

# WoodWorks Connection Design Workshop

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.



# Description

For engineers new to mass timber design, connections can pose a particular challenge. This course focuses on connection design principles and analysis techniques unique to mass timber products such as cross-laminated timber, glued-laminated timber and nail-laminated timber. The session will focus on design options for connection solutions ranging from commodity fasteners, pre-engineered wood products and custom-designed connections. Discussion will also include a review of timber mechanics and load transfer, as well as considerations such as tolerances, fabrication, durability, fire and shrinkage that are relevant to structural design.

# Learning Objectives

1. Review the timber mechanics that are relevant to mass timber design including, grain orientation and dimensional stability and define how loads are transferred in timber connections.
2. Consider practical aspects of design that are not traditionally in the scope of a structural design for other materials but may be relevant for mass timber such as tolerances, fabrication, durability, fire, and shrinkage.
3. Explore connection solutions available including commodity fasteners, pre-engineered products and custom designed connections.
4. Learn about cutting edge connection technologies and resources for learning more.

# Agenda

1. Timber Mechanics
2. Principles of Connection Design
3. Practical Considerations
4. Design Solutions
5. Next Generation of Connections

# 3 Things to remember

1. NEVER use lag screws again
2. Small Ø are better than large
3. Get to know the fabricators / installers

First - Lets Build some Context...



## **Context...**

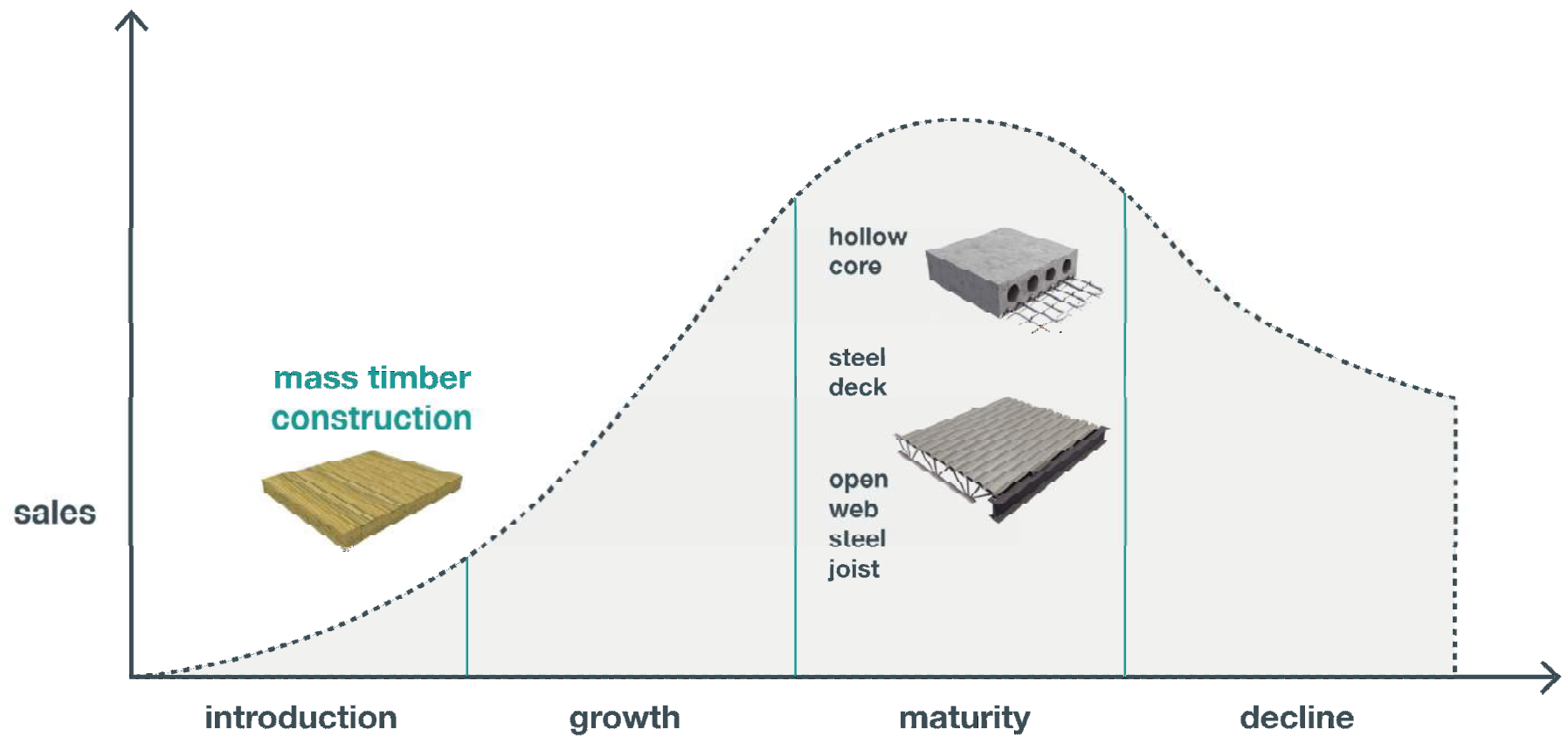
Building context is  
collecting the dots

## **...leads to Design**

Design is  
connecting the  
dots



# Where are we at?

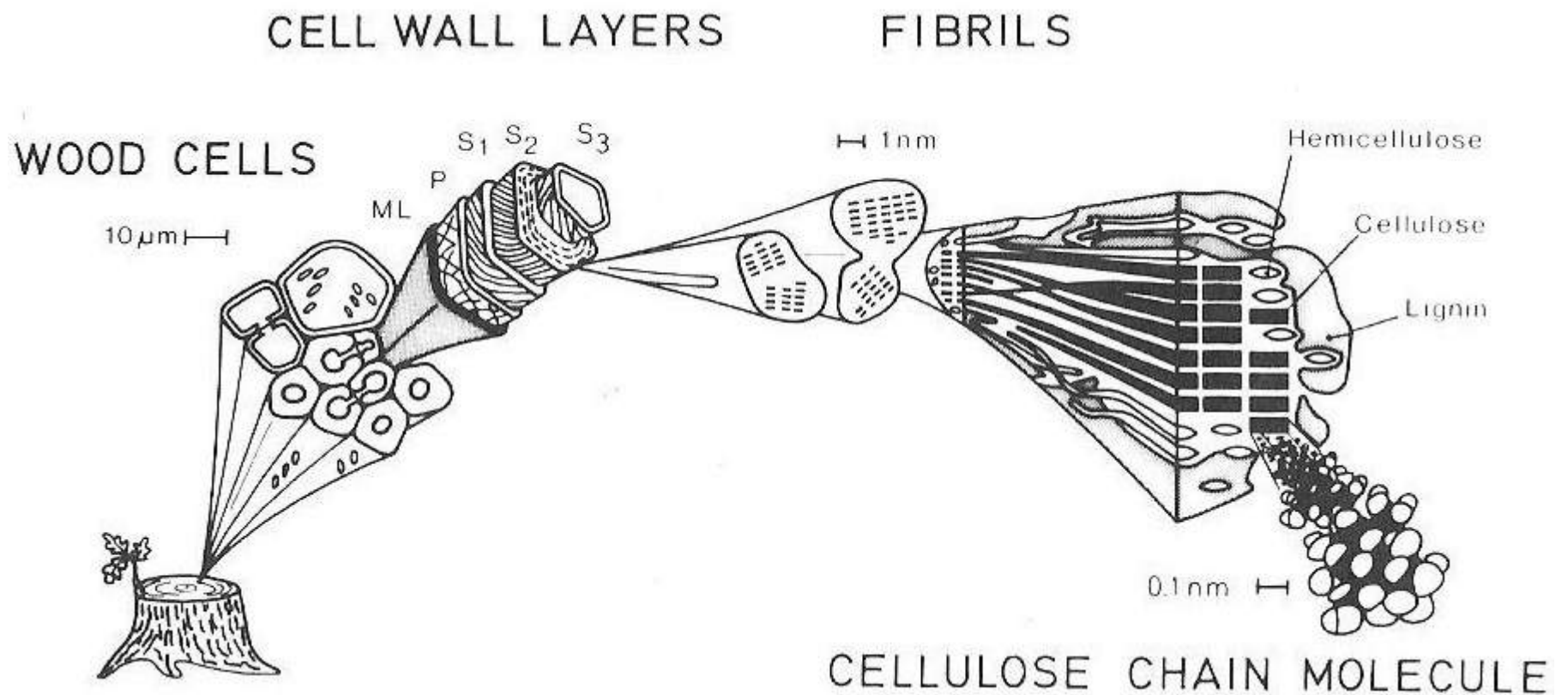


But we have this

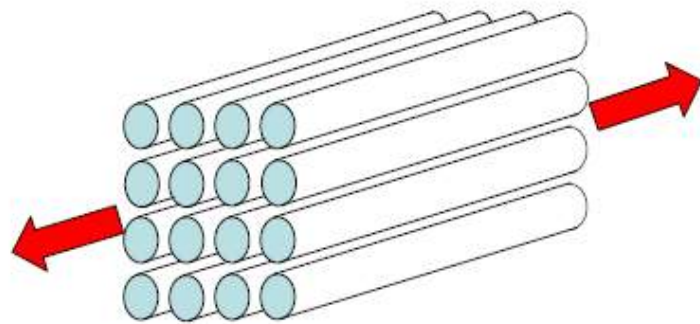


# 1. Timber Mechanics

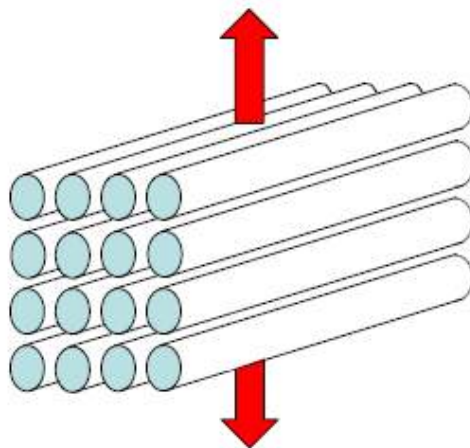
# 1.1 How it's Built



# 1.1 How it's Built



Parallel



Perpendicular

1. Growth rings create a cylindrical structure, longitudinal arrangements of fibers
2. Properties vary between parallel/perpendicular directions and between the transverse directions

# 1.1 Moisture

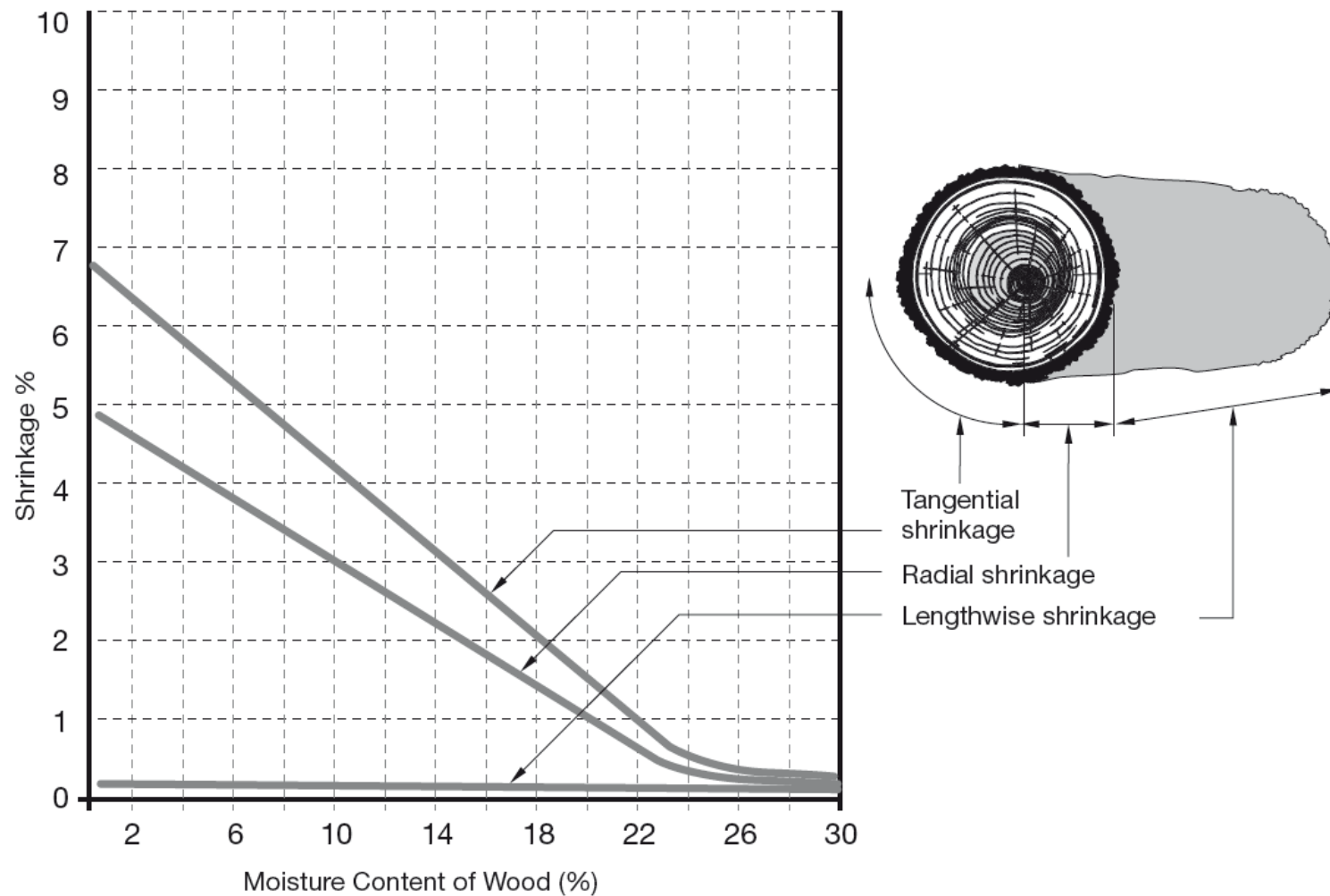
Temperature		Moisture content (%) at various relative humidity values																		
(°C)	(°F))	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%
-1.1	(30)	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.4	13.5	14.9	16.5	18.5	21.0	24.3
4.4	(40)	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.3	13.5	14.9	16.5	18.5	21.0	24.3
10.0	(50)	1.4	2.6	3.6	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3
15.6	(60)	1.3	2.5	3.6	4.6	5.4	6.2	7.0	7.8	8.6	9.4	10.2	11.1	12.1	13.3	14.6	16.2	18.2	20.7	24.1
21.1	(70)	1.3	2.5	3.5	4.5	5.4	6.2	6.9	7.7	8.5	9.2	10.1	11.0	12.0	13.1	14.4	16.0	17.9	20.5	23.9
26.7	(80)	1.3	2.4	3.5	4.4	5.3	6.1	6.8	7.6	8.3	9.1	9.9	10.8	11.7	12.9	14.2	15.7	17.7	20.2	23.6
32.2	(90)	1.2	2.3	3.4	4.3	5.1	5.9	6.7	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3
37.8	(100)	1.2	2.3	3.3	4.2	5.0	5.8	6.5	7.2	7.9	8.7	9.5	10.3	11.2	12.3	13.6	15.1	17.0	19.5	22.9
43.3	(110)	1.1	2.2	3.2	4.0	4.9	5.6	6.3	7.0	7.7	8.4	9.2	10.0	11.0	12.0	13.2	14.7	16.6	19.1	22.4
48.9	(120)	1.1	2.1	3.0	3.9	4.7	5.4	6.1	6.8	7.5	8.2	8.9	9.7	10.6	11.7	12.9	14.4	16.2	18.6	22.0
54.4	(130)	1.0	2.0	2.9	3.7	4.5	5.2	5.9	6.6	7.2	7.9	8.7	9.4	10.3	11.3	12.5	14.0	15.8	18.2	21.5
60.0	(140)	0.9	1.9	2.8	3.6	4.3	5.0	5.7	6.3	7.0	7.7	8.4	9.1	10.0	11.0	12.1	13.6	15.3	17.7	21.0
65.6	(150)	0.9	1.8	2.6	3.4	4.1	4.8	5.5	6.1	6.7	7.4	8.1	8.8	9.7	10.6	11.8	13.1	14.9	17.2	20.4
71.1	(160)	0.8	1.6	2.4	3.2	3.9	4.6	5.2	5.8	6.4	7.1	7.8	8.5	9.3	10.3	11.4	12.7	14.4	16.7	19.9
76.7	(170)	0.7	1.5	2.3	3.0	3.7	4.3	4.9	5.6	6.2	6.8	7.4	8.2	9.0	9.9	11.0	12.3	14.0	16.2	19.3
82.2	(180)	0.7	1.4	2.1	2.8	3.5	4.1	4.7	5.3	5.9	6.5	7.1	7.8	8.6	9.5	10.5	11.8	13.5	15.7	18.7
87.8	(190)	0.6	1.3	1.9	2.6	3.2	3.8	4.4	5.0	5.5	6.1	6.8	7.5	8.2	9.1	10.1	11.4	13.0	15.1	18.1
93.3	(200)	0.5	1.1	1.7	2.4	3.0	3.5	4.1	4.6	5.2	5.8	6.4	7.1	7.8	8.7	9.7	10.9	12.5	14.6	17.5
98.9	(210)	0.5	1.0	1.6	2.1	2.7	3.2	3.8	4.3	4.9	5.4	6.0	6.7	7.4	8.3	9.2	10.4	12.0	14.0	16.9
104.4	(220)	0.4	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.5	5.0	5.6	6.3	7.0	7.8	8.8	9.9			
110.0	(230)	0.3	0.8	1.2	1.6	2.1	2.6	3.1	3.6	4.2	4.7	5.3	6.0	6.7						
115.6	(240)	0.3	0.6	0.9	1.3	1.7	2.1	2.6	3.1	3.5	4.1	4.6								
121.1	(250)	0.2	0.4	0.7	1.0	1.3	1.7	2.1	2.5	2.9										
126.7	(260)	0.2	0.3	0.5	0.7	0.9	1.1	1.4												
132.2	(270)	0.1	0.1	0.2	0.3	0.4	0.4													

## Equilibrium Moisture Content (EMC):

MC that is in equilibrium with the environment

Dry service conditions: average EMC over a year is 15% or less and < 19%

# 1.1 Shrinkage / Swelling



## 2. Principles of Connection Design

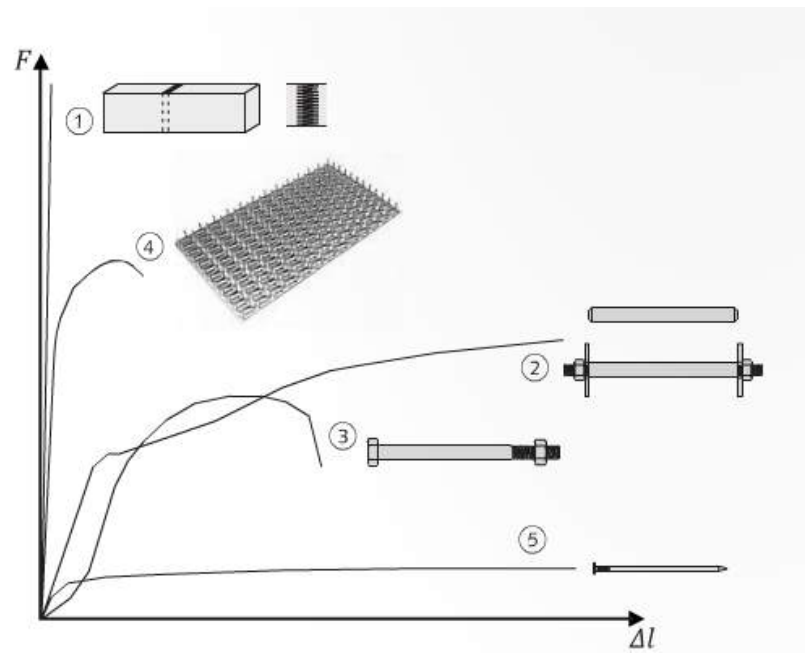


“Connection design will depend on various factors: nature of the forces and their magnitude, practicality, production, environmental conditions, aesthetics and cost”

