# Steel-Timber Hybrid Floor Vibrations in Life Science Laboratory Buildings

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Council on Tall Buildings and Urban Habitat
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# Steel-Timber Hybrid Floor Vibrations in Life Science Laboratory Buildings



LeMessurier.

# Introductions

- Presenter

Structural Engineer
Ian Neill, PE
LeMessurier
Associate

- Contributors
  - Perkins & Will
    - Jacob Werner
    - Elizabeth Mikula
  - Jensen Hughes
    - Jeremy Liebowitz
  - Acentech
    - Jeff Zapfe
    - Rose Mary Su
  - LeMessurier
    - Mike Gryniuk
    - Mithila Madvahan
    - Eric Johnson
    - Emma Rubin
    - Priya Dewan
    - Sebastian Torrente

# Life Sciences Tall Buildings

Fenway Center Phase 2, Boston, MA
*Image courtesy of Gensler and IQHQ*

Seaport Parcels N & P, Boston, MA
*Image courtesy of Morris Adjimi Architects*

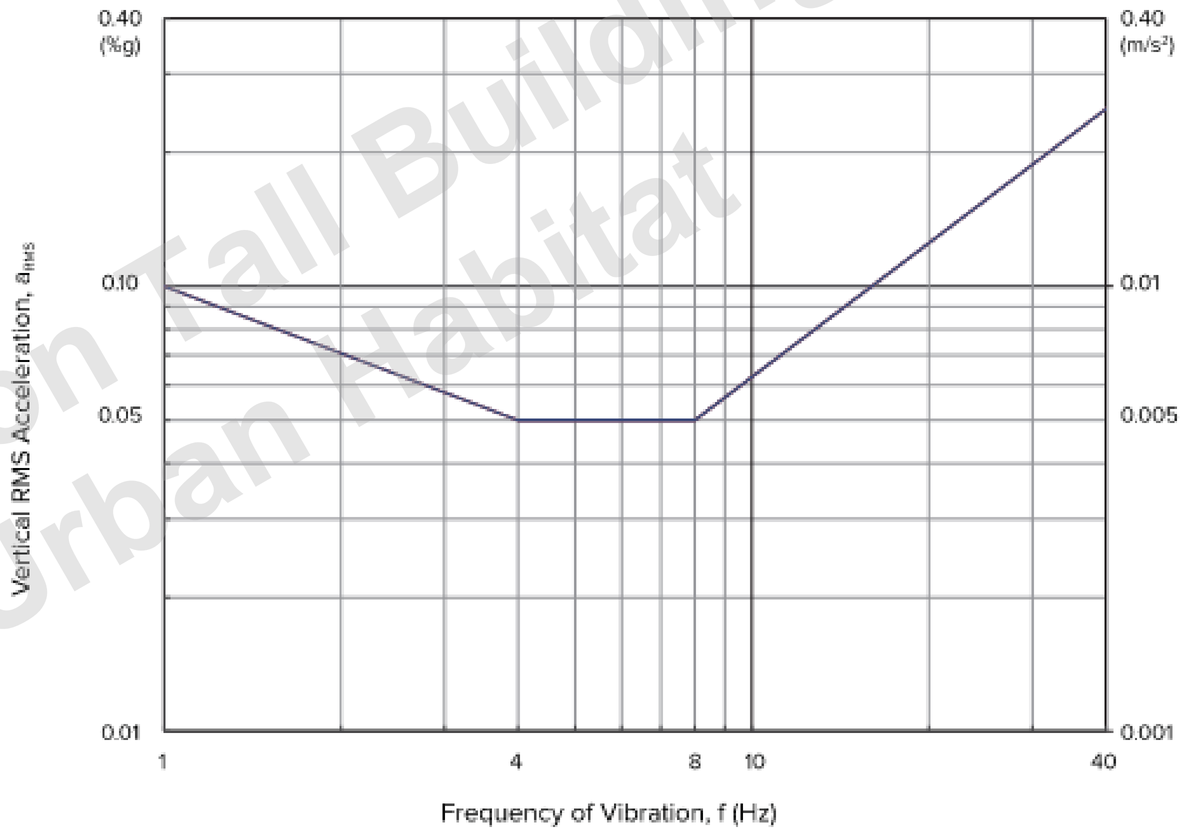
# Lab Building Design Considerations

- Control Areas / Hazardous Uses
- Fire ratings
- Loading docks
- Elevator access
- Acoustics
- Air handling – large ducts
- Tenant MEP
- Large floor-to-floor height
- **Floor Vibrations for Sensitive Equipment**

*Images courtesy of Perkins&Will*

# Vibration Limits for Occupant Comfort

- Typical vibration criteria for offices and residences
- Criteria is typically expressed as an acceleration in %g

