Project Information

- I-93 Just north of “Big Dig”
- 180,000+ ADT
- Bridges Built in late 1950’s
- Decks were shot
- 14 Bridges
  - Pairs of two
  - 7 Northbound, 7 Southbound
  - Most were 3 span
  - Simple spans with joints
  - All are steel stringer bridges
  - Needed repairs and painting due to leaking deck joints

July 2010

- Deck Patching Project underway
- Condition worse than anticipated
- CME brought in to investigate deck replacement using ABC
  - Goals
    - Replace 14 bridge decks
    - Weekend only construction
  - Construction in 2012 (Design Bid Build)
- Initial work
  - Changed to superstructure replacement quickly
  - Condition of beam ends
  - Allowed for modular construction without the need to connect the decks to the beams during the weekend (time consuming task)
Why Use ABC?

• Stage Construction options
Why Use ABC?

- 5 Stages required
- 4-5 years of construction
- Potential Work Zone was not desirable
  - Island work zones
- Traffic impacts were significant
- User Costs were very high
- Decision to use ABC was a “no brainer”

July 2010

- Options investigated
  - Modular Deck/Beam Elements
  - New steel with precast decks
  - NEXT Beams
  - SPMT/Lateral Slides
  - Traffic Management Options
    - Staged
      - Build portions of the bridge on each weekend
      - Narrow joints between old and new
      - 3 lane option
      - 4 lane option
      - Full closure of one bound on weekends
        - Span by span
        - Entire bridge

August 4, 2010 - Then came the Hole

- Large punch through on the Fellsway Bridge
  - Major traffic jam
- Entire project changed
  - Construction moved up to 2011
  - Contracting method changed to Design Build
  - Commitment to build 14 bridges in 10 weekends
  - This was chosen based on the preliminary studies
Project Approach

- Replace entire superstructures
- Accelerate construction to minimize mobility impacts to I-93 Traffic
- Limit work to weekends and nights
- Keep 8 lanes open during the weekday rush hours

Project Commitments

Accelerated Project Delivery – Design Build
- Concept Development & Preliminary Design: 2 Months
- Team Selection: 3 months
- Notice to Proceed: February, 2011
- Fabrication: 4 months (500 beams)
- Rehabilitate all bridges during the summer of 2011
- Replace 14 bridge superstructures in 10 weekends
- No disruption to weekday rush-hour traffic
- Manage weekend traffic
  - Minimize use of I-93
  - Reduce weekend volume
  - Investigate long-haul detours for through traffic

Results of Alternate Analysis

- The modular prefabricated beam unit system was chosen
- The weight of units was critical
  - Substructure capacities
  - Weights are the same as existing structure
  - Crane pick limitations
  - Controlled the entire project
- Prefabricated steel beam units offer the best potential for success
  - Very adaptable for different geometries
    - Skew
    - Vertical curves
    - Cross slopes
  - Sections can be made shallow to accommodate vertical clearances
Traffic Management

- Close entire bound during weekends
  - 55 Hour closure
  - Give entire other bound over to the contractor (6+ miles)
- Production:
  - Two bridges per weekend
- Cross overs were constructed at each end of the project limits
- Weekend ADT
  - Less, but far from ideal
  - Multi-level detours used
  - Public outreach used to reduce volume

Anticipated Construction Methods

- Cranes above and below

- Cranes Above Only
Anticipated Construction Methods

Cranes assembly areas

Monday Morning: 8 Lanes open to traffic

Preliminary Substructure Analysis

- Goal: To re-use substructures with rehabilitation
- Service Life
  - By eliminating joints, source of potential deterioration would be limited
  - Sealer coating added for additional protection
  - Additional rehabilitation or even replacement could be done in the future
- Strength
  - One beam was added in the cross section (even number)
  - This shifted the load locations
  - LRFD (HL-93) did cause some issues: Truck + Lane load?
  - LFD (HS-25) was acceptable
  - Decision made to accept LFD rating
Deck Connections

Options
- Narrow Closure pour with straight bars and UHPC
- Medium width closure pour with hooked bars and grout
- Wider pour with lapped bars and High Early Strength Concrete
- Last 2 were both allowed

Wide pour was preferred
- Reduced precast deck width:
  - Shipping width and weight
  - Crane pick weight
- Ease of installation
  - Easier to install with extended bars
  - Interfering bars will spring into place

More room for adjustment = Less Risk to the Contractor

Continuity?

