An ACI Center of Excellence for Advancing Productivity

Optimizing Formwork Efficiency through Constructable Design

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Objectives

- Understand what aspects of formwork systems lead to productive building designs
- Review several specialized formwork systems
- Learn what productivity gains can be made implementing these systems

Constructability <=> Efficiency <=> Productivity

- Constructability: Making it easier to use our resources
- Efficiency: Using fewer resources
- Productivity: Getting more from our resources

Formwork Costs

Cost of a concrete structure

- Formwork: 50-60%
- Concrete: ~30%
- Rebar: ~ 20%

Form materials 10-25% of Formwork cost

That makes Formwork Labor the major focus of productivity increases

The 3 Key Factors

- **C**onsistency: Allows for reuse and continuity of process. Reuse and continuity allow for innovative solutions.

- **S**tandardization: Allows for reuse from project to project. Solutions can become more innovative.

- **M**echanization: Allow the machines to do the work. The more consistent and standard, the more machines can do

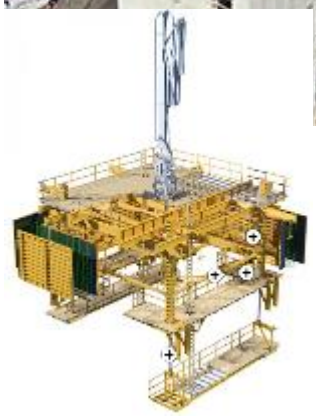
No one size fits all

- Almost any formwork system can be productive given the right set of conditions.
- Any of these systems we are about to discuss can be extremely unproductive given the wrong set of conditions.
- Using a more expensive formwork solution in the wrong conditions will not lead to higher productivities.
- The most important and variable resource is the people. Utilizing that resource properly with the right formwork solution is the key to success.

Going Vertical

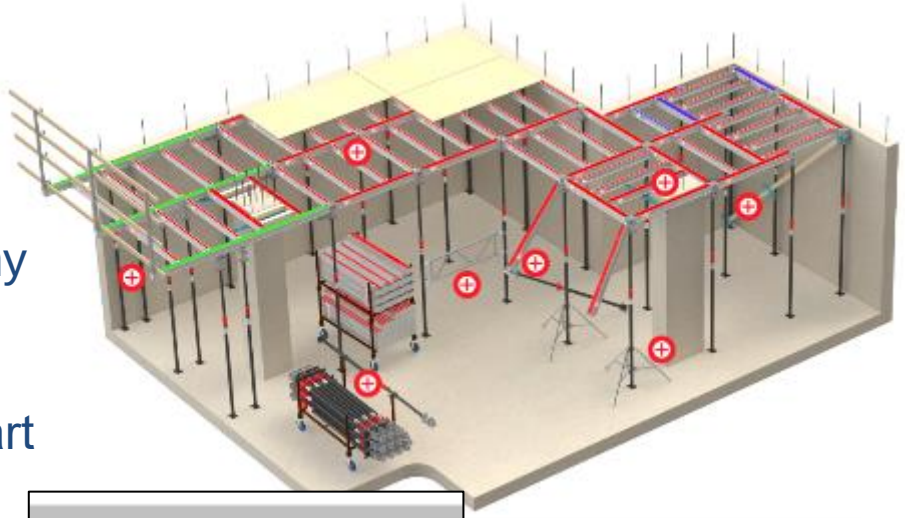
Self-Climbing Wall Forms

- **C:** Walls must remain the same thickness and in the same arrangement. Added material cost for wall remaining the same thickness from bottom to top is insignificant compared to costs and people resources for reworking forms. Efficiency of structural cross-section does not lead to efficient construction or cost savings.
- **S:** Standard sizes and shapes allow for off the shelf system. These are expensive. Up front costs from customization may drive contractors away from this solution.
- **M:** Full system moves at the push of a button. Independent of crane schedule. People resources can be used elsewhere while the machine does the work.



Flat work

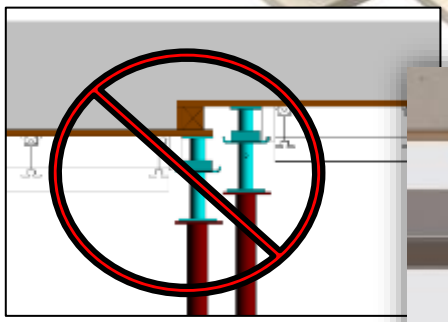
Modular Drophead System



- **C:** Changes in slab soffit elevation for any horizontal formwork system results in lower productivity. For this most basic of systems, we need to be able to stay “Start here and fill in with this spacing”.

