Western Bridge Engineer Seminar

Accelerated Bridge Construction in Washington State

Jugesh Kapur
State Bridge and Structures Engineer

Bijan Khaleghi
State Bridge Design Engineer

Washington State Department of Transportation
Bridge and Structures Office

Washington State Department of Transportation

WBES, Sacramento CA, September 22-24 2009

PRESENTATION OUTLINE

- Accelerated Bridge Construction
- Precast Concrete Bridges
  - Precast Superstructure
  - Precast Substructure
- Seismic Connection Design/Detail
- ABC – HFL Projects

BRIDGE DESIGN SPECIFICATIONS

Effective 2008 - LRFD SEISMIC GUIDE

"Displacement-based Seismic Provisions"

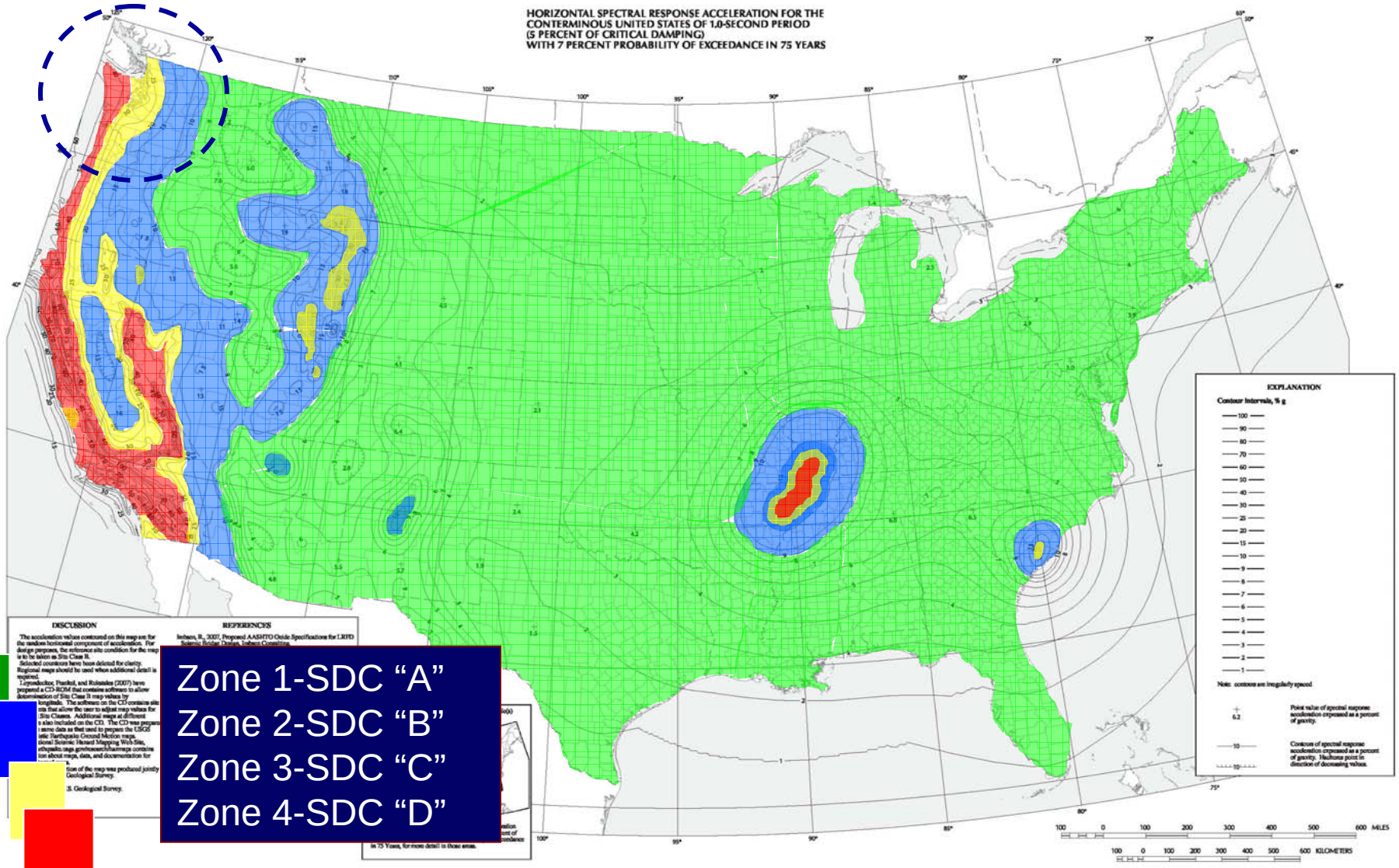
Life Safety Performance Criteria During an EQ with 7% Probability of Exceedance in 75 years =1000 Years Return Period

AND

WSDOT Design Policy

Limitations on: ERS, ERE, Design and Details

Seismic Design Category (zone)
(1000 Year Return Period)



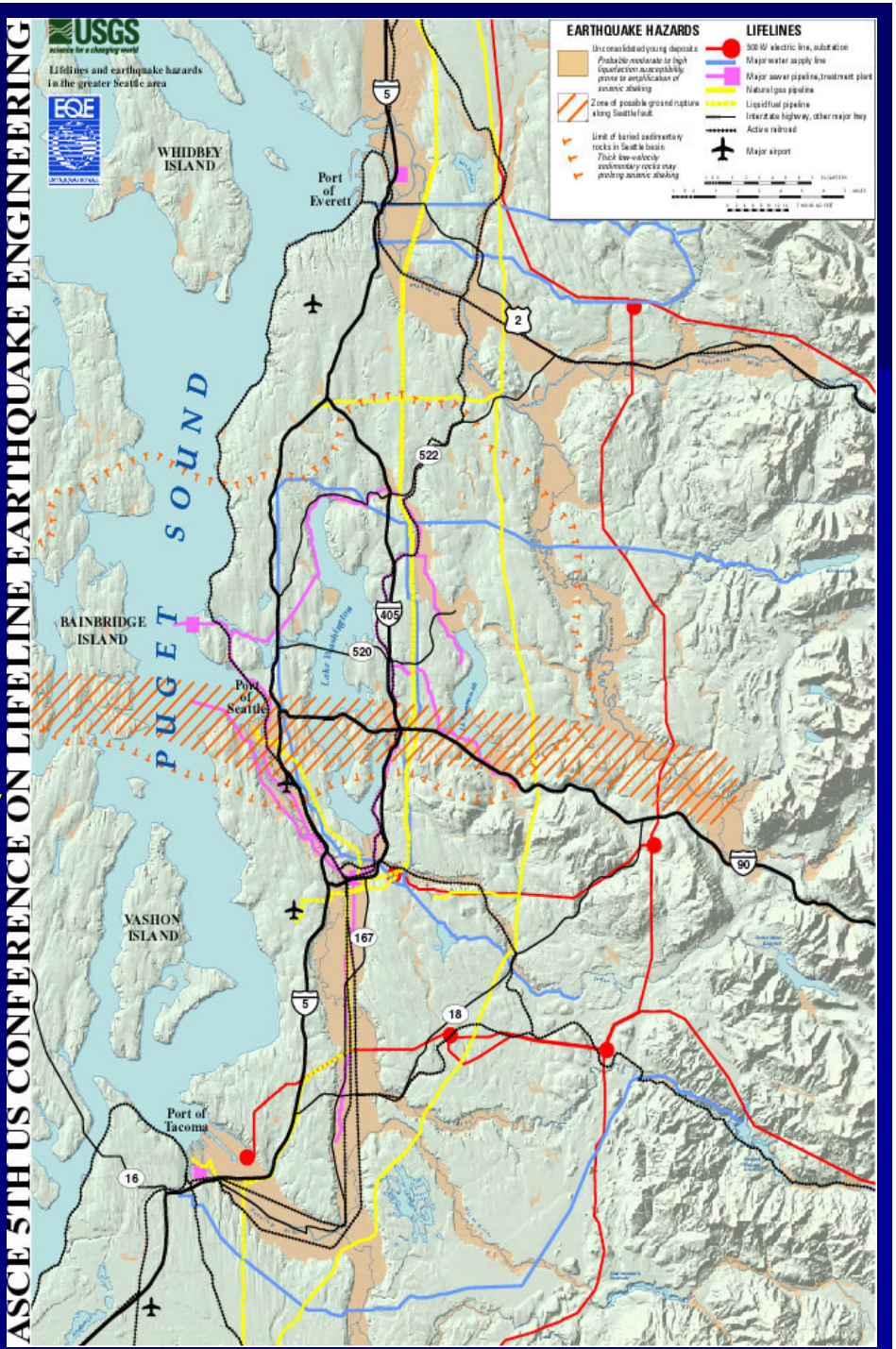
Western Washington:

- Liquefaction

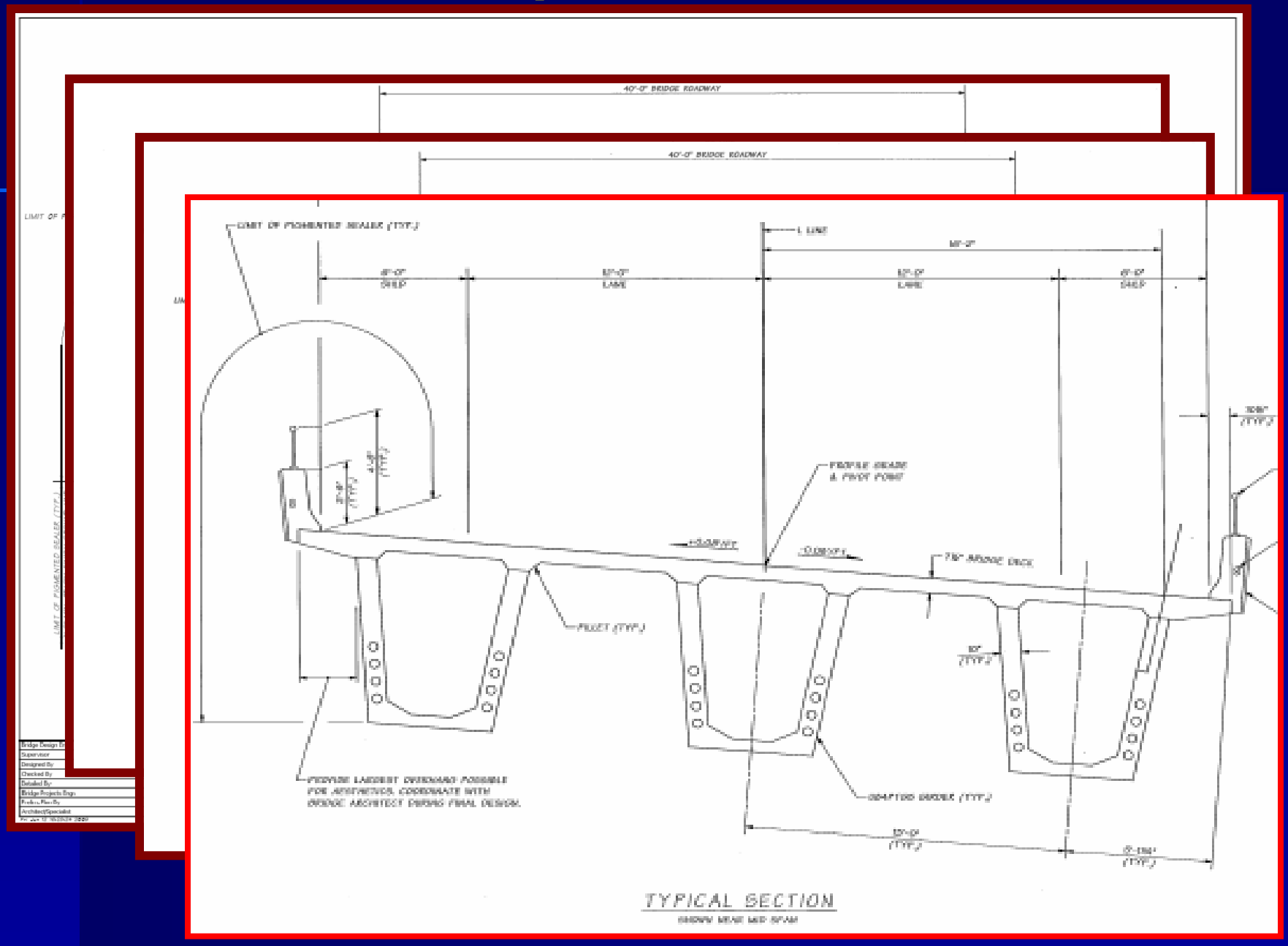
New Bridges

Bridge Widenings

(WSDOT Executive Policy for Bridge Widenings in Liquefiable Sites



Precast Superstructure - ABC

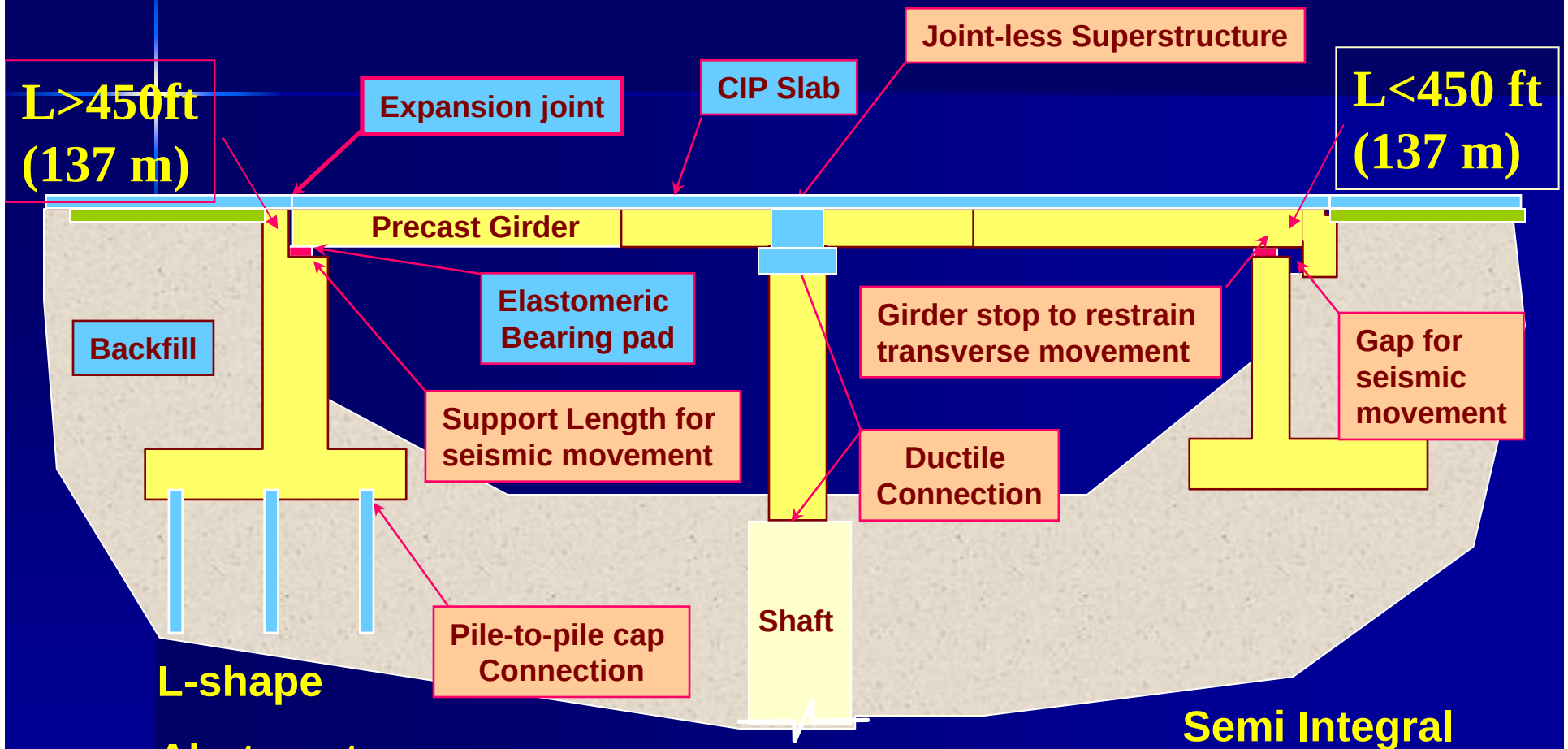


Accelerated Bridge Construction Project

5 Span PS Girder Superstructure Replacement – Hood Canal Bidge

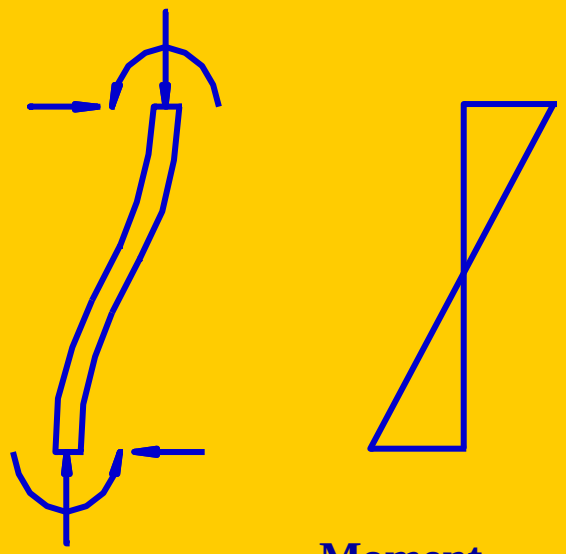
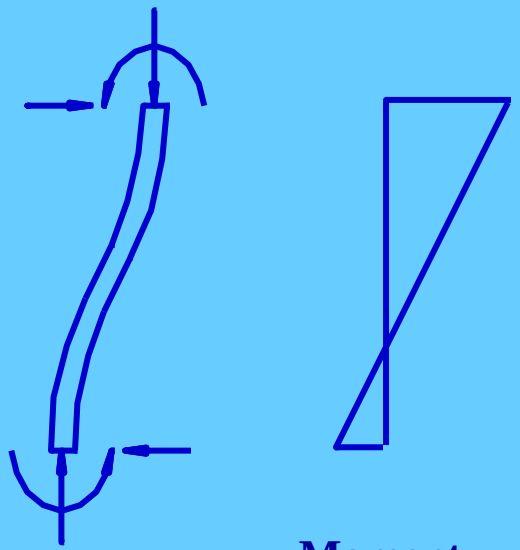
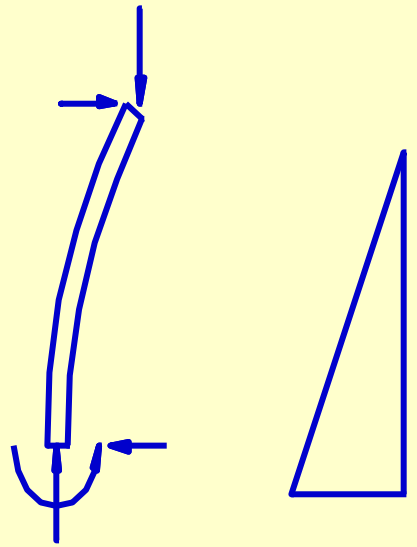
WSDOT ABC Website: http://www.wsdot.wa.gov/eesc/bridge/ABC/

Seismic Design of Concrete Bridges

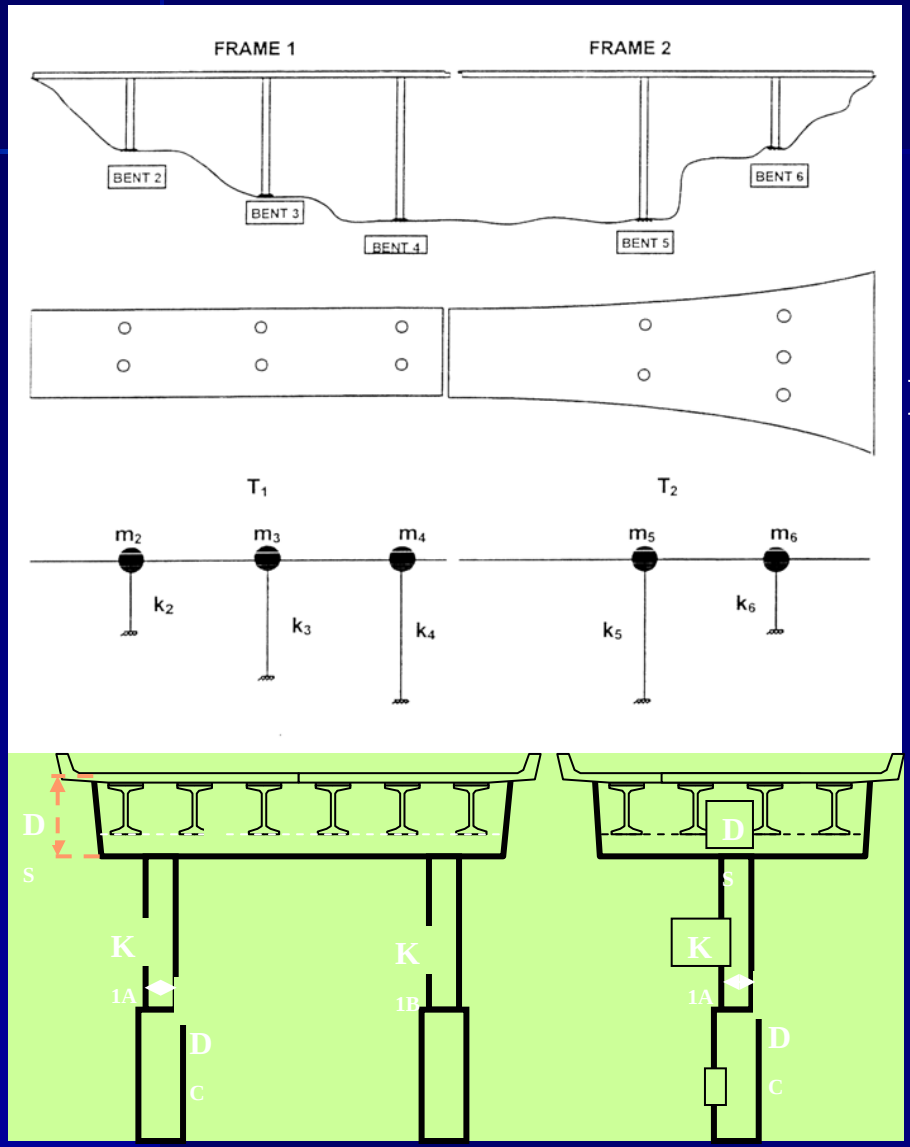


Elevation

Connection at Intermediate Piers
Seismic Design of Concrete Bridges

High Seismic Zone Fixed Connection	High Seismic Zone Reduced Fixity	Low Seismic Zone Hinge Connection
 Shape Moment Diagram	 Shape Moment Diagram	 Shape Moment Diagram

BALANCING STIFFNESS



Constant Width Frames

$$\frac{k_i^e}{k_j^e} \geq 0.5$$

Variable Width Frames

$$\frac{k_i^e m_j}{k_j^e m_i} \geq 0.5$$

Between Two Column Within A Bents

$$\frac{k_i^e}{k_j^e} \geq 0.75$$

$$\frac{k_i^e m_j}{k_j^e m_i} \geq 0.75$$

Between Adjacent Bents Within A Frame

$$\frac{Ti}{Tj} \geq 0.7$$

Ratio of Fundamental Period of Vibration Between Adjacent Frames

Extended Strands for Positive Seismic Moment Capacity At Intermediate Piers Of Prestressed Girder Bridges

