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**Connection Design**  
Tips, Tricks, and Lessons Learned



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### Course Description

#### 19.8 Lessons Learned April 8, 2019

In this session, the speakers will share stories, from their respective careers, that have shaped their views on how delegated connection design can be successfully implemented on structural steel projects. The speakers will use real-life case studies and examples to illustrate the importance of teamwork and communication in the construction industry.



### Learning Objectives

- Explain how a flexible bidding process can ensure that all parties have the same understanding on a construction project.
- List key components of an effective design-assist relationship between engineers of record and fabricators / connection designers, and how they can lead to economical and safe connections.
- Explain the importance of the engineer of record having awareness of special design requirements, and clearly communicating those special requirements to the construction team.
- Describe procedures to follow when unsafe conditions are found during construction.



## Night School 19 Connection Design: Tips, Tricks, and Lessons Learned

Session 8: Lessons Learned  
April 8, 2019



Patrick J. Fortney, PhD, PE, SE



Larry S. Muir, PE



William A. Thornton, PhD, PE, NAE



## Some Lessons Learned

- Communication is the key.
- The *Code of Standard Practice* provides a foundation for effective communication.
- The fabricator and connection designer should work as a unit.
- Provide actual loads.
- Do not make up requirements.
- Verify do not guess.

9

## Lessons Learned in the Trenches

The following stories are meant to illustrate how the delegated design process and communications between the parties either worked to provide good outcomes or broke down resulting in challenges that had to be overcome.

10

### 1. Imagined

11

### Misty Water-Colored Memories

In Session 2 of this Night School Cliff Schwinger cautioned against the use of made-up requirements.

12



## Misty Water-Colored Memories

In Session 3 of this Night School Pat Fortney advised fabricators and delegated connection designers not to guess but to verify.

13

## Misty Water-Colored Memories

Let's see these ideas in practice.

14

## Some Project Specifics

- Power plant in a high-seismic area (Special Concentrically Braced Frames)
- A unit price project
- Neither the Engineer nor the Owner were familiar with the *Seismic Provisions* or the potential cost associated with meeting its requirements.

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## Some Project Specifics

- The owner was very concerned with cost.
- The Engineer of Record actively sought cost-saving ideas from the fabricator.
- The Engineer of Record rejected virtually all cost-saving ideas from the fabricator.
- The Engineer of Record imposed "imagined" requirements and took a very rigid approach to code requirements.

16



## Interpretations and Imaginations

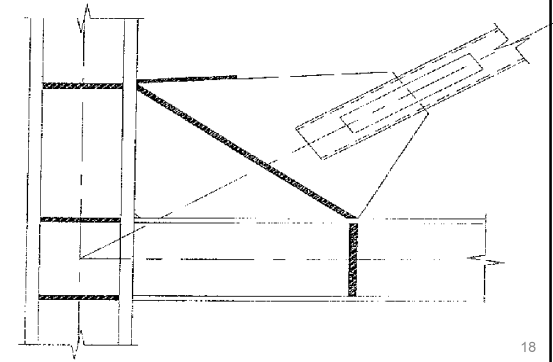
Example of Imagined Requirement:

Vertical brace connections shall be stiffened.

17

## Interpretations and Imaginations

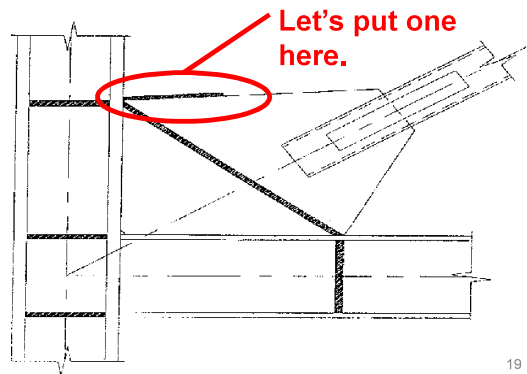
1. Stiffened where?
2. What is the load?
3. How thick should the stiffener be?
4. How should it be welded?



18

## Interpretations and Imaginations

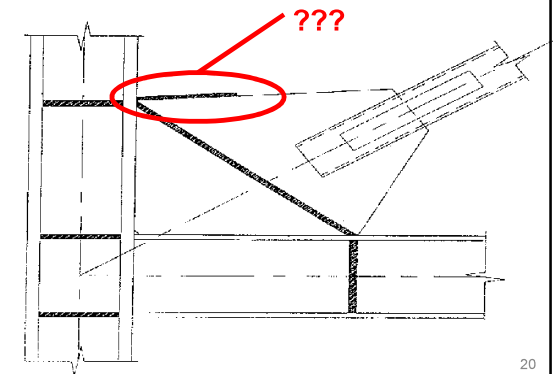
1. Stiffened where?



19

## Interpretations and Imaginations

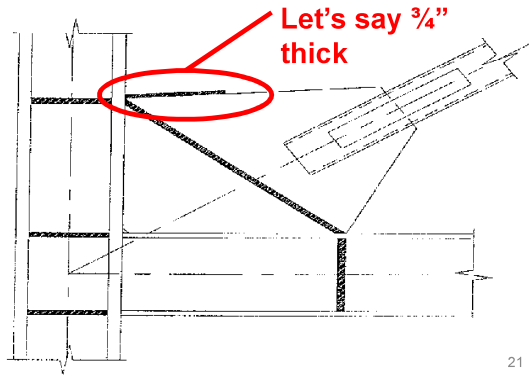
2. What is the load?



