Forming Concrete Elevated Structures

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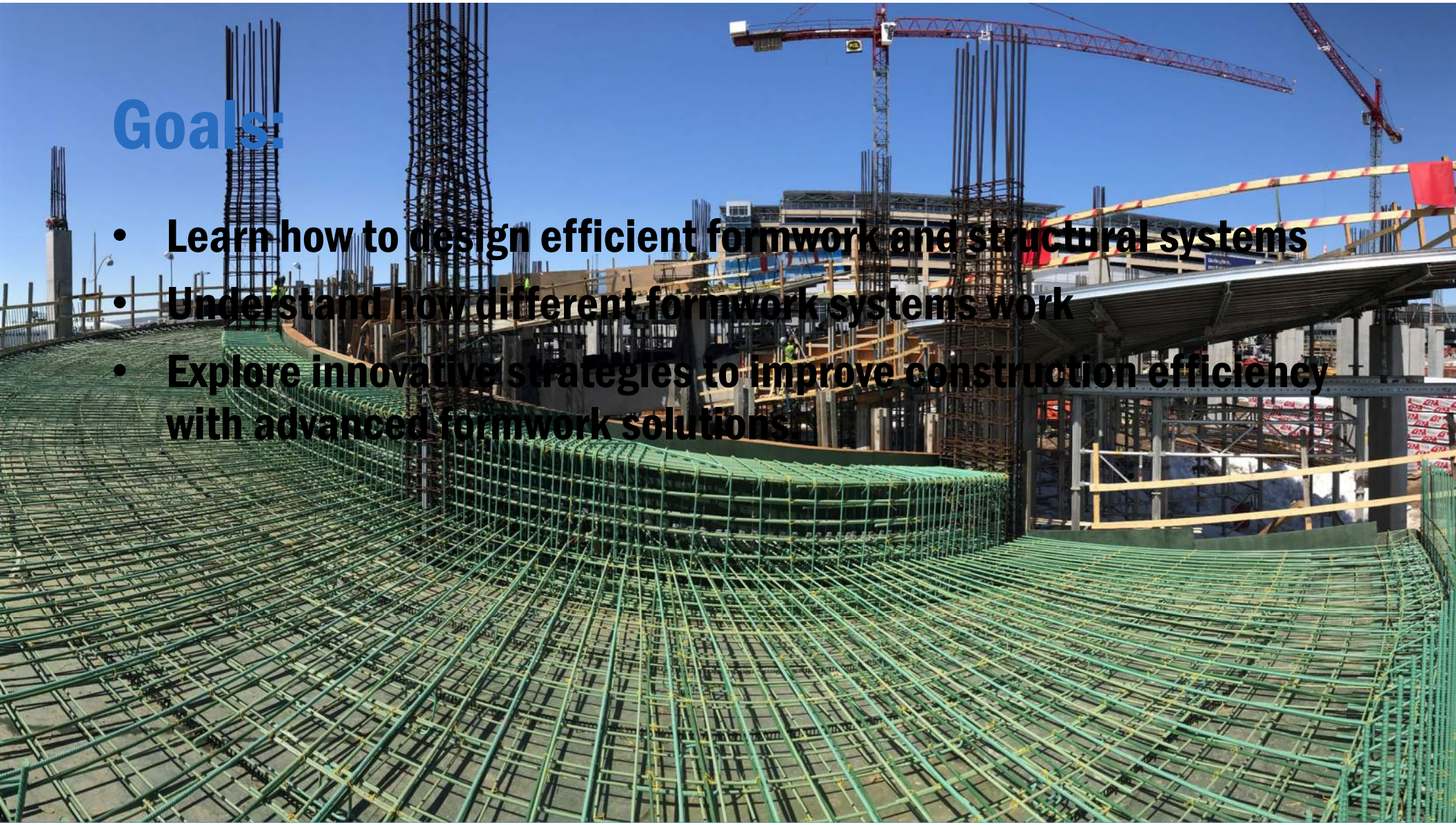


Goals:

- Learn how to design efficient formwork and structural systems
- Understand how different formwork systems work
- Explore innovative strategies to improve construction efficiency with advanced formwork solutions.

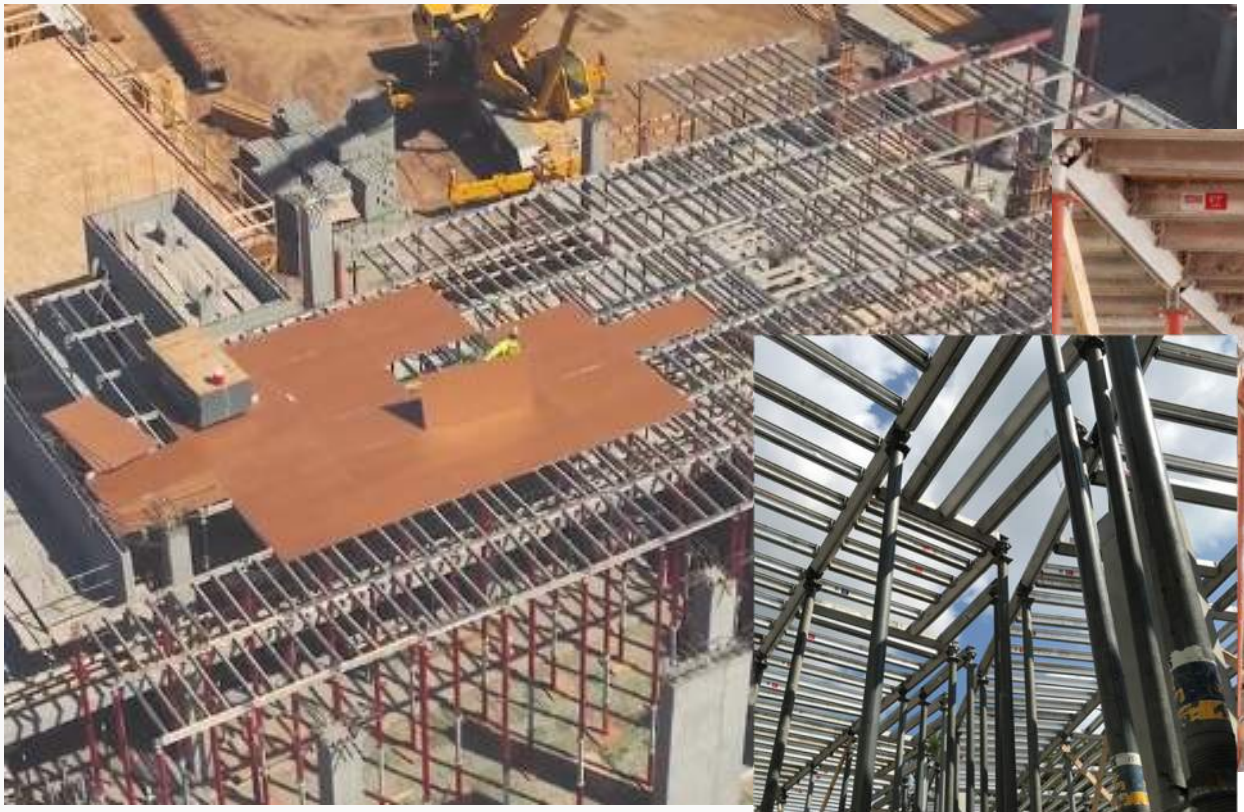
Common Forming Systems

- **Stick Framing**
- Modular Framing
- Flying Tables
- Perimeter Barrier Systems
- Slab & Joist Pan Forms
- PG Steel Beam Forms
- Tall Shoring Systems

- Hand-set piece by piece
- Least Efficient
- Flexable to any condition

Common Forming Systems

- Stick Framing
- **Modular Framing**
- Flying Tables
- Perimeter Barrier Systems
- Slab & Joist Pan Forms
- PG Steel Beam Forms
- Tall Shoring Systems



- Hand-set piece by piece
- Moderately Efficient
- Flexable to most conditions

Common Forming Systems

- Stick Framing
- Modular Framing
- **Flying Tables**
- Perimeter Barrier Systems
- Slab & Joist Pan Forms
- PG Steel Beam Forms
- Tall Shoring Systems

- Prefabricated into Panels
- Very Efficient
- Requires Repeatability

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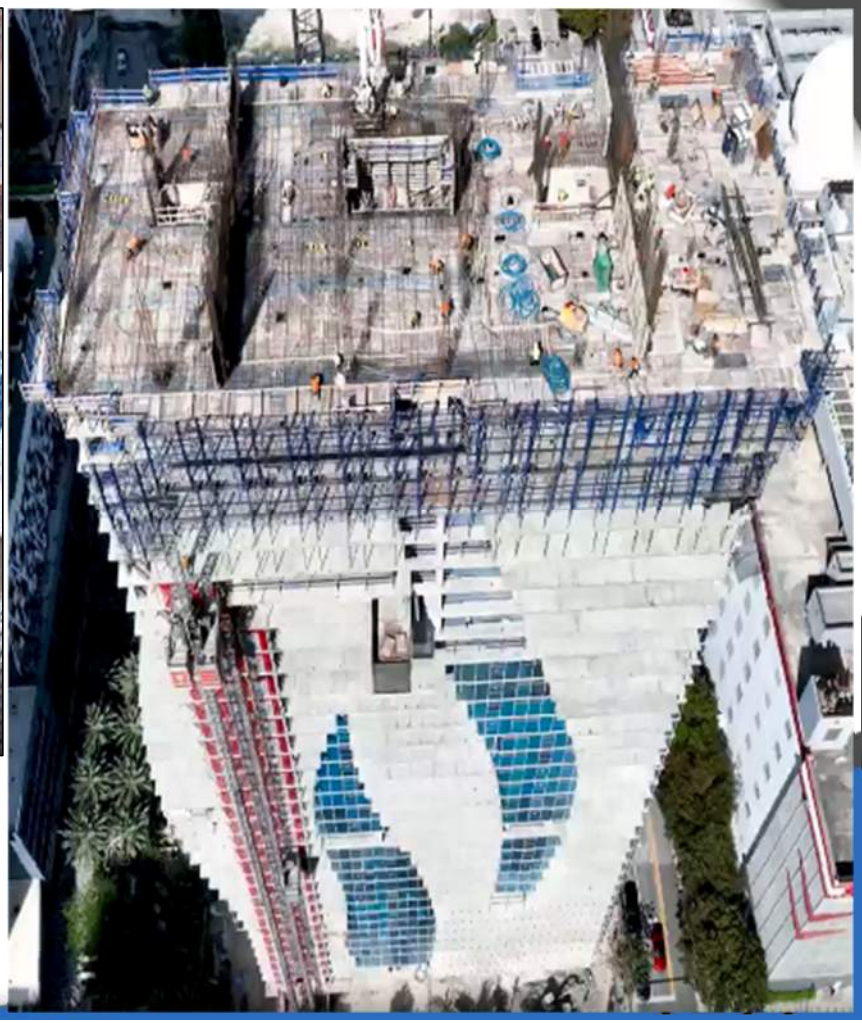
Common Forming Systems

