Bridge Deck Crack Prevention

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Division Of Engineering Services

Deck cracking is a long standing problem.

We spend annually on deck crack mitigation.

$50 Million

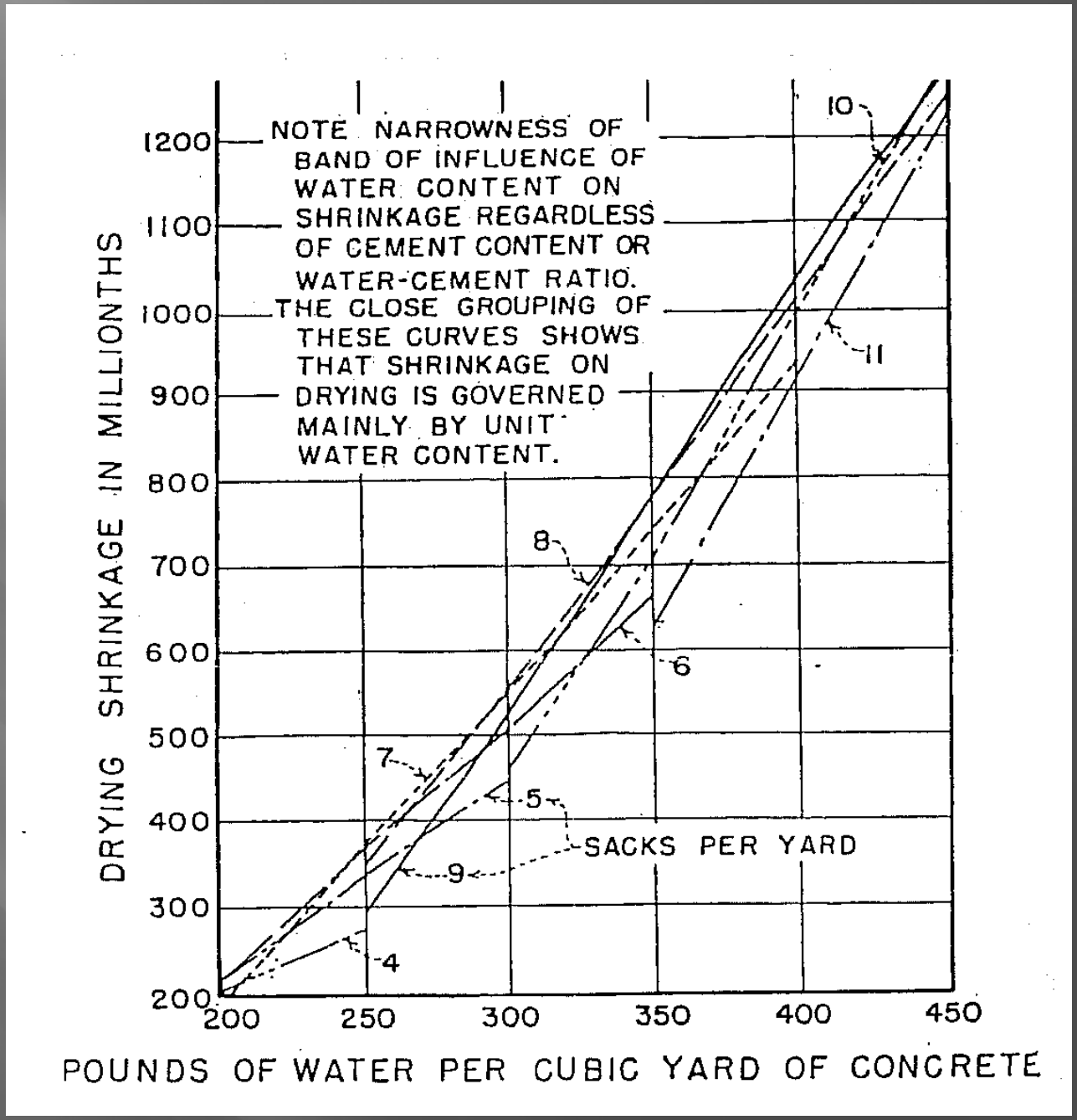
- In 1930 Raymond Davis* summarized investigations ranging from the 19th century up to 1930 about facts of moisture as well as thermal-related volume changes in concrete.