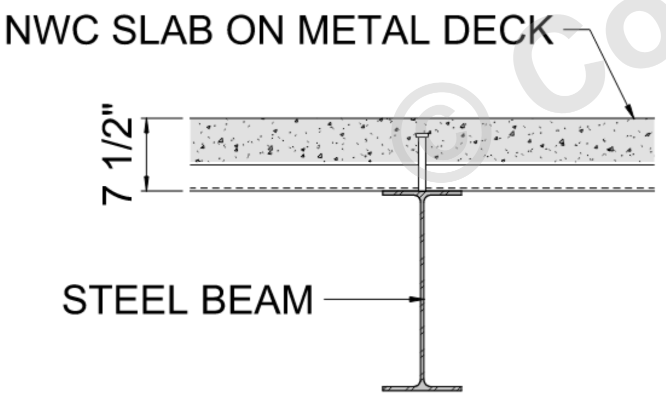


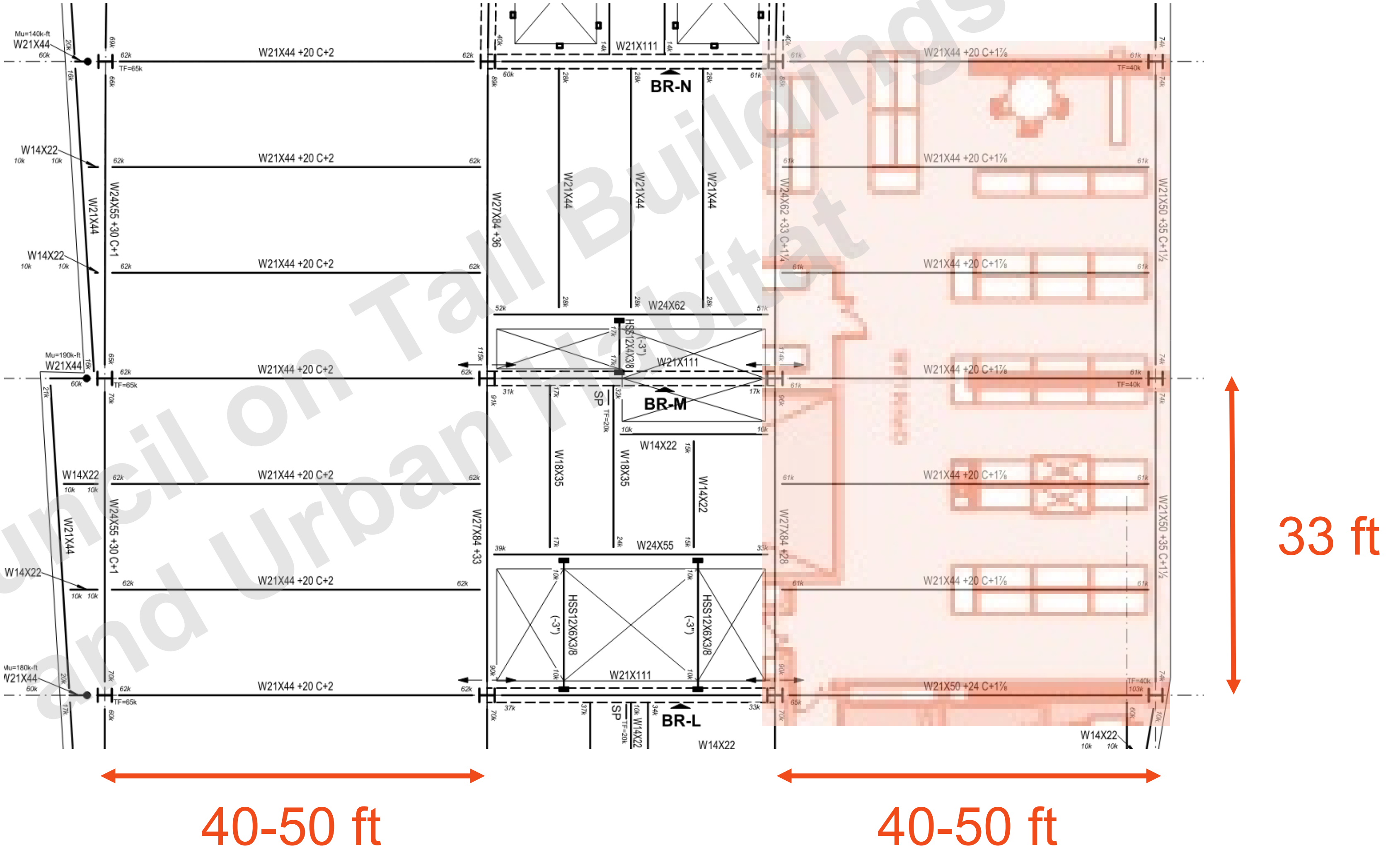
# Vibration Limits for Sensitive Equipment

| Designation | Tolerance Limit µin/s | Applicability |
|---|---|---|
| -- | 32,000 | Ordinary workshops |
| -- | 16,000 | Offices |
| -- | 8,000 | Computer equipment<br>Residences |
| -- | 6,000 | Hospital patient rooms |
| -- | 4,000 | Surgery facilities, laboratory robots<br>Bench microscopes up to 100x, operating rooms |
| VC-A | 2,000 | Microbalances, optical comparators, mass spectrometers<br>Industrial metrology laboratories, spectrophotometers<br>Bench microscopes up to 400x |
| VC-B | 1,000 | Microsurgery, microtomes and cryotomes for 5 to 10 µm slices<br>Tissue and cell cultures, optical equipment on isolation tables<br>Bench microscopes at greater than 400x, atomic force microscopes |

# Current Construction Practice

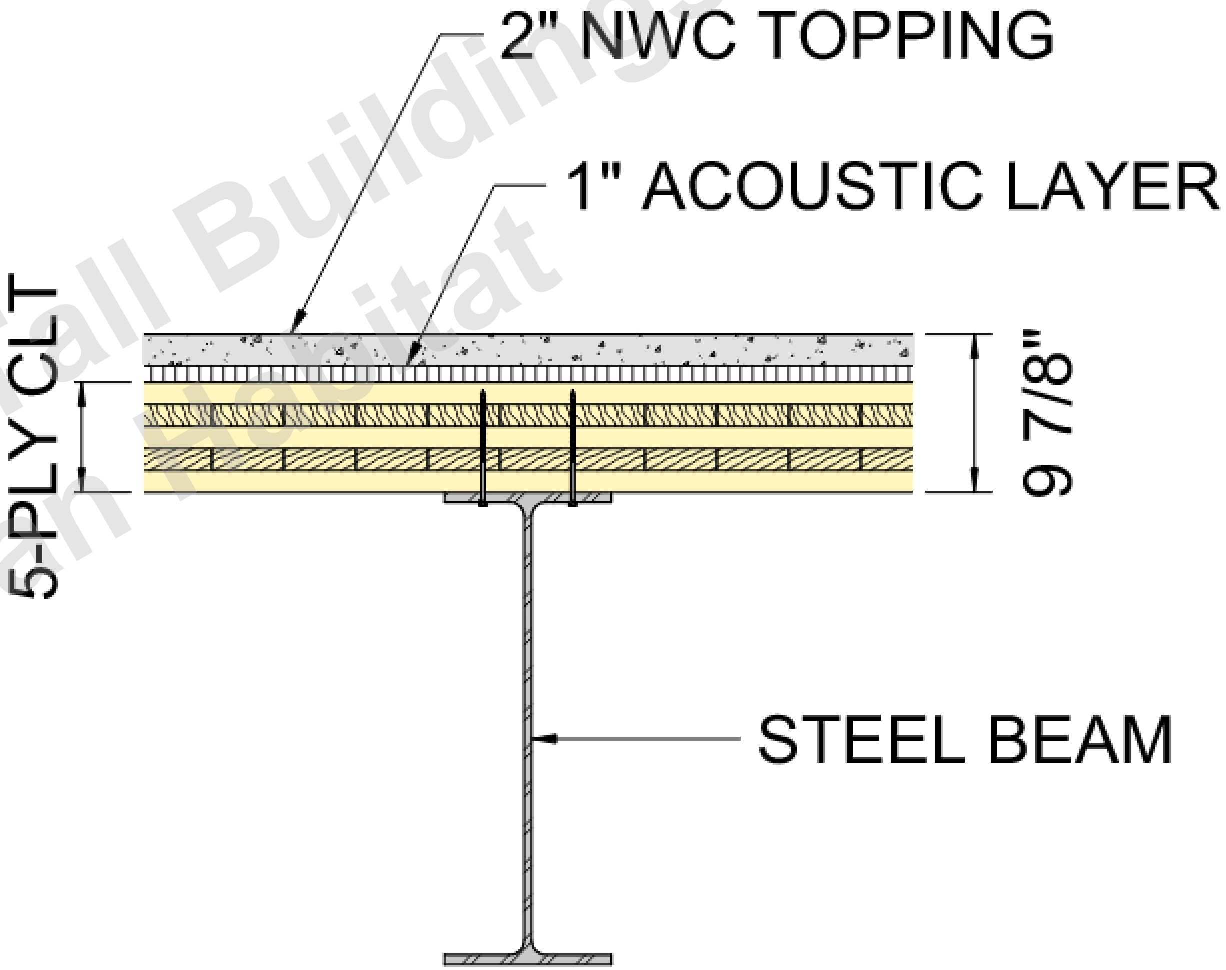
- Steel frame construction
- Normal weight concrete slab-on-deck
- Steel-concrete composite



