Western Bridge Engineers' Seminar

WELCOME TO THE 2017 Western Bridge Engineers' Seminar

DESIGN AND CONSTRUCTION OF THE TILIKUM CROSSING IN PORTLAND OREGON

Kevin Almer PhD PE SE

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- ❑Project Overview
- ❑Design
- ❑Seismic Time-History Analyses
- ❑Construction

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Project Overview

- ❑ **7.3-mile** light rail extension
- ❑ ~ **25,500** weekday rides by 2030
- ❑ **Two** Park & Ride lots
- ❑ Up to **460 bike spaces**
- ❑ New **multi-modal bridges**
- ❑ Up to **14,500 jobs**
- ❑ Improved light rail, bus, streetcar, bike/pedestrian and freight service

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Tilikum Crossing Transit Bridge

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Program Requirements

- Prescriptive vs. Performance Requirements
  - Prescriptive – "Fixed" elements of PE Design
    - Bridge Type
    - Shape
    - Dimensions
    - Architectural Features
  - Performance – Opportunity for Innovation
    - Means & Methods
    - Pile Caps
    - Ground
    - Work Bridges and access

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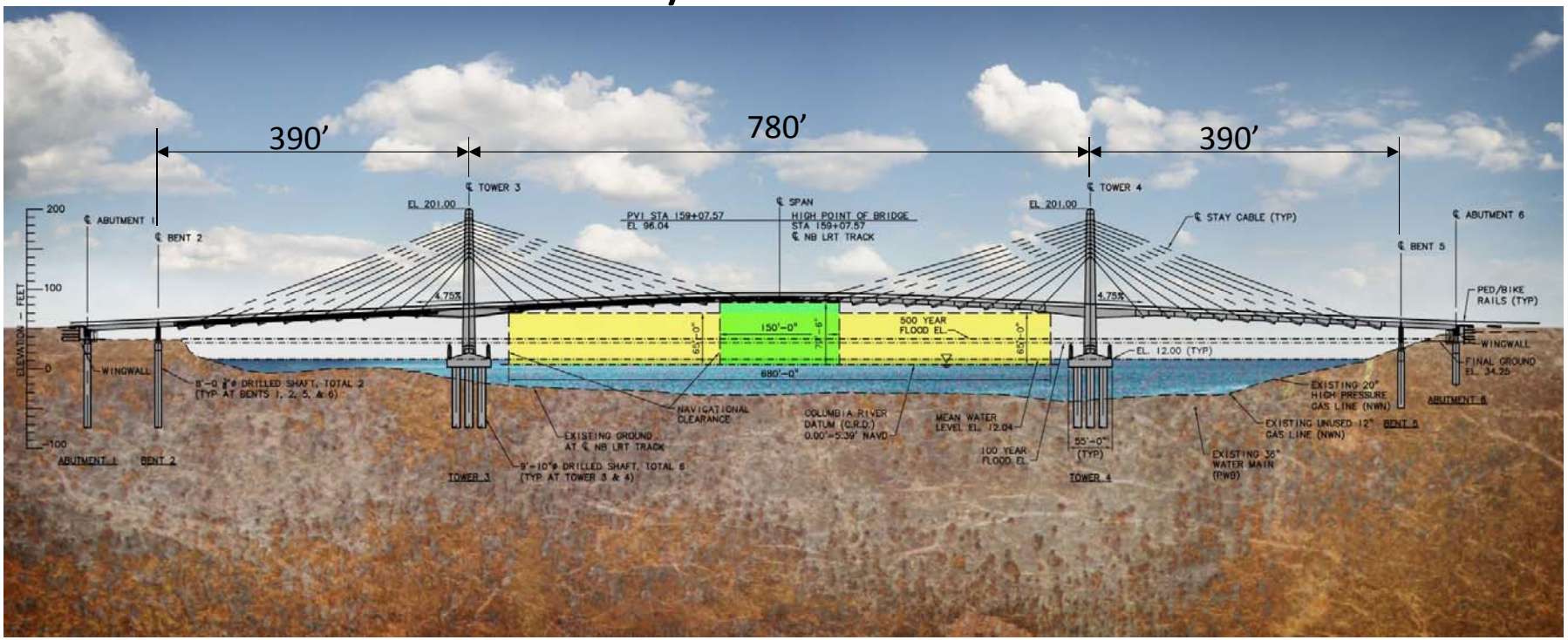
Structure Geometry



Main Span Framing

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Program Options

- ❑Deep foundations at main pier
- ❑Approach foundations
- ❑Soil liquefaction / ground improvement

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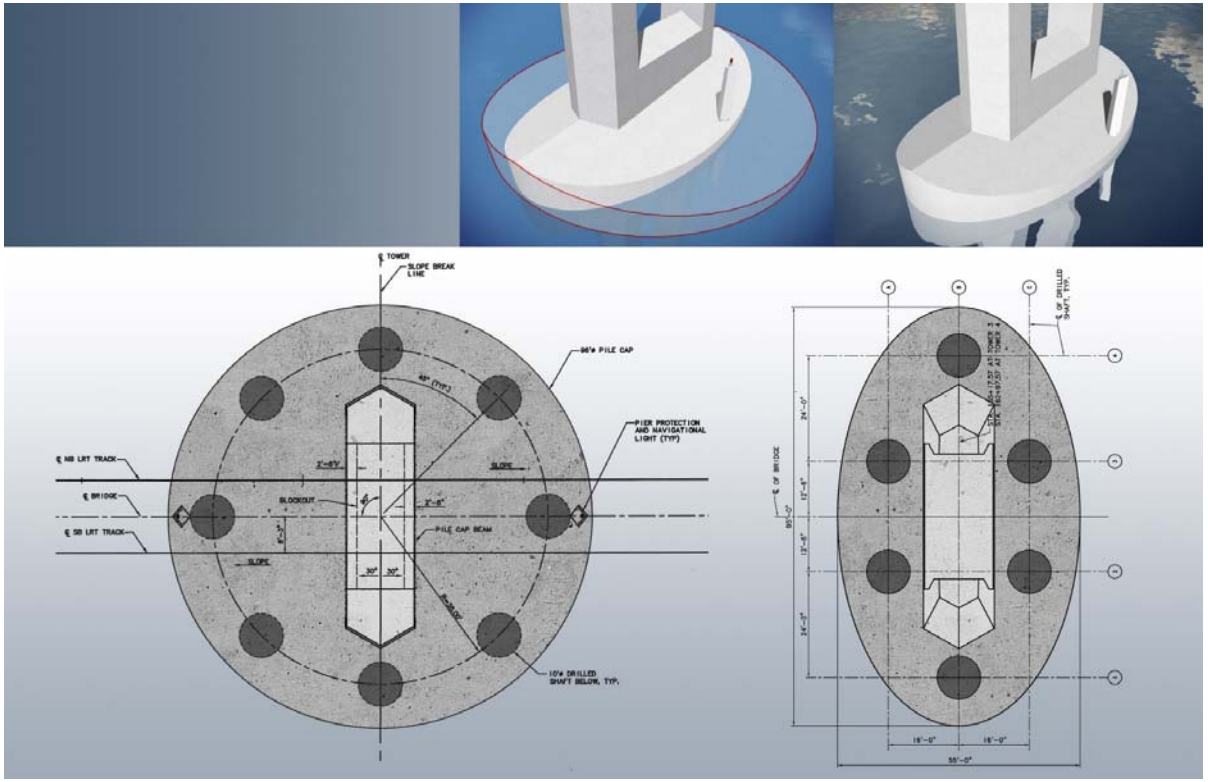
Main Footings



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Bridge Design

- Operating Loads
  - Dead Load (permanent loads)
  - Live Loads (moving loads: trains, buses, bikes/pedestrians)

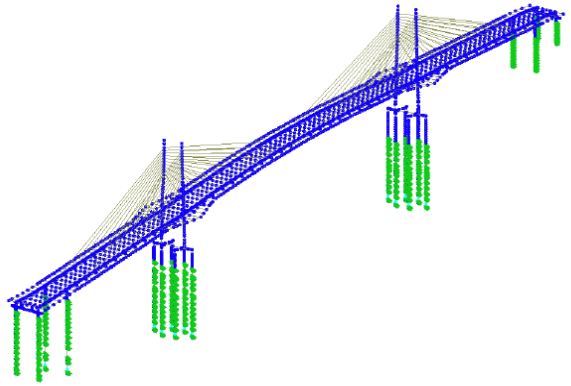
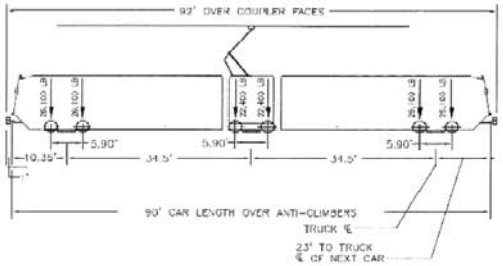
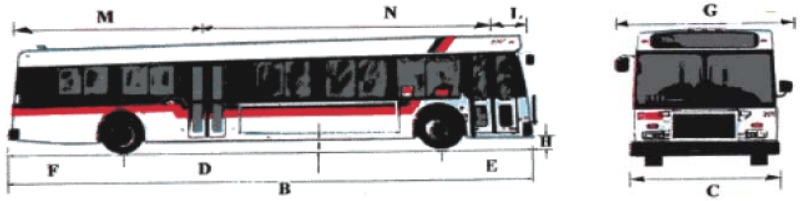


Figure 1 – Global LARSA Model

LRV LOADING DIAGRAM



TriMet Low Floor Bus (TriMet Design Criteria Figure 23.3.B.1.c-1)



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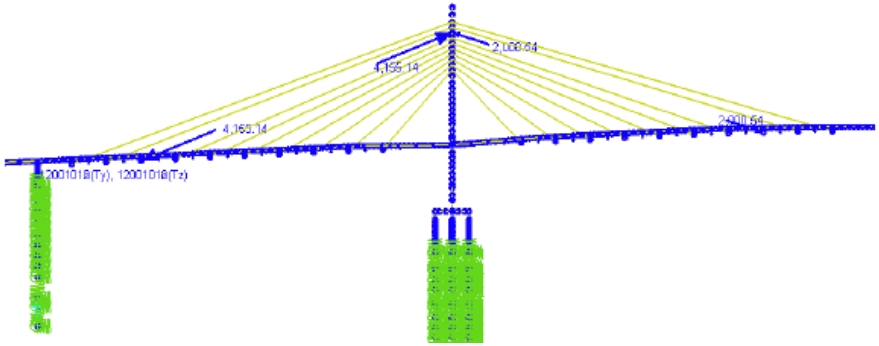
Bridge Design

- Other Loads
  - Seismic Loads (earthquake)
  - Wind Loads
  - Ship/Vessel Impact
  - Cable Loss (rupture of one stay cable)



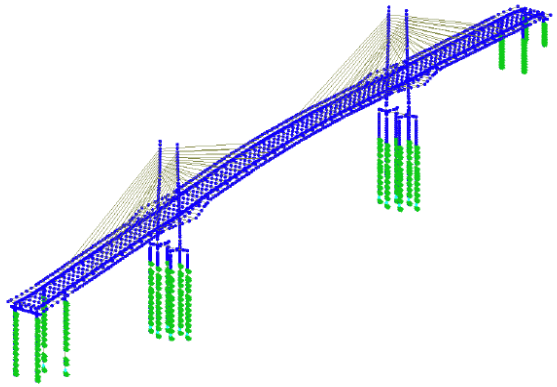
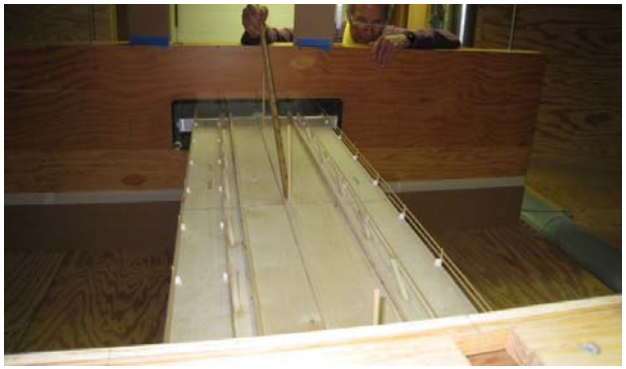
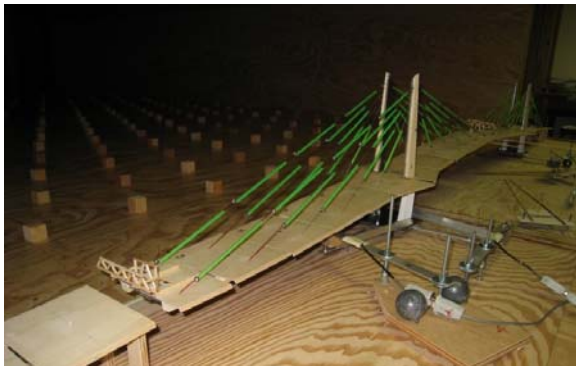