Positive Seismic Moment Capacity

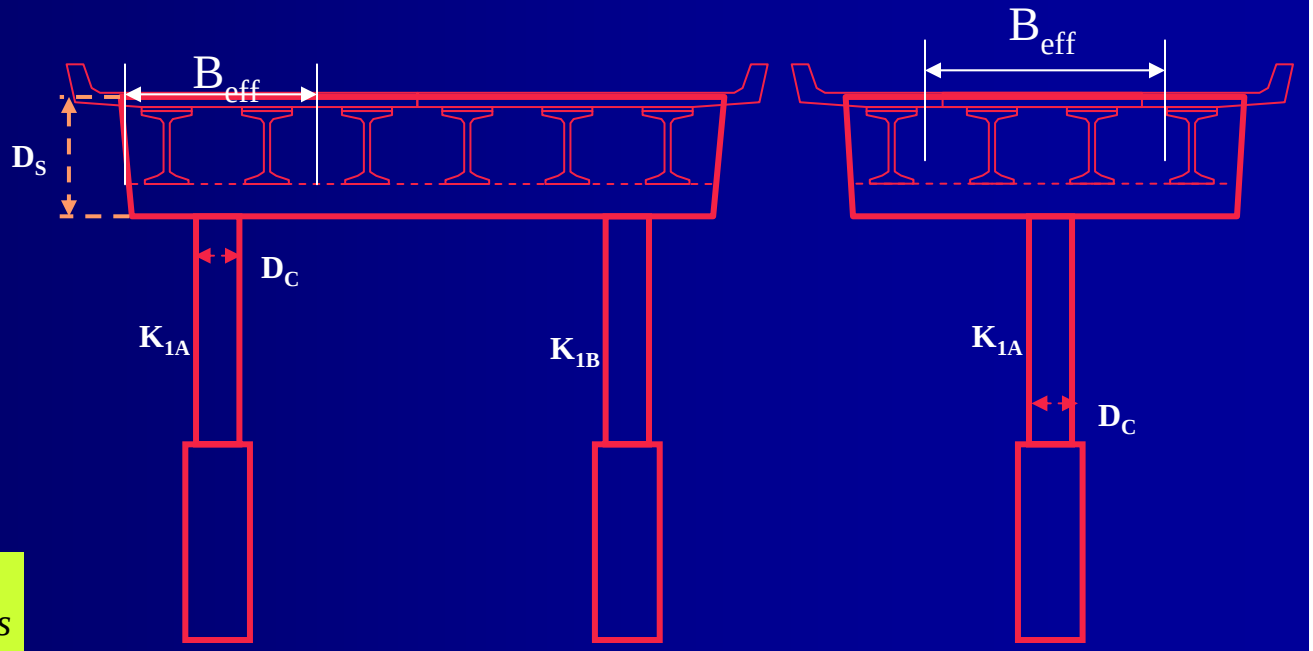
$$M_{po}^{CG} = M_{po}^{top} + \frac{\left(M_{po}^{top} + M_{po}^{Base}\right)}{L_c} h$$

UC San Diego (Holombo 2000)

$$M_{sei}^{Int} = \frac{2M_{po}^{CG}}{3N_g^{int}}$$

$$M_{sei}^{Ext} = \frac{M_{po}^{CG}}{3N_g^{ext}}$$

$$B_{eff} = D_c + D_s$$



Extended Strands:

$$N_{ps} = 12\left[M_{sei} \bullet K - M_{SIDL}\right] \bullet \frac{1}{0.9\phi A_{ps} f_{py} d}$$

PRECAST COLUMN ON SPREAD FOOTING

Monolithic (Ductile) Connection

Bellevue Direct Access Project

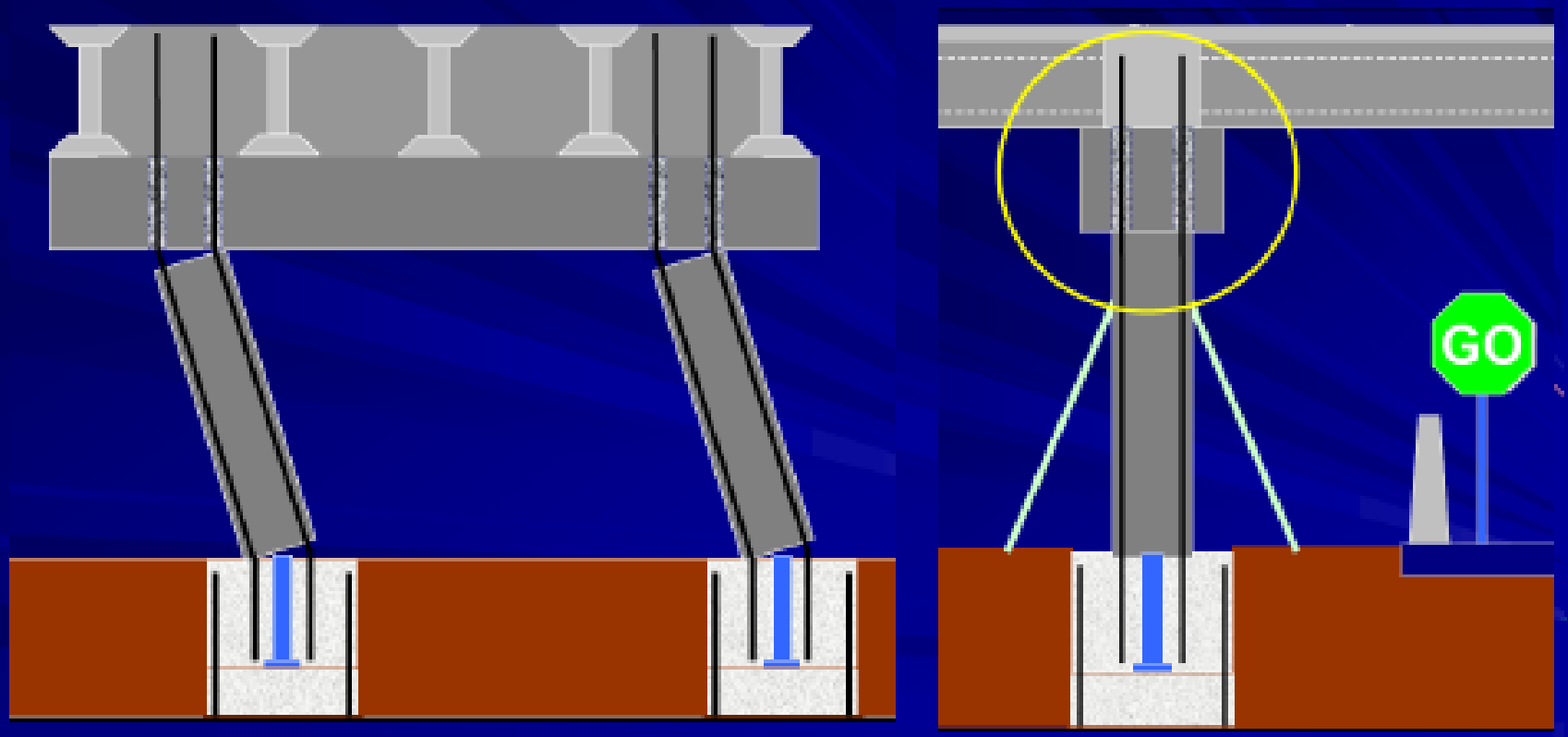
SR 16 Union Ave. Bridge

UW Project:

Design of Precast Concrete Piers for Rapid Bridge Construction In seismic Regions

