Prestressed Concrete Fabrication Process

Jordan Pelphrey, P.E.

Michigan Bridge Design Conference

March 17, 2021

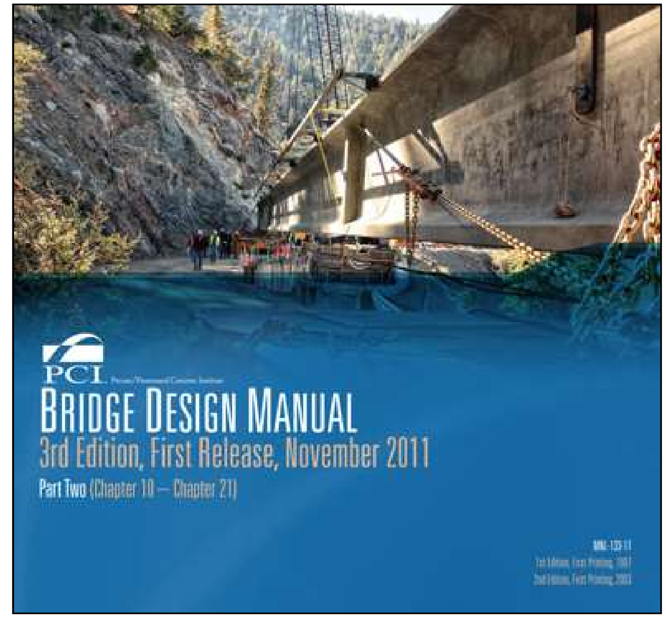
Introduction

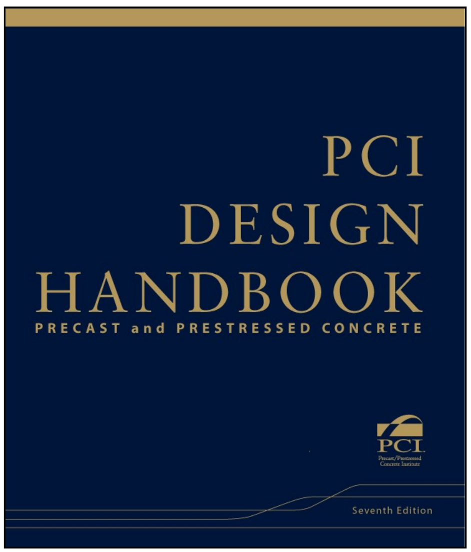
- Oregon State University
- Prestressed Concrete Course at OSU
- Keith Kaufman – Adjunct Professor at OSU, from Michigan Tech (BSCE) and Purdue (MSCE, PhD)
- Graduate School – Research Project developing Oregon State-Specific Live Load Factors using Weigh-In-Motion data for ODOT
- Knife River Prestress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

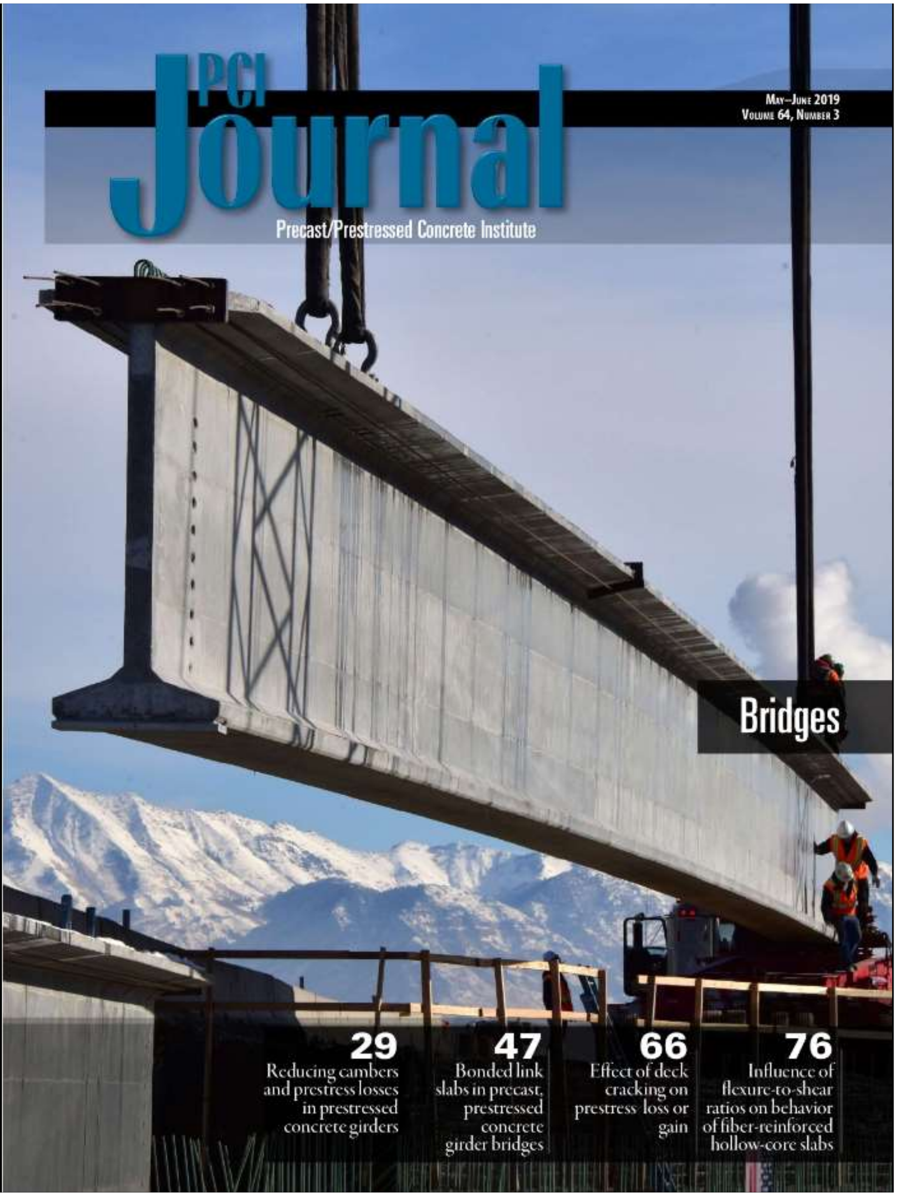




Common Design Resources:

PCI Design Handbook

PCI Bridge Design Manual



CERTIFICATION

PLANT CERTIFICATION

- Ensures plants meet established quality standards

ERECTOR CERTIFICATION

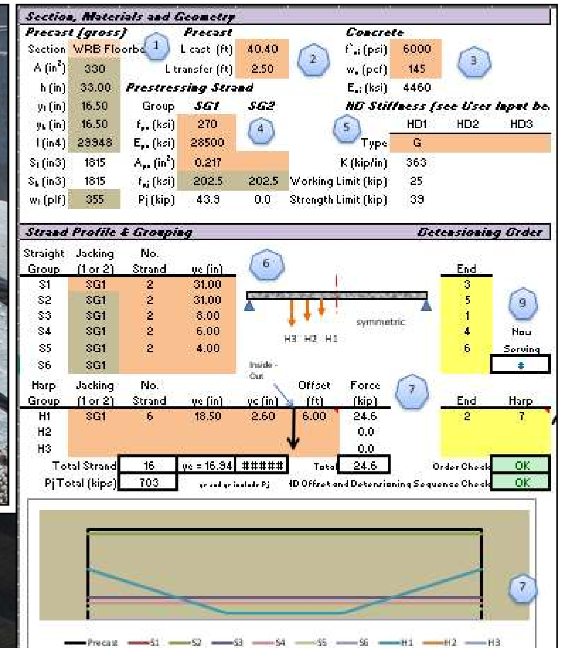
- Ensures erection techniques meet industry standards

PERSONNEL CERTIFICATION

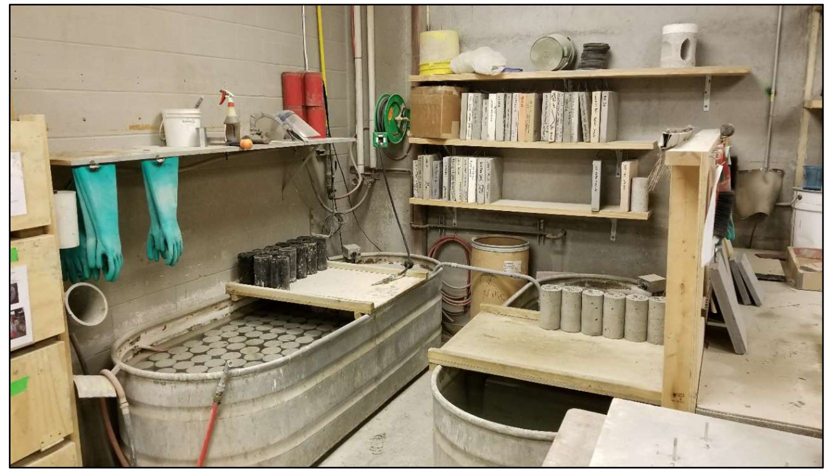
- Sets standards and verifies competence
- PCI Level I/II/III

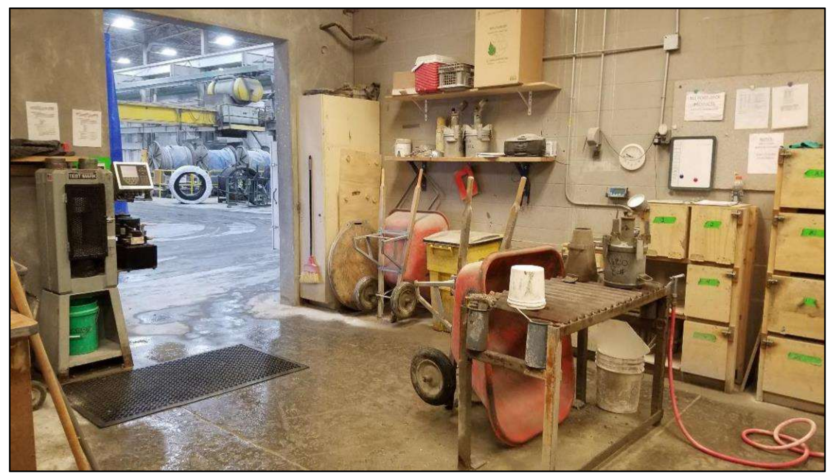
Precast Benefits

- Benefits
  - Construction Speed
  - Plant-Fabricated Quality Control
  - Fire Resistance and Durability
  - Greater Span-to-Depth Ratio
  - All-Weather Construction
  - LEED Points
  - Design Flexibility
  - Cost

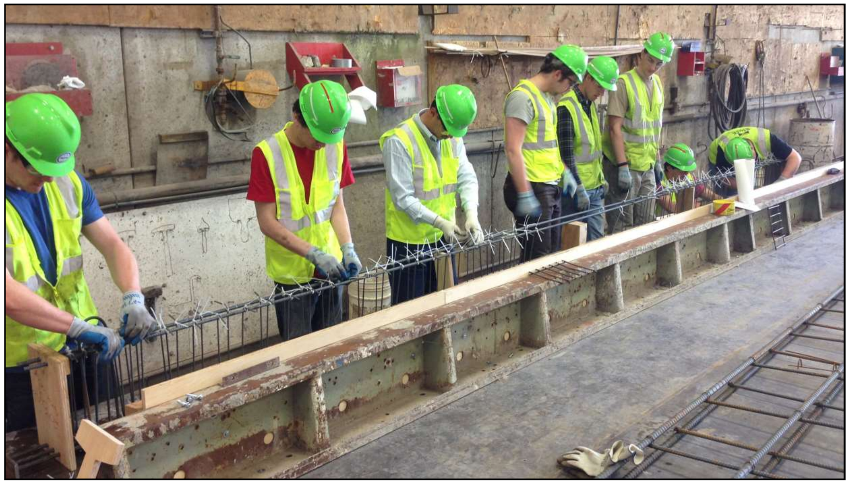


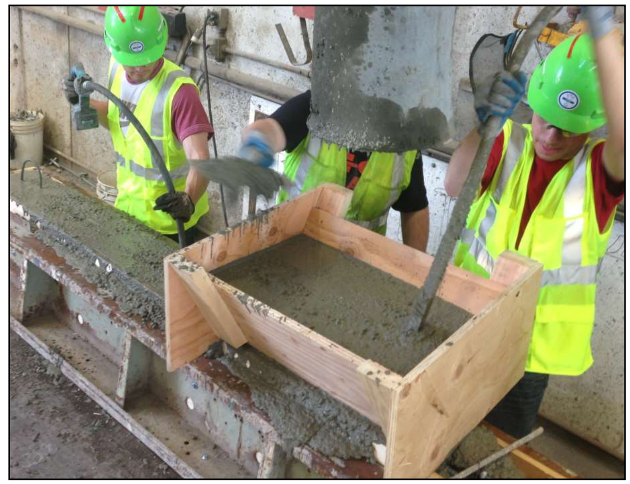
Quality Assurance / Quality Control

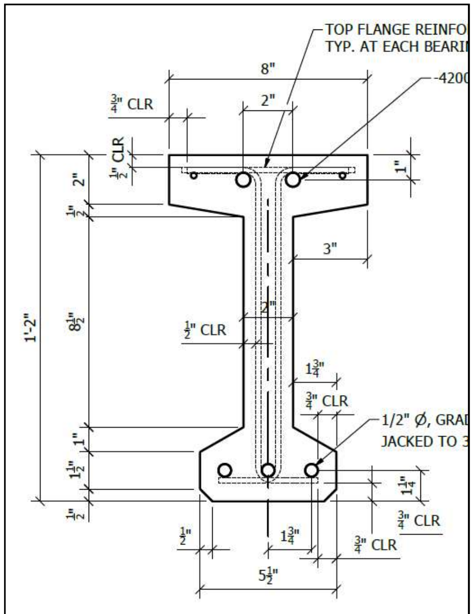




PCI’s Big Beam Competition







TYPICAL SECTION A-A

SCALE: 3" = 1'-0"

PCI

HISTORY

Walnut Lane Bridge

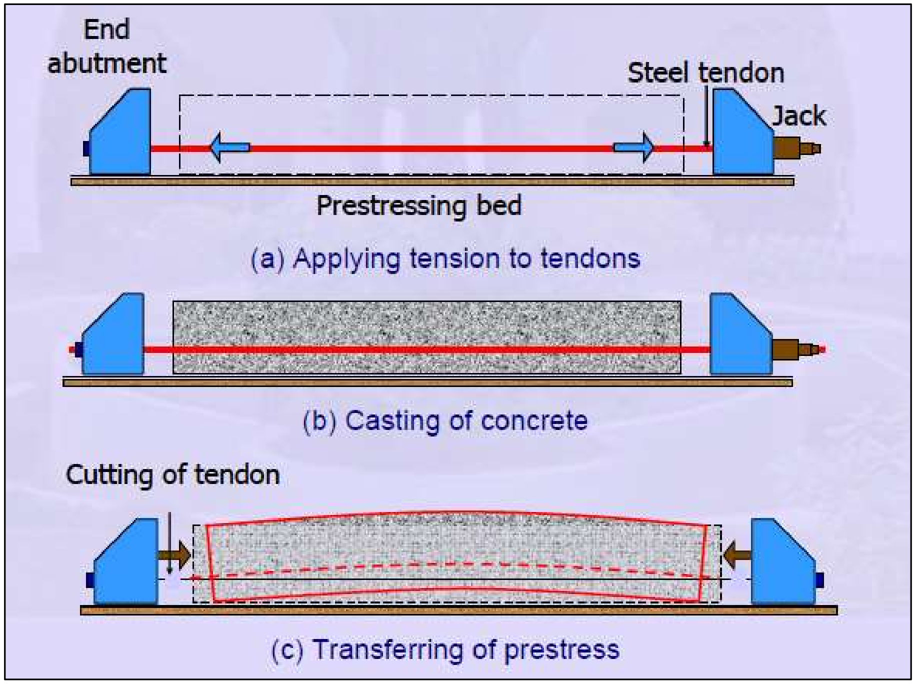
- First Prestressed Concrete Bridge in the US
  - Precast, post-tensioned beams
- Constructed in Early 1950s
- Spans Lincoln Drive in Philadelphia, PA
- Designed by Gustave Magnel, a Belgian engineer, and Charles Zollman, Magnel's student

- Since been replaced (with prestressed concrete girders) in ~1989

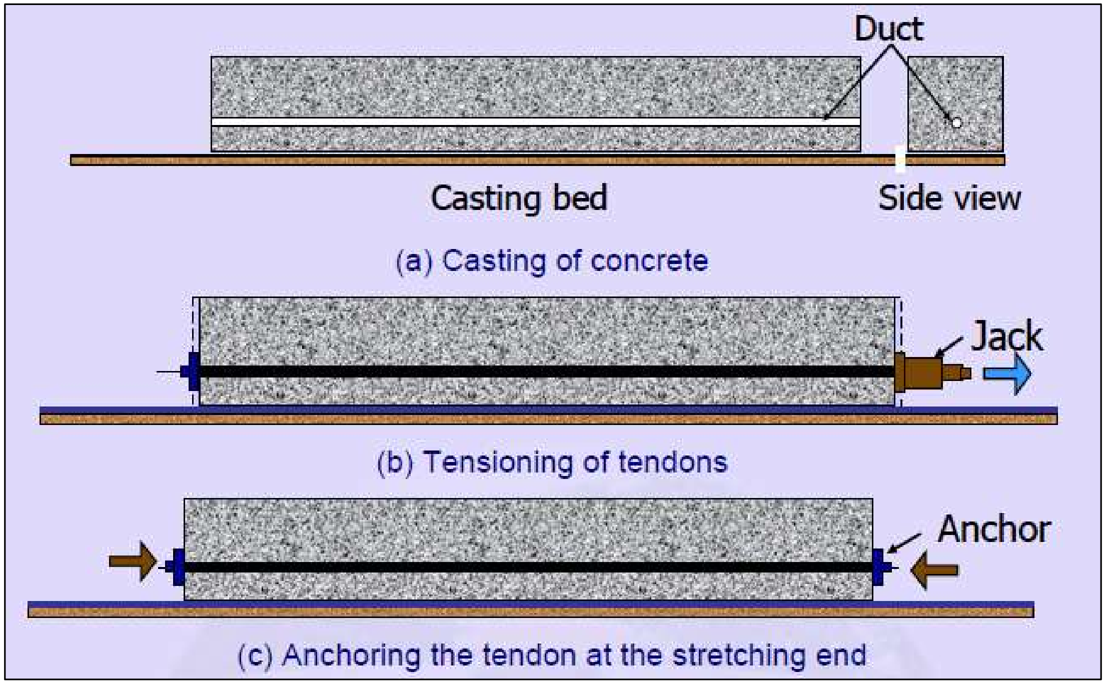
Prestressed Concrete

Two different types:

- Pretensioned

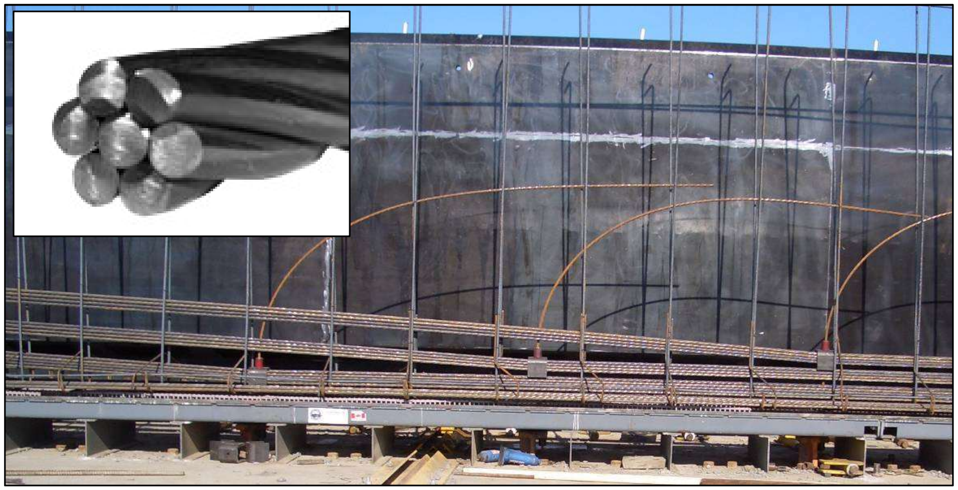


- Post-Tensioned



Materials

- Concrete
  - f’ci ~ 5.0-7.5 ksi, f’c ~ 8.0-12.0 ksi
- Prestressing Strand
  - ½”ø, ½”ø Special and 0.6”ø (most common types)
  - fpu = 270 ksi, fpj = 202.5 ksi (@ 75%)



Stressing

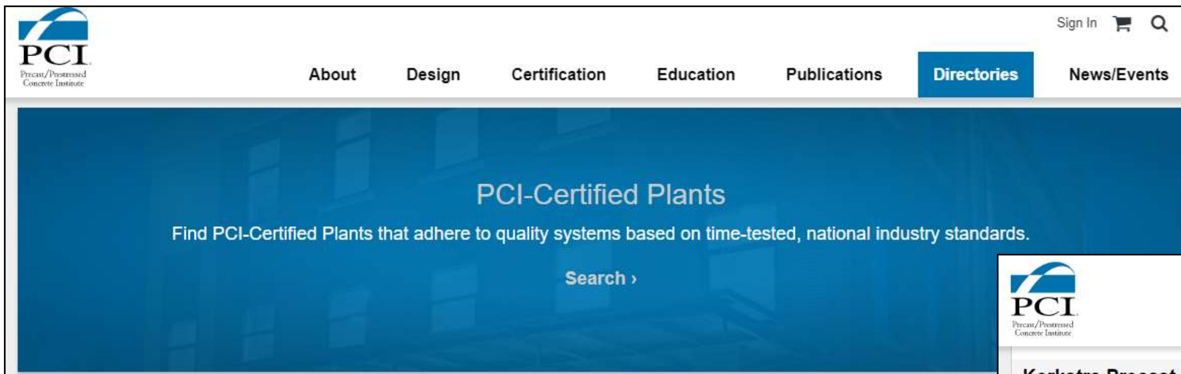
Single Strand

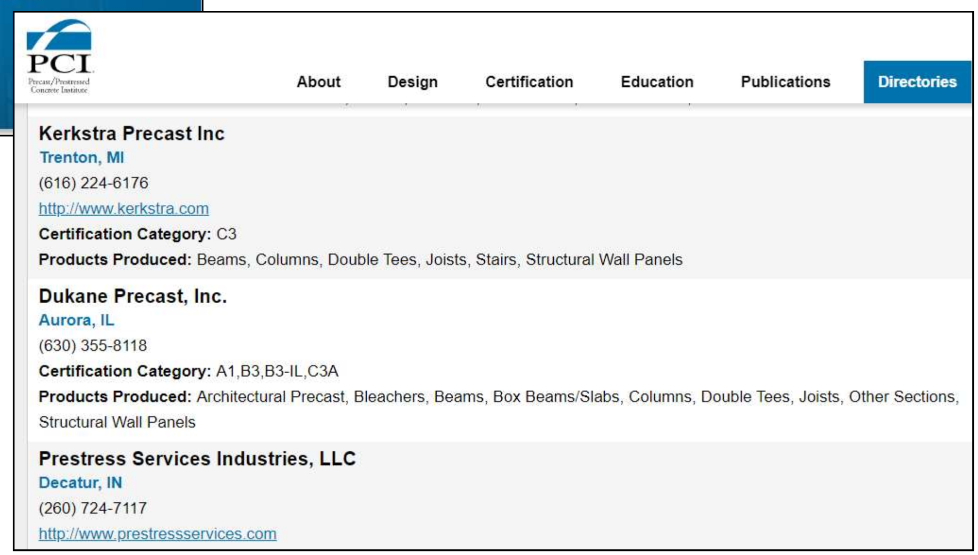
Gang Pull

Harping

Fabricator Sections & Capabilities

- Know Your Fabricators and Their Sections & Capabilities
- https://www.pci.org/





Typical Precast/Prestressed Concrete Sections

- Bulb Tee
- Bulb I
- Voided Slabs
- Box Beams
- Deck Bulb Tees
- Tubs
- Segmental

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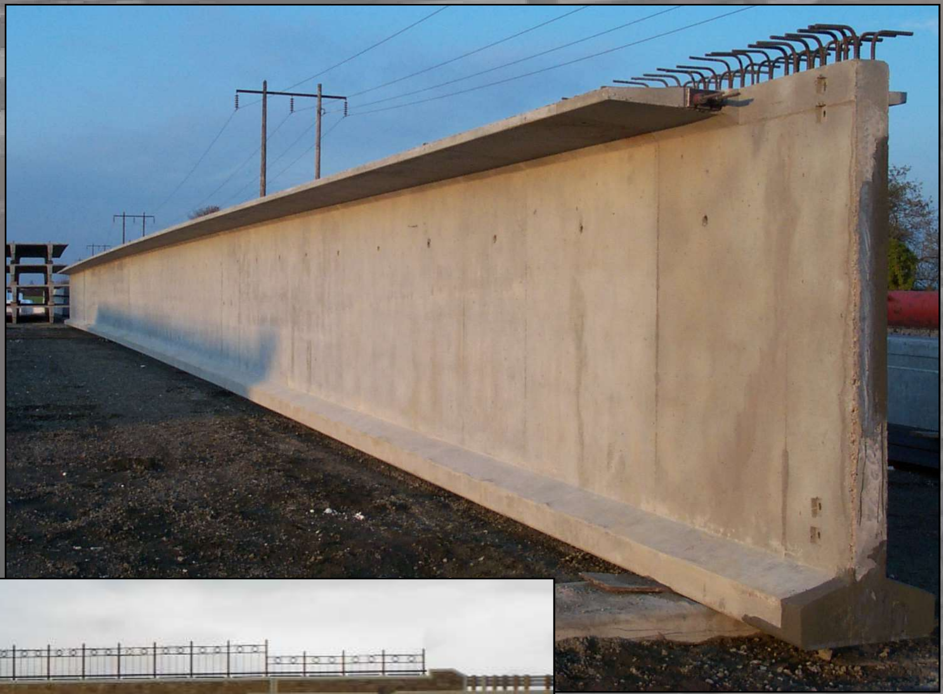

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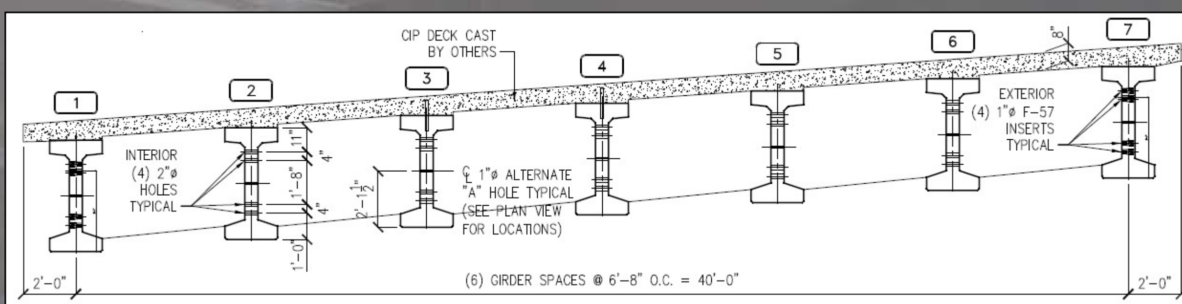

