Mass Timber Structural Design Considerations

Presented by Matt Timmers, S.E.

JOHN A. MARTIN ASSOCIATES
STRUCTURAL ENGINEERS

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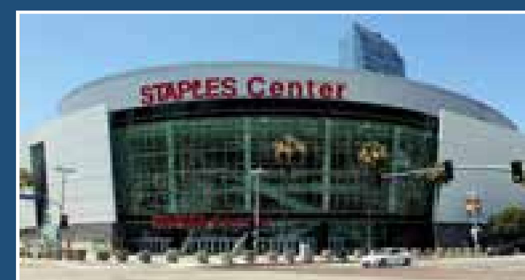
- Founded in Los Angeles in 1953 and delivering innovative Structural Engineering solutions for over 65 years
- Nationally-recognized, award-winning portfolio including the Walt Disney Concert Hall, Emerson College, Ten50 Tower, Tom Bradley International Terminal at LAX, Staples Center, and LA County Natural History Museum



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

Course Description

With more developers and architects exploring mass timber construction, there is a greater need for members of the design team to understand the unique considerations required to successfully implement these projects. This presentation will give an overview of structural-related aspects of mass timber design, including computer modeling, connections, gravity and lateral systems, moisture and shrinkage, construction tolerances, and erection. Discussion will include building code considerations such as fire resistance and construction type selection, along with lessons learned from the presenter's experience designing mass timber projects.

Learning Objectives

1. Review IBC building code requirements for mass timber including fire resistance and construction type.
2. Review gravity and lateral design of mass timber buildings and discuss the available options.
3. Discuss construction-related aspects of mass timber and provide tips to successful erection.
4. Discuss structural design lessons learned from the prospective of a structural engineer.

Sawn Lumber

Glulam

Nail-laminated Timber

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Cross-laminated Timber


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2019 CALIFORNIA BUILDING CODE
2018
IBC
INTERNATIONAL BUILDING CODE
2018
EDITION
NDS
NATIONAL DESIGN SPECIFICATION
for Wood Construction
AMERICAN WOOD COUNCIL
AMERICAN NATIONAL STANDARD
Standard for Performance-Rated Cross-Laminated Timber
ANSI
APA

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a,b]	2[a,b]	1[b]	0	1[b]	0	HT	1[b]	0
Bearing walls Exterior[e,f] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1^1/_2$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

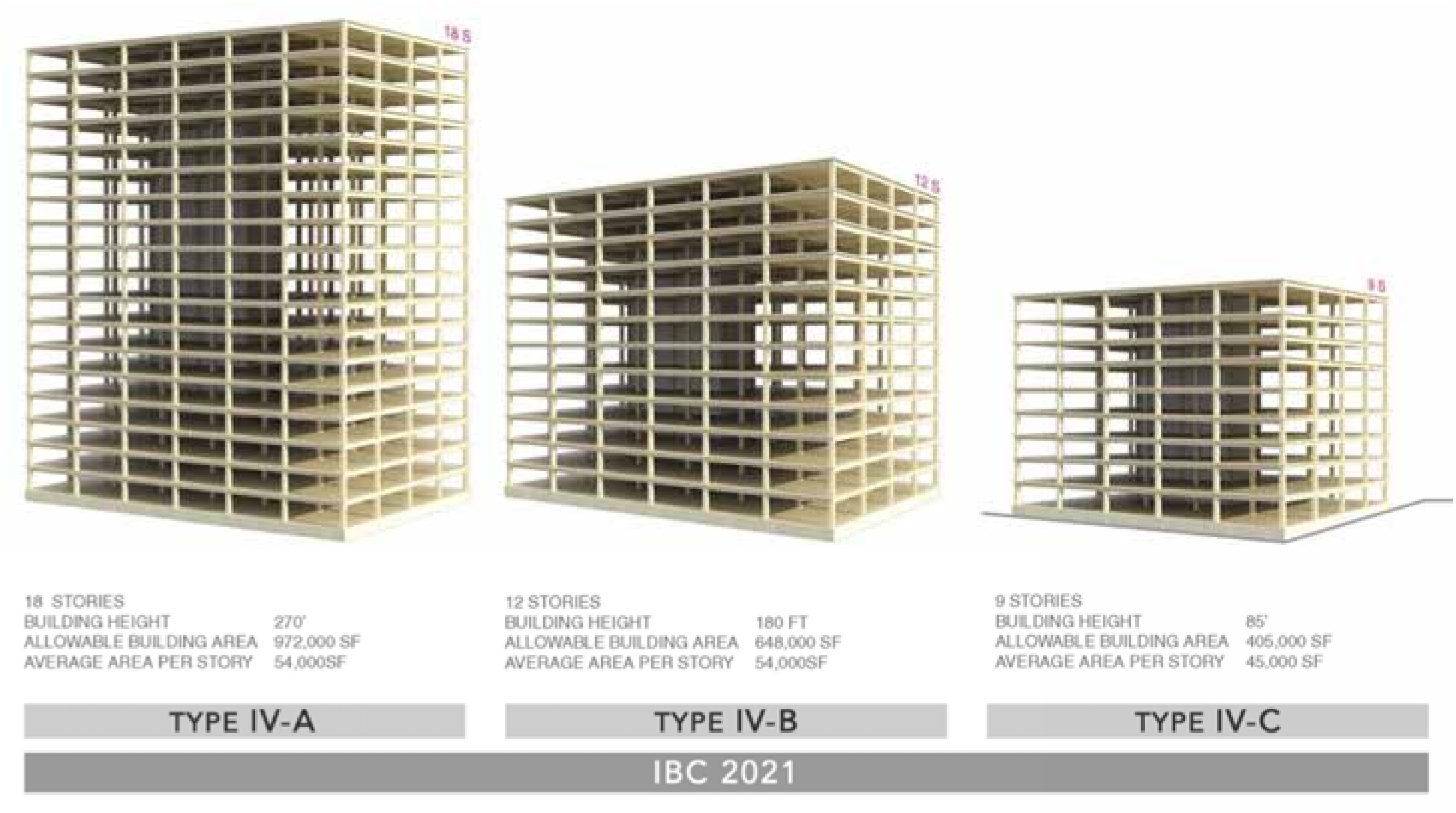
BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a,b]	2[a,b]	1[b]	0	1[b]	0	HT	1[b]	0
Bearing walls Exterior[e,f] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1^1/_2$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

TABLE 504.3
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
H-1, H-2, H-3, H-5	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S									
H-4	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 1, I-3	NS[d, e]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 2, I-2	NS[d, e, f]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85						
I-4	NS[d, g]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
R[h]	NS[d]	UL	160	65	55	65	55	65	50	40
	S13D	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	85	70	60

TABLE 504.3
ALLOWABLE BUILDING HEIGHT IN FEET ABOVE GRADE PLANE[a]

OCCUPANCY CLASSIFICATION	TYPE OF CONSTRUCTION									
	SEE FOOTNOTES	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A, B, E, F, M, S, U	NS[b]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
H-1, H-2, H-3, H-5	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S									
H-4	NS[c, d]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 1, I-3	NS[d, e]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
I-1 Condition 2, I-2	NS[d, e, f]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85						
I-4	NS[d, g]	UL	160	65	55	65	55	65	50	40
	S	UL	180	85	75	85	75	85	70	60
R[h]	NS[d]	UL	160	65	55	65	55	65	50	40
	S13D	60	60	60	60	60	60	60	50	40
	S13R	60	60	60	60	60	60	60	60	60
	S	UL	180	85	75	85	75	85	70	60



Graphic credit: atelierjones, LLC

Table 10.3.1 Applicability of Adjustment Factors for Cross-Laminated Timber

		ASD only	ASD and LRFD						LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Column Stability Factor	Bearing Area Factor	Format Conversion Factor	Resistance Factor	Time Effect Factor
$F_b(S_{eff})' = F_b(S_{eff})$	x	C_D	C_M	C_t	C_L	-	-	2.54	0.85	λ
$F_t(A_{parallel})' = F_t(A_{parallel})$	x	C_D	C_M	C_t	-	-	-	2.70	0.80	λ
$F_v(t_v)' = F_v(t_v)$	x	C_D	C_M	C_t	-	-	-	2.88	0.75	λ
$F_s(Ib/Q)_{eff}' = F_s(Ib/Q)_{eff}$	x	-	C_M	C_t	-	-	-	2.00	0.75	-
$F_c(A_{parallel})' = F_c(A_{parallel})$	x	C_D	C_M	C_t	-	C_P	-	2.40	0.90	λ
$F_{c\perp}(A)' = F_{c\perp}(A)$	x	-	C_M	C_t	-	-	C_b	1.67	0.90	-
$(EI)_{app}' = (EI)_{app}$	x	-	C_M	C_t	-	-	-	-	-	-
$(EI)_{app\text{-}min}' = (EI)_{app\text{-}min}$	x	-	C_M	C_t	-	-	-	1.76	0.85	-

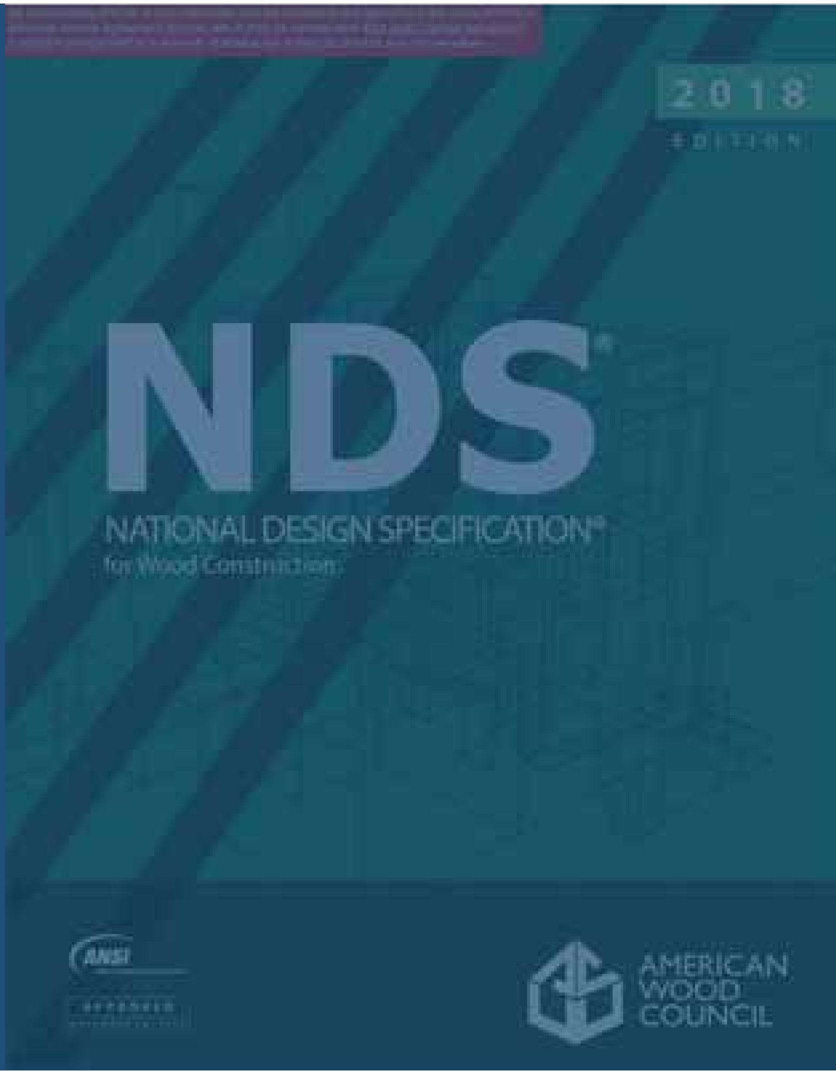


TABLE A2

ASD REFERENCE DESIGN VALUES[a,b,c] FOR CLT (FOR USE IN THE U.S.)

