EUCLID CHEMICAL

Low Shrinkage Fiber-Reinforced Concrete for Improved Crack Control and Durability

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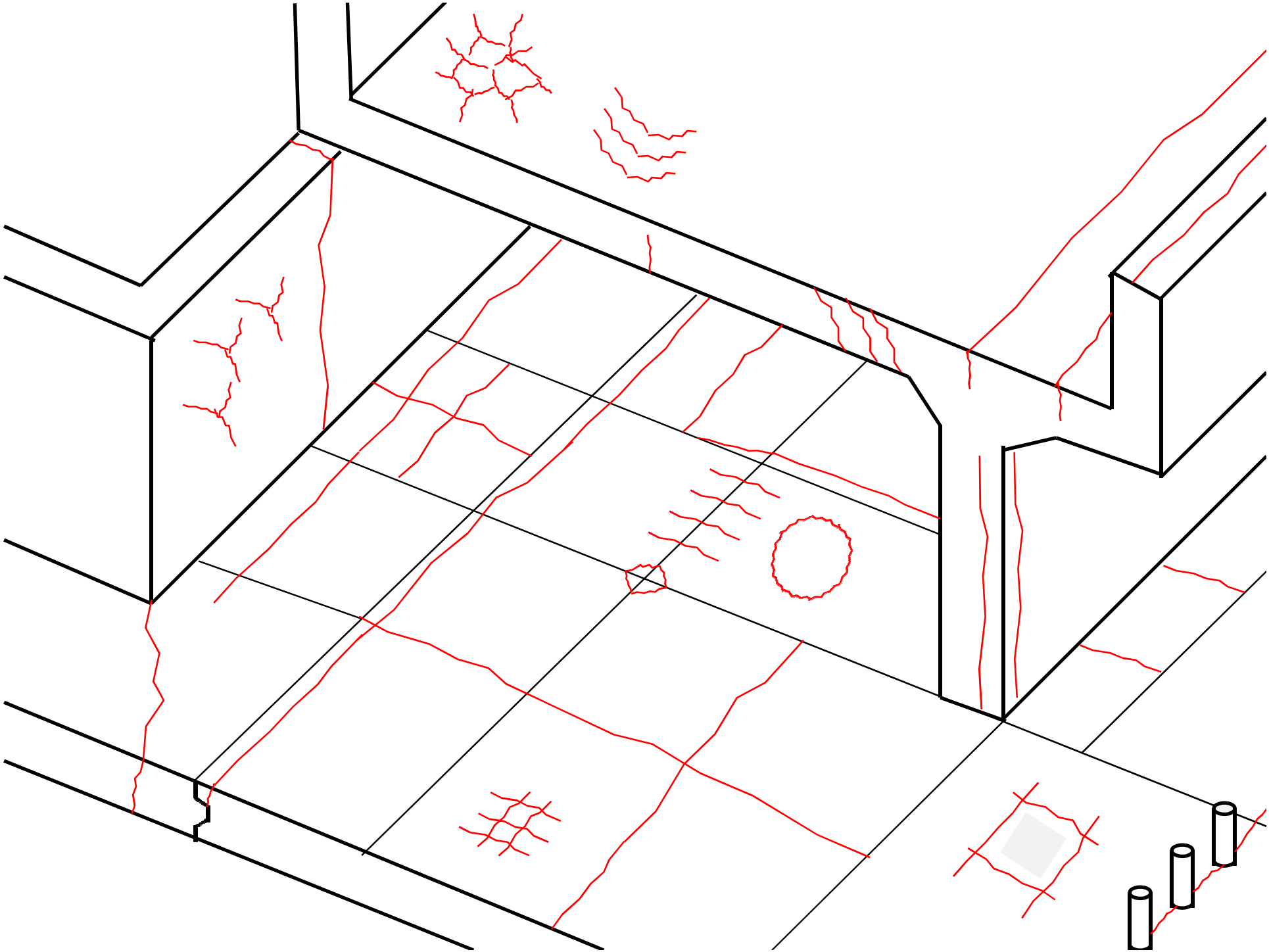
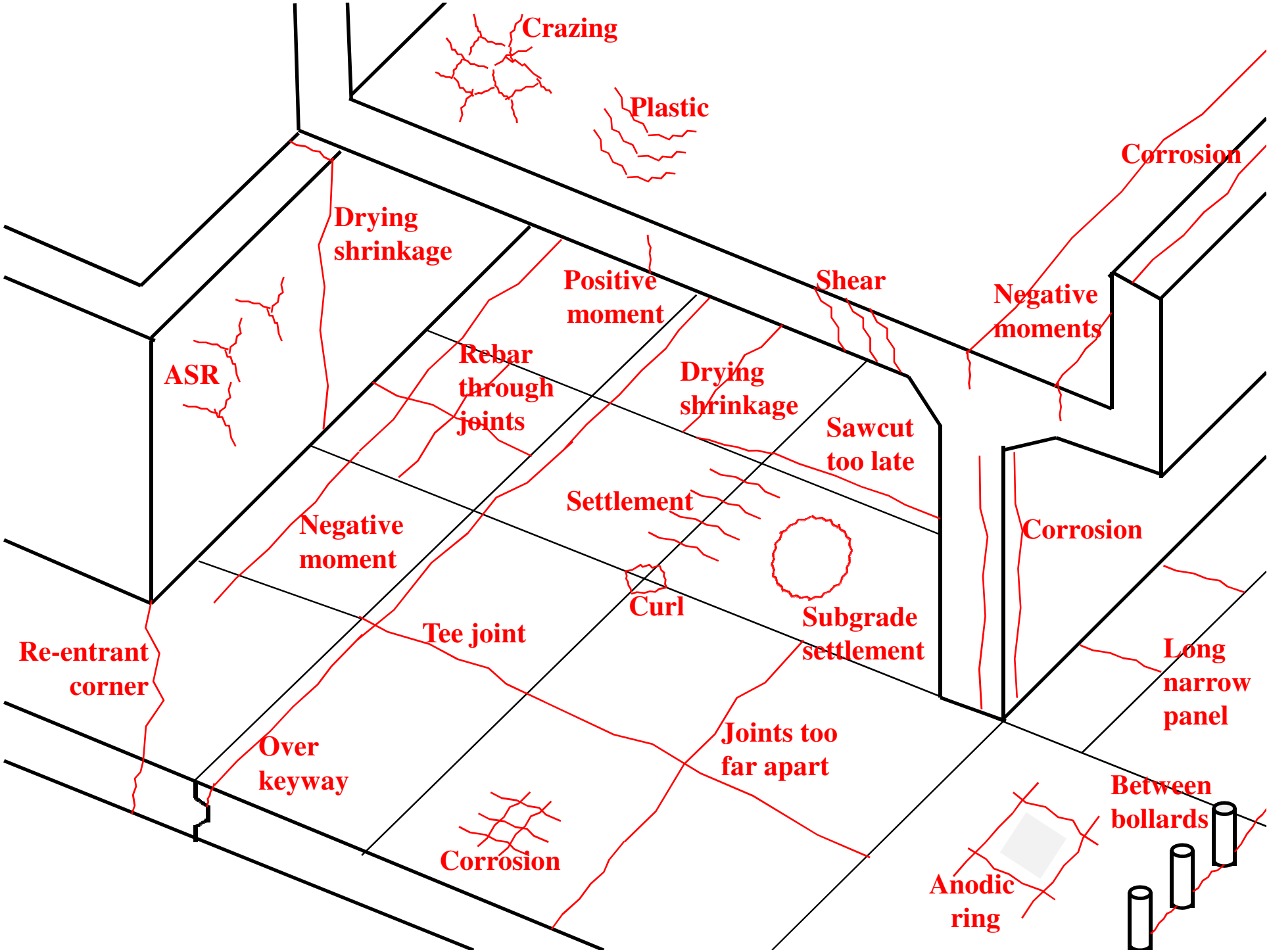
Concrete is cracked by …

