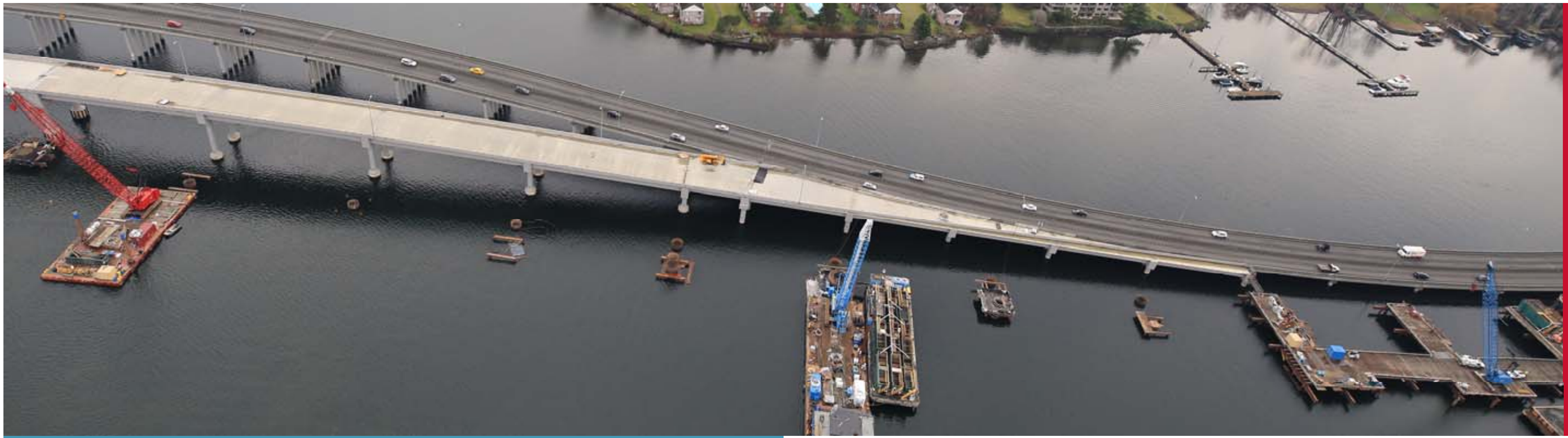


Design and Construction of the SR 520 West Approach Bridge North

Greg Knutson, P.E., S.E.

Washington State Department of Transportation

OBJECTIVES

01 Introduction to Project

02 Project Setting

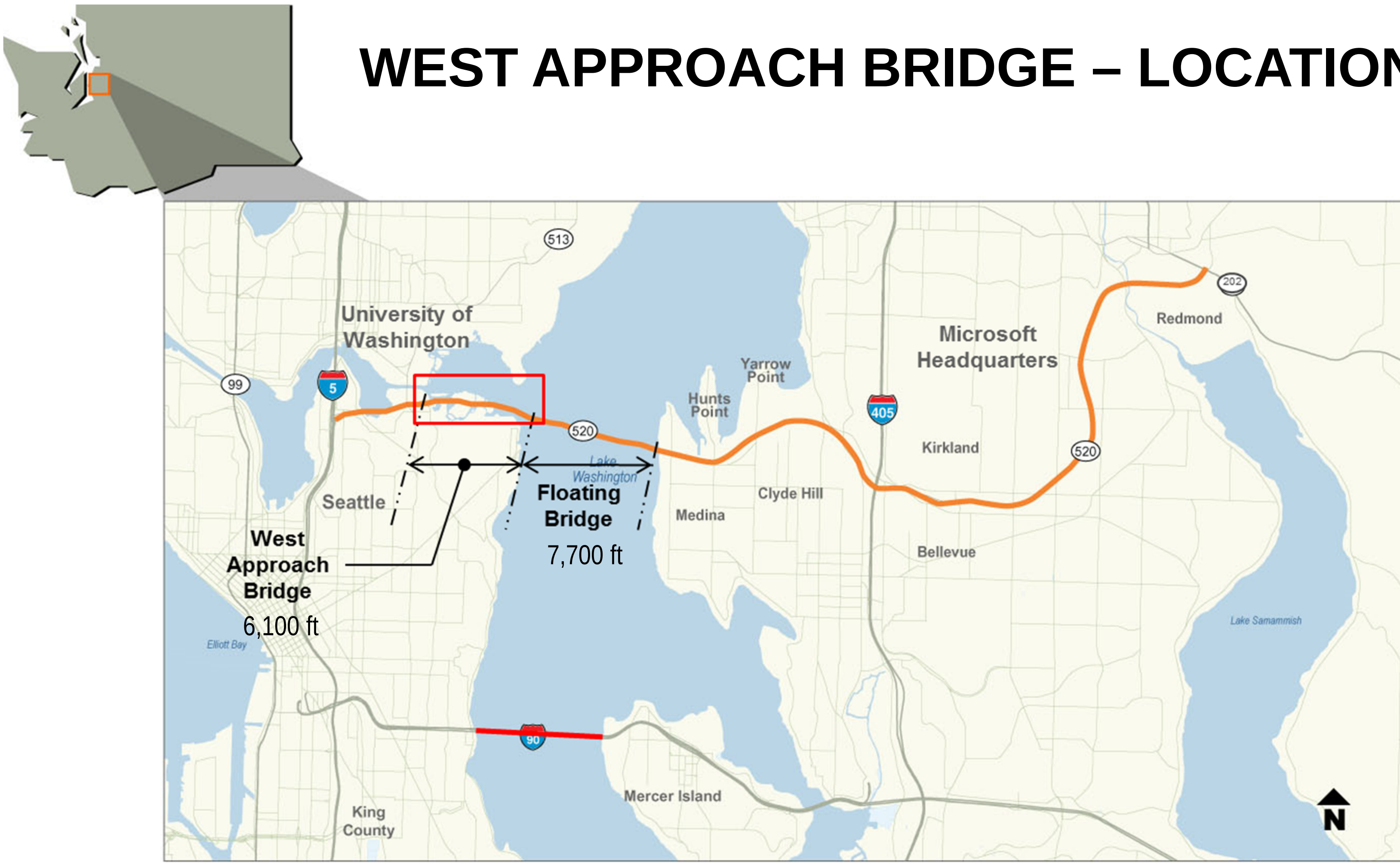
03 Project Constraints

04 Structural Design Criteria

05 Bridge Design

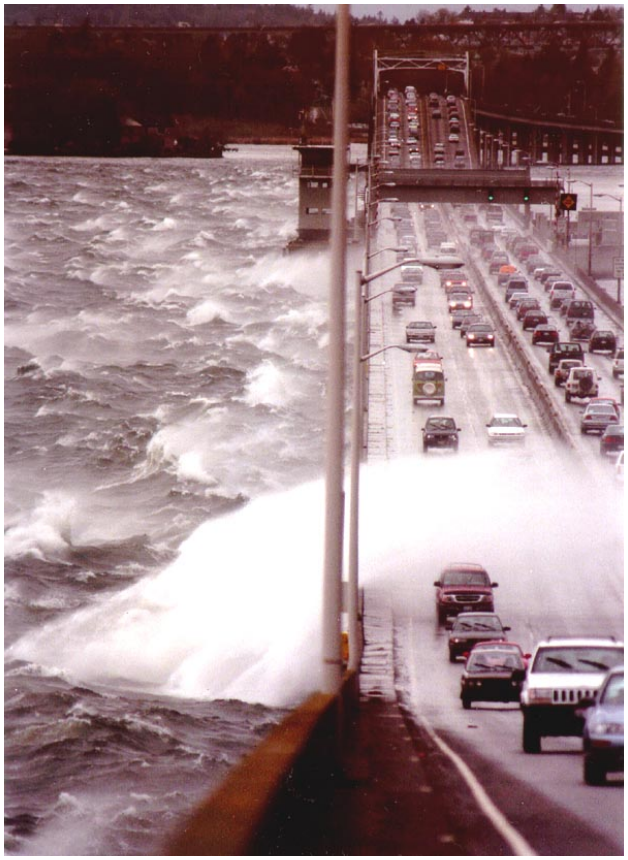
06 Bridge Construction

WEST APPROACH BRIDGE – LOCATION

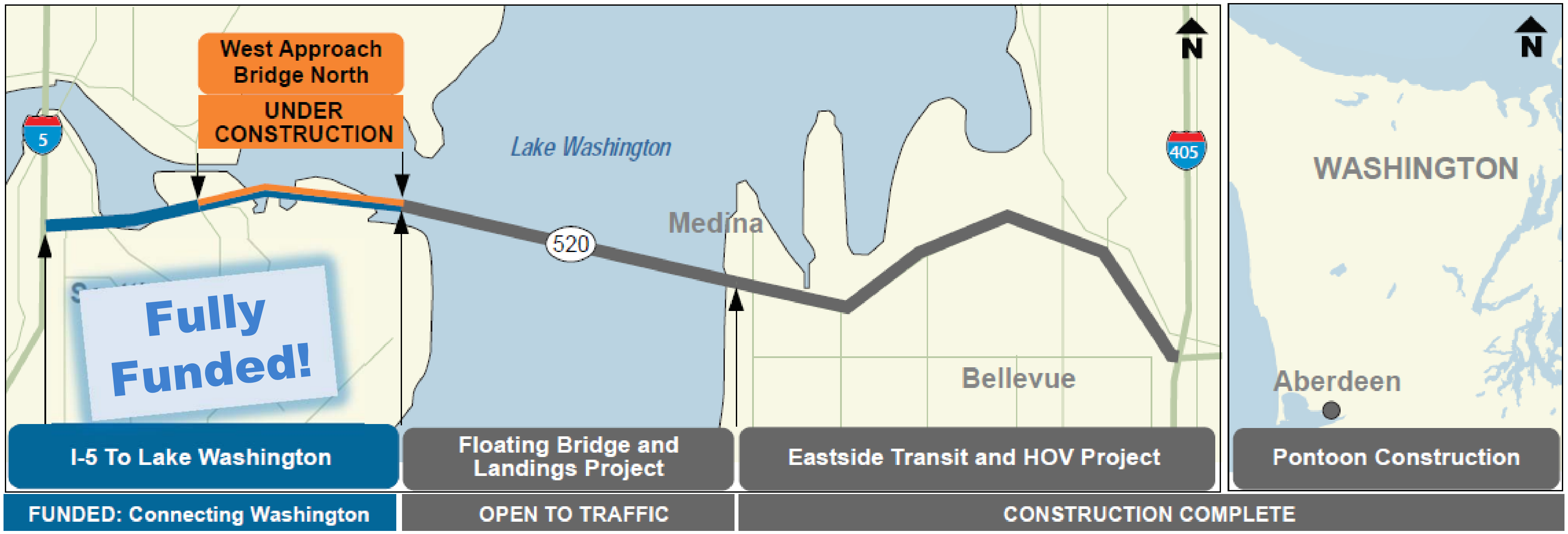


SR 520 PROGRAM GOALS

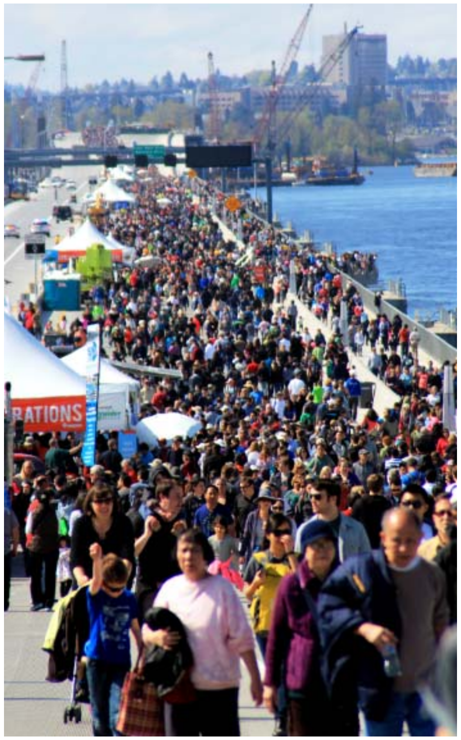
- Improve safety and reliability
- Increase mobility for people and goods
- Avoid, minimize, and/or mitigate the project effects on the environment and neighborhoods



