

Fire Design for Beam Hanger Connections

Thursday May 2 @ 10:00AM PST | 1:00PM EST

Is Your Connection Fire Rated?



About MyTiCon



Your Host

- Neda Naderi, MEng, EIT

MyTiCon

- Specialized Mass Timber Connection Systems Supplier

Webinar Agenda

- Pre-engineered Beam Hanger
 - Overview
 - Advantages
 - Fire Testing
- Fire Design
 - Relevant Codes
 - Fire Design Example



Fire Rated Connections

- Drywall and wood cover
- Regular connections
- Pre-engineered Connections



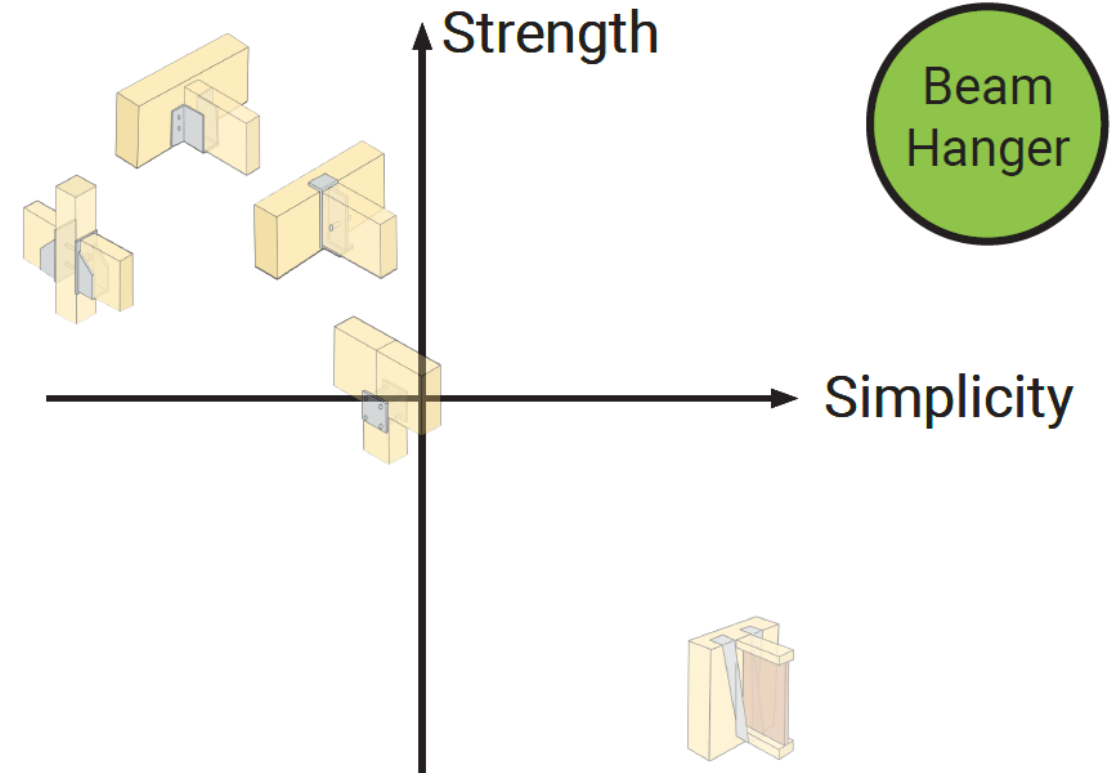
Pre-Engineered Connection



Courtesy of: Oregon Forest Research Institute

Beam Hanger System

- Beam Hanger Webinar Part 1
- Answered:
 - What is the beam hanger?
 - Why use the beam hanger?
 - How to use the beam hanger?



Pre-engineered

- Tabulated Design values
- Clear and detailed instructions
- Installer-friendly tolerance



Pre-Installed

- Simple installation
- Controlled work environment
- Superior quality control



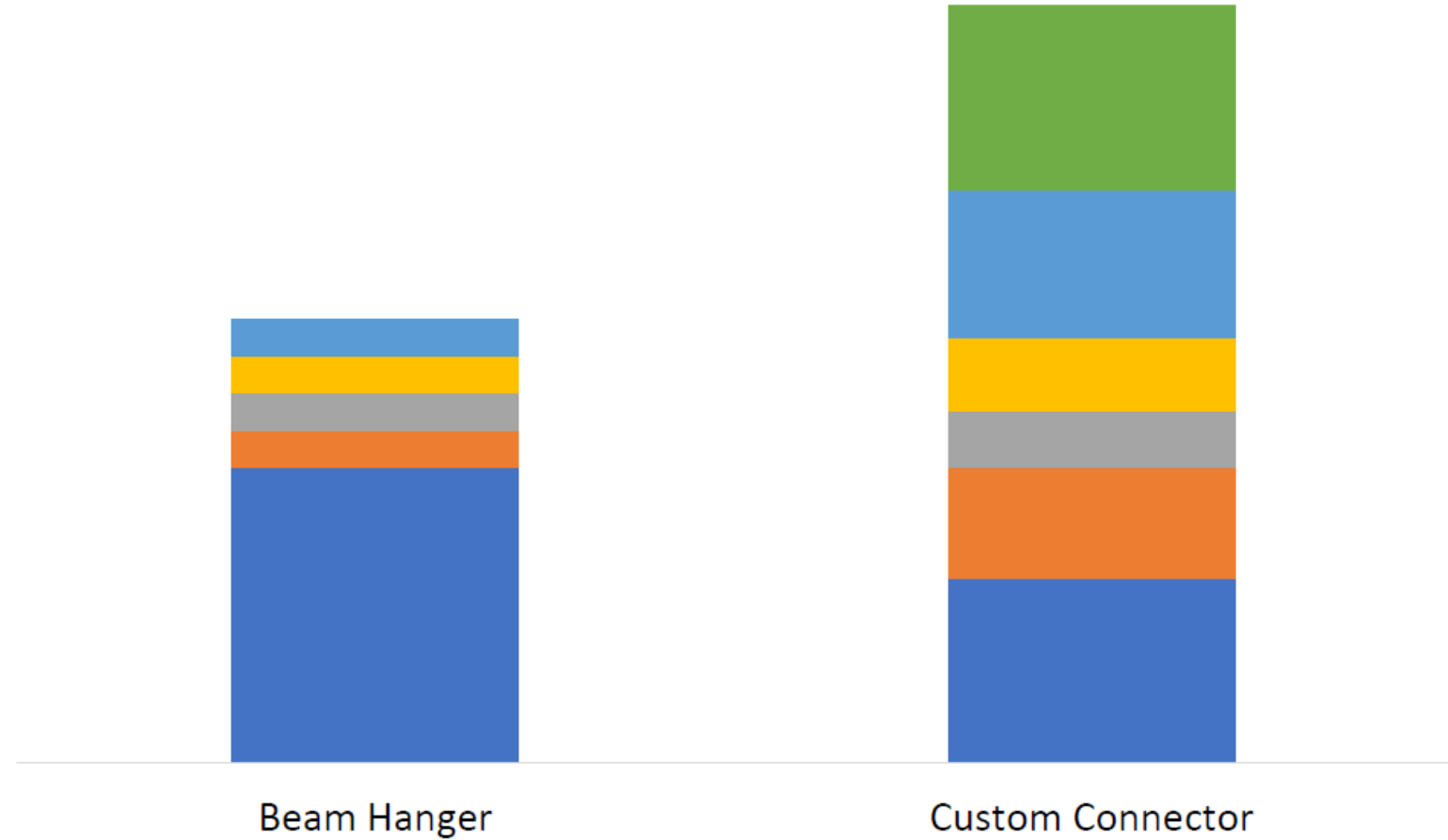
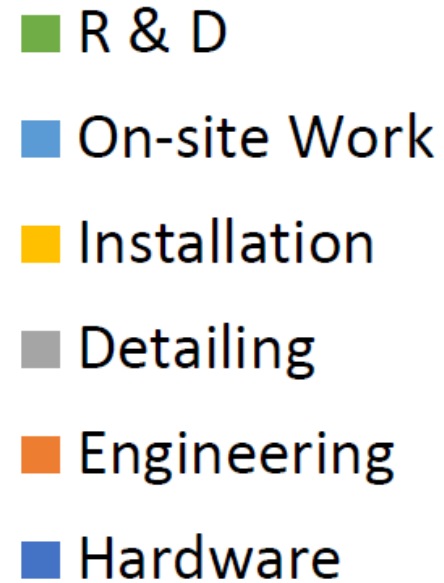
Drop-in Assembly

- Reduced crane time
- Reduced personnel
- No power tools required

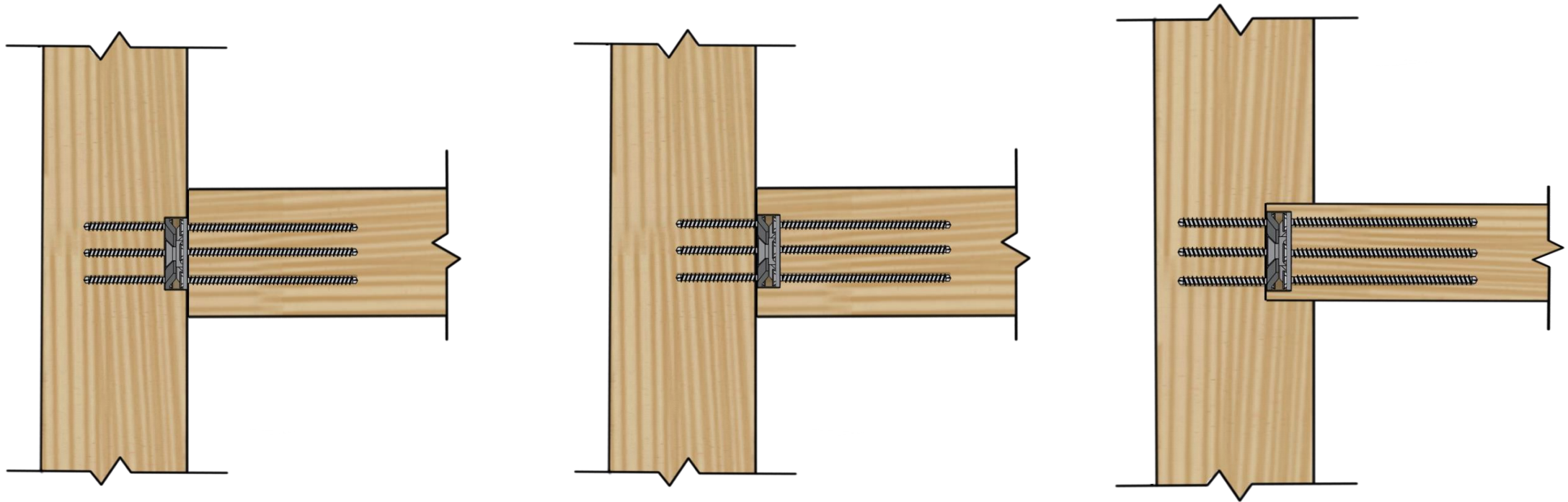


Courtesy of: Oregon Forest Research Institute

Cost Effective



Concealed

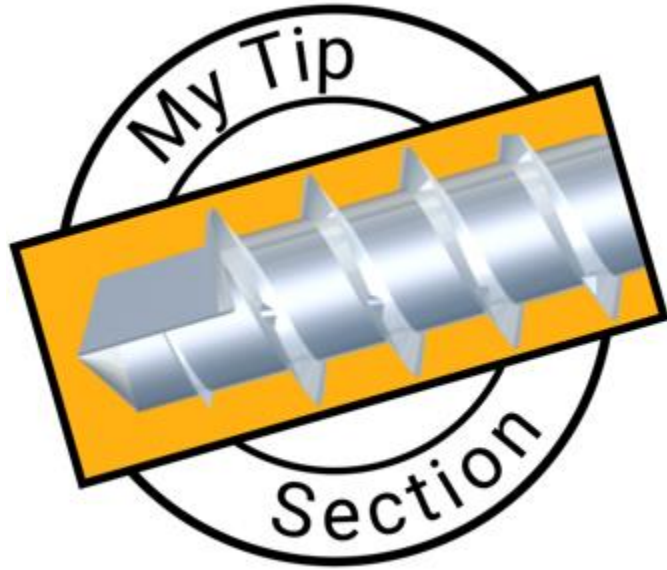


**Concealed Options:
Top View of a Purlin to Girder Connection**

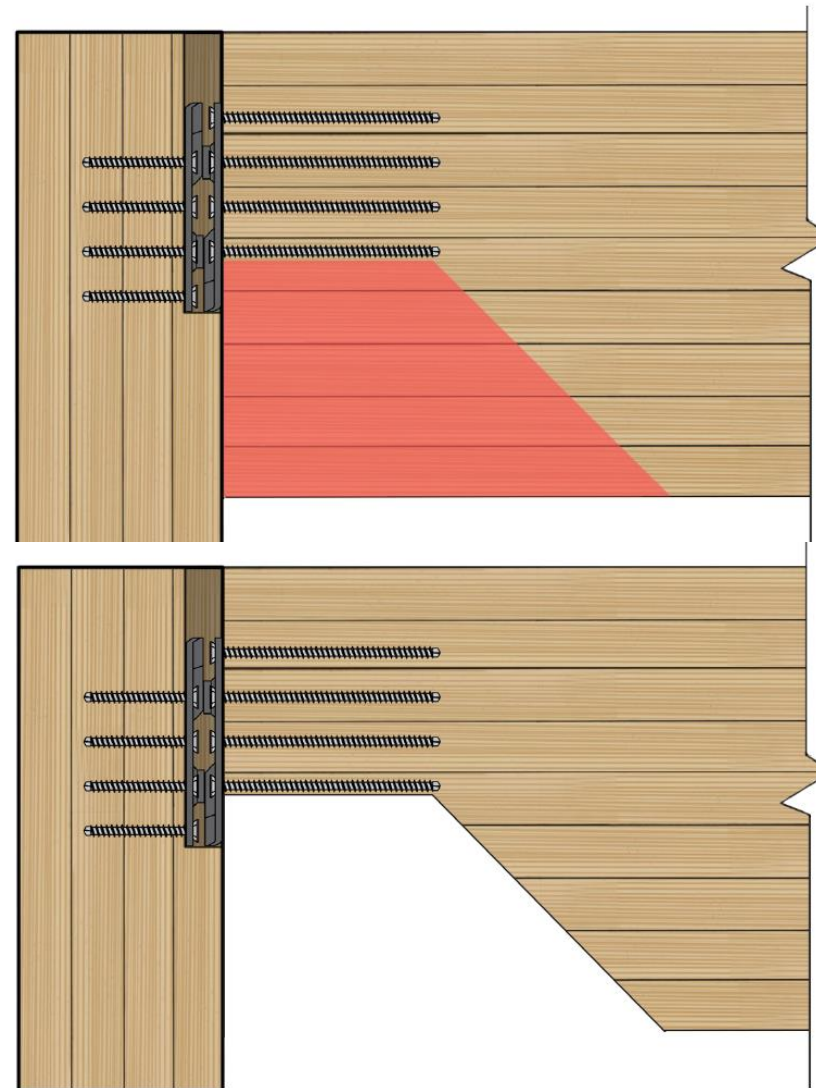
Concealed



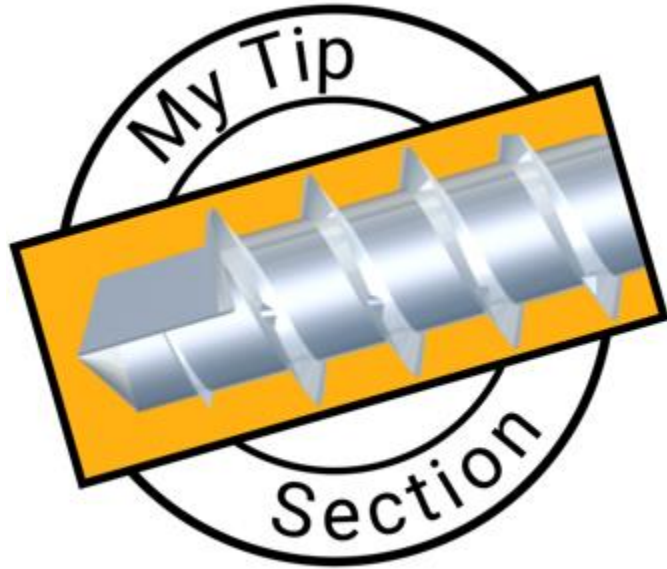
**Concealed Options:
Side View of a Purlin to Girder Connection**



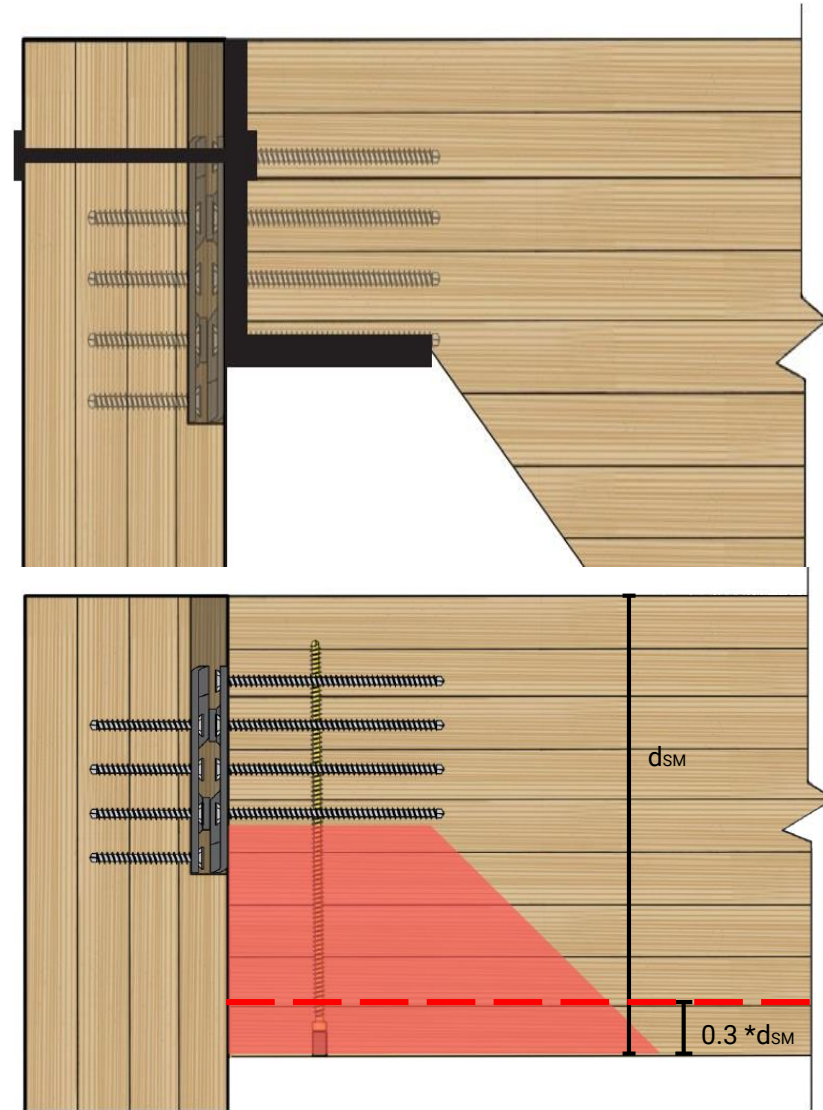
- System positioning is important



Side View

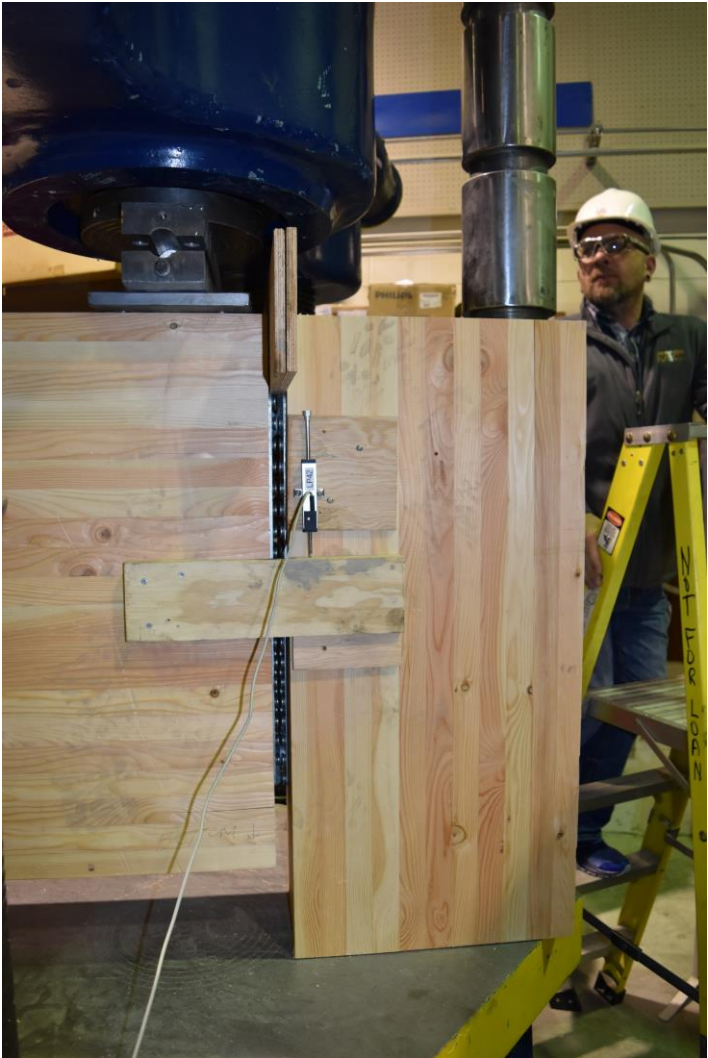


- Placed in the lowest most section of the secondary member ($0.3 * d_{SM}$)



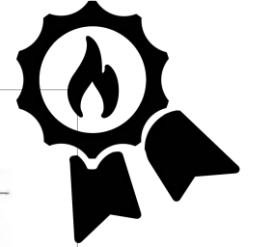
Side View

Tested Solution



Fire Testing

- Full Scale Fire Testing in San Antonio
- In Partnership with:
 - Softwood Lumber Board
 - Arup
 - D.R. Johnson
- Certified 1.5h fire rating



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CHEMISTRY AND CHEMICAL ENGINEERING DIVISION FIRE TECHNOLOGY DEPARTMENT
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FIRE PERFORMANCE EVALUATION OF A LOAD BEARING GLULAM BEAM TO COLUMN CONNECTION, INCLUDING A CLT PANEL, TESTED IN GENERAL ACCORDANCE WITH ASTM E119-16a, STANDARD TEST METHODS FOR FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS

FINAL REPORT
Consisting of 32 Pages

SwRI[®] Project No. 01.22532.01.001
Test Date: March 6, 2017
Report Date: May 26, 2017

Prepared for:
Softwood Lumber Board
1101 K Street N.W., Suite 700
Washington, DC 20005

Submitted by: 
SC^v Bill B. Bendele
Principal Engineering Technologist
Fire Resistance Section

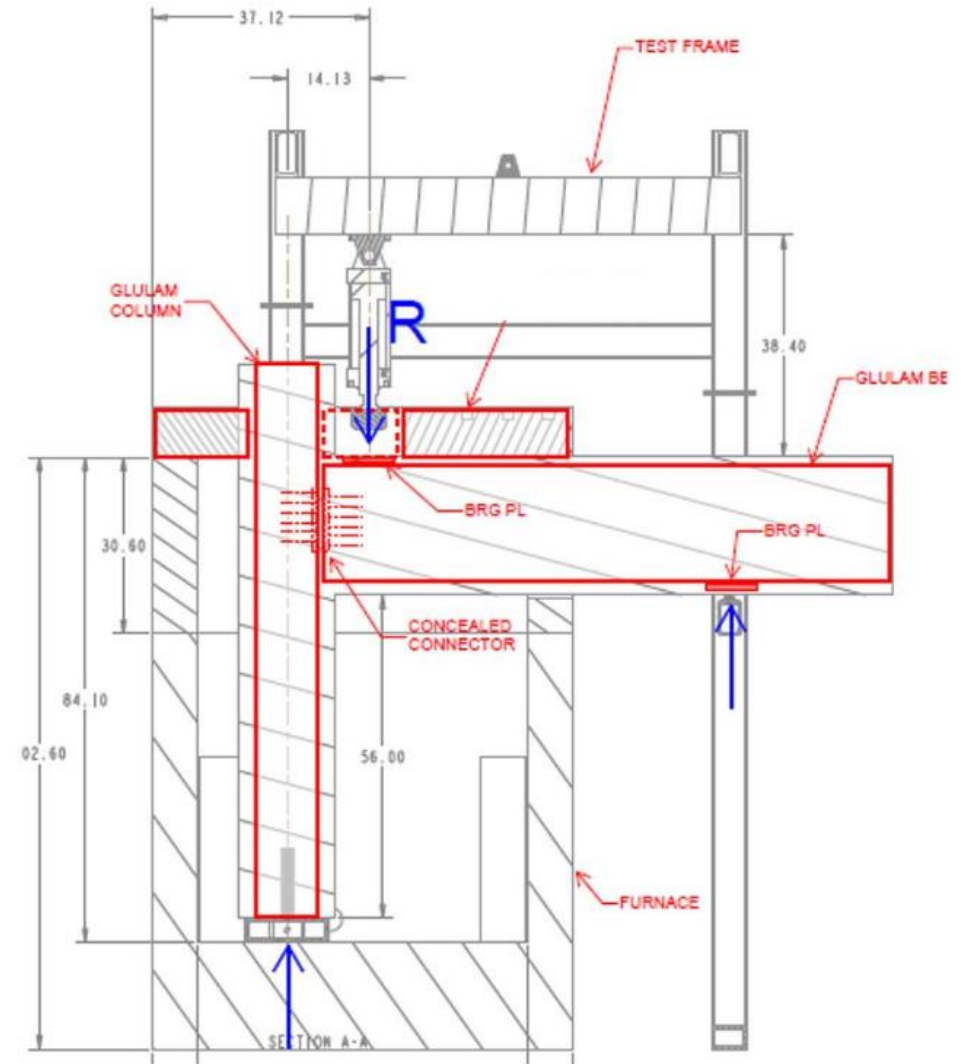
Approved by: 
Karen C. Carpenter, M.S., P.E.
Manager
Fire Resistance Section

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Fire Testing

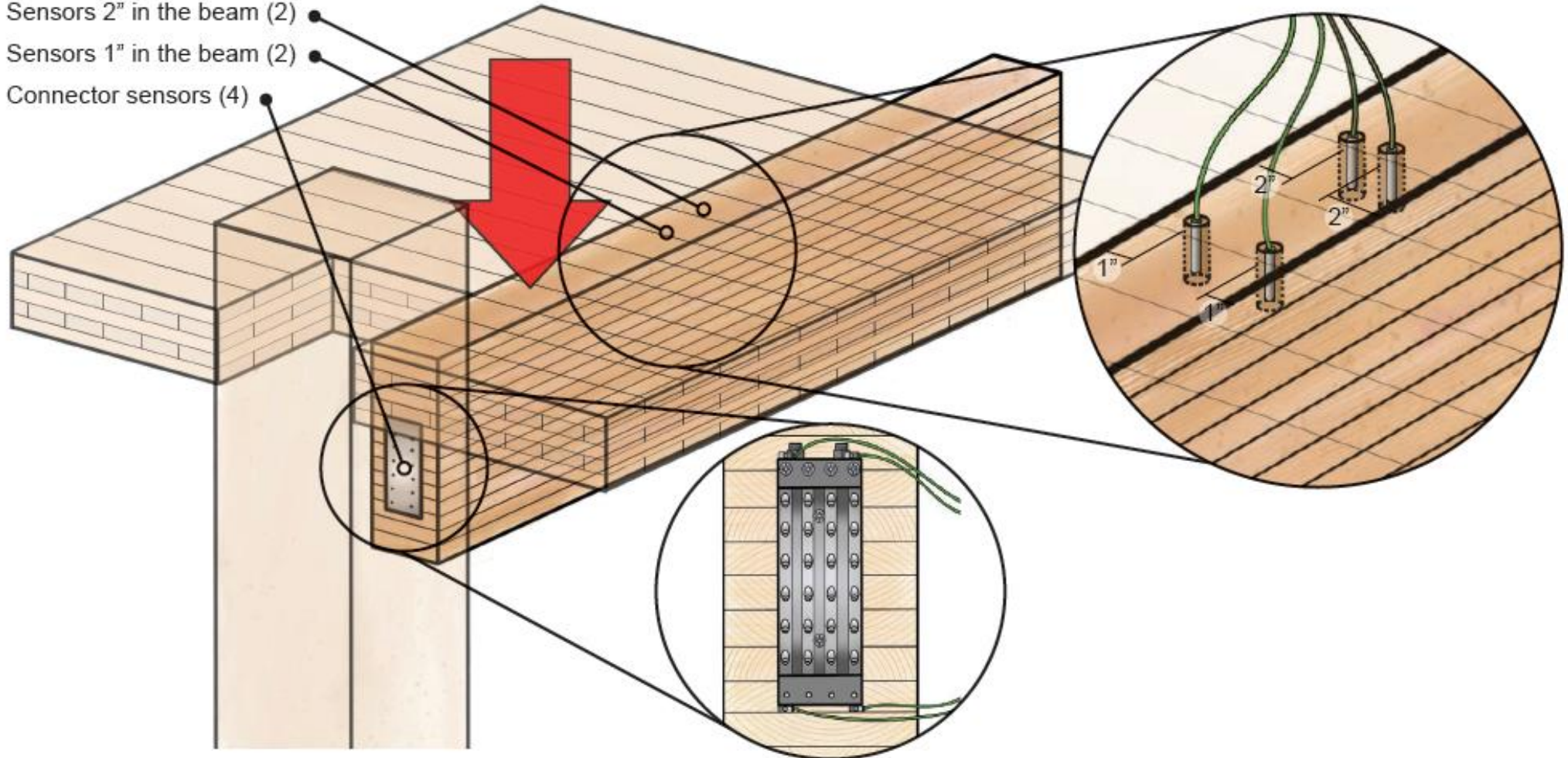
- Comply with ASTM E119
- Constant Load During Testing
- Test Durations:
 - 60 minutes
 - 90 minutes



Courtesy of: Softwood Lumber Board

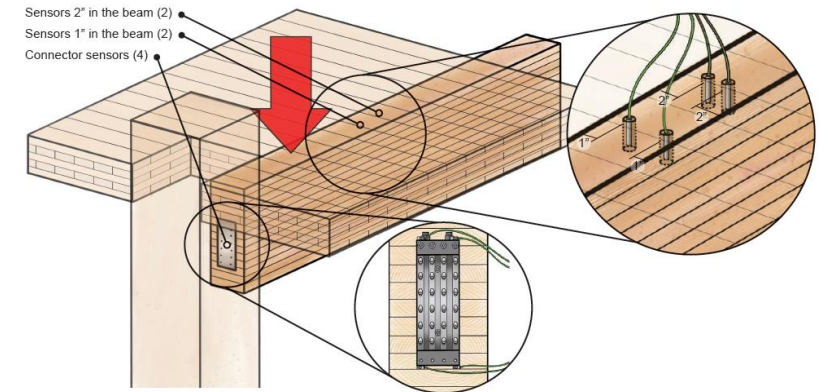
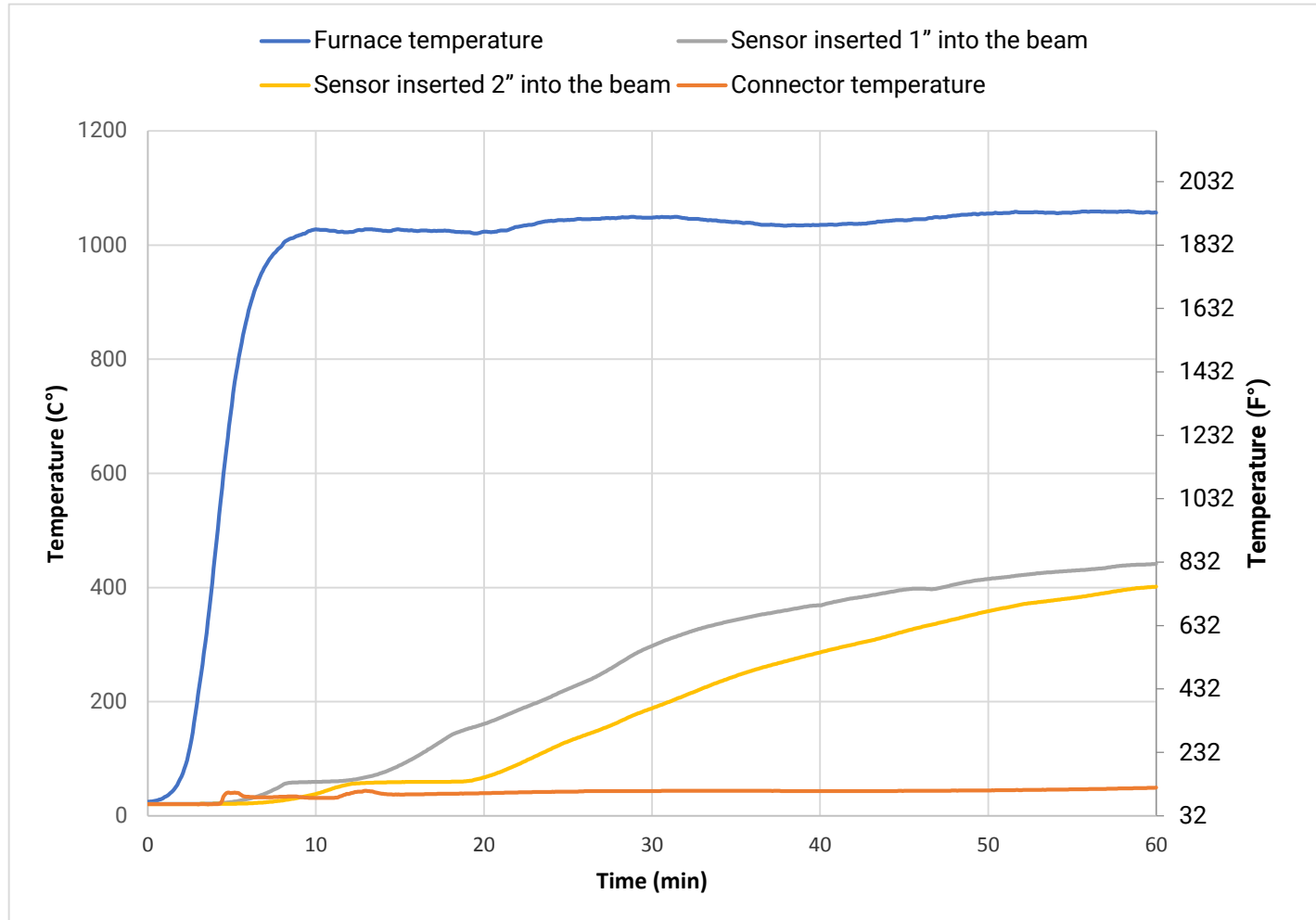
Test Setup

- Sensors 2" in the beam (2)
- Sensors 1" in the beam (2)
- Connector sensors (4)





Fire Testing Results



Fire Testing Results

- Test duration: 90 minutes
- Screws embedded in char
- Codes provide conservative approaches for fire design



Fire Testing Results

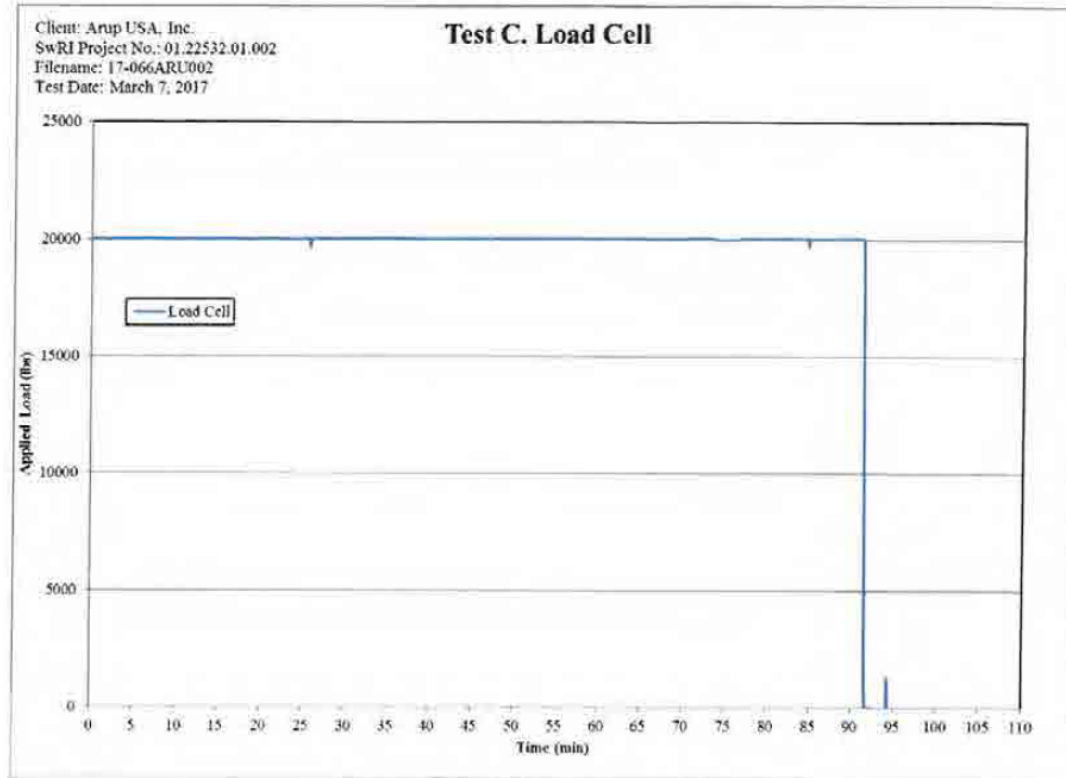


Figure D-7. Test C: Load Data.

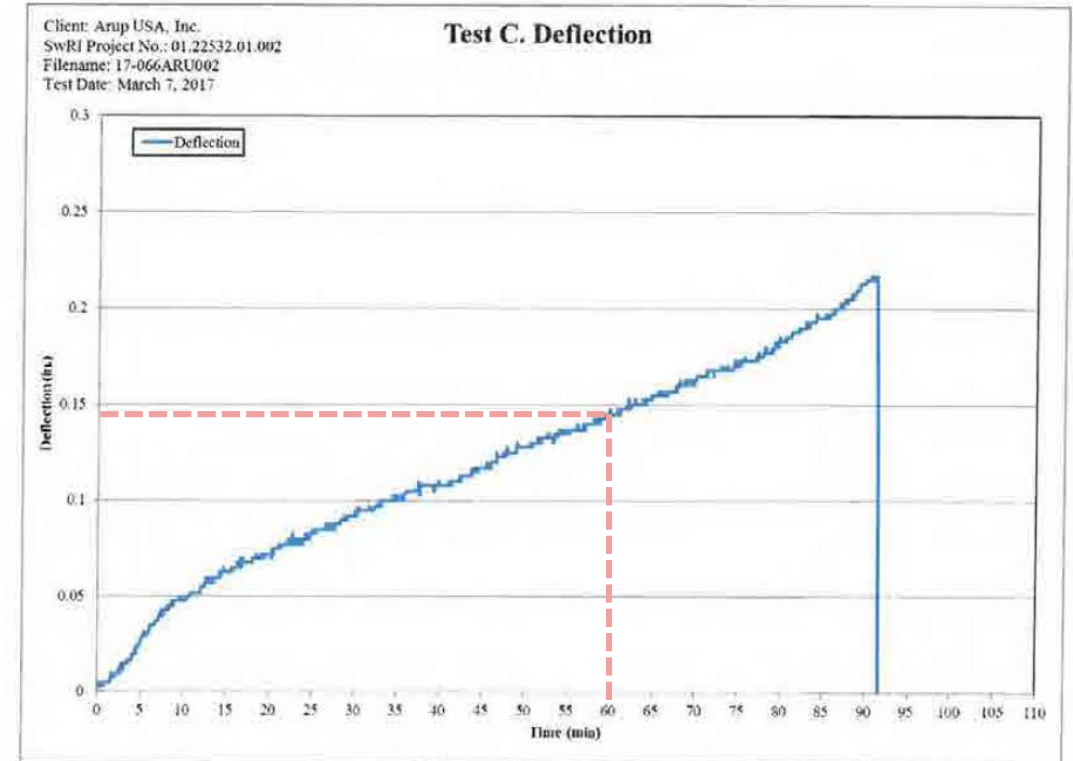


Figure D-8. Test C: Deflection Curve.

Courtesy of: Softwood Lumber Board

Fire Testing Results

- Fire caulking used
- 1.5" from the beam edge
- No apparent effect on char layer



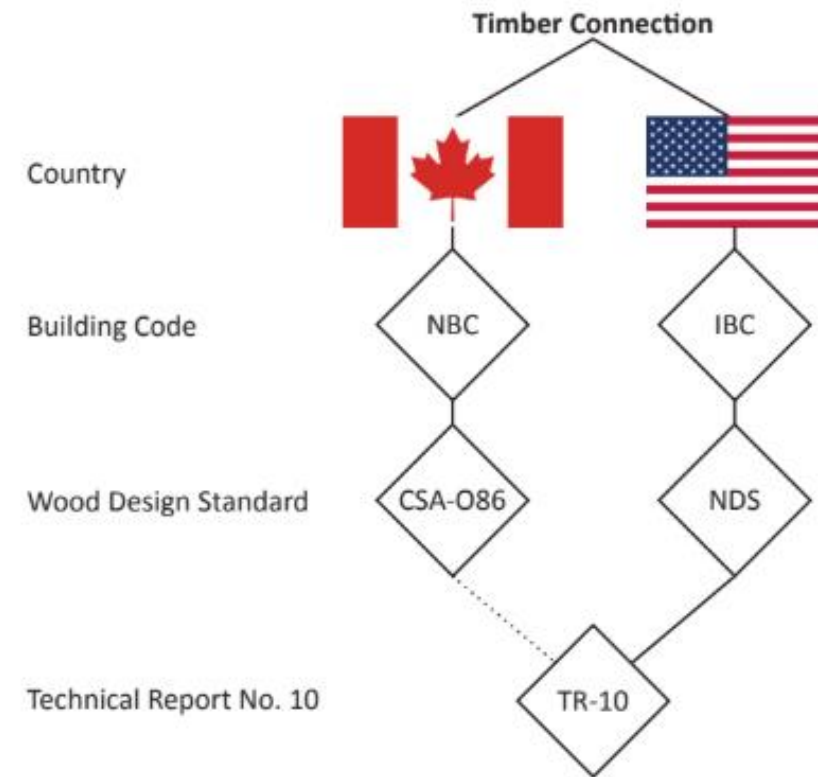
Beam Hanger System

- Pre-Engineered
- Pre-installed
- Cost-effective
- Concealed
- Fire Tested
 - Certified 1.5hour rating



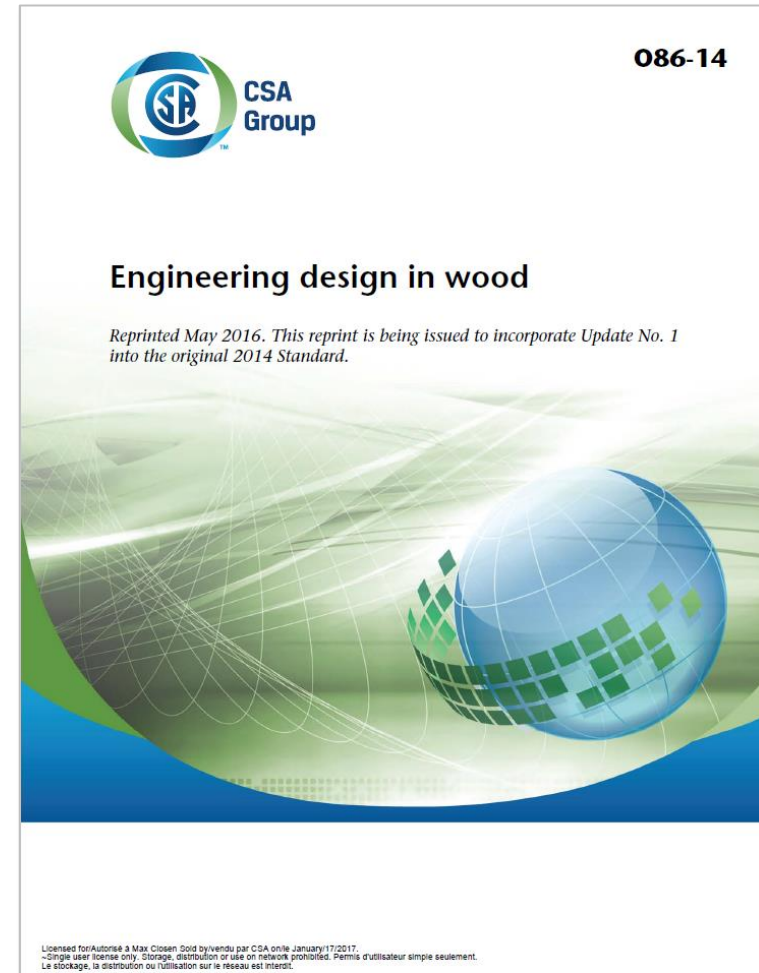
How is Fire Design Done?

