AMERICAN INSTITUTE OF STEEL CONSTRUCTION

FastFloor R Workshop

MEETING NOTES AND PRESENTATIONS
Baltimore, MD
December 3, 2024

Smarter.
Stronger.
Steel.

## Acknowledgments and Authorship

This workshop report was prepared by Caitlin Colsia, American Institute of Steel Construction (AISC); Ben Schafer, Johns Hopkins University (JHU); and Devin Huber, AISC. The reported research was developed by Cas Caswell, JHU; Sophrenia David, JHU; Fidence Rukundo JHU, Ahmed Kahn, JHU; and Shahab Torabian JHU/Simpson, Gumpertz & Heger (SGH). The reported work was sponsored by AISC and the Steel Deck Institute (SDI) with in-kind contributions from USG, DACS, SGH, New Millenium, Hilti, and ClarkDietrich.

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# 1 Executive Summary

Over the past three years, the American Institute of Steel Construction (AISC) and the Steel Deck Institute (SDI) have partnered with researchers at Johns Hopkins University (JHU) to develop and evaluate a novel modular floor system known as **FastFloor R (FF-R)**. This non-proprietary system, designed for low- to mid-rise steel-framed construction, aims to significantly reduce construction time and complexity by eliminating the need for cast-in-place concrete, using prefabricated modules comprised of steel deck and cementitious panels.

Through **Phase 1 and Phase 2** of research, the team has completed a series of structural and serviceability evaluations. Phase 1 focused on proof-of-concept testing of composite floor modules, including flexural strength and stiffness characterization. Phase 2 expanded the program with refined end details, connection (pushout) testing, development of an alternative 6-inch deep deck configuration, and vibration performance assessment under a range of finish conditions. Analytical tools, including preliminary beam span tables, were developed in coordination with United States Gypsum (USG) and Simpson, Gumpertz and Heger (SGH) These results provide a strong technical foundation for system validation.

A **one-day workshop** held on **December 3, 2024**, brought together key stakeholders to evaluate the current state of development and identify the critical needs and opportunities ahead. Workshop discussions highlighted several key insights: serviceability criteria (vibration, acoustics, deflection) are likely to govern design acceptance; diaphragm behavior and fire resistance must be better quantified; and integration of FF-R into real-world construction will depend heavily on clear design tools, modularization strategies, and cost competitiveness. Attendees identified application opportunities in residential, hospitality, and cold-formed steel framing-based construction systems, while also emphasizing the importance of benchmarking FF-R against existing floor systems in terms of strength, cost, time, and non-structural performance.

Based on these insights, the research team is developing a comprehensive **Phase 3 scope of work**, including expanded technical testing (e.g., edge compression, connection behavior, web crippling), continued serviceability evaluations, initiating acoustic strategies and assessments, supporting finite element modeling and design tool development, and work with AISC to develop archetype building layouts and benchmarking comparisons across floor system alternatives.

A formal Phase 3 proposal will be submitted to AISC in early 2025.

# 2 Workshop Information

**Date:** December 03, 2024
**Time:** 8:00 AM – 2:30 PM EST
**Location:** Baltimore, MD

## Workshop Purpose

Gather industry expertise and potential end users together and brainstorm on potential details that could be implemented to allow wider adoption of this modular, lightweight, dry (no placement of concrete in the field), and faster-to-erect floor system that are compatible with structural steel framing. Now that basic prototyping and proof-of-concept are established, AISC aims to use this workshop to help bridge the gap between the research and implementation of this innovation. AISC and the Research Team will also use this forum to help identify any additional research needs for the FastFloor *R* system so that they can be quickly addressed.

The desired outcomes of this workshop include both technical and strategic aspects, of particular interest are driving towards actionable plans to implement the proposed system in actual projects. Using an archetype building structure designed by AISC as a starting point, participants were asked to provide their relevant expertise on aspects of the system that have not been fully worked through in the research to date. Some technical items to be discussed include connection details, modularization optimization (shop vs. field work), fireproofing options, and various architectural considerations. The other key component the workshop focused on are the pathways to implementation for the system - including the challenges, opportunities, and needed actions to go from innovation to use in an actual project.

## Desired Outcomes

Tangible deliverables will be finalized and agreed upon at the Workshop through interaction with participants, but AISC notionally envisions multiple potential publications. These would include a Workshop Summary Document posted on AISC's website similar to other workshops AISC has held on SpeedCore and Adhesives. Other forms of dissemination could include white papers, design examples, and, potentially, a Design Guide.

## Workshop Agenda

The workshop agenda was as follows.

| FastFloor R Workshop – Final Schedule \| December 3, 2024 | |
|---|---|
| **Tuesday, December 3** | |
| **8:00 AM** | Welcome and Group Breakfast |
| **8:30AM** | Overview of system and discussion of workshop purpose and desired outcomes<br>1. Concept<br>2. Research to Date<br>3. Workshop Purpose |
| **9:30 AM** | Tour of lab facilities, review of tested specimens (as space available) |
| **10:00 AM** | Break |
| **10:15 AM** | 10:15 – 10:30 - Presentation of case study using the system with group discussion and feedback<br>1. Archetype structure using system (show floor plans, typicals, renderings, etc.)<br>2. Highlight details where input from the group is needed and discuss as a group<br>a. Panel to structural framing connections (gravity and diaphragm)<br>b. Inter-module connections |

| FastFloor R Workshop – Final Schedule \| December 3, 2024 | |
|---|---|
| | c. Dry system assumption - challenges and opportunities<br>d. Fireproof assemblies<br>e. Architectural details at critical locations (spandrels, demising walls, etc.)<br>3. Assumed modularization philosophy for system<br>4. Pathways to implementation - merging of cold-formed and hot-rolled systems<br>Challenges to go from research/paper study to an actual built project |
| **12:00 PM** | Group Lunch |
| **1:00 PM** | Finalize and capture items from initial large group brainstorm |
| **1:30 PM** | Discussion of next steps and actions from participants<br>1. Discuss potential outputs from Workshop<br>2. Capture relevant actions to help advance the system<br>3. Potential projects that could use system<br>4. Other items |
| **2:30 PM** | Departure/Adjournment |

## Attendees

A broad suite of attendees were sought for the workshop. The workshop was only offered in person. On December 3rd there were 10 people in attendance, see Table 1.

Table 1. Attendees List

| Attendee | Organization | Role |
|---|---|---|
| Devin Huber | AISC | Dir. of Research |
| Tom Sputo | SDI | Tech. Dir. |
| Ben Schafer | JHU | Researcher, Professor, JHU |
| Caitlin Colsia | AISC | Engineer, Engineering & Research |
| Shahab Torabian | SGH | Engineer, SGH |
| Sophrenia David | JHU | Research student, JHU |
| Fidence Rukundo | JHU | Research student, JHU |
| Mike Martignetti | Canam Steel Corp | Deck manufacturer |
| Bethany Myelle | MKA | Design engineer |
| Marty Williams | New Millennium | Deck manufacturer |

Note: solicitation of workshop participants included design engineers, structural steel fabricators, building supply manufacturers, trade associations, general contractor, construction hardware and tools, metal deck producers, and sales engineers. The workshop report will be shared with participants and those solicited to participate in the workshop.

## Tasks and Action Items

Task and action items from this meeting are noted throughout the document and summarized in Section 5.4.

# 3 FastFloor R Background and Motivation

Common floor systems in steel construction provide excellent structural response (flexure, shear/diaphragm) and if designed with care equally excellent non-structural (fire, acoustic, thermal/energy) response. However, most floor systems suffer from slower fabrication and erection times. Erection of conventional floors is largely completed in the field and involves multiple components and connections back to the structural frame. Further, typical floors utilize concrete in some form resulting in more trades involved, slower turnaround time, and high embodied carbon. As part of the American Institute of Steel Construction's (AISC) Need for Speed initiative[1] AISC and the Steel Deck Institute (SDI), recognizing the potential benefits of faster systems, is exploring options in novel floors compatible with conventional structural steel framing.

The objective of the investigations is to develop a new non-proprietary floor system: FastFloor, compatible with current steel construction, that has structural and non-structural performance that meets all needs of a building system and is markedly more efficient in its time from conception to installation. Investigation of this problem has led to the consideration of two primary solutions for FastFloor: "commercial" and "residential" – where commercial systems may typically span 40 ft (12.2 m) and residential systems may typically span < 20 ft (6.1 m). The longer span system, known as FastFloor C is being studied in a separate effort[2], this workshop addresses FastFloor R, and thus examines shorter span solutions. FastFloor R is equally applicable to commercial construction – its target is a **r**eliable and **r**esilient solution for intermediate to short spans.

The basic FastFloor R concept is to utilize lightweight, dry, floor modules to span between structural beams, where the modules are comprised of steel deck topped with a cementitious panel, such as USG's Structocrete. The intent is that the composite floor module of deck and panel can provide adequate structural capacity and non-structural performance. Perceived benefits of the initial concept include: dry (no wet concrete), easily panelized/fabricated, all off-the-shelf components, lightweight, non-combustible, potentially fast to erect, and further the use of USG's Structocrete panel may help leverage their research on fire and acoustic allowing the system to market more expeditiously.

A cross-section of the initial FastFloor R prototype is provided in Fig. 1. The testing of this system is being conducted at Johns Hopkins University in Baltimore, Maryland. This is also the site of the workshop so that participants can see the sample specimens in the lab.

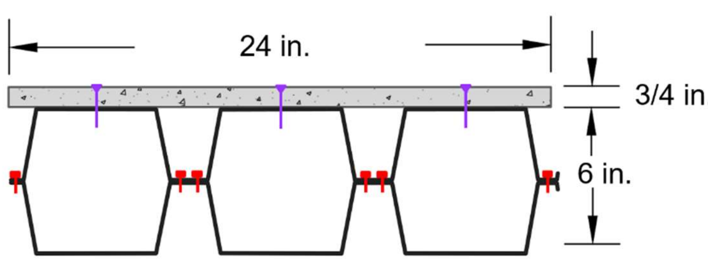



Fig. 1 FastFloor R Initial Prototype Configuration

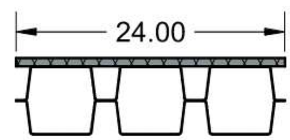
[1] https://www.aisc.org/technical-resources/need-for-speed/
[2] https://steeli.org/?p=406

# 4 Research to Date

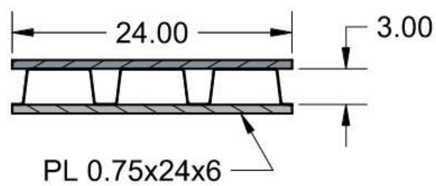
Researchers at Johns Hopkins University have, to date, completed two Phases of preliminary work on FastFloor R. Phase 1 provided initial proof of concept including flexural stiffness and strength for the 6 in. deep, 24 in. wide module of Fig. 1. Phase 2 provided connection testing, improved end detailing, a new variant of the system using 6 in. deep deck instead of two 3 in. deck connected together, vibration testing, and flexural stiffness and strength testing. The workshop was conducted during the Phase 2 work at the time in which vibration testing of the 6 in. deep specimens was underway.

**Phase 1 Work Background:** Working with SDI and AISC the research team detailed and structurally tested the first FastFloor R concept, as shown in Fig. 2. The floor modules consisted of two 3 in. deep deck screw connected to form a "cellular deck" with cementitious board screw connected to the top flange. Special detailing was utilized to ensure failure occurred in the moment span. The structural performance of the system was excellent, with significant composite action achieved. Flexural stiffness and strength were established for the prototype system.

(a) photo of 4 point bending test conducted in JHU lab




(b) typical section in span

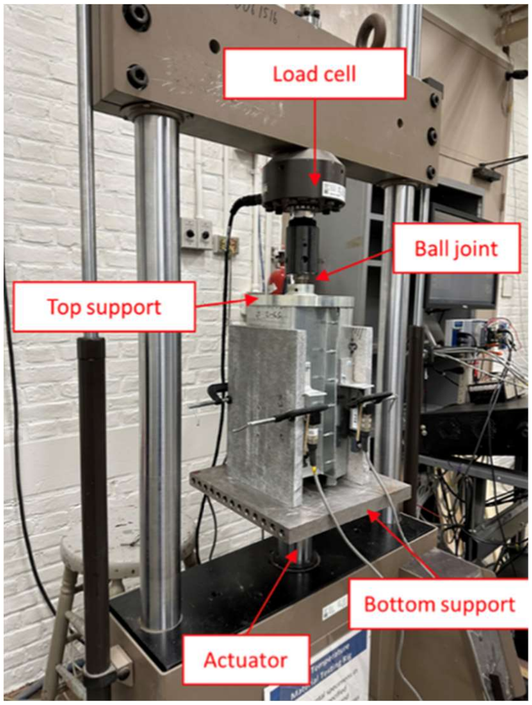



(c) typical section at support

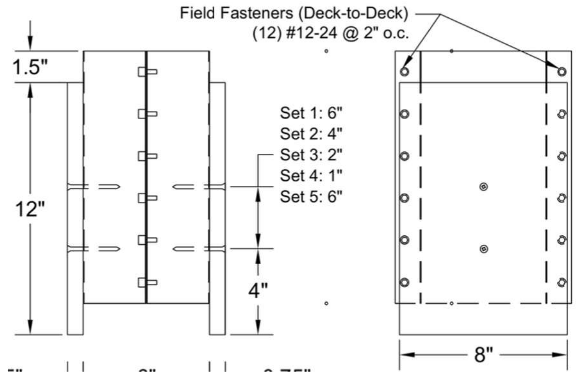
Fig. 2 Phase 1 FastFloor R tested concept – two 3 in. deep deck screw connected to form "cellular deck" with cementitious board screw connected to top flange.

Phase 1 work is summarized in the following documents:
Caswell, H.L., Torabian, S., Schafer, B.W. (2022). "FastFloor Residential Testing Report." CFSRC Report. http://jhir.library.jhu.edu/handle/1774.2/67741
Caswell, H.L., Torabian, S., Sputo, T., Schafer, B.W. (2022). "Cold-formed steel profiled decks topped with cementitious structural panels to enable fast floor construction of residential buildings." CFRSC Colloquium http://jhir.library.jhu.edu/handle/1774.2/67711

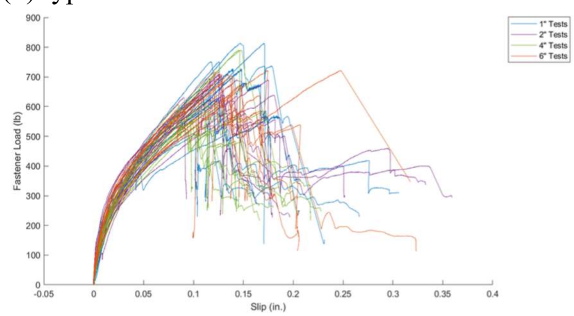
**Phase 2 Work Background:**
Connection Testing: the Phase 1 testing demonstrated that the fasteners (Grabber) connecting the cementitious panel (USG ¾ in. Structocrete) to the deck top flange (18 g) play a critical role: the stiffness and load-slip response control the composite behavior, and the ultimate strength of this connection limits the flexural and shear strength of the module. In Phase 2, the research team developed a pushout test similar in spirt to that used to examine shear stud strength in concrete-filled steel deck as shown in Fig. 3. These tests provide stiffness, and strength (load-slip) data which are critical inputs to any engineering-based design method.




(a) photo of pushout test conducted in JHU lab




(b) typical details

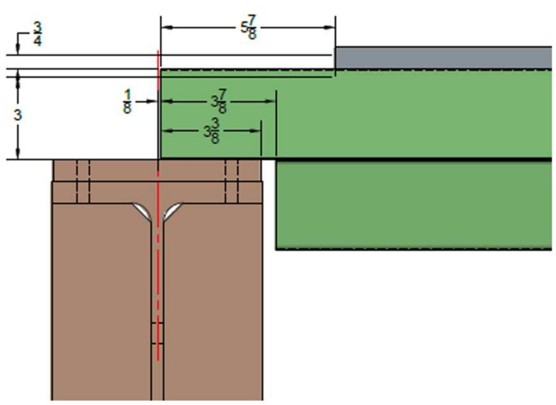



(c) typical load-slip behavior

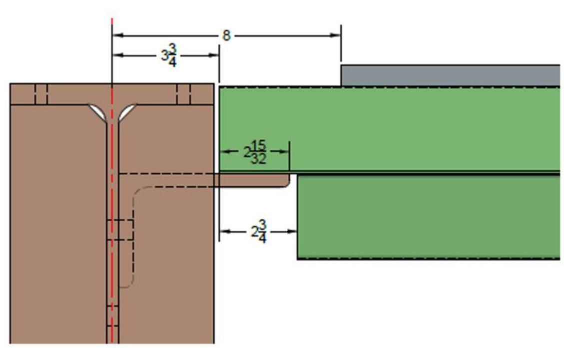
Fig. 3 Phase 2 pushout tests to establish stiffness and strength of fasteners connecting cementitious panel to top flange of deck

Phase 2 fastener work is provided in the following
Caswell, H.L., Torabian, S., Schafer, B.W. (2023). “Shear Response of Fastened Assemblies of Cementitious Panel to Steel Deck for FastFloor Residential Project.” CFSRC Report [https://jscholarship.library.jhu.edu/handle/1774.2/69200](https://jscholarship.library.jhu.edu/handle/1774.2/69200)

End Detailing: The tested Phase 1 FastFloor R modules used idealized end conditions and special fixtures at the ends of the specimens and underneath the load points to ensure web crippling did not occur. In collaboration with AISC and SDI in Phase 2 the team developed two end conditions with potential for use in typical steel construction as shown in Fig. 4. These solutions use PAFs to connect to the structural system and provide two potential forms of drop-in solutions for the modules.



(a) deck top half, PAF to support beam



(b) deck top half PAF to shelf angle, with structocrete flush over beam

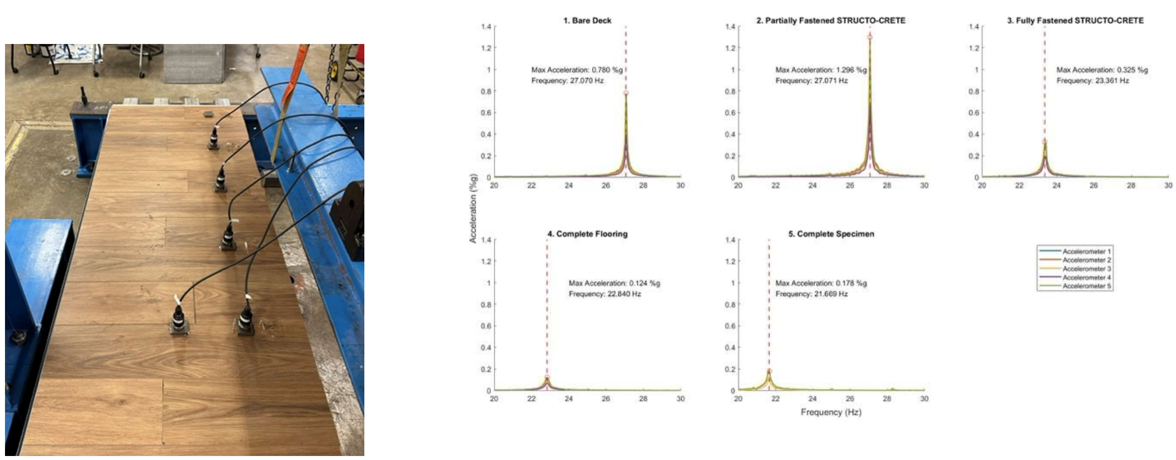
Fig. 4 Phase 2 new end details developed and tested, supporting beam in brown,
two 3 in. deck in green, panel in grey

<u>6 in. variant</u>: In Phase 2 the research team also examined the performance of using a single inverted 6 in. deep deck as opposed to the 2 x 3 in. “cellular” deck explored to date, see Fig. 5. Calculation methods indicate reduced mass and increased structural efficiency for the inverted deep deck. Initial structural performance shows adequate strength, though a much more dramatic mode of failure post-peak, and reduced non-structural performance, more work is needed for the deep deck solution to be pursued. Workshop participants were able to observe ambient vibration in the 6 in. deep deck option, and walk on this floor variant.

(a) “cellular” 2x3 (two 3 in. deck) option (b) inverted, 6 in. deep deck option
Fig. 5 Phase 2 two deck-panel options explored

<u>Flexural testing</u>: In Phase 2 the research team continued flexural testing of the specimens, completing work on the 2 x 3 in. and the 6 in. deep specimens of Fig. 5 with the end details of Fig. 4 for the 2 x 3 tests. The team have collected this benchmark data and will provide in a forthcoming Master’s thesis (David 2025). (Note as of this writing on 16 March 2025 all Phase 2 flexural testing on both the 2x3in. deck and the 6 in. deep deck is complete.). This work provides benchmark flexural capacities and observed failure modes.

<u>Vibration testing</u>: In Phase 2 the research team also completed basic vibration testing (bag drop, heal drop, walking tests) on the fast floor modules, both in their bare structural state and with a simple floor finish (LVL flooring) and ceiling finish (resilient channels and gypsum board), see Fig. 6. As discussed in the Phase 2 proposal, the idea was not so much to establish that the module is definitively acceptable/not acceptable for vibration, but rather providing an example of observed behavior and the actual damping of the system. Vibration results for the 6 in. deep deck (Fig. 4b) were not as favorable as the 2 x 3 in. deck – quantitative summaries will be provided in a forthcoming Master’s thesis (David 2025) and additional processing work is proposed for Phase 3.




(a) “cellular” 2x3 option fully finished with accelerometers (b) measured frequencies of floor from bare deck to fully finished
Fig. 6 Phase 2 vibration testing on 2x3 in. specimen

Phase 2 flexural and vibration testing work will be provided in the following
David, S. (2025). "Flexural and vibration testing of a novel modular floor system" <*draft title*> M.S. Thesis. – expected May 2025, schafer@jhu.edu can provide copies once available.

Collaboration with USG/SGH: In Phase 2 the research team continued an active collaboration with USG and SGH – this effort is separate from, but coordinated with, FastFloor R. In particular, Dr. Torabian and Dr. Schafer developed engineering calculation methods for strength prediction. The calculation method considered: bending, deflection, shear, web crippling, combined shear and bending, combined bending and web crippling. The methods allow for analytical prediction of span tables as shown in Fig. 7. USG is developing a guide to re-roofing utilizing this engineering model and USG has continued to contribute in-kind materials to the effort.

**Allowable Uniform Loads (psf)**
**Criteria:** Stress, Deflection Limited to L/360

Controlling Limit States
- Deflection: L/360
- Bearing
- Flexure

| SPANS | DECK DEPTH (in) | COMPOSITE DECK VIEW | GAGE [mil] | SPAN (ft) 4 | 6 | 8 | 10 | 12 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SINGLE | 1.5 | | 16 [54] | 300 | 101 | 45 | 24 | 15 | 10 | 8 | 7 |
| | 1.5 | | 18 [43] | 264 | 83 | 37 | 20 | 12 | 8 | 7 | 6 |
| | 1.5 | | 20 [33] | 208 | 67 | 31 | 17 | 11 | 7 | 6 | 5 |
| | 1.5 | | 22 [27] | 182 | 59 | 28 | 15 | 10 | 7 | 6 | 5 |
| | 1.5 | | 24 [23] | 138 | 46 | 22 | 12 | 8 | 5 | 5 | 4 |
| | 3 | | 16 [54] | 300 | 300 | 174 | 92 | 55 | 36 | 30 | 25 |
| | 3 | | 18 [43] | 300 | 300 | 143 | 76 | 46 | 30 | 25 | 21 |
| | 3 | | 20 [33] | 300 | 255 | 114 | 62 | 38 | 25 | 21 | 18 |
| | 3 | | 22 [27] | 300 | 218 | 101 | 55 | 34 | 23 | 19 | 17 |
| | 4.5 | | 14 [68] | 300 | 300 | 300 | 300 | 189 | 122 | 100 | 84 |
| | 4.5 | | 16 [54] | 300 | 300 | 300 | 261 | 155 | 100 | 82 | 69 |
| | 4.5 | | 18 [43] | 300 | 300 | 300 | 210 | 125 | 82 | 68 | 57 |
| | 4.5 | | 20 [33] | 300 | 300 | 300 | 165 | 100 | 66 | 55 | 46 |
| | 6 | | 14 [68] | 300 | 300 | 300 | 300 | 300 | 228 | 187 | 156 |
| | 6 | | 16 [54] | 300 | 300 | 300 | 300 | 292 | 188 | 155 | 129 |
| | 6 | | 18 [43] | 300 | 300 | 300 | 300 | 236 | 153 | 126 | 105 |
| | 6 | | 20 [33] | 300 | 300 | 300 | 300 | 187 | 122 | 101 | 85 |
| | 2X3 | | 16 [54] | 300 | 300 | 300 | 300 | 196 | 128 | 105 | 88 |
| | 2X3 | | 18 [43] | 300 | 300 | 300 | 280 | 169 | 110 | 91 | 77 |
| | 2X3 | | 20 [33] | 300 | 300 | 300 | 209 | 128 | 85 | 71 | 60 |
| | 2X3 | | 22 [27] | 300 | 300 | 300 | 177 | 109 | 73 | 62 | 52 |

Fig. 7 Variations on FastFloor R concept and estimated allowable loads (as controlled by strength or deflection) – Phase 1 concept is the 2x3 variation with 18 gauge shown in the last four rows of table.

Collaboration with AISC Solutions Center: Prototype structures from the AISC Steel Solution Center were adapted to model a theoretical FastFloor R system in a mid-rise residential structure. The analysis done only represented a gravity design of the system and as modeled, allowed for a decrease in the existing column sizes. This reduction in overall tonnage of a structure could potentially lead to reduced foundation sizes, providing even further cost and time savings on a project. Further prototype structural studies are expected.

# 5 Workshop Attendees Input: Challenges, Opportunities, and Potential Future Research Needs

Following the prepared presentations, the attendees engaged in a discussion around various items including foreseen challenges, future opportunities, and potential research needs related to the FastFloor R system. The attendees were asked to provide their key takeaways and general thoughts and feedback. These remarks are organized and summarized below.

## Key Observations from Workshop Attendees

Several themes and critical technical and strategic insights emerged during the workshop discussions and group brainstorm. Observations reflect both positive reactions to the FastFloor R (FF-R) concept and pointed questions regarding design practicality, market fit, and remaining barriers to implementation.

• **Serviceability Considerations Dominate**: Multiple attendees highlighted that vibration, acoustics, and deflection are primary serviceability concerns. Many noted that these would likely govern design and adoption in practice, even before structural capacity becomes limiting.

• **Diaphragm Action Requires Clarification**: Participants emphasized a need to understand and quantify diaphragm behavior of the system. Attendees noted the importance of clearly defining what role the cementitious panel plays in the diaphragm and how continuity between panels is handled. Multiple options exist, but work is needed.

• **Market Fit and Span Length Sensitivity**: Manufacturers raised concerns about where FF-R fits into the current product ecosystem. A common question: "Is this meant to replace short-span or long-span systems?" Many noted that cost competitiveness and framing optimization must match market expectations. A 15 ft. sweet spot for simple spans was often cited.

• **Fire Rating and Assembly Detailing**: Fire protection details (including ceiling-based 2-hour ratings and fire-stops) must be fully vetted. Collaboration with USG and referencing existing UL assemblies is underway, but further testing and standardization are needed.

• **Delegated Design Pathways**: Questions were raised regarding whether FF-R would be designed by the Engineer of Record (EOR) or delegated to suppliers/panelizers, similar to Open Web Steel Joists (OWSJ). Opinions were split, but the need to streamline design tools was clear.

• **Modular Optimization & Fabrication Feasibility**: Several participants reflected on fabrication considerations – modular single-span systems were viewed favorably, while multi-span designs raised concerns about lifting weight and system complexity.

• **Lightweight System Advantage**: The reduced mass was seen as beneficial, especially for seismic design. The research team discussed a preliminary study showing performance gains in seismic zones due to lower system weight.

## Key Opportunities Identified by Participants

Workshop attendees were generally optimistic about the potential applications of FastFloor R. Several opportunities were highlighted:

• **Replacement for Concrete-Filled Deck in Residential Steel Framing**: FF-R could provide a dry alternative to poured concrete slabs in low to mid-rise steel-framed buildings.

• **Compatibility with Light Gauge Steel (LGS) Framing**: Several attendees noted the possibility of using FF-R as a floor system in LGS-framed structures, such as hotels and senior living facilities.

• **Retrofit and Re-roofing Markets**: Opportunities exist for lightweight retrofit solutions, especially in re-roofing applications where structural weight savings are valuable.

• **Tighter Floor-to-Floor Heights**: The modular system could enable tighter vertical spacing in buildings where this is a design priority, such as hotels or dormitories.

• **Simplified Structural System Options**: The FF-R system may enable new framing configurations, such as skeletal framing with "infill" floor modules or simplified girder-slab approaches.

• **Reduction in Foundation Loads and Overall Building Weight**: Gravity design studies by AISC and JHU suggest tonnage savings from FF-R implementation may reduce foundation requirements and project costs.

• **Design Tool Development**: An opportunity exists to develop engineering design tools (e.g., span tables, calculators, web tools) to support FF-R adoption in design offices.

## Key Challenges Identified by Attendees

Key challenges and recommended actions / mitigation strategies are summarized in Table 2.

Table 2. Key challenges and recommended actions

| **Challenge** | **Recommended Action / Mitigation Strategy** |
|---|---|
| Serviceability control (vibration, deflection, acoustics) | Conduct dedicated Phase 3 research. Partner with interested participants with additional expertise. |
| Diaphragm behavior of FF-R system unclear | Develop diaphragm capacity tests and analytical methods. |
| Fire rating details and approval pathways | Partner with USG (and potentially SGH) to formalize fire-rated UL assemblies. |
| Fabrication feasibility and end detailing | Pursue alternate end stiffener strategies and fabrication-friendly solutions. |
| Multi-span system weight and complexity | Focus on single-span solutions; simplify lifting strategies in collaboration with fabricators and builders. |
| Delegation of design responsibility | Develop example workflows and design guides. |
| Integration of utilities and MEP systems | Develop case studies and guidance documents. |
| Acoustic testing and spec. development | Initiate acoustic testing program and define performance targets. |
| Market positioning and cost competitiveness | Conduct comparative cost analysis and define sweet spot applications. |
| Structural system taxonomy unclear | Develop concept case studies and evaluate different archetypes. |

## Potential Research Needs

The workshop discussions clearly indicated that while the FastFloor R system has shown strong promise in terms of constructability, speed, and structural adequacy, several targeted areas of technical and implementation research are needed to bridge the gap between concept validation and broad industry adoption. The following research needs reflect both insights raised during the workshop and potential Phase 3 research efforts, organized to reflect emerging themes.

**Material Properties and Component Behavior**

A gap raised during the workshop is the lack of fundamental mechanical properties for the cementitious panels used in the system. In particular, **the edge compression strength of the panel** is a missing design parameter analogous to $f_c'$ in concrete. This material property is essential for engineering strength calculations and diaphragm modeling. **Proposed Work:** Develop an edge compression rig to establish compressive capacity of cementitious panels.

Workshop attendees also emphasized the importance of **reliable connection performance data**. The pushout tests conducted in Phase 2 were well received, and expanding this work to understand gauge dependence, alternate panels, and fastener combinations could be beneficial. **Proposed Work:** Conduct additional connection tests varying deck thickness and panel/fastener combinations to broaden design applicability and reduce proprietary constraints.

**System Behavior and Structural Detailing**

Several workshop discussions raised concern about **bearing and end support detailing**, including **web crippling behavior**, especially given the use of inverted deck configurations. Attendees noted that AISI S100-based web crippling formulas may not capture actual system performance, especially with composite panels and field conditions like PAF connections. **Proposed Work:** Conduct web crippling (patch load) testing in realistic configurations using Phase 2 end details and common panel/deck combinations.

There is also a need to **better define diaphragm behavior**, both in terms of **strength and stiffness**, particularly how the composite panel-deck system contributes and what role the panel fasteners play in shear transfer. **Proposed Work:** Develop calculation methods for diaphragm capacity and compare with test data and analytical modeling. Full-scale diaphragm tests may not be needed at this stage, but predictive engineering models should be established.

**Serviceability Performance and Design Criteria**

Vibration and acoustic performance were dominant themes in the workshop. While Phase 2 provided baseline **vibration** testing, participants stressed the importance of processing the data further and contextualizing results for **design acceptance criteria**. **Proposed Work:** Extend vibration analysis to estimate damping, convert acceleration data to ESPA, and extrapolate to larger floor areas using engineering models.

Attendees also emphasized **acoustics** as a primary barrier to adoption in residential and hospitality applications. Early input suggested that **an acoustical mat or underlayment may be required**, but further study is needed as such a solution is likely to make the system cost prohibitive. **Proposed Work:** Engage with USG acoustic experts to evaluate assembly configurations and generate a preliminary design path for sound performance.

**Modeling, Tools, and Engineering Support**

There is strong interest in creating **engineering design tools** that lower the barrier for EORs to adopt the system—especially if FF-R is to be treated as a delegated system. Participants emphasized that adoption would be accelerated with span charts, calculation methods, and user-friendly design aids. **Proposed Work:** Develop shell finite element models to support validation of strength and serviceability performance. Extend engineering calculation tools to include both strength and diaphragm behavior.

### System Benchmarking and Comparative Assessment

Many attendees requested a clear benchmarking of FF-R against other floor systems in the short-span market: traditional composite deck, engineered wood joists, proprietary hybrid systems (Hambro, EcoSpan, etc.), and CFS trusses. Understanding FF-R's **cost, weight, erection time, structural capacity, and non-structural performance** relative to competitors is vital. **Proposed Work:** Build on initial benchmarking by JHU and develop a structured comparison matrix in collaboration with AISC.

### Building Archetypes and System Integration

To help the system transition to actual projects, workshop participants supported the development of **building archetypes** that incorporate FF-R modules. These archetypes can serve as reference designs and test beds for future system refinement. **Proposed Work:** Work with AISC and the Steel Solutions Center to develop sample building layouts using FF-R modules. Provide structural support, span tables, and integration guidance.

### Fabrication and Erection Logistics

The success of FF-R hinges on how it is packaged and delivered: **on-site panelized assembly vs. off-site modular floor units**. Workshop feedback indicated that understanding the trade-offs in labor, transportation, and crane time is essential for adoption. **Proposed Work:** Gather and document feedback from fabricators and erectors; define logistical implications and best practices for installation.

# 6 Wrap-Up and Final Recommendations

Phase 3 of the work is currently being discussed between AISC, SDI, and the Research Team. A formal proposal will be submitted to AISC in early 2025 and additional development of the system is anticipated.

# Appendix A

## Workshop Presentations

# FastFloor R

AISC-SDI Workshop

3 December 2024

<table>
<tr><th colspan="2">Tuesday, December 3</th></tr>
<tr><td>8:00 AM</td><td>Welcome and Group Breakfast</td></tr>
<tr><td>8:30AM</td><td>Overview of the system and discussion of workshop purpose and desired outcomes<br>1. Concept<br>2. Research to Date<br>3. Workshop Purpose</td></tr>
<tr><td>9:30 AM</td><td>Tour of lab facilities, review of tested specimens (as space available)</td></tr>
<tr><td>10:00 AM</td><td>Break</td></tr>
<tr><td>10:15 AM</td><td>10:15 – 10:30 - Presentation of case study using the system with group discussion and feedback<br>1. Archetype structure using system (show floor plans, typicals, renderings, etc.)<br>2. Highlight details where input from the group is needed and discuss as a group<br>a. Panel to structural framing connections (gravity and diaphragm)<br>b. Inter-module connections<br>c. Dry system assumption - challenges and opportunities<br>d. Fireproof assemblies<br>e. Architectural details at critical locations (spandrels, demising walls, etc.)<br>3. Assumed modularization philosophy for system<br>4. Pathways to implementation - merging of cold-formed and hot-rolled systems<br>Challenges to go from research/paper study to an actual built project</td></tr>
<tr><td>12:00 PM</td><td>Group Lunch</td></tr>
<tr><td>1:00 PM</td><td>Finalize and capture items from initial large group brainstorm</td></tr>
<tr><td>1:30 PM</td><td>Discussion of next steps and actions from participants<br>1. Discuss potential outputs from Workshop<br>2. Capture relevant actions to help advance the system<br>3. Potential projects that could use system<br>4. Other items</td></tr>
<tr><td>2:30 PM</td><td>Departure/Adjournment</td></tr>
</table>

# FastFloor R Team

**Research Team**

- Ben Schafer
- Shahab Torabian
- Cas Caswell (Phase 1)
- Sophia David (Phase 2)
- Fidence Rukundo (Phase 2)

**Sponsor Team**

- Thomas Sputo, SDI
- Devin Huber, AISC
- Caitlin Colsia, AISC

- Financial Sponsors
- In-Kind Donations

# FastFloor R – Introduction and Research to Date

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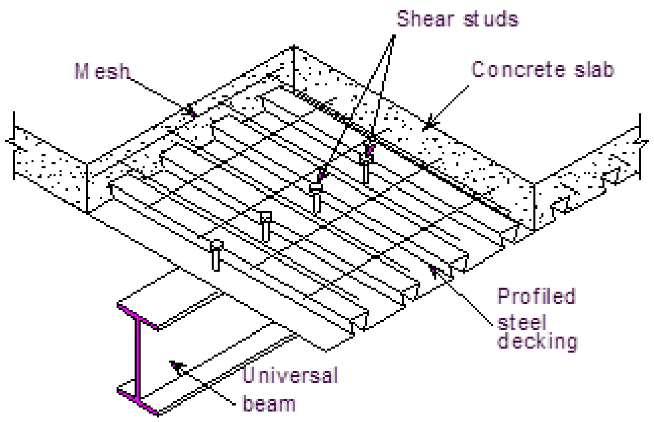
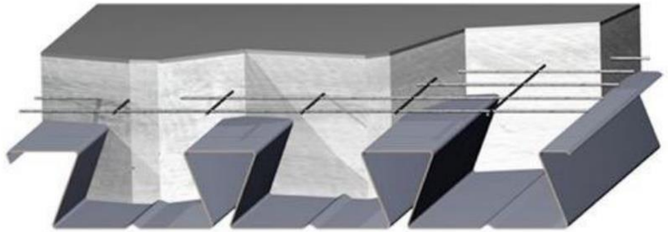
- Summary and transition to the lab (Ben)

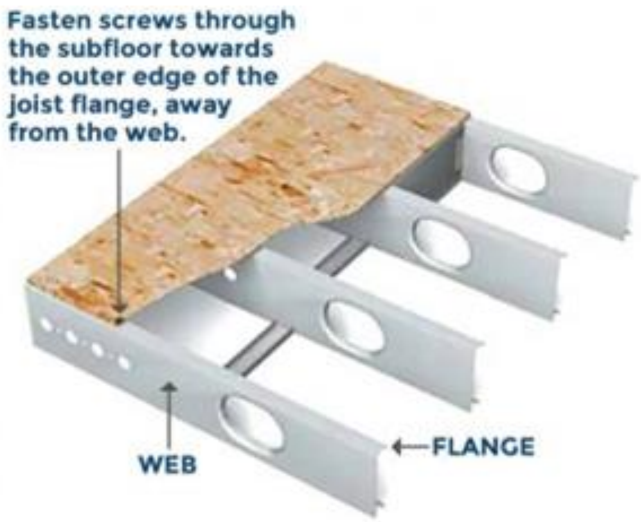
# Many steel floor systems exist, examples:



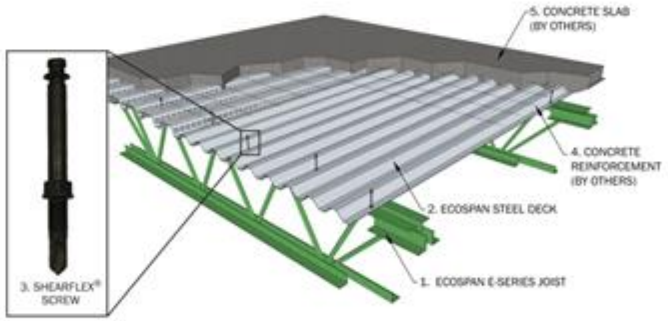

concrete-filled steel deck



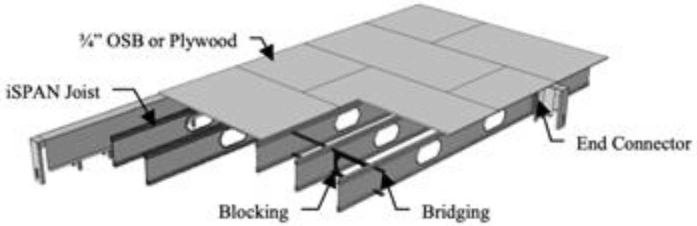
dovetail deck



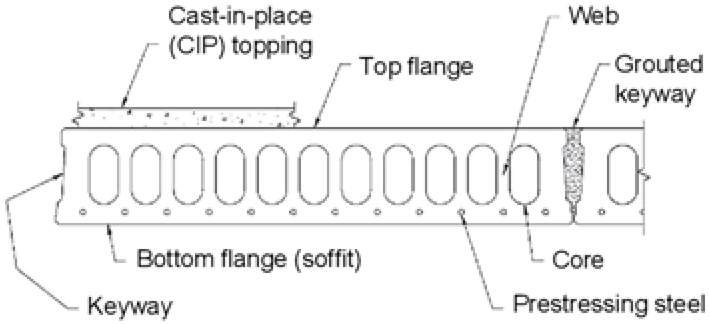

OSB on CFS joists or




Ecospan

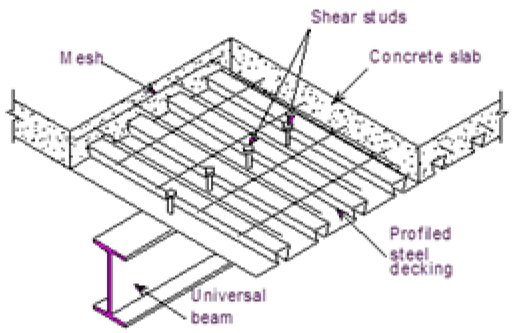


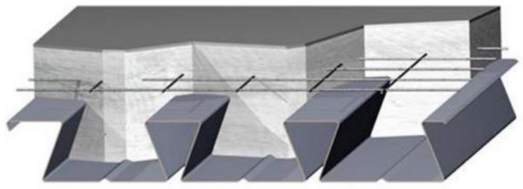

Ispan

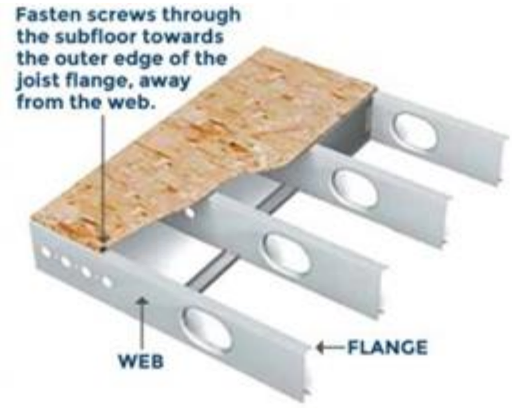


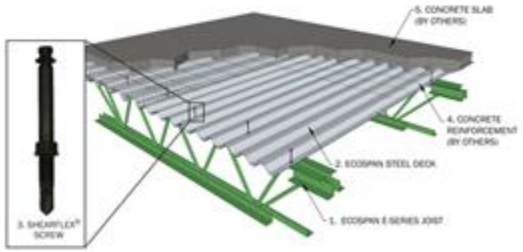

Hollowcore

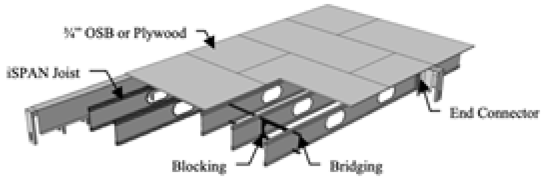
# Why new system(s)?

