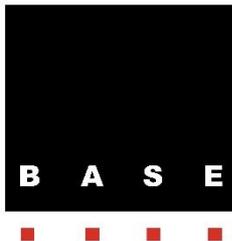


Tunnels in Paradise

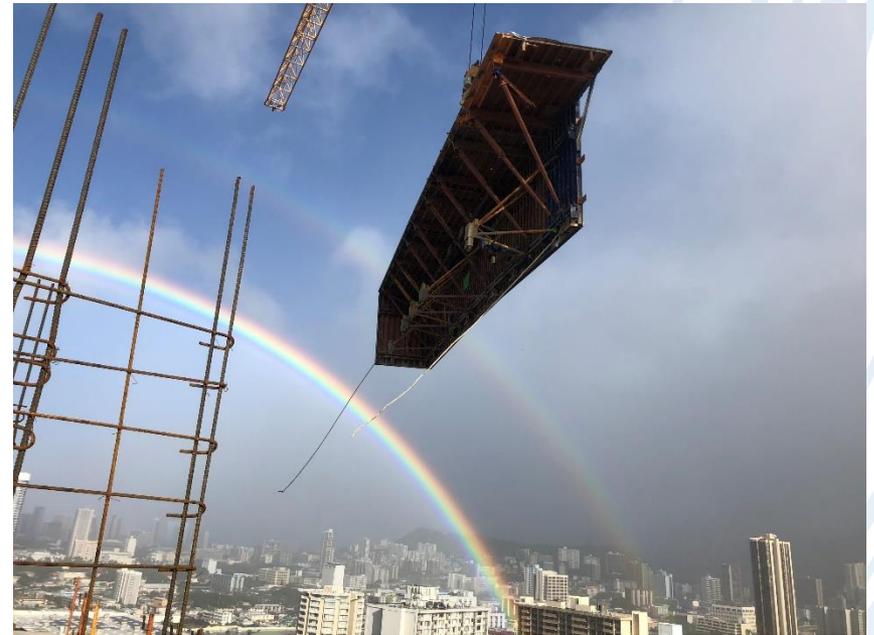
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ACI Convention, Fall 2019



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Overview

- Introduction to Tunnels
- Benefits
- Challenges
- Tips for Success
- Questions



Introduction to Tunnels

- Specialty concrete formwork system
- Prefabricated, modular steel forms
 - Can be rented or bought
- Each form makes up half of a ‘tunnel’
 - Walls + Slabs
 - Cast in one pour
- Proven system with 40+ year history worldwide
- First used in Hawaii 20-25 years ago, popularity exploded in last 5-10 years

Introduction to Tunnels

- Tunnels come in different heights and widths
- Combination of form widths and infill panels yields range of possible spans from ~8-20 feet
- Starter curbs give forms an edge to align with
 - Can use taller starter walls where story height exceeds available form height
- Supplementary wall panels used to form exterior faces of end walls and perpendicular interior walls



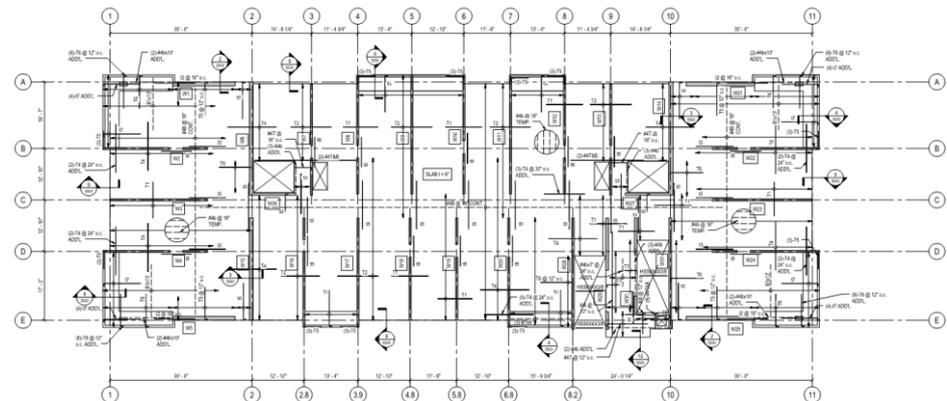
Introduction to Tunnels

- Tunnels flown into place by crane
- Wheels on bottom allow for easy adjustment before pour and extraction of forms after pour
- Can get creative with lifts and use of lifting aids to place tunnels in unusual places
 - Under overhangs
 - In tight spaces



Introduction to Tunnels

- Typical floor plans broken into 2-4 pours
- Typical three day cycle:
 - Day 1: Strip previous floor, pour starter curb, wall rebar and embedments installation
 - Day 2: Install forms, floor rebar and embedments installation
 - Day 3: Pour/finish/cure
- Forms cycled so each pour is on different day
 - Fewer forms needed
 - Results in near daily concrete pours



Benefits

- Extremely fast sequencing
 - Walls and slabs poured together
 - Forms typically stripped the following day
 - Often minimal reshoring required
 - High level of repetition
 - Walls and slabs typically work with minimal reinforcing
 - Zone columns may add to cycle time by requiring crane time to install



Benefits

- Less non-structural build out
 - More concrete walls = fewer framed infill walls
 - More control over schedule and costs for contractors that self-perform concrete
 - May result in specific estimating metrics appearing to be inefficient
 - Rebar #/SF of floor area may be higher due to high frequency of walls
 - Rebar #/cubic yard of concrete likely lower as virtually everything is minimum steel
 - Look at numbers critically before gauging design efficiency



