Night School 26: Developing an Eye for Connection Design

Thank you for joining our live webinar. We will begin shortly. Please standby.

Session 4 – Bolts
August 3, 2021 | Larry Muir

Smarter. Stronger. Steel.

AISC Live Webinars

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AISC Live Webinars

Course Description

Bolts
August 3, 2021

The session will cover the basics of bolted connections. The session will address common connection types, design limit states and slip critical connections. Practical suggestions for economical use and standard practices will be presented. This session will also allow for an extended Q&A and requested topics from the audience, collected in advance of the session.

AISC Live Webinars

Learning Objectives

1. List three types of design assumptions in a bolted connection.
2. List the differences between pretensioned and slip critical connections.
3. List the advantages of snug-tight bolts in bearing joints.
4. Describe how to derive the nominal bolt strength.

Night School 26: Developing an Eye for Connection Design

Session 4: Bolts
August 3, 2021

Larry Muir, PE, Consultant

Smarter.
Stronger.
Steel.

Developing an Eye For Connection Design

by Larry S. Muir, P.E.

Attendee-based Content

We received quite a few questions and comments up to this point. Thank you for participating in our experiment.

The discussion that follows addresses four attendee questions and touches on some others.

By the very nature of this process I have had limited time to produce this discussion. The broad ideas are sound; it is possible that some of the details may be off a bit.

It is intended to be a useful introduction, not a definitive and comprehensive resource.

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Attendee-based Content

I once had an inquirer at the Steel Solutions Center tell me that one of my answers sounded like it should have been delivered bellied up to the bar sharing a beer.

I took this as a great compliment.

Let's talk about your questions and topics.

Warning: Since I'm the guy with the microphone, I guess I am also that guy at the bar who just won't shut-up… only armed with slides!!!!

What are we going to talk about?

In Session 3 I stated that:

- Boundary conditions are assumed when the members are designed.
- The connections should be designed based on the same (or at least very similar) boundary conditions.

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What are we going to talk about?

In Session 3 we discussed how this is accomplished relative to communication.

A number of the questions received relate to how this is accomplished from a technical perspective.

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What are we going to talk about?

I will address these questions by:

- Evaluating a connection “known to be okay”.
- Discussing how this approach might be help us build the skills necessary to address unusual or controversial conditions.
- Highlighting some of the pitfalls.

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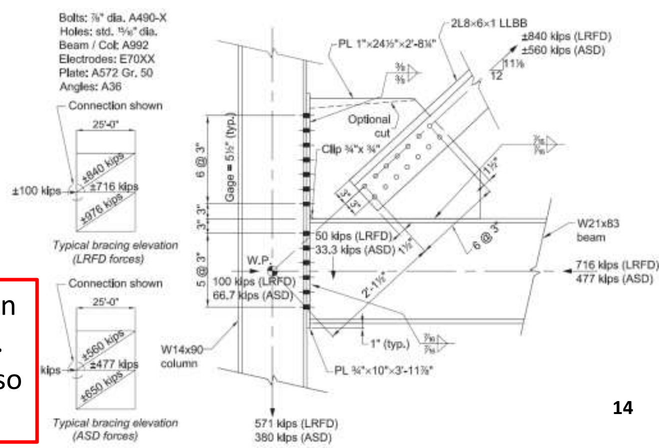
Connection Stiffness

For the sake of this discussion we will consider the connection in Example 5.1 of Design Guide 29:

We will assume* the ASD load of 560 kips is the service load.



* Choosing the “right” load has been complicated by changes to ASCE7. Having the right load may not be so important if things remain elastic.

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Connection Stiffness

Let's start by calculating the extension of the double angle brace under the maximum service load consistent with what was likely assumed in the analysis.

$$\delta = \frac{PL}{AE} = \frac{(560^{k})(34.1')\left(12\frac{in}{ft}\right)}{(26.2in^{2})(29{,}000ksi)} = 0.30"$$

This is simple because it is not true. Centerline models are simplifications. Evaluating the "real" condition will not be so simple (it is actually impossible) and will require some judgment and assumptions to not be too wrong.

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Connection Stiffness

We will now move from the simple centerline (main member design) model and consider the behavior of the individual connection elements.

Our goal is to compare an estimate of the stiffness of the real-world condition to the stiffness inherent in the original design model.

We will "prove" that our common conditions are okay – that the design of the connections is "consistent with the intended behavior of the framing system and the assumptions made in the structural analysis".

What is shown in the next several sides in implicit in "by inspection".

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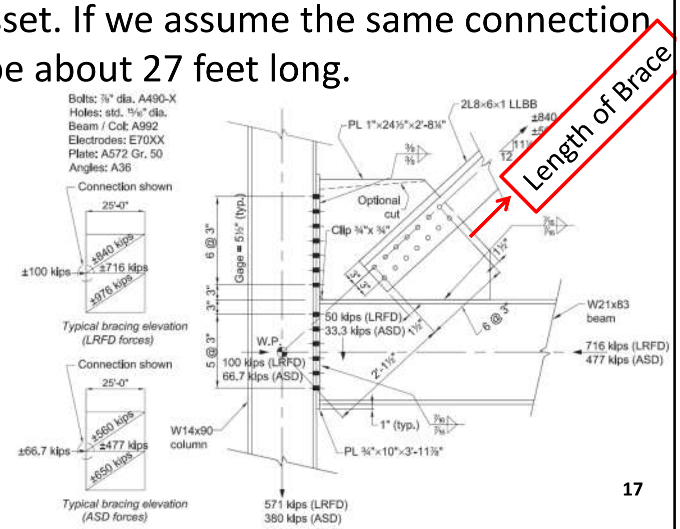
Connection Stiffness

In the real condition the brace is not approximately 34' long as it ends somewhere in the gusset. If we assume the same connection at each end the brace will be about 27 feet long.

The deflection due to the brace can be calculated as:

$$\delta = 1.27" \frac{(26.9')}{(34.1')} = 0.238"$$

Note: I am showing 3 sig. fig. out of habit. It does not reflect delusions of precision.



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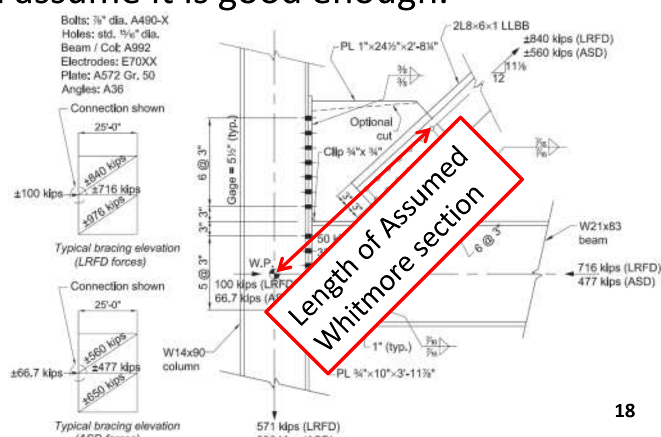
Connection Stiffness

Let's assume the rest of the original brace length is represented by the Whitmore section. This is an incorrect and sort of arbitrary assumption. Arbitrarily I will assume it is good enough.

The area of the Whitmore section is:

$$A_w = (23.8")(1") = 23.8in^2$$



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Connection Stiffness

Calculate the extension of the assumed “Whitmore section” under the maximum service load:

$$\delta_w = \frac{PL}{AE} = \frac{(560^k)(3.63\prime)}{(23.8in^2)(29{,}000ksi)} = 0.035\text{” each end}$$

This model is wrong. It neglects some beneficial effects (like the overlap of the brace and the gusset) and neglects some detrimental effects (like the fact that part of the assumed section will consist of beam and column webs that are thinner than the gusset). It is only an estimate.

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Connection Stiffness

Attendee Question: Bolt holes are generally 1/16" larger than the diameter of the bolt, what effect does this have on the deformation?

Answer: It is generally assumed that due to fabrication and erection tolerances bolts will slip about half the oversize of the hole. This assumption is derived from tests and is generally consistent with tests that I have seen.

For our current analysis let’s assume 1/16” slip total for both ends.

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Connection Stiffness

Will the bolts really slip?

AISC Design Guide 16 provides data that indicates significant pretension even in snug-tight joints. Let’s assume 37.5% of the pretension of a 7/8” A325 bolt exists. For bare steel let’s assume slip coefficient of 0.3.

Slip resistance=$0.3\left(14.6^{k}\right)(14\ bolts)(2\ double\ shear)$=$123^{k}$

Yes. The bolted connection is likely to slip – even with a more realistic estimate of pretension.

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Connection Stiffness

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(37.5%)T_b

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Yes. The bolted connection is likely to slip – even with a more realistic estimate of pretension.

22

Connection Stiffness

Attendee Question: Does the deformation of welded connections depend mostly on the deformation of the connected elements?

Answer: Yes. I usually neglect the deformation at the weld.

Does this make sense? Let's talk about that.

Insider Tip: If you want to sound informed when talking about welds refer to Lesik & Kennedy. If you want to be informed – read it.

Lesik, D.F. and Kennedy, D.J.L. (1990), "Ultimate Strength of Fillet-Welded Connections Loaded in Plane," *Canadian Journal of Civil Engineering*, National Research Council of Canada, Vol. 17, No. 1, Ottawa, Canada.

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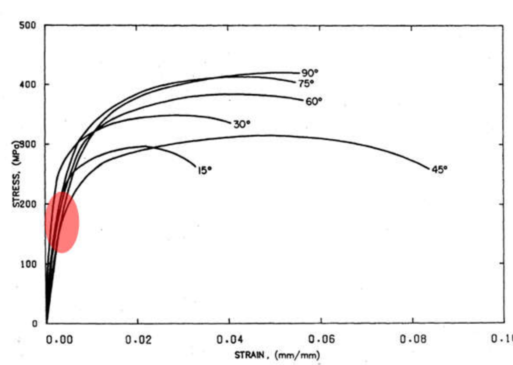
Connection Stiffness

Does this make sense? The plot shown is from Miazga and Kennedy (1986 – referenced in Lesik and Kennedy). There is a factor of safety of approximately two on welds so at service loads we will be somewhere in the red shaded area.