# Steel-Timber Hybrid Floor System

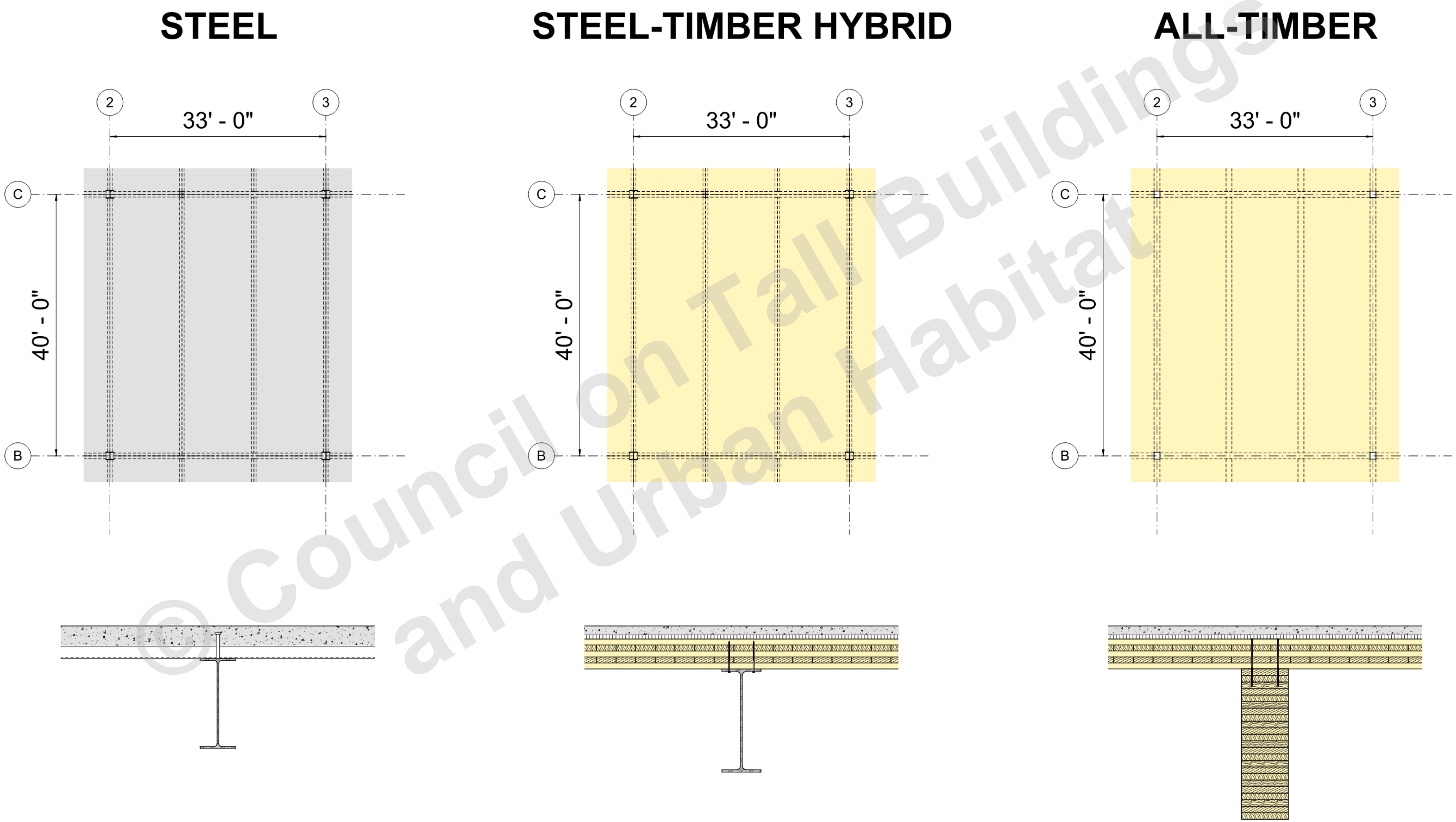
- Framing system as described in AISC DG 37
- Steel floor beams and girders
- 5-ply CLT timber floor panels spanning between floor beams
- 1” acoustic layer
- 2” normal-weight concrete topping
- STC = 50 to 60
- IIC = 40 to 50