## 2.1 Environment

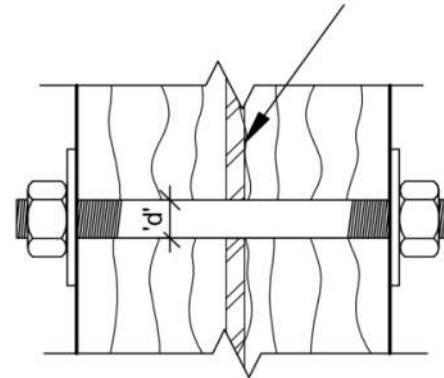
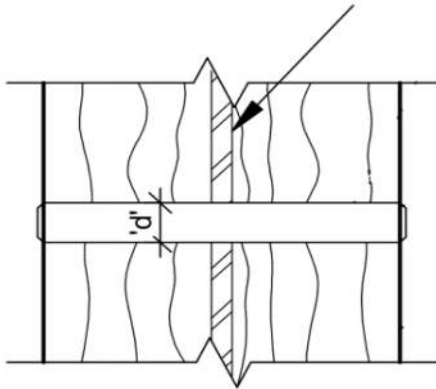


## 2.2 Connection Stiffness



1. Glued Connection
2. Tight Fit Dowel / Bolt  $\Phi = 14$  mm
3. Through Bolts  $\Phi = 14$  mm
4. Truss Plate 10'000 mm<sup>2</sup>
5. Nail  $\Phi = 4.4$  mm

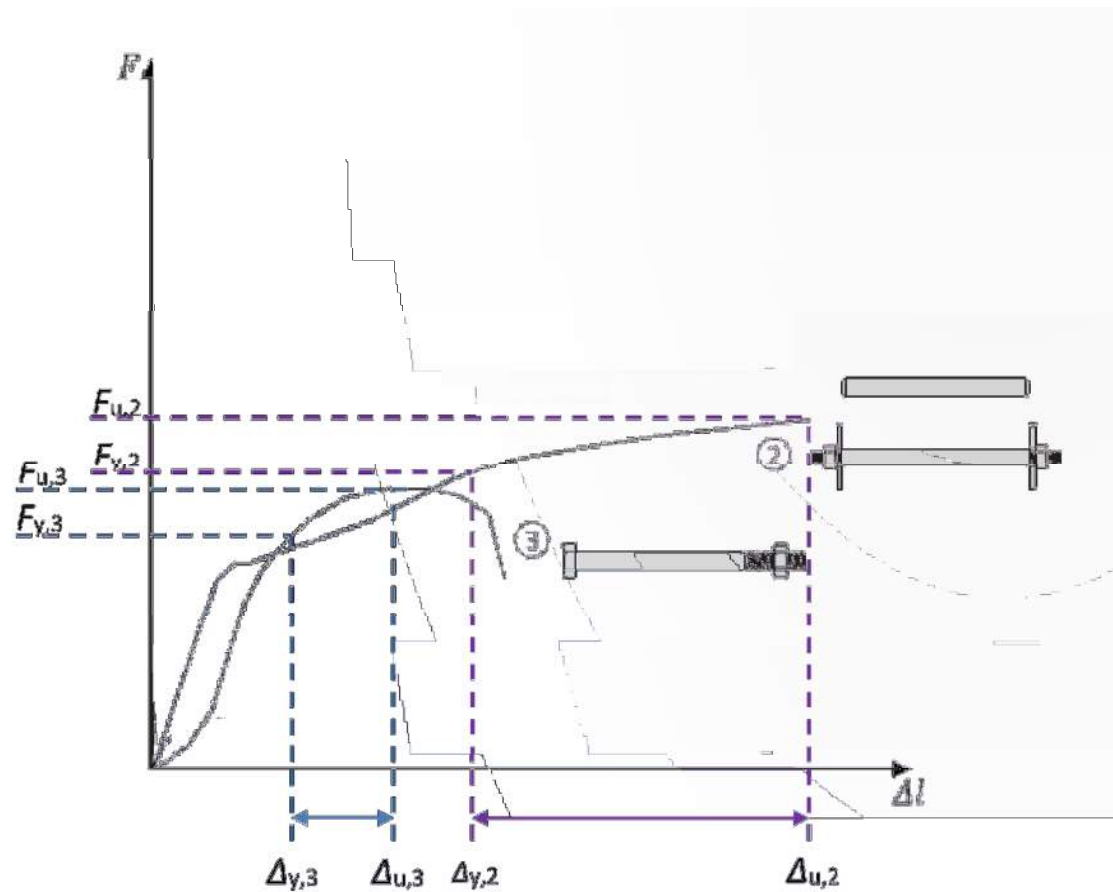
## 2.3 Bolt vs. Tight Fit Dowels



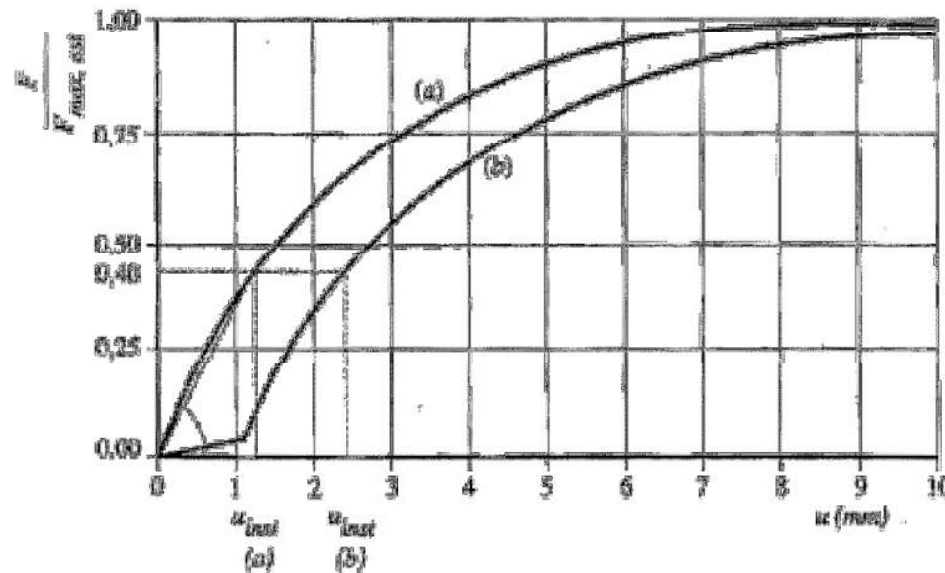
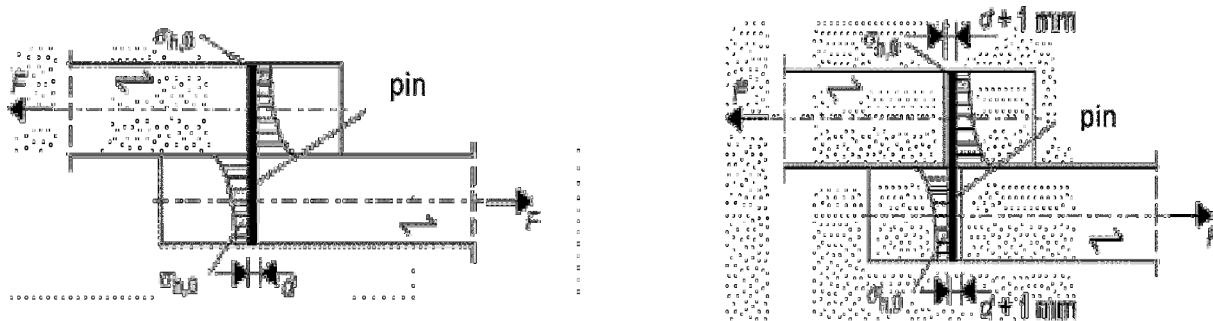
## 2.3 Bolt vs. Tight Fit Dowels

	Size of hole in Wood	Size of hole in Steel	Use of Connection
<b>Tight Fit Dowel/Bolt</b>	Same size as pin/bolt diameter	Up to 1/32" larger than pin/bolt diameter	Typically used for engineered connections without additional load transfers (ie. w/o bearing plates for example).
<b>Through Bolt</b>	Up to 1/16" larger than bolt diameter	Up to 1/16" larger than pin/bolt diameter	<p>Typically used in connections where the bolt serves as a positioning aid.</p> <p>Traditional heavy timber buildings may also feature such a connection.</p> <p>This type of connection should be avoided in heavily loaded connections or if part of the SFRS.</p> <p>(In Germany for example, this connection is only allowed in structures of low importance or temporary installations.)</p>

## 2.3 Bolt vs. Tight Fit Dowels



## 2.3 Bolt vs. Tight Fit Dowels



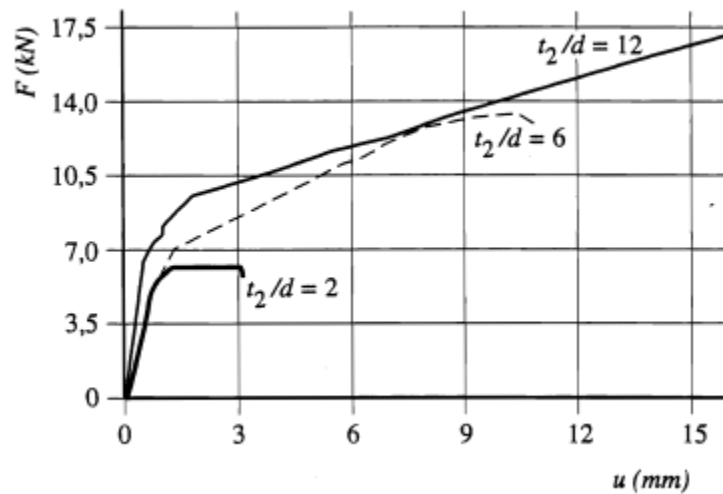
a) Tight Fit Dowel/Bolt

b) Through Bolts

$F_u$  = Ultimate Strength

$F_y$  = Yield Strength

## 2.4 Bolts / Dowels - Slenderness



$$\lambda = \frac{t}{d}$$

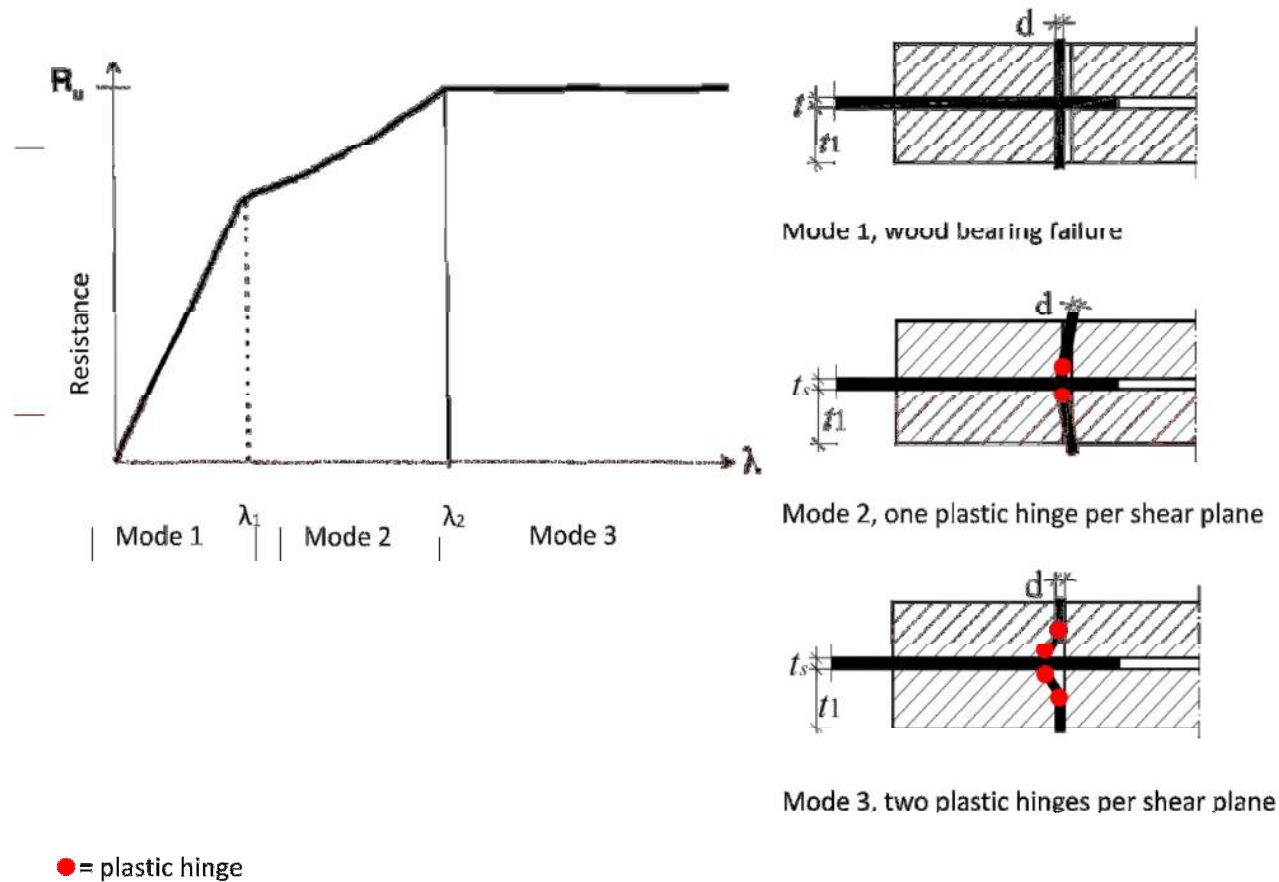
Where;

$t$  = member thickness

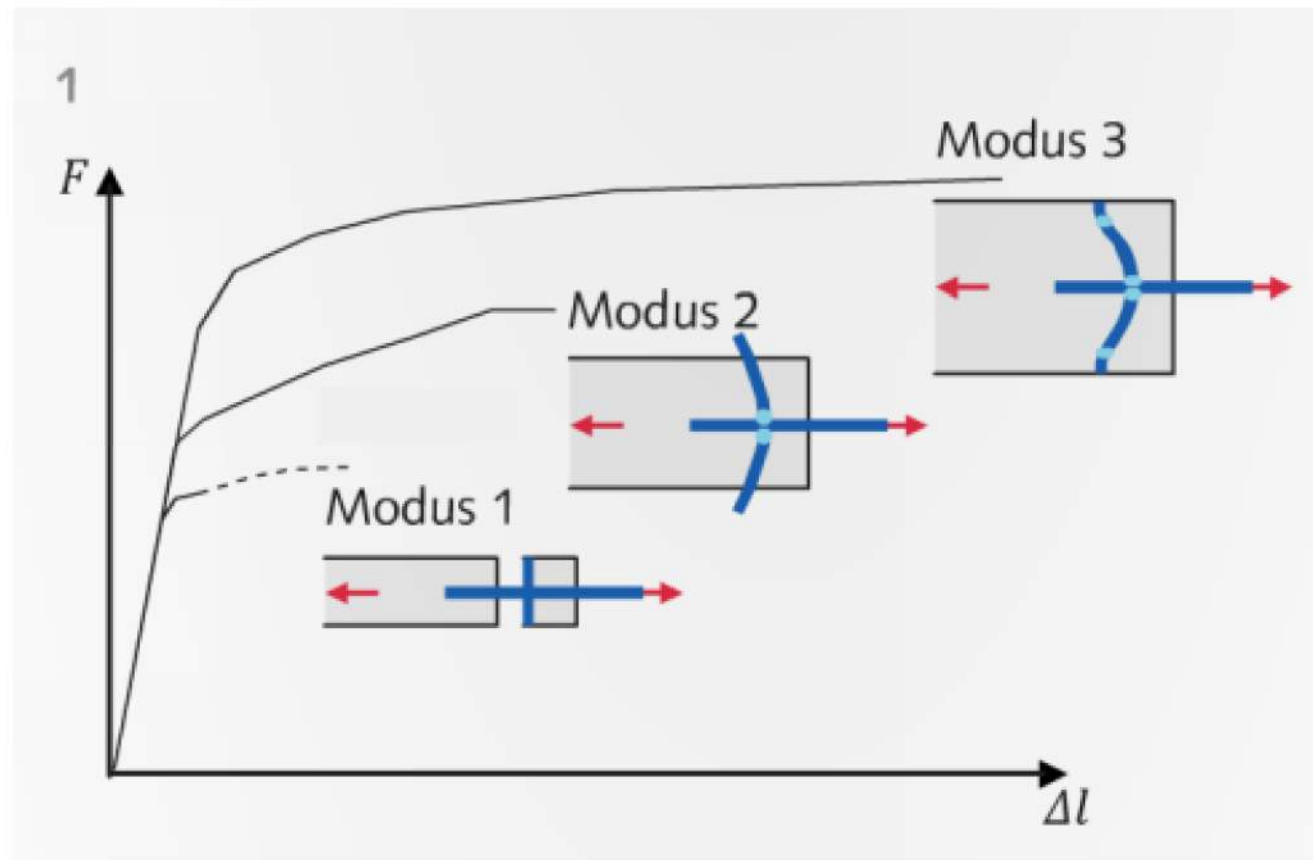
$d$  = dowel or bolt diameter



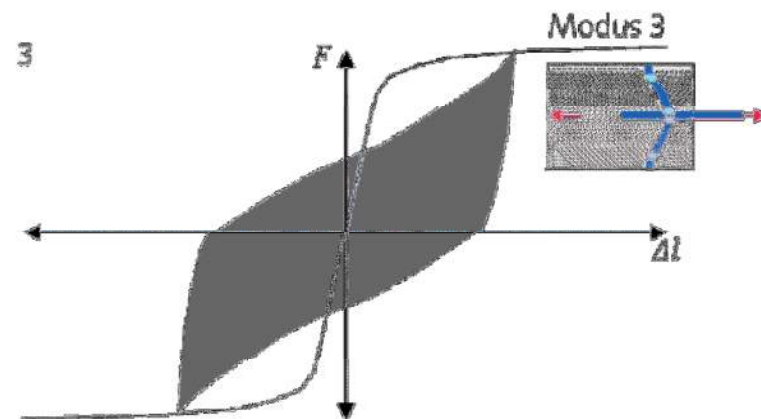
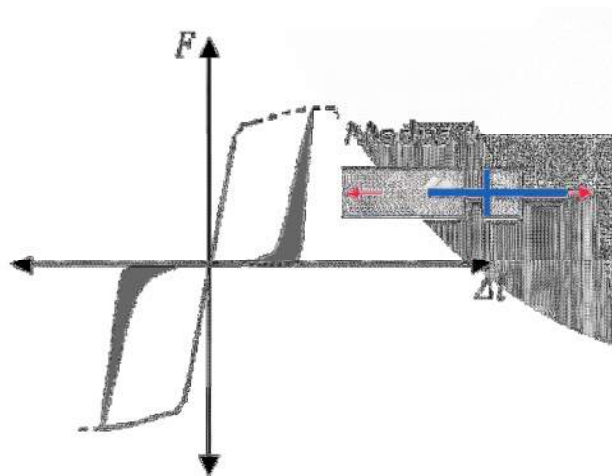
## 2.5 Bolts / Dowels – Failure Mode