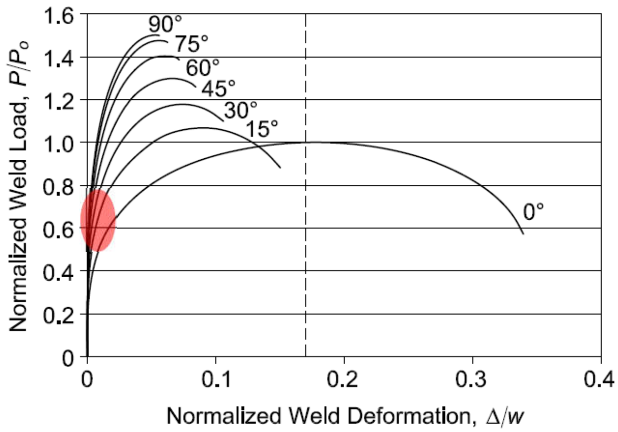
The deformation will be very small.

Don't tell anyone I am talking about factors of safety. I think it is a hanging offense. If anyone asks I only discussed reliability.



Connection Stiffness

Manual Figure 9-5 leads to a similar conclusion.



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Connection Stiffness

What else are we missing?

Probably a lot, and some of what we have included is wrong… but let's evaluate where we are.

The original design model assumed a deformation of 0.302". So far we have an estimated deformation of:

0.238"+2(0.035")+(0.0625")=0.242"

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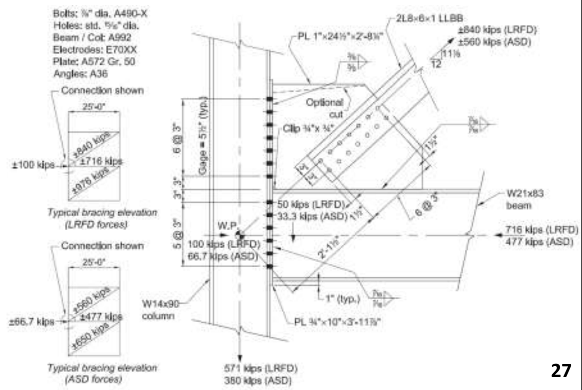
Connection Stiffness

We could continue to seek and account for sources of deformation like bolt slip at the gusset-to-column connection or flexure of the end plate.

We could also hone our model significantly. I would argue this is unnecessary.

It seems the connection deformation is “in the ballpark” of the modelled condition.



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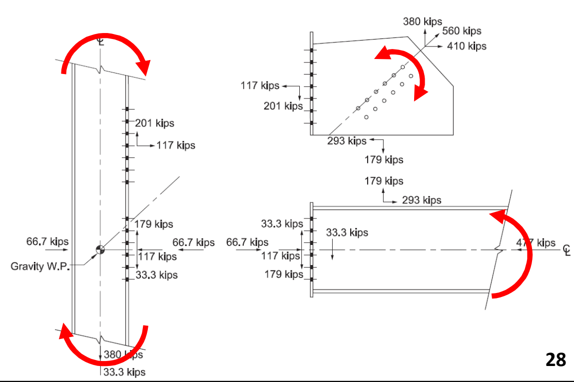
Connection Stiffness

What else are we missing?

The free-body diagram shown in Design Guide 29 is fictional; it is a model.

It is statically admissible & safe.

It neglects the stiffness and restraint provided by the members. The least stiff elements will not resist the moment at service loads.



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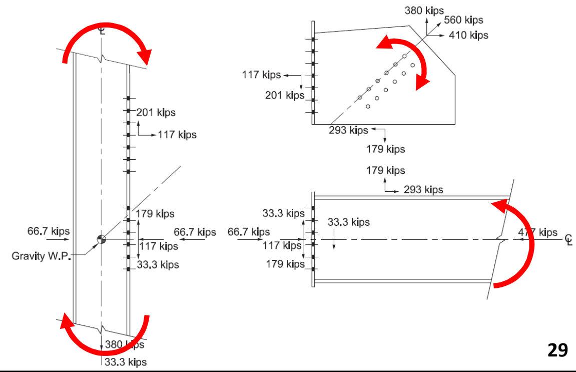
Another Corollary

You cannot reduce the plastic collapse load of a structure by adding material or restraint to it.

This should be obvious.

The collapse load remains unchanged if I add material but distribute no stress to the additional material. If I then distribute load to the additional material the structure cannot get weaker.



29

Connection Stiffness

"In the fight between you and the world, back the world."
~~~ Franz Kafka

Our models are always wrong. The world is always right.

Seeking to "prove" that conditions are okay that you know to be okay is good exercise for:

- Shop drawing review
- Addressing unusual conditions
- Controversies with other engineers

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Connection Stiffness

- Shop drawing review

From Session 1: “This is a major advantage of highly developed mental representations: you can assimilate and consider a great deal more information at once… see… data not as isolated bits of information but as pieces of larger patterns…”

Seeking to “prove” that conditions are okay that you know to be okay will help you develop “mental representations” aka “models” aka “a feel for connections”.

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Connection Stiffness

- Addressing unusual conditions

From Session 1: “When a condition becomes so unusual that it cannot be evaluated based on engineering judgment, then the condition should be abandoned or more rigorously evaluated.”

In seeking to “prove” that conditions are okay that you know to be okay you will be more rigorously evaluating known conditions. This will provide a template (or model) as to how unusual conditions can be more rigorously evaluated.

Being able to do so may mean the difference between abandoning preferred conditions or giving your clients what they want.

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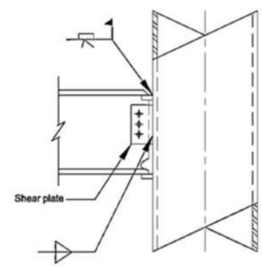
Connection Stiffness

- Addressing unusual conditions

Reviewer Question: What is an unusual case that should be abandoned for something more traditional?

Answer: One that you cannot judge okay by inspection, does not make intuitive sense to you, or that you cannot or do not want to more rigorously evaluate.



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Connection Stiffness

- Controversies with other engineers

From Session 1: “Be willing and able to defend your design decisions.”

In seeking to “prove” that conditions are okay that you know to be okay you will be “in training” for the big fights. You will be building skills necessary to defend your design decisions.

Being able to do so may mean the difference between abandoning preferred conditions or giving your clients what they want.

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Connection Stiffness

Attendee Question: When must the EOR provide a specific stiffness that is required to satisfy the overall design intent?

Answer: This was a question I briefly addressed after Session 1. At that time I stated it is unusual for the EOR to provide a specific required stiffness for connections. As stated in this discussion such evaluations are typically done by inspection based on engineering judgment and experience.

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Connection Stiffness

Attendee Question: When must the EOR provide a specific stiffness that is required to satisfy the overall design intent?

Answer (cont.): Engineers do not all make the same judgments or have the same experiences. Therefore controversies can arise.

The sort of analysis I illustrated here can be used to convince other engineers (and yourself) that what is being proposed is okay.

The connection generally need not be any stiffer than the condition reflected in the analysis.

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Connection Stiffness

Attendee Question: When must the EOR provide a specific stiffness that is required to satisfy the overall design intent?

Answer (cont.): It may not be necessary to ask for the stiffness from the EoR. It may be sufficient to estimate the required stiffness as I have done here.

As stated in Session 1, "Accept that you may not have perfect information." The EoR likely did not provide information expecting it to be used to determine required stiffness so your initial argument may have to be modified based on new information.

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Connection Stiffness

Attendee Question: When must the EOR provide a specific stiffness that is required to satisfy the overall design intent?

Answer (cont.): The Commentary to *Specification* Section B3.4 also provides a "standard".

"If $K_sL/EI \geq 20$, it is acceptable to consider the connection to be fully restrained… If $K_sL/EI \leq 2$, it is acceptable to consider the connection to be simple."

$$K_S = \frac{M_S}{\theta_S}$$

38

Connection Stiffness

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"If $K_s L/EI \geq 20$, it is acceptable to consider the connection to be fully restrained… If $K_s L/EI \leq 2$, it is acceptable to consider the connection to be simple."

$$K_s = \frac{M_S}{\theta_S}$$

This can be estimated in a similar manner as was used for the "known to be okay" condition.

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Beware: Confirmation Bias

Seeking to "prove" that conditions are okay that you know to be okay may also unintentionally train you to do bad things.

Confirmation Bias: The tendency to process information by looking for, or interpreting, information that is consistent with one's existing beliefs. This biased approach to decision making is largely unintentional and often results in ignoring inconsistent information.

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Beware: Confirmation Bias

Vigorous debate can guard against confirmation bias.

From Session 2:

- The delegated connection engineer should be prepared to vigorously defend design decisions using rational methods.
- The delegating engineer should be prepared to evaluate a vigorous defense using rational methods.

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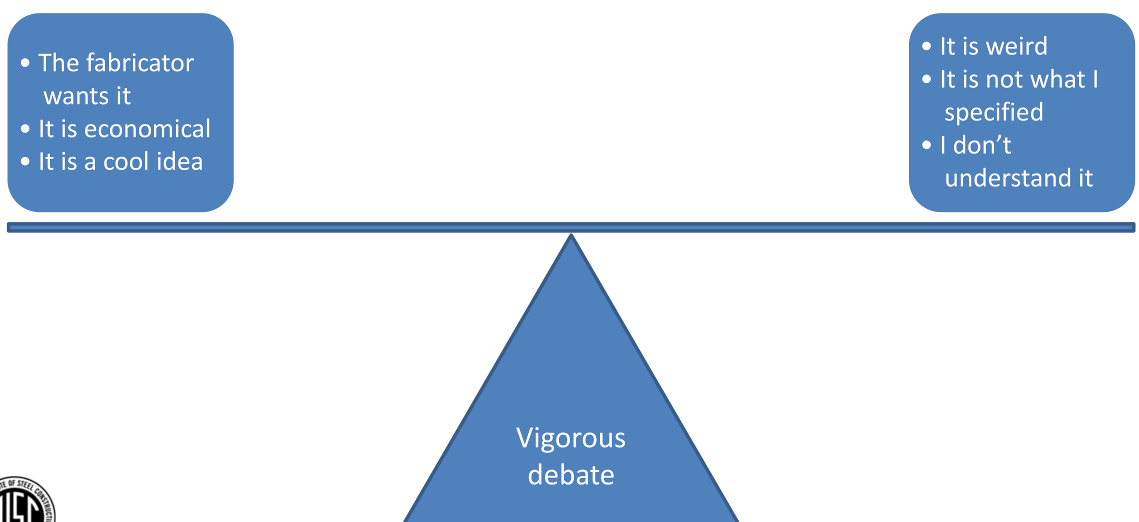
Beware: Confirmation Bias



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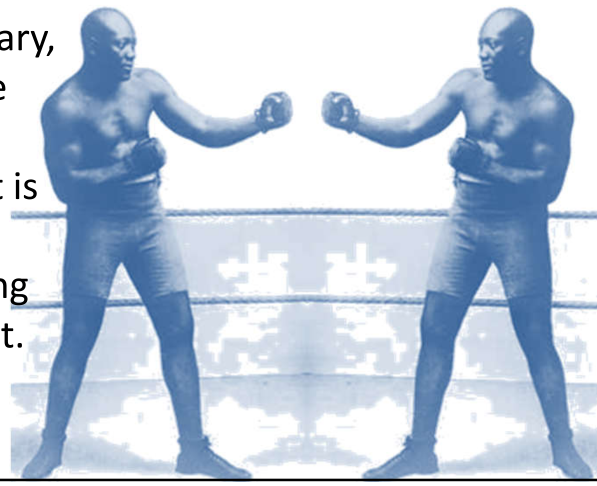
Beware: Confirmation Bias

Being your own best enemy can guard against confirmation bias.

If there is no worthy adversary, then you may have to battle with yourself. Set out to "prove" that what you want is wrong and accept it only when shown to be not wrong beyond a shadow of a doubt.



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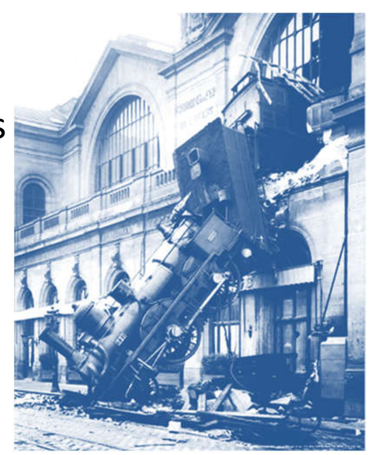
Beware: Confirmation Bias

Looking the consequences "square in the eye" can guard against confirmation bias.

When field fixes were proposed I sometimes suggested that the proposer live with them for a day: "Picture your mother, your girlfriend, your child, your dog, your car – whatever is most important to you standing under your fix – and if you still think it is a good idea tomorrow then we will try to design it."



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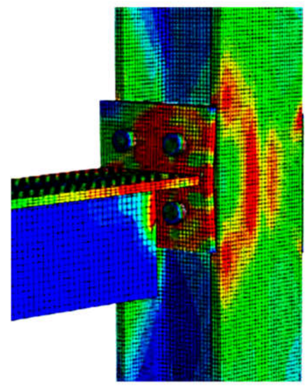
FEA

Attendee Question: Can FEA (finite element analysis) be used to model realistic connection behavior?

Answer: Yes, but…



45

FEA

Attendee Question: Can FEA (finite element analysis) be used to model realistic connection behavior?

Answer: Yes, but…

This bomb can also be used to kill a mosquito, and…

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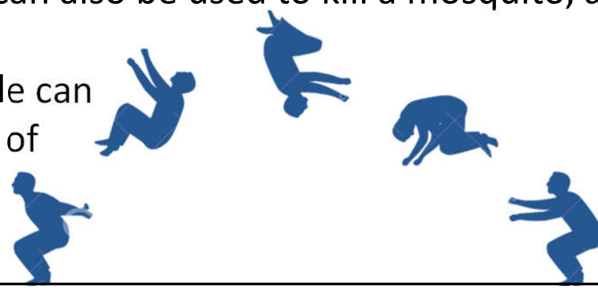
FEA

Attendee Question: Can FEA (finite element analysis) be used to model realistic connection behavior?

Answer: Yes, but…

This bomb can also be used to kill a mosquito, and…

Some people can do this sort of thing.



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FEA

Attendee Question: Can FEA (finite element analysis) be used to model realistic connection behavior?

Answer (cont.): FEA has a lot of power, but it takes a lot of work.

In my opinion it takes more effort and judgment to build an adequate FEA model than to do the sort of thing I did here.

FEA can produce very precise, but very inaccurate results.

FEA can probably get you any answer you want.

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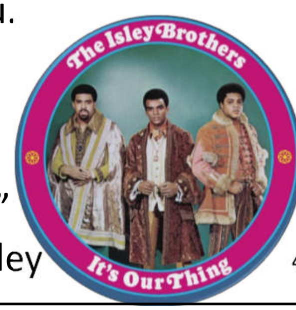
FEA

Answer (cont.): FEA is not my thing.

If it is your thing and you are good at and you are confident with the results then you should use it.

If not, do not assume it will do the work for you.

Getting good answers out of FEA is hard work.



"It's your thing, do what you wanna do."
~~~ Isley, Isley, & Isley