*R.E. Davis *"Summary of Results of Investigations Having to Do with Volumetric Changes in Cement, Mortars, and Concretes Due to Causes Other than Stress"* - Journal of ACI Proceedings, 1930 Vol. 26

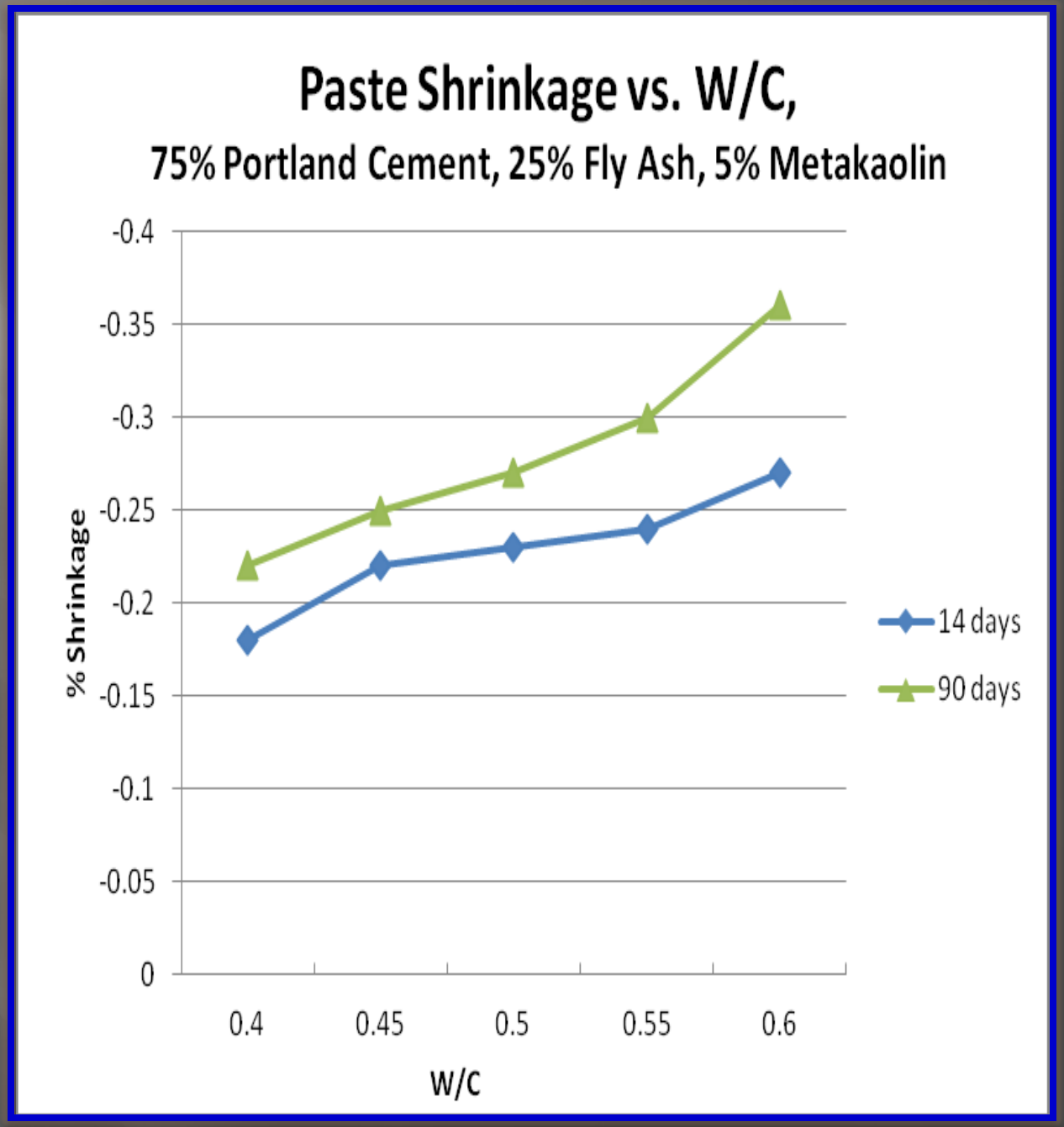
Four Were Mix Design Factors

1. *Water content*
2. *Composition and fineness of cement*
3. *Proportions of cement and aggregate*
4. *Type and gradation of aggregate*

Concrete Manual, 6th edition,1956 U.S. Depart. of Interior, Bureau of Reclamation



