Term Project
14.551 Advanced Steel Design

Fall 2014 | Section 201 | Team: GLZ Design

Ana Gouveia, E.I.T.
Matthew Laskey, E.I.T.
Zachary Zavalianos, E.I.T.

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UMASS LOWELL

DESIGN TEAM

Design Team

MATTHEW LASKEY, EIT
STRUCTURAL ENGINEER

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Matt continued working as a Structural Engineer at CDM Smith after his summer internship at the firm.

Matt has a bachelor's degree in Environmental and Resources Economics from UNH and a Civil Engineering degree from UMass Lowell.

ANA GOUVEIA, EIT
STRUCTURAL ENGINEER

agouveia465@uml.edu

Ana was born in Brazil where she started her college education in Civil Engineering. As a challenge-seeker, she immigrated to Massachusetts in 2009. Since then studied at Harvard University Extension School, acquired an associate's degree in Engineering from Bunker Hill Community College, a bachelor's degree in Civil Engineering from the University of Massachusetts Lowell.

ZAC ZAVALIANOS, EIT
STRUCTURAL ENGINEER

Zachary_Zavalianos@student.uml.edu

Hardworking and enthusiastic structural engineer with experience in design and inspection of bridge structures. Certified in bridge inspection and proficient in inspection databases such as PONTIS and 4-D, as well as MDX and CSI-bridge analysis programs. Seeking to progress career by obtaining a masters degree and working towards a PE license through the upcoming years.

Company Information

GLZ Design
Always Going Farther

GLZ Design, LLC
| University Ave, Lowell, MA
www.glzdesigns.com

DESIGN SUMMARY

Project Summary

Project Riverside is a two-story, steel-framed, office building located in Lowell, MA. GLZ Design has assigned the design team composed by Structural Engineers: Matthew Laskey, Ana Gouveia and Zachary Zavalianos to perform the structural analysis, evaluation and design of this project.

Guided by local regulations, the design team used of the most up to date references, associated to outstanding optimization analysis, along efficient construction practices as the project's design criteria. A more accurate overview of these values can be found in page 7 of this report. Building classifications and initial information can be found in page 8 of this report.

Riverside's design process started through a complete identification vertical and lateral loads, which were further analyzed by the Load & Resistance Factor Design (LRFD). These initial values were used in the preliminary-sizing of project horizontal and vertical members.

In the second phase of the project, these preliminary members were further evaluated and analyzed. Final framing plans for both first and roof floor were obtained. Two different lateral load resisting systems (LLRS were designed: a moment-frame resists longitudinal loads, and braced-frames are responsible for transverse loads. Given building risk categories, per code used, ordinary moment-frame and braced-frame were allowed in the design, reducing the project's final budget.

In the project's final phase, composite floor deck, roof joists, girders and diaphragms, and connections were designed. For quality assurance and control, all of the project's information, calculations, analysis and drawings were further back checked. The final results of this project can be found in this report. Calculations, Analysis and Drawings are referred in its respective section on the report and can also be found at this report's appendixes.

DESIGN CRITERIA

Design Criteria

Design Criteria and Constraints

The following figure represents the design criteria which guided the team:

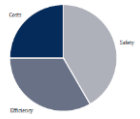

Figure A – Riverside's guiding criteria.

Building Information and Requirements

Classifications

- Occupancy: Group B, Office
- Construction: Type IIB
- Risk Category: II
- Seismic Site Class: C
- Environmental Exposure: C

Building Layout

- Total Area = Approx. 17,000 sf (gross)
- Floor Plan: 110 ft. x 74ft
- Column Grid: 36 ft. x 24 ft.

References and Regulations

- Massachusetts Building Code (CMR 780)
- 2012 International Building Code (2012 IBC)
- Minimum Design Loads for Buildings and Other Structures, (ASCE/SEI 7-10)
- 14th Edition of the Steel Construction Manual (AISC 14th)
- American Concrete Institute Manual (ACI)
- 2007 Steel Deck Institute Design Manual (2007 SDI)
- Vulcraft Joists and Girders (VJG)
- 5th Edition Structural Steel Design, McCormac & Csernak (SSD 5th)

30% SUBMITTAL

- Load Analysis
- Preliminary Sizing

Presented by: Ana Gouveia, E.I.T.

