the supports in MicasPlus do not have this feature.

3.3.7 Loading Conditions

The building is acted upon by seven different load cases. The load cases include: wind from the north (LC1), wind from the west (LC2), dead load acting on the structure and the weight of the girders (LC3), weight of the columns (LC4), dead and live load acting on the structure and the weight of the girders (LC5), earthquake load in the north/south direction (LC6), and wind load from the east (LC7). All of the loads were modeled as joint loads or concentrated element end forces acting at the ends of the members except for the weight of the columns, which are body loads. There are no load combinations.

3.3.8 Creation of Tennessee Eastman Building 17L09 in MicasPlus

Tennessee Eastman building 17L09 was created in MicasPlus by using a neutral file. The building had already been modeled and analyzed by the Tennessee Eastman Company in GTSTRUDL. The GTSTRUDL input file was used to create neutral file B17L09.GEO. This neutral file was then read into a newly created MicasPlus Analysis file through the PSD. Some editing was then done to ensure that the proper member sizes, member end conditions, support conditions, and rigid end offsets were entered in the structure. All of the springs; the loads in load cases 2, 3, 4, 5, and 7; rigid end offsets; and element properties for the plated columns had to be entered manually since they were not contained in the neutral file. The loads were not entered until the structural model had been copied and the second version created. Also, approximately 65% of the beam, column, and brace member sizes had to be changed.

After editing, the structural model was copied into another file and the element properties of the vertical bracing were modified in order to create the second structural model.

Chapter 4

Design and Analysis Results

In this chapter the numerical results obtained from MicasPlus and GTSTRUDL for the three structural models described in Chapter 3 are presented. The results include support reactions, element end forces, nodal displacements, code checks, and member sizes from steel design. The results from the two programs are compared to determine the accuracy of MicasPlus (it is assumed that the results from GTSTRUDL are correct). The results for each of the three structures are discussed individually and then an overview of the results is presented.

4.1 Tennessee Eastman Building 267g

A representative sample of the numerical results for Tennessee Eastman Building 267g is shown in Tables 1-4. Table 1 shows the support reactions Fx, Fy, and Fz at nodes 1, 7, 10, and 21 for load cases 1 through 7 from MicasPlus and GTSTRUDL and the percentage difference between the two.

Table 1. Support reactions for building 267g

Load Case 1(kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
1	20.9729	263.667	0.008326	20.9454	263.68	0.0075	0.13%	0.00%	- -
7	-0.004624	155.3389	21.7525	-0.0045	155.3277	21.7516	- -	0.01%	0.00%
10	28.4702	331.1685	-28.1667	28.4342	331.144	-28.1502	0.13%	0.01%	0.06%
21	0.002846	222.723	-17.5395	0.0028	222.7285	-17.5396	- -	0.00%	0.00%

Load Case 2 (kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
1	9.836	140.5146	0.0108	9.8224	140.5211	0.0104	0.14%	0.00%	- -
7	-0.003084	119.8421	16.5561	-0.003	119.8364	16.556	- -	0.00%	0.00%
10	14.4841	173.5658	-14.6885	14.4663	173.5538	-14.6799	0.12%	0.01%	0.06%
21	0.0004455	171.9585	-13.8611	0.0004	171.963	-13.861	- -	0.00%	0.00%

Load Case 3 (kips)

Node no.	Micas Plus			GTStrudl			Percentage Diference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
1	11.1298	44.8426	0.0428	11.137	44.8415	0.0421	0.06%	0.00%	- -
7	-0.0216	-0.8014	-0.3871	-0.0217	-0.7964	-0.387	- -	- -	- -
10	10.368	45.3936	-1.1328	10.3716	45.3977	-1.1291	0.03%	0.01%	0.33%
21	-0.0194	-1.1446	-0.1084	-0.0195	-1.1422	-0.1088	- -	0.21%	- -

Load Case 4 (kips)

Node no.	Micas Plus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
1	0.4862	2.4592	-0.00662	0.4883	2.4619	-0.0065	- -	0.11%	- -
7	0.002484	52.6904	12.1484	0.0025	52.6888	12.1452	- -	0.00%	0.03%
10	-1.9244	-50.1938	11.8098	-1.9224	-50.197	11.8107	0.10%	0.01%	0.01%
21	-0.000188	-52.4395	11.8898	-0.0002	-52.4384	11.8872	- -	0.00%	0.02%

Load Case 5 (kips)

Node no.	Micas Plus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
1	0.6504	6.7953	0.000977	0.6508	6.803	0.001	- -	0.11%	- -
7	-0.0003232	5.8601	0.7157	-0.0003	5.8665	0.7165	- -	0.11%	- -
10	0.6694	8.0431	-0.6562	0.6697	8.0518	-0.6567	- -	0.11%	- -
21	-0.0002003	5.6669	-0.7136	-0.0002	5.6734	-0.7143	- -	0.11%	- -

Load Case 6 (kips)

Node no.	Micas Plus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
1	23.4477	87.4366	0.0779	23.4618	87.4326	0.0766	0.06%	0.00%	- -
7	-0.0238	-1.6048	-0.8168	-0.0239	-1.5983	-0.8168	- -	0.41%	- -
10	22.2357	90.1294	-2.0238	22.2422	90.1387	-2.0169	0.03%	0.01%	0.34%
21	-0.0222	0.2785	-0.5459	-0.0223	0.2776	-0.546	- -	- -	- -

Load Case 7 (kips)

Node no.	Micas Plus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
1	0.1409	0.6088	-0.0125	0.1441	0.6127	-0.0118	- -	- -	- -
7	0.002182	89.7835	22.2773	0.0022	89.7811	22.2725	- -	0.00%	0.02%
10	-2.7858	-90.1606	23.0209	-2.7832	-90.1668	23.0229	0.09%	0.01%	0.01%
21	0.0009461	-89.5875	21.7887	0.0009	-89.5867	21.7848	- -	0.00%	0.02%

Table 2. Element end forces for building 267g

Load Combination MAXGR

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-317.872	0.1499	-0.112	-317.877	0.1488	-0.1195	0.00%	- -	- -
14	29	-182.534	-0.8971	-0.6881	-182.549	-0.8977	-0.6701	0.01%	0.07%	2.69%
20	29	-2.4188	0	0	-2.5874	0	0	6.52%	- -	- -
107	111	-33.9521	0.2344	-0.0355	-33.9136	-0.2339	0.0345	0.11%	- -	- -
148	116	-1.3594	-0.0733	-0.0809	-1.3805	-0.0733	-0.0807	1.53%	- -	- -

Load Combination MAXDSW

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-184.259	0.1164	0.9335	-184.265	0.1172	0.9137	0.00%	- -	2.17%
14	29	-93.5243	-0.3847	-0.1889	-93.5316	-0.3845	-0.1812	0.01%	- -	- -
20	29	-1.3031	0	0	-1.3999	0	0	6.91%	- -	- -
107	111	-28.7887	0.2577	-0.0718	-28.7811	-0.2574	0.0709	0.03%	- -	- -
148	116	-1.5669	-0.0748	-0.0897	-1.5845	-0.0748	-0.0894	1.11%	- -	- -

Load Combination MAXDNE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-184.245	0.12	-0.8089	-184.249	0.1186	-0.796	0.00%	- -	1.62%
14	29	-95.352	-0.376	0.6658	-95.3599	-0.3765	0.6599	0.01%	- -	0.89%
20	29	-1.5928	0	0	-1.6864	0	0	5.55%	- -	- -
107	111	4.696	0.2974	0.0334	4.7295	-0.297	-0.0335	0.71%	- -	- -
148	116	-1.2014	-0.0787	0.0125	-1.2067	-0.0787	0.0125	0.44%	- -	- -

Load Combination MAXGSW

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-238.463	0.104	0.469	-238.467	0.1043	0.4539	0.00%	- -	- -
14	29	-135.763	-0.6659	-0.5246	-135.773	-0.666	-0.5112	0.01%	0.02%	2.62%
20	29	-1.7791	0	0	-1.9087	0	0	6.79%	- -	- -
107	111	-33.9787	0.1645	-0.0613	-33.9586	-0.1641	0.0602	0.06%	- -	- -
148	116	-1.3334	-0.0538	-0.0942	-1.3538	-0.0538	-0.0939	1.51%	- -	- -

Table 3. Nodal displacements for building 267g

Load Case 1 (inch)

Node	MicasPlus			GTStrudl			Percentage Difference		
no.	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
24	0.0235	-0.1478	0.0654	0.0234	-0.1478	0.0657	- -	0.00%	0.46%
26	0.0201	-0.0891	0.003916	0.0198	-0.0891	0.0038	- -	0.00%	- -
32	0.0407	-0.0925	0.0269	0.0406	-0.0925	0.0269	- -	0.00%	- -
86	0.0378	-0.3112	0.0908	0.0381	-0.3112	0.0906	- -	0.00%	0.22%

Load Case 2 (inch)

Node	MicasPlus			GTStrudl			Percentage Difference		
no.	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
24	-0.0102	-0.1108	0.0561	-0.0103	-0.1108	0.0562	- -	0.00%	0.18%
26	0.007778	-0.0401	0.005088	0.0076	-0.0401	0.005	- -	- -	- -
32	0.0133	-0.0714	0.0249	0.0133	-0.0714	0.0248	- -	0.00%	- -
86	0.0135	-0.1628	0.0779	0.0135	-0.1628	0.0779	- -	0.00%	0.00%

Load Case 3 (inch)

Node	Micas Plus			GTStrudl			Percentage Diference		
no.	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
24	-0.1359	0.000954	0.000416	-0.1358	0.0009	0.0004	0.07%	- -	- -
26	-0.0443	0.007384	0.003127	-0.0443	0.0074	0.0031	- -	- -	- -
32	-0.1103	0.000611	-0.00212	-0.1102	0.0006	-0.0021	0.09%	- -	- -
86	-0.7039	-0.00055	0.008931	-0.7047	-0.0005	0.009	0.11%	- -	- -

Load Case 4 (inch)

Node	Micas Plus			GTStrudl			Percentage Difference		
no.	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
24	0.0394	9E-05	-0.2029	0.0394	0.0001	-0.2027	- -	- -	0.10%
26	-0.00211	0.000431	-0.0517	-0.002	0.0004	-0.0516	- -	- -	0.19%
32	-0.00565	-0.0249	-0.1262	-0.0056	-0.0249	-0.1263	- -	- -	0.08%
86	0.0278	0.000267	-0.2582	0.0279	0.0003	-0.2584	- -	- -	0.08%

Load Case 5 (inch)

Node	Micas Plus			GTStrudl			Percentage Difference		
no.	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
24	-7E-05	-0.00305	-0.00027	-0.0001	-0.0031	-0.0003	- -	- -	- -
26	2.04E-05	-0.00147	6.17E-05	0	-0.0015	0.0001	- -	- -	- -
32	-0.00062	-0.00288	-0.00029	-0.0006	-0.0029	-0.0003	- -	- -	- -
86	-1.2E-05	-0.00294	-4E-05	0	-0.0029	0	- -	- -	- -

Load Case 6 (inch)

Node	Micas Plus			GTStrudl			Percentage Difference		
no.	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
24	-0.2645	0.000668	0.004276	-0.2644	0.0007	0.0043	0.04%	- -	- -
26	-0.0918	0.014	0.006139	-0.0918	0.014	0.0061	0.00%	- -	- -
32	-0.222	0.000899	-0.00069	-0.2218	0.0009	-0.0007	0.09%	- -	- -
86	-0.6822	-0.00039	0.012	-0.6825	-0.0004	0.012	0.04%	- -	- -

Load Case 7 (inch)

Node	Micas Plus			GTStrudl			Percentage Difference		
no.	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
24	0.0606	1.55E-05	-0.3369	0.0606	0	-0.3366	0.00%	- -	0.09%
26	-0.00069	0.000101	-0.0963	-0.0006	0.0001	-0.0961	- -	- -	0.21%
32	-0.00099	-0.0403	-0.2182	-0.0008	-0.0403	-0.2183	- -	- -	0.05%
86	0.0388	0.000419	-0.3941	0.039	0.0004	-0.3942	- -	- -	0.03%

Table 4. Code check for (a) building 267g and (b) moment resisting frame

(a) building 267g

Element no.	Code Check		Percentage Difference
	Micas Plus	GTStrudl	
11	0.871	0.8708	0.02%
14	0.376	0.3759	0.03%
18	0.041	0.0427	- -
20	0.02	0.0206	- -
24	0.21	0.2098	0.10%
32	0.004	0.0045	- -
34	0.015	0.0155	- -
37	0.012	0.0123	- -
43	0.008	0.0081	- -
46	0.01	0.0109	- -
48	0.389	0.3891	0.03%
53	0.258	0.2582	0.08%
58	0.654	0.6544	0.06%
60	0.219	0.2187	0.14%
91	0.564	0.5519	2.19%
102	0.063	0.0633	- -
110	0.625	0.6246	0.06%
118	0.226	0.2264	0.18%
120	0.579	0.589	1.70%
124	0.526	0.5263	0.06%
131	0.499	0.5086	1.89%
139	0.345	0.3536	2.43%
149	0.598	0.5863	2.00%
153	0.537	0.5451	1.49%

(b) moment resisting frame

Element no.	Code Check		Percentage Difference
	Micas Plus	GTStrudl	
2	0.63	0.631	0.16%
5	0.901	0.9017	0.08%
6	0.67	0.6703	0.04%
13	0.747	0.755	1.06%
19	0.257	0.2456	4.64%
23	0.341	0.3478	1.96%
24	0.154	0.1522	1.18%
28	0.178	0.1791	0.61%
30	0.855	0.8654	1.20%
35	0.871	0.8484	2.66%
38	0.428	0.434	1.38%
41	0.562	0.549	2.37%
43	0.23	0.2295	0.22%
49	0.342	0.3419	0.03%
54	0.183	0.1816	0.77%
56	0.334	0.3291	1.49%
57	0.379	0.3764	0.69%
63	0.149	0.145	2.76%
87	0.142	0.1428	0.56%
88	0.612	0.6148	0.46%
89	0.9	0.9009	0.10%
97	0.158	0.1586	0.38%
101	0.107	0.1073	0.28%
104	0.083	0.0835	- -

The nodes, selected at random, are located at the bottom of columns A4 (node 1), D4 (node 7), A2 (node 10), and D3 (node 21). Table 2 shows the axial force and moments about the local y and z axes from MicasPlus and GTSTRUDL and the percentage difference between the two for elements 3, 14, 34, 107, and 148 for load combinations MAXGR, MAXDSW, MAXDNE, and MAXGSW. The forces and moments are acting at node 27 of element 3, node 29 of element 14, node 29 of element 20, node 111 of element 107, and node 116 of element 148. The elements are beam (element 20), column (elements 3 and 14), and brace (elements 107 and 148) elements. Table 3 shows the translational nodal displacement in the three global directions at nodes 24, 26, 32, and 86 for load cases 1 through 7 in MicasPlus and GTSTRUDL and the corresponding difference difference. The nodes, selected at random, are located along columns B4 (node 26), D4 (node 32), C3 (node 86), and D2 (node 24). Table 4 shows the code checks for a total of 24 different elements in MicasPlus and GTSTRUDL and the percentage difference between these values. The elements consist of eight beam (elements 18, 20, 32, 34, 37, 43, 46, 48, and 102), eight column (elements 11, 14, 24, 48, 53, 58, 60, and 91), and eight bracing members (elements 110, 118, 120, 124, 131, 139, 149, and 153). The two dash lines in the percentage difference columns of the tables throughout this chapter and in the appendices indicate that the values were not considered to be significant. This is because the magnitude of the computed results is so small that it would be greatly affected by round-off errors in the computer and therefore a percentage error evaluation would not be useful. The remainder of the results for Building 267g are shown in Appendix A.

The support reactions from MicasPlus and GTSTRUDL agreed within 0.4%. The results for the element end forces agreed within 1.5% except for the axial loads in the beam elements, which agreed consistantly within approximately 6.5%. The results for the nodal displacements agreed within 0.5%. The results for the code check agreed within 3%. These results imply that MicasPlus produces accurate results for the analysis and design of structures similar to Building 267g and that MicasPlus or GTSTRUDL does not compute axial forces accurately for members with transverse loading only.

4.2 *Moment Resisting Frame*

A representative sample of the numerical results for the moment resisting frame are shown in Tables 4-8. Table 4 shows the code checks for a total of 24 different elements in MicasPlus and GTSTRUDL and the percentage difference between the two. The elements consist of twelve beams (elements 13, 23, 28, 30, 35, 38, 41, 43, 87, 97, 101 and 104) and twelve columns (elements 2, 5, 6, 19, 24, 49, 54, 56, 57, 63, 88, and 89). Table 5 shows the support reactions Fx, Fy, and Fz at nodes 3, 13, 15, and 22 for load cases 1 through 7 from MicasPlus and GTSTRUDL and the percentage difference between the two. The nodes, selected at random, are located at the bottom of columns B4 (node 3), B3 (node 13), C3 (node 15), and D2 (node 22). Table 6 shows the axial force and moments about the local y and z axes from MicasPlus and GTSTRUDL and the percentage difference between the two for elements 7, 20, 54, 66, and 94 for load combinations MAXGR, MAXDSW, MAXDNE, and MAXGSW. The forces and moments are acting at node 43 of element 7, node 29 of element 20, node 20 of element 54, node 49 of element 66, and node 98 of element 94. The elements are beam (elements 20 and 66) and column (elements 7, 54, and 94) elements. Table 7 shows the translational nodal displacement in the three global directions at nodes 2, 41, 52, and 98 for load cases 1 through 7 in MicasPlus and GTSTRUDL and the percentage difference between the two. The nodes, selected at random, are located along columns A4 (node 2), A3 (node 41), B2 (node 52), and C4 (node 98). Table 8 shows the final design results for all of the columns. The final member sizes, code check values, and total weight of the structure in both MicasPlus and GTSTRUDL are given. The remainder of the results for the frame with moment resisting connections are shown in Appendix B.

The results from MicasPlus and GTSTRUDL for the support reactions, element end forces, and code checks agreed within 2% except for a few isolated cases. The results for the nodal displacements agreed within 1% except for a few isolated cases. MicasPlus designed columns that overall were slightly (1%) lighter than the columns designed in GTSTRUDL. It should be noted here that

Table 5. Support reactions for moment resisting frame

Load Case 1 (kips)

Node no.	MicasPlus Fx	MicasPlus Fy	MicasPlus Fz	GTStrudl Fx	GTStrudl Fy	GTStrudl Fz	Percentage Difference Fx	Percentage Difference Fy	Percentage Difference Fz
3	0.0353	417.2683	0.1025	0.0348	417.2941	0.1076	- -	0.01%	- -
13	0.0938	752.6734	0.0562	0.09	752.5916	0.0572	- -	0.01%	- -
15	0.0104	605.7806	0.0353	0.0083	605.9004	0.0382	- -	0.02%	- -
22	-0.1436	186.5325	-0.0501	-0.1391	186.3464	-0.0531	- -	0.10%	- -

Load Case 2 (kips)

Node no.	MicasPlus Fx	MicasPlus Fy	MicasPlus Fz	GTStrudl Fx	GTStrudl Fy	GTStrudl Fz	Percentage Difference Fx	Percentage Difference Fy	Percentage Difference Fz
3	-0.0033	184.8325	0.0426	-0.0032	184.8596	0.0444	- -	0.01%	- -
13	0.041	327.8681	0.0259	0.0394	327.8518	0.0263	- -	0.00%	- -
14	0.0588	249.2466	-0.0219	0.0579	249.2544	-0.0239	- -	0.00%	- -
22	-0.0738	137.1276	-0.033	-0.0714	137.0356	-0.035	- -	0.07%	- -

Load Case 3 (kips)

Node no.	Micas Plus Fx	Micas Plus Fy	Micas Plus Fz	GTStrudl Fx	GTStrudl Fy	GTStrudl Fz	Percentage Diference Fx	Percentage Diference Fy	Percentage Diference Fz
3	4.0327	-0.4167	-0.0404	4.0641	-0.3575	-0.0402	0.77%	- -	- -
13	6.0691	5.6067	-0.0519	6.0976	5.6422	-0.0517	0.47%	0.63%	- -
15	5.4734	6.7622	0.0975	5.4609	5.8298	0.0976	0.23%	- -	- -
22	2.0168	-17.7905	0.0361	1.993	-17.1923	0.0363	1.19%	3.48%	- -

Load Case 4 (kips)

Node no.	Micas Plus Fx	Micas Plus Fy	Micas Plus Fz	GTStrudl Fx	GTStrudl Fy	GTStrudl Fz	Percentage Difference Fx	Percentage Difference Fy	Percentage Difference Fz
3	0.0106	25.3468	6.6165	0.0135	25.3727	6.6275	- -	0.10%	0.17%
13	0.0298	-7.2879	8.3052	0.0303	-7.31	8.3246	- -	0.30%	0.23%
15	0.0283	-1.3444	5.8784	0.0288	-1.2428	5.8929	- -	- -	0.25%
22	-0.0136	-6.7981	1.7074	-0.015	-6.9371	1.7207	- -	2.00%	0.77%

Load Case 5 (kips)

Node no.	Micas Plus Fx	Micas Plus Fy	Micas Plus Fz	GTStrudl Fx	GTStrudl Fy	GTStrudl Fz	Percentage Difference Fx	Percentage Difference Fy	Percentage Difference Fz
3	0.000234	7.951	0.00037	0.0002	7.9454	0.0004	- -	0.07%	- -
13	0.000329	9.9318	0.000313	0.0003	9.9188	0.0003	- -	0.13%	- -
15	0.000133	8.3644	-0.0002	0.0001	8.3601	-0.0002	- -	0.05%	- -
22	-0.00056	4.5349	3.27E-05	-0.0005	4.535	0	- -	0.00%	- -

Load Case 6 (kips)

Node no.	Micas Plus Fx	Micas Plus Fy	Micas Plus Fz	GTStrudl Fx	GTStrudl Fy	GTStrudl Fz	Percentage Difference Fx	Percentage Difference Fy	Percentage Difference Fz
3	8.5412	-0.8445	-0.00717	8.6045	-0.7392	-0.007	0.74%	- -	- -
13	12.8854	10.3695	-0.0122	12.9456	10.425	-0.012	0.47%	0.53%	- -
15	11.6033	12.739	0.1122	11.5763	10.9099	0.1116	0.23%	16.77%	- -
22	4.3787	-35.1596	-0.00203	4.3263	-33.9277	-0.0016	1.21%	3.63%	- -

Load Case 7 (kips)

Node no.	Micas Plus Fx	Micas Plus Fy	Micas Plus Fz	GTStrudl Fx	GTStrudl Fy	GTStrudl Fz	Percentage Difference Fx	Percentage Difference Fy	Percentage Difference Fz
3	0.0264	38.1981	10.5512	0.0314	38.2678	10.574	- -	0.18%	0.22%
13	0.019	-13.1213	13.2619	0.0192	-13.1725	13.2982	- -	0.39%	0.27%
15	0.0185	-3.0135	10.8019	0.0192	-2.8379	10.8299	- -	6.19%	0.26%
22	-0.0138	-12.1677	3.3614	-0.0162	-12.4243	3.3865	- -	2.07%	0.74%

Table 6. Element end forces for moment resisting frame

Load Combination MAXGR

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
7	43	-761.015	-1.8829	1.1294	-759.335	-1.8057	1.1498	0.22%	4.28%	1.77%
20	29	0.0194	0.1371	2.1221	0.0209	0.1737	2.0514	- -	- -	3.45%
54	20	-152.845	2.1932	-0.7812	-151.942	2.1741	-0.7624	0.59%	0.88%	2.47%
66	49	0.2081	-0.1735	9.3703	0.2025	-0.1725	9.4545	- -	- -	0.89%
94	98	-17.491	0.0364	2.1985	-17.2823	0.037	2.2054	1.21%	- -	0.31%

Load Combination MAXDSW

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
7	43	-343.498	-0.2305	-165.579	-341.905	-0.1884	-165.96	0.47%	- -	0.23%
20	29	0.1519	1.2548	-1.4426	0.1512	1.2466	-1.565	- -	0.66%	7.82%
54	20	-96.8966	0.6808	-12.9048	-95.965	0.6389	-12.9961	0.97%	6.56%	0.70%
66	49	1.103	-1.3714	-22.1858	1.0991	-1.3623	-22.0391	0.35%	0.67%	0.67%
94	98	-9.5999	-0.1318	-2.2496	-9.3884	-0.1293	-2.2627	2.25%	- -	0.58%

Load Combination MAXDNE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
7	43	-323.089	-1.2063	265.7636	-321.423	-1.1795	266.4968	0.52%	2.27%	0.28%
20	29	0.0906	0.3542	-0.4526	0.0945	0.3772	-0.4685	- -	- -	- -
54	20	-92.5362	0.9748	20.1168	-91.562	0.9968	20.2712	1.06%	2.21%	0.76%
66	49	-2.9846	-0.3395	75.358	-2.9811	-0.3637	75.0599	0.12%	- -	0.40%
94	98	-10.0861	0.0171	4.1723	-9.8799	0.0106	4.192	2.09%	- -	0.47%

Load Combination MAXGSW

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
7	43	-576.227	-0.9646	-123.731	-574.984	-0.8991	-124.007	0.22%	- -	0.22%
20	29	0.0887	0.9785	1.2689	0.0888	0.9724	1.1848	- -	0.63%	- -
54	20	-116.049	1.7765	-10.4857	-115.386	1.7462	-10.5517	0.57%	1.74%	0.63%
66	49	0.9303	-1.0667	-12.172	0.9246	-1.0599	-12.0221	- -	0.64%	1.25%
94	98	-12.9573	-0.0866	-0.6721	-12.7992	-0.0839	-0.6787	1.24%	- -	0.97%

Table 7. Nodal displacements for moment resisting frame

Load Case 1 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
2	-0.0463	-0.0717	-4.9E-05	-0.0445	-0.0717	0	- -	0.00%	- -
41	-0.011	-0.0417	0.002018	-0.0112	-0.0417	0.0021	- -	- -	- -
52	-0.0215	-0.0745	0.0179	-0.0199	-0.0745	0.0179	- -	0.00%	- -
98	-0.0858	-0.0848	0.037	-0.0838	-0.0848	0.0365	2.39%	0.00%	- -

Load Case 2 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
2	-0.00793	-0.0389	-0.0026	-0.0074	-0.0389	0	- -	- -	- -
41	-0.00147	-0.0209	0.000488	-0.0012	-0.0209	0.0005	- -	- -	- -
52	-0.00094	-0.0355	0.008967	-0.0003	-0.0355	0.009	- -	- -	- -
98	-0.0173	-0.0485	0.0226	-0.0168	-0.0485	0.0223	- -	- -	- -

Load Case 3 (inch)