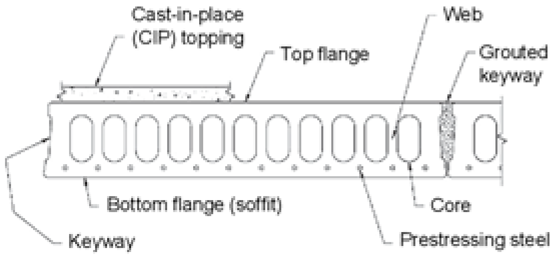





- All existing systems have a niche and many good features – they win in the market for specific positive reasons, but
- Composite concrete floor systems are relatively heavy, have high embodied carbon, and relatively slow to construct
- Systems on CFS or timber joists have short span lengths and a relatively high amount of steel per sq. ft., lots of parts
- Hollow core plank and precast concreate are fast, but heavy and high embodied carbon

# AISC Need for Speed – FastFloor Systems

- FastFloor R


- Non-proprietary, modular, dry
- Steel deck with cementitious panel attached to the top
- Short to intermediate span
- *R* for reliable, resilient, clearly applicable to residential

- FastFloor C

- Non-proprietary, modular, dry
- Steel beams and plate with raised access floor on top
- Intermediate to long span
- *C* for cost-effective clearly applicable to commercial

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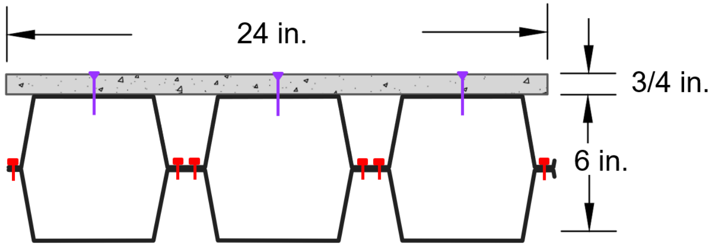
Discussion of objectives

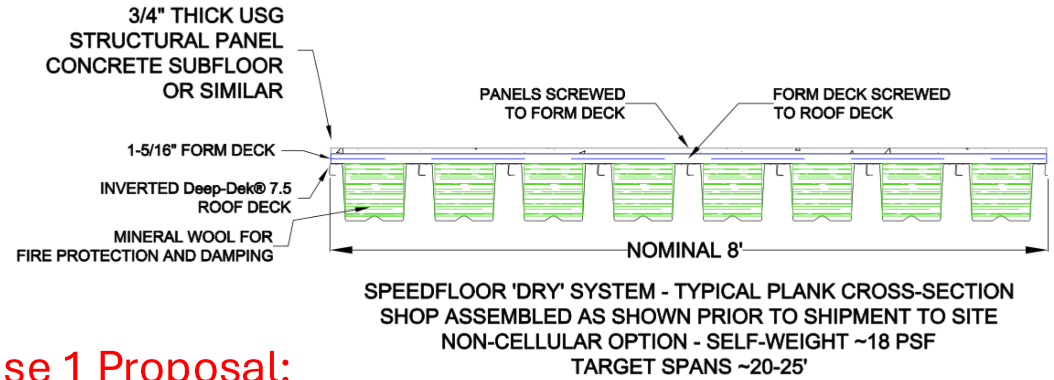
- Fast – need for speed
- Non-proprietary – ok to imagine proprietary derivatives in the future - but want any fab to be able to make
- Modular, want speed for construction, but variations possible as are module sizes
- Dry, with no wet concrete, for speed primarily, also helps with trades on the job
- Spans up to 16 or 18 ft targeted

# FastFloor R Concepts

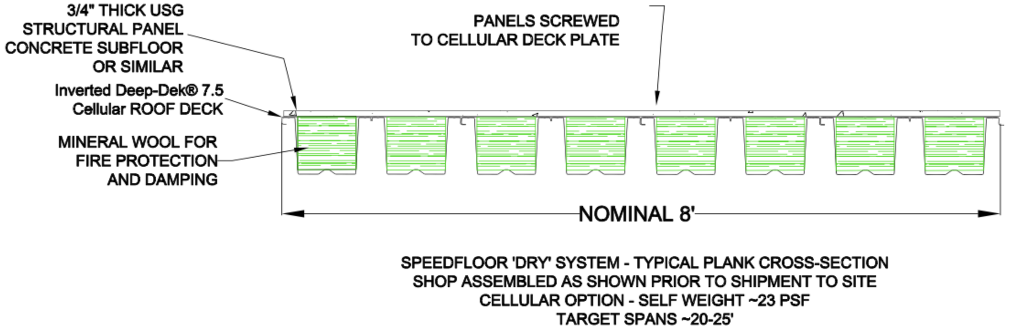
Phase 1 Testing:




Phase 1 Proposal:



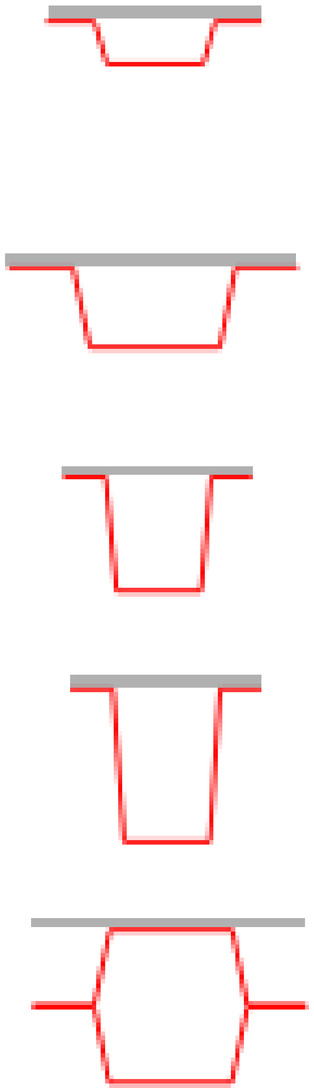

(a) option a (non-cellular)




(b) option b (cellular)

Fig. 1 AISC SpeedFloor Residential section – initial concepts (image credit: D. Huber, AISC)

Phase 2 Concepts:



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# Workshop Goals and Objectives

Gather industry expertise and potential end users together and **brainstorm on potential details** that could be implemented to allow wider adoption of this modular, lightweight, dry (no placement of concrete in the field), and faster-to-erect floor system that are compatible with structural steel framing. Now that basic prototyping and proof-of-concept are established AISC aims to use this workshop to help **bridge the gap between the research and implementation** of this innovation. AISC and the Research Team will also use this forum to help **identify any additional research needs** for the FastFloor *R* system so that they can be quickly addressed.

The desired outcomes of this workshop include both technical and strategic aspects, of particular interest are driving towards **actionable plans to implement** the proposed system in actual projects. Using an archetype building structure designed by AISC as a starting point, participants will be asked to provide their relevant expertise on aspects of the system that have not been fully worked through in the research to date. Some technical items to be discussed include connection details, modularization optimization (shop vs. field work), fireproofing options, and various architectural considerations. The other key component the workshop will focus on are the **pathways to implementation for the system** - including the challenges, opportunities, and needed actions to go from innovation to use in an actual project.

**Tangible deliverables** will be finalized and agreed upon at the Workshop through interaction with participants, but AISC notionally envisions multiple potential publications. These would include a Workshop Summary Document posted on AISC's website similar to other workshops AISC has held on SpeedCore and Adhesives. Other forms of dissemination could include white papers, design examples, and, potentially, a Design Guide.

# So you want to make a new floor? Ben's taxonomy

| PHYSICAL CREATION |
|---|
| Fabrication |
| Transportation |
| Erection |
| Construction Sequence |
| Deconstruction |

| STRUCTURAL |
|---|
| Gravity Perf. |
| Gravity Conn. |
| Diaphragm Perf. |
| Diaphragm Conn. |

| NON-STRUCTURAL |
|---|
| Deflection |
| Vibration |
| Acoustics |

| EXTREME |
|---|
| Seismic |
| Blast |
| Fire |

| KEY METRICS |
|---|
| Weight |
| Speed |
| Sustainability/LCA |
| First Cost |

| REGULATORY/EDUCATION |
|---|
| IP issues/plan |
| Codes/Standards |
| Design Examples |

| SYSTEMS |
|---|
| Bldg. Design Feasibility |
| Module Layout |
| Gravity sys. Integ. |
| Lateral sys. Integ. |
| Arch. sys. Integ. |
| System Performance |

| ELEGANCE and FUNCTION |
|---|
| Architecture |
| MEP Services |

| PILOT EXAMPLES |
|---|
| Building Projects |

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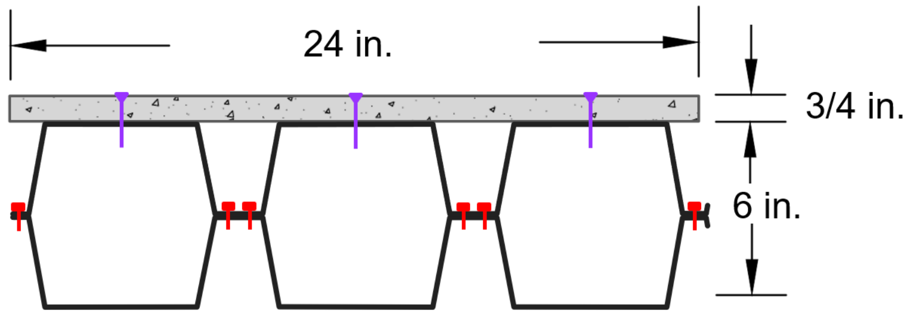
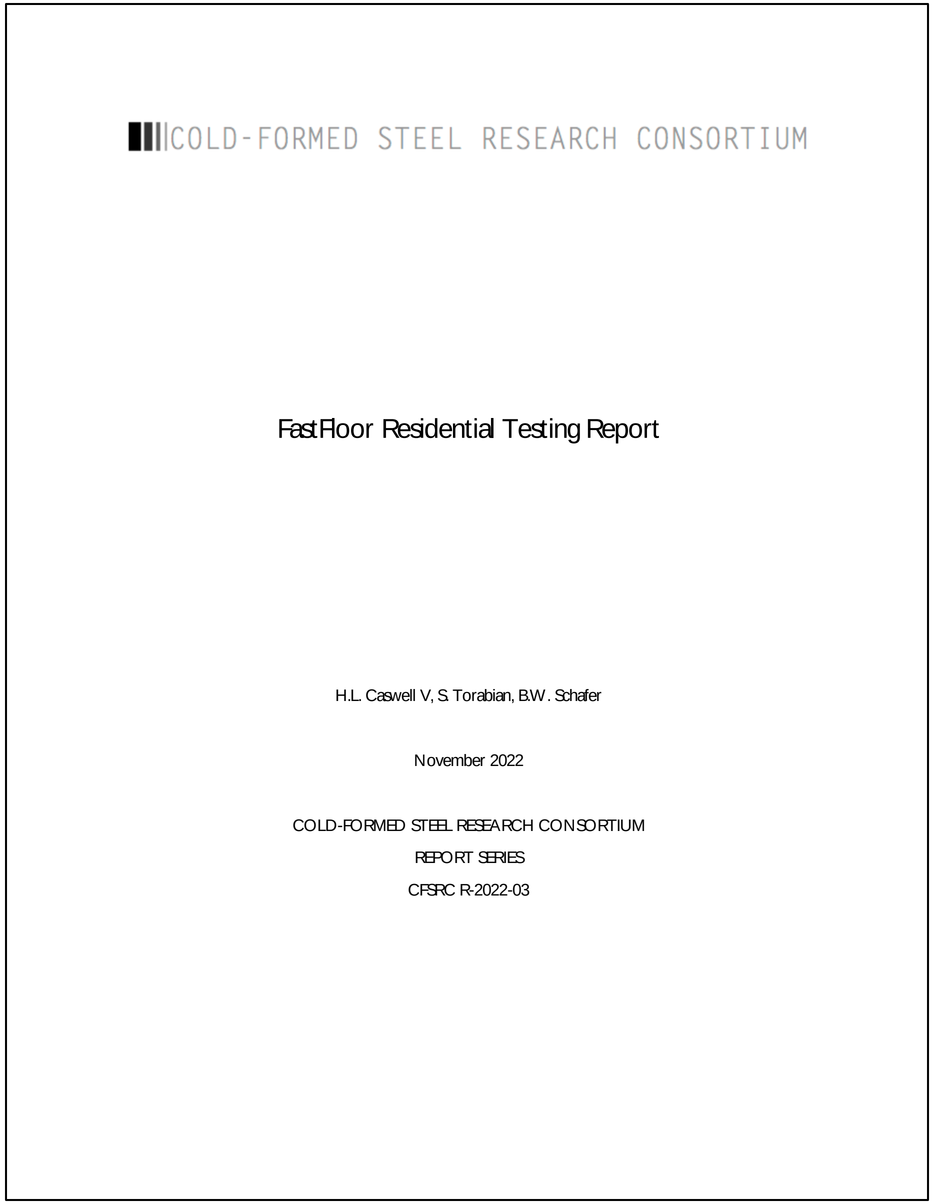
# Phase 1 - Prototype and Flexural Tests





COLD-FORMED STEEL RESEARCH CONSORTIUM

FastFloor Residential Testing Report

H.L. Caswell V, S. Torabian, B.W. Schafer

November 2022

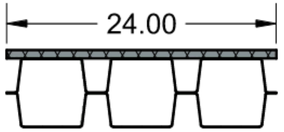
COLD-FORMED STEEL RESEARCH CONSORTIUM
REPORT SERIES
CFSRC R-2022-03

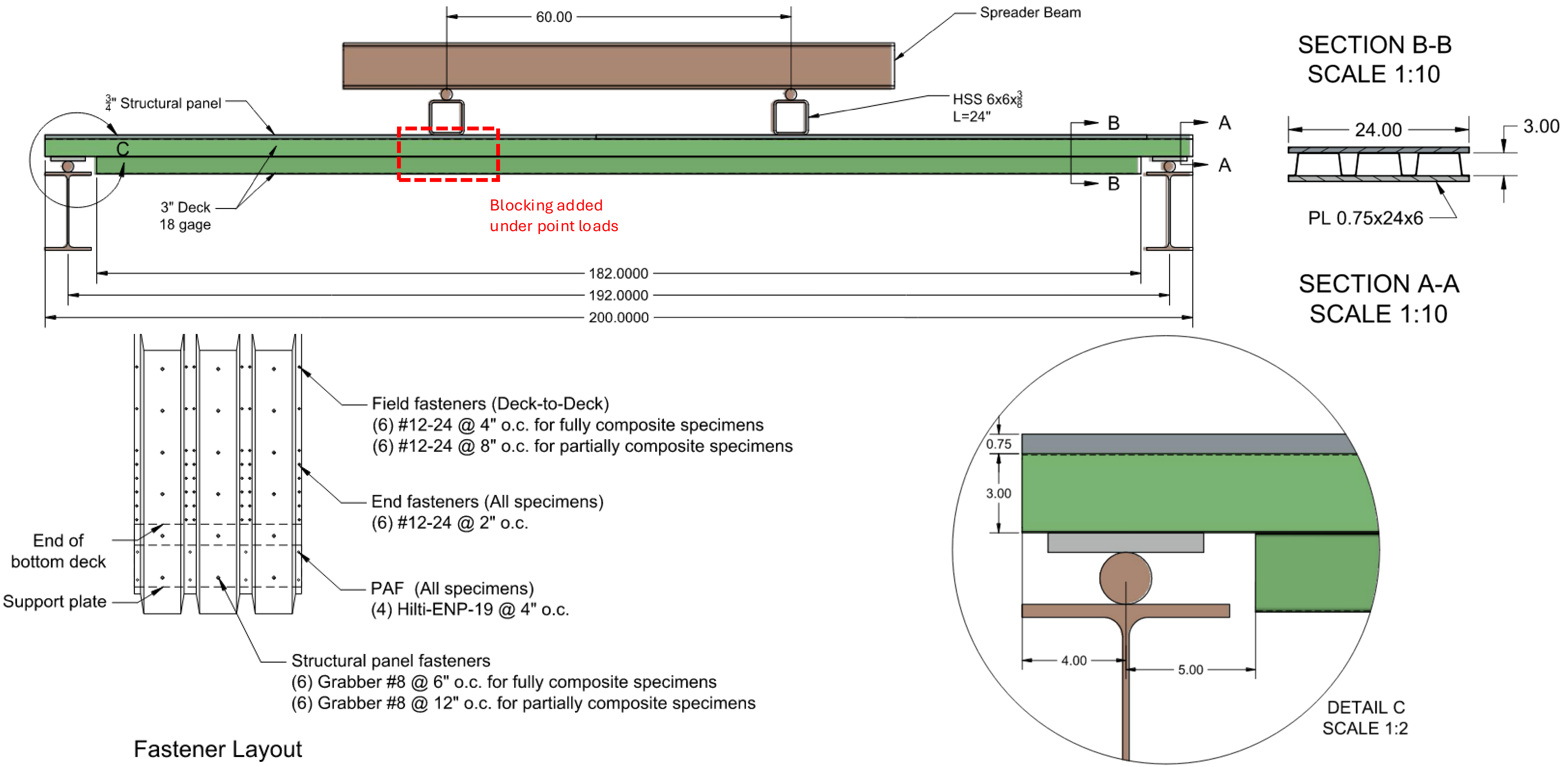
# Test matrix

| | Specimen | span | Top deck | Bottom deck | Middle span | Steel deck | Thickness | Structural panel thickness [1] | Steel-to-steel fasteners | Panel-to-steel fasteners spacing |
|---|---|---|---|---|---|---|---|---|---|---|
| | - | ft | ft | ft | ft | in/type | in | in | | in |
| Main testing program | 1 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | - | Fully-Composite | - |
| | 2 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | - | Fully-Composite | - |
| | 3 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | 0.75 | Fully-Composite | 6 |
| | 4 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | 0.75 | Fully-Composite | 6 |
| | 5 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | 0.75 | Fully-Composite | 12 |
| | 6 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | 0.75 | Fully-Composite | 12 |
| Additional Specimens | 7 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | - | Partially-Composite | - |
| | 8 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | - | Partially-Composite | - |
| | 9 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | 0.75 | Partially-Composite | 6 |
| | 10 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | 0.75 | Partially-Composite | 6 |
| | 11 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | 0.75 | Partially-Composite | 12 |
| | 12 | 16 | 16.67 | 15.27 | 5 | 3" Nestable - 24" wide | 0.0478 | 0.75 | Partially-Composite | 12 |

1 #12-24 @ 4" o.c. for fully composite specimens
#12-24 @ 8" o.c. for partially composite specimens

# JHU 4-Point Bending Test (16 ft span)




SPECIMEN FABRICATION

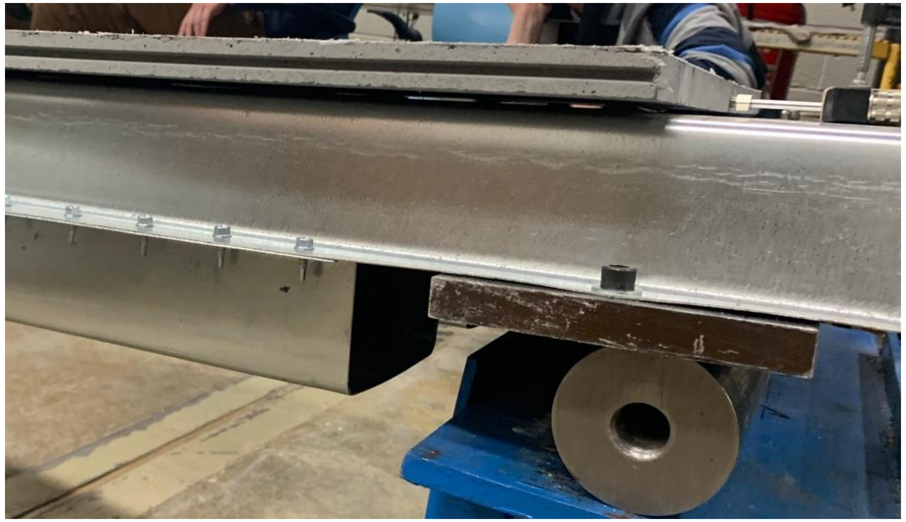
Deck only (#12 @ 8” o.c.)


Deck (#12 @ 8” o.c.) Panel (#8 @ 12” o.c.)

# Post-peak fastener failure

**Deck (#12@4” o.c.) Panel (#8@6”o.c.)**

Screw tilt and fracture

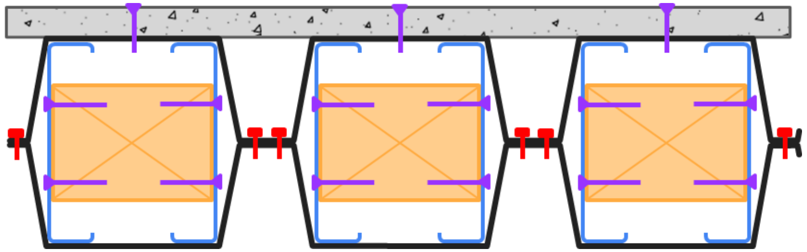


Panel uplift

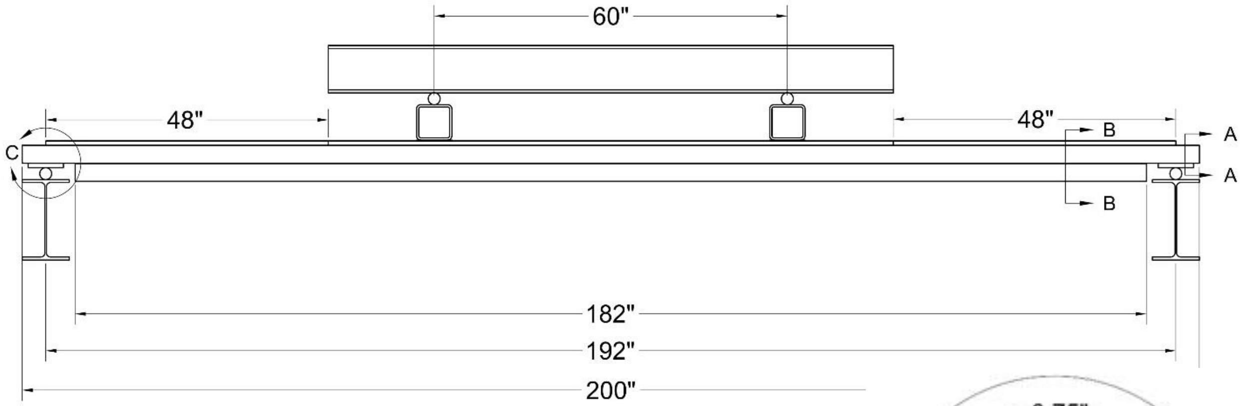
Screw tilt and fracture

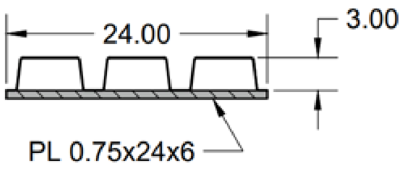
# Details to note

## Bearing stiffeners

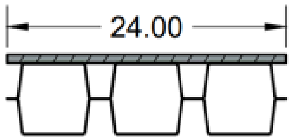


## On girder, ideal simply supported end conditions

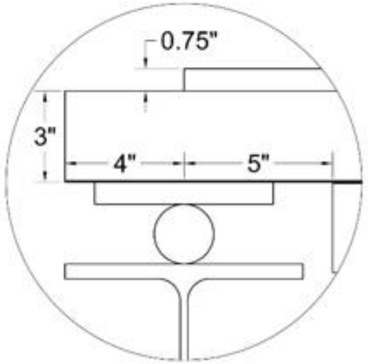



Section A-A

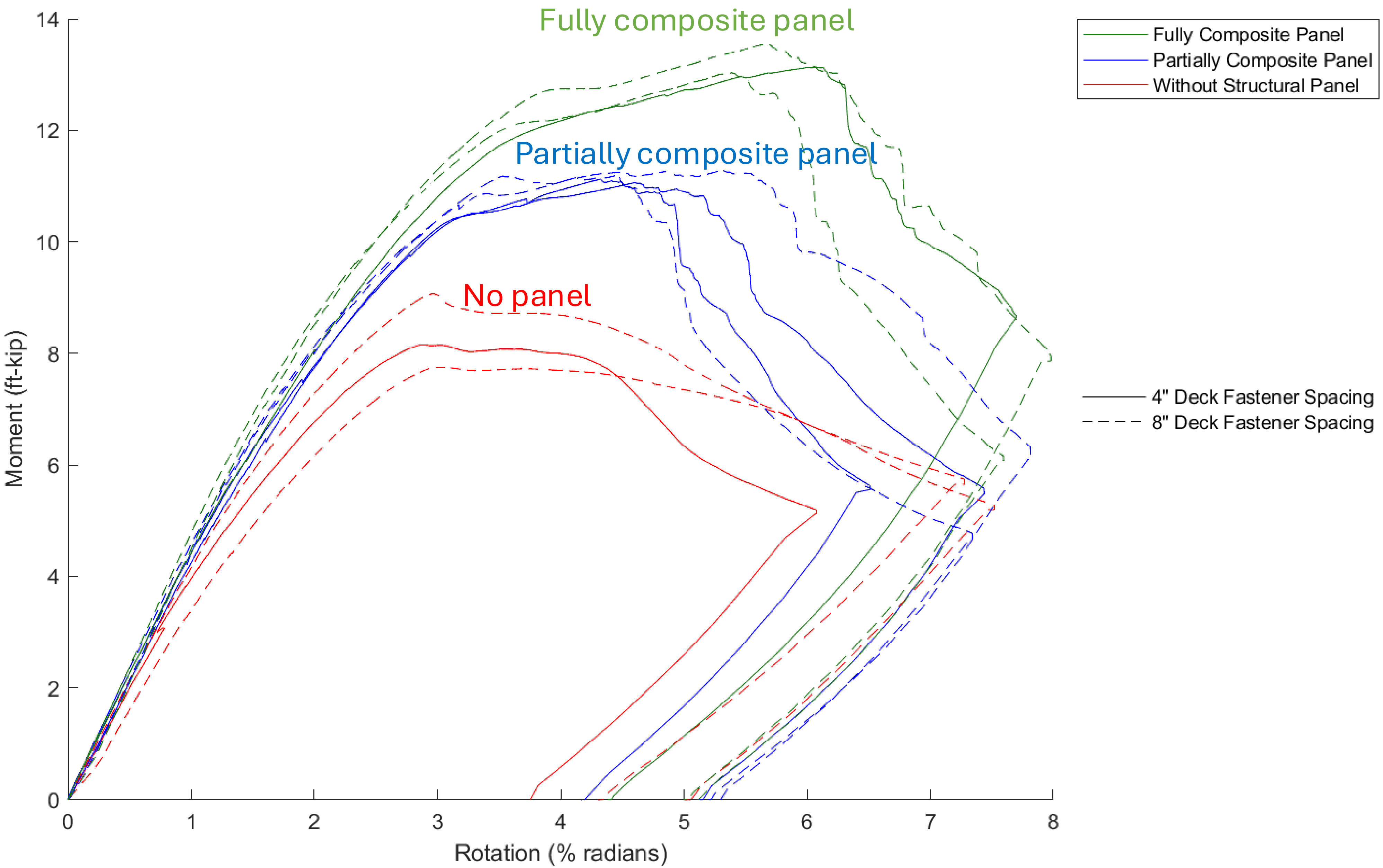



Section B-B




Detail C

# Observed moment-rotation



# Numerical Results for Strength and Stiffness

Strength

| Specimen Name | Load, $P_{ult}$ (kip) | Moment, $M_{ult}$ (kip-ft) | Avg. $M_{ult}$, $M_{ult,avg}$ (kip-ft) | $M/M_{bare}$ | $M/M_y$* |
|---|---|---|---|---|---|
| FC[1] Bare Deck | 6.13<br>5.93 | 8.43<br>8.16 | 8.30 | 1.00 | 0.28 |
| FC Deck + PC[2] Panel | 8.05<br>8.09 | 11.06<br>11.13 | 11.10 | 1.34 | 0.33 |
| FC Deck + FC Panel | 9.82<br>9.56 | 13.50<br>13.14 | 13.32 | 1.60 | 0.40 |
| PC Bare Deck | 5.64<br>6.59 | 7.75<br>9.06 | 8.41 | 1.00 | 0.28 |
| PC Deck + PC Panel | 8.14<br>8.21 | 11.19<br>11.29 | 11.24 | 1.34 | 0.34 |
| PC Deck + FC Panel | 9.48<br>9.85 | 13.03<br>13.54 | 13.29 | 1.58 | 0.40 |

Stiffness

| Specimen Name | Analytical EI - Fully Composite ($10^5 \times$ kip-in$^2$) | Experimental EI - at 40% $P_{max}$ ($10^5 \times$ kip-in$^2$) | Ratio of Analytical EI |
|---|---|---|---|
| FC[1] Bare Deck | 5.47 | --<br>5.25 | --<br>0.96 |
| FC Deck + PC[2] Panel | 6.84 | 5.70<br>5.45 | 0.83<br>0.80 |
| FC Deck + FC Panel | 6.84 | --<br>5.52 | --<br>0.81 |
| PC Bare Deck | 5.47 | 4.46<br>5.36 | 0.82<br>0.98 |
| PC Deck + PC Panel | 6.84 | 5.85<br>5.67 | 0.86<br>0.83 |
| PC Deck + FC Panel | 6.84 | 6.06<br>5.78 | 0.89<br>0.84 |

# Phase 1 findings

- Constructible – possible
- Favorable flexural failure modes, benign response, beneficial neutral axis shift with panel added on compression flange
- Non-composite, partially-composite, fully-composite all available depending on deck-to-deck and panel-to-deck fastener spacing
- Predictable stiffness and high percentage of analytical stiffness available at service moment levels
- Benchmark for design methods and supports development of span tables – more on that later!

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  - Phase 2 Prototypes - Vibration and Flexural Results (Sophia)
- Component Testing
  - "Push-out tests" - board-fastener-deck shear testing (Fidence)
  - $f_c'$ tests - board edge compression testing (Sophia)
- Design Approaches and Preliminary Span Tables (Shahab)
- Summary and transition to the lab (Ben)

# Summary and transition to lab

- Summary
  - A “deck+panel” based floor (roof) system seems more than possible
  - Engineering of such a system is possible and initially proofed out
  - Consistent with workshop objectives plenty of details remain
  - Recall Ben’s taxonomy of areas for creating a new floor
  - Non-proprietary construction innovation is an unusual space thanks for joining us today and thinking hard on this – its not easy!
- Lab notes
  - Safety
  - Huge array of lighter steel tests conducted in the past, happy to tell more
  - 2x3 in. deck partial specimen provided, happy to talk about it
  - 6 in. deck with Structocrete installed/testing is currently ongoing
  - We will perform some simple acceleration measurements live

# FastFloor R Motivation

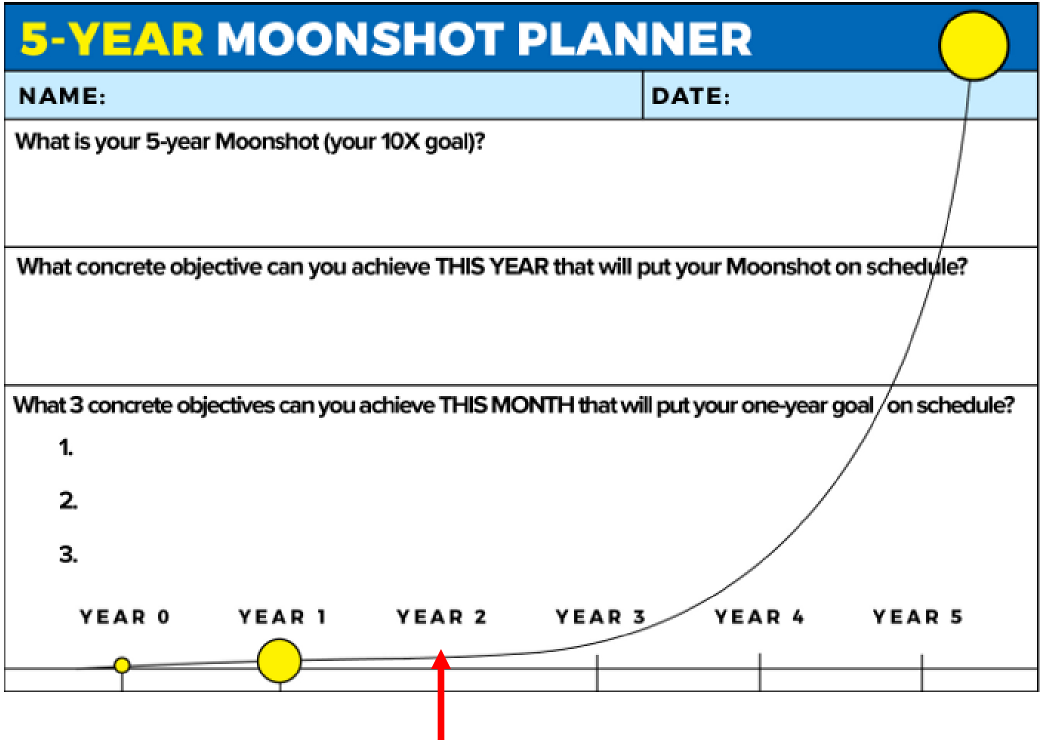
## Speed through Innovation

Devin Huber | Director of Research | AISC

Smarter.
Stronger.
Steel.

# Big Hairy Audacious Goal / Moonshot


**BHAG**


5-YEAR MOONSHOT PLANNER

NAME: DATE:

What is your 5-year Moonshot (your 10X goal)?

What concrete objective can you achieve THIS YEAR that will put your Moonshot on schedule?

What 3 concrete objectives can you achieve THIS MONTH that will put your one-year goal on schedule?

1.

2.

3.

YEAR 0 YEAR 1 YEAR 2 YEAR 3 YEAR 4 YEAR 5

NEED
FOR
SPEED

NEED FOR SPEED

# Goal

Increase the speed at which a steel project (building or bridge) can be designed, fabricated, and erected by 50% by the end of 2025


# Why Focus on Speed?

- **The material selection is often based on the time to completion**
- **Increasing speed drives innovation and industry advancements**
- **Faster construction has downstream impacts**
  - Owners can occupy earlier
  - Reduced time on site
  - Efficiency with other trades
  - More projects completed annually

# Need for Speed – Overview

**How?**

- **Focused projects aimed at speeding up steel design, fabrication, and erection**
- **Collaborating with our industry partners to identify what they are doing now related to speed (Need for Speed Now)**

**<u>Genius Panel</u>**
Mills
Designers
Fabricators
Erectors

# Need for Speed – Overview

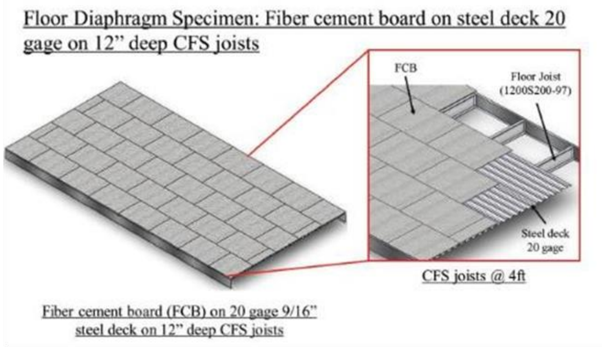
## Why Speed?

- **Historical and emerging market trends point to speed (in both design and construction) being a primary driver for what structural material is utilized**
- **Increasing speed drives innovation and advancements in industry**
- **Faster structures have downstream impacts**
  - Faster design and construction allowing owners to get a better return on investment (ROI)
  - Reduced time on site leading to project savings
  - Faster projects lead to more projects being done

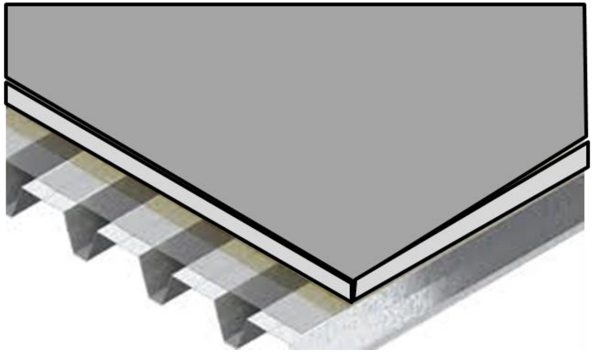

# Multi-Story Residential Modular Floor System

**General Concept**

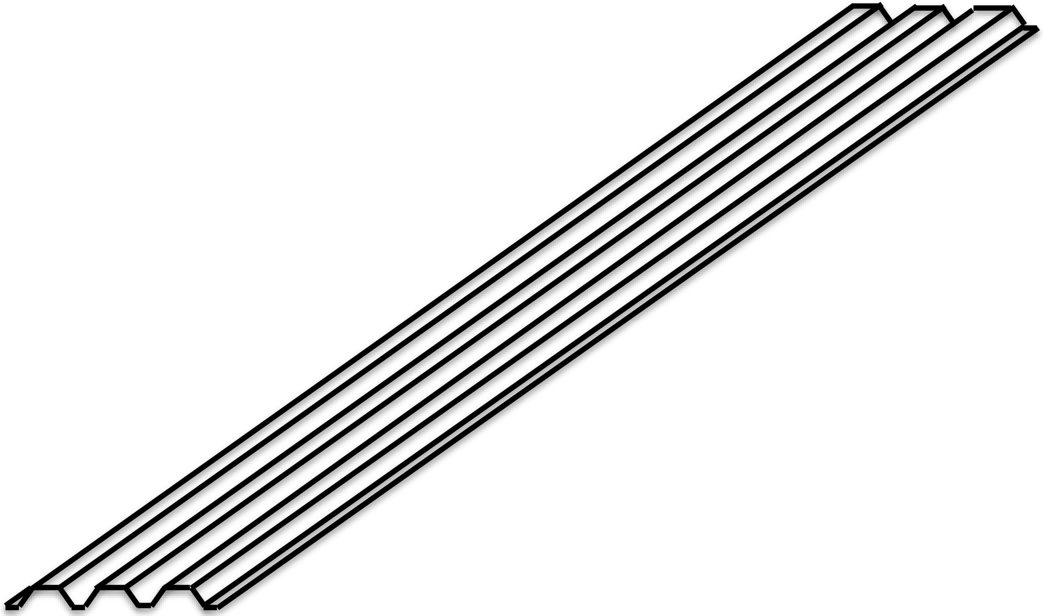
- We are borrowing a bit from our cold-formed steel friends…
- Use existing metal deck products in conjunction with factory-made cement board panels for walking surface
  - Target spans of 20’-25’
  - Intended use in multi-story residential
  - System pre-fabricated in 8’-10’ modules and shipped to site for erection

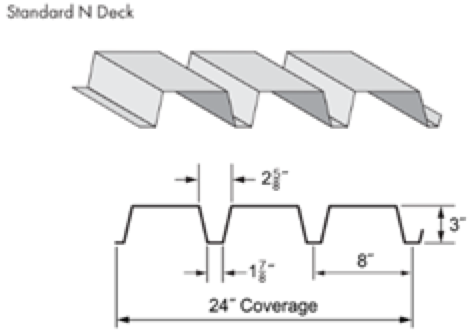



Cold Formed Steel Floor System (Peterman)



# FastFloor R – Original Concept

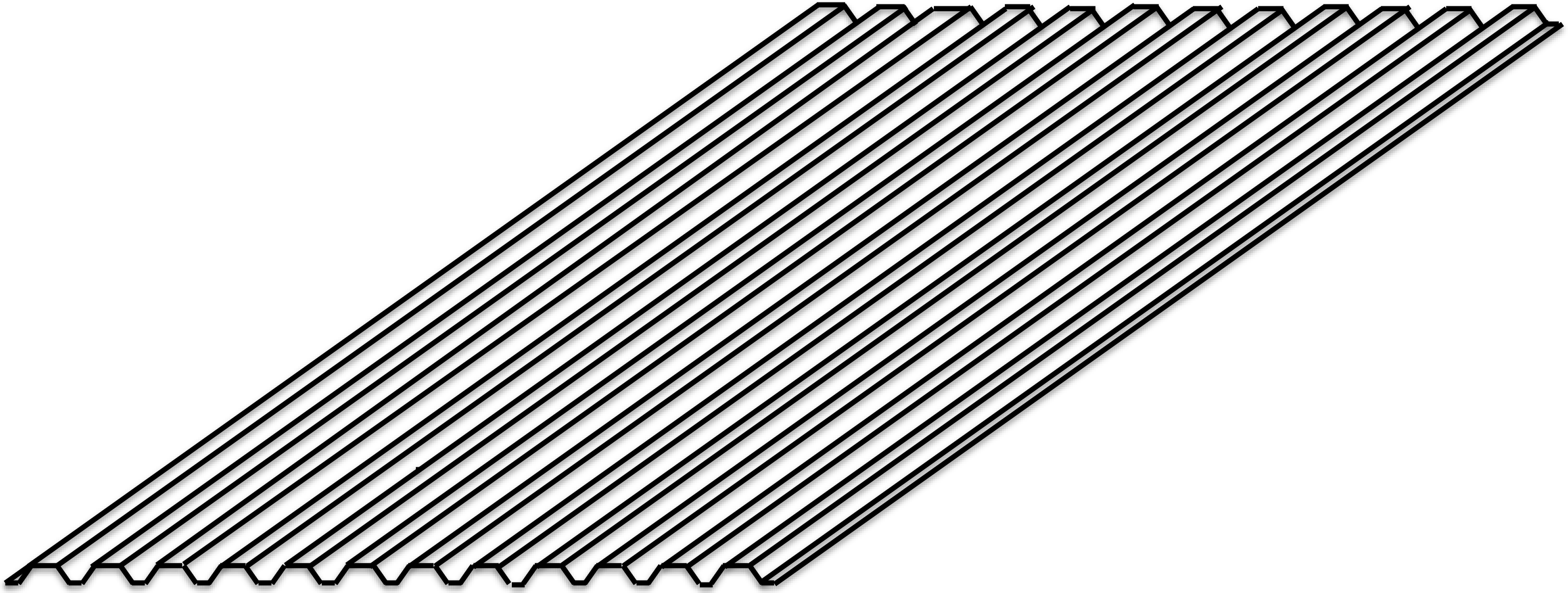





Shop Fabrication Process

1) Light gage metal deck profiles ~20'-25' long attached together to make 8'-10' wide geometries

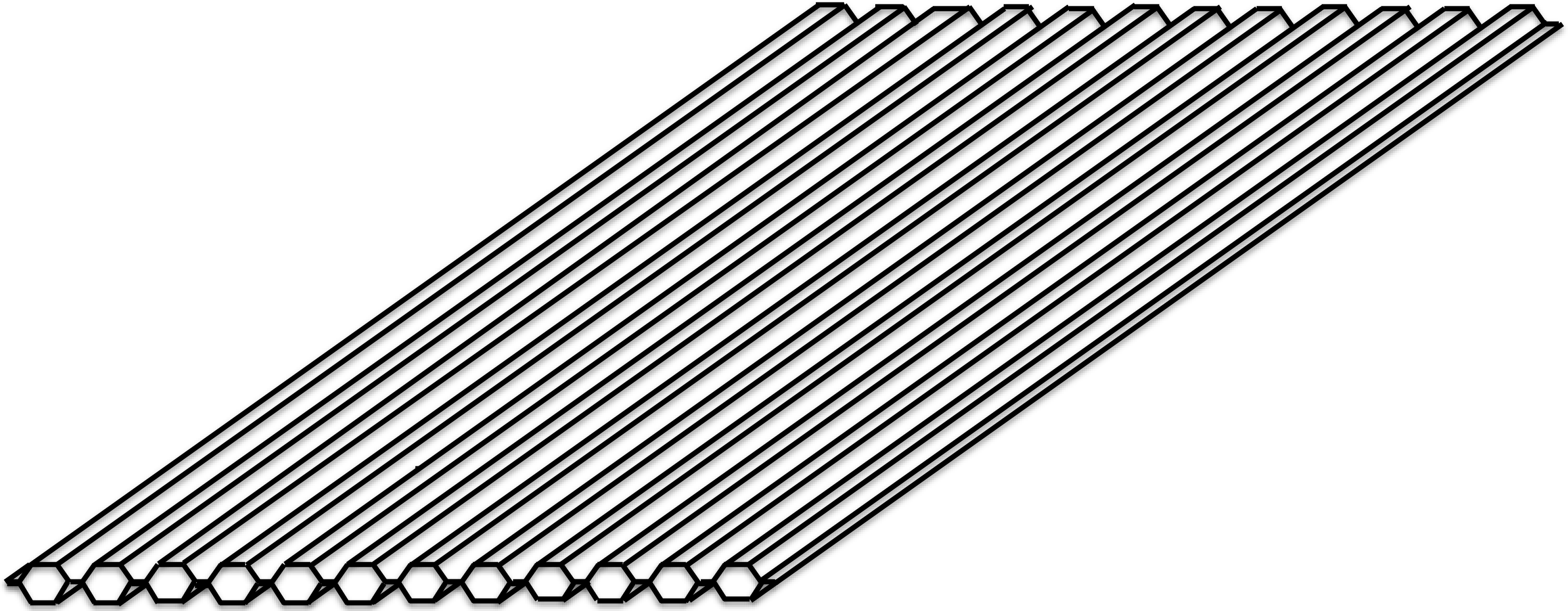
# FastFloor R – Original Concept



Shop Fabrication Process

2) Light gage metal deck profiles ~20-25’ long attached together to make 8’-10’ wide geometries

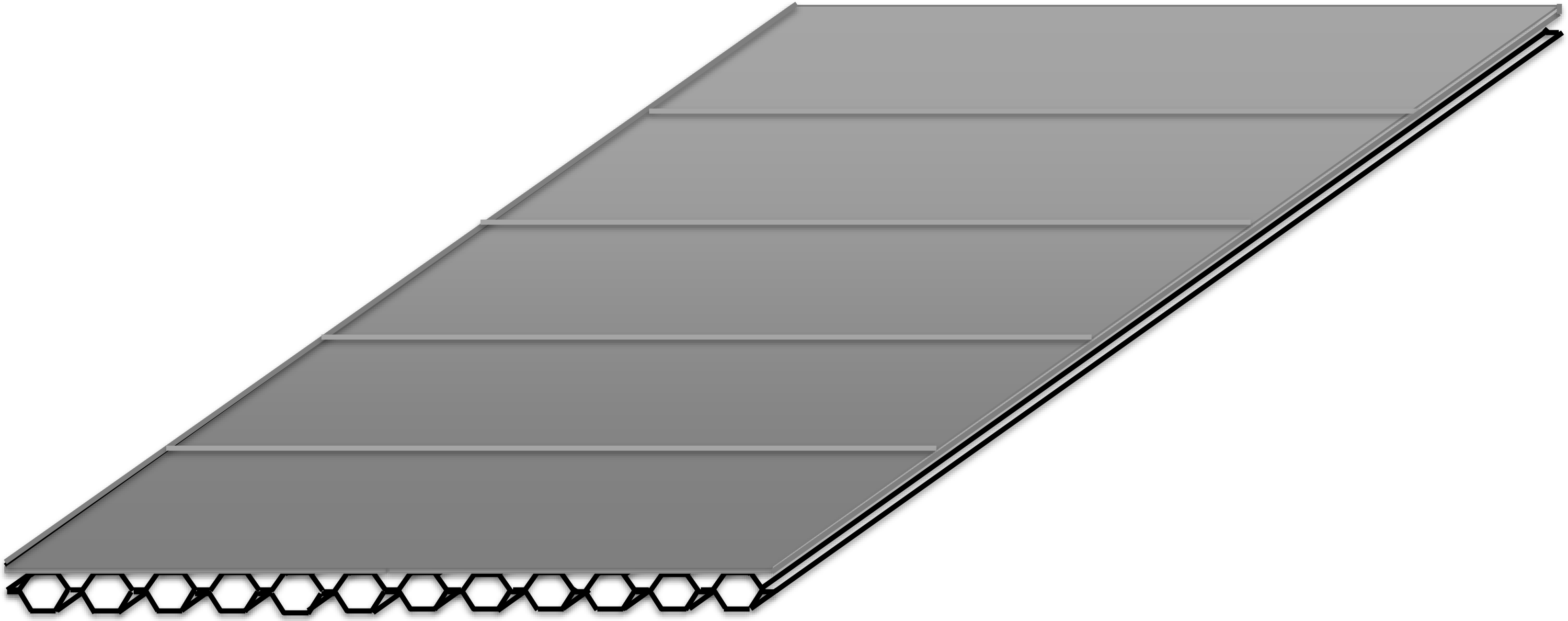
# FastFloor R – Original Concept



Shop Fabrication Process

3) Second 8'-10' wide panel assembled, inverted, and attached underneath first panel

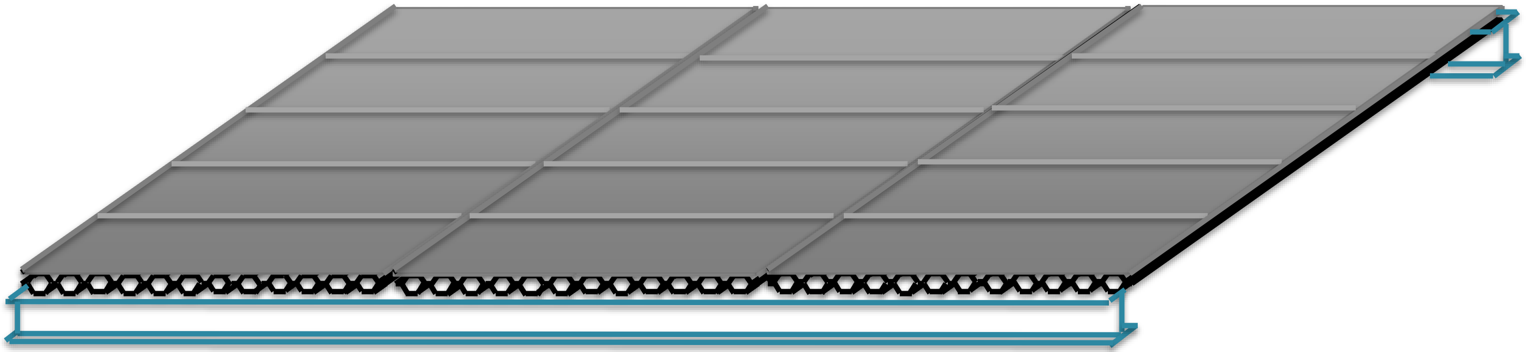
# FastFloor R – Original Concept



Shop Fabrication Process

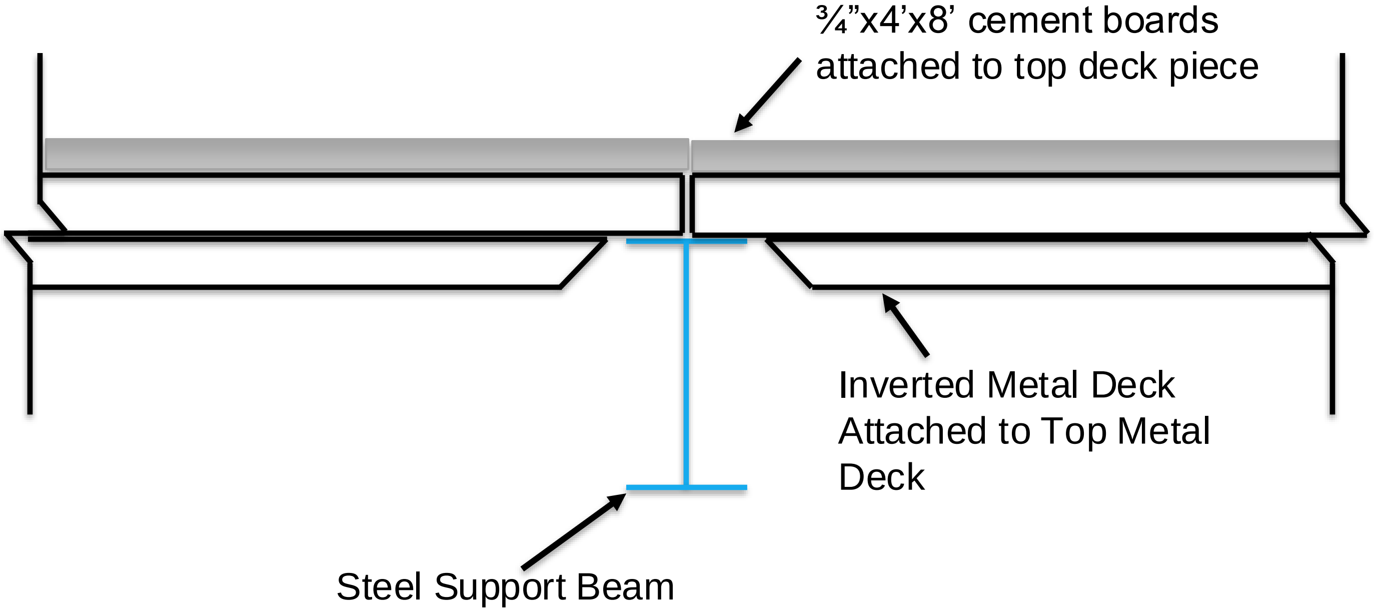
4) ¾"x4'x8' fiber cement boards attached to top deck piece
5) Completed modules shipped to site

# FastFloor R – Original Concept



# FastFloor R – Original Concept

## Potential Detail




AMERICAN INSTITUTE OF STEEL CONSTRUCTION
AISC
FOUNDED 1921
Smarter.
Stronger.
Steel.

