Photo: Structurlam

Modern Timber Design: A Dive into Nail-Laminated Timber & Tall Wood

Presented by
Archie Landreman, WoodWorks
December 15, 2021

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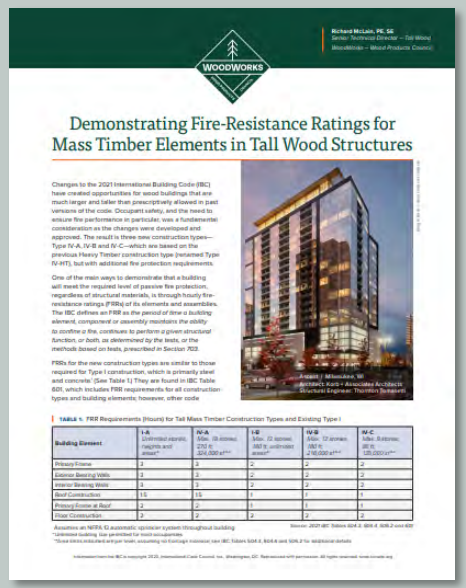
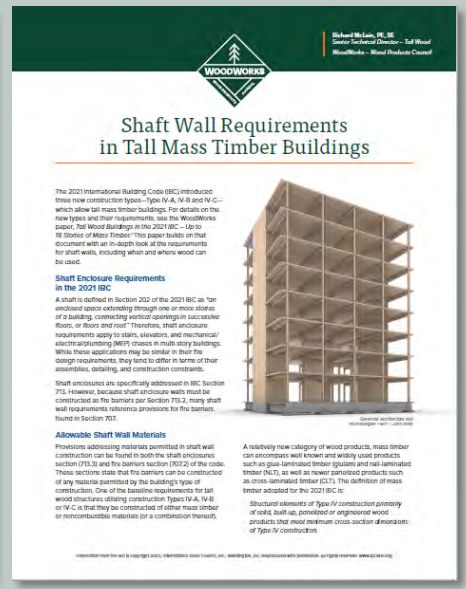
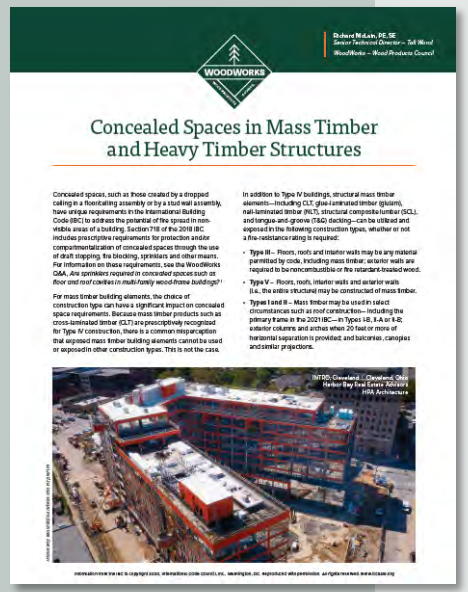
New WOOD SOLUTION PAPER

Taking the Guesswork out of Mixed-Use Building Requirements

Updated TALL WOOD WOOD SOLUTION PAPERS







January 12th | WEBINAR

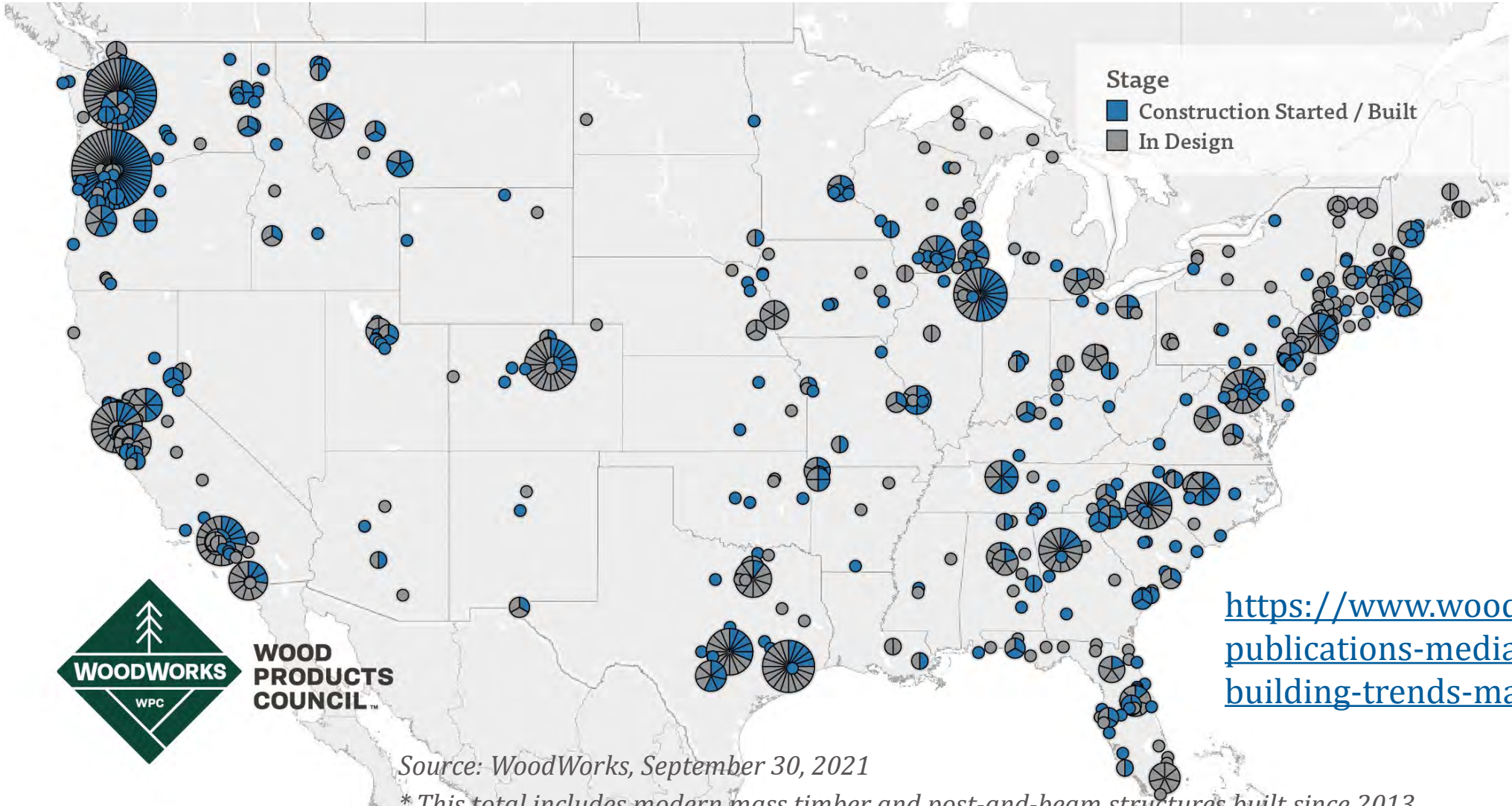
The World's Tallest Mass Timber Tower: A Behind the Scenes Look at Ascent

February 9th & 16th | SYMPOSIUM

Save the date—online event

Current State of Mass Timber Projects

As of September 2021, in the US, **1,241** multi-family, commercial, or institutional projects have been constructed with, or are in design with, mass timber.



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https://www.woodworks.org/publications-media/building-trends-mass-timber/

Source: WoodWorks, September 30, 2021

** This total includes modern mass timber and post-and-beam structures built since 2013*

New for GCs and installers:

U.S. Mass Timber Construction Manual

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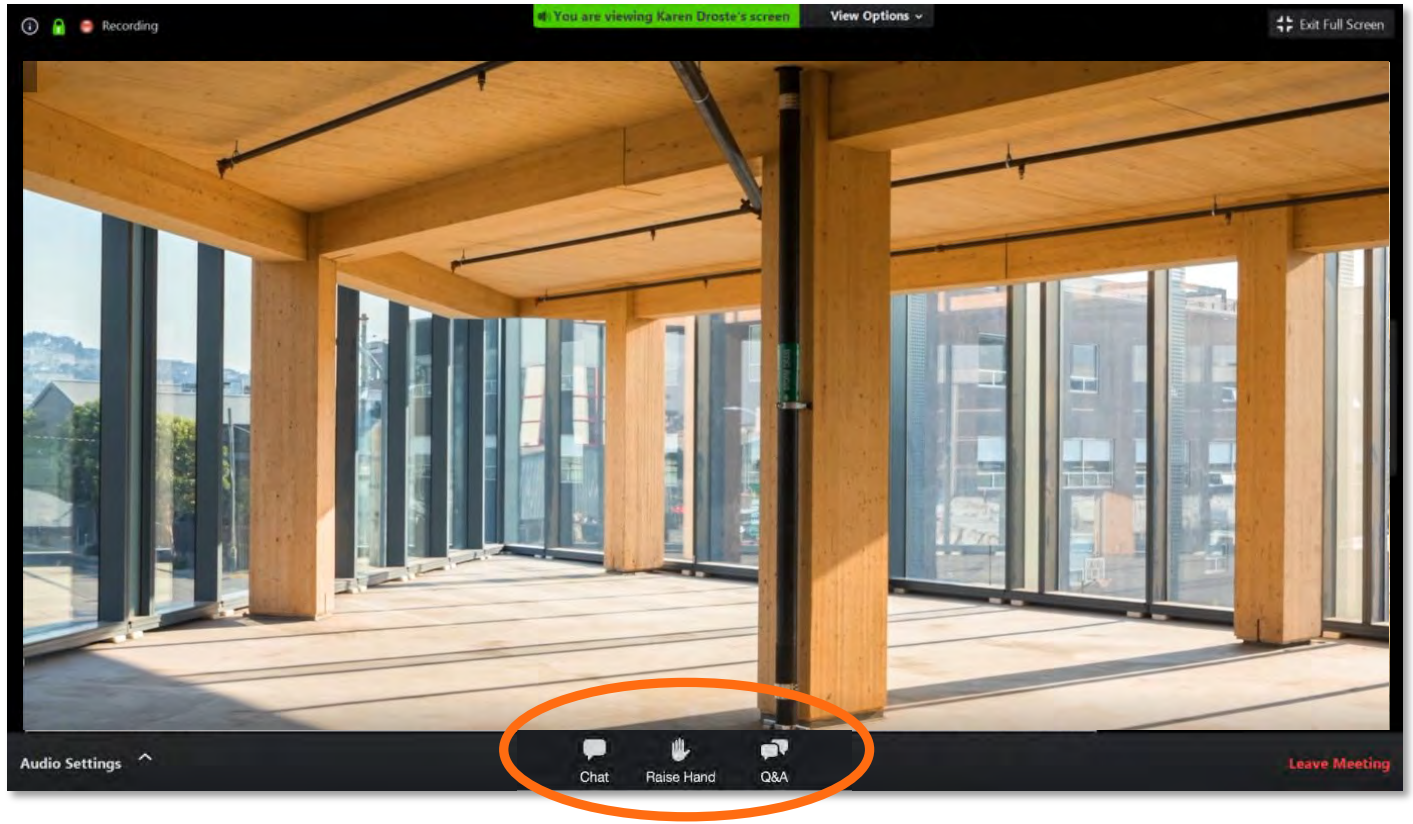
PHOTO: MARCUS KAUFFMAN

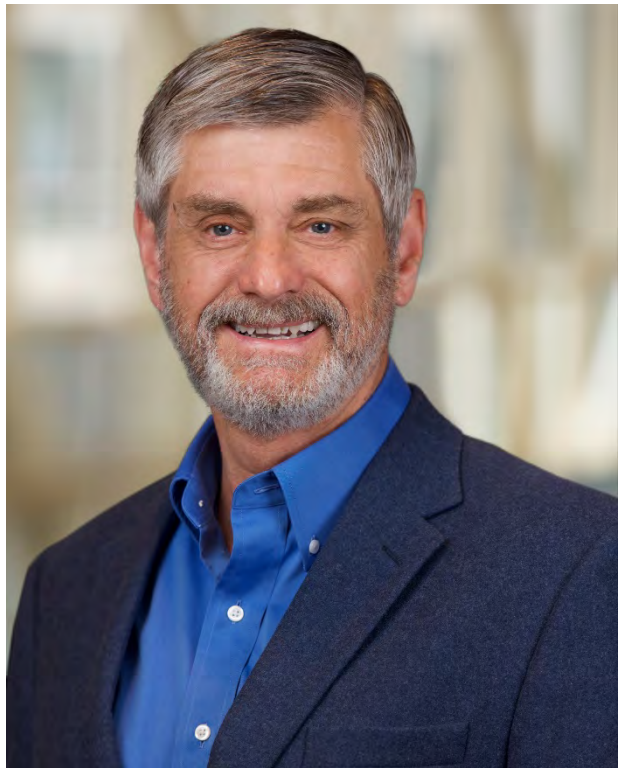
Download free at woodworks.org

Watch the Chat Window, Ask Questions through the Q&A Box

- During today's event we will be sending links, files and other pertinent information through the **Chat** window, located at the bottom of your screen.
- Submit questions in the **Q&A** box at the bottom of your screen as they come up in the presentations. We will **get to as many questions as possible.**



Questions? Ask me anything.



Archie Landreman

Regional Director | IA, IL, MN, WI

262.497.5550

archie@woodworks.org

901 East Sixth, Thoughtbarn-Delineate Studio, Leap!Structures, photo Casey Dunn

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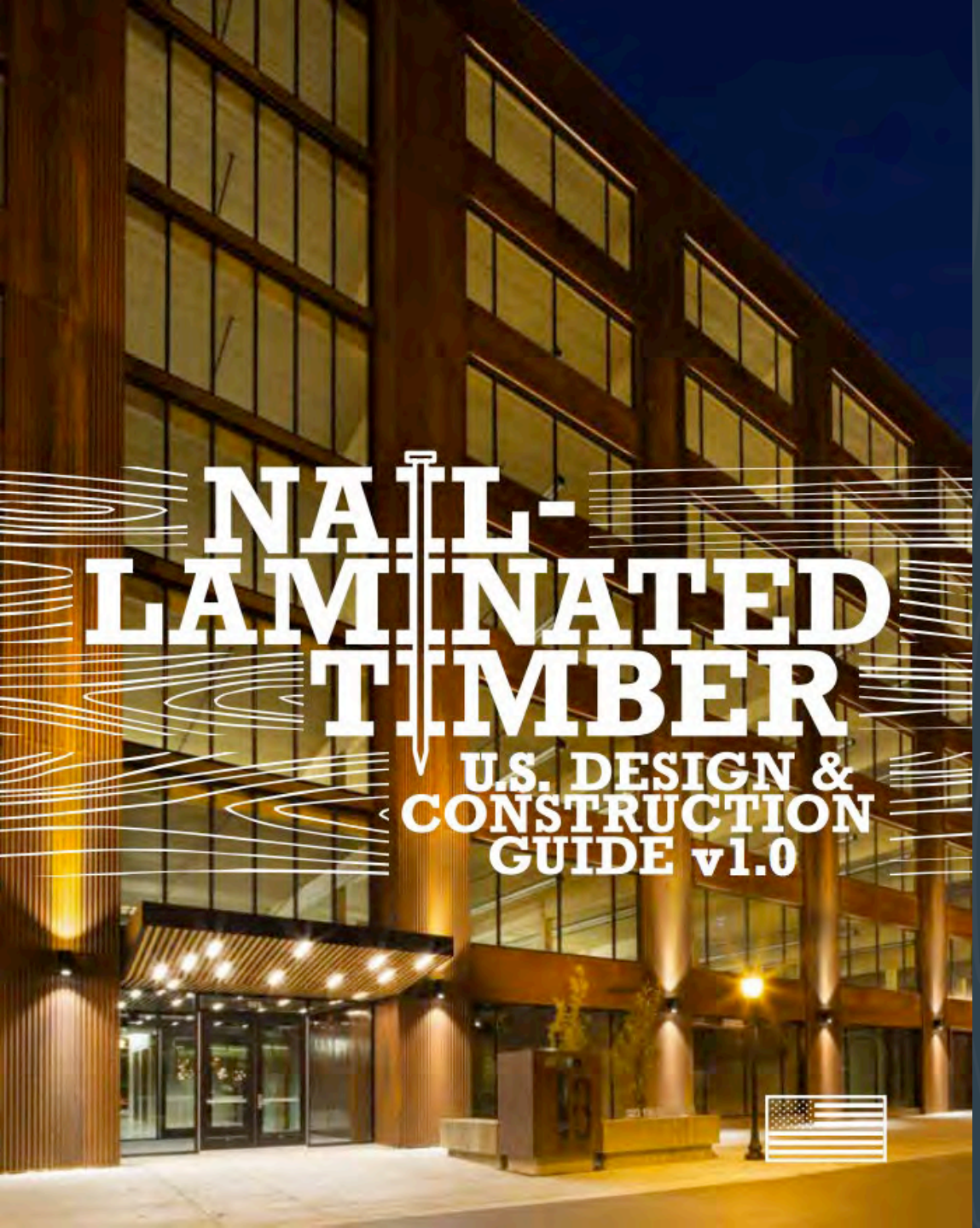
Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

Part of the family of mass timber products, nail-laminated timber (NLT) is mechanically laminated from dimension lumber to create solid timber panels for floor, roof and wall applications. Based on the NLT Design and Construction Guide, this presentation will explore architectural and engineering topics associated with the use of NLT in modern timber structures. Construction types, code applications, specifications and appearance grades, fire-resistance, acoustics, enclosure, structural gravity and lateral loading will all be discussed, with an emphasis on structures that comply with current code provisions. Project examples will be highlighted to show how these topics have been addressed in modern buildings, and to illustrate the many application and grid possibilities.

Learning Objectives

1. Review nail-laminated timber as a structural building material and demonstrate its code-compliance and permitted uses.
2. Discuss common specification aspects of NLT such as species, appearance grade and structural properties.
3. Highlight methods for designing NLT to achieve fire resistance and acoustical performance when exposed on one side as a floor, roof or wall panel system.
4. Explore structural design topics associated with NLT, including joint lay-up and diaphragm capacity.



NLT Design Guide

Content includes:

- Architecture
- Fire
- Structure
- Enclosure
- Supply and Fabrication
- Construction and Installation
- Erection engineering

Free download at
www.thinkwood.com/nltguide

Mass Timber

Mass timber is a category of framing styles often using small wood members formed into large panelized solid wood construction including CLT, NLT or glulam panels for floor, roof and wall framing

Glue Laminated Timber
GLT

Laminated Veneer Lumber
LVL

Parallel Strand Lumber
PSL

Laminated Strand Lumber
LSL

Cross Laminated Timber
CLT

Nail Laminated Timber
NLT

Timber-Concrete Composite
TCC

DLT

MPP

Mass Timber Products

Photo credit: StructureCraft Builders/Freres Lumber

Nail-Laminated Timber

Photo credit: StructureCraft Builders

Nail-Laminated Timber

What is it?

Part of the family of mass timber products, Nail-laminated timber (NLT) is mechanically laminated to create a solid timber panel. NLT is created by placing dimension lumber (nominal 2x, 3x, or 4x thickness and 4 in. to 12 in. width) on edge and fastening the individual laminations together with nails.

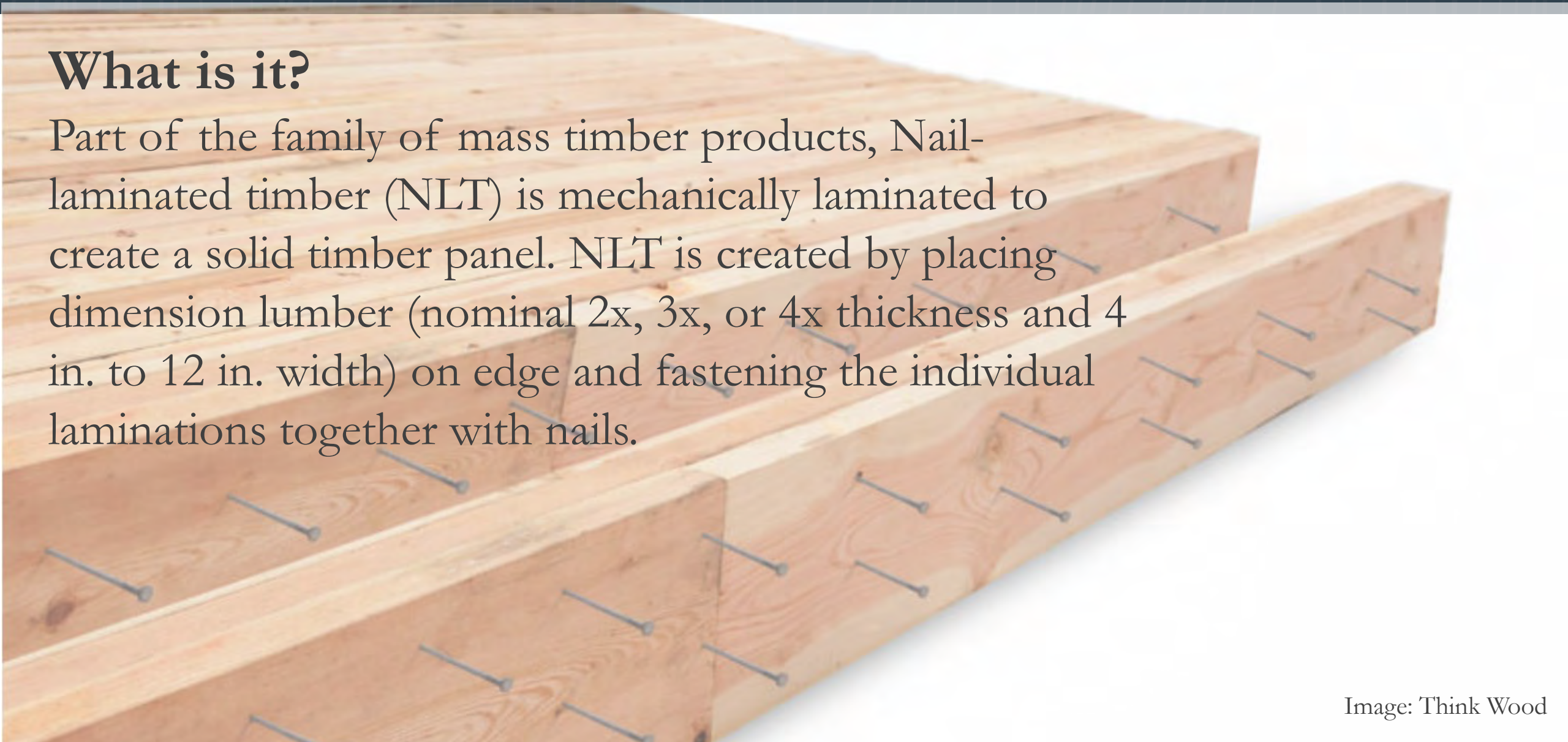


Image: Think Wood

Nail-Laminated Timber

What is it?