- Low strength from improper curing
- Low strength from excess water
- Shrinkage cracking
- Freeze thaw cycles
- Chloride attack
- Alkali silica reaction
- Sulfate attack
- Acid attack
- Carbonation
- Fatigue and overloading (least)




Crazing
Plastic
Corrosion
Drying shrinkage
Positive moment
Shear
Negative moments
ASR
Rebar through joints
Drying shrinkage
Sawcut too late
Settlement
Negative moment
Corrosion
Curl
Subgrade settlement
Tee joint
Re-entrant corner
Long narrow panel
Joints too far apart
Over keyway
Between bollards
Corrosion
Anodic ring


STOP

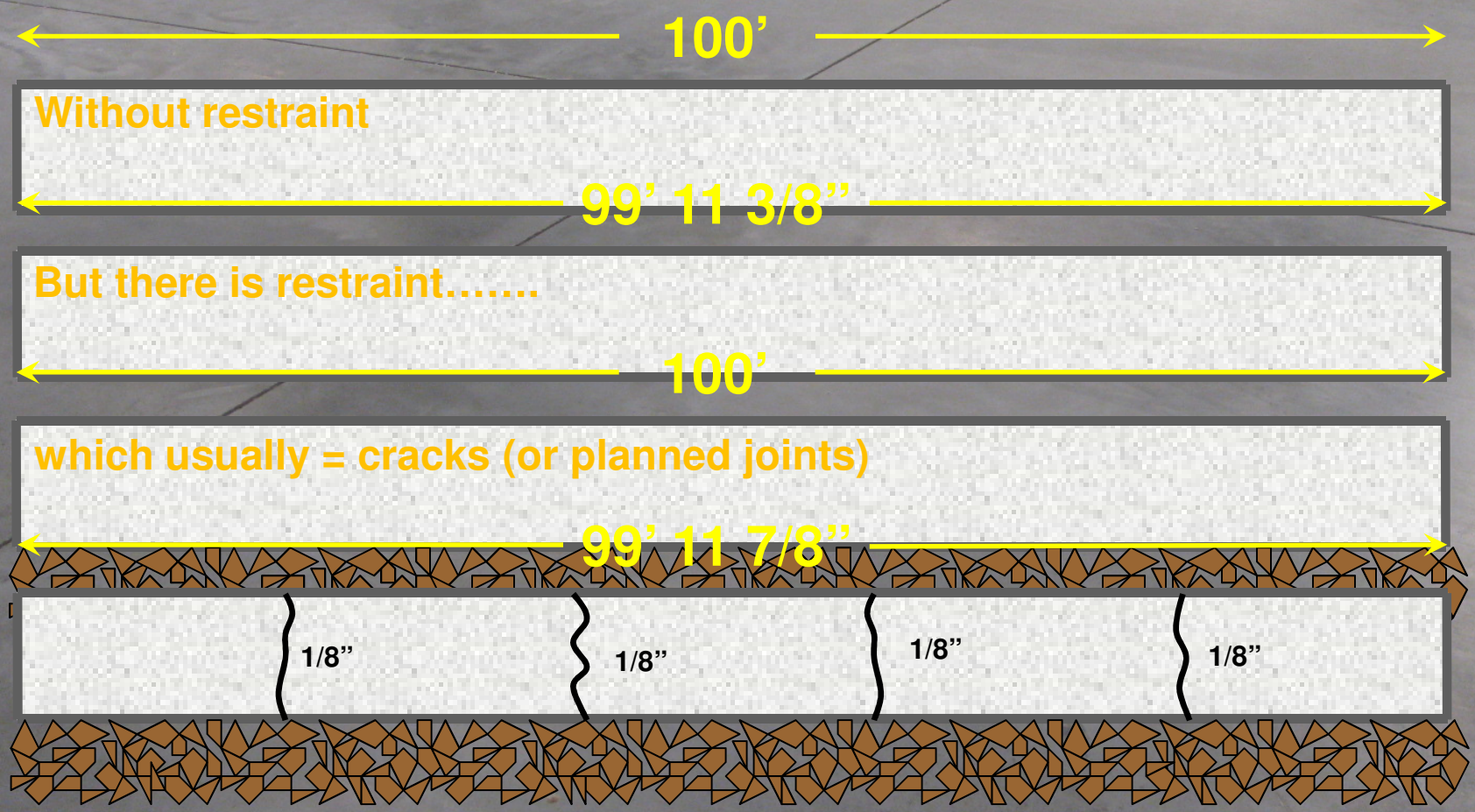
Dry heat and windy conditions caused widespread cracking

