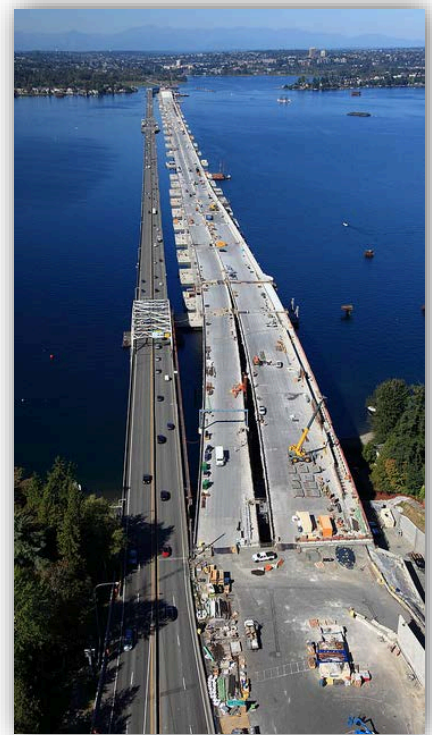


Evaluation of Performance Based Concrete For Bridge Decks

DeWayne Wilson

WSDOT Bridge Asset Management Engineer



Problem - WSDOT has observed abnormal cracking in many concrete bridge decks over the last 10-15 years



SR303 Manette Bridge (Bremerton, Wa)

Built in 2011

SR303 Manette Bridge (Bremerton, Wa)



Length – 1,550' (Max span of 250')

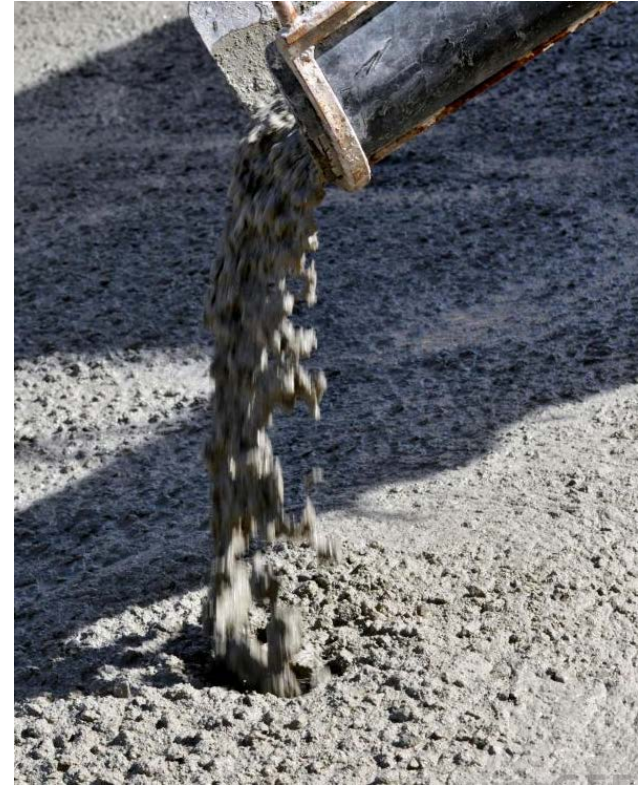
Built in 2011

SR303 Manette Bridge (Bremerton, Wa)



What can we do to fix the cracking problem?

- ✓ Develop a performance based Concrete mix design for Bridge Decks



Concrete Bridge Deck Shrinkage Cracking Study

Washington State University (WSU) Study

Objectives:

- Determine causes of shrinkage cracking
- Identify mitigation strategies
- Evaluate old WSDOT 4000D Mix Design
- Develop new mix designs (with improved properties)
- Provide recommendations on improved mix designs and practices.

Mitigation Strategies for Early-Age Shrinkage Cracking in Bridge Decks

WA-RD 747.1

Pizhong Qiao
David McLean
Jianmin Zhuang

April 2010



Full-Depth Shrinkage Cracking on Prestressed Girder Bridge



Restrained Shrinkage Cracking Test

 Washington State
Department of Transportation
Office of Research & Library Services

