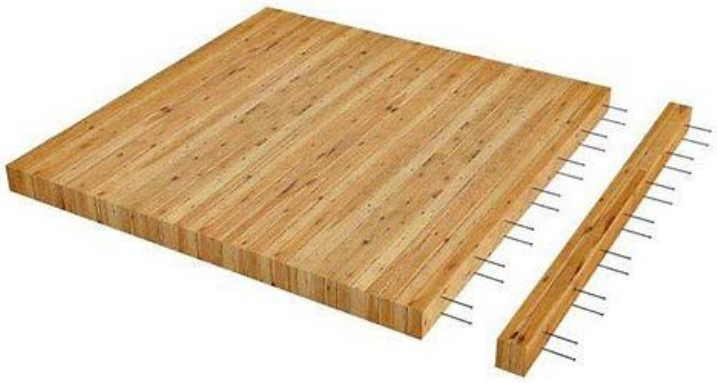
Nail Laminated Timber (NLT)

[Strategy]

BRIEF DESCRIPTION



Nail Laminated Timber (NLT) is a mass timber product created by turning dimensional lumber on edge and mechanically fastening the laminations together with nails. NLT is most commonly utilized for floor and roof systems, though it can also be used for walls, elevator shafts, and stair shafts. Wood Structural Panel sheathing (plywood or OSB) is added to the face of NLT to provide in-plane shear capacity for shearwalls and diaphragms. NLT can be fabricated on the project site or in a more controlled (factory or shop) environment. Architectural and structural options are numerous since NLT can be created from any size, species, or grade of lumber and can be formed to the shape of its support (i.e. curved roofs, etc.).

Applications

NLT delivers design flexibility

Clay Creative Photos: Christian Columbres

- NLT is a historical construction method that is regaining popularity with designers due to several factors including:
  - Relative ease of fabrication.
  - Lightweight when compared to similar floor/roof systems of concrete and steel.
  - Ability to use readily-available lumber.
  - Aesthetic features created by differing species of wood, finish options (rough or sanded), depth of laminations, curved or straight forms,
  - Ability to use in Construction Types III, IV, & V, with limited use in Type I & II roof construction.
- NLT can be used for both Residential and Commercial structures.

Architecture

- NLT can achieve a variety of forms, including dramatic cantilevers, simple and compound curves.

Nail Laminated Timber

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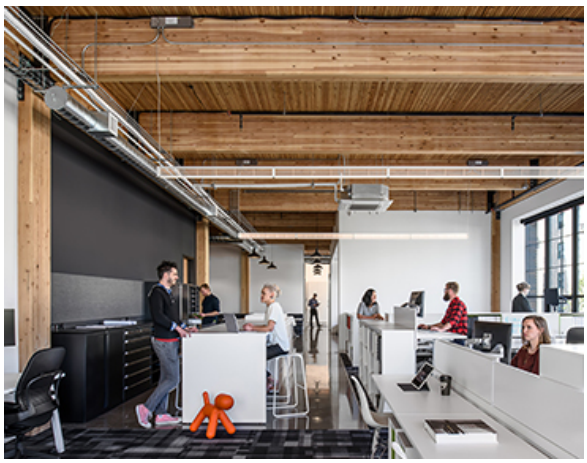
Design Notes

Any species of wood can be specified, though most common would be species listed in the National Design Specification (NDS) for Wood Construction (American Wood Council).