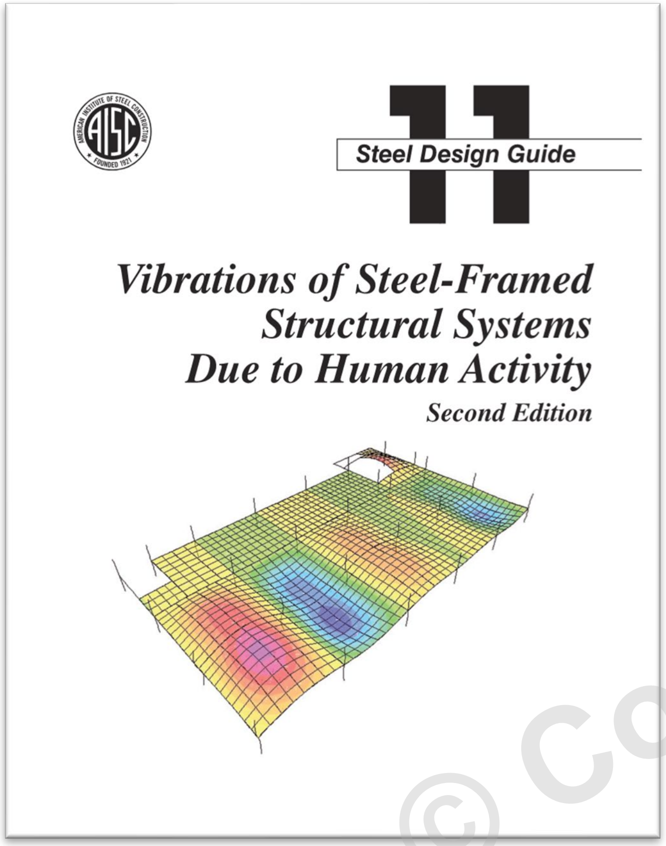
# Why Steel-Timber Hybrid?

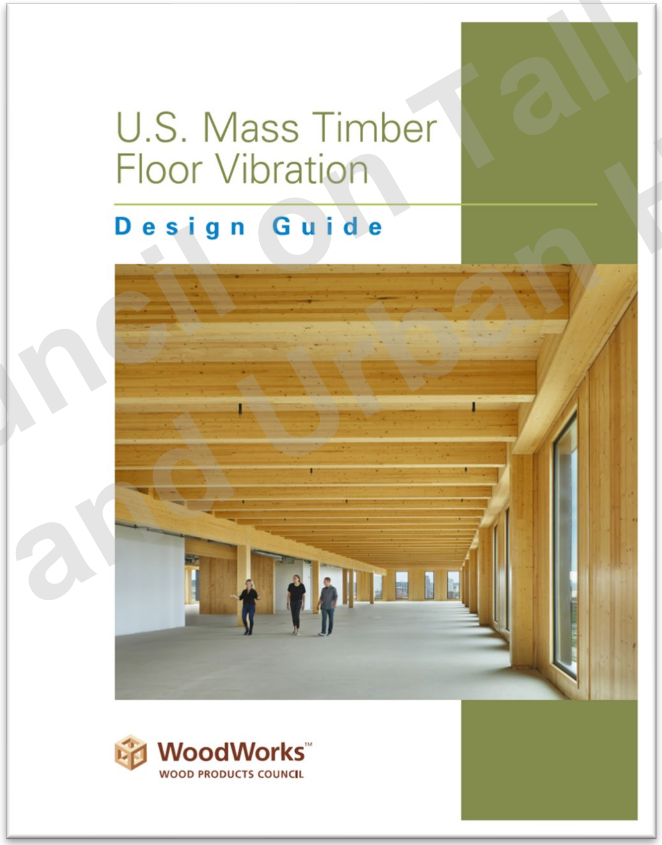
- Mass Timber is a differentiator in the marketplace
- High span-to-depth ratio compared to All-Timber
- Versatility of steel
- Embodied Carbon
- **Does Steel-Timber Hybrid meet vibration performance?**