WSDOT Research Report

WA-RD 747.1

<http://www.wsdot.wa.gov/research/reports/fullreports/747.1.pdf>

Shrinkage Tests - WSU



Free Shrinkage

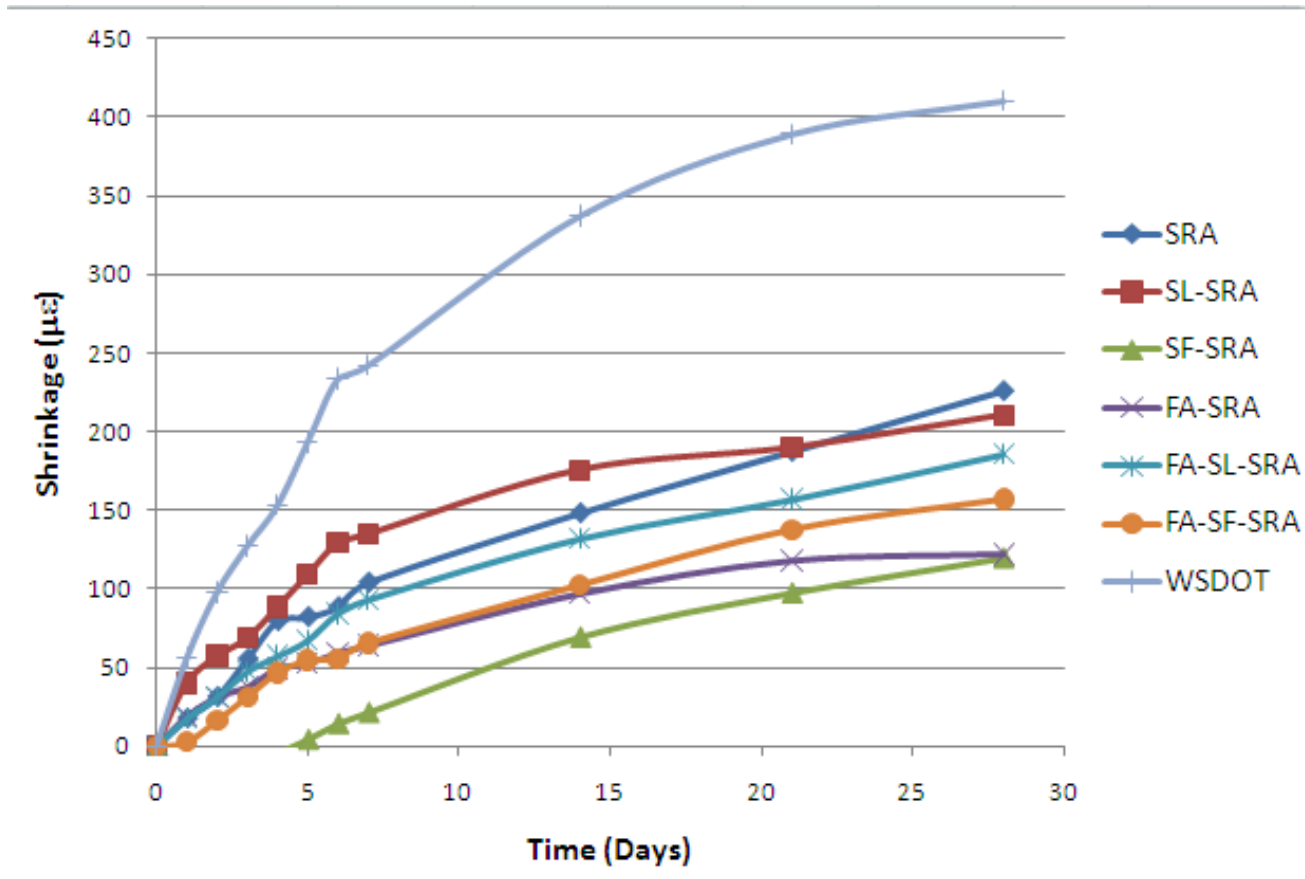


Restrained
Shrinkage



AASHTO T 160

Shrinkage Test Results



- WSDOT Class 4000D mix: $420 \pm$ microstrains.

Summary of WSU Recommendations

- Recommend use of Shrinkage Reducing Admixture (SRA)
- Limit use of fly ash
- Use mix designs with less paste volume
- Increase size of coarse aggregate
- Recommend trial batches prior to production work

WSDOT Bridge Deck Performance Concrete Specs

Standard Specifications

for Road, Bridge, and
Municipal Construction

2016

M 41-10



<http://www.wsdot.wa.gov/publications/manuals/fulltext/M41-10/SS2016.pdf>

Performance Mix Design Requirements

	Traditional	Performance Based
Minimum 28-day Compressive Strength	4,000 psi	4,000 psi
Cement	Type I or II Portland	Type I or II Portland
Cementitious Content	735lbs minimum (660lbs cement & 75lbs fly ash)	No set limits <i>(565lbs – 610lbs)</i>
Fly Ash	Required	Optional
Nominal Max. Size Aggregate	1-inch	1½-inch
Water Reducing Admixture	Required	Optional

Performance Mix Design Requirements

	Traditional	Performance Based
Air Content	4.5% to 7.5%	4.5% to 7.5%
Freeze-Thaw Durability (instead of above air content requirement)	Not an option	3.0% min. air content 90% minimum durability factor after 300 cycles (AASHTO T 161)
Permeability	No requirement	Less than 2000 coulombs at 56 days (AASHTO T 277)
Length Change (shrinkage)	No requirement	Less than 0.032% at 28 days (AASHTO T 160)
Scaling	No requirement	Visual rating ≤ 2 after 50 cycles (ASTM C 672)
Crack Reducing Admixture	Not Used	Optional (Typically used)