20

### Interpretations and Imaginations

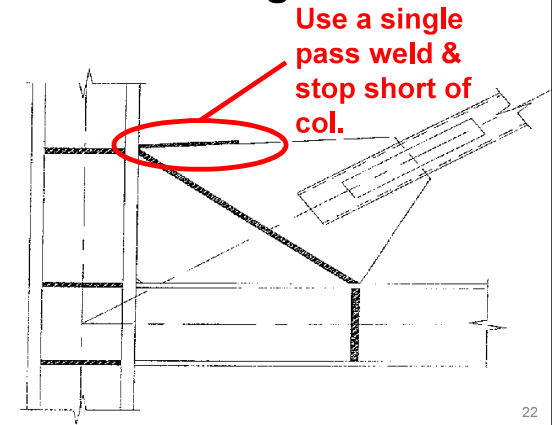
3. How thick should the stiffener be?



21

### Interpretations and Imaginations

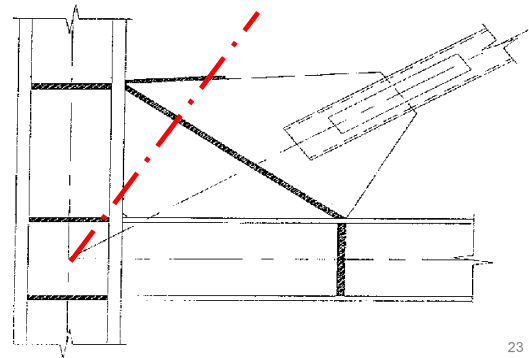
4. How should it be welded?



22

### Interpretations and Imaginations

- In some cases the bevel was more like this and the stiffener resembled a cube  $\frac{3}{4}$ " x  $\frac{3}{4}$ " x  $\frac{3}{4}$ ".
- The benefit was difficult to quantify, but the cost was not.



23

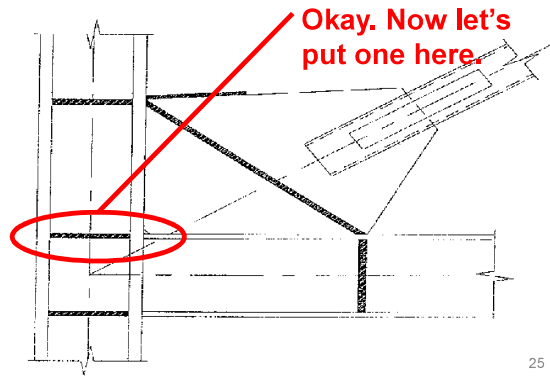
### Interpretations and Imaginations

RINSE AND REPEAT

24

## Interpretations and Imaginations

1. Stiffened where?



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## Interpretations and Imaginations

- If as the Engineer of Record you are going to make-up requirements follow through to develop clear project-specific requirements.
- There is no way to account for made-up requirements during bidding unless they are clearly defined in the contract documents. If they are not clearly defined in the contract documents, they will be a change to the contract.

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## Interpretations and Imaginations

As the connection design engineer when imaginary requirements are imposed:

- Point out the discrepancy.
- Make the EoR clearly define what is required. **DO NOT GUESS.**
- Document the change.
- Evaluate cost and schedule impacts as indicated in the COSP.

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## Post-Mortem

- The EoR asked the Fabricator to help them explain to the Owner why this project had cost multiples of similar past projects.
- Some of the increased cost could be explained by the inherent costs associated with satisfying the *Seismic Provisions*.

However...

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## Post-Mortem

... much of the cost was directly attributable to imagined requirements and interpretations the Engineer chose to make.

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## 1. Imagined

### Lessons Learned

- If Engineer of Record has special project requirements, those should be clearly defined.
- There is no way to account for special project requirements during bidding unless they are clearly defined.
- Connection designers should point out discrepancies and make the Engineer of Record clearly define what is required.

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## 2. Design Assist: When it Works



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## Teamwork

Design Assist

"If everyone is moving forward together,  
then success takes care of itself."

~Henry Ford

32

**Teamwork**

Design Assist

When it Works


33

**Teamwork**

Design Assist

- Really!

So, the SEoR wants pre-bid meetings with the fabricator to discuss design assist in regard to connection design




34

**Teamwork**

Design Assist

- Really!

So, the SEoR wants pre-bid meetings with the fabricator to discuss design assist in regard to connection design



The SEoR, fabricator, connection designer, and erector bring specialized and critical skills to a project


35

**Teamwork**

Design Assist

- Really!

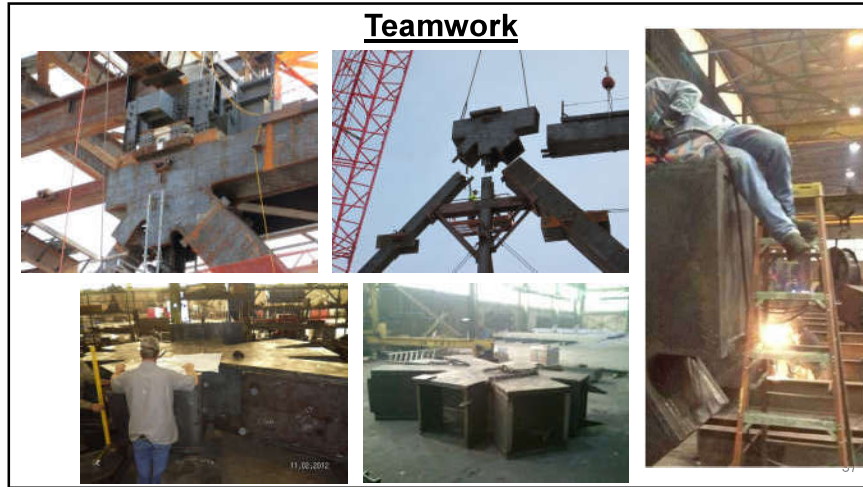
So, the SEoR wants pre-bid meetings with the fabricator to discuss design assist in regard to connection design



The SEoR, fabricator, connection designer, and erector bring specialized and critical skills to a project

Each brings an important piece of the puzzle!

36



**Teamwork**

**Design Assist**

- Really!