- Building codes used for reference
 - CAN: CSA 086 Annex B
 - USA: NDS
- AWC Technical Report 10



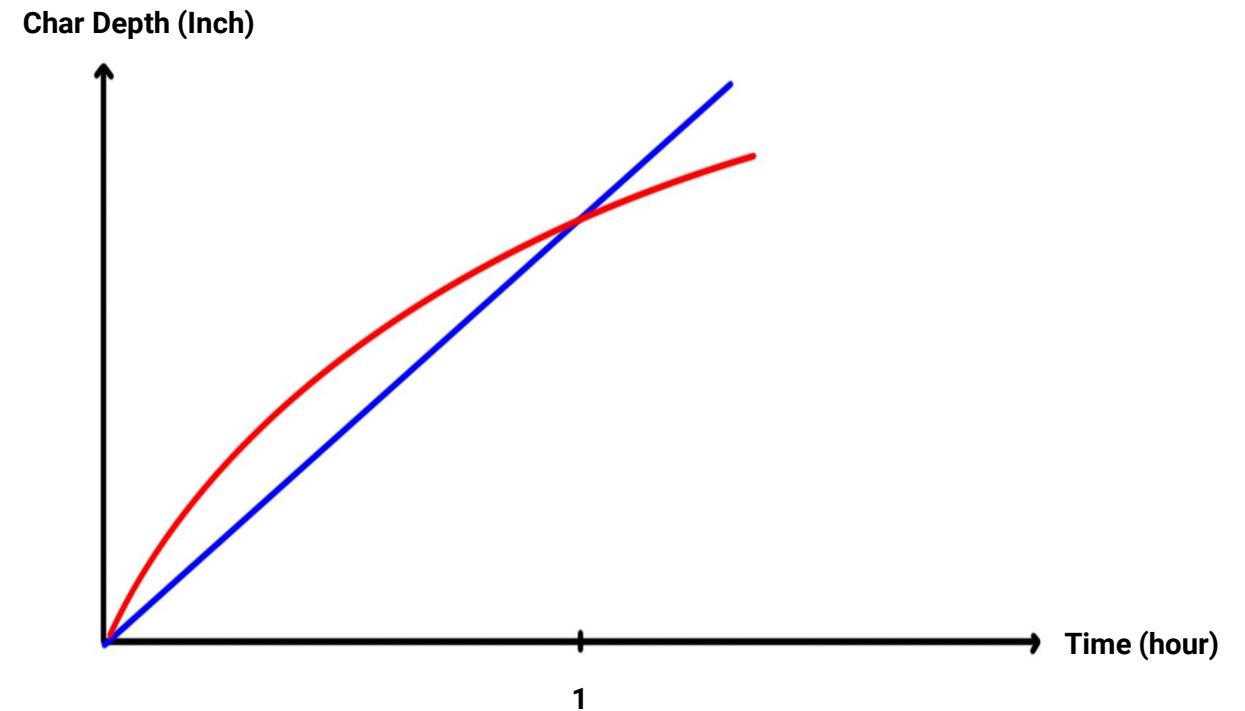
CSA-086

- Annex B:
 - Fire resistance of large cross-section wood elements
- One-dimensional char depth
- Linear char model



Linear Char vs. Nonlinear Char Model

- Linear Char Model
 - Short periods (<60minutes)
 - Long periods (>60minutes)



International Building Code

- IBC 2015 types of construction:

- | | |
|----------------------------------|----------------|
| 1. Non-combustible Construction | Type I and II |
| 2. Light Frame Wood Construction | Type III and V |
| 3. Heavy Timber Construction | IV HT |

Noncombustible Construction

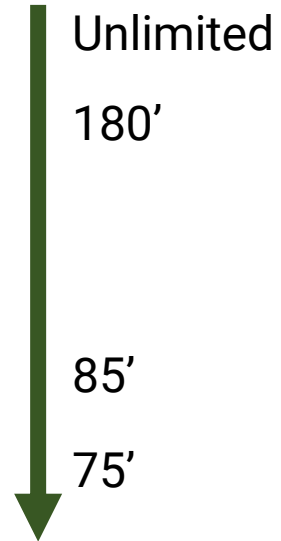
- Type I

- I-A
- I-B

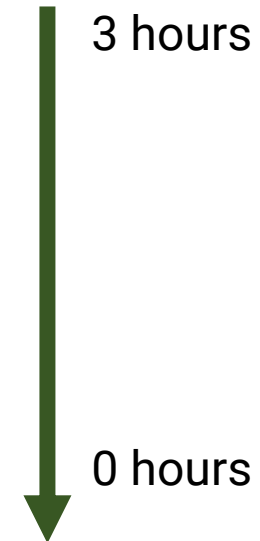
- Type II

- II-A
- II-B

Maximum Height



Primary Structural Frame



Light Frame Wood Construction

- Type III

- III-A
- III-B

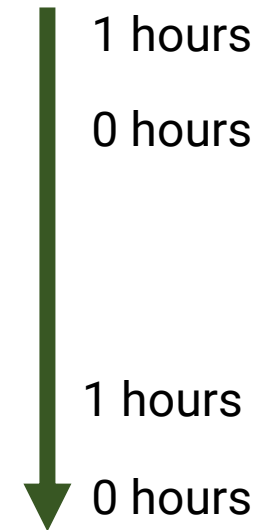
- Type V

- V-A
- V-B

Maximum Height



Primary Structural Frame



Light Frame Wood Construction

- Type III
 - III-A
 - III-B
- Exterior walls
 - Non-combustible material
- Interior elements
 - Any material (per code)

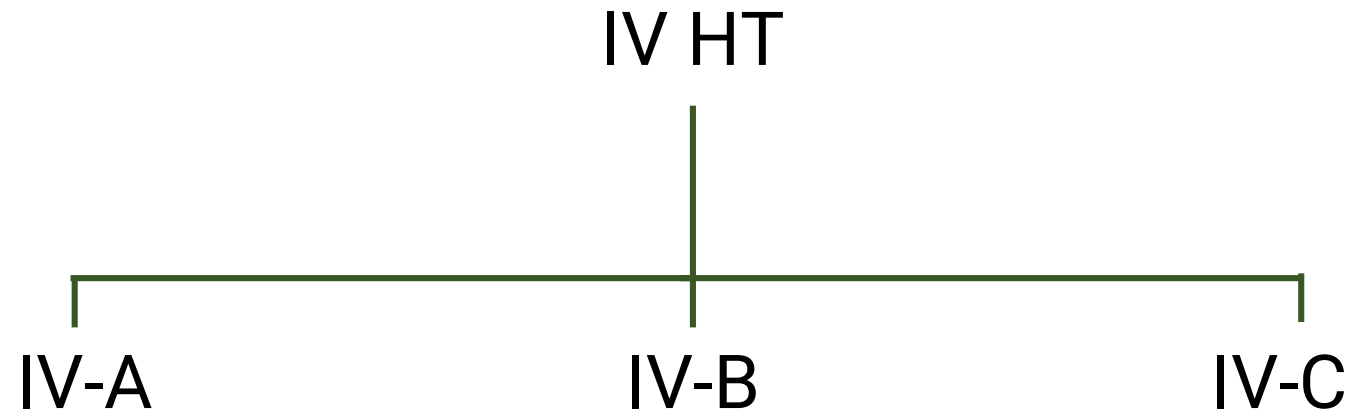


Light Frame Wood Construction

- Type III
 - III-A
 - III-B
- Type V
 - V-A
 - V-B
- Exterior walls
 - Non-combustible material
- Interior elements
 - Any material (per code)
- Structural Elements, Exterior and Interior Walls
 - Any Material (per code)



IBC 2021



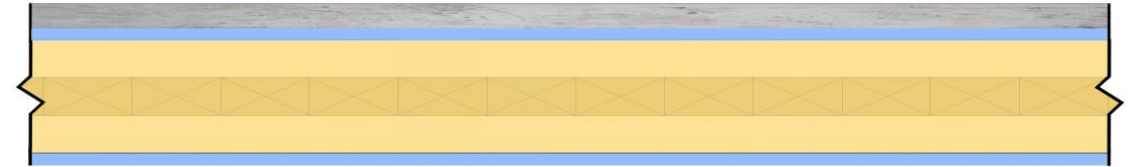
- Height and Area Requirements
- Element Fire Protection

IBC 2021

	IV-A	IV-B	IV-C
Allowable Building Height	270'	180'	85'
Allowable Number of Stories	18	12	9
Allowable Area (ft²)	324,000	216,000	135,000
Primary Structural Frame Fire Rating (hours)	3	2	2

Noncombustible Protection

- Unique requirement for Type IV
- Increase fire-resistance rating
- IBC 2021:
 - ½" Type X gypsum board (25min)
 - 5/8" Type X gypsum board (40min)



General FRR Requirements

- Type IV-A
 - No exposed mass timber
 - Non-combustible protection on all elements
- Type IV-B
 - Some exposed mass timber
 - Area of ceilings < 20% of floor area
 - Area of walls < 40% of floor area
- Type IV-C
 - Exposed mass timber
 - Structural elements 2-hour FRR

Other Requirements

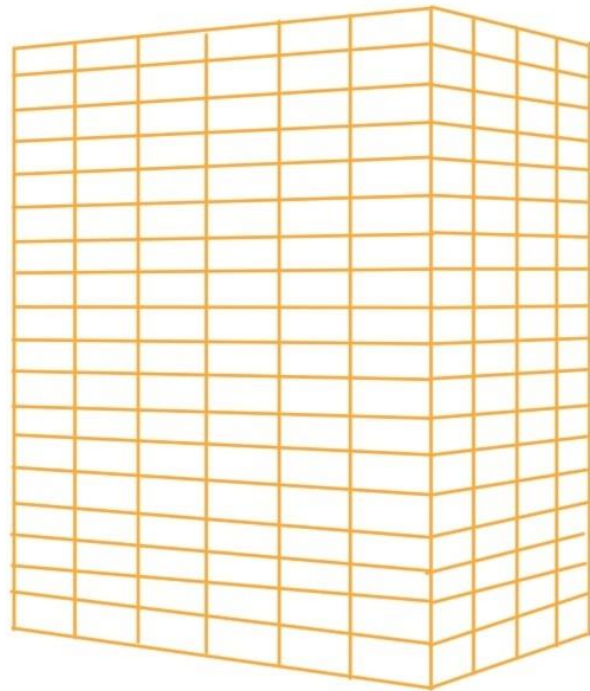
- Use of sealant at timber edges
- No exposed mass timber in:
 - Concealed spaces
 - Exit enclosures and elevator hoistways
- Use of sprinklers

Fire Design

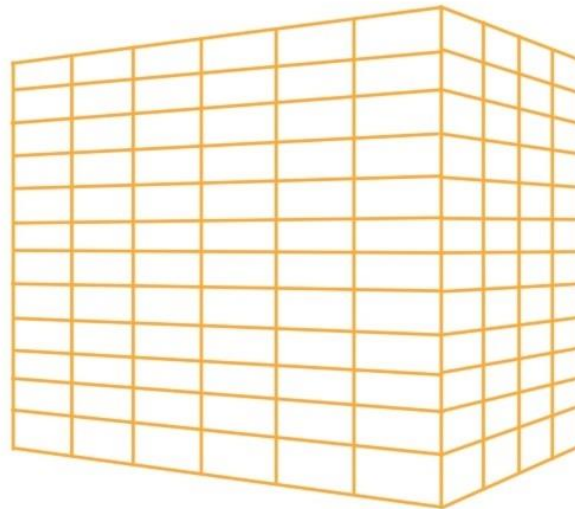
18 Stories

12 Stories

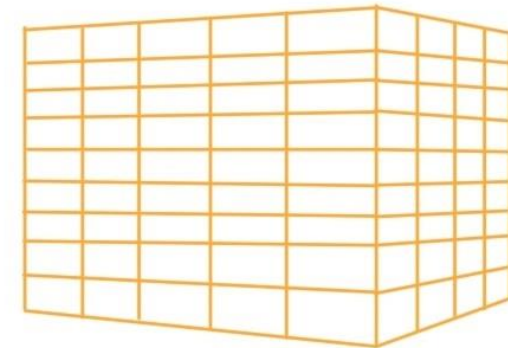
9 Stories



Type IV-A



Type IV-B

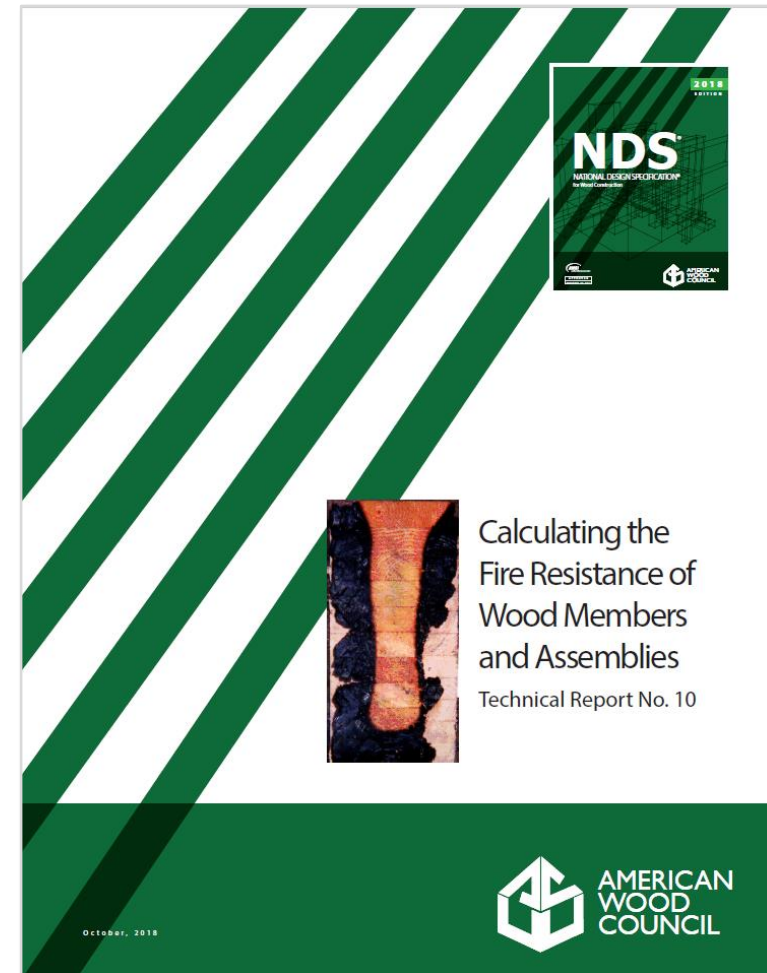


Type IV-C



Technical Report No.10

- American Wood Council
- Assist in fire design



Technical Report No.10

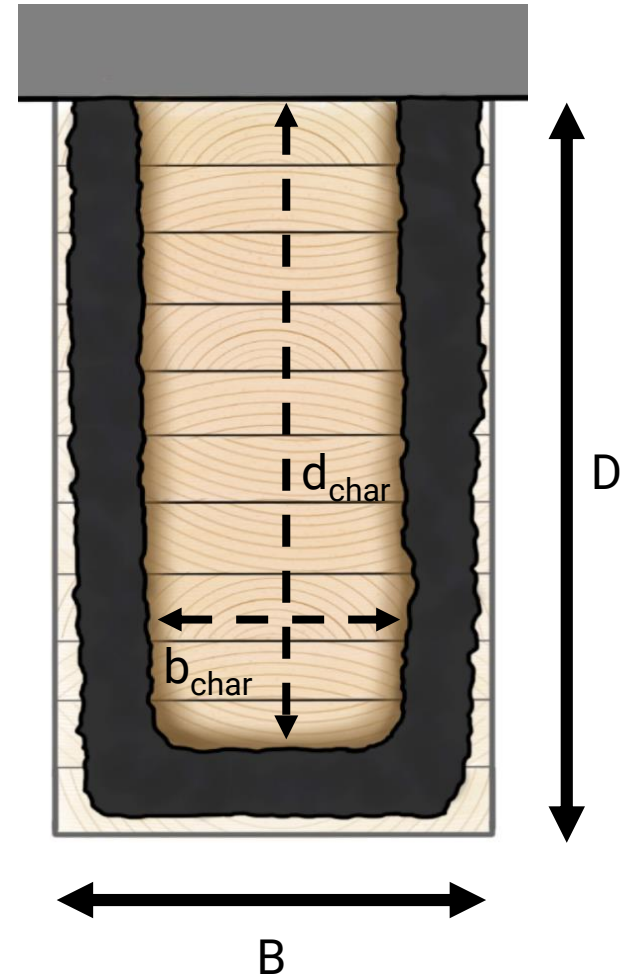
- Mass Timber is naturally fire resistant
- Maintains structural integrity through:
 - Char layer on outside



Fire Design Concept

- Initial Beam Width: B
- Initial Beam Depth: D

- Charred Beam Width: b_{char}
- Charred Beam Depth: d_{char}



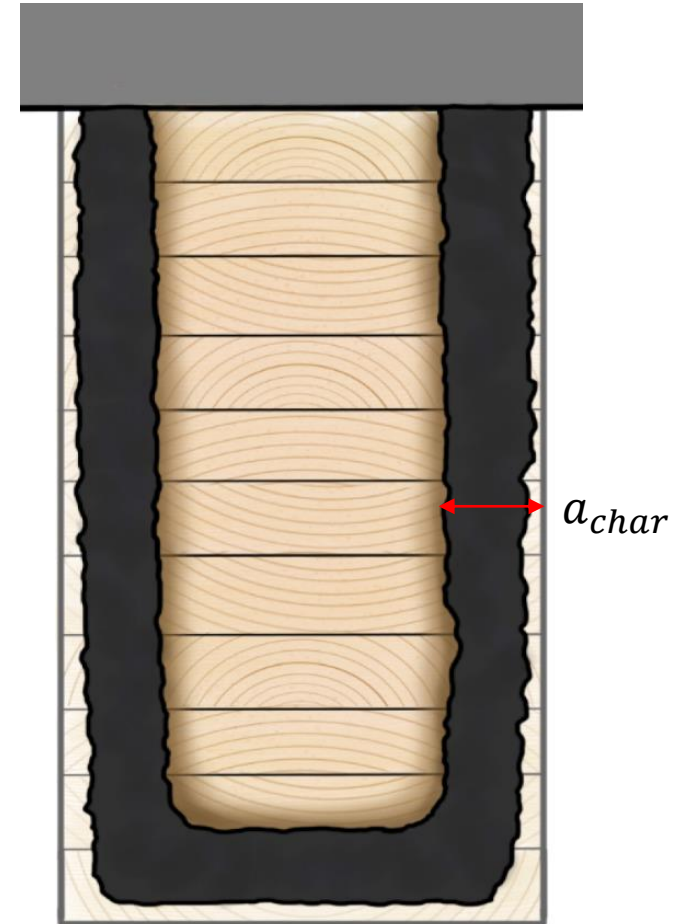
Char Rate

- Nonlinear char rate model
- A function of:
 - Time, t
 - Reference nominal char rate, β_n
 - Nonlinear char constant, β_t

$$a_{char} = \beta_t t^{0.813}$$

$$t = 1\text{-Hour} \quad a_{char} = 1.5 \text{ inch}$$

$$t = 2\text{-Hour} \quad a_{char} = 2.6 \text{ inch}$$



Effective Char Depth

- For structural calculation:

$$a_{eff} = 1.2 a_{char}$$

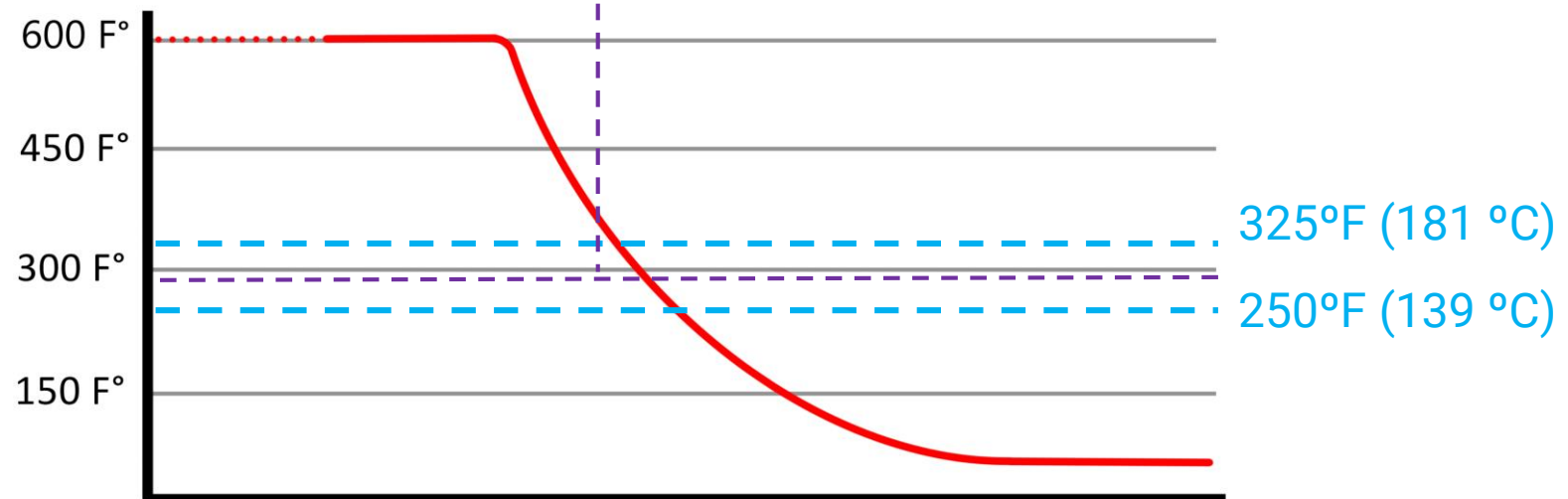


Connection Protection Performance

4.5.1 Connection Protection Performance

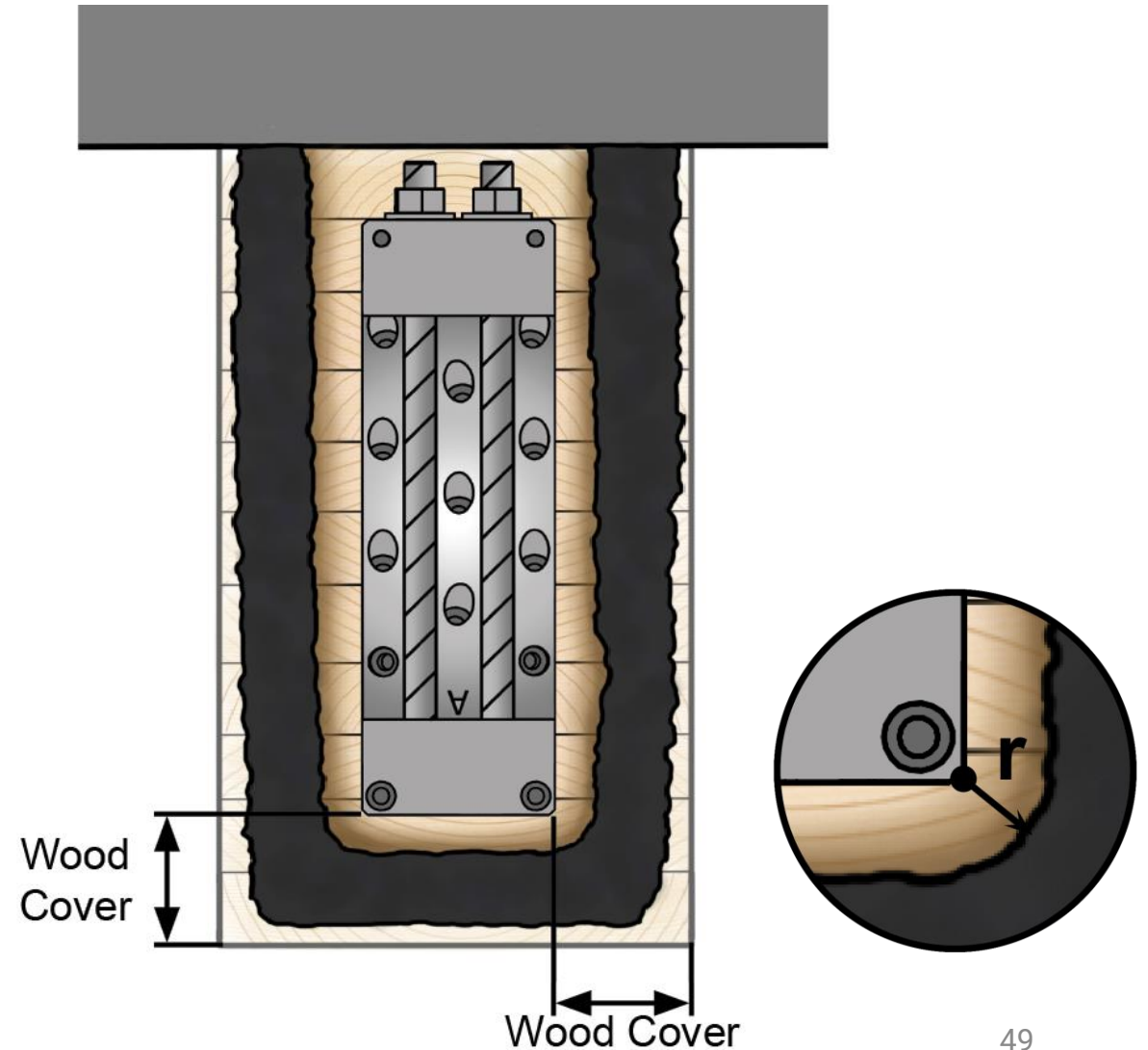
Protection of wood structural connections shall be designed to limit the average temperature rise to 250 °F (139 °C), and the maximum temperature rise at any point to 325 °F (181 °C), at the interface between the connection and the protection. Design of the protection shall be in accordance with the thermal separation provisions of 4.4.1.3 for wood protection and 4.4.2.3 for gypsum board protection.

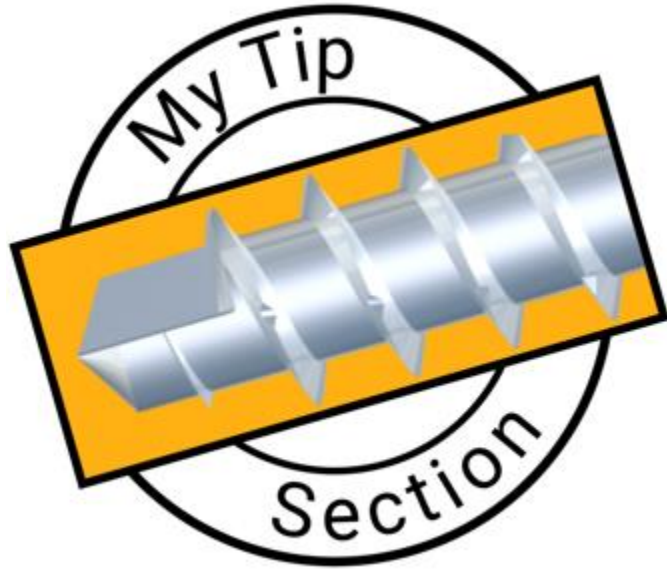
Exception: Connections in assemblies tested in accordance with ASTM E119. For tested assemblies, an option for the preliminary design of the protection would be to limit the average temperature at the interface between the connection and the protection to the charring temperature



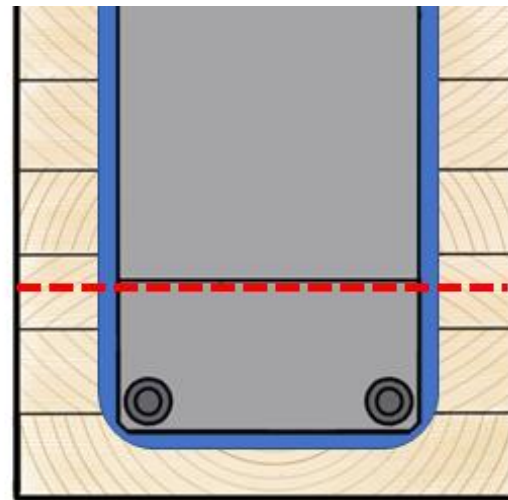
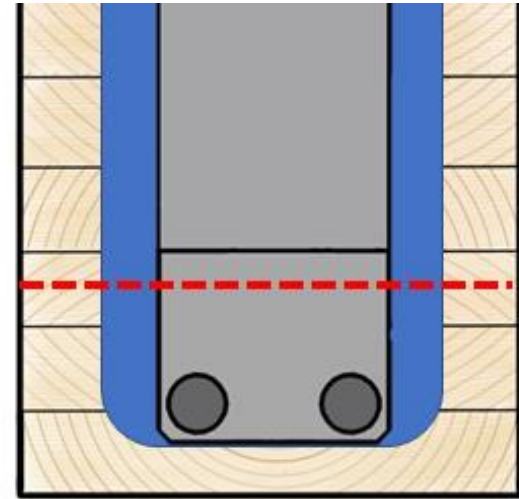
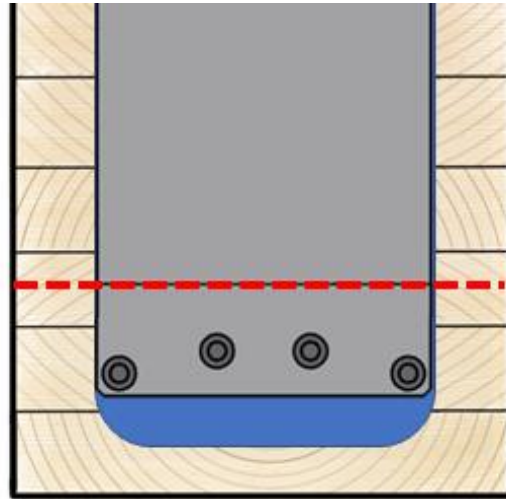
Corner Rounding Effect

- Charring faster in corners
- Cross-section no longer same
- Inner core at initial temperature
- Char layer thickness = r



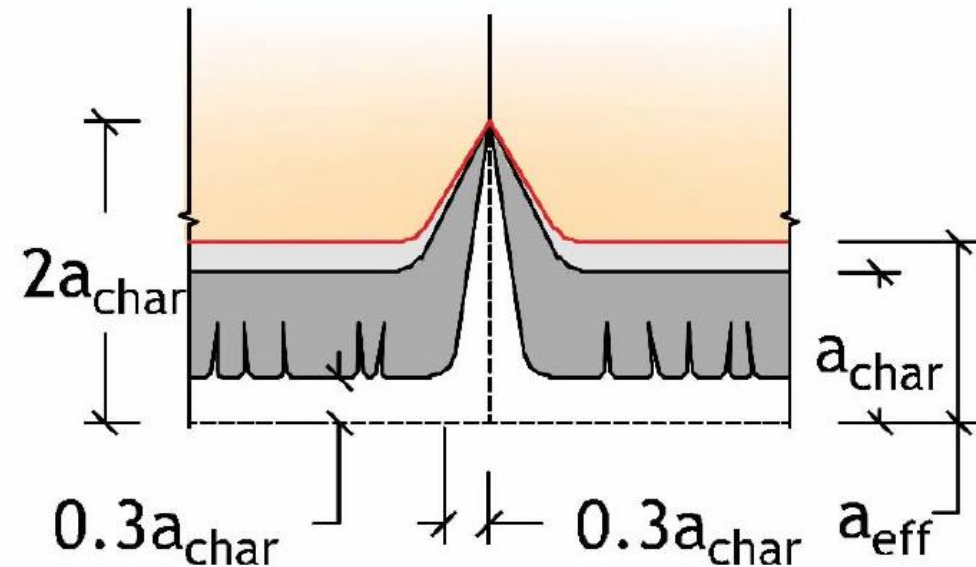


- Corner rounding effect possibilities for small and big beam hangers



Char Contraction

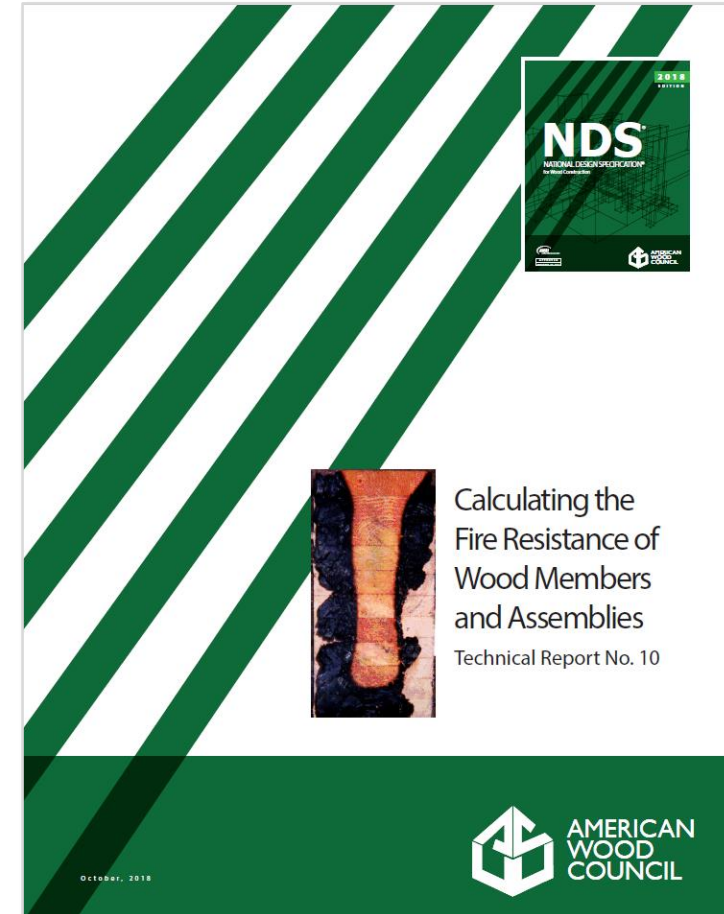
- Char contraction at unbonded wood members
- Ends and edges
- Ignition extends into gaps
 - Twice the char depth, $2a_{char}$



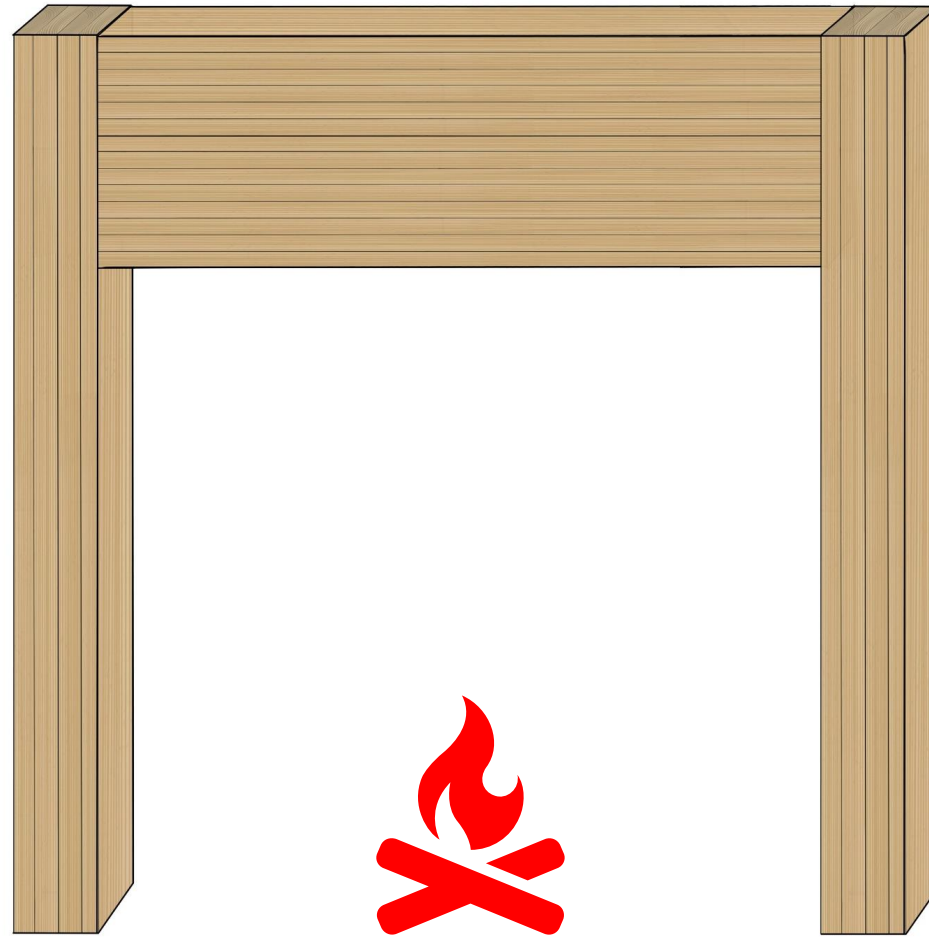
Reference: TR10

Technical Report No.10

- Supplement to the NDS
- Step by step procedures
- Fire Design:
 1. Char rate
 2. Corner rounding effect
 3. Char contraction

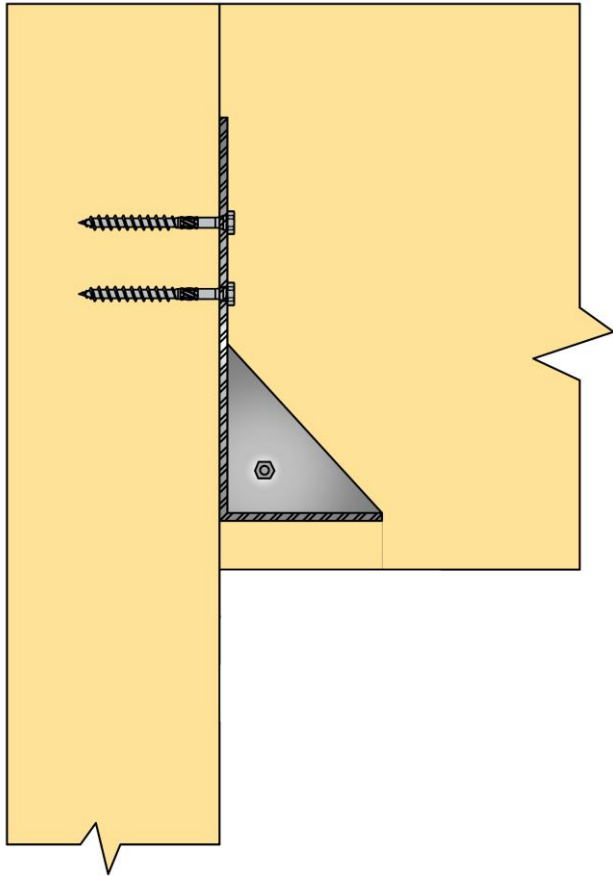


Example - Fire Design

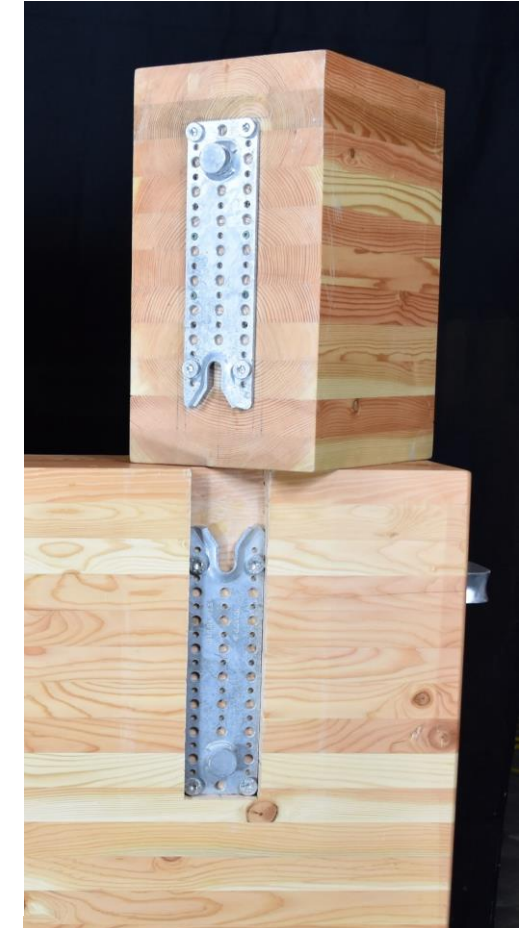
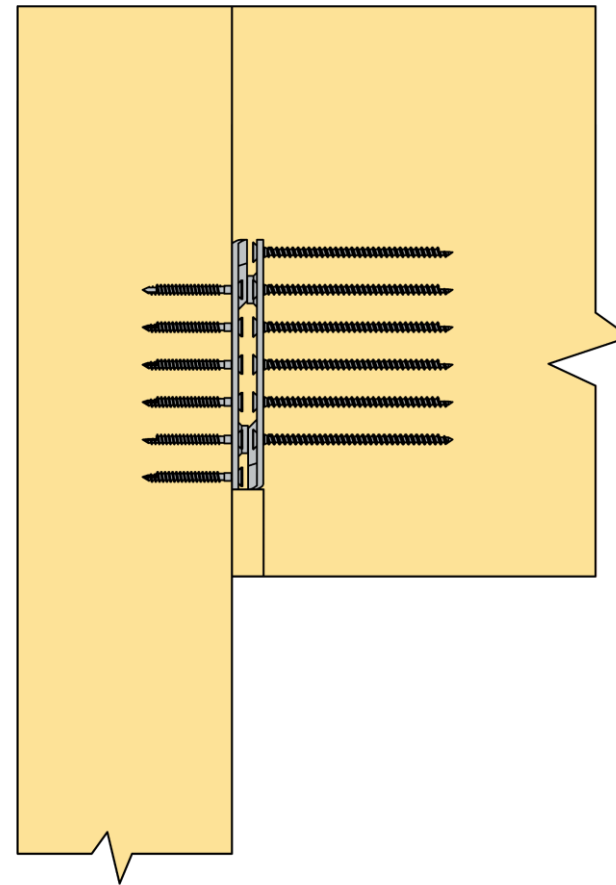


Example - Fire Design

Standard Connectors

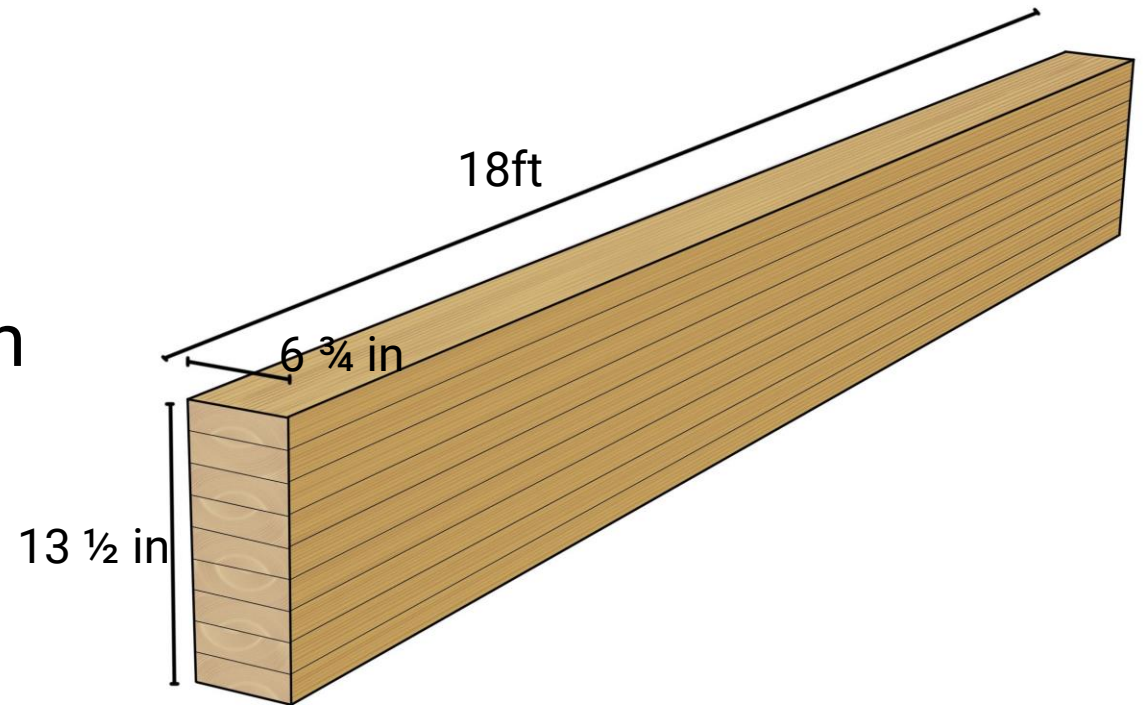


Beam Hanger System



Example - Beam to Column Connection

- 1 hr FRR connection fire design done in the TR10 using glulam size $6\frac{3}{4} \times 13\frac{1}{2}$ inches
- Simply supported glulam beam
- Loads:
 - $M_{\text{Max}} = 30,375 \text{ ft-lb}$
 - $V_{\text{Max}} = 6,750 \text{ lb}$