Benefits

- Tight wall spacing + continuous slabs = minimal slab deflections
 - Allows for early stripping without compromising long-term performance
- Good performance for fire resistance and acoustics
 - 3 hour rating for ~6 inch walls/slabs, 4 hour rating for 7 inch walls/slabs
 - 6 inch walls/slab equate to STC-53 (minimal sound transmission)
- Steel forms give good surface texture and limit surface deformities
 - Depending on project, may not need additional finishes beyond paint
 - Also green, forms get reused from project to project

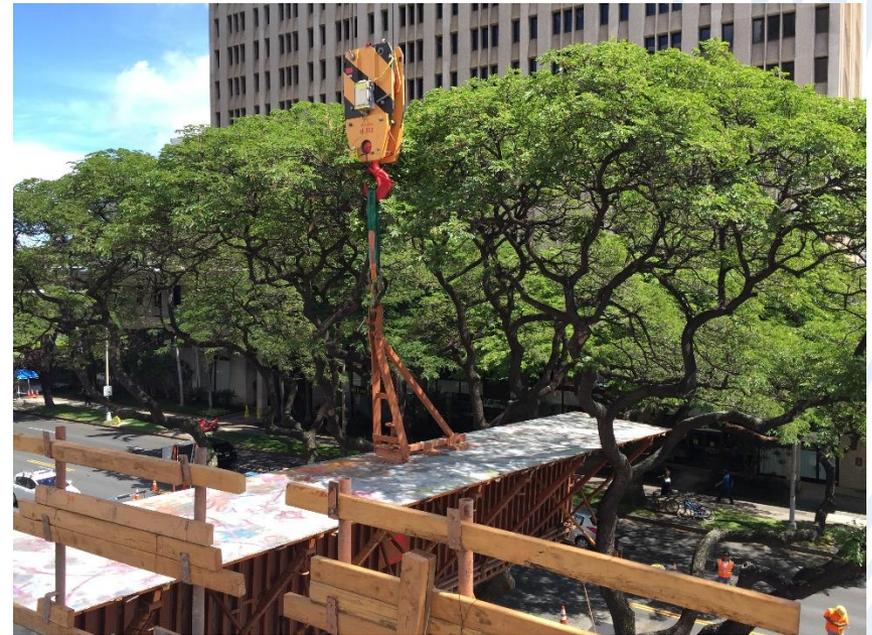
Challenges

- Can be architecturally limiting
 - Tight wall spacing can mean tight rooms
 - Less opportunity to change layout without compromising efficiency
 - However can combine with conventionally formed and post-tensioned elements to give more flexibility where required
- Higher up front cost
 - Form purchase/rental
 - BIG learning curve
 - Can combat by using same subcontractors, but hurts competitive bidding



Challenges

- Can be difficult on tight sites
 - Require significant access for pulling forms out
 - However not much laydown area often required as forms are typically in near continuous use
 - Can ‘park’ forms in poured bays when not in use and save ground space
- Local practices may limit efficiency and competitiveness
 - Plumbing fixtures sometimes dictate slab thickness
 - Shipping/rental costs may be expensive depending on local availability
 - Busy contractors like to stick with familiar methods



Challenges

- Requires careful coordination and teamwork between trades
 - Large portion of utilities embedded in walls and floors
 - Fast sequence requires multiple trades working in same area and some trades to work faster than they're used to
 - Thinner slabs and walls mean less space for embedded items



Challenges

- May not be great solution for high seismic environment
 - Lots of wall = very stiff system = higher seismic load
 - Lots of wall = high weight = higher seismic load
 - Though possible to include, thickness required for boundary elements takes away from system efficiency
 - New drift capacity requirements in ACI 318-19 for special shear walls may be difficult to meet without diminishing system efficiency
- Conversely, great for high wind environments



Challenges

- Potentially higher propensity for minor cosmetic cracking in walls on higher floors
 - Very stiff system, cannot accommodate system-wide shrinkage or thermal effects as easily as more flexible systems
 - Not as much weight per wall to help close up cracks
 - Typically cracks are very small and well within reasonable widths proposed by ACI 224
 - Potentially combat with:
 - Additional rebar at high floors
 - Extra insulation at roof deck to combat thermal swings
 - Heavier/more flexible paint or finishes
 - Educating owner

Tips for Success

- Pick projects carefully
- Ideal projects have:
 - Highly segmented spaces
 - Regular bay spacing that doesn't change throughout building
 - Small likelihood of reconfiguration in future

Tips for Success

- Ideal:
 - Workforce or affordable housing
 - Hotels/resorts
 - Dorms/barracks
 - Prisons
 - Any highly segmented/regular spaces
 - Projects requiring high durability



Image: Trip Advisor

Tips for Success

- Potentially not ideal:
 - Office buildings
 - Retail
 - Parking garages
 - Mixed use
 - High-end residential
 - Anything requiring a large amount of large open spaces or open floor plans

Tips for Success

- Involve qualified contractor (and designers!) early in process
 - Preferably as early as schematic/concept phase
 - Set slab spans based on available formwork
 - Review for constructability
 - Strategize forming of unusual or irregular areas and be open to revisions



Tips for Success

- Design team and owner/developer need to recognize rules of thumb
 - Walls need to align and maintain thickness
 - Maintain same layout to maximize reuse of forms
 - Maintain similar slab spans throughout building so forms can be cycled between areas
 - Review layout to ensure forms can be extracted easily
 - Limit perimeter upturns/downturns and curbs
 - Pay attention to site obstructions
 - Make sure crane can reach



Tips for Success

- Coordination is key
 - Monitor crossing of PEX plumbing and conduit in slabs
 - Watch for electrical outlet boxes back-to-back in walls
 - Coordinate slab and wall edges with perimeter cladding



Questions?

- Special thanks to:
 - ACI Committee 134
 - BASE
 - Hawaiian Dredging Construction Company