Domestic Scan
Advances in FRP Composites

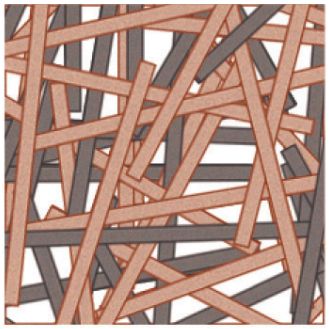
DeWayne Wilson
WSDOT Bridge Asset Management Engineer



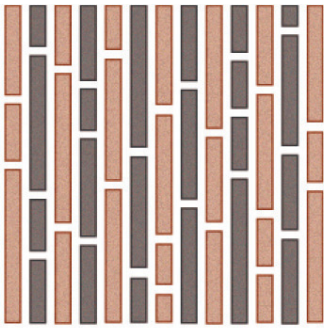



What is FRP?

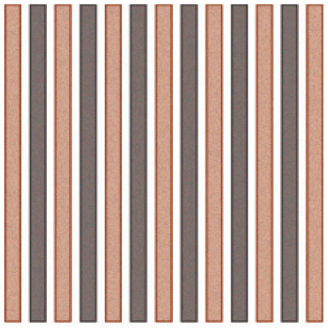
Fiber-reinforced polymer (FRP)……
is a composite material made of a polymer (Epoxy/Vinyl Ester/Polyester) matrix reinforced with fibers (Carbon / E-Glass / Aramid / Phenolics).



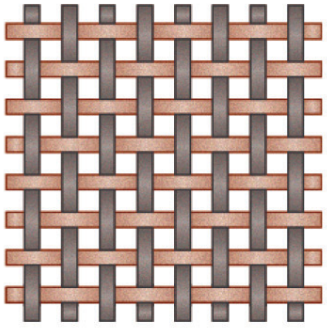
Discontinuous and randomly oriented



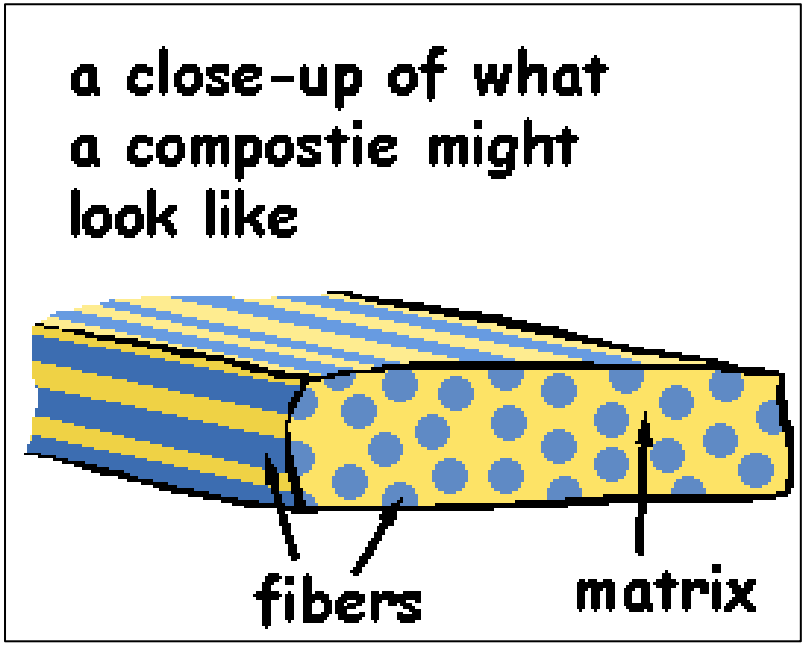
Discontinuous and aligned



Continuous and aligned



Fabric



NCHRP (National Cooperative Highway Research Program)

FRP Domestic Scan

- NCHRP Funded (at the request of AASHTO)
- FRP Scan Tour conducted in 2015
- Focus on FRP use in Bridges and Highway structures

Final Report should be completed by August 2016

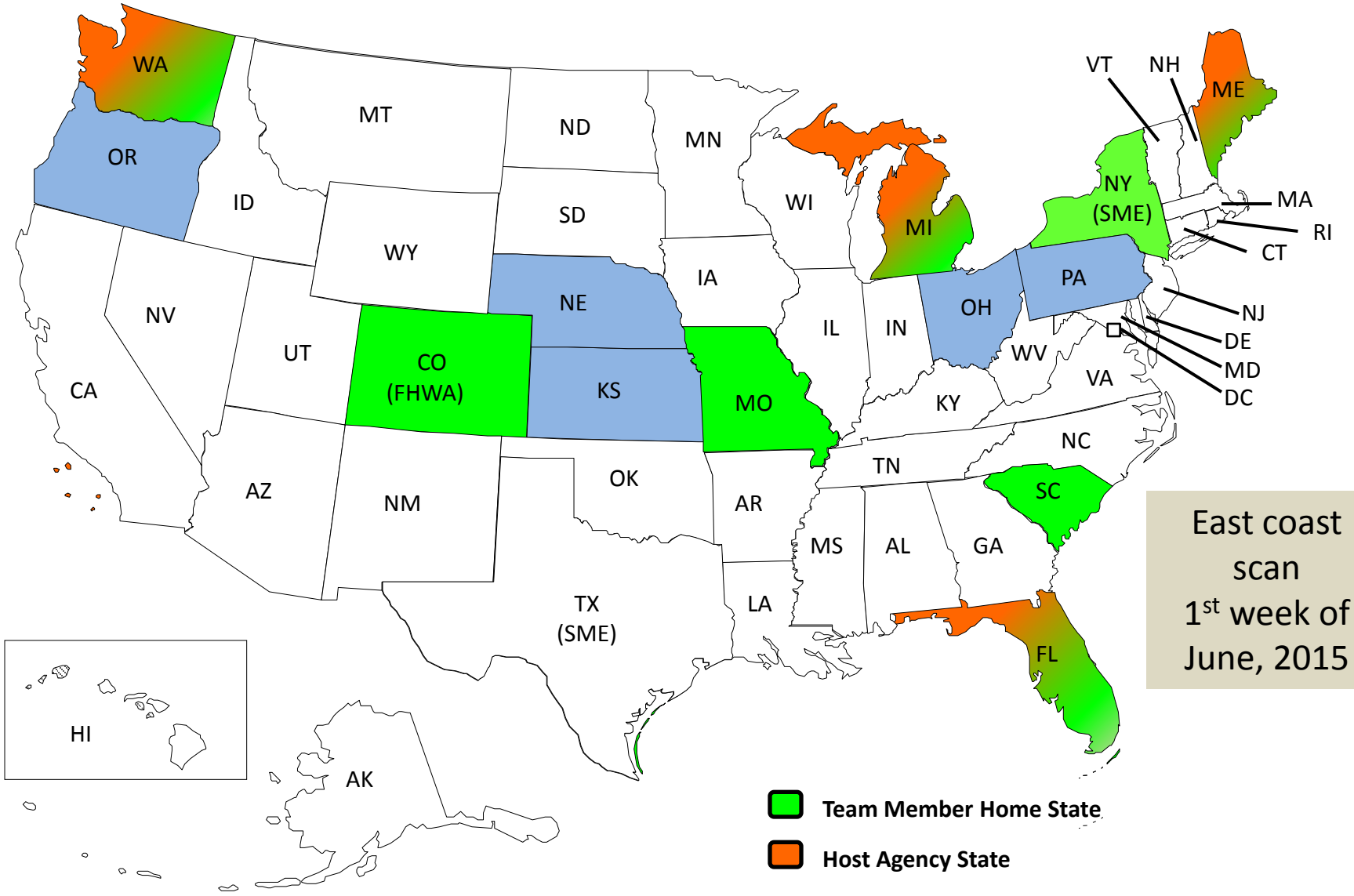
13-03 — Leading Practices in Use of Fiber Reinforced Polymer (FRP) Composites in Transportation Infrastructure

Fiber reinforced polymer (FRP) composite materials have been researched and demonstrated in structural applications for more than 25 years. Among transportation agencies, FRP materials have been used for bridge decks, beams, piling, buried structures, concrete reinforcing, and post-tensioning, as well as for repair and strengthening of existing structures. However, FRP has been used used little as a primary structural material.