# FastFloor R – Phase 2

AISC-SDI Workshop

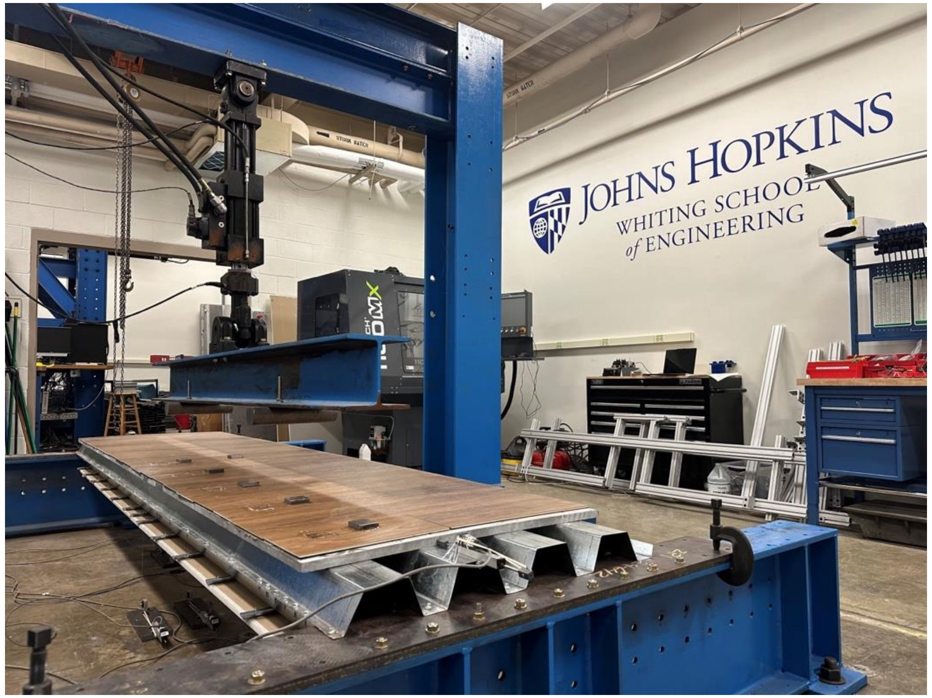
3 December 2024

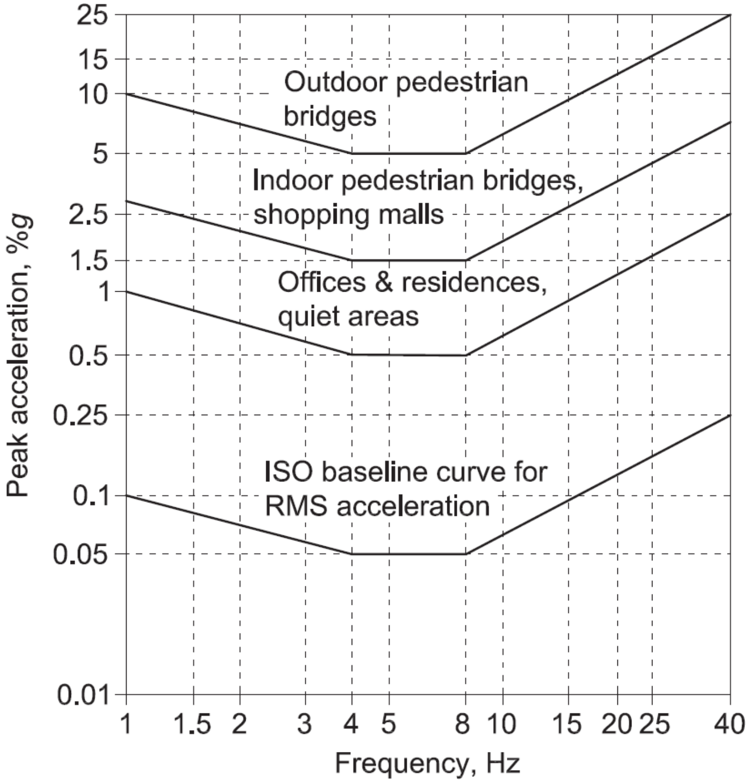
# Outline

- Introduction & Motivation
- Test Matrix
- 2x3 Assembly Process
- 2x3 Flexural Results
- 6” Deep Deck Assembly Process
- 6” Deep Deck Flexural Results to Date
- Vibration Tests
- Vibration Results in Progress

# Introduction & Motivation

- Lightweight, fast to construct, and nonproprietary floor system
- 18-gauge steel deck topped with cementitious panel
- Structural and vibration tests



# Phase 2

# Test Matrix – Phase 2

| Test | | Specimen Type | Deck Type | Structural panel | Strcutural panel to deck connectors | Nominal Span ft | Actual Span ft | Width in | Testing protocol | End connection | Ceiling and floor assembly |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SG - 2x3 | 1 | Baseline bare specimen on Girder | 2x 3" PLN24 | | | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 2 | Composite specimen on girder | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 3 | Composite specimen on girder with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| SA - 2x3 | 1 | Baseline bare specimen on Angle | 2x 3" PLN24 | | | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| SA - 6 | 1 | Baseline bare specimen on Angle | 6" Deep-Dek | | | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests - Composite deck-3 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 7 | Strength Tests | 6" Deep-Dek | | | 12 | 11.125 | 24 | 4-point bending | Seat on Angle | No |

# Test Matrix – Phase 2

| Test | | Specimen Type | Deck Type | Structural panel | Strcutural panel to deck connectors | Nominal Span ft | Actual Span ft | Width in | Testing protocol | End connection | Ceiling and floor assembly |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SG - 2x3 | 1 | Baseline bare specimen on Girder | 2x 3" PLN24 | | | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
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| | 3 | Composite specimen on girder with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| SA - 2x3 | 1 | Baseline bare specimen on Angle | 2x 3" PLN24 | | | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| SA - 6 | 1 | Baseline bare specimen on Angle | 6" Deep-Dek | | | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
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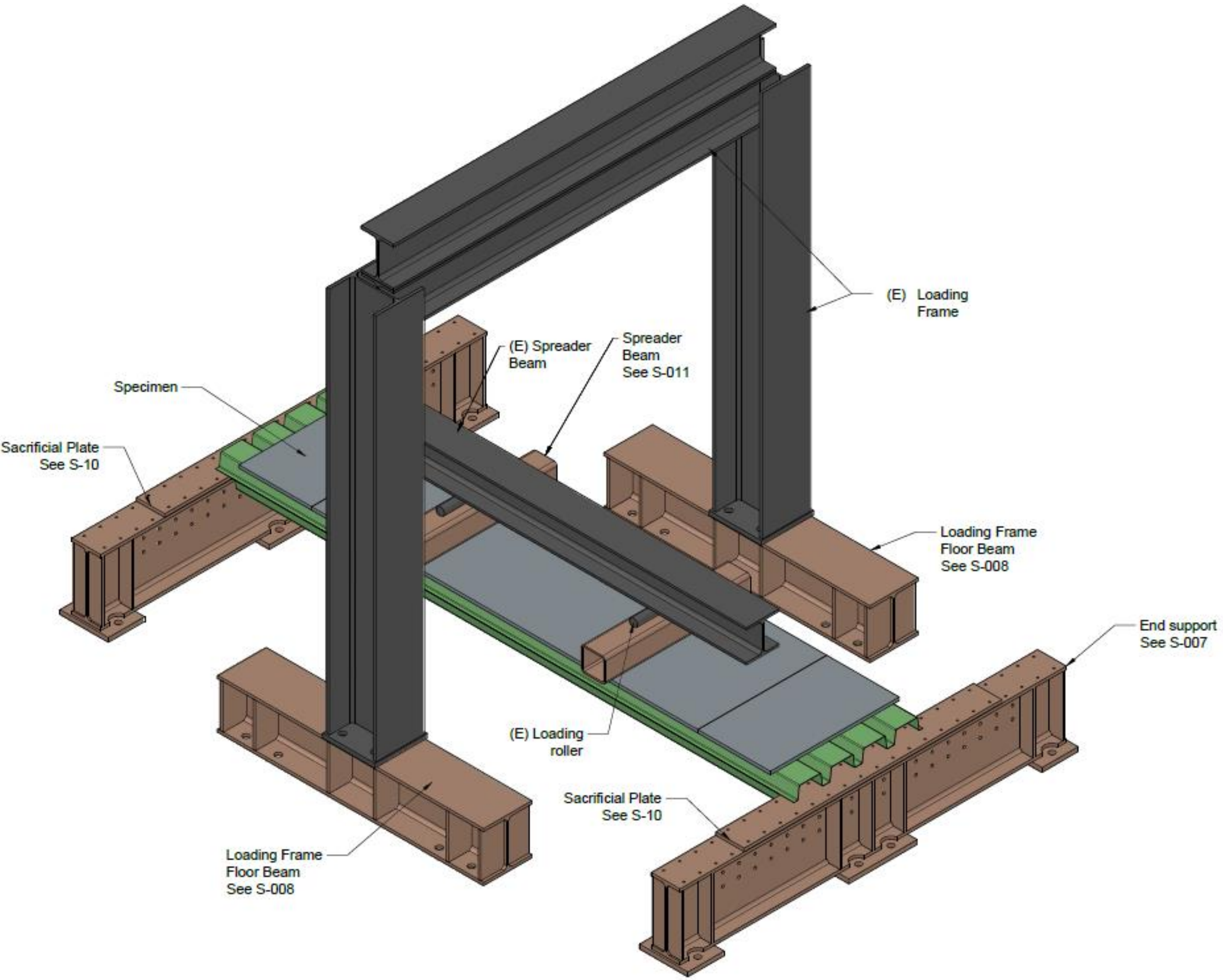
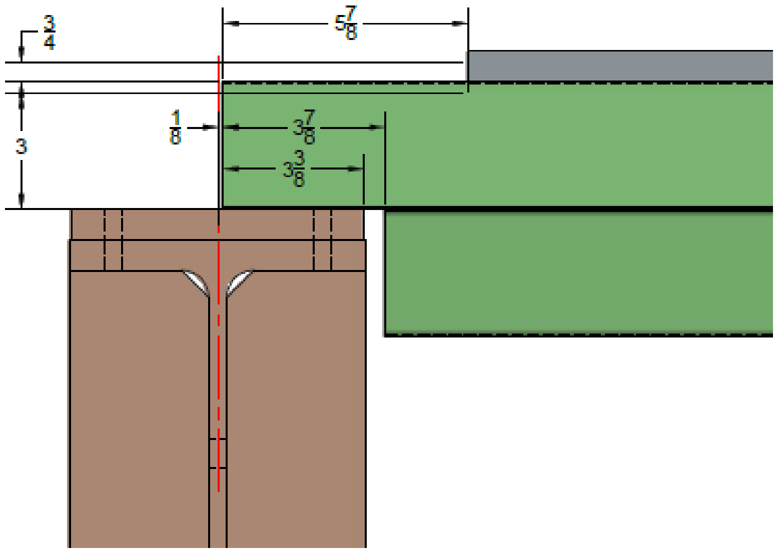
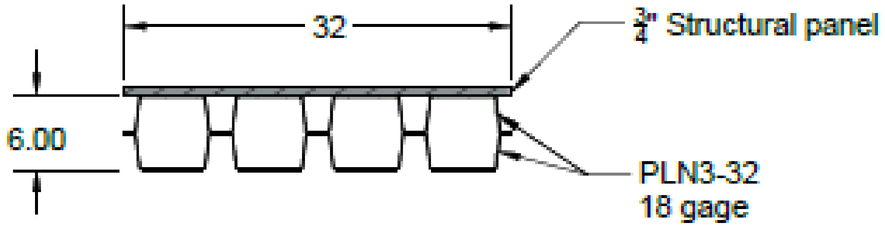
| | 4 | Strength Tests - Composite deck-1 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests - Composite deck-3 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 7 | Strength Tests | 6" Deep-Dek | | | 12 | 11.125 | 24 | 4-point bending | Seat on Angle | No |

# Test Matrix - Phase 2 – 2x3 SG



# Test Matrix – Phase 2

| Test | | Specimen Type | Deck Type | Structural panel | Strcutural panel to deck connectors | Nominal Span ft | Actual Span ft | Width in | Testing protocol | End connection | Ceiling and floor assembly |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SG - 2x3 | 1 | Baseline bare specimen on Girder | 2x 3" PLN24 | | | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 2 | Composite specimen on girder | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 3 | Composite specimen on girder with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| SA - 2x3 | 1 | Baseline bare specimen on Angle | 2x 3" PLN24 | | | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| SA - 6 | 1 | Baseline bare specimen on Angle | 6" Deep-Dek | | | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
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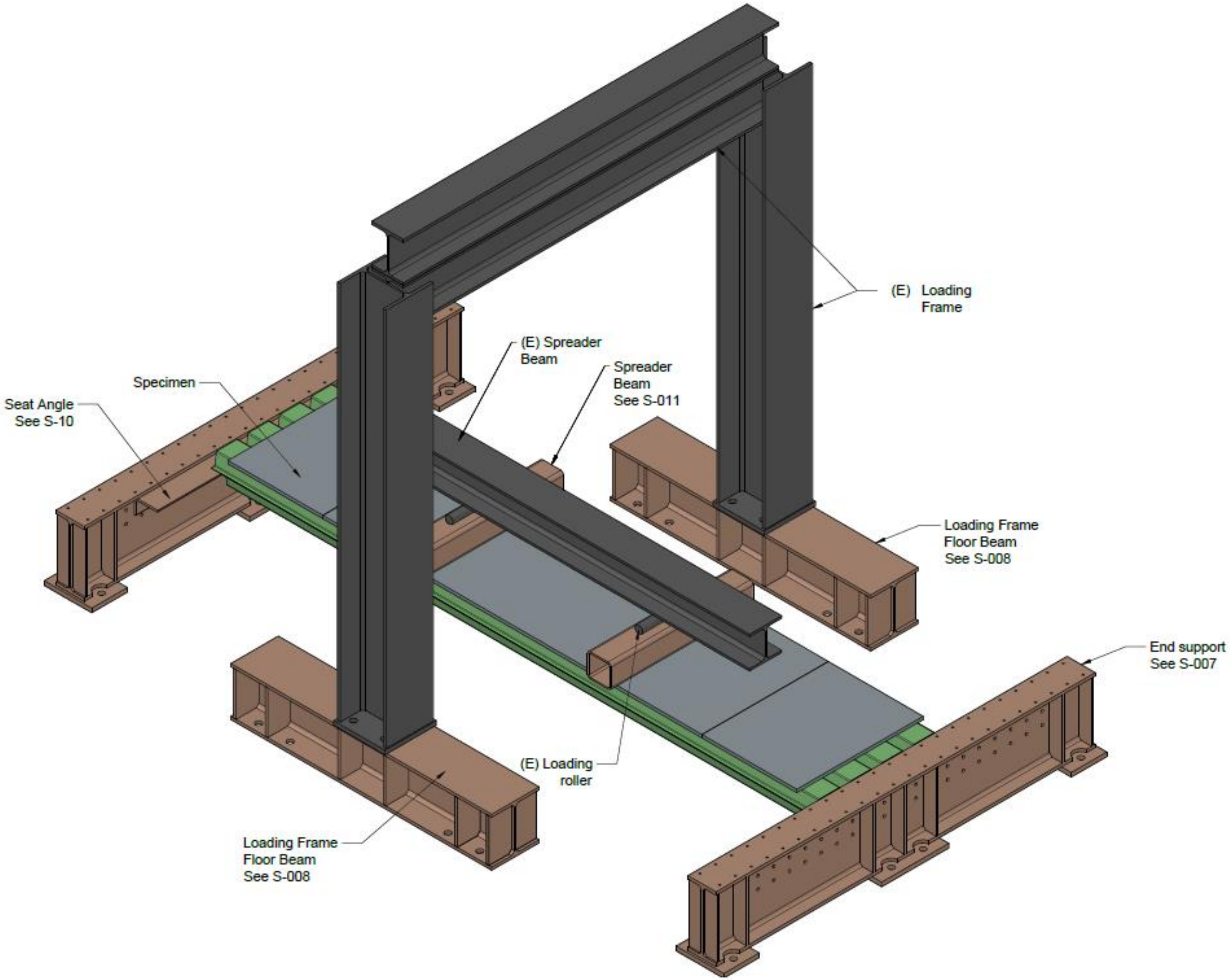
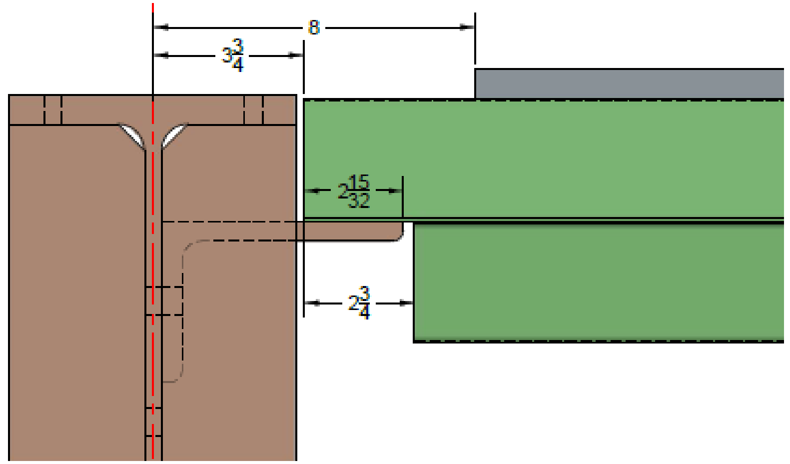
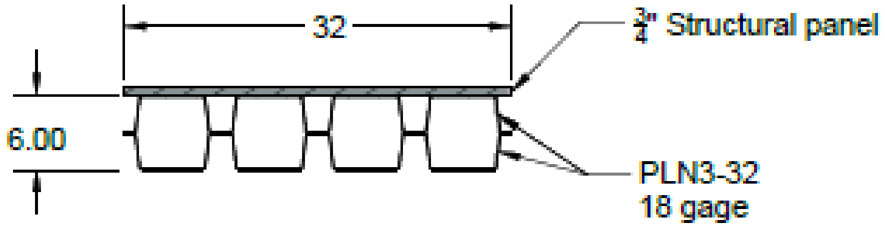
| | 5 | Strength Tests - Composite deck-2 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests - Composite deck-3 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 7 | Strength Tests | 6" Deep-Dek | | | 12 | 11.125 | 24 | 4-point bending | Seat on Angle | No |

# Test Matrix - Phase 2 – 2x3 SA



# Test Matrix – Phase 2

| Test | | Specimen Type | Deck Type | Structural panel | Strcutural panel to deck connectors | Nominal Span ft | Actual Span ft | Width in | Testing protocol | End connection | Ceiling and floor assembly |
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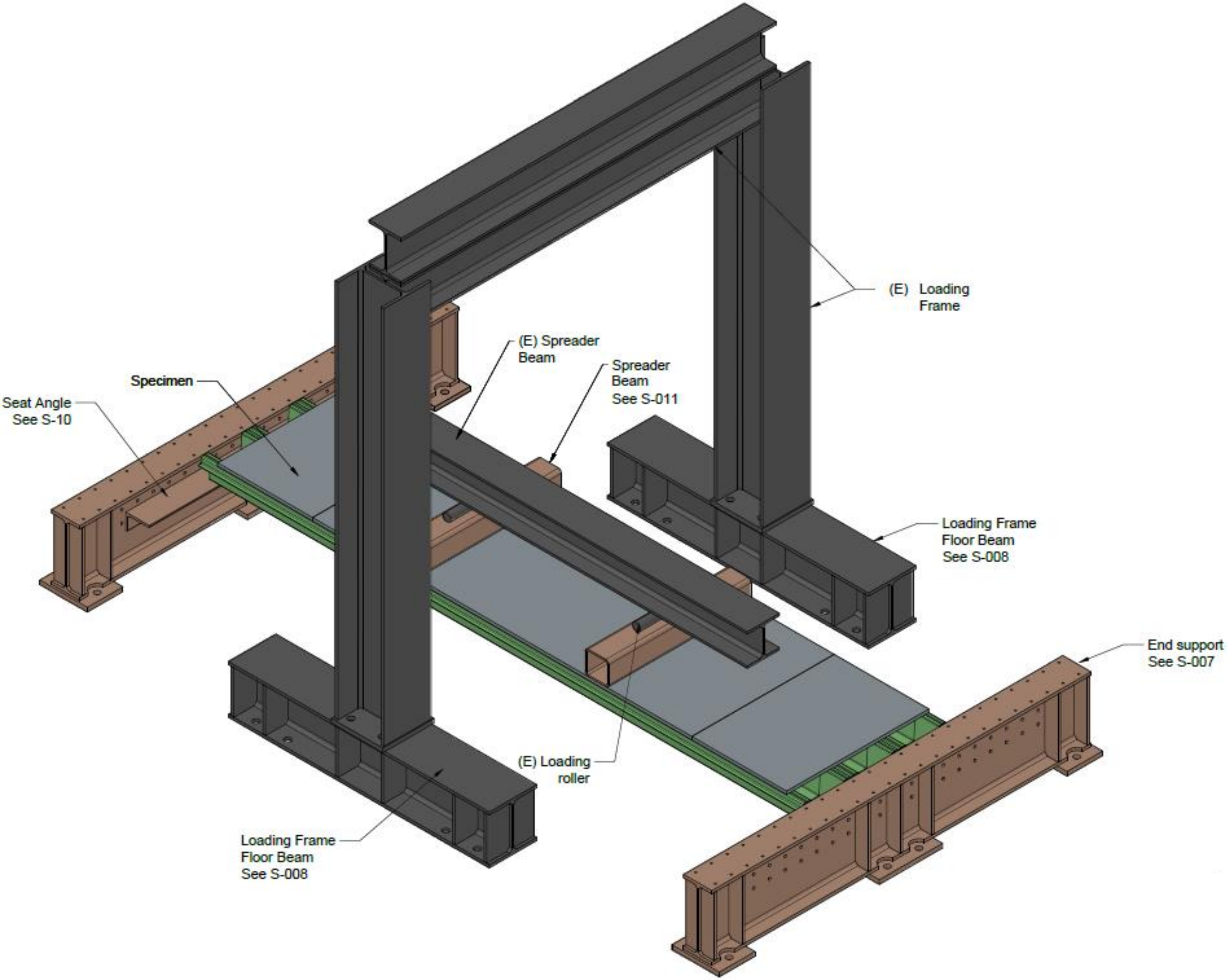
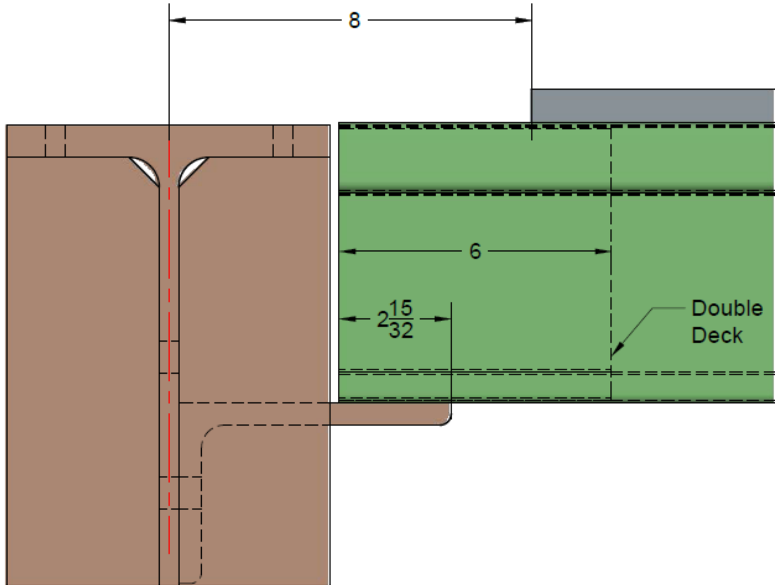
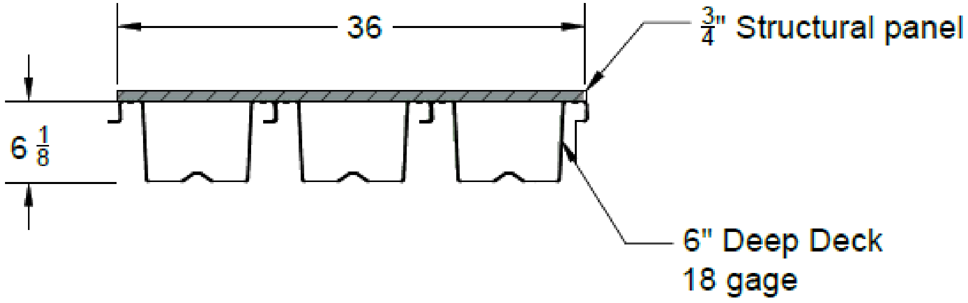
| | 2 | Composite specimen on girder | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 3 | Composite specimen on girder with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| SA - 2x3 | 1 | Baseline bare specimen on Angle | 2x 3" PLN24 | | | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| SA - 6 | 1 | Baseline bare specimen on Angle | 6" Deep-Dek | | | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests - Composite deck-3 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 7 | Strength Tests | 6" Deep-Dek | | | 12 | 11.125 | 24 | 4-point bending | Seat on Angle | No |

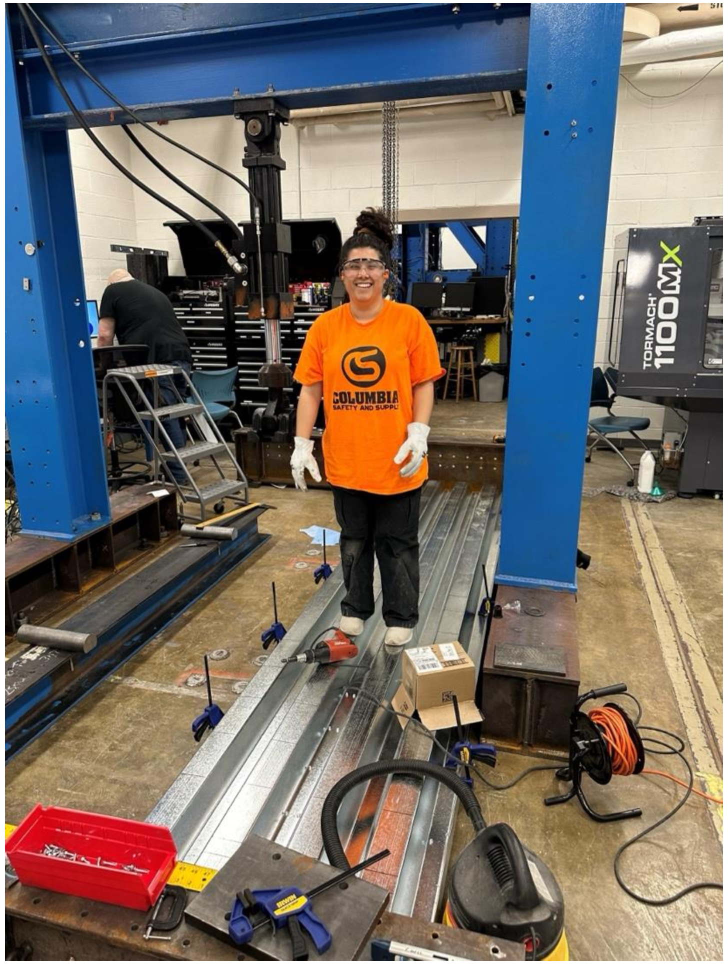
# Test Matrix - Phase 2 – 6 SA



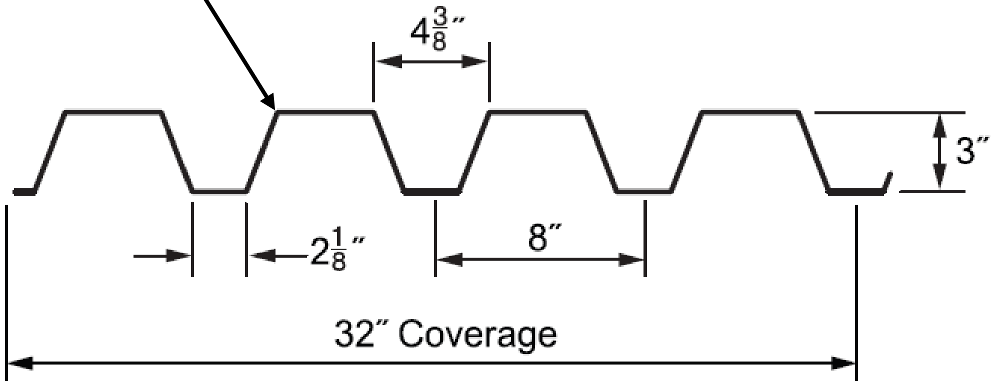
# Assembly


TORMACH
1100MX
COLUMBIA
SAFETY AND SUPPLY

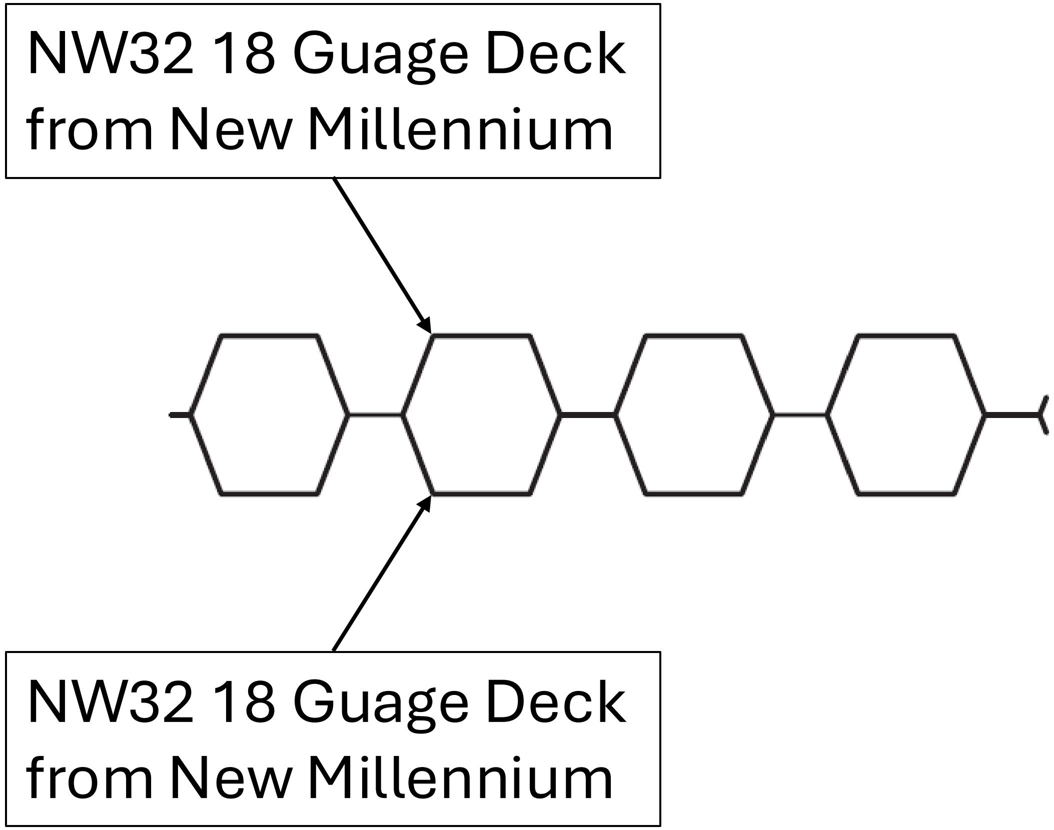

USG
STRUCTO-CRETE

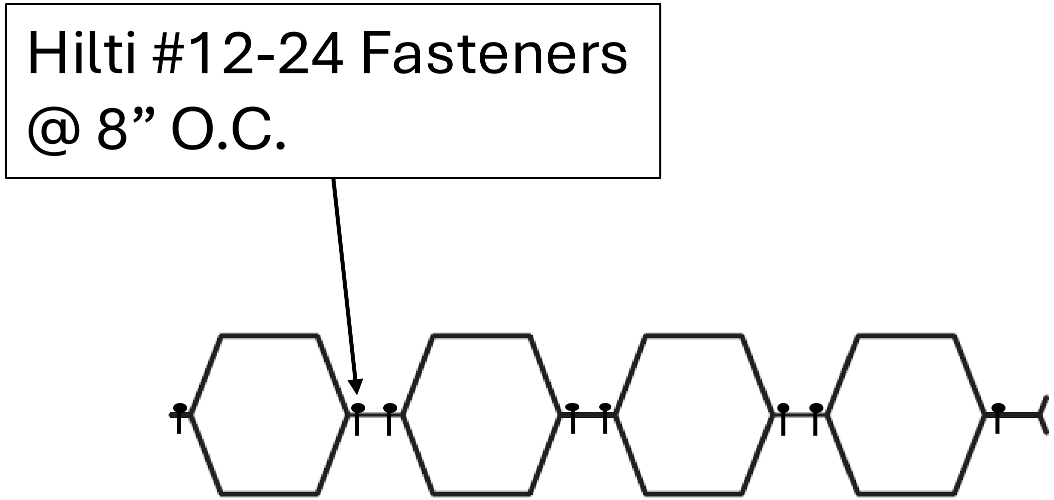
# Assembly Process for 2x3

NW32 18 Guage Deck
from New Millennium

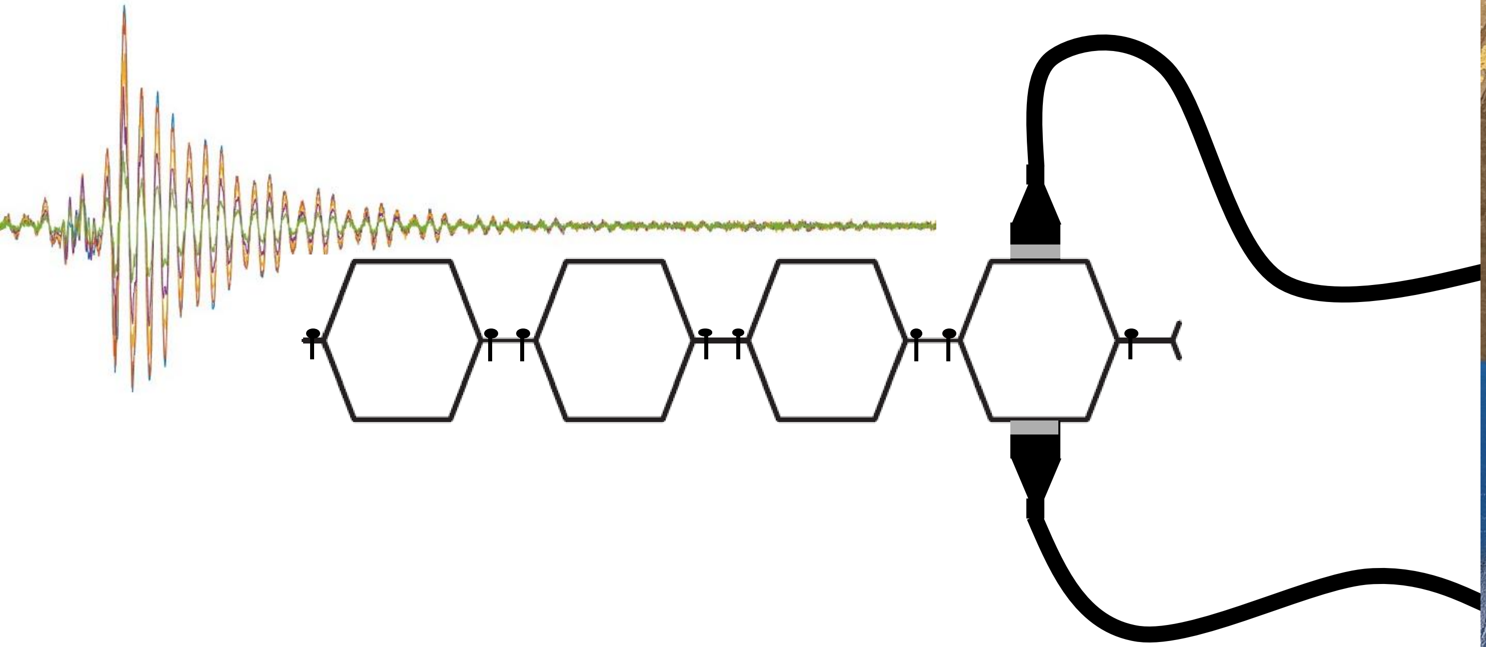


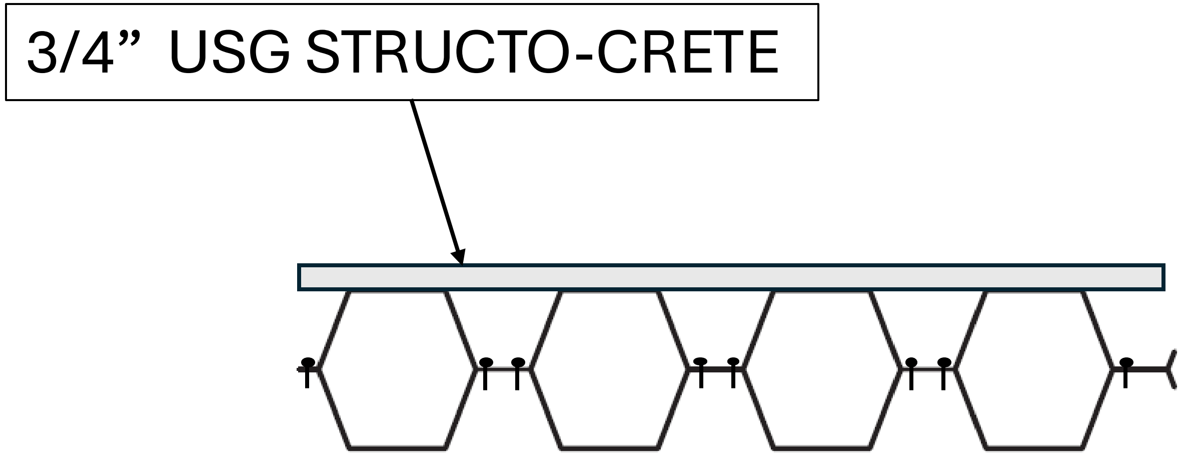

Spacers to Prevent
Web Crippling


NW32 18 Guage Deck
from New Millennium
NW32 18 Guage Deck
from New Millennium


Hilti #12-24 Fasteners
@ 8” O.C.