SEoR wants to meet prospective fabricators during bid process to discuss connection design and potential for collaboration

Intent is to finalize structural design with input from erectors and connection designers

38

**Teamwork**

**Design Assist**

- Really!

This proved to be a wholesome offer

SEoR finalized structural design based on collaboration with the erector and connection designer

39

**Teamwork**

**Design Assist**

- Really!

Clear, concise engineering sketches to communicate with SEoR, fabricator, and detailer

40

### Teamwork

#### Design Assist

- Really!

Nodal approach led to the SEoR performing several iterations of analysis and redesign to accommodate type of connections

The SEoR was willing to take this approach



41

### Teamwork

#### Design Assist

- Really!

Iterations of analysis with changes in boundary conditions led to additional combined connection design loads

The connection designer was willing to take this approach



42

### Teamwork

#### Design Assist

- Really!

Most all of the nodal connections used mill-to-bear joints to transfer large brace forces in the range of 10,000 to 20,000 kips

Fabricator and erector worked closely with each other to ensure fit-up



43

### Teamwork

#### Design Assist

- Really!

Original design documents required all built-up members to be joined with CJP welds

With input from connection designer, approximately \$2M was saved by using combinations of fillet, PJP, and CJP welds where appropriate



44


**Teamwork**

**Design Assist**

- Really!

SEoR, fabricator, and erector collaborated continually throughout design phase.

Each bring value engineering and compromise for the good of the project




46

**Teamwork**

**Design Assist**

- Really!
- ~11,000 tons of fabricated steel,
- 72 nodal connections weighing as much as 25 tons each
- ~8 miles of linear welds on built-up shapes
- 14-member nodes



1 fit-up problem that required rework (early in erection) on entire project

46


**Teamwork**

**Design Assist**

- Really!

Teamwork,  
Clear and effective communication,  
Compromise

Successful project from every perspective



Each brings an important piece of the puzzle!

47

**2. Design Assist: When it Works**

**Lessons Learned**

- The talents and skills of all parties are critical to the success of a project.
- Respect for each other is crucial.
- Trust in our colleagues and counterparts is crucial.
- Open and clear conversation between parties is crucial.
- This is a give and take process and reasonable compromises must be made.
- Everyone benefits in a healthy team environment.



48

## 2. Design Assist: When it Works

Poll Question



49

## 3. Clear and Present Danger



50

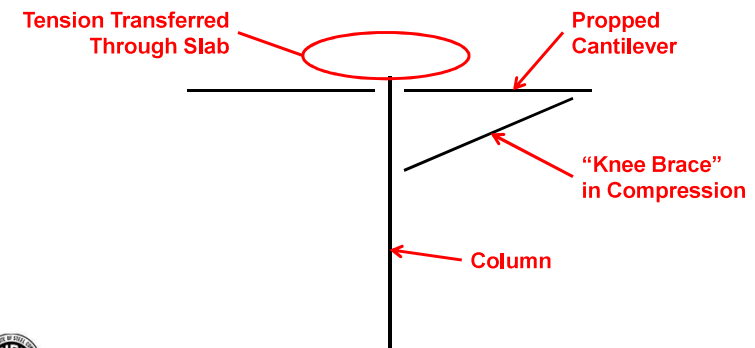
## Some Project Specifics

- An outdoor theater accommodating about 15,000 spectators.
- A tight schedule constrained by an “opening day” concert.
- Propped cantilever beams supporting seating.

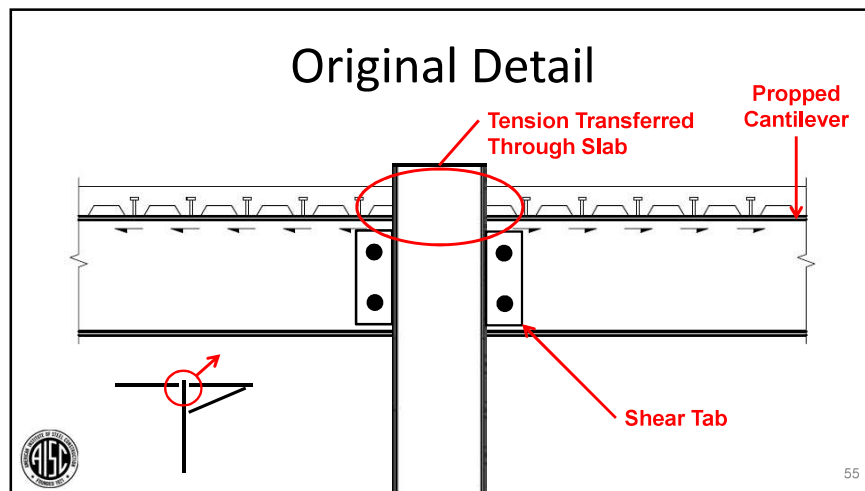
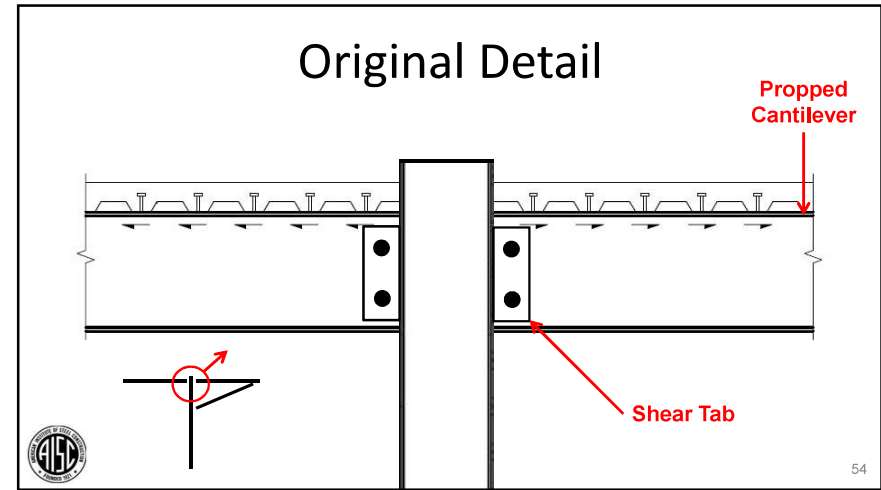
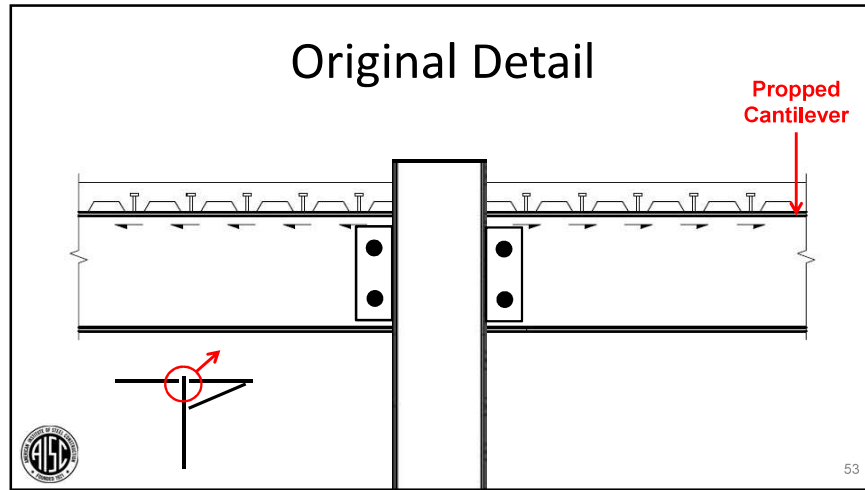