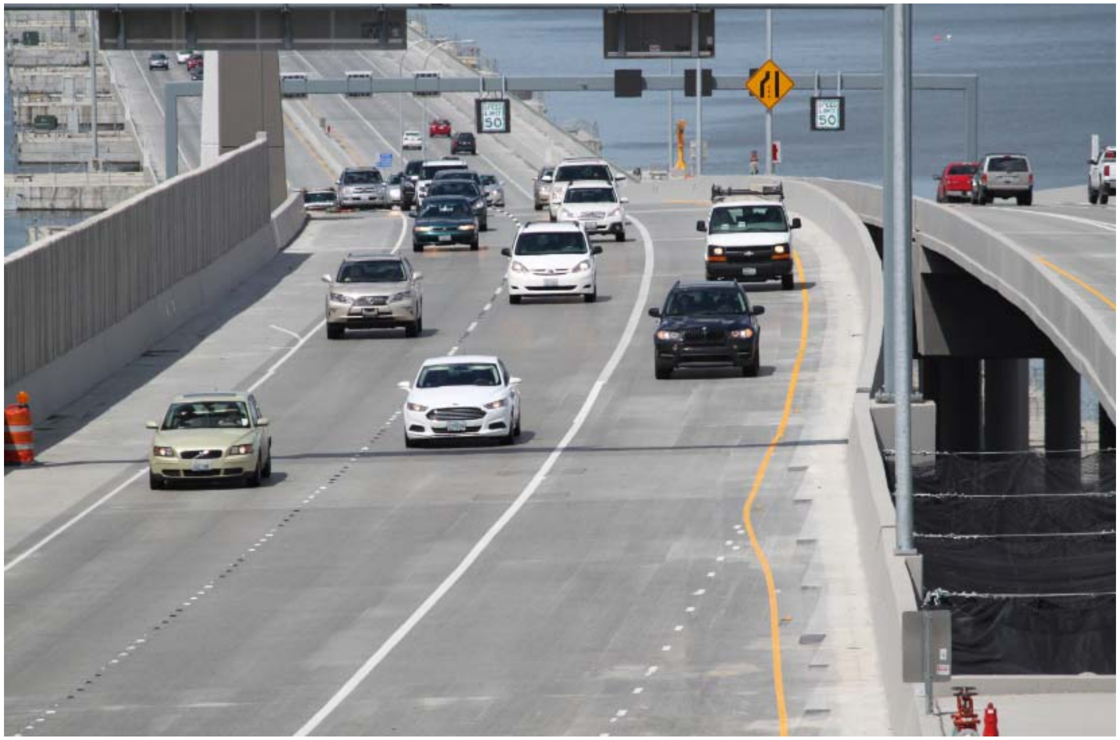
SR 520 PROGRAM OVERVIEW



FLOATING BRIDGE OPEN TO TRAFFIC



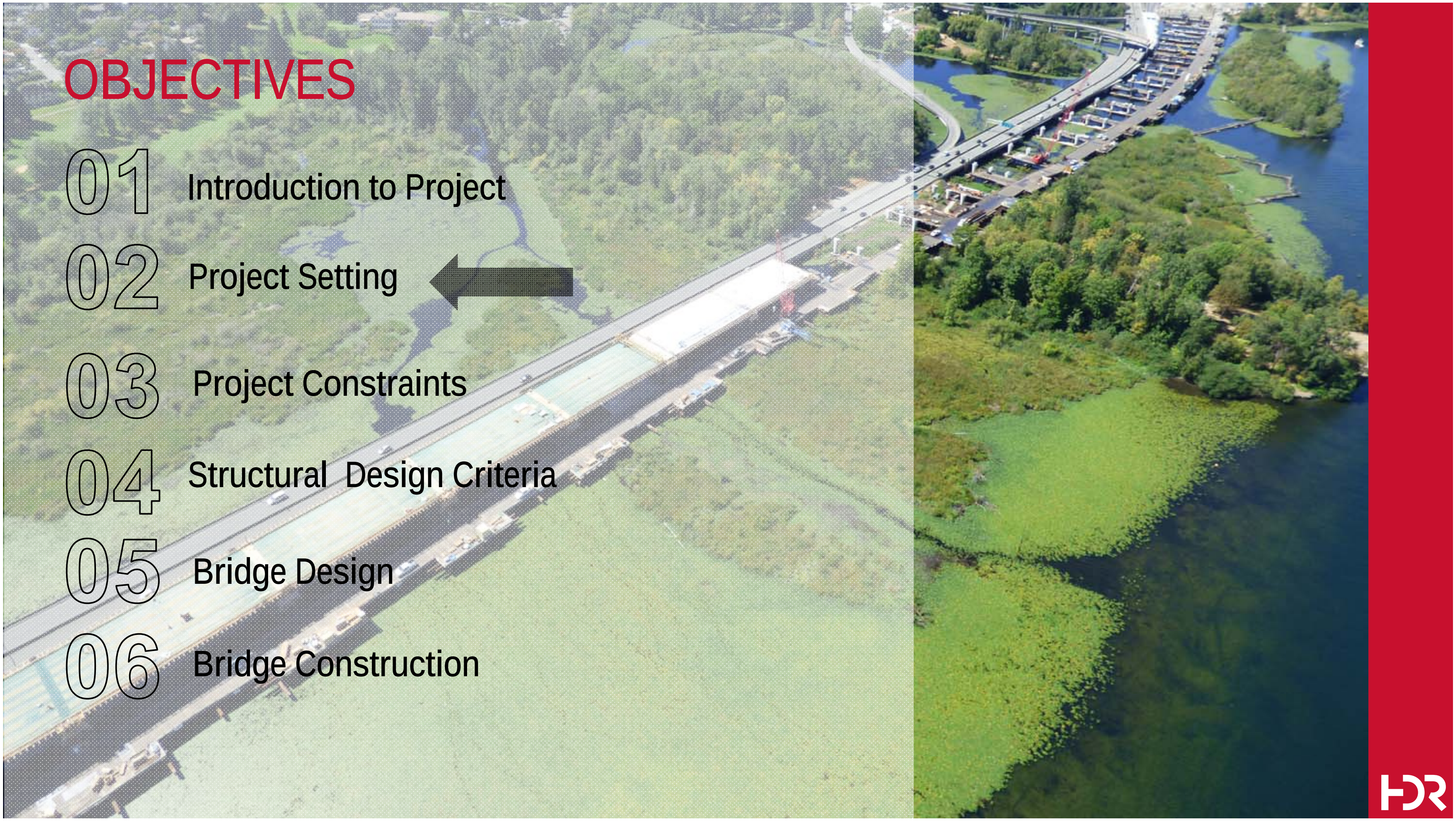
Grand Opening April 2 – 3, 2016



Open to Traffic on April 11, 2012, looking west from Medina.

REMOVAL OF THE OLD FLOATING BRIDGE

- Crews plan to remove the entire old floating bridge by the end of 2016.


OBJECTIVES
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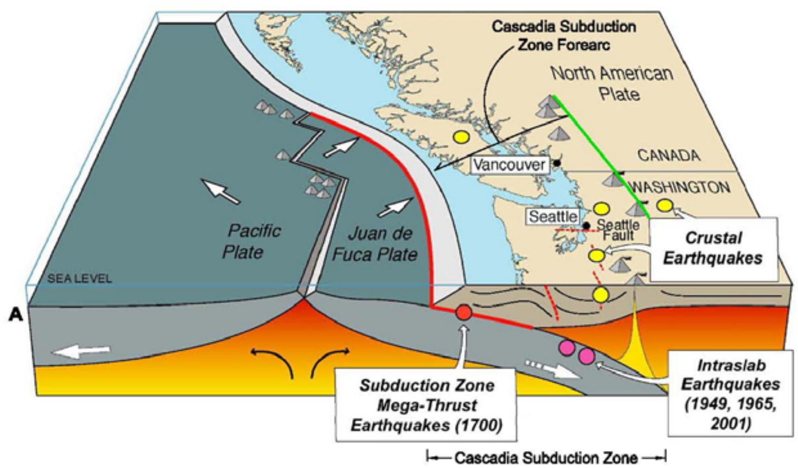
06 Bridge Construction
HDR

PROJECT SETTING

- Major intersection and connections
- Wetlands
- Parklands
- Urban neighborhoods
- University property
- Navigable waterways
- Recreational waters
- Endangered species habitat
- Tribal fishing waters
- Historical and cultural resources
- Earthquake hazard from Cascadia subduction zone

NORTHWEST REGION SEISMIC SETTING

- Cascadia Subduction Zone
  - Interplate Mega-Thrust Earthquakes - M_{Max} = 9.2
  - Intraslab Earthquakes - M_{Max} = 7.5



TYPICAL GEOLOGIC CROSS SECTION

Not to Scale

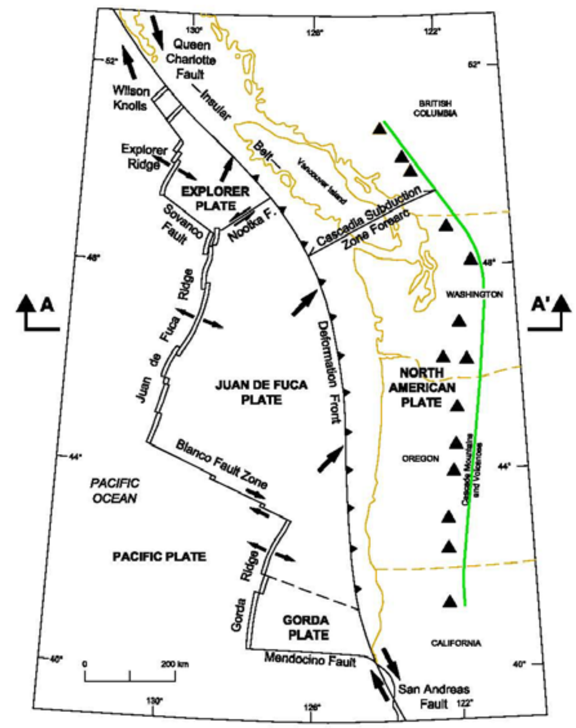


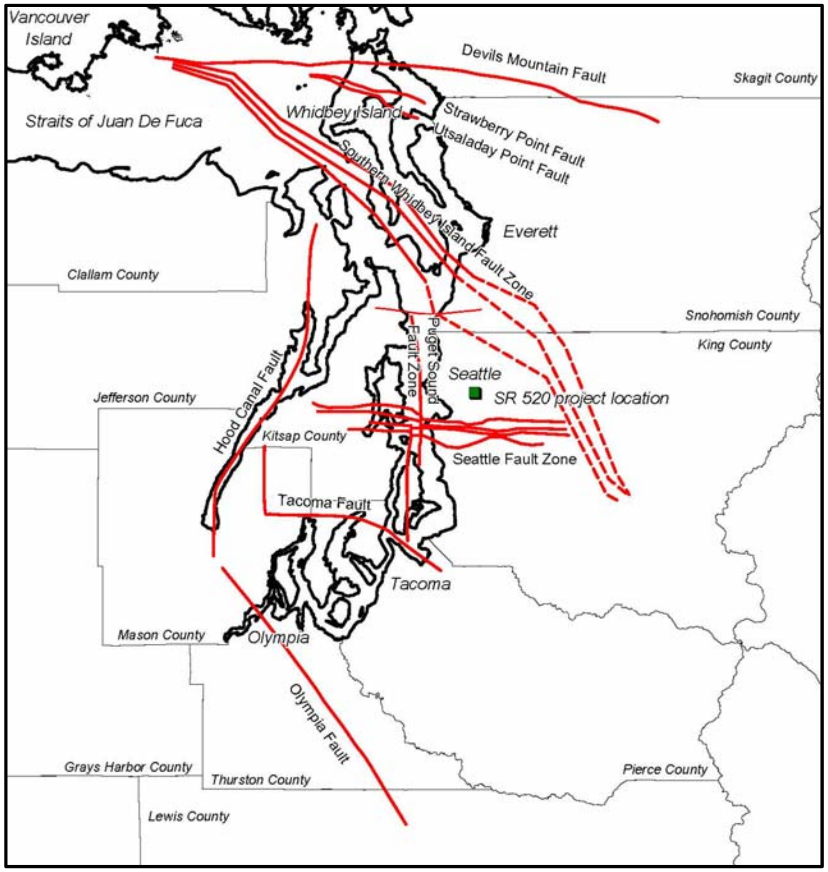
PLATE BOUNDARIES

LEGEND

A — Typical Geologic Cross Section Location

PUGET SOUND REGION SEISMIC SETTING

- Numerous crustal faults
- Significant sources:
  - Seattle Fault Zone (Less than 6 miles from the SR 520 Project)
  - South Whidbey Island Fault Zone
- These two sources are thought to be capable of $M_{Max} = 7.5$

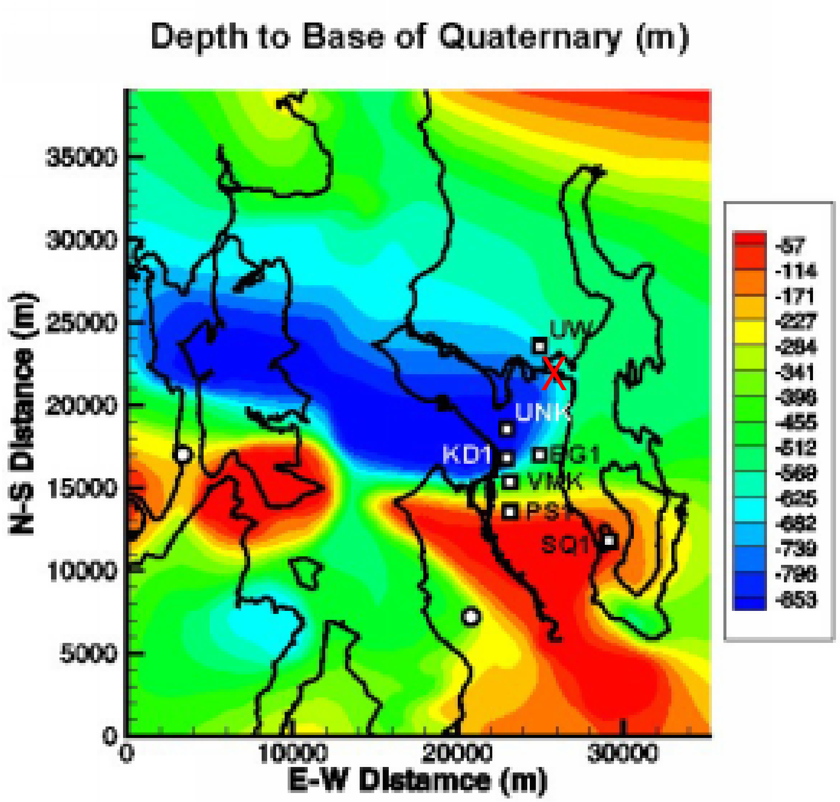


SEATTLE BASIN EFFECT

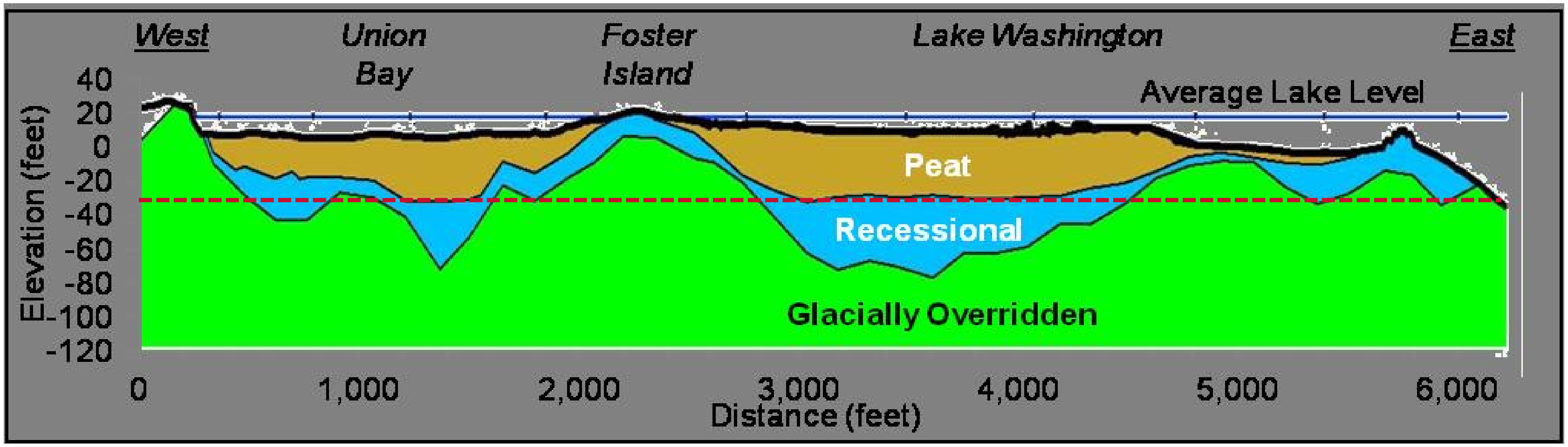
USGS
science for a changing world

Seismic Hazard Maps for Seattle, Washington, Incorporating 3D Sedimentary Basin Effects, Nonlinear Site Response, and Rupture Directivity

By Arthur D. Frankel, William J. Stephenson, David L. Carver, Robert A. Williams, Jack K. Odum, and Susan Rhea



WABN - SUBSURFACE PROFILE



- Peat from 6 ft to 40 ft deep
- Soft soils from 6 ft to 80 ft deep

OBJECTIVES

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06 Bridge Construction

PROJECT CONSTRAINTS

- Maintenance of Traffic
- Maintain 44’ Navigation Clearance
- Compatibility with Existing Structures and Structures under Construction
- Compatibility with Local Geology and Geography
- Minimize Environmental Impacts to:
  - Ecosystems and Neighborhoods
  - Water, Noise, Air and Visual Quality
  - Endangered Species
- Tribal Commitments
- Forward Compatibility with Future Construction and Light Rail

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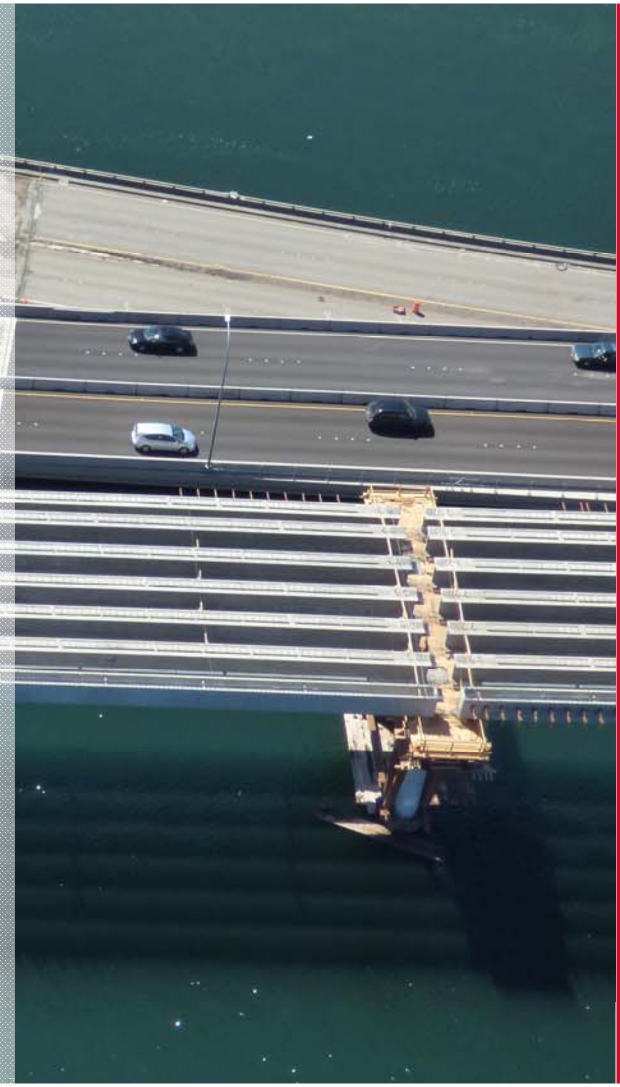

ESSENTIAL BRIDGE DESIGNATION

- A reliable lake crossing is essential to the post – earthquake emergency mobility of the entire region.
- Combined average daily traffic across the lake on I-90 and SR 520 is about 220,000 trips.
- I-90 bridges across Lake Washington were not designed to current seismic standards.
- In October 2009 WSDOT designated the mainline bridges on the SR 520 corridor as "essential" bridges.

