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Steel Construction | From the Mill to Topping Out

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AISC Night School

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AISC Night School

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Session Description

18.1 Introduction to the Steel Construction Process
October 15, 2018

All parties involved in the steel construction process play a critical role, from the office (structural design, connection design, and erection engineering), to the plant (steel production and fabrication), to the field (erection and quality assurance). Using the AISC Code of Standard Practice as a framework, this session discusses the team of contributors who are responsible for creating a structural steel building.

AISC Night School Learning Objectives

- Describe the roles and responsibilities of key team members on a structural steel project.
- Describe how understanding and integrating constructability into your building design leads to safe, efficient designs.
- Define the role the AISC Code of Standard Practice has in steel buildings.
- List the different relationship arrangements of team members based on the type of contractual agreement: design-bid-build, design-build, and design-detail.

Night School 18: Steel Construction

From the Mill to Topping Out
Session 1: Introduction to the Steel Construction Process
October 15, 2018 (The Team Behind the Building)

Andrew Twarek, PE, SE
Project Manager
Ruby+Associates, Inc. Structural Engineers
Bingham Farms, MI

Smarter. Stronger. Steel.

About Me

ruby+associates
STRUCTURAL ENGINEERS

ROSE-HULMAN FIGHTIN' ENGINEERS

SEAMi
Structural Engineers Association of Michigan

Night School 18

- 18.1 **Introduction** to the Steel Construction Process — Oct. 15
- 18.2 The **Manufacturing** of Structural Steel Shapes — Oct. 22
- 18.3 A Virtual, Detailed Tour of the **Steel Fabrication** Process — Oct. 29
- 18.4 **Connection Design** as the Fabricator's Representative — Nov. 5
- 18.5 It Doesn't Get Built Without the **Erector** — Nov. 19
- 18.6 **Erection Engineering** – Stability During Construction — Nov. 26
- 18.7 **Field Fixes** and Solutions — Dec. 3
- 18.8 **Quality** Control and Quality Assurance — Dec. 10

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1. The Team
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9. The Erector
10. The Erection Engineer
11. Quality Control

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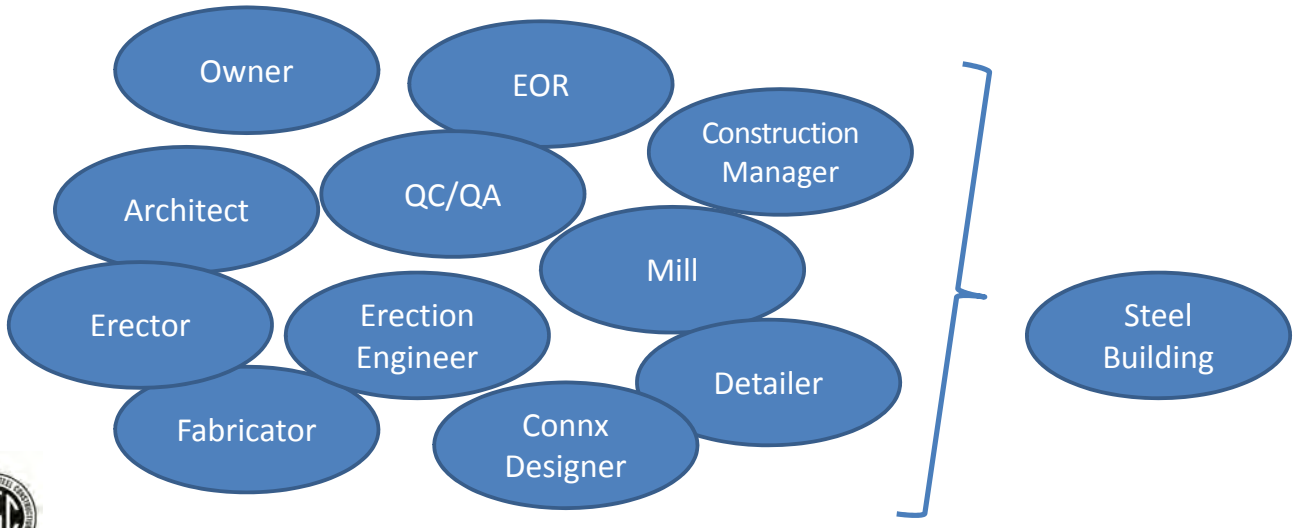
1. The Team



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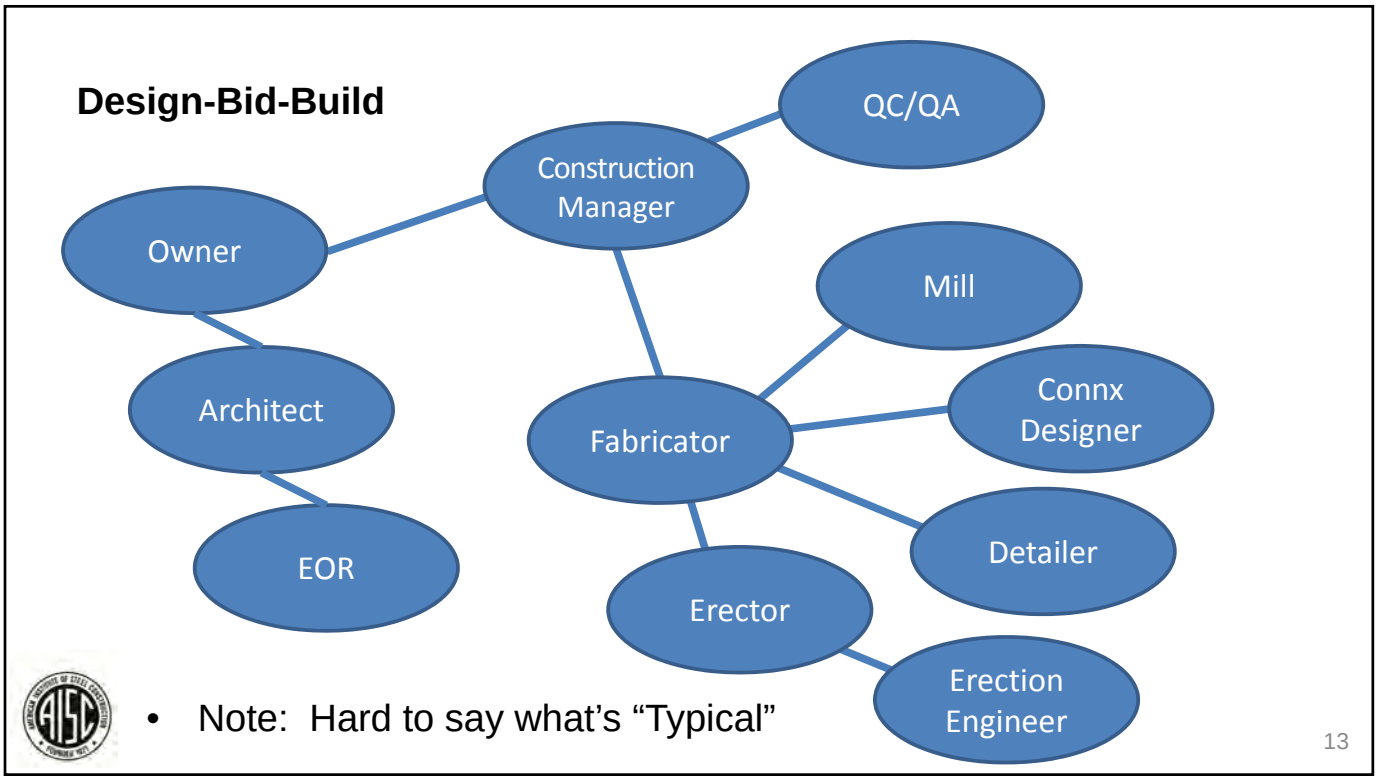
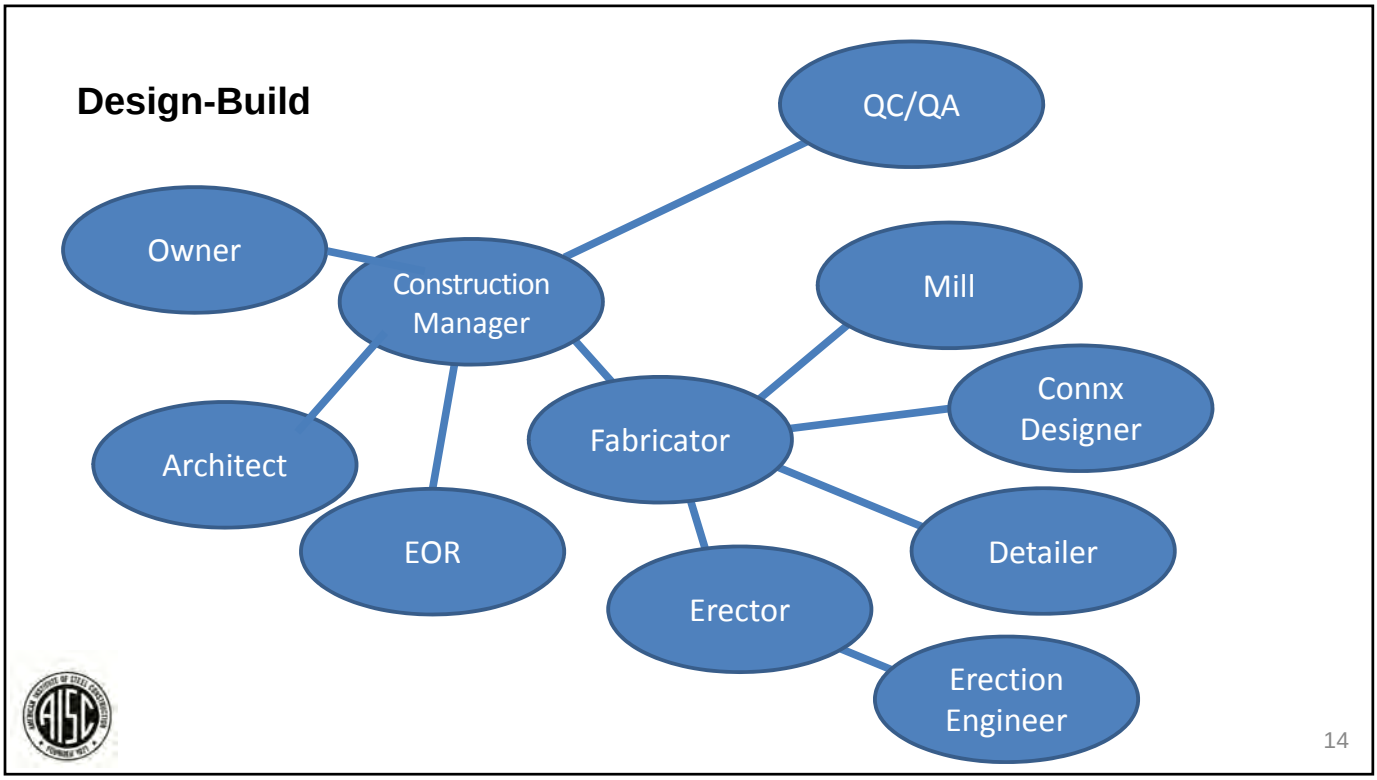
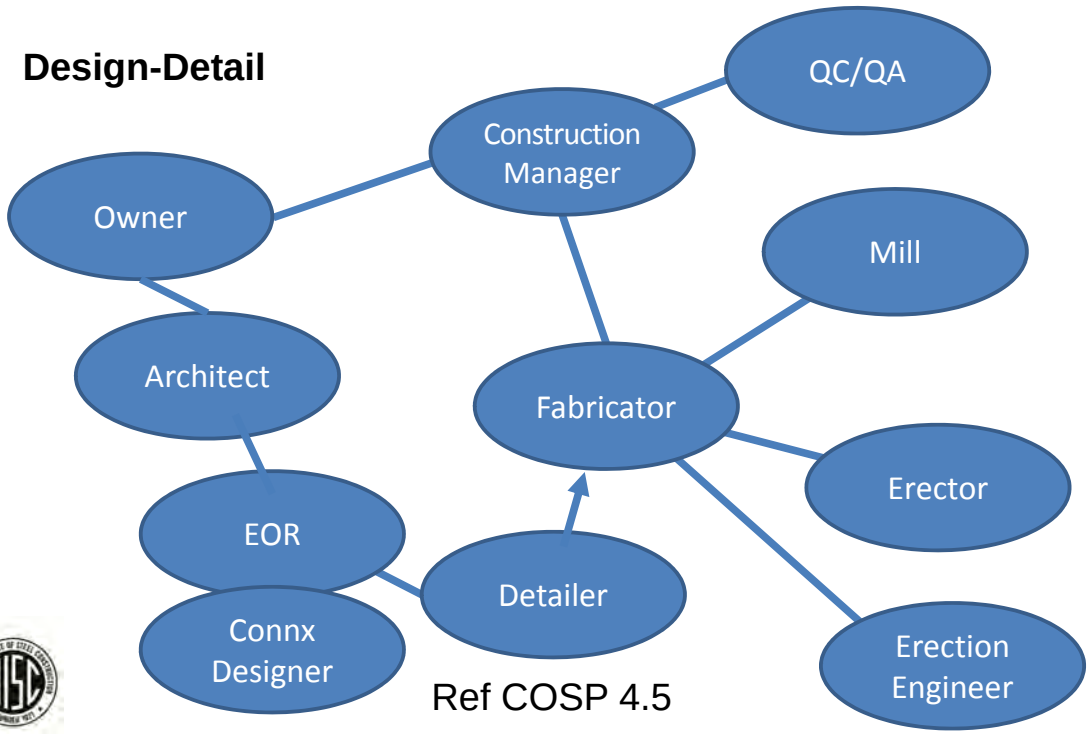