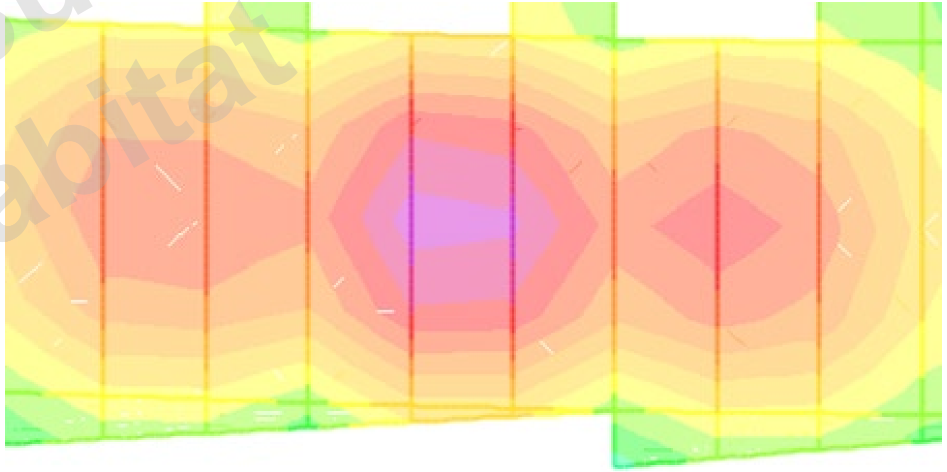
# Floor Vibration Study



# Floor Vibration Design Guides

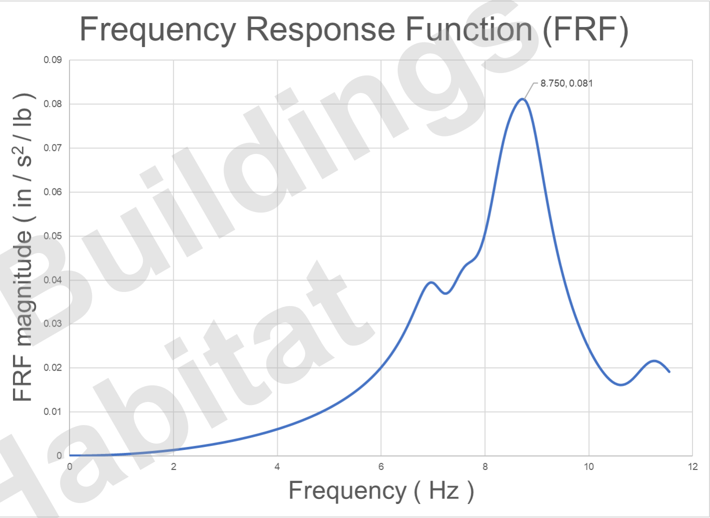


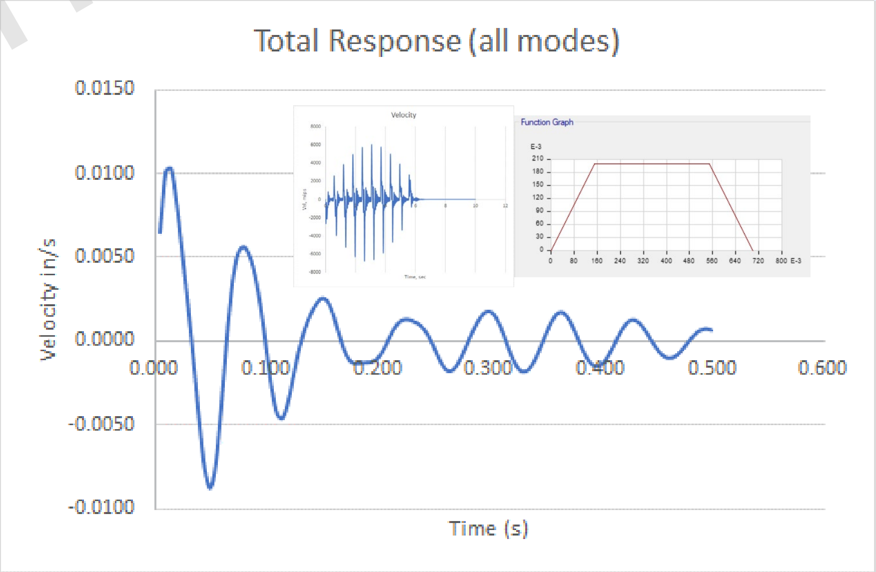



# Vibration Analysis Methods

- AISC DG-11 Simplified Method
  - Approximate and conservative
  - Material-specific calibrations
- **AISC DG 11 Frequency Response Function (FRF)**
- CCIP-016 Design Guide (Cement and Concrete Industry Publication)
- Walking path time history analysis
  - Most precise
  - Most difficult to implement



