

# **Innovative Structural Slab Practices**

## **– Voided Slabs**

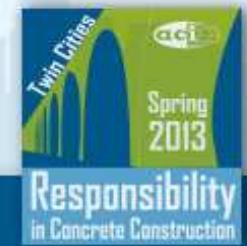
**Session sponsored by ACI/ASCE 421**

**Mike Mota Ph.D., P.E., F.ASCE**  
**CRSI - Atlantic Region Manager**  
**Session Moderator**

**April 14, 2013**  
**Minneapolis, MN**

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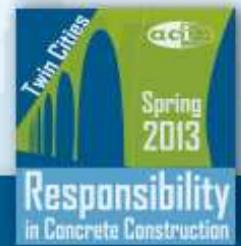
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# Agenda

- Historical Overview
- CRSI Design Guide for Voided-Slabs
- New Trends – Case Studies
  - Miami Art Museum
  - UW LaBahn Arena
  - Harvey Mudd College

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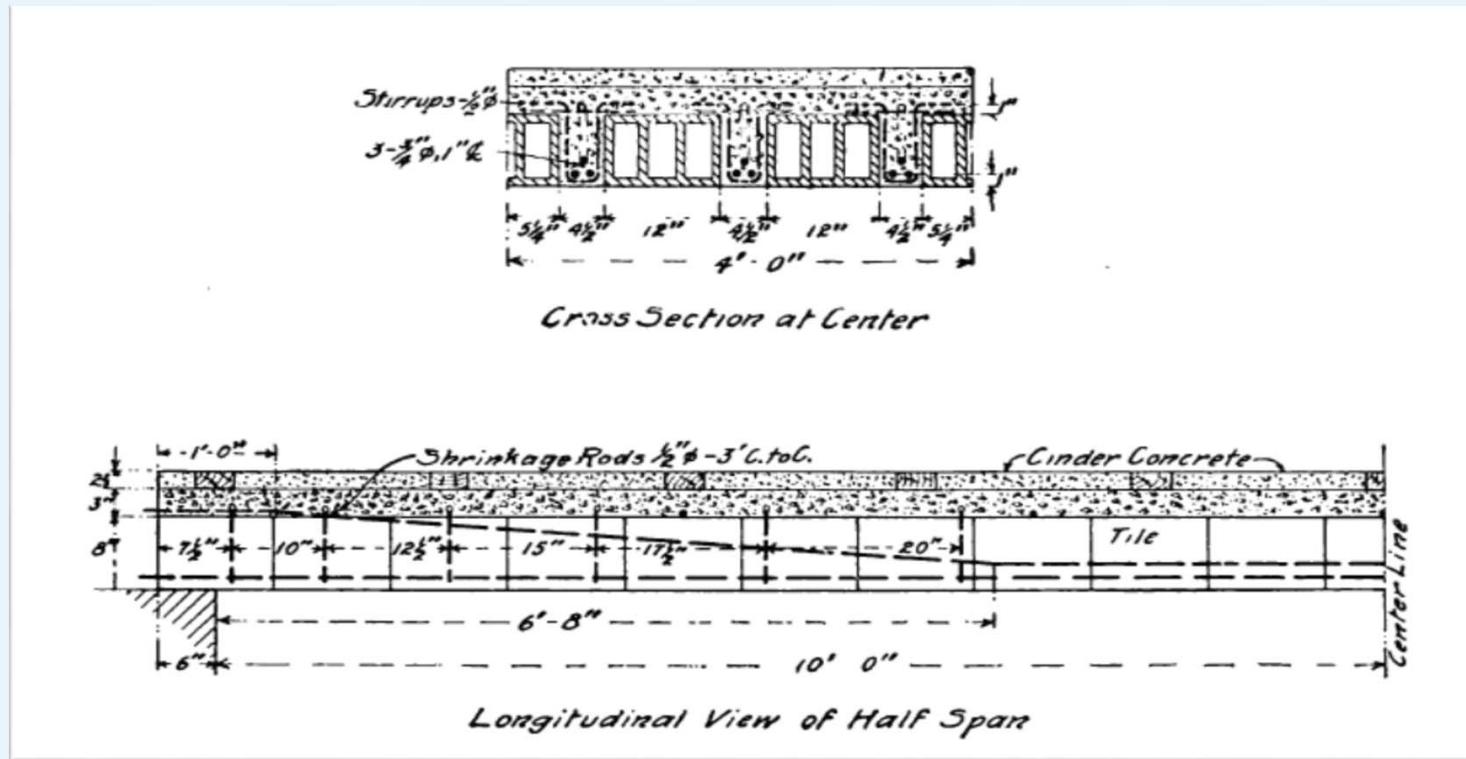
# Historical Overview

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# Tests of RC Hollow Tile (Purdue U.- Oct. 1907)



Source: W. K. Hatt

# Material Properties

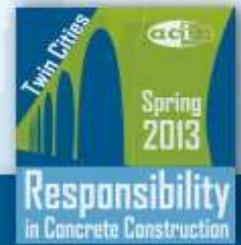
- Tension in steel – 16,000 psi
- Concrete  $f' c$  – 750 psi
- Shear in Concrete – 75 psi
  - One-way shear  $2 \sqrt{f' c} = 55$  psi

# Loading the slab

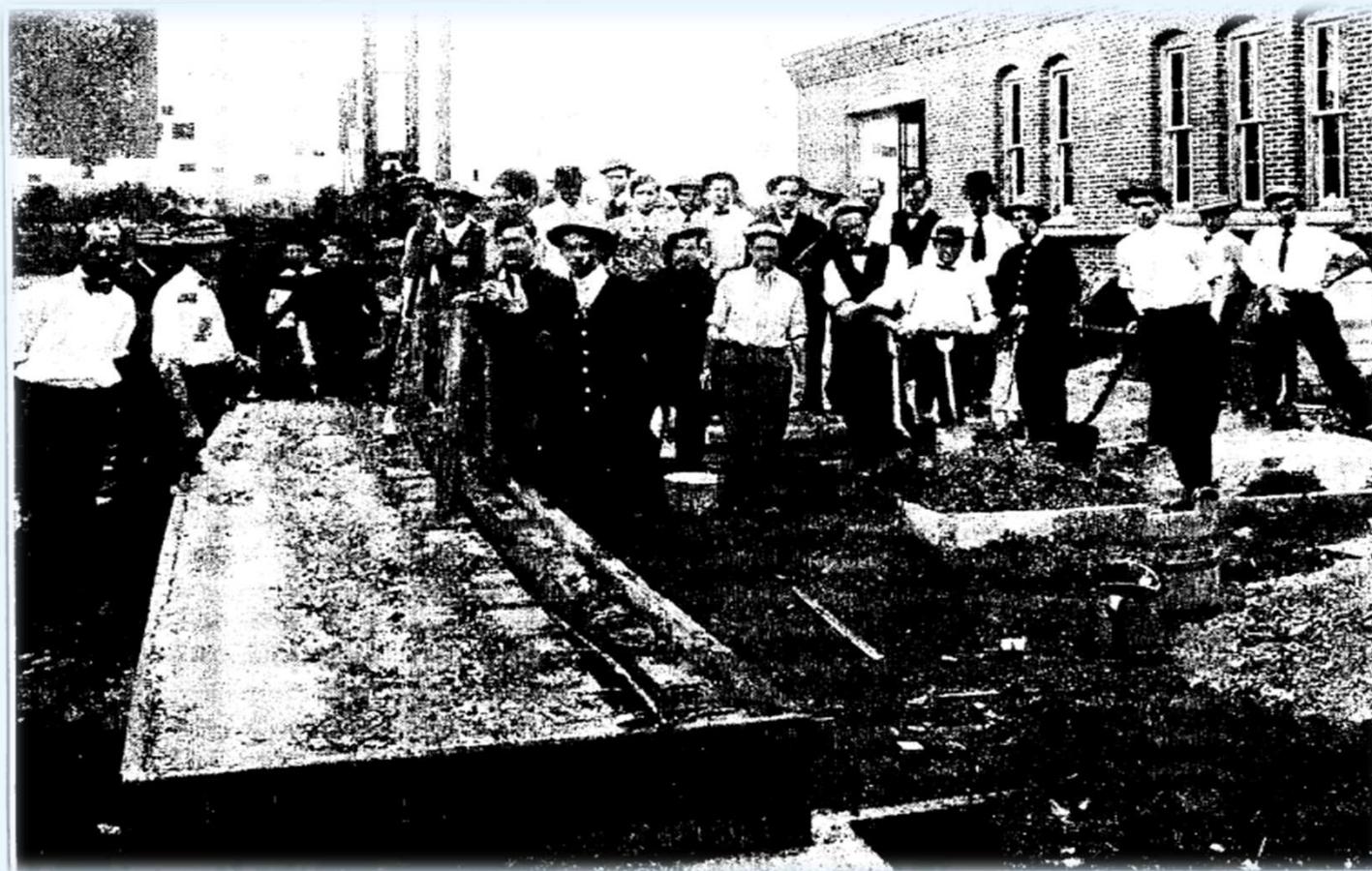


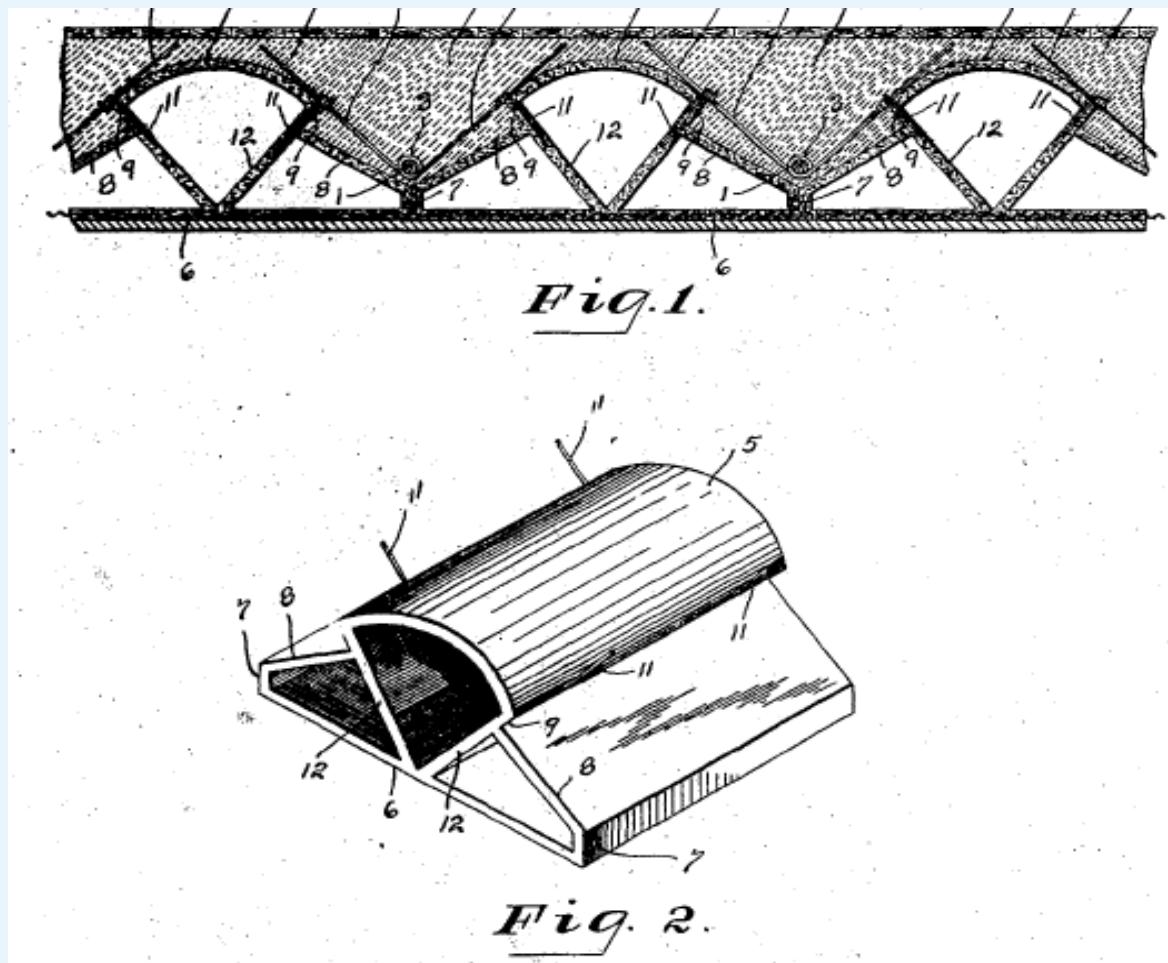
# Load Test Results

- Slab designed for 100 psf (LL)
- Maximum LL
  - 510 psf at yield
  - 710 psf at end of test
- Max. Deflection
  - 3" deflection caused slab to bottom out ~ L/75



# Purdue University - Oct. 1907

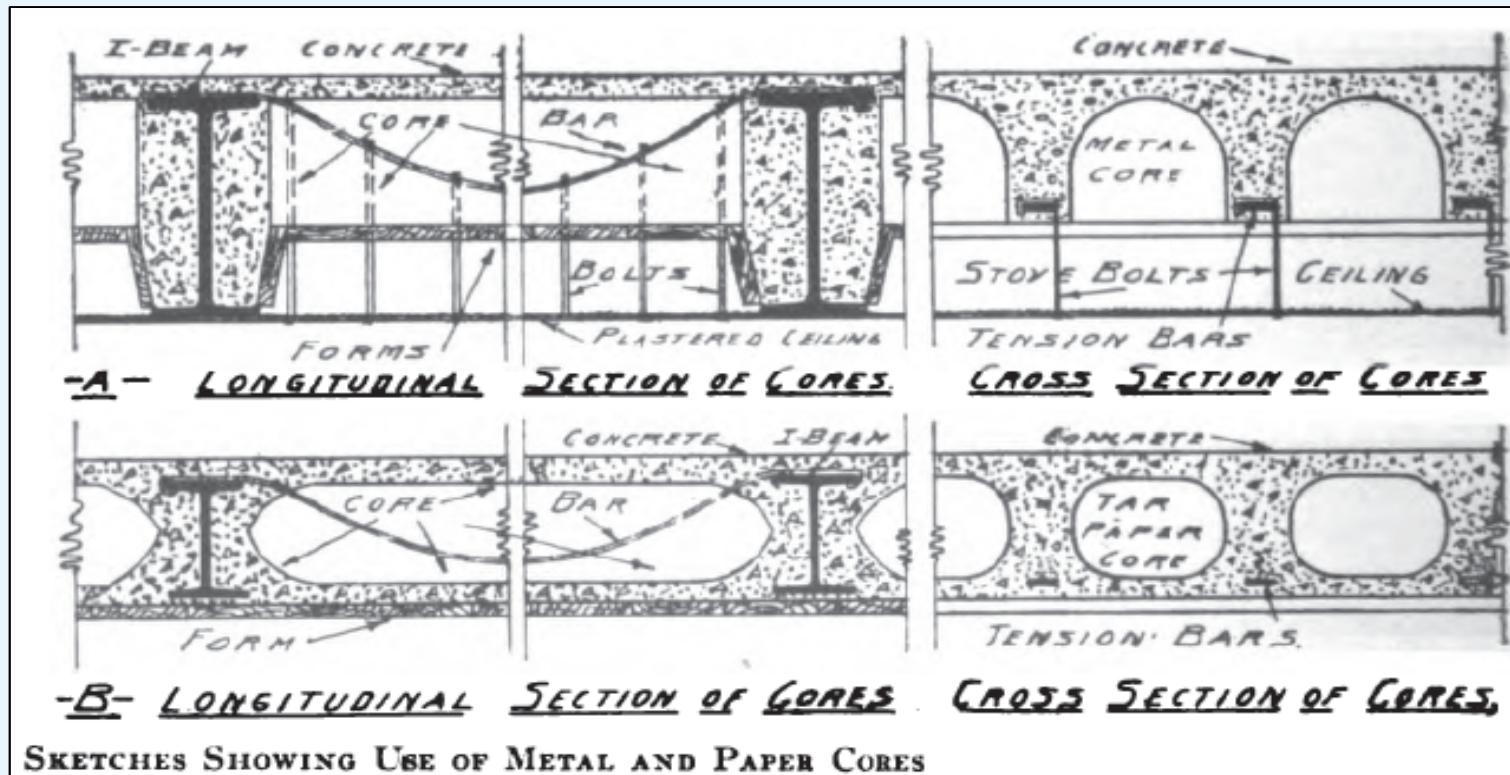




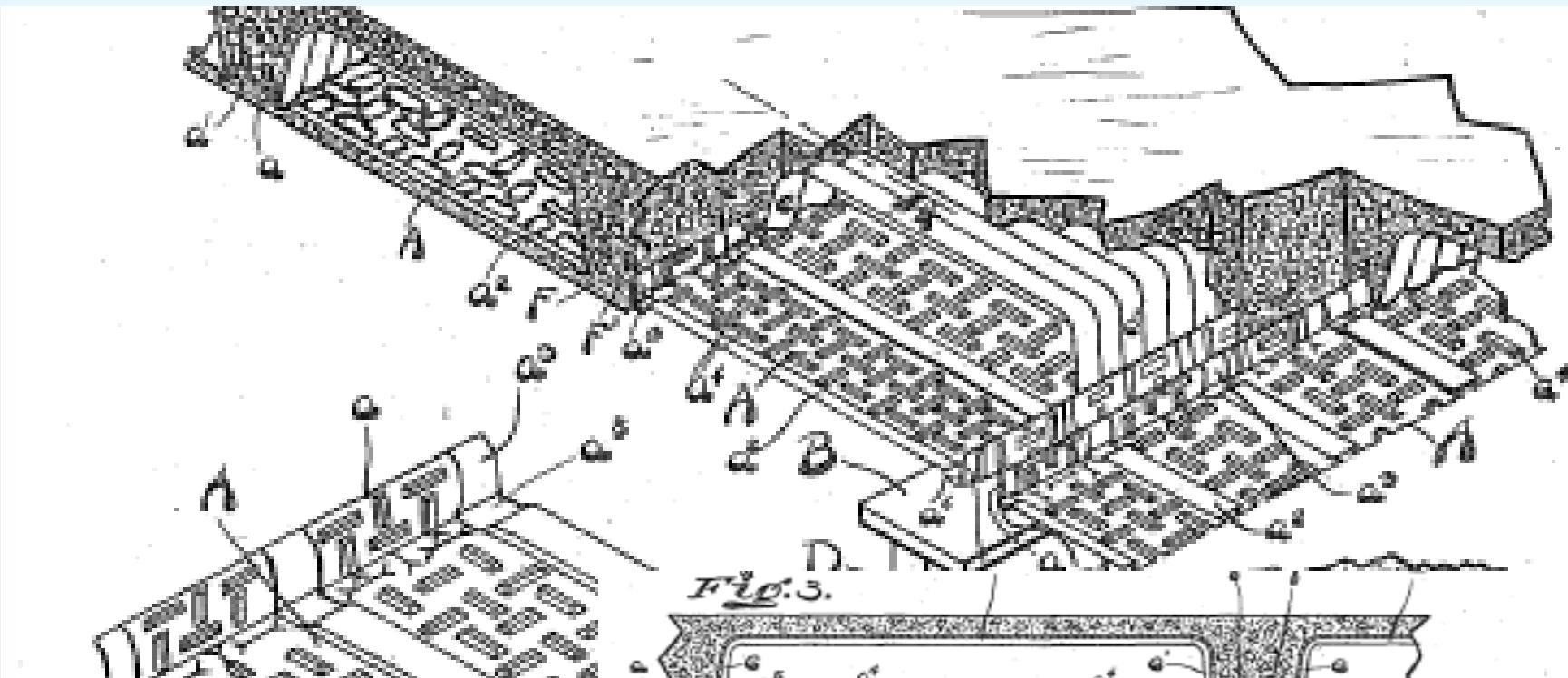
Source: USPO 1909

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# Use of Cores in RC Floors



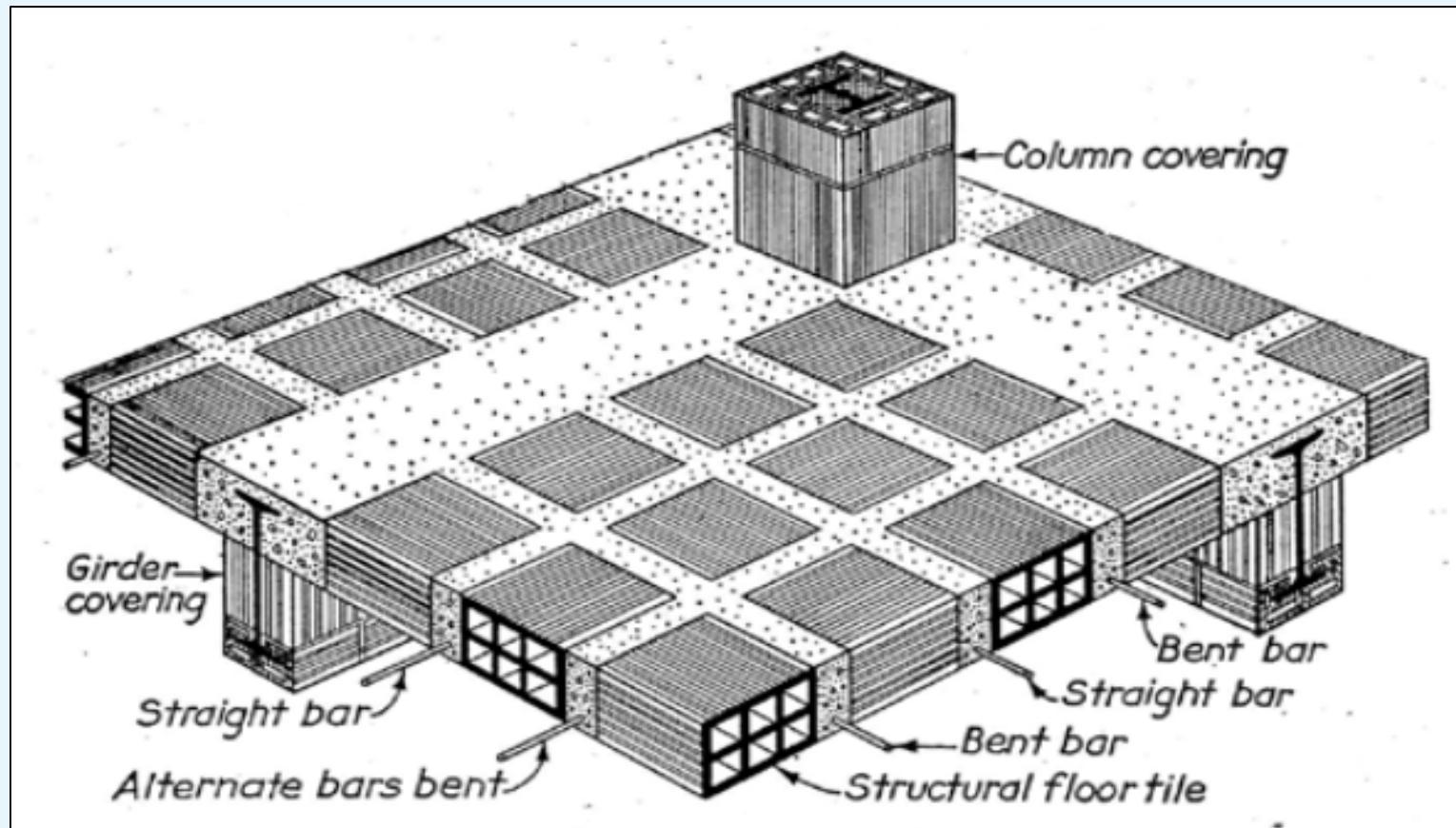
Source: Concrete-Cement Age: August 1914



Source: USPO 1916

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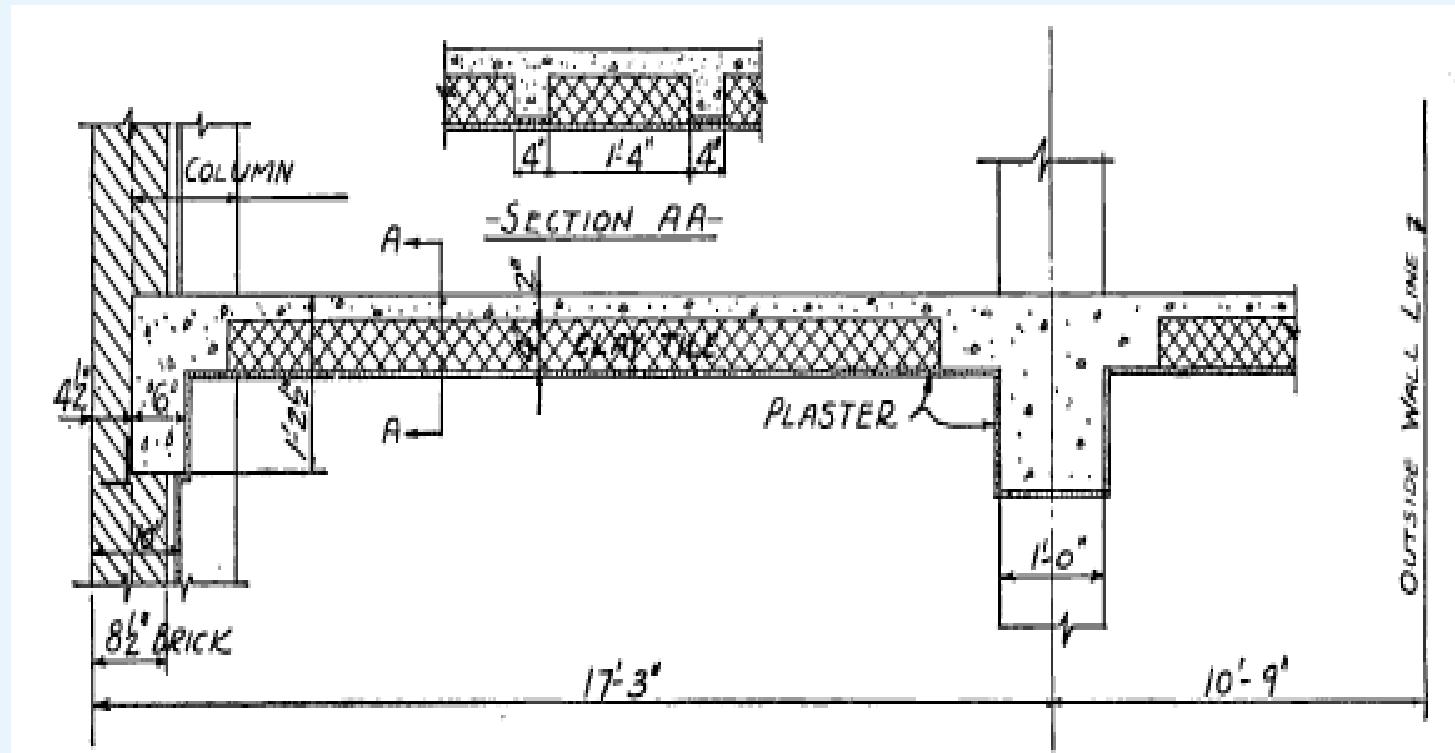
# (two-way) slab - 1915