Design-Detail



Ref COSP 4.5

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Other Contractual Arrangements

- Fast Track Projects
  - Begin construction before design is complete
  - Not atypical on large projects
  - Design may be conservative (i.e. more costly) at front end, but shortens schedule
  - Occupancy = owner revenue
  - COSP 3.6
- Design-Fab
  - Fabricator both designs and fabricates
  - Typical for “Metal Building Systems” (Butler, Nucor)

www.nucorbuildingsystems.com

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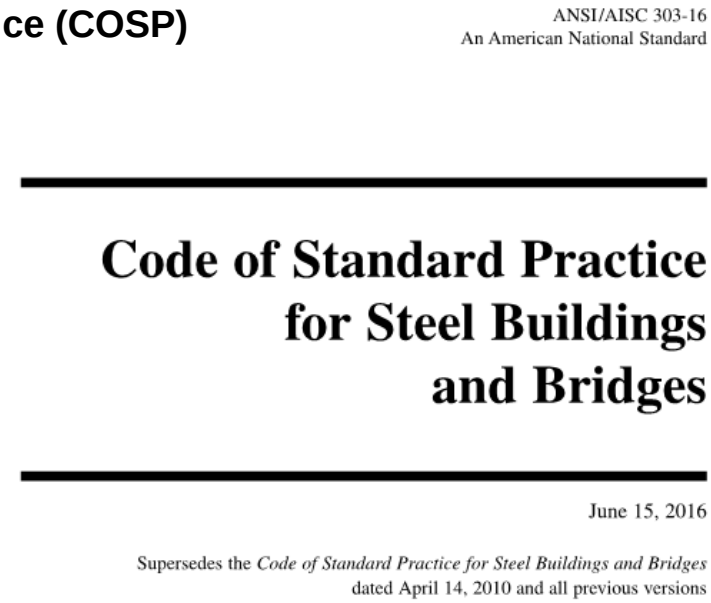
AISC Code of Standard Practice (COSP)

- Defines "…criteria for the trade practices involved in steel buildings…" (Sec. 1.1)
- Identifies who's responsible for what
- May be modified by contract documents


ANSI/AISC 303-16
An American National Standard

Code of Standard Practice for Steel Buildings and Bridges

June 15, 2016

Supersedes the *Code of Standard Practice for Steel Buildings and Bridges* dated April 14, 2010 and all previous versions

Approved by the Committee on the Code of Standard Practice

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What is Structural Steel?

COSP (or other document) Reference → Section 2.1

- Elements of the structural frame, shown & sized in the structural design documents, essential to support the design loads
- Normally furnished by fabricator

- Anchor rods
- Base plates*
- Beams*
- Bearing plates*
- Bracing, if permanent
- Columns*
- Connection materials
- Door frames*
- Embedded structural steel parts*
- Floor-opening frames*
- Girders*
- Girts*
- Leveling plates
- Posts*
- Purlins*
- Tie rods*

* "If part of/attached to the structural frame" or "if made from structural shapes or plates"
Note: See COSP for entire list

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What is NOT Structural Steel?

Section 2.2 MM1 DT4

- May be furnished by fabricator if contracted to do so

- Cables for permanent bracing
- Castings
- Cold-formed steel products
- Expansion joints*
- Flagpole support steel
- Gage-metal products
- Grating
- Handrail
- Ladders
- Lintels*
- Roof screen support frames*
- Stairs
- Steel deck
- Steel (open-web) joists
- Toe plates

* "If **not** part of/**not** attached to the structural frame," "if **not** made from structural shapes/plates"
Note: See COSP for entire list

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10. The Erection Engineer
11. Quality Control

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Slide 19

MM1 What does * indicate?
Michelle McCulloch, 10/9/2018

DT4 Added * to the statement at the bottom
Drew Twarek, 10/9/2018

2. The Owner/Architect

Responsibilities include:

- Determine size, configuration, performance criteria for building
- Provide life safety (maximum occupant load, vertical/horizontal circulation, exits, construction fire rating, etc.)
- Finishes (ceiling, floor, wall covering, furniture layouts and selection, door/window schedule)
- Determine contract arrangement
- Pay for building

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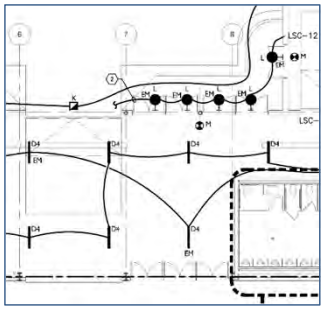
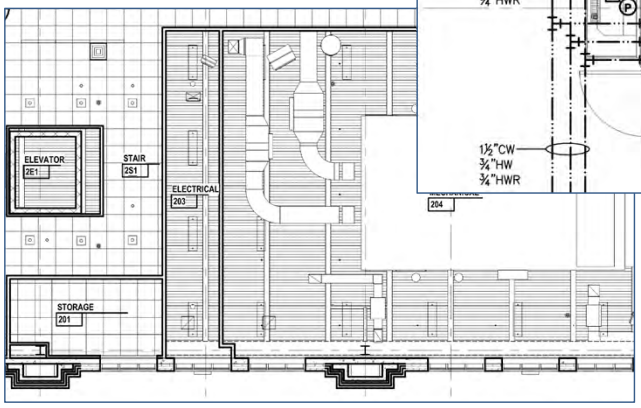
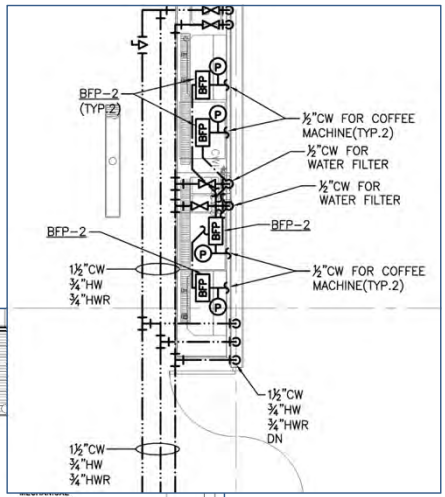
Other Trades

- Civil (earthwork)
- Electrical
- HVAC (heating, ventilating, air conditioning)
- Plumbing







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Constructability

- Ability to influence the cost and quality of construction over the life of a project
- Cost and schedule impacts of making changes

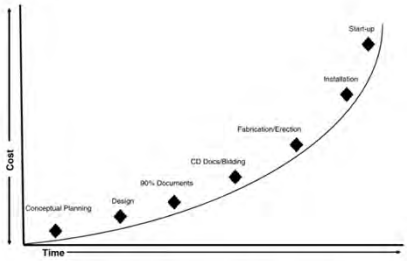
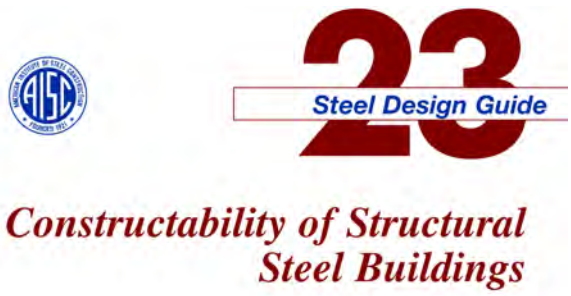
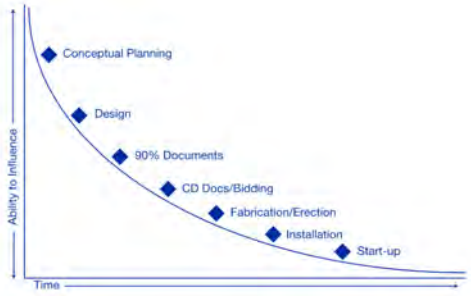


Fig. 1-2. Cost of change over time.





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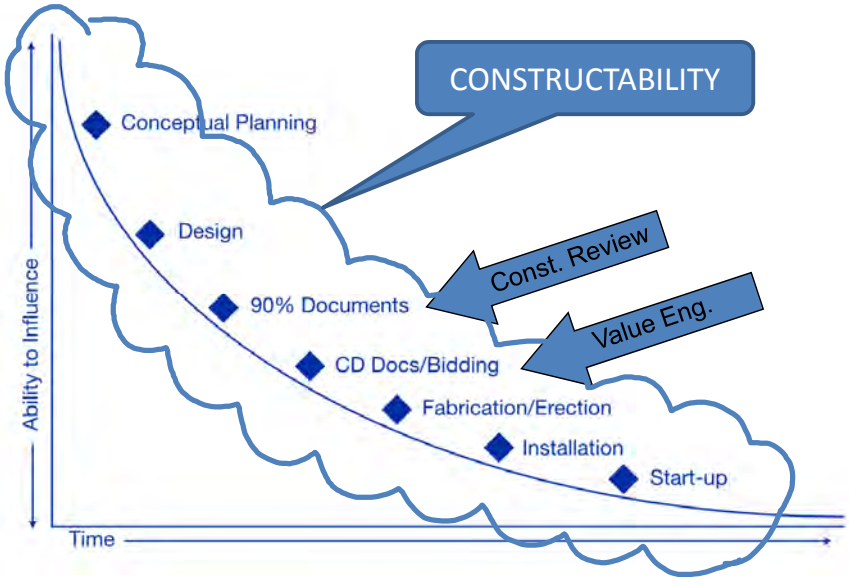
MM2

Constructability



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Slide 24

MM2 Drew, I've been helping DIR revamp an older but still valide Constructability presentation. Use some of the content from this pres for this slide/s: M: Presentations: DG 23 Chapters 1-2 2018.pptx
Michelle McCulloch, 10/9/2018

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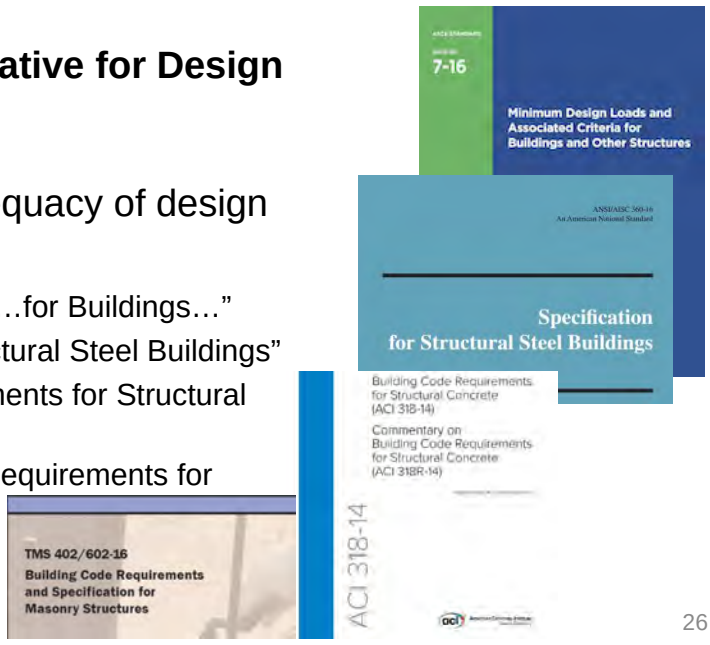
3. The ODRD

Section 3

Owner's Designated Representative for Design

- Engineer of Record (EOR)
- Responsible for structural adequacy of design (Building Code Compliance)
  - ASCE7 "Minimum Design Loads…for Buildings…"
  - AISC 360 "Specification for Structural Steel Buildings"
  - ACI318 "Building Code Requirements for Structural Concrete"
  - MSJC/TMS402 "Building Code Requirements for Masonry Structures"
  - Etc.



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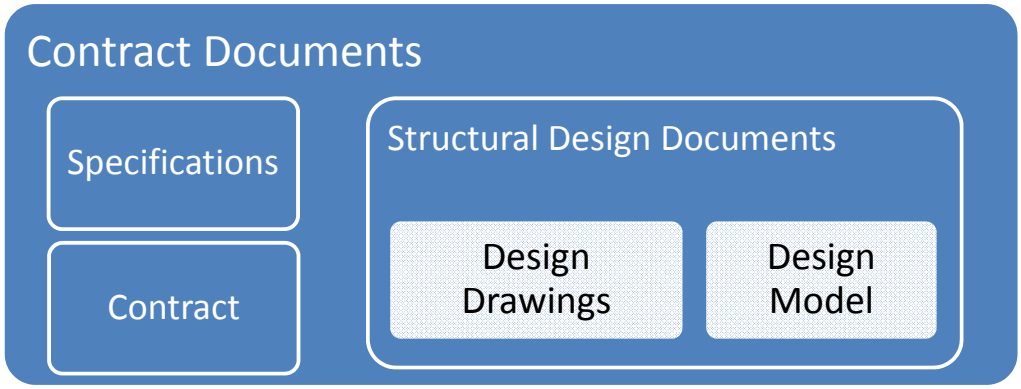
Contract Documents

Section 3.1

- Define responsibility of the parties involved in bidding, fabricating, erecting structural steel



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Design Documents

- Schematic Design (SD)
  - Rough sketches and analysis to determine project scope, estimated costs
- Design Development (DD)
  - Engineering design, usually issued in sets (50%DD, 75%DD) to coordinate with owner, architect, other trades, as design is firmed up
  - Mill order – sometimes issued prior to CDs so fabricator can begin to source steel directly from mill
- Construction Documents (CD) – Bid Set
  - Design should be complete with all information fabricator and erector need to provide accurate and complete bids to owner
- Revisions

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Design Documents

Section 3.1

- Basic Requirements (bare minimum)
  a) The size, section, material grade and location of all members.
  b) All geometry and working points necessary for layout.
  c) Floor elevations.
  d) Column centers and offsets.
  e) The camber requirements for members.
  f) Preset elevation requirements, if any, at free ends of cantilevered members relative to their fixed-end elevations.
  g) Joining requirements between elements of built-up members.
  h) Information required by AISC341 Section A4.
- Special limitations, fab/erect tolerances, AESS* (Section 10)

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Design Documents

Section 3.1

- Connection Design Information (3.1.1)
  - Three options (More later!)
- Lateral Force Resisting System (7.10.1)
  - Must define the LFRS and connecting diaphragm elements (both steel and nonsteel) so stability of the structure is clearly understood.
- Non-Structural Steel Elements in LFRS (3.1.4)
  - "When the [completed] structural steel frame…requires interaction with non-structural steel elements (see Section 2) *[sic]* for strength and/or stability, those non-structural steel elements shall be identified in the contract documents as required in Section 7.10."