## 2.5 Bolts / Dowels – Failure Mode



## 2.6 Bolts / Dowels – Seismic Design



## 2.7 How to Achieve Modus 3?

The slenderness limit  $\lambda_{y,1}$  in order to achieve Mode 2 is described as:

$$\lambda_{y,1} = \sqrt{2} * \sqrt{\frac{M_u}{f_h * d^3}}$$

Or a minimum wood thickness for a given fastener per:

$$t_{y,1} = \sqrt{2} * \sqrt{\frac{M_u}{f_h * d}}$$

The slenderness limit  $\lambda_{y,2}$  in order to achieve Mode 3 is described as:

$$\lambda_{y,2} = 4 * \sqrt{\frac{M_u}{f_h * d^3}}$$

Similarly, this can be represented as a minimum wood thickness for a given fastener per:

$$t_{y,2} = 4 * \sqrt{\frac{M_u}{f_h * d}}$$

Where;

$M_u$  = Plastic bending resistance of the dowel/bolt  
in [N-mm]

$f_h$  = Characteristic embedment strength [N/mm<sup>2</sup>]

$d$  = Dowel/bolt diameter in [mm]

$M_u$  =  $0.26 * f_u * d^{2.7}$  [N-mm]

$f_{h,0,k}$  =  $0.082 (1 - 0.01 d) \rho_k$  [N/mm<sup>2</sup>]

$f_{h,90,k}$  =  $f_{h,0,k} / (1.35 + 0.015 d)$  [N/mm<sup>2</sup>]

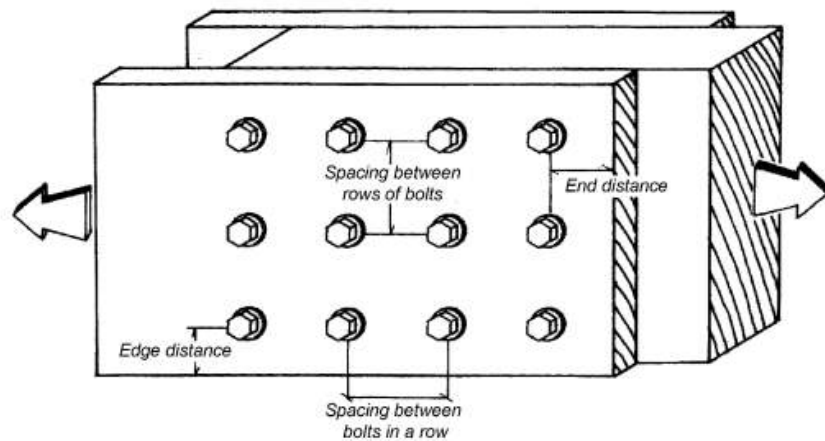
$f_{h,\alpha,k}$  = Embedment strength at any angle to grain;  
interpolate between  $f_{h,0,k}$  and  $f_{h,90,k}$  in [N/mm<sup>2</sup>]

$\rho_k$  = Characteristic density of wood in [kg/m<sup>3</sup>]

For design purposes,  $t_{y,1}$  should be considered the minimum member thickness used (Mode 2), where  $t_{y,2}$  should be considered the ideal thickness (Mode 3).

For connections with multiple knife plates, the minimum member thickness should be taken only based on Mode 3.

## 2.7 How to Achieve Modus 3?



Parallel to grain loading in all wood members ( $Z_{||}$ )

Previous slides based on:  
Spacing between bolts in a row:  
 $7 \times \varnothing$   
End distance:  
 $10 \times \varnothing$

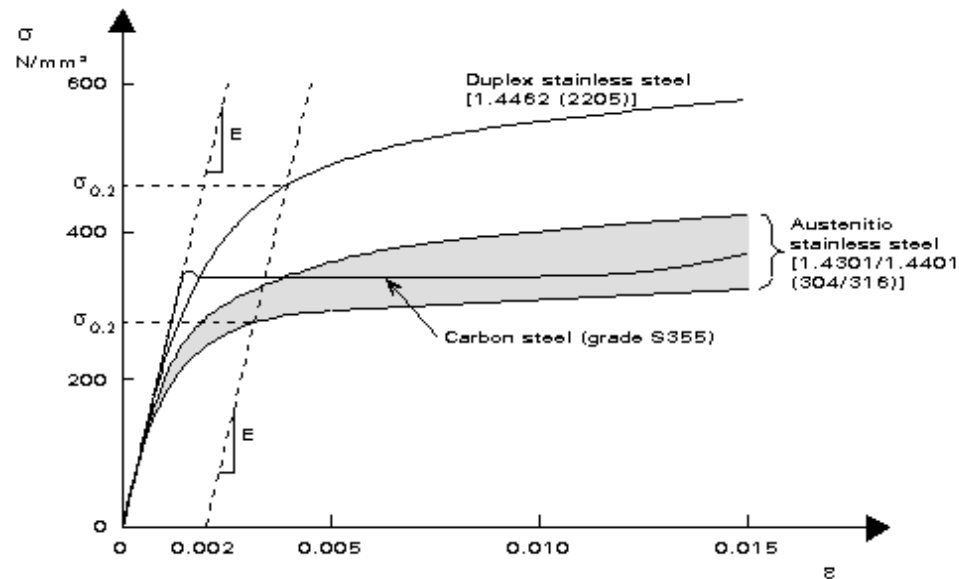
NDS based on:  
Spacing between bolts in a row:  
 $4 \times \varnothing$   
End distance:  
 $7 \times \varnothing$

## 2.7 How to Achieve Modus 3?

In order to obtain the characteristic density, the mean oven-dry relative density can be multiplied with a factor of approximately 0.84.

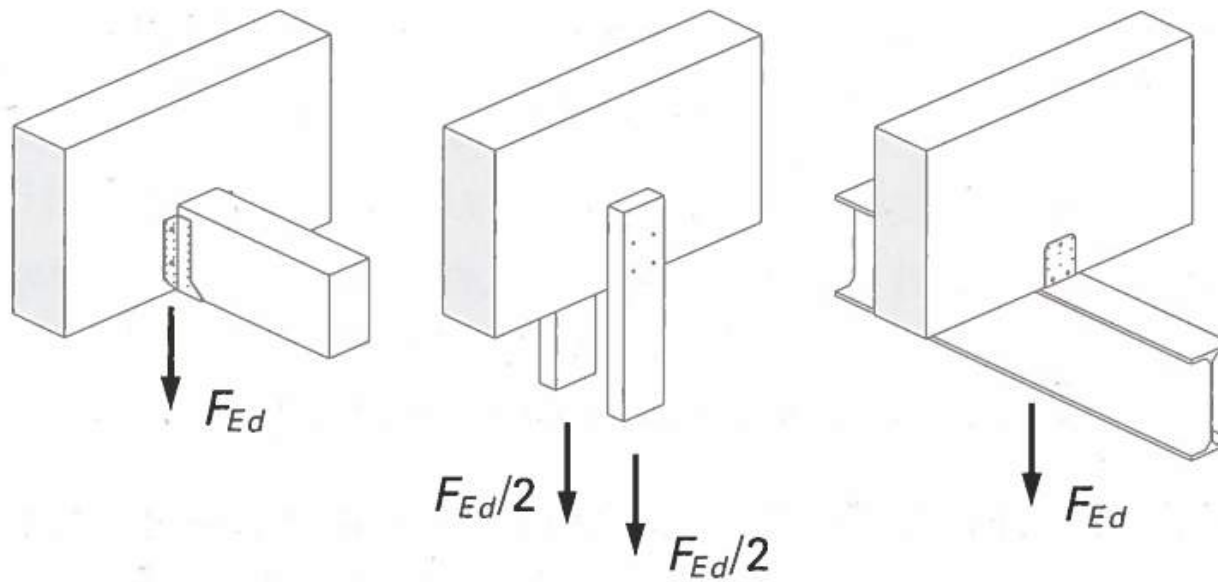
Species	Mean Oven-Dry Relative Density (i.e. oven dry specific gravity)	Characteristic Density at 12%MC (i.e. 5th percentile)
D.Fir-Larch (sawn lumber and Glulam)	0.49	410 Kg/m <sup>3</sup>
Hem-Fir (sawn lumber and Glulam)	0.46	385 Kg/m <sup>3</sup>
Spruce-Pine-Fir (sawn Lumber)	0.42	350 Kg/m <sup>3</sup>
Spruce-Pine (Glulam)	0.44	370 Kg/m <sup>3</sup>
Northern Species	0.35	300 Kg/m <sup>3</sup>
Black Spruce (Glulam)	0.56	470 Kg/m <sup>3</sup>
Parallam (PSL)	0.50	420 Kg/m <sup>3</sup>
Laminated Strand Lumber (LSL)	0.50	420 Kg/m <sup>3</sup>
Laminated Veneer Lumber (LVL)	0.50	420 Kg/m <sup>3</sup>

## 2.8 Mild vs. Stainless Steel



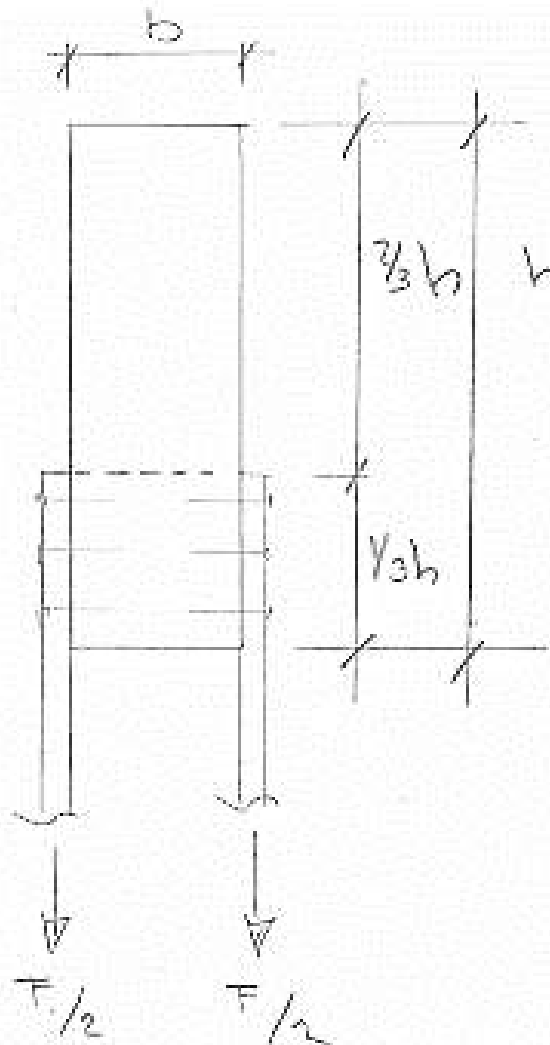
Galvanic Corrosion?!

## 2.9 Tension Perpendicular





## 2.9 Tension Perpendicular



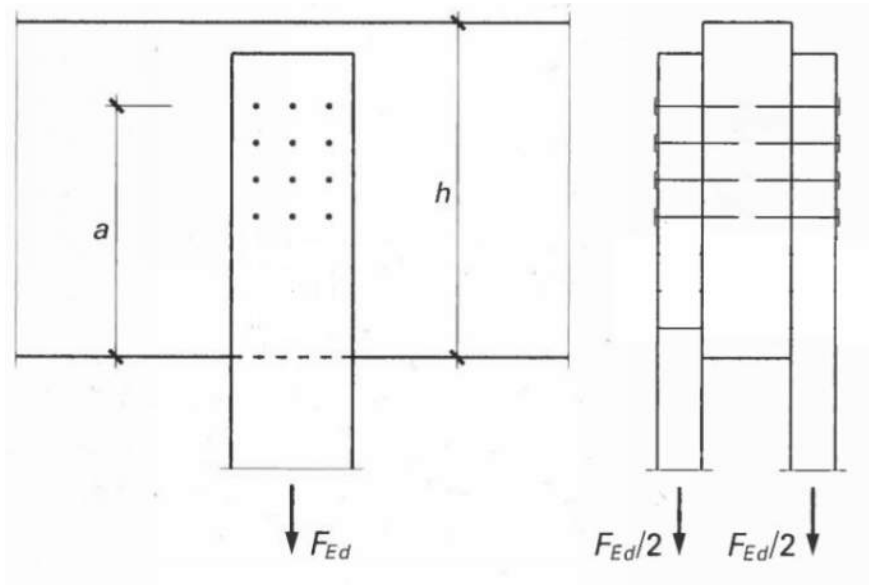
$$\begin{aligned} I_1 &= b \times \left(\frac{2}{3}h\right)^3 / 12 \\ &= b \times 0,024 \cdot h^3 \end{aligned}$$

$$\begin{aligned} I_2 &= b \times \left(\frac{1}{3}h\right)^3 / 12 \\ &= b \times 0,003 \cdot h^3 \end{aligned}$$

↳ UPPER PORTION IS 8 TIMES STIFFER !

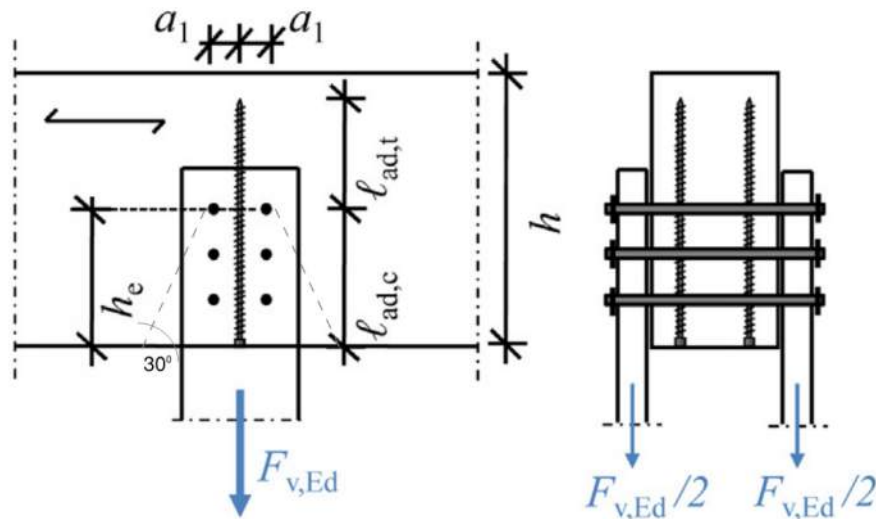
↳ BEAMS NEED TO DEFLECT SAME WAY  $\Delta_1 = \Delta_2$

## 2.9 Tension Perpendicular



In general, if  $a/h \geq 0.7$ , the effect of tension perpendicular can be ignored. This should be the preferred approach to any connection

## 2.9 Tension Perpendicular



$$F_{t,90,d} = [1 - 3 * (a/h)^2 + 2 * (a/h)^3] * F_{v,Ed}$$

with:

$F_{t,90,d}$  = design tension perpendicular to grain

$F_{v,Ed}$  = design connection force

The reinforcing is to be designed for  $F_{t,90,d}$ .

Embedment length for design  $l_{ad} = \min \{l_{ad,c}; l_{ad,t}\}$ .

$l_{ad,t}$  should extend at least up to 75% of the beam height.

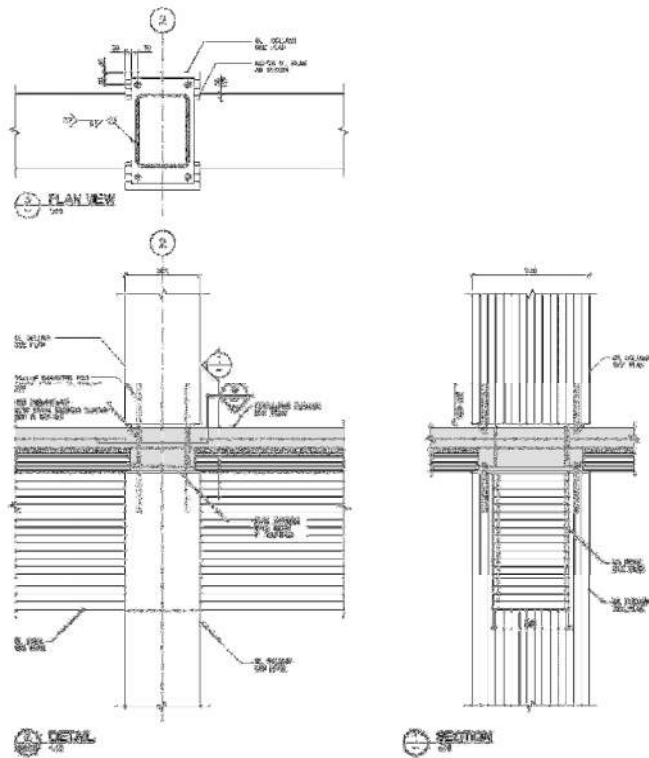
Reinforcement should be placed within an area based on 30° measured from the top of the connection.