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FEA

Attendee Question: Can FEA (finite element analysis) be used to model realistic connection behavior?

Answer: Yes, but… FEA can also be used to model UNREALISTIC connection behavior… and it can be hard to tell the difference from FEA results without a lot of work.

"Delight at having understood a very abstract and obscure system leads most people to believe in the truth of what it demonstrates."
~~~ Lichtenberg

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Bonus Quote

"The more experience and experiments are accumulated during the exploration of nature, the more faltering its theories become. It is always good though not to abandon them instantly. For every hypothesis which used to be good at least serves the purpose of duly summarizing and keeping all phenomena until its own time. One should lay down the conflicting experience separately, until it has accumulated sufficiently to justify the efforts necessary to edifice a new theory."

~~~ Lichtenberg

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Attendee-based Content

Thanks for sharing your questions and concerns…
and listening to me ramble.

Let's do it again.

Cheers.


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Developing an Eye For Connection Design

Session 4: Bolted Connections

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Bolts

- Bolted connections are intended to be simple and easy.
- Keep them simple.

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Bolts

- Bolted connections are intended to be simple and easy.
- Keep them simple.

~~Pretension~~
~~Slip critical~~

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Bolts

Due to time constraints we will only provide a brief overview of the behavior and design of bolts.

For a more in-depth discussion of bolted connections please refer to the **AISC Steel Design Guide 17 "High Strength Bolts - A Primer for Structural Engineers"** by Geoffrey Kulak.

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Bolts

- Classification of Bolts and Joints
  - ASTM Bolt Specifications
  - Bolt Installation
  - Pretensioned and Slip Critical Connections
- Specifying Bolts
- Behavior of Bolted Joints
  - Shear
  - Tension
- Design of Bolts and Derivation of Design Values
- Economy of Bolted Details

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Classification of Bolts and Joints

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Design Models

The nuts and bolts of nuts and bolts

Several "kinds" are often referred to:

- Bearing Bolts
  - X-bolts
  - N-bolts
- Slip Critical Bolts

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Design Models

The nuts and bolts of nuts and bolts

Several "kinds" are often referred to:

- **Bearing Bolts**
  - X-bolts
  - N-bolts
- Slip Critical Bolts

Loads resisted by bolt bearing on connected parts and shear on the bolt.

Almost all structural steel connections can be designed as bearing.

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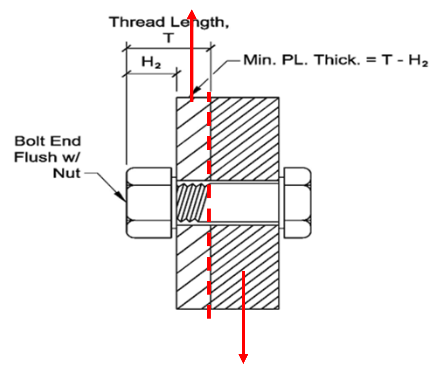
Design Models

The nuts and bolts of nuts and bolts

Several "kinds" are often referred to:

- Bearing Bolts
  - **X-bolts**
  - N-bolts
- Slip Critical Bolts

Threads are eXcluded from the shear plane.



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Design Models

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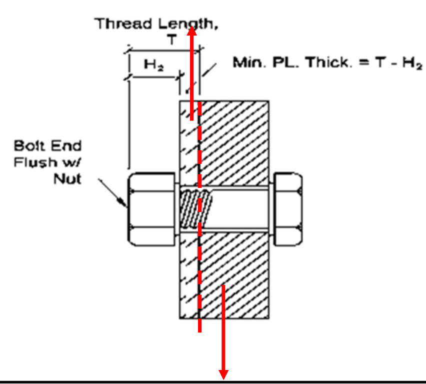

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Design Models

The nuts and bolts of nuts and bolts

Several "kinds" are often referred to:

- Bearing Bolts
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  - N-bolts
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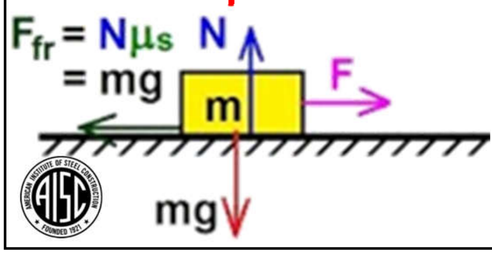

Loads resisted by friction between the connected parts.

Slip-critical connections rarely required. The most common application is oversize holes.

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Design Models

The nuts and bolts of nuts and bolts

Several "kinds" are often referred to:

- Bearing Bolts
  - X-bolts
  - N-bolts
- Slip Critical Bolts

These do not represent physically different bolts.

They represent different design assumptions.

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ASTM

Classification of Bolts and Joints

ASTM Bolt Specifications

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ASTM

Bolt Types

There is a new bolt standard, F3148 Grade 144, with a strength between A325 and A490.

Nearly all structural connections are made with

- ASTM F3125 bolts
  - Grade A325
  - Grade F1852 (twist-off)
  - Grade A490
  - Grade F2280 (twist-off)

A490 & F2280 bolts are about 25% stronger than A325 & 1852 bolts.

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ASTM

Bolt Types

Use ASTM A354 and A449 bolts for:

- Lengths exceeding 12 diameters
- Diameters exceeding 1½ in. (38 mm)

When used in pretensioned connections:

- Pitch
- Thread length
- Head
- Nut(s)

Equal to or proportional to that required by the RCSC *Specification*.

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ASTM

Bolt Types

ASTM A354 and A449 (and to a lesser extent F3125) allow a wide range of configurations. The RCSC *Specification* (and therefore the AISC *Specification*) addresses only heavy hex and TC bolts conforming to ASME B18.2.6.

Countersunk bolts and bolts with odd geometries (heads, thread lengths, etc.) fall outside the scope of the specifications.