2x4, 2x6 and 2x8 most common

Uses commodity softwood lumber framing – common species are SPF, Southern Pine, Douglas Fir

NLT DEPTH	TYPICAL SPAN RANGE
4 in. nominal	up to 12 ft.
6 in. nominal	10 to 17 ft.
8 in. nominal	14 to 21 ft.
10 in. nominal	17 to 24 ft.
12 in. nominal	20 to 26 ft.

Spans will vary and may fall outside these ranges depending on use, loading, and vibration criteria.

Source: NLT Design & Construction Guide

Nail-Laminated Timber

When is it used?

NLT is typically used for floor and roof panels. Plywood/OSB added to one face can provide in-plane shear capacity, functioning as a diaphragm.

Image: StructureCraft Builders

Nail-Laminated Timber

When is it used?

NLT can also be used for walls, elevator shafts, and stair shafts. Plywood/OSB added to one face can provide in-plane shear capacity, allowing it to also function as a shear wall

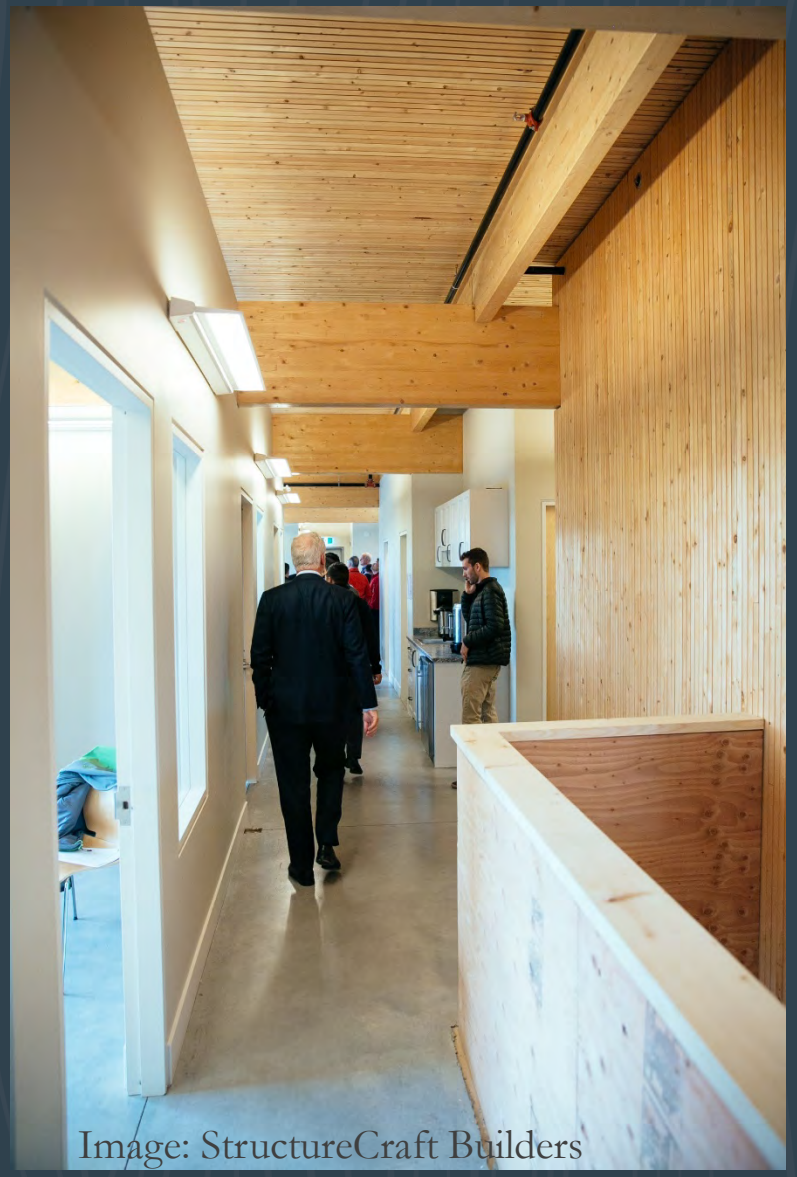


Image: StructureCraft Builders

Nail-Laminated Timber

When is it used?

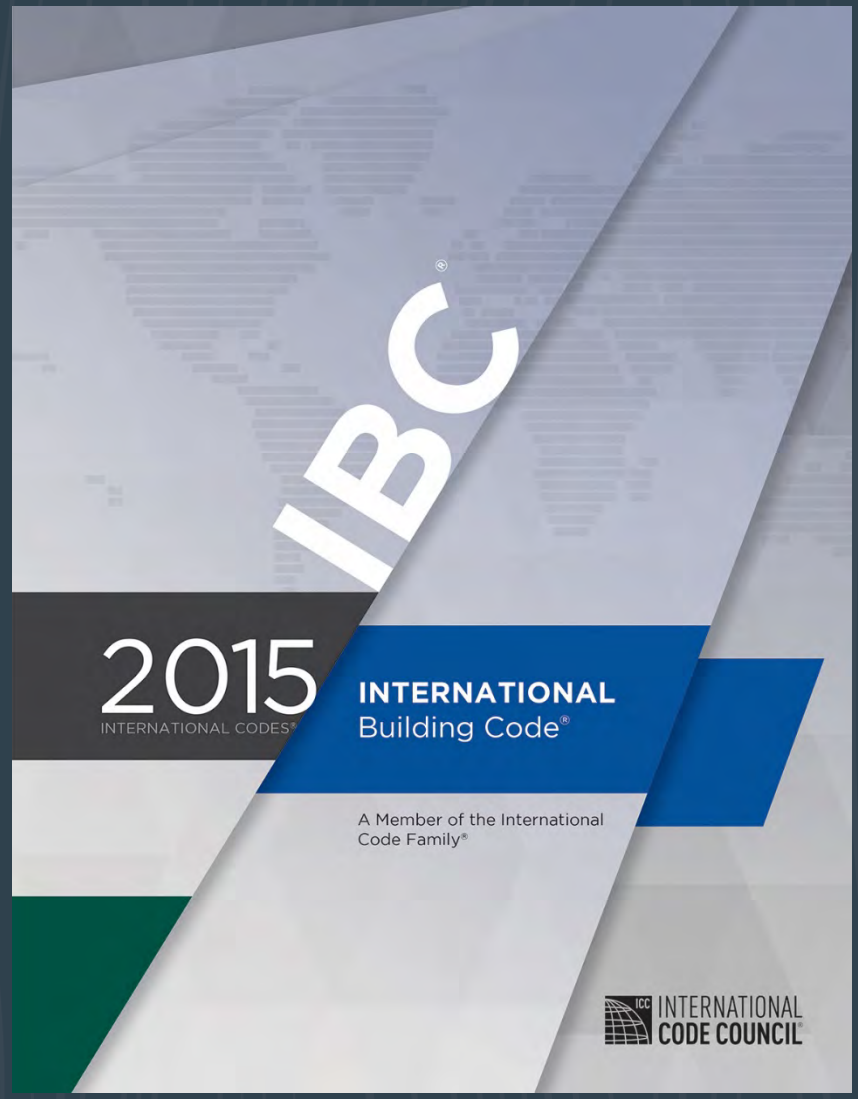
Can use preservative treated or naturally decay resistant wood for exterior applications

Nail-Laminated Timber

When does the code allow it to be used?

IBC defines NLT as mechanically laminated decking per IBC 2304.9.3

Permitted anywhere that combustible materials and heavy timber are allowed



Nail-Laminated Timber

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]	2[a]	1	0	1	0	HT	1	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 602.4.6	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)	$1\frac{1}{2}$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

c. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

d. Not less than the fire-resistance rating required by other sections of this code.

e. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

f. Not less than the fire-resistance rating as referenced in Section 704.10.

Source: IBC 2015 Table 601

Nail-Laminated Timber

Image: StructureCraft Builders

Chapter 6: Types of Construction

Where does the code allow NLT to be used?

- Type IB & II: Roof Decking

Nail-Laminated Timber

Image: StructureCraft Builders

Chapter 6: Types of Construction

Where does the code allow NLT to be used?

- Type III: Interior elements (floors, roofs, partitions/shafts) and exterior walls if FRT

120 Clay

Portland, OR

Photo Credit: Christian Columbres

120 Clay

Portland, OR

5 stories, 72,000 SF, Type IIIA

Mostly office, some retail and amenity

Photo Credit: Christian Columbres

Nail-Laminated Timber

Where does the code allow NLT to be used?

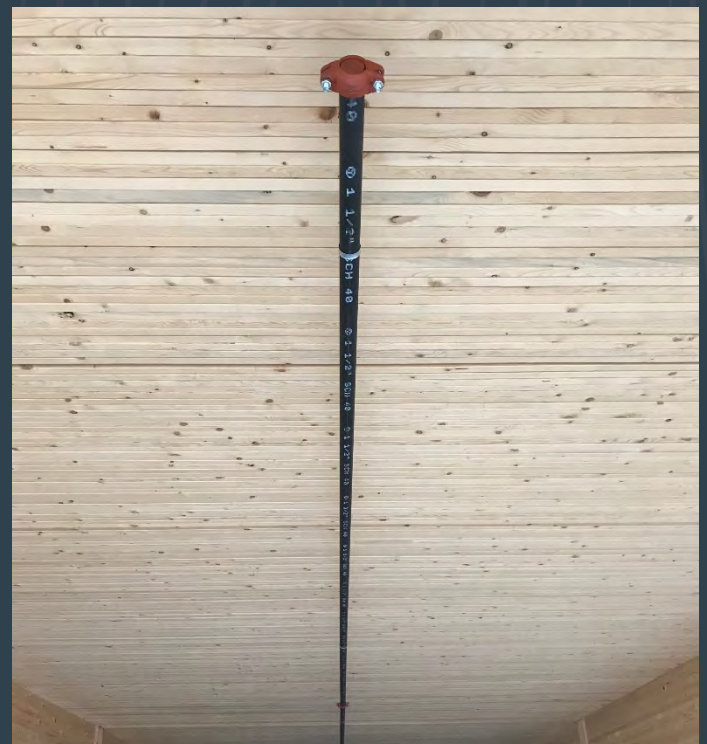
- Type IV: Any interior elements & roofs if meets min. size; exterior walls if FRT. No concealed spaces permitted

Image: Perkins + Will

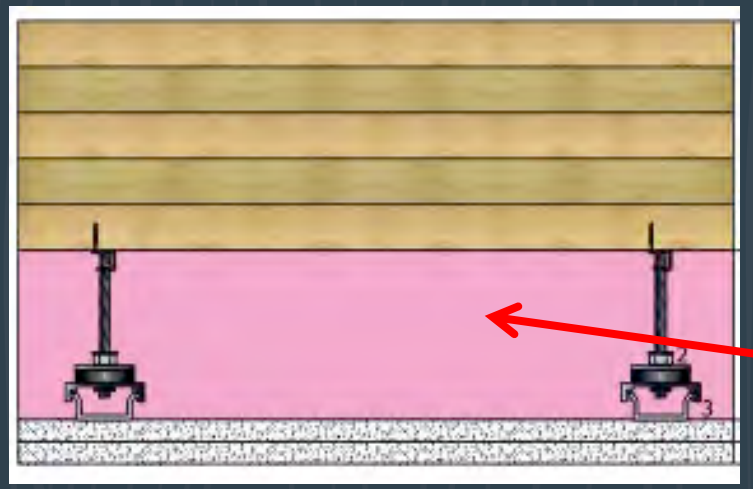
NLT Fire Resistance

NLT in Type IV Construction (minimum sizes, no concealed spaces):

- Floor decking:
  - 4” nominal (2x4) set on edge, well spiked, covered with 1” nominal flooring or 15/32” WSP or ½” particleboard
- Roof decking:
  - 3” nominal (2x3) set on edge, well spiked
- Interior partitions:
  - 4” depth or 1-hour rating
- Exterior walls:
  - FRT NLT



NLT Fire Resistance



Example of concealed space

NLT in Type IV Construction - no concealed spaces

- Concealed spaces include dropped ceilings, attics, chases, others
- Concealed space restriction does not apply to any other construction type. If using mass timber elements in non type IV construction, concealed spaces are permitted but may be required to be sprinklered
- IBC 602.4.8 permits 1 hour fire resistance rated construction for partitions

T3 Minneapolis

Minneapolis, MN

Photo Credit: Blaine Brownell

T3 Minneapolis

Minneapolis, MN

Type IV Construction
7 stories (6 Timber on 1 Concrete)
234,000 sf

Image Credit: StructureCraft Builders

T3 Minneapolis

Minneapolis, MN

Photo Credit: Blaine Brownell

Nail-Laminated Timber

Chapter 6: Types of Construction

Image: Christian Columbres Photography

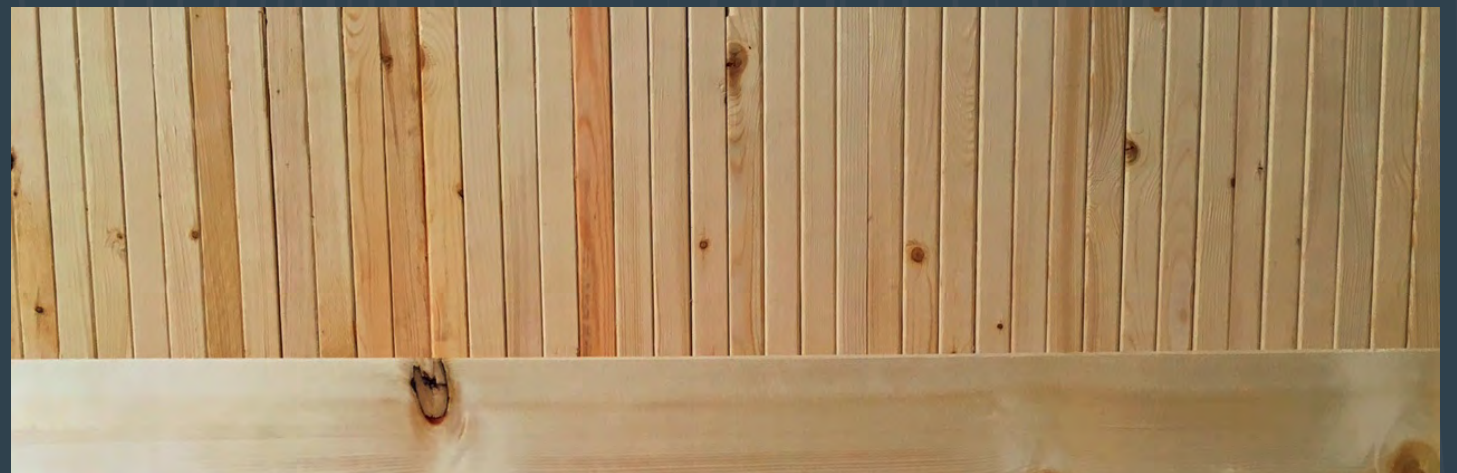
Where does the code allow NLT to be used?

- Type V: Interior elements, roofs & exterior walls

NLT Fire Resistance

NLT in **other than** Type IV Construction:

- Permitted where no fire-resistance rating is required:
  - Roofs in Types IB, II
  - Floors, roofs & certain walls in types IIIB & VB
- Testing is on-going to determine fire-resistance characteristics of NLT in various applications – contact WoodWorks for additional information



Hudson Building

Vancouver, WA

3 stories
45,000 SF
Type VA

Photo Credit: Christian Columbres

Hudson Building

Vancouver, WA

Nail-Laminated Timber

Type III: 6 stories

Allowable building size for group B occupancy with NFPA 13 Sprinkler

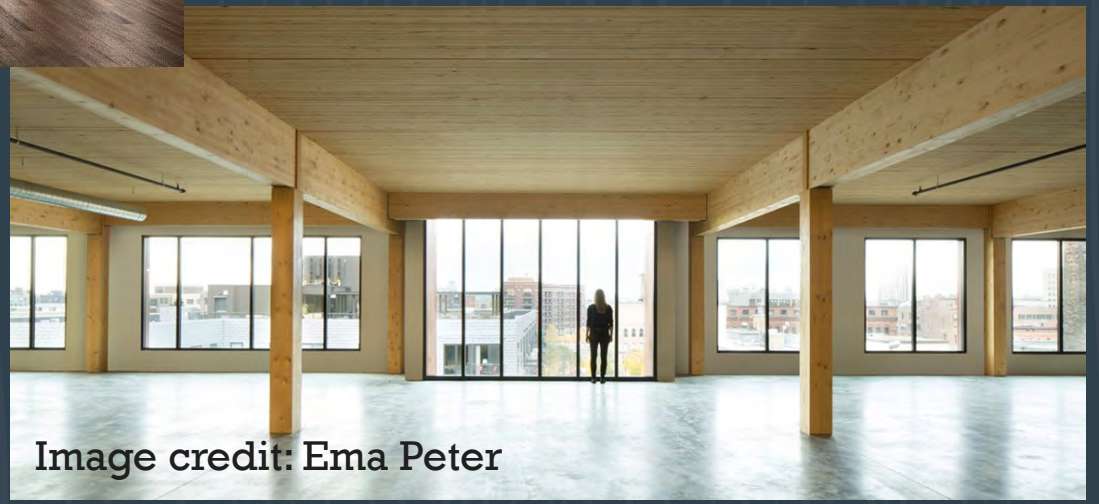


Image credit: Ema Peter

Type IV: 6 stories

Image credit: Christian Columbres

Type V: 4 stories

NLT Appearance Options

Photo Credit: StructureCraft Builders


Image Credit: John Stamets

Nail-Laminated Timber

- NLT does not have an accepted standard for production; project specifications should address this
- Raw material is standardized (ASLC/IBC/NDS)
- Some requirements for assembly (lam to lam nailing) are in IBC
- Quality control a key factor in overall project success

Nail-Laminated Timber

Specifications:

- Issue NLT specs as a complete resource for the fabricator and contractor teams
- Require the GC to submit a weather protection plan
- Outline special inspection requirements
- List limits for tolerances, field modifications
- Expectations for delegated design items
- Species, appearance, profiles
- Sealers - coordinate with Div. 9

Source: NLT Design & Construction Guide

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary C and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes nail-laminated timber (NLT) floor and roof decking, prefabricated in pan

B. Related Sections:

1. Section 01 81 13 "Sustainable Design Requirements" for LEED requirements.
2. Section 05 12 00 "Structural Steel Framing" for custom-fabricated steel connection
3. Section 06 10 00 "Rough Carpentry" for dimension lumber framing.
4. Section 06 16 00 "Sheathing" for floor and roof sheathing.
5. Section 09 91 00 "Painting" for sealing and finishing requirements.

C. References:

1. ALSC, American Lumber Standard Committee Board of Review.
2. ALSC DOC PS20-15 American Softwood Lumber Standard.
3. APA, The Engineered Wood Association.
4. ASTM A153/A153M-16a Standard Specification for Zinc Coating (Hot-Dip) on Iron Hardware.
5. ASTM E488/E488M-15 Standard Test Methods for Strength of Anchors in Concrete
6. ASTM F1667-15 Standard Specification for Driven Fasteners: Nails, Spikes, and St
7. ICC-ES ESR-1539 Power-Driven Staples and Nails.
8. NDS 2015 National Design Specification for Wood Construction.
9. 2015 International Building Code.
10. For Projects overseen by a Construction Manager or Design-Build Contractor ir General Contractor, references to "Contractor" shall apply to the relevant Subcont

1.3 ACTION SUBMITTALS

A. Product Data: For each type of factory-fabricated product. Submit proposed sealer for re

Nail-Laminated Timber

Image Credit: StructureCraft Builders

Samples & Mock-Ups

- Even with good specifications, some items are difficult to communicate in writing – require sample panels and/or mockups to review appearance, color, knots, etc.
- Review manufacturer's culling process and QA/QC

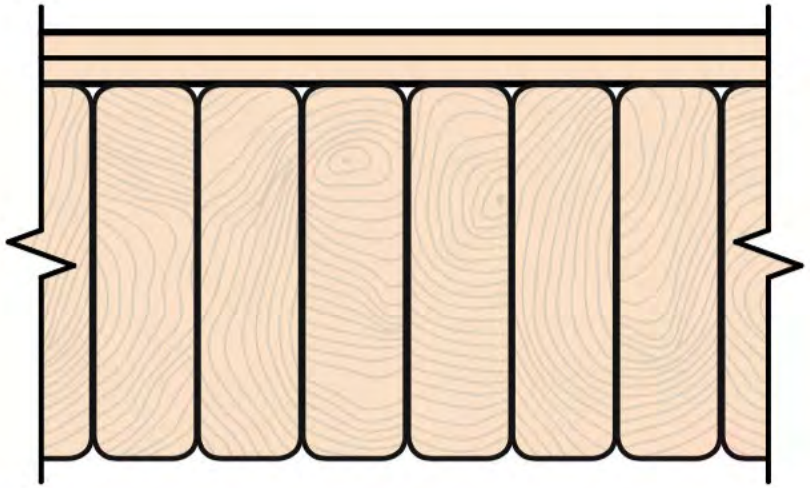
Nail-Laminated Timber

Appearance

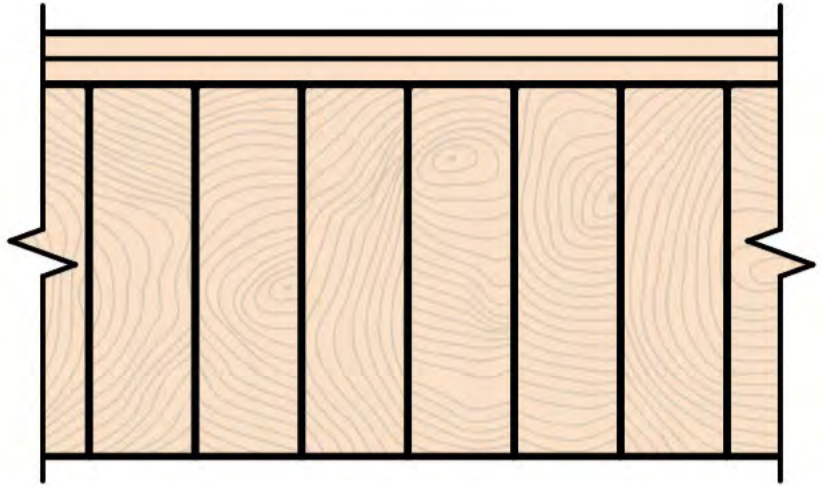
Appearance of panels in direct control of designers:

- Species
- Grade
- Color
- Lamination Edges
- Lamination Depth(s)
- Wane, Knots

Nail-Laminated Timber



Ribbed



Smooth

Figure 2.9: *Ribbed and smooth surfaces on NLT from un-planed and planed laminations.*

