BRIDGE DESIGN FOR CONSTRUCTION SAFETY

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Construction is one of the most hazardous occupations. This industry accounts for

- 8% of the U.S. workforce, but 20% of fatalities
- About 1,100 deaths annually
- About 170,000 serious injuries annually

[CPWR 2008]
Bridge Design For Construction Safety

ELIMINATION
Design it out

SUBSTITUTION
Use something else

ENGINEERING CONTROLS
Isolation and guarding

ADMINISTRATIVE CONTROLS
Training and work scheduling

PERSONAL PROTECTIVE EQUIPMENT
Last resort

Hierarchy of Controls per ANSI/AIHA Z10-2005
Why Design for Construction Safety?
§137.55 Engineers Shall Protect the Public

(a) Engineers shall be entrusted to protect the health, safety, property, and welfare of the public in the practice of their profession. The public as used in this section and other rules is defined as any individual(s), client(s), business or public entities, or any member of the general population whose normal course of life might reasonably include an interaction of any sort with the engineering work of the license holder.
How to Design for Construction Safety
Bridge Design For Construction Safety

- Identify the hazards
  - Utilities
  - Excavations
  - Falls and falling objects
  - Structural Collapse
  - Traffic
Bridge Design For Construction Safety

- Design to mitigate the hazards, if possible
  - Foundations
  - Columns
  - Bent Caps
  - Beam Erection
    - Concrete
    - Steel
  - Slab
  - Phased Construction
  - Traffic
Foundations
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- Foundations
  - Utilities
  - Excavations
Utilities

- Clearance of Underground Utilities
  
  • Try to have one diameter clear distance between the edge of the pipe and the edge of the foundation element.
  
  • Increase this distance if uncertainty exists.

- Location of Aboveground Utilities
Foundations

- **Excavations**

  - Temporary Special Shoring will likely be needed

  - To replace a bridge with a longer bridge
Foundations
Foundations

- Excavations
  - Temporary Special Shoring will likely be needed
    - For footing installation
Columns
Columns

- Falls and Falling Hazards
- Structural Collapse
- Traffic
Columns

- Precast Columns
Columns

- Segmental Columns
Bent Caps
Bent Caps

- Falls and Falling Hazards
- Structural Collapse
- Traffic
Bent Caps

- Consider Precast
  - For standard bridges, just include the standards.
    - PBC-RC for round columns
    - PBC-P for piles
  - For larger or non-standard precast bents,
    - Consider the weight
    - Design for erection
Precast Bent Caps on Round Column
Precast Bent and Abutment Cap on Concrete Piles
Precast Bent Cap on Steel Piles
Bent Caps

- Pre-Tensioned Precast Cap
  - Currently designing for standard bridges
  - Replaces conventional flexure reinforcing with 0.6” prestressing strands
  - Multiple shear reinforcing options
    - Welded wire reinforcing
    - Conventional stirrups
    - Square spirals
  - Look for upcoming details
Bent Caps

- Inverted-T Straddle
- Rectangular Straddle
Beam Erection
Concrete
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- Beam Erection - Concrete
  - Falls and Falling Objects
  - Structural Collapse
  - Traffic
Beam Erection - Concrete
New Minimum Bracing and Erection Standards

- MEBR-C, Released May 2013
- For I-Girders and I-Beams
- Cross-bracing, which was shown to be ineffective at stabilizing girders, is eliminated and horizontal bracing is now used at all locations.
- A new option for top bracing, a steel strap placed beneath the prestressed concrete panels, is provided. This option eliminates the need to remove and reattach bracing during panel placement.
- The bracing spacing is simplified, to aide installation and inspection of the bracing.
Beam Erection - Concrete

HAULING & ERECTING

The contractor's attention is directed to the possible lateral instability of prestressed concrete girders and beams over 139' long, especially during hauling and erection. The use of the following remarks is encouraged to improve stability is encouraged. Lifting devices at the maximum practical distance from girth ends, use external lateral assistance devices during hauling and erection. Lift with vertical lines using two hoists and take care in handling to minimize lateral and impact forces.

ERECTION BRACING

Erection bracing details shown are considered the minimum for fulfilling the bracing requirements of Item 4.8. Required erection bracing must be placed immediately after erection of each girder and remain in place until additional bracing is provided for slab placement bracing. This standard is needed in all cases to meet requirements for slab placement bracing.

PHASED CONSTRUCTION

Phase erection with slab placement bracing for all girders in one phase is not allowed. Phases after the first, also place erection and slab placement bracing between outer girders of adjacent spans for all girders installed up to the phase construction point. When the phase construction point is between girders, top bracing can be omitted.

HORIZONTAL BRACING DETAILS

FOR ERECTION BRACING, OPTION 1

(This option is not allowed when also is formed with RCP or BIM)
Beam Erection
Steel
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- Beam Erection - Steel
  - Falls and Falling Objects
  - Structural Collapse
  - Traffic
Beam Erection - Steel

- Prefabrication
  - Shop work
    - Safer
    - Minimize the number of field splices
      - Keep in mind the weight and size of sections

- Connections
  - Allow a bolted option
  - Avoid awkward or dangerous connection locations.
  - Avoid sharp corners
  - Keep the connection simple.

