Segmental Bridge Technology – Established and Evolving

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FIGG
Segmental Bridge Topics Addressed

• Definition of concrete segmental bridge construction methods and related design considerations.
• The evolution of concrete segmental bridge technology over the past 30 years in the U.S.
• Design principles and practices that provide the economic and durability value for this structure type.
• Continuing evolution of the segmental bridge construction technology and related design concepts.
Definition of Segmental Bridges

Bridges, that are typically concrete box structure types, constructed using repetitive elements that are progressively connected together to form a completed structure. Construction Load Cases are particularly critical considerations in developing the design and building methods for segmental bridges.
SEGMENTAL BRIDGE APPLICATIONS

URBAN BRIDGES

LONG SPAN BRIDGES

ENVIRONMENTALLY SENSITIVE

LONG BRIDGES OVER WATER

ARCHES

CABLE STAYED BRIDGES

RAIL BRIDGES
Segmental Bridge Methods, Components and Evolution of the Technique
Segmental Construction Methods

- SPAN-by-SPAN (Precast)
- CANTILEVER (Precast or Cast-in-Place)
  > Balanced
  > Uni-Directional
- INCREMENTAL LAUNCH
  (Typically an Inefficient use of materials, so Not commonly used – need tangent or constant curvature)
Segmental Construction Methods

• Span by Span

JFK AirTrain, NY City
Segmental Construction Methods

- Balanced Cantilever

Sagadahoc Bridge, ME
Segmental Construction Methods

- Uni-Directional Cantilever (shown)
- Mixed Methods
Precast Joints

- Keys (i.e. no reinforcing across joints)
- Epoxy
  - Temporary Clamping
  - Temperature
Cast-in-Place Joints

- Reinforcing Bars
- Joint Preparation
- Bulkheads
Post-Tensioning (PT) Arrangements

Placement Type
• Internal Tendons
• External Tendons

Layout Orientation
• Longitudinal
  – Span by Span
  – Cantilever
• Transverse
• Vertical
Post-Tensioning (PT) Arrangements

- Internal Tendons
  - Transverse
  - Longitudinal (Cantilever)
Internal Transverse Pre-Stressing

Pre-Tensioning

Post-Tensioning
Post-Tensioning (PT) Arrangements

- External Tendons, Longitudinal Single Point Deviators
Post-Tensioning (PT) Arrangements

- External Tendons, Longitudinal Multi-Point Deviators
Post-Tensioning (PT) Arrangements

- Vertical Tendons
  (in Precast Piers)
Construction Engineering

- Camber
- Geometry Control
- Prestressing Parameters
- Erection Loads
- Erection Equipment
- Casting and Erection Manuals
- Integrated Shop Drawings
Precasting Yard Operations

- Pre-Tied Reinforcing Cage Jigs
- Casting Beds
  - Long Line
  - Short Line
- Storage & Delivery
• Long Line Segment Casting
• Short Line Segment Casting
TYPICAL CASTING YARD LAYOUT

1. Straddle Crane Runway
2. Casting Beds
3. Warehouse
4. Segment Storage
5. Rebar Jigs
6. Batch Plant
7. Segments in Storage
8. Possible Double Stack
9 Miles of Elevated Precast Segmental Bridge

JFK AirTrain, NY, NY
Precasting Facility - JFK AirTrain

- 5,500 Segments
- 14 Casting Cells
Precasting Facility - JFK AirTrain
Precasting Facility - JFK AirTrain
Segment Delivery

Trucked 100 Miles

JFK Airport
Camden, NJ
Barged 250 Miles
Cape Charles, VA
I-93 Viaducts & Ramps, Boston, MA
Precasting Facility – I-93 Viaducts, Boston
Precast plant 85 miles away by truck
Precasting Facility – I-93 Viaducts, Boston
Precast plant in Sanford, ME

- 15 Acres
- 1250 Segments
- Casting Cells
  4 Typ., 1 Combined
Precasting Facility – I-93 Viaducts, Boston
Central concrete delivery - casting 3 beds / day
Precasting Facility – Susquahanna River, PA.