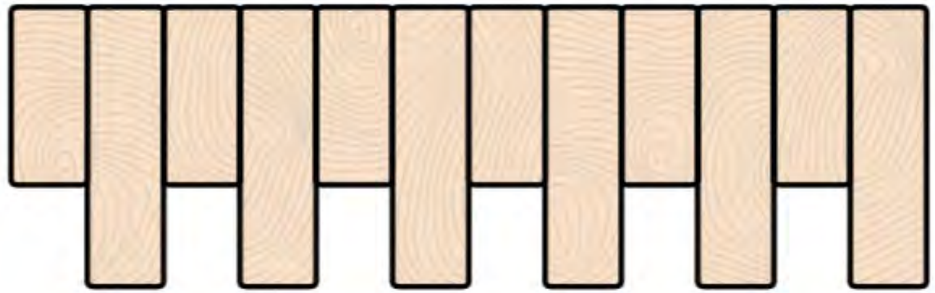


Figure 2.11: *1:1 Alternating Staggered Depth Cross Section.*

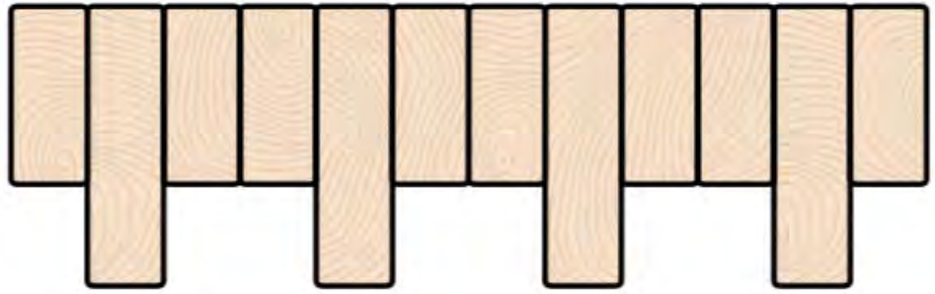


Figure 2.12: *2:1 Alternating Staggered Depth Cross Section.*

Options:

- Stock materials or planed edges
- Fluted profiles
- Rough or sanded

Source: NLT Design & Construction Guide

Nail-Laminated Timber

Fluted profiles provide texture, shadow lines

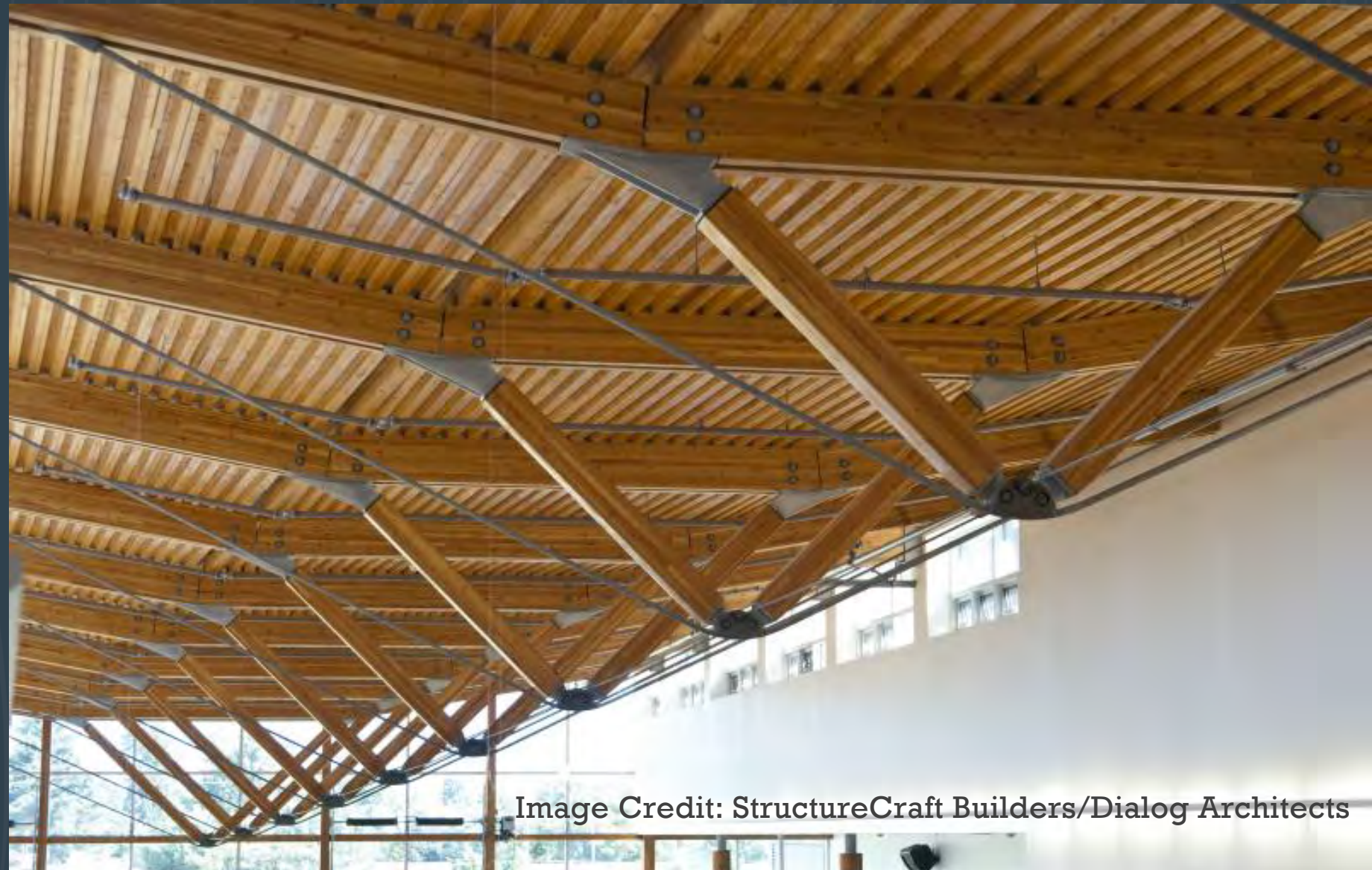
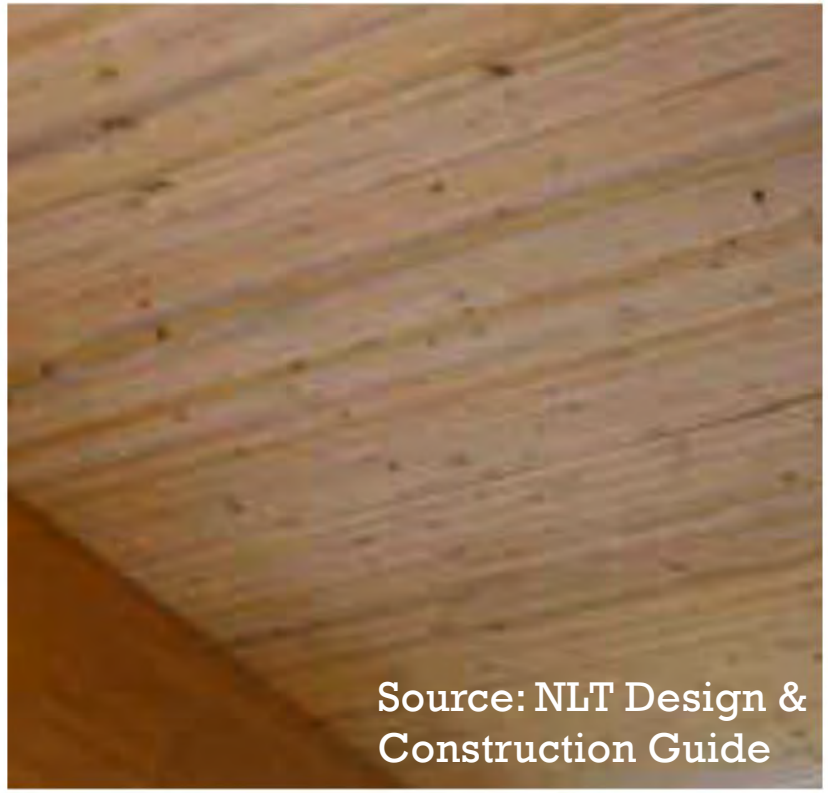


Image Credit: StructureCraft Builders/Dialog Architects

Figure A.1: *Significant wane and knots, inconsistent coloration. Loose vertical tolerance on placement of laminations.*



Source: NLT Design & Construction Guide

Figure A.3: *No wane, minimal knot holes, variable coloration. Tight vertical tolerance on placement of laminations.*

Figure A.4: *No wane, no knot holes, consistent coloration. Tight vertical tolerance on placement of laminations.*

Compelling Architecture

Photo Credit: StructureCraft Builders/ Bohlin Cywinski Jackson Architects

Curved Profiles

Photo Credit: StructureCraft Builders/Perkins + Will

Free-Form Structures

Photo Credit: Nic Lehoux

Nail-Laminated Timber

Stair Profiles

Photo Credit: StructureCraft Builders

Compound Curves

Photo Credit: Perkins + Will

Stair Profiles

Photo Credit: StructureCraft Builders

NLT Acoustical Design

NLT Acoustical Design

<u>Air-Borne Sound:</u>

Sound Transmission Class (STC)

- Measures how effectively an assembly isolates air-borne sound and reduces the level that passes from one side to the other
- Applies to walls and floor/ceiling assemblies

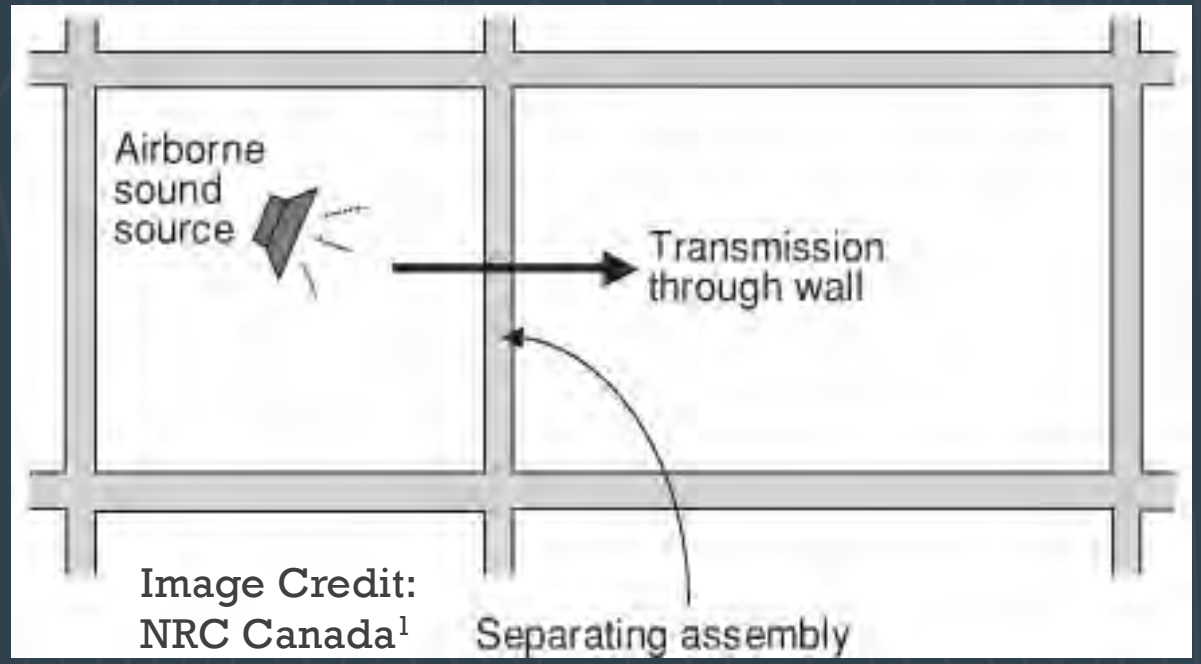


Image Credit: NRC Canada[1]

Photo Credit: Shutterstock

NLT Acoustical Design

<u>Structure-borne sound:</u>

Impact Insulation Class (IIC)

- Evaluates how effectively an assembly blocks impact sound from passing through it
- Only applies to floor/ceiling assemblies

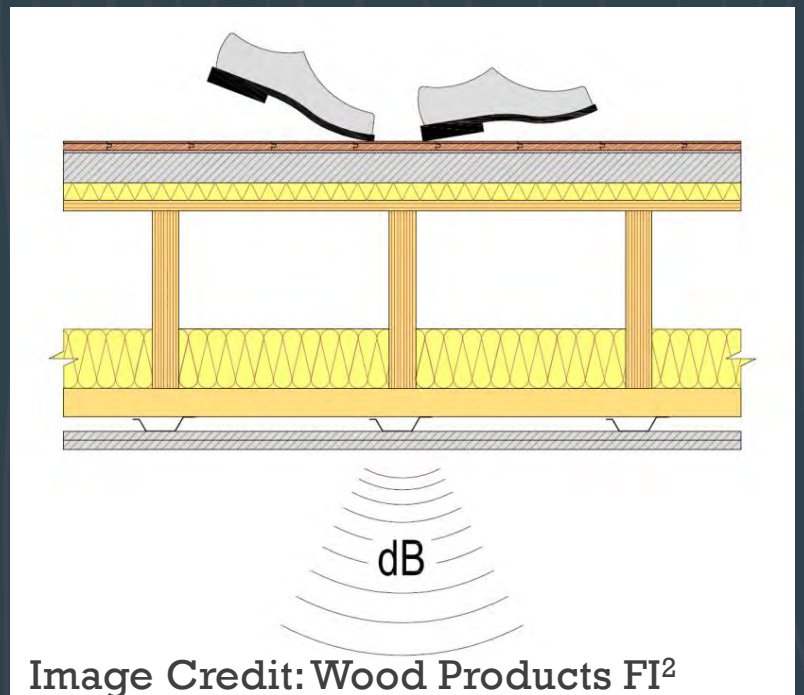


Image Credit: Wood Products FI[2]

Photo Credit: Shutterstock

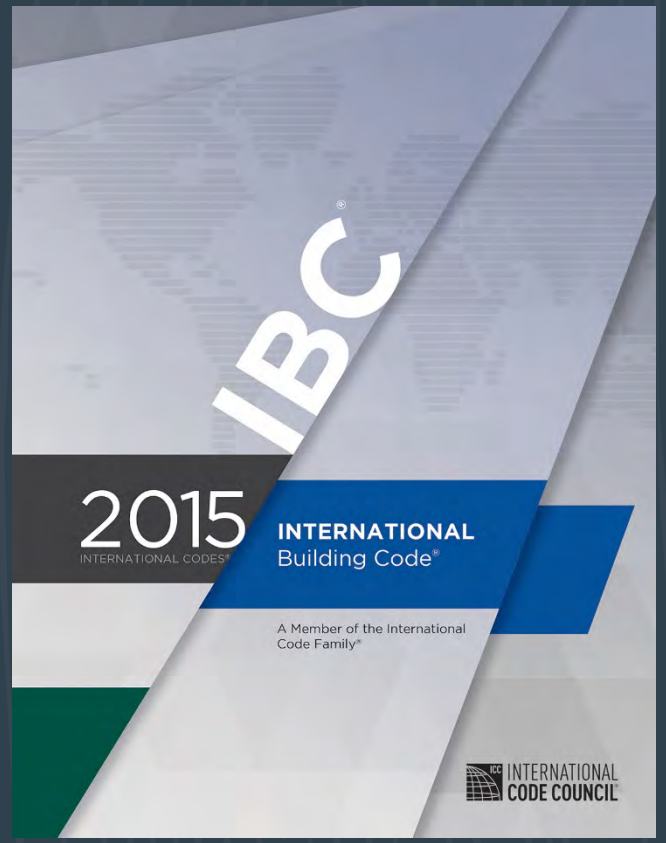
NLT Acoustical Design

Code requirements (IBC 1207) only address residential occupancies:

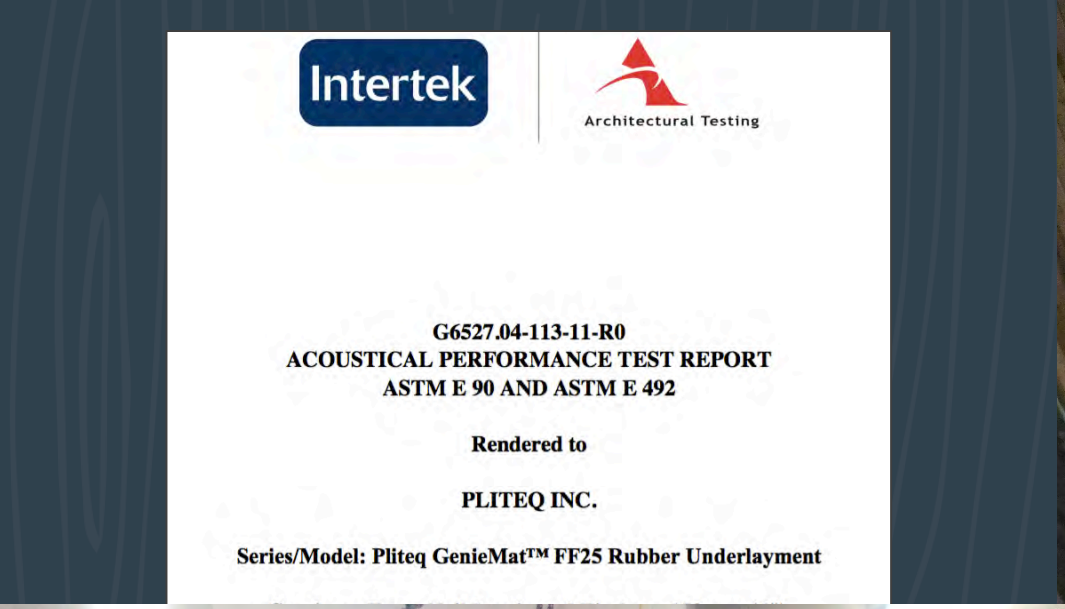
For unit to unit or unit to public or service areas:

Min. STC of 50 (45 if field tested):
Walls, Partitions, and Floor/Ceiling Assemblies

Min. IIC of 50 (45 if field tested) for:
Floor/Ceiling Assemblies



NLT Acoustical Design



Intertek

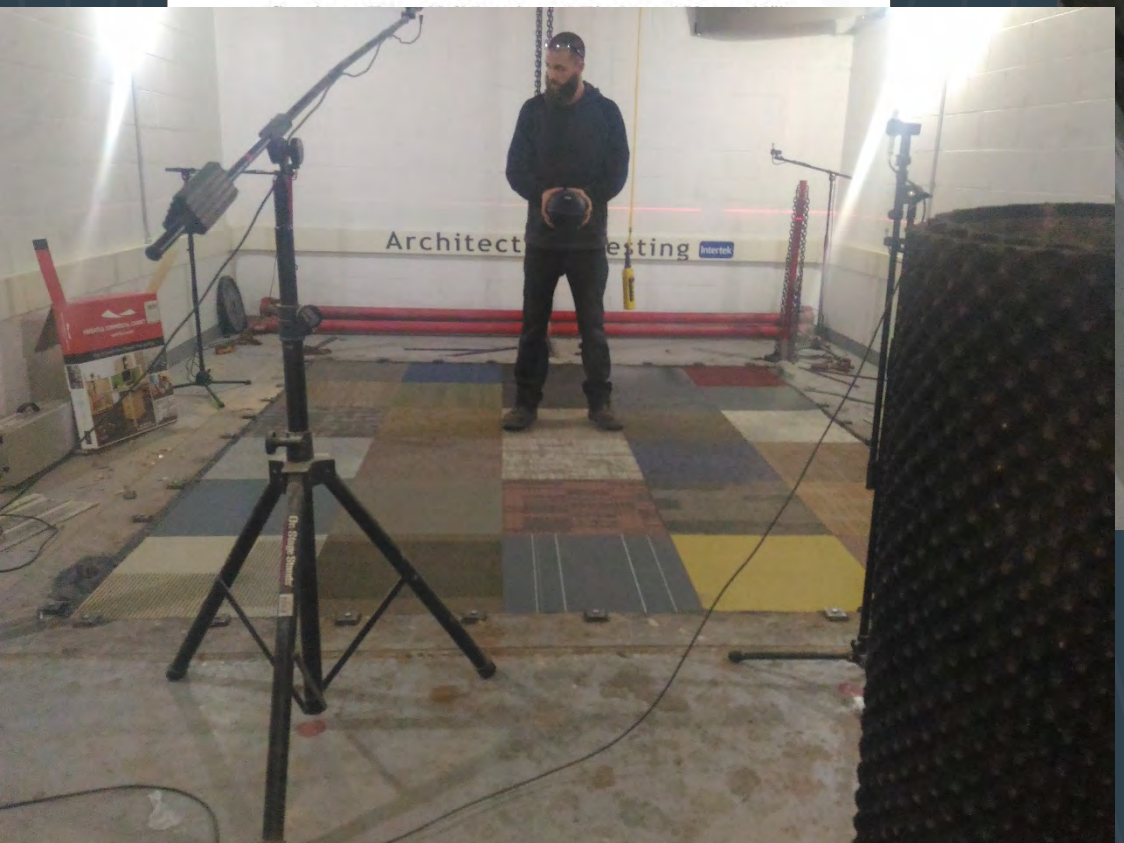
Architectural Testing

G6527.04-113-11-R0
ACOUSTICAL PERFORMANCE TEST REPORT
ASTM E 90 AND ASTM E 492

Rendered to

PLITEQ INC.