		Lamination Thickness (in.) in CLT Layup							Major Strength Direction				Minor Strength Direction			
CLT Layup	CLT t_p (in.)	=	⊥	=	⊥	=	⊥	=	$(F_bS)_{eff,f,0}$ (lbf-ft/ft of width)	$(EI)_{eff,f,0}$ (10^6 lbf-in.^{2}/ft of width)	$(GA)_{eff,f,0}$ (10^6 lbf/ft of width)	$V_{s,0}$ (lbf/ft of width)	$(F_bS)_{eff,f,90}$ (lbf-ft/ft of width)	$(EI)_{eff,f,90}$ (10^6 lbf-in.^{2}/ft of width)	$(GA)_{eff,f,90}$ (10^6 lbf/ft of width)	$V_{s,90}$ (lbf/ft of width)
E1	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.46	1,430	160	3.1	0.61	495
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			10,400	440	0.92	1,970	1,370	81	1.2	1,430
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	18,375	1,089	1.4	2,490	3,125	309	1.8	1,960
E2	4 1/8	1 3/8	1 3/8	1 3/8					3,825	102	0.53	1,910	165	3.6	0.56	660
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			8,825	389	1.1	2,625	1,430	95	1.1	1,910
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	15,600	963	1.6	3,325	3,275	360	1.7	2,625
E3	4 1/8	1 3/8	1 3/8	1 3/8					2,800	81	0.35	1,110	110	2.3	0.44	385
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			6,400	311	0.69	1,530	955	61	0.87	1,110
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	11,325	769	1.0	1,940	2,180	232	1.3	1,520
E4	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.50	1,750	140	3.4	0.62	605
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			10,400	440	1.0	2,410	1,230	88	1.2	1,750
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	18,400	1,089	1.5	3,050	2,800	335	1.9	2,400
V1	4 1/8	1 3/8	1 3/8	1 3/8					2,090	108	0.53	1,910	165	3.6	0.59	660
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,800	415	1.1	2,625	1,430	95	1.2	1,910
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	8,500	1,027	1.6	3,325	3,275	360	1.8	2,625
V2	4 1/8	1 3/8	1 3/8	1 3/8					2,030	95	0.46	1,430	160	3.1	0.52	495
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,675	363	0.91	1,970	1,370	81	1.0	1,430
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	8,275	898	1.4	2,490	3,125	309	1.6	1,960
V3	4 1/8	1 3/8	1 3/8	1 3/8					1,740	95	0.49	1,750	140	3.4	0.52	605
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			4,000	363	0.98	2,420	1,230	88	1.0	1,750
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	7,100	899	1.5	3,050	2,800	335	1.6	2,400

For SI: 1 in. = 25.4 mm; 1 ft = 304.8 mm; 1 lbf = 4.448 N

a. See Section 4 for symbols.

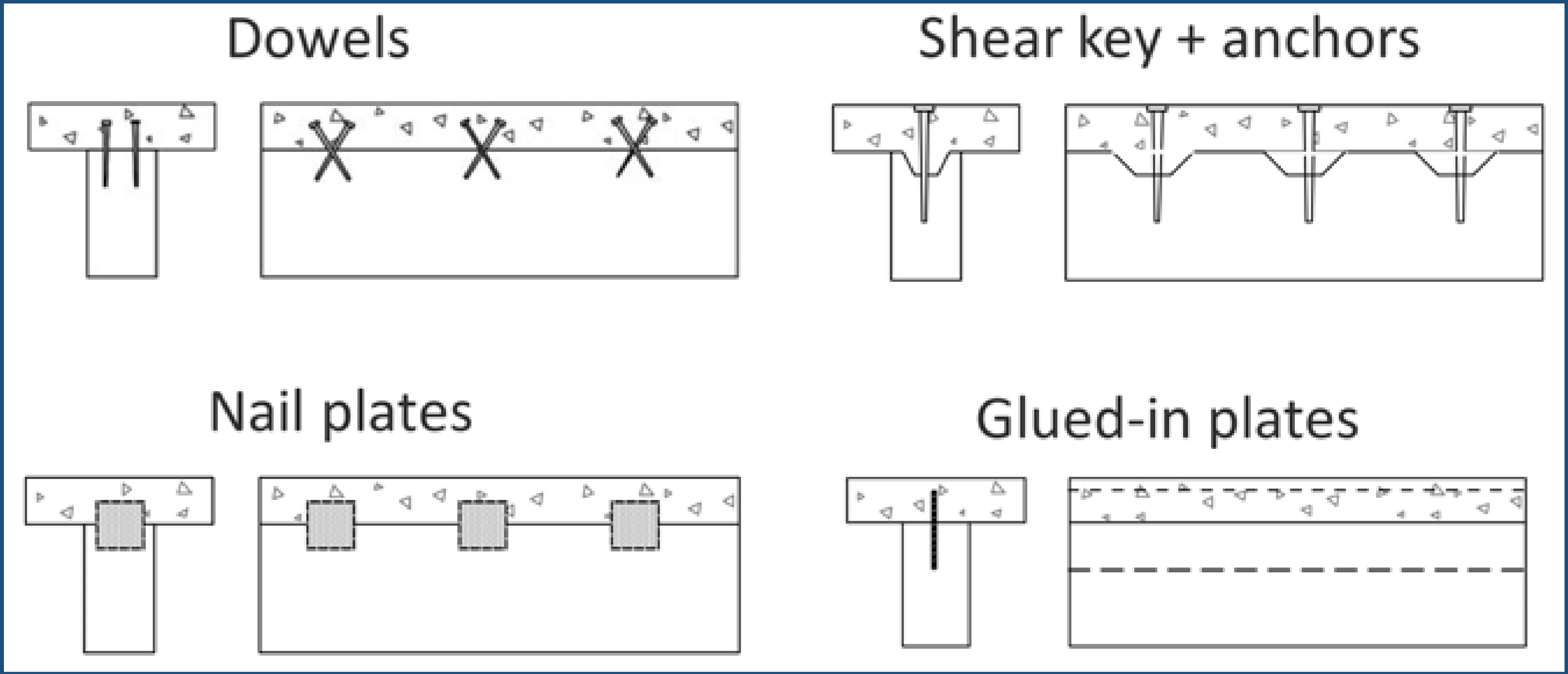
b. This table represents one of many possibilities that the CLT could be manufactured by varying lamination grades, thicknesses, orientations, and layer arrangements in the layup.

c. Custom CLT layups that are not listed in this table shall be permitted in accordance with 7.2.1.

Timber-Concrete Composite

Graphic credit: Structurecraft

Types of Shear Connectors



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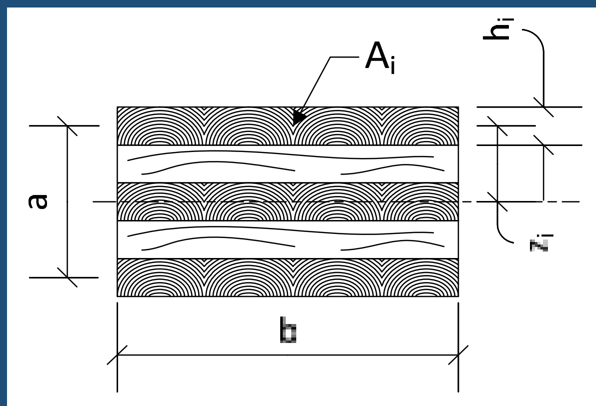
Computer Modelling Composite CLT Floor



$$EI_{eff} = \sum_{i=1}^{n} E_i b_i \frac{{E_i}^3}{12} + \sum_{i=1}^{n} E_i A_i {z_i}^2$$

$$GA_{eff} = \frac{a^2}{\left[\left(\frac{h_1}{2G_1 b}\right) + \left(\sum_{i=2}^{n-1} \frac{h_i}{G_i b}\right) + \left(\frac{h_1}{2G_1 b}\right)\right]}$$

Layer	h (in)	Orientation to Span	Material	E (psi)	z (in)	$Ebh^3/12$ (lb-in^2)	EAz^2 (lb-in^2)	$Ebh^3/12+EAz^2$ (lb-in^2)	G (psi)	h/(Gb) (in^2/lb)
1	1.375	Parallel	Wood	1,500,000	2.75	3,899,414	187,171,875	191,071,289	93,750	0.00000122
2	1.375	Perpendicular	Wood	46,667	1.375	121,315	1,455,781	1,577,096	8,750	0.00001310
3	1.375	Parallel	Wood	1,500,000	0	3,899,414	0	3,899,414	93,750	0.00000122
4	1.375	Perpendicular	Wood	46,667	1.375	121,315	1,455,781	1,577,096	8,750	0.00001310
5	1.375	Parallel	Wood	1,500,000	2.75	3,899,414	187,171,875	191,071,289	93,750	0.00000122
t_{total} =	6.875				Effective Bending Stiffness EI_{eff} =			389,196,185 lb-in^2		
					Effective Shear Stiffness GA_{eff} =			1,056,402 lb		

Calculated Effective Stiffness Properties for five-ply CLT Panel

Layer	h (in)	Orientation to Span	Material	E (psi)	z (in)	$Ebh^3/12$ (lb-in^2)	EAz^2 (lb-in^2)	Sum of Layer	G (psi)	h/(Gb) (in^2/lb)
1	2.500	Parallel	Concrete	3,155,924	3.4375	49,311,316	1,118,750,491	1,168,061,808	1,314,968	0.00000016
2	1.375	Parallel	Wood	1,500,000	1.5	3,899,414	55,687,500	59,586,914	93,750	0.00000122
3	1.375	Perpendicular	Wood	46,667	0.125	121,315	12,031	133,346	8,750	0.00001310
4	1.375	Parallel	Wood	1,500,000	1.25	3,899,414	38,671,875	42,571,289	93,750	0.00000122
5	1.375	Perpendicular	Wood	46,667	2.625	121,315	5,305,781	5,427,096	8,750	0.00001310
6	1.375	Parallel	Wood	1,500,000	4	3,899,414	396,000,000	399,899,414	93,750	0.00000122
t_{total} =	9.375				Effective Bending Stiffness EI_{eff} =			1,675,679,867 lb-in^2		
					Effective Shear Stiffness GA_{eff} =			1,886,307 lb		

Calculated Effective Stiffness Properties for five-ply CLT Panel with 2.5" Concrete

Layer	h (in)	Orientation to Span	Material	E (psi)	z (in)	$Ebh^3/12$ (lb-in^2)	EAz^2 (lb-in^2)	$Ebh^3/12+EAz^2$ (lb-in^2)	G (psi)	h/(Gb) (in^2/lb)
1	1.375	Parallel	Wood	1,500,000	2.75	3,899,414	187,171,875	191,071,289	93,750	0.00000122
2	1.375	Perpendicular	Wood	46,667	1.375	121,315	1,455,781	1,577,096	8,750	0.00001310
3	1.375	Parallel	Wood	1,500,000	0	3,899,414	0	3,899,414	93,750	0.00000122
4	1.375	Perpendicular	Wood	46,667	1.375	121,315	1,455,781	1,577,096	8,750	0.00001310
5	1.375	Parallel	Wood	1,500,000	2.75	3,899,414	187,171,875	191,071,289	93,750	0.00000122
t_{total} =	6.875				Effective Bending Stiffness EI_{eff} =			389,196,185 lb-in^2		
					Effective Shear Stiffness GA_{eff} =			1,056,402 lb		

