CONSTRUCTING A CRACK-FREE BRIDGE DECK IN WASHINGTON STATE

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Overview of Presentation

- Describe WSDOT's deck cracking issues
- Summarize WSU research work
- Show results of trial project
- Discuss lessons learned and the way forward

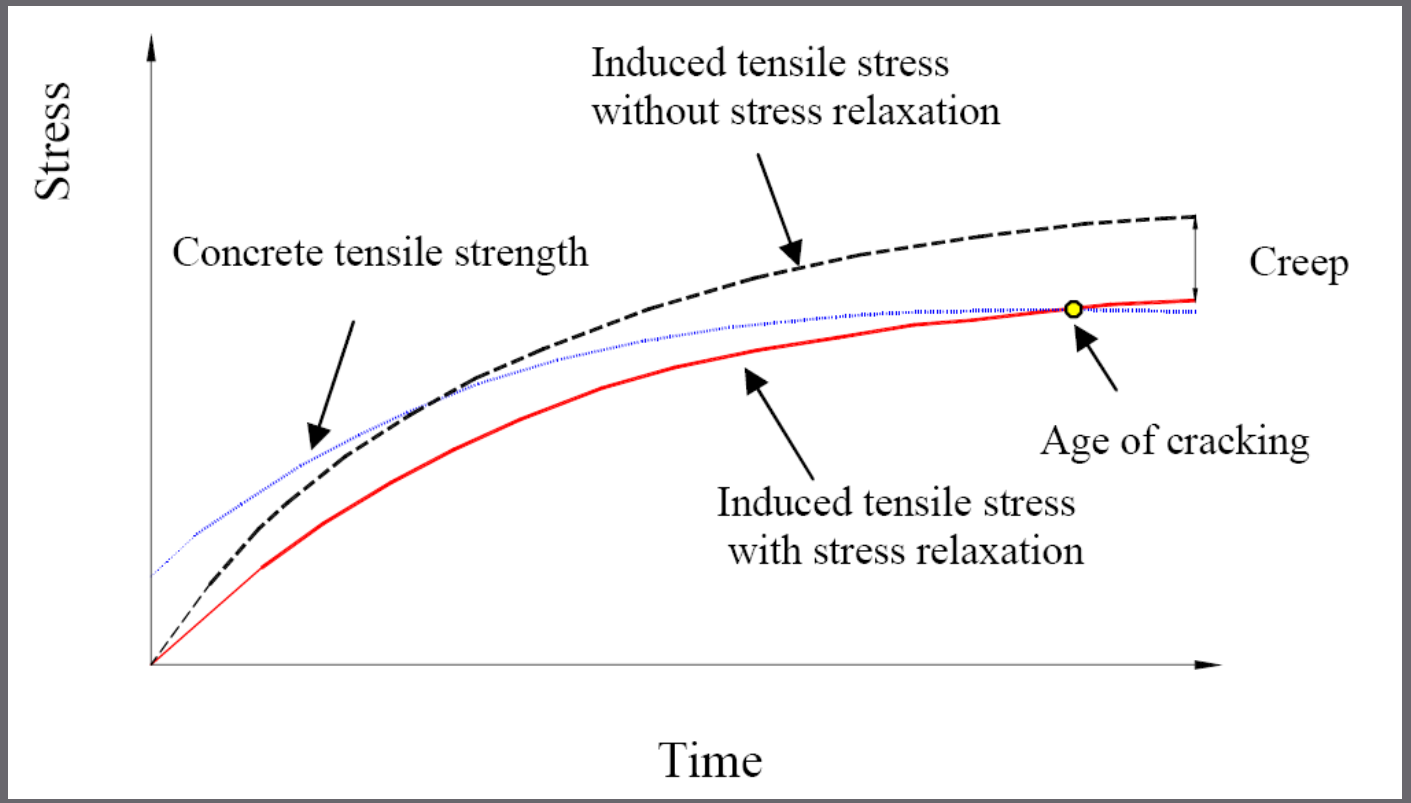
Typical Deck Performance

- WSDOT has observed bridge deck cracking in newly-constructed decks for about 10-15 years.