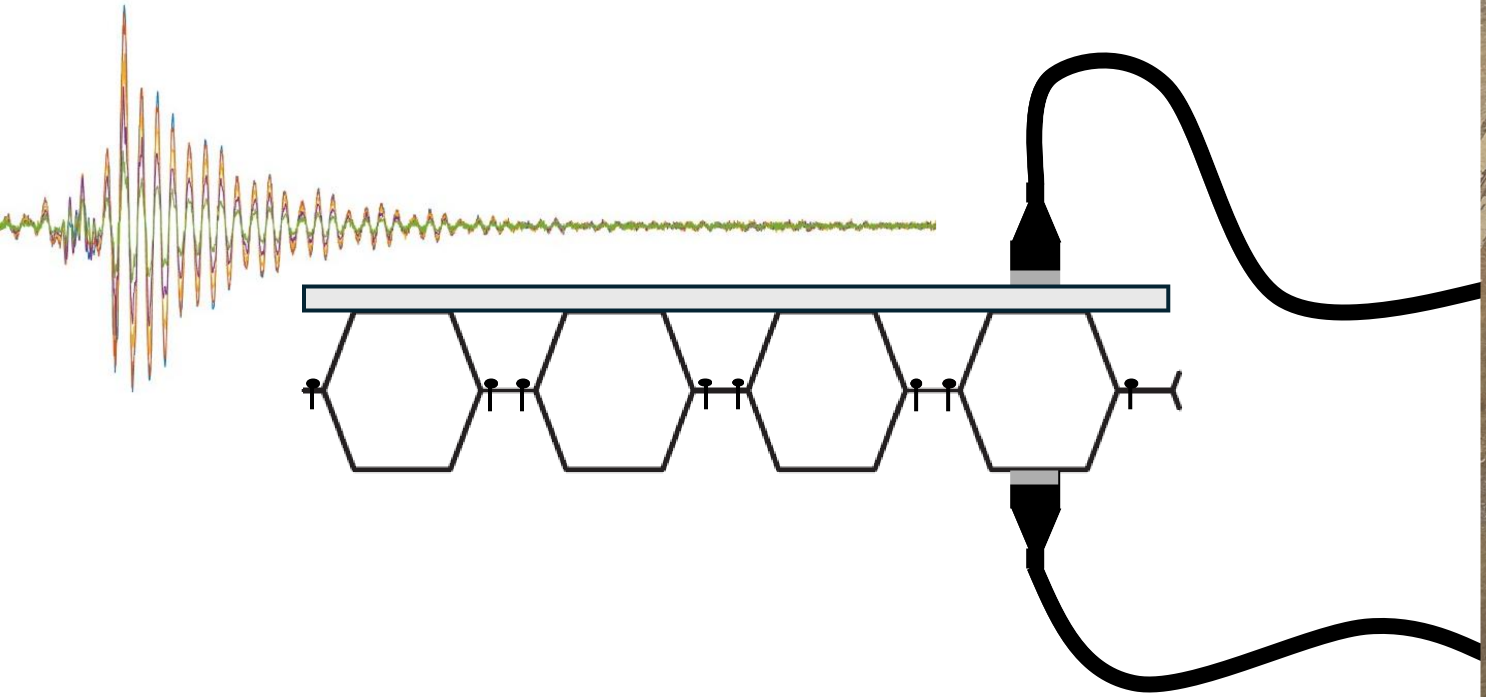
# Vibration Test



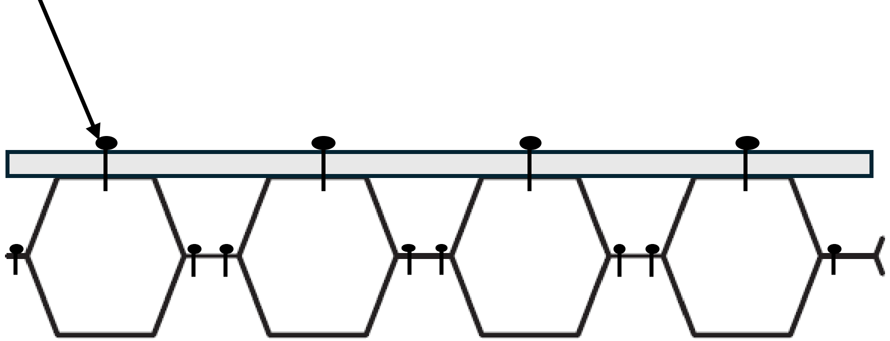

3/4”  USG STRUCTO-CRETE


USG
STRUCTO-CRETE

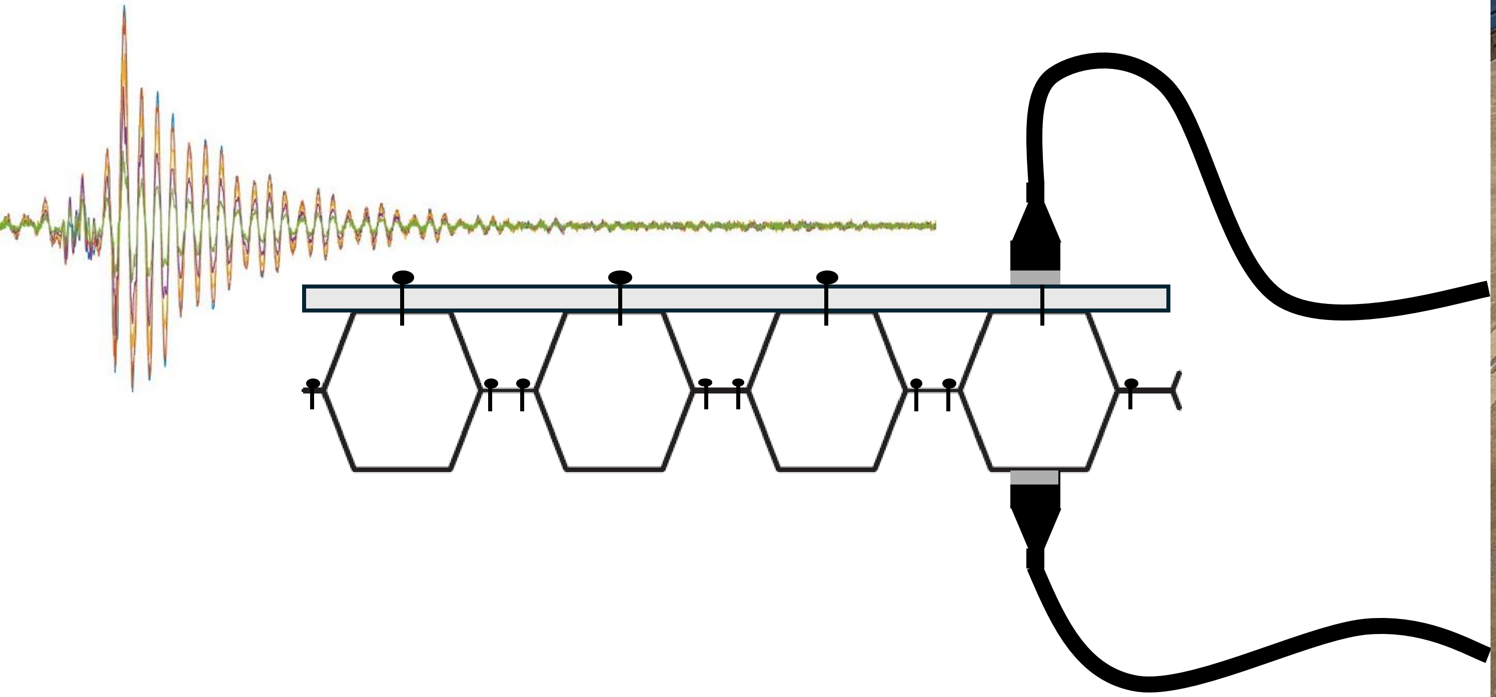
# Vibration Test



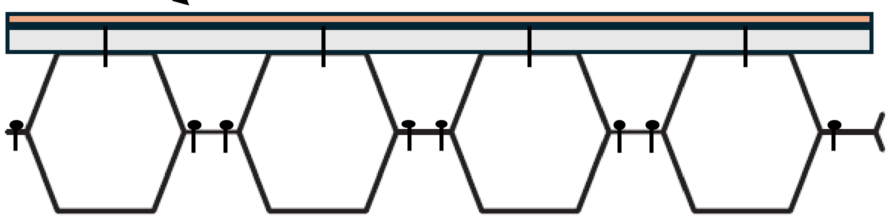
Structural panel fasteners Grabber #8 @12" O.C.



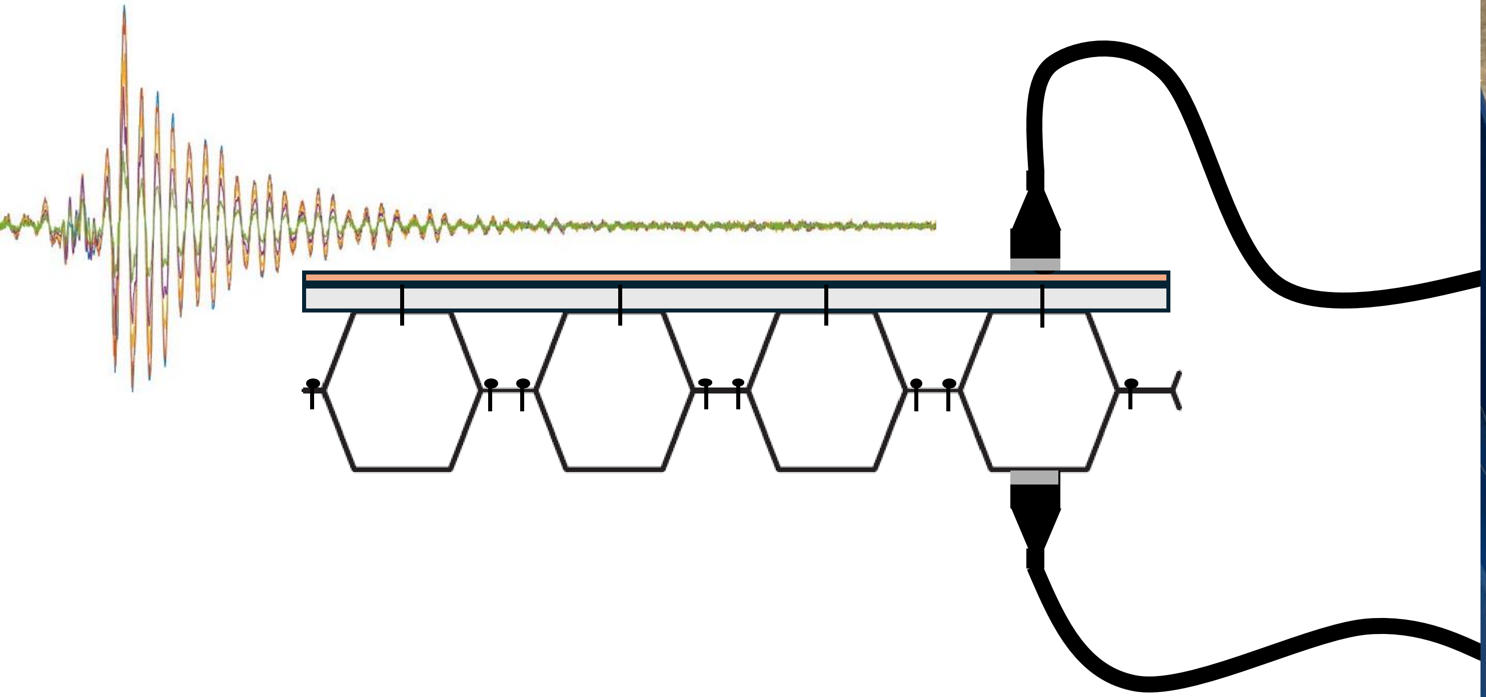
# Vibration Test

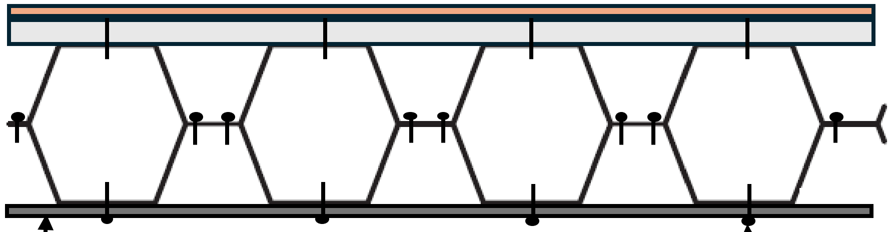


Luxury Vinyl Plank,
French Oak Covelo
20 MIL 7.2 in. x 60 in.



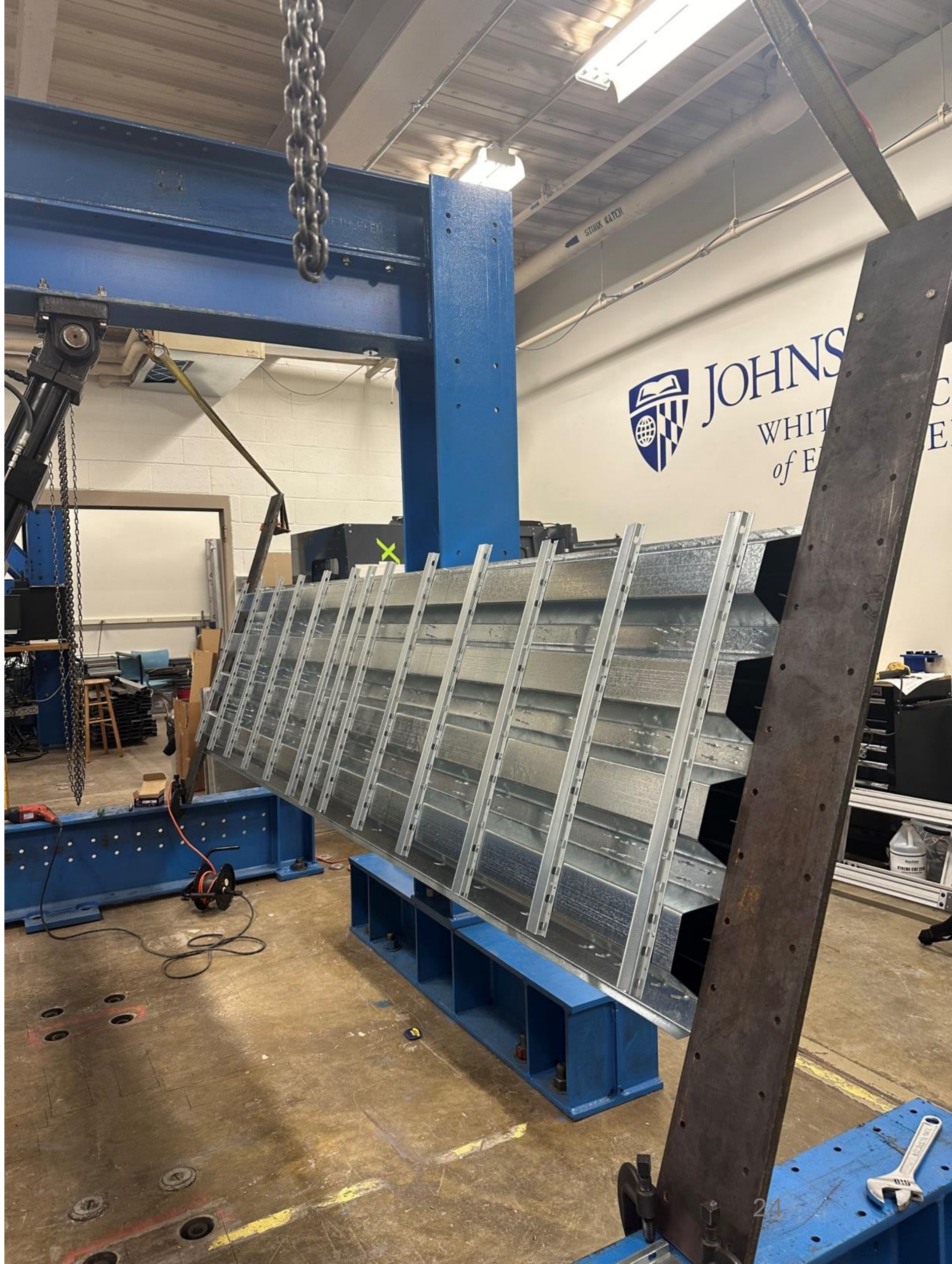
# Vibration Test

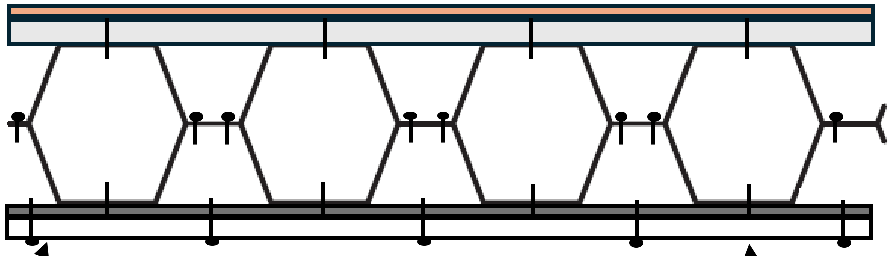




Resilient Channels are ClarkDietrich 18 Guage 1 5/8” depth spaced @12” O.C.

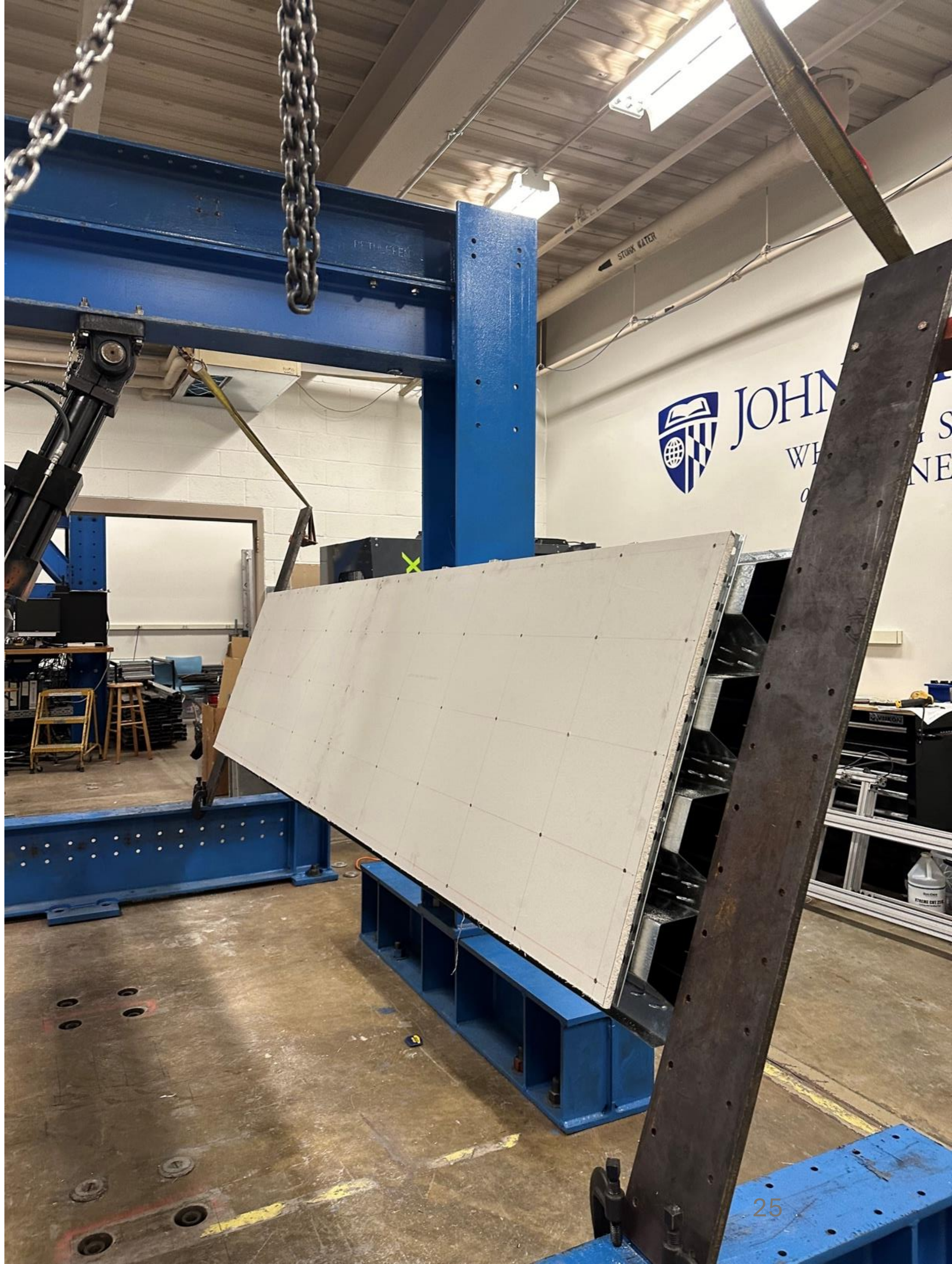
Pan Head Framing Screws are #7 x 7/16” @ 8” O.C.



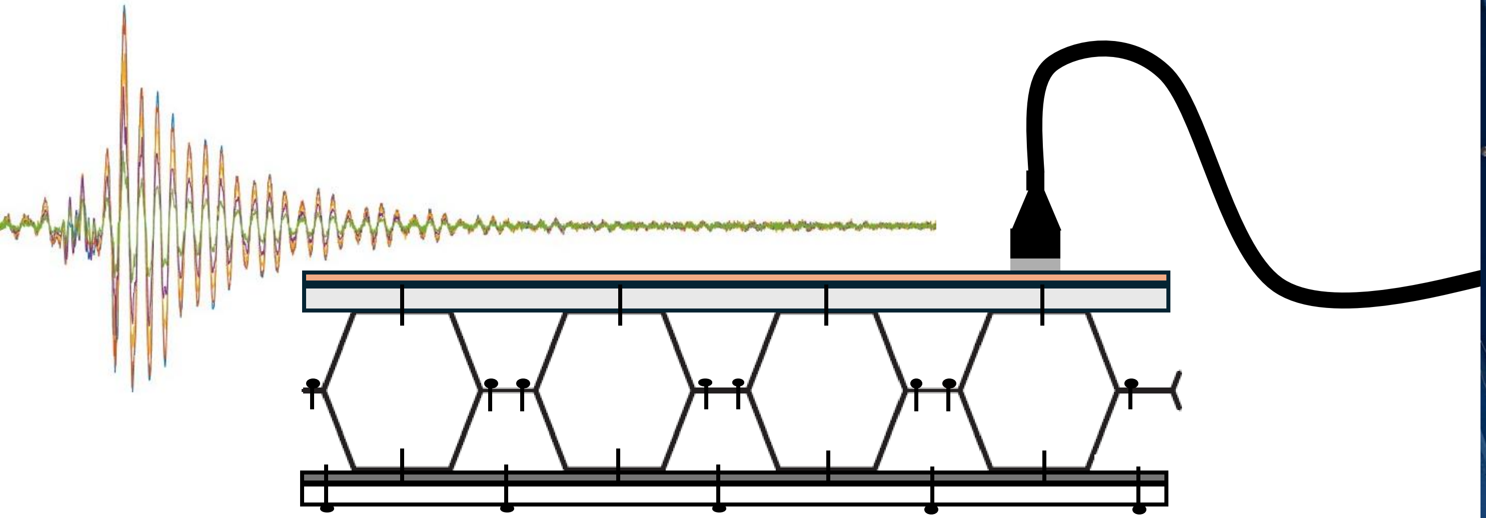


Drywall is 5/8” USG Sheetrock Brand EcoSmart Panels Firecode X

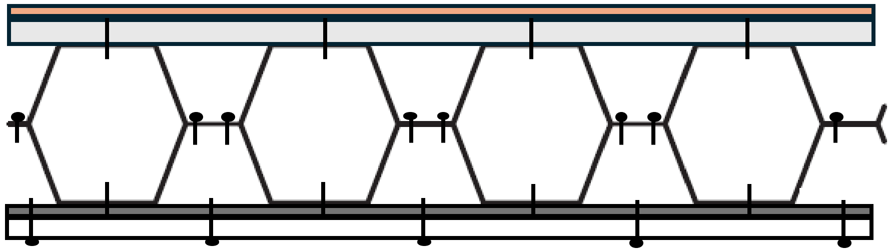
Fasteners are Quik Drive #6 x ¼” drywall screws @ 8” O.C. from Simpson Strong-Tie



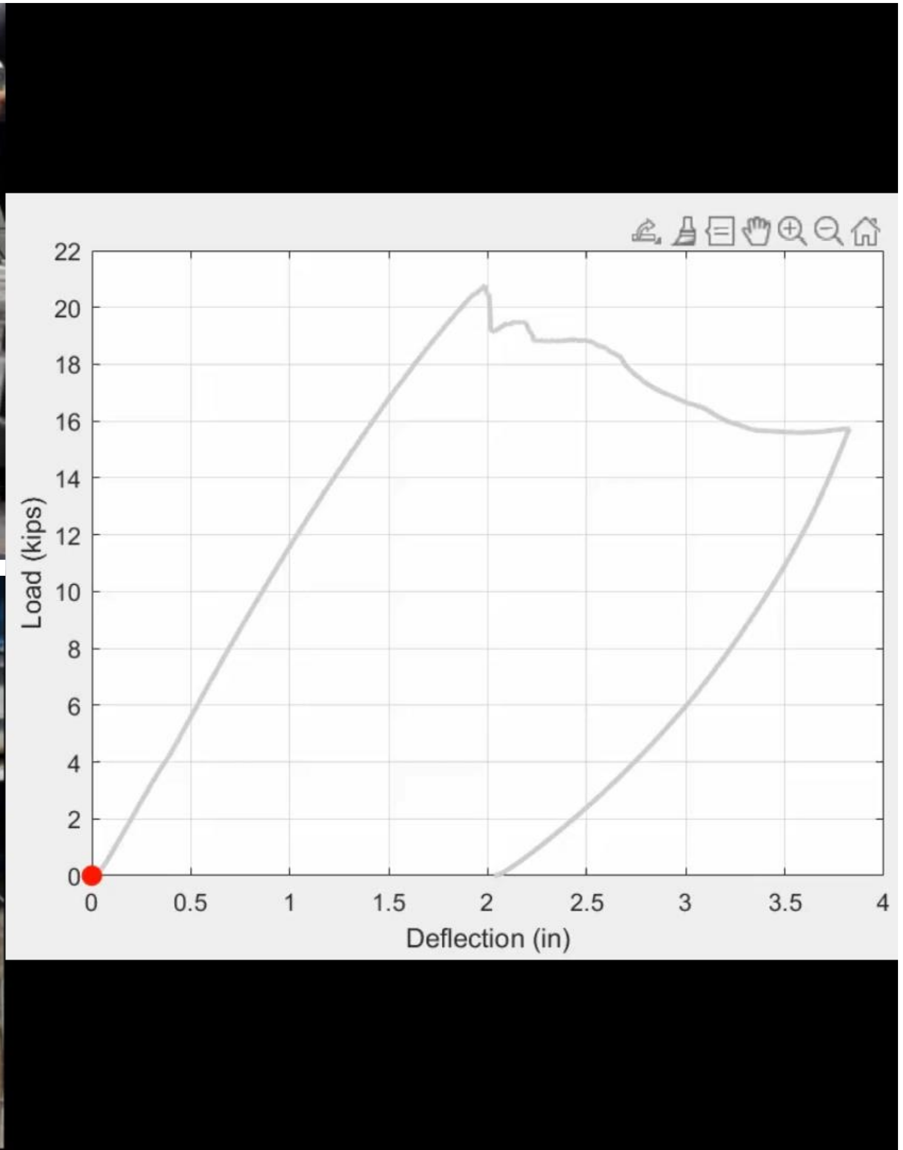
# Vibration Test



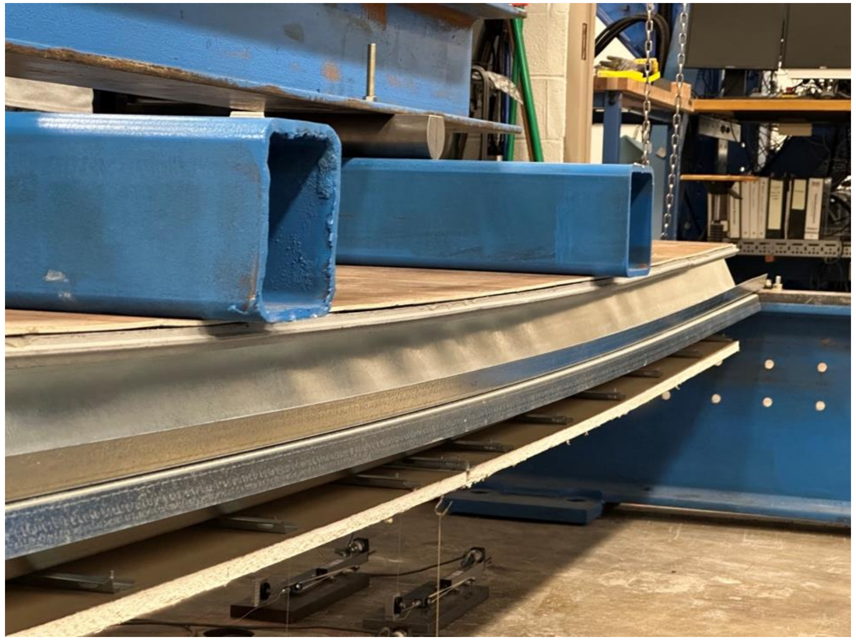
# 4-Point Bending Test

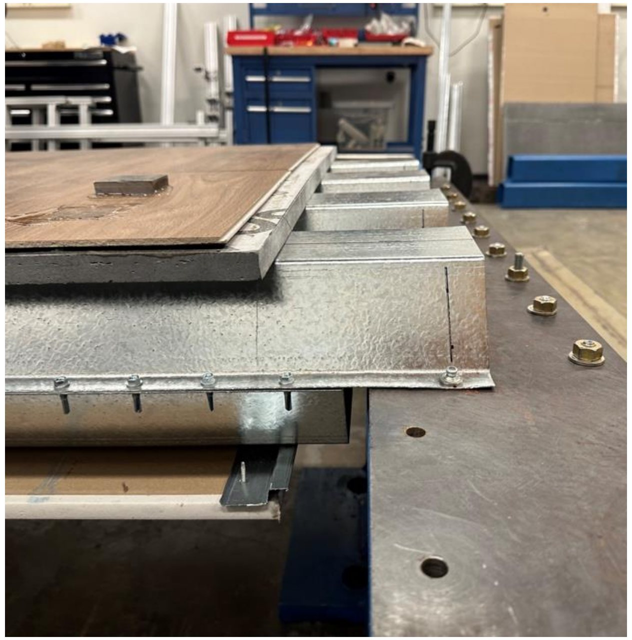


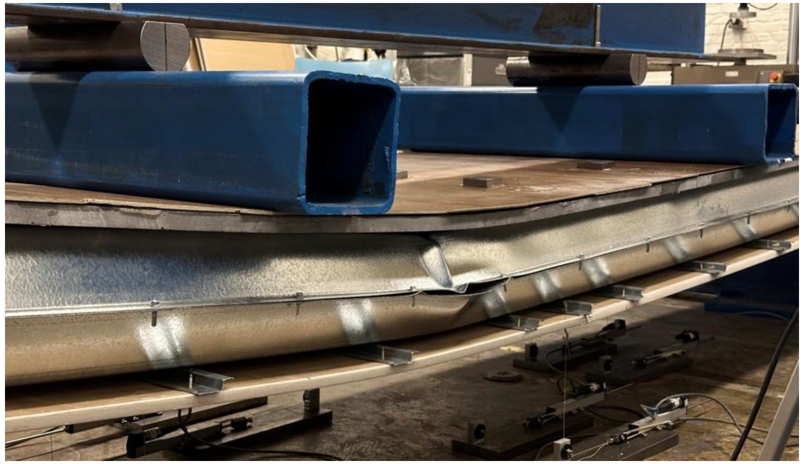
# 4-Point Bending Test on Composite Specimen on Girder with Finishing

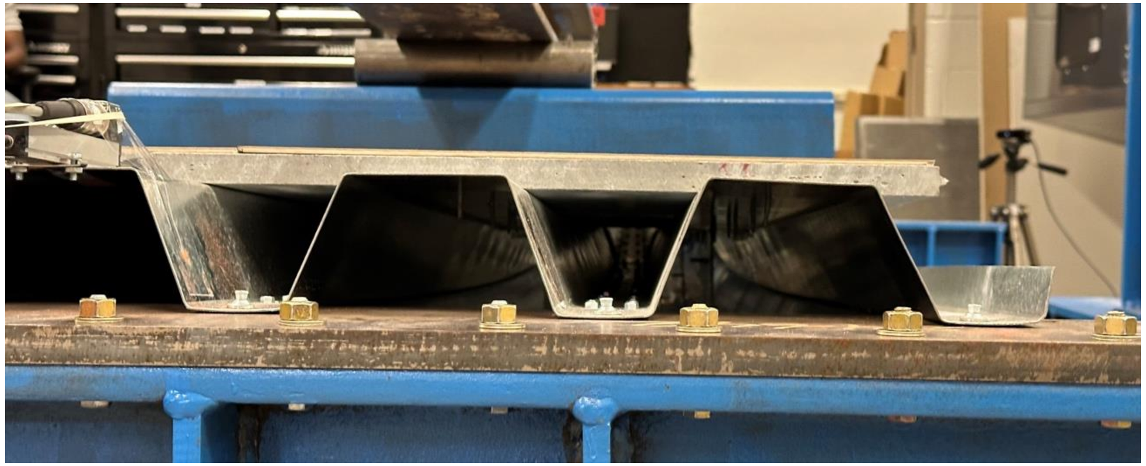


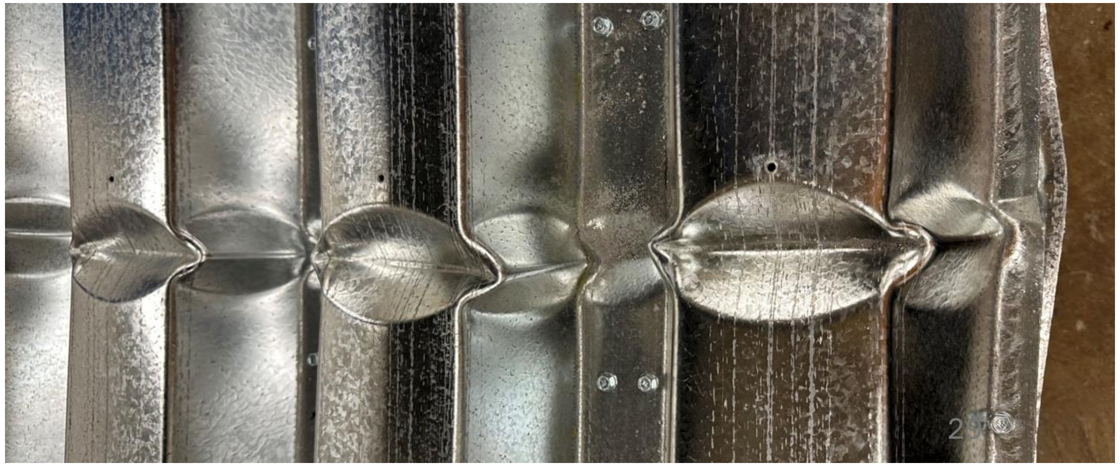
# 4-Point Bending Test on Composite Specimen on Girder with Finishing



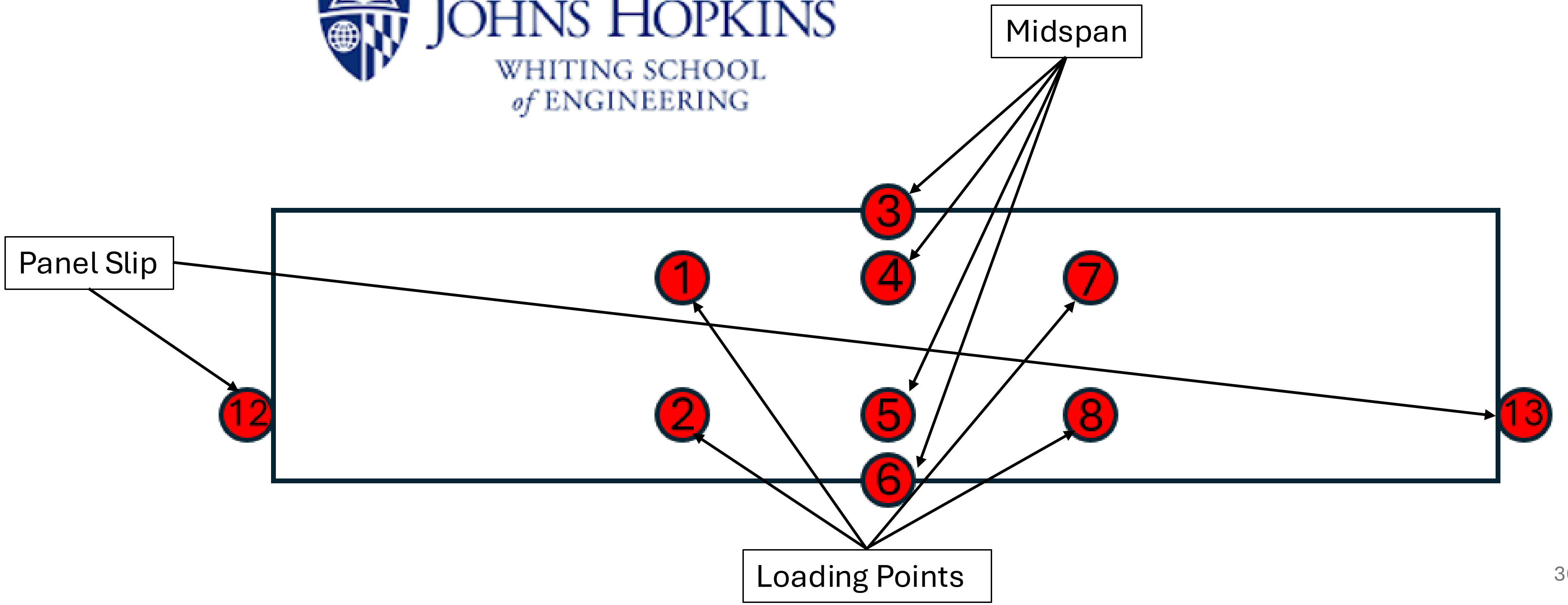




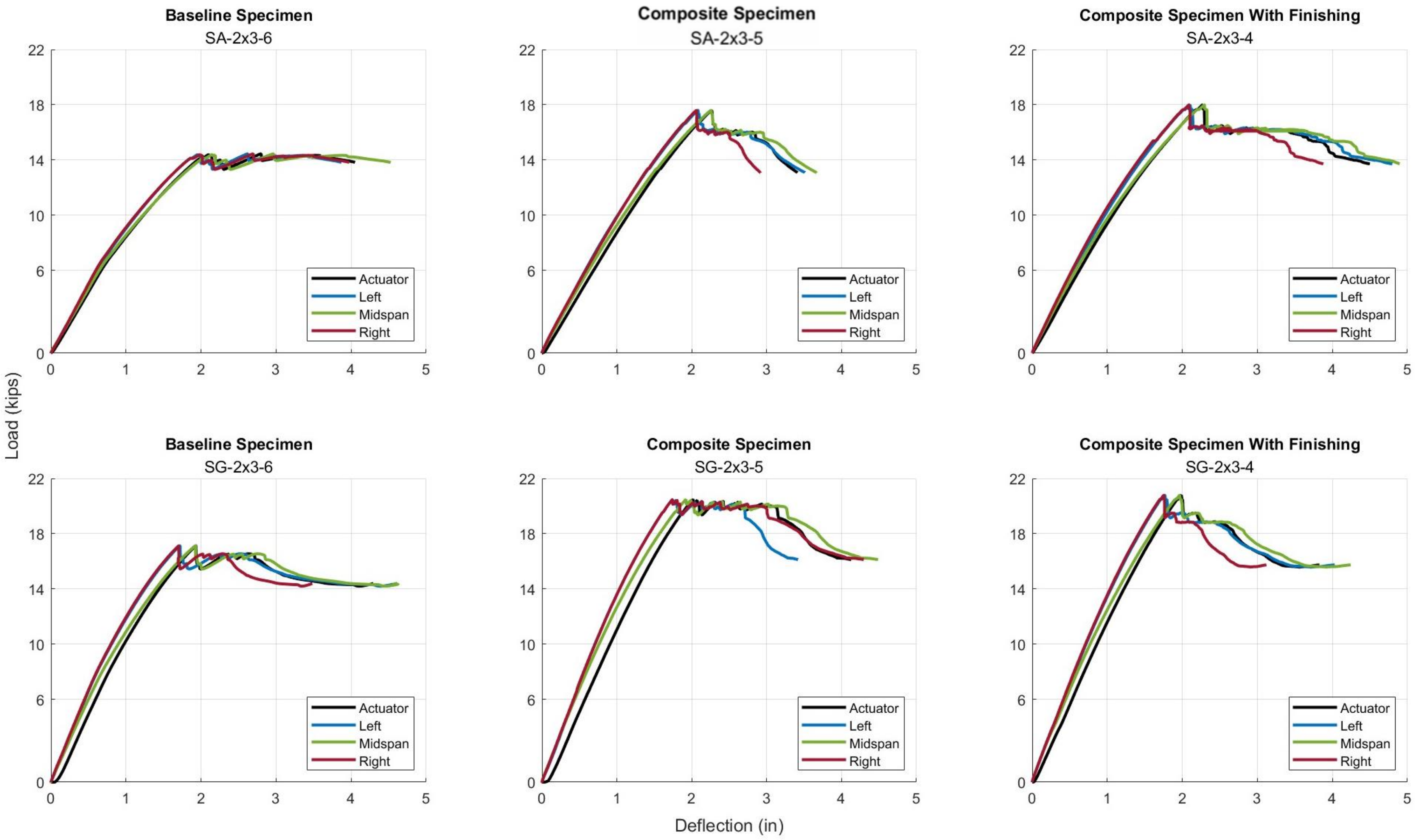




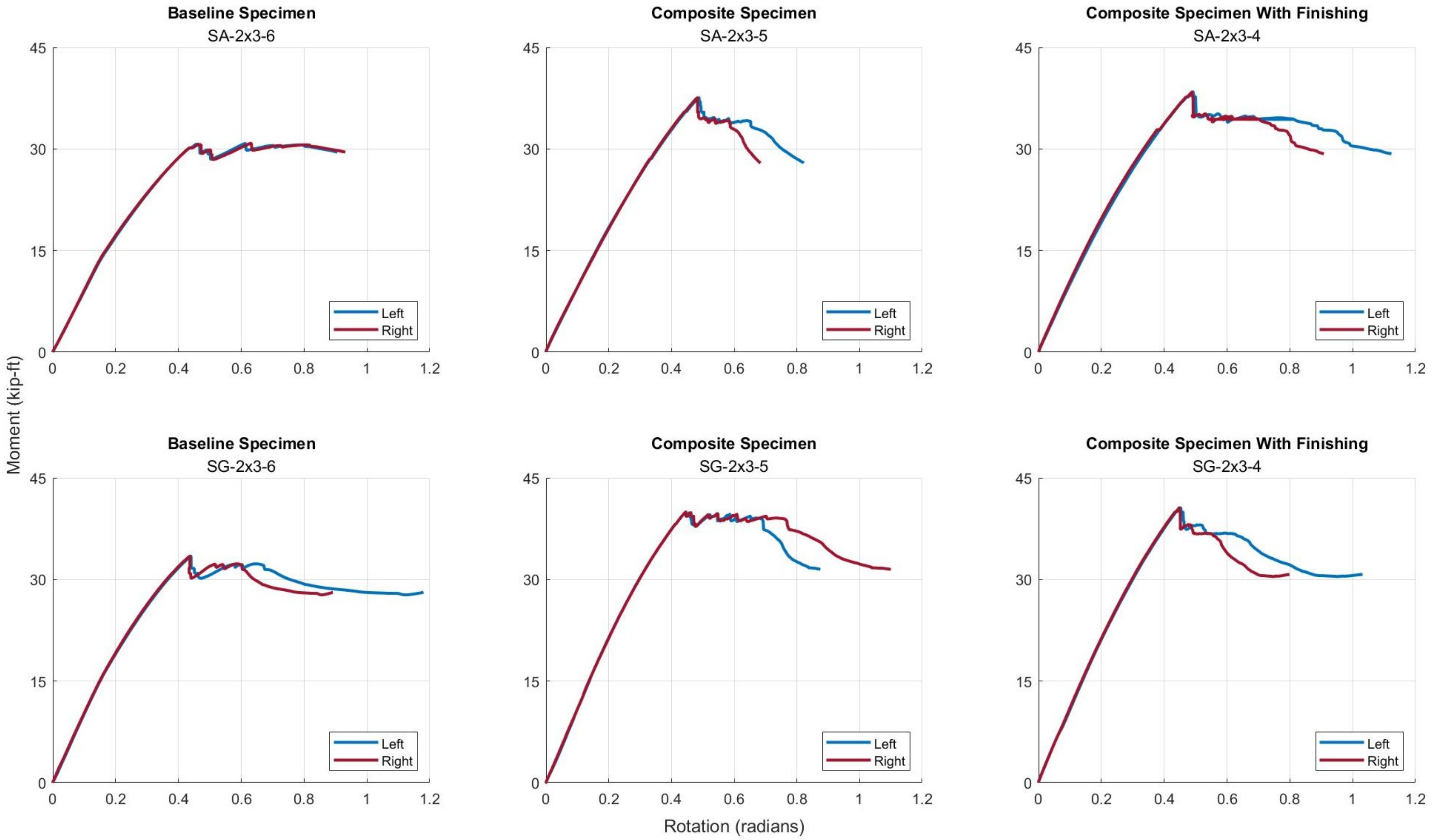
# Position Transducer Placement



# Results: Load - Deflection



# Results: Moment - Rotation



# Results: Load & Moment

| Specimen Name | Descriptive Name | Load, $P_{ult}$ (kip) | Moment, $M_{ult}$ (kip-ft) | $M_{ult}/M_{bare}$ | $M_y$ (kip-ft) | $M_{ult}/M_y$ |
|---|---|---|---|---|---|---|
| SG - 2x3 - 4 | Floor + Ceiling | 20.79 | 40.60 | 1.21 | - | - |
| SG - 2x3 - 5 | Bare + Panel | 20.47 | 39.99 | 1.20 | 62.4 | 0.641 |
| SG - 2x3 - 6 | Bare | 17.13 | 33.45 | 1.00 | 54.1 | 0.618 |
| SA - 2x3 - 4 | Floor + Ceiling | 17.99 | 38.43 | 1.25 | - | - |
| SA - 2x3 - 5 | Bare + Panel | 17.60 | 37.57 | 1.22 | 62.4 | 0.602 |
| SA - 2x3 - 6 | Bare | 14.44 | 30.85 | 1.00 | 54.1 | 0.570 |
| SA - 6 - 4 | | | | | | |
| SA - 6 - 5 | | | | | | |
| SA - 6 - 6 | | | TBA | | | |
| SA - 6 - 7 | | | | | | |

**Calculations for $M_y$ can be found in the Appendix

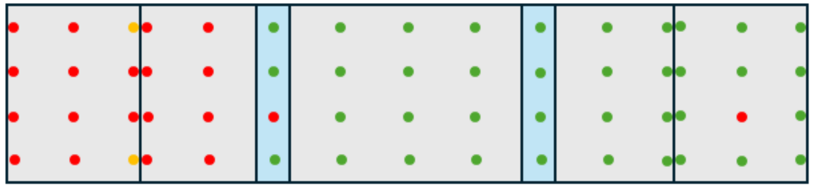
# Results: Stiffness

| Specimen Name | Descriptive Name | Analytical EI ($10^5$ x kip-in$^2$) | Experimental EI at 40% $P_{max}$ ($10^5$ x kip-in$^2$) | Ratio of Analytical EI |
|---|---|---|---|---|
| SG - 2x3 - 4 | Floor + Ceiling | - | 5.8 | - |
| SG - 2x3 - 5 | Bare + Panel | 7.7 | 5.5 | 0.71 |
| SG - 2x3 - 6 | Bare | 5.9 | 5.5 | 0.93 |
| SA - 2x3 - 4 | Floor + Ceiling | - | 6.0 | - |
| SA - 2x3 - 5 | Bare + Panel | 7.7 | 6.0 | 0.78 |
| SA - 2x3 - 6 | Bare | 5.9 | 5.6 | 0.95 |
| SA - 6 - 4 | | | | |
| SA - 6 - 5 | | | TBA | |
| SA - 6 - 6 | | | | |
| SA - 6 - 7 | | | | |

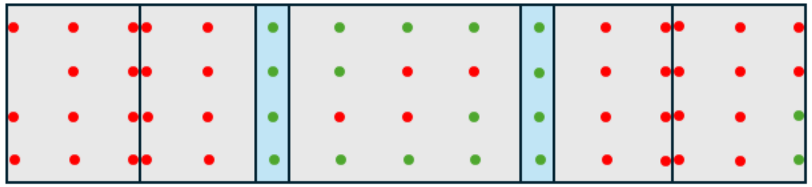
**Calculations for EI can be found in the Appendix

# Results: Fastener Failure

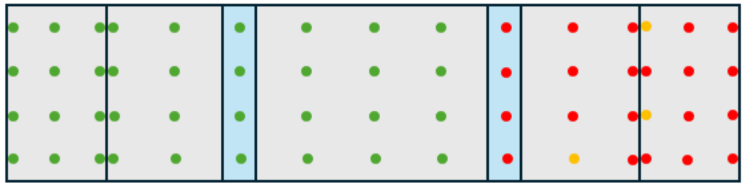
SA 2x3 – 5 (Deck + STRUCTOCRETE)