WSDOT ESSENTIAL BRIDGE CRITERIA

- Essential bridges should be open to emergency traffic immediately after the design earthquake and open to all traffic within days.
- Performance objective is to be capable of essential vehicle service immediately after the 1000 year return period event.
- Requires site specific hazard and ground motion response analysis.
- Places more stringent limits on concrete and steel strains.
- Requires consideration of vertical effects of ground motion on the superstructure.

WSDOT CRITERIA FOR BRIDGES SUBJECTED TO LIGHT RAIL LOADING

- Released Nov. 18, 2010.
- Specifies seismic analysis requirements for WSDOT bridges carrying light rail.
- Requires that the mass of an AW1 light rail vehicle be included in the seismic analysis.
- Requires that the live load of AW1 light rail vehicle be applied concurrently with the seismic load.

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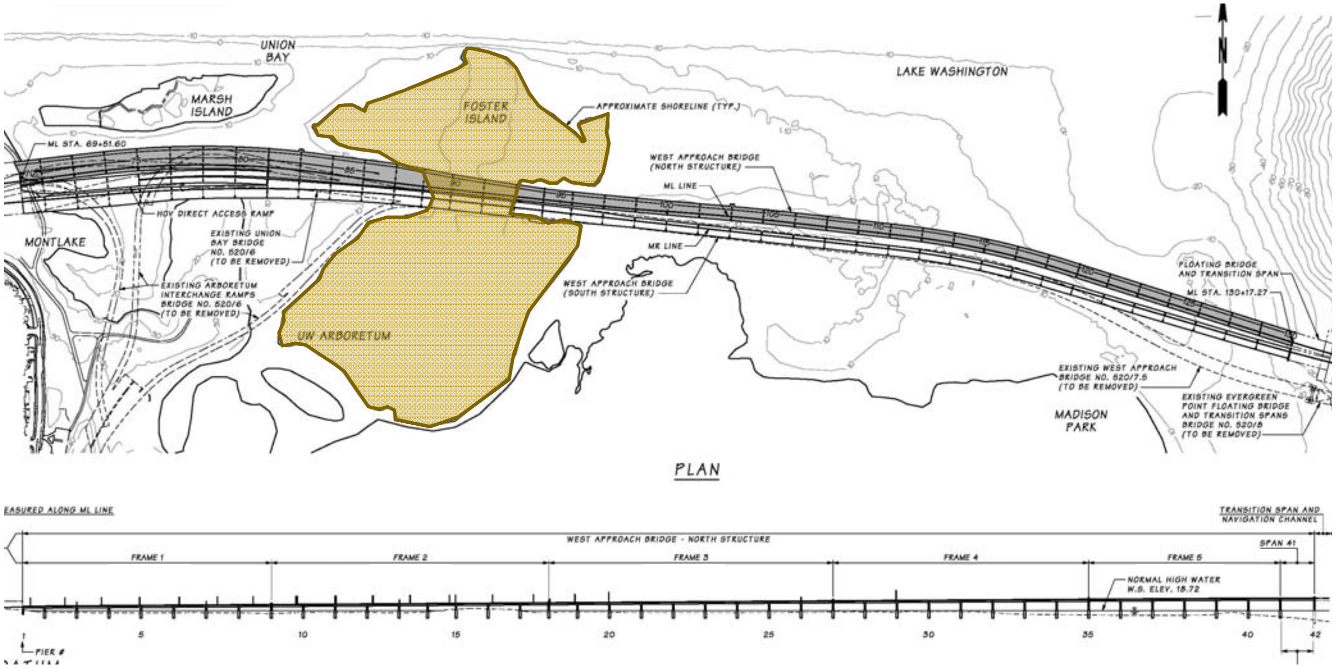
BRIDGE DESIGN – OVERALL STATISTICS

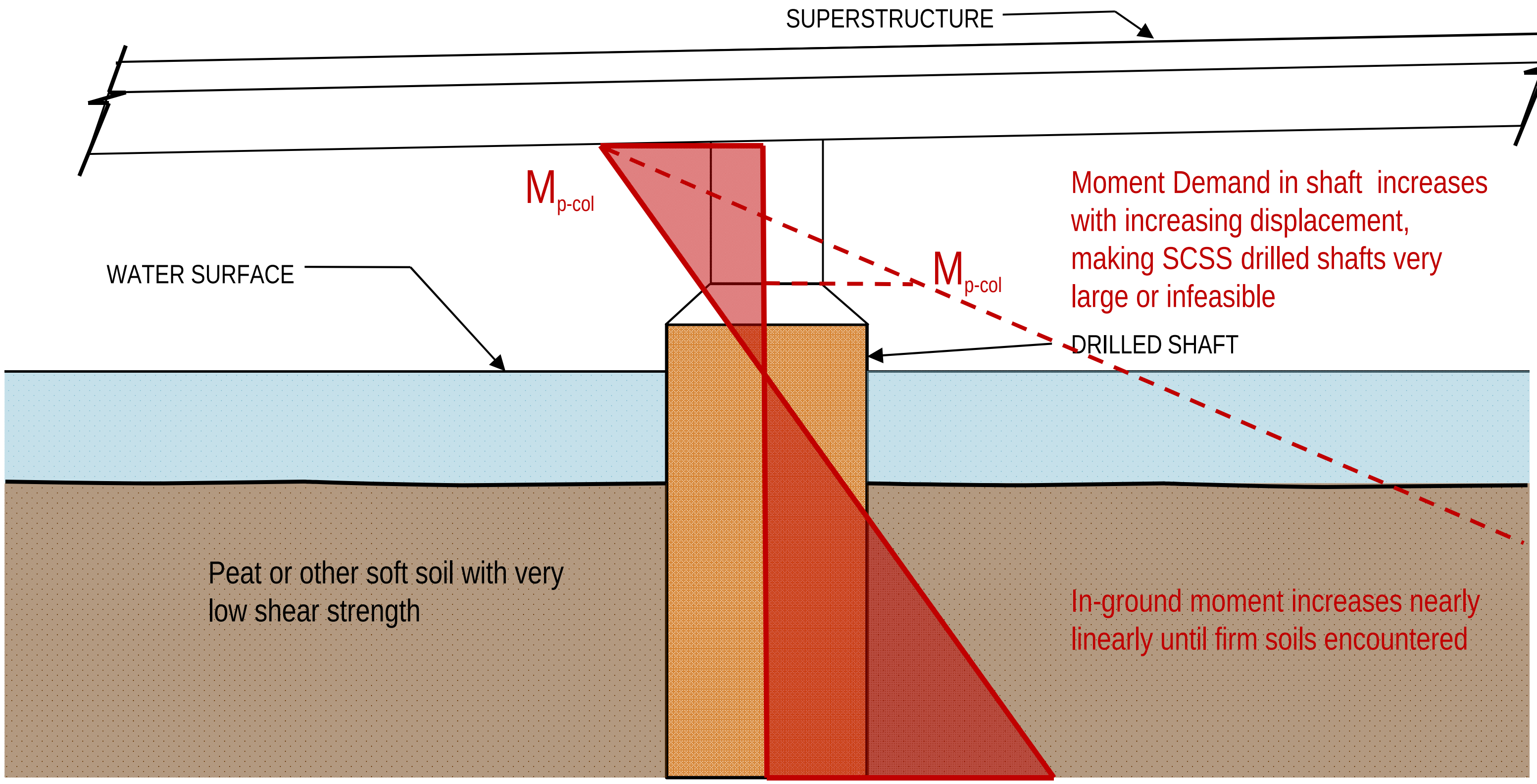


- Deck area = 500,000 sf (approx.)
- Average width = 81 ft (typ. = 65 .4 ft, Max = 137')
- Number of columns = 95
- Column heights vary from 4 ft to 40 ft. (0.7% Slope)
- Prestressed girders : WF74G (TYP.), One span WF66G, and WF83G
- Typical span length = 150'
- Single column /single shaft foundations (8' to 12' dia. Shafts)
- S-Curves with 4100' radius and super-elevation transitions

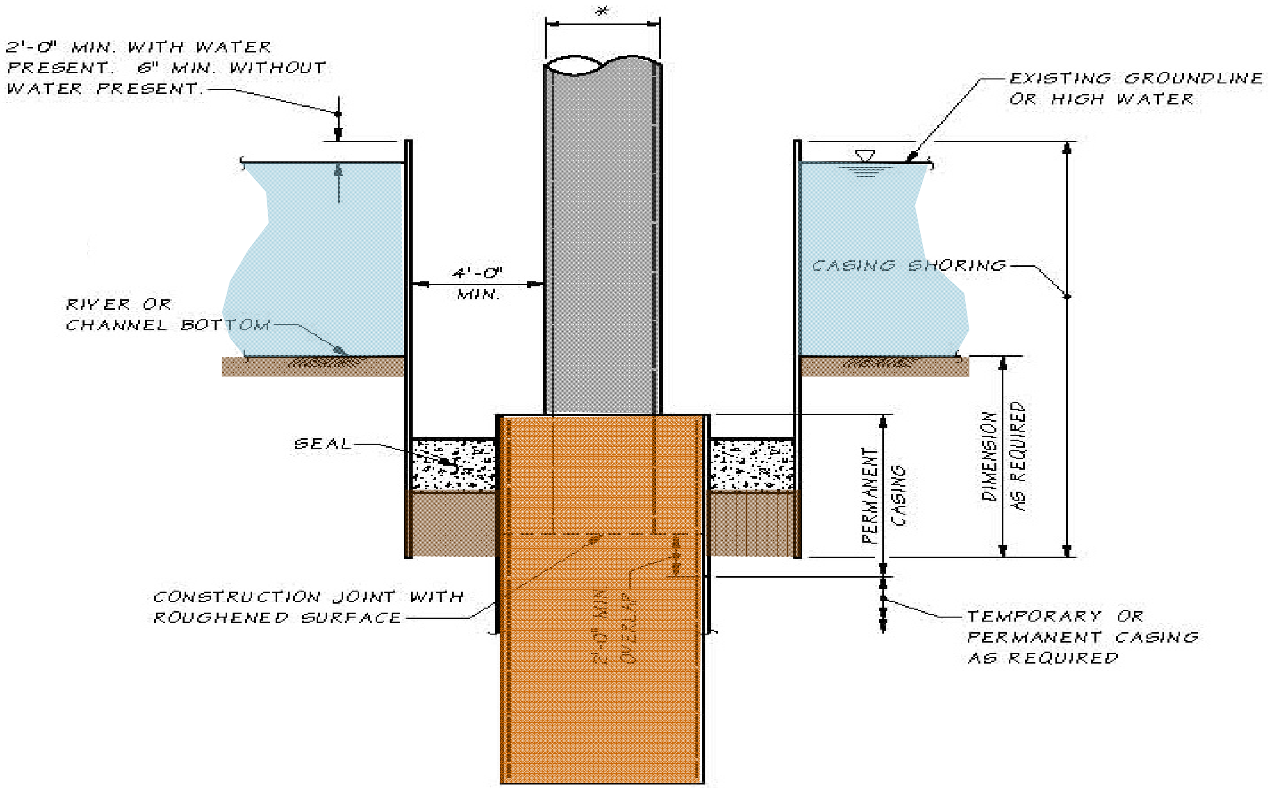
NOTEWORTHY BRIDGE DESIGN FEATURES

- Utilizes Seismic Isolation
- Incorporates Uniquely Shaped Cantilever Columns without Crossbeams
- Has Unique Bridge Drainage System Details
- Employs Noise Reducing Modular Expansion Joints
- Requires Extensive Work Access Structures
- Requires a Specialized Falsework System