Do not specify ASTM A354 Grade BD to get around prohibitions on galvanizing.

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Installation

Classification of Bolts and Joints

Bolt Installation

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Installation

Bolt Installation

- Bolts can be installed
  - Snug tight
  - Pretensioned
    - In Bearing Joints
    - In Slip Critical Joints
    - Tensioning Methods
      1. Turn-of-Nut
      2. Calibrated Wrench
      3. Twist-Off Type Tension-Control (TC) Bolt
      4. Direct-Tension-Indicator (DTI) Pretensioning
      5. Combined Method Pretensioning - **NEW**

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Installation

Classification of Bolts and Joints

Contrasting Pretensioned Bolts with Slip-Critical Joints

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Installation

Pretensioned Vs. Slip Critical Connections

- Just because bolts are required to be pretensioned or fully tensioned does not indicate that it is a slip critical connection.
- Slip critical connections are rarely required by code for most work.
- Engineers will sometimes specify slip critical connections in an attempt to increase the strength of the structure.

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Installation

Pretensioned Vs. Slip Critical Connections

Specifying slip critical connections may not increase the safety of the structure, since other limit states may govern.

It is effective however if the goal is an increased number of bolts and cost escalation.

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Installation

Pretensioned Vs. Slip Critical Connections

Bolted connections should be simple to design, install, and inspect.

Historically the AISC Steel Solutions Center has received more questions about bolting than any other topic.

Much of the time the questions are about pretensioning

Most of the time the solution to the "problem" is to recognize there was no reason to pretension the joint to begin with.

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Specify
ing

Specifying Bolts

75

Specifying

Specifying Bolts

Snug-tight bolts in bearing connections should be allowed whenever possible.

When applicable the threads excluded value should be allowed.

X-Type bolts have about twice the capacity of a Slip Critical Class A bolt of the same grade and diameter.

76

Specifying

Specifying Bolts

Specifying snug-tight bolts in bearing joints has several advantages:

- –Higher design values and smaller connections than slip critical connections
- –Simplified installation
- –Less Inspection
- –No preparation of the faying surfaces

77

Specifying

Slip Critical Connections

Slip Critical Connections are required for:

- – Fatigue loads with reversal
- – Oversized holes
- – Slots parallel to the direction of the load (beyond 80 to 100 degrees)
- – Joints in which slip at the faying surfaces would be detrimental to the performance of the structure.

78

Specifying

Critical Connections

Even when slip critical connections are required. They will only be required for some joints. Do not make all joint slip critical. Put your money and effort where it will do the most good.

Slip Critic… required for:

- Fatigue lo…
- Oversized holes
- Slots parallel to the di… (beyond 80 to 100 degrees)
- Joints in which slip at the faying s… detrimental to the performance of the …

79

Specifying

The Hybrid SC/Pretensioned Joint

The Specification Section E6.2 requires that the end connections of built-up compression members be welded or bolted connections with pretensioned bolts and Class A or B faying surfaces.

The Seismic Provisions have similar requirements.

80

Specifying

The Hybrid SC/Pretensioned Joint

In other words these joints

- Must have pretensioned bolts
- May be designed as bearing connections
- Must be detailed as a slip-critical connection

81

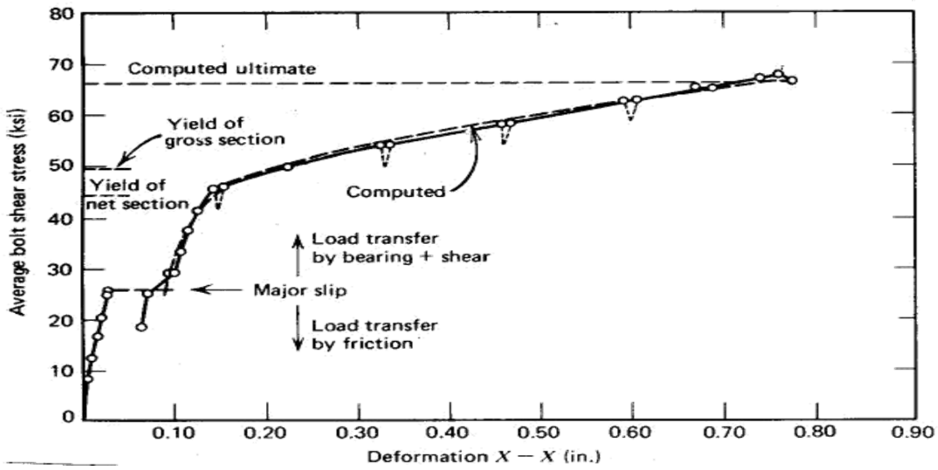
Behavior

Behavior of a Bolted Joint in Shear

82

Behavior

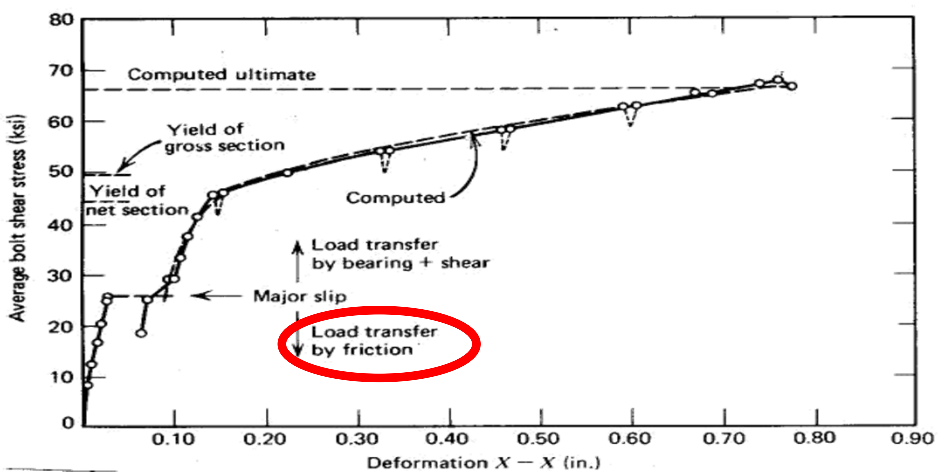
Behavior of a Bolted Joint in Shear



83

Behavior

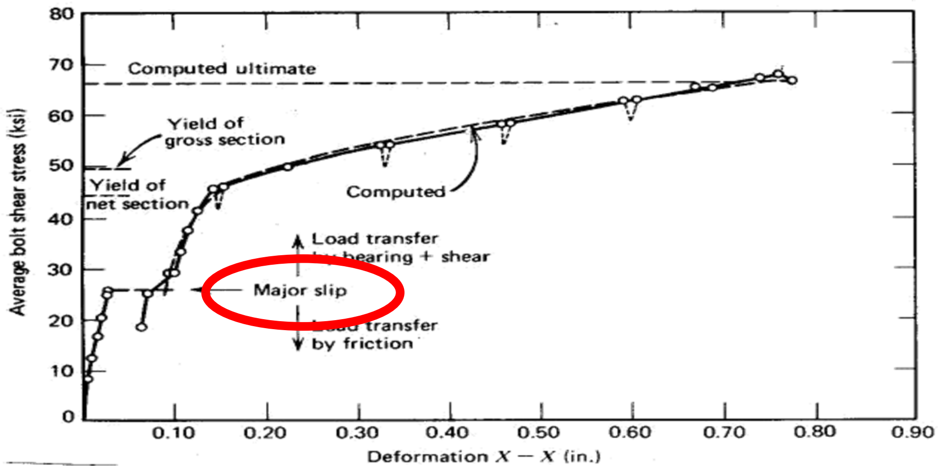
Behavior of a Bolted Joint in Shear



84

Behavior

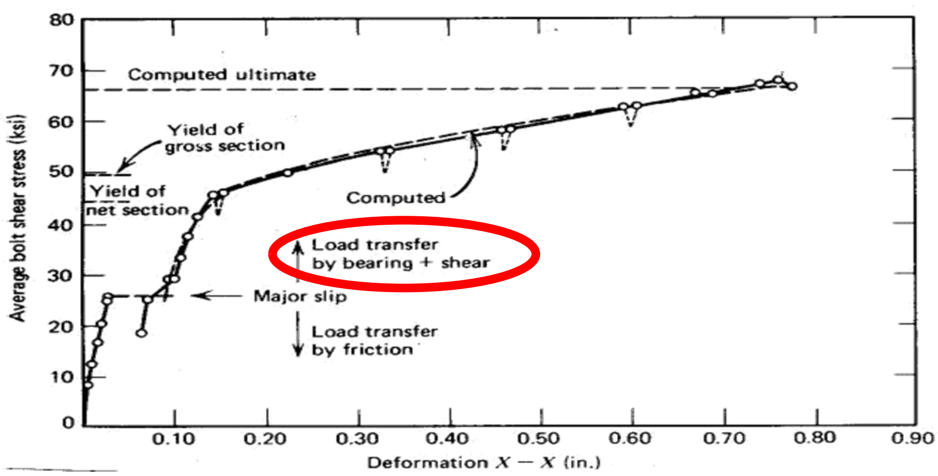
Behavior of a Bolted Joint in Shear



85

Behavior

Behavior of a Bolted Joint in Shear



86

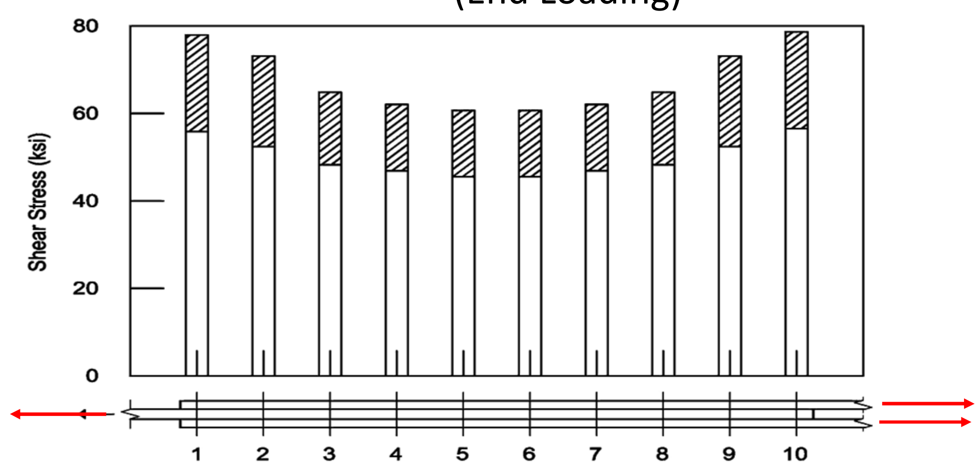
Behavior

Behavior of a Bolted Joint in Shear

(End Loading)

The bolts in end loaded connections, such as splices, are not equally loaded, as is assumed in typical design calculations.