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MEMBERS

Members

The members in the project were labeled as shown in the figures below:

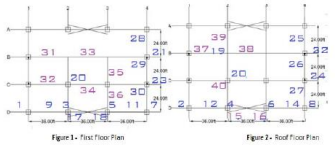


Figure 1 - First Floor Plan

Figure 2 - Roof Floor Plan

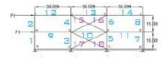
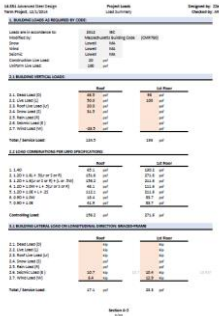


Figure 3 - Braced-Elevation

Figure 4 - Moment Frame - Elevation

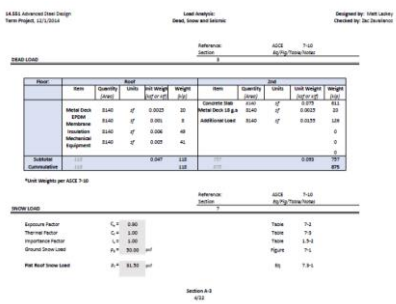
BUILDING LOADS

- **BUILDING LOADS:**
  - DEAD
  - LIVE
  - SNOW
  - WIND
  - SEISMIC
- **REGULATIONS:**
  - 2012 IBC
  - CMR 780
  - ASCE 7-10
- **METHOD OF LOAD ANALYSIS:**
  - LRFD



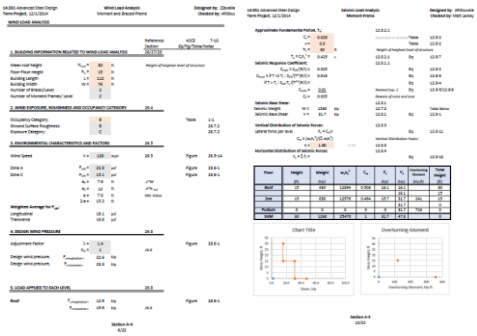
VERTICAL LOADS

- DEAD
- LIVE
- SNOW
- WIND

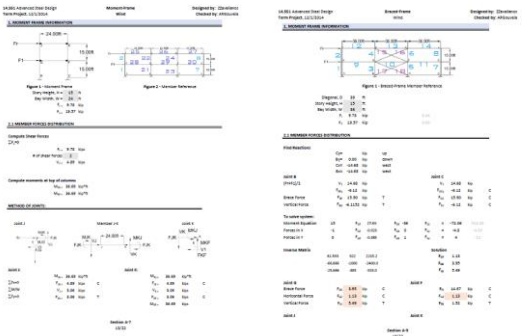


LATERAL LOADS

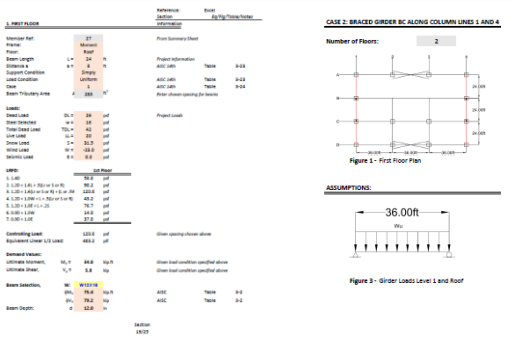
- SEISMIC
- WIND



PRELIMINARY SIZING



PRELIMINARY SIZING



60% Material

- Braced Frame
- Moment Frame
- Floor/Roof System

Presented by: Zac Zavalianos, E.I.T.