## 2.10 Carpenter Connections



Carpenter connections often economical  
Combine with modern fastener

## 2.10 Carpenter Connections



## 2.11 Movement



Be realistic about actual fluctuation of EMC

It takes quite a while for larger cross sections to equalize throughout the cross section



## 2.12 Summary

- Direct loadpath
- Respect Wood Movement (and design for it!)
- Bolts / Dowels to have ductile failure modes
- Careful with tension perpendicular
- Avoid horizontal wood in the vertical load path
- Old school bearing type connections often economical
- Design with fabrication and installation in mind → next chapter

# 3. Practical Considerations



# 3.1 Equipment



- Hand Tools



## 3.1 Equipment



- CNC



## 3.2 Installers



## 3.3 Overview

Practical Considerations for Connection Designs		Origin of Issue					Where to address the Issue				
		Design	Fabrication	Transportation	Installation	Use	Design	Fabrication	Transportation	Installation	Use
Supply Capabilities	CNC machining vs Hand-framing of wood members		x				x				
Supply Capabilities	Welding / machining of custom steel pieces		x		x		x				
Shrinkage	Movement (or restricted movement) of wood due to fluctuation of moisture content					x	x				
Tolerances	Missing tolerance level in standards		x		x		x				
Tolerances	Member size not as per specs, assembly of members doesn't fit		x		x		x	x			
Tolerances	Interface to other materials (steel and concrete) doesn't fit. Steel and concrete have much larger tolerances		x		x		x	x			
Fire Resistance	Charring of wood, reduction of cross section, heat transfer					x	x	x		x	
Fire Resistance	Exposed connectors					x	x	x		x	

## 3.3 Overview

Practical Considerations for Connection Designs		Origin of Issue					Where to address the Issue				
		Design	Fabrication	Transportation	Installation	Use	Design	Fabrication	Transportation	Installation	Use
Local Workforce	Installation strategy needs to respect labor skill sets available.				x		x				
Site Conditions	Crane type and locations may impact member length and require add'l splices.			x	x		x				
Speed of installation	Maximize site production, limited crane time available				x		x				
Speed of installation	Connection types		x		x		x				
AHJ	AHJ is not familiar with the type of construction	x					x				
AHJ	AHJ does not facilitate the use of alternate connectors	x					x				
Drift Compatibility	Connections need to accommodate lateral movement	x				x	x			x	
Detail Complexity	Multiple members framing coming together	x					x				

## 4. Design Solutions

# 4.1 Commodity (NDS Dowel-Type)

## 4.1.0 General – Resistance Values

**Table 11.3.1 Applicability of Adjustment Factors for Connections**

	ASD Only	ASD and LRFD										LRFD Only		
		Load Duration Factor <sup>1</sup>	Wet Service Factor	Temperature Factor	Group Action Factor	Geometry Factor <sup>3</sup>	Penetration Depth Factor <sup>3</sup>	End Grain Factor <sup>3</sup>	Metal Side Plate Factor <sup>3</sup>	Diaphragm Factor <sup>3</sup>	Toe-Nail Factor <sup>3</sup>	Format Conversion Factor	Resistance Factor	Time Effect Factor
												$K_F$	$\phi$	
<b>Lateral Loads</b>														
Dowel-type Fasteners (e.g. bolts, lag screws, wood screws, nails, spikes, drift bolts, & drift pins)	$Z' = Z \times$	$C_D$	$C_M$	$C_t$	$C_g$	$C_\Delta$	-	$C_{eg}$	-	$C_{di}$	$C_{tn}$	3.32	0.65	$\lambda$
Split Ring and Shear Plate Connectors	$P' = P \times$ $Q' = Q \times$	$C_D$	$C_M$	$C_t$	$C_g$	$C_\Delta$	$C_d$	-	$C_{st}$	-	-	3.32	0.65	$\lambda$
Timber Rivets	$P' = P \times$ $Q' = Q \times$	$C_D$	$C_M$	$C_t$	-	-	-	-	$C_{st}^4$	-	-	3.32	0.65	$\lambda$
Spike Grids	$Z' = Z \times$	$C_D$	$C_M$	$C_t$	-	$C_\Delta^5$	-	-	$C_{st}^4$	-	-	3.32	0.65	$\lambda$
<b>Withdrawal Loads</b>														
Nails, spikes, lag screws, wood screws, & drift pins	$W' = W \times$	$C_D$	$C_M^2$	$C_t$	-	-	-	$C_{eg}$	-	-	$C_{tn}$	3.32	0.65	$\lambda$

1. The load duration factor,  $C_D$ , shall not exceed 1.6 for connections (see 11.3.2).

2. The wet service factor,  $C_M$ , shall not apply to toe-nails loaded in withdrawal (see 12.5.4.1).

3. Specific information concerning geometry factors  $C_\Delta$ , penetration depth factors  $C_d$ , end grain factors,  $C_{eg}$ , metal side plate factors,  $C_{st}$ , diaphragm factors,  $C_{di}$ , and toe-nail factors,  $C_{tn}$ , is provided in Chapters 12, 13, and 14.

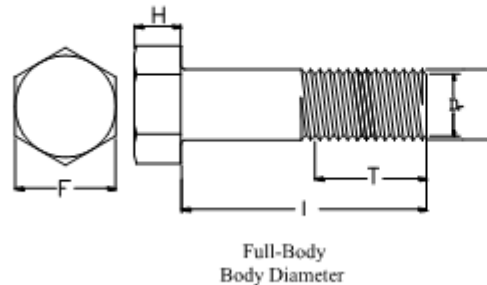
4. The metal side plate factor,  $C_{st}$ , is only applied when rivet capacity ( $P_r$ ,  $Q_r$ ) controls (see Chapter 14).

5. The geometry factor,  $C_\Delta$ , is only applied when wood capacity,  $Q_w$ , controls (see Chapter 14).

# 4.1 Commodity (NDS Dowel-Type)

## 4.1.1 Standard Hex Bolts

**Table L1**      **Standard Hex Bolts<sup>1</sup>**

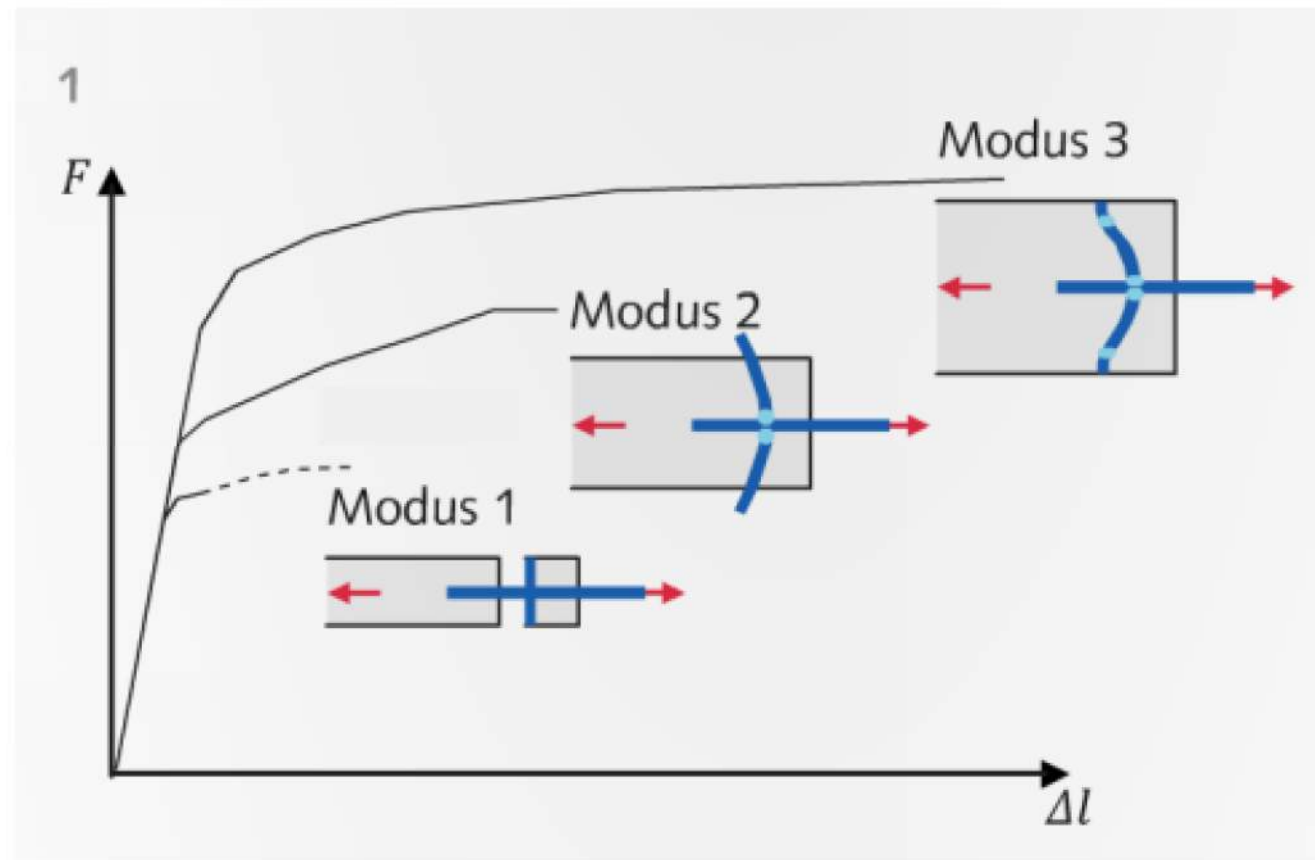


D = diameter  
 $D_r$  = root diameter  
T = thread length  
L = bolt length  
F = width of head across flats  
H = height of head

Applications	Pros	Cons
<ul style="list-style-type: none"><li>• Direct beam to beam connections (in shear)</li><li>• Beam to beam or beam to column connections via knife or side plates</li><li>• Nominal connectors for plate saddles/bearing connections</li></ul>	<ul style="list-style-type: none"><li>• Readily Available</li><li>• Skilled trades not required for installation</li><li>• Can keep bolt heads exposed for architecturally expressive exposed old-school heavy timber connections</li><li>• Can be used for timber connection to any material (concrete, steel, masonry)</li></ul>	<ul style="list-style-type: none"><li>• Connections are naturally exposed</li><li>• Both sides of connection must be accessible</li><li>• Bolt head/nut and washer must be perpendicular to connected surfaces (or shimmed or notched/recessed to suit)</li></ul>

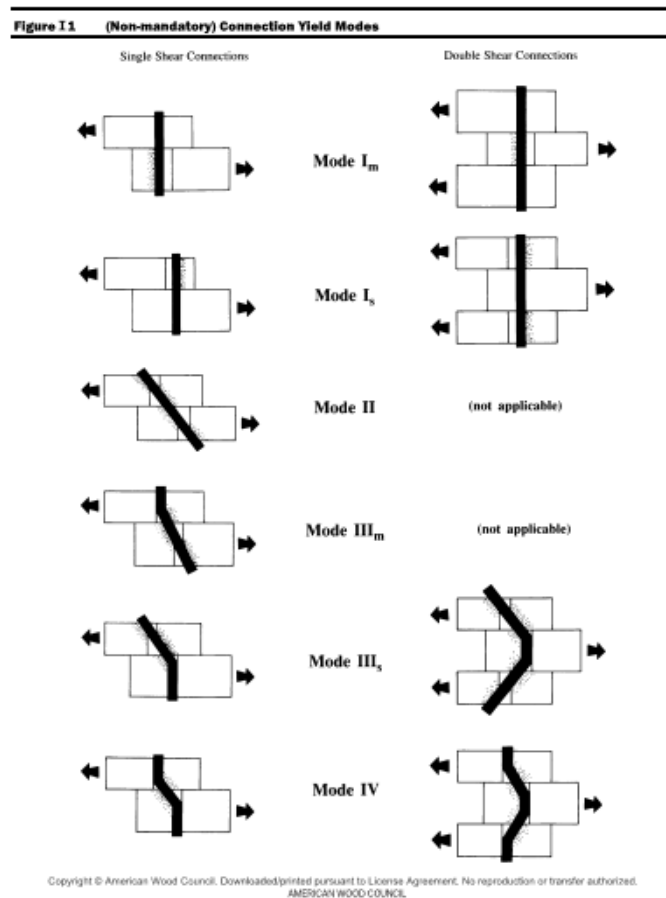


Remember....?!



# 4.1 Commodity (NDS Dowel-Type)

## 4.1.6 General – Failure Modes

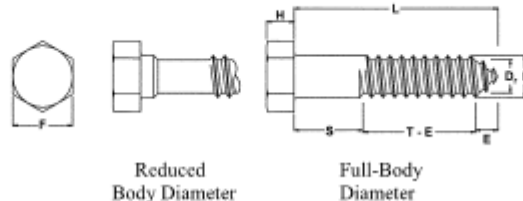


# 4.1 Commodity (NDS Dowel-Type)

## 4.1.2 Standard Hex Lag Screws

**Table L2**      **Standard Hex Lag Screws<sup>1</sup>**

D = diameter  
D<sub>r</sub> = root diameter  
S = unthreaded body length  
T = minimum thread length<sup>2</sup>



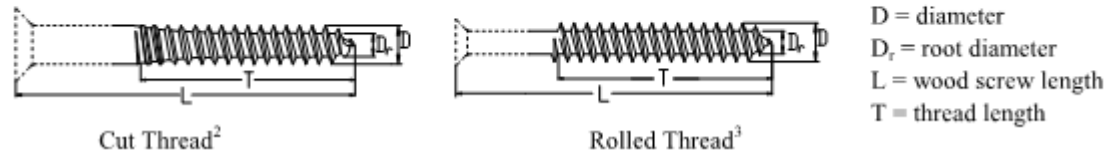
E = length of tapered tip  
L = lag screw length  
N = number of threads/inch  
F = width of head across flats  
H = height of head

Applications	Pros	Cons
<ul style="list-style-type: none"><li>• Direct beam to beam connections (in shear)</li><li>• Beam to beam or beam to column connections via side plates</li><li>• Nominal connectors for plate saddles/bearing connections where only one side is accessible</li></ul>	<ul style="list-style-type: none"><li>• Readily Available</li><li>• Can keep bolt heads exposed for architecturally expressive old-school exposed heavy timber connections</li><li>• Only one side of connection needs to be accessible</li><li>• May be loaded in tension/withdrawl (but please avoid it)</li></ul>	<ul style="list-style-type: none"><li>• Very time consuming to install (skill needed)</li><li>• Connections are naturally exposed</li><li>• Lag screw head must be perpendicular to side member surface</li></ul>

# 4.1 Commodity (NDS Dowel-Type)

## 4.1.3 Standard Wood Screws

**Table L3**      **Standard Wood Screws<sup>1,5</sup>**

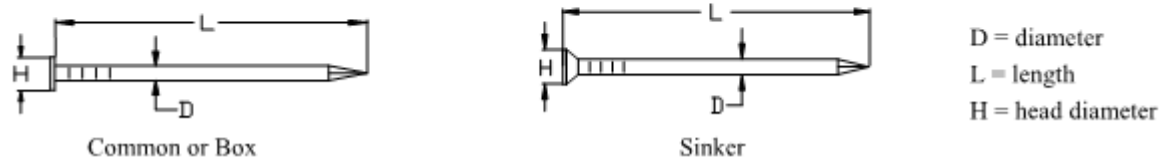


Applications	Pros	Cons
<ul style="list-style-type: none"><li>• Light wood frame connections (side members &lt;1 ½")</li><li>• Loading permitted in shear and tension/withdrawl</li></ul>	<ul style="list-style-type: none"><li>• Readily Available</li><li>• Relatively quick to install with a power drill</li><li>• Skilled trades not required</li><li>• Variable head sizes and shapes – can be flush or recessed if required</li><li>• Small heads = low connection visibility</li><li>• May be installed at an angle to the surface (with reduction factor)</li><li>• Only one side of connection needs to be exposed</li><li>• Predrilling not required</li></ul>	<ul style="list-style-type: none"><li>• Design diameter varies. Important to clearly specify screws.</li><li>• Relatively short standard lengths available</li><li>• Small resistances</li></ul>

# 4.1 Commodity (NDS Dowel-Type)

## 4.1.4 Common, Box, & Sinker Steel Wire Nails

**Table L4**      **Standard Common, Box, and Sinker Steel Wire Nails<sup>1,2</sup>**



Applications	Pros	Cons
<ul style="list-style-type: none"><li>• Light wood frame connections (side members &lt;1 ½")</li><li>• Shearwalls and diaphragms</li></ul>	<ul style="list-style-type: none"><li>• Readily Available</li><li>• Quick to install with a nail gun</li><li>• Skilled trades not required</li><li>• Flush or (minimally) recessed heads</li><li>• May be installed at an angle to the surface (with reduction factor)</li><li>• Small heads = low connection visibility</li><li>• Only one side of connection needs to be exposed</li></ul>	<ul style="list-style-type: none"><li>• Low capacity per fastener</li><li>• Loading permitted in shear only</li><li>• Small resistances</li></ul>

## 4.2 Pre-Engineered / Proprietary

### 4.2.1 Screws



Lag Screw



Self Tapping Screw

## 4.2 Pre-Engineered / Proprietary

### 4.2.1.1 Partially Threaded Screws

Partially threaded screws are the most common used screws. The thread extents are only over a certain length of the shaft, depending on the total length of the screws



These screws are mainly used in shear applications.

## 4.2 Pre-Engineered / Proprietary

### 4.2.1.2 Fully Threaded Screws

Fully threaded screws are mostly used in connections with tension forces to be transferred. The thread extents are over the full length of the shaft, regardless of the total length of the screws. After a certain length of screw, the actual steel tension capacity of the screw is the governing factor.



These screws are mainly used in tension and compression applications, to reinforce beams and for butt joints.



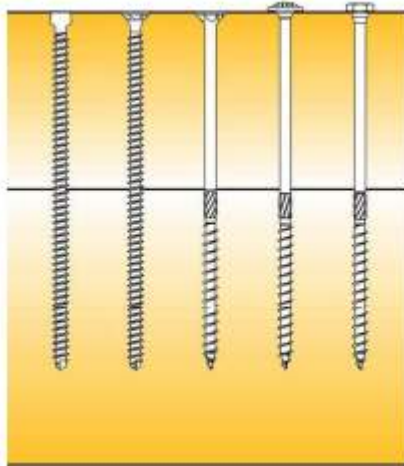
## 4.2 Pre-Engineered / Proprietary

### 4.2.1.3 Screw Heads

<b>Washer Head</b> (partially threaded screws only)	
<b>Hex Head</b> (partially threaded screws only)	
<b>Countersunk Head</b> (partially and fully threaded screws)	
<b>Cylindrical Head</b> (fully threaded screws only)	

## 4.2 Pre-Engineered / Proprietary

### 4.2.1.4 Screw Length



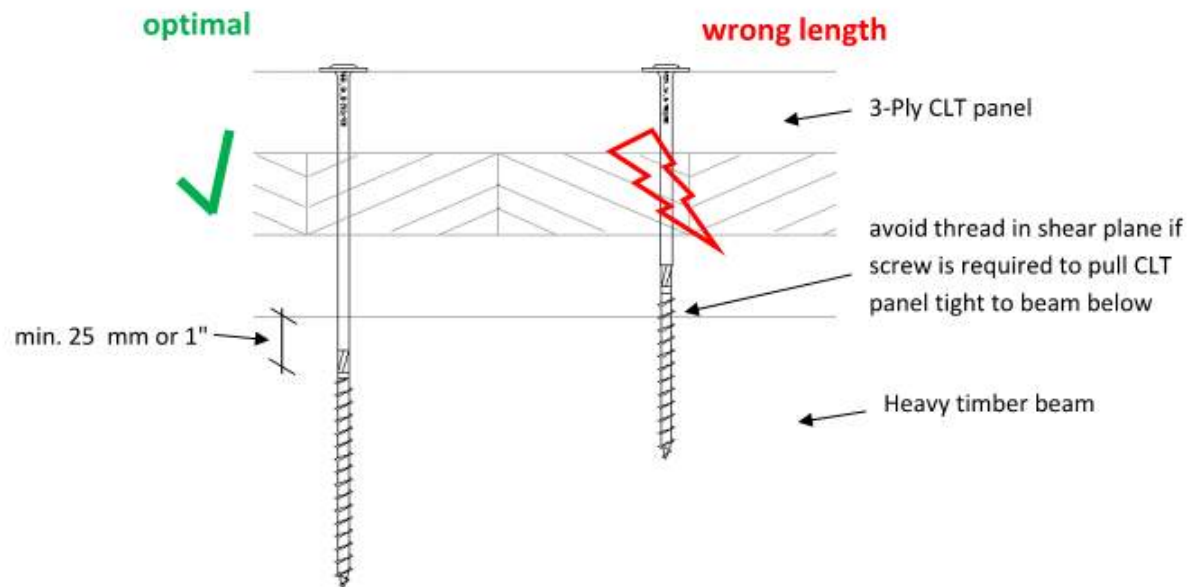
For screws in shear, the shear plane should be in the shank and not in the threaded portion of the screw. Otherwise the members won't close during the installation.

If fully threaded screws are used, consider combining them with partially threaded screws.

Careful with diameter used for the design!