Node no.	Micas Plus Tx	Micas Plus Ty	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Diference Tx	Percentage Diference Ty	Percentage Diference Tz
2	-0.971	-0.00158	0.008552	-0.9623	-0.0016	0.0086	0.90%	- -	- -
41	-0.6451	-0.00093	0.005607	-0.641	-0.0009	0.0056	0.64%	- -	- -
52	-0.7857	-0.00058	0.003797	-0.7791	-0.0006	0.0038	0.85%	- -	- -
98	-1.5238	-0.00302	-0.00965	-1.5166	-0.0029	-0.0097	0.47%	- -	- -

Load Case 4 (inch)

Node no.	Micas Plus Tx	Micas Plus Ty	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
2	-0.00403	-0.00162	-0.3197	-0.0047	-0.0016	-0.3221	- -	- -	0.75%
41	-0.00293	0.00016	-0.2143	-0.0029	0.0002	-0.2157	- -	- -	0.65%
52	0.008025	0.002421	-0.4779	0.0085	0.0024	-0.4798	- -	- -	0.40%
98	0.0121	-0.00265	-0.5939	0.011	-0.0027	-0.5992	- -	- -	0.88%

Load Case 5 (inch)

Node no.	Micas Plus Tx	Micas Plus Ty	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
2	-0.00012	-0.00107	-7.3E-06	-0.0001	-0.0011	0	- -	- -	- -
41	-3.5E-05	-0.00054	1.97E-06	0	-0.0005	0	- -	- -	- -
52	-4.2E-05	-0.00094	4.55E-05	0	-0.0009	0	- -	- -	- -
98	-0.00024	-0.00135	4E-05	-0.0002	-0.0013	0	- -	- -	- -

Load Case 6 (inch)

Node no.	Micas Plus Tx	Micas Plus Ty	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
2	-1.9537	-0.00304	0.00785	-1.9365	-0.0031	0.0079	0.89%	- -	- -
41	-1.3642	-0.00185	0.005123	-1.3554	-0.0019	0.0052	0.65%	- -	- -
52	-1.7125	-0.00097	0.001837	-1.6982	-0.001	0.0018	0.84%	- -	- -
98	-2.2412	-0.00394	-0.0148	-2.2244	-0.0036	-0.0148	0.76%	- -	- -

Load Case 7 (inch)

Node no.	Micas Plus Tx	Micas Plus Ty	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
2	-0.0113	-0.00448	-0.8604	-0.0126	-0.0045	-0.8668	- -	- -	0.74%
41	-0.00145	0.000437	-0.5672	-0.0014	0.0004	-0.5709	- -	- -	0.65%
52	0.009163	0.003267	-0.7517	0.01	0.0033	-0.7552	- -	- -	0.46%
98	-0.0135	-0.00435	-1.0063	-0.0156	-0.0044	-1.0155	- -	- -	0.91%

Table 8. Final design results for moment resisting frame

Member no.	MicasPlus		GTStrudl	
	Member Size	Code Check	Member Size	Code Check
1	W14X233	0.825	W14X233	0.7393
2	W14X370	0.582	W14X342	0.631
3	W14X233	0.743	W14X233	0.7138
4	W14X145	0.619	W14X193	0.6372
5	W14X370	0.841	W14X342	0.90174
6	W14X233	0.753	W14X233	0.6703
7	W14X398	0.915	W14X398	0.87847
8	W14X370	0.648	W14X342	0.7187
9	W14X370	0.714	W14X342	0.84014
10	W14X233	0.884	W14X233	0.86213
11	W14X145	0.915	W14X193	0.87916
12	W14X145	0.704	W14X193	0.6858
88	W14X34	0.619	W14X34	0.6148
89	W14X34	0.876	W14X34	0.90089
90	W14X30	0.766	W14X30	0.72683
91	W14X34	0.592	W14X34	0.559
92	W14X34	0.631	W14X34	0.6226
93	W14X30	0.541	W14X30	0.4584
94	W14X30	0.536	W14X30	0.5168
95	W14X30	0.598	W14X30	0.5636

Total weight(GTStrudl)=200.51 kips

Total weight(MicasPlus)=198.592 kips

the effective length factor (K) could not be calculated properly in MicasPlus for the lower columns because it uses a relative stiffness factor (G) of infinity instead of 10 for a pinned support. Therefore, the K factors for these columns were taken from the GTSTRUDL design runs and assigned to the model in MicasPlus. This could have had some effect on the results in MicasPlus. The results imply that MicasPlus produces accurate results for both analysis and design of structures similar to the moment resisting frame and that MicasPlus designs an adequate, and possibly more efficient, structure.

4.3 Tennessee Eastman Building 17L09

Some of the results for Tennessee Eastman Building 17L09 are shown in Tables 9-10. Table 9 shows the support reactions Fx, Fy, and Fz at nodes 5, 417, 422, and 423 for load cases 1 through 7 from MicasPlus and GTSTRUDL and the percentage difference between the two. The nodes, selected at random, are located at the bottom of columns A4 (node 417), B5 (node 422), and A5 (node 423) and at the top of the grade beam (6 ft above the bottom of the column) at column G2 (node 5). Node 5 is a support that was modeled with linear springs. Table 10 shows the translational nodal displacement in the three global directions at nodes 115, 121, 123, and 133 for load cases 1 through 7 in MicasPlus and GTSTRUDL and the percentage difference between the two. The nodes, selected at random, are located at the roof level (see Fig. 23). The remainder of the results for building 17L09 are shown in Appendix C.

The results from MicasPlus and GTSTRUDL for the support reactions only agreed within 15% but agreed within 8% for reactions greater than 20 kips. The nodal displacements only agreed within 10% but agreed within 8% for load cases 1 and 6 and 1% for load cases 2 and 7 when the displacement was greater than one inch. The results for building 17L09 imply that MicasPlus is

Table 9. Support reactions for building 17L09

Load Case 1 (kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
5	-27.2	0.581	0	-26.52	0.498	0	2.56%	- -	- -
417	-0.1417	-0.5533	87.7528	-0.112	-0.477	82.93	- -	- -	5.82%
422	0.1907	-0.6171	-116.404	0.197	-0.601	-111.61	- -	- -	4.30%
423	-0.7533	0.7906	122.85	-0.873	0.555	117.512	- -	- -	4.54%

Load Case 2 (kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
5	4.758	-4.752	0	4.293	-5.897	0	10.83%	19.42%	- -
417	-0.759	2.7995	-26.7284	-0.592	2.641	-28.019	- -	6.00%	4.61%
422	-0.1716	-0.709	-52.7508	-0.182	-0.742	-52.547	- -	- -	0.39%
423	0.8948	-2.5534	-176.318	0.904	-2.346	-173.751	- -	8.84%	1.48%

Load Case 3 (kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
5	0.14662	-1.417	0	0.124	-1.505	0	- -	5.85%	- -
417	-0.00643	0.5405	145.8835	-0.005	0.457	145.936	- -	- -	0.04%
422	-0.00971	0.0674	47.7878	-0.006	0.076	47.803	- -	- -	0.03%
423	-0.02	0.258	34.6841	-0.015	0.194	34.788	- -	- -	0.30%

Load Case 4 (kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
5	0.010168	-0.0189	0	0.008	-0.022	0	- -	- -	- -
417	8.97E-05	0.008947	14.8893	0	0.007	14.914	- -	- -	0.17%
422	-0.00015	0.000123	3.9429	0	0	3.948	- -	- -	0.13%
423	-0.00077	0.007143	4.2292	-0.001	0.006	4.238	- -	- -	0.21%

Load Case 5 (kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
5	0.3524	-2.734	0	0.309	-2.979	0	- -	8.22%	- -
417	-0.0104	1.4375	363.9821	-0.007	1.234	364.08	- -	16.49%	0.03%
422	0.007922	0.1835	116.0888	0.014	0.209	116.096	- -	- -	0.01%
423	0.004972	0.7189	90.557	0.015	0.547	90.767	- -	- -	0.23%

Load Case 6 (kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
5	39.8	-0.7538	0	38.634	-0.605	0	3.02%	- -	- -
417	0.2133	0.909	-144.922	0.172	0.783	-137.111	- -	- -	5.70%
422	-0.2975	0.9096	179.7361	-0.306	0.88	171.788	- -	- -	4.63%
423	1.1546	-1.286	-198.381	1.338	-0.892	-189.436	13.71%	- -	4.72%

Load Case 7 (kips)

Node no.	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
5	-4.742	4.77	0	-4.276	5.92	0	10.90%	19.43%	- -
417	0.7553	-2.8008	27.1069	0.589	-2.642	28.361	- -	6.01%	4.42%
422	0.1713	0.7034	52.614	0.181	0.737	52.408	- -	- -	0.39%
423	-0.8953	2.5632	176.118	-0.905	2.353	173.545	- -	8.93%	1.48%

Table 10. Nodal displacements for building 17L09

Load Case 1 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Fz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
115	2.1853	0.5047	0.1667	2.1	0.475	0.152	4.06%	6.25%	- -
121	2.0203	-0.074	0.006287	1.946	-0.065	0.006	3.82%	- -	- -
123	2.1853	0.1751	-1.9E-07	2.1	0.167	0	4.06%	- -	- -
133	1.7959	-0.4057	0.1203	1.736	-0.375	0.115	3.45%	8.19%	- -

Load Case 2 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Fz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
115	-0.2547	2.5479	-0.0976	-0.23	2.568	-0.09	- -	0.78%	- -
121	-0.1488	2.9136	-0.1721	-0.127	2.924	-0.174	- -	0.36%	- -
123	-0.2516	2.7606	-3.2E-07	-0.227	2.775	0	- -	0.52%	- -
133	-0.0224	3.1076	0.1689	-0.003	3.113	0.168	- -	0.17%	- -

Load Case 3 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Fz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
115	-0.161	0.3663	-0.3469	-0.17	0.402	-0.315	- -	8.88%	10.13%
121	-0.1367	0.4515	-0.3026	-0.162	0.432	-0.303	- -	4.51%	0.13%
123	-0.1609	0.415	-0.1644	-0.17	0.419	-0.164	- -	0.95%	- -
133	-0.1042	0.5	-0.251	-0.151	0.449	-0.255	- -	11.36%	1.57%

Load Case 4 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Fz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
115	0.002144	-0.0046	-0.018	0.002	-0.003	-0.016	- -	- -	- -
121	0.002391	-0.00373	-0.0161	0.002	-0.004	-0.016	- -	- -	- -
123	0.002144	-0.0041	-0.0182	0.002	-0.004	-0.018	- -	- -	- -
133	0.002723	-0.00323	-0.0175	0.001	-0.005	-0.018	- -	- -	- -

Load Case 5 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Fz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
115	-0.131	0.9244	-0.554	-0.109	1.007	-0.501	- -	8.20%	10.58%
121	-0.1018	1.0271	-0.823	-0.103	1.025	-0.823	- -	0.20%	0.00%
123	-0.1308	0.9832	-0.4196	-0.109	1.018	-0.42	- -	3.42%	0.10%
133	-0.0629	1.0852	-0.6328	-0.097	1.035	-0.635	- -	4.85%	0.35%

Load Case 6 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Fz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
115	-3.6437	-0.9296	-0.281	-3.503	-0.883	-0.257	4.02%	5.28%	9.34%
121	-3.3445	0.1391	-0.0123	-3.221	0.124	-0.012	3.83%	- -	- -
123	-3.6456	-0.3195	3.23E-07	-3.505	-0.308	0	4.01%	3.73%	- -
133	-2.9379	0.7471	-0.1951	-2.839	0.697	-0.187	3.48%	7.19%	- -

Load Case 7 (inch)

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Fz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
115	0.2537	-2.5504	0.0975	0.229	-2.57	0.089	- -	0.76%	- -
121	0.1484	-2.9146	0.1741	0.126	-2.925	0.176	- -	0.36%	- -
123	0.2509	-2.7624	3.28E-07	0.226	-2.777	0	- -	0.53%	- -
133	0.0223	-3.1076	-0.1683	0.004	-3.112	-0.167	- -	0.14%	- -

not as accurate for the analysis of larger models as it is for smaller models and also that the accuracy improves as the magnitude of the result increases.

4.4 General

The results from GTSTRUDL and MicasPlus for the four story braced frame were almost identical, with the results for the worst cases agreeing within 3%. The only significant deviation in the results occurred in the axial forces of the beams, which agreed within only 6.5%. The results from MicasPlus and GTSTRUDL for the four story frame with moment resisting connections were also almost identical, with the results for the worst case agreeing within 2%. The designs for both GTSTRUDL and MicasPlus converged after four iterations, with MicasPlus designing a structure that was slightly lighter and with a slightly higher code check. The results from MicasPlus and GTSTRUDL for building 17L09 were not as close as those from the other two structures. The support reactions only agreed within 15% and the joint displacements only agreed within 10%. However, the agreement did improve as the magnitude of the result increased. The support reactions greater than 20 kips and the nodal displacements greater than one inch agreed within 8%.

These results imply that MicasPlus provides accurate analysis and design results for structures with a smaller number of members (less than 200) and reasonably accurate analysis results for structures with a larger number of members (approximately 1100). The results also imply that the accuracy of MicasPlus improves as the magnitude of the result increases.

Chapter 5

Functionality of MicasPlus

In this chapter the functionality of MicasPlus is discussed. Functionality, which is a non-technical evaluation of the software, is a measure of the non-technical strengths and weaknesses. It provides valuable information to the end user of the program regarding the ease of use, user friendliness, potential for user errors, quality of output and documentation, and a number of other factors, all of which are related to the use and performance of the program. Functionality can be determined by comparing the performance of different packages performing the same or similar tasks. Functionality is somewhat subjective since the importance of a particular task varies from user to user. However, there are some standard categories that can be evaluated between programs, such as user interface, printed output, and quality of support and documentation.

5.1 User Interface

The MicasPlus program employs a graphical user interface. This interface consists of a series of icons located along the top and right of the screen, a command line located at the very top of the screen, and the drawing area. It enables the user to construct a structural model by selecting icons to issue commands. The graphical user interface makes it easy to identify mistakes in the model since it provides constant visual feedback. MicasPlus works in conjunction with Microstation 32, which is a CAD program designed to operate on Intergraph workstations. This core graphics software provides MicasPlus with true three dimensional graphics capabilities and multiple display screens and views per screen.

The enhancements in graphics capabilities in the past few years has been reflected in the increase in the number of programs employing a graphical user interface. A graphical user interface has many advantages over character based interfaces. It provides the user with constant visual feedback on the model, which makes it easy to detect any errors in entering the geometry of the structure. It also makes model generation easier because only the end points of a linear member must be entered, member(s) may be copied and placed elsewhere, points and loads may be placed graphically instead of alphanumerically, large numbers of members may be accessed by use of a fence block to assign member or element properties. When editing a structure, the graphical interface enables the user to access as many members at a time as desired for editing and to display important information such as material properties and element properties on the screen for easy identification of errors. The disadvantage of a graphical interface is that it is relatively easy to overlook a minor error, such as an incorrect member or element property, because the hard copy of the input file is often not referenced and it is difficult to detect the error on the screen.

MicasPlus has all of the advantages of a graphical interface that were mentioned previously. There are, however, a few minor shortcomings with the graphical interface. The displays for the element type, UID number, and other entities do not always appear correctly on the screen. The text is sometimes inclined to the member or perpendicular to the screen. Some criteria, for example the active/inactive status of a member, cannot be displayed on the screen, thus making it difficult to check the accuracy of the structural model. Also, the fence block can be deleted only by placing another fence block.

5.2 Learning to Use the Software

MicasPlus is a relatively easy package to learn. No prior experience with CAD or any other software package is necessary to learn to use MicasPlus. The easiest and most efficient way to the software is to experiment with the program by creating several different types of structural models and analyzing and designing these (that is, hands on training). These models should have solutions available or already known so that the user can detect errors. The new user will make mistakes by learning this way, but will benefit from the exposure to the software and the manuals. Thoroughly learning the software is a gradual process that takes months of continued use.

5.3 Documentation

The documentation provided with MicasPlus is very good. The manuals are clear and concise and are easy to understand and follow. Almost any question that may arise about use of the software is answered in the manuals. The documentation provided with the program consists of the operator manual for ModelDraft and Analysis; reference guide for ModelDraft, Analysis (alphanumeric and graphical interface), and Design (Steel and Concrete); Parametric Modeling Language (PML) Programming Guide; IRM Analysis Theoretical Information; Intergraph/Finite Element Neutral File System Specification; and IRMD & MPD Design Theoretical Information and Verification Process User's Guide (Steel and Concrete). The output from the software is thorough but rather lengthy and cumbersome.

However, the documentation for MicasPlus could be improved. The number of manuals prepared by Intergraph for the MicasPlus software is large. In order to efficiently operate the software, only the operator manuals for MicasPlus ModelDraft, Analysis, and Design are needed. It would be useful if Intergraph had provided an introductory manual that demonstrated the use of the software by leading the user through all of the steps required for creating and analyzing a small model. This type of example problem would allow the novice user to have some type of hands-on experience with MicasPlus without attending a user workshop.

5.3.1 Program Output

The output from MicasPlus Analysis can be improved considerably. It is rather lengthy. This is due to the fact that: a) it is printed on standard letter size paper(8-1/2 x 11) instead of the wider computer paper, which reduces the number of available columns, b) a full heading is printed at the top of each page, which takes up an extra ten lines per page and, c) MicasPlus Analysis does not have any capabilities for specifying the number of member or joints for which the output is required and the program prints the output for all members and joints. For a large structure this could result in several hundred pages of output.

Another problem with the output is that only the first six characters of a load combination name are printed, and the characters are repeated, for the input data file. Therefore, if there is more than one load combination in which the first six characters are identical, it is difficult to distinguish these load combinations in the output. MicasPlus does not provide an option for overwriting existing output files. The user has to manually delete output files from the previous analysis from the hard disk.

MicasPlus Design allows the user to select the members for which output is required. Thus, the user can elect to print output for those members that are critical for the design. It also gives the user the option of printing to the screen or to a file, which is useful if a hard copy is required. The output from MicasPlus Design still has some of the same limitations as MicasPlus Analysis of being printed on standard size paper and containing too many headings.

5.4 Analysis

MicasPlus Analysis is very efficient for the construction and analysis of a structural model. The graphical interface makes it easy to construct a model. It also has the capability to perform many types of analysis (linear, non-linear, and dynamic) and to do them quickly and efficiently.

MicasPlus performs both matrix structural analysis and finite element analysis. It uses bandwidth minimization and to enhance the analysis process. Bandwidth minimization renumbers the model nodes so that the bandwidth and profile of the global stiffness matrix is a minimum. MicasPlus automatically switches to an out of core solver when a problem becomes too large to be solved in core.

There are a few limitations in the analysis features. One is that it is not possible to get a listing of the input data of the model without analyzing it. This can be an inconvenience for very large models because of all the time and computational effort that is necessary to analyze the structure. Another limitation is in the number of available planar finite elements. As of this writing, only five different planar In the version that was evaluated (IRM version 3) only five planar finite elements were available in MicasPlus Analysis, as compared to the 30 available in GTSTRUDL. This limits the modeling accuracy since there is a limited choice of elements.

Another limitation is that the user has no control over the numbering of the elements and nodes in the graphical interface. The computer numbers the elements and nodes in the order in which they are placed, and it is not possible to renumber the nodes and elements. Thus, the only way to ensure that the elements and nodes are numbered as desired/required is to create the structural model in the alphanumeric interface. In most situations, however, the numbering scheme for the elements and nodes is not important. It, however, becomes most critical when one is trying to compare the results with other programs, in which case it is much easier if the structural models in each program have the same element and node numbers.

Other limitations relate to load combinations. It is not possible to determine what load combinations have been formed because there is no list command in the load combination tutorial. This is true for both MicasPlus Analysis and MicasPlus Design. The only way to determine if a correct load combination has been formed, without analyzing the model, is to type in the title of the load combination in the tutorial and see if a combination having that name is found. It is also not possible to simply edit one load case or combination in the load combination equation. The entire equation must be reentered.

5.5 Design

MicasPlus Design steel design module is very good. It was easy to assign the design information to the structural members and also to display information about the structure. The design process itself was very efficient.

The MicasPlus Design module has one important limitation. It is not possible to specify a "G" (or relative stiffness) value for a member for the purpose of computing its effective length. This, coupled with the fact that MicasPlus Design uses a "G" value of infinity (instead of the customary 10) for a pinned support, makes it difficult to accurately calculate the effective length factors (K) for columns framing into a pinned support. This results in higher K values, which in turn result in longer effective lengths, reduced load carrying capacity for the member, higher code check values because the load on the member will not be reduced, and larger member sizes in design.

The greatest potential source for errors in MicasPlus Design is from the user not having a complete understanding of the design parameters to be assigned to the members. Some of the problems that were encountered include the fact that the K factor and beam unbraced lengths are based on span lengths, not physical member or finite element lengths and that a member bending unbraced length about the strong axis is taken as the largest value of either the top or the bottom unbraced length (both top and bottom unbraced length can be specified in MicasPlus). A thorough understanding and careful checking of the parameters must be done to ensure that these and other similar problems do not occur. The problem is further complicated because many of the design parameters cannot be displayed on the screen.

5.6 General Comments

Some of the other shortcomings in the MicasPlus software include:

1. Grid placement in ModelDraft must be done in a two- dimensional view or it will not come out correctly.

2. When constructing a plane frame model, the screen displays a three-dimensional model of the frame and the global-Y direction is not vertical.

3. The beta angles (angle which locates the member local Y and Z axis relative to the member local X axis) in MicasPlus and GTSTRUDL are different.

4. When entities such as elements and nodes are deleted, the file must be compressed in order to reduce the file size.

5. Loads cannot be re-oriented.

6. The "rotate section properties" command changes the major and minor axis of the element, but does not change them in the graphical interface.

7. When placing a member end in an isometric view, and a node of the member overlaps another node, the member end node is often placed at the same location as the existing node, even if coordinates for the node are typed in.

8. If a structure contains many loads, and some of the loads overlap, it is very difficult to delete a single load.

9. Mark groups sometimes have default parameters (such as alternate section tables) in Design.

10. It is important that the design data for the independent members and mark groups be checked in Design.

11. The "rotate view" command is difficult to understand and to use.

12. The program does not plot shear, moment, and deflection diagrams for the members.

Chapter 6

Summary and Conclusions

Two structures, a four story braced frame structure and a four story frame with moment resisting connections, were analyzed and designed, and a third structure, a 10 story braced frame structure, was analyzed in MicasPlus and GTSTRUDL in order to verify the accuracy of the Intergraph MicasPlus structural analysis and design software and to evaluate its functionality. Support reactions, element end forces, nodal displacements, code checks, and steel design were compared. Only linear static analysis and steel design based on the 1978 AISC Allowable Stress Design specification was considered. MicasPlus was run on an Intergraph Interpro 360 workstation and GTSTRUDL on a VAX.

The analysis and code check results from MicasPlus and GTSTRUDL for the four story braced frame structure and the four story frame with moment resisting connections were very similar (results agreed within 2%). MicasPlus Design designed a slightly (1%) lighter structure than GTSTRUDL for the four story frame with moment resisting connections. The analysis results from MicasPlus and GTSTRUDL for the 10 story braced frame structure were not in as close agreement for support reactions (within 15%) and nodal displacements (within 10%). However, the agreement of the results between the two software packages did improve to 8% for displacements greater than one inch and reactions greater than 20 kips.

The results show that MicasPlus is a reliable and accurate structural software package for linear static analysis and design of a smaller three dimensional steel frame structures (less than 200 members) and a somewhat less reliable and accurate software package for the linear static analysis of larger three dimensional steel frame structure (approximately 1100 members). This seems to indicate that MicasPlus suffers a loss in accuracy as the size of the structure increases, but more studies are needed to determine if and to what extent this is the case. The results also imply that the accuracy of MicasPlus improves as the magnitude of the result increases.

The functionality of MicasPlus is very good. The graphical interface in MicasPlus provides the user with a series of icons, pop-up and pull-down menus which allow for easy and accurate creation and revision of a structural model and any accompanying loads and boundary conditions. The graphics are excellent and the support documentation is very good, though quite extensive. There are, however, some minor deficiencies in the functionality of MicasPlus. These are documented earlier in the thesis.

There are some areas in which further studies could be focused in the area of verification and evaluation of analysis and design software. The areas include: verification and evaluation of dynamic and non-linear analysis and concrete design in MicasPlus, establishment of benchmarks that could be used as standards for all future verification and evaluation tests, continued tests on MicasPlus to determine if model size affects the accuracy of the model, and a study to determine how effectively an actual structure is modeled by a computer model. The final area of proposed study is especially important because if the computer cannot accurately model the structure, the results produced will not reflect the true behavior of the structure.

Bibliography

1. Rojiani, K. B., Hemler, S. R., Divecha, D., and White, M. W., *Verification and Evaluation of Intergraph MicasPlus Structural Analysis and Design Software*, Proceedings of International Intergraph Graphics Users Group Meeting, 5-7 October, 1990, New Orleans.

2. *Intergraph MicasPlus Technical Overviews.*, Intergraph Corportation, One Madison Industrial Park, Huntsville, Alabama.

3. *Engineering Systems - GTSTRUDL on VAX.*, Digital Equipment Corporation, Marlboro, Massachusetts.

4. Emkin, L. Z., *Computers in Structural Engineering Practice: the Issue of Quality*, Conference on Computing in Civil Engineering, 28-30 Oct., 1988, Alexandria, VA.

5. Melosh, R. J., and Senol, U., "Verification Tests for Computer-Aided Structural Analysis", *Microcomputers in Civil Engineering*, Vol. 3, No. 4, Dec., 1988, pp. 289-297.

6. Wallace, D., and Fujii, R. U., "Verification and Validation: Techniques to Assure Reliability", *IEEE Software (USA)*, Vol. 6, No. 3, May, 1989, pp. 8-9.

7. Wallace, D., and Fujii, R. U., "Software Verification and Validation: an Overview", *IEEE Software (USA)*, Vol. 6, No. 3, May, 1989, pp. 10-17.

8. Priest, J., *Engineering Design for Producibility and Reliability*, Marcel Decker, Inc., New York, 1988.

9. Vora, V., *Selection of Software*, ASCE, Conference on Computing in Civil Engineering, 28-30 October, 1988, Alexandria, VA.

10. Eskenasi, H., "Evaluation of Software Product Quality by Means of Classification Methods", *Journal of Systems and Software*, Vol. 10, No 3, Oct., 1989, pp. 213-216.

11. Chalabi, A., *Evaluation of ICES Reinforced Concrete Design Facilities*, ASCE, Conference on Computing in Civil Engineering, 26-29 June, 1978, Atlanta.

12. Machover, H., "How Good is PC CAD?", *Computer-Aided Engineering*, Vol. 8, No. 11, Nov. 1989, pp. 26-28, 30-31, 34.

13. *GTSTRUDL - Overview and Summary of Main Features.*, GTICES Systems Laboratory, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia.

