STABILITY OF A FOUR STORY STEEL FRAME BUILDING UNDER SEISMIC LOADING

A Thesis

by

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MASTER OF SCIENCE

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ABSTRACT

Progressive collapse and seismic resistance are separate topics that have many examples in the literature. However, because both of these events occur rarely, there are not many accurate research examples that have been conducted. Life threatening earthquakes occur once in every 50 years in high risk earthquake zones. Inelastic behavior of steel using a simple and reliable approach is an ongoing process. There are some conclusions about using lateral bracing and shear wall but this makes the design and the cost of the structure inaccurate for the contractor as well as limits the architectural designs.

In this project, a time history analysis of a four story moment resisting steel frame will be conducted. For the distribution of the energy released from the ground motion, a strong column-weak beam approach will be used. The structural system and every element in the system will be compact to resist flexure and lateral torsion that occur during the acceleration. Specific columns from the first floor will be removed and the structure will be accelerated under specific earthquake examples.

As a result of this project, an ideal four story steel frame resisting collapse under seismic loading will be obtained. Pros and cons of this method will be explained. This will influence further research development on the related topic. Postponing collapse events or limiting the local failure will save many lives and keep the economy stable.

DEDICATION

This Master's Thesis is dedicated my supportive mother, father and Pali. Without their love and support this degree would not have been possible.

ACKNOWLEDGEMENTS

I would like to start by thanking with my committee chair, Dr. Fry for giving me such an amazing project which fits my research interests. He has always been supportive, pushed me further to achieve my goals and has giving me a chance to join his research team. Dr. Reddy, whom always had an open door and helped me have a smooth transition with his guidance when I first started this degree here at Texas A&M University. Dr. Strouboulis, thank you for being in my committee and reviewing my project. Amanda Pelton, thank you reviewing my writings numerous times and always motivating me to work harder.

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NOMENCLATURE

AISC	American Institute of Steel Construction
$A_{\inf luence}$	Influence area
A_g	Gross area
A_k	Load from extraordinary events
ASCE	American Society of Civil Engineering
ASD	Allowable Strength Design
ASTM	American Society for Testing and Materials
$A_{tributary}$	Tributary area
B	Beam
C	Column
CBC Ratio	Beam to column connection ratio
C_d	Deflection Amplification Factor
CSI	Computers and Structures Inc.
D	Dead load
DCR	Demand Capacity Ratio
E_l	Earthquake load
E	Elasticity modulus
FEMA	Federal Emergency Management Agency
FNA	Fast Nonlinear Analysis

FSL	Facility Security Level
ft	Feet
ft^2	Square feet
F_v	Sum of forces in vertical, y direction
F_y	Yield strength
F_{yb}	Beam yield strength
F_{yc}	Column yield strength
g	Gravity
G	Girder
GSA	General Services Administration
I	Moment of inertia
IBC	International Building Code
IMF	Intermediate Moment Frames
Ksf	kips per square foot
L_f	Live load
L	Span length
L_r	Live roof load
LRFD	Load and Resistance Factor Design
M_o	Initial moment

Ma	Moment at point A
Mb	Moment at point B
Mc	Moment at point C
$M_{plastic}$	Plastic moment
M_{pb}	Beam plastic moment
M_{pc}	Column plastic moment
$M_{plastic-strainhardening}$	Plastic moment with strain hardening
M_{yield}	Yield moment
M_{uv}	Additional moment due to shear amplification
M3	Moment in Z direction at the removed column
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
OMF	Ordinary Moment Frames
P	Axial stress at the removed column
P_{uc}	Required compressive strength
R	Response Modification Coefficient
R1	First column removal
R2	Second column removal
R3	Third column removal
R4	Fourth column removal

R5	Fifth column removal
R6	Sixth column removal
R7	Seventh column removal
R_A	Support reaction at point A
R_B	Support reaction at point B
R_C	Support reaction at point C
R_y	Ratio of the expected yield stress to the specified min. yield stress
S	Snow load
SAC	Strategic Air Command
SDC	Seismic Design Category
SEI	Structural Engineering Institution
sec	Seconds
SMF	Special Moment Frames
S_x	Section modulus
v_B	Deflection at point B
$(v_B)_1$	Deflection at point B after first loading
$(v_B)_2$	Deflection at point B after second loading
$V(0)$	Shear at the zero point
$V(L)$	Shear at distance L
V_o	Initial shear

V_a	Shear at point A
V_b	Shear at point B
V_c	Shear at point C
V_d	Shear at point D
V2	Shear in y direction at the removed column
w	Uniform distributed load
W	Wide flange
x	x Direction
y	y Direction
Z_b	Beam plastic section modulus
Z_c	Column plastic section modulus
Z_x	Plastic section modulus
Z_{RBS}	Minimum plastic section modulus at the reduced beam section
Ω_o	Overstrength Factor
ρ	Redundancy Factor
δ_o	Initial deflection
θ_o	Initial rotation
$\delta(x)$	Deflection at x distance
$\delta(\mathrm{L}/2)$	Deflection at $\mathrm{L}/2$ distance

$\delta(L)$	Deflection at L distance
$\delta(2L)$	Deflection at $2L$ distance

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1. INTRODUCTION AND BACKGROUND INFORMATION

1.1 Introduction

A load path mechanism is the redistribution of loads and forces of a vertical element when it is instantly removed. The idea of this method is to design a structure redundant enough to resist the lateral and gravity loads with absence of a critical vertical element. Alternative load path and redundancy are two major requirements for structural stability under blast loading (GSA, 2013). This is already a challenging process even when a structure without any loading must resist its dead load with a member missing. With today's technology, this process can be conducted using super computers and advanced finite element commercial software. In these softwares, along with the member removal some real life dynamic loading can be added and the structure could be analyzed under a dynamic load with some selected members missing.

Any loading that is not considered in the design of the structure is blast or abnormal loading (Breen, 1975). Blast loading can be manmade or a natural hazard. Manmade events include; sabotage, fire explosion, vehicle impact, lack of maintenance, and construction errors. Natural hazards can be flood, fire, tornado or earthquakes (Breen, 1975). All of these loading types require different consideration parameters. Blast loading has a very low probability of occurrence and leads to dynamic instability of the structure. For that reason, it is still not necessary to be included in every structure that has been built. It is usually taken into consideration for federal buildings, hospitals and schools which need to operate right after a blast loading event, and for skyscrapers which have a very high cost and have greater significance to a community or region.

Resistance to earthquake loading became a very serious issue after the Northridge earthquake in 1994 (Yun et al.), which is also known as a historic earthquake. Even though the duration of the Northridge earthquake was 10-20 seconds, it lead to 57 fatalities, 8700 injuries and $13-$40 billion worth property damage (Dreger, 1997). The ground motion was the highest recorded in North America, with a magnitude of 6.7 on the Richter scale, and could be felt about 220 miles from the epicenter. Federal Emergency Management Agency and Strategic Air Command (FEMA/SAC) started funding projects for earthquake hazard reduction programs after the Northridge Earthquake. Even though it has been titled as the prevention of structural collapse in literature, the priority is life safety in these structures, and then the economical loses are considered.

1.2 Background Information

Maintaining stability after blast loading has been a popular research topic since the 1960s when the Ronan building in London partially collapsed due to a fire explosion. Research increased steadily after the Murrah building attack in 1995 and the World Trade Center attack in 2001 (Nair, 2004). These are the three most recently discussed topics regarding collapse prevention. When the stability issues due to earthquake loads are considered, the research increased after the Northridge earthquake in 1994 in the United States (Yun et al. 2002). Much research has been conducted on connection, element and eventually overall structural ductility and stability. Although these factors are important, the primary motivation of research is life safety. In specifications, collapse prevention of federal buildings has more regulations due to their importance to the nation. They are designed to be operational right after an earthquake or any abnormal loading.

There are four types of analysis methods that are used in the literature and allowed by the relevant codes. These methods are; linear static, nonlinear static, linear dynamic and nonlinear dynamic. Linear static analysis is the simplest and most conservative way to approach resistance. Previous General Services Administration Guidelines for collapse resistance (2003) recommended multiplying the load combination by two for consideration of dynamic factors. Because the dynamic amplification factor was too conservative (Hamburger, 2006), GSA (2013) removed this requirement in the latest revised publication. Nonlinear static analysis is a more accurate approach because material nonlinearities and geometric nonlinearities are included. This method has become increasingly used in the past decade due to its simplicity, compared to dynamic analysis and because less computation time is required now since the computers were not as accurate and as fast as they are today. This method is also called "pushover analysis" and is primarily used for seismic loading. The structure is laterally loaded using a triangular or linear load distribution, and the response of the structure to this loading is examined (Tavakoli and Alashti, 2013). The results were acceptably imperfect; however, because the earthquakes produce cyclic ground motions, the application of lateral forces did not exactly show the response under real seismic events.

Linear dynamic analysis has a level of accuracy between nonlinear static and nonlinear dynamic. Even though the dynamic loading has been included, material and geometric nonlinearities are not included. These nonlinearities can make a significant increase in forces. An example for this is the P-delta effect; which is when axial loading acting on the member with a lateral deflection produces extra moment. If the connections are not designed for this extra moment, it can lead to inelastic failure, which is not an acceptable failure for load distribution. GSA (2013) guidelines do not include this in their analysis methods any longer for these reasons. The most complex and most accurate analysis method is nonlinear dynamic analysis, commonly referred to as time-history analysis in seismic related areas. It includes both nonlinearities and dynamic motions during the analysis. The only limitations are that it is very sensitive to how the structure is modeled and can take more time and effort compared to other methods. However, with careful modelling and inputs, it produces a response very close to real life under dynamic loading. Therefore, it is very reliable and fast with the computer technology today.

Another modelling criteria is dimensional aspects. The analytical research literature shows two-dimensional and three-dimensional analysis are used for collapse resistance. Two-dimensional is preferred due to its simplicity and fast computation. However, it has been proven that three-dimensional model is more reliable not because it is a real life model but because the load distribution is more accurate in the third dimension. Song and Sezen (2013) proved that their experimental field results fits the best when three-dimensional nonlinear dynamic analysis was used. In addition, compared to two-dimensional analysis another research has shown that three-dimensional analysis gives actual failure modes of the structure (Gerasimidis et al., 2015). With 3D analysis, the torsional effects will be considered and the results will not be conservative (Ficanha and Pravia, 2012).

Steel moment frames resist lateral loading by flexural and shear strength. There are three types of moment frames: Ordinary moment frames (OMF), intermediate moment frames (IMF) and special moment frames (SMF). Each type consists of column to beam moment-resisting connections. OMFs do not have any special requirements. For this reason they are usually one story and limited with 65ft of structural height for Seismic Design Category, Figure 1, F and 35ft for SDC D and E (ASCE/SEI 7, 2013). Therefore they are permitted to be used in low seismic zones. IMF and SMF are more detailed versions of OMF and are systems resulting from the research conducted after the Northridge earthquake (AISC, 2012). The main difference between IMF and SMF is the allowable story drift angle. However, SMF is called “special” for satisfying specific details and expected high resistance under strong ground motion (Hamburger et al., 2009). Hamburger (2006) also recommended that having moment resisting frames at each floor level leads to a better load distribution by resisting blast loading or vertical member removal.

Some of the researchers were also able to conduct experimental analysis for collapse resistance. In these cases, a reinforced concrete building was evaluated before demolishment. Sasani and Sagiroglu (2008) measured the collapse resistance of Hotel San Diego. Their project only included experimental data and results. Sezen and

Giriunas (2009), were able to analyze a three story building located in Northbrook, Illinois. They conducted both analytical and experimental analysis. In both of the papers, the stress has been measured using strain obtained by strain gauge instrumentation. Even though both of the buildings analyzed were built with regulations from decades ago, they both satisfied current GSA (2003) deflection limitations. Song and Sezen (2013) analyzed a steel building using the same methodology. They analytically evaluated the structure with nonlinear static and nonlinear dynamic analysis. Both two-dimensional and three dimensional models are analyzed with both methods. These studies obtained very similar results when using three dimensional nonlinear analyses. Unfortunately, there are only few real life scale experiments conducted due to the cost associated with collapse analysis of an actual structure. Most of the structures are rather retrofitted without any demolishment again for economic reasons. More information about structural stability, which is not in scope of this research project, and different frame type and behaviors could be found in Guide to Design Criteria for Metal Structures (Ziemian, 2010). It includes very detailed summary of the research on stability.

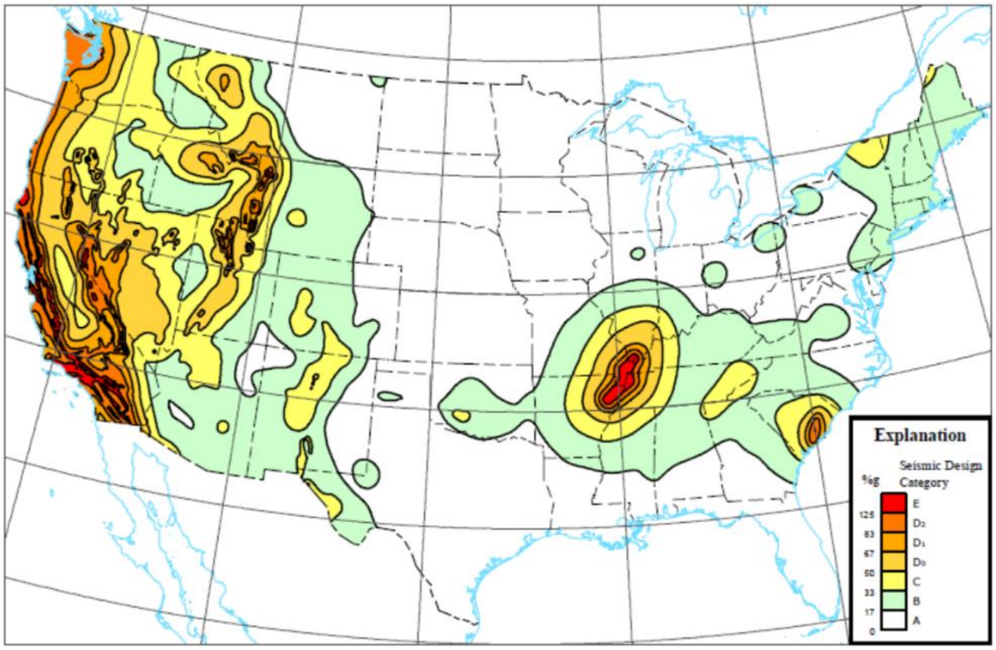


Figure 1 Seismic Design Category (IBC, 2012)

1.3 Objective

Although there has been plenty of research on seismic stability resistance of frame structures, more information is needed about the fundamentals of mechanics. For that reason, in this master's thesis a simple indeterminate beam is analyzed and the same analysis steps are applied to a four story steel SMF as an application example. For the reasons given in the background section, nonlinear dynamic analysis of a three-dimensional model will be used in this research project. The main goal of this research is to answer following questions:

1. The reason why vertical load members are important for load distribution.
2. How small details can change the overall stability and occupant safety.

3. Why is load redistribution path an important process to be considered in the design of any structure?
4. How to evaluate dynamic stability of a four story steel frame with a primary load member missing?
5. Is design for collapse resistance and seismic resistance good enough also to delay potential failure caused by fire in post-earthquake?

2. CODE REQUIREMENTS

2.1 General Services Administration Requirements

GSA has regulations for Alternative path analysis (2013). The main purpose of this document is to increase collapse resistance of any structure under any type of blast loading treatment. To reduce collapse potential, limitation of localized failure, bridging the lost member and providing proportioned and redundant design is required. The two main requirements are;

1. Load redistribution path – redistribution of loads when a load carrying vertical member is removed. In Figure 2, recommended column removal from (GSA,2013) has been shown.

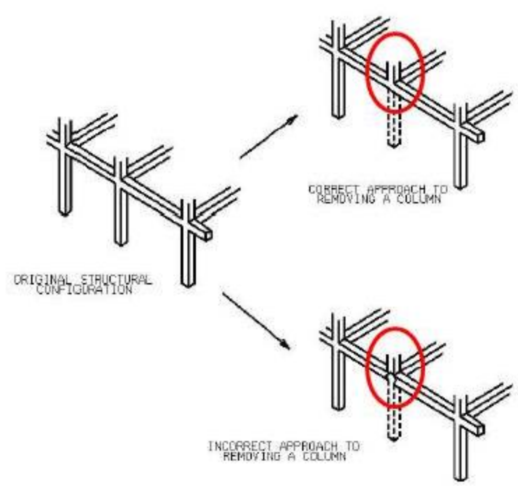


Figure 2 Column removal for alternative load path (GSA, 2013)

2. Redundancy – having a balanced design of member symmetry, and no column is removed for architectural reasons. This should be in good conjunction with load redistribution path.

The structure under consideration should be grouped under one of the five Facility Security Levels (FSL). Each of these levels has different requirements for this regulation to be applicable. In this project, the structure is assumed to be FSL 3&4, which by the guideline means all the required steps and analysis mentioned in this document must be satisfied for structures with four or more number of stories. It is allowed only for first story columns to be removed. Column removal of first story is chosen in this thesis for the reasons that will be explained in chapter 3. When a column is removed, beam-to-beam continuity is assumed to be maintained. Below is recommended column removal locations shown in Figure 3 for external column removal and Figure 4 for internal column removal.

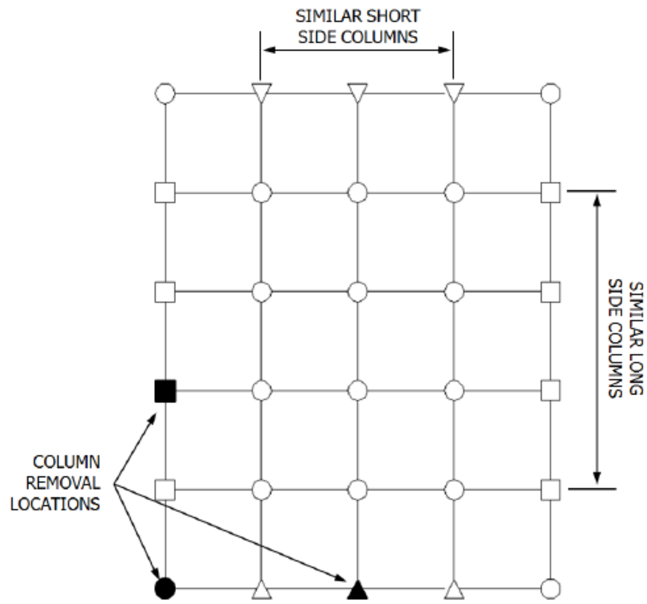


Figure 3 External column removal location in plan view GSA (2013)

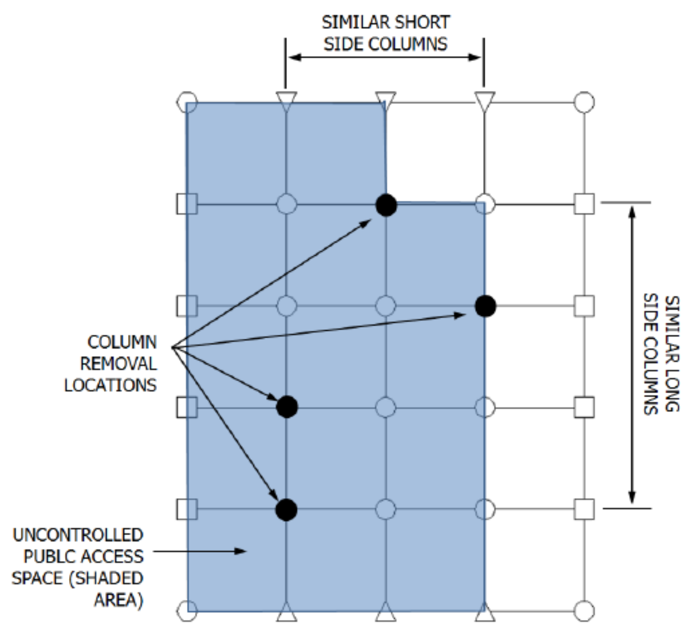


Figure 4 Internal column removal location in plan view GSA (2013)

For nonlinear dynamic analysis;

- Stiffness requirement in ASCE/SEI 41 (ASCE, 2014) should be satisfied. In this project, AISC Seismic Provisions (AISC, 2012) are used because they are for steel structures, specifically.
- There should be no geometric irregularities in the model used. However, this model irregular model is used to prove irregular buildings can be collapse resistance as well.
- Ductile connections must be used.
- Local stability and global stability in both vertical and horizontal direction should be satisfied.
- Lateral torsional buckling must be included. Due to limitations in finite element modelling in SAP 2000, this effect is not considered in this thesis.
- Load combination given in ASCE/SEI 7 for extraordinary events should be used.
- Column removal duration must be less than one tenth of the natural period of the structure. To avoid bad practice of this, the columns will be removed when the structure is statically stable.
- Design strengths, rotation capacities and beam-to-column connections should be determined from ASCE/SEI 07.

Most of the requirements mentioned by GSA (2013) and summarized above is included during modelling and analysis of the structure used in this thesis.

2.2 Minimum Design Loads for Buildings and Other Structures Requirements

Minimum Design Loads for Buildings and Other Structures Requirements, ASCE/SEI 7-10 (2013) is used in this research project for loads and load combinations, and some seismic requirements. This document recommends use of AISC 341 in conjunction to the requirements in this regulation to satisfy seismic requirements for steel buildings.

2.2.1 Load Combinations

Basic load combinations that include earthquake loading and blast loading from ASCE/SEI 07 (2013), section 2.3.2;

Load Combination 1;

$$1.4D$$

Load Combination 2;

$$1.2D+1.6L_f+0.5(L_r \; or \; S \; or \; R)$$

Load Combination 3;

$$1.2D+1.6(L_r \; or \; S \; or \; R)+(L_f \; or \; 0.5W)$$

Load Combination 4;

$$1.2D+1.0E_l+L_f+0.2S$$

Load Combination 5;

$$0.9D+1.0E_l$$

Where D is the dead load, L_f is the live load, L_r is the live roof load, S is the snow load and E_l is the earthquake loading. Section 2.5.2.1 gives the following load combination for extraordinary events which are explained earlier as blast loading.

Below is the equation from Section 2.5.2, this equation is used as two different combinations;

$$(0.9 or 1.2)D + A_k + 0.5L_f + 0.2S$$

Load Combination 6;

$$(0.9)D + A_k + 0.5L_f + 0.2S$$

Load Combination 7;

$$(1.2)D + A_k + 0.5L_f + 0.2S$$

Where, A_k, is the load from extraordinary events. It is a pressure loading and is not within the scope of this thesis for the modelling reasons. Snow load is taken as zero because most of the SDC E given in IBC (2012) is zero snow loading according to Figure 7-1 in ASCE/SEI 07 (2013).

3. TECHNICAL INFORMATION

3.1 Hand Calculation of a Simple Continuous Beam

In this subsection, effect of support removal of an indeterminate structure will be analyzed. The continuous simple beam is stable, robust and redundant and it has been optimally designed for case 1. The requirements mention in Design Guidelines for Progressive Collapse Resistance (GSA, 2013) are followed, and accordingly first the load path has been determined. When each support is removed, one at a time, the change in remaining support reactions, shear and moment diagrams are analyzed. The effect of this change on on overall structure is explained using basic engineering judgement. Examining the effects when support at B and support at C is removed one at a time. Figure 5 shows case 1 for the beam.

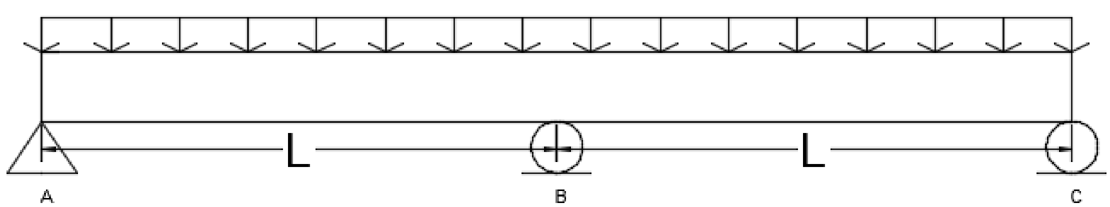


Figure 5 Simple indeterminate beam

Assumptions

- The beam is design to be elastic (optimal) for case 1.

- The beam is made Gr. 50 structural steel.
- The supports represent vertical load carrying members

3.1.1 Comparison of Case 1 and Case 2

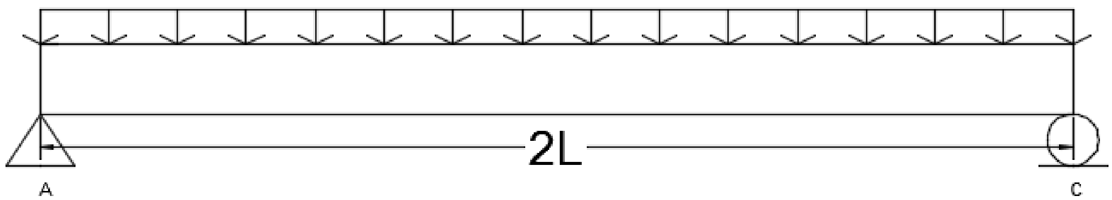


Figure 6 Simple beam with support B removed

In this case support at B is removed, as shown in Figure 6. The remaining support reactions are now 2.67 times what they carried in the 1st case. This also leads to increase at the initial shear value. The maximum moment carried by the 1st case increased 4 times and on the opposite direction (negative to positive). The maximum moment the beam has to carry is a lot greater in the 2nd case. The deflection at L/2 increased almost by 3.5 times and now there is a high mid-deflection which it was not considered in the design process. In this situation, the beam will no longer remain elastic since the beam was designed to have a zero deflection at the mid-span. Now has deflection caused by the beam and the loading. The calculation of support reactions, deflection, shear and moment and the diagrams can be found in Appendix A.

Table 1 Comparison of Case 1 and Case 2

	Case 1	Case 2	Increase (%)
R_A	(3/8)wL	wL	267
R_B	(5/4)wL	0	0
R_C	(3/8)wL	wL	267
$V(0)$	(3/8)wL	wL	267
$V(L)$	(5/8)wL	0	0
$M(L)$	(-1/8)wL^2	wL^2/2	-400
δ_o	0	0	0
$\delta(\mathrm{L}/2)$	(17/384)wL^4/EI	(57/384)wL^4/EI	335
$\delta(L)$	0	(5/24)wL^4/EI	inf
$\delta(2L)$	0	0	0

3.1.2 Comparison of Case 1 and Case 3

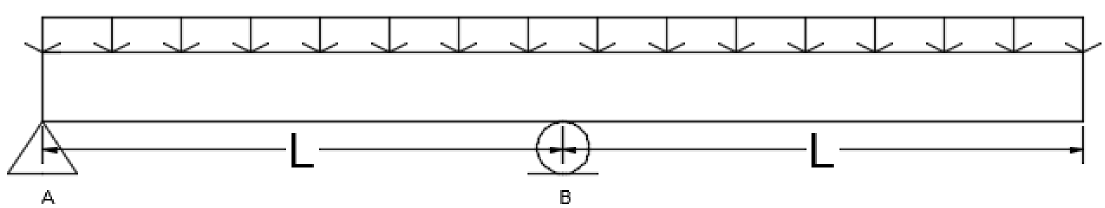


Figure 7 Simple beam with support C removed

In this case the support at right hand side is removed as shown in the Figure 7, above. Because the loading is symmetric, now only the support at B is carrying the loading and support at left hand side does not have any reaction force. The mid-span moment has increased 4 times on the same direction. Under this condition the point C faces good amount of deflection. This again causes the beam to pass beyond the elastic range since it was designed for no deflection.

Table 2 Comparison of Case 1 and Case 3

	Case 1	Case 3	Increase (%)
R_A	(3/8)wL	0	0
R_B	(5/4)wL	2wL	160
R_C	(3/8)wL	0	0
$V(0)$	(3/8)wL	0	0
$V(L)$	(5/8)wL	wL	160
$M(L)$	(-1/8)wL^2	(-wL^2/2)	400
δ_o	0	0	0
$\delta(\mathrm{L}/2)$	(17/384)wL^4/EI	(-7/384)wL^4/EI	-41
$\delta(L)$	0	0	0
$\delta(2L)$	0	(7/12)wL^4/EI	inf

3.1.3 Result

After static analysis of the simple indeterminate beam it has been concluded that redundancy alone is not enough to maintain the stability after a vertical member has been removed.

$$M_{yield} = \frac{w(2L)^2}{8} = \frac{wL^2}{2} \tag{1}$$

$$\frac{M_{plastic}}{M_{yield}} = \frac{Z_x}{S_x} = 1.20 \tag{2}$$

$$M_{plastic} = 1.2\left(\frac{wL^2}{2}\right) = \frac{3wL^2}{5} \tag{3}$$

If strain hardening is assumed, another 50% will be added to plastic moment which gives;

$$M_{plastic-strainhardening} = 1.5\left(\frac{3wL^2}{5}\right) = \frac{9wL^2}{10} \tag{4}$$

For both support removal case;

- The moment is 2.2 times the strain hardening.
- The moment is 3.3 times the ultimate capacity.
- The beam collapsed in both cases because they were not designed such force increase.

3.2 Load Patterning

In this subsection effect of influence area and tributary area of the following floor plan to overall structure will be explained. Figure 8 shows the floor plan of the model used.

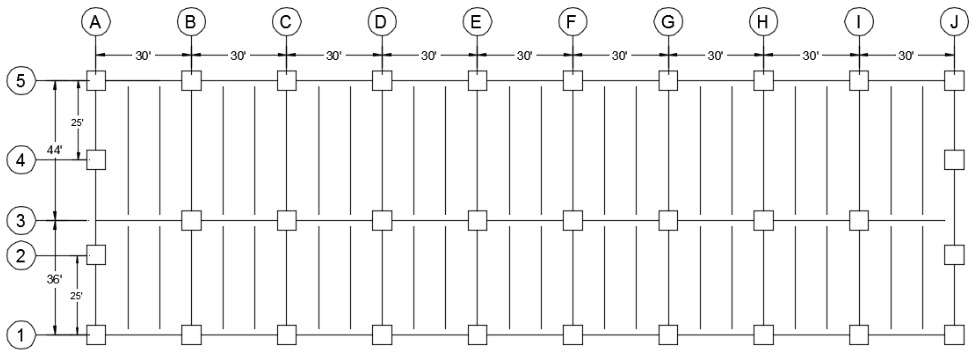


Figure 8 Floor plan

3.2.1 Floor Beam

Tributary area is the half of the area from one beam to the next beam from both sides, as illustrated in the Figure 9 below. Influence area is the area covered from the damaged beam to beams surrounding it. In the plan given below, if the blue floor beam is damaged, total of “L” times the length of the floor beam area will be affected from this when tributary area is the concern. However, “2L” times the length of the beam is the area affected because of the influence area.

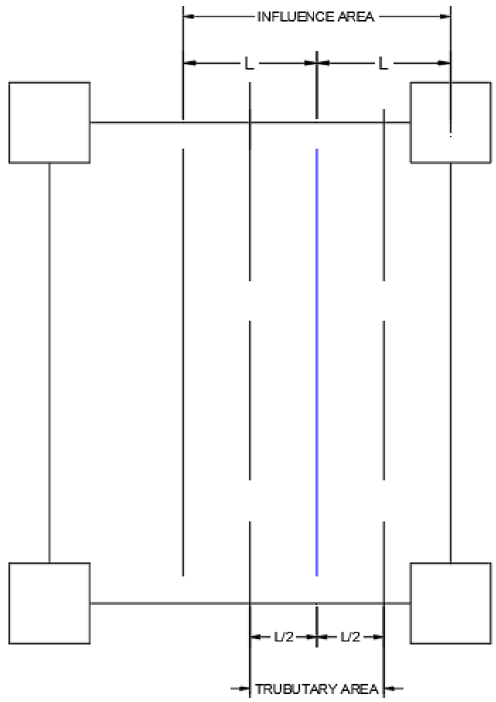


Figure 9 Influence area and tributary area of floor beams

For top beams the area is;

$$A_{tributary} = \left(\frac{10+10}{2}\right)\times 44 = 440\, ft^2$$

$$A_{\inf luence} = (10+10)\times 44 = 880\, ft^2$$

For bottom beams the area is;

$$A_{tributary} = \left(\frac{10+10}{2}\right)\times 36 = 360\, ft^2$$

$$A_{\inf luence} = (10+10)\times 36 = 720\, ft^2$$

3.2.2 Girder

Tributary area is the half of the area from one girder to the next girder from both sides, as illustrated in the Figure 10 below. Influence area of the area covered from the damaged girder to girders surrounding it.