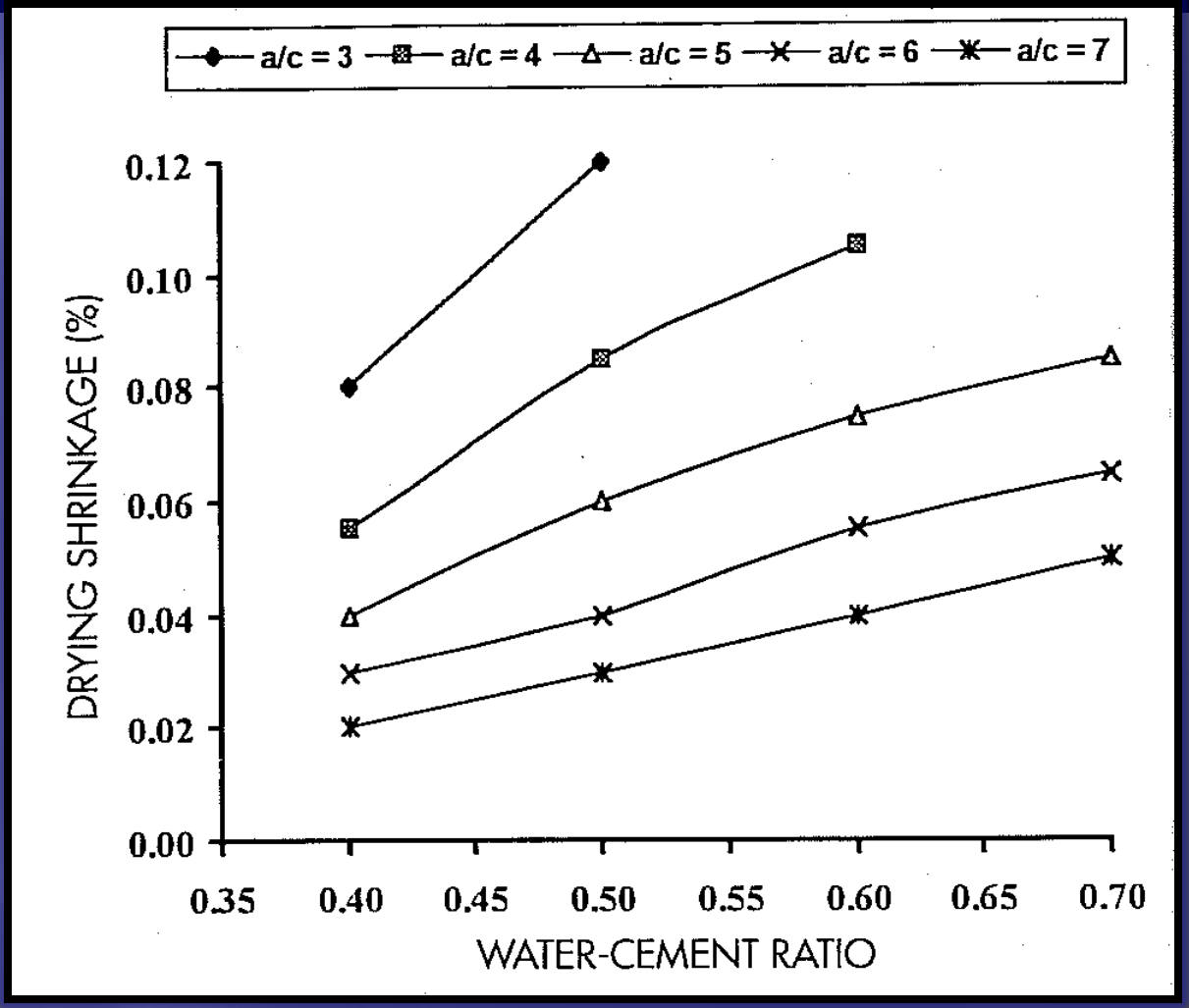
How does the observation (phenomenon) of direct relation of water content exclusively to dry shrinkage fit with the observation that water to cement ratio of paste directly relates to drying shrinkage of paste???



