

SIKANDAR PORTER-GILL

ADVISOR: DR. THOMAS BOOTHBY

DEPARTMENT OF ARCHITECTURAL ENGINEERING

THE PENNSYLVANIA STATE UNIVERSITY

STRUCTURAL OPTION

SPRING 2014

HEIFER INTERNATIONAL CENTER



LITTLE ROCK, ARKANSAS



SITE LOCATION



BUILDING INTRODUCTION

PROBLEM STATEMENT

PROPOSED SOLUTION

GRAVITY REDESIGN

LATERAL REDESIGN

MECHANICAL & ENVELOPE

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SITE LOCATION



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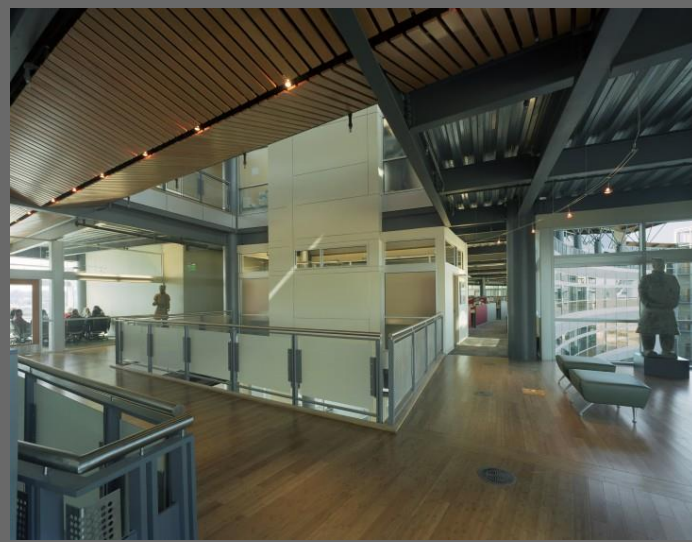
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BUILDING STATISTICS

Height	65'-0"
Stories	4
Square Footage	98,000 GSF
Construction Dates	February 2004 – January 2006
Approximate Cost	\$18 million
Project Delivery	Construction Management at Risk
USGBC Rating	LEED Platinum



OWNER



ARCHITECT
INTERIOR DESIGNER



CROMWELL

STRUCTURAL
MECHANICAL

- Moses Tucker Real Estate, Inc. | Owner's Project Adviser
- McClelland Engineers | Civil Engineer
- BNIM/Elements | Sustainable Consultant
- CDI Contractors, Inc. | General Contractor
- Larson Burns & Smith, Inc. | Landscape Architect
- Cambridge Seven Associates | Global Village Consultant

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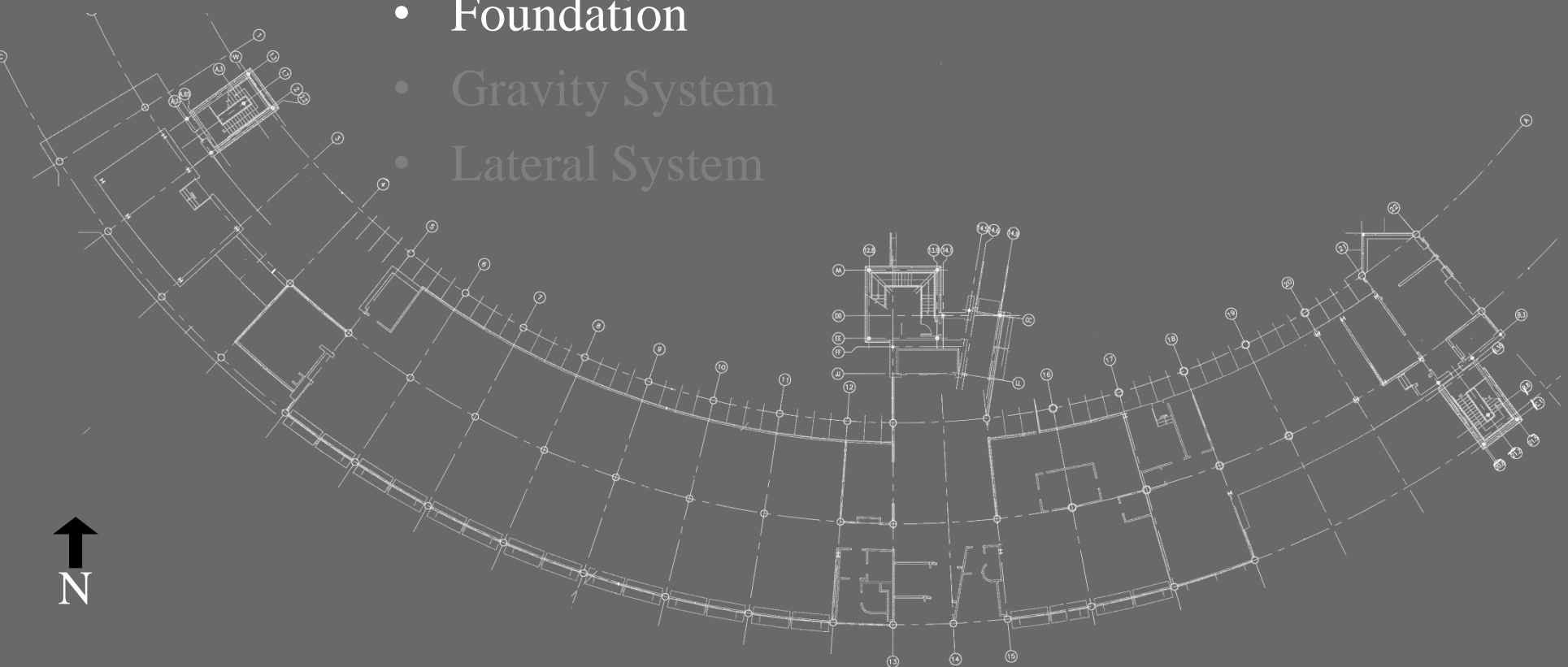
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EXISTING STRUCTURAL SYSTEM

- Foundation
- Gravity System
- Lateral System



- Geopier™ Rammed Aggregate Pier® System
 - Increase soil capacity to 5 to 7 ksf
- Grade Beams
- Slab On Grade



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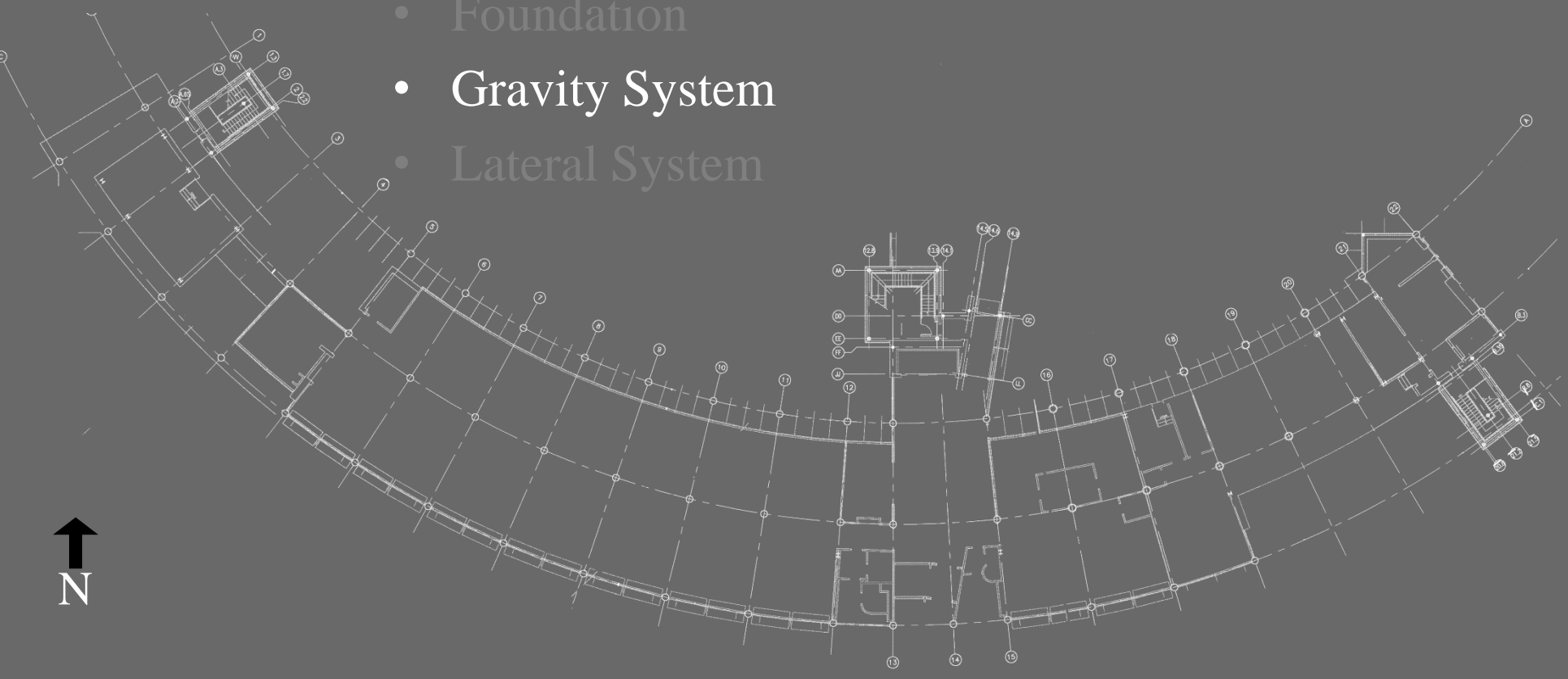
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- Composite Deck, Beam and Girder System
 - 3VLI Decking with 2 ½” NWC Topping
 - Beams and Girders Cambered
- HSS Columns



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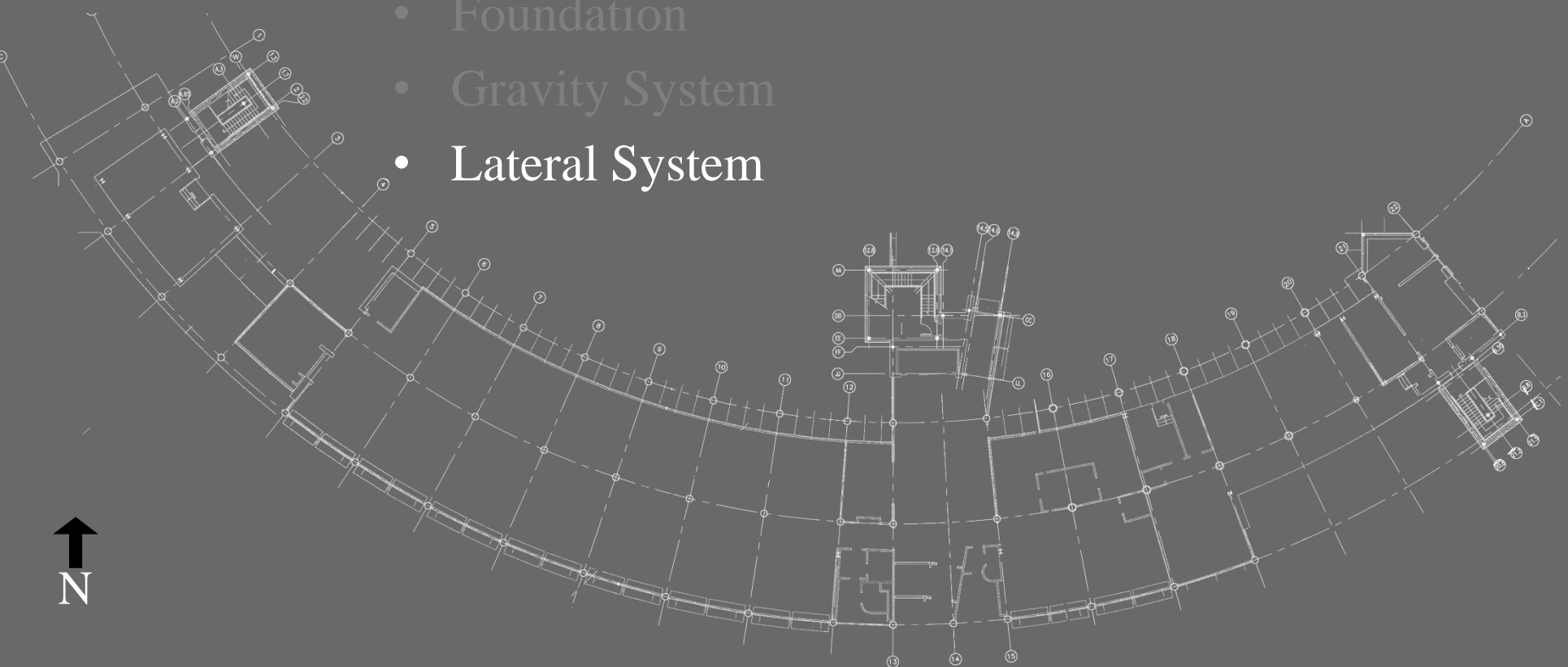
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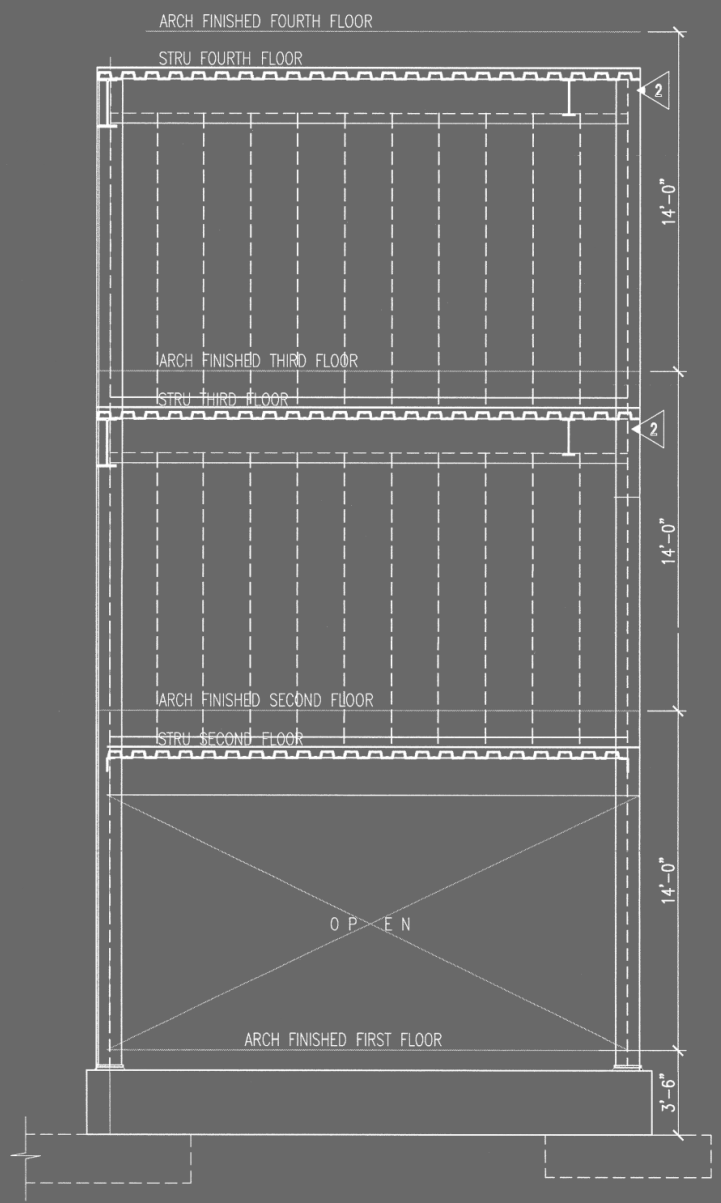
EXISTING STRUCTURAL SYSTEM

- Foundation
- Gravity System
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– Composite Lateral System

- Steel Plate Shear Wall
- CMU Masonry Wall



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SCENARIO



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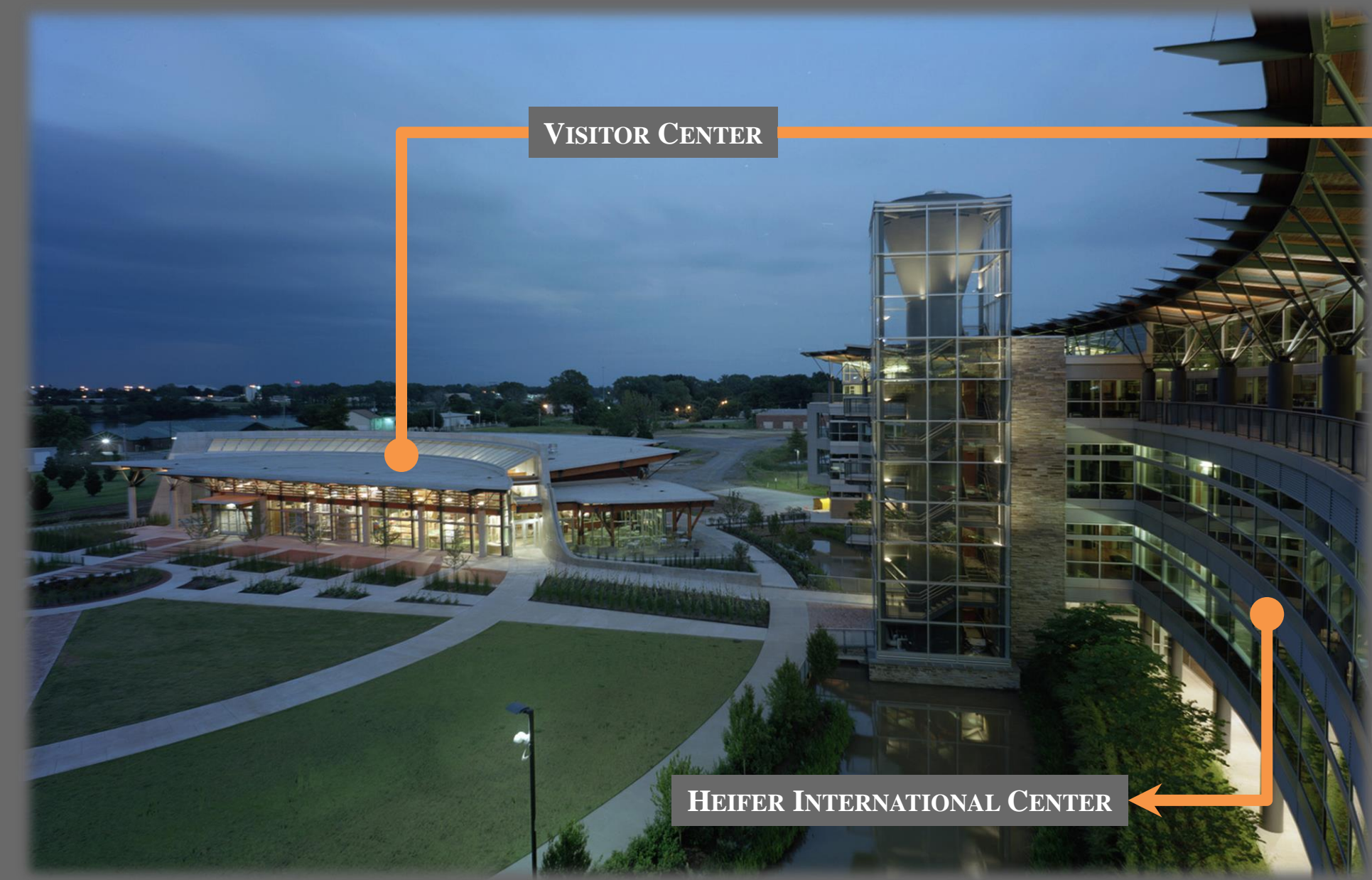
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SCENARIO

- Integrated architectural theme with glulam
- Achieve engineering system integration



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Timothy Hursley



Timothy Hursley

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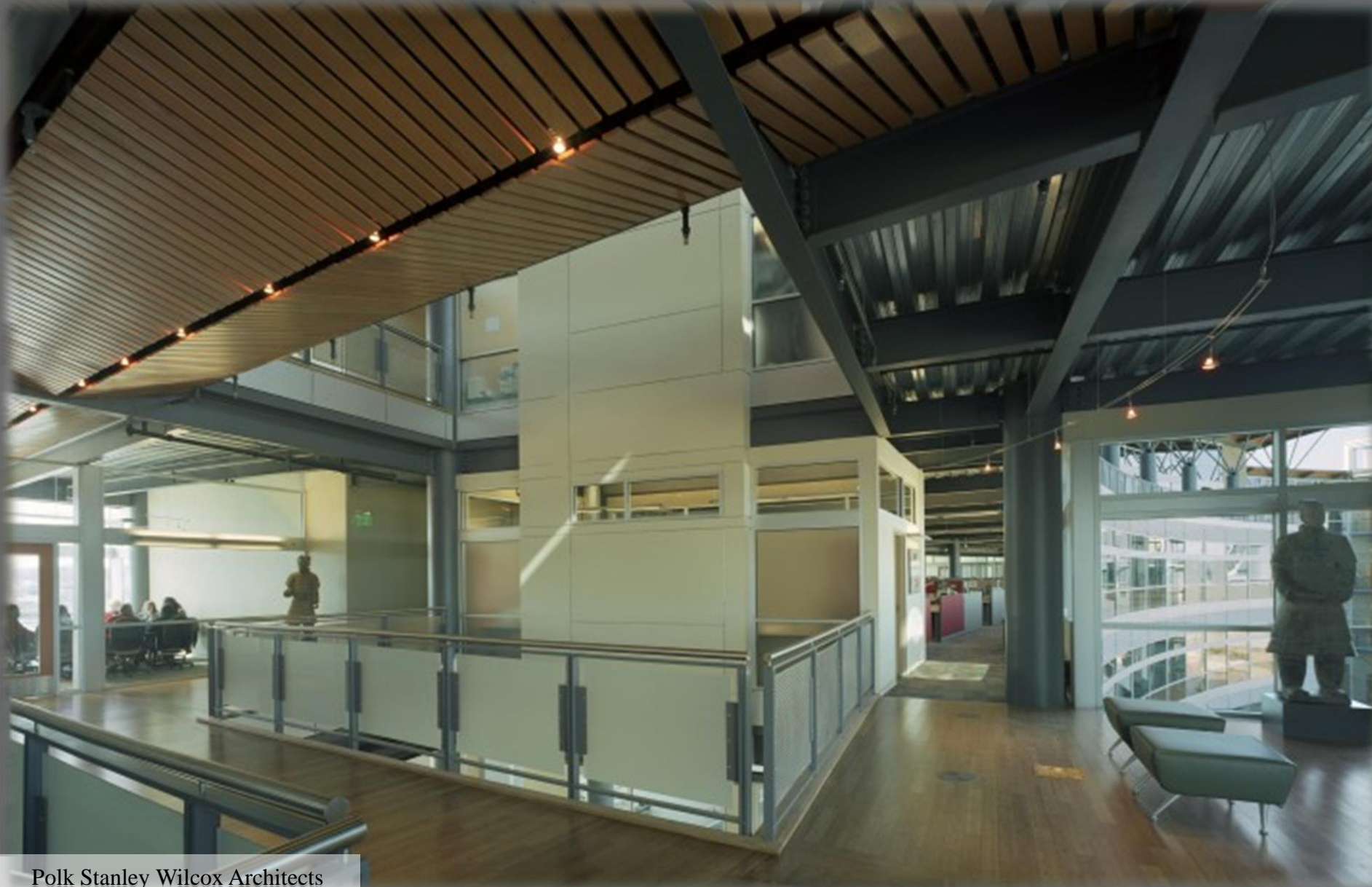
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PROPOSAL

- Heifer International Education and Visitor Center
- Gravity
 - Floor system
 - Queen post girder
- Lateral System
 - Case-in-place concrete shear wall