The Hudson Photos: Christian Columbres

- The exposed surface of individual laminations can have smooth or ribbed edges depending on the desired aesthetic.
- Cross section depth can be constant or varied, using differing sizes of lumber in alternating laminations. Size differential is typically kept within 2" to maximize structural efficiency (example: 2x6's and 2x8's).
- Specified lumber grade contributes to the presence of knots and other defects in the wood, which may or may not be desirable.
- Sealers and stains are often applied to the exposed faces of NLT for aesthetics.
- Galvanized nails should be used to attach laminations together as iron staining can occur if the NLT panels are exposed to moisture during construction. Screws used to connect NLT to supports should also be galvanized

Structural

- NLT panels span in one direction (one-way system) and require support from beams or other structure (can't be supported on columns alone). Consideration should be given to grid spacing.
- Plywood or OSB is attached to the face of NLT to provide in-plane shear capacity for diaphragms and shear walls. Capacities from AWC's Special Design Provisions for Wind & Seismic (SDPWS) can be used.
- NLT is treated as a built-up beam for gravity loading.
- Adjustment factors for NLT gravity design are specified in the NDS and the Nail-Laminated Timber Design & Construction Guide.
- Lamination layup patterns include continuous (single & multi-span) and controlled random (butt joints over 4 or more supports and butt joints over fewer than 4 supports).

TABLE 2.1 TYPICAL NLT FLOOR SPANS

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 US Design & Construction Guide

Nail Laminated Timber

[Strategy]

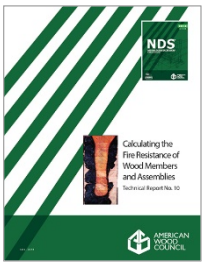
Design Notes

- Lamination boards will typically be continuous in a panel that is less than 20’ in length. Longer length panels can have boards that are placed in a layup specific pattern or are finger-jointed.
- Refer to table 4.6 from the NLT Guide and the International Building Code (IBC) 2304.9.3.2 for minimum lamination nailing.
- Where large point or line loads are not stacked from floor to floor, loads should be supported by additional framing rather than by the NLT itself.
- Cantilevers in the direction of the NLT span are viable. Cantilevers perpendicular to laminations require reinforcing detailing, often with screws.
- Given timber construction’s high strength-to-weight ratio, serviceability or vibration requirements may govern the design.
- Refer to the Nail-Laminated Timber U.S. Design & Construction Guide chapter 4 for further considerations.

Fire Protection

- Calculated fire resistance of fully exposed NLT is based on chapter 16 of the NDS and AWC TR 10.

- NLT connections must also be protected to the appropriate rating of the elements they are connecting. Protection can be provided by additional wood (for charring), gypsum board, other approved materials, or a combination of approved materials.



Moisture and Wood Shrinkage

- As a hygroscopic material, wood takes on moisture from the surrounding environment. In-service moisture content will likely differ from the moisture content seen during the construction process, and as such, wood will experience dimensional changes.
- Tangential shrinkage is most significant, followed by radial shrinkage (approximately ½ that of tangential shrinkage), and longitudinal shrinkage (minimal).
- Wood shrinkage can be calculated using the formula prescribed in Chapter 13 of the US Forest Products Lab Wood Handbook.
- Project specifications need to address the handling of wood during construction to manage exposure to moisture. Strategies can include Temporary Moisture Management Systems (TMMS). Panels should be covered when stored on site.
- For larger NLT areas, it is recommended to include a 1-1/2” gap approximately every 20’ to account for swelling due to changing moisture content during construction.

Nail Laminated Timber

[Strategy]

Design Notes

Acoustic Performance

- NLT with a consistent cross section will allow sound waves to reflect similar to other hard-surface systems (concrete slab, CLT, etc).
- Staggered cross sections can provide opportunity for sound waves to be diffused. Inserting sound absorbing materials into the recessed laminations will further improve performance.
- Finish floor materials, sheathing, and/or topping slabs can help diffuse sound through spaces between individual laminations.