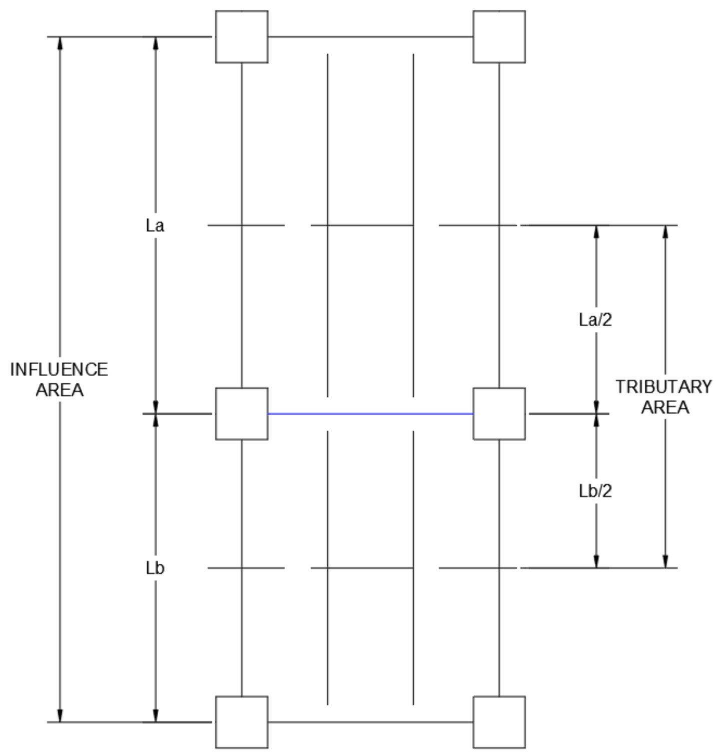


Figure 10 Influence area and tributary area of girders

In the plan given above, if the blue girder is damaged, total of "(La+Lb)/2" times the length of the girder area will be affected from this when tributary area is the concern. However, "(La+Lb)" times the length of the girder is the area affected because of the influence area.

For middle girder the area is;

$$A_{tributary} = \left(\frac{44+36}{2}\right)\times(30) = 1200\,ft^2$$
$$A_{\inf luence} = 80\times 30 = 2400\,ft^2$$

3.2.3 Column

Tributary area is the half of the area from one column to the next column from both sides, as illustrated in the Figure 11 below. Influence area of the area covered from the damaged column to columns surrounding it.

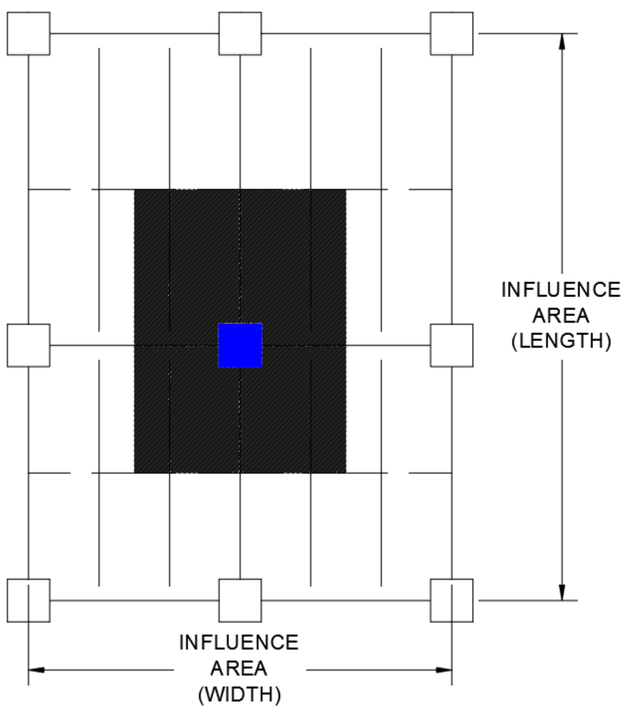


Figure 11 Influence area and tributary area of floors

In the plan given above, if the blue column is damaged, the shaded area will be affected from this when tributary area is the concern. However, the entire plan given is the area affected because of the influence area.

For middle column the area is;

$$A_{tributary} = \left(\frac{44+36}{2}\right) \times \left(\frac{60}{2}\right) = 1200\, ft^2$$

$$A_{\inf luence} = 80 \times 60 = 4800\, ft^2$$

From the explanation above;

1. Most critical structural member in this case is a column. The area it effects is a lot larger than the other structural members
2. If most critical case is needed, a column should be removed from the first story. Same area calculated as in first story will be effected on higher floors.
3. According to the information above, removal of an internal column is more critical. For all possibilities to be observed, it is required in GSA (2013) both the external and internal columns at different locations will be removed.
4. Strong column-weak beam design recommended in all seismic regulations is because of the influence and tributary area.

3.3 Panel Zones

First requirement for inelastic response by AISC (2012) is ductile beam to column connections. In other words, the failure shouldn't start at the connection, which is worse practice of ductile design. Panel zone is column web portion of element limited by the beam. It improves strength, stiffness and ductility of beam to column connections (Davila-Arbona, 2007). In panel zones moment forces are converted into shear forces and resisted. It also improves overall lateral flexibility of the entire structure (AISC, 2012). FEMA 355c (2000) has all the details required for welded moment resisting frames.

For its proven resistance to seismic resistance, panel zones are within scope of this project. As shown in Figure 2, the panel zones are kept in the system while vertical load carrying members are removed.

4. MODEL

4.1 Model Used

In this project, four story steel frame from Appendix E of GSA (2013) document is analyzed. This example is designed for a non-seismic region and is grouped in FSL 4. Alternative path and redundancy requirements are satisfied. It is a perimeter frame braced in transverse direction. All beam elements include a moment connection except for columns connecting to weak axis. The gravity connections are pinned connections. The structures soil connection is a pin connection as well. Roof is a metal deck and the floors are in composite action with metal deck and reinforced concrete. ASTM A992, Grade 50 Steel is used for all of the members. The roof and floor loading is obtained from IBC (2012) and the structure is mainly designed for wind. Member orientation and sizes can be found in the Appendix B. The member orientations and overall size of the frame is given below. Each structural member is given a specific label. The labels are given to member from bottom floor to the stop and from left to right. Each member's specific label is given in a spread sheet given in the Appendix B. Below is an example of the floor plan and elevations. Figure 12 shows initial plan used, Figure 13, Figure 14 and Figure 15 shows elevations for different gridlines.

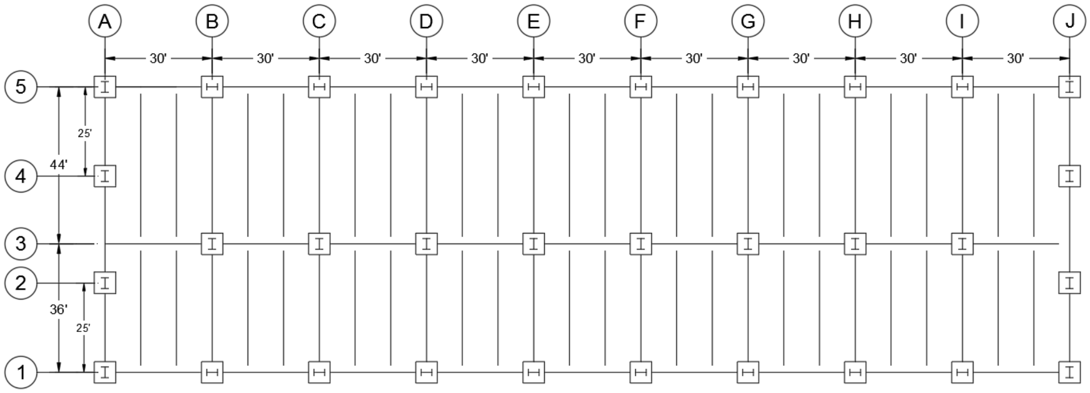


Figure 12 Initial floor plan of model used

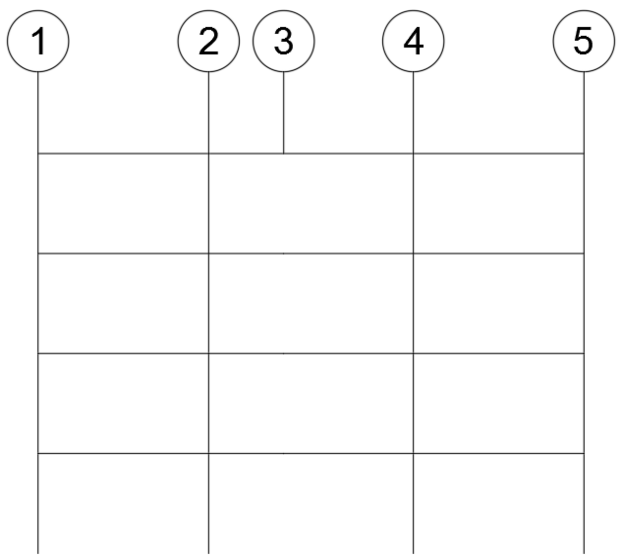


Figure 13 Gridline A and J elevations

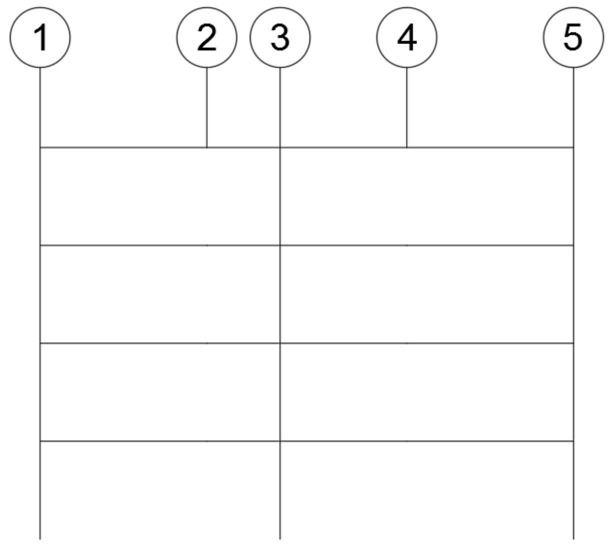


Figure 14 Gridlines B-I elevations

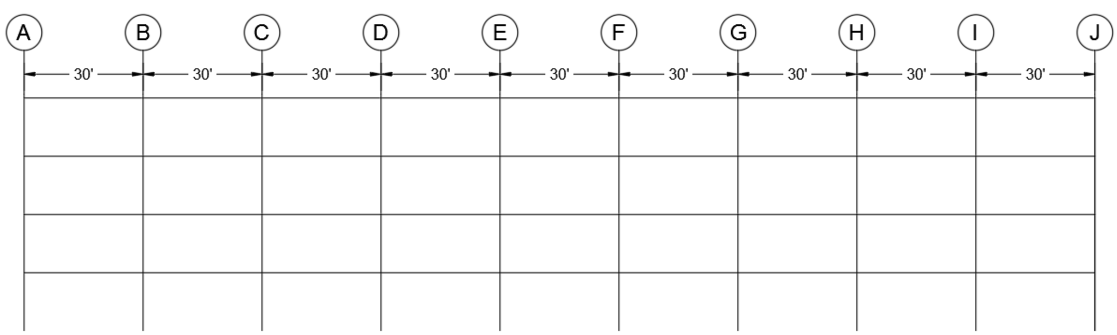


Figure 15 Gridline 1-5 elevations

4.2 Modifications In The Model

The main change made in this structure will be satisfying seismic regulations, mainly the strong column weak beam approach. For the first analysis the shapes given in GSA (2013) will be used. The only change made in the model is in the connections. The floor beams are changed into pin connections to avoid torsion development. The main skeleton of the frame’s beam-to column connections are changed into moment connections. As the seismic code requirements and limitations are applied, the member shapes will change. Another major change to the structure will be the change in slabs. Since the main objective of this project is to observe load path distribution between beams and columns, the slabs are not the major structural elements. However, the mass has effect to the inertia force and therefore it will affect the analysis under ground motion. For this reason, the slab will be assumed as an area and hand calculated loads and forces will be applied manually, the calculations can be found in Appendix C. All beam –to-column connections of the long side of the frame will be changed into moment connections to satisfy the special moment frame requirements. As explained in subchapter 3.3, panel zones will be included because of the improved resistance they add to the structure and for the non-conservative drift calculation reasons (AISC, 2012). Figure 16 shows screenshot of three dimensional model used.

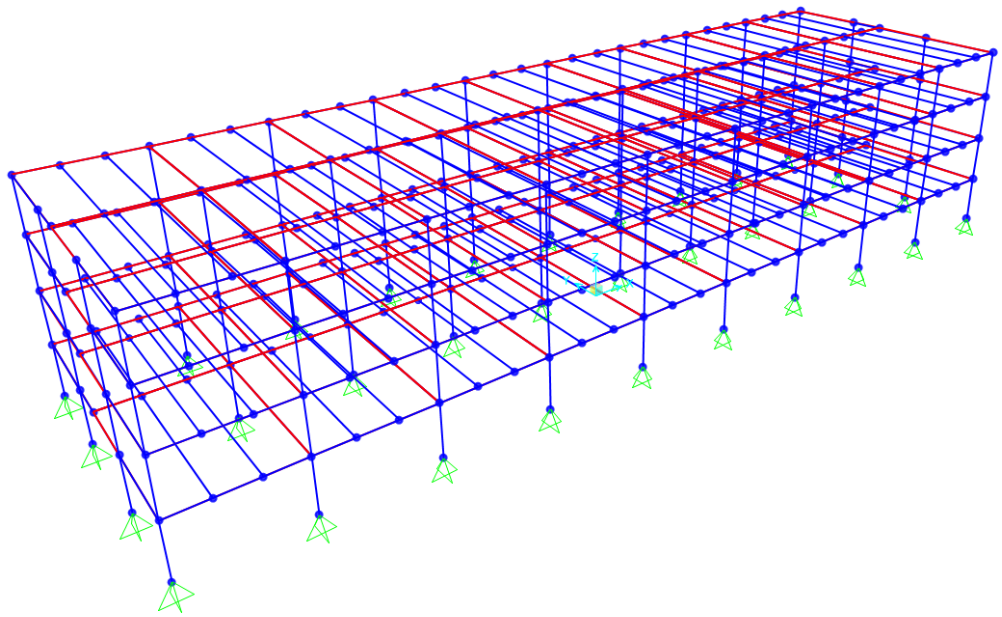


Figure 16 Three dimensional model

4.3 Seismic Region

This structure is assumed to located in Seismic Risk Category I, and SDC E. The model is converted into a SMF and all the properties given in ASCE/SEI 7-10 are used for the model inputs. SMFs are not limited to any SDC. From Table 12.2-1, design coefficients for steel SMF are;

- Response Modification Coefficient, $R = 8$
- Overstrength Factor, $\Omega_o = 3$
- Deflection Amplification Factor, $C_d = 5.5$.

Requirements for Risk Category I, from ASCE/SEI 7-10 Section 12.3.4.2 are;

Redundancy Factor, $\rho = 1.3$

For this project, earthquake records from Northridge, El Centro and Izmit earthquakes are used. The ground motions are applied in both X and Y direction to capture the most critical response. Ground motion graphs are plotted and can be found in Appendix D. The reason past earthquakes are preferred is they are unique accelerations and there are so many examples in the literature. Unscaled earthquake records are imported in to SAP 2000 and are scaled by $g = 32.2 \frac{ft}{\sec^2}$. The beam members' unbraced lengths are modified into zero because the members are laterally supported by the slab. The software package determines it differently before of the composite action modelling of the slab to the bare frame.

4.4 Modelling In SAP 2000

The structural members, columns and beams are oriented as it is given in Appendix B. The soil structure interaction is modelled as a pinned connection. For second order effects to be included, the time history analysis is nonlinear. Large P-delta effects are included, the elements are meshed manually into 10 pieces. The slabs are not in composite action with the frame.

Modelling steps are;

1. Grid definition
2. Material and section definition
3. Drawing structural elements (beams, column and slabs)
4. Assigning sections
5. Applying material properties

6. Defining restraints
7. Assigning loads (Uniform load to frames on area loading)
8. Importing ground motion data
9. Defining load patterns
10. Defining load combinations
11. Analyzing

Every time a member fails because of exceeding demand capacity ratio or beam/column moment ratio, step 4 will be repeated. Because the loading and load patterns will not change, only analysis has to be repeated.

4.5 Columns Removed

The floor plan below shows the columns being removed. Column removal locations satisfy the recommended locations (GSA, 2013). Figure 17 shows columns removed from the model used in this thesis.

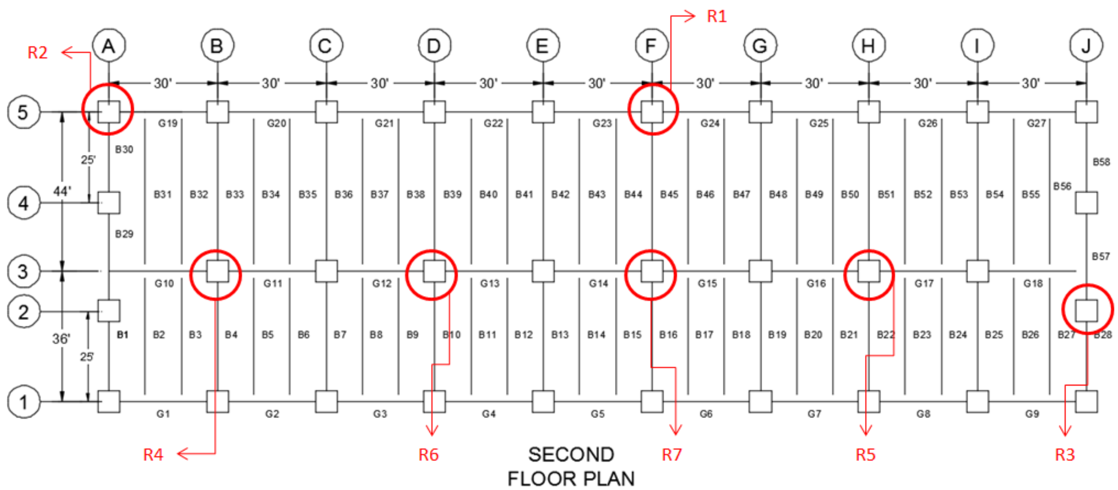


Figure 17 Column removals

Table below shows each column label for each removal case.

Table 3 Column Labels For Each Removal

R1	C 67
R2	C 4
R3	C 114
R4	C 18
R5	C 90
R6	C 42
R7	C 66

5. ANALYSIS

5.1 Analysis

In this chapter analysis methods and steps are explained. Three dimensional nonlinear time history analysis is applied to each model. In SAP 2000 (CSI, 2016), it is named as Fast Nonlinear Analysis, FNA and load dependent Ritz vectors are used during nonlinear modal time analysis. The modal damping is 5%.

At each analysis step, the controlling property of each section is explained and supported with the code requirements. After each column removal and for each earthquake, failed members will be replaced with more compact sections for failure cases. The member properties on AISC Database v14.1 is used. The failures are determined by the Demand Capacity Ratio;

$$DCR = \frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \right) \leq 1.0 \tag{5}$$

As given in flow chart below, first the seismic requirements are applied. Main controlling factor at this step is strong column- weak beam approach. AISC 341-05 requires the plastic moment ration of columns to the beams should be equal to or more than 2. This requirement has to be satisfied for both strong axis bending and weak axis bending. Because $F_y = 50$, this could be easily obtained by plastic section modulus ratio.

$$\frac{M_{pc}}{M_{pb}} = \frac{F_y Z_c}{F_y Z_b} \geq 2.0 \tag{6}$$

Figure 18 contains steps of analysis. For each earthquake, the ground motions are applied in the X and Y direction to capture the most critical loading direction. Once the structure is stable under the ground motion given, the specific columns given in Chapter 3 are removed individually and the effect is recorded. The analysis will be carried in 9 steps and they are;

1. Analyzing the model by applying the earthquake in X direction and removing the Nth column
2. Fixing the failed members
3. Adding the removed column and analyzing the structure again
4. Fixing the model if any elements failed
5. Analyzing the model by applying the earthquake in Y direction, fixing if anything fails
6. Removing Nth column and analyzing the structure
7. Fixing failed members
8. Adding the removed column and analyzing the structure again
9. Fixing the model for the last time and using same model and repeating all the steps for (N+1)th column.

Where N represents column removal 1 to 7.

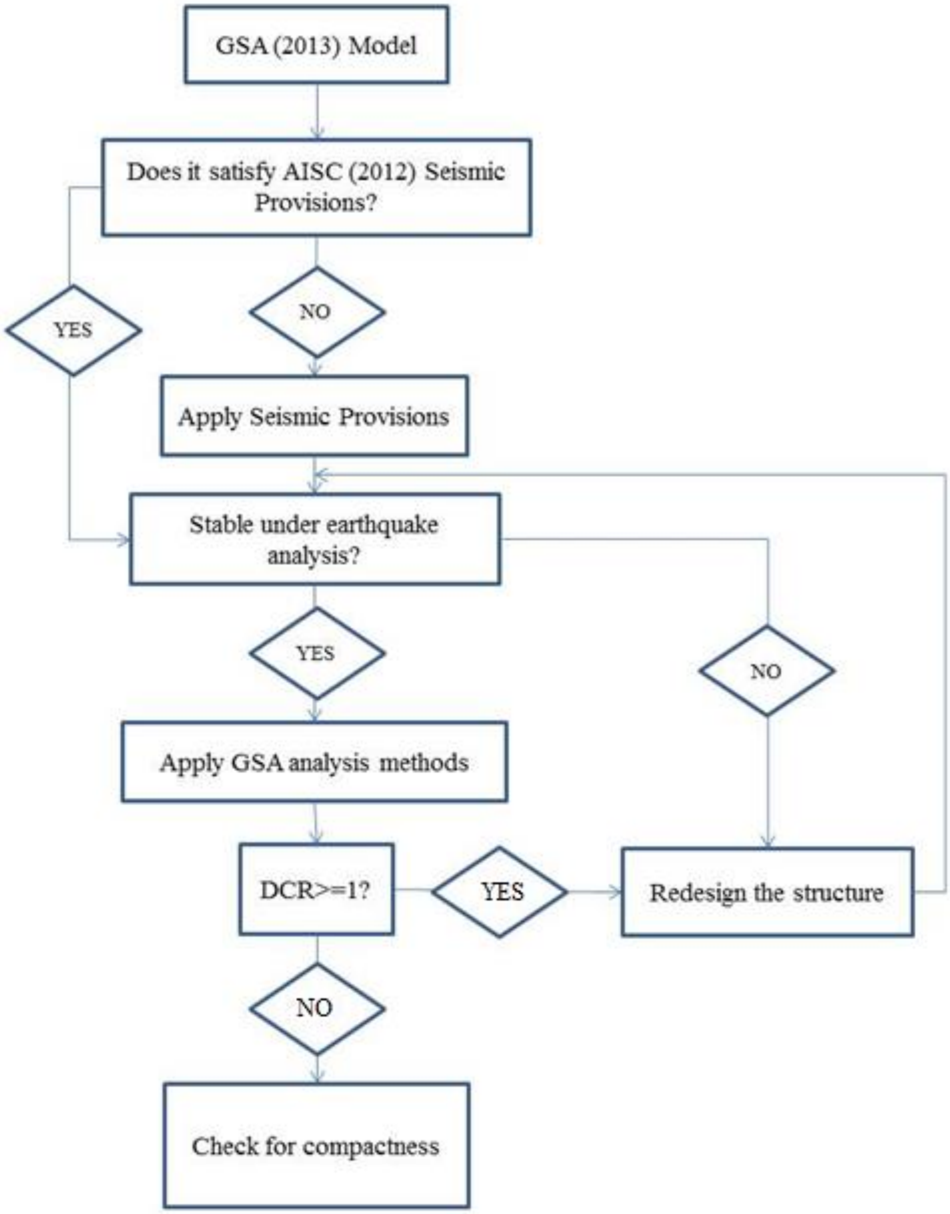


Figure 18 Analysis plan

5.2 Loads Applied

Below are the loads applied to the slab.

Table 4 Slab Area Loads

Droof	0.068 ksf
Dfloor	0.085 ksf
Lroof	0.02 ksf
Lfloor	0.1 ksf
Snow	0

6. RESULTS

6.1 Results

In this chapter, results from analysis are represented. The shape changes are given in the tables below for each earthquake, separately for ground acceleration in X and Y direction, and for each column removal case. The earthquakes for analysis are El Centro, Northridge and Izmit earthquake. Because they all have similar high magnitudes, the failures are almost identical. In Appendix D, the screen shots of failures and their DCR (P-M) ratios are given.

Some members fail because they exceed the DCR and some interior columns fail because the beam/column moment ratio exceeds. This is controlled by the AISC 341 (2012). Below is the equation for LRFD, when beam sections are not reduced and it should be satisfied for beam-to-column connection.

$$\frac{\sum M_{pc}}{\sum M_{pb}} > 1.0$$
$$\frac{\sum Z_c (F_{yc} - P_{uc} / A_g)}{\sum \left(1.1 R_y F_{yb} Z_{RBS} + M_{uv}\right)} > 1.0 \tag{7}$$

It can be seen from the Appendix D that after the column removal, when the surrounding failed beams are iterated, the failure in columns are due to beam/column ratio exceedance. When the above equation is solved, it has been found that the weak axis plastic section moduli of the interior columns are causing the ratio to exceed. Using

AISC 360 (AISC, 2010), it has been determined that the shape W14X730 has the largest plastic section modulus in weak axis. Once the columns failing due to beam to column ratio are replaced with the largest section, the error is still occurring. This cannot be fixed due to manufacturing limitation. It shows that in today's society, the buildings are optimally designed and they have just enough structural elements. When a column is removed however, to satisfy the redundancy and stability either the existing members will be replaced with stiffer sections, which adds extra load to the frame, or fails because of the beam to column ratio as shown in this project. Another solution can be adding extra columns, however, due to architectural reasons it is not a preferred option.

Even though the analysis show that some of the members failed, their failure will affect the members connecting to them. For example if a girder failed, the floor beams will fail because they no longer have a girder to support them.

Here are results from each removal case

6.1.1 Column Removal 1

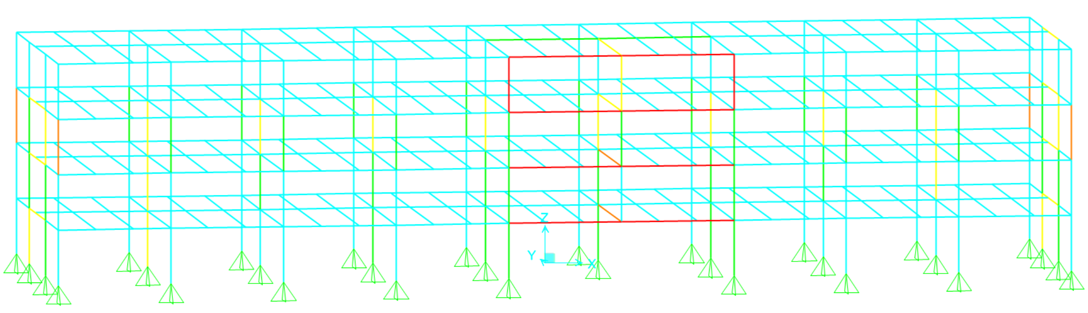


Figure 19 Failed 3D model after column removal 1

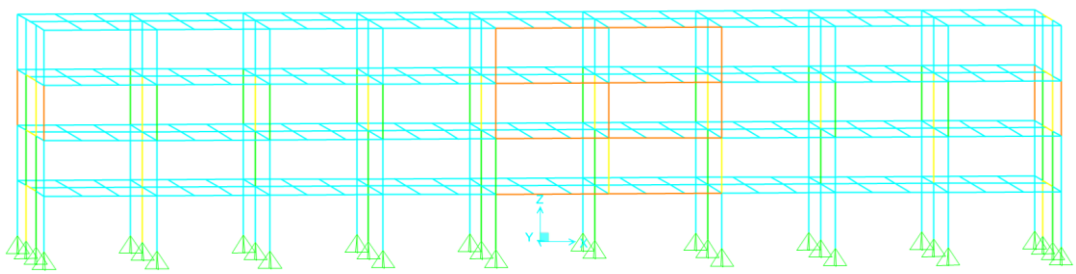


Figure 20 Fixed 3D model after column removal 1

In this removal case, 8 girders and 2 columns failed. This leads to failure of all the floor beams connecting to those failed girders. Eventually the frame column is removed will partially collapse. Figure 19 shows the failed structure and Figure 20 shows the fixed model.

6.1.2 Column Removal 2

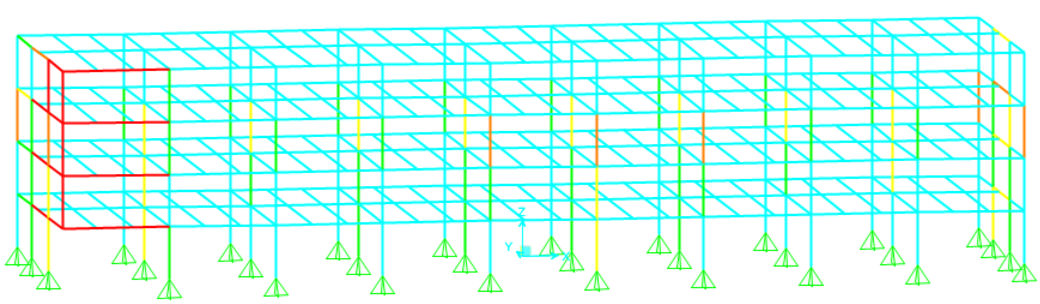


Figure 21 Failed 3D model after column removal 2

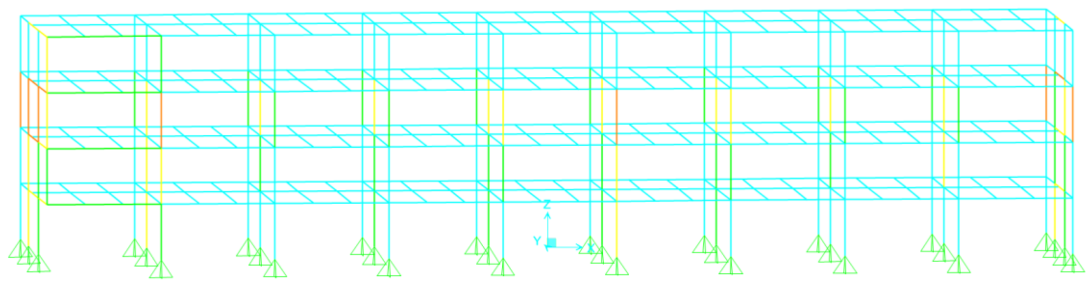


Figure 22 Fixed 3D model after column removal 2

In this removal case, 4 floor beams, 4 girders and 2 columns failed. This leads to failure of all the floor beams and girders connecting to those failed members. Eventually the frame column is removed will partially collapse. Figure 21 shows the failed structure and Figure 22 shows the fixed model.

6.1.3 Column Removal 3

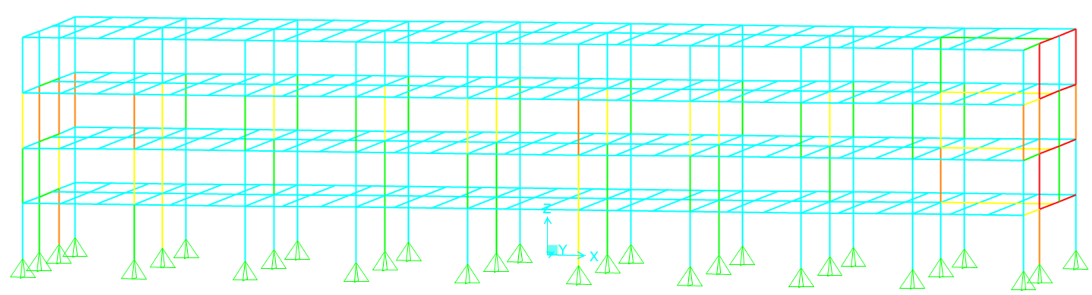


Figure 23 Failed 3D model after column removal 3

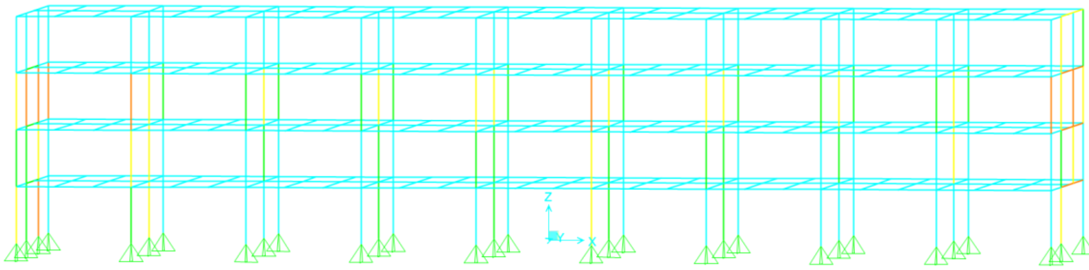


Figure 24 Fixed 3D model after column removal 3

In this removal case, 8 floor beams and 3 columns failed. This leads to failure of all the girders connecting to those failed floor beams. Eventually the frame column is removed will partially collapse. Figure 23 shows the failed structure and Figure 24 shows the fixed model.