Figure 1 – Global LARSA Model

Wind Tunnel Analysis

- ❑Deck Cross Section
- ❑Completed Bridge
- ❑During Construction





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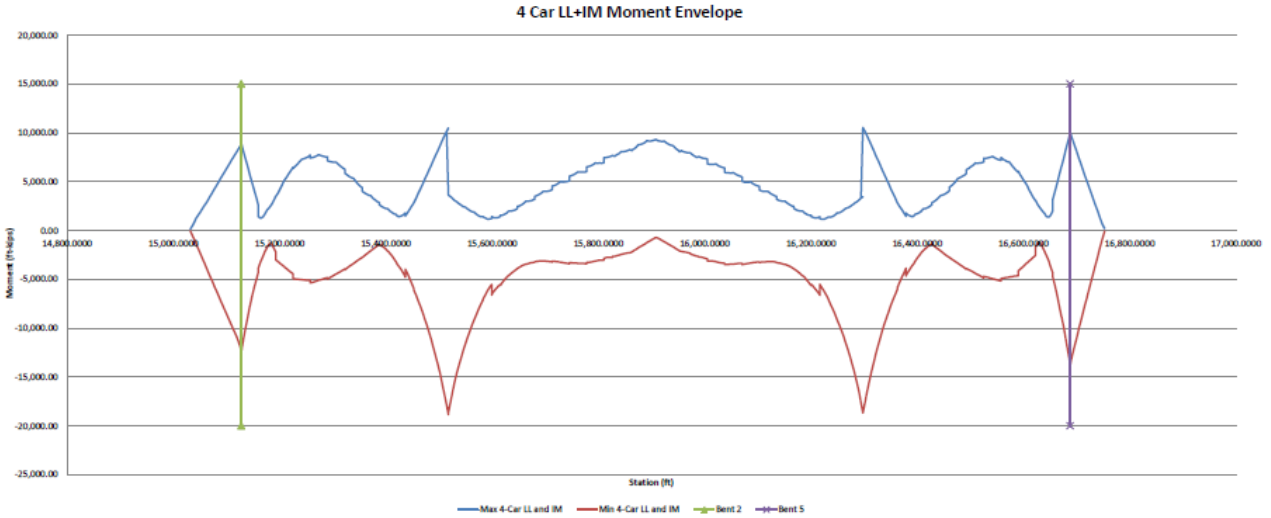
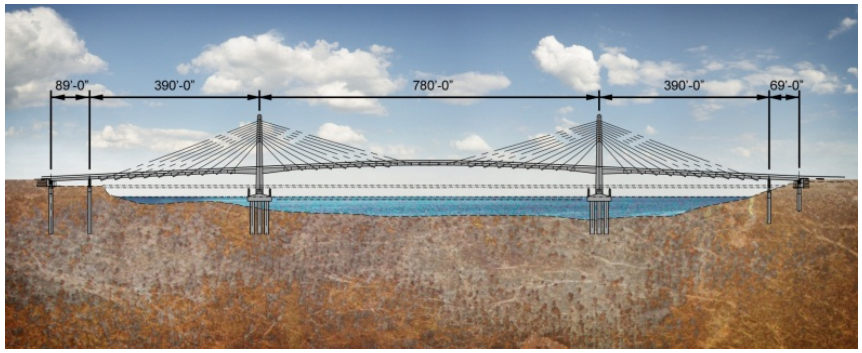
Structural Behavior





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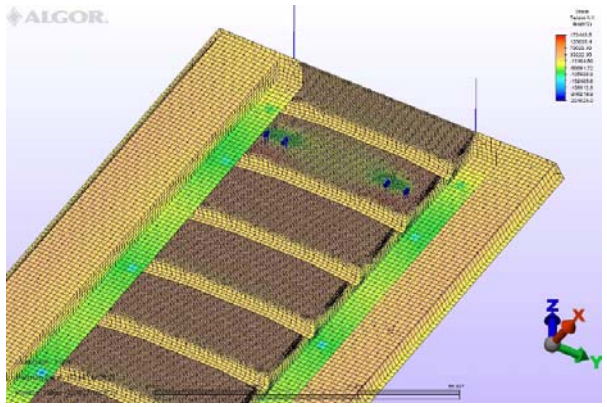
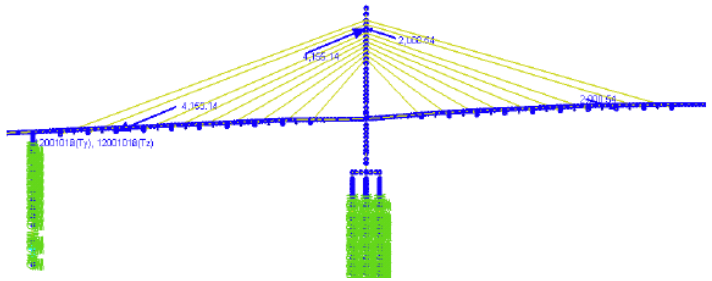
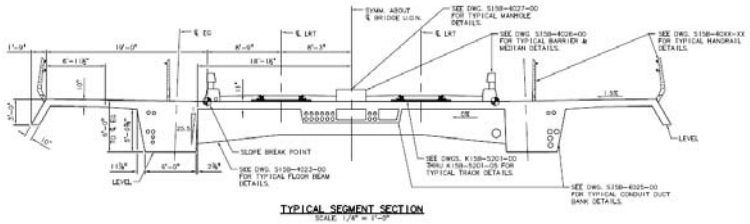
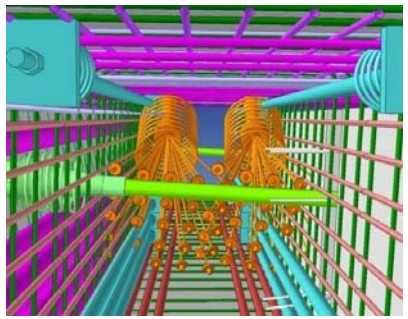
Component Design Summary

- Edge girders controlled by Cable Loss









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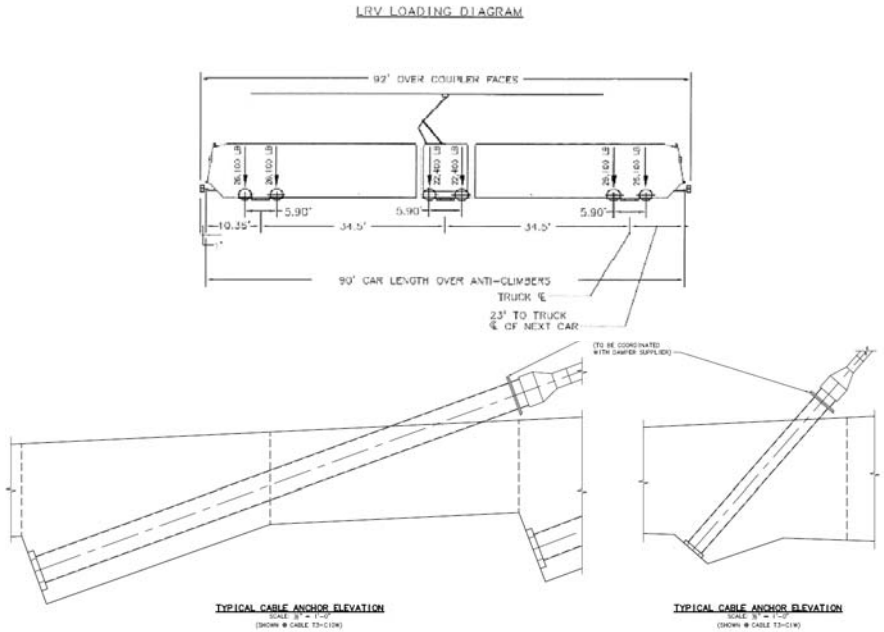
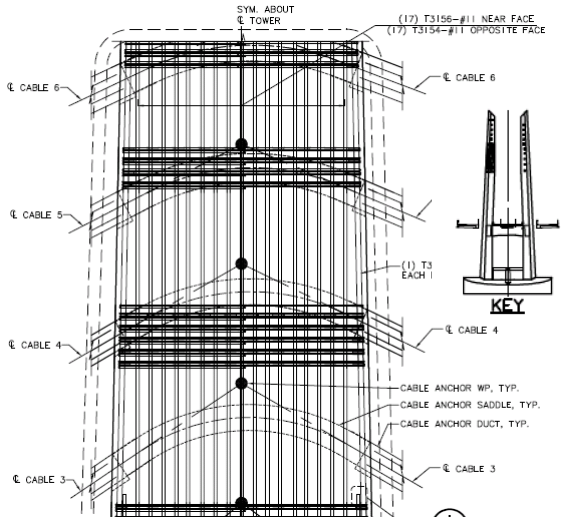
Component Design Summary

- Cables controlled by Live Load





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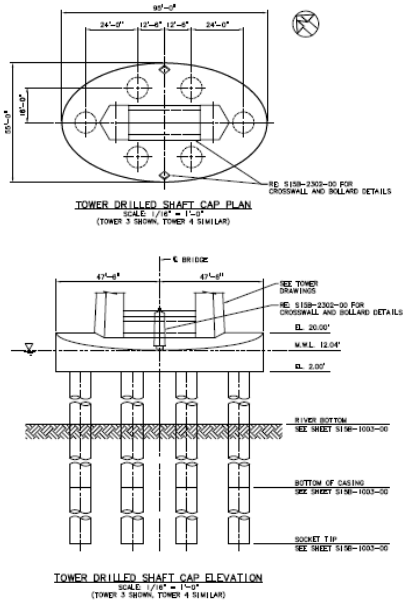
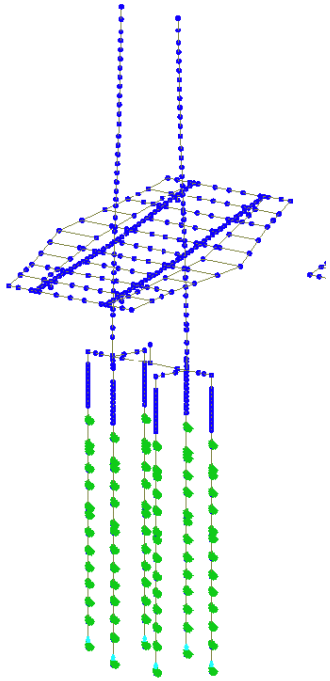
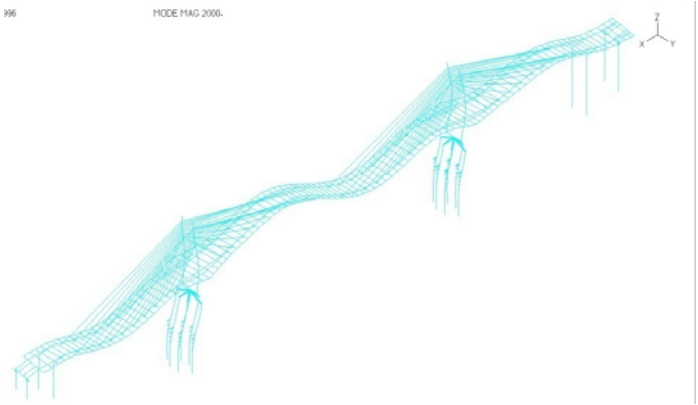
Component Design Summary

- Foundations generally controlled by Seismic in the NW

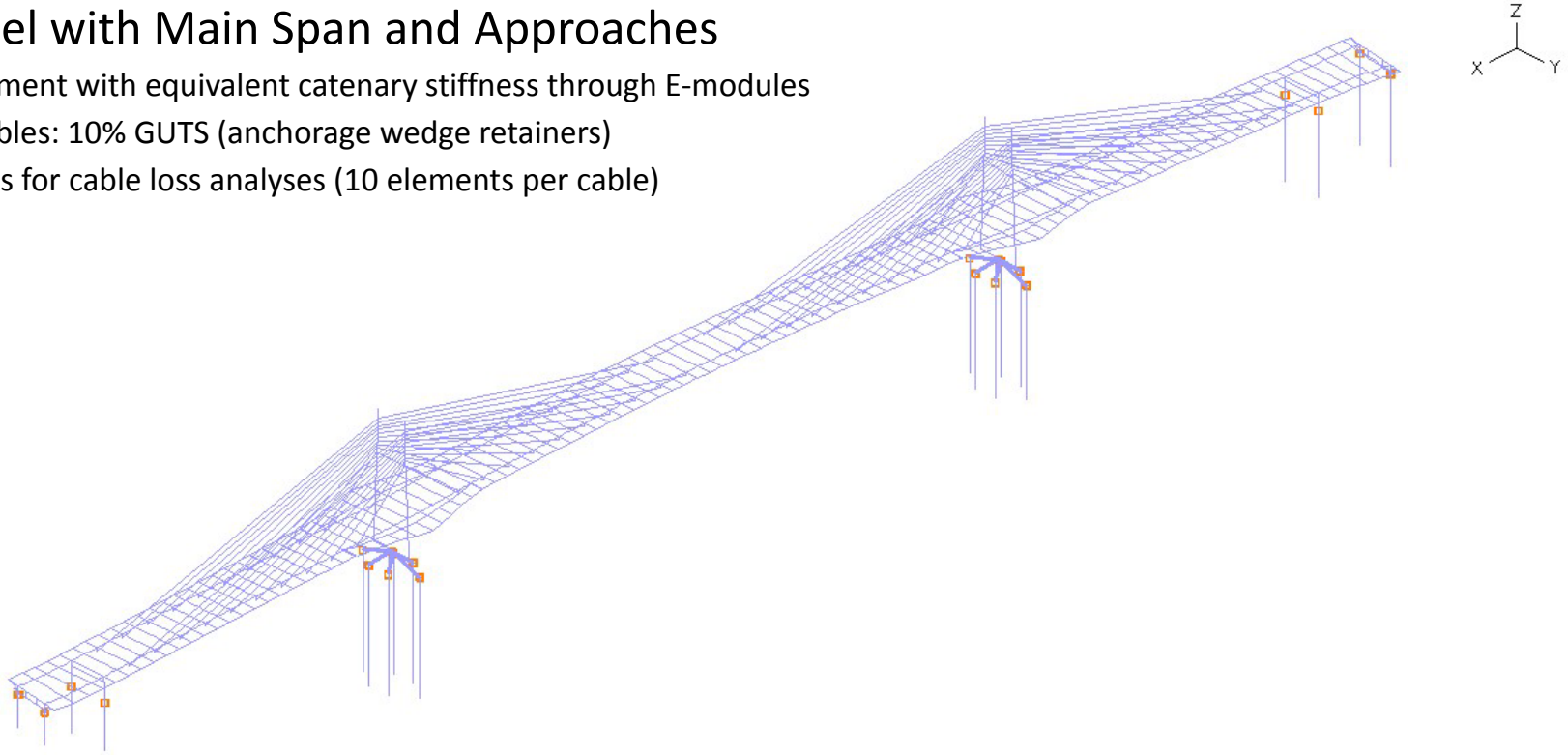






Seismic Time-History Analyses

- Complete Model with Main Span and Approaches
  - Cables single element with equivalent catenary stiffness through E-modules
  - Monitor slack cables: 10% GUTS (anchorage wedge retainers)
  - Discretized cables for cable loss analyses (10 elements per cable)
  - ADINA Software



- Ground Motions
  - 2 performance levels
    - 475 yr return period (SEE): Serviceable Earthquake Evaluation
    - 975 yr return period (NCE): No Collapse Event
  - 3 time histories for each ground motion return period, 50% scour and no scour, lateral spreading