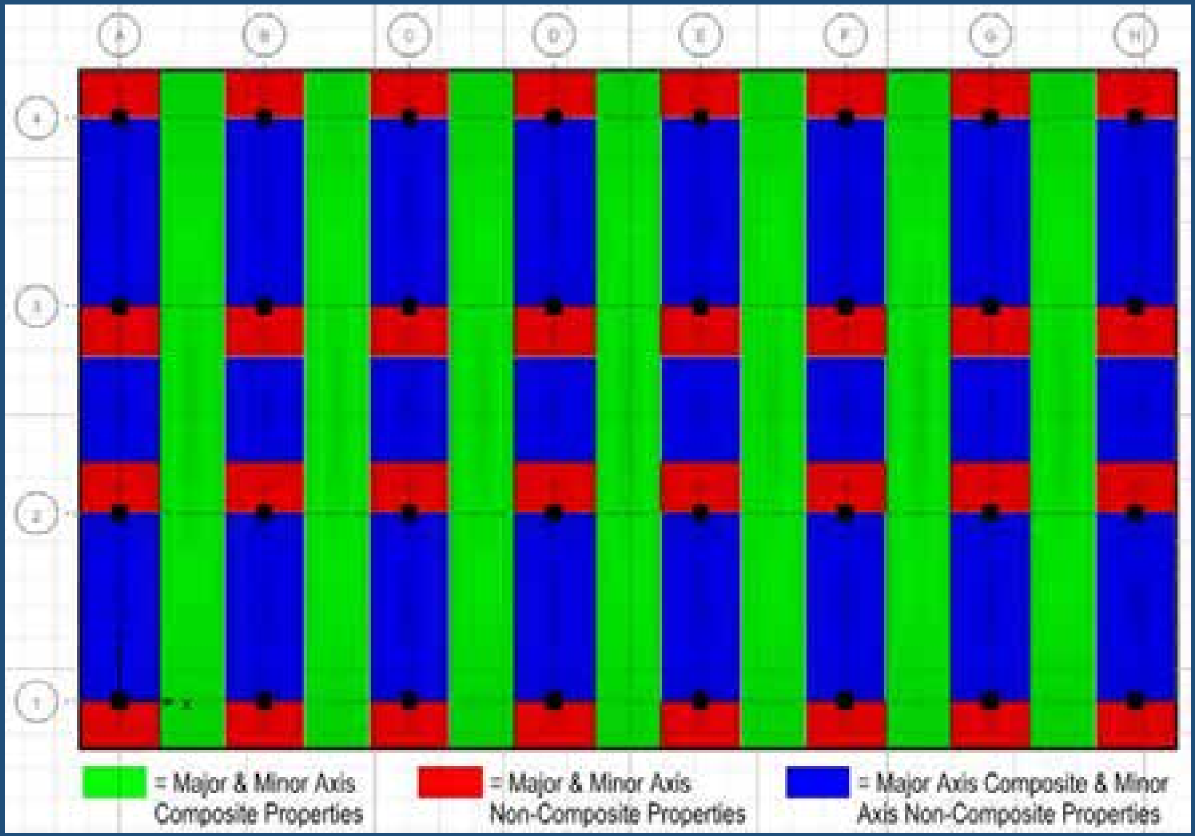
Calculated Effective Stiffness Properties for five-ply CLT Panel

Layer	h (in)	Orientation to Span	Material	E (psi)	z (in)	$Ebh^3/12$ (lb-in^2)	EAz^2 (lb-in^2)	Sum of Layer	G (psi)	h/(Gb) (in^2/lb)
1	2.500	Parallel	Concrete	3,155,924	3.4375	49,311,316	1,118,750,491	1,168,061,808	1,314,968	0.00000016
2	1.375	Parallel	Wood	1,500,000	1.5	3,899,414	55,687,500	59,586,914	93,750	0.00000122
3	1.375	Perpendicular	Wood	46,667	0.125	121,315	12,031	133,346	8,750	0.00001310
4	1.375	Parallel	Wood	1,500,000	1.25	3,899,414	38,671,875	42,571,289	93,750	0.00000122
5	1.375	Perpendicular	Wood	46,667	2.625	121,315	5,305,781	5,427,096	8,750	0.00001310
6	1.375	Parallel	Wood	1,500,000	4	3,899,414	396,000,000	399,899,414	93,750	0.00000122
t_{total} =	9.375				Effective Bending Stiffness EI_{eff} =			1,675,679,867 lb-in^2		
					Effective Shear Stiffness GA_{eff} =			1,886,307 lb		

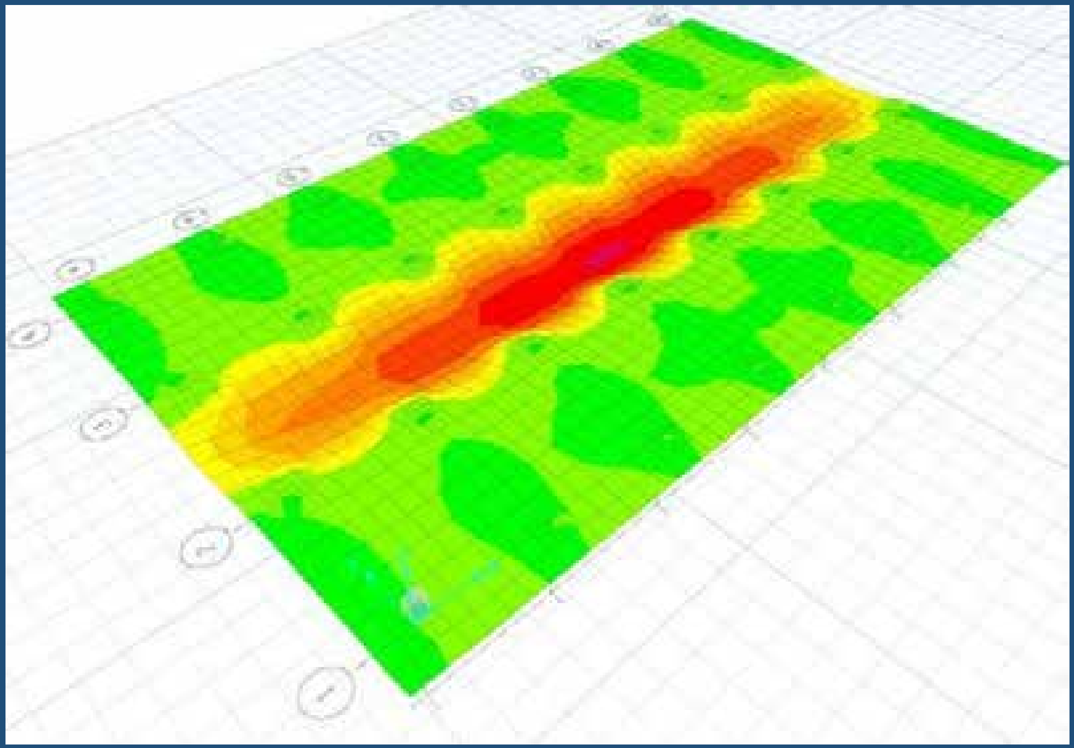
= 4.3 TIMES!

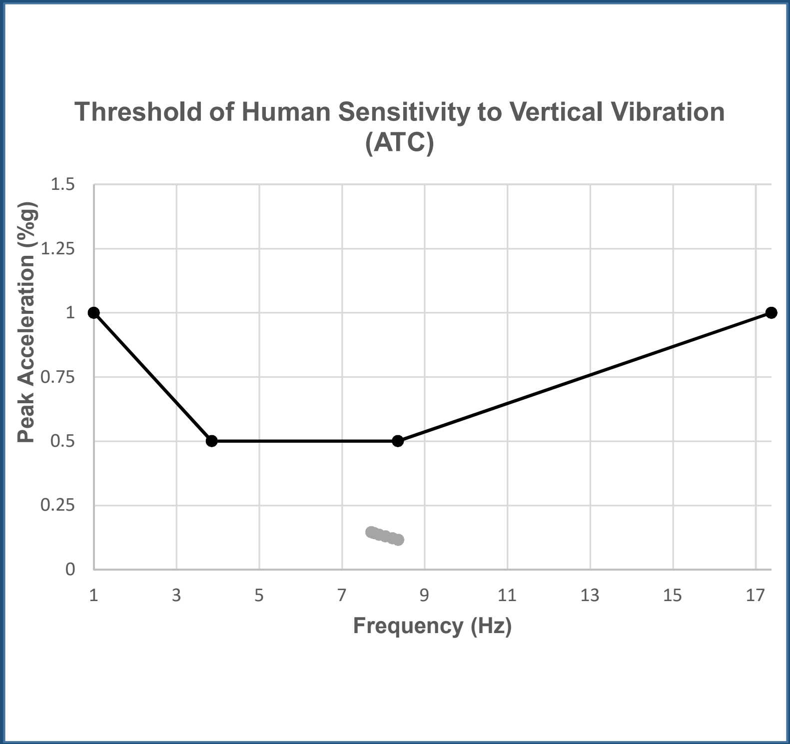
Calculated Effective Stiffness Properties for five-ply CLT Panel with 2.5" Concrete