Appendix A. Numerical Results from Tennessee Eastman Building 267g

Tennessee Eastman Building 267g

Support Reactions

Load Case 1

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	20.9729	263.667	0.008326	20.9454	263.68	0.0075	0.13%	0.00%	- -
3	-26.0019	443.533	-0.00397	-25.9735	443.5201	-0.0034	0.11%	0.00%	- -
4	-0.006447	313.4981	-0.00454	-0.0064	313.4984	-0.0049	- -	0.00%	- -
7	-0.004624	155.3389	21.7525	-0.0045	155.3277	21.7516	- -	0.01%	0.00%
9	-0.0107	482.644	23.9621	-0.0114	482.6551	23.9467	- -	0.00%	0.06%
10	28.4702	331.1685	-28.1667	28.4342	331.144	-28.1502	0.13%	0.01%	0.06%
13	-0.006686	764.7088	-0.00881	-0.0066	764.7067	-0.0091	- -	0.00%	- -
14	-23.4013	481.782	-0.00766	-23.3652	481.7928	-0.0075	0.15%	0.00%	- -
15	-0.005586	613.4502	-0.00096	-0.0058	613.4578	-0.0005	- -	0.00%	- -
16	-0.007027	439.9916	0.00304	-0.0073	440.0014	0.0034	- -	0.00%	- -
21	0.002846	222.723	-17.5395	0.0028	222.7285	-17.5396	- -	0.00%	0.00%
22	-0.00171	173.8949	0.006055	-0.0018	173.8878	0.006	- -	0.00%	- -

Load Case 2

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	9.836	140.5146	0.0108	9.8224	140.5211	0.0104	0.14%	0.00%	- -
3	-13.1215	201.2854	0.0107	-13.1071	201.2789	0.0109	0.11%	0.00%	- -
4	-0.005332	179.8064	0.0109	-0.0053	179.8065	0.0105	- -	0.00%	- -
7	-0.003084	119.8421	16.5561	-0.003	119.8364	16.556	- -	0.00%	0.00%
9	-0.0105	239.8345	11.896	-0.0108	239.84	11.8884	- -	0.00%	0.06%
10	14.4841	173.5658	-14.6885	14.4663	173.5538	-14.6799	0.12%	0.01%	0.06%
13	-0.009528	331.9597	0.0118	-0.0095	331.9592	0.0115	- -	0.00%	- -
14	-11.153	226.0259	0.008983	-11.1354	226.0314	0.009	0.16%	0.00%	- -
15	-0.007533	320.8504	0.0173	-0.0077	320.8519	0.0173	- -	0.00%	- -
16	-0.007975	255.9549	0.0145	-0.0081	255.9592	0.0145	- -	0.00%	- -
21	0.0004455	171.9585	-13.8611	0.0004	171.963	-13.861	- -	0.00%	0.00%
22	-0.002163	130.8018	0.0125	-0.0022	130.7986	0.0124	- -	0.00%	- -

Load Case 3

Node	Micas Plus			GTStrudl			Percentage Diference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
No.	kips			kips			%		
1	11.1298	44.8426	0.0428	11.137	44.8415	0.0421	0.06%	0.00%	- -
3	10.1858	-44.8426	0.0181	10.1799	-44.8415	0.0178	0.06%	0.00%	- -
4	-0.0457	1.1417	-0.0147	-0.0464	1.1389	-0.0143	- -	0.25%	- -
7	-0.0216	-0.8014	-0.3871	-0.0217	-0.7964	-0.387	- -	- -	- -
9	-0.0275	-0.1452	1.5812	-0.0277	-0.1466	1.5782	- -	- -	0.19%
10	10.368	45.3936	-1.1328	10.3716	45.3977	-1.1291	0.03%	0.01%	0.33%
13	-0.0531	0.187	0.0259	-0.0543	0.1879	0.0252	- -	- -	- -
14	9.6686	-44.6722	0.0226	9.6675	-44.6724	0.0221	0.01%	0.00%	- -
15	-0.0432	0.4222	-0.0188	-0.0441	0.4158	-0.0182	- -	- -	- -
16	-0.0259	0.3873	-0.013	-0.0265	0.3812	-0.0126	- -	- -	- -
21	-0.0194	-1.1446	-0.1084	-0.0195	-1.1422	-0.1088	- -	0.21%	- -
22	-0.0158	-0.7684	-0.0158	-0.0159	-0.7639	-0.0155	- -	- -	- -

Load Case 4

Node	Micas Plus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
1	0.4862	2.4592	-0.00662	0.4883	2.4619	-0.0065	- -	0.11%	- -
3	0.4513	-2.4592	-0.025	0.4511	-2.4619	-0.0249	- -	0.11%	- -
4	-0.000565	-0.0782	-0.0369	-0.0005	-0.0794	-0.0362	- -	- -	- -
7	0.002484	52.6904	12.1484	0.0025	52.6888	12.1452	- -	0.00%	0.03%
9	0.006517	47.7372	11.0462	0.0066	47.7378	11.0433	- -	0.00%	0.03%
10	-1.9244	-50.1938	11.8098	-1.9224	-50.197	11.8107	0.10%	0.01%	0.01%
13	0.006286	1.1145	-0.0615	0.0063	1.1161	-0.0585	- -	0.14%	- -
14	0.9584	1.4108	-0.0509	0.9543	1.4118	-0.0482	- -	0.07%	- -
15	0.004759	-0.2066	-0.0507	0.0048	-0.2044	-0.05	- -	- -	- -
16	0.007692	0.0375	-0.0374	0.0077	0.0372	-0.0368	- -	- -	- -
21	-0.000188	-52.4395	11.8898	-0.0002	-52.4384	11.8872	- -	0.00%	0.02%
22	0.001535	-0.0724	-0.0252	0.0015	-0.0724	-0.0251	- -	- -	- -

Load Case 5

Node no.	Micas Plus Fx (kips)	Micas Plus Fy (kips)	Micas Plus Fz (kips)	GTStrudl Fx (kips)	GTStrudl Fy (kips)	GTStrudl Fz (kips)	Percentage Difference Fx (%)	Percentage Difference Fy (%)	Percentage Difference Fz (%)
1	0.6504	6.7953	0.000977	0.6508	6.803	0.001	- -	0.11%	- -
3	-0.6453	8.9982	-8.9E-05	-0.6458	9.0018	-0.0001	- -	0.04%	- -
4	-0.001051	6.3503	-0.00106	-0.0011	6.3574	-0.0011	- -	0.11%	- -
7	-0.0003232	5.8601	0.7157	-0.0003	5.8665	0.7165	- -	0.11%	- -
9	-0.0009412	8.7866	0.6578	-0.001	8.7965	0.6582	- -	0.11%	- -
10	0.6694	8.0431	-0.6562	0.6697	8.0518	-0.6567	- -	0.11%	- -
13	-0.001205	9.9348	-0.00018	-0.0012	9.9458	-0.0002	- -	0.11%	- -
14	-0.6693	9.2359	-0.00011	-0.6696	9.2463	-0.0001	- -	0.11%	- -
15	-0.0009019	8.3312	-0.0013	-0.0009	8.3404	-0.0014	- -	0.11%	- -
16	-0.0003413	6.3506	-0.00096	-0.0003	6.3576	-0.0009	- -	0.11%	- -
21	-0.0002003	5.6669	-0.7136	-0.0002	5.6734	-0.7143	- -	0.11%	- -
22	-0.0001068	4.4953	-0.00084	-0.0001	4.5003	-0.0008	- -	0.11%	- -

Load Case 6

Node no.	Micas Plus Fx (kips)	Micas Plus Fy (kips)	Micas Plus Fz (kips)	GTStrudl Fx (kips)	GTStrudl Fy (kips)	GTStrudl Fz (kips)	Percentage Difference Fx (%)	Percentage Difference Fy (%)	Percentage Difference Fz (%)
1	23.4477	87.4366	0.0779	23.4618	87.4326	0.0766	0.06%	0.00%	- -
3	21.5964	-87.4366	0.0345	21.5829	-87.4326	0.0338	0.06%	0.00%	- -
4	-0.0681	0.7595	-0.0235	-0.069	0.7574	-0.0228	- -	- -	- -
7	-0.0238	-1.6048	-0.8168	-0.0239	-1.5983	-0.8168	- -	0.41%	- -
9	-0.0558	0.8551	3.3026	-0.0564	0.851	3.2956	- -	- -	0.21%
10	22.2357	90.1294	-2.0238	22.2422	90.1387	-2.0169	0.03%	0.01%	0.34%
13	-0.0872	0.2542	0.038	-0.0888	0.2552	0.0374	- -	- -	- -
14	20.997	-90.6855	0.0321	20.9951	-90.6894	0.32	0.01%	0.00%	- -
15	-0.0667	0.3027	-0.03	-0.0678	0.2981	-0.0291	- -	- -	- -
16	-0.0361	0.2486	-0.0209	-0.0369	0.2445	-0.0202	- -	- -	- -
21	-0.0222	0.2785	-0.5459	-0.0223	0.2776	-0.546	- -	- -	- -
22	-0.0168	-0.5378	-0.0241	-0.017	-0.5348	-0.0237	- -	- -	- -

Load Case 7

Node no.	Micas Plus Fx (kips)	Micas Plus Fy (kips)	Micas Plus Fz (kips)	GTStrudl Fx (kips)	GTStrudl Fy (kips)	GTStrudl Fz (kips)	Percentage Difference Fx (%)	Percentage Difference Fy (%)	Percentage Difference Fz (%)
1	0.1409	0.6088	-0.0125	0.1441	0.6127	-0.0118	- -	- -	- -
3	0.1584	-0.6088	-0.0401	0.1592	-0.6127	-0.0393	- -	- -	- -
4	0.0003832	0.0648	-0.0503	0.0004	0.0639	-0.0492	- -	- -	- -
7	0.002182	89.7835	22.2773	0.0022	89.7811	22.2725	- -	0.00%	0.02%
9	0.0132	89.5564	21.8844	0.0134	89.5586	21.8817	- -	0.00%	0.01%
10	-2.7858	-90.1606	23.0209	-2.7832	-90.1668	23.0229	0.09%	0.01%	0.01%
13	0.0146	0.6781	-0.0623	0.0147	0.6784	-0.0599	- -	- -	- -
14	2.4241	-0.005	-0.0481	2.4169	-0.0021	-0.046	0.30%	- -	- -
15	0.0109	-0.3237	-0.0703	0.011	-0.3203	-0.069	- -	- -	- -
16	0.0156	0.006203	-0.0506	0.0157	0.0062	-0.0498	- -	- -	- -
21	0.0009461	-89.5875	21.7887	0.0009	-89.5867	21.7848	- -	0.00%	0.02%
22	0.004518	-0.0123	-0.0372	0.0045	-0.0124	-0.0368	- -	- -	- -

Note: (- -) indicates that the values were not considered to be significant

Tennessee Eastman Building 267g

Element End Forces

Load Combination MAXGR

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-317.872	0.1499	-0.112	-317.877	0.1488	-0.1195	0.00%	- -	- -
7	43	-771.472	0.1578	-0.1799	-771.477	0.1559	-0.1862	0.00%	- -	- -
14	29	-182.534	-0.8971	-0.6881	-182.549	-0.8977	-0.6701	0.01%	0.07%	2.69%
20	29	-2.4188	0	0	-2.5874	0	0	6.52%	- -	- -
24	31	99.8957	0.8551	-0.5948	99.8985	0.8563	-0.5967	0.00%	0.14%	0.32%
34	45	0.2451	0	0	0.2627	0	0	- -	- -	- -
54	20	-156.813	0.6132	1.1085	-156.823	0.6122	1.1037	0.01%	0.16%	0.43%
59	55	-152.697	-0.1414	0.2635	-152.698	-0.1417	0.2704	0.00%	- -	- -
107	111	-33.9521	0.2344	-0.0355	-33.9136	-0.2339	0.0345	0.11%	- -	- -
127	110	30.1466	0.5941	-0.0422	30.1075	0.5947	-0.0414	0.13%	0.10%	- -
139	113	9.3959	0.0611	0.0417	9.4052	-0.061	-0.0418	0.10%	- -	- -
148	116	-1.3594	-0.0733	-0.0809	-1.3805	-0.0733	-0.0807	1.53%	- -	- -

Load Combination MAXDNW

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-184.102	0.139	-0.5412	-184.106	0.1368	-0.5357	0.00%	- -	1.03%
7	43	-339.837	0.0889	-0.9985	-339.846	0.0871	-0.9432	0.00%	- -	5.86%
14	29	-96.5582	-0.4031	-0.1661	-96.567	-0.4038	-0.1583	0.01%	- -	- -
20	29	-1.3964	0	0	-1.4849	0	0	5.96%	- -	- -
24	31	60.4257	0.2308	-0.4356	60.4274	0.2271	-0.4271	0.00%	- -	- -
34	45	-0.0649	0	0	-0.0676	0	0	- -	- -	- -
54	20	-96.6139	0.7385	-0.1175	-96.6183	0.7422	-0.1274	0.00%	0.50%	- -
59	55	-93.9931	-0.0332	-0.0562	-93.9968	-0.0331	-0.0466	0.00%	- -	- -
107	111	-6.083	0.2877	0.0205	-6.0521	-0.2874	-0.0207	0.51%	- -	- -
127	110	15.0816	0.496	-0.00148	15.0654	0.4962	-0.0014	0.11%	- -	- -
139	113	-2.9299	0.0444	-0.0186	-2.9316	-0.0443	0.0183	0.06%	- -	- -
148	116	-0.7301	-0.0781	-0.00045	-0.7353	-0.0781	-0.0004	- -	- -	- -

Load Combination MAXDSW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-184.259	0.1164	0.9335	-184.265	0.1172	0.9137	0.00%	- -	2.17%
7	43	-337.608	0.3404	1.4631	-337.614	0.3409	1.3967	0.00%	- -	4.75%
14	29	-93.5243	-0.3847	-0.1889	-93.5316	-0.3845	-0.1812	0.01%	- -	- -
20	29	-1.3031	0	0	-1.3999	0	0	6.91%	- -	- -
24	31	60.5822	0.468	-0.2577	60.5861	0.4721	-0.2731	0.01%	- -	- -
34	45	0.3249	0	0	0.3462	0	0	- -	- -	- -
54	20	-96.5389	-0.2564	1.5897	-96.544	-0.2606	1.5925	0.01%	- -	0.18%
59	55	-134.039	-0.1179	0.3476	-134.042	-0.1179	0.3489	0.00%	- -	- -
107	111	-28.7887	0.2577	-0.0718	-28.7811	-0.2574	0.0709	0.03%	- -	- -
127	110	13.7011	0.4989	-0.0492	13.6788	0.4991	-0.0484	0.16%	- -	- -
139	113	20.5965	0.0948	0.0756	20.6105	-0.0947	-0.0753	0.07%	- -	- -
148	116	-1.5669	-0.0748	-0.0897	-1.5845	-0.0748	-0.0894	1.11%	- -	- -

Load Combination MAXDEW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-185.322	1.0409	-0.0984	-185.324	1.0547	-0.0964	0.00%	1.31%	- -
7	43	-338.91	1.2773	0.7509	-338.918	1.2993	0.7305	0.00%	1.69%	2.79%
14	29	-118.492	-0.88	-0.5693	-118.497	-0.8857	-0.5499	0.00%	0.64%	3.53%
20	29	-0.0575	0	0	-0.0869	0	0	- -	- -	- -
24	31	61.6457	2.0333	-0.8385	61.6457	2.0599	-0.8313	0.00%	1.29%	0.87%
34	45	0.6188	0	0	0.6488	0	0	- -	- -	- -
54	20	-96.9637	5.0401	0.6787	-96.9624	5.0449	0.6811	0.00%	0.10%	0.35%
59	55	-113.291	-1.1928	0.5429	-113.299	-1.1982	0.5418	0.01%	0.45%	0.20%
107	111	-19.3808	0.2609	0.0166	-19.3616	-0.2606	-0.0169	0.10%	- -	- -
127	110	30.1767	0.4695	-0.0205	30.1682	0.4696	-0.0202	0.03%	- -	- -
139	113	7.5741	0.0717	-0.0139	7.5765	-0.0716	0.0136	0.03%	- -	- -
148	116	-7.0448	-0.0754	-0.0297	-7.0543	-0.0754	-0.0296	0.13%	- -	- -

Load Combination MAXDWW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-183.039	-0.7856	0.4906	-183.046	-0.8008	0.4743	0.00%	1.90%	- -
7	43	-338.536	-0.848	-0.2863	-338.542	-0.8712	-0.277	0.00%	2.66%	- -
14	29	-71.5908	0.0922	0.2143	-71.6021	0.0974	0.2104	0.02%	- -	- -
20	29	-2.6419	0	0	-2.7979	0	0	5.58%	- -	- -
24	31	59.3622	-1.3344	0.1452	59.3678	-1.3607	0.1311	0.01%	1.93%	- -
34	45	-0.3589	0	0	-0.3702	0	0	- -	- -	- -
54	20	-96.1891	-4.5579	0.7935	-96.1999	-4.5633	0.7839	0.01%	0.12%	1.22%
59	55	-114.741	1.0417	-0.2515	-114.74	1.0472	-0.2395	0.00%	0.53%	- -
107	111	-15.4909	0.2845	-0.0679	-15.4717	-0.2842	0.0671	0.12%	- -	- -
127	110	-1.394	0.5254	-0.0302	-1.4241	0.5258	-0.0296	2.11%	0.08%	- -
139	113	10.0924	0.0675	0.0709	10.1024	-0.0674	-0.0705	0.10%	- -	- -
148	116	4.7478	-0.0776	-0.0604	4.7344	-0.0776	-0.0601	0.28%	- -	- -

Load Combination MAXDNE

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-184.245	0.12	-0.8089	-184.249	0.1186	-0.796	0.00%	- -	1.62%
7	43	-339.401	-0.077	-1.0136	-339.408	-0.08	-0.9714	0.00%	- -	4.34%
14	29	-95.352	-0.376	0.6658	-95.3599	-0.3765	0.6599	0.01%	- -	0.89%
20	29	-1.5928	0	0	-1.6864	0	0	5.55%	- -	- -
24	31	60.5688	0.3333	-0.8831	60.5707	0.3326	-0.8726	0.00%	- -	1.20%
34	45	-0.2404	0	0	-0.2539	0	0	- -	- -	- -
54	20	-96.5826	0.3856	0.9966	-96.5873	0.387	0.9887	0.00%	- -	0.80%
59	55	-83.1204	-0.0191	0.3405	-83.1208	-0.0191	0.3443	0.00%	- -	- -
107	111	4.696	0.2974	0.0334	4.7295	-0.297	-0.0335	0.71%	- -	- -
127	110	14.5897	0.4974	0.00278	14.575	0.4975	0.0027	0.10%	- -	- -
139	113	-11.7242	0.0325	-0.0321	-11.7265	-0.0324	0.0317	0.02%	- -	- -
148	116	-1.2014	-0.0787	0.0125	-1.2067	-0.0787	0.0125	0.44%	- -	- -

Load Combination MAXDSE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-184.116	0.1353	1.2012	-184.122	0.1354	1.174	0.00%	- -	2.32%
7	43	-338.045	0.5063	1.4782	-338.051	0.508	1.4249	0.00%	0.33%	3.74%
14	29	-94.7304	-0.4118	-1.0208	-94.7387	-0.4118	-0.9993	0.01%	- -	2.15%
20	29	-1.1066	0	0	-1.1984	0	0	7.66%	- -	- -
24	31	60.4391	0.3655	0.1897	60.4429	0.3666	0.1723	0.01%	- -	- -
34	45	0.5004	0	0	0.5325	0	0	- -	- -	- -
54	20	-96.5702	0.0965	0.4756	-96.575	0.0946	0.4764	0.00%	- -	- -
59	55	-144.912	-0.132	-0.0491	-144.918	-0.1319	-0.042	0.00%	- -	- -
107	111	-39.5677	0.248	-0.0846	-39.5628	-0.2477	0.0836	0.01%	- -	- -
127	110	14.193	0.4976	-0.0535	14.1691	0.4978	-0.0525	0.17%	- -	- -
139	113	29.3908	0.1066	0.089	29.4055	-0.1066	-0.0887	0.05%	- -	- -
148	116	-1.0955	-0.0743	-0.1026	-1.1131	-0.0743	-0.1023	1.58%	- -	- -

Load Combination MAXDEE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-184.94	1.4904	-0.2738	-184.943	1.5064	-0.2663	0.00%	1.06%	- -
7	43	-338.977	1.9585	0.9919	-338.985	1.99	0.9757	0.00%	1.58%	1.66%
14	29	-137.287	-1.6864	-0.8425	-137.289	-1.7008	-0.8111	0.00%	0.85%	3.87%
20	29	1.5083	0	0	1.5502	0	0	2.70%	- -	- -
24	31	61.2635	2.3904	-1.2021	61.2642	2.4159	-1.1883	0.00%	1.06%	1.16%
34	45	1.2129	0	0	1.2703	0	0	4.52%	- -	- -
54	20	-96.825	3.6598	0.243	-96.8257	3.6642	0.2464	0.00%	0.12%	- -
59	55	-114.186	-1.0758	0.7123	-114.192	-1.0796	0.7092	0.00%	0.35%	0.44%
107	111	-20.479	0.2522	0.0485	-20.4563	-0.2517	-0.0486	0.11%	- -	- -
127	110	47.6389	0.4439	-0.0204	47.6406	0.4438	-0.0204	0.00%	- -	- -
139	113	7.1136	0.0729	-0.0379	7.1131	-0.0728	0.0375	0.01%	- -	- -
148	116	-9.3401	-0.0748	-0.0177	-9.3455	-0.0748	-0.0178	0.06%	- -	- -

Load Combination MAXDWE

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-183.421	-1.2351	0.6661	-183.428	-1.2524	0.6443	0.00%	1.38%	3.38%
7	43	-338.469	-1.5292	-0.5273	-338.475	-1.5619	-0.5222	0.00%	2.09%	0.98%
14	29	-52.7957	0.8986	0.4875	-52.81	0.9125	0.4716	0.03%	1.52%	- -
20	29	-4.2077	0	0	-4.435	0	0	5.13%	- -	- -
24	31	59.7444	-1.6915	0.5087	59.7494	-1.7167	0.488	0.01%	1.47%	- -
34	45	-0.9529	0	0	-0.9918	0	0	- -	- -	- -
54	20	-96.3278	-3.1777	1.2292	-96.3366	-3.1826	1.2186	0.01%	0.15%	0.87%
59	55	-113.847	0.9247	-0.4209	-113.847	0.9286	-0.4069	0.00%	0.42%	- -
107	111	-14.3927	0.2932	-0.0997	-14.3797	-0.293	0.0988	0.09%	- -	- -
127	110	-18.8562	0.551	-0.0302	-18.8965	0.5515	-0.0294	0.21%	0.09%	- -
139	113	10.5529	0.0663	0.0949	10.5659	-0.0662	-0.0944	0.12%	- -	- -
148	116	7.0432	-0.0781	-0.0724	7.0257	-0.0781	-0.0719	0.25%	- -	- -

Load Combination MAXGNW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-238.345	0.1209	-0.637	-238.344	0.119	-0.6332	0.00%	- -	0.60%
7	43	-579.44	0.0241	-1.0581	-579.445	0.0217	-1.0171	0.00%	- -	4.03%
14	29	-138.039	-0.6797	-0.5076	-138.05	-0.6805	-0.494	0.01%	0.12%	- -
20	29	-1.8491	0	0	-1.9724	0	0	6.25%	- -	- -
24	31	74.8631	0.5523	-0.5128	74.8644	0.5504	-0.5053	0.00%	0.35%	1.48%
34	45	0.0377	0	0	0.0419	0	0	- -	- -	- -
54	20	-117.638	0.833	0.1912	-117.645	0.8351	0.1828	0.01%	0.25%	- -
59	55	-99.5056	-0.0743	0.0462	-99.5069	-0.0745	0.0545	0.00%	- -	- -
107	111	-16.9494	0.187	0.00796	-16.9118	-0.1866	-0.0085	0.22%	- -	- -
127	110	23.1277	0.4445	-0.0138	23.1006	0.4449	-0.0134	0.12%	- -	- -
139	113	-1.7755	0.0269	-0.00402	-1.7744	-0.0268	0.0037	0.06%	- -	- -
148	116	-0.7058	-0.0562	-0.0272	-0.7169	-0.0562	-0.0272	- -	- -	- -

Load Combination MAXGSW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-238.463	0.104	0.469	-238.467	0.1043	0.4539	0.00%	- -	- -
7	43	-577.768	0.2127	0.7882	-577.771	0.2121	0.7378	0.00%	- -	6.83%
14	29	-135.763	-0.6659	-0.5246	-135.773	-0.666	-0.5112	0.01%	0.02%	2.62%
20	29	-1.7791	0	0	-1.9087	0	0	6.79%	- -	- -
24	31	74.9804	0.7303	-0.3794	74.9834	0.3741	-0.3898	0.00%	- -	- -
34	45	0.33	0	0	0.3522	0	0	- -	- -	- -
54	20	-117.582	0.0868	1.4716	-117.59	0.0831	1.4727	0.01%	- -	0.07%
59	55	-129.54	-0.1378	0.3491	-129.541	-0.1381	0.3511	0.00%	- -	- -
107	111	-33.9787	0.1645	-0.0613	-33.9586	-0.1641	0.0602	0.06%	- -	- -
127	110	22.0922	0.4467	-0.0496	22.0606	0.4471	-0.0487	0.14%	- -	- -
139	113	15.8693	0.0647	0.0666	15.8822	-0.0647	-0.0665	0.08%	- -	- -
148	116	-1.3334	-0.0538	-0.0942	-1.3538	-0.0538	-0.0939	1.51%	- -	- -

Load Combination MAXGEW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-239.26	0.7974	-0.3049	-239.262	0.8074	-0.3037	0.00%	1.24%	- -
7	43	-578.744	0.9154	0.254	-578.749	0.9308	0.2382	0.00%	1.65%	- -
14	29	-154.489	-1.0374	-0.8099	-154.497	-1.0419	-0.7877	0.01%	0.43%	2.82%
20	29	-0.845	0	0	-0.9239	0	0	- -	- -	- -
24	31	75.778	1.9042	-0.815	75.7781	1.925	-0.8084	0.00%	1.08%	0.82%
34	45	0.5505	0	0	0.5792	0	0	- -	- -	- -
54	20	-117.9	4.0592	0.7884	-117.903	4.0622	0.7892	0.00%	0.07%	0.10%
59	55	-113.979	-0.9441	0.4955	-113.983	-0.9483	0.4958	0.00%	0.44%	- -
107	111	-26.9228	0.167	0.005046	-26.894	-0.1665	-0.0056	0.11%	- -	- -
127	110	34.449	0.4246	-0.028	34.4277	0.4249	-0.0276	0.06%	- -	- -
139	113	6.1025	0.0474	-0.00047	6.1067	-0.0473	0.0002	0.07%	- -	- -
148	116	-5.4418	-0.0541	-0.0492	-5.4561	-0.0542	-0.0491	0.26%	- -	- -