Polk Stanley Wilcox Architects

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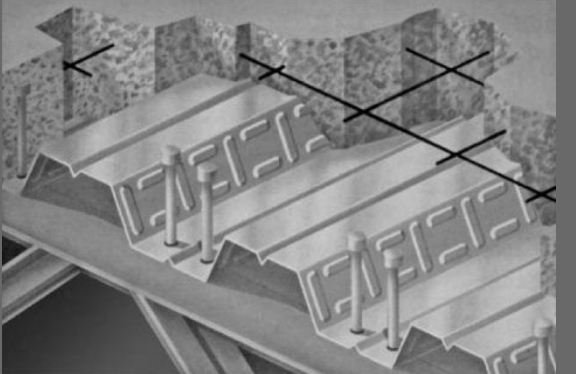
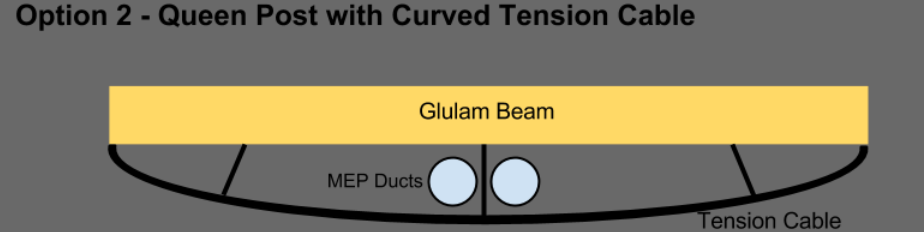
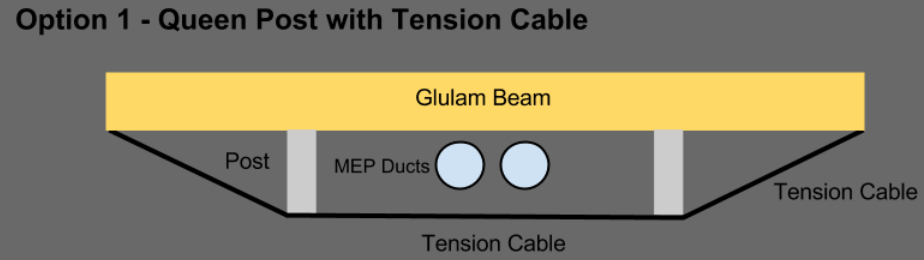
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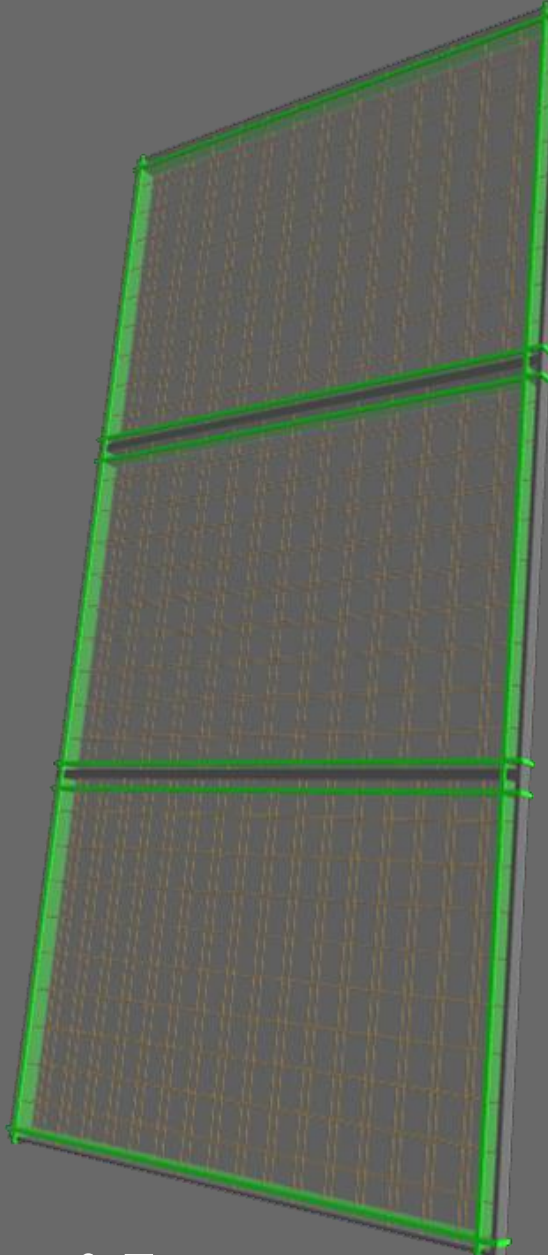
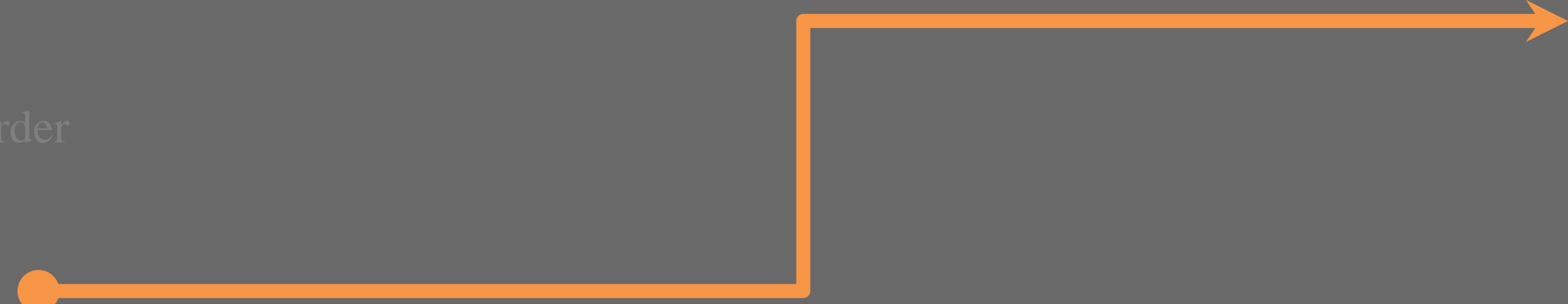
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GOALS

- No change in building layout
 - Sense of open office should be kept
- Enhance architectural components
 - Visual link between occupant and engineering systems
- Better understanding of building irregularities

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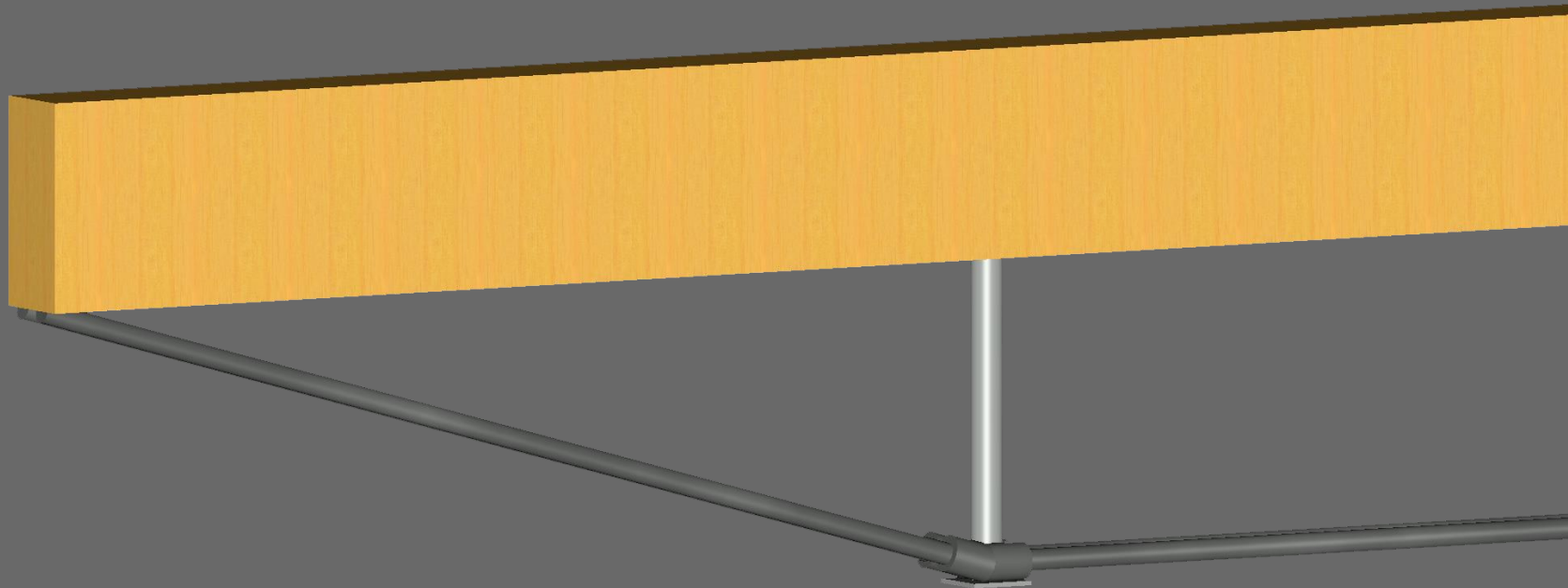


GRAVITY REDESIGN

- Queen Post Girder
- Floor System Selection
- Queen Post Design
- Queen Post Connection Detail
- System Comparison

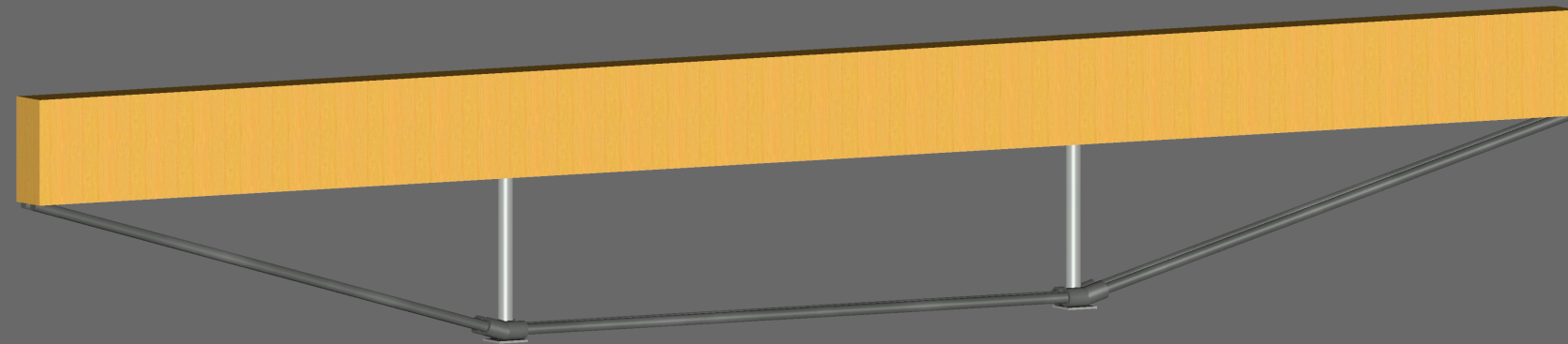
- Queen Post Girder
 - Longer spans possible
 - Offers the ability to integrate other engineering disciplines

- Underfloor Air Distribution System
 - Negated due to use of glulam in redesign



GRAVITY REDESIGN

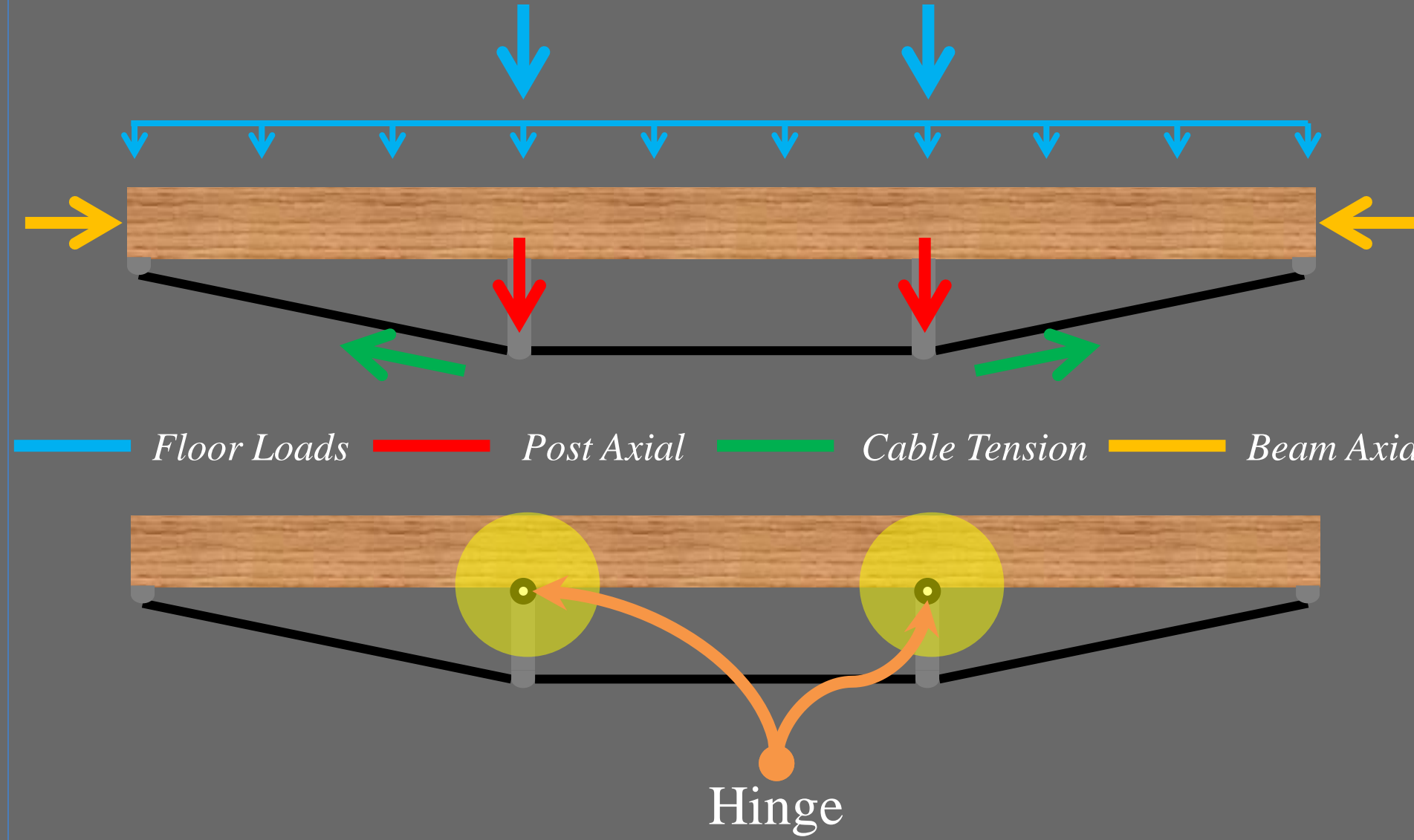
- Queen Post Girder
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- Queen Post Girder
 - Combined axial and bending member
 - Reduce flexure on member

$$\left[\frac{f_c}{F'_c} \right]^2 + \frac{f_{b1}}{F'_{b1} \cdot \left(1 - f_c / F_{cE1} \right)} + \frac{f_{b2}}{F'_{b2} \cdot \left(1 - f_c / F_{cE2} - \left(f_{b1} / F_{bE} \right)^2 \right)} \leq 1.0$$

§3.9.2
National Design Specification for Wood Construction



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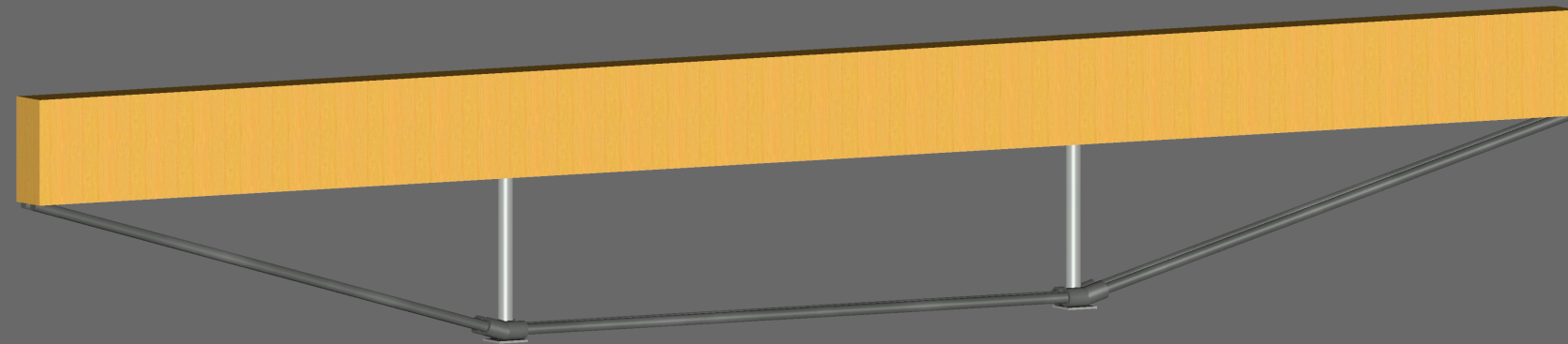
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- Queen Post Girder
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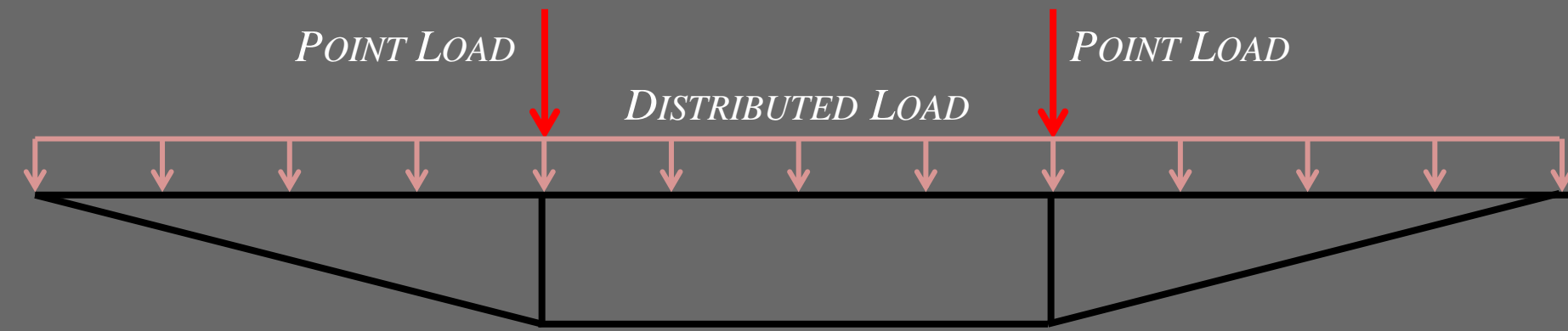
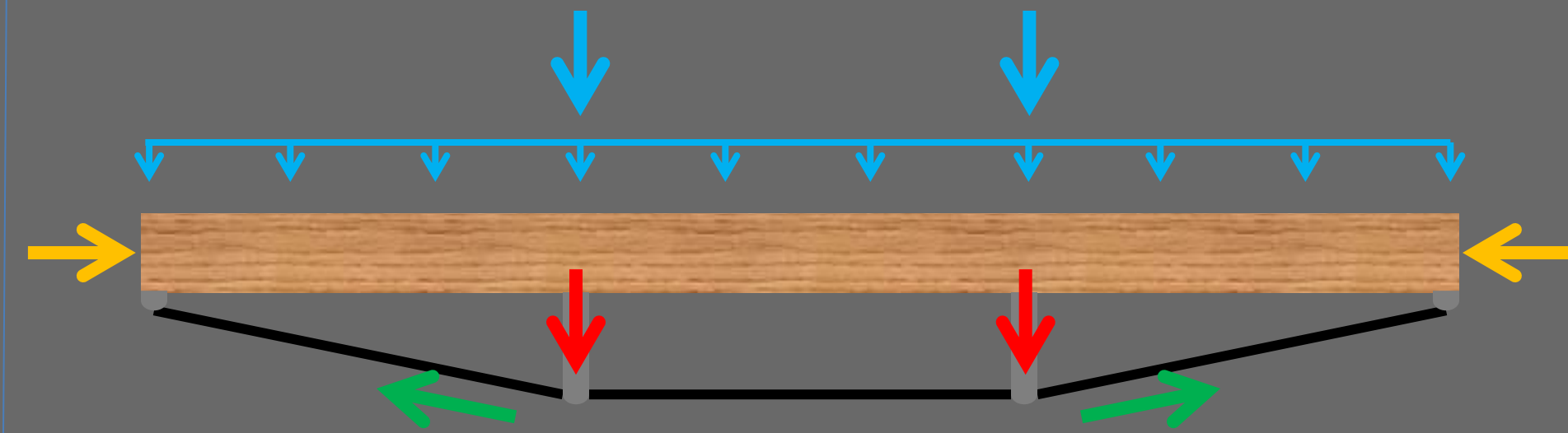


- Queen Post Girder
 - Compression Parallel to Beam

$$F'_c = F_c \times C_M \times C_t \times C_P$$

$$C_P = \frac{1 + F_{CE}/F_c^*}{2c} - \sqrt{\left(\frac{1 + F_{CE}/F_c^*}{2c}\right)^2 - \frac{F_{CE}/F_c}{c}}$$

§5.3.1
National Design Specification for Wood Construction



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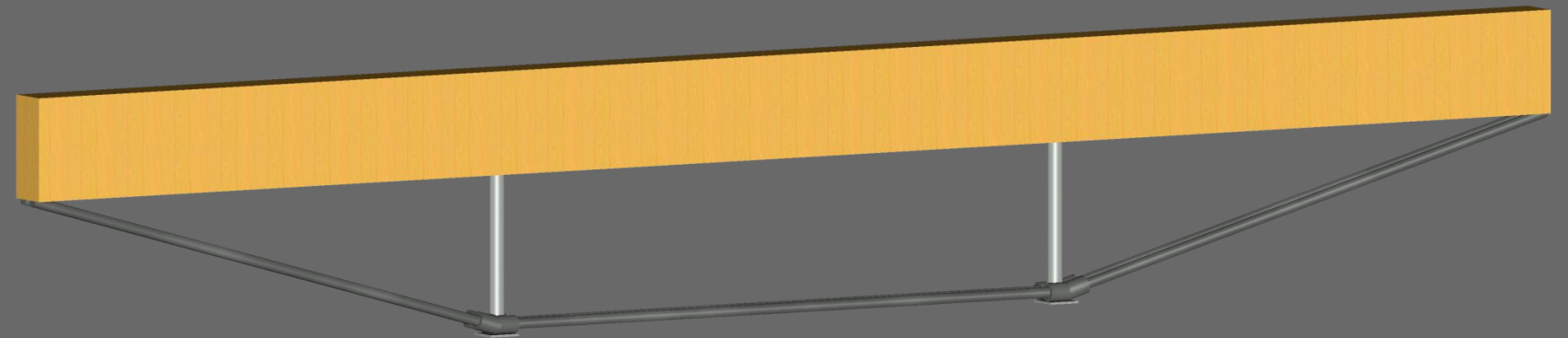
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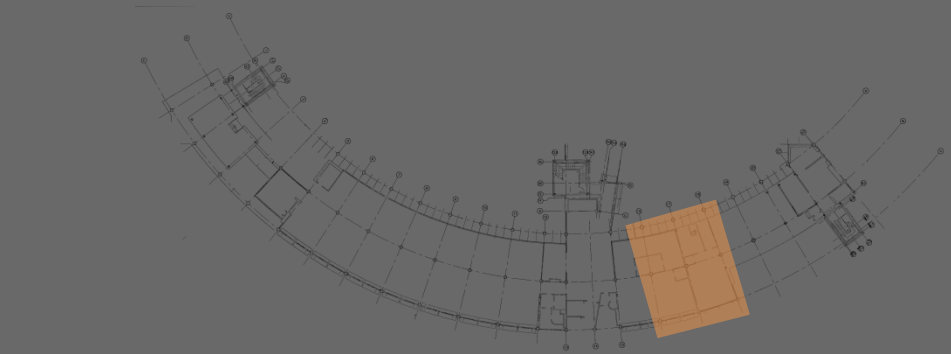
GRAVITY REDESIGN

- Queen Post Girder
- Floor System Selection
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- System Comparison