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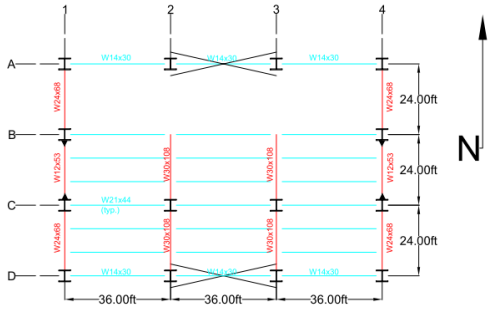
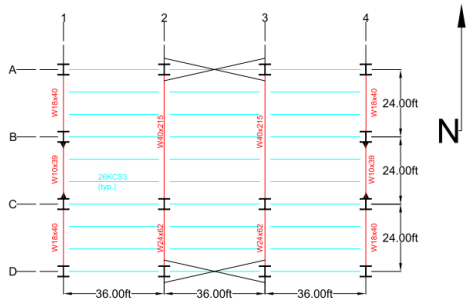
BRACED/MOMENT FRAMES-LEVEL 2

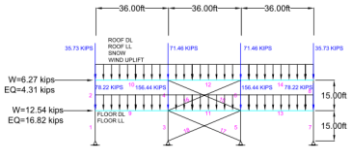


BRACED/MOMENT FRAMES-ROOF LEVEL



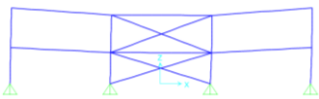
BRACED FRAME

- Braced frame analyzed using the direct analysis method
- Developed braced frame model in SAP2000 using loading as shown
- Model reflected beam/column sizes determined from 30% design



BRACED FRAME

- Deformed shape:



- First order analysis forces found from SAP output:

First Order Analysis Forces	Top	Bottom
Ultimate Axial Load, P_{uo}	295.93 kips	295.93 kips
Ultimate Moment, M_{uo}	13.37 kip*ft	0 kip*ft

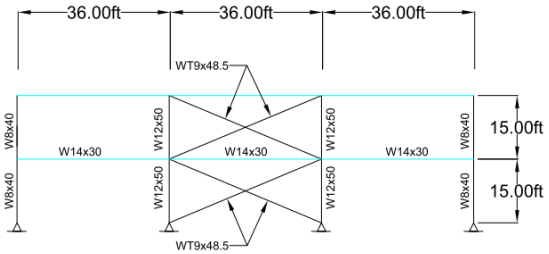
BRACED FRAME

- Columns determined in 30%: **W12x40**
  - This section did not satisfy requirements for combined moment/bending
- Re-run calculation with **W12x50**
  - Section satisfied requirements as seen below:

Summary		
Moment Required, M_r	13.37 kip*ft	*Eq A-8-1*
Moment Capacity, M_c	270.00 kip*ft	*Referenced Above*
Axial Required, P_r	295.9 kips	*Eq A-8-2*
Axial Capacity, P_c	355 kips	*Referenced Above*
Combined Forces Interaction Equation		
P_r/P_c	0.83	
$P_r/P_c>0.2$	0.88	Eq H1-1a
$P_r/P_c<0.3$	0.47	Eq H1-1b
Design Check	0.88 SECTION OK	

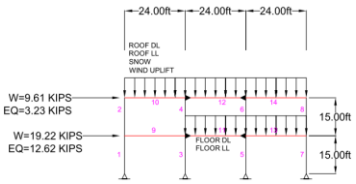
BRACED FRAME

- Final braced frame shown below:



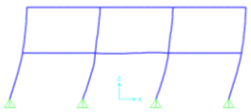
MOMENT FRAME

- Moment frame analyzed using the direct analysis method
- Developed moment frame model in SAP2000 using loading as shown
- Model reflected beam/column sizes determined from 30% design

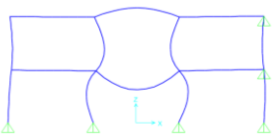


MOMENT FRAME

- Deformed shape (Lateral translation):



- Deformed shape (No lateral translation)



MOMENT FRAME

- Columns determined in 30%: **W8x40**
  - This section did not satisfy requirements for combined moment/bending
- Re-run calculation with **W10X68**
  - Section satisfied requirements as seen below:

Moment Required, M_r	261.96	kip*ft	*Eq A-8-1*
Moment Capacity, M_c	320.00	kip*ft	*Referenced Above*
Axial Required, P_r	99.8	kips	*Eq A-8-2*
Axial Capacity, P_c	629.06	kips	*Referenced Above*
Combined Forces Ineraction Equation			
P_r/P_c	0.16		
$P_r/P_c>0.2$	0.89		Eq H1-1a
$P_r/P_c<0.2$	0.90		Eq H1-1b
Design Check	0.90	SECTION OK	