6.1.4 Column Removal 4

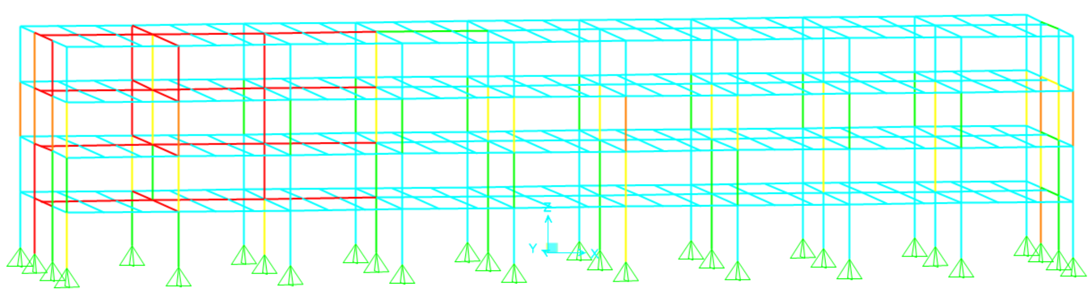


Figure 25 Failed 3D model after column removal 4

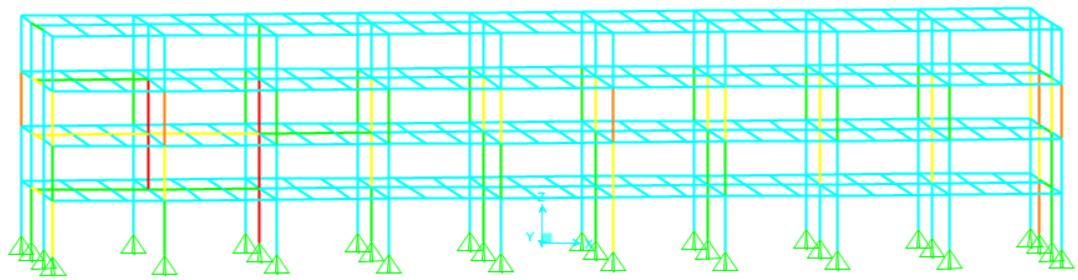


Figure 26 Fixed 3D model after column removal 4

In this removal case, 12 floor beams, 12 girders and 9 columns failed. This leads to failure of all the beams and girders connecting to those failed elements. Eventually the frame column is removed will partially collapse. The 5 columns in Figure 25 are shown as failed because they do not satisfy column to beam connection ratio and as explained in this chapter earlier, there are no available shapes to satisfy the ratio because 2 floor beams and 2 girders are connecting to a single column joint. Figure 26 shows the fixed model.

6.1.5 Column Removal 5

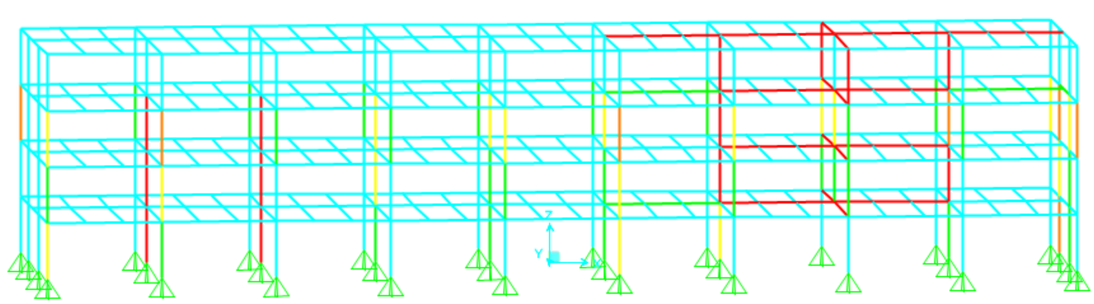


Figure 27 Failed 3D model after column removal 5

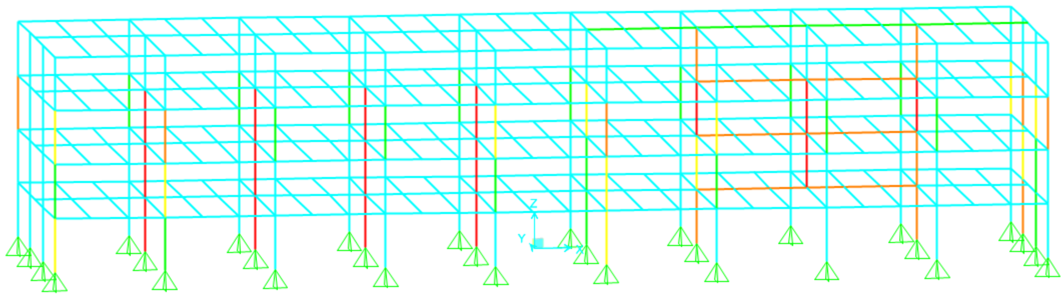


Figure 28 Fixed 3D model after column removal 5

In this removal case, 8 floor beams, 10 girders and 13 columns, 6 from previous case, failed. This leads to failure of all the beams and girders connecting to those failed elements. Eventually the frame column is removed will partially collapse. The 13 columns in Figure 27 are shown as failed because they do not satisfy column to beam connection ratio and as explained in this chapter earlier, there are no available shapes to satisfy the ratio because 2 floor beams and 2 girders are connecting to a single column joint. Figure 28 shows the fixed model.

6.1.6 Column Removal 6

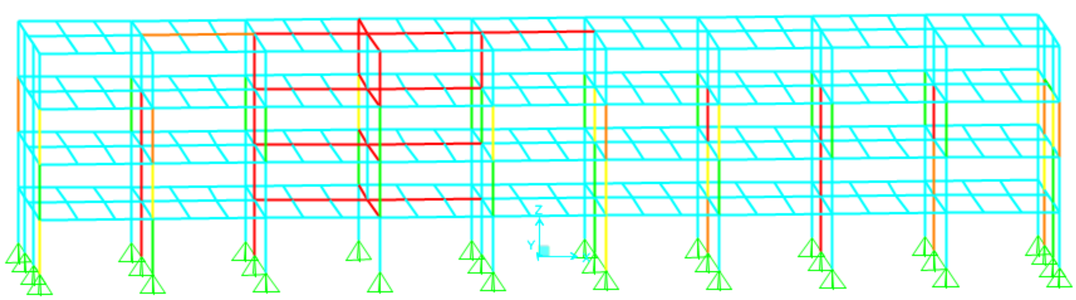


Figure 29 Failed 3D model after column removal 6

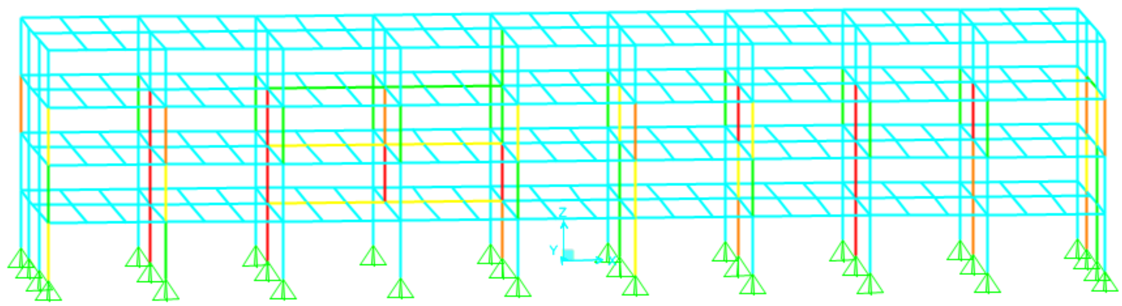


Figure 30 Fixed 3D model after column removal 6

In this removal case, 8 floor beams, 9 girders and 15 columns, 13 from previous case, failed. This leads to failure of all the beams and girders connecting to those failed elements. Eventually the frame column is removed will partially collapse. The 15 columns in Figure 29 are shown as failed because they do not satisfy column to beam connection ratio and as explained in this chapter earlier, there are no available shapes to satisfy the ratio because 2 floor beams and 2 girders are connecting to a single column joint. Figure 30 shows the fixed model.

6.1.7 Column Removal 7

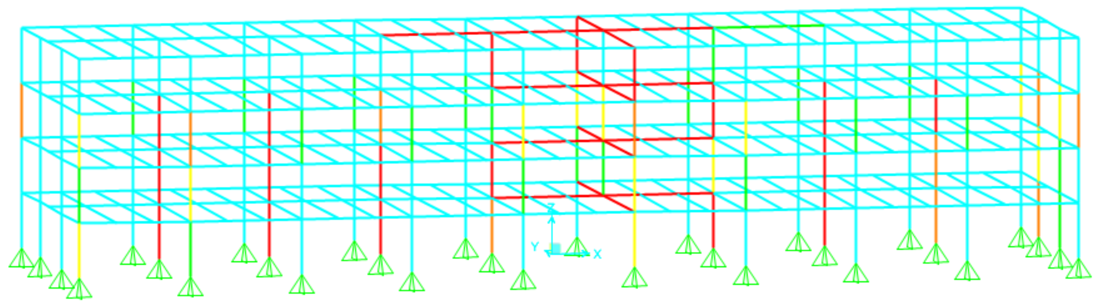


Figure 31 Failed 3D model after column removal 7

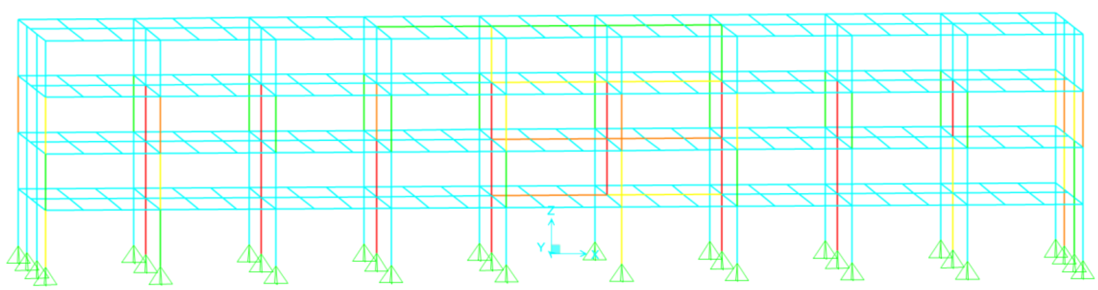


Figure 32 Fixed 3D model after column removal 7

In this removal case, 8 floor beams, 9 girders and 18 columns, 15 from previous case, failed. This leads to failure of all the beams and girders connecting to those failed elements. Eventually the frame column is removed will partially collapse. The 20 columns in Figure 31 are shown as failed because they do not satisfy column to beam connection ratio and as explained in this chapter earlier, there are no available shapes to satisfy the ratio because 2 floor beams and 2 girders are connecting to a single column joint. Figure 32 shows the fixed model.

7. CONCLUSIONS

7.1 Conclusion

In this project, load redistribution path for a steel frame under seismic loading is analyzed. It can be seen from the analysis and results that, once a structure is partially stable to resist ground motion, it also increases to resistance to vertical load bearing member loss. Even though the columns are removed from most critical location, first story due to the influence area, mainly the members surrounding the removal failed under strong ground motion. All the girders connecting to removed column failed and their demand capacity ratio is almost 4 (in the simple beam problem in Chapter 3, the moments were almost 400% more). It is possible to fix the failures for exterior columns, however, when it comes to interior columns, some of the columns surrounding the removed column are failing because the beam/column ratio exceeds the capacity. With some hand calculations using the equation given in E3-1, AISC 341, it is the weak axis plastic section modulus controlling the beam/column ratio. Even though the section with the highest plastic section modulus in weak axis (AISC 360, shape W14x730), the error still occurs. Even though with final design, the structure is somewhat stable, it is inherently redundant. Due to manufacturing limitations, beam to column ratios are not satisfied because the beams needed very high weight shapes in order the transfer the high shear and moment caused in the system after the column removal.

It has been mentioned in Chapter 1, that blast loading can be fire explosions as well. One issue after earthquakes is post-earthquake fires. There are barely any comments on that when designing for seismic resistance. The analysis steps in this project, with design iteration, partially add resistance to any post-earthquake effects. In a worst case scenario, because the load redistribution and redundancy is provided, the potential partial collapse will be delayed, leading to many life savings.

Although structural continuity and symmetry is very important both for seismic resistance and alternative load path, this research has shown that once all the required steps are followed, an irregular, asymmetric frame had a very decent response. Due to the distance in center of mass and center of rigidity, torsion effects were formed. However, this did not lead to any local torsional buckling of elements.

7.2 Future Research

As mentioned in AISC (2012), failure of connection is explicitly showing non-ductile design, the effect of beam-to-column connections will be examined. For that reason, similar analysis should be carried in a highly developed finite element software, where each element can be detailed. Even though it is recommended to keep the panel zones when a column is removed, in SAP 2000, the effect could not be examined.

Although GSA (2013) regulations only require one column removal at a time, examining effects of few column removal at a time can be beneficial and represent real life effects better. Removing a few columns from different stories at once can give interesting results.

Cost analysis and weight increase percentage and economical and seismic effects of these changes on the structure can be performed.

ASCE/SEI 7-10 has no load combination which includes both the extraordinary events and earthquake loading. By conducting analytical and experimental studies, a new load combination could be derived. That load combination will increase overall resistance of the structure and simplify the design process.

REFERENCES

AISC. (2012). “Seismic Design Manual.” American Institute of Steel Construction, Chicago, IL.

AISC. (2010). “Specifications for Structural Steel Buildings.” American Institute of Steel Construction, Chicago, IL.

ASCE. (2013). “Minimum Design Loads for Buildings and Other Structures.” American Society of Civil Engineers, Reston, VA.

ASCE. (2014). “Seismic Evaluation and Retrofit of Existing Buildings.” American Society of Civil Engineers, Reston, VA

Breen, J. E. (1975). Research Workshop on Progressive Collapse of Building Structures, University of Texas at Austin, Austin, Texas, National Bureau of Standards, Washington, D. C.

CSI. (2016). "SAP2000 Advanced." Computer and Structures Inc, Berkeley, CA.

Davila-Arbona, F. J. (2007). “Panel Zone Behaviour in Steel Moment Resisting Frames.” European School For Advanced Studies In Reduction Of Seismic Risk, Rose School.

Dreger, D. (1997). “The Large Aftershocks of the Northridge Earthquake and their Relationship to Mainshock Slip and Fault Zone Complexity.” Bulletin of the Seismological Society of America, Vol. 87, No. 5, pp.1259-1266.

FEMA. (2000). “State of the Art Report on Systems Performance of Steel Moment Frames Subject to Earthquake Ground Shaking.” Federal Emergency Management Agency – 355-C.

Ficanha, R.A. and Pravia, C. Z. M. (2012). “3D second order analysis of industrial buildings.” Annual Stability Conference Structural Stability Research Council,Grapevine, Texas, April 18-21, 2012.

Gerasimidis, S., Deodatis, G., Kontoroupi, T., Ettouney, M. (2015). “Loss-of-stability induced progressive collapse modes in 3D steel moment frames.” Structure and Infrastructure Engineering, Vol. 11, No. 3, 334–344.

GSA. (2003). “Progressive Collapse Analysis and Design Guidelines for New Federal Buildings and Major Modernization Projects.” General Services Administration.

GSA. (2013). “Alternative Path Analysis & Design guidelines for Progressive Collapse Resistance.” General Services Administration http://www.gsa.gov/portal/mediaId/189799/fileName/GSA_Progressive_Collapse_Guidlines_Final.action.

Hamburger, R. (2006). “Alternative Methods of Evaluating and Achieving Progressive Collapse Resistance.” North American Steel Construction Conference, San Antonio, Texas.

Hamburger, R. O., Krawinkler, H., Malley, J. O., Adan, S. M. (2009). “Seismic Design of Steel Special Moment Frames: A Guide For Practicing Engineers.” NEHRP Seismic Design Technical Brief No.2, NIST GCR 09-917-3.

Sasani, M. and Sagiroglu, S. (2008). “Progressive collapse resistance of hotel San Diego.” Journal of Structural Engineering, Vol. 134, No. 3, 478-488.

Sezen, H. and Giriunas, K. A. (2009). “Progressive Collapse Analysis of an Existing Building.” Civil Engineering Honors Undergraduate Program Thesis, The Ohio State University https://kb.osu.edu/dspace/bitstream/handle/1811/36948/Giriunas_Kevin_thesis.pdf.

Song, B. I. and Sezen, H. (2013). “Experimental and Analytical Progressive Collapse Assessment of a steel frame building.” Engineering Structures 56, 664-672.

Tavakoli, H. R. and Alashti, A. R. (2013). “Evaluation of progressive collapse potential of multistory moment resisting steel frame buildings under lateral loading.” Scientia Iranica, Volume 20, Issue 1, Pages 77–86.

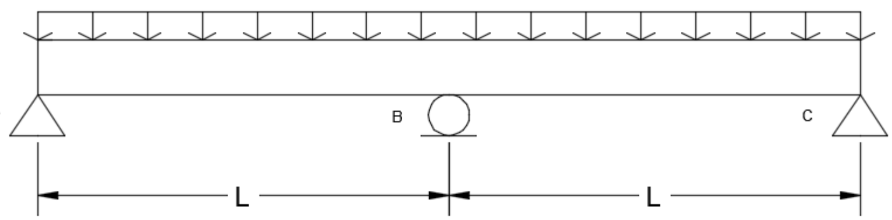
Yun, S. Y., Hamburger, R.O., Cornell, C. A. and Foutch, D.A. (2002). “Seismic performance evaluation for steel moment frames.” Journal of Structural Engineering ASCE, Vol. 128, No. 4, 534-545.

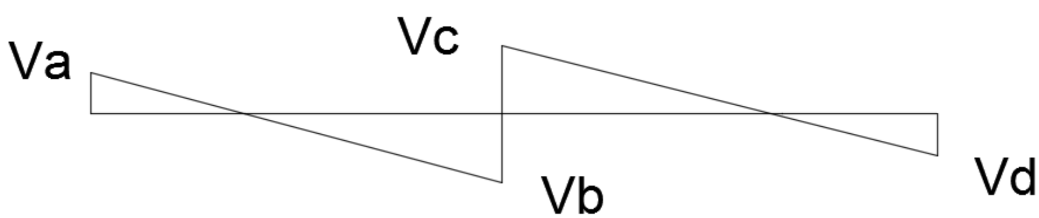
Ziemian, R. D. (2010). “Guide to Design Criteria for Metal Structures.” Sixth Edition, Hoboken, N.J. : John Wiley & Sons, New Jersey.

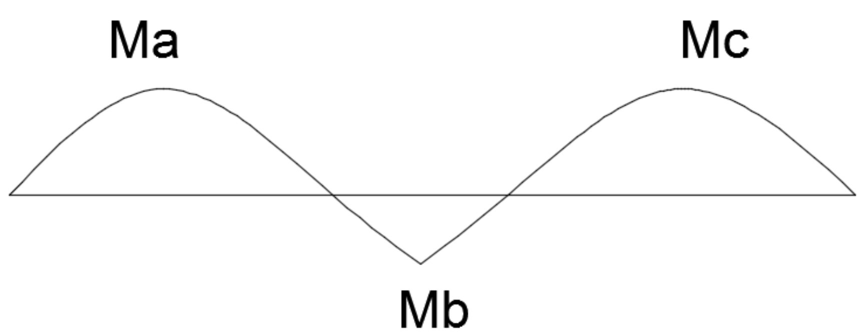
APPENDIX A

CALCULATIONS FOR SIMPLE CONTINUOUS BEAM

Case 1







If R_B is redundant, $R_A = R_C = wL$.

Force-displacement relationship;

$$\left(v_B\right)_1 = \frac{5wL(2L)^4}{384EI} = \frac{5wL^4}{24EI}$$

$$\left(v_B\right)_2 = \frac{R_B(2L)^3}{48EI} = \frac{R_B L^3}{6EI}$$

$$v_B = (v_B)_1 - (v_B)_2 = 0$$

$$\frac{5wL^4}{24EI} = \frac{R_B L^3}{6EI} \Rightarrow R_B = \frac{5wL}{4}$$

Due to conservation of forces in vertical, y direction,

$$\sum F_y = 0$$

$$R_A = R_C = \frac{1}{2}\left(2wL - \frac{5wL}{4}\right) = \frac{3wL}{8}$$

$$V_a = -V_d = \frac{3wL}{8}$$
$$V_c = -V_b = \frac{5wL}{8}$$

$$M_a = M_c = \frac{3}{8}\times\frac{3}{8}\times\frac{wL^2}{2} = \frac{9wL^2}{128}$$
$$M_b = \frac{9wL^2}{128} - \frac{5}{8}\times\frac{5}{8}\times\frac{wL^2}{2} = -\frac{16wL^2}{128} = -\frac{wL^2}{8}$$

To find the maximum deflection, method of initial parameters is used;

$$\delta(x) = \delta_o + \theta_o x + \frac{M_o x^2}{2EI} - \frac{V_o x^3}{6EI} + \frac{wx^4}{24EI}$$

Initial conditions are:

$$\delta_o = M_o = 0$$

Therefore,

$$V_o = R_A = \frac{3wL}{8}$$

$$\delta(\mathrm{L}) = \theta_o L - \frac{wL^4}{16EI} + \frac{wL^4}{24EI} = 0$$

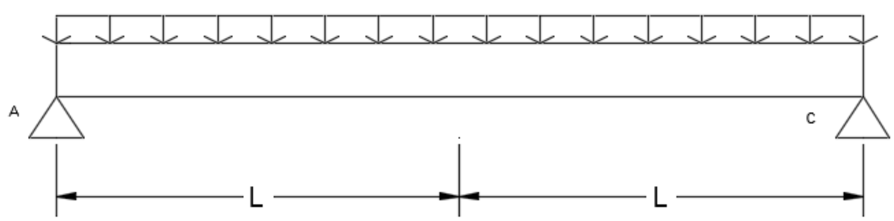
$$\theta_o L = \frac{wL^4}{16EI} - \frac{wL^4}{24EI}$$

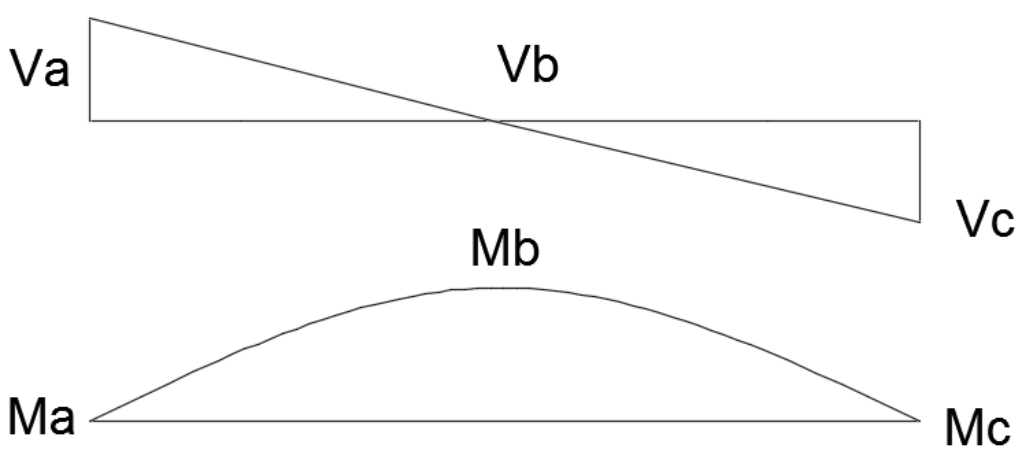
$$\theta_o = \frac{wL^3}{48EI}$$

$$\delta(\mathrm{x}) = \frac{wL^3 x}{48EI} - \frac{wLx^3}{16EI} + \frac{wL^4}{24EI}$$

$$\delta(\mathrm{L}/2) = \frac{wL^3 L}{96EI} - \frac{wLL^3}{128EI} + \frac{wL^4}{24EI} = \frac{17wL^4}{384EI}$$

Case 2





$$R_A = R_C = wL$$

$$V_a = -V_c = wL$$
$$V_b = 0$$

$$M_a = M_c = 0$$
$$M_b = \frac{wL^2}{2}$$

To find the maximum deflection, method of initial parameters is used;

$$\delta(\mathrm{x}) = \delta_o + \theta_o x + \frac{M_o x^2}{2EI} - \frac{V_o x^3}{6EI} + \frac{wx^4}{24EI}$$

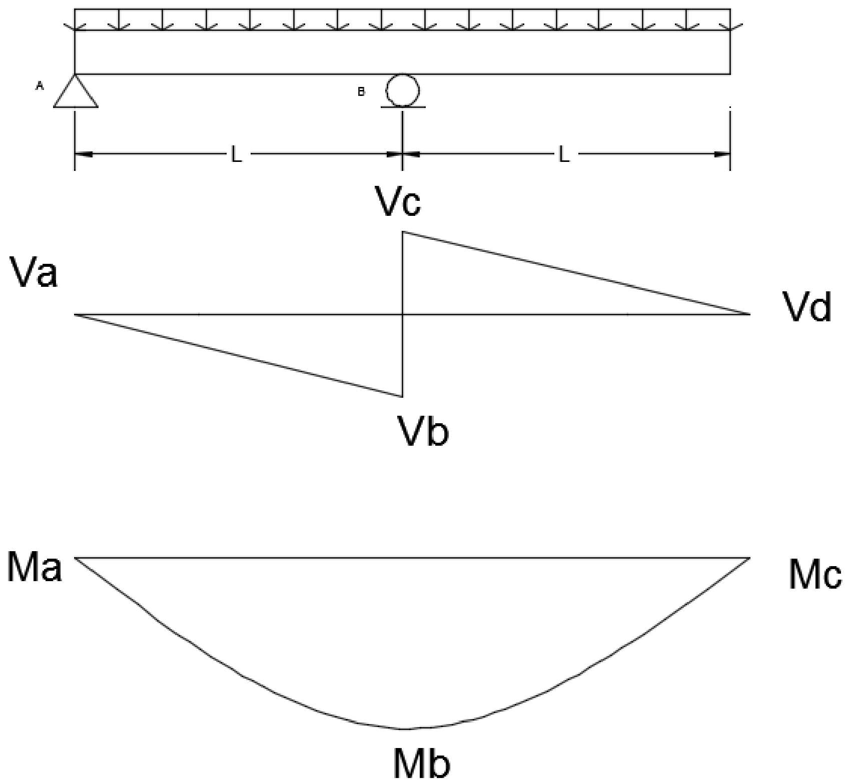
Initial conditions are:

$$\delta_o = M_o = 0$$

Therefore,

$$V_o = R_A = wL$$
$$\delta(2L) = \theta_o 2L - \frac{8wL^4}{6EI} + \frac{16wL^4}{24EI} = 0$$
$$\theta_o = \frac{4wL^3}{6EI} - \frac{8wL^3}{24EI}$$
$$\theta_o = \frac{wL^3}{3EI}$$
$$\delta(\mathrm{L}/2) = \frac{wL^3 L}{6EI} - \frac{wLL^3}{48EI} + \frac{wL^4}{384EI} = \frac{57wL^4}{384EI}$$
$$\delta(\mathrm{L}) = \frac{wL^3 L}{3EI} - \frac{wLL^3}{6EI} + \frac{wL^4}{24EI} = \frac{5wL^4}{24EI}$$

Case 3



$$\sum M_a = 0$$

$$M_a = R_B L - \frac{w4L^2}{2} = 0$$
$$R_B = 2wL$$

$$V_c = -V_b = wL$$
$$V_a = V_d = 0$$

$$M_a = M_c = 0$$
$$M_b = \frac{wL^2}{2}$$

To find the maximum deflection, method of initial parameters is used;

$$\delta(x) = \delta_o + \theta_o x + \frac{M_o x^2}{2EI} - \frac{V_o x^3}{6EI} + \frac{wx^4}{24EI}$$

Initial conditions are:

$$\delta_o = M_o = 0$$

Therefore,

$$V_o = R_A = 0$$

$$\delta(L) = \theta_o L + \frac{wL^4}{24EI} = 0$$

$$\theta_o = -\frac{wL^3}{24EI}$$

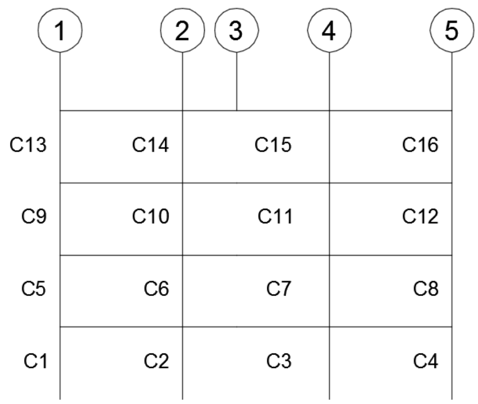
$$\delta(\mathrm{L}/2) = -\frac{wLL^3}{48EI} + \frac{wL^4}{384EI} = -\frac{7wL^4}{384EI}$$

$$\delta(2\mathrm{L}) = -\frac{2wLL^3}{24EI} + \frac{16wL^4}{24EI} = \frac{7wL^4}{12EI}$$