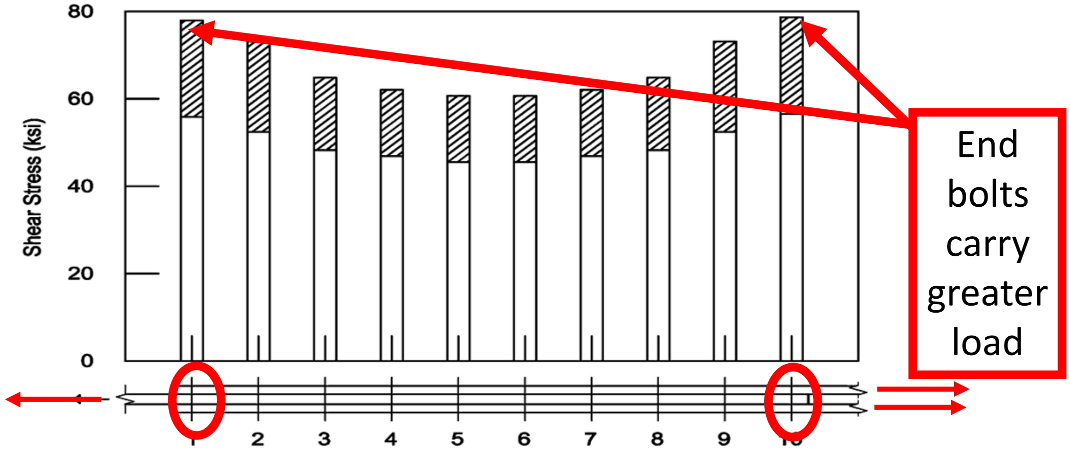
Remember Session 3?

"All models are wrong, but some are useful"
~~~ George E.P. Box

Engineers don't need the right model.

Engineers need useful models in order to produce safe and useful designs.

87

Behavior

Behavior of a Bolted Joint in Shear

(End Loading)



88
~~~

Behavior

Behavior of a Bolted Joint in Shear

(End Loading)



89

Behavior

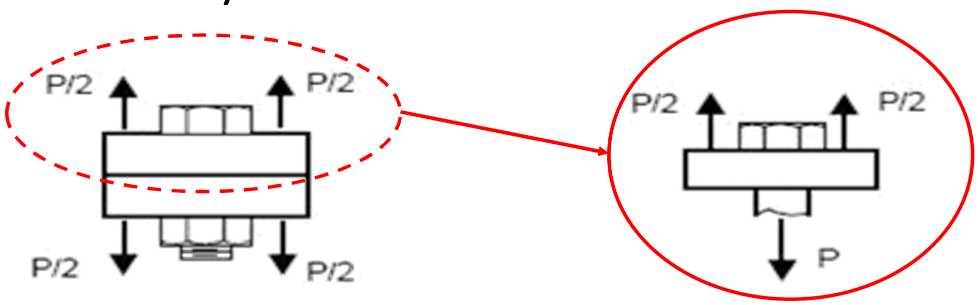
Behavior of a Bolted Joint in Tension

90

Behavior

Behavior of a Bolted Joint in Tension

In a bolted joint with no pretension the entire applied tension will be transferred to the bolts immediately.

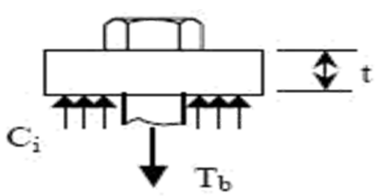


91

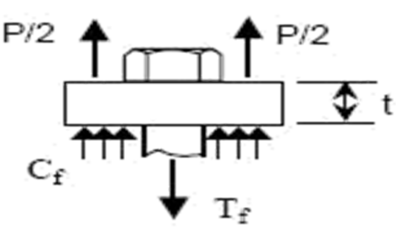
Behavior

Behavior of a Bolted Joint in Tension

In a bolted joint with pretension some of the applied tension will be used to overcome the pretension.



Pretension applied



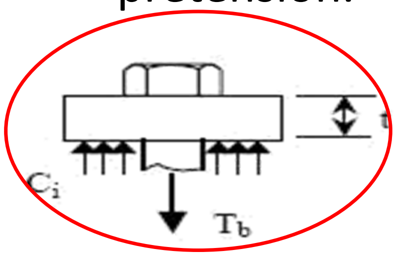
Applied load and Pretension

92

Behavior

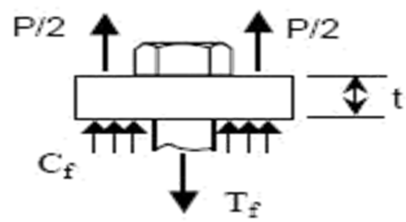
Behavior of a Bolted Joint in Tension

In a bolted joint with pretension some of the applied tension will be used to overcome the pretension.



By statics

$T_b = C_i$



Pretension applied

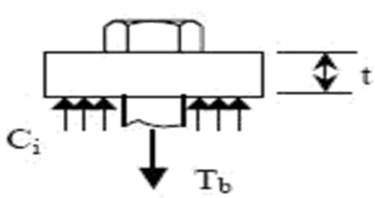
Applied load and Pretension

93

Behavior

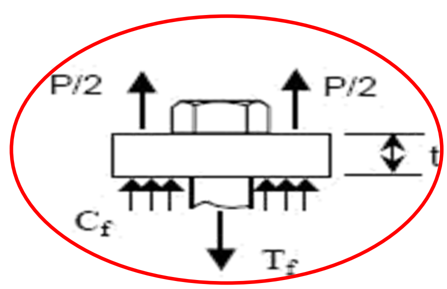
Behavior of a Bolted Joint in Tension

In a bolted joint with pretension some of the applied tension will be used to overcome the pretension.



By statics

$T_f = P + C_f$



Pretension applied

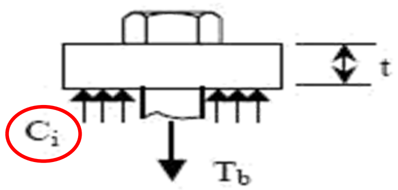
Applied load and Pretension

94

Behavior

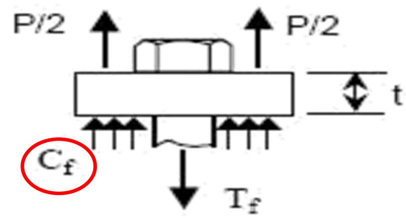
Behavior of a Bolted Joint in Tension

In a bolted joint with pretension some of the applied tension will be used to overcome the pretension.



NOTE:

$C_f < C_i$



Pretension applied

Applied load and Pretension

95

Behavior

Effect of Pretension on Tensile Capacity

Q: Does the tension applied to the bolt during pretensioning reduce the applied tension that the bolt can carry?

A: Yes – but not enough to be concerned.

96

Behavior

Effect of Pretension on Tensile Capacity

Up to the point where the applied tension overcomes the pretension and the plates separate the following relationship applies.

$$T_{final} = T_b + \frac{P}{1 + \frac{A_{plate}}{A_{bolt}}}$$

97

Behavior

Effect of Pretension on Tensile Capacity

Up to the point where the applied tension overcomes the pretension and the plates separate the following relationship applies.

$$T_{final} = T_b + \frac{P}{1 + \frac{A_{plate}}{A_{bolt}}}$$

Typically the area of plate is large relative to the bolt area.

98

Behavior

Effect of Pretension on Tensile Capacity

Up to the point where the applied tension overcomes the pretension and the plates separate the following relationship applies.