Motion #	Description	Ground Motion
1	50% scour, 475, 1st motion	1985 Central Chile Valparaiso (Subduction Zone EQ)
2	50% scour, 975, 1st motion	1985 Central Chile Valparaiso (Subduction Zone EQ)
3	No scour, 475, 1st motion	1985 Central Chile Valparaiso (Subduction Zone EQ)
4	No scour, 975, 1st motion	1985 Central Chile Valparaiso (Subduction Zone EQ)
Liquefaction	Lateral Spreading Displacements	
5	50% scour, 475, 2nd motion	1985 Central Chile Endessa (Subduction Zone EQ)
6	50% scour, 475, 3rd motion	1986 Palm Springs Sunnymead (Crustal EQ)
7	No scour, 975, 2nd motion	1985 Michoacan La Union (Subduction Zone EQ)
8	50% scour, 975, 2nd motion	1985 Michoacan La Union (Subduction Zone EQ)
9	No scour, 975, 3rd motion	1989 Loma Prieta Capitola (Crustal EQ)
10	No scour, 475, 2nd motion	1985 Central Chile Endessa (Subduction Zone EQ)
11	No scour, 475, 3rd motion	1986 Palm Springs Sunnymead (Crustal EQ)
12	50% scour, 975, 3rd motion	1989 Loma Prieta Capitola (Crustal EQ)

HL1

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- Typical Structural Strain Limits
  - Component Specific Strain Limits:

Willamette River Transit Bridge

Criteria Strain Limits

Event	Component	Concrete (1/1)	Rebar (1/1)	Steel Shell (1/1)
0475	Towers	0.0050	0.0100	NA
	Piers	0.0050	0.0150	NA
	Drilled Shafts	0.0050	0.0100	0.0100
0975	Towers	0.0110	0.0500	NA
	Piers	0.0075	0.0500	NA
	Drilled Shafts	0.0110	0.0200	0.0200

Slide 19

HL1 Hans Lund, 9/8/2016

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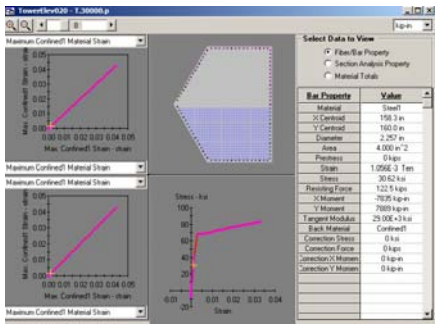
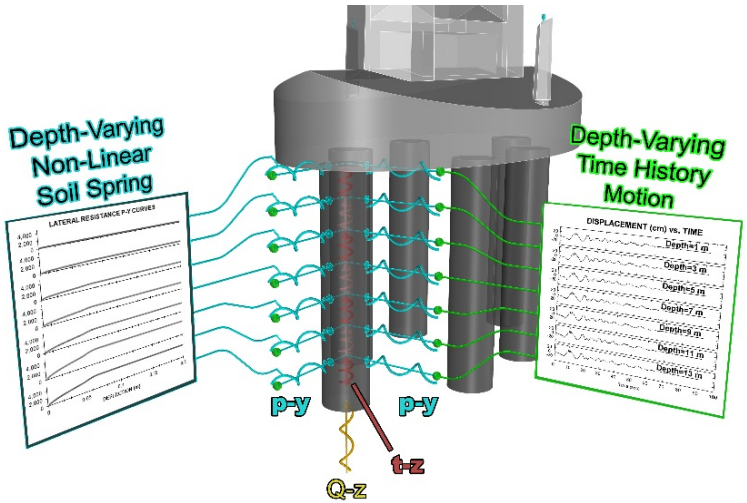
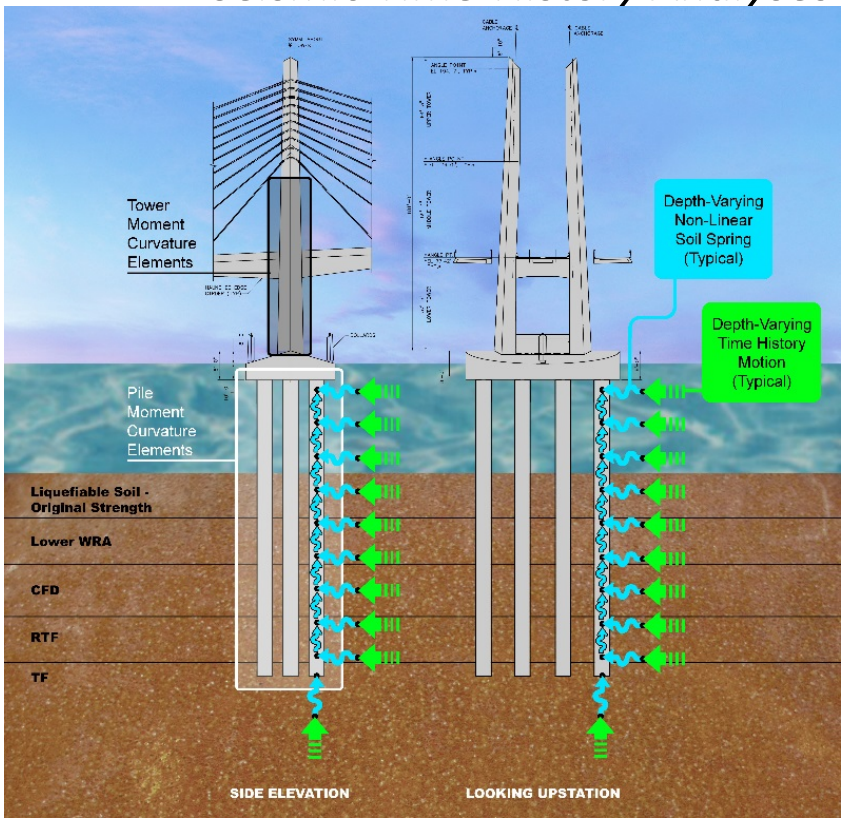
Seismic Time-History Analyses

- Summery of Process
  - Non-linear Moment-Curvature Input for all substructure elements from Xtract runs (including tower except in saddle region).
  - Ground Motions varied with depth (every 2m) and location
  - Soil stiffness varied with depth (every 2m) and location
  - Non-scour, 50% scour and lateral spreading in separate runs
  - (P,M) demands post-processed for all element and all time steps (0.02s) and feed back into Xtract to back-calculate concrete and rebar strains
  - Strains evaluated against Criteria limits
  - Structural solution to lateral spreading – more economical to upsize shafts in lieu of ground improvement.







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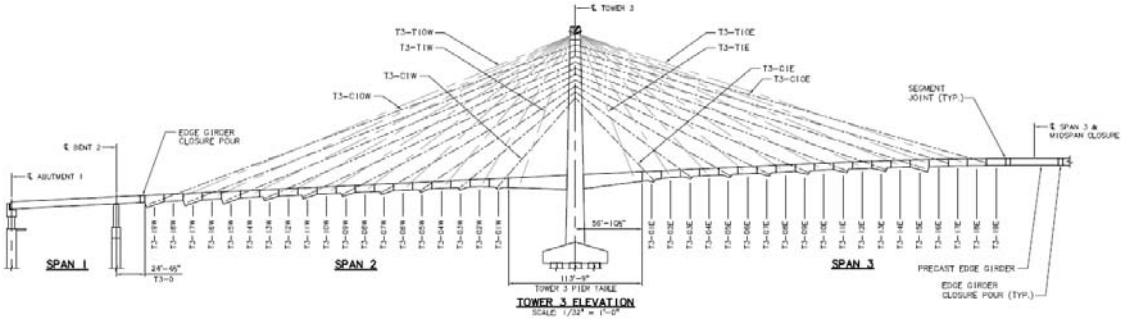
Construction Means and Methods Analysis

- ❑Superstructure erected using Balanced Cantilever Construction
- ❑Tower checked for out-of-balance forces
- ❑Cables installed and adjusted to elevation
- ❑Geometry controlled at each stage to achieve final profile



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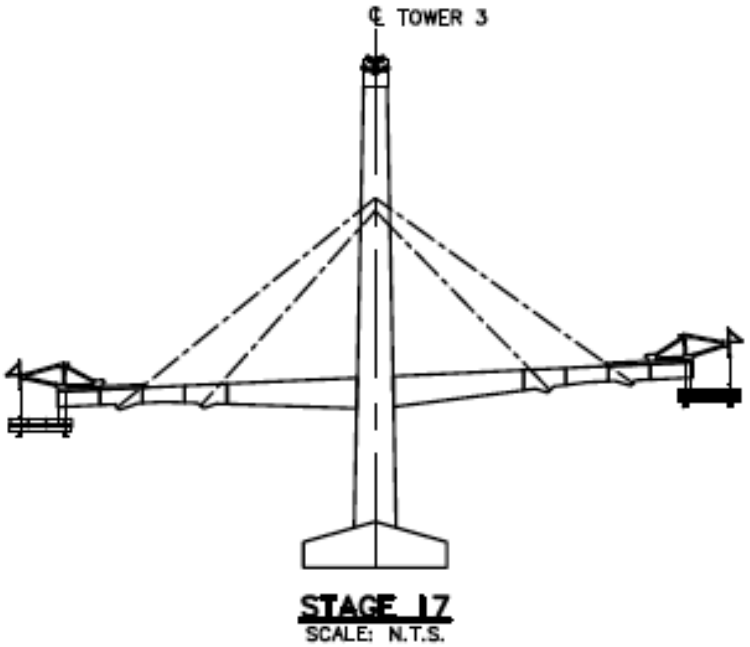
Erection Controls

- Intermediate stiffness allows modest grade adjustment
- CIP target settings and adjustments primary control with form traveler setting



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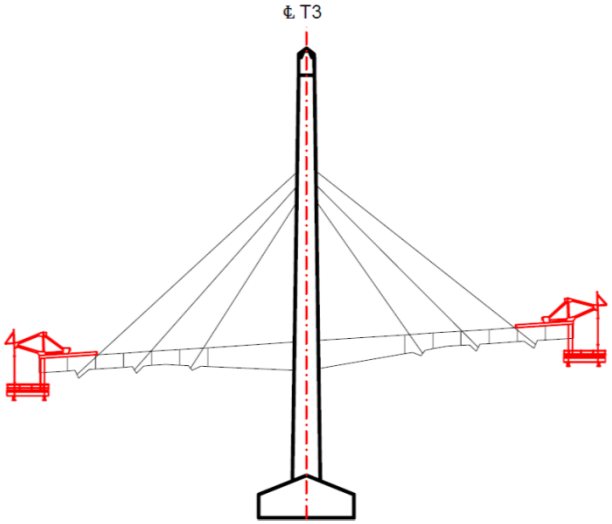
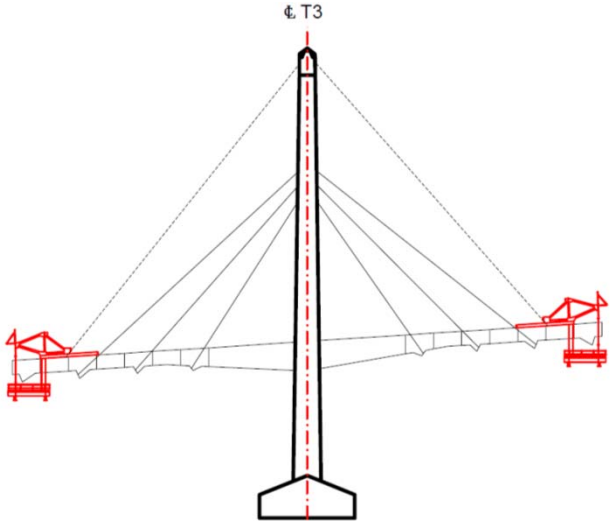
Construction Cycle – Segment 07



- ❑ Adv. Traveler



- ❑ Install Temp Stay
- ❑ Build Segments
- ❑ Adjust Trailing Perm. Stay

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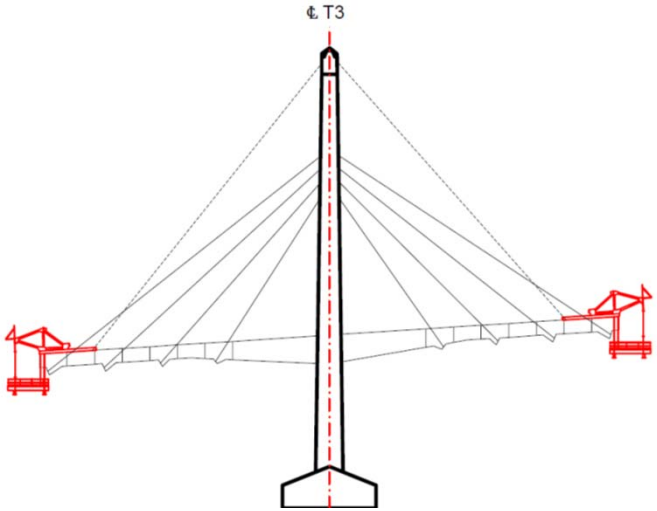
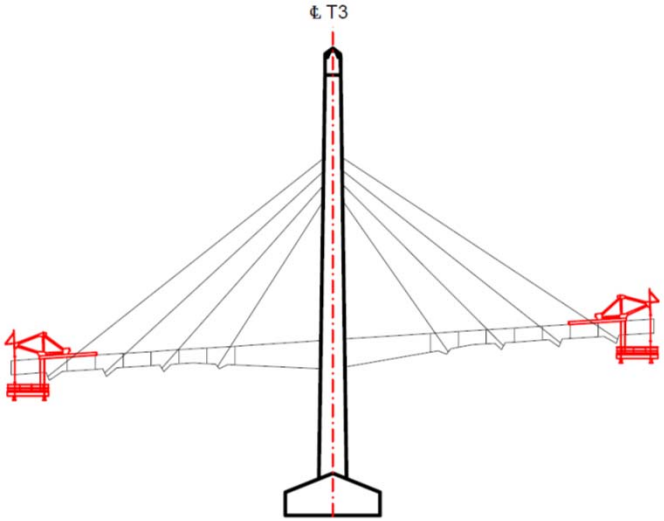
Construction Cycle – Segment 08