51

## General Layout



52



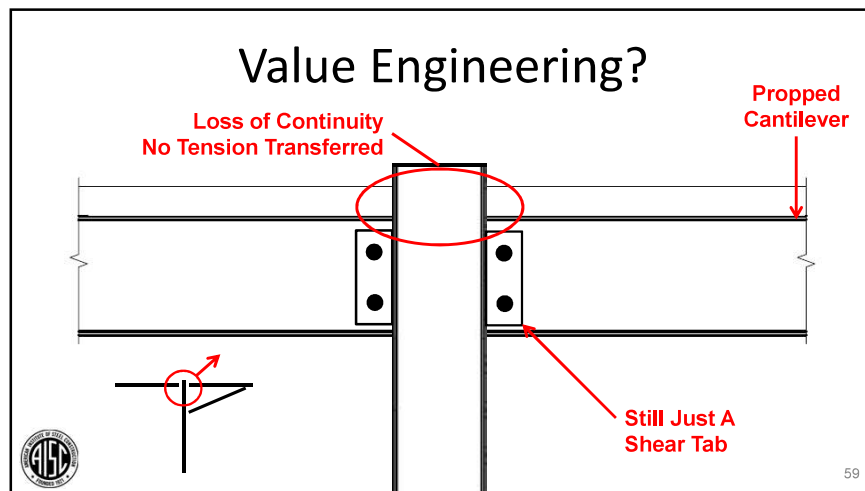
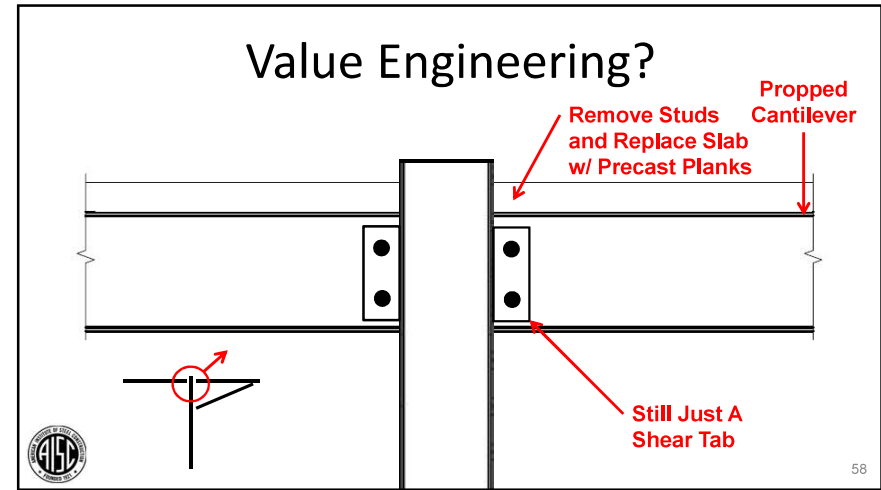
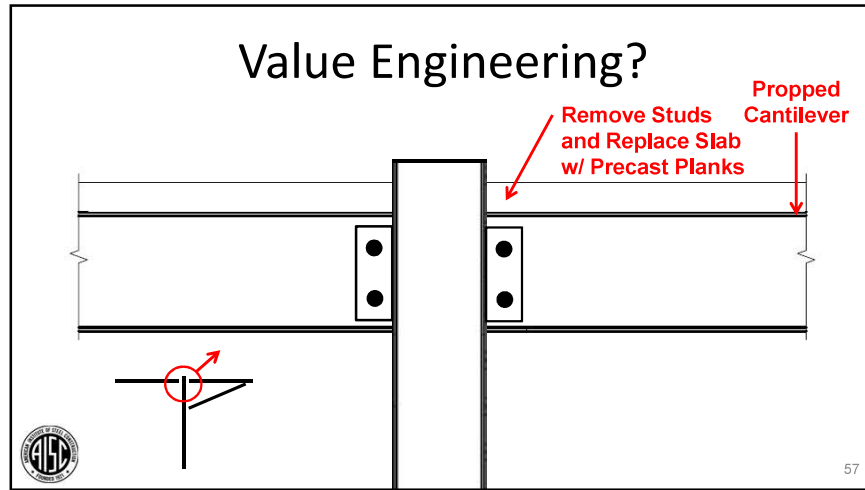
### Let's Add Some Value!!!