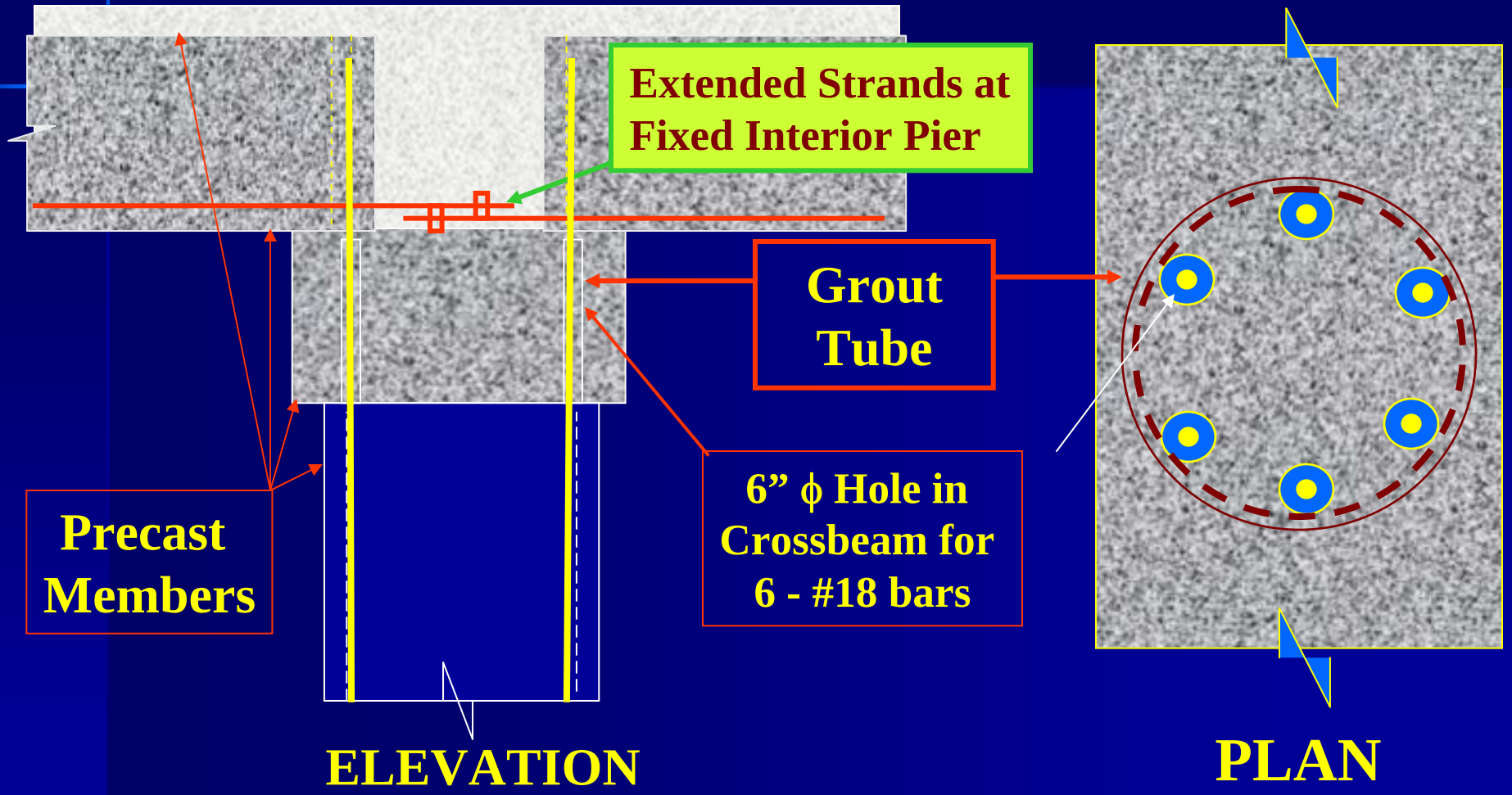
Phase I: Analytical

Phase II: Experimental



PRECAST SUBSTRUCTURE RESEARCH AT UW

Precast Substructure Research UW

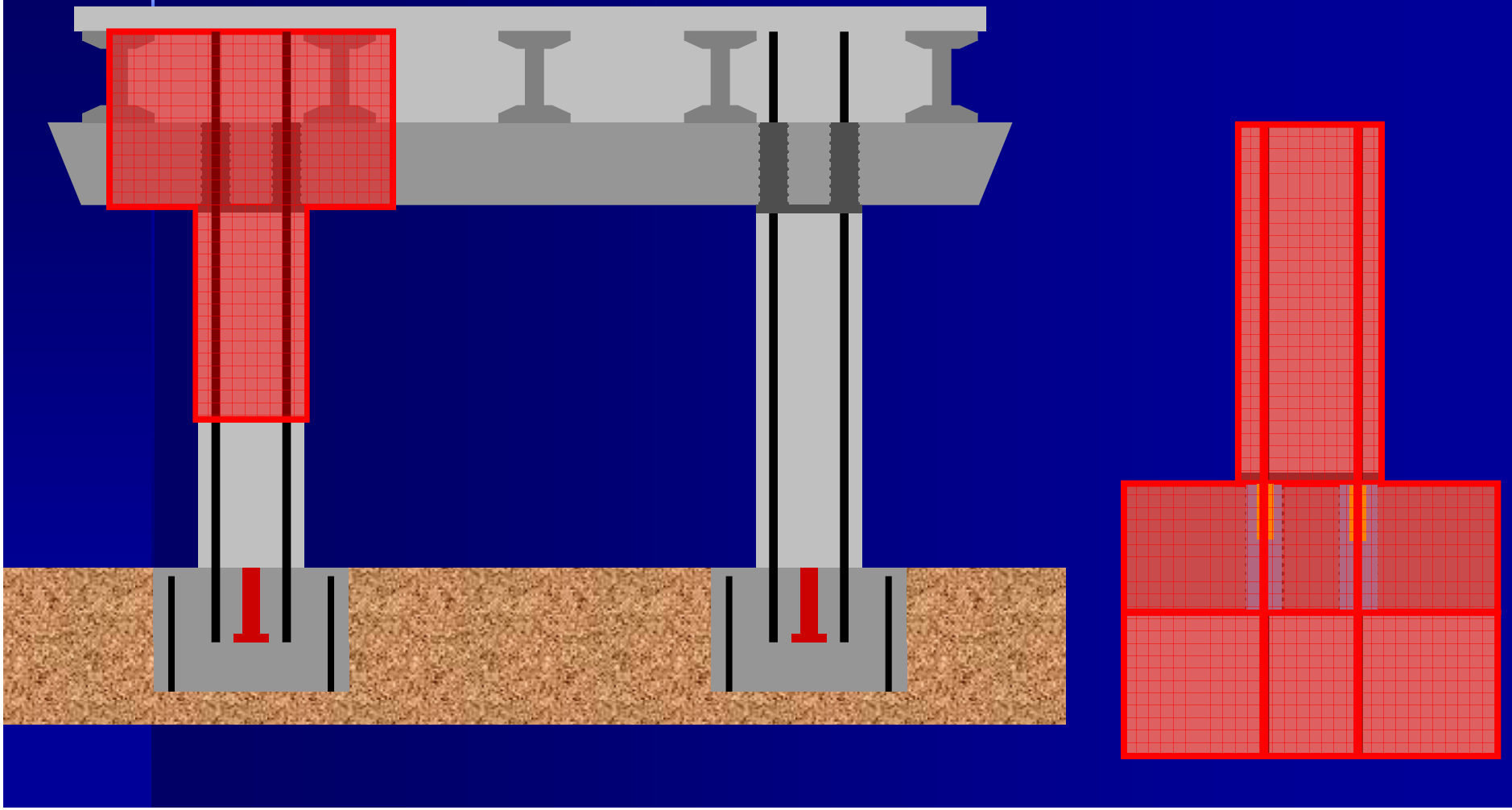


Seismic Performance

WARD 648.2 Rapidly Constructible Large-Bar Precast Bridge-Bent Seismic Connection

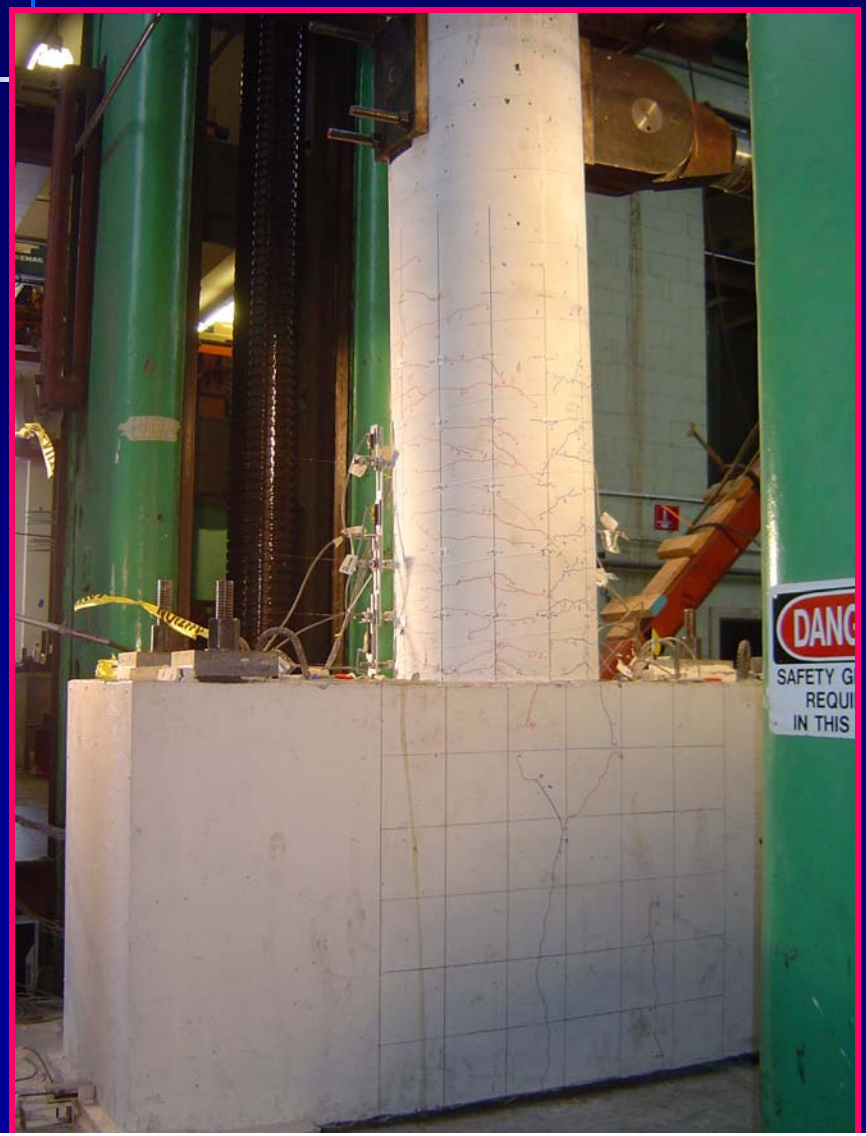
Seismic Performance – UW Test

WARD 648.2 Rapidly Constructible Large-Bar Precast Bridge-Bent Seismic Connection



PRECAST SUBSTRUCTURE RESEARCH AT UW

Phase II: Beam-column assembly: (Scaled tests)