"The purpose of this scan is to inform the transportation industry on successful applications of FRP within DOT's as well as techniques that may be appropriate / adaptable for use."

West coast scan
Mid July, 2015

Participating States



East coast scan
1st week of June, 2015

Advances in FRP Composites in Transportation Infrastructure
NCHRP 20-68A Domestic Scan 13-03

Scan Members

- Wayne Frankhauser, Maine DOT, AASHTO Chair
- Jamal Elkaissi, FHWA
- Steven Kahl, Michigan DOT
- Stacy McMillan, Missouri DOT
- William Potter, Florida DOT

Scan Members

- David Rister, South Carolina DOT
- DeWayne Wilson, Washington State DOT
- Jerome O'Connor, University at Buffalo, Subject Matter Expert
- Li Melissa Jiang, Arora and Associates, Scan Coordinator

Sites Visited

- Harbor Technologies and Kenway (Maine)
- AIT Bridge Systems (Maine)
- Maine DOT
- University of Maine
- Florida DOT
- University of Florida
- Michigan DOT
- Lawrence Technological University
- Oregon DOT
- Washington State DOT

Mature Applications of FRP

New construction

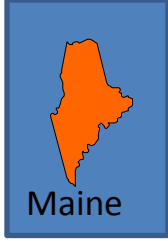
- Hybrid structures
  - Composite Arch
  - Composite Beam
- Reinforcement in concrete (rebar) {GFR and CFR}
- Prestressing strands
- Transverse post tensioning
- Marine fenders and piles
- Drain pipes, scuppers

Mature Applications of FRP

Existing bridges

- Concrete repair (collision, deterioration)
- Concrete strengthening
- Seismic retrofit

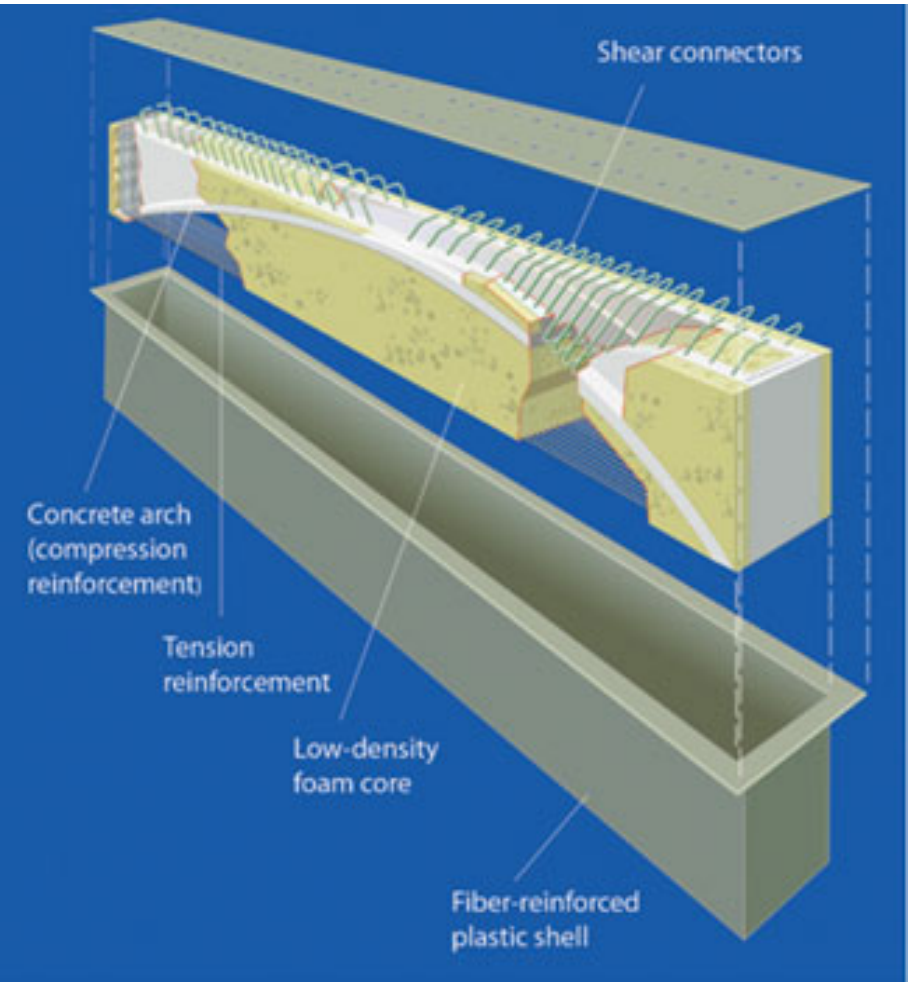
Maine



The Maine DOT has leveraged the experience of the state's composite boat builders and partnering with university researchers to develop new infrastructure applications

Composite Item	# Installations
Concrete filled FRP Arch	9 Structures
Hybrid Composite beams (HCB)	4 bridges
GFRP deck rebar	3 bridges
Composite bridge drains	10 bridges
CFRP post tensioning	2 bridges
Fender piles	1 bridge
Load bearing piles	4 research trials

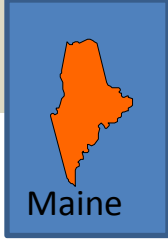
Hybrid Composite Beams (HCB)



Harbor Technologies
A DIVISION OF KENWAY CORPORATION

Maine

Hybrid Composite Beams (HCB)



Railroad Bridge in Canada


HCB Piece Weight
Empty: 5,250 lbs.
Filled: 17,150 lbs.
Maine
HCB – Hybrid Composite Beams
13

Hybrid Composite Beams (HCB)

Knickerbocker Bridge (Boothbay Maine)

70ft Main Spans – 8 total spans

Completed 2011

Knickerbocker Bridge (Boothbay Maine)

Hybrid Structures

Hybrid Structures

Projects with Hybrid Composite Beams

Composite Arch

Maine

ADVANCED INFRASTRUCTURE TECHNOLOGIES

Composite Arch

Composite Arch

Composite Arch

Florida

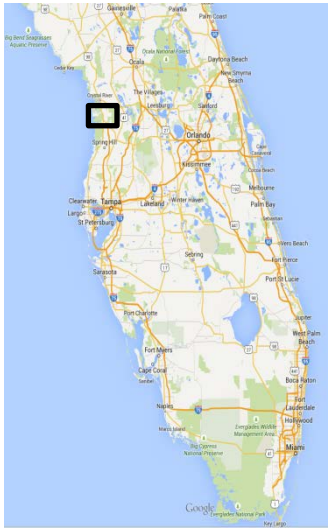
The Florida DOT has performed a variety of research and performed multiple FRP applications that focuses on concrete repair of bridges (mainly over height vehicular loads)

Composite Item	# Installations
FRP repairs to Concrete	Many bridges
FRP fender systems	22 systems
Hybrid Composite beams (HCB)	1 bridge (under construction)