# Modal Analysis

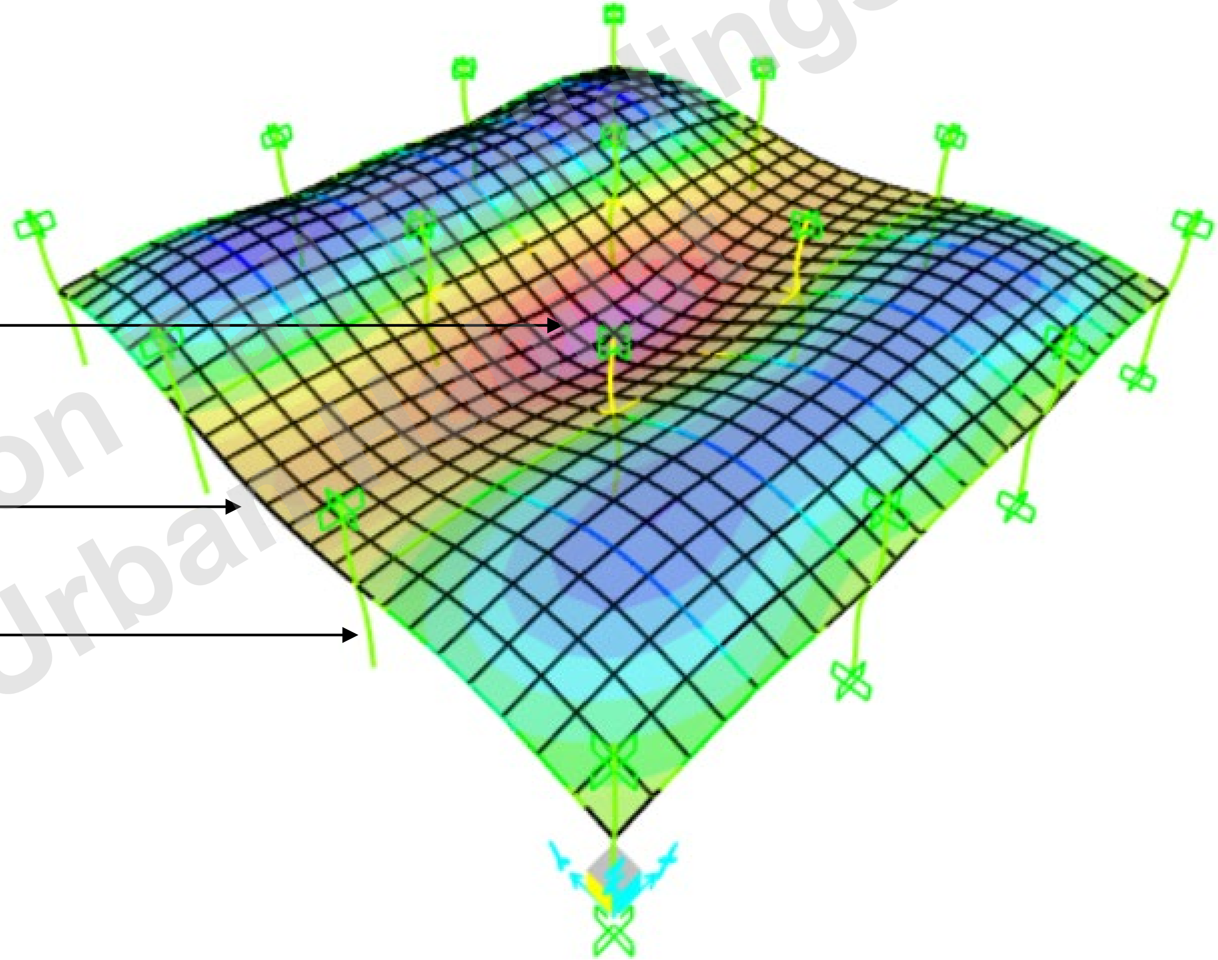
3x3 Bay System

Velocities measured at center of interior bay

Free edge at perimeter

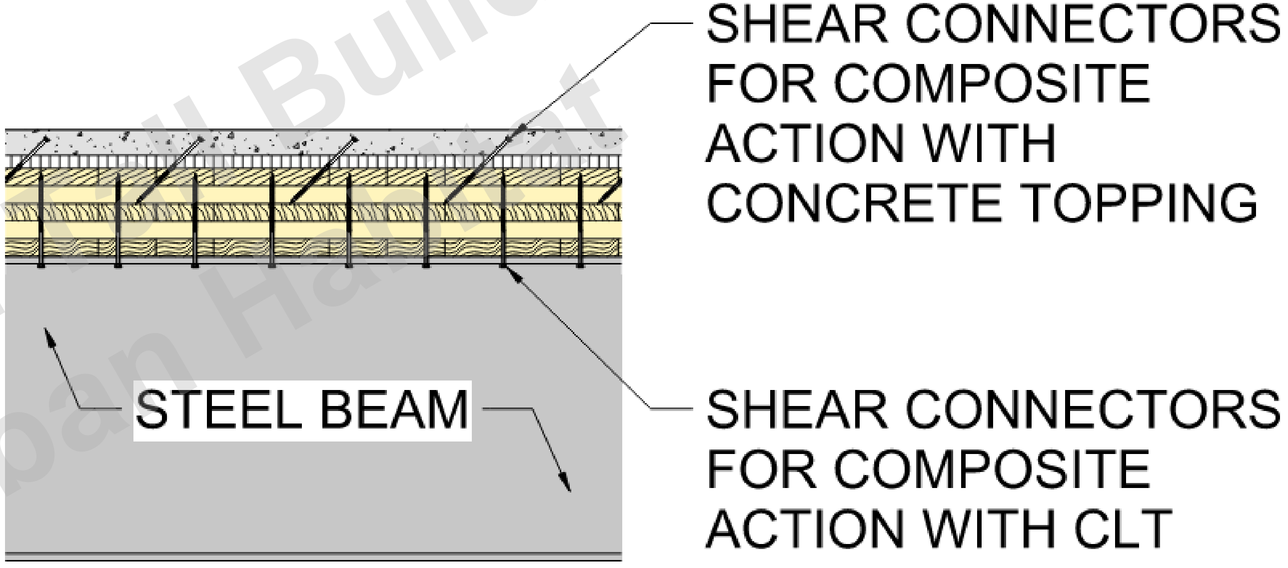
1-story column stiffness included

Multiple modes of vibration considered

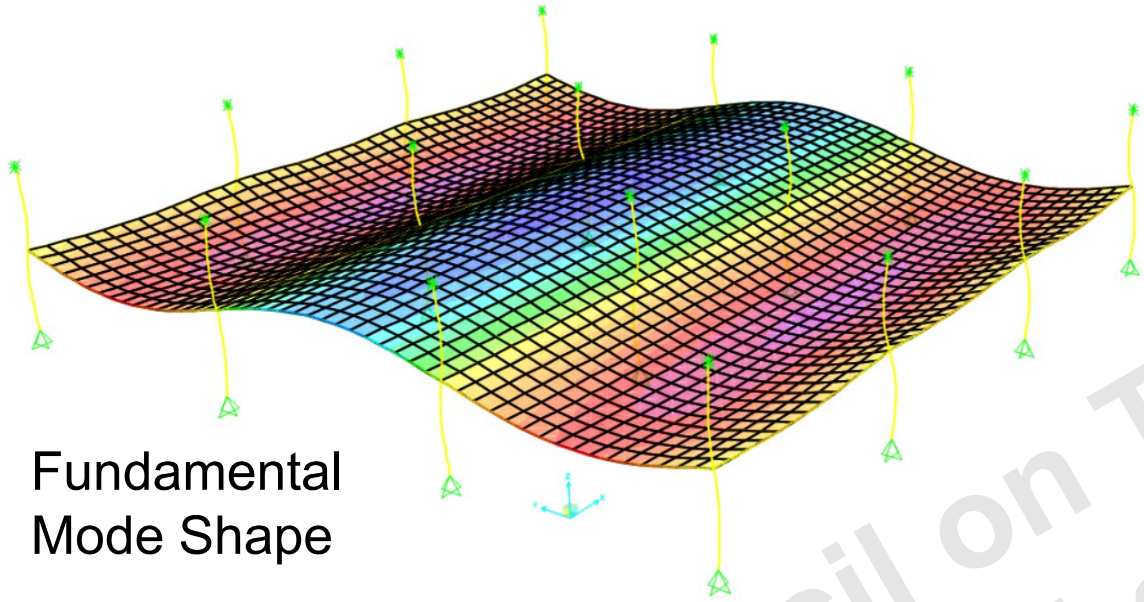


# Composite Section Properties

- Full composite action with CLT assumed for vibration analysis
- Additional stiffness could be achieved through composite action with the concrete topping
  - Composite action with concrete topping was not assumed for baseline study
- Limited testing and observations for composite action of topping above acoustic layer