## 4.2 Pre-Engineered / Proprietary

### 4.2.1.4 Screw Length



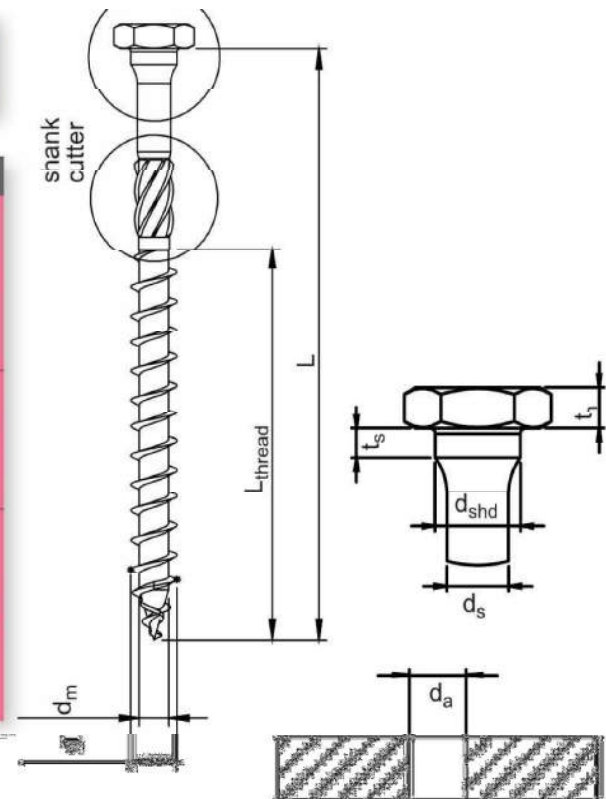
## 4.2 Pre-Engineered / Proprietary

### 4.2.1.5 Screw diameter



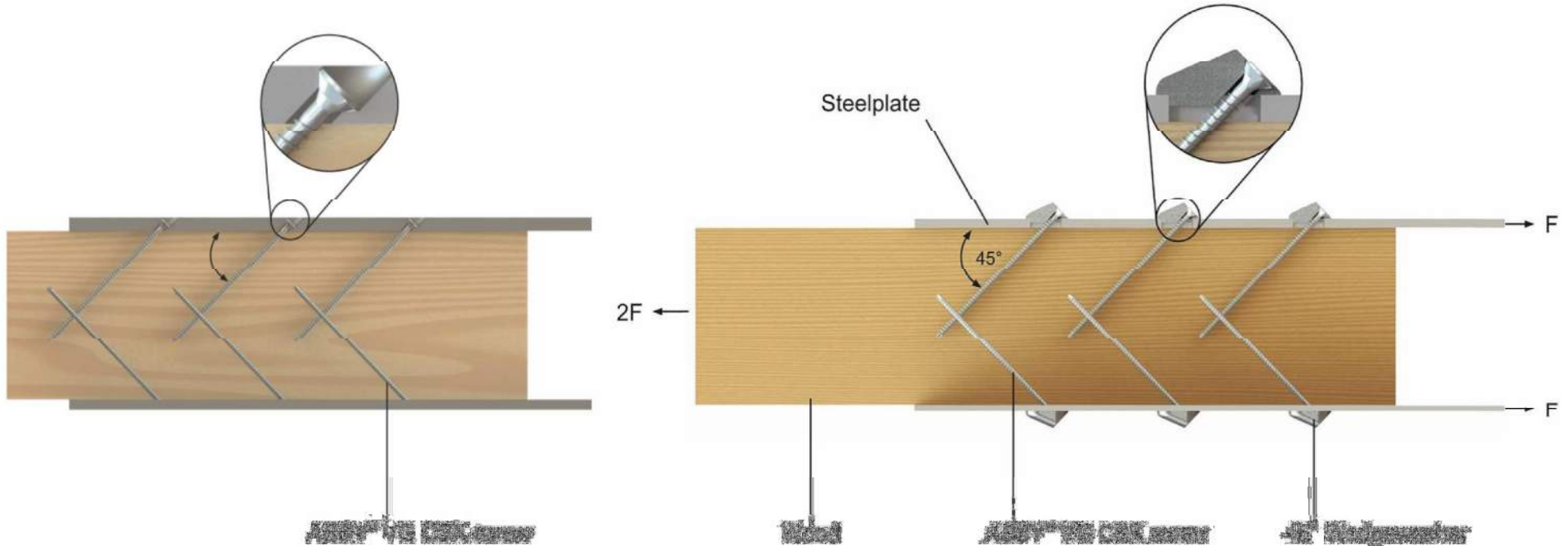
Specs metric [Specs imperial]

d	L	L <sub>Thread</sub>	L <sub>Tip</sub>	d <sub>Head</sub>	d <sub>min</sub>	d <sub>s</sub>	d <sub>a</sub>	d <sub>shd</sub>	t <sub>h</sub>	t <sub>s</sub>	Bit
8 [5/16]	60	[2-3/8]	40	[1-1/2]							AW® 40 / 12 mm socket
	80	[3 1/8]	60	[2]							
	100	[4]	60	[2-3/8]	8	12	5,3	5,8	9	7,8	
	120-200 <sup>1</sup>	[4-3/4 – 7-7/8] <sup>2</sup>	80	[3-1/8]							
	220-300 <sup>1</sup>	[8-5/8 – 12] <sup>2</sup>	100	[4]							
10 [3/8]	140	[5-1/2]	80	[3-1/8]							AW® 40 / 15 mm socket
	160-300 <sup>1</sup>	[6-1/4–12] <sup>2</sup>	100	[4]							
	320-400 <sup>1</sup>	[12-5/8–15-3/4] <sup>2</sup>	120	[4-3/4]	10	15	6,3	7,2	11	9,8	
	440-520 <sup>3</sup>	[17-3/4 – 20-1/2] <sup>4</sup>	120	[4-3/4]							
12 [1/2]	100	[4]	60	[2-3/8]							AW® 40 / 17 mm socket
	120	[4-3/4]	80	[3-1/8]							
	140	[5-1/2]	80	[3-1/8]	12	17	7,2	8,2	13	11,8	
	160-200 <sup>1</sup>	[6-1/4 – 7-7/8] <sup>2</sup>	100	[4]							
	220-360 <sup>1</sup>	[8-5/8 – 14-1/8] <sup>2</sup>	120	[4-3/4]							
	380-600 <sup>1</sup>	[15 – 23-5/8] <sup>2</sup>	145	[5-3/4]							



## 4.2 Pre-Engineered / Proprietary

### 4.2.1.6 Tension Connections



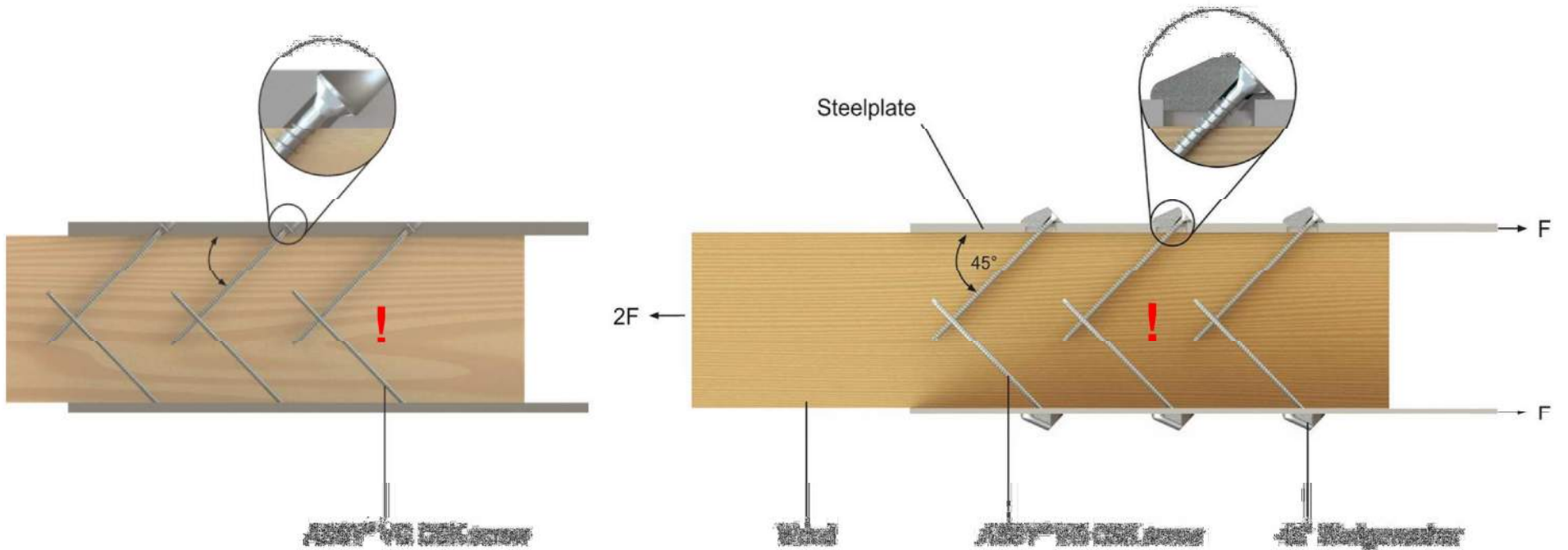
## 4.2 Pre-Engineered / Proprietary

### 4.2.1.6 Tension Connections



## 4.2 Pre-Engineered / Proprietary

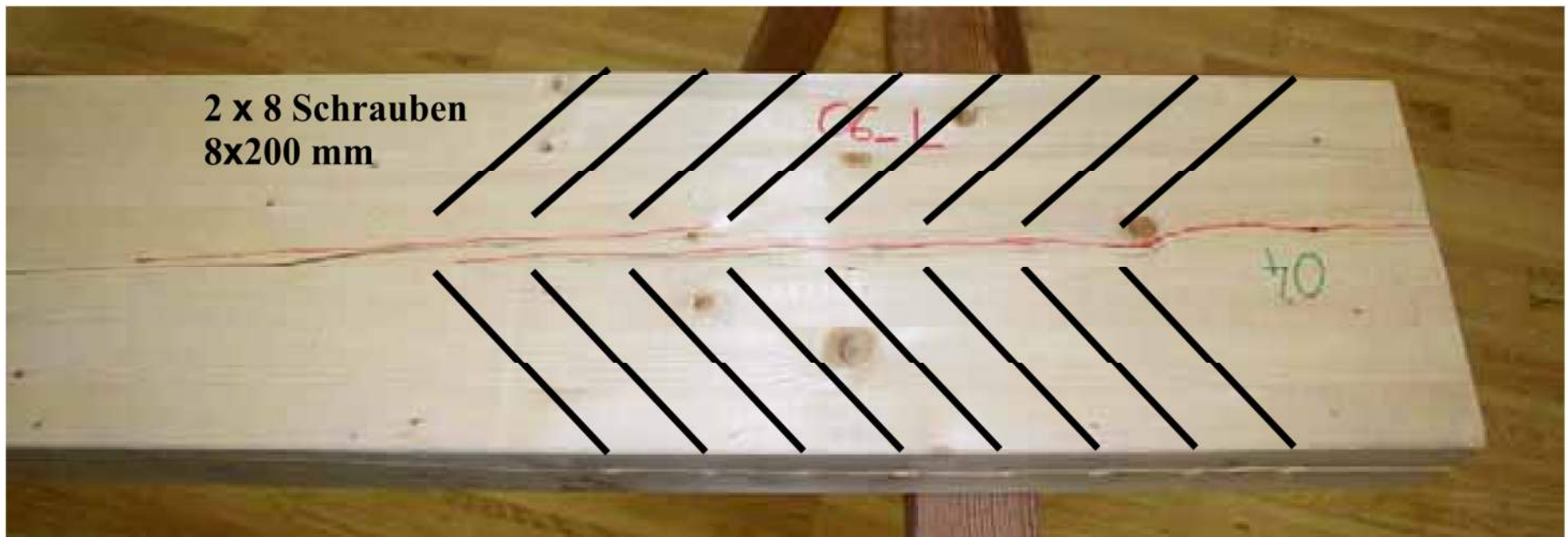
### 4.2.1.6 Tension Connections





## 4.2 Pre-Engineered / Proprietary

### 4.2.1.6 Tension Connections

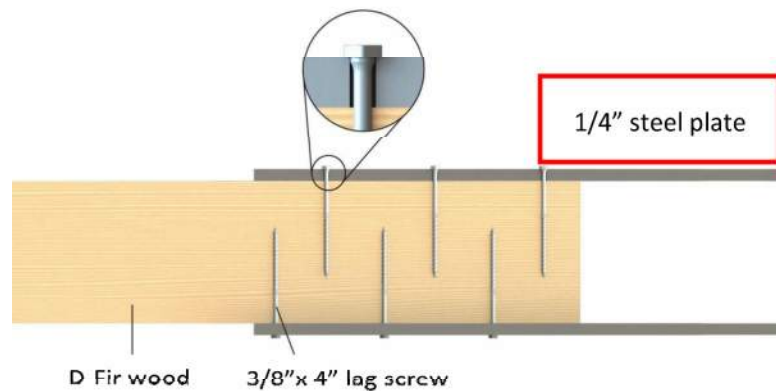


Reference: Grazer Holzbau-Fachtagung 2007: Traglast von auf Zugbeanspruchten Schraubenverbindungen mit Stahlblechen [http://www.holzbauforschung.at/uploads/tx\\_sbdownloader/6GraHFT07\\_Tagungsband.pdf](http://www.holzbauforschung.at/uploads/tx_sbdownloader/6GraHFT07_Tagungsband.pdf)

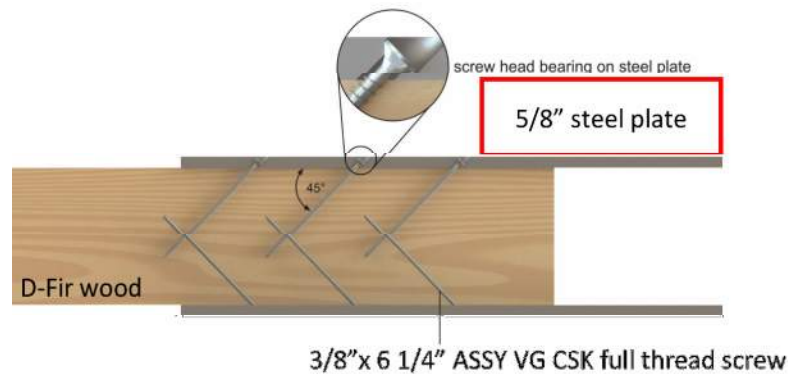


## 4.2 Pre-Engineered / Proprietary

### 4.2.1.7 Tension vs Shear

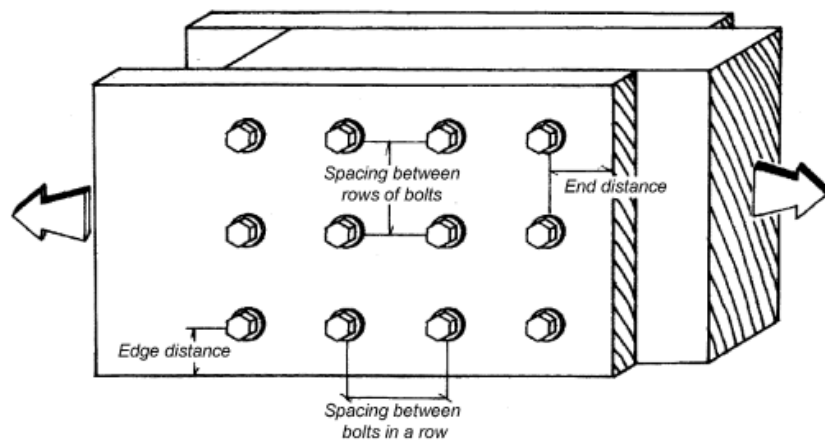


Increase of resistance by  $\approx 100\%$

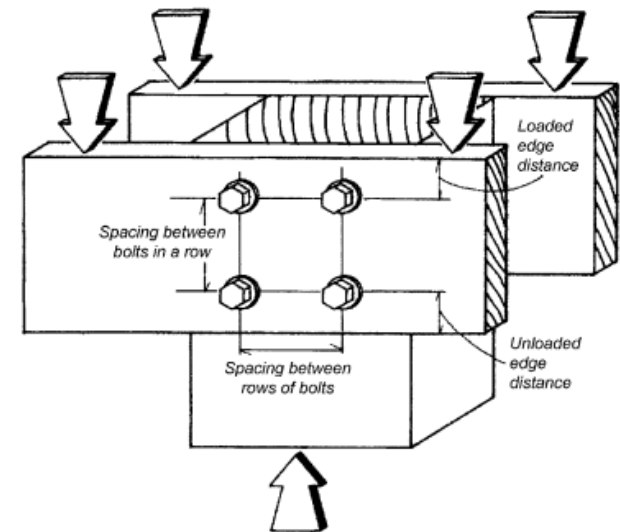


## 4.2 Pre-Engineered / Proprietary

### 4.2.1.8 Spacing



Parallel to grain loading in all wood members ( $Z_{||}$ )



Perpendicular to grain loading in the side member and parallel to grain loading in the main member ( $Z_{\perp}$ )

**Follow the approvals for spacings!**

**Group Factors....!?**  
**( $n_{ef} = n^{0.9}$ )**

## 4.2 Pre-Engineered / Proprietary

### 4.2.1.9 Overview

		Partially Threaded Screws				Fully Threaded Screws			Others
		Countersunk Head	Countersunk Head w/ Cup Washer	Hex Head	Washer Head	Countersunk Head	Countersunk Head w/ Cup Washer	Cylindrical Head	
Wood to Wood Connections	Shear	x	(x)	x	(x)	(x)		(x)	
	Tension		x		x	x		x	
	Pulling Members together		x		x				1)
Wood to Steel Connection	Shear	x	(x)	x	(x)	(x)	(x)		
	Tension	(x)	(x)	(x)	(x)	x	x		
	Pulling Members together	x	x	x	x	x	x		2)
Others	Compression Reinforcement					(x)		x	3)
	Tension Perpendicular to Grain					(x)		x	4)

x = recommended use

(x) = use with limitations

1) Heco Unix is also an option - has strong clamping effect. SFS WT-T is also an option - has some clamping effect, but screw needs to be located properly

2) Heco Unix is also an option - has strong clamping effect

3) SFS WT-T is also an option - has some clamping effect. But screw needs to be located properly

4) SFS WT-T is also an option

## 4.2 Pre-Engineered / Proprietary

### 4.2.2 Brackets



(Simpson ABR 105)



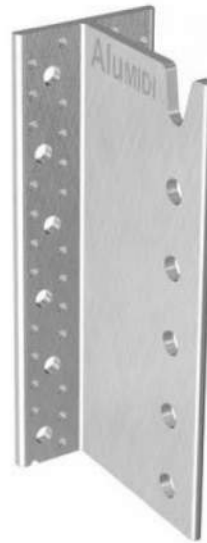
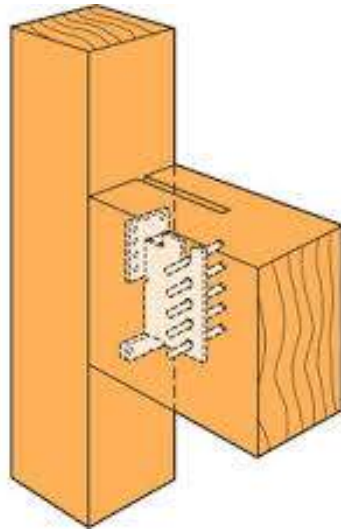
(RothoBlaas Titan)

## 4.2 Pre-Engineered / Proprietary

### 4.2.3 Hangers



(Simpson CJT1)