Concrete Girder Repair

Concrete Girder Repair

Concrete Girder Repair



Extremely Aggressive Environment

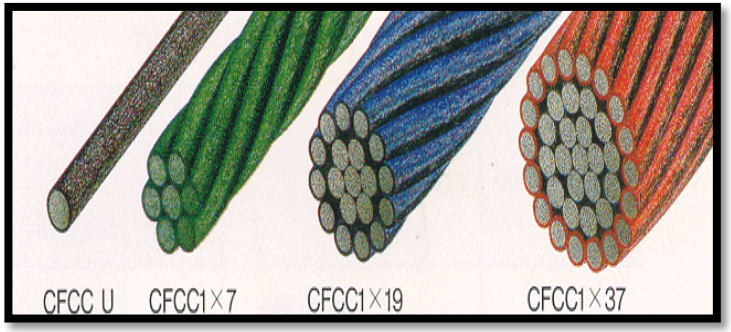
Halls River:
Existing Bridge

Centennial FDOT 1915 ★ 2015

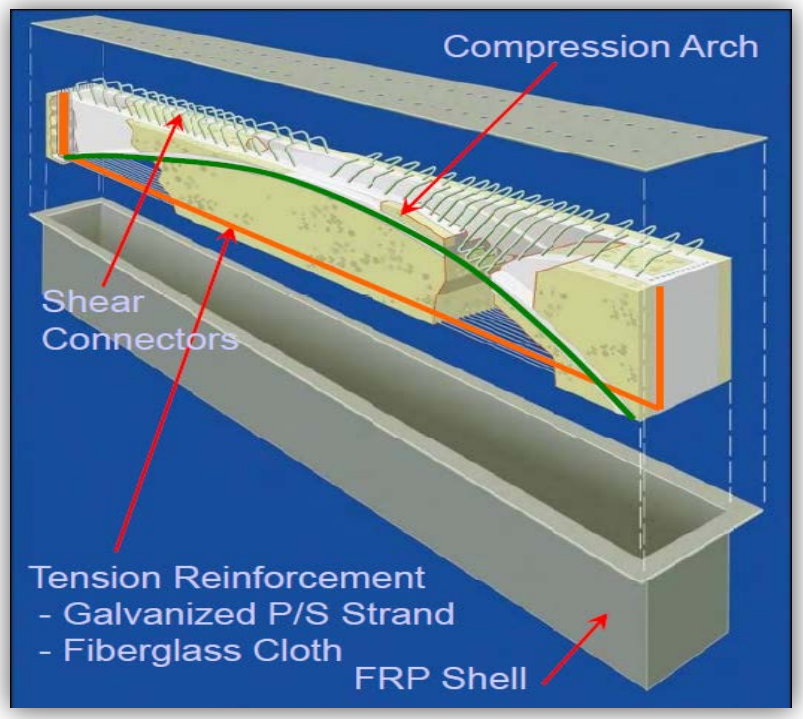
Halls River: FRP Materials

Glass Fiber Reinforced (GFRP) Bars

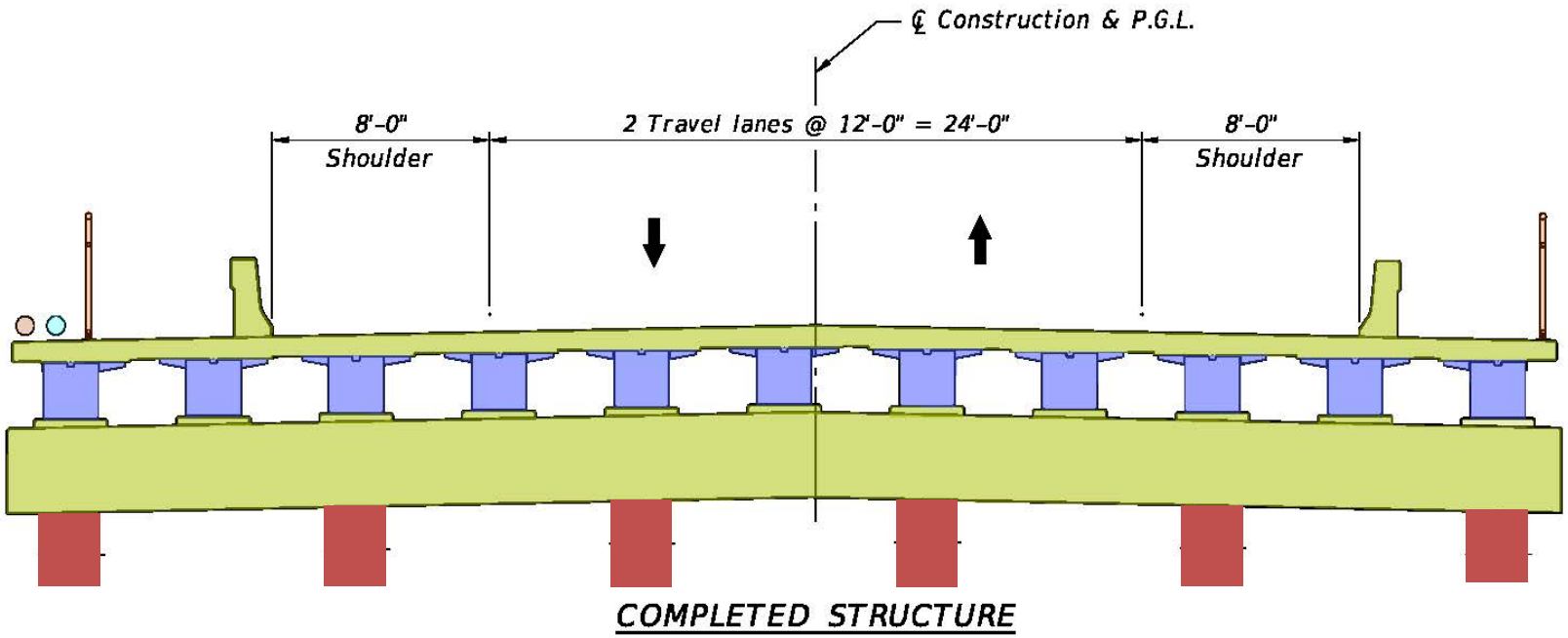
Carbon Fiber Composite Cable (CFCC)



Hybrid Composite Beam (HCB)



Halls River: FRP Materials



GFRP HCB CFCC

Project to have bids opened in June 2016

Florida Halls River Bridge

Cost Per Unit Deck Area

Bridge Type	$/SF
Conventional Concrete Bridge (PSB, Steel Reinforcement)	166.00
Proposed Composite Bridge (HCB, FRP Reinforcement)	282.00

Hybrid GFR (Glass Fiber Reinforced Bar)-RC Bridge Deck

53rd Ave Bridge, City of Bettendorf, Iowa

FRP Fender Piles

FRP Fender Piles

FRP Fender Piles

Michigan

Composite Item	# Installations
Concrete filled FRP Arch	1 bridges
Column Wraps	11 bridges
CFRP post tensioning (CFCC)	4 bridges
Beam Shear strengthening	2 bridge
CFRP reinforcement	1 bridge