- Stick Framing
- Modular Framing
- Flying Tables
- **Perimeter Barrier Systems**
- Slab & Joist Pan Forms
- PG Steel Beam Forms
- Tall Shoring Systems



- Provides Edge Protection for Modular Framing System
- Increases Efficiency
- Requires Repeatability

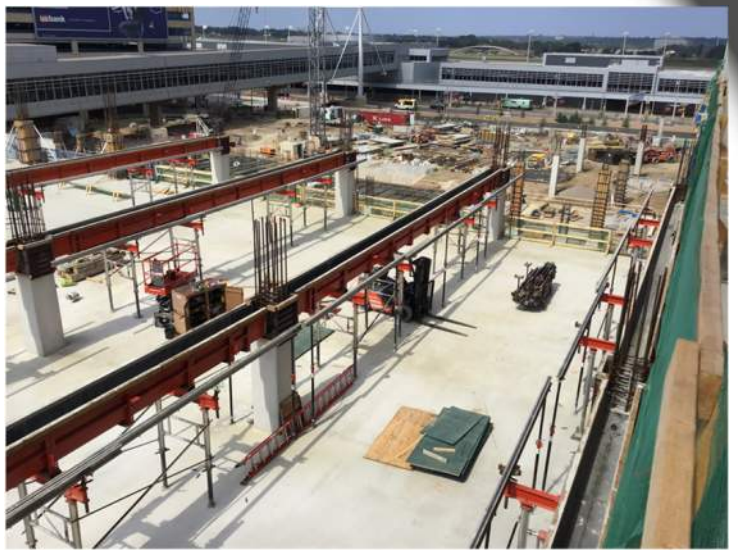
Common Forming Systems

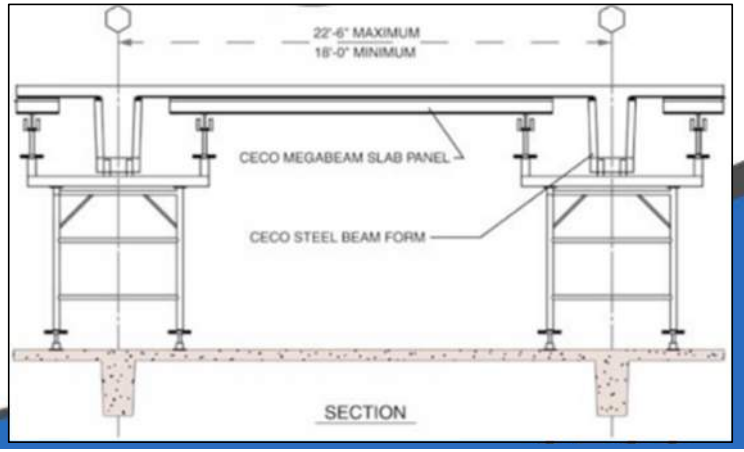
- Stick Framing
- Modular Framing
- Flying Tables
- Perimeter Barrier Systems
- **Slab & Joist Pan Forms**
- PG Steel Beam Forms
- Tall Shoring Systems

- Used with other framing systems
- Efficient method of creating beam-slab system
- Set Standard Sizes

Common Forming Systems

- Stick Framing
- Modular Framing
- Flying Tables
- Perimeter Barrier Systems
- Slab & Joist Pan Forms
- **PG Steel Beam Forms**
- Tall Shoring Systems

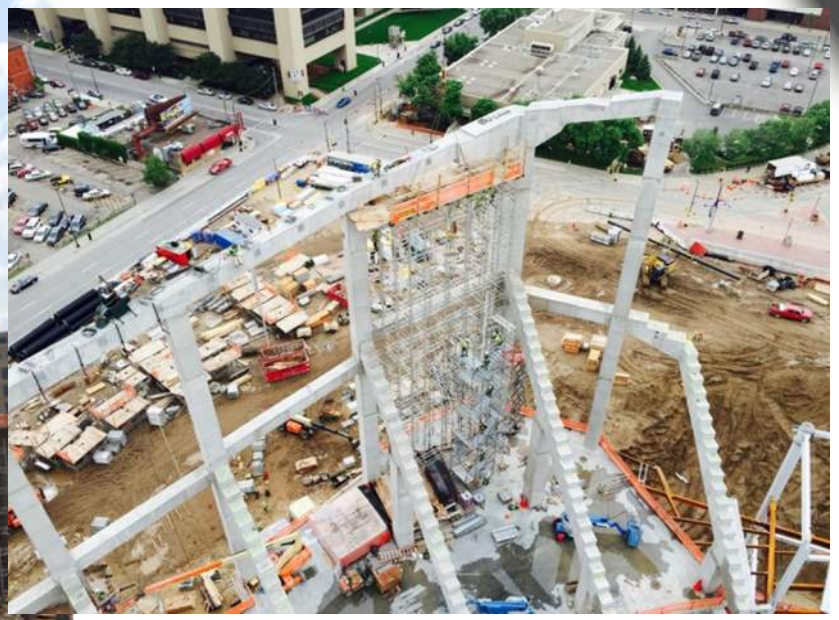




- Prefabricated into Panels and Beam Forms
- Very Efficient
- Requires Repeatability

Common Forming Systems

- Stick Framing
- Modular Framing
- Flying Tables
- Perimeter Barrier Systems
- Slab & Joist Pan Forms
- PG Steel Beam Forms
- **Tall Shoring Systems**



- Prefabricated into Panels
- Very Efficient
- Somewhat Flexible (Tetris)

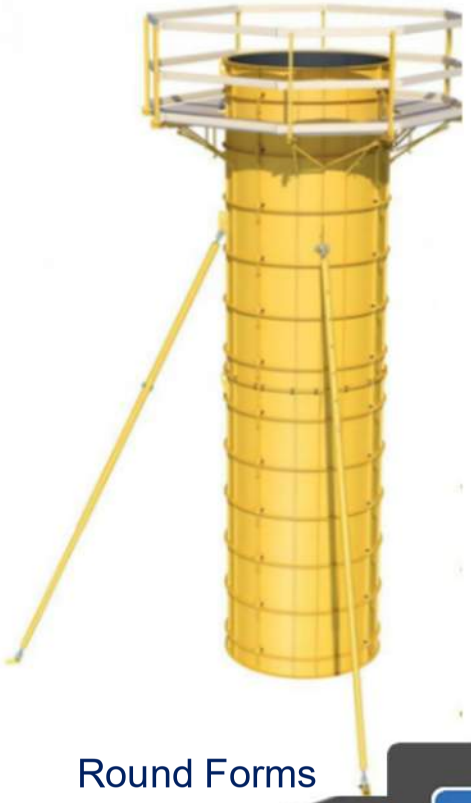
Common Forming Systems

Column Forms

Wall Forms

Lumber & Clamps

Prefabricated Panels



Round Forms

Common Forming Systems

Column Forms

Wall Forms

Handset Lumber

Prefabricated Panels

Self Climbing Cores

Common Forming Systems

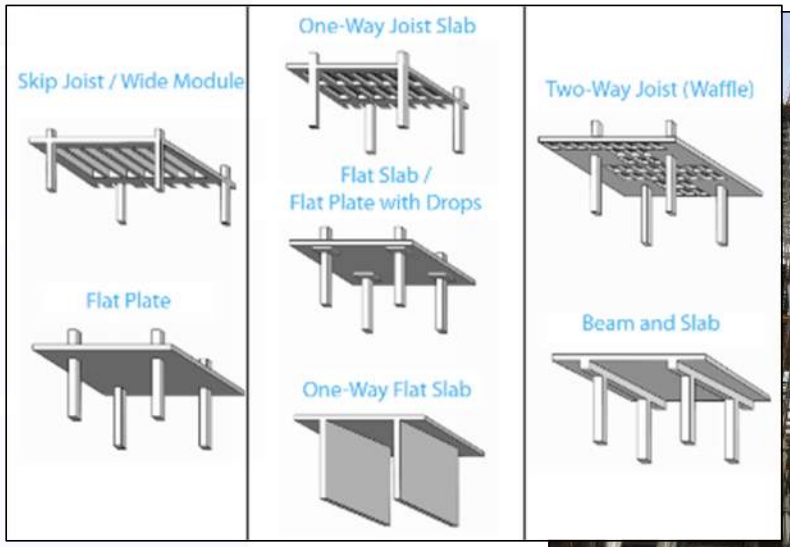
- Column Forms
- Wall Forms

One-sided Wall Forms

Formwork System Selection

Formwork System Driven by Building Design

- Beam-Slab Parking Garage & One & Two-way Joist Floors have set systems
- Open plans with consistency from level to level = Flying Tables
- Odd size and shape, low uses, lend to stick framing or modular framing
- Very tall story heights require tables for safety during recovery



Formwork System Selection

Construction Schedule

- Faster Schedules requires more equipment. Doesn't always mean more efficient
- Schedule drives the number of uses on equipment.
- Labor Shortages may drive decisions as well.

Formwork System Selection

Equipment Cost vs. Labor Cost

- Labor savings must pay for “Fancy” Equipment
- Equipment selection dependent on number of uses and speed of reuse
- Company owned equipment vs. Rental

Formwork System Selection

Site Factors

- Crane Capacity & Reach
- Site Obstructions
  - Main Streets
  - Train Tracks
- Make-up /Tear-down Area

Formwork System Selection

Repeatability

- Consistency in building design allows for consistency of formwork
- Panelized systems require repeatability
- Modifications require a modifiable system

Structure Cost VS. Labor Costs

Fixed Costs:
Concrete
Rebar
Finishes
(Materials and Equipment)

Variable Cost:
Labor

The structure costs far less than the labor required to build it

Structure Design Load Considerations

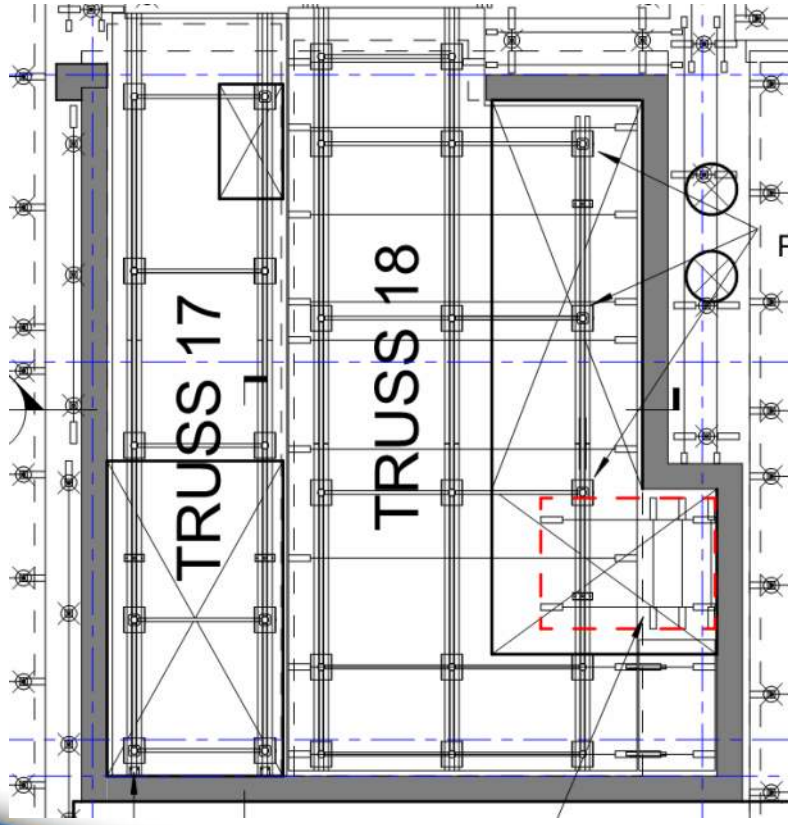
- **Design Live loads and Superimposed Dead Loads**
- **Slab on grade design**