Structure Magazine (2008)



# Ida B. Wells Housing (Chicago)



Source: Journal of ACI (Nov, 1941)

# Ida B. Wells Housing (Chicago)

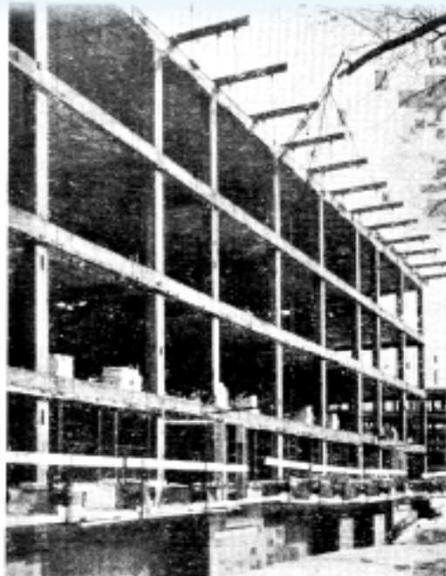
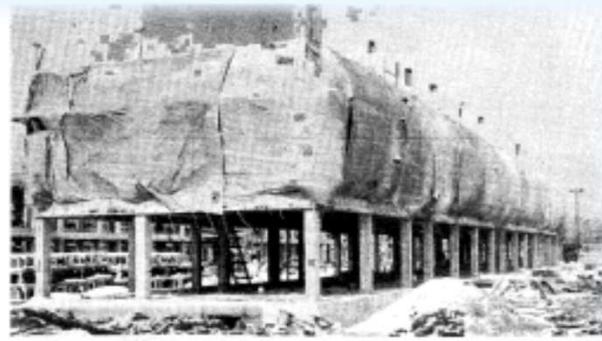
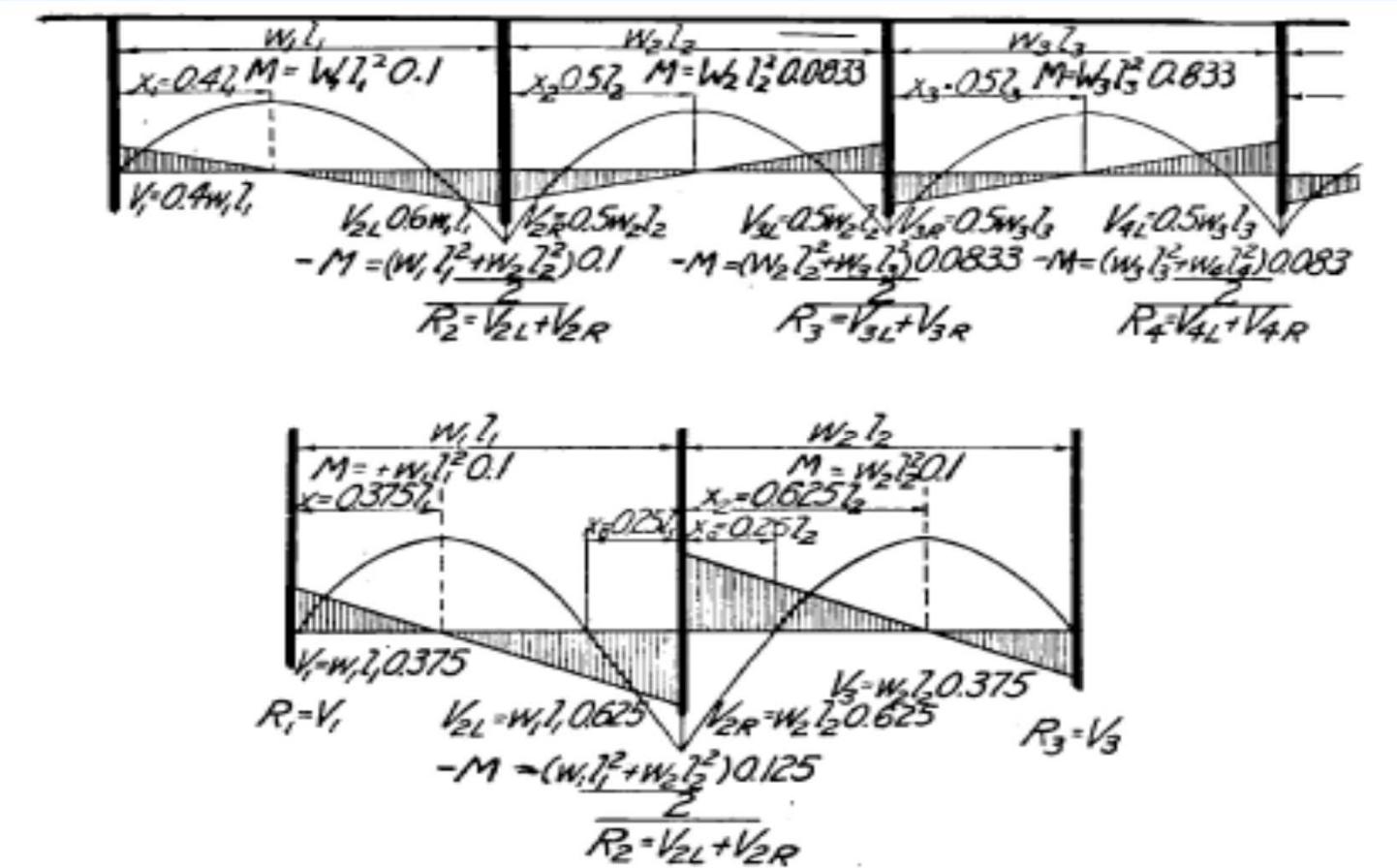


FIG. 6, AND 7, 8—CONSTRUCTION VIEWS  
IDA B. WELLS HOUSING BUILDINGS



- 124 Buildings
- 3,000 tons of rebar
- 46,000 cy of concrete

Journal of ACI (Nov, 1941)



Journal of ACI (Nov, 1941)

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Fig. 1 — Rendering shows design concept for a 688,000 sq ft operations center Austin's Western District in Irvine, Calif., has designed and is building for Security Pacific National Bank.

# CI Article (May 1983)

## Voided Flat Plate Slabs Reduce Cost and Speed Up Construction

by H. J. Benet and Bill Williams, Jr.

This article describes an unbiased approach utilized to select the best combination of materials and types of structures for an operations center building. After the concrete voided flat plate slab system was selected as the most appropriate type of structure, it is shown how the final design was made. A brief description of the innovations incorporated in the actual construction and how they were developed and tested prior to their usage is also explained. The completion of the concrete structure ahead of schedule and below the estimated cost proved all the predictions and attested the reaching of all the objectives.

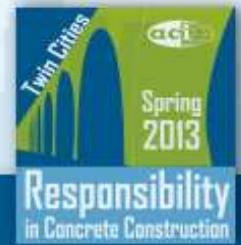
**Keywords:** computer programs; concrete construction; costs; earthquake-resistant structures; flat concrete plates; flat concrete slabs; fly ash; framing systems; hollow core slabs; models; office buildings; quality control; reinforced concrete; structural design.

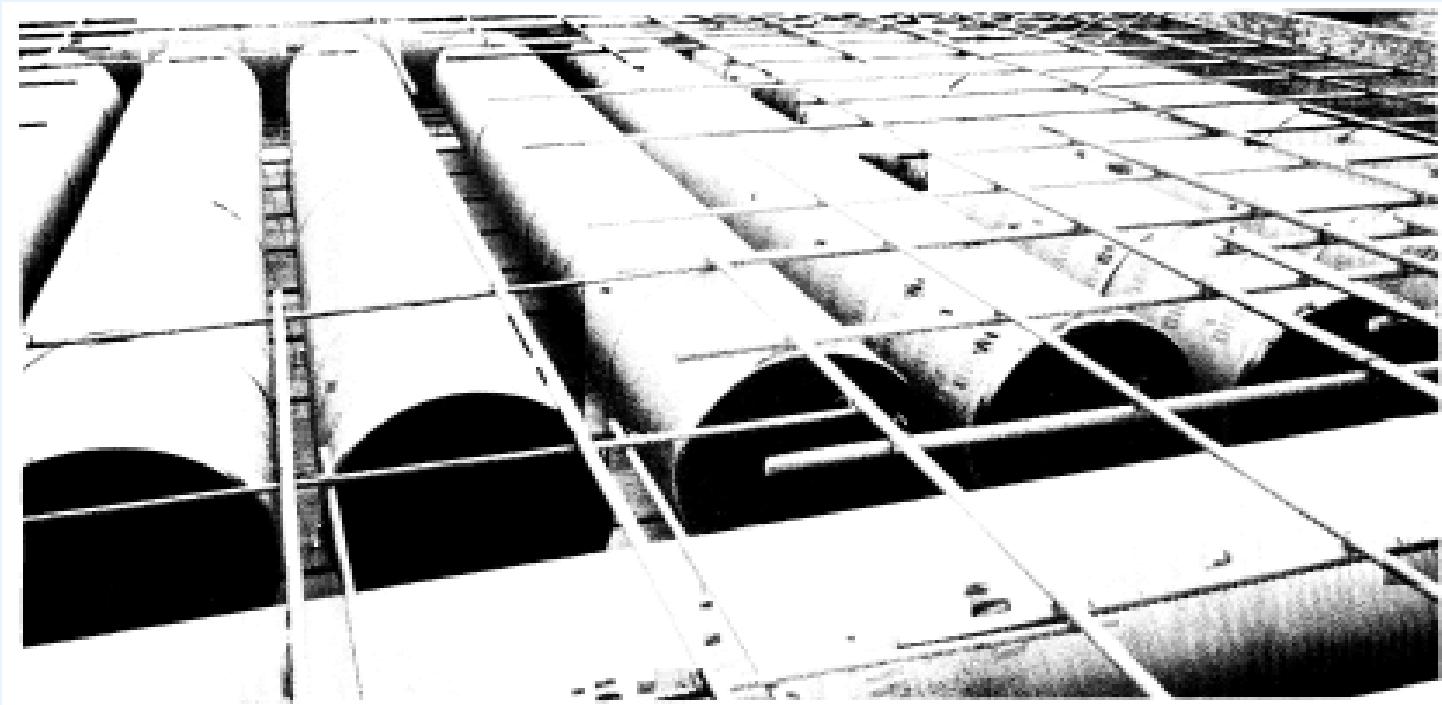
CONCRETE INTERNATIONAL/MAY 1983

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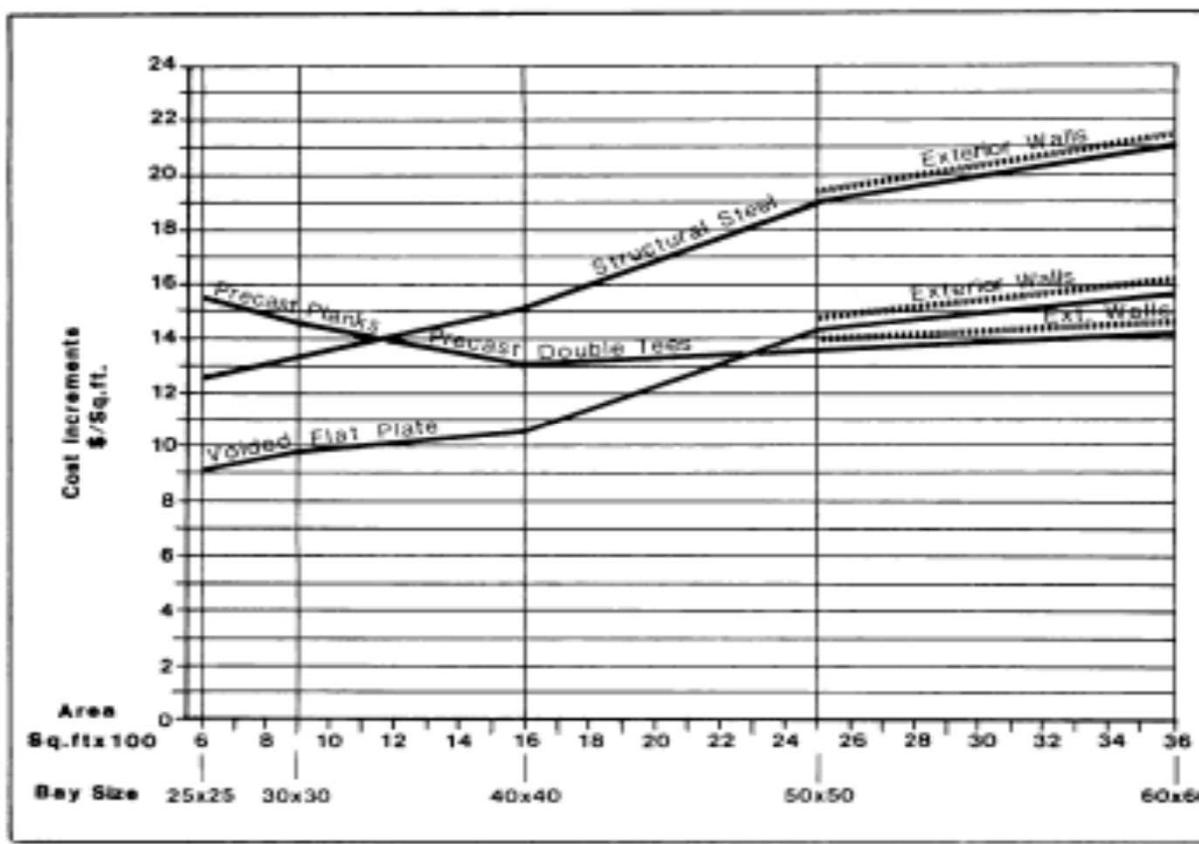




688,000 sq. ft. “Low-rise”  
40 feet Unobstructed Spans  
Heavy LL (125 PSF)

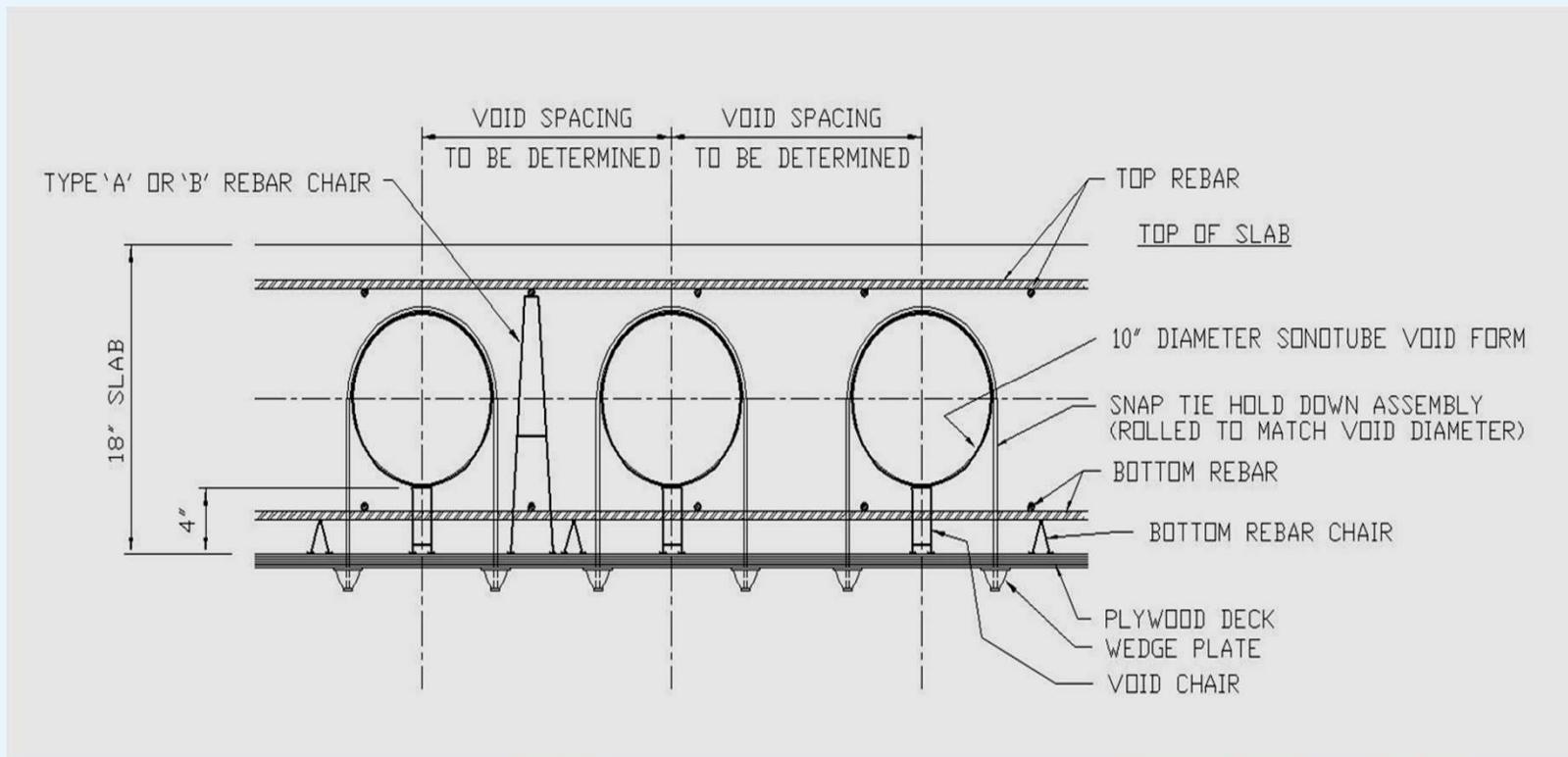
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# Cost (sq. ft.) Comparison

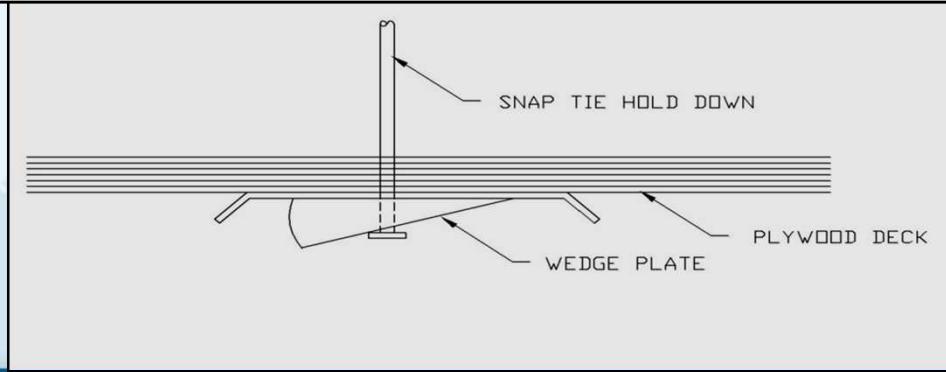
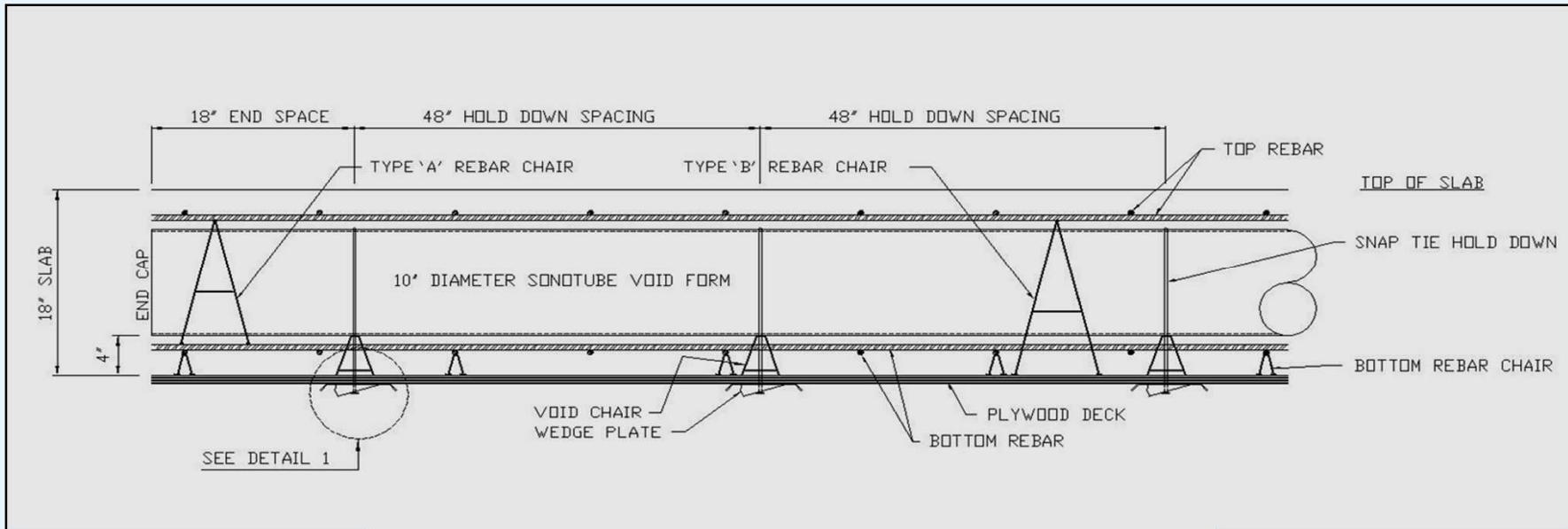


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# Anchoring The Voids



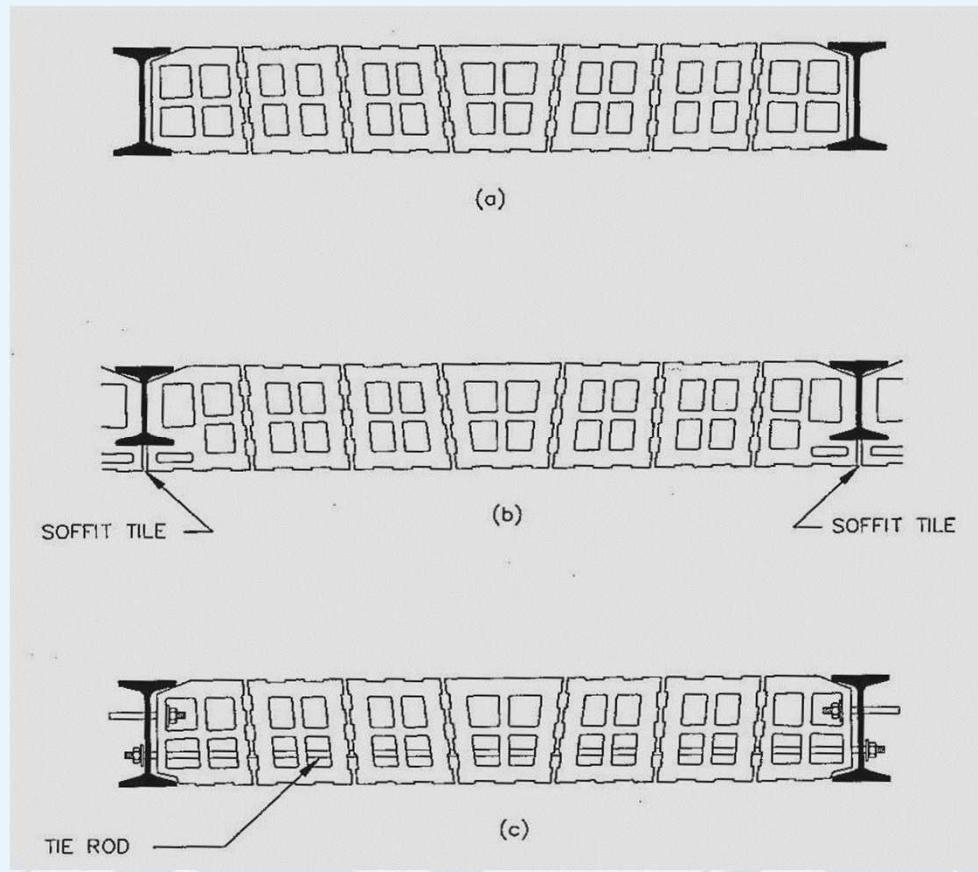
# Anchoring The Voids



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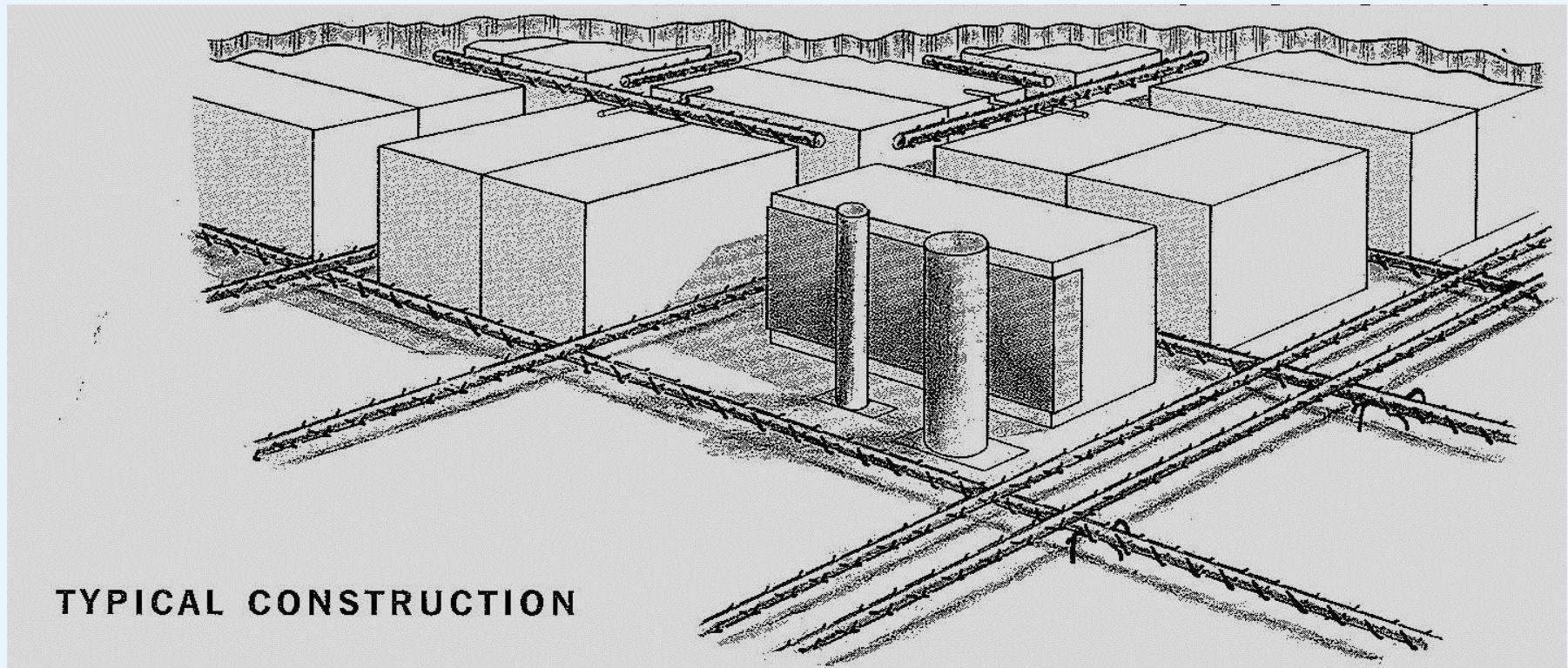
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# Flat Terra Cotta Arch