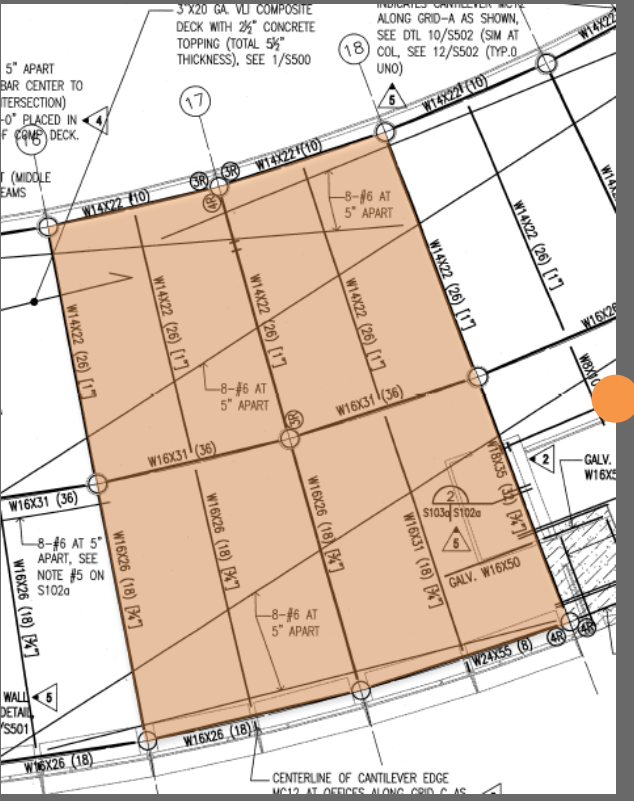


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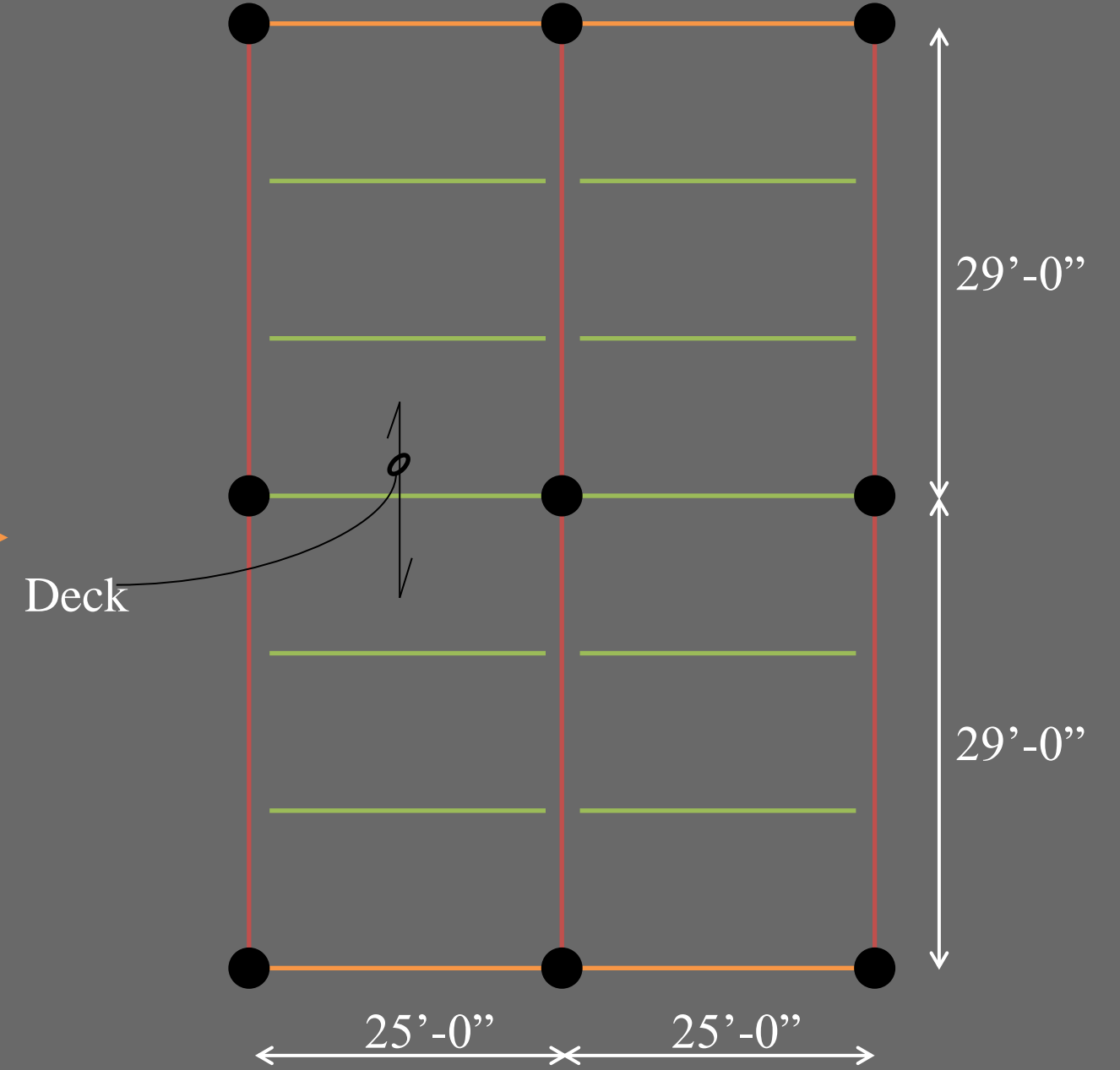
PROPOSED SOLUTION



GRAVITY REDESIGN

– Conservative bay size selected

LATERAL REDESIGN

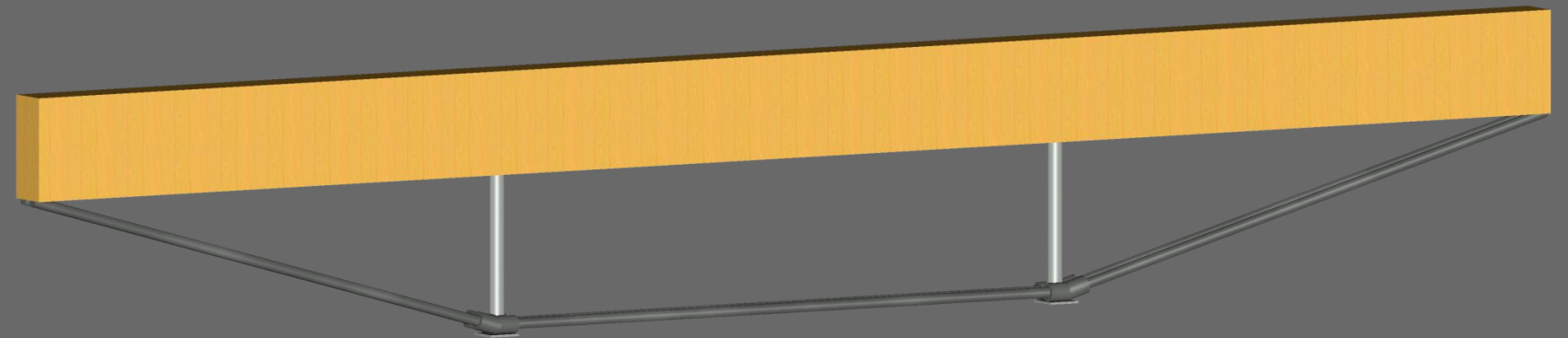


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- Queen Post Girder
- Floor System Selection
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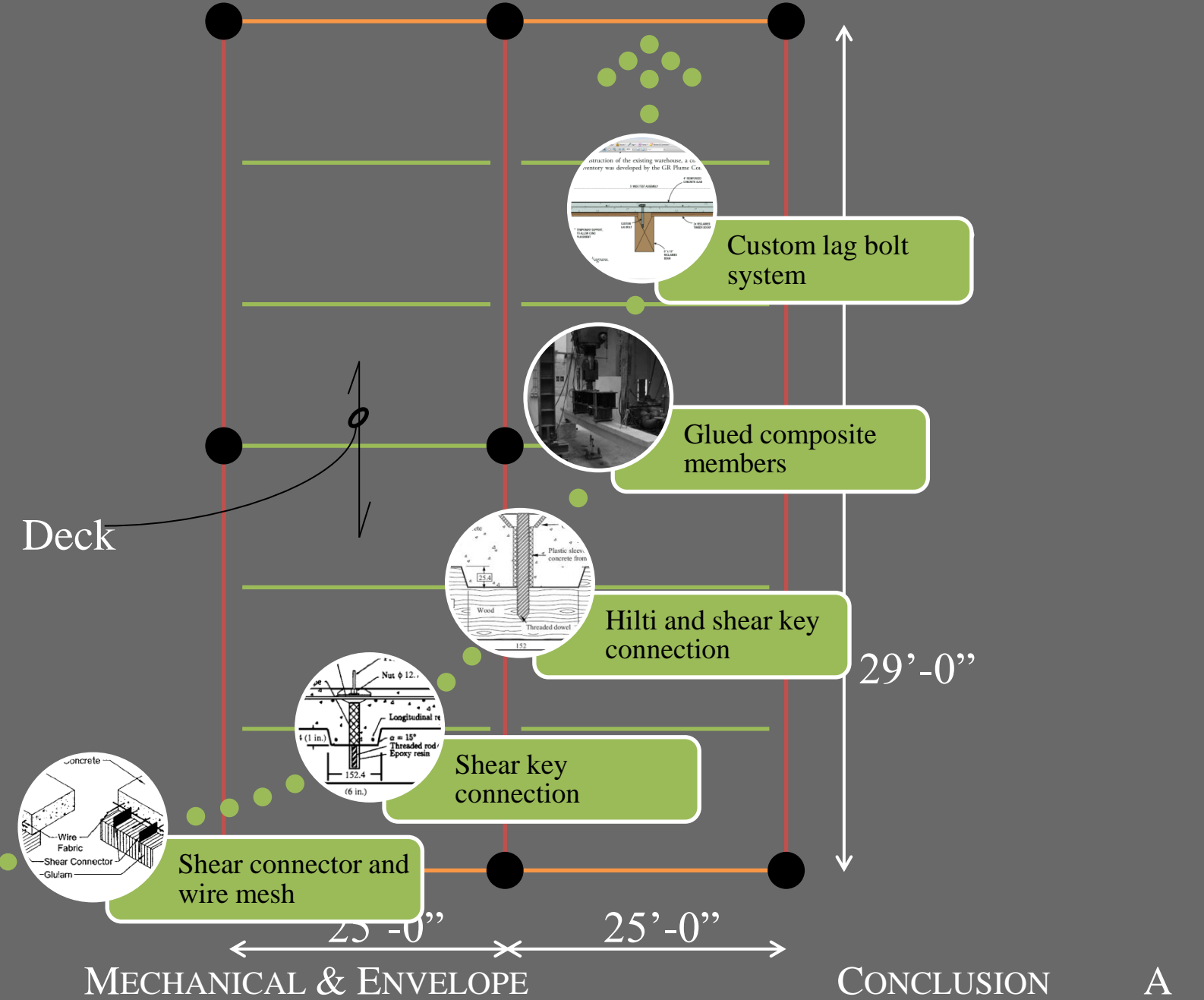
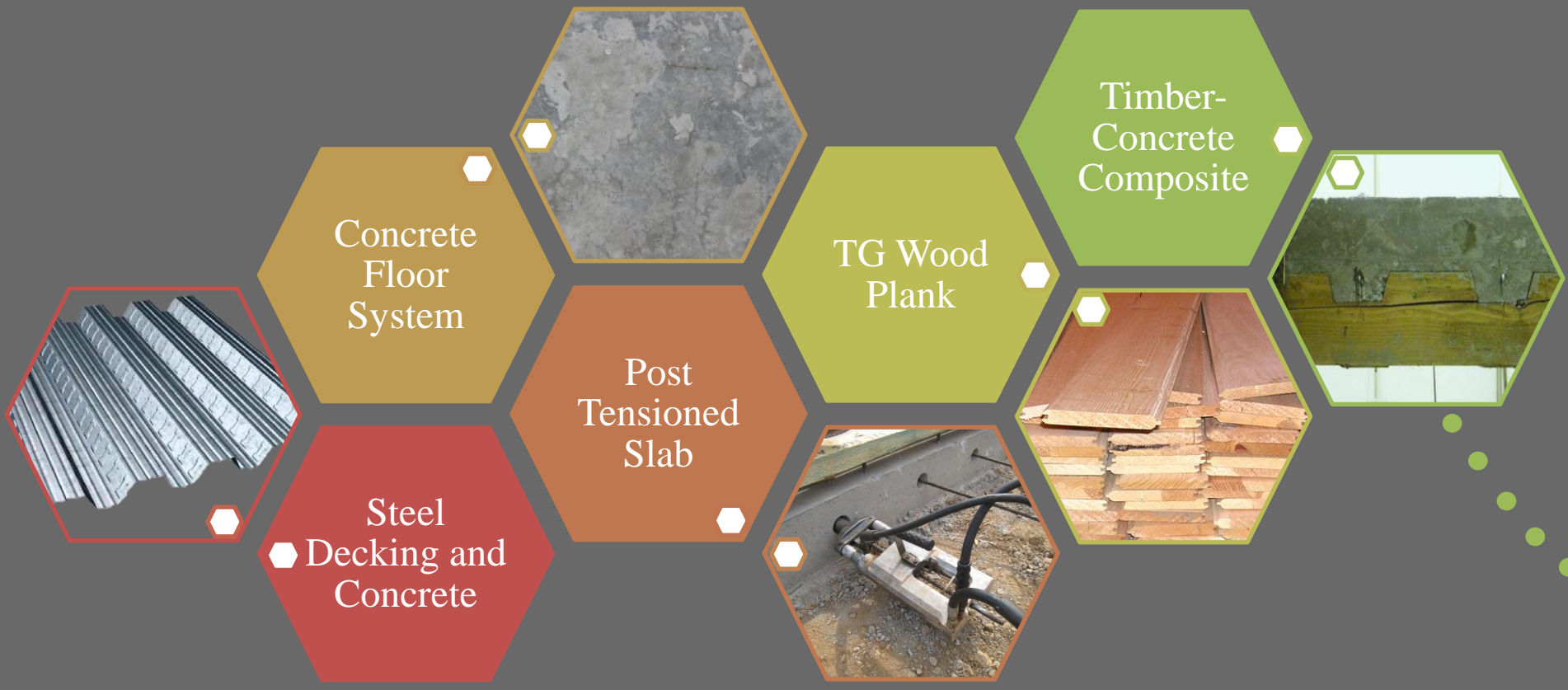
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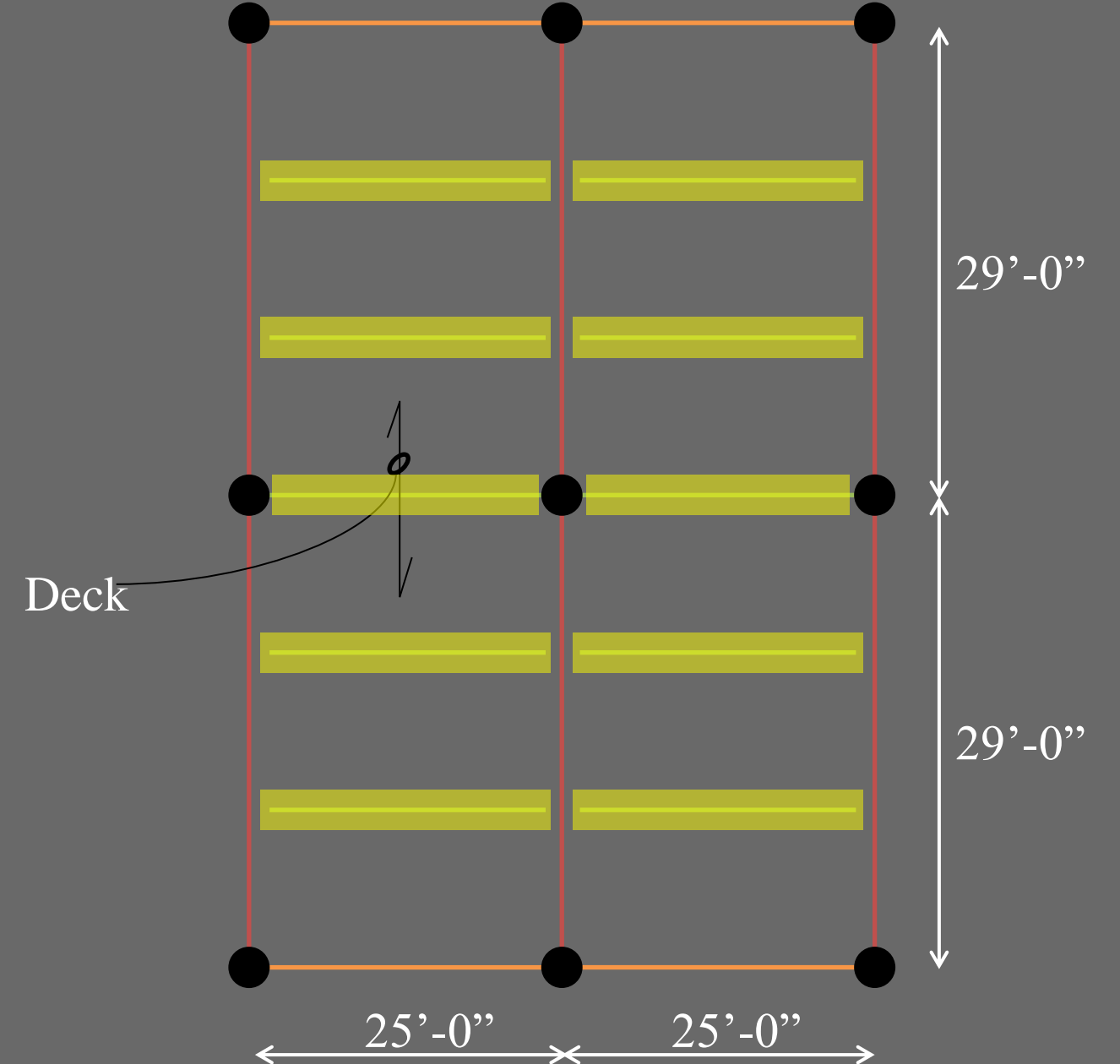
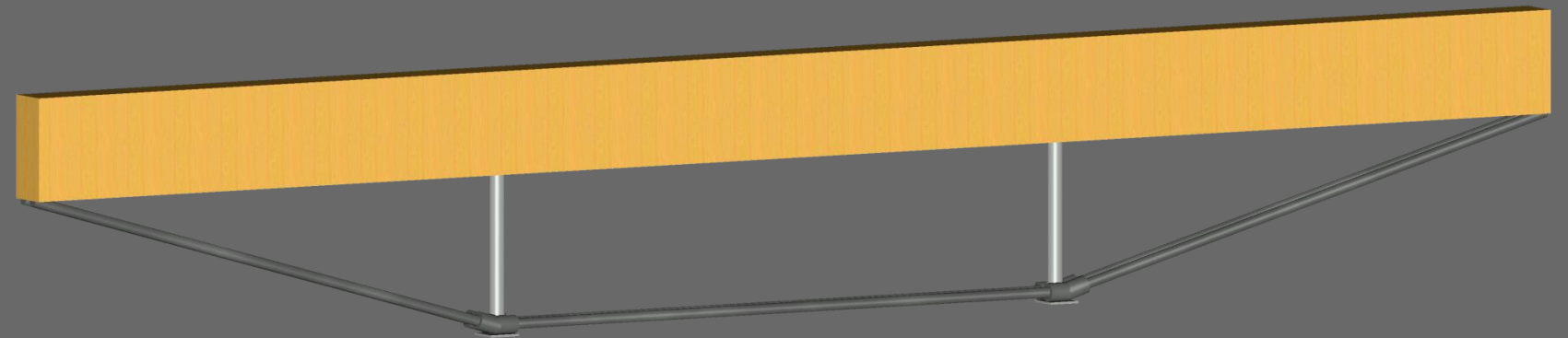
– Floor system selection



GRAVITY REDESIGN

- Queen Post Girder
- Floor System Selection
- **Queen Post Design**
- Queen Post Connection Detail
- System Comparison

– Beam
• 10 1/2" x 19 1/4" 30F-2.1E SP



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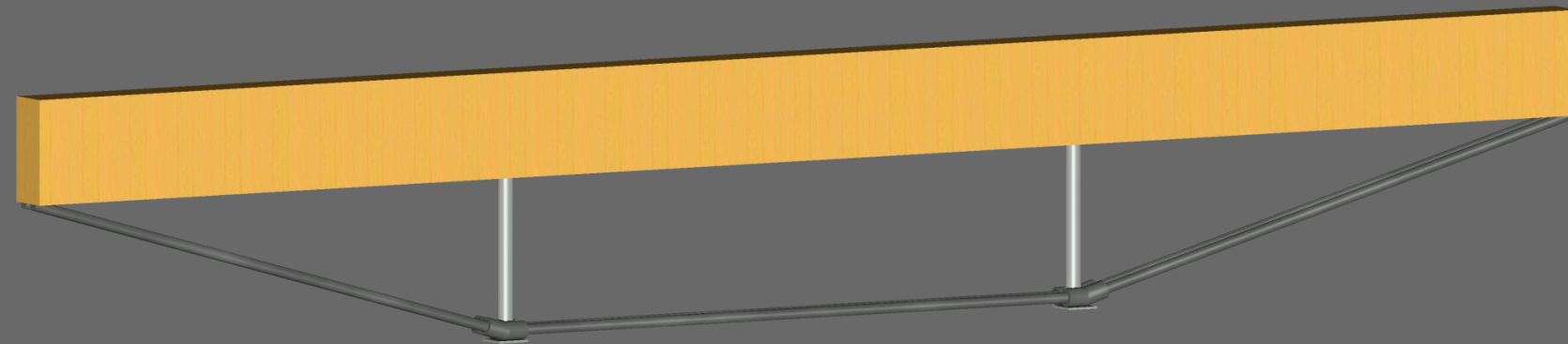
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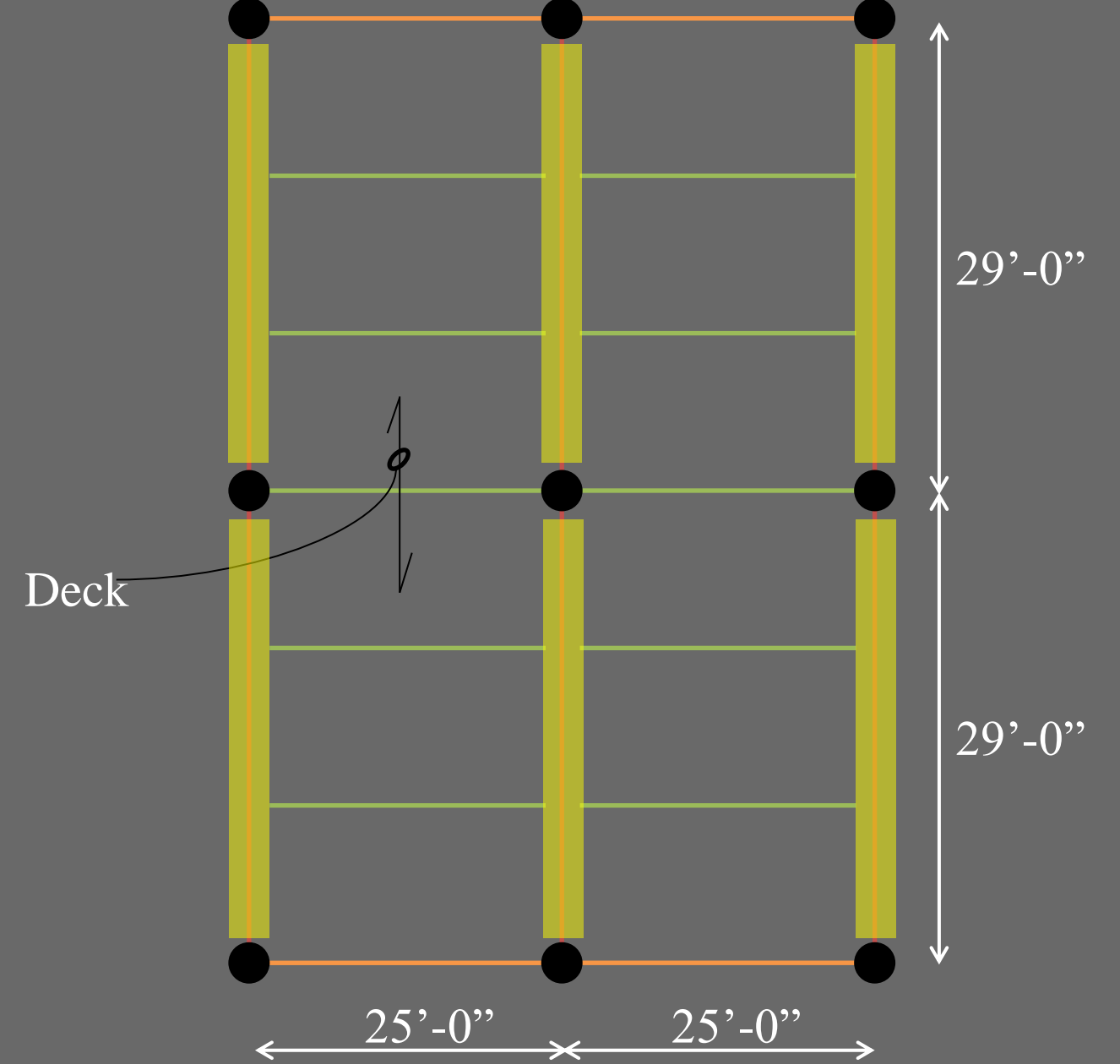
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GRAVITY REDESIGN

- Queen Post Girder
- Floor System Selection
- Queen Post Design
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- System Comparison