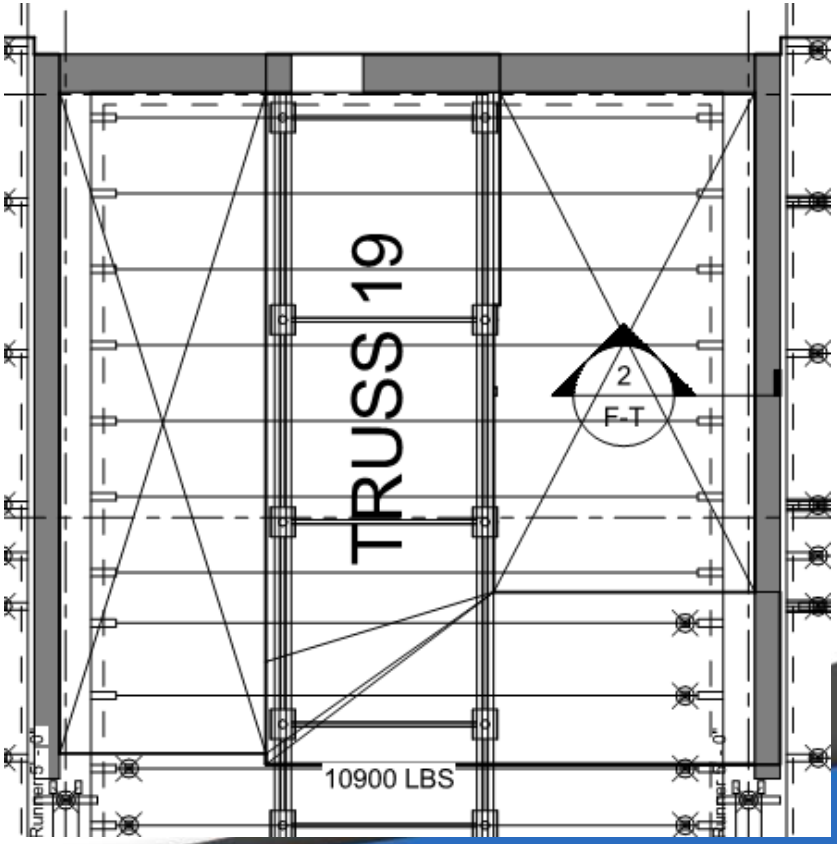
2.3. RESIDENTIAL FLOOR LOADS	
LIVE LOAD (LL)	40 PSF*
PRIVATE BALCONIES (LL)	60 PSF*
DEAD LOAD (SUPERIMPOSED)	20 PSF (INCLUDES NLB PARTITIONS)
2.5. STAIRS, CORRIDORS & LOBBIES	
LIVE LOAD (LL)	100 PSF
CORRIDORS UNO (LL)	100 PSF
CORRIDORS SERVING RESIDENTIAL ONLY (LL)	40 PSF
CORRIDORS SERVING AMENITY AREAS	100 PSF
DEAD LOAD SUPERIMPOSED (SDL)	20 PSF
2.6. AMENITY FLOOR LOAD	
MECHANICAL ROOM (LL)	125 PSF
AMENITY INDOOR AND OUTDOOR AREAS (LL)	100 PSF*
AMENITY INDOOR AREA DEAD LOAD (SDL)	20 PSF
AMENITY OUTDOOR AREA DEAD LOAD (SDL)	90 PSF
POOL (LL)	100 PSF
POOL MAX 4' WATER (SDL)	250 PSF
2.8. PARKING LOADS	
LIVE LOADS (LL)	40 PSF*
BUMPER LOAD OVER 1 FT SQ @ 18" HIGH	6 (HORIZONTAL) KIPS
CONCENTRATED WHEEL LOAD	3 KIPS (OVER A 4 1/2"x4 1/2" AREA)
TRUCK DRIVE LANES AND TRASH AREAS	250 PSF