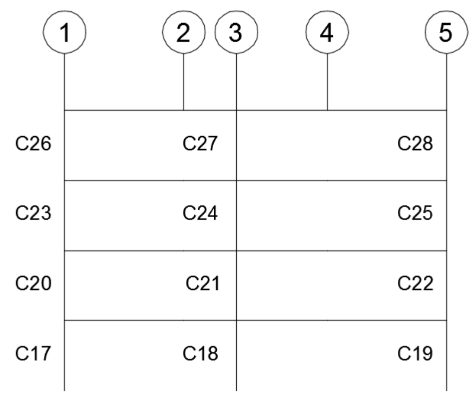
APPENDIX B

LABELS FOR EACH ELEMENT

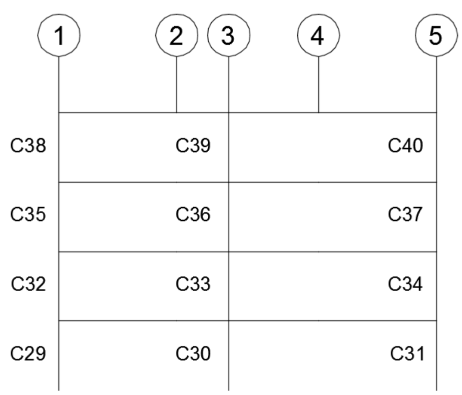
Elevations of Gridline A-J



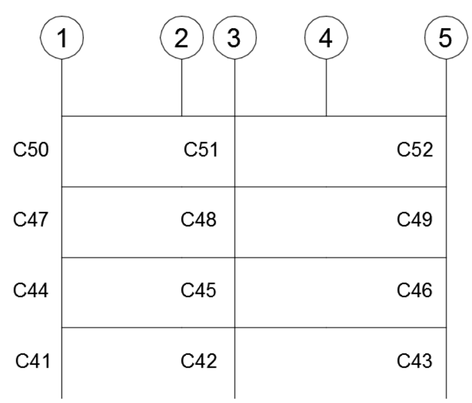
Gridline A



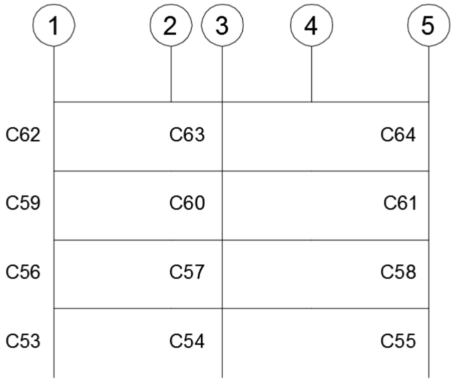
Gridline B



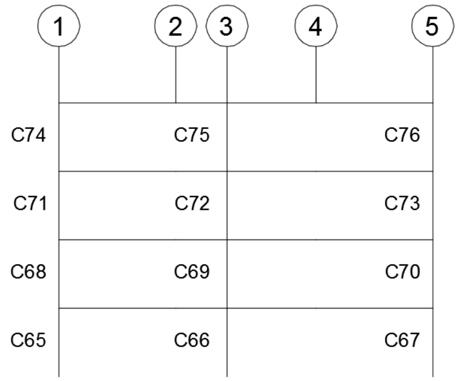
Gridline C



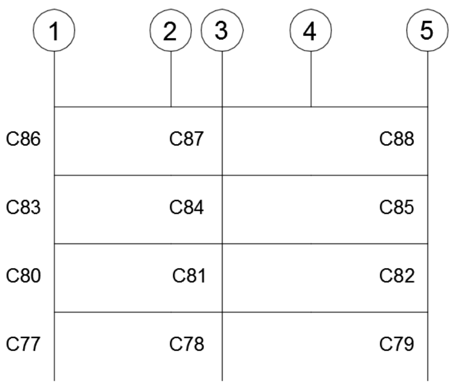
Gridline D



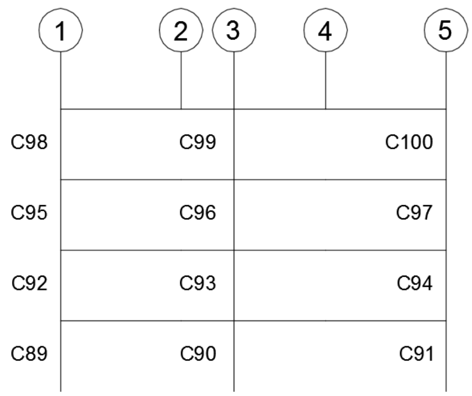
Gridline E



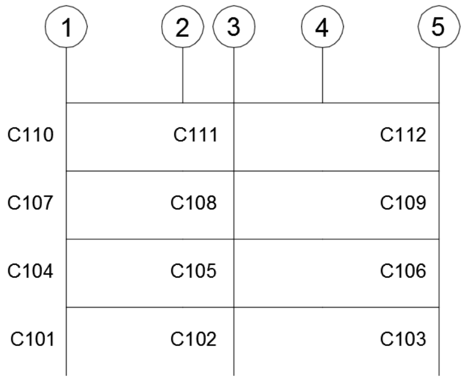
Gridline F



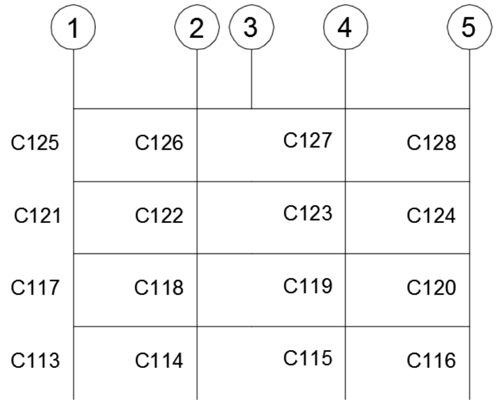
Gridline G



Gridline H

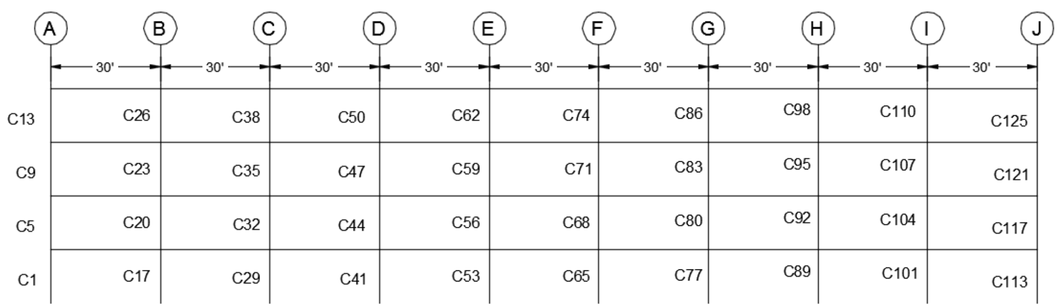


Gridline I

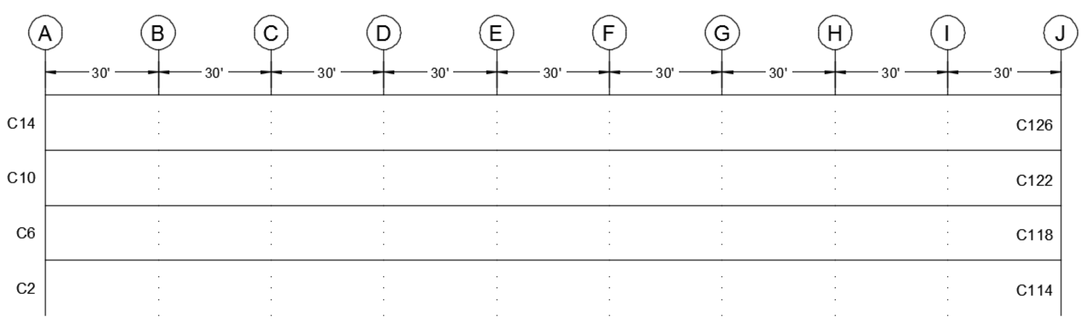


Gridline J

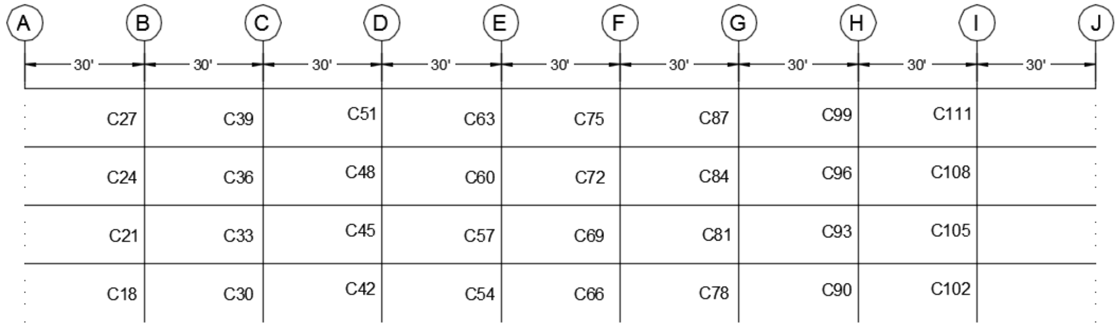
Elevations of Gridline 1-5



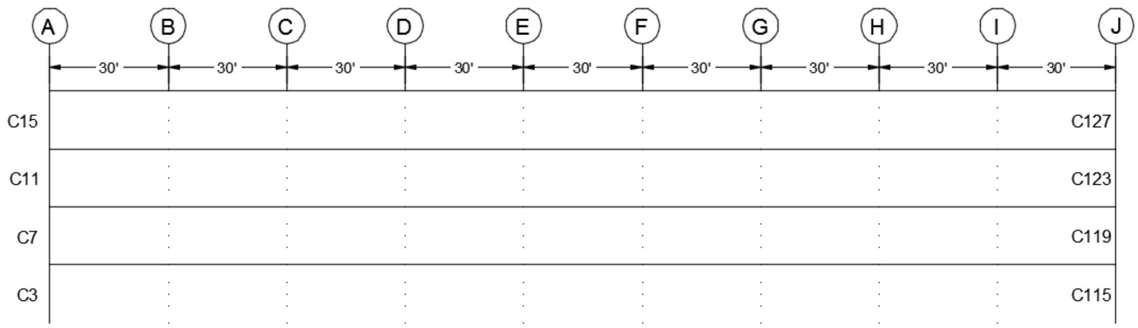
GRIDLINE 1



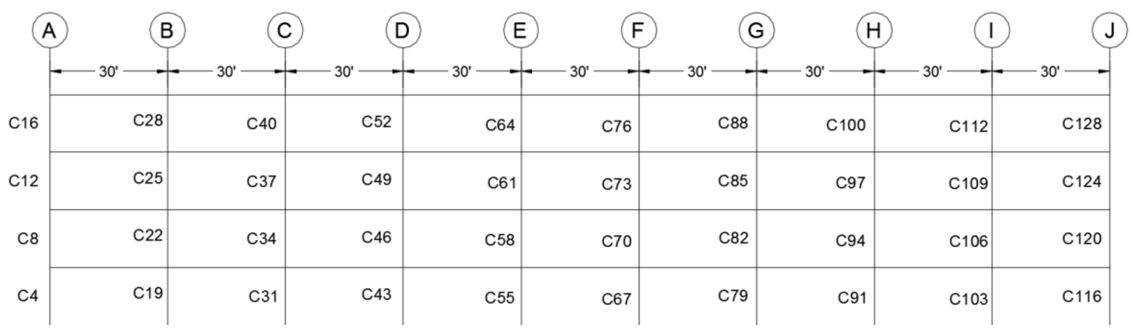
GRIDLINE 2



GRIDLINE 3



GRIDLINE 4

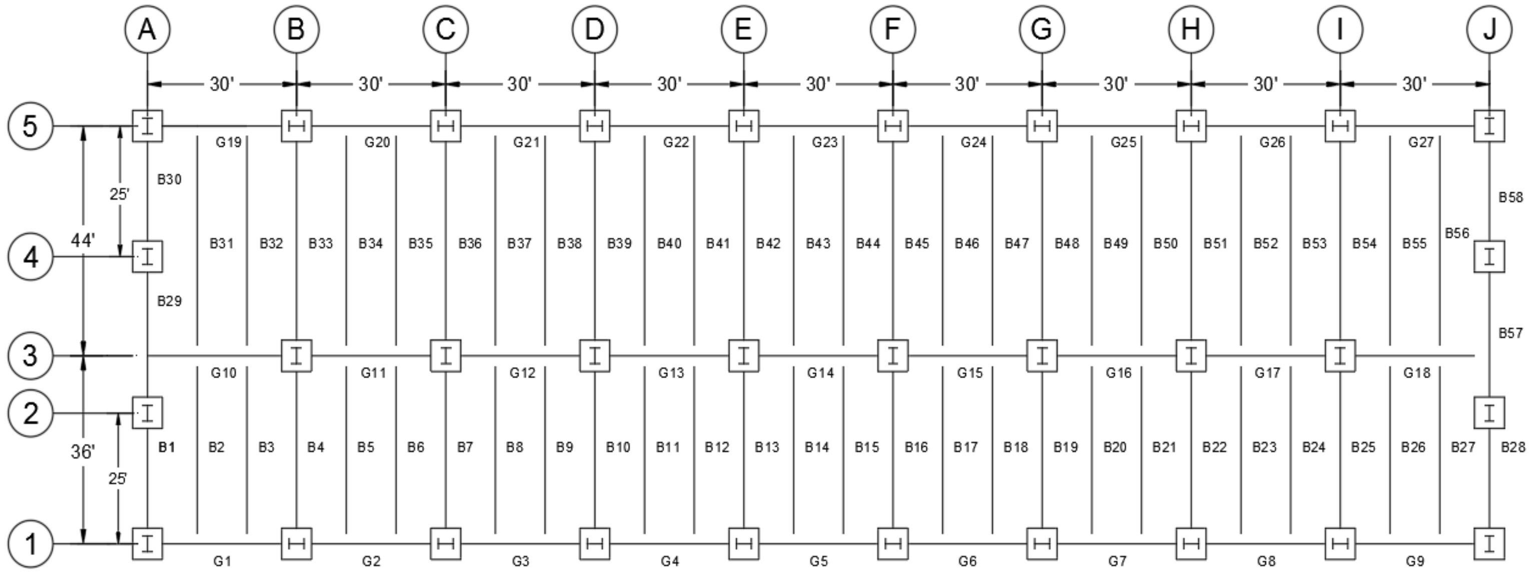


GRIDLINE 5

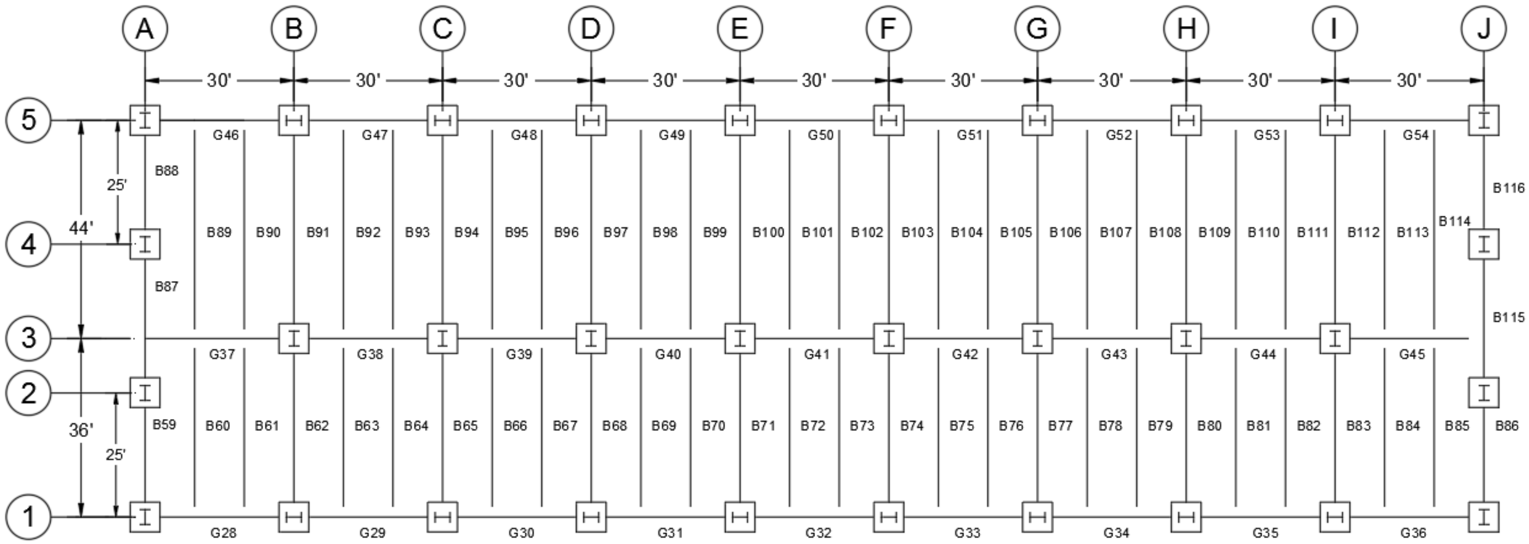
		Section name	A		B		C		D		E
FIRST	1	C1	W18x86	C17	W18x86	C29	W18x86	C41	W18x86	C53	W18x86
	2	C2	W18x97	0	0	0	0	0	0	0	0
	3	0	0	C18	W18x175	C30	W18x175	C42	W18x175	C54	W18x175
	4	C3	W18x97	0	0	0	0	0	0	0	0
	5	C4	W18x86	C19	W18x86	C31	W18x86	C43	W18x86	C55	W18x86
SECOND	1	C5	W18x86	C20	W18x86	C32	W18x86	C44	W18x86	C56	W18x86
	2	C6	W18x97	0	0	0	0	0	0	0	0
	3	0	0	C21	W18x130	C33	W18x130	C45	W18x130	C57	W18x130
	4	C7	W18x97	0	0	0	0	0	0	0	0
	5	C8	W18x86	C22	W18x86	C34	W18x86	C46	W18x86	C58	W18x86
THIRD	1	C9	W18x40	C23	W18x55	C35	W18x55	C47	W18x55	C59	W18x55
	2	C10	W18x60	0	0	0	0	0	0	0	0
	3	0	0	C24	W18x86	C36	W18x86	C48	W18x86	C60	W18x86
	4	C11	W18x60	0	0	0	0	0	0	0	0
	5	C12	W18x40	C25	W18x55	C37	W18x55	C49	W18x55	C61	W18x55
FOURTH	1	C13	W18x40	C26	W18x55	C38	W18x55	C50	W18x55	C62	W18x55
	2	C14	W18x60	0	0	0	0	0	0	0	0
	3	0	0	C27	W18x55	C39	W18x55	C51	W18x55	C63	W18x55
	4	C15	W18x60	0	0	0	0	0	0	C	0
	5	C16	W18x40	C28	W18x55	C40	W18x55	C52	W18x55	C64	W18x55

		Section name	F		G		H		I		J
FIRST	1	C65	W18x86	C77	W18x86	C89	W18x86	C101	W18x86	C113	W18x86
	2	0	0	0	0	0	0	0	0	C114	W18x97
	3	C66	W18x175	C78	W18x175	C90	W18x175	C102	W18x175	0	0
	4	0	0	0	0	0	0	0	0	C115	W18x97
	5	C67	W18x86	C79	W18x86	C91	W18x86	C103	W18x86	C116	W18x86
SECOND	1	C68	W18x86	C80	W18x86	C92	W18x86	C104	W18x86	C117	W18x86
	2	0	0	0	0	0	0	0	0	C118	W18x97
	3	C69	W18x130	C81	W18x130	C93	W18x130	C105	W18x130	0	0
	4	0	0	0	0	0	0	0	0	C119	W18x97
	5	C70	W18x86	C82	W18x86	C94	W18x86	C106	W18x86	C120	W18x86
THIRD	1	C71	W18x55	C83	W18x55	C95	W18x55	C107	W18x55	C121	W18x40
	2	0	0	0	0	0	0	0	0	C122	W18x60
	3	C72	W18x86	C84	W18x86	C96	W18x86	C108	W18x86	0	0
	4	0	0	0	0	0	0	0	0	C123	W18x60
	5	C73	W18x55	C85	W18x55	C97	W18x55	C109	W18x55	C124	W18x40
FOURTH	1	C74	W18x55	C86	W18x55	C98	W18x55	C110	W18x55	C125	W18x40
	2	0	0	0	0	0	0	0	0	C126	W18x60
	3	C75	W18x55	C87	W18x55	C99	W18x55	C111	W18x55	0	0
	4	0	0	0	0	0	0	0	0	C127	W18x60
	5	C76	W18x55	C88	W18x55	C100	W18x55	C112	W18x55	C128	W18x40

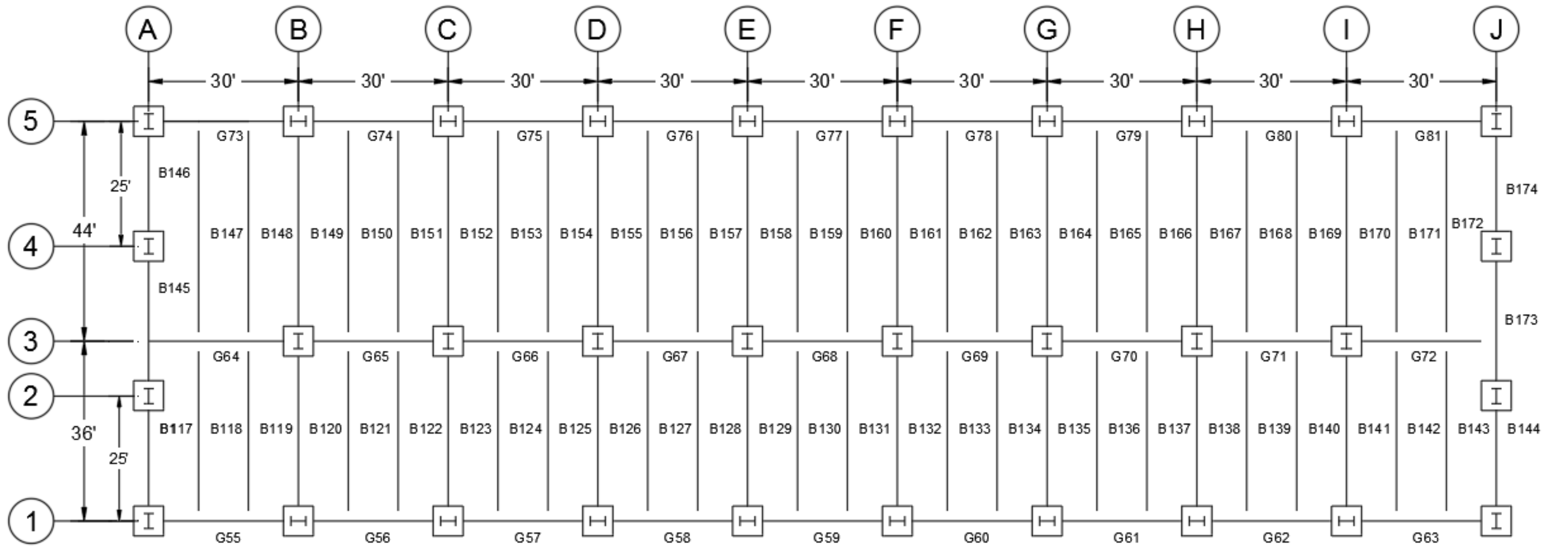
Floor plans of each story



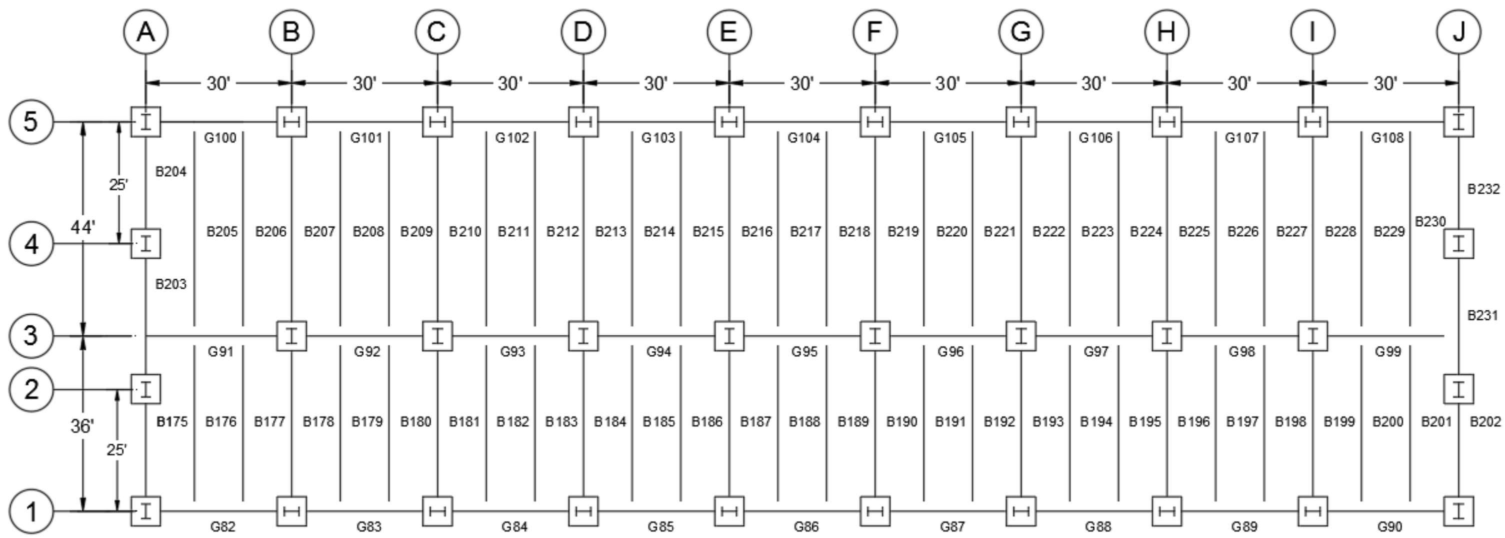
SECOND
FLOOR PLAN



THIRD FLOOR
PLAN



FOURTH
FLOOR PLAN



ROOF FLOOR
PLAN

SECOND FLOOR	B1	W24x94	B15	W16x31	B29	W24x76	B43	W21x44
	B2	W16x31	B16	W16x31	B30	W24x94	B44	W21x44
	B3	W16x31	B17	W16x31	B31	W21x44	B45	W21x44
	B4	W16x31	B18	W16x31	B32	W21x44	B46	W21x44
	B5	W16x31	B19	W16x31	B33	W21x44	B47	W21x44
	B6	W16x31	B20	W16x31	B34	W21x44	B48	W21x44
	B7	W16x31	B21	W16x31	B35	W21x44	B49	W21x44
	B8	W16x31	B22	W16x31	B36	W21x44	B50	W21x44
	B9	W16x31	B23	W16x31	B37	W21x44	B51	W21x44
	B10	W16x31	B24	W16x31	B38	W21x44	B52	W21x44
	B11	W16x31	B25	W16x31	B39	W21x44	B53	W21x44
	B12	W16x31	B26	W16x31	B40	W21x44	B54	W21x44
	B13	W16x31	B27	W16x31	B41	W21x44	B55	W21x44
	B14	W16x31	B28	W24x94	B42	W21x44	B56	W21x44
							B57	W24x76
							B58	W24x94

THIRD FLOOR	B59	W24x62	B73	W16x31	B87	W24x68	B101	W21x44
	B60	W16x31	B74	W16x31	B88	W24x62	B102	W21x44
	B61	W16x31	B75	W16x31	B89	W21x44	B103	W21x44
	B62	W16x31	B76	W16x31	B90	W21x44	B104	W21x44
	B63	W16x31	B77	W16x31	B91	W21x44	B105	W21x44
	B64	W16x31	B78	W16x31	B92	W21x44	B106	W21x44
	B65	W16x31	B79	W16x31	B93	W21x44	B107	W21x44
	B66	W16x31	B80	W16x31	B94	W21x44	B108	W21x44
	B67	W16x31	B81	W16x31	B95	W21x44	B109	W21x44
	B68	W16x31	B82	W16x31	B96	W21x44	B110	W21x44
	B69	W16x31	B83	W16x31	B97	W21x44	B111	W21x44
	B70	W16x31	B84	W16x31	B98	W21x44	B112	W21x44
	B71	W16x31	B85	W16x31	B99	W21x44	B113	W21x44
	B72	W16x31	B86	W24x62	B100	W21x44	B114	W21x44
							B115	W24x68
							B116	W24x62

FOURTH FLOOR	B117	W24x62	B131	W16x31	B145	W24x68	B159	W21x44
	B118	W16x31	B132	W16x31	B146	W24x62	B160	W21x44
	B119	W16x31	B133	W16x31	B147	W21x44	B161	W21x44
	B120	W16x31	B134	W16x31	B148	W21x44	B162	W21x44
	B121	W16x31	B135	W16x31	B149	W21x44	B163	W21x44
	B122	W16x31	B136	W16x31	B150	W21x44	B164	W21x44
	B123	W16x31	B137	W16x31	B151	W21x44	B165	W21x44
	B124	W16x31	B138	W16x31	B152	W21x44	B166	W21x44
	B125	W16x31	B139	W16x31	B153	W21x44	B167	W21x44
	B126	W16x31	B140	W16x31	B154	W21x44	B168	W21x44
	B127	W16x31	B141	W16x31	B155	W21x44	B169	W21x44
	B128	W16x31	B142	W16x31	B156	W21x44	B170	W21x44
	B129	W16x31	B143	W16x31	B157	W21x44	B171	W21x44
	B130	W16x31	B144	W24x62	B158	W21x44	B172	W21x44
							B173	W24x68
							B174	W24x62

ROOF FLOOR	B175	W24x55	B189	W16x31	B203	W24x55	B217	W21x44
	B176	W16x31	B190	W16x31	B204	W24x55	B218	W21x44
	B177	W16x31	B191	W16x31	B205	W21x44	B219	W21x44
	B178	W16x31	B192	W16x31	B206	W21x44	B220	W21x44
	B179	W16x31	B193	W16x31	B207	W21x44	B221	W21x44
	B180	W16x31	B194	W16x31	B208	W21x44	B222	W21x44
	B181	W16x31	B195	W16x31	B209	W21x44	B223	W21x44
	B182	W16x31	B196	W16x31	B210	W21x44	B224	W21x44
	B183	W16x31	B197	W16x31	B211	W21x44	B225	W21x44
	B184	W16x31	B198	W16x31	B212	W21x44	B226	W21x44
	B185	W16x31	B199	W16x31	B213	W21x44	B227	W21x44
	B186	W16x31	B200	W16x31	B214	W21x44	B228	W21x44
	B187	W16x31	B201	W16x31	B215	W21x44	B229	W21x44
	B188	W16x31	B202	W24x55	B216	W21x44	B230	W21x44
							B231	W24x55
							B232	W24x55

SECOND FLOOR	G1	W24x68	G10	W24x62	G19	W24x68
	G2	W24x68	G11	W24x62	G20	W24x68
	G3	W24x68	G12	W24x62	G21	W24x68
	G4	W24x68	G13	W24x62	G22	W24x68
	G5	W24x68	G14	W24x62	G23	W24x68
	G6	W24x68	G15	W24x62	G24	W24x68
	G7	W24x68	G16	W24x62	G25	W24x68
	G8	W24x68	G17	W24x62	G26	W24x68
	G9	W24x68	G18	W24x62	G27	W24x68

THIRD FLOOR	G28	W24x68	G37	W24x62	G46	W24x68
	G29	W24x68	G38	W24x62	G47	W24x68
	G30	W24x68	G39	W24x62	G48	W24x68
	G31	W24x68	G40	W24x62	G49	W24x68
	G32	W24x68	G41	W24x62	G50	W24x68
	G33	W24x68	G42	W24x62	G51	W24x68
	G34	W24x68	G43	W24x62	G52	W24x68
	G35	W24x68	G44	W24x62	G53	W24x68
	G36	W24x68	G45	W24x62	G54	W24x68

FOURTH FLOOR	G55	W24x68	G64	W24x62	G73	W24x68
	G56	W24x68	G65	W24x62	G74	W24x68
	G57	W24x68	G66	W24x62	G75	W24x68
	G58	W24x68	G67	W24x62	G76	W24x68
	G59	W24x68	G68	W24x62	G77	W24x68
	G60	W24x68	G69	W24x62	G78	W24x68
	G61	W24x68	G70	W24x62	G79	W24x68
	G62	W24x68	G71	W24x62	G80	W24x68
	G63	W24x68	G72	W24x62	G81	W24x68

ROOF FLOOR	G82	W24x55	G91	W24x62	G100	W24x55
	G83	W24x55	G92	W24x62	G101	W24x55
	G84	W24x55	G93	W24x62	G102	W24x55
	G85	W24x55	G94	W24x62	G103	W24x55
	G86	W24x55	G95	W24x62	G104	W24x55
	G87	W24x55	G96	W24x62	G105	W24x55
	G88	W24x55	G97	W24x62	G106	W24x55
	G89	W24x55	G98	W24x62	G107	W24x55
	G90	W24x55	G99	W24x62	G108	W24x55

APPENDIX C

SLAB CALCULATION

To ignore the composite interaction and slab modelling, an area for slab has been defined. Mass and loads are calculated and applied manually to the slabs. SAP 2000 requires mass input as mass per unit area. Below is the mass used for per slab area.