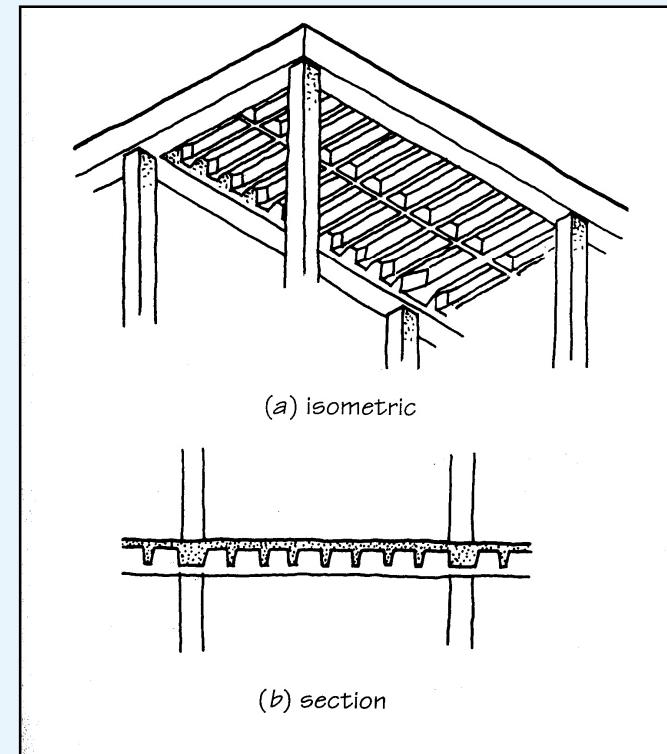
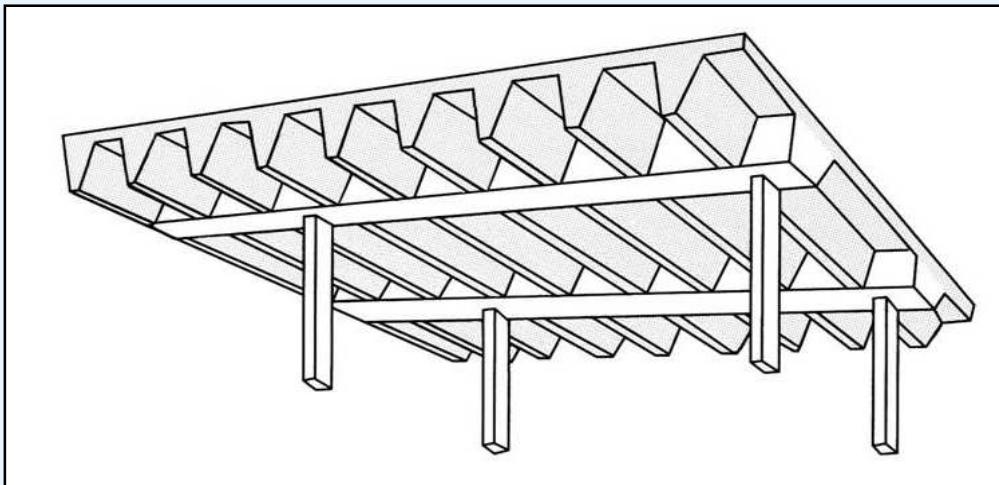
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# Slag Block

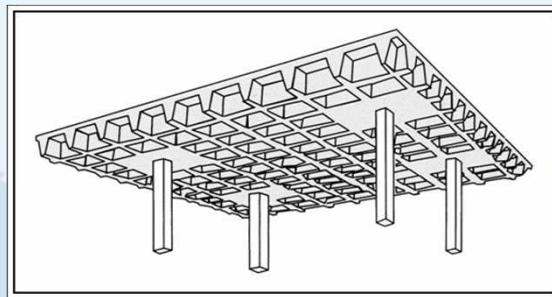


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# Wide-Module Joists



# Waffle Slabs



# Hollow Core Plank



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# Foam voided Systems



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# Questions?

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# **CRSI Design Guidelines**

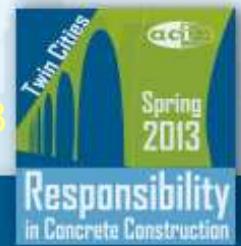
## **Voided Slabs**

Attila Beres Ph.D., P.E.

CRSI - Senior Structural Engineering Consultant

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# Motivation

To provide guidance to design professionals to introduce an innovative and unconventional system

Associated CRSI publications geared towards contractors:

- Articles in trade publications
- Sample specifications, general notes, typical details etc.

# Current Innovation in Void-former Creation



Crate type voids



Tubes

Plastic Balls

# Reviewers/Collaborators

## *Purveyors of Systems/Designers*

- Michael Russillo, Christian Roggenbuck (Cobiax)
- Jerry Ames Clark, Dan Windorski (BubbleDeck/Graef)
- Ricardo Levinton, Ron Klemencic (Prenova/MKA)

## *Contractors*

- Rocky Bowe (Titan Builders),
- Elan Hertzberg, Dan Stafford (Matt Construction)

# Significant Projects Around the World



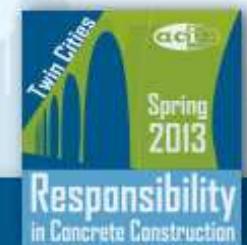
Millenium Tower  
Rotterdam, Netherlands



Airport  
Yerevan, Armenia



Palazzo Lombardia  
Milan, Italy



# Content of Guidelines

- Introduction of Voided Slab Concept
- Historical Overview
- Construction Issues
- Design Regulations
- Design Tools (Tables and Charts)
- Featured Projects
- References

# Construction Methods

Why to address constructability in a “Design Guideline”?

- The design means and methods make this system unique
- GCs and Subcontractors are viewing any new systems with skepticism – Who is taking the risk?
- Constructability issues essential to understand to develop design
- For any novel systems the designer is “promoting” the system

# Construction Methods

Understanding building methodology:

- Securing void formers against buoyancy
- Sequencing/placement of rebar, void formers, and concrete

# Construction Methods

Understanding implications of procedures:

- Shoring, Forming
- Placement of rebar, void formers, and concrete

Where are the \$?

# Construction Methods

Addressing constructability concerns:

- Are there any concrete consolidation issues?
- Is there any concern with the interface of 2 concrete lifts?
- Resiliency of void formers at the construction site (handling+ building site foot traffic)?
- Field repositioning
- Time to completion

# Construction Methods

## Detailing concerns:

- Post-installed anchors
- Intentional drilling into void formers
- Transition between voided areas and solid zones
- Interconnectivity of precast components
- Accommodation of electrical, mechanical, PT conduits

# Construction Methods

## Administrative implications:

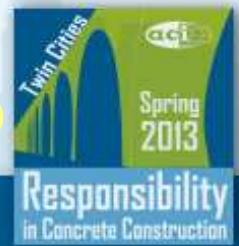
- Placement/shop drawings
- Specifications
- Inspection issues

# Design Regulations

## Code Compliance:

- ACI 318
- Other IBC Requirements (fire)

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# Design Regulations

Compliance with non-mandatory considerations:

- Sustainability
- Vibration
- Sound insulation
- Thermal

# Design Concepts and Issues

## Steps of the Design Procedure:

1. Defining the computational model and parameters
2. Establish adjustment factors specific to the voided slab system
3. Creation of negative dead load patterns
4. Perform initial analysis
5. Shear analysis to establish solid zones
6. Refine iterations
7. Flexural design

# Design Concepts and Issues

## Parameters Used in Structural Analyses and Design:

- Stiffness
- Flexural strength
- Shear capacity
- Punching shear

# Design Concepts and Issues

## Example of Weight Reduction:

(shorter span and light load)

- 10" thick slab
- 5.5" tall x 12 3/8" wide void former
- 1 3/8" spacing
- 0.25 ft<sup>3</sup>/ft<sup>2</sup> concrete eliminated
- Self weight reduction from 125 psf to 88 psf **-30%**

# Design Concepts and Issues

## Example of Weight Reduction:

(longer span and heavy load)

- 21" thick slab
- 16" wide spherical void former
- 1 3/4" spacing
- $0.56 \text{ ft}^3/\text{ft}^2$  concrete eliminated
- Self weight reduction from 269 psf to 185 psf **-31%**

# Design Concepts and Issues

## Other Engineering Design Considerations:

- Diaphragm performance (in plane shear and flexure)
- Design models (similitude with equivalent 2–way solid slabs, 2-way joists)
- Deflection considerations
- Crack-width considerations

# Design Concepts and Issues

## Detailing issues:

- Layout in typical scenarios
- Layout for complex geometries (non-rectilinear floorplan, upturn beams, steps, openings/edge conditions)

# Design Tools

- ◆ Preliminary sizing - RC Concept
- ◆ Samples of Design Documents:

- General Notes
- Typical Details
- Floor Plan Layouts
- Specifications



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# RC Concept

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**VOIDED SLAB**

Economically viable for medium to long spans and for moderate live loads.

**Economical Span Range (ft)**

Typical slab depths vary from 14" to 24"  
Typical "spherical" void-former diameter varies from 9" to 18"

**Advantages**

- Larger spans without beams
- Larger open floor areas
- Lower floor to floor heights
- Improved Earthquake Performance
- Resource efficiency

**Click to Close**

Placing:  \$/yd<sup>3</sup>      ■ Consult manufacturers for the cost of voids in place.  
Finishing:  \$/ft<sup>2</sup>      ■ Edge forms unit cost is applicable in all systems.  
Curing:  \$/ft<sup>2</sup>

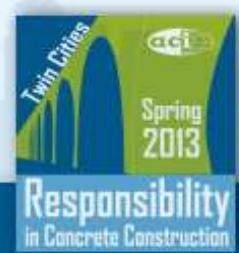
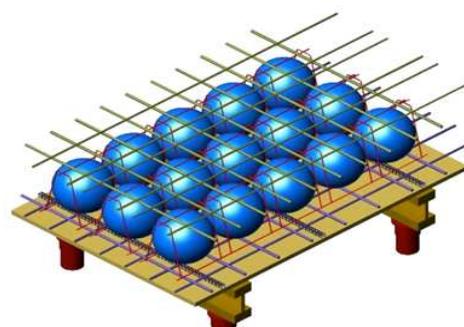
**Reinforcing in Place:**

Rebar:  \$/ton

**Voids in Place:**  \$/ft<sup>2</sup>

**Forms in Place**

Edge forms:  \$/ft<sup>2</sup>  
Beam forms:  \$/ft<sup>2</sup> contact area



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Overview of my courses CONCEPT Reinforced Concrete Concept

## VOIDED SLAB (CLICK FOR MORE INFO) ?

**Loads**

Superimposed dead loads:  psf  
Live loads:  psf

**Material Properties**

Concrete compressive strength  $f'_c$ :  psi  
Concrete unit weight  $w_c$ :  pcf  
Reinforcing steel yield strength  $f_y$ :  psi

**IN-PLACE UNIT COSTS**

**Concrete**

Material:  \$/yd<sup>3</sup>  
Placing:  \$/yd<sup>3</sup>  
Finishing:  \$/ft<sup>2</sup>  
Curing:  \$/ft<sup>2</sup>

**Reinforcing in Place:**

Rebar:  \$/ton

**Voids in Place:**  \$/ft<sup>2</sup>

**Forms in Place**

Edge forms:  \$/ft<sup>2</sup>  
Beam forms:  \$/ft<sup>2</sup> contact area

**Notes**

- Superimposed dead loads include topping slabs, floor finishes, and HVAC.
- See IBC Table 1607.1 or ASCE/SEI Table 4-1 for minimum uniformly distributed loads for various occupancies.

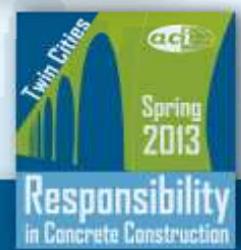
**Notes**

- For typical cases, 3000 - 5000 psi concrete is the most economical for floor systems.
- Enter 110 or 120 pcf for lightweight concrete; 150 pcf for normal weight concrete.
- Grade 60 ( $f_y = 60$  ksi) reinforcement is the most commonly used for floor systems.

**Notes**

- In-place unit costs can be obtained from numerous references, including RS Means or can be obtained from local concrete contractors.
- Consult manufacturers for the cost of voids in place.
- Edge forms unit cost is applicable in all systems.

**NEXT ➤**



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## reinforced concrete CONCEPT

### VOIDED SLAB (CLICK FOR MORE INFO) ?

Columns (in. x in.)

|           | $c_{EW}$ | $c_{NS}$ |
|-----------|----------|----------|
| Interior: | 24       | 24       |
| Edge:     | 20       | 20       |
| Corner:   | 20       | 20       |

$c_{EW}$

$c_{NS}$

N

Notes

- $c_{EW}$  = column dimension in the east-west direction in inches
- $c_{NS}$  = column dimension in the north-south direction in inches
- Using no more than three different column sizes usually results in the most economical structure.

Center-to-Center Span Lengths (ft) - Enter the first 3 spans in order for additional spans to become available.

|    | A               | B               | C               | D            | E            | F            | G            | H            | I            | J            | K |
|----|-----------------|-----------------|-----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|---|
| 1  | $\ell_{A-B}$ 30 |                 |                 |              |              |              |              |              |              |              |   |
| 2  |                 | $\ell_{B-C}$ 30 |                 |              |              |              |              |              |              |              |   |
| 3  |                 |                 | $\ell_{C-D}$ 30 |              |              |              |              |              |              |              |   |
| 4  |                 |                 |                 | $\ell_{D-E}$ |              |              |              |              |              |              |   |
| 5  |                 |                 |                 |              | $\ell_{E-F}$ |              |              |              |              |              |   |
| 6  |                 |                 |                 |              |              | $\ell_{F-G}$ |              |              |              |              |   |
| 7  |                 |                 |                 |              |              |              | $\ell_{G-H}$ |              |              |              |   |
| 8  |                 |                 |                 |              |              |              |              | $\ell_{H-I}$ |              |              |   |
| 9  |                 |                 |                 |              |              |              |              |              | $\ell_{I-J}$ |              |   |
| 10 |                 |                 |                 |              |              |              |              |              |              | $\ell_{J-K}$ |   |
| 11 |                 |                 |                 |              |              |              |              |              |              |              |   |

Building Footprint

Dimensions / Void Parameters Notes



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# RC Concept

Reinforced Concrete Concept

concept.crsi.org/index.cfm/concept/project/page2

CRSI: CRSI Home Page

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**Dimensions / Void Parameters**

Total slab thickness:  in.

Void type:

Void diameter:  in.

Horizontal clear space between voids:  in.

Stiffness reduction factor:

Shear reduction factor:

Average void area in slab:  %

**Notes**

- ACI 9.5.3 contains minimum slab thickness requirements for slabs without beams, which pertain to serviceability only.
- Calculated minimum slab thickness is based on critical span(s).
- Input a slab thickness greater than or equal to that according to ACI 9.5.3. Verify that the deflection of the slab including the stiffness reduction factor meets all applicable limiting criteria.
- The solid slab thickness above and below the voids is assumed to be the same; the sum of the solid slab thicknesses and the void height is equal to the total slab thickness. Also ensure that a total slab thickness is chosen that results in a solid slab thickness above and below the voids that can accommodate the required cover and reinforcing bar diameter for a given void depth.
- Stiffness and shear reduction factors take into account the reduced stiffness and shear capacity of the slab due to the presence of the voids, respectively; consult manufacturers' literature for appropriate values.
- The average void area in a slab is typically in the range of 70 to 80%. For preliminary design, it is recommended to use a value of 70%.

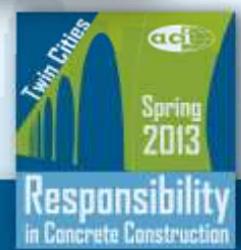
**Material Quantities**

Top bar size:

Bottom bar size:

Additional reinforcement:  psf

Width of solid concrete along the perimeter of the slab:  ft.

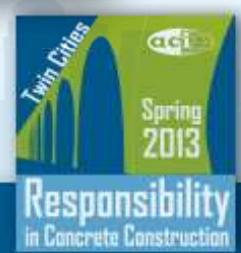


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# RC Concept

The screenshot shows the 'reinforced concrete CONCEPT' software interface. At the top, there's a navigation bar with links like 'YOUR CONCEPTS', 'ABOUT', 'PROFILE', 'CONTACT', 'LOGOUT', and 'CRSI WEB SITE - CRSI.ORG'. Below the header, a section titled 'VOIDED SLAB (CLICK FOR MORE INFO)' is displayed. On the left, there's a table for 'Columns (in. x in.)' with columns for 'C<sub>EW</sub>' and 'C<sub>NS</sub>', listing values for Interior, Edge, and Corner columns. To the right of the table is a diagram of a slab with columns labeled C<sub>EW</sub> and C<sub>NS</sub>, and a north arrow. A 'Notes' section defines C<sub>EW</sub> and C<sub>NS</sub> and states that using no more than three different column sizes usually results in the most. A 'Warnings Encountered!' dialog box is open, listing several errors related to two-way shear requirements failing at edge and corner columns. The main area shows a grid-based 'Building Footprint' with numbered columns from 1 to 11 and rows A to C. A legend indicates 'E1-2' through 'E10-11' for the columns and 'F1-2' through 'F10-11' for the rows. At the bottom, there are tabs for 'Dimensions / Void Parameters' and 'Notes'.

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# RC Concept

Reinforced Concrete Concept

concept.crsi.org/index.cfm/concept/project/finish

VOIDED SLAB (CLICK FOR MORE INFO) ?

**Dimensions**

Slab thickness: **18** in.  
Minimum thickness (ACI 9.5.3): **11.2** in.  
Void type: **Spherical** in.  
Void diameter: **12** in.  
Solid slab thickness above and below voids: **3.0** in.  
Horizontal clear space between voids: **2** in.  
Stiffness reduction factor: **0.9**  
Shear reduction factor: **0.5**  
Average void area in slab: **70** %

**Notes**

- ACI 9.5.3 contains minimum slab thickness requirements for slabs without beams, which pertain to serviceability only.
- Calculated minimum slab thickness is based on critical span(s).
- Input a slab thickness greater than or equal to that according to ACI 9.5.3. Verify that the deflection of the slab including the stiffness reduction factor meets all applicable limiting criteria.
- The solid slab thickness above and below the voids is assumed to be the same; the sum of the solid slab thicknesses and the void height is equal to the total slab thickness. Also ensure that a total slab thickness is chosen that results in a solid slab thickness above and below the voids that can accommodate the required cover and reinforcing bar diameter for a given void depth.
- Stiffness and shear reduction factors take into account the reduced stiffness and shear capacity of the slab due to the presence of the voids, respectively; consult manufacturers' literature for appropriate values.
- The average void area in a slab is typically in the range of 70 to 80%. For preliminary design, it is recommended to use a value of 70%.

**Factored Loads**

Concrete displacement: **0.4** ft<sup>3</sup>/ft<sup>2</sup>  
Dead load reduction: **57.8** psf  
Average dead load of slab: **184.5** psf  
Total factored dead load: **245.4** psf  
Total factored live load: **160.0** psf  
Total factored load  $q_u$ : **405.4** psf  
Load check per the Direct Design Method of ACI 13.6: **OK**

**Notes**

- The concrete displacement corresponds to the amount of concrete that is displaced by the voids.
- The dead load reduction corresponds to the average reduction in slab dead load based on the average volume of voids in the slab.
- The average dead load of the slab takes into consideration the solid areas of the slab that are required around the columns and is determined by subtracting the percentage of the dead load reduction based on the assumed average void area in the slab from the weight of a solid slab based on the total assumed slab thickness.
- Maximum factored gravity loads are obtained using Eq. (9-2) in ACI 9.2.1 for dead loads (D) and floor live loads (L).
- If the load check is "NG", the Direct Design Method should not be used to analyze the system, and the results obtained from this analysis may not be realistic.



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# RC Concept

Reinforced Concrete Concept

concept.crsi.org/index.cfm/concept/project/finish

**Material Quantities**

|  |   |
|--|---|
| Top bar size:  | <input type="text" value="6"/>  |
| Width of solid concrete along the perimeter of the slab: | <input type="text" value="3"/> ft.                                    |
| Bottom Bar Size:   | <input type="text" value="7"/>  |
| Concrete:  | <input type="text" value="1.22"/> (ft <sup>3</sup> /ft <sup>2</sup> ) |

**Minimum required area of solid concrete around each column:**

|                           |   |
|---------------------------|---|
| Corner:                   | <input type="text" value="9.00"/> (ft <sup>2</sup> )                  |
| Edge:                     | <input type="text" value="67.00"/> (ft <sup>2</sup> )                 |
| Interior:                 | <input type="text" value="262.00"/> (ft <sup>2</sup> )                |
| Reinforcement:            | <input type="text" value="4.27"/> psf                                 |
| Additional Reinforcement: | <input type="text" value="5"/> psf                                    |
| Total reinforcement:      | <input type="text" value="9.27"/> psf                                 |
| Formwork:                 | <input type="text" value="1.00"/> (ft <sup>3</sup> /ft <sup>2</sup> ) |
| Number of voids:          | <input type="text" value="0.74"/> (1/ft <sup>2</sup> )                |
| Void area in slab:        | <input type="text" value="71.58"/> %                                  |

**Notes**

- For purposes of preliminary design, a program limitation is that the neutral axis must fall within the solid slab portion above or below the voids; a warning message is generated if the neutral axis falls within the void region.
- The width of solid concrete around the perimeter of the slab is usually 2 feet, but should not be taken less than 1 foot.
- An additional amount of reinforcement can be added to account for miscellaneous steel or flexural reinforcement.
- The required area of solid concrete around each column is determined using the shear reduction factor. The lower bound for this area is determined assuming that there is one row of voids placed around the perimeter of each column.
- It is recommended to leave out at least one row of voids along openings in the slabs even if the allowable shear force for the voided slab is not exceeded in these areas.
- The percent of void area in the slab, which is equal to the area of the slab that contains voids divided by the total area, is calculated using the minimum required area of solid concrete around each column and the width of solid concrete along the perimeter of the slab. The analysis can be refined by inputting this value for the average void area in slab.