5" SLAB ON GRADE
W/ FIBERS, TYP UNO
TSE 836-2 3/4

Formwork System Selection

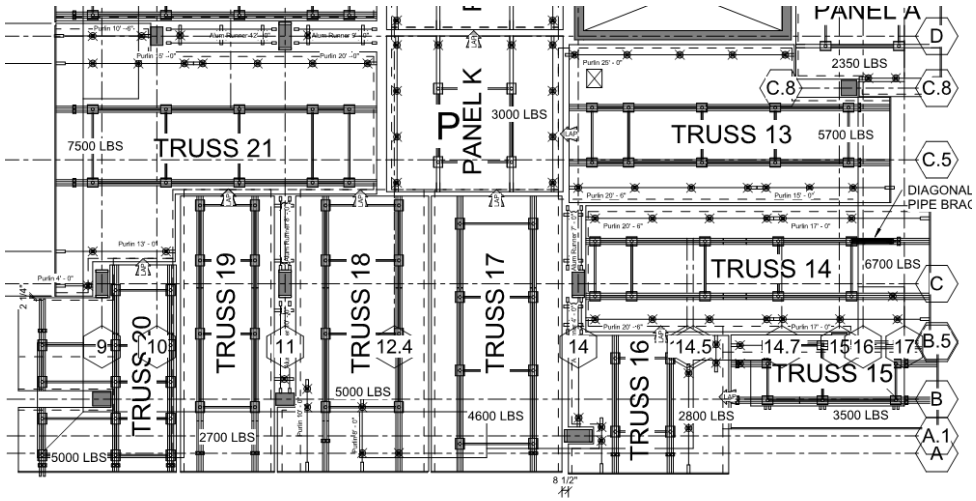
Core Wall Configurations

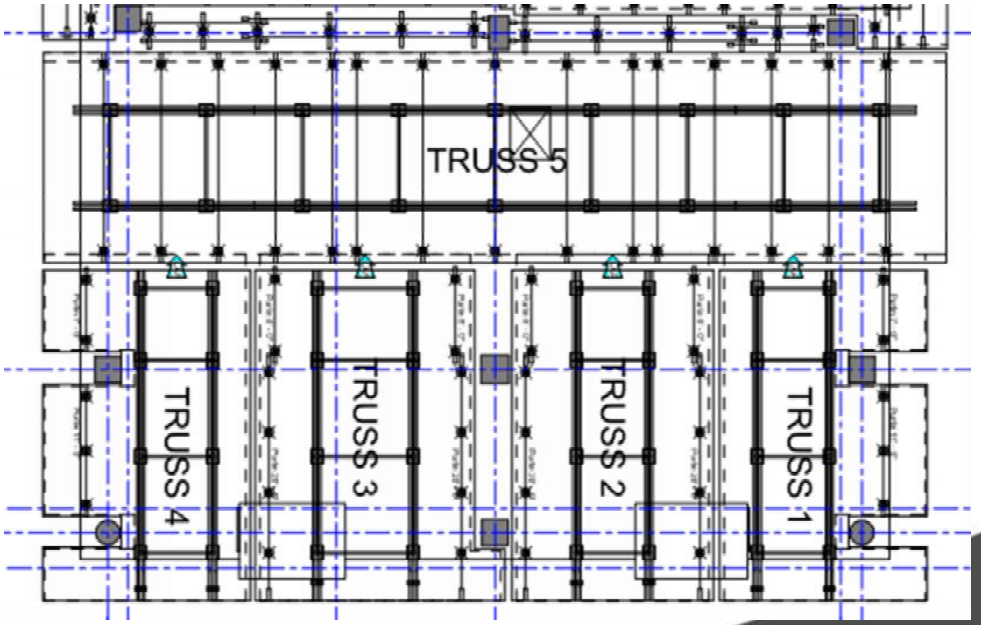




Formwork System Selection

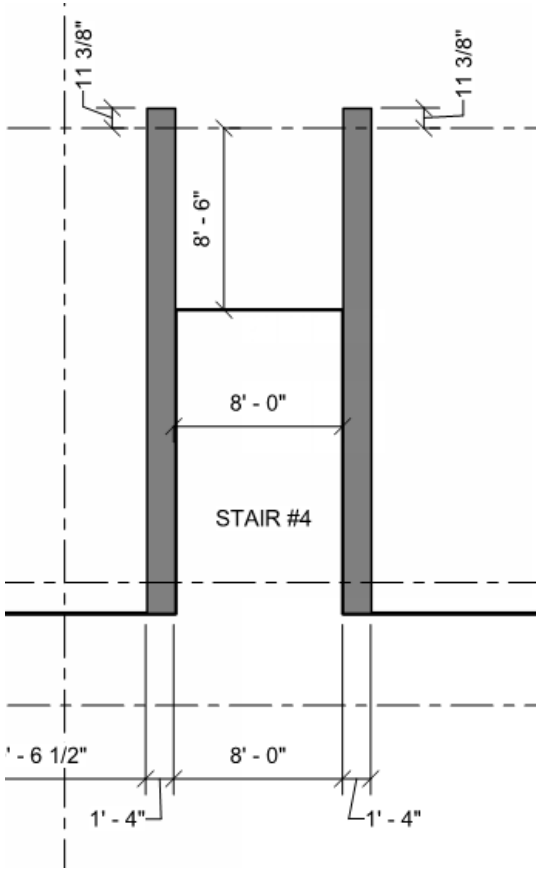
Column Layouts

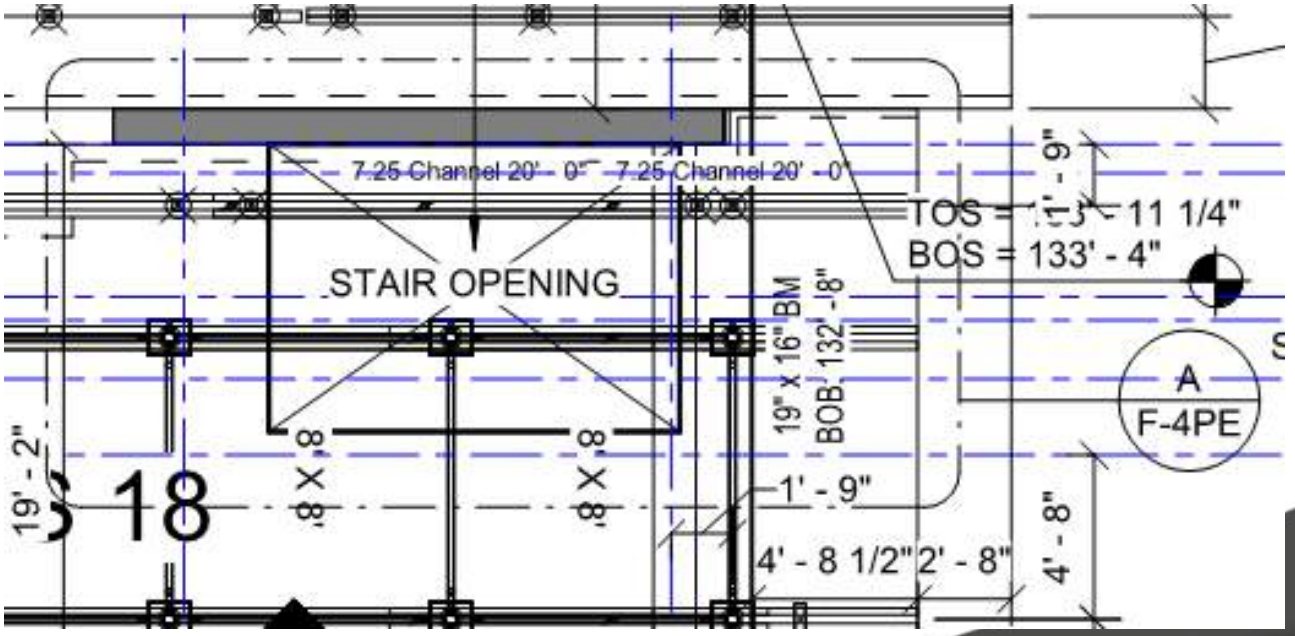




Formwork System Selection

Shear Walls





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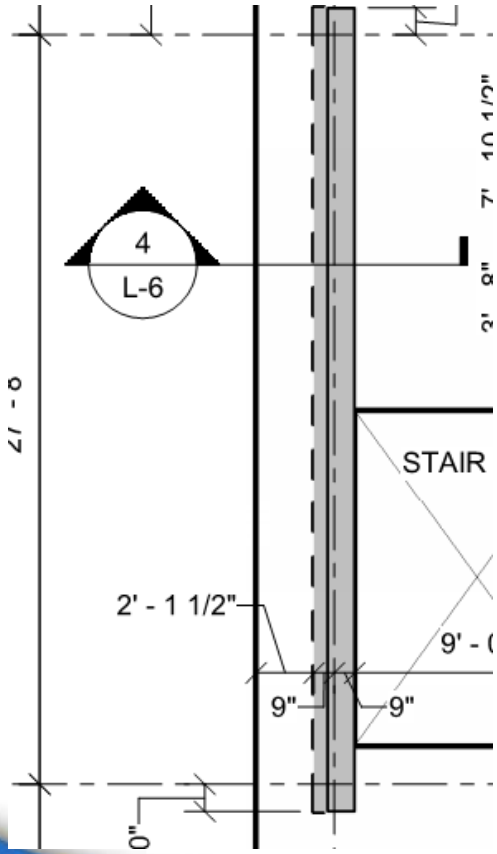
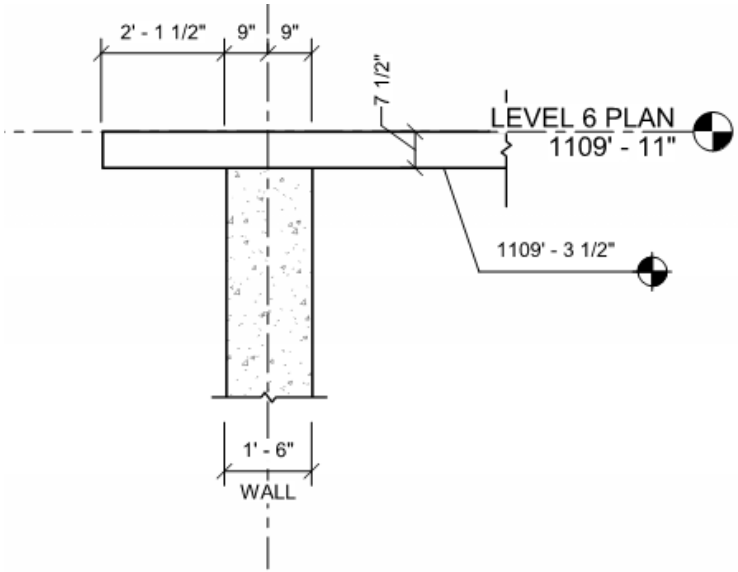
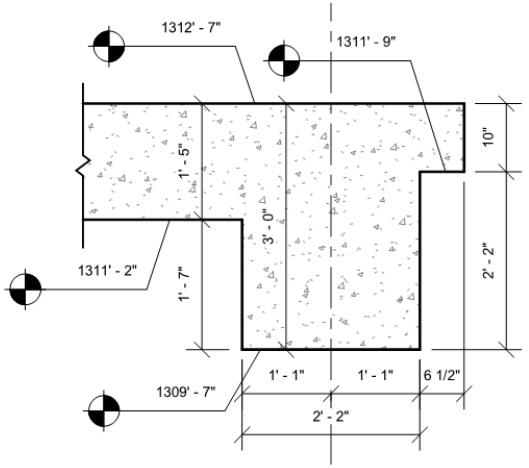
Formwork System Selection

Lip Slabs





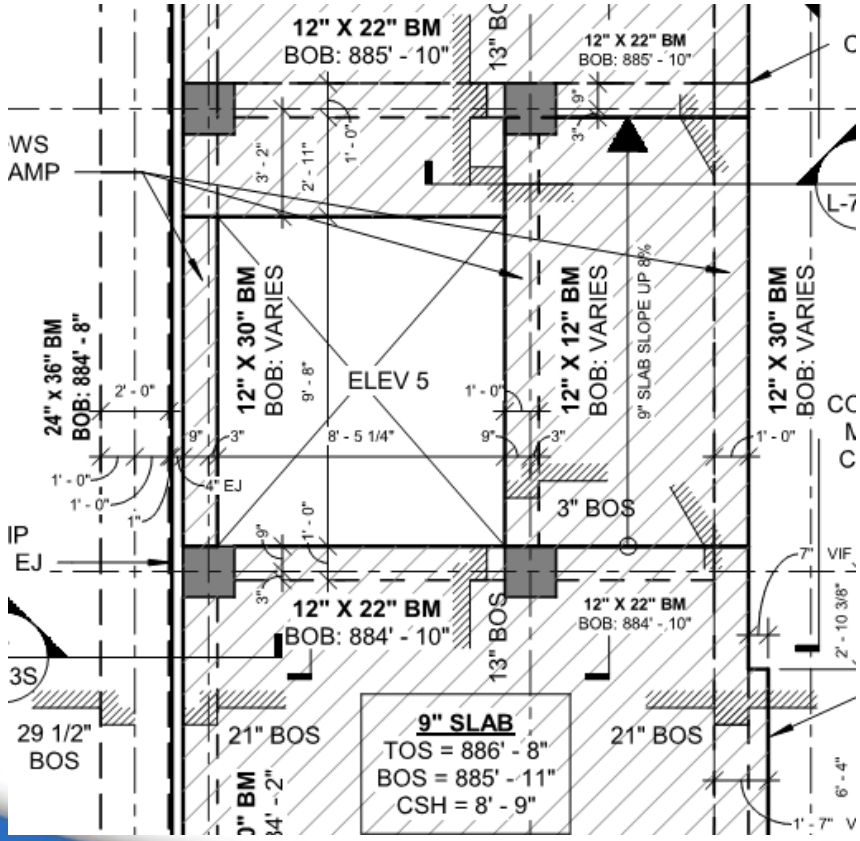
4 SECTION 4-LEVEL 6
3/8" = 1'-0"

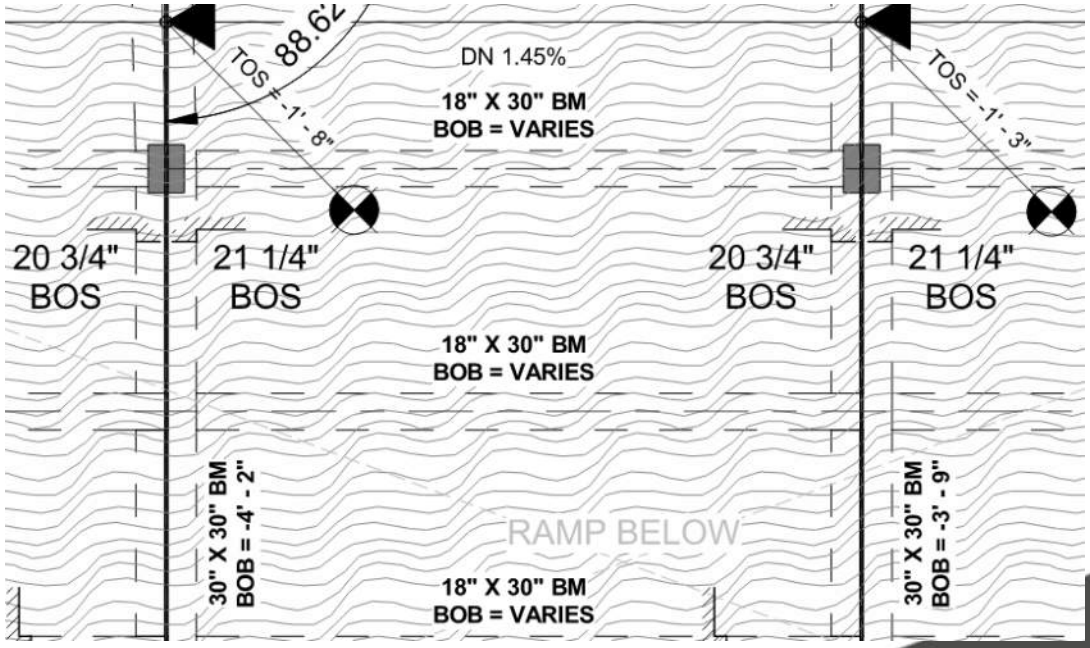


3 L42 SECTION 3
1/2" = 1'-0"

Formwork System Selection

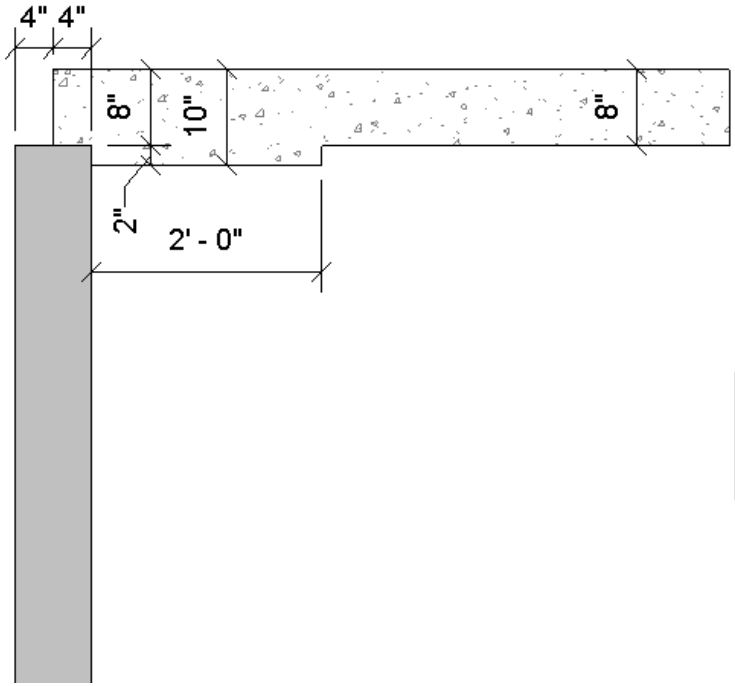
Uniformity (Depths, Widths, Thicknesses)