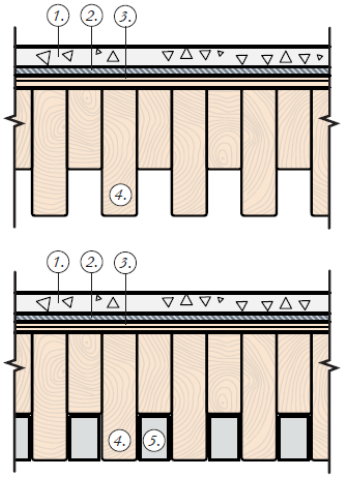


Figure 2.16: *Alternating 2x4 and 2x6 lumber with and without sound absorbing material.*

Key

1. *Concrete topping*
2. *Acoustic mat*
3. *Plywood/OSB*
4. *NLT*
5. *Sound absorbing material*

Source: NLT US Design & Construction Guide

Vibration

- Perform a detailed design by calculating maximum acceleration.
- More likely to govern a design as spans increase.
- See NLT U.S. Design & Construction Guide 4.1.5 for more information.

Blast Protection

- Blast testing research for NLT was done through a collaborative effort between WoodWorks, The USDA Forest Service Forest Products Lab and the Softwood Lumber board. Further information is available through the WoodWorks website, www.woodworks.org
- Mass timber structural systems can effectively resist blast loads in the elastic range with little noticeable damage. Due to the relatively high strength and low stiffness of mass timber panels, significant blast loads can be resisted by mass timber panels in the elastic response range.

Building Enclosure

- Enclosure assemblies will vary based on climate conditions.
- Additional insulation needed to satisfy energy code requirements is best placed to the exterior side of NLT to help with temperature and moisture concerns.
- NLT is not an air-tight system (there can be spaces/gaps between laminations), so detailing is needed for the air and vapor barrier systems.
- Air and vapor barrier systems can inhibit NLT's ability to dry if it received moisture during the construction process.
- NLT is classified as a Class I vapor retarder per the IBC at common lamination thicknesses.

Nail Laminated Timber

[Strategy]

Design Notes

- While possible, designers should avoid having interior NLT extend to the exterior of the building envelope due to difficulties in sealing linear elements to the underside of NLT.
- Common NLT roof and floor assemblies can be found in the NLT Guide, chapter 5.

MEP Considerations

- MEP elements running parallel to laminations can be hidden by utilizing a service chase that is incorporated into the face of the panels. A cap is then placed over the service elements following installation.
- Holes can be drilled in NLT for elements running perpendicular to laminations, provided holes are acceptable structurally.
- If cuts are to be made after fabrication for items such as mechanical or electrical equipment, consider implementing zones that do not have nails installed for easier cutting.

Fabrication, Shipping, and Construction

- NLT fabrication is best done with the use of jigs to help ensure straight, square panels. Jigs also help speed up fabrication. Jigs should be routinely checked to make sure they remain true.
- Consider shipping and lifting constraints when deciding how big panels will be.
- On-site management of panels should include a lifting plan.
- Consider scheduling delivery of NLT panels to minimize site storage.

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[Energy and Environment]

Energy

Energy Performance

- Wood has a relatively low thermal conductivity when compared to other building materials such as steel or concrete.
- Typical NLT lamination R-values are:
  - 2x4 = R3.5 – 5.0
  - 2x6 = R5.5 – 7.9
  - 2x8 = R7.3 – 10.4
  - 2x10 = R9.3 – 13.2
- Species specific R-Values (per inch):
  - Hem-Fir / Spruce-Pine-Fir = R1.11 – 1.35
  - Douglas Fir-Larch = R0.99 – 1.05
  - Southern Yellow Pine = R1.1

Environmental Impact

Carbon Sequestration

- Since NLT panels are made of wood, they are a *carbon sink*. Carbon sinks sequester carbon in solid form and keep it from entering the atmosphere as CO2.
- Wood is 49% carbon by weight.
- Carbon calculator is available through WoodWorks at http://cc.woodworks.org/

Sustainability

- Lumber can be sourced from companies that participate in sustainable practices. The five major certification systems in North America are the Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), American Tree Farm System (ATFS), Canadian Standards Association (CSA), and the Programme for the Endorsement of Forest Certification (PEFC).
- A Life Cycle Assessment (LCA) measures the environmental impacts of materials, assemblies, or buildings over their entire lives. Wood products consistently outperform their counterparts in LCA studies.
- At the end of the building's life, NLT panels can be re-used or recycled.