Load Combination MAXGWW

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-237.548	-0.5724	0.1369	-237.554	-0.5842	0.1244	0.00%	2.02%	- -
7	43	-578.464	-0.6787	-0.5239	-578.467	-0.697	-0.5175	0.00%	2.63%	1.24%
14	29	-119.313	-0.3082	-0.2223	-119.326	-0.3046	-0.2175	0.01%	- -	- -
20	29	-2.7833	0	0	-2.9572	0	0	5.88%	- -	- -
24	31	74.0655	-0.6216	-0.0772	74.0697	-0.6405	-0.0866	0.01%	2.95%	- -
34	45	-0.1828	0	0	-0.1851	0	0	- -	- -	- -
54	20	-117.319	-3.1393	0.8744	-117.332	-3.1439	0.8663	0.01%	0.15%	0.94%
59	55	-115.067	0.7319	-0.1002	-115.064	0.7358	-0.0902	0.00%	0.53%	- -
107	111	-24.0053	0.1846	-0.0584	-23.9765	-0.1843	0.0574	0.12%	- -	- -
127	110	10.7709	0.4665	-0.0353	10.7335	0.4671	-0.0346	0.35%	- -	- -
139	113	7.9913	0.0442	0.0631	8.0011	-0.0442	-0.0629	0.12%	- -	- -
148	116	3.4026	-0.0558	-0.0722	3.3854	-0.0558	-0.0719	0.51%	- -	- -

Load Combination MAXGNE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-238.453	0.1067	-0.8377	-238.456	0.1053	-0.8284	0.00%	- -	1.12%
7	43	-579.113	-0.1004	-1.0694	-579.117	-0.1036	-1.0382	0.00%	- -	3.01%
14	29	-137.134	-0.6594	0.1164	-137.145	-0.66	0.1196	0.01%	0.09%	- -
20	29	-1.9965	0	0	-2.1235	0	0	5.98%	- -	- -
24	31	74.9704	0.6292	-0.8484	74.9718	0.6295	-0.8393	0.00%	0.05%	1.08%
34	45	-0.0939	0	0	-0.0979	0	0	- -	- -	- -
54	20	-117.615	0.5683	1.0267	-117.622	0.5688	1.0199	0.01%	0.09%	0.67%
59	55	-91.3511	-0.0637	0.3437	-91.3499	-0.064	0.3477	0.00%	- -	- -
107	111	-8.8651	0.1943	0.0176	-8.8256	-0.1939	-0.018	0.45%	- -	- -
127	110	22.7587	0.4455	-0.0106	22.7328	0.4459	-0.0104	0.11%	- -	- -
139	113	-8.3712	0.018	-0.0141	-8.3706	-0.0179	0.0138	0.01%	- -	- -
148	116	-1.0593	-0.0566	-0.0175	-1.0704	-0.0566	-0.0175	1.04%	- -	- -

Load Combination MAXGSE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-238.355	0.1182	0.6698	-238.36	0.1179	0.6491	0.00%	- -	3.19%
7	43	-578.095	0.3371	0.7995	-578.099	0.3374	0.759	0.00%	- -	5.34%
14	29	-136.668	-0.6862	-1.1486	-136.679	-0.6865	-1.1248	0.01%	0.04%	2.12%
20	29	-1.6318	0	0	-1.7576	0	0	7.16%	- -	- -
24	31	74.8731	0.6534	-0.0438	74.876	0.655	-0.0557	0.00%	0.24%	- -
34	45	0.4616	0	0	0.492	0	0	- -	- -	- -
54	20	-117.605	0.3515	0.636	-117.613	0.3494	0.6357	0.01%	- -	0.05%
59	55	-137.695	-0.1484	0.0516	-137.698	-0.1486	0.058	0.00%	- -	- -
107	111	-42.063	0.1573	-0.0709	-42.0448	-0.1569	0.0698	0.04%	- -	- -
127	110	22.4612	0.4457	-0.0528	22.4284	0.4461	-0.0518	0.15%	- -	- -
139	113	22.465	0.0736	0.0767	22.4784	-0.0736	-0.0765	0.06%	- -	- -
148	116	-0.9799	-0.0533	-0.1039	-1.0003	-0.0533	-0.1035	- -	- -	- -

Load Combination MAXGEE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-238.974	1.1345	-0.4365	-238.976	1.1461	-0.4312	0.00%	1.01%	- -
7	43	-578.795	1.4262	0.4348	-578.799	1.4488	0.422	0.00%	1.56%	- -
14	29	-168.585	-1.6422	-1.0148	-168.591	-1.6532	-0.9836	0.00%	0.67%	3.17%
20	29	0.3294	0	0	0.3039	0	0	- -	- -	- -
24	31	75.4914	2.172	-1.0876	75.492	2.192	-1.0761	0.00%	0.91%	1.07%
34	45	0.996	0	0	1.0453	0	0	- -	- -	- -
54	20	-117.796	3.024	0.4616	-117.801	3.0267	0.4632	0.00%	0.09%	- -
59	55	-114.65	-0.8563	0.6226	-114.653	-0.8593	0.6213	0.00%	0.35%	0.21%
107	111	-27.7464	0.1604	0.0289	-27.7129	-0.1599	-0.0294	0.12%	- -	- -
127	110	47.5456	0.4054	-0.028	47.532	0.4056	-0.0277	0.03%	- -	- -
139	113	5.7572	0.0483	-0.0185	5.7591	-0.0482	0.0181	0.03%	- -	- -
148	116	-7.1633	-0.0537	-0.0402	-7.1746	-0.0537	-0.0402	0.16%	- -	- -

Load Combination MAXGWE

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-237.834	-0.9096	0.2685	-237.84	-0.9229	0.2518	0.00%	1.44%	- -
7	43	-578.413	-1.1895	-0.7046	-578.417	-1.215	-0.7013	0.00%	2.10%	0.47%
14	29	-105.217	0.2966	-0.0174	-105.232	0.3067	-0.0216	0.01%	- -	- -
20	29	-3.9577	0	0	-4.185	0	0	5.43%	- -	- -
24	31	74.3521	-0.8894	0.1954	74.3559	-0.9075	0.1811	0.01%	1.99%	- -
34	45	-0.6284	0	0	-0.6512	0	0	- -	- -	- -
54	20	-117.423	-2.1041	1.2012	-117.434	-2.1085	1.1924	0.01%	0.21%	0.74%
59	55	-114.396	0.6441	-0.2273	-114.395	0.6468	-0.2157	0.00%	0.42%	- -
107	111	-23.1817	0.1912	-0.0822	-23.1575	-0.1909	0.0812	0.10%	- -	- -
127	110	-2.3257	0.4857	-0.0354	-2.3708	0.4864	-0.0344	1.90%	- -	- -
139	113	8.3366	0.0433	0.0811	8.3487	-0.0433	-0.0808	0.14%	- -	- -
148	116	5.1241	-0.0562	-0.0812	5.1039	-0.0562	-0.0808	0.40%	- -	- -

Note: (- -) indicates that the values were not considered to be significant

Tennessee Eastman Building 267g

Joint Displacements

Load Case 1

Node	MicasPlus			GTStrudl			Percentage Difference		
	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
no.	inch			inch			%		
2	0.0965	-0.1409	-0.0238	0.0966	-0.1409	-0.0237	0.10%	0.00%	- -
24	0.0235	-0.1478	0.0654	0.0234	-0.1478	0.0657	- -	0.00%	0.46%
26	0.0201	-0.0891	0.003916	0.0198	-0.0891	0.0038	- -	0.00%	- -
32	0.0407	-0.0925	0.0269	0.0406	-0.0925	0.0269	- -	0.00%	- -
41	0.011	-0.0979	-0.00475	0.0108	-0.0978	-0.0048	- -	0.10%	- -
52	0.00727	-0.1706	0.007935	0.0072	-0.1706	0.0079	- -	0.00%	- -
86	0.0378	-0.3112	0.0908	0.0381	-0.3112	0.0906	- -	0.00%	0.22%
88	0.0378	-0.2045	0.1293	0.0381	-0.2045	0.129	- -	0.00%	0.23%
92	-0.0584	-0.1611	0.1292	-0.0579	-0.161	0.129	0.86%	0.06%	0.16%
93	-0.0584	-0.2306	-0.00549	-0.0579	-0.2305	-0.0054	0.86%	0.04%	- -
97	0.1338	-0.1253	0.1292	0.1339	-0.1254	0.129	0.07%	0.08%	0.16%
98	0.1338	-0.188	0.0908	0.1339	-0.188	0.0907	0.07%	0.00%	0.11%

Load Case 2

Node	MicasPlus			GTStrudl			Percentage Difference		
	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
no		inch		inch			%		
2	0.0333	-0.0763	0.002913	0.0333	-0.0762	0.0029	- -	0.13%	- -
24	-0.0102	-0.1108	0.0561	-0.0103	-0.1108	0.0562	- -	0.00%	0.18%
26	0.007778	-0.0401	0.005088	0.0076	-0.0401	0.005	- -	- -	- -
32	0.0133	-0.0714	0.0249	0.0133	-0.0714	0.0248	- -	0.00%	- -
41	0.002435	-0.0486	-6.7E-05	0.0023	-0.0486	-0.0001	- -	- -	- -
52	-0.00819	-0.0801	0.0134	-0.0082	-0.08	0.0134	- -	0.13%	- -
86	0.0135	-0.1628	0.0779	0.0135	-0.1628	0.0779	- -	0.00%	0.00%
88	0.0135	-0.1497	0.1	0.0135	-0.1497	0.0999	- -	0.00%	0.10%
92	-0.0418	-0.1189	0.1	-0.0416	-0.1189	0.0999	- -	0.00%	0.10%
93	-0.0418	-0.1141	0.0226	-0.0416	-0.114	0.0227	- -	0.09%	- -
97	0.0686	-0.0941	0.1	0.0686	-0.0941	0.0999	0.00%	0.00%	0.10%
98	0.0686	-0.1074	0.078	0.0686	-0.1074	0.0779	0.00%	0.00%	0.13%

Load Case 3

Node No.	Micas Plus Tx	Micas Plus Ty (inch)	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty (inch)	GTStrudl Tz	Percentage Diference Tx	Percentage Diference Ty (%)	Percentage Diference Tz
2	-0.161	-0.0178	0.0316	-0.1609	-0.0178	0.0316	0.06%	- -	- -
24	-0.1359	0.000954	0.000416	-0.1358	0.0009	0.0004	0.07%	- -	- -
26	-0.0443	0.007384	0.003127	-0.0443	0.0074	0.0031	- -	- -	- -
32	-0.1103	0.000611	-0.00212	-0.1102	0.0006	-0.0021	0.09%	- -	- -
41	-0.0433	0.000356	0.004225	-0.0432	0.0004	0.0042	- -	- -	- -
52	-0.0905	0.011	0.00997	-0.0905	0.011	0.01	0.00%	- -	- -
86	-0.7039	-0.00055	0.008931	-0.7047	-0.0005	0.009	0.11%	- -	- -
88	-0.704	0.001729	-0.00136	-0.7047	0.0017	-0.0013	0.10%	- -	- -
92	-0.6781	0.001457	-0.00139	-0.6789	0.0014	-0.0013	0.12%	- -	- -
93	-0.6781	0.0114	0.0346	-0.6788	0.0114	0.0348	0.10%	- -	- -
97	-0.7297	0.00191	-0.00137	-0.7305	0.0019	-0.0013	0.11%	- -	- -
98	-0.7297	-0.00172	0.008931	-0.7305	-0.0017	0.009	0.11%	- -	- -

Load Case 4

Node no.	Micas Plus Tx	Micas Plus Ty (inch)	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty (inch)	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty (%)	Percentage Difference Tz
2	-0.00933	-0.00112	-0.144	-0.0093	-0.0011	-0.144	- -	- -	0.00%
24	0.0394	9E-05	-0.2029	0.0394	0.0001	-0.2027	- -	- -	0.10%
26	-0.00211	0.000431	-0.0517	-0.002	0.0004	-0.0516	- -	- -	0.19%
32	-0.00565	-0.0249	-0.1262	-0.0056	-0.0249	-0.1263	- -	- -	0.08%
41	0.002357	-0.00783	-0.047	0.0024	-0.0078	-0.0469	- -	- -	- -
52	0.0215	-0.00066	-0.1094	0.0214	-0.0007	-0.1093	- -	- -	0.09%
86	0.0278	0.000267	-0.2582	0.0279	0.0003	-0.2584	- -	- -	0.08%
88	0.0278	0.0285	-0.2445	0.0279	0.0285	-0.2445	- -	- -	0.00%
92	-0.00606	0.000138	-0.2448	-0.0064	0.0001	-0.2447	- -	- -	0.04%
93	-0.00603	0.000134	-0.2921	-0.0063	0.0001	-0.2927	- -	- -	0.20%
97	0.0619	-0.0276	-0.2446	0.0624	-0.0276	-0.2446	0.80%	- -	0.00%
98	0.0619	0.000119	-0.2581	0.0624	0.0001	-0.2583	0.80%	- -	0.08%

Load Case 5

Node	Micas Plus			GTStrudl			Percentage Difference		
	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
no.		inch			inch			%	
2	-0.00064	-0.0026	0.000419	-0.0006	-0.0026	0.0004	- -	- -	- -
24	-7E-05	-0.00305	-0.00027	-0.0001	-0.0031	-0.0003	- -	- -	- -
26	2.04E-05	-0.00147	6.17E-05	0	-0.0015	0.0001	- -	- -	- -
32	-0.00062	-0.00288	-0.00029	-0.0006	-0.0029	-0.0003	- -	- -	- -
41	9.66E-07	-0.00143	4.43E-05	0	-0.0014	0	- -	- -	- -
52	-0.00017	-0.00242	0.000104	-0.0002	-0.0024	0.0001	- -	- -	- -
86	-1.2E-05	-0.00294	-4E-05	0	-0.0029	0	- -	- -	- -
88	-1.2E-05	-0.00369	-0.00011	0	-0.0037	-0.0001	- -	- -	- -
92	0.000157	-0.00319	-0.1075	0.0002	-0.0032	-0.0001	- -	- -	- -
93	0.000157	-0.00292	0.000129	0.0002	-0.0029	0.0001	- -	- -	- -
97	-0.00018	-0.00356	-0.00011	-0.0002	-0.0036	-0.0001	- -	- -	- -
98	-0.00018	-0.00303	-4.1E-05	-0.0002	-0.003	0	- -	- -	- -

Load Case 6

Node	Micas Plus			GTStrudl			Percentage Difference		
	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
no.		inch			inch			%	
2	-0.3075	-0.0326	0.0573	-0.3074	-0.0326	0.0573	0.03%	- -	0.00%
24	-0.2645	0.000668	0.004276	-0.2644	0.0007	0.0043	0.04%	- -	- -
26	-0.0918	0.014	0.006139	-0.0918	0.014	0.0061	0.00%	- -	- -
32	-0.222	0.000899	-0.00069	-0.2218	0.0009	-0.0007	0.09%	- -	- -
41	-0.0907	0.0005	0.007412	-0.0905	0.0005	0.0074	0.22%	- -	- -
52	-0.1887	0.0212	0.0192	-0.1886	0.0212	0.0193	0.05%	- -	- -
86	-0.6822	-0.00039	0.012	-0.6825	-0.0004	0.012	0.04%	- -	- -
88	-0.6822	8.32E-05	0.005556	-0.6825	0.0001	0.0056	0.04%	- -	- -
92	-0.6658	0.00102	0.005483	-0.6663	0.001	0.0056	0.08%	- -	- -
93	-0.6657	0.0223	0.0284	-0.6662	0.0223	0.0283	0.08%	- -	- -
97	-0.6978	0.002125	0.005708	-0.6983	0.0021	0.0057	0.07%	- -	- -
98	-0.6978	-0.00115	0.0119	-0.6983	-0.0011	0.012	0.07%	- -	- -

Load Case 7

Node	Micas Plus			GTStrudl			Percentage Difference		
	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
no.		inch			inch			%	
2	-0.00209	-0.00026	-0.2611	-0.002	-0.0003	-0.261	- -	- -	0.04%
24	0.0606	1.55E-05	-0.3369	0.0606	0	-0.3366	0.00%	- -	0.09%
26	-0.00069	0.000101	-0.0963	-0.0006	0.0001	-0.0961	- -	- -	0.21%
32	-0.00099	-0.0403	-0.2182	-0.0008	-0.0403	-0.2183	- -	- -	0.05%
41	0.004512	-0.0144	-0.0907	0.0045	-0.0144	-0.0906	- -	- -	0.11%
52	0.0328	-0.00064	-0.1994	0.0327	-0.0007	-0.1992	- -	- -	0.10%
86	0.0388	0.000419	-0.3941	0.039	0.0004	-0.3942	- -	- -	0.03%
88	0.0389	0.0454	-0.4017	0.039	0.0454	-0.4018	- -	- -	0.02%
92	0.0585	2.37E-05	-0.4022	0.0585	0	-0.4021	0.00%	- -	0.02%
93	0.0586	-0.00018	-0.3744	0.0586	-0.0002	-0.3745	0.00%	- -	0.03%
97	0.0199	-0.0437	-0.4017	0.0199	-0.0437	-0.4018	- -	- -	0.02%
98	0.0199	-9.6E-05	-0.3942	0.0199	-0.0001	-0.3942	- -	- -	0.00%

Note: (- -) indicates that the values were not considered to be significant

Tennessee Eastman Building 267g

Code Check

Element	Code Check		Percentage
no.	Micas Plus	GTStrudl	Difference
1	0.504	0.5037	0.06%
2	0.643	0.6434	0.06%
3	0.648	0.6477	0.05%
4	0.662	0.6617	0.05%
5	0.705	0.7052	0.03%
6	0.569	0.5691	0.02%
7	0.952	0.9517	0.03%
8	0.705	0.7055	0.07%
9	0.94	0.9396	0.04%
10	0.904	0.9038	0.02%
11	0.871	0.8708	0.02%
12	0.671	0.6714	0.06%
13	0.02	0.0209	- -
14	0.376	0.3759	0.03%
15	0.418	0.418	0.00%
16	0.042	0.0447	- -
17	0.439	0.4389	0.02%
18	0.041	0.0427	- -
19	0.386	0.3864	0.10%
20	0.02	0.0206	- -
21	0.159	0.1563	1.73%
22	0.177	0.1766	0.23%
23	0.014	0.0142	- -
24	0.21	0.2098	0.10%
25	0.03	0.0315	- -
26	0.227	0.2272	0.09%
27	0.006	0.0064	- -
28	0.009	0.0098	- -
29	0.036	0.0376	- -
30	0.027	0.0348	- -
31	0.025	0.0262	- -
32	0.004	0.0045	- -
33	0.004	0.0055	- -
34	0.015	0.0155	- -
35	0.003	0.0032	- -
36	0.005	0.0066	- -
37	0.012	0.0123	- -
38	0.008	0.0068	- -
39	0.039	0.0404	- -
40	0.012	0.0122	- -
41	0.007	0.0063	- -
42	0.004	0.0052	- -
43	0.008	0.0081	- -
44	0.003	0.0026	- -
45	0.01	0.0111	- -
46	0.01	0.0109	- -
47	0.004	0.0048	- -
48	0.389	0.3891	0.03%
49	0.525	0.5252	0.04%
50	0.653	0.6528	0.03%
51	0.488	0.4878	0.04%
52	0.134	0.134	0.00%

Code Check

Element no.	Code Check		Percentage Difference
	Micas Plus	GTStrudl	
53	0.258	0.2582	0.08%
54	0.325	0.3253	0.09%
55	0.225	0.2245	0.22%
56	0.486	0.4862	0.04%
57	0.68	0.6804	0.06%
58	0.654	0.6544	0.06%
59	0.581	0.581	0.00%
60	0.219	0.2187	0.14%
61	0.35	0.3497	0.09%
62	0.349	0.3485	0.14%
63	0.308	0.308	0.00%
64	0.007	0.0087	- -
65	0.02	0.021	- -
66	0.004	0.0052	- -
67	0.009	0.0093	- -
68	0.006	0.0061	- -
69	0.003	0.0038	- -
70	0.003	0.0037	- -
71	0.008	0.0094	- -
72	0.006	0.0065	- -
73	0.006	0.0063	- -
74	0.002	0.0021	- -
75	0.003	0.0034	- -
76	0.003	0.0039	- -
77	0.002	0.0027	- -
78	0.003	0.0031	- -

Element no.	Code Check		Percentage Difference
	Micas Plus	GTStrudl	
79	0.002	0.002	- -
80	0.003	0.0036	- -
81	0.001	0.0013	- -
82	0.059	0.0591	- -
83	0.03	0.0305	- -
84	0.033	0.0332	- -
85	0.02	0.0205	- -
86	0.008	0.0082	- -
87	0.043	0.0437	- -
88	0.53	0.518	2.32%
89	0.714	0.7119	0.29%
90	0.46	0.4594	0.13%
91	0.564	0.5519	2.19%
92	0.561	0.5592	0.32%
93	0.469	0.4678	0.26%
94	0.494	0.4812	2.66%
95	0.499	0.498	0.20%
96	0.169	0.1686	0.24%
97	0.076	0.0762	- -
98	0.09	0.0896	- -
99	0.144	0.1434	0.42%
100	0.167	0.1654	0.97%
101	0.002	0.0023	- -
102	0.063	0.0633	- -
103	0.001	0	- -
104	0.001	0.0011	- -

Code Check

Element no.	Code Check Micas Plus	Code Check GTStrudl	Percentage Difference
105	0.01	0.0101	- -
106	0.607	0.6075	0.08%
107	0.52	0.5202	0.04%
108	0.252	0.252	0.00%
109	0.681	0.6818	0.12%
110	0.625	0.6246	0.06%
111	0.681	0.71	4.08%
112	0.697	0.6972	0.03%
113	0.629	0.6483	2.98%
114	0.728	0.7281	0.01%
115	0.629	0.6597	4.65%
116	0.517	0.5177	0.14%
117	0.292	0.2922	0.07%
118	0.226	0.2264	0.18%
119	0.668	0.6678	0.03%
120	0.579	0.589	1.70%
121	0.7	0.7003	0.04%
122	0.579	0.6052	4.33%
123	0.402	0.4027	0.17%
124	0.526	0.5263	0.06%
125	0.601	0.6013	0.05%
126	0.627	0.6303	0.52%
127	0.619	0.619	0.00%
128	0.627	0.6475	3.17%
129	0.598	0.5973	0.12%

Element no.	Code Check Micas Plus	Code Check GTStrudl	Percentage Difference
130	0.312	0.3125	0.16%
131	0.499	0.5086	1.89%
132	0.336	0.3375	0.44%
133	0.336	0.3432	2.10%
134	0.22	0.226	2.65%
135	0.465	0.4704	1.15%
136	0.465	0.4665	0.32%
137	0.486	0.4954	1.90%
138	0.345	0.3438	0.35%
139	0.345	0.3536	2.43%
140	0.26	0.2664	2.40%
141	0.509	0.5166	1.47%
142	0.509	0.5145	1.07%
143	0.374	0.3811	1.86%
144	0.54	0.5394	0.11%
145	0.54	0.5389	0.20%
146	0.492	0.5014	1.87%
147	0.182	0.1859	2.10%
148	0.182	0.1869	2.62%
149	0.598	0.5863	2.00%
150	0.001	0.0085	- -
151	0.278	0.2846	2.32%
152	0.537	0.5453	1.52%
153	0.537	0.5451	1.49%

Note: (- -) indicates that the values were not considered to be significant

Appendix B. Numerical Results from Moment Resisting Frame

Frame with Moment Resisting Connections

Support Reactions

Load Case 1

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	0.00591	299.1913	0.0111	0.0058	299.1727	0.0117	- -	0.01%	- -
3	0.0353	417.2683	0.1025	0.0348	417.2941	0.1076	- -	0.01%	- -
4	-0.0561	306.8384	0.047	-0.0546	306.9377	0.05	- -	0.03%	- -
7	-0.091	135.1987	0.0164	-0.0889	135.0793	0.0162	- -	0.09%	- -
9	0.055	508.4715	-0.0468	0.0544	508.4757	-0.0474	- -	0.00%	- -
10	0.0195	272.9232	-0.0699	0.0195	272.9013	-0.0172	- -	0.01%	- -
13	0.0938	752.6734	0.0562	0.09	752.5916	0.0572	- -	0.01%	- -
14	0.1313	522.4513	-0.0726	0.1285	522.4514	-0.0781	- -	0.00%	- -
15	0.0104	605.7806	0.0353	0.0083	605.9004	0.0382	- -	0.02%	- -
16	-0.00827	427.3897	-0.0114	-0.0075	427.5847	-0.0112	- -	0.05%	- -
21	-0.0522	251.6811	-0.0175	-0.0512	251.6651	-0.0199	- -	0.01%	- -
22	-0.1436	186.5325	-0.0501	-0.1391	186.3464	-0.0531	- -	0.10%	- -

Load Case 2

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	-0.017	160.7432	-0.00054	-0.0169	160.7275	-0.0004	- -	0.01%	- -
3	-0.0033	184.8325	0.0426	-0.0032	184.8596	0.0444	- -	0.01%	- -
4	-0.0255	176.6167	0.0147	-0.0245	176.6547	0.0161	- -	0.02%	- -
7	-0.042	106.7983	0.0152	-0.0409	106.7345	0.015	- -	0.06%	- -
9	0.0199	255.1664	-0.0277	0.0191	255.1646	-0.0282	- -	0.00%	- -
10	-0.0037	138.1111	-0.0335	-0.0037	138.0982	-0.0341	- -	0.01%	- -
13	0.041	327.8681	0.0259	0.0394	327.8518	0.0263	- -	0.00%	- -
14	0.0588	249.2466	-0.0219	0.0579	249.2544	-0.0239	- -	0.00%	- -
15	0.0361	320.5887	0.0188	0.0345	320.5857	0.021	- -	0.00%	- -
16	-0.00249	249.4053	0.007673	-0.0017	249.4881	0.0086	- -	0.03%	- -
21	0.0119	185.8955	-0.00808	0.0112	185.9454	-0.0098	- -	0.03%	- -
22	-0.0738	137.1276	-0.033	-0.0714	137.0356	-0.035	- -	0.07%	- -