Computer Modelling Composite CLT Floor

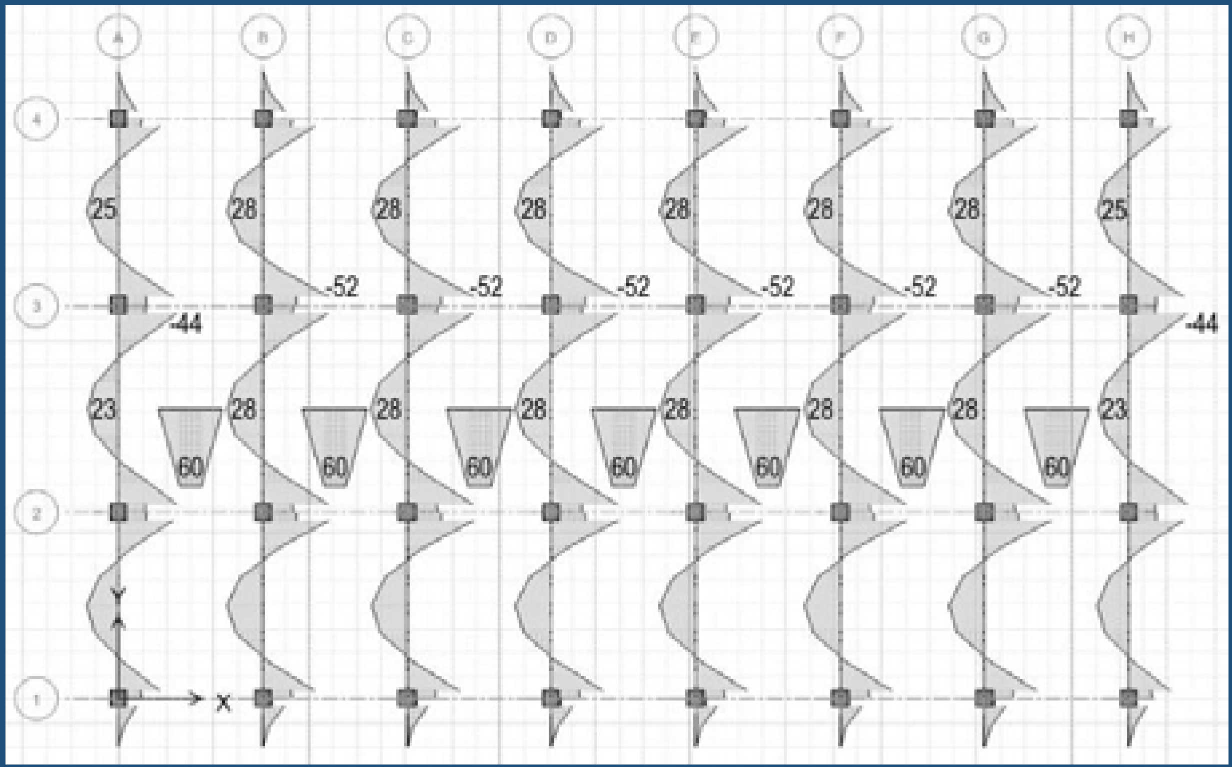


Vibration of Composite CLT Floor





Flexural Strength of CLT Floor

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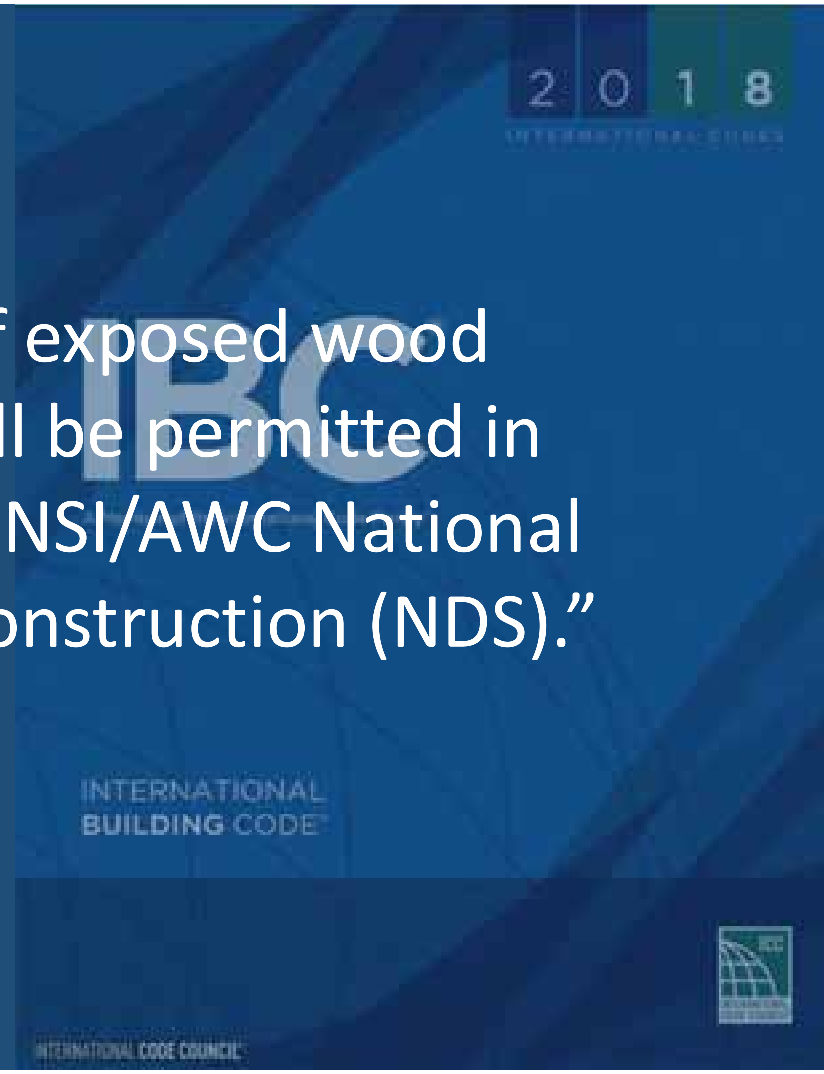
AMERICAN WOOD COUNCIL
NDS
Calculating the Fire Resistance of Wood Members and Assemblies
Technical Report No. 10
AMERICAN WOOD COUNCIL

IBC Section 722

"The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AWC National Design Specification for Wood Construction (NDS)."



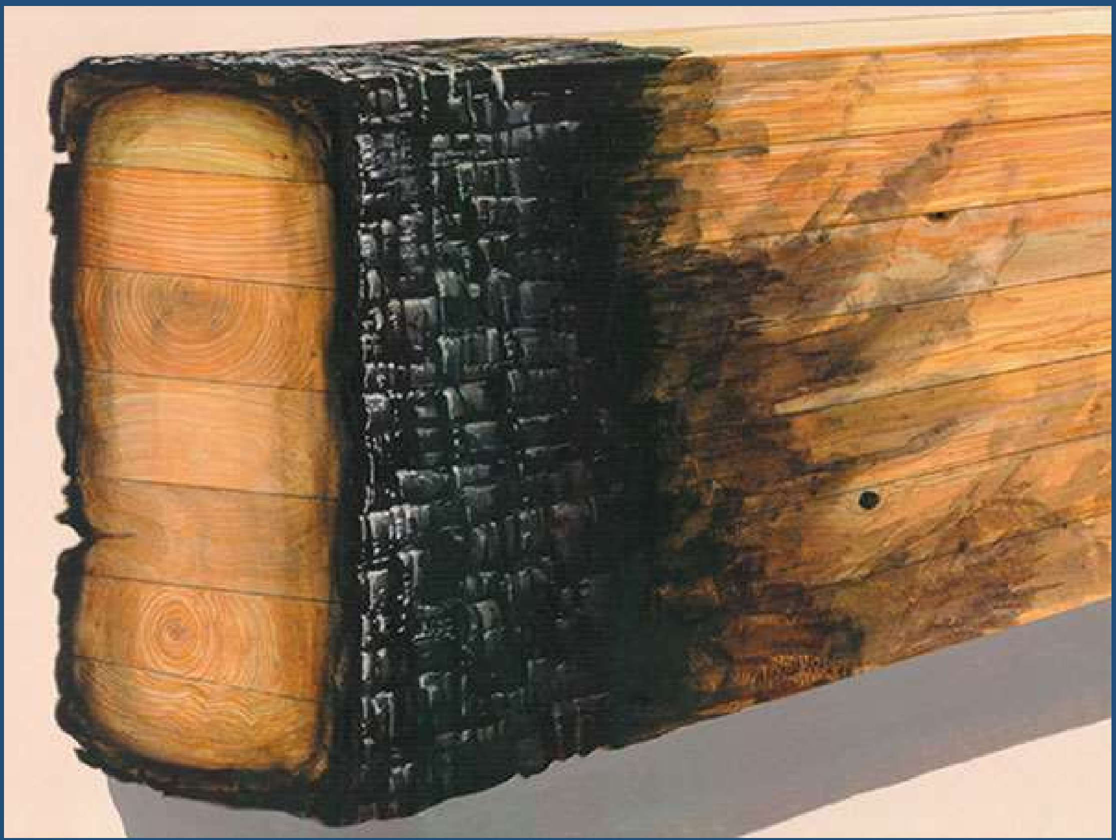


Table 16.2.1A Char Depth and Effective Char Depth (for β_n = 1.5 in./hr.)

Required Fire Resistance (hr.)	Char Depth, a_{char} (in.)	Effective Char Depth, a_{eff} (in.)
1-Hour	1.5	1.8
1½-Hour	2.1	2.5
2-Hour	2.6	3.2

Table 16.2.1B Effective Char Depths (for CLT with β_n = 1.5in./hr.)

Required Fire Resistance (hr.)	Effective Char Depths, a_{eff} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

Table 16.2.2 Adjustment Factors for Fire Design[1]

			ASD					
			Design Stress to Member Strength Factor	Size Factor [2]	Volume Factor [2]	Flat Use Factor [2]	Beam Stability Factor [3]	Column Stability Factor [3]
Bending Strength	F_b	x	2.85	C_F	C_V	C_{fu}	C_L	-
Beam Buckling Strength	F_{bE}	x	2.03	-	-	-	-	-
Tensile Strength	F_t	x	2.85	C_F	-	-	-	-
Compressive Strength	F_c	x	2.58	C_F	-	-	-	C_P
Column Buckling Strength	F_{cE}	x	2.03	-	-	-	-	-

1. See 4.3, 5.3, 8.3, and 10.3 for applicability of adjustment factors for specific products.
2. Factor shall be based on initial cross-section dimensions.
3. Factor shall be based on reduced cross-section dimensions.

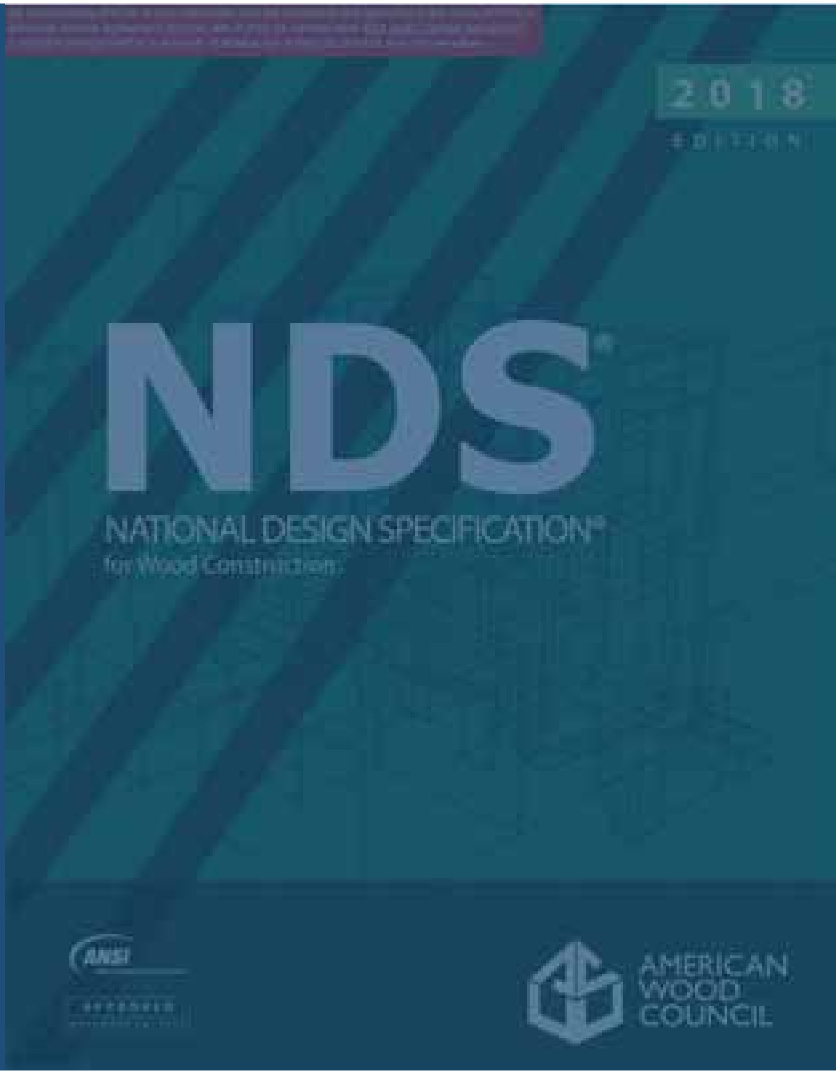
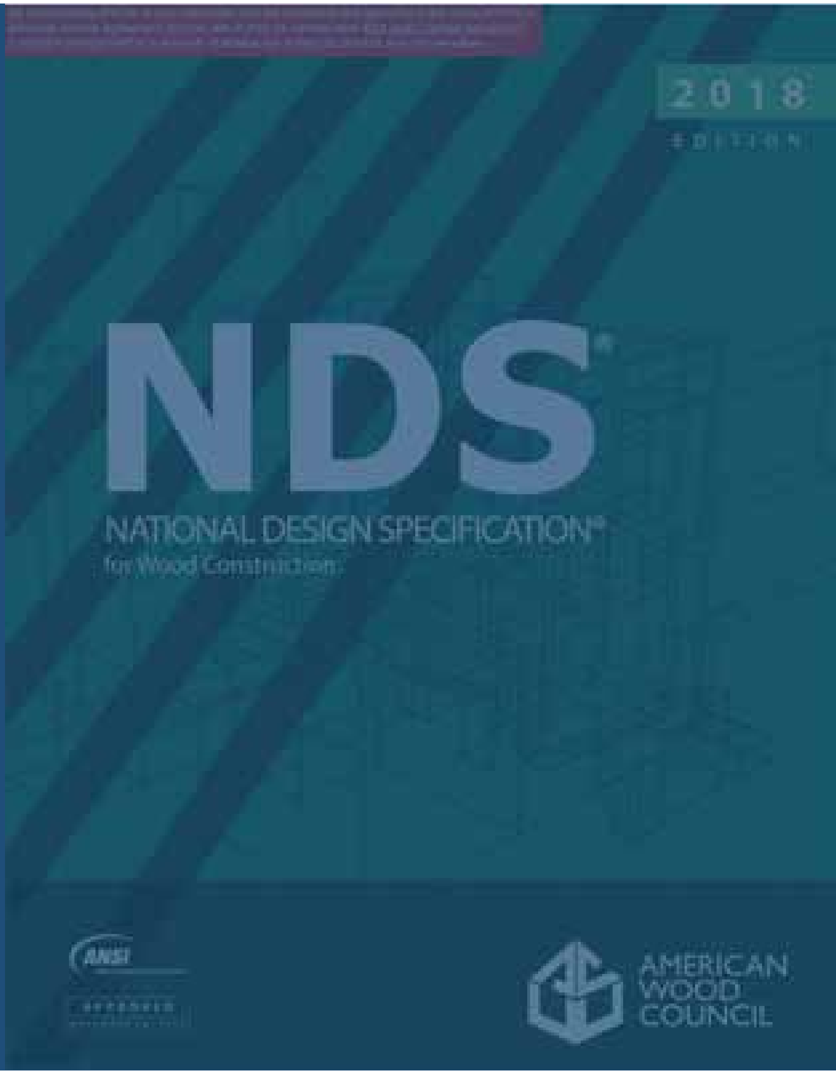


