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Mass Timber Floor Vibration Design Guide: A New Resource for Engineers

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Photo: Lever Architecture

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

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Course Description

This webinar introduces a new resource developed to address a gap in available knowledge: the U.S. Mass Timber Floor Vibration Design Guide. The decision to use mass timber floors over competing materials is largely driven by economics. In almost all floor applications, the design of the mass timber panels and framing is determined by limiting the floor vibrations perceived by occupants (or sensitive equipment) to acceptable levels. While it is widely recognized that floor vibration design has a significant impact on cost, there has been little information on how to cost-effectively design mass timber floors for vibration. In addition to introducing the design guide and its contents, this webinar will cover the range of mass timber panel products used for floors, as well as design methodologies, and example calculations.

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Learning Objectives

1. Discuss criteria for acceptable floor vibration performance of mass timber systems in varying occupancies including multi-family and laboratories with sensitive equipment.
2. Review floor vibration design parameters through a systems rather than product-based approach.
3. Demonstrate methods of designing mass timber floors for vibration and highlight appropriate design methods for different system characteristics.
4. Introduce the U.S. Mass Timber Floor Vibration Design Guide and highlight its applicability to mass timber floor panel design for code-compliant projects.

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"One might almost say that **strength is essential** and **otherwise unimportant**"

- Hardy Cross

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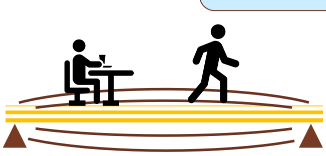
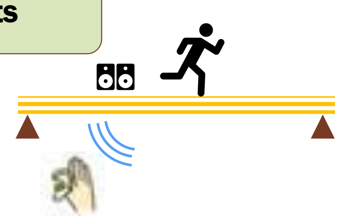
Vibrations vs Acoustics

Structural Vibrations	Acoustic Vibrations
1 Hz – 100 Hz	20 Hz – 15,000 Hz
Transmitted through structure or through ground	Transmitted through air, walls, floors, windows
Physical effects	Audible effects





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US Building Code Requirements for Vibration

None

Barely discussed in IBC, NDS, etc.
ASCE 7 Commentary Appendix C has some discussion, no metrics

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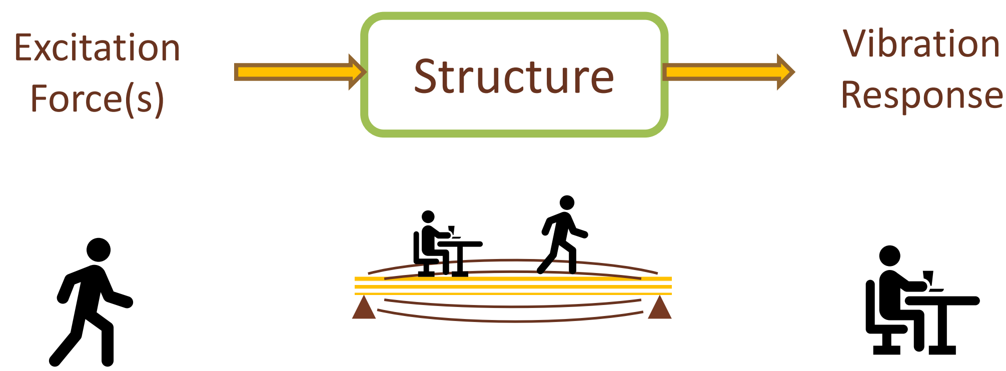
Systems View of Vibration



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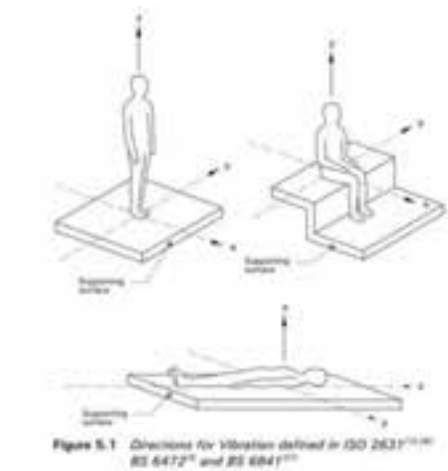
Vibration Sensitivities

- People
  Sitting, Standing, Laying
- Equipment



Direction of Vibration in ISO 2631

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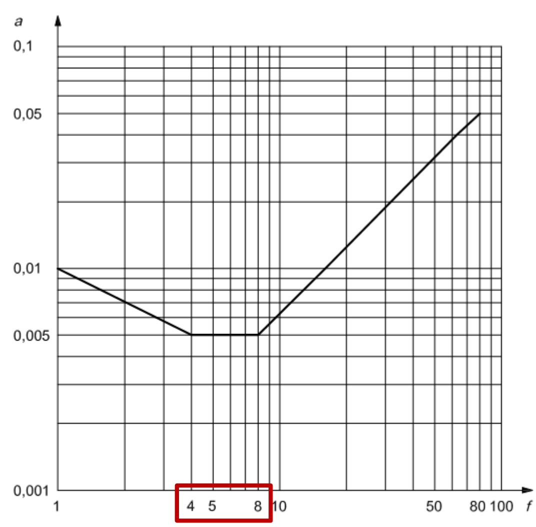
Limits of Human Perception of Vertical Acceleration

Acceleration

0.05% g



Frequency

Most sensitive to Acceleration around 4-8 Hz

Key

a acceleration (r.m.s.), m/s²

f frequency, Hz

ISO 10137:2007

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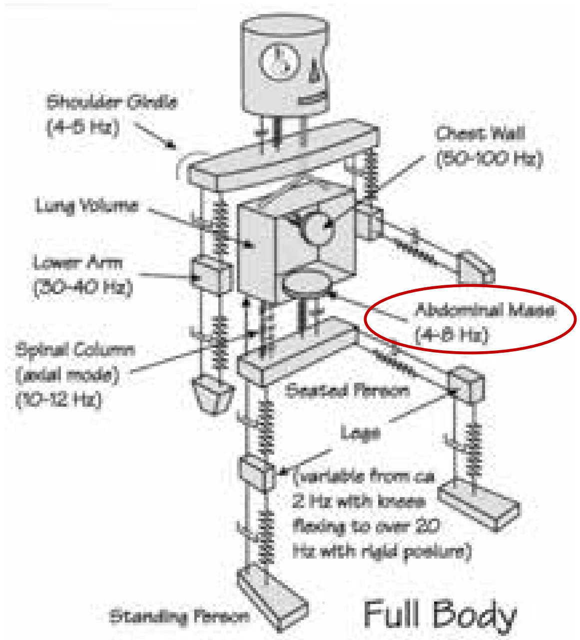