Placing, Curing and Finishing Requirements

	Traditional	Performance Based
Temperature During Placement	Between 55°F and 90°F	Between 55°F and 75°F
Temperature Monitoring After Placement	Not Required	Seven days after placement
Curing & Finishing	<ol style="list-style-type: none">1. Transverse grooves are tined into the deck with metal combs after the concrete is sufficiently stiff2. Curing compound applied to surface a max. of 15 min. after tining3. Presoaked wet burlap and soaker hoses are applied to deck surface when deck has taken initial set.4. Wet burlap is kept in place for 14 days	<ol style="list-style-type: none">1. Fog the deck immediately after finishing machine passes2. Apply presoaked burlap to top surface (no curing compound)3. Keep the burlap wet by fog spraying until initial set and it can be covered with soaker hoses and white reflective sheeting4. Wet burlap is kept in place for 14 days5. After cured, longitudinal grooves are ground into the deck using a diamond tipped saw.

Performance Deck Concrete Mix Design



Washington State
Department of Transportation

3-20-13

Concrete Mix Design

Contractor Cascade Bridge		Submitted By Bayview Redi-Mix, Inc.	Date 3-12-2013
Concrete Supplier Bayview Redi-Mix, Inc.		Plant Location Aberdeen 011, Raymond 041	
Contract Number	Contract Name SR 101 Bone River		

Mix Design No. WSDT4DS130 Plant No. 011, 041

Cementitious Materials	Source	Type, Class or Grade	Sp. Gr.	Lbs/cy
Cement 16	Ashgrove, Seattle, WA	Type I-II 6-02.3(2)	3.15	460
Fly Ash ^a	Lafarge, Centralia, WA	Type F	2.58	150
GGBFS (Slag)				
Latex				
Microsilica				



Washington State
Department of Transportation

Performance Deck Concrete Mix Design

Concrete Admixtures	Manufacturer	Product	Type	Est. Range (oz/cy)
Air Entrainment	BASF, Cleveland, OH	Micro-Air		1.15
Water Reducer				
High-Range Water Reducer	BASF, Cleveland, OH	Glenium 7500	F	20-30
Set Retarder				
Other Shrinkage	BASF, Cleveland, OH	Masterlife		120-140

HIGH
30.5-52
NORMAL
12.2-91.5
64-192

Water (Maximum) 230 lbs/cy Is any of the water Recycled or Reclaimed? ☐ Yes ☒ No

Water Cementitious Ratio (Maximum) 0.38 Mix Design Density 150.1 lbs/cf^d

Design Performance	1	2	3	4	5	Average ^f
28 Day Compressive Strength (cylinders) psi	5,775	5,766	5,623	5,561	5,730	5,691
14 Day Flexural ^d Strength (beams) psi						

Agency Use Only (Check appropriate Box)

- ☒ This Mix Design MEETS CONTRACT SPECIFICATIONS and may be used on the bid items noted above
☐ This Mix Design DOES NOT MEET CONTRACT SPECIFICATIONS and is being returned for corrections