Improving durability of concrete

- Making the concrete denser and less permeable
  - Lower w/c, use SCM, proper gradation, curing …
- Minimizing cracking potential
  - …low shrinkage concrete
- Controlling the cracks / crack widths
  - … fiber reinforcement

Concrete shrinkage

Typical Concrete Drying Shrinkage is 0.05% = 5/8” in 100’



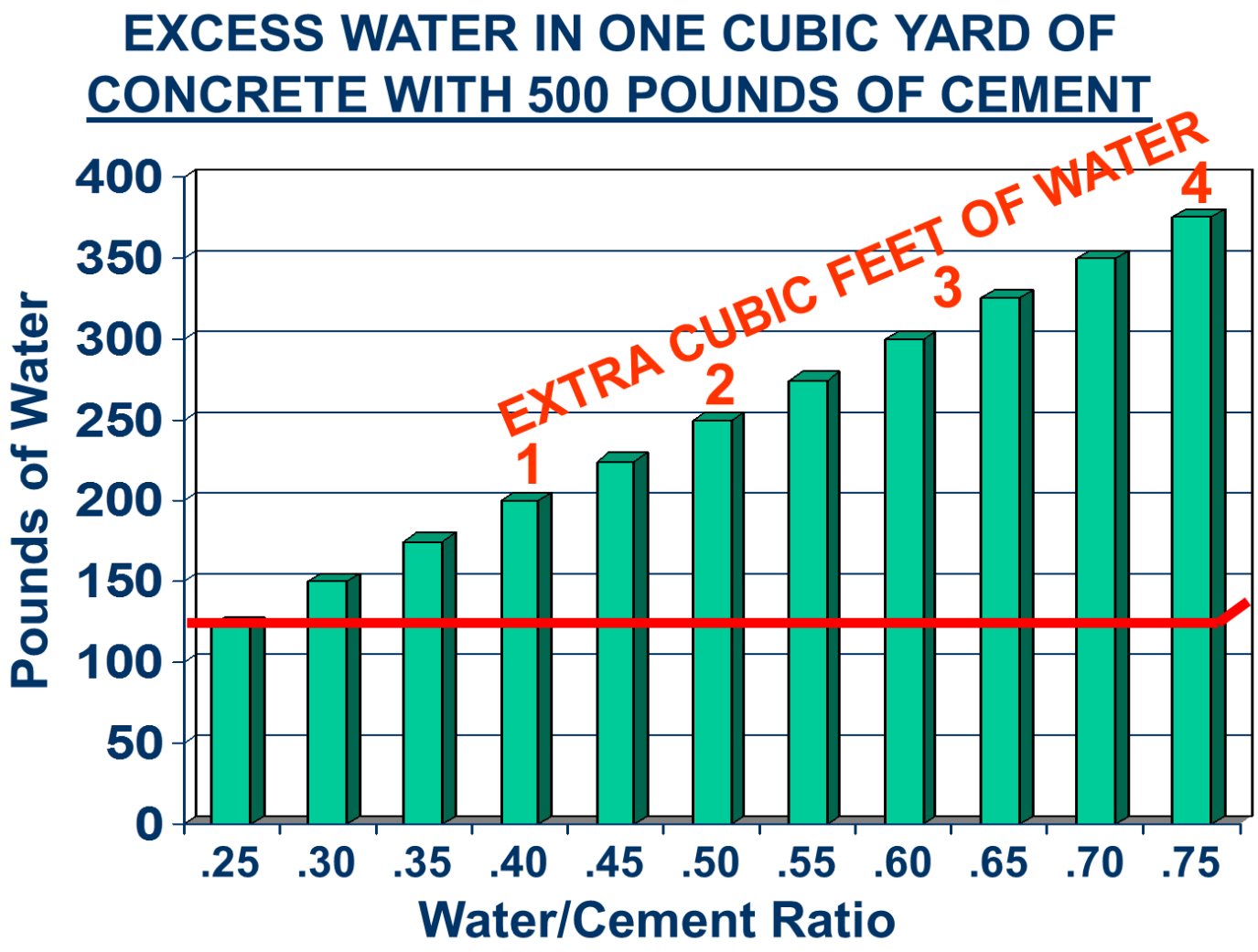
Minimizing Shrinkage

Approaches to minimize cracking and curling due to shrinkage

1. Mix design approach
2. Shrinkage reducing admixtures
3. Shrinkage compensation

Less joints and less cracking

Water in concrete



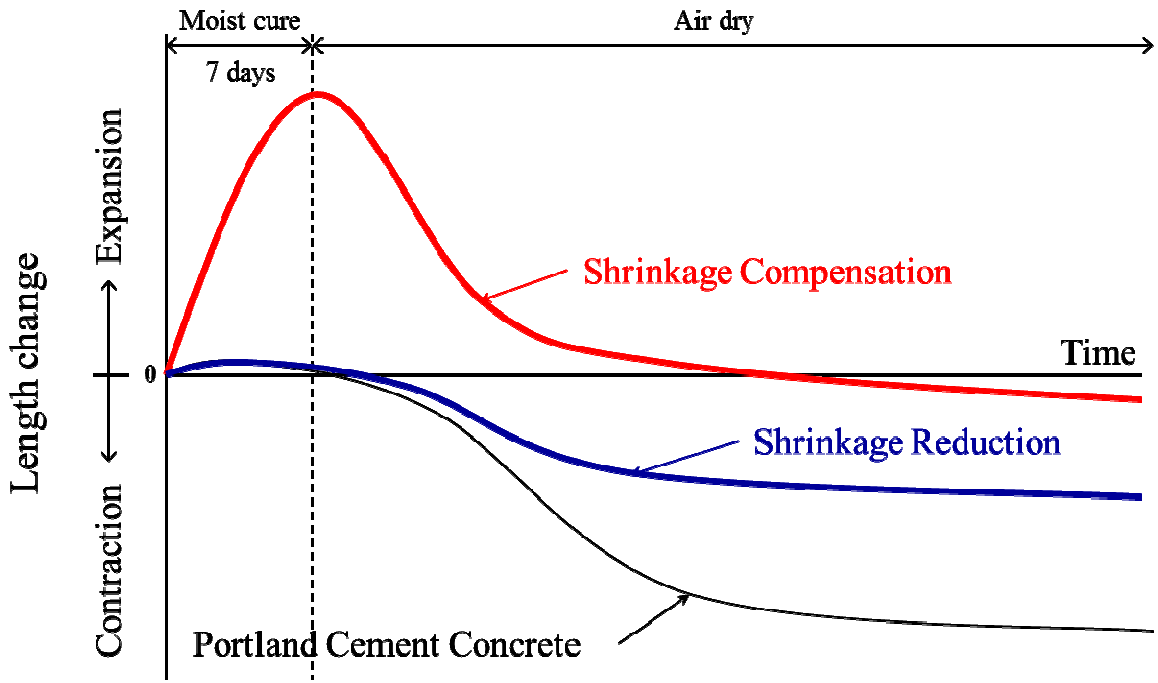
Water reducing / plasticizing admixtures

Aggregate size

MORE AND LARGER COARSE AGGREGATES