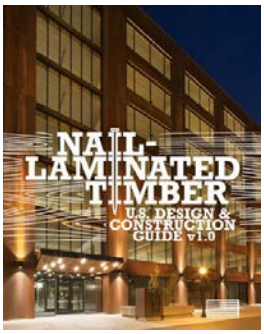
Nail Laminated Timber (NLT)

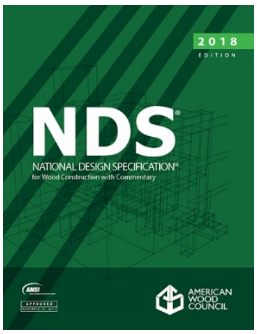
[Case Study]

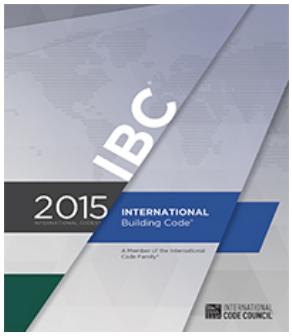
Guidelines

Getting Started

- The **Nail-Laminated Timber U.S. Design & Construction Guide** can be downloaded without charge from http://www.thinkwood.com. ★ START HERE
- The **National Design Specification** (NDS) can be acquired through American Wood Council (AWC) at http://www.awc.org.







IBC Code

NLT and the IBC code

- NLT is referenced in the IBC as mechanically laminated decking (2304.9.3).
- Specifications on the nails required for laminations (2304.9.3.2) differs between the 2015 and 2018 IBC versions; 2018 IBC adds fastening Table 2304.9.3.2 for nominal 2x laminations.
- Controlled random pattern layup requirements listed in IBC 2304.9.3.3.
- NLT is well suited for use in Construction Types V, IV, and III. NLT can also be used in Type IB and II construction in the roof system where a 1-hour or less fire-resistance rating is required.

Specifications

Guide Specifications

- The **Nail-Laminated Timber U.S. Design & Construction Guide** has a sample specification in Appendix B that can be used as a reference.

Design Specification / Manufacturing Standards

- Currently there is no industry-wide adopted design specification or manufacturing standard for NLT.

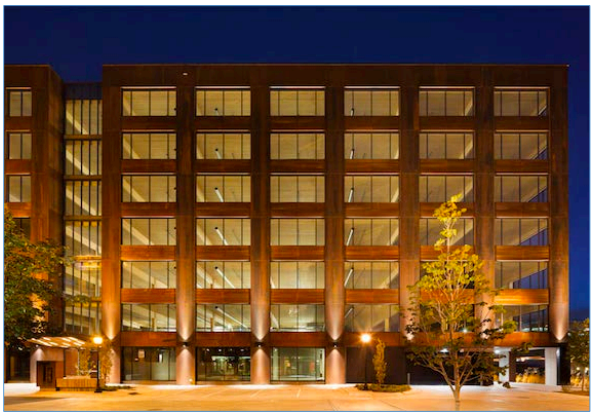
Nail Laminated Timber

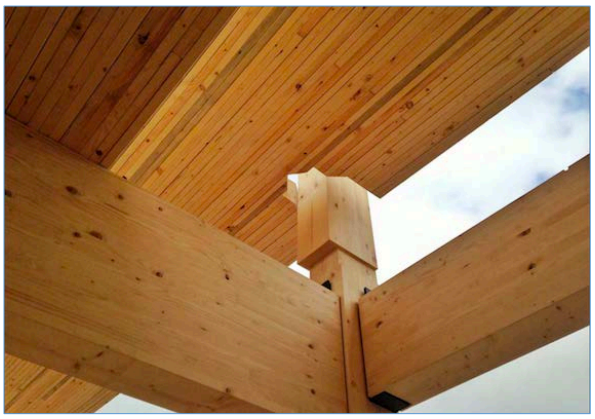
[Case Study]