Series/Model: Pliteq GenieMat™ FF25 Rubber Underlayment



Several acoustically tested NLT assemblies exist, WoodWorks is working with acoustical mat manufacturers on others, contact WW for info

NLT Acoustical Design

More acoustically tested assemblies exist for CLT than NLT

- Some designers use CLT values and subtract 3 points (STC & IIC) as an approximation
- Can use comparative data to perform an acoustical engineering analysis of CLT vs. NLT, permitted in IBC 1206

TABLE 2.2 STC AND IIC TESTING DATA COMPLETED FOR NLT FLOORS

	FLOOR ASSEMBLY (TOP TO BOTTOM)	STC	IIC
1	1/2 in. plywood + 2x6 NLT **(baseline measurement)**	34	32
2	Bare CLT (5-ply, 6-7/8 in. thick)	39	25

Source: NLT Design & Construction Guide

NLT Acoustical Design

Common NLT floor assembly:

- Finish floor (if applicable)
- Underlayment (if finish floor)
- 1.5” to 3” thick concrete/gypcrete topping
- Acoustical mat
- WSP (plywood/OSB)
- NLT panel

Image credit: AcoustiTECH

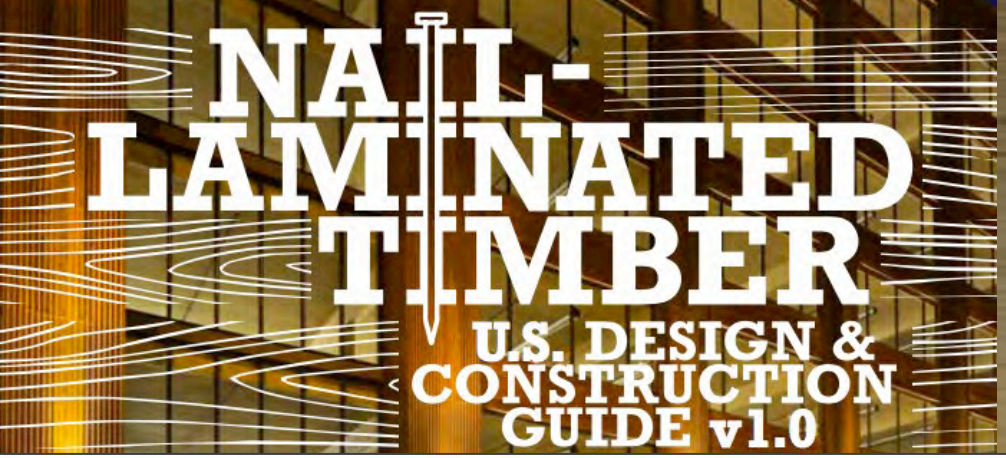
Table A.2 - 13: Tested 5-ply CLT floor specimens with descriptions and STC and IIC-ratings

	Id	Description	Floor Topping		Gypsum Board Ceiling			Test-#, STC	Test-# IIC
			Topping	Interlayer	Face Layer	Base Layer	Fastening Method		
Ben									
1							N/A	TLF-12-039	IIF-12-0 IIC 25
5-pl									
2								1	IIF-13-0 IIC 25
3								4	IIF-13-0 IIC 36
4								6	IIF-13-0 IIC 54

CLT/NLT Acoustics Resources:

- US CLT Handbook
- Acoustics Manufacturers Literature:
  - Maxxon
  - Pliteq
  - AcoustiTECH
  - Kinetics
  - USG
  - Regupol
  - Rothoblaas
- Industry tests – FP Innovations, NRCAN

Contact WoodWorks for information



NLT Acoustical Design

TABLE 2.2 STC AND IIC TESTING DATA COMPLETED FOR NLT FLOORS

Source: NLT Design & Construction Guide

	FLOOR ASSEMBLY (TOP TO BOTTOM)	STC	IIC
1	1/2 in. plywood + 2x6 NLT **(baseline measurement)**	34	32
2	Bare CLT (5-ply, 6-7/8 in. thick)	39	25
3	4 in. normal weight concrete topping + Pliteq GenieMat FF06 acoustical mat + 1/2 in. plywood + 2x6 NLT	51	44
4	Carpet + 4 in. normal weight concrete topping + Pliteq GenieMat FF06 acoustical mat + 1/2 in. plywood + 2x6 NLT	51	58
5	4 in. normal weight concrete topping + Pliteq GenieMat FF25 acoustical mat + 1/2 in. plywood + 2x6 NLT	54	50
6	4 in. normal weight concrete topping + Pliteq GenieMat FF50 acoustical mat + 1/2 in. plywood + 2x6 NLT	56	52
7	4 in. normal weight concrete topping + Pliteq GenieMat FF06 acoustical mat + 1/2 in. plywood + 2x6 NLT + RC + 5/8 in. Type C Gypsum	55	49
8	4 in. normal weight concrete topping + Pliteq GenieMat FF06 acoustical mat + 1/2 in. plywood + 2x6 NLT + Pliteq GenieClip RST Clip + R8 Fiberglass batts + 5/8 in. Type C Gypsum	60	59

Image credit: Ema Peter

MEP in NLT

Photo Credit: StructureCraft Builders/KMBR

Photo Credit: StructureCraft Builders

MEP in NLT

Due to exposed NLT structure and finish, unique MEP accommodation solutions are required

If using type IV construction, no concealed spaces are allowed

MEP in NLT

Two most common approaches in NLT buildings are exposing services on ceiling side or concealing in raised access floor system – or a combination

Photo Credit: StructureCraft Builders

MEP in NLT

Exposed services – contemporary, industrial aesthetic

Credit: Steve Bergerson

MEP in NLT

Photo Credit: KK Law, Courtesy: naturally:wood

Raised access floor

Installed on top of floor structure

Provides 2” to 18”+ of plenum space for MEP

MEP in NLT

Raised access floor

Results in simpler aesthetic on ceiling side, requires thicker floor profile, can't be used in type IV

Photo Credit: StructureCraft Builders

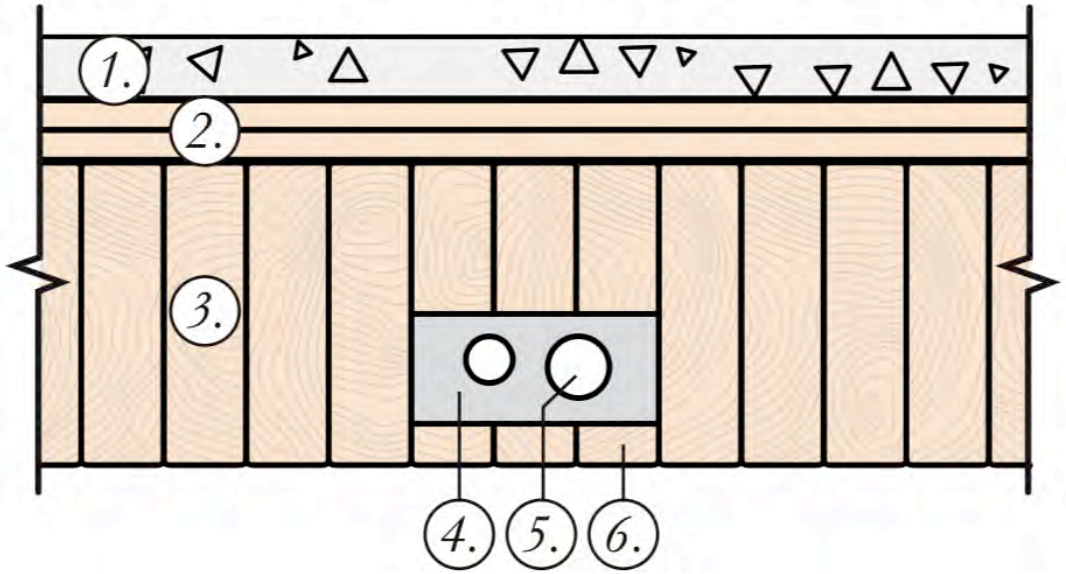


Figure 2.15: *Service chase in NLT.*

Key

1. *Concrete topping*
2. *Plywood/OSB*
3. *NLT*
4. *Gap for mechanical fire stopped as required*
5. *Mechanical services*
6. *Wood cover to hide services as required*

MEP in NLT

Small service lines (sprinklers, electrical conduit) – possible to conceal within NLT panel

Source: NLT Design & Construction Guide

MEC Head Office

Vancouver, BC

Photo Credit: Ed White Photographics

MEC Head Office

Vancouver, BC

4 Stories, 112,000 SF
2x8 NLT includes
sacrificial charring zone

Photo Credit: Ed White Photographics

Photo Credit: Seagate Structures

Carbon Summary

Results

Volume of wood products used:
2,394 cubic meters (84,543 cubic ft) of lumber and sheathing

Carbon stored in the wood*:
1,726 metric tons of carbon dioxide

Avoided greenhouse gas emissions:
3,668 metric tons of carbon dioxide

Total potential carbon benefit:
5,393 metric tons of carbon dioxide

Equivalent to:

1,030 cars off the road for a year

Energy to operate a home for 458 years

MEC Head Office

Vancouver, BC

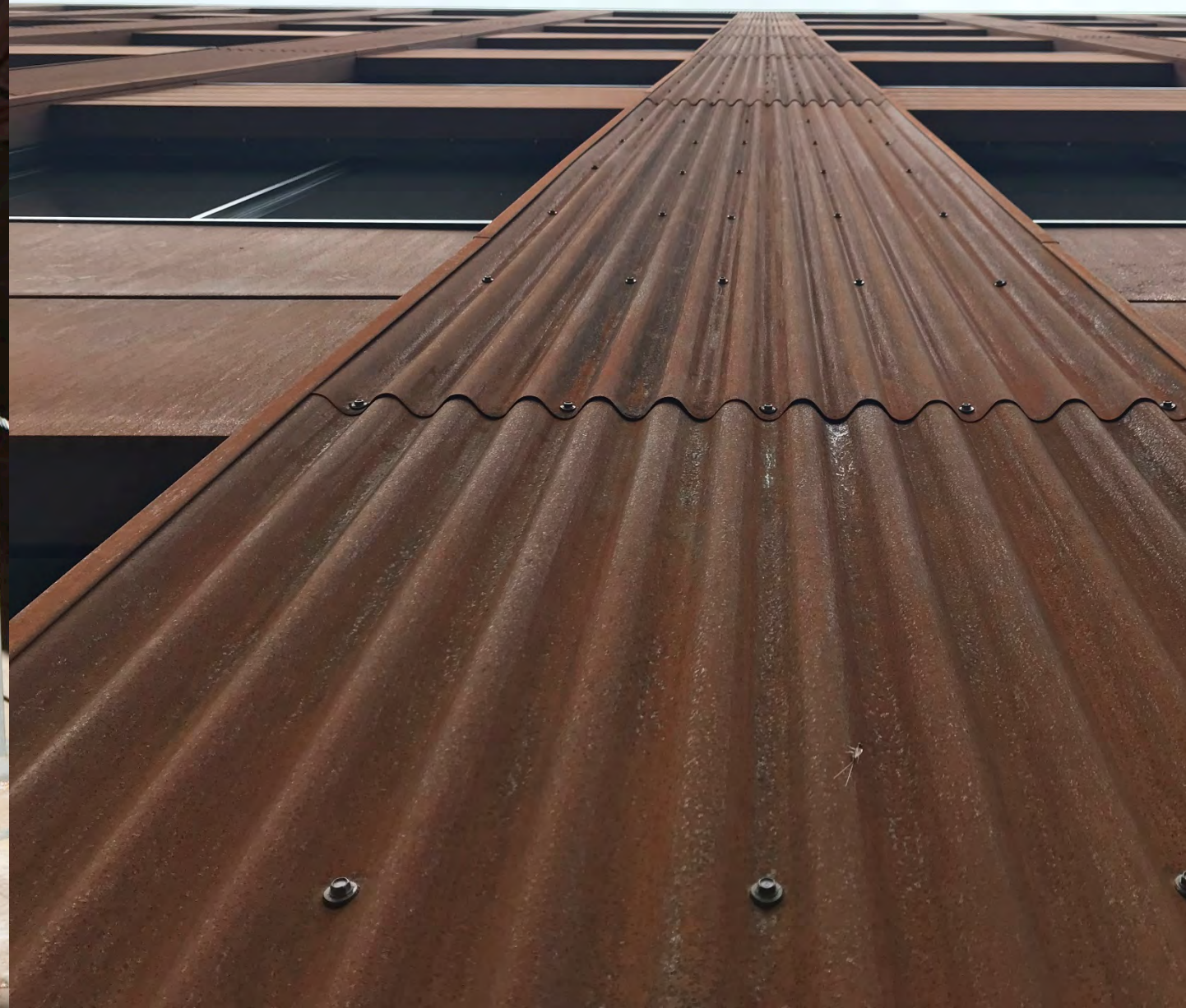
"We realized that wood could give the space the atmosphere the client wanted; at the same time being the most environmentally responsible choice."
Hugh Cochlin, Principal - Proscenium Architecture + Interiors Inc.

Quote & Carbon Summary Source: MEC WW! CA Case Study: http://cwc.ca/wp-content/uploads/2015/05/Mountain-Equipment-Co-Op-Case-Study_.pdf

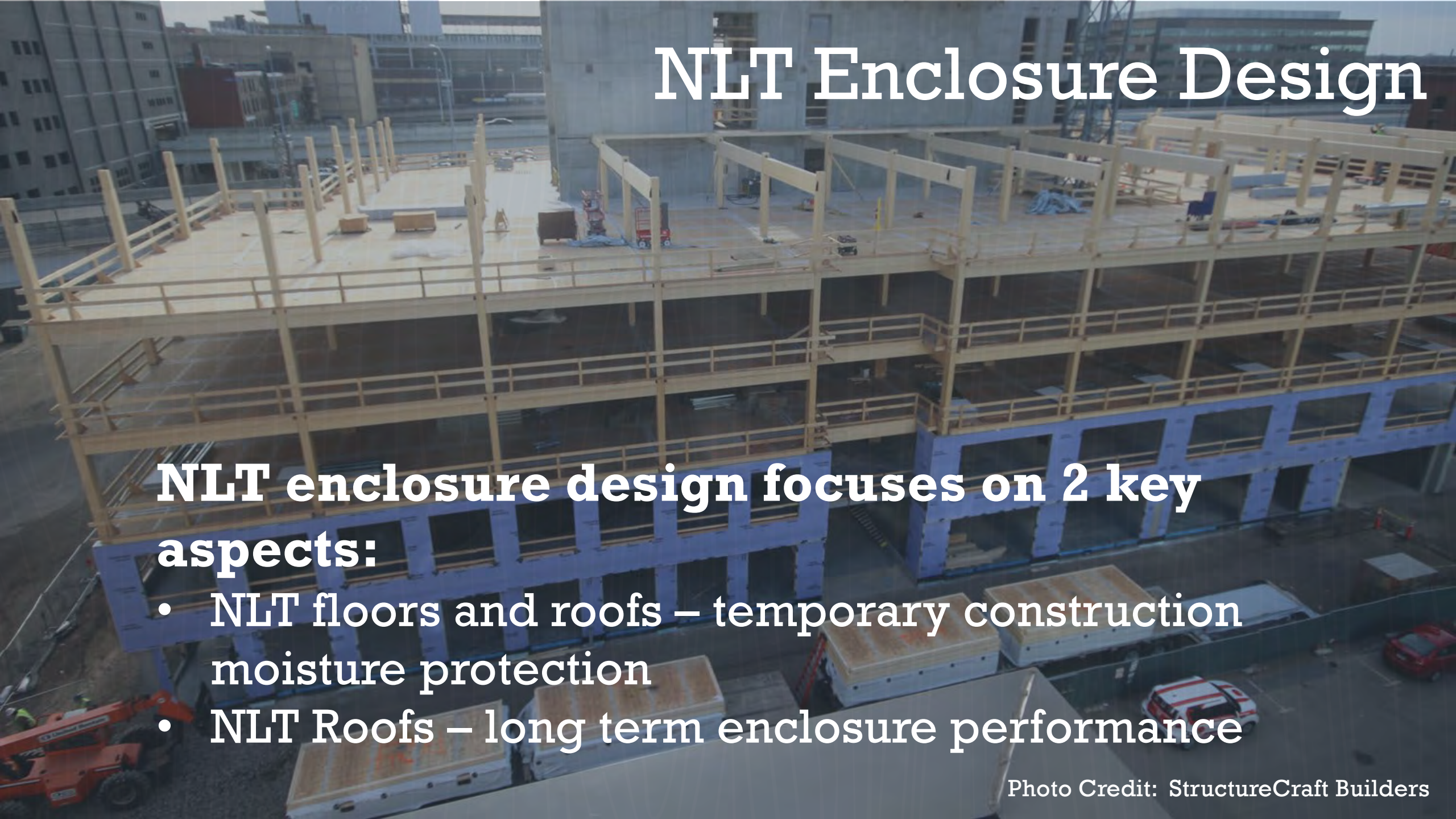
Photo Credit: Seagate Structures

NLT Enclosure Design

Photo Credit: John Stamets



NLT Enclosure Design

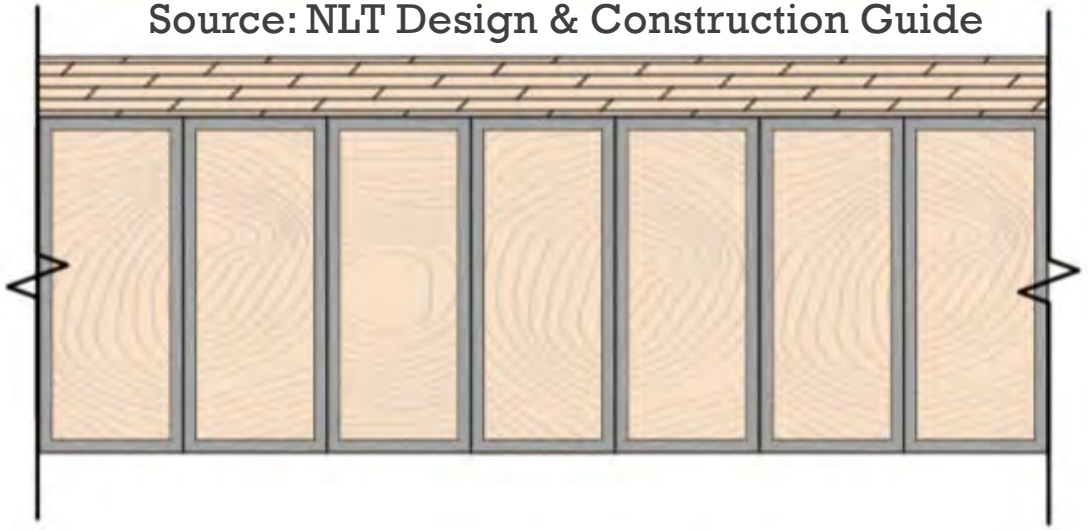


NLT enclosure design focuses on 2 key aspects:

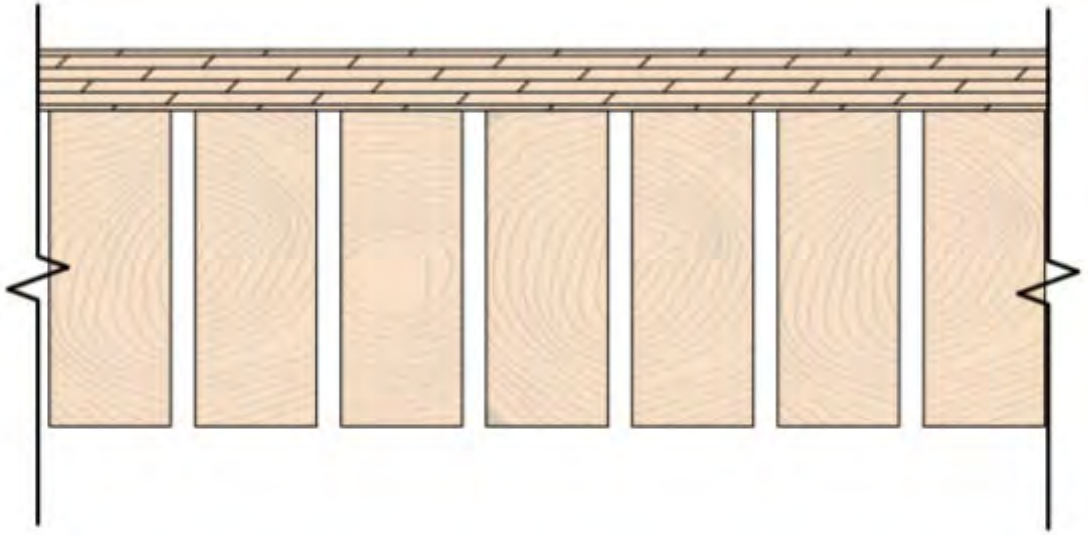
- NLT floors and roofs – temporary construction moisture protection
- NLT Roofs – long term enclosure performance

Photo Credit: StructureCraft Builders

Source: NLT Design & Construction Guide



Lamination expansion due to swelling



Lamination position after NLT has returned to lower moisture

NLT Enclosure Design

NLT floor and roof panels exposed to moisture during construction can cause expansion in lam widths

Photo Credit: StructureCraft Builders

NLT Enclosure Design

NLT shrinkage/expansion design:

Rule of thumb: leave gap between ½ ” and one ply wide per 8’-10’ wide panel

NLT Enclosure Design

Photo Credit: StructureCraft Builders

NLT panels often pre-sheathed

Once installed on site, add stitching strips. Some recommend taping panel joints, keeping standing water off system – helps minimize moisture absorption by NLT

NLT Enclosure Design

Water Control

Protect NLT from wetting and condensation: Dry = Durable

Thermal Control/Insulation

Wood provides some thermal resistance, but additional insulation still needed in assemblies/details

Vapor Control

Wood is a vapor barrier, no supplemental VB needed. Consider drying by design & material placement in NLT assemblies

Air Flow Control

NLT is not an airtight material supplemental materials & details needed for air barrier system

Source: RDH Building Science

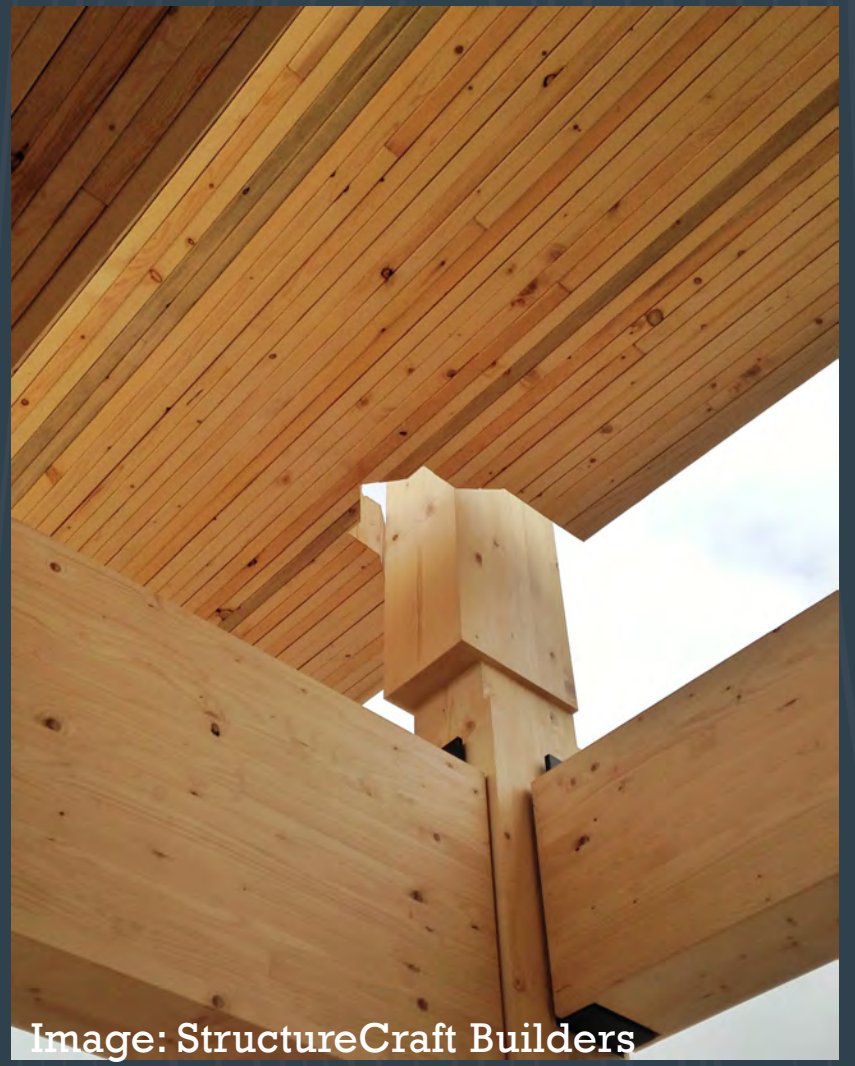


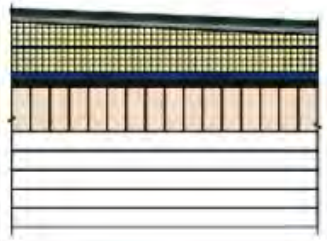
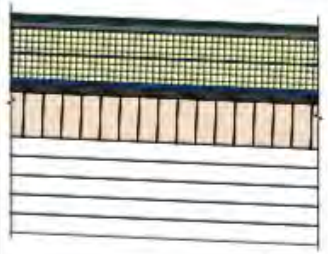
Image: StructureCraft Builders

