Instructions for Instructors

Topic	Slide #s	Approx. minutes
Prevention through Design Concept	5-27	30
Steel Design, Detailing, and Fabrication Process	28-33	10
Steel Erection Process	34-38	10
Specific Steel PtD Examples	39-74	50
Recap and Citations	75-80	5

Overview

- Prevention through Design Concept
- Steel Design, Detailing, and Fabrication Process
- Steel Erection Process
- Specific Steel PtD Examples

INTRODUCTION TO PREVENTION THROUGH DESIGN

What is Prevention through Design?

Eliminating work-related hazards and minimizing risks associated with…

- Construction or Manufacture
- Maintenance
- Use, re-use and disposal

…of

- Facilities
- Materials and
- Equipment

Successful Firms Using PtD

- Design Builders:
  - URS/Washington Group
  - Jacobs
  - Parsons
  - Fluor
  - Bechtel
- Owners:
  - Southern Company
  - Intel

Why Prevention Through Design?

- Construction is dangerous
- Design does affect safety
- Ethical reasons
- Practical benefits

http://www.alasdairmethven.com/communities/5/004/006/908/565/images/4529948731.jpg

Typical Annual Construction Accidents in the U.S. [1]

Construction is one of the most hazardous occupations

- 7% of the US workforce but 21% of fatalities
- About 1,000 deaths
- About 200,000 serious injuries

Design Contribution to Occupational Fatalities: Australian Study 2000-2002

- Main finding: design continues to be a significant contribution to work-related serious injury.
- 37% of workplace fatalities involved design-related issues.
- In another 14% of fatalities, design-related issues may have played a role.

Driscoll, T.R., Harrison, J. E., Bradley, C., Newton, R.S. (2005)

Accidents Linked to Design

- 22% of 226 injuries that occurred from 2000-2002 in Oregon, WA, and CA linked partly to design [2]
- 42% of 224 fatalities in U.S. between 1990-2003 linked to design [2]
- In Europe, a 1991 study concluded that 60% of fatal accidents resulted in part from decisions made before site work began [3]
- 63% of all fatalities and injuries could be attributed to design decisions or lack of planning[4]

Ethical Reasons for PtD

- National Society of Professional Engineers' Code of Ethics:
  - Engineers shall hold paramount the safety, health, and welfare of the public
- American Society of Civil Engineers' Code of Ethics:
  - Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering decisions…

Hierarchy of Controls

- Engineers are vital to minimizing occupational risks through the application of the hierarchy of controls
- The engineering design process provides the framework for the application of prevention through design

Constructability

Constructability is an evaluation of how reasonable the design is to construct in terms of:

- Cost
- Duration
- Quality
- Safety

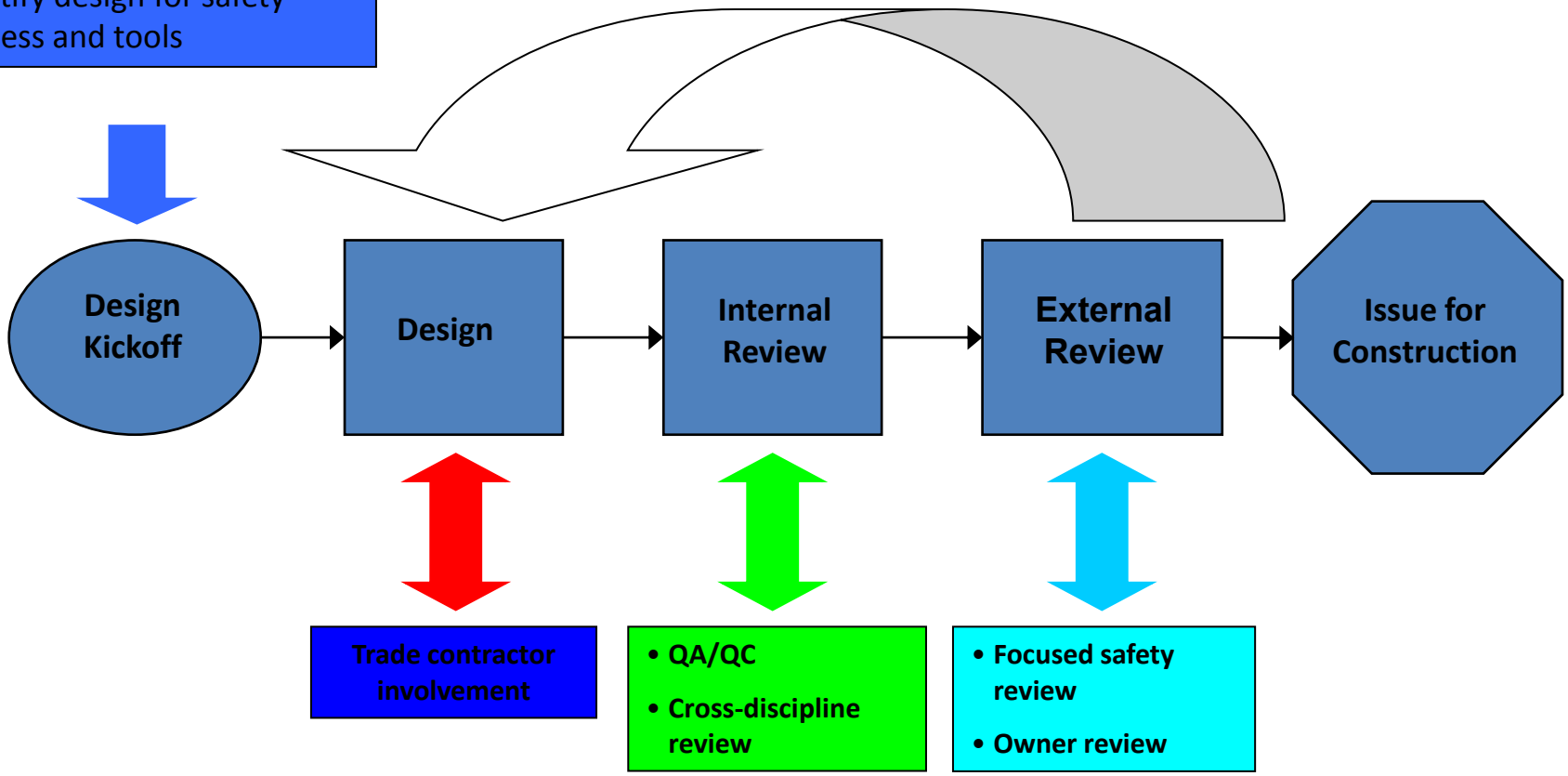
Safety is an often neglected aspect of constructability

http://upload.wikimedia.org/wikipedia/commons/0/08/Spiegel_Building_Hamburg_1.jpg

http://www.mattmarko.com/gallery/albums/Prague/Fred_and_Ginger_Gehry_Building.jpg

PtD Process [6]

- Establish design for safety expectations
- Include construction and operation perspective
- Identify design for safety process and tools



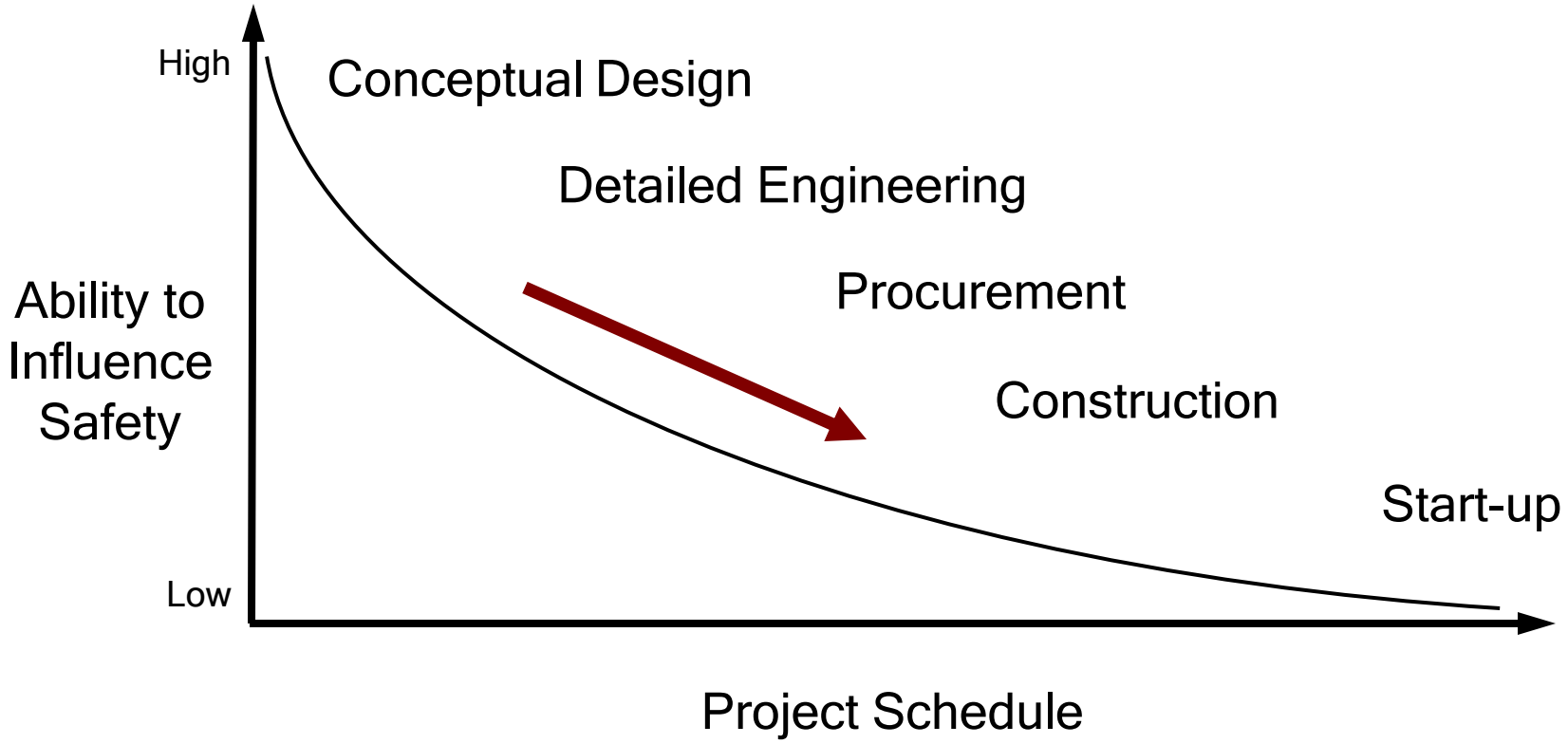
[1] Gambatese

Success will only be achieved by integrating occupational safety and health with ***engineering design process***