Table 16.2.2 Adjustment Factors for Fire Design[1]

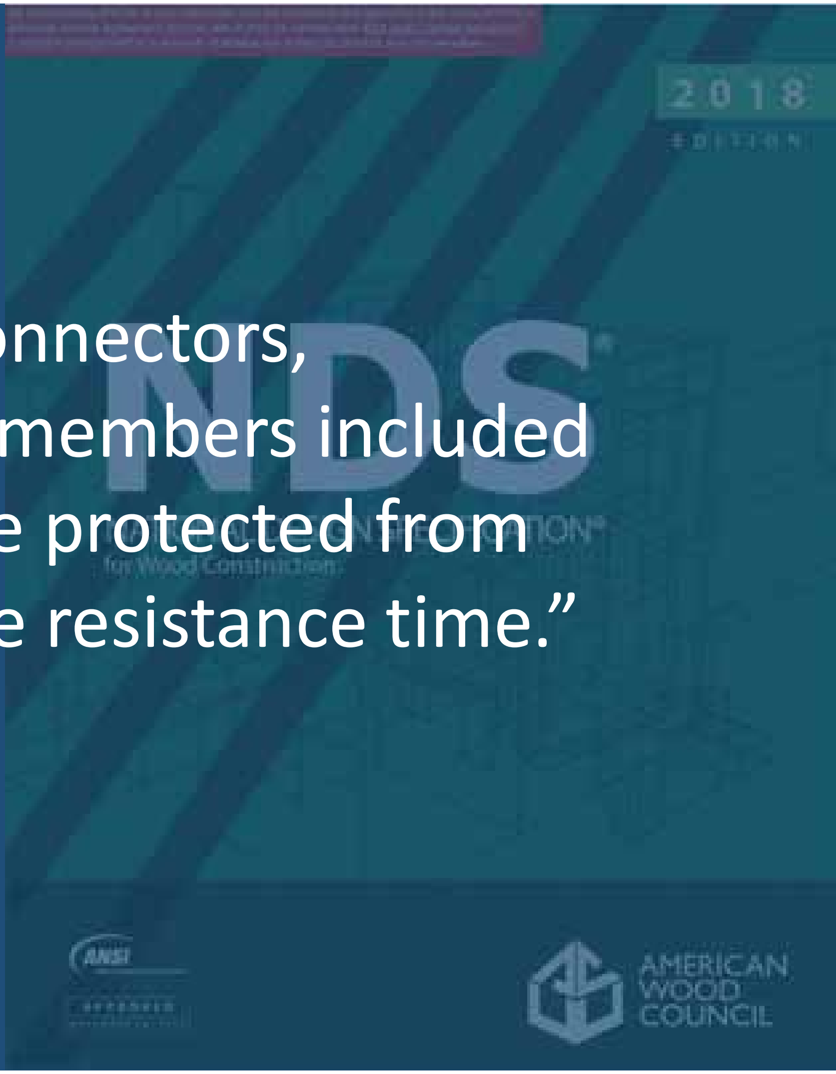
			ASD					
			Design Stress to Member Strength Factor	Size Factor [2]	Volume Factor [2]	Flat Use Factor [2]	Beam Stability Factor [3]	Column Stability Factor [3]
Bending Strength	F_b	x	2.85	C_F	C_V	C_{fu}	C_L	-
Beam Buckling Strength	F_{bE}	x	2.03	-	-	-	-	-
Tensile Strength	F_t	x	2.85	C_F	-	-	-	-
Compressive Strength	F_c	x	2.58	C_F	-	-	-	C_P
Column Buckling Strength	F_{cE}	x	2.03	-	-	-	-	-

1. See 4.3, 5.3, 8.3, and 10.3 for applicability of adjustment factors for specific products.
2. Factor shall be based on initial cross-section dimensions.
3. Factor shall be based on reduced cross-section dimensions.



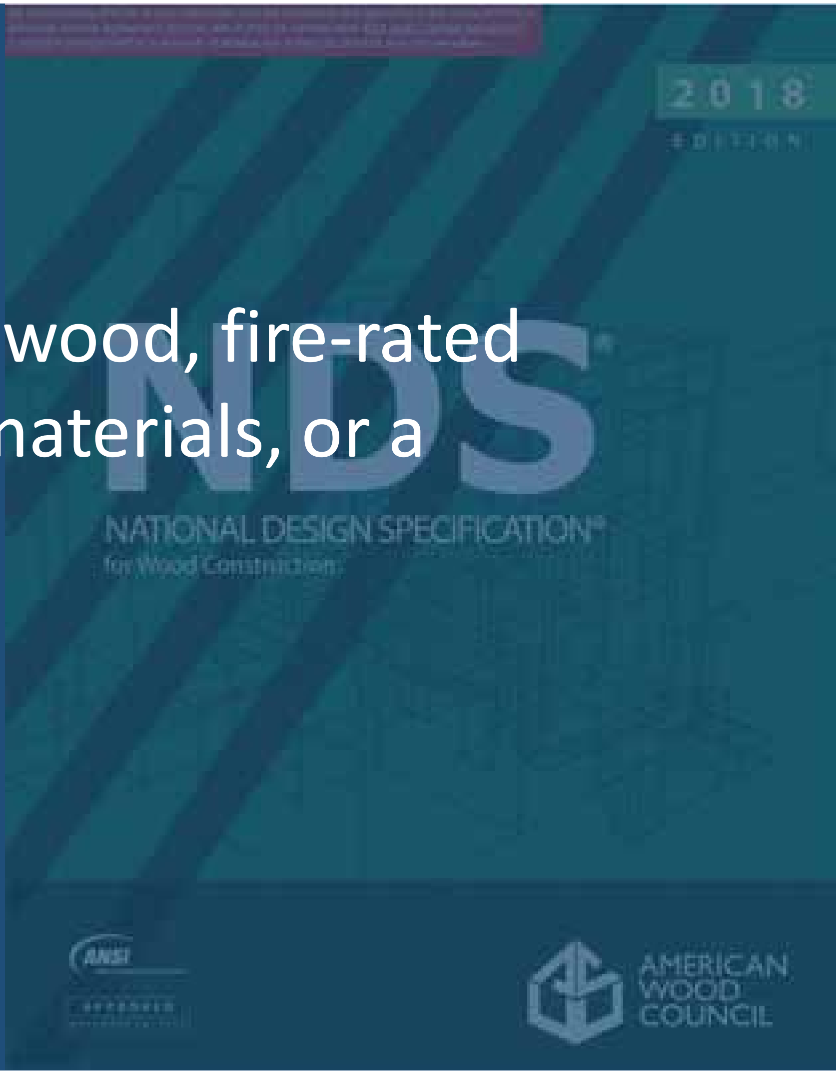
NDS Section 16.3

“Wood connections, including connectors, fasteners, and portions of wood members included in the connection design, shall be protected from fire exposure for the required fire resistance time.”



NDS Section 16.3

"Protection shall be provided by wood, fire-rated gypsum board, other approved materials, or a combination thereof."



NDS Section C16.2

“The mechanics-based design procedures in the Specification for exposed wood members are based on research described in AWC’s Technical Report 10: Calculating the Fire Resistance of Exposed and Protected Wood Members.”

TR10 Section 4.4

"Where protective materials are used to increase the fire resistance of structural wood members and connections, the added contribution from the protective material shall be determined either by testing or engineering based on assigned design values."

TR10 Part IV

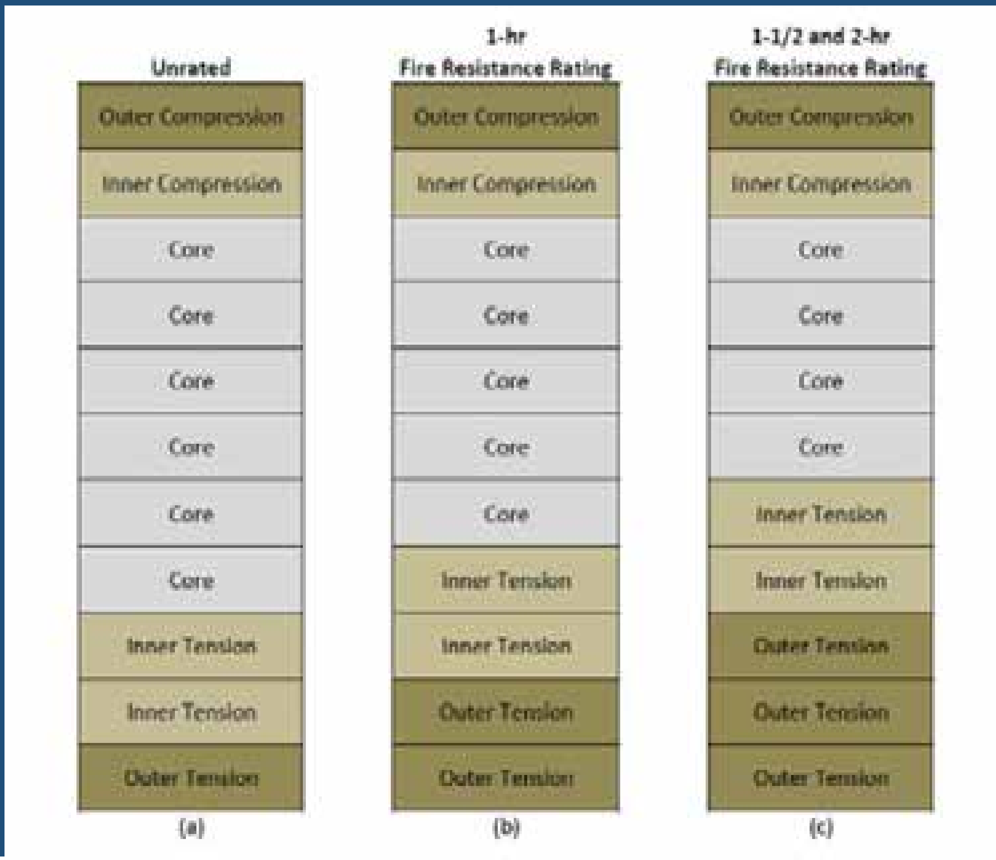
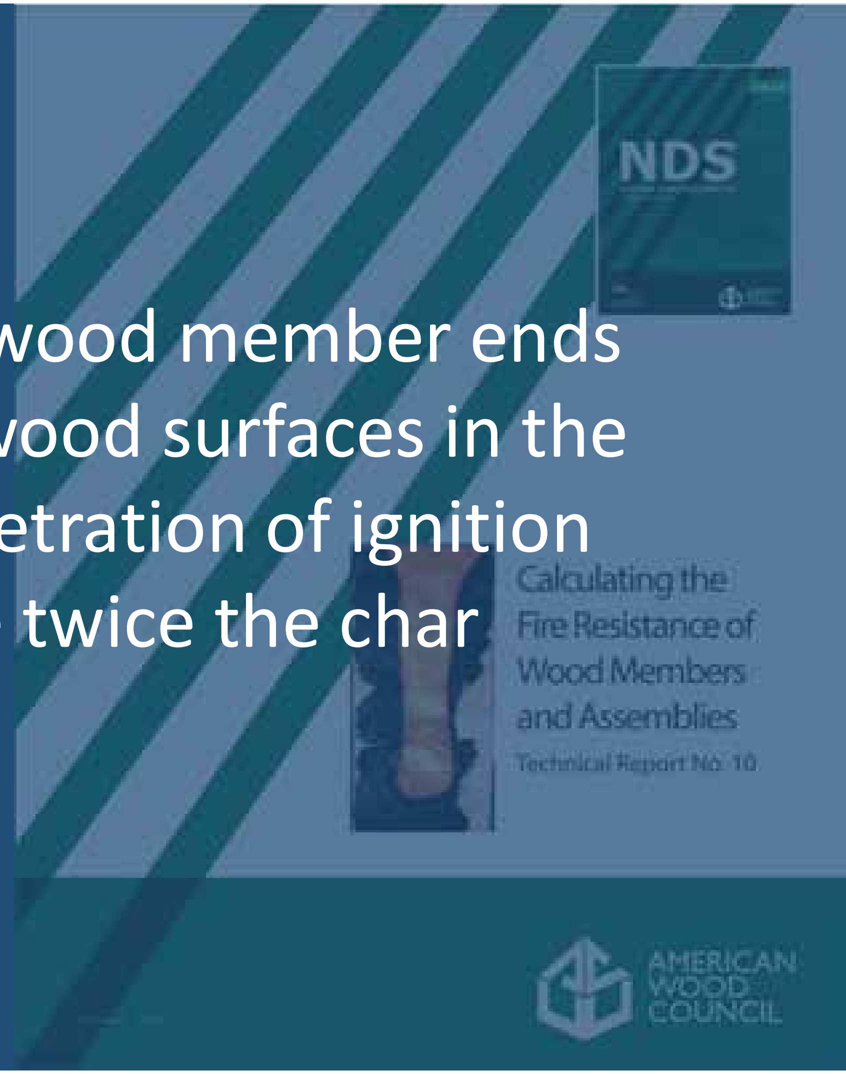