Reviewed By: *Ami Tjorne*

PE Signature

4/16/13

Date

DOT Form 350-040 EF
Revised 6/06

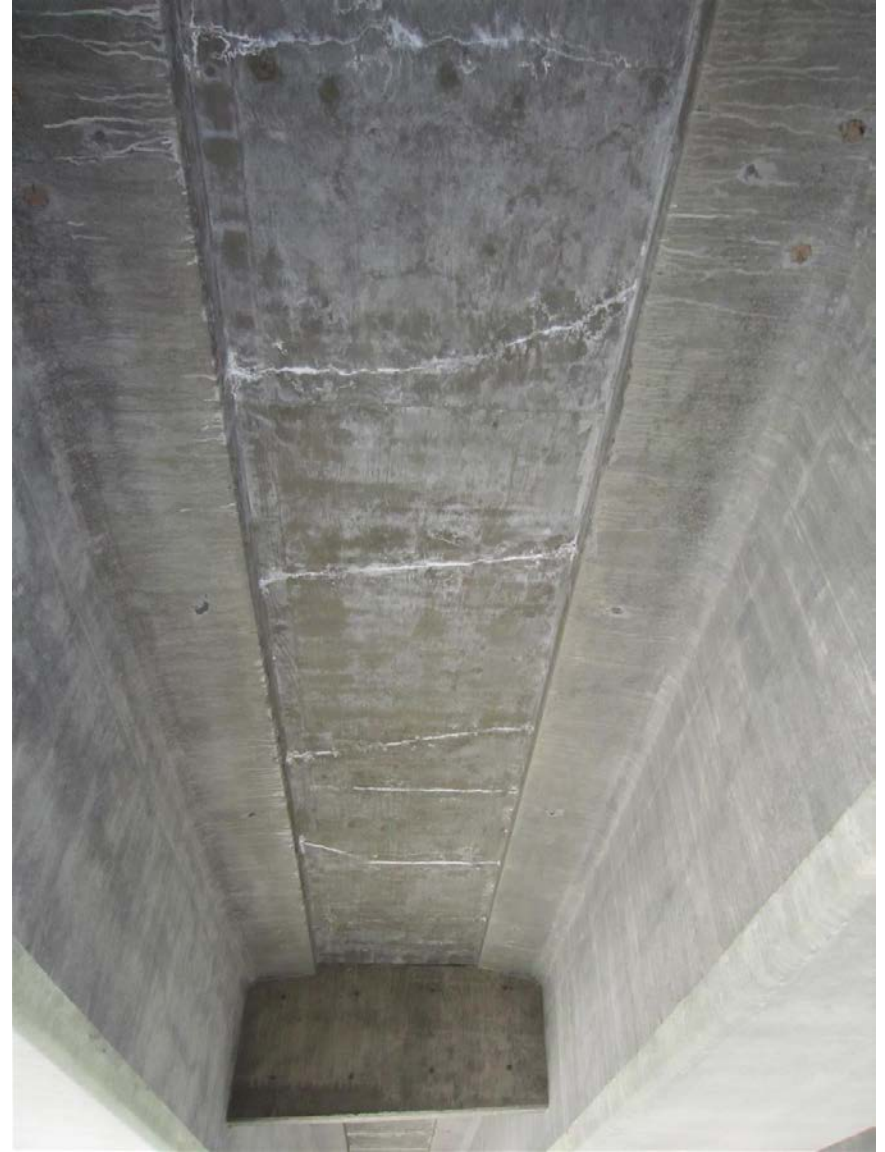
Distribution: Original - Contractor

Copies To - State Materials Lab-Structural Materials Eng. ; Regional Materials Lab; Project Inspector