Illustration: "Sven Jr." by Sven-Olof Emanuelsson

Human Body Dynamics

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Common Vibration Sources for Buildings

Vibration sources are complex:

- **Footfall**, running, aerobics, etc.
- Machinery and equipment
- Vehicular traffic, rail traffic, forklifts
- Ground-borne, structure-borne, air-borne
- Steady-state, episodic, periodic
- Harmonic, pulse, random
- Moving, stationary





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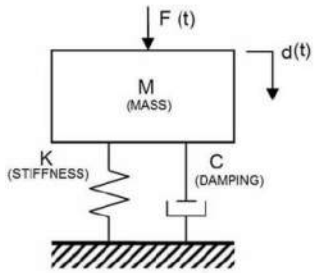
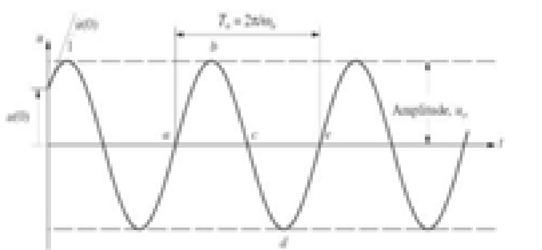
Structural Dynamics



Undamped Free Response



Natural Frequency

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Measured in cycles/sec a.k.a. Hertz (Hz)

Period T = 1 / f_n (sec/cycle)

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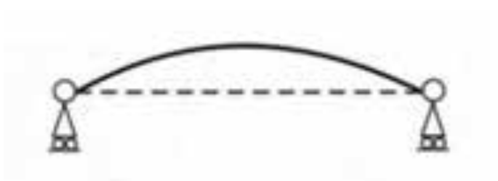
Natural Frequency of Uniform Beam



Uniform simple span beam

- Span, L
- Flexural stiffness, EI
- Mass per length, m, or w/g

$$f_n = \frac{\pi}{2L^2}\sqrt{\frac{EI}{m}}$$

$$f_n = \frac{\pi}{2L^2}\sqrt{\frac{gEI}{w}}$$

In floors, practical frequencies range from 5 Hz to 15+ Hz.
Generally, the higher the frequency the better

See Chopra "Dynamic of Structures", etc for more information

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Framing Materials Properties for Vibration

Material	Floor Weight (psf)	Damping	Material Stiffness (10^6 psi)	Material Mass (pcf)	Example Floor System
Concrete	100-150	1-5%	3.2-5.8	120-150	2-way slab on columns
Steel	50-100	0.5-5%	30	490	Concrete on metal deck on purlins and girders
Mass Timber	15-65	1-5%	1.2-1.8	30-40	Beam or wall supported panels
Wood Frame	10-40	2-12%	1.2-2.0	30-40	Wall supported joists or trusses

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Vibration Design Methods

Rules of Thumb → Empirical Methods → Simplified Analytical → FEM/Modal Superposition → FEM/Time History

Less:

- ***Design Effort***
- ***Modelling and Analysis***
- ***Judgement***
- ***Flexibility***
- ***Room for Innovation***

More:

- ***Design Effort***
- ***Modelling and Analysis***
- ***Judgement***
- ***Flexibility***
- ***Room for Innovation***

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Vibration Design Methods

Rules of Thumb → Empirical Methods → Simplified Analytical → FEM/Modal Superposition → FEM/Time History

Δ ≤ L/360 for floor live load

IBC code limit on floor deflection

Wood Frame

Joists:
Δ ≤ L/360 for L < 15 ft
Δ < 0.5" for L ≥ 15 ft
Trusses:
Δ ≤ L/480 with strong-backs

Woeste and Dolan
Beyond Code: Preventing Floor Vibration.
1998, Journal of Light Construction

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Vibration Design Methods

Rules of Thumb → Empirical Methods → Simplified Analytical → FEM/Modal Superposition → FEM/Time History

Wood Frame

f_n ≥ 14 Hz for occupied (e.g. furnished) floors
f_n ≥ 15 Hz for unoccupied floors

Dolan, Murray, et al.
Preventing Annoying Wood Floor Vibration
1999, Journal of Structural Engineering

Proprietary rating systems from Joist Manufacturers

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Vibration Design Methods

Rules of Thumb → Empirical Methods → Simplified Analytical → FEM/Modal Superposition → FEM/Time History

Mass Timber CLT Handbook Method

U.S. CLT Handbook, 2013
Canadian CLT Handbook 2nd Ed., 2019
FPInnovations

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CLT Handbook Method

Recommended CLT Floor Span Limit (base value)

$$L_{lim} \leq \frac{1}{12.05}\frac{\left(EI_{eff}\right)^{0.293}}{(\overline{\rho}A)^{0.122}} \text{ [ft]}$$

Where, for 12 in wide strip:

EI_{eff} = effective flexural stiffness (lbf-in^2)

$\overline{\rho}$ = in-service specific gravity of the CLT, unitless
e.g. weight normalized by weight of water

A = the cross-section area (in^2) = thickness * 12 in

Reference: US & Canadian CLT Handbooks, Chapter 7

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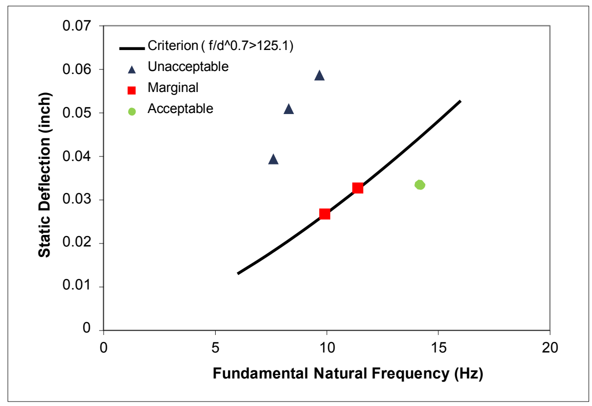
CLT Handbook Method

Experimentally Derived Relationship



Research by Lin Hu, et al. at FPInnovations

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CLT Handbook Method

Recommended CLT Floor Span Limit (base value)

$$L_{lim} \leq \frac{1}{12.05} \frac{\left(EI_{eff}\right)^{0.293}}{(\overline{\rho}A)^{0.122}}$$

2013 US CLT Handbook uses EI_{app}
2019 Canadian CLT Handbook uses EI_{eff}

Recommend using EI_{eff}

Easier to implement.
Less conservative.