MEANS:	**LESS SURFACE AREA AND LESS SPACE TO FILL**
WHICH MEANS	**LESS PASTE**
WHICH MEANS	**LESS CEMENT**
WHICH MEANS	**LESS WATER**
WHICH MEANS	**LESS EXCESS WATER**
WHICH MEANS	**LESS SHRINKAGE**
WHICH MEANS	**LESS CRACKING & CURLING**

Theories of Shrinkage



- ACI 223 graphic
- curves dependent on many factors
- no influence from fibers

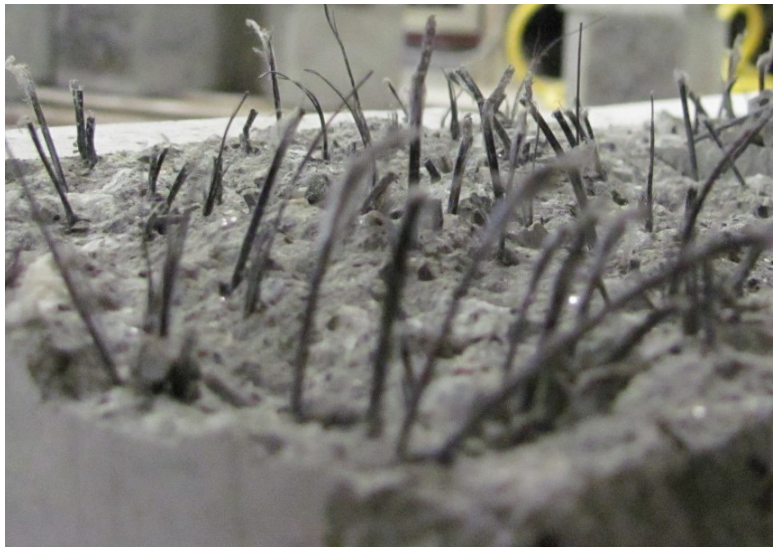
- importance of curing illustrated
- mix design can influence
- testing diligence is very important

Summary of Mix design goals

- **High quality paste but not too much**
- **Maximize well graded coarse aggregates**
- **Enough water for hydration and finishing; use plasticizers**
- **Use SRA / SCA to lower the concrete shrinkage**