All lateral force resistance and stability of the building in the completed structure is provided exclusively by cast-in-place reinforced concrete shear walls in the building core and stairwells (see plan sheets for locations). These walls provide all lateral force resistance in each orthogonal building direction. The composite metal deck and concrete floors serve as horizontal diaphragms that distribute the lateral wind and seismic forces horizontally to the concrete shear walls. The concrete shear walls carry the applied lateral loads to the building foundation.

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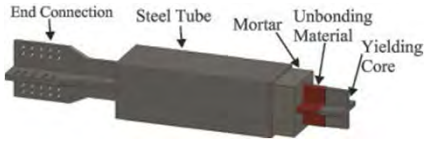
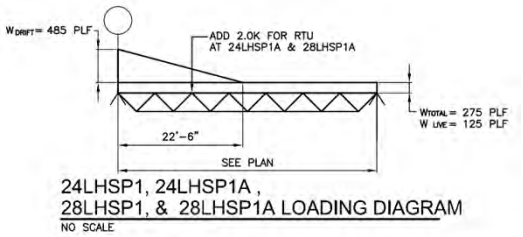
Design Documents Section 3

- Criteria for Specialty Structural Engineer (SSE)
  - Load, deflection, performance requirements for “buy out” items such as:
  - Joists
  - Proprietary Connections
    - Structural Castings
    - Manufactured Moment Connections
    - Buckling-Restrained Braces



Buckling restrained brace, sciencedirect.com



Example joist special loading diagram

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4. The ODRC

Owner's Designated Representative for Construction

- General Contractor (GC)
- Construction Manager (CM)
- Responsible for "…the overall construction of the project, including its planning, quality, and completion." (Glossary)
- Maintains latest contract documents and other information flow and Requests for Information (RFI's) between parties
- Manages construction budget

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ODRC

Section 7

- Provides material access and workable jobsite conditions
- Also responsible for prepwork:
  - Foundations,
  - Lines & benchmarks
  - Anchor bolts installation
  - Leveling plates/loose base plates (not requiring a crane)
- Column base grouting

Photo by Ben Hur, Inc.

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5. The Mill

- Responsible for transforming raw materials into new steel, controlling chemistry, creating (rolling) shapes suitable for steel construction
- Uses iron (produced from ore in a blast furnace) and/or scrap steel
- Iron – more than 2% carbon
- Steel – 0.05% - 1% carbon (structural typically less than 0.25%)

Photo by Rio Grand Guardian

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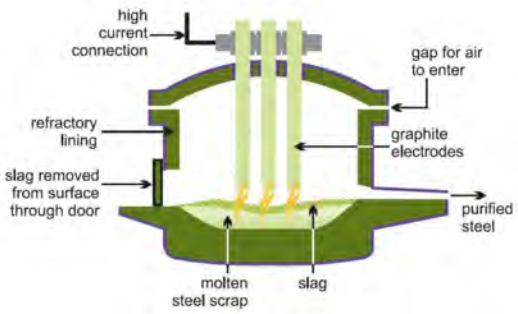
Steel Production Process

- Electric Arc Furnace –
  - "Minimill" – smaller batches made using mostly scrap steel
  - Virtually all of US structural shape production
  - Much more adaptable to vary production
  - Can be located near markets



www.sfsa.org/sc3/downloads/E14_Steel Castings in Architecture.pdf (NASCC 2017)

Photo by Steel Dynamics

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Steel Recycles!

- Structural steel production in US averages 93% recycled scrap steel
- At the end of a building's life, 98% of all structural steel is recycled into new steel products

(statistics by AISC)

Recycled Content – LEED 2009 MR 4; LEED v4 MR Credit: Sourcing of Raw Material

2017 Recycled Steel Content of Nucor Products (% by Total Weight)	
Product Group	**Average Recycled Content**
Nucor Bar Products	96.1%
Nucor Engineered Bar Products	86.5%
Nucor Beam Products	80.7%
Nucor Plate Products	63.1%
Nucor Sheet Products	58.9%
Nucor Castrip®	86.0%
Total Nucor Steel Combined	**72.6%**
Vulcraft Structural Products	96.1%
Vulcraft / Verco Decking	58.9%
Nucor Grating / Fisher-Ludlow Grating	96.1%
Nucor Building Group	72.6%
Harris Rebar	96.1%
Nucor Fastener Products	96.1%
Nucor Wire Products	96.1%
Nucor Cold Finish	86.5%

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Steel Production Process Flow Sheet

Night School 18.2!

Courtesy of Nucor Yamato

Scrap Yard

EAF (Melting)

LMF (Refining)

Caster (Liquid-Solid)

Semi-Finished

Reheat (Hot-Bloom)

Rolling (Forming)

Quality Check

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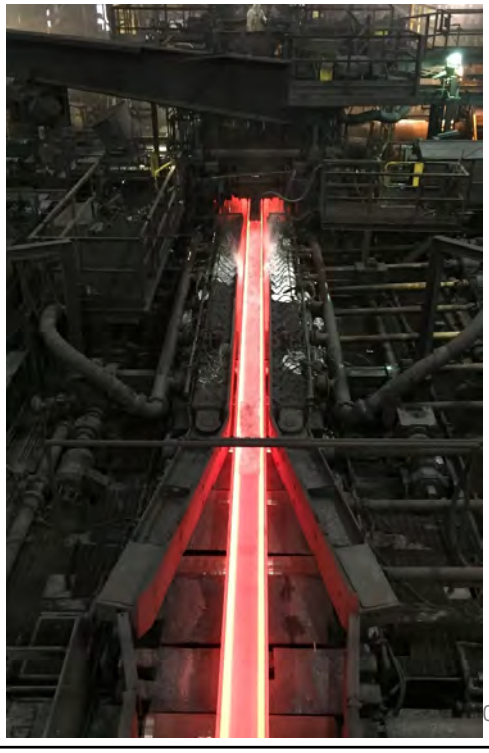
Steel Production Process

- Rolling a W14x176



Photos courtesy of Nucor

Steel Production Process

Photo courtesy of Nucor

View from the gondola

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Steel Chemistry (A992 maximums, e.g.)

• Carbon	0.23%	Fundamental ingredient in steel. Increases yield strength, hardness
• Silicon	0.4%	Deoxidation, increases tensile strength
• Vanadium	0.15%	Finer grains, less weldability, better wear resist
• Sulfur	0.045%	Can cause cracking
• Manganese	~1%	Neutralizes sulfur, deoxidation
• Nickel	0.45%	Reduce brittleness, increase toughness
• Chromium	0.35%	Hardening, corrosion resistance (high amounts)
• Molybdenum	0.15%	Hardening, increase tensile strength

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Preferred Grades

- Wide Flange – ASTM A992
- HSS – ASTM A500 Gr. C or A1085
- A36 still default steel for:
  - Standard and Misc. I shapes
  - Channels and MCs
  - Angles
- Plate
  - ASTM A36 or ASTM A572 Gr. 50
  - Often no surcharge for 50 ksi plate
  - No reason not to take advantage of it!

Table 2-4
Applicable ASTM Specifications for Various Structural Shapes

Steel Type	ASTM Designation		F_y Yield Stress[a] (ksi)	F_u Tensile Stress[a] (ksi)	Applicable Shape Series: W	M	S	HP	C	MC	L	HSS: Rect.	Round	Pipe
Carbon	A36		36	58–80[b]	■	■	■	■	■	■	■			
	A53 Gr. B		35	60										■
	A500	Gr. B	42	58										
			46	58								■		
		Gr. C	46	62									■	
			50	62								■		
	A501	Gr. A	36	58								■	■	
		Gr. B	50	70								■	■	

Table 2-5
Applicable ASTM Specifications for Plates and Bars

Steel Type	ASTM Designation		F_y Yield Stress[a] (ksi)	F_u Tensile Stress[a] (ksi)	Plates and Bars, in.: to 0.75 incl.	over 0.75 to 1.25 incl.	over 1.25 to 1.5 incl.	over 1.5 to 2 incl.	over 2 to 2.5 incl.	over 2.5 to 4 incl.	over 4 to 5 incl.	over 5 to 6 incl.	over 6 to 8 incl.	over 8
Carbon	A36		32	58–80										
			36	58–80	■	■	■	■	■	■	■	■	■	
	A283[e]	Gr. C	30	55–75					[d]					
		Gr. D	33	60–80					[d]					
	A529	Gr. 50	50	65–100		[b]	[b]	[b]	[b]	[b]				
		Gr. 55	55	70–100		[c]	[c]	[c]	[c]	[c]				
	A709	Gr. 36	36	58–80										
	A572	Gr. 42	42	60										
		Gr. 50	50	65	■	■	■	■	■	■				
		Gr. 55	55	70										

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Preferred Grades

Bolts

- Group A - 120ksi
  - A325, A325M, F1852
- Group B - 150ksi
  - A490, A490M, F2280
- Group C - 200ksi
  - “XTB”, ASTM F3043 and F3111
- ASTM F3125 Grade A325, e.g.

Table 2-6
Applicable ASTM Specifications for Various Types of Structural Fasteners

ASTM Designation		F_y Min. Yield Stress (ksi)	F_u Tensile Stress[a] (ksi)	Diameter Range (in.)	Bolts: High-Strength: Conventional	High-Strength: Twist-Off-Type Tension-Control	Bolts: Common Bolts	Nuts	Washers: Hardened	Washers: Plain	Washers: Direct-Tension Indicator	Threaded Rods	Anchor Rods: Hooked	Anchor Rods: Headed	Anchor Rods: Threaded & Nutted
F3125	Gr. A325[f]	–	120	0.5 to 1.5	■										
	Gr. F1852[g]	–	120	0.5 to 1.25		■									
	Gr. A490[f]	–	150	0.5 to 1.5	■										
	Gr. F2280[g]	–	150	0.5 to 1.25		■									
F3111		–	200	1 to 1.25 incl.	[h]										
F3043		–	200	1 to 1.25 incl.		[h]									
A194 Gr. 2H		–	–	0.25 to 4				■							
A563		–	–	0.25 to 4					■						
F436		–	–	0.25 to 4[b]						■					
F844		–	–	any							■				
F959		–	–	0.5 to 1.5								■			
A36		36	58–80	to 10								■	[i]	[i]	[i]
F1554	Gr. 36	36	58–80	0.25 to 4								[i]	■	■	■
	Gr. 55	55	75–95	0.25 to 4								[i]	■	■	■
	Gr. 105	105	125–150	0.25 to 3								[i]	[i]	[i]	[i]

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Steel Availability

- AISC website lookup
- More producers = more common
- May still need to check rolling schedule

https://www.aisc.org/steelavailability/search-results/?shape=W||A7

AISC MEMBERS

W Shapes	Grade	Gerdau AmeriSteel	Nucor-Berkeley	Nucor-Yamato Steel Co.	Steel Dynamics
4 x 13 x 4	A992	✓	✓		✓
4 x 13 x 4	A709				✓
5 x 16 x 5	A709				✓
5 x 16 x 5	A992		✓		✓
5 x 19 x 5	A992		✓		✓
5 x 19 x 5	A709				✓
6 x 8.5 x 4	A709				✓
6 x 8.5 x 4	A992	✓	✓		✓
6 x 9 x 4	A992	✓	✓		✓
6 x 9 x 4	A709				✓
6 x 12 x 4	A709				✓
6 x 12 x 4	A992	✓	✓		✓

Rolling Schedules / Advanced Bill of Materials (ABM)

- Shapes only rolled every several weeks
- To get “first choice” of mill products, fabricator must purchase via mill order. Important to get accurate ABM from fabricator. EOR must lock member sizes, lengths.