- 1040 – Total Segments (958 Typical, 82 Specialty)
- 3 - Typical Casting Cells
- 1 - Specialty Casting Cell
• Assembly Line – Reinforcing Cage Jig
• Assembly Line – Casting Bed Set-Up
• Assembly Line – Segment Pour
• Assembly Line – Steam Cured Segments

Susquehanna River Bridge, PA
- Segment Storage Handling,
  Lifting with Strap under Wing

Susquehanna River Bridge, PA
• Segment Handling

Lifting with Bars through Lifting Holes
• Segment Storage

Three Point Supports
• Segment Storage

Double Stacking
## PRECAST SUPERSTRUCTURE
### Comparison Table

<table>
<thead>
<tr>
<th>Project:</th>
<th>Susq. (Pa.)</th>
<th>I-93 (Ma.)</th>
<th>JFK (NY)</th>
<th>Victory (NJ)</th>
<th>Sagadahoc (Maine)</th>
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<tbody>
<tr>
<td>No. Segments</td>
<td>1040</td>
<td>1250</td>
<td>5409</td>
<td>927</td>
<td>202</td>
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<tr>
<td>Max. Wt. (Tons)</td>
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<td>80</td>
<td>38</td>
<td>82</td>
<td>100</td>
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<tr>
<td>No. Typical Beds</td>
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<td>4</td>
<td>11</td>
<td>8</td>
<td>1</td>
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<tr>
<td>Casting Yard Size</td>
<td>20 A</td>
<td>15 A</td>
<td>N/A</td>
<td>N/A</td>
<td>12 A</td>
</tr>
</tbody>
</table>

Cast 1 Segment / Day / Bed
Precast Segmental Span-by-Span Construction
Typical Span-by-Span Erection

SECTION A-A
Typical Span-by-Span Erection

• Advance Truss to Next Span
Typical Span-by-Span Erection

- Deliver Segments
- Set Segments
Typical Span-by-Span Erection

• Deliver Segments
• Set Segments
Typical Span-by-Span Erection

- Deliver Segments
- Set Segments

- Epoxy Joints
- Join Segments
Typical Span-by-Span Erection

- Deliver Segments
- Set Segments
- Epoxy Joints
- Align Pier Segm.
Typical Span-by-Span Erection

• Deliver Segments
• Set Segments
• Epoxy Joints

• Align Pier Segm.
  • Thread Tendons
  • Cast Closure
Typical Span-by-Span Erection

• Stress Tendons
• Lower Truss and Repeat Process

SECTION A-A
Precast Span-by-Span Segments Erected using:

- Underslung Trusses
- Overhead Gantry
- Falsework Supports
ERECTION TRUSSES – Under Bottom Soffit
ERECTION TRUSSES – Under Wings
Deck Designed for Support Condition
ERECTION with OVERHEAD GANTRY
ERECTION TRUSS SUPPORTS

- Tower on Foundation
ERECITION TRUSS SUPPORTS

- Pier Bracket
Specialized Erection Equipment
Delivery of Segments from Above

WMATA, VA
SPAN-BY-SPAN CONSTRUCTION EXAMPLE

May 2007

Susquehanna River Bridge, PA
Susquehanna River Bridge, PA

**Existing Bridge**

**East End**

**Calver Island**

**West End**

**New EB**

**New WB**

**Casting Yard**

**Twin Bridges with each:**
- 5,910’ Long by 57’ Wide
- 40 Spans – 35 @ 150’, 5 @ 132’
- 21 River Piers
- 18 Land Piers
ERECTION PHASES

Susquehanna River Bridge, PA
Segments Delivered from Storage

Susquehanna River Bridge, PA
Segments Delivered from Above

Susquehanna River Bridge, PA
Susquehanna River Bridge, PA
Susquehanna River Bridge, PA
Segment Alignment