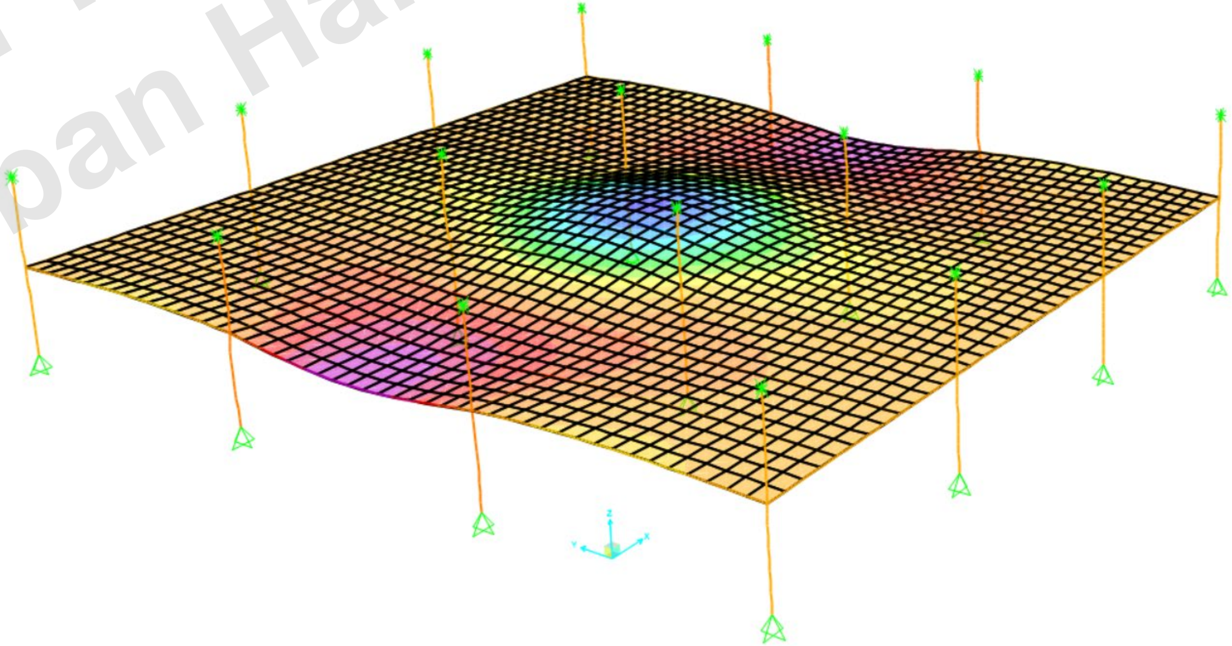


# Modal Analysis Results



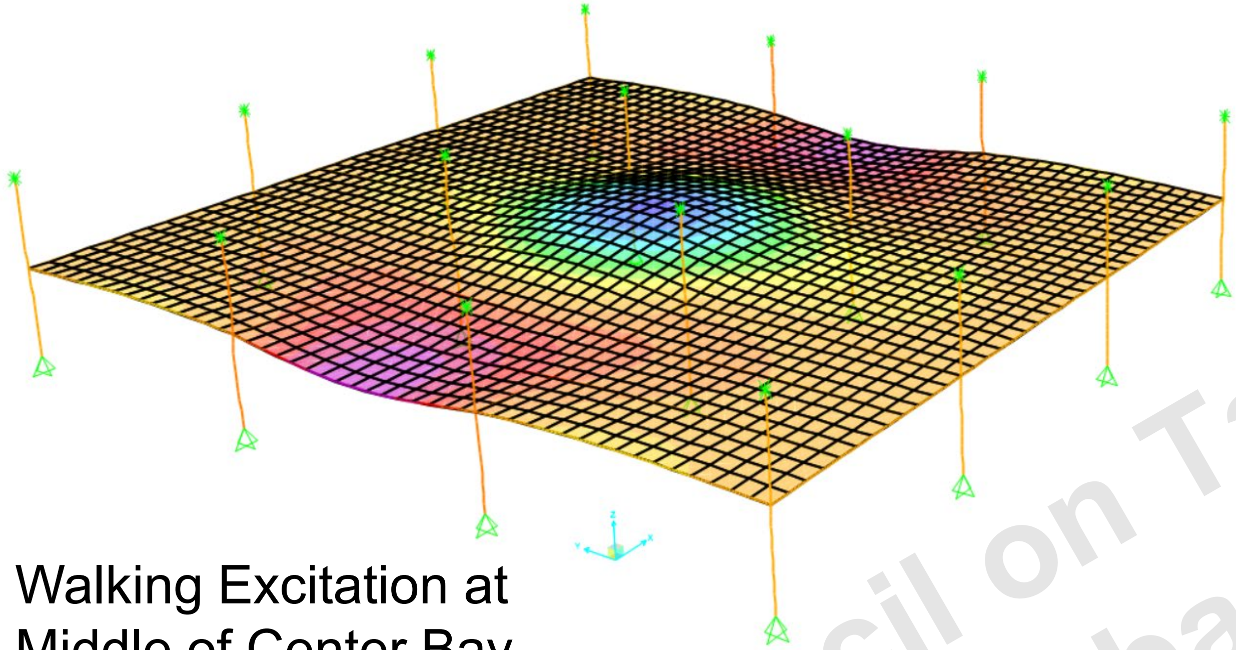
Fundamental Mode Shape

Walking Excitation at Middle of Center Bay



- Low correlation between mode shape and excitation
- Good vibration performance

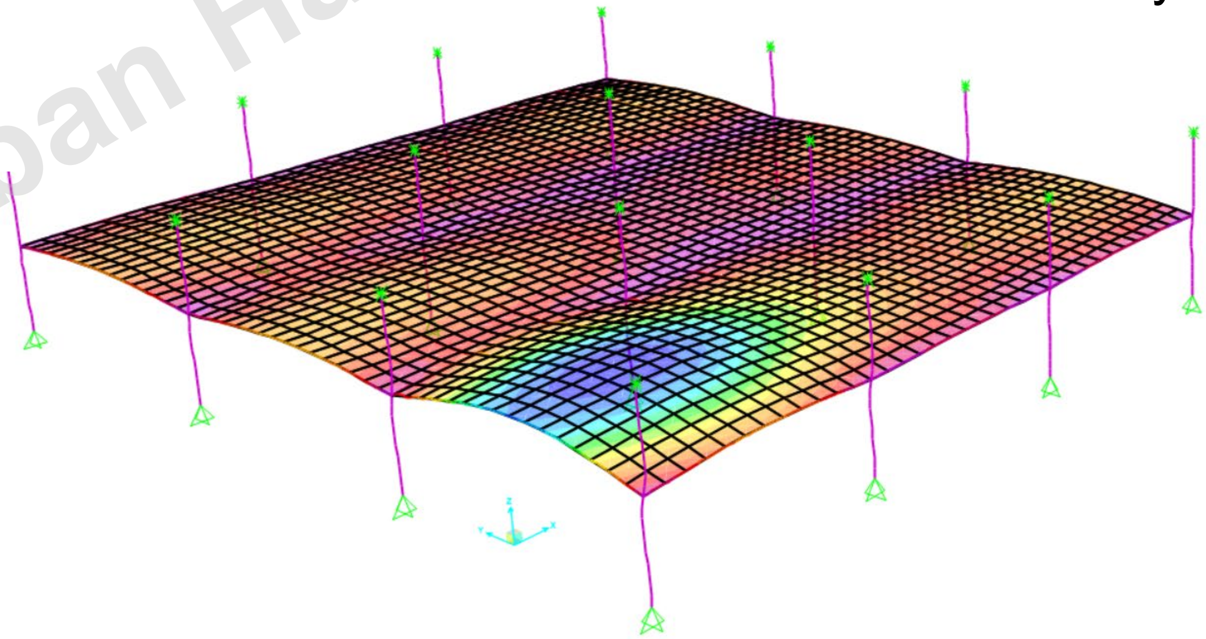
# Variability in Vibration Performance



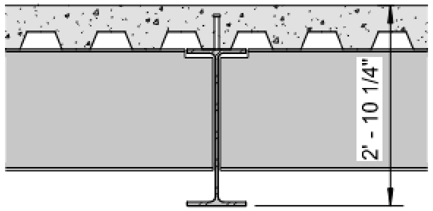
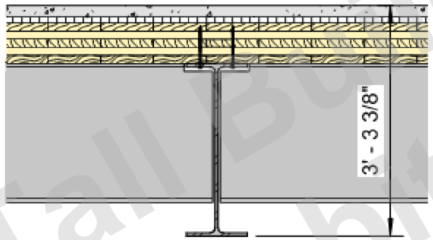
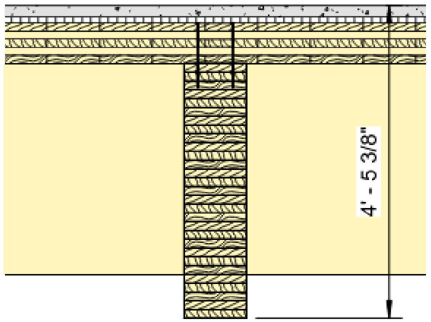
Walking Excitation at
Middle of Center Bay