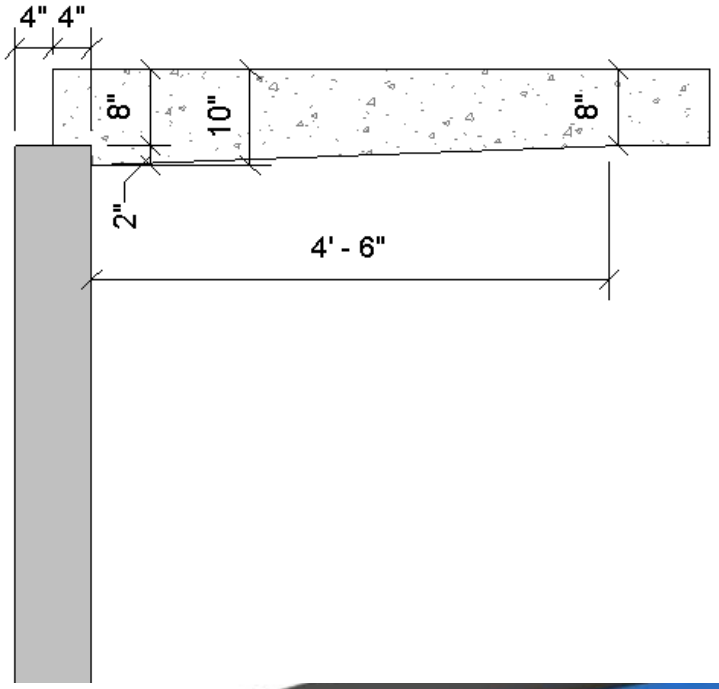


Formwork System Selection

Conditions at Walls

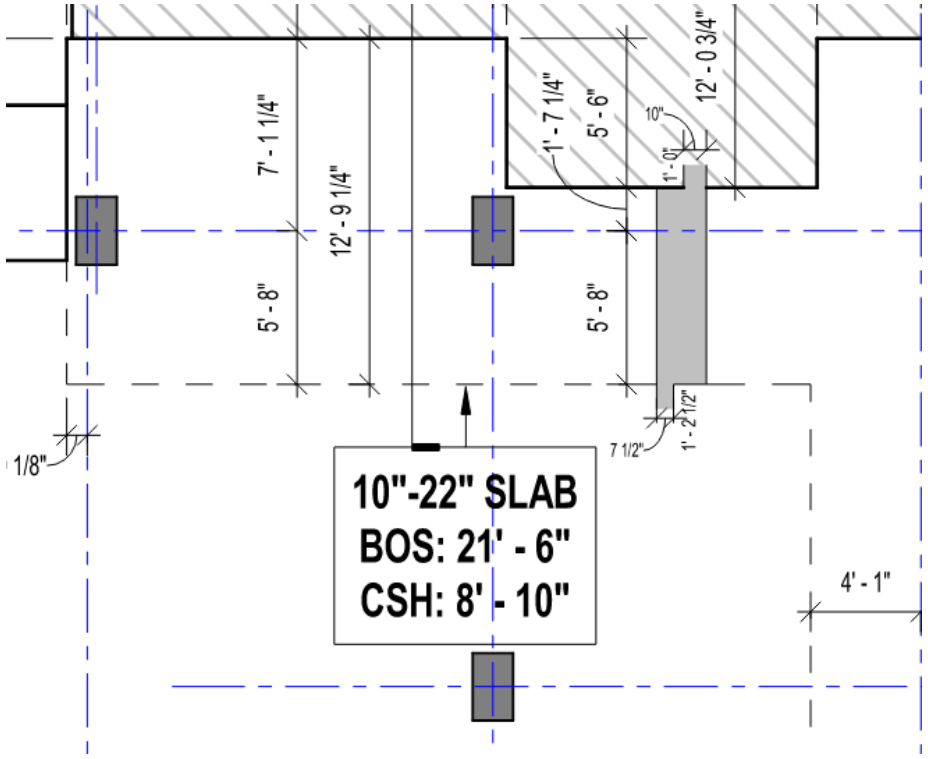


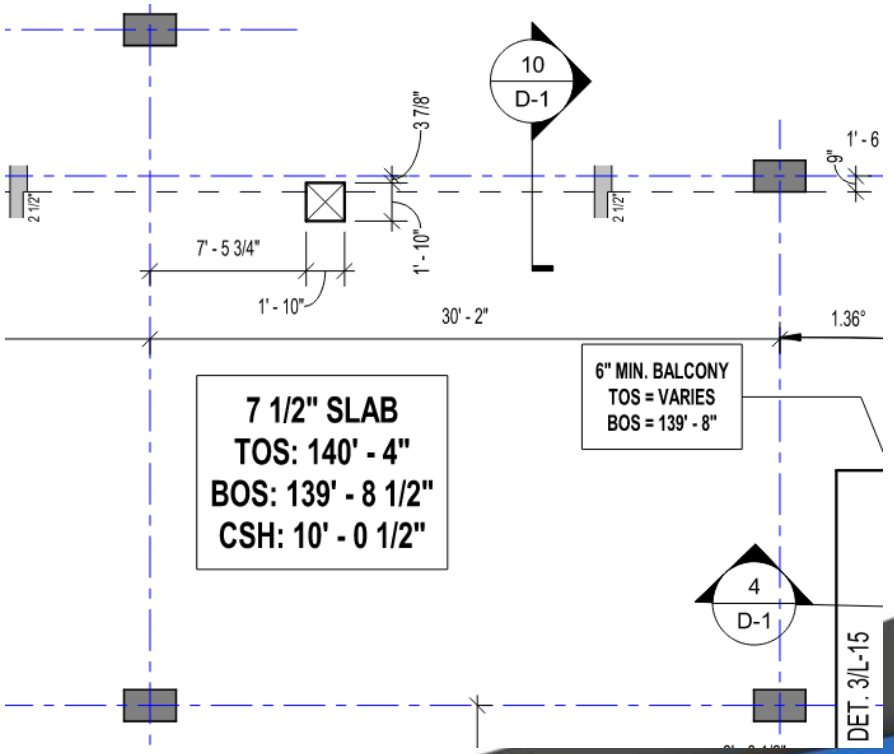
VS



Formwork System Selection

Slab Steps





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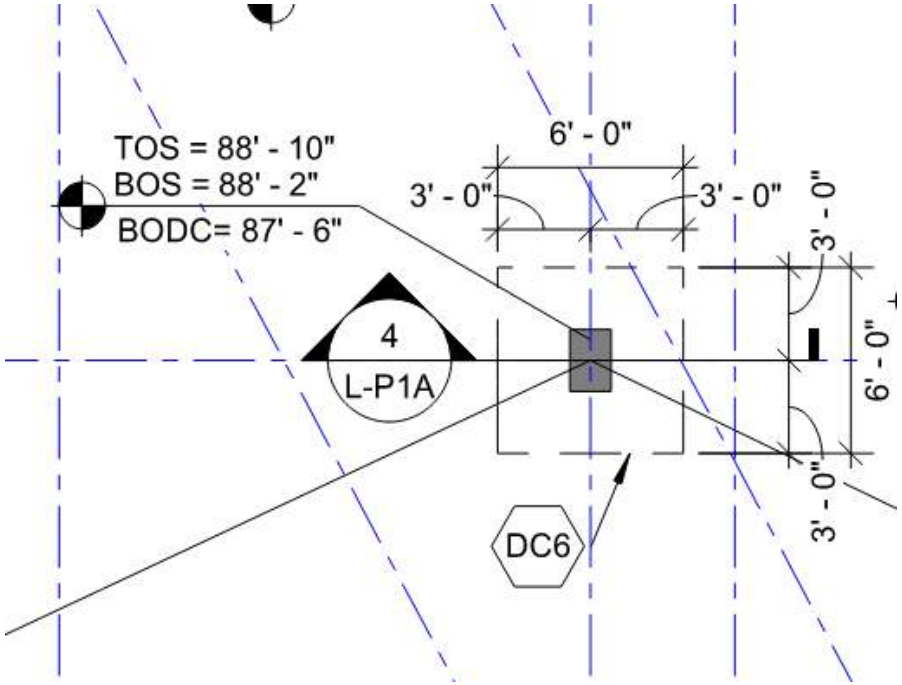
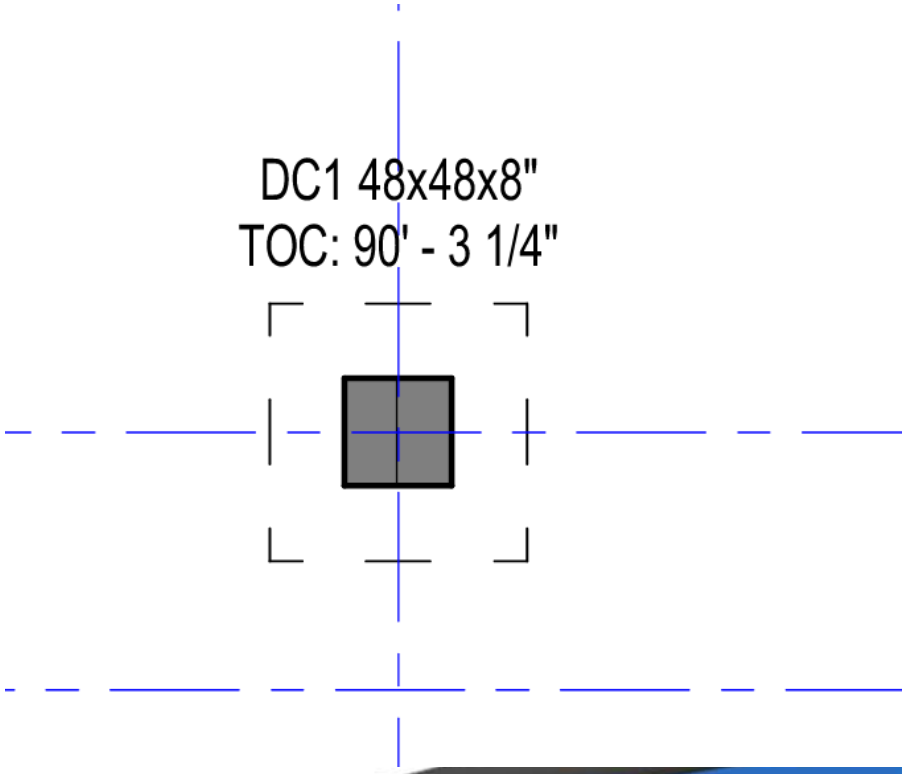
Formwork System Selection