Source: NLT Design & Construction Guide

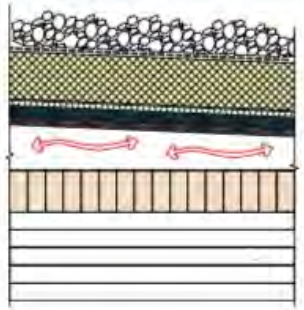
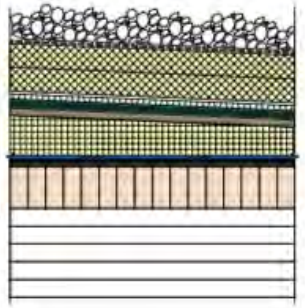
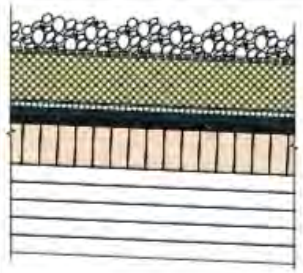
NLT Enclosure Design

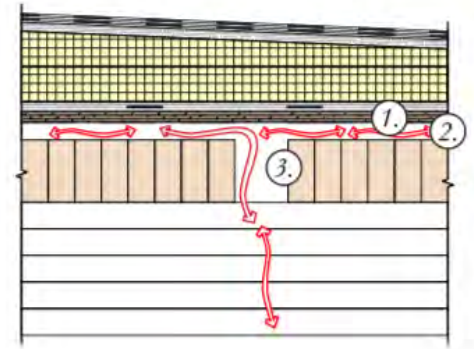
Many configuration options

CONVENTIONAL ROOF MEMBRANE ASSEMBLIES

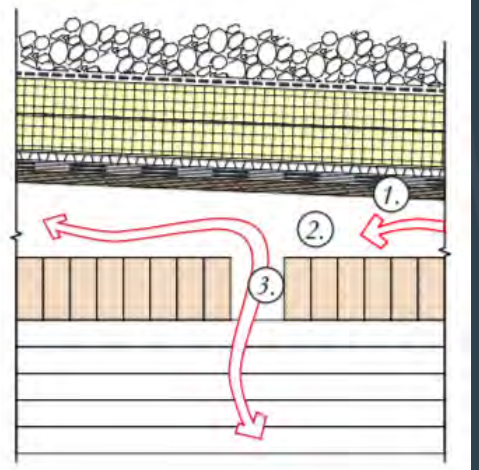
	DETAILS	TYPICAL ASSEMBLY LAYERS (TOP TO BOTTOM)
SLOPED OVER-FRAMING		Roof membrane Coverboard Rigid insulation Air/vapor control membrane/TMMS Structural Plywood/OSB Sloped over-framing, Air cavity, vented to interior. (Refer to section 5.4.1) NLT Roof support (beyond)
TAPERED INSULATION		Roof membrane Coverboard Tapered rigid insulation Air/vapor control membrane/TMMS Structural Plywood/OSB NLT Roof support (beyond)
SLOPED STRUCTURE		Roof membrane Coverboard Rigid insulation Air/vapor control membrane/TMMS Structural Plywood/OSB NLT Sloped roof support (beyond)

INVERTED ROOF MEMBRANE ASSEMBLIES

	DETAILS	TYPICAL ASSEMBLY LAYERS (TOP TO BOTTOM)
SLOPED OVER-FRAMING		Overburden/ballast Extruded polystyrene insulation Drainage composite Roof membrane/TMMS Structural Plywood/OSB Sloped over-framing Air cavity, vented to interior NLT Structural support (beyond)
TAPERED INSULATION		Overburden/ballast Extruded polystyrene insulation Drainage composite Roof membrane Coverboard Tapered rigid insulation Air/Vapor Control Membrane/TMMS Structural Plywood/OSB NLT Structural support (beyond)
SLOPED STRUCTURE		Overburden/ballast Extruded polystyrene insulation Drainage composite Roof membrane/TMMS Structural Plywood/OSB NLT Structural support (beyond)

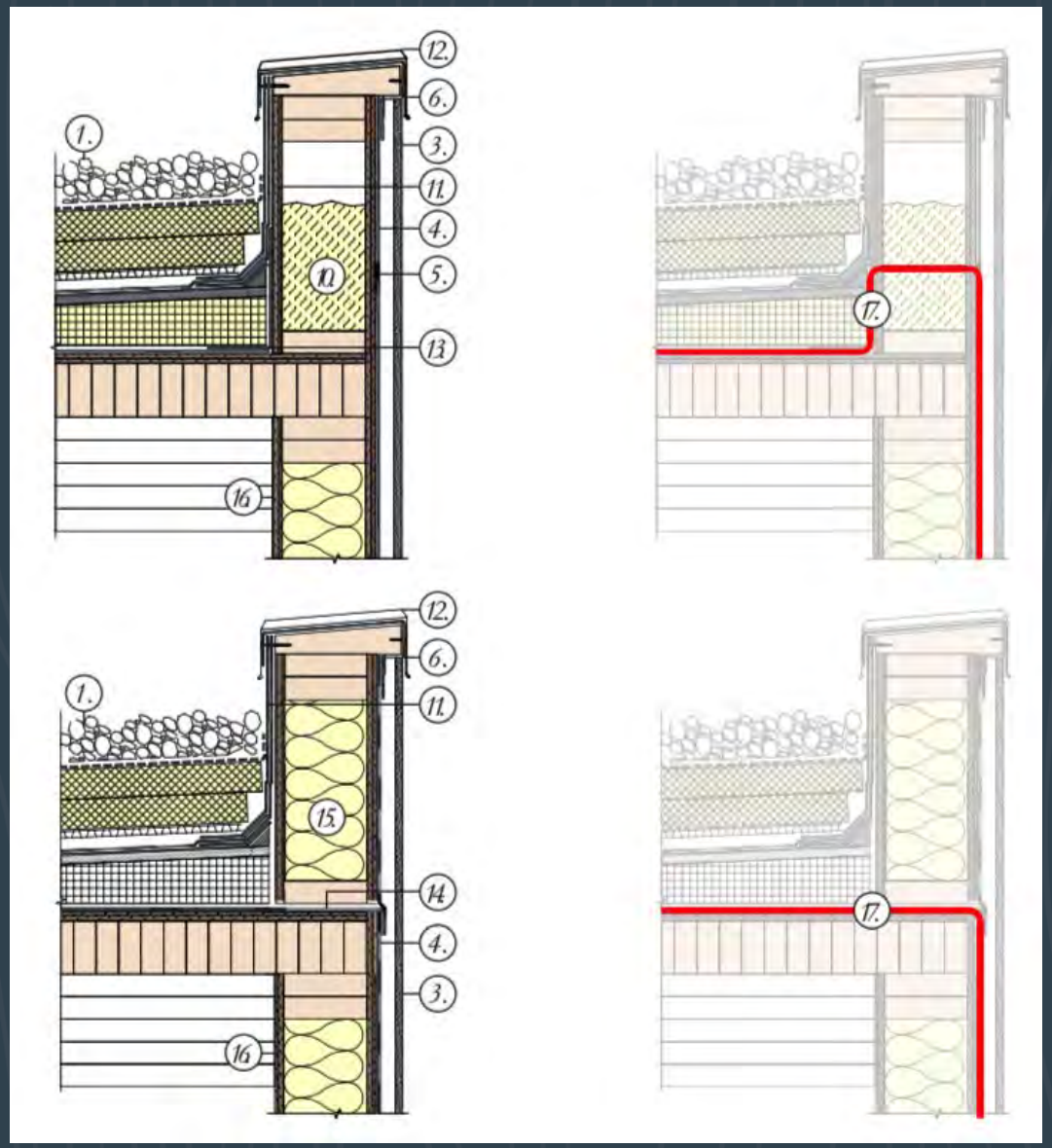


Vented Battens

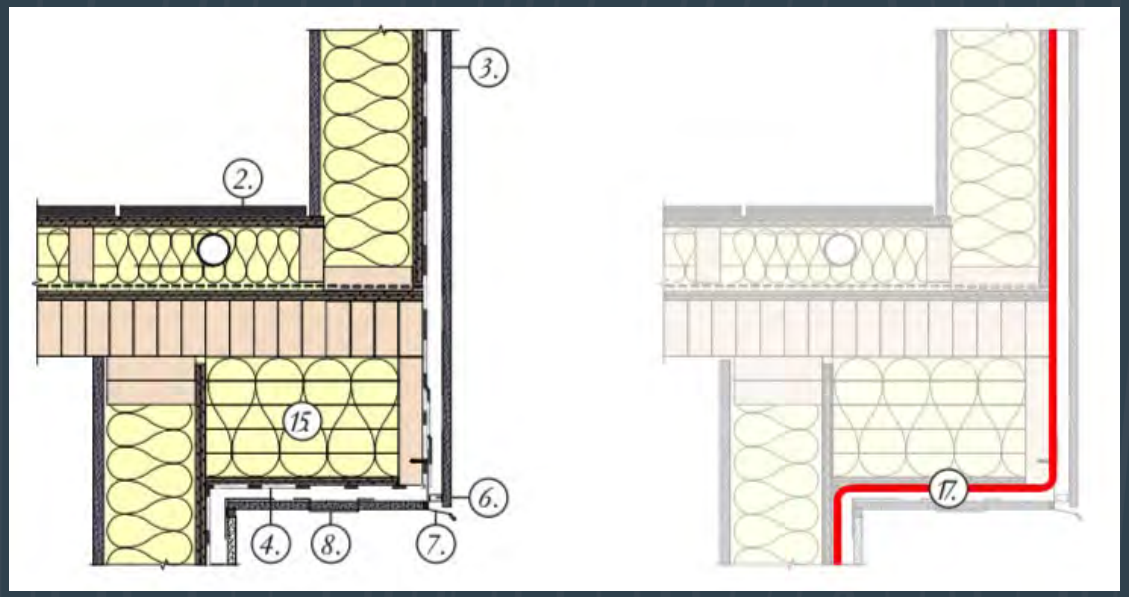


Sloped and Vented Over-Framing

NLT Enclosure Design



Source: NLT Design & Construction Guide



Consider importance of continuity of control layers at assembly intersections: balconies, parapets, wall offsets, floor soffits

NLT Enclosure Design

Wood has inherent thermal benefits

- NLT wall and roof panels can contribute to envelope's thermal needs
- R1-1.3 per inch of NLT thickness

Source: NLT Design & Construction Guide

TABLE 5.1 THERMAL CONDUCTIVITY AND R-VALUES OF COMMON NLT SOFTWOOD LAMINATIONS AND SHEATHING

A. THERMAL CONDUCTIVITY VALUES FOR COMMON NLT SOTWOOD SPECIES

SPECIES	THERMAL CONDUCTIVITY (Btu-in/h-ft²-°F)	THERMAL RESISTANCE PER INCH (h-ft²-°F/Btu)
Hem-Fir / Spruce-Pine-Fir	0.74-0.90	1.11-1.35
Douglas Fir-Larch	0.95-1.01	0.99-1.05
Southern Yellow Pine	0.9	1.1

B. TYPICAL SHEATHING R-VALUES

SHEATHING TYPE	THICKNESS (INCHES)	THERMAL RESISTANCE PER INCH (h-ft²-°F/Btu)
Plywood	1/2	0.79
Plywood	5/8	0.85
Plywood	3/4	1.08
OSB	7/16	0.62

C. TYPICAL NLT LAMINATION R-VALUES

WOOD LAMINATION NOMINAL DIMENSION	ACTUAL THICKNESS (INCHES)	THERMAL RESISTANCE PER INCH (h-ft²-°F/Btu)
2x4	3.5	3.5-5.0
2x6	5.5	5.5-7.9
2x8	7.25	7.3-10.4
2x10	9.25	9.3-13.2

NLT Structural Design

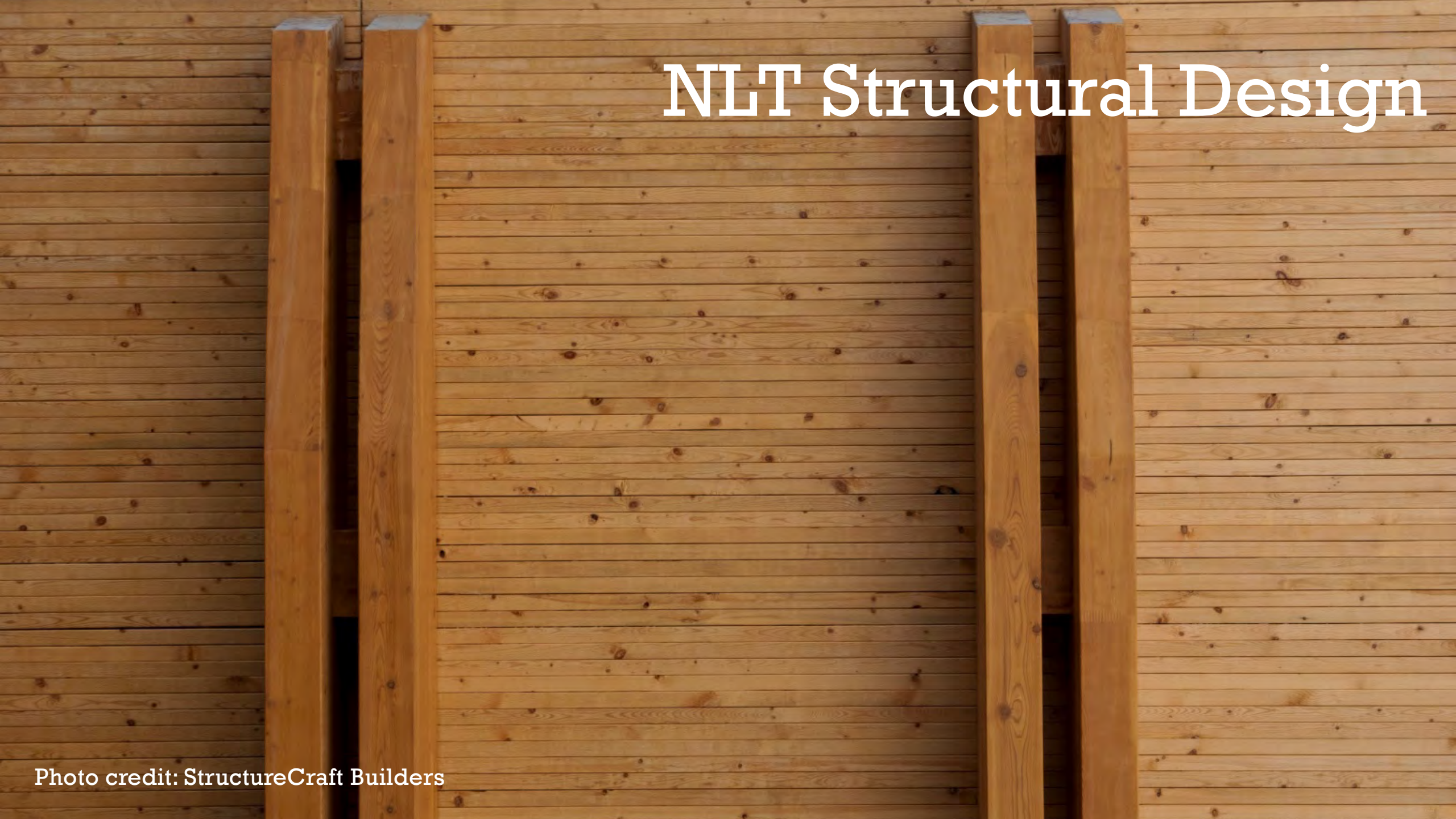


Photo credit: StructureCraft Builders

NLT Structural Design

Simplistically, NLT Gravity design is 2x Joists @ 1-1/2” o.c.
However, there are a few nuances to consider

NLT Structural Design

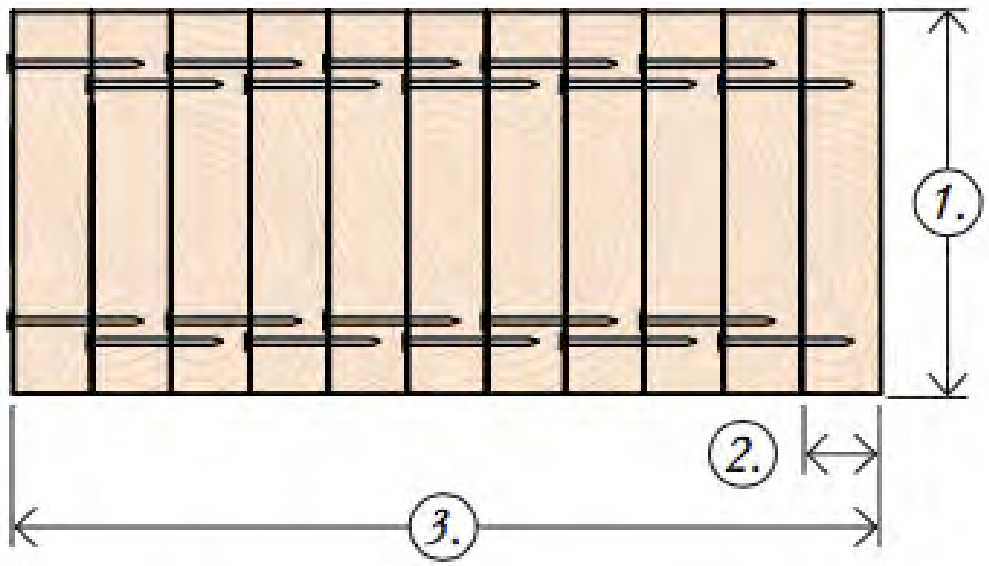


Figure 4.1: *NLT Cross Section*

Key

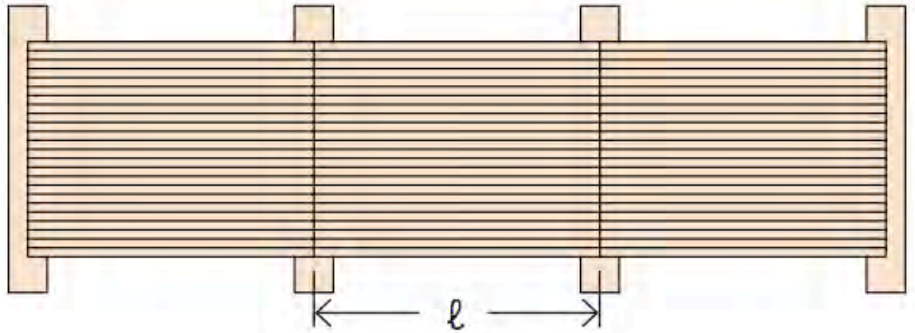
1. *NLT depth (d)*
2. *Lamination thickness (b_{lam})*
3. *NLT panel width (b)*

Source: NLT Design & Construction Guide

NLT Lam to Lam Nailing

- Prescriptive lam to lam and lam to support nailing patterns given in IBC 2304.9.3.2
- 2018 IBC Revisions allow alternate nailing patterns
- Can also specify nailing pattern based on an engineered design
- Under type IV, IBC 602.4.6.1 only requires that lams are “well spiked”

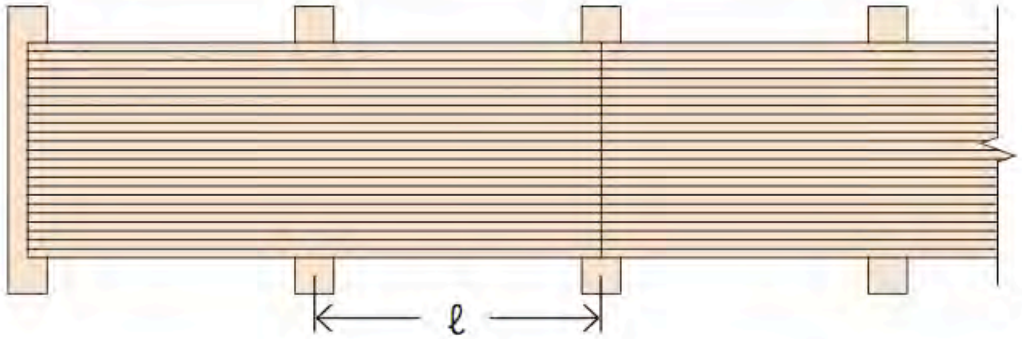
NLT Structural Design

LAYUP TYPE	
Laminations continuous and single span	

ADJUSTMENT FACTOR		NOTES
Bending Strength ($K_{layup.b}$)	Stiffness ($K_{layup.E}$)	
$K_{layup.b} = 1.0$ $M = \frac{w\ell^2}{8}$	$K_{layup.E} = 1.0$ $\Delta = \frac{5w\ell^4}{384E\,(d^3/12)}$	Maximum strength for a given depth. Typical maximum length for laminations of 16 to 20 feet. Longer laminations can be fabricated with structural finger joints (certified exterior joints or certified end joints).

Source: NLT Design & Construction Guide

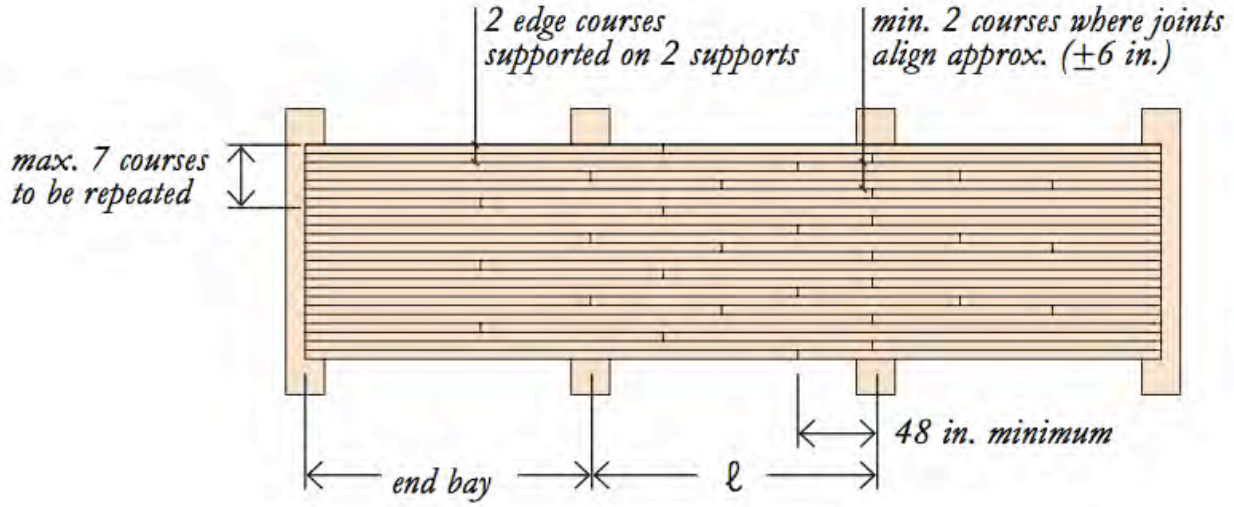
NLT Structural Design

LAYUP TYPE	
Laminations continuous and multi-span	

ADJUSTMENT FACTOR		NOTES
Bending Strength ($K_{layup.b}$)	Stiffness ($K_{layup.E}$)	
$K_{layup.b} = 1.0$ $M = \frac{w\ell^2}{8}$	$K_{layup.E} = 1.0$ $\Delta = \frac{w\ell^4}{185E\,(d^3/12)}$	Maximum strength and stiffness for a given depth. Typical maximum length for laminations of 16 to 20 feet. Longer laminations can be fabricated with structural finger joints (certified exterior joints or certified end joints).