For 4 inch metal deck, it is assumed to be structural steel.

$$m = \frac{w}{g}$$

$$g = 32.2\, ft/\sec^2$$

$$d = \frac{w}{V}$$

$$d_{steel} = 488.2 lb/\ ft^3$$

$$\frac{mass}{unitarea} = \frac{488.2*0.25}{32.2*1000} \cong 0.004 \frac{kips*s^2}{ft^3}$$

For 4.5 inch reinforced concrete deck below is the mass per area.

$$m = \frac{w}{g}$$

$$g = 32.2\, ft/\sec^2$$

$$d = \frac{w}{V}$$

$$d_{RC} = 150 lb/\ ft^3$$

$$\frac{mass}{unitarea} = \frac{150*0.375}{32.2*1000} \cong 0.0017 \frac{kips*s^2}{ft^3}$$

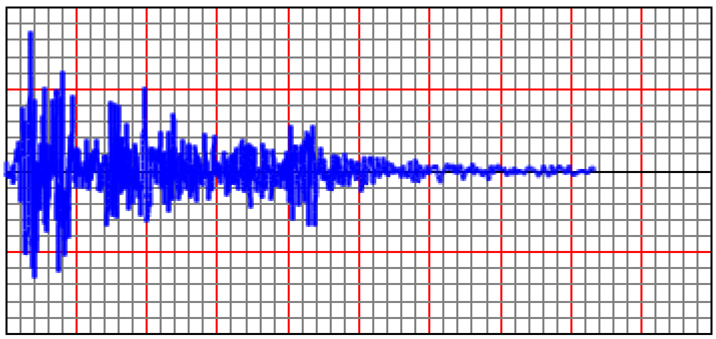
Total mass per area is;

$$\sum \frac{mass}{area} = 0.0057 \frac{kips * s^2}{ft^3}$$

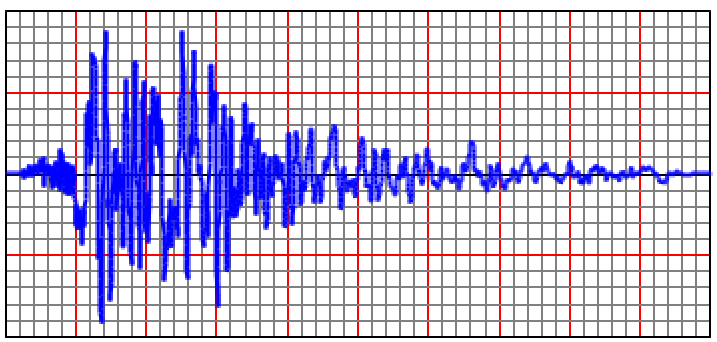
APPENDIX D

EARTHQUAKE PLOTS

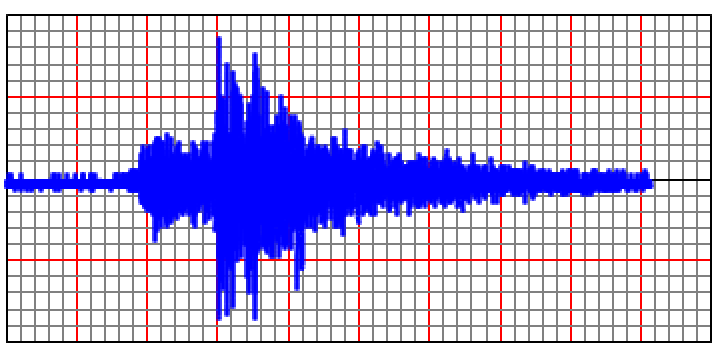
El Centro



Northridge



Izmit

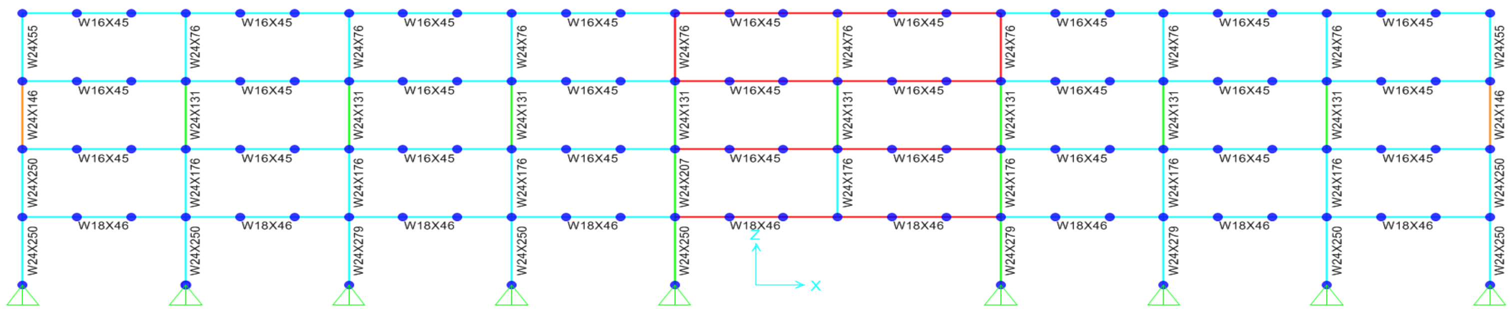


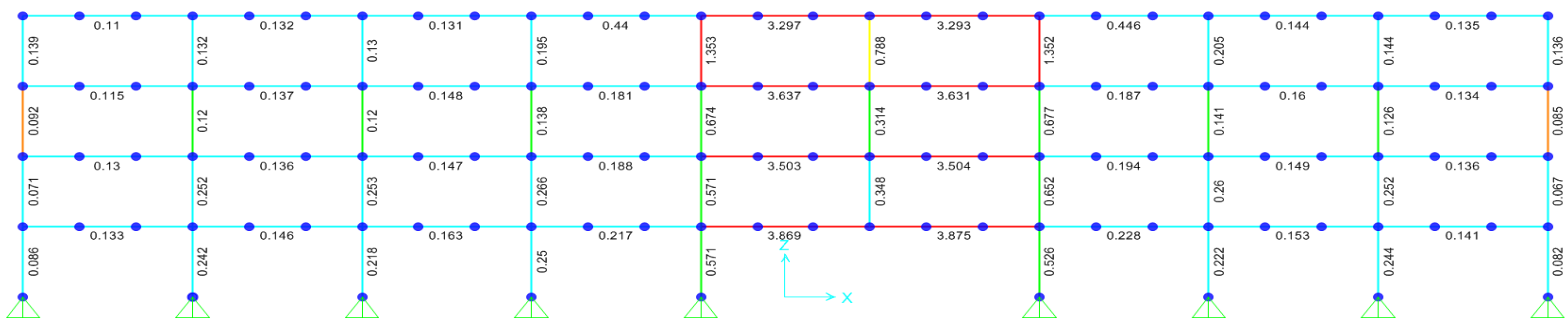
APPENDIX E

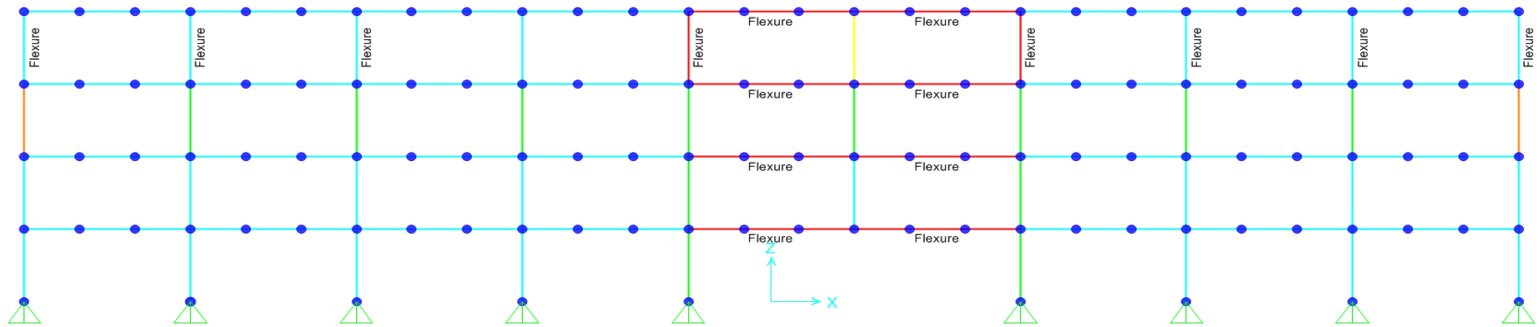
SCREENSHOTS OF THE MODEL AFTER THE COLUMN REMOVAL

REMOVAL 1

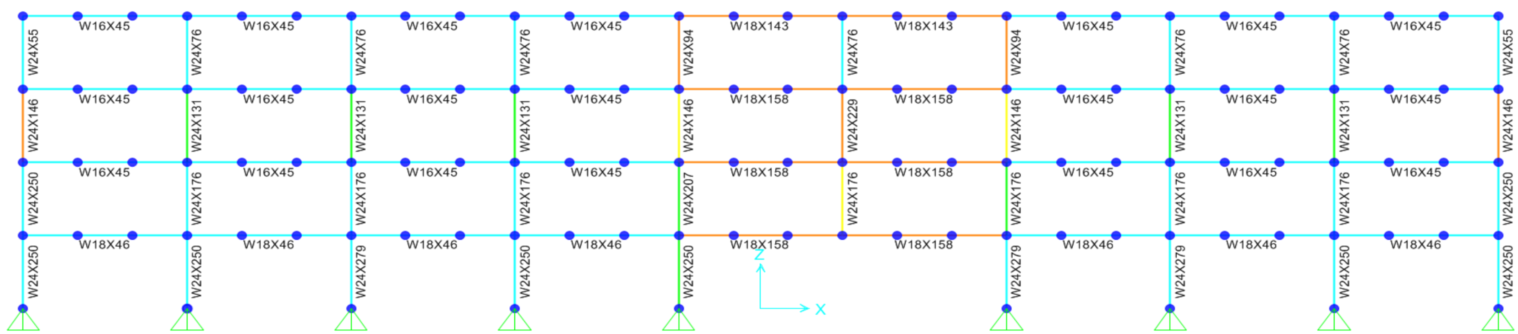
STEP 1






Flexure
Z
X

STEP 2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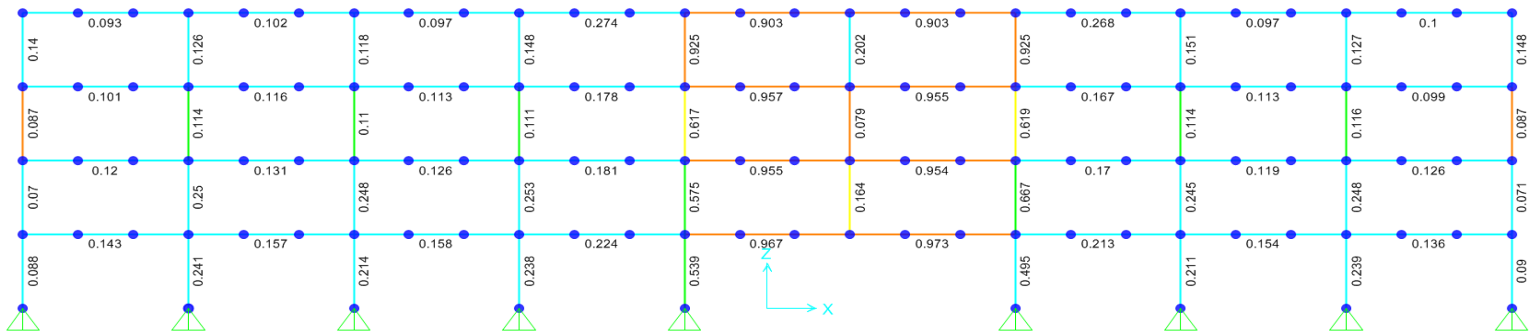
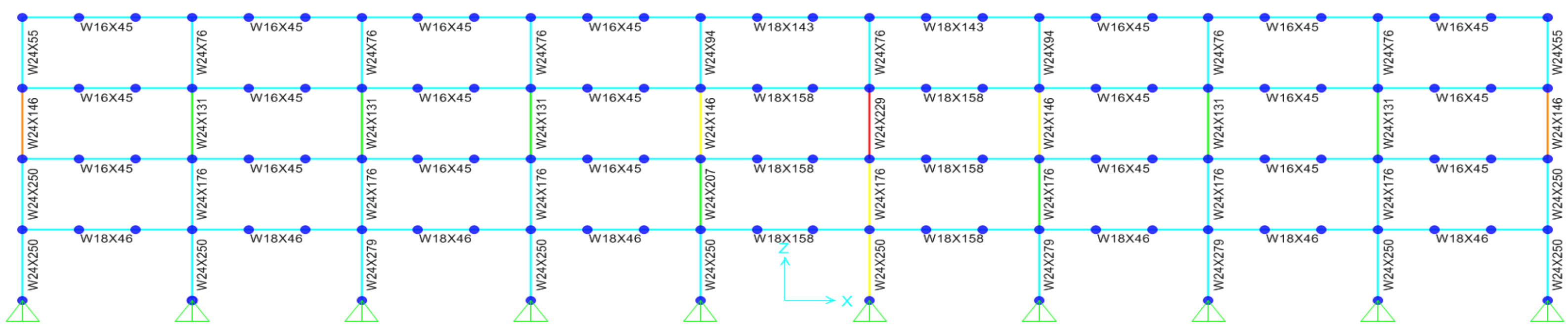
W18X143
W18X158
W18X46
W24X55
W24X76
W24X94
W24X131
W24X146
W24X176
W24X207
W24X229
W24X250
W24X279
Z
X


0.093
0.102
0.097
0.274
0.903
0.903
0.268
0.097
0.1
0.14
0.126
0.118
0.148
0.925
0.202
0.925
0.151
0.127
0.148
0.101
0.116
0.113
0.178
0.957
0.955
0.167
0.113
0.099
0.087
0.114
0.11
0.111
0.617
0.079
0.619
0.114
0.116
0.087
0.12
0.131
0.126
0.181
0.955
0.954
0.17
0.119
0.126
0.07
0.25
0.248
0.253
0.575
0.164
0.667
0.245
0.248
0.071
0.143
0.157
0.158
0.224
0.967
0.973
0.213
0.154
0.136
0.088
0.241
0.214
0.238
0.539
0.495
0.211
0.239
0.09
Z
X

STEP 3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W16X45
W16X45
W16X45
W24X55
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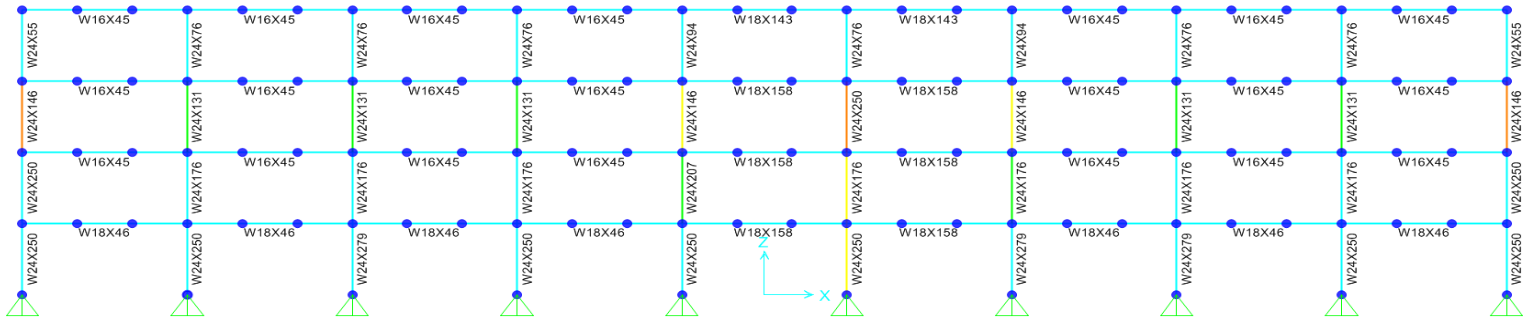
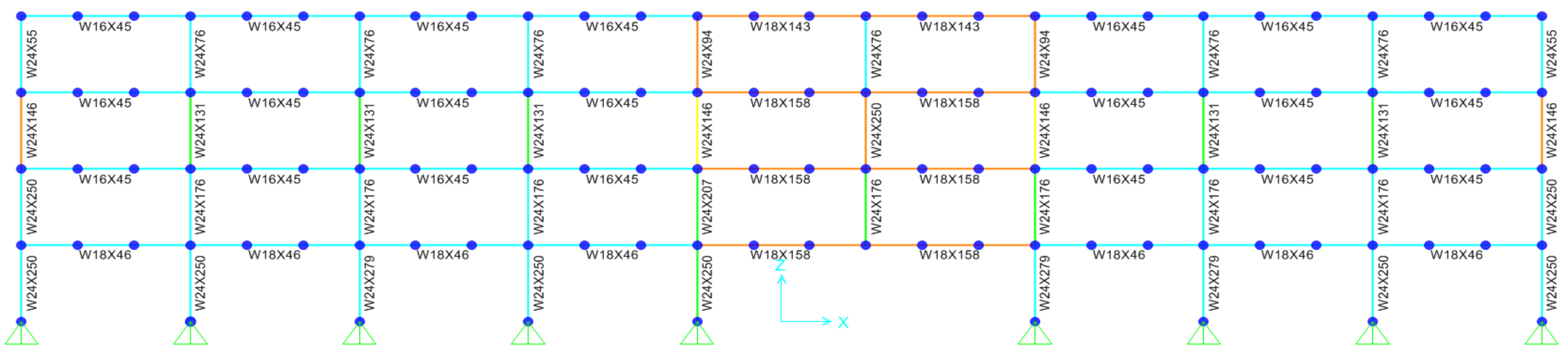
W24X76
W24X76
W24X94
W24X76
W24X94
W24X76
W24X76
W24X55
W16X45
W16X45
W16X45
W16X45
W18X158
W18X158
W16X45
W16X45
W16X45
W24X146
W24X131
W24X131
W24X131
W24X146
W24X229
W24X146
W24X131
W24X131
W24X146
W16X45
W16X45
W16X45
W16X45
W18X158
W18X158
W16X45
W16X45
W16X45
W24X250
W24X176
W24X176
W24X176
W24X207
W24X176
W24X176
W24X176
W24X176
W24X250
W18X46
W18X46
W18X46
W18X46
W18X158
W18X158
W18X46
W18X46
W18X46
W24X250
W24X250
W24X279
W24X250
W24X250
W24X250
W24X279
W24X279
W24X250
W24X250
Z
X

STEP 4

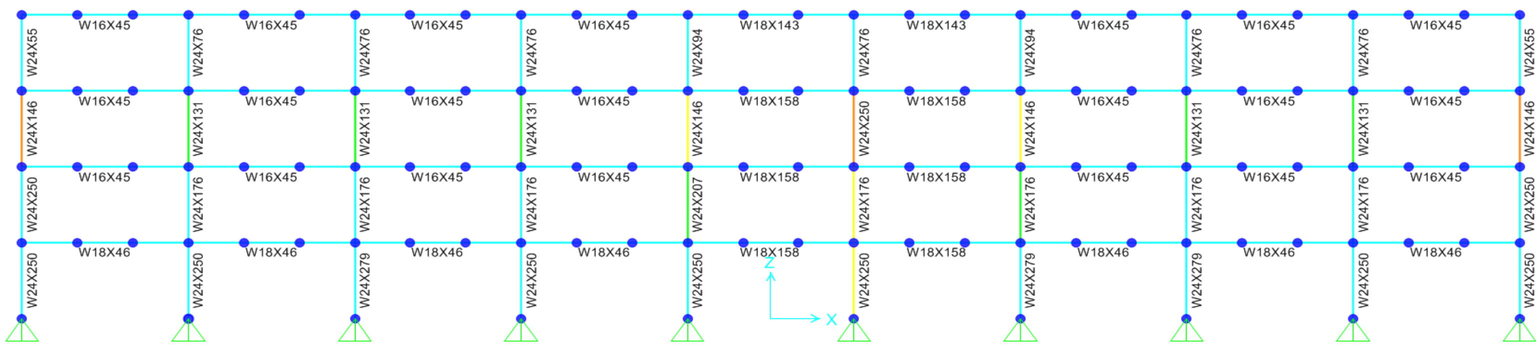


STEP 5

STEP 6



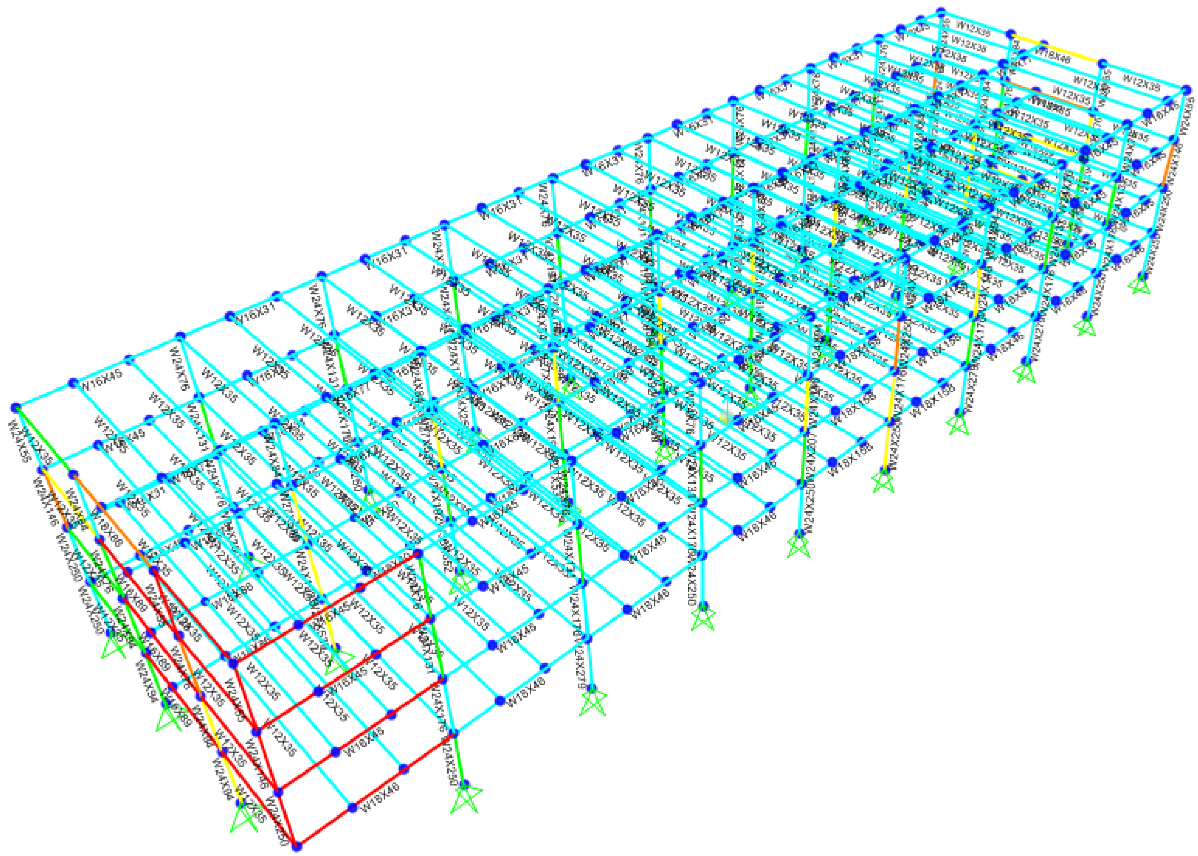
STEP 7

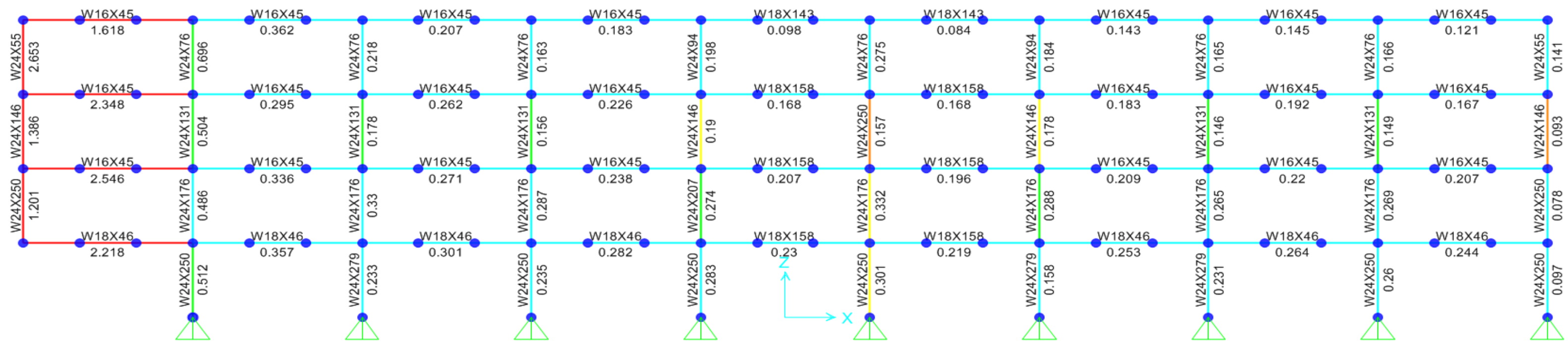


REMOVAL 2

THE FINAL MODEL GIVEN ABOVE IS USED

STEP 1

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W16X45 0.362
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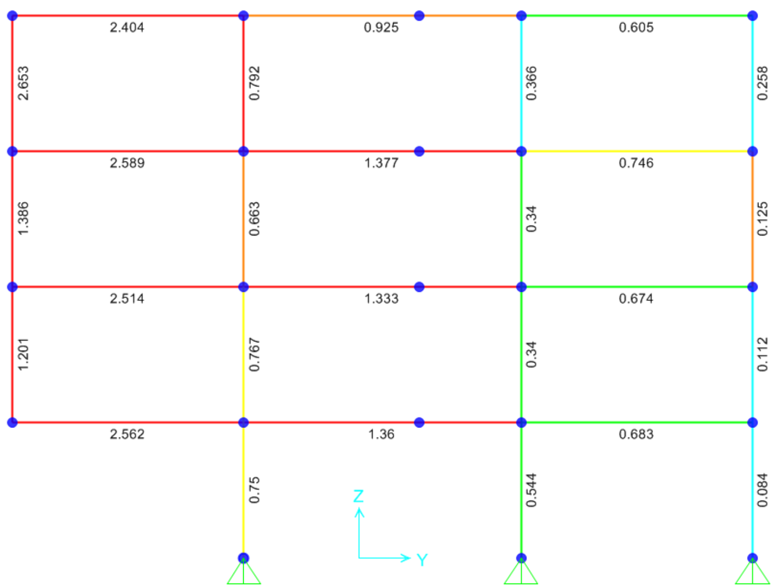
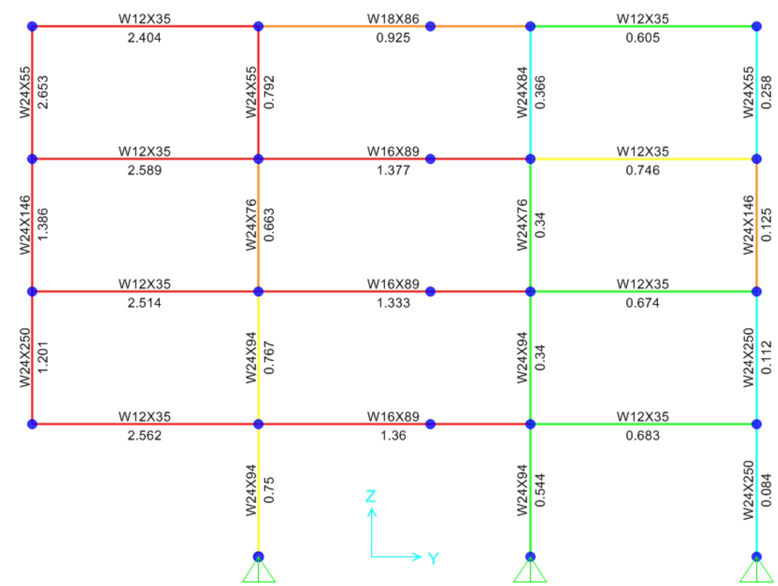
W16X45 0.183
W18X143 0.098
W18X143 0.084
W16X45 0.143
W16X45 0.145
W16X45 0.121
W24X55 2.653
W24X76 0.696
W24X76 0.218
W24X76 0.163
W24X94 0.198
W24X76 0.275
W24X94 0.184
W24X76 0.165
W24X76 0.166
W24X55 0.141
W16X45 2.348
W16X45 0.295
W16X45 0.262
W16X45 0.226
W18X158 0.168
W18X158 0.168
W16X45 0.183
W16X45 0.192
W16X45 0.167
W24X146 1.386
W24X131 0.504
W24X131 0.178
W24X131 0.156
W24X146 0.19
W24X250 0.157
W24X146 0.178
W24X131 0.146
W24X131 0.149
W24X146 0.093
W16X45 2.546
W16X45 0.336
W16X45 0.271
W16X45 0.238
W18X158 0.207
W18X158 0.196
W16X45 0.209
W16X45 0.22
W16X45 0.207
W24X250 1.201
W24X176 0.486
W24X176 0.33
W24X176 0.287
W24X207 0.274
W24X176 0.332
W24X176 0.288
W24X176 0.265
W24X176 0.269
W24X250 0.078
W18X46 2.218
W18X46 0.357
W18X46 0.301
W18X46 0.282
W18X158 0.23
W18X158 0.219
W18X46 0.253
W18X46 0.264
W18X46 0.244
W24X250 0.512
W24X279 0.233
W24X250 0.235
W24X250 0.283
W24X250 0.301
W24X279 0.158
W24X279 0.231
W24X250 0.26
W24X250 0.097
Z
X


2.404
0.925
0.605
2.653
0.792
0.366
0.258
2.589
1.377
0.746
1.386
0.663
0.34
0.125
2.514
1.333
0.674
1.201
0.767
0.34
0.112
2.562
1.36
0.683
0.75
0.544
0.084
Z
Y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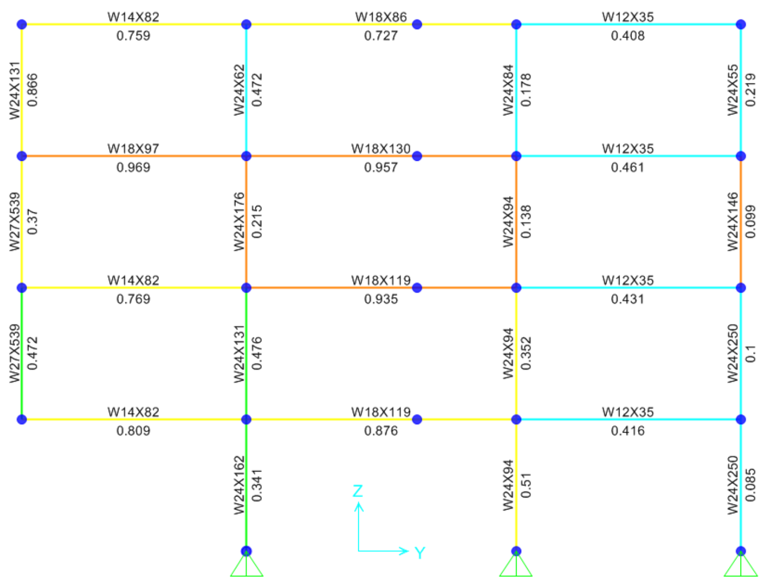
W18X86 0.925
W12X35 0.605
W24X55 2.653
W24X55 0.792
W24X84 0.366
W24X55 0.258
W12X35 2.589
W16X89 1.377
W12X35 0.746
W24X146 1.386
W24X76 0.663
W24X76 0.34
W24X146 0.125
W12X35 2.514
W16X89 1.333
W12X35 0.674
W24X250 1.201
W24X94 0.767
W24X94 0.34
W24X250 0.112
W12X35 2.562
W16X89 1.36
W12X35 0.683
W24X94 0.75
W24X94 0.544
W24X250 0.084
Z
Y

STEP 2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W12X35
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W24X131
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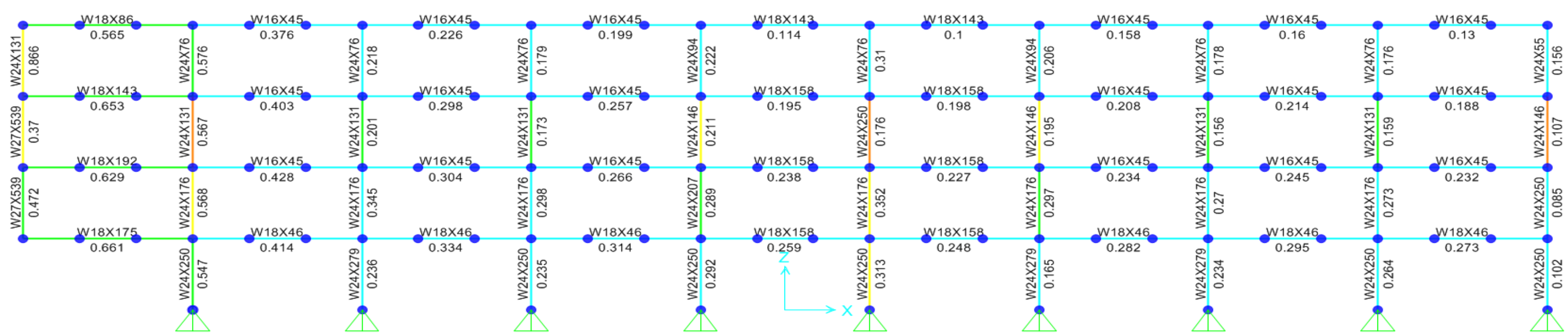
W24X62
0.472
W24X84
0.178
W24X55
0.219
W18X97
0.969
W18X130
0.957
W12X35
0.461
W27X539
0.37
W24X176
0.215
W24X94
0.138
W24X146
0.099
W14X82
0.769
W18X119
0.935
W12X35
0.431
W27X539
0.472
W24X131
0.476
W24X94
0.352
W24X250
0.1
W14X82
0.809
W18X119
0.876
W12X35
0.416
W24X162
0.341
W24X94
0.51
W24X250
0.085
Z
Y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W16X45
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W16X45
0.226
W16X45
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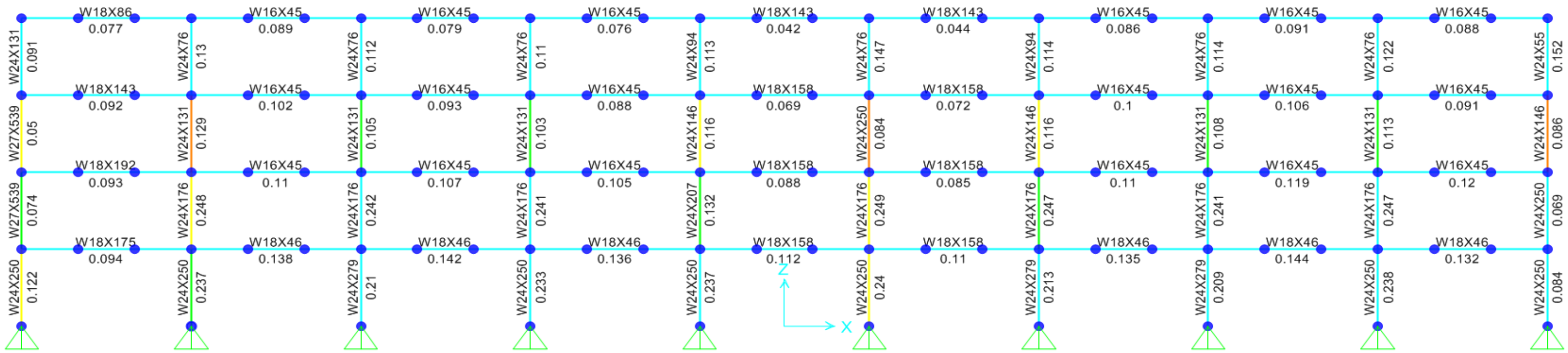
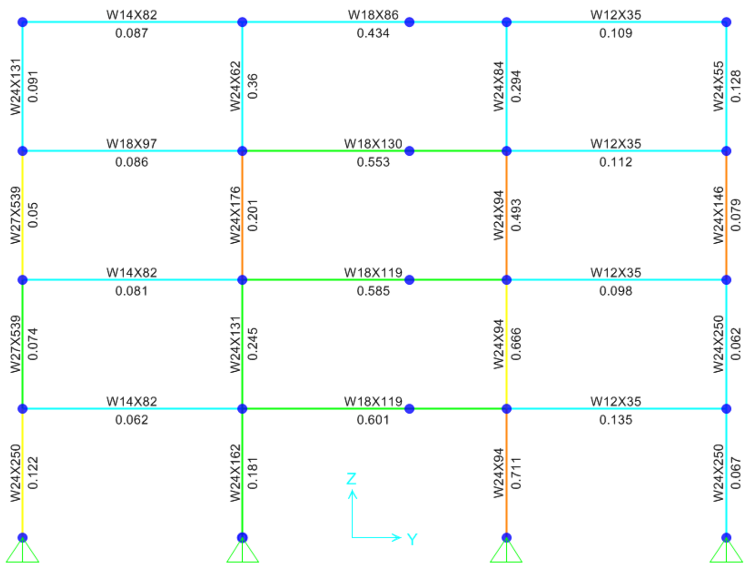
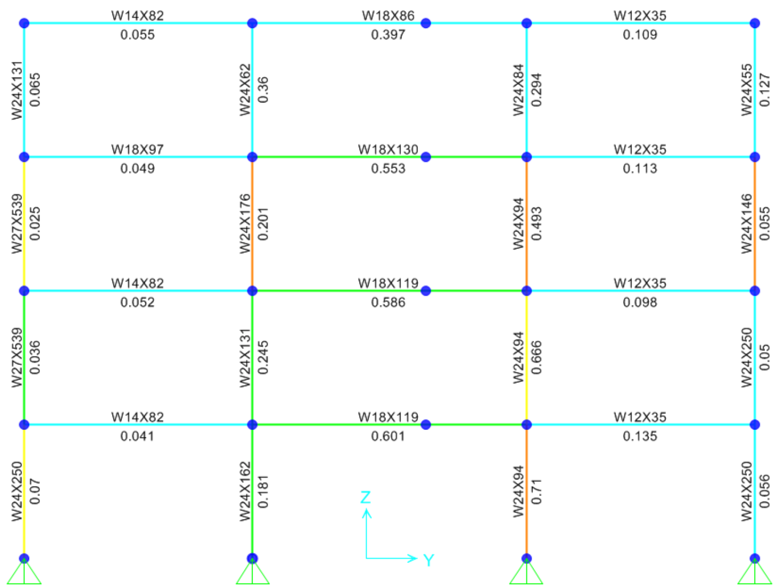
W18X143
0.114
W18X143
0.1
W16X45
0.158
W16X45
0.16
W16X45
0.13
W24X131
0.866
W24X76
0.576
W24X76
0.218
W24X76
0.179
W24X94
0.222
W24X76
0.31
W24X94
0.206
W24X76
0.178
W24X76
0.176
W24X55
0.156
W18X143
0.653
W16X45
0.403
W16X45
0.298
W16X45
0.257
W18X158
0.195
W18X158
0.198
W16X45
0.208
W16X45
0.214
W16X45
0.188
W27X539
0.37
W24X131
0.567
W24X131
0.201
W24X131
0.173
W24X146
0.211
W24X250
0.176
W24X146
0.195
W24X131
0.156
W24X131
0.159
W24X146
0.107
W18X192
0.629
W16X45
0.428
W16X45
0.304
W16X45
0.266
W18X158
0.238
W18X158
0.227
W16X45
0.234
W16X45
0.245
W16X45
0.232
W27X539
0.472
W24X176
0.568
W24X176
0.345
W24X176
0.298
W24X207
0.289
W24X176
0.352
W24X176
0.297
W24X176
0.27
W24X176
0.273
W24X250
0.085
W18X175
0.661
W18X46
0.414
W18X46
0.334
W18X46
0.314
W18X158
0.259
W18X158
0.248
W18X46
0.282
W18X46
0.295
W18X46
0.273
W24X250
0.547
W24X279
0.236
W24X250
0.235
W24X250
0.292
W24X250
0.313
W24X279
0.165
W24X279
0.234
W24X250
0.264
W24X250
0.102
Z
X