Dropheads





Steel Beam and Steel Pan Sizes and Shapes

PAN

END CAP

QTY.	CODE	DESCRIPTION
135	001-506	**16"x30"**x 1'-0" PAN
90	001-505	16"x30"x 2'-0" PAN
45	001-504	16"x30"x 3'-0" PAN
100	001-503	16"x30" END CAP
200	001-760	12"x30" DIAPHRAGM
45	306-012	**16"x53"**x 1'-0" PAN
30	306-024	16"x53"x 2'-0" PAN
15	306-036	16"x53"x 3'-0" PAN
15	306-048	16"x53"x 4'-0" PAN
60	306-001	16"x53" END CAP
100	303-006	10"x53" DIAPHRAGM
45	301-012	**16"x66"**x 1'-0" PAN
30	301-024	16"x66"x 2'-0" PAN
15	301-036	16"x66"x 3'-0" PAN
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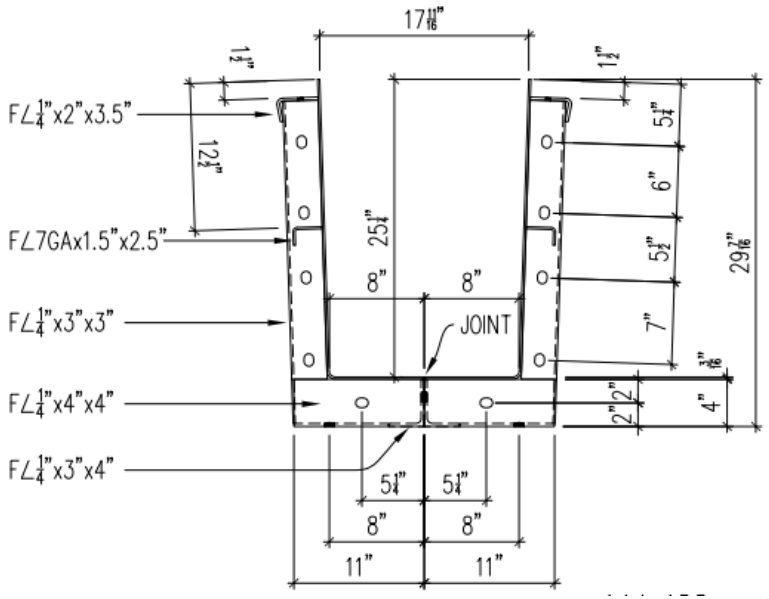

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Formwork System Selection

Visual Quality

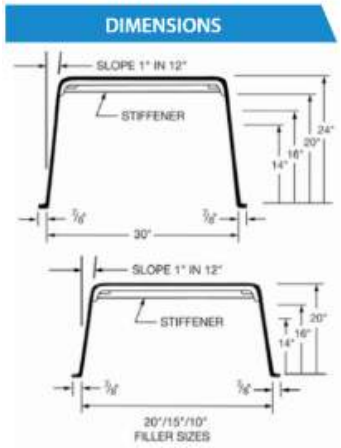
- Higher Quality = Higher Cost
- Does it need to look that nice?
  - Exposed vs. “Critically” Exposed
- Set clear expectations

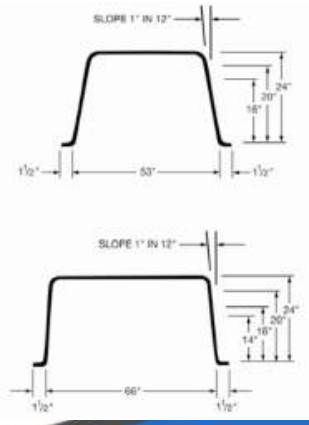
Formwork System Selection

Stick to Standards

- Discover what industry standards are and use them
  - Call Ceco. We set a lot of the standards

- Custom = Cost

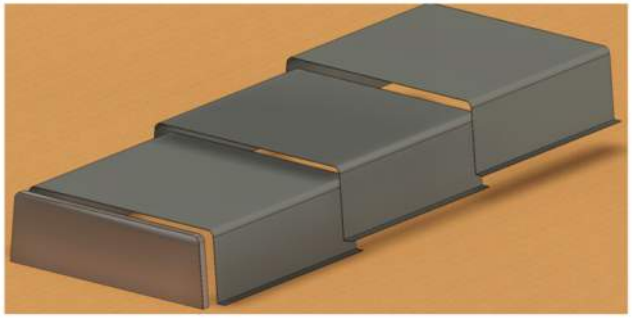




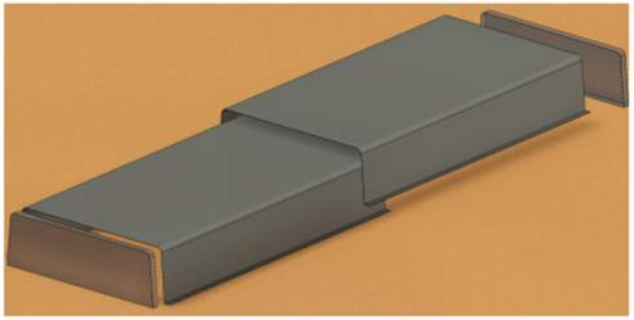
Formwork System Selection

Pan Types

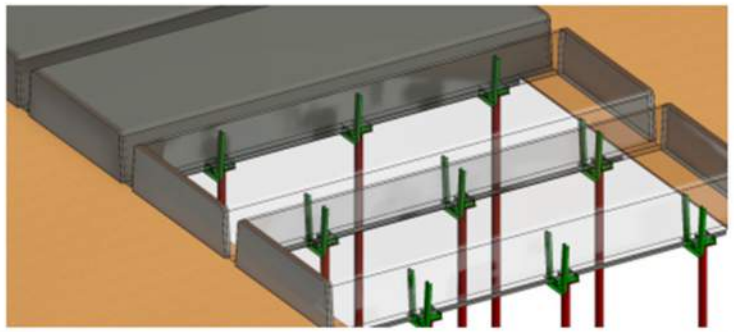
FLANGEFORMS:



LONG-FLANGEFORMS



LONGFORMS:



Stories Built

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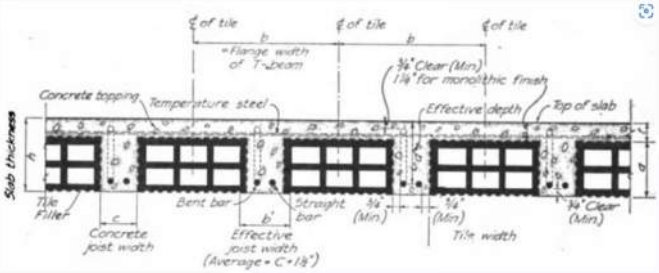
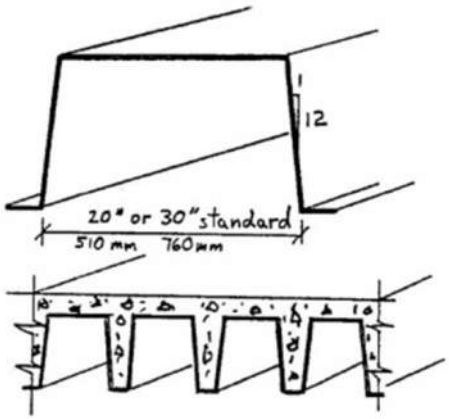
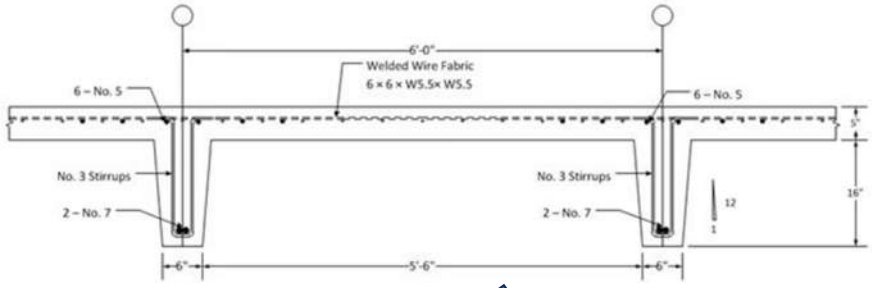
Formwork System Selection

Pan Evolution







BEYOND!

Stories Built

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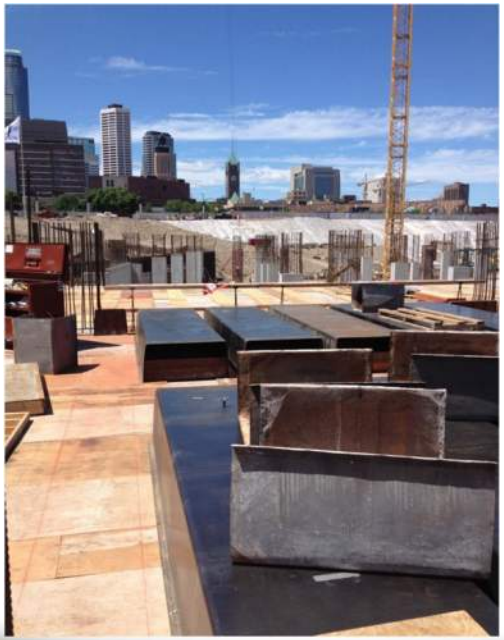
Flangeform Pan Construction

- Standard Lengths 4', 3', 2', & 1'
- Lots of piece
- Flexable
- Not intended for public view.

Long-Flangeform Pan Construction

- Standard Lengths: 12', 10', 8', & 6'
- Less pieces – Used with Std FF
- Still Flexable
- Less joints = slightly better finish.
- Crane dependent



Longform Pan Construction

- Typically used when finish is important.
- Needs 4-5 uses to offset the cost of making.
- Because it's a one-piece pan there is very little flexibility.
- Approx 60-70% increase in cost on material over Std lap pans (Rental Cost).
- An efficient layout can result in substantial formwork savings (lower building cost)
- Custom depths & widths are available at a cost.