Reference: Canadian CLT Handbook, Chapter 7

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CLT Handbook Method

Recommended CLT Floor Span Limit (base value)

$$L_{lim} \leq \frac{1}{13.34} \frac{\left(EI_{eff}\right)^{0.293}}{(w)^{0.122}}$$

Alternative form if manufacturer provides weight of panel, w (psf)

Reference: US Mass Timber Floor Vibration Design Guide

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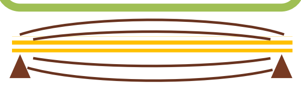
CLT Handbook Method

Excitation Force → Structure → Vibration Response



Normal Walking

Normal Human Sensitivities

Method NOT applicable to other Excitations or Sensitivities

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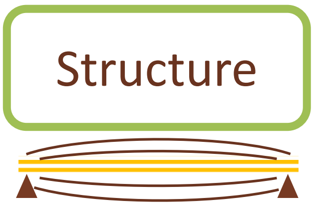
CLT Handbook Method



Base Recommended Span Limit assumes:

- Single simply span CLT panel
- No heavy topping layer
- Rigid, pin supports (bearing walls)

Also, lab tests used a 5-ply CLT.

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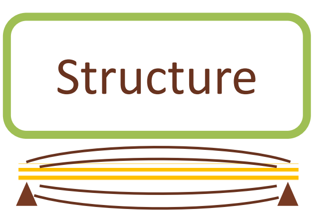
CLT Handbook Method



Multi-Span Conditions?

- Check the ~~shortest~~ **Longest** span
- Recommend a 20% increase in the Basic Span Limit when non-structural elements are present which provide enhanced stiffening effect*
  *Partition walls, finishes, ceilings

Reference: 2019 Canadian CLT Handbook, Chapter 7

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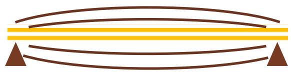
CLT Handbook Method

Structure



Heavy Topping, e.g. concrete or gypcrete?

Use Base Limit if
weight of topping ≤ twice weight of CLT

Reduce Basic Limit by 10% if
weight of topping > twice weight of CLT

Reference: 2019 Canadian CLT Handbook, Chapter 7

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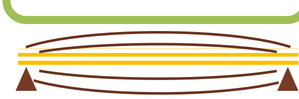
CLT Handbook Method

Structure



Supports are not bearing walls?

- CLT Handbook Method is a good starting point for selecting panels
- Flexibility of supports (e.g. beams) increases floor response and decreases natural frequency
- Additional analysis needed to evaluate whole floor system

Reference: 2019 Canadian CLT Handbook, Chapter 7

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CLT Handbook Base Span Limit

For PRG 320-2019 Basic CLT Grades and Layups from Solid Sawn Lumber

Grade	Layup	Thickness	Base Span Limit
	3ply	4 1/8”	13.1
E1	5ply	6 7/8”	18.2
	7ply	9 5/8”	22.7
	3ply	4 1/8”	12.4
E2	5ply	6 7/8”	17.2
	7ply	9 5/8”	21.6
	3ply	4 1/8”	12.0
E3	5ply	6 7/8”	16.7
	7ply	9 5/8”	20.9
	3ply	4 1/8”	12.7
E4	5ply	6 7/8”	17.6
	7ply	9 5/8”	22.1
	3ply	4 1/8”	12.6
E5	5ply	6 7/8”	17.5
	7ply	9 5/8”	21.9

Grade	Layup	Thickness	FPI Span Limit
	3ply	4 1/8”	12.6
V1	5ply	6 7/8”	17.6
	7ply	9 5/8”	22.0
	3ply	4 1/8”	12.6
V1(N)	5ply	6 7/8”	17.6
	7ply	9 5/8”	22.0
	3ply	4 1/8”	12.4
V2	5ply	6 7/8”	17.2
	7ply	9 5/8”	21.5
	3ply	4 1/8”	12.0
V3	5ply	6 7/8”	16.7
	7ply	9 5/8”	20.9
	3ply	4 1/8”	11.7
V4	5ply	6 7/8”	16.3
	7ply	9 5/8”	20.4
	3ply	4 1/8”	12.1
V5	5ply	6 7/8”	16.8
	7ply	9 5/8”	21.0

Reference: US Mass Timber Floor Vibration Design Guide, assuming 12% M.C.

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CLT Handbook Base Span Limit

For PRG 320-2019 Basic CLT Grades and Layups from Solid Sawn Lumber

Approximate Base Span Limits:

4 $^{1}/_{8}$” 3-ply: ~12 to 13 ft

6 $^{7}/_{8}$” 5-ply: ~16 to 18 ft

9 $^{5}/_{8}$” 7-ply: ~20 to 22 ft

Limitations:

- **Does not account for strength or deflections**
- **Does not account for beam flexibility**
- **Does not account for project specifics**

Reference: US Mass Timber Floor Vibration Design Guide, assuming 12% M.C.