STEP 3





STEP 5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W18X86
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W12X35
0.109
W24X131
0.065
W24X62
0.36
W24X84
0.294
W24X55
0.127
W18X97
0.049
W18X130
0.553
W12X35
0.113
W27X539
0.025
W24X176
0.201
W24X94
0.493
W24X146
0.055
W14X82
0.052
W18X119
0.586
W12X35
0.098
W27X539
0.036
W24X131
0.245
W24X94
0.666
W24X250
0.05
W14X82
0.041
W18X119
0.601
W12X35
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0.07
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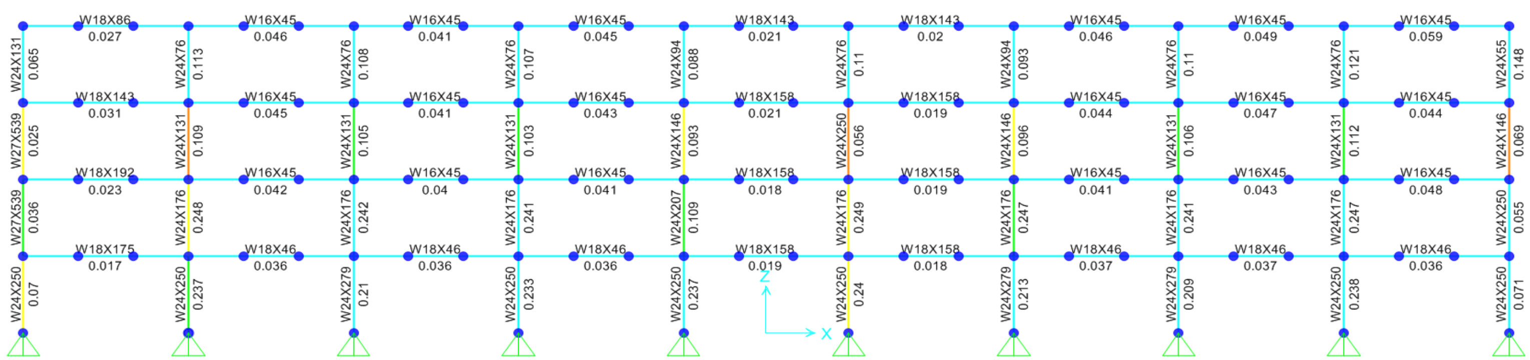
W24X94
0.71
W24X250
0.056
Z
Y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W16X45
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W16X45
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W18X143
0.021
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0.02
W16X45
0.046
W16X45
0.049
W16X45
0.059
W24X131
0.065
W24X76
0.113
W24X76
0.108
W24X76
0.107
W24X94
0.088
W24X76
0.11
W24X94
0.093
W24X76
0.11
W24X76
0.121
W24X55
0.148
W18X143
0.031
W16X45
0.045
W16X45
0.041
W16X45
0.043
W18X158
0.021
W18X158
0.019
W16X45
0.044
W16X45
0.047
W16X45
0.044
W27X539
0.025
W24X131
0.109
W24X131
0.105
W24X131
0.103
W24X146
0.093
W24X250
0.056
W24X146
0.096
W24X131
0.106
W24X131
0.112
W24X146
0.069
W18X192
0.023
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0.04
W16X45
0.041
W18X158
0.018
W18X158
0.019
W16X45
0.041
W16X45
0.043
W16X45
0.048
W27X539
0.036
W24X176
0.248
W24X176
0.242
W24X176
0.241
W24X207
0.109
W24X176
0.249
W24X176
0.247
W24X176
0.241
W24X176
0.247
W24X250
0.055
W18X175
0.017
W18X46
0.036
W18X46
0.036
W18X46
0.036
W18X158
0.019
W18X158
0.018
W18X46
0.037
W18X46
0.037
W18X46
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W24X250
0.07
W24X250
0.237
W24X279
0.21
W24X250
0.233
W24X250
0.237
W24X250
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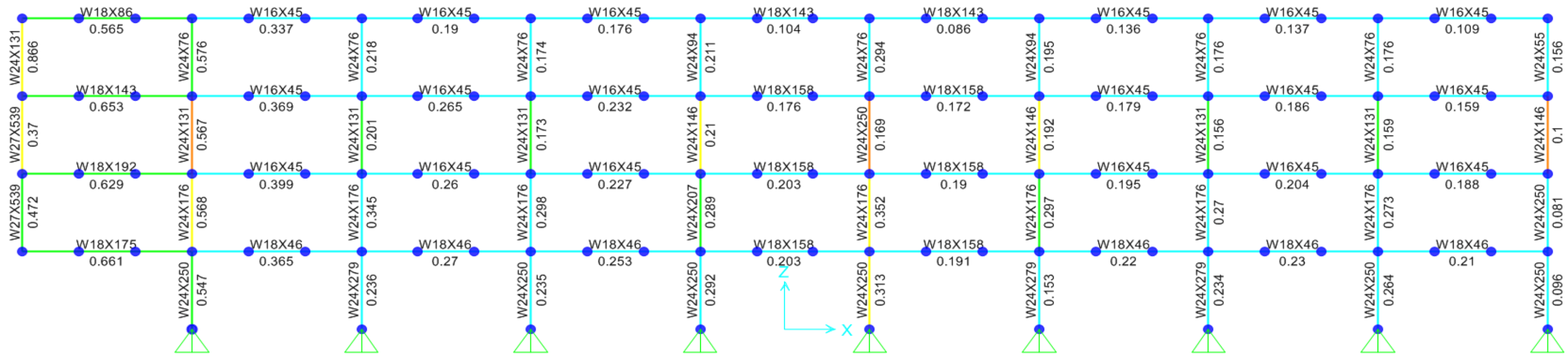
0.238
W24X250
0.071
Z
X

STEP 6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W16X45
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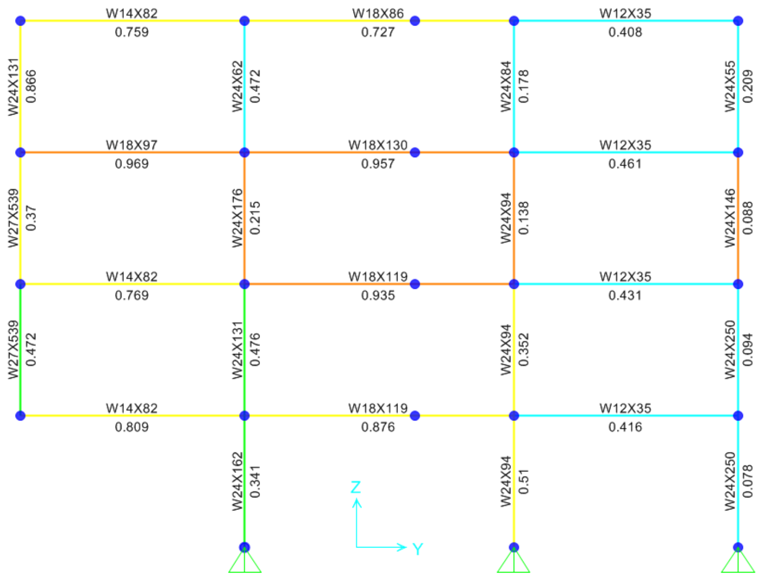
W16X45
0.19
W16X45
0.176
W18X143
0.104
W18X143
0.086
W16X45
0.136
W16X45
0.137
W16X45
0.109
W18X143
0.653
W18X192
0.629
W18X175
0.661
W24X131
0.866
W27X539
0.37
W27X539
0.472
Z
X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0.759
W18X86
0.727
W12X35
0.408
W18X97
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W18X130
0.957
W12X35
0.461
W14X82
0.769
W18X119
0.935
W12X35
0.431
W14X82
0.809
W18X119
0.876
W12X35
0.416
W24X131
0.866
W24X62
0.472
W24X84
0.178
W24X55
0.209
W27X539
0.37
W24X176
0.215
W24X94
0.138
W24X146
0.088
W27X539
0.472
W24X131
0.476
W24X94
0.352
W24X250
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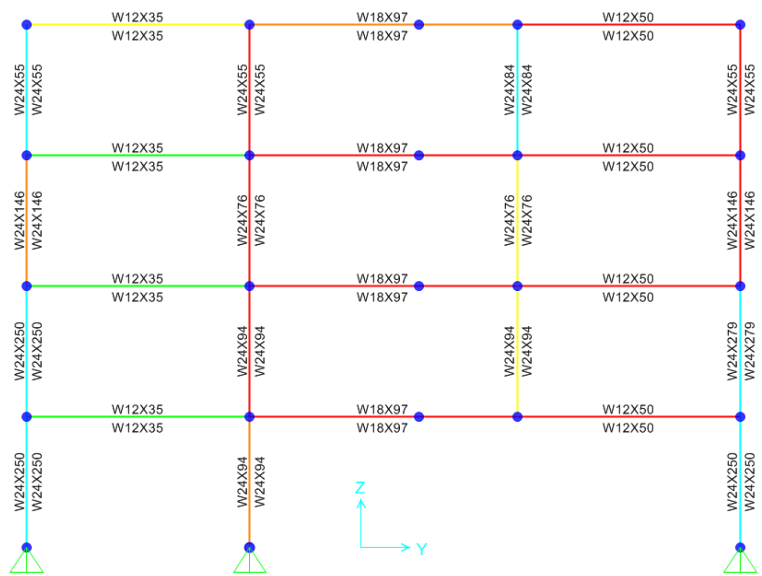
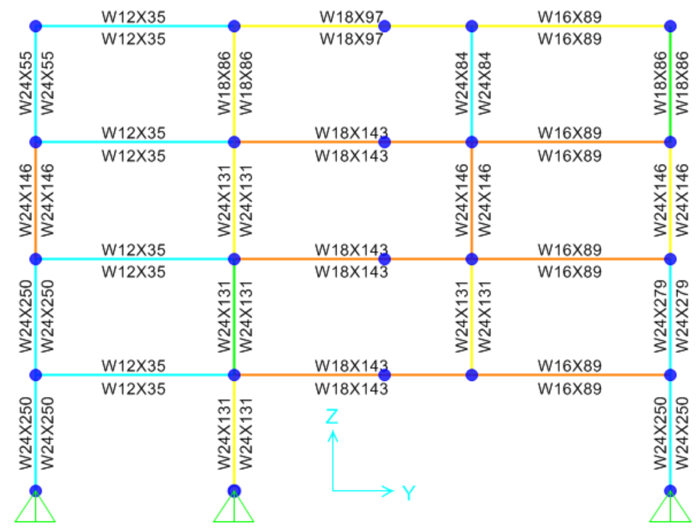
0.341
W24X94
0.51
W24X250
0.078
Z
Y

REMOVAL 3

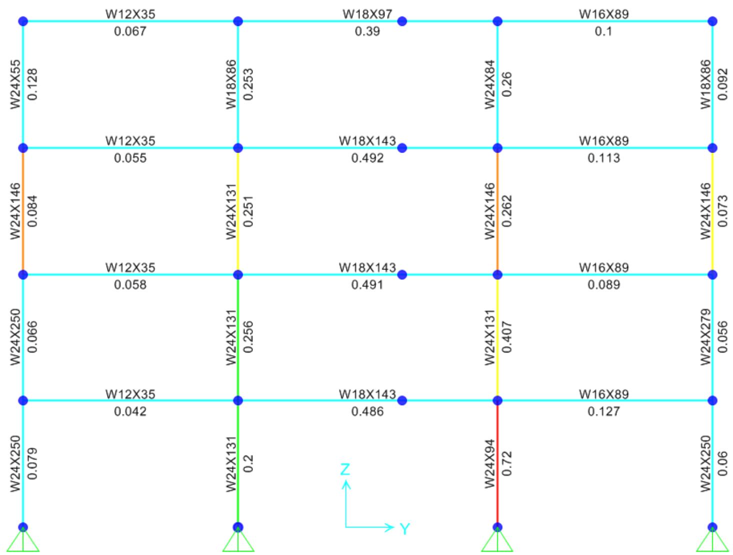
STEP 1



STEP 2



STEP 3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0.26
W18X86
0.092
W12X35
0.055
W18X143
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W16X89
0.113
W24X146
0.084
W24X131
0.251
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W24X146
0.073
W12X35
0.058
W18X143
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W16X89
0.089
W24X250
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W24X131
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W24X131
0.407
W24X279
0.056
W12X35
0.042
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Z
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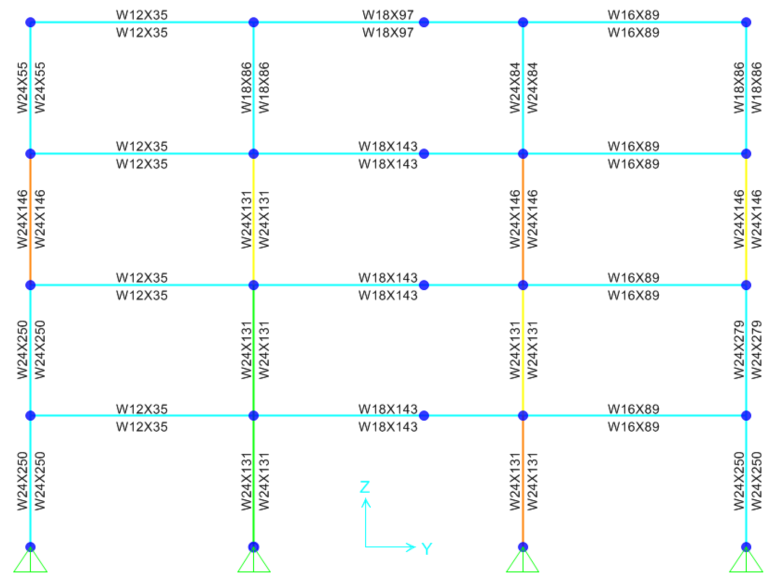
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W18X143
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W16X89
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W24X131
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W24X279
W24X279
W12X35
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W16X89
W16X89
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W24X131
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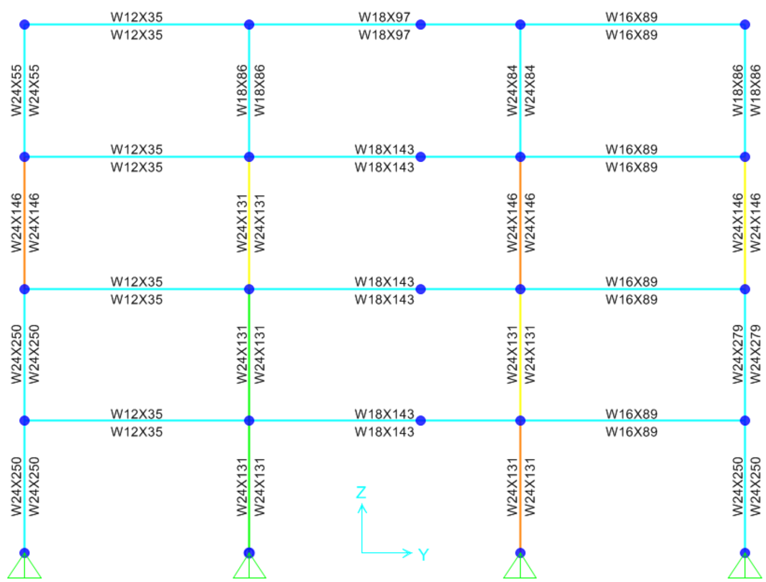
Z
Y

STEP 5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W24X250
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W24X131
W24X131
W24X279
W24X279
W12X35
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W18X143
W18X143
W16X89
W16X89
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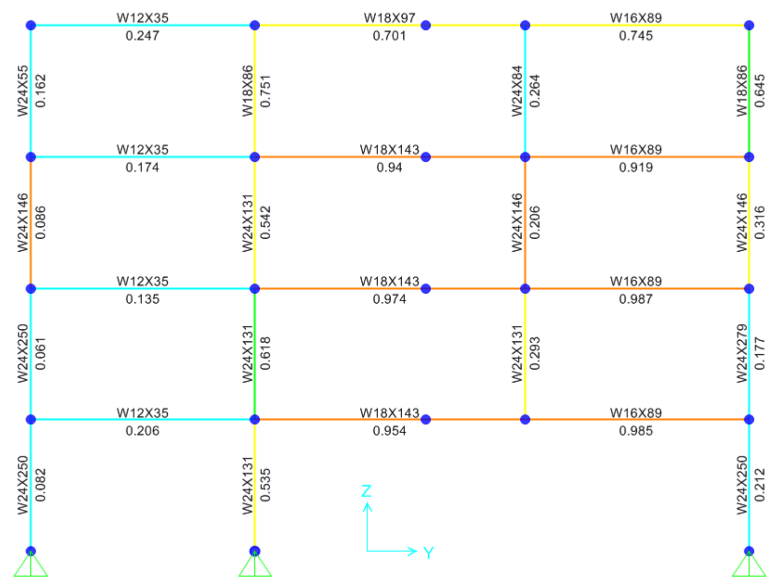
W24X250
W24X131
W24X131
W24X131
W24X131
W24X250
W24X250
Z
Y

STEP 6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W18X86
0.645
W12X35
0.174
W18X143
0.94
W16X89
0.919
W24X146
0.086
W24X131
0.542
W24X146
0.206
W24X146
0.316
W12X35
0.135
W18X143
0.974
W16X89
0.987
W24X250
0.061
W24X131
0.618
W24X131
0.293
W24X279
0.177
W12X35
0.206
W18X143
0.954
W16X89
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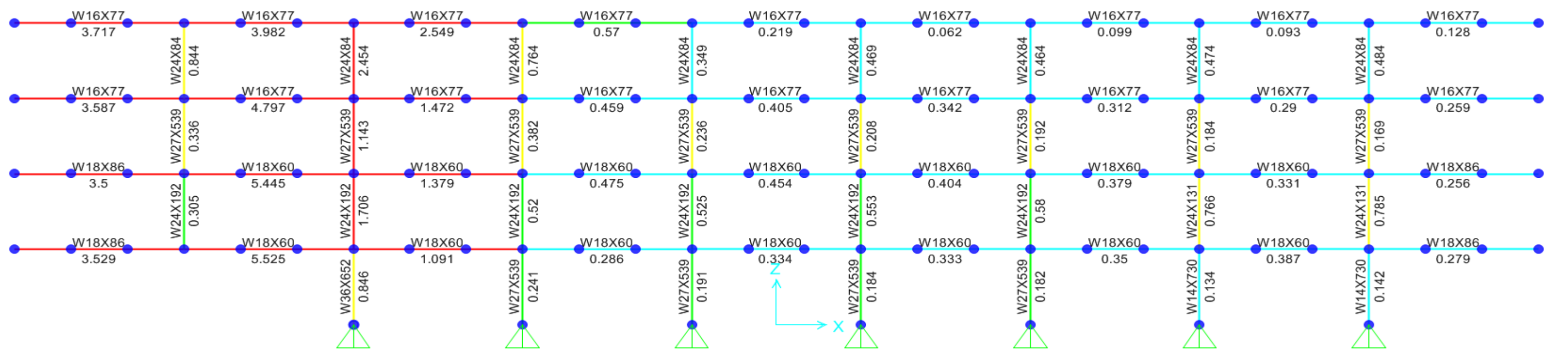
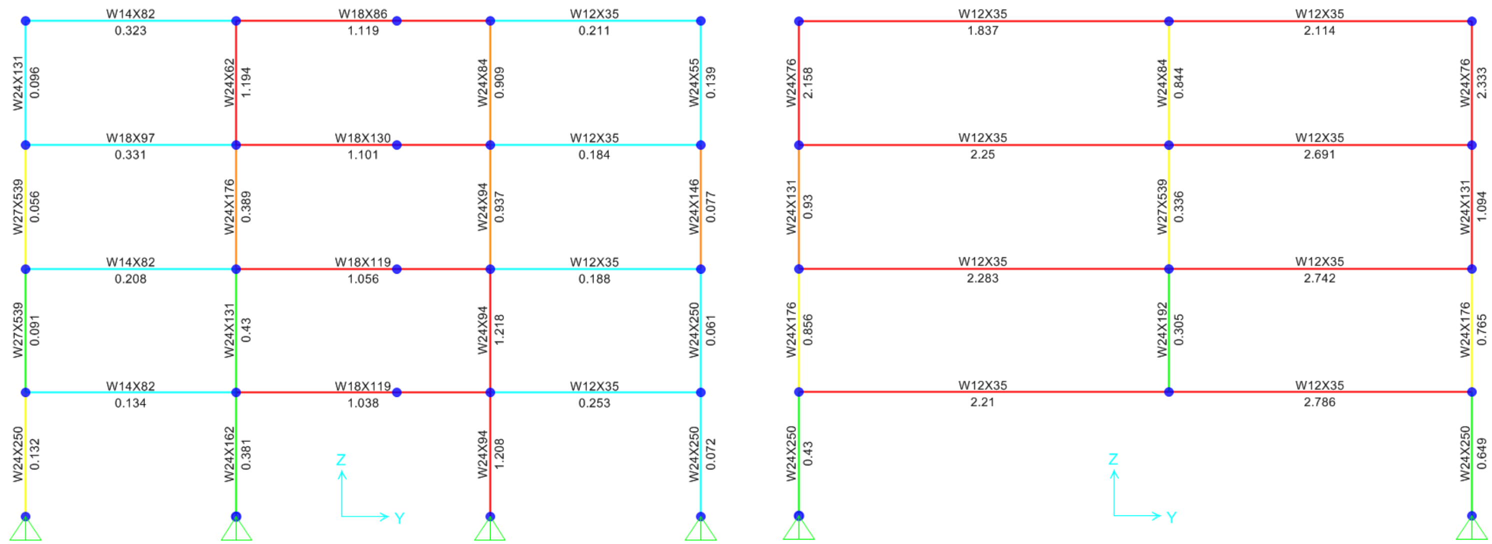
Z
Y

REMOVAL 4

STEP 1





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W24X62
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W24X84
0.909
W24X55
0.139
W18X97
0.331
W18X130
1.101
W12X35
0.184
W27X539
0.056
W24X176
0.389
W24X94
0.937
W24X146
0.077
W14X82
0.208
W18X119
1.056
W12X35
0.188
W27X539
0.091
W24X131
0.43
W24X94
1.218
W24X250
0.061
W14X82
0.134
W18X119
1.038
W12X35
0.253
W24X250
0.132
W24X162
0.381
W24X94
1.208
W24X250
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Z
Y
W12X35
1.837
W12X35
2.114
W24X76
2.158
W24X84
0.844
W24X76
2.333
W12X35
2.25
W12X35
2.691
W24X131
0.93
W27X539
0.336
W24X131
1.094
W12X35
2.283
W12X35
2.742
W24X176
0.856
W24X192
0.305
W24X176
0.765
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2.21
W12X35
2.786
W24X250
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W24X250
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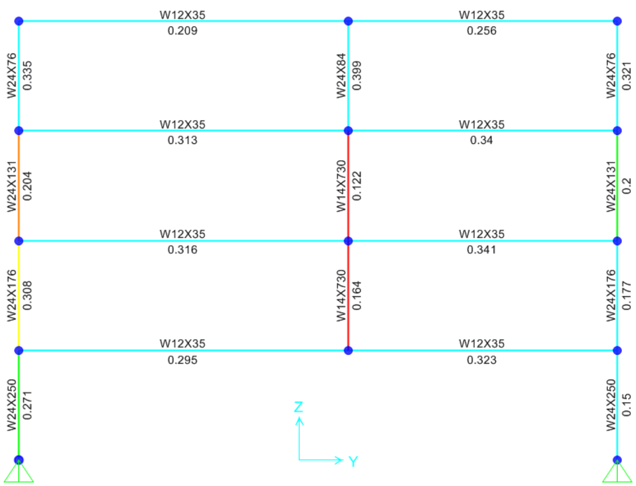
Z
Y

STEP 2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0.313
W12X35
0.34
W24X131
0.204
W14X730
0.122
W24X131
0.2
W12X35
0.316
W12X35
0.341
W24X176
0.308
W14X730
0.164
W24X176
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W12X35
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W12X35
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W24X250
0.15
Z
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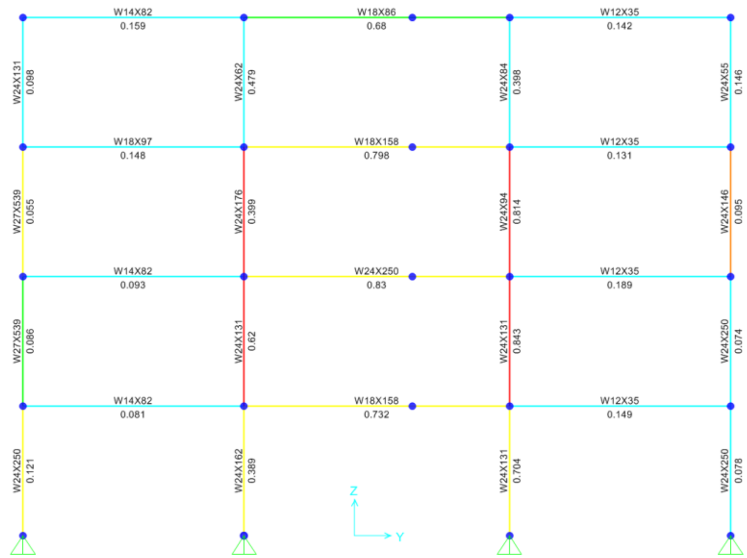
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W24X62
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W24X55
0.146
W18X97
0.148
W18X158
0.798
W12X35
0.131
W27X539
0.055
W24X176
0.399
W24X94
0.814
W24X146
0.095
W14X82
0.093
W24X250
0.83
W12X35
0.189
W27X539
0.086
W24X131
0.62
W24X131
0.843
W24X250
0.074
W14X82
0.081
W18X158
0.732
W12X35
0.149
W24X250
0.121
W24X162
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0.704
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0.078
Z
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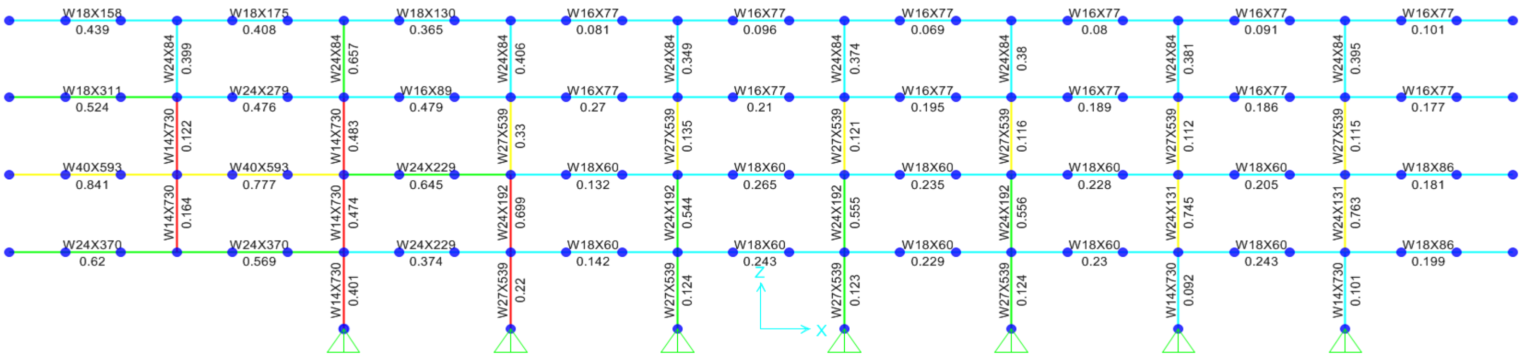
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0.069
W16X77
0.08
W16X77
0.091
W16X77
0.101
W24X84
0.399
W24X84
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W24X84
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W24X84
0.349
W24X84
0.374
W24X84
0.38
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0.381
W24X84
0.395
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W24X279
0.476
W16X89
0.479
W16X77
0.27
W16X77
0.21
W16X77
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W16X77
0.189
W16X77
0.186
W16X77
0.177
W14X730
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W14X730
0.483
W27X539
0.33
W27X539
0.135
W27X539
0.121
W27X539
0.116
W27X539
0.112
W27X539
0.115
W40X593
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W40X593
0.777
W24X229
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W18X60
0.132
W18X60
0.265
W18X60
0.235
W18X60
0.228
W18X60
0.205
W18X86
0.181
W14X730
0.164
W14X730
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W24X192
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W24X192
0.544
W24X192
0.555
W24X192
0.556
W24X131
0.745
W24X131
0.763
W24X370
0.62
W24X370
0.569
W24X229
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W18X60
0.142
W18X60
0.243
W18X60
0.229
W18X60
0.23
W18X60
0.243
W18X86
0.199
W14X730
0.401
W27X539
0.22
W27X539
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W27X539
0.123
W27X539
0.124
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Z
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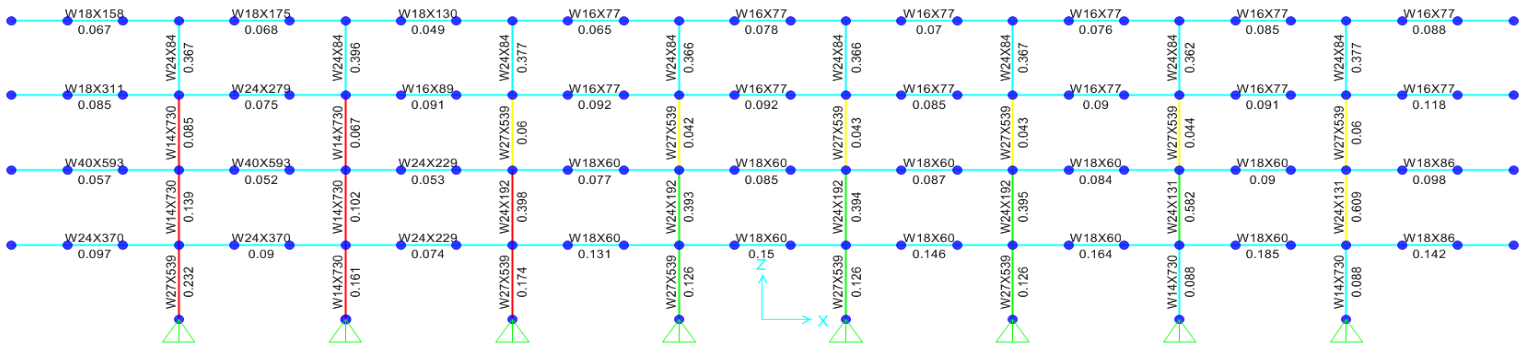
STEP 3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W16X77
0.076
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0.085
W16X77
0.088
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W24X84
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0.085
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0.091
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0.092
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0.092
W16X77
0.085
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0.09
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W16X77
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0.09
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0.09
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W18X60
0.146
W18X60
0.164
W18X60
0.185
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0.142
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W14X730
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W27X539
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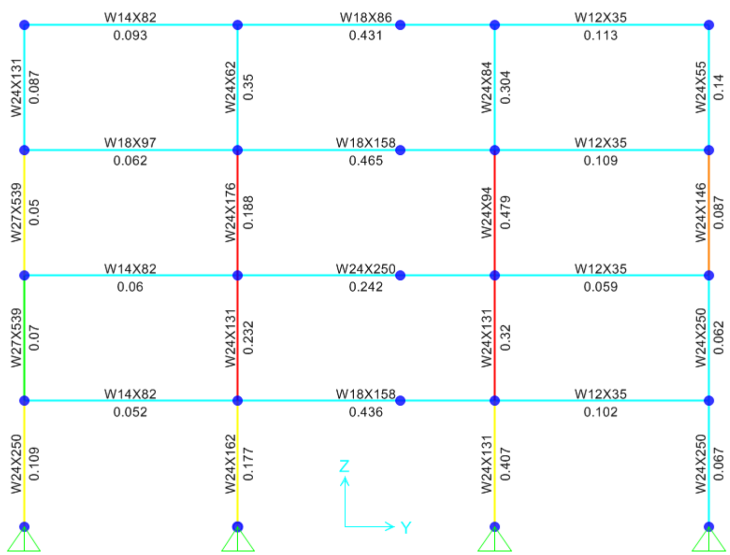
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W24X55
0.14
W18X97
0.062
W18X158
0.465
W12X35
0.109
W27X539
0.05
W24X176
0.188
W24X94
0.479
W24X146
0.087
W14X82
0.06
W24X250
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W12X35
0.059
W27X539
0.07
W24X131
0.232
W24X131
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W24X250
0.062
W14X82
0.052
W18X158
0.436
W12X35
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0.109
W24X162
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W24X250
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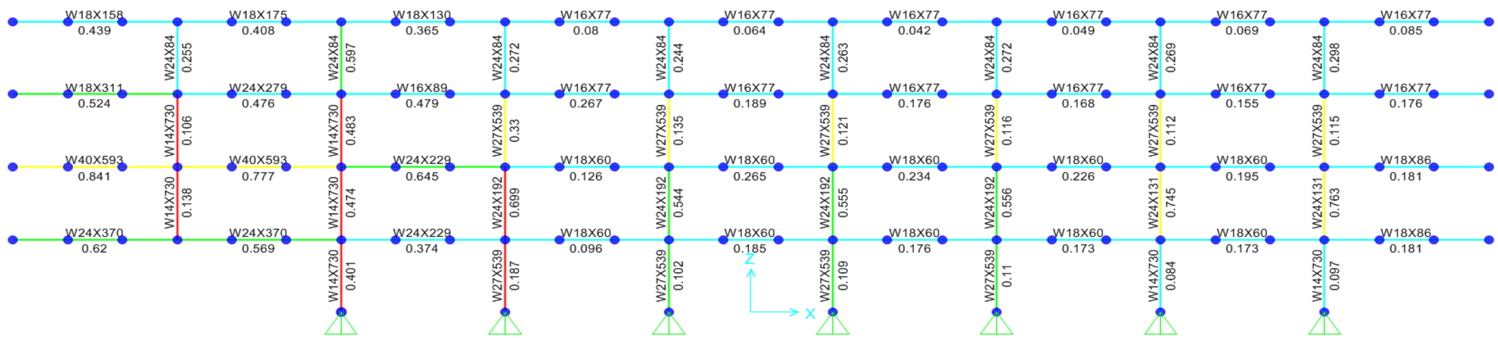
Z
Y