---

**COSTS**

**Concrete**

|                 |   |
|-----------------|---|
| Material:       | <input type="text" value="0.05"/> \$/ft <sup>2</sup>                                      |
| Placing:        | <input type="text" value="0.05"/> \$/ft <sup>2</sup>                                      |
| Finishing:      | <input type="text" value="1.00"/> \$/ft <sup>2</sup>                                      |
| Curing:         | <input type="text" value="1.00"/> \$/ft <sup>2</sup>                                      |
| Total concrete: | <input type="text" value="2.10"/> \$/ft <sup>2</sup> <input type="text" value="20.71"/> % |

**Reinforcing in Place:**  \$/ft<sup>2</sup>     %

**Voids in Place**  \$/ft<sup>2</sup>     %

**Forms in Place**

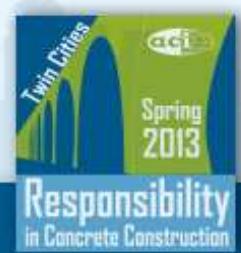
|              |   |
|--------------|---|
| Flat forms:  | <input type="text" value="7.00"/> \$/ft <sup>2</sup>                                      |
| Edge forms:  | <input type="text" value="0.04"/> \$/ft <sup>2</sup>                                      |
| Total forms: | <input type="text" value="7.04"/> \$/ft <sup>2</sup> <input type="text" value="69.43"/> % |

---

**TOTAL COST:**  \$/ft<sup>2</sup>

**Processing Time:** 12 sec

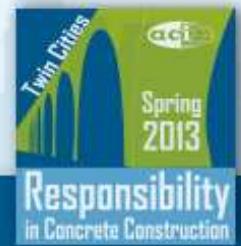
 



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# New Trends - Case Studies:

Miami Art Museum  
UW LaBahn Arena  
Harvey Mudd College

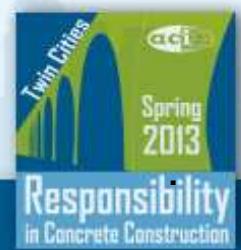


# **Miami Art Museum Construction Progress Report**

## **ACI 421 Session on Innovative Slab Design**

**VOIDED SLAB TECHNOLOGY  
OPTIMIZING DESIGN AND IMPROVING  
CONSTRUCTABILITY**

**Michael A. Russillo, President  
Cobiax USA Inc.  
April 14, 2013**



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- Brief description of voided slab technology
- How the concept is implemented
- Sequence of construction
- Special features
- Concrete facts and project credits
- Questions ?

# Perez Art Museum Miami (PAMM)

Museum Park

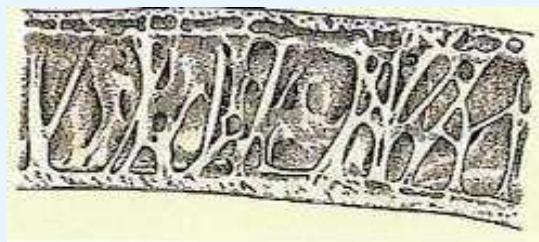


- Opening: Fall 2013
- 4 levels: Interior 120,000sf; exterior 80,000sf
- 6 void sizes covering 80,000 sf
- Exposed Concrete w/ Architectural finishes
- Voided Slab Drivers:
  - Large spans with flat soffit
  - Thick slabs due to 4" and 6" rebates
  - 2" cover for slab reinforcing
  - Reduction of weight on piles
  - Silver LEED Certification



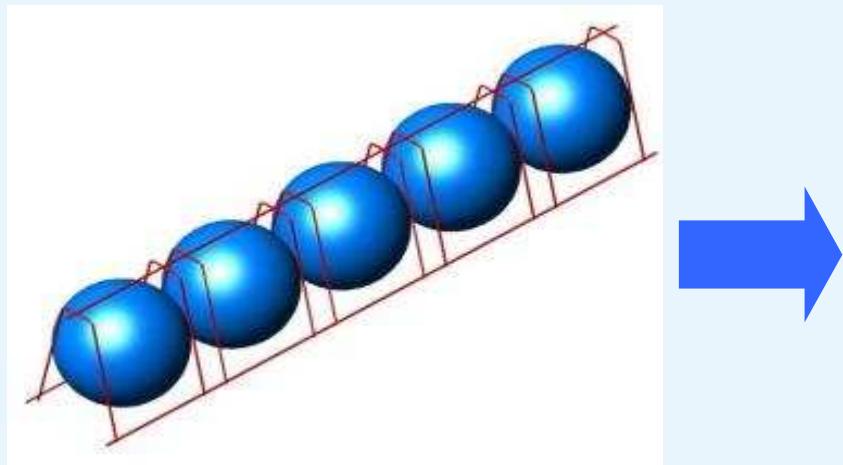
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# Basic idea of the voided slab technology



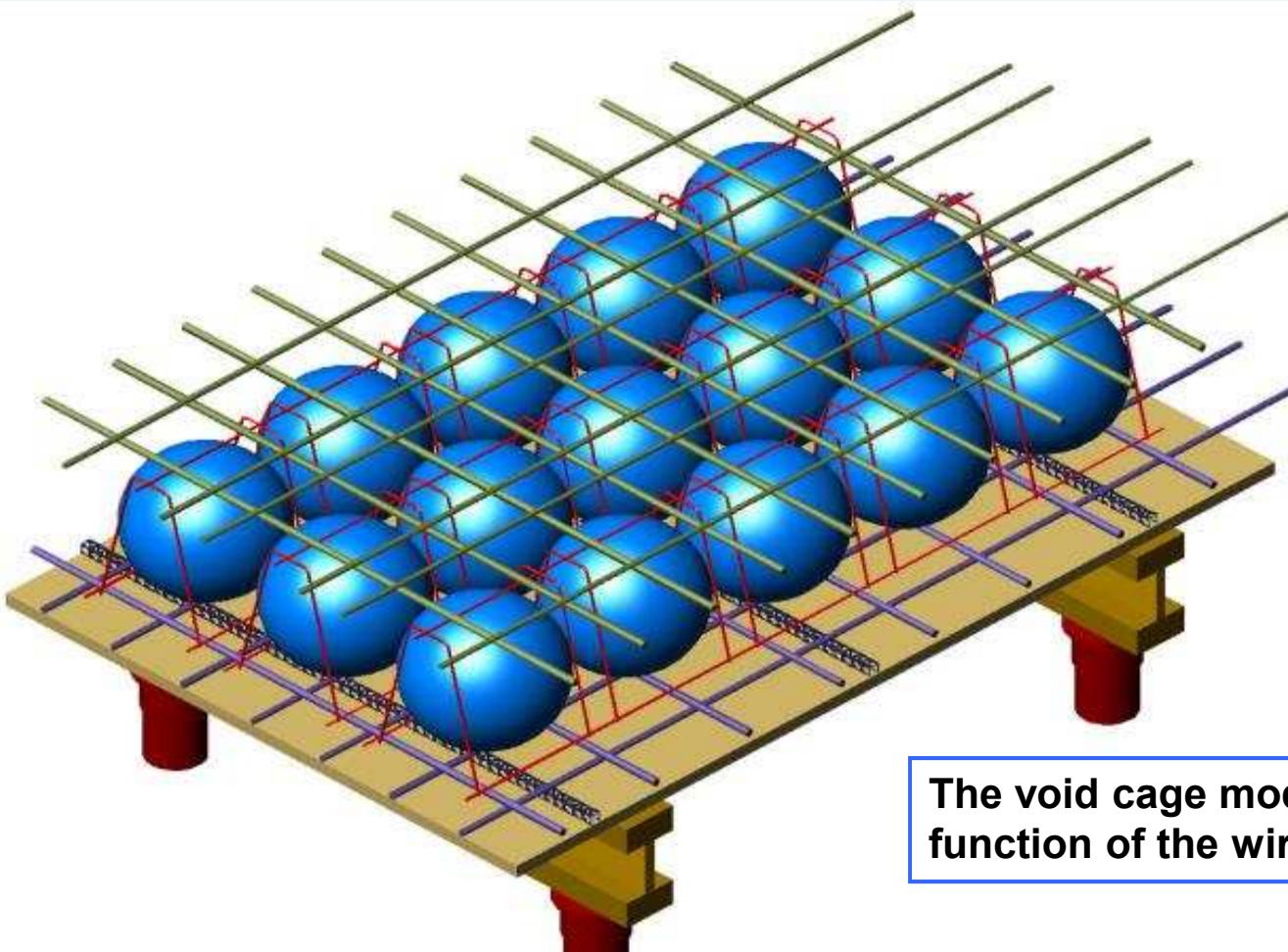
Eliminate concrete in the zones of a slab where from a static perspective there is no necessity for it. At the same time, optimize the slab's thickness and building material volume.

# Implementation of the idea



Hollow voids of recycled plastic, positioned in appropriate zones of flat plate slabs, contribute to dead load reduction without modifying flexural strength and load transfer to supports.

# Mounting of cobiax in an in-situ slab



→ Top static reinforcement

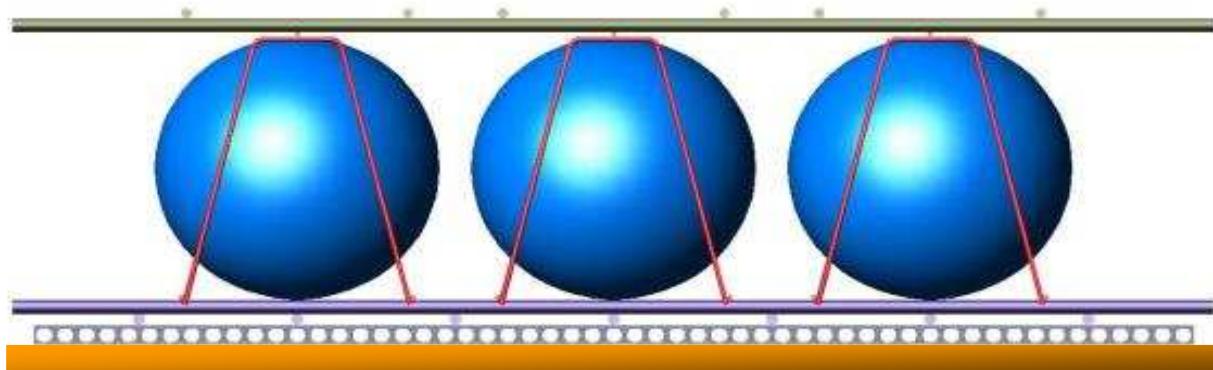
→ **void cage modules**

→ Bottom static reinforcement

→ Formwork & bracing

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# Cross section with voids (in-situ slab)



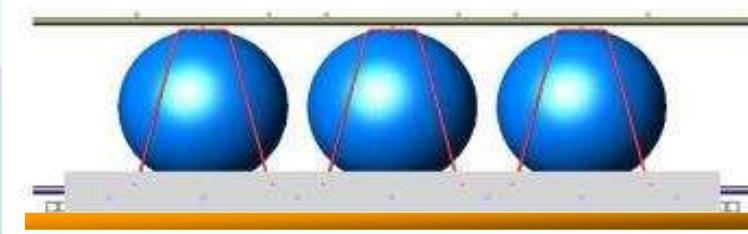
→ Top static reinforcement

→ **void cage modules**

→ Bottom static reinforcement

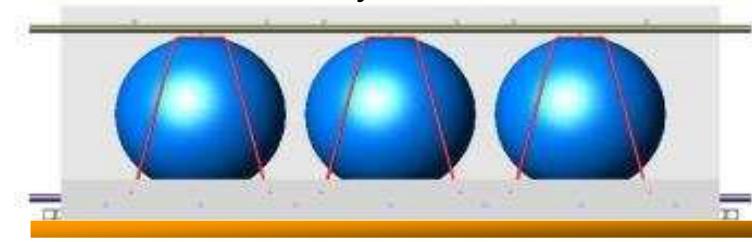
→ Formwork & bracing

1<sup>st</sup> concreting stage: Anchorage layer to prevent buoyancy



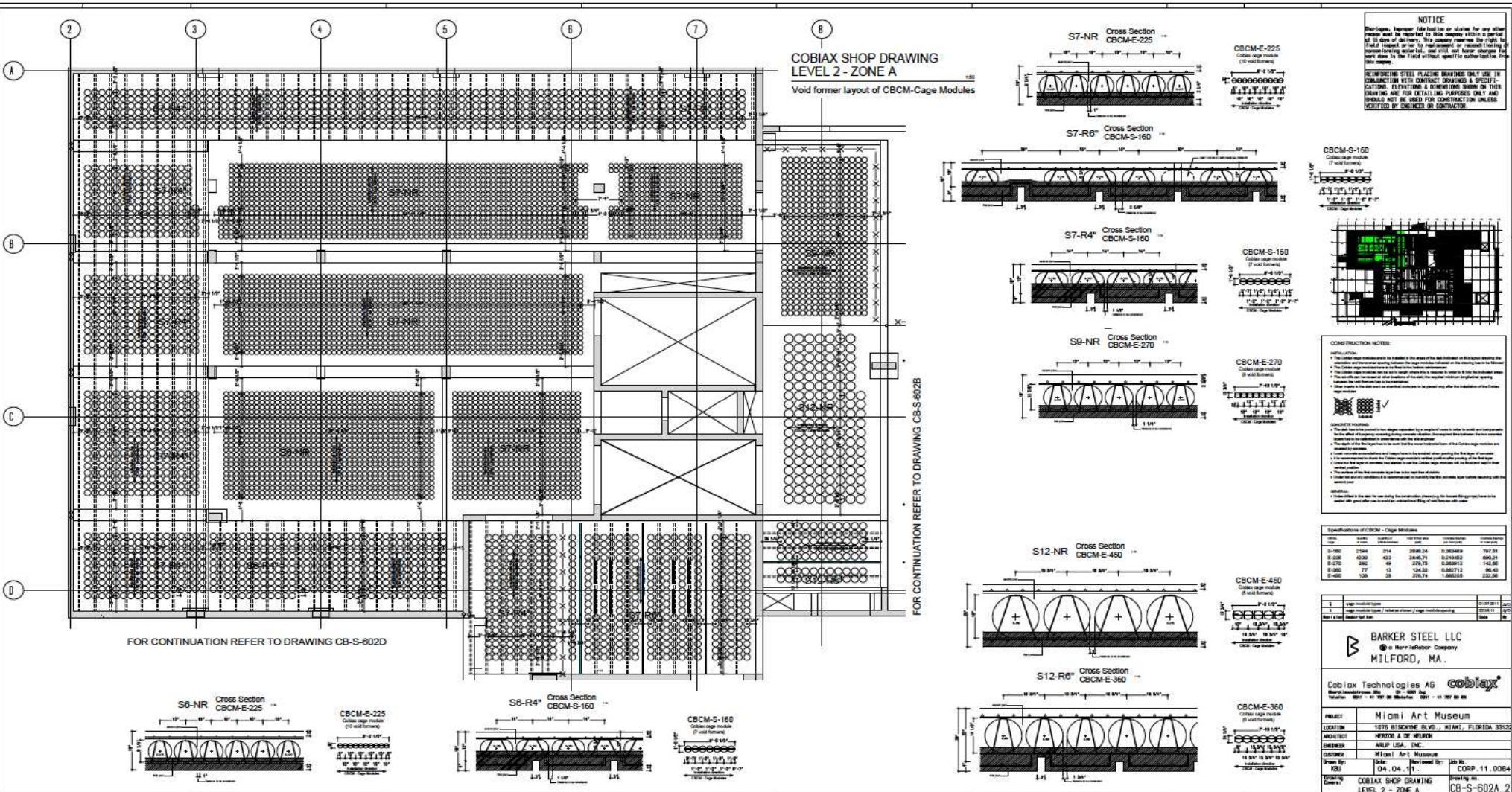
x hours  
→

2<sup>nd</sup> concreting stage: Remaining concrete after initial setting of 1<sup>st</sup> layer

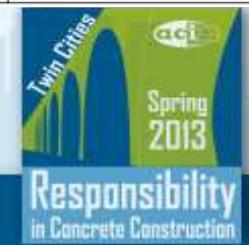


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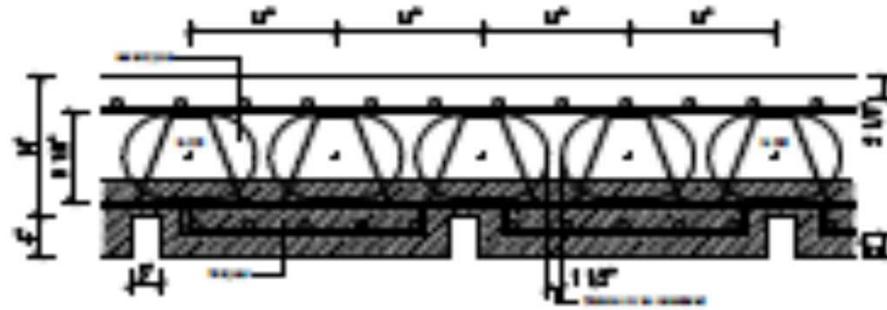
Responsibility  
in Concrete Construction



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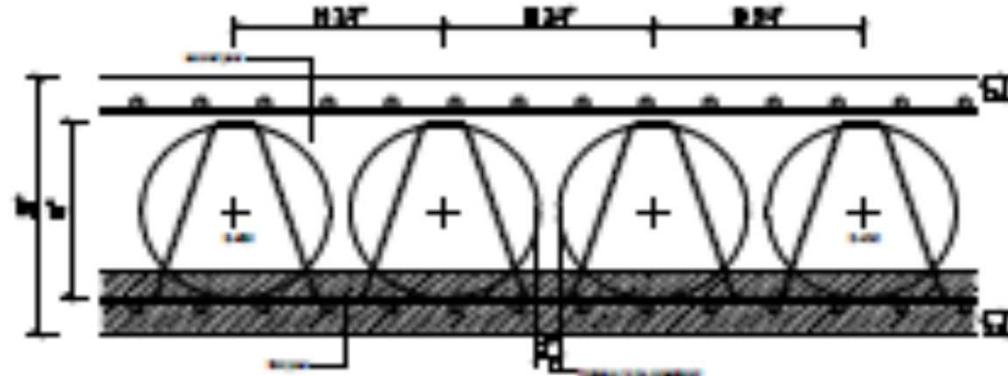
S9-R4\* Cross Section  
CBCM-S-220



CBCM-S-220  
Concrete cage module  
(4 vertical columns)



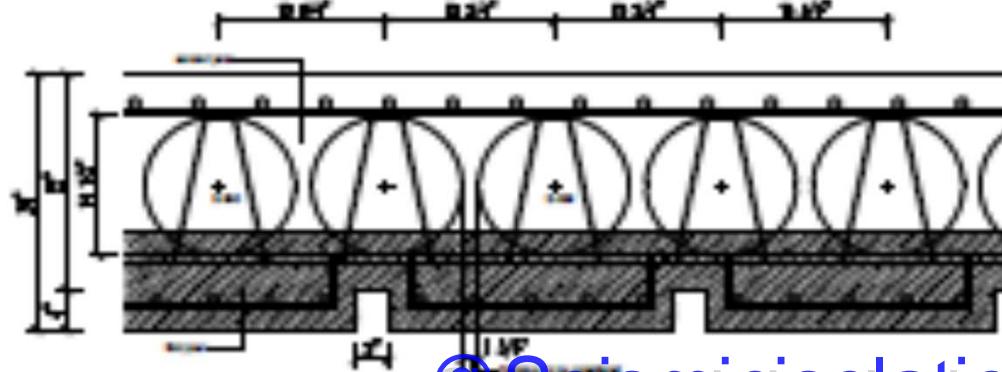
S12-NR Cross Section  
CBCM-E-450



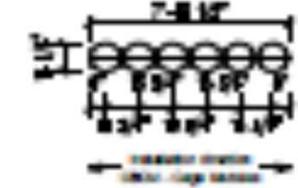
CBCM-E-450  
Concrete cage module  
(4 vertical columns)



S12-R6\* Cross Section  
CBCM-S-360



CBCM-E-360  
Concrete cage module  
(6 vertical columns)



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**VOID CAGE STORAGE ON SITE**  
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# Sunrise on Biscayne Bay....



04/25/2012

.....More Voids to Install  
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**Responsibility**  
in Concrete Construction



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# Installing & Spacing Voids @Seismicisolation

Responsibility  
in Concrete Construction



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**450 mm voids**

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04/17/2012

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04/19/2012

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**Clean-out before the  
concrete placement**

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03/05/2012

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# Mockup

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**Responsibility**  
in Concrete Construction



# MAM Mockup:

## Exposed Ceiling / Rebates / Textured Wall

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09/11/2012

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09/11/2012

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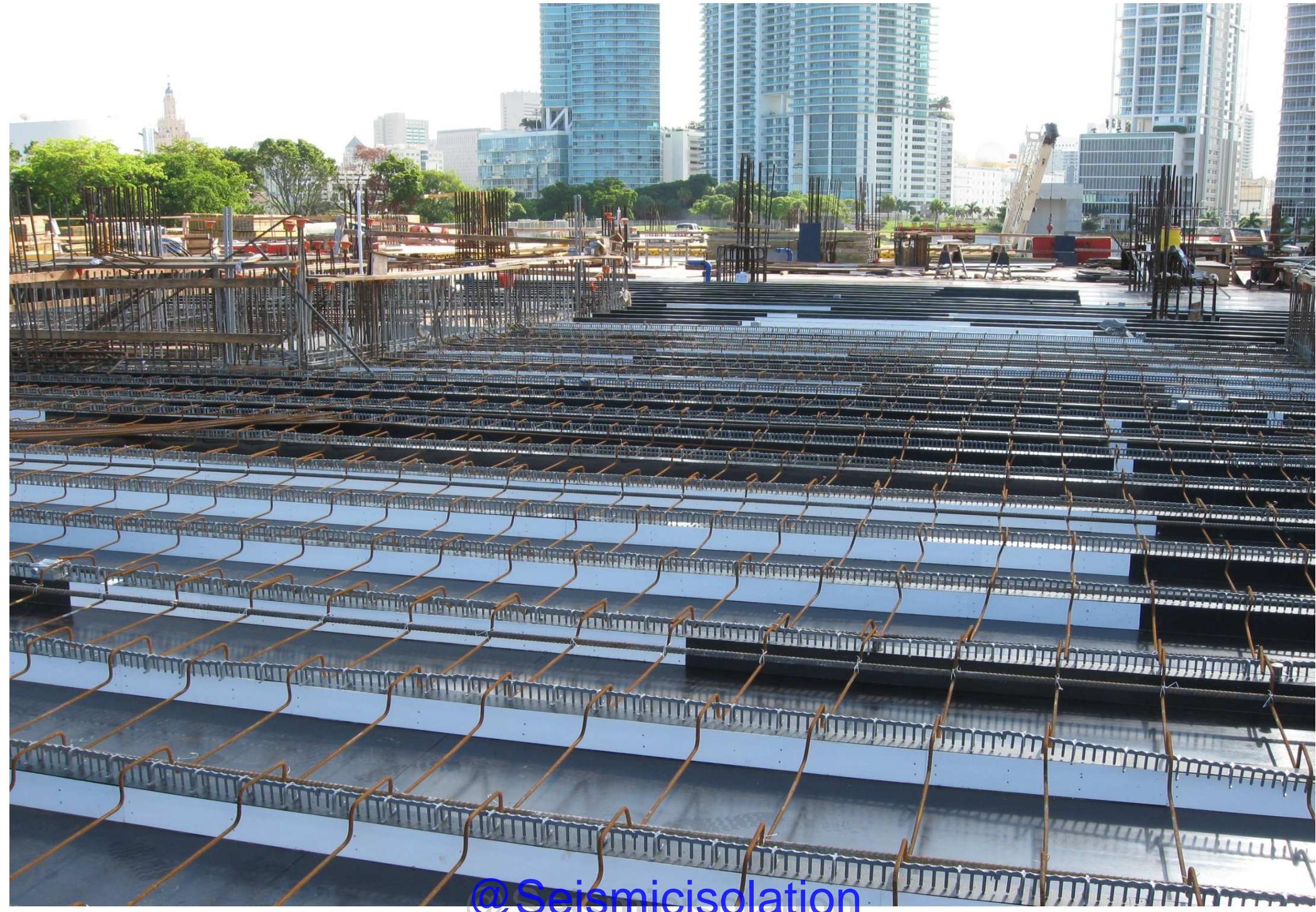


09/11/2012

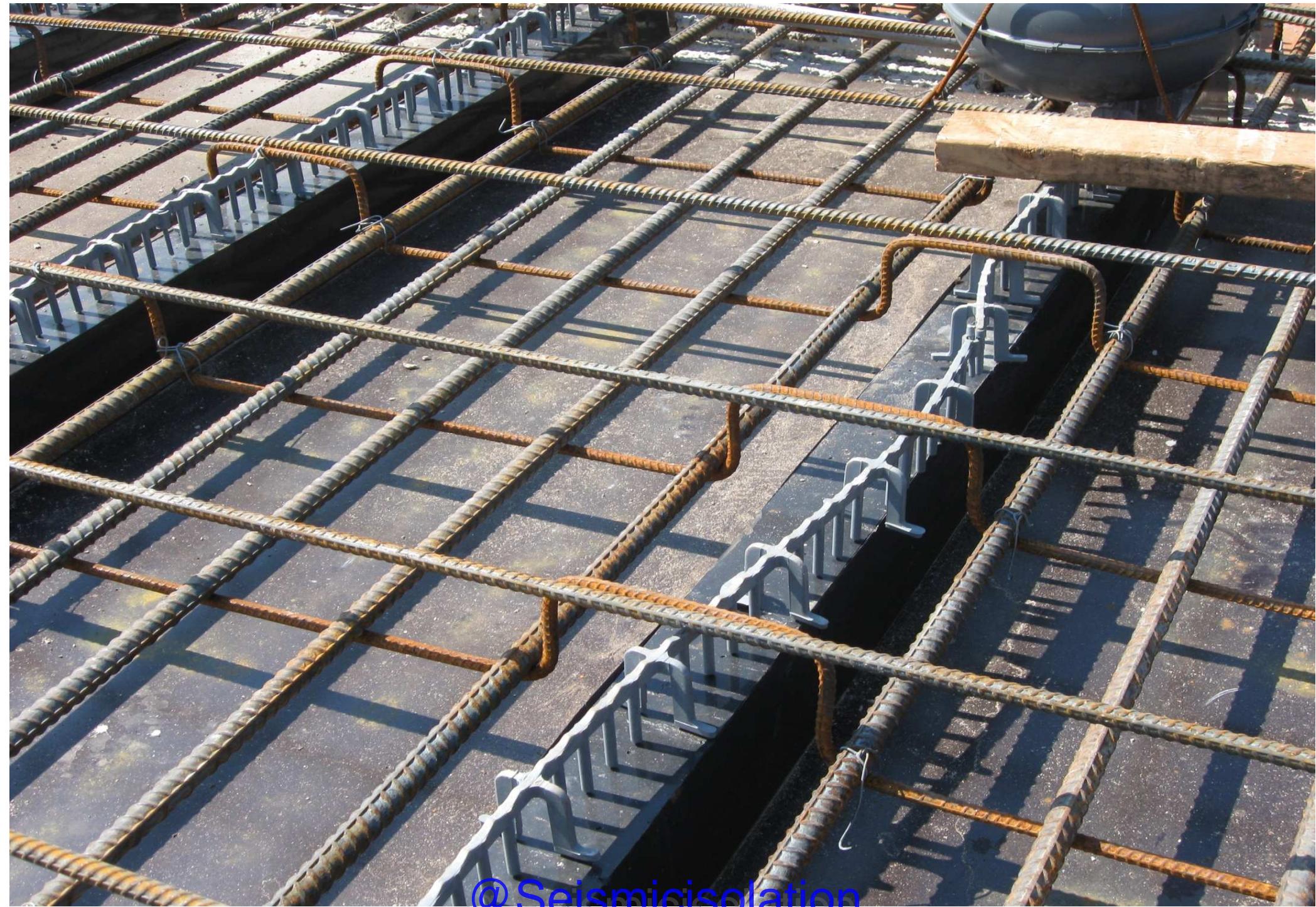
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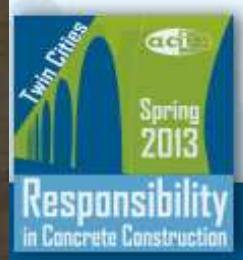
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Reshore of Exposed Ceiling  
@Seismicisolation