Precast Bent cap
SR 202 / SR 520

Tolerances - Tack Weld

Duct Template

Spirals

Precast Bent cap
SR 202 / SR 520

$1^{1/2}$ Hours +/-
Bent Cap Erection

FHWA - Highways for LIFE (IBRD)
Fully Precast Bridge in Seismic Regions

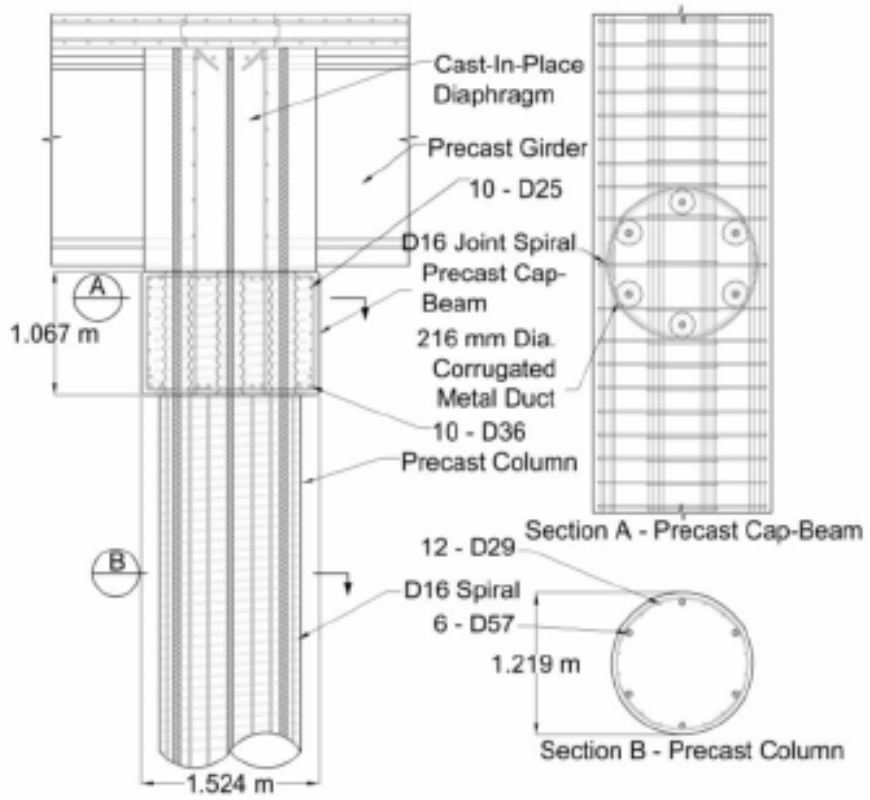


Figure 1. Typical Implementation of Product Concept

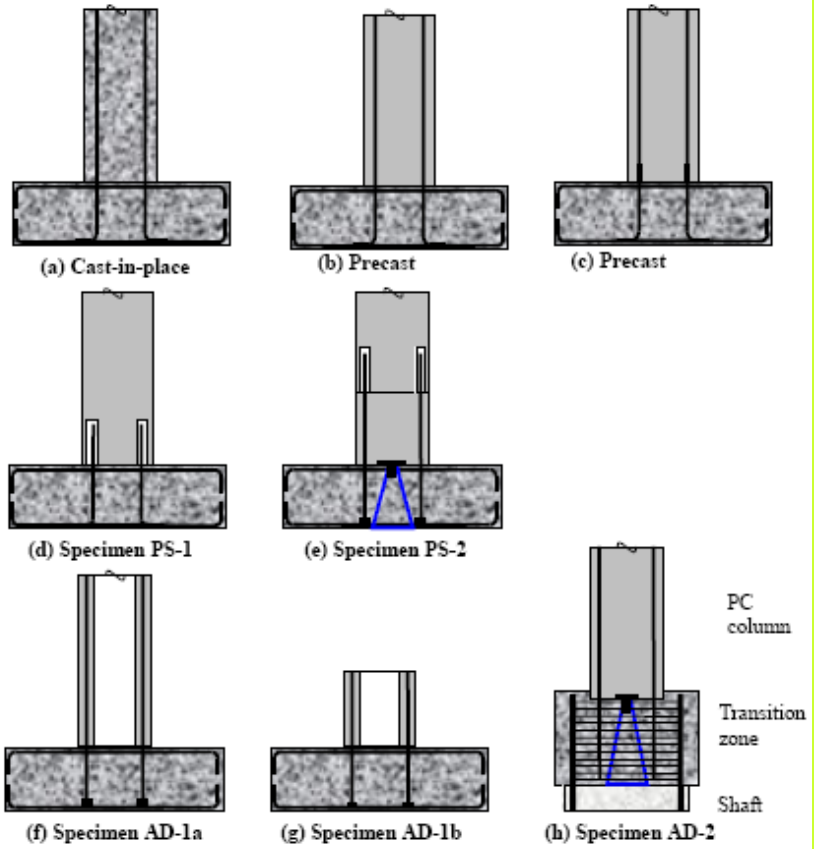
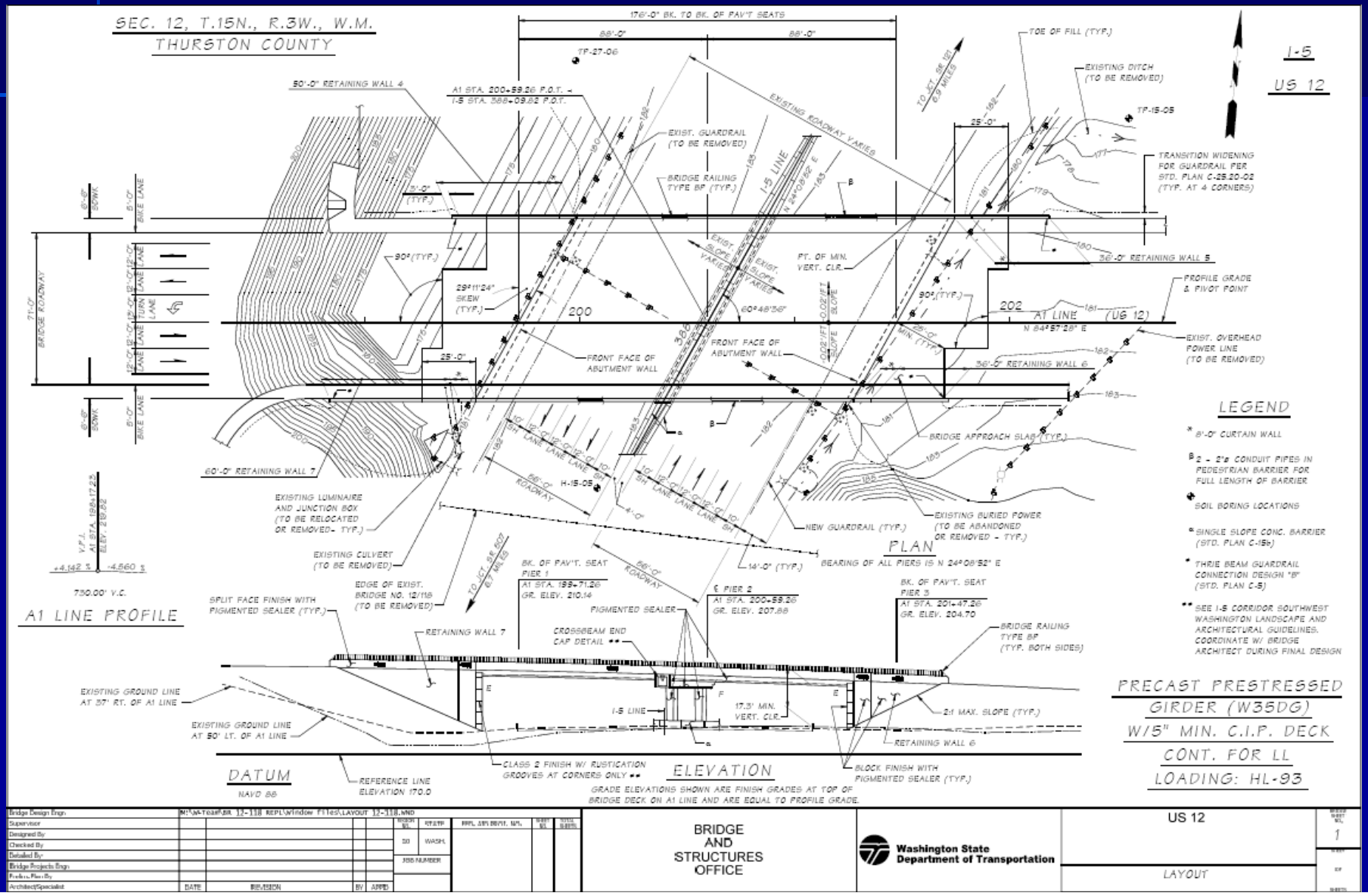


Figure 3. Test Specimens

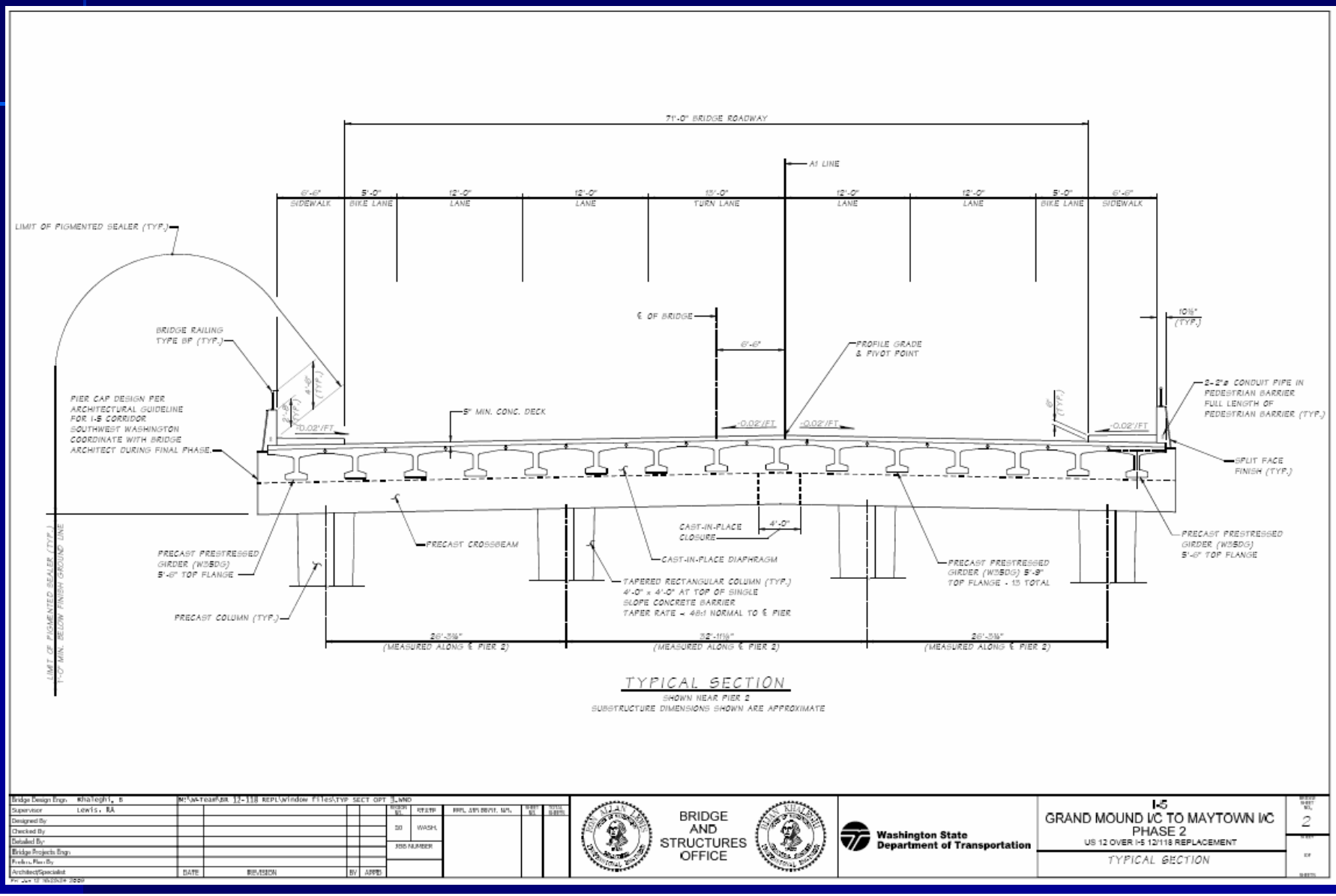
FHWA Highways for LIFE
Fully Precast Bridge in Seismic Regions

Figure 5. Existing SR 12 Overcrossing of I-5 to be Replaced

FHWA Highways for LIFE
Fully Precast Bridge in Seismic Regions



FHWA Highways for LIFE (IBRD)
Fully Precast Bridge in Seismic Regions



TYPICAL SECTION

SHOWN NEAR PIER 2

SUBSTRUCTURE DIMENSIONS SHOWN ARE APPROXIMATE

Bridge Design Engr: KhaTeight, B
Supervisor: LEWIS, RA
Designed By
Checked By
Detailed By
Bridge Projects Engr:
Prelim. Plan By
Architect/Specialist
DATE | REVISION | BY | APPD

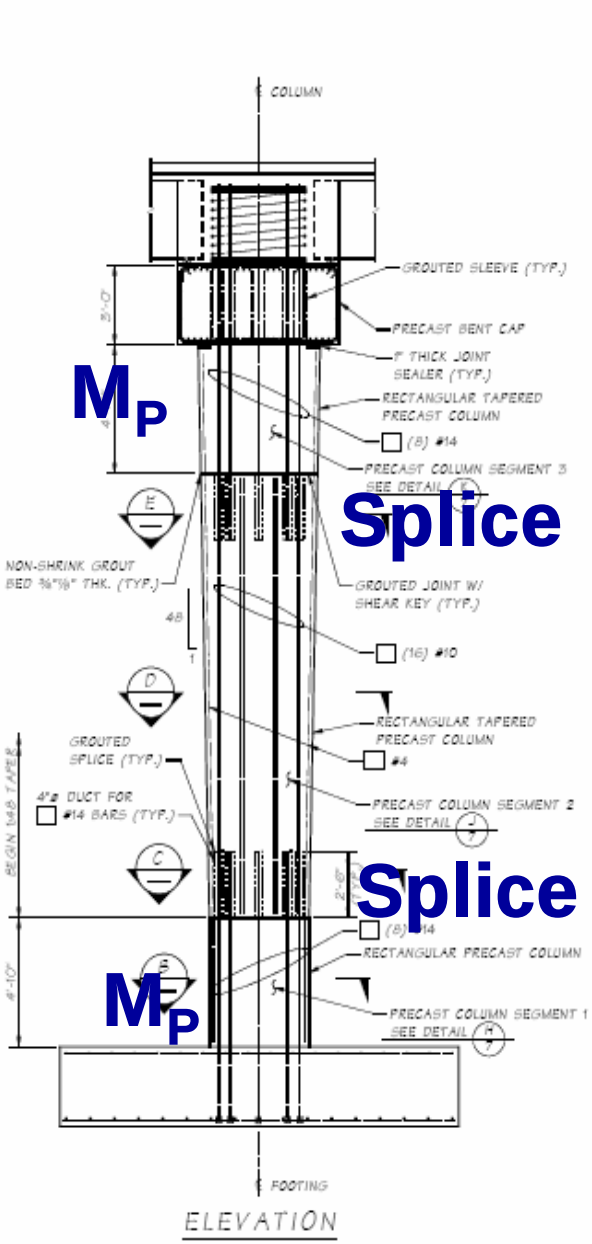
BRIDGE AND STRUCTURES OFFICE

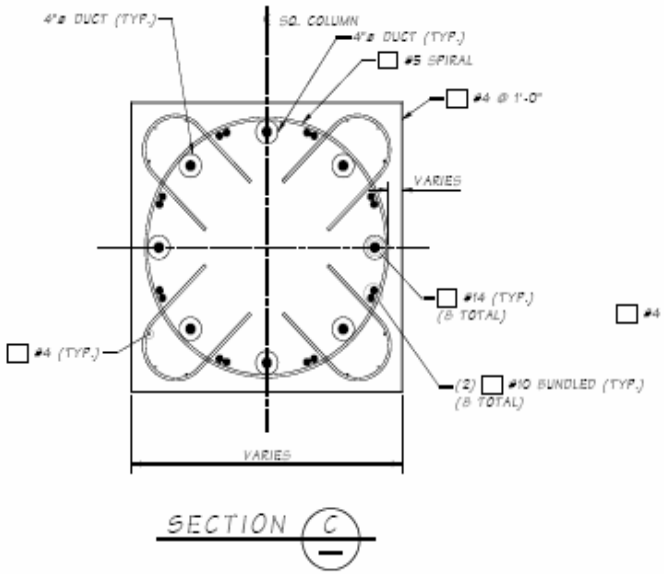
Washington State Department of Transportation