Relatively late in the project someone suggested that money could be saved by replacing the cast-in-place slab with precast planks.

The Engineer of Record approved the change.

56

The slide features a cartoon illustration of a man in blue pants and a white shirt carrying a large, overflowing green money bag with a dollar sign on it. The text describes a cost-saving measure approved by the Engineer of Record.



### Let's Add Some REAL Value!!!

Fortunately a connection design engineer working for the fabricator noticed the loss of continuity and submitted an RFI...

60

## Let's Add Some REAL Value!!!



Fortunately a connection design engineer working for the fabricator noticed the loss of continuity and submitted an RFI...  
But the Engineer said there was no problem...



61

## Let's Add Some REAL Value!!!



Fortunately a connection design engineer working for the fabricator noticed the loss of continuity and submitted an RFI...  
But the Engineer said there was no problem...  
So the Fabricator Tried Again...



62

## Let's Add Some REAL Value!!!



Fortunately a connection design engineer working for the fabricator noticed the loss of continuity and submitted an RFI...  
But the Engineer said there was no problem...  
So the Fabricator Tried Again...And Again



63

## Let's Add Some REAL Value!!!



Fortunately a connection design engineer working for the fabricator noticed the loss of continuity and submitted an RFI...  
But the Engineer said there was no problem...  
So the Fabricator Tried Again...And Again  
...And Again...And Again... And Again...A



64

## Let's Add Some REAL Value!!!



Finally the Fabricator had to issue a letter stating it was unsafe to continue erection.

This forced a face-to-face meeting with the Engineer of Record – who was unaware of the concerns his employee had dismissed.



65

## The Show Must Go On

The issue was ultimately resolved and the project was completed on time.



The first concert was performed as scheduled



66

### 3. Clear and Present Danger

#### Lessons Learned

- Carefully consider the possible unintended consequences of value engineering changes.
- Do not quickly dismiss the concerns of other project team members.
- Be willing to admit mistakes.



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### 3. Clear and Present Danger

#### Poll Question



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## 4. The Road Less Traveled



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## Just the Facts

- Meeting the *Seismic Provisions* increases the cost of projects.
- Fabricators should bid what they see. This is the position inherent in the COSP.
- When the scope of work changes from that established in the Contract Documents, a modification of the contract price shall be made. (paraphrased from the COSP)



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## The Reality

- Contract documents are often not clear or complete – especially at the bid-stage.
- Some bidding processes are not flexible enough to accommodate proper clarifications.



71

## The Contractors' Dilemma

Bid what I see and fight for extras later.



Bid what I think the engineer wants and lose the project to a lower bidder.



72

## Some Project Specifics

- Large hospital
- Building codes in process of being updated – *Seismic Provisions* could either be incorporated or not
- Engineer expressed desire to incorporate latest and greatest provisions



73

## The Road Less Traveled



74

## The Road Less Traveled

- Fabricator provided preliminary costs – excluding extra seismic detailing.
- Fabricator was aware that including all the seismic detailing costs would inflate the bid relative to other less knowledgeable competitors.
- Extensive meetings were held to hammer out the differences between seismic and “non-seismic” bids.



75

## The Road Less Traveled

- It may be better to walk away from a job than to accept an unfavorable or uncertain contract.
- However, there are other options. Bid clarifications and exceptions should not disqualify contractors. They should be taken as an indication that the contractor has thought through the project.



76

## Final Result

- Owner, General Contractor and Engineer all understood what was and was not included in the bid.
- Fabricator was ultimately awarded the contract.
- An “ala carte” approach was taken with the seismic requirements.



77

## 4. The Road Less Traveled

### Lessons Learned

- Fabricators and connection designers should not shy away from clarifying project requirements during the bid phase.
- When it would benefit the project, Engineers of Record should be flexible on project requirements.



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## 5. Design Assist: When it Doesn't Work



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## Teamwork

Design Assist

When it Doesn't Work

80

### Teamwork

#### Design Assist

- **Not Really!**

Short-listed fabricators meet with SEoR three times prior to award to discuss design assist issues

Several big ticket items are identified...

- High seismic systems in SDC B,
- SMF beam loads are UDL; connections will not satisfy AISC 358 requirements with this kind of loading
- Reinforcement requirements are inconsistent with limit state needs

81

### Teamwork

#### Design Assist

- **Not Really!**

Several big ticket items are identified...

- Structural details are inconsistent with AISC 341,
  - "...it's not really seismic, we just used R=8 to reduce the base shear..."
- Design drawings have no indication of transfer forces in the braced frames
- No indication of collector beams or chords
- etc.

82

### Teamwork

#### Design Assist

- **Not Really!**

Several big ticket items are identified...

- After award, IFCs do not address any of the issues identified pre-award
- After award, SEoR refuses to communicate with fabricator and connection designer
- ~90% of responses to CDQs are "...refer to the drawings..."
- Fabricator learns that one-sided connections are not permitted just toward the end of the shop drawing approval process

83

### Teamwork

#### Design Assist

- **Not Really!**

Result...

- Multi-million dollar disputes
  - Resolution takes years
- Budget overrun
- Schedule overrun
- Mistrust that lasts a lifetime

84



## 5. Design Assist: When it Doesn't Work

### Lessons Learned

- Verbal agreements need to be documented.
- A lack of respect and mistrust is detrimental to the success of a project.
- Incomplete or unclear requirements on design documents will lead to costly change orders.
- Bad experiences last forever and can damage future relationships.