Responsibility  
in Concrete Construction

# Exposed ceiling w/ 4" & 6" rebates



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@Seismicisolation



@Seismicisolation



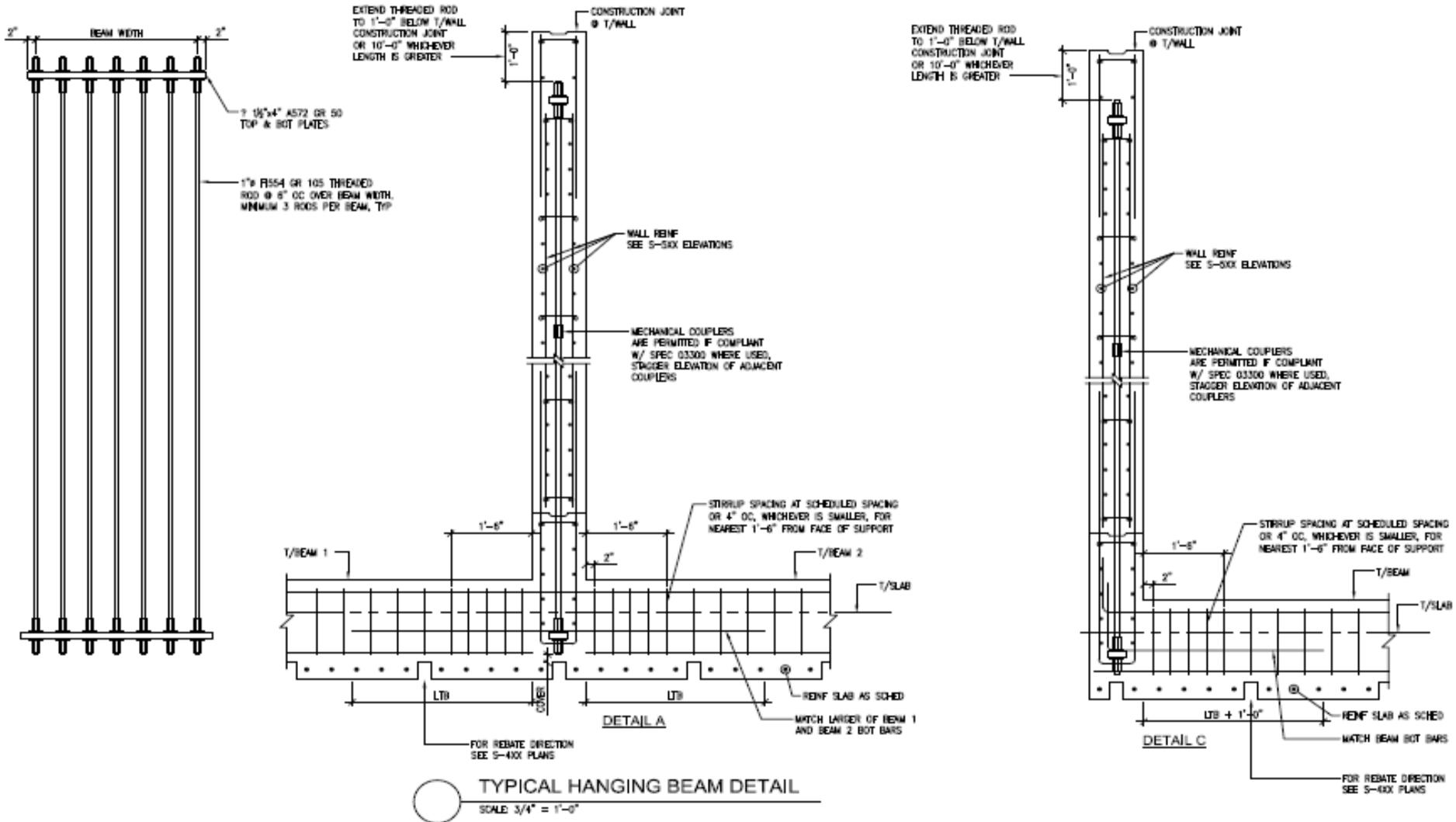
@Seismicisolation



**Upturned Beam**  
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# Sloped Auditorium Slab



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**EXPOSED BEAMS**  
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# Flying in Rebar for a Wall



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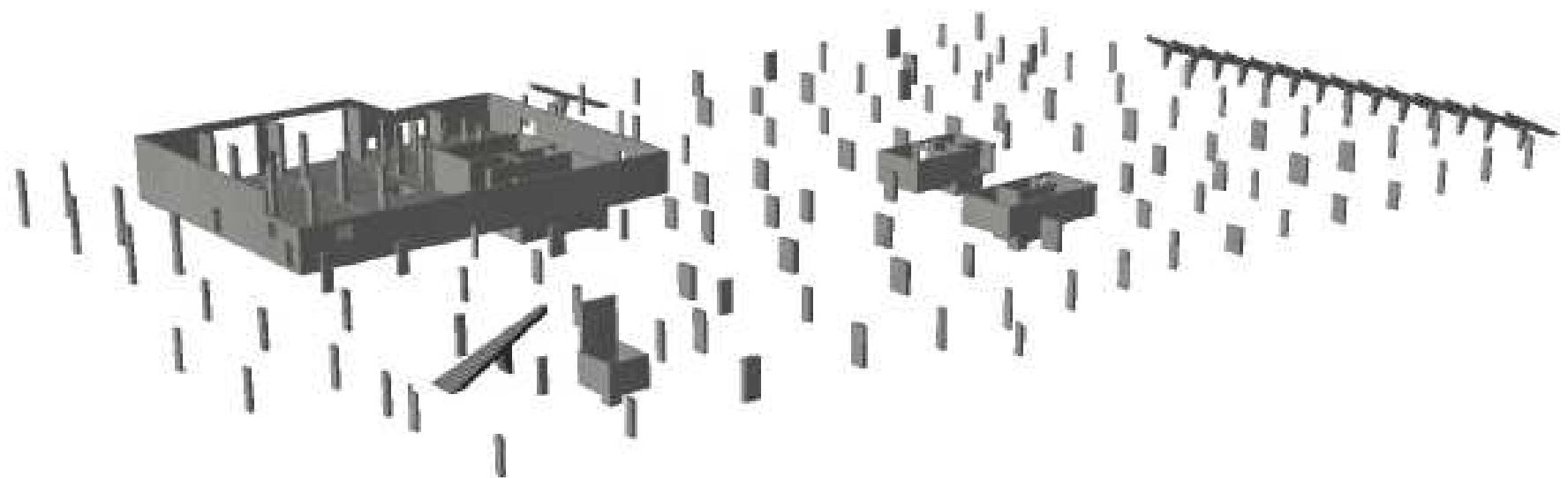


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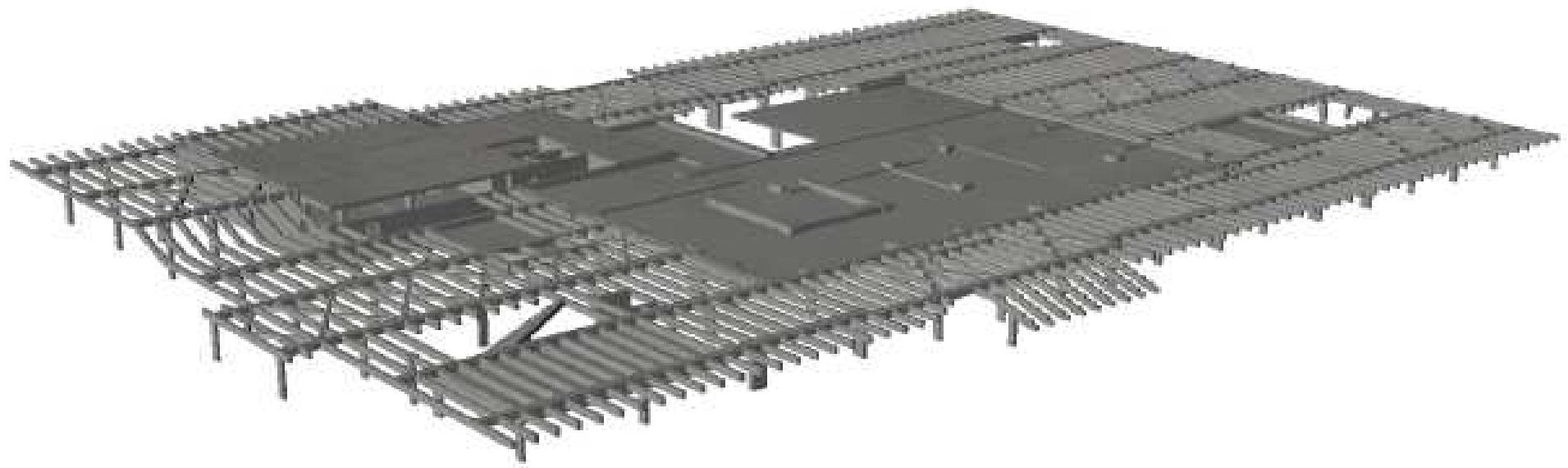


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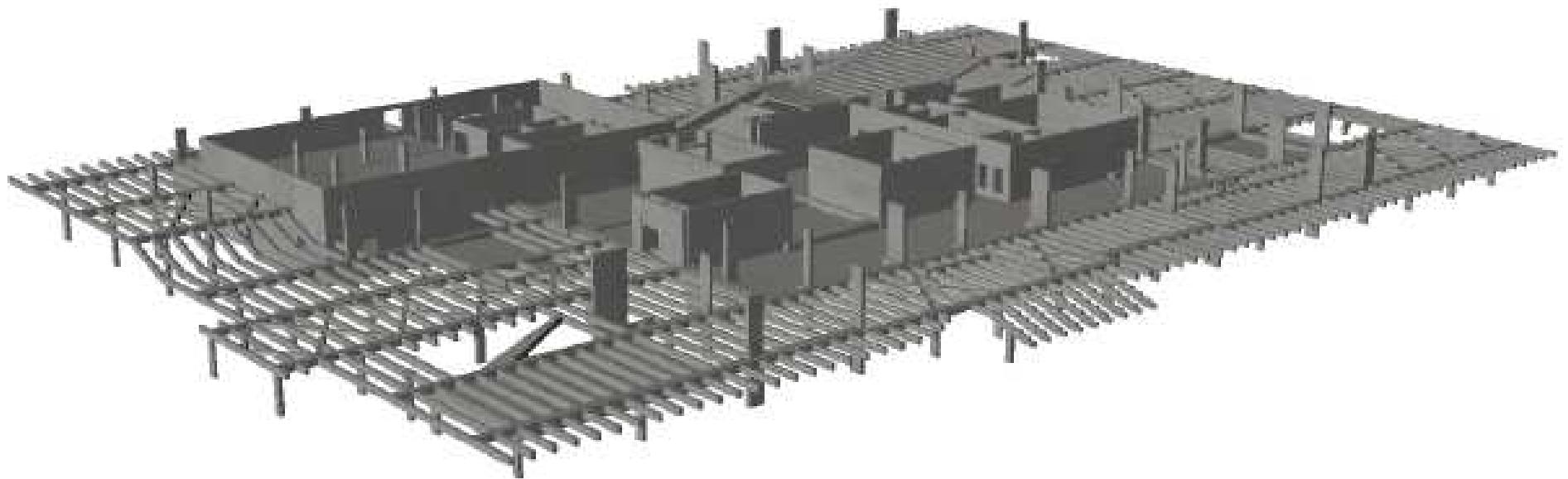
# CONSTRUCTION SEQUENCE