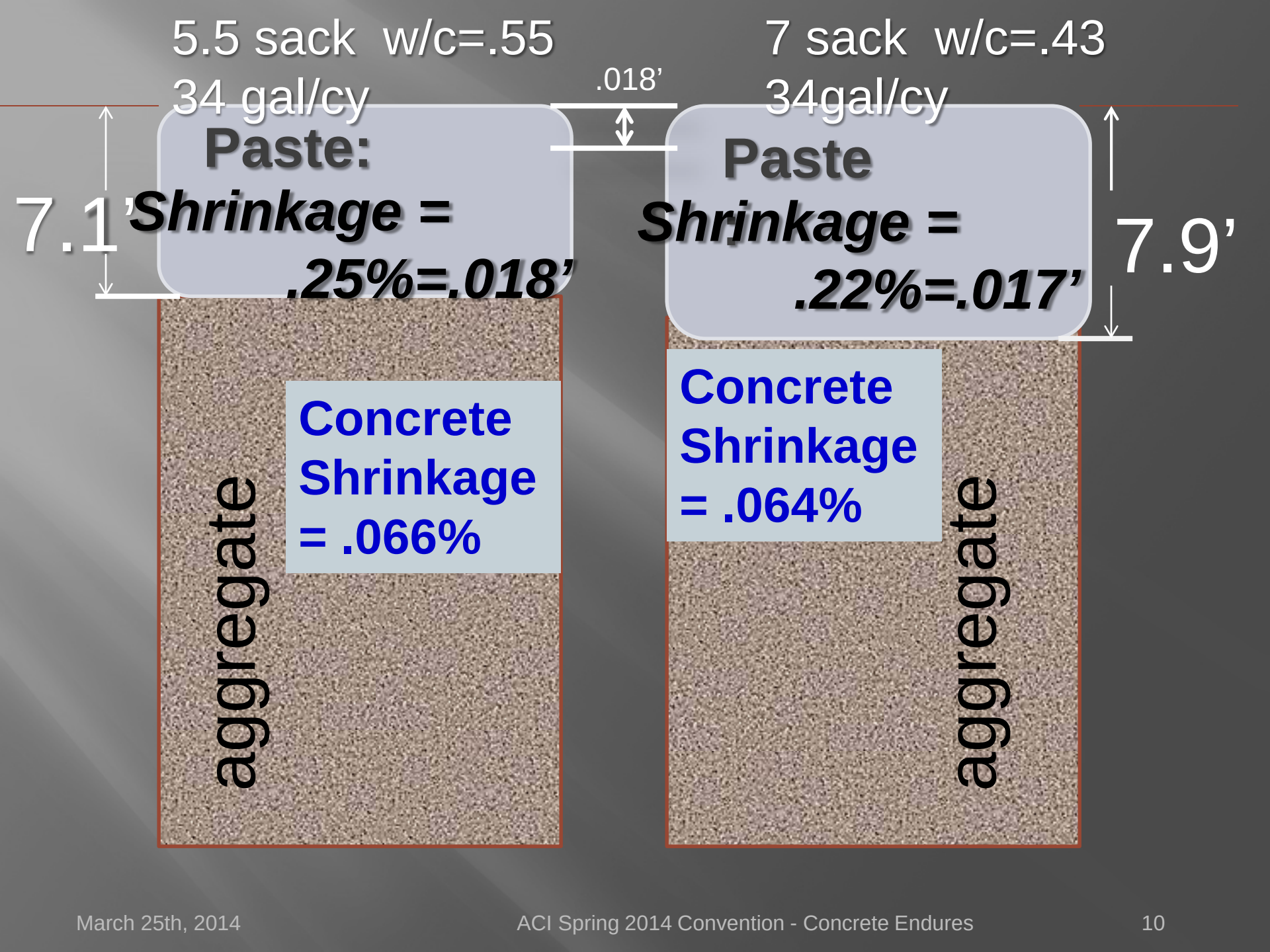
And how does the aggregate to cement ratio's direct relationship to drying shrinkage fit with the observation of water content exclusive's direct relation to drying shrinkage ??

Effect of Aggregate Cement Ratio (a/c) and W/C on Dry Shrinkage. Source: Lea, F.M. Chemistry of Cement & Concrete,1971.

Reprinted in *Concrete International* , April 1998



Though it may appear that water itself is the cause of shrinkage, the shrinkage depends on the paste content and the nature, including w/c, of the paste.


5.5 sack w/c=.55
34 gal/cy
.018’
7 sack w/c=.43
34gal/cy
7.1’
Paste:
Shrinkage =
.25%=.018’
Paste
Shrinkage =
.22%=.017’
7.9’
Concrete
Shrinkage
= .066%
Concrete
Shrinkage
= .064%
aggregate
aggregate

Role of Aggregate

The aggregates' rigidity restrains the paste's shrinkage.

