Prestressed Concrete Fabrication Process

Jordan Pelphrey, P.E.
Michigan Bridge Design Conference
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Introduction

- Oregon State University
- Prestressed Concrete Course at OSU
- Keith Kaufman – Adjunct Professor at OSU, from Michigan Tech (BSCE) and Purdue (MSCE, PhD)
- Graduate School – Research Project developing Oregon State-Specific Live Load Factors using Weigh-In-Motion data for ODOT
- Knife River Prestress 2006 – 2017
- Kerkstra Precast – 2017 – 2019
PCI

PCI → International Trade Association and Technical Institute
- Founded in 1954
- Promotes technical understanding and use of high-quality precast and prestressed concrete

Common Design Resources:
- PCI Design Handbook
- PCI Bridge Design Manual
CERTIFICATION

▷ PLANT CERTIFICATION
  - Ensures plants meet established quality standards

▷ ERECTOR CERTIFICATION
  - Ensures erection techniques meet industry standards

▷ PERSONNEL CERTIFICATION
  - Sets standards and verifies competence
  - PCI Level I/II/III
Precast Benefits

• Benefits
  • Construction Speed
  • Plant-Fabricated Quality Control
  • Fire Resistance and Durability
  • Greater Span-to-Depth Ratio
  • All-Weather Construction
  • LEED Points
  • Design Flexibility
  • Cost
Quality Assurance / Quality Control
PCI’s Big Beam Competition
HISTORY

Walnut Lane Bridge

- First Prestressed Concrete Bridge in the US
  - Precast, post-tensioned beams
- Constructed in Early 1950s
- Spans Lincoln Drive in Philadelphia, PA
- Designed by Gustave Magnel, a Belgian engineer, and Charles Zollman, Magnel’s student
- Since been replaced (with prestressed concrete girders) in ~1989
Prestressed Concrete

Two different types:
- Pretensioned
- Post-Tensioned
Materials

- Concrete
  - $f_{ci} \approx 5.0-7.5$ ksi, $f'c \approx 8.0-12.0$ ksi

- Prestressing Strand
  - $\frac{1}{2}'' \phi$, $\frac{3}{4}'' \phi$ Special and $0.6'' \phi$ (most common types)
  - $fpu = 270$ ksi, $fpj = 202.5$ ksi (@ 75%)
Stressing

Single Strand

Gang Pull

Harping
Fabricator Sections & Capabilities

• Know Your Fabricators and Their Sections & Capabilities
• [https://www.pci.org/](https://www.pci.org/)
Typical Precast/Prestressed Concrete Sections

- Bulb Tee
- Bulb I
- Voided Slabs
- Box Beams
- Deck Bulb Tees
- Tubs
- Segmental
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- Segmental
Void Drains
Tie Rod Hardware

Cardboard Voids

Load Indicating Washer (Squirter)
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Deck Bulb Tees

• Section Advantages
• Options for deck casting/HMA
Deck Bulb Tees
Deck Bulb Tees
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INTERIOR GIRDER - REDUCE ELEV.

EXTERIOR GIRDER - REDUCE ELEV.

INTERIOR GIRDER - INCREASE ELEV.

EXTERIOR GIRDER - INCREASE ELEV.
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Fabrication Considerations – Forms
Common Fabrication Issues

- Spalls
Common Fabrication Issues

• Stirrup Spacing Too Tight
Common Fabrication Issues

- Inserts and Hardware
Common Fabrication Issues

• Rock Pockets
External Post-Tensioning

• Viable option to increase capacity of Prestressed Concrete members in service
External Post-Tensioning
External Post-Tensioning
Sweep
Fabricator’s Bed Capabilities

- Stressing Equipment
- Force on Posts
- Force on Bed
Fabricator’s Bed Capabilities

- End Strand Pattern – Post Forces

\[ V = P_{\text{Jack}} \]

\[ M = (P_{\text{Jack}}) \times H \]
Build It and They Will Come

Section Development Case Study
Overview

• History of the BT90 Section
• Case Study
  • Chemult, OR → US97 over UPRR
  • South Medford Interchange
History of the BT90

- Bulb Tee Spanning Capabilities Prior to the BT90
History of the BT90

• Production of a Larger Girder Limited By:
  – Available Fabrication Bed Lengths
  – Adequate Shipping Equipment
  – Jacking Limitations
  – Industry Demand
Casting Bed Construction

\[ P_{\text{Jack}} = 3 \text{ Million lbs. @ 4 feet Eccentricity} \]
Form Installation
Stressing Setup

- (60) 0.6” Diameter Strands
- $P_{\text{Jack}} = 2,640$ kips
- (6) Holddown Points
  - Fabricator must account for adequate design of their facilities
Mt. Hood to Chemult
Design-Build
US97 Over UPRR
Chemult, OR
Chemult, OR

Project Information:

- US97 (2 Lanes & Shoulders) Over UPRR
- Existing Bridge: (3) Span Reinforced Concrete Deck Girder
- Existing Bridge Included a Straddle Bent over Railroad, and had a Severe Skew
- UPRR - Future Track Considerations
- UPRR - Vertical Clearance
New Section Development Process

March 2005:

- Contractor Contacts Precast Fabricator
- Requests New Section Capable of Spanning 170 feet
- Fabricator’s Shipping Capacity at 185 kips
- Fabricator Proposes BT90 at 177 feet
- Contractor Directs Engineer To Consider BT90
New Section Development Process

April 2005:
- BT90 Proposed to Owner as Alternative
- Owner Reviews and Requests BT90 Be Considered
- Engineer, Contractor & Fabricator Reevaluate and Agree to Proceed with BT90 Option

Girder Properties:
- $f'_{ci} = 7,000$ psi
- $f'_{c} = 9,000$ psi
- (60) 0.6” Diameter, Grade 270, Low-Lax Strands
- $L = 183’-3”$ o.-o.
- Weight = 185 kips
New Section Development Process

May 2005:

- Notice to Proceed by Contractor
- ODOT Develops Bulb Tee 90 Standard Drawing
- Fabricator Orders New Form
- Engineer Completes Contract Drawings
- Fabricator Develops Shop Drawings
New Section Development Process

June 2005:
- Materials Ordered
- Forms Installed
- Bed Hardware is Engineered and Installed
- Production Begins

July 2005:
- Girders Shipped and Erected
Fabrication
Loading on Trucks

- Max grade ~ 7%
- Exact route must be checked
- Permits issued
Transportation

4 Pilot Cars per Truck
Transportation

- Up the Mountain and Through the Tunnel
- 7% Grade at 10 MPH with Construction in the Tunnel!
Erection
Chemult Recap

• Chemult Project Originally Supposed to use Box Beams
• BT90 Met Industry Demands
• Allowed Structure Type to be Constructed
• Opened the Door for Future Long-Span BT90 Projects!
BT90 Development

South Medford Interchange:
• Highland Drive Over Bear Creek
• (34) BT90’s in Southern Oregon
• Originally Supposed to be BT84’s
• Project Demands Pushed the Span Length → BT90 = Perfect Solution!
BT90 Development - South Medford Interchange

Shipping:
Where to Now?

How to Start Down the Road of Precast?
  • Where to start?
  • What to do before reaching out?
  • Preliminary design/full design?
  • Are there span tables?
  • What all do the fabricators do?
  • Relationship between various entities?
Thank You!
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Specialty/Innovative Precast Solutions

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Michigan Bridge Design Conference
March 17, 2021
Overview

Projects to Discuss:
  • Springwater Road Bridge
  • Burnt River Bridge
  • Spencer Creek
  • OMSI Viaduct
  • Precast Fascia Panels
  • Murphy Road Bridge
  • Precast Post-Tensioned Tubs
  • Pedestrian Bridges – Precast Deck Panels & Pylons
Springwater Road

- Bridge Location
Springwater Road

- Colorado Tubs
Springwater Road

- Innovative Construction Solution
- Precast End Segments
- Pier Segments
  - Initially CIP
  - Changed to Precast through VE proposal
Springwater Road

- Contract Awarded based on two parts:
  - Project Proposal (VE included in Spec)
  - Price Proposal

<table>
<thead>
<tr>
<th>6. Value Engineering</th>
<th>Points: 0 – 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe your firm’s methodology and experience with Value Engineering (VE). Identify any particular successful experiences and/or unique services in this area. Share any significant lessons learned on innovative delivery projects and provide a narrative on how you would approach the issues differently. How would you apply the lessons learned in those experiences on this project?</td>
<td></td>
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</tbody>
</table>

Does your team see any potential value engineering proposals that could be applied on this project that could save time and/or money? What are they and do you see any value engineering proposals being implemented?
Springwater Road

- Stage I Construction

SUBSTRUCTURE AND TEMPORARY TOWERS
Springwater Road

- Stage II Construction
Springwater Road

- Stage III Construction
Springwater Road

- Stage IV Construction
Springwater Road

• Stage V Construction
Springwater Road

• Stage VI Construction
Springwater Road
Springwater Road
Springwater Road

Pier Segment Moment Diagram

PT Equivalent Loading Moment Diagram

Apply PT
Springwater Road

- Pier Segment Moment Diagram
- Add Deck, Sidewalk, Rails
- PT Equivalent Loading Moment Diagram
- Deck/SW/Rail Loading Moment Diagram
Springwater Road

• Fabrication (Pier Segments Shown)
Springwater Road

- Precast Pier Segments
Springwater Road

- 120,000 LBS
- 95-feet long
Springwater Road

• Straight Segments ~ 140,000 LBS, 141-feet long
Springwater Road

Installing and Caulking the PT Duct Splices:
Springwater Road
Precast Deck Panels