Load Case 3

Node No.	Micas Plus Fx (kips)	Micas Plus Fy (kips)	Micas Plus Fz (kips)	GTStrudl Fx (kips)	GTStrudl Fy (kips)	GTStrudl Fz (kips)	Percentage Diference Fx (%)	Percentage Diference Fy (%)	Percentage Diference Fz (%)
1	2.3833	8.6465	-0.0632	2.3997	8.7659	-0.0629	0.68%	1.36%	- -
3	4.0327	-0.4167	-0.0404	4.0641	-0.3575	-0.0402	0.77%	- -	- -
4	3.1125	12.6584	0.058	3.0961	11.773	0.0581	0.53%	7.52%	- -
7	2.1889	-21.0016	0.0408	2.1587	-20.2968	0.0395	1.40%	3.47%	- -
9	3.2525	11.4535	-0.1033	3.2707	11.5829	-0.1029	0.56%	1.12%	- -
10	2.1838	8.0849	-0.0527	2.1975	8.1344	-0.0524	0.62%	0.61%	- -
13	6.0691	5.6067	-0.0519	6.0976	5.6422	-0.0517	0.47%	0.63%	- -
14	4.6696	5.4249	-0.0296	4.6882	5.5634	-0.0293	0.40%	2.49%	- -
15	5.4734	6.7622	0.0975	5.4609	5.8298	0.0976	0.23%	- -	- -
16	3.4599	4.1673	0.0537	3.4498	3.379	0.0536	0.29%	- -	- -
21	2.2576	-23.5957	0.0549	2.2236	-22.8241	0.0543	1.53%	3.38%	- -
22	2.0168	-17.7905	0.0361	1.993	-17.1923	0.0363	1.19%	3.48%	- -

Load Case 4

Node no.	Micas Plus Fx (kips)	Micas Plus Fy (kips)	Micas Plus Fz (kips)	GTStrudl Fx (kips)	GTStrudl Fy (kips)	GTStrudl Fz (kips)	Percentage Difference Fx (%)	Percentage Difference Fy (%)	Percentage Difference Fz (%)
1	0.007205	9.2928	2.4532	0.0089	9.286	2.4525	- -	0.07%	0.03%
3	0.0106	25.3468	6.6165	0.0135	25.3727	6.6275	- -	0.10%	0.17%
4	0.003618	14.3801	3.6593	0.0056	14.3725	3.6622	- -	0.05%	0.08%
7	0.000503	7.1825	1.9632	0.0017	6.9206	1.9266	- -	3.78%	1.90%
9	0.0141	-1.9487	4.0555	0.0144	-1.929	4.0541	- -	1.02%	0.03%
10	-0.0189	-7.3391	2.1457	-0.0207	-7.3501	2.1414	- -	0.15%	0.20%
13	0.0298	-7.2879	8.3052	0.0303	-7.31	8.3246	- -	0.30%	0.23%
14	-0.043	-18.0725	4.3985	-0.0467	-18.0821	4.3845	- -	0.05%	0.32%
15	0.0283	-1.3444	5.8784	0.0288	-1.2428	5.8929	- -	- -	0.25%
16	-0.0299	-13.0181	2.9833	-0.0325	-13.1061	2.9902	- -	0.67%	0.23%
21	0.0113	-0.3933	2.4337	0.0116	0.0027	2.4228	- -	- -	0.45%
22	-0.0136	-6.7981	1.7074	-0.015	-6.9371	1.7207	- -	2.00%	0.77%

Load Case 5

Node	Micas Plus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
1	-8.1E-05	5.9232	-0.00042	-0.0001	5.9187	-0.0004	- -	0.08%	- -
3	0.000234	7.951	0.00037	0.0002	7.9454	0.0004	- -	0.07%	- -
4	-0.00015	6.2967	-0.00042	-0.0001	6.2941	-0.0004	- -	0.04%	- -
7	-0.00045	4.5332	1.05E-05	-0.0004	4.5334	0	- -	0.00%	- -
9	0.000287	7.9507	-0.0002	0.0003	7.9448	-0.0002	- -	0.07%	- -
10	-0.00012	5.927	0.00023	-0.0001	5.9226	0.0002	- -	0.07%	- -
13	0.000329	9.9318	0.000313	0.0003	9.9188	0.0003	- -	0.13%	- -
14	0.00039	8.3645	-3.1E-05	0.0004	8.36	0	- -	0.05%	- -
15	0.000133	8.3644	-0.0002	0.0001	8.3601	-0.0002	- -	0.05%	- -
16	-5.9E-06	6.2977	0.000288	0	6.2954	0.0003	- -	0.04%	- -
21	1.57E-06	4.5048	2.34E-05	0	4.5055	0	- -	0.02%	- -
22	-0.00056	4.5349	3.27E-05	-0.0005	4.535	0	- -	0.00%	- -

Load Case 6

Node	Micas Plus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
1	5.0607	17.0979	-0.058	5.0935	17.3261	-0.0581	0.64%	1.32%	- -
3	8.5412	-0.8445	-0.00717	8.6045	-0.7392	-0.007	0.74%	- -	- -
4	6.564	22.7819	0.0647	6.5297	21.0777	0.0644	0.53%	8.09%	- -
7	4.6429	-39.2489	-0.00685	4.5805	-37.8694	-0.0067	1.36%	3.64%	- -
9	6.9614	22.5172	-0.0936	7.0008	22.7809	-0.0937	0.56%	1.16%	- -
10	4.7506	16.5166	-0.0464	4.7817	16.6319	-0.0464	0.65%	0.69%	- -
13	12.8854	10.3695	-0.0122	12.9456	10.425	-0.012	0.47%	0.53%	- -
14	10.165	10.0887	-0.0126	10.2073	10.3551	-0.0124	0.41%	2.57%	- -
15	11.6033	12.739	0.1122	11.5763	10.9099	0.1116	0.23%	16.77%	- -
16	7.5382	0.3409	0.0644	7.5168	6.7359	0.0638	0.28%	- -	- -
21	4.8087	-45.1987	-0.00232	4.737	-43.7062	-0.0019	1.51%	3.41%	- -
22	4.3787	-35.1596	-0.00203	4.3263	-33.9277	-0.0016	1.21%	3.63%	- -

Load Case 7

Node	Micas Plus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
1	0.015	25.316	6.4494	0.0179	25.282	6.4468	- -	0.13%	0.04%
3	0.0264	38.1981	10.5512	0.0314	38.2678	10.574	- -	0.18%	0.22%
4	0.0156	24.7309	6.7157	0.0188	24.7218	6.7222	- -	0.04%	0.10%
7	0.00726	12.8922	3.8431	0.0092	12.4107	3.7721	- -	3.88%	1.88%
9	0.008379	-5.3305	10.6603	0.0086	-5.2745	10.6553	- -	1.06%	0.05%
10	-0.019	-19.9682	5.6196	-0.0217	-19.9872	5.6076	- -	0.10%	0.21%
13	0.019	-13.1213	13.2619	0.0192	-13.1725	13.2982	- -	0.39%	0.27%
14	-0.0497	-25.1371	7.074	-0.0554	-25.1651	7.055	- -	0.11%	0.27%
15	0.0185	-3.0135	10.8019	0.0192	-2.8379	10.8299	- -	6.19%	0.26%
16	-0.0345	-21.6098	5.5044	-0.0387	-21.7612	5.5177	- -	0.70%	0.24%
21	0.007054	-0.7891	4.7569	0.0077	-0.0595	4.7347	- -	- -	0.47%
22	-0.0138	-12.1677	3.3614	-0.0162	-12.4243	3.3865	- -	2.07%	0.74%

Note: (- -) indicates that the values were not considered to be significant

Frame with Moment Resisting Connections

Element End Forces

Load Combination MAXGR

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-312.145	1.1246	0.931	-311.253	1.0941	0.9913	0.29%	2.79%	6.08%
7	43	-761.015	-1.8829	1.1294	-759.335	-1.8057	1.1498	0.22%	4.28%	1.77%
14	29	-213.429	-0.8795	2.6367	-212.424	-0.8538	2.6472	0.47%	3.01%	0.40%
20	29	0.0194	0.1371	2.1221	0.0209	0.1737	2.0514	- -	- -	3.45%
24	31	96.2879	1.208	2.3686	97.32	1.1379	2.3964	1.06%	6.16%	1.16%
34	45	-0.2303	0.0574	-4.7899	-0.2282	0.0618	-4.7158	- -	- -	1.57%
54	20	-152.845	2.1932	-0.7812	-151.942	2.1741	-0.7624	0.59%	0.88%	2.47%
59	55	-183.922	2.973	-0.787	-183.235	2.9315	-0.8353	0.37%	1.42%	5.78%
66	49	0.2081	-0.1735	9.3703	0.2025	-0.1725	9.4545	- -	- -	0.89%
87	23	0.1143	0.1039	-6.2144	0.1025	0.1013	-6.1677	- -	- -	0.76%
90	88	-37.735	0.361	-0.0953	-37.5201	0.3579	-0.0881	0.57%	- -	- -
94	98	-17.491	0.0364	2.1985	-17.2823	0.037	2.2054	1.21%	- -	0.31%

Load Combination MAXDNW

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-196.304	0.4408	73.4719	-195.346	0.3813	73.5578	0.49%	- -	0.12%
7	43	-328.922	-1.424	166.6292	-327.285	-1.402	167.0245	0.50%	1.57%	0.24%
14	29	-116.147	0.0474	24.5373	-115.136	0.0541	24.4821	0.88%	- -	0.23%
20	29	-0.0459	-1.0803	-0.582	-0.0438	-1.0719	-0.6217	- -	0.78%	6.39%
24	31	59.4467	0.0368	10.4392	60.4527	0.0287	10.5195	1.66%	- -	0.76%
34	45	0.0657	1.045	0.3433	0.0663	1.0546	0.3335	- -	0.91%	- -
54	20	-93.1224	0.3299	13.4945	-92.1538	0.3305	13.6169	1.05%	- -	0.90%
59	55	-132.906	-0.4116	31.6978	-132.423	-0.4042	31.3548	0.37%	- -	1.09%
66	49	-0.9617	1.1262	29.0134	-0.9614	1.119	28.9288	- -	0.64%	0.29%
87	23	0.8734	-0.1802	4.3605	0.8505	-0.1734	4.6085	- -	- -	5.38%
90	88	-22.771	0.0938	2.8493	-22.5574	0.0918	2.8531	0.95%	- -	0.13%
94	98	-10.0292	0.172	3.9398	-9.822	0.1686	3.9579	2.11%	- -	0.46%

Load Combination MAXDSW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-167.543	0.5856	-72.9019	-166.595	0.604	-72.9294	0.57%	3.05%	0.04%
7	43	-343.498	-0.2305	-165.579	-341.905	-0.1884	-165.96	0.47%	- -	0.23%
14	29	-109.343	0.7845	-22.8119	-108.347	0.8429	-22.7538	0.92%	6.93%	0.26%
20	29	0.1519	1.2548	-1.4426	0.1512	1.2466	-1.565	- -	0.66%	7.82%
24	31	57.1528	-0.4364	-10.1274	58.1602	-0.4838	-10.1727	1.73%	- -	0.45%
34	45	-0.0548	-0.9692	-0.0374	-0.0557	-0.9724	-0.0725	- -	0.33%	- -
54	20	-96.8966	0.6808	-12.9048	-95.965	0.6389	-12.9961	0.97%	6.56%	0.70%
59	55	-131.685	-0.2321	-32.6753	-130.891	0.004	-32.4011	0.61%	- -	0.85%
66	49	1.103	-1.3714	-22.1858	1.0991	-1.3623	-22.0391	0.35%	0.67%	0.67%
87	23	-0.7132	0.3596	-12.7162	-0.706	0.3485	-12.9062	- -	- -	1.47%
90	88	-22.7657	-0.0251	-2.993	-22.5545	-0.0223	-2.987	0.94%	- -	0.20%
94	98	-9.5999	-0.1318	-2.2496	-9.3884	-0.1293	-2.2627	2.25%	- -	0.58%

Load Combination MAXDEW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-194.582	-61.7366	1.4458	-192.743	-61.4298	1.4756	0.95%	0.50%	2.02%
7	43	-341.817	-122.21	-0.5125	-340.238	-122.747	-0.5019	0.46%	0.44%	2.11%
14	29	-116.351	-22.4456	0.0681	-115.395	-22.6804	0.0743	0.83%	1.04%	- -
20	29	0.5754	-0.436	28.2377	0.5999	-0.4364	28.6085	- -	- -	1.30%
24	31	60.0831	-12.9602	0.4162	61.0134	-12.9859	0.4467	1.52%	0.20%	- -
34	45	4.7532	-0.00628	45.1448	4.7087	-0.0001	43.1548	0.95%	- -	4.61%
54	20	-95.2542	-19.0527	0.8607	-94.227	-19.1003	0.8743	1.09%	0.25%	1.56%
59	55	-121.283	-21.8481	0.7083	-120.967	-21.1487	0.651	0.26%	3.31%	- -
66	49	0.1727	1.7542	2.6167	0.1707	1.7565	2.6553	- -	0.13%	1.45%
87	23	0.2497	-0.9069	-3.3653	0.2428	-0.9146	-3.3302	- -	0.84%	1.05%
90	88	-21.9758	-4.1009	0.6051	-21.7669	-4.0902	0.612	0.96%	0.26%	1.13%
94	98	-10.9679	-4.702	0.6652	-10.7575	-4.6975	0.668	1.96%	0.10%	0.42%

Load Combination MAXDWW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-169.265	62.763	-0.8758	-169.197	62.4152	-0.8471	0.04%	0.56%	3.39%
7	43	-330.603	120.5556	1.5627	-328.953	121.1566	1.5664	0.50%	0.50%	0.24%
14	29	-109.139	23.2775	1.6573	-108.088	23.5773	1.654	0.97%	1.27%	0.20%
20	29	-0.4693	0.6104	-30.2623	-0.4925	0.611	-30.7952	- -	0.10%	1.73%
24	31	56.5164	12.5605	-0.1043	57.5995	12.4734	-0.0999	1.88%	0.70%	- -
34	45	-4.7423	0.082	-44.8389	-4.6982	0.0821	-42.8939	0.94%	- -	4.53%
54	20	-94.7649	20.0634	-0.271	-93.8918	20.0697	-0.2534	0.93%	0.03%	- -
59	55	-143.307	21.2045	-1.6858	-142.347	20.535	-1.6973	0.67%	3.26%	0.68%
66	49	-0.0314	-1.9994	4.2109	-0.033	-1.9997	4.2344	- -	0.02%	0.55%
87	23	-0.0895	1.0864	-4.9904	-0.0983	1.0896	-4.9676	- -	0.29%	0.46%
90	88	-23.5608	4.1696	-0.7488	-23.3449	4.1597	-0.7459	0.92%	0.24%	0.39%
94	98	-8.6612	4.7422	1.025	-8.4528	4.7368	1.0272	2.47%	0.11%	0.21%

Load Combination MAXDNE

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-206.654	0.2018	134.5998	-205.692	0.116	134.7578	0.47%	- -	0.12%
7	43	-323.089	-1.2063	265.7636	-321.423	-1.1795	266.4968	0.52%	2.27%	0.28%
14	29	-122.352	0.0415	65.5499	-121.321	0.0328	65.3964	0.85%	- -	0.23%
20	29	0.0906	0.3542	-0.4526	0.0945	0.3772	-0.4685	- -	- -	- -
24	31	59.8561	-0.3313	10.8959	60.8593	-0.4084	11.0445	1.65%	- -	1.35%
34	45	0.0454	0.9406	0.2266	0.0467	0.9538	0.237	- -	1.38%	- -
54	20	-92.5362	0.9748	20.1168	-91.562	0.9968	20.2712	1.06%	2.21%	0.76%
59	55	-133.35	-0.3213	60.9055	-132.98	-0.3229	60.2707	0.28%	- -	1.05%
66	49	-2.9846	-0.3395	75.358	-2.9811	-0.3637	75.0599	0.12%	- -	0.40%
87	23	1.8542	0.03	9.6978	1.824	0.0431	10.0703	1.66%	- -	3.70%
90	88	-22.7434	-0.0169	4.4532	-22.5287	-0.0214	4.4497	0.95%	- -	0.08%
94	98	-10.0861	0.0171	4.1723	-9.8799	0.0106	4.192	2.09%	- -	0.47%

Load Combination MAXDSE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-157.193	0.8246	-134.03	-156.249	0.8694	-134.13	0.60%	5.15%	0.07%
7	43	-349.331	-0.4483	-264.713	-347.762	-0.4108	-265.432	0.45%	- -	0.27%
14	29	-103.138	0.7904	-63.8245	-102.162	0.8641	-63.6681	0.96%	- -	0.25%
20	29	0.0155	-0.1797	-1.572	0.0129	-0.2026	-1.7182	- -	- -	8.51%
24	31	56.7434	-0.0683	-10.5841	57.7536	-0.1041	-10.6978	1.75%	- -	1.06%
34	45	-0.0345	-0.8649	0.0794	-0.0362	-0.8716	0.024	- -	0.77%	- -
54	20	-97.4828	0.0358	-19.5271	-96.5568	-0.0274	-19.6504	0.96%	- -	0.63%
59	55	-131.241	-0.3224	-61.8829	-130.333	-0.2908	-61.3169	0.70%	- -	0.92%
66	49	3.1259	0.0943	-68.5303	3.1189	0.1204	-68.1702	0.22%	- -	0.53%
87	23	-1.694	0.1495	-18.0535	-1.6795	0.132	-18.368	0.86%	- -	1.71%
90	88	-22.7932	0.0855	-4.5968	-22.5832	0.0909	-4.5836	0.93%	- -	0.29%
94	98	-9.543	0.023	-2.4822	-9.3305	0.0287	-2.4968	2.28%	- -	0.58%

Load Combination MAXDEE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-204.705	-130.766	1.5789	-202.048	-130.1	1.6024	1.32%	0.51%	1.47%
7	43	-346.579	-258.535	0.2809	-345.02	-259.708	0.2918	0.45%	0.45%	- -
14	29	-119.399	-43.7411	0.0658	-118.48	-44.2084	0.0686	0.78%	1.06%	- -
20	29	1.0614	-1.2016	53.0262	1.1122	-1.1987	53.7685	4.57%	0.24%	1.38%
24	31	59.2938	-21.7507	0.5358	60.2	-21.7447	0.5785	1.51%	0.03%	- -
34	45	10.5302	0.000428	94.9797	10.4381	0.0077	90.8149	0.88%	- -	4.59%
54	20	-94.8544	-30.8094	0.9093	-93.8074	-30.8595	0.9203	1.12%	0.16%	1.20%
59	55	-113.536	-45.8274	0.0383	-113.456	-44.3991	-0.0055	0.07%	3.22%	- -
66	49	0.2507	3.8308	2.6035	0.2488	3.8276	2.6394	- -	0.08%	1.36%
87	23	0.3847	-1.8245	-3.6491	0.3803	-1.8385	-3.6344	- -	0.76%	0.40%
90	88	-22.3311	-2.4552	0.163	-22.1187	-2.45	0.1683	0.96%	0.21%	- -
94	98	-10.3642	-2.2626	0.8082	-10.1555	-2.2627	0.8151	2.06%	0.00%	0.85%

Load Combination MAXDWE

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-159.141	131.7927	-1.009	-159.893	131.0857	-0.9739	0.47%	0.54%	3.60%
7	43	-325.84	256.8806	0.7693	-324.17	258.1175	0.7727	0.52%	0.48%	0.44%
14	29	-106.09	44.573	1.6595	-105.003	45.1053	1.6596	1.04%	1.18%	0.01%
20	29	-0.9554	1.3761	-55.0508	-1.0048	1.3733	-55.9552	- -	0.20%	1.62%
24	31	57.3056	21.3511	-0.2239	58.413	21.2322	-0.2318	1.90%	0.56%	- -
34	45	-10.5193	0.0753	-94.6738	-10.4276	0.0745	-90.5539	0.88%	- -	4.55%
54	20	-95.1647	31.82	-0.3196	-94.3113	31.8289	-0.2995	0.90%	0.03%	- -
59	55	-151.055	45.1837	-1.0158	-149.858	43.7854	-1.0408	0.80%	3.19%	2.40%
66	49	-0.1095	-4.076	4.2242	-0.1111	-4.0708	4.2503	- -	0.13%	0.61%
87	23	-0.2245	2.0039	-4.7066	-0.2358	2.0135	-4.6634	- -	0.48%	0.93%
90	88	-23.2056	2.5239	-0.3066	-22.9932	2.5195	-0.3023	0.92%	0.17%	- -
94	98	-9.2649	2.3028	0.8819	-9.0548	2.3019	0.8802	2.32%	0.04%	0.19%

Load Combination MAXGNW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-244.894	0.7892	55.5884	-244.221	0.737	55.6761	0.28%	- -	0.16%
7	43	-565.296	-1.8597	125.4252	-564.019	-1.8093	125.7316	0.23%	2.79%	0.24%
14	29	-162.623	-0.936	19.7335	-161.864	-0.9362	19.6988	0.47%	0.02%	0.18%
20	29	-0.0596	-0.7728	1.9143	-0.0574	-0.7665	1.8922	- -	0.82%	1.17%
24	31	73.0761	1.0835	9.4889	73.8497	1.0241	9.5569	1.05%	- -	0.71%
34	45	-0.1276	0.7983	-3.4496	-0.1254	0.8065	-3.3846	- -	1.02%	1.92%
54	20	-113.219	1.5133	9.3138	-112.527	1.5149	9.4081	0.61%	0.11%	1.00%
59	55	-138.399	2.1624	23.5497	-138.001	2.1256	23.282	0.29%	1.73%	1.15%
66	49	-0.6182	0.8065	26.2274	-0.6208	0.8011	26.2039	- -	0.67%	0.09%
87	23	0.6807	-0.1245	1.743	0.6606	-0.1197	1.9422	- -	- -	- -
90	88	-28.3032	0.3153	2.1194	-28.1412	0.3112	2.124	0.58%	- -	0.22%
94	98	-13.2792	0.1413	3.9699	-13.1243	0.1395	3.9868	1.18%	- -	0.42%

Load Combination MAXGSW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-223.324	0.8978	-54.1919	-222.659	0.9041	-54.1893	0.30%	0.70%	0.00%
7	43	-576.227	-0.9646	-123.731	-574.984	-0.8991	-124.007	0.22%	- -	0.22%
14	29	-157.52	-0.3833	-15.7785	-156.772	-0.3446	-15.7281	0.48%	- -	0.32%
20	29	0.0887	0.9785	1.2689	0.0888	0.9724	1.1848	- -	0.63%	- -
24	31	71.3557	0.7286	-5.936	72.1304	0.6828	-5.9623	1.07%	- -	0.44%
34	45	-0.2179	-0.7123	-3.7352	-0.2169	-0.7137	-3.6891	- -	0.20%	1.25%
54	20	-116.049	1.7765	-10.4857	-115.386	1.7462	-10.5517	0.57%	1.74%	0.63%
59	55	-137.483	2.2971	-24.7302	-136.852	2.2717	-24.5349	0.46%	1.12%	0.80%
66	49	0.9303	-1.0667	-12.172	0.9246	-1.0599	-12.0221	- -	0.64%	1.25%
87	23	-0.5092	0.2804	-11.0645	-0.5068	0.2717	-11.1938	- -	- -	1.16%
90	88	-28.2993	0.2261	-2.2623	-28.139	0.2257	-2.2561	0.57%	- -	0.27%
94	98	-12.9573	-0.0866	-0.6721	-12.7992	-0.0839	-0.6787	1.24%	- -	0.97%

Load Combination MAXGEW

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-243.603	-45.8439	1.5688	-242.27	-45.6213	1.6145	0.55%	0.49%	2.83%
7	43	-574.966	-92.4493	0.0689	-573.733	-92.818	0.0868	0.21%	0.40%	- -
14	29	-162.776	-17.8058	1.3816	-162.058	-17.987	1.393	0.44%	1.01%	0.82%
20	29	0.4063	-0.2896	23.5291	0.4253	-0.2898	23.8149	- -	- -	1.20%
24	31	73.5535	-8.6642	1.9717	74.2702	-8.6938	2.0023	0.96%	0.34%	1.53%
34	45	3.3881	0.009915	30.1514	3.3564	0.0156	28.7314	0.94%	- -	4.94%
54	20	-114.818	-13.0237	-0.1616	-114.082	-13.0582	-0.1489	0.64%	0.26%	- -
59	55	-129.682	-13.915	0.3075	-129.409	-13.4327	0.2542	0.21%	3.59%	- -
66	49	0.2326	1.2774	6.4299	0.2283	1.2792	6.4987	- -	0.14%	1.06%
87	23	0.2129	-0.6695	-4.0513	0.2048	-0.6756	-4.0117	- -	0.90%	0.99%
90	88	-27.7069	-2.8307	0.4363	-27.5483	-2.8252	0.4432	0.58%	0.19%	- -
94	98	-13.9833	-3.5143	1.514	-13.826	-3.5101	1.5193	1.14%	0.12%	0.35%

Load Combination MAXGWW

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-224.615	47.5308	-0.1723	-224.61	47.2624	-0.1276	0.00%	0.57%	- -
7	43	-566.556	89.625	1.6253	-565.27	90.1096	1.638	0.23%	0.54%	0.78%
14	29	-157.367	16.4865	2.5735	-156.578	16.7062	2.5778	0.50%	1.32%	0.17%
20	29	-0.3772	0.4952	-20.3459	-0.3939	0.4957	-20.7379	- -	- -	1.89%
24	31	70.8784	10.4763	1.5813	71.7098	10.4006	1.5923	1.16%	0.73%	0.69%
34	45	-3.7335	0.0761	-37.3363	-3.6987	0.0771	-35.8051	0.94%	- -	4.28%
54	20	-114.451	16.3134	-1.0103	-113.831	16.3193	-0.9947	0.54%	0.04%	1.57%
59	55	-146.2	18.3745	-1.488	-145.444	17.83	-1.5071	0.52%	3.05%	1.27%
66	49	0.0795	-1.5377	7.6255	0.0755	-1.5379	7.6831	- -	0.01%	0.75%
87	23	-0.0415	0.8254	-5.2702	-0.051	0.8276	-5.2398	- -	0.27%	0.58%
90	88	-28.8956	3.3721	-0.5792	-28.7318	3.3622	-0.5752	0.57%	0.29%	0.70%
94	98	-12.2532	3.5689	1.7838	-12.0975	3.5657	1.7888	1.29%	0.09%	0.28%

Load Combination MAXGNE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-252.657	0.6099	101.4343	-251.981	0.538	101.5726	0.27%	- -	0.14%
7	43	-560.92	-1.6964	199.7759	-559.622	-1.6425	200.3358	0.23%	3.28%	0.28%
14	29	-167.277	-0.9405	50.4929	-166.503	-0.9521	50.3846	0.47%	1.22%	0.21%
20	29	0.0427	0.303	2.0114	0.0463	0.3204	2.0071	- -	- -	0.21%
24	31	73.3832	0.8074	9.8315	74.1547	0.7393	9.9507	1.04%	- -	1.20%
34	45	-0.1428	0.7201	-3.5372	-0.1401	0.7309	-3.457	- -	1.48%	2.32%
54	20	-112.779	1.997	14.2806	-112.083	2.0146	14.3988	0.62%	0.87%	0.82%
59	55	-138.733	2.2302	45.4554	-138.419	2.1866	44.9689	0.23%	1.99%	1.08%
66	49	-2.1354	-0.2928	60.9858	-2.1356	-0.3109	60.8022	0.01%	- -	0.30%
87	23	1.4163	0.0331	5.746	1.3907	0.0427	6.0386	1.84%	- -	4.85%
90	88	-28.2826	0.2323	3.3223	-28.1197	0.2264	3.3215	0.58%	- -	0.02%
94	98	-13.3219	0.0251	4.1444	-13.1678	0.021	4.1623	1.17%	- -	0.43%