Example - Beam to Column Connection

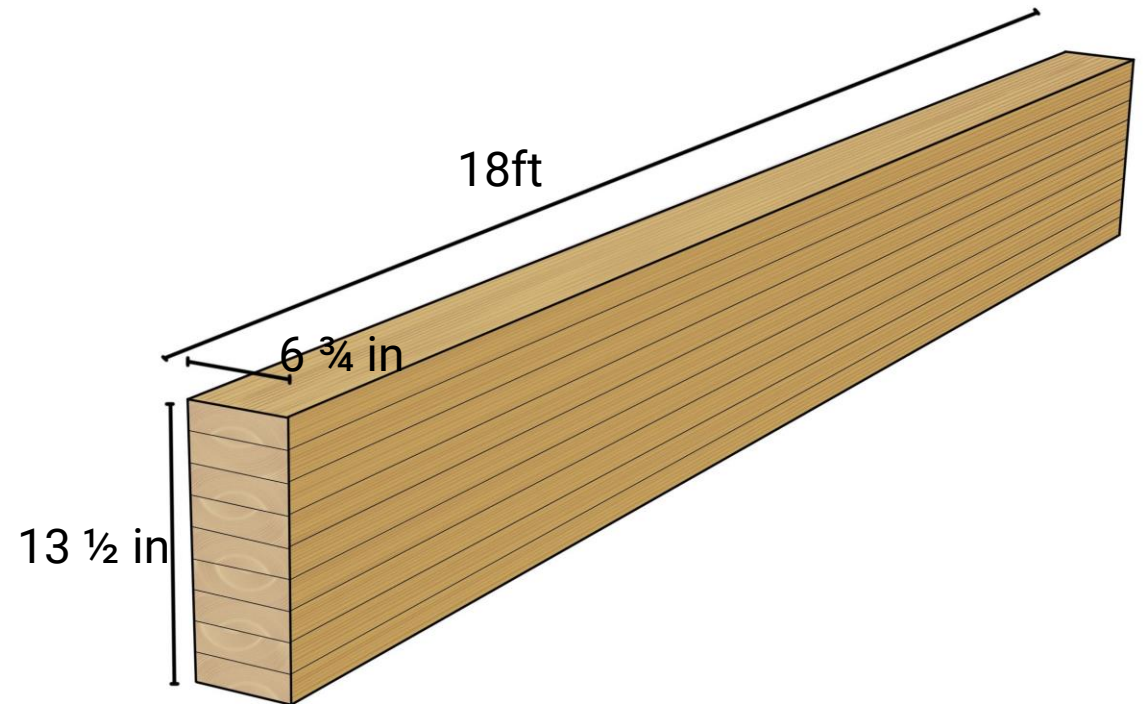
- For fire design check:

- Section modulus
- Shear Area

- For 2hr FRR:

$$a_{eff} = 3.2 \text{ in}$$

$$\times S_f = \frac{(6.75 - 6.4)(13.5 - 3.2)^2}{6} = 6.2 \text{ in}^2$$



beam size in TR10 too small for a 2hr fire rating, which we are aiming for in this example, therefore need to increase the beam size that can withstand a 2hr FRR

Example - Beam to Column Connection

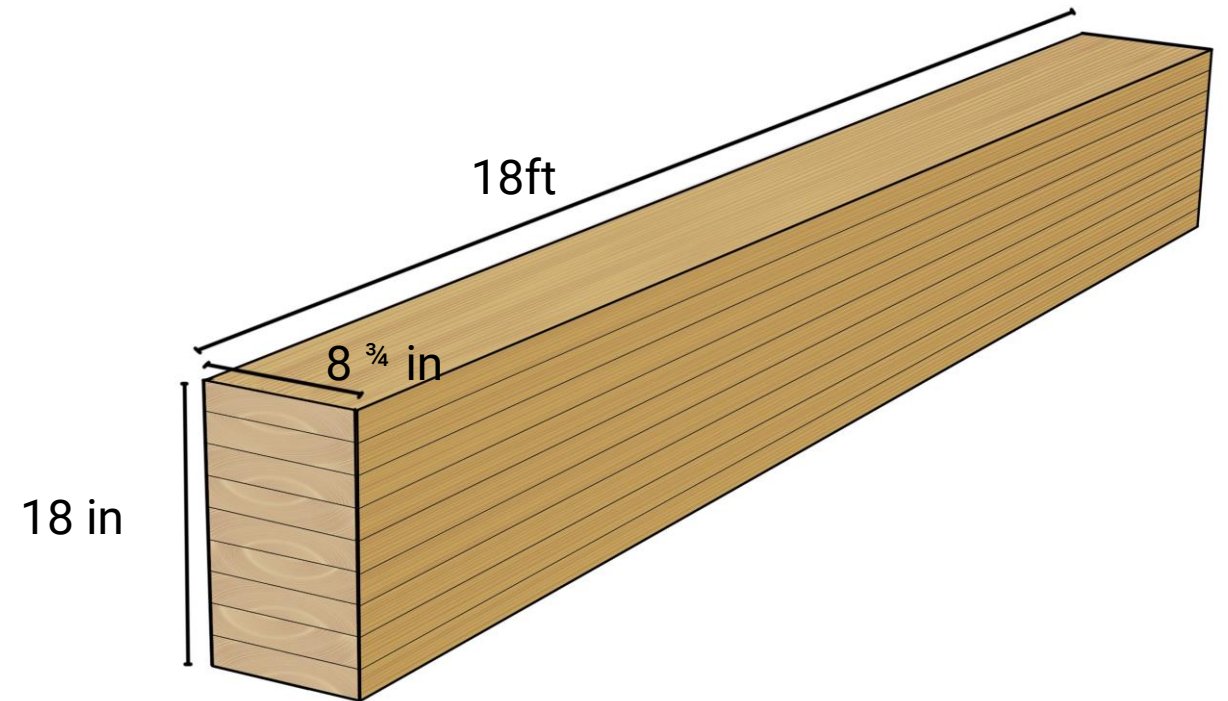
- Increase beam size:

$8 \frac{3}{4} \times 18$

- Check moment and shear:

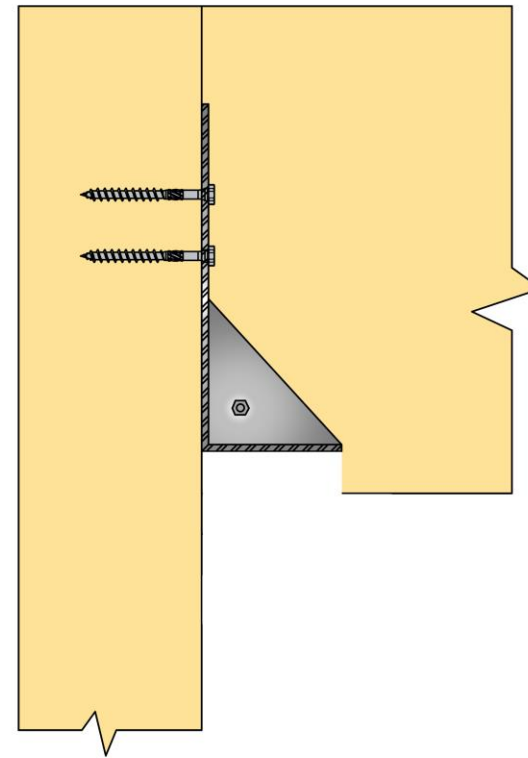
$$M_f = 47,920 \text{ ft-lb} > M_{\text{Max}} = 30,375 \text{ ft-lb}$$

$$V_f = 25,354 \text{ lb} > V_{\text{Max}} = 6,750 \text{ lb}$$

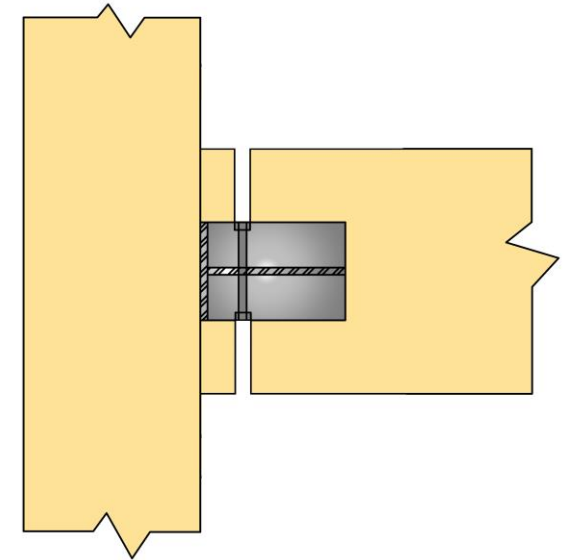


Example - Beam to Column Connection

- 8 ³/₄ x 18 Glulam Beam
- Internal Bearing Connector
- 3.5" wide and 0.375" thick



Side View



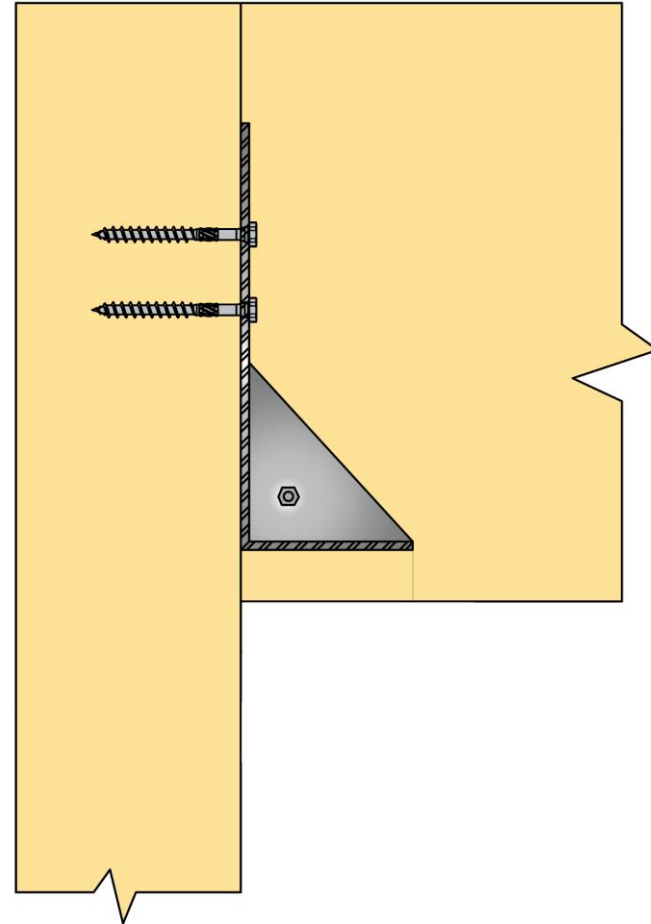
Top View

Example - Beam to Column Connection

- **Maximum notch depth**
 - $\text{Min} \{1/10 * \text{Beam Depth}, 3''\}$
- Maximum notch depth: 1.8"
- Wood Plug:

$$t_p = 60 \left(\frac{1.55}{1.5} \right)^{1.23}$$

$$t_p = 62.46 \text{ min}$$



Example - Beam to Column Connection

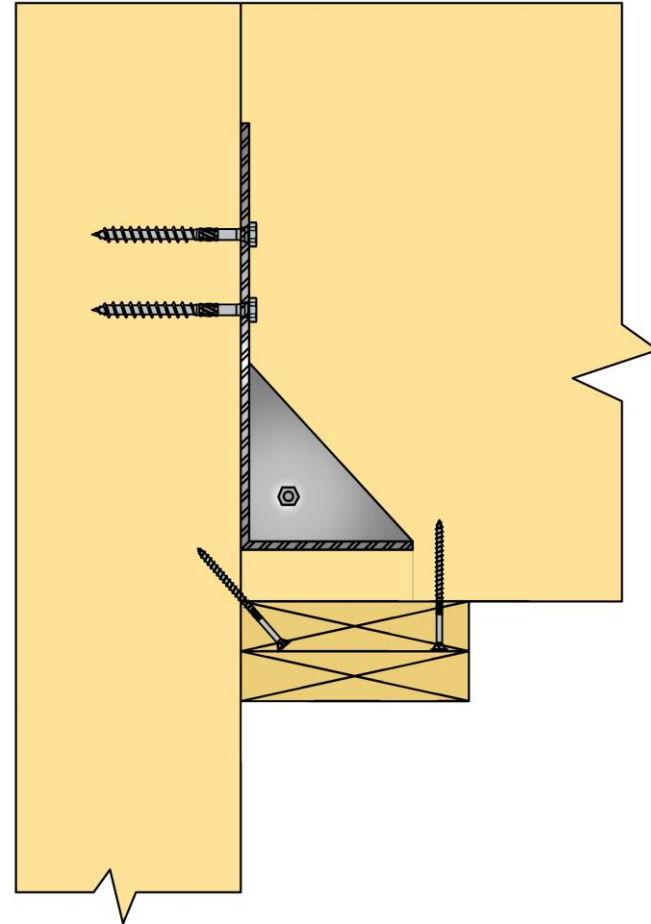
- Additional Wood Cover:

Clause 4.4.1.3

$$t_p = 0.85 * 60 \left(\frac{1.55}{1.5} \right)^{1.23} = 51 \text{ min}$$

$$51 \text{ min} + 62 = 113 \text{ min}$$

More Cover needed!!



Example - Beam to Column Connection

- Cover on the side:

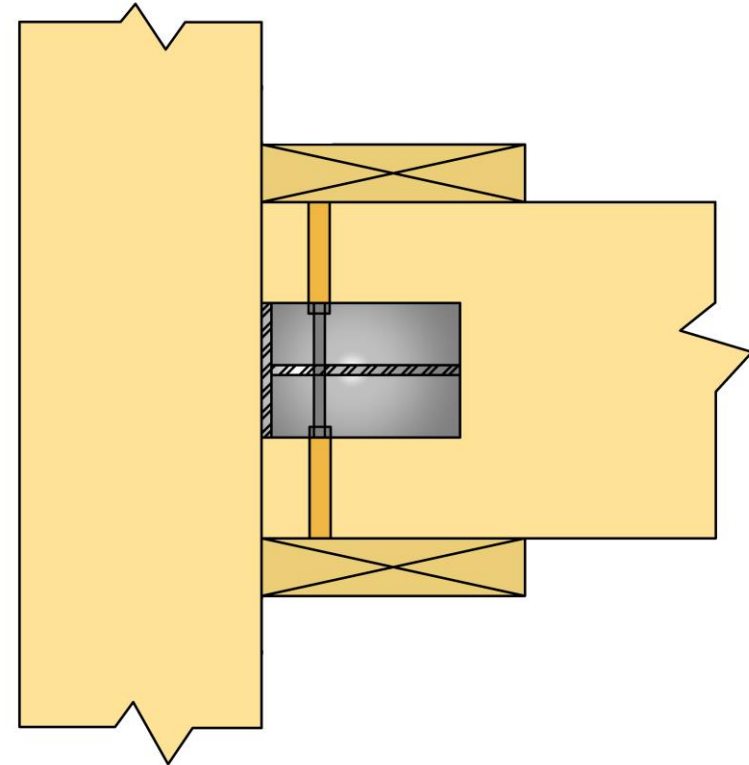
$$t_p = 60 \left(\frac{2.62}{1.5} \right)^{1.23}$$

$$t_p = 119 \text{ min}$$

- Additional Cover:

$$t_p = 0.85 * 60 \left(\frac{1.55}{1.5} \right)^{1.23}$$

$$t_p = 51 \text{ min}$$

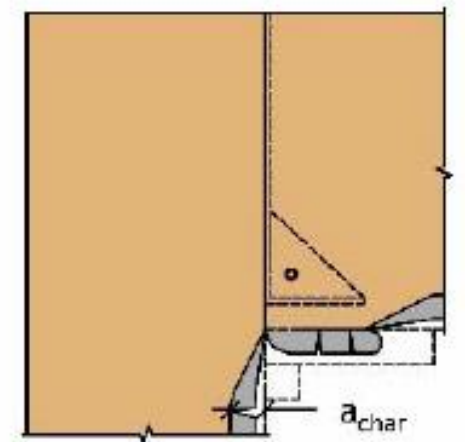
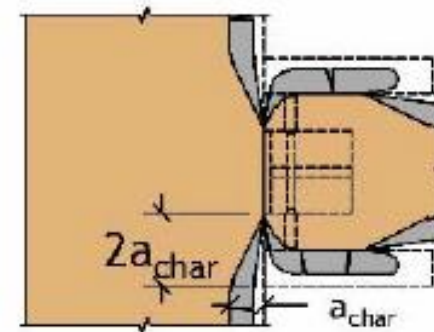
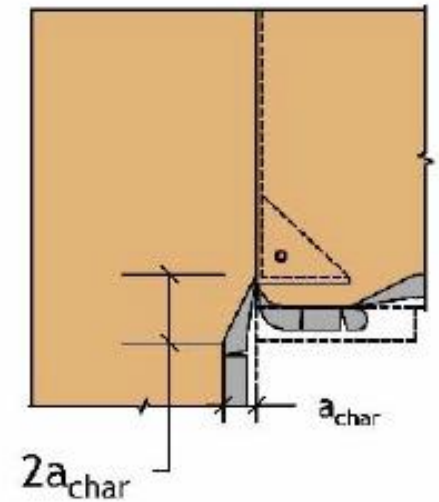
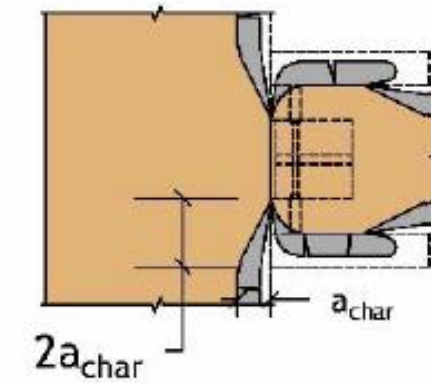


Unbonded Gaps

- Char contraction creating gaps
- Depth of gaps:

$$2a_{char}$$

Additional cover needed!



Reference: TR10

Example - Beam to Column Connection

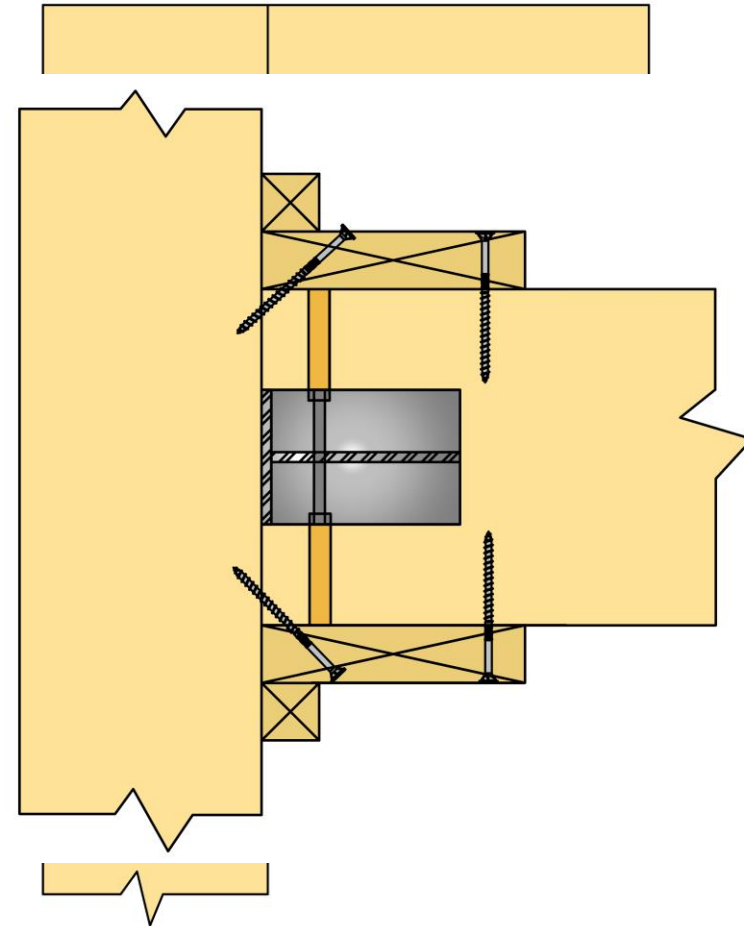
$$d_{cover} + d_{strip} \geq 2a_{char}$$

- Bottom of beam:

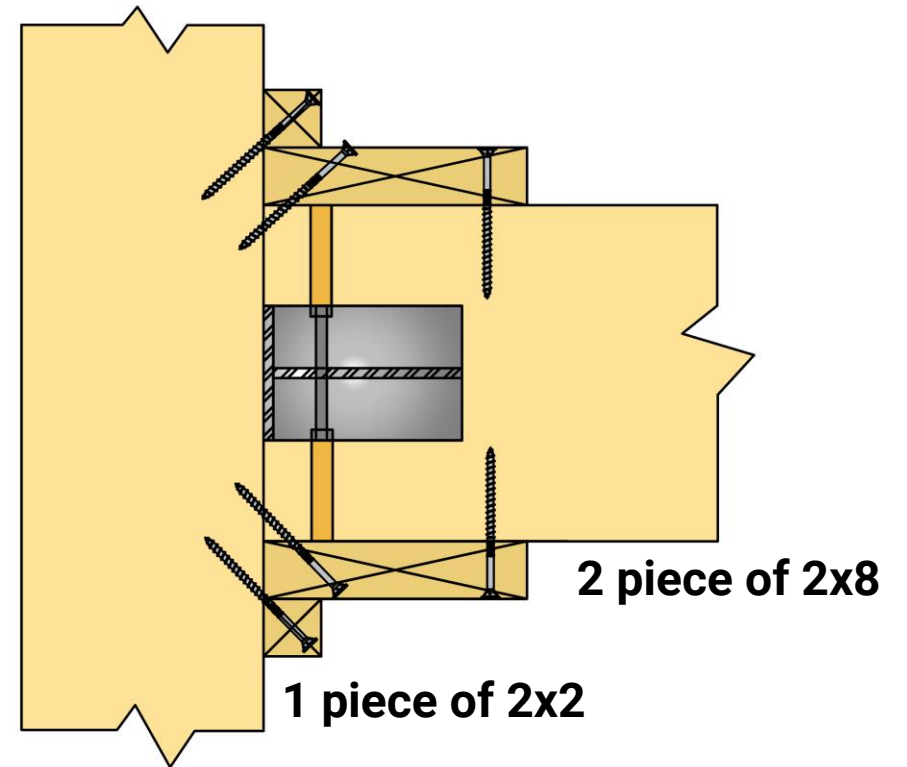
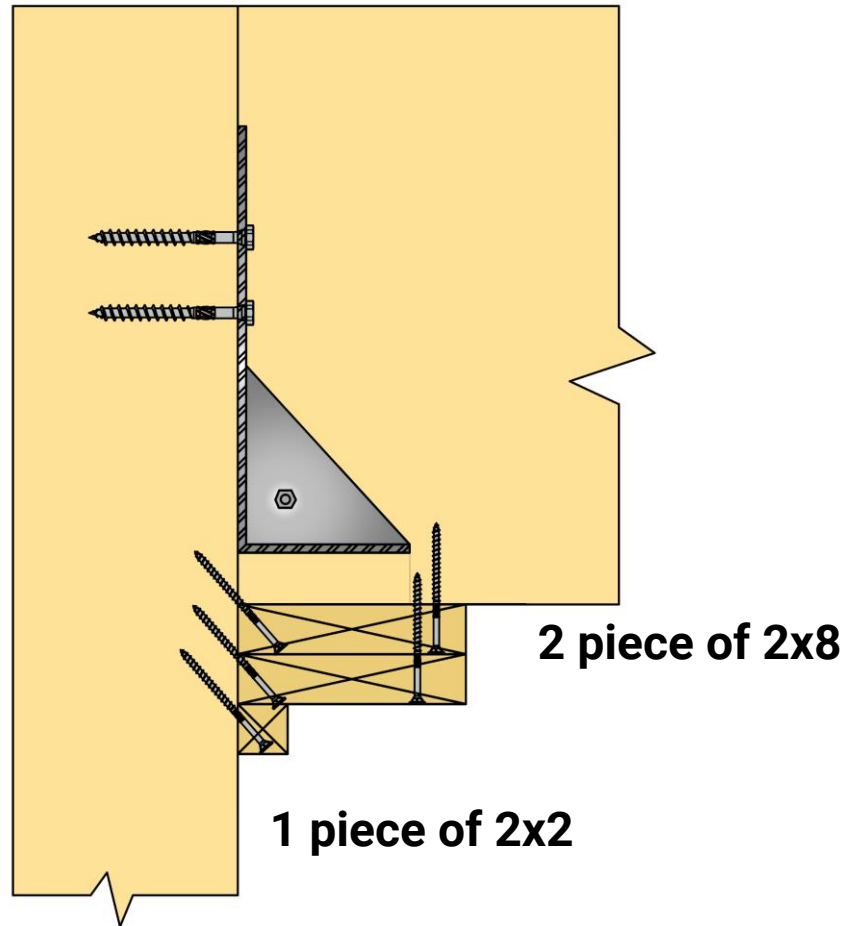
$$\begin{aligned} d_{strip} &\geq (5.2 - 1.55 - 1.5 - 1.5) \\ &\rightarrow d_{strip} \geq 0.65'' \end{aligned}$$

- Side of beam:

$$\begin{aligned} d_{strip} &\geq (5.2 - 2.62 - 1.5) \\ &\rightarrow d_{strip} \geq 1.08'' \end{aligned}$$

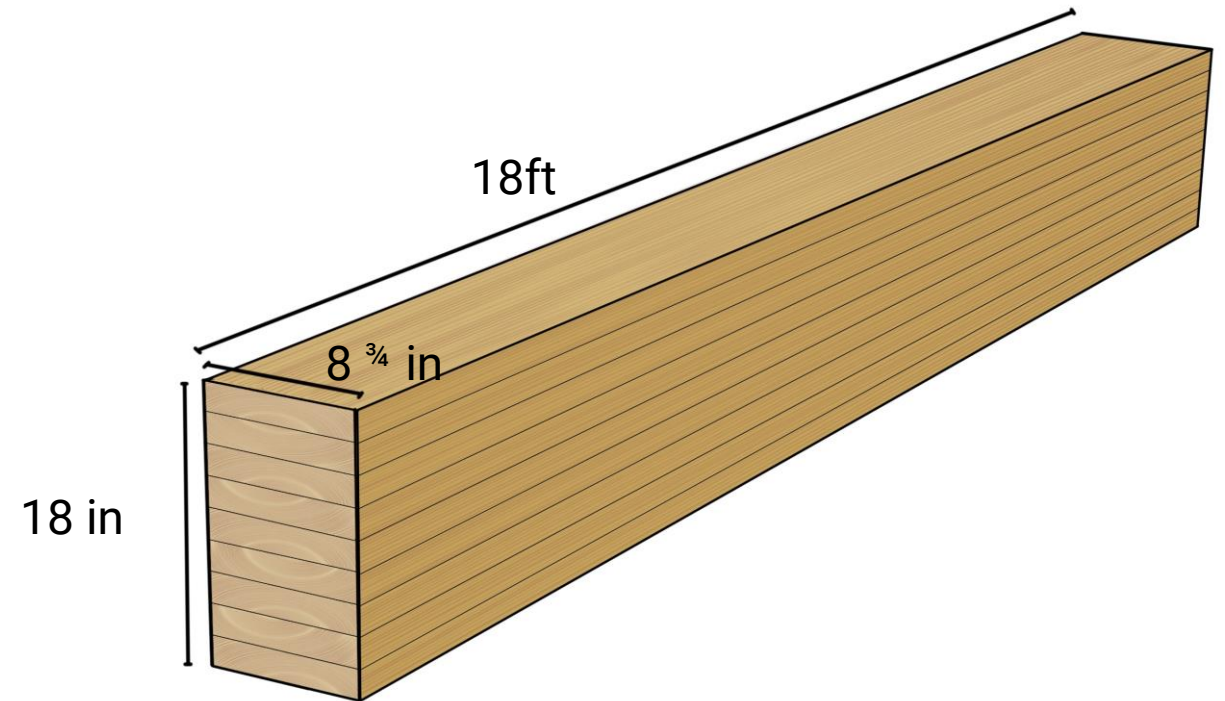


Example - Beam to Column Connection



Example – Beam Hanger System

- $8\frac{3}{4}$ x 18 Glulam Beam
- Shear load: 6,750 lbf.
- 2hr FRR



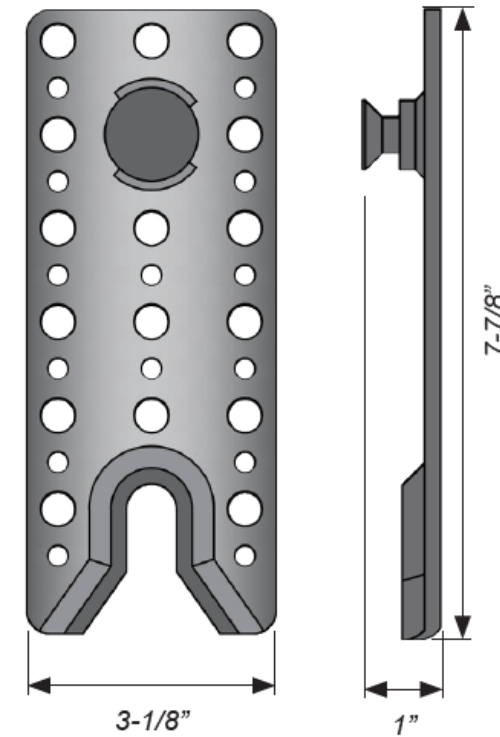
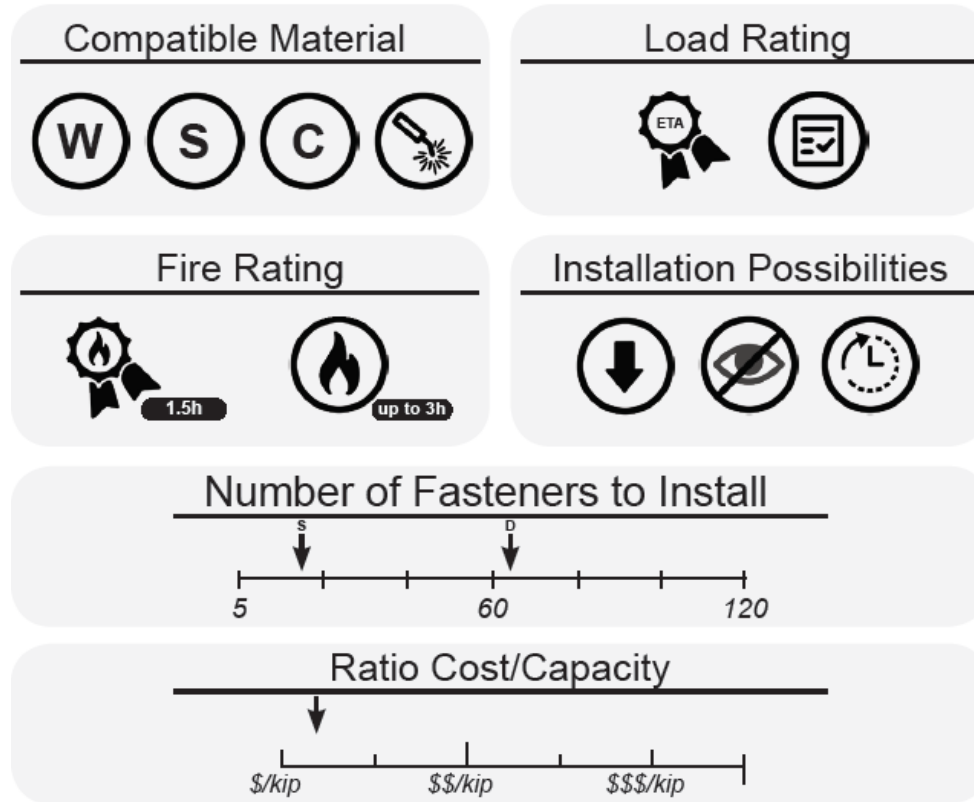
Beam Hanger - Selection Tool

Minimum Beam Width	Minimum Beam Depth	Allowable Load	Connector		Page	
			inch	[mm]		
2-3/8"	6-1/4" [160]	1.2			Gigant 120x40	16
	7-7/8" [200]	1.9			Gigant 150x40	17
	8-3/4" [222]	2.5			Gigant 180x40	18
4"	7" [180]	3.7			Ricon S VS 140x60	20
	9-1/2" [240]	5.2			Ricon S VS 200x60	22
	15-3/4" [400]	8.2			Megant 310x60	30
	20-1/2" [520]	12.8			Megant 430x60	32
	25-1/4" [640]	12.8			Megant 550x60	34
4-3/4"	9-1/2" [240]	7.5			Ricon S VS 200x80	24
	13" [330]	9.1			Ricon S VS 290x80	26
	17" [430]	17.1			Ricon XL 390x80	28
5-5/8"	15-3/4" [400]	10.5			Megant 310x100	36
	20-7/8" [530]	17.5			Megant 430x100	38
	25-5/8" [650]	19.5			Megant 550x100	40
7-1/2"	15-3/4" [400]	13.6			Megant 310x150	42
	20-1/2" [520]	22.7			Megant 430x150	44
	25-1/4" [640]	31.8			Megant 550x150	46
	33-1/8" [830]	32.6			Megant 730x150	48



RICON S VS 200 x 80

Connector Parameters and Dimensions

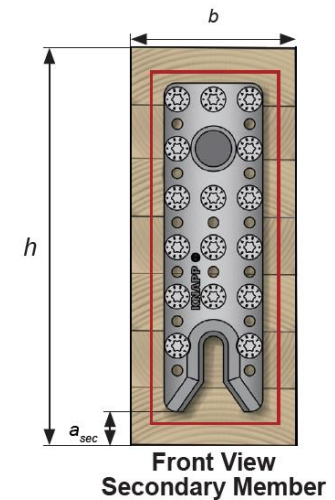
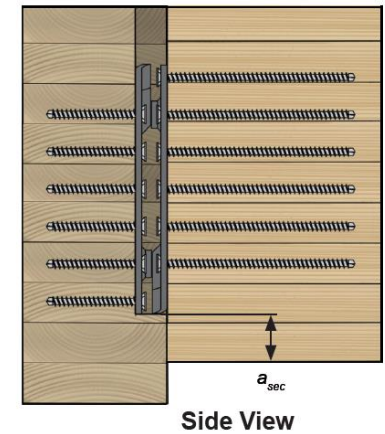


Beam Hanger - Fire Design

Connector		Fire Resistance Rating					
		1 hour			2 hours		
		Min. Beam Width (b) [in]	Min. Beam Height (h) [in]	a _{sec} [in]	Min. Beam Width (b) [in]	Min. Beam Height (h) [in]	a _{sec} [in]
RICON S VS 140x60	Single	6-1/4"	9-1/4"	1-1/2"	9-5/8"	14-1/4"	2-3/4"
	Double	8-1/8"	11-7/8"	2"	10-1/2"	17-1/4"	3-5/8"
RICON S VS 200x60	Single	5-1/4"	11-7/8"	2"	9-5/8"	14-1/4"	2-3/4"
	Double	8-1/8"	11-7/8"	2"	10-1/2"	17-1/4"	3-5/8"
RICON S VS 200x80	Single	6-1/8"	11-7/8"	2"	8-5/8"	17-1/4"	3-5/8"
	Double	9-3/4"	11-7/8"	2"	12-1/8"	17-1/4"	3-5/8"
RICON S VS 290x80	Single	6-1/8"	14-1/4"	2"	8-5/8"	17-1/4"	3-5/8"
	Double	9-3/4"	14-1/4"	2"	12-1/8"	17-1/4"	3-5/8"
RICON XL 390x80	Single	6-1/8"	18-1/4"	2"	8-5/8"	19-3/4"	3-5/8"
	Double	9-3/4"	18-1/4"	2"	12-1/8"	19-3/4"	3-5/8"

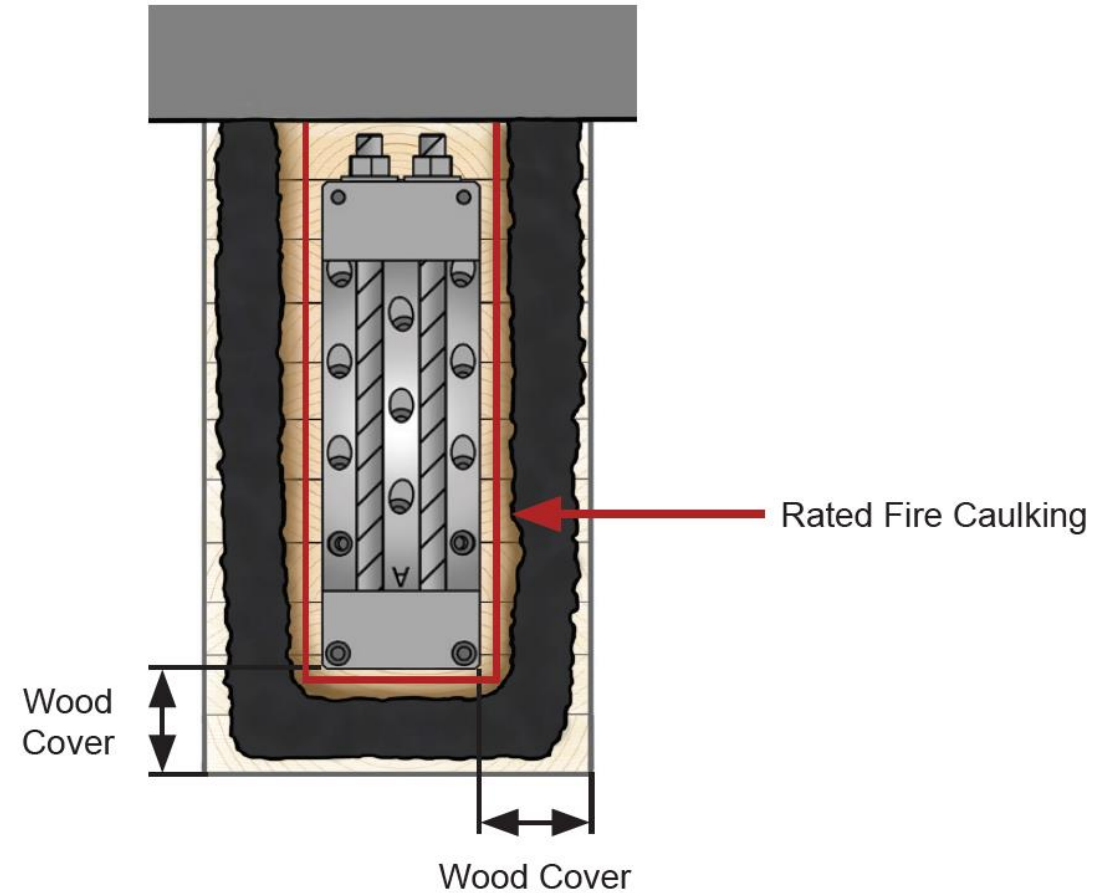
Notes:

1. All minimum beam requirements account for the corner effect rounding when beams are designed for three-sided fire exposure.
2. Beam Hanger Systems must be installed with fire rated caulking within the non charring area.



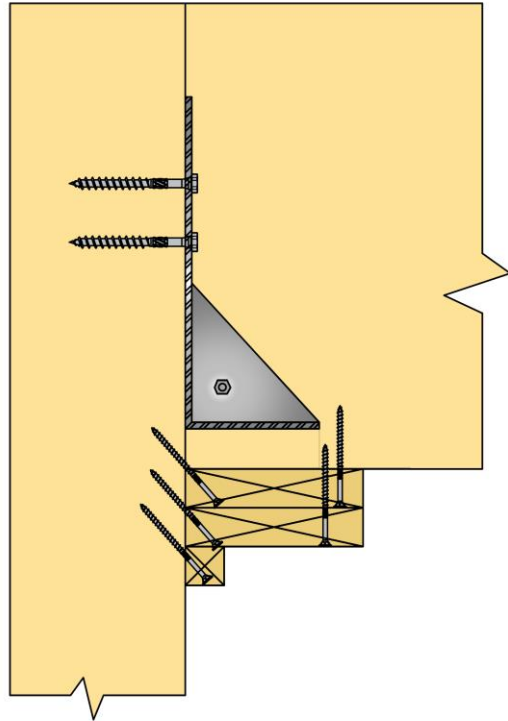
Beam Hanger - Fire Design

- Values based on testing
- Provide sufficient wood cover
- Provide fire rated caulking

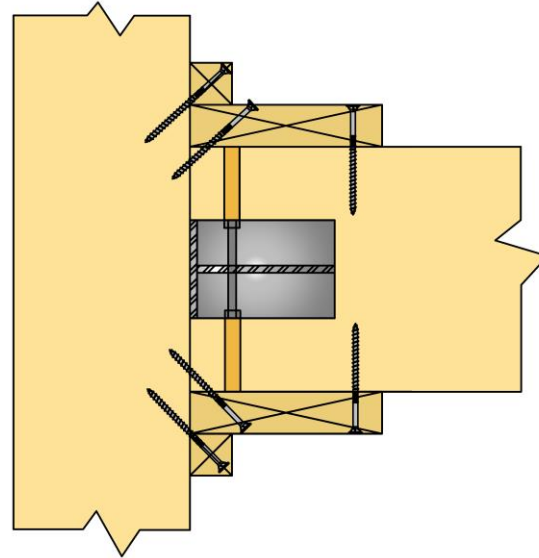


Fire Design Made Simple

Standard Connectors

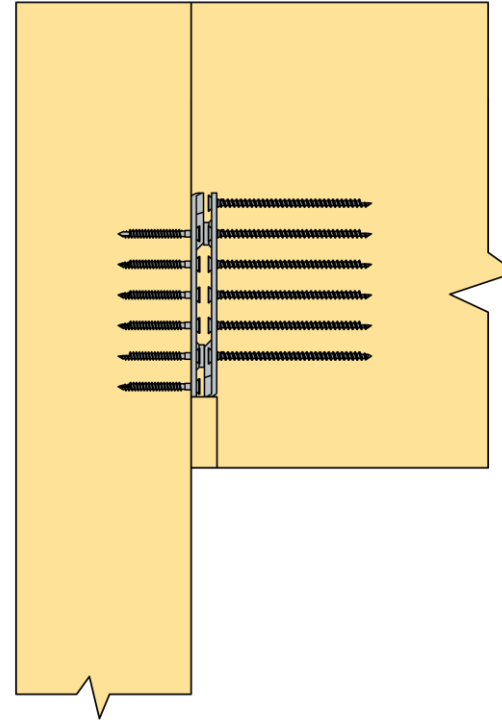


Side View

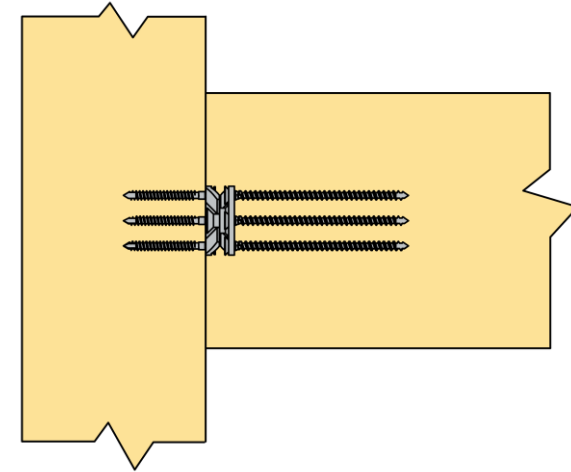


Top View

Beam Hanger System



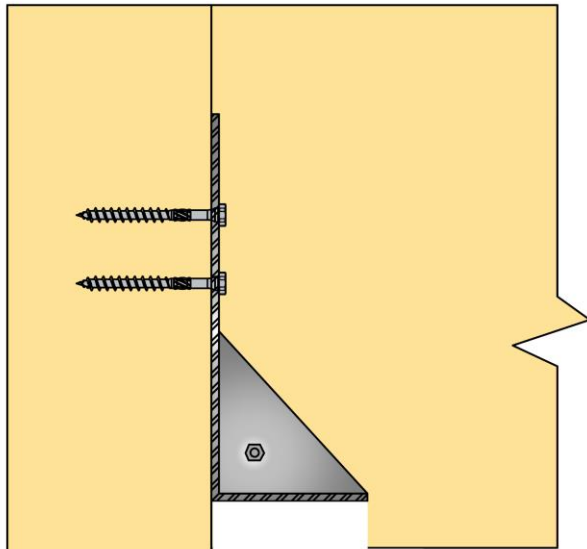
Side View



Top View

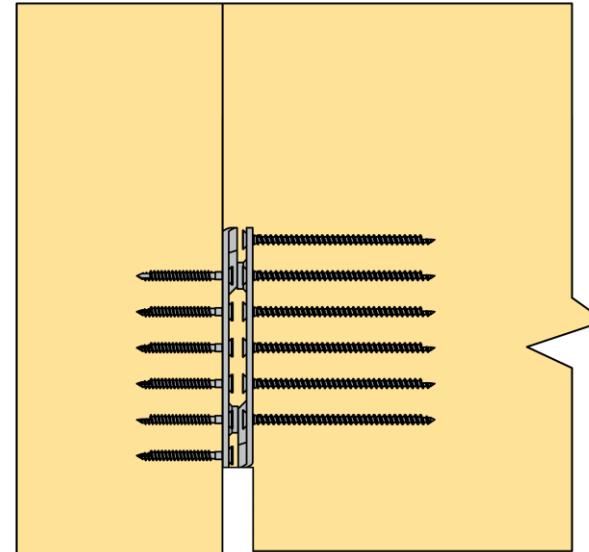
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Standard Connectors