STEP 5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W16X77 0.069
W16X77 0.085
W24X84 0.255
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W24X84 0.272
W24X84 0.244
W24X84 0.263
W24X84 0.272
W24X84 0.269
W24X84 0.298
W18X311 0.524
W24X279 0.476
W16X89 0.479
W16X77 0.267
W16X77 0.189
W16X77 0.176
W16X77 0.168
W16X77 0.155
W16X77 0.176
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W27X539 0.115
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W24X192 0.556
W24X131 0.745
W24X131 0.763
W24X370 0.62
W24X370 0.569
W24X229 0.374
W18X60 0.096
W18X60 0.185
W18X60 0.176
W18X60 0.173
W18X60 0.173
W18X86 0.181
W14X730 0.401
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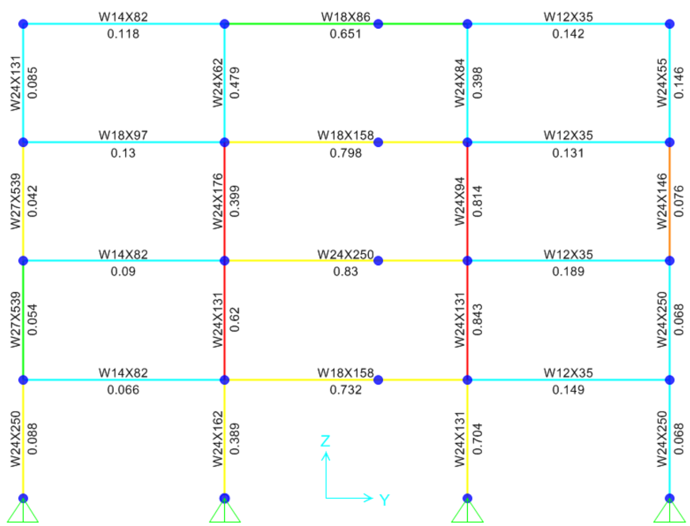
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W18X158 0.798
W12X35 0.131
W27X539 0.042
W24X176 0.399
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W24X146 0.076
W14X82 0.09
W24X250 0.83
W12X35 0.189
W27X539 0.054
W24X131 0.62
W24X131 0.843
W24X250 0.068
W14X82 0.066
W18X158 0.732
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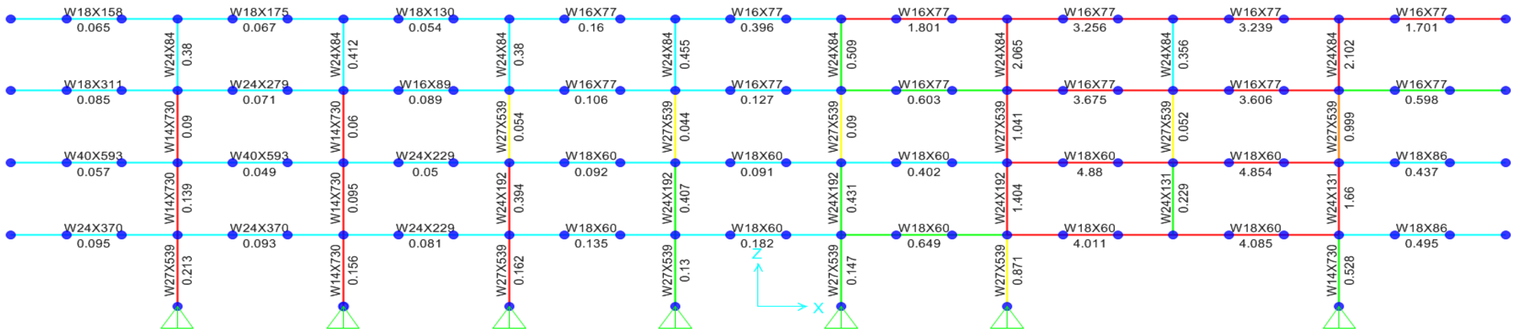
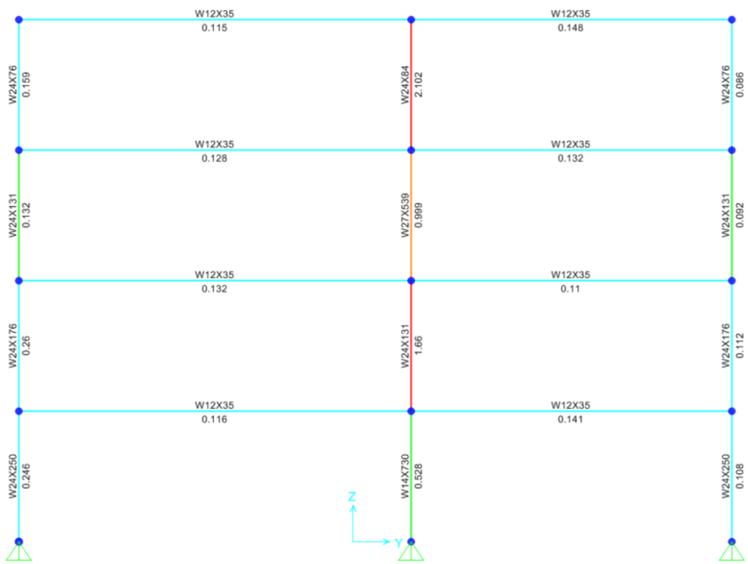
Z
Y

REMOVAL 5

STEP 1





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W24X84
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W24X76
0.086
W12X35
0.128
W12X35
0.132
W24X131
0.132
W27X539
0.999
W24X131
0.092
W12X35
0.132
W12X35
0.11
W24X176
0.26
W24X131
1.66
W24X176
0.112
W12X35
0.116
W12X35
0.141
W24X250
0.246
W14X730
0.528
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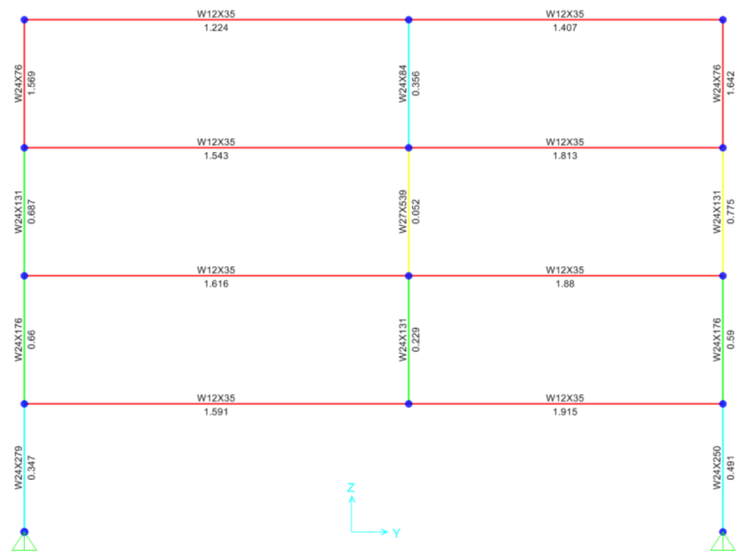
Z
Y



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W12X35
1.543
W12X35
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W24X131
0.687
W27X539
0.052
W24X131
0.775
W12X35
1.616
W12X35
1.88
W24X176
0.66
W24X131
0.229
W24X176
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W12X35
1.591
W12X35
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W24X250
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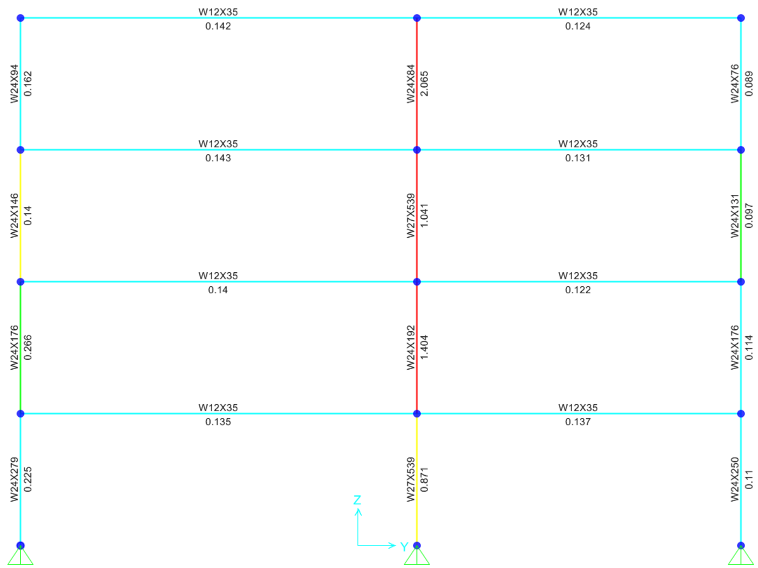
Z
Y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0.143
W12X35
0.131
W24X146
0.14
W27X539
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W24X131
0.097
W12X35
0.14
W12X35
0.122
W24X176
0.266
W24X192
1.404
W24X176
0.114
W12X35
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W24X279
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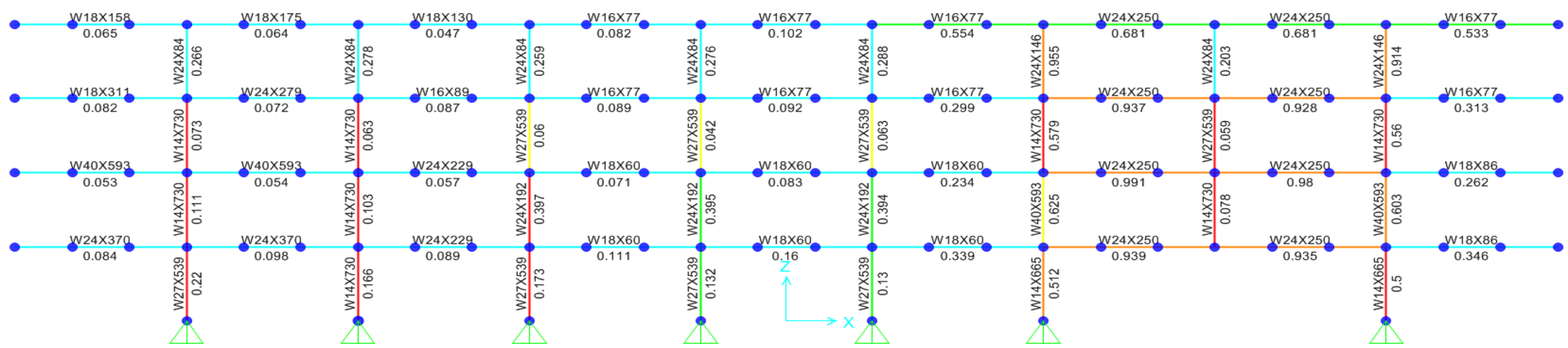
Y

STEP 2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W24X250
0.681
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W40X593
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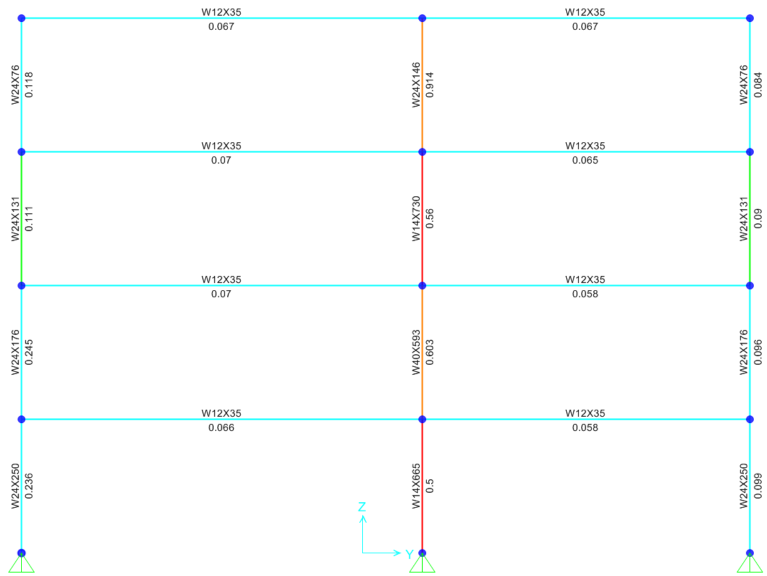
Z
X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W24X76
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0.07
W12X35
0.065
W24X131
0.111
W14X730
0.56
W24X131
0.09
W12X35
0.07
W12X35
0.058
W24X176
0.245
W40X593
0.603
W24X176
0.096
W12X35
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W12X35
0.058
W24X250
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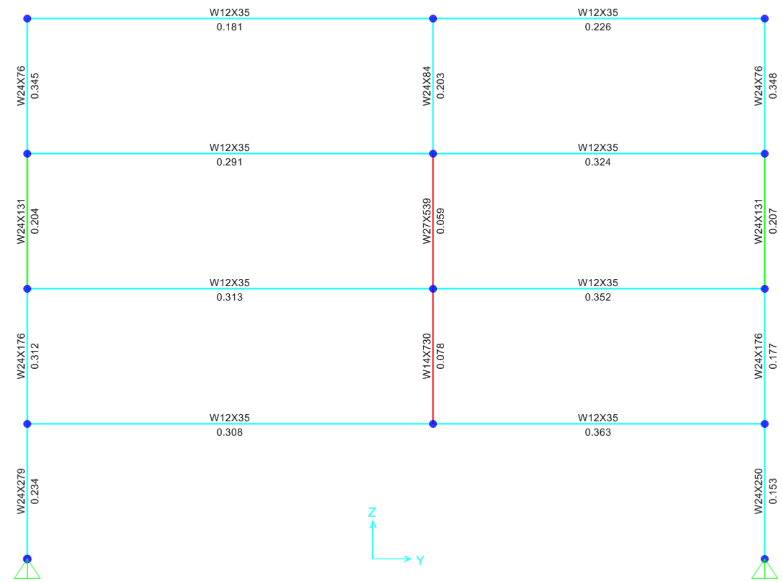
0.5
W24X250
0.099
Z
Y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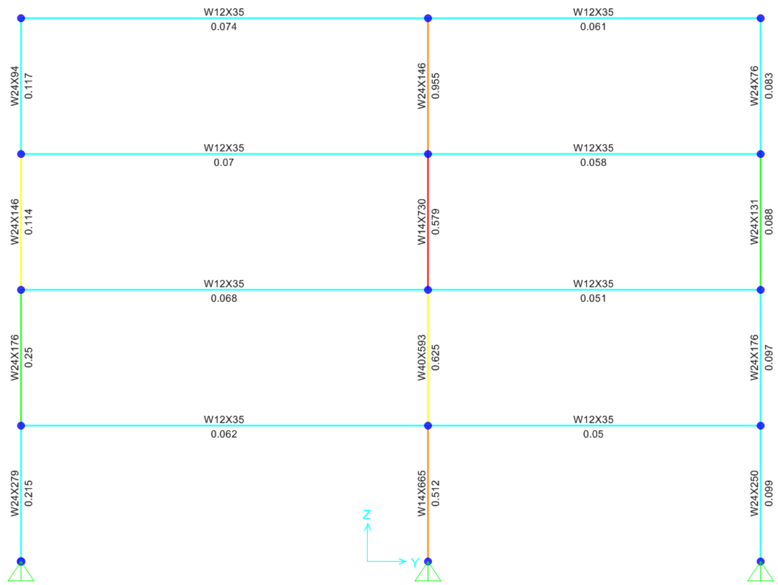
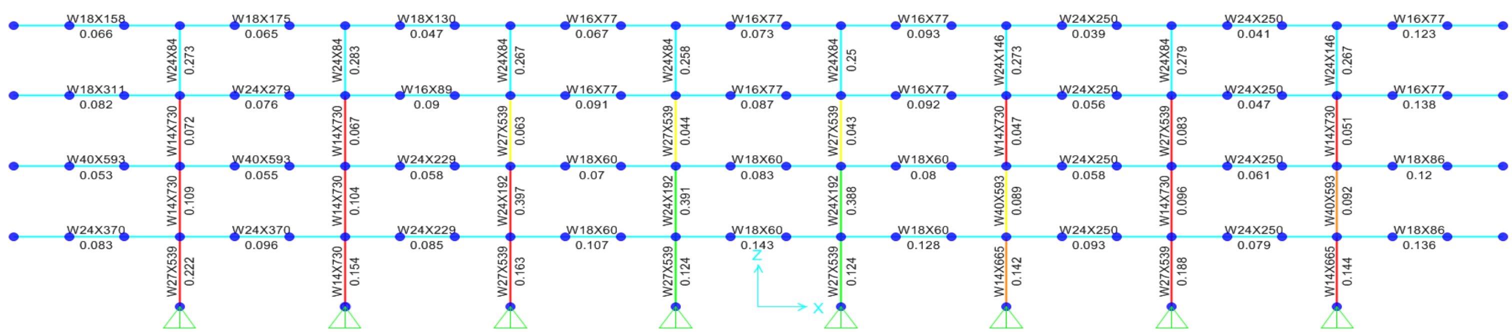
W24X76
0.345
W24X84
0.203
W24X76
0.348
W12X35
0.291
W12X35
0.324
W24X131
0.204
W27X539
0.059
W24X131
0.207
W12X35
0.313
W12X35
0.352
W24X176
0.312
W14X730
0.078
W24X176
0.177
W12X35
0.308
W12X35
0.363
W24X279
0.234
W24X250
0.153
Z
Y


W12X35 0.074
W12X35 0.061
W24X94 0.117
W24X146 0.955
W24X76 0.083
W12X35 0.07
W12X35 0.058
W24X146 0.114
W14X730 0.579
W24X131 0.088
W12X35 0.068
W12X35 0.051
W24X176 0.25
W40X593 0.625
W24X176 0.097
W12X35 0.062
W12X35 0.05
W24X279 0.215
W14X665 0.512
W24X250 0.099
Z
Y

STEP 3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W18X175 0.065
W18X130 0.047
W16X77 0.067
W16X77 0.073
W16X77 0.093
W24X250 0.039
W24X250 0.041
W16X77 0.123
W24X84 0.273
W24X84 0.283
W24X84 0.267
W24X84 0.258
W24X84 0.25
W24X146 0.273
W24X84 0.279
W24X146 0.267
W18X311 0.082
W24X279 0.076
W16X89 0.09
W16X77 0.091
W16X77 0.087
W16X77 0.092
W24X250 0.056
W24X250 0.047
W16X77 0.138
W14X730 0.072
W14X730 0.067
W27X539 0.063
W27X539 0.044
W27X539 0.043
W14X730 0.047
W27X539 0.083
W14X730 0.051
W40X593 0.053
W40X593 0.055
W24X229 0.058
W18X60 0.07
W18X60 0.083
W18X60 0.08
W24X250 0.058
W24X250 0.061
W18X86 0.12
W14X730 0.109
W14X730 0.104
W24X192 0.397
W24X192 0.391
W24X192 0.388
W40X593 0.089
W14X730 0.096
W40X593 0.092
W24X370 0.083
W24X370 0.096
W24X229 0.085
W18X60 0.107
W18X60 0.143
W18X60 0.128
W24X250 0.093
W24X250 0.079
W18X86 0.136
W27X539 0.222
W14X730 0.154
W27X539 0.163
W27X539 0.124
W27X539 0.124
W14X665 0.142
W27X539 0.188
W14X665 0.144
Z
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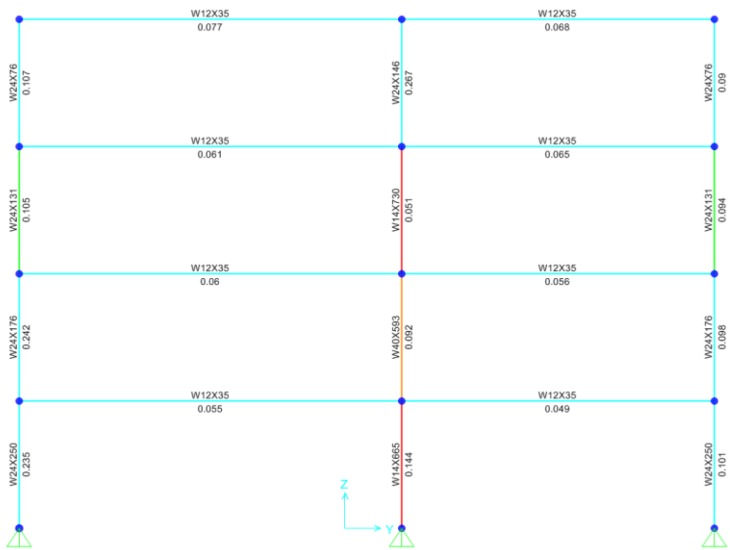
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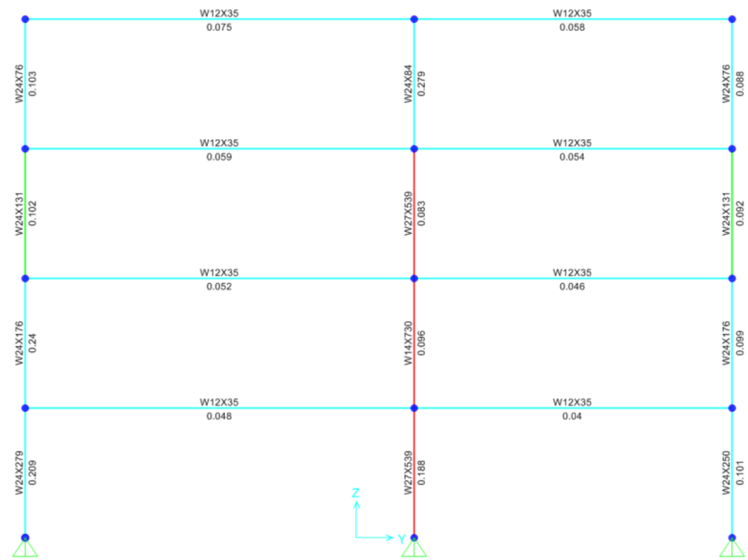
W24X146
0.267
W24X76
0.09
W12X35
0.061
W12X35
0.065
W24X131
0.105
W14X730
0.051
W24X131
0.094
W12X35
0.06
W12X35
0.056
W24X176
0.242
W40X593
0.092
W24X176
0.098
W12X35
0.055
W12X35
0.049
W24X250
0.235
W14X665
0.144
W24X250
0.101
Z
Y


W12X35
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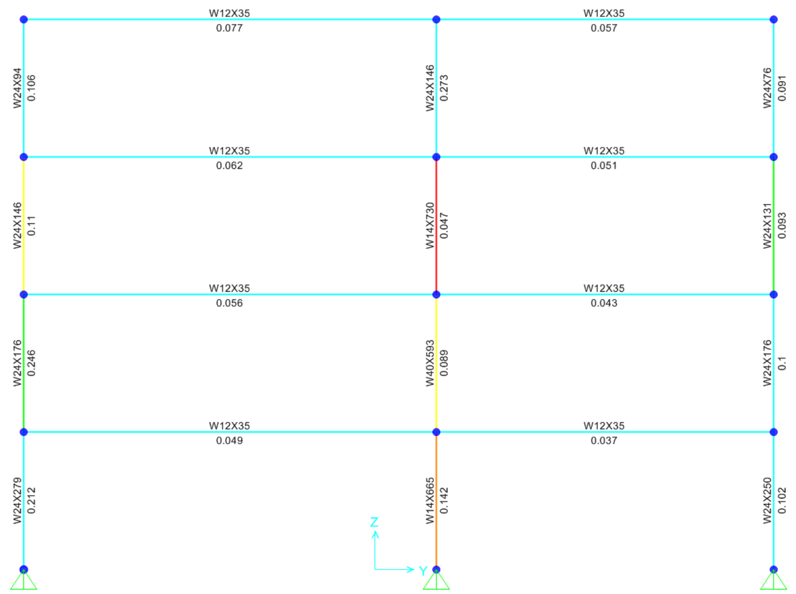
W12X35
0.058
W24X76
0.103
W24X84
0.279
W24X76
0.088
W12X35
0.059
W12X35
0.054
W24X131
0.102
W27X539
0.083
W24X131
0.092
W12X35
0.052
W12X35
0.046
W24X176
0.24
W14X730
0.096
W24X176
0.099
W12X35
0.048
W12X35
0.04
W24X279
0.209
W27X539
0.188
W24X250
0.101
Z
Y



STEP 4

NO FAILURE

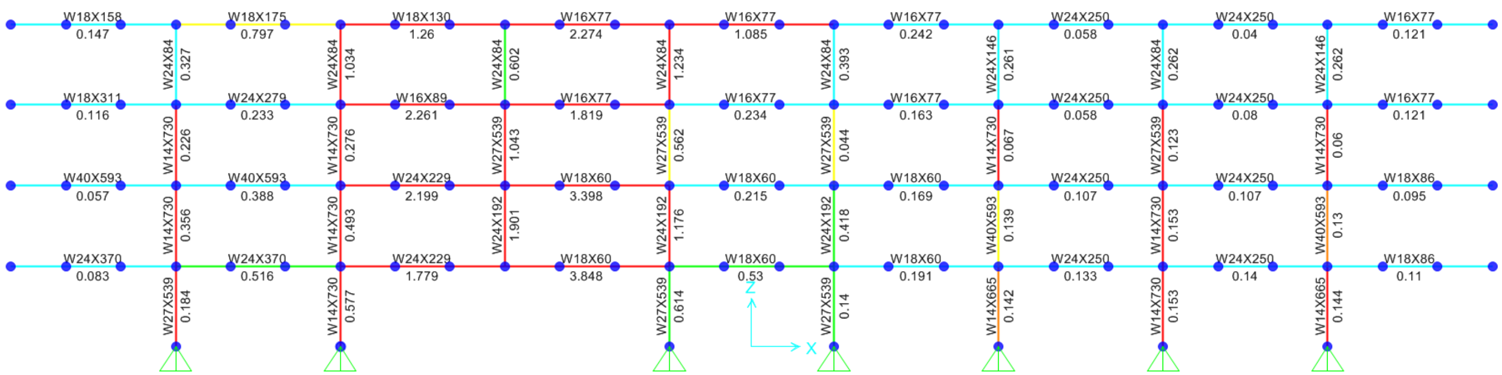
STEP 5

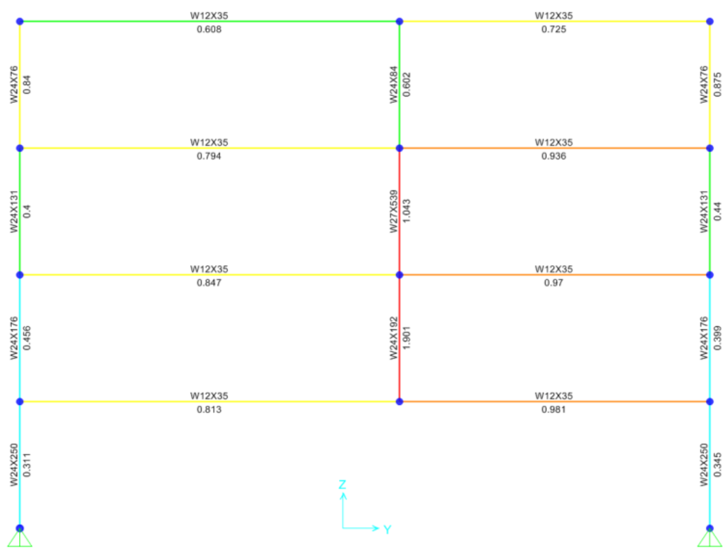
NO FAILURE

STEP 6

NO FAILURE

REMOVAL 6


W18X158 0.147
W18X175 0.797
W18X130 1.26
W16X77 2.274
W16X77 1.085
W16X77 0.242
W24X250 0.058
W24X250 0.04
W16X77 0.121
W24X84 0.327
W24X84 1.034
W24X84 0.602
W24X84 1.234
W24X84 0.393
W24X146 0.261
W24X84 0.262
W24X146 0.262
W18X311 0.116
W24X279 0.233
W16X89 2.261
W16X77 1.819
W16X77 0.234
W16X77 0.163
W24X250 0.058
W24X250 0.08
W16X77 0.121
W14X730 0.226
W14X730 0.276
W27X539 1.043
W27X539 0.562
W27X539 0.044
W14X730 0.067
W27X539 0.123
W14X730 0.06
W40X593 0.057
W40X593 0.388
W24X229 2.199
W18X60 3.398
W18X60 0.215
W18X60 0.169
W24X250 0.107
W24X250 0.107
W18X86 0.095
W14X730 0.356
W14X730 0.493
W24X192 1.901
W24X192 1.176
W24X192 0.418
W40X593 0.139
W14X730 0.153
W40X593 0.13
W24X370 0.083
W24X370 0.516
W24X229 1.779
W18X60 3.848
W18X60 0.53
W18X60 0.191
W24X250 0.133
W24X250 0.14
W18X86 0.11
W27X539 0.184
W14X730 0.577
W27X539 0.614
W27X539 0.14
W14X665 0.142
W14X730 0.153
W14X665 0.144
Z
X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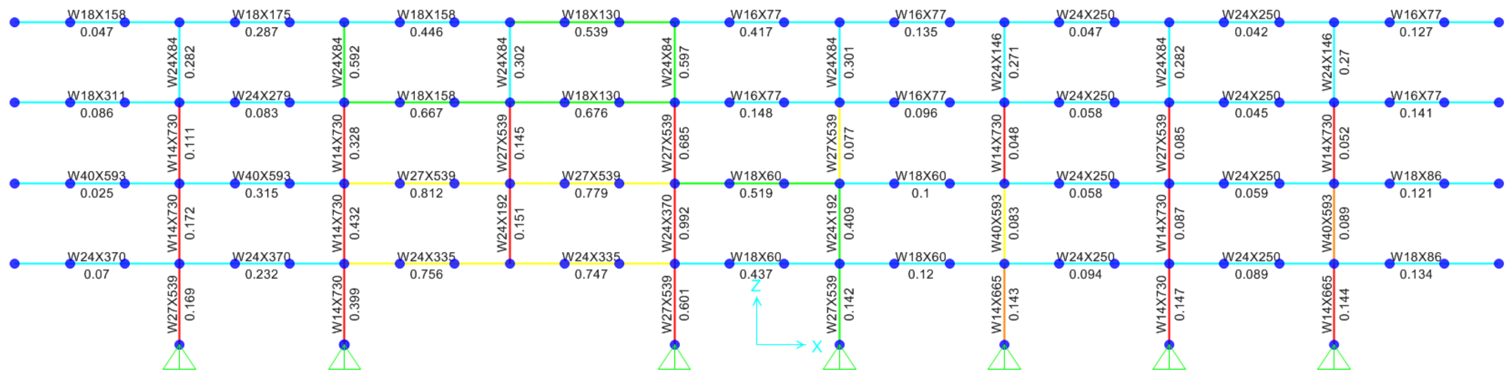
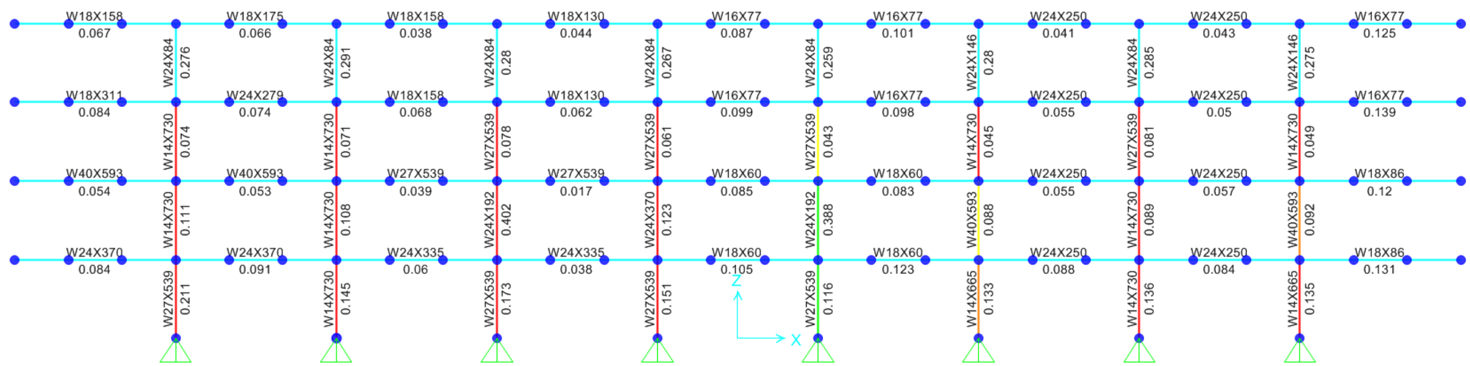
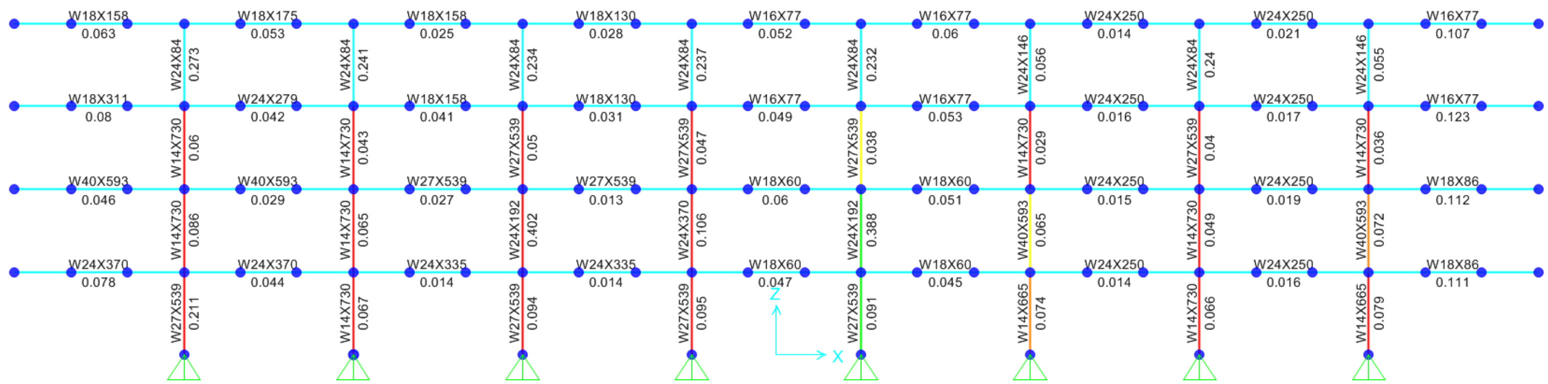
W24X76 0.84
W24X84 0.602
W24X76 0.875
W12X35 0.794
W12X35 0.936
W24X131 0.4
W27X539 1.043
W24X131 0.44
W12X35 0.847
W12X35 0.97
W24X176 0.456
W24X192 1.901
W24X176 0.399
W12X35 0.813
W12X35 0.981
W24X250 0.311
W24X250 0.345
Z
Y