MOMENT FRAME

- Level 2 Beams determined in 30%: **W18x35**
  - This section did not satisfy requirements for combined moment/bending
- Re-run calculation with **W12x53**
  - Section satisfied requirements as seen below:

Moment Required, M_r	239.01	kip*ft	*Eq A-8-1*
Moment Capacity, M_c	249.06	kip*ft	*Referenced Above*
Axial Required, P_r	19.9	kips	*Eq A-8-2*
Axial Capacity, P_c	261.33	kips	*Referenced Above*
Combined Forces Ineraction Equation			
P_r/P_c	0.08		
$P_r/P_c>0.2$	0.93		Eq H1-1a
$P_r/P_c<0.2$	1.00		Eq H1-1b
Design Check	0.998	SECTION OK	

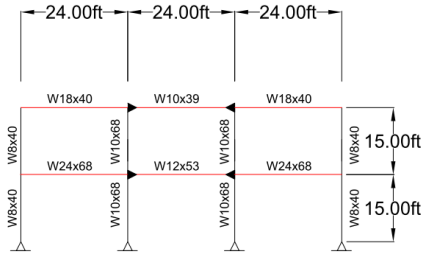
MOMENT FRAME

- Roof Level Beams determined in 30%: **W12x19**
  - This section did not satisfy requirements for combined moment/bending
- Re-run calculation with **W10x39**
  - Section satisfied requirements as seen below:

Moment Required, M_r	77.18	kip*ft	*Eq A-8-1*
Moment Capacity, M_c	136.34	kip*ft	*Referenced Above*
Axial Required, P_r	10.7	kips	*Eq A-8-2*
Axial Capacity, P_c	122.80	kips	*Referenced Above*
Combined Forces Ineraction Equation			
P_r/P_c	0.09		
$P_r/P_c>0.2$	0.59		Eq H1-1a
$P_r/P_c<0.2$	0.61		Eq H1-1b
Design Check	0.61	SECTION OK	

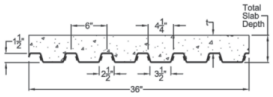
MOMENT FRAME

- Final moment frame shown below:



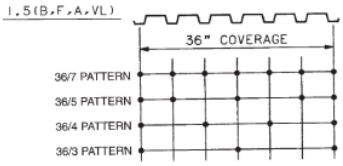
FLOOR SYSTEM

- Utilized composite design
- Floor System Specifications:
  - Total Slab Depth=5”
  - Normal weight concrete (145pcf)
  - Camber=1”
  - # of Studs/beam=60
  - Stud diameter=3/4”
  - Stud Length=4”
  - Equally Spaced
  - Temporary bracing required
  - 1.5VLR19 (Vulcraft) Metal Deck
  - Ribs perpendicular to beam



ROOF SYSTEM

- Open web steel joists with steel (W) girders
  - Vulcraft 26KCS3 joists
- Metal Deck:Vulcraft B18 (3span)
- 36/3 fastener layout
- Support Fasteners: 5/8” puddle welds
- Side lap fasteners: (2) #10 tek screws
- Vertical and Lateral deflections under allowable limit



100% Material

- Bracing Connections
- Hanger Connection
- Shear and Moment Connections
- Cost Estimation
- Drawings

Presented by: Matt Laskey, E.I.T.

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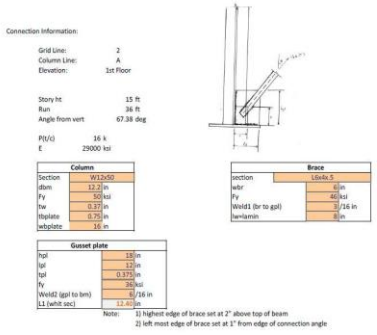
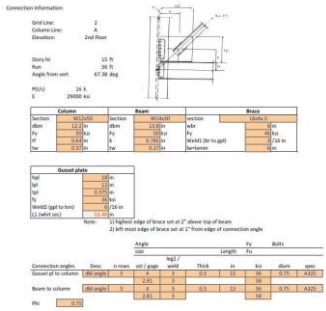
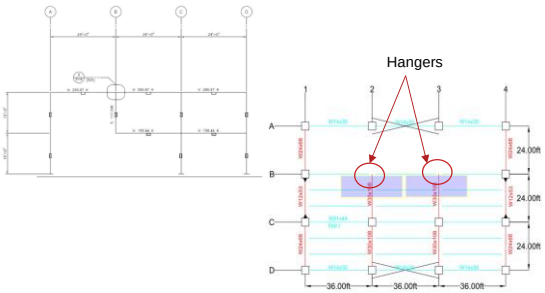
Gusset Plate Connection- 1st Floor