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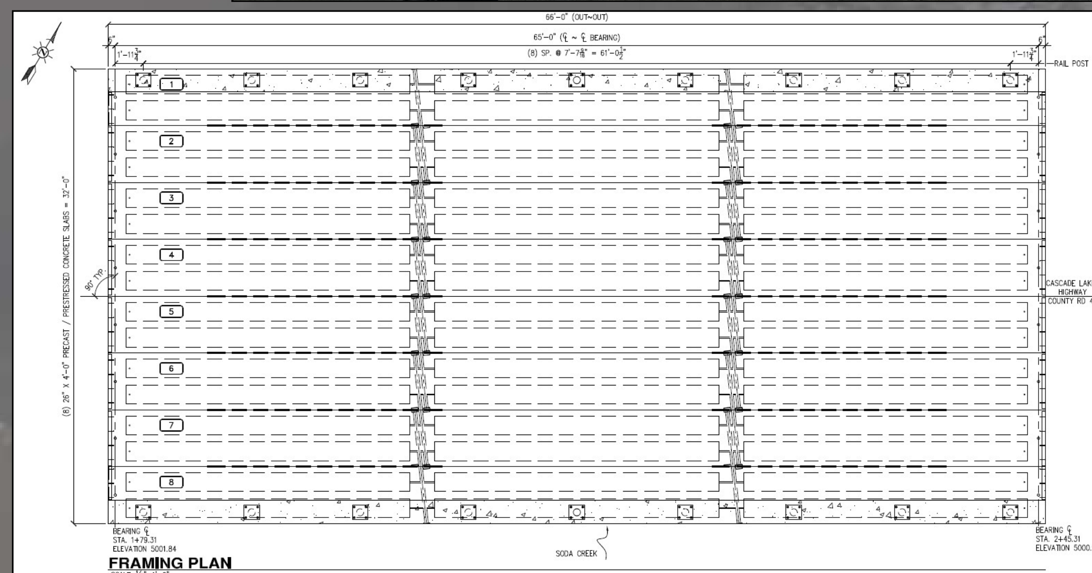

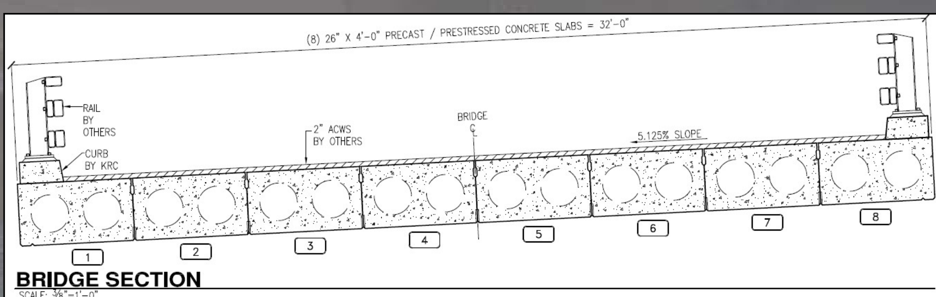

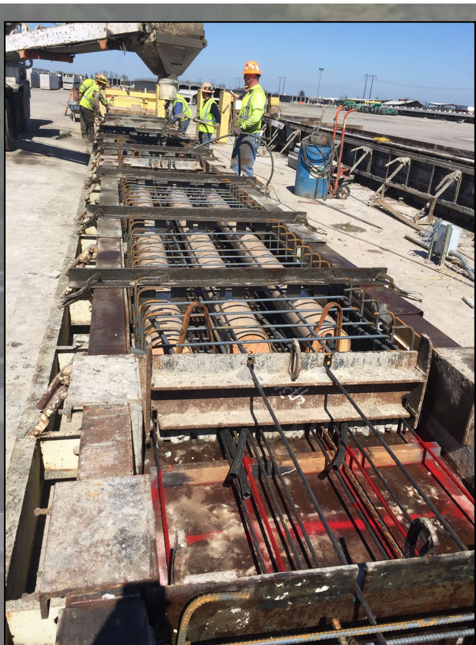

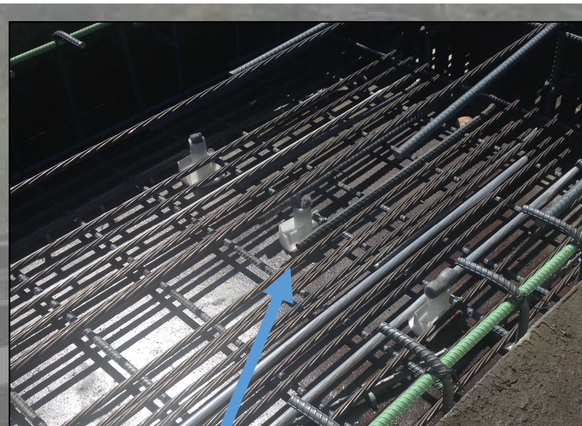

Void Drains

Tie Rod Hardware

Cardboard Voids

Load Indicating Washer (Squirter)

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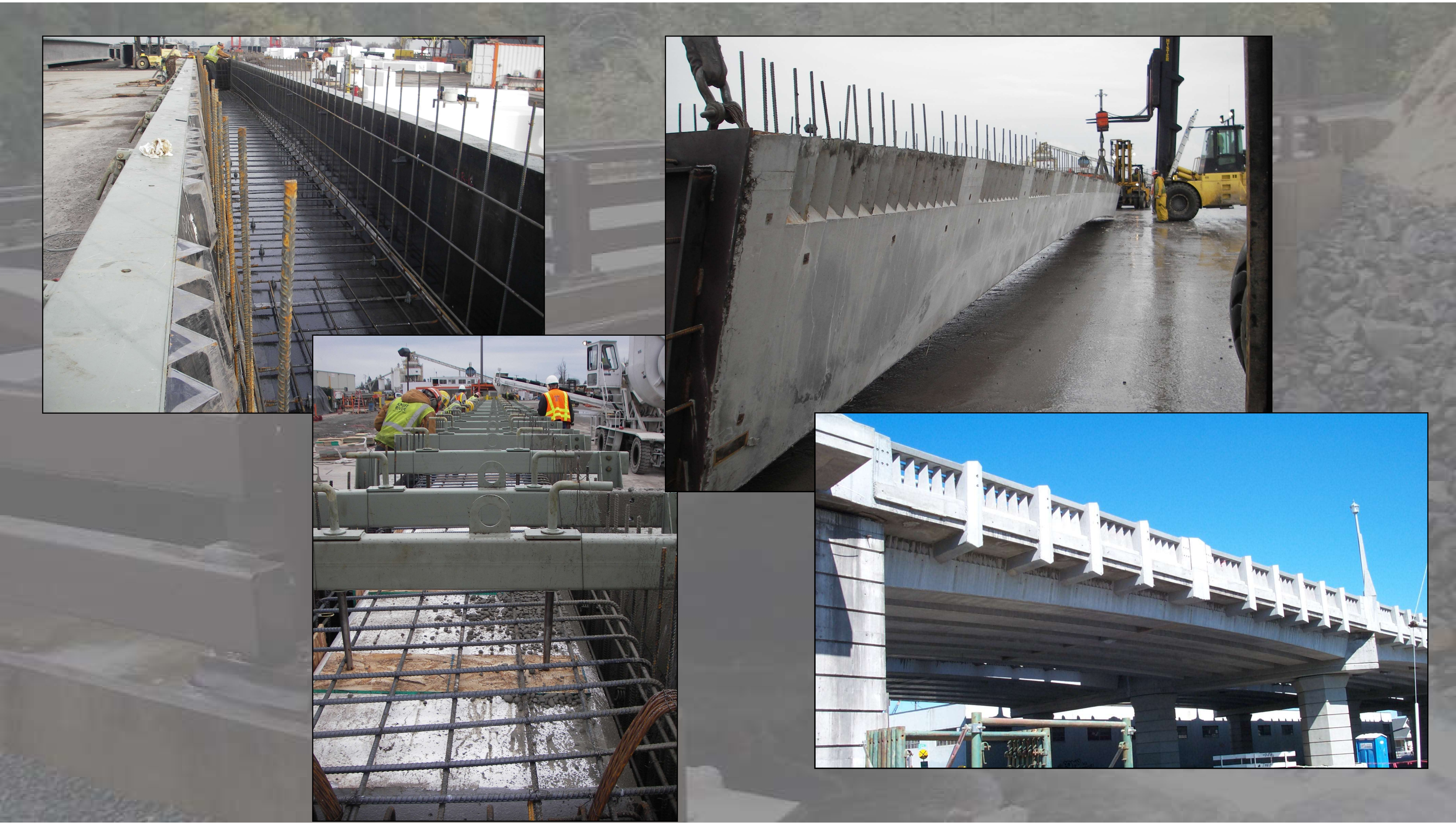

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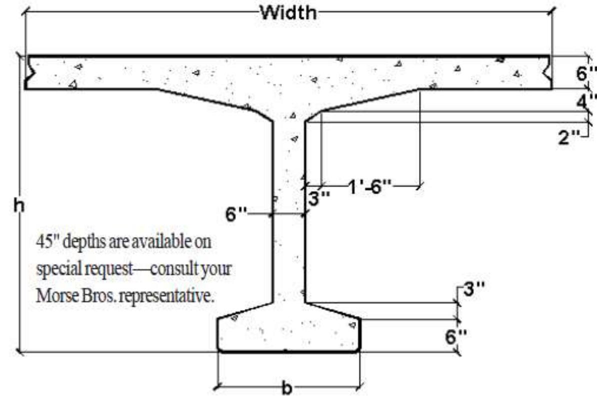
Deck Bulb Tees

- Section Advantages
- Options for deck casting/HMA

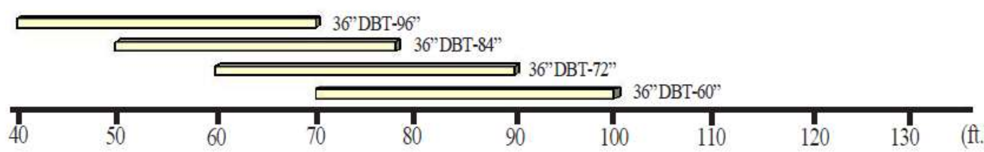
Deck Bulb T



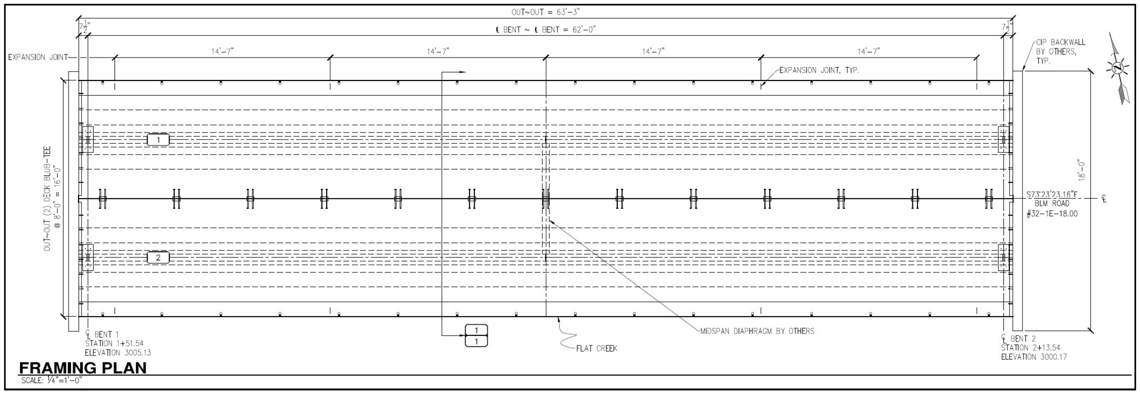
Section Properties (gross)

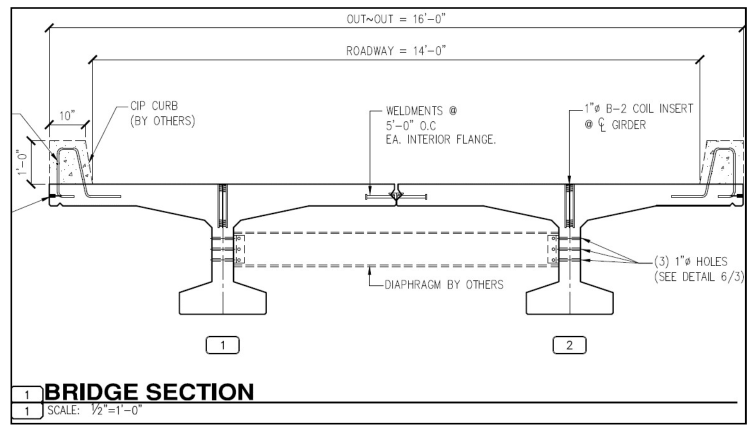
Width	h (in.)	b (in.)	A (in.²)	I (in.⁴)	y_b (in.)	S_t (in.³)	S_b (in.³)	V/S (in.)	wt. (plf)
60	36	24	771	115491	23.11	8960	4997	3.62	803
72	36	24	843	122143	23.96	10145	5098	3.57	878
84	36	24	915	127782	24.67	11278	5180	3.51	953
96	36	24	987	132630	25.28	12372	5246	3.46	1028

Estimated Span Length (ft.)



Deck Bulb Tees





Deck Bulb Tees

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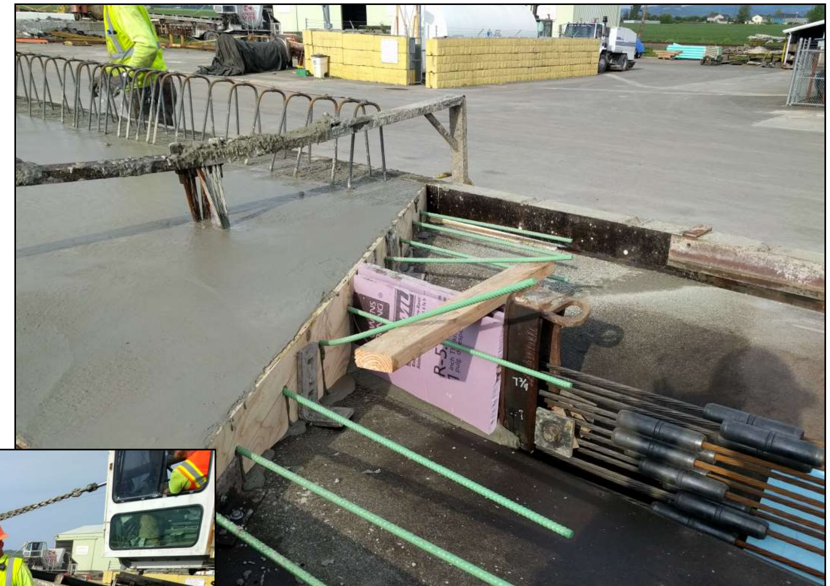

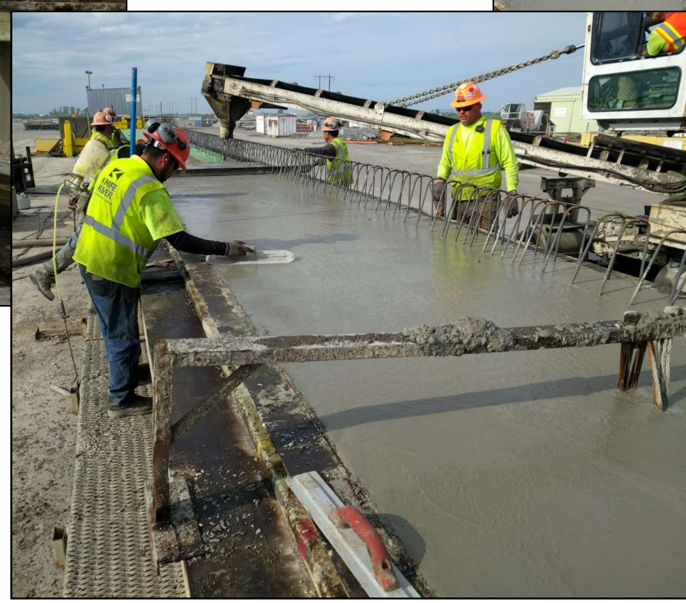

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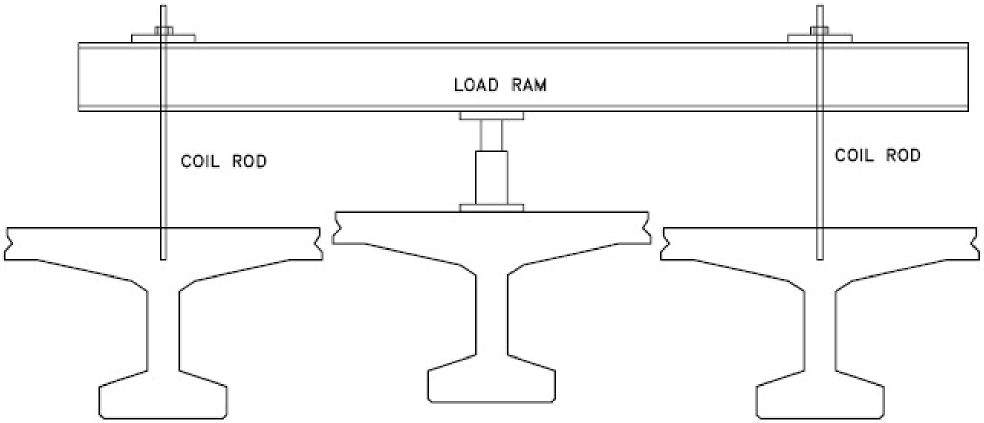
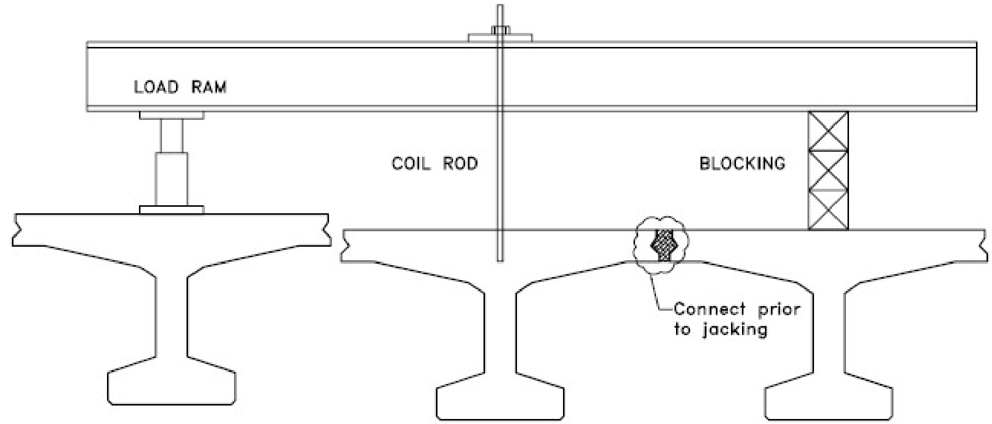
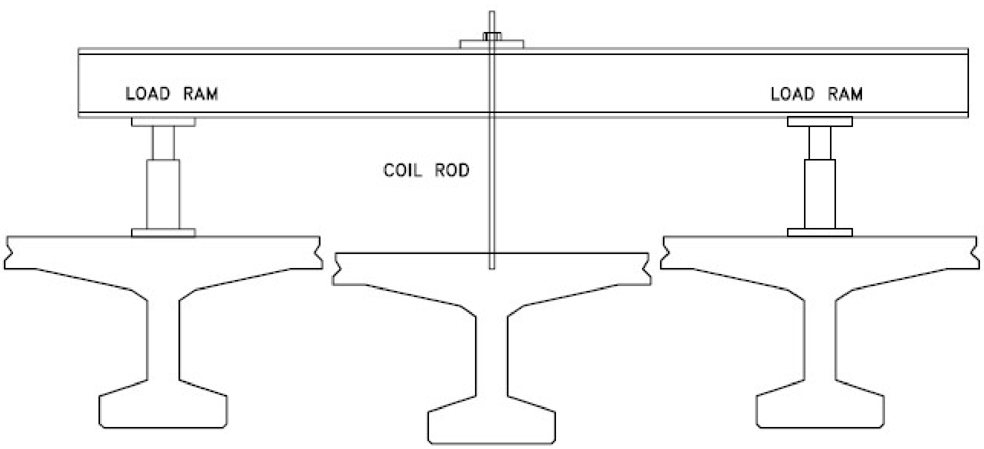


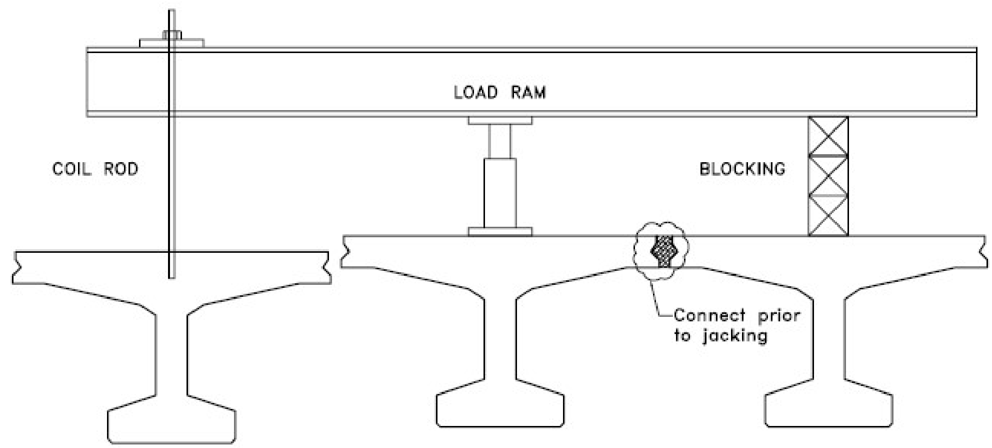
INTERIOR GIRDER - REDUCE ELEV.



EXTERIOR GIRDER - REDUCE ELEV.



INTERIOR GIRDER - INCREASE ELEV.



EXTERIOR GIRDER - INCREASE ELEV.

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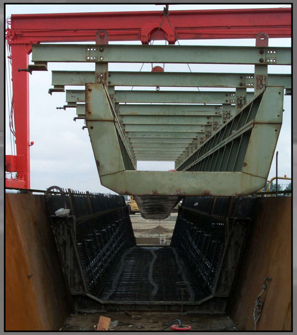

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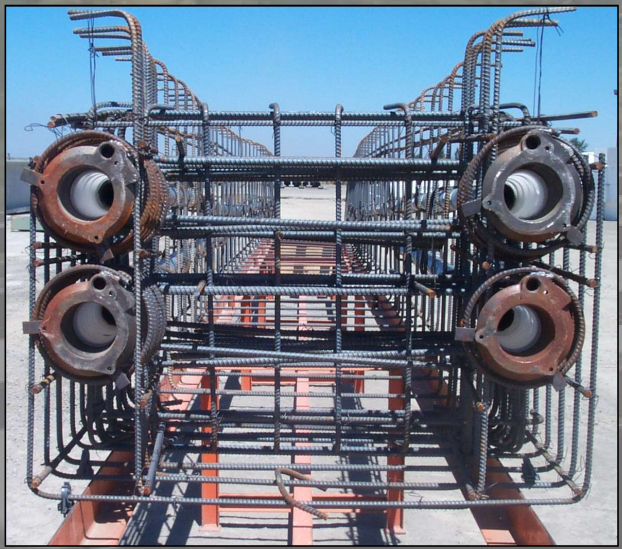
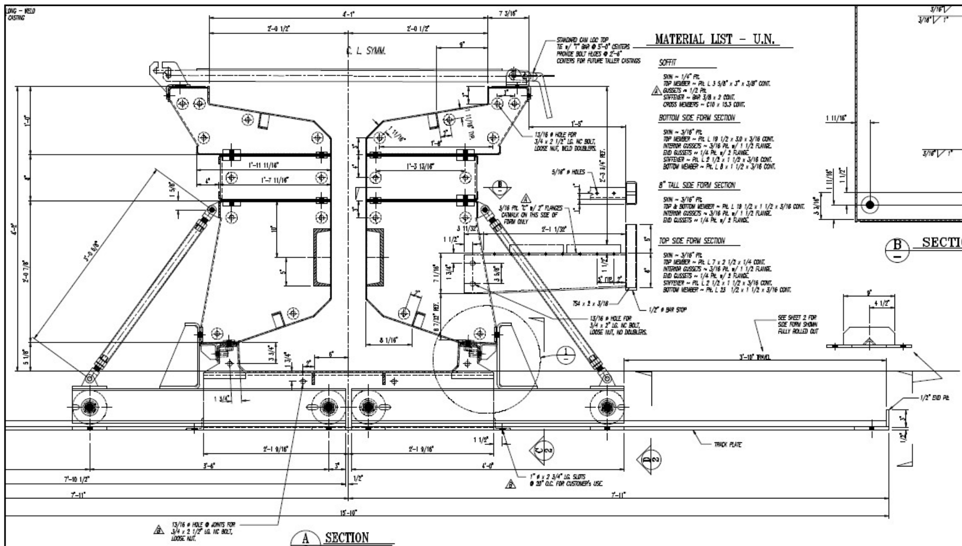



OVERSIZE LOAD

Fabrication Considerations – Forms



Hamilton Form Company, Ltd.