Nucor-Yamato Proposed Roll/Close Schedule * ISO 9001:2015 Registered * October 10, 2018

Inquire items are followed immediately by the last order date of the book week if available --- Highlighted items will close in the next week

Week Beginning		7-Oct	14-Oct	21-Oct	28-Oct	4-Nov	11-Nov	18-Nov	25-Nov	
NYS Fiscal Week		41	42	43	44	45	46	47	48	
Wide Flange Sections	Mill #									Projected next roll week
W44x16x230-335	2							47 I		1/27-2/3 Wks
W40x16x199-593	2							47 I		1/27-2/3 Wks
W40x12x149-392	2		42 C					47 I		12/23-12/30 Wks
W36x17x487-652	2								48 I	1/27-2/3 Wks
W36x16.5x231-441	2		42 C	42 C					48 I	12/23-12/30 Wks
W36x12x135-256	2			42 C					48 I	12/23-12/30 Wks
W33x15.75x201-387	2			42 C					48 I	12/23-12/30 Wks
W33x11.5x118-169	2			42 C					48 I	12/23-12/30 Wks
W30x15x173-433	2			43 C					48 I	12/23-12/30 Wks
W30x10.5x90-148	2			43 C					48 I	12/23-12/30 Wks
W27x14x146-368	2			43 C	43 C				48 I	12/23-12/30 Wks
W27x10x84-129	2				43 C				48 I	12/30-1/6 Wks
W24x12.75x104-370	2				44 C					12/2-12/9 Wks
W24x9x56-103	2				44 C	44 C				12/2-12/9 Wks
W24x7x55-62	1					45 I 10/22				12/23-12/30 Wks
W21x12.25x101-275	2					44 I 10/15				1/6-1/13 Wks

I = Inquire O = Open PS = Planned Stock SA = Subject to Accumulation E = Controlled C = Closed

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Service Centers

- Steel not purchased via mill order may come from fabricator stock or steel service center
- Expensive to keep stockpile of steel in fabricator's yard
- Service center can order in bulk, pass along savings (along with warehousing, handling costs)
- Service center may sell steel marked, cut to length, ready for fab

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https://www.ryerson.com/services/what-we-do

Outline

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10. The Erection Engineer
11. Quality Control

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6. The Fabricator

Section 6

- Turns steel stock into assemblies for site installation
- Main point of contact for steel supply per COSP
  - Sources steel, as well as other “buy out” items like bolts
  - Usually holds contract for connection designer and detailer
  - Must sequence work with erector to avoid storing too much material (especially at a busy jobsite)

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Fabrication Process

Night School 18.3!

- Quick overview of fabrication shop stations
- Shops vary in level of complexity and automation – everywhere between fully manual and fully computer-controlled
- Photos courtesy of Voortman and Cianbro Corporation

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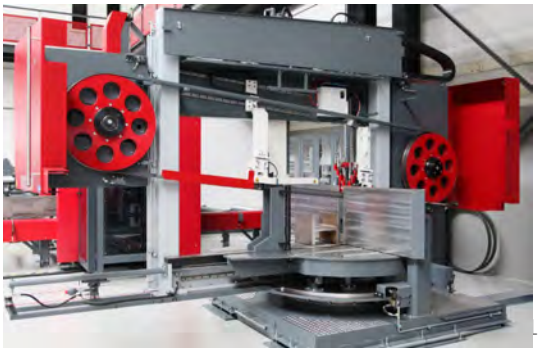
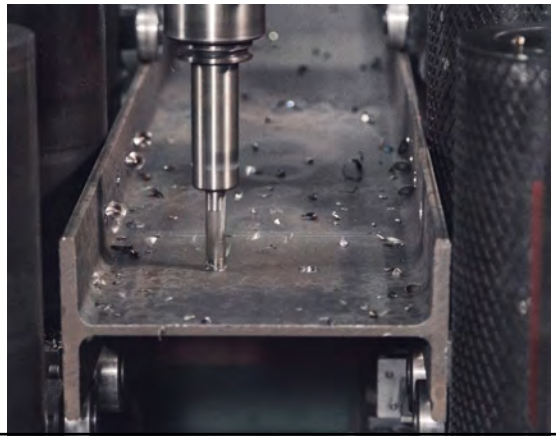
Cutting – Bandsaw



Holes – Drilling



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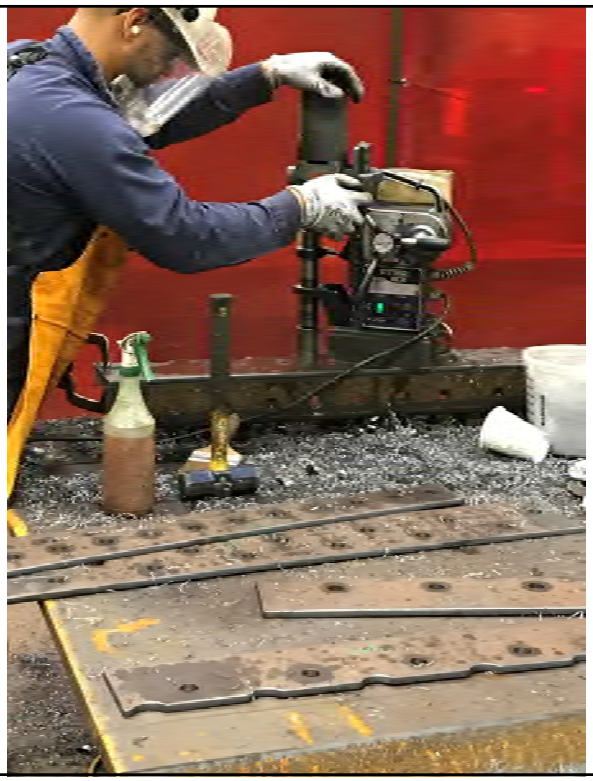
Holes – Drilling



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Holes – Punching (and Shearing)

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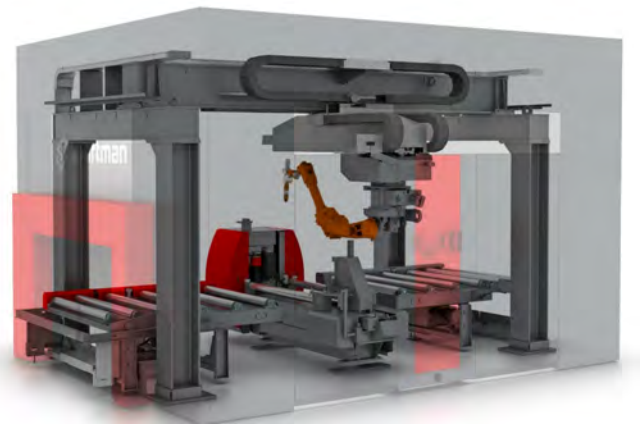
Coping



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Coping

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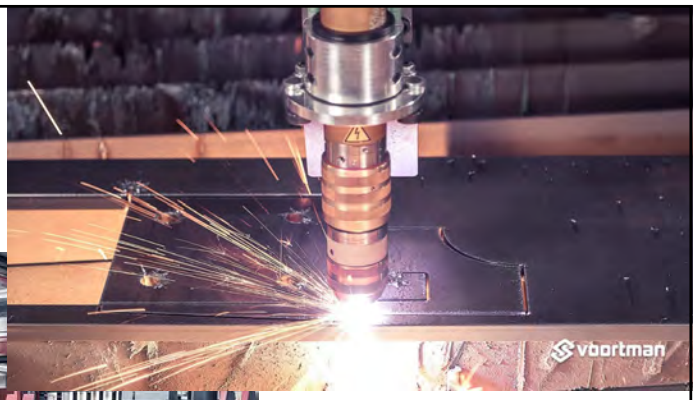
Plate Work – Plasma Table



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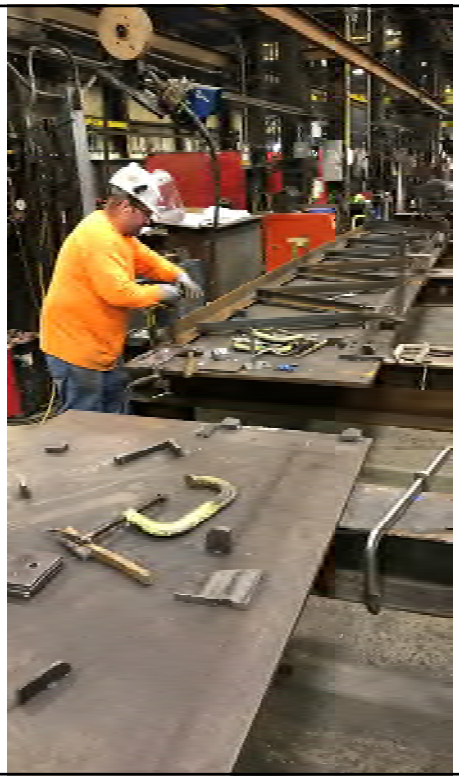
Layout



Welding

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Blasting

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Painting

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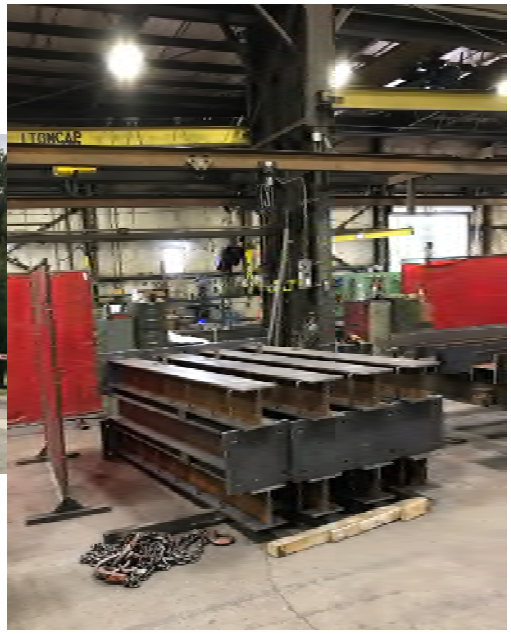
Shipping



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7. The Detailer

Section 4

- Produces *approval documents* for structural steel from ODRD design documents
- Structural steel shop drawings & erection drawings—and/or digital fabrication & erection models
- Often hired by fabricator – Can work to the strengths of the fabricator (shop welded vs. shop bolted, connection types, marking scheme, phasing/sequencing)
- Input from connection designer

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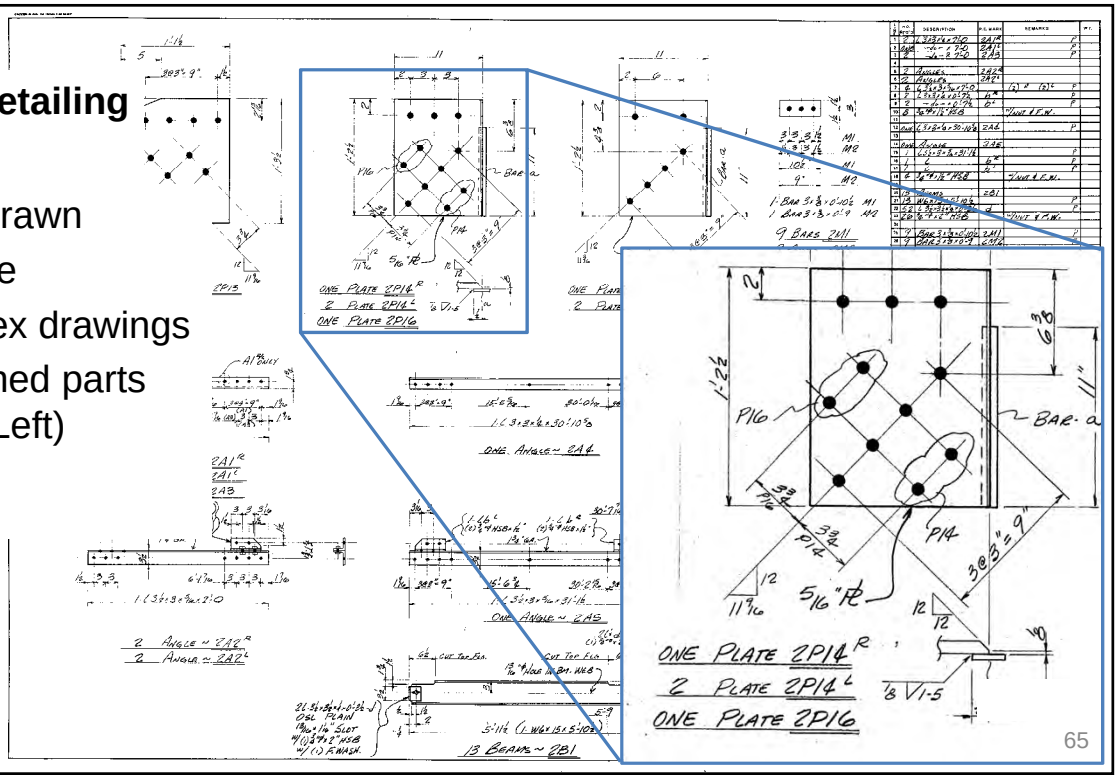
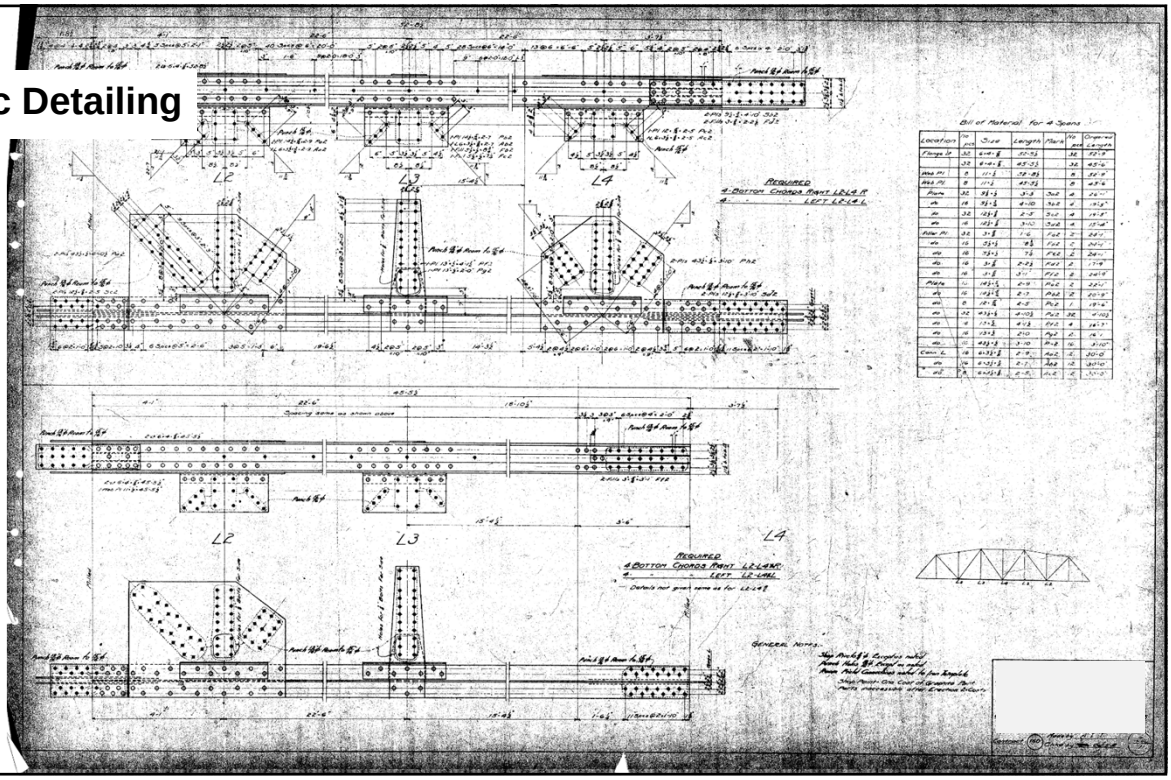
Historic Detailing