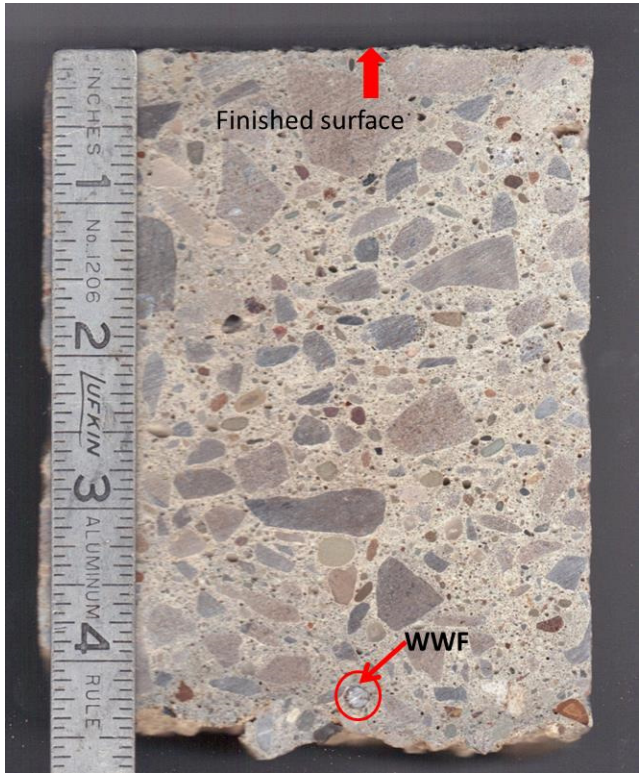
Fiber reinforcement

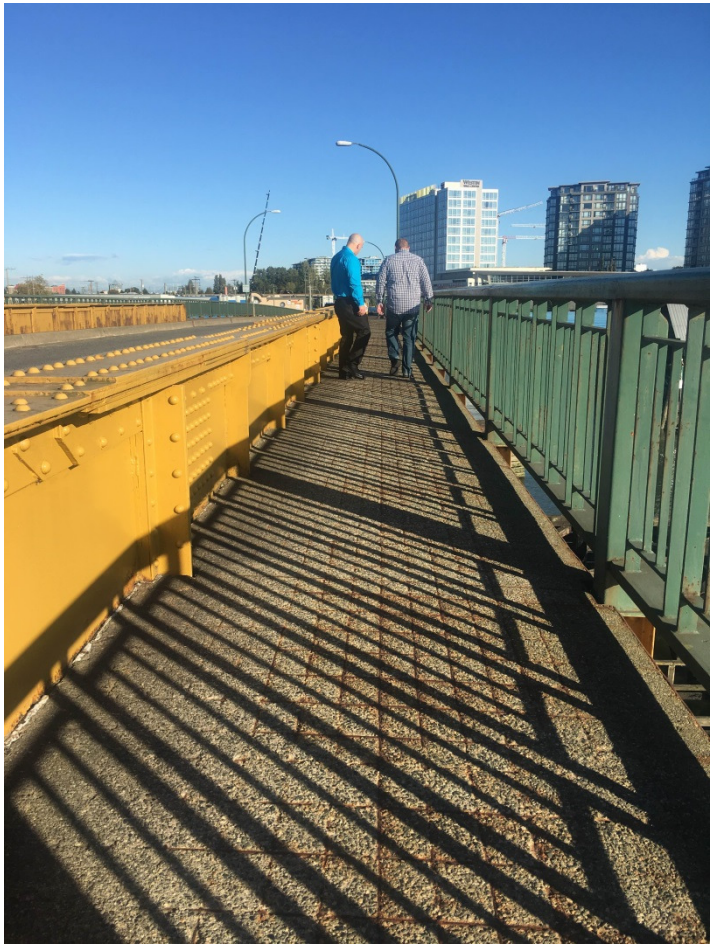
- Fibers are used in concrete for the same reason that straws were used in mud bricks thousands of years ago: **post-crack strength**.
- Structural fibers provide additional tensile and flexural capacity. (not compressive)



Why not mesh or bars?

- If placed too low, it doesn't work!
- If placed too high, it will be exposed!
- Always corrosion issue (deicing salts)!



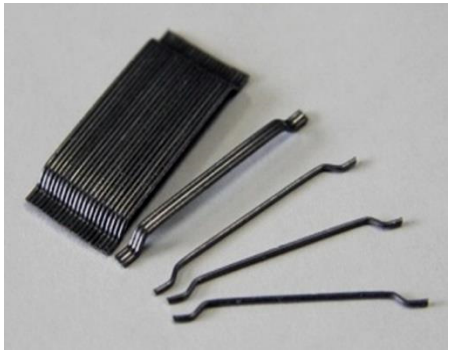


Types of Fibers

- **Synthetic microfibers**: “secondary” reinforcement; shorter and finer strands, plastic shrinkage crack control only. They can be monofilament or fibrillated (0.5-1.5 pcy)

- **Synthetic macrofibers**: longer and coarser strands, shrinkage crack control and limited structural applications. Dosage rates should be calculated by engineering requirements and equations (3-20 pcy)

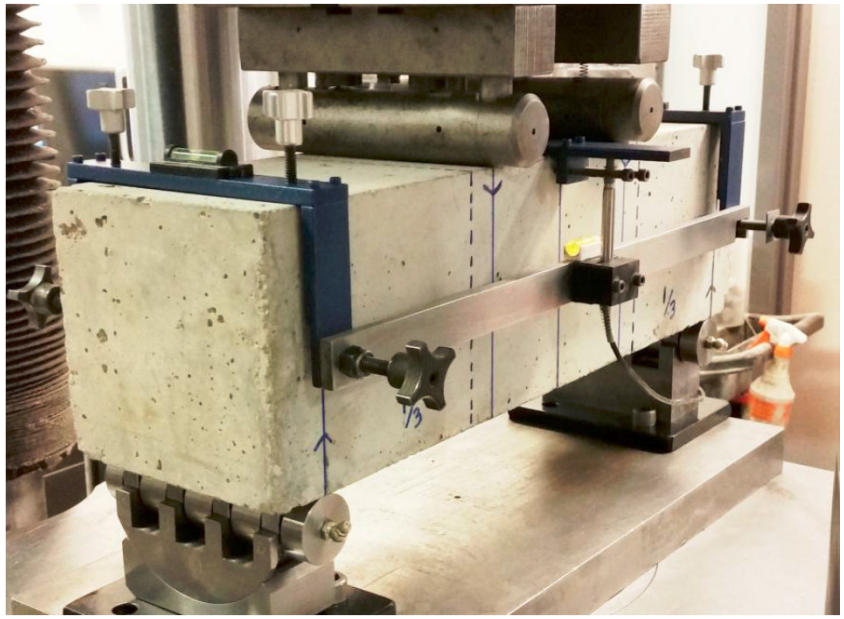
- **Steel fibers**: longer and coarser pieces, extended structural applications. Dosage rates should be calculated by engineering requirements and equations (15-100 pcy)