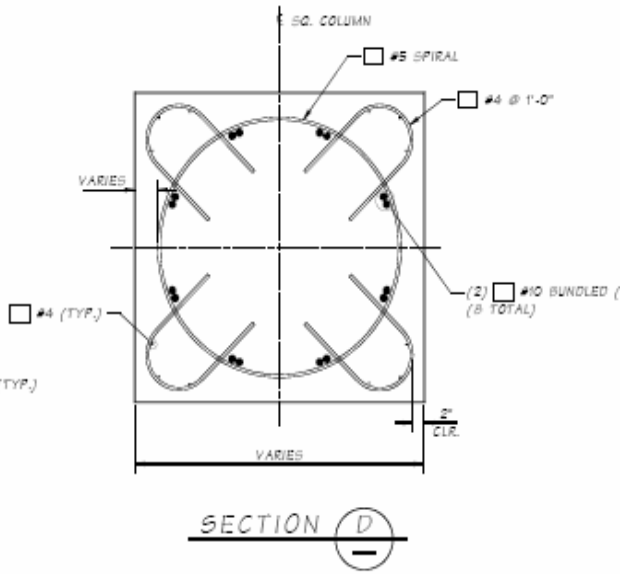
I-5
GRAND MOUND I/C TO MAYTOWN I/C
PHASE 2
US 12 OVER I-5 12/118 REPLACEMENT
TYPICAL SECTION

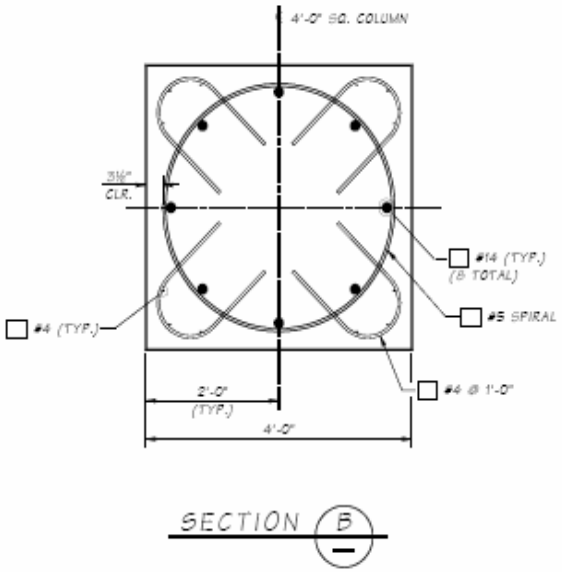
2

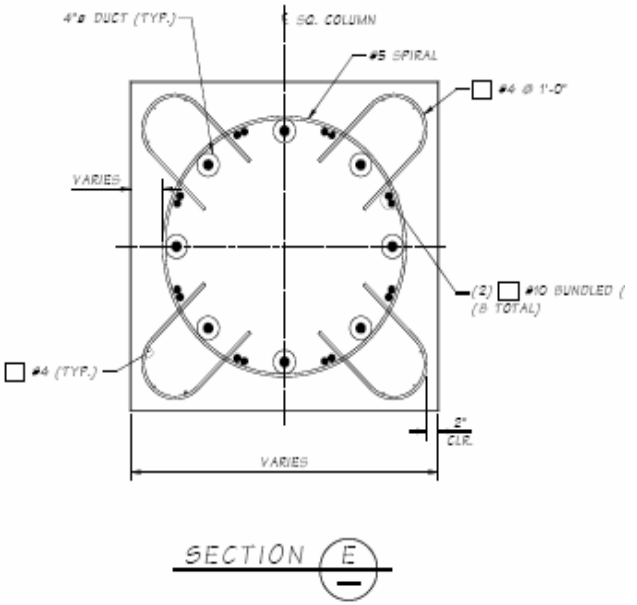
HFL Fully Precast Bridge Bents for Seismic Regions

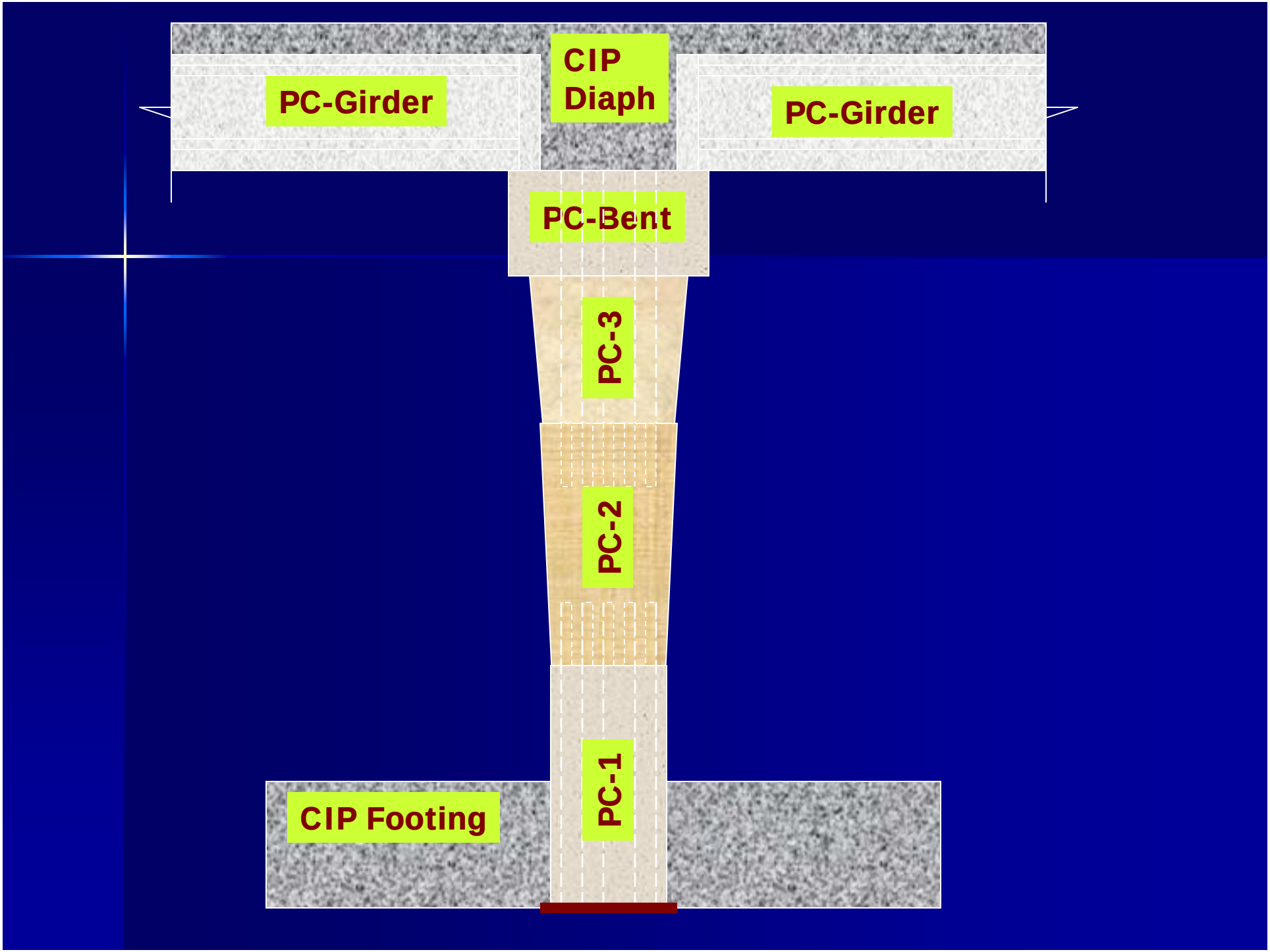






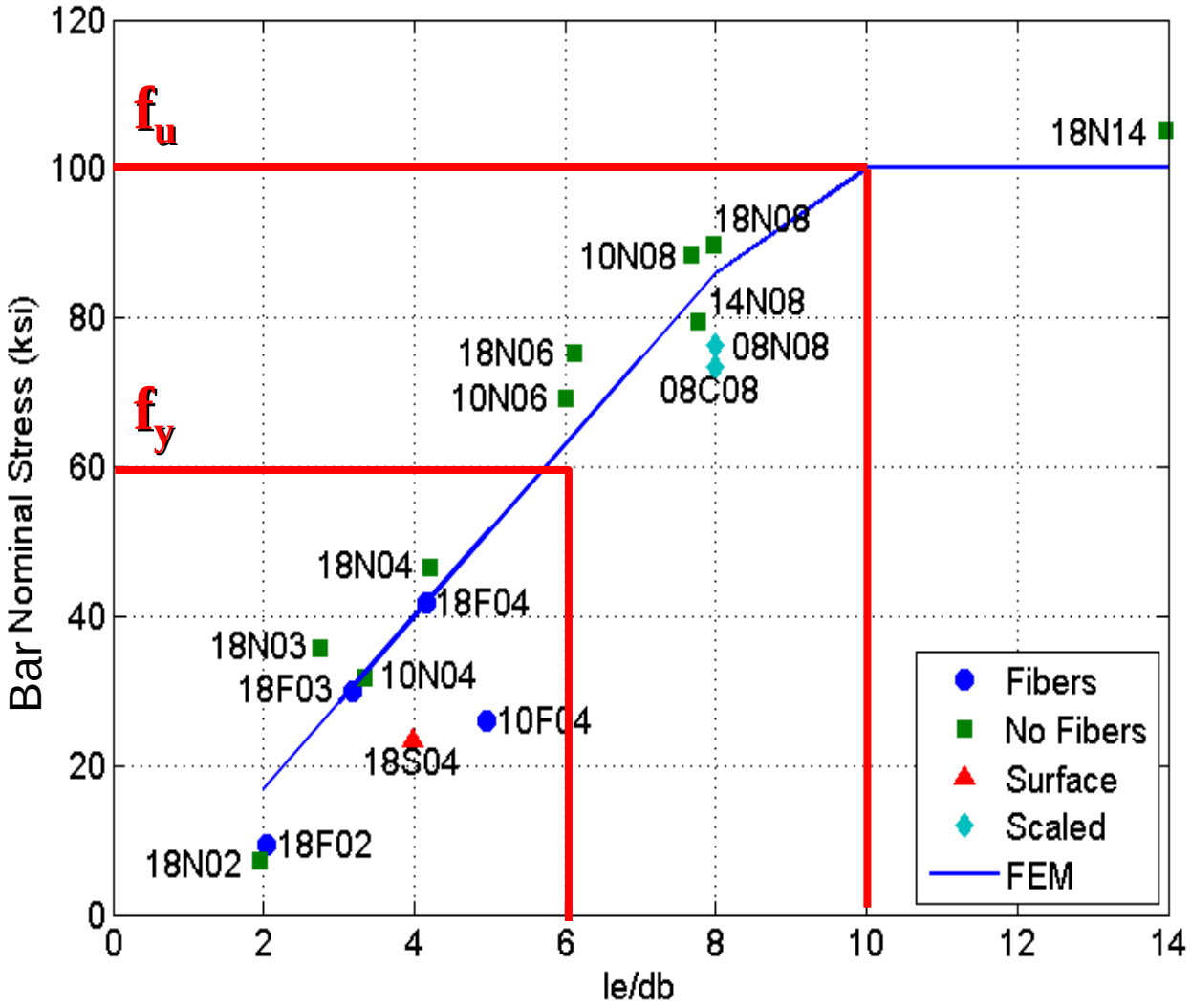





CIP
Diaph
PC-Girder
PC-Girder
PC-Bent
PC-3
PC-2
PC-1
CIP Footing

Seismic Performance – UW Test

WARD 648.2 Rapidly Constructible Large-Bar Precast Bridge-Bent Seismic Connection