- Hand drawn
- To scale
- Complex drawings
- Combined parts (Right/Left)

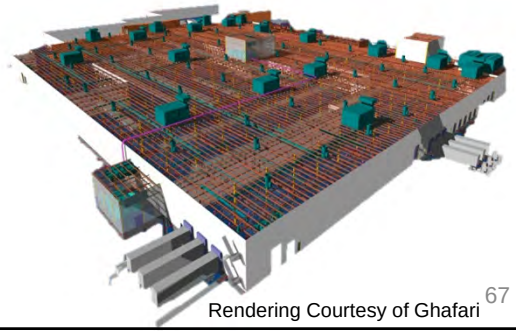


Historic Detailing



Modern Detailing

- BIM = Building Information Modeling
- Full steel structure modeled in 3D software (Tekla, SDS/2)
  - Sometimes using input from design model, but often built from scratch
- Phasing, scheduling can be built in via user-defined attributes
- Computer-generated drawings are a “snapshot” of the model
- Many thousands of drawings, transmitted and reviewed electronically
- Coordinate with other trades working in 3D



Rendering Courtesy of Ghafari

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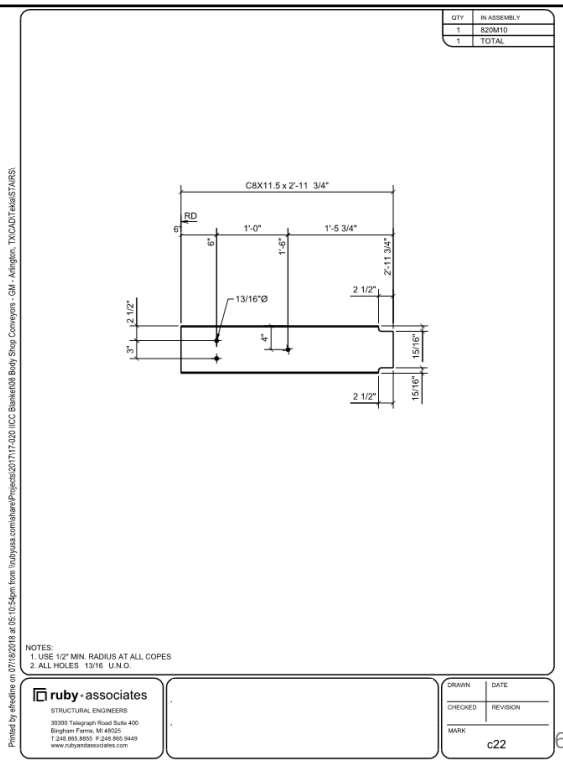
Part Drawings

- Show information required to fabricate a single piece of steel (gusset plate, connection angle, etc)
- Gather sheet – collection of part details
- Computer generated CNC files, DXF files



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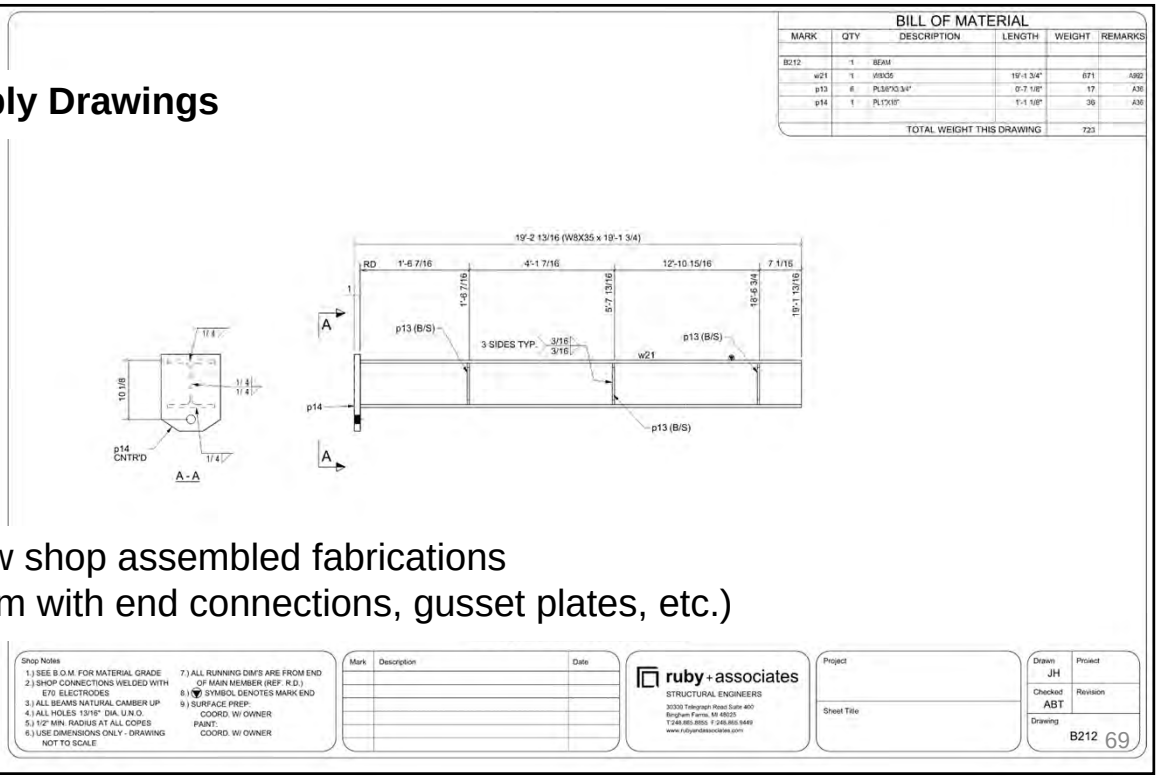
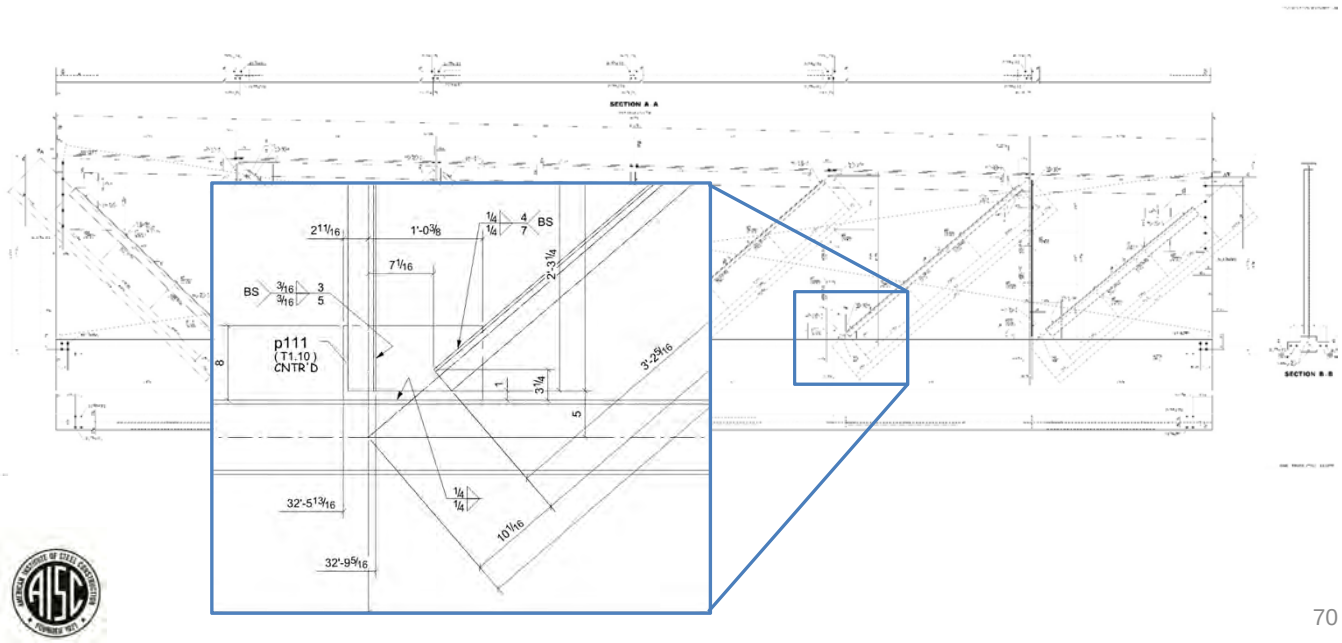
Assembly Drawings



- Show shop assembled fabrications (beam with end connections, gusset plates, etc.)

Truss Drawing



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Erection Drawings

- Instructions for field installation
- Show enough detail that erector can put everything in place and connect it, but no “design” information

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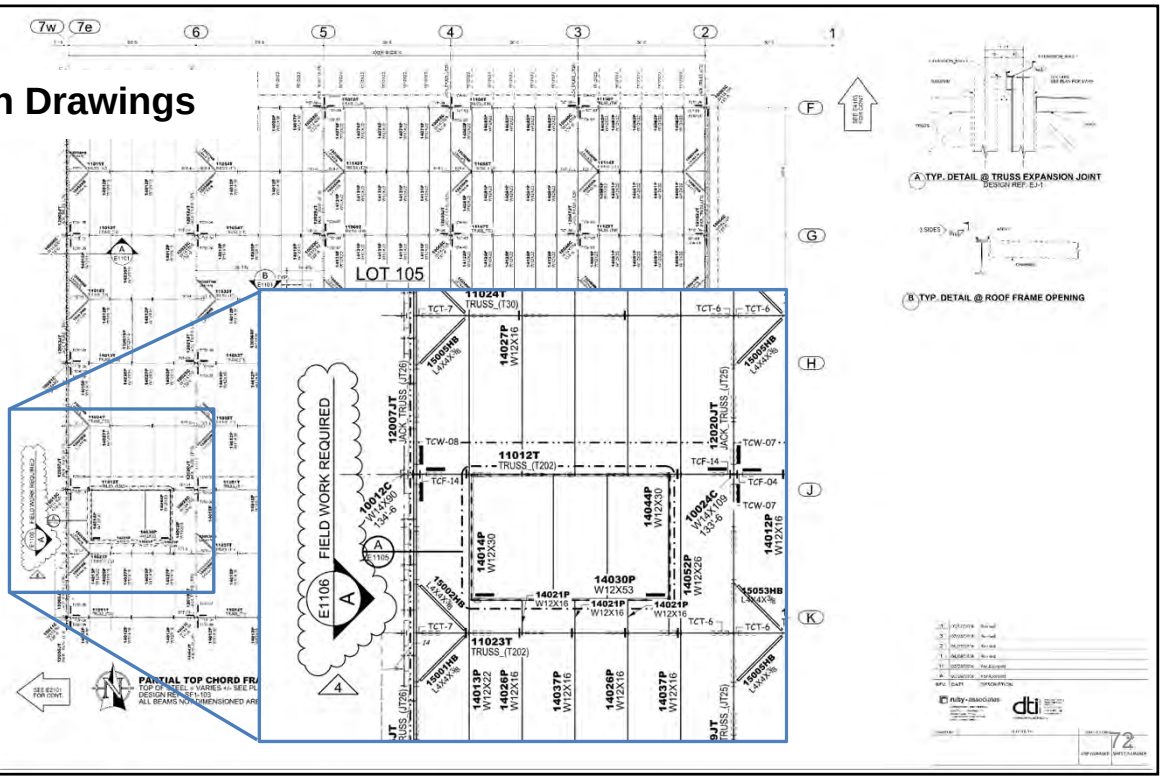
Erection Drawings



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Approval Document Review Section 4

- Owner required to deliver design documents
  - Expected to be “Frozen” or “Locked Layout” so detailing can proceed smoothly
- Fabricator required to produce approval documents
- Shop detail drawings and E-sheets – or model can be used as approval document and reviewed along with/instead of drawings
- Reviewed by ODRD & ODRC (Sec. 4.4)
  - Confirmation fabricator has correctly interpreted contract documents
  - Confirmation ODRD has reviewed & approved connection details
  - Release to begin fabrication
- Fabricator still responsible for accuracy of dimensions, general fitup

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8. The Connection Designer

Night School 18.4!