Figure 4-1 Typical Unbalanced Beam Layup

TR10 Section 4.5

"Char contraction at unbonded wood member ends and edges results in ignition of wood surfaces in the gaps at these locations. The penetration of ignition into these gaps is assumed to be twice the char depth, $2a_{char}$."



TR10 Section 1.5.1 Char Contraction

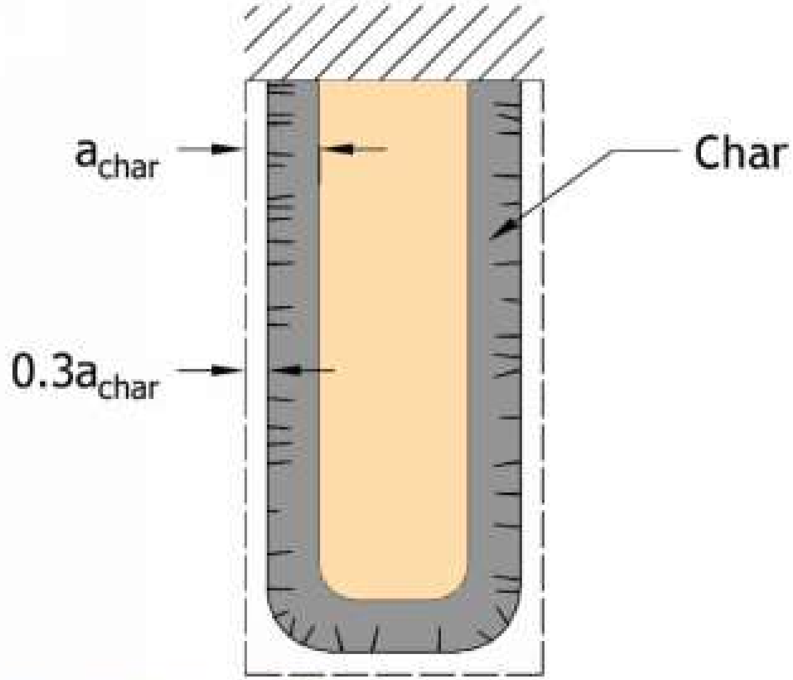


Figure 1-3: Char contraction

TR10 Section 1.5.1 Char Contraction

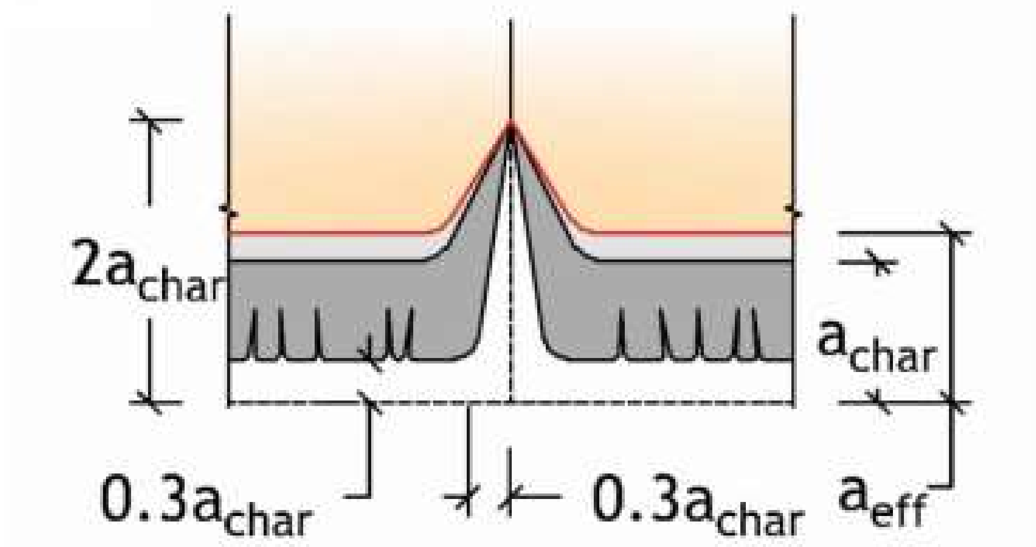
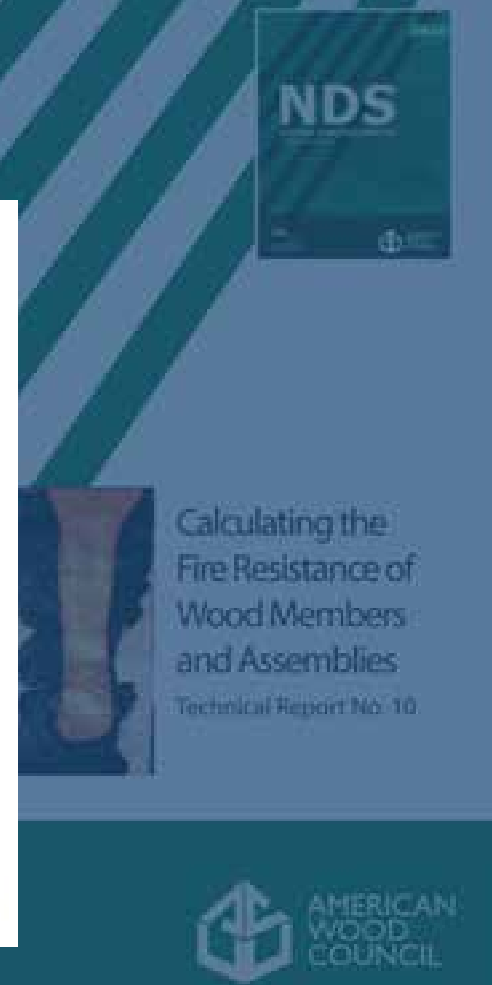