Load Combination MAXGSE

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-215.561	1.077	-100.038	-214.899	1.1031	-100.089	0.31%	2.37%	0.05%
7	43	-580.602	-1.1279	-198.082	-579.381	-1.066	-198.611	0.21%	5.81%	0.27%
14	29	-152.866	-0.3788	-46.5379	-152.133	-0.3287	-46.4138	0.48%	- -	0.27%
20	29	-0.0136	-0.0974	1.1718	-0.0149	-0.1374	0.7932	- -	- -	- -
24	31	71.0487	1.0046	-6.2785	71.8254	0.9675	-6.356	1.08%	3.83%	1.22%
34	45	-0.2027	-0.634	-3.6476	-0.2022	-0.6381	-3.6167	- -	0.64%	0.85%
54	20	-116.489	1.2928	-15.4524	-115.83	1.2465	-15.5424	0.57%	3.71%	0.58%
59	55	-137.15	2.2294	-46.6359	-136.434	2.2107	-46.2218	0.52%	0.85%	0.90%
66	49	2.4475	0.0326	-46.9304	2.4394	0.0522	-46.6204	0.33%	- -	0.66%
87	23	-1.2449	0.1227	-15.0675	-1.2369	0.1093	-15.2901	0.65%	- -	1.46%
90	88	-28.3199	0.3091	-3.4652	-28.1605	0.3105	-3.4535	0.57%	- -	0.34%
94	98	-12.9146	0.0295	-0.8466	-12.7557	0.0345	-0.8542	1.25%	- -	0.89%

Load Combination MAXGEE

El. no.	Nd. no.	MicasPlus Axial	MicasPlus My	MicasPlus Mz	GTStrudl Axial	GTStrudl My	GTStrudl Mz	Percentage Difference Axial	Percentage Difference My	Percentage Difference Mz
		kips or kip-ft			kips or kip-ft			%		
3	27	-251.195	-97.6161	1.6687	-249.248	-97.1242	1.7096	0.78%	0.51%	2.39%
7	43	-578.539	-194.693	0.6639	-577.32	-195.539	0.682	0.21%	0.43%	2.65%
14	29	-165.062	-33.7774	1.3799	-164.372	-34.133	1.3887	0.42%	1.04%	0.63%
20	29	0.7709	-0.8638	42.1205	0.8095	-0.8615	42.6849	- -	0.27%	1.32%
24	31	72.9615	-15.2571	2.0614	73.6601	-15.2629	2.1012	0.95%	0.04%	1.89%
34	45	7.7208	0.0149	67.5276	7.6535	0.0213	64.4765	0.88%	- -	4.73%
54	20	-114.518	-21.8412	-0.1251	-113.768	-21.8776	-0.1144	0.66%	0.17%	- -
59	55	-123.872	-31.8994	-0.195	-123.776	-30.8705	-0.2382	0.08%	3.33%	- -
66	49	0.2911	2.8349	6.42	0.2868	2.8325	6.4868	- -	0.08%	1.03%
87	23	0.3142	-1.3577	-4.2642	0.3079	-1.33685	-4.2399	- -	1.56%	0.57%
90	88	-27.9733	-1.5964	0.1047	-27.8121	-1.5951	0.1104	0.58%	0.08%	- -
94	98	-13.5305	-1.6847	1.6213	-13.3745	-1.6839	1.6296	1.17%	0.05%	0.51%

Load Combination MAXGWE

El.	Nd.	MicasPlus			GTStrudl			Percentage Difference		
		Axial	My	Mz	Axial	My	Mz	Axial	My	Mz
no.	no.	kips or kip-ft			kips or kip-ft			%		
3	27	-217.022	99.3031	-0.2722	-217.632	98.7653	-0.2227	0.28%	0.54%	- -
7	43	-562.984	191.8687	1.0303	-561.683	192.8303	1.0427	0.23%	0.50%	1.19%
14	29	-155.081	32.4581	2.5751	-154.264	32.8523	2.582	0.53%	1.20%	0.27%
20	29	-0.7418	1.0695	-38.9373	-0.7782	1.0675	-39.6079	- -	0.19%	1.69%
24	31	71.4704	17.0692	1.4916	72.3199	16.9697	1.4934	1.17%	0.59%	0.12%
34	45	-8.0663	0.0711	-74.7125	-7.9958	0.0714	-71.5502	0.88%	- -	4.42%
54	20	-114.75	25.1309	-1.0468	-114.145	25.1387	-1.0292	0.53%	0.03%	1.71%
59	55	-152.011	36.3589	-0.9855	-151.077	35.2678	-1.0147	0.62%	3.09%	2.88%
66	49	0.021	-3.0952	7.6354	0.0169	-3.0913	7.695	- -	0.13%	0.77%
87	23	-0.1427	1.5136	-5.0574	-0.1542	1.5205	-5.0117	- -	0.45%	0.91%
90	88	-28.6292	2.1379	-0.2476	-28.468	2.132	-0.2425	0.57%	0.28%	- -
94	98	-12.706	1.7393	1.6765	-12.549	1.7395	1.6784	1.25%	0.01%	0.11%

Note: (- -) indicates that the values were not considered to be significant

Frame with Moment Resisting Connections

Joint Displacements

Load Case 1

Node no.	MicasPlus Tx (inch)	MicasPlus Ty (inch)	MicasPlus Tz (inch)	GTStrudl Tx (inch)	GTStrudl Ty (inch)	GTStrudl Tz (inch)	Percentage Difference Tx (%)	Percentage Difference Ty (%)	Percentage Difference Tz (%)
2	-0.0463	-0.0717	-4.9E-05	-0.0445	-0.0717	0	- -	0.00%	- -
24	-0.0399	-0.0561	0.0231	-0.0372	-0.056	0.0221	- -	0.18%	- -
26	-0.0106	-0.0342	0.009095	-0.0102	-0.0342	0.0091	- -	- -	- -
32	-0.0262	-0.033	0.0151	-0.0252	-0.033	0.0146	- -	- -	- -
41	-0.011	-0.0417	0.002018	-0.0112	-0.0417	0.0021	- -	- -	- -
52	-0.0215	-0.0745	0.0179	-0.0199	-0.0745	0.0179	- -	0.00%	- -
86	-0.0594	-0.139	0.0368	-0.0572	-0.139	0.0363	3.85%	0.00%	- -
88	-0.0595	-0.1007	0.0299	-0.0572	-0.1007	0.0287	4.02%	0.00%	- -
92	-0.0687	-0.0693	0.0297	-0.0653	-0.0692	0.0285	5.21%	0.14%	- -
93	-0.0685	-0.1108	0.0178	-0.0652	-0.1108	0.0177	5.06%	0.00%	- -
97	-0.0858	-0.0534	0.0301	-0.0838	-0.0534	0.0289	2.39%	0.00%	- -
98	-0.0858	-0.0848	0.037	-0.0838	-0.0848	0.0365	2.39%	0.00%	- -

Load Case 2

Node no	MicasPlus Tx (inch)	MicasPlus Ty (inch)	MicasPlus Tz (inch)	GTStrudl Tx (inch)	GTStrudl Ty (inch)	GTStrudl Tz (inch)	Percentage Difference Tx (%)	Percentage Difference Ty (%)	Percentage Difference Tz (%)
2	-0.00793	-0.0389	-0.0026	-0.0074	-0.0389	0	- -	- -	- -
24	-0.00324	-0.041	0.0136	-0.0021	-0.041	0.013	- -	- -	- -
26	-0.00028	-0.0151	0.004276	-0.0002	-0.0151	0.0043	- -	- -	- -
32	-0.00354	-0.0259	0.008798	-0.0033	-0.0259	0.0085	- -	- -	- -
41	-0.00147	-0.0209	0.000488	-0.0012	-0.0209	0.0005	- -	- -	- -
52	-0.00094	-0.0355	0.008967	-0.0003	-0.0355	0.009	- -	- -	- -
86	0.000824	-0.0737	0.0226	0.0015	-0.0737	0.0222	- -	0.00%	- -
88	0.000817	-0.0698	0.018	0.0015	-0.0698	0.0172	- -	0.00%	- -
92	-0.00909	-0.0491	0.0178	-0.0076	-0.0491	0.017	- -	- -	- -
93	-0.00902	-0.0559	0.0126	-0.0076	-0.0559	0.0126	- -	0.00%	- -
97	-0.0173	-0.0394	0.0181	-0.0168	-0.0394	0.0173	- -	- -	- -
98	-0.0173	-0.0485	0.0226	-0.0168	-0.0485	0.0223	- -	- -	- -

Load Case 3

Node No.	Micas Plus			GTStrudl			Percentage Diference		
	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
		inch			inch			%	
2	-0.971	-0.00158	0.008552	-0.9623	-0.0016	0.0086	0.90%	- -	- -
24	-0.9012	0.004179	-0.0151	-0.8932	0.004	-0.0151	0.90%	- -	- -
26	-0.6155	3.41E-05	0.0025	-0.6118	0	0.0025	0.60%	- -	- -
32	-0.8502	0.00431	-0.0119	-0.8513	0.0042	-0.0119	0.13%	- -	- -
41	-0.6451	-0.00093	0.005607	-0.641	-0.0009	0.0056	0.64%	- -	- -
52	-0.7857	-0.00058	0.003797	-0.7791	-0.0006	0.0038	0.85%	- -	- -
86	-1.5662	-0.00119	-0.00957	-1.5589	-0.0011	-0.0096	0.47%	- -	- -
88	-1.5674	0.00605	-0.021	-1.5601	0.0059	-0.0211	0.47%	- -	- -
92	-1.2788	0.004594	-0.0211	-1.2712	0.0045	-0.0212	0.60%	- -	- -
93	-1.2777	-0.00096	0.01	-1.27	-0.001	0.0101	0.61%	- -	- -
97	-1.5242	0.005545	-0.0209	-1.517	0.0054	-0.021	0.47%	- -	- -
98	-1.5238	-0.00302	-0.00965	-1.5166	-0.0029	-0.0097	0.47%	- -	- -

Load Case 4

Node no.	Micas Plus			GTStrudl			Percentage Difference		
	Tx	Ty	Tz	Tx	Ty	Tz	Tx	Ty	Tz
		inch			inch			%	
2	-0.00403	-0.00162	-0.3197	-0.0047	-0.0016	-0.3221	- -	- -	0.75%
24	0.008014	0.001725	-0.5042	0.0086	0.0018	-0.5108	- -	- -	1.29%
26	-0.00212	-0.00208	-0.0298	-0.0025	-0.0021	-0.3429	- -	- -	- -
32	-0.00378	-0.00152	-0.4331	-0.0044	-0.0015	-0.4382	- -	- -	1.16%
41	-0.00293	0.00016	-0.2143	-0.0029	0.0002	-0.2157	- -	- -	0.65%
52	0.008025	0.002421	-0.4779	0.0085	0.0024	-0.4798	- -	- -	0.40%
86	0.002746	-0.0002	-0.5943	0.0027	-0.0002	-0.5995	- -	- -	0.87%
88	0.002742	-2.4E-05	-0.5377	0.0027	-0.0001	-0.5444	- -	- -	1.23%
92	-0.0081	0.001853	-0.538	-0.0072	0.0019	-0.5447	- -	- -	1.23%
93	-0.00808	0.003275	-0.6346	-0.0072	0.0033	-0.6379	- -	- -	0.52%
97	0.0121	-0.00184	-0.5375	0.011	-0.0018	-0.5443	- -	- -	1.25%
98	0.0121	-0.00265	-0.5939	0.011	-0.0027	-0.5992	- -	- -	0.88%

Load Case 5

Node no.	Micas Plus Tx	Micas Plus Ty	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
		inch			inch			%	
2	-0.00012	-0.00107	-7.3E-06	-0.0001	-0.0011	0	- -	- -	- -
24	-7.1E-05	-0.00109	-8.6E-07	-0.0001	-0.0011	0	- -	- -	- -
26	-3.6E-05	-0.00054	1.91E-05	0	-0.0005	0	- -	- -	- -
32	-8.2E-05	-0.00092	-2.7E-06	-0.0001	-0.0009	0	- -	- -	- -
41	-3.5E-05	-0.00054	1.97E-06	0	-0.0005	0	- -	- -	- -
52	-4.2E-05	-0.00094	4.55E-05	0	-0.0009	0	- -	- -	- -
86	-7.3E-05	-0.0012	4.08E-05	-0.0001	-0.0012	0	- -	- -	- -
88	-7.3E-05	-0.00121	1.13E-06	-0.0001	-0.0012	0	- -	- -	- -
92	-7.8E-05	-0.00122	1.23E-06	-0.0001	-0.0012	0	- -	- -	- -
93	-7.8E-05	-0.0012	7.93E-05	-0.0001	-0.0012	0.0001	- -	- -	- -
97	-0.00024	-0.00122	1.01E-06	-0.0002	-0.0012	0	- -	- -	- -
98	-0.00024	-0.00135	4E-05	-0.0002	-0.0013	0	- -	- -	- -

Load Case 6

Node no.	Micas Plus Tx	Micas Plus Ty	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
		inch			inch			%	
2	-1.9537	-0.00304	0.00785	-1.9365	-0.0031	0.0079	0.89%	- -	- -
24	-1.9097	0.007671	-0.00196	-1.893	0.0074	-0.0019	0.88%	- -	- -
26	-1.2826	6.92E-05	0.001092	-1.2748	0.0001	0.0011	0.61%	- -	- -
32	-1.7752	0.007714	-0.00148	-1.7414	0.0074	-0.0015	1.94%	- -	- -
41	-1.3642	-0.00185	0.005123	-1.3554	-0.0019	0.0052	0.65%	- -	- -
52	-1.7125	-0.00097	0.001837	-1.6982	-0.001	0.0018	0.84%	- -	- -
86	-2.4878	-0.00185	-0.0146	-2.4721	-0.0016	-0.0147	0.64%	- -	- -
88	-2.4886	0.0102	-0.00372	-2.4729	0.0099	-0.0036	0.63%	- -	- -
92	-2.2865	0.00805	-0.00383	-2.2703	0.0078	-0.0038	0.71%	- -	- -
93	-2.2854	-0.00141	0.006393	-2.2692	-0.0015	0.0065	0.71%	- -	- -
97	-2.2414	0.00862	-0.00359	-2.2246	0.0083	-0.0035	0.76%	- -	- -
98	-2.2412	-0.00394	-0.0148	-2.2244	-0.0036	-0.0148	0.76%	- -	- -

Load Case 7

Node no.	Micas Plus Tx	Micas Plus Ty	Micas Plus Tz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
		inch			inch			%	
2	-0.0113	-0.00448	-0.8604	-0.0126	-0.0045	-0.8668	- -	- -	0.74%
24	0.0122	0.002967	-0.9506	0.0132	0.003	-0.9624	- -	- -	1.23%
26	-0.00507	-0.00313	-0.5423	-0.0058	-0.0031	-0.5446	- -	- -	0.42%
32	-0.00878	-0.00265	-0.8306	-0.0098	-0.0026	-0.8401	- -	- -	1.13%
41	-0.00145	0.000437	-0.5672	-0.0014	0.0004	-0.5709	- -	- -	0.65%
52	0.009163	0.003267	-0.7517	0.01	0.0033	-0.7552	- -	- -	0.46%
86	-0.00858	-0.00016	-1.0066	-0.0088	-0.0002	-1.0157	- -	- -	0.90%
88	-0.00857	9.04E-07	-1.0029	-0.0088	-0.0002	-1.0149	- -	- -	1.18%
92	0.0199	0.003129	-1.0036	0.0216	0.0032	-1.0156	- -	- -	1.18%
93	0.0199	0.003833	-0.885	0.0217	0.0038	-0.8892	- -	- -	0.47%
97	-0.0135	-0.00311	-1.0026	-0.0156	-0.003	-1.0146	- -	- -	1.18%
98	-0.0135	-0.00435	-1.0063	-0.0156	-0.0044	-1.0155	- -	- -	0.91%

Note: (- -) indicates that the values were not considered to be significant

Frame with Moment Resisting Connections

Code Check

Element no.	Code Check		Percentage Difference
	Micas Plus	GTStrudl	
1	0.739	0.7393	0.04%
2	0.63	0.631	0.16%
3	0.722	0.7138	1.15%
4	0.648	0.6372	1.69%
5	0.901	0.9017	0.08%
6	0.67	0.6703	0.04%
7	0.878	0.8785	0.06%
8	0.718	0.7187	0.10%
9	0.844	0.8401	0.46%
10	0.869	0.8621	0.80%
11	0.893	0.8792	1.57%
12	0.696	0.6858	1.49%
13	0.747	0.755	1.06%
14	0.286	0.2843	0.60%
15	0.269	0.269	0.00%
16	0.72	0.7271	0.98%
17	0.321	0.3174	1.13%
18	1.031	1.0027	2.82%
19	0.257	0.2456	4.64%
20	0.32	0.3243	1.33%
21	0.11	0.1085	1.38%
22	0.137	0.1366	0.29%
23	0.341	0.3478	1.96%
24	0.154	0.1522	1.18%
25	0.528	0.5134	2.84%
26	0.117	0.113	3.54%
27	0.199	0.1997	0.35%
28	0.178	0.1791	0.61%
29	0.272	0.2685	1.30%
30	0.855	0.8654	1.20%
31	0.694	0.7011	1.01%
32	0.617	0.6211	0.66%
33	0.5	0.5021	0.42%
34	1.01	0.9676	4.38%
35	0.871	0.8484	2.66%
36	0.351	0.3548	1.07%
37	0.314	0.3132	0.26%
38	0.428	0.434	1.38%
39	0.387	0.3963	2.35%
40	0.592	0.5775	2.51%
41	0.562	0.549	2.37%
42	0.223	0.224	0.45%
43	0.23	0.2295	0.22%
44	0.114	0.1152	1.04%
45	0.162	0.1639	1.16%
46	0.283	0.2643	7.08%
47	0.27	0.2678	0.82%
48	0.275	0.2724	0.95%
49	0.342	0.3419	0.03%
50	0.389	0.3851	1.01%
51	0.299	0.2864	4.40%
52	0.097	0.0968	- -

Code Check

Element no.	Code Check		Percentage Difference
	Micas Plus	GTStrudl	
53	0.173	0.1723	0.41%
54	0.183	0.1816	0.77%
55	0.137	0.1329	3.09%
56	0.334	0.3291	1.49%
57	0.379	0.3764	0.69%
58	0.354	0.3457	2.40%
59	0.359	0.3412	5.22%
60	0.124	0.1248	0.64%
61	0.201	0.2009	0.05%
62	0.189	0.1871	1.02%
63	0.149	0.145	2.76%
64	0.336	0.3365	0.15%
65	0.363	0.3628	0.06%
66	0.132	0.1324	0.30%
67	0.14	0.1427	1.89%
68	0.068	0.0681	- -
69	0.088	0.0878	- -
70	0.339	0.3409	0.56%
71	0.355	0.3555	0.14%
72	0.4	0.4015	0.37%
73	0.402	0.4054	0.84%
74	0.156	0.1565	0.32%
75	0.168	0.1693	0.77%
76	0.135	0.1349	0.07%
77	0.158	0.1596	1.00%
78	0.116	0.1165	0.43%

Element no.	Code Check		Percentage Difference
	Micas Plus	GTStrudl	
79	0.143	0.1453	1.58%
80	0.112	0.1125	0.44%
81	0.204	0.2071	1.50%
82	0.294	0.2839	3.56%
83	0.412	0.424	2.83%
84	0.143	0.1381	3.55%
85	0.18	0.1833	1.80%
86	0.074	0.0718	- -
87	0.142	0.1428	0.56%
88	0.612	0.6148	0.46%
89	0.9	0.9009	0.10%
90	0.754	0.7268	3.74%
91	0.557	0.559	0.36%
92	0.62	0.6226	0.42%
93	0.47	0.4584	2.53%
94	0.515	0.5168	0.35%
95	0.572	0.5636	1.49%
96	0.209	0.2084	0.29%
97	0.158	0.1586	0.38%
98	0.133	0.1334	0.30%
99	0.217	0.2177	0.32%
100	0.229	0.2287	0.13%
101	0.107	0.1073	0.28%
102	0.074	0.0738	- -
103	0.059	0.0589	- -
104	0.083	0.0835	- -
105	0.098	0.0987	- -

Note: (- -) indicates that the values were not considered to be significant

Frame with Moment Resisting Connections

Design Run 1

Member	Micas Plus		GTSt rudl	
no.	Mem. Size	Cd. Check	Mem. Size	Cd. Check
1	W14X193	0.945	W14x193	0.94379
2	W14X257	0.897	W14X257	0.89604
3	W14X193	0.917	W14X193	0.90985
4	W14X109	0.889	W14X109	0.87629
5	W14X311	0.907	W14X311	0.90641
6	W14X193	0.874	W14X193	0.87326
7	W14X398	0.866	W14X398	0.86563
8	W14X283	0.903	W14X283	0.90231
9	W14X311	0.875	W14X311	0.8735
10	W14X233	0.866	W14X233	0.86494
11	W14X145	0.791	W14X145	0.78355
12	W14X120	0.892	W14X120	0.88173
88	W14X30	0.761	W14X30	0.72604
89	W14X34	0.861	W14X34	0.83398
90	W14X30	0.765	W14X30	0.68445
91	W14X30	0.701	W14X30	0.66554
92	W14X30	0.775	W14X30	0.75099
93	W14X30	0.527	W14X30	0.59195
94	W14X30	0.533	W14X30	0.59758
95	W14X30	0.583	W14X30	0.59195

Design Run 2

Member	MicasPlus		GTStrudl	
no.	Mem. Size	Cd. Check	Mem. Size	Cd. Check
1	W14X233	0.825	W14X211	0.87764
2	W14X283	0.842	W14X257	0.90887
3	W14X211	0.85	W14X193	0.94856
4	W14X120	0.865	W14X145	0.80491
5	W14X342	0.933	W14X342	0.87279
6	W14X211	0.874	W14X193	0.8884
7	W14X398	0.915	W14X398	0.91106
8	W14X283	0.943	W14X283	0.91751
9	W14X311	0.908	W14X311	0.94483
10	W14X233	0.884	W14X233	0.89915
11	W14X145	0.868	W14X176	0.86976
12	W14X132	0.864	W14X145	0.87428
88	W14X30	0.762	W14X30	0.74441
89	W14X34	0.862	W14X34	0.88694
90	W14X30	0.766	W14X30	0.6895
91	W14X30	0.702	W14X30	0.6336
92	W14X30	0.776	W14X30	0.77492
93	W14X30	0.531	W14X26	0.93009
94	W14X30	0.534	W14X30	0.62013
95	W14X30	0.586	W14X30	0.63141

Design Run 3

Member	MicasPlus		GTStrudl	
no.	Mem. Size	Cd. Check	Mem. Size	Cd. Check
1	W14X233	0.825	W14X211	0.85143
2	W14X283	0.854	W14X257	0.93524
3	W14X211	0.85	W14X193	0.91404
4	W14X120	0.88	W14X145	0.87042
5	W14X370	0.841	W14X342	0.90611
6	W14X211	0.874	W14X193	0.85837
7	W14X398	0.915	W14X398	0.88277
8	W14X283	0.95	W14X283	0.94231
9	W14X311	0.919	W14X342	0.84457
10	W14X233	0.884	W14X233	0.86734
11	W14X145	0.907	W14X193	0.83631
12	W14X132	0.88	W14X145	0.94704
88	W14X30	0.762	W14X30	0.74793
89	W14X34	0.862	W14X34	0.90074
90	W14X30	0.766	W14X30	0.71203
91	W14X30	0.702	W14X30	0.67919
92	W14X30	0.776	W14X30	0.77153
93	W14X30	0.531	W14X30	0.64268
94	W14X30	0.534	W14X30	0.62013
95	W14X30	0.586	W14X30	0.64268

Design Run 4

Member	MicasPlus		GTStrudl	
no.	Mem. Size	Cd. Check	Mem. Size	Cd. Check
1	W14X233	0.825	W14X211	0.84637
2	W14X283	0.854	W14X257	0.92896
3	W14X211	0.85	W14X193	0.90876
4	W14X120	0.895	W14X145	0.92093
5	W14X370	0.841	W14X342	0.90174
6	W14X211	0.874	W14X193	0.85332
7	W14X398	0.915	W14X398	0.87847
8	W14X283	0.95	W14X283	0.9368
9	W14X311	0.919	W14X342	0.84014
10	W14X233	0.884	W14X233	0.86213
11	W14X145	0.915	W14X193	0.87916
12	W14X132	0.904	W14X159	0.88595
88	W14X30	0.762	W14X30	0.75156
89	W14X34	0.862	W14X34	0.90089
90	W14X30	0.766	W14X30	0.72683
91	W14X30	0.702	W14X30	0.68192
92	W14X30	0.776	W14X30	0.77133
93	W14X30	0.531	W14X30	0.64832
94	W14X30	0.534	W14X30	0.,62013
95	W14X30	0.586	W14X30	0.64832

Final Design

Member	MicasPlus		GTStrudl	
no.	Mem. Size	Cd. Check	Mem. Size	Cd. Check
1	W14X233	0.825	W14X233	0.7393
2	W14X370	0.582	W14X342	0.631
3	W14X233	0.743	W14X233	0.7138
4	W14X145	0.619	W14X193	0.6372
5	W14X370	0.841	W14X342	0.90174
6	W14X233	0.753	W14X233	0.6703
7	W14X398	0.915	W14X398	0.87847
8	W14X370	0.648	W14X342	0.7187
9	W14X370	0.714	W14X342	0.84014
10	W14X233	0.884	W14X233	0.86213
11	W14X145	0.915	W14X193	0.87916
12	W14X145	0.704	W14X193	0.6858
88	W14X34	0.619	W14X34	0.6148
89	W14X34	0.876	W14X34	0.90089
90	W14X30	0.766	W14X30	0.72683
91	W14X34	0.592	W14X34	0.559
92	W14X34	0.631	W14X34	0.6226
93	W14X30	0.541	W14X30	0.4584
94	W14X30	0.536	W14X30	0.5168
95	W14X30	0.598	W14X30	0.5636