- Designs connections…
- Can be provided in-house by EOR, or contracted by owner, fabricator, or detailer

AISC Steel Sculpture, Polytechnic University of Puerto Rico

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Three Connection Design Options

Section 3.1.1

- Option 1: The complete connection design shall be shown on the structural design documents.
- Option 2: The connection shall be designated to be selected or completed by an experienced steel detailer.
- Option 3: The connection shall be designated to be designed by a licensed engineer.
  - Option 3A vs 3B

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Option 1 – Shown on design documents

- Connection design performed as part of the EOR team
- Almost always used on west coast, especially in seismic design where EOR needs more control of connections

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Option 2 – Selected/completed by detailer

- EOR to provide:
  - Loads that are to be resisted at each connection
    - "% of UDL" (% of maximum capacity per AISC load tables) is discouraged
  - Whether LRFD or ASD is to be used
  - Any restrictions on the types of connections permitted
  - What substantiating information must be provided with approval documents
- Loads can be provided on drawings, tables, or in design model.
- Intent is that detailer selects connection materials from tables (AISC Manual section 9, e.g.)
- Per commentary, not intended "…when the practice of engineering is required."

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Option 3 – Delegated Connection Design

- During the 1960s, fabricators were switching from rivets to bolts and welding, and offered to EORs that they could design their own connections
- Why delegate?
  - Connections can be hard! Connection design can be very specialized
  - Fabricators have different preferences
  - Take advantage to provide economy to project
- Finally added to COSP in 2010

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Option 3A/3B – Member Reinforcing

Section 3.1.2

- Member reinforcing ≠ connection design
- EOR **shall** provide design of web openings, bearing stiffeners, doublers, and other reinforcement **away** from connections
- **Option 3A** – EOR designs all member reinforcement at connections
- **Option 3B** – EOR provides project-specific conceptual details and estimated quantity for bidding purposes
- "Clean Columns" may save cost over reinforcing
  - AISC Spreadsheet at www.steeltools.org/column.php

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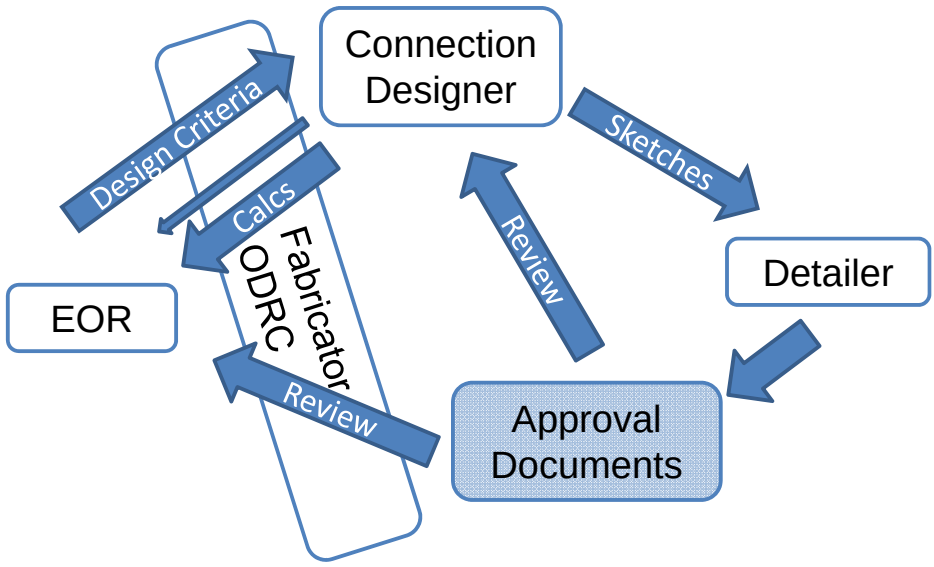
Option 3 – Approval Documents

Section 3.1.1(3)



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Option 3 – Delegated Connection Design

- May be used for only a portion of the design
  - Shear connections may be selected from tables or computer-designed (SDS/2, Qnect, Giza, etc.)
  - Bracing or truss connections are commonly delegated
- Substantiating information may vary from a signed and sealed cover letter, to full calculation package
  - Representative samples reviewed before preparation of full set
- Each sheet of shop and erection drawings should not be sealed by a PE (Commentary 3.1.1(3))

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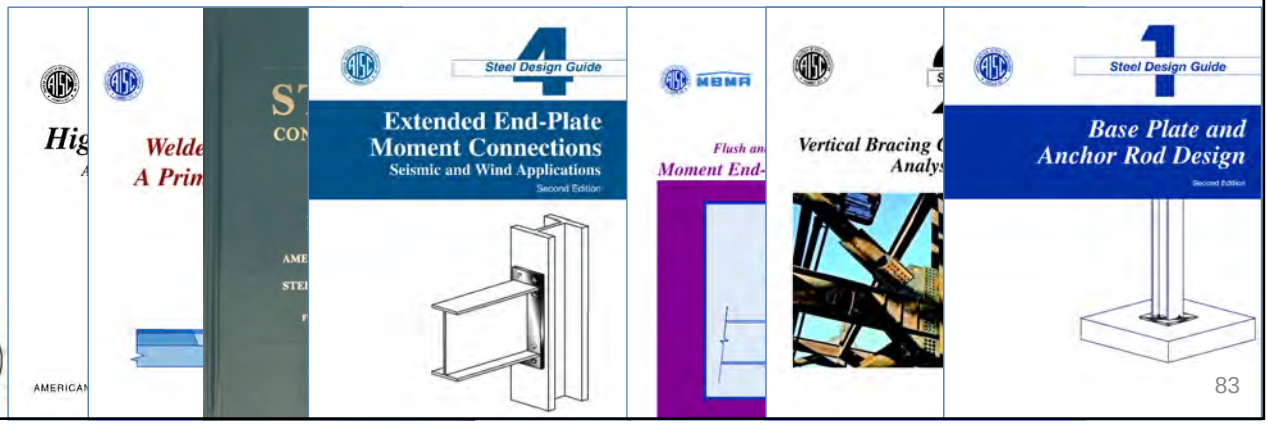
Types of Connections – Reference Information

www.aisc.org/dg

- Bolts
- Welds
- Simple Shear
- Moment
- Bracing
- Column Base



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Coordination with Fabricator

- Connection designer must work closely with fabricator, detailer, and erector (and EOR) to provide efficient designs
  - Bolt sizes & grades: Maintain few bolt types, preferably each type is a different size, preferably skip 1/8" increments
    e.g. 3/4" dia. Group A and 1" dia. Group B
  - Hole types: Standard, short slot, or oversized for ease of erection
  - Welding preferences: Shop or field, preferred process and groove type
  - Shear connection preferences: single angle, shear tab, extended shear tab
  - Moment connection preferences: flange plate vs direct, welds vs bolts, etc.

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9. The Erector

Night School 18.5!

- "The erector shall be responsible for the means, methods, and safety of erection of the structural steel frame" (Section 1.9)
- Section 7, "Erection," starts with a list of responsibilities of the ODRC before the erector can begin

Ruby+Associates

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Means, Methods, and Safety of Erection

- "'Means and methods' refers to the approach to or manner of construction, including amount of labor, material, and equipment necessary to implement the selected technique adopted by the contractor to perform work. In general, a contractor's 'means and methods' refers to the course of construction undertaken by the contractor." (American Bar Association, via AISC)
- Erection engineering – helps erector determine his/her 'approach' and 'manner' and provides stability of the structure during erection.

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Tolerances

Section 7.13

- A major portion of the COSP defines erection tolerances
- These tolerances are coordinated with fabrication tolerances (Section 6.4), with other trades (concrete, façade, etc.) and with design practices
  - Direct analysis notional load 0.002Y comes directly from H/500 maximum out of plumbness of the constructed structure
- These tolerances haven't changed significantly since 1959
  - The owner/EOR/ODRC shouldn't try to change them arbitrarily
  - Architecturally Exposed Structural Steel (AESS) may be specified (in accordance with COSP Section 10), but this can add project cost

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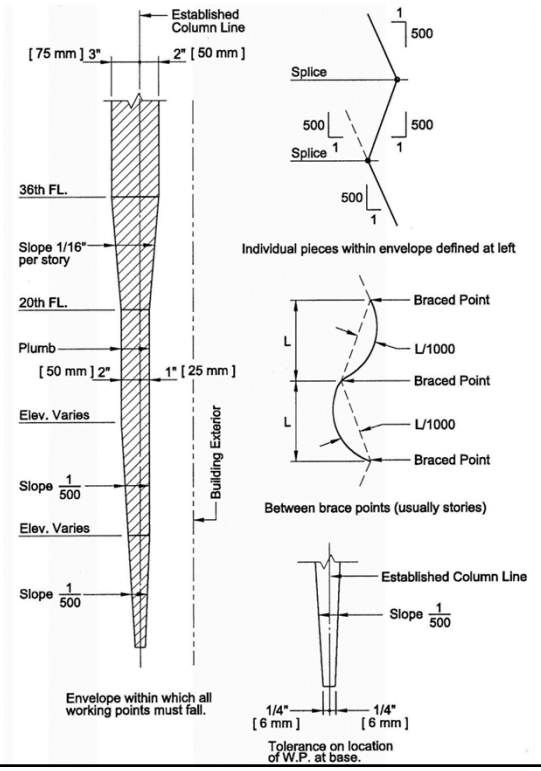
Tolerances

- Written tolerance descriptions summarized graphically in commentary
- Column location summary chart (Fig C-7.5)



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Anchor Bolt Tolerances

Section 7.5.1

- As noted, ODRC responsible for setting anchor bolts
- Tolerances provided in 7.5.1
- Coordinated with recommended base plate hole sizes in AISC Steel Construction Manual

(b) The horizontal variation in location from the specified position of each *anchor rod* centerline at any location along its projection above the concrete shall be equal to or less than the dimensions given for the *anchor rod* diameters listed as follows:

Anchor Rod Diameter, in. (mm)	Horizontal Variation, in. (mm)
3/4 and 7/8 (19 and 22)	1/4 (6)
1, 1 1/4, 1 1/2 (25, 31, 38)	3/8 (10)
1 3/4, 2, 2 1/2 (44, 50, 63)	1/2 (13)

Table 14-2
Recommended Sizes for Washers and Anchor Rod Holes in Base Plates

Anchor Rod Diameter	Hole Diameter	Washer Size	Min. Washer Thickness	Anchor Rod Diameter	Hole Diameter	Washer Size	Min. Washer Thickness
in.	in.	in.	in.	in.	in.	in.	in.
3/4	1 5/16	2	1/4	1 1/2	2 3/8	4	1/2
7/8	1 9/16	2 1/2	5/16	1 3/4	2 7/8	4 1/2	5/8
1	1 7/8	3	3/8	2	3 1/4	5	3/4
1 1/4	2 1/8	3 1/2	1/2	2 1/2	3 3/4	5 1/2	7/8

Notes:
1. Hole sizes provided are based on anchor rod size and correlate with ACI 117 (ACI, 2010).
2. Circular or square washers meeting the washer size are acceptable.
3. Clearance must be considered when choosing an appropriate anchor rod hole location, noting effects such as the position of the rod in the hole with respect to the column, weld size, and other interferences.
4. ASTM F844 washers are permitted instead of plate washers when hole clearances are limited to 5/16 in. for rod diameters up to 1 in., 1/2 in. for rod diameters over 1 in. up to 2 in., and 1 in. for rod diameters over 2 in. This exception should not be used unless the general contractor has agreed to meet smaller tolerances for anchor rod placement than those permitted in ACI 117.

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Correction of Errors

Section 7.14

Night School 18.7!

- "Moderate amounts of reaming, grinding, welding, or cutting, and the drawing of elements into line with drift pins, shall be considered to be normal erection operations."

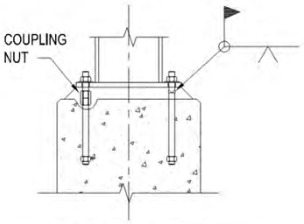

Fig. 7-4. Typical anchor rod extension.

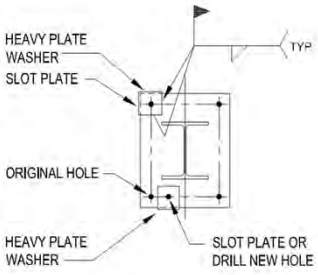

Fig. 7-7. Anchor rod correction—severe mislocation.

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"Why a Christmas Tree?"
Modern Steel Construction,
December 2000
www.modernsteel.org

Courtesy of Williams Enterprises

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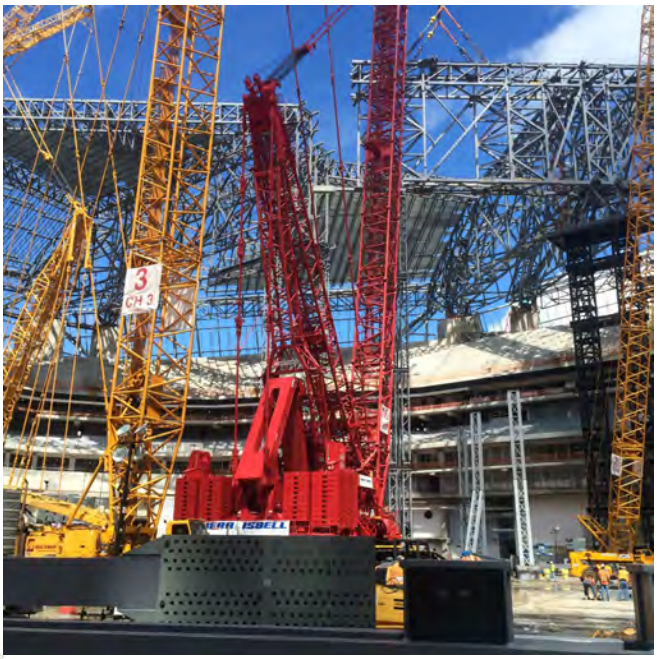

Courtesy of Williams Enterprises

Courtesy of Williams Enterprises

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10. The Erection Engineer

Night School 18.6!