- Center-bay response used for comparison purposes
- Comprehensive evaluation of a building floor plate needs to account for many factors and performance will not be uniform

Walking Excitation at
Middle of Corner Bay



# Design Results and Vibration Performance

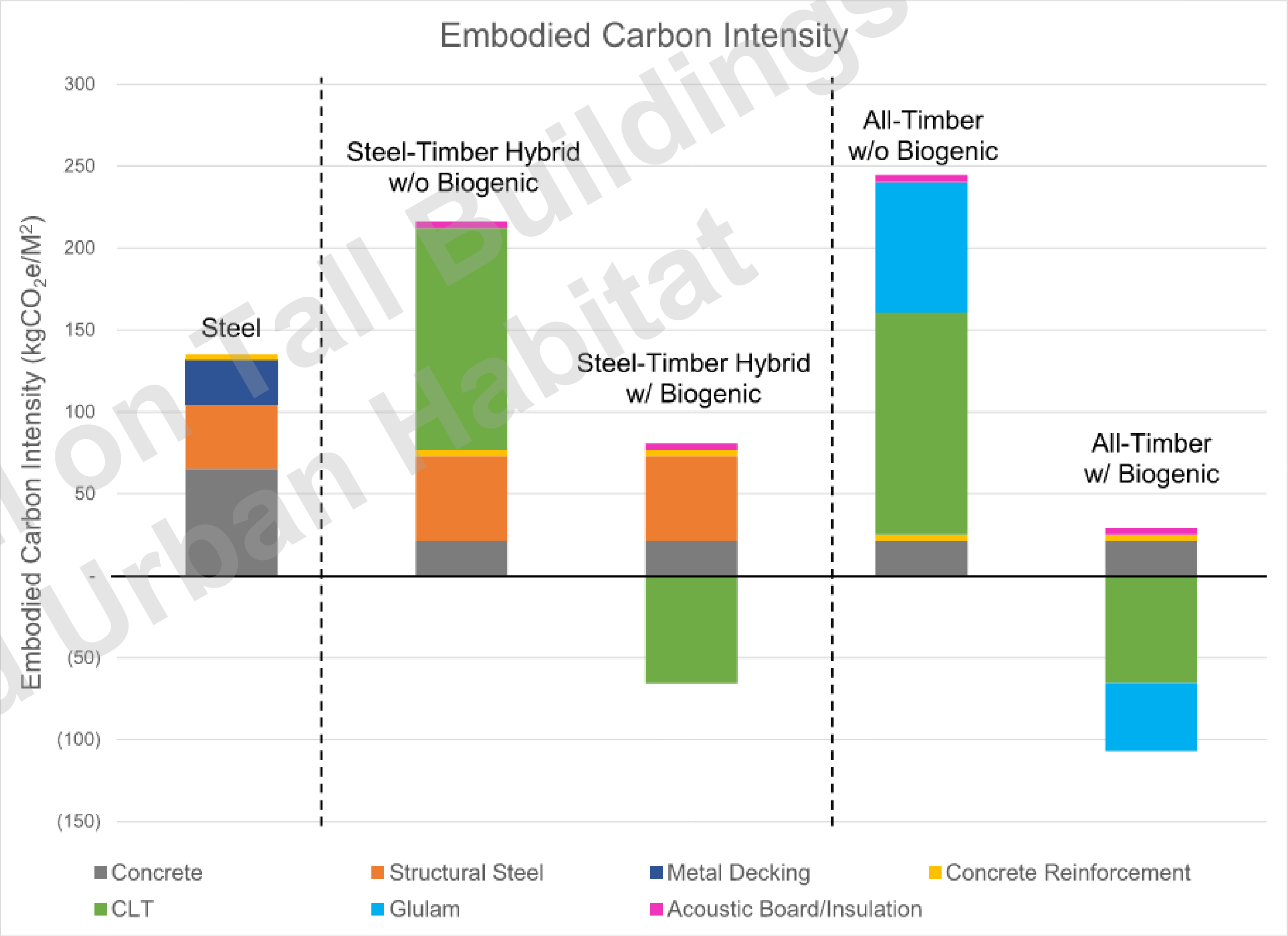
| | STEEL | STEEL-TIMBER | ALL-TIMBER |
|---|---|---|---|
| |   |   |   |
| **Total Structure Depth** | **2’-10”** | **+5” more depth than steel** | **+1’-7” more depth than steel** |
| Girder Size | W27x84 | W30x90 | 11½ x 43⅝ |
| Beam Size | W21x48 | W24x68 | 11½ x 35⅝ |
| FRF Vibration Velocity (Center Bay)** | 2300 mips | 2800 mips | 2700 mips |
| | ( 3200 at Corner Bay ) | Composite w/ conc topping 1600 mips | Composite w/ conc topping 1500 mips |



Design results governed by code requirements for strength and deflection based on 100psf live load
**5% damping, and 96 steps/min per AISC DG11 2nd Ed.

# Embodied Carbon Performance

- Floor framing and slab only
  - Columns, foundations, façade, etc not included
- Results for Hybrid and All-Timber are reported both with and without the effects of Biogenic Carbon
- Results include Life-Cycle Assessment Stages A to C
- Larger variability in Impact Factors for Timber than for other materials



# Summary

- Steel-Timber Hybrid balances the versatility of steel with the benefits of Mass Timber
- Steel-Timber Hybrid can achieve good vibration performance while minimizing depth of structure compared to the All-Timber option
- Embodied Carbon performance of Steel-Timber Hybrid is an improvement over traditional construction

# Thank you!



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