ABC Concrete Bridges – Continuity Considerations

Francesco M Russo, PE, PhD
Michael Baker Jr Inc – Philadelphia, PA
Objective

- Discuss the process for creating continuity in ABC prestressed concrete bridges
ABC Variations

- “Ultra Fast” ABC
  - Closure times measured in hours
  - Prefabricated complete spans

- “Really Fast” ABC
  - Closure time measured in days
  - Might use prefabricated elements or complete modules

- “Selective” ABC
  - Use of certain ABC elements to accomplish time savings, i.e., decked bulb-t superstructures
Continuous Concrete Bridges And ABC

- Basic premise - Eliminate deck joints from the bridge
  - Reduced joint installation and maintenance costs
  - Protection of beam ends and pier caps
  - Improved ride quality
Design For Continuity

- Three concepts
  - “Full Section” continuity
    - Possible to design for continuous behavior for superimposed dead and live loads
  - “Deck Only” continuity
    - Only the deck is continuous
    - Spans behave as a series of simple spans
  - “No C.I.P. Deck” continuity
    - Continuous beam behavior without a c.i.p. concrete deck
- Each concept has unique design, construction and ABC implications
FULL SECTION CONTINUITY

Design and Construction Considerations
Full Section Continuity

- Requires girder ends to be embedded in a common diaphragm
- Requires connection for positive and negative moments to be established
Phase 1 – Girder / Span Placement

- Erect pretensioned girders
  - For some ABC projects this might happen at the “bridge farm”
- Forms and rebar are installed for deck slab
Phase 2 – Deck Placement / Span Assembly

- For ABC projects with c.i.p. decks, cast slab on erected girders in assembly areas
- Leave slab blockout for eventual closure pour and pier diaphragm
Phase 3 – Establish Continuity

- Form pier diaphragm and closure slab
- Place diaphragm and slab reinforcing
- Pour and cure the final closure
- Complete railing closures
Now What Happens?

- Subsequent applied loads (railing, FWS, LL+I) applied to a continuous system
- Remaining creep and shrinkage potential of the system must be resisted by the pier joints
  - Need to check joint effectiveness
  - Might still have to design as simple spans
Restraint Moment Effects – AASHTO 5.14.1.4

Creep in girder causes positive moment in the connection

Differential Shrinkage causes negative moment in the connection
Restraint Moments – Calculation Options

- Methods and theory date to the 1960’s
  - PCA Engineering Bulletin
    - “Design of Continuous Highway Bridges with Precast, Prestressed Concrete Girders”
  - NCHRP Report 322
    - “Design of Precast Prestressed Bridge Girders Made Continuous”
  - Software Programs
    - RMCALC from Washington DOT
Age Effects - AASHTO 5.14.1.4.4

- LRFD provides special exceptions if the continuity is established at 90 days or later
  - Computation of restraint moments not required
  - However...a positive moment connection is still required
- ABC implication – “old girders” can simplify the design requirements for continuity joints
JOINT DETAILS
+M Connection With Extended Strands
+M Connection With Bent Bars
-M Connection With Spliced Bars

- Construction compromise
  - Engineers don’t like to splice bars in regions of high stress. However, a Class C splice is the appropriate solution
  - Large bars required for some connections. Double laps can make this blockout large
  - ABC and traditional construction face the same issues

Lap Spliced Tension Bars
Grouted Splice Sleeve Couplers

- Unquowa Rd – Fairfield, CT
Mechanical Couplers

- Used to splice up to #6 bars
- Production rate – 600 per 2 man crew per shift
Typical Fixed Pier Diaphragm Condition

- Time consuming forming to conform to girder and pier top shape
  - It’s not hard – it just takes a while
  - Does this interfere with the “A” of ABC?
  - What benefit will you derive from continuity?
SAMPLE PROJECT

US89 over I-15 – Utah DOT
- 2 Span – 290 ft. total length
- SPMT span installation
- Deck closure pours for continuity
Full Section Continuity Summary

- Project conditions may impact the ability to achieve continuity
  - Required speed of construction might preclude the use of a c.i.p. closure pour. This is assumed to be rare however
- Full section continuity requires a more complicated forming and pouring operation
  - Might not be compatible with “ultra rapid” ABC
  - Would be more compatible with a multi-day closure for ABC
Full Section Continuity

- Practical Considerations
  - Evaluate time of construction vs. structural benefit
  - Continuity unlikely to materially affect the design
    - i.e. wont change girder depth or number of beam lines
    - So...in an ABC context is there really a benefit?
DECK ONLY CONTINUITY

Design and Construction Considerations
Deck Only Continuity

- Only requires the deck to be made continuous for "practical" reasons
  - i.e. reduced exposure of beam ends, ride quality
- May have some ABC advantages over full continuity due to simpler forming and reduced field pour volumes
Link Slab Concept

Transverse Cross-Section

- TYPE III AASHTO GIRDER
- 8"
- 3'  6'-11"  6'-11"  6'-11"  6'-11"  3'
- 33'-8"
- Link Slab
- 2" (Typical)
- Debonded
- 71'-6" (Typical)
- 73'-0"
Link Slabs

- Convenient option for establishing continuity between discrete spans
- Eliminates joints
- Do NOT provide structural continuity
- See...
  - *Behavior and Design of Link Slabs for Jointless Bridge Decks* – Caner and Zia – PCI Journal May June 98
  - *Field Demonstration of Durable Link Slabs*…* Research Report RC1471* – Michigan DOT
Link Slab Theory