- EOR responsible for the structural adequacy and code compliance of the completed structure, but how does it get built?
- Erection Engineering provides an analysis of the structure at various stages of construction to ensure an adequate load path is provided at all times.
- Usually hired by erector, but may be retained by ODRC to prepare erection plan so all erectors have a consistent baseline for bidding.

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Lateral Force Resisting System

Section 7.10

- EOR shall identify:
  a) "The LFRS and connecting diaphragm elements that provide for lateral strength and stability in the completed structure"
  b) "Any special erection conditions…such as the use of shores, jacks, or loads that must be adjusted…to set or maintain camber, position within specified tolerances, or prestress." (7.10.1)
- ODRC shall identify installation schedule for non-steel elements of the LFRS and connecting diaphragm – prior to bidding
  – E.g. erector may need to leave temporary bracing in place until concrete shear walls have reached sufficient strength.

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Bracing Provided by Erector

Section 7.10.3

- "…the erector shall determine, furnish and install all temporary supports, such as temporary guys, beams, falsework, cribbing or other elements required for the erection operation. These temporary supports shall be sufficient to secure the bare structural steel framing or any portion thereof against loads that are likely to be encountered during erection, including those due to wind and those that result from erection operations.

  "The erector need not consider loads during erection that result from the performance of work by, or the acts of, others, except as specifically identified by the owner's designated representatives for design and construction, nor those that are unpredictable, such as loads due to hurricane, tornado, earthquake, explosion or collision.

  "Temporary supports that are required during or after the erection of the structural steel frame for the support of loads caused by non-structural steel elements, including cladding, interior partitions and other such elements that will induce or transmit loads to the structural steel frame during or after erection, shall be the responsibility of others."

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Bracing Provided by Erector

Section 7.10.3

- "… the erector shall determine, furnish and install all temporary supports, such as temporary guys, beams, falsework, cribbing or other elements required for the erection operation. These temporary supports shall be sufficient to secure the bare structural steel framing or any portion thereof against loads that are likely to be encountered during erection, including those due to wind and those that result from erection operations.

  "The erector need not consider loads during erection that result from the performance of work by, or the acts of, others, except as specifically identified by the owner's designated representatives for design and construction, nor those that are unpredictable, such as loads due to hurricane, tornado, earthquake, explosion or collision.

  "Temporary supports that are required during or after the erection of the structural steel frame for the support of loads caused by non-structural steel elements, including cladding, interior partitions and other such elements that will induce or transmit loads to the structural steel frame during or after erection, shall be the responsibility of others."

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Loads

ASCE7, ASCE37

- Other than gravity load, mainly concerned about wind (ice?)
- Per ASCE37-14 (6.2.1), reduce design wind speed by a factor for project duration to adjust for risk
- 115mph * 0.8 → 64% of EOR's design wind pressure
- However! Wind load collected by the open structure can be much higher than wind on the final enclosed building
  - Shape Factor, Cf
  - Shielding

6.2.1 Design Wind Speed The design wind speed shall be taken as the following factor times the basic wind speed in ASCE/SEI 7-10, except as required in Section 6.2.1.1.1.

Construction Period	Factor
Less than six weeks	0.75
From six weeks to one year	0.8
From one to two years	0.85
From two to five years	0.9

Other Structures		All Heights
Figure 29.5-2	Force Coefficients, C_f	Open Signs & Lattice Frameworks

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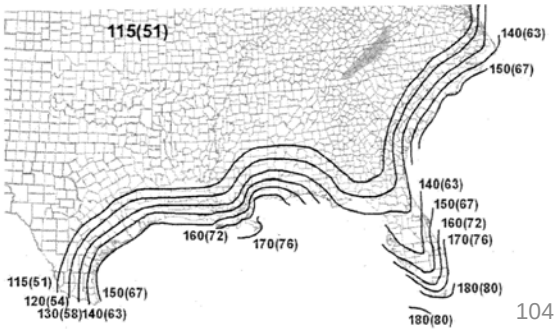
Hurricane Loads

ASCE37-14 6.2.1.1.1

- Per COSP, hurricane loads not required to be considered
- ASCE37 provides wind reduction outside hurricane season, but July through October allows a 115 mph wind speed even near the coast "provided additional bracing is prepared in advance and applied in time before the onset of an announced hurricane."
- Hurricane contingency plan can be very costly. Communications with erector, ODRC, and owner are crucial at the beginning of the project (not when the wind picks up!)



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Erection Engineering

- Structure stability – analysis of partially completed structure at each stage of the procedure
- Element stability – analysis of installation of a major element of the structure (truss, subassembled module, cantilever)
- Staged construction – accumulation of dead load stresses that are “locked in” as portions of structure are added

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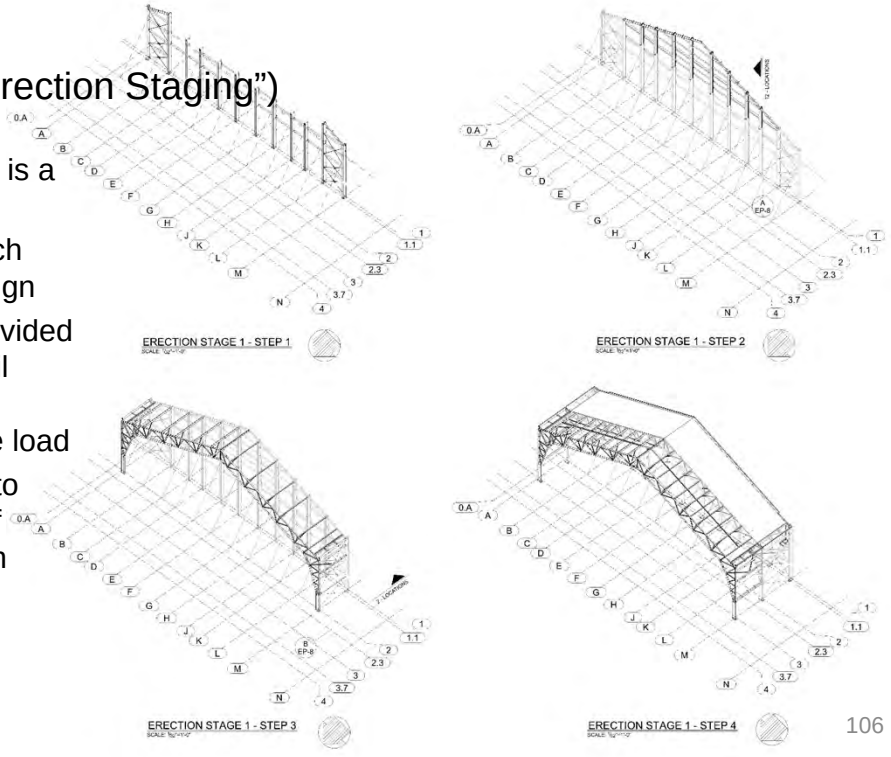
Structure Stability (“Erection Staging”)

- Each stage of erection is a separate analysis
- Load path may be much different than final design
- Temporary bracing provided (usually wire rope) until enough structure is complete to handle the load
- Erector usually wants to know how far ahead of steel deck erection can proceed



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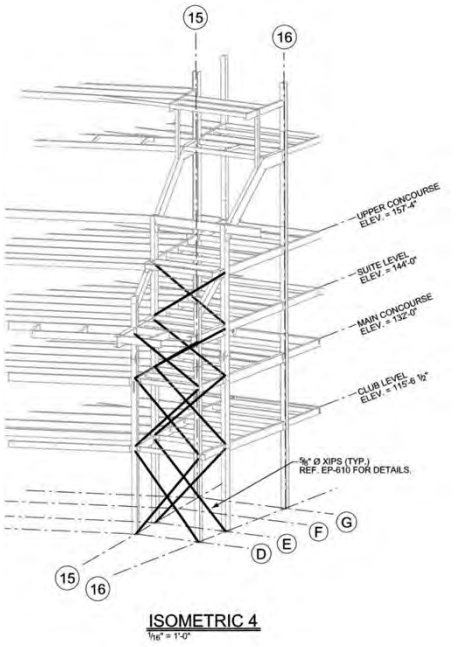
Structure Stability (“Erection Staging”)



ISOMETRIC 4
1/16" = 1'-0"

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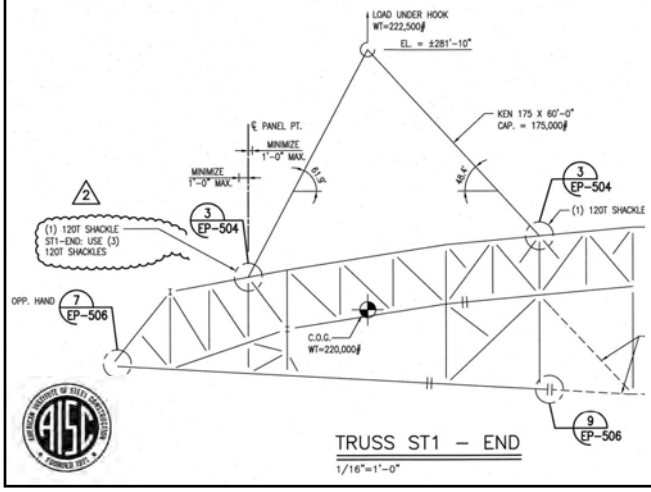
Element stability

- Analysis of truss or girder under the hook, review of stability before releasing crane



TRUSS ST1 – END
1/16"=1'-0"

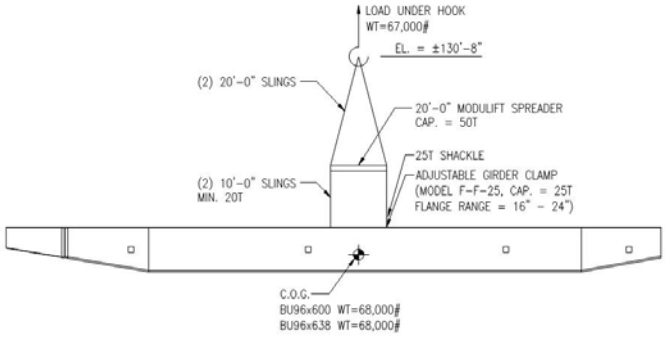


PLATE GIRDER
1/16"=1'-0"

Staged Construction Analysis

- Highly indeterminate buildings, multiple load paths
- Especially on cable supported structures
- Construction or cable tensioning sequence can greatly affect stresses within the structure

Ruby+Associates

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Outline

1. The Team
2. The Owner/Architect
3. The ODRD (EOR)
4. The ODRC (Construction Manager)
5. The Mill
6. The Fabricator
7. The Detailer
8. The Connection Designer
9. The Erector
10. The Erection Engineer
11. Quality Control

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11. Quality Control

Section 8.1

Night School 18.8!

- Fabricator (8.1.1) and Erector (8.1.2) shall maintain a quality control program to ensure work is in conformance with COSP, AISC360 “Specification,” and contract documents.
- AISC Specification Chapter N “…addresses the minimum requirements for quality control, quality assurance and nondestructive testing...” (Chapter N Scope)

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Specification Chapter N

- Provides guidance for steel inspection, quality program for *all* fabricators & erectors
- New chapter in 2010, but not necessarily new requirements—pulls together all of the quality requirements necessary for steel construction in one place.
- Best part: EOR just has to specify AISC360 and COSP to ensure consistent quality program is required.

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Courtesy of Williams Enterprises

QC vs. QA?