Role of Aggregate

Some aggregate are more rigid than others:

1) quartz
2) limestone
3) granite
4) basalt
5) sandstone

"Dry Shrinkage of Concrete as Affected by Many Factors"
Roy W. Carlson, ASTM Proceedings, 1938, Volume 38, Part II

Webber Creek Bridge Deck Study*

Division of Highways (Caltrans)

1972 Final Report

8 year study of the Webber Creek Bridge Deck.

***M. Horn, C., Stewart, and R. Boulware; "Webber Creek Deck Crack Study Final Report", State of California, Division of Highways, Bridge Department. March 1972**

Webber Creek Bridge Deck Study

- **The deck was divided into 8 sections, each section consisting of a 137 foot simple span.**
- **The variables were 2 aggregate sources, 2 cement types and 2 rebar loadings.**
  1. *Aggregate: Sandstone and Quartz*
  2. *Cement: Type 1 and Type II cement*
  3. *Rebar: "Typical" & added longitudinal rebar*

Webber Creek Bridge Deck Study

- Type II cement and the denser rebar spacing had some beneficial effect reducing deck cracking.
- After 8 years the spans having the Type II cement and "dense rebar" were again compared:

Webber Creek Bridge Deck Study

- Quartz aggregate - 26 ft of soffit cracking with no leaking cracks
- Sandstone aggregate - 533 ft of soffit cracking with 18 cracks leaking.

Webber Creek Bridge Deck Study

Conclusion:

"Aggregate…was the most important factor regarding deck cracking."

The Structural Engineers Association of Calif.'s Committee on Shrinkage of Concrete reported in May 1965:

- 28 day shrinkage on 4X4 prisms
  - Represent about 40% of ultimate
  - Ultimate occurs in approximately 64 weeks.
  - Based on 20 years of testing done by Troxell, Raphael & Davis.

The Report rated concrete based on 28 day shrinkage as follows:

- Class A - shrinkage ≤ .032%
- Class B - .032%<shrinkage ≤ .048%
- Class C - .048%< shrinkage ≤ .064%

The California Producers Committee on Volume Change

"Drying Shrinkage of Concrete"

March 1966*

Reported that for aggregates in California:

- **5% could produce Class A (.032%)**
- **90% could produce Class B (.048%)**

***R Gaynor, R. Barneyback, E. Howard, E. Jumper, R. Tobin; "Drying Shrinkage of Concrete"; prepared & published by The California Producers Committee on Volume Change and Affiliated Technical Organizations, March, 1966**

The best bridge deck performance obtained at the Webber Creek Bridge could only be achieved in the best of circumstances.

To date we have

- Limits on water.
- Min and Max cement content
- Gradation requirements
- Aggregate property requirements
- And