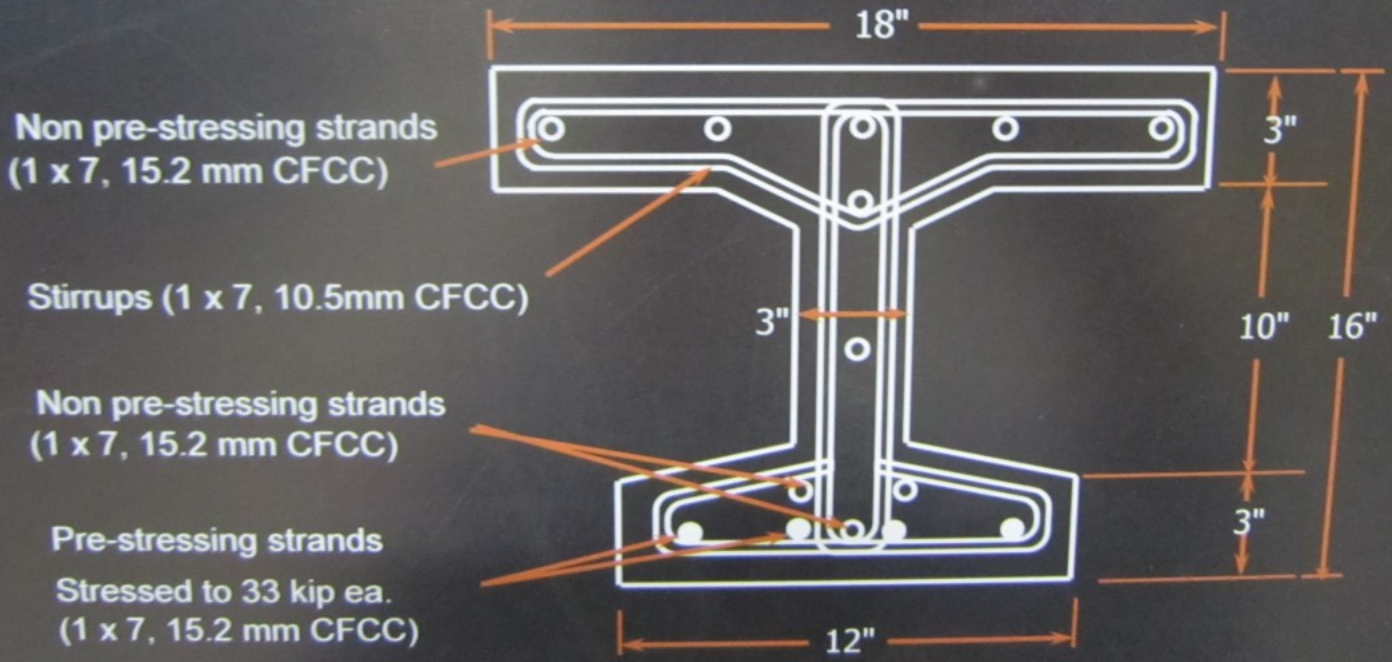

Michigan
Lawrence Tech
THEORY AND PRACTICE
1932


Lawrence Technological University
Michigan
Projects

Lawrence Technological University

Michigan

Decked Bulb-T Beam Detail (CFCC)



Cross section (CFCC)


Lawrence Technological University
Surface Combustion
Surface Combustion, Inc.
CAUTION
DANGER
Michigan


Lawrence Technological University
Michigan


Michigan
Rouge River
Main
Branch
OURS TO PROTECT


Michigan

Oregon

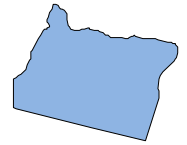

Oregon

Composite Item	# Installations
Arch Rib Strengthening - CFRP	1 bridge
Deck Strengthening – CFRP rods	8 bridges
GFRP deck rebar	2 bridges
Girder Strengthening – CFRP strips	40 bridges
FRP Bridge Decks	4 bridges
Pier cap Strengthening – CFRP strips	13 bridges

Interstate 84 Rock Creek Bridges (Girder Strengthening)

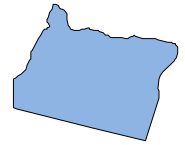
Oregon

Interstate 84 Rock Creek



Oregon

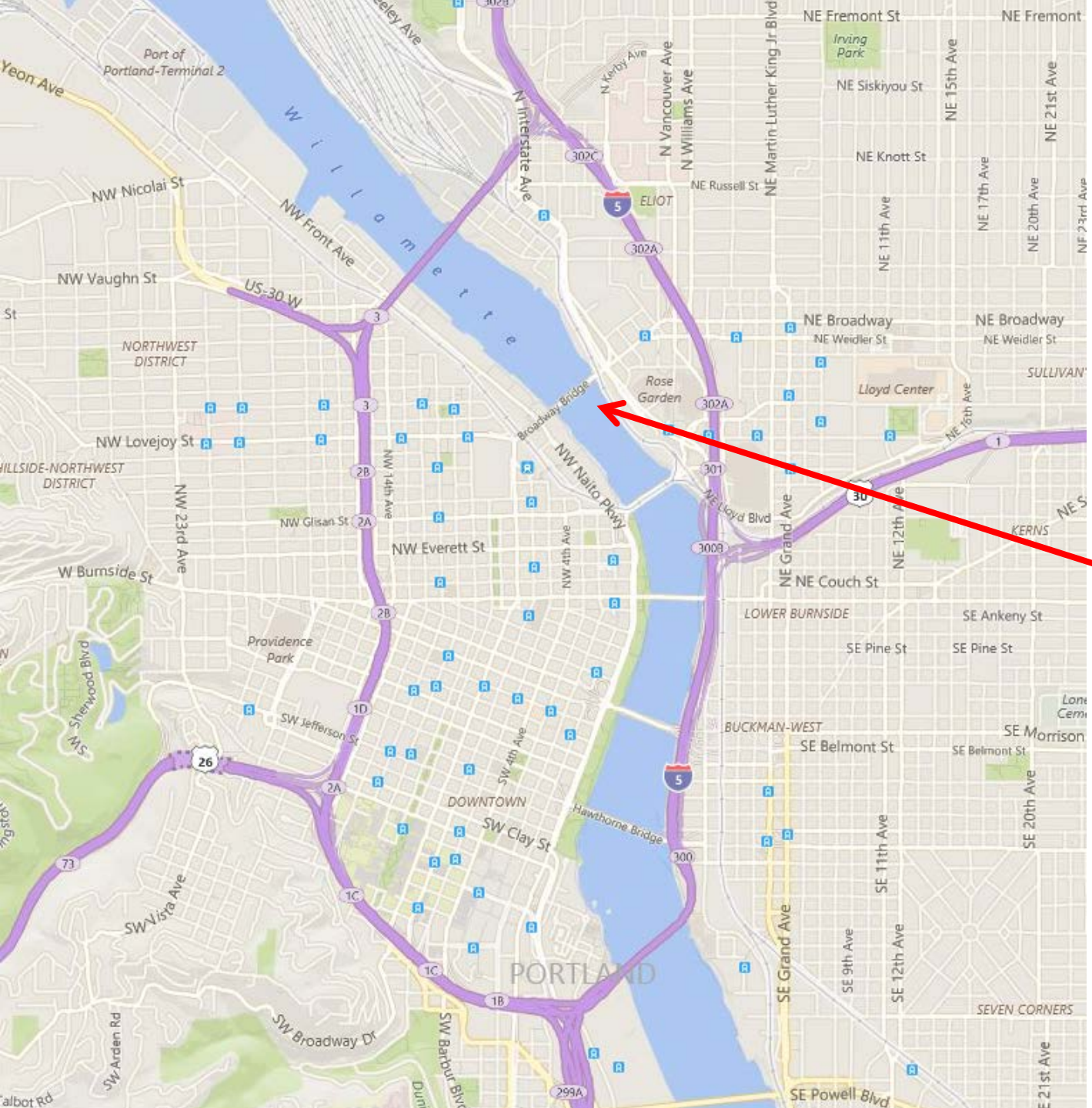
Interstate 84 Rock Creek



Oregon

Interstate 84 Rock Creek

Oregon

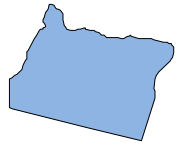


Broadway Bridge

Oregon

Broadway Bridge

Owner - Multnomah County (Located in Portland, Oregon)

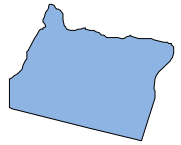


Oregon

Willamette River

Broadway Bridge

Owner - Multnomah County (Located in Portland, Oregon)