Common Fabrication Issues

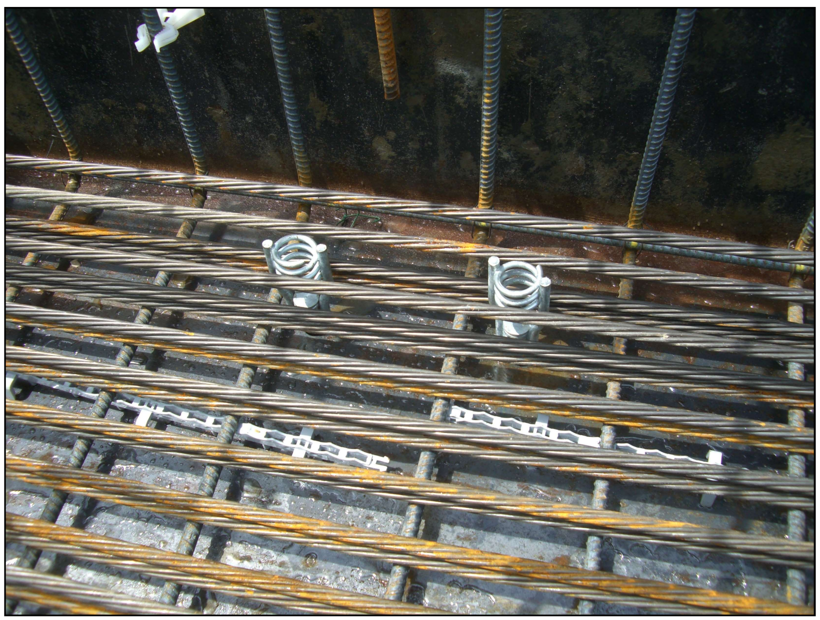
- Spalls

Common Fabrication Issues

- Stirrup Spacing Too Tight


Common Fabrication Issues

- Inserts and Hardware



Common Fabrication Issues

- Rock Pockets


SAW CUT
AVOID


SAW CUT


SAW CUT


CAMPBELL

External Post-Tensioning

- Viable option to increase capacity of Prestressed Concrete members in service

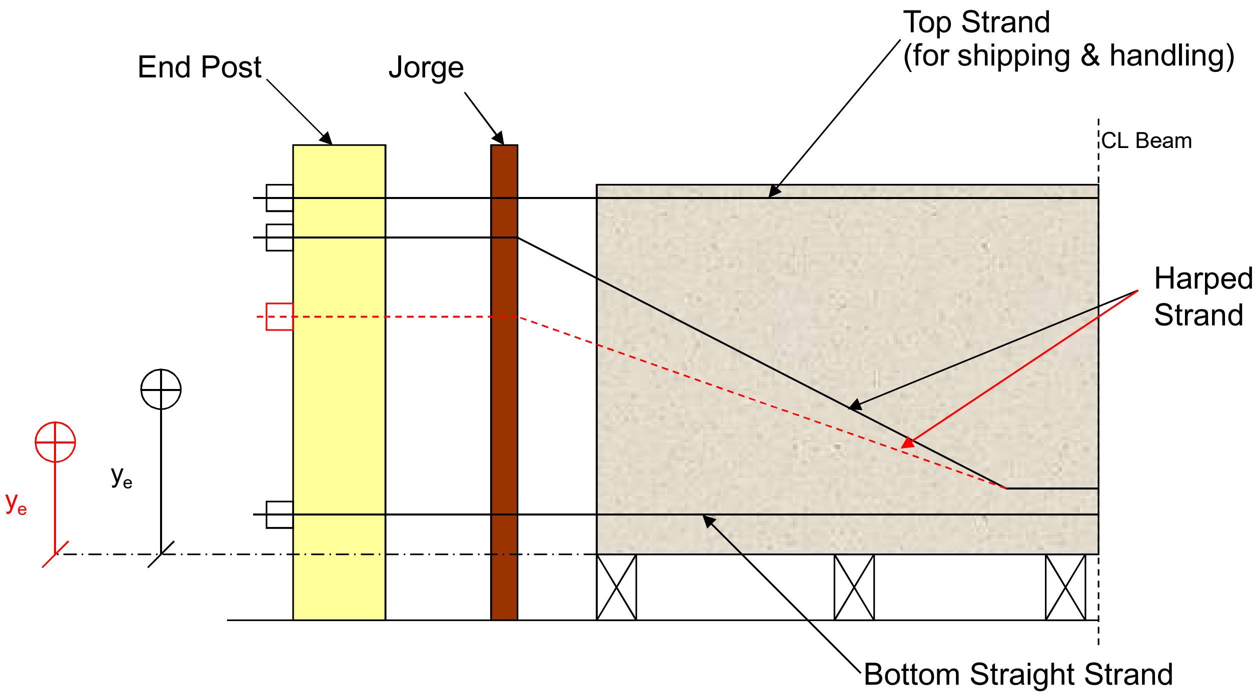
External Post-Tensioning

External Post-Tensioning

Sweep

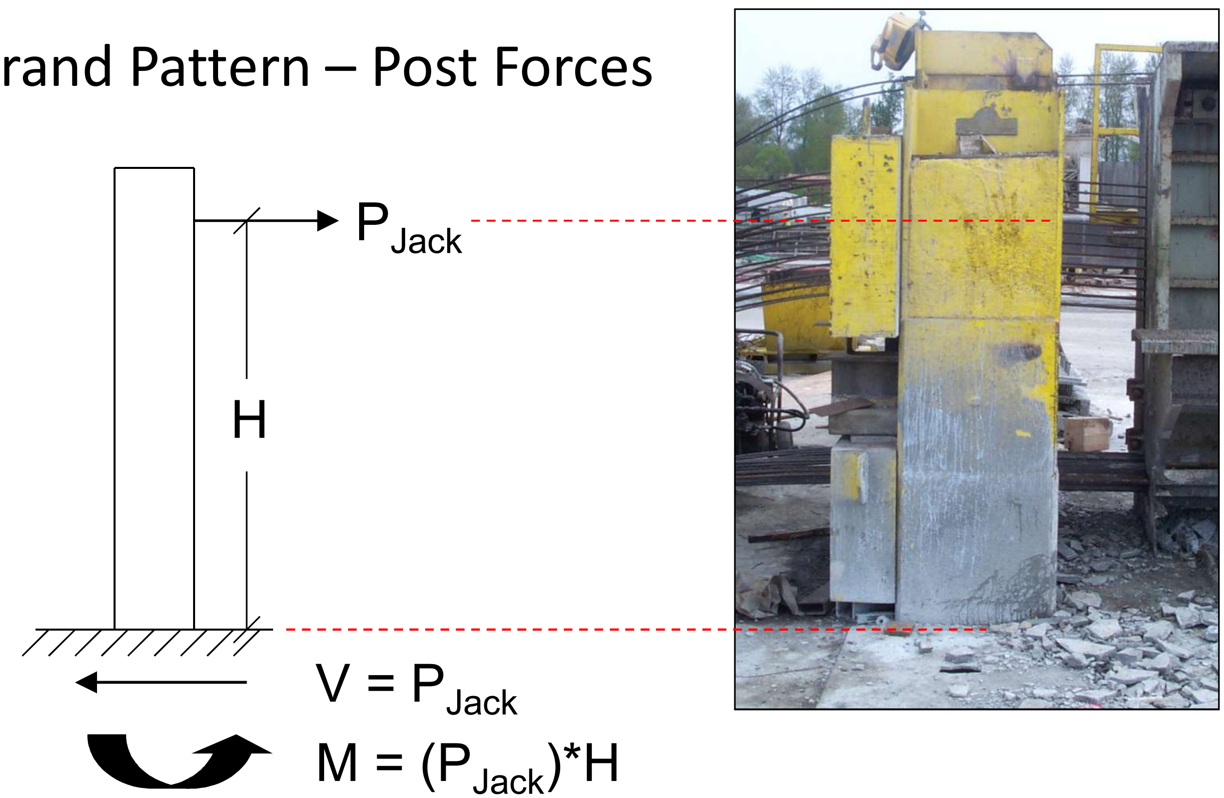
Fabricator's Bed Capabilities

- Stressing Equipment
- Force on Posts
- Force on Bed



Fabricator’s Bed Capabilities

- End Strand Pattern – Post Forces



Build It and They Will Come
Section Development Case Study

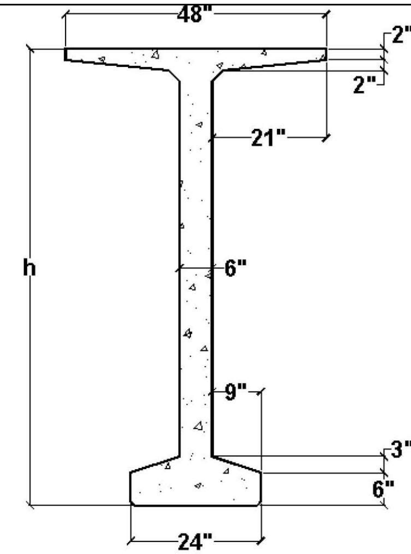
Overview

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

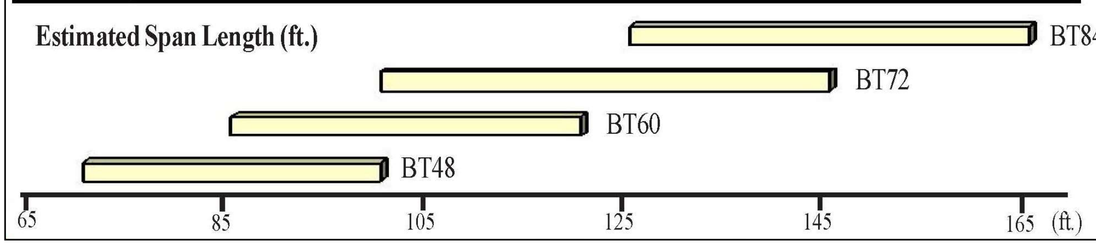
History of the BT90

- Bulb Tee Spanning Capabilities Prior to the BT90

Bulb T



Section Properties (gross)										
Type	h	A	I strong axis	I weak axis	y_t	y_b	S_t	S_b	V/S	wt.
	(in.)	(in.^{2})	(in.^{4})	(in.^{4})	(in.)	(in.)	(in.^{3})	(in.^{3})	(in.)	(plf)
BT48	48	557	177736	32986	23.53	24.47	7553	7264	2.57	600
BT60	60	629	308722	33202	29.59	30.31	10432	10154	2.61	677
BT72	72	701	484993	33418	35.64	36.36	13606	13340	2.65	755
BT84	84	773	711733	33634	41.69	42.31	17074	16820	2.68	832



History of the BT90

- Production of a Larger Girder Limited By:
  - Available Fabrication Bed Lengths
  - Adequate Shipping Equipment
  - Jacking Limitations
  - Industry Demand

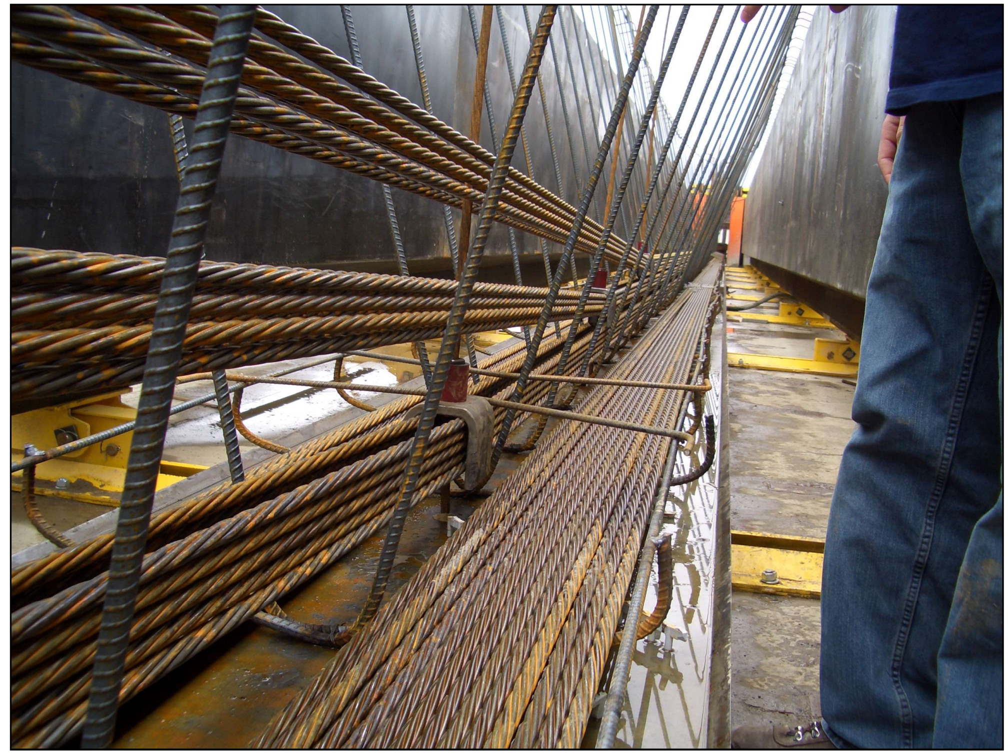
Casting Bed Construction

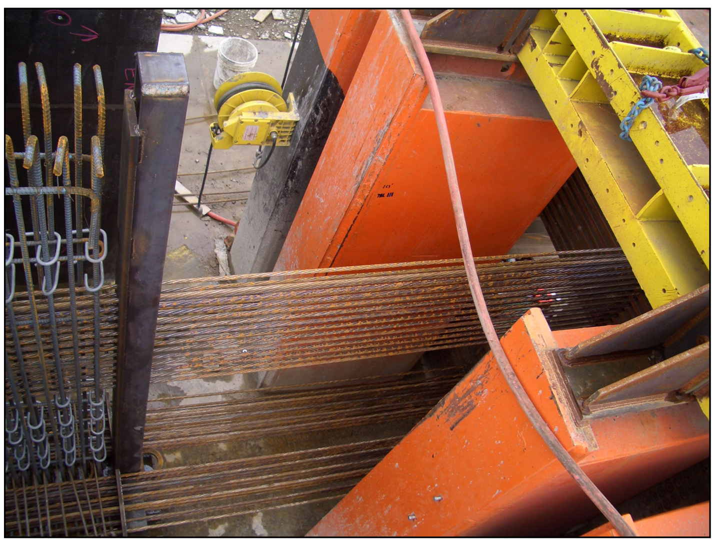
P_{Jack} = 3 Million lbs. @ 4 feet Eccentricity

Form Installation

Stressing Setup

- (60) 0.6” Diameter Strands
- P_{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

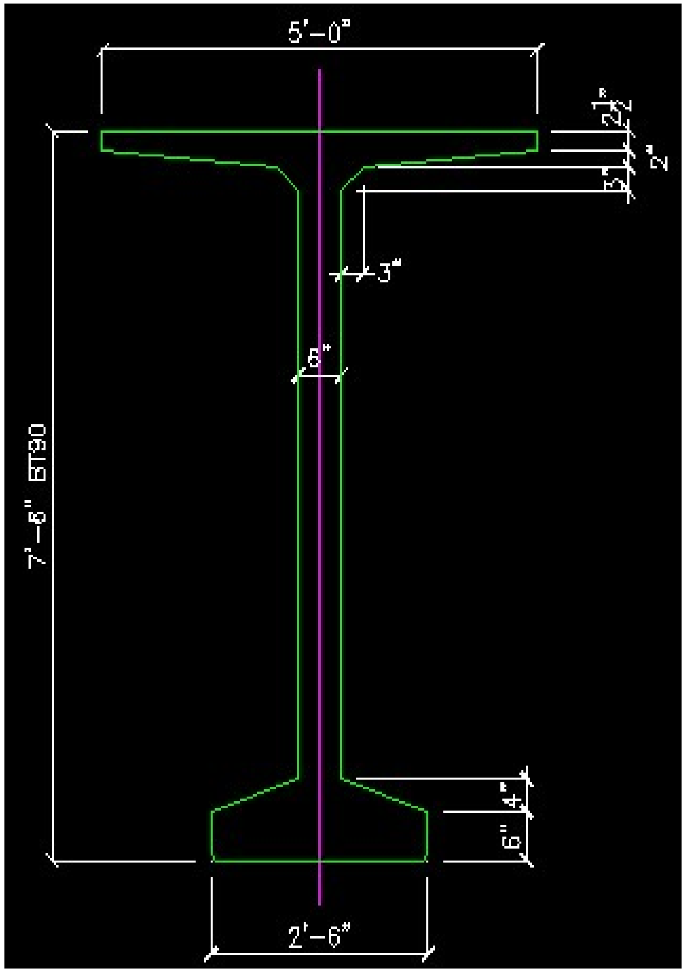
New Section Development Process

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:

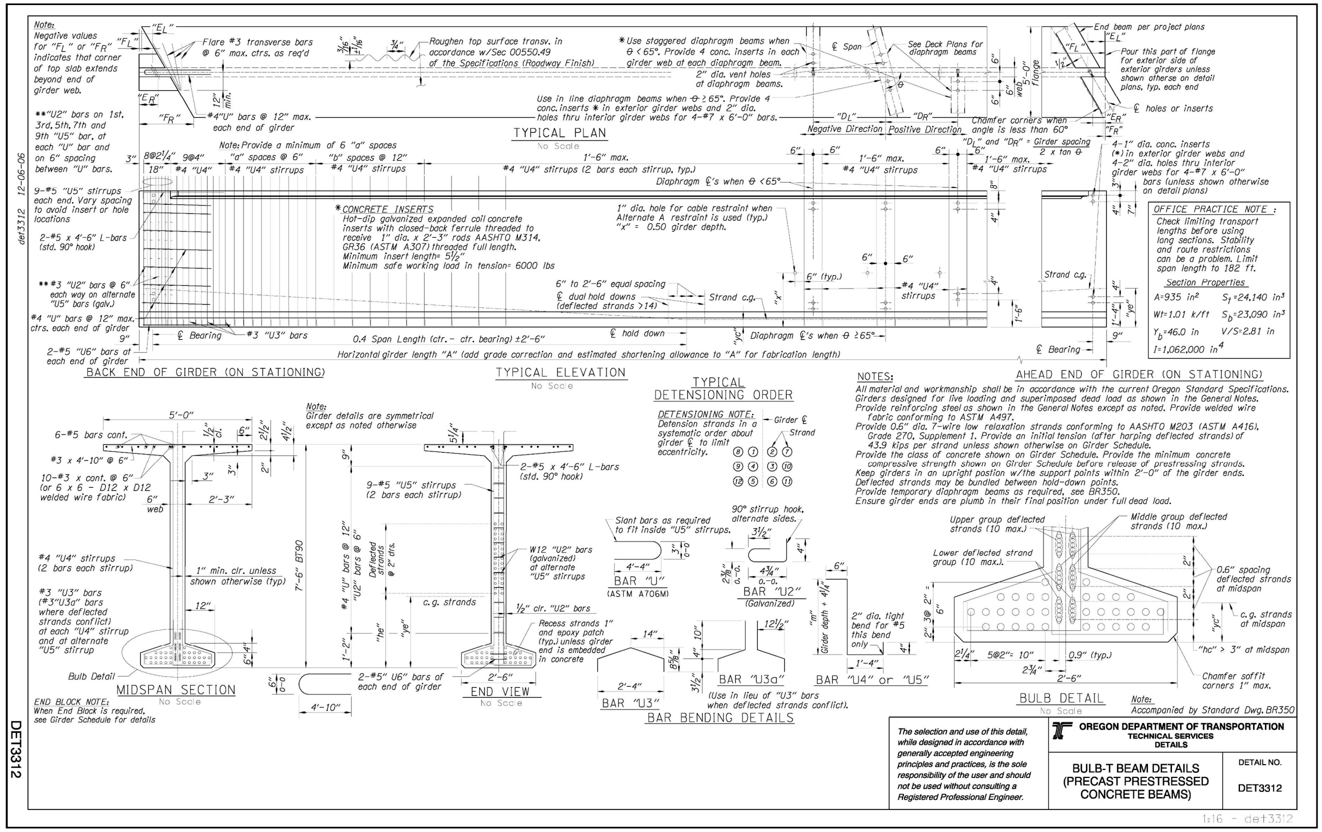
- f’ci = 7,000 psi
- f’c = 9,000 psi
- (60) 0.6” Diameter, Grade 270, Low-Lax Strands
- L = 183’-3” o.-o.
- Weight = 185 kips



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:

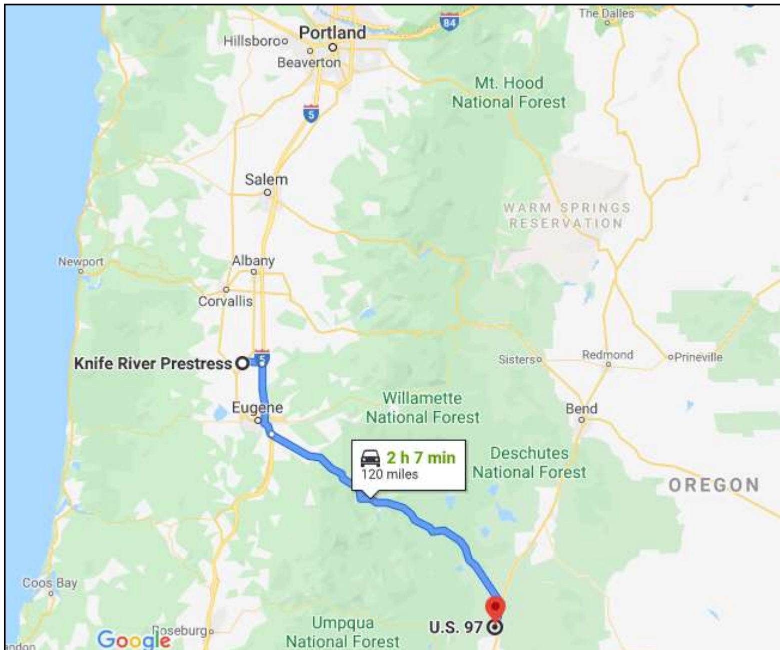
- Girders Shipped and Erected

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

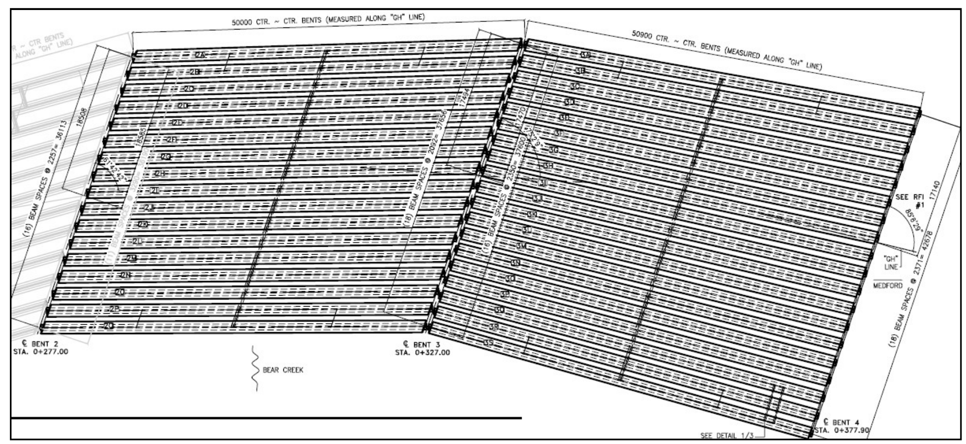
Chemult Recap

- 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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williams&works
engineers | surveyors | planners

Specialty/Innovative Precast Solutions

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Michigan Bridge Design Conference

March 17, 2021

PCI

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engineers | surveyors | planners

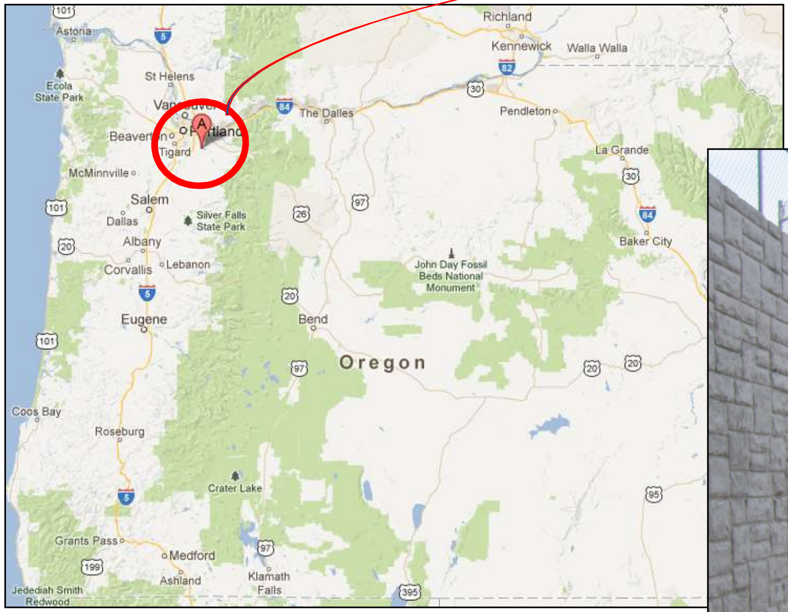
Overview

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

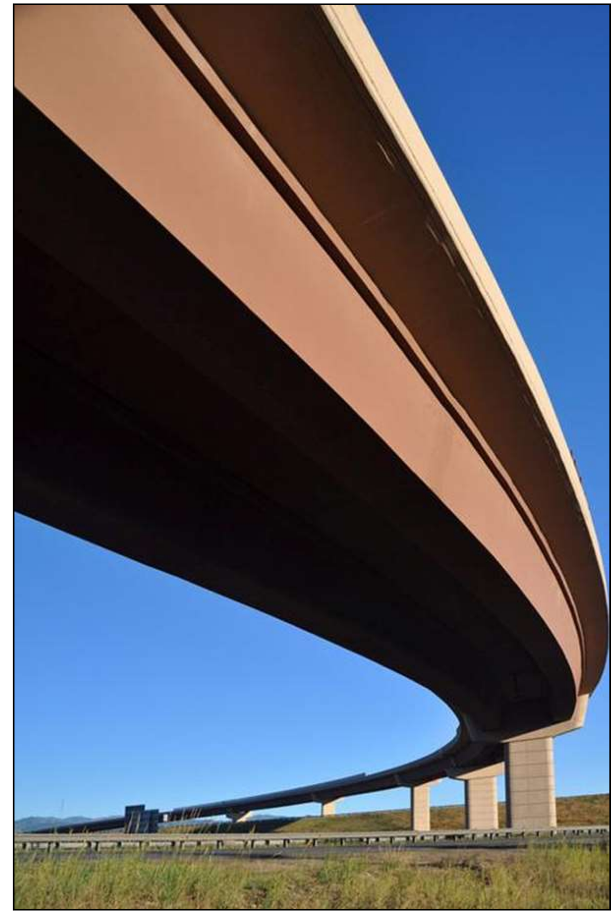
Springwater Road

- Bridge Location



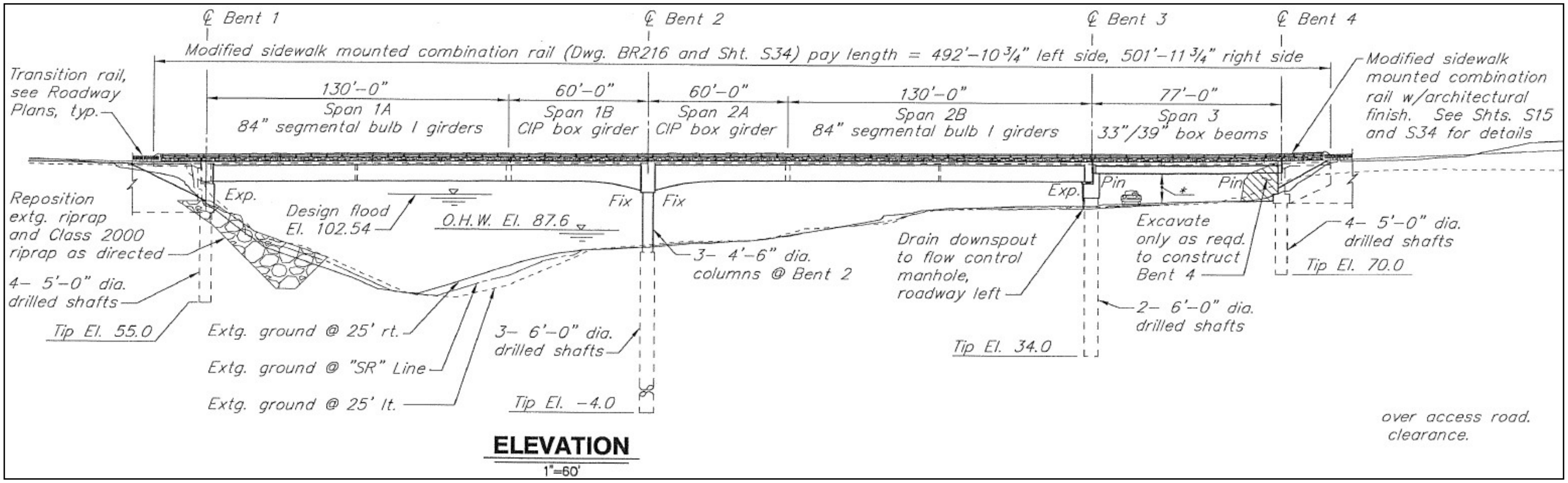
Springwater Road

- 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

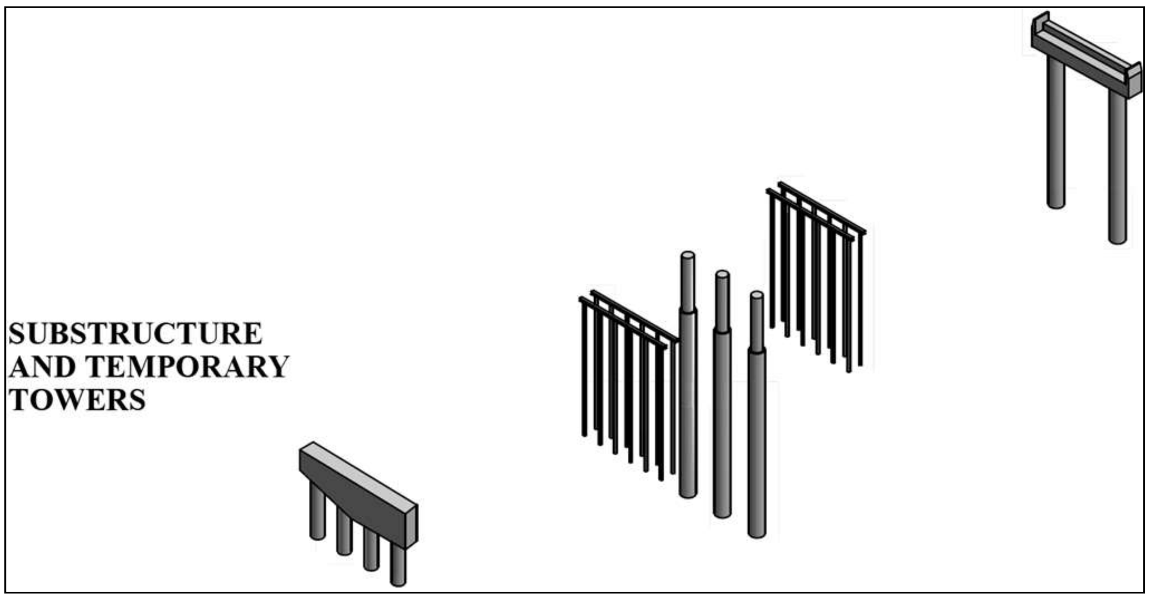
6.	Value Engineering	Points: 0 – 10

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?