Side View

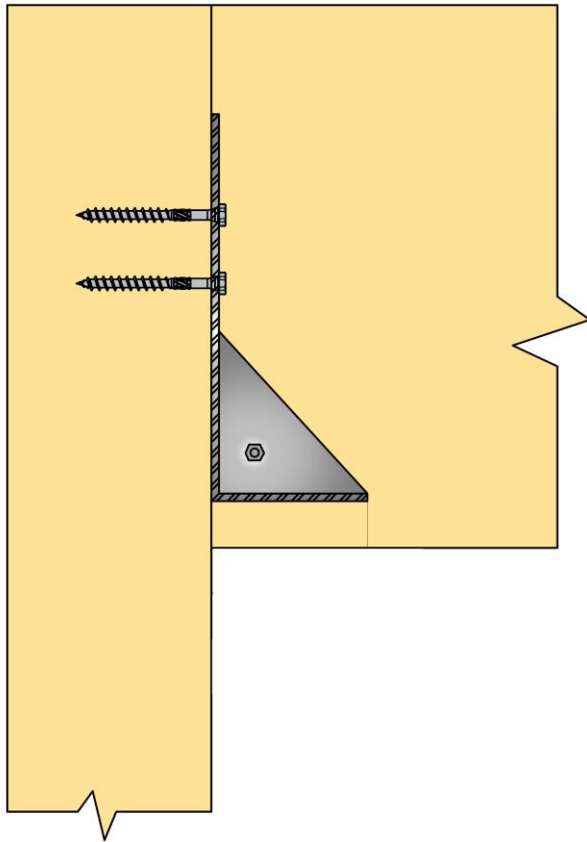
Beam Hanger System



Side View

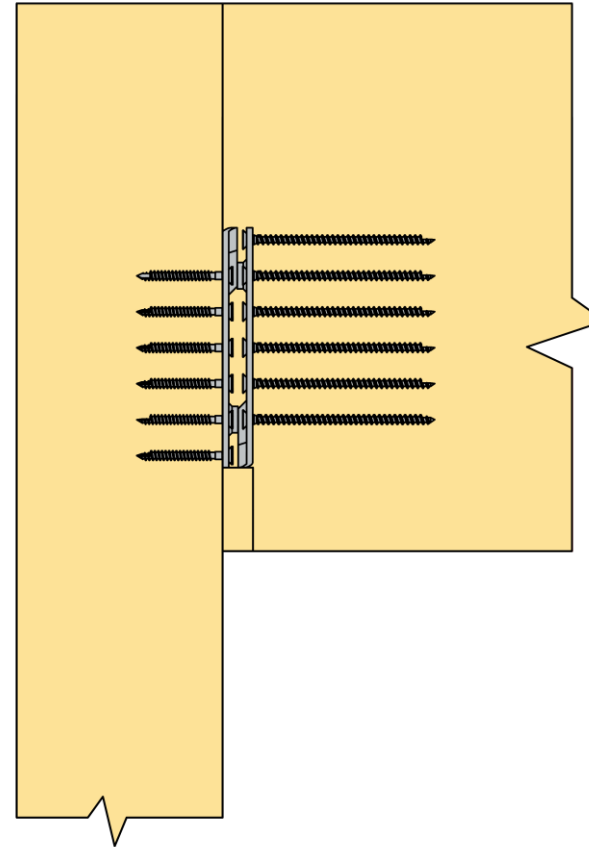
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Standard Connectors



Side View

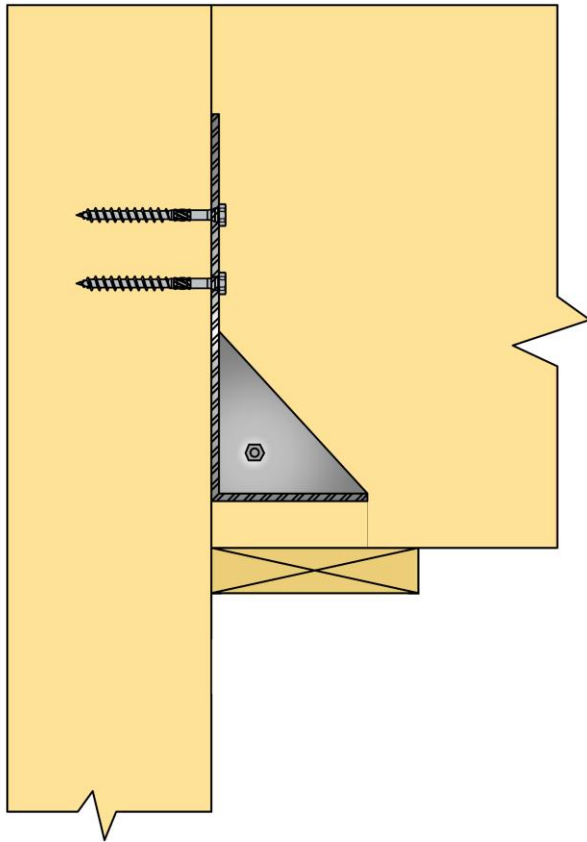
Beam Hanger System



Side View

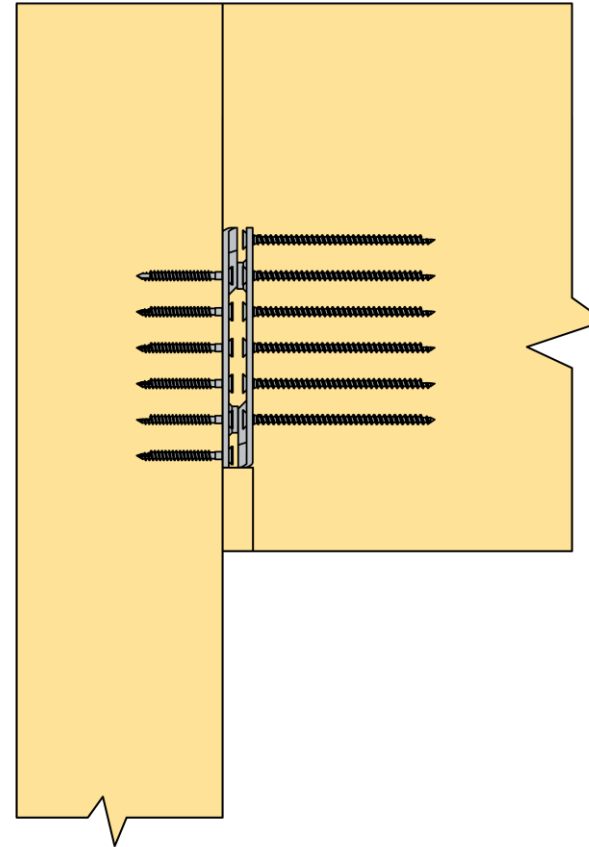
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Side View

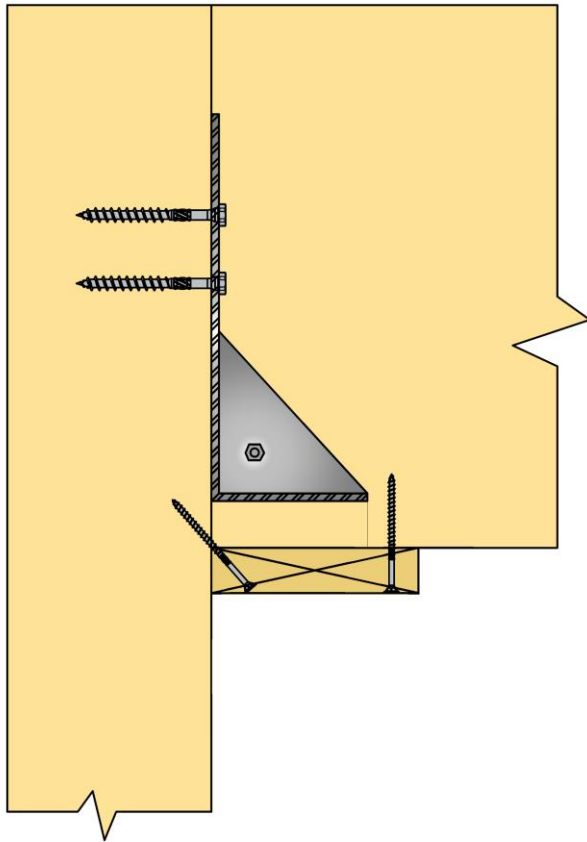
Beam Hanger System



Side View

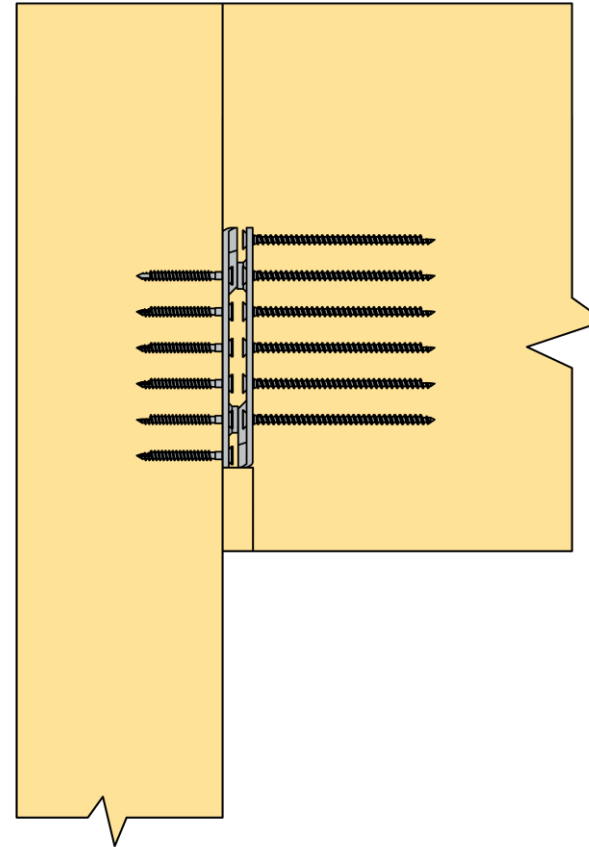
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Side View

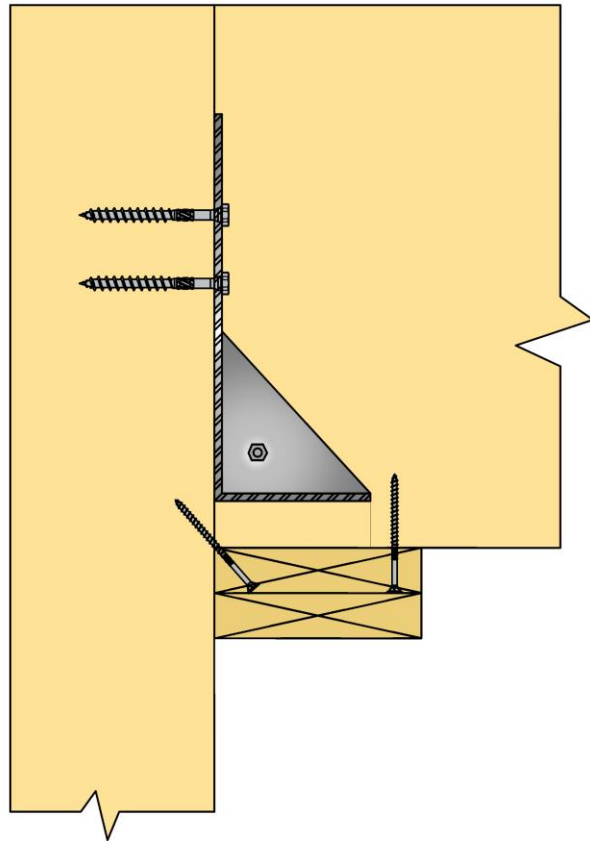
Beam Hanger System



Side View

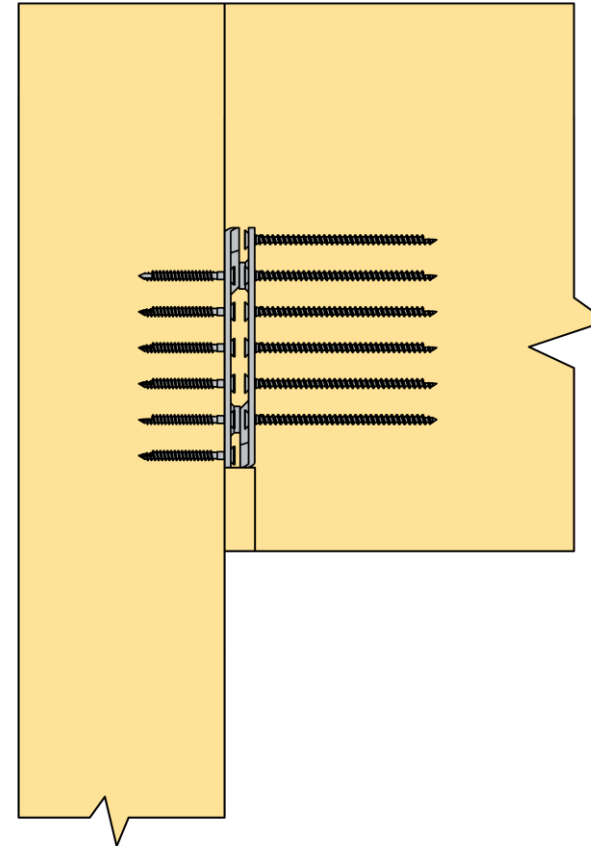
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Standard Connectors



Side View

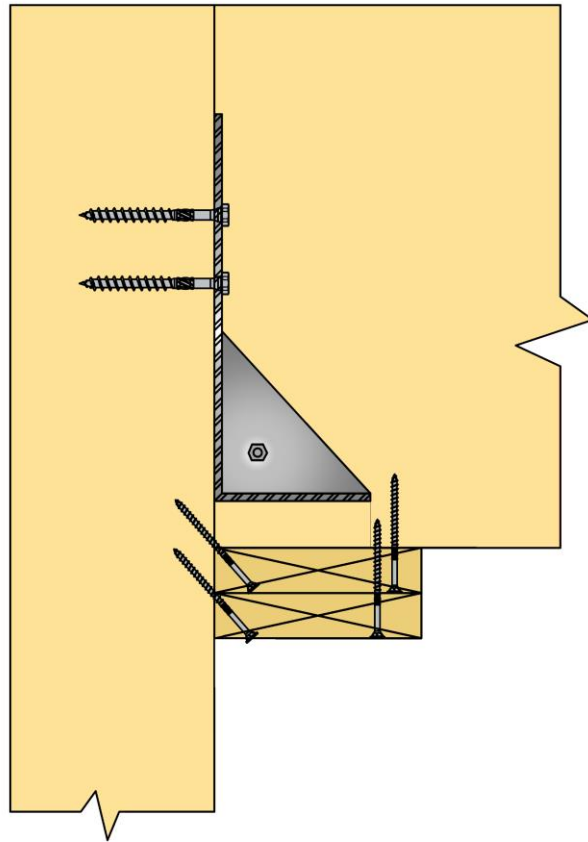
Beam Hanger System



Side View

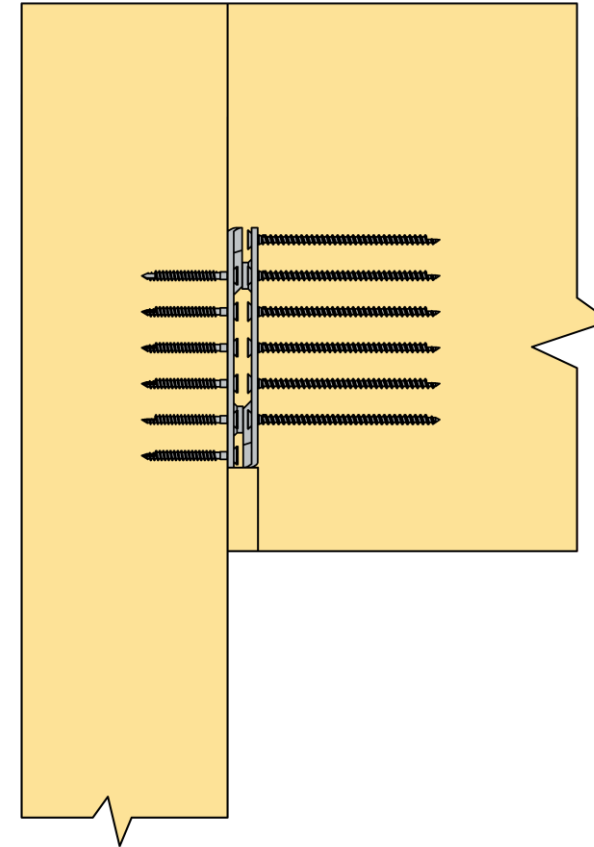
Fire Design Made Simple

Standard Connectors



Side View

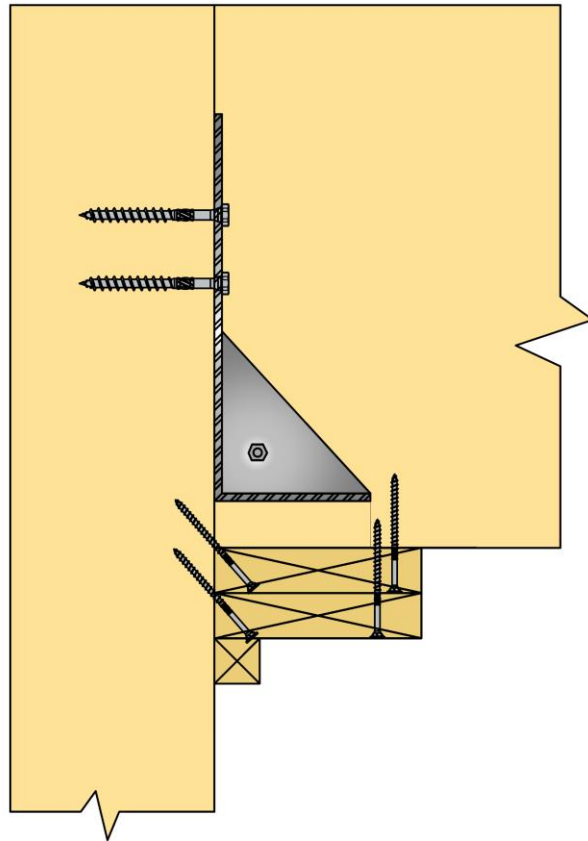
Beam Hanger System



Side View

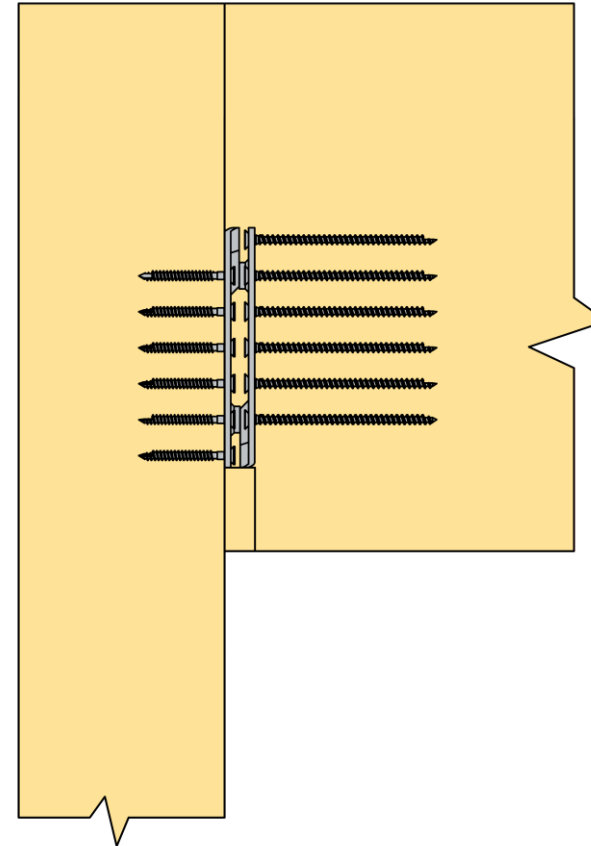
Fire Design Made Simple

Standard Connectors



Side View

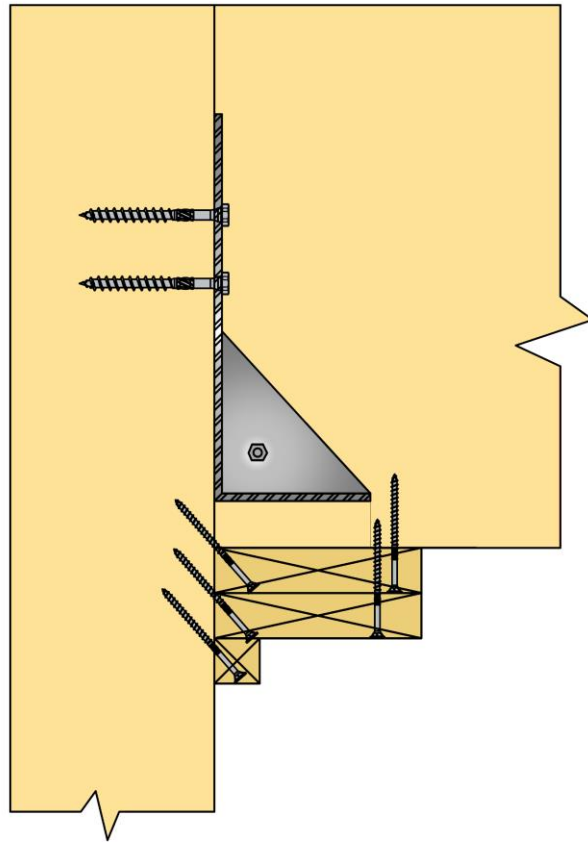
Beam Hanger System



Side View

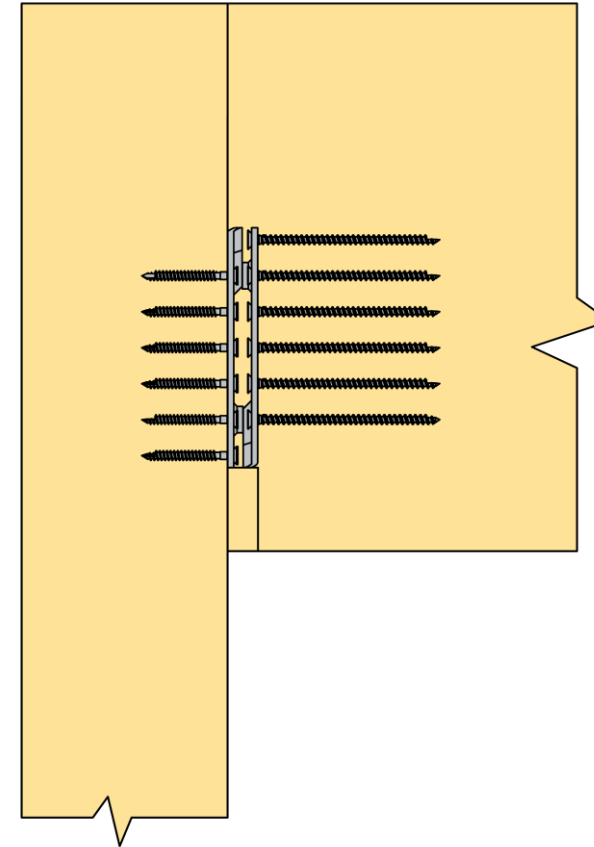
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Standard Connectors



