Bridge Deck Crack Prevention

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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??
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 = 0.55
34 gal/cy

7.1‘

Paste:
Shrinkage = 0.25% = 0.018’

Concrete Shrinkage = 0.066%

aggregate

0.018’

7 sack w/c = 0.43
34 gal/cy

7.9‘

Paste
Shrinkage = 0.22% = 0.017’

Concrete Shrinkage = 0.064%

aggregate

March 25th, 2014
Role of Aggregate

The aggregates’ rigidity restraints 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
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
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.
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 ≤ 0.032%
- **Class B** - 0.032% < shrinkage ≤ 0.048%
- **Class C** - 0.048% < shrinkage ≤ 0.064%
The California Producers Committee on Volume Change
“Drying Shrinkage of Concrete”
March 1966*

Reported that for aggregates in California:

- 5% could produce Class A (0.032%)
- 90% could produce Class B (0.048%)

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.
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
6 months old
1 year old
7 years old
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 1/2 Sacks per Cubic Yard

Not crushed aggregate
Crushed aggregate

SHRINKAGE (PERCENT)