Stage	Activities
Conceptual Design	Establish occupational safety and health goals, identify occupational hazards
Preliminary Design	Eliminate hazards, if possible. Substitute less hazardous agents / processes, and establish risk minimization targets for remaining hazards. Assess risk and develop risk control alternatives.
Detailed Design	Select controls. Conduct Process Hazard Reviews.
Procurement	Develop specifications and include in procurements. Develop "checks and tests" for factory acceptance testing and commissioning
Construction	Construction site safety and contractor safety.
Commissioning	Conduct "checks and tests" including factory acceptance. Pre-start up safety reviews. Development of SOPs. Risk / exposure assessment. Management of residual risks.
Start Up and Occupancy	Education. Management of change. Modification of SOPs

Safety Payoff During Design

Considering Safety During Design Offers the Most Payoff [5]



Benefits from PtD

- Reduced site hazards so fewer injuries
- Savings from reduced workers compensation insurance costs
- Increased productivity
- Fewer delays due to accidents
- Encourages designer-constructor collaboration

Business Value

- The AIHA Value Strategy* demonstrated the most significant business contributions result from…
  - Anticipating worker exposures and designing process improvements to reduce or eliminate these exposures
  - Aligning health and safety interventions with business goals
  - Integrating health and safety risk management requirements into the design process
    - Facilities, equipment, tools, processes, products and work flows
- …resulting in significant contributions to business profitability

www.ihvalue.org

OSHA Regulations

- ‘‘Code of Federal Regulations’’ (29 CFR 1926)
- States can have more stringent regulations
- Updated annually

Steel Erection eTool Website, Available at *www.osha.gov/SLTC/**etools/steelerection**/index.html*

Construction Hazards [7, 8]

- Falls
- Ergonomics/Musculoskeletal Injuries
- Falling Objects
- Tripping

http://nycammlaw.com/personal_construct.html

Falls

- Number one cause of construction fatalities; in 2004, they accounted for 445 of 1,234 deaths, or 36 percent [7]
- Common fall situations include making connections, walking on beams or near openings such as floors or windows
- Fall protection for steel erection required at height of 15 feet above a surface [10]
- Causes include slippery surfaces due to water, ice or oil, unexpected vibrations, misalignment, and unexpected construction loads.

Personal Protection Equipment (PPE)

- Last line of defense against injury [4]

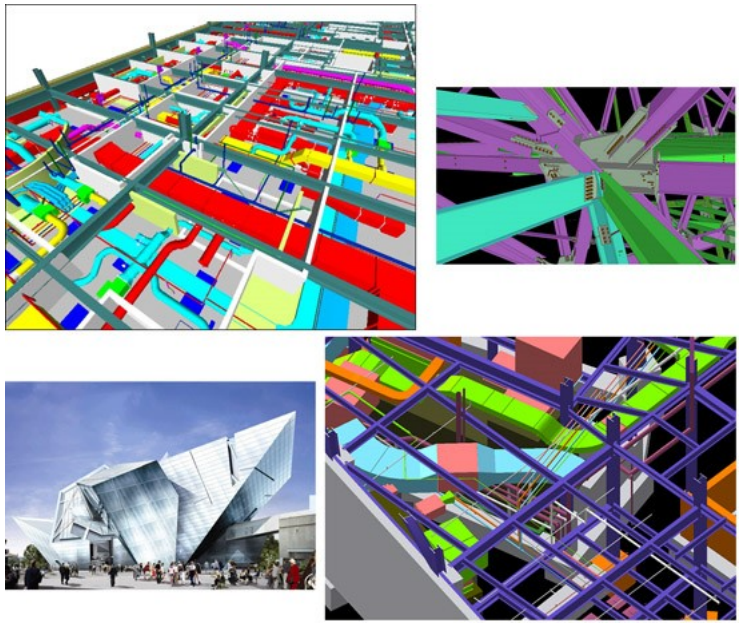
Includes but not limited to:

- Hardhats
- Steel-toed boots
- Safety glasses
- Gloves
- Fall harnesses

http://www.safetyexpress.com/images/product/msa-technacurv.jpg

PtD Process Tasks [11, 12]

- Perform a hazard analysis
- Incorporate safety into the design documents
- Make a CAD model for member labeling and erection sequencing



http://dcom.arch.gatech.edu/class/BIMCaseStudies/Readings/BIM_Symposium_files/fig9small.jpg

Designer Tools

- Checklists for Construction Safety [13]
- Design for Construction Safety Toolbox [14]
- Construction Safety Tools from the UK or Australia
  - CHAIR [4]

Example Checklist

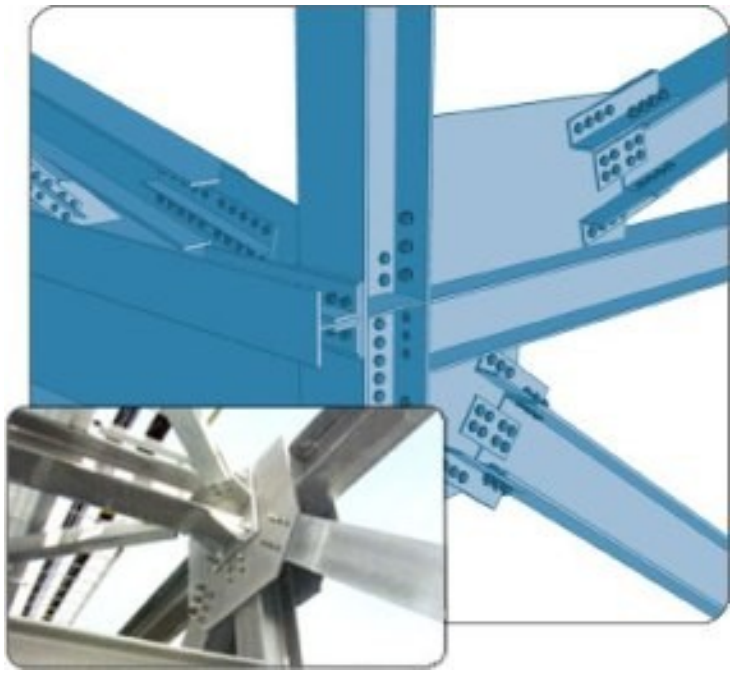
Item	Description
1.0	**Structural Framing**
1.1	Space slab and mat foundation top reinforcing steel at no more than 6 inches on center each way to provide a safe walking surface.
1.2	Design floor perimeter beams and beams above floor openings to support lanyards.
1.3	Design steel columns with holes at 21 and 42 inches above the floor level to support guardrail cables.
2.0	**Accessibility**
2.1	Provide adequate access to all valves and controls.
2.2	Orient equipment and controls so that they do not obstruct walkways and work areas.
2.3	Locate shutoff valves and switches in sight of the equipment which they control.
2.4	Provide adequate head room for access to equipment, electrical panels, and storage areas.
2.5	Design welded connections such that the weld locations can be safely accessed.

Steel

DESIGN, DETAILING AND FABRICATION PROCESS

Three Entities Associated with Design

- Engineer
- Detailer
- Fabricator



http://www.prlog.org/10246402-affordable-cad-steel-detailing-structural-steel-drafting-services.html

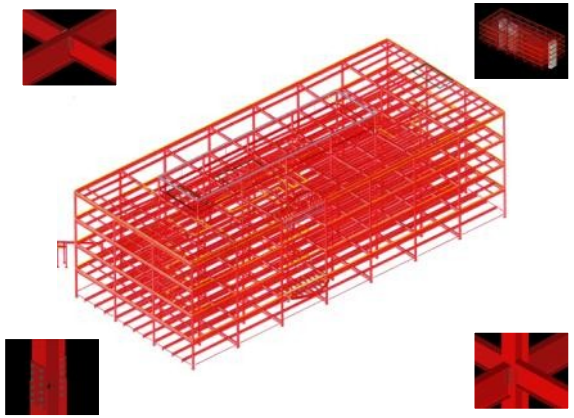
Design process across the U.S.

Design Phase

- Owner tells A/E requirements for building
- Designer runs analysis on design according to building codes
- Building is designed for:
- Safety, serviceability, constructability, and economy
- Final Design Specifications and Drawings are given to client
- Design calculations are safely stored by designer

Detailing [15]

The fabricator receives the engineer's drawings; then they will be programmed into computer software to help visualize the connections



[15] Daccarett, V., and T. Mrozowski. "Structural Steel Construction Process: Technical."