Total weight (MicasPlus) =198.592 kips

Total weight (GTStrudl) =200.51 kips

Average code check in MPD=0.7151

Average code check in GTStrudl=0.7060

Appendix C. Numerical Results from Tennessee Eastman Building 17L09

Tennessee Eastman Building 17L09

Support Reactions

Load Case 1

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
1	0	7.4992	0	0	5.951	0	- -	26.02%	- -
3	0	-6.1072	0	0	-5.012	0	- -	21.85%	- -
5	-27.2	0.581	0	-26.52	0.498	0	2.56%	- -	- -
7	-28.2	7.206	0	-30.508	7.116	0	7.57%	1.26%	- -
9	0	0.7516	0	0	0.718	0	- -	- -	- -
11	0	-17.96	0	0	-14.571	0	- -	23.26%	- -
13	-1.584	1.0896	0	-2.147	0.946	0	26.22%	- -	- -
15	-2.6872	1.1456	0	-2.826	1.025	0	4.91%	11.77%	- -
17	-6.4128	1.3752	0	-6.869	1.198	0	6.64%	14.79%	- -
19	-22.72	0	0	-22.652	0	0	0.30%	- -	- -
21	0.0508	0.0161	0.000101	0.049	0.004	0	- -	- -	- -
23	-1.4396	0	0	-2.189	0	0	34.23%	- -	- -
25	-28.8	0	0	-28.794	0	0	0.02%	- -	- -
27	0.1696	-0.0199	0.000896	0.15	-0.041	0.001	- -	- -	- -
29	0.1692	-0.00156	-4.8E-06	0.15	-0.014	0	- -	- -	- -
35	0.027	-0.0304	40.1108	0.022	-0.066	43.56	- -	- -	7.92%
37	0.024	-0.0126	56.8633	0.019	-0.028	55.726	- -	- -	2.04%
39	0.0351	-0.1019	-60.3373	0.03	-0.112	-59.572	- -	- -	1.28%
41	0.0314	-0.0473	-45.0906	0.026	-0.048	-41.464	- -	- -	8.75%
43	-24.2	-5.45	0	-23.915	-5.266	0	1.19%	3.49%	- -
45	-24	8.354	0	-23.699	6.693	0	1.27%	24.82%	- -
47	-1.188	2.162	0	-1.241	1.838	0	4.27%	17.63%	- -
49	-30.656	0	0	-29.291	0	0	4.66%	- -	- -
51	-0.3012	0	0	-0.295	0	0	- -	- -	- -
53	-0.29856	0	0	-0.292	0	0	- -	- -	- -
55	-30.248	0	0	-28.665	0	0	5.52%	- -	- -

Load Case 1

Node	Micas Plus			GTStrudl			Percentage Diference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
57	6.05E-05	1.78E-06	0	0	0	0	- -	- -	- -
59	-6E-05	2.42E-06	0	0	0	0	- -	- -	- -
61	3.15E-05	-2.8E-07	0	0	0	0	- -	- -	- -
63	-2.8E-05	7.69E-07	0	0	0	0	- -	- -	- -
65	-1.5E-05	-1.1E-06	0	0	0	0	- -	- -	- -
67	2.28E-05	1.03E-06	0	0	0	0	- -	- -	- -
69	-8.1E-06	-1.1E-06	0	0	0	0	- -	- -	- -
403	0.9385	0.1764	5.0053	0.983	0.13	3.594	- -	- -	39.27%
404	1.1261	0.00496	-0.0464	1.506	-0.028	0.4	25.23%	- -	- -
405	2.5863	0.0163	-0.7777	5.128	0.008	-1.562	49.57%	- -	- -
406	1.9222	0.7278	-4.1859	2.05	0.545	-2.459	6.23%	- -	70.23%
407	-3.1366	-0.6484	203.8181	-3.472	-0.687	204.165	9.66%	- -	0.17%
408	0.2898	-0.0355	-132.58	0.586	0.029	-143.937	- -	- -	7.89%
409	0.995	-0.0804	-0.00076	1.5	-0.096	-0.001	- -	- -	- -
410	-0.4969	0.5653	-202.01	-0.824	0.526	-219.424	- -	- -	7.94%
411	0.2521	-0.2288	148.2027	0.399	-0.272	172.382	- -	- -	14.03%
412	-0.3412	-0.1821	-79.2389	-0.315	-0.141	-70.353	- -	- -	12.63%
413	0.2707	-0.0541	0.000665	0.25	-0.06	0.001	- -	- -	- -
414	0.2737	-0.0361	-0.00146	0.253	-0.041	-0.001	- -	- -	- -
415	-0.0568	-0.46	65.1724	-0.071	-0.426	59.889	- -	- -	8.82%
416	-0.2258	0.2492	-94.6054	-0.141	0.218	-87.428	- -	- -	8.21%
417	-0.1417	-0.5533	87.7528	-0.112	-0.477	82.93	- -	- -	5.82%
418	-0.6494	-0.6643	-120.218	-0.71	-0.539	-114.57	- -	- -	4.93%
419	0.1908	0.6082	117.7194	0.197	0.574	112.222	- -	- -	4.90%
420	0.2178	-0.00604	0	0.214	-0.012	0	- -	- -	- -
421	0.2161	-0.0316	0	0.212	-0.032	0	- -	- -	- -
422	0.1907	-0.6171	-116.404	0.197	-0.601	-111.61	- -	- -	4.30%
423	-0.7533	0.7906	122.85	-0.873	0.555	117.512	- -	- -	4.54%

Tennessee Eastman Building 17L09

Support Reactions

Load Case 2

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	0	-67.824	0	0	-64.086	0	- -	5.83%	- -
3	0	-45.552	0	0	-43.876	0	- -	3.82%	- -
5	4.758	-4.752	0	4.293	-5.897	0	10.83%	19.42%	- -
7	-0.876	-86	0	-0.28	-87.064	0	- -	1.22%	- -
9	0	-4.0864	0	0	-4.311	0	- -	5.21%	- -
11	0	-82.4	0	0	-87.296	0	- -	5.61%	- -
13	0.03568	-21.28	0	0.044	-21.72	0	- -	2.03%	- -
15	0.16088	-25.52	0	0.169	-27.201	0	- -	6.18%	- -
17	0.36736	-21.6	0	0.385	-21.938	0	- -	1.54%	- -
19	-5.8	0	0	-4.547	0	0	27.56%	- -	- -
21	-0.0181	0.0463	0.00017	-0.015	0.035	0	- -	- -	- -
23	0.0929	0	0	0.155	0	0	- -	- -	- -
25	6.816	0	0	5.7	0	0	19.58%	- -	- -
27	-0.0698	-0.00867	0.00043	-0.064	-0.019	0	- -	- -	- -
29	-0.0555	-0.00372	0.000227	-0.05	-0.015	0	- -	- -	- -
35	-0.00528	-0.0349	-71.4658	0	-0.055	-69.62	- -	- -	2.65%
37	-0.00451	-0.00325	-39.4479	0.019	-0.013	-41.136	- -	- -	4.10%
39	-0.00846	-0.0829	-42.2652	-0.003	-0.096	-44.345	- -	- -	4.69%
41	-0.00796	-0.0654	-70.8342	-0.003	-0.071	-69.578	- -	- -	1.81%
43	-0.4638	-39.4	0	-0.1	-38.221	0	- -	3.08%	- -
45	-0.04528	-42.6	0	-0.66	-42.453	0	- -	0.35%	- -
47	-0.01824	-52.2	0	0.003	-53.112	0	- -	1.72%	- -
49	16.416	0	0	16.487	0	0	0.43%	- -	- -
51	0.015216	0	0	0.016	0	0	- -	- -	- -
53	-0.01631	0	0	-0.017	0	0	- -	- -	- -
55	-18.352	0	0	-18.237	0	0	0.63%	- -	- -

Load Case 2

Node	Micas Plus			GTStrudl			Percentage Diference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
57	0.000167	1.24E-06	0	0	0	0	- -	- -	- -
59	0.000189	-1.2E-06	0	0	0	0	- -	- -	- -
61	-1.4E-07	-2.9E-07	0	0	0	0	- -	- -	- -
63	-1.7E-05	-1.7E-07	0	0	0	0	- -	- -	- -
65	-4E-06	1.02E-06	0	0	0	0	- -	- -	- -
67	-4.1E-07	-5.8E-07	0	0	0	0	- -	- -	- -
69	9.27E-06	8.44E-07	0	0	0	0	- -	- -	- -
403	0.005158	-5.2383	-263.223	-0.002	-4.585	-262.671	- -	14.25%	0.21%
404	-0.0273	0.2592	-81.8448	-0.033	0.448	-82.588	- -	- -	0.90%
405	-0.1446	0.267	-0.617	-0.28	0.401	1.518	- -	- -	- -
406	-0.1289	-17.2496	345.8888	-0.134	-15.209	345.184	- -	13.42%	0.20%
407	-1.3692	-0.8438	43.2141	-1.216	-0.828	37.991	12.60%	- -	13.75%
408	-0.8617	3.163	166.2029	-1.154	3.971	180.451	- -	20.35%	7.90%
409	-0.0682	0.00991	0.000304	-0.108	0.02	0	- -	- -	- -
410	0.3598	-1.039	43.8521	0.462	-1.281	40.467	- -	18.89%	8.37%
411	-1.0645	-1.6955	130.3499	-1.206	-1.937	137.122	11.73%	12.47%	4.94%
412	0.0871	1.431	191.6772	-0.168	1.444	178.678	- -	0.90%	7.28%
413	0.0365	0.003965	0.000143	0.045	-0.004	0	- -	- -	- -
414	0.0622	0.0132	0.000929	0.069	0.007	0.001	- -	- -	- -
415	0.8176	2.6656	194.584	0.829	2.804	189.885	- -	4.94%	2.47%
416	0.2073	1.9999	-75.812	0.151	1.902	-75.405	- -	5.15%	0.54%
417	-0.759	2.7995	-26.7284	-0.592	2.641	-28.019	- -	6.00%	4.61%
418	-0.77	-2.5255	-159.794	-0.83	-2.229	-158.228	- -	13.30%	0.99%
419	0.1565	-0.6427	-54.6706	0.165	-0.672	-53.41	- -	- -	2.36%
420	-0.00752	0.0143	0	-0.008	0.011	0	- -	- -	- -
421	0.00731	-0.00634	0	0.008	-0.008	0	- -	- -	- -
422	-0.1716	-0.709	-52.7508	-0.182	-0.742	-52.547	- -	- -	0.39%
423	0.8948	-2.5534	-176.318	0.904	-2.346	-173.751	- -	8.84%	1.48%

Tennessee Eastman Building 17L09

Support Reactions

Load Case 3

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	0	-0.588	0	0	-0.509	0	- -	- -	- -
3	0	-0.8482	0	0	-0.677	0	- -	- -	- -
5	0.14662	-1.417	0	0.124	-1.505	0	- -	5.85%	- -
7	-0.12744	-1.8058	0	-0.061	-1.888	0	- -	4.35%	- -
9	0	-0.6184	0	0	-0.581	0	- -	- -	- -
11	0	-0.61344	0	0	-0.666	0	- -	- -	- -
13	0.045904	-0.36712	0	0.034	-0.484	0	- -	- -	- -
15	0.09344	-1.34	0	0.06	-1.194	0	- -	12.23%	- -
17	0.2904	-0.43416	0	0.204	-0.635	0	- -	- -	- -
19	-0.11664	0	0	-0.086	0	0	- -	- -	- -
21	-0.00734	-0.0595	118.3	-0.005	-0.062	118.3	- -	- -	0.00%
23	0.04948	0	0	0.044	0	0	- -	- -	- -
25	0.296	0	0	0.209	0	0	- -	- -	- -
27	-0.0657	0.002142	247.8999	-0.065	0.001	247.9	- -	- -	0.00%
29	0.0314	0.001793	241.7	0.033	0.001	241.7	- -	- -	0.00%
35	-0.00467	0.0923	203.5752	-0.005	0.101	200.465	- -	- -	1.55%
37	-0.0039	0.0506	189.399	-0.004	0.049	192.338	- -	- -	1.53%
39	-0.00502	0.1004	203.2265	-0.005	0.104	201.033	- -	- -	1.09%
41	-0.00417	0.0591	187.888	-0.004	0.053	190.317	- -	- -	1.28%
43	0.0778	-0.1599	0	0.043	-0.072	0	- -	- -	- -
45	-0.01423	-0.207	0	-0.008	-0.132	0	- -	- -	- -
47	0.028592	-0.4306	0	0.018	-0.451	0	- -	- -	- -
49	-0.01379	0	0	-0.048	0	0	- -	- -	- -
51	0.007406	0	0	0.004	0	0	- -	- -	- -
53	0.007683	0	0	0.004	0	0	- -	- -	- -
55	0.062976	0	0	0.07	0	0	- -	- -	- -

Load Case 3

Node	Micas Plus			GTStrudl			Percentage Diference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
57	-1.8E-06	0.3452	13.3	0	0.345	13.3	- -	- -	0.00%
59	-1.9E-05	0.8492	28.8	0	0.849	28	- -	- -	2.86%
61	-4E-06	0.68	26.3	0	0.68	26.3	- -	- -	0.00%
63	-3.5E-06	0.4522	17.5	0	0.452	17.5	- -	- -	0.00%
65	-1.4E-06	0.4523	17.5	0	0.452	17.5	- -	- -	0.00%
67	-2.6E-06	0.4523	17.5	0	0.452	17.5	- -	- -	0.00%
69	-2.4E-06	0.4592	17.8	0	0.459	17.8	- -	- -	0.00%
403	-0.0243	0.3039	81.0438	-0.016	0.218	81.105	- -	- -	0.08%
404	-0.0366	0.3774	294.4727	-0.029	0.563	294.503	- -	- -	0.01%
405	-0.1079	0.3165	379.5201	-0.146	0.458	379.503	- -	- -	0.00%
406	-0.078	0.4918	18.6633	-0.052	0.389	188.589	- -	- -	90.10%
407	-0.0833	-0.2584	125.0735	-0.059	-0.246	123.91	- -	- -	0.94%
408	-0.041	0.8072	249.7282	-0.039	0.873	251.233	- -	- -	0.60%
409	-0.0393	-0.1529	255.9	-0.036	-0.153	255.9	- -	- -	0.00%
410	-0.0387	-0.4227	257.4324	-0.035	-0.45	257.574	- -	- -	0.05%
411	-0.0563	0.8651	270.3897	-0.054	0.91	270.419	- -	- -	0.01%
412	0.0596	0.375	357.9311	0.062	0.367	357.906	- -	- -	0.01%
413	-0.0574	0.0136	328.5999	-0.055	0.01	328.6	- -	- -	0.00%
414	0.0159	0.0146	322.5001	0.02	0.011	322.5	- -	- -	0.00%
415	-0.0776	0.4403	350.9097	-0.074	0.409	350.331	- -	- -	0.17%
416	-0.00085	0.4267	165.261	-0.002	0.38	165.113	- -	- -	0.09%
417	-0.00643	0.5405	145.8835	-0.005	0.457	145.936	- -	- -	0.04%
418	-0.00807	0.2426	49.5764	-0.003	0.2	49.564	- -	- -	0.03%
419	-0.00772	0.0495	54.1557	-0.005	0.058	54.172	- -	- -	0.03%
420	-0.00582	0.0693	51	-0.004	0.069	51	- -	- -	0.00%
421	-0.00599	0.0608	53.5	-0.004	0.06	53.5	- -	- -	0.00%
422	-0.00971	0.0674	47.7878	-0.006	0.076	47.803	- -	- -	0.03%
423	-0.02	0.258	34.6841	-0.015	0.194	34.788	- -	- -	0.30%

Tennessee Eastman Building 17L09

Support Reactions

Load Case 4

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
1	0	-0.01326	0	0	-0.011	0	- -	- -	- -
3	0	-0.01051	0	0	-0.005	0	- -	- -	- -
5	0.010168	-0.0189	0	0.008	-0.022	0	- -	- -	- -
7	-0.01232	-0.02462	0	-0.01	-0.026	0	- -	- -	- -
9	0	-0.00731	0	0	-0.006	0	- -	- -	- -
11	0	-0.01688	0	0	-0.019	0	- -	- -	- -
13	0.0005	-0.00949	0	0	-0.012	0	- -	- -	- -
15	-0.00103	-0.0231	0	-0.002	-0.021	0	- -	- -	- -
17	-2.3E-05	0.002991	0	-0.003	-0.001	0	- -	- -	- -
19	-0.0103	0	0	-0.008	0	0	- -	- -	- -
21	-0.00012	0.001393	15.5339	0	0.001	15.551	- -	- -	0.11%
23	-0.00056	0	0	-0.002	0	0	- -	- -	- -
25	0.009702	0	0	0.005	0	0	- -	- -	- -
27	0.000162	0.00078	18.012	0	0.001	18.032	- -	- -	0.11%
29	0.000153	0.000807	18.012	0	0.001	18.032	- -	- -	0.11%
35	0.000173	0.001699	14.7392	0	0.002	14.619	- -	- -	0.82%
37	0.000154	0.001495	13.1061	0	0.001	13.25	- -	- -	1.09%
39	0.000132	0.002733	14.6245	0	0.003	14.548	- -	- -	0.53%
41	0.00012	0.002369	13.1703	0	0.002	13.285	- -	- -	0.86%
43	0.003206	0.000911	0	0.002	0.004	0	- -	- -	- -
45	-0.00235	0.00382	0	-0.002	0.004	0	- -	- -	- -
47	0.000614	-0.01031	0	0	-0.01	0	- -	- -	- -
49	-0.00348	0	0	-0.007	0	0	- -	- -	- -
51	0.000173	0	0	0	0	0	- -	- -	- -
53	0.000193	0	0	0	0	0	- -	- -	- -
55	0.00449	0	0	0.007	0	0	- -	- -	- -

Load Case 4

Node no.	Micas Plus Fx	Micas Plus Fy	Micas Plus Fz	GTStrudl Fx	GTStrudl Fy	GTStrudl Fz	Percentage Diference Fx	Percentage Diference Fy	Percentage Diference Fz
	kips			kips			%		
57	-5.4E-08	-6.4E-09	0.8853	0	0	0.886	- -	- -	- -
59	-4.4E-07	7.02E-09	0.8853	0	0	0.886	- -	- -	- -
61	-1.1E-07	-2E-11	0.8853	0	0	0.886	- -	- -	- -
63	-1E-07	4.26E-09	0.8853	0	0	0.886	- -	- -	- -
65	-9.8E-08	-2.4E-09	0.8853	0	0	0.886	- -	- -	- -
67	-6.5E-08	3.45E-09	0.8853	0	0	0.886	- -	- -	- -
69	-5.9E-08	-2.1E-09	0.8853	0	0	0.886	- -	- -	- -
403	-0.00038	0.0109	6.172	0	0.008	6.181	- -	- -	0.15%
404	-0.00019	0.008883	20.0781	0	0.013	20.099	- -	- -	0.10%
405	0.000198	0.007564	27.1209	0.003	0.01	27.153	- -	- -	0.12%
406	0.000505	0.006769	22.4214	0.002	0.005	22.443	- -	- -	0.10%
407	-0.00157	-0.00151	15.5436	-0.001	-0.001	15.496	- -	- -	0.31%
408	0.000597	0.0135	15.8112	0.001	0.016	17.582	- -	- -	10.07%
409	0.000287	0.001992	15.8796	0.001	0.002	17.589	- -	- -	9.72%
410	0.001084	0.000105	15.8612	0.002	0	17.568	- -	- -	9.72%
411	-0.00036	0.008312	15.8461	0	0.009	17.547	- -	- -	9.69%
412	0.000544	0.00967	21.8239	0.001	0.009	21.846	- -	- -	0.10%
413	0.000125	0.001344	21.3452	0	0.001	21.369	- -	- -	0.11%
414	0.000114	0.001739	21.3452	0	0.001	21.369	- -	- -	0.11%
415	4.32E-05	0.006547	21.8317	0	0.006	21.827	- -	- -	0.02%
416	5.93E-05	0.0131	14.8498	0	0.012	14.859	- -	- -	0.06%
417	8.97E-05	0.008947	14.8893	0	0.007	14.914	- -	- -	0.17%
418	0.000301	0.009009	4.2263	0	0.009	4.23	- -	- -	0.09%
419	-0.00011	-0.00039	3.9492	0	0	3.955	- -	- -	0.15%
420	-8.9E-05	0.000485	3.3893	0	0	3.393	- -	- -	0.11%
421	-1E-04	0.000696	3.3893	0	0.001	3.393	- -	- -	0.11%
422	-0.00015	0.000123	3.9429	0	0	3.948	- -	- -	0.13%
423	-0.00077	0.007143	4.2292	-0.001	0.006	4.238	- -	- -	0.21%

Tennessee Eastman Building 17L09

Support Reactions

Load Case 5

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	0	-1.5512	0	0	-1.347	0	- -	15.16%	- -
3	0	-2.2656	0	0	-1.816	0	- -	24.76%	- -
5	0.3524	-2.734	0	0.309	-2.979	0	- -	8.22%	- -
7	-0.2484	-4.008	0	-0.158	-4.298	0	- -	6.75%	- -
9	0	-1.6568	0	0	-1.567	0	- -	5.73%	- -
11	0	-1.6848	0	0	-1.757	0	- -	4.11%	- -
13	-0.0049	-0.916	0	-0.05	-1.27	0	- -	- -	- -
15	0.13112	-3.3856	0	0.069	-3.029	0	- -	11.77%	- -
17	0.27152	-1.0472	0	0.115	-1.555	0	- -	32.66%	- -
19	-0.192	0	0	-0.158	0	0	- -	- -	- -
21	-0.00574	-0.1382	313.6601	-0.001	-0.142	313.66	- -	- -	0.00%
23	0.07	0	0	0.05	0	0	- -	- -	- -
25	0.4748	0	0	0.328	0	0	- -	- -	- -
27	-0.1501	0.0151	661.2596	-0.145	0.015	661.26	- -	- -	0.00%
29	0.1261	0.014	616.66	0.135	0.014	616.66	- -	- -	0.00%
35	-0.00402	0.0674	537.2173	-0.003	0.071	531.786	- -	- -	1.02%
37	-0.00321	0.1135	472.9222	-0.002	0.111	478.457	- -	- -	1.16%
39	-0.00482	0.075	533.9378	-0.003	0.073	533.17	- -	- -	0.14%
41	-0.00385	0.124	465.7693	-0.002	0.115	466.938	- -	- -	0.25%
43	0.0855	0.19022	0	0.017	-0.042	0	- -	- -	- -
45	-0.14118	-0.6366	0	-0.12	-0.488	0	- -	- -	- -
47	-0.04218	-0.9492	0	-0.061	-1.064	0	- -	- -	- -
49	-0.12816	0	0	-0.205	0	0	- -	- -	- -
51	-0.01192	0	0	-0.016	0	0	- -	- -	- -
53	-0.01156	0	0	-0.016	0	0	- -	- -	- -
55	-0.04876	0	0	0.078	0	0	- -	- -	- -

Load Case 5

Node	Micas Plus			GTStrudl			Percentage Diference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
57	2.13E-06	0.7457	28.8	0	0.746	28.8	- -	- -	0.00%
59	1.52E-05	1.8676	88.8	0	1.868	88.8	- -	0.02%	0.00%
61	3.36E-06	1.4808	57.3	0	1.481	57.3	- -	0.01%	0.00%
63	4.03E-07	0.9838	38.1	0	0.984	38.1	- -	- -	0.00%
65	4.04E-06	0.984	38.1	0	0.984	38.1	- -	- -	0.00%
67	1.93E-06	1.0496	43.6	0	1.05	43.6	- -	0.04%	0.00%
69	3.3E-06	1.2567	60.9	0	1.257	60.9	- -	0.02%	0.00%
403	0.0288	0.6839	186.4166	0.045	0.483	186.537	- -	- -	0.06%
404	-0.00062	0.9661	756.163	0.032	1.5	755.972	- -	- -	0.03%
405	-0.0859	0.739	1019.017	-0.056	1.152	1019.223	- -	- -	0.02%
406	-0.1011	1.2196	518.8135	-0.051	0.977	518.677	- -	- -	0.03%
407	-0.1168	-0.6265	324.0603	-0.066	-0.595	322.038	- -	- -	0.63%
408	-0.0555	1.6402	412.1528	-0.045	1.827	414.715	- -	10.22%	0.62%
409	-0.0518	-0.2338	436.23	-0.036	-0.223	436.23	- -	- -	0.00%
410	-0.0475	-0.7647	439.5075	-0.037	-0.833	439.402	- -	- -	0.02%
411	-0.0837	2.0265	462.3759	-0.064	2.214	462.768	- -	8.47%	0.08%
412	0.2022	0.8583	694.5576	0.211	0.843	694.338	- -	- -	0.03%
413	-0.1197	0.0383	733.7599	-0.111	0.034	733.76	- -	- -	0.00%
414	0.089	0.0402	689.2601	0.1	0.055	689.26	- -	- -	0.00%
415	-0.1948	1.1757	680.0129	-0.185	1.107	679.011	- -	6.21%	0.15%
416	0.000856	1.0722	416.3893	-0.001	0.966	415.946	- -	- -	0.11%
417	-0.0104	1.4375	363.9821	-0.007	1.234	364.08	- -	16.49%	0.03%
418	0.0343	0.4558	111.065	0.043	0.377	111.013	- -	- -	0.05%
419	0.0128	0.2769	133.6672	0.018	0.307	133.738	- -	- -	0.05%
420	0.00742	0.1887	121.7	0.011	0.19	121.7	- -	- -	0.00%
421	0.007161	0.2369	133	0.011	0.237	133	- -	- -	0.00%
422	0.007922	0.1835	116.0888	0.014	0.209	116.096	- -	- -	0.01%
423	0.004972	0.7189	90.557	0.015	0.547	90.767	- -	- -	0.23%