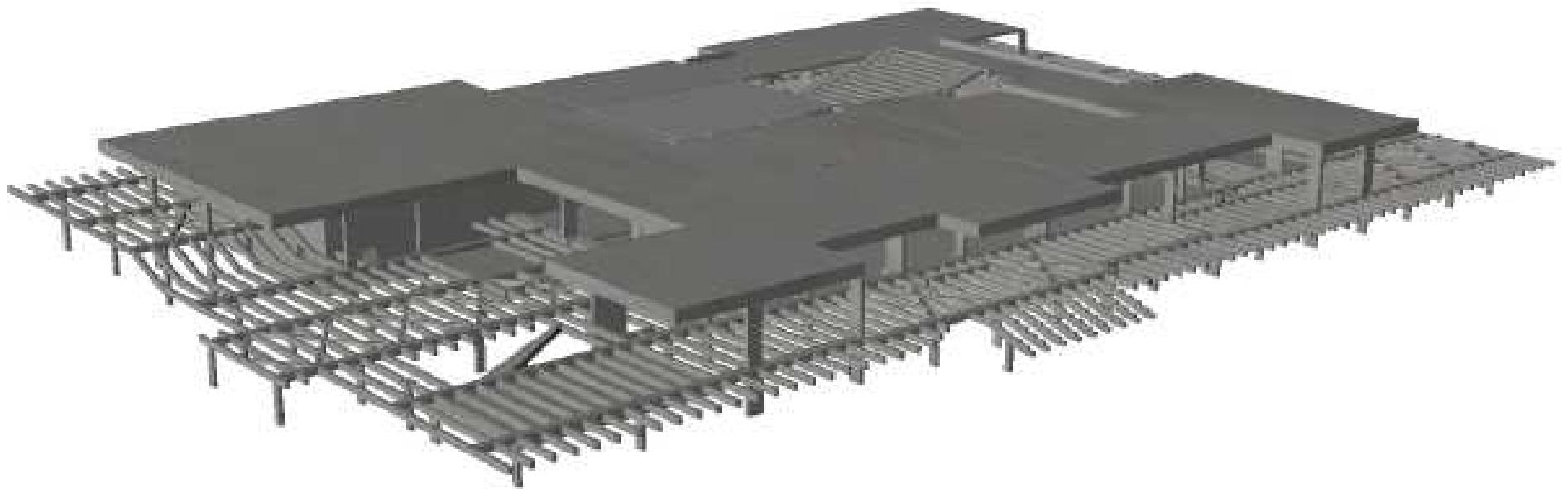
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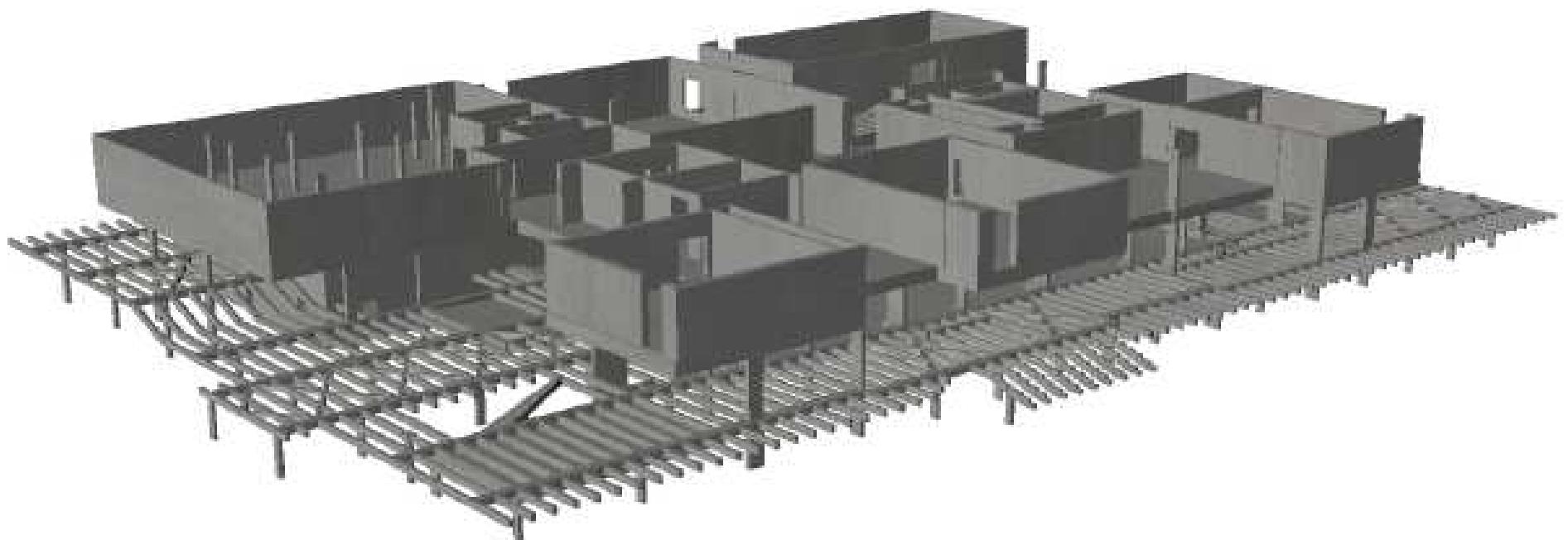
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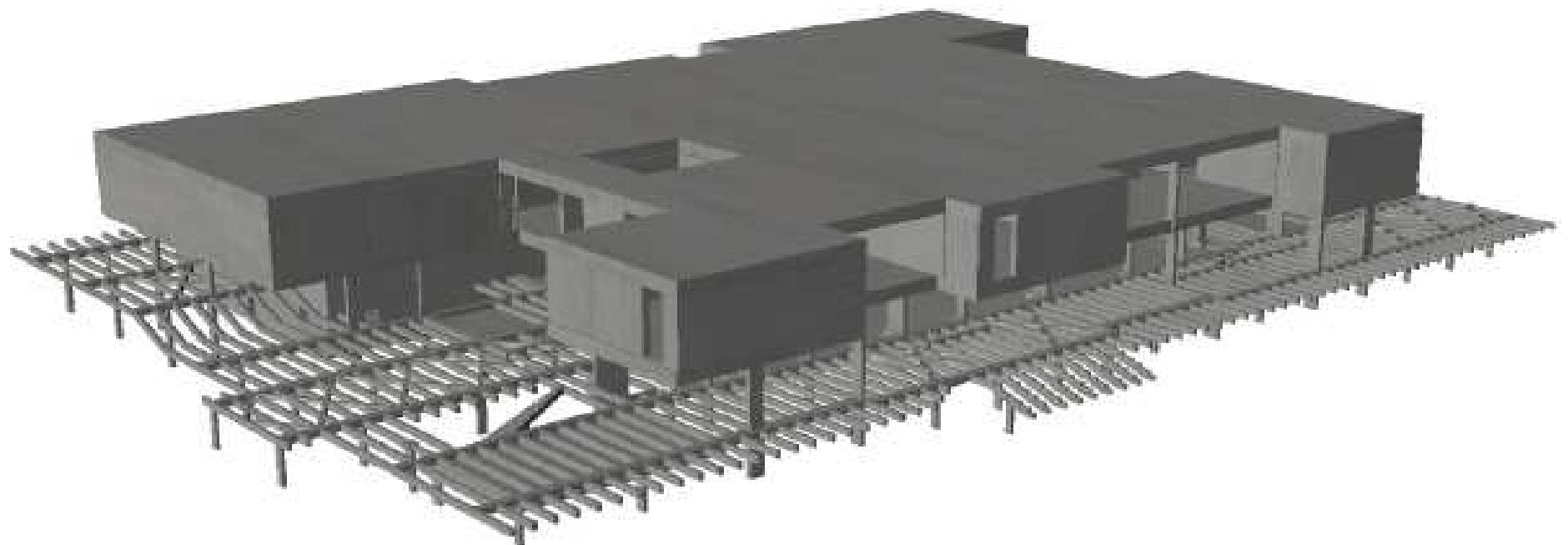
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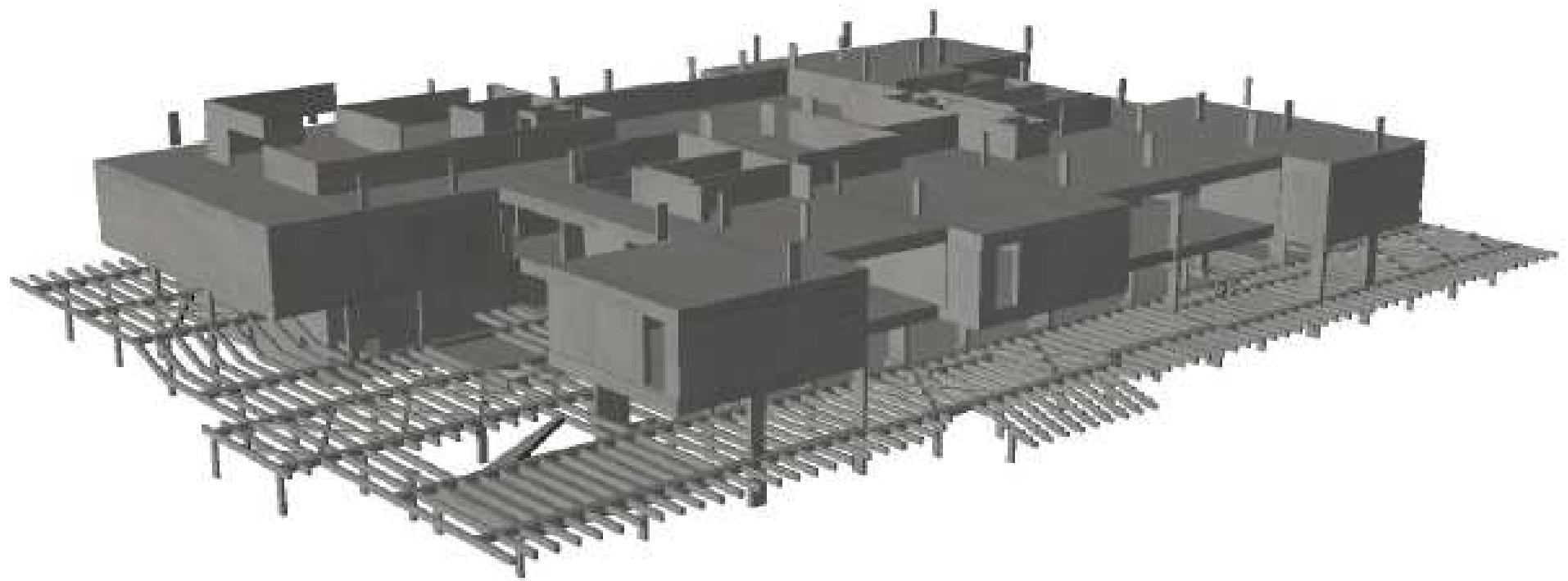
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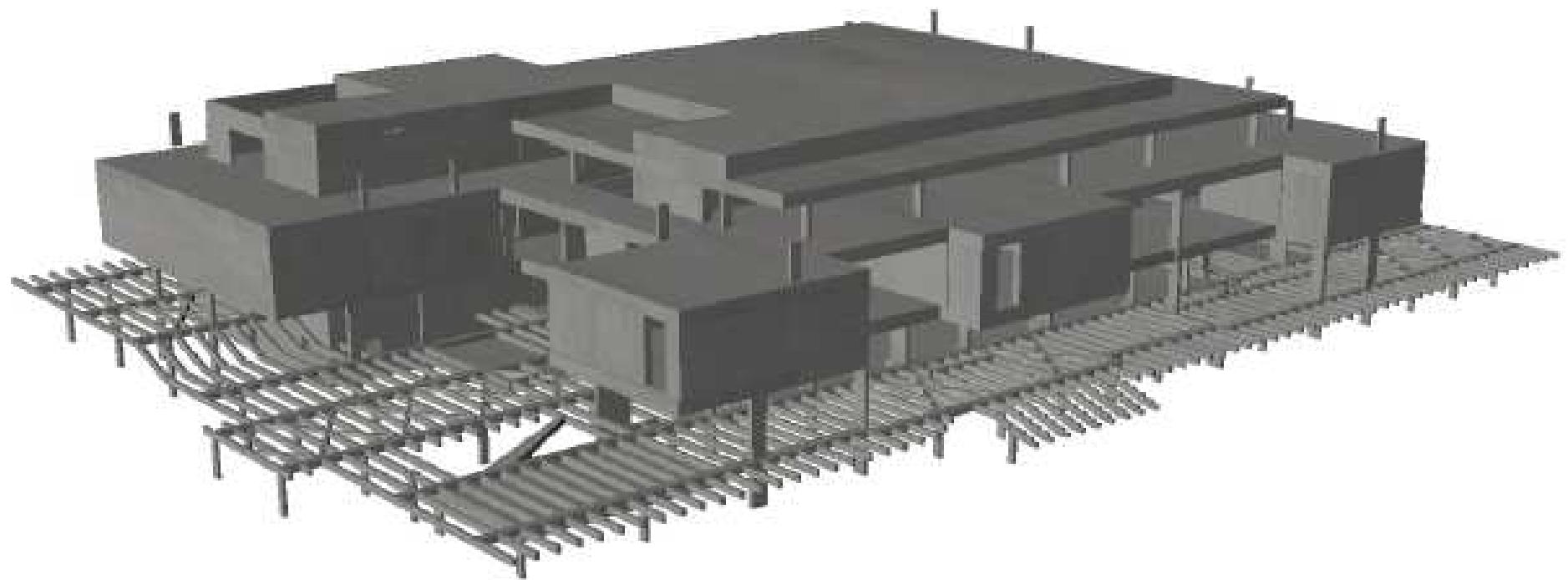
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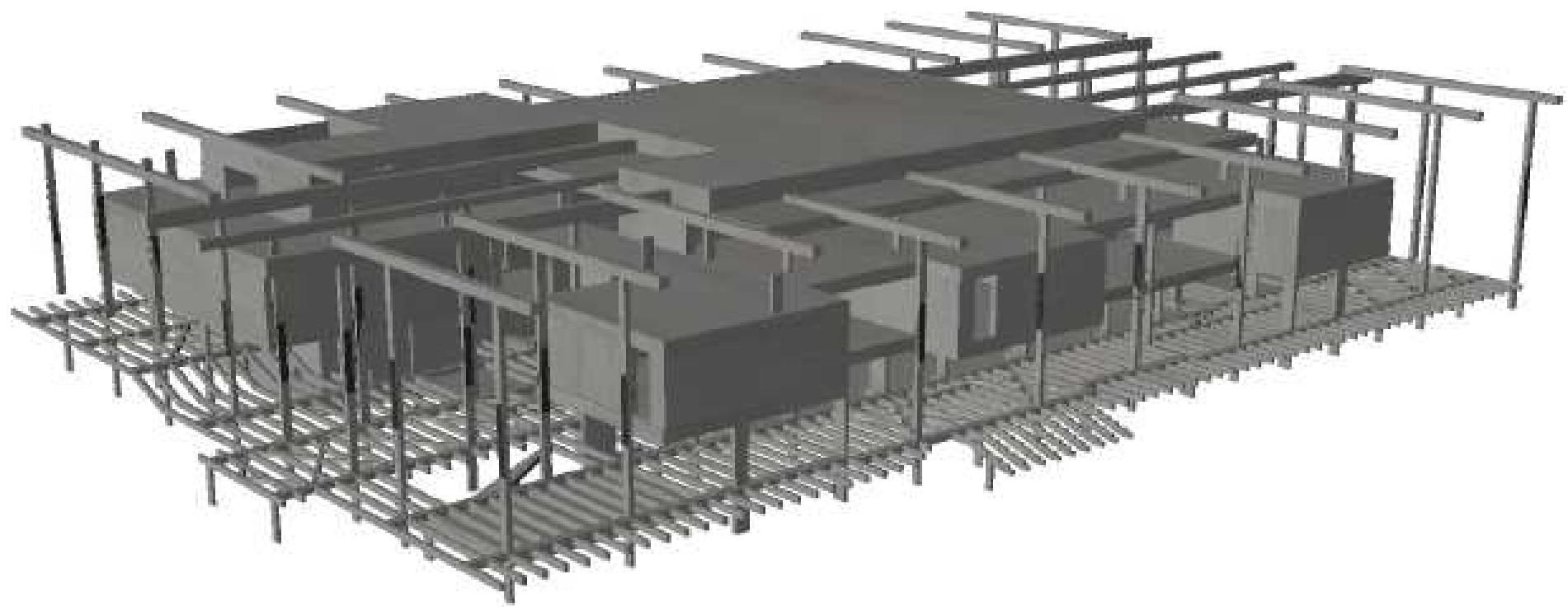
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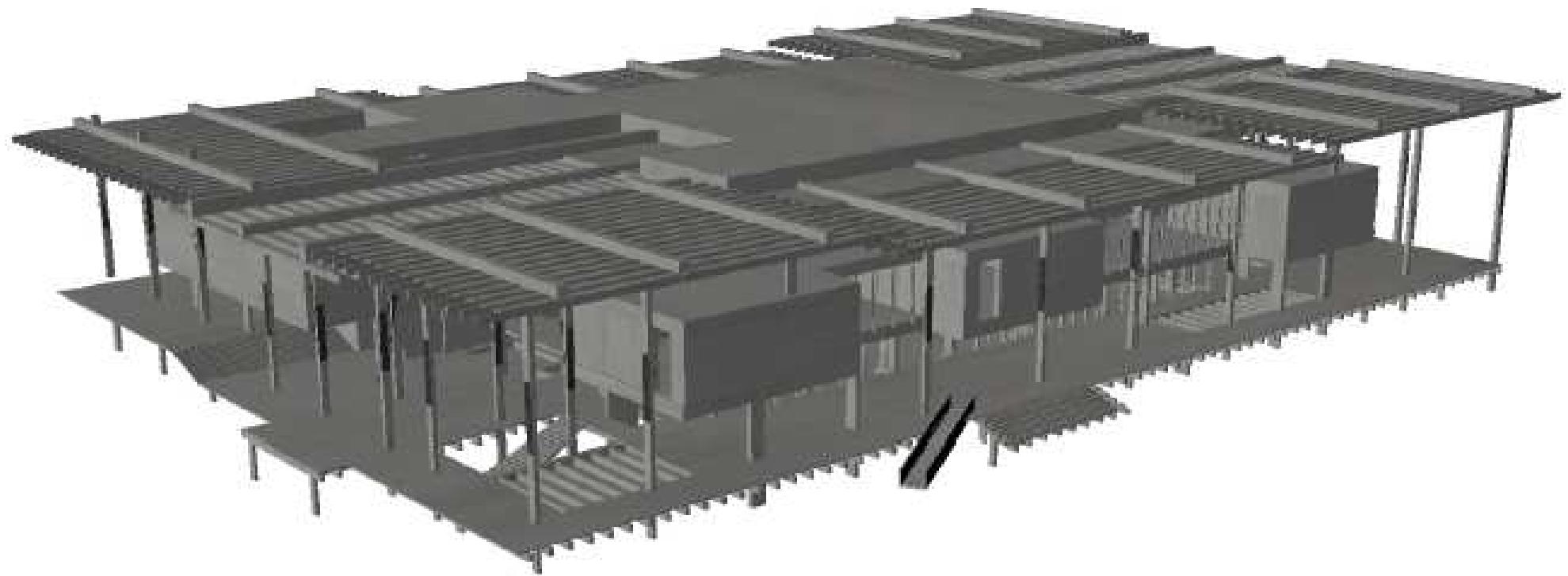
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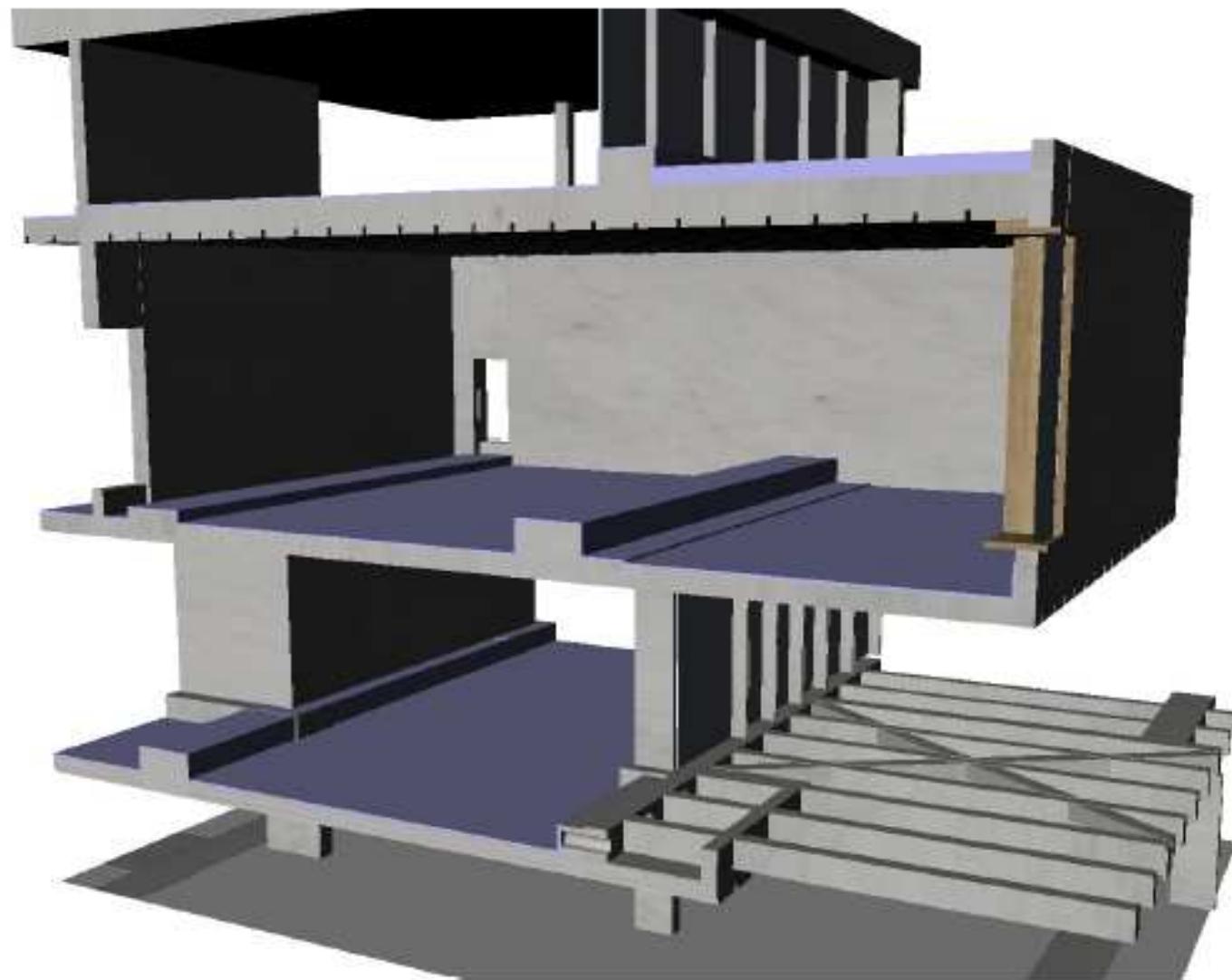
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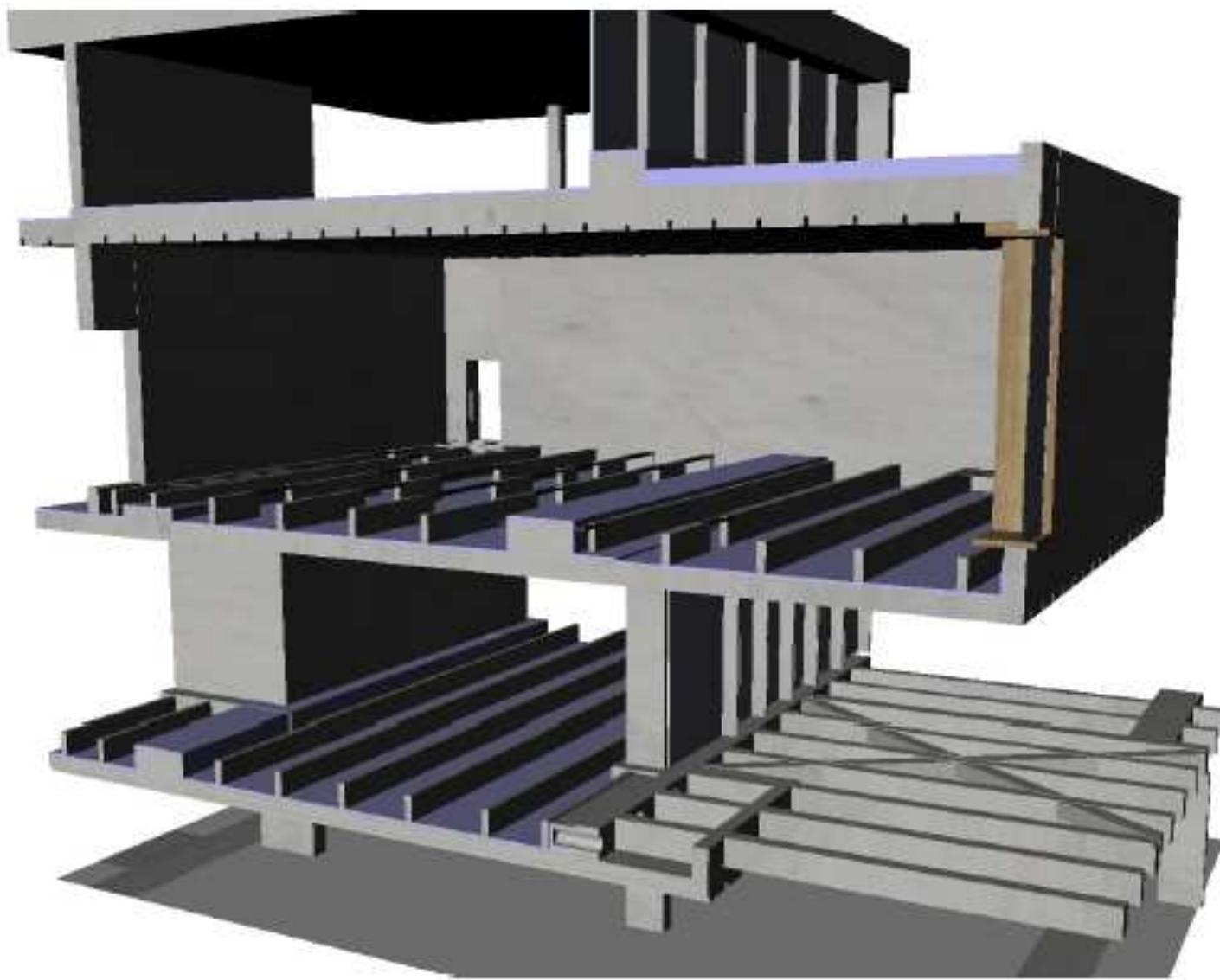
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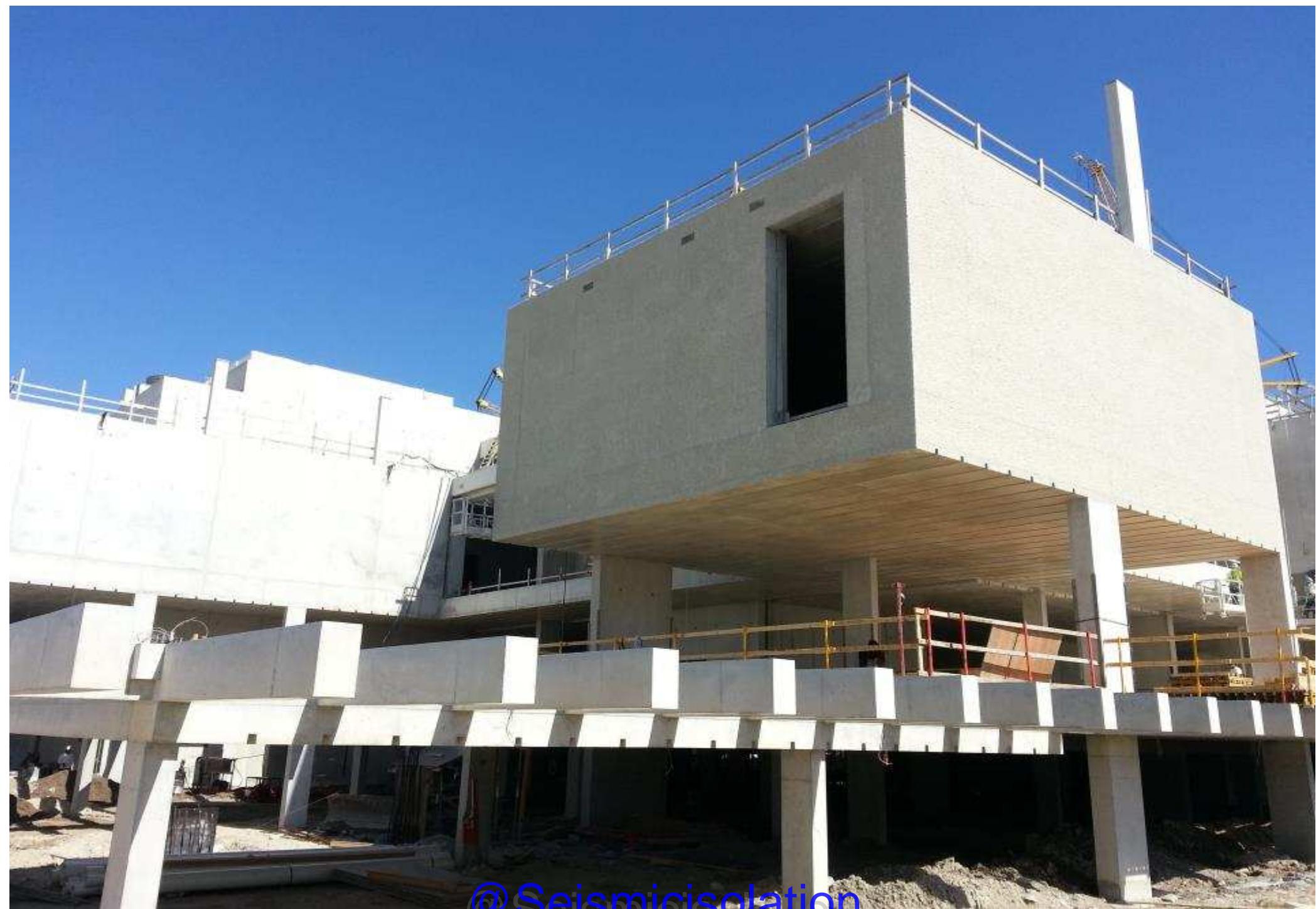
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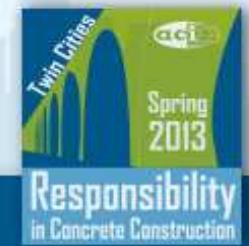
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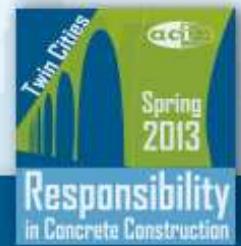


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# MIAMI ART MUSEUM Significant numbers

- GROSS AREA: 200,000 sf: 120,000 interior + 80,000 exterior
- TOTAL CONCRETE YARDAGE: 17,500 CY; 6,000 psi  
Supplier: Tarmac Concrete (Titan America)
- TOTAL REBAR TONNAGE: 3,000 tons  
Supplier: Gancedo Rebar Services
- VOIDS COVERED AREA: 80,000 sf
- 6 VOID SIZES: S-180, S-220, E-225, E-270, E-360 & E-450
- VOLUME OF CONCRETE DISPLACED: 935 CY
- WEIGHT REDUCTION ON PILES: 1,750 tons



## MIAMI ART MUSEUM Formwork and Concrete info

- Slab forms :  $\frac{3}{4}$ " sacrificial deck/back-up (MDO plywood) to minimize deflection with 5'x10' sheets of either Riga or Finn Form on top for form finish.
- Wall forms of Finn Maxi-Ply on good side, backed with  $\frac{3}{4}$ " plyform also to minimize deflection.
- Rebates were formed with beveled 4x4 fir in 10' lengths, faced with 5/8" Exactu.
- Cover: 2" for slabs; 2-1/2" for beams and columns
- Slag used to lighten w/ a blend of pea rock and regular rock. 5,000 psi specified / 6,000 psi delivered
- Shrinkage reducing admixtures used in most of the concrete.

# **Perez Art Museum Miami (PAMM)**

**Project Director: Paratus Group, NY, NY**

**Design Consultant: Herzog & de Meuron, Basel, Switzerland**

**Executive Architect: Handel Architects, NY, NY**

**Structural Engineer & M/E Engineer: Arup, NY, NY**

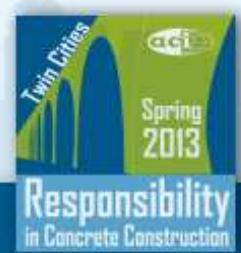
**Construction Manager: John Moriarty & Assoc., Florida**

**Concrete Contractor:**

**Baker Concrete / Reinforced Structures Inc., JV**

**Reinforcing & Cobiax Supply and Installation:**

**Titon Builders Inc.**





# Perez Art Museum Miami (PAMM)

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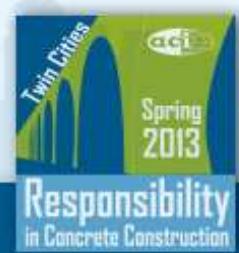
# THANK YOU!



Inquiries: Michael A. Russillo, President  
Cobiax USA Inc.  
90 Pleasant Street  
Dedham, MA 02026  
Tel: (781) 381-0111

[mrussillo@cobiaxusa.com](mailto:mrussillo@cobiaxusa.com)  
[Internet: www.cobiaxusa.com](http://www.cobiaxusa.com)

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# Precast Voided Slabs

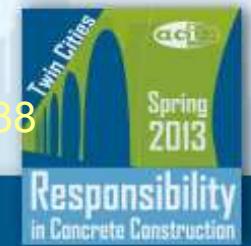
Dan Windorski, PE

GRAEF

Session sponsored by ACI 421

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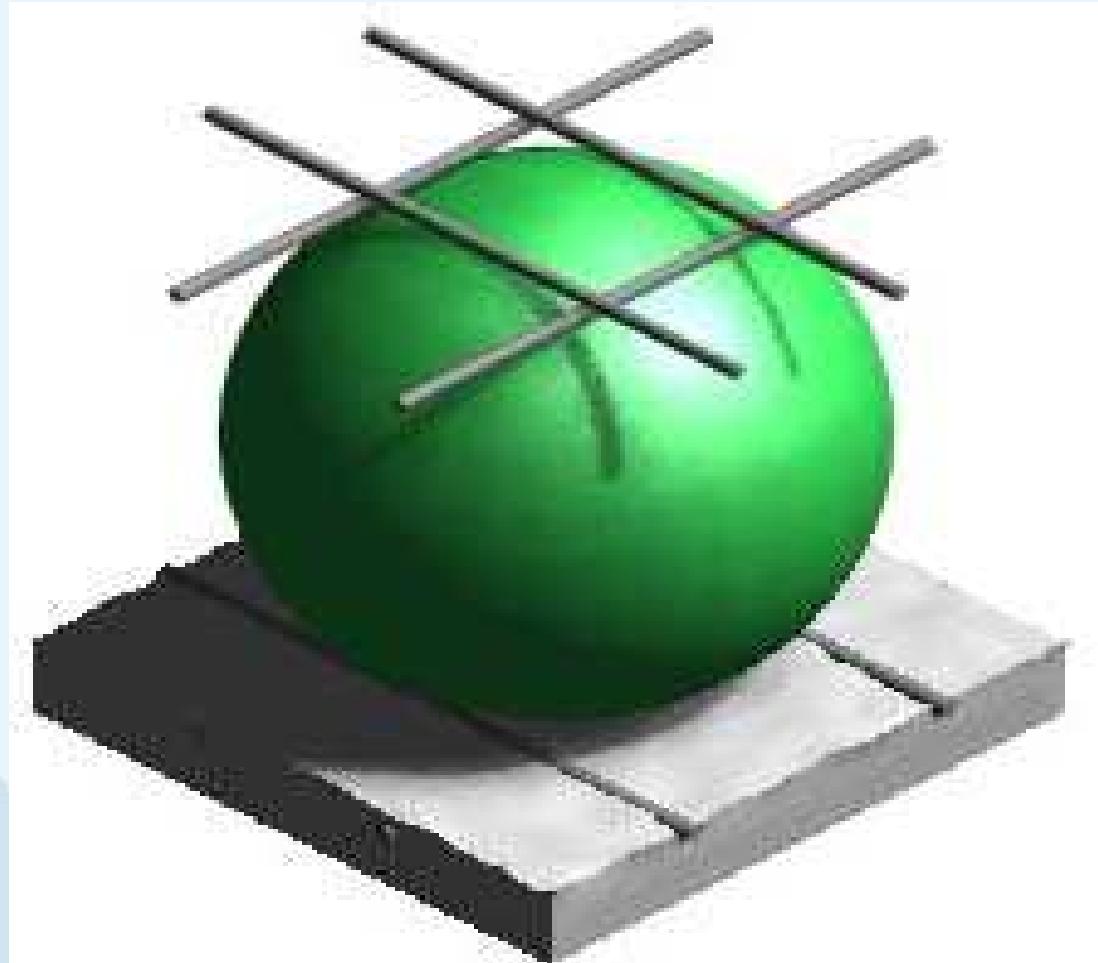
138



## Voided Slab w/ precast stay in place form

- Voided Two-Way Flat Plate
- Use plastic spheres (bubbles) to displace concrete
- Designs and Behaves like monolithic concrete
- A merger of the best aspects of cast in place and precast concrete construction