85

## 5. Design Assist: When it Doesn't Work

### Poll Question



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## 6. EOR—Erector—Fabricator Cooperation



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EOR, Erector,  
And  
Fabricator  
Cooperation



88



# 46 Story “Diagrid” Building

89



**A standardized “node” was used to connect the diagrid members and form the exoskeleton of the building.**

90



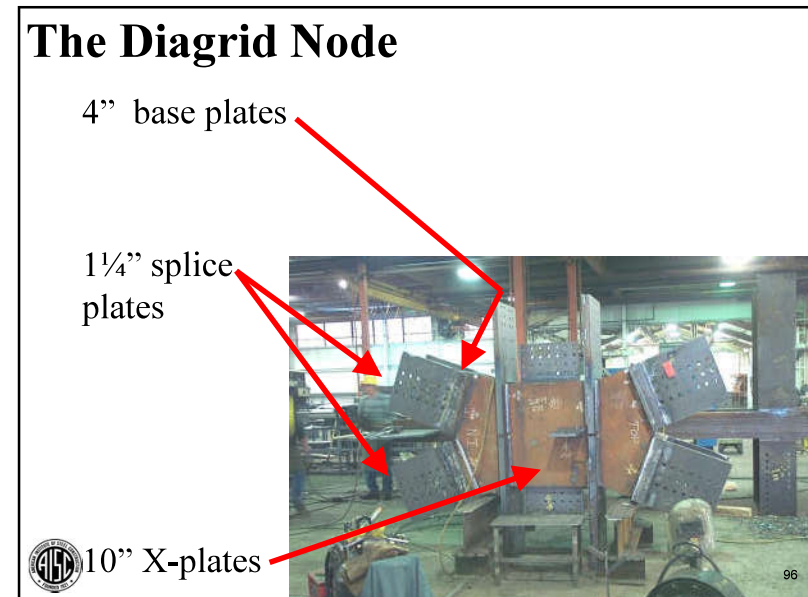
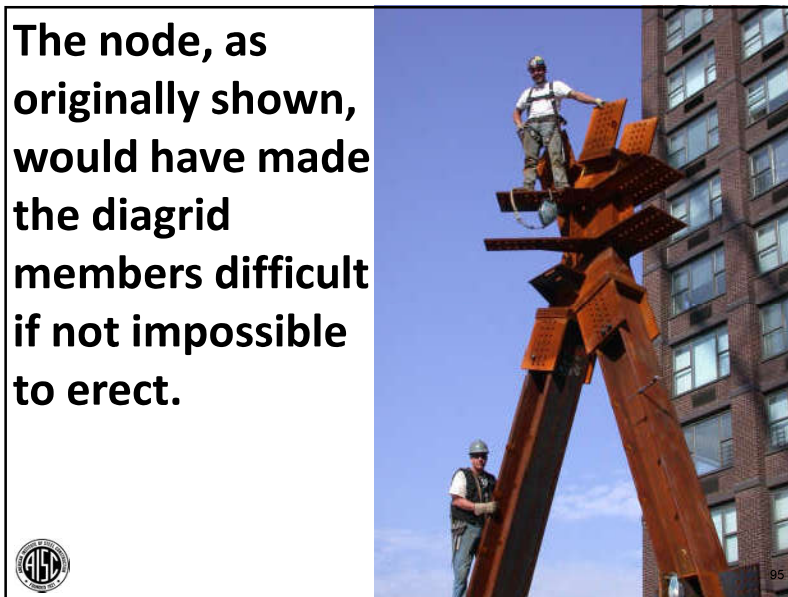
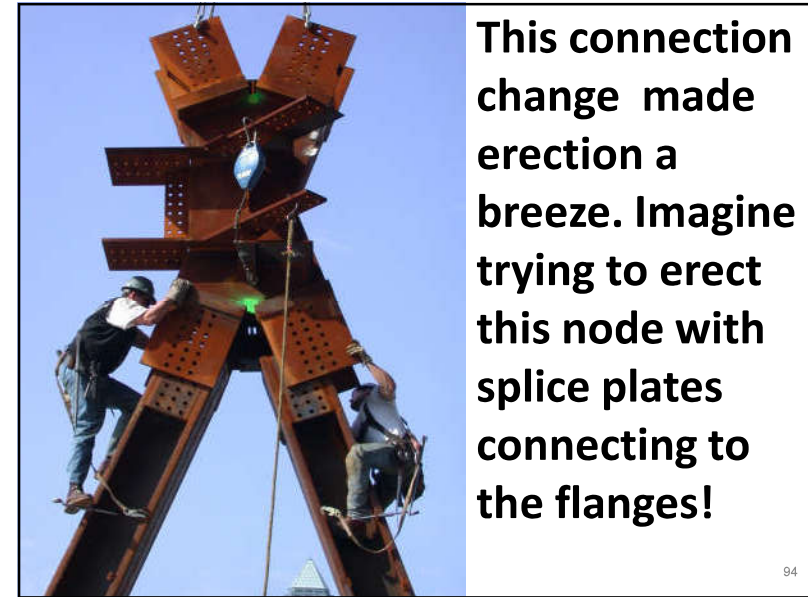
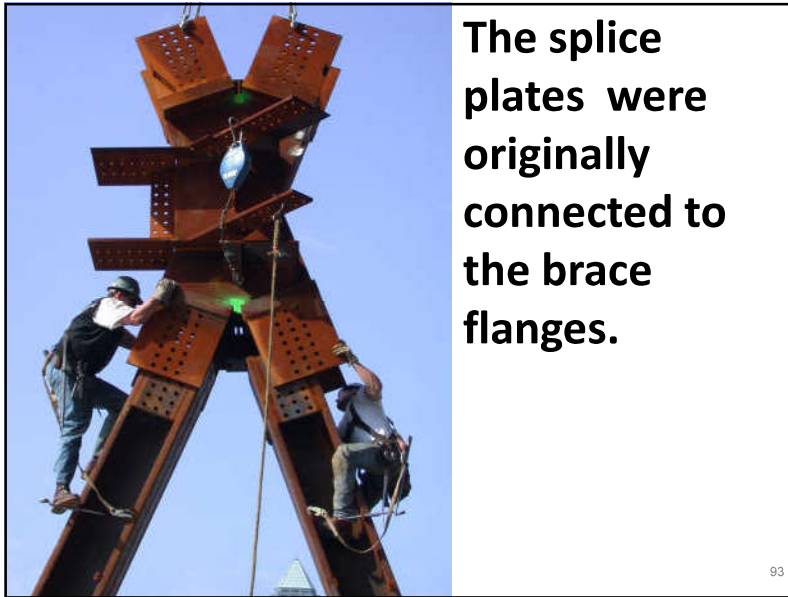
**This node was developed by the erector and the fabricator in cooperation with the EOR**