Performance Deck Concrete

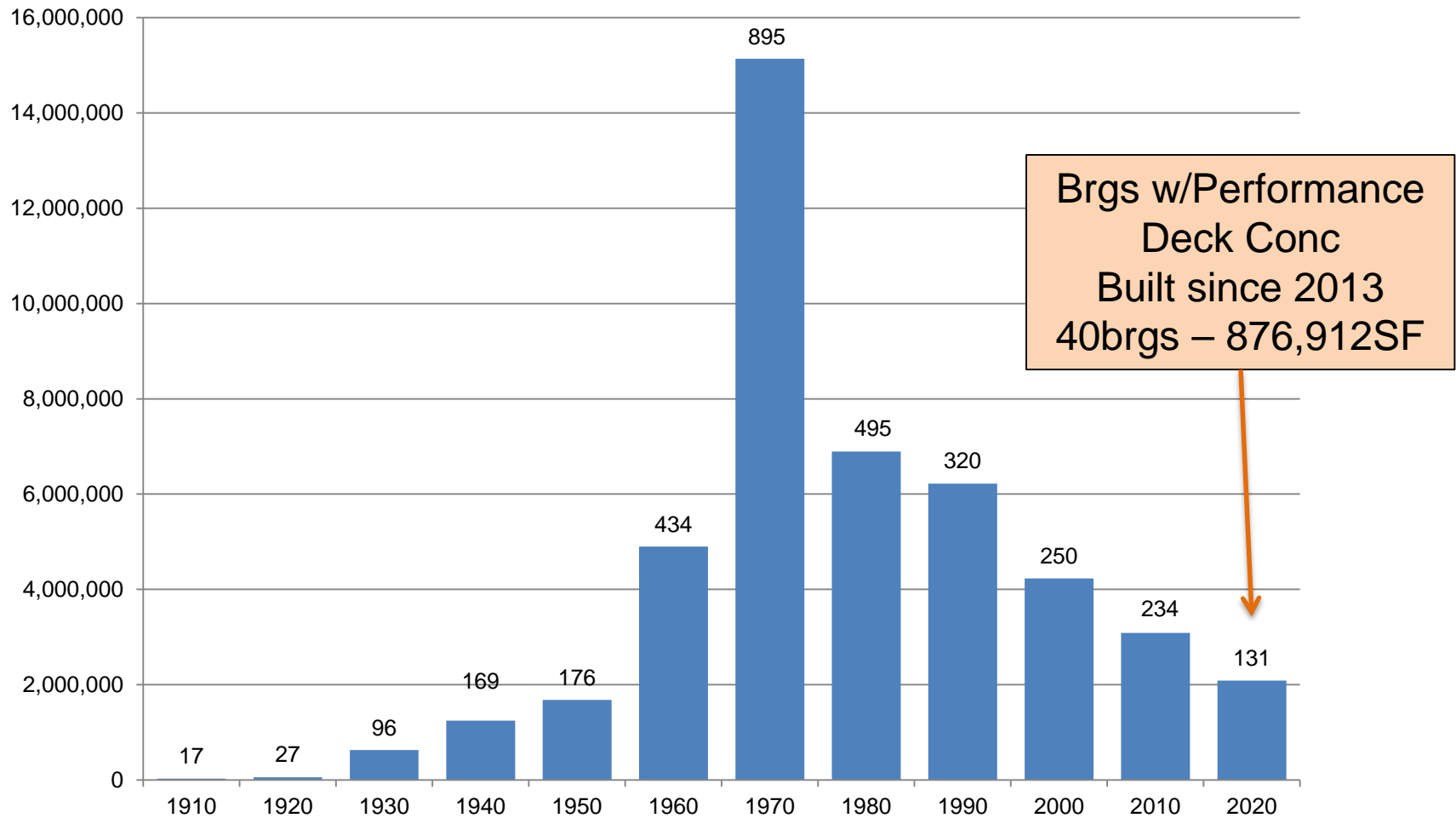


SR105 Smith Creek Bridge
Built in 2014



I-90 Gold Creek Bridge
Built in 2012

WSDOT Vehicular Bridges >20 feet in length



3,241 Vehicular Structures (46.2M sq. ft.) *(Average Age = 46 yrs)*

New Bridges - Performance Deck Concrete

Pre-Deck Pour Meeting

5 – 10 days before placing concrete

Discuss Construction Procedures



Placing Performance Deck Concrete



Curing Performance Deck Concrete

“Fogging”



Curing Performance Deck Concrete

Curing Bridge Deck Concrete

- Presoak burlap
- Continue to Fog during burlap placement
- Cover burlap with soaker hoses and white reflective sheeting
- 14 day wet cure



07/29/2010 14:09

Performance Deck Concrete Texture

Texture Bridge Deck

- Self-propelled machine
- Diamond tipped saw



Performance Deck Concrete Texture



Texture Bridge Deck

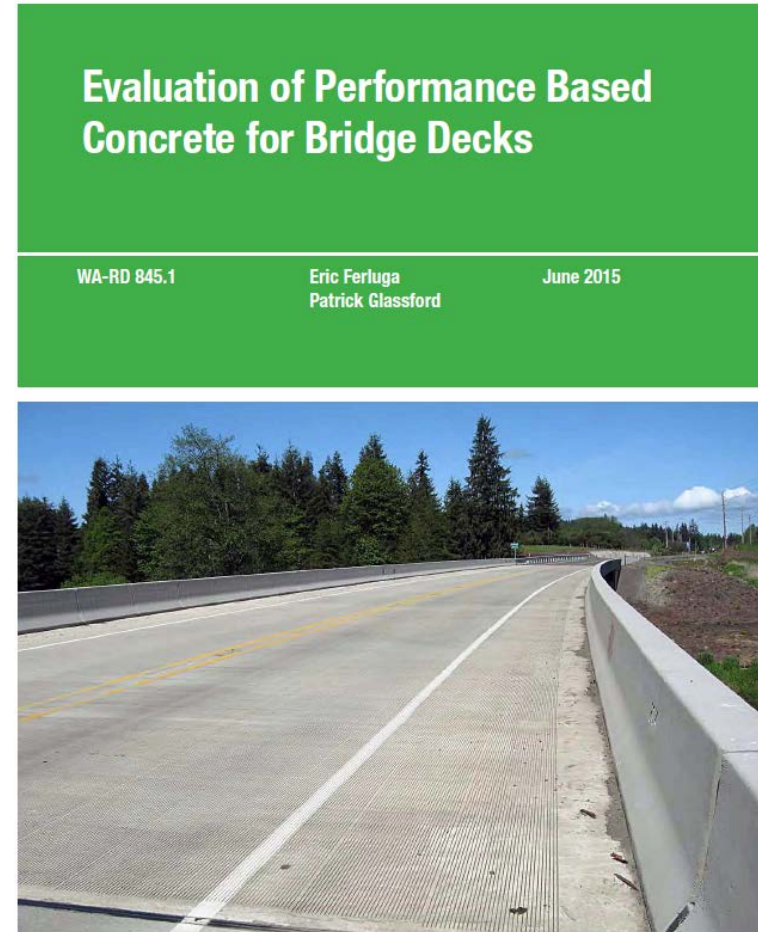
- Grooves 1/8" wide
- 3/16" Deep
- Spacing of 3/4"

Concrete Decks Evaluation Study

- Document the difference in cracking (Traditional vs Performance)
- Bridges built after 2008
- Visibility of the underside of deck
- Relatively simple geometry and easy access

WA-RD 845.1

<http://www.wsdot.wa.gov/research/reports/fullreports/845.1.pdf>



Bridges Evaluated

- A total of 28 bridges were evaluated
 - 15 constructed using the Performance Based Specification
 - 13 constructed using the Traditional WSDOT Specification
- Prestressed I-girders or Steel Plate girders selected for ability to inspect the underside of the deck between girders from the ground.