- ❑ Adv. Traveler
- ❑ Install Perm. Stay



- ❑ Remove Temp. Stay
- ❑ Adjust Leading Perm. Stay
- ❑ Build Segments

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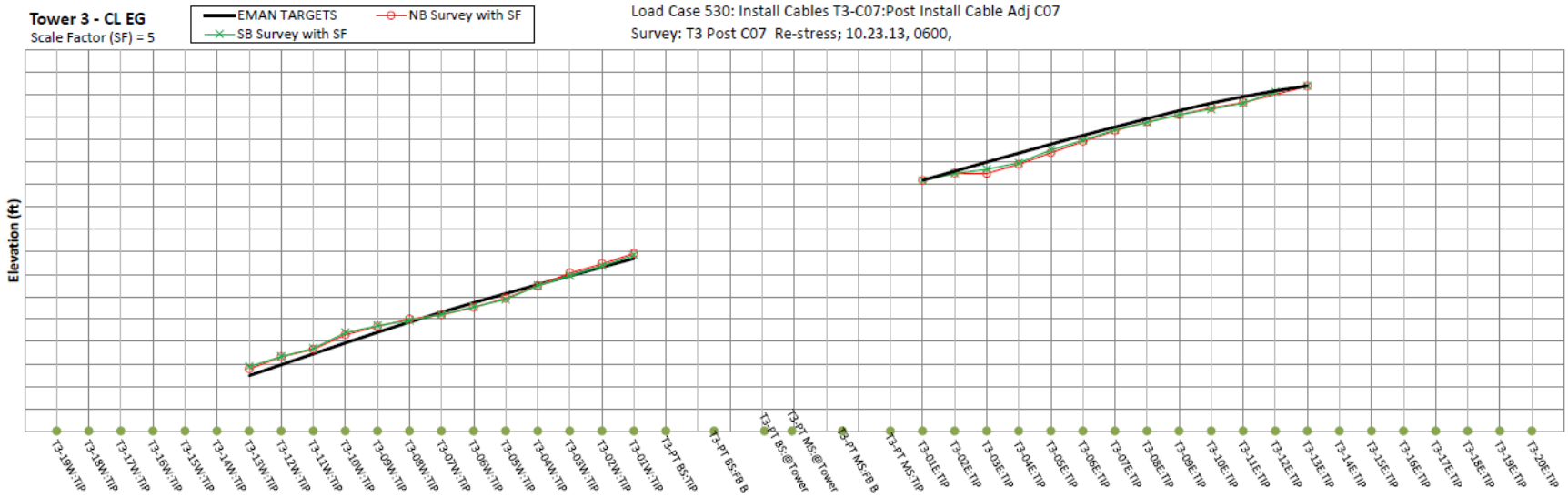
Geometry Tracking



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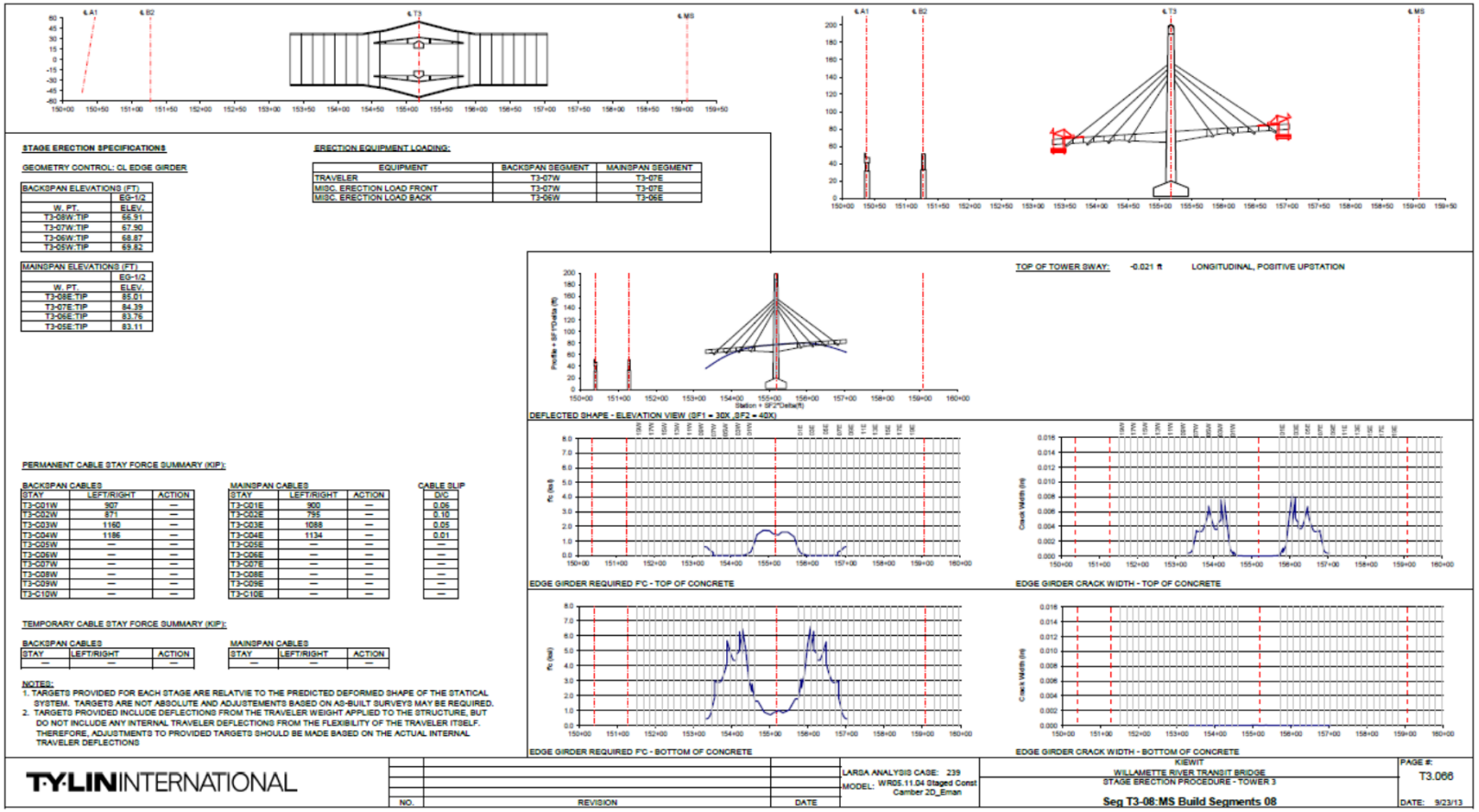
Erection Manual Stage Plot



STAGE ERECTION SPECIFICATIONS

GEOMETRY CONTROL: CL EDGE GIRDER

BACKSPAN ELEVATIONS (FT)

W. PT.	EG-1/2 ELEV.
T3-08W:TIP	68.91
T3-07W:TIP	67.90
T3-06W:TIP	68.87
T3-05W:TIP	69.82

MAINSPAN ELEVATIONS (FT)

W. PT.	EG-1/2 ELEV.
T3-08E:TIP	85.01
T3-07E:TIP	84.39
T3-06E:TIP	83.76
T3-05E:TIP	83.11

ERECTION EQUIPMENT LOADING:

EQUIPMENT	BACKSPAN SEGMENT	MAINSPAN SEGMENT
TRAVELER	T3-07W	T3-07E
MISC. ERECTION LOAD FRONT	T3-07W	T3-07E
MISC. ERECTION LOAD BACK	T3-06W	T3-06E

TOP OF TOWER SWAY: -0.021 ft LONGITUDINAL, POSITIVE UPSTATION

DEFLECTED SHAPE - ELEVATION VIEW (@F1 = 30X, @F2 = 40X)

EDGE GIRDER REQUIRED FC - TOP OF CONCRETE

EDGE GIRDER CRACK WIDTH - TOP OF CONCRETE

EDGE GIRDER REQUIRED FC - BOTTOM OF CONCRETE

EDGE GIRDER CRACK WIDTH - BOTTOM OF CONCRETE

PERMANENT CABLE STAY FORCE SUMMARY (KIP):

BACKSPAN CABLES

STAY	LEFT/RIGHT	ACTION
T3-C01W	907	—
T3-C02W	871	—
T3-C03W	1160	—
T3-C04W	1186	—
T3-C05W	—	—
T3-C06W	—	—
T3-C07W	—	—
T3-C08W	—	—
T3-C09W	—	—
T3-C10W	—	—

MAINSPAN CABLES

STAY	LEFT/RIGHT	ACTION
T3-C01E	900	—
T3-C02E	795	—
T3-C03E	1088	—
T3-C04E	1134	—
T3-C05E	—	—
T3-C06E	—	—
T3-C07E	—	—
T3-C08E	—	—
T3-C09E	—	—
T3-C10E	—	—

CABLE SLIP

D/C
0.06
0.10
0.05
0.01
—
—
—
—
—
—

TEMPORARY CABLE STAY FORCE SUMMARY (KIP):

BACKSPAN CABLES

STAY	LEFT/RIGHT	ACTION
—	—	—

MAINSPAN CABLES

STAY	LEFT/RIGHT	ACTION
—	—	—

NOTES:
1. TARGETS PROVIDED FOR EACH STAGE ARE RELATVIE TO THE PREDICTED DEFORMED SHAPE OF THE STATICAL SYSTEM. TARGETS ARE NOT ABSOLUTE AND ADJUSTEMENTS BASED ON AS-BUILT SURVEYS MAY BE REQUIRED.
2. TARGETS PROVIDED INCLUDE DEFLECTIONS FROM THE TRAVELER WEIGHT APPLIED TO THE STRUCTURE, BUT DO NOT INCLUDE ANY INTERNAL TRAVELER DEFLECTIONS FROM THE FLEXIBILITY OF THE TRAVELER ITSELF. THEREFORE, ADJUSTMENTS TO PROVIDED TARGETS SHOULD BE MADE BASED ON THE ACTUAL INTERNAL TRAVELER DEFLECTIONS

T·Y LIN INTERNATIONAL

NO. REVISION DATE

LARSA ANALYSIS CASE: 239
MODEL: WR05.11.04 Staged Const Camber 2D_Eman

KIEWIT
WILLAMETTE RIVER TRANSIT BRIDGE
STAGE ERECTION PROCEDURE - TOWER 3

Seg T3-08:MS Build Segments 08

PAGE #: T3.066

DATE: 9/23/13

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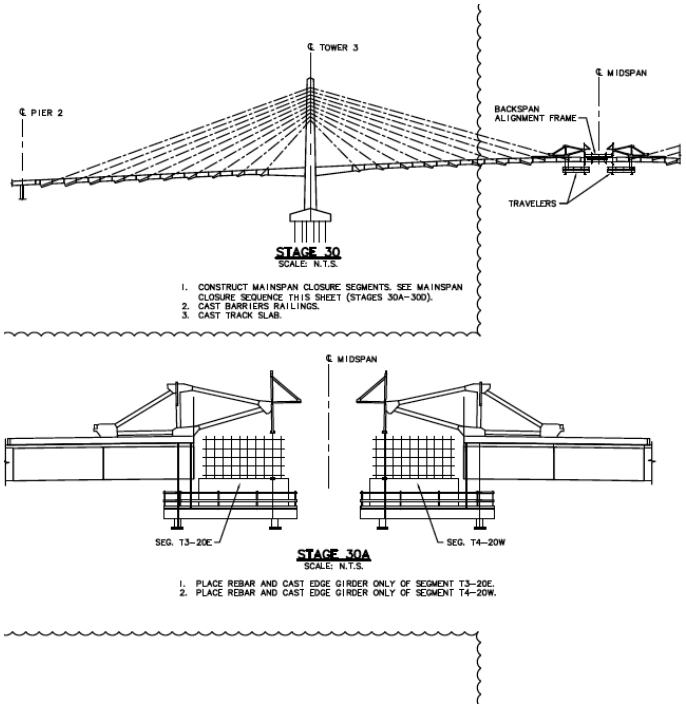
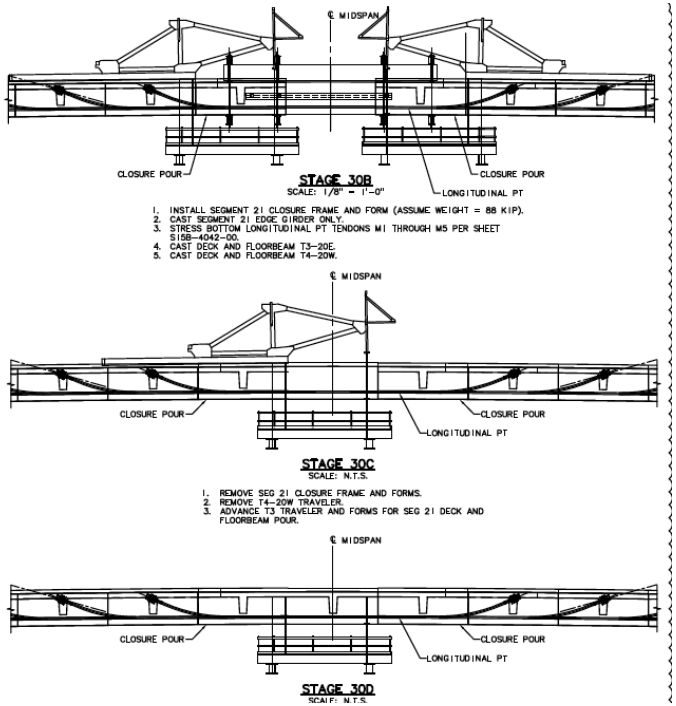
Closure Scheme with Travelers

- Original scheme called for precast MS closure
- Modification to use travelers and CIP





