ABC Techniques for Rapid Bridge Replacement

Bala Sivakumar  |  03.08.2017  |  HNTB Corporation

Purdue Road School 2017
What is ABC?
Accelerated Bridge Construction (ABC)

ABC is bridge construction that uses innovative methods to reduce mobility impacts when replacing/rehabilitating existing bridges.

ABC is a platform for innovation
Reasons for ABC include:
• Heavily traveled route (high ADT)
• Long or non-existent detours
• Stage construction is not a preferred option
ABC Advantages

- Reduces disruption to traffic/avoids congestion
- Safer; reduces exposure of workers and public to construction activities
- Better quality control due to prefabricated elements
- Reduced environmental impacts
TRAFFIC IMPACTS WITHIN

Tier 1  24 hours
Tier 2  3 days
Tier 3  2 weeks
Tier 4  3 months
Tier 5  > 3 months but overall project schedule significantly reduced
Prefabricated Elements and Systems (PBES)
Full Depth Precast Deck Panels
Prefabricated Superstructure Units — MassDOT I-93 FAST 14 Project

14 bridges in 10 weekends
Prefabricated Abutment & Wingwalls on H Piles

Iowa DOT
Build the entire bridge superstructures (where ROW is available) and then moving them into place in a few hours.

Bridge movement technologies:
- Self-Propelled Modular Transporters (SPMT)
- Lateral Sliding
- Launching/Skidding
- Float-In
Bridge Movement – Float-In
Bridge Movement – Self-Propelled Modular Transporters (SPMT)  Utah DOT
Bridge Replacement – SPMT

Caltrain Railroad Bridge replaced in a single weekend using SPMTs
• Sliding technique allows the new superstructure to be built alongside the exiting, reducing traffic impacts.
• Requires availability of ROW/space.
Bridge Movement – Roll-Out/Roll-In

New York City

- Bridge over I-678 – Van Wyck Expressway
Precast Decks
Rapid Deck Replacement with Precast Concrete Deck Panels
Precast Deck System

- Advantages to Owners / Contractors:
  - Crack free decks
  - Off site production
  - Accelerated on-site schedule
  - Reduced Maintenance
  - Lower Life Cycle costs
Barriers Prefabricated with Deck
Precast Deck Connections to Girders - Open and Hidden Shear Pockets
Ultra High Performance Concrete (UHPC)

**Compressive Strength:**
20,000 to 32,000 psi

**Flexural Strength:**
3,000 to 7,000 psi

**Ductility:**
Greater capacity to deform and support flexural and tensile loads, even after initial cracking

**Abrasion Resistance:**
Similar to natural rock

**Impermeability:**
Almost no carbonation and penetration of chlorides

**Strength Gain**
10 to 14 ksi usually in 48 hours

Stainless steel fibers in UHPC
Precast Deck Connections to Girders

- The design of the connectors attached to the girder shall be completed according to the provisions of AASHTO LRFD Bridge Design Specifications 5.8.4 and 6.10.10
Shear Connectors --- Studs with Haunch Forms
Shear Connector Spacing

- In 2013 AASHTO approved a change to LRFD Article 5.8.4.2 to permit longitudinal spacing of studs up to 48 inches, but not greater than beam depth.
- However large spacing of blockouts will require a greater number of shear studs per pocket.
- Explore use of 1” or 1 ¼” shear studs to minimize number of studs per pocket.
Hidden Shear Pockets -- Rebars not Interrupted

Examples of minimum shear planes for horizontal shear transfer
Precast Panels with Hidden Pockets
Precast Deck Panel to Panel Connections

Panel to Panel Connection with Closure pours

Narrow Width
- UHPC

Intermediate Width
- Rapid Set Concrete

Larger Width
- Rapid Set Conc.
Headed Bars & U Bars
Post-tensioning with match cast shear keys has been used in precast deck slabs to transfer shear and some moments and to keep joints in compression.