Evaluation Criteria

- Develop a “Crack Intensity” diagram for each bridge.
- Easily identified cracks (leaching or large enough to see from the ground) in the underside of the deck are counted
- Cracks are grouped into “bays” (bounded by girders and diaphragms)
- A crack intensity percentage is calculated for each bay = N_{cr}/N_{100}
 - N_{cr} = counted number of cracks
 - N_{100} = No. of cracks for 100% intensity
- 100% crack intensity = a crack spaced every 2-feet

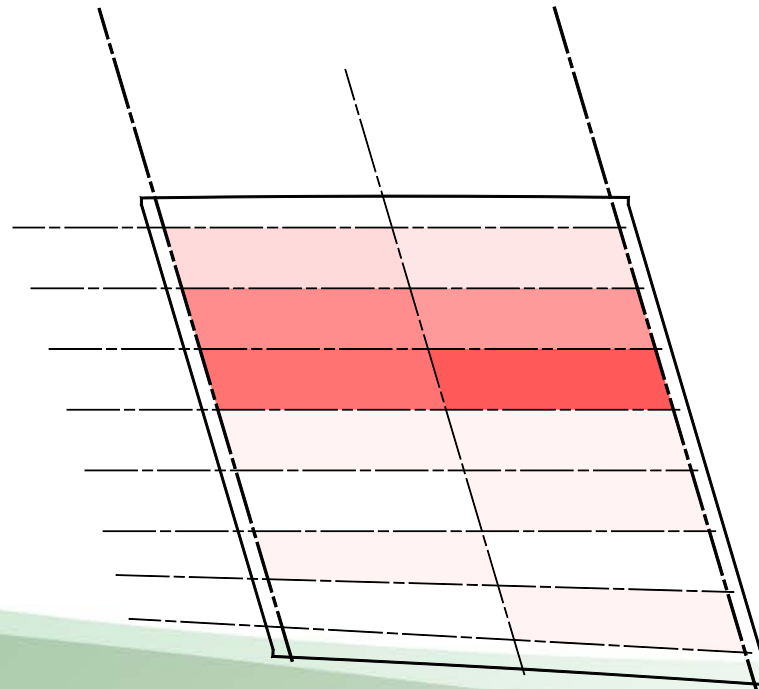


Sample Crack Intensity Diagram



Interstate 5 – Prairie Creek Brgs (near Olympia)

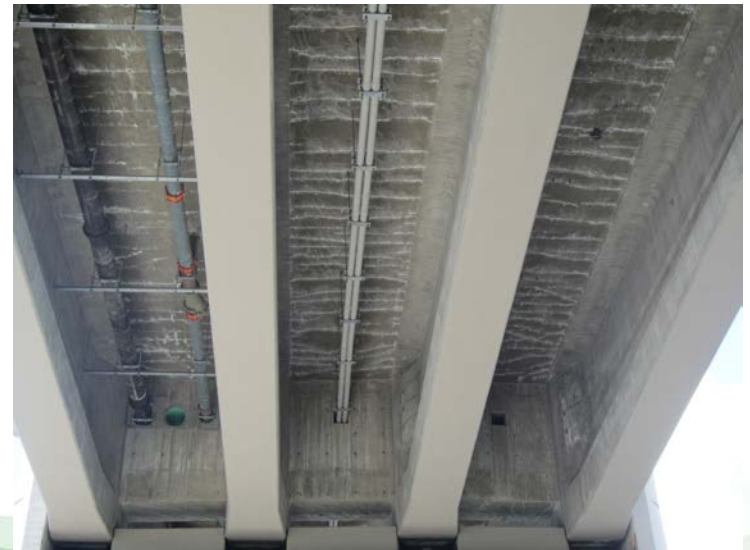
Single Span prestress girders



Bridges Ranked by Average Crack Intensity

Br. No.	Bridge Name	Contract	Year	Perform.	Intensity	Cement.	Shrink.
303/4A	MANETTE BRIDGE	7926	2011	No	73%	735	--
16/7S-E	S SPRAGUE RAMP	7594	2010	No	59%	735	--
90/106N	GOLD CREEK WB	7852	2012	No	44%	735	--
90/105.5S	GOLD CREEK ANIMAL CROSSING EB	7852	2010	No	40%	735	--
529/25	EBEY SLOUGH	7948	2012	No	36%	735	--
6/115	S FORK CHEHALIS R	7587	2009	No	32%	735	--
90/105.5N	GOLD CREEK ANIMAL CROSSING WB	7852	2012	No	32%	735	--
5/302E	PRAIRIE CREEK NB	7465	2009	No	18%	735	--
2/651W-S	W-S RAMP OVER US 2/US 395	7610	2011	No	13%	735	--