Cracked Decks

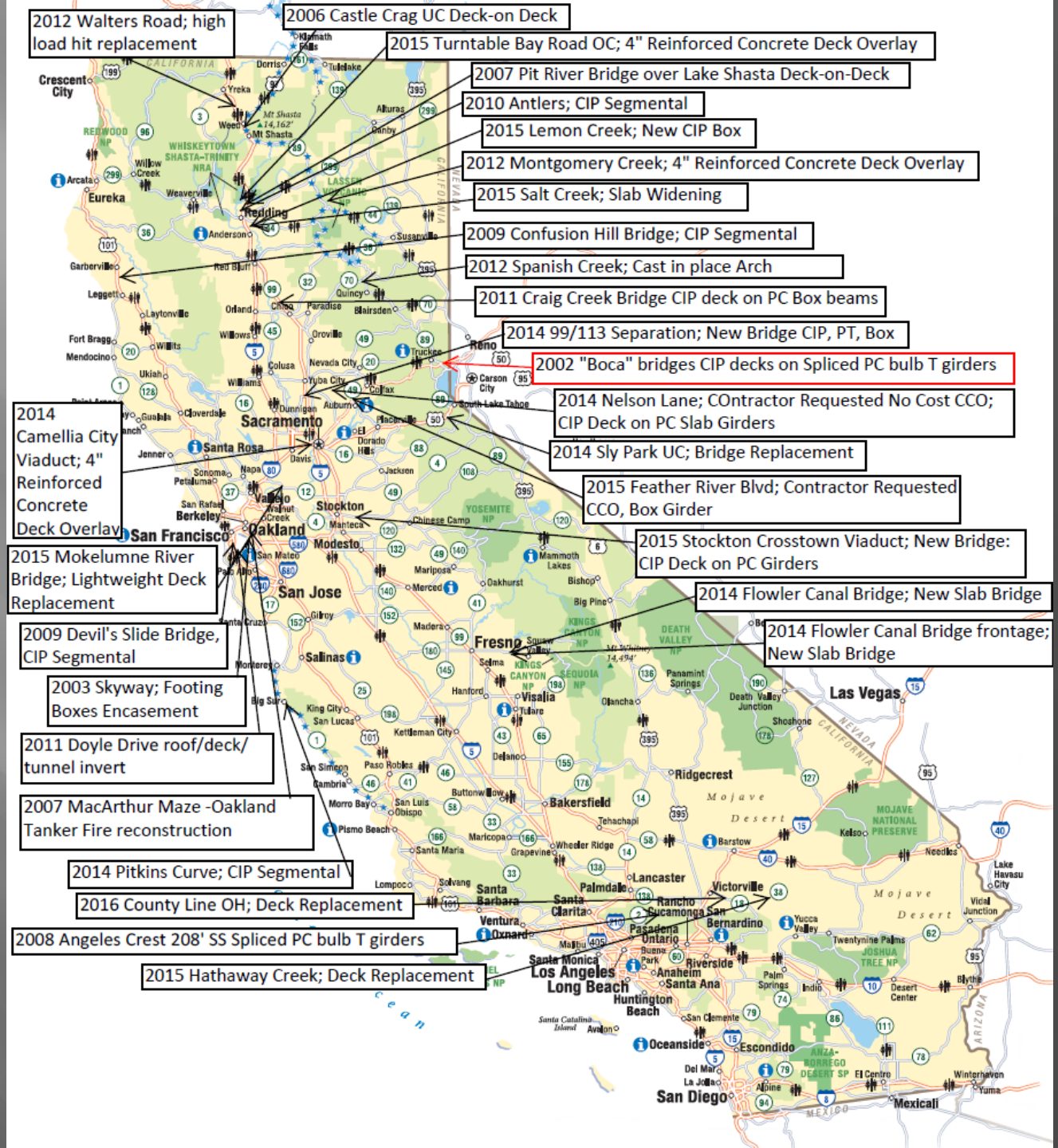
We now have a solution.

Draft Specifications

- The 28 day shrinkage required maximum of 0.032%.
- Min SRA ¾ gal/cy
- Require 1 lb/cy of micro fibers and 3lb/cy of macro fibers.
- Continuous misting from finished strike off until curing medium is applied.

This is what it costs.