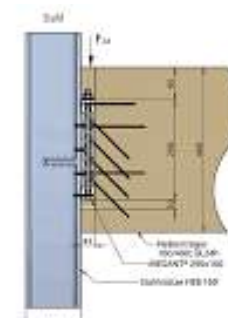
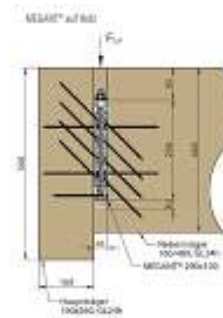
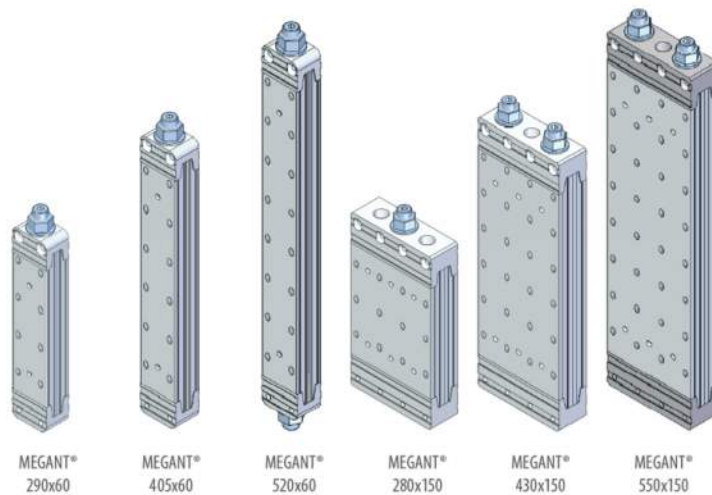


(RothoBlaas AluMaxi)



## 4.2 Pre-Engineered / Proprietary

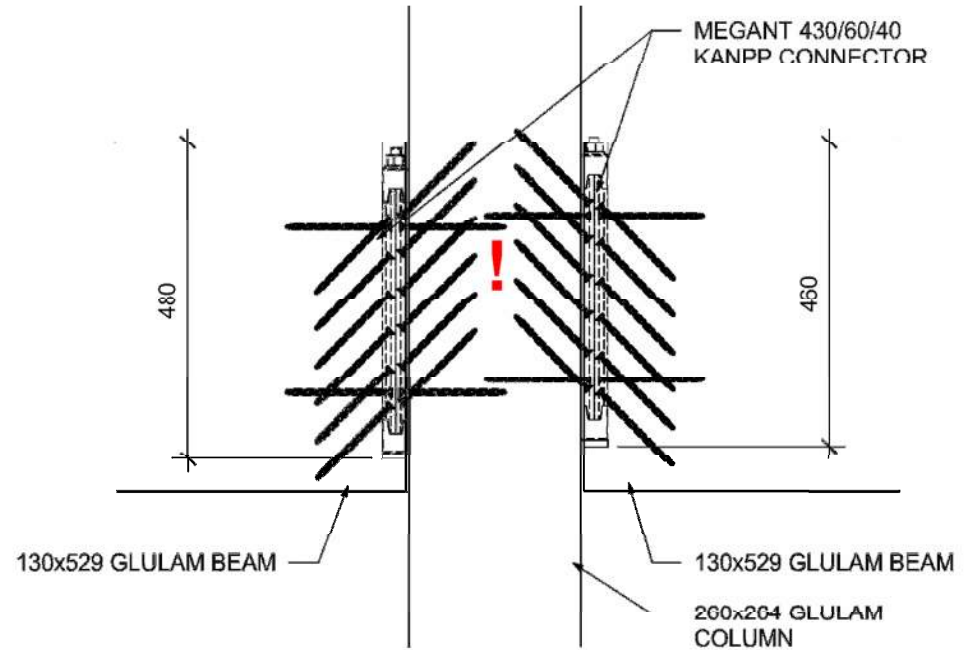
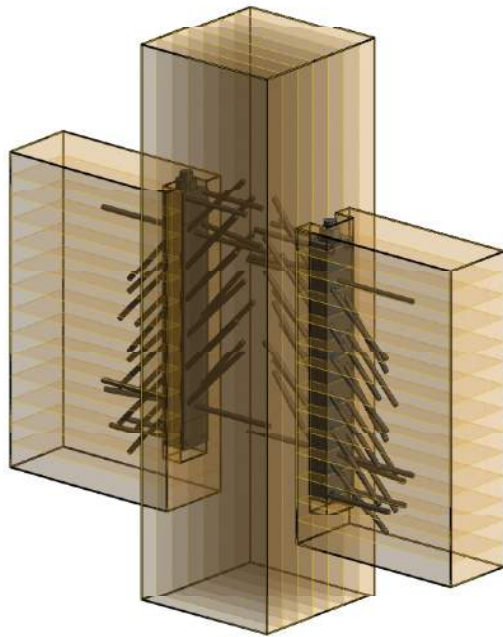
### 4.2.3 Hangers



(Knapp Megant)

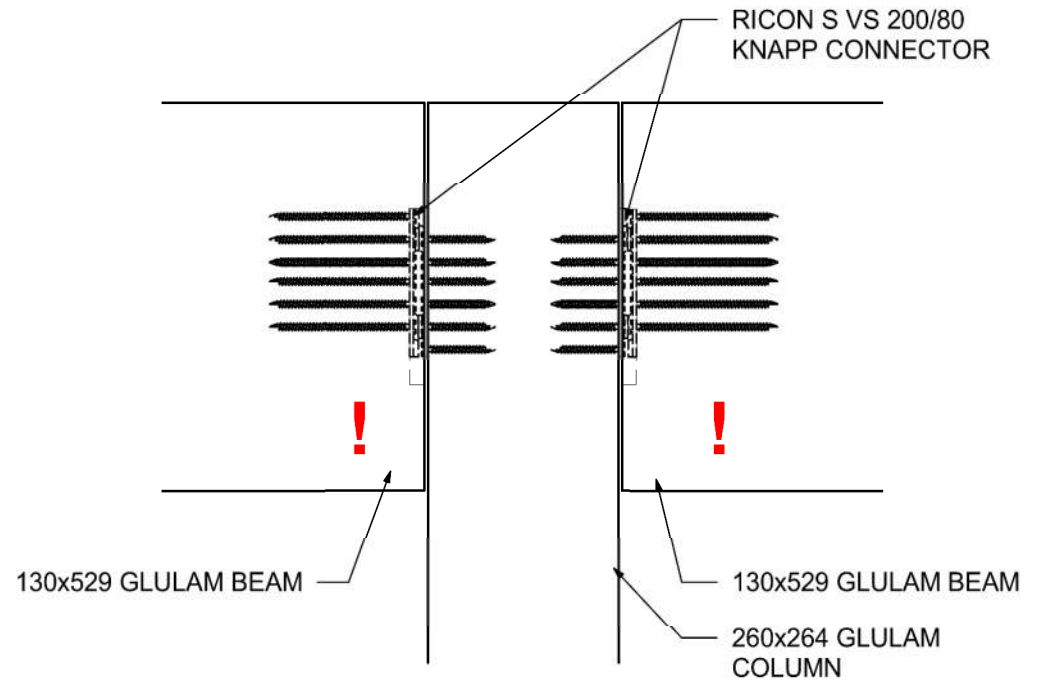
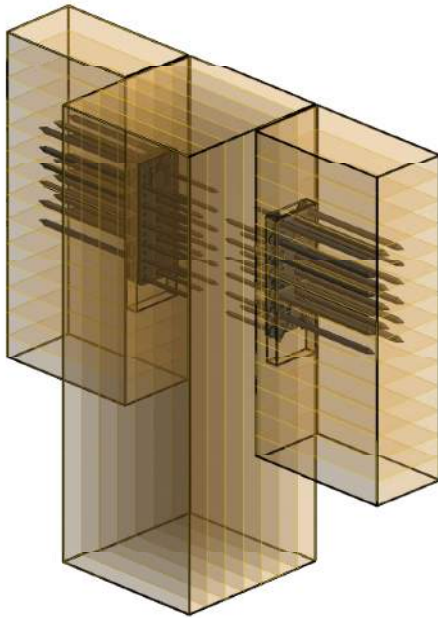
## 4.2 Pre-Engineered / Proprietary

### 4.2.3 Hangers



## 4.2 Pre-Engineered / Proprietary

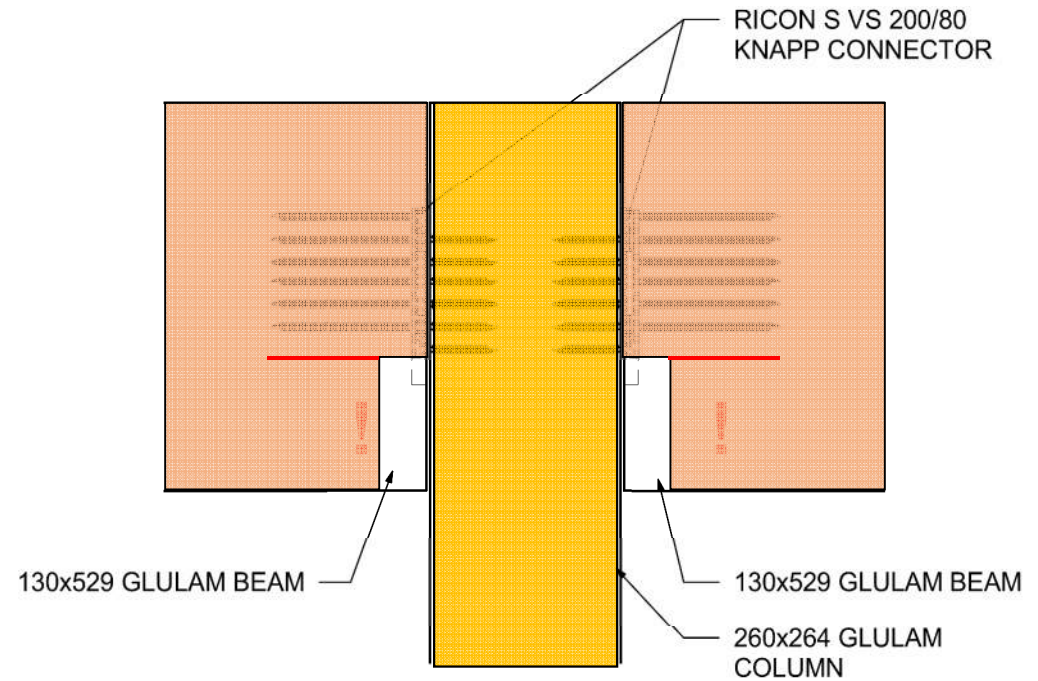
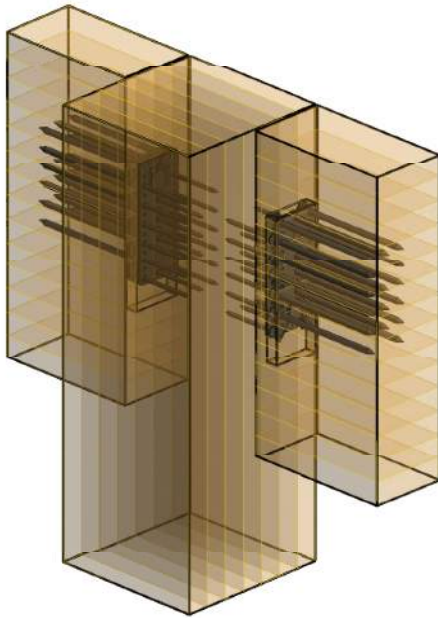
### 4.2.3 Hangers





## 4.2 Pre-Engineered / Proprietary

### 4.2.3 Hangers



## 4.2 Pre-Engineered / Proprietary

### 4.2.4 Overview

Modern Fastener Overview				
Supplier	Screws	Brackets	Hangers	Comments
Simpson Strong-Tie	SDS SDWS SDWH SD	ABR 105 ABR 9020 AD116	CJT (ETB)	US approvals/testing values
USP	WS	-	-	US approvals/testing values
ASSY	ECO KOMBI SK FWH VG CSK VG CYL VG RH	-	-	US approvals/testing values
KNAPP	-	-	RICON GIGANT MEGANT	US approvals/testing values FOR SCREWS EU approvals/testing values FOR BODY

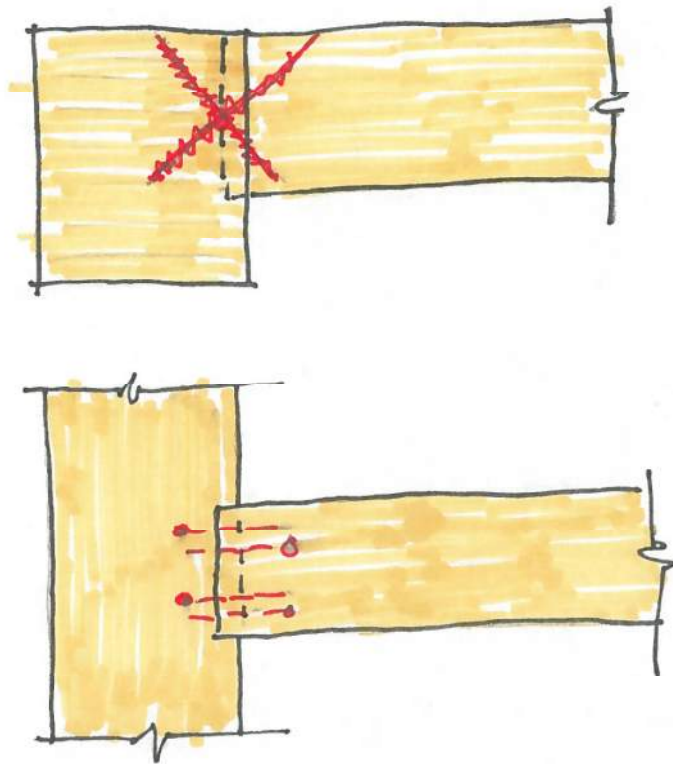
## 4.2 Pre-Engineered / Proprietary

### 4.2.4 Overview

Supplier	Screws	Brackets	Hangers	Comments
ROTHO BLAAS (SFS)	HBS TBS VGZ VGS WRT WS WT WB	TITAN WVB WKR WKF WINK	ALL MINI/MIDI/MAX LIV	EU approvals/testing values
PITZL	-	-	HVP	EU approvals/testing values
SHERPA	-	-	SHERPA	EU approvals/testing values
HECO	TOPIX UNIX	-	-	EU approvals/testing values

## 4.3 Custom

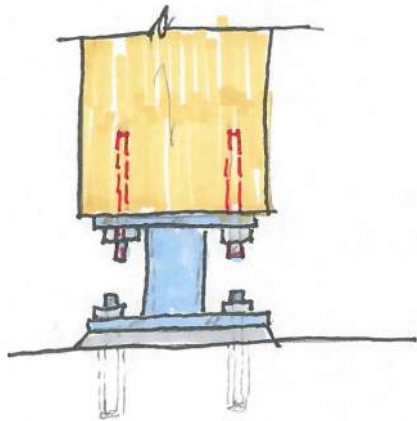
### 4.3.1 Housing & Fully Threaded Screws



- Screws in tension and compression take load
- Housing helps to set purlins
- Screws for tolerance
- Connection is protected from fire

# 4.3 Custom

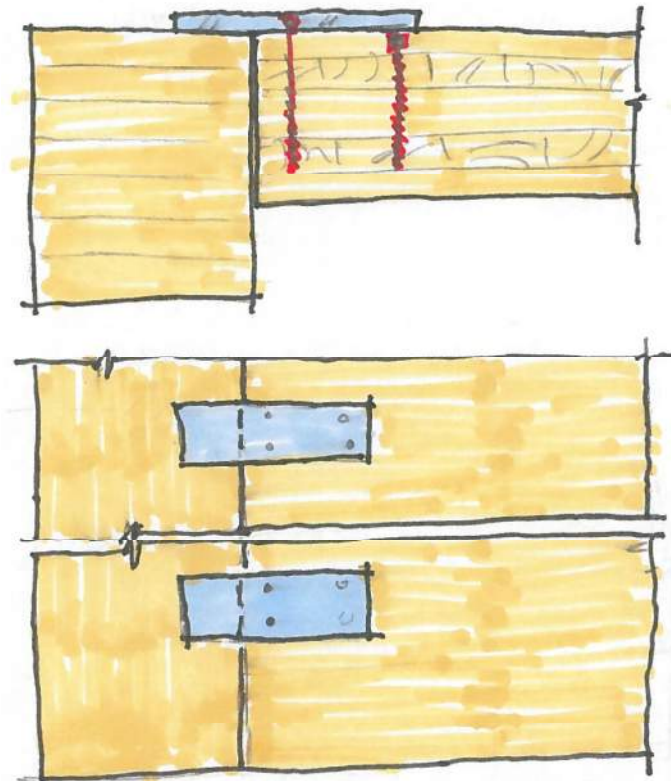
## 4.3.2 Column Base Connection



- Glued in rods (5/8") in end of column
- Rods take shear only (typ.) and set as locator pulling assembly
- HSS tube with steel plate top and bottom
- Simple connection to steel plate – 4 sets
- Set and level steel piece first, prior to landing column
- Steel could be pre-attached to column, especially for column to column connection
- Steel to be intumescent painted or filled with concrete for fire protection

## 4.3 Custom

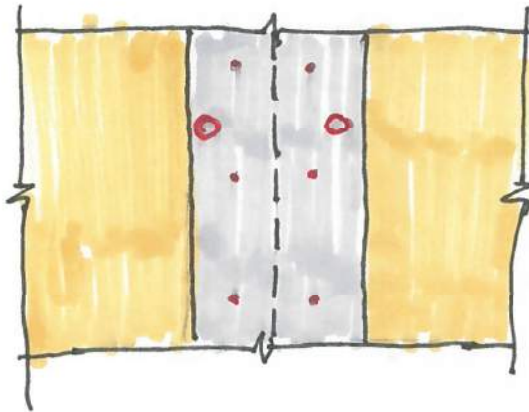
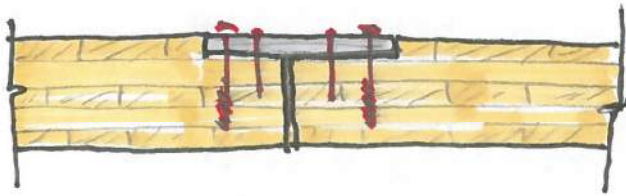
### 4.3.3 Top Bearing Plate



- Simple assembly using steel plate and fully threaded screws
- Steel plate in bending
- Fully threaded screws in tension and compression (if needed to prevent crushing), respectively
- Ensure screw in tension is long enough to avoid tension perpendicular (screw is grabbing), shear in panel vertical
- Steel plate to be attached in shop
- Steel plate could be notched into below to be top flush
- Additional screws needed to secure assembly
- Allows for tolerances
- Connection is protected from fire