Simple for DL Cont. for LL
- Jointless deck
- Requires a bottom flange connection (closure pour or bolted splice)
- Concerns about forming time and alignment (fit-up)
- Concerns about live load tension across the joint (leakage)

Link Slab Design

- Another option
- Jointless, not continuous
  - Less complicated
- Used to accommodate the end rotations in the beams
Link Slab Design

- Theory
  - Based on research

\[
M = 2EI \theta / L
\]

\( \theta \) = Girder end rotation
\( L \) = debond length
\( E \) = modulus of elasticity of link slab
\( I \) = Gross moment of inertia of slab

Jointless Deck Technology

- Cost effectiveness?
  - Easier forming
  - Less Expensive
    - More structural steel
    - Less Longitudinal Deck reinforcement than continuous girder designs
    - See article in September 2014 issue of Modern Steel Construction

Concrete Closure Pours

Options
- Narrow Closure pour with straight bars - UHPC
- Medium width closure pour with hooked bars
- Wider pour with lapped bars and High Early Strength Concrete
**Design of Closure Pour**

- **Speed of Construction**
  - UHPC: 3 days to reach final strength
  - Grout: 12 to 48 hours
  - Concrete: 7 days
  - High early strength concrete: 6 to 18 hours
    - Depending on the mix design

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**Design of Closure Pours**

To achieve High Early Strength Concrete, Use one or more of the following:

- Type III High Early Strength Cement
- Pre-blended cements with accelerating admixtures, including silica fume
- Special cements
- High cement/cementitious content (over 600 lb./cy)
- Reduced water/cement Ratio (less than 0.36 by weight)
- Heated fresh concrete to temperatures up to 158 degrees Fahrenheit
- Higher curing temperature
- Chemical admixtures
- Silica Fume
- Insulation to retain heat of hydration
- Use a performance specification for bidding

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**Design of Closure Pours**

**Issues with High Early Strength Concrete**

- Shrinkage Control
  - Use larger aggregate if possible
  - Curing:
    - Have tensile strength gain outpace internal shrinkage tension stress
    - Use shrinkage reducing admixtures
- Curing
  - Use liquid curing compounds and wet burlap if possible
  - Research on lightweight sand
  - Porous sand retains water during hydration process
  - Cures internally
Design of Closure Pours

Other ways to reduce construction time

• Design connection for lower interim strength

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<th>5 ksi</th>
<th>3 ksi</th>
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Use higher strength concrete

- 10 ksi mix
- 5 ksi mix

Closure Pour Concrete

- Fast 14 Project Specification
  - Performance based specification
  - High early strength (2000 psi before bridge opening)
  - 4000 psi final strength
  - Low shrinkage
  - Confined shrinkage testing required
  - AASHTO T334
  - Confined shrinkage test panel will be required
  - 10’x14’ with 10’x32” hole
  - Trial batch to be submitted within 15 days of NTP
  - Test pour more than 90 days before first placement
Preliminary Design Calculations

- **Superstructure design was the same as conventional**
  - Simple Span Design, standard parapets
- **Link Slab Design**
  - Based on Research completed in North Carolina
  - PCI Journal Paper
- **Bearings**
  - Standard AASHTO Design
  - Round Bearings used
  - Not bonded to beam or substructure (Mass DOT Standard)

Significant Challenges

- **Timeline for design development**
  - Emergency Project
  - Concept formulated in 2 weeks
  - 30% Plans in 2 months
- **Condition of existing decks**
  - Placed limitations on construction options
- **Traffic Management**
  - Both local and regional

Cost – ABC vs. Conventional

- **ABC cost is a function of…**
  - Speed
  - Complexity
  - Risk
- **The 93 Fast 14 project had elements of all three**
  - It was understood that it would be more expensive than conventional construction
  - Conventional construction in the greater Boston area is also expensive
  - Cost of staged construction is significant
  - 5 stages of construction would be pricey
  - Actual cost was approximately 15% to 25% more than conventional
  - Easily offset by road user costs and reduction in MassDOT Construction engineering staff costs
Role of Designer in Construction

- Design Build projects will generate a lot of paperwork and submissions
- Design calculations and drawings
- Quality Management Plans
- Shop Drawings
- CME was kept on to assist with:
  - Outreach to DB Teams during procurement — Info meetings
  - Review of submissions
  - Attendance at "over the shoulder" review meetings
  - Attendance at weekly project status meetings
  - On site assistance for troubleshooting
  - On-site decision making with Mass DOT staff

What worked well?

1. Teamwork
   - Preliminary Design team worked hand-in-hand with all MassDOT Units
   - Construction staff were involved from DAY ONE
   - Bridge Design and Traffic Management Design were done in parallel
   - Significant outreach efforts with potential DB Teams and local municipalities
   - DB Team/MassDOT Coordination during Construction
2. Modular Element Concepts
   - Flexible and Adaptable

Recommendations

3 Recommendations for other DOT’s planning a similar project

1. Establish a design team up front
   - Department staff
   - Consultants
   - Get construction staff involved from the beginning
2. Consider CMGC
   - Get a contractor on board ASAP
   - Use contractor input during design development
3. Engage contractors, consultants and the public