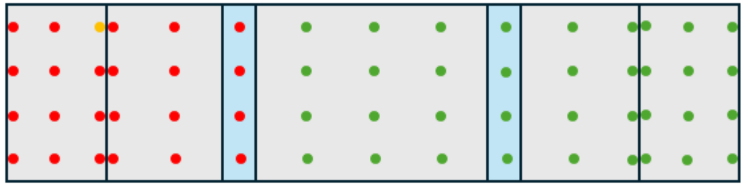
SA 2x3 – 4 (Complete Specimen)



SG 2x3 – 5 (Deck + STRUCTOCRETE)



SG 2x3 – 4 (Complete Specimen)



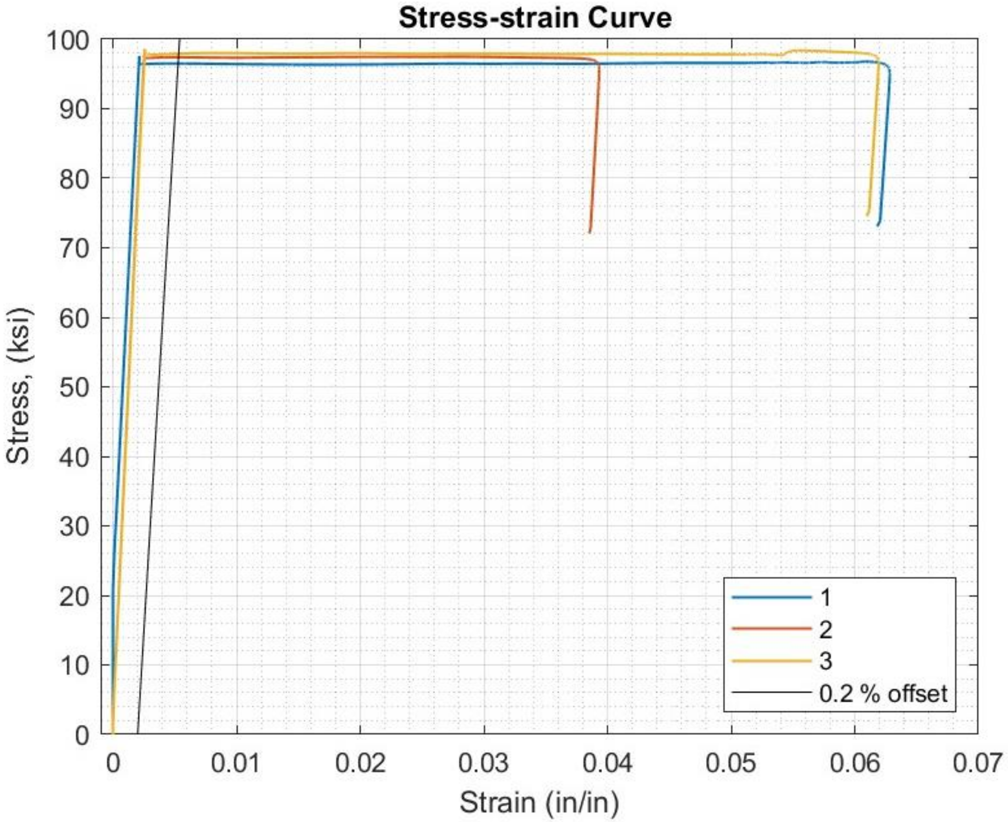
Key

- Intact
- Bearing accompanied by edge tear-out
- Fastener Shear
- Loading Point

# Coupon Test

| Coupon ID | Uncoated thickness, t (in.) | Yield Strength (ksi) | | Ultimate Strength (ksi) | | Yield Strain, $\varepsilon_y$ (-) | Fracture Strain, $\varepsilon_f$ (-) |
|---|---|---|---|---|---|---|---|
| | | $F_y$ | $0.9F_y$** | $F_u$ | $0.9F_u$** | | |
| 1 | 0.0470 | 96.5 | 86.8 | 97.6 | 87.9 | 0.00527 | 0.0628 |
| 2 | 0.0475 | 97.4 | 87.7 | 98.5 | 88.7 | 0.00530 | 0.0393 |
| 3 | 0.0474 | 97.9 | 88.1 | 98.6 | 88.7 | 0.00532 | 0.0619 |
| $\mu$ | 0.0473 | 97.3 | 87.5 | 98.2 | 88.4 | 0.0053 | 0.0547 |
| $\sigma$ | 0.0003 | 0.7 | 0.6 | 0.5 | 0.5 | 0.00003 | 0.013 |
| $COV$ (%) | 0.6 | 0.7 | 0.7 | 0.6 | 0.6 | 0.5 | 24.4 |

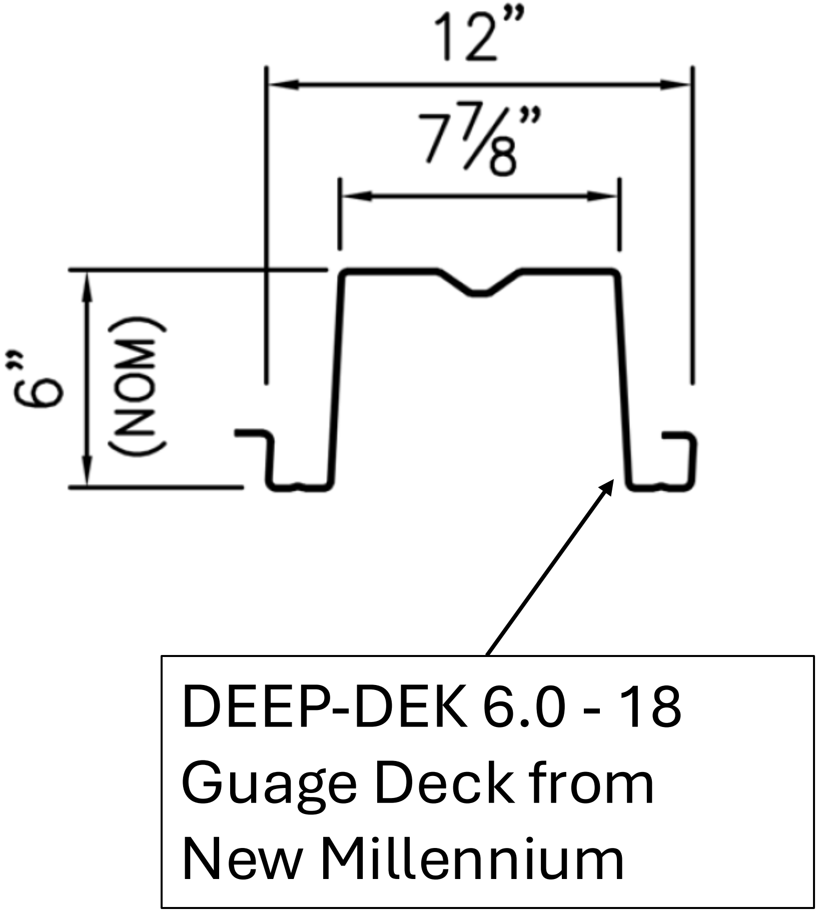
**Adjustment per AISI, Chapter A3.1.2

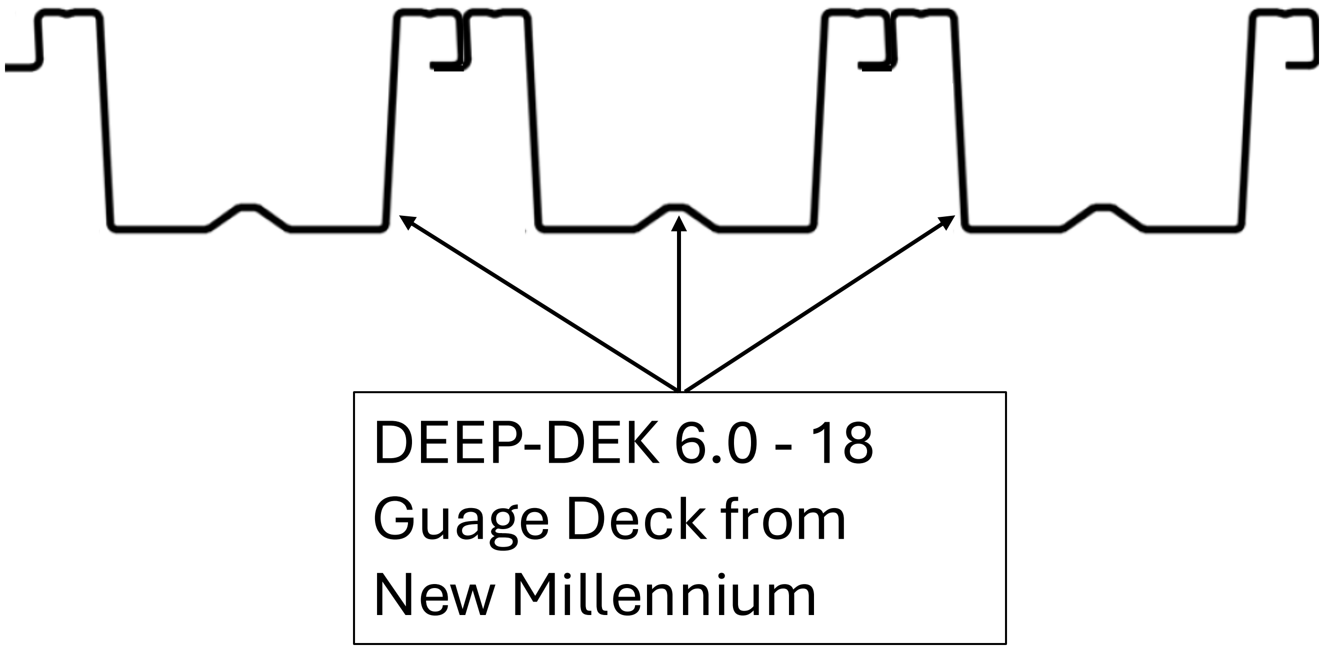


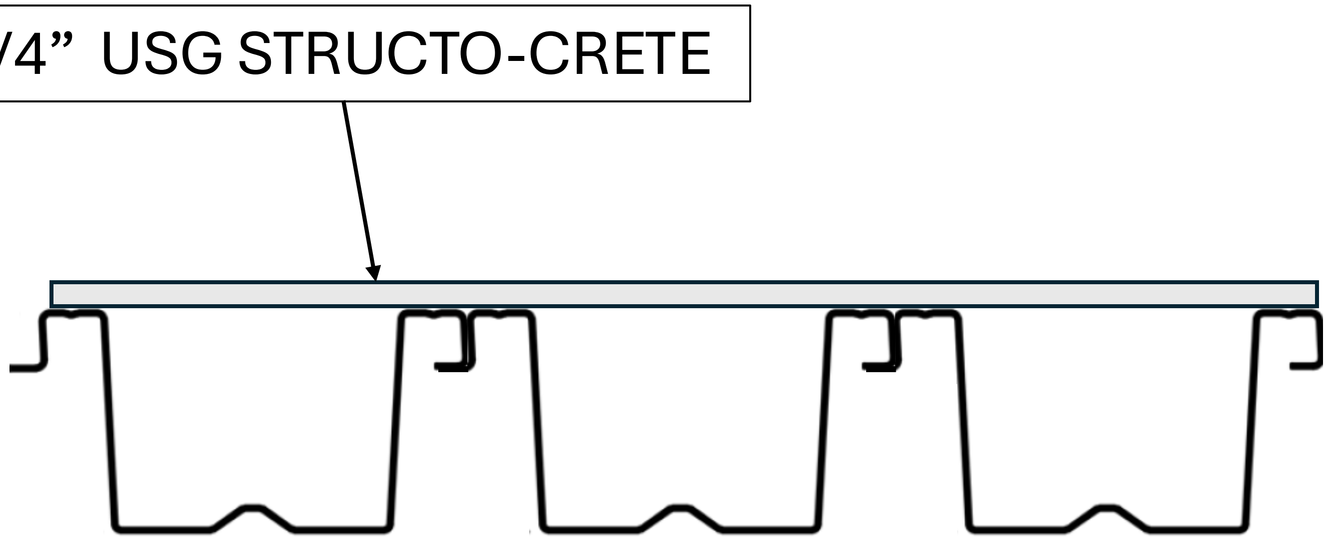
# Test Matrix – Phase 2

| Test | | Specimen Type | Deck Type | Structural panel | Strcutural panel to deck connectors | Nominal Span ft | Actual Span ft | Width in | Testing protocol | End connection | Ceiling and floor assembly |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SG - 2x3 | 1 | Baseline bare specimen on Girder | 2x 3" PLN24 | | | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 2 | Composite specimen on girder | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 3 | Composite specimen on girder with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| SA - 2x3 | 1 | Baseline bare specimen on Angle | 2x 3" PLN24 | | | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| SA - 6 | 1 | Baseline bare specimen on Angle | 6" Deep-Dek | | | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests - Composite deck-3 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 7 | Strength Tests | 6" Deep-Dek | | | 12 | 11.125 | 24 | 4-point bending | Seat on Angle | No |

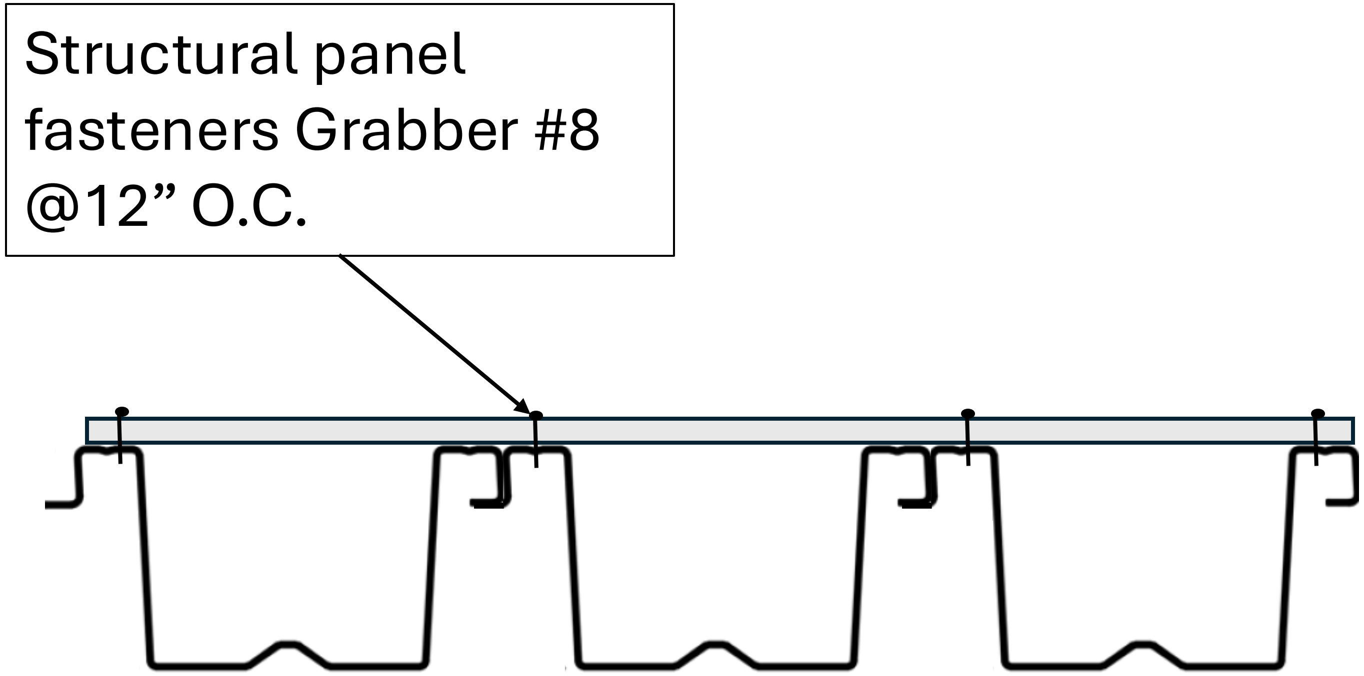
# Assembly Process for 6” Deep Deck

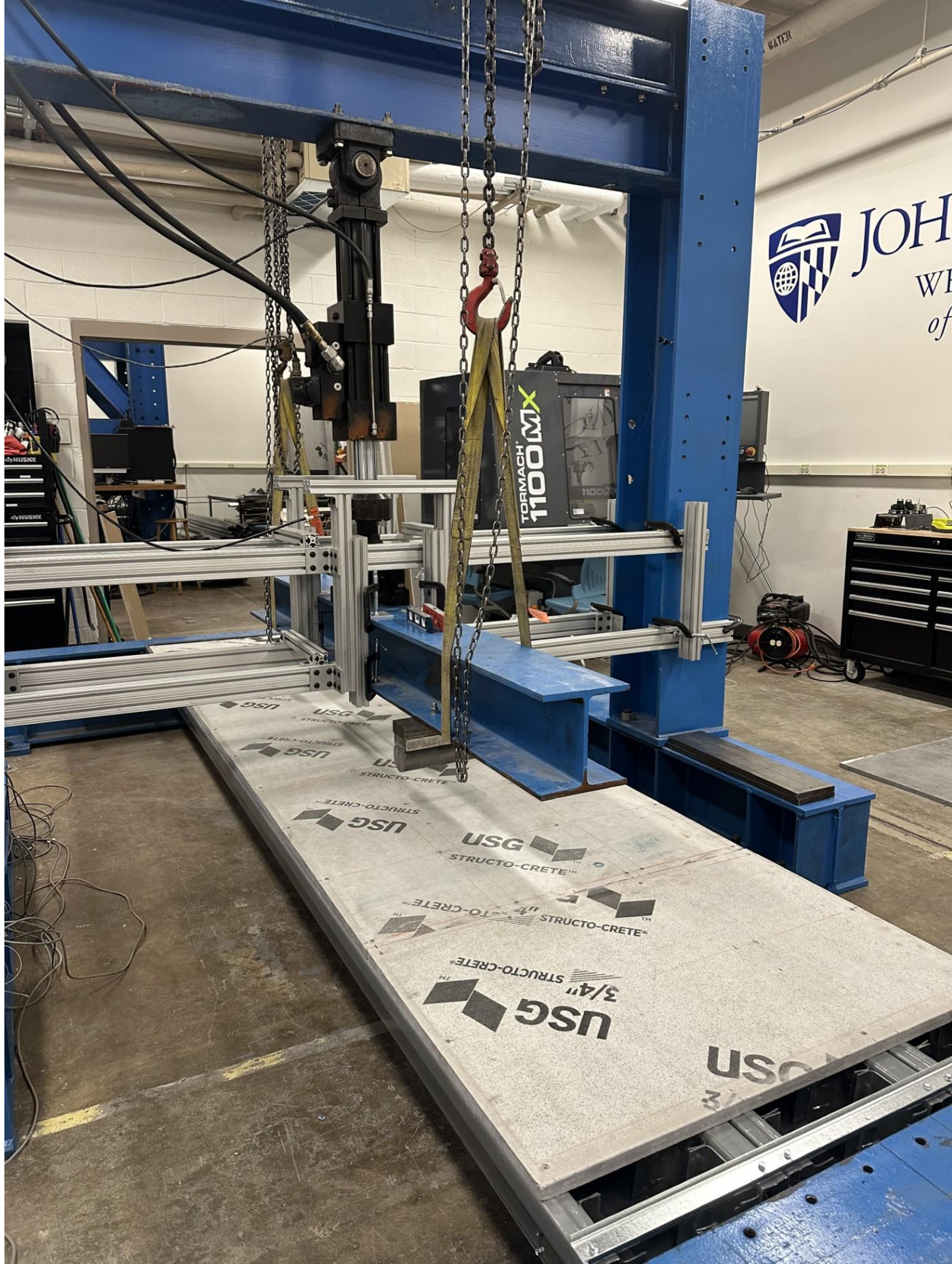

12"
7⅞"
6"
(NOM)
DEEP-DEK 6.0 - 18
Guage Deck from
New Millennium


DEEP-DEK 6.0 - 18
Guage Deck from
New Millennium


3/4”  USG STRUCTO-CRETE

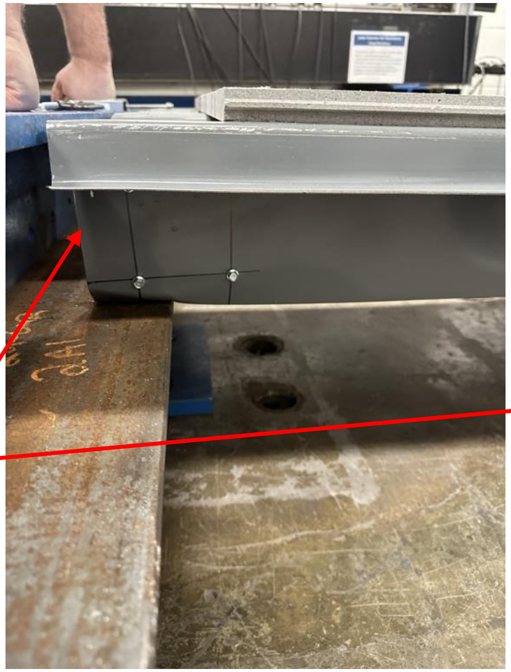

USG
STRUCTO-CRETE

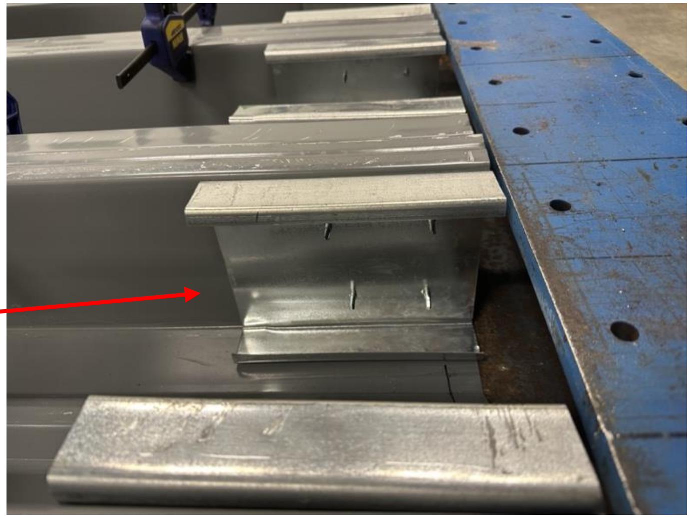

Structural panel fasteners Grabber #8 @12” O.C.

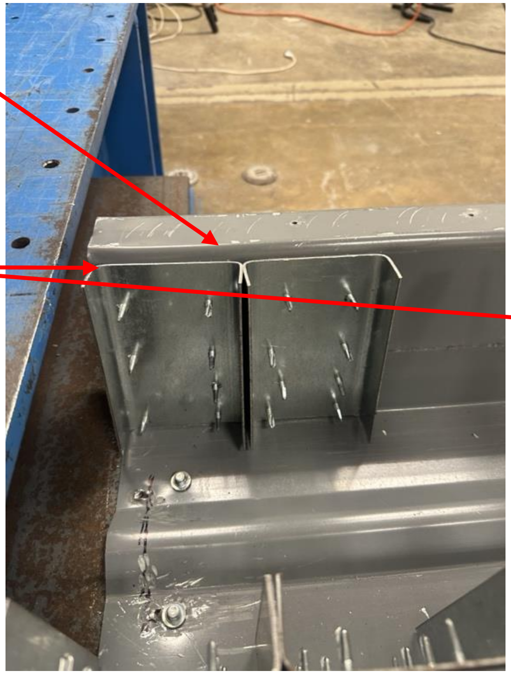

TORMACH 1100MX
USG
STRUCTO-CRETE
3/4"

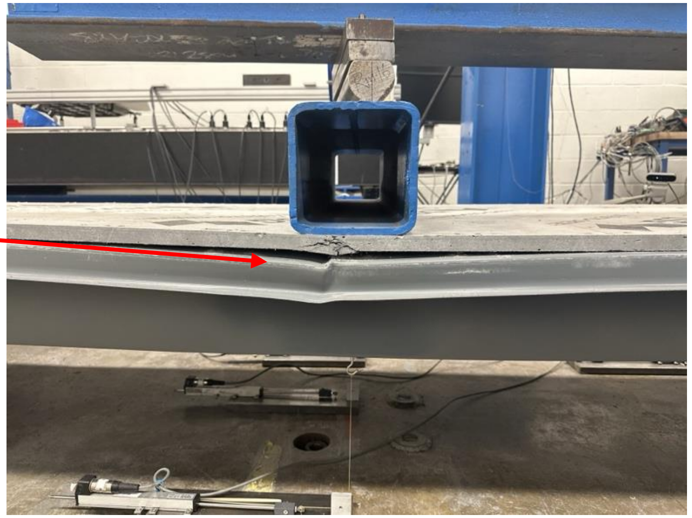
# 6” Deep Deck

- Trial 1: Web failure + 6” fastener spacing – Actuator slipped off
- Trial 2: New stiffeners + 6” fastener spacing – No failure
- Trial 3: Specimen successfully fails with 12” spacing @ load of 19.85 kips – Actuator slipped off

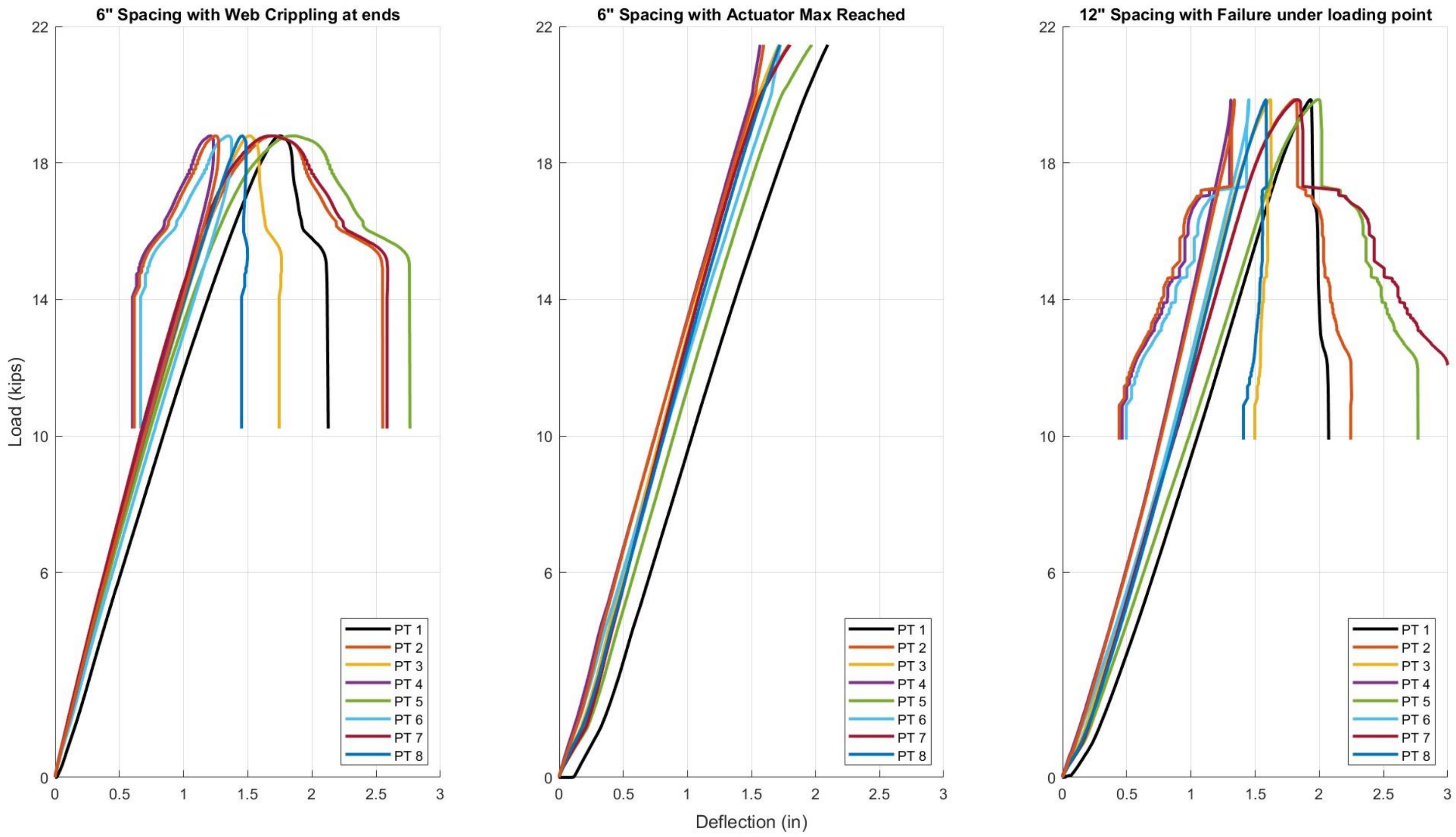




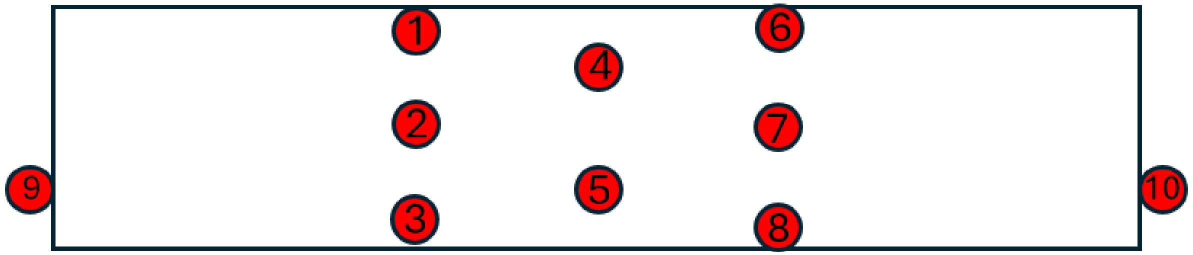




# 6” Deep Deck

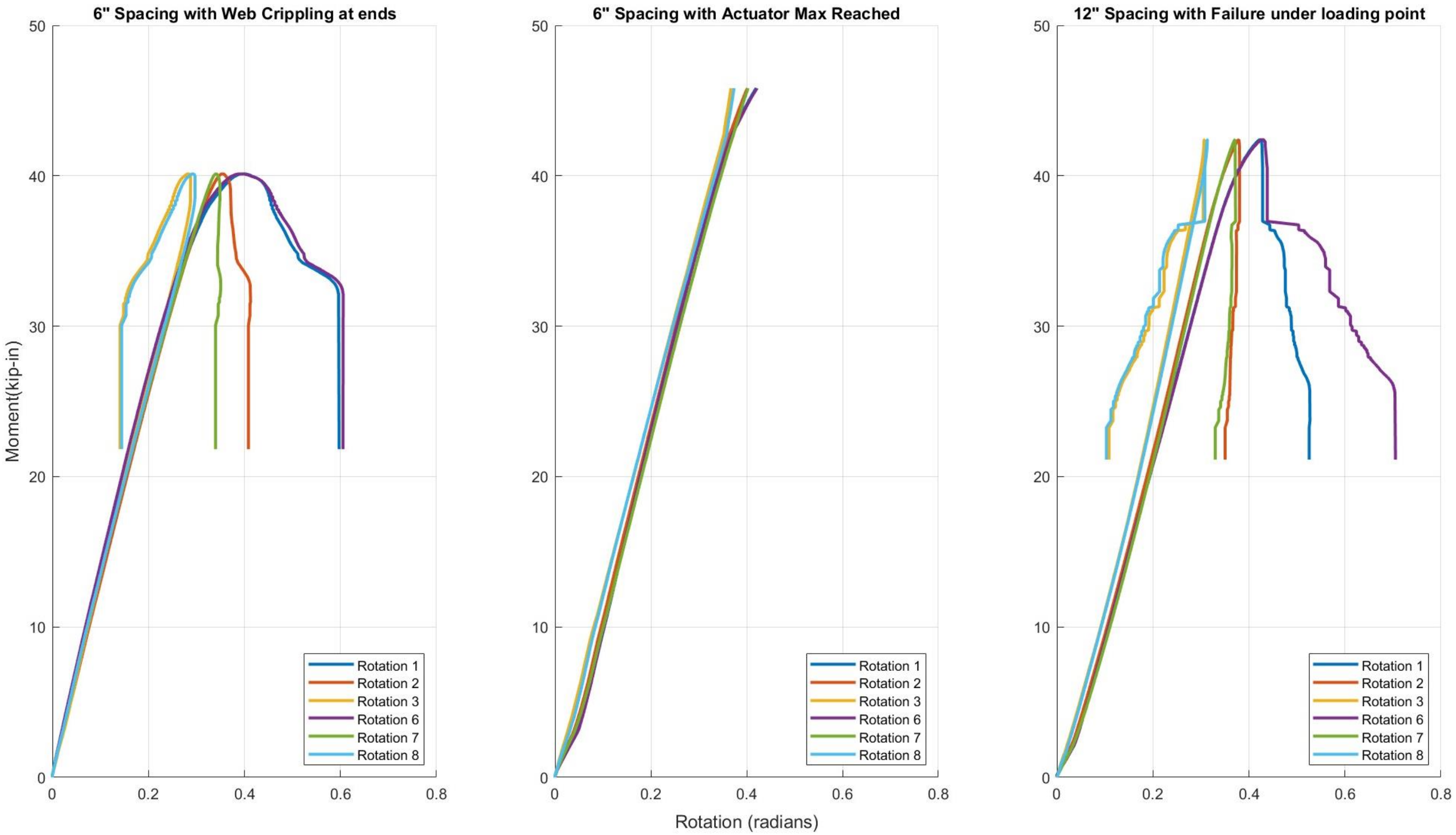


6" Spacing with Web Crippling at ends
6" Spacing with Actuator Max Reached
12" Spacing with Failure under loading point
Load (kips)
Deflection (in)
0
6
10
14
18
22
0
0.5
1
1.5
2
2.5
3
PT 1
PT 2
PT 3
PT 4
PT 5
PT 6
PT 7
PT 8

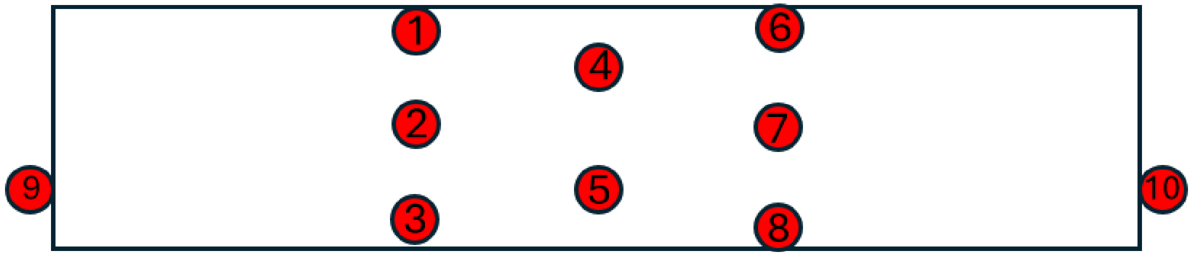



1
2
3
4
5
6
7
8
9
10

# 6” Deep Deck



6" Spacing with Web Crippling at ends
6" Spacing with Actuator Max Reached
12" Spacing with Failure under loading point
Moment(kip-in)
Rotation (radians)
0
10
20
30
40
50
0
0.2
0.4
0.6
0.8
Rotation 1
Rotation 2
Rotation 3
Rotation 6
Rotation 7
Rotation 8

1
2
3
4
5
6
7
8
9
10

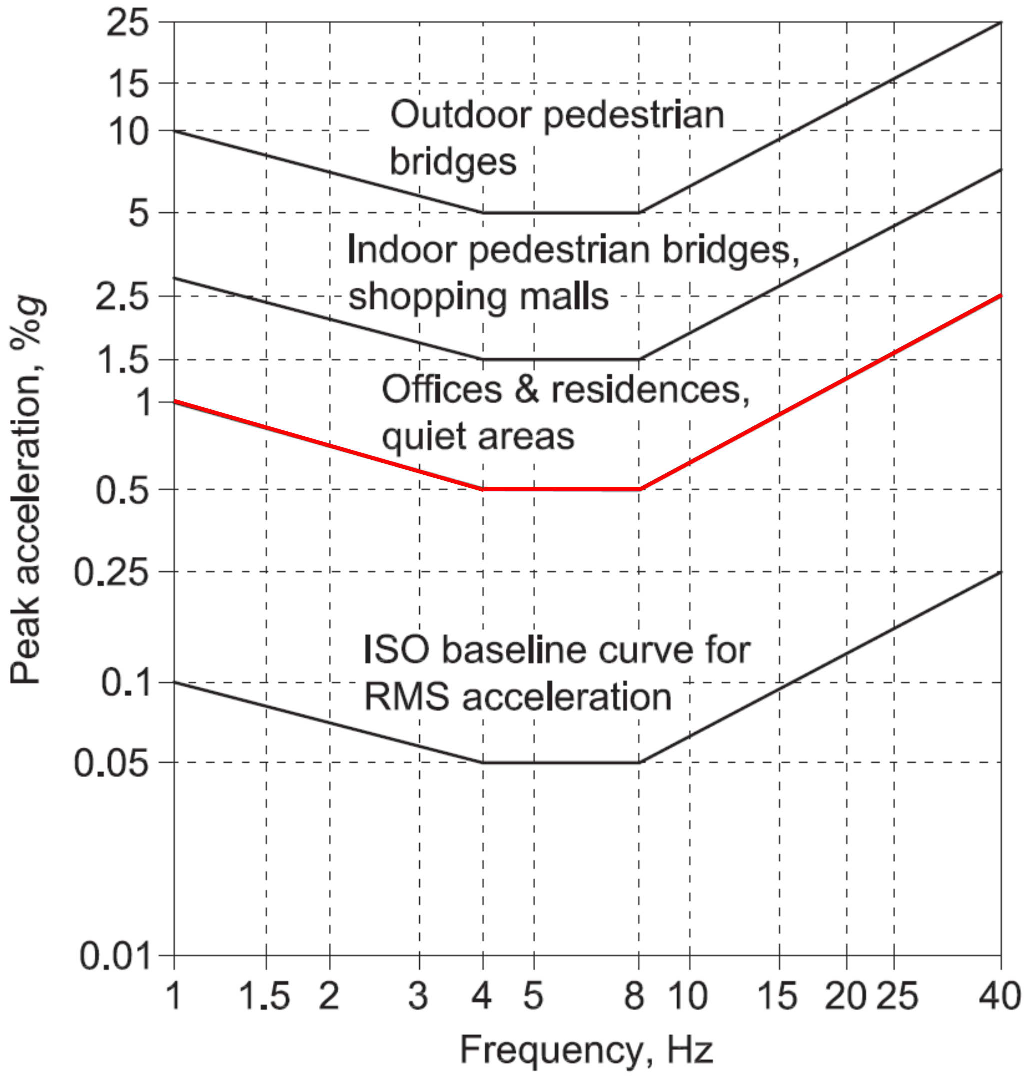
# Conclusions

- 2x3
  - The seated on girder and seated on the angle results were very similar and compared well
  - This compared well with our predicted results
  - More result processing to come
- 6” Deep Deck
  - More tests to come
  - Need to find out how to test bare deck in this set

# Vibration Tests
# for 2x3

# Vibration Tests

- Design Guide 11
- Conducted as each assembly test to understand how components change the natural frequency and acceleration
- Comfort levels in residential buildings



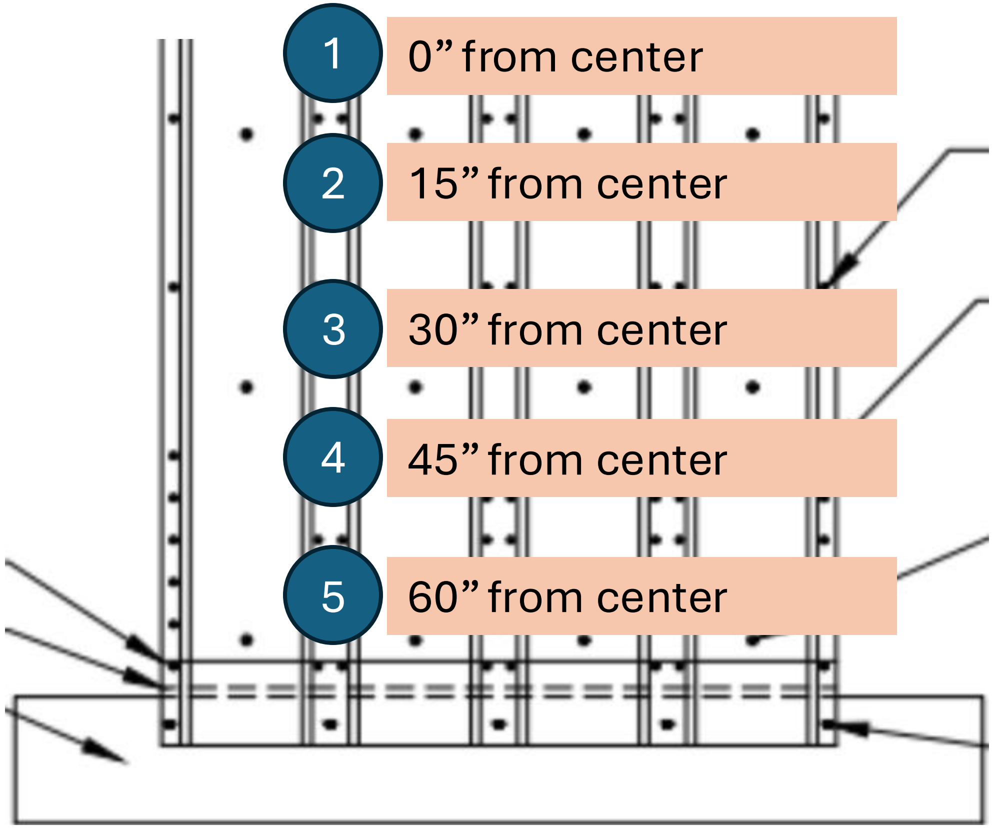
# Vibration Tests

- Ambient
- Bag Drop
- Impact Hammer
- Heel Drop
- Walking Tests
  - 60 BPM
  - 90 BPM
  - 100 BPM
  - 120 BPM
  - Random Walking

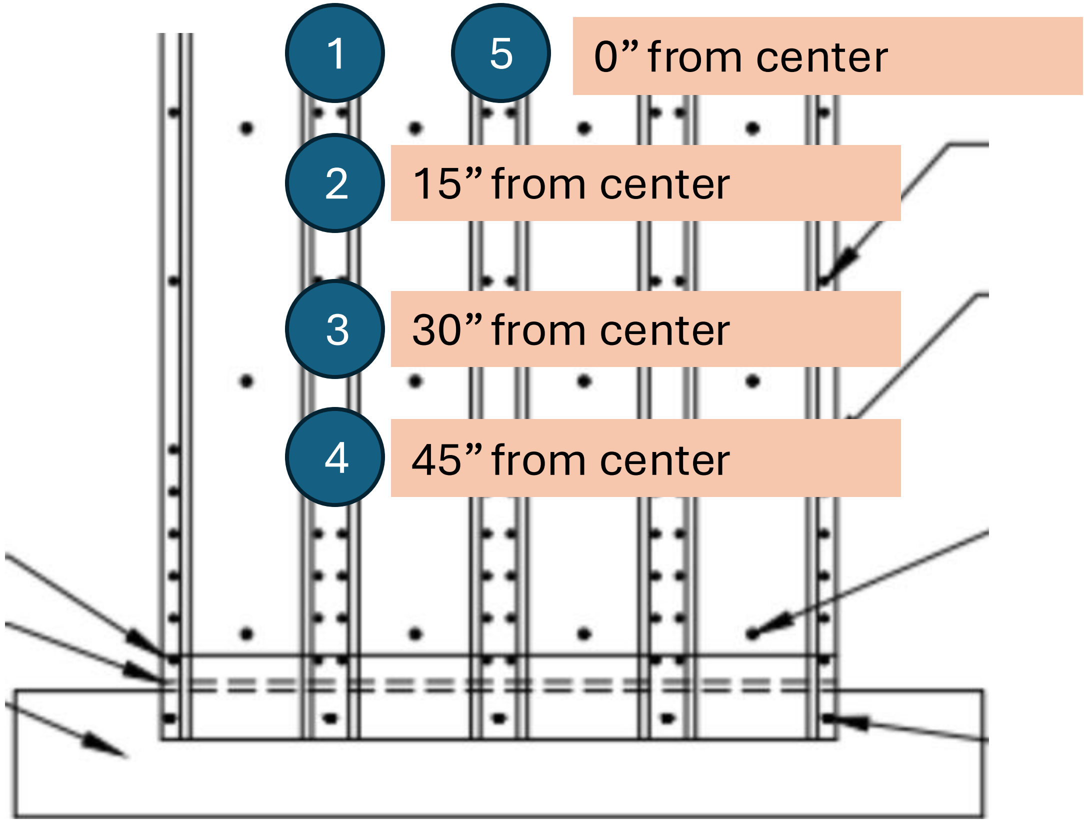


# Accelerometer Setup

### Case 1 (Top of specimen) + Case 2 (Bottom of specimen)

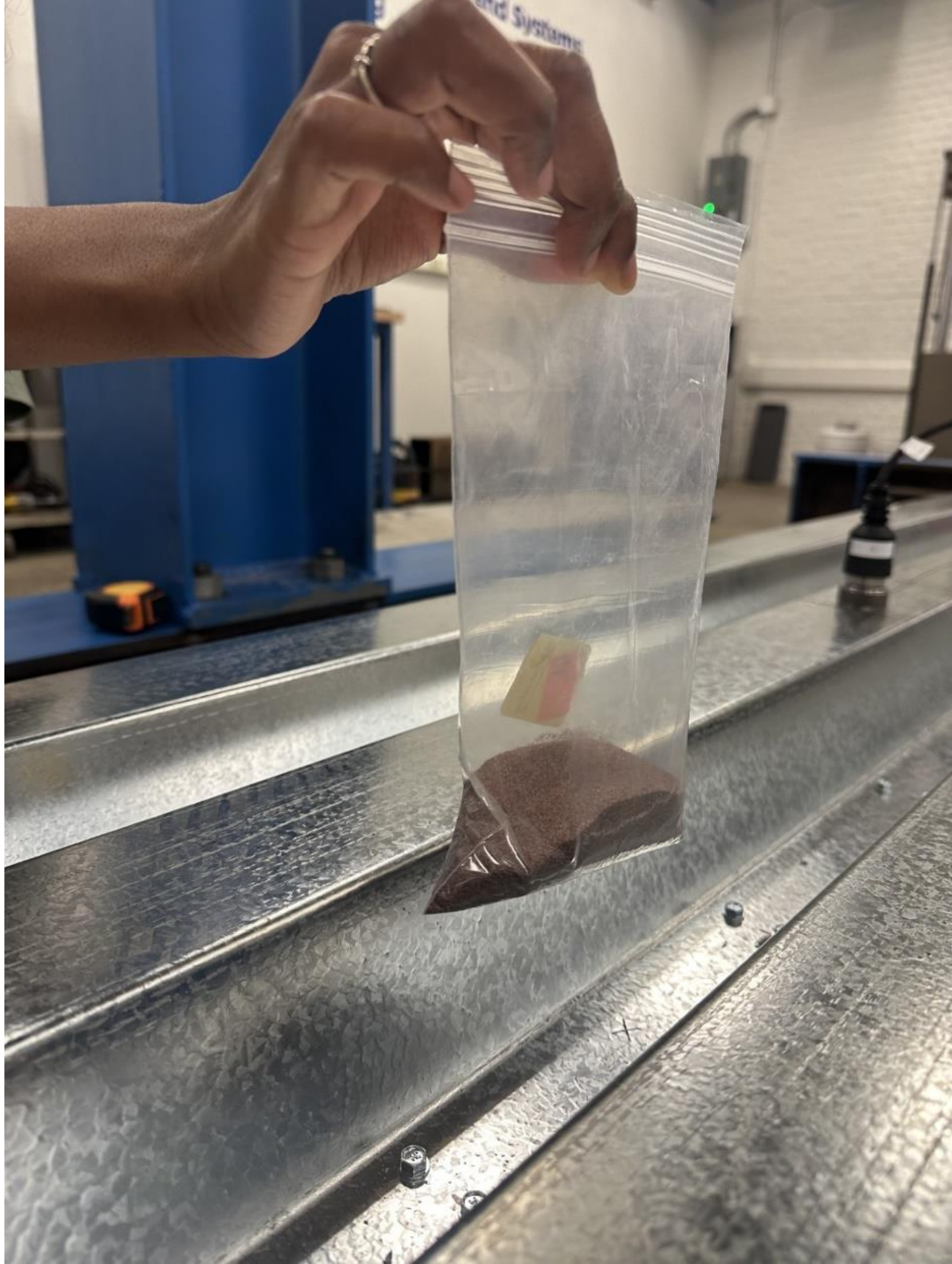



### Case 3 (Top of specimen) + Case 4 (Bottom of specimen)



# Bag Drop

- 250 grams (0.55130 pounds)
- Height" 1.5" above center flute, 18" from center bolt