## 4.3 Custom

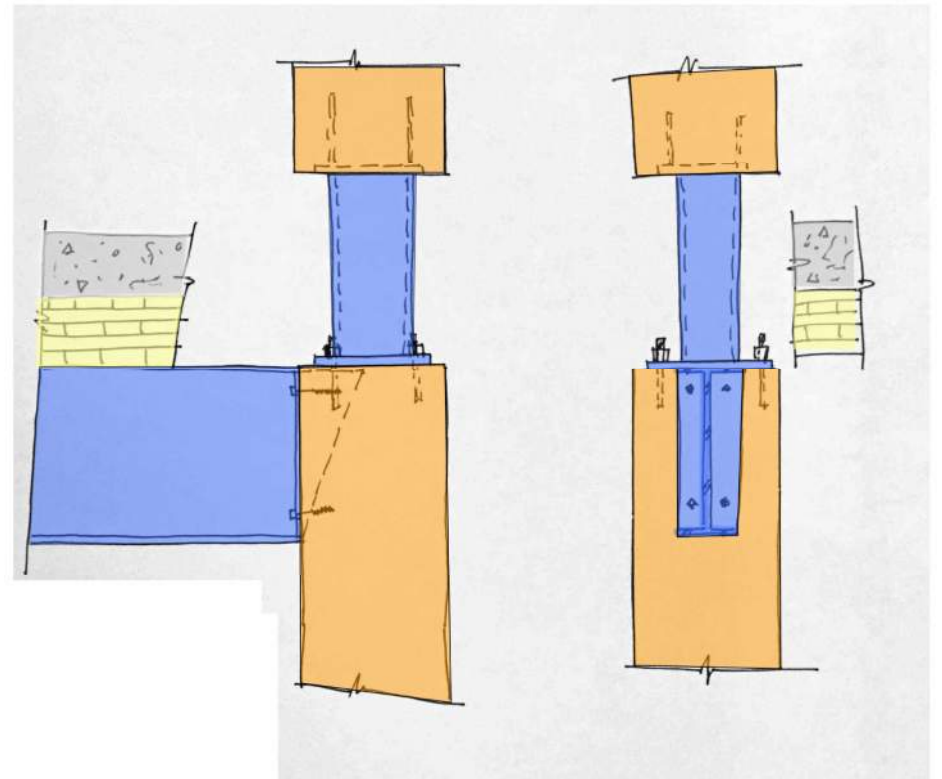
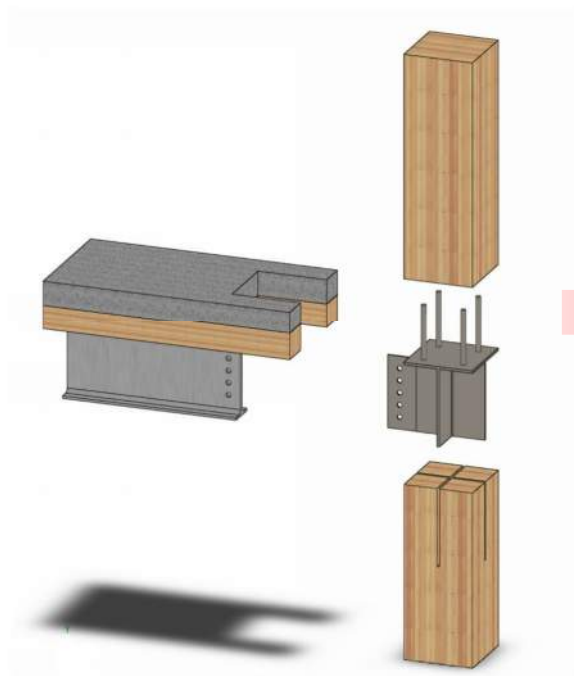
### 4.3.4 CLT to CLT Surface Spline



- Washer head screws to pull panel flush
- Nails to transfer in-plane shear loads
- Out of plane shear loads to be taken by washer head screw and plywood bending or provide pairs of fully threaded screws (high heads)
- $\frac{3}{4}$ " plywood, 5  $\frac{1}{2}$ " side. 4' plywood sheet will yield 8 strips with minimal waste

## 4.3 Custom

### 4.3.5 Interface with other materials

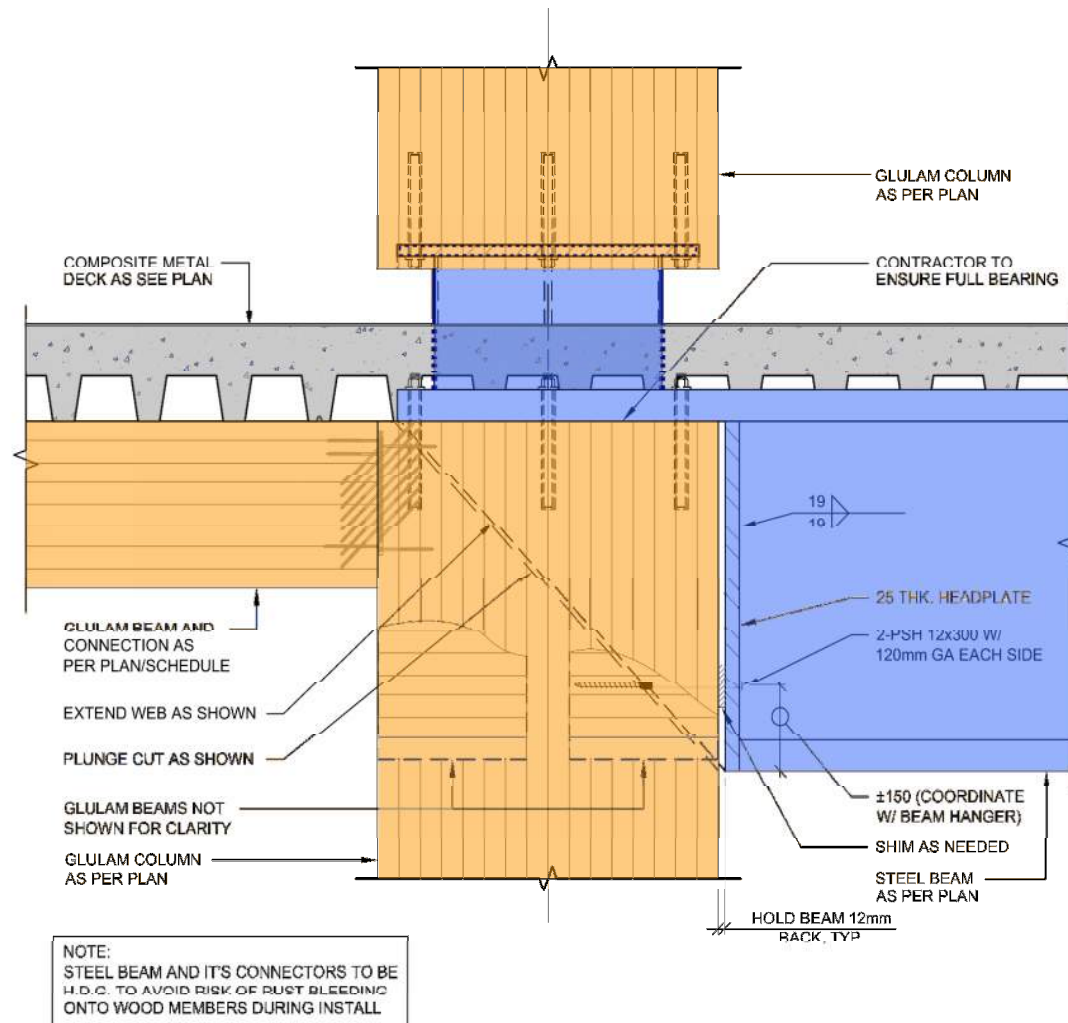


- Tolerances
- Delineation of Scope



## 4.3 Custom

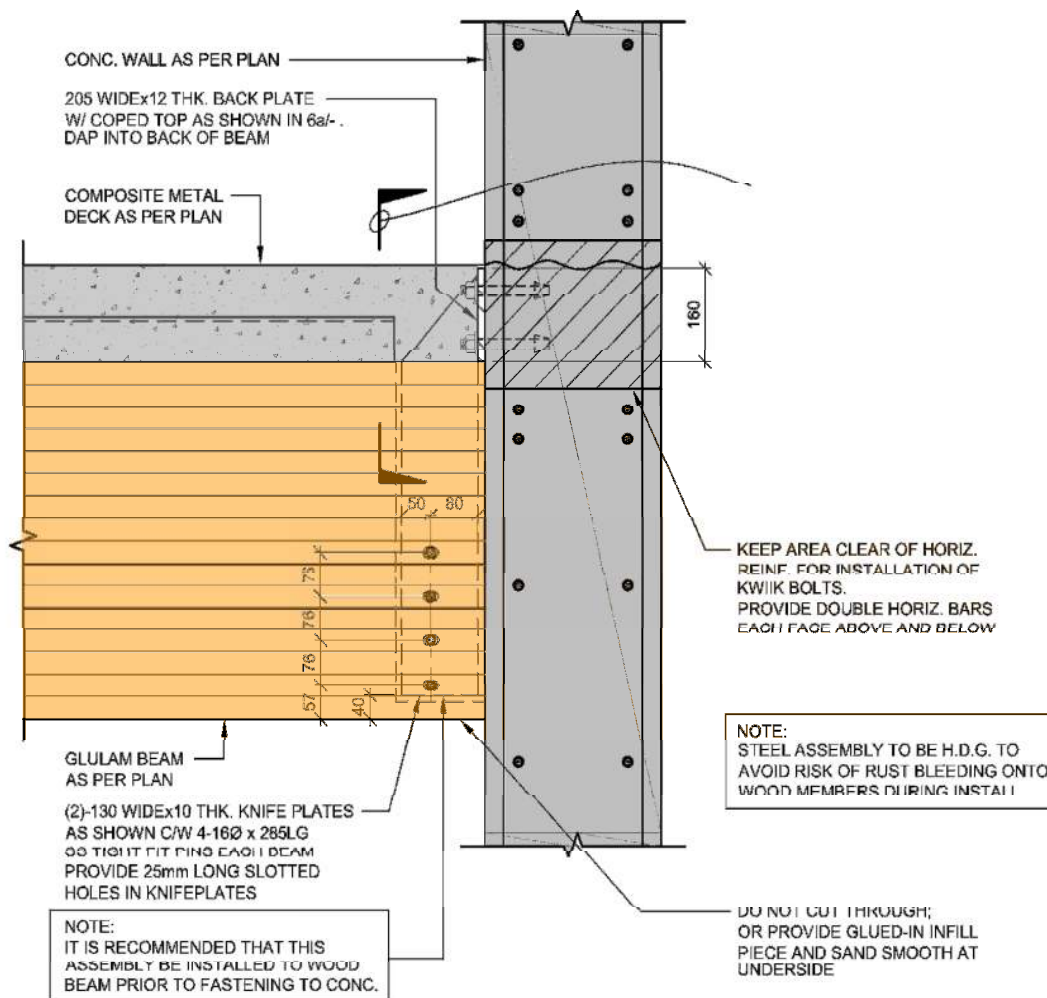
### 4.3.5 Interface with other materials



- Tolerances
- Delineation of Scope

## 4.3 Custom

### 4.3.5 Interface with other materials

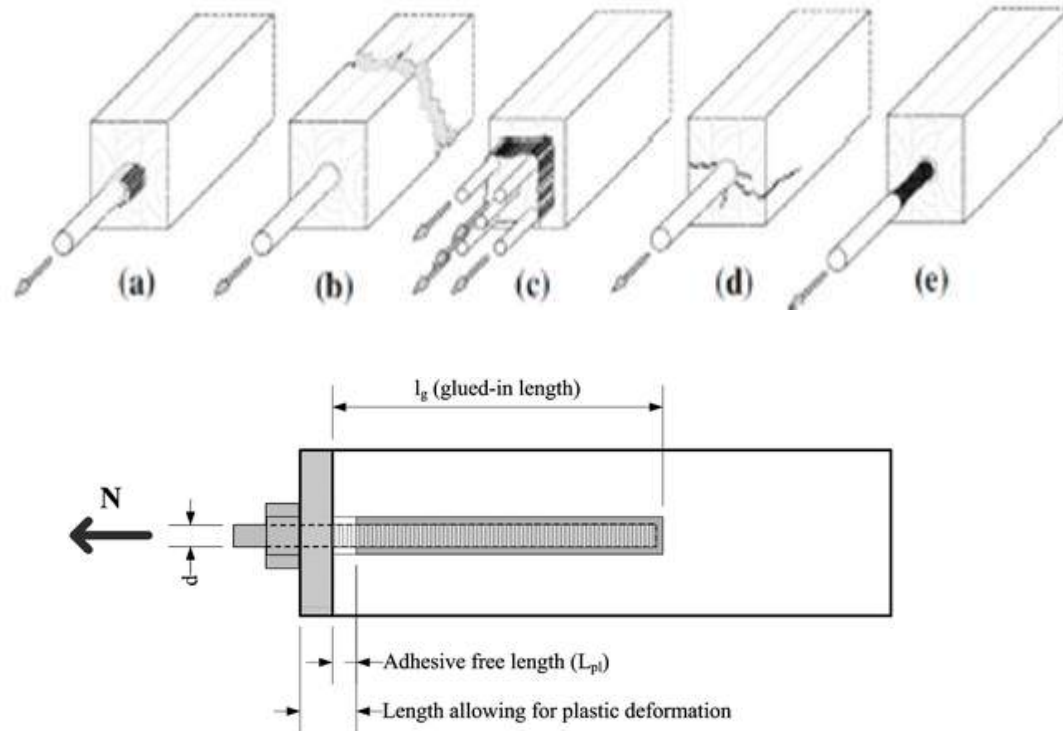


- Tolerances
- Delineation of Scope

# 5. Next Generation

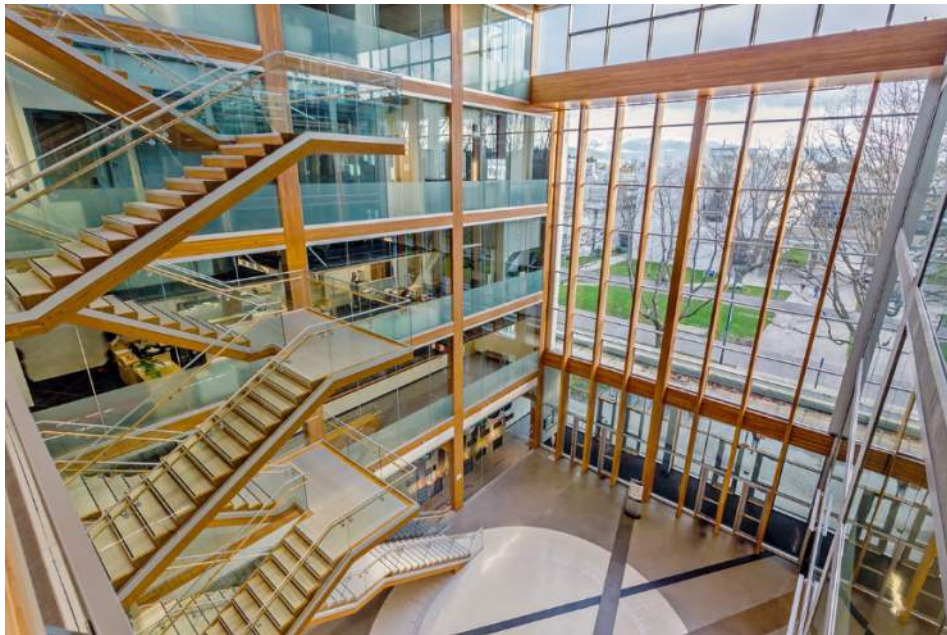
# 5.1 Adhesive Connections

## 5.1.1 Glued in Rods



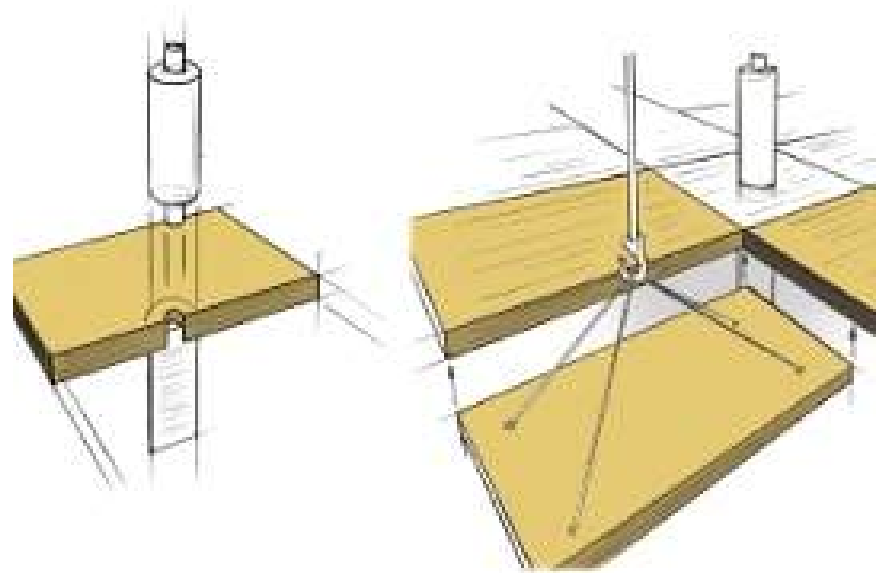
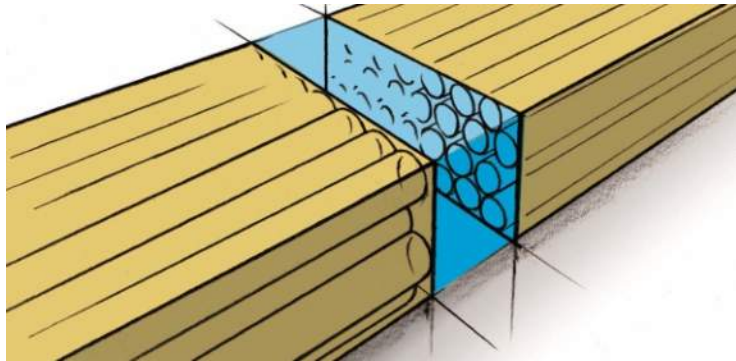
# 5.1 Adhesive Connections

## 5.1.2 HSK



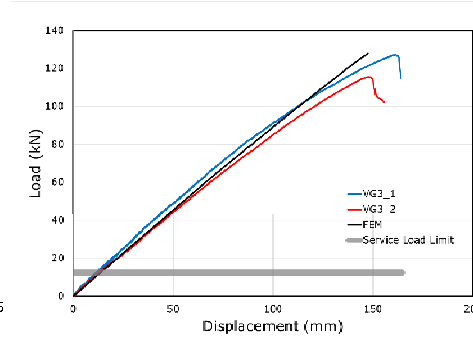
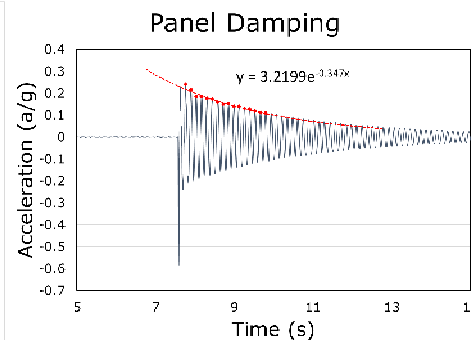
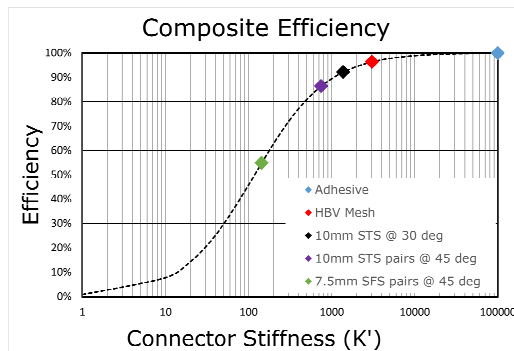
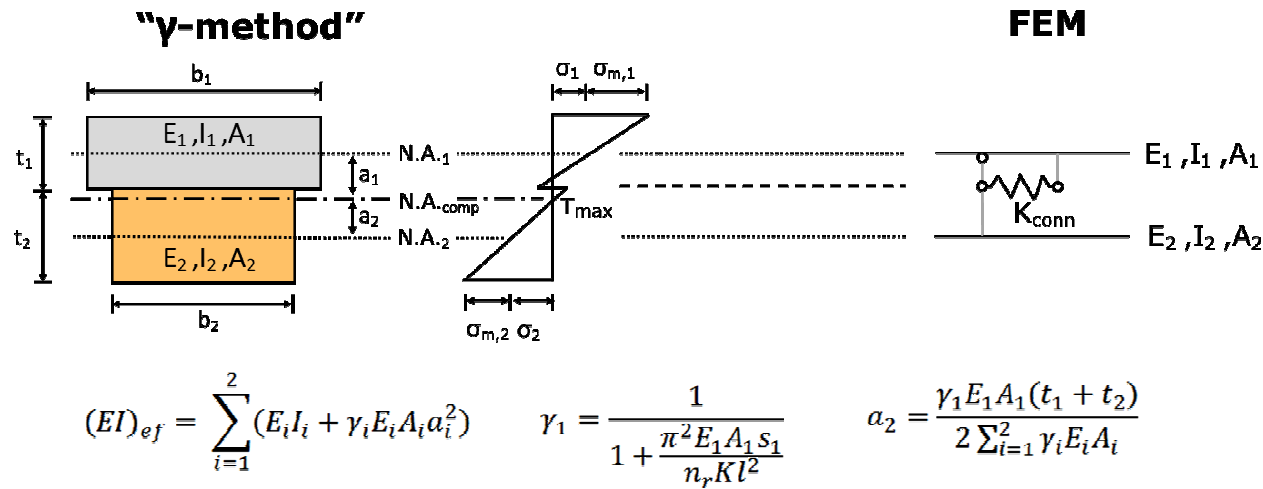
# 5.1 Adhesive Connections