Typical Deck Performance

Causes of Bridge Deck Cracking

- Many factors involved, but essentially a shrinkage/tensile strength problem:



Mechanism of Cracking (from Neville 1996)

What can we do to fix the problem?

- Three "areas" we can adjust to reduce bridge deck cracking:
  - Design/detailing of the deck slab (NCHRP Synthesis 333, etc.) ★
  - Deck curing/environmental conditions ★
  - Concrete mix design ✖

Evaluation of Concrete Mix Designs

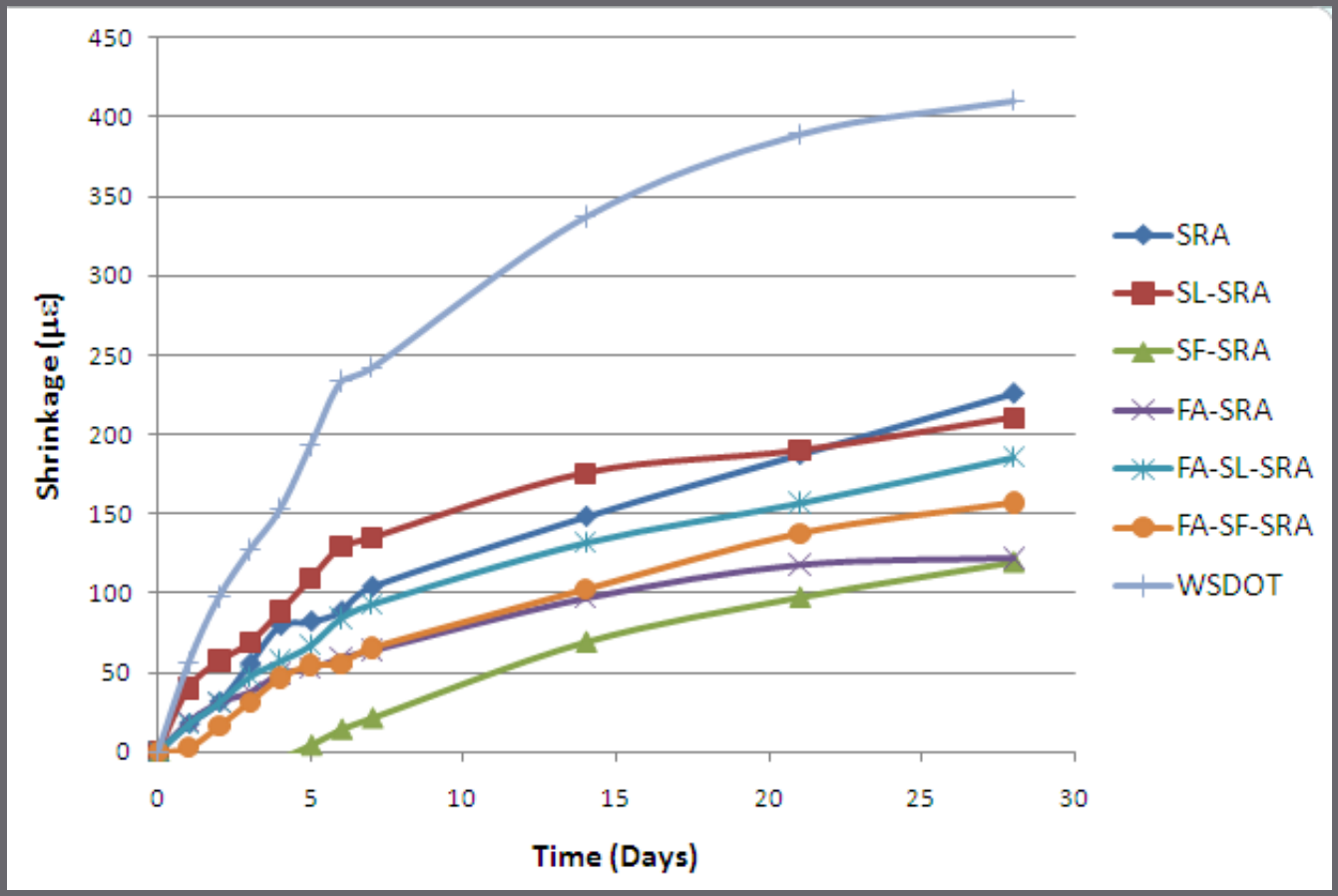
- Brought in Washington State University (WSU)* to study the issue. Objectives:
  - Determine causes of shrinkage cracking
  - Identify mitigation strategies
  - Evaluate current WSDOT mix designs
  - Develop new mix deigns (with improved properties)
  - Provide recommendations on improved mix designs and practices.