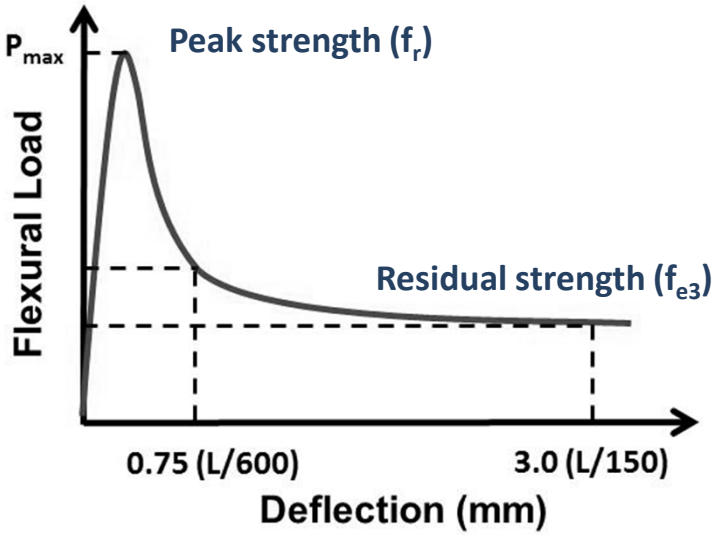


Testing FRC

Designation: C1609/C1609M – 12

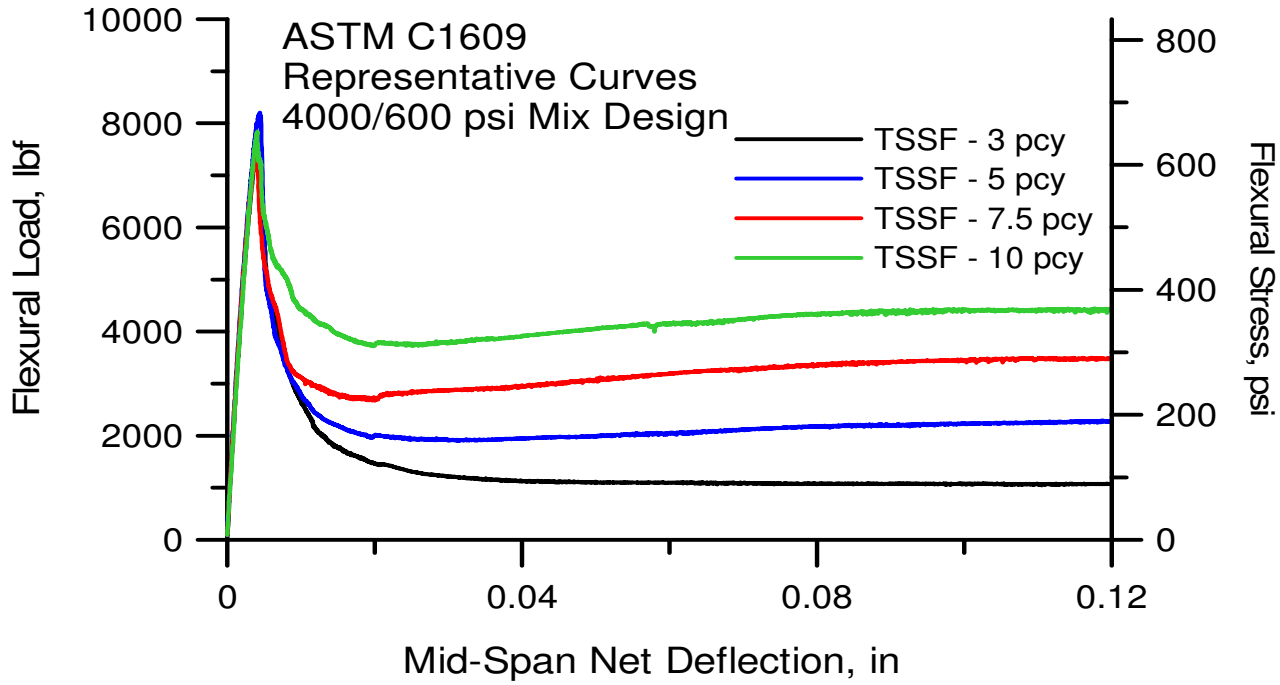
Standard Test Method for
Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)[1]