$$T_{final} = T_b\,(1.05 \text{ to } 1.10)$$

5 to 10% increase per tests, considered negligible

99

Behavior

Effect of Pretension on Tensile Capacity

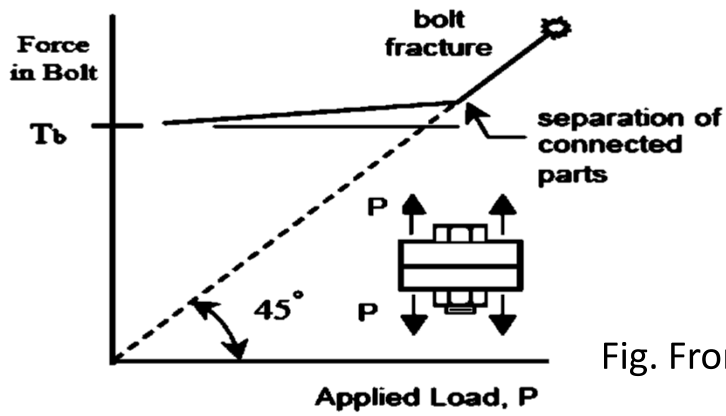


Fig. From DG17

100

Behavior

Effect of Pretension on Tensile Capacity

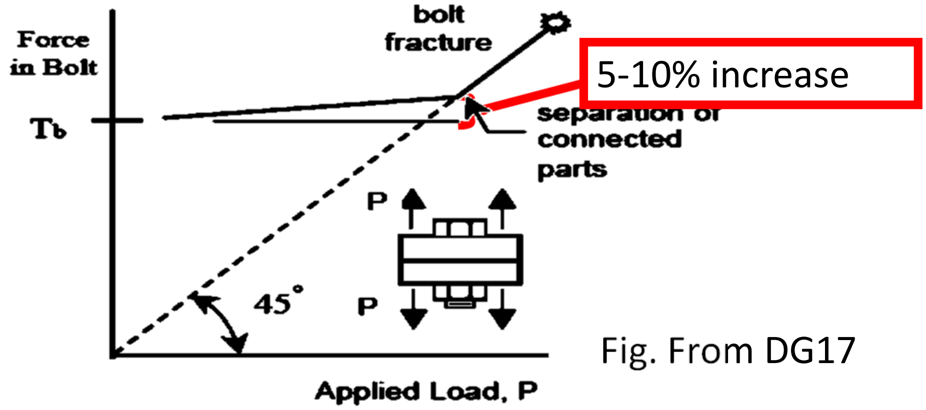


Fig. From DG17

101

Behavior

Effect of Pretension on Tensile Capacity

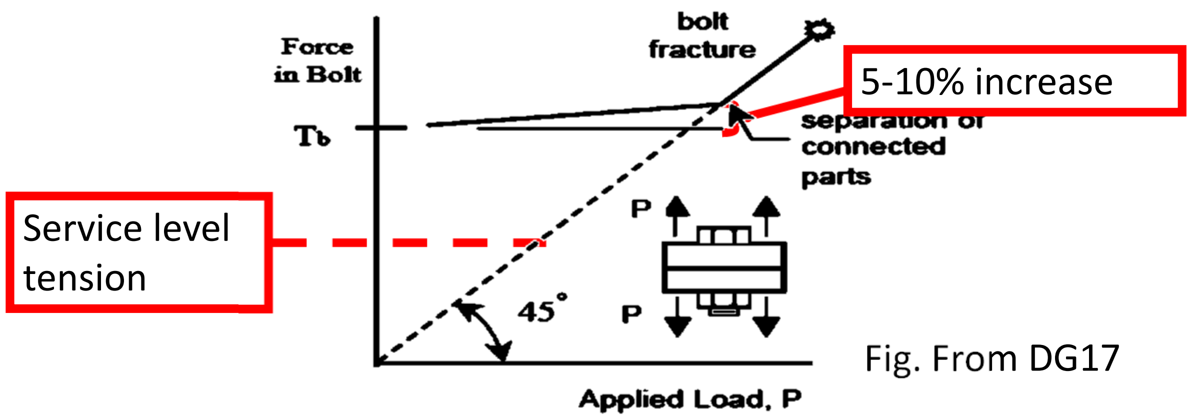


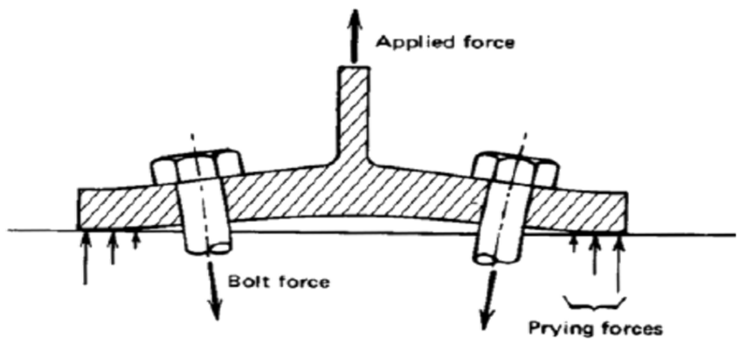
Fig. From DG17

102

Behavior

Prying Action

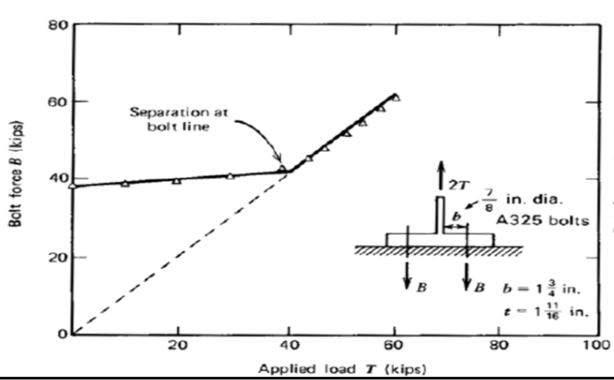
If the connected elements are relatively flexible, then prying forces can develop. Prying action is discussed in Part 9 of the AISC Manual.

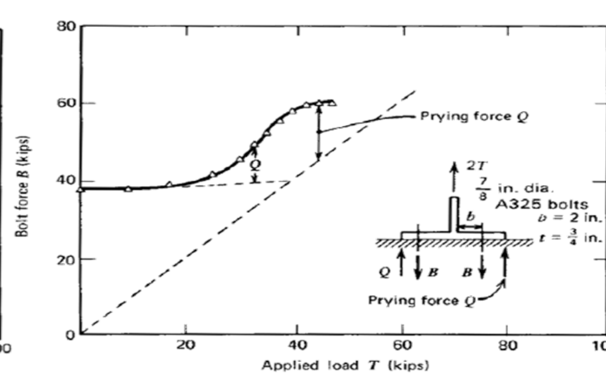


103

Behavior

Prying Action

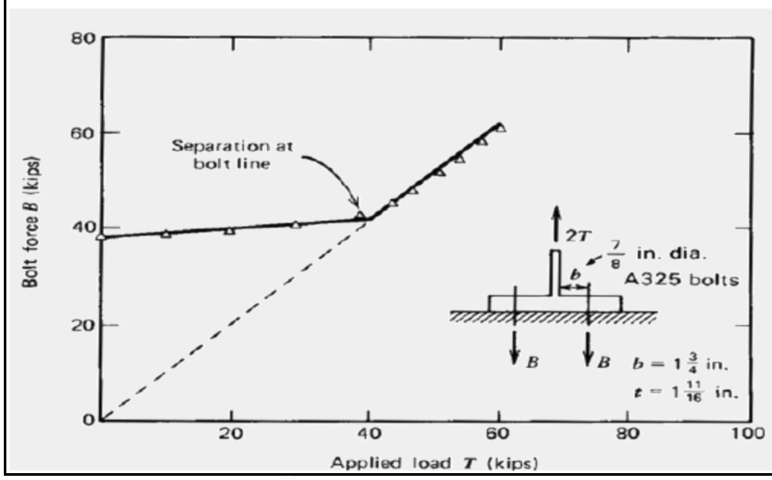


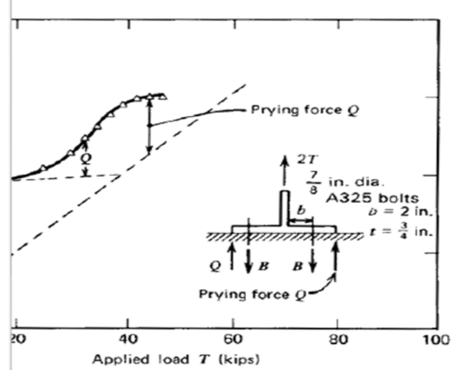


Behavior

Prying Action

If the element thickness is greater than t_c, then no prying will develop.

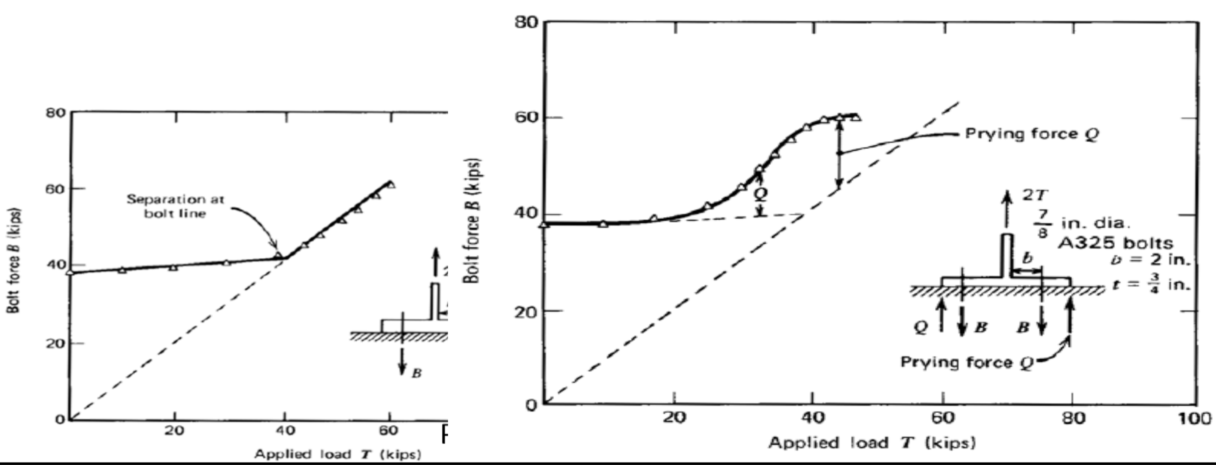




Behavior

Prying Action

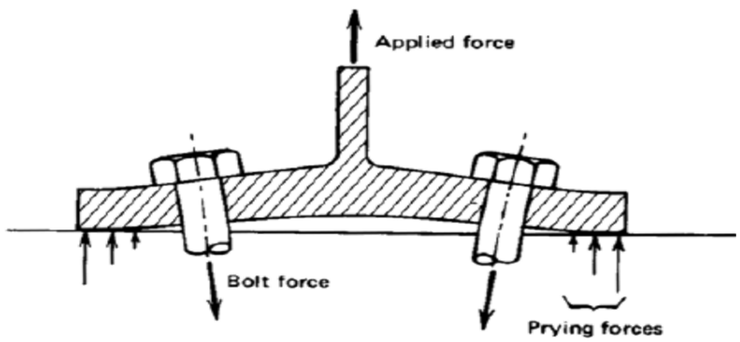
If the element thickness is less than t_c, then prying occurs.



Behavior

Prying Action

Prying cannot occur without bending in one or both of the connected elements.