91



**The original node used splice plates perpendicular to those shown here.**

92





This building was  
completed on  
time and on  
budget

97

## 6. EOR—Erector—Fabricator Cooperation

### Lessons Learned

- Engaging the fabricator and erector during the design phase can greatly improve constructability.
- Collaboration between EOR, erector, and fabricator can provide economic benefits to the client.



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## 7. How We Interact is Important




99


## Respect and Trust


How we Interact is important




100


<b><u>Respect and Trust</u></b>	
<b><u>Billboard 100 exchanges</u></b>	
DCD:	The drawings provide no loading information for connection design. For what loads do we design the connections?
SEoR:	Whatever loads you think are reasonable!
 101	


<b><u>Respect and Trust</u></b>	
<b><u>Billboard 100 exchanges</u></b>	
<b>Between two Delegated Designers...</b>	
DCD 1:	I attended your presentation on effective communication.
DCD 2:	What did you think?
DCD 1:	Personally, I think if the SEoR delegates connection design they should just shut up and get out of my way.
 102	


<b><u>Respect and Trust</u></b>	
<b><u>Billboard 100 exchanges</u></b>	
DCD:	Why are the moment connection designs rejected?
SEoR:	You can't use story shear to reduce panel zone demands.
DCD:	Why not?
SEoR:	This building has no story shear.
 103	


<b><u>Respect and Trust</u></b>	
<b><u>Billboard 100 exchanges</u></b>	
DCD 1:	If you want to understand the flow of forces through the connecting elements, you really have to draw a FBD.
DCD 2:	Nah! I haven't drawn a FBD since my senior year of college.
 104	



<b><u>Respect and Trust</u></b>	
<b><u>Billboard 100 exchanges</u></b>	
DCD:	So, these are three ideas for the field fix.
SEoR:	Wait, do you have any options that don't use welds?
DCD:	No! This condition is not conducive to bolted options.
SEoR:	You are using welds to transfer loads, I don't like that; welds should be used to hold parts together, not transfer loads.
	105

<b><u>Respect and Trust</u></b>	
<b><u>Billboard 100 exchanges</u></b>	
DCD 1:	I spent about three weeks designing these moment connections.
DCD 2:	I just make everything CJP to cut down on design time. The fabricator never question it (wry smile)!
	106

<b><u>Respect and Trust</u></b>	
<b><u>Billboard 100 exchanges</u></b>	
My all time top favorite...	
DCD:	What you are suggesting violates the requirements of AISC 360.
SEoR:	Well maybe when you grow up and become an engineer you will understand!
	107

<b>7. How We Interact is Important</b>	
<b>Lessons Learned</b>	
<ul style="list-style-type: none"><li>• Perceived lack of interest is infectious.</li><li>• Blatant disrespect and an unwillingness to recognize others' value damages relationships as well as project success.</li><li>• The AISC COSP clearly identifies the SEoR as the final authority relative to connections.</li><li>• Free body diagrams are the "bee's knees".</li></ul>	
	108



## 8. Keep Your Eye on the Details

109

## Keep Your Eye on the Details

110



**Ductile Seismic Design ?**



111



**Ductile Seismic Design ?  
These were called “barn  
door” gussets by the owner**



112

### Special Concentric Braced Frames Detailed for Inelastic Rotation

**BRACE ROTATED & DESIGNED FOR WEAK-AXIS MOMENT AT HEAVILY LOADED MEMBERS AND AREAS OF TIGHT GEOMETRY (BRACES NOT SHOWN)**

**2t**

113

Wide Flange "Flange to View" Connection

114

### Here is a better idea In-Plane Brace Buckling

From  
 "Satisfying Inelastic Rotation Requirements For In-Plane Critical Axis Brace Buckling For High Seismic Design", W.A. Thornton and P.J. Fortney, AISC Engineering Journal, Third QTR.,2012, pp.99-108