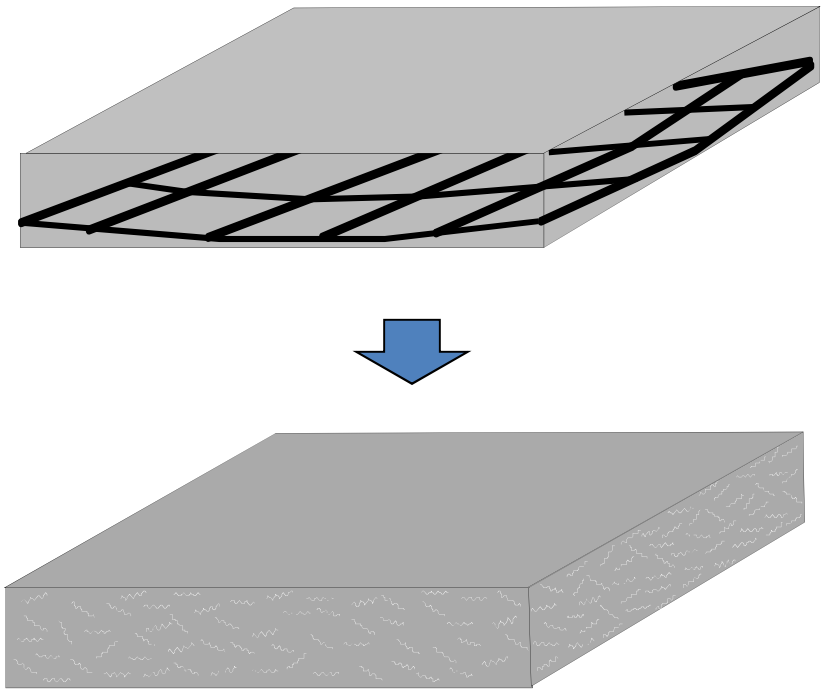
$R_{e3} = f_{e3} / f_r$

Effect of Fiber Dosage



TSSF	f_r (psi)	f_{e3} (psi)	R_{e3} (%)
3 pcy	597±43	133±9	22±3
5 py	669±9	209±15	31±2
7.5 pcy	651±25	293±29	45±4
10 pcy	662±8	372±39	56±6

FRC benefits



During the construction

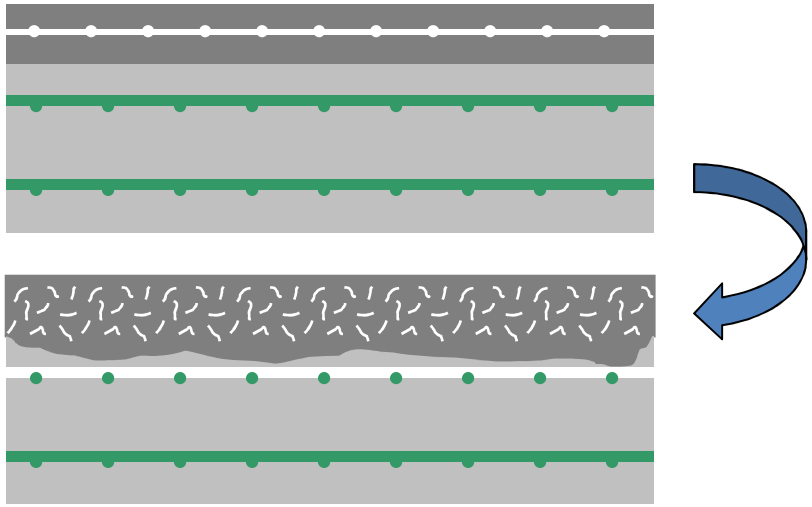
- Reduced labor and costs
- Reduced construction time
- Increased safety
- Potential reduction in thickness

After the construction (in service)

- Three dimensional reinforcement
- Shorter and thinner cracks (in any)
- Less spalling and chipping
- Increase in long-term durability
- Lower maintenance costs

Salmon River Jeddore Bridge repair
Nova Scotia, Canada

3” thick topping
(11 lb/yd macrofiber)



<u>Mud Creek Bridge, Iowa</u>.
122 feet length, 47 feet largest span, 30 feet width.

1.5” overlay with UHPC (high strength, high dosage steel fiber, SCC mix.)

Several CALTRANS new/repair projects for bridge decks using synthetic fibers + SRA

(CI, July 2013)

fibers. Deck-on-deck construction is especially prone to cracking due to drying shrinkage stresses. Relying upon our earlier experience of using SRAs to reduce early-age deck cracking and several previous successful applications of synthetic polyolefin macrofibers to restrain plastic and drying shrinkage cracking, the two technologies were combined for a "crackless" concrete deck (771 lb/yd^3 [8.2 sacks or 457 kg/m^3] of cement, 6% air, *w/c* of 0.51, SRA at 0.75 to 1.5 gal./yd^3 [3.7 to 7.4 L/m^3], and fibers at 3 lb/yd^3 [1.8 kg/m^3]). After 5 years of service, sections of the deck comprising both SRA and fibers exhibited very limited cracking. Cores taken at cracked locations indicated that cracks were very thin and most were arrested near the surface. Two cores extracted at full-depth (4 in. [102 mm]) crack locations showed finelined cracks kept intact by the fibers. In contrast, the control sections of the deck, placed without SRA and without fibers, exhibited substantial cracking within 6 weeks.

In 2011, a 5 in. (127 mm) "crack-free" deck was placed on

Fig. 6: Cast-in-place decks and spliced precast bulb-T girders on I-80 near Truckee, CA: (a) deck constructed without SRA; and (b) deck constructed with SRA *(photos courtesy of Ric Maggenti)*

ABC's of CRACK-Less Bridge Decks

With Applications in

ACCELERATED

BRIDGE CONSTRUCTION

Sonny Fereira, PE California Department of Transportation
March 21, 2014
Bridge Contractors/ Caltrans Liaison Committee Meeting

Formula for the CRACK-Less Bridge Deck

A. Shrinkage Reducing Admixture*

B. Water Reducing Admixture*

C. Fibers*

*add to concrete mix

The Current Cost Of Doing Business v. CRACK-Less Deck

$50 MILLION TO SEAL CRACKS

$2 MILLION FOR CRACK-Less DECKS

02

STATE OF CALIFORNIA

DEPARTMENT OF TRANSPORTATION

NOTICE TO BIDDERS

AND

SPECIAL PROVISIONS

FOR CONSTRUCTION ON STATE HIGHWAY IN SISKIYOU COUNTY NEAR SEIAD VALLEY AT VARIOUS LOCATIONS FROM 0.1 MILE WEST OF THOMPSON CREEK BRIDGE TO 0.2 MILE EAST OF BEAVER CREEK BRIDGE