Gusset Plate Connection- 2nd Floor

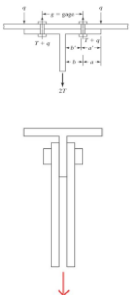


Hanger Detail



Hanger Detail

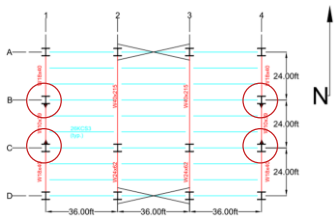
- Hanger connection: WT12x96
  - Connected to roof using ¾" diameter A325 bolts
- Hanger member is constructed of two 1"x14" steel plates
  - Treated as tension-only members
  - Connected to WT member by one horizontal row of (3) ¾" diameter A325 bolts.
    - Double shear
- Trib Area = 432 ft^2
- Wu = 271.6 psf
- Pu = 117.33 k per hanger



Moment Connection – Roof Level

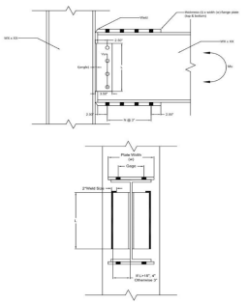
- Girder: W10x39
- Column: W10x68

- Mu = 77.18 k-ft
- Vu = 35.73 k



Moment Connection – Roof Level

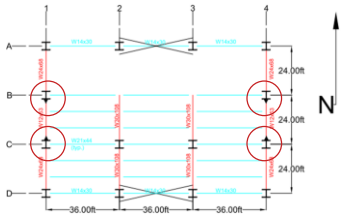
- Flange Plate:
  - t= 0.5 in
  - w = 8 in
  - Connection
    - 7/8" Dia A325 Bolts
    - n = 2 rows
    - # bolts per row = 4 (per flange)
    - Gage = 6 in
- Flange – Column Weld:
  - Electrode: 70 ksi
  - Complete Joint Penetration weld (CJP)
    - Length = 8 in
    - Size = 0.5 in
- Double Angle Connection: L3.5x3x1/4
  - Length = 8.5 in
  - Weld to column
    - Electrode: 70 ksi
    - Leg = 3in
    - Weld size = 0.25 in
  - Bolt to girder
    - ¾" dia STD hole A325 bolts
    - # bolts = 3 bolts (spaced 3 in on center)



Moment Connection – 2nd Level

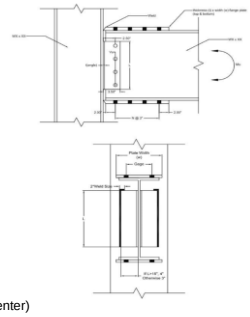
- Girder: W12x53
- Column: W10x68

- Mu = 239.01 k-ft
- Vu = 78.22 k



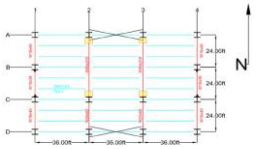
Moment Connection – 2nd Level

- Flange Plate:
  - t= 0.75 in
  - w = 10 in
  - Connection
    - 7/8" Dia A325 Bolts
    - n = 2 rows
    - # bolts per row = 10 (per flange)
    - Gage = 7 in
- Flange – Column Weld:
  - Electrode: 70 ksi
  - Complete Joint Penetration weld (CJP)
    - Length = 10 in
    - Size = 0.5 in
- Double Angle Connection: L3.5x3x1/4
  - Length = 11.5 in
  - Weld to column
    - Electrode: 70 ksi
    - Leg = 3in
    - Weld size = 0.25 in
  - Bolt to girder
    - ¾" dia STD hole A325 bolts
    - # bolts = 4 bolts (spaced 3 in on center)