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MS Closure Frame

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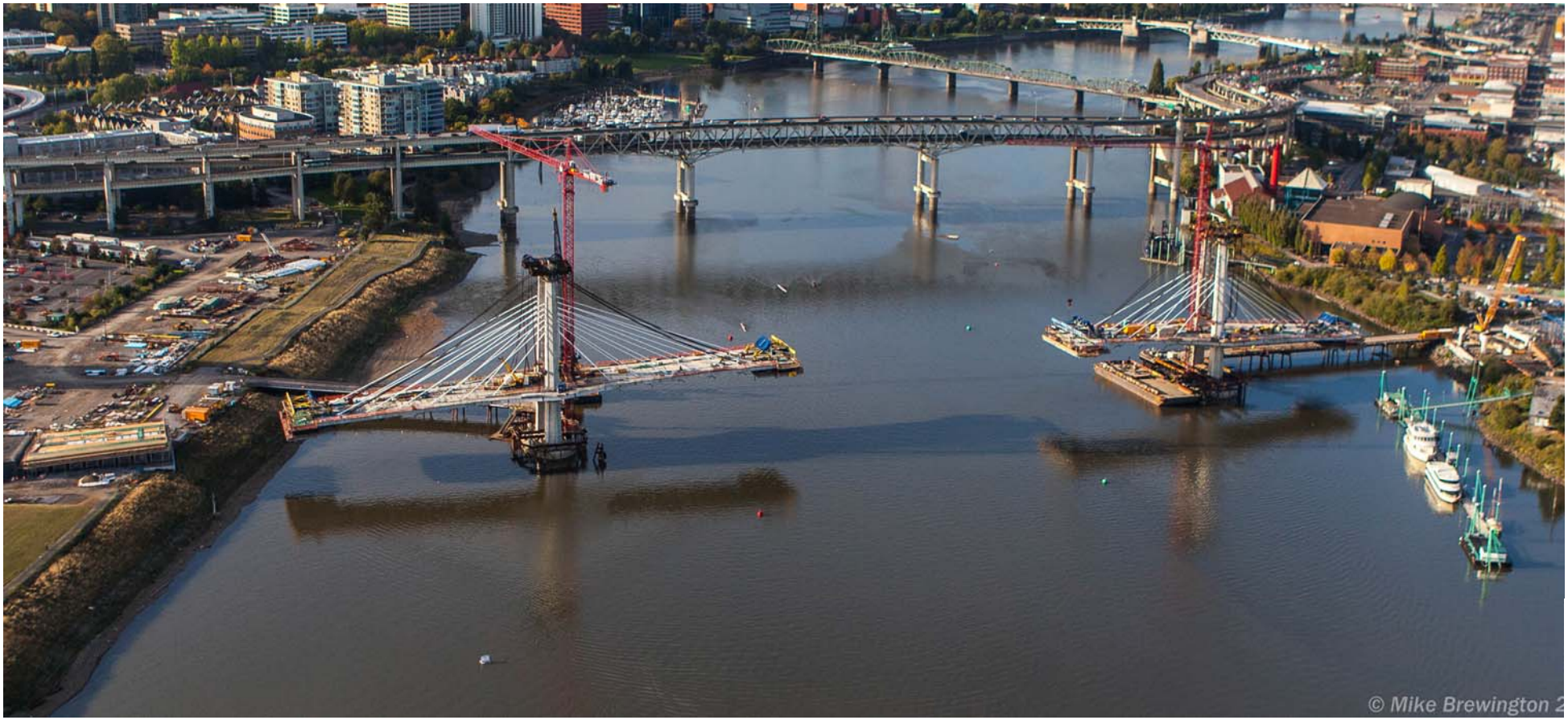
Construction



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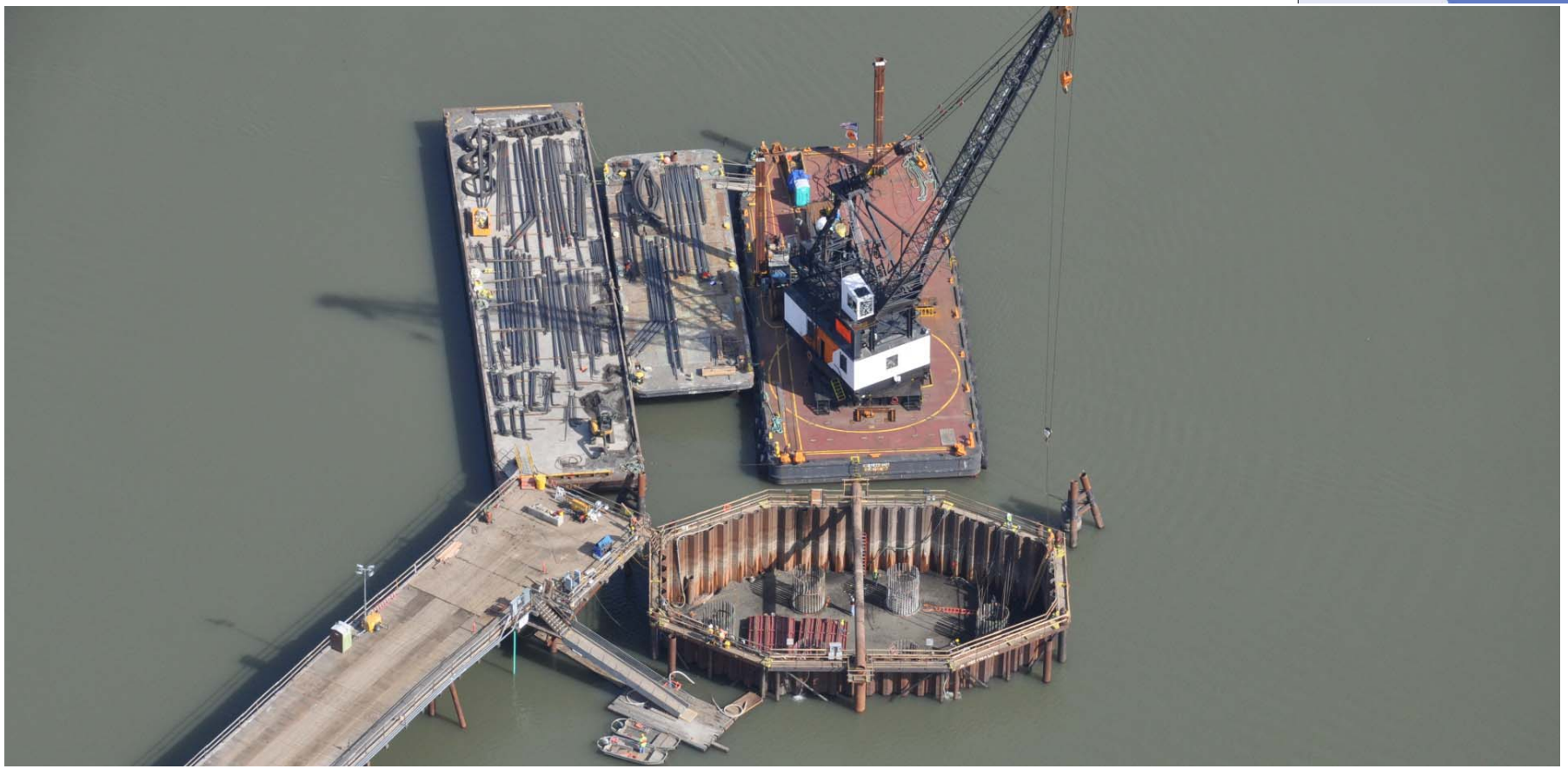
Tower Cofferdams



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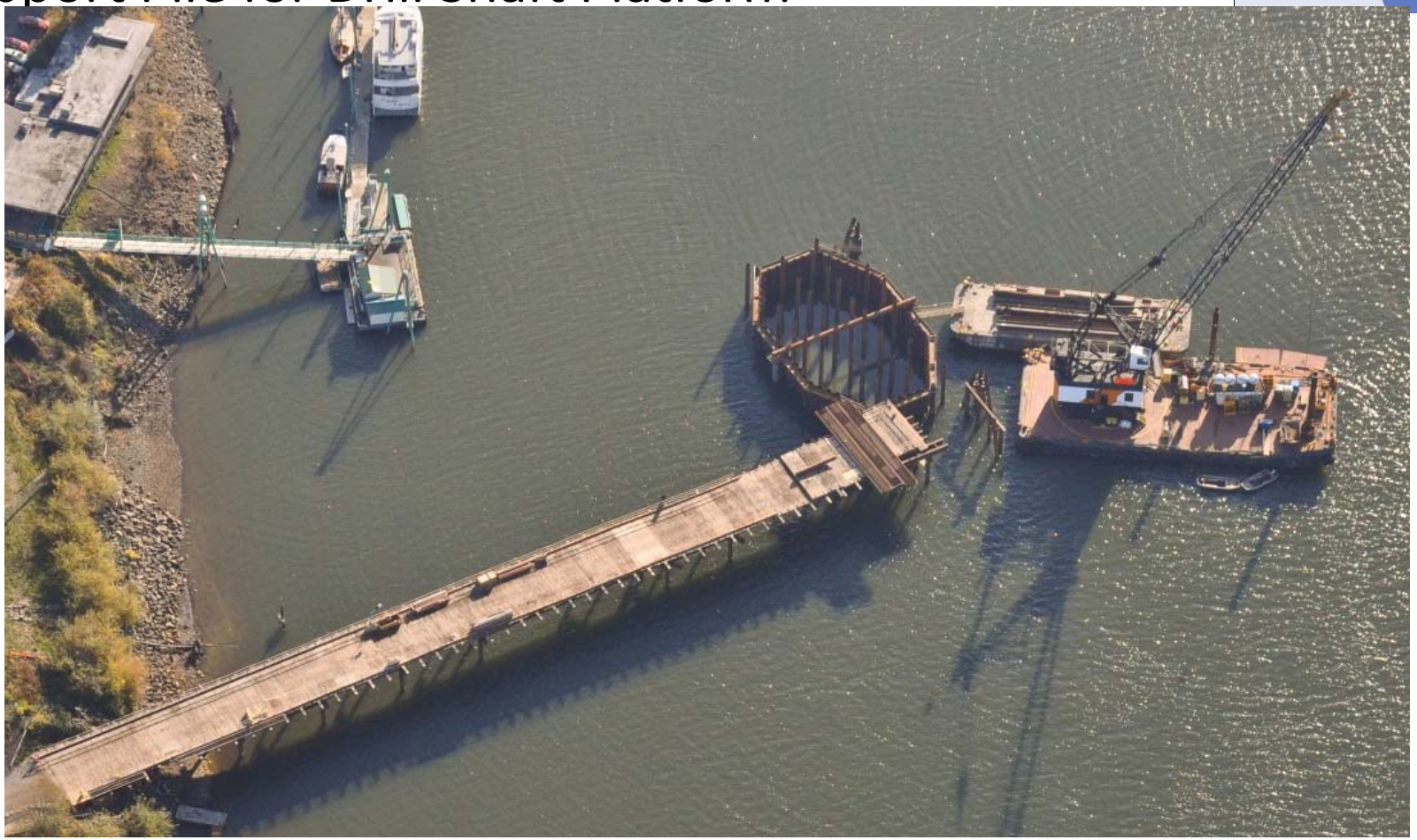
Support Pile for Drill Shaft Platform



Drill Shaft Platform

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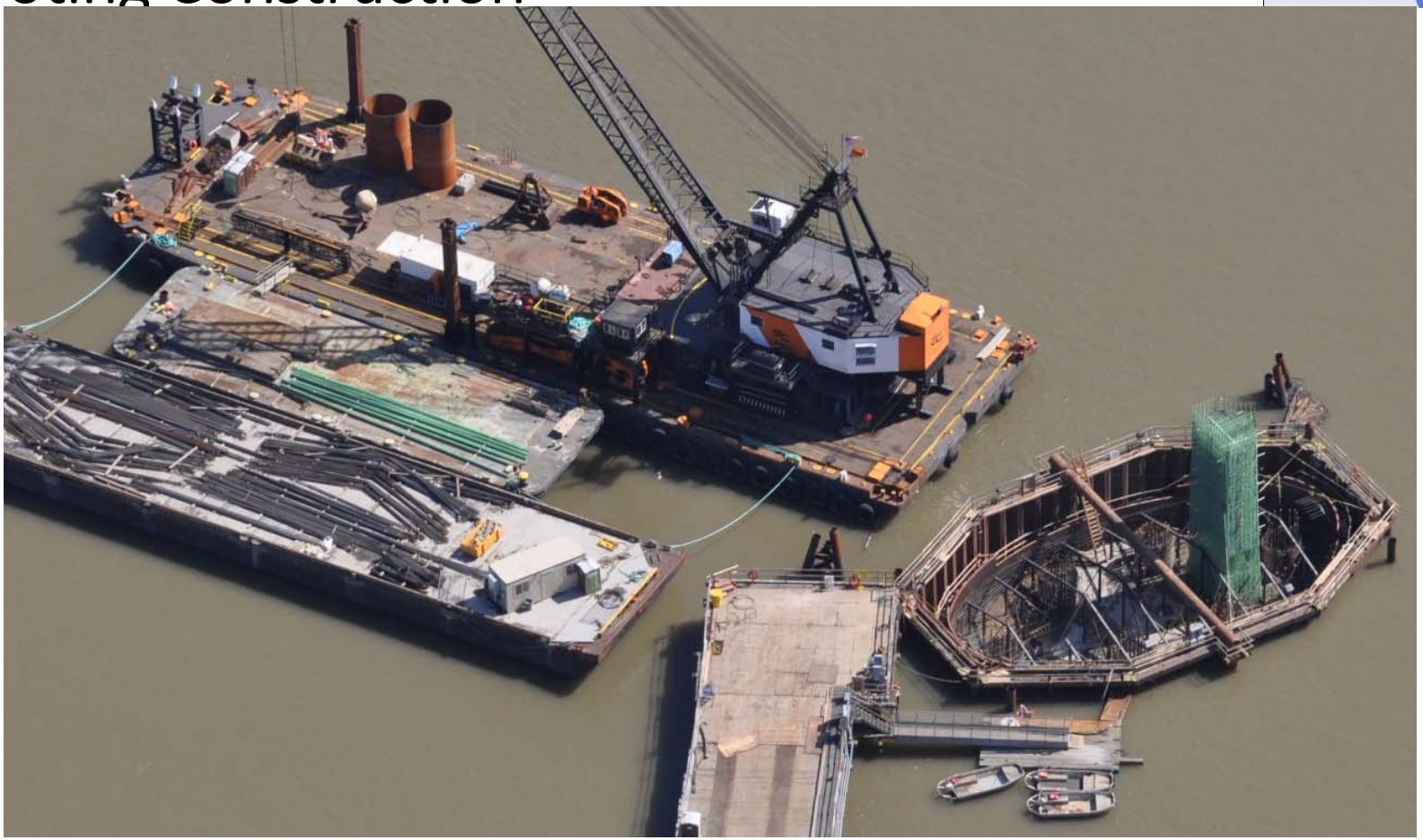
Footing Construction