# Voided Slab w/ precast stay in place form



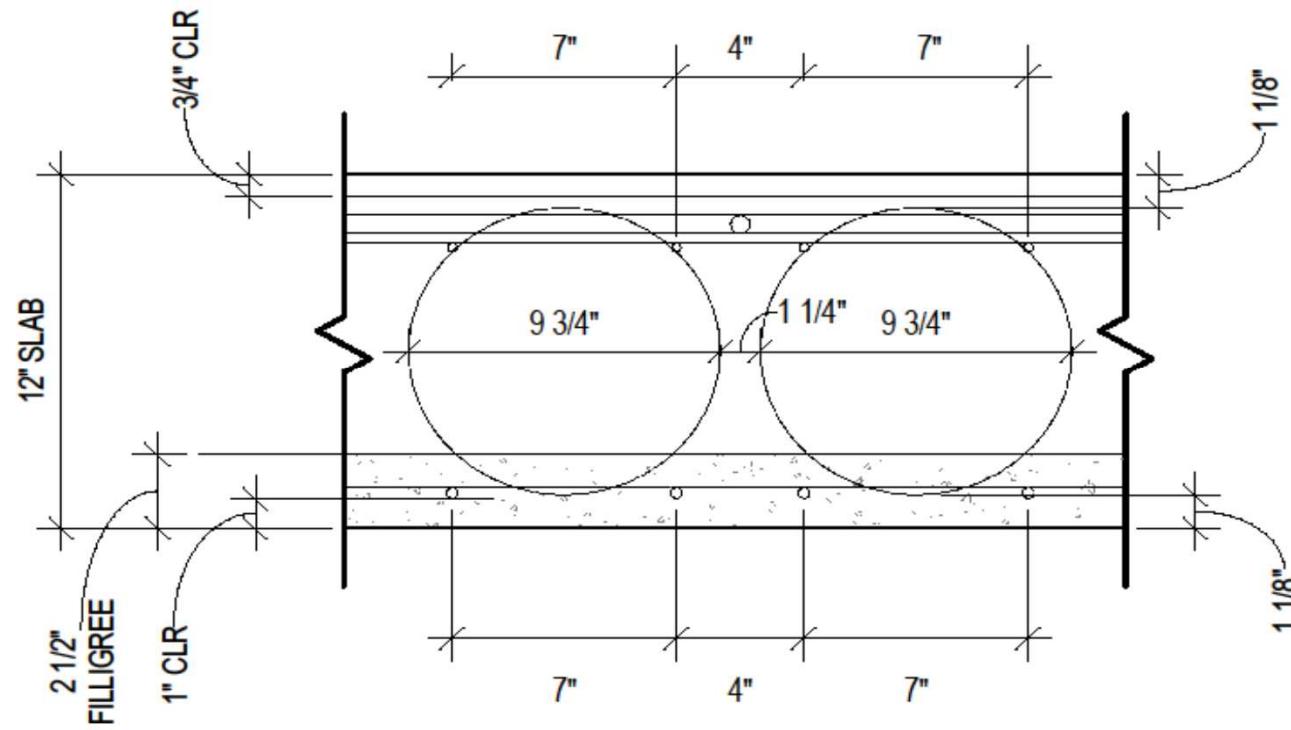
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# Voided Slab w/ precast stay in place form



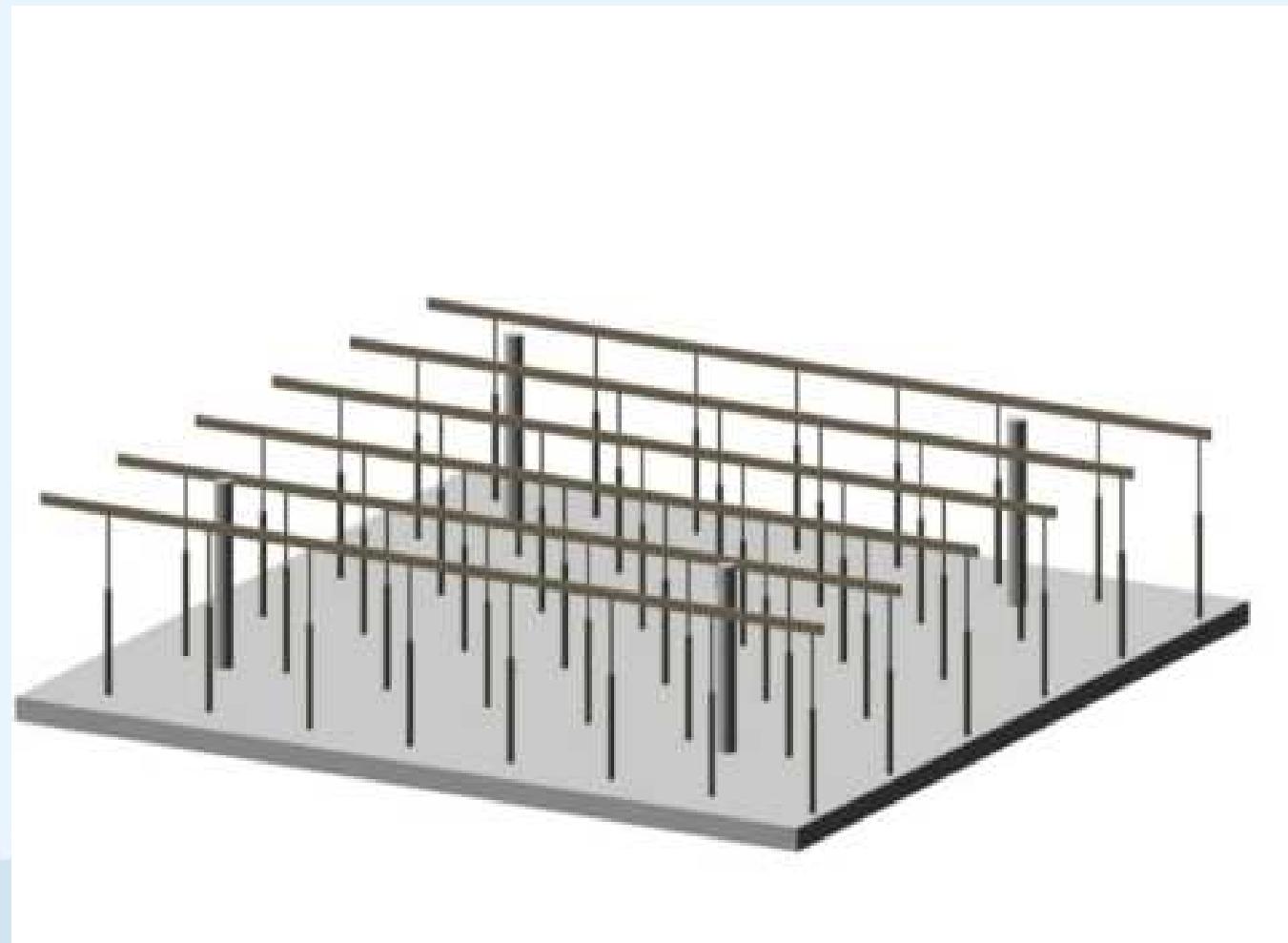
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# Voided Slab w/ precast stay in place form

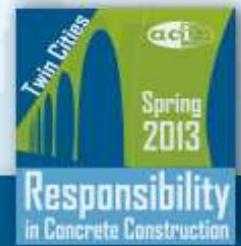


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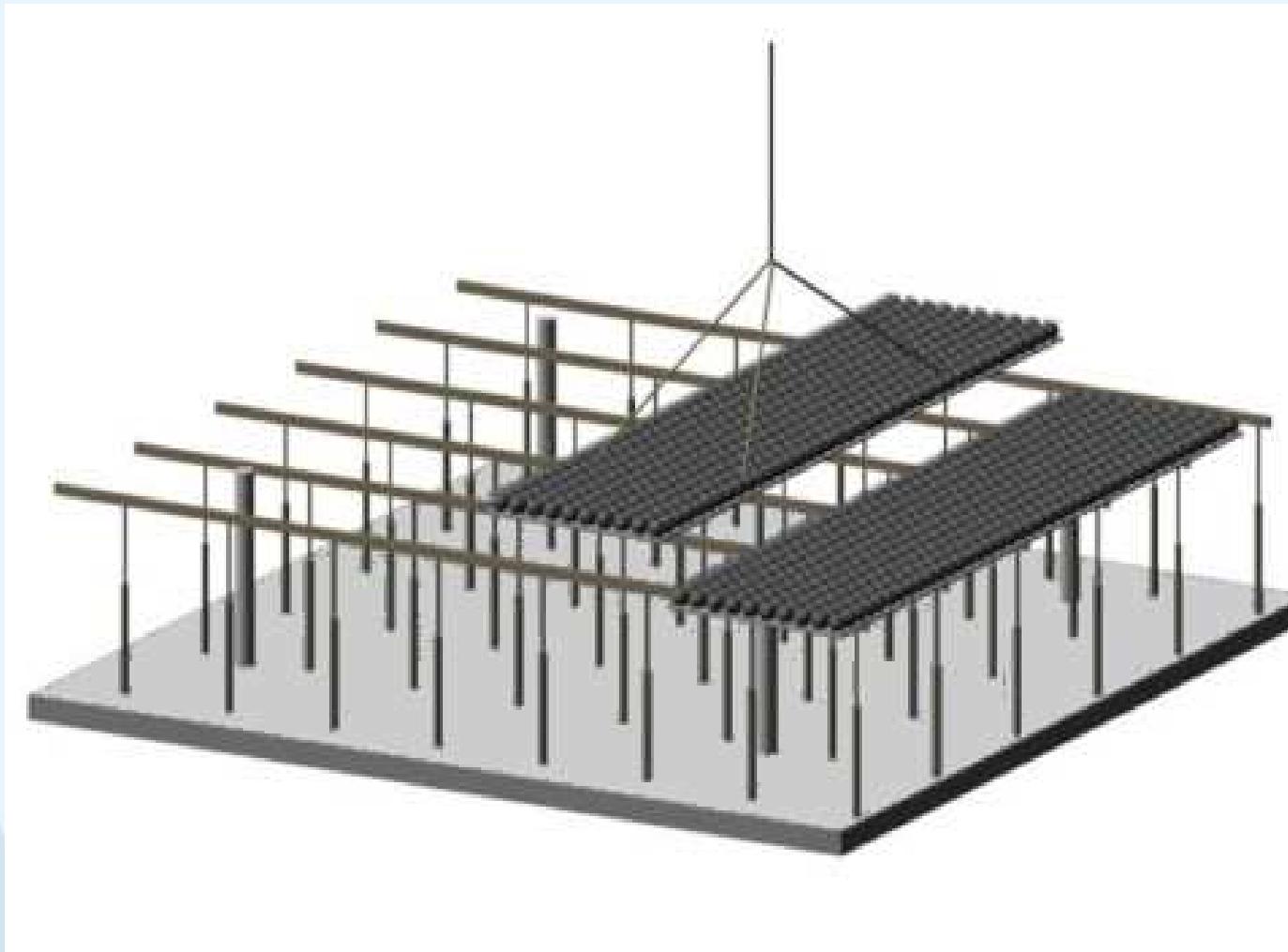
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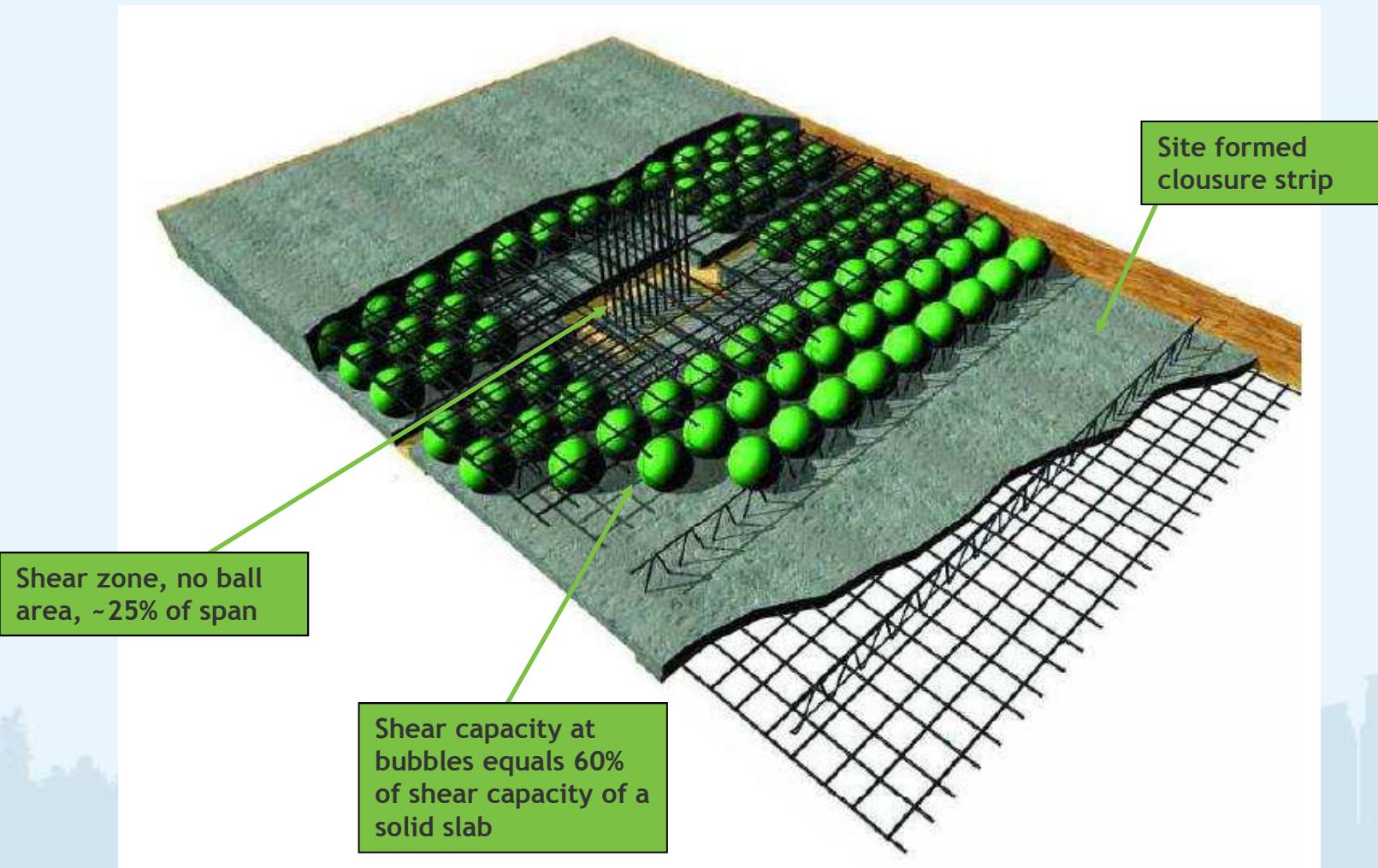


# Voided Slab w/ precast stay in place form



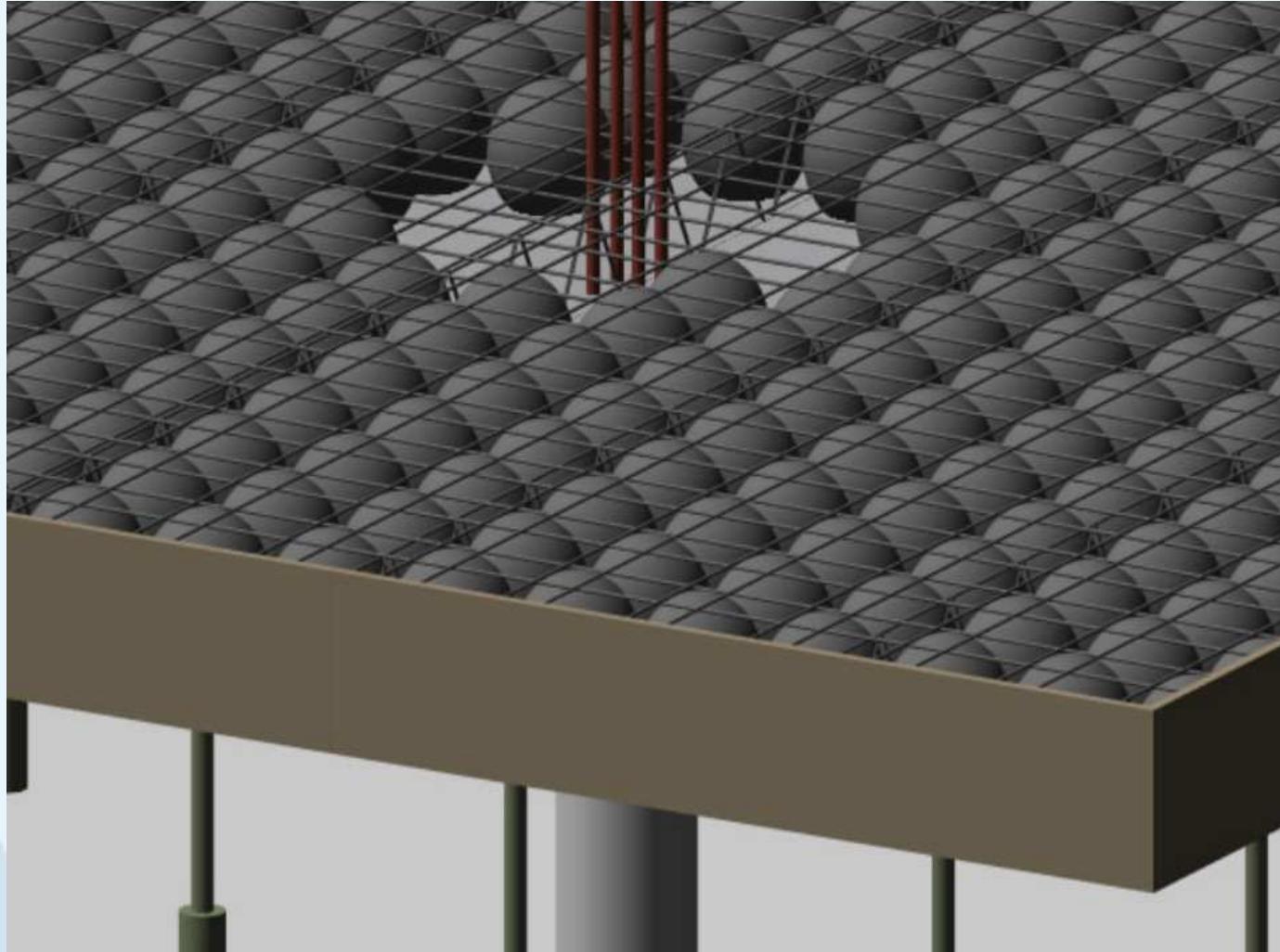
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# Voided Slab w/ precast stay in place form



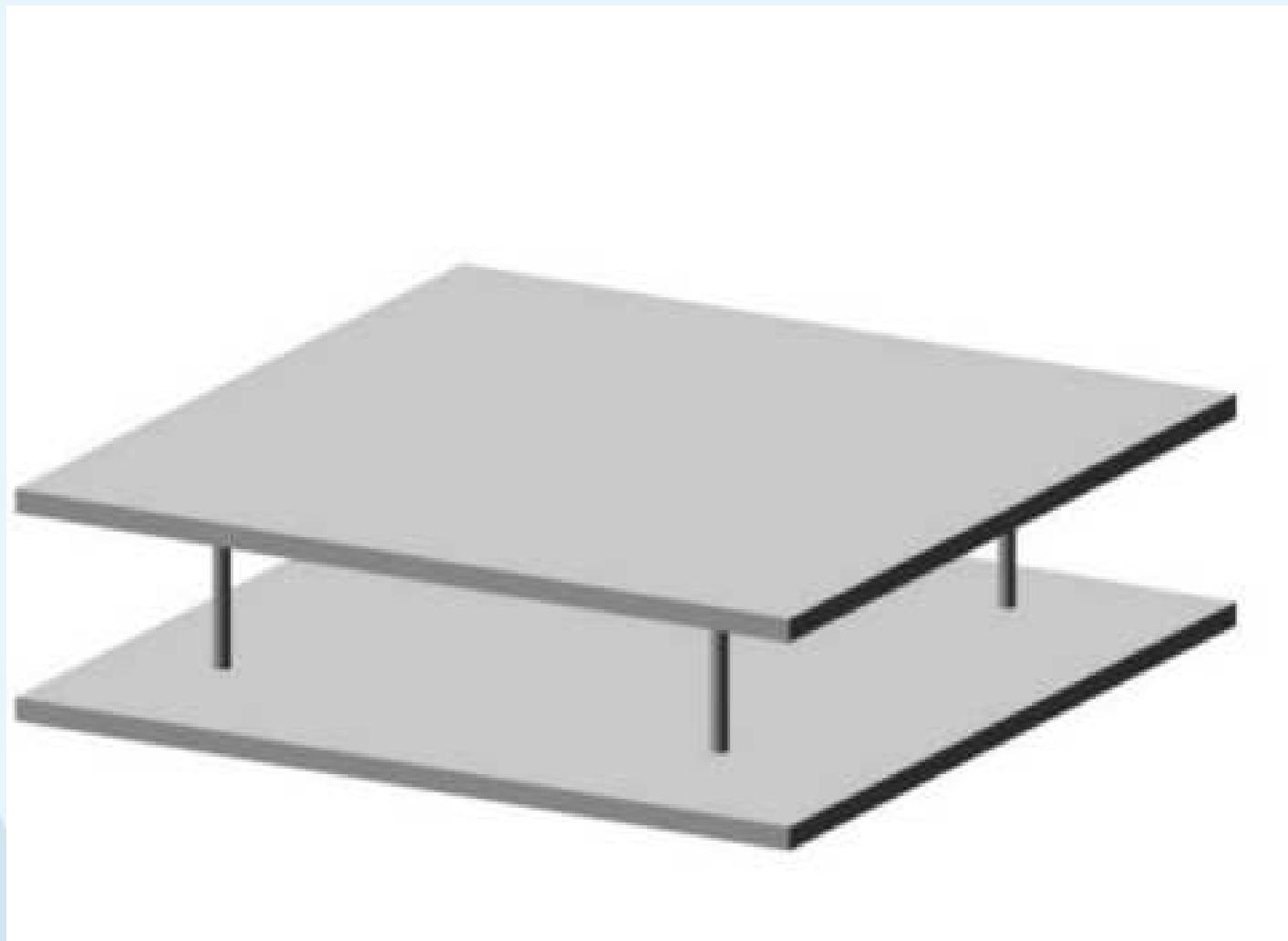
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# Voided Slab w/ precast stay in place form



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# Voided Slab w/ precast stay in place form



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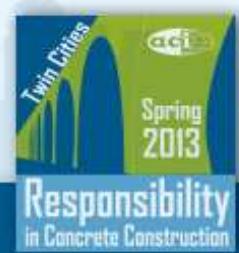
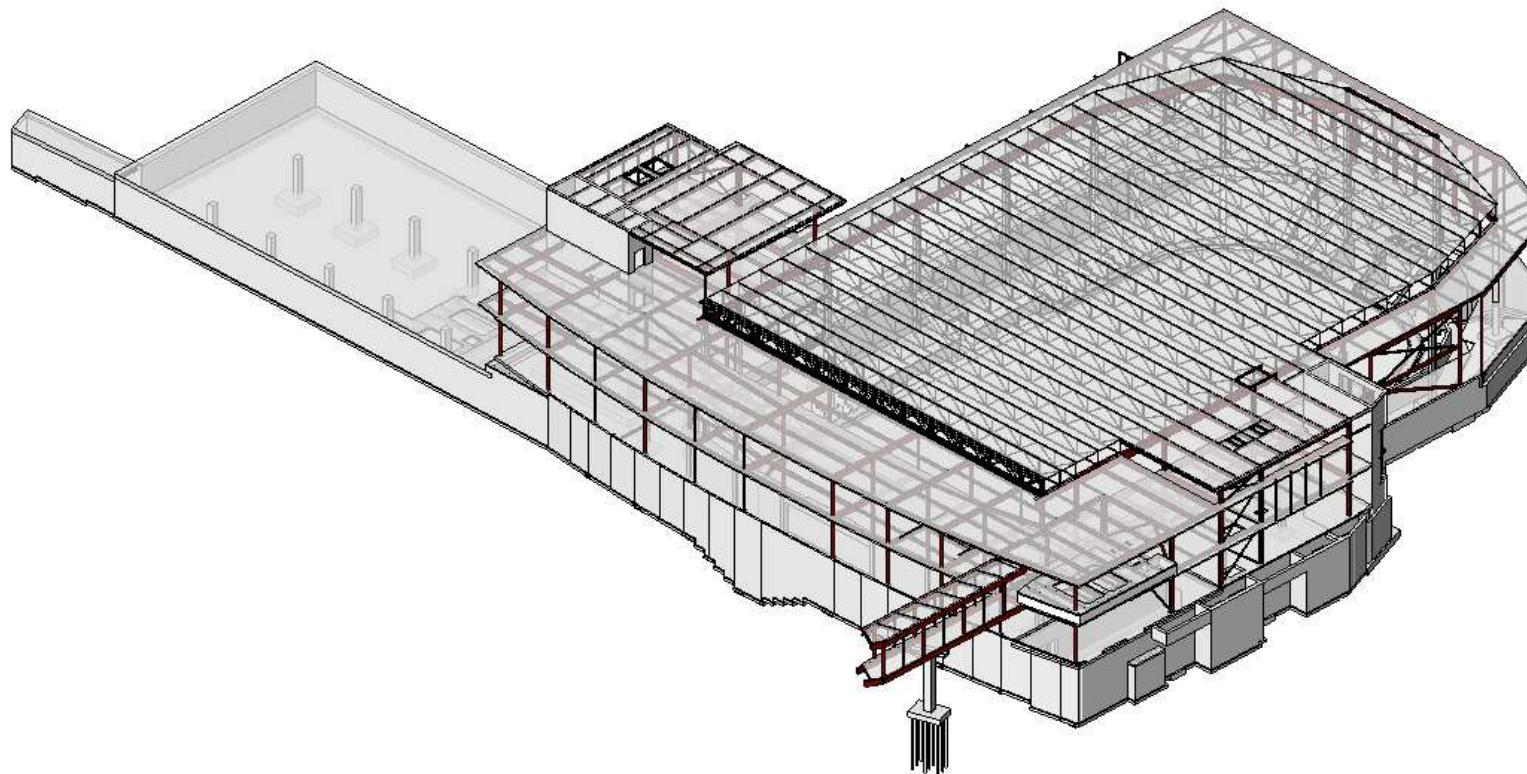
# UW LaBahn Arena

## Madison WI



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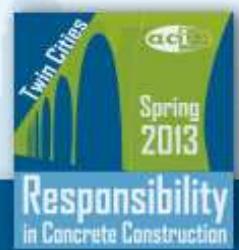
# BIM Structural Model - LaBahn Arena



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# LaBahn Arena

- 21 inch Voided slab
  - Plaza Slab
    - Supports 3.5 feet of soil
    - Designed for fire truck loading
- 11,000 Square Feet
- Serves as roof of Badger hockey locker rooms