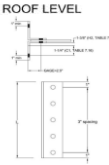


Shear Connection – Roof Level

- Use all **bolted** double angle connections
  - Pu = 295.97 k
  - n = 9 rows
  - ¾ in diameter bolts
    - STD Hole
    - Group A
    - Threads included
  - t, Angle = 3/8 in
  - # Spaces, N = 8
  - tw, Girder = 0.65 in
  - Gage = 2.5 in
  - Min edge dist = 1 in
  - Length of leg bolted to Girder = 3.5 in
  - Length of leg bolted to Column = 4 in
  - Angle Length = 26 in
- (2) 4 x 3.5 x 3/8 x 2'-2" Angles Used

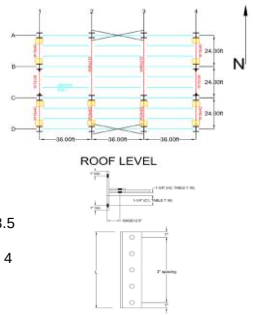


ROOF LEVEL



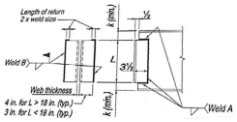
Shear Connection – Roof Level

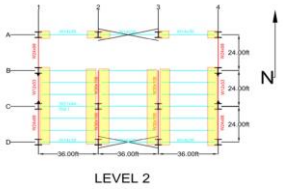
- Use all **bolted** double angle connections
  - Pu = 71.46 k
  - n = 4 rows
  - ¾ in diameter bolts
    - STD Hole
    - Group A
    - Threads included
  - t, Angle = 1/4 in
  - # Spaces, N = 3
  - tw, Girder = 0.43 in
  - Gage = 2.5 in
  - Min edge dist = 1 in
  - Length of leg bolted to Girder = 3.5 in
  - Length of leg bolted to Column = 4 in
  - Angle Length = 11 in
- (2) 4 x 3.5 x 1/4 x 11" Angles Used



Shear Connection – 2nd Level

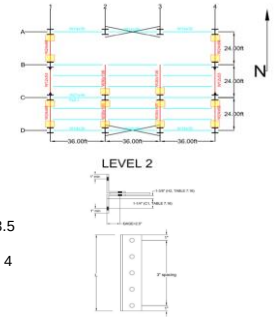
- Use all **welded** double angle connections
- Pu = 39.11 k
  - L = 6 in
  - Weld A = 3/16 in
  - Weld B = 5/16 in
  - Angle used: (2) L3.5x3x1/4 angl





Shear Connection – 2nd Level

- Use all **bolted** double angle connections
  - Pu = 156.44 k
  - n = 5 rows
  - ¾ in diameter bolts
    - STD Hole
    - Group A
    - Threads included
  - t, Angle = 3/8 in
  - # Spaces, N = 4
  - tw, Girder = 0.545 in
  - Gage = 2.5 in
  - Min edge dist = 1 in
  - Length of leg bolted to Girder = 3.5 in
  - Length of leg bolted to Column = 4 in
  - Angle Length = 14 in
- (2) 4 x 3.5 x 3/8 x 1'-2" Angles Used



Cost Estimation

- The cost of the project will be determined using R.S. Means Online Cost Estimating Tool.
  - Factors to consider
    - Material types
    - Sizes
    - Quantities (lengths, area, volume, weight etc.)
    - Location of project
    - Labor
- The type of cost estimation will be an engineer's estimation
  - Determine reasonable price point for this job

FINAL DRAWINGS

Presented by: Matt Laskey, E.I.T.