W18X158 0.047
W18X175 0.287
W18X158 0.446
W18X130 0.539
W16X77 0.417
W16X77 0.135
W24X250 0.047
W24X250 0.042
W16X77 0.127
W24X84 0.282
W24X84 0.592
W24X84 0.302
W24X84 0.597
W24X84 0.301
W24X146 0.271
W24X84 0.282
W24X146 0.27
W18X311 0.086
W24X279 0.083
W18X158 0.667
W18X130 0.676
W16X77 0.148
W16X77 0.096
W24X250 0.058
W24X250 0.045
W16X77 0.141
W14X730 0.111
W14X730 0.328
W27X539 0.145
W27X539 0.685
W27X539 0.077
W14X730 0.048
W27X539 0.085
W14X730 0.052
W40X593 0.025
W40X593 0.315
W27X539 0.812
W27X539 0.779
W18X60 0.519
W18X60 0.1
W24X250 0.058
W24X250 0.059
W18X86 0.121
W14X730 0.172
W14X730 0.432
W24X192 0.151
W24X370 0.992
W24X192 0.409
W40X593 0.083
W14X730 0.087
W40X593 0.089
W24X370 0.07
W24X370 0.232
W24X335 0.756
W24X335 0.747
W18X60 0.437
W18X60 0.12
W24X250 0.094
W24X250 0.089
W18X86 0.134
W27X539 0.169
W14X730 0.399
W27X539 0.601
Z
X
W27X539 0.142
W14X665 0.143
W14X730 0.147
W14X665 0.144


W18X158 0.067
W18X175 0.066
W18X158 0.038
W18X130 0.044
W16X77 0.087
W16X77 0.101
W24X250 0.041
W24X250 0.043
W16X77 0.125
W24X84 0.276
W24X84 0.291
W24X84 0.28
W24X84 0.267
W24X84 0.259
W24X146 0.28
W24X84 0.285
W24X146 0.275
W18X311 0.084
W24X279 0.074
W18X158 0.068
W18X130 0.062
W16X77 0.099
W16X77 0.098
W24X250 0.055
W24X250 0.05
W16X77 0.139
W14X730 0.074
W14X730 0.071
W27X539 0.078
W27X539 0.061
W27X539 0.043
W14X730 0.045
W27X539 0.081
W14X730 0.049
W40X593 0.054
W40X593 0.053
W27X539 0.039
W27X539 0.017
W18X60 0.085
W18X60 0.083
W24X250 0.055
W24X250 0.057
W18X86 0.12
W14X730 0.111
W14X730 0.108
W24X192 0.402
W24X370 0.123
W24X192 0.388
W40X593 0.088
W14X730 0.089
W40X593 0.092
W24X370 0.084
W24X370 0.091
W24X335 0.06
W24X335 0.038
W18X60 0.105
W18X60 0.123
W24X250 0.088
W24X250 0.084
W18X86 0.131
W27X539 0.211
W14X730 0.145
W27X539 0.173
W27X539 0.151
Z
X
W27X539 0.116
W14X665 0.133
W14X730 0.136
W14X665 0.135

STEP 5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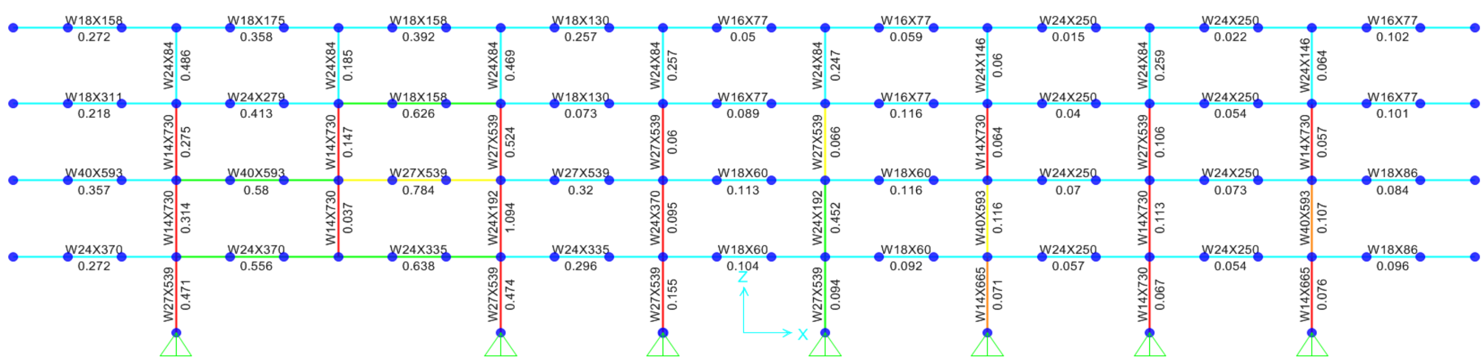
W18X130
0.028
W16X77
0.052
W16X77
0.06
W24X250
0.014
W24X250
0.021
W16X77
0.107
W24X84
0.273
W24X84
0.241
W24X84
0.234
W24X84
0.237
W24X84
0.232
W24X146
0.056
W24X84
0.24
W24X146
0.055
W18X311
0.08
W24X279
0.042
W18X158
0.041
W18X130
0.031
W16X77
0.049
W16X77
0.053
W24X250
0.016
W24X250
0.017
W16X77
0.123
W14X730
0.06
W14X730
0.043
W27X539
0.05
W27X539
0.047
W27X539
0.038
W14X730
0.029
W27X539
0.04
W14X730
0.036
W40X593
0.046
W40X593
0.029
W27X539
0.027
W27X539
0.013
W18X60
0.06
W18X60
0.051
W24X250
0.015
W24X250
0.019
W18X86
0.112
W14X730
0.086
W14X730
0.065
W24X192
0.402
W24X370
0.106
W24X192
0.388
W40X593
0.065
W14X730
0.049
W40X593
0.072
W24X370
0.078
W24X370
0.044
W24X335
0.014
W24X335
0.014
W18X60
0.047
W18X60
0.045
W24X250
0.014
W24X250
0.016
W18X86
0.111
W27X539
0.211
W14X730
0.067
W27X539
0.094
W27X539
0.095
W27X539
0.091
W14X665
0.074
W14X730
0.066
W14X665
0.079
Z
X

STEP 6


W18X158
0.272
W18X175
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W18X158
0.392
W18X130
0.257
W16X77
0.05
W16X77
0.059
W24X250
0.015
W24X250
0.022
W16X77
0.102
W24X84
0.486
W24X84
0.185
W24X84
0.469
W24X84
0.257
W24X84
0.247
W24X146
0.06
W24X84
0.259
W24X146
0.064
W18X311
0.218
W24X279
0.413
W18X158
0.626
W18X130
0.073
W16X77
0.089
W16X77
0.116
W24X250
0.04
W24X250
0.054
W16X77
0.101
W14X730
0.275
W14X730
0.147
W27X539
0.524
W27X539
0.06
W27X539
0.066
W14X730
0.064
W27X539
0.106
W14X730
0.057
W40X593
0.357
W40X593
0.58
W27X539
0.784
W27X539
0.32
W18X60
0.113
W18X60
0.116
W24X250
0.07
W24X250
0.073
W18X86
0.084
W14X730
0.314
W14X730
0.037
W24X192
1.094
W24X370
0.095
W24X192
0.452
W40X593
0.116
W14X730
0.113
W40X593
0.107
W24X370
0.272
W24X370
0.556
W24X335
0.638
W24X335
0.296
W18X60
0.104
W18X60
0.092
W24X250
0.057
W24X250
0.054
W18X86
0.096
W27X539
0.471
W27X539
0.474
W27X539
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W27X539
0.094
W14X665
0.071
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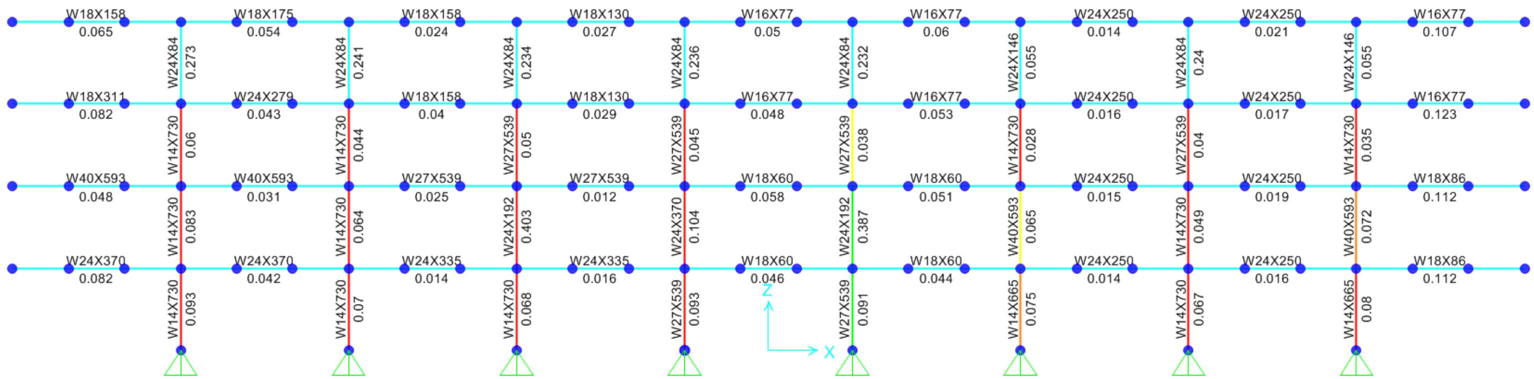
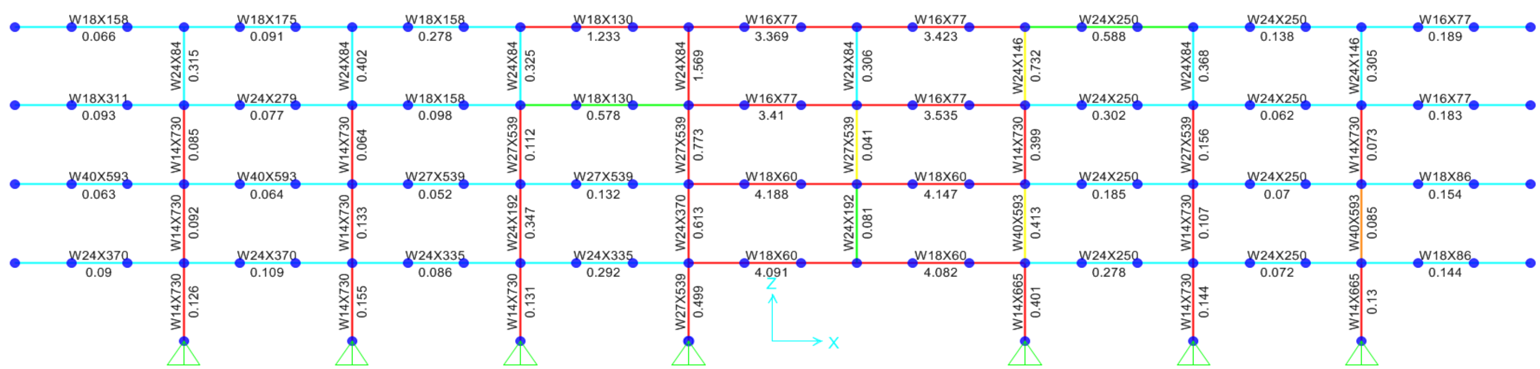
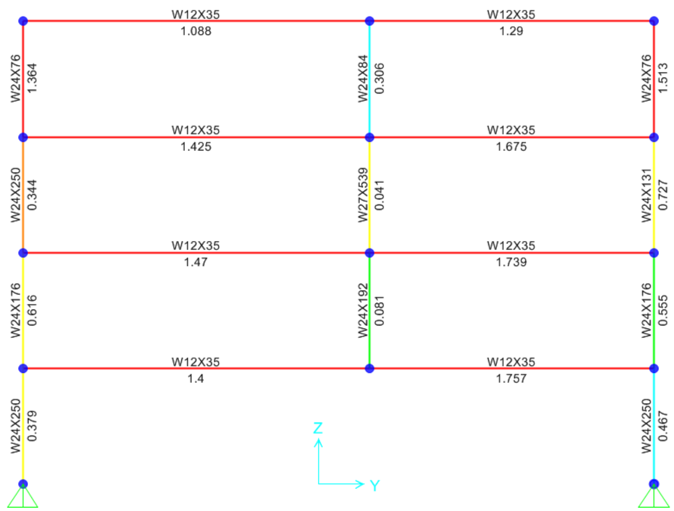
0.067
W14X665
0.076
Z
X



REMOVAL 7

CASE 1

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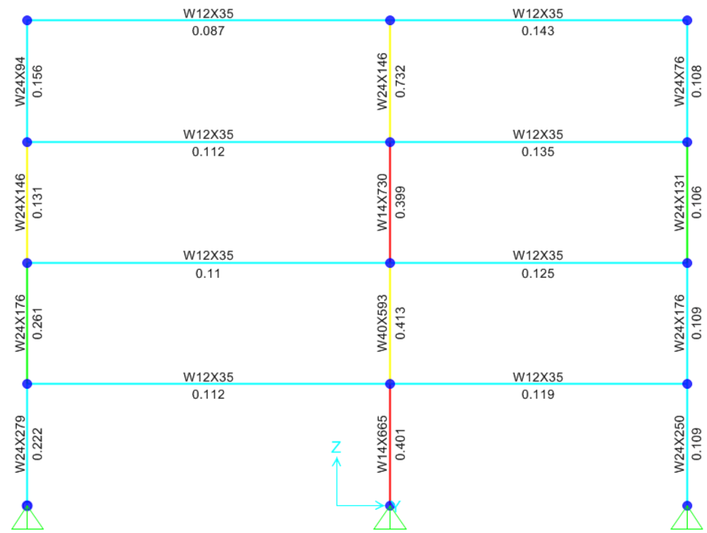
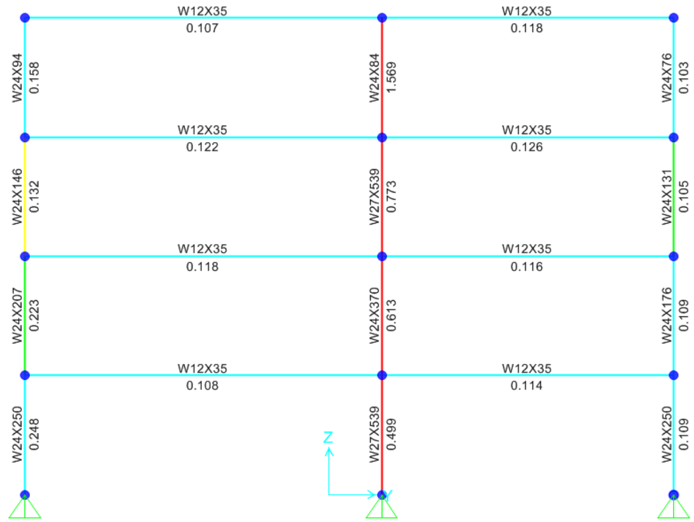
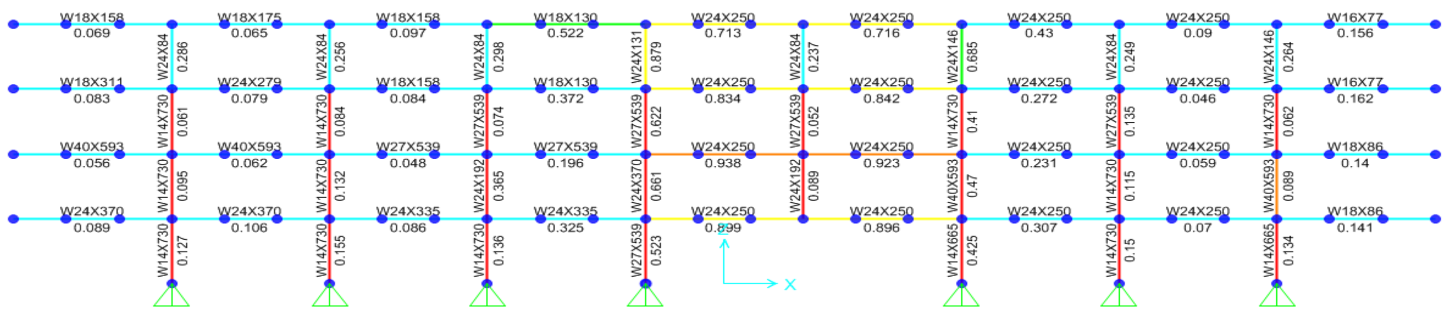
W12X35
1.29
W24X76
1.364
W24X84
0.306
W24X76
1.513
W12X35
1.425
W12X35
1.675
W24X250
0.344
W27X539
0.041
W24X131
0.727
W12X35
1.47
W12X35
1.739
W24X176
0.616
W24X192
0.081
W24X176
0.555
W12X35
1.4
W12X35
1.757
W24X250
0.379
W24X250
0.467
Z
Y


W12X35
0.087
W12X35
0.143
W24X94
0.156
W24X146
0.732
W24X76
0.108
W12X35
0.112
W12X35
0.135
W24X146
0.131
W14X730
0.399
W24X131
0.106
W12X35
0.11
W12X35
0.125
W24X176
0.261
W40X593
0.413
W24X176
0.109
W12X35
0.112
W12X35
0.119
W24X279
0.222
W14X665
0.401
W24X250
0.109
Z



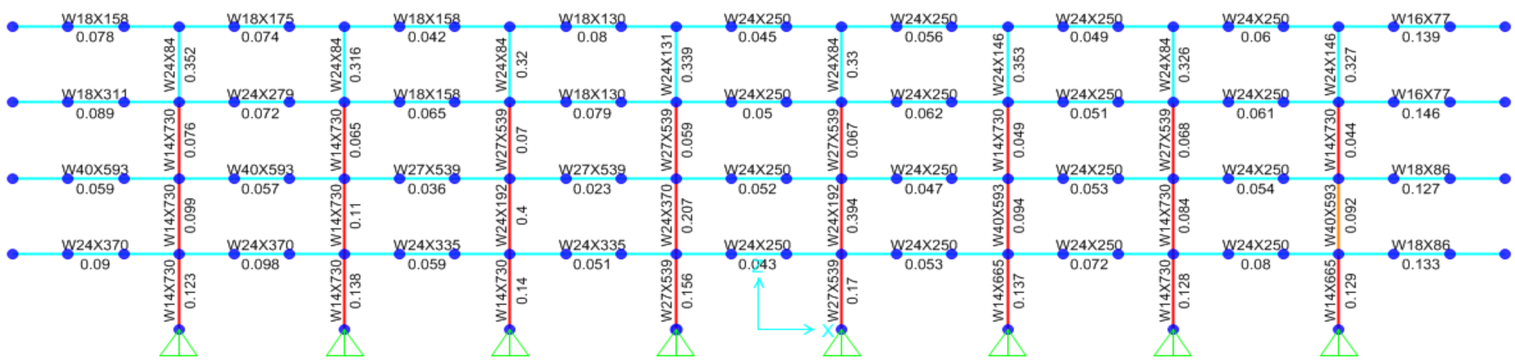
W12X35
0.107
W12X35
0.118
W24X94
0.158
W24X84
1.569
W24X76
0.103
W12X35
0.122
W12X35
0.126
W24X146
0.132
W27X539
0.773
W24X131
0.105
W12X35
0.118
W12X35
0.116
W24X207
0.223
W24X370
0.613
W24X176
0.109
W12X35
0.108
W12X35
0.114
W24X250
0.248
Z
W27X539
0.499
W24X250
0.109

STEP 2



W18X158
0.069
W18X175
0.065
W18X158
0.097
W18X130
0.522
W24X250
0.713
W24X250
0.716
W24X250
0.43
W24X250
0.09
W16X77
0.156
W24X84
0.286
W24X84
0.256
W24X84
0.298
W24X131
0.879
W24X84
0.237
W24X146
0.685
W24X84
0.249
W24X146
0.264
W18X311
0.083
W24X279
0.079
W18X158
0.084
W18X130
0.372
W24X250
0.834
W24X250
0.842
W24X250
0.272
W24X250
0.046
W16X77
0.162
W14X730
0.061
W14X730
0.084
W27X539
0.074
W27X539
0.622
W27X539
0.052
W14X730
0.41
W27X539
0.135
W14X730
0.062
W40X593
0.056
W40X593
0.062
W27X539
0.048
W27X539
0.196
W24X250
0.938
W24X250
0.923
W24X250
0.231
W24X250
0.059
W18X86
0.14
W14X730
0.095
W14X730
0.132
W24X192
0.365
W24X370
0.661
W24X192
0.089
W40X593
0.47
W14X730
0.115
W40X593
0.089
W24X370
0.089
W24X370
0.106
W24X335
0.086
W24X335
0.325
W24X250
0.899
W24X250
0.896
W24X250
0.307
W24X250
0.07
W18X86
0.141
W14X730
0.127
W14X730
0.155
W14X730
0.136
W27X539
0.523
W14X665
0.425
W14X730
0.15
W14X665
0.134
Z
X

STEP 3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W18X175 0.074
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W18X130 0.08
W24X250 0.045
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W24X250 0.06
W16X77 0.139
W24X84 0.352
W24X84 0.316
W24X84 0.32
W24X131 0.339
W24X84 0.33
W24X146 0.353
W24X84 0.326
W24X146 0.327
W18X311 0.089
W24X279 0.072
W18X158 0.065
W18X130 0.079
W24X250 0.05
W24X250 0.062
W24X250 0.051
W24X250 0.061
W16X77 0.146
W14X730 0.076
W14X730 0.065
W27X539 0.07
W27X539 0.059
W27X539 0.067
W14X730 0.049
W27X539 0.068
W14X730 0.044
W40X593 0.059
W40X593 0.057
W27X539 0.036
W27X539 0.023
W24X250 0.052
W24X250 0.047
W24X250 0.053
W24X250 0.054
W18X86 0.127
W14X730 0.099
W14X730 0.11
W24X192 0.4
W24X370 0.207
W24X192 0.394
W40X593 0.094
W14X730 0.084
W40X593 0.092
W24X370 0.09
W24X370 0.098
W24X335 0.059
W24X335 0.051
W24X250 0.043
W24X250 0.053
W24X250 0.072
W24X250 0.08
W18X86 0.133
W14X730 0.123
W14X730 0.138
W14X730 0.14
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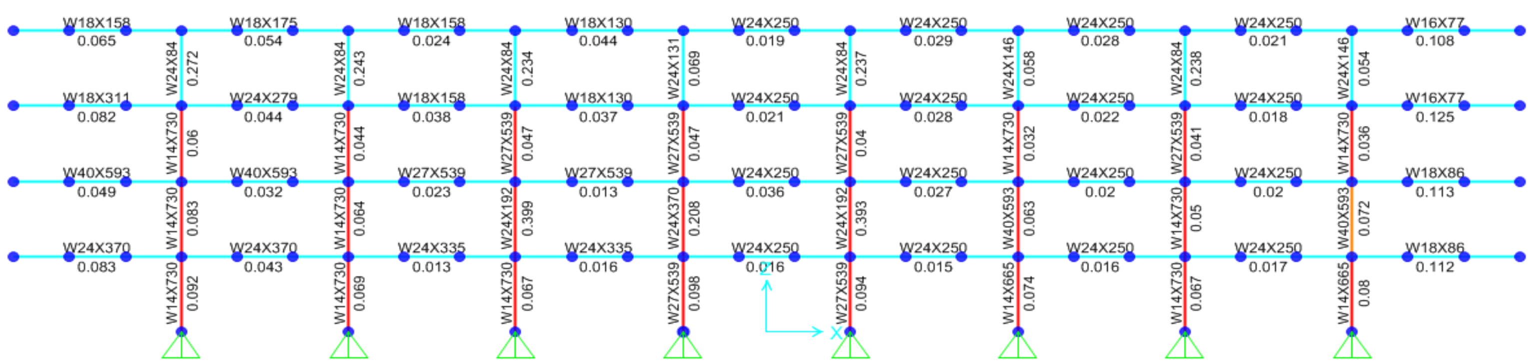
W27X539 0.17
W14X665 0.137
W14X730 0.128
W14X665 0.129
Z
X

STEP 5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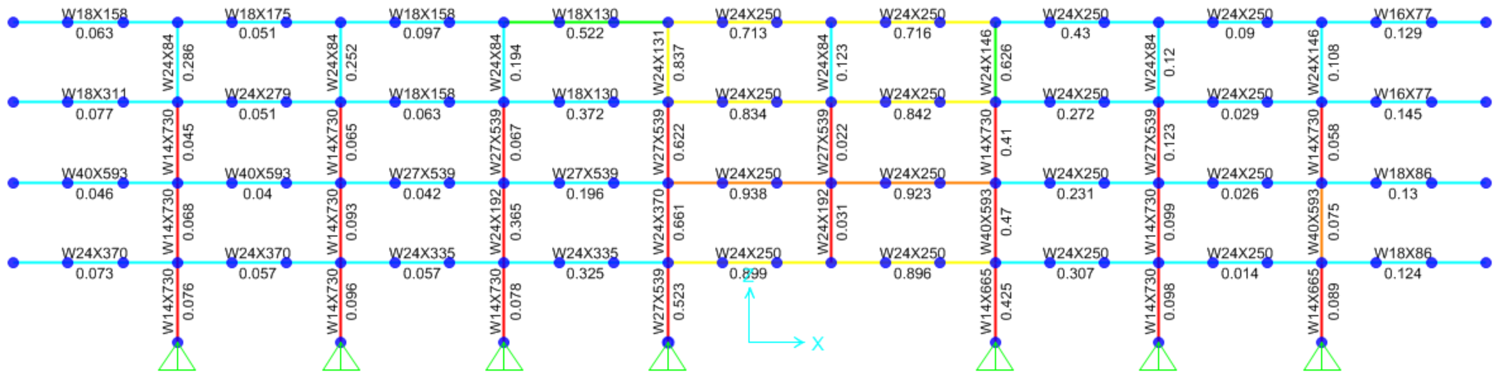
W24X250 0.021
W16X77 0.108
W24X84 0.272
W24X84 0.243
W24X84 0.234
W24X131 0.069
W24X84 0.237
W24X146 0.058
W24X84 0.238
W24X146 0.054
W18X311 0.082
W24X279 0.044
W18X158 0.038
W18X130 0.037
W24X250 0.021
W24X250 0.028
W24X250 0.022
W24X250 0.018
W16X77 0.125
W14X730 0.06
W14X730 0.044
W27X539 0.047
W27X539 0.047
W27X539 0.04
W14X730 0.032
W27X539 0.041
W14X730 0.036
W40X593 0.049
W40X593 0.032
W27X539 0.023
W27X539 0.013
W24X250 0.036
W24X250 0.027
W24X250 0.02
W24X250 0.02
W18X86 0.113
W14X730 0.083
W14X730 0.064
W24X192 0.399
W24X370 0.208
W24X192 0.393
W40X593 0.063
W14X730 0.05
W40X593 0.072
W24X370 0.083
W24X370 0.043
W24X335 0.013
W24X335 0.016
W24X250 0.016
W24X250 0.015
W24X250 0.016
W24X250 0.017
W18X86 0.112
W14X730 0.092
W14X730 0.069
W14X730 0.067
W27X539 0.098
W27X539 0.094
W14X665 0.074
W14X730 0.067
W14X665 0.08
Z
X

STEP 6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W18X158
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W18X130
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W24X250
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W24X250
0.716
W24X250
0.43
W24X250
0.09
W16X77
0.129
W24X84
0.286
W24X84
0.252
W24X84
0.194
W24X131
0.837
W24X84
0.123
W24X146
0.626
W24X84
0.12
W24X146
0.108
W18X311
0.077
W24X279
0.051
W18X158
0.063
W18X130
0.372
W24X250
0.834
W24X250
0.842
W24X250
0.272
W24X250
0.029
W16X77
0.145
W14X730
0.045
W14X730
0.065
W27X539
0.067
W27X539
0.622
W27X539
0.022
W14X730
0.41
W27X539
0.123
W14X730
0.058
W40X593
0.046
W40X593
0.04
W27X539
0.042
W27X539
0.196
W24X250
0.938
W24X250
0.923
W24X250
0.231
W24X250
0.026
W18X86
0.13
W14X730
0.068
W14X730
0.093
W24X192
0.365
W24X370
0.661
W24X192
0.031
W40X593
0.47
W14X730
0.099
W40X593
0.075
W24X370
0.073
W24X370
0.057
W24X335
0.057
W24X335
0.325
W24X250
0.899
W24X250
0.896
W24X250
0.307
W24X250
0.014
W18X86
0.124
W14X730
0.076
W14X730
0.096
W14X730
0.078
W27X539
0.523
W14X665
0.425
W14X730
0.098
W14X665
0.089
Z
X