• Prevents tension cracking under live load
• LRFD requires an effective prestress force not less than 250 psi.
Post Tensioned Connections of Panels
Deck stress criteria for “no discernible cracking” should be followed during lifting.
Precast Deck Panel Erection with Gantries
Riding Surface Quality -- Deck Grinding

- Use diamond grinding or a deck overlay for a smooth deck
- Extra ½ inch for grinding for smooth riding surface
- Longitudinal grooving for skid resistance
Precast Deck After Grinding
1” Polyester Polymer Concrete Overlay (PPC)
Jointless Decks -- Link Slabs at Piers

- Spans are jointless but not continuous
- No moment transfer
- 0.05L of deck debonded (from girder) at each girder end – eliminate shear studs
- Allows end rotation
- Simple details at piers
SHRP2 Project R04 – Making ABC Standard Practice
Project R04
Innovative Bridge Designs for Rapid Renewal
2008 – 2013
HNTB – Prime Contractor
Iowa State University
Genesis Structures
SHRP2 Project R04 – Goals

Make accelerated bridge construction (ABC) standard practice nationally

Develop standardized approaches to designing and constructing ABC projects

Identify and overcome impediments to widespread ABC use
Identify obstacles to ABC Implementation
Plan to overcome obstacles
ABC Design Standards & Specifications
ABC Toolkit
ABC Training Course
ABC demonstration projects
ABC implementation assistance
Obstacles to Implementing ABC - Owners’ Perspective

• Seek ability to balance the increase in construction costs for ABC projects against the user costs savings.
• Durability of connections.
• Need to standardizing components and designs for ABC
• Challenges in getting industry support for ABC
Obstacles to Implementing ABC - Contractors’ Perspective

• ABC is perceived as raising the level of risk.
• Contractors concerns about the diminished profitability
• Greater outsourcing of work to precasters and specialty subcontractors with ABC.
• Contractors will be more willing to make equipment purchases if there are a greater number of projects to use the same equipment. Need a program of ABC projects
Obstacles to Implementing ABC - Engineers’ Perspective

- Lack of familiarity with ABC methods
- Looking for design manuals, specifications and design aids for ABC.
- Erection methods for large prefabricated elements
- Need for ABC training.

ABC: ENGINEERS NEED TO – “THINK LIKE A CONTRACTOR”
SHRP2 ABC Toolkit
• **SHRP2 ABC Tool Kit** was developed for PBES and Lateral slide

• Focus on “workhorse” bridges

• Standards will foster more widespread use of ABC

• Make best use of program dollars by standardizing ABC design

• ABC standards can be incrementally improved through repeated use
SHRP2 R04 ABC Toolkit

1. ABC Standard Design Concepts
2. ABC Erection Concepts
3. ABC Sample Design Calculations
4. ABC Design Calculations (LRFD)
5. ABC Construction Specifications
ABC Toolkit – Benefits

- Standardization of designs
  - Superstructure
  - Substructure
- Can be built by any bridge contractor
- No special equipment needed
Prefabricated Decked Beam Elements

Deck Bulb Tees

Double Tees

Composite Steel System
ABC Standard Designs

- ABC designs for common bridge spans
- Simple / continuous spans from 40 ft to 130 ft.
- Plans are grouped in the following span ranges:
  - 40 ft to 70 ft
  - 70 ft to 100 ft
  - 100 ft to 130 ft.
- Plans for integral and semi-Integral abutments
- Plans for precast piers
- Plans for precast approach slabs
Recommended special requirements for ABC construction

PROPOSED SECTION IN LRFD CONSTRUCTION SPECIFICATIONS

Xx.1  General
Xx.2  Responsibilities
Xx.3  Materials
Xx.4  Fabrication
Xx.5  Submittals
Xx.6  Quality Assurance

Xx.7  Handling, Storing, and Transportation
Xx.8  Geometry Control
Xx.9  Connections
Xx.10  Erection Methods
Xx.11  Erection Procedures
Ultra High Performance Concrete – UHPC -- Joints in Bridge Deck