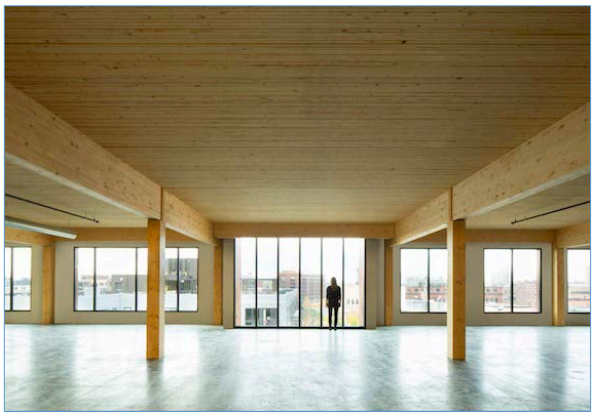
Project Name **T3 Minneapolis**
Project Location Minneapolis, MN
Year Built 2016

Description

At seven stories and 220,000 sf, T3 is a game changer for the commercial building industry, demonstrating the feasibility of exceptionally large timber projects as a means to reduce the carbon footprint of the built environment while creating warm, appealing spaces. Inside, exposed glulam columns and beams, and nail-laminated timber (NLT) floors, offer a modern interpretation of historic wood buildings found in many U.S. cities. From a cost and construction standpoint, a great deal of effort went into developing efficient systems to reduce schedule. The timber erection was completed in 2.5 months at an average of nine days per 30,000-sf floor. The project team estimates that T3 is 30% lighter than a comparable steel design and 60% lighter than post-tensioned concrete, which allowed them to reduce the depth of the foundation. Developer Hines plans to leverage the design for a suite of similar wood office buildings. concrete, which allowed them to reduce the depth of the foundation. Developer Hines plans to leverage the design for a suite of similar wood office buildings.







ARCHITECT: MGA | Michael Green Architecture, DLR Group
STRUCTURAL ENGINEER: Magnusson Klemencic Associates
DESIGN ASSIST + BUILD: StructureCraft
CONTRACTOR: Kraus-Anderson Construction Company
AWARD CATEGORY: Special Achievement Award
PHOTOS: Ema Peter; MGA

Nail Laminated Timber

[References]

Additional Resources

- **WoodWorks** ★
  WoodWorks – Wood Products Council (www.woodworks.org) provides free project assistance as well as education and resources related to the code-compliant design, engineering and construction of commercial and multi-family wood buildings. WoodWorks technical experts offer support from design through construction on a wide range of building types, including multi-family/mixed-use, educational, commercial, retail, office, institutional, and public.

  Designers can email the help desk (help@woodworks.org) or get in contact with the Regional Director for their area at:
  http://www.woodworks.org/project-assistance-map/

- ***Wetting and Drying Performance and On-site Moisture Protection of Nail-Laminated Timber Assemblies*** **– FPInnovations**
  https://www.bchousing.org/research-centre/library/building-science-reports/nail-laminated-timber-protection&sortType=sortByDate

- **Webinar:** ***Exploring Efficient Design for a Mass Timber Office: The Nail Laminated Timber Solution*** http://www.woodworks.org/education/online-seminars/

- ***Full-Scale Tests In A Furnish Living Room To Evaluate The Fire Performance Of Protected Cross-Laminated And Nail-Laminated Timber Construction*** – AWC
  https://www.awc.org/pdf/awc/AWC-NLT_CLT_Compartment_Fire-Final_Report.pdf

- ***Acoustically-Tested Mass Timber Assemblies*** http://www.woodworks.org/wp-content/uploads/Acoustically-Tested-Mass-Timber-Assemblies-WoodWorks.pdf

- ***Design to Minimize Annoying Wood-Floor Vibrations*** – Woeste and Dolan
  https://docplayer.net/storage/64/51076080/1549645133/Y9KhbRkGsal25ORPMn-4Hw/51076080.pdf