Footing placement within Cofferdam

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Pylon Jump Forms

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Stay Cable Saddles

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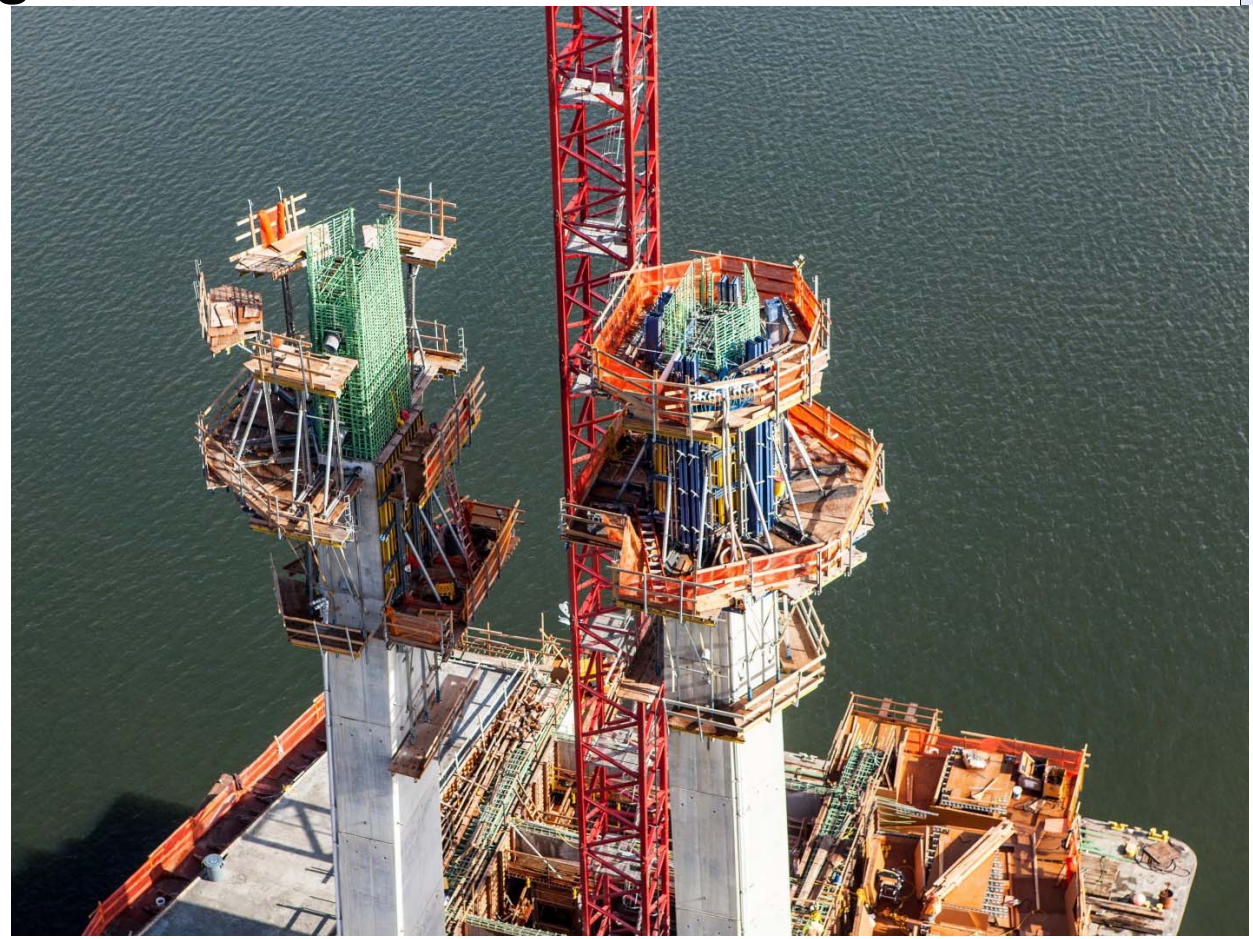
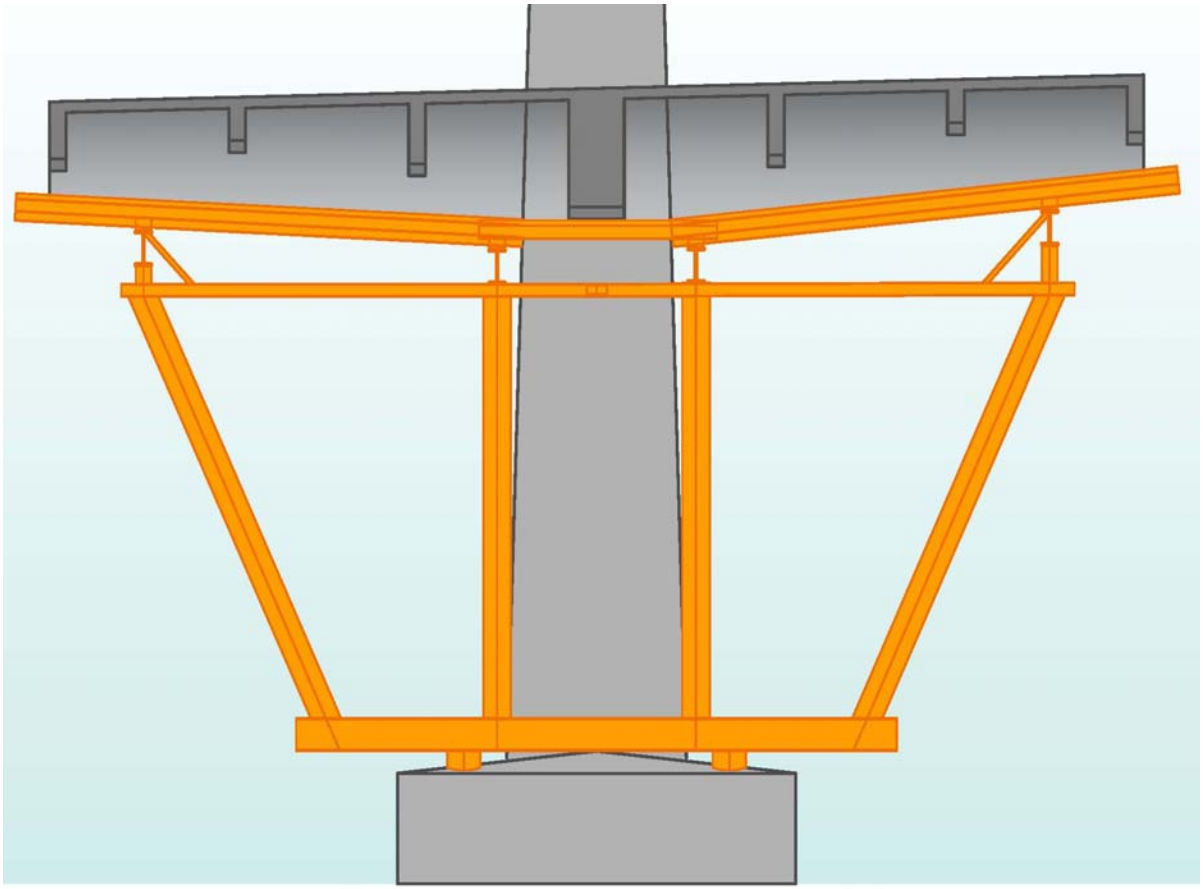
Pylon Legs



Pier Table Falsework



Pylon Pour

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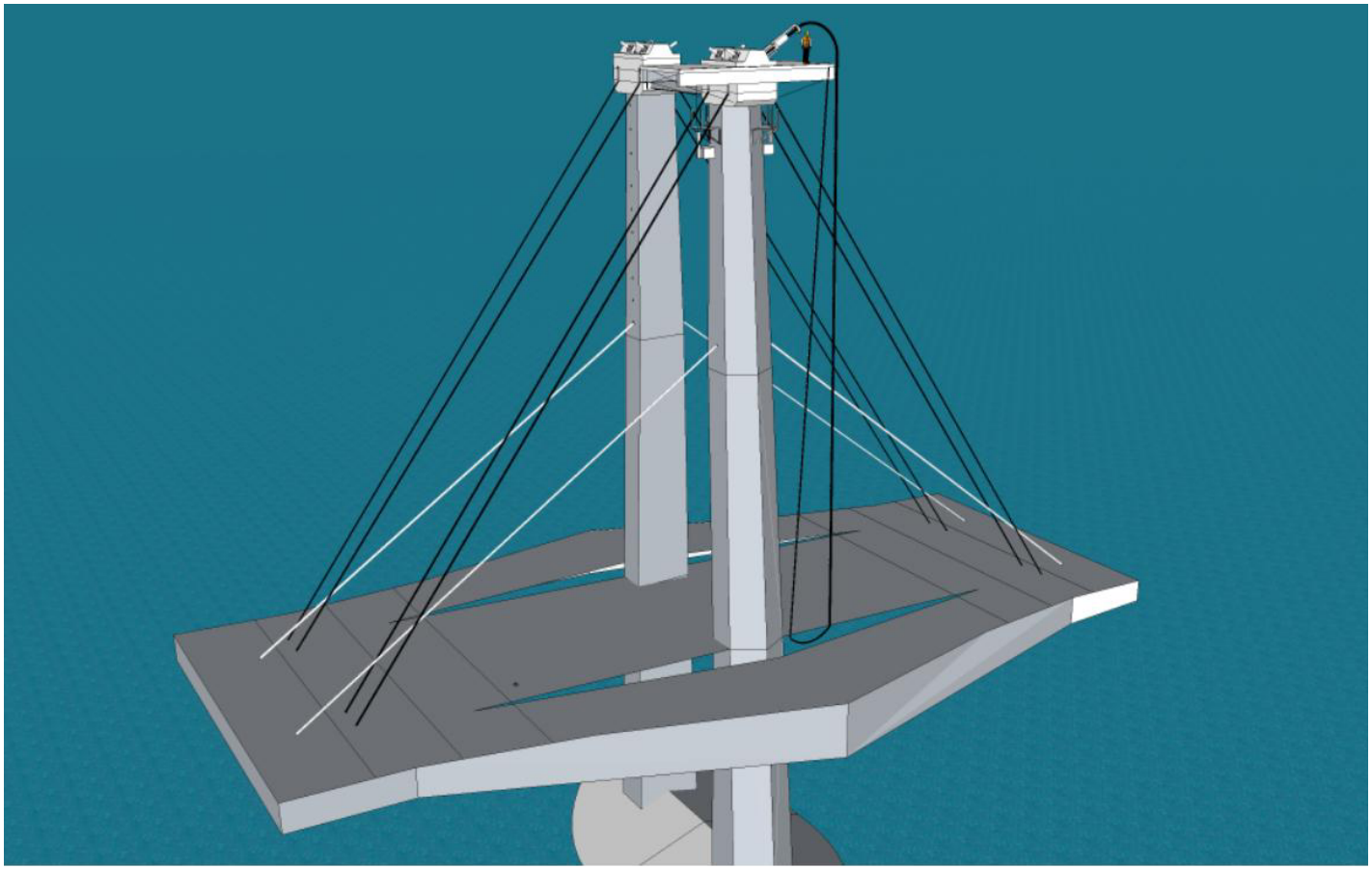
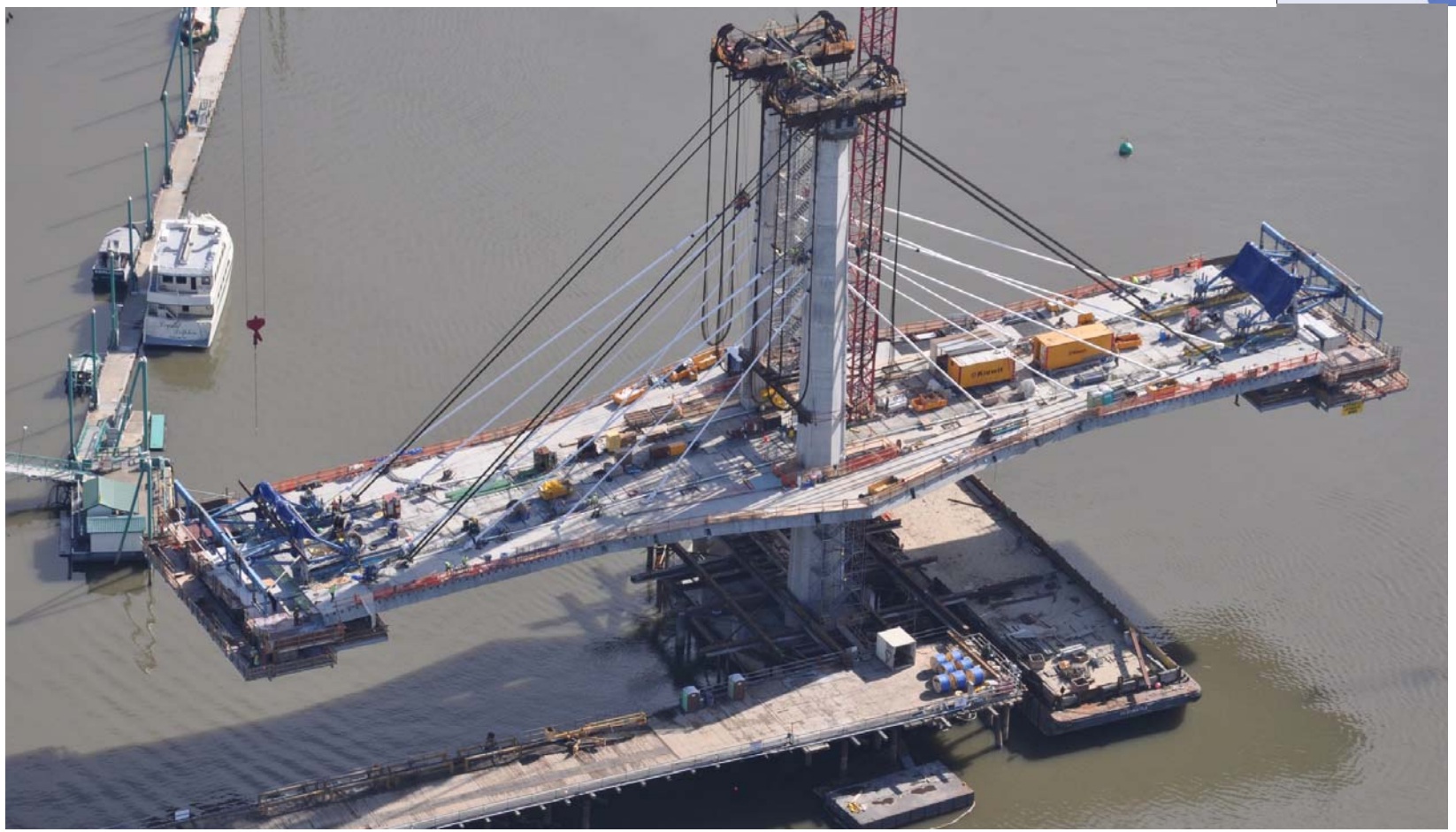
Aesthetics Trumps Constructability