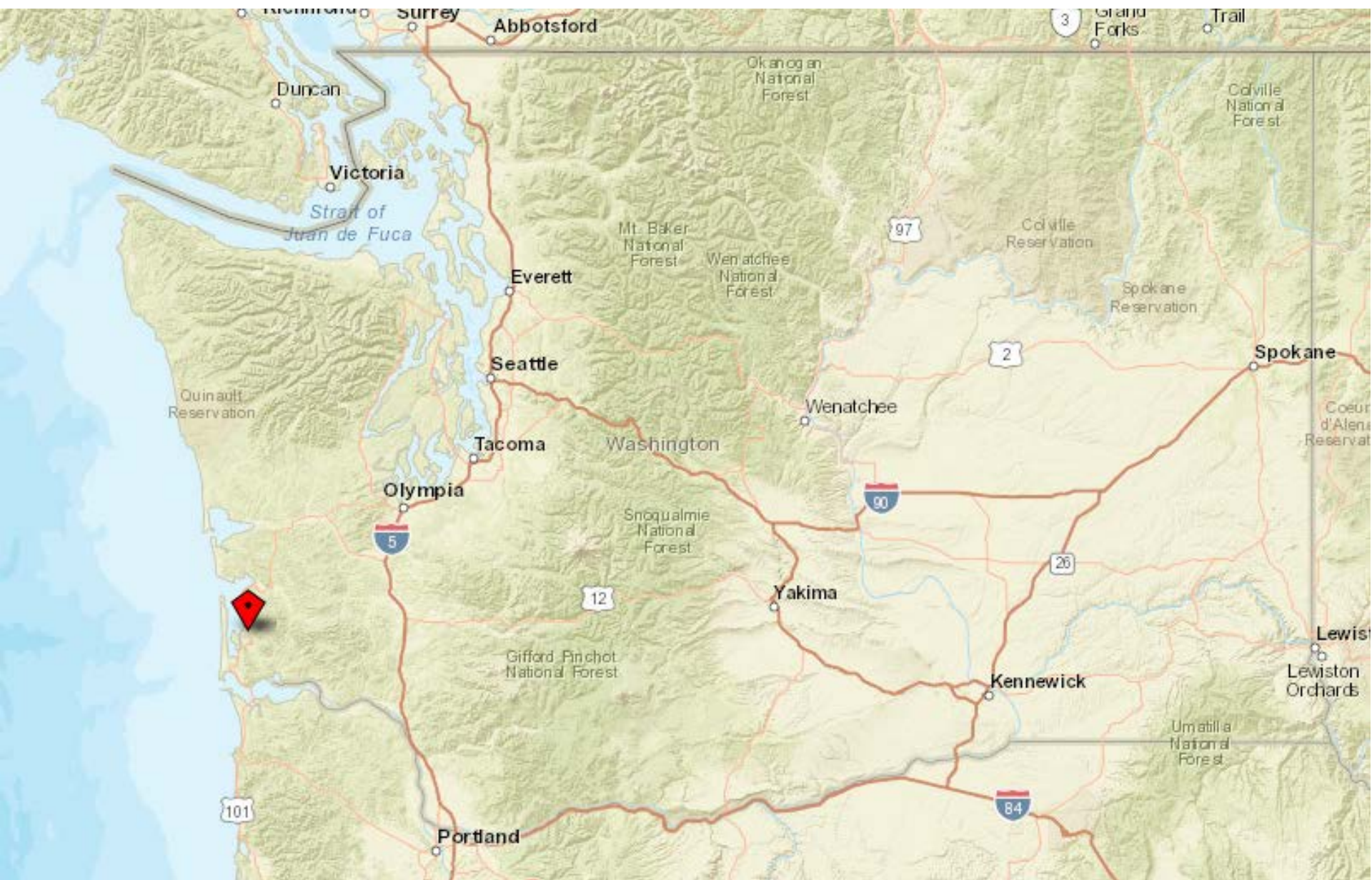
**Traditional
Mix Design
Br Deck Concrete**



Bridges Ranked by Average Crack Intensity

Br. No.	Bridge Name	Contract	Year	Perform.	Intensity	Cement.	Shrink.
5/434SCD	SBCD OVER SR 16 HOV & RAMPS	8189	2013	Yes	36%	565	0.028%
195/117	CHENEY SPOKANE RD OVER US 195	8378	2014	Yes	10%		
5/234W	I-5 OVER BLAKESLEE JCT RR	8272	2013	Yes	9%	580	0.030%
16/3W	SR 16 OVER HOV	8189	2014	Yes	9%	565	0.028%
9/134	PILCHUCK CREEK	8383	2014	Yes	7%	611	0.031%
105/4	NORTH RIVER	8345	2014	Yes	7%	610	0.018%
2/8.5N-W	N-W RAMP (BICKFORD AVE) OVER US 2	8286	2013	Yes	6%	610	0.032%
105/3	SMITH CREEK	8345	2013	Yes	6%	610	0.018%
6/8	WILLAPA RIVER	8464	2014	Yes	5%	610	0.018%
5/232NCD	SKOOKUMCHUCK RIVER NCD	8272	2013	Yes	2%	580	0.030%
5/232SCD	SKOOKUMCHUCK RIVER SCD	8272	2013	Yes	1%	580	0.030%
5/229	MELLON STREET COUPLET	8473	2014	Yes	< 1%	580	0.028%
395/441N-E	N-E RAMP OVER N-N RAMP	7610	2011	Yes	< 1%	565	0.034%
101/44	BONE RIVER	8292	2013	Yes	< 1%	610	0.018%
101/31	MIDDLE NEMAH RIVER	8344	2014	Yes	0%	610	0.018%