Side View

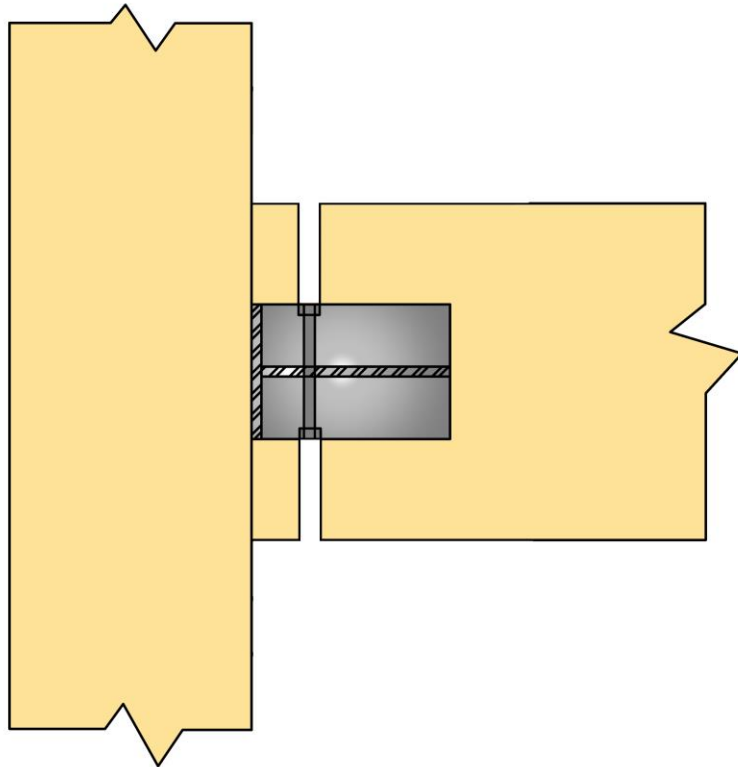
Beam Hanger System



Side View

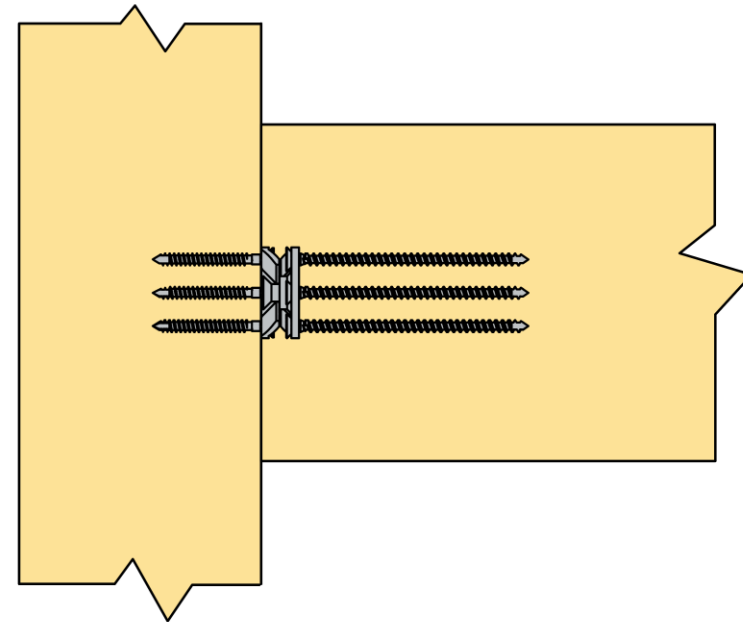
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Standard Connectors



Top View

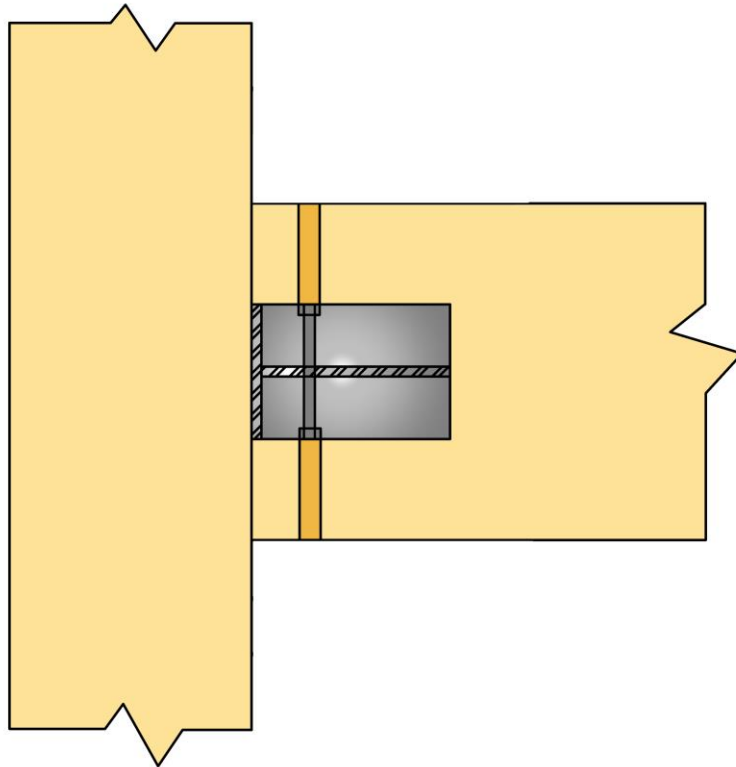
Beam Hanger System



Top View

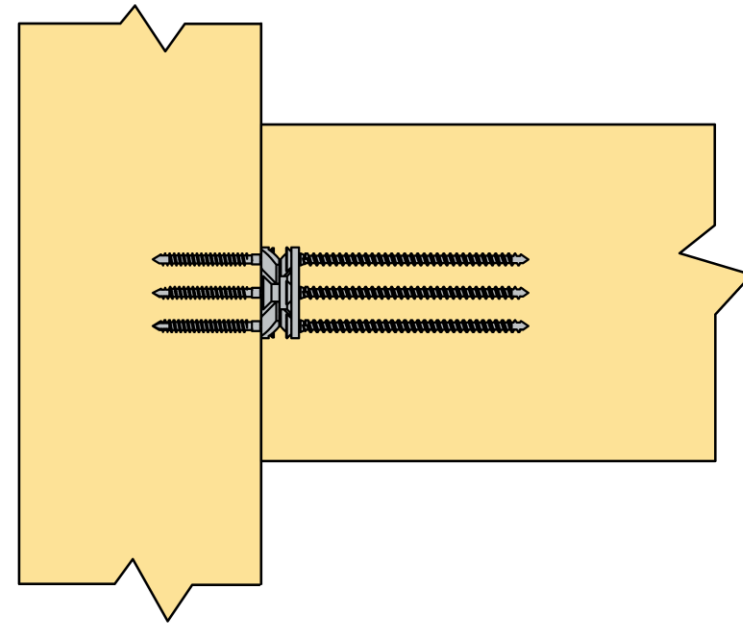
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Top View

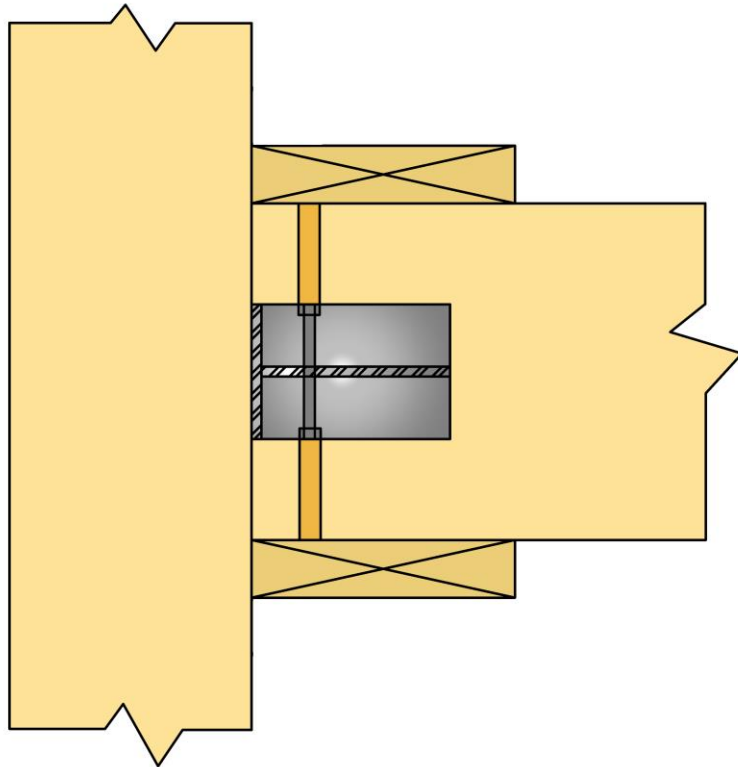
Beam Hanger System



Top View

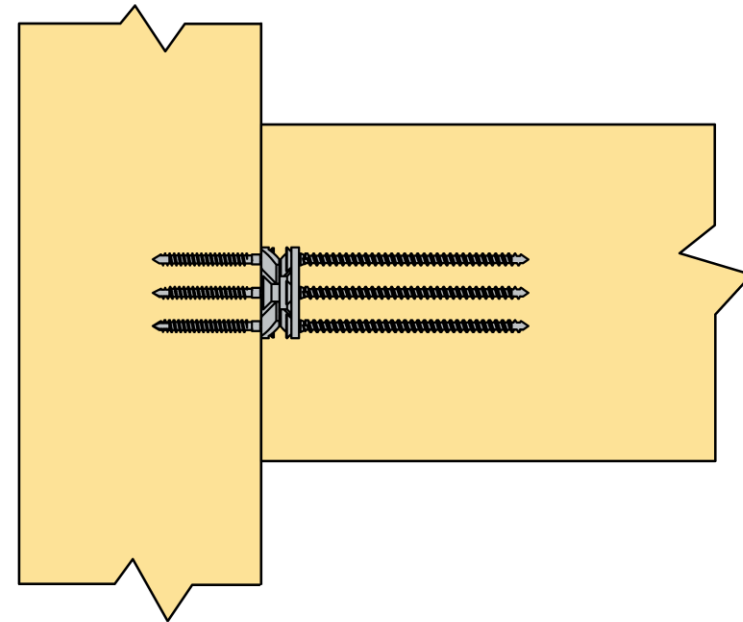
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Top View

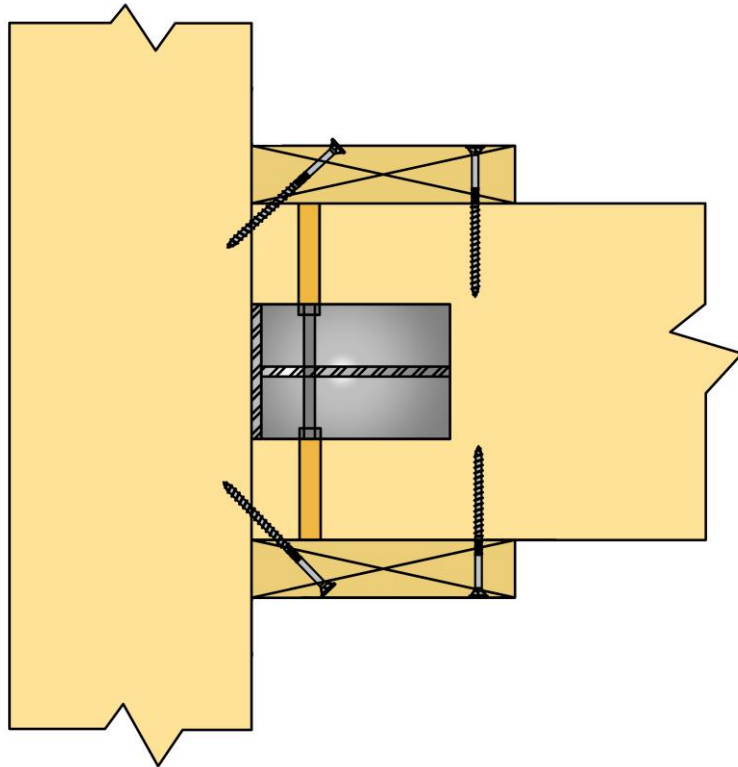
Beam Hanger System



Top View

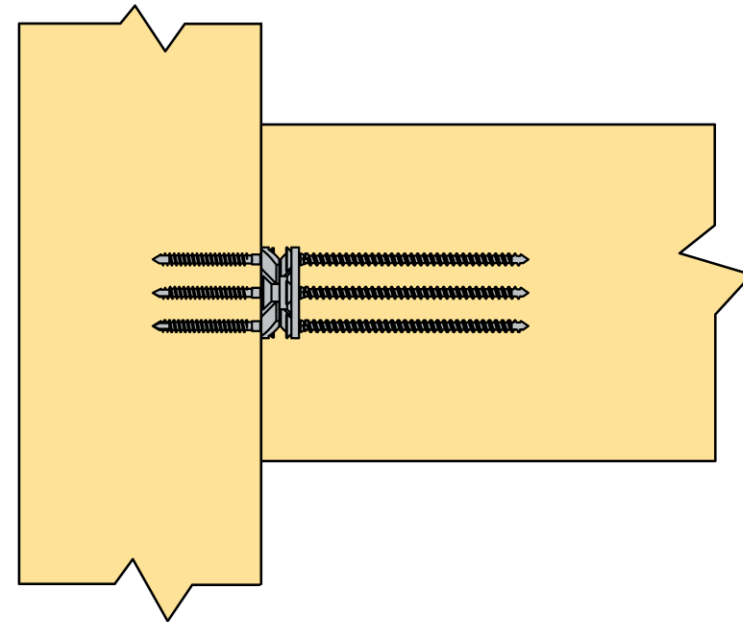
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Top View

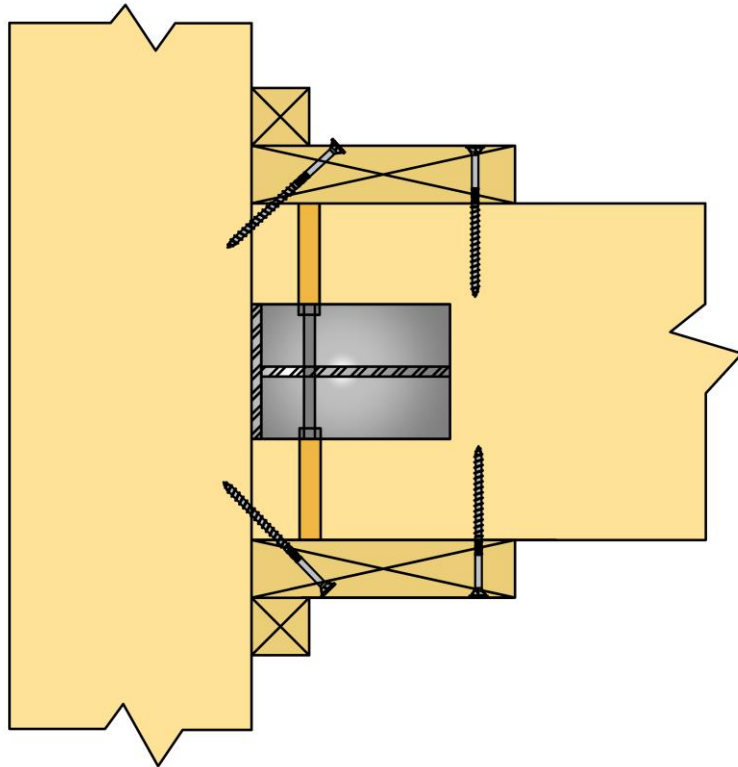
Beam Hanger System



Top View

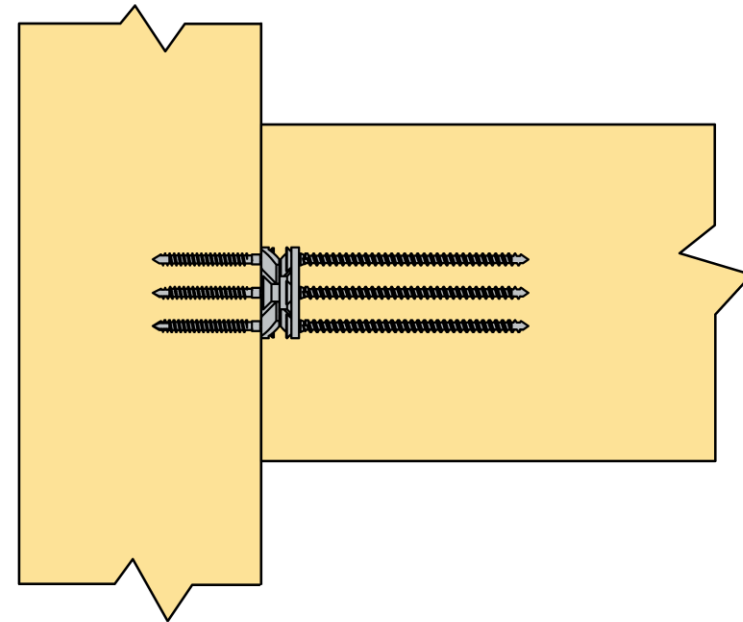
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Top View

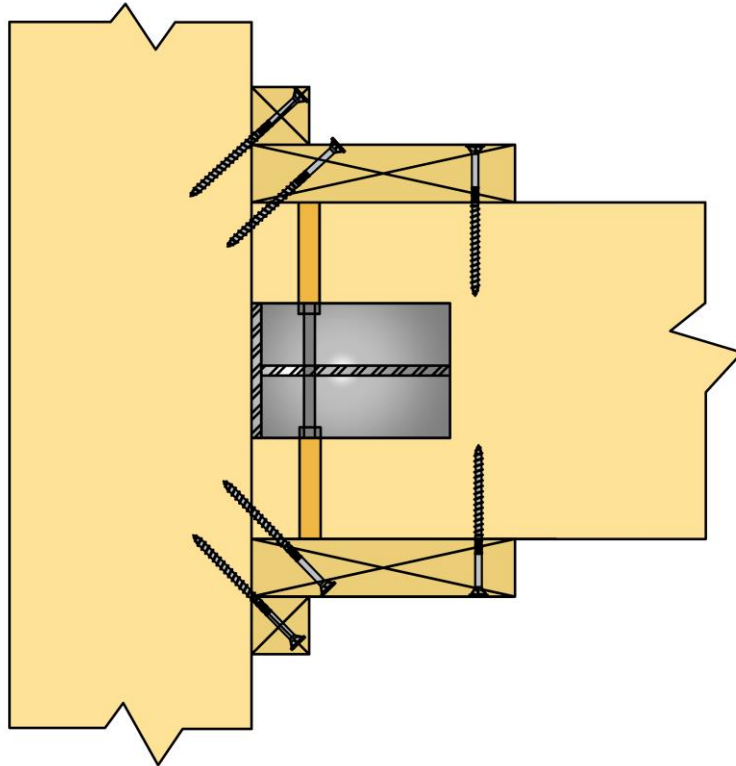
Beam Hanger System



Top View

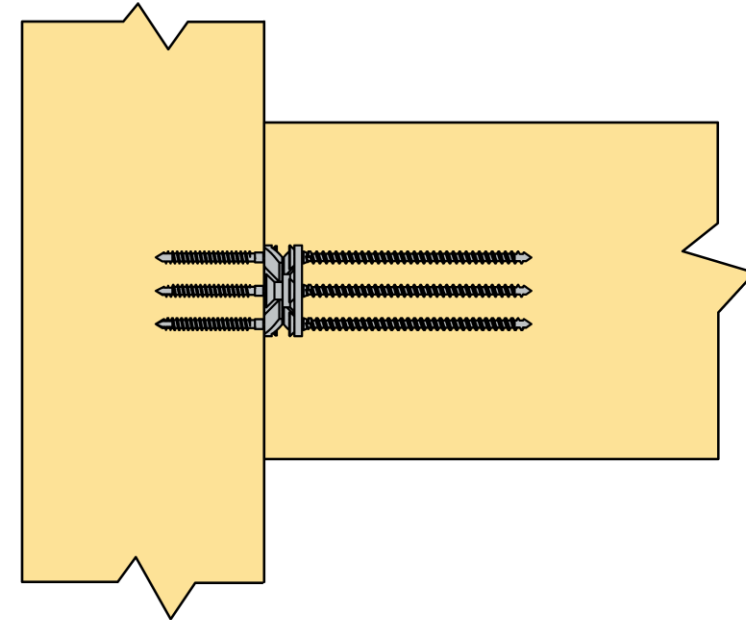
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Standard Connectors



Top View

Beam Hanger System



Top View

Future Testing



References

- WoodWorks Tall Wood Design Resources
 - *Tall Wood Buildings in the 2021 IBC up to 18 Stories of Mass Timber*
(Scott Breneman WoodWorks, Matt Timmers John A. Martin & Associates, Dennis Richardson American Wood Council)
- American Wood Council
 - *Calculating the Fire Resistance of Wood Members and Assemblies*
Technical Report No. 10

Questions?

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