## 5.1.3 TS3.0 – Glued Butt Joints



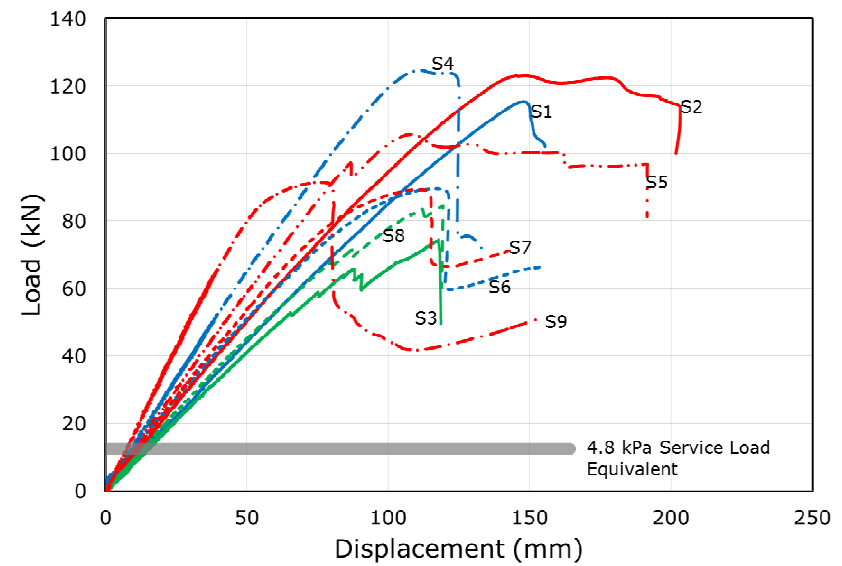


# 5.2 Timber-Concrete Composite Systems



# 5.2 Timber-Concrete Composite Systems

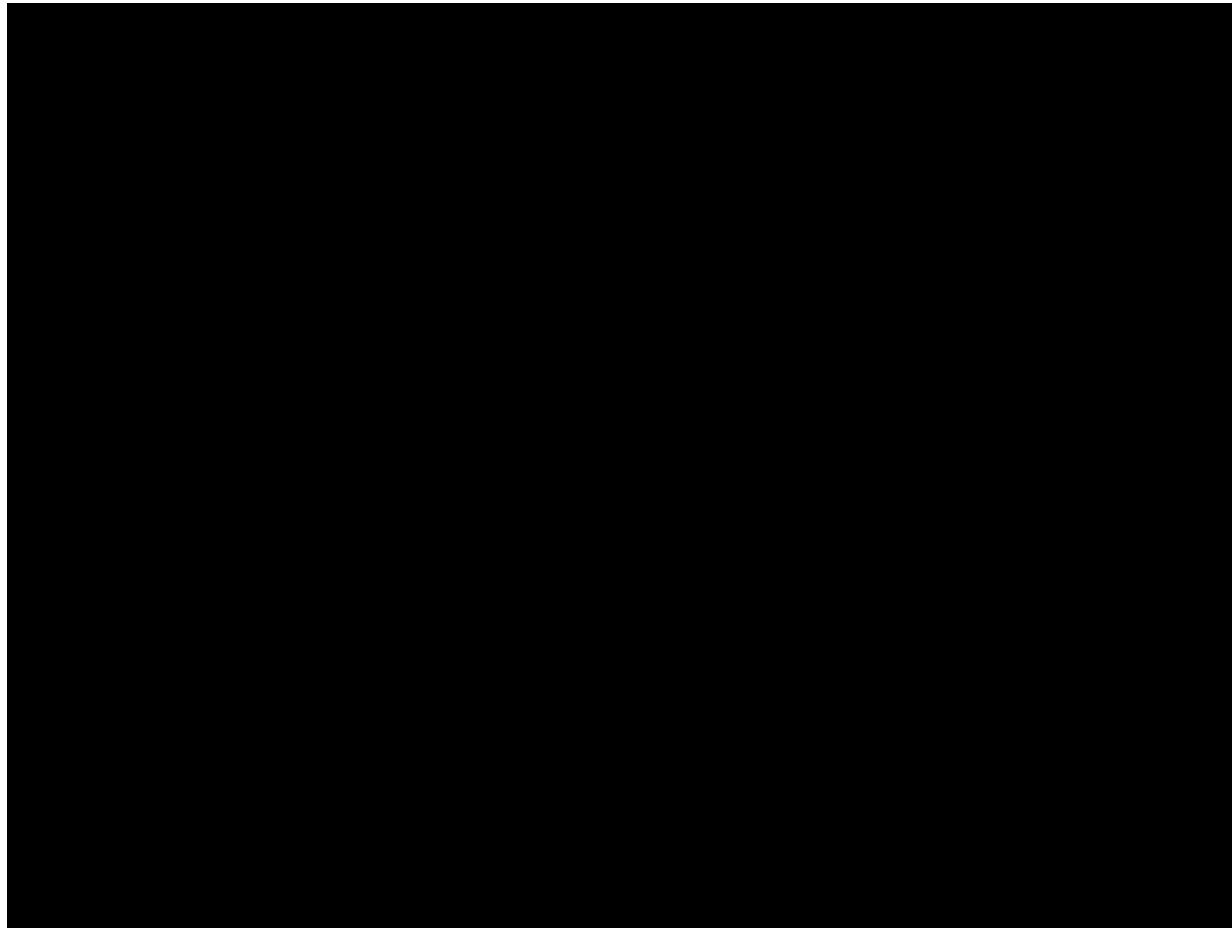
## 5.2.1 TCC Connectors





# 5.2 Timber-Concrete Composite Systems

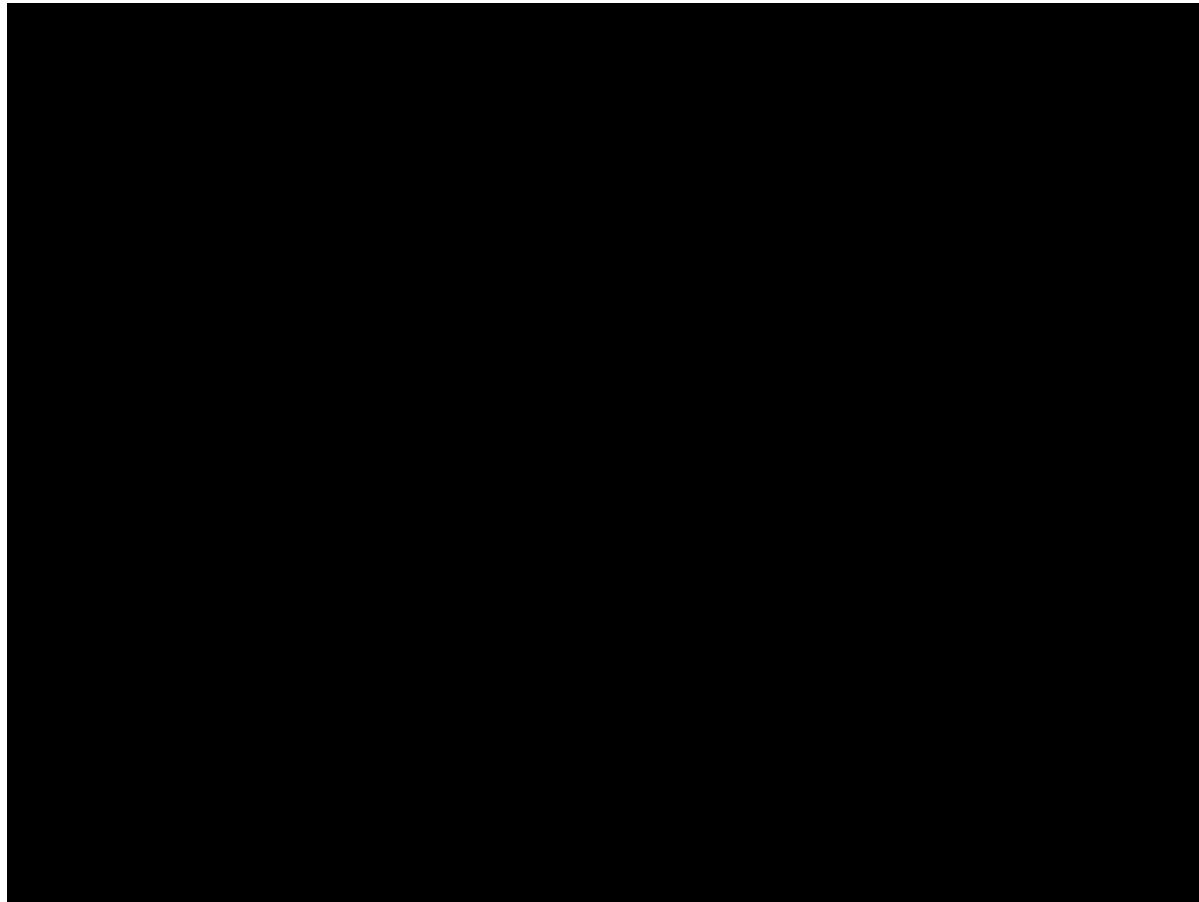
## 5.2.2 Panel Performance



<https://www.youtube.com/watch?v=VLqJDoALrwM>

# 5.2 Timber-Concrete Composite Systems

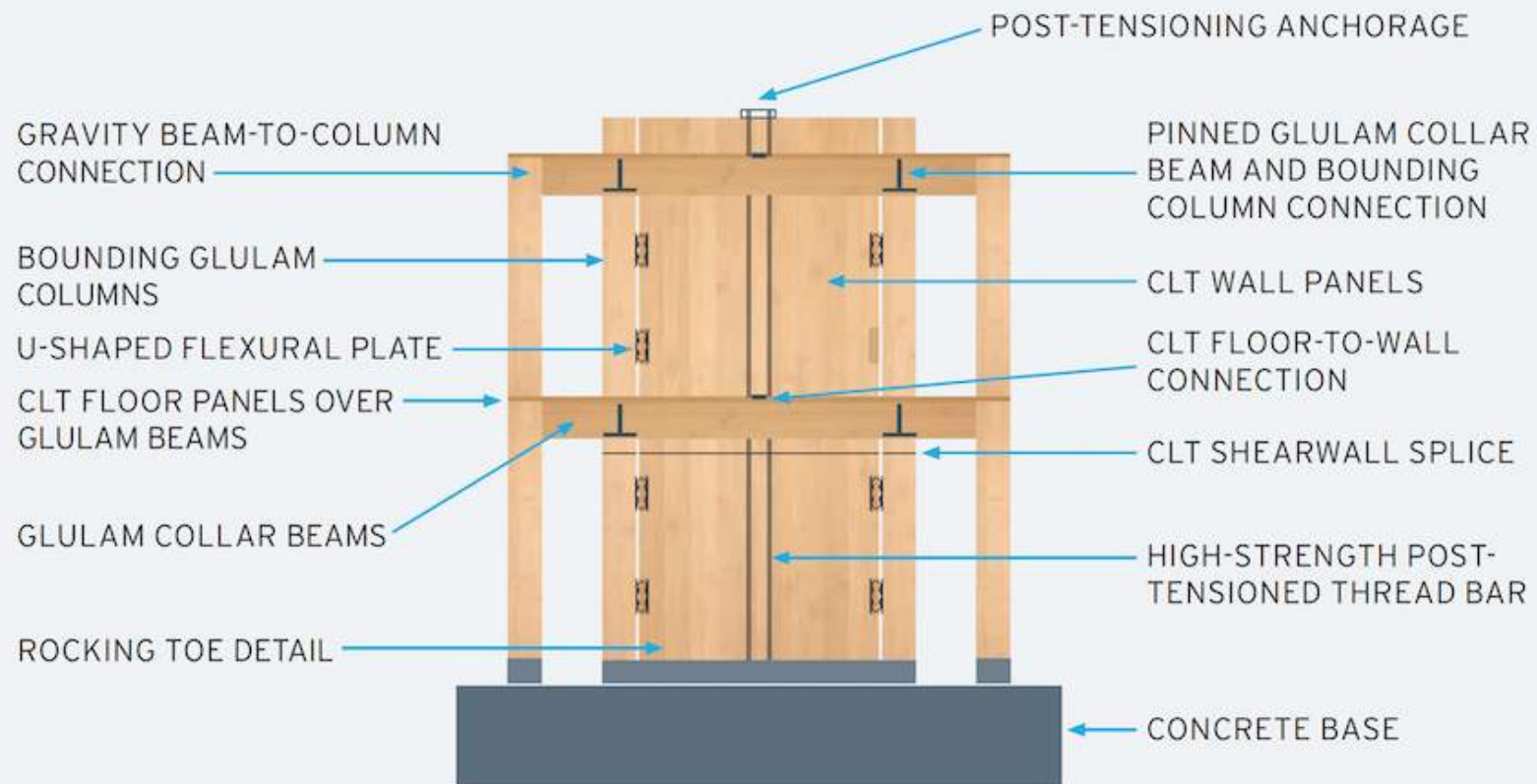
## 5.2.2 Panel Performance



<https://www.youtube.com/watch?v=Fb4J5JIjH4>

## 5.3 Post-Tensioned Systems

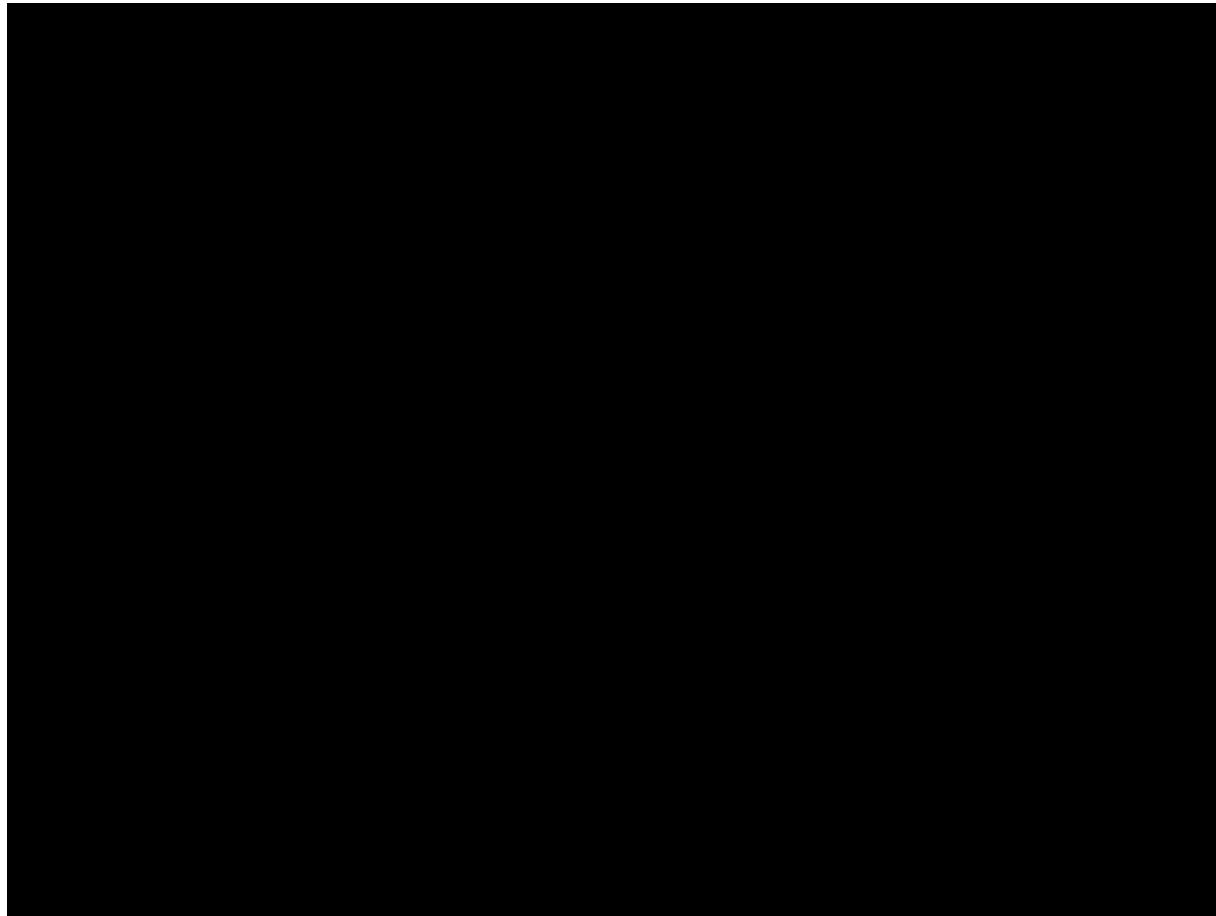
### 5.3.1 Post-tensioned shearwalls



ELEVATION – POST-TENSIONED ROCKING WALL (STATIC STATE)

## 5.3 Post-Tensioned Systems

### 5.3.1 Post-tensioned shearwalls



<https://www.youtube.com/watch?v=c-CrDPyrxPQ>

## 5.3 Post-Tensioned Systems

### 5.3.1 Post-tensioned glulam moment frames



Further Resources

Load-carrying behaviour of steel-to-timber dowel connections; Adrian Mischler, Helmut Prion, Frank Lam

<http://timber.ce.wsu.edu/Resources/papers/2-4-1.pdf>

Grazer Holzbau-Fachtagung 2007: Traglast von auf Zugbeanspruchten Schraubenverbindungen mit Stahlbleche; H. Krenn, G. Schickhofer

[http://www.holzbauforschung.at/uploads/tx\\_sbdownloader/6GraHFT07\\_Tagungsband.pdf](http://www.holzbauforschung.at/uploads/tx_sbdownloader/6GraHFT07_Tagungsband.pdf)

EN 1995 design of timber structures (Eurocode 5)

→ See also supplier specific documents and white papers

# Questions?

This concludes the American  
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Education Course.

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