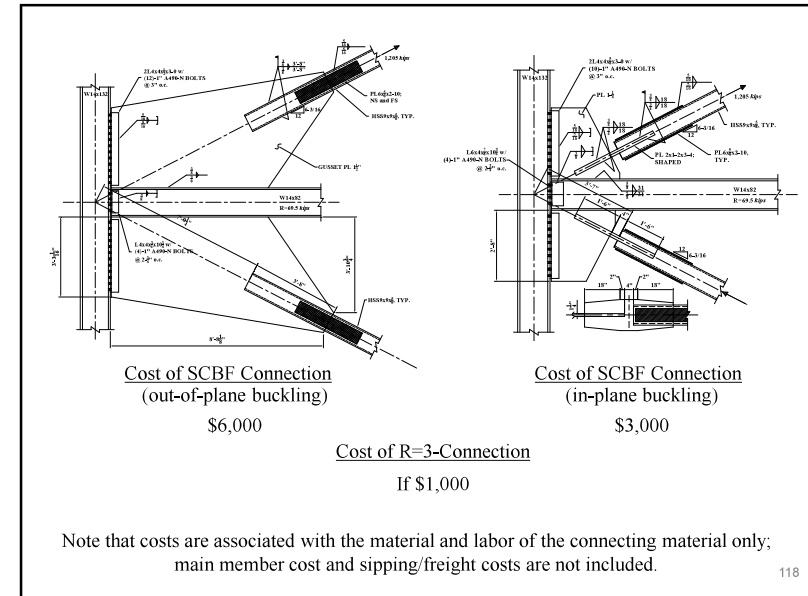
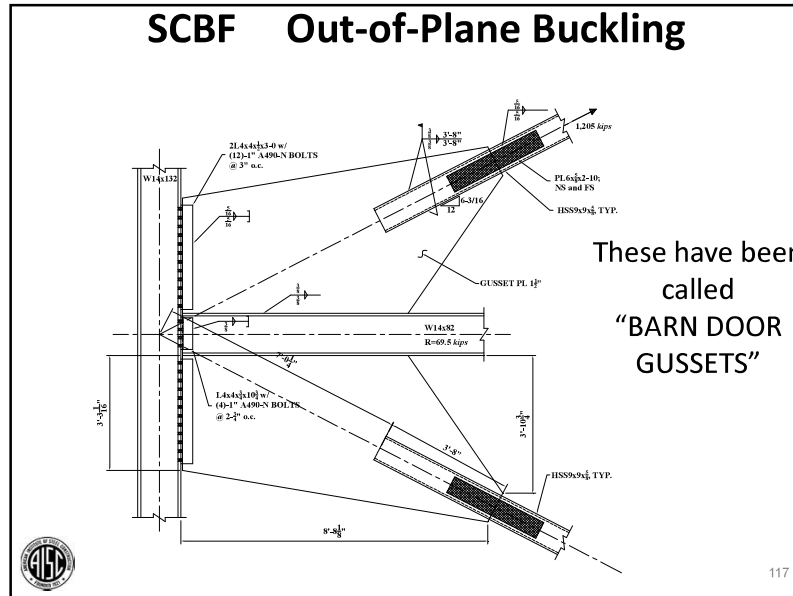
115

### SCBF In-Plane Buckling

From  
 "Satisfying Inelastic Rotation Requirements For In-Plane Critical Axis Brace Buckling For High Seismic Design", W.A. Thornton and P.J. Fortney, AISC Engineering Journal, Third QTR.,2012, pp. 99-108

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## 8. Keep Your Eye on the Details

### Lessons Learned

- There are multiple details for achieving ductility in brace connections of special concentrically braced frames.
- Be open to alternative detailing solutions.
- Thoroughly detail your connections to-scale to assess practicality of the design.

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AISC | Questions?

**Smarter.  
Stronger.  
Steel.**

## Individual Session Registrants

### CEU / PDH Certificates

- You will receive an email on how to report attendance from: [registration@aisc.org](mailto: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 Session Registrants

### CEU / PDH Certificates

- 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](mailto:NIGHTSCHOOL@AISC.ORG).

### Quiz and attendance records

Posted Tuesday mornings. [www.aisc.org/nightschool](http://www.aisc.org/nightschool) -- Click on Current Course Details.

### Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- CEUs/PDHs – If you watch a recorded session, you must pass quiz for CEUs/PDHs.
- REINFORCEMENT – Reinforce what you learn 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 Wednesday. The recording will be available for three weeks. (For 8-session registrants only.) EMAIL COMES FROM [NIGHTSCHOOL@AISC.ORG](mailto:NIGHTSCHOOL@AISC.ORG).

### CEUs / PDHs via recording

If you watch a recorded session, you must take *and pass* the quiz for CEUs/PDHs.



## 8-Session Registrants

### Night School Resources

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



## 8-Session Registrants

### Night School Resources

Go to [www.aisc.org](http://www.aisc.org) and sign in.



#### Login

If you're an existing customer, please enter your username and password.

##### USERNAME

Enter your username

##### PASSWORD

Enter your password

Remember Me

##### DON'T HAVE AN ACCOUNT?

My AISC allows you to access Engineering Journal articles and Design Guides you have downloaded from the bookstore.

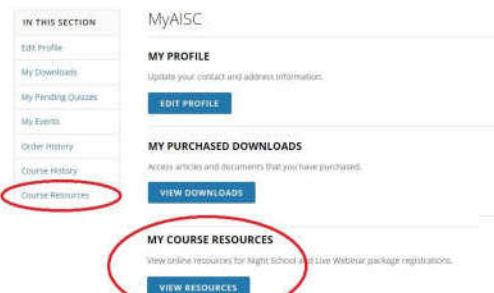
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## 8-Session Registrants

### Night School Resources




Event	Start Date
NS 13 8-Session Package Night School 13 - Design of Industrial Buildings	1/15/2017 7:00:00 PM
NS 14 8-Session Package Night School 14 - Fundamentals of Quality	6/5/2017 7:00:00 PM



## 8-Session Registrants


### Night School Resources



#### Night School 13: Design of Industrial Buildings

##### 8-SESSION PACKAGE RESOURCES


Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/10/2017 7:00:00 PM			Pass Score: 10	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM			Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	3/13/2017 7:00:00 PM			Available 02/13/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM			Available 03/01/2017 5pm EST	Pending
NS13 - Crane Order Design and Frame Analysis	3/6/2017 7:00:00 PM			Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM			Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girders & Longitudinal Brag Bracing Detail	3/27/2017 7:00:00 PM			Available 03/28/2017 5pm EST	Pending



## 8-Session Registrants

### Night School Resources

- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at [www.aisc.org/nightschool19](http://www.aisc.org/nightschool19). Scroll down to Quiz and Attendance records.
  - Updated on Tuesday mornings.



## 8-Session Registrants

### Night School Resources

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