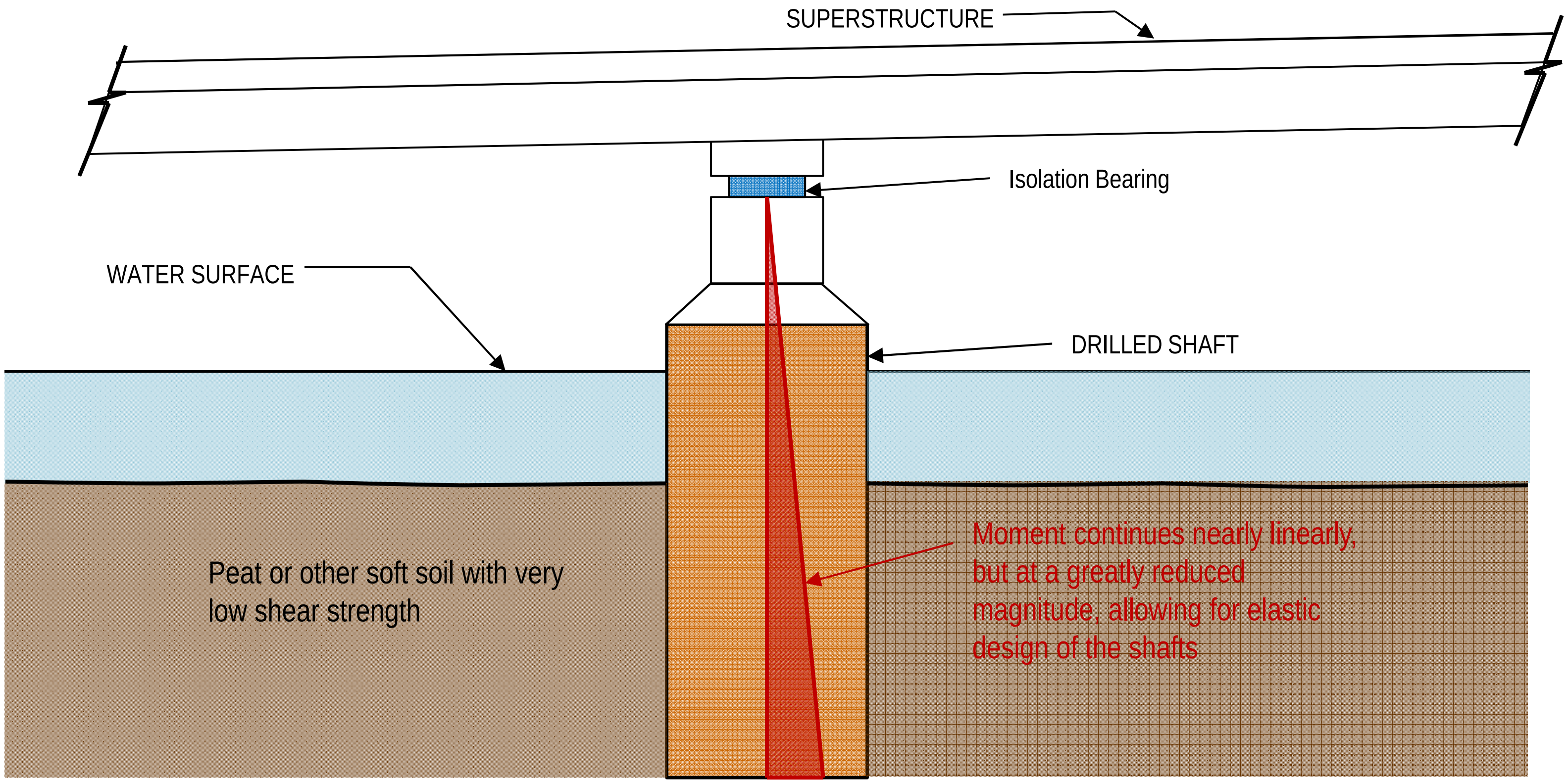
SHORT COLUMNS AND SOFT SOILS POSE CHALLENGES FOR CONVENTIONAL SEISMIC DESIGN



A CONVENTIONAL SOLUTION IS CASING SHORING

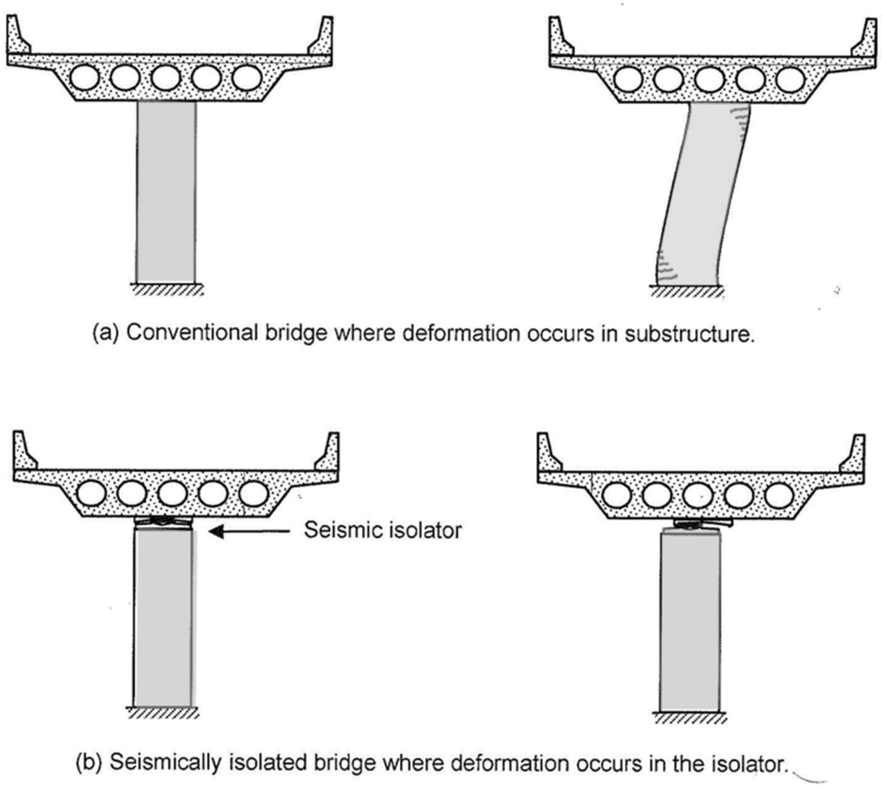


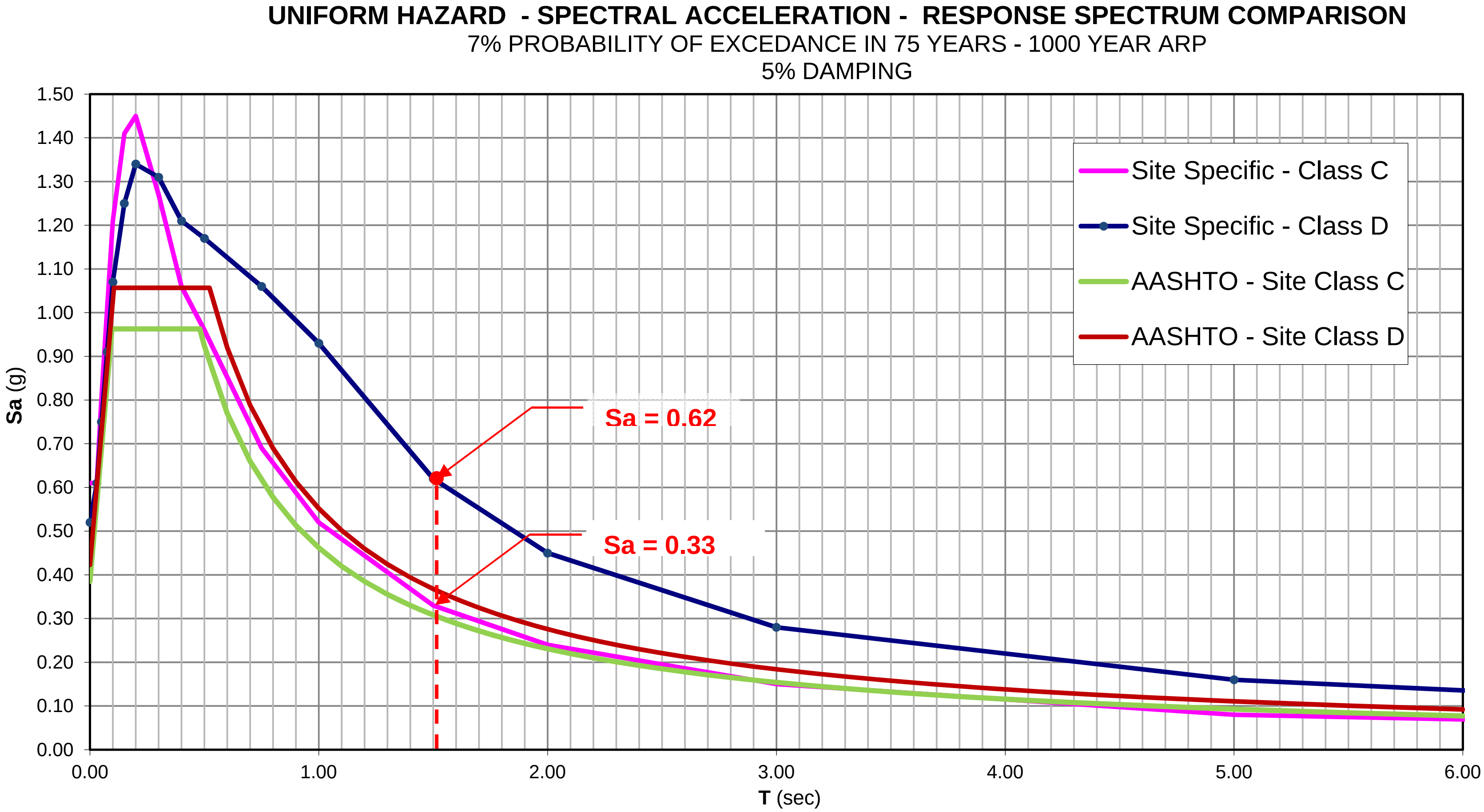
SEISMIC ISOLATION ELIMINATES THE NEED FOR CASING SHORING



BASIC PRINCIPLES OF SEISMIC ISOLATION

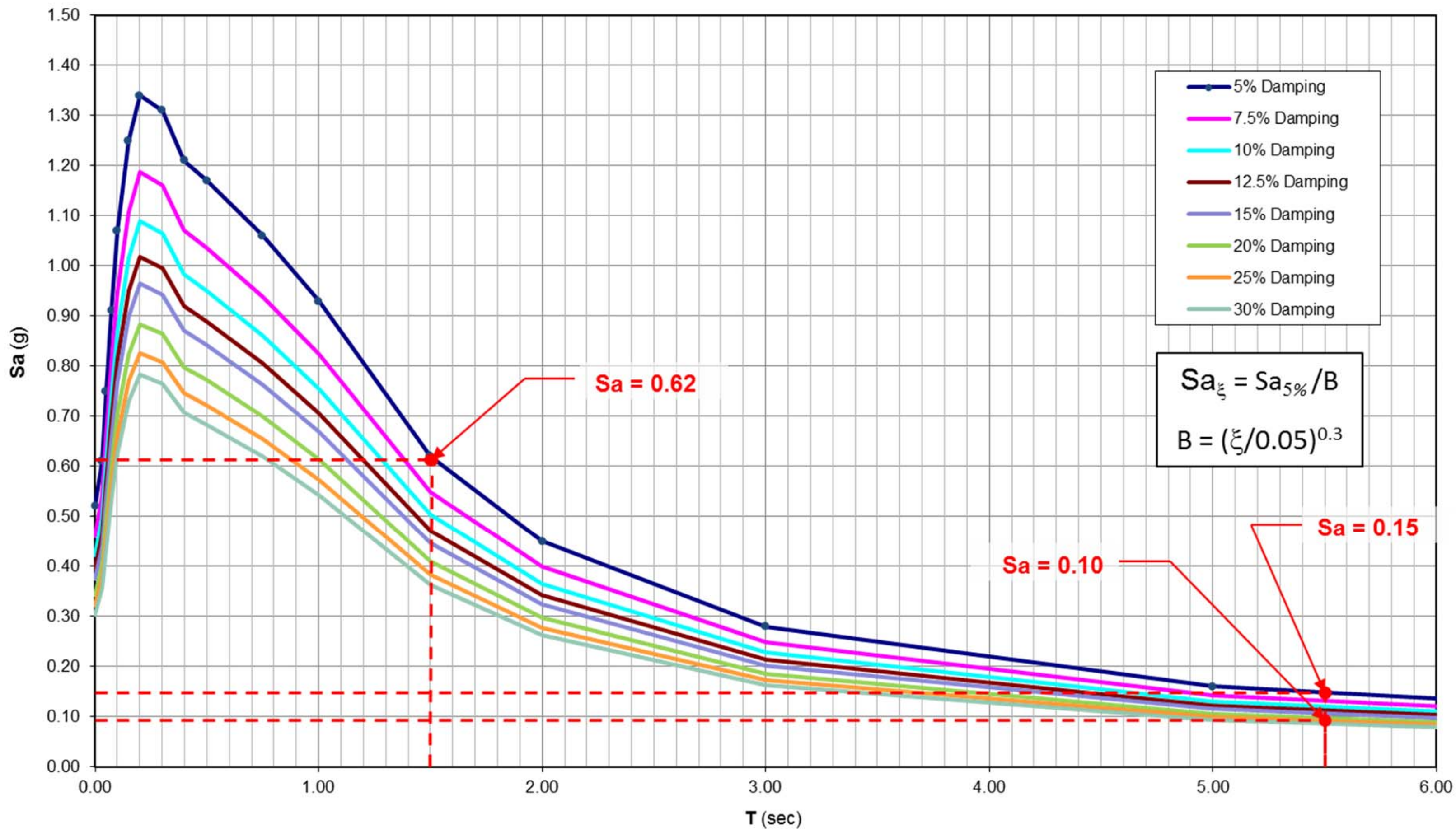
- Accommodates structure displacement in specially designed bearings
- Lengthens the structures fundamental period
- Adds damping to the system
- Reduces structure acceleration
- Reduces structure force demands
- Can increase structure displacement demands



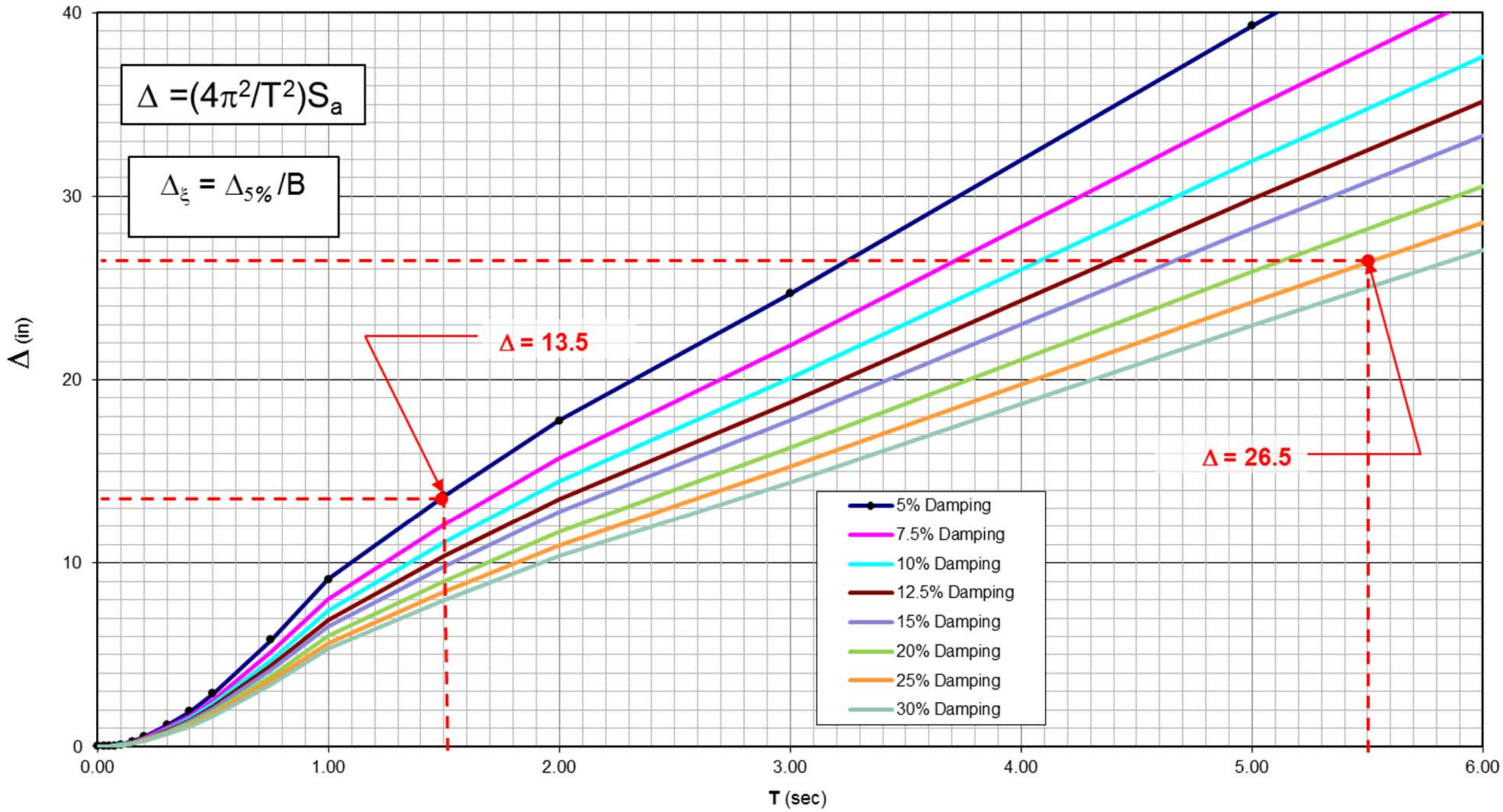


UNIFORM HAZARD - SPECTRAL ACCELERATION - RESPONSE SPECTRUM COMPARISON
7% PROBABILITY OF EXCEDANCE IN 75 YEARS - 1000 YEAR ARP
5% DAMPING
Sa (g)
T (sec)
Site Specific - Class C
Site Specific - Class D
AASHTO - Site Class C
AASHTO - Site Class D
Sa = 0.62
Sa = 0.33
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
1.50
0.00
1.00
2.00
3.00
4.00
5.00
6.00