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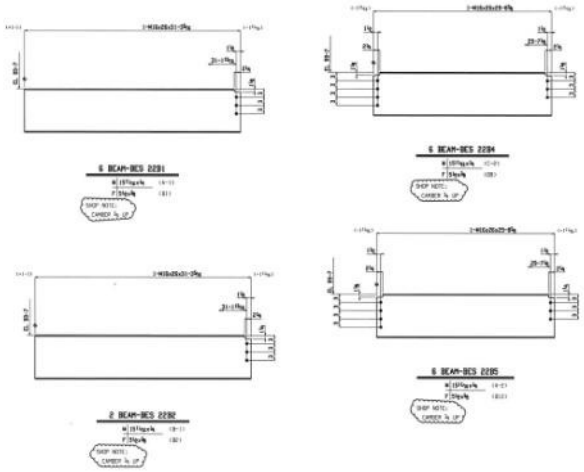


Shop Drawings [15]

While detailing, the fabricator makes drawings containing specific information about how to fabricate each member

Fabrication[15]

To achieve its final configuration the steel may be:

- Cut
- Sheared
- Punched
- Drilled
- Fit
- Welded

www.steel-fabrication-workshop.cn/

Each final member is labeled with a piece mark, length, and job number for identification

Transportation

Members are transported via:

- Flatbed truck
- Train
- Waterways

www.cranetruckservices.com.au/cranetrucks.html

cs.trains.com/trccs/forums/p/161645/1780701.aspx

Steel

ERECTION PROCESS

Unloading and Shake-Out [15]

- Steel members are unloaded from the trucks and placed on blocking to allow chokers to be easily attached.

- Shake Out: when members are sorted on the ground to allow for efficient erection.

[15] Daccarett, V., and T. Mrozowski. "Structural Steel Construction Process: Technical."

Picking and Hoisting [15]

- Cranes are used to lift members into place
- Columns have a hole at an end that is used to pick it up
- Beams have chokers tied around their center of gravity, and multiple beams can be lifted at once

[15] Daccarett, V., and T. Mrozowski. "Structural Steel Construction Process: Technical."

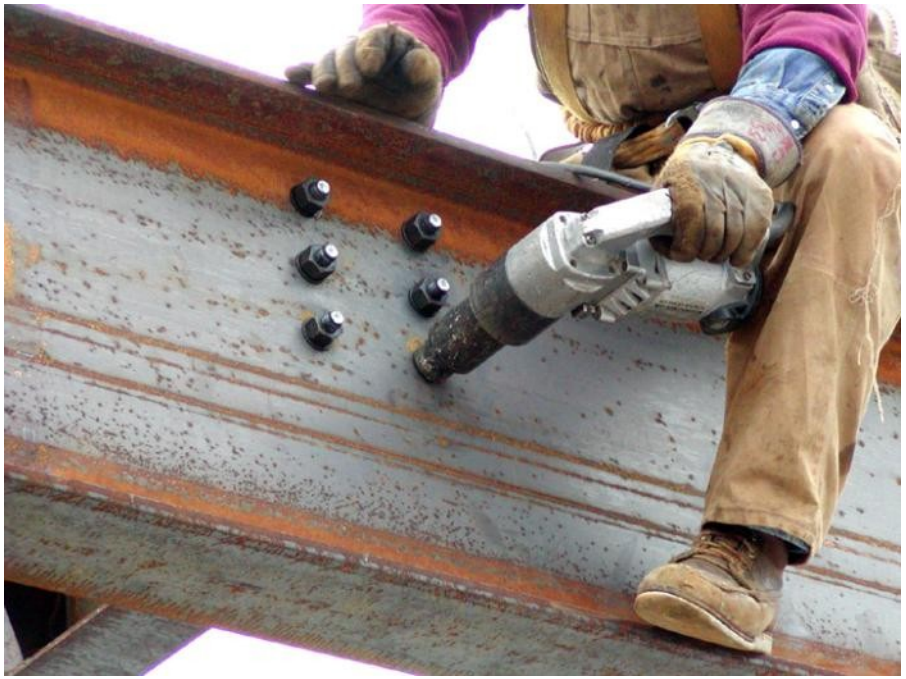
Positioning and Initial Bolting [15]

Each beam is lowered into place, and a worker will line it up correctly using drift pins. At least two bolts are attached before the crane releases the load (OSHA requirement).

[15] Daccarett, V., and T. Mrozowski. "Structural Steel Construction Process: Technical."

Final Bolting[15]

Once everything is assured to be in the correct position, the final bolting is performed using a torque wrench or similar tool.



[15] Daccarett, V., and T. Mrozowski. "Structural Steel Construction Process: Technical."

Steel

EXAMPLES OF PREVENTION THROUGH DESIGN

Topics

Topics	Slide Numbers
Prefabrication	
Access Platforms	
Columns	
Beams	
Connections	
-Bolts	
-Welds	
Miscellaneous	

Prefabrication [16]

- Shop work is often faster than field work
- Shop work is less expensive than fieldwork
- Shop work is more consistent due to a controlled environment
- Shop work yields better quality than fieldwork
- Less work is done at high elevations which reduces the risks of falling and falling objects

Example: Prefabricated Truss

- Less connections to make in the air
- Safer and faster

www.niconengineering.com

Access Help

- Shop installed vertical ladders
- Bolt on ladders and platforms can be removed later, or kept for maintenance

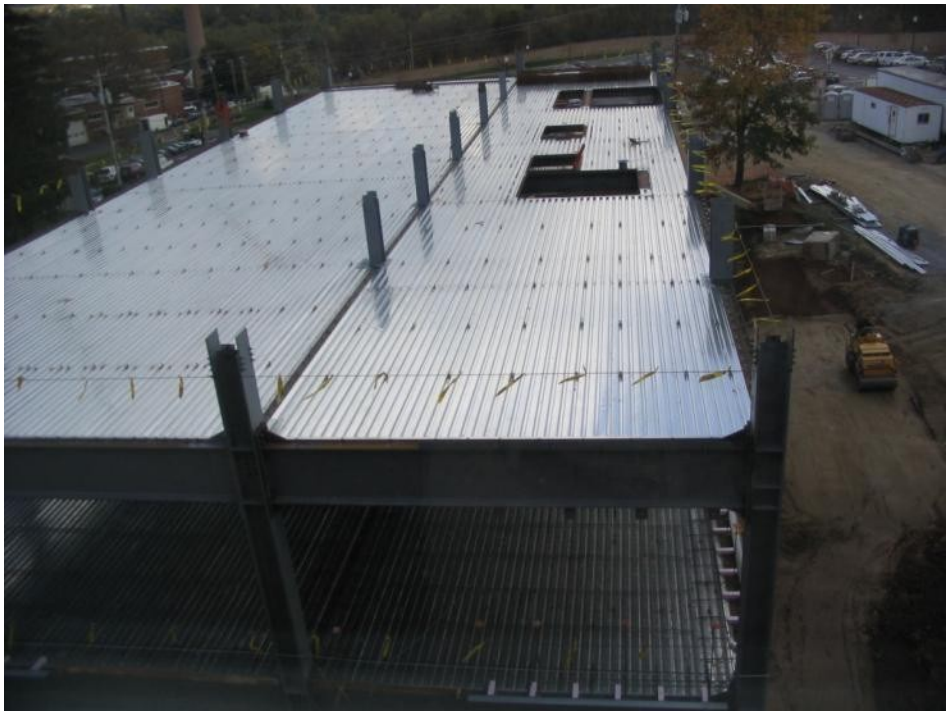
Column Safety

- Column Splices
- Holes for safety lines
- Base plates

http://www.dartmouth.edu/~opdc/images/nvh/summer06/071906_1.jpg

Column Splices

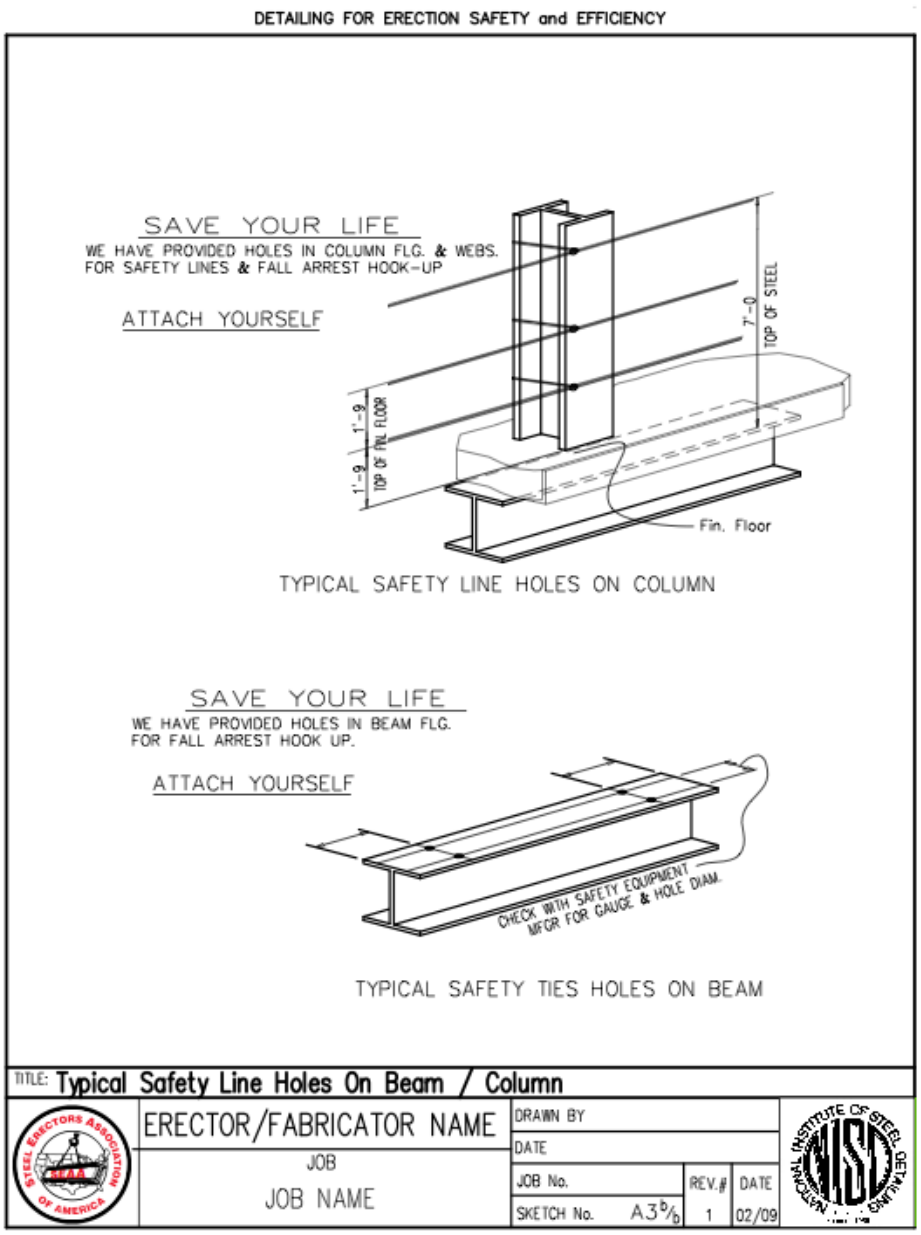
- Have column splice around 4 feet above the working floor [17]
- OSHA Requirement