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Vibration Design Methods

Rules of Thumb
Empirical Methods
Simplified Analytical
FEM/Modal Superposition
FEM/Time History

Simplified Analytical Methods Exist for Floor Design in these Guides

Steel	AISC Design Guide 11	*Chapter 2 & 4*
Concrete	CCIP 016	*Section 4.4*
Steel	SCI P354	*Chapter 7*
Concrete	CRSI Design Guide 10	

They are each calibrated for specific materials and floor framing styles

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Vibration Design Methods

Rules of Thumb
Empirical Methods
Simplified Analytical
FEM/Modal Superposition
FEM/Time History

Modal Superposition Methods are similar and material independent

Steel	AISC Design Guide 11
Concrete	CCIP 016
Steel	SCI P354
Concrete	CRSI Design Guide 10

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Vibration Design Methods

Rules of Thumb → Empirical Methods → Simplified Analytical → FEM/Modal Superposition → FEM/Time History

Mass Timber — CLT Handbook Method

Steel — AISC Design Guide 11

Concrete — CCIP 016

Mass Timber — **U.S Mass Timber Floor Vibration Design Guide**

Under Development

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US Mass Timber Vibration Design Guide

USDA Wood Innovations Grant funded project in progress

US MASS TIMBER FLOOR VIBRATION DESIGN GUIDE

APPROXIMATE OUTLINE

1 Introduction
- 1.1 Preface
- 1.2 Scope of this Guide
- 1.3 Terminology
- 1.4 Symbols
- 1.5 Vibration Characteristics of Floor Structures
- 1.6 Building Codes and Standards

2 Understanding Floor Vibration
- 2.1 Structural Response to Footfall Forces
- 2.2 Vibration Background
- 2.3 Methods for Evaluating Vibration
- 2.4 Human Perception of Vibration

3 Vibration Design Considerations
- 3.1 Floor Loading / Mass
- 3.2 Damping
- 3.3 Component Stiffness
- 3.4 Composite Behavior
- 3.5 Structural and Floor Configurations
- 3.6 Excitation Parameters
- 3.7 Floor Vibration Performance Targets

Guide to be published by WoodWorks Later in 2020

Project Team: WoodWorks, KPFF, Aspect, StructureCraft, & Fast+Epp

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Vibration Design Methods

Rules of Thumb → Empirical Methods → Simplified Analytical → FEM/Modal Superposition → FEM/Time History

Mass Timber CLT Handbook Method

Steel AISC Design Guide 11

Concrete CCIP 016

Mass Timber **U.S Mass Timber Floor Vibration Design Guide**

Under Development

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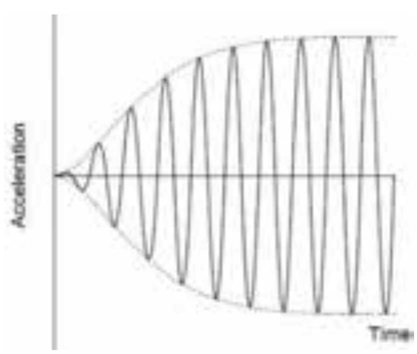
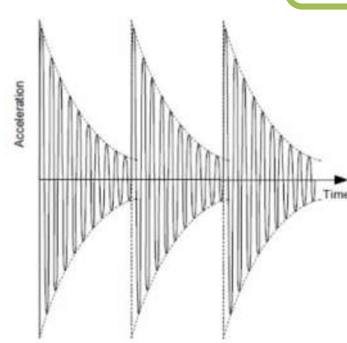
Review: Resonant vs Impulsive Response





Cyclic excitation leads to resonant build-up of vibration

Response decays out between load impulses

Resonant Response

Impulsive or Transient Response

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Walking Frequency f_w

Walking Speed	Walking Frequency	Steps Per Minute
Very Slow	1.25 Hz	75 SPM
Slow	1.6 Hz	95 SPM
Moderate	1.85 Hz	110 SPM
Fast	2.1 Hz	126 SPM
Running	Up to 4.0 Hz	240 SPM
Practical Tip - walk to a metronome too understand the range		

The range of walking frequencies considered is an important aspect of vibration analysis

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Resonant Response

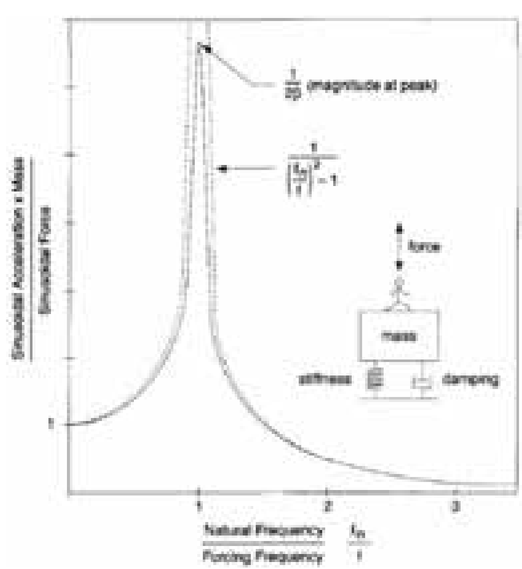

Illustration: Murray et al., 1997

Natural Frequency: f_n

Forcing Frequency: f (or f_w)

Magnitude highly depends on damping coefficient

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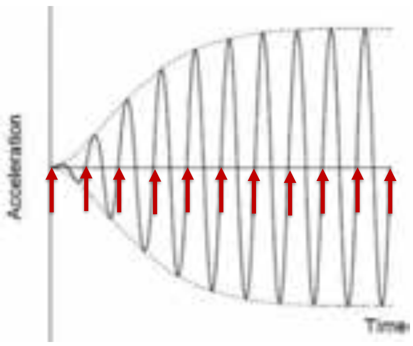
Resonant vs Impulsive Response



Excitation Frequency not >> Natural Frequency
Excitation Creates Resonant Build-up of Vibration