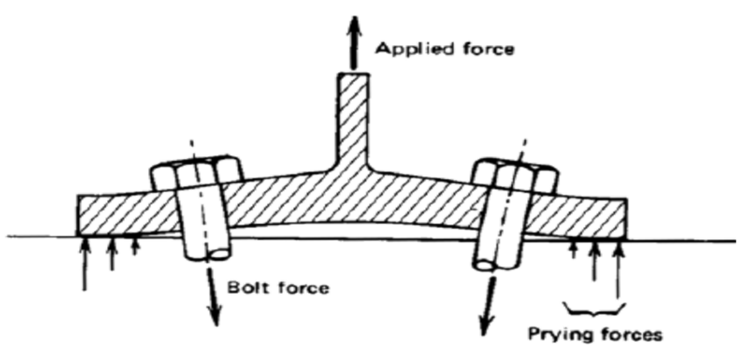


107

Behavior

Prying Action

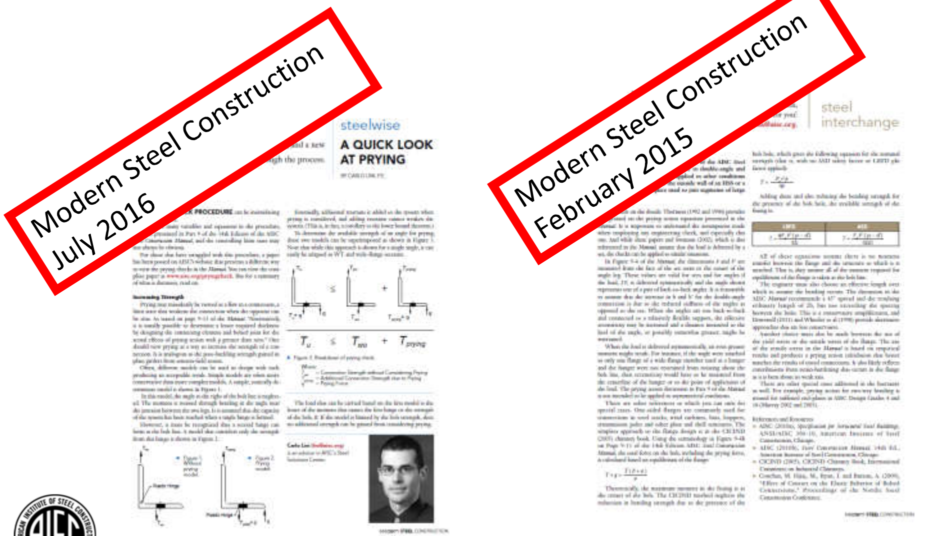
The *Manual* prying checks assume a symmetrical condition .



108

Behavior

Prying Action – Further Reading



109

Design

Design of Bolted Connections

110

Design

Derivation of Nominal Bolt Strength

Per ASTM F3125, Gr A325 bolts have a specified minimum tensile strength of 120 ksi.

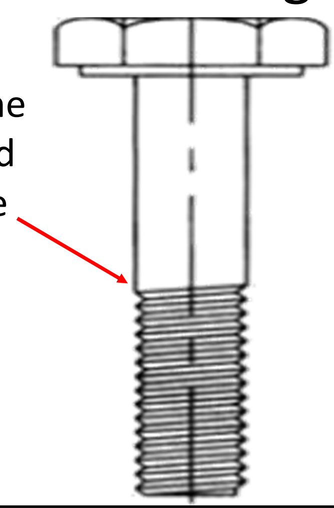
Where do the values from Table J3.2 come from?

111

Design

Derivation of Nominal Bolt Strength
Nominal Design Tensile Strength

When tension is applied to a bolt the effective area is less than that based on the nominal diameter due to the presence of threads.



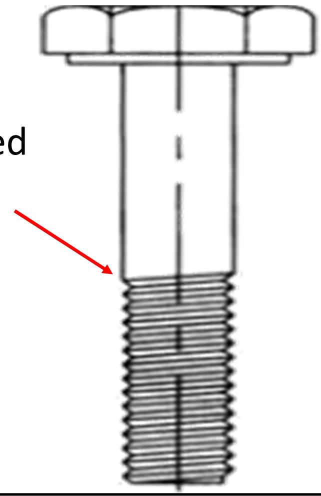
112

Design

Derivation of Nominal Bolt Strength

Nominal Design Tensile Strength

Specification assumes that the ratio of the reduced area to the area based on the nominal diameter of the bolt is equal to 0.75.



113

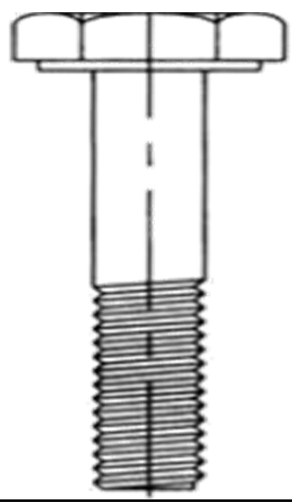
Design

Derivation of Nominal Bolt Strength

Nominal Design Tensile Strength

The nominal design tensile stress is therefore:

$$(0.75)(120) = 90 \text{ ksi}$$

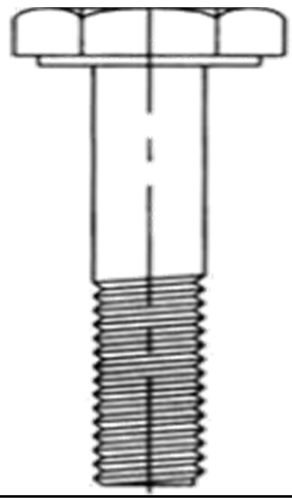


114

Design

Derivation of Nominal Bolt Strength
Nominal Design Shear Strength

The ratio of shear strength to tensile strength given in the Commentary to the RCSC Specification is 0.625.



115

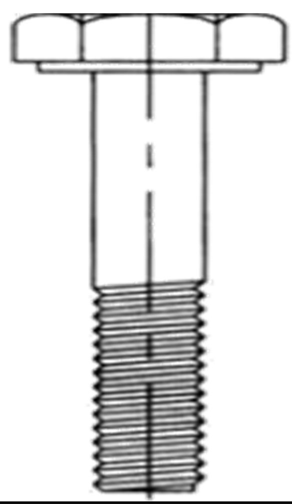
Design

Derivation of Nominal Bolt Strength
Nominal Design Shear Strength

This would result in a nominal shear stress of:

$$(0.625)(120) = 75 \text{ ksi}$$

This is considerably higher than the value given in Table J3.2. Why???



116

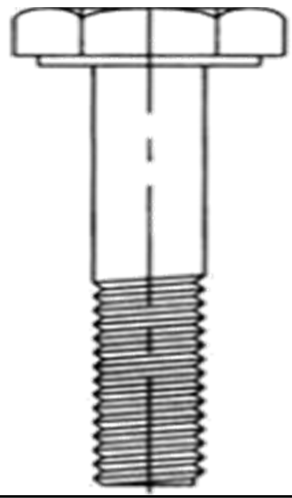
Design

Derivation of Nominal Bolt Strength
Nominal Design Shear Strength

There is an additional 10% reduction applied to the bolt value resulting in:

(0.625)(0.9)(120) = 67.5 ksi

This is the origin of the 68 ksi value.



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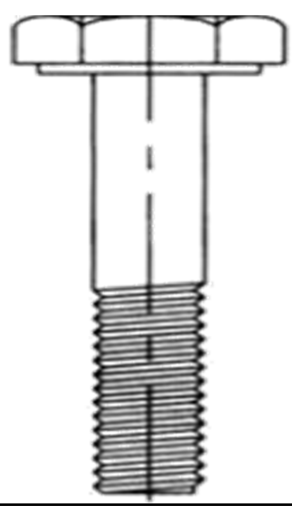
Design

Derivation of Nominal Bolt Strength
Nominal Design Shear Strength

This additional 10% reduction was discussed previously for end loaded connections.

Though the reduction is not necessary for many common connections, such as beam end connections, which are not end loaded, it is applied to all bolted connections in the Specification.



118

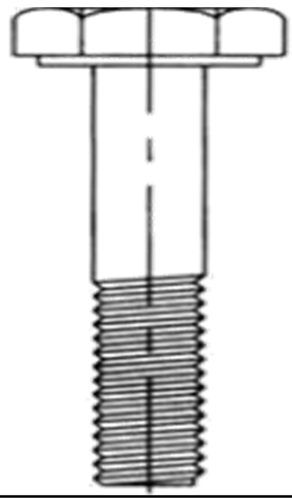
Design

Derivation of Nominal Bolt Strength
Nominal Design Shear Strength

To close the loop we will derive the value for N-type bolts as well. Recalling that the reduction for the threads. This time 0.8 instead of 0.75.

(0.80)(68) = 54.4 ksi

54 ksi is the value given in Table J3.2.



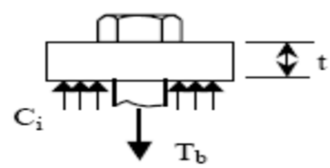
119

Design

Slip Resistance of Bolted Joints

The pretension on the bolt (T_b) will cause the plates to be pushed together at the faying surfaces (C_i).

This normal force causes friction between the plates that can be utilized to resist shearing forces.

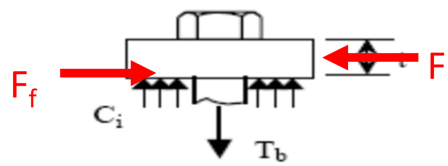


120

Design

Slip Resistance of Bolted Joints

The slip resistance is dependent primarily on the bolt pretension, T_b and the slip coefficient (roughness), μ, at the faying surfaces.

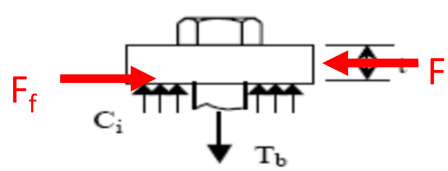


121

Design

Slip Resistance of Bolted Joints

This is reflected in the design equation (J3-4):



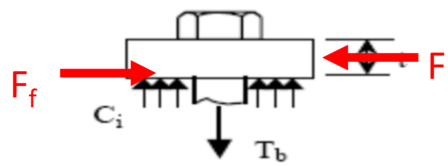
$R_n = \mu D_u h_f T_b n_s$

122

Design

Slip Resistance of Bolted Joints

This is reflected in the design equation (J3-4):



$R_n = \mu D_u h_f T_b n_s$

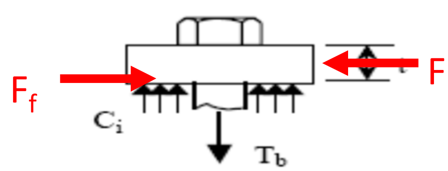
mean slip coefficient dependent on surface prep

123

Design

Slip Resistance of Bolted Joints

This is reflected in the design equation (J3-4):



$R_n = \mu D_u h_f T_b n_s$

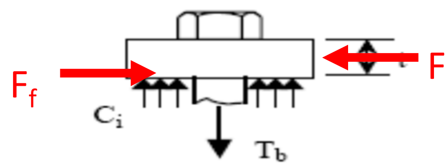
calibration factor, usually 1.13

124

Design

Slip Resistance of Bolted Joints

This is reflected in the design equation (J3-4):



$R_n=\mu D_u h_f T_b n_s$

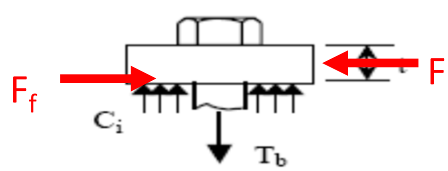
factor for fillers

125

Design

Slip Resistance of Bolted Joints

This is reflected in the design equation (J3-4):