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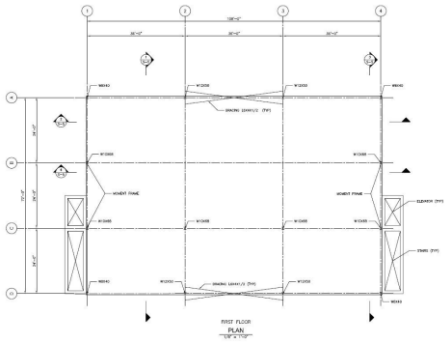
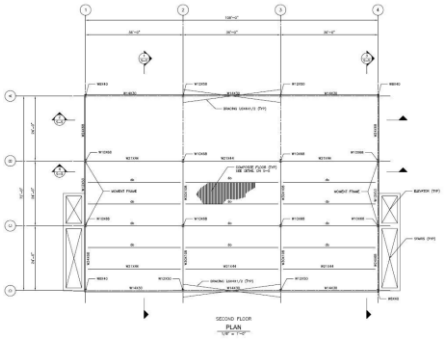
UMASS LOWELL

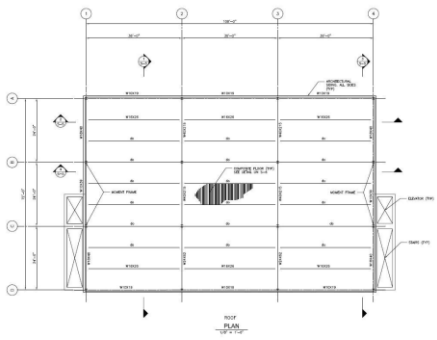
Drafting – 1st Floor Steel



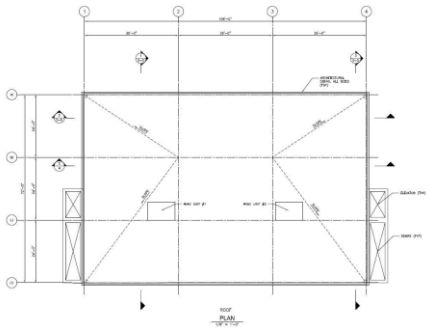
Drafting – 2nd Floor Steel



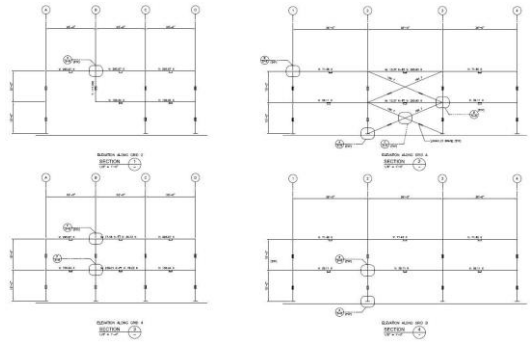
Drafting – 3nd Floor Steel



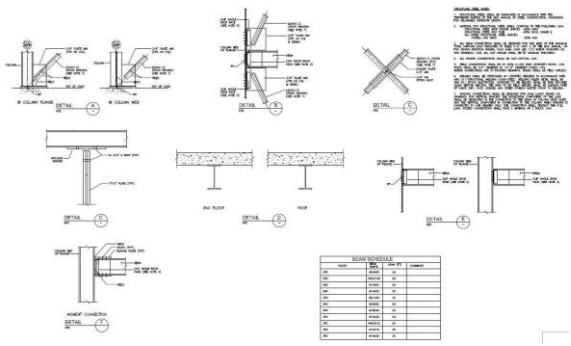
Drafting – Roof



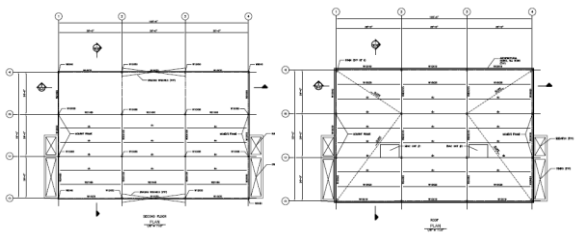
Drafting – Steel Sections



Drafting – Standard Details



DRAWINGS:



(a) (b)

Figure 7. (a) First Floor Plan **(b)** Roof Plan

DRAWINGS:

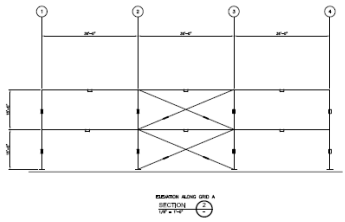


Figure 8. Elevation

QUESTIONS?

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