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?

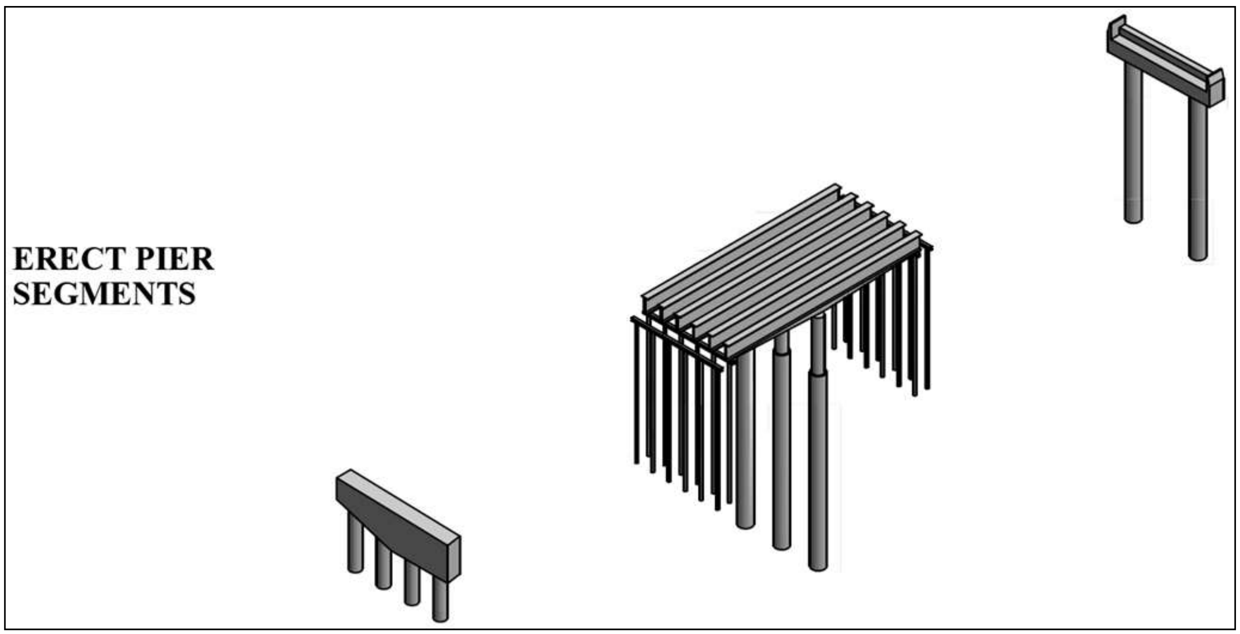
Springwater Road

- Stage I Construction



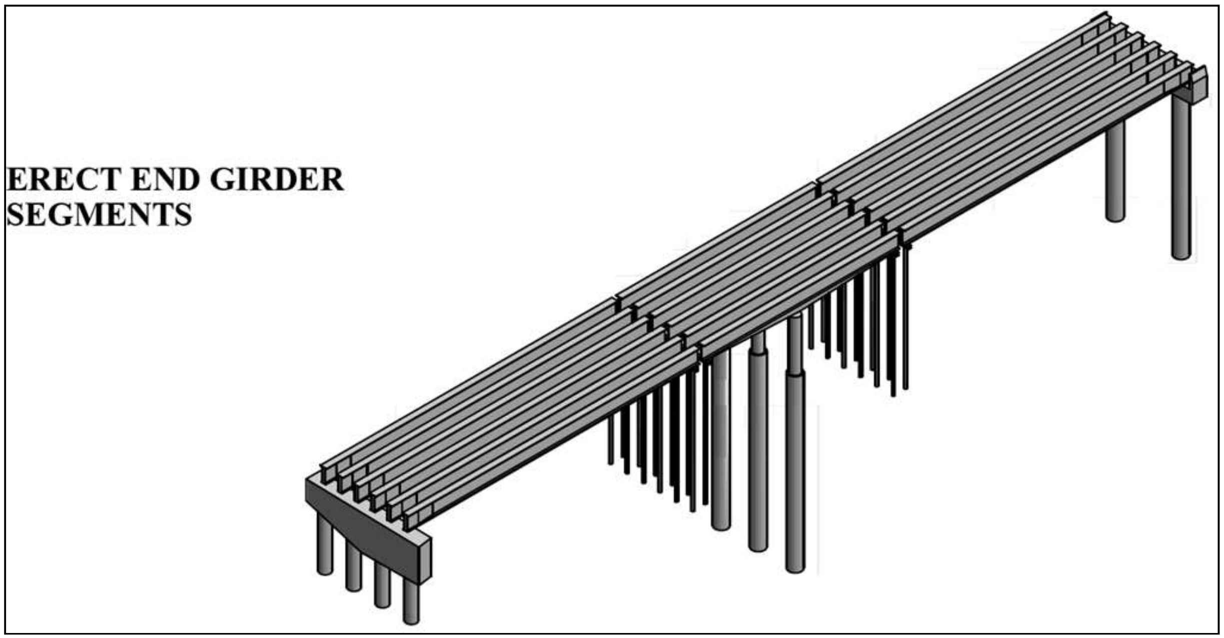
Springwater Road

- Stage II Construction



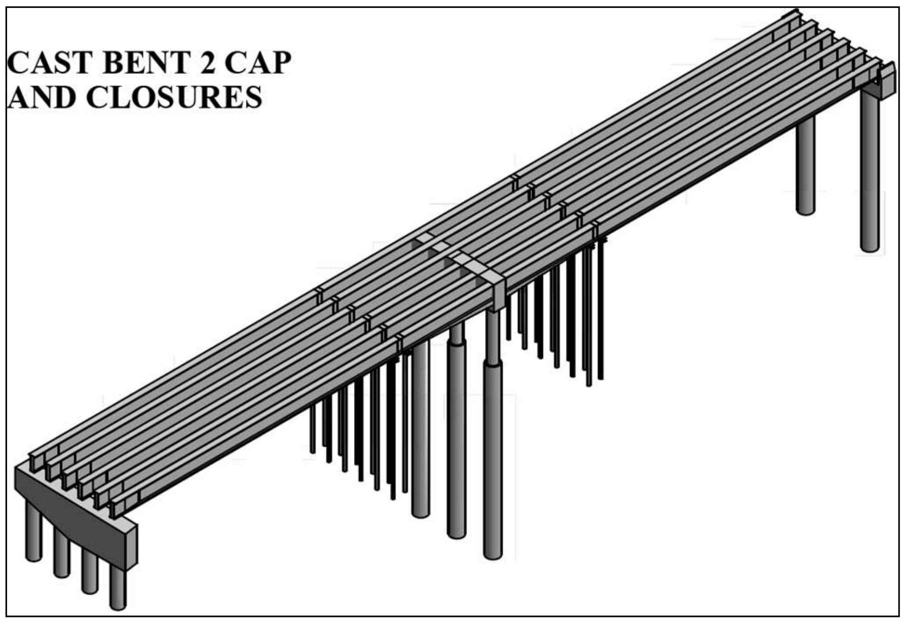
Springwater Road

- Stage III Construction



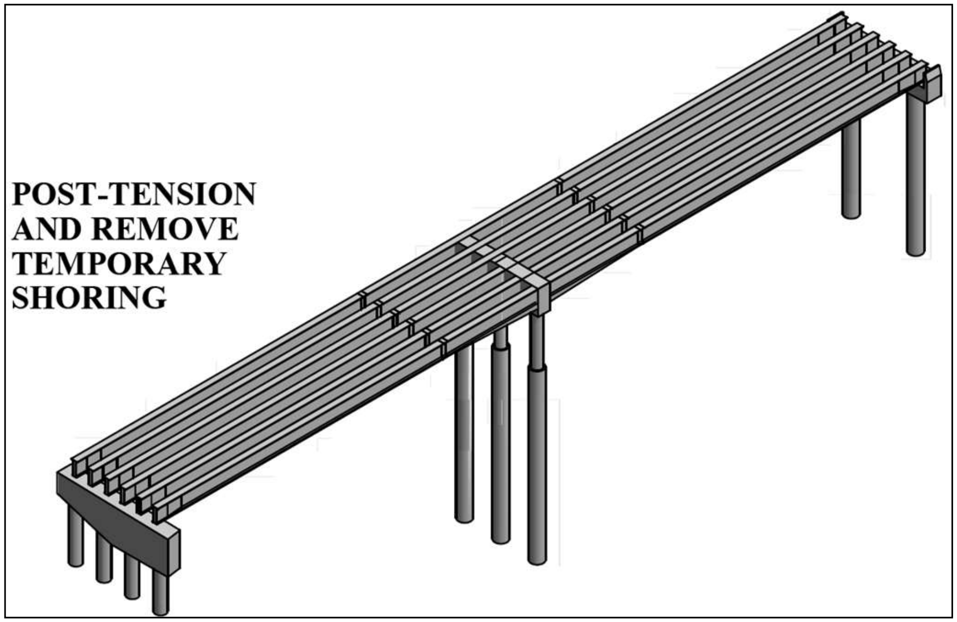
Springwater Road

- Stage IV Construction



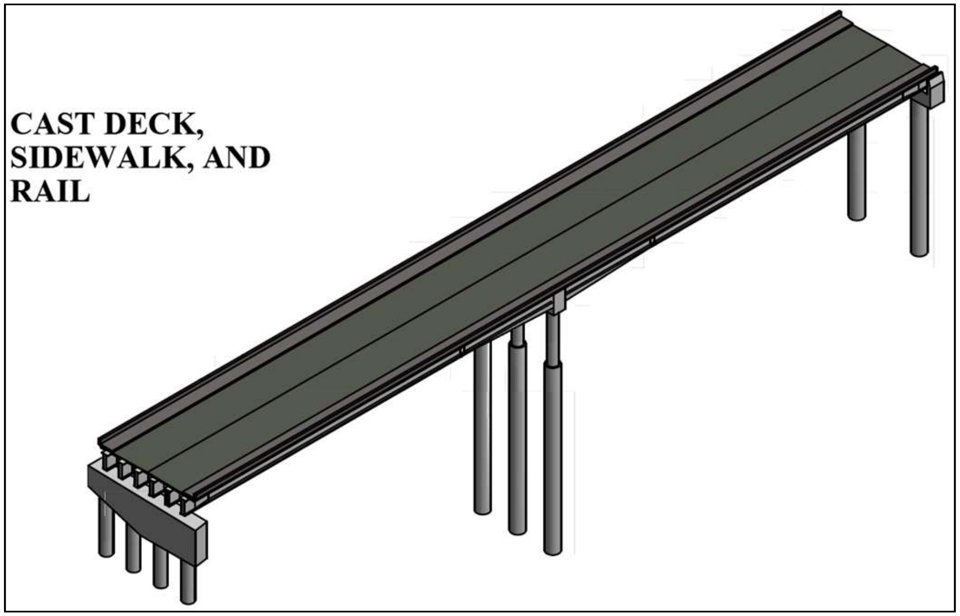
Springwater Road

- Stage V Construction

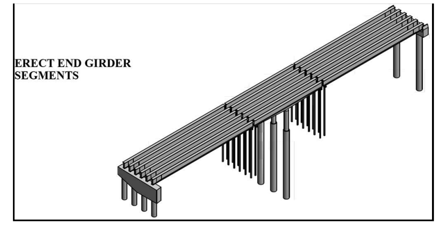


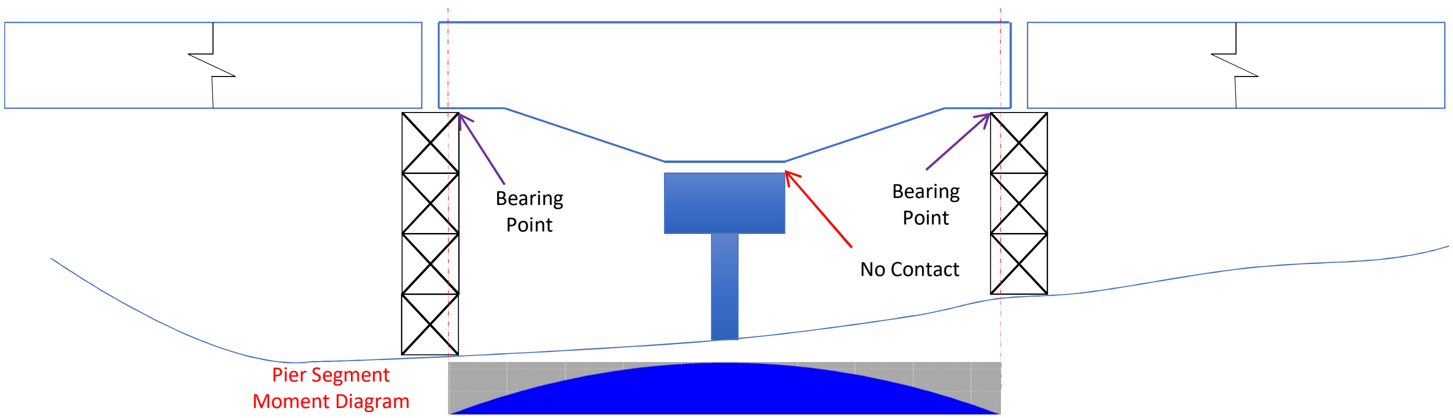
Springwater Road

- Stage VI Construction

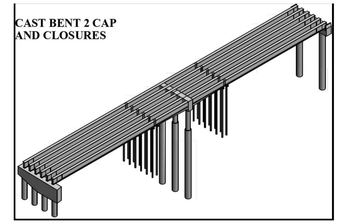


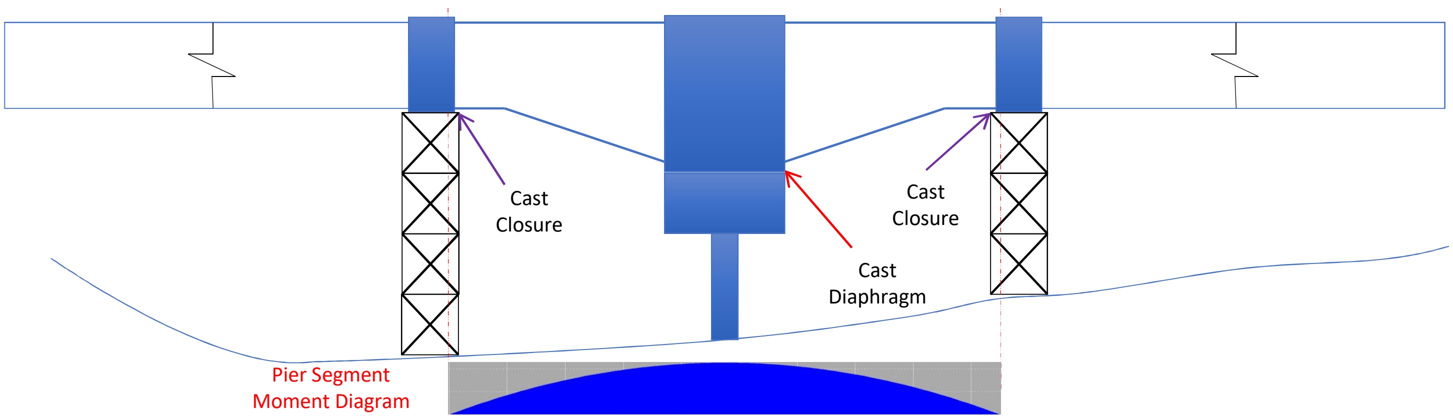
Springwater Road



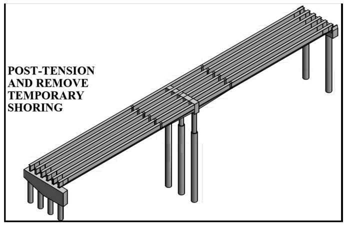


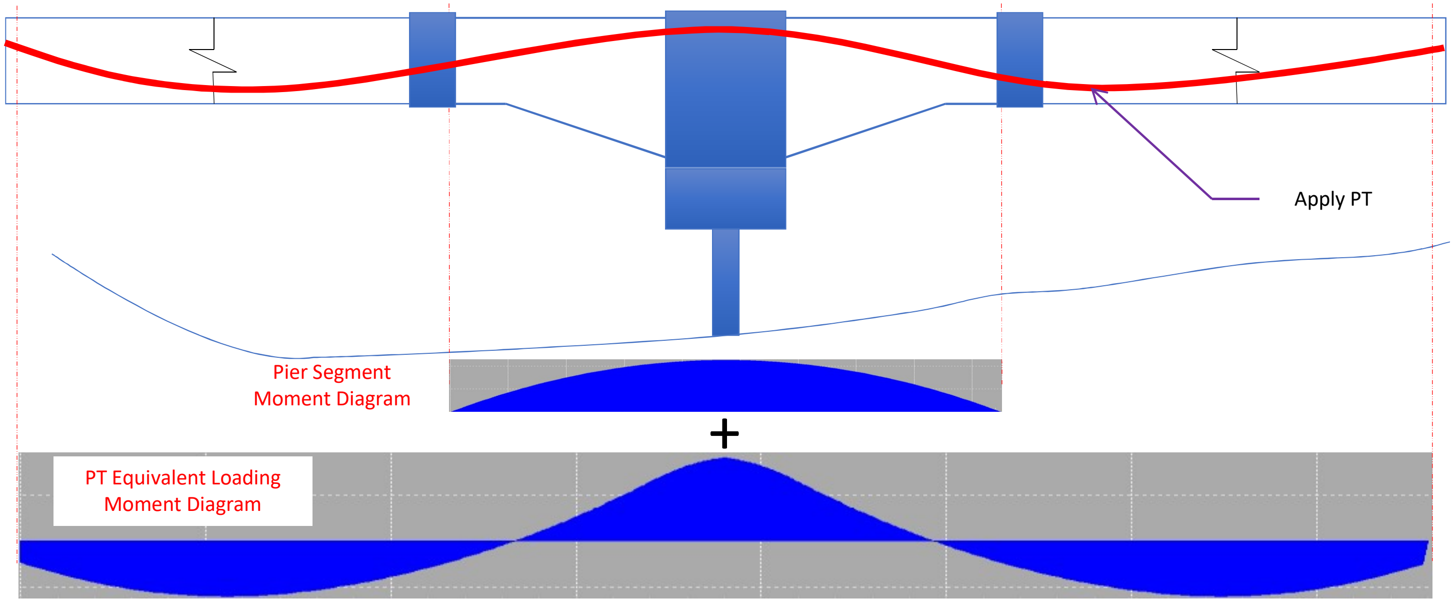
Springwater Road



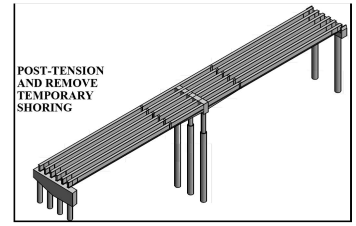


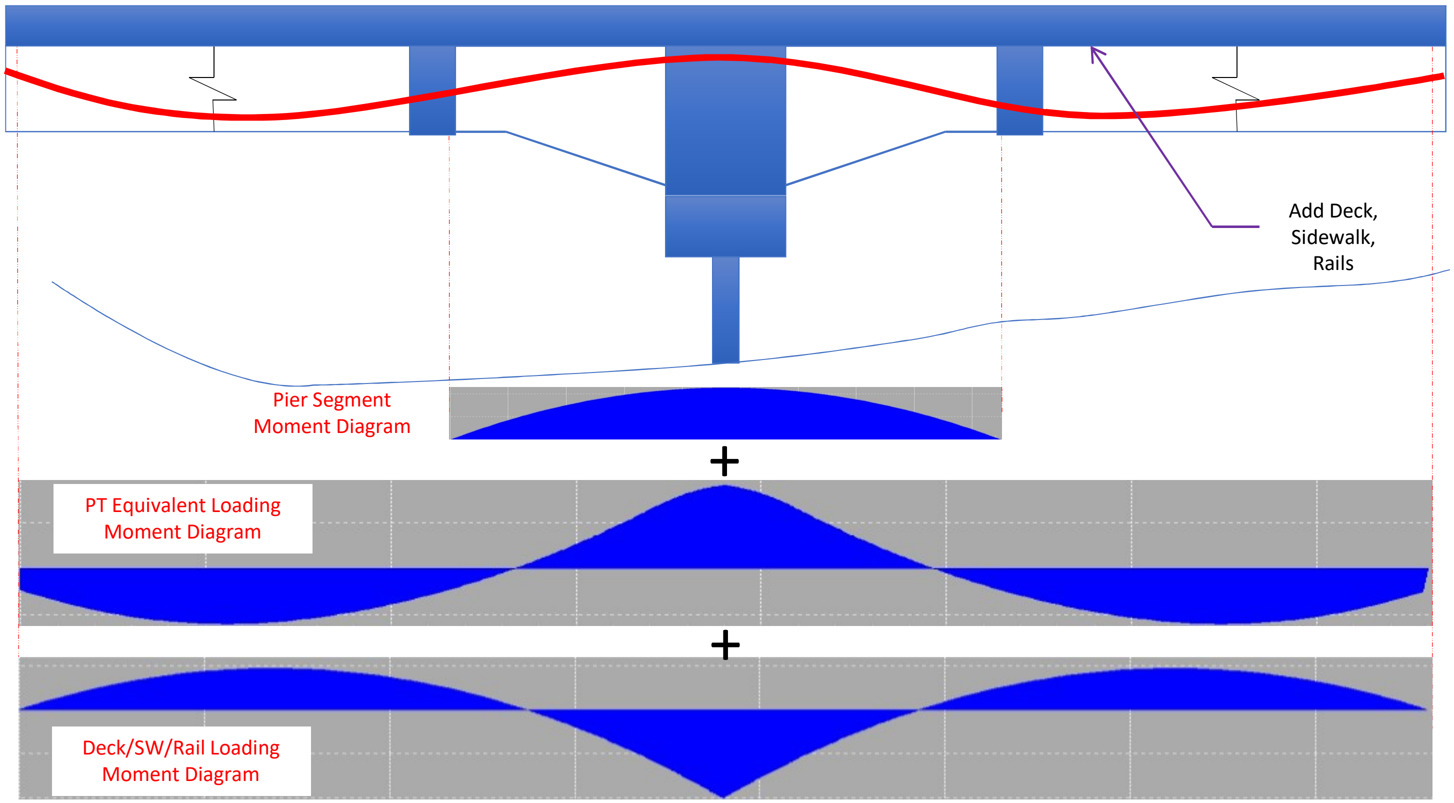
Springwater Road





Springwater Road





Springwater Road

- Fabrication (Pier Segments Shown)

Springwater Road

- Precast Pier Segments

Springwater Road

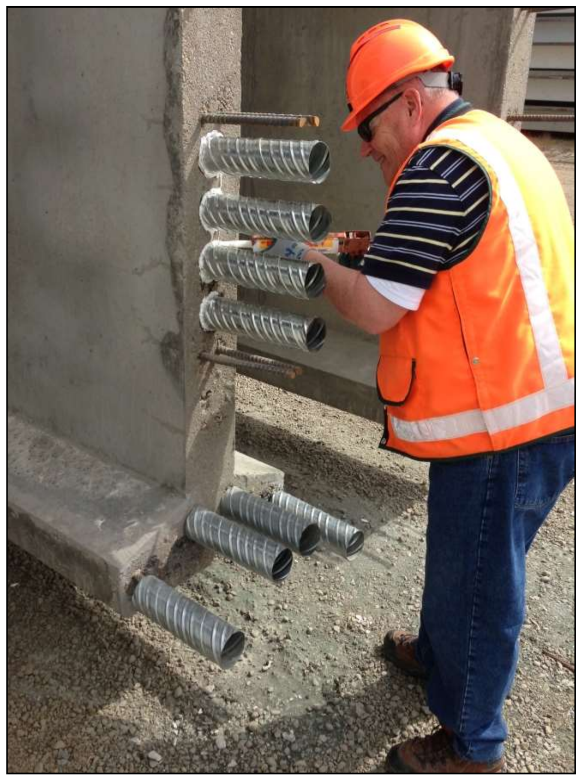
- 120,000 LBS
- 95-feet long

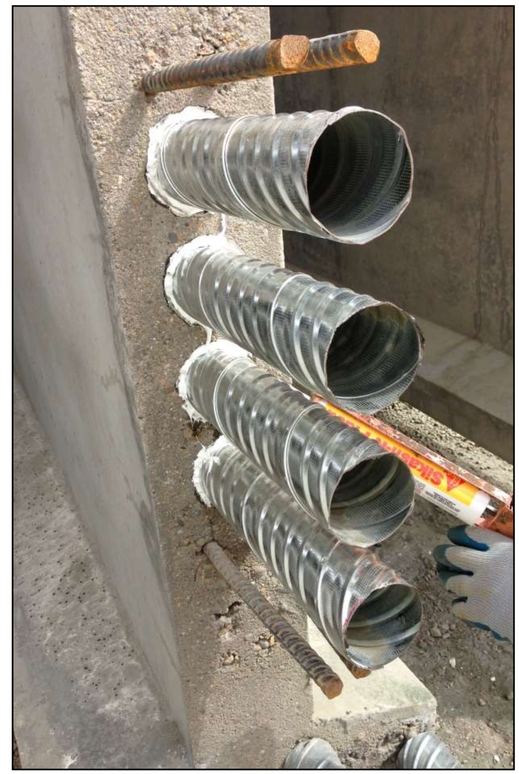
Springwater Road

- Straight Segments ~ 140,000 LBS, 141-feet long

Springwater Road

Installing and Caulking the PT Duct Splices:

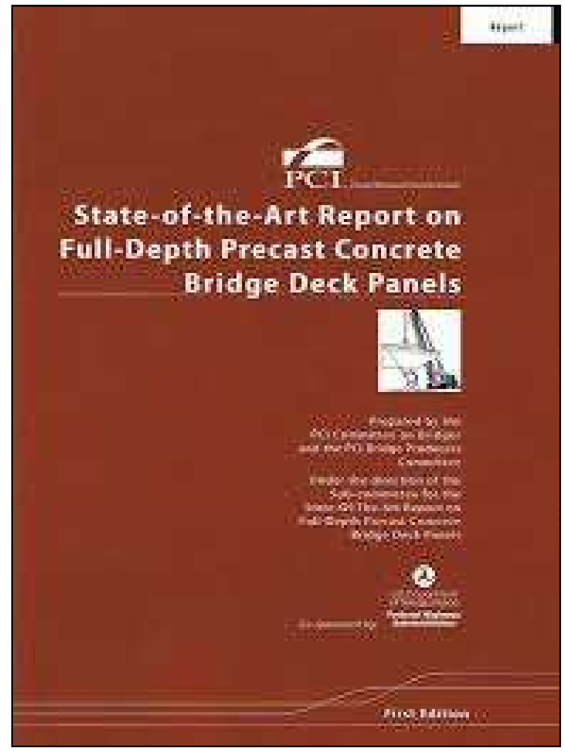




Springwater Road

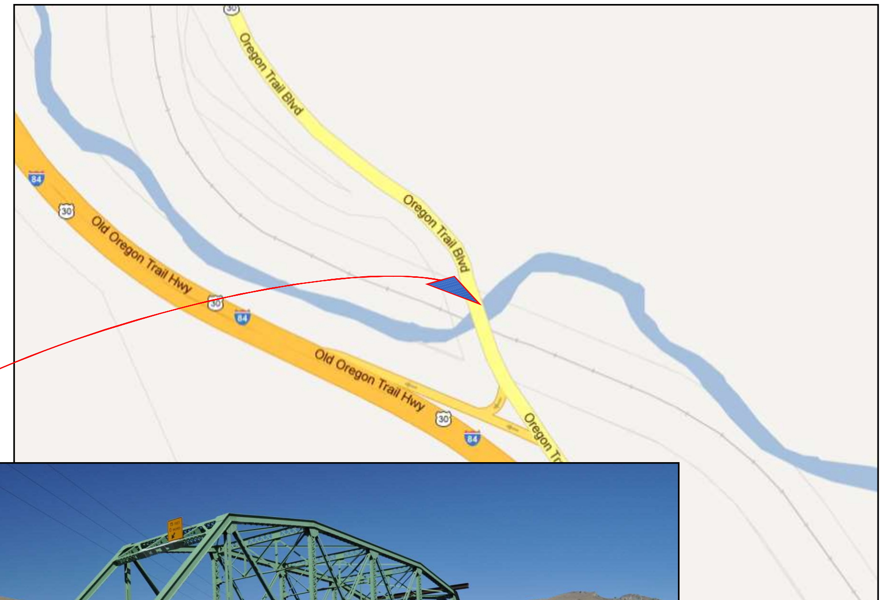
Precast Deck Panels

- Burnt River Bridge

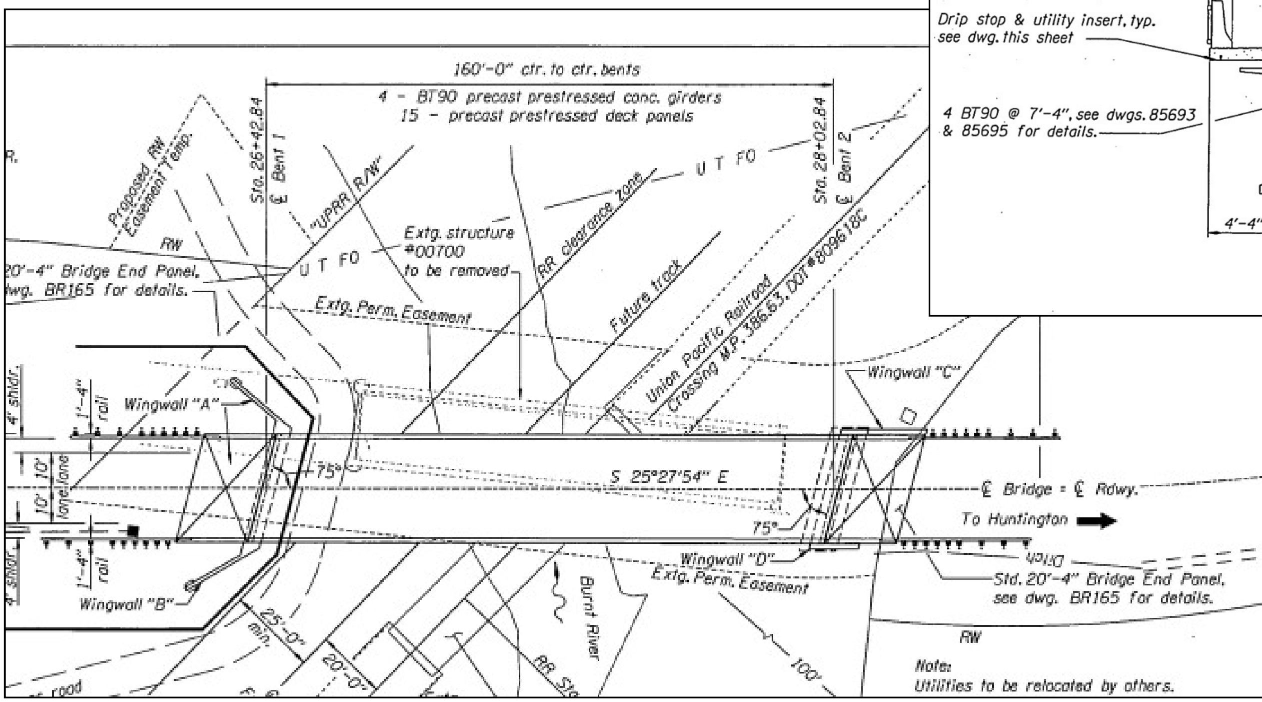


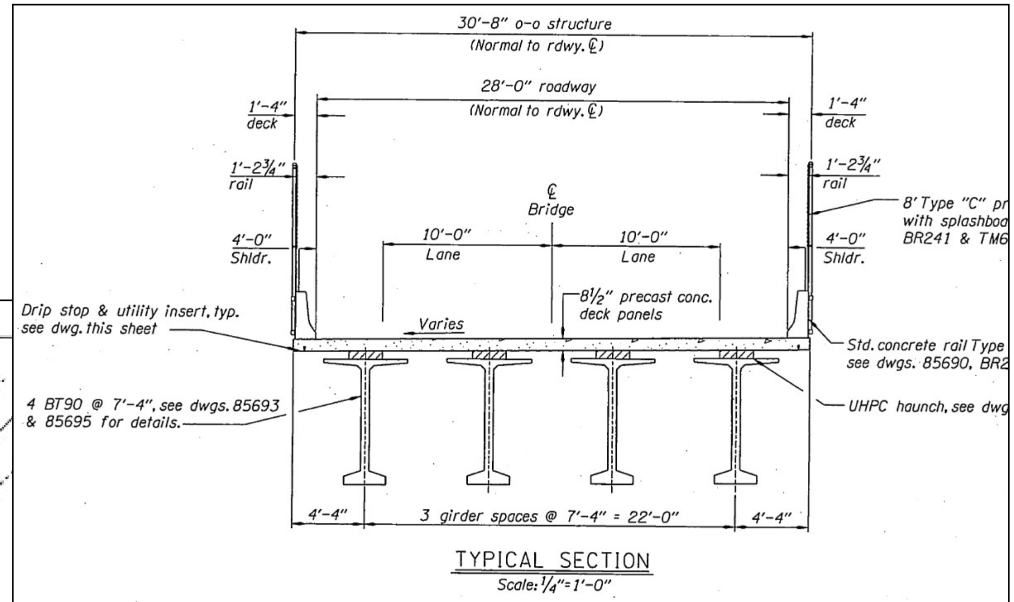
Burnt River

- Bridge Location

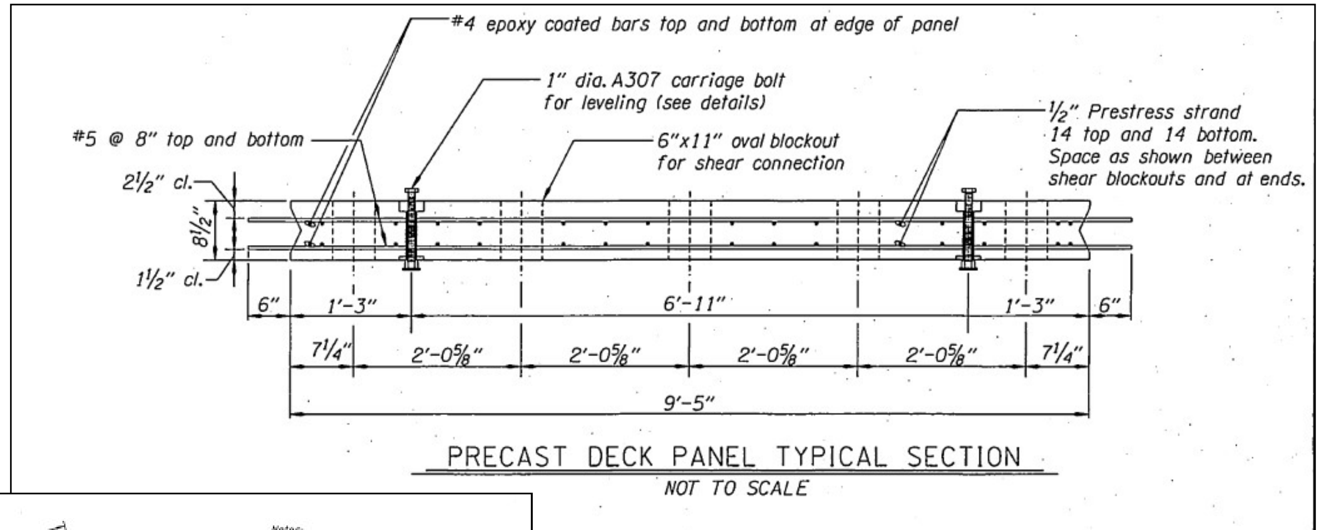


Burnt River

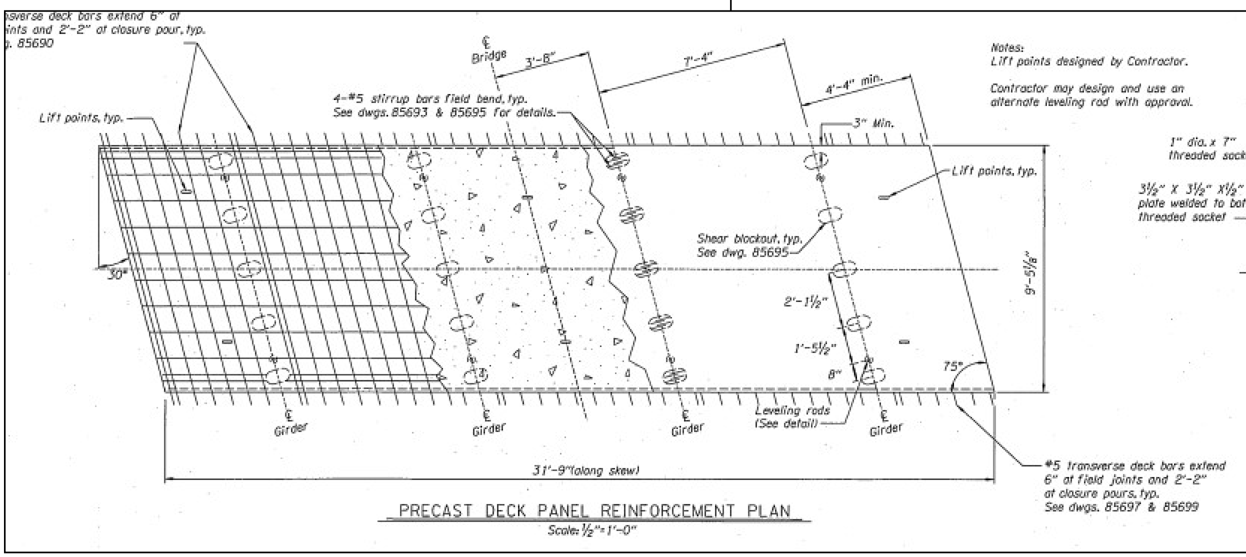

160'-0" ctr. to ctr. bents
4 - BT90 precast prestressed conc. girders
15 - precast prestressed deck panels
Sta. 26+42.84
℄ Bent 1
Sta. 28+02.84
℄ Bent 2
Proposed RW Easement Temp.
"UPRR R/W"
U T FO
Extg. structure #00700 to be removed
RR clearance zone
Future track
Union Pacific Railroad Crossing M.P. 386.63, DOT #809618C
RW
20'-4" Bridge End Panel, dwg. BR165 for details.
Extg. Perm. Easement
Wingwall "A"
Wingwall "B"
Wingwall "C"
Wingwall "D"
4' shldr.
1'-4" rail
10' lane
10' lane
75°
S 25°27'54" E
℄ Bridge = ℄ Rdwy.
To Huntington
Ditch
Std. 20'-4" Bridge End Panel, see dwg. BR165 for details.
Burnt River
25'-0" min.
20'-0"
100'
Note:
Utilities to be relocated by others.


30'-8" o-o structure
(Normal to rdwy. ℄)
28'-0" roadway
(Normal to rdwy. ℄)
1'-4" deck
1'-2¾" rail
℄ Bridge
10'-0" Lane
10'-0" Lane
4'-0" Shldr.
8' Type "C" pr with splashboa BR241 & TM6
8½" precast conc. deck panels
Varies
Drip stop & utility insert, typ. see dwg. this sheet
Std. concrete rail Type see dwgs. 85690, BR2
4 BT90 @ 7'-4", see dwgs. 85693 & 85695 for details.
UHPC haunch, see dwg
4'-4"
3 girder spaces @ 7'-4" = 22'-0"
TYPICAL SECTION
Scale: ¼"=1'-0"

Burnt River



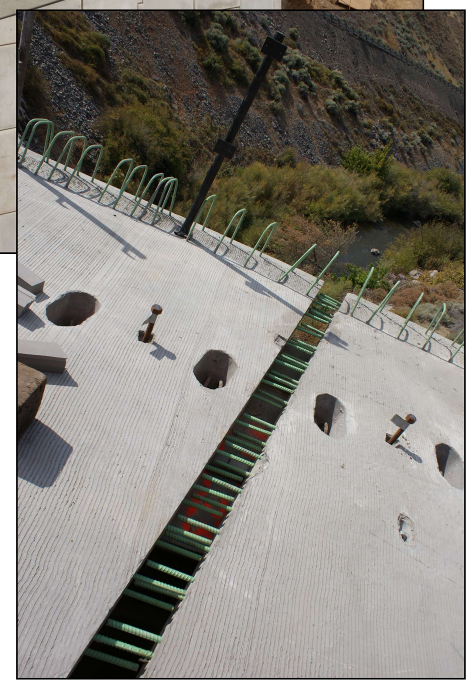
#4 epoxy coated bars top and bottom at edge of panel
1" dia. A307 carriage bolt for leveling (see details)
½" Prestress strand 14 top and 14 bottom. Space as shown between shear blockouts and at ends.
#5 @ 8" top and bottom
6"x11" oval blockout for shear connection
2½" cl.
8½"
1½" cl.
6"
1'-3"
6'-11"
1'-3"
6"
7¼"
2'-0⅝"
2'-0⅝"
2'-0⅝"
2'-0⅝"
7¼"
9'-5"
PRECAST DECK PANEL TYPICAL SECTION
NOT TO SCALE



Notes:
Lift points designed by Contractor.
Contractor may design and use an alternate leveling rod with approval.
Bridge
3'-8"
7'-4"
4'-4" min.
3" Min.
4-#5 stirrup bars field bend, typ. See dwgs. 85693 & 85695 for details.
Lift points, typ.
Lift points, typ.
1" dia. x 7" threaded socke
3½" x 3½" x½" plate welded to bott threaded socket
Shear blockout, typ. See dwg. 85695
30°
2'-1½"
1'-5½"
8"
75°
9'-5⅝"
Girder
Girder
Girder
Girder
Leveling rods (See detail)
#5 transverse deck bars extend 6" at field joints and 2'-2" at closure pours, typ. See dwgs. 85697 & 85699
31'-9"(along skew)
PRECAST DECK PANEL REINFORCEMENT PLAN
Scale: ½"=1'-0"