- **S:** Limited numbers of light standard size pieces allow for simplicity of supply and use.

- **M:** The “drophead” mechanism allows for the removal of decking elements while shoring elements remain in place. Allowing this process to be utilized creates efficiencies by reducing equipment needs.



Flat work

Panelized Handset Systems

- **C:** Consistency of slab elevation and arrangement is even more important for a panelized system. Eliminating open framing reduces productivity loses due to fall protection requirements.
- **S:** Being able to use standard size panels for large areas of a formwork deck reduces the amount of custom cut plywood.
- **M:** Even though these panels are set by hand, having the joist, stringers, and plywood all in one reduces the number of crane picks per sf of deck.

Flat work

Floor Mounted Flying Forms

- **C:** Consistency of size and location of vertical elements (column & walls) is essential to using a large panelized flying system. Once assembled, the forms are moved from level to level with limited people resources.

- These panels are strong enough to accommodate a wildly varying slab edge with level to level changes.

- **M:** The crane does all the heavy lifting. Reshores and supplemental shores at panel intersections will be added by hand, but beyond that it is all machine.

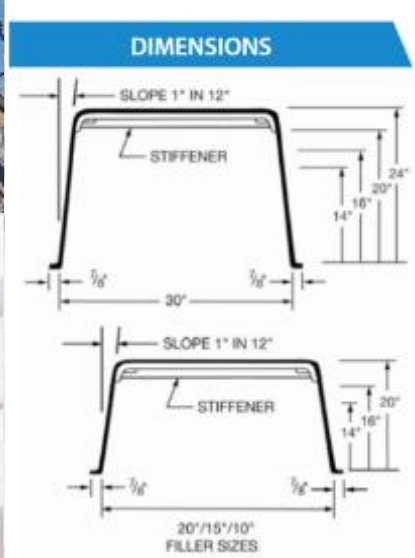
Flat work

Column Mounted Flying Forms

- **C:** Column mounted systems rely even more on vertical consistency.
- **S:** The vertical element arrangement to allow for column mounting not only must be consistent but work within the limitations of the system. Bay span, support point locations, and column a strength must all be within standard ranges.
- **M:** Everything put into place by the crane. As there are no primary shores, there is no reshoring required. Fewer people and physical resources are needed, thus greatly increasing efficiency.

Beams Beams Everywhere

Pan Form Construction



- **C:** When consistent sized beams are placed at a uniform spacing, instead of forming the slab and beams it is more productive to form the voids between them. Pan form construction can handle variability, but productivity increase significantly with consistent layout.
- **S:** Using standard size pans is essential to efficiency with pan form construction. The cost of non-standard pans can lead to hand building voids out of lumber which is not productive.
- **M:** Consistent size voids can utilize long or full-length pans. These can be placed with the crane and removed more easily with a forklift mounted device.

“Super Wide” Pans

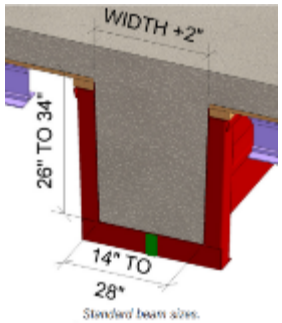
- Standard wide pan widths are 53” and 66” (5’ and 6’ beam spacing)
- “Super Wide” Pan systems are now accommodating void widths of 89”, 99”, and 112”.
- This design mimics a structural steel building and can more easily be used to convert one to cast-in-place concrete.
- These pan systems have no decking below most of the pan. This built in efficiency reduces plywood and form material needs as well as people resources and time for installation.

Parking Garage Beam Forms

- **C:** Beam & Slab parking garages are typically very consistent based on parking space requirements. However, the column sizes are often inconsistent due to perceived optimization of concrete material. The beam length variations created by this can result in loss of productivity from part changes.

- **S:** Standard beam sizing is essential to the use of these beam forms. If the beam to slab depth difference is beyond a standard range, a custom solution will be required.