# Impact Hammer

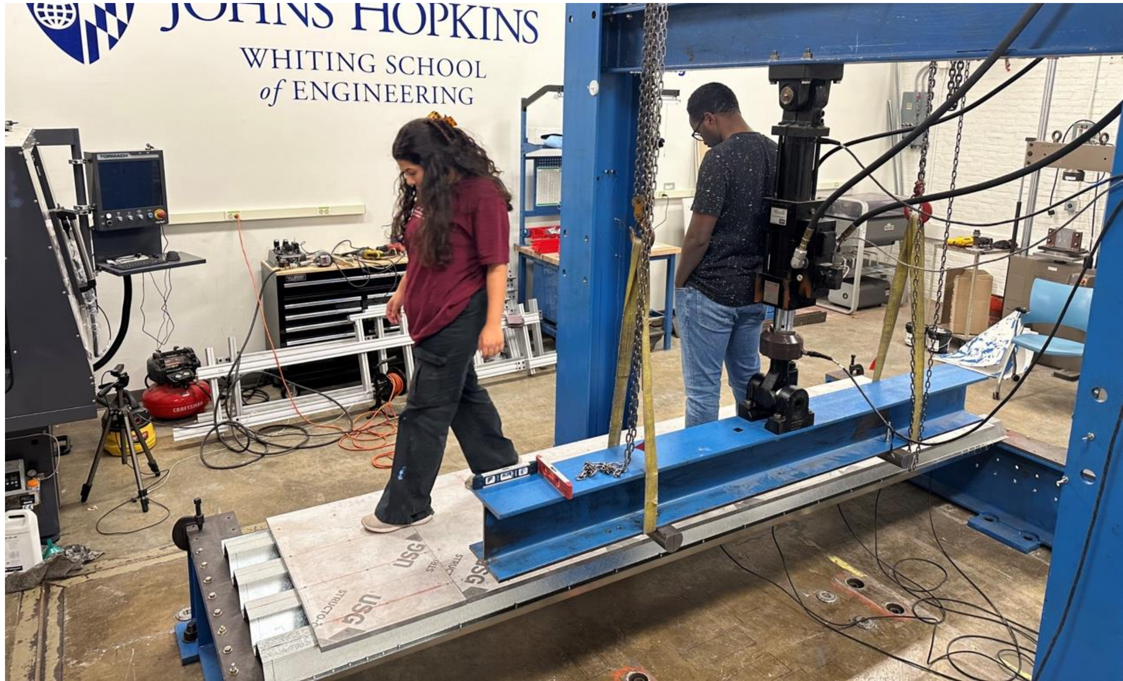
- Tap on left and right of each accelerometer
- Measure both acceleration and force of hammer

# Heel Drop

- Weight: 155 pounds
- Location: Center flute, 3’ from center fasteners

# Walking Test

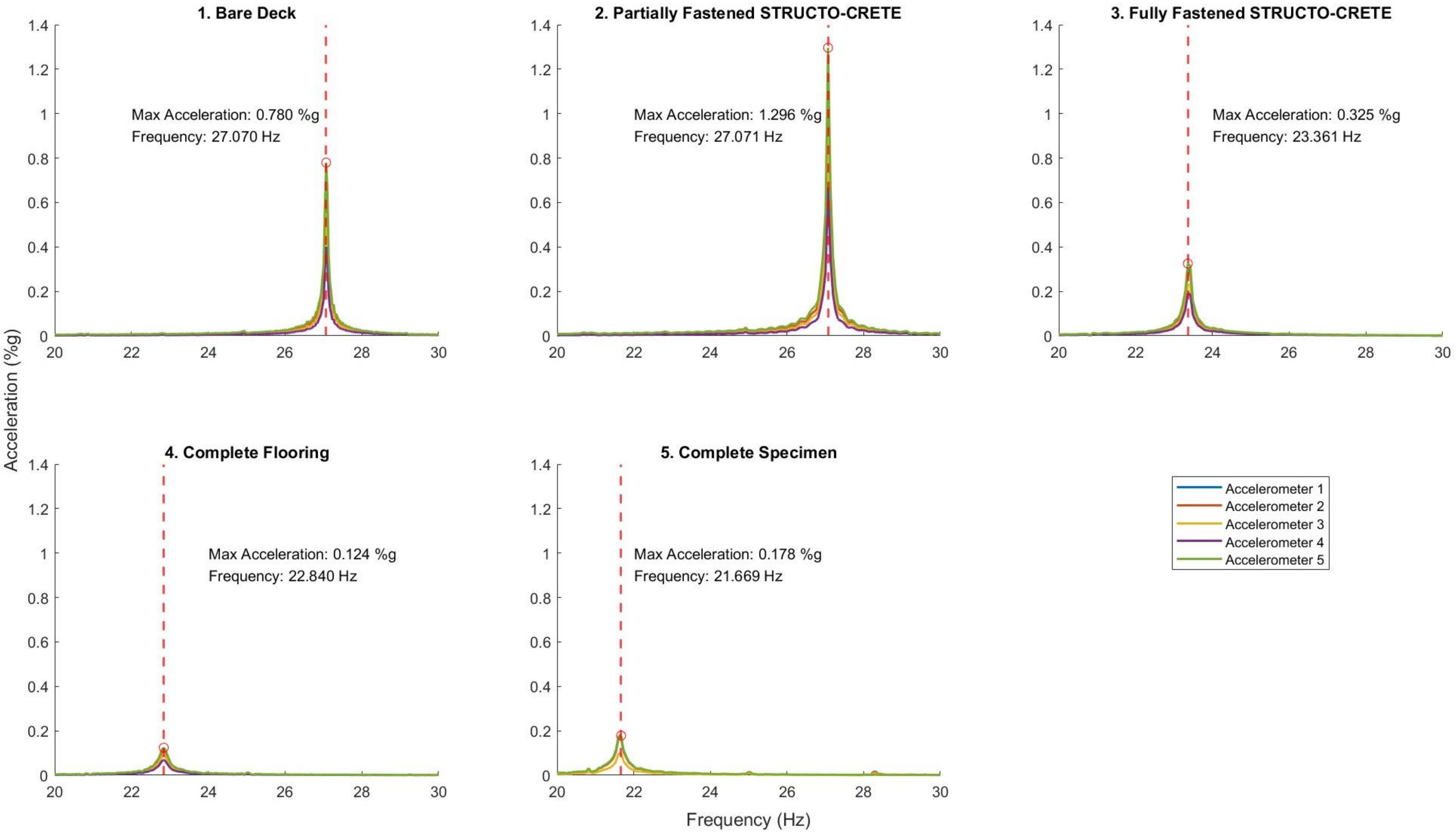
- 60 BMP – 120 BMP
- Random Walking
- Walking + Additional Person
- Weight: 155 (Walker and Additional Person)



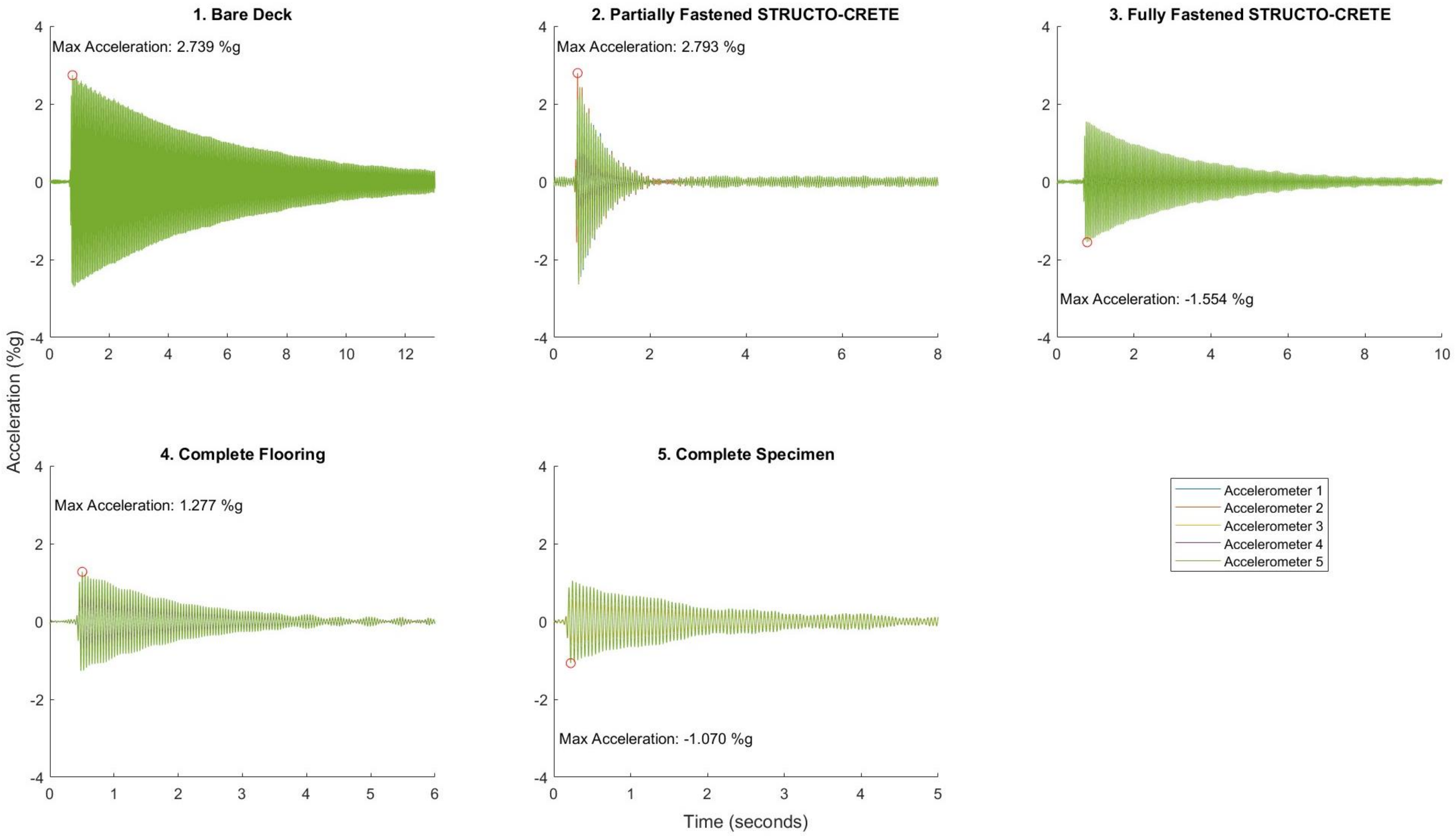
# Test Matrix – Phase 2

| Test | | Specimen Type | Deck Type | Structural panel | Strcutural panel to deck connectors | Nominal Span ft | Actual Span ft | Width in | Testing protocol | End connection | Ceiling and floor assembly |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SG - 2x3 | 1 | Baseline bare specimen on Girder | 2x 3" PLN24 | | | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 2 | Composite specimen on girder | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | No |
| | 3 | Composite specimen on girder with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | Floor Vibration Tests | Seat on Girder | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.71 | 32 | 4-point bending | Seat on Girder | No |
| SA - 2x3 | 1 | Baseline bare specimen on Angle | 2x 3" PLN24 | | | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 2x 3" PLN24 | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests | 2x 3" PLN24 | | | 12 | 11.125 | 32 | 4-point bending | Seat on Angle | No |
| SA - 6 | 1 | Baseline bare specimen on Angle | 6" Deep-Dek | | | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 2 | Composite specimen on Angle | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | No |
| | 3 | Composite specimen on Angle with Finishing | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | Floor Vibration Tests | Seat on Angle | Yes |
| | 4 | Strength Tests - Composite deck-1 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | Yes |
| | 5 | Strength Tests - Composite deck-2 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 6 | Strength Tests - Composite deck-3 | 6" Deep-Dek | 3/4" Stroctocrete | #8 Grabber @ 12" o.c. | 12 | 11.125 | 36 | 4-point bending | Seat on Angle | No |
| | 7 | Strength Tests | 6" Deep-Dek | | | 12 | 11.125 | 24 | 4-point bending | Seat on Angle | No |

# Vibration Results – FFT (Bag Drop)



# Vibration Results – Acceleration v Time (Bag Drop)



# Conclusions

- All pass peak allowable acceleration so far
- More filtering to acceleration data will done
- Comparisons with Design Guide 11 will be done as well

# Acknowledgements

JOHNS HOPKINS UNIVERSITY

Thin-Walled Structures Group

# “Push-out Tests”

## Shear Response of Panels-to-Steel-Deck Fasteners

H.L. Caswell V, S. Torabian, B.W. Schafer

AISC-SDI Workshop

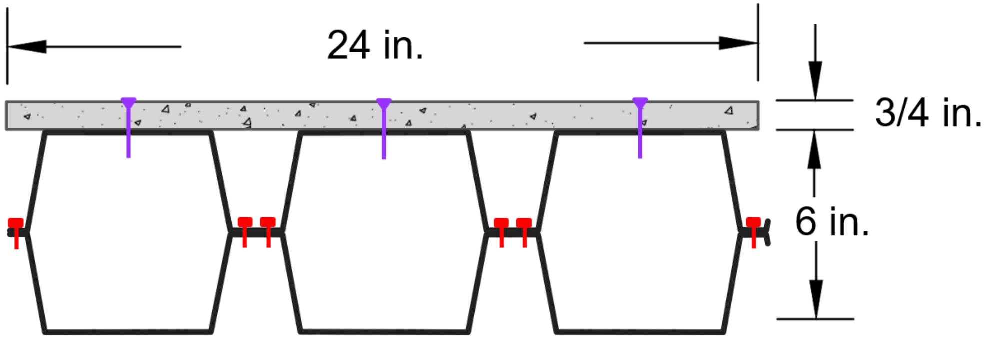
3 December 2024

NEED FOR SPEED

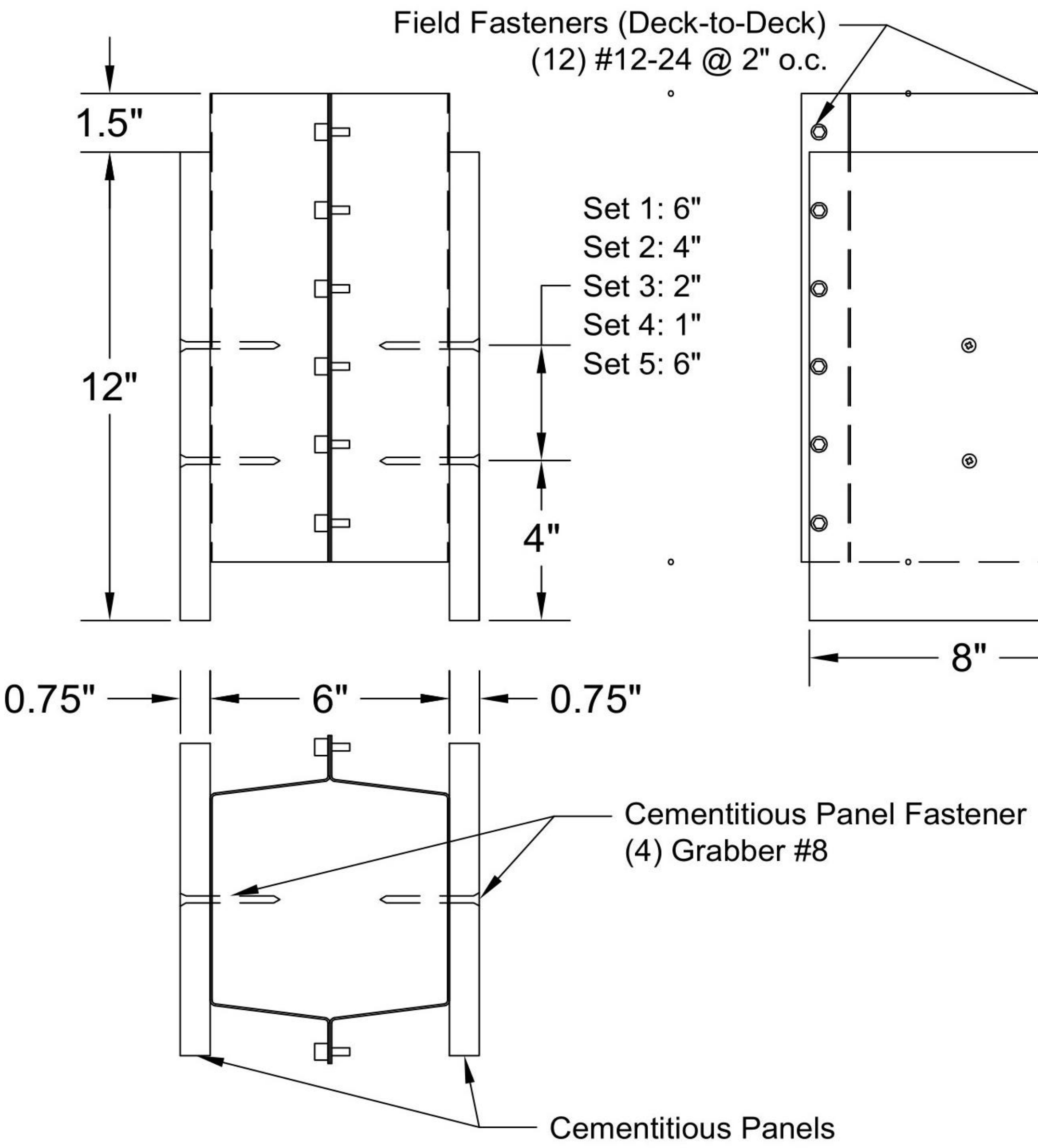
AMERICAN INSTITUTE OF STEEL CONSTRUCTION AISC FOUNDED 1921

STEEL DECK INSTITUTE sdi

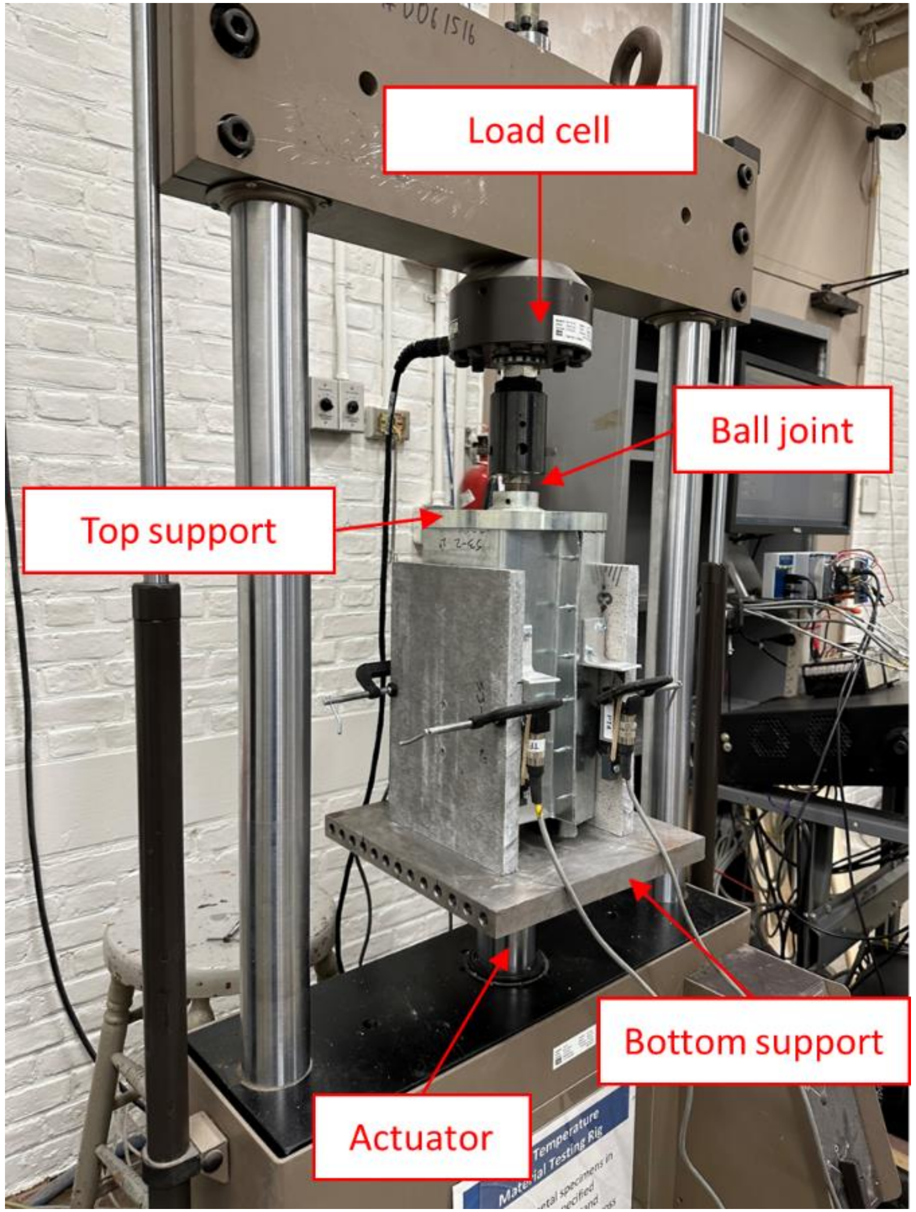
# Background and Motivation


# Test Setup



Field Fasteners (Deck-to-Deck)
(12) #12-24 @ 2" o.c.
1.5"
12"
Set 1: 6"
Set 2: 4"
Set 3: 2"
Set 4: 1"
Set 5: 6"
4"
8"
0.75"
6"
0.75"
Cementitious Panel Fastener
(4) Grabber #8
Cementitious Panels

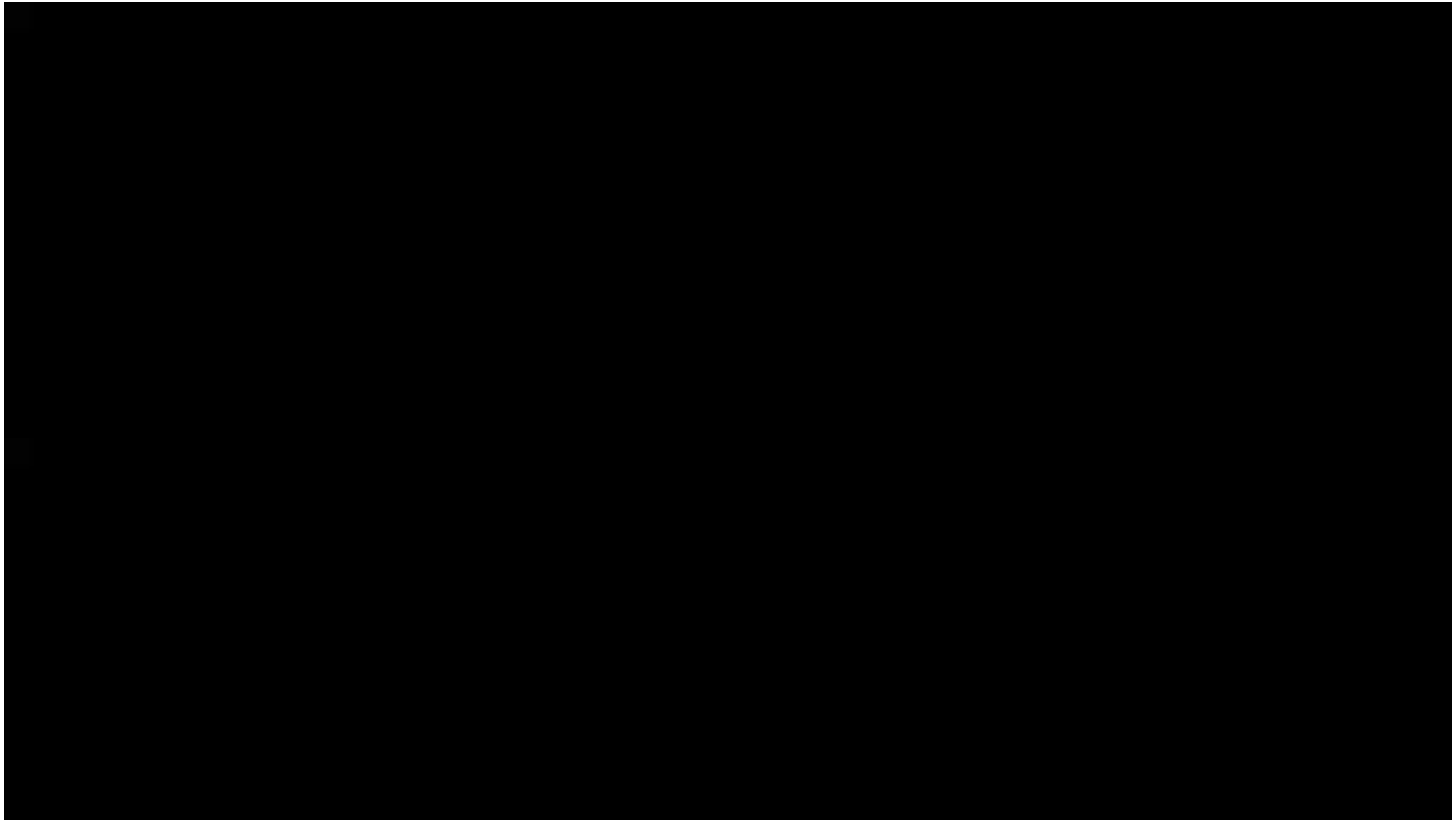



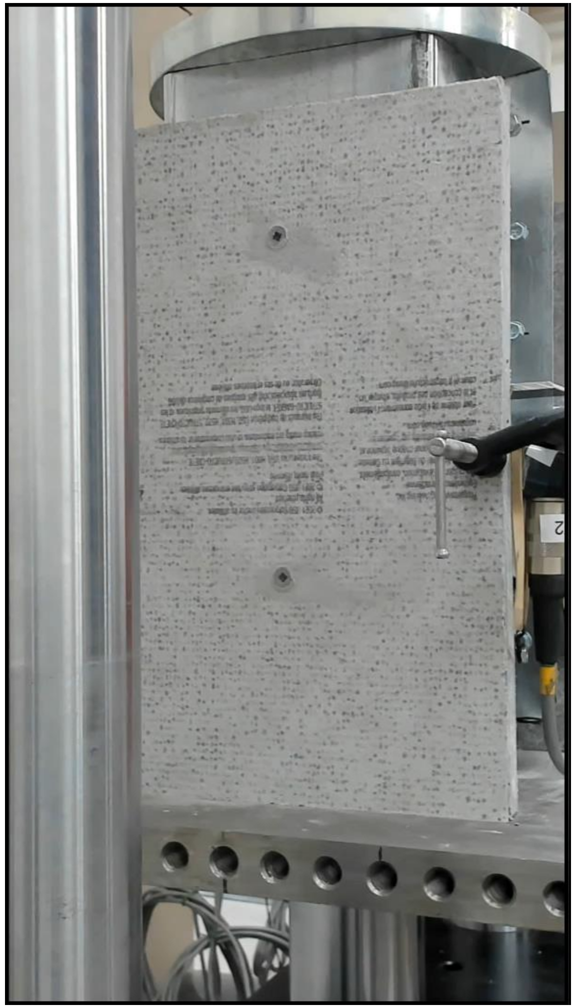
Load cell
Ball joint
Top support
Bottom support
Actuator

# Test Matrix

| Name | Grabber Fastener Spacing (in.) | Overdriven Depth (in.) | Quantity (#) |
|---|---|---|---|
| Set 1 | 6 | -- | 7 |
| Set 2 | 4 | -- | 7 |
| Set 3 | 2 | -- | 7 |
| Set 4 | 1 | -- | 7 |
| Set 5 | 6 | 1/16 | 7 |

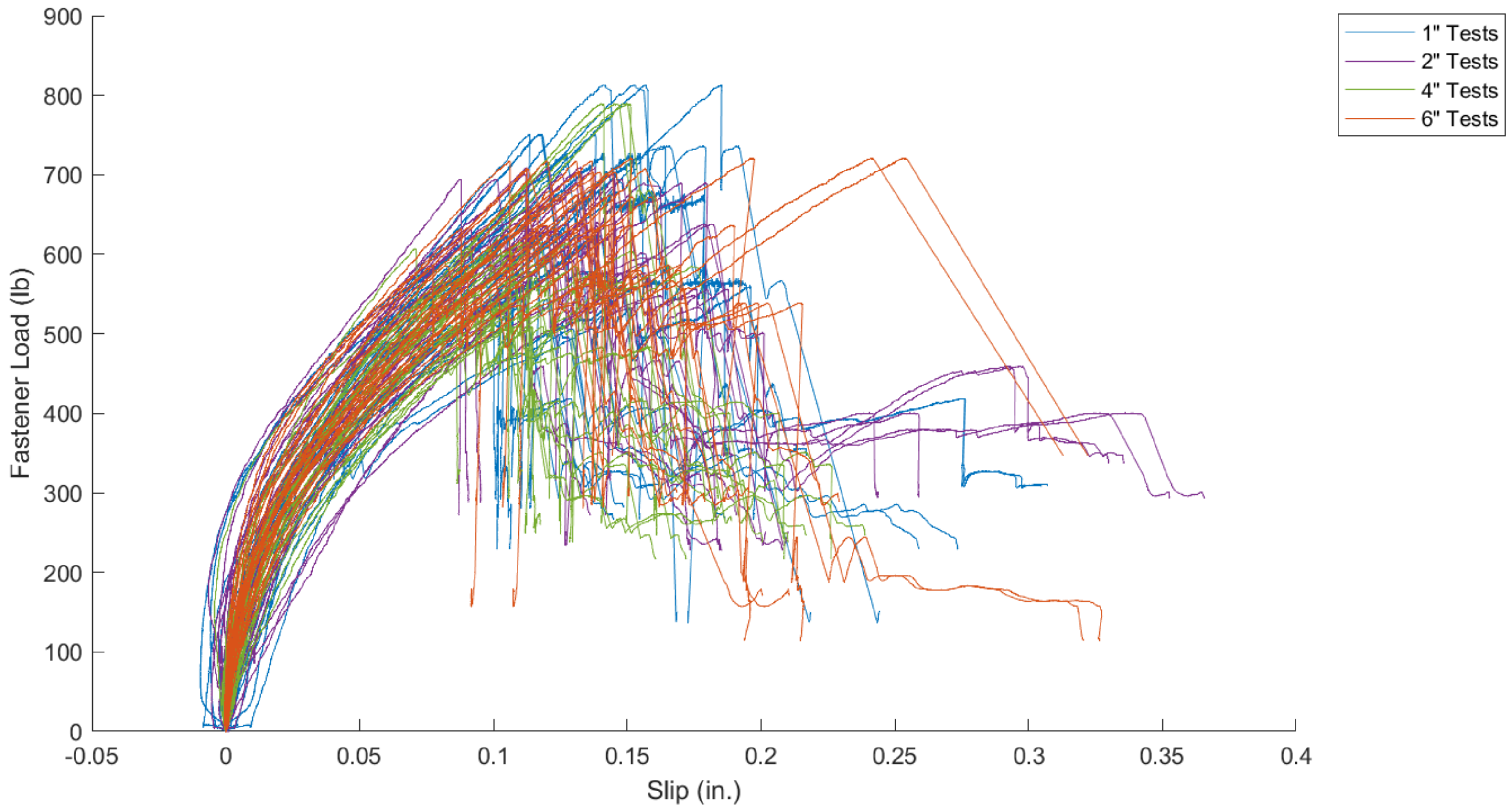
# Test Video





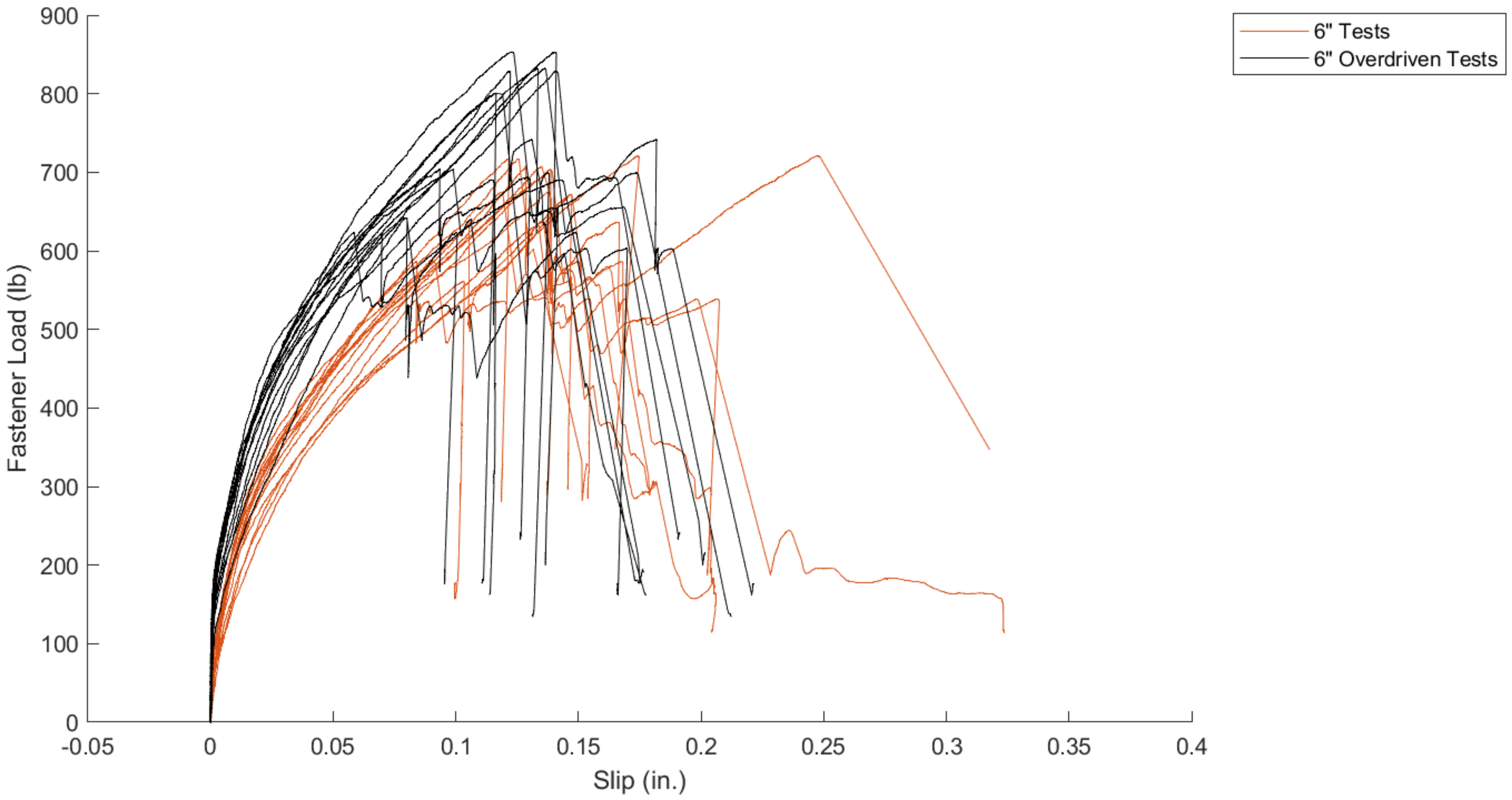
220VAC
TF2


# Test Results



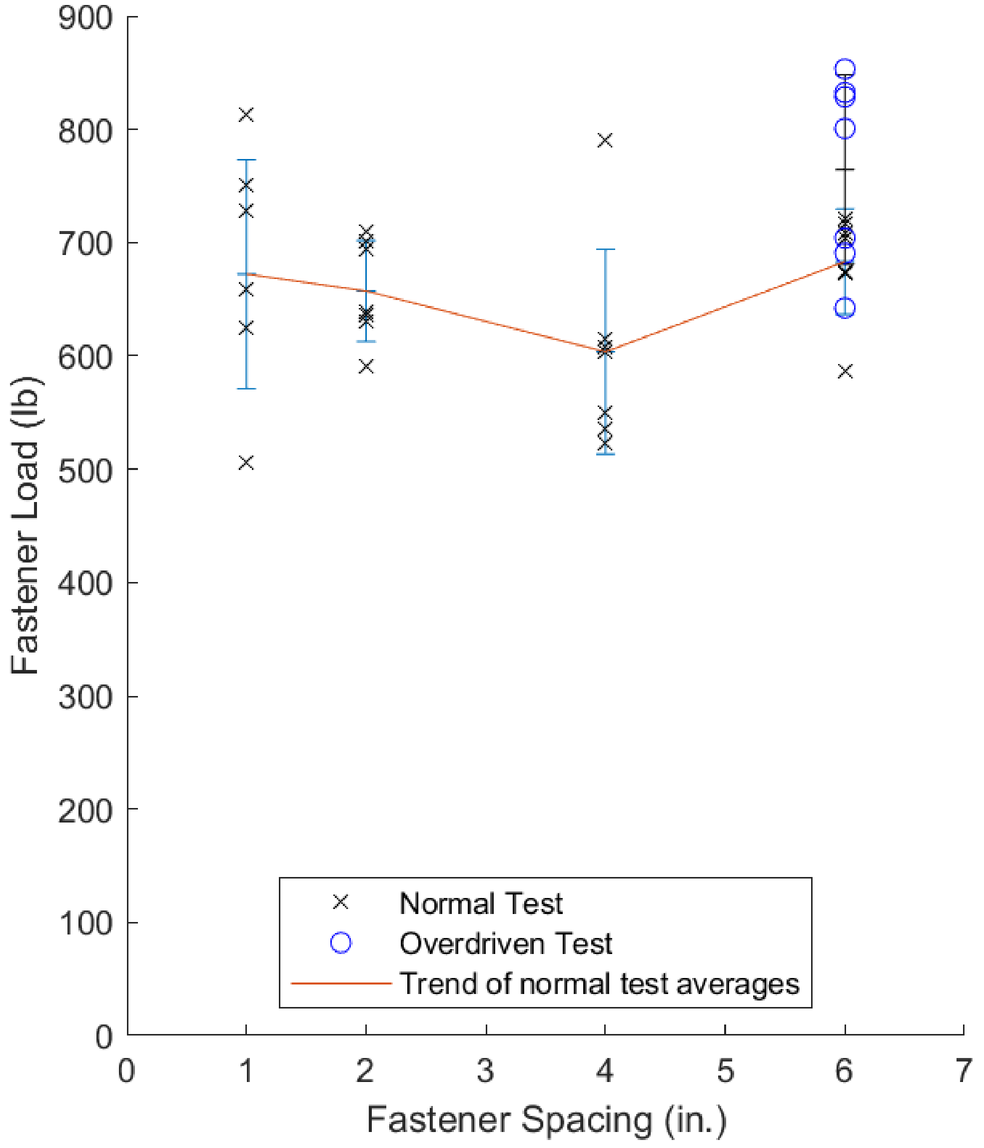

Averaged panel-deck slip for different fasteners spacings

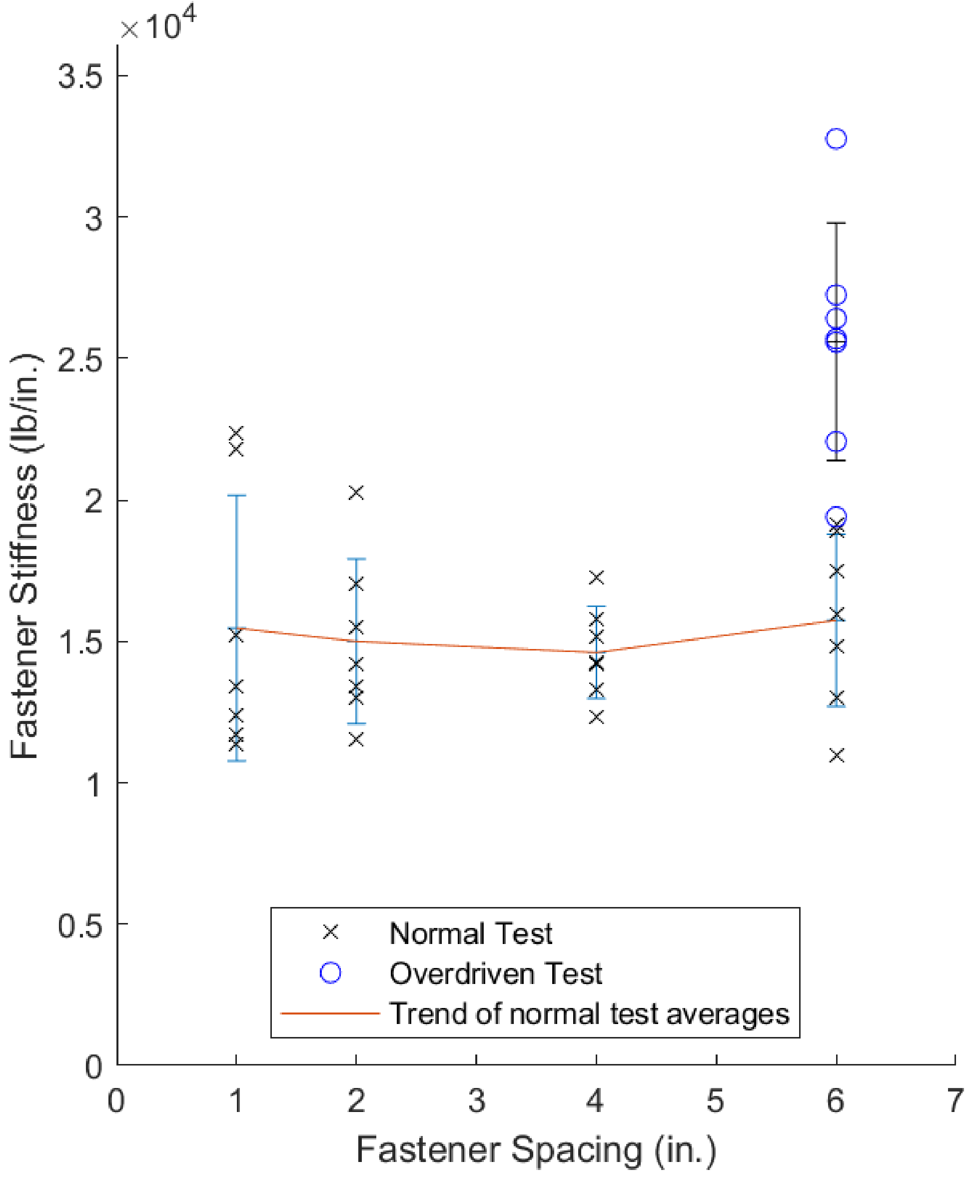
# Test Results




Load-displacement response of set-5 overdriven with set-1

# Test Results



# Summary of Results

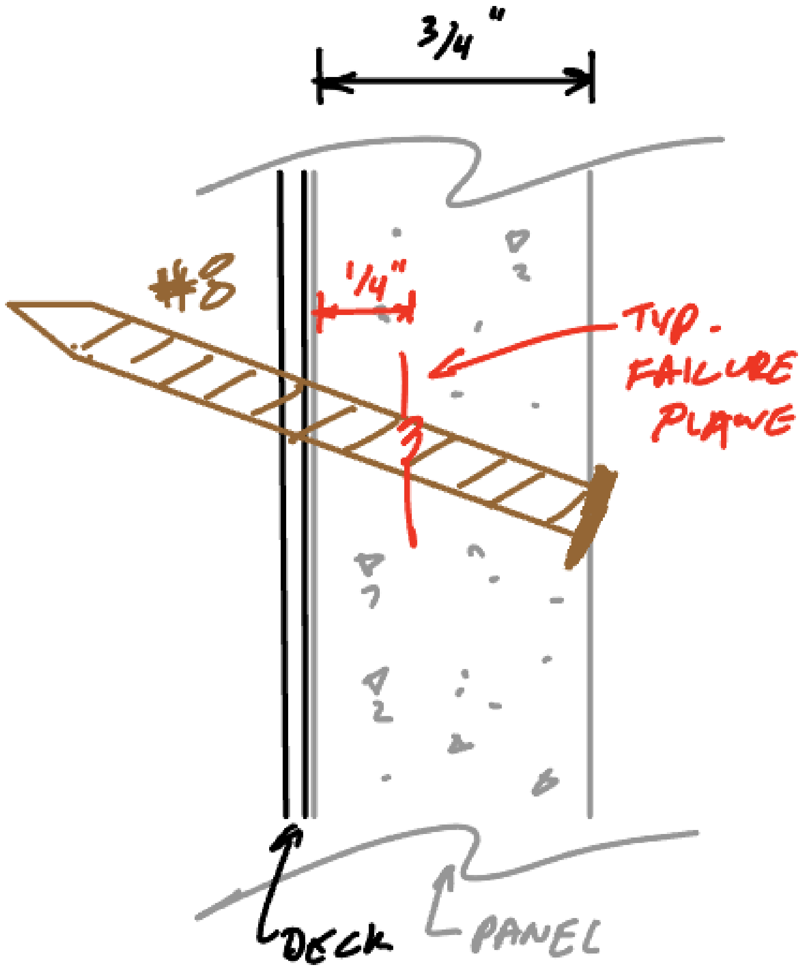
Summary of Strength and stiffness for each set of tests

| Fastener Spacings | Average Ultimate Load (lb) | Average Stiffness at 40% Ultimate Load (kip/in.) |
|---|---|---|
| 6 in. Spacing | 672.3 [1.00] * | 15.5 [1.00] |
| 4 in. Spacing | 657.3 [0.97] | 15.0 [0.97] |
| 2 in. Spacing | 603.6 [0.90] | 14.6 [0.94] |
| 1 in. Spacing | 683.3 [1.02] | 15.7 [1.01] |
| 6 in. Spacing Overdriven | 703.9 [1.05] | 25.6 [1.65] |

*Bracketed numbers are a ratio of the value shown to the equivalent 6 in. spacing value

# Discussion

- No trend with fastener spacing
- Over-driving is not problematic
- Average shear capacity: 655 lb per screw.
- Reported nominal shear capacity: 1045 lb.