Source: NLT Design & Construction Guide

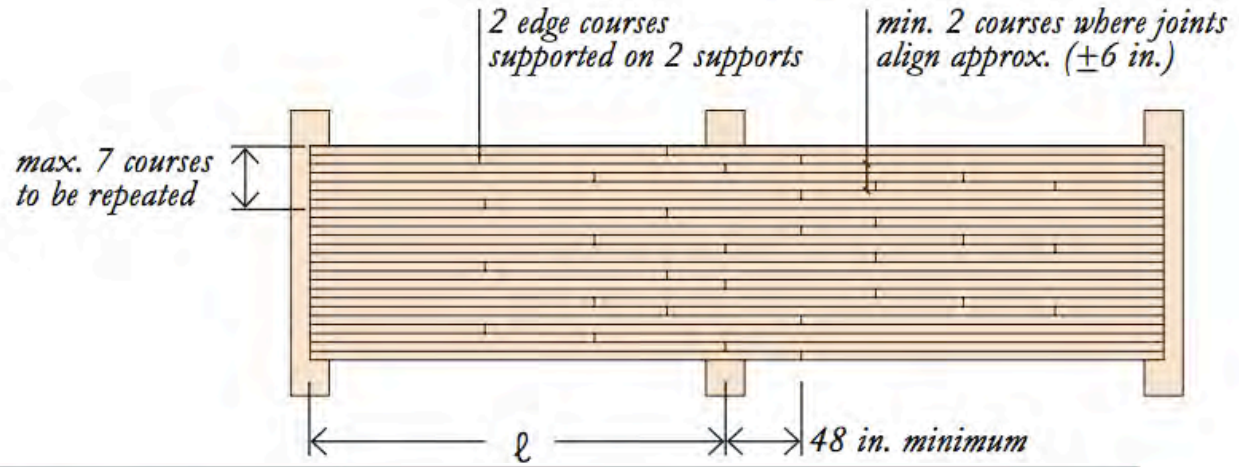
NLT Structural Design

LAYUP TYPE	
Laminations with controlled random butt joints over 4 or more supports	

ADJUSTMENT FACTOR		NOTES
Bending Strength ($K_{layup.b}$)	Stiffness ($K_{layup.E}$)	
$K_{layup.b} = 0.67$ $M = 0.10w\ell^2$	$K_{layup.E} = 0.69$ $\Delta = \frac{0.0069w\ell^4}{E\,(d^3/12)}$	Maximum stiffness for a butt-jointed system. Rules for joint locations are given in IBC 2304.9.2.5 and 2304.9.3.3, and illustrated in the adjacent figure.

Source: NLT Design & Construction Guide

NLT Structural Design

LAYUP TYPE	
Laminations with controlled random butt joints over fewer than 4 supports	

ADJUSTMENT FACTOR		NOTES
Bending Strength ($K_{layup.b}$)	**Stiffness** ($K_{layup.E}$)	
$K_{layup.b}=0.202\frac{(\ell/d)^{1/4}}{s^{1/9}}$	$M=\frac{w\ell^2}{8}$	Based on European research, rules for joint locations per IBC should be amended as follows: • Where butt joints occur in the same general line (±6 in.), they must be separated by a minimum of three intervening laminations. • Each lamination must extend over a minimum of one support. • See Section 4.3.1 for minimum nailing requirements.
$K_{layup.E}=0.0436\frac{(\ell/d)^{9/10}}{s^{1/5}}$	for single span: $\Delta=\frac{5w\ell^4}{384E\,(d^3/12)}$ for double span: $\Delta=\frac{w\ell^4}{185E\,(d^3/12)}$	

Source: NLT Design & Construction Guide

Note: This method may require building official approval as it is not prescriptively in IBC

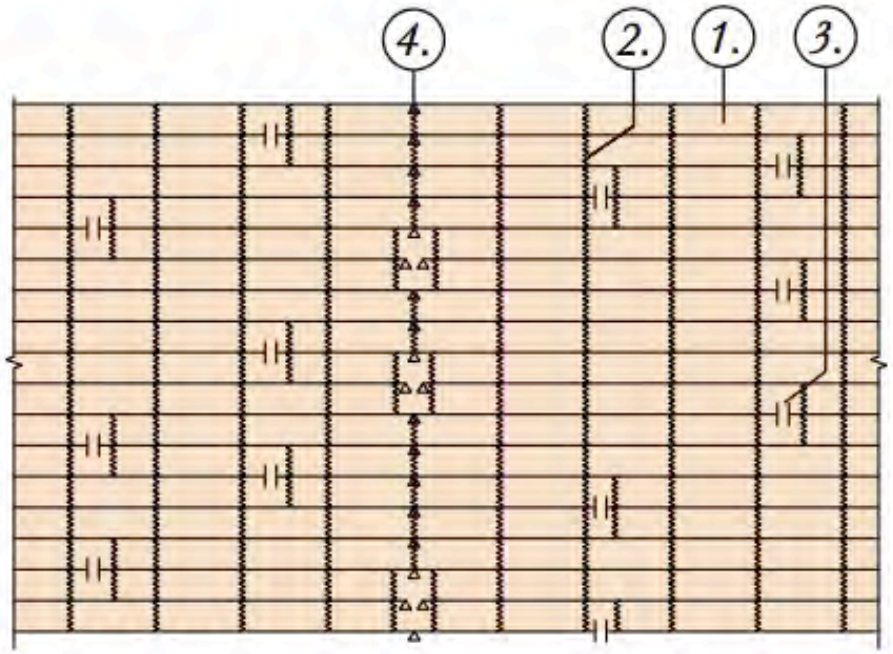


Figure 4.2: *Grillage Model*

Key

1. *NLT lamination (modeled as beam element)*
2. *Spring between lams representing nails (model stiffness to match nail shear behavior)*
3. *Break in lamination at butt joint (modeled without connection to lam within the course)*
4. *Support location (modeled as pinned supports at each lam)*

NLT Structural Design

NLT Joint Layup

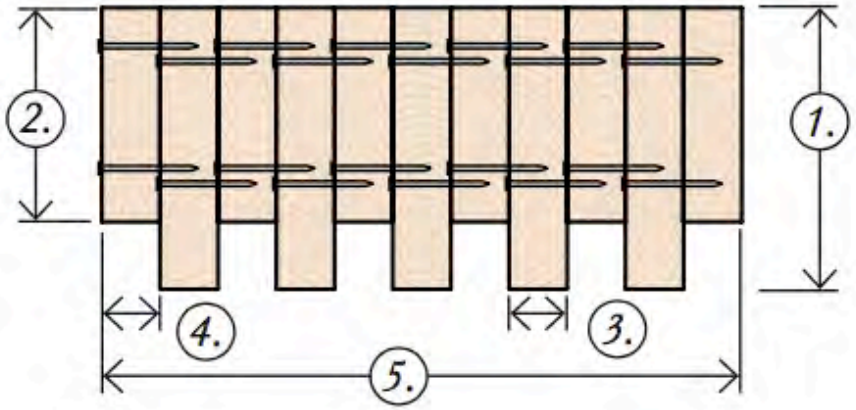
- **Factors based on IBC Table 2306.1.4 & European research**
- **Other layups possible**
  - IBC 2304.9.2
  - Custom designs for alternate layups

Source: NLT Design & Construction Guide

NLT Structural Design

Fluted panel options
Vary lamination depths

Photo credit: Structure Craft Builders



$$6.\quad x_i = \frac{n_i\, b_{lam\ i}}{b_{panel}}$$

Figure 4.3: *Staggered NLT Cross Section*

Key

1. *NLT deep lamination depth (d_1)*
2. *NLT shallow lamination depth (d_2)*
3. *NLT deep lamination thickness (b_{lam1})*
4. *NLT shallow lamination thickness (b_{lam2})*
5. *NLT panel width (b)*
6. *Ratio of lamination depths (x_i), where n_i = the number of laminations of depth d_i*

NLT Structural Design

STIFFNESS ($K_{section.E}$)	BENDING ($K_{section.b}$)	SHEAR ($K_{section.v}$)
$K_{section.E} = X_1 + X_2\left[\frac{d_2}{d_1}\right]^3$	$K_{section.b} = X_1 + X_2\left[\frac{d_2}{d_1}\right]^3$	$K_{section.v} = X_1$

$K_{section}$ is always < 1 and applied assuming full panel depth of x_1

Example: 2x4 and 2x6 alternating lams

$$x_1 = x_2 = 0.5$$

$$K_{section,b} = 0.5 + 0.5\left[\frac{3.5}{5.5}\right]^3 = 0.63$$

Source: NLT Design & Construction Guide

NLT Structural Design

NLT STRESS	NLT CAPACITY
$f_b = \frac{6M}{b_{panel} d^2}$	$F_{b.NLT}' = F_b' K_{layup.b} K_{section.b}$

NLT STRESS	NLT CAPACITY
$f_v = \frac{3V}{2 b_{panel} d}$	$F_{v.NLT}' = F_v' K_{section.v}$

$$EI = E_{NLT}' I = E' K_{layup.E} K_{section.E} \frac{b_{panel} d^3}{12}$$

Source: NLT Design & Construction Guide

NLT Structural Design

NLT Vibration Design Options:

- Deflection limits (L/480, L/600, etc)
- Fundamental frequency Lower limits (8-9 hz)
- AISC Design Guide For Steel Structure Vibrations
- ISO 10137

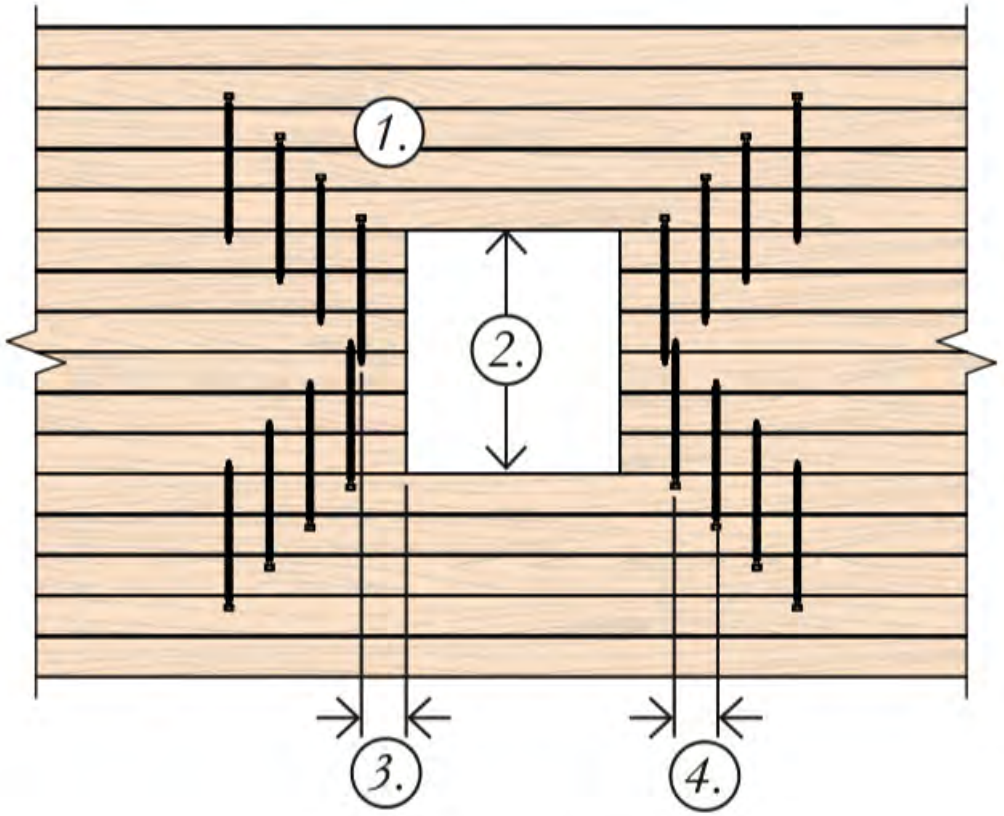
Consider impact of partitions, structural supports

Damping value of 2%-4% assumed for bare NLT

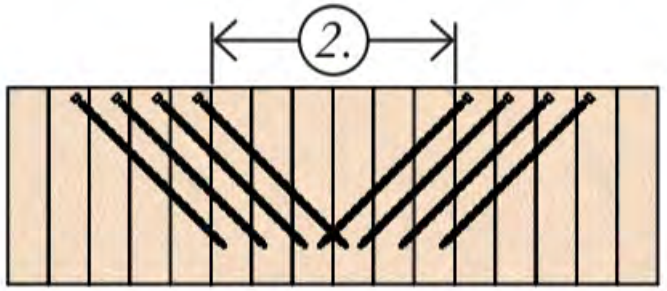
NLT DEPTH	TYPICAL SPAN RANGE
4 in. nominal	up to 12 ft.
6 in. nominal	10 to 17 ft.
8 in. nominal	14 to 21 ft.
10 in. nominal	17 to 24 ft.
12 in. nominal	20 to 26 ft.

Spans will vary and may fall outside these ranges depending on use, loading, and vibration criteria.

Source: NLT Design & Construction Guide



Plan View of Opening



Section Beyond Opening

NLT Structural Design

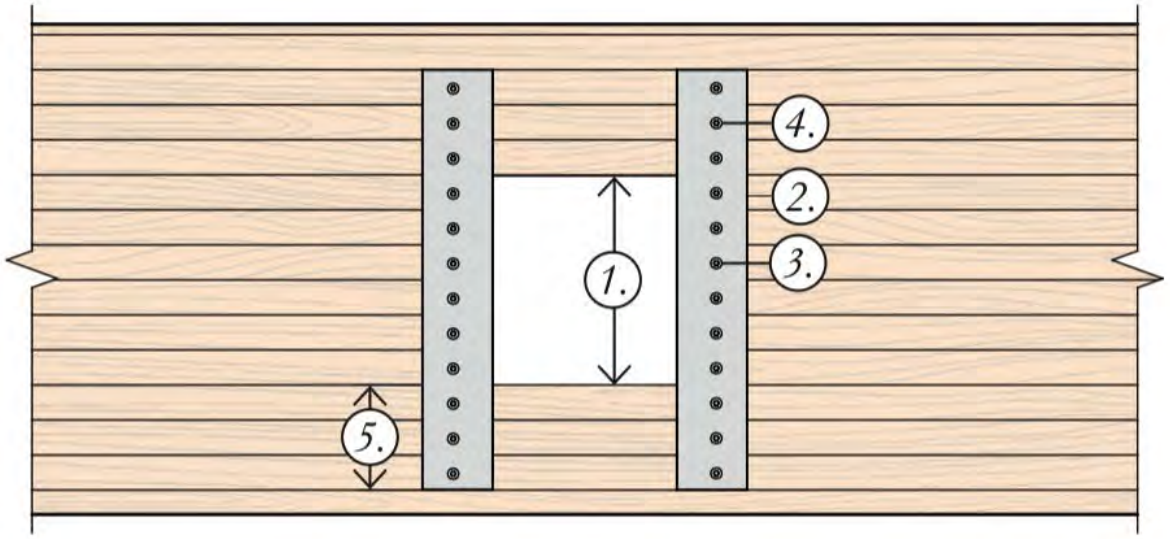
Openings up to 3” dia. (pipes) – typ. no reinforcing req’d

Openings between 3” & 9” typ. Reinforced with self tapping screws or supplemental steel angles or channels

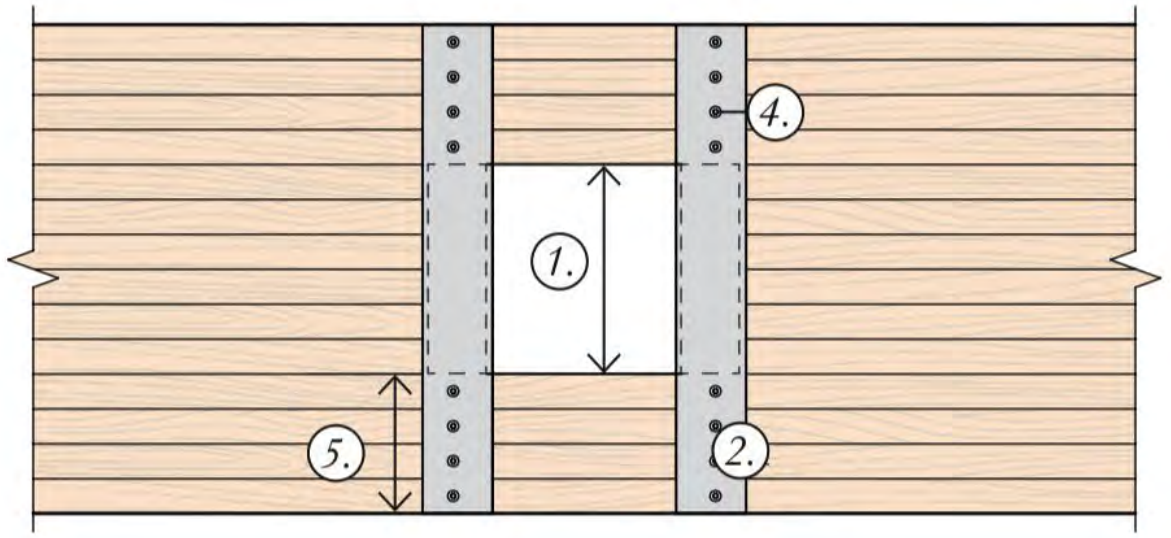
Source: NLT Design & Construction Guide

Openings between 3” & 9” reinforced with steel

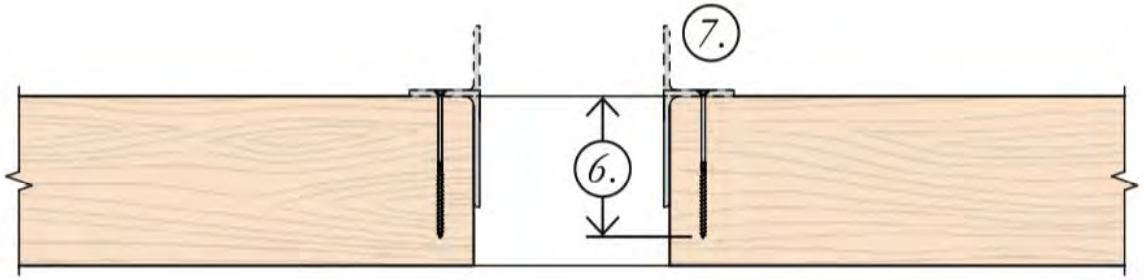
NLT Structural Design



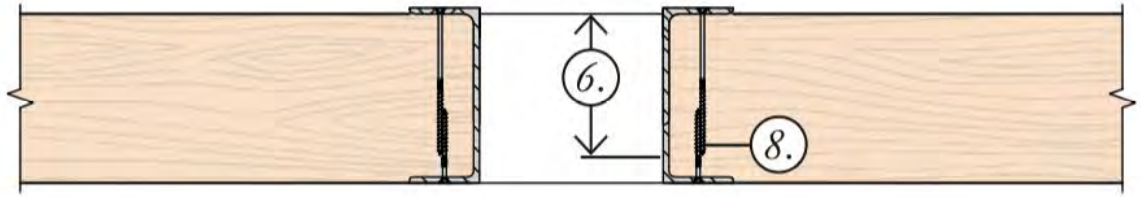
Plan View of Opening with Steel Angle Framing



Plan View of Opening with Steel Channel Framing



Section of Opening with Steel Angle Framing



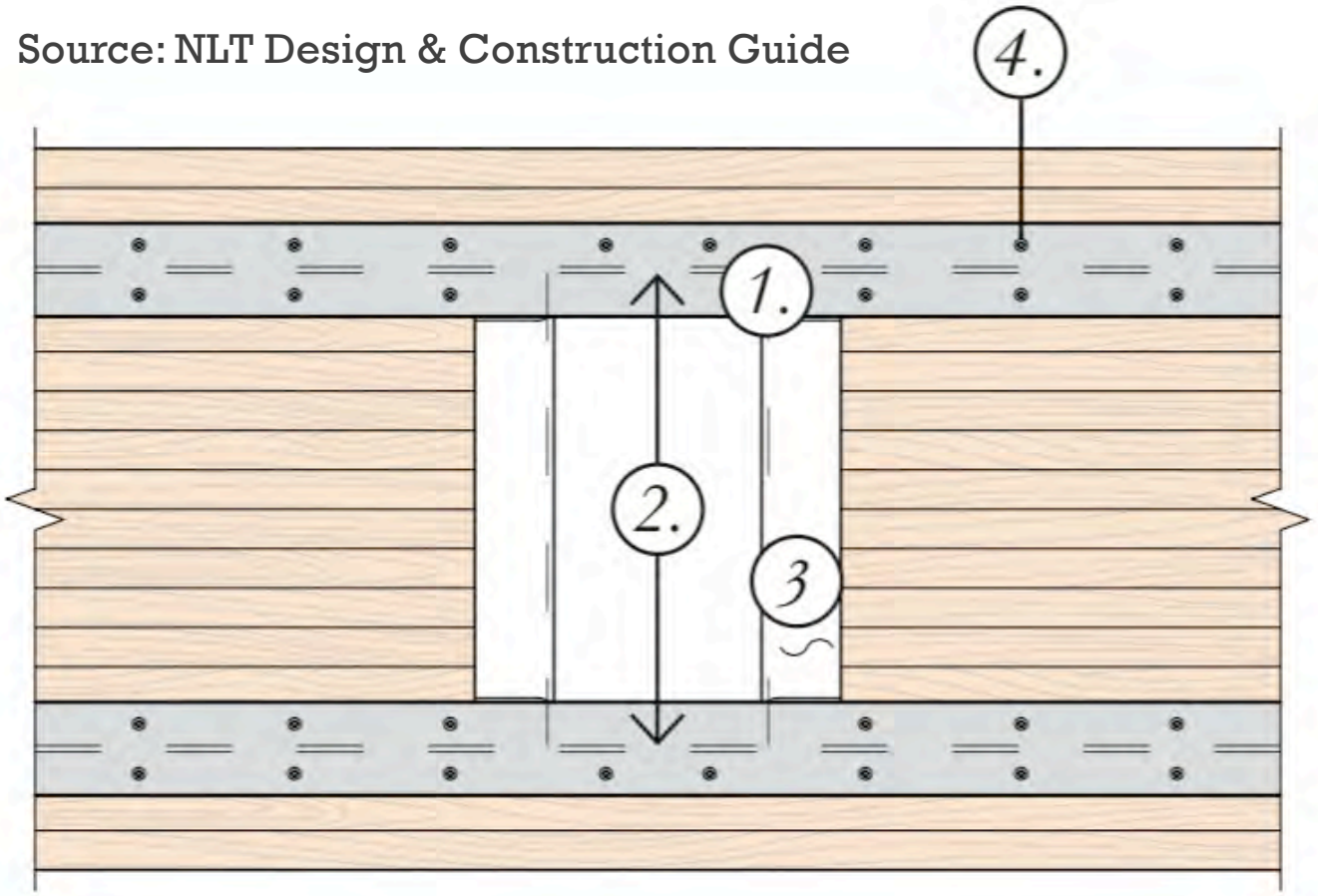
Section of Opening with Steel Channel Framing