**New Performance Spec
For Br Deck Concrete**



US101 Middle Nemah River Bridge



Prestress Concrete Girder Bridge

Built in 2014

US101 Middle Nemah River Bridge



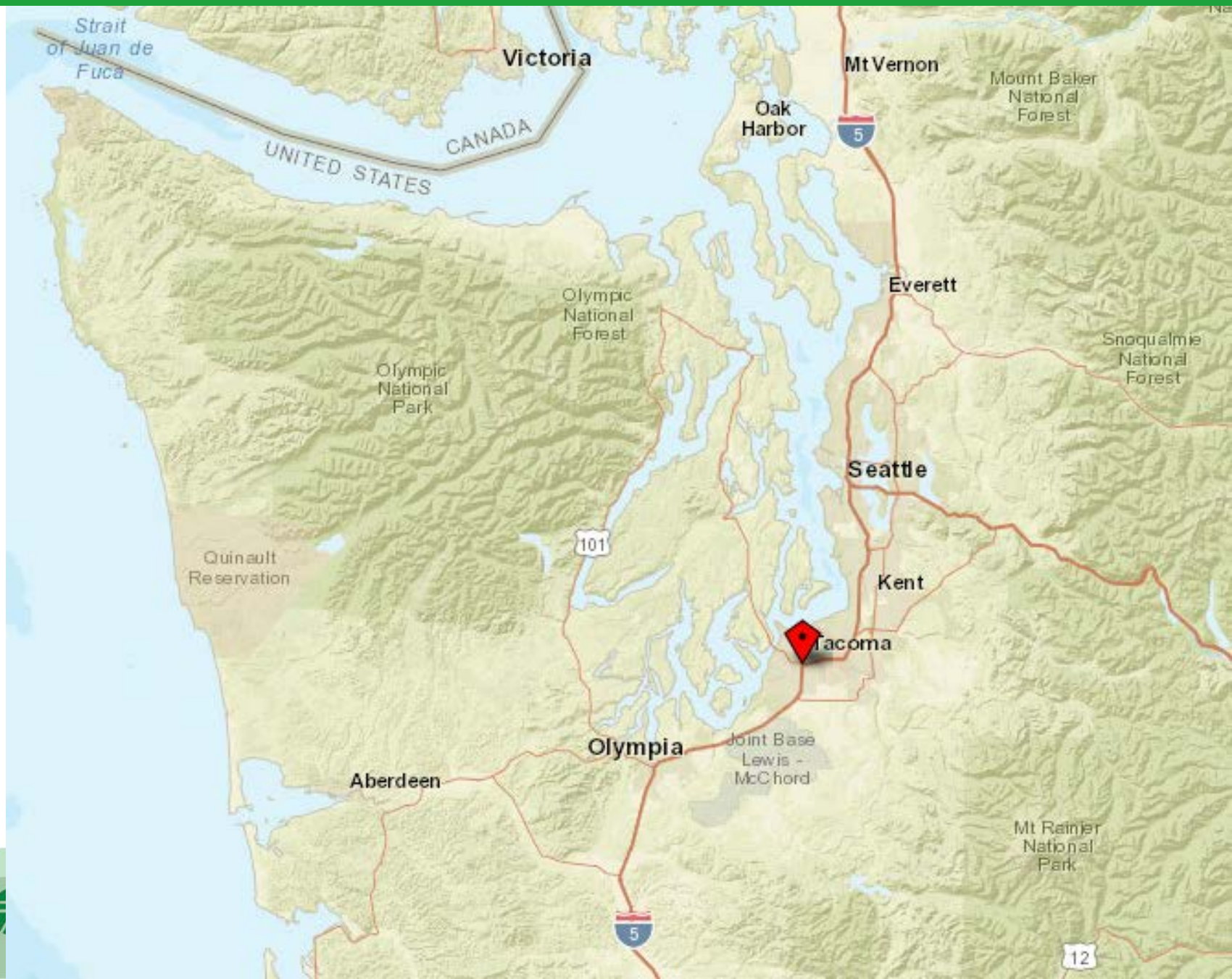
US101 Middle Nemah River Bridge



US101 Middle Nemah River Bridge



Interstate 5 / State Route 16 Ramp bridge



Interstate 5 / State Route 16 Ramp bridge

**New Performance Concrete
for Bridge Decks**

Steel Girder Bridge

Built in 2013

Interstate 5 / State Route 16 Ramp bridge

**New Performance Concrete
for Bridge Decks**

Crack Intensity 36%

Built in 2013



Interstate 5 / State Route 16 Ramp bridge

New Performance Concrete
for Bridge Decks



Crack Intensity 36%



Built in 2013

Summary

1. Fewer cracks in the performance mixes compared to the traditional Concrete Mix Design (Concrete Bridges).
2. A few of the traditional bridge decks performed similar to the performance based bridge decks.
3. Only one of the 15 performance based concrete decks in the study had a high intensity of cracking (Steel Girder Bridge).

Questions?