SPECTRAL ACCELERATION RESPONSE SPECTRUM
Site Class D

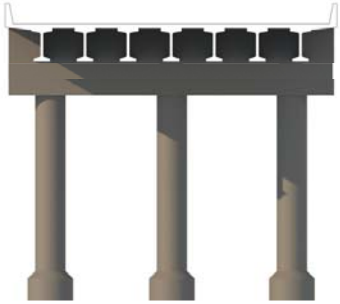


DISPLACEMENT RESPONSE SPECTRUM
Site Class D

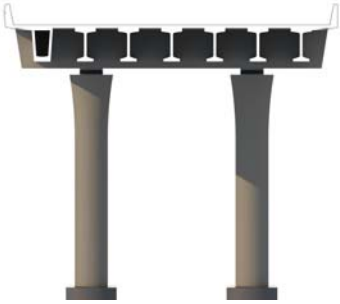


BENEFITS REALIZED WITH SEISMIC ISOLATION

- Reduced force demands on the substructure by a factor of 5 or more.
- Provided an elegant solution to meeting project specific Essential Bridge Criteria
- Provided improved performance over conventional bridge construction (structure remains elastic)
- Eliminated balanced stiffness requirements
- Accommodated aesthetic enhancements
- Minimized Environmental Impacts
- Reduced construction cost by approx. $50 Million



Without



With

COSTS OF UTILIZING SEISMIC ISOLATION

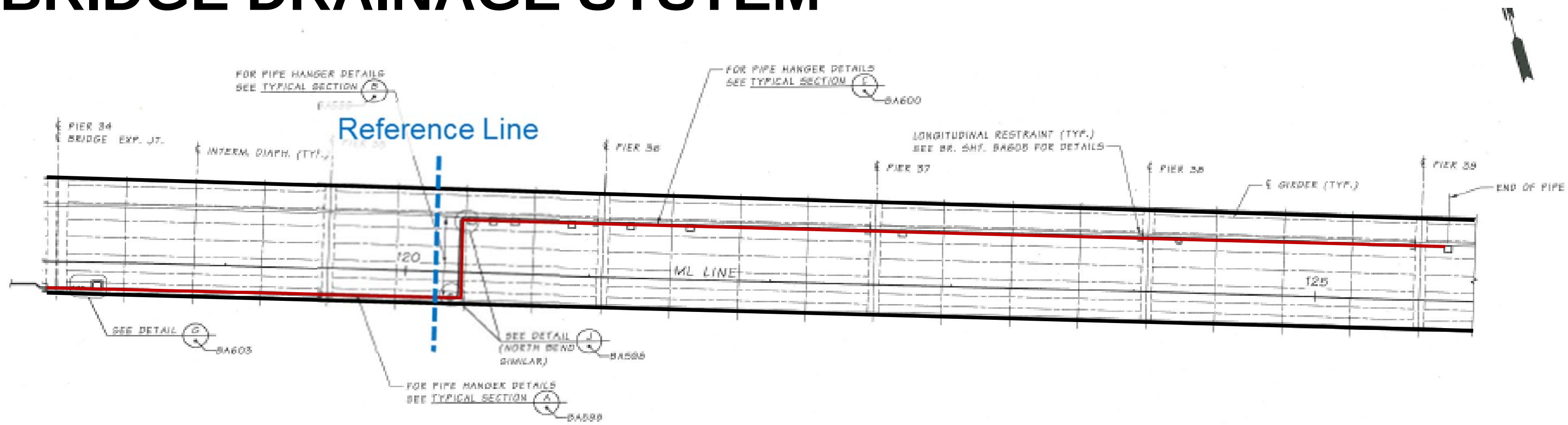
- Increases structure displacements
- Requires large expansion joints
- Requires specialized bearings
- May require additional effort for bearing selection and procurement.
- Requires additional analysis
- Increases design costs
- May increase maintenance cost

IN SUMMARY

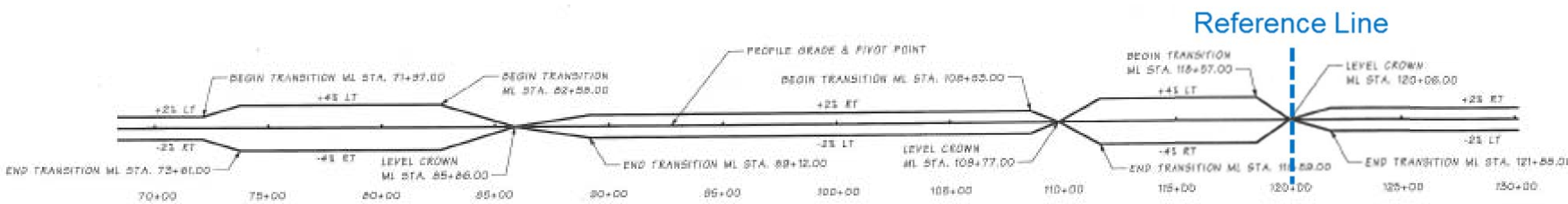
- The SR 520 West Approach Bridge - North is using a seismic isolation system that results in:
  - Significant cost savings – Estimated at $70M
  - Improved seismic performance (Safety and Reliability)
  - Minimized environmental impacts

The 6500 ft long isolated Los Caras Bridge in Ecuador was open to traffic immediately after the nearby 7.8 Magnitude Earthquake struck in 2016.