Full-Scale Anchorage Tests

Yield in 6 db

Fracture in 14 db

Enough length for debonding and anchorage

Recommended Duct size and embedment length for Grouted Sleeves

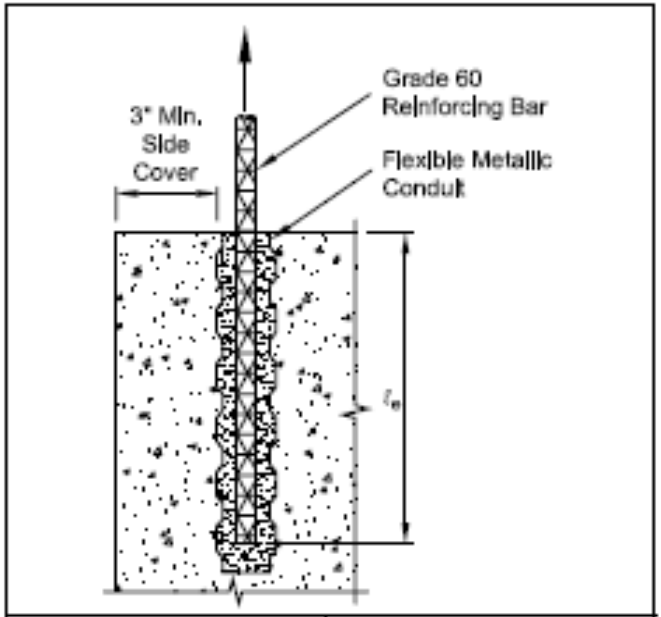
Precast Substructure Elements

UDOT - Specification 03131S

Bar Size	Outside Diameter (inches)	Length of Sleeve (inches)
4	2.625	14.125
5	3.000	14.125
6	3.000	14.125
7	3.000	18.75
8	3.500	18.75
9	3.500	18.75
10	3.500	23.5
11	4.000	23.5
14	4.000	28.375
18	4.500	39.625

PCI Figure 6.4.3.1

Figure 6.4.3.1 Anchorage in grouted conduit [25]



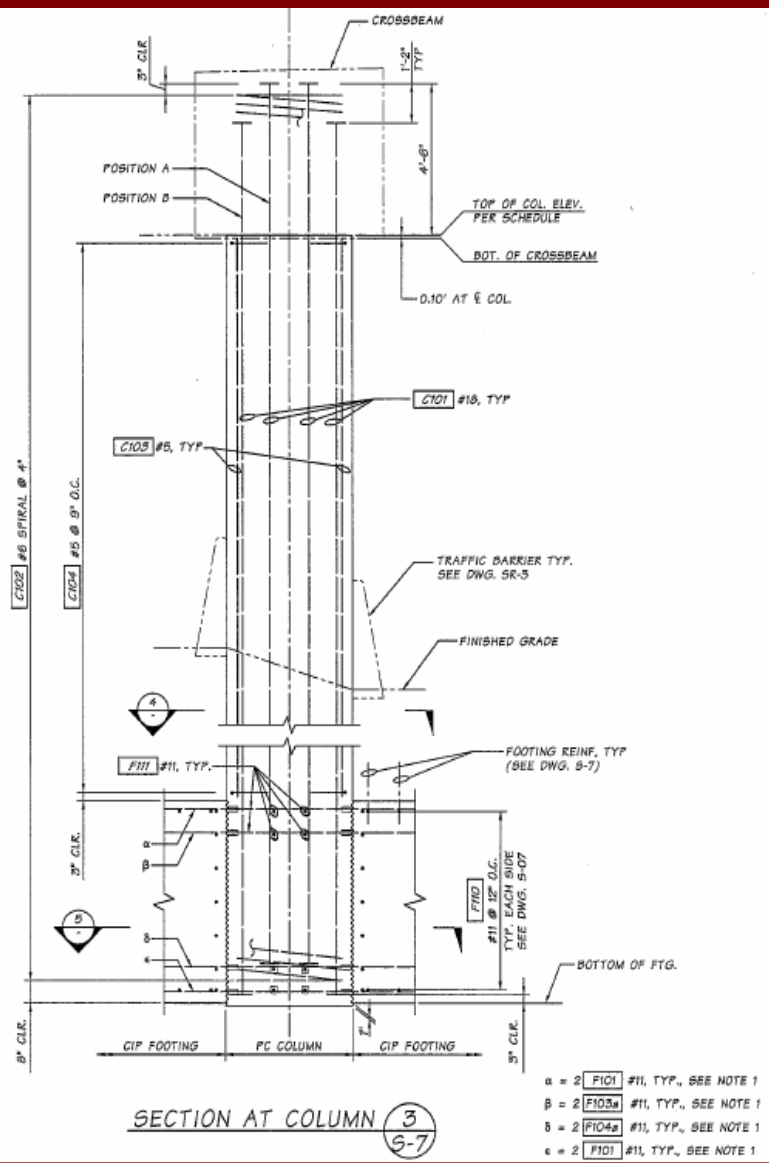
Bar Size	Bar embedment length, ℓ_e in.*
3	12
4	12
5	12
6	15
7	21
8	27

* For grout strengths higher than 5000 psi, multiply table values by $\sqrt{5000/f'_c}$.

WSDOT Recommended Duct Size And Embedment Length For Grouted Sleeves

Bar Size	Nominal Duct Size, in.	Embedment Length, in.	Embedment / Bar Diameter
#3	2	12	29
#4	2.5	15	27
#5	3	15	21
#6	3	15	18
#7	3	20	21
#8	3.5	20	18
#9	3.5	20	16
#10	3.5	25	18
#11	4	25	16
#14	4	30	16
#18	4.5	40	16

Continuous Bridge in Redmond WA



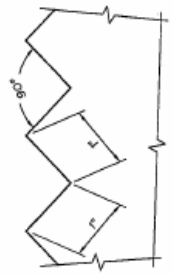
SECTION AT COLUMN 3 / S-7

α = 2 F101 #11, TYP., SEE NOTE 1
β = 2 F103α #11, TYP., SEE NOTE 1
δ = 2 F104α #11, TYP., SEE NOTE 1
ε = 2 F101 #11, TYP., SEE NOTE 1

COLUMN SCHEDULE		
COLUMN	COLUMN TOP ELEVATION	COLUMN ℄ BEARING
C2-1	354.52	N62°05'10"W
C2-2	354.44	N61°44'15"W
C2-3	354.37	N61°25'19"W
C2-4	354.28	N61°02'24"W
C2-5	354.19	N60°41'28"W
C2-6	354.10	N60°20'32"W
C2-7	354.00	N59°59'37"W
C2-8	353.90	N59°38'41"W
C2-9	353.79	N59°17'46"W
C2-10	353.67	N58°56'50"W
C2-11	353.55	N58°35'54"W
C2-12	353.43	N58°14'59"W
C2-13	353.30	N57°54'03"W
C2-14	353.16	N57°33'07"W

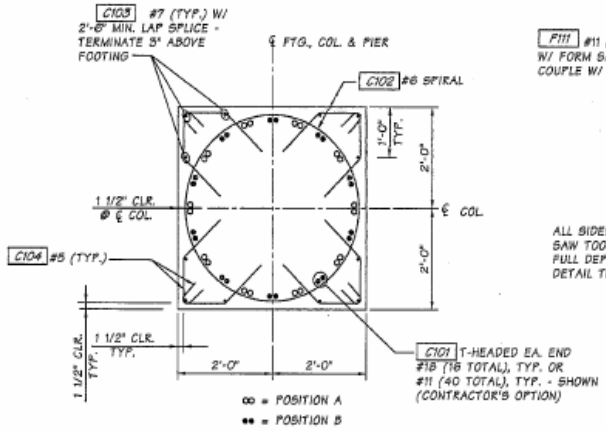
NOTE:

1. TWO F101 TOP & BOTTOM, F103α & F104α BARS SHALL BE MODIFIED @ EACH COLUMN @ 6" EITHER SIDE OF THE COLUMN CENTERLINE TO THREAD INTO THE COLUMN F111 #11 FORM SAVERS.

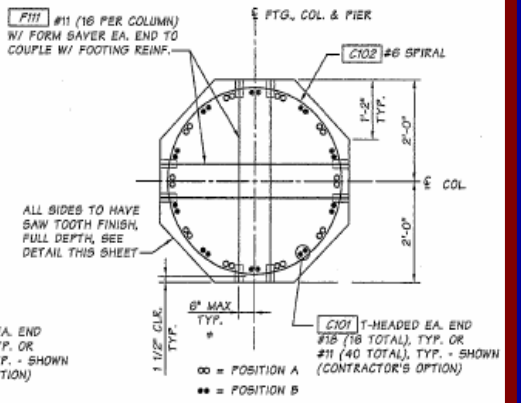


SAWTOOTH DETAILS

SAWTOOTH TO BE USED FULL DEPTH OF FOOTING ON ALL SIDES OF THE COLUMN



COLUMN SECTION 4 / -



COLUMN SECTION 5 / -

* ADJUST TO FIT BETWEEN VERTICAL COLUMN REINF.

Column – Shaft Connection

- **Connection Design of Column-Oversized Shafts Based On Expected Nominal Flexural Capacity at 1.00 Times The Overstrength Moment, Mpo of Column.**
- **Column longitudinal reinforcement into enlarged shafts in a staggered manner with the minimum embedment lengths of 2*Dc,max* and 3*Dc,max*,**

(WSU).

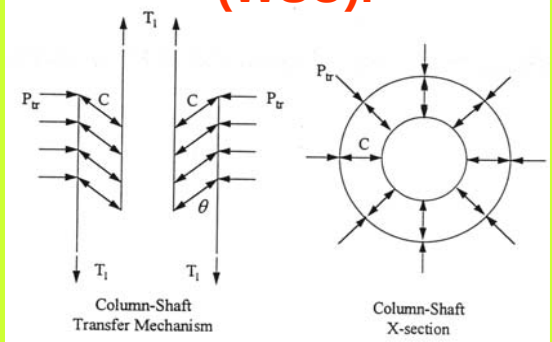


Figure 3 Proposed Three-Dimensional Behavioral Model for Noncontact Lap Splices.