Resonant Response

Resonance occurs when
walking frequency = natural frequency

$f_w = f_n$

Also occurs when a harmonic of the walking frequency ~= natural frequency

$n\ f_w = f_n$

For 'n' up to around 4

Walking at f_w =2 Hz creates resonance in floor with natural frequency, f_n, at

2Hz, 4 Hz, 6 Hz, and 8Hz

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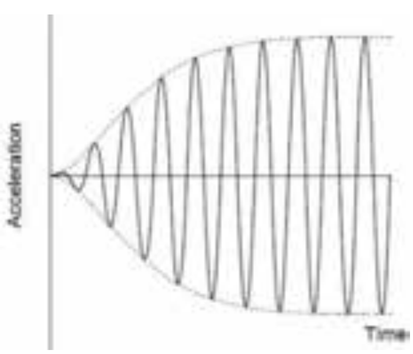
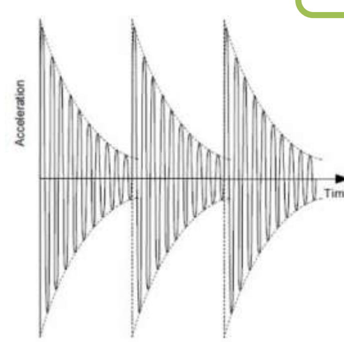
Resonant vs Impulsive Response



Excitation Creates Resonant Build-up of Vibration

Low Frequency Floor (LFF)



Responses decays out between load cycles

High Frequency Floor (HFF)

For walking excitations

f_n ~< 8-10 Hz

f_n ~> 8-10 Hz

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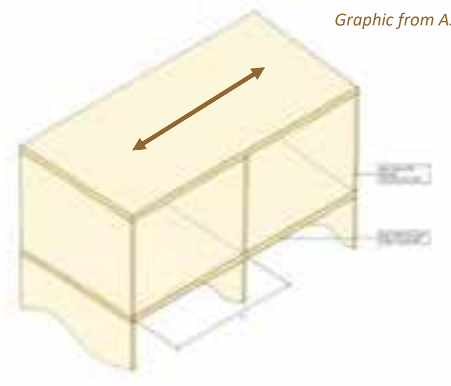
Beam vs Wall Supported Floors

Graphic from StructureCraft



Graphic from ASPECT

Mass Timber Panels on Grid of Beams.
Frequency of Floor < Frequency of Panel
Vibration of Floor > Vibration of Panel
Vibration Design Depends on Beams

Mass Timber Panels on Bearing Walls

Low Frequency Floor?

Maybe

High Frequency Floor?

Yes, for all but long floor spans

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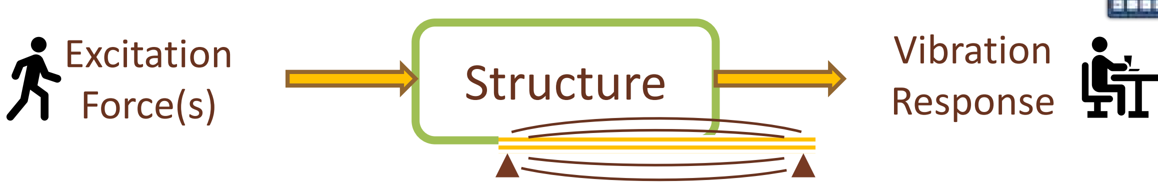
Parameters of Modal Superposition Methods



Walking Frequency, f_w
…
Walking Location
Walking Path

Stiffness
Mass/Weight
Damping
Boundary Conditions

Performance Targets

For analysis, select a range of walking frequencies.

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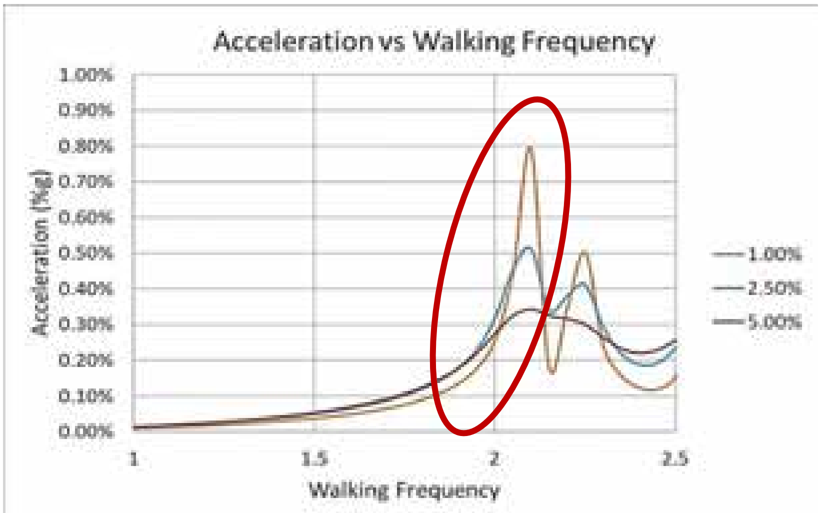
Example Resonant Response Analysis



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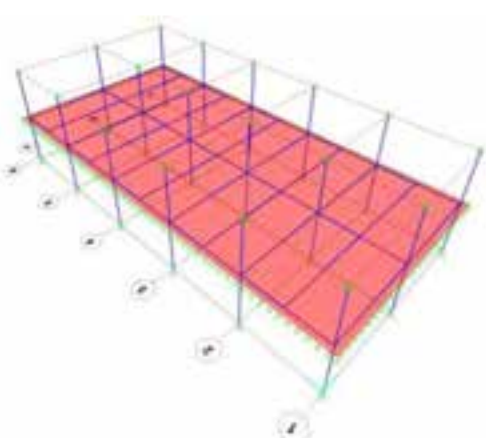
Stiffness

Beneficial to have a vibration specific structural analysis model. When considering low amplitude deflection to walking excitation, following AISC Design Guide 11 et al:



- Perimeter non-load bearing walls provide vertical restraint or stiffness
- “Gravity” connections often behave as rigid connections
- Use dynamic stiffness values where different that static stiffness value (Concrete)
- “Non-composite” components can have some composite behavior

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Mass Timber Panel Stiffness

Cross-Laminated Timber

CLT modelled as orthotropic plate using stiffness values:

$EI_{eff,0}$ and $GA_{eff,0}$ for major strength direction
$EI_{eff,90}$ and $GA_{eff,90}$ for minor strength direction

From the manufacturer, evaluation reports or product standard

Images from StructureCraft

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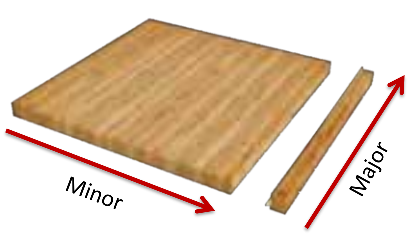
Mass Timber Panel Stiffness