Tennessee Eastman Building 17L09

Support Reactions

Load Case 6

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	0	-11.256	0	0	-9.01	0	- -	24.93%	- -
3	0	9.352	0	0	7.701	0	- -	21.44%	- -
5	39.8	-0.7538	0	38.634	-0.605	0	3.02%	- -	- -
7	41.2	-12.994	0	45.323	-12.99	0	9.10%	0.03%	- -
9	0	-1.2568	0	0	-1.199	0	- -	4.82%	- -
11	0	30.44	0	0	25.169	0	- -	20.94%	- -
13	2.36	-1.8112	0	3.177	-1.558	0	25.72%	16.25%	- -
15	4.0552	-1.9168	0	4.237	-1.707	0	4.29%	12.29%	- -
17	9.7072	-2.2856	0	10.32	-1.975	0	5.94%	15.73%	- -
19	33.84	0	0	33.709	0	0	0.39%	- -	- -
21	-0.084	-0.0249	-0.00017	-0.081	-0.004	0	- -	- -	- -
23	2.156	0	0	3.255	0	0	33.76%	- -	- -
25	43	0	0	43.177	0	0	0.41%	- -	- -
27	-0.2954	0.0256	-0.00152	-0.266	0.059	-0.002	- -	- -	- -
29	-0.2982	-0.00058	1.68E-05	-0.269	0.02	0	- -	- -	- -
35	-0.0657	0.0401	-76.315	-0.059	0.099	-68.896	- -	- -	10.77%
37	-0.055	0.0112	-92.2616	-0.048	0.038	-90.288	- -	- -	2.19%
39	-0.0699	0.1461	98.2858	-0.063	0.162	96.983	- -	- -	1.34%
41	-0.06	0.065	71.6419	-0.052	0.067	65.71	- -	- -	9.03%
43	35.6	9.386	0	35.249	8.994	0	1.00%	4.36%	- -
45	36	-13.932	0	35.325	-11.14	0	1.91%	25.06%	- -
47	1.764	-3.62	0	1.832	-3.06	0	3.71%	18.30%	- -
49	44.248	0	0	42.04	0	0	5.25%	- -	- -
51	0.44624	0	0	0.432	0	0	- -	- -	- -
53	0.44616	0	0	0.433	0	0	- -	- -	- -
55	44.488	0	0	41.802	0	0	6.43%	- -	- -

Load Case 6

Node	Micas Plus			GTStrudl			Percentage Diference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
57	-0.00011	3.32E-06	0	0	0	0	- -	- -	- -
59	-6E-05	2.42E-06	0	0	0	0	- -	- -	- -
61	5.43E-07	1.34E-06	0	0	0	0	- -	- -	- -
63	3.7E-05	-1.5E-06	0	0	0	0	- -	- -	- -
65	2.07E-05	1.82E-06	0	0	0	0	- -	- -	- -
67	-4.2E-05	-1.8E-06	0	0	0	0	- -	- -	- -
69	3.42E-06	1.84E-06	0	0	0	0	- -	- -	- -
403	-1.4043	-0.3056	-7.3716	-1.461	-0.224	-5.078	3.88%	- -	45.17%
404	-1.6972	-0.0141	-2.3315	-2.249	0.038	-2.981	24.54%	- -	21.79%
405	-3.9667	-0.0304	3.5009	-7.767	-0.018	4.719	48.93%	- -	25.81%
406	-2.9265	-1.2245	6.2126	-3.1	-0.913	3.402	5.60%	- -	82.62%
407	4.6361	0.953	-332.117	5.135	1.021	-332.551	9.72%	- -	0.13%
408	-0.3875	-0.0139	211.7509	-0.836	-0.13	229.936	- -	- -	7.91%
409	-1.5065	0.1176	0.00128	-2.257	0.14	0.001	33.25%	- -	- -
410	0.7062	-0.8837	331.6688	1.216	-0.842	360.674	- -	- -	8.04%
411	-0.4758	0.2917	-239.522	-0.688	0.322	-279.62	- -	- -	14.34%
412	0.1275	0.2697	121.1749	0.125	0.2	106.986	- -	- -	13.26%
413	-0.4537	0.0794	-0.00111	-0.423	0.089	-0.001	- -	- -	- -
414	-0.4621	0.0529	0.002454	-0.43	0.061	0.002	- -	- -	- -
415	0.3763	0.7465	-98.7352	0.382	0.712	-90.066	- -	- -	9.63%
416	0.314	-0.4295	155.4591	0.181	-0.385	143.85	- -	- -	8.07%
417	0.2133	0.909	-144.922	0.172	0.783	-137.111	- -	- -	5.70%
418	0.9972	1.0834	192.9814	1.096	0.863	183.443	- -	- -	5.20%
419	-0.2961	-0.8866	-180.458	-0.303	-0.831	-171.467	- -	- -	5.24%
420	-0.3251	0.006859	0	-0.316	0.016	0	- -	- -	- -
421	-0.325	0.0462	0	-0.316	0.047	0	- -	- -	- -
422	-0.2975	0.9096	179.7361	-0.306	0.88	171.788	- -	- -	4.63%
423	1.1546	-1.286	-198.381	1.338	-0.892	-189.436	13.71%	- -	4.72%

Tennessee Eastman Building 17L09

Support Reactions

Load Case 7

Node	MicasPlus			GTStrudl			Percentage Difference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no	kips			kips			%		
1	0	67.672	0	0	63.939	0	- -	5.84%	- -
3	0	45.376	0	0	43.722	0	- -	3.78%	- -
5	-4.742	4.77	0	-4.276	5.92	0	10.90%	19.43%	- -
7	0.8214	86.2	0	0.241	87.207	0	- -	1.15%	- -
9	0	4.1064	0	0	4.332	0	- -	5.21%	- -
11	0	83.2	0	0	87.475	0	- -	4.89%	- -
13	-0.03552	21.2	0	-0.044	21.654	0	- -	2.10%	- -
15	-0.1616	25.6	0	-0.17	27.235	0	- -	6.00%	- -
17	-0.36704	21.68	0	-0.384	22.066	0	- -	1.75%	- -
19	5.8368	0	0	4.572	0	0	27.66%	- -	- -
21	0.0181	-0.0423	-0.00017	0.015	-0.031	0	- -	- -	- -
23	-0.09444	0	0	-0.157	0	0	- -	- -	- -
25	-6.896	0	0	-5.763	0	0	19.66%	- -	- -
27	0.0696	0.0105	-0.00043	0.064	0.021	0	- -	- -	- -
29	0.0555	0.005578	-0.00023	0.05	0.017	0	- -	- -	- -
35	0.00533	0.0339	71.3645	0	0.054	69.545	- -	- -	2.62%
37	0.004537	0.002696	39.3804	0	0.013	41.074	- -	- -	4.12%
39	0.008423	0.0839	42.1696	0.003	0.097	44.253	- -	- -	4.71%
41	0.007939	0.0661	70.7206	0.003	0.072	69.501	- -	- -	1.75%
43	0.5136	39.4	0	0.158	38.169	0	- -	3.23%	- -
45	0.0215	42.6	0	0.628	42.406	0	- -	0.46%	- -
47	0.0196	52.2	0	-0.002	53.05	0	- -	1.60%	- -
49	-16.296	0	0	-16.393	0	0	0.59%	- -	- -
51	-0.01458	0	0	-0.016	0	0	- -	- -	- -
53	0.016184	0	0	0.016	0	0	- -	- -	- -
55	18.264	0	0	18.173	0	0	0.50%	- -	- -

Load Case 7

Node	Micas Plus			GTStrudl			Percentage Diference		
	Fx	Fy	Fz	Fx	Fy	Fz	Fx	Fy	Fz
no.	kips			kips			%		
57	-0.00017	-1.2E-06	0	0	0	0	- -	- -	- -
59	-0.00019	1.2E-06	0	0	0	0	- -	- -	- -
61	-1.6E-08	2.95E-07	0	0	0	0	- -	- -	- -
63	1.7E-05	8.5E-08	0	0	0	0	- -	- -	- -
65	4.01E-06	-1E-06	0	0	0	0	- -	- -	- -
67	2.9E-07	5.88E-07	0	0	0	0	- -	- -	- -
69	-9.5E-06	-8.6E-07	0	0	0	0	- -	- -	- -
403	-0.006	5.2458	262.8246	0.001	4.591	262.273	- -	14.26%	0.21%
404	0.027	-0.2645	82.2571	0.032	-0.46	83.012	- -	- -	0.91%
405	0.1443	-0.2642	1.4928	0.279	-0.4	-0.647	- -	- -	- -
406	0.1292	17.2668	-346.779	0.134	15.223	-346.082	- -	13.43%	0.20%
407	1.3764	0.8558	-43.3185	1.22	0.839	-38.086	12.82%	- -	13.74%
408	0.8619	-3.1754	-166.281	1.154	-3.986	-180.51	- -	20.34%	7.88%
409	0.0691	-0.0091	-0.00031	0.109	-0.019	0	- -	- -	- -
410	-0.3636	1.0461	-43.9325	-0.466	1.289	-40.522	- -	18.84%	8.42%
411	1.0669	1.6821	-130.674	1.21	1.92	-137.48	11.83%	12.39%	4.95%
412	-0.0804	-1.4353	-191.476	0.173	-1.449	-178.492	- -	0.95%	7.27%
413	-0.0369	-0.00149	-0.00014	-0.045	0.007	0	- -	- -	- -
414	-0.0625	-0.0108	-0.00093	-0.07	-0.004	-0.001	- -	- -	- -
415	-0.8221	-2.677	-194.012	-0.833	-2.816	-189.299	- -	4.94%	2.49%
416	-0.2026	-1.9959	76.2889	-0.149	-1.899	75.827	- -	5.10%	0.61%
417	0.7553	-2.8008	27.1069	0.589	-2.642	28.361	- -	6.01%	4.42%
418	0.7693	2.5359	159.6296	0.829	2.237	158.053	- -	13.36%	1.00%
419	-0.1565	0.6361	54.5069	-0.165	0.667	53.268	- -	- -	2.33%
420	0.007145	-0.0166	0	0.007	-0.013	0	- -	- -	- -
421	-0.00723	0.004648	0	-0.008	0.007	0	- -	- -	- -
422	0.1713	0.7034	52.614	0.181	0.737	52.408	- -	- -	0.39%
423	-0.8953	2.5632	176.118	-0.905	2.353	173.545	- -	8.93%	1.48%

Note: (- -) indicates that the values were not considered to be significant

Tennessee Eastman Building 17L09

Joint Displacements

Load Case 1

Node	MicasPlus			GTStrudl			Percentage Difference		
	Tx	Ty	Fz	Tx	Ty	Tz	Tx	Ty	Tz
no.	inch			inch			%		
31	0.0273	-0.00047	-3.4E-08	0.027	0	0	- -	- -	- -
33	0.0272	-0.00172	7.5E-08	0.027	-0.001	0	- -	- -	- -
113	1.8011	0.5051	0.1627	1.741	0.475	0.155	3.45%	6.34%	- -
114	1.7951	-0.6556	-0.1595	1.735	-0.608	-0.152	3.46%	7.83%	- -
115	2.1853	0.5047	0.1667	2.1	0.475	0.152	4.06%	6.25%	- -
116	2.1832	-0.6551	-0.1723	2.098	-0.608	-0.169	4.06%	7.75%	- -
117	2.0237	0.5049	0.0216	1.949	0.475	0.021	3.83%	6.29%	- -
118	2.0191	-0.6553	-0.0138	1.944	-0.608	-0.015	3.86%	7.78%	- -
119	1.7979	-0.0742	-0.00784	1.738	-0.066	-0.007	3.45%	- -	- -
120	2.1848	-0.0739	0.000748	2.099	-0.065	0	4.09%	- -	- -
121	2.0203	-0.074	0.006287	1.946	-0.065	0.006	3.82%	- -	- -
122	2.1852	0.2573	-0.2043	2.1	0.244	-0.204	4.06%	- -	- -
123	2.1853	0.1751	-1.9E-07	2.1	0.167	0	4.06%	- -	- -
124	2.184	-0.3233	1.41E-06	2.099	-0.298	0	4.05%	8.49%	- -
125	2.1837	-0.4057	0.1996	2.098	-0.375	0.188	4.08%	8.19%	- -
128	2.0195	-0.3233	-9.4E-07	1.945	-0.298	0	3.83%	8.49%	- -
129	2.0194	-0.4057	1.61E-06	1.945	-0.375	0	3.83%	8.19%	- -
130	1.7996	0.2566	-0.1165	1.74	0.243	-0.111	3.43%	- -	- -
131	1.7992	0.1747	-0.0836	1.739	0.167	-0.081	3.46%	- -	- -
132	1.7965	-0.3233	0.0829	1.737	-0.298	0.081	3.43%	8.49%	- -
133	1.7959	-0.4057	0.1203	1.736	-0.375	0.115	3.45%	8.19%	- -

Load Case 2

Node no.	MicasPlus Tx	MicasPlus Ty	MicasPlus Fz	GTStrudl Tx	GTStrudl Ty	GTStrudl Tz	Percentage Difference Tx	Percentage Difference Ty	Percentage Difference Tz
	inch			inch			%		
31	-0.00238	0.0351	-7.3E-09	-0.002	0.036	0	- -	- -	- -
33	-0.00273	0.0349	-4.8E-08	-0.003	0.035	0	- -	- -	- -
113	-0.00489	2.5474	0.2088	0.014	2.567	0.213	- -	0.76%	- -
114	-0.025	3.2454	0.2301	-0.006	3.247	0.23	- -	0.05%	- -
115	-0.2547	2.5479	-0.0976	-0.23	2.568	-0.09	- -	0.78%	- -
116	-0.2409	3.246	-0.00263	-0.216	3.247	0.001	- -	0.03%	- -
117	-0.1491	2.5476	-0.2277	-0.127	2.567	-0.225	- -	0.76%	- -
118	-0.1485	3.2456	-0.3257	-0.126	3.247	-0.324	- -	0.04%	0.52%
119	-0.015	2.9136	0.3208	0.004	2.924	0.322	- -	0.36%	0.37%
120	-0.2477	2.9135	-0.1286	-0.223	2.924	-0.129	- -	0.36%	- -
121	-0.1488	2.9136	-0.1721	-0.127	2.924	-0.174	- -	0.36%	- -
122	-0.2531	2.7084	-0.0401	-0.228	2.724	-0.035	- -	0.57%	- -
123	-0.2516	2.7606	-3.2E-07	-0.227	2.775	0	- -	0.52%	- -
124	-0.2437	3.0601	-5.7E-07	-0.219	3.066	0	- -	0.19%	- -
125	-0.2424	3.1069	-0.0499	-0.218	3.112	-0.042	- -	0.16%	- -
128	-0.1488	3.0605	-4.3E-08	-0.126	3.067	0	- -	0.21%	- -
129	-0.1486	3.1072	-8.4E-07	-0.126	3.112	0	- -	0.15%	- -
130	-0.00755	2.7092	0.1559	0.011	2.725	0.153	- -	0.58%	- -
131	-0.00964	2.7612	0.057	0.009	2.775	0.06	- -	0.50%	- -
132	-0.0204	3.0607	0.0576	-0.002	3.067	0.06	- -	0.21%	- -
133	-0.0224	3.1076	0.1689	-0.003	3.113	0.168	- -	0.17%	- -

Load Case 3

Node	MicasPlus			GTStrudl			Percentage Difference		
	Tx	Ty	Fz	Tx	Ty	Tz	Tx	Ty	Tz
no.	inch			inch			%		
31	-0.00038	0.006085	-0.0171	0	0.006	-0.017	- -	- -	- -
33	-0.00163	0.006124	-0.0167	-0.001	0.006	-0.017	- -	- -	- -
113	-0.104	0.3664	-0.2112	-0.15	0.403	-0.211	- -	9.08%	- -
114	-0.1042	0.5364	-0.1919	-0.151	0.461	-0.192	- -	16.36%	- -
115	-0.161	0.3663	-0.3469	-0.17	0.402	-0.315	- -	8.88%	10.13%
116	-0.1608	0.5363	-0.3555	-0.17	0.461	-0.32	- -	16.33%	11.09%
117	-0.1367	0.3663	-0.3539	-0.162	0.402	-0.354	- -	8.88%	0.03%
118	-0.1367	0.5364	-0.3467	-0.162	0.461	-0.346	- -	16.36%	0.20%
119	-0.1041	0.4515	-0.2688	-0.151	0.432	-0.269	- -	4.51%	0.07%
120	-0.1608	0.4515	-0.1757	-0.17	0.432	-0.176	- -	4.51%	- -
121	-0.1367	0.4515	-0.3026	-0.162	0.432	-0.303	- -	4.51%	0.13%
122	-0.1609	0.4029	-0.1701	-0.17	0.415	-0.168	- -	2.92%	- -
123	-0.1609	0.415	-0.1644	-0.17	0.419	-0.164	- -	0.95%	- -
124	-0.1608	0.4879	-0.3595	-0.17	0.444	-0.324	- -	9.89%	10.96%
125	-0.1608	0.4999	-0.3629	-0.17	0.448	-0.328	- -	11.58%	10.64%
128	-0.1367	0.4879	-0.3347	-0.162	0.444	-0.335	- -	9.89%	0.09%
129	-0.1367	0.4999	-0.3344	-0.162	0.448	-0.334	- -	11.58%	0.12%
130	-0.1041	0.403	-0.2433	-0.15	0.415	-0.239	- -	2.89%	- -
131	-0.1041	0.415	-0.2521	-0.15	0.419	-0.256	- -	0.95%	1.52%
132	-0.1042	0.4879	-0.2451	-0.151	0.444	-0.242	- -	9.89%	- -
133	-0.1042	0.5	-0.251	-0.151	0.449	-0.255	- -	11.36%	1.57%

Load Case 4

Node	MicasPlus			GTStrudl			Percentage Difference		
	Tx	Ty	Fz	Tx	Ty	Tz	Tx	Ty	Tz
no.	inch			inch			%		
31	-6.4E-07	8.56E-05	-0.00111	0	0	-0.001	- -	- -	- -
33	-4.1E-07	8.26E-05	-0.00111	0	0	-0.001	- -	- -	- -
113	0.002723	-0.0046	-0.0185	0.001	-0.003	-0.019	- -	- -	- -
114	0.002724	-0.00286	-0.0186	0.001	-0.006	-0.019	- -	- -	- -
115	0.002144	-0.0046	-0.018	0.002	-0.003	-0.016	- -	- -	- -
116	0.002146	-0.00286	-0.018	0.002	-0.006	-0.016	- -	- -	- -
117	0.00239	-0.0046	-0.0158	0.002	-0.003	-0.016	- -	- -	- -
118	0.002391	-0.00286	-0.0159	0.002	-0.006	-0.016	- -	- -	- -
119	0.002723	-0.00373	-0.0167	0.001	-0.004	-0.017	- -	- -	- -
120	0.002145	-0.00373	-0.0166	0.002	-0.004	-0.017	- -	- -	- -
121	0.002391	-0.00373	-0.0161	0.002	-0.004	-0.016	- -	- -	- -
122	0.002144	-0.00423	-0.0182	0.002	-0.003	-0.018	- -	- -	- -
123	0.002144	-0.0041	-0.0182	0.002	-0.004	-0.018	- -	- -	- -
124	0.002145	-0.00336	-0.0181	0.002	-0.005	-0.017	- -	- -	- -
125	0.002145	-0.00323	-0.0181	0.002	-0.005	-0.016	- -	- -	- -
128	0.002391	-0.00336	-0.0167	0.002	-0.005	-0.017	- -	- -	- -
129	0.002391	-0.00323	-0.0167	0.002	-0.005	-0.017	- -	- -	- -
130	0.002723	-0.00423	-0.0169	0.001	-0.003	-0.017	- -	- -	- -
131	0.002723	-0.0041	-0.0175	0.001	-0.004	-0.018	- -	- -	- -
132	0.002723	-0.00336	-0.0168	0.001	-0.005	-0.017	- -	- -	- -
133	0.002723	-0.00323	-0.0175	0.001	-0.005	-0.018	- -	- -	- -

Load Case 5

Node	MicasPlus			GTStrudl			Percentage Difference		
	Tx	Ty	Fz	Tx	Ty	Tz	Tx	Ty	Tz
no.	inch			inch			%		
31	0.000916	0.0155	-0.0381	0.002	0.014	-0.038	- -	- -	- -
33	-0.00263	0.0158	-0.0358	-0.002	0.015	-0.036	- -	- -	- -
113	-0.0623	0.9245	-0.5346	-0.096	1.007	-0.534	- -	8.19%	0.11%
114	-0.063	1.1286	-0.4744	-0.097	1.043	-0.475	- -	8.21%	0.13%
115	-0.131	0.9244	-0.554	-0.109	1.007	-0.501	- -	8.20%	10.58%
116	-0.1305	1.1285	-0.5616	-0.108	1.043	-0.501	- -	8.20%	12.10%
117	-0.1017	0.9244	-0.7038	-0.103	1.007	-0.704	- -	8.20%	0.03%
118	-0.1019	1.1285	-0.6741	-0.104	1.043	-0.673	- -	8.20%	0.16%
119	-0.0627	1.0271	-0.7125	-0.097	1.025	-0.712	- -	0.20%	0.07%
120	-0.1307	1.027	-0.4525	-0.108	1.025	-0.452	- -	0.20%	0.11%
121	-0.1018	1.0271	-0.823	-0.103	1.025	-0.823	- -	0.20%	0.00%
122	-0.1309	0.9686	-0.4196	-0.109	1.015	-0.417	- -	4.57%	0.62%
123	-0.1308	0.9832	-0.4196	-0.109	1.018	-0.42	- -	3.42%	0.10%
124	-0.1306	1.0706	-0.5792	-0.108	1.033	-0.52	- -	3.64%	11.38%
125	-0.1306	1.085	-0.5731	-0.108	1.035	-0.514	- -	4.83%	11.50%
128	-0.1018	1.0707	-0.7386	-0.103	1.033	-0.739	- -	3.65%	0.05%
129	-0.1018	1.0851	-0.7236	-0.103	1.035	-0.724	- -	4.84%	0.06%
130	-0.0623	0.9688	-0.6265	-0.096	1.015	-0.62	- -	4.55%	1.05%
131	-0.0624	0.9833	-0.645	-0.096	1.018	-0.653	- -	3.41%	1.23%
132	-0.0629	1.0708	-0.6256	-0.097	1.033	-0.625	- -	3.66%	0.10%
133	-0.0629	1.0852	-0.6328	-0.097	1.035	-0.635	- -	4.85%	0.35%

Load Case 6

Node	MicasPlus			GTStrudl			Percentage Difference		
	Tx	Ty	Fz	Tx	Ty	Tz	Tx	Ty	Tz
no.	inch			inch			%		
31	-0.0414	0.001225	5.7E-08	-0.04	0	0	- -	- -	- -
33	-0.0412	0.003137	-1.3E-07	-0.04	0.002	0	- -	- -	- -
113	-2.9308	-0.9306	-0.2777	-2.831	-0.883	-0.266	3.53%	5.39%	4.40%
114	-2.9407	1.2042	0.2754	-2.841	1.128	0.264	3.51%	6.76%	4.32%
115	-3.6437	-0.9296	-0.281	-3.503	-0.883	-0.257	4.02%	5.28%	9.34%
116	-3.6496	1.2041	0.2922	-3.509	1.128	0.287	4.01%	6.75%	1.81%
117	-3.3423	-0.93	-0.0245	-3.219	-0.883	-0.023	3.83%	5.32%	- -
118	-3.3499	1.2041	0.0107	-3.227	1.128	0.012	3.81%	6.75%	- -
119	-2.9354	0.1389	0.0158	-2.836	0.124	0.015	3.50%	- -	- -
120	-3.647	0.1392	-0.00116	-3.506	0.125	0	4.02%	- -	- -
121	-3.3445	0.1391	-0.0123	-3.221	0.124	-0.012	3.83%	- -	- -
122	-3.6448	-0.4711	0.3484	-3.504	-0.45	0.348	4.02%	4.69%	0.11%
123	-3.6456	-0.3195	3.23E-07	-3.505	-0.308	0	4.01%	3.73%	- -
124	-3.648	0.5969	-2.4E-06	-3.507	0.556	0	4.02%	7.36%	- -
125	-3.6481	0.7479	-0.3361	-3.507	0.698	-0.316	4.02%	7.15%	6.36%
128	-3.3463	0.5967	1.58E-06	-3.223	0.555	0	3.83%	7.51%	- -
129	-3.3471	0.7476	-2.7E-06	-3.224	0.698	0	3.82%	7.11%	- -
130	-2.9321	-0.471	0.1915	-2.833	-0.45	0.182	3.50%	4.67%	- -
131	-2.933	-0.3196	0.1354	-2.834	-0.308	0.131	3.49%	3.77%	- -
132	-2.9374	0.5963	-0.1348	-2.838	0.555	-0.132	3.50%	7.44%	- -
133	-2.9379	0.7471	-0.1951	-2.839	0.697	-0.187	3.48%	7.19%	- -

Load Case 7

Node	MicasPlus			GTStrudl			Percentage Difference		
	Tx	Ty	Fz	Tx	Ty	Tz	Tx	Ty	Tz
no.	inch			inch			%		
31	0.002399	-0.0353	7.27E-09	0.002	-0.036	0	- -	- -	- -
33	0.002756	-0.0351	4.81E-08	0.003	-0.036	0	- -	- -	- -
113	0.004494	-2.5484	-0.2074	-0.014	-2.568	-0.212	- -	0.76%	- -
114	0.025	-3.2452	-0.2287	0.006	-3.246	-0.229	- -	0.02%	- -
115	0.2537	-2.5504	0.0975	0.229	-2.57	0.089	- -	0.76%	- -
116	0.2406	-3.2472	0.002723	0.216	-3.248	-0.001	- -	0.02%	- -
117	0.1484	-2.5494	0.2293	0.126	-2.569	0.226	- -	0.76%	- -
118	0.1483	-3.2462	0.3272	0.126	-3.247	0.325	- -	0.02%	0.68%
119	0.0148	-2.9139	-0.3187	-0.004	-2.924	-0.32	- -	0.35%	0.41%
120	0.247	-2.9152	0.1293	0.222	-2.925	0.129	- -	0.34%	- -
121	0.1484	-2.9146	0.1741	0.126	-2.925	0.176	- -	0.36%	- -
122	0.2523	-2.7105	0.0403	0.227	-2.726	0.035	- -	0.57%	- -
123	0.2509	-2.7624	3.28E-07	0.226	-2.777	0	- -	0.53%	- -
124	0.2432	-3.0614	5.68E-07	0.218	-3.067	0	- -	0.18%	- -
125	0.242	-3.1081	0.05	0.217	-3.113	0.042	- -	0.16%	- -
128	0.1484	-3.0613	4.2E-08	0.126	-3.067	0	- -	0.19%	- -
129	0.1483	-3.108	8.44E-07	0.126	-3.113	0	- -	0.16%	- -
130	0.007258	-2.71	-0.1554	-0.011	-2.725	-0.153	- -	0.55%	- -
131	0.009377	-2.7618	-0.057	-0.009	-2.776	-0.06	- -	0.51%	- -
132	0.0202	-3.0608	-0.0574	0.002	-3.067	-0.06	- -	0.20%	- -
133	0.0223	-3.1076	-0.1683	0.004	-3.112	-0.167	- -	0.14%	- -

Note: (- -) indicates that the values were not considered to be significant

Vita

Maurice Walter White was born on July 12, 1967, in Harve de Grace, Maryland. He graduated from Aberdeen High School, Aberdeen, Maryland in June 1985. He entered the University of Delaware, Newark, Delaware in July 1985 and graduated with the degree of Bachelor of Science in Civil Engineering in May 1989. Graduate work towards the degree of Masters of Civil Engineering was begun in August 1989 at Virginia Polytecnic Institute and State University. He will complete the requirements for the degree in April 1991.

Maurice Walter White