– Typical Floor and Roof Bay Layout



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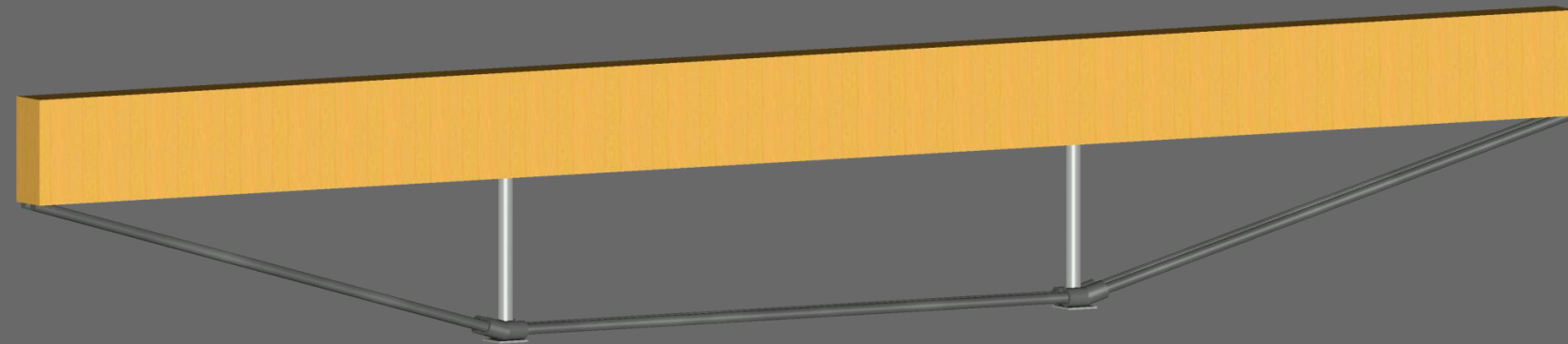
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GRAVITY REDESIGN

- Queen Post Girder
- Floor System Selection
- Queen Post Design
- Queen Post Connection Detail
- System Comparison

– Typical Floor Girder
• 8 ½” x 19 ¼” Stress Class 50 Visual SP

– Typical Roof Girder
• 8 ½” x 12 ¾” Stress Class 50 Visual SP



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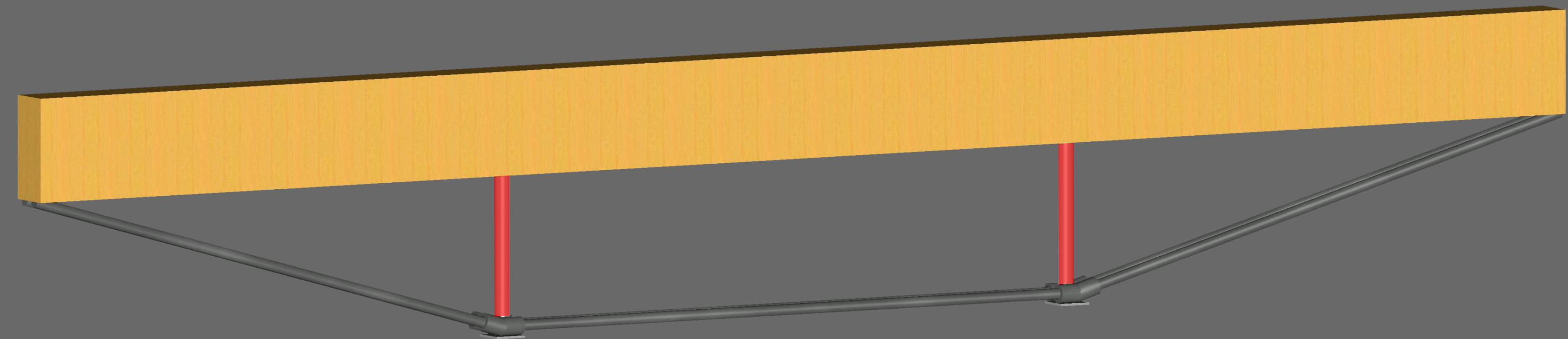
- Queen Post Girder
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- Queen Post Connection Detail
- System Comparison

– Typical Floor Girder

- 8 1/2" x 19 1/4" Stress Class 50 Visual SP
- 3 1/2" x 3 1/2" x 3/8" Square HSS Post

– Typical Roof Girder

- 8 1/2" x 12 3/8" Stress Class 50 Visual SP
- 3 1/2" x 3 1/2" x 3/8" Square HSS Post



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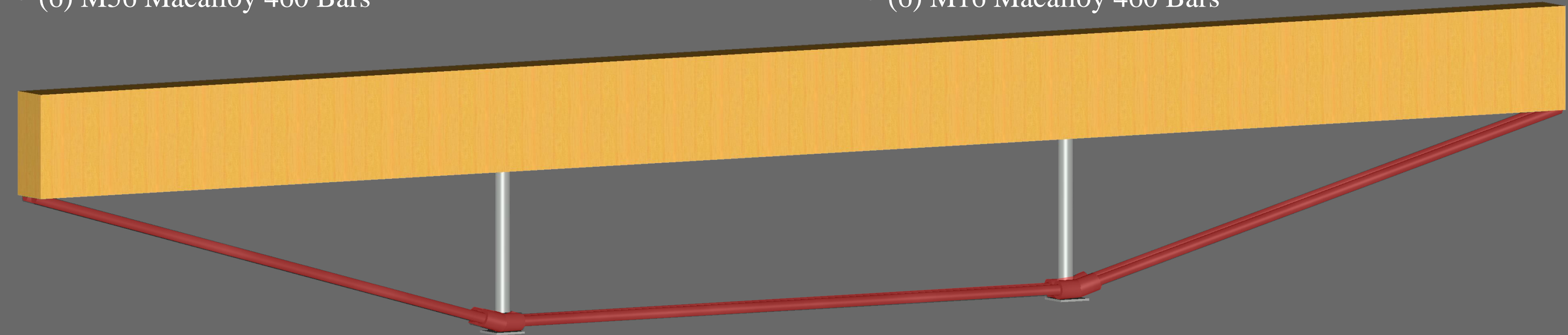
- Queen Post Girder
- Floor System Selection
- **Queen Post Design**
- Queen Post Connection Detail
- System Comparison

– Typical Floor Girder

- 8 ½” x 19 ¼” Stress Class 50 Visual SP
- 3 ½” x 3 ½” x 3/8” Square HSS Post
- (6) M56 Macalloy 460 Bars

– Typical Roof Girder

- 8 ½” x 12 ¾” Stress Class 50 Visual SP
- 3 ½” x 3 ½” x 3/8” Square HSS Post
- (6) M16 Macalloy 460 Bars



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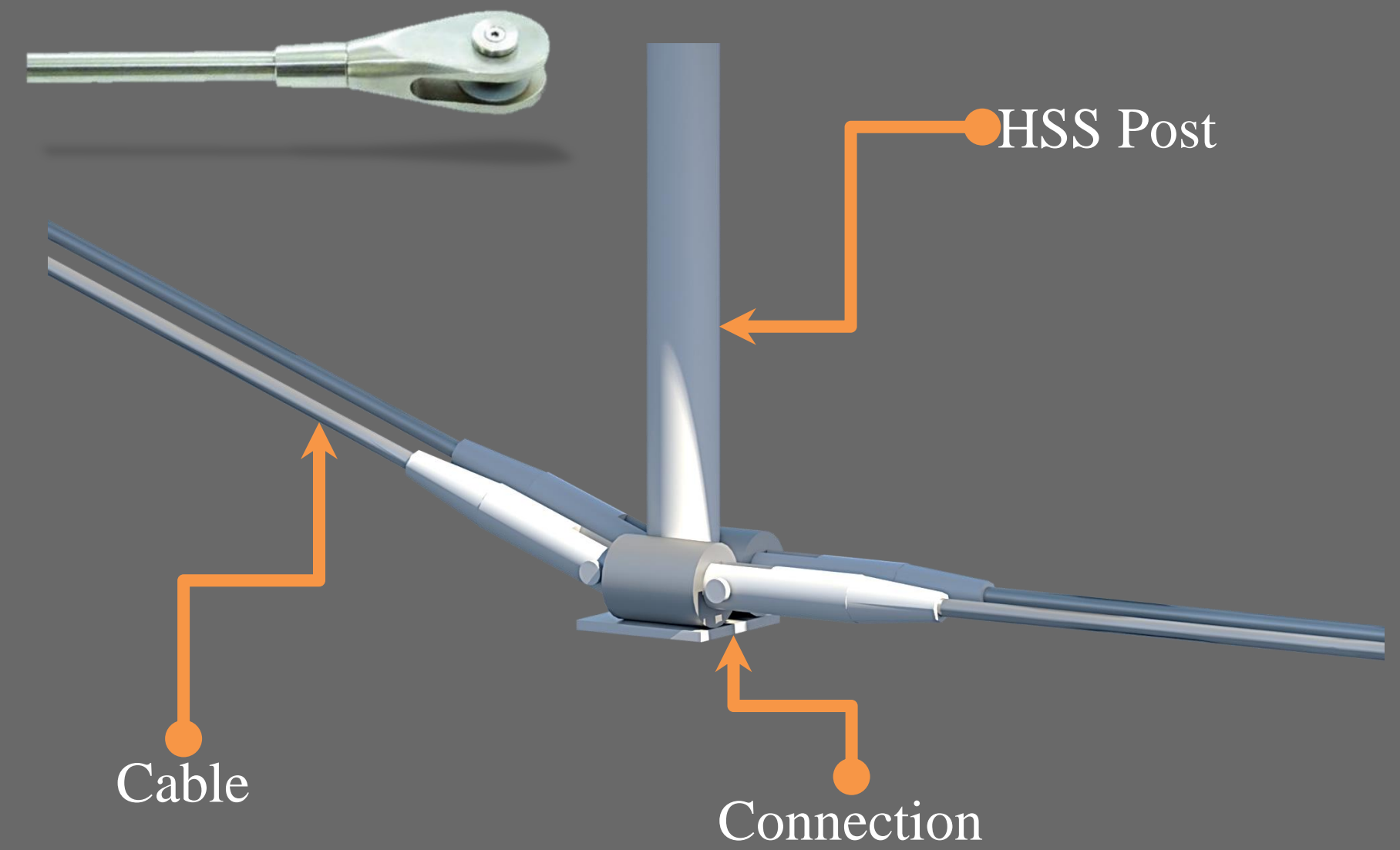
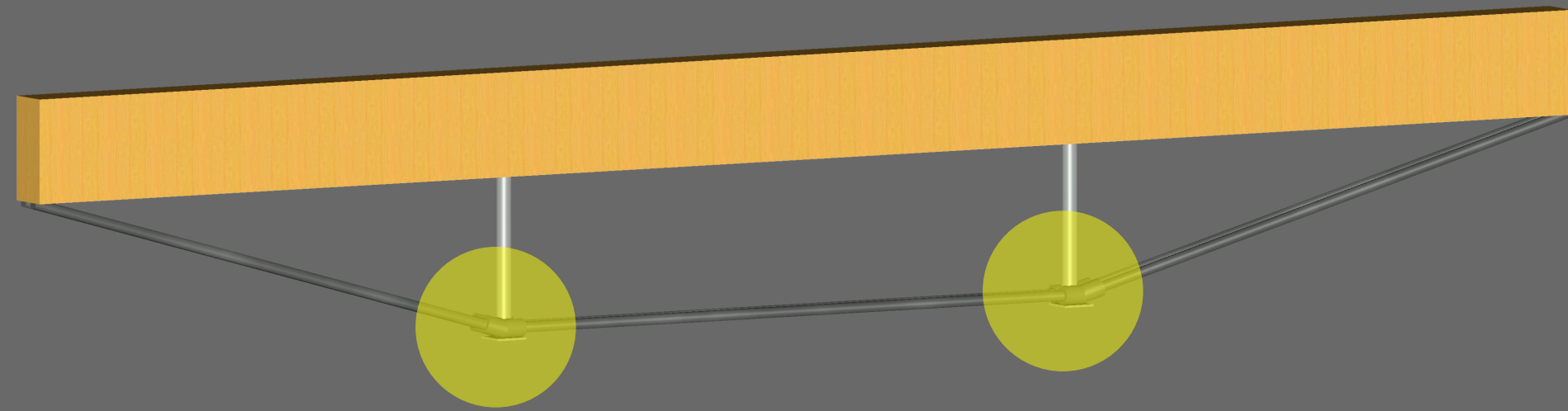
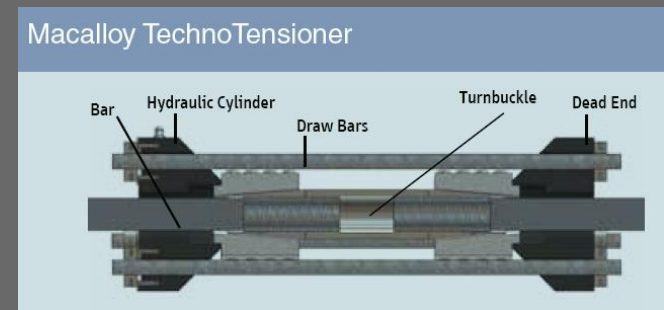
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– Macalloy Bar & Cable Systems



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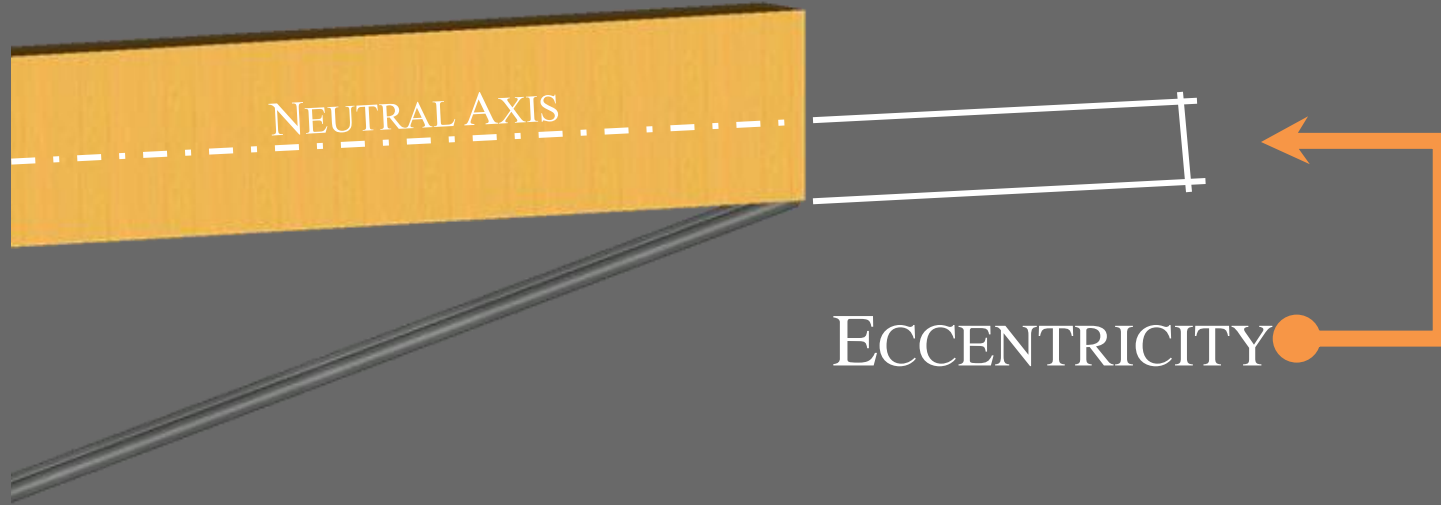
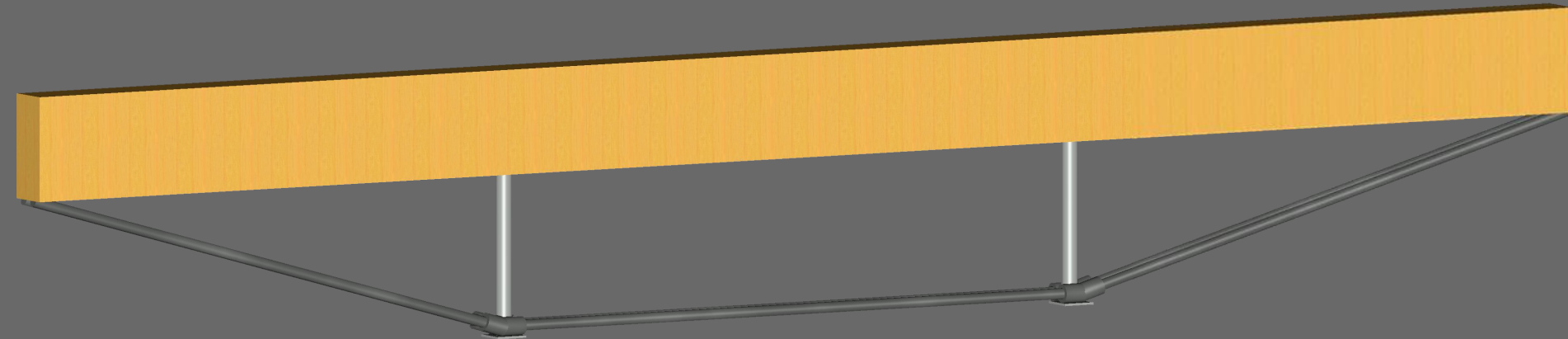
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– Macalloy Bar & Cable Systems

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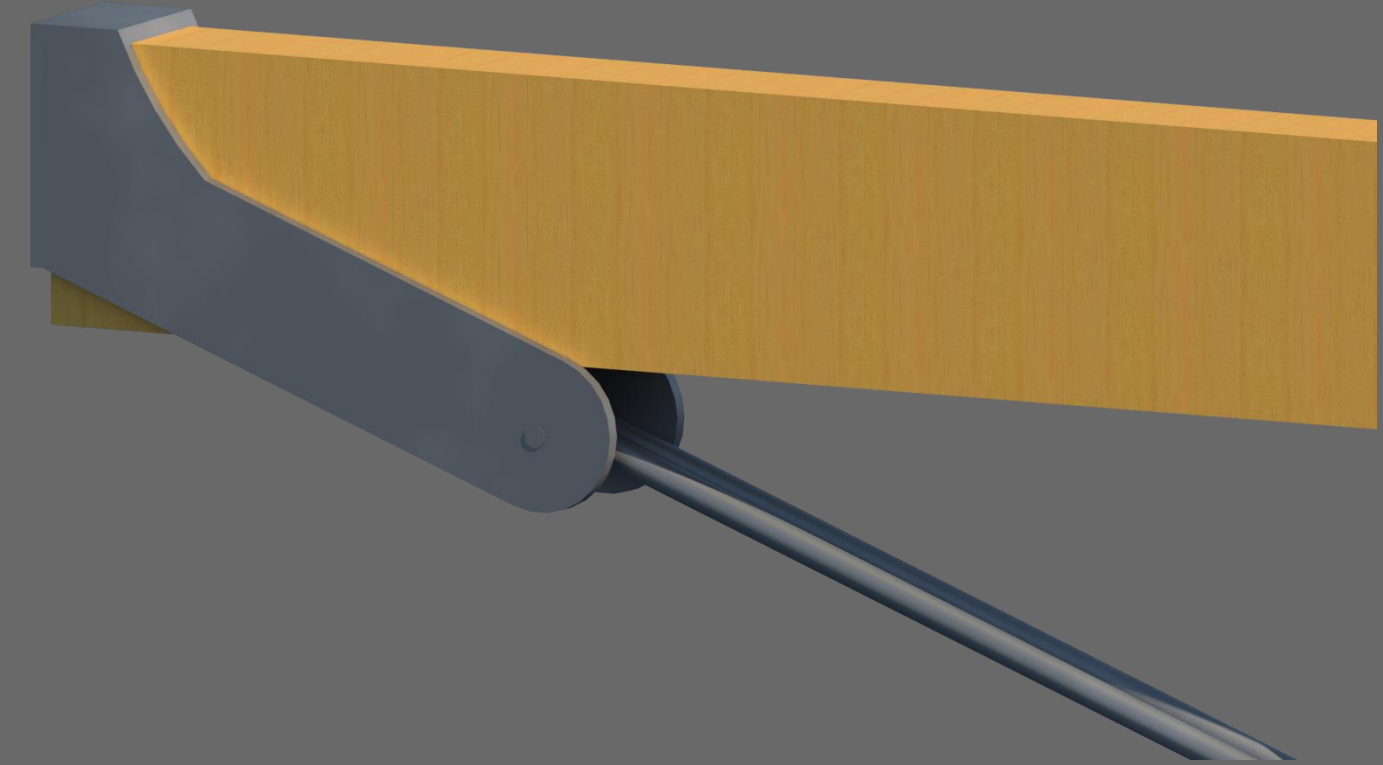
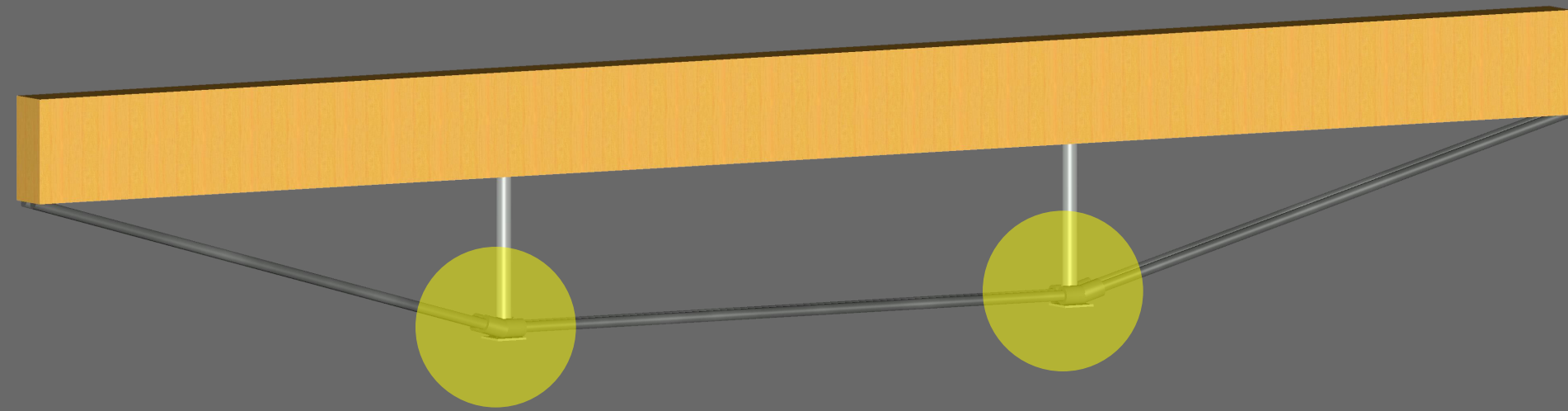
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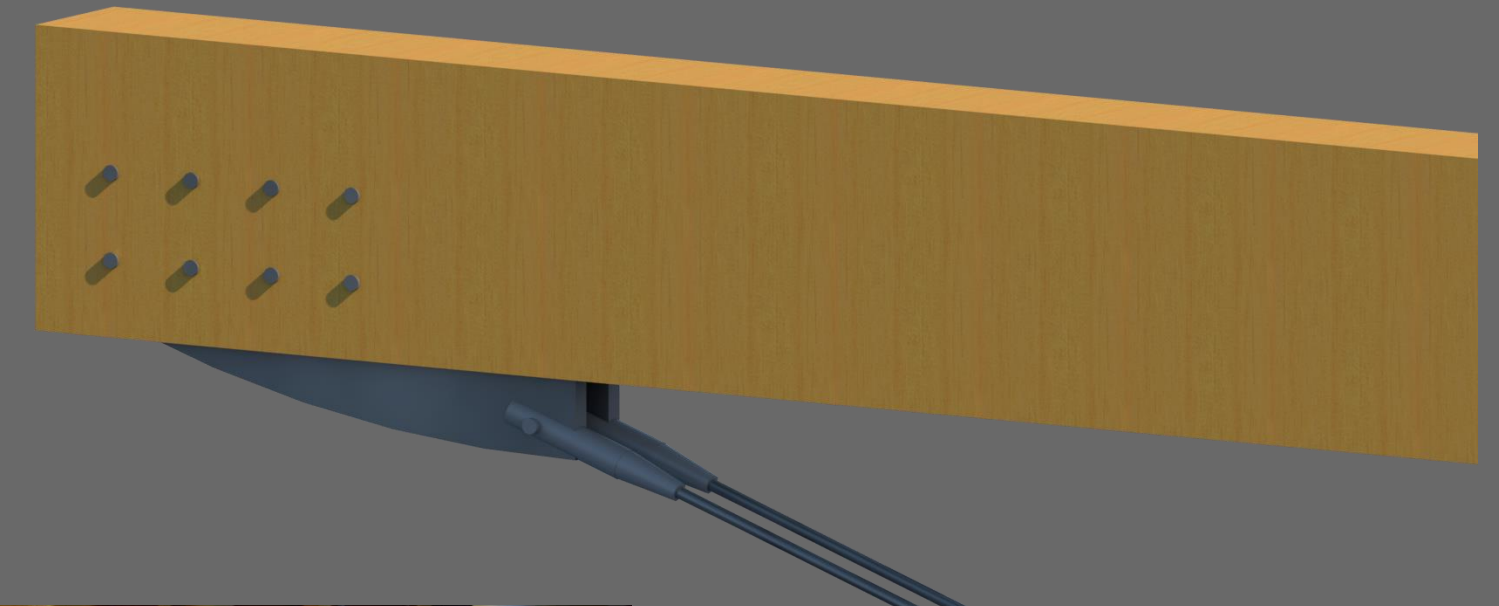
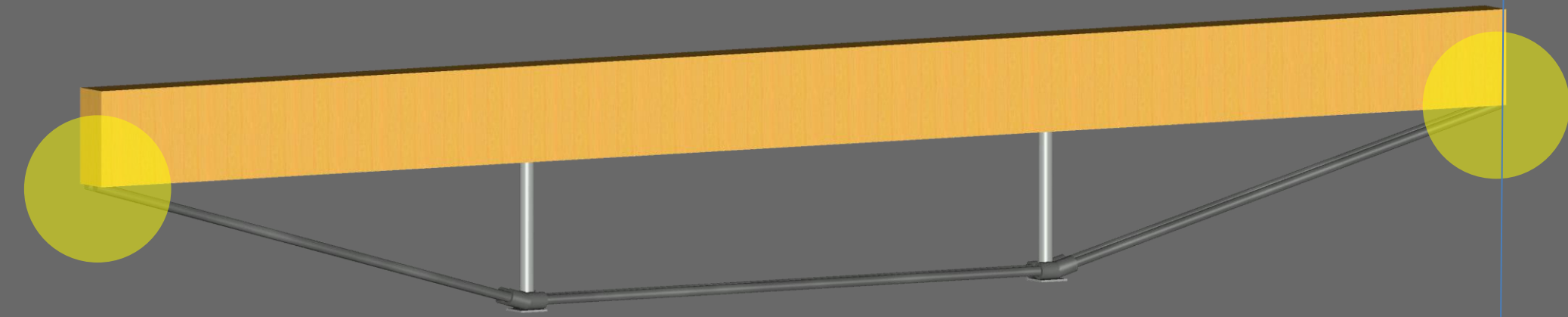
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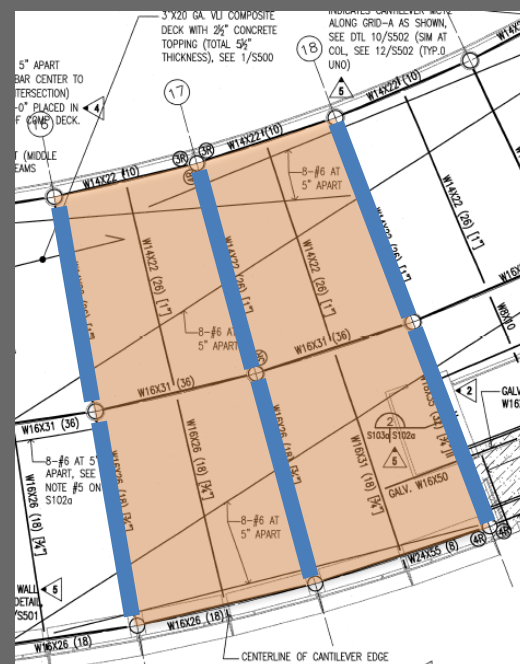
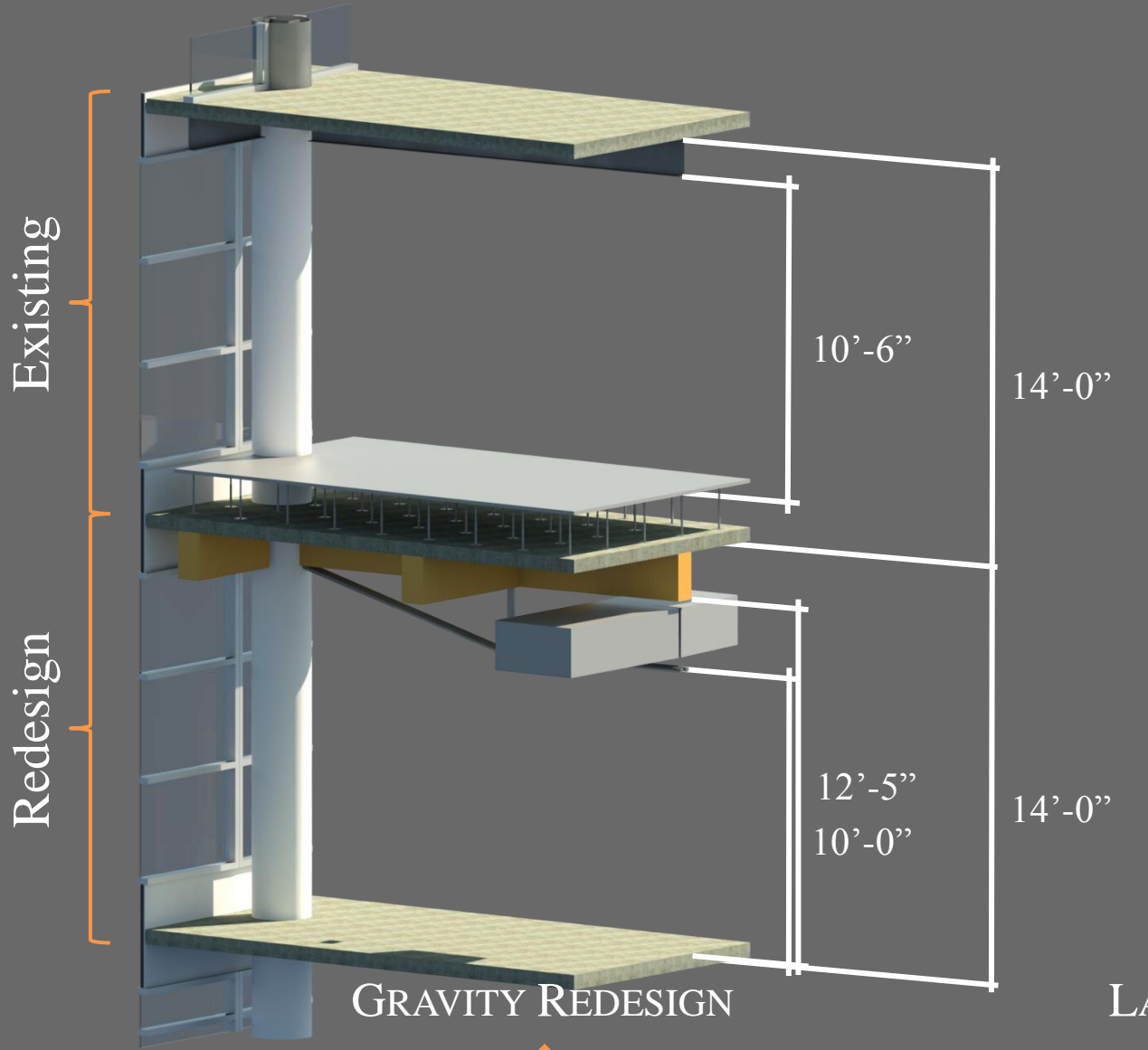
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- Queen Post Girder
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– Floor-to-Floor Height Comparison