- Slab provides minimal continuity over center supports
- Applied loads produce end rotations
- Slab is forced to bend / comply with the induced curvatures
Zia study recommends 5% debonding between slab and girder to allow for spread of cracking into a longer free length.
Link Slab Moments

\[ M = \frac{2EI\theta}{L} \]

- \( M = \frac{2EI\theta}{L} \) where \( E, I \) are of the slab, \( \theta \) is due to imposed loads and \( L \) is the design length of the link slab
- For \( L/800 \) deflection limit, \( \theta = 0.00375 \) rad
Design of Reinforcing

- Design reinforcing using 40% $F_y$ for imposed moments
- Space reinforcing for crack control
- Limit crack width to 0.013” – use $\gamma_e = 0.75$ for this condition
Link Slab Guidance

- Consider the effects of ALL sources of end rotations
  - Superimposed loads producing downward rotations
    - Governs top of slab tension steel
  - Possible camber growth
    - Governs bottom tension steel
  - Thermal gradients
    - Can affect either mat
Some Additional Guidance

- For instance....what if we are interested in thermal loads / gradients
  - Rotations due to these effects can be computed using the following procedure
    - *ASCE Journal of Bridge Engineering* March / April 2005

**Effects of Temperature Variations on Precast, Prestressed Concrete Bridge Girders**

P. J. Barr, M.ASCE⁴; J. F. Stanton, M.ASCE²; and M. O. Eberhard, M.ASCE³
MICHIGAN DOT AND U OF MI LINK SLAB STUDIES
- Performance of traditional link slabs in Michigan
  - Link slabs used to redeck / retrofit existing multi-span bridges to eliminate joints
  - Crack width of traditional link slabs was generally good
  - Performance found to be linked to reinforcing density and field execution
  - Some slabs with excessive crack width
    - Appear to be related to improper design and poor construction practices
Design and Field Demonstration of ECC Link Slabs for Jointless Bridge Decks
Michael Lepech and Victor Li

- Impose rotation corresponding to max span deflection i.e. L/800
- Use Engineered Cement Composites, a high performance fiber reinforced concrete for its high tensile capacity and crack tolerance
ECC Link Slab Features

- Use fiber reinforced and high tensile strength HPC to create more durable link slabs
- Reinforcing density much lower than traditional link slabs
- Early mixes shown to be shrinkage crack prone and susceptible to high skew
- Refined mix designs and 25° skew limit recommended
- 7 day wet cure required – ABC implication
I-84 OVER UPRR – REDECKING PROJECT

Innovative use of full depth precast decks in a link slab concept
- ABC redecking project
- Existing multi-span PC beam bridge
I-84 over UPRR

- 3 Span Simple Span Bridge w/ Joint Seals
- 85 ft., 78 ft., 75 ft.
- Project converted to 3-span jointless
Full Width Panel – Continuous Over Skewed
Transverse Joint Details

- Shear stud blockout typ.
- Fabricator responsible for connections matching on adjacent panels.
- Vertical adjustment typ.
- Equal spa at 2'-0" max. typ. 1"-0" typ.
- 1'-0" typ.
- 1'-0" typ.
**Keyway Details**

- **Fill Blockout with Non-Shrink GROUT**
- **Drop-in Hot Dipped Galvanized #6 x 2'-0" Splice Bar at 2'-0" Maximum Spacing**
- **Place Transverse Reinforcing Below Longitudinal Reinforcing as Shown Within Blockout**
- **HOT DIPPED GALVANIZED HSS 12" x 4" x 3/8" x 4"**
- **Foam Backer Rod**
- **Fill HSS and Area Above with Foam During Precasting Procedures**
“NO C.I.P. DECK” CONTINUITY
No C.I.P. Deck Continuity Concept

- Attain continuous structural behavior for bridges without a c.i.p. or precast deck

- Challenge
  - How to establish the –M continuity
O’MALLEY ROAD – ALASKA DOT
Typical Section

- ABC Concept – Decked Bulb T
- 2 Spans – 110 ft. each
Pier Diaphragm

- Extended strands for +M connection
- Hooked flange bars for –M connection

3 ft. closure pour
SIBLEY POND - MAINE
- Series of 79 ft. spans made continuous for LL
- Next Type D sections chosen for ABC
- ABC challenge – achieving continuity without a c.i.p. concrete deck
Longitudinal Continuity

- Bottom bars hooked into diaphragm
- Top bars spliced with couplers
  - Small gap would not allow lap splices
- HPC closure pour
CONCLUSIONS AND OBSERVATIONS
Conclusions & Observations

- Continuity can be achieved by
  - Full section continuity
  - Deck only continuity
  - No-Deck continuity
- Continuity details for ABC borrow many elements from conventional construction
Some Things to Consider

- May require special high early strength closure materials
- This is only a small part of complete ABC solutions
- Other activities such as railing completion still required
  - Maybe this takes the continuity connection off the critical path anyway?
Some Thoughts

- ABC can take a long time – just somewhere else
  - Once you get to the site everything needs to be simple, predictable and achievable
- Make the field work as simple as possible
  - Construct forms in advance
  - Pour as little concrete as possible
  - Simplify the operations
- Durability can not be sacrificed in the name of speed or we will just be out there doing it again
Potential New Solutions

- Could consider a precast link slab like the UDOT Taggart project to eliminate a c.i.p. closure
Acknowledgements

- Thanks to many who provided information
  - Mary Lou Ralls
  - Reid Castrodale
  - William Nickas
  - Mike Culmo
  - Utah DOT
  - My colleagues at Michael Baker

- The time is yours....