- Full moment transfer – no post tensioning required
- Only 6 inches wide— 25 Ksi ; low permeability

Longitudinal Joint
Grouted Splice Sleeve Couplers

Manufacturers of Splice Sleeve Coupler

- Splice Sleeve North American ("NMB Splice Sleeve").
- Dayton Superior ("Dayton Superior DB Grout Sleeve").
- ERICO United States ("Lenton Interlok").
Grouted Splice Sleeve Couplers
• Allows fast rate of erection
• Rides on existing bridge or new bridge
• Ideal for bridges with many spans, long viaducts
Erection Using Launched Temporary Bridges

• Sites with limited ground access
• Launched across to act as a “temporary bridge”
• Used to deliver the heavier modules without inducing large erection stresses.
ABC Toolkit provides guidance on:

1. Permanent bridge design
2. Temporary support system
3. Push/pull system
4. Sliding bearings
5. Sliding forces
Bridge Movement Systems

Push/pull hydraulic jacks

Pulling with
• strand jacks
• power winch
Roller Bearings
Coefficient of Friction: 5% of Vertical Load

Teflon-Coated Neoprene Bearing Pads
Coefficient of Friction: 10% of Vertical Load
Implementing the SHRP2 ABC Toolkit
ABC and SHRP2 ABC Toolkit Training Courses

ABC Training Courses (One Day)
- PennDOT
- MIDOT
- MNDOT
- VTDOT
- National bridge conferences

National ABC Webinars
- FIU Webinars
- FHWA Webinars
Vermont Agency of Transportation
Using the SHRP2 ABC Toolkit for Hurricane Irene damaged bridges (17 bridges replaced)
Use of ABC Toolkit Concepts
Developed in SHRP2 R04
• Total prefabricated bridge
• 14 day closure
• 14 day ABC period
• Opened November 1, 2011
Keg Creek Bridge Rapid Replacement 2011

- IowaDOT Design – Conventional Construction
  - 6-month closure
  - ADT = 4000; 14 mile detour
- Redesigned for ABC by HNTB
  - Modular construction
  - 14 day ABC period (Road closure)
  - 3 span bridge
  - Jointless construction
  - Predecked steel beam units
Cross-Sections/Plan

UHPC Joints
• Seven local bidders
• Contract letting: February 2011
• Contractor: Godbersen-Smith, Ida Grove, Iowa
• Low bid: $2.67 million
• Bridge cost = $231 / SF
• Incentive / disincentive = $ 22,000 / day during 14 day ABC period
• HFL funds $600,000; SHRP2 funds $250,000
Prefabrication of Abutments and Piers
Completed within a single day
Two hydraulic breakers mounted on excavators
Crane with wrecking ball
Precast Abutment Assembly – Days 3 and 4
Precast Abutment Assembly – Days 3 and 4
• Pier caps: 168 kips
• Required two 110 ton cranes to lift into place
Erection of Superstructure Elements – Days 7 and 8

112 K

Span – 70 ft
Erection of the Superstructure Elements – Days 7 and 8
Semi-Integral Abutment – Suspended Backwall – Days 7 and 8

- Allows superstructure expansion / contraction
- Easy fit up
- Well suited for **rapid construction**
• Full moment transfer
• No post-tensioning required
• Only 6 in. wide; low-permeability
• Hairpin bars or straight bars
Precast Approach Slab — Day 10

Precast Sleeper Slab
• Weekend Replacement
• 20 Hr Closure
NY I-84 Bridges

- Over 75,000 ADT
- 16% trucks
- Existing bridges are too narrow for cross-overs
- Elevation differences between EB & WB roadways
- Underpassing road at 16% grade
Original Plan

- Build new temporary bridge in the median
- Build substantial cross-over roadway system due to grade differences
- Additional cost of approximately $2.0 M
- One construction season for each bridge
- Significant traffic impact
- Planned construction duration: 2 years
• Slide-In replacement over two weekend nights
• Traffic disruption on I-84 reduced from two years to two Saturday nights (20 hour closures).
Superstructure Sections