- Per ISO9000 (Section 3.2.10 and 11)
  - QC: “A part of quality management focused on fulfilling quality requirements”
  - QA: “part of quality management focused on providing confidence that quality requirements will be fulfilled”

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QC vs. QA

- ~~Per ISO9000 (Section 3.2.10 and 11)~~
  - ~~QC: “A part of quality management focused on fulfilling quality requirements”~~
  - ~~QA: “part of quality management focused on providing confidence that quality requirements will be fulfilled”~~
- Per Chapter N1:
  - “Quality Control…shall be provided by **fabricator** and **erector**.”
  - “Quality Assurance…shall be provided by **others** when required by the authority having jurisdiction (AHJ), applicable building code, purchaser, owner, or engineer of record (EOR).”
- Coordinated QC & QA is permitted
  - If approved by EOR or AHJ, QA inspector can rely on QC inspector for overlapping tasks

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Observe vs. Perform

- Observe (O): Inspector shall observe these items on a random basis
- Perform (P): Tasks shall be performed for each welded joint/bolted connection
- Similar to IBC "Continuous vs. Periodic" for special inspections
  - IBC only provides tables for joists, concrete, soils, and foundations

TABLE 1705.3
REQUIRED SPECIAL INSPECTIONS AND TESTS OF CONCRETE CONSTRUCTION

TYPE	CONTINUOUS SPECIAL INSPECTION	PERIODIC SPECIAL INSPECTION	REFERENCED STANDARD[1]	IBC REFERENCE
1. Inspect reinforcement, including prestressing tendons, and verify placement.	—	X	ACI 318 Ch. 20, 25.2, 25.3, 26.6.1-26.6.3	1908.4
2. Reinforcing bar welding:				
a. Verify weldability of reinforcing bars other than ASTM A706;	—	X	AWS D1.4	—
b. Inspect single-pass fillet welds, maximum $^5/_{16}$"; and		X	ACI 318: 26.6.4	
c. Inspect all other welds.	X			
3. Inspect anchors cast in concrete.	—	X	ACI 318: 17.8.2	—
4. Inspect anchors post-installed in hardened concrete members.[5]				
a. Adhesive anchors installed in horizontally or upwardly inclined orientations to resist sustained tension loads.	X		ACI 318: 17.8.2.4	—
b. Mechanical anchors and adhesive anchors not defined in 4.a.		X	ACI 318: 17.8.2	
5. Verify use of required design mix.	—	X	ACI 318: Ch. 19, 26.4.3, 26.4.4	1904.1, 1904.2, 1908.2, 1908.3
6. Prior to concrete placement, fabricate speci-			ASTM C172	

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Inspection requirements

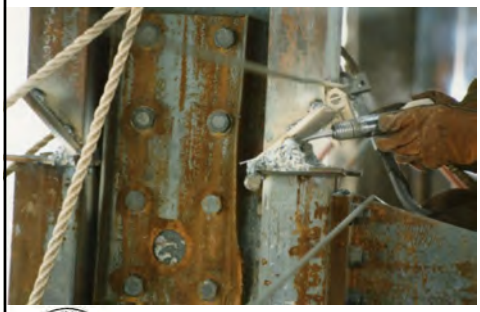
- N5.4 – Welding
- N5.5 – NDT
- N5.6 - Bolting

TABLE N5.6-1
Inspection Tasks Prior to Bolting

Inspection Tasks Prior to Bolting	QC	QA
Manufacturer's certifications available for fastener materials	O	P
	O	O
	O	O
	O	O
	O	O
	P	O
	O	O

TABLE N5.4-1
Inspection Tasks Prior to Welding

Inspection Tasks Prior to Welding	QC	QA
Welding procedure specifications (WPSs) available	P	P
Manufacturer certifications for welding consumables available	P	P
Material identification (type/grade)	O	O
Welder identification system[1]	O	O
Fit-up of groove welds (including joint geometry) • Joint preparation • Dimensions (alignment, root opening, root face, bevel) • Cleanliness (condition of steel surfaces) • Tacking (tack weld quality and location)	O	O



Courtesy of Williams Enterprises

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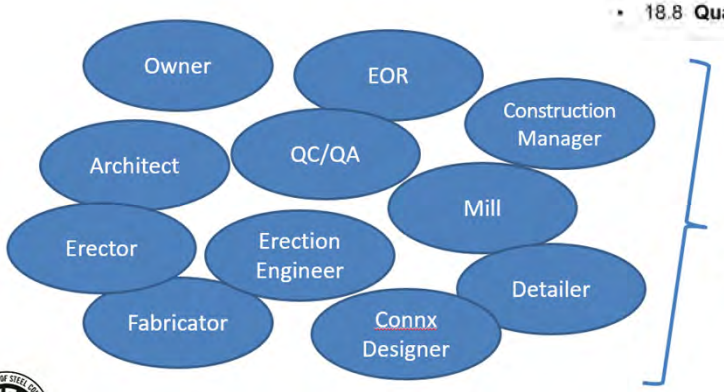
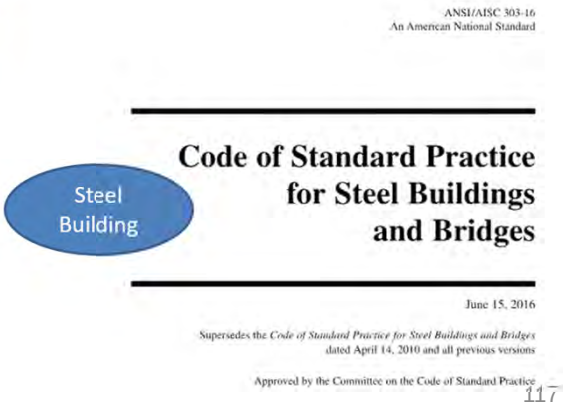
Conclusion

Night School 18

- 18.1 **Introduction** to the Steel Construction Process — Oct. 15
- 18.2 The **Manufacturing** of Structural Steel Shapes — Oct. 22
- 18.3 A Virtual, Detailed Tour of the **Steel Fabrication** Process — Oct. 29
- 18.4 **Connection Design** as the Fabricator's Representative — Nov. 5
- 18.5 It Doesn't Get Built Without the **Erector** — Nov. 19
- 18.6 **Erection Engineering** – Stability During Construction — Nov. 26
- 18.7 **Field Fixes** and Solutions — Dec. 3
- 18.8 **Quality** Control and Quality Assurance — Dec. 10





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Night School 18: Steel Construction

From the Mill to Topping Out
Session 1: Introduction to the Steel Construction Process
October 15, 2018 (The Team Behind the Building)

AISC | Questions?

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Individual Webinar Registrants

CEU/PDH Certificates

Within 2 business days…

- You will receive an email on how to report attendance from: registration@aisc.org.
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

Individual Webinar Registrants

CEU/PDH Certificates

Within 2 business days…

- New reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.

8-Session Registrants

CEU/PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.

8-Session Registrants

Access to the quiz: Information for accessing the quiz will be emailed to you by Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG

Quiz and Attendance records: Posted Tuesday mornings.
www.aisc.org/nightschool - click on Current Course Details.

Reasons for quiz:

- EEU – must take all quizzes and final to receive EEU
- CEUs/PDHS – If you watch a recorded session you must take quiz for CEUs/PDHs.
- REINFORCEMENT – Reinforce what you learned tonight. Get more out of the course.

NOTE: If you attend the live presentation, you do not have to take the quizzes to receive CEUs/PDHs.

8-Session Registrants

Access to the recording: Information for accessing the recording will be emailed to you by this Wednesday. The recording will be available for three weeks. For 8-session registrants only. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

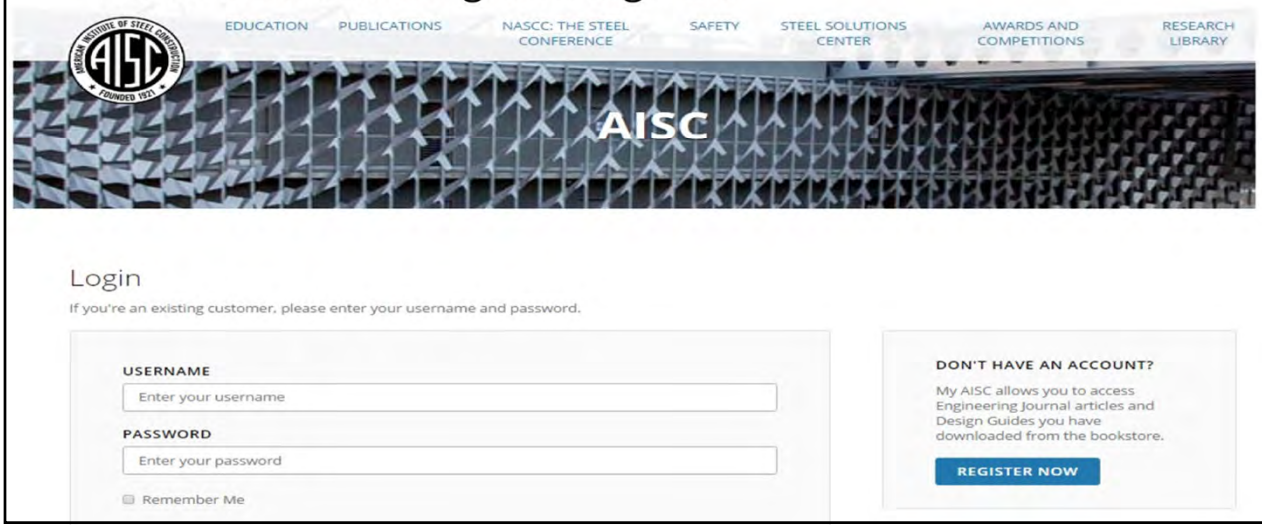
CEUs/PDHS – If you watch a recorded session you must take AND PASS the quiz for CEUs/PDHs.

Night School Resources for 8-session package Registrants

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!

Night School Resources for 8-session package Registrants

Go to www.aisc.org and sign in.



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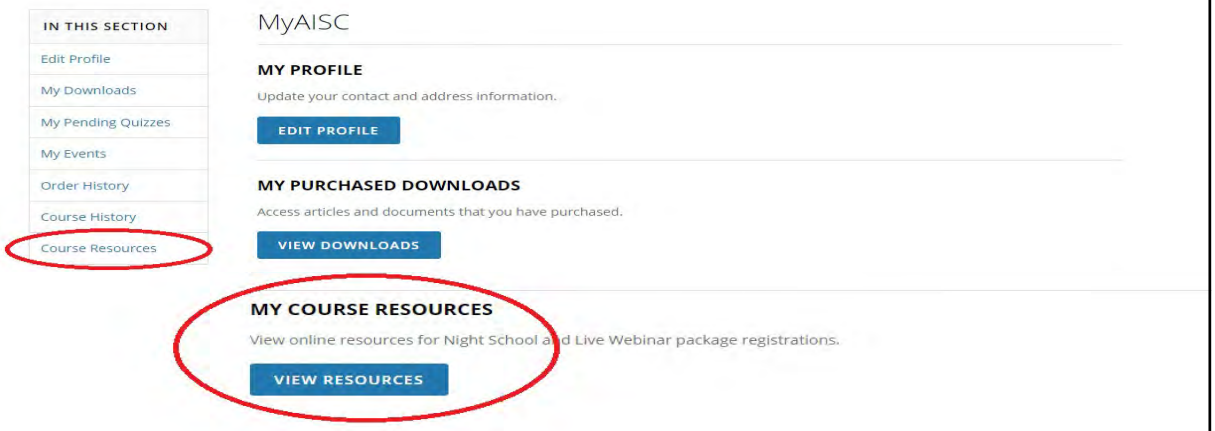


Night School Resources for 8-session package Registrants

Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

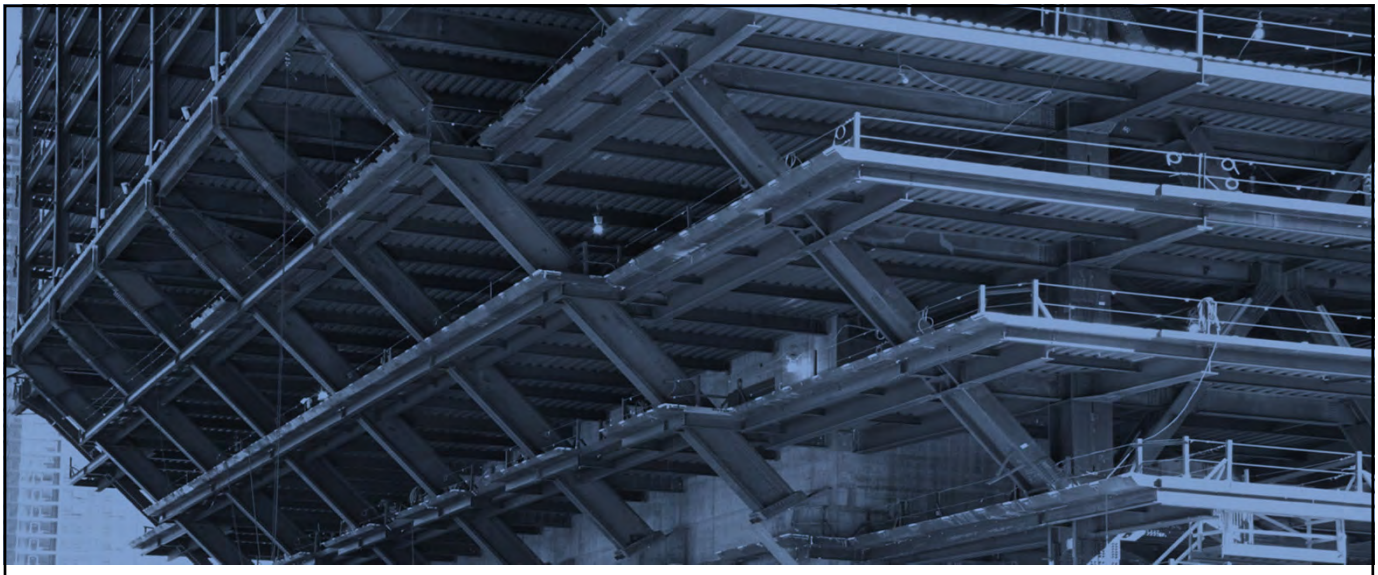
Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending
NS13 - Final Exam	4/10/2017 7:00:00 PM			Available 04/12/2017 5pm EST	

Night School Resources for 8-session package Registrants

- Weekly “quiz and recording” email.
- Weekly updates of the master Quiz and Attendance record found at www.aisc.org/nightschool. Scroll down to Quiz and Attendance records.
  - Updated on Tuesday mornings.

Night School Resources for 8-session package Registrants

- Webinar connection information:
  - Found in your registration confirmation/receipt.
  - Reminder email sent out Monday mornings.
- Link to handouts also found here.



AISC | Thank you

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