Courtesy Bucknell University Facilities

Holes for Safety Lines [18, 19]

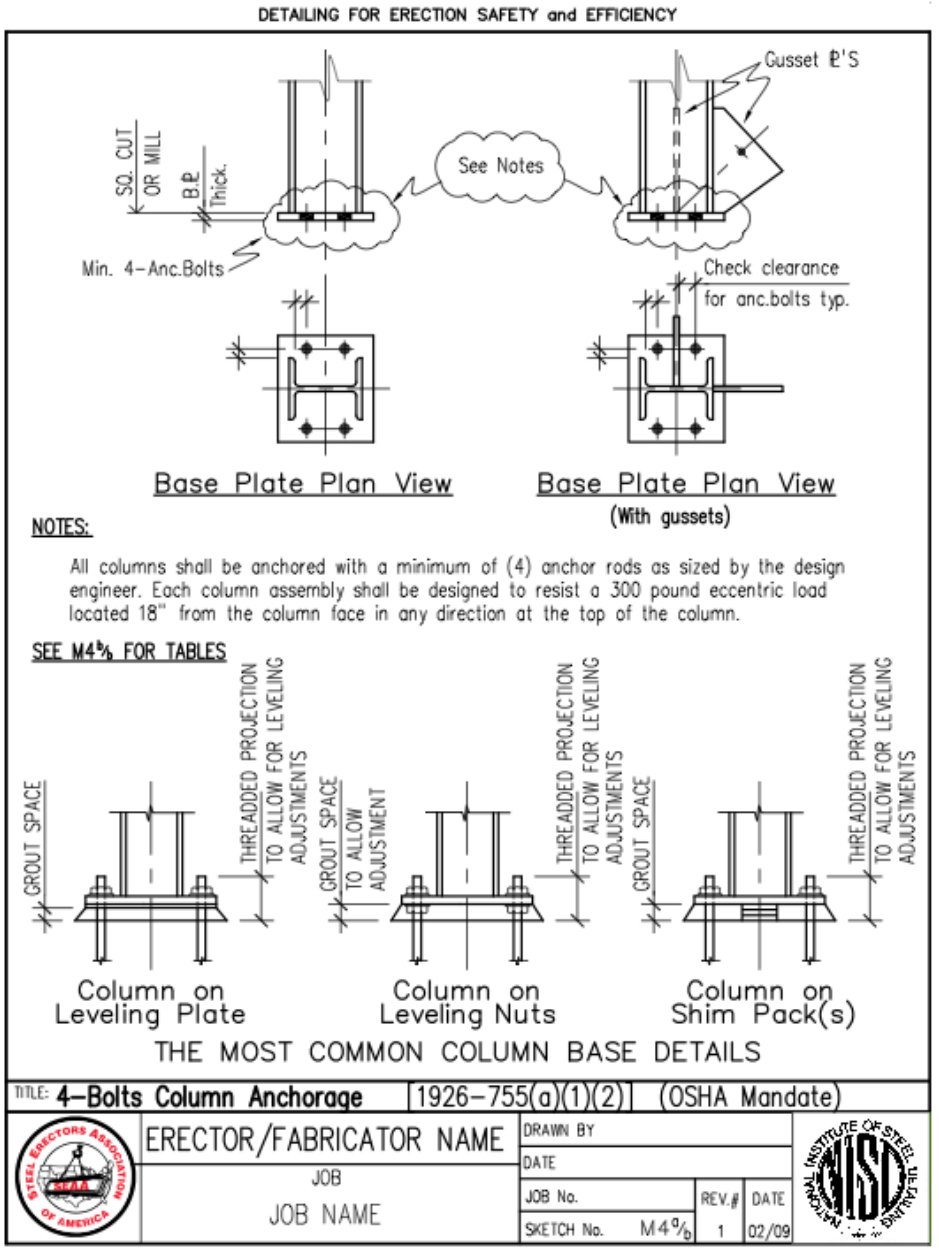
- Include holes at 21 inches and 42 inches for guardrails.
- Additional higher holes can also be included for lifeline support.



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Base Plates [18, 19]

- Column Base Plates should always have at least 4 anchor rods bolted in.
- OSHA Requirement



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Beams and Girders

Workers walk on beams to get to connections or other columns, which makes falling a common hazard. Being mindful of the following can greatly increase safety:

- Beam Width
- Use of Cantilevers
- Ability to Support Lifelines

http://pacosteel.com/images/photos/Paco%20Floor%20joists.jpg

Beam Width 18

For good walking surface, use a minimum beam width of 6 inches.

http://www.rayconsteel.com/Pictures/WalkingSteel.JPG

Use of Cantilevers[18]

Minimize the use of cantilevers for the following reasons:

- Cantilevers are not good for tying off
- It is harder to make connection

http://www.carpenterscenter.com/2009/05/cantilever-erected_14.html

Ability to Support Lifelines [18, 19]

- Design beams near or above openings to be able to support lifelines.

- The contract drawings should make clear how many lifelines each beam can support, and at what locations they can be attached.

Connections

Connections are very important, but they can be very difficult to install during construction.

There are two main methods of making connections:

- Bolts
- Welds

Bolts

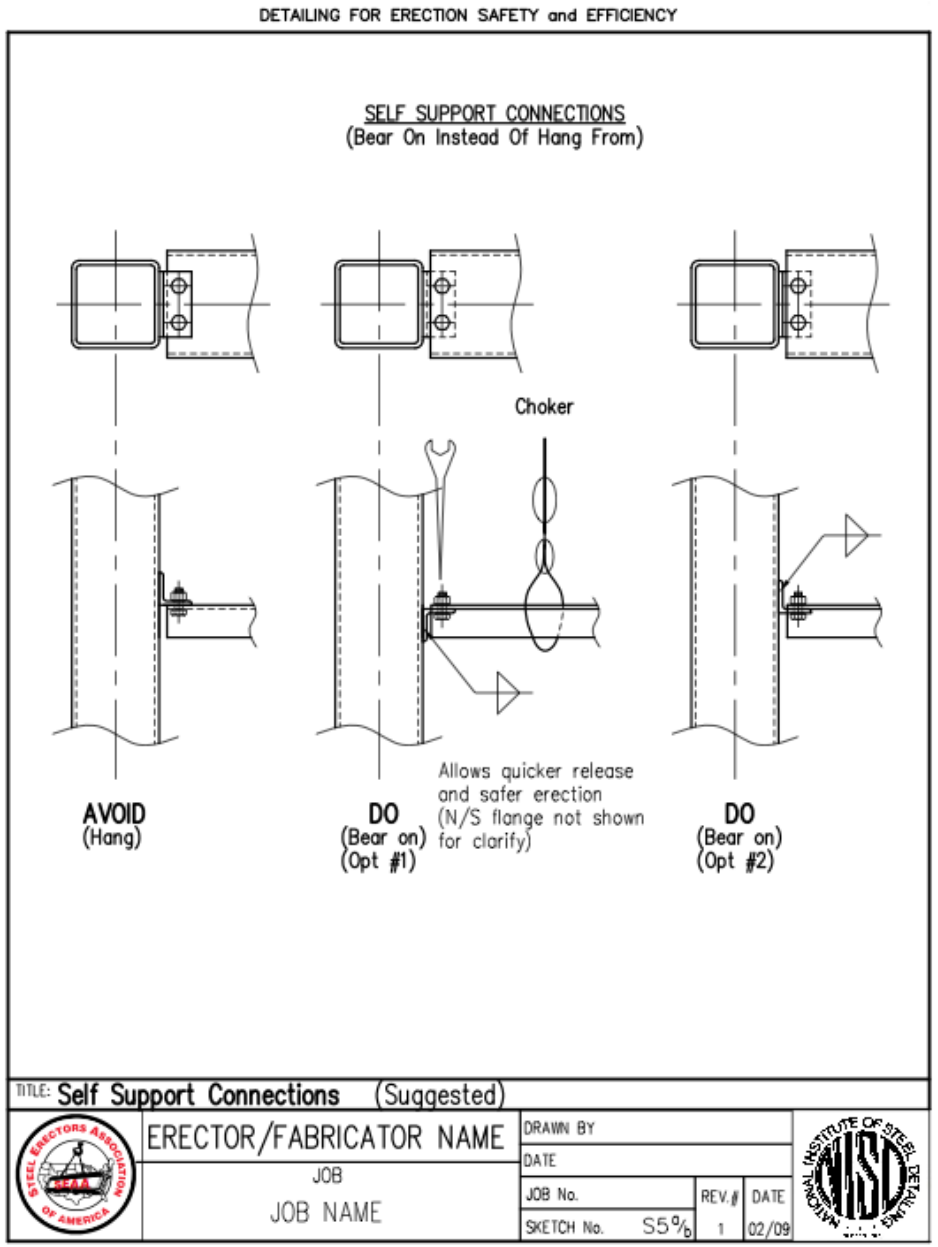
For safe bolted connections, consider:

- Self-Supporting Connections
- Double Connections
- Erection Aids “Dummy Holes”
- Bolt Sizes
- Minimum Number of Bolts
- Awkward or Dangerous Connection Locations

[21] AISC “Bolting and Welding”

Self Supporting Connections [18, 19]