* Dr. Qiao, Dr. McLean, and graduate student Jianmin Zhuang

Free Shrinkage Test
AASHTO T 160 (ASTM C 157)

- Unrestrained shrinkage
- WSDOT deck mix: 420 microstrains
- Much lower shrinkage possible

High Performance Concrete Decks



- WSDOT Class 4000D mix: 410 ± microstrains.
- Identified much room for improvement

Restrained Shrinkage Test
AASHTO T 334

- Tests combination of tensile strength and shrinkage
- WSDOT mix cracks between 8-11 days
- Several mix designs developed that don't crack

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

Implementation of Research

- Based on WSU research, developed a performance concrete mix design.
- Included performance requirements in a contract for a bridge in eastern Washington (Spokane)
- Made significant changes in bridge deck curing and finishing

Mix Design Performance Requirements

- Summary of performance requirements
  - 28-day compressive strength: 4000 psi min.
  - Air content: 6.5% to 9.5%
  - Mix paste (cement + water) < 25% of tot. mix volume.
  - Nominal max. aggregate size: 1 ½”
  - Permeability: < 2000 coulombs at 56 days
  - Freeze-thaw Durability: 90% min. after 300 cycles
  - Scaling: Visual rating ≤ 1
  - Shrinkage: <320 με at 28 days

Performance Mix Design

Property	Required	Proposed Mix	Typical WSDOT
Compressive Strength, psi (AASHTO T23)	4000	5660	7230
Rapid Chloride, coulombs (ASTM C-1202)	2000	1452	
Freeze-thaw resist., 300 cyc. (ASTM C-666)	90% min.	101%	
Scaling resistance (ASTM C-672)	<= 1	0	
Shrinkage, micro-strains (AASHTO T160)	< 320	340	410
Paste content, % by volume of mix	<=25	25	31+
Aggregate size, nominal max.	1 ½"	1 ½"	1"
Air content, %	6.5-9.5	6.5	6.5

High Performance Concrete Decks

- Highlights of deck finishing/curing requirements:
  - Continuous fogging until wet cure is established
    - Maintain 100% R.H.
  - Apply wet burlap immediately behind bidwell
    - No tining
    - No curing compound
  - Longitudinal grooves installed post-cure.

High Performance Concrete Decks

- Before constructing bridge deck, contractor did some mock-up work.

High Performance Concrete Decks

- Mock-up used to fine-tune concrete mixing and placement.
- Once adjustments were made, it was time to construct the bridge deck.

Fogging Video

Burlap Placement – Video

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Deck Fogging

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Diamond Grinding

Results: a crack-free deck!

High Performance Concrete Decks

- Lessons Learned
  - Extra costs for mix design development ($10-15k)
  - Difficult to maintain 100% R.H. at high temps. (90°F)
  - Impossible to maintain humidity when it's freezing.
  - Maintaining consistent air content was a challenge.
  - Finishing took some practice.
  - Successful -- produced a crack-free deck
- Industry partnership made this possible
- WSDOT began full implementation starting August 2011.

Resources

- More details on WSDOT's performance deck concrete can be found at:

  http://www.wsdot.wa.gov/biz/construction/WBESPresentation.cfm

  - Copies of current performance deck concrete specifications
  - WSU research report
  - Presentation based on WSU research report
  - Documentation and photos from WSDOT's first performance deck concrete project.
- Contact information:
  - gainesm@wsdot.wa.gov
  - (360) 705-7827 (office)

THANK YOU!

Any comments?