# FastFloor R - $f_c'$

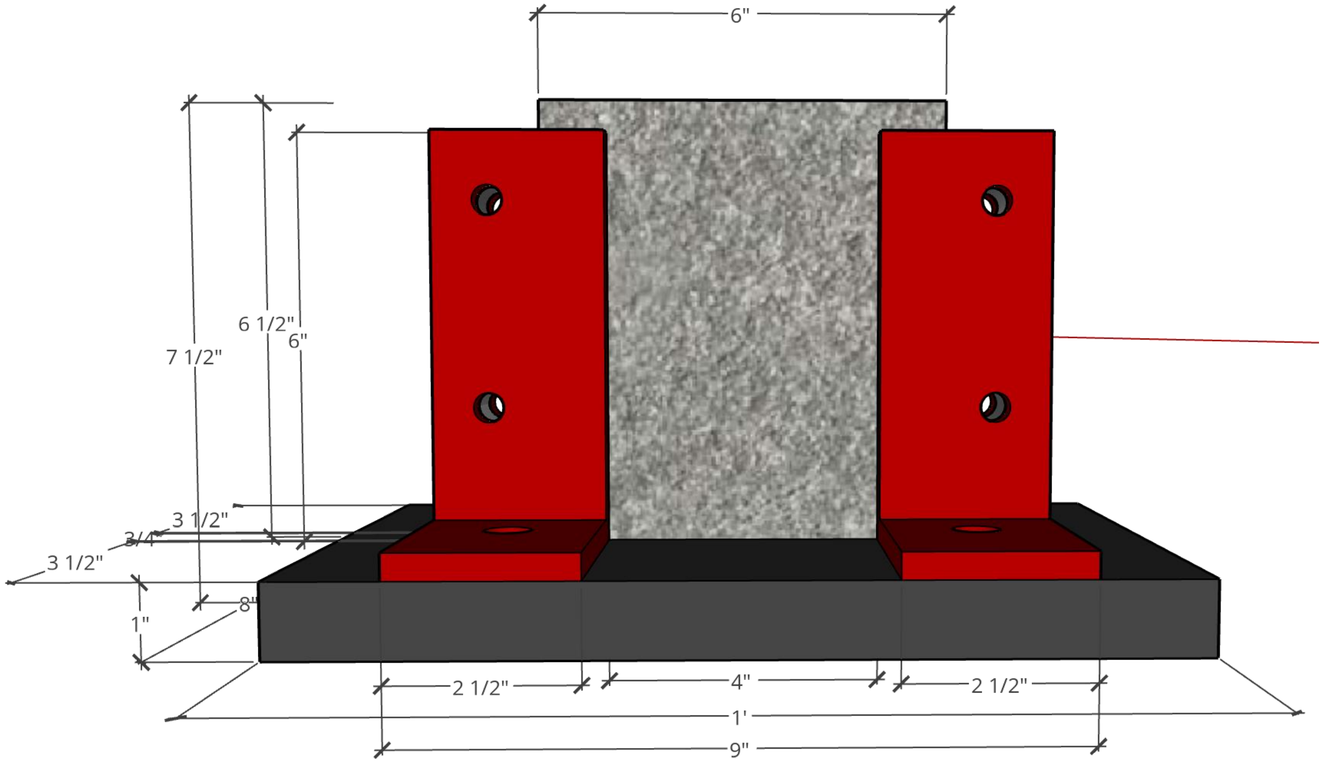
AISC-SDI Workshop

3 December 2024

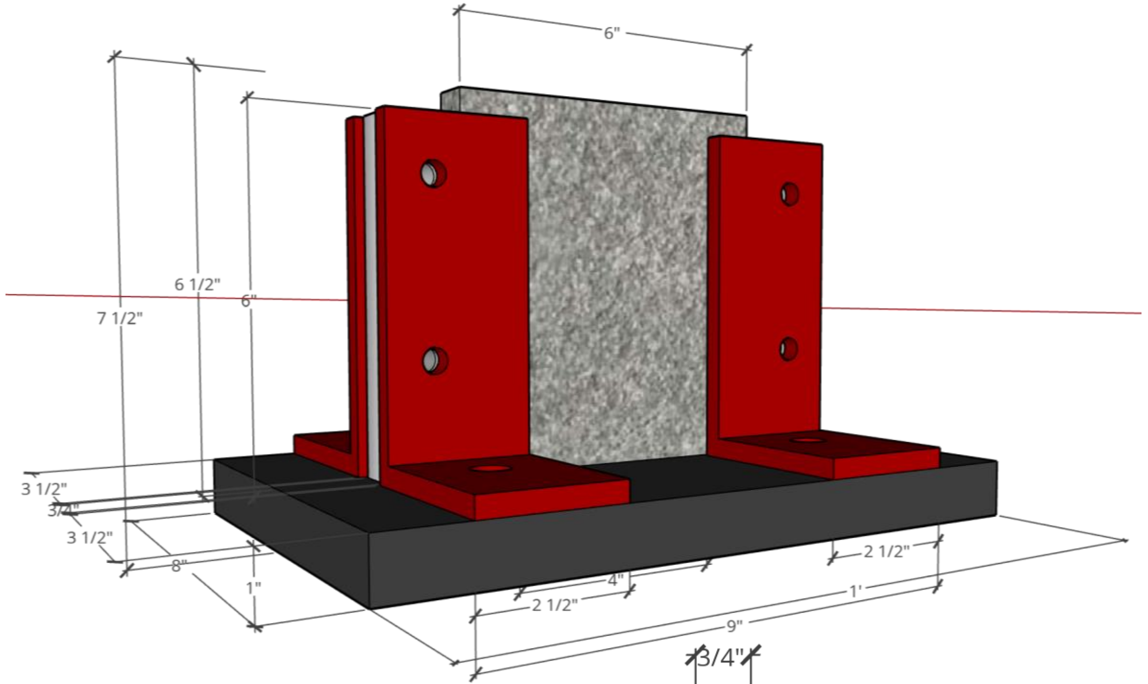
# Motivation

- STRUCTOCRETE is in compression in bending test
- Need to know strength to fully understand composite specimen
- Looking for $f_c'$
- ASTM doesn't currently have a standard test

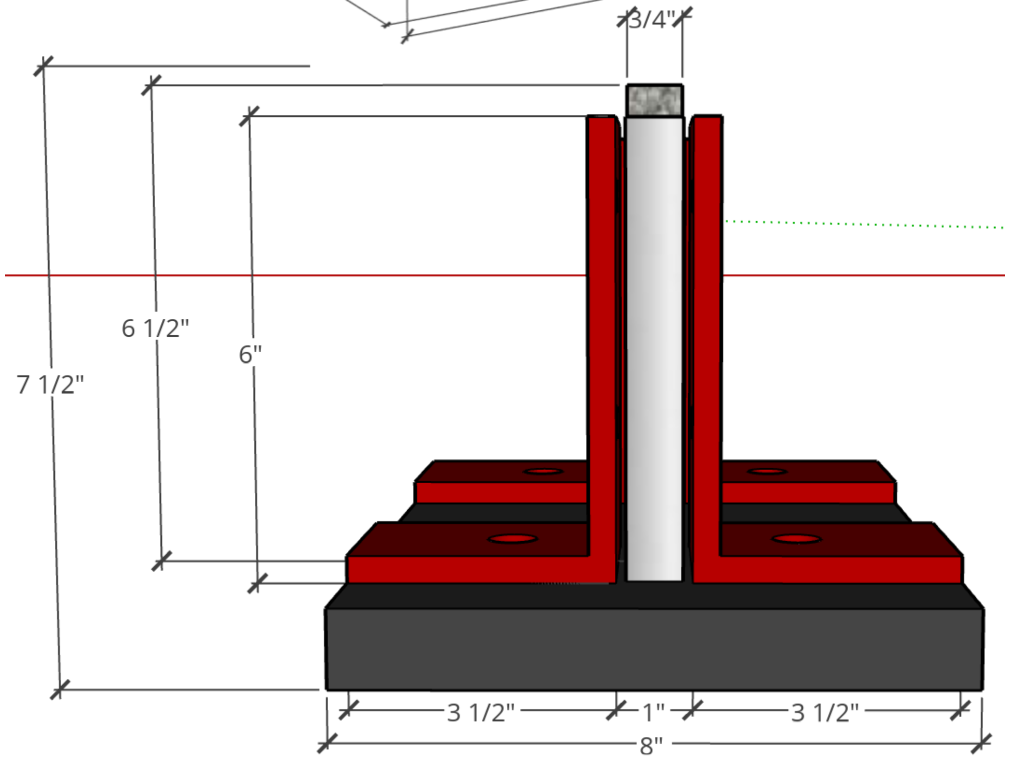
# Drawings



6"
7 1/2"
6 1/2"
6"
3 1/2"
3/4"
3 1/2"
8"
1"
2 1/2"
4"
2 1/2"
1'
9"

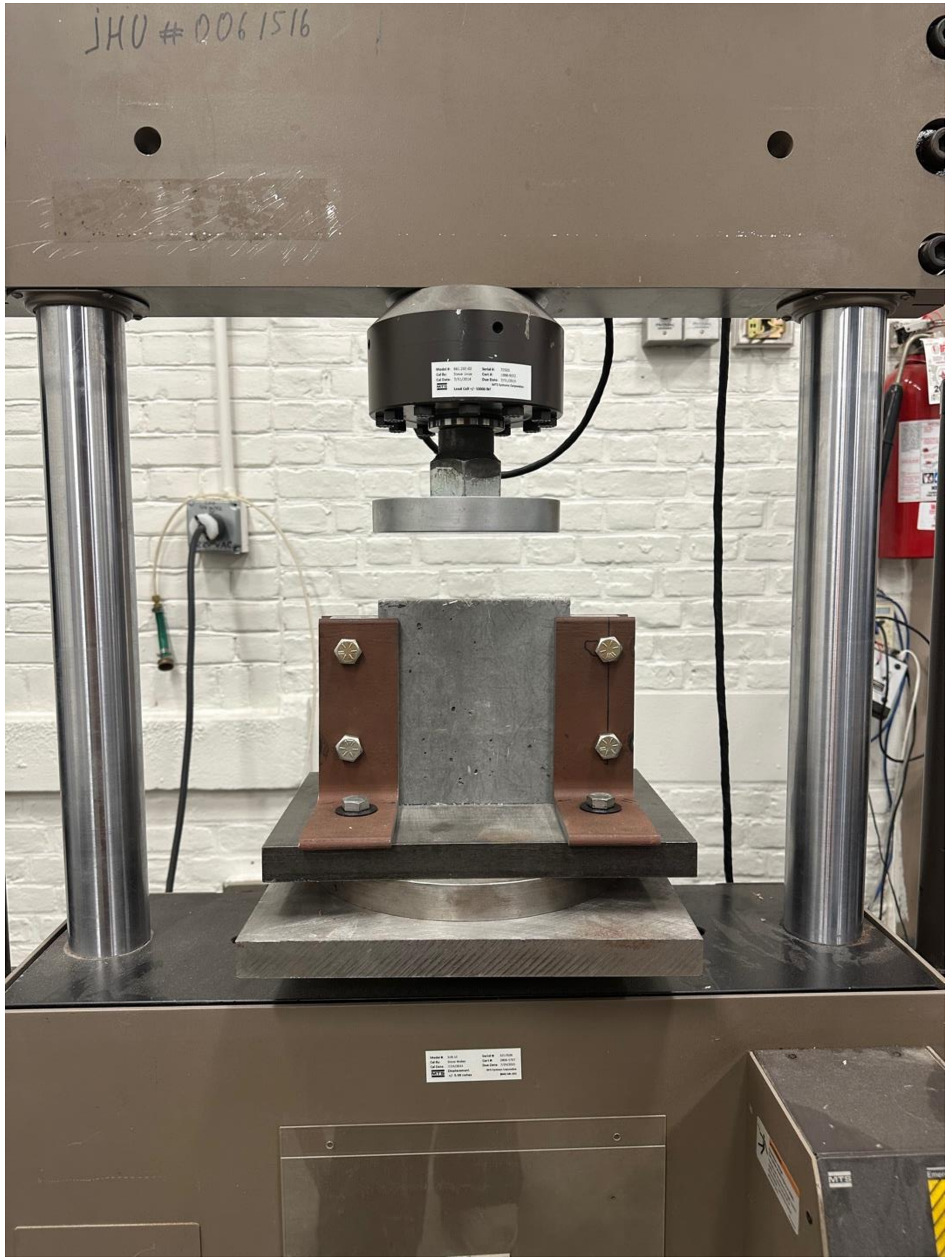



6"
6 1/2"
6"
7 1/2"
3 1/2"
3/4"
3 1/2"
8"
1"
4"
2 1/2"
2 1/2"
1'
9"

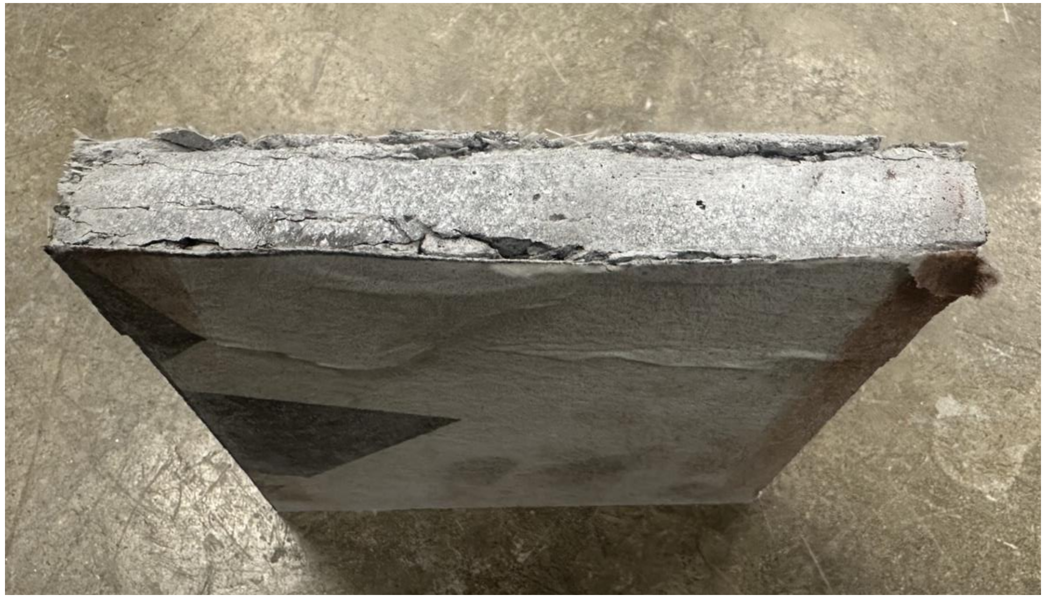
3/4"
6 1/2"
6"
7 1/2"
3 1/2"
1"
3 1/2"
8"

# Setup




# To Date

- Using DIC paint to measure strain during test
- Testing to come…



# FAST FLOOR RESIDENTIAL

## Gravity Design


**Shahab Torabian, PhD, SE, PE**

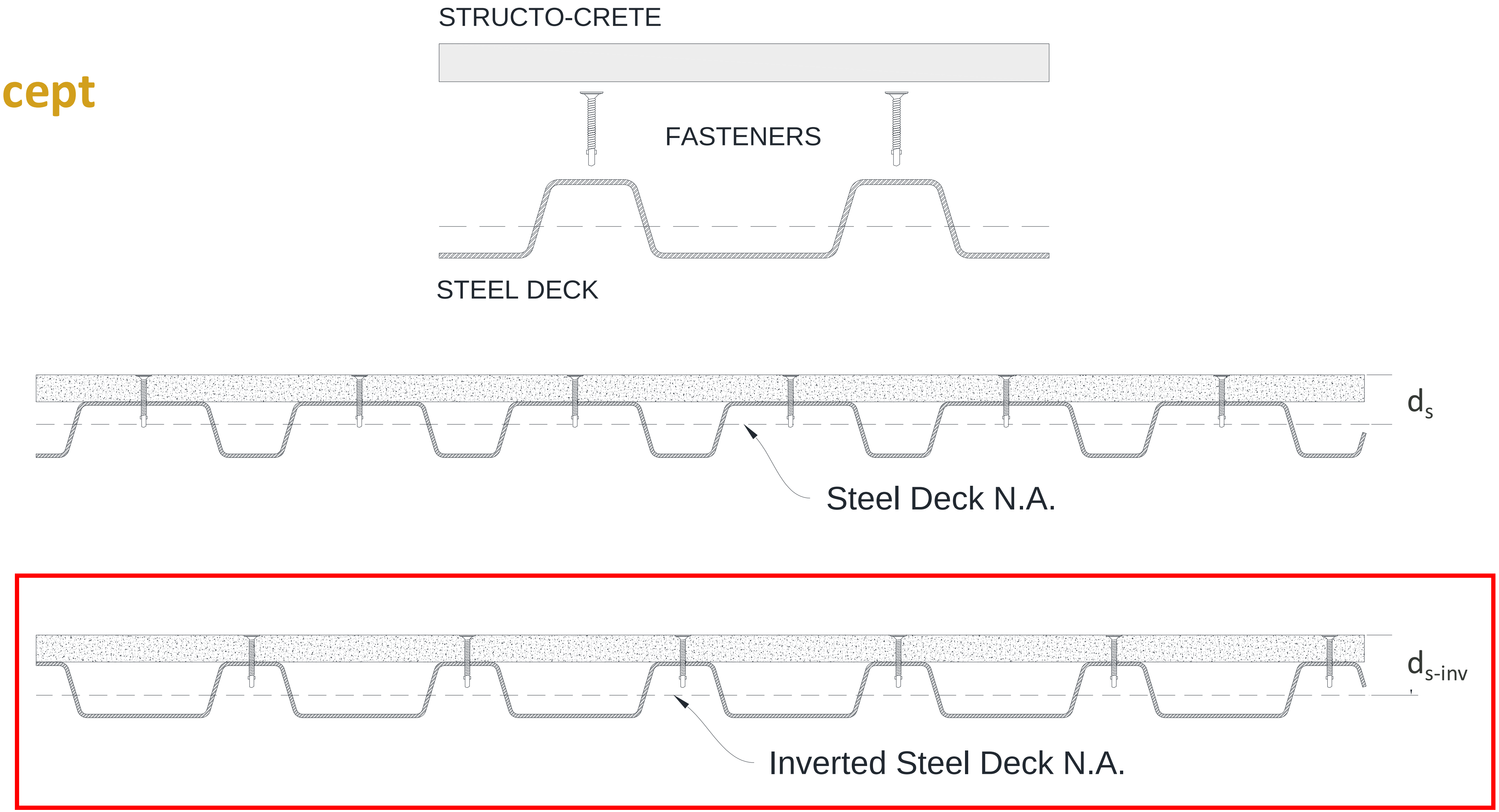
Senior Project Manager/Associate Research Scientist


03.12.2024

# Outline

- Introduction
- Gravity Design
  - Design Method
  - Design Method Validation
  - Span Charts
- Modular Ideas
- Next Steps

## Concept


STRUCTO-CRETE
FASTENERS
STEEL DECK
$d_s$
Steel Deck N.A.
$d_{s\text{-}inv}$
Inverted Steel Deck N.A.

## Allowable Stress Design (ASD)

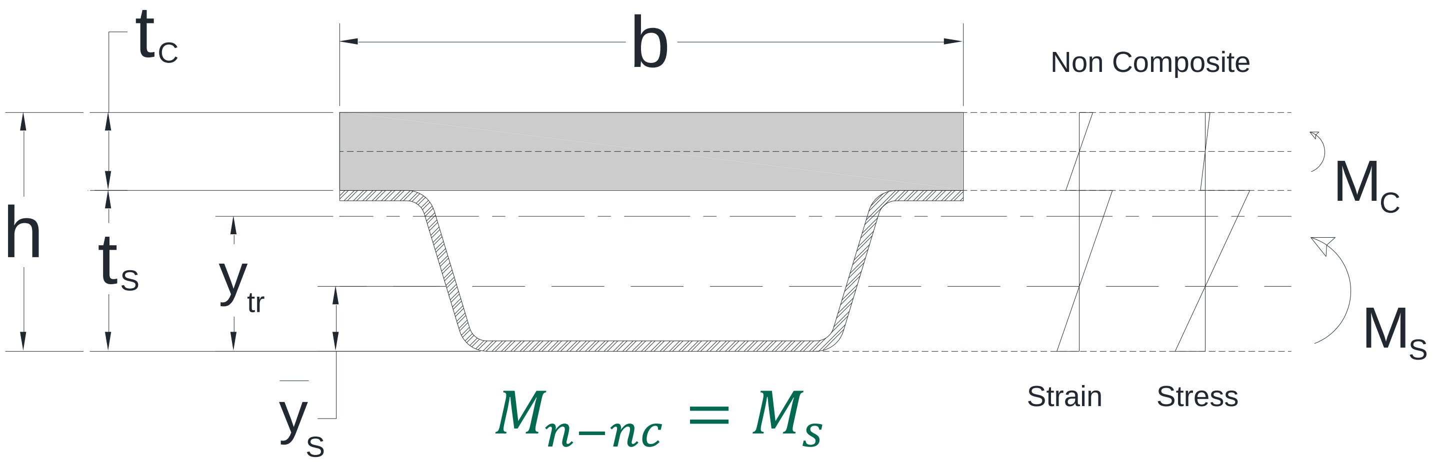
Limit states considered:

- Bending
- Deflection
- Shear
- Web crippling
- Combined shear and bending
- Combined bending and web crippling

Note: Vibration is not included.

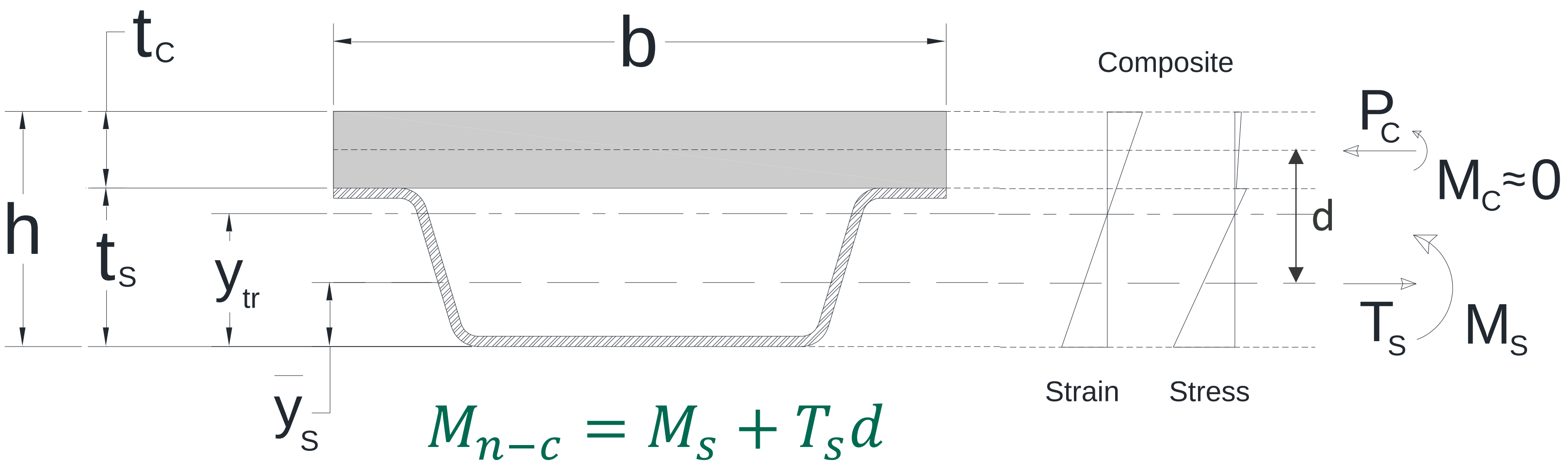
# Bending

Non-Composite




$$M_{n-nc} = M_s$$

Fully-Composite




$$M_{n-c} = M_s + T_s d$$

**Bending**

- Non-composite ($M_{n\text{-}nc}$): $M_{n\text{-}nc} = M_{steel}$
- Fully-composite ($M_{n\text{-}c}$): $M_{n\text{-}c}$ is taken as the flexural capacities determined by:
  - Direct Strength Method on elastic transformed section with no fastener failure
- Semi-composite ($M_n$):

$$M_n = M_{n-nc} + R_{sc}\left(M_{n-c} - M_{n-nc}\right)$$

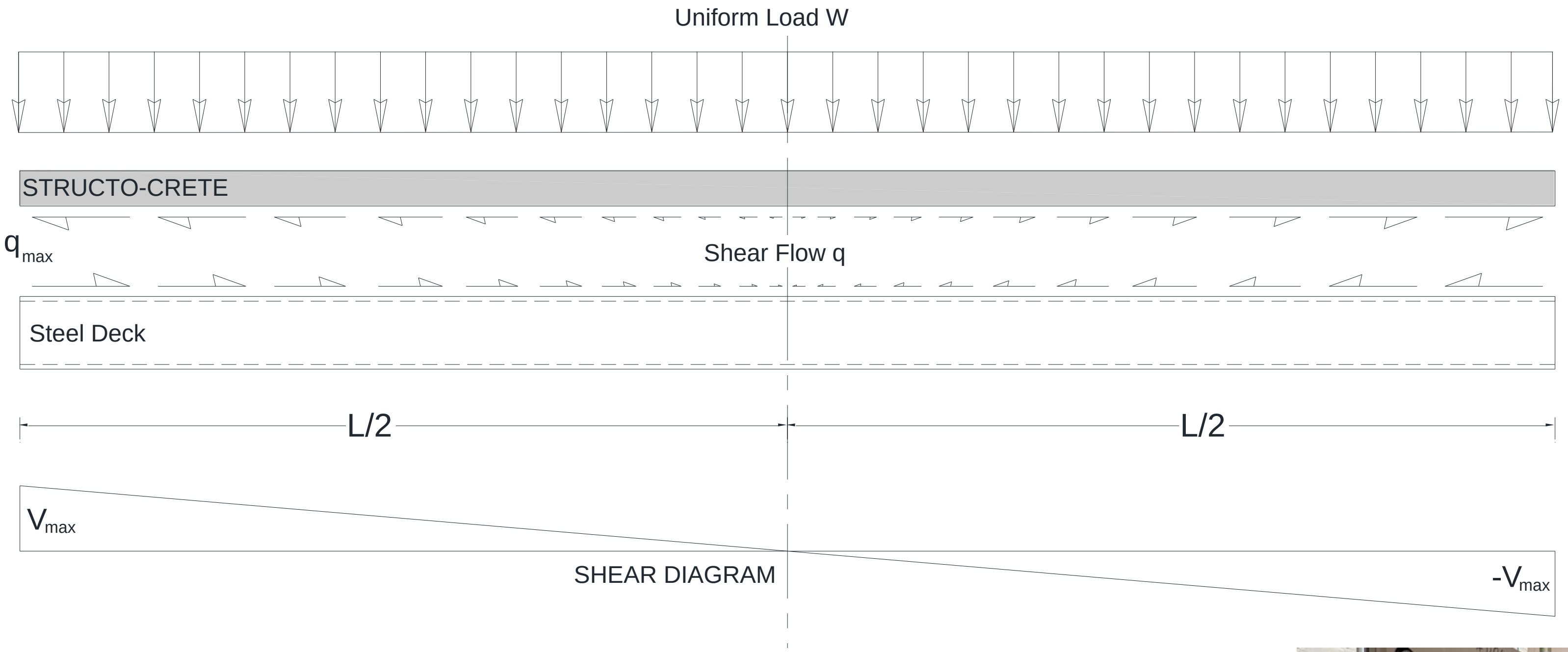
$$R_{sc} = \frac{S_f}{S_t} \leq 1.0$$

$S_f$ is the total fastener capacity along the half-span of the beam

The total horizontal shear, $S_t$, applied on one side of the beam

- Negative moment: Equal to bare deck; Structo-Crete is assumed to crack and therefore provide no additional negative moment strength

# Design Method: Fastener Yielding Model




Typical fastener failure shows fasteners reach ultimate shear capacity

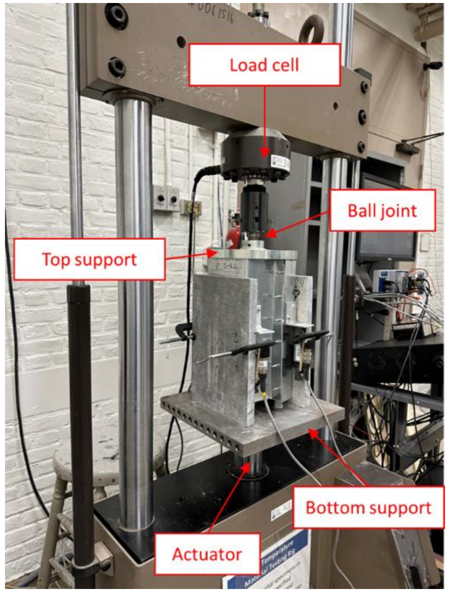
$$q_{max} = \frac{V_{max} Q_{tr}}{I_{tr}}$$

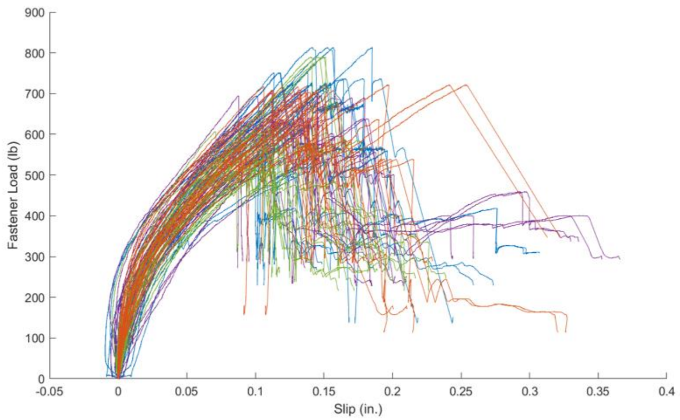
$$S_t = \frac{q_{max} L}{4}$$

$$R_{sc} = \frac{S_f}{S_t} \leq 1.0$$

**$S_t$ Total fastener shear demand:** Integration of shear flow over the half-length=Area under shear flow

**$S_f$ Total fastener capacity:** Sum of fastener shear capacity over the half-length of the beam



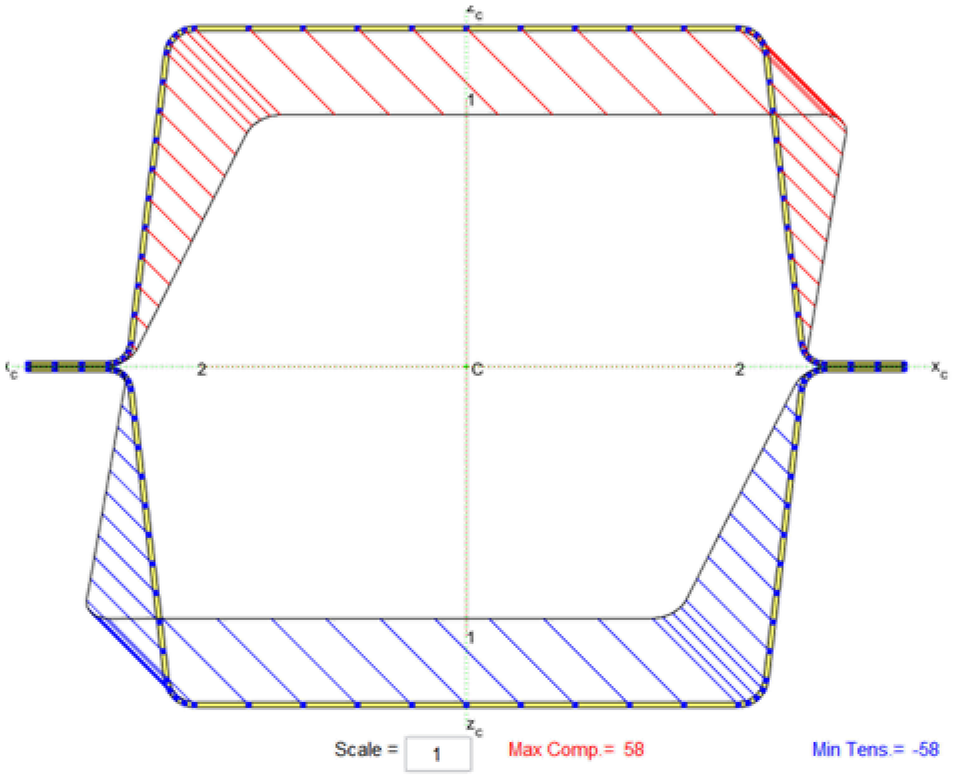



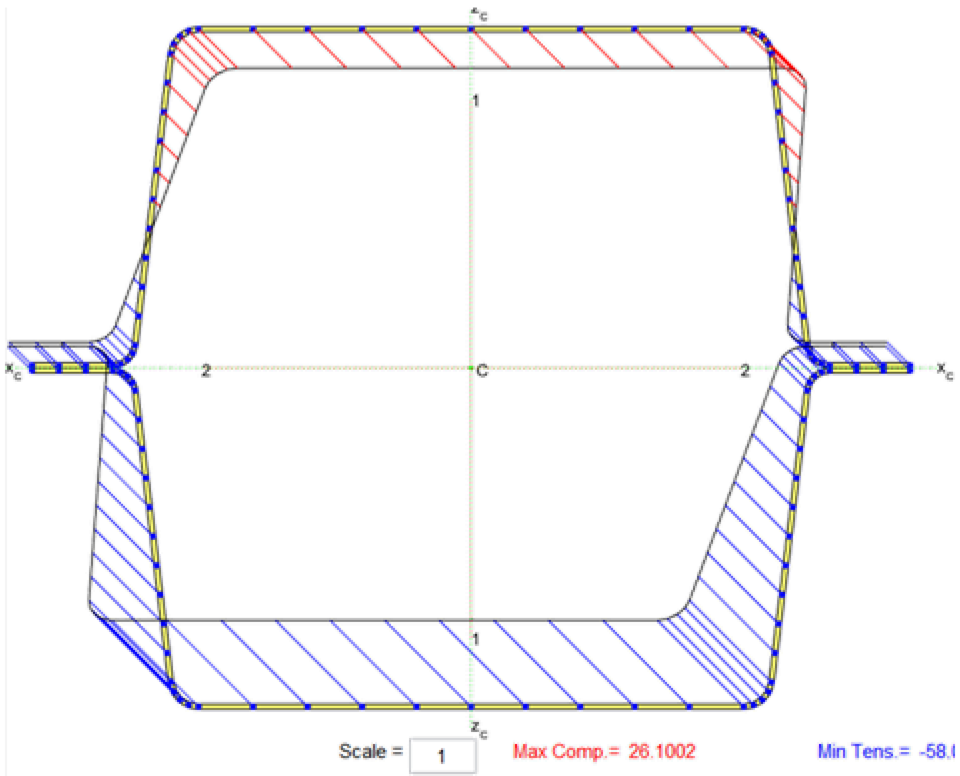
# Bending

-58 ksi

Reduction in compressive stress

-26 ksi

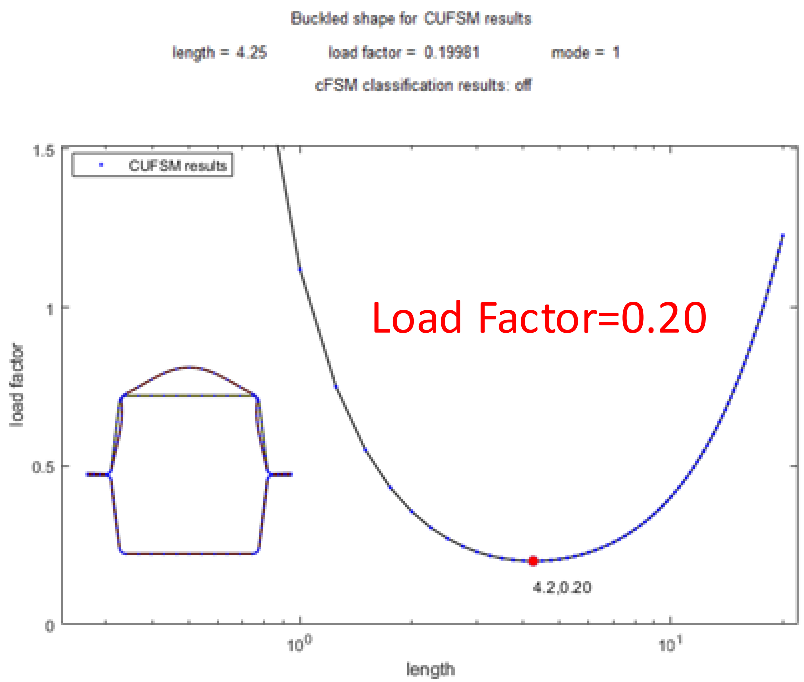


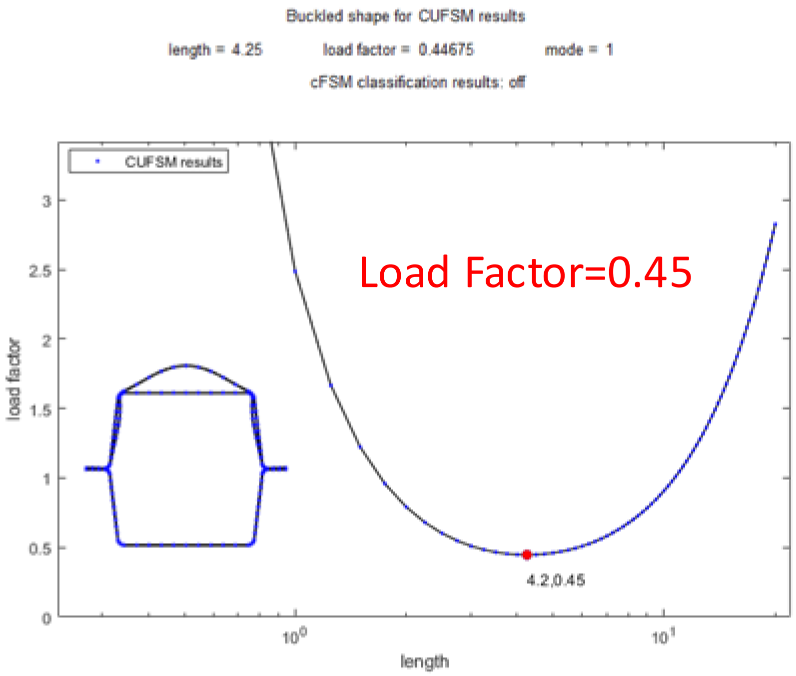

**Non-Composite**

**Fully-Composite**

# Bending




225% Increase in elastic critical load ratio to My




$M_n$=91 kip-in/ft

DSM

46% Increase in flexural capacity as observed in the tests

$M_n$=133 kip-in/ft

$M_{n\text{-}test}$=159.5 kip-in/ft

$M_{n\text{-}test}/M_n$=1.20 (slightly conservative)

## Non-Composite

## Fully-Composite

## Deflection

- Non-composite: $I_c/n + I_{s-eff}$
- Fully-composite: $I_{tr-eff}$
- Semi-composite:

$$I_{eff} = I_c/n + I_{s-eff} + R_{sc}\left(I_{tr-eff} - (I_c/n + I_{s-eff})\right)$$

SDI-RD-2017 Standard

| Roof Deck Construction | Live Load | Snow or Wind [1] | Dead + Live Load |
|---|---|---|---|
| Supporting plaster ceiling | L/360 | L/360 | L/240 |
| Supporting non-plaster ceiling | L/240 | L/240 | L/180 |
| Not supporting ceiling | L/180 | L/180 | L/120 |

1. Ultimate wind loads shall be permitted to be multiplied by 0.42

$I_c$ is the structural panel moment of inertia, $n = E_s/E_c$, $I_{s-eff}$ is an effective moment of inertia of the steel deck and $I_{tr-eff}$ is the effective transformed moment of inertia

# Design Method: Limit states

**Shear** per AISI-S100 Section G2 (deck only)

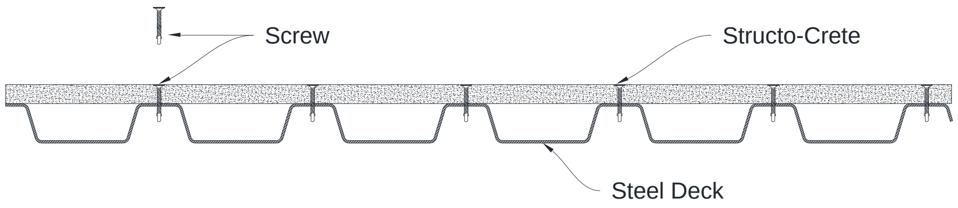
**Web-Crippling** per AISI-S100 Section G5 (deck only)

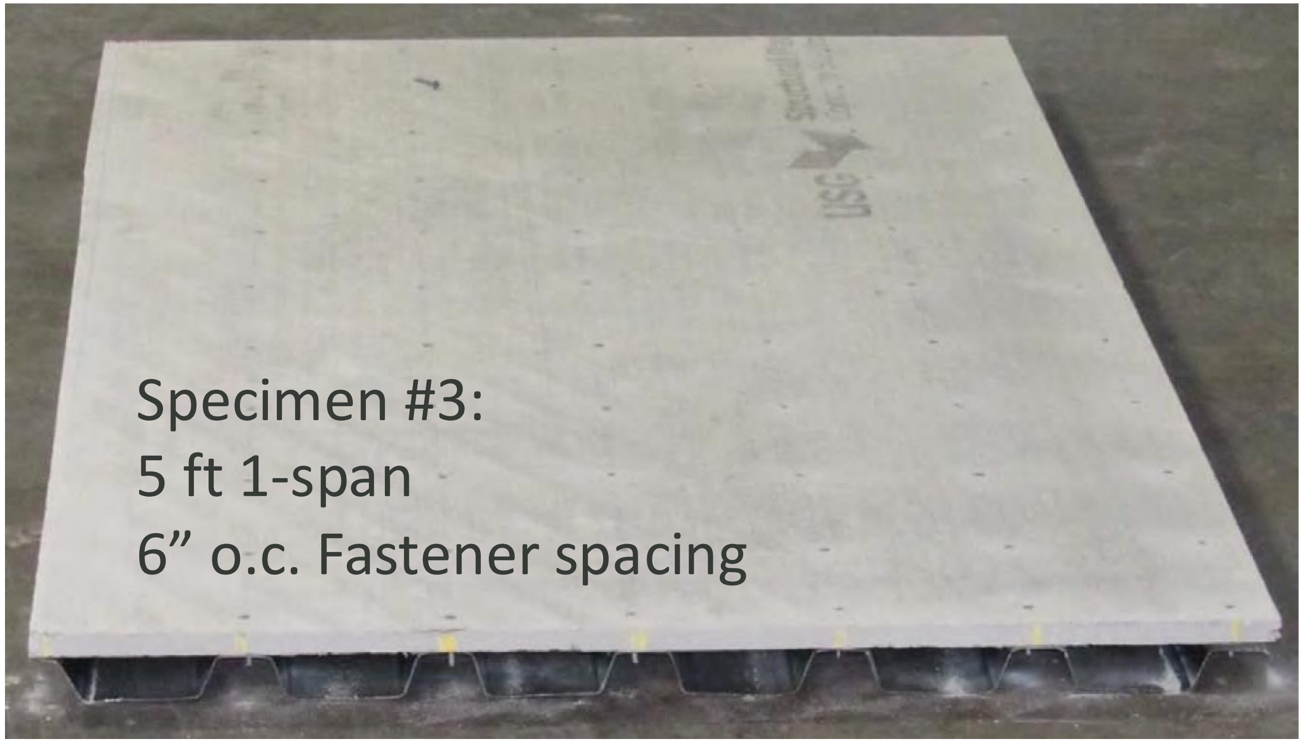
**Combined Bending and Shear** per AISI-S100 Section H2 (composite in deck bending)

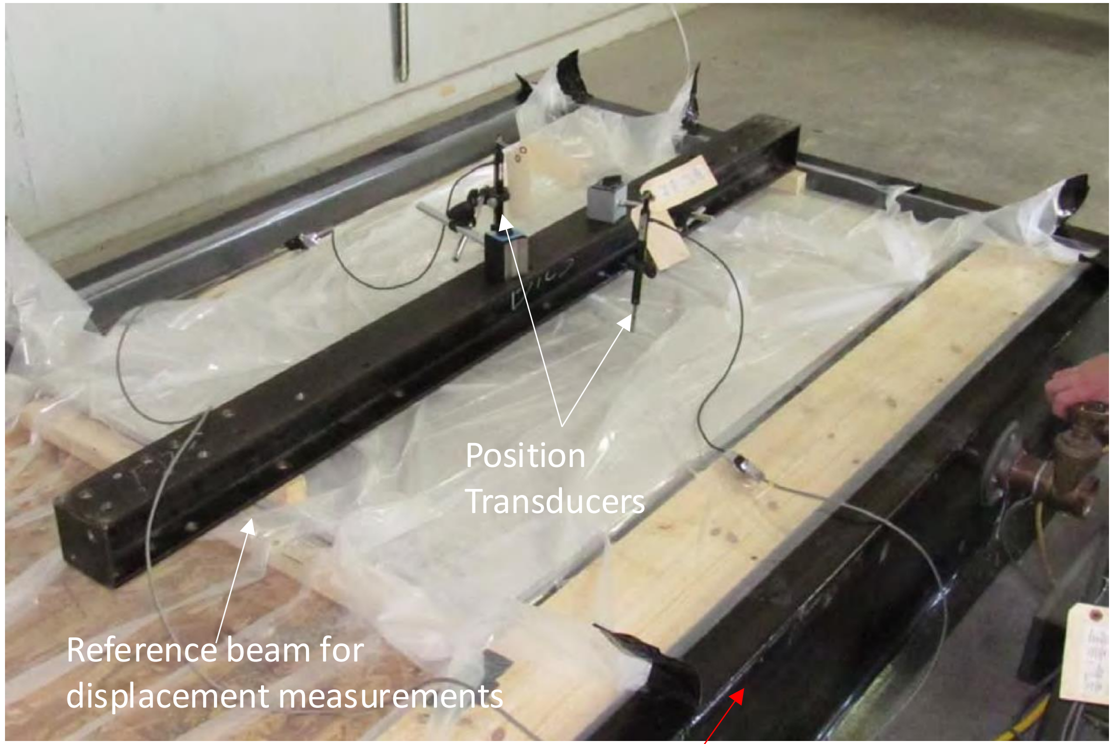
**Combined Bending and Web-Crippling** per AISI-S100 Section H3 (composite in deck bending)

## Specimens and Test setup (Typical 1-span)

# USG Experimental Program: Pressure Box




Pressure box

Testing lab: Progressive Engineering Inc.