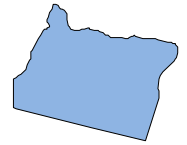


Oregon

FRP Deck installed in 2004 and 2010

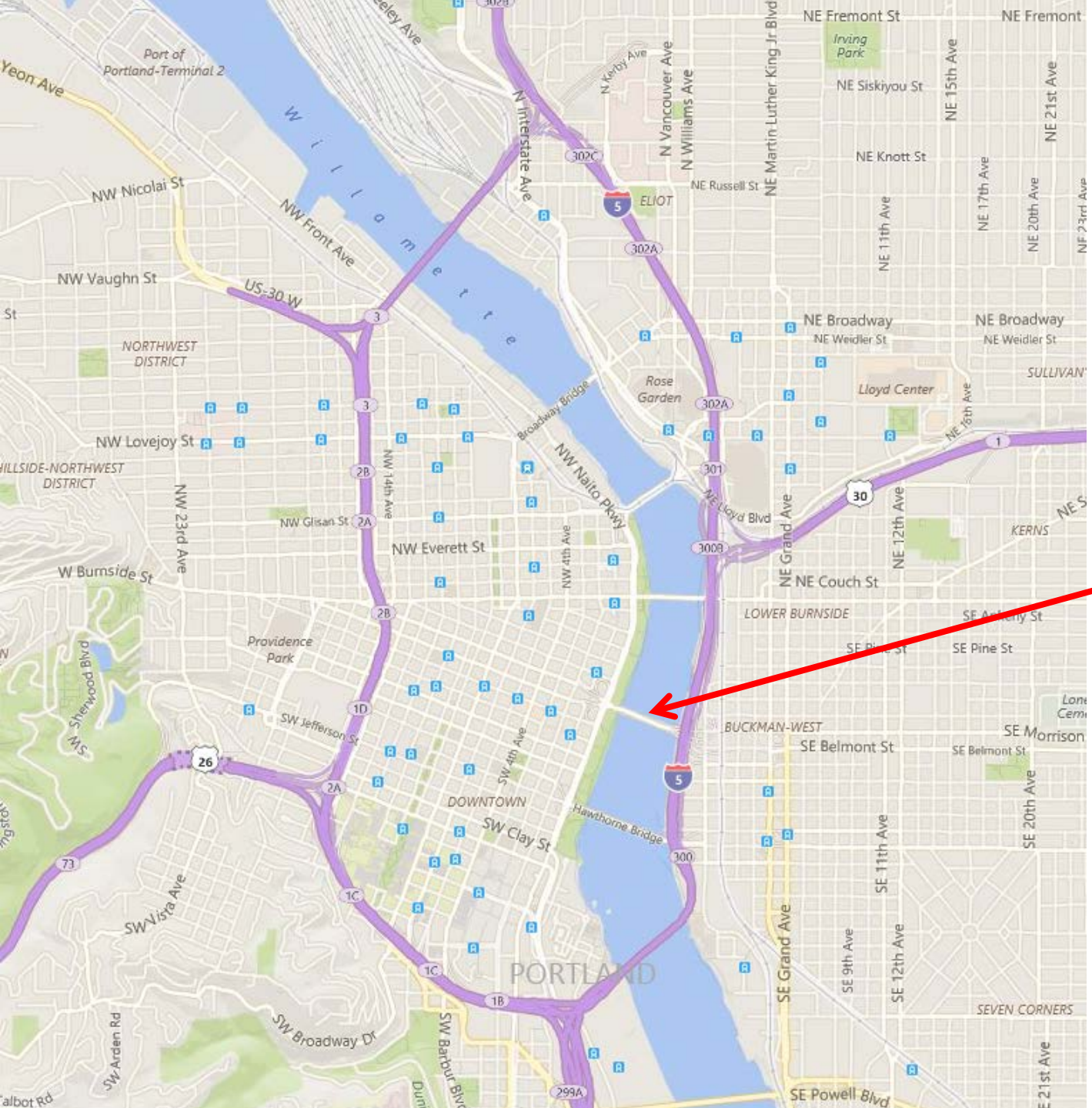
Broadway Bridge

Owner - Multnomah County (Located in Portland, Oregon)



Oregon

Picture taken in 2015


Port of Portland-Terminal 2
Willamette
NW Nicolai St
NW Front Ave
NW Vaughn St
US-30 W
NORTHWEST DISTRICT
NW Lovejoy St
NW 23rd Ave
NW Glisan St
NW Everett St
W Burnside St
Providence Park
SW Jefferson St
SW 4th Ave
DOWNTOWN
SW Clay St
SW Vista Ave
SW Broadway Dr
PORTLAND
Broadway Bridge
NW Naito Pkwy
Rose Garden
ELIOT
N Interstate Ave
N Vancouver Ave
N Williams Ave
N Martin Luther King Jr Blvd
NE Fremont St
Irving Park
NE Siskiyou St
NE Knott St
NE Russell St
NE Broadway
NE Weidler St
Lloyd Center
NE Lloyd Blvd
NE Grand Ave
NE 12th Ave
NE 15th Ave
NE 21st Ave
KERNS
NE Couch St
LOWER BURNSIDE
SE Pine St
BUCKMAN-WEST
SE Belmont St
SE Morrison
Hawthorne Bridge
SE Grand Ave
SE 11th Ave
SE 20th Ave
SEVEN CORNERS
SE Powell Blvd
Morrison Bridge


Oregon

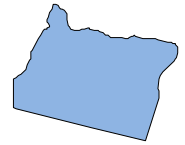
Morrison Bridge
Owner - Multnomah County
(Located in Portland, Oregon)

FRP Deck installed in 2012

Owner - Multnomah County (Located in Portland, Oregon)

Morrison Bridge

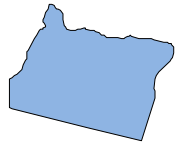
Owner - Multnomah County (Located in Portland, Oregon)



Oregon

Morrison Bridge

Owner - Multnomah County (Located in Portland, Oregon)