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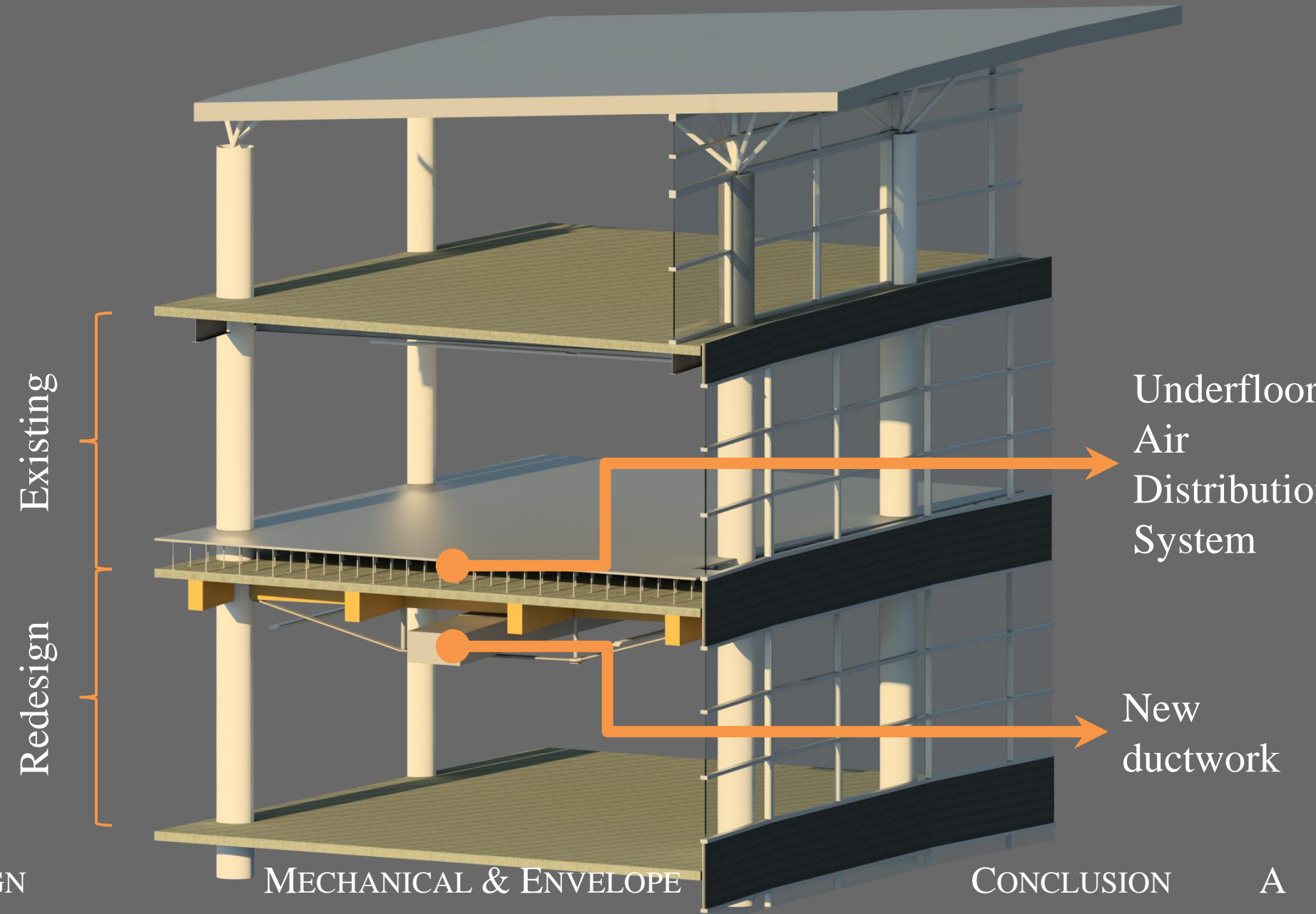
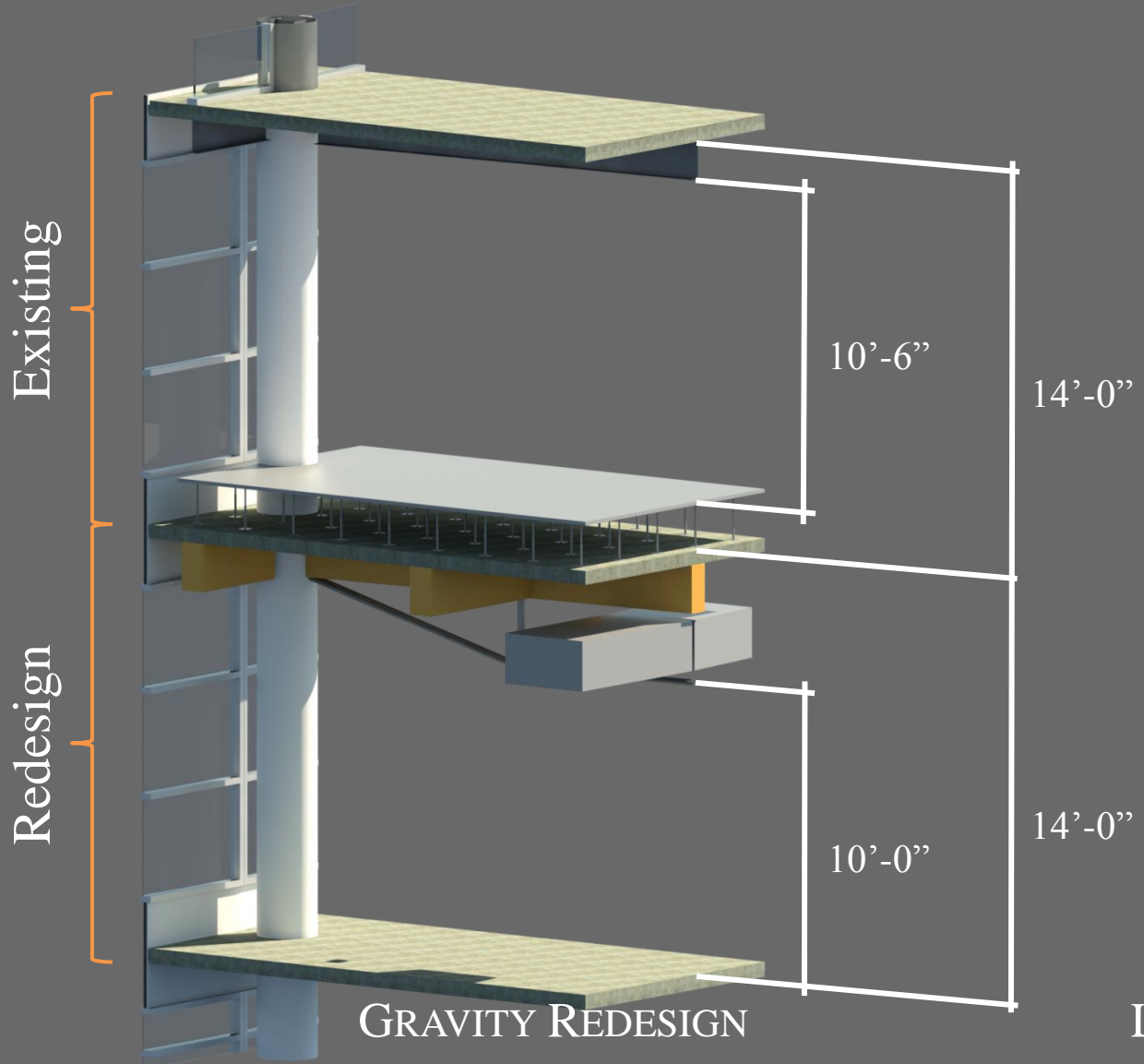
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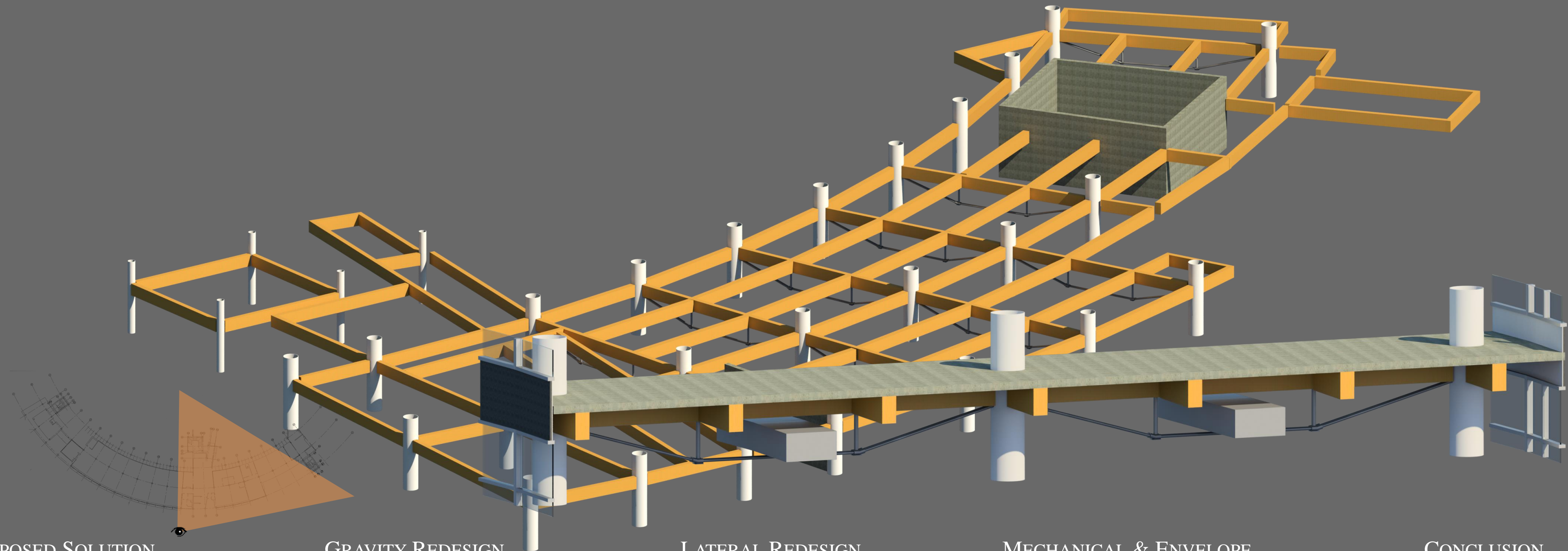
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- **System Comparison**

+ System Advantages

- + Prefabrication
- + Decreased on-site construction
- + Two feet of space immediately below offices
- + Aesthetic and feel of new office environment

➤ Integration between engineering systems



➤ Void between top and bottom chord of queen post girder

- System Disadvantages

- Increased material and labor cost of queen post and glulam beams
- Negated underfloor air distribution system

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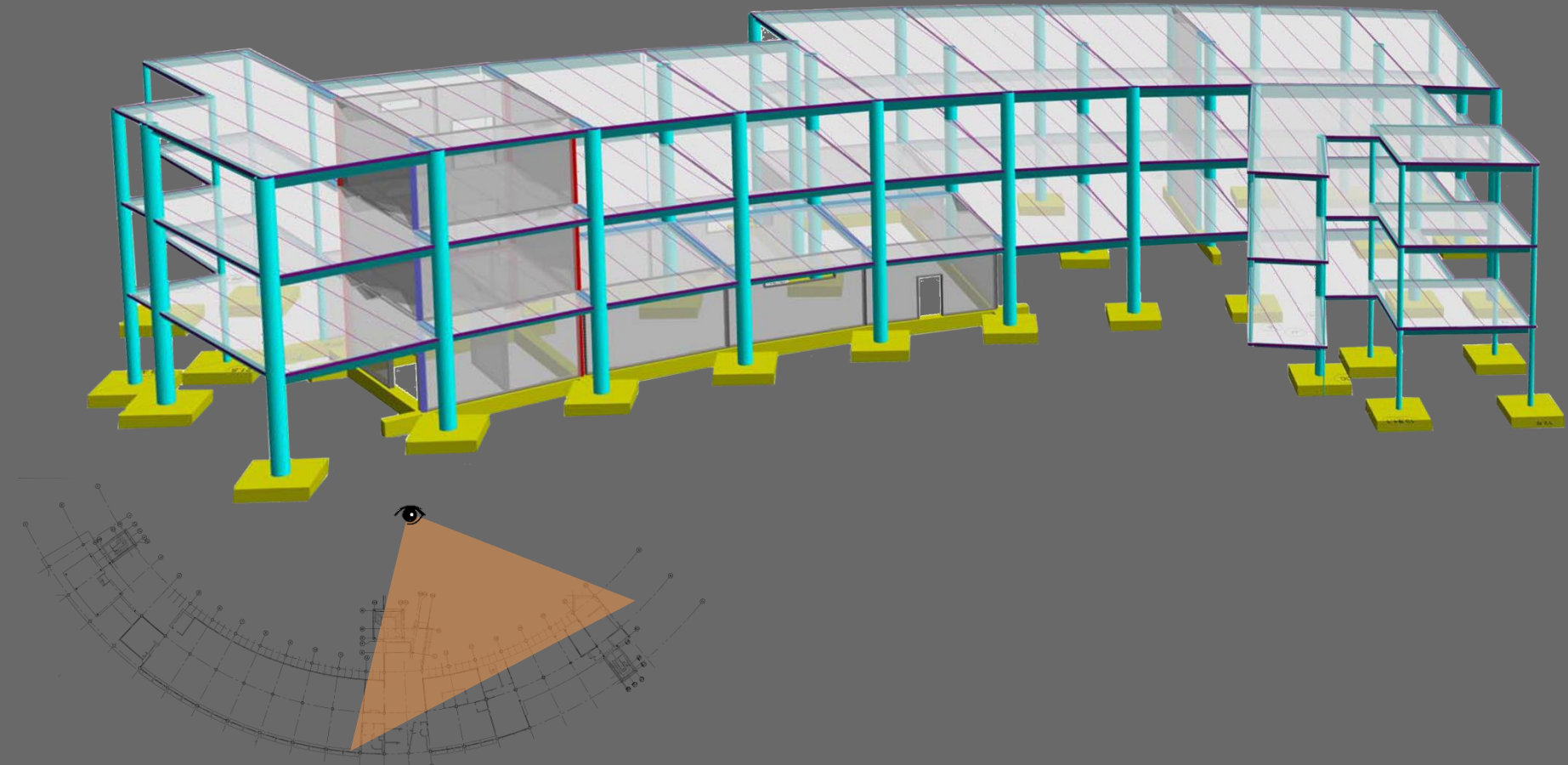
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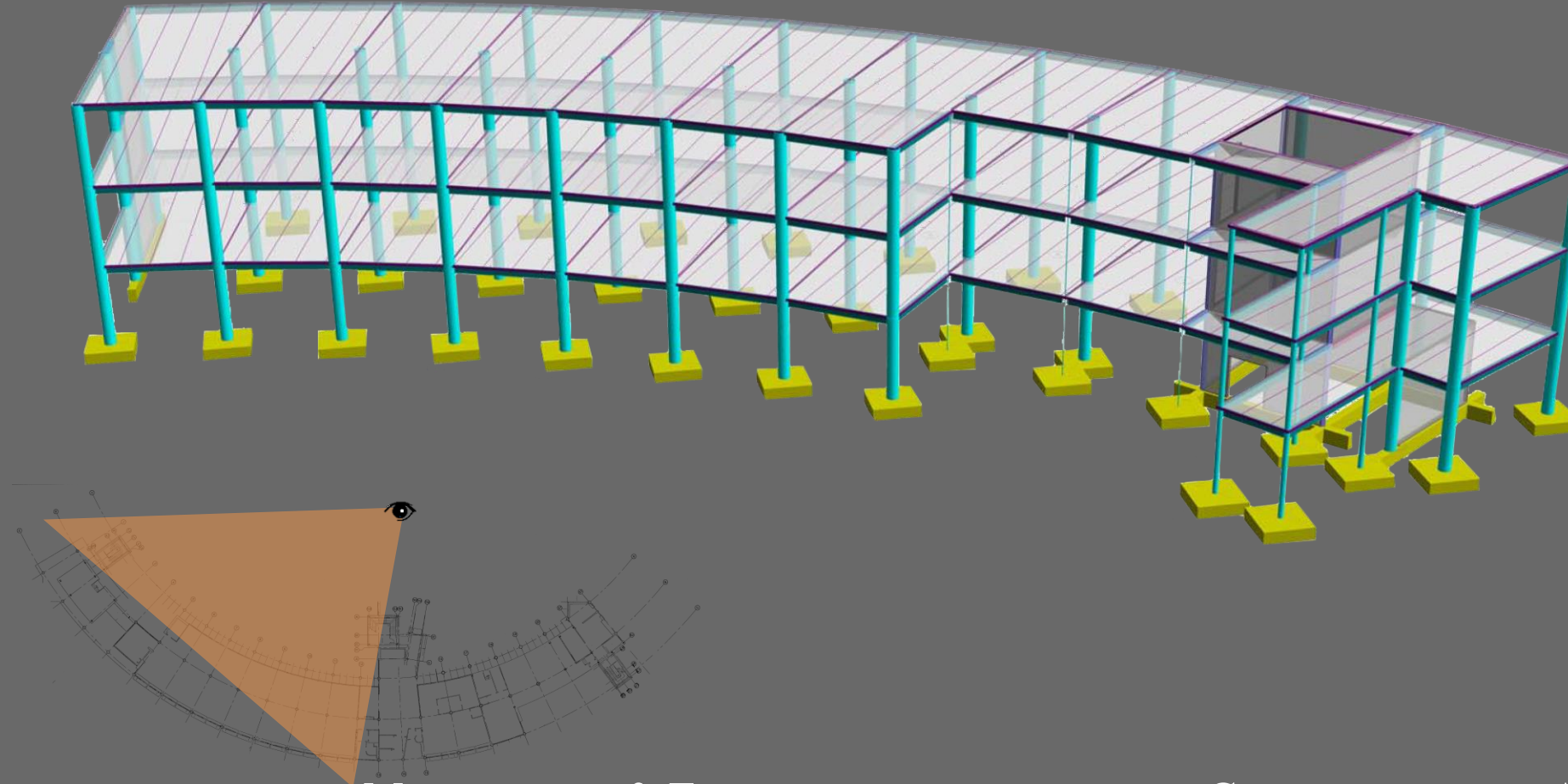
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- RAM SS Modeling
- Load Path and Irregularity
- Shear Wall Design
- System Comparison