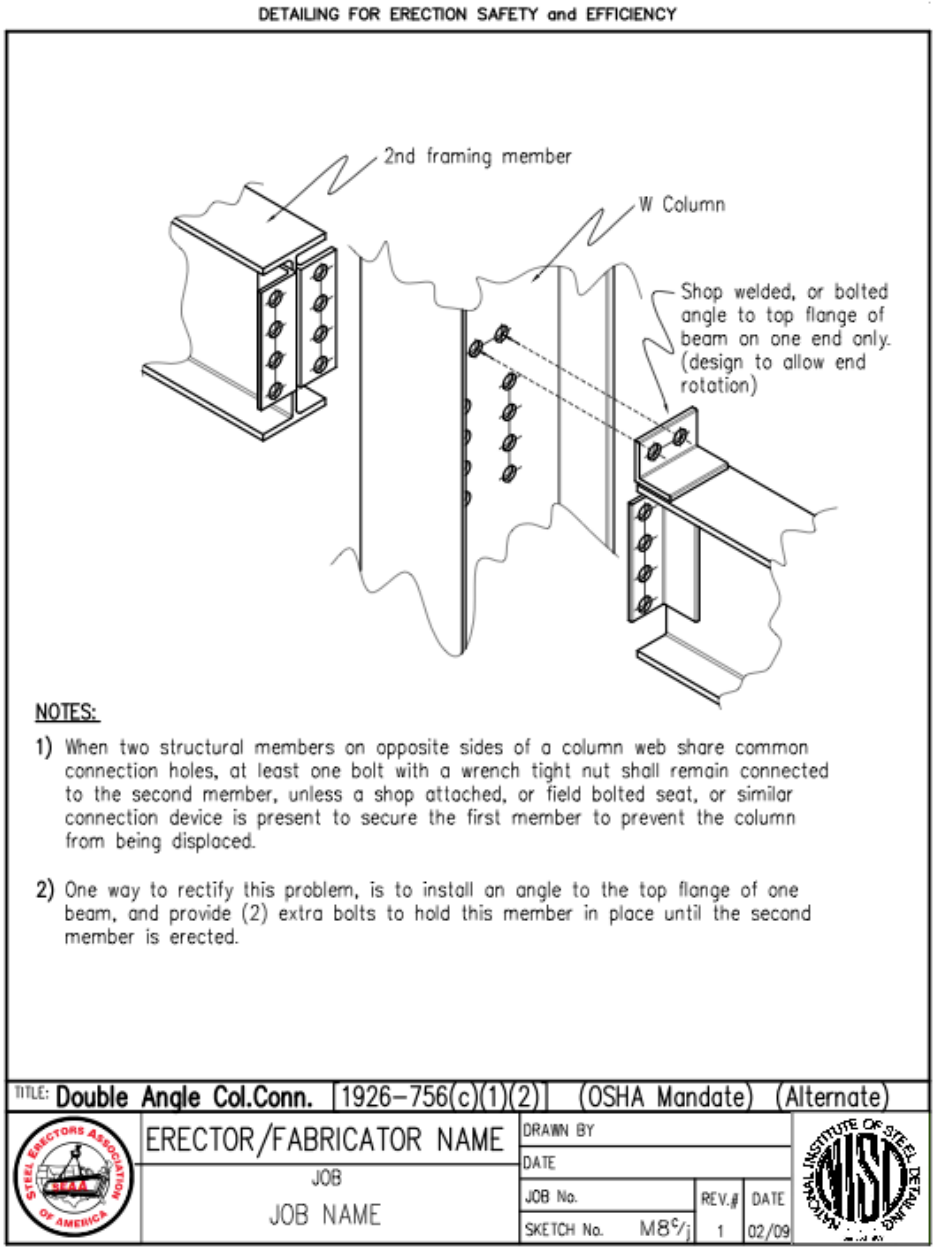
- Avoid hanging connections
- Consider using beam seats



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

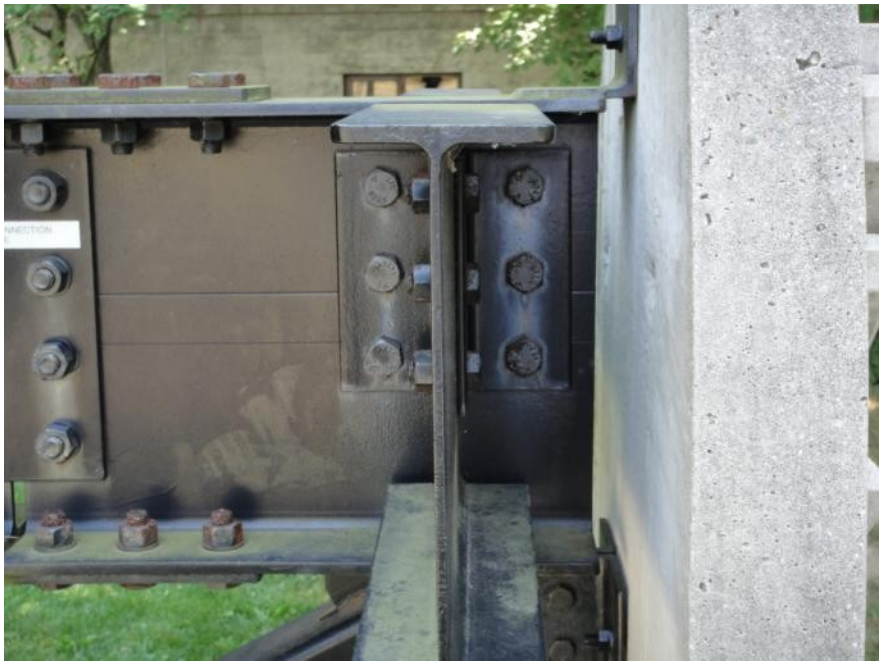
Double Connections [18, 19]

- Avoid beams of common depth connecting into the column web at the same location
- If double connections are necessary, design them to have full support during the connection process.
- OSHA Requirement



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Alternate Double Connection



Erection Aids “Dummy Holes”

- Provide an extra “dummy hole” in the connection, where a spud wrench can be inserted.

- This is most appropriate when there are only two bolts

Courtesy Bucknell University Facilities

Bolt Sizes[18]

- Use as few bolt sizes as possible

http://www.ascenthardware.com/full-images/648601.jpg

Minimum Number of Bolts [18]

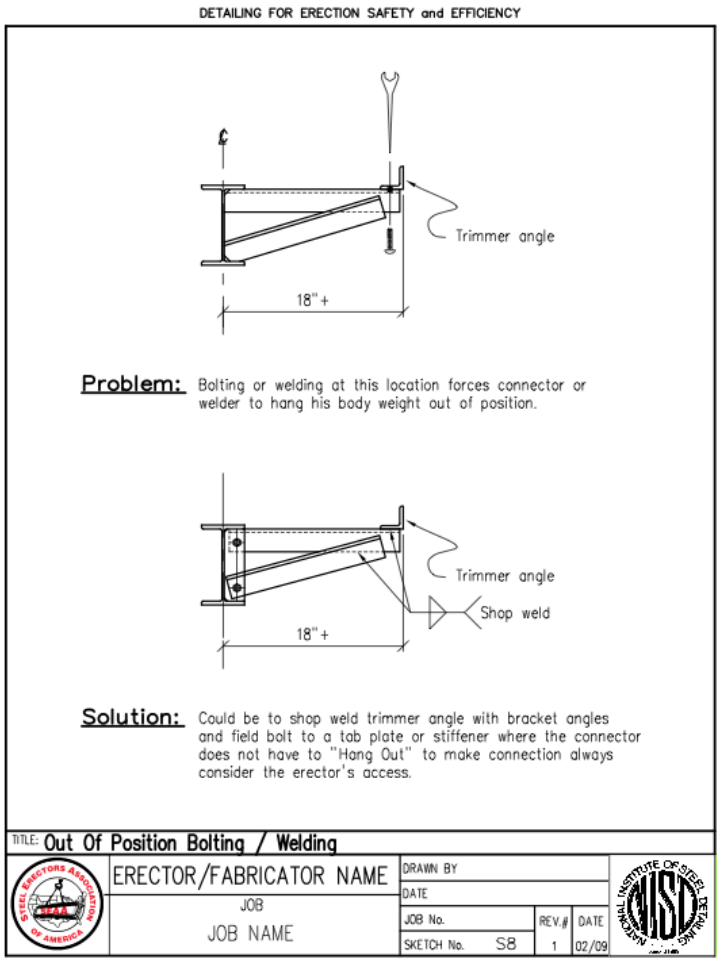
- Use a minimum of two bolts per connection

- OSHA Requirement

[21] AISC “Bolting and Welding”

Avoid Awkward or Dangerous Connection Locations [18, 19]

- Time-consuming and dangerous
- Can cause strain



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Welds

Welding is when the base metal of the desired components is heated and fused together. For safe welded connections, you should consider:

- Avoiding Awkward or Dangerous Connection Locations
- Immediate Stability
- Welding Location
- Welding Material

http://www.wildeck.com/images/about_us/manufacturing_welding_lg.jpg

Immediate Stability [18]

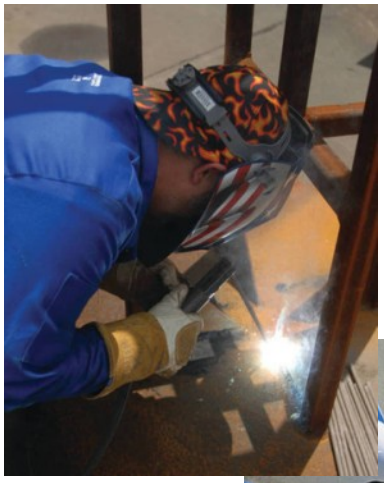
Provide pin-holed or bolted connections to provide immediate stability after placement of members.