Longform Pan Construction

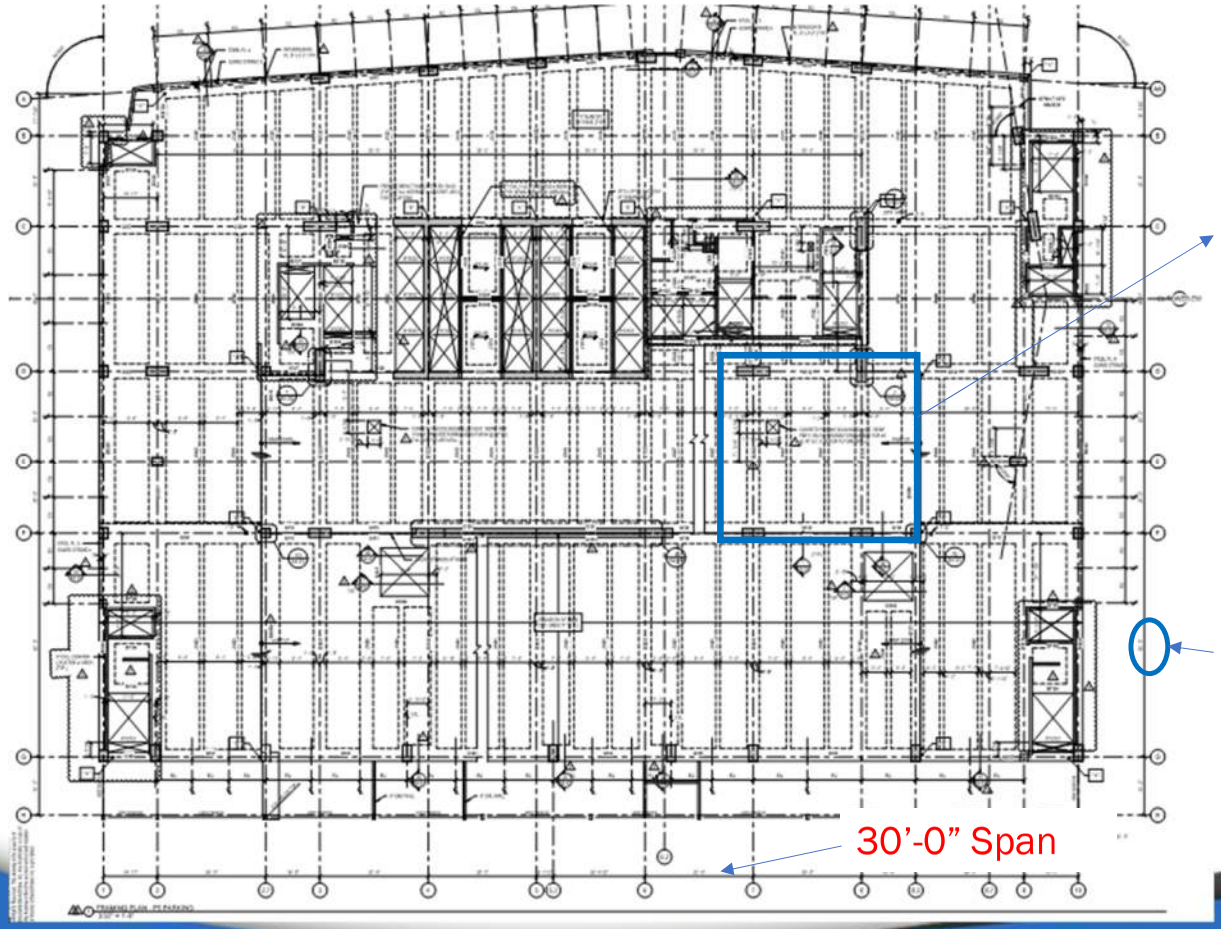
- One Piece = Not Flexable
- High End Finish

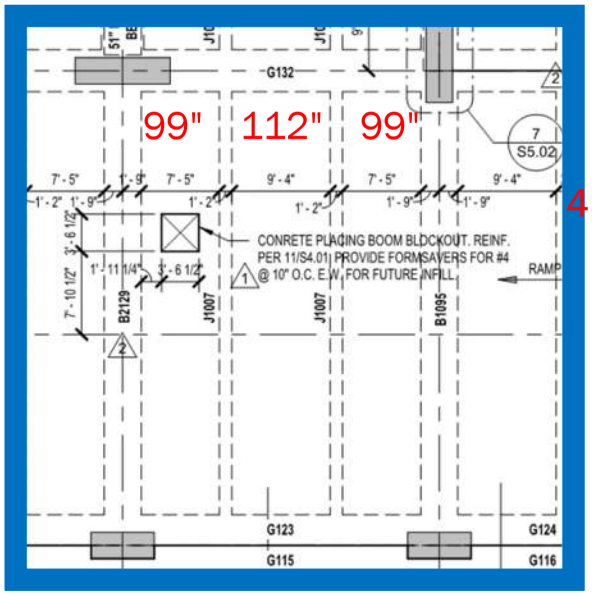
Longform Pan Construction

Super Wide Module

- Started using pans 8 -10 years ago. Mostly TX, GA, TN, & NC.
- Typ. pan depth is 16” with 5” slabs. Joists are typ. 14” wide.
- Standard Widths: 112”, 99”, 89” (86” & 76” are less common).
- The design mimics a structural steel building.
- Gateway Hotel in Minneapolis

Super Wide Module – The Republic – Austin, TX





62’-0” Span

Stories Built

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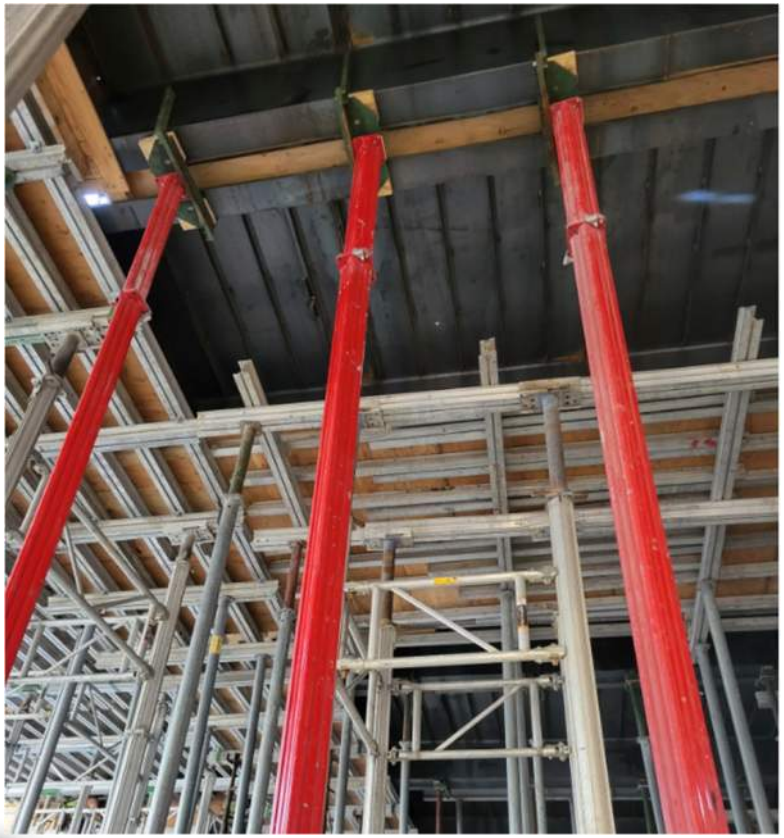
Super Wide Module



Waffle Slab Construction

- Steel vs. Fiberglass
- High End Finish
- Very stiff slabs
- Institutional & Industrial Projects

Structural System Considerations

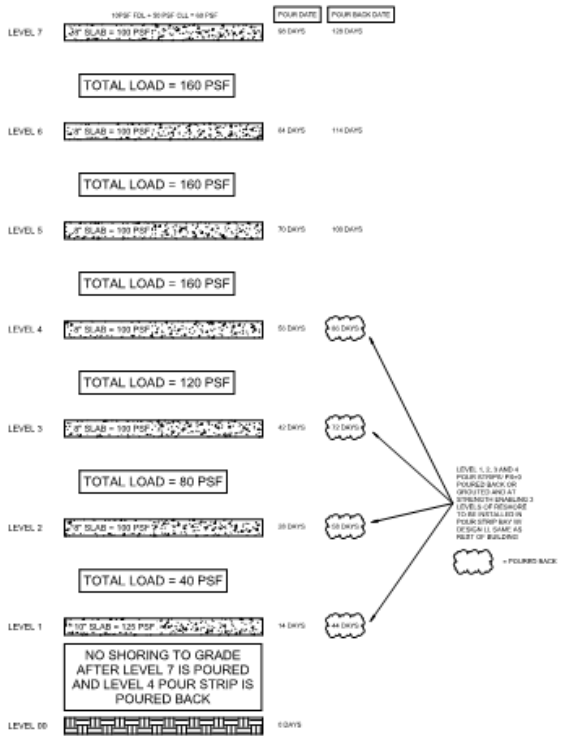
- **Pour Strips and delayed pours**
- **Relative stiffness of slabs**
- **Constructability of structure related to formwork**

Pour Strips

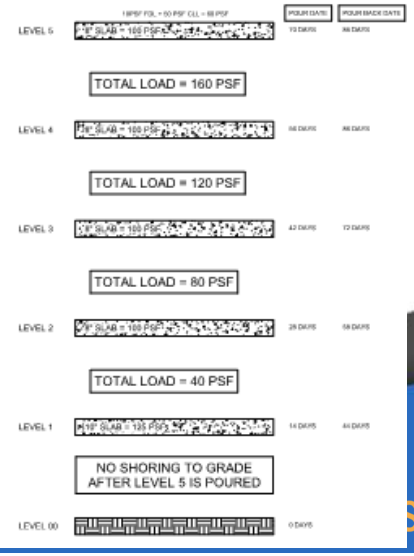
BAY NOT DESIGNED AS CANTILEVER

-ASSUME 30 DAY POUR BACK FOR POUR STRIP
-CANTILEVER DESIGN CONSDIERATION ASSUMES SHORING CAN BE RELEASED TO TAKE ITS OWN WEIGHT AND THEN RESHORED ATERWARD
-TOTAL LOAD = CONCRETE DEAD WEIGHT + FORMWORK DEAD LOAD + CONSTRUCTION LIVE LOAD (COMPOUNDING IF NOT RELEASED)
-RESHORING - SLAB FORMWORK IS STRIPPED AND SLAB IS RELEASED AND ALLOWED TO TAKE ITS SELF WEIGHT. THEN RESHORES ARE ADDED TO HELP SUPPORT LEVELS ABOVE. LOAD DOES NOT ACCUMULATE
-BACK SHORING - SLAB IS NEVER RELEASED AND SHORES ARE LEFT IN AND ADDITIONAL SHORES ARE ADDED TO SUPPORT THE LOAD ACCUMULATING FROM POURS ABOVE.