– East LFRS



– West LFRS



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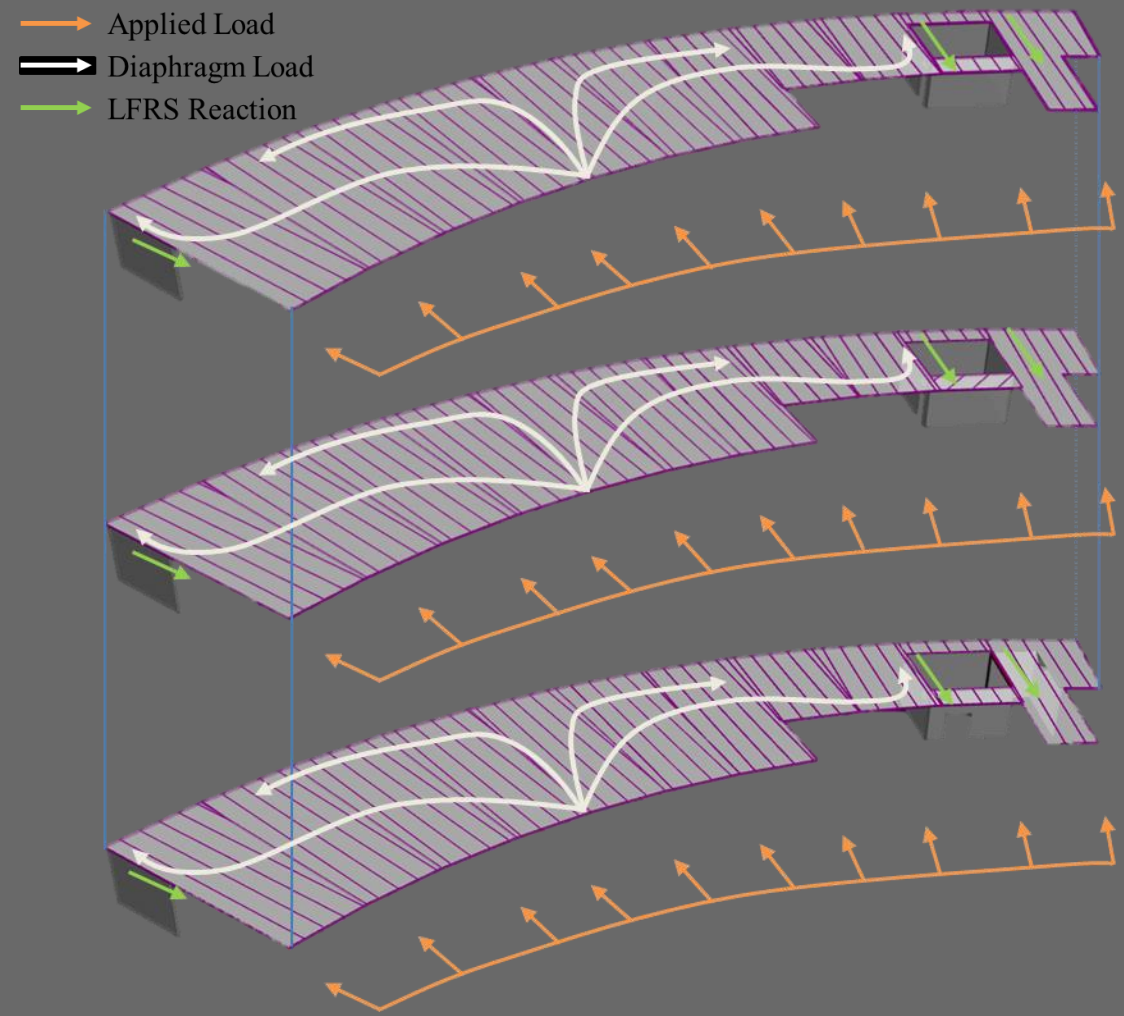
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LATERAL REDESIGN

- RAM SS Modeling
- Load Path and Irregularity
- Shear Wall Design
- System Comparison

– Load Path



– Horizontal and Vertical Irregularity

- Horizontal
 - Type 1a Torsional Irregularity
 - Type 1b Extreme Torsional Irregularity
 - Type 5 Nonparallel System Irregularity
- Vertical
 - Type 4 In-Plane Discontinuity in Vertical LFR Element Irregularity
 - Type 5b Discontinuity in Lateral Strength-Extreme Weak Story Irregularity

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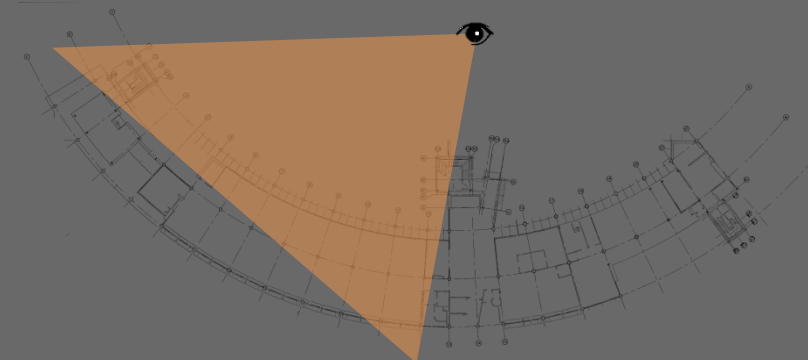
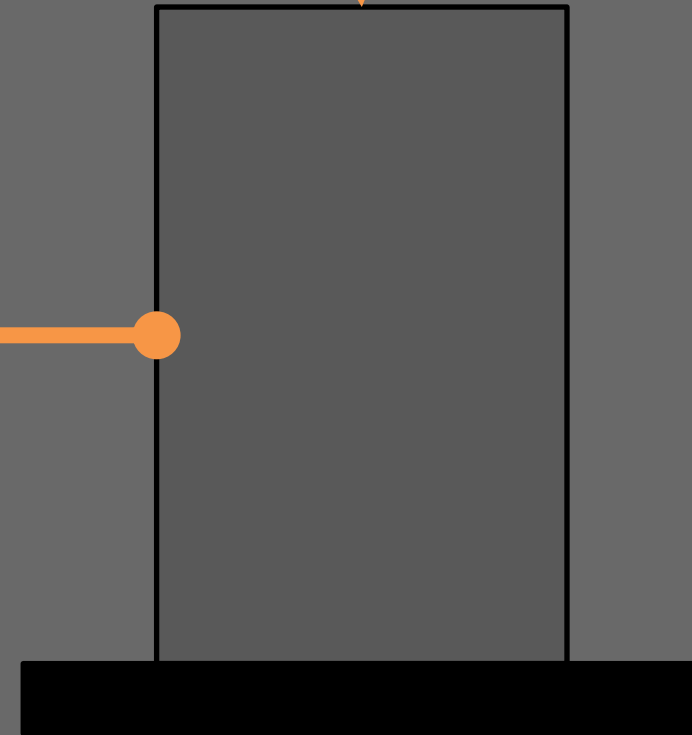
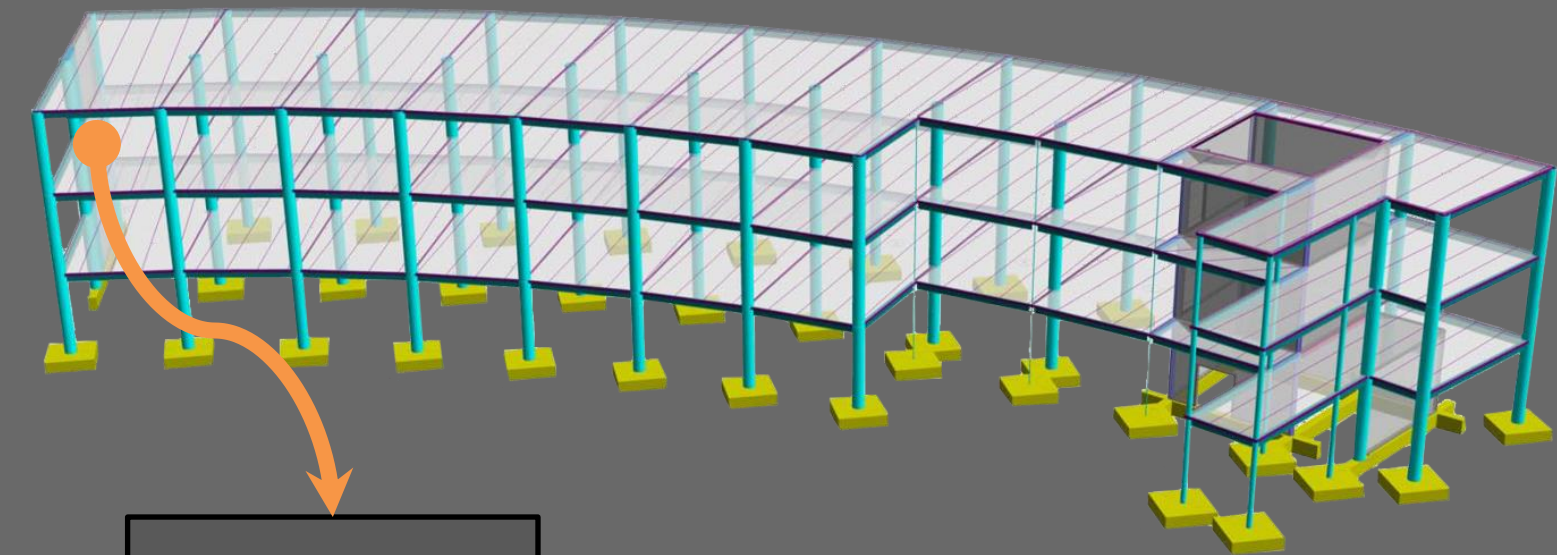
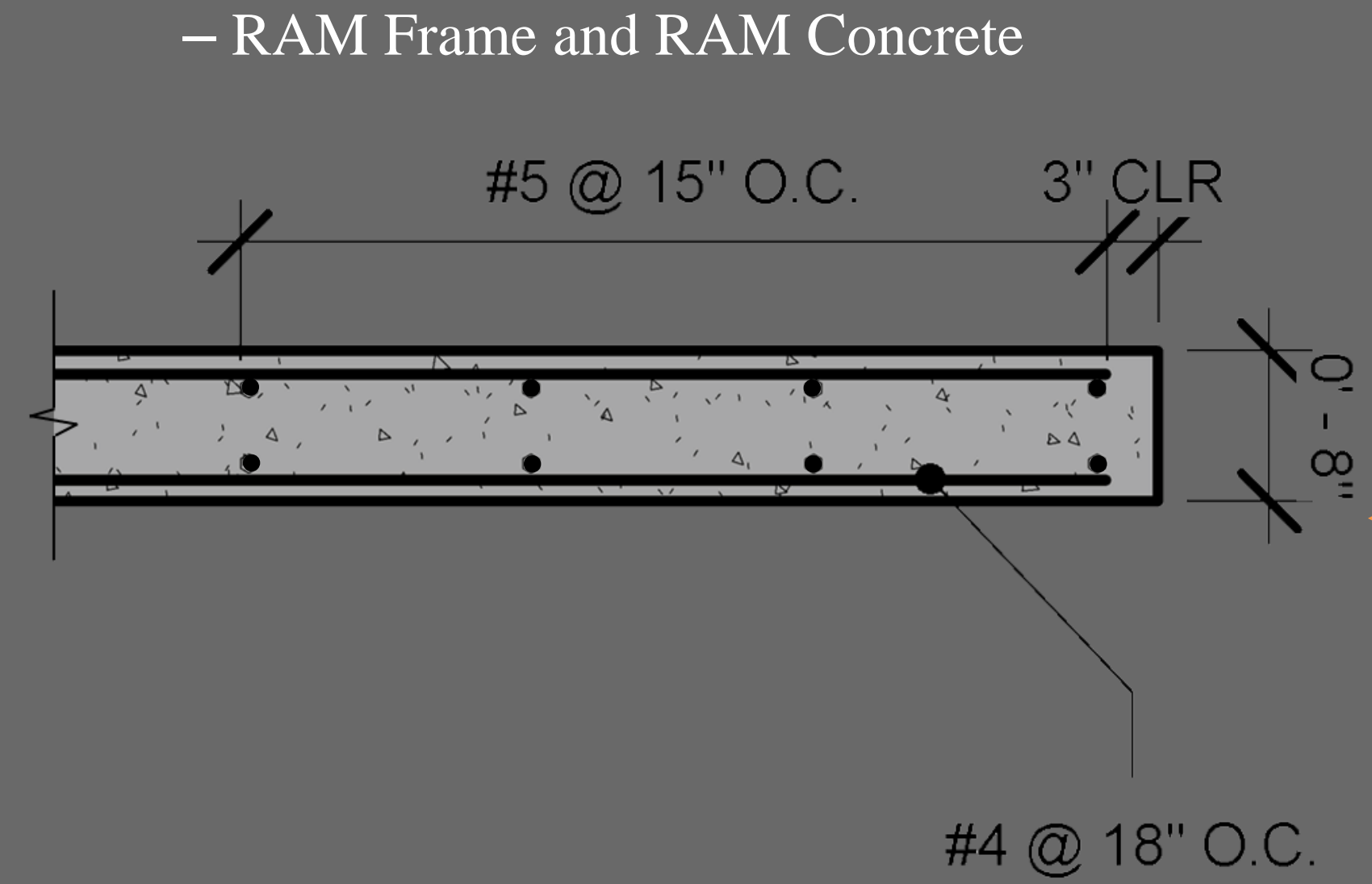
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- RAM SS Modeling
- Load Path and Irregularity
- **Shear Wall Design**
- System Comparison



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- RAM SS Modeling
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+ System Advantages

+ Ubiquitous use of concrete shear walls in industry

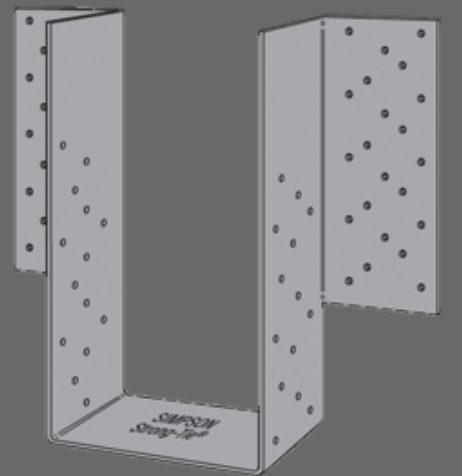
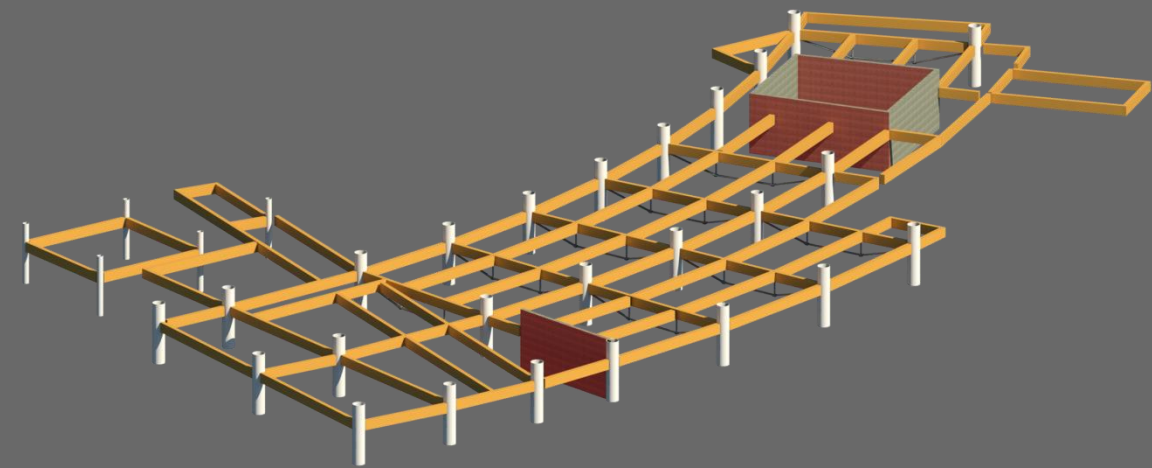


➤ No change to building's LFRS layout



- System Disadvantages

- High capacity hangers for glulam beams will be required to frame into concrete shear walls



Simpson Strong-Tie
High Capacity Girder Hangers for Concrete and Glulam

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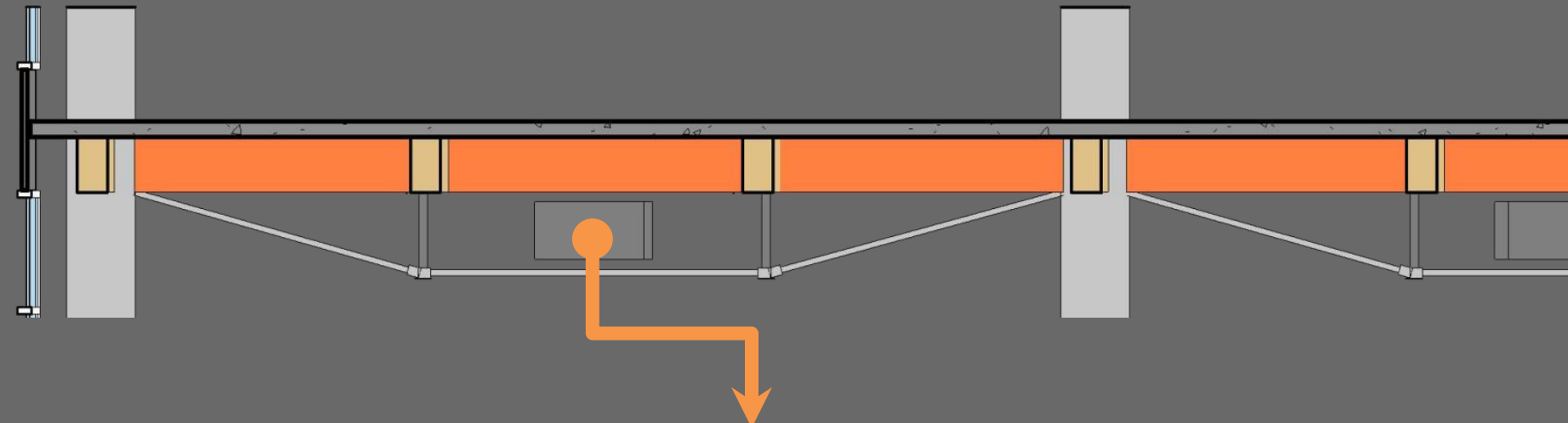
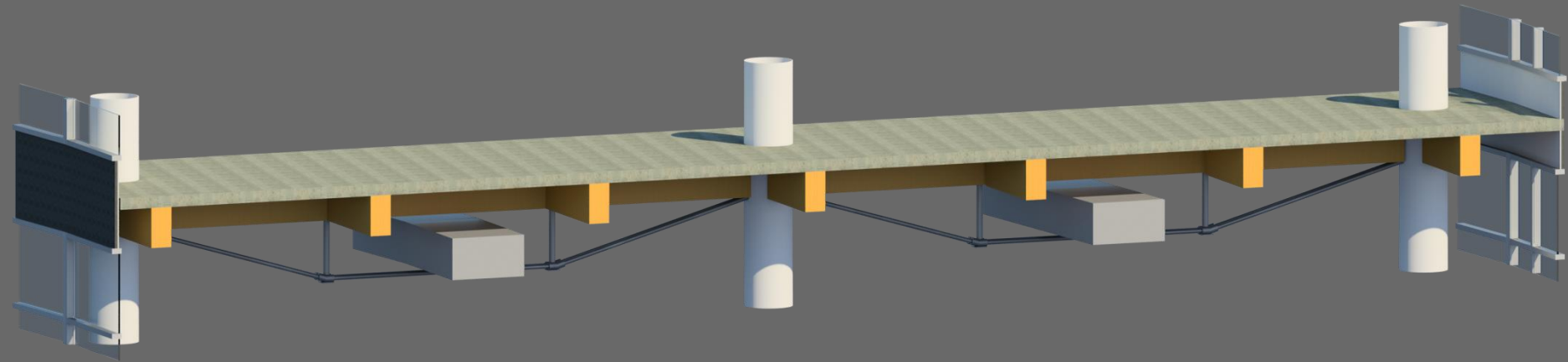
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MECHANICAL

- Ductwork Sizing
- Thermal Bridge Elimination
- Construction Sequence



Unit	Duct Size
AHU-1E	20x38
AHU-1W	20x48
AHU-2E	20x55
AHU-2W	20x70
AHU-3E	20x55
AHU-3W	20x75
AHU-4E	20x50
AHU-4W	20x65
OSA-1E	20x42
OSA-1W	20x50