Nail-Laminated Timber
Dowel-Laminated Timber



NLT, and DLT modelled as orthotropic plates using:

E_t and G_t from timber for major strength direction

I_{eff} and A_v in major strength direction from geometry for rectangular continuous elements. Otherwise from NLT Design Guide or the manufacturer

Timber commonly assumed to not contribute to minor direction floor plate stiffness

Images from StructureCraft

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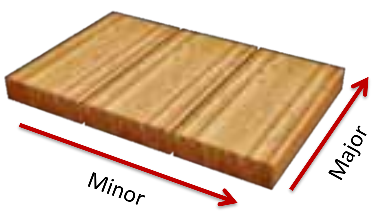
Mass Timber Panel Stiffness

Glue-Laminated Timber



GLT modelled as orthotropic plates using:

E_y from NDS supplement, or manufacturer for major strength direction (plankwise bending of glulam beam)

I_y and A_v in major strength direction from geometry for rectangular continuous elements.

Timber commonly assumed to not contribute to minor direction floor plate stiffness

Images from StructureCraft

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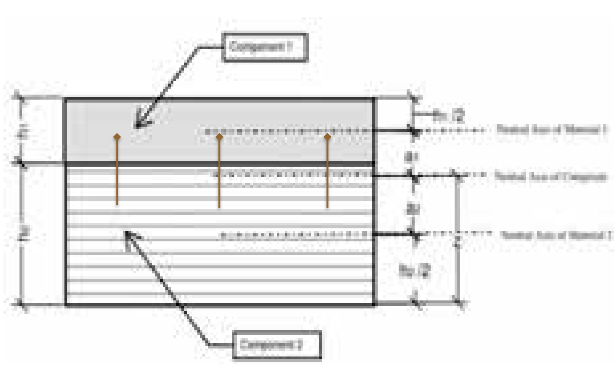
Composite Behavior



For NLT, DLT and GLT, *for vibrations*, can use stiffness of topping layer for *minor direction stiffness*.

- concrete and/or wood structural panel topping.
- use dynamic stiffness of concrete

$$EI_{eff,90} = EI_{1,90}$$
$$GA_{eff,90} = GA_{1,90}$$

Reference: US Mass Timber Floor Vibration Design Guide

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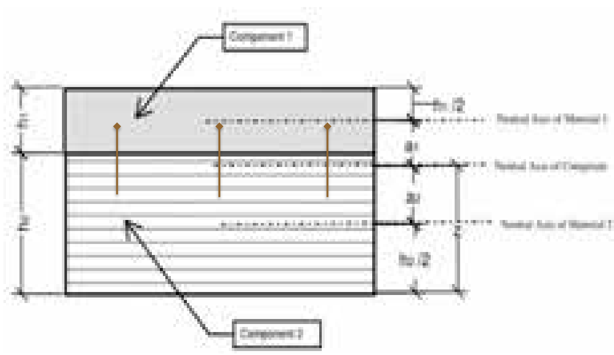
Composite Behavior



For *major strength direction* of CLT, NLT, DLT and GLT, and *minor strength direction* of CLT, *for vibrations,* can add stiffness of topping layer to stiffness of panel.

$$EI_{eff,0} = EI_{1,0} + EI_{2,0}$$

$$GA_{eff,0} = GA_{1,0} + GA_{2,0}$$

Non-Composite Behavior

Reference: US Mass Timber Floor Vibration Design Guide

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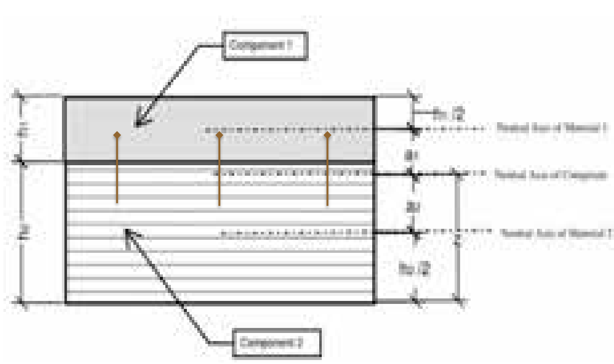
Composite Behavior



Even if NOT designed as a composite for code required strength and stiffness, real systems can show *partial composite action* for vibrations

$$EI_{eff} > EI_1 + EI_2$$

$$GA_{eff} > GA_1 + GA_2$$

Incidental Composite Behavior

	Consider Composite for:		
Composite Behavior	Strength	Deflection	Vibration
Explicit	Yes	Yes	Yes
Incidental	No	No	Yes

Reference: US Mass Timber Floor Vibration Design Guide

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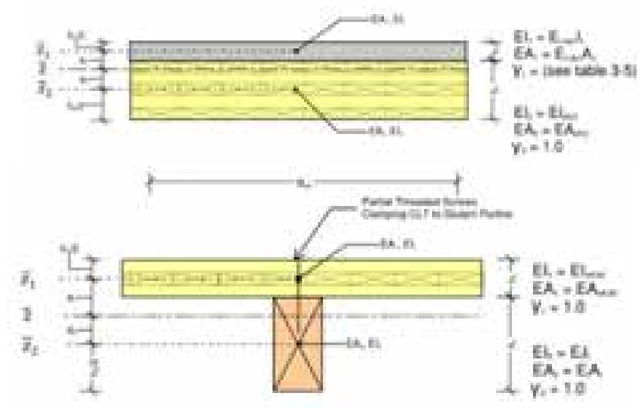
Composite Behavior

Potential partial composite action at:
- Concrete topping over MT panel
- MT panel over Glulam Beam



Reference: US Mass Timber Floor Vibration Design Guide

2020 Publication by FPInnovations
"Design Guide for Timber-Concrete Composite Floors in Canada"

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Damping Values

Selection Based on Judgement and Experience

Category	Range of Damping ζ (% critical)	Discussion
Lightly damped	1-2%	The lower end includes bare floors without topping and with minimal furnishing. The higher end includes floors with concrete topping and furnishings.
Moderately damped	2-4%	Lower values include bare timber-concrete composite floors, or timber floors with a floating concrete layer and full furnishings. The higher values include floors with floating floor layers, raised floors, full furnishings, and mechanical systems. Floors with both furnishings and permanent partitions, not otherwise accounted for, could also be represented on the higher end of this damping range.
Heavily damped	4-5%	Floors in this range represent the upper limit of inherent damping. These floors likely include floating toppings, raised floors, suspended ceilings, furnishings, fixtures, and/or permanent partitions not otherwise accounted for.