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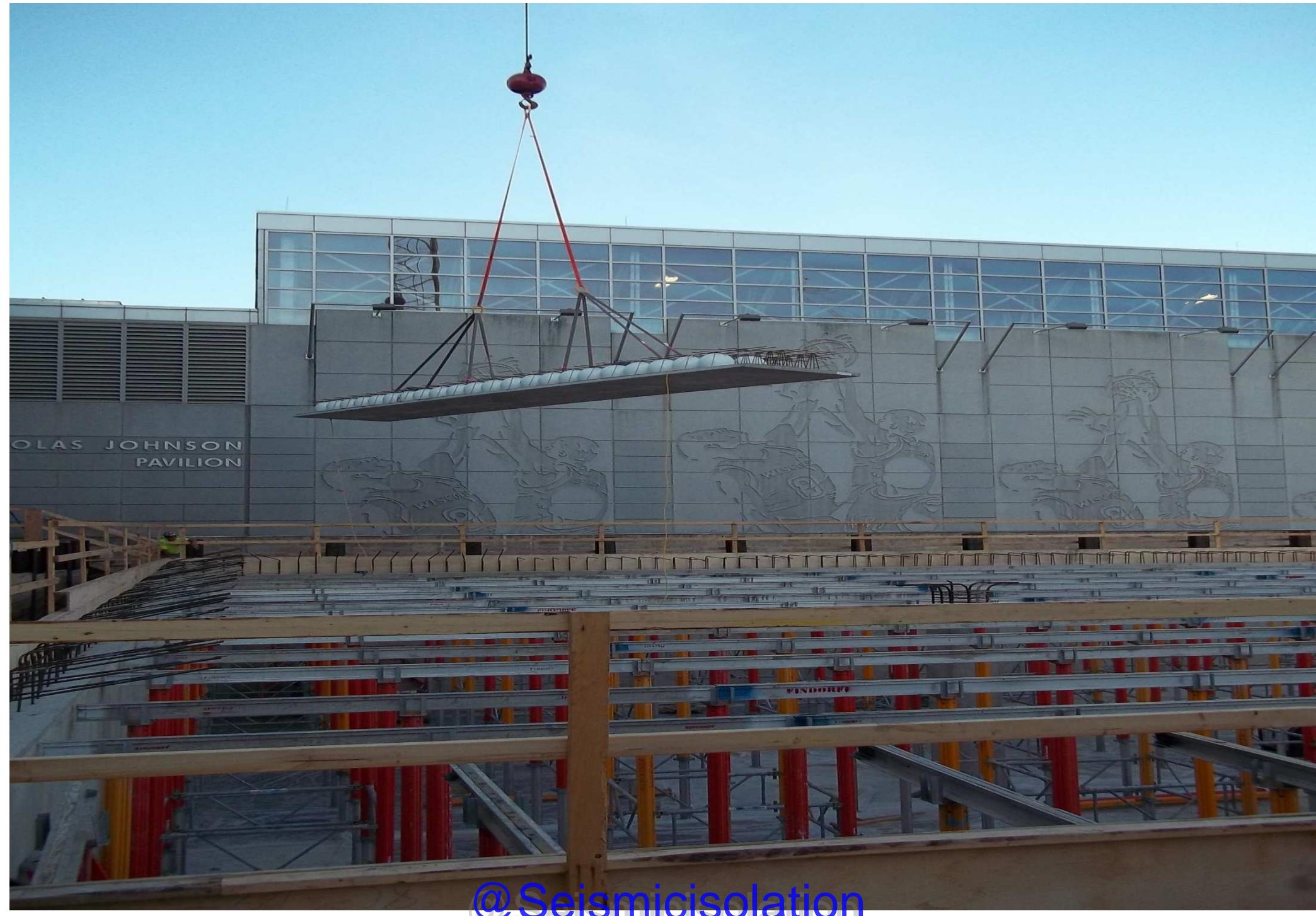
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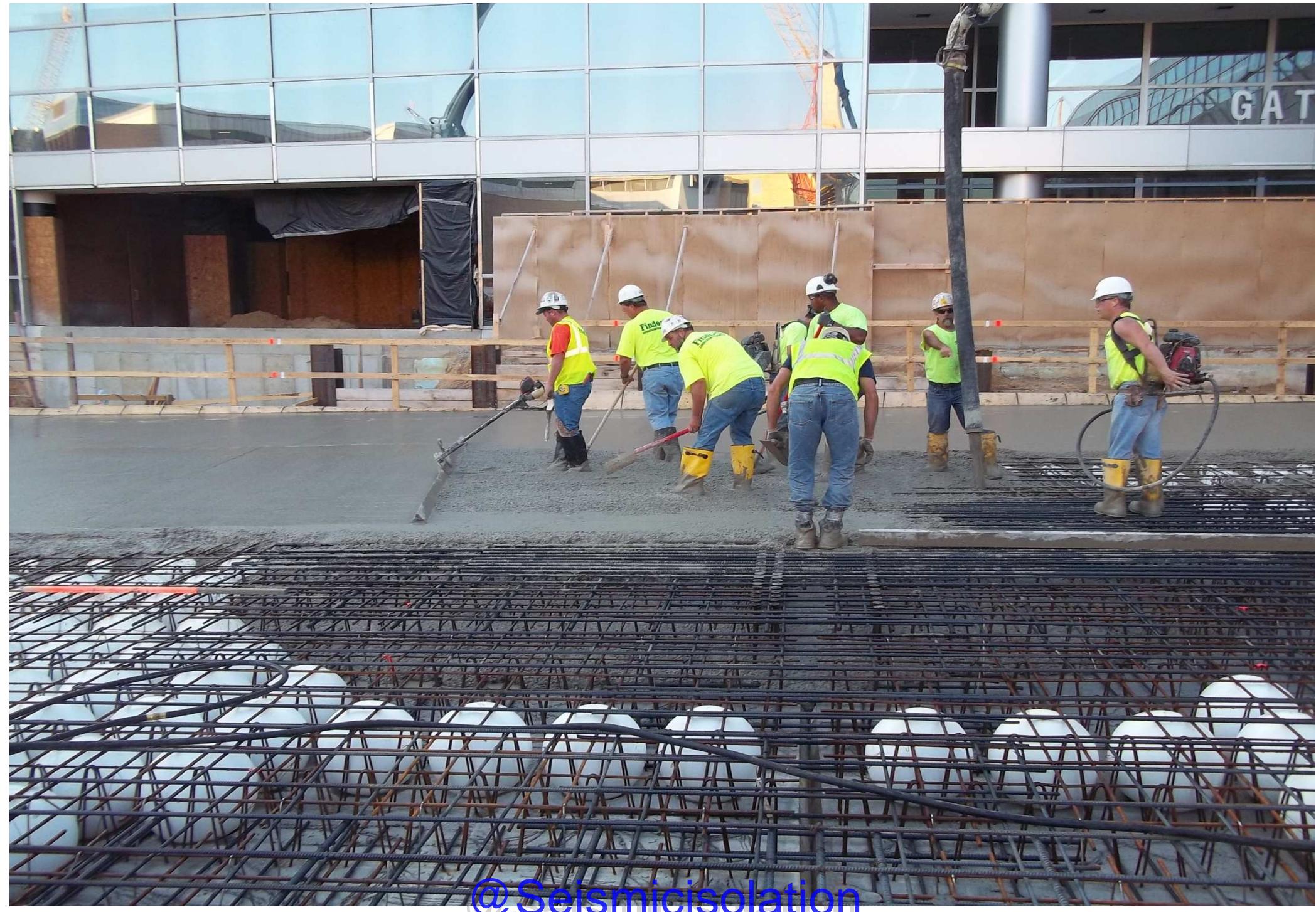


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GATE B

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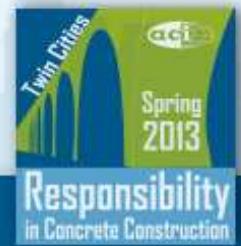
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# Why Voided Slab for UW LaBahn?

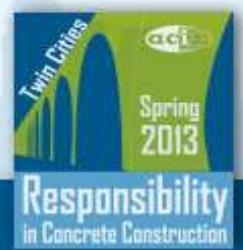
- Saved \$2/SF
- Saved 174 CY of concrete
- Saved 3 days off of schedule
- Saved on shoring cost
- Saved structural depth



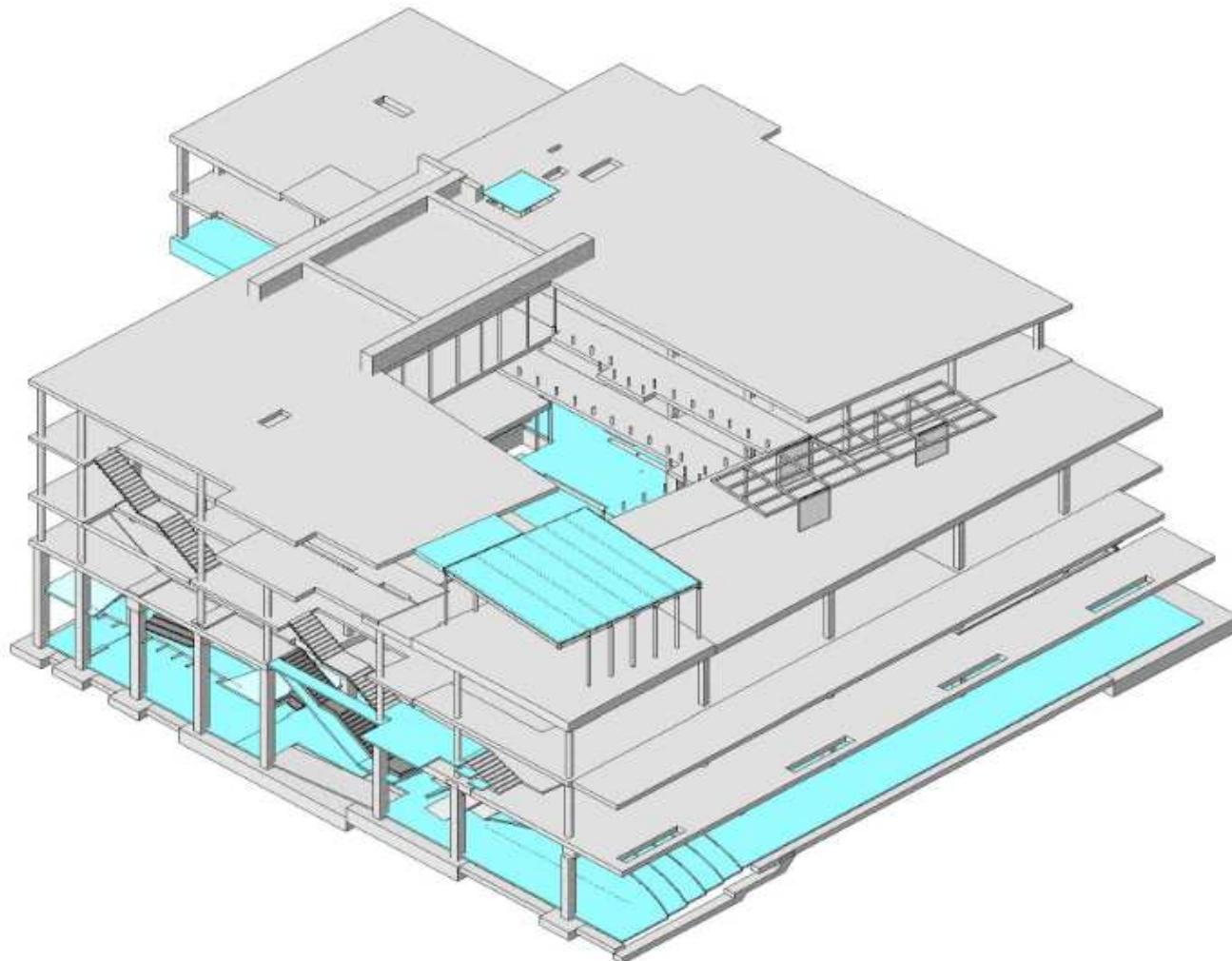
# Harvey Mudd College Teaching and Learning Building Claremont, CA

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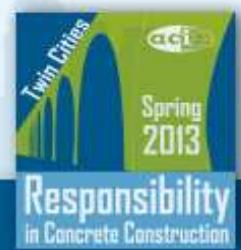
# BIM Structural Model - Harvey Mudd College



(courtesy of KPFF)

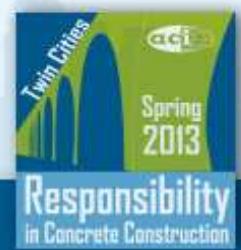
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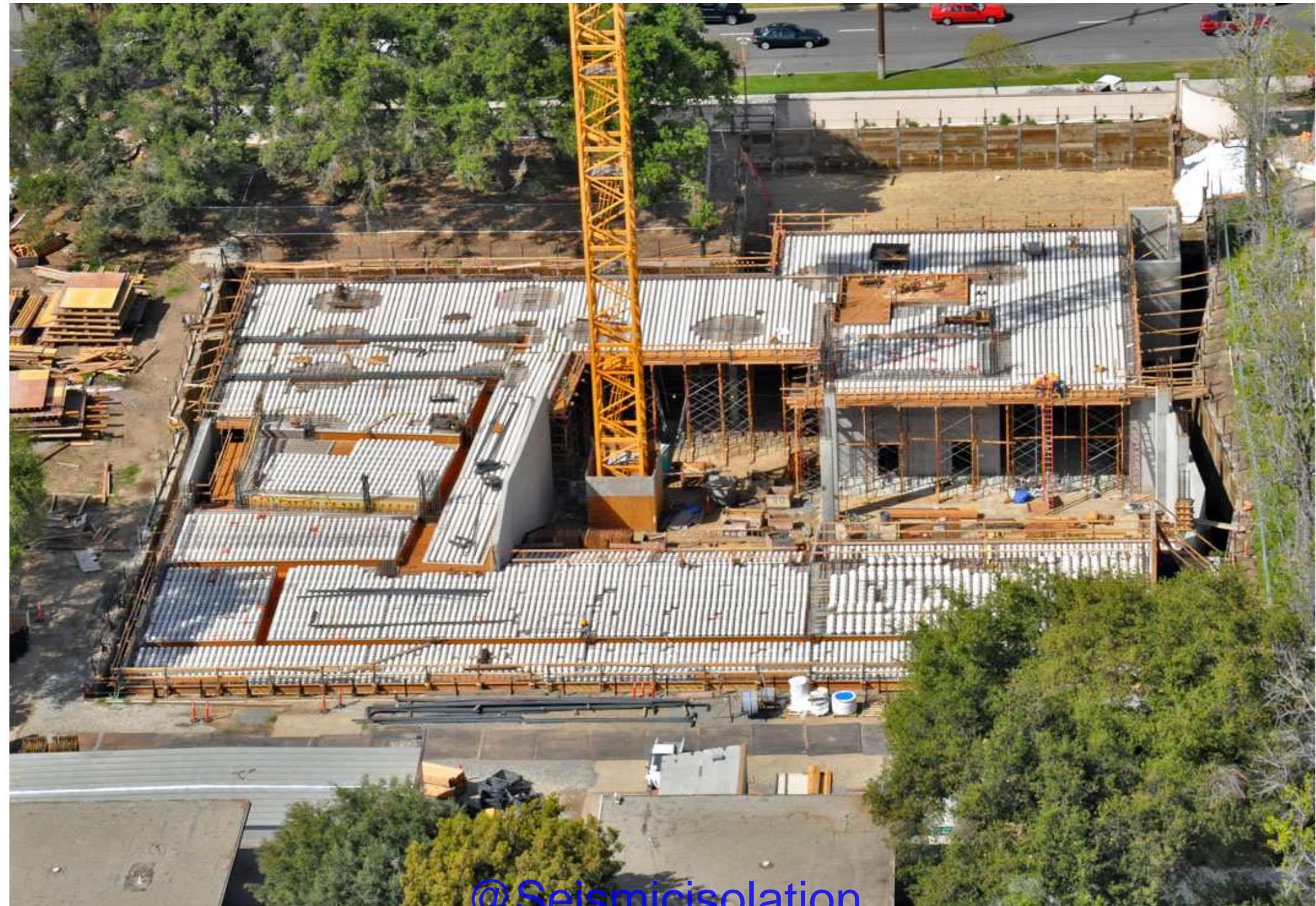
169



# Harvey Mudd - TLC

- 4 –Story Education Building
- 80,000 square feet of Voided slab
- 9, 11, 13.5, 17.5 and 20 inch slab thicknesses used
- Located in high seismic zone





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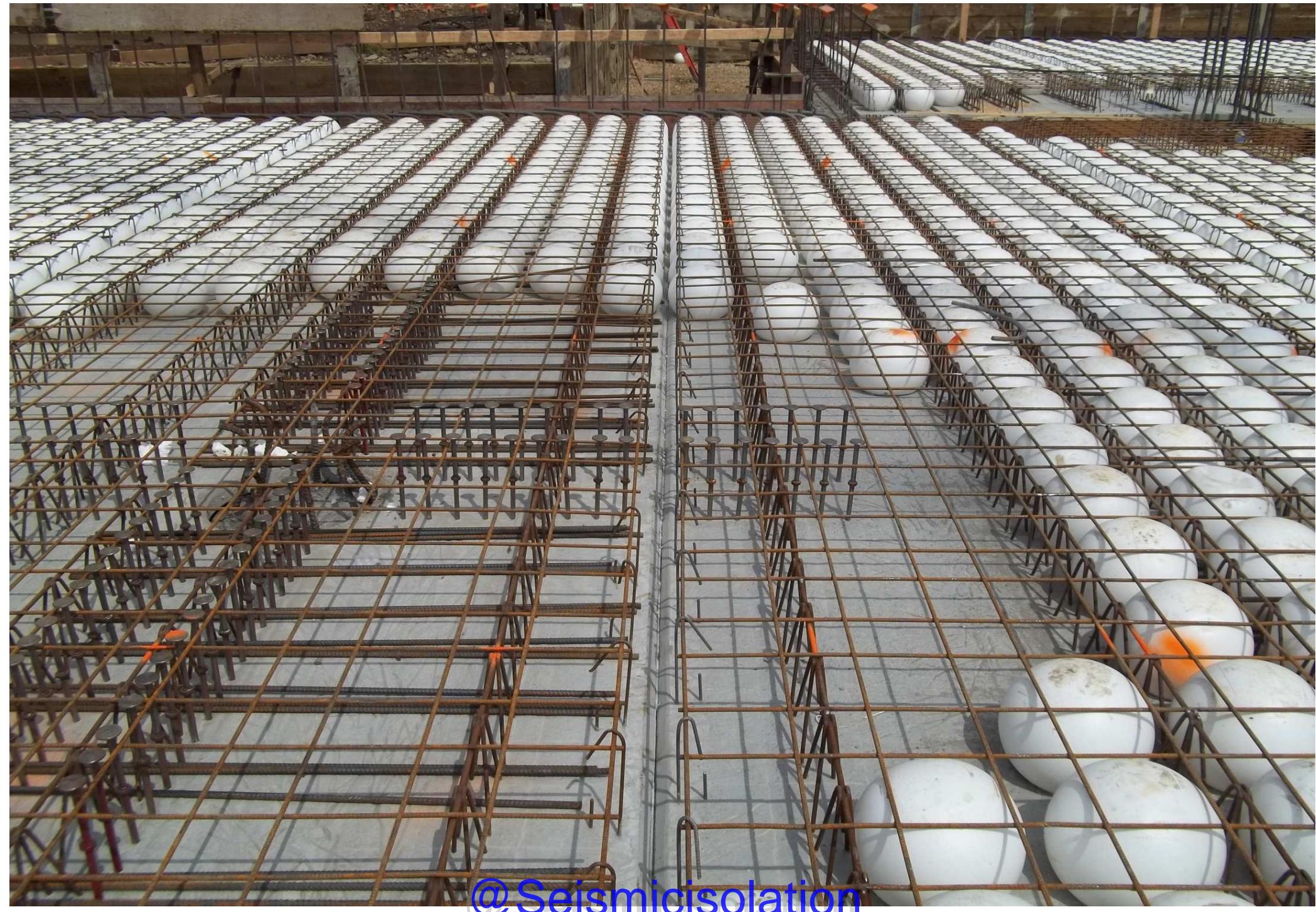
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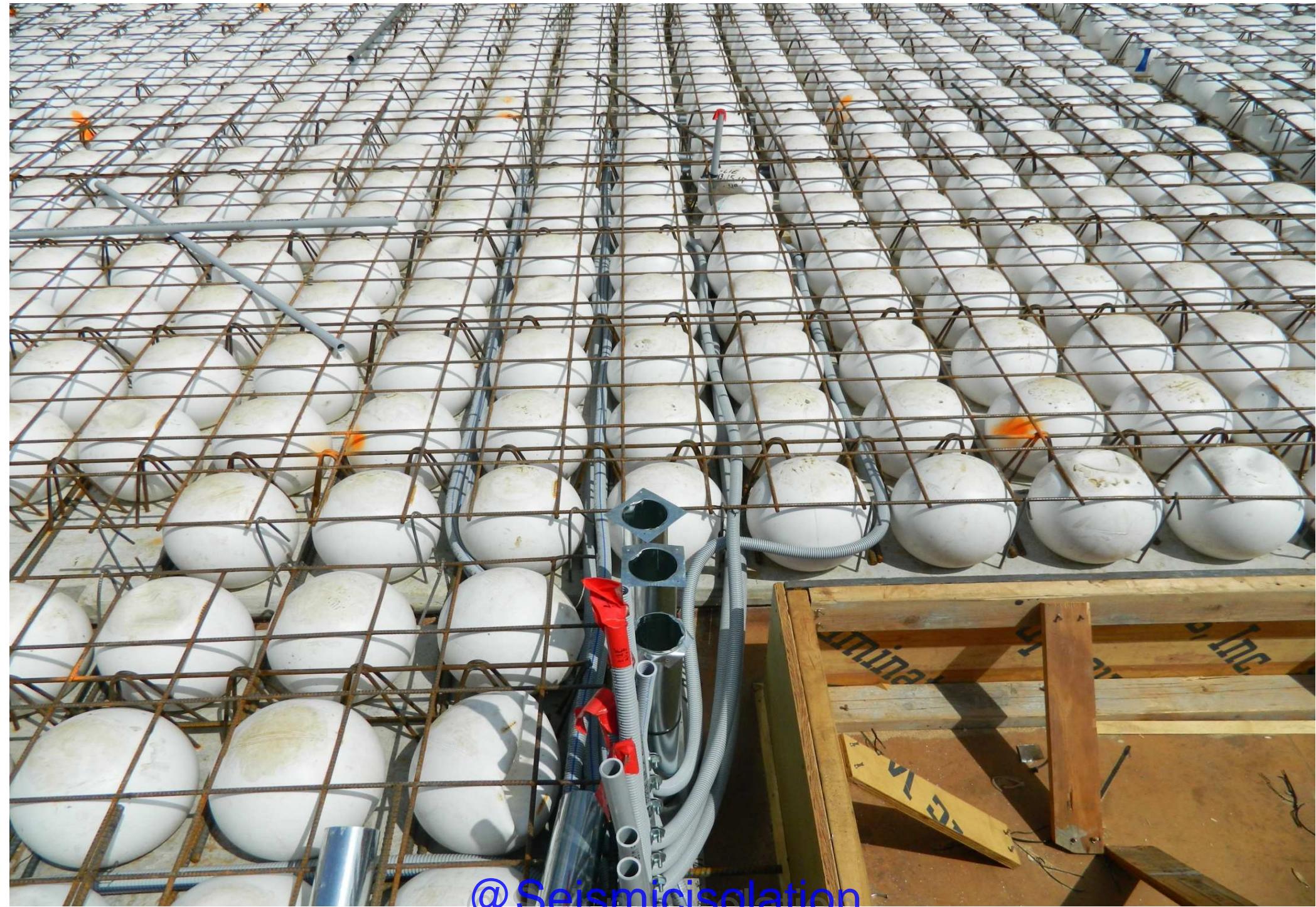
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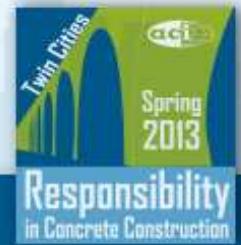
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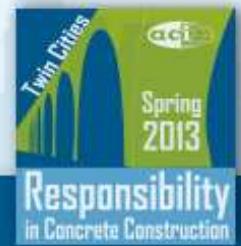
# Why Voided slab for Harvey Mudd?

- Highly Visible Exposed Concrete Ceilings
- MEP Coordination/Pre-Installation
- Seismic Mass Reduced
- Long-term Deflection Considerations
- Saved 750 CY of Concrete



# **Watertown Regional Medical Center East Addition**

**Watertown, WI**



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# Watertown Regional Medical Center

- Emergency Dept & Women's Health Addn
- 2-Story & 30,000 square feet
- Existing construction systems:
  - Concrete waffle slabs
  - Concrete pan joist
  - Precast concrete and steel beams
- System selection for healthcare facilities
  - Grid layout
  - Story height

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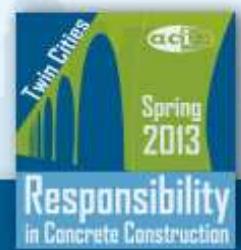
# Why Voided slab for WRMC?

- Flexible and larger column grid
- Thin structural system leads to higher headroom for MEP/medical systems.
- Material savings
- Increased construction speed by minimizing on-site labor

# Summary

- Form work is virtually eliminated. Fewer lines of shoring.
- The finished underside of the panel can be left exposed and untreated.
- Overall building height is minimized reducing building façade.

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# Summary Cont.

- Reduced site labor, increased safety.
- Less onsite concrete, quicker pour time.
- Core holes are faster to drill.
- Building is more efficient, reduced carbon footprint, has potential for LEED credits.