BAY DESIGNED AS CANTILEVER NO DESIGN LIVE LOAD CAPACITY



BAY DESIGNED AS CANTILEVER 40 PSF DESIGN LIVE LOAD CAPACITY



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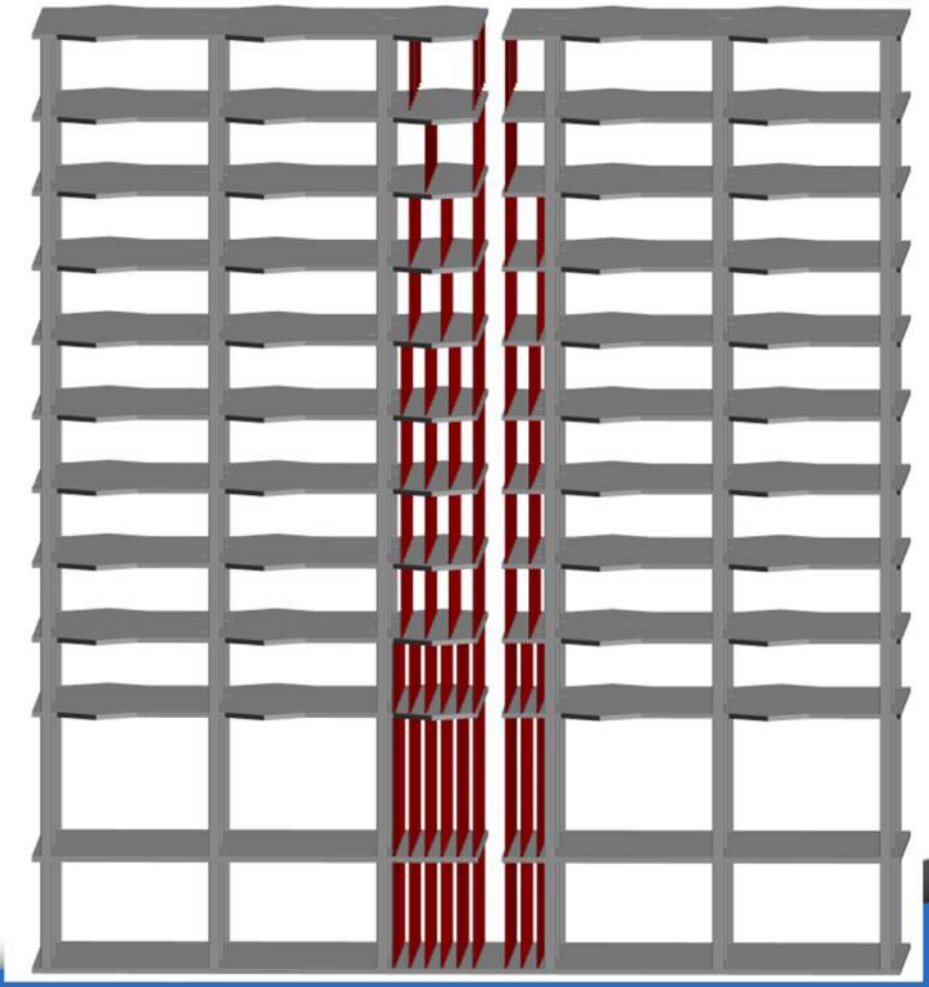
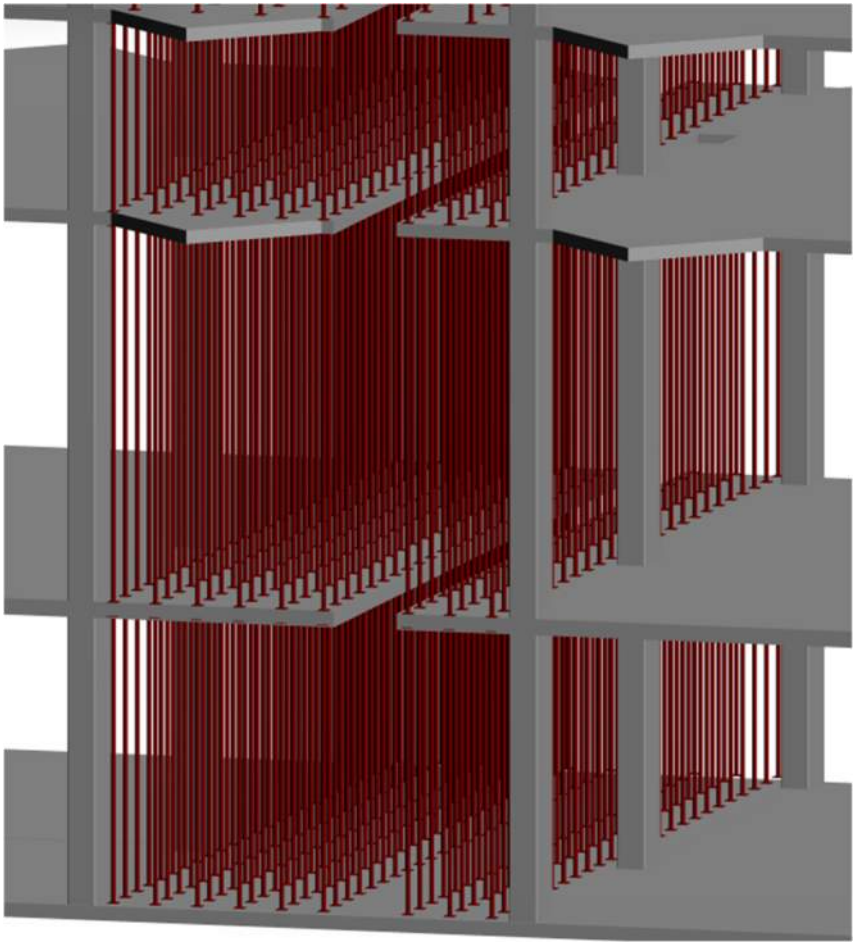
Pour Strips



Pour Strips

- Levels 2-4: 2’X2’ Backshore Spacing
  - 1185psf max load in floor
- Levels 5-8: 3’X3’ Backshore Spacing
  - 810psf max load in floor
- Levels 9-10: 4’X4’ Backshore Spacing
  - 435psf max load in floor
- Level 11: 6’X6’ Backshore Spacing
  - 247.5psf max load in floor
- Level 12: Typical Formwork Shore Spacing
  - 153.75psf max load in floor
- Floor Design Live Load: 40psf



Formwork Failures

Reshoring Issues

Skyline Towers: Alexandria, VA
March 1973
14 Dead

Berkman Plaza 2: Jacksonville, FL
December 2007
1 Dead, 21 Injured

Pour Strip Solutions

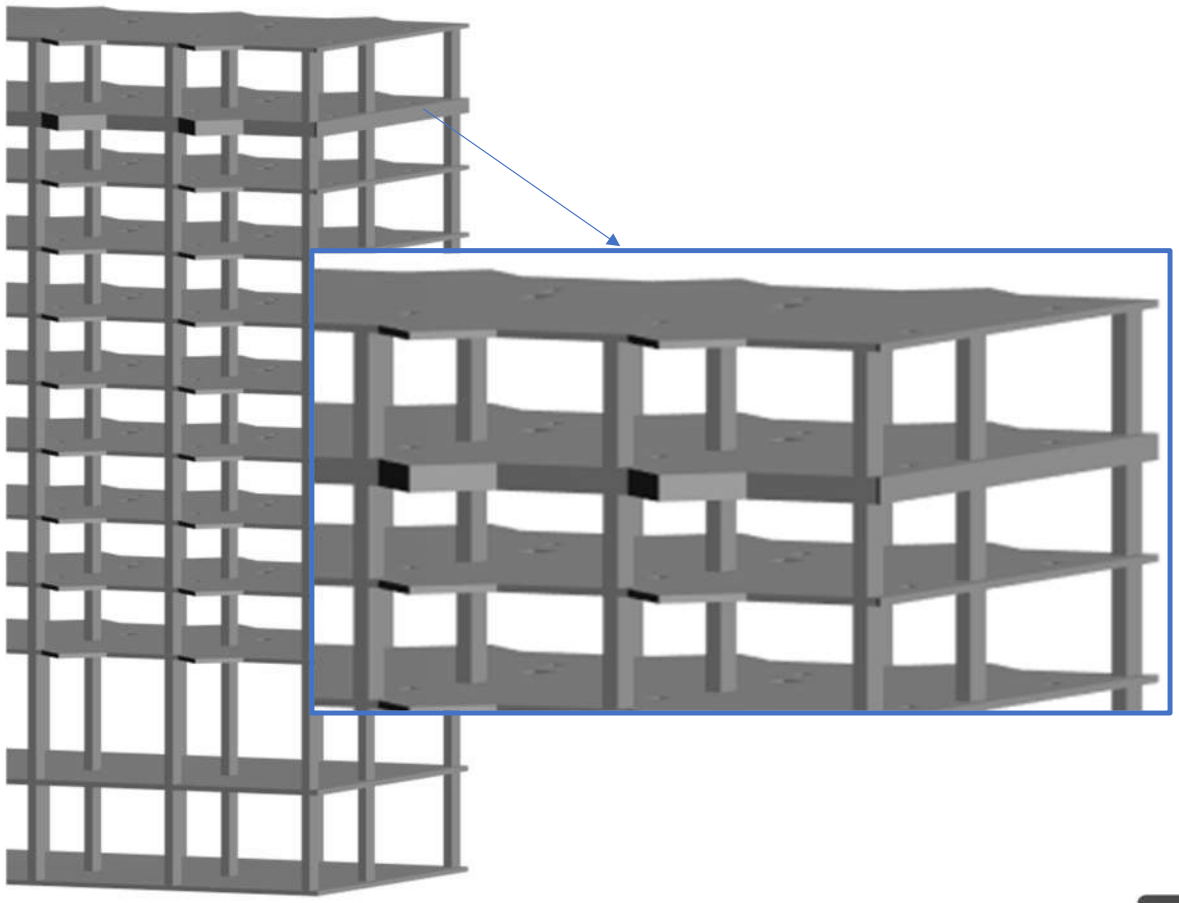
Self Supporting with no live load capacity

Cantilever Design with full Live load capacity

Mechanical Couplers with full live load capacity

Relative Stiffness of Slabs

- The stiffness ratio between floors dictates load distribution.
- Stiffer slabs receive a higher portion of the load from adjacent floors.
- Require additional levels of reshore due to difference in stiffness of thick slab vs. typical slab.
- 6+ levels of reshore vs. 2 for a typical slab
- Can affect finish trades lagging behind formwork operations



Concrete Construction Innovation

Reduce Labor

Reduce Materials

Reduce Schedule

Increase Safety

New Technology and Innovation

Layout

Increase Safety

- Perimeter Enclosure Systems
- Wearable Exoskeleton

New Technology and Innovation
In-House developments

EZ Quick Release #2 on Vimeo

In Summation…

- Repeatability and Consistency
- Great building design with a construction perspective can lead to low construction costs.
- We use innovation to improve labor, increase safety, and increase speed.
- Labor is everything!

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Resources

- Resources include Design Guides and tools for Pan Slabs, Parking Structures, Ceco's BIM Capabilities, and More all available online
- Beyond what is available online feel free to reach out to me, or one of our other engineers or project managers
- Available to do in person or virtual Lunch and Learn sessions
- Ryan Brozek, ryan.brozek@cecoconcrete.com, 763-479-9326
- https://cecoconcrete.com/resources/

Questions?