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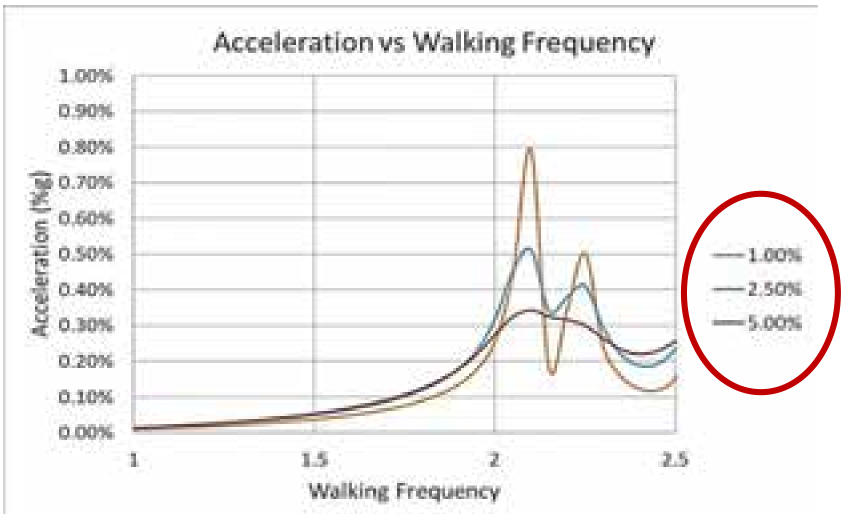
Example Resonant Response Analysis



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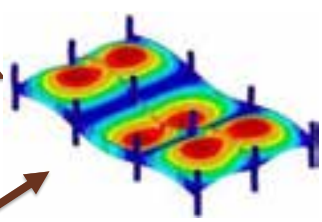
Modal Superposition Method

FEA Model



Walking frequency, f_w
Walker weight
Walking location(s)
Observation location(s)
Damping
etc.

Modes of Vibration

Measures of Performance:

Accelerations for Resonant Low Frequency Floors

Velocities for Transient High Frequency Floors

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Example Acceleration Performance Targets

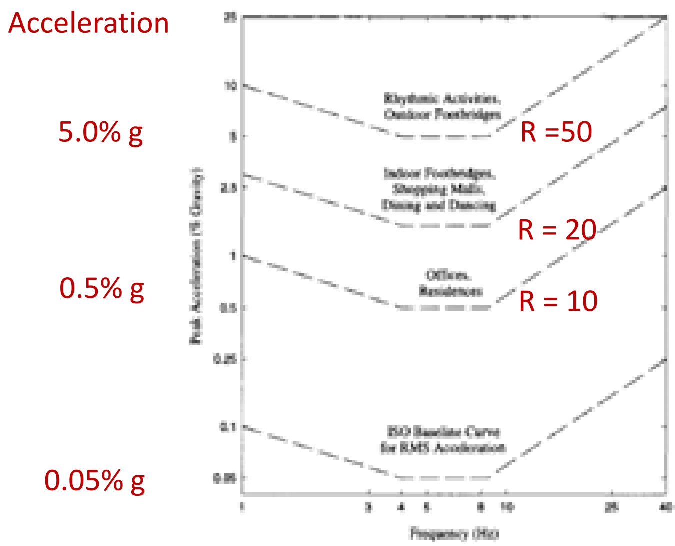

Illustration: Murray et al., 1997
AISC Design Guide 11, 1st Ed.

Range of Acceptable Perception of Acceleration

0.5% to 5% g (vertical)

European Methods (CCIP) use "R" values:
R = predicted value/baseline value

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Low Frequency Floor Resonance Performance Targets

CCIP-016 Performance Targets

Place	Peak Accel. in 4-8 Hz Range	Response Factor, R
Commercial buildings including offices, retail, restaurants, airports	0.57% g	8
Residential (day)	0.28% to 0.57% g	4 to 8
Premium quality office, open office with busy corridors near mid-span, heavily trafficked public areas with seating	0.28% g	4
Residential (night)*	0.20% g	2.8
Hospitals and critical work areas	0.071% g	1

** CCIP-016 suggests that this more restrictive target may not be necessary.*

AISC DG 11 Performance Targets

Place	Peak Accel. Target in 4-8 Hz range	Equivalent Response Factor, R
Outdoor pedestrian bridges	5% g	70
Indoor pedestrian bridges, shopping malls	1.5% g	21
Offices, residences, quiet areas	0.5% g	7

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High Frequency Floor Transient Performance Targets

CCIP-016 Performance Targets

Place	RMS Velocity Target*	RMS Velocity Target*	Target Response Factor, R
Commercial buildings including offices, retail, restaurants, airports	8×10^{-4} m/s	32,000 mips	8
Residential	4 to 8×10^{-4} m/s	16,000 to 32,000 mips	4 to 8
Premium quality office, open office with busy corridors near mid-span, heavily trafficked public areas with seating	4×10^{-4} m/s	16,000 mips	4

AISC DG 11 Performance Targets

Place	RMS Velocity Target*	RMS Velocity Target*	Equivalent Response Factor, R
Ordinary Workshops	8 x 10-4 m/s	32,000 mips	8
Offices	4 x 10-4 m/s	16,000 mips	4
Residences	2 x 10-4 m/s	8,000 mips	2
Hospital patient rooms	1.5 x 10-4 m/s	6,000 mips	1.5

"mips" = micro-inches per second

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US MTFVDG Suggested Performance Targets

Place	Peak Acceleration Target	RMS Velocity Target
Offices, residences	0.5% g	16,000 – 32,000 mips
Premium offices or luxury residences	0.3% g	8,000 – 16,000 mips

There are many assumptions and judgements which go into predicting the response.
This is not an exact compliance check.