Oregon

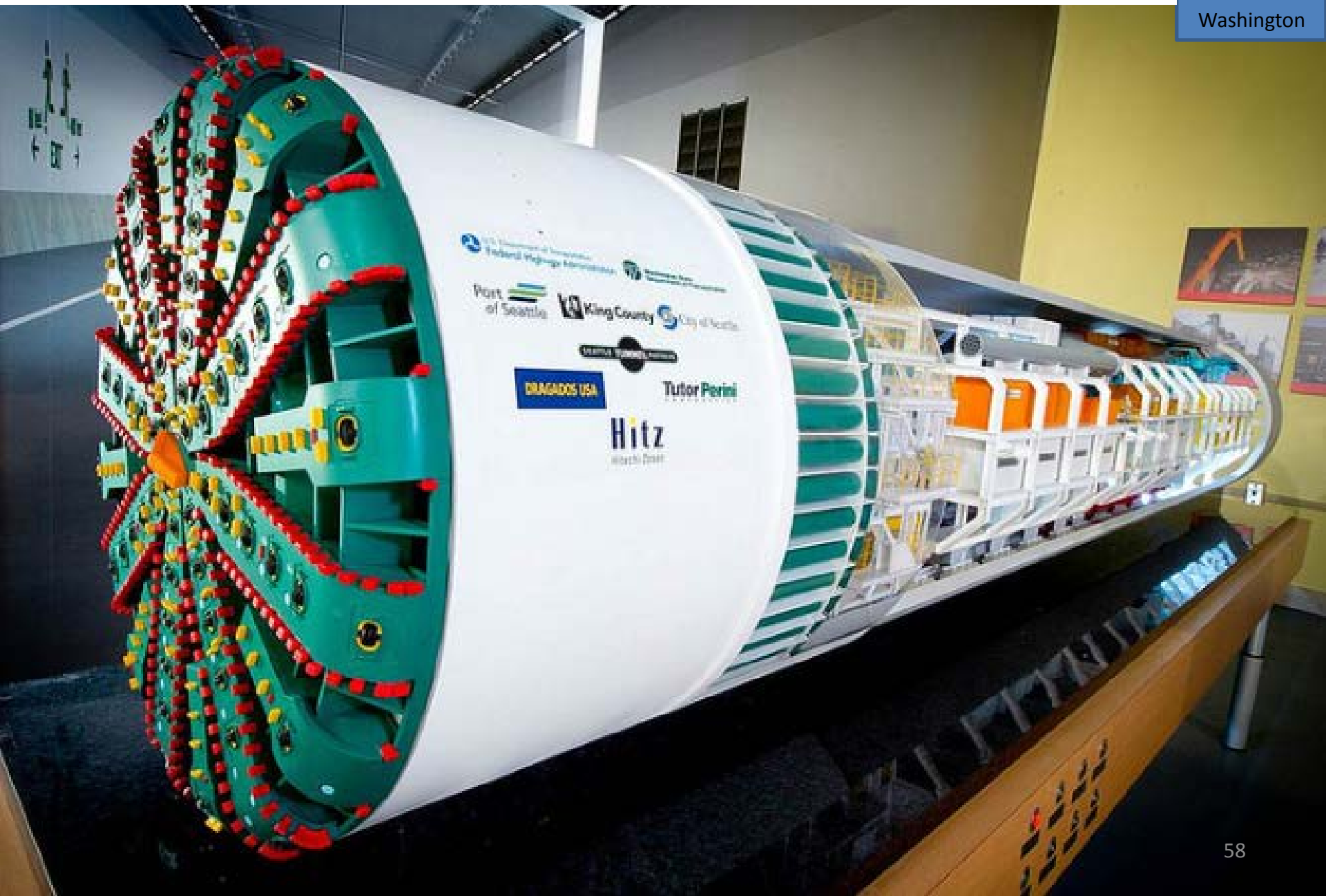
Picture taken in 2015

Washington

The Washington DOT has used FRP for the Seismic Retrofit of bridges and the repair of concrete deteriorated elements.

Composite Item	# Installations
Seismic Retrofit	10 bridges
CFRP Strengthening	1 bridge
CFRP Pontoon Repair	1 bridge
GFRP rebar	Tunneling
Composite bridge deck	1 bridge (replaced)

SR99 Alaskan Way Tunnel
(Model of Tunnel Boring Machine “BERTHA”)



SR99 Alaskan Way Tunnel

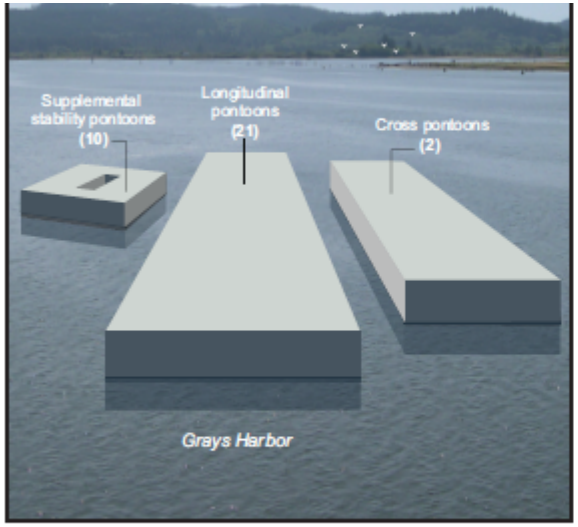
(Model of Tunnel Boring Machine “BERTHA”)

SR99 Alaskan Way Tunnel

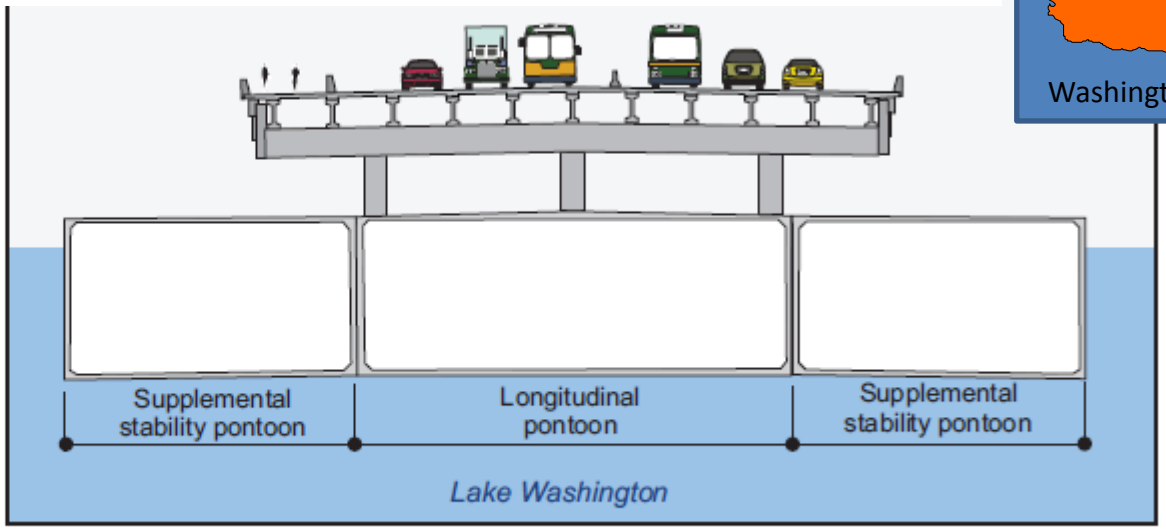
(Model of Tunnel Boring Machine “BERTHA”)

SR520 Lake Washington Floating Bridge (Located near Seattle, Wa)

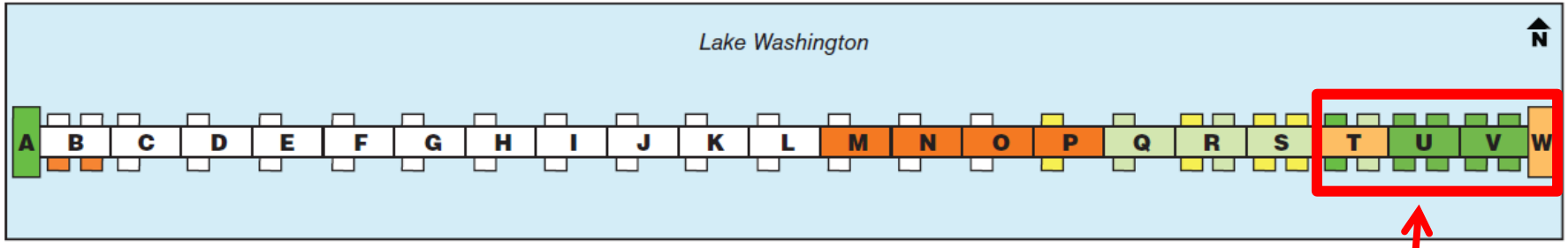
SR520 Lake Washington Floating Bridge (Located near Seattle, Wa)



Three types of pontoons will support the new SR 520 floating bridge.



Conceptual graphic of the new SR 520 floating bridge with two general-purpose lanes and one transit/HOV lane in each direction, and a new bicycle/pedestrian path.