[21] AISC “Bolting and Welding”

Welding Locations

Design to have welding performed in shop rather than in field

If field welds are necessary, design should attempt to have them in convenient locations



http://www.archithings.com/new-70z24-stick-electrode-from-hobart-brothers/2009/01/08/7024-stick-electrode-hobart-brothers

http://www.powermag.com/issues/departments/focus_on_o_and_m/Focus-on-O-and-M-August-2008_1382_p3.html

Welding Material

Welding can be a fire hazard and can emit toxic fumes. Always be aware of what material is being welded.

http://romeiron.com/images/Welding-3.jpg

Other Methods for Safer Construction

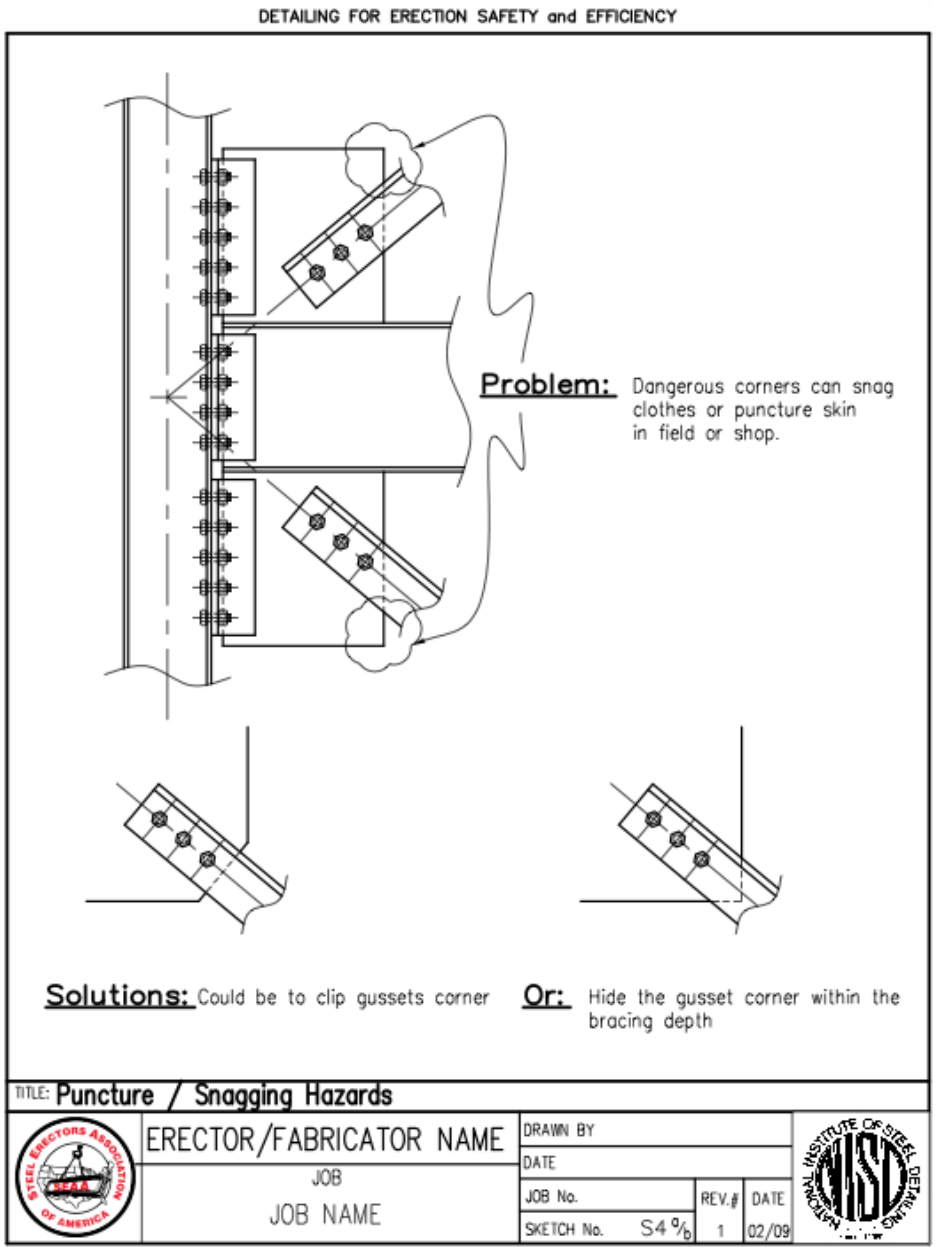
- Avoid Sharp Corners
- Access Problems
- Temporary Bracing
- Crane Safety
- Member Placement
- Tripping Hazards

http://www.gic-edu.com/uploads/structural%20steel%20cxn2.jpg

Avoid Sharp Corners [19]

Corners can cause clothing or wires to get snagged resulting in falling objects or tripping hazards.

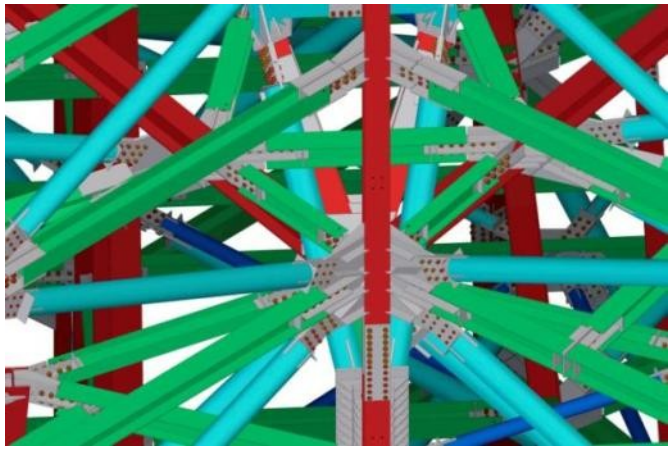
They could also cause scratches or cuts.



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Access Problems

A complicated connection will take much more time to complete, and are potentially more dangerous if they require awkward positioning



http://www.tekla.com/SiteCollectionImages/about-us/press-room-images/ts_Steel_connections.jpg

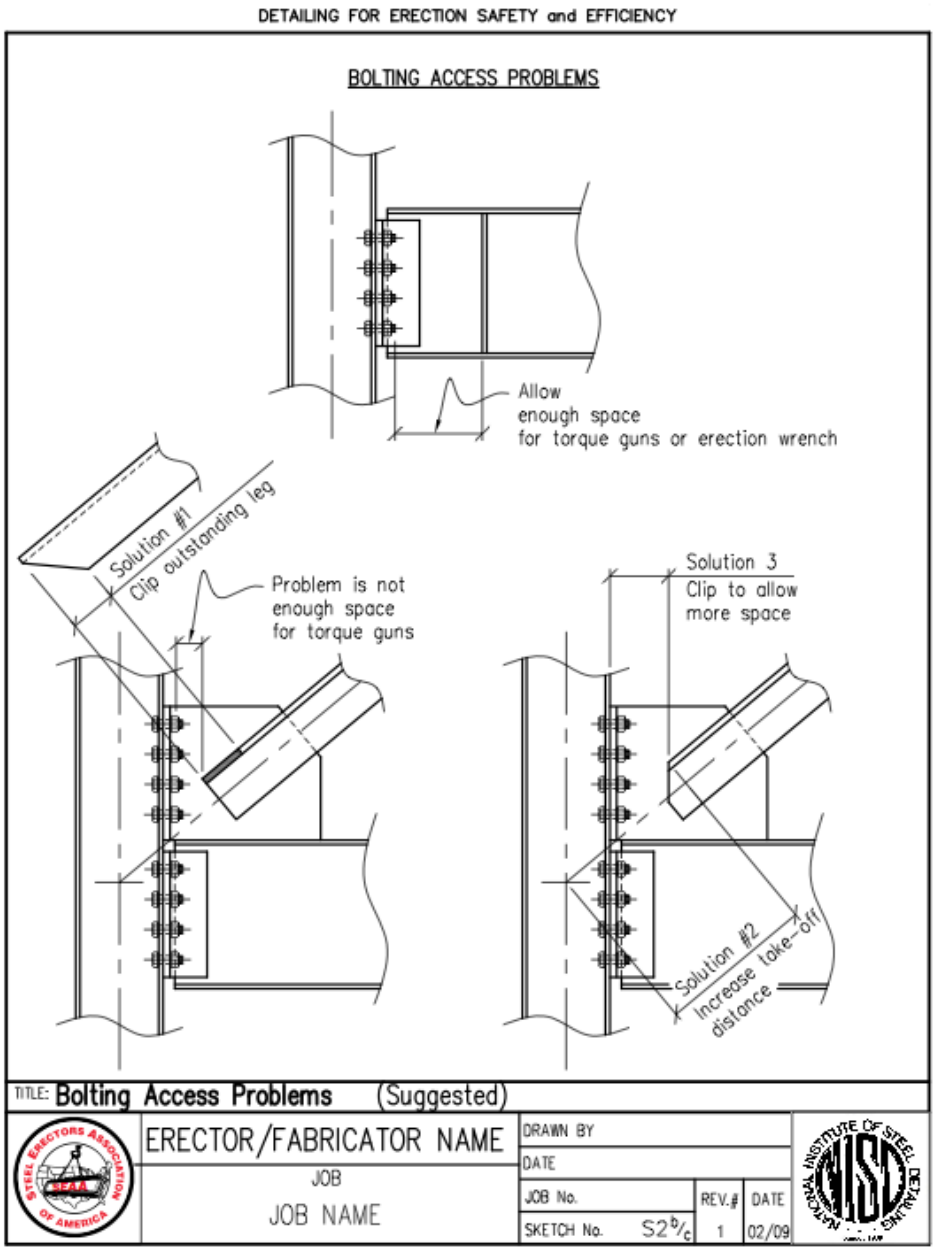
- Provide Enough Space for Making Connections
- Small Column Size Access
- Hand Trap

http://www.rta.nsw.gov.au/environment/images/heritage/4305027b5.jpg

Provide Enough Space for Making Connections [19]