Plant Fit-Up

Site Prep



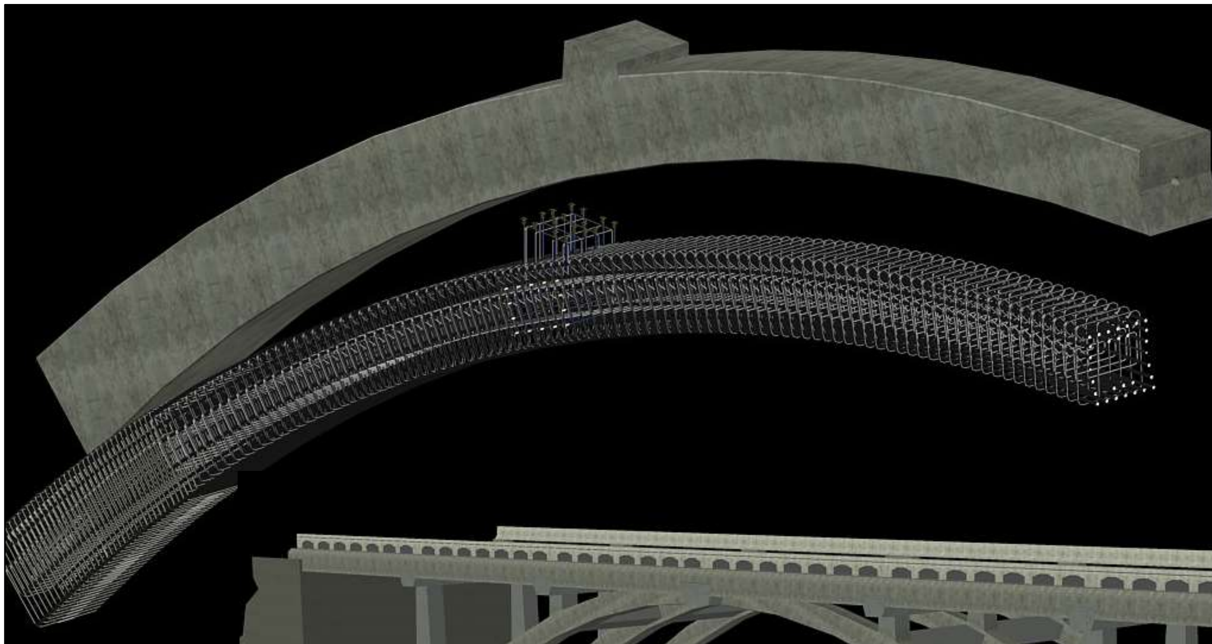
Erection

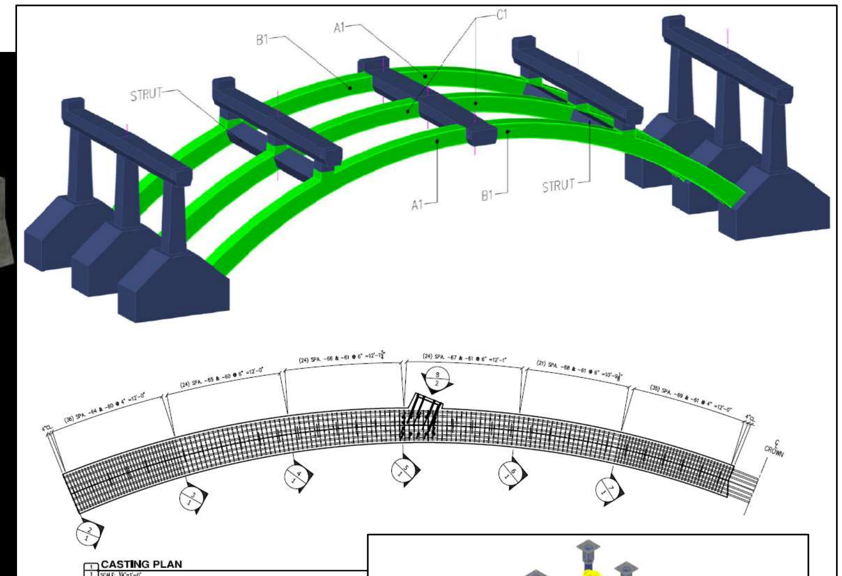
Erection

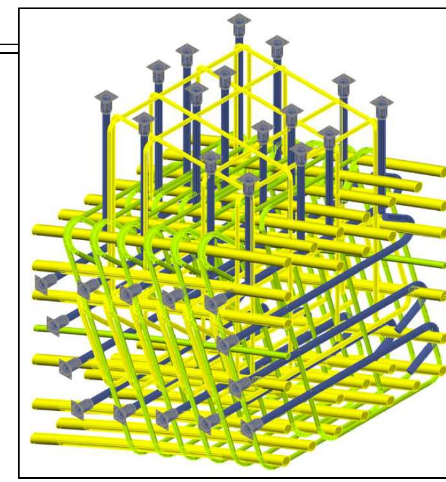
Burnt River Bridge

Spencer Creek Bridge

Spencer Creek – 3D Model

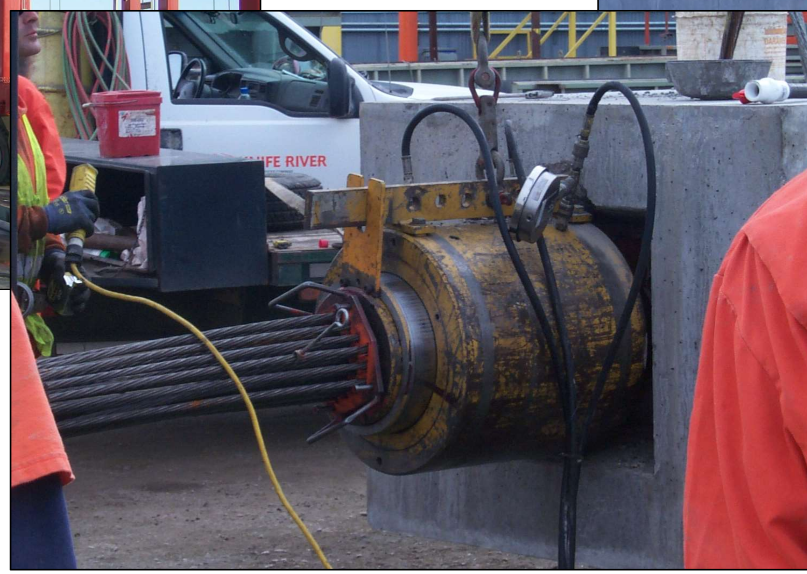








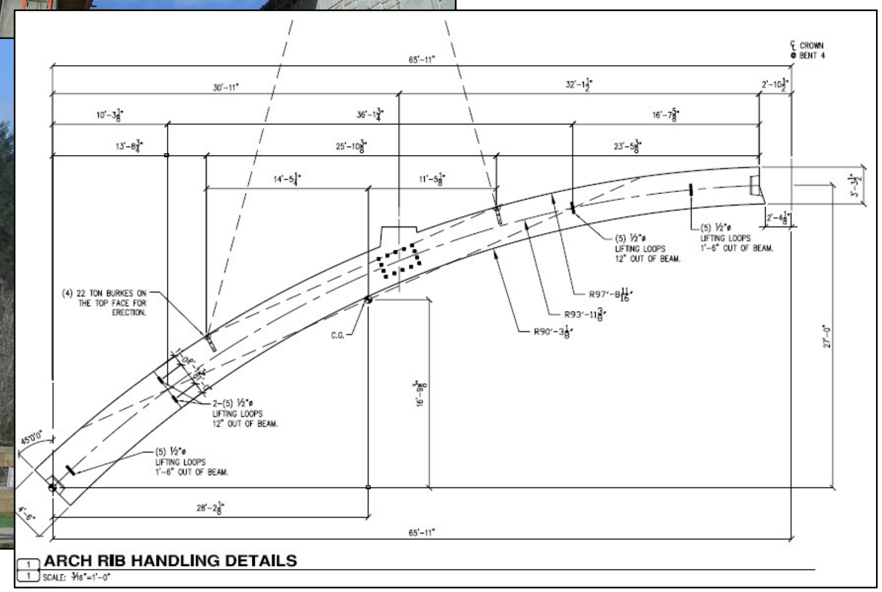

Spencer Creek – Plant Stripping & Tensioning



Spencer Creek – Rolling the Arch

Spencer Creek – Construction

80 Ton Precast
Arch Rib
Segments

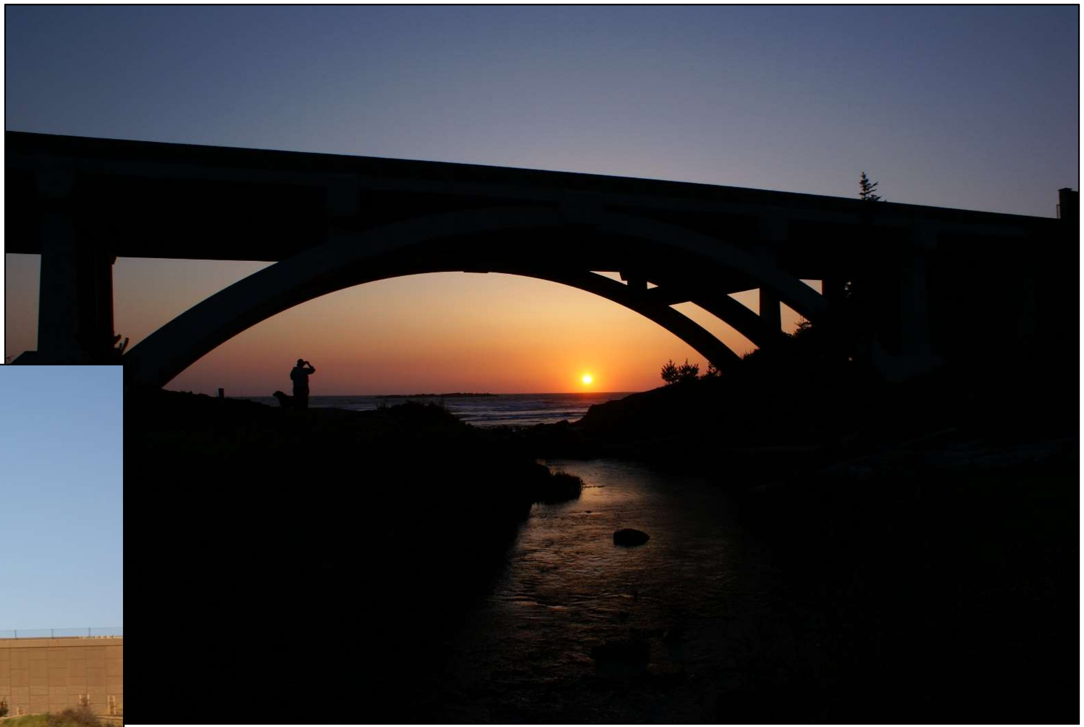


Spencer Creek – Foundation

Spencer Creek – Columns & Caps

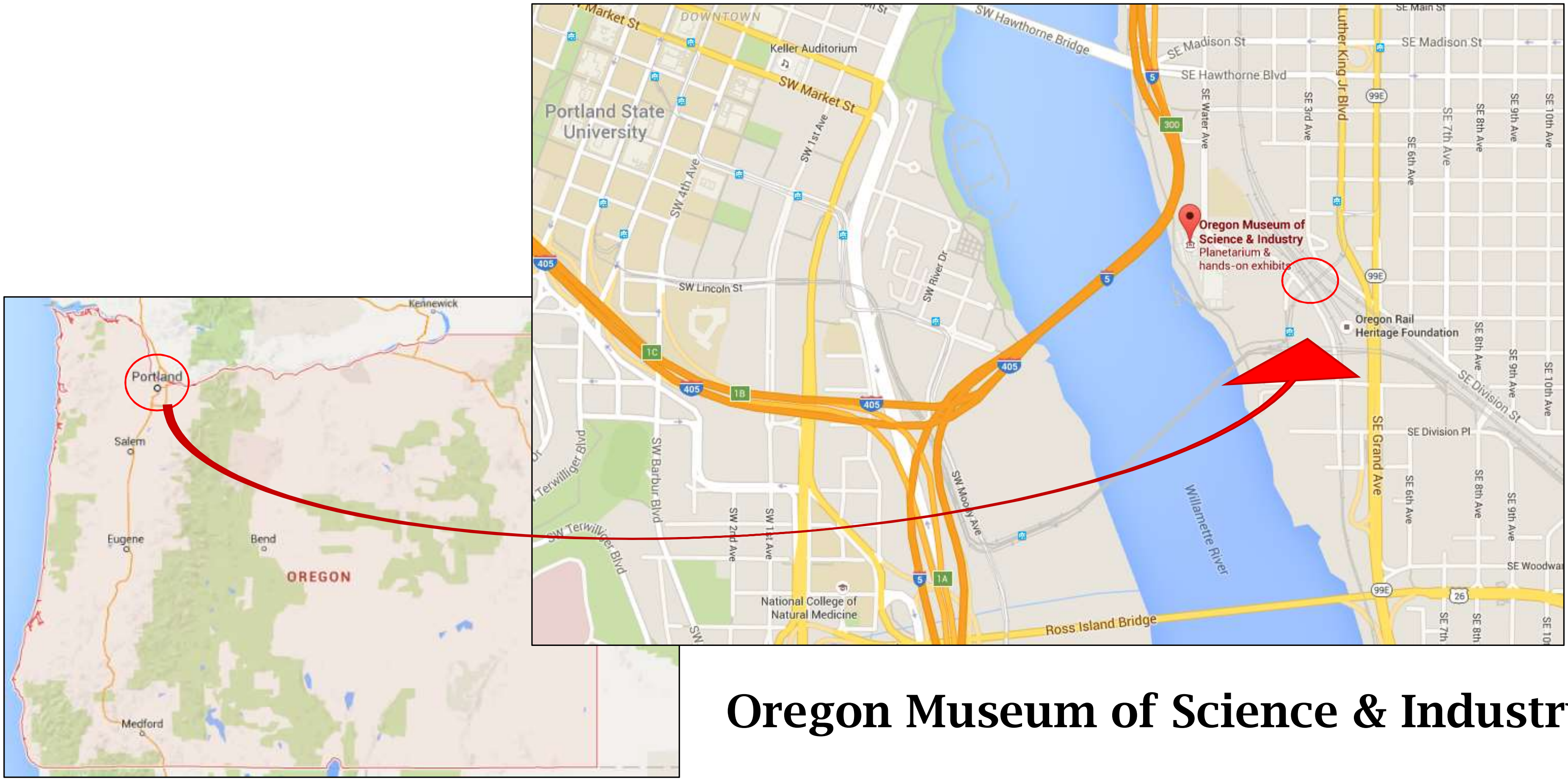
Spencer Creek – Precast Fascia

Spencer Creek



OMSI Viaduct Bridge

OMSI Viaduct



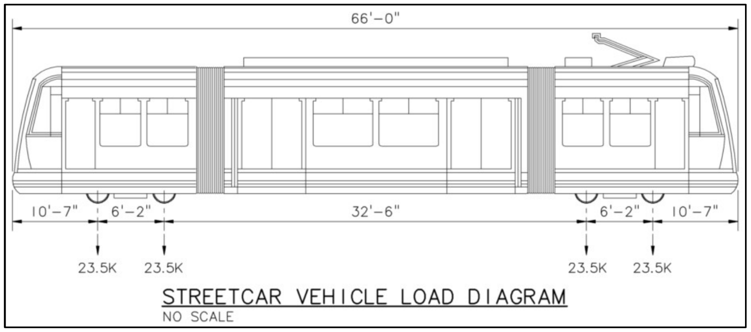
Oregon Museum of Science & Industry

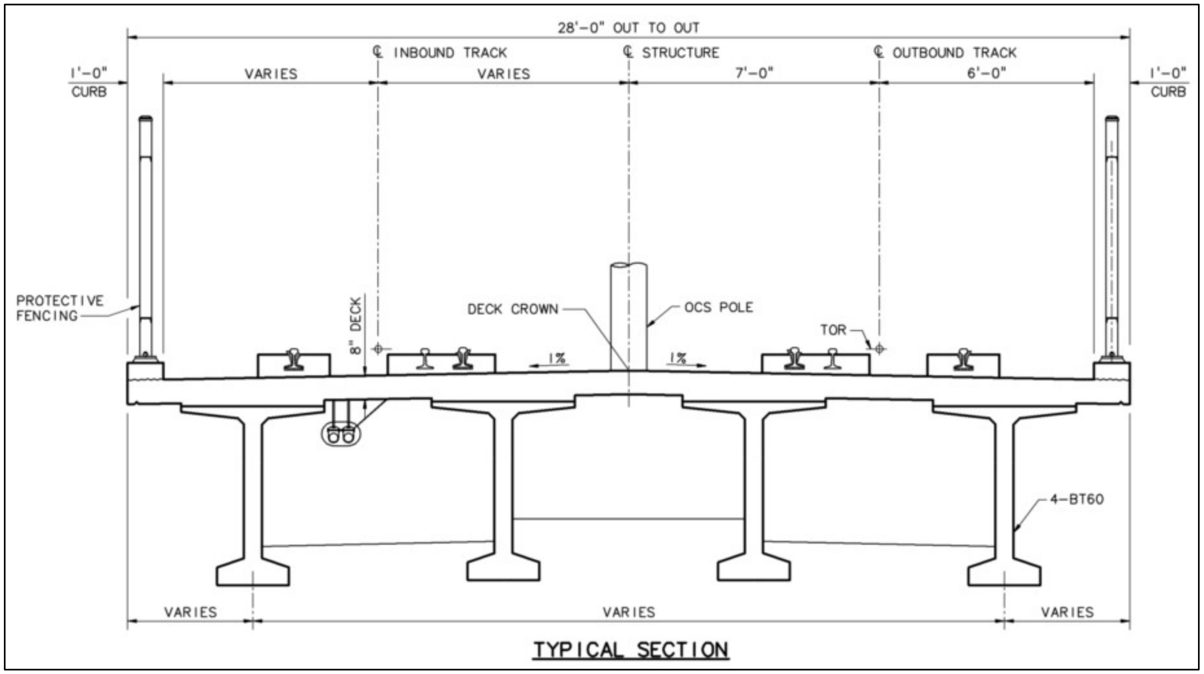
OMSI Viaduct

OMSI Viaduct

Bridge Info

- Length = 425 FT
- Four Spans (BT60)
  - 118'/115'/125'/67'
- Streetcar Loading
- (4) BT60 Girders

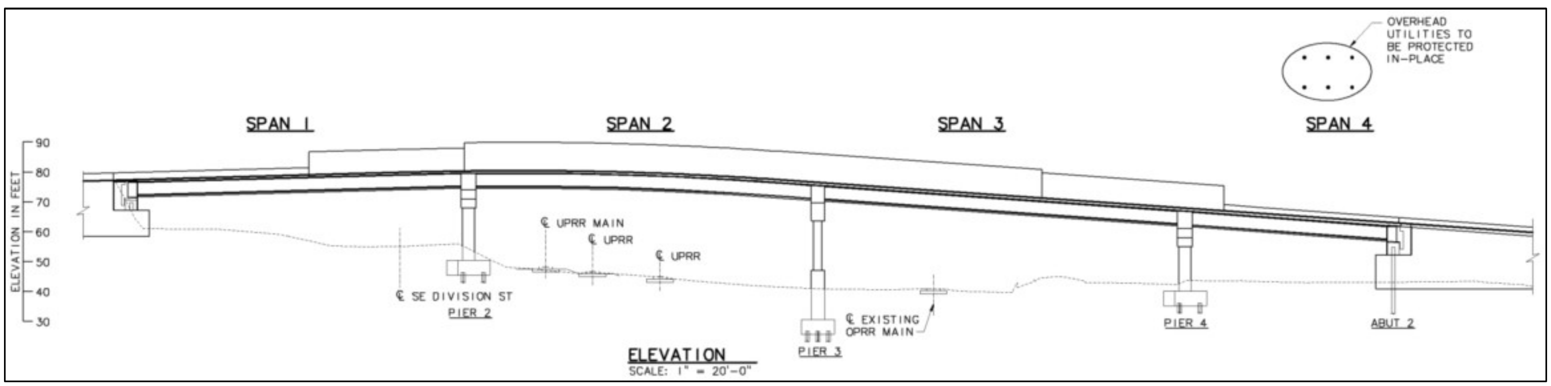




OMSI Viaduct

Site Challenges → Vertical Clearance

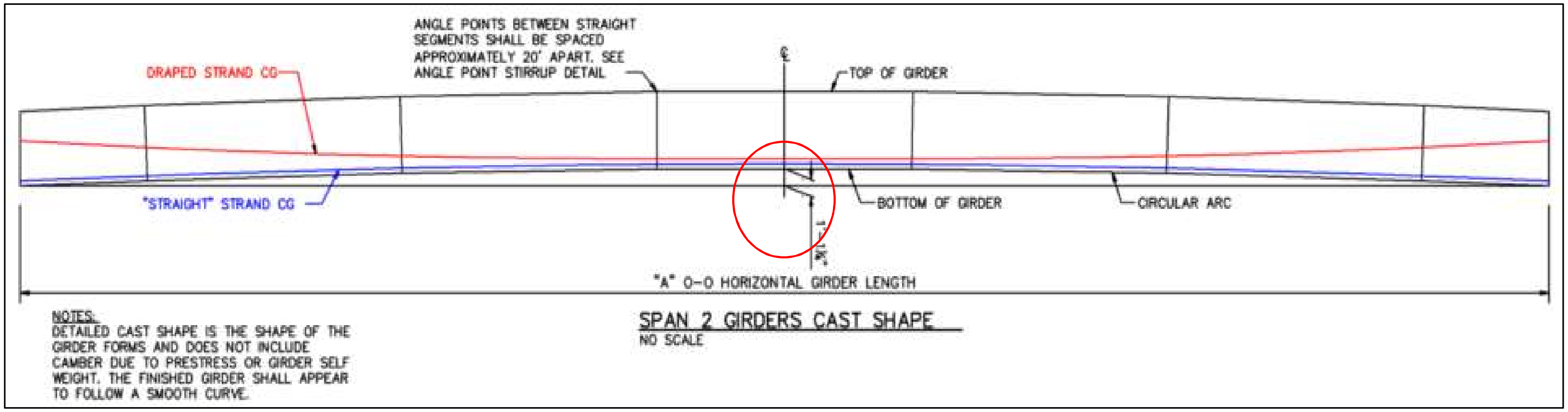
- Overhead Utilities
- Railroad Tracks Below

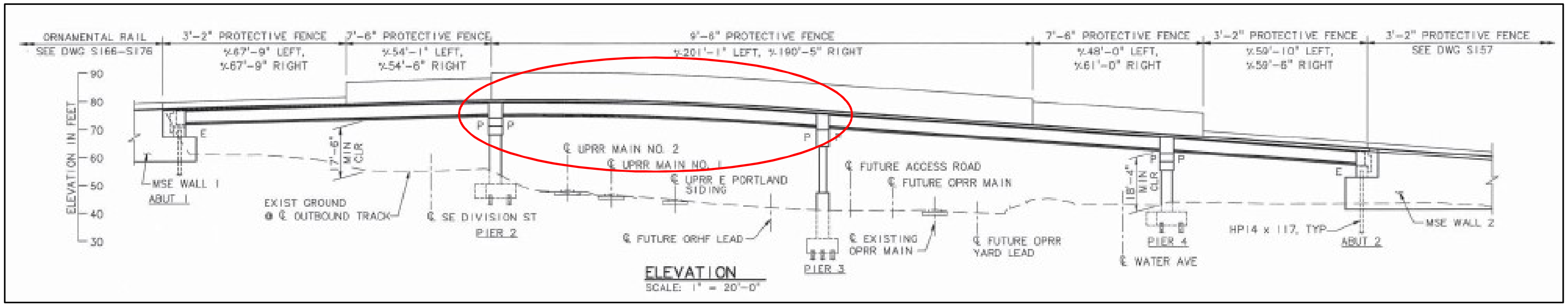


OMSI Viaduct

The Solution → Vertically Curved Girder

– ~13” of Built-In Camber

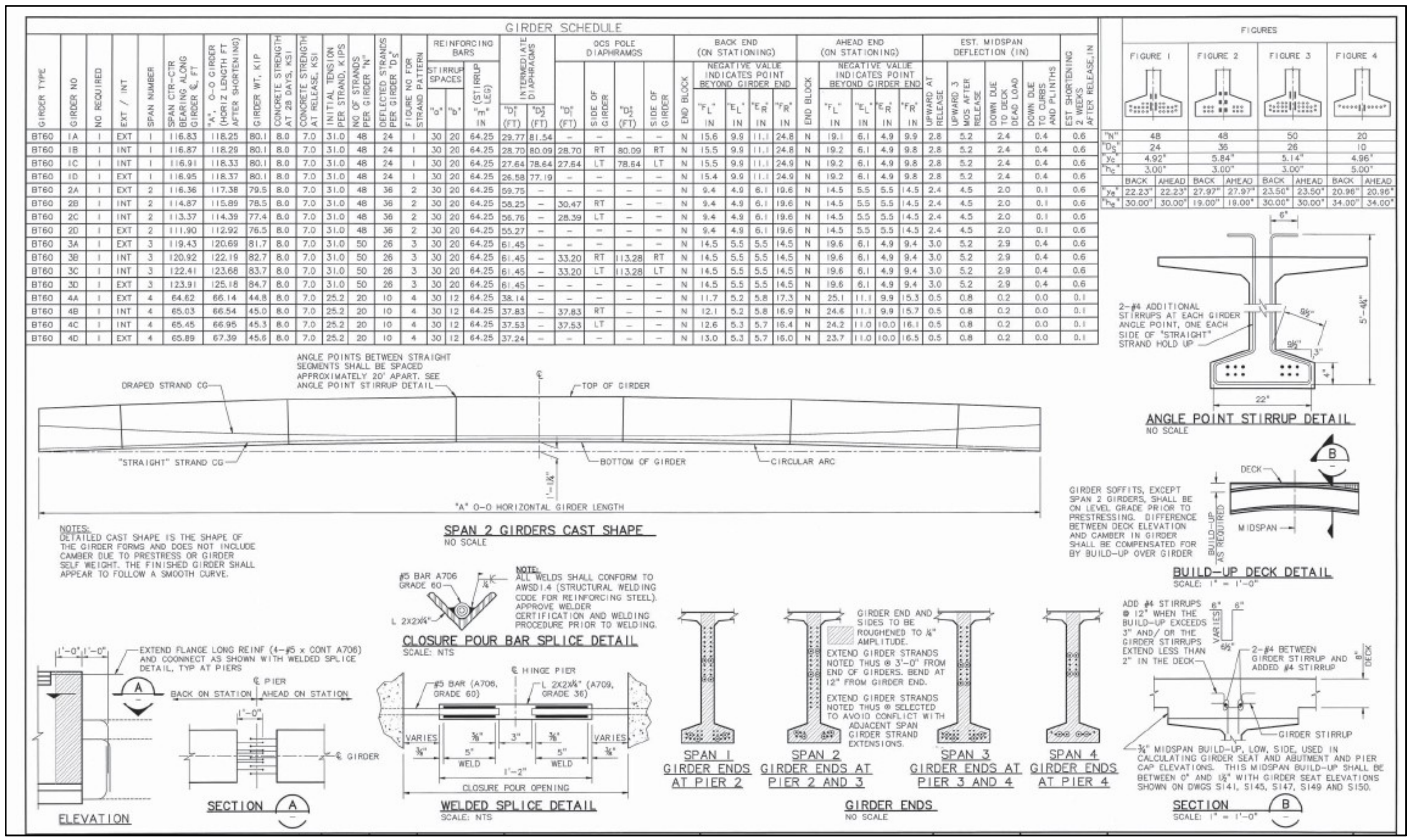




OMSI Viaduct

Fabrication Challenges

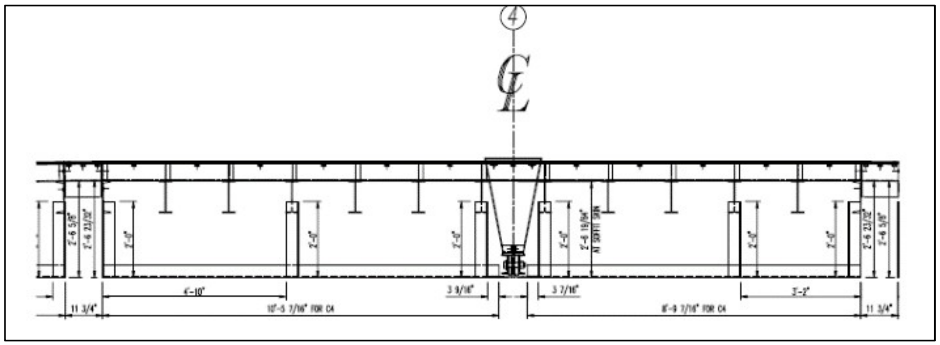
- Form Modifications
- Stressing
- Casting
- Shipping

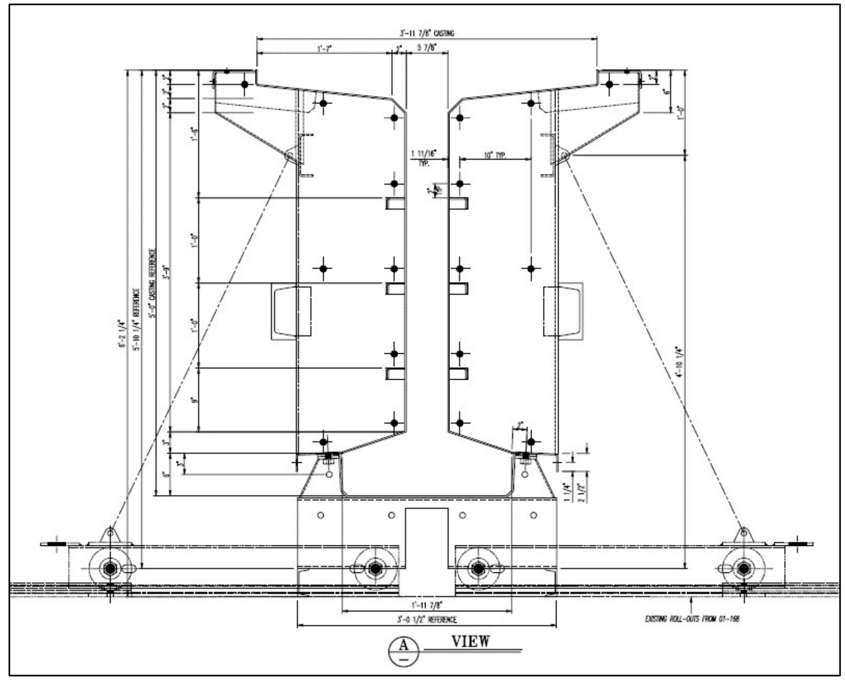


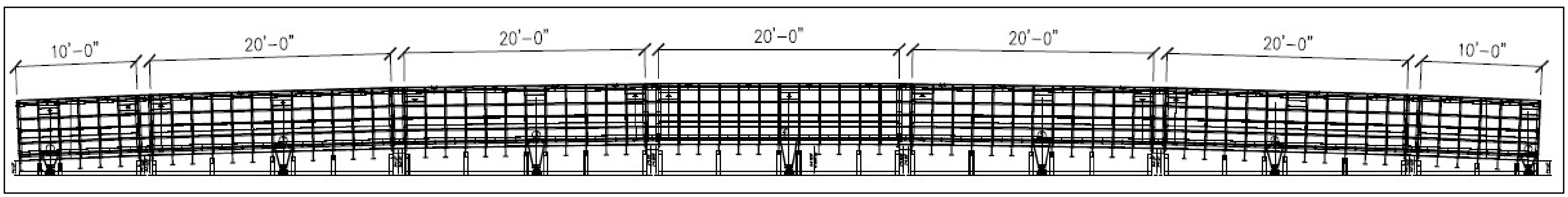
OMSI Viaduct

Form Geometry

- Segmented Versus Curved
- Custom Soffit
- Side Form Wedges







OMSI Viaduct

OMSI Viaduct

Strand Pattern

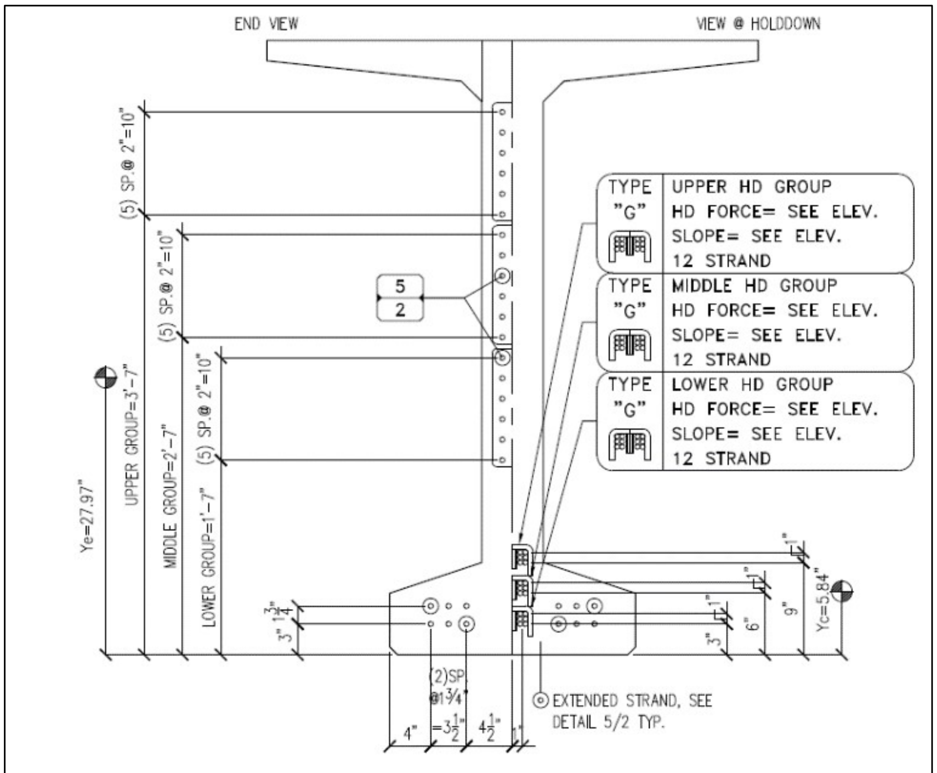
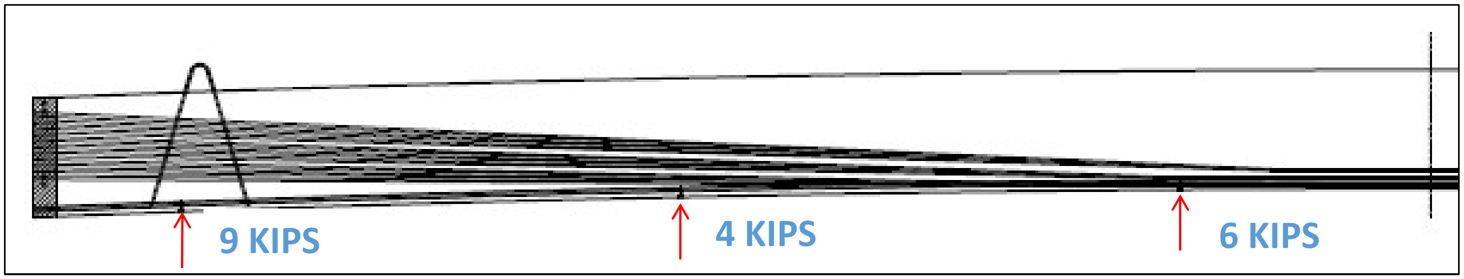


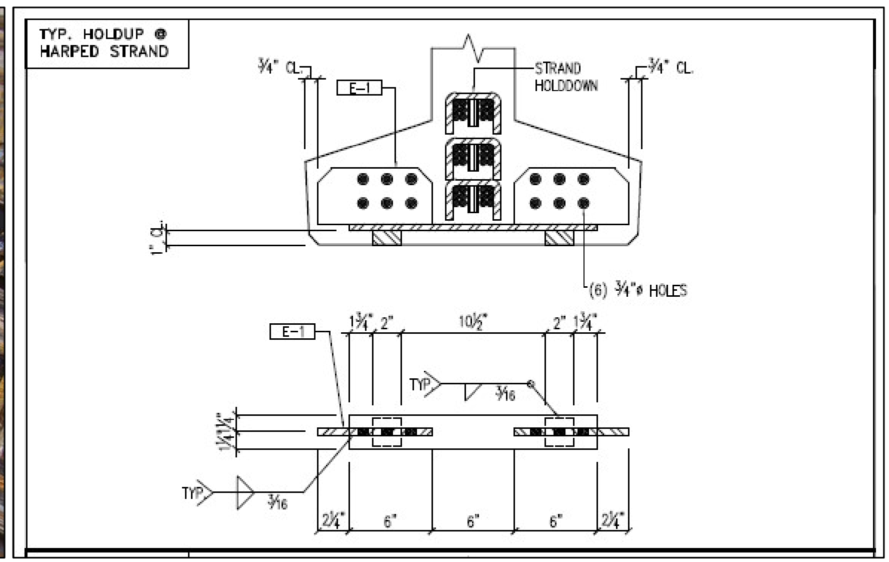
FIGURE 2 STRAND PATTERN (BEAMS 2A-2D)