• NEXT beams
• Precast approach slabs
• UHPC closure pour
New Abutment Construction
New Straddle Bent Abutment – Modular Wingwalls

Drilled shafts supporting cap beam
Slide-In Replacement Concept

Temporary end span

Slide Surface

During Slide

Modular walls
End Diaphragm and Slide Shoe

Slide Shoe
Precast Approach Slabs – Temporary End Spans Carrying Traffic
7 hours to demolish existing bridge and slide in new bridge
Both Bridge Slides Completed 10 Months After NTP
ABC for Rehabilitation Projects
ABC for Bridge Rehabilitation

- Prefabricated elements provide
- Off-the-shelf ABC details and standards rarely work in a rehab situation.
- Modified standard ABC details or completely new details may be required.
- In a new bridge project, the designer has full control of all the dimensions from the ground up.
- In rehab, the accuracy and completeness of available bridge plans introduces added risks of proper fit-up
- There is increased risk of all elements fitting properly
- Field verify all dimensions -- *Lidar* surveys may be used
ABC Rehabilitation of Historic Franklin Avenue Bridge, Minneapolis, MN
Project Description

- Concrete restoration
  - Repair abutments, piers, arch ribs
- Replace existing deck, cap beams, railings
  - ABC methods
  - Precast elements (Deck panels, cap beams, ornamental railings)
  - Address functional needs
  - Restore historic features
- Project Construction Cost: $43.1 million
Functional Needs

• Address non-motorized travel (Multi-Modal)
Structural Updates

• Repair arch ribs, pier walls and abutments
• New deck, cap beams, railings, overlooks
• Polyester Polymer Overlay
• Reduce the number of deck expansion joints
ABC Preferred Option

- Staged construction not a viable option: Unbalanced arch loads and costly temporary supports

- Full closure was the least costly way

- Conventional construction would have taken two construction seasons.

- The bridge fully reopened to traffic Sept. 1, 2016 after being closed for only 16 weeks. (May 8 to Sept 1, 2016)
ABC Schedule

- Open to traffic 116 days after closure

Start of ABC – May 8th

End of ABC – September 1st
Deck Panels Assembly

UHPC joints with polyester polymer overlay for added protection
Deck Panels Erected Using Cranes
Precast Cap Beams
Polyester Polymer Concrete Placement
PENNDOT State Route 30 over Bessemer Ave.

- Abutment Rehab / Superstructure replacement in 57 hours
Quick Facts

• Project was let on 11/5/2015
• Low bidder: $2,333,212.
• Pre-Cast Abutment Caps, steel beam modules with concrete
deck/barrier, UHPC joints between the modules, pre-cast
approach slabs, rapid set LMC overlay
• ADT is 21,798 (2015) with 4% trucks
• No available detour for weekday traffic
ABC Design Decisions

- Limited as-built Information for bridge
- Choice of ABC method that fits site constraints and 57 hour closure period
- Skew, curvature, super-elevation considerations for ABC design
- Removal and replacement of deteriorated portions of abutment walls
- Approach slab replacement
- ABC connections with accelerated cure UHPC
- Lidar Survey
Weekend Closure (57 Hours) : Close Friday 9 PM

- Demolish superstructure, remove approach slabs and excavate backfill
- Saw-cut abutment along backface and remove sections
- Connect abutments caps with dowels
- Erect the six superstructure modules with cranes
- Erect precast sleeper slabs and approach slabs
- Place accelerated cure UHPC closure pours
- Reopen to traffic — **Monday 6 AM**
Abutment Rehab -- Precast Abutment Cap & Concrete Repairs
New Superstructure Cross Section

- 54’-0” Curved single Span
- Composite Steel Modular Superstructure
Module Erection
New Structure
Thank You

Q & A