BRIDGE DRAINAGE SYSTEM

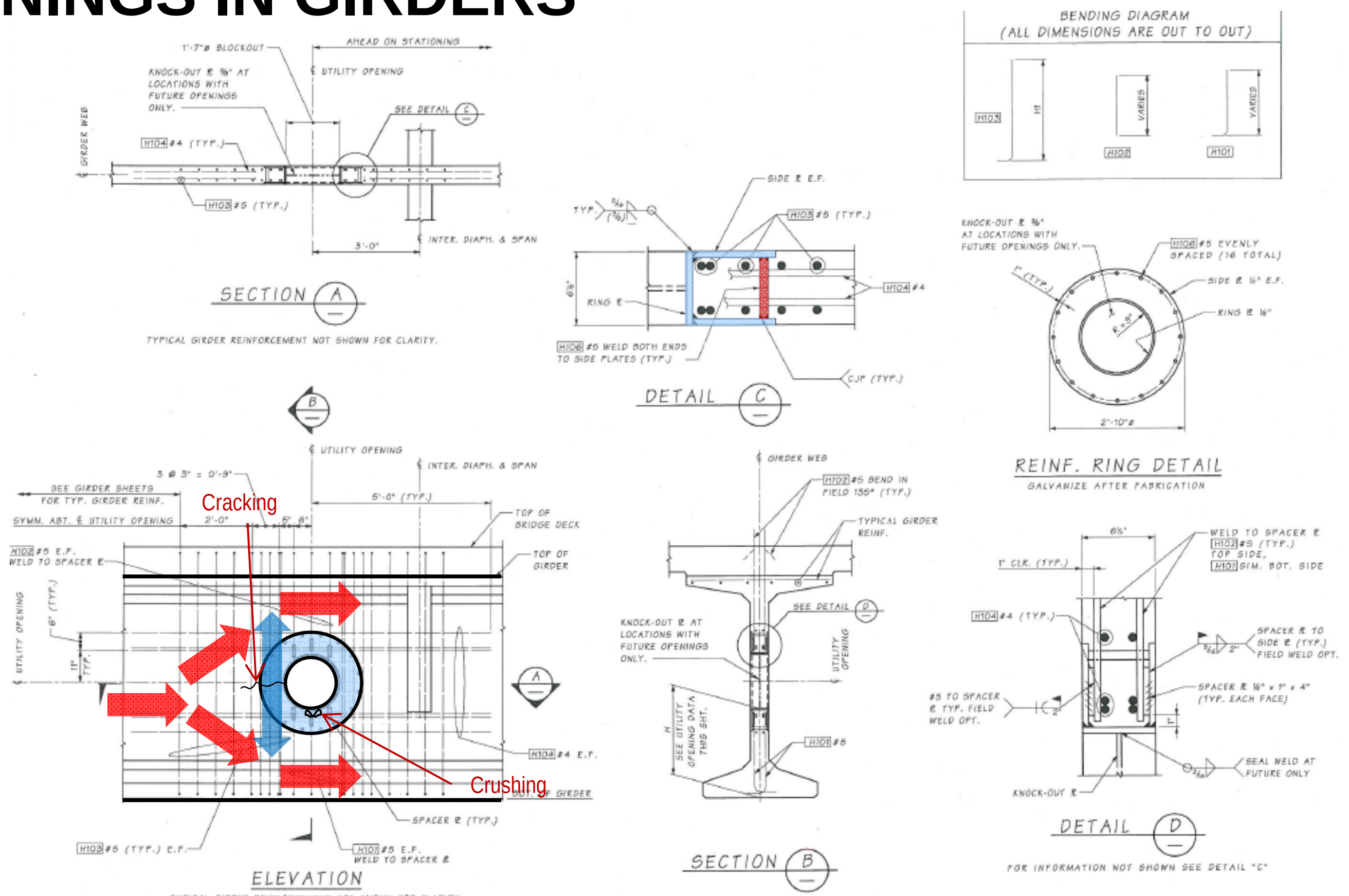


Bridge Drainage Layout Plan



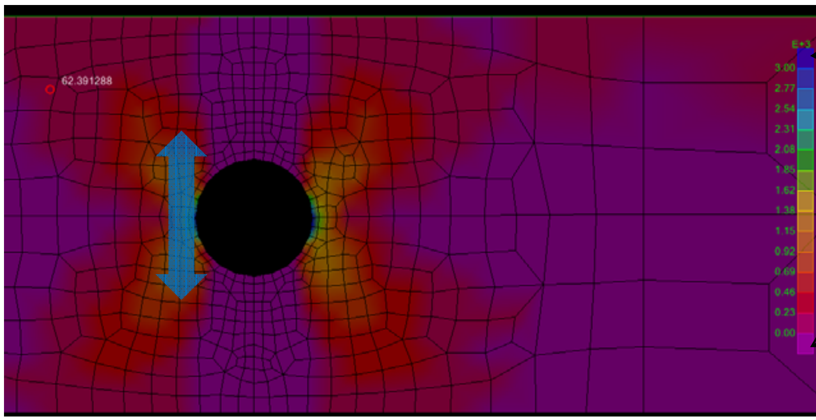
Superelevation Diagram

OPENINGS IN GIRDERS



CONCRETE MAXIMUM TENSILE STRESS

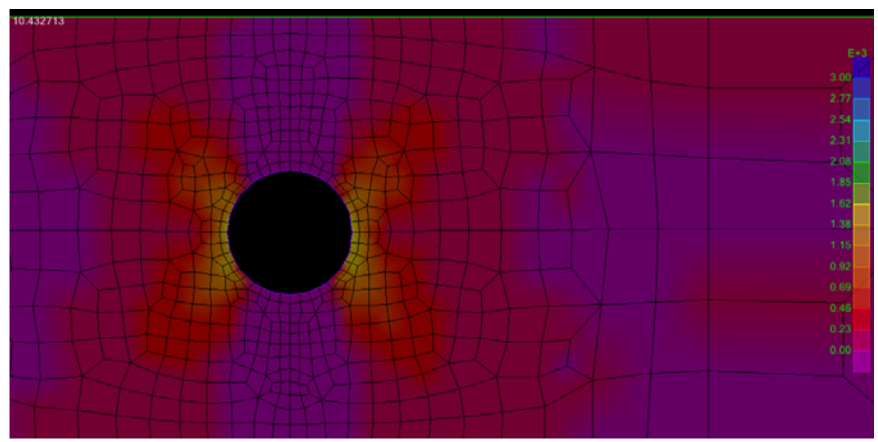
IMMEDIATELY AFTER P/S TRANSFER



Blue = 3000 psi Tension

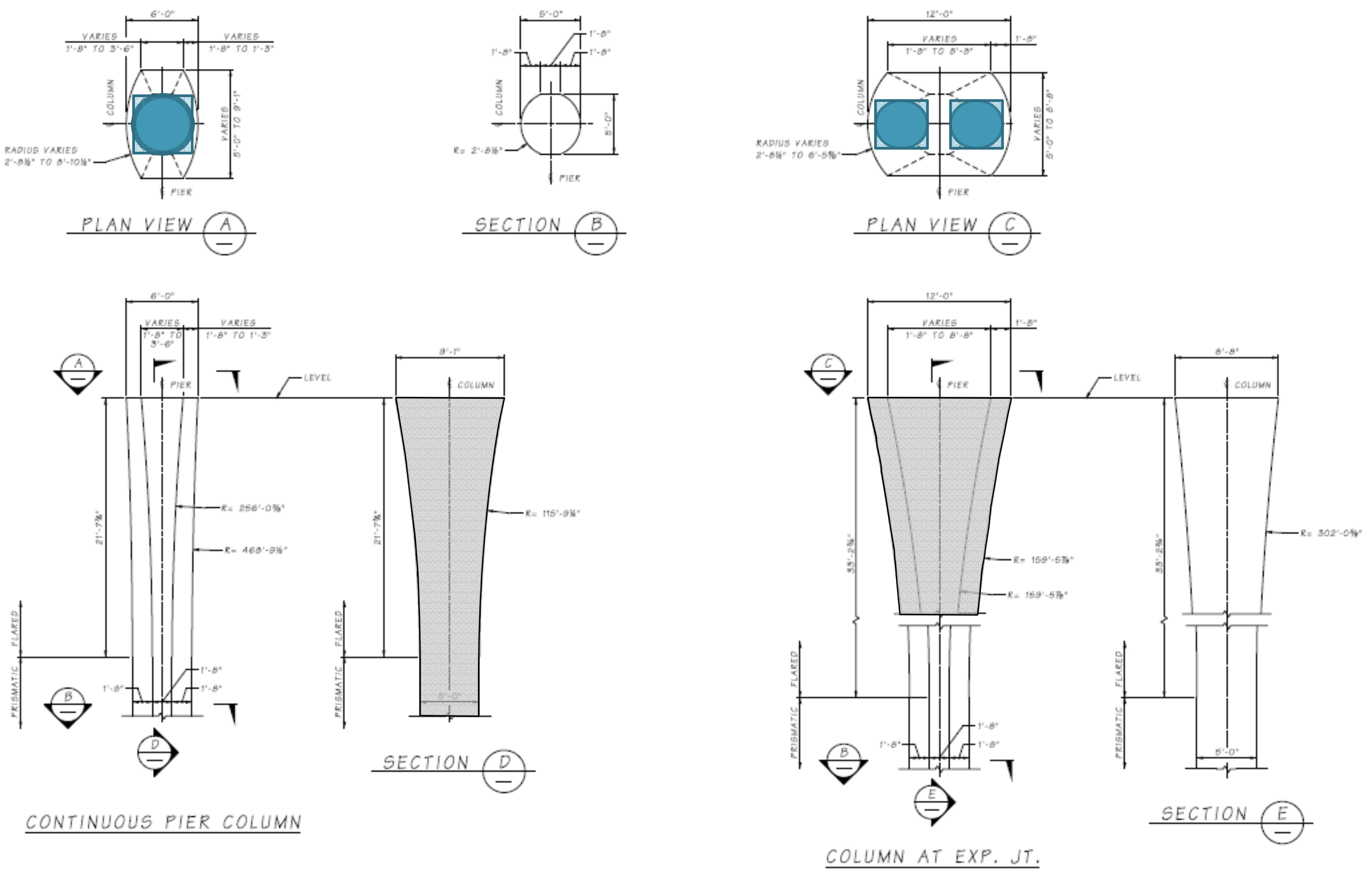
Violet = 0 psi

Without Steel Ring

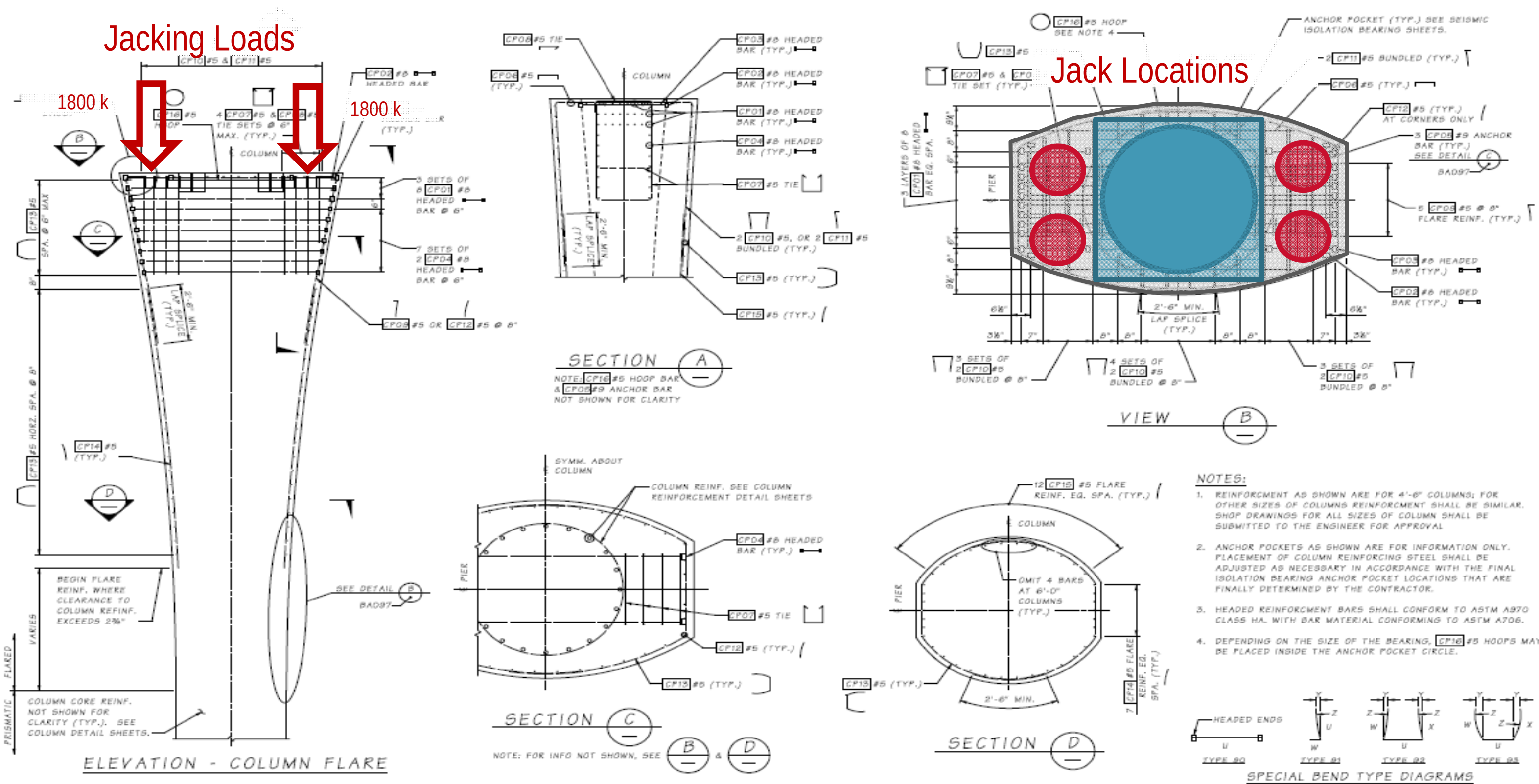


With Steel Ring

FLARED COLUMN GEOMETRY

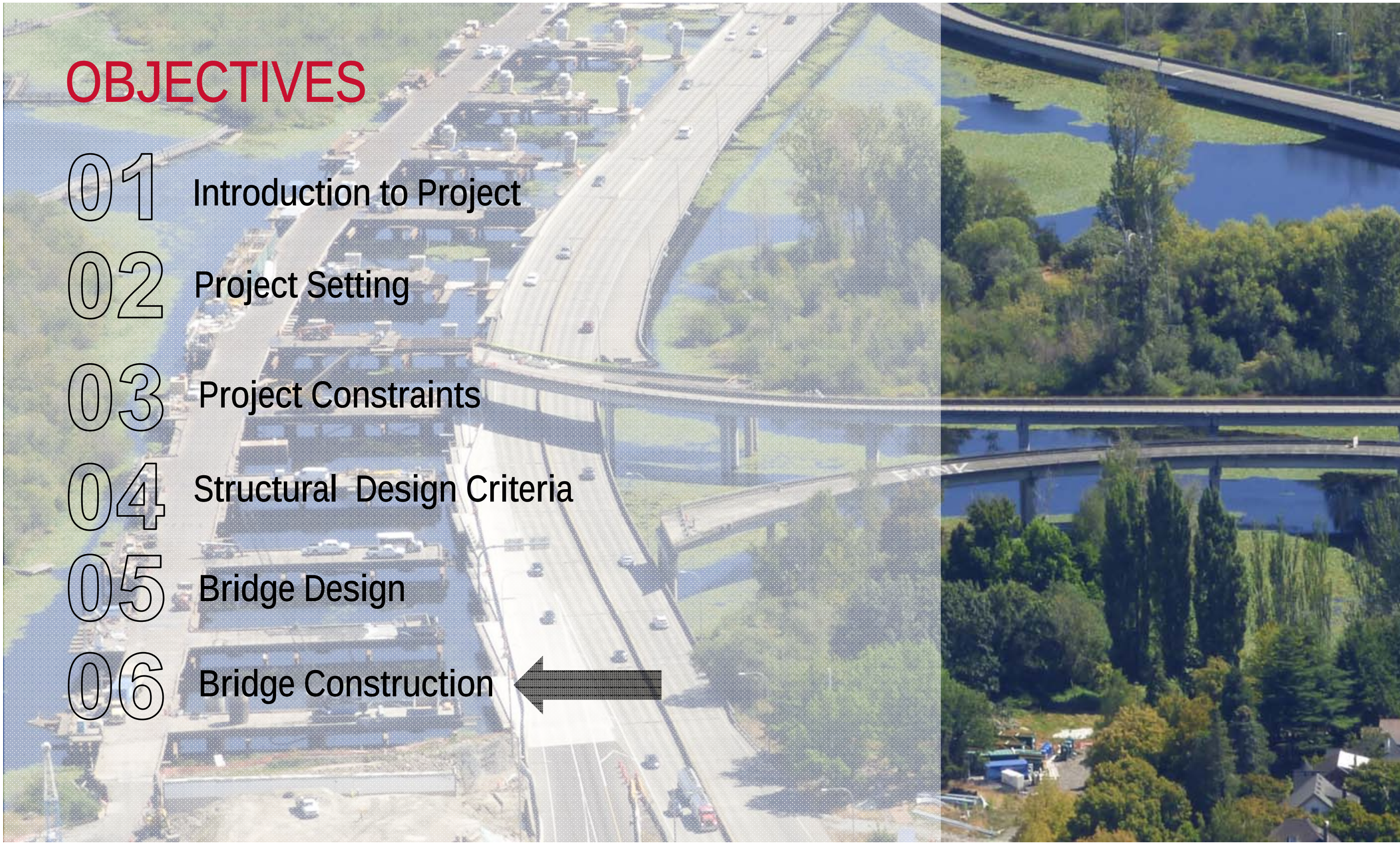


FLARED COLUMN REINFORCING



NOISE REDUCING MODULAR EXPANSION JOINTS

- Noise Reducing Sinus Plates Bolted to Centerbeams
- Noise Encapsulating "Robo-Mute" System
- First use of this technology in the U.S.A.
- Compliments NGCS "Quieter Concrete" Roadway Surface and 4 ft tall Traffic Barriers