SCALE: 1"=1'-0"
(48) ½"ø GRADE 270 KSI LOW RELAXATION STRAND, PULL TO 31 KIP EACH
DETAILS SYMMETRICAL ABOUT THE CENTERLINE UNLESS OTHERWISE NOTED

OMSI Viaduct

Strand Hold-Up Devices





OMSI Viaduct

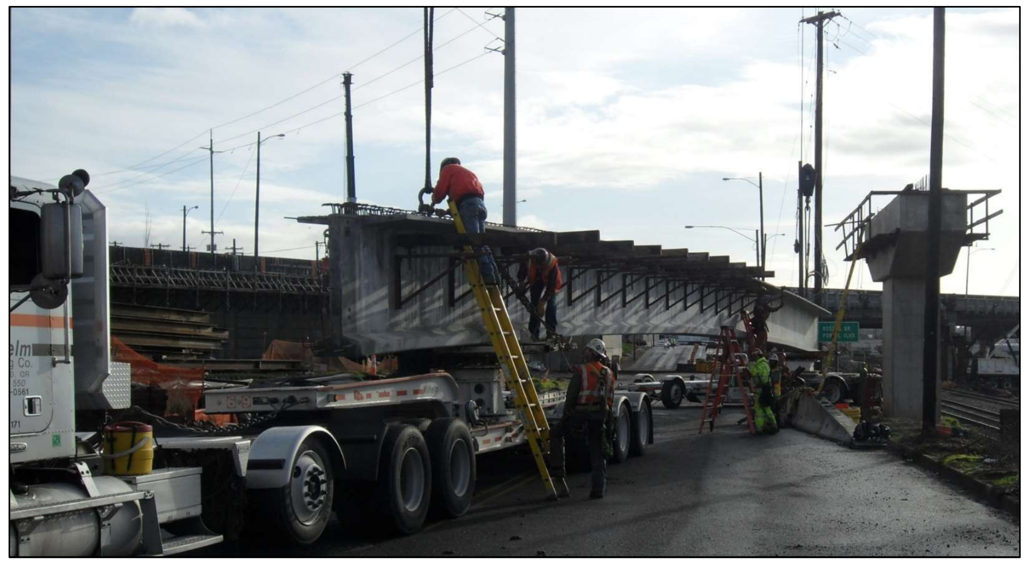
Strand Profile

OMSI Viaduct

Form Stripping, Product Picking, & Storage

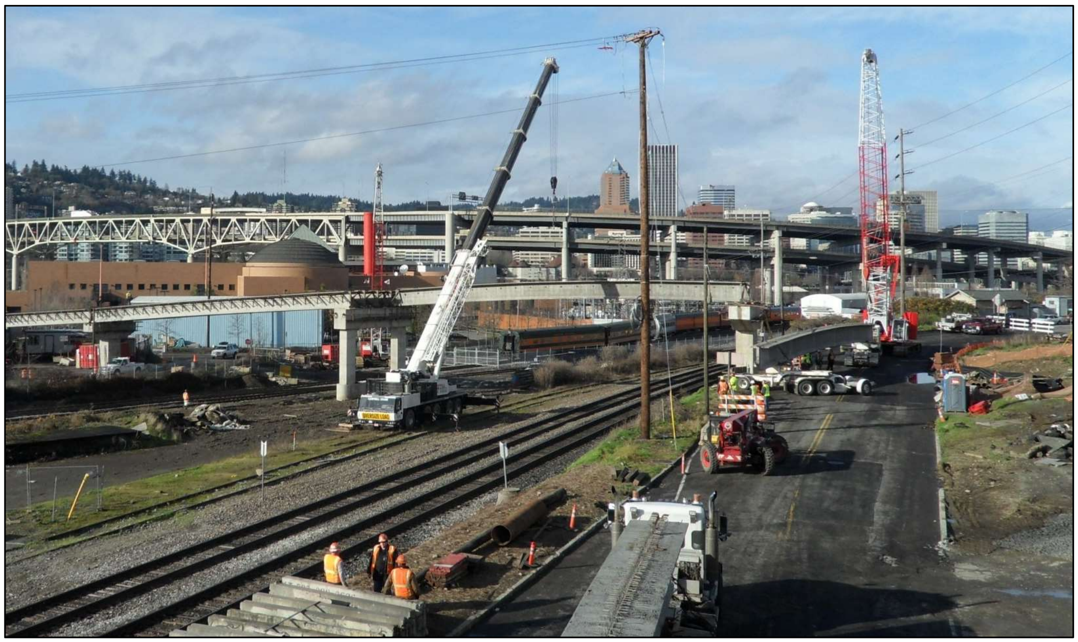
OMSI Viaduct

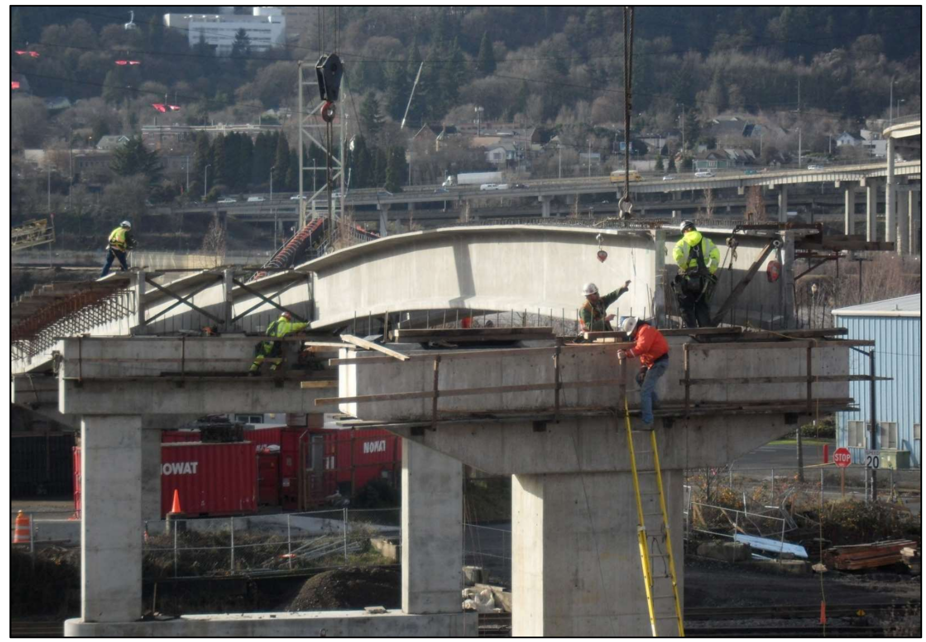
Shipping



OMSI Viaduct

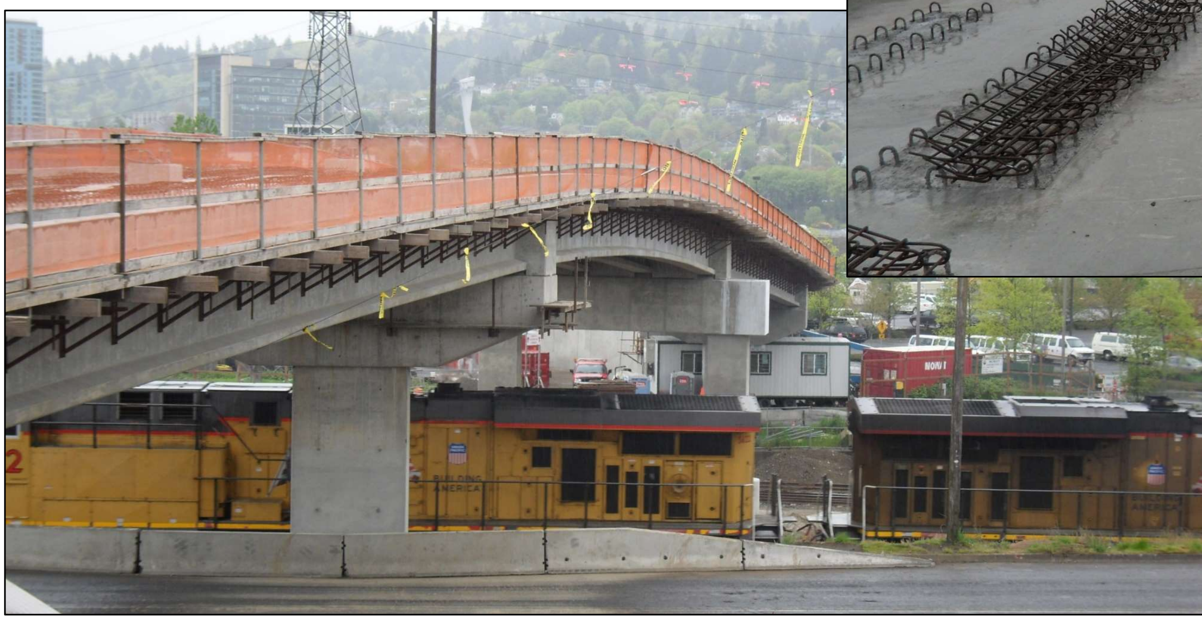
Girder Erection





OMSI Viaduct

Completed Deck & Tracks Below In Use

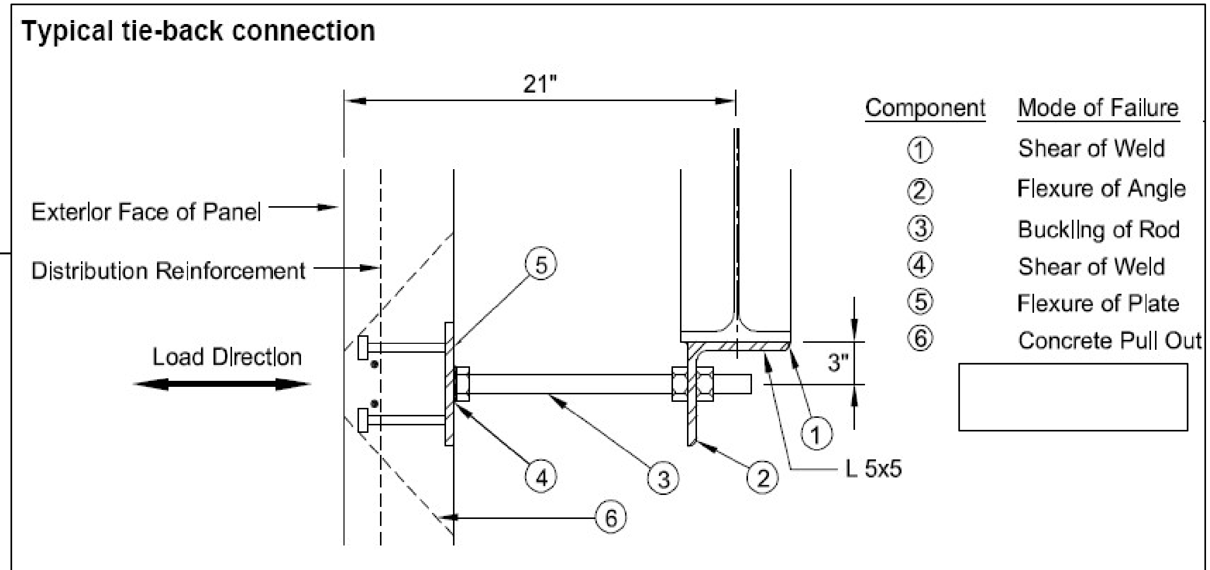


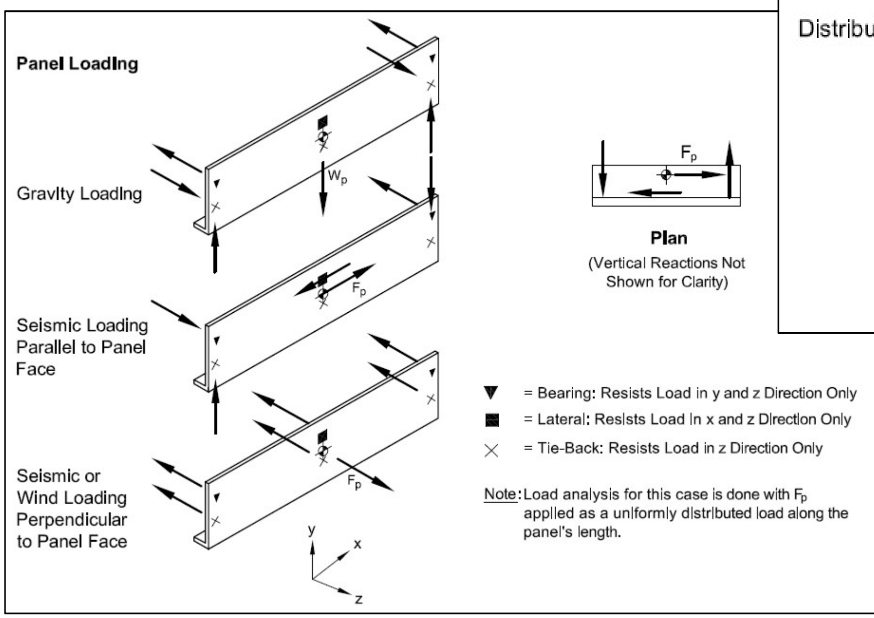
Precast Fascia Panels

Precast Fascia Panels

Design

- Design Guidelines & Loads
- Connection Type

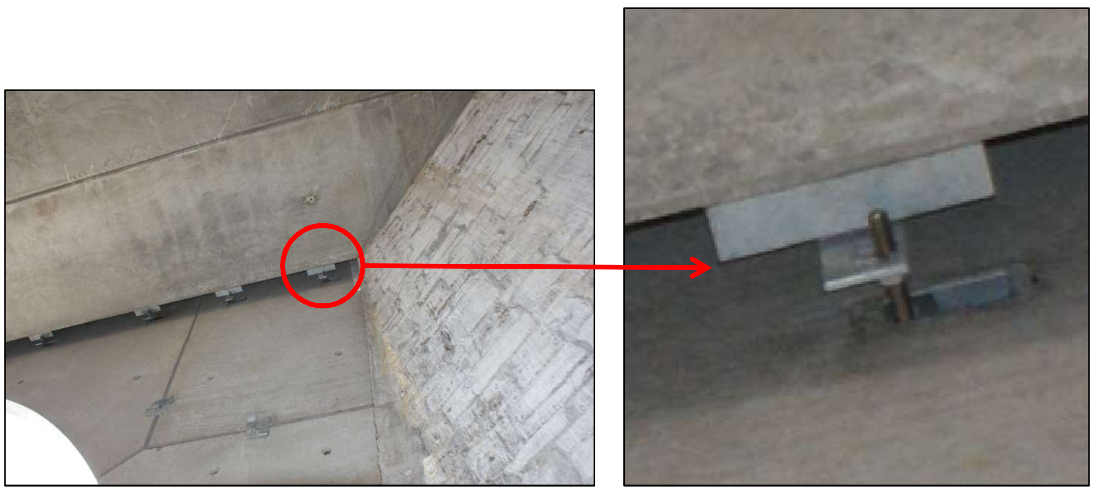




Fascia Panel Considerations

Design

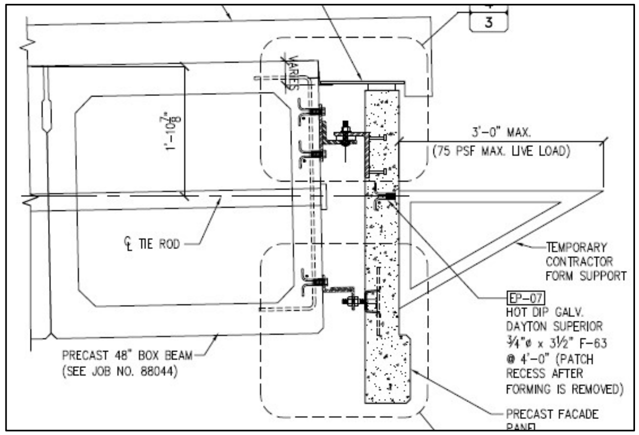
- **Panel Size & Weight**
- **Tolerances (Steel & Precast)**
- **Project History & Experience**
- **Specifications & Drawings**

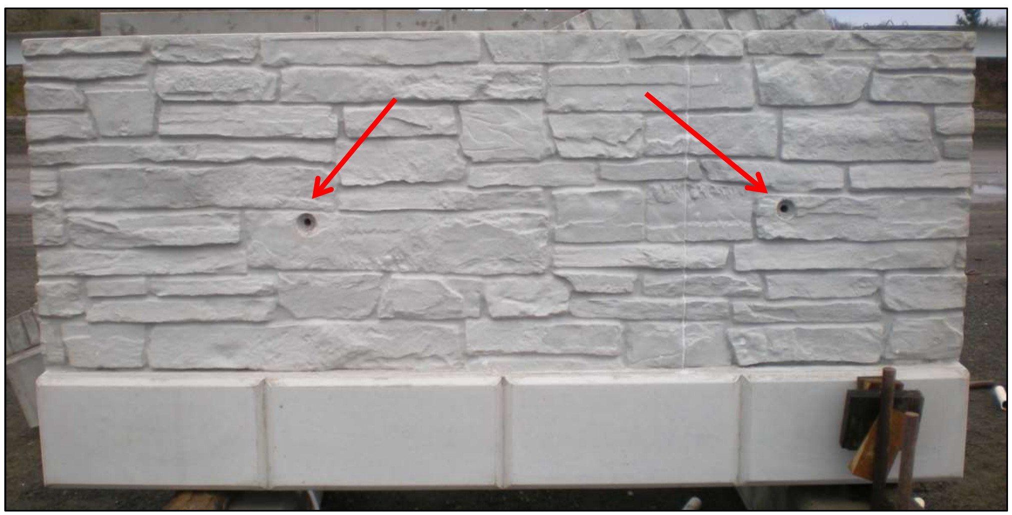


Fascia Panel Considerations

Fabrication

- Handling
- Shipping
- Erection
- Construction Staging
- Contractor Forming





Fascia Panel Considerations

Specifications

- Form Liners
- Finish/Color
- Price $$

Maintenance

- Inspection
- Replacement

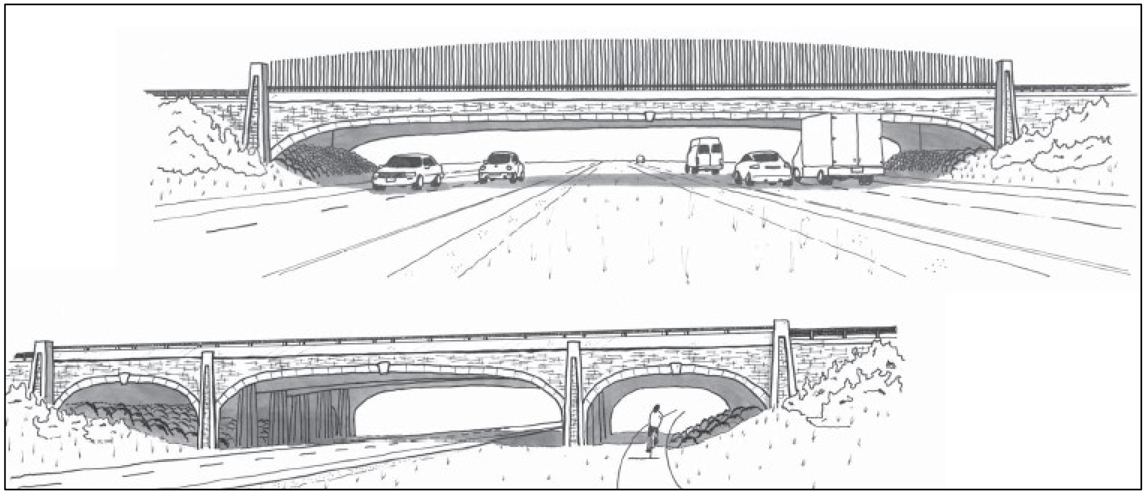
Columbia River Gorge National Scenic Area

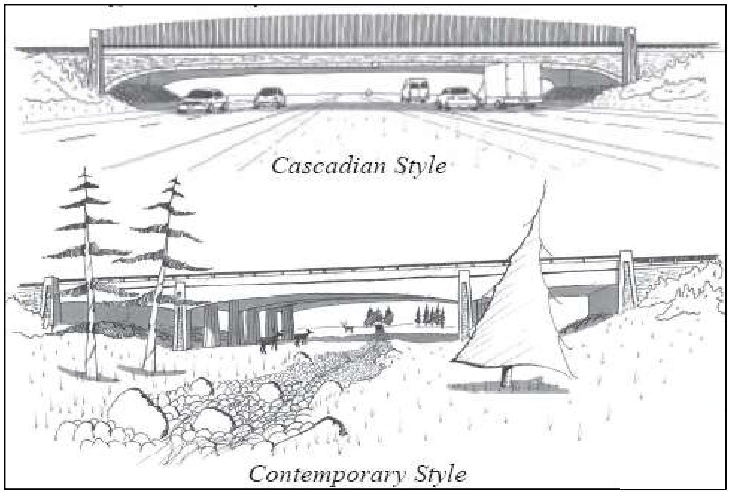
- Established by Congress in 1986

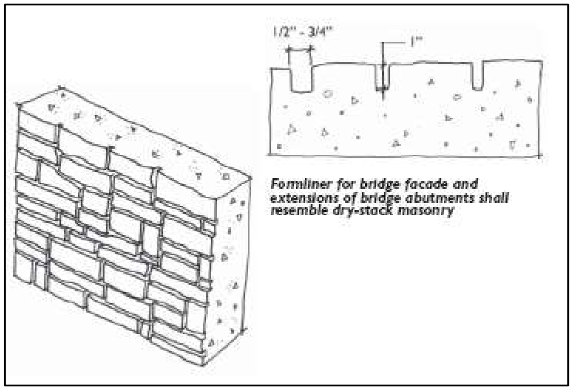
- I-84 Corridor Strategy – November 2005
  - ODOT – Regions 1 and 4, Technical Services
  - Columbia River Gorge Commission
  - USDA Forest Service
  - Federal Highway Administration
  - Hood River, Multnomah and Wasco Counties
  - Consultant - OTAK, Inc.

- Provides framework for ODOT to manage and improve I-84 facilities within the CRGNSA.

I-84 Corridor Strategy







Formliner for bridge facade and extensions of bridge abutments shall resemble dry-stack masonry

Color 1
- Steel portion of bridge rail (paint)
- Bridge girders (weathering steel or stain if concrete)
- Steel portion of roadside guardrail (weathering steel)
- Back of signs (paint)
- Eastern stone facade (stain)
- Eastern retaining walls (stain)

Color 2
- Western stone facade (stain)
- Western retaining walls (stain)

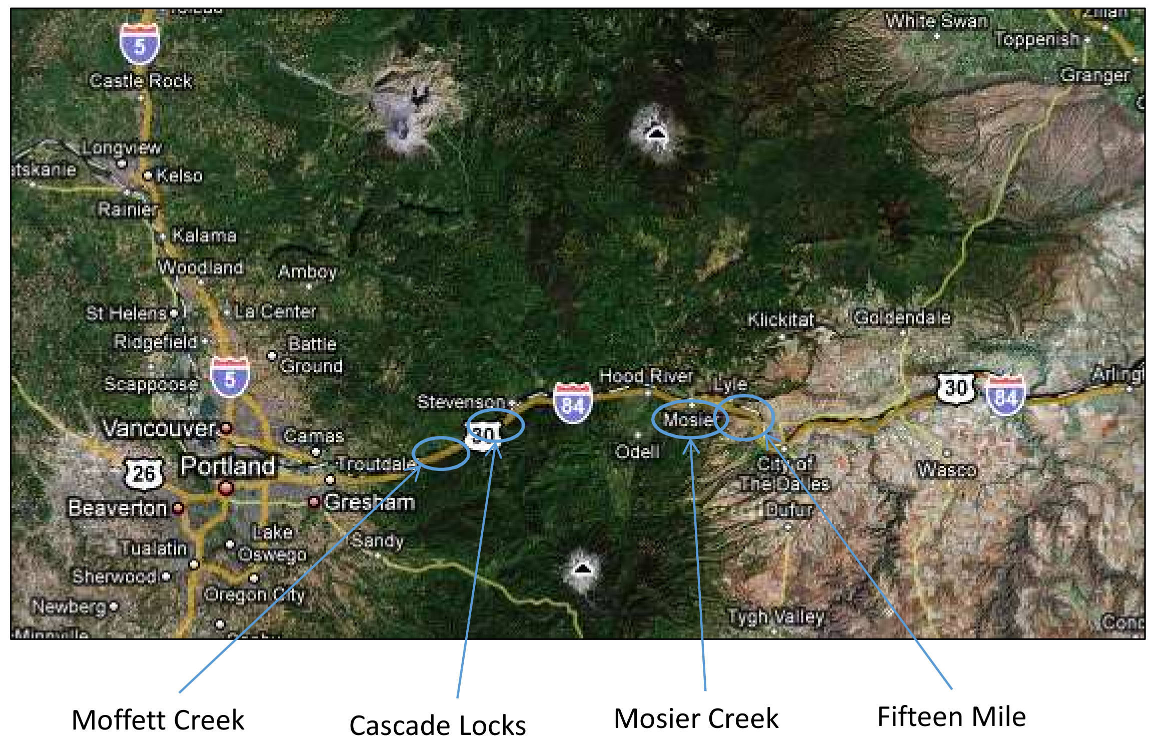
Color 3
- Bridge screen (paint)

Color 4
- Fences (weathering steel)
- Weigh-in-motion facilities (paint)
- Lighting (paint)
- Sign posts (paint)
- Permanent de-icing systems (paint)
- Truck weigh station facilities (paint)