- Cross-Frame Half Pipe Stiffeners
  - Skewed Bridges

- Lean-On Bracing
  - Straight Bridges
Specification Controls for Erection (Effective July 2013)

- Item 5 – “Control of the Work”
  - Table 1 includes Erection Drawings
  - Requires submittal with PE Seal
  - Requires TxDOT Approval if Engineers deems Work could affect Public Safety

Steel Girder Erection/Construction One Main Concern of Owner

SAFETY

- Has a PE designed a plan that will not put public safety at risk?
- Has lateral loading been considered?
- Are traffic control issues clearly defined?
- Site conditions have an influence on the thoroughness of our review.
- Is the plan being followed?
- Interchange Construction
  - Traffic Control
  - Shoring Towers
  - Staging of cranes
  - Typically require weekend closures
Beam Erection - Steel
Slab
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- Slab
  - Falls and Falling Objects
- Precast Concrete Panels
  - Safety (immediate work platform)
  - Quicker
  - Panels seal better than PMDF
  - No PMDF-Beam welds to break loose
Panels can be used

- For clear distance between beam flanges of 2’-10” to 10’-0”.

- For straight or skewed concrete beams

- For straight steel beams.
- Traditional Construction at the end of a span/unit
Slab

- Precast Panels to the end of a span/unit
Slab

- Slab Overhangs
Precast Overhangs

- Currently developing standards
- Look for upcoming details
Alternatives to Precast Panels

- Full Depth Prefab Decks
  - NCHRP 12-65: Tested Details and LRFD Specs
  - NCHRP 12-96: Second Generation Full Depth Panels (ongoing)
  - PCI Guidelines
  - Challenges
    - Panel-to-Panel Joints
    - Panel to Girder Connection
Alternatives to Precast Panels

- Adjacently Spaced Precast, Prestressed Beams (Box, Slab, and Decked Slab)
  - Beams Placed Side-by-Side
  - With Composite Slab
    - Simpler Stay-in-place Formwork vs Typical Bridges
    - Shear Keys
  - With ACP Overlay Only
    - Post-Tensioning or Welded Connections
    - Durability Considerations
Phased Construction
Phase Construction

- Consider traffic needs and the placement of any temporary barriers. If the clear distance between the back of the barrier and the edge of the slab is less than 2 feet, anchor the barrier to the deck.
Phase Construction

- Consider how much space is needed for traffic.
Phase Construction

- Consider how much space is needed between the two phases.
Phase Construction

- When building next to an existing structure (such as for phased replacements), provide enough space between the existing structure and the new construction to accommodate splicing of the deck reinforcement, the portion of the beam that extends beyond the edge of slab, the portion of bent or abutment that extends past the beam edge, and form work.

Top reinforcement extends about 12.5 feet past the end of the cap and about 14.5 feet past the phase line.
Phase Construction

14'-3" ~ Existing
11'-0" Traffic Lane
2'-0"
4'-0"
2'-5"
16'-0 3/4" ~ PHASE I
11'-0" Traffic Lane

Exsit Struct and FM 2045
Future FM 2045

CSB
Future PGL

4SB12 4SB12 4SB12 4SB12

NEW STRUCTURE

16" Sq Piles (Typ)

T223 Rail

EXISTING STRUCTURE

11'0" Traffic Lane
Phase Construction

- How to you get the space needed for the bent or abutment?
  - Use mechanical couplers or welded splices for Bent and Abutment Reinforcement.

Mechanical couplers need about 1 foot past the end of the cap and about 3 feet past the phase line.
How do I get more space for the phase?

- Consider reducing traffic to one-lane.
- Consider offsetting the alignment.
- Consider building a slightly wider bridge than is needed for the final condition.
- WORK with the TRAFFIC CONTROL PLAN designer.
Traffic
Traffic

- Probably the biggest hazard on a construction site

- Try to design so that the construction occurs behind a positive barrier at all phases.

- WORK with your Traffic Engineers to come up with a plan that keeps the workers safe and still moves traffic.

- ASK yourself would I feel safe doing this work?
Fully Prefabricated Spans
Fully Prefabricated Spans

- Fully Constructed on Simulated Bearings
- Transported to Final Location via SPMT’s or Other Means
- Erected in a Few Hours
- Significant Equipment Mobilization and Site Preparation
Graves Ave over I-4 NE of Orlando, FL

143’ – 143’ Replacement

Each Prestr Beam Span Fully Fabricated in ROW

Mammoet Heavy Lift Equipment
- Removes Existing Spans
- Installs New Spans (1300 Tons Each)
Florida SPMT Bridge

- **Original Design**
  - Graves Ave (overhead) 11 month detour
  - Interstate 4 (underneath) 28 nights lane closure

- **Change Order**
  - Cost $570,000
    - 60% to Heavy Lift Ops
    - 40% for Site Prep, Etc
  - Savings $2.2M in user delay
  - Graves Ave: 7 month detour
  - Interstate 4: 5 nights of lane closure
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QUESTIONS?

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