Source: NLT Design & Construction Guide

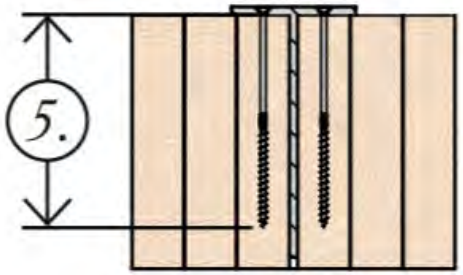
NLT Structural Design

Openings > 9” reinforced with steel both directions

Source: NLT Design & Construction Guide



Plan View of Opening



Section Beyond Opening

Figure 4.19: *Supplementary Steel Framing at Large Openings*

Key

1. *Steel T-section spanning between supports*
2. *Opening width*
3. *Steel framing at opening (channel or angle)*
4. *Nominal screws into NLT laminations*
5. *Screw length of 80% of NLT depth*

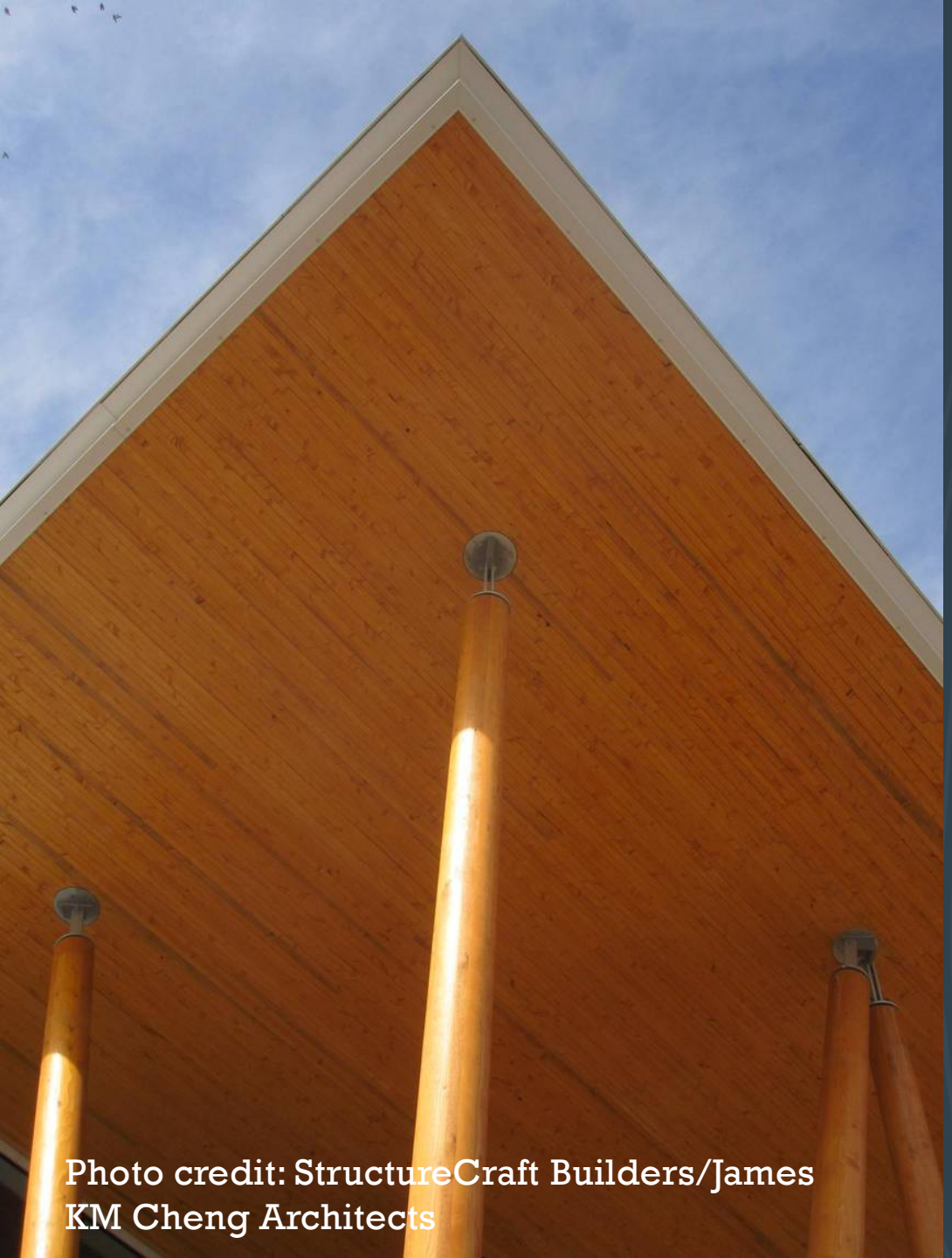
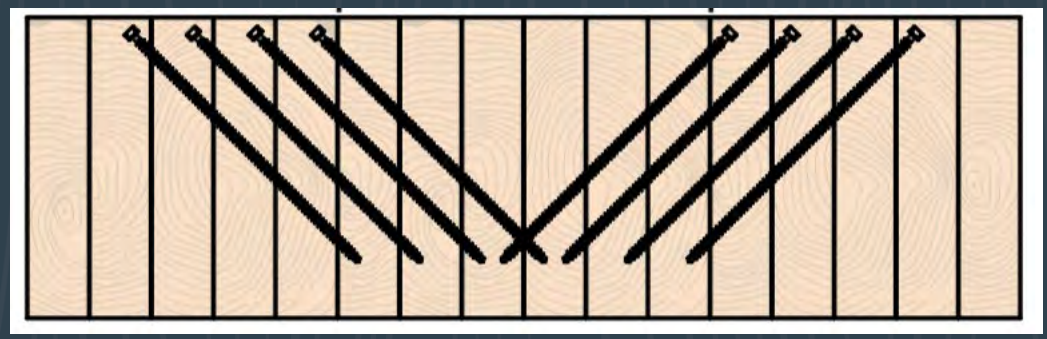


Photo credit: StructureCraft Builders/James KM Cheng Architects

NLT Structural Design

Cantilevers

- NLT cantilevers in strong axis are straightforward
- NLT cantilevers in weak axis require reinforcing screws or supplemental framing



Source: NLT Design & Construction Guide

NLT Structural Design

Grid Options and Member Sizes: What's Been Done

Photo Credit: John Stamets

Bullitt Center

Seattle, WA

11’-6” Beam Spacing

11’-6” column spacing at exterior

23’-0” Column Spacing at interior

2x6 NLT Floor Deck

Photo Credit: John Stamets

120 Clay

Portland, OR

- ~8’ finished floor to bottom of beam
- 25’x30’ at perimeter
- 30’x30’ bays at center
- 2x6 NLT Spans 15’
- Exterior steel moment frame keeps core area more versatile

Hudson Building

Vancouver, WA

- 25’x25’ Grid, 1 row intermediate beams
- 15’-18’ floor to floor heights
- Composite floor: 2x4 and 2x6 NLT floor panels with 3 ½” reinforced concrete topping

Image Credit: Christian Columbres

T3 Minneapolis

Minneapolis, MN

20’x25’ Grid

2x8 NLT Floor Panels span 20’ w/3” Concrete Topping

Image Credit: Ema Peter

NLT Connections

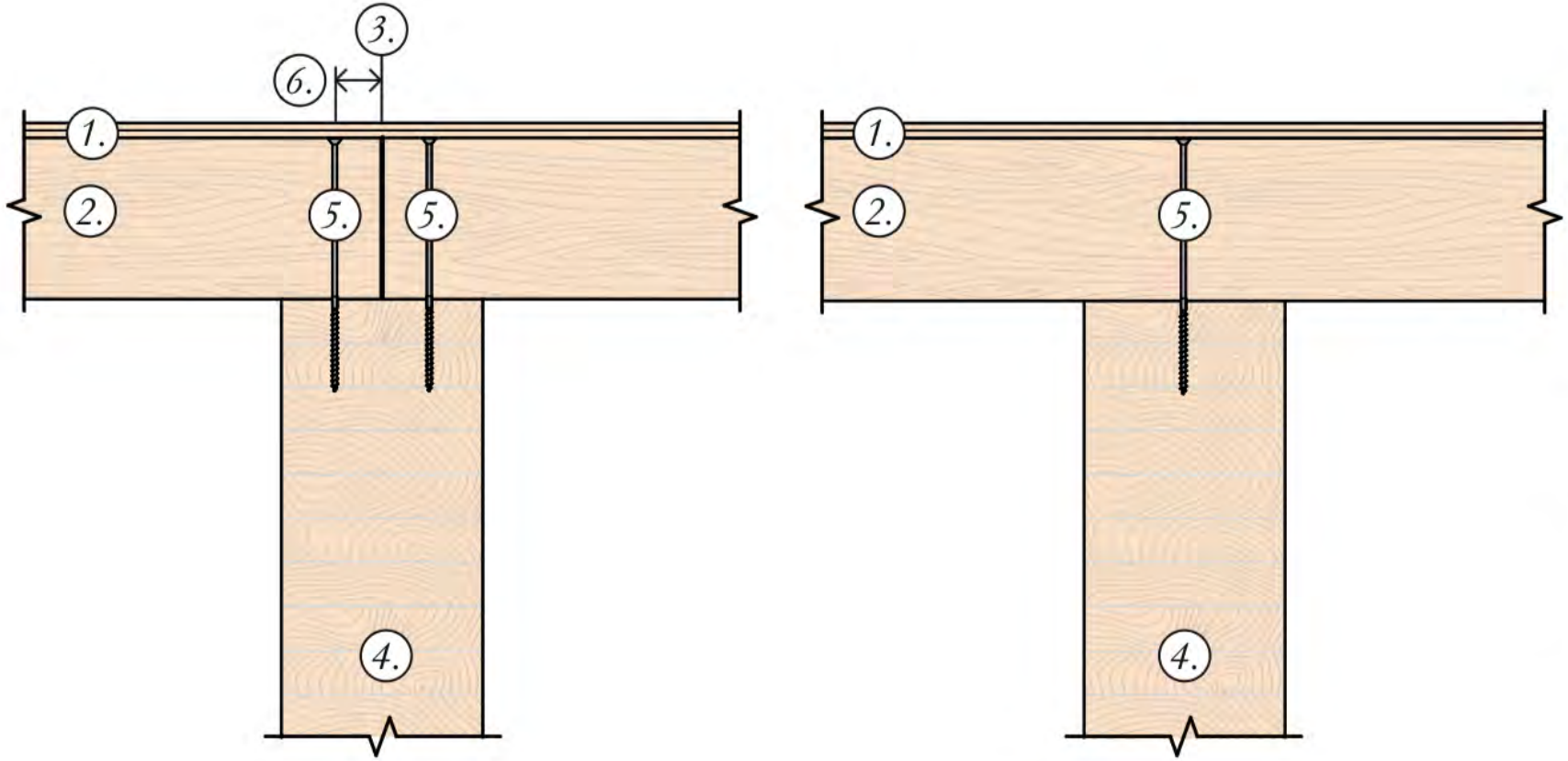
NLT Connections

Photo Credit: Alex Schreyer

Long self tapping screws used extensively throughout NLT construction

NLT Connections

NLT to Bearing Support



Key

1. *Plywood/ OSB installed over countersunk screws*
2. *NLT*
3. *Prefabricated NLT panel joint*
4. *Wood support beam*
5. *Self-tapping partially threaded screws with countersunk heads*
6. *Self-tapping screw fastener end distance*

Figure 4.11: *NLT Connection to Wood Beam*

Source: NLT Design & Construction Guide

NLT Connections

NLT to Bearing Support

Source: NLT Design & Construction Guide

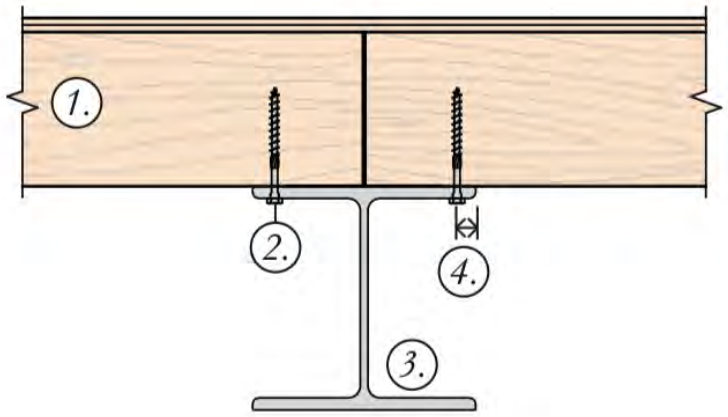


Figure 4.12: *NLT Connection to Steel Beam*

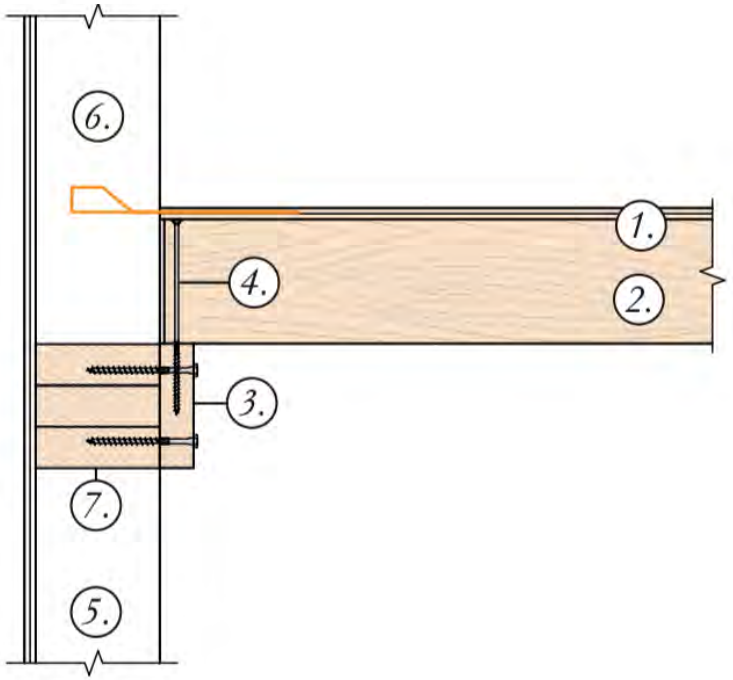
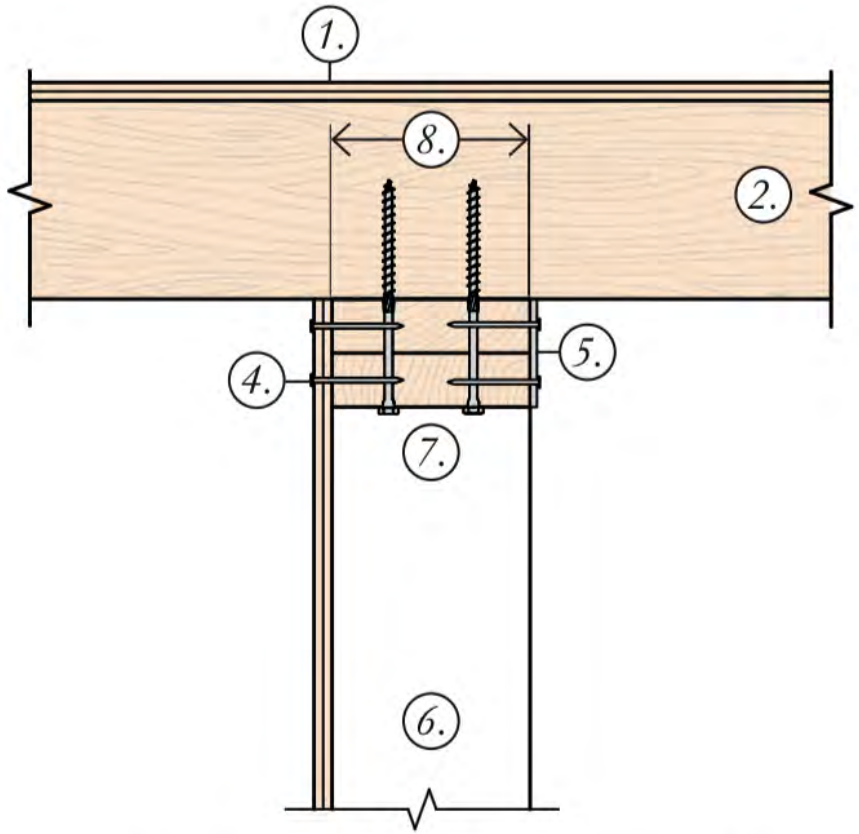
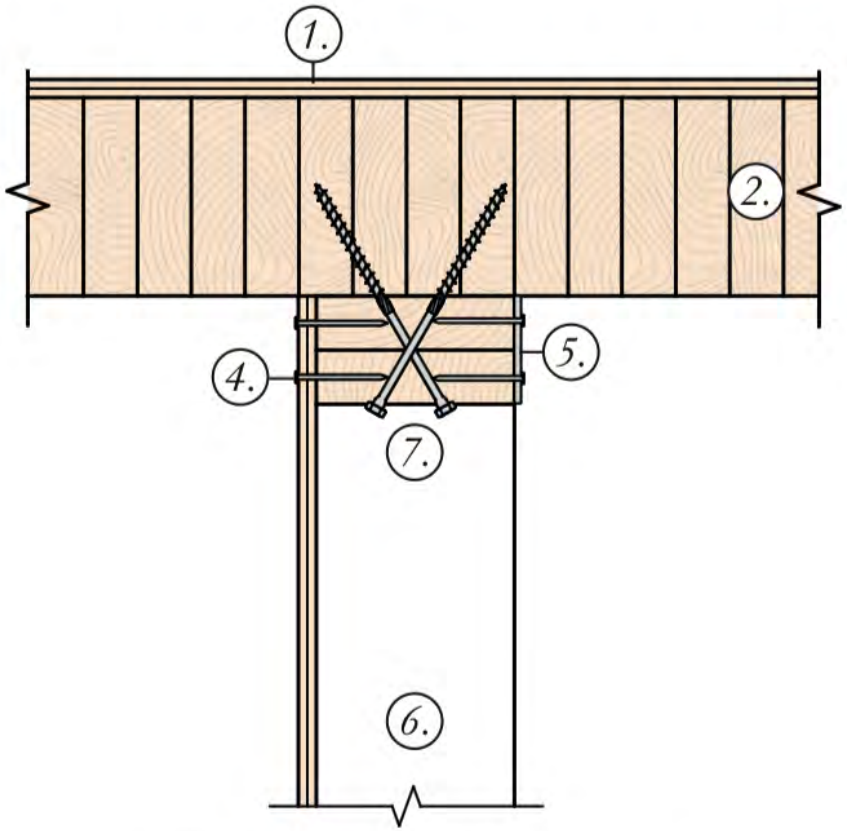