Note: not to scale

Pontoon status:

- On Lake Washington
- Temporarily moored
- Under construction
- Repairs underway
- In transit
- Future construction

Crack repair locations:

- Pontoon T: Drydock in Portland, OR
- Pontoon W: Drydock in Seattle, WA
- Pontoon U: Using coffer cell on Lake Washington
- Pontoon V: Using coffer cell on Lake Washington

Carbon Fiber wrap of pontoon ends

SR520 Lake Washington Floating Bridge (Located near Seattle, Wa)

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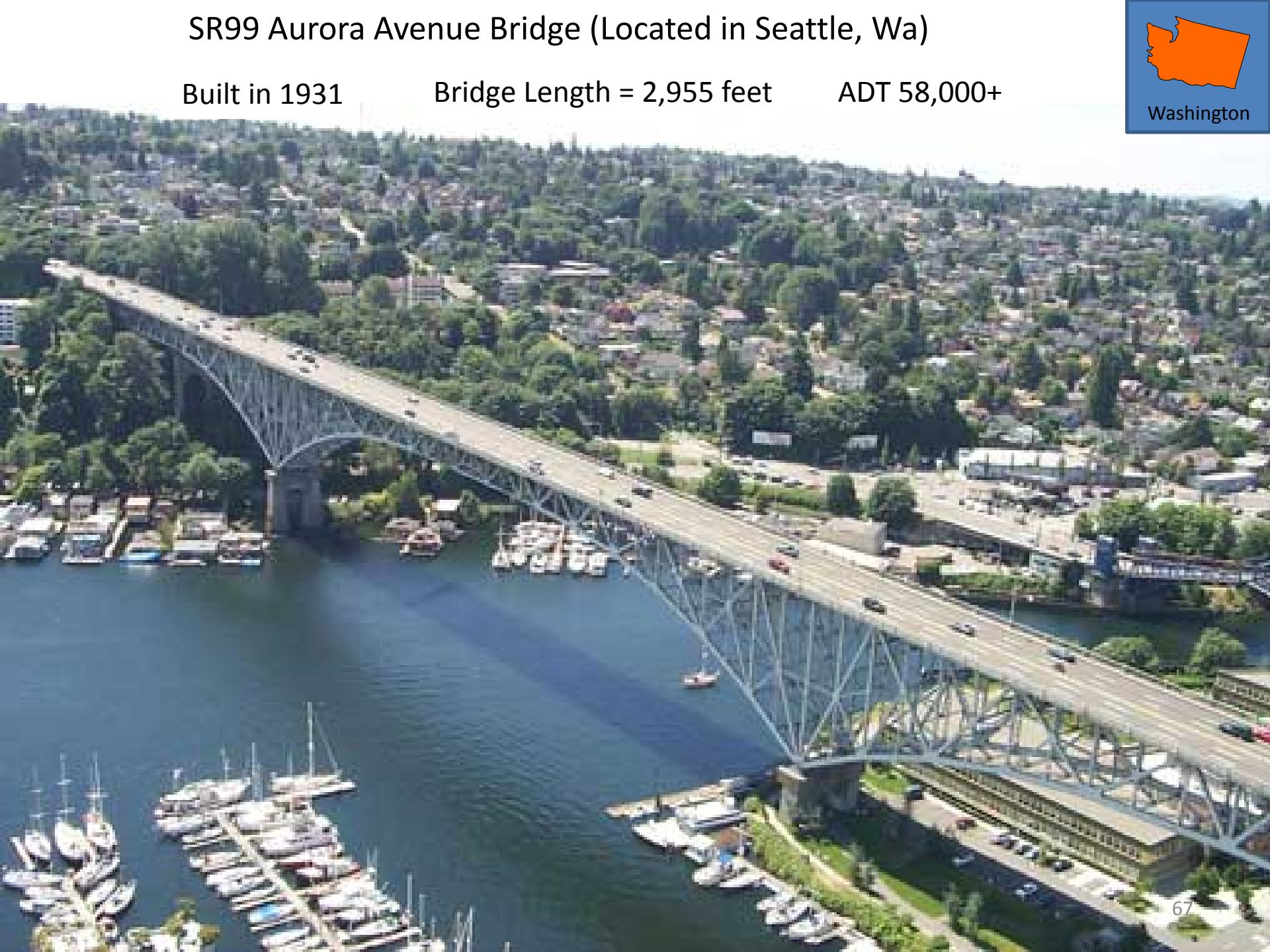
SR520 Lake Washington Floating Bridge (Located near Seattle, Wa)

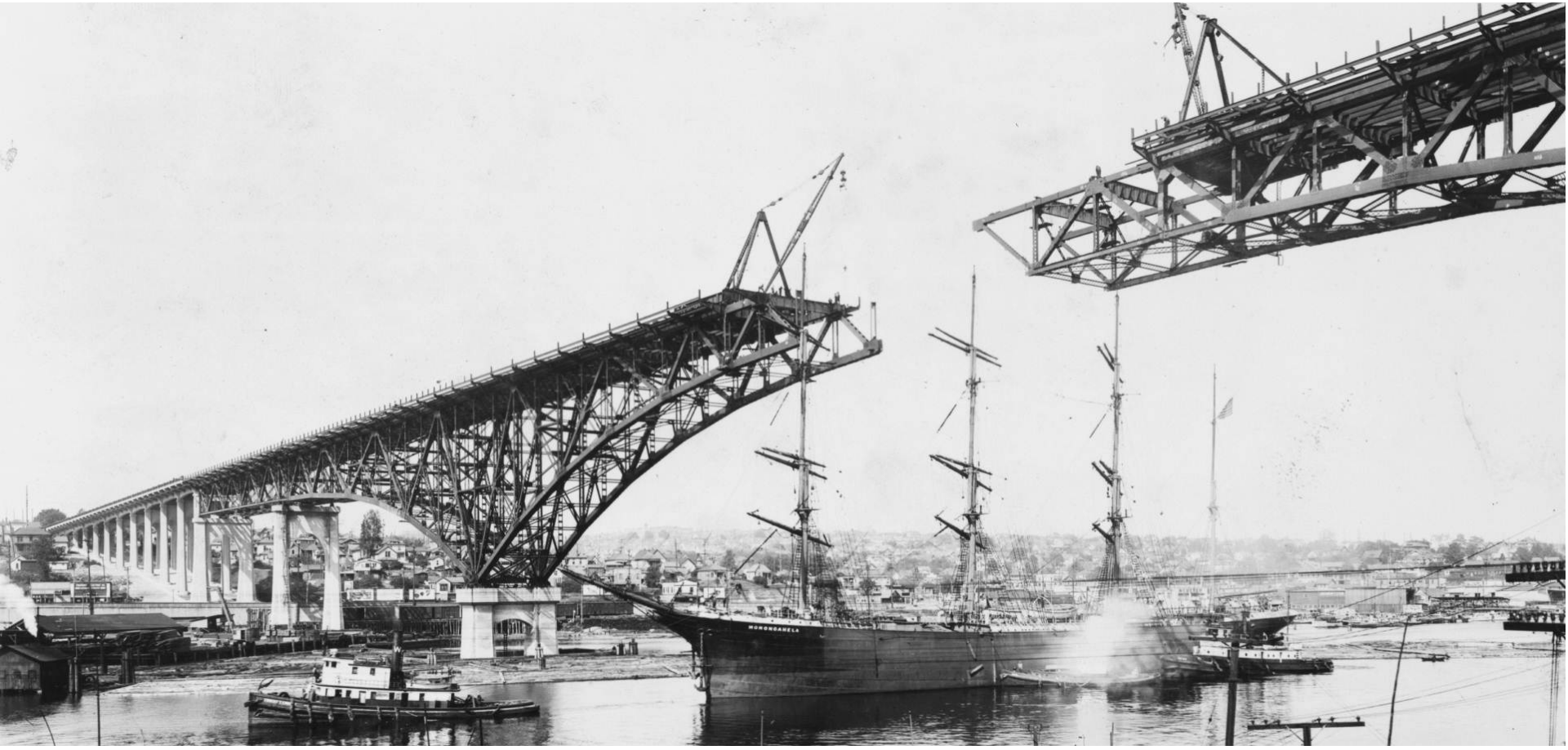
SR99 Aurora Avenue Bridge (Located in Seattle, Wa)