Overhead Form Traveler

Temporary Stays Every Other Segment



Temporary Stays Every Other Segment



Temp Stay Anchor

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Temporary Stay Anchor at Deck

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Permanent and Temporary Deck Anchors

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Temporary Stay Precast Anchor

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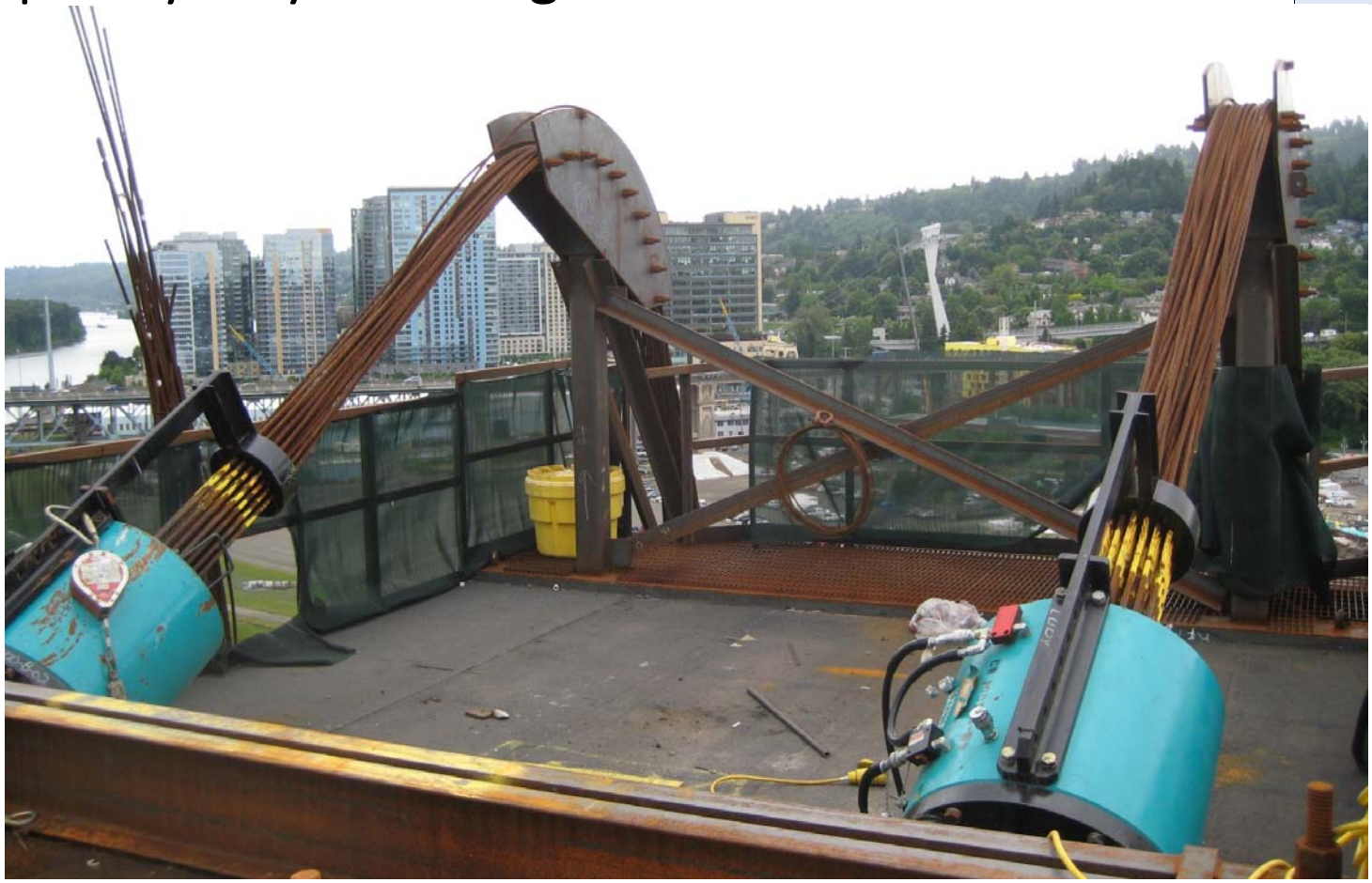
Temporary Stay Stressing Rams



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Temporary Stay Access Platform

Permanent Stays

Strand Pusher Feeding Strand Up Stay Pipe

Strand Continuous thru Pylon

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Temp Stays Supporting the Leading Edge

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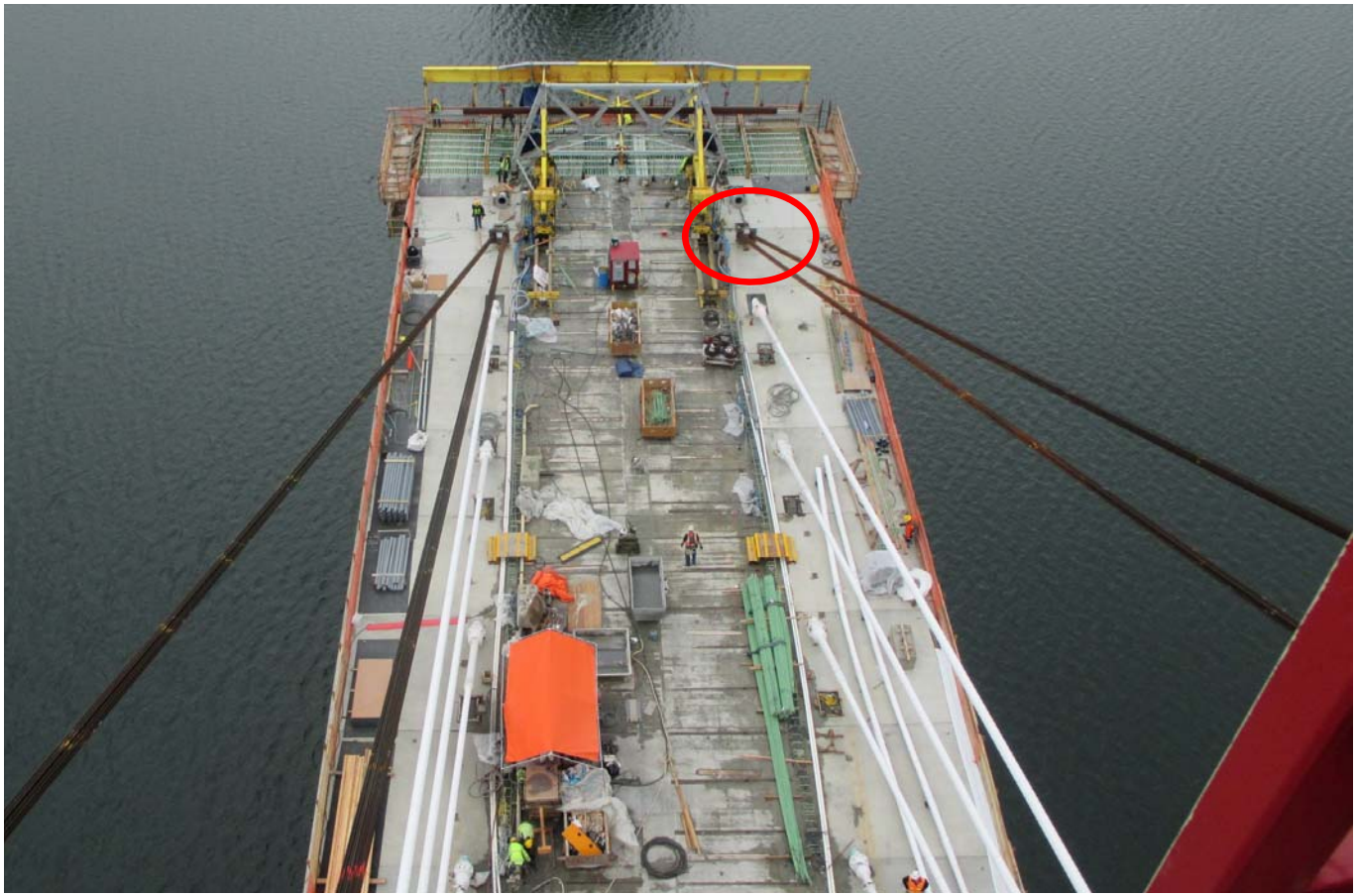
Temp Stay Deck Connection



Temp stays slacked. Permanent stays support the leading edge.

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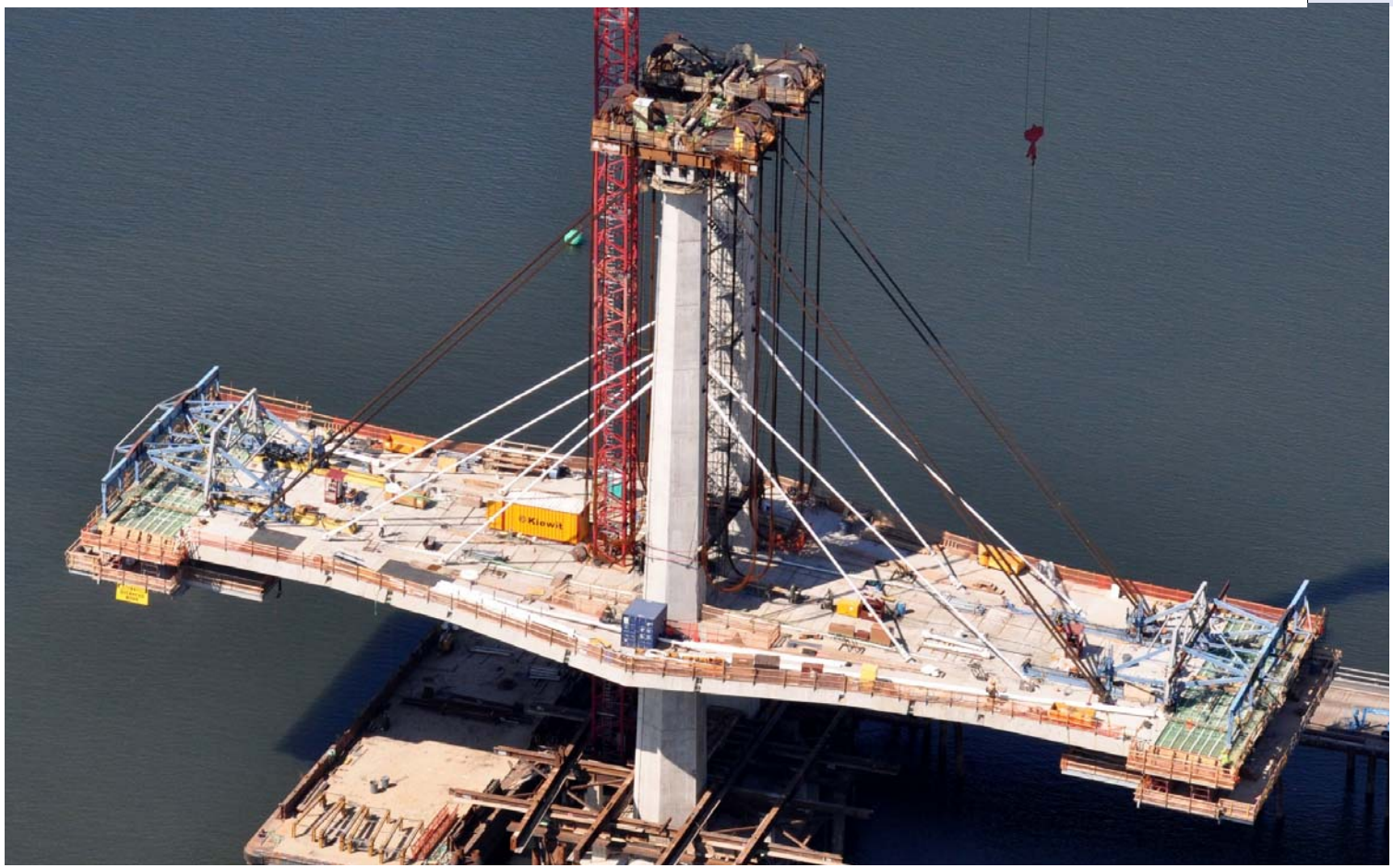
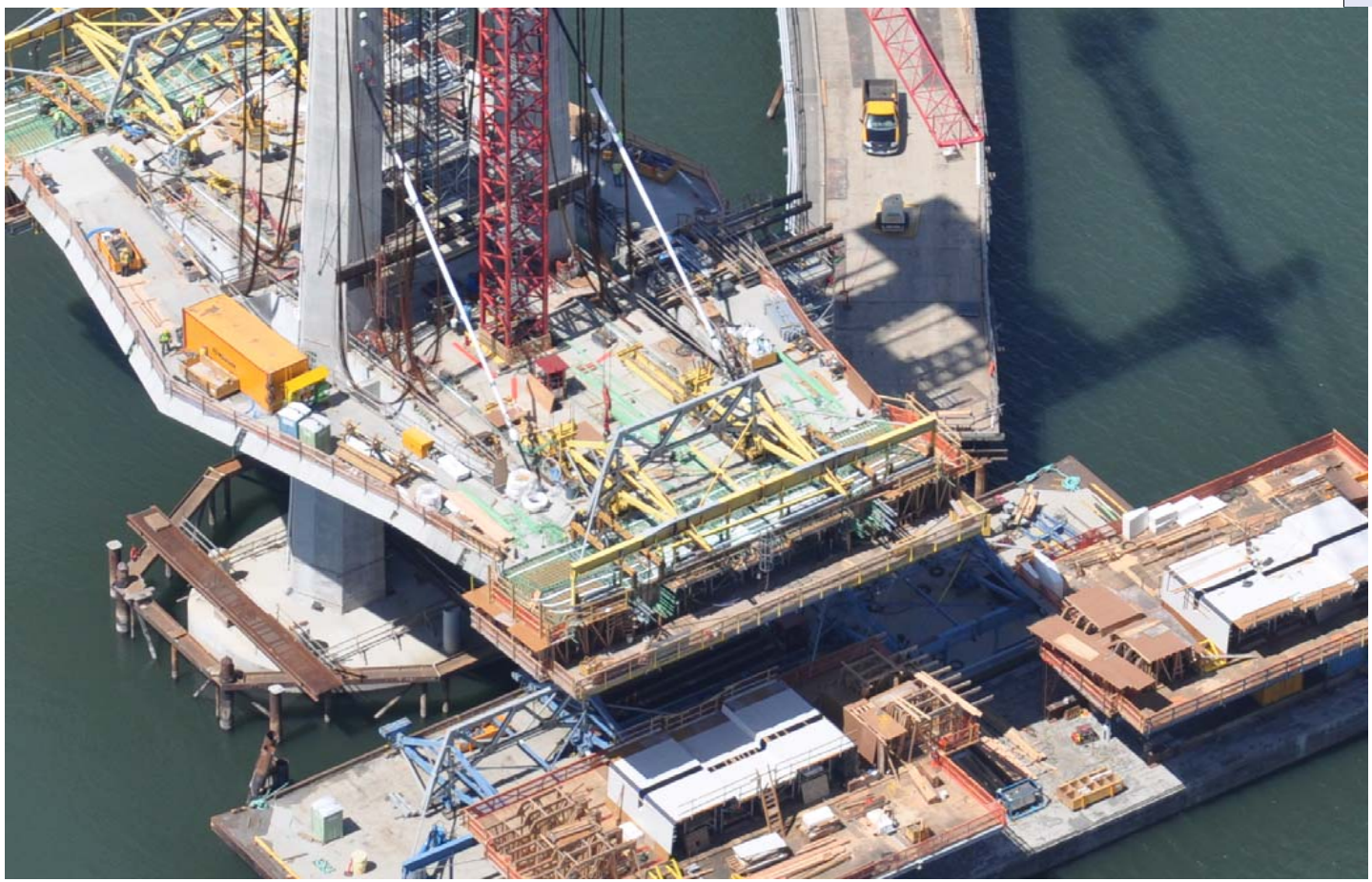
Form Travelers