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WORK ACCESS


Work Access accounted for approx. $36 M of the
$200 M Contract Bid Price

WORK ACCESS

Environmental Restrictions

WORK ACCESS

Pile Driving

WORK ACCESS

Pile Driving

WORK ACCESS

Setting Girder

WORK ACCESS

Foster Island

DEMOLITION

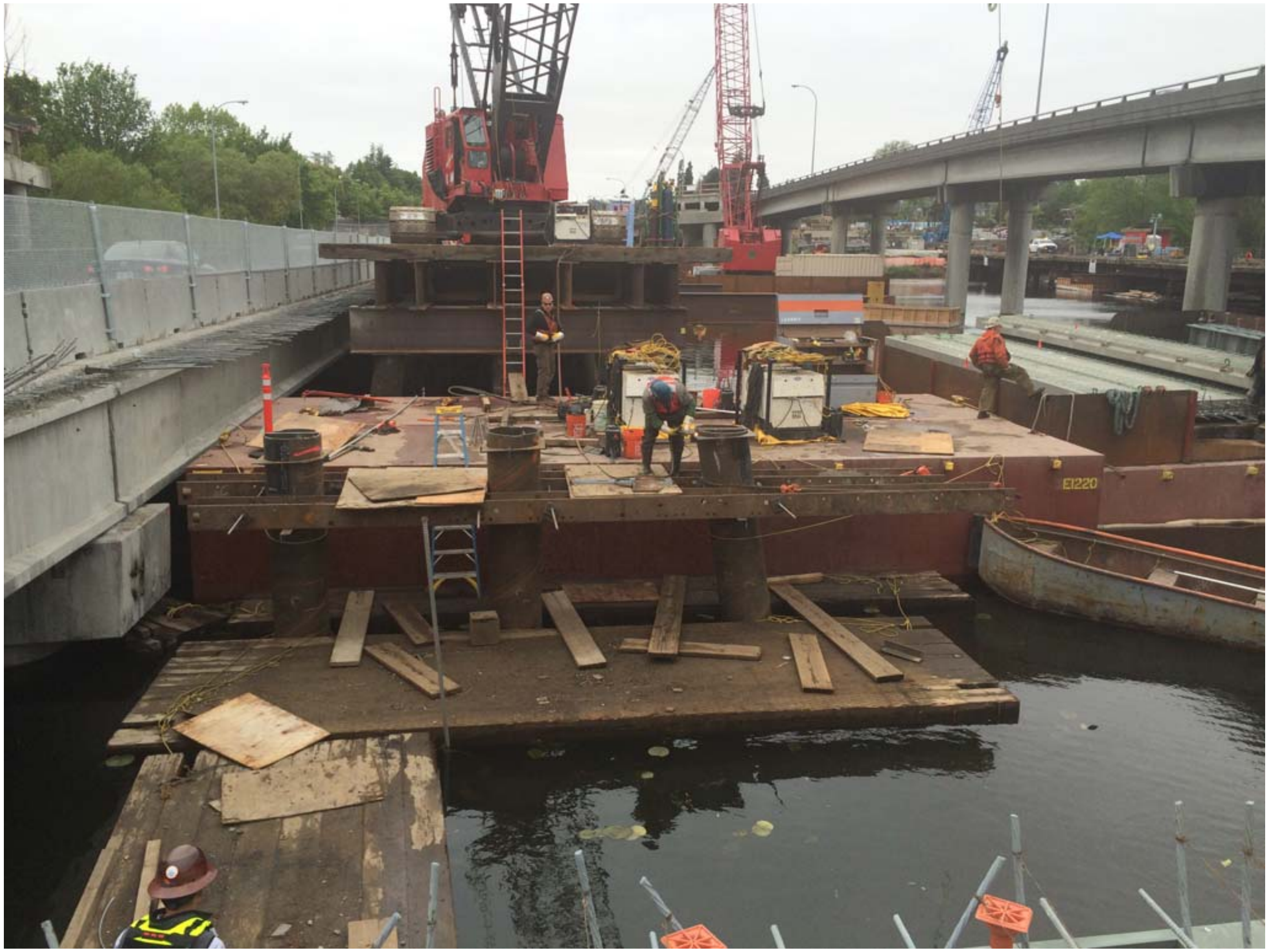
Access by
Flexi-Float

MOT

Maintenance of Traffic

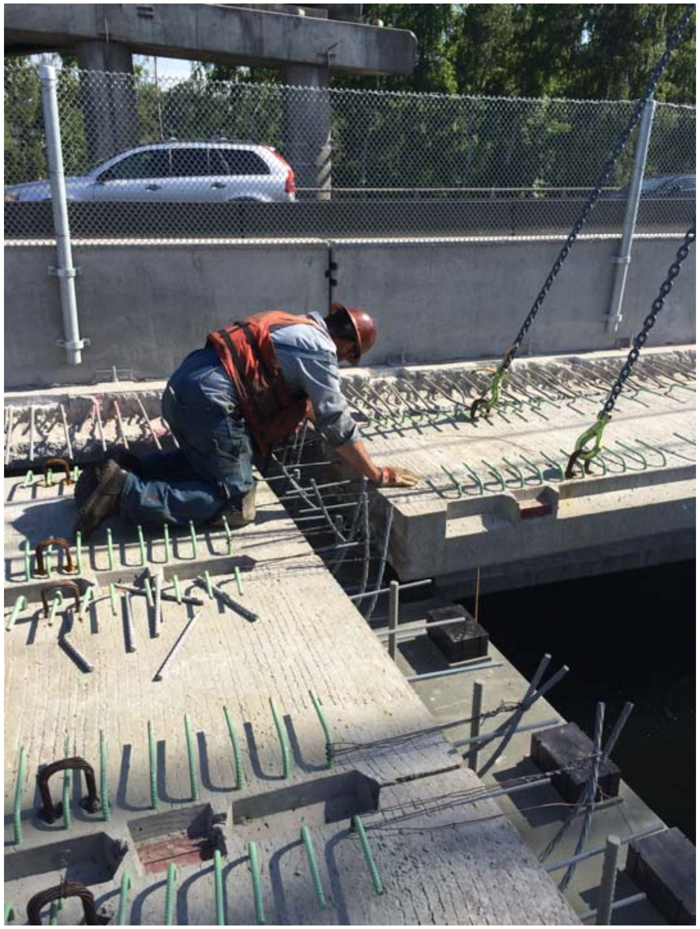
MOT

Widening of
Existing Bridge



MOT

Widening
of Existing
Bridge



DRILLED SHAFTS

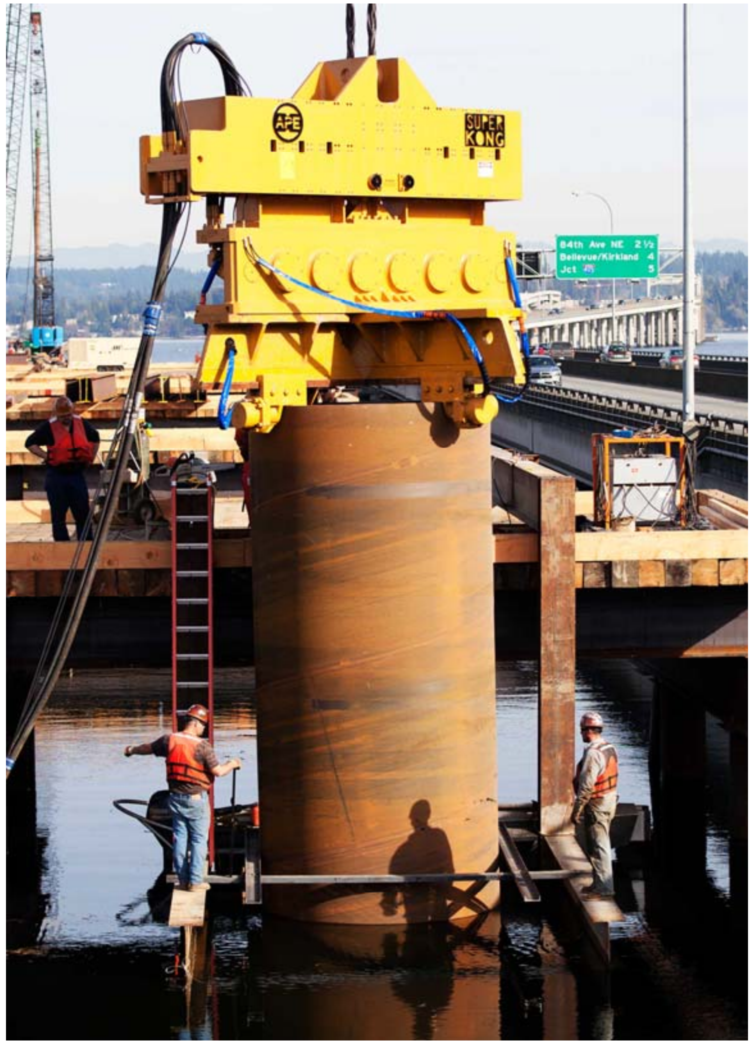
Locating Casing From Work Bridge

DRILLED SHAFTS

Locating
Marine
Casings

DRILLED SHAFTS

Driving Casing



DRILLED SHAFTS

Excavation and Containment

DRILLED SHAFTS

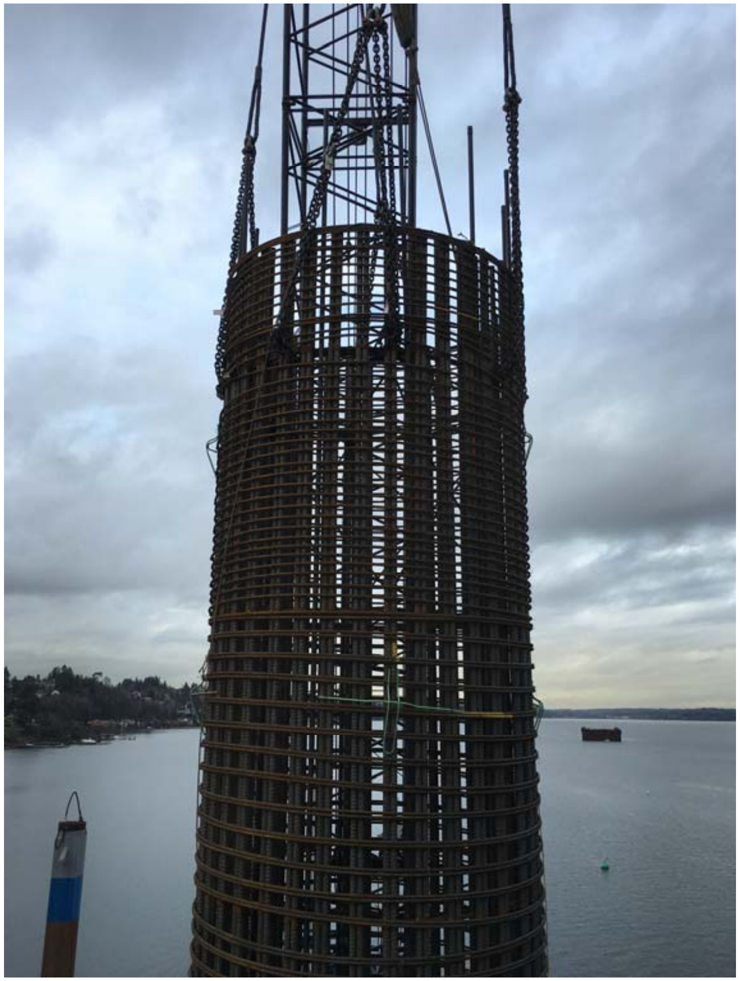
Tying Cages

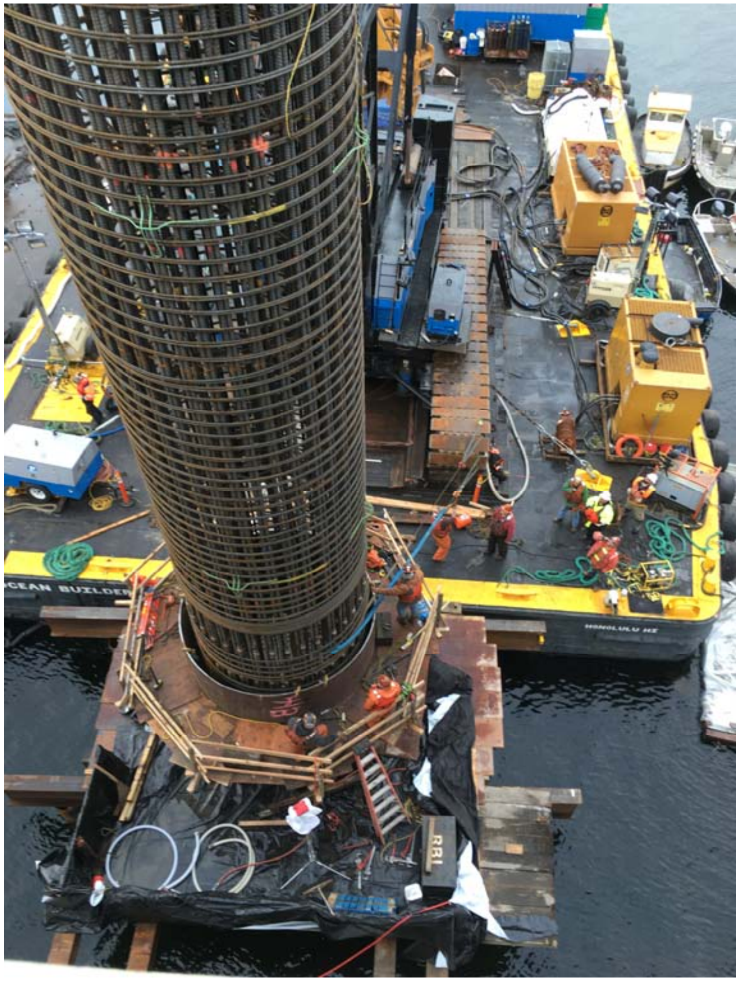
DRILLED SHAFTS

Placing Cage

DRILLED SHAFTS

Cage Splice





DRILLED SHAFTS

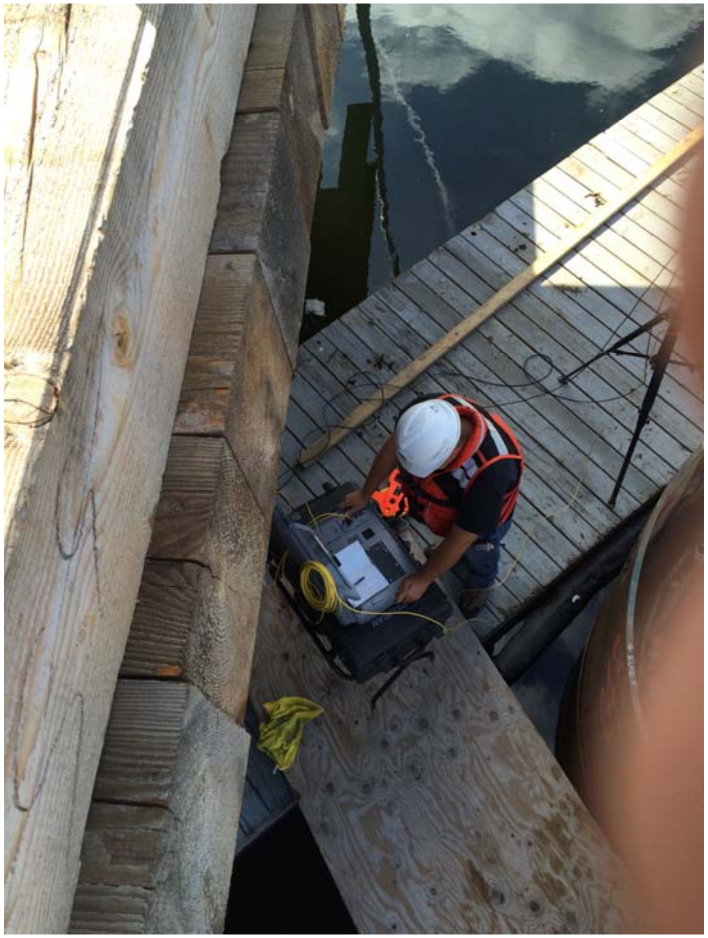
Placing Concrete

DRILLED SHAFTS

Preparing Construction Joint

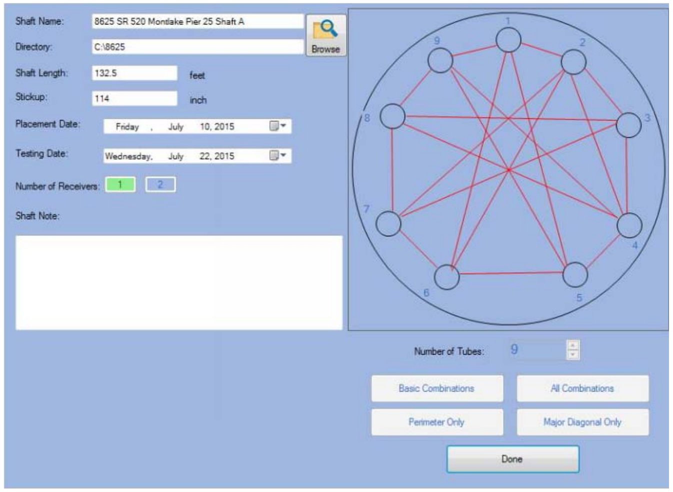
DRILLED SHAFTS

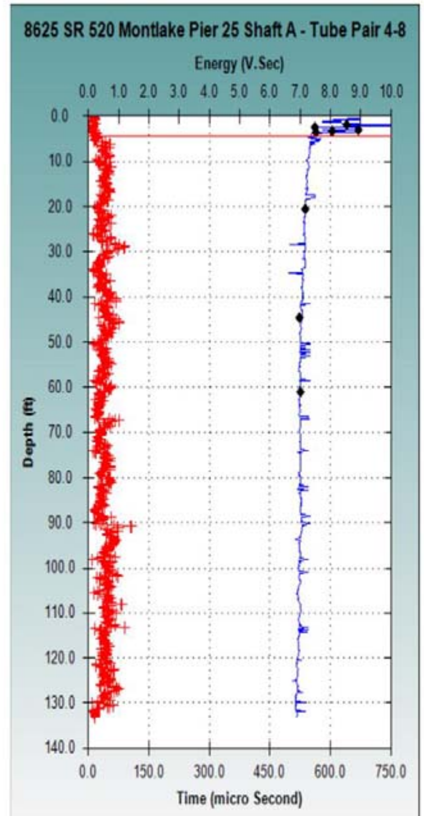
CSL Testing

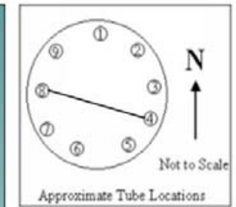


DRILLED SHAFTS

CSL Testing







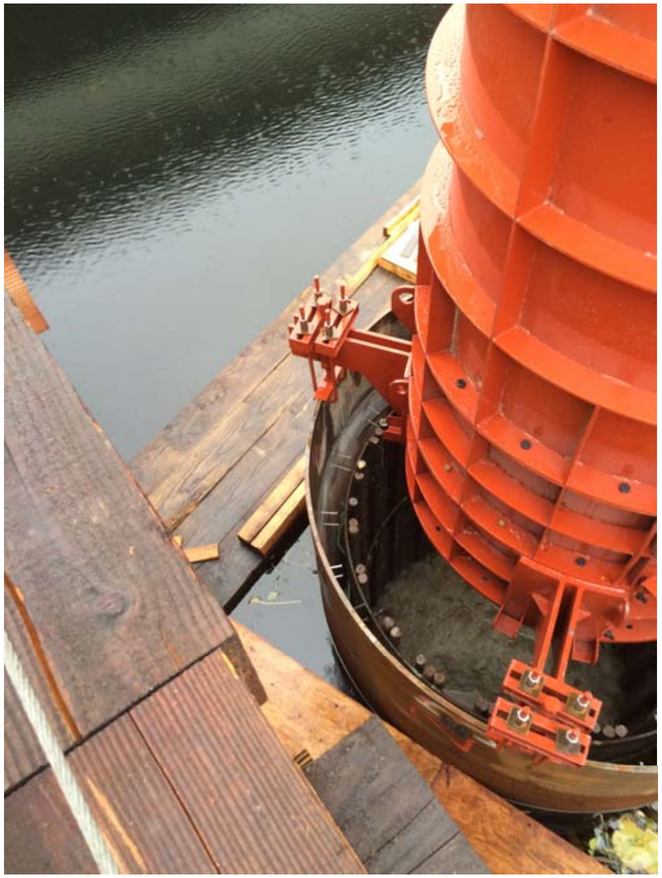
Shaft Length - 132.5 ft
Stickup - 132 inches
Placement Date - 7/10/2015
Test Date - 7/22/2015
Tubepair Depth - 133 ft

DRILLED SHAFTS

Obstructions

COLUMNS

Locating Columns

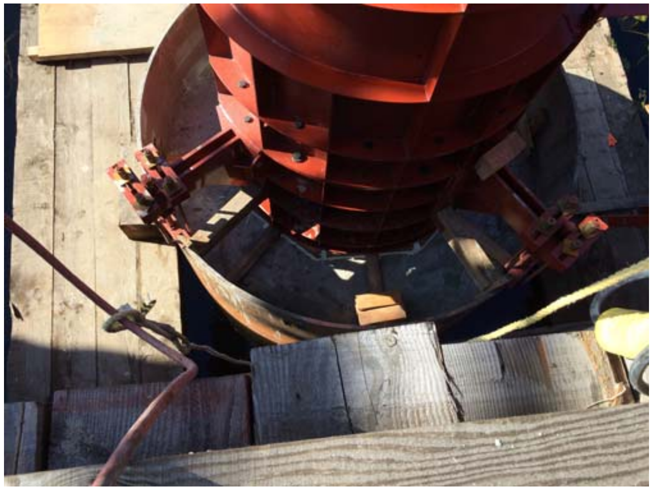


COLUMNS

Reinforcing Cage

COLUMNS

Placing Concrete



COLUMNS

Forms
Removed

BEARINGS

Fabrication at EPS

BEARINGS

Fabrication

BEARINGS

Prototype
Testing

Stability 13.2.2.6	Extreme Event I	1.5*DE+offset-Shrinkage		
PT-F1	4400	± 18	1 Cycle	120
	Min. 0.8D-OT			
PT-F2	1600	± 18	1 Cycle	120