Susquehanna River Bridge, PA
Susquehanna River Bridge, PA
Susquehanna River Bridge, PA

ELEVATION

SECTION VIEWS
Activities Off the Critical Path

Susquehanna River Bridge, PA
Achieved Typical Span x Span Erection Rate of 2 Spans per Week

Susquehanna River Bridge, PA
VERTICAL CLEARANCES

RAILROAD LINES

Susquehanna River Bridge, PA

LOCAL AIRPORT
November 2004 - NTP
May 2007 - New Bridge Complete
Susquehanna River Bridge, PA
ADVANTAGES OF SPAN-BY-SPAN

- Quick, Simple Erection (2 - 3 Spans / Week)
- Easy Geometry Control
- Savings from less MOT
- Minimum User Delays
- Cost Effective
- Simple Design
- Durable Structures

Beautiful Bridges
Precast Segmental Balanced Cantilever Construction
Balanced Cantilever Erection

**ERECTION SEQUENCE I**

**PHASE 1 – STEPS 1 AND 2**

**STEP 1**
Foundations and Pier Shafts of all permanent piers in the main unit are constructed.

**STEP 2**
Construct Pier Table.

**PHASE 1 – STEP 3**

**STEP 3**
Erect Starter Segments.

**ERECTION SEQUENCE I**

**FIGG BRIDGE ENGINEERS**
Balanced Cantilever Erection

**ERECITION SEQUENCE II**

**PHASE 1 - STEP 4**
- STRESSING PLATFORM WITH FLOOR GRATING, HANDRAILS, ETC.
- MAIN SPAN
- BARGE MOUNTED CRANE

**STEP 4**
- TYPICAL CANTILEVER SEGMENT ERECTION

**PHASE 1 - STEP 5**
- STRESSING PLATFORM WITH FLOOR GRATING, HANDRAILS, ETC.
- MAIN SPAN
- BARGE MOUNTED CRANE

**STEP 5**
- ERECTION OF RADIAL CLOSURE SEGMENTS

FIGG BRIDGE ENGINEERS
Balanced Cantilever Erection

**Erection Sequence III**

**Step 1**
MOVE ALL CWT

**Step 2**
JACK MAIN SPAN APART USING SPECIFIED JACKING FORCE AND APPROVED METHODS

**Erection Sequence IV**

**PHASE I**

**Step 1**
REPEAT STEPS 1 THRU 7 AS DESCRIBED IN CANTILEVER 15 ERECTION
Precast Balanced Cantilever Segments Erected using:

- Barge-mounted cranes
- Ground based cranes
- Beam and Winch
- Overhead Gantry
Twin 3,971’ Long Bridges
Main Span Unit 330’, 440’, 330’
100’ Tall Precast Piers
SxS Appr., B.C. Main Span Unit

Victory Bridge, NJ
Victory Bridge, NJ
Victory Bridge, NJ
Balanced Cantilever Erection

Average production:
4 to 6 segments/day (45 ft)

Victory Bridge, NJ
1st Bridge Open to Traffic in 15 mo.
2nd Bridge Completed in 9 mo.

Victory Bridge, NJ
Cast-in-Place Segmental Balanced Cantilever Construction
1,248’ Long Twin Bridges with 398’ Main Spans

Wabasha Street Bridge, MN
Continue through the Winter

Wabasha Street Bridge, MN
Blending shapes, texture and color

Wabasha Street Bridge, MN
Segmental Bridges
Mixing Construction Erection Methods
3,000’ Bridge with 420’ Main Span over Kennebec River
68’ Roadway with 2 Cell Box Girder

Cast-in-Place Approach Units, with Precast Main Span Unit

Sagadahoc Bridge, ME
520,000 sf of Structures - Completed Nov. 2002

I-93 Ramps & Viaducts, Boston MA
Span-by-Span Construction

I-93 Ramps & Viaducts, Boston MA
Balanced Cantilever Construction

I-93 Ramps & Viaducts, Boston MA
- Span-by-Span Approaches
- One-Directional Cantilever Main Span