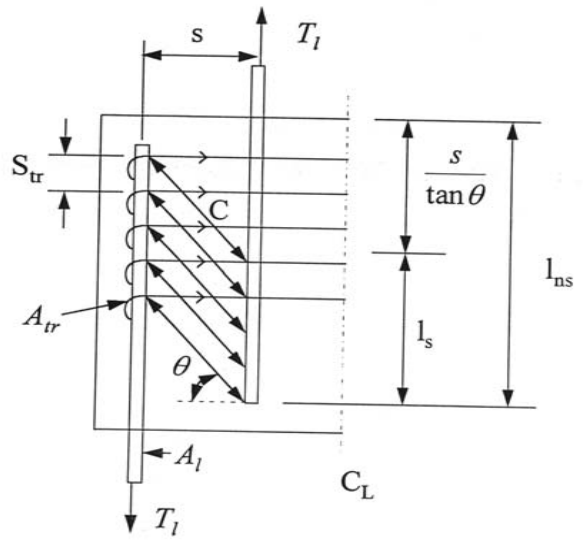
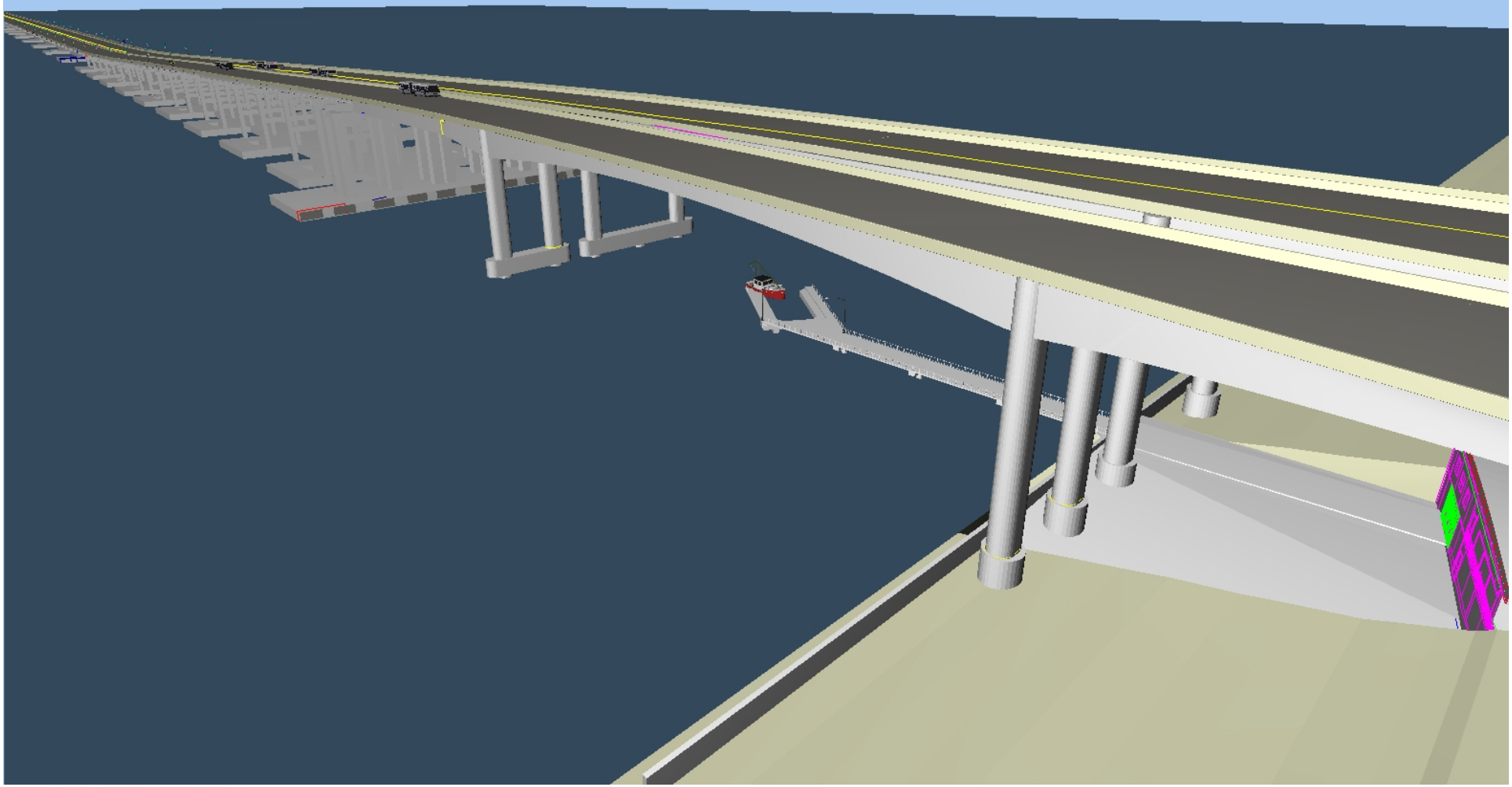


Figure 2 Proposed Two-Dimensional Behavioral Model for Noncontact Lap Splices.

Column Dia	CIP Joint
4 ft	12 ft
5 ft	15 ft
6 ft	18 ft

$$S_{tr} = \frac{2\pi A_{sp} f_{ytr} l_s}{k A_l f_{ul}}$$

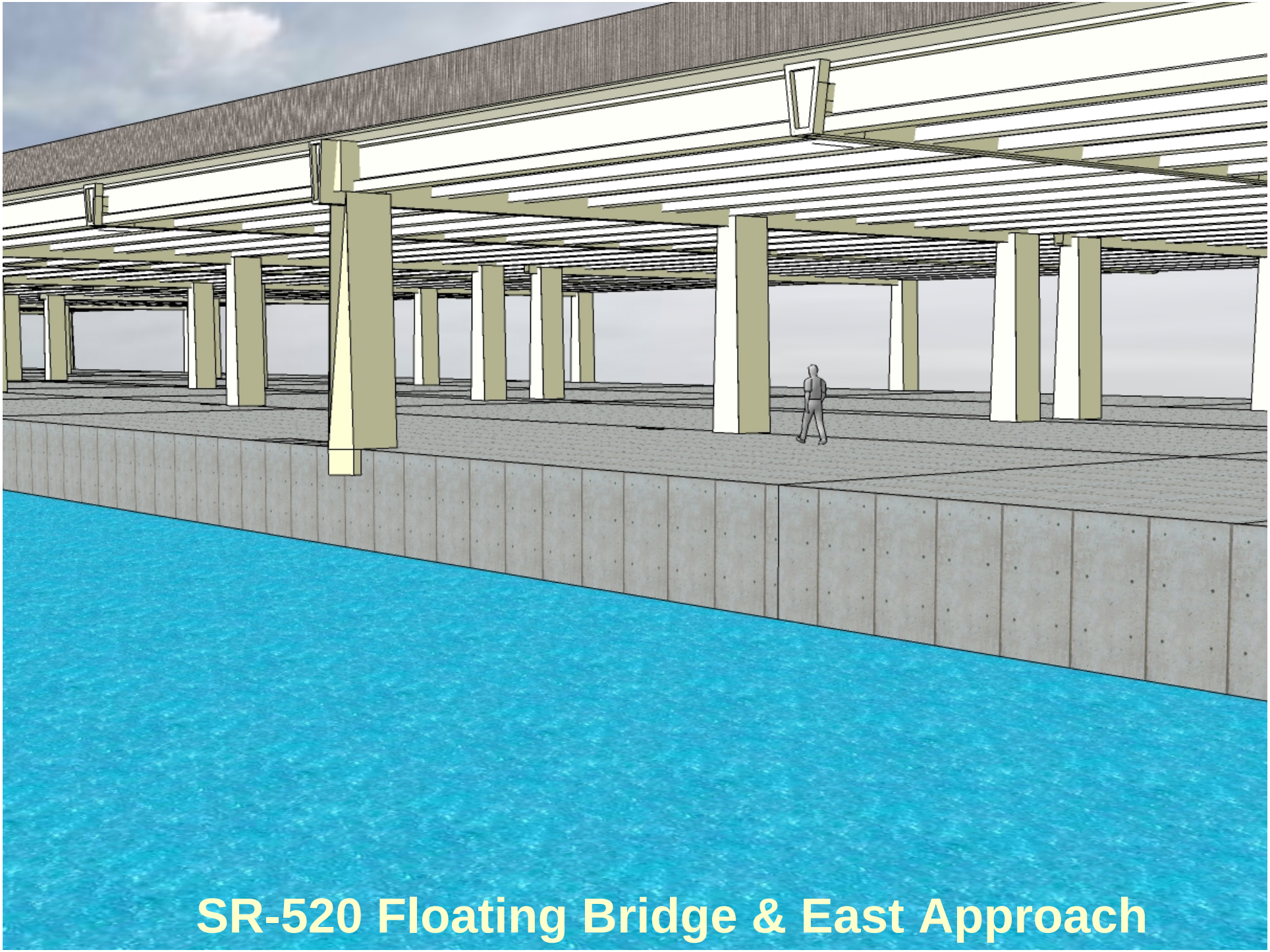
SR-520 Floating Bridge & East Approach



Washington State Department of Transportation

SR 520 Pontoon Construction Project

STATE ROUTE 520


SR-520 Floating Bridge & East Approach

AWV Bridge Replacement – Bored Tunnel

for Roadway Structure

Accelerated Bridge Construction (ABC)

- Strategic Plan
- ABC Advisory Committee
- ABC Website
- ABC Decision-Making Matrix
- ABC Impact Quantification
- ABC Chapter for WSDOT BDM
  - Design Criteria
  - Design Examples
  - STD Details - Connections

WSDOT Strategic Plan for Accelerated Bridge Construction (ABC)

WSDOT ABC Website

Washington State Department of Transportation

News | Search | Contact WSDOT | WSDOT Home

TRAFFIC & ROADS | PROJECTS | BUSINESS | ENVIRONMENTAL | MAPS & DATA

Bridge Office — Accelerated Bridge Construction

WSDOT BRIDGE
- Bridge Home
- Bridge Architect
- Bridge Design Manual
- Engineering Software
- Bridge Standard Drawings
- Bridge Design Schedule
- Bridge Preservation Program
- Contract Submittal Log
- Light and Signal Standards
- Employment
- Contact Us

INDUSTRY ACTIVITIES
- WSDOT/ACEC Structures Team
- Accelerated Bridge Construction

BRIDGE INFORMATION
- Bridge Engineering Information System

ADMINISTRATION
- Login

BRIDGE LINKS
- WSDOT Standard Plans
- Bridge List (PDF 7MB)
- Posted/Restricted Bridge List
- Historic Bridges
- Bridge Research
- Highway and Local Programs Bridge Office
- Environmental

Accelerated Bridge Construction Resources

Reports

- WSDOT ABC Strategic Plan (draft)
- FHWA Seismic ABC Workshop Report
- ABC Seismic Connections - TRB Research Proposal (Oct 15, 2008)
- Design of Precast Concrte Piers for Rapid Bridge Construction in Seismic Regions
- A Precast Concrete Bridge Bent Designed to Re-center after an Earthquake

Presentations

- Presentations from WSDOT ABC Workshop (September 30, 2008) (500 MB)
- Presentations from WSDOT-CalTrans TRB 2009 Seismic ABC Collaboration (612 MB)
- Lewis and Clark Bridge Deck Replacement
- Rapid Replacement of the Hood Canal Bridge Approach Spans

Links

- Highways for Life

Decision-Making Matrix -ABC Checklist

- Emergency replacement?
- Lane closures or detours?
- High traffic volume?
- High daily traffic control costs?
- Critical path of project?
- Innovative contracting strategies?
- Weather constraints?
- Worker safety concerns?
- Environmentally sensitive site?
- Multiple similar spans (Bridge type)?
- Delay-related user cost concern?
- Adequate owner staffing?

ABC may be considered if Number of YES > NO

Next Step: Bridge Construction Index (BCI) Calculations

ABC Impact Quantification

Calculate the Bridge Construction Index (BCI)

Baseline Measure-

Calculate BCI's for conventional construction - (BCI-C)x

ABC Measure-

Calculate BCI's for ABC - (BCI-A)x.

Calculate Earnings by ABC (ERN) – Construction Time

ERN (in days) = (BCI-C) – (BCI-A)

Convert ERN (in days) into $ = $[(BCI\text{-}C)_{ERN} – (BCI\text{-}A)_{ERN}]x$/day

Calculate Savings by ABC (SAV)- Traffic Delay Reduction

SAV (days) = (BCI-C) – (BCI-A)

Convert SAV (in days) into $ = $[(BCI\text{-}C)_{SAV} – (BCI\text{-}A)_{SAV}]x$/day

+ Safety + Environment …..

Compare: ABC Earning vs. Construction Cost

Case Study:
ABC Impact Quantification: Baseline Measure

Construction Time Difference - Study of 3 Bridge Scenarios:

- Case 1: 2-Span Post-Tensioned Box Girder Bridge Over SR 18
- Case 2: 4-Span Prestressed Girder Bridge Under I-5
- Case 3: 2-Span Steel Box Girder Bridge Over I-5

Lane Closure Cost:

- Case 1: 1 Month Lane Closure – Traffic Control
- Case 2: 3 Months Lane Closure – Traffic Control
- Case 3: 4 Months Lane Closure – Traffic Control

Risks:

At Work Zone to WSDOT And Contractors' Staff
At Work Zone to Travelling Public
Cost Risk Estimating

Environmental Impact


Thank you
khalegb@wsdot.wa.gov
(360) 705-7181