Built in 1931 Bridge Length = 2,955 feet ADT 58,000+



SR99 Aurora Avenue Bridge (Located in Seattle, Wa)

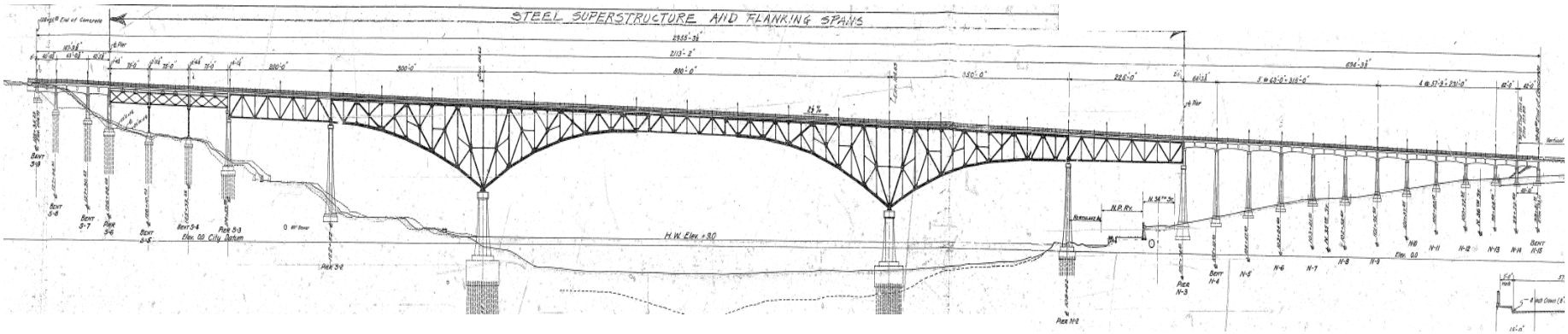
Currently listed in the National Register of Historic Places



SR99 Aurora Avenue Bridge (Located in Seattle, Wa)

SR99 Aurora Avenue Bridge (Located in Seattle, Wa)

- Total bridge length = 2,955 ft
- 3 Units:
  - South Approach (6 concrete girder and steel truss spans) = 380 ft
  - Main Unit (5 steel deck truss spans) = 1,881 ft
  - North Approach (12 concrete girder spans) = 694 ft



SR99 Aurora Avenue Bridge (Located in Seattle, Wa)

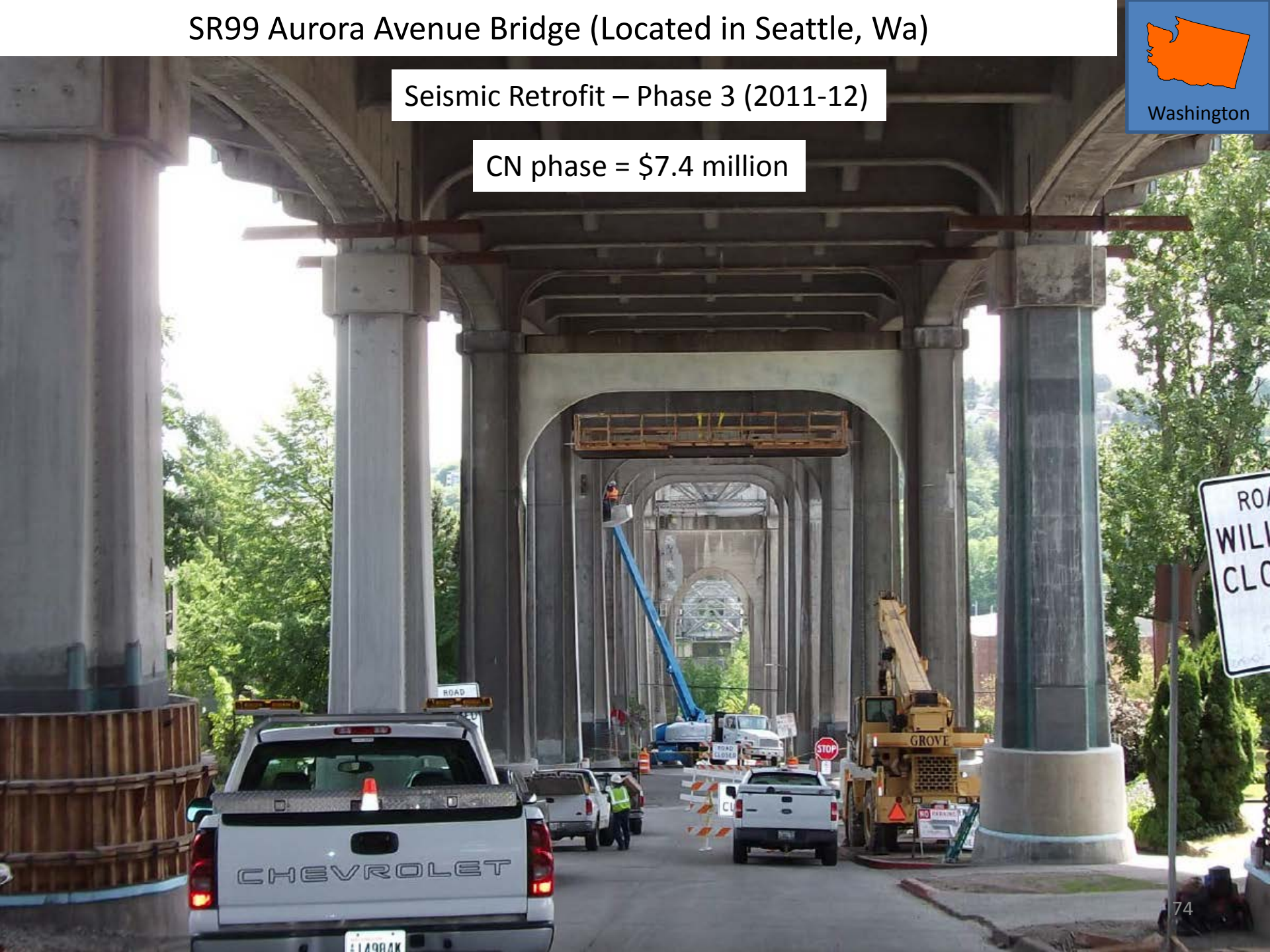
Aurora Avenue Bridge
Approach Retrofit Considerations

- ***Aesthetics – look of the columns can't change***
- ***Split columns provide for thermal movements***
- ***What to do?***

Aurora Avenue Bridge
Column Testing Overview

- Washington State University
- Goal: Verify the effectiveness of FRP wrapping for improving shear performance in cruciform columns

SR99 Aurora Avenue Bridge (Located in Seattle, Wa)




Seismic Retrofit
Phase 3 (2011-12)
Washington

SR99 Aurora Avenue Bridge (Located in Seattle, Wa)

Seismic Retrofit
Phase 3 (2011-12)

SR99 Aurora Avenue Bridge (Located in Seattle, Wa)

Obstacles to the use of FRP

1. Lack of AASHTO guide specifications
2. Insufficient information sharing (project summaries, research…)
3. Proprietary nature of products
4. Image problem stemming from poor performance of some products

Consider FRP when…

- a truck hits a concrete bridge
- strengthening is needed for current truck loads
- a design deficiency in a concrete member
- corrosion-resistance is desired to extend service life
- prestressing strands are going to be exposed to harsh environmental conditions
- Need for a lightweight superstructure
- Seismic retrofit

Questions?