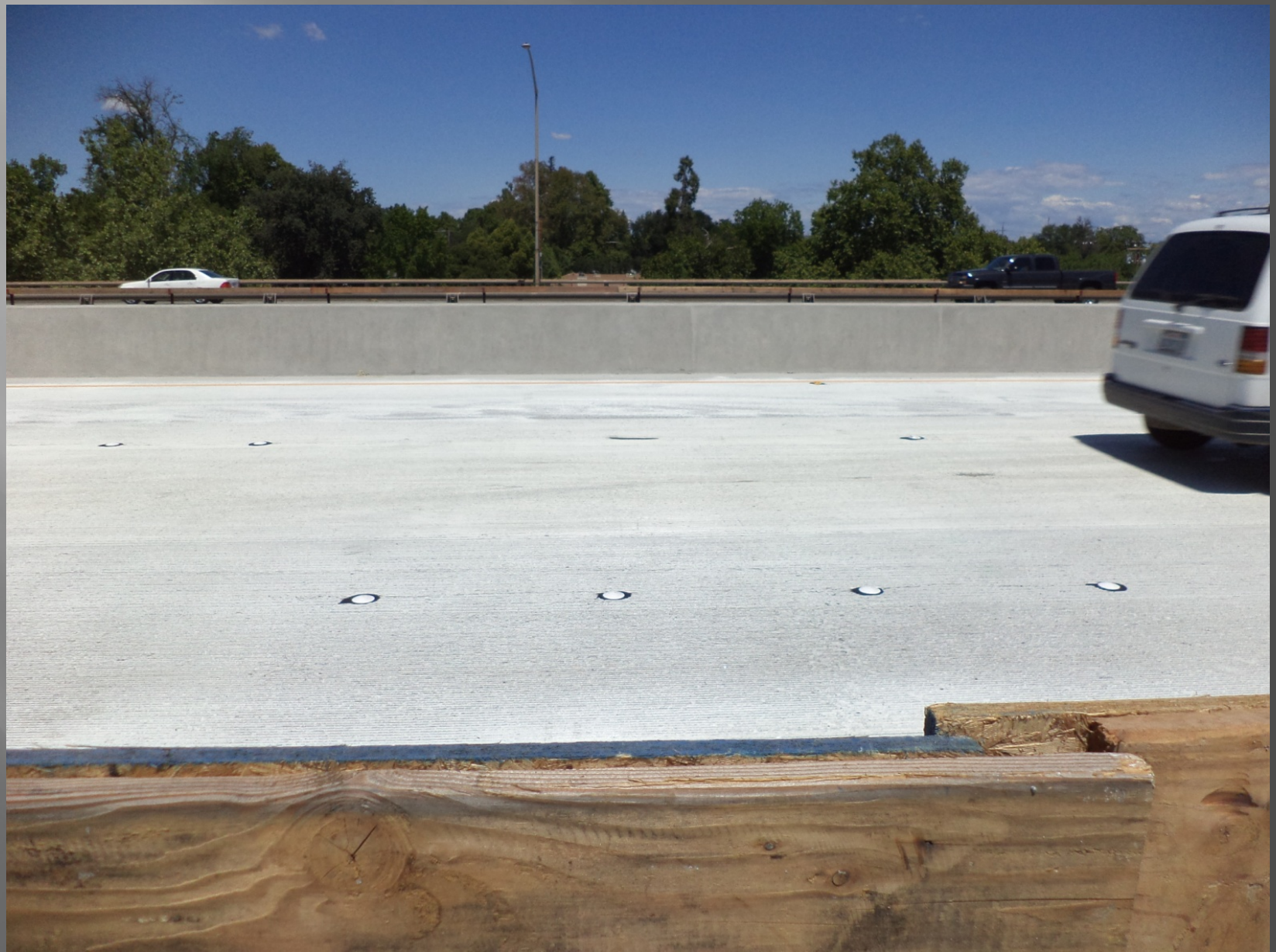
- **The pilot projects show no measurable change to the price bid for structure concrete.**
- **When implemented via CCO the cost has been about:**
  - **SRA @ 1 Gal/CY = $25/CY**
  - **Fibers @ 4 lb/CY = $25/CY**


2012 Walters Road; high load hit replacement
2006 Castle Crag UC Deck-on Deck
2015 Turntable Bay Road OC; 4" Reinforced Concrete Deck Overlay
2007 Pit River Bridge over Lake Shasta Deck-on-Deck
2010 Antlers; CIP Segmental
2015 Lemon Creek; New CIP Box
2012 Montgomery Creek; 4" Reinforced Concrete Deck Overlay
2015 Salt Creek; Slab Widening
2009 Confusion Hill Bridge; CIP Segmental
2012 Spanish Creek; Cast in place Arch
2011 Craig Creek Bridge CIP deck on PC Box beams
2014 99/113 Separation; New Bridge CIP, PT, Box
2002 "Boca" bridges CIP decks on Spliced PC bulb T girders
2014 Nelson Lane; COntractor Requested No Cost CCO; CIP Deck on PC Slab Girders
2014 Sly Park UC; Bridge Replacement
2015 Feather River Blvd; Contractor Requested CCO, Box Girder
2014 Camellia City Viaduct; 4" Reinforced Concrete Deck Overlay
2015 Stockton Crosstown Viaduct; New Bridge: CIP Deck on PC Girders
2015 Mokelumne River Bridge; Lightweight Deck Replacement
2014 Flowler Canal Bridge; New Slab Bridge
2014 Flowler Canal Bridge frontage; New Slab Bridge
2009 Devil's Slide Bridge, CIP Segmental
2003 Skyway; Footing Boxes Encasement
2011 Doyle Drive roof/deck/ tunnel invert
2007 MacArthur Maze -Oakland Tanker Fire reconstruction
2014 Pitkins Curve; CIP Segmental
2016 County Line OH; Deck Replacement
2008 Angeles Crest 208' SS Spliced PC bulb T girders
2015 Hathaway Creek; Deck Replacement
Crescent City
Eureka
Redding
Sacramento
San Francisco
Oakland
San Jose
Stockton
Modesto
Fresno
Bakersford
Las Vegas
Los Angeles
Long Beach
San Diego
Reno
Mexicali