# Design Method Validation: Specimens

| Steel Deck Properties | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *h* | *Span* | *Width* | $A_s$ | $I_s$ | $y_s$ | *d* | $S_t$ | $S_b$ | $E_s$ | $F_y$ |
| *Test Set* | *Specimen* | *Report Number* | *Inverted Metal Deck (1.5" B-deck)* | *in* | *ft* | *in* | $in^2$ | $in^4$ | *in* | *in* | $in^3$ | $in^3$ | *ksi* | *ksi* |
| I | | | 20-Gauge (Inv) | 1.5 | 8 | 12 | 0.570 | 0.206 | 0.554 | 0.946 | 0.218 | 0.371 | 29500 | 95.3 |
| | 12 | PEI - 2017-491 | 20-Gauge (Inv) | 1.5 | 8 | 12 | 0.570 | 0.206 | 0.554 | 1.321 | 0.218 | 0.371 | 29500 | 95.3 |
| | 13 | PEI - 2017-491 | 20-Gauge (Inv) | 1.5 | 8 | 12 | 0.570 | 0.206 | 0.554 | 1.321 | 0.218 | 0.371 | 29500 | 95.3 |
| II | | | 22-Gauge (Inv) | 1.45 | 5 | 12 | 0.470 | 0.17 | 0.554 | 0.896 | 0.189 | 0.306 | 29500 | 82.9 |
| | B-Deck-60-1 | PEI- 2018-6165 | 22-Gauge (Inv) | 1.45 | 5 | 12 | 0.470 | 0.17 | 0.554 | 1.271 | 0.189 | 0.306 | 29500 | 82.9 |
| | B-Deck-60-2 | PEI- 2018-6165 | 22-Gauge (Inv) | 1.45 | 5 | 12 | 0.470 | 0.17 | 0.554 | 1.271 | 0.189 | 0.306 | 29500 | 82.9 |
| | B-Deck-60-3 | PEI- 2018-6165 | 22-Gauge (Inv) | 1.45 | 5 | 12 | 0.470 | 0.17 | 0.554 | 1.271 | 0.189 | 0.306 | 29500 | 82.9 |
| | B-Deck-72-1 | PEI- 2018-6165 | 22-Gauge (Inv) | 1.45 | 6 | 12 | 0.470 | 0.17 | 0.554 | 1.271 | 0.189 | 0.306 | 29500 | 82.9 |
| | B-Deck-72-2 | PEI- 2018-6165 | 22-Gauge (Inv) | 1.45 | 6 | 12 | 0.470 | 0.17 | 0.554 | 1.271 | 0.189 | 0.306 | 29500 | 82.9 |
| | B-Deck-72-3 | PEI- 2018-6165 | 22-Gauge (Inv) | 1.45 | 6 | 12 | 0.470 | 0.17 | 0.554 | 1.271 | 0.189 | 0.306 | 29500 | 82.9 |

# Design Method Validation: Specimens

| Elastic Buckling Analysis and Direct Strength Method | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\sigma_{sb}$ | $\sigma_{st}$ | $M_{s\text{-}fy}$ | $T_{s\text{-}fy}$ | $e_s$ | $M_{crl}$ | $\lambda_l$ | $M_s$ | $T_s$ | $M_{n\text{-}c}$ |
| **Test Set** | **Specimen** | $in^3$ | $in^3$ | kip-in/ft | kip/ft | in | kip-in/ft | - | kip-in/ft | kip/ft | kip-in/ft |
| | | 55.86 | -95.30 | 20.75 | | 0.00 | 17.02 | 1.10 | 16.51 | | 16.51 |
| I | 12 | 95.30 | -47.74 | 19.64 | 24.20 | 0.81 | 36.72 | 0.73 | 19.64 | 24.20 | 51.60 |
| | 13 | 95.30 | -47.74 | 19.64 | 24.20 | 0.81 | 36.72 | 0.73 | 19.64 | 24.20 | 51.60 |
| | | 51.26 | -82.90 | 15.69 | 0.00 | 0.00 | 10.35 | 1.23 | 11.60 | | 11.60 |
| | B-Deck-60-1 | 82.90 | -32.80 | 13.53 | 18.18 | 0.74 | 23.27 | 0.76 | 13.53 | 18.18 | 36.63 |
| | B-Deck-60-2 | 82.90 | -32.80 | 13.53 | 18.18 | 0.74 | 23.27 | 0.76 | 13.53 | 18.18 | 36.63 |
| II | B-Deck-60-3 | 82.90 | -32.80 | 13.53 | 18.18 | 0.74 | 23.27 | 0.76 | 13.53 | 18.18 | 36.63 |
| | B-Deck-72-1 | 82.90 | -32.80 | 13.53 | 18.18 | 0.74 | 23.27 | 0.76 | 13.53 | 18.18 | 36.63 |
| | B-Deck-72-2 | 82.90 | -32.80 | 13.53 | 18.18 | 0.74 | 23.27 | 0.76 | 13.53 | 18.18 | 36.63 |
| | B-Deck-72-3 | 82.90 | -32.80 | 13.53 | 18.18 | 0.74 | 23.27 | 0.76 | 13.53 | 18.18 | 36.63 |

# Design Method Validation: Flexural Strength

| Semi-Composite Capacity and Comparison to Test Results | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $V_{max}$ | $q_{max}$ | Fastener Demand for half length | $S_{max}$ | $R_{sc}$ | $M_n$ | Iteration error | Test results Ultimate | $M_{test}$ | $M_{test}/M_n$ |
| Test Set | Specimen | lb | lb/in | Ib | Ib | - | kip-in/ft | % | psf | kip-in/ft | - |
| | | | | | | | 16.5 | | 228 | | |
| I | 12 | 1210 | 554 | 13292 | 4744 | 0.36 | 29.0 | 0.0% | 287 | 27.6 | 0.95 |
| | 13 | 1210 | 554 | 13292 | 4744 | 0.36 | 29.0 | 0.0% | 350 | 33.6 | 1.16 |
| | | | | | | | 11.6 | | | | |
| | B-Deck-60-1 | 1300 | 627 | 9398 | 2965 | 0.32 | 19.5 | 0.0% | 498 | 18.7 | 0.96 |
| | B-Deck-60-2 | 1300 | 627 | 9398 | 2965 | 0.32 | 19.5 | 0.0% | 539 | 20.2 | 1.04 |
| II | B-Deck-60-3 | 1300 | 627 | 9398 | 2965 | 0.32 | 19.5 | 0.0% | 546 | 20.5 | 1.05 |
| | B-Deck-72-1 | 1144 | 552 | 9928 | 3558 | 0.36 | 20.6 | -0.1% | 390 | 21.0 | 1.02 |
| | B-Deck-72-2 | 1144 | 552 | 9928 | 3558 | 0.36 | 20.6 | -0.1% | 345 | 18.6 | 0.90 |
| | B-Deck-72-3 | 1144 | 552 | 9928 | 3558 | 0.36 | 20.6 | -0.1% | 374 | 20.2 | 0.98 |
| | | | | | | | | | | Average | 1.01 |
| | | | | | | | | | | std | 0.078 |
| | | | | | | | | | | cov | 7.7% |

SGH

# Allowable distributed load capacity:

**Semi-composite Allowable Distributed Load Capacity Based on Deflection Limit State: L/240 limit** D

**Semi-composite Allowable Distributed Load Capacity Based on Bending Limit State** M

**Semi-composite Allowable Distributed Load Capacity Based on Shear Limit State** V

**Semi-composite Allowable Distributed Load Capacity Based on Bearing (Web Crippling) Limit State** B

**Semi-composite Allowable Distributed Load Capacity Based on Combined Bending and Shear Limit State** M+V

**Semi-composite Allowable Distributed Load Capacity Based on Combined Bending and Bearing (Web Crippling) Limit State** M+B

| | | Fastener Spacing (in) | No Fastener | | | | | 12 | | | | | 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Joist Spacig (ft) | 4 | 4.5 | 5 | 5.5 | 6 | 4 | 4.5 | 5 | 5.5 | 6 | 4 | 4.5 | 5 | 5.5 | 6 |
| # Spans | Structo-Crete | Metal Deck | | | | | | | | | | | | | | | |
| 1 | 0.75" | 20ga, 1.5B-Deck, 60ksi | 5E+07 | 4E+07 | 3E+07 | 3E+07 | 2E+07 | 5E+07 | 4E+07 | 3E+07 | 3E+07 | 2E+07 | 5E+07 | 4E+07 | 3E+07 | 3E+07 | 2E+07 |
| 1 | 0.75" | 21ga, 1.5B-Deck, 60ksi | 4E+07 | 3E+07 | 3E+07 | 2E+07 | 2E+07 | 4E+07 | 3E+07 | 3E+07 | 2E+07 | 2E+07 | 4E+07 | 3E+07 | 3E+07 | 2E+07 | 2E+07 |
| 1 | 0.75" | 22ga, 1.5B-Deck, 60ksi | 3E+07 | 3E+07 | 2E+07 | 2E+07 | 2E+07 | 3E+07 | 3E+07 | 2E+07 | 2E+07 | 2E+07 | 3E+07 | 3E+07 | 2E+07 | 2E+07 | 2E+07 |
| 1 | 0.75" | 24ga, 1.5B-Deck, 60ksi | 2E+07 | 2E+07 | 2E+07 | 1E+07 | 1E+07 | 2E+07 | 2E+07 | 2E+07 | 1E+07 | 1E+07 | 2E+07 | 2E+07 | 2E+07 | 1E+07 | 1E+07 |
| 2 | 0.75" | 20ga, 1.5B-Deck, 60ksi | 362 | 297 | 248 | 210 | 180 | 362 | 297 | 248 | 210 | 180 | 362 | 297 | 248 | 210 | 180 |
| 2 | 0.75" | 21ga, 1.5B-Deck, 60ksi | 322 | 264 | 221 | 188 | 162 | 322 | 264 | 221 | 188 | 162 | 322 | 264 | 221 | 188 | 162 |
| 2 | 0.75" | 22ga, 1.5B-Deck, 60ksi | 282 | 232 | 194 | 165 | 142 | 282 | 232 | 194 | 165 | 142 | 282 | 232 | 194 | 165 | 142 |
| 2 | 0.75" | 24ga, 1.5B-Deck, 60ksi | 190 | 156 | 131 | 111 | 95 | 190 | 156 | 131 | 111 | 95 | 190 | 156 | 131 | 111 | 95 |
| 3 | 0.75" | 20ga, 1.5B-Deck, 60ksi | 394 | 323 | 269 | 228 | 196 | 394 | 323 | 269 | 228 | 196 | 394 | 323 | 269 | 228 | 196 |
| 3 | 0.75" | 21ga, 1.5B-Deck, 60ksi | 351 | 288 | 241 | 204 | 175 | 351 | 288 | 241 | 204 | 175 | 351 | 288 | 241 | 204 | 175 |
| 3 | 0.75" | 22ga, 1.5B-Deck, 60ksi | 307 | 252 | 211 | 179 | 154 | 307 | 252 | 211 | 179 | 154 | 307 | 252 | 211 | 179 | 154 |
| 3 | 0.75" | 24ga, 1.5B-Deck, 60ksi | 207 | 170 | 142 | 121 | 104 | 207 | 170 | 142 | 121 | 104 | 207 | 170 | 142 | 121 | 104 |

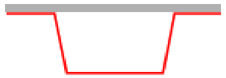
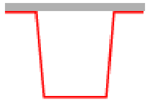
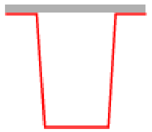
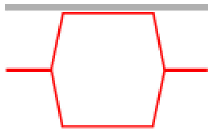
# Sample Span Chart (DRAFT)

## Allowable Uniform Loads (psf)

**Criteria:** Stress, Deflection Limited to L/360

**Controlling Limit States**

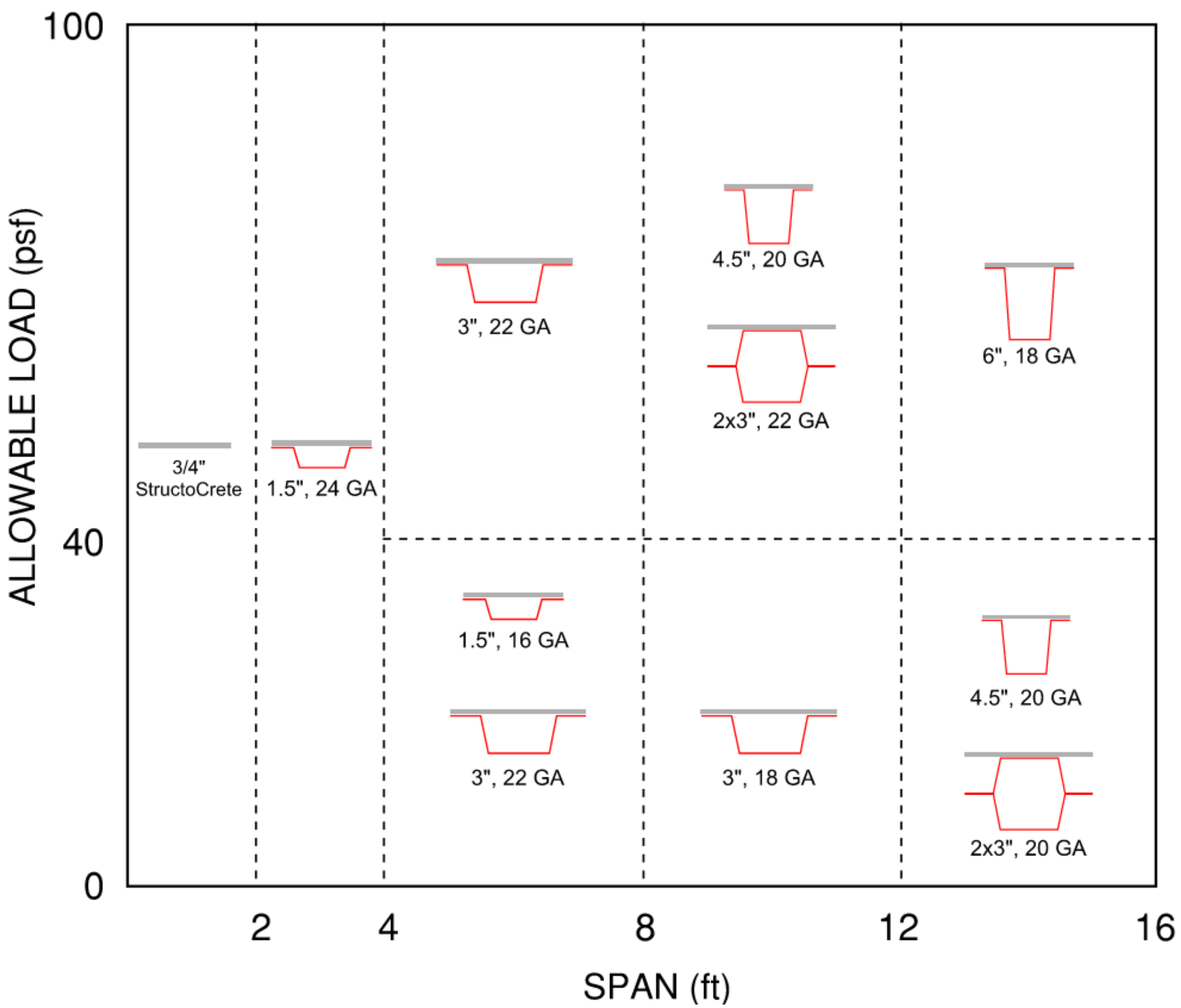
- Deflection: L/360
- Bearing
- Flexure

| SPANS | DECK DEPTH (in) | COMPOSITE DECK VIEW | GAGE [mil] | SPAN (ft) 4 | 6 | 8 | 10 | 12 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SINGLE | 1.5 |  | 16 [54] | 300 | 101 | 45 | 24 | 15 | 10 | 8 | 7 |
| | 1.5 | | 18 [43] | 264 | 83 | 37 | 20 | 12 | 8 | 7 | 6 |
| | 1.5 | | 20 [33] | 208 | 67 | 31 | 17 | 11 | 7 | 6 | 5 |
| | 1.5 | | 22 [27] | 182 | 59 | 28 | 15 | 10 | 7 | 6 | 5 |
| | 1.5 | | 24 [23] | 138 | 46 | 22 | 12 | 8 | 5 | 5 | 4 |
| | 3 |  | 16 [54] | 300 | 300 | 174 | 92 | 55 | 36 | 30 | 25 |
| | 3 | | 18 [43] | 300 | 300 | 143 | 76 | 46 | 30 | 25 | 21 |
| | 3 | | 20 [33] | 300 | 255 | 114 | 62 | 38 | 25 | 21 | 18 |
| | 3 | | 22 [27] | 300 | 218 | 101 | 55 | 34 | 23 | 19 | 17 |
| | 4.5 |  | 14 [68] | 300 | 300 | 300 | 300 | 189 | 122 | 100 | 84 |
| | 4.5 | | 16 [54] | 300 | 300 | 300 | 261 | 155 | 100 | 82 | 69 |
| | 4.5 | | 18 [43] | 300 | 300 | 300 | 210 | 125 | 82 | 68 | 57 |
| | 4.5 | | 20 [33] | 300 | 300 | 300 | 165 | 100 | 66 | 55 | 46 |
| | 6 |  | 14 [68] | 300 | 300 | 300 | 300 | 300 | 228 | 187 | 156 |
| | 6 | | 16 [54] | 300 | 300 | 300 | 300 | 292 | 188 | 155 | 129 |
| | 6 | | 18 [43] | 300 | 300 | 300 | 300 | 236 | 153 | 126 | 105 |
| | 6 | | 20 [33] | 300 | 300 | 300 | 300 | 187 | 122 | 101 | 85 |
| | 2X3 |  | 16 [54] | 300 | 300 | 300 | 300 | 196 | 128 | 105 | 88 |
| | 2X3 | | 18 [43] | 300 | 300 | 300 | 280 | 169 | 110 | 91 | 77 |
| | 2X3 | | 20 [33] | 300 | 300 | 300 | 209 | 128 | 85 | 71 | 60 |
| | 2X3 | | 22 [27] | 300 | 300 | 300 | 177 | 109 | 73 | 62 | 52 |

# Sample Span Chart (DRAFT)

**Allowable Uniform Loads (psf) vs Span (ft)**

**Criteria:** Stress, Deflection Limited to L/360

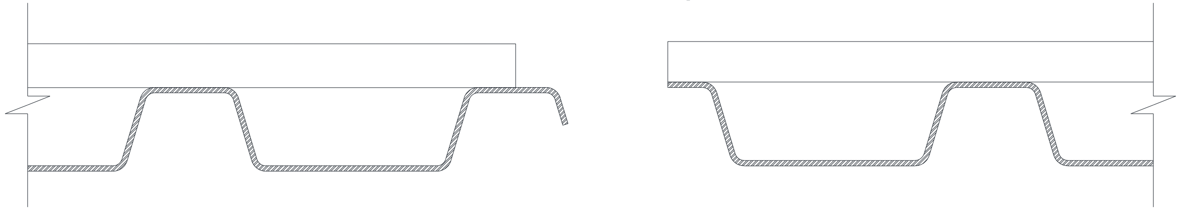



**Notes:**

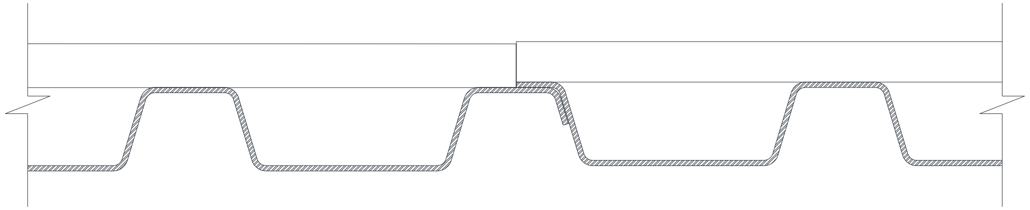
1. StructoCrete thickness is 3/4" and needs to be installed per USG construction manual.
2. The fastener between the deck and StructoCrete is Grabber #8, 1-5/8" with 12" o.c. spacing per flute.
3. Deck steel yield strength is Fy = 50 ksi for gages 14-22, and Fy = 60 ksi for gage 24.
4. The end and interior bearing strength is based on deck bearing length of 2" at end supports and 4" at interior supports for 1.5" and 3" decks. For decks with 4.5" and 6" depth, the end and interior bearing strength is based on deck bearing length of 1.5" at end supports and 3" at interior supports.
5. The EOR needs to control the bearing capacity of the composite decks for transfer loads from load-bearing walls to the bearing walls below.
6. For the 2x3 decks, it is assumed that the web crippling limit state does not control.
7. Vibration, acoustic, and fire rating requirements need to be controlled by the EOR.
8. Self-weight and superimposed dead loads are not included in the allowable loads.
9. Built-up steel decks are assumed to be fully composite.
10. All decks are used inverted.
11. Non-composite strength of the steel deck during construction needs to be controlled by the EOR.
12. All composite decks are assumed to be single-span.
13. Allowable capacities are limited to 300 psf. For higher loads, additional calculations is needed.
14. Steel deck to frame and side laps need to be designed for construction and diaphragm requirements.

# Modular ideas

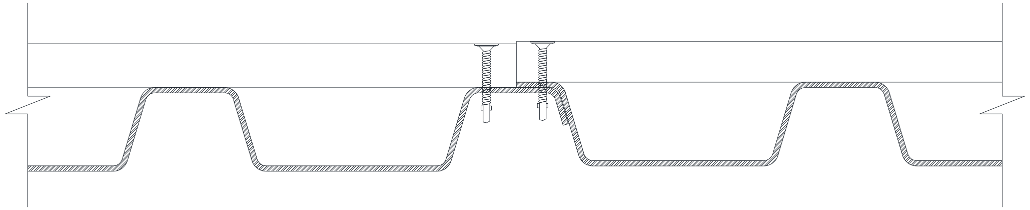
Pre-fabricated composite decks



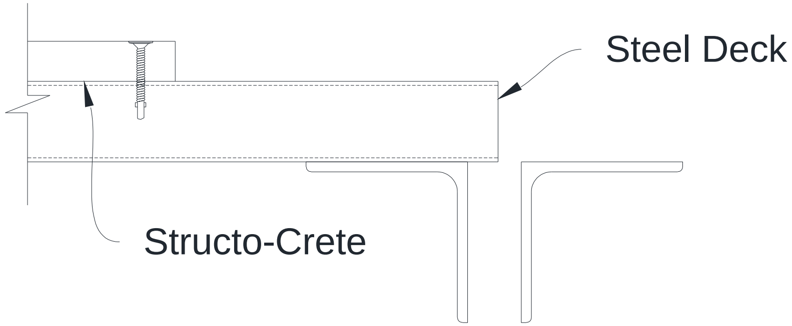
Sidelap Nested connection



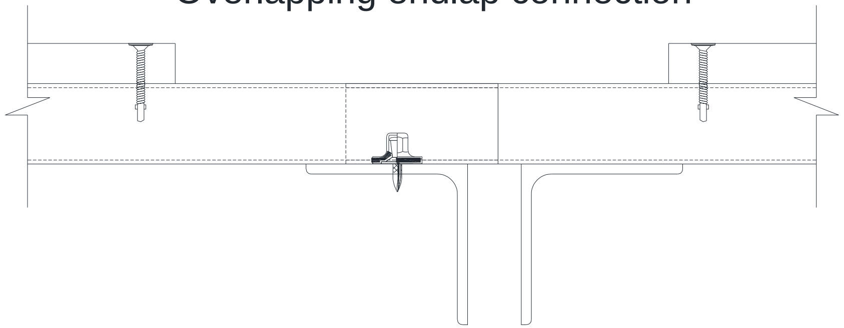
Sidelap Fasteners



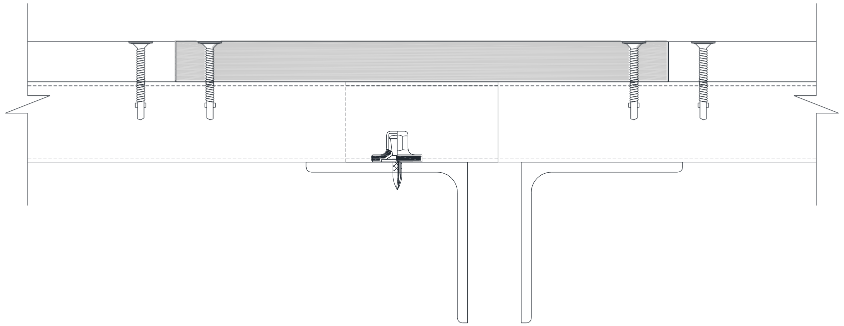
Pre-fabricated composite decks




Overlapping endlap connection



Structural panel cover plate



## Future Work

- The design procedure needs to be further validated with more test results.
- Structo-Crete modulus of elasticity in compression I needed (testing in progress)
- Floor Vibration (testing in progress)
- Point loads

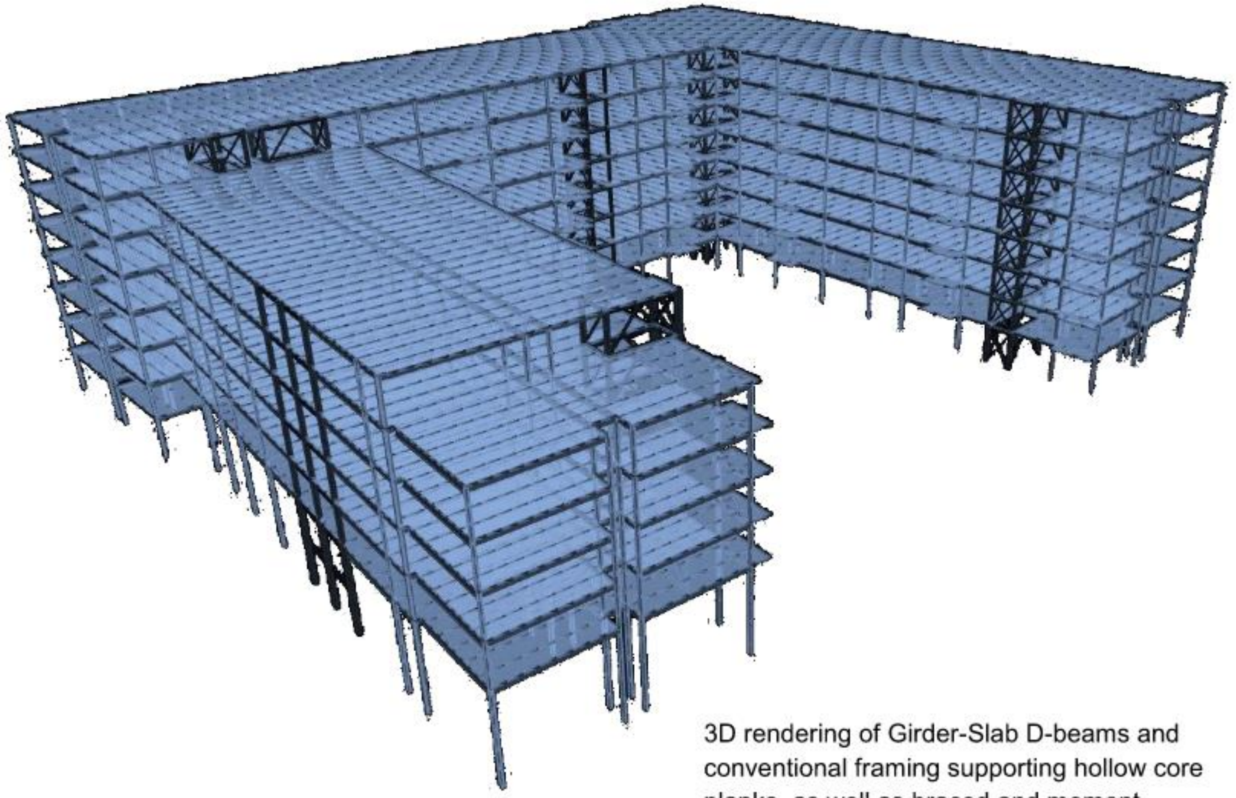
# FastFloor R Sample Buildings

Workshop 12/3/2024

# Building Type Examples

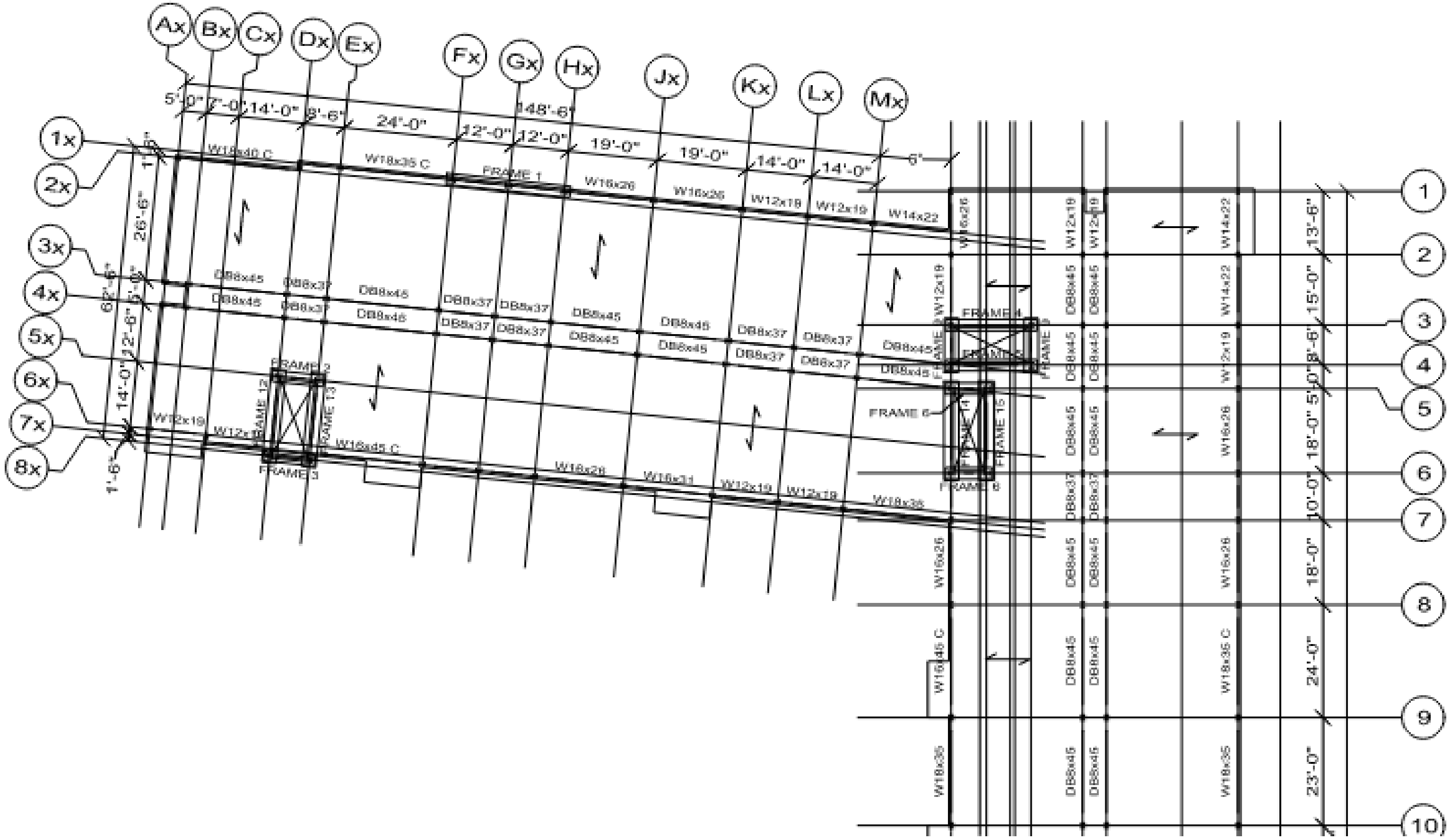
- Multistory residential projects
- Examples are pulled from the AISC conceptual solution database and include
  - Apartment building
  - Mixed-use development
  - University residence hall

# Example 1



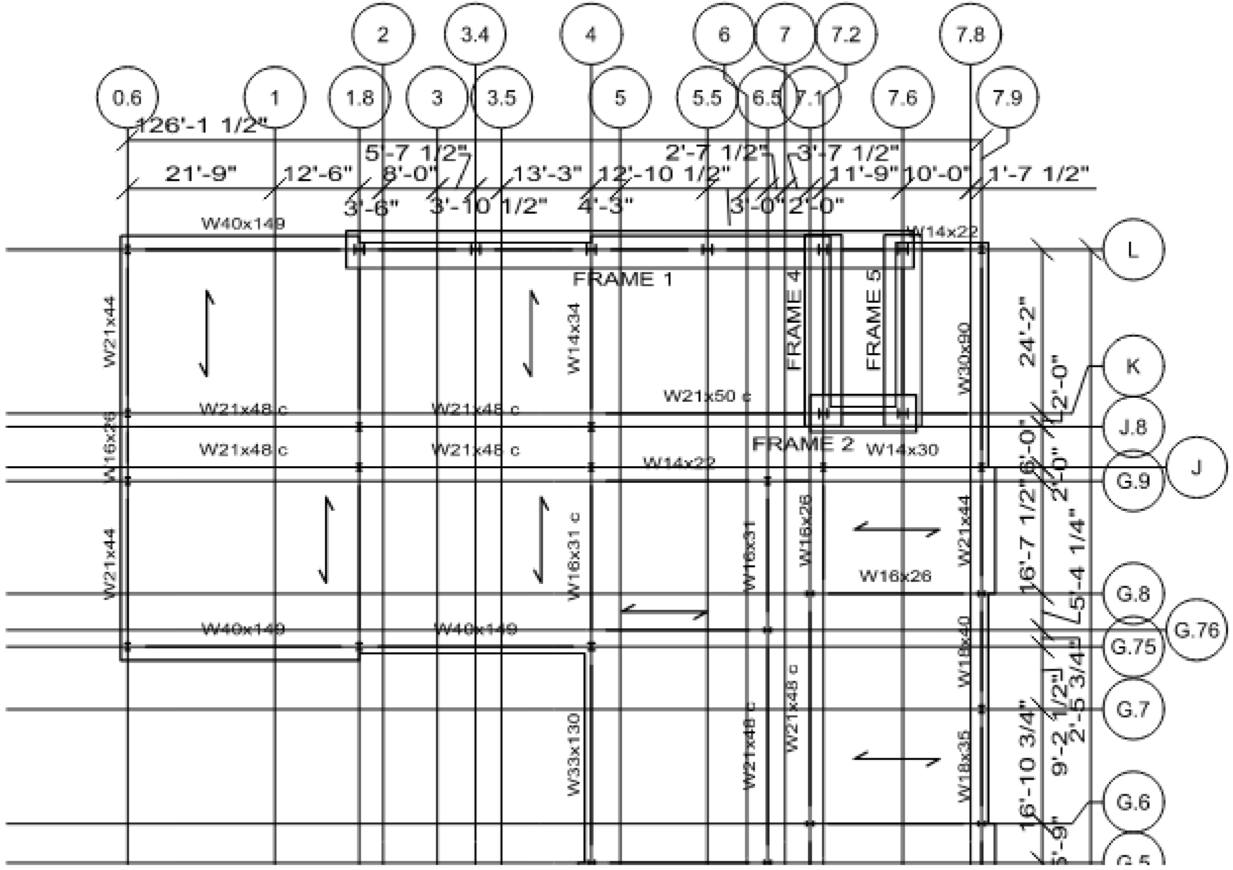
3D rendering of Girder-Slab D-beams and conventional framing supporting hollow core planks, as well as braced and moment frames for the lateral elements.

# Example 1 Proposed Framing Plan

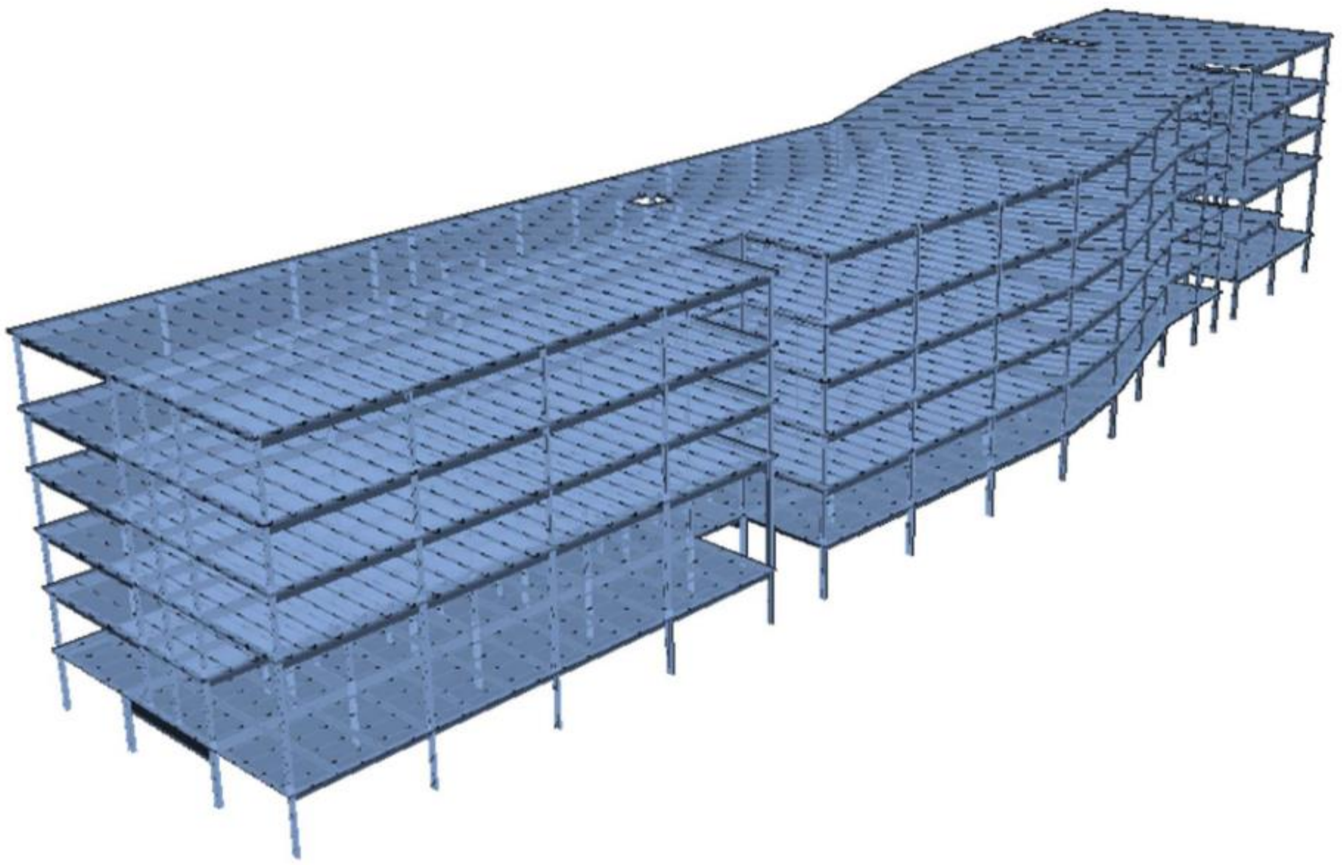


# Example 2

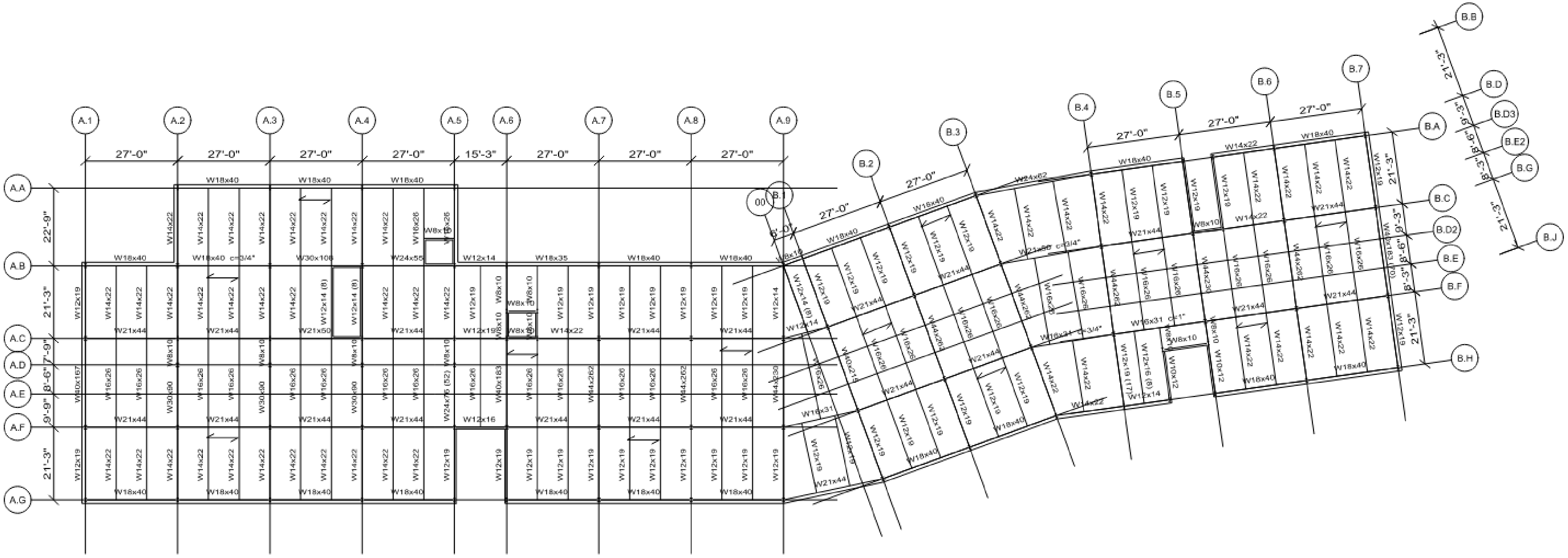
# Example 2 Proposed Framing Plan



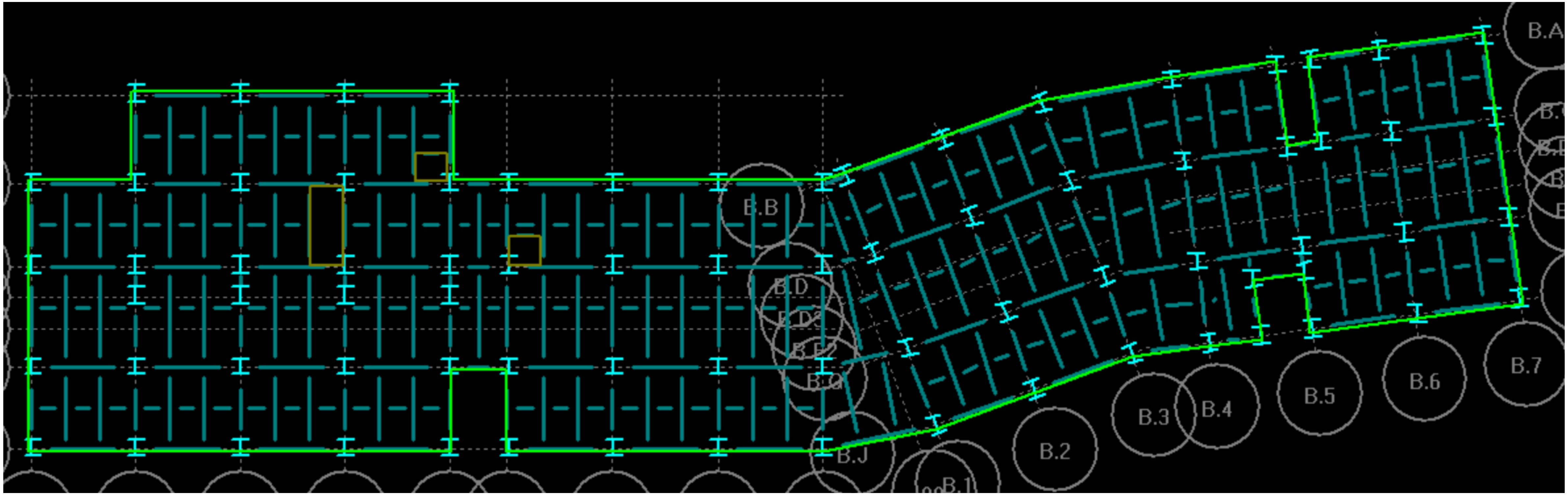
# Highlighted Example: University Residence Hall



# Original Proposed Plans – 1st Floor



# Proposed layout with FastFloor R



# Original Proposed Column Schedule