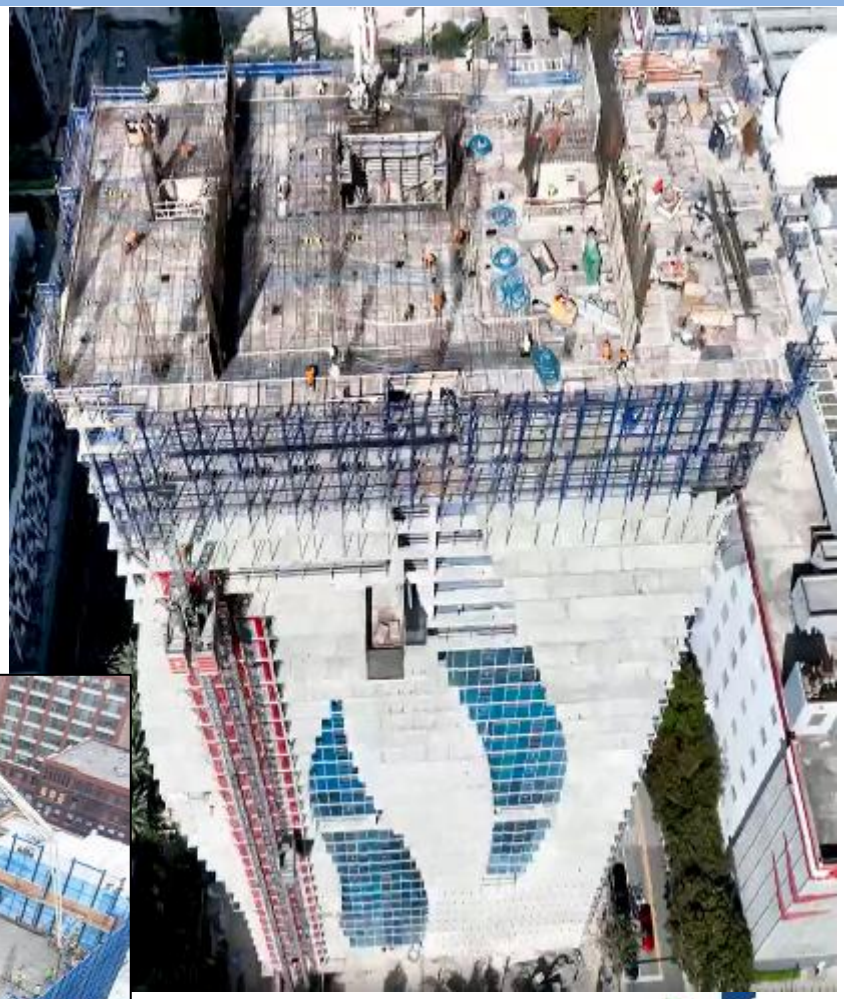
- **M:** Beams and slab tables are flown into place with the crane. If the beam spacing is such that the slab tables do not require shoring, there can be significant productivity gains do to ease of material movement.



Standard beam sizes.

That's a Wrap

Perimeter Enclosure Systems



- **C:** These systems work best with a consistent slab edge that allows the system to move directly upwards. While it can accommodate varying edges, it results in a loss of productivity.

- **M:** The entire building perimeter is raised mechanically without coming off the building.

There is not only a gain in productivity from the mechanical lifting of the system, but additionally from increased productivity of people working in a protected area.

Robotic Assistance

- **C:** The use of mechanization and robotics in manufacturing is a main factor in their ability to increase total productivity. The aspect of the business that allows for that is repeatability due to consistency. The exact same process over and over under the exact same conditions.

- **M:** The formwork industry continues to try to innovate by incorporating robotic assistance into the installation, movement, and removal processes. Upfront costs can quickly be covered through increase productivity, injury prevention, and worker satisfaction.

To Review…

- Consistency. Standardization. Mechanization.
- Provide the opportunity for innovation.
- Work with your formwork contractor early in the process to identify barriers and opportunities to increasing Productivity through Constructable Design.

Thank you

- Thank you to Phil Diekemper and PRO for inviting me to speak.
- ACI 347 – Formwork for Concrete Committee welcomes those interested in learning or contributing to future of formwork innovation in our industry.
- We hope to not be a roadblock against innovative productivity, but a catalyst to allow for new ideas.