6 months old

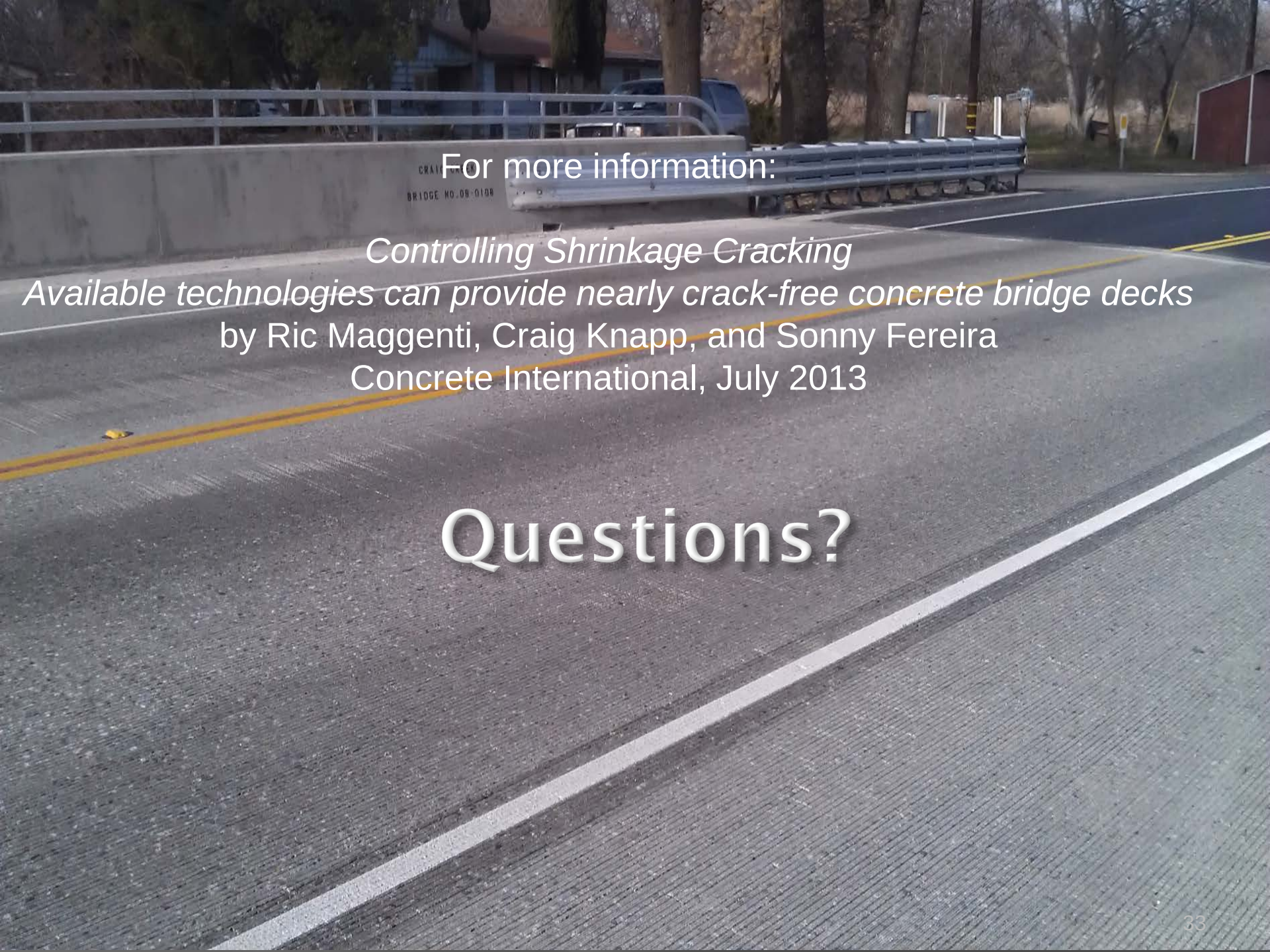
9 months old

1 year old



2.5 years old

7 years old



For more information:

Controlling Shrinkage Cracking
Available technologies can provide nearly crack-free concrete bridge decks
by Ric Maggenti, Craig Knapp, and Sonny Fereira
Concrete International, July 2013

Questions?

28 shrinkage = .032 with SRA

28 shrinkage = .032 without SRA

28 shrinkage = .032 with SRA

Misting

Drying Shrinkage (Percent) 28-Days Drying at 7 ½ Sacks per Cubic Yard