Figure 1-4 Char contraction at abutting wood members that are unbonded



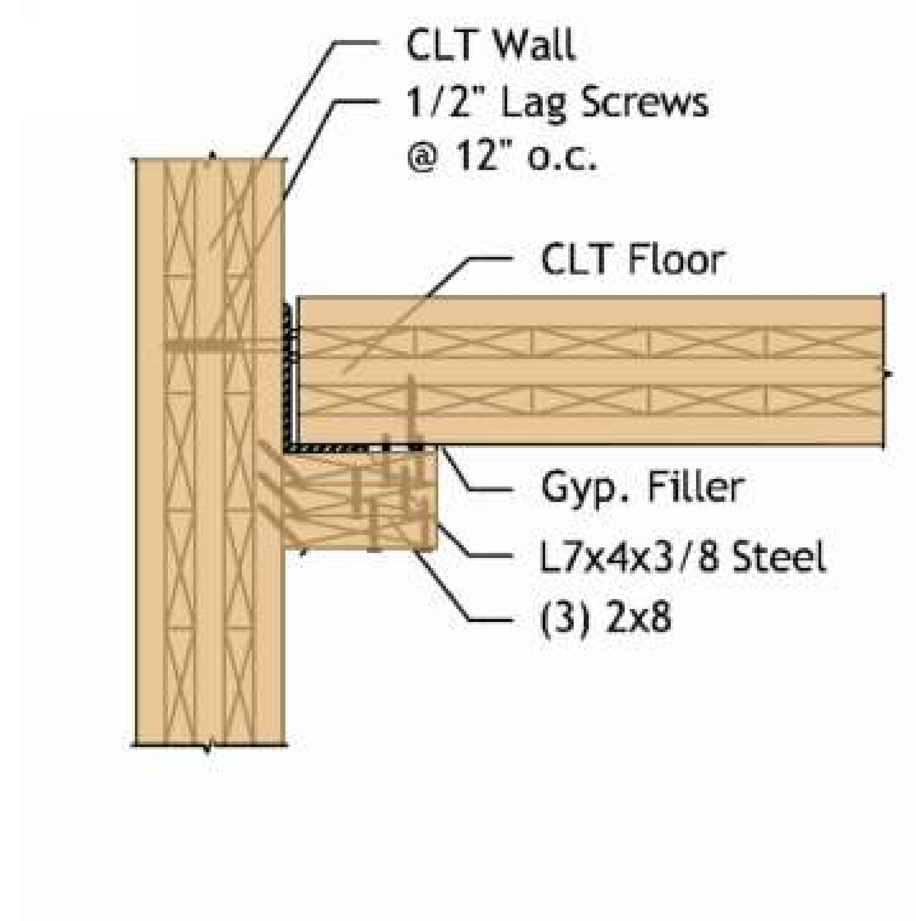


Figure 8-1. Initial wood cover design

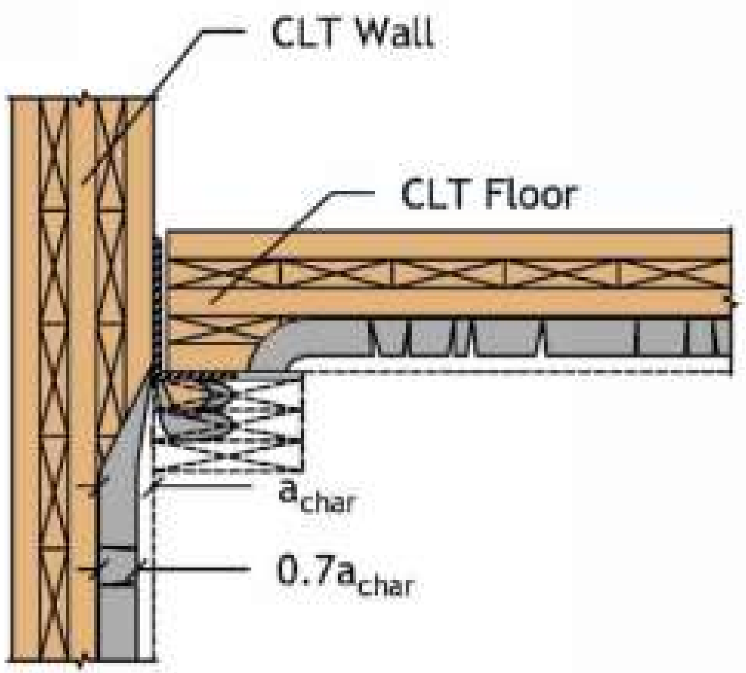


Figure 8-2. Char pattern due to char contraction

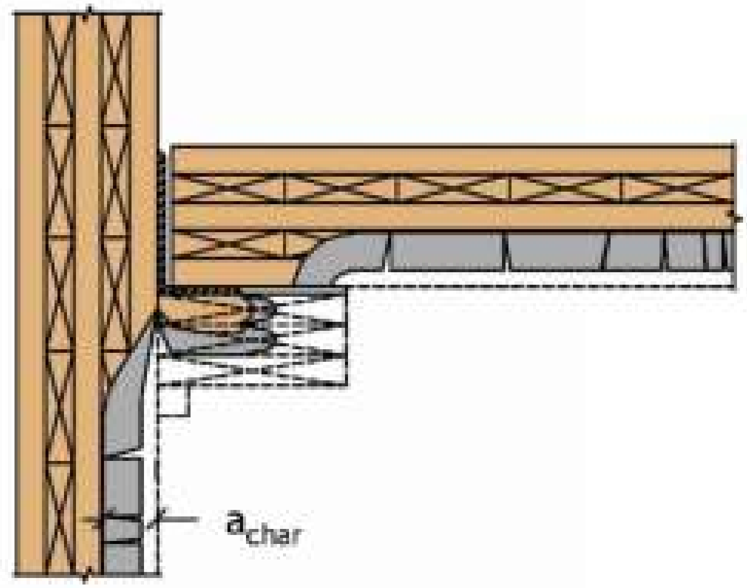


Figure 8-3. Char pattern with wood strip added

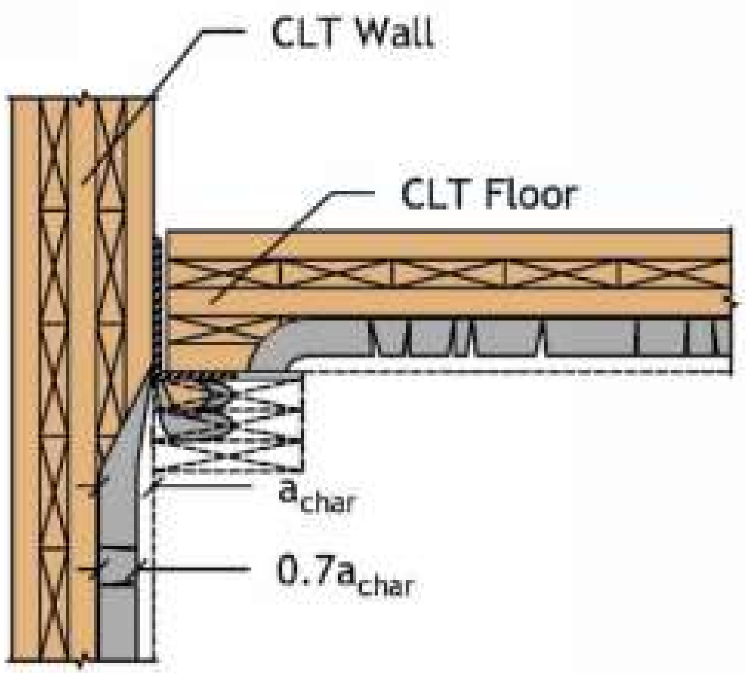


Figure 8-2. Char pattern due to char contraction

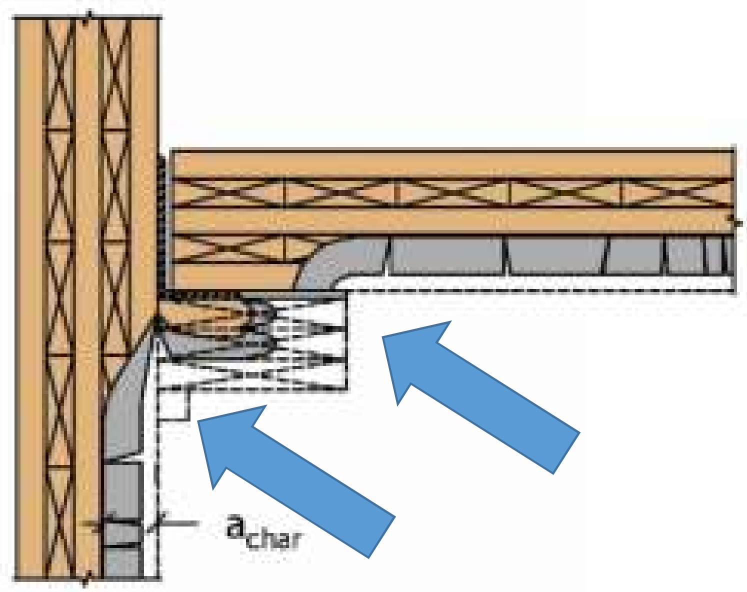


Figure 8-3. Char pattern with wood strip added

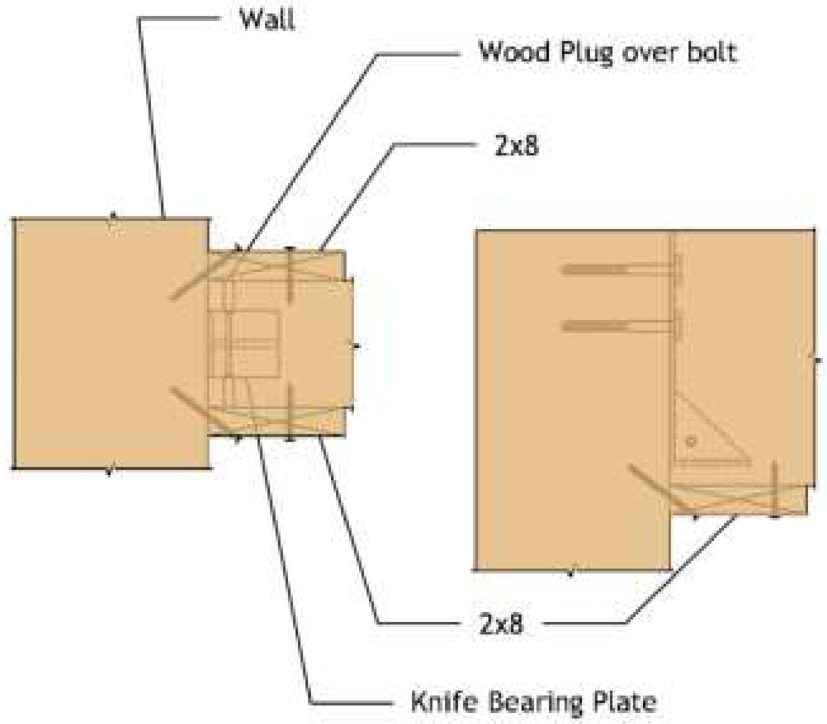


Figure 9-2. Design of wood cover

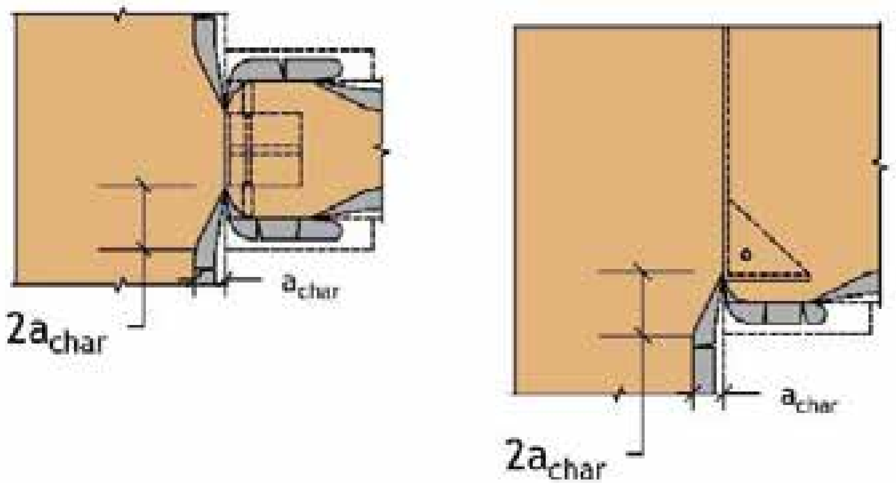


Figure 9-3. Char pattern due to char contraction

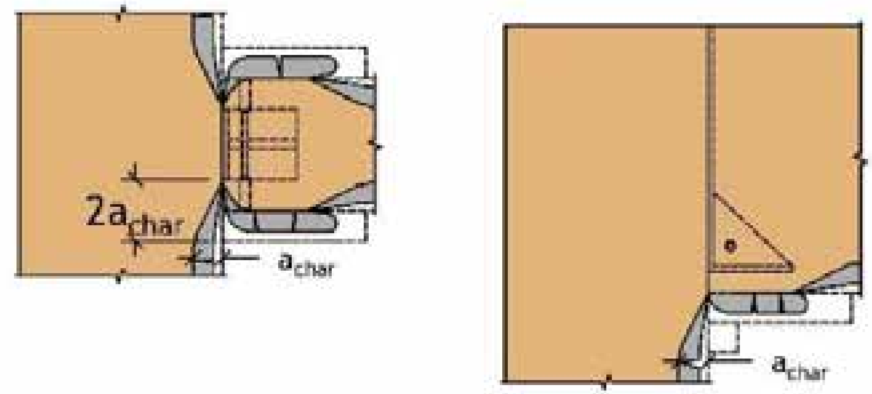


Figure 9-4. Char pattern with wood strip added

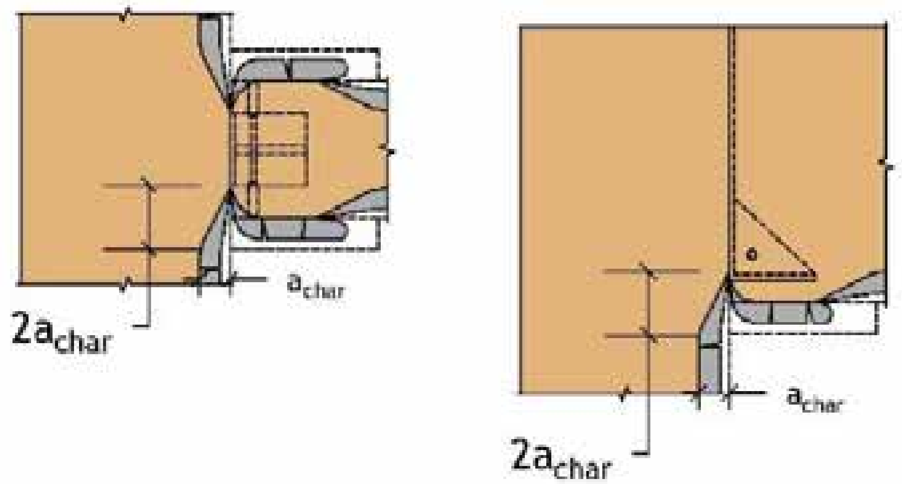


Figure 9-3. Char pattern due to char contraction

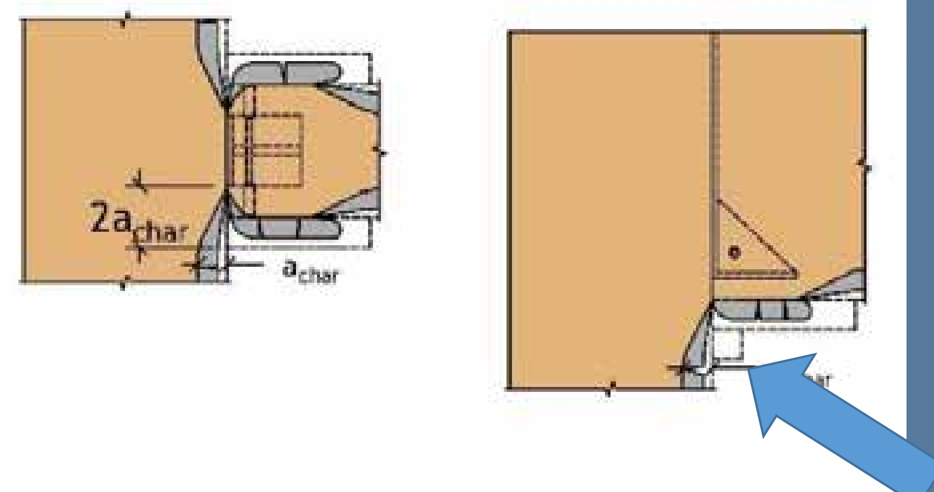
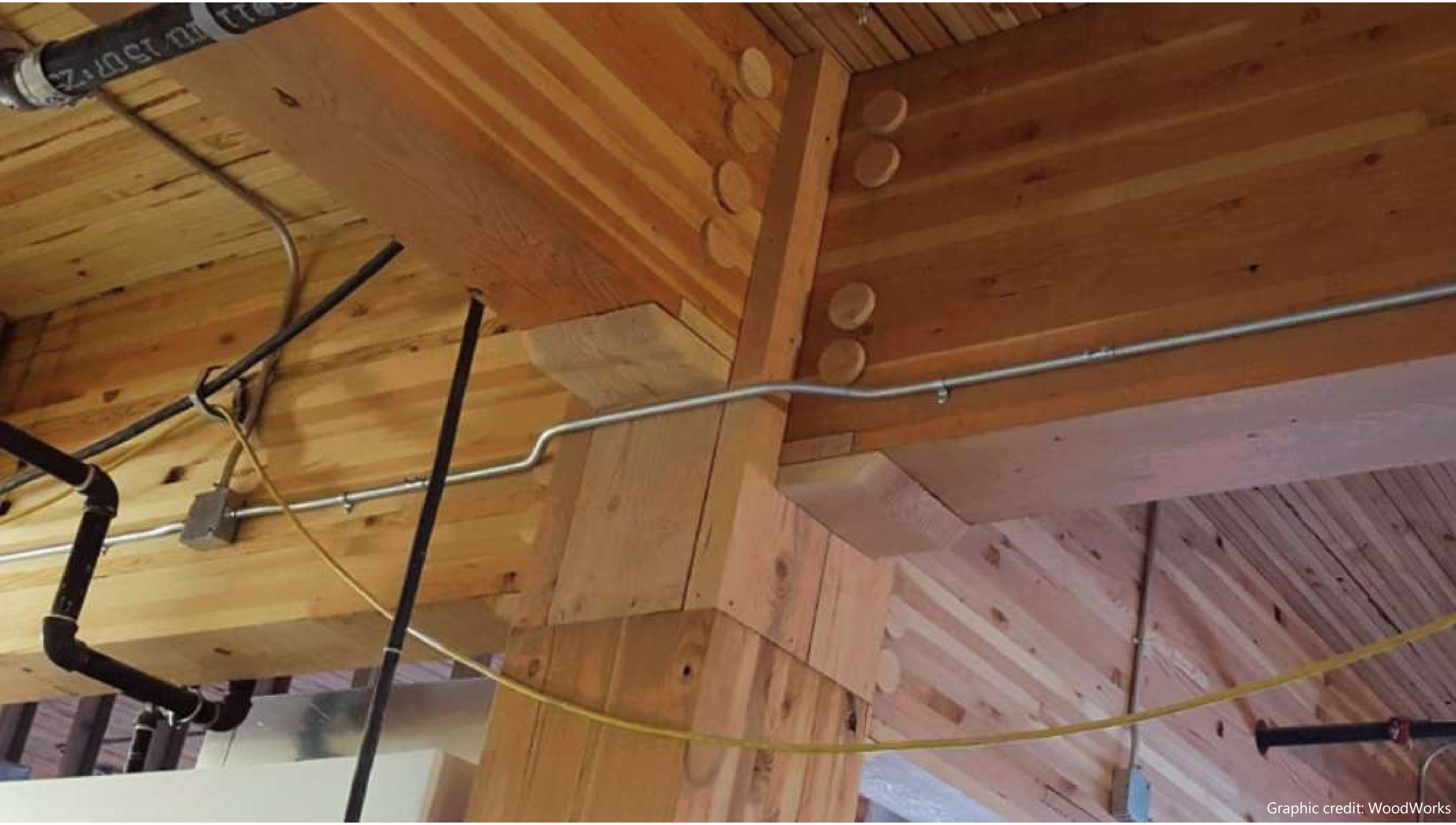


Figure 9-4. Char pattern with wood strip added



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2019 CALIFORNIA BUILDING CODE
A REPUBLIC
2018
IBC
INTERNATIONAL BUILDING CODE
7-16
Minimum Design Loads and Associated Criteria for Buildings and Other Structures
ASCE


SPACES
CO-WORKING & FLEXIBLE
OFFICE SPACE


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CLT Shear Walls – ASCE 7 Change Proposal (PRELIMINARY!)

Modifications to CHAPTER 12, SEISMIC DESIGN REQUIREMENTS FOR BUILDING STRUCTURES

Add line items to Table 12.2-1 on Bearing Wall Systems featuring CLT shear walls as follows:

Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	R	Ω_0	C_d	Structural System Limitations Including Structural Height, h_n (ft) Limits[d]				
					Seismic Design Category				
					B	C	D	E	F
A. BEARING WALL SYSTEMS									
…									