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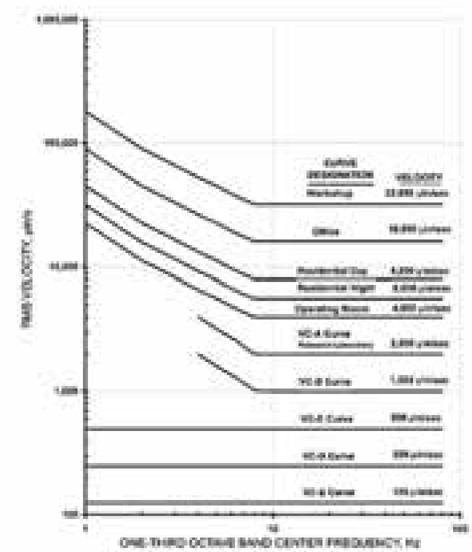
Criteria for Labs and Sensitive Equipment

- Specific equipment will have set floor vibration limits.
- Lacking those, generic vibration criteria (VC curves) are available from ASHRAE, et al.
- Defined using velocity limits
- Higher performance floors, avoid resonance with walking, higher frequency floors
- Use Transient Analysis/HFF methods to estimate velocities.



ASHRAE Handbook – Sound and Vibration Control

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US Mass Timber Vibration Design Guide

USDA Wood Innovations Grant funded project in progress

US MASS TIMBER FLOOR VIBRATION DESIGN GUIDE

APPROXIMATE OUTLINE

1 Introduction
- 1.1 Preface
- 1.2 Scope of this Guide
- 1.3 Terminology
- 1.4 Symbols
- 1.5 Vibration Characteristics of Floor Structures
- 1.6 Building Codes and Standards

2 Understanding Floor Vibration
- 2.1 Structural Response to Footfall Forces
- 2.2 Vibration Background
- 2.3 Methods for Evaluating Vibration
- 2.4 Human Perception of Vibration

3 Vibration Design Considerations
- 3.1 Floor Loading / Mass
- 3.2 Damping
- 3.3 Component Stiffness
- 3.4 Composite Behavior
- 3.5 Structural and Floor Configurations
- 3.6 Excitation Parameters
- 3.7 Floor Vibration Performance Targets

Guide to be published by WoodWorks Later in 2020

Project Team: WoodWorks, KPFF, Aspect, StructureCraft, & Fast+Epp

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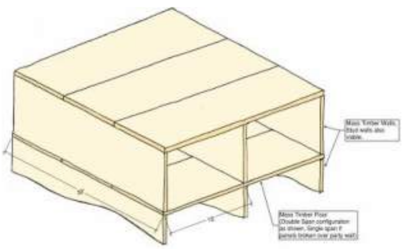
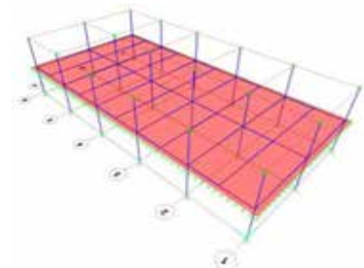
Details of U.S. Mass Timber Floor Vibration Design Guide

Vibration Design Examples



Residential Bearing Wall Building with CLT

Open Office with NLT on Glulam Frame



High Performance Lab Space with CLT on Glulam Frame

Scheduled to be available by year end

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Additional Resources – WoodWorks.org

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Additional Resources – WoodWorks.org

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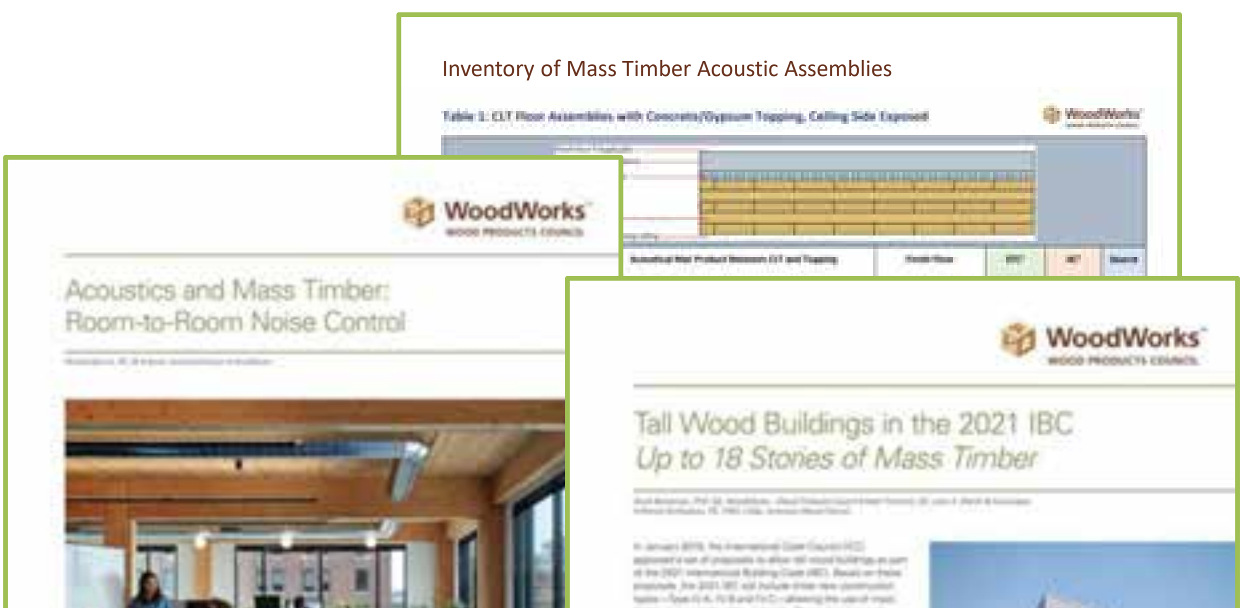
Additional Resources – WoodWorks.org



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Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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