CIP low level piers

P/C high level piers

Mid-Bay Bridge, FL
Precast Segmental Piers
Precast Piers
Erect 1 Segment an Hour,
Approximately 1 Pier per Day

Direction of Erection
Precast Piers

First segment cast 6 weeks after NTP

Victory Bridge, NJ
Precast Piers Casting Bed

Victory Bridge, NJ
Typical Precast Pier Details

- Epoxy coated strands internal to concrete and grouted
- Secondary footing pour
- Blockout
- Water level
- Footing
- Single piece schedule 40 pipe (duct)
- Victory Bridge Pier

Points of Interest:
- Tendon duct
- PT tendon
- Blockout extents to be poured back
- Secondary footing pour
- Top of footing
- Duct from footing
- 4" recess
- 6" recess

Diagram details:
- Detail A
- Blockout detail A
Precast Pier Erection

Victory Bridge, NJ
Precast Pier Erection
Precast Pier Erection

Victory Bridge, NJ
Precast Pier Erection
Precast Pier Erection

Victory Bridge, NJ
Precast Pier Erection

Victory Bridge, NJ
Completed Precast Piers

First pier erected
5 months after NTP

Victory Bridge, NJ
Cable Stayed Segmented Superstructure
1st concrete cable-stayed bridge in the Northeast – 1995

U.S. Senator William V. Roth Jr. Bridge over C&D Canal, DE
Entirely Precast Segmental Bridge

U.S. Senator William V. Roth Jr. Bridge over C&D Canal, DE
Segmental Cable-Stay Bridges

I-280 Veterans’ Glass City Skyway, Ohio
1,225’ main span (2 @ 612’-6”)

Open June 2007

Penobscot Narrows Bridge & Observatory, Maine (1,161’ main span)

Open Dec. 2006
Veterans’ Glass City Skyway
Precast Superstructure
Completed in 8 Months

New Penobscot Narrows Bridge
Cast-in-Place Superstructure
Completed in 15 Months
CIP Balanced Cantilever Construction

Penobscot Narrows Bridge & Observatory, ME
Construction - Superstructure

Bridge Superstructure Type allowed for concurrent construction in 6 directions and friendly competition

Cianbro/Reed & Reed, Joint Venture - 1st Cable-Stayed Bridge

Penobscot Narrows Bridge & Observatory, ME
Penobscot Narrows Bridge & Observatory, ME
Carbon Fiber Composite Strand Demonstration Project

Penobscot Narrows Bridge & Observatory, ME
Veteran’s Glass City Skyway, OH
Typical Pre-Cast Cross-Sections: Main Span
Veteran’s Glass City Skyway, OH
Main Span Precast Segmental Construction

- Backspans: Span-by Span
- Mainspan: One-Directional Cantilever

Veteran’s Glass City Skyway, OH
• 3 pairs of segments erected in cantilever
  – Epoxied segment joints
  – Segments post-tensioned

Veteran’s Glass City Skyway, OH
Segmental Bridge Construction Benefits

• Rapid Construction
• Segments Delivered over Completed Spans
  – No Need for Barge Delivery
• Maintained Shipping Lanes at All Times
  – Access to Port of Toledo

Veteran’s Glass City Skyway, OH
Review Questions

• Define a segmental concrete bridge structure type?
• List 3 methods for constructing segmental bridges?
• List benefits during construction that result from using a segmental bridge construction technique?
• List permanent bridge site layout benefits resulting from using a segmental box girder bridge type?
• What structural benefits apply to using a closed cell box girder for a segmental bridge?
• What segmental bridge technological advances offer the most immediate benefits?
Open-ended Assignment Questions

Can you identify a viable candidate location for a segmental bridge given your understanding of the potential benefits from using this structure type?

What new innovative applications of the segmental bridge construction technique can you envision?
America
Deserves Beautiful Bridges