19. Cross laminated timber shear walls	14.5	3	3	3	65	65	65	65	65
20. Cross laminated timber shear walls with shear resistance provided by high aspect ratio panels only	14.5	4	3	4	65	65	65	65	65
…									

Graphic credit: Proposal PL-1-Rev.1-2019-10-20, van de Lindt, Amini, and Line

CLT Shear Walls – Oregon

Table 12.2-1 Design Coefficients and Factors for Seismic Force-Resisting Systems

Seismic Force-Resisting System	ASCE 7 Section Where Detailing Requirements Are Specified	Response Modification Coefficient, R^a	Overstrength Factor, Ω_0^g	Deflection Amplification Factor, C_d^b	Structural System Limitations Including Structural Height, h_n (ft) Limits[c] — Seismic Design Category B	C	D^d	E^d	F^e
A. BEARING WALL SYSTEMS									
19. Cross-laminated timber shear walls[f]	14.1 and 14.5	2	2 ½	2	NL	NL	NL	NL	NL

RICON S VS

Pre-engineered Post to Beam Connector

VIEW DETAILS →

MEGANT

Pre-engineered Connection System

VIEW DETAILS →

GIGANT

Pre-engineered Connection System

VIEW DETAILS →

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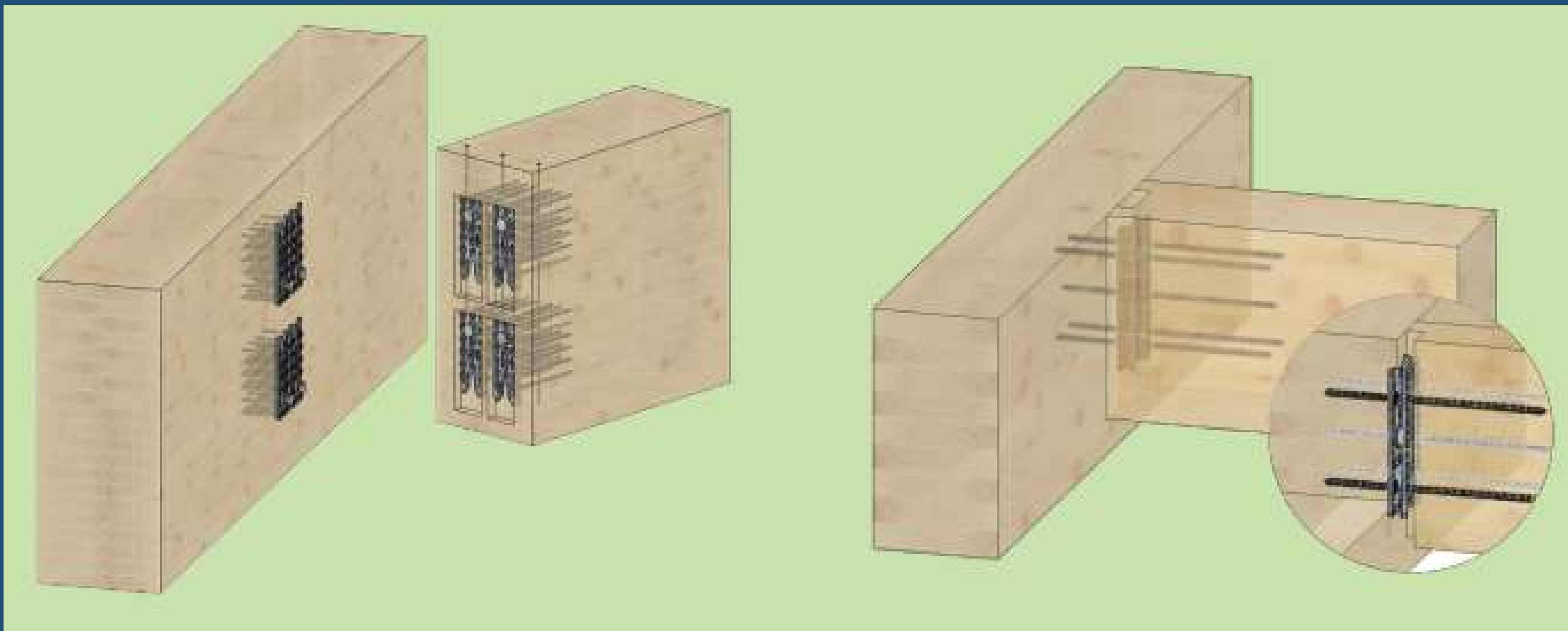

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Table 1: Summary of test results

Test	Test connector type	Max Gap* [in]	Max Rotation** + [°]	Max Total Shear [kip]	Max Moment*** [kip-in]	Max Static Design Shear Resistance**** [kip]
Small-1	200x60-1	0.37	2.5	10.8	123.5	9.6
Small-2	200x60-2	0.43	2.5	10.5	124.4	
Small-3	200x60-3	0.40	2.6	10.5	119.9	
	Average 200x60	0.40	2.5	10.6	122.6	
	COV 200x60 [%]	7%	1%	2%	2%	
Large-1	200x80-1	0.43	2.5	15.7	169.8	13.7
Large-2	200x80-2	0.49	2.6	13.7	168.9	
Large-3	200x80-3	0.42	2.5	14.8	162.4	
	Average 200x80	0.44	2.5	14.7	167.0	
	COV 200x80 [%]	9%	1%	7%	2%	

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QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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