Form Travelers



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Placing Concrete at Segment 9

Placing Concrete at Segment 9

Placing Concrete at Segment 9

Placing Concrete at Segment 9

Placing Concrete at Segment 9

Western Bridge Engineers' Seminar

Placing Concrete at Segment 9

Lower & Launch Traveler

Western Bridge Engineers' Seminar

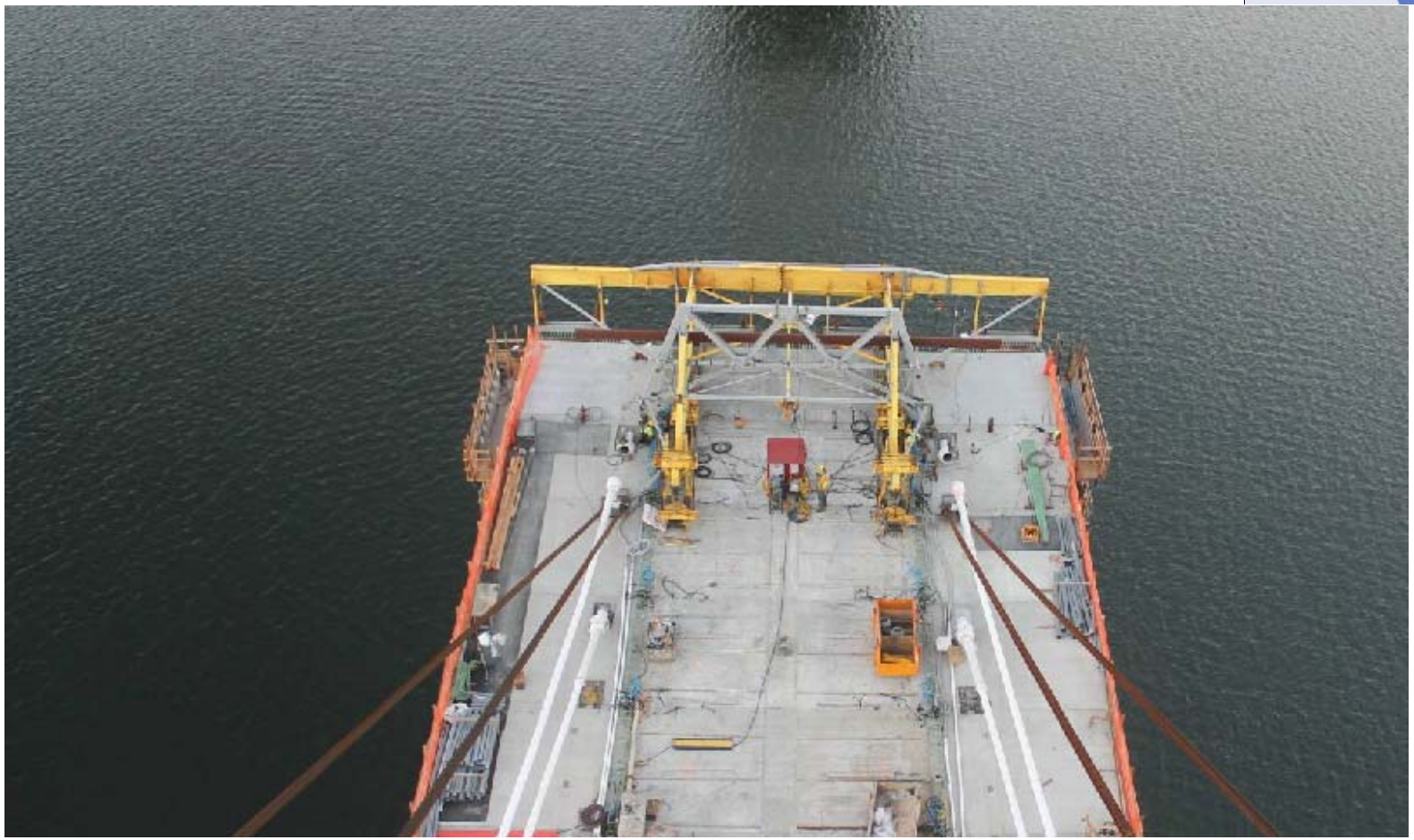
Lower & Launch Traveler

Western Bridge Engineers' Seminar

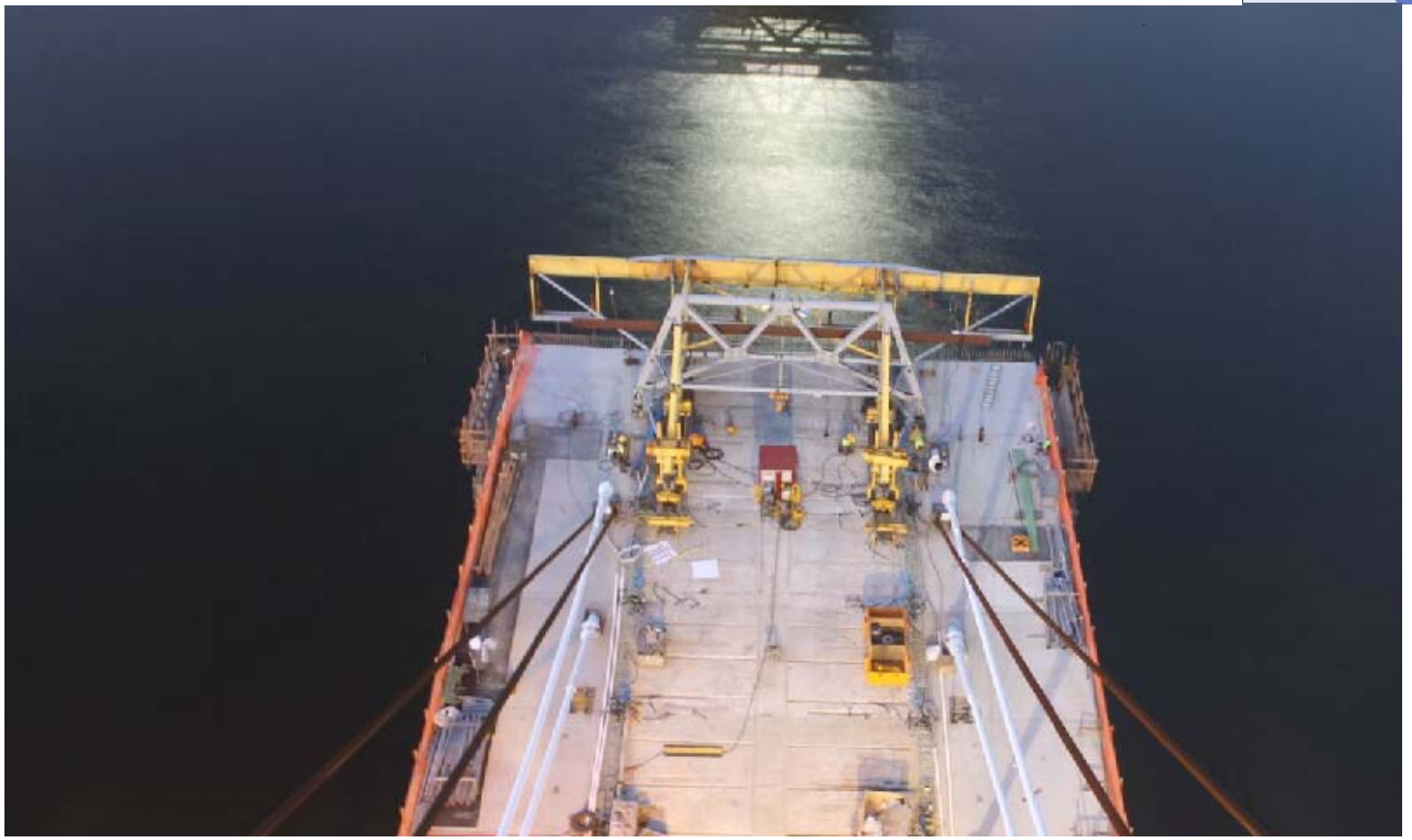
Lower & Launch Traveler

Western Bridge Engineers' Seminar

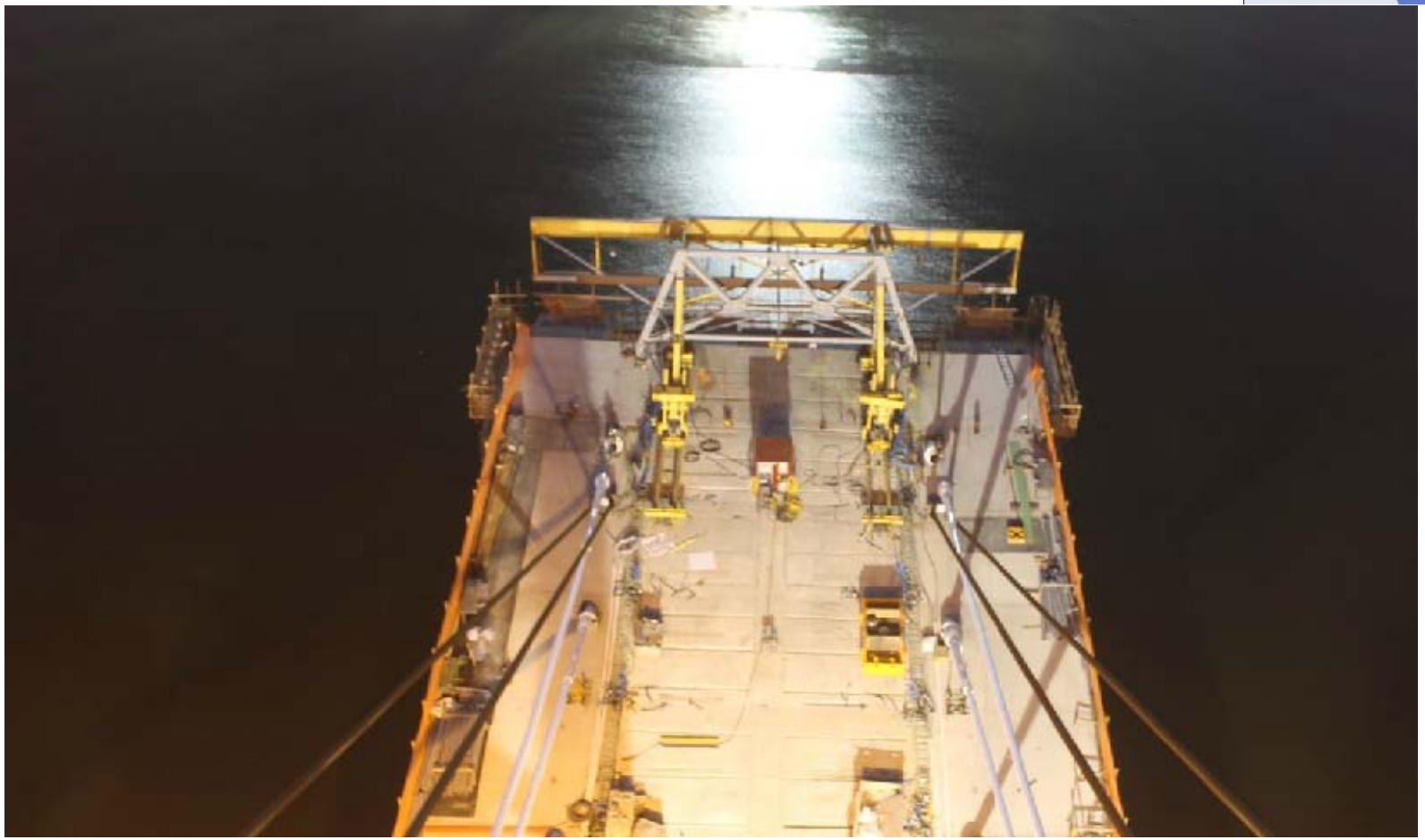
Lower & Launch Traveler



Lower & Launch Traveler



Lower & Launch Traveler



Lower & Launch Traveler

Traveler in Launched Position

Edge Girder Reinforcing

West Cantilever

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East Cantilever – 5 Segments Behind

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Completed Bridge

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Thank you

Design Team

Bridge - TY Lin International
Geotechnical - EMI, Northwest Geotechnical
Electrical - Reyes
Main Foundations - BSE
Wind Analysis – West Wind Laboratories
Track – STV
Owners Engineer – HNTB