Figure 4.15: *NLT Support at Balloon-Framed Wood Shear Wall*



NLT Span Perpendicular to Shear Wall

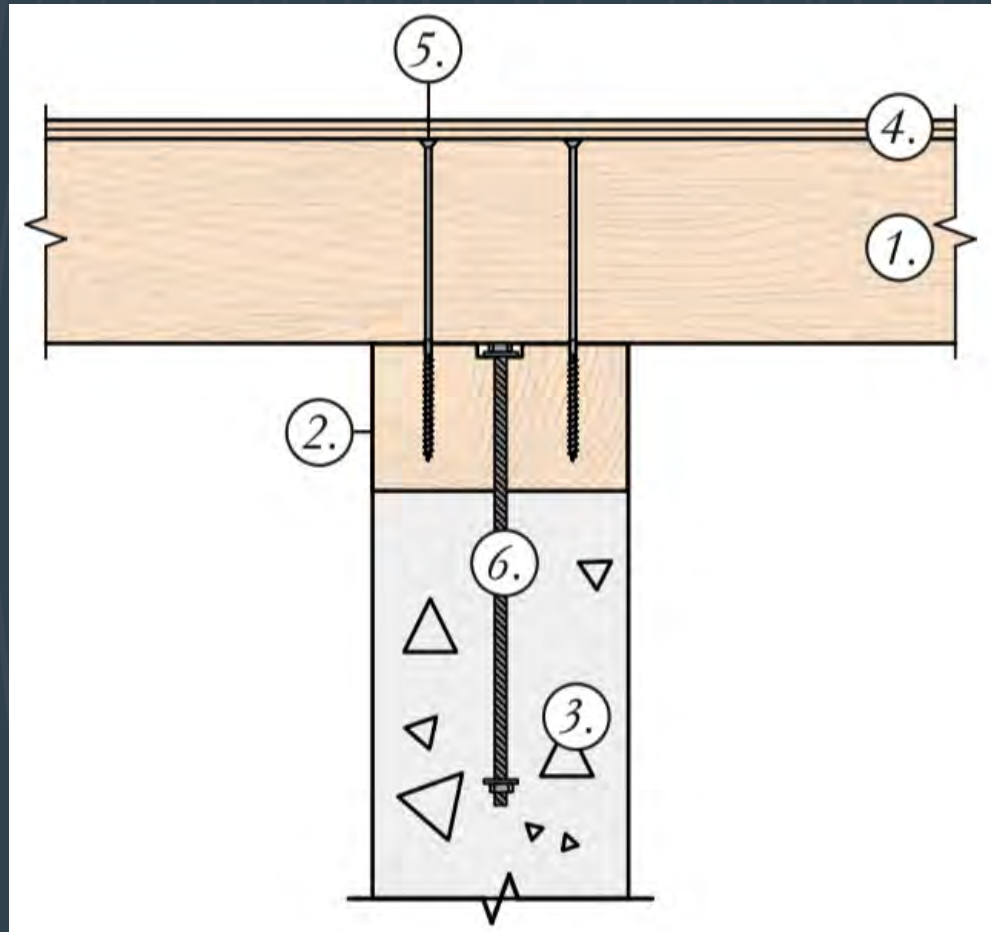


NLT Span Parallel to Shear Wall

NLT Connections

NLT to Foundation

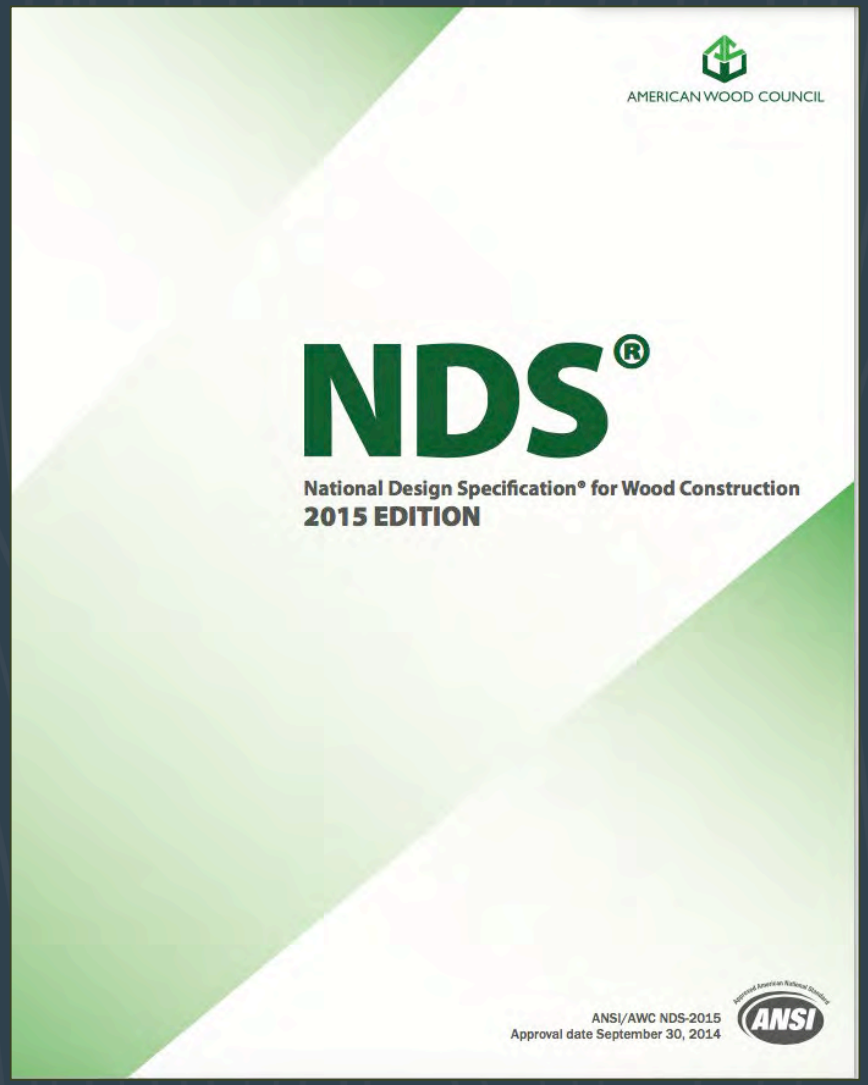
Source: StructureCraft Builders

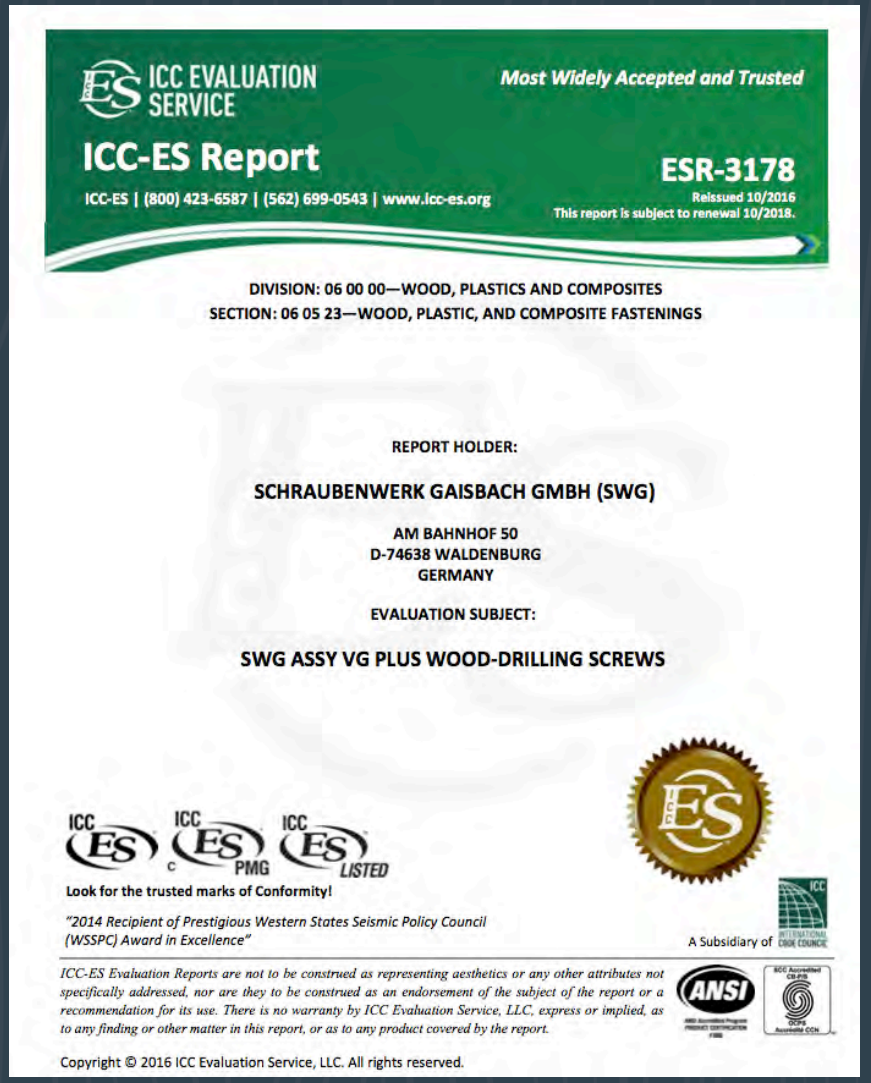


Source: NLT Design & Construction Guide

Figure 4.16: *NLT Connection to Concrete Wall*

NLT Connections





Long self tapping screws not covered in NDS connection provisions. Reference ICC ESR or other product reports

Bullitt Center

Seattle, WA

Photo Credit: Bullitt Center

Bullitt Center

Seattle, WA

2x4 NLT Roof Deck

2x6 NLT Floor Deck

Floor assembly top to bottom:

3” concrete topping, acoustical mat, WSP, 2x6 NLT

Photo Credit: John Stamets

Bullitt Center

Seattle, WA

Beam to column & column to column connections

Photo Credit: John Stamets

NLT Diaphragms

Photo credit: John Stamets

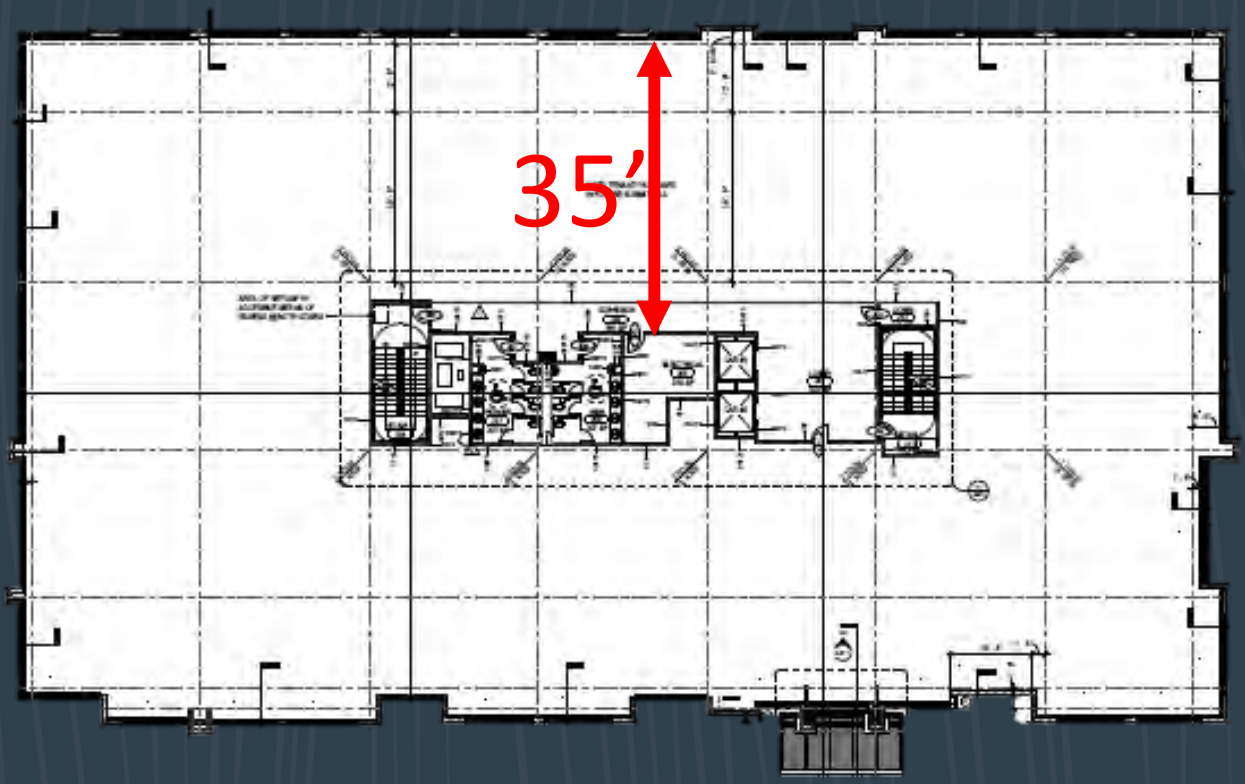
Lack of tested, published diaphragm values for bare NLT lead many engineers to covering with wood structural panels. Design as a blocked, sheathed diaphragm. Use SDPWS Table 4.2A/4.2B

Photo credit: StructureCraft Builders

NLT Diaphragms

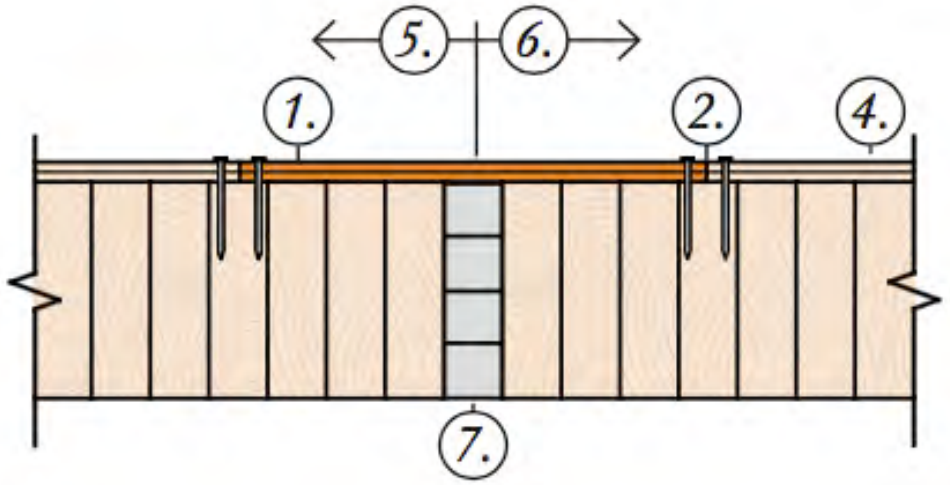
Diaphragm design Options for central core:

- AWC's 2015 special design provisions for wind and seismic (SDPWS) 4.2.5.2 permits a semi-rigid or rigid, cantilever diaphragm up to 35 ft
- If more than 35 ft, consider perimeter lateral resistance such as moment frame

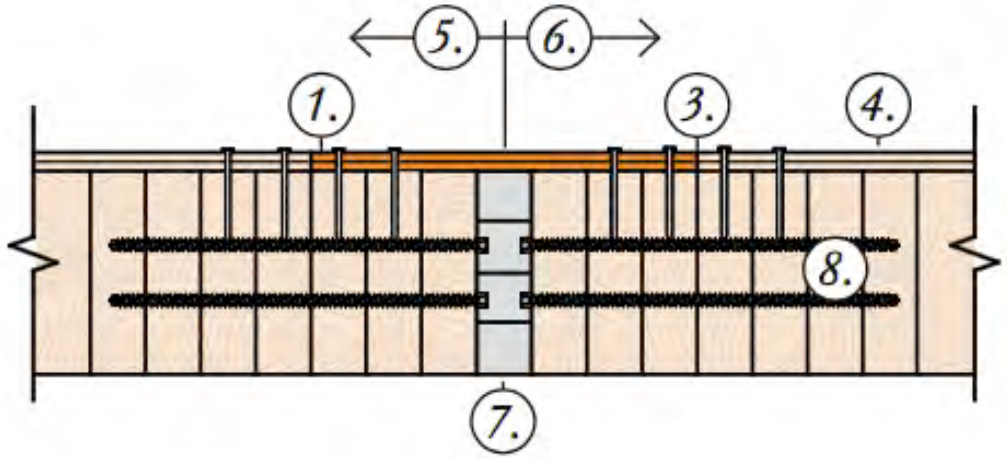


Courtesy of Arch Nexus

NLT Diaphragms



Typical Diaphragm



High Load Diaphragm

Figure 4.7: *Prefabricated Pre-sheathed Panels*

Key

1. *Field-intalled Plywood/OSB*
2. *Plywood/OSB splice location with typical diaphragm nailing*
3. *Plywood/OSB splice location for high load daiphragm nailing*
4. *Shop-installed plywood/OSB diaphragm sheathing*
5. *Prefabricated NLT panel A*
6. *Prefabricated NLT panel B*
7. *NLT expansion gap location fire stopped as required*
8. *Self-tapping screw pairs crossing plywood/OSB splice location*

Source: NLT Design & Construction Guide

NLT Diaphragms

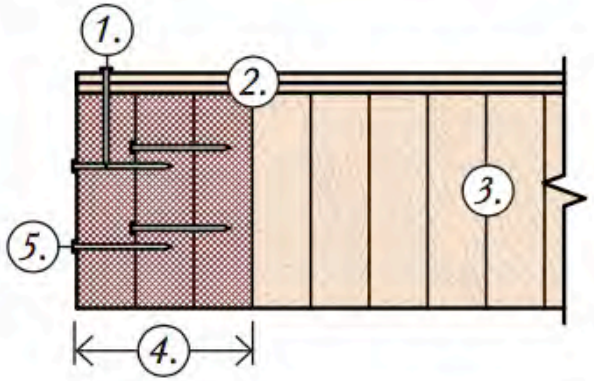
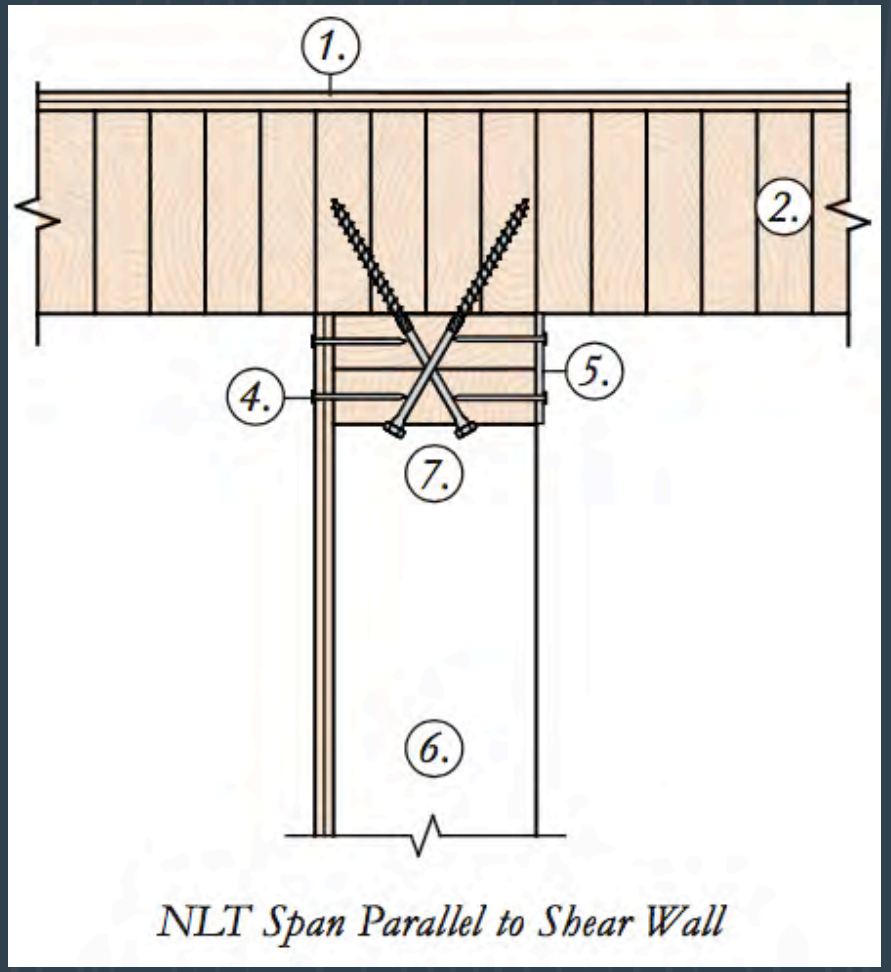


Figure 4.8: *Effective Discrete Chord Element*

Key

1. *Diaphragm perimeter nailing*
2. *Plywood/OSB diaphragm sheathing*
3. *NLT*
4. *Built-up chord width*
5. *Chord fastening for load transfer*



NLT Span Parallel to Shear Wall

NLT diaphragm chords & collectors can be edge lams, wall top plates, supplemental steel or other

Source: NLT Design & Construction Guide

NLT Lateral Systems

Although NLT can be sheathed with WSP and used as a shearwall, typical approaches use other vertical lateral force resisting systems

NLT Lateral Systems

Light-frame wood shearwalls

NLT Lateral Systems

Central core: concrete shearwalls

Photo Credit: StructureCraft Builders

NLT Lateral Systems

Steel moment frame

NLT Lateral Systems

Steel Braced Frame

Photo Credit: John Stamets

Sourcing NLT

Can source NLT from a manufacturer that specializes in NLT or from a competent framer/GC/timber install crew

Photo Credit: StructureCraft Builders

Sourcing NLT

NLT does not require a dedicated manufacturing facility. Is fabricated with readily available dimension lumber.

Photo Credit: John Stamets

Installing NIT

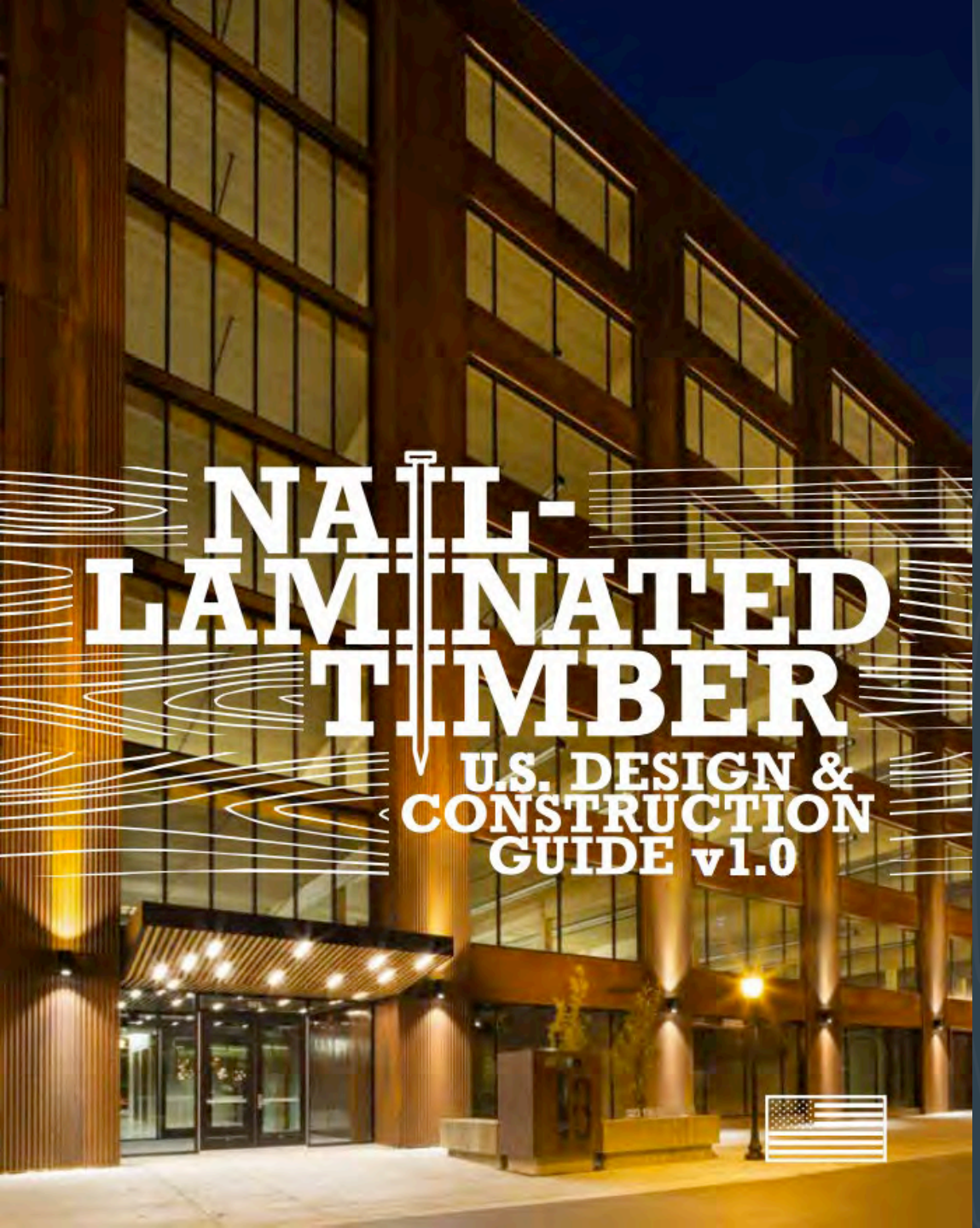
Photo Credit: StructureCraft Builders

Crane with pick points on panels, typically direct from truck to install
Consider erection engineering

Nail-Laminated Timber

Using ordinary lumber to create extraordinary buildings

Photo Credit: Ema Peter



NLT Design Guide

Free download at
www.thinkwood.com/nltguide

Thank You

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