In District 02 On Route 96

Under

Bid book dated September 26, 2016	*Standard Specifications* dated 2010
Project plans approved June 15, 2016	*Standard Plans* dated 2010

Identified by

Contract No. 02-4E6504

02-Sis-96-R52.5/88.4

Project ID 0212000012

Federal-Aid Project
ACST-P096(060)E

Electronic Bidding Contract

XS
AADD
OSD
IH

Bids open Tuesday, November 15, 2016
Dated September 26, 2016

^^

51 CONCRETE STRUCTURES

Add to section 51-1.01C(1):

If the methacrylate crack treatment is performed within 100 feet of a residence, business, or public space, submit a public safety plan that includes the following:

1. Public notification letter with a list of delivery and posting addresses. The letter must describe the work to be performed and state the treatment work locations, dates, and times. Deliver the letter to residences and businesses within 100 feet of overlay work and to local fire and police officials not less than 7 days before starting overlay activities. Post the letter at the job site.
2. Airborne emissions monitoring plan. A CIH certified in comprehensive practice by the American Board of Industrial Hygiene must prepare and execute the plan. The plan must have at least 4 monitoring points including the mixing point, application point, and point of nearest public contact. Monitor airborne emissions during overlay activities.
3. Action plan for protecting the public if levels of airborne emissions exceed permissible levels.
4. Copy of the CIH's certification.

After completing methacrylate crack treatment activities, submit results from monitoring production airborne emissions as an informational submittal.

Replace the 2nd paragraph of section 51-1.01C(1) with:

Submit a deck placement plan for concrete bridge decks. Include in the placement plan your method and equipment for ensuring that the concrete bridge deck is kept damp by misting immediately after finishing the concrete surface.

Add to section 51-1.02B:

For the portions of structures shown in the following table, concrete must contain at least 675 pounds of cementitious material per cubic yard:

Bridge name and no.	Portion of structure
Thompson Creek Bridge (Bridge no. 02-0068)	All except footings and piles
Seiad Creek Bridge (Bridge no. 02-0072)	All except footings and piles
Beaver Creek Bridge (Bridge no. 02-0081)	All except footings and piles

Concrete for concrete bridge decks must contain polymer fibers. Each cubic yard of concrete must contain at least 1 pound of microfibers and at least 3 pounds of macrofibers.

Concrete for concrete bridge decks must contain a shrinkage reducing chemical admixture. Each cubic yard of concrete must contain at least 3/4 gallon of a shrinkage reducing admixture. If you use the maximum dosage rate shown on the Authorized Material List for the shrinkage reducing admixture, your submitted shrinkage test data does not need to meet the shrinkage limitation specified.

Delete the 2nd sentence of the 1st paragraph of section 51-1.03E(5).

CALTRANS spec:
1 lb/yd^3 micro and 3 lb/yd^3 macro fibers
¾ gal SRA (0.032% shrinkage)

New Jersey Turnpike - Route 1 & 9 Bayonne

July 2017

4 placements of 5 lbs Macro Synthetic Fibers

NJ Turnpike

NJ Turnpike

NJ Turnpike

Bus Parking / Maintenance Facility – Herndon, VA

Mix contained 3 lbs of macro synthetic fibers for a VDOT A-4 modified mix – placed October 2017


vulcan
Materials Company
US DOT 1918577
MACK

10 lbs of macro fibers - Bridge Deck

CR44 Bridge Deck Overlay Hinckley Ohio

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ACI 330.2R-17

Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities

Reported by ACI Committee 330

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Christopher R. Tull
Diep T. Tu
Jason D. Wimberly

*Chair of the task group that prepared this guide.

Consulting Members

D. Gene Daniel
Don J. Wade

Where odd-shaped panels cannot be avoided, or special circumstances require panels with an aspect ratio of greater than 1.5 to 1, designers should consider using reinforcement—macro-synthetic or steel fibers, or distributed steel—to minimize the width of random cracks. This reinforcement is normally furnished in the form of deformed steel bars, welded wire reinforcement, or macro-synthetic fibers. Steel reinforcing bars or welded wire reinforcement should be positioned in the upper one-third of the pavement thickness and should be supported during all placing and finishing operations. Light-gauge welded wire fabric should not be used because of the number of chairs necessary to hold it in the proper position and the safety hazards associated with its use. Using macro-synthetic fibers in dosages as high as 7.5 lb/yd^3 (4.4 kg/m^3) has proved successful in limiting crack widths in pavements with odd-shaped panels or in locations where the aspect ratio of panels exceeds 1.5 to 1.

corrosion-resistant coating on the dowel is recommended where deicing chemicals are used on pavements where steel corrosion may be an issue. The designer should discuss corrosion resistance costs and advantages with the owner to determine if the additional cost is of value. The benefit of using dowels in concrete pavements has been recognized for nearly 100 years with the first reported U.S. installation in 1917. These earlier dowels were generally much longer, up to 48 in. (1219 mm), with smaller diameters as little as 1/2 in. (13 mm), and greater spacing as few as two bars per travel lane. Numerous dowel bar studies and tests conducted by Bradbury (1932), and Teller and Sutherland (1935, 1936, 1943) resulted in the use of dowels that were stiffer and larger in diameter, more closely spaced, and shorter in length (Snyder 2011). Repeated load testing of dowels in slabs performed at Bureau of Public Roads labs in the 1950s (National Research Council (U.S.) 1952) led to the development of design recommendations that eventually became the

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Although plastic shrinkage cracking is a result of adverse combinations of