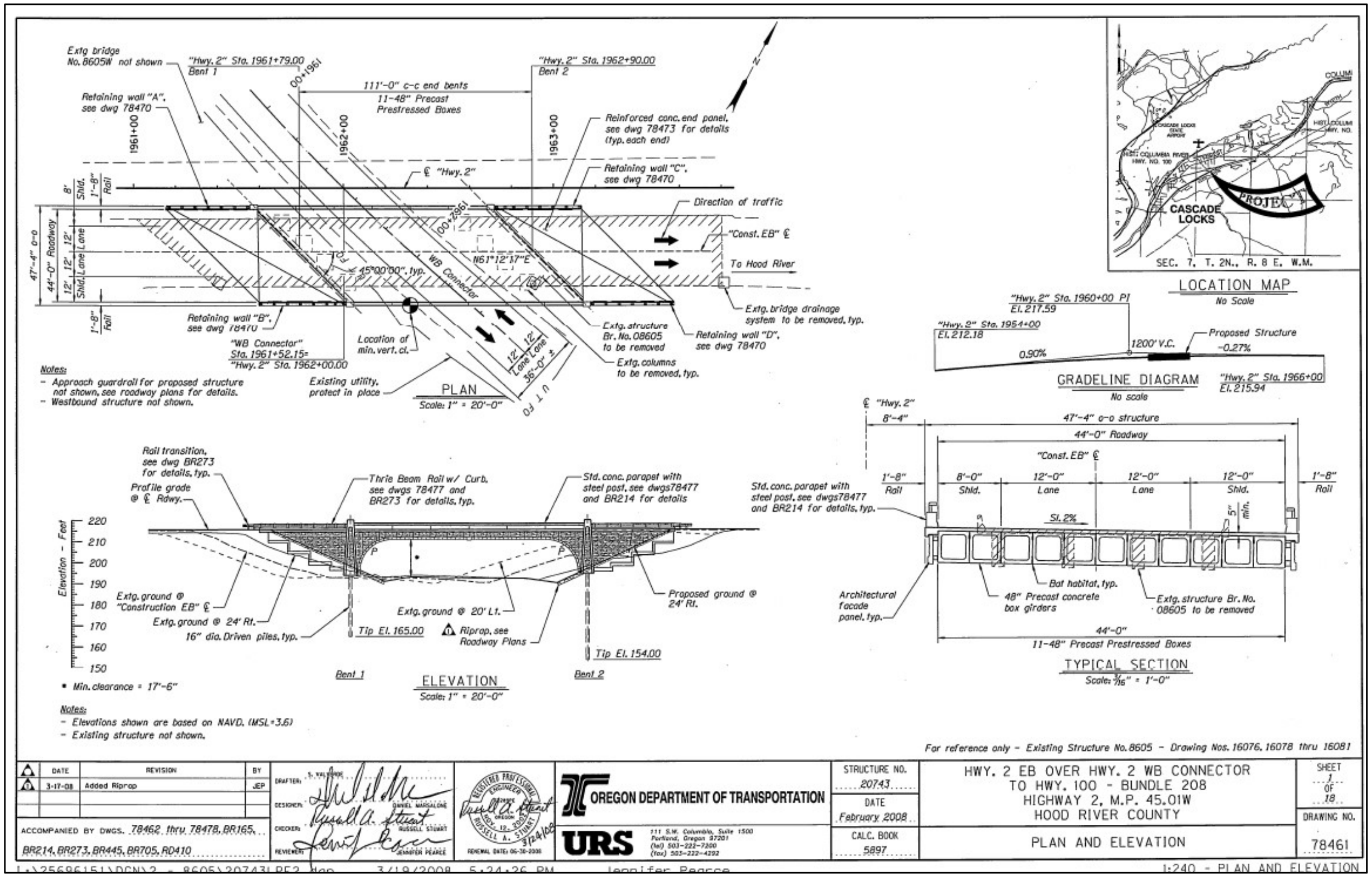
Color 5
- Median barrier (paint)
- Bridge rail base (stain)
- Abutment wall and pier trim for bridges and culverts (stain)

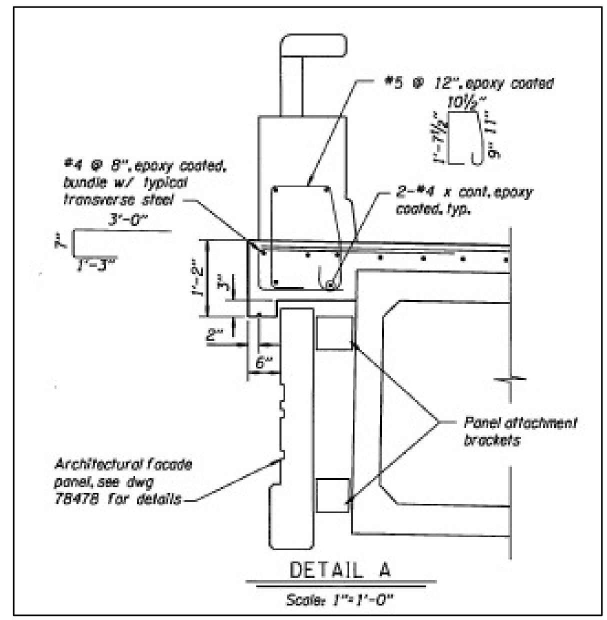
Columbia River Gorge Bridges

- 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



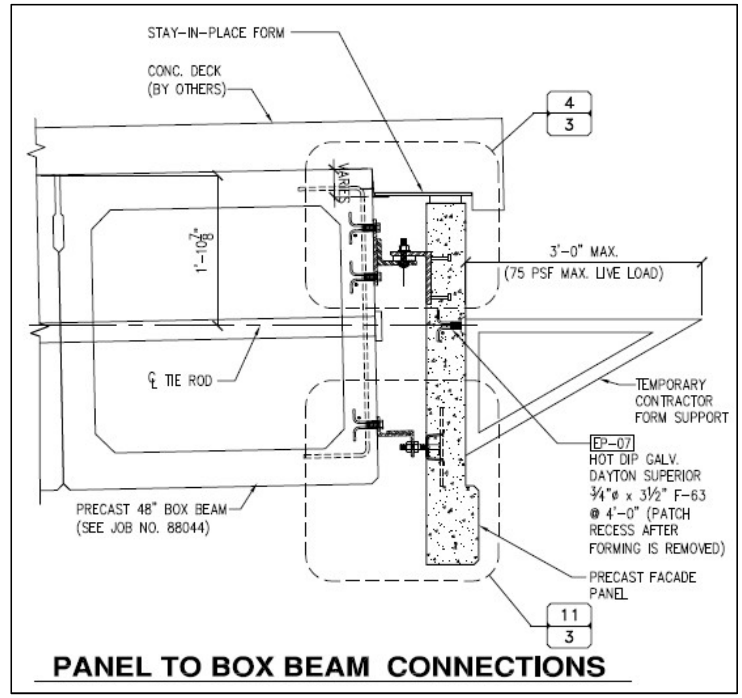


Cascade Locks

Cascade Locks - Fabrication

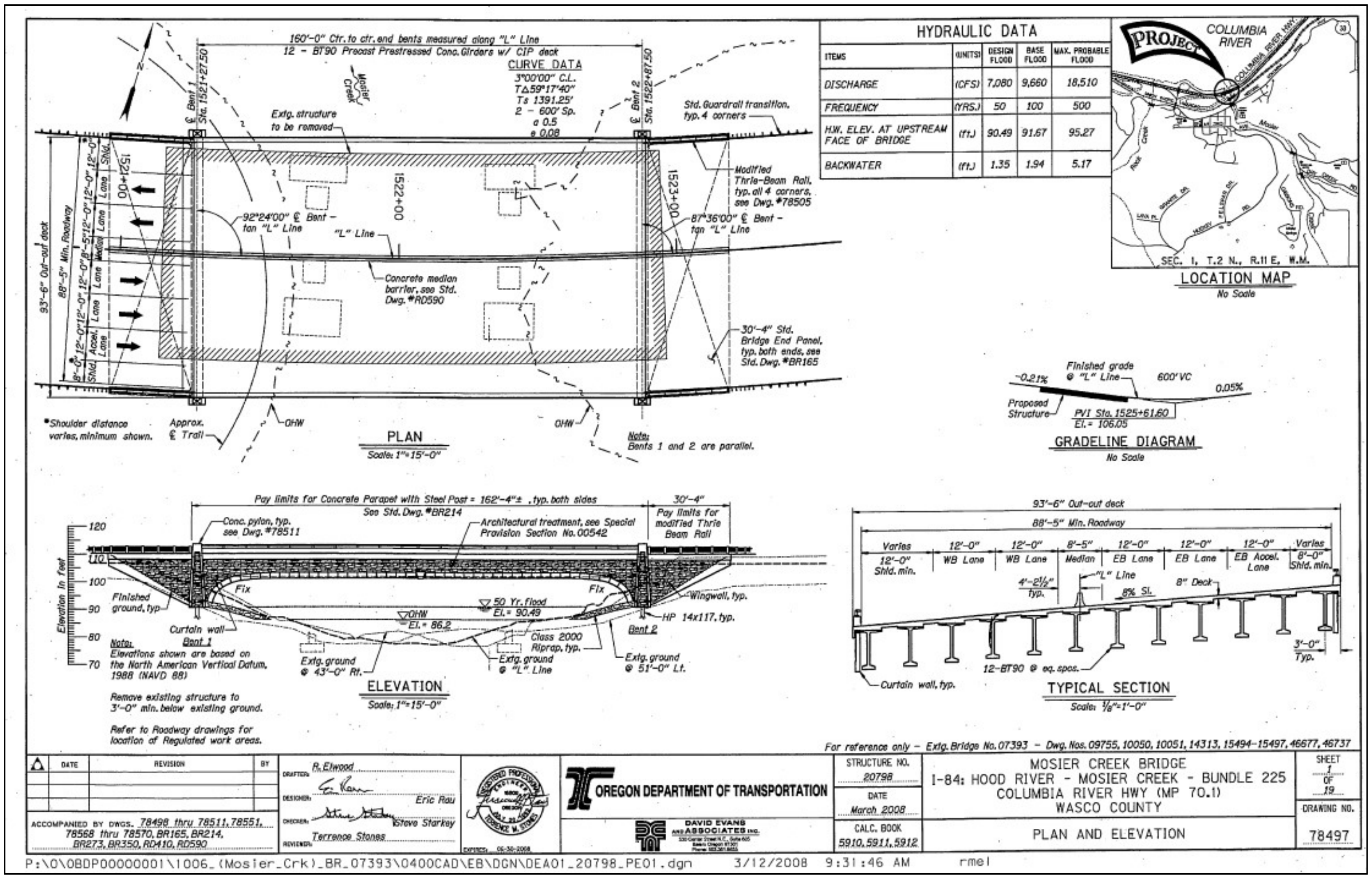
Cascade Locks

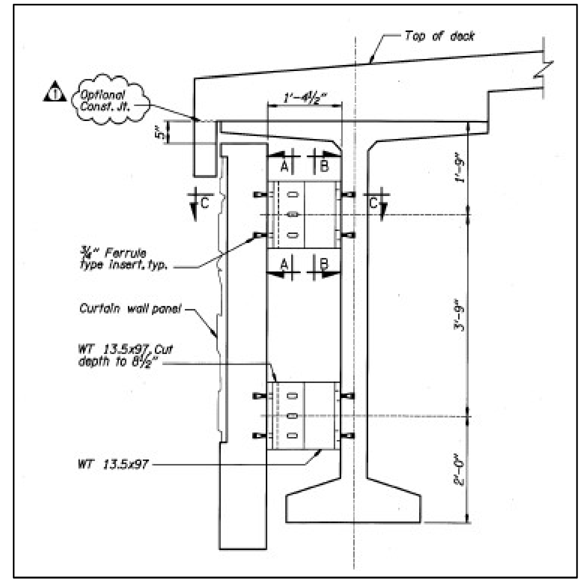
Cascade Locks - Connection

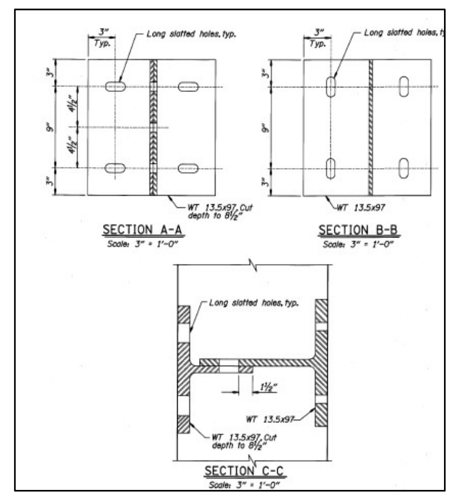


Cascade Locks

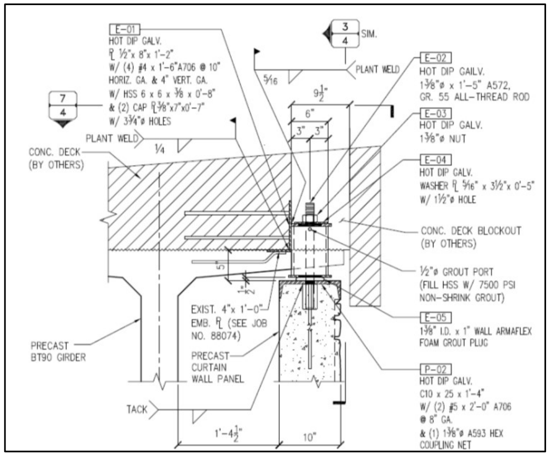
Mosier Creek

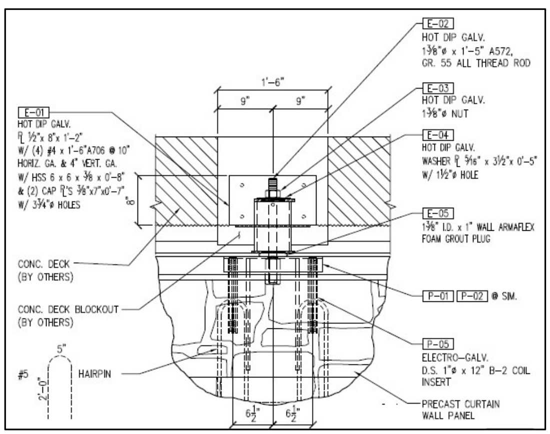


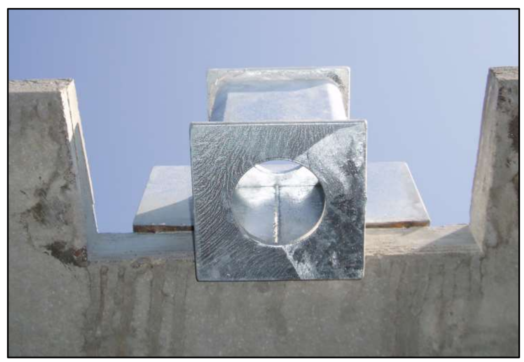




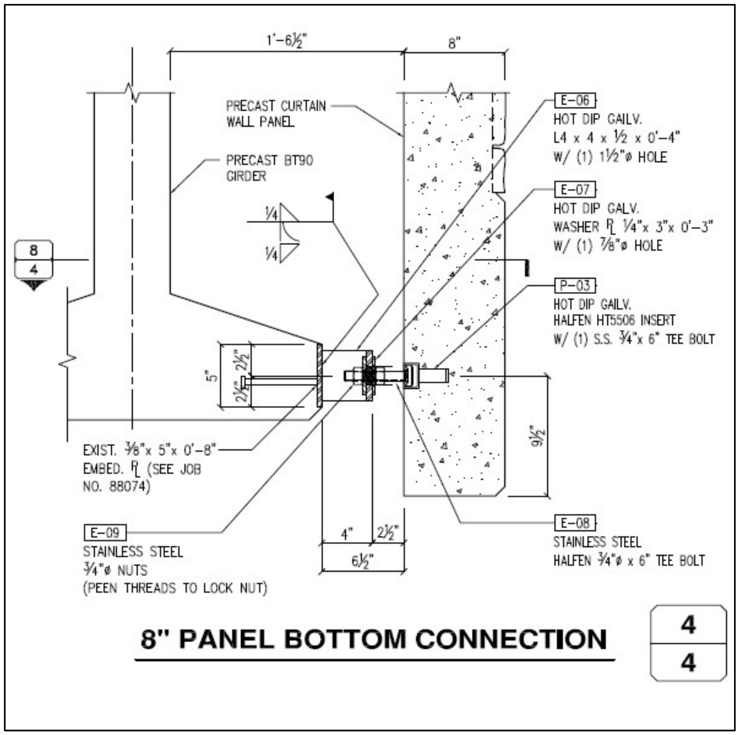
Mosier Creek Bridge – Top Connection



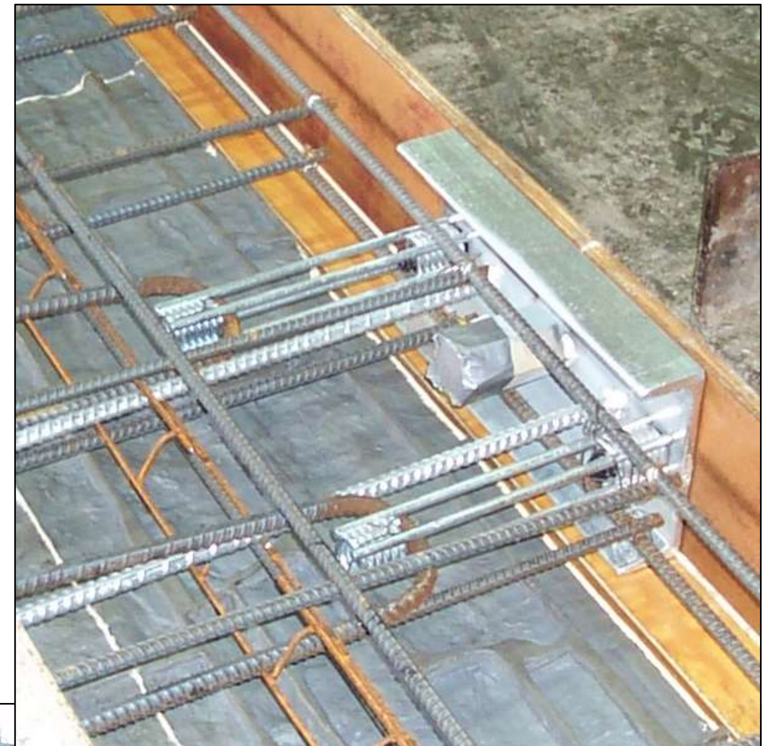




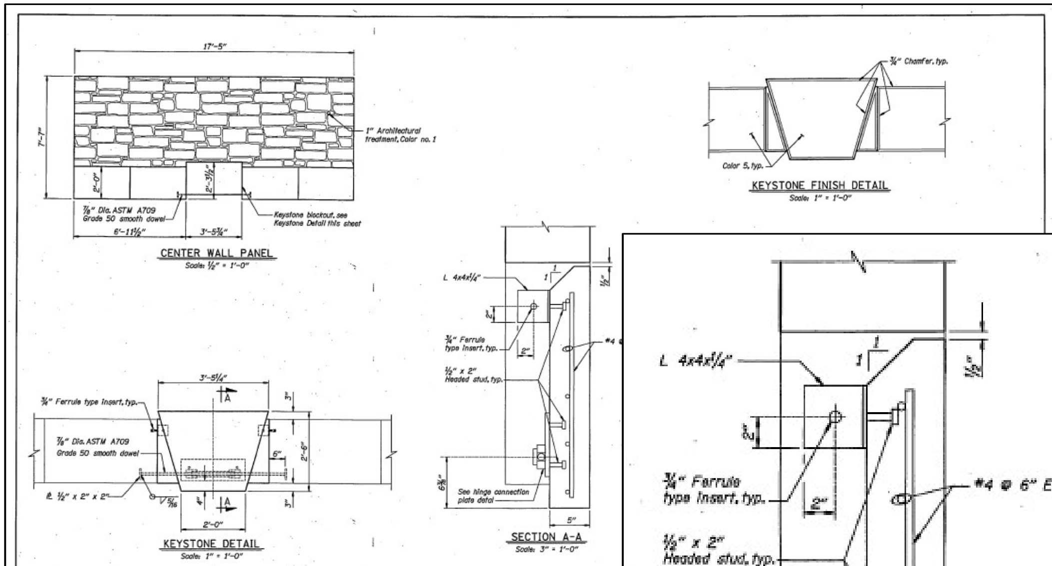
Mosier Creek Bridge – Bottom Connection

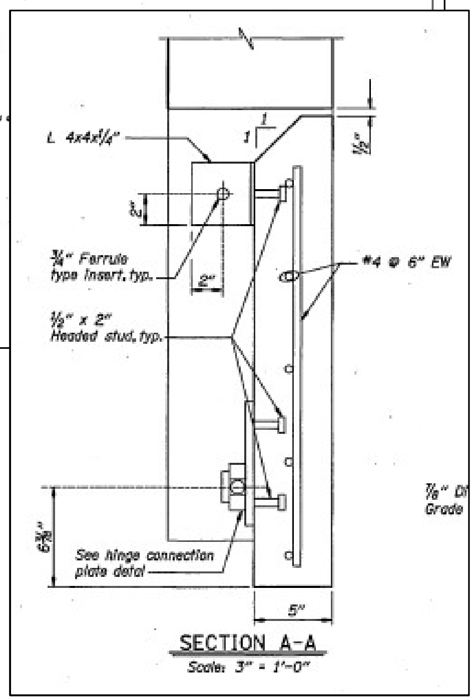


Mosier Creek – Fabrication

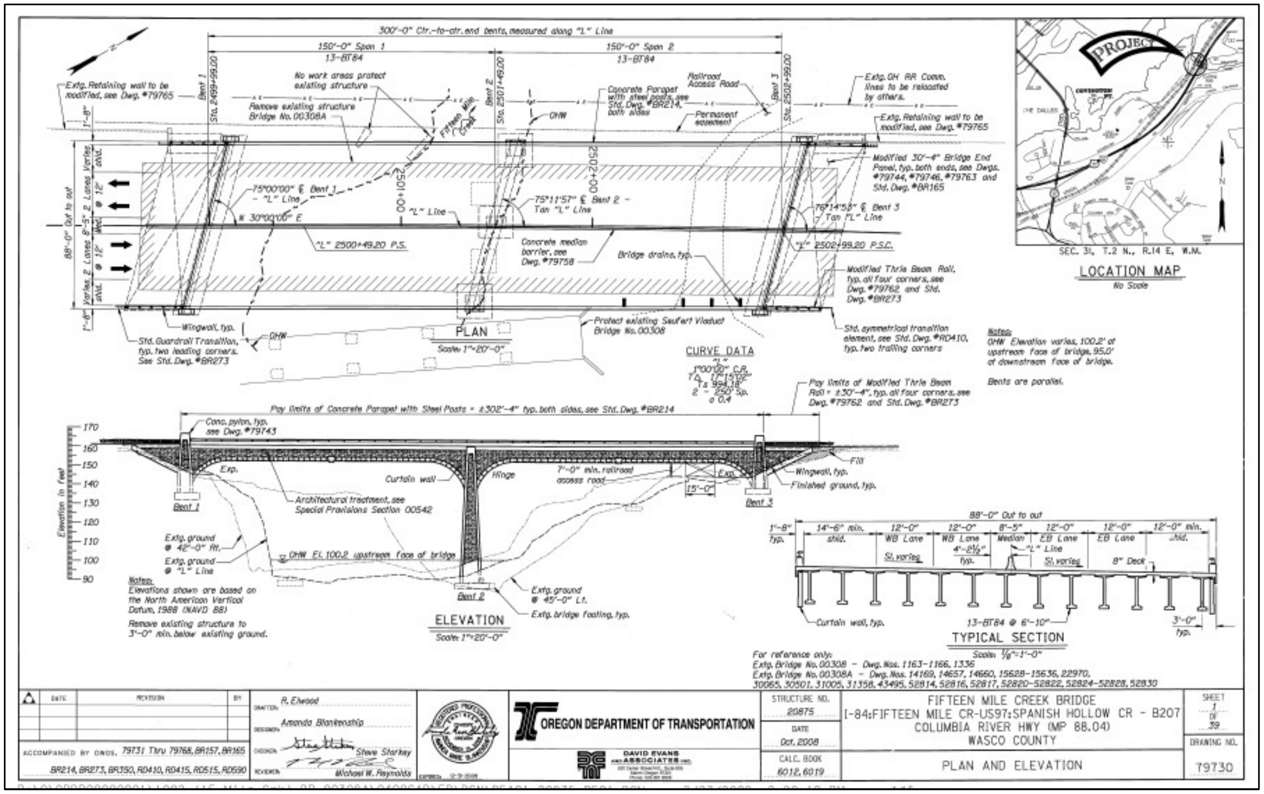


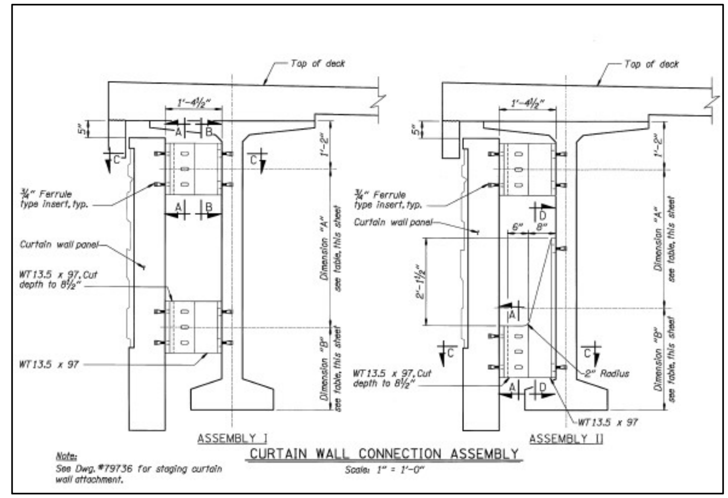
Mosier Creek – Access Hatch

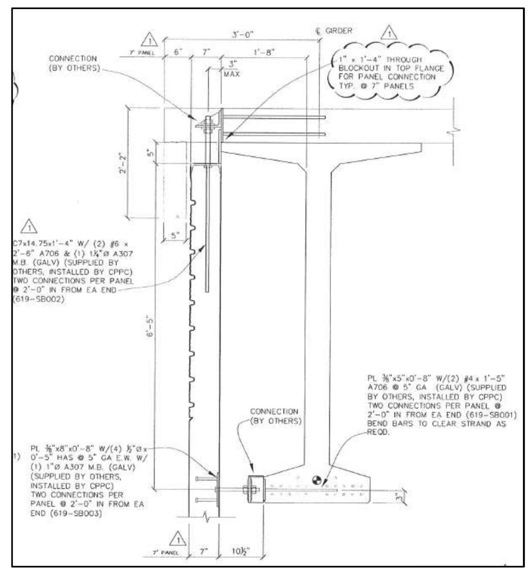




Fifteen Mile Creek







Fifteen Mile Creek

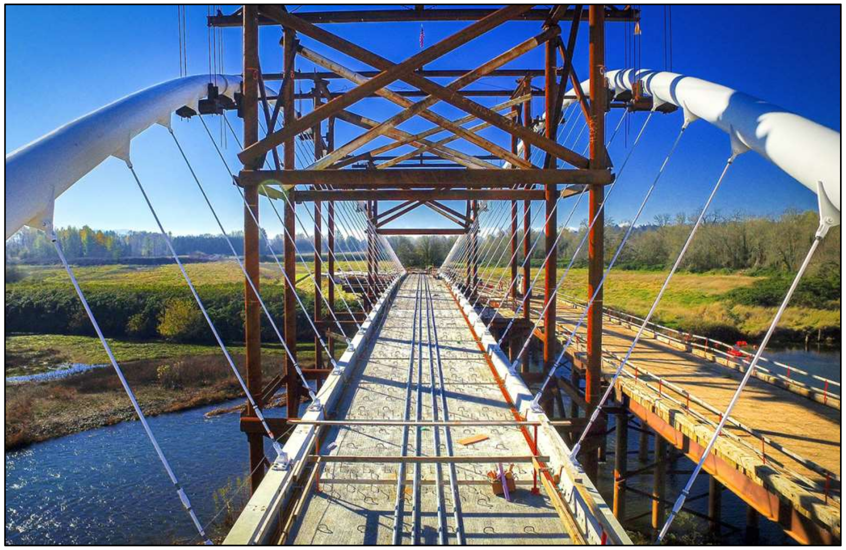
Other Specialty Solutions

- 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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PCI

williams&works
engineers | surveyors | planners