There may not be enough space for common tools

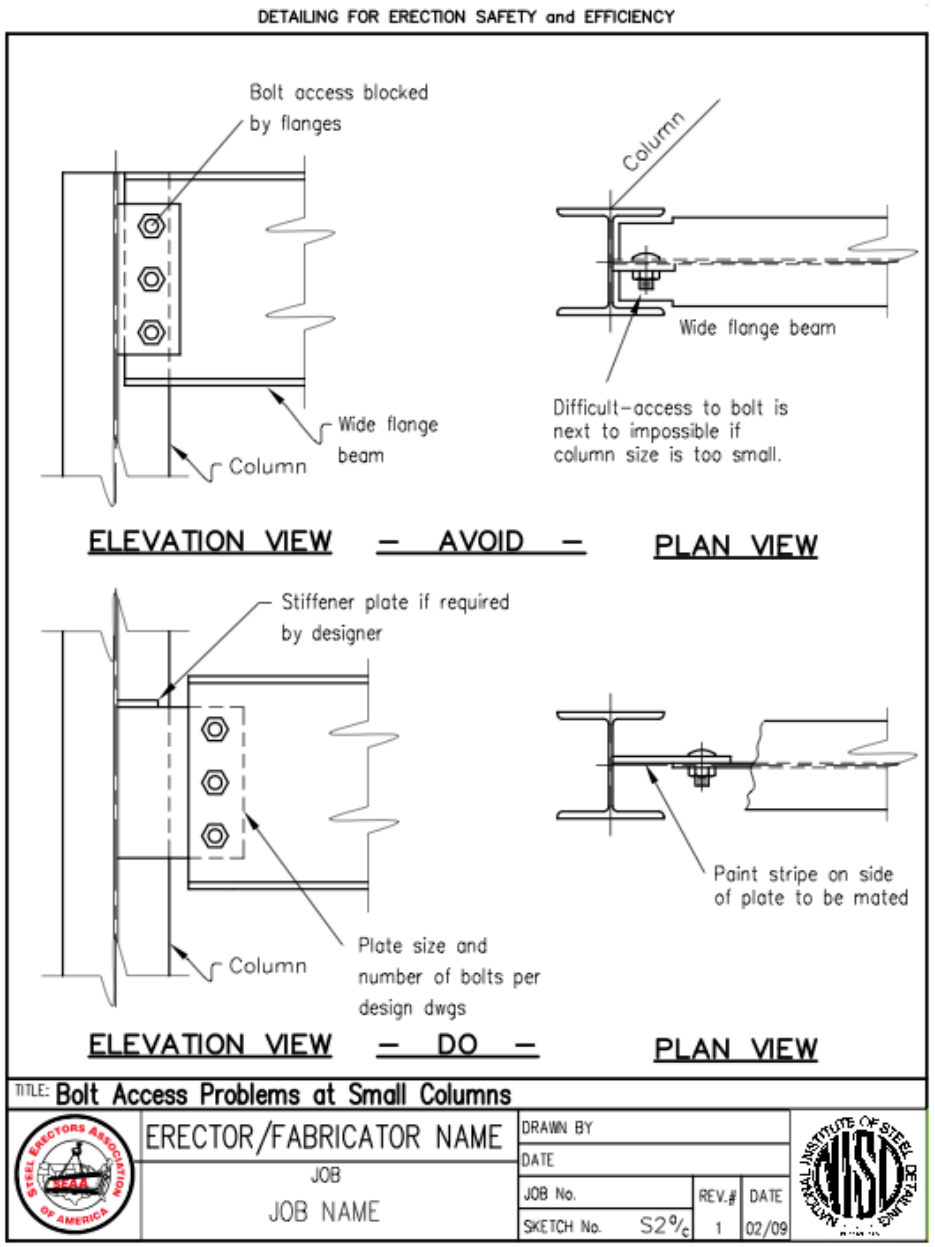
These connections can be made better by clipping away portions or increasing distances



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Small Column Size Access [19]

- Small column depth can make connections difficult
- Access to bolts can be blocked by the column flanges
- Attach a tab to the column

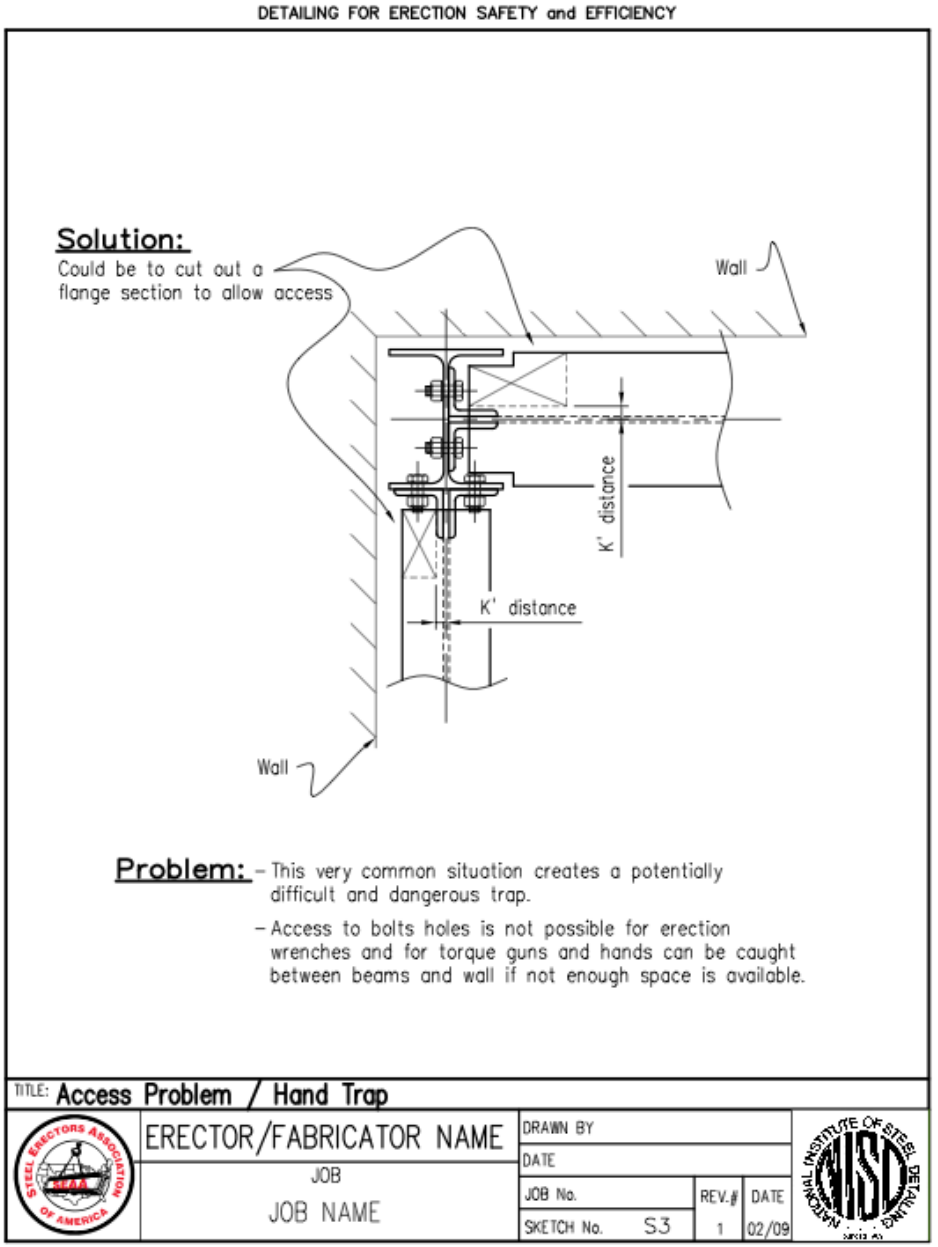


[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Hand Trap [19]