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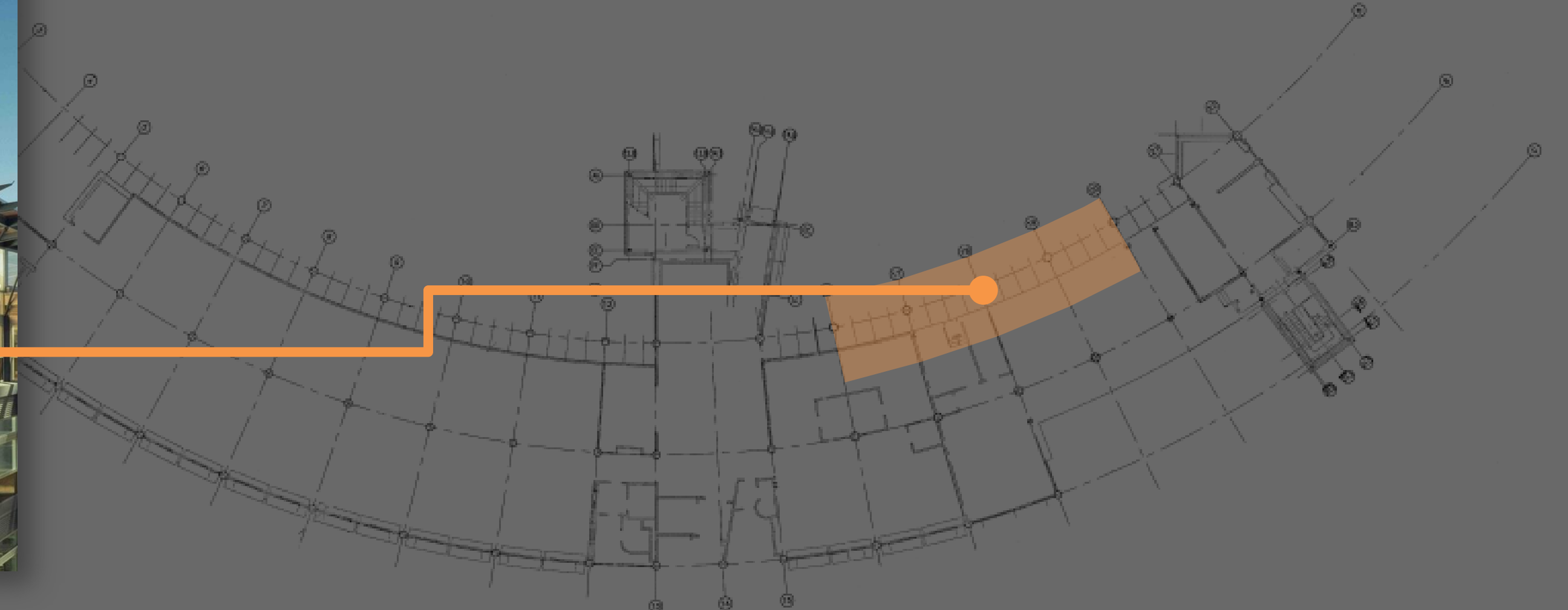
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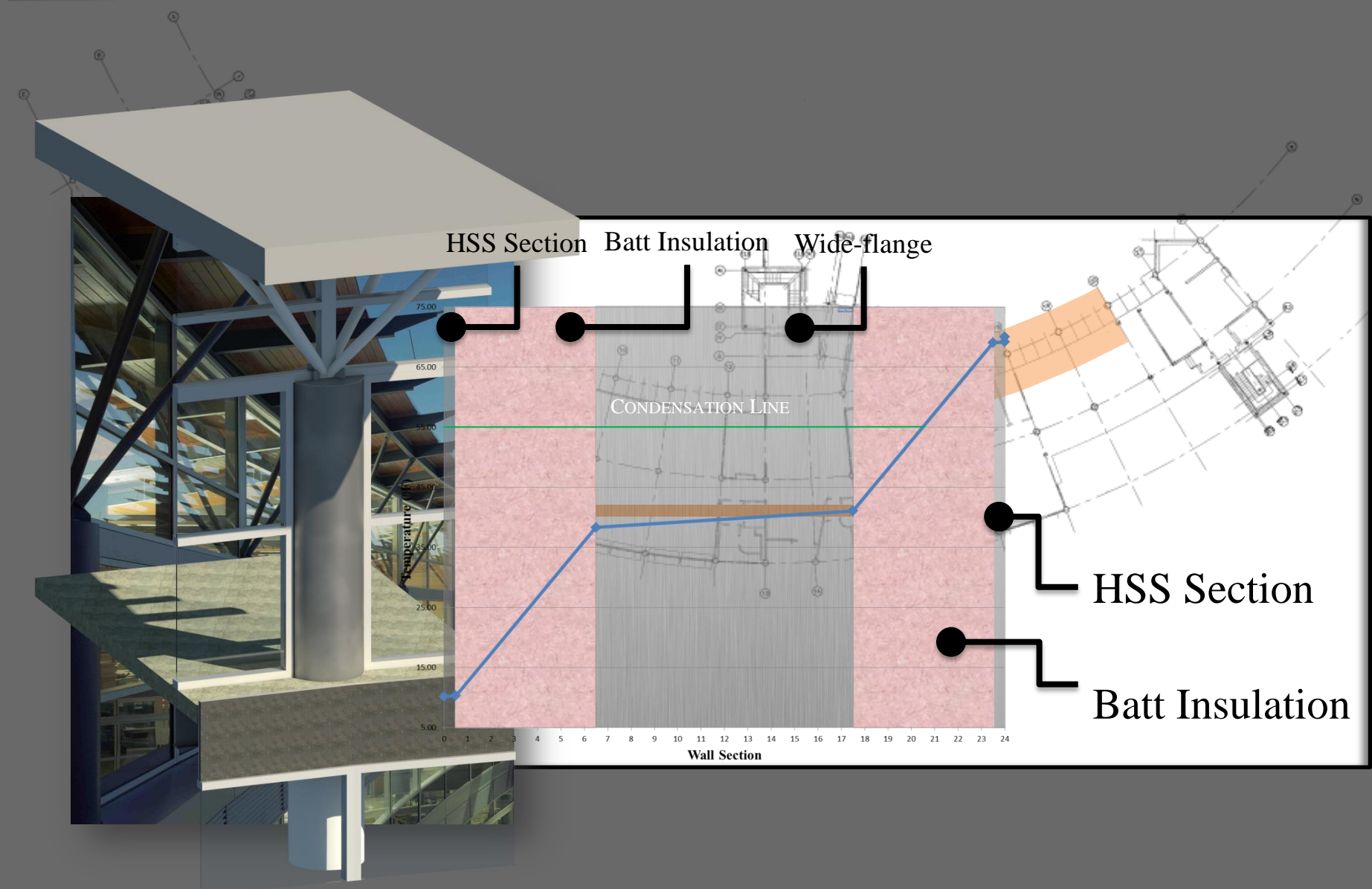
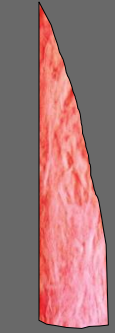
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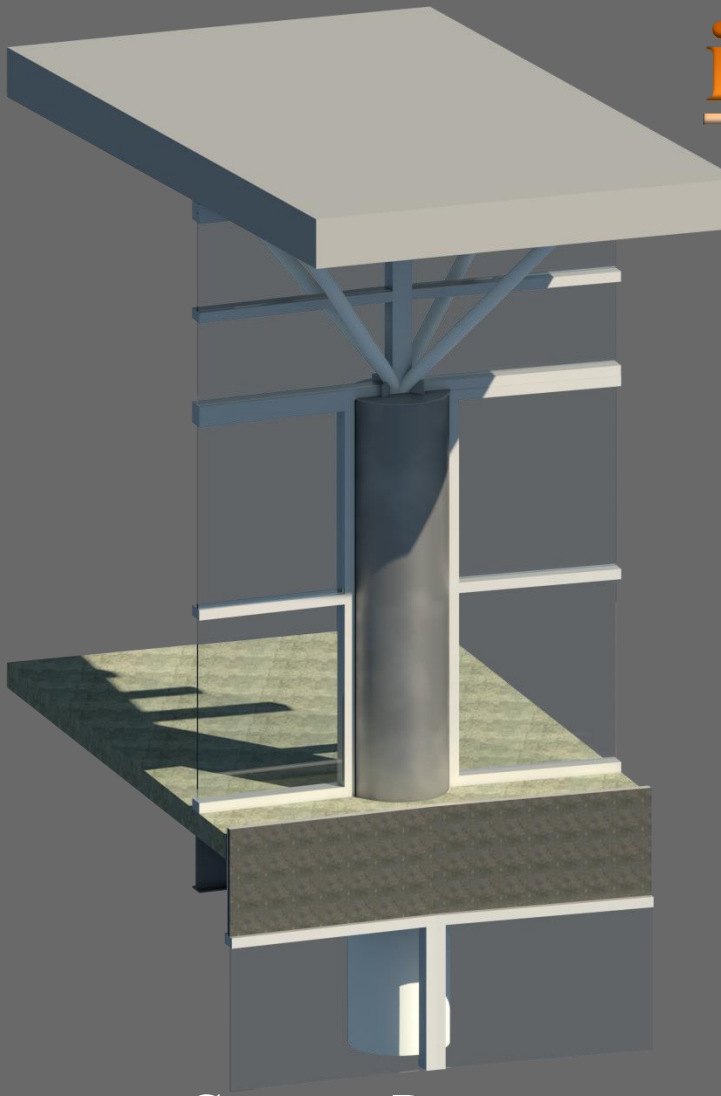
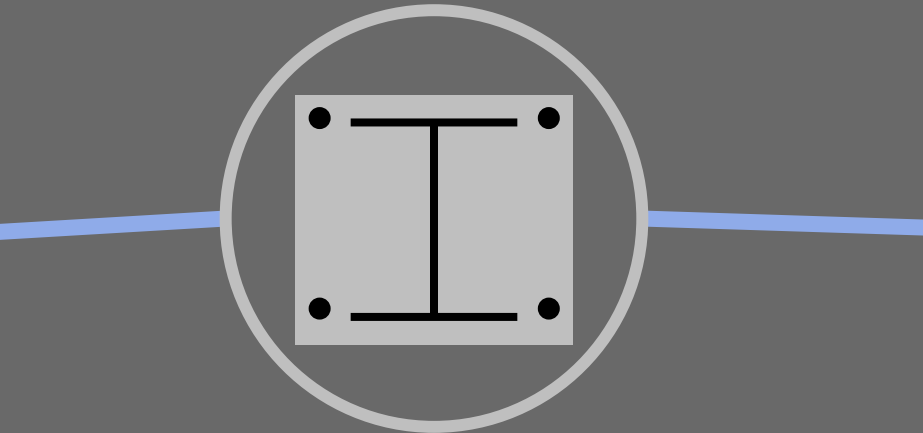
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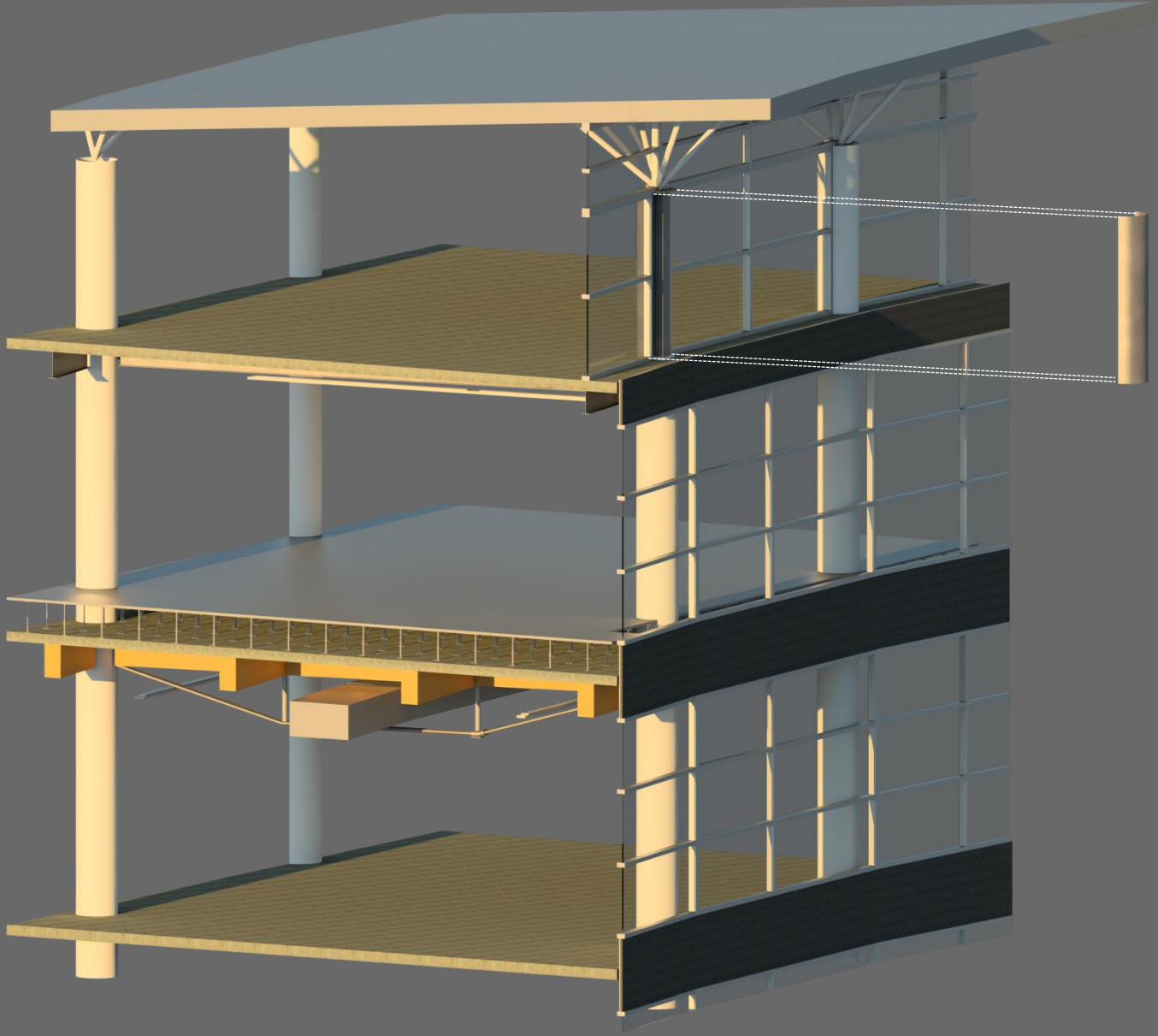
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MECHANICAL

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140% Increase
in U-value



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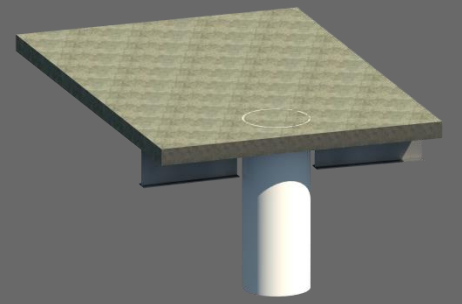
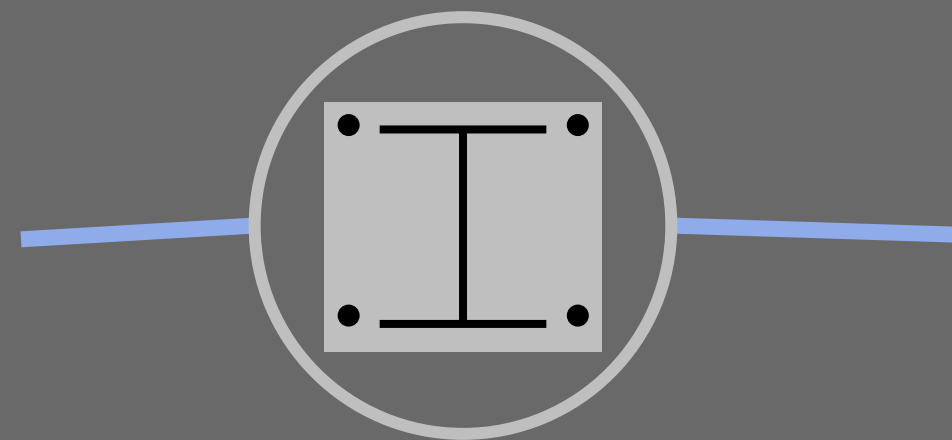
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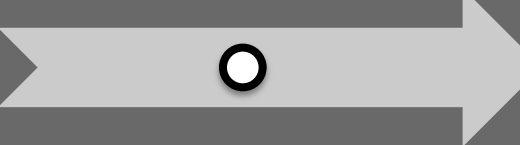
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Finish 4th Floor Slab



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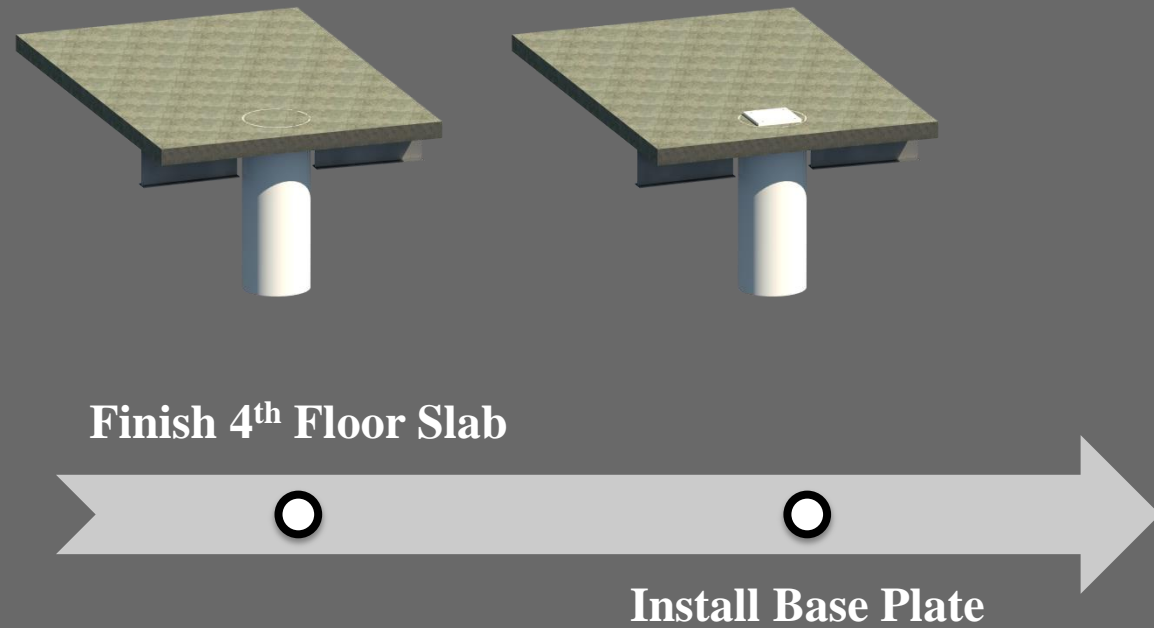
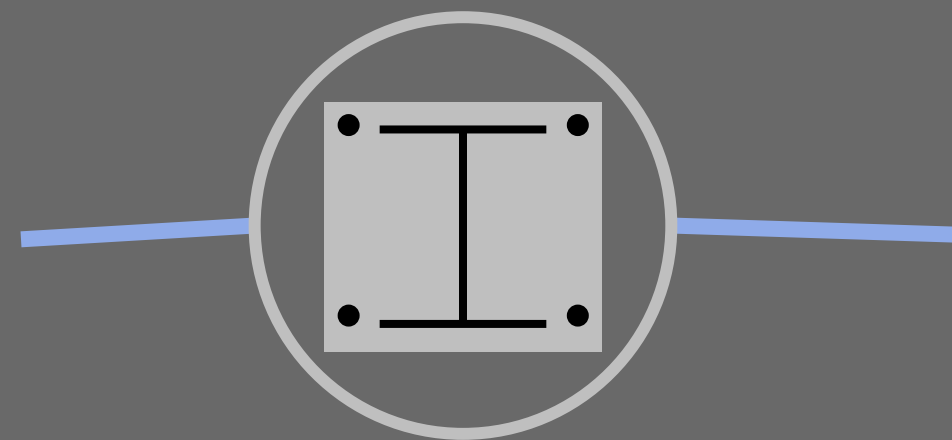
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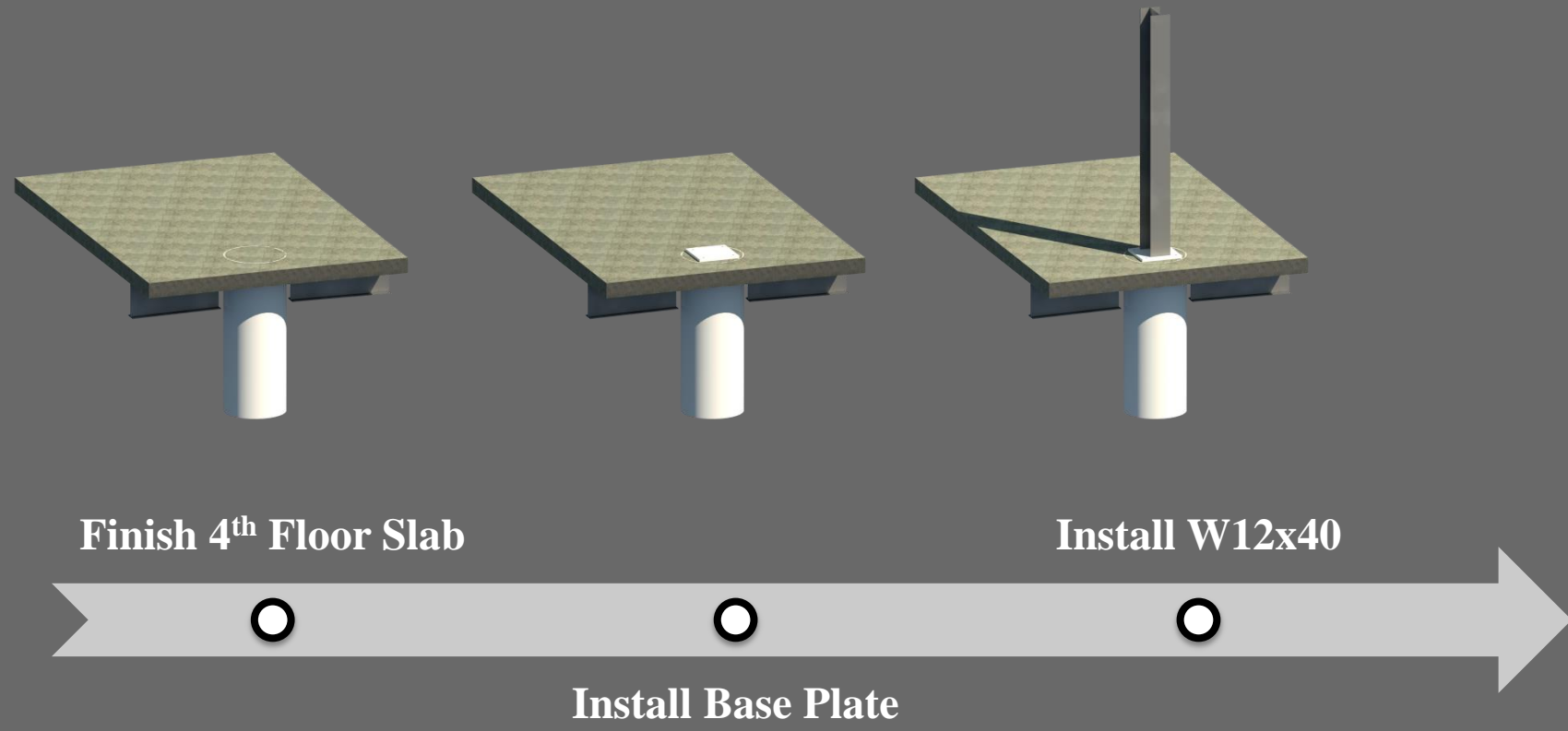
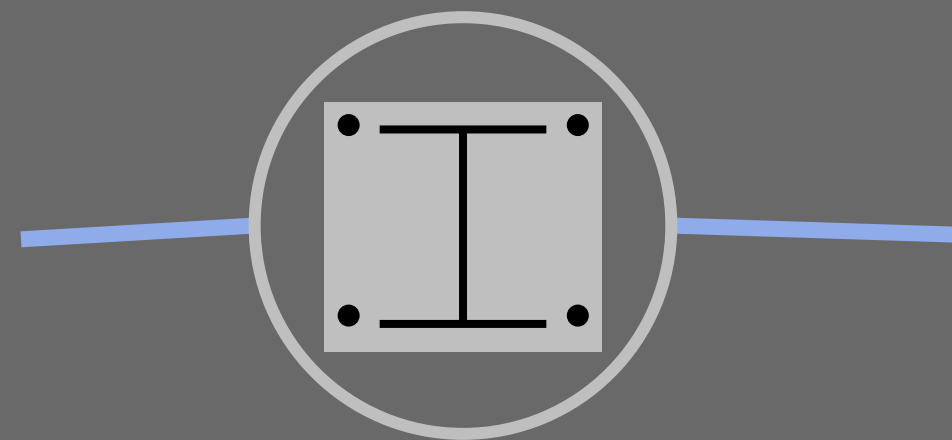
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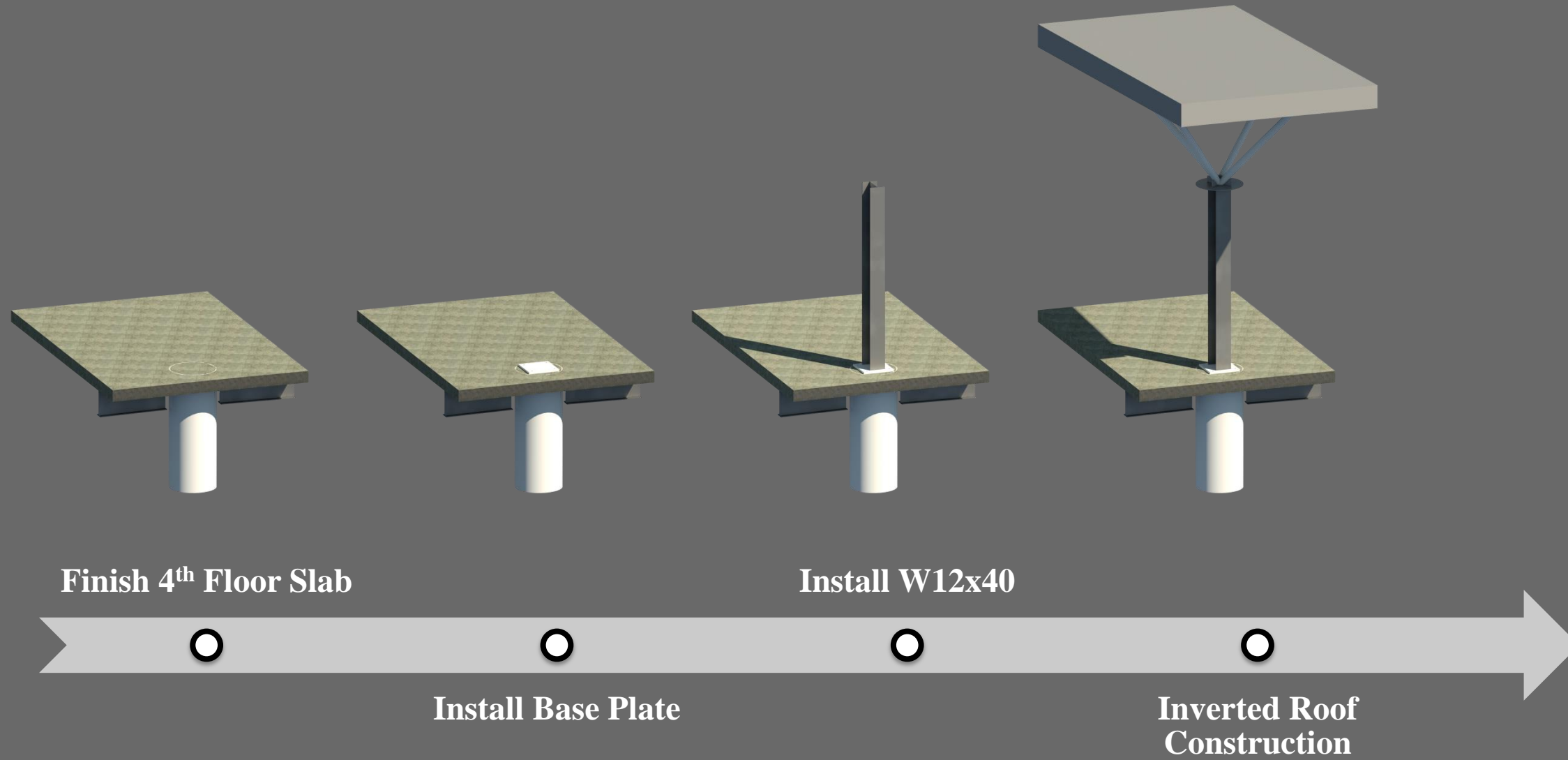
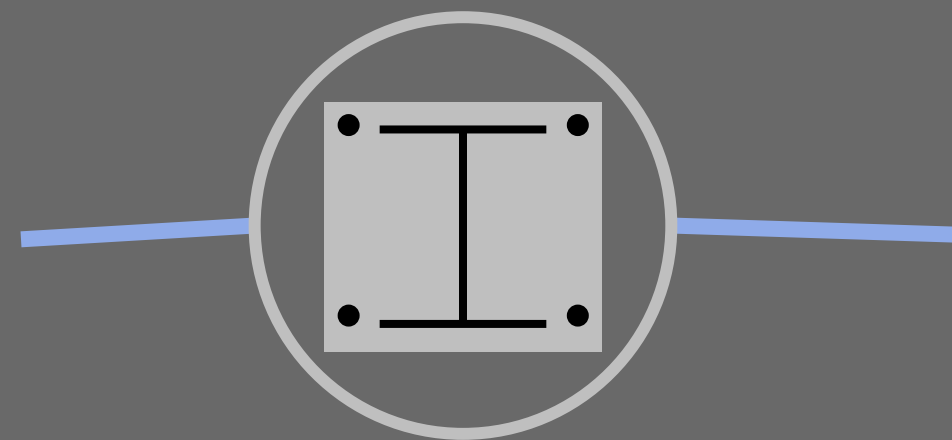
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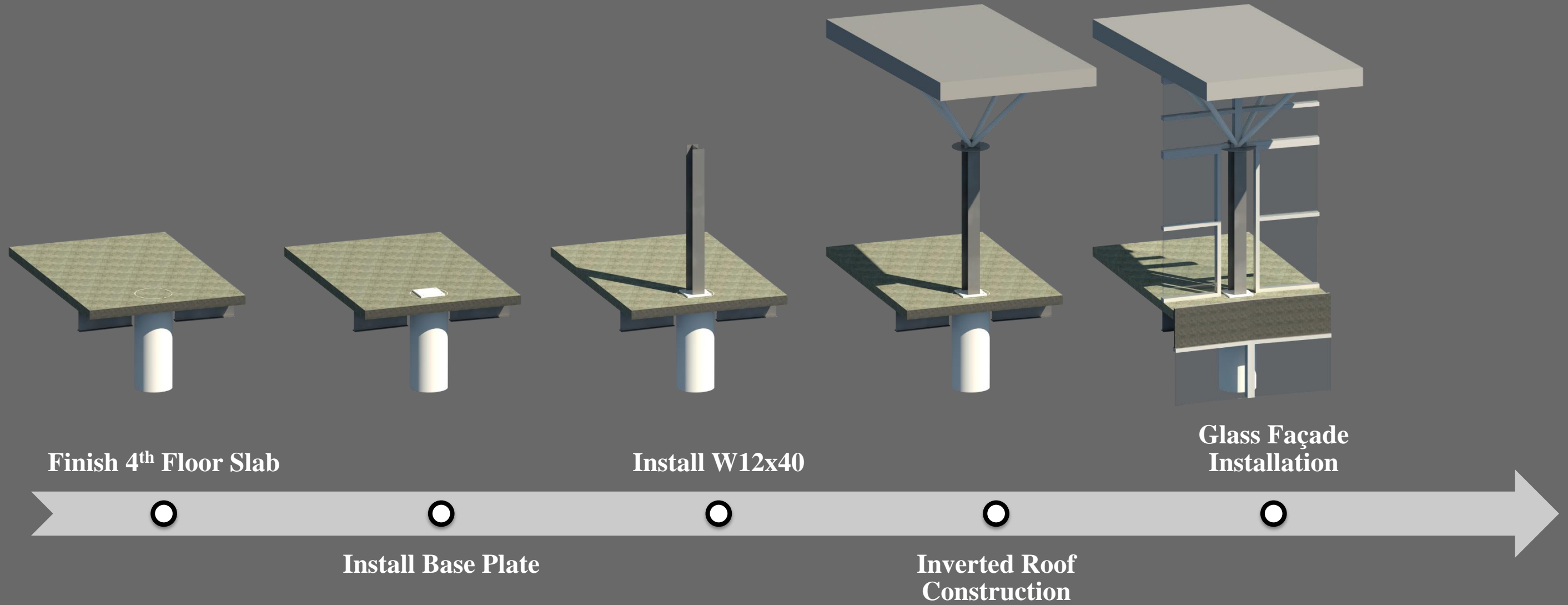
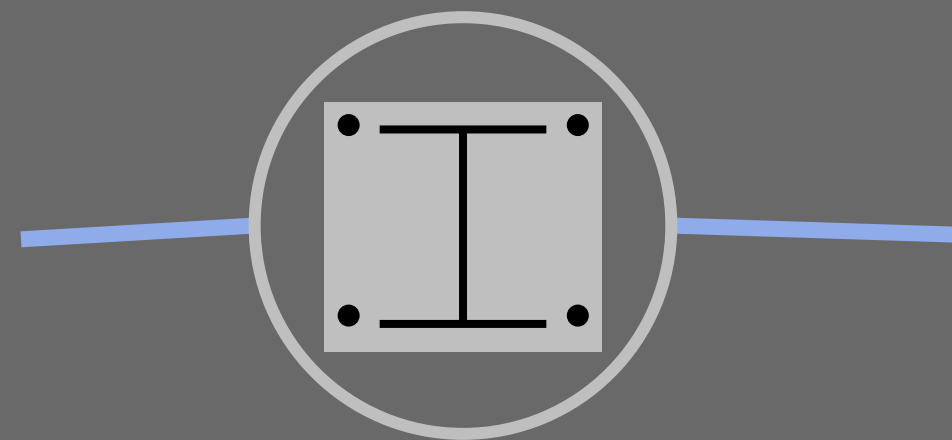
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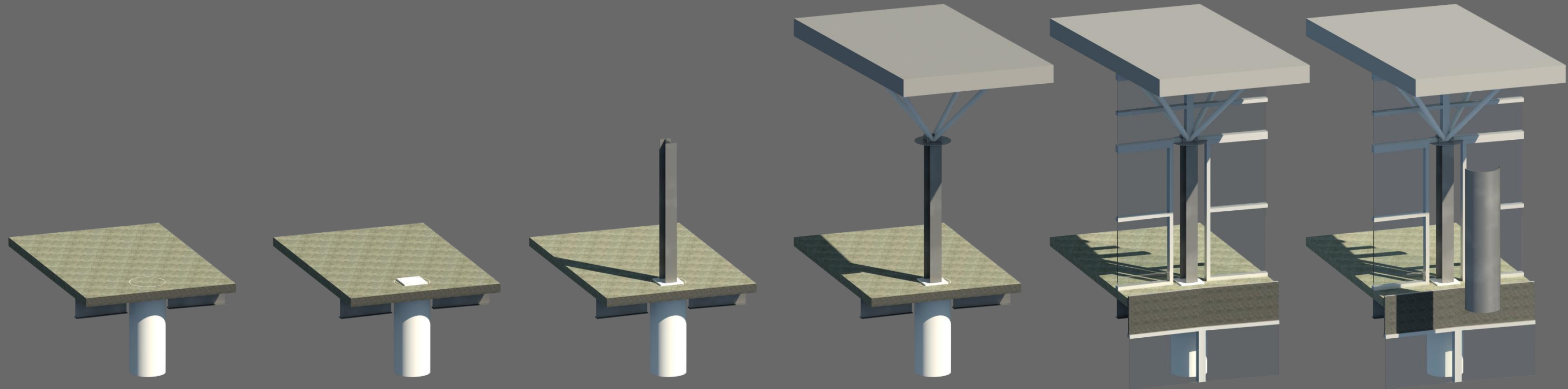
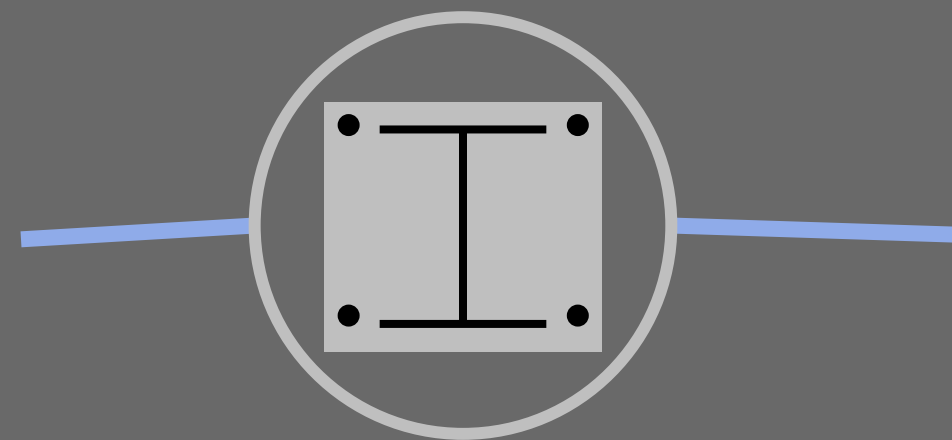
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- Ductwork Sizing
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Finish 4th Floor Slab