BEARINGS

Corrosion Concerns Identified on Snohomish River Bridge

BEARINGS

Adjustments made to Seal Design and Testing of Bearings for SR 520

BEARINGS

Storage Requirements Strictly Enforced

BEARINGS

Grout Pad Testing

BEARINGS

Installed on Column

- Total of 108 seismic Isolation bearings for a bid price of approx. $5 M

FALSEWORK

Continuous
Pier

FALSEWORK

Continuous
Pier

FALSEWORK

Continuous
Pier

FALSEWORK

Bearing on Shaft

FALSEWORK

Expansion
Pier

GIRDER FABRICATION

GIRDER FABRICATION

GIRDER DELIVERY

By Land

GIRDER ERECTION

From Workbridge

GIRDER DELIVERY AND ERECTION

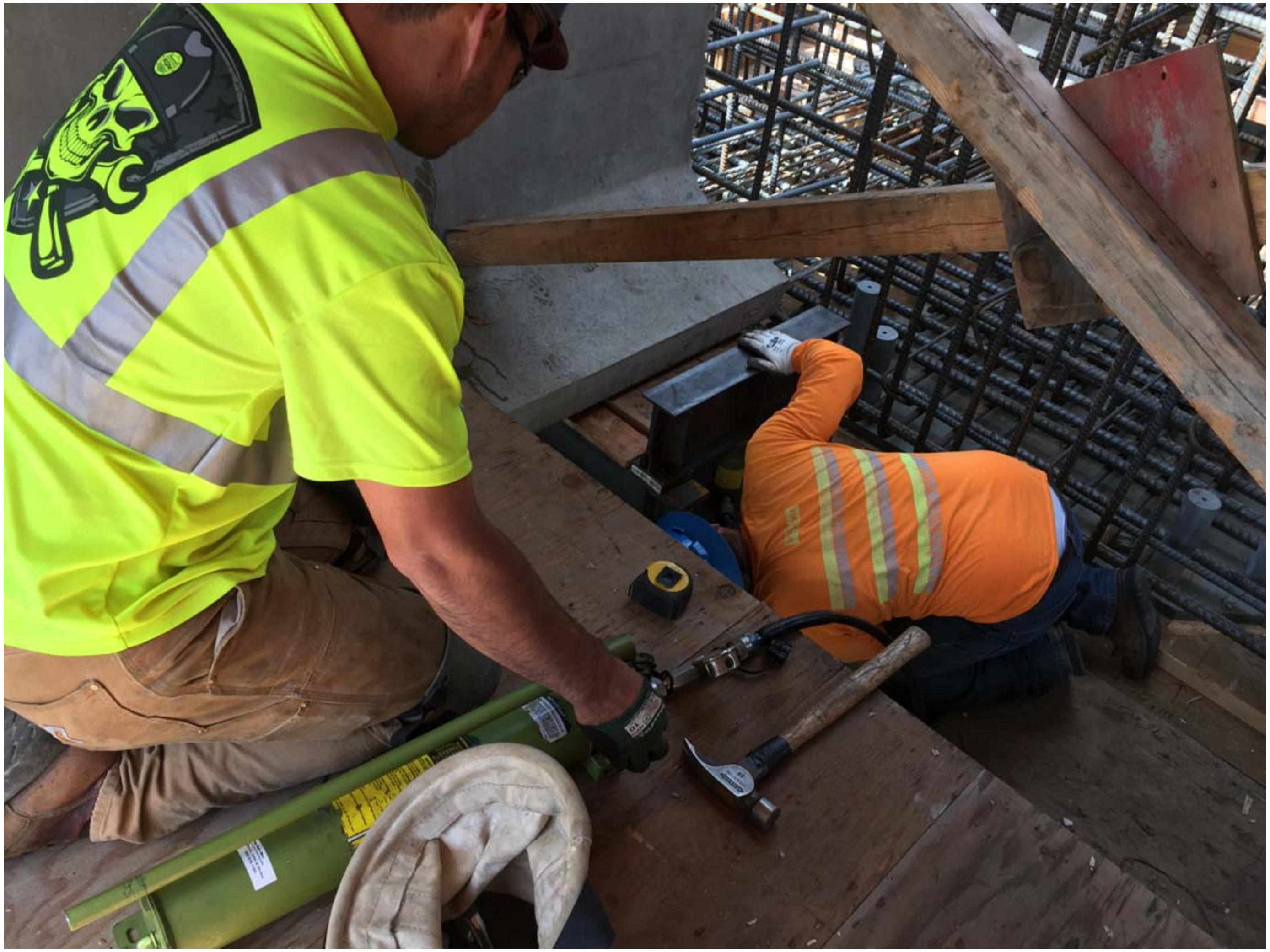
By Barge

HDR

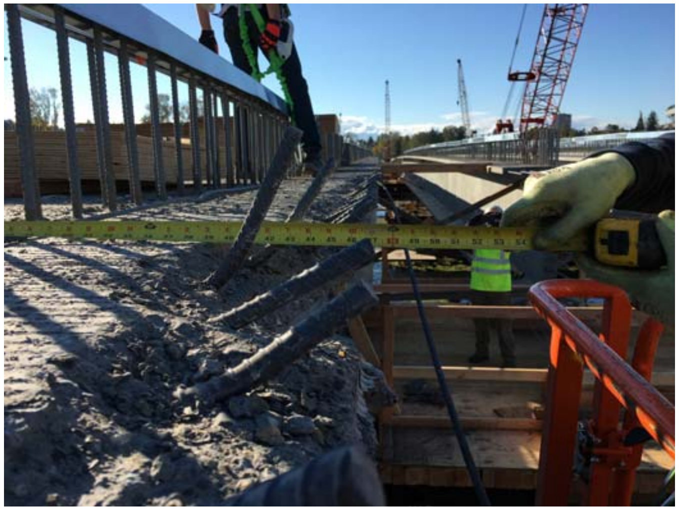
GIRDERS IN PLACE

GIRDER ADJUSTMENTS

Jacking to adjust vertical and horizontal position



GIRDER DAMAGE



PIER DIAPHRAGMS

Reinforcing Placement

BRIDGE

DECK

Field Bending Girder Stirrups and Sealing Formwork

BRIDGE

DECK

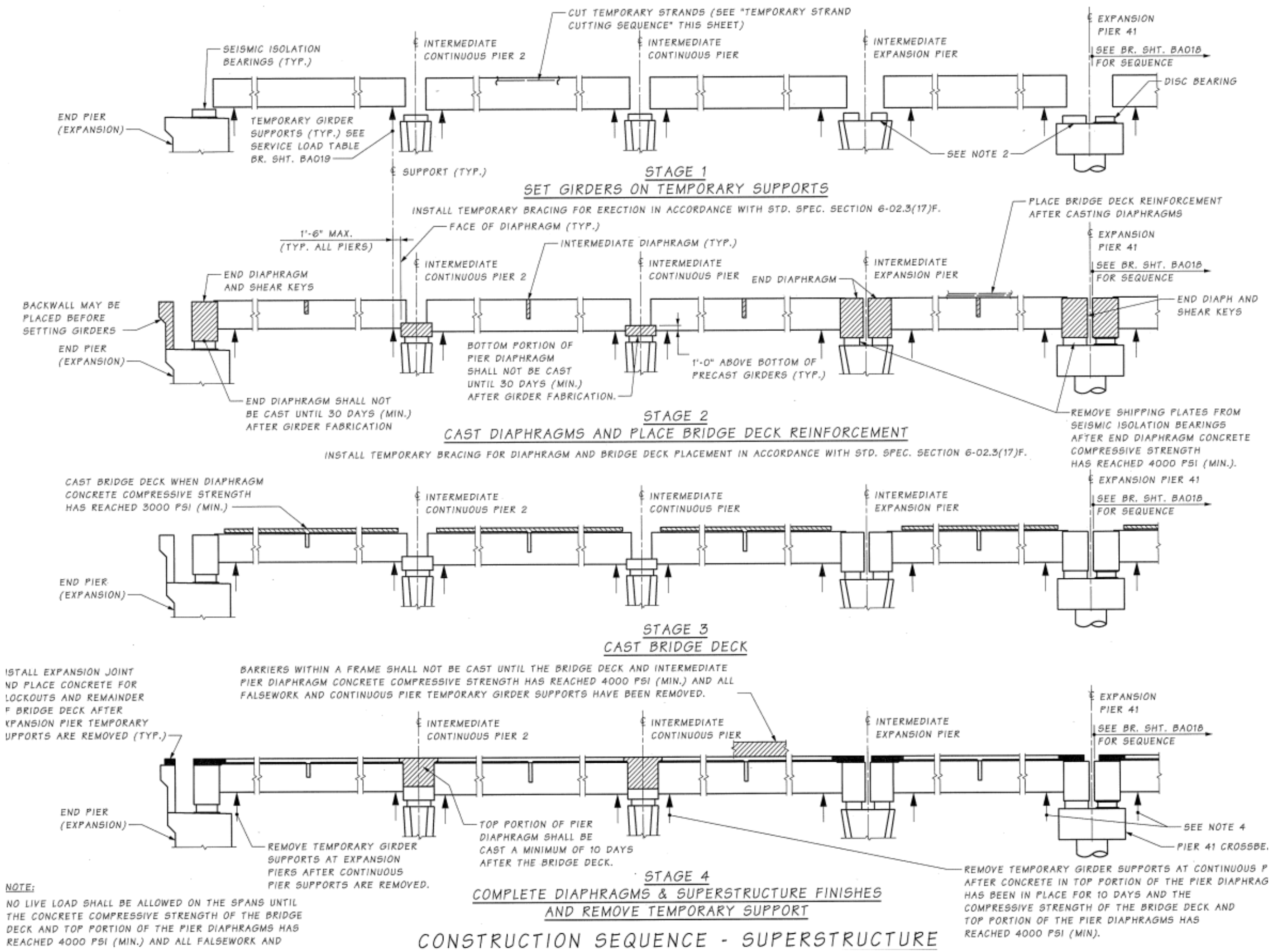
Deck Reinforcing in place

BRIDGE DECK

Deck Finishing and Curing

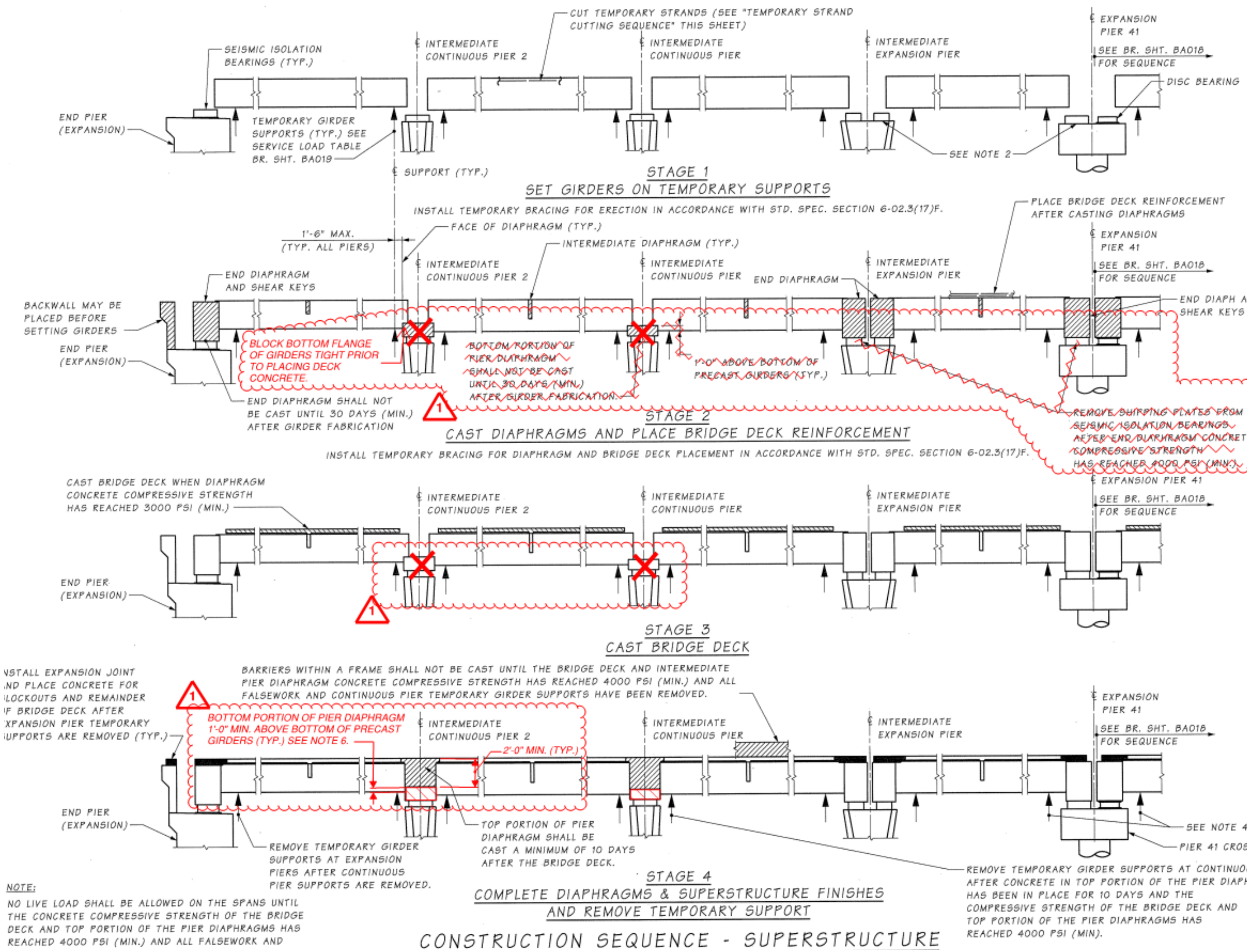
DIAPHRAGM CONCRETE

Construction Sequence



DIAPHRAGM CONCRETE

Construction Sequence Revisions



PIER

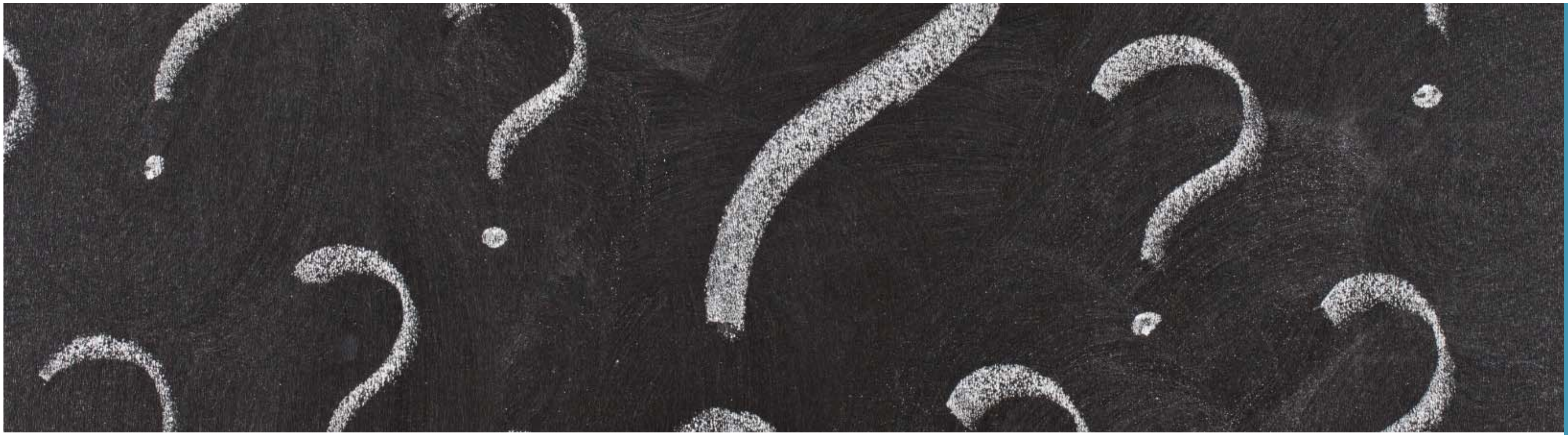
DIAPHRAGM

CONCRETE

FALSEWORK RELEASE

PROGRESS UPDATE

- All Major Structural Elements Complete
- Finalizing Utility Systems, Ped. Railing, Painting, and Misc.
- Bridge Opened to Traffic on August 25, 2017
- Bridge Complete in Fall 2017



QUESTIONS?

Web Site:

www.wsdot.wa.gov/projects/SR520Bridge