$R_n=\mu D_u h_f T_b n_s$

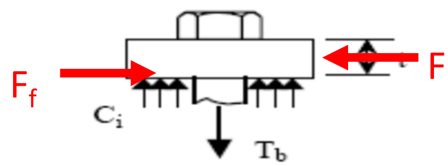
bolt pretension – required to meet Table J3.1

126

Design

Slip Resistance of Bolted Joints

This is reflected in the design equation (J3-4):



$R_n = \mu D_u h_f T_b n_s$

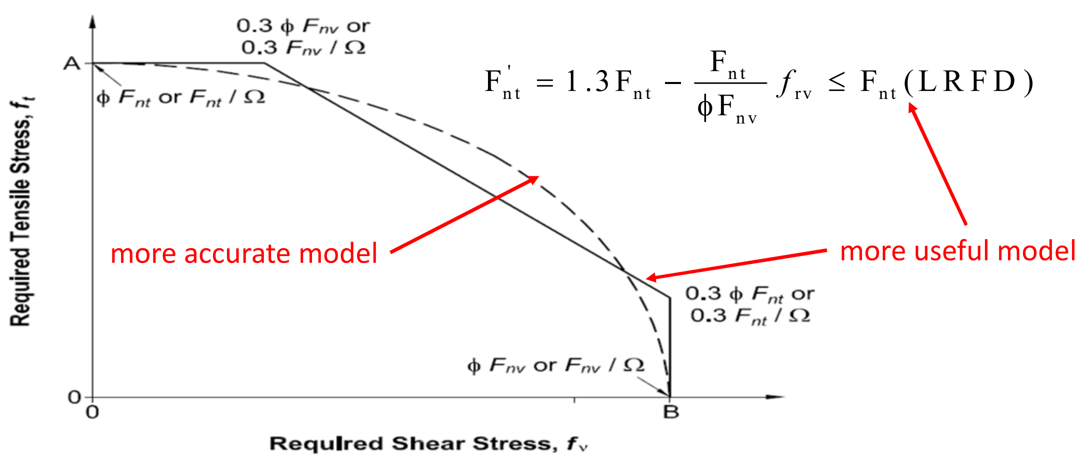
number of shear planes

127

Design

Combined Shear and Tension - Bearing

$$F'_{nt} = 1.3F_{nt} - \frac{F_{nt}}{\phi F_{nv}} f_{rv} \leq F_{nt} \ (LRFD)$$



128

Design

Combined Shear and Tension - Bearing

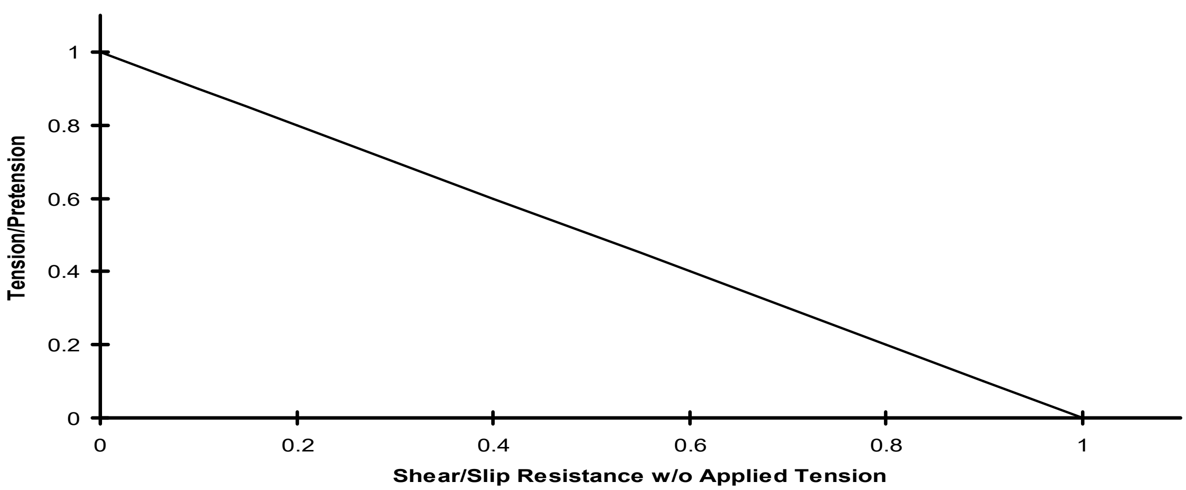
As discussed previously any applied tension reduces the clamping force on the faying surfaces.

This reduces the slip resistance to shear in direct proportion to the applied tension.

129

Design

Combined Shear and Tension - Slip



130

Economy

Economy of Bolted Details

131

Economy

Economy of Bolted Details

- Never use the same diameter bolts with different strengths on the same project.
- Use bearing joints when allowed by the Specification.
- Use snug tight bolts when allowed by the Specification.
- Use X-type bolts when threads are excluded due to ply thickness.
- Limit bolt diameter to 1” when practical.

132

Economy

Economy of Bolted Details

- Use short slots or oversize holes to ease erection.

My position on this has changed somewhat over the years.

Improvements in fabrication practices mean oversize holes are not as necessary as they once were.

133

Economy

Economy of Bolted Details

- Use short slots or oversize holes to ease erection.

The hole clearance for larger diameter bolts in the *Specification* has increased further reducing the need for oversize holes.

I personally would tend not to use oversize holes except for specific and unusual conditions.

134

Economy

Economy of Bolted Details

- Use short slots or oversize holes to ease erection.
- Open holes need not be filled for structural purposes – **AND SHOULD NOT BE FILLED.**

- Another common misconception is that larger holes are allowed for connections in galvanized material. This is not true.

135

Thank you!

AISC | Questions

Smarter.
Stronger.
Steel.

Individual Session Registrants

PDH Certificates

- All WFH individuals associated with a group registration will be issued a certificate.
- All individuals attending at your connection: you will receive an email on how to report their 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!

8-Session Registrants

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 Thursday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

Quiz and attendance records

Posted Thursday mornings. 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.
- PDHs – If you watch a recorded session, you must pass quiz for 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 PDHs

8-Session Registrants

Access to the recording

Information for accessing the recording will be emailed to you by Thursday. The recording will be available for four weeks. (For 8-session registrants only.) EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

PDHs via recording

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

8-Session Registrants

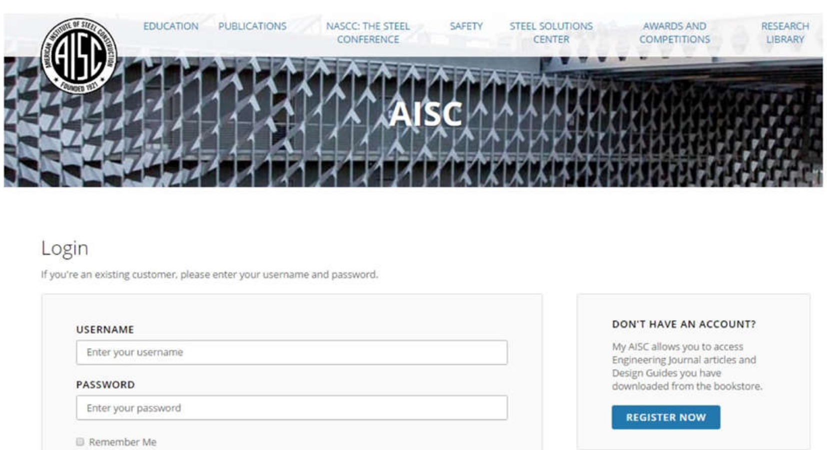
Night School Resources

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 and sign in.



8-Session Registrants

Night School Resources

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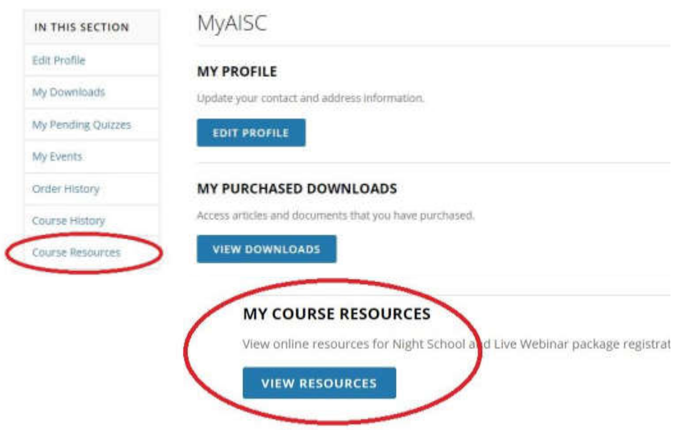
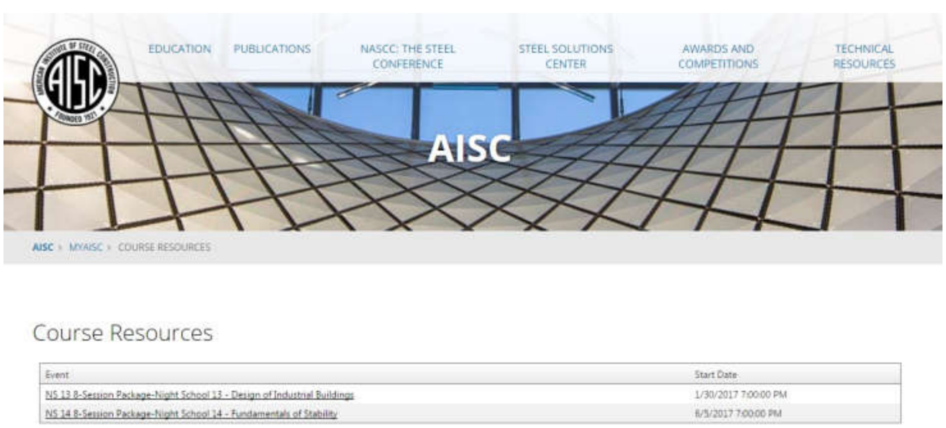


8-Session Registrants

Night School Resources



8-Session Registrants

Night School 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

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/nightschool26. Scroll down to Quiz and Attendance records.
    - Updated on Friday mornings.

8-Session Registrants

Night School Resources

- Webinar connection information
  - Reminder email sent out Tuesday mornings
- Links to handouts also found here

AISC | Thank you

Smarter.
Stronger.
Steel.