The situation shown can create a dangerous hand trap

A solution is to cut out a section of the flange to allow access to the bolts

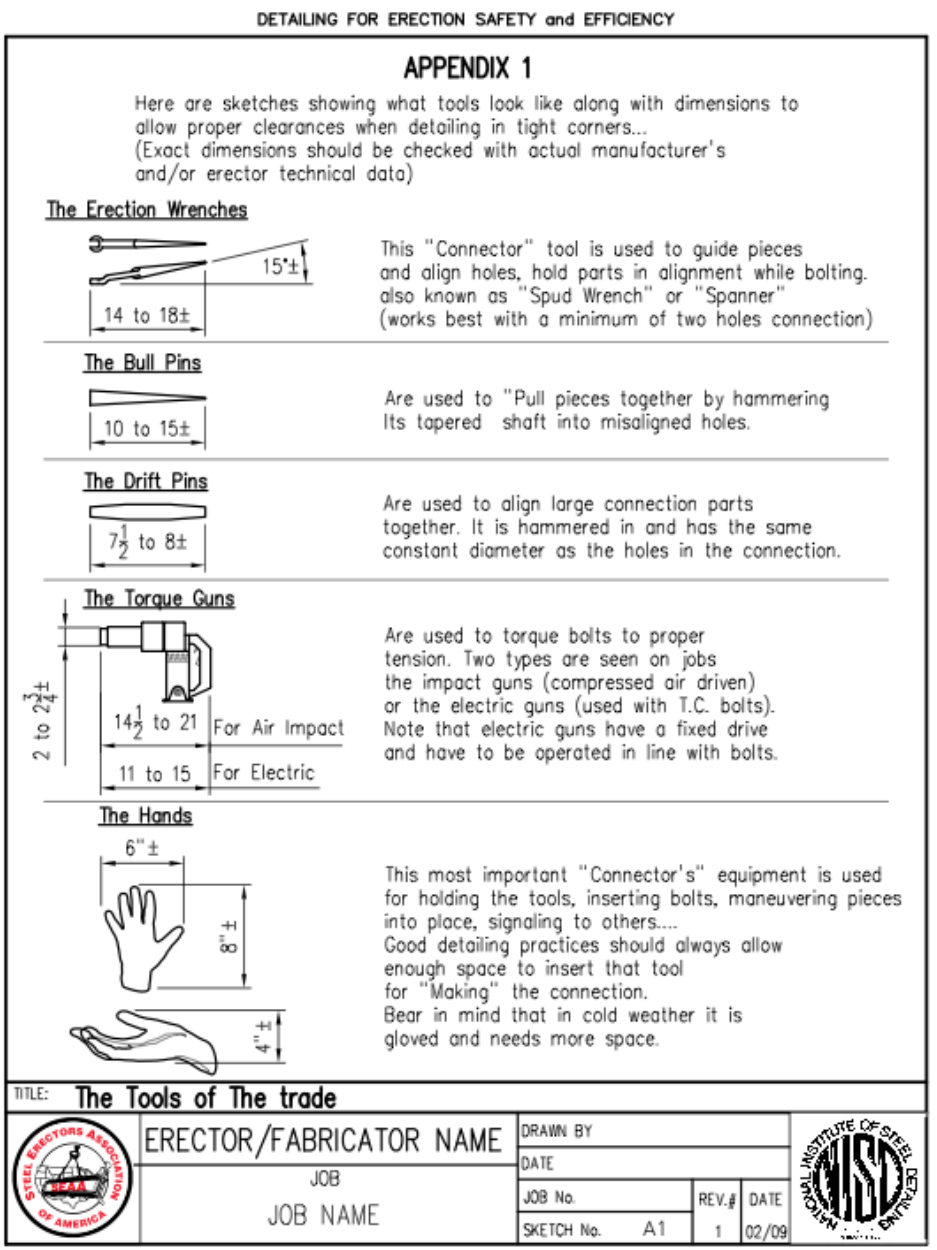


[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Know Approximate Sizes of Tools [19]

"Knuckle-busting" – when workers' knuckles get damaged from trying to fit their hands into a tight space

http://www.northerntool.com/images/product/zoom_images/258509.jpg



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Crane Safety

- Erection will require cranes to lift members into place, which can be difficult due to the site layout.
- It is very useful to put the site utilities on plans to assist with crane management.
- It is ideal to consult with the contractor when designing for crane safety.

http://image.made-in-china.com/2f0j00IMNTSlRWHfzK/Tower-Crane.jpg

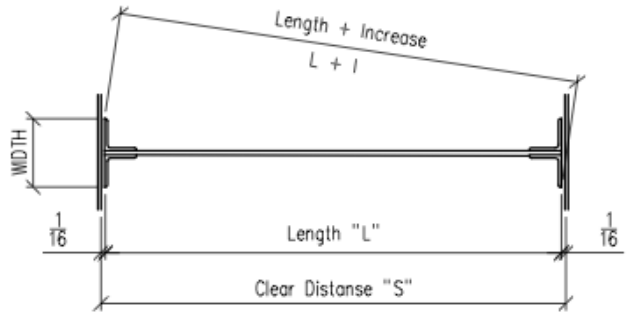
Member Placement [19]

All members must have enough space to fit between columns

Not enough space can lead workers to tilt columns to make it fit

DETAILING FOR ERECTION SAFETY and EFFICIENCY

Swinging Beams To Beams Horizontally



Note: If length plus increase exceeds clear span "S", beams cannot be swung without moving supporting beams or beating into place. This is objectionable and in some cases impossible. Refer such conditions to Project Manager.

Width in Inches	INCREASE "I" — CLEAR DISTANCE "S" IN FEET																		
	6	8	10	12	14	16	18	20	22	24	26	28	30	35	40	45	50	55	60
6	1/4	1/4	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	0	0
7	3/8	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	0
8	1/2	3/8	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
9	5/8	1/2	3/8	3/8	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
10	3/4	1/2	1/2	3/8	3/8	1/4	1/4	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
11	7/8	5/8	1/2	1/2	3/8	3/8	3/8	1/4	1/4	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/8	1/8
12	1	3/4	5/8	1/2	1/2	3/8	3/8	3/8	1/4	1/4	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/8	1/8
13	1 1/4	7/8	3/4	5/8	1/2	1/2	3/8	3/8	3/8	3/8	1/4	1/4	1/4	1/4	1/4	1/4	1/8	1/8	1/8
14	1 3/8	1	7/8	3/4	5/8	1/2	1/2	1/2	3/8	3/8	3/8	3/8	1/4	1/4	1/4	1/4	1/4	1/8	1/8
15	1 5/8	1 1/4	1	7/8	3/4	5/8	5/8	1/2	1/2	3/8	3/8	3/8	3/8	1/4	1/4	1/4	1/4	1/4	1/4
16	1 3/4	1 3/8	1 1/8	7/8	3/4	3/4	5/8	5/8	1/2	1/2	1/2	3/8	3/8	3/8	1/4	1/4	1/4	1/4	1/4
17	2	1 1/2	1 1/4	1	7/8	3/4	3/4	5/8	5/8	1/2	1/2	1/2	1/2	3/8	3/8	1/4	1/4	1/4	1/4
18	2 1/4	1 3/4	1 3/8	1 1/8	1	7/8	3/4	3/4	5/8	5/8	5/8	1/2	1/2	3/8	3/8	3/8	1/4	1/4	1/4

TITLE: Swinging Beams To Beams Horizontally

ERECTOR/FABRICATOR NAME

JOB

JOB NAME

DRAWN BY

DATE

JOB No.

SKETCH No. A4

REV.# 1

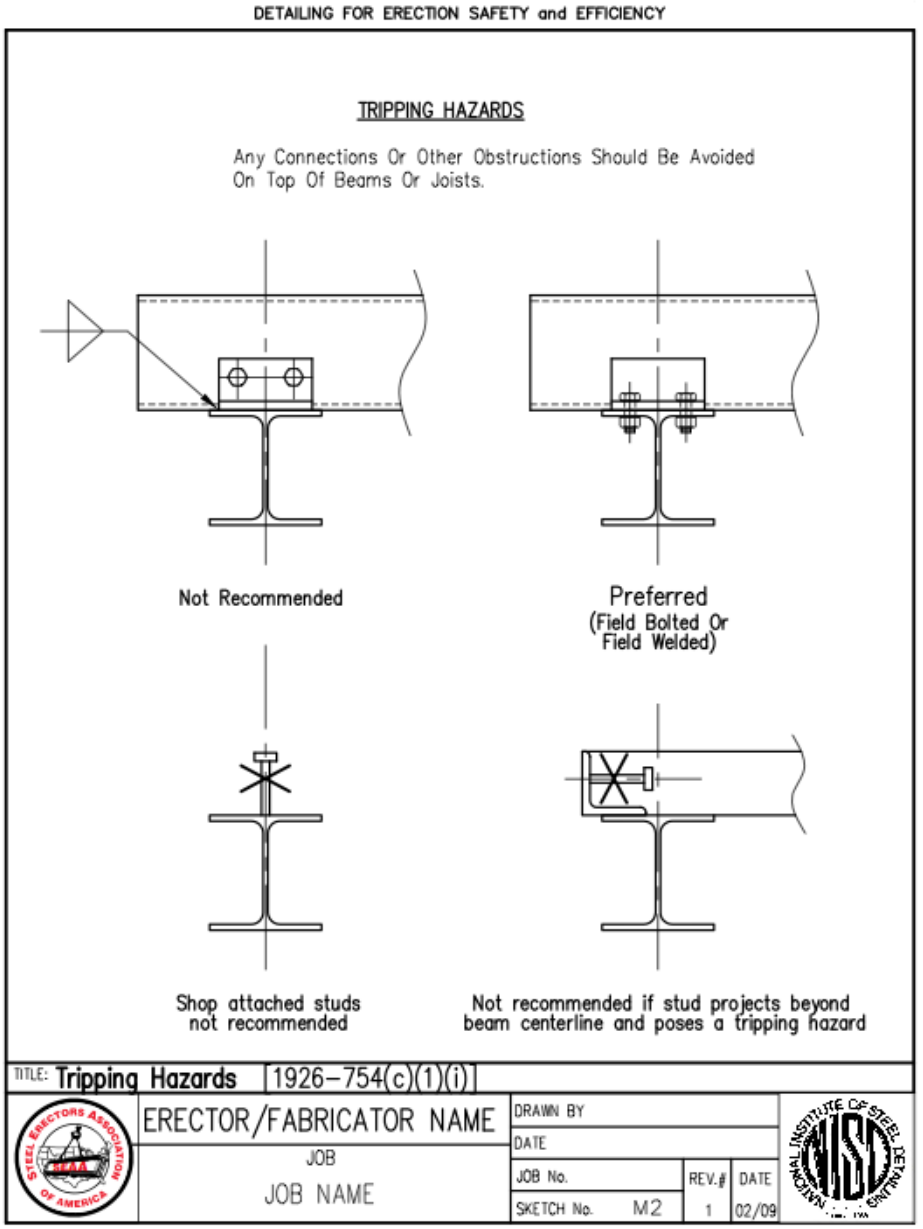
DATE 02/09

[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Tripping Hazards [19]

Avoid having connections on top of beams and joists

http://www.shingleberrysigns.com/design_icon/warning%2016%20trip%20hazard.gif



[19] NISD and SEAA, *Detailing Guide For Erector's Safety & Efficiency*

Recap

- Prevention through Design is an emerging process for saving lives, time and money.
- PtD is the smart thing to do. PtD is right thing to do.
- While site safety is ultimately the contractor's responsibility, the designer has the most power to create drawings with good constructability.
- There are tools and examples to facilitate Prevention through Design.

Help make the world a safer place

Perform Prevention through Design on your projects

For more information please contact National Institute for Occupational Safety and Health (NIOSH)
800-CDC-INFO (800-232-4636) TTY: (888) 232-6348 24 Hours/Every Day
cdcinfo@cdc.gov

DISCLAIMER: *The findings and conclusions in this presentation have not been formally reviewed by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.*

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