Install W12x40

Glass Façade Installation

Install Base Plate

Inverted Roof Construction

Aluminum Sheathing Placement

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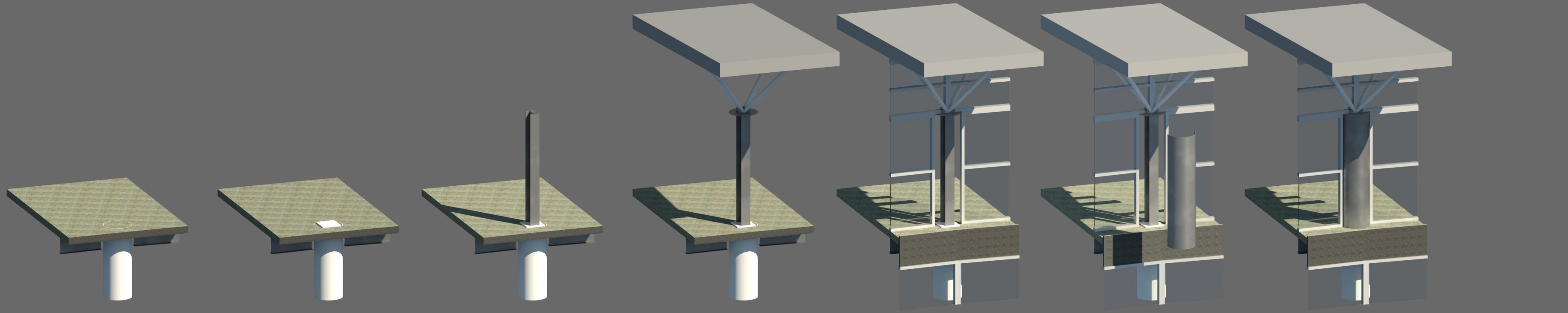
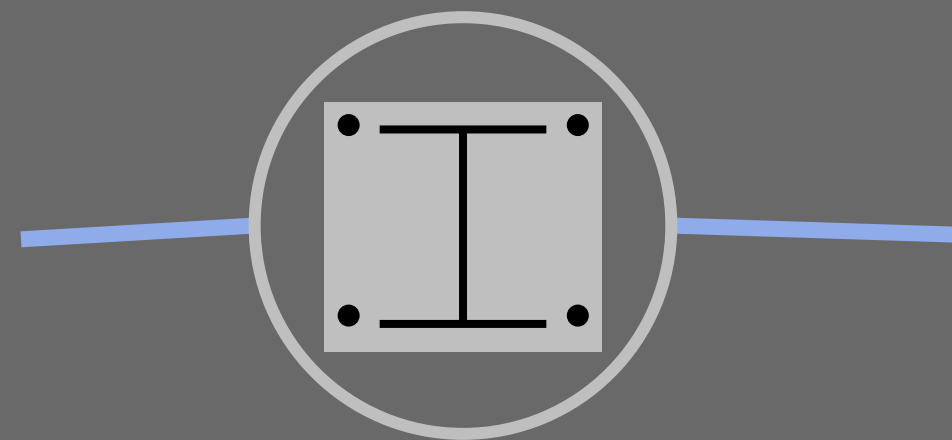
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Finish 4th Floor Slab

Install W12x40

Glass Façade Installation

Batt Insulation

Install Base Plate

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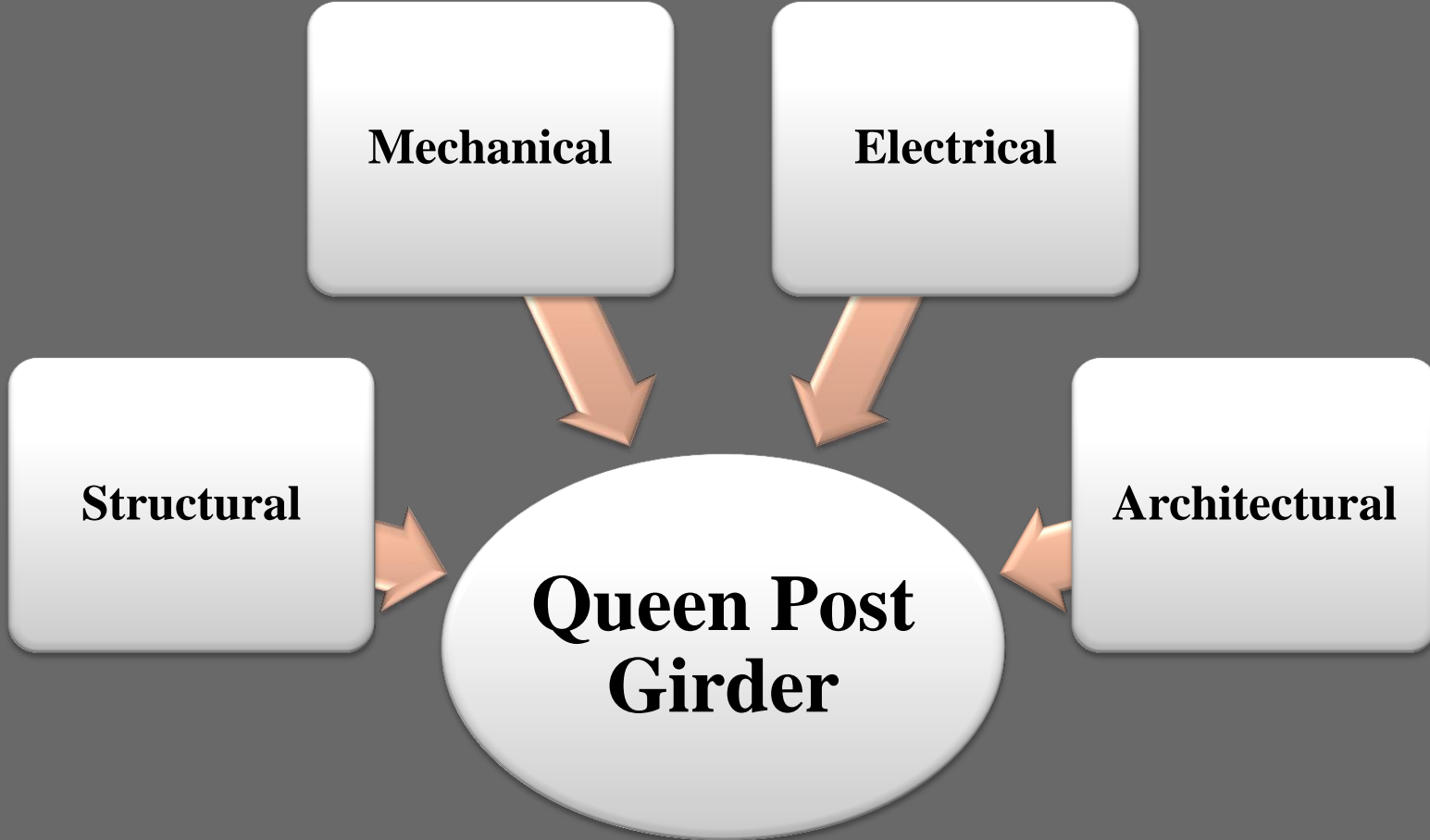
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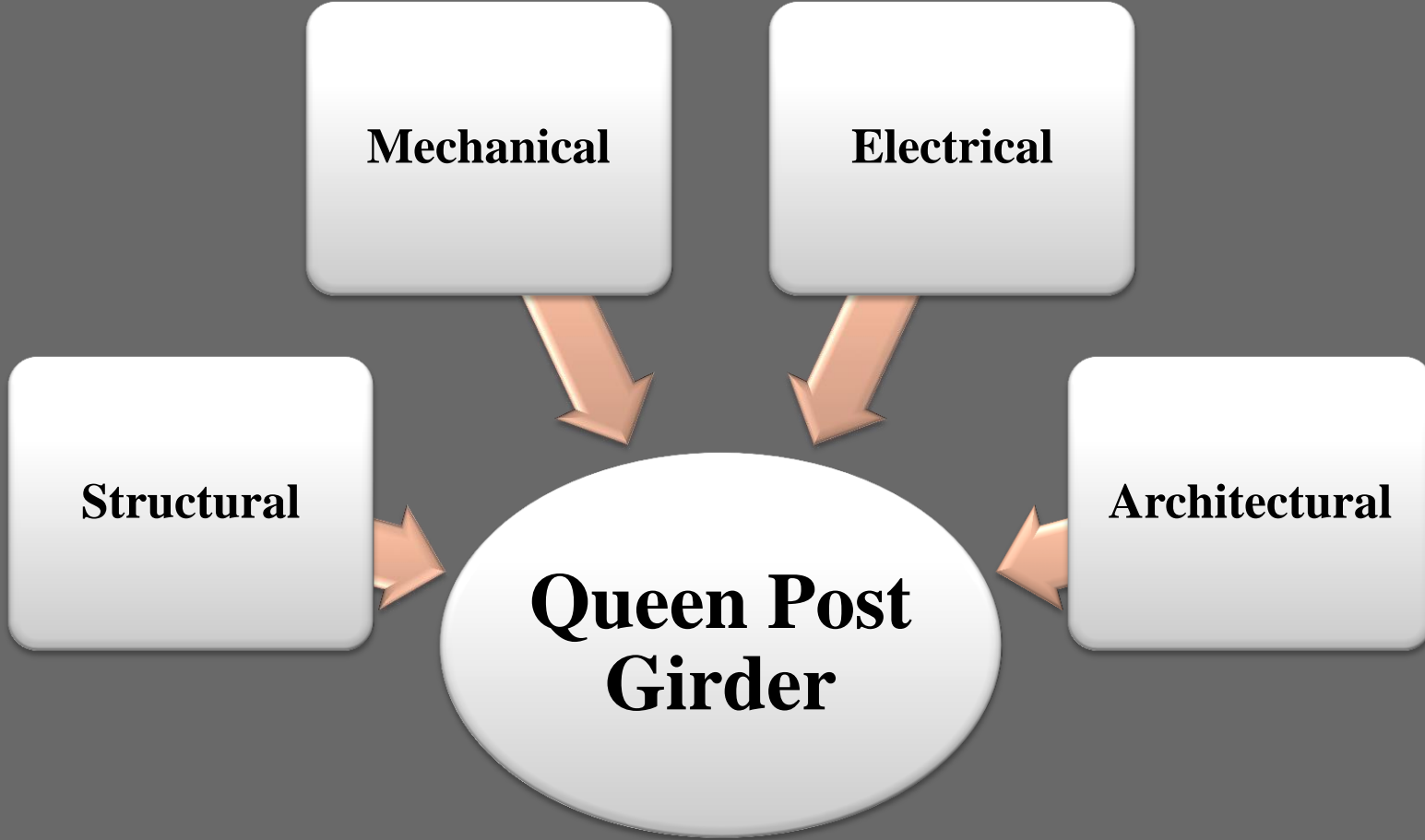
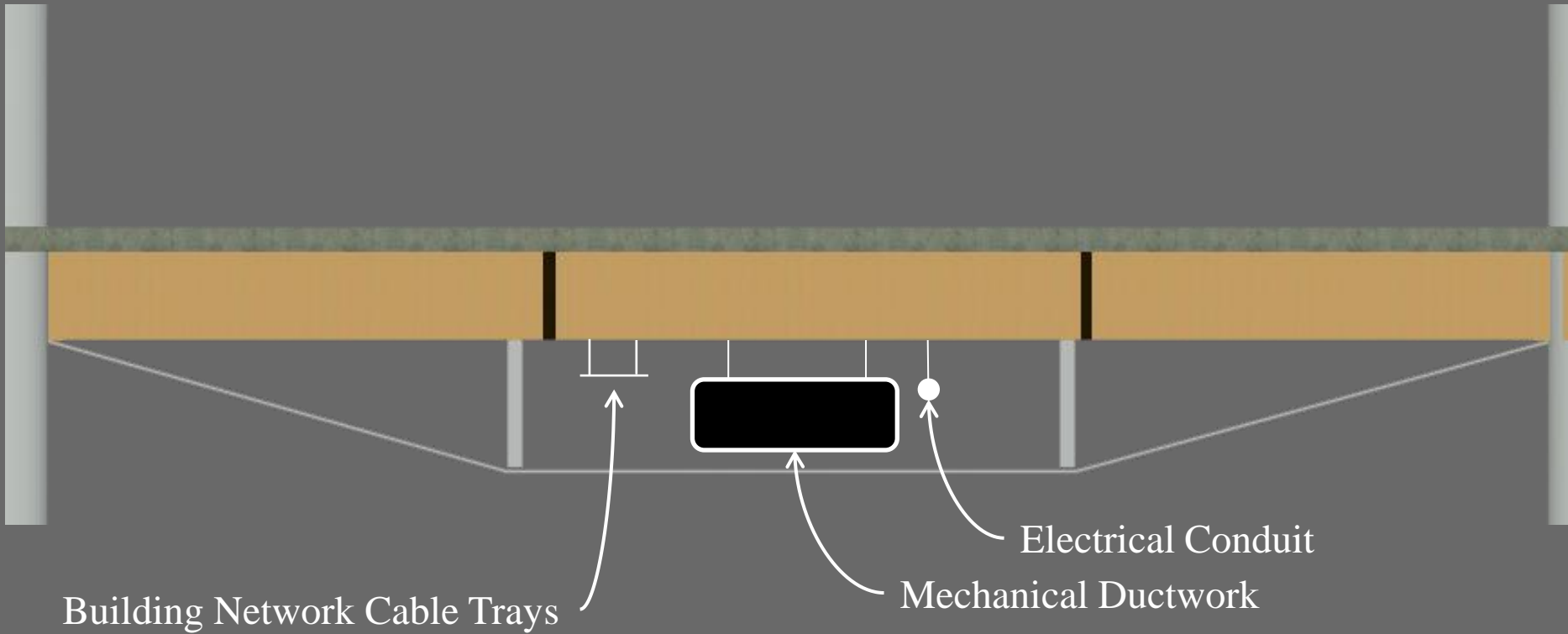
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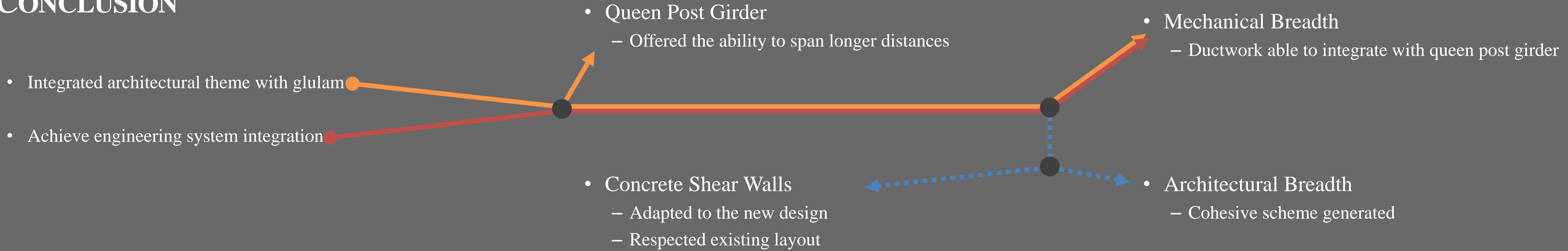
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- No change in building layout
 - Sense of open office should be kept
- Enhance architectural components
 - Visual link between occupant and engineering systems
- Better understanding of building irregularities



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- Special thanks to,
 - Heifer International
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 - My friends and family whom inspired me throughout my academic career
 - Prof. Robert Holland
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 - Prof. Moses Ling
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Timothy Hursley

QUESTIONS AND COMMENTS



Heifer International Flickr

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