• Burnt River Bridge
Burnt River

- Bridge Location
Burnt River
Plant Fit-Up
Site Prep
Erection
Erection
Burnt River Bridge
Spencer Creek – 3D Model
Spencer Creek – Plant Stripping & Tensioning
Spencer Creek – Rolling the Arch
Spencer Creek – Construction

80 Ton Precast Arch Rib Segments
Spencer Creek – Foundation
Spencer Creek – Columns & Caps
Spencer Creek – Precast Fascia
Spencer Creek
OMSI Viaduct Bridge
OMSI Viaduct
OMSI Viaduct

Bridge Info
- Length = 425 FT
- Four Spans (BT60)
  - 118’/115’/125’/67’
- Streetcar Loading
- (4) BT60 Girders
OMSI Viaduct

Site Challenges → Vertical Clearance
- Overhead Utilities
- Railroad Tracks Below
OMSI Viaduct

The Solution → Vertically Curved Girder
– ~13” of Built-In Camber
OMSI Viaduct

Fabrication Challenges

- Form Modifications
- Stressing
- Casting
- Shipping
OMSI Viaduct

Form Geometry
- Segmented Versus Curved
- Custom Soffit
- Side Form Wedges
OMSI Viaduct

Form Geometry

Form Wedges
OMSI Viaduct

Strand Pattern

**FIGURE 2 STRAND PATTERN (BEAMS 2A-2D)**

Scale: 1" = 1'-0"

(45) 7/8" GRADE 270 KS LOW RELAXATION STRAND, PULL TO 31 KIP EACH
DETAILS SYMMETRICAL ABOUT THE CENTERLINE UNLESS OTHERWISE NOTED.
OMSI Viaduct

Strand Hold-Up Devices

9 KIPS

4 KIPS

6 KIPS
OMSI Viaduct

Strand Profile
OMSI Viaduct

Form Stripping, Product Picking, & Storage

Stripping

Picking

Storage
OMSI Viaduct

Shipping
OMSI Viaduct

Girder Erection
OMSI Viaduct

Completed Deck & Tracks Below In Use
Precast Fascia Panels
Precast Fascia Panels

Design
- Design Guidelines & Loads
- Connection Type

Typical tie-back connection

Component | Mode of Failure
--- | ---
1 | Shear of Weld
2 | Flexure of Angle
3 | Buckling of Rod
4 | Shear of Weld
5 | Flexure of Plate
6 | Concrete Pull Out

Panel Loading

Gravity Loading

Seismic Loading Parallel to Panel Face

Seismic or Wind Loading Perpendicular to Panel Face

Plan

Exterior Face of Panel

Distribution Reinforcement

Load Direction

Note: Load analysis for this case is done with \( F_y \) applied as a uniformly distributed load along the panel's length.
Fascia Panel Considerations

Design
- Panel Size & Weight
- Tolerances (Steel & Precast)
- Project History & Experience
- Specifications & Drawings
Fascia Panel Considerations

**Fabrication**
- Handling
- Shipping
- Erection
- Construction Staging
- Contractor Forming
Fascia Panel Considerations

Specifications
- Form Liners
- Finish/Color
- Price $$

Maintenance
- Inspection
- Replacement
Columbia River Gorge National Scenic Area

• Established by Congress in 1986

• I-84 Corridor Strategy – November 2005
  • ODOT – Regions 1 and 4, Technical Services
  • Columbia River Gorge Commission
  • USDA Forest Service
  • Federal Highway Administration
  • Hood River, Multnomah and Wasco Counties
  • Consultant - OTAK, Inc.

• Provides framework for ODOT to manage and improve I-84 facilities within the CRGNSA.
I-84 Corridor Strategy
Columbia River Gorge Bridges

- Cascade Locks
  - EB and WB I-84 (Twin Bridges)
  - Single Span Precast Box Beams
- Moffett Creek Bridge
  - EB I-84
  - Three-Span Steel Plate Girders
- Mosier Creek
  - EB and WB I-84 (Single Bridge)
  - Single Span 90” Precast Bulb Tees
- Fifteen Mile Creek
  - EB and WB I-84 (Single Bridge)
  - Two-Span 84” Precast Bulb Tees
Cascade Locks
Cascade Locks
Cascade Locks - Fabrication
Cascade Locks
Cascade Locks - Connection
Cascade Locks
Mosier Creek
Mosier Creek Bridge – Top Connection
Mosier Creek Bridge – Bottom Connection
Mosier Creek – Fabrication
Mosier Creek – Access Hatch
Fifteen Mile Creek
Fifteen Mile Creek
Other Specialty Solutions

- Floor Beams (pictured here)
- Parabolic Bottom Soffit
- Precast Tubs
- Pedestrian Bridges:
  - Deck Panels
  - Pylons
Parabolic Bottom Soffit
Precast Post-Tensioned Tubs
Precast Deck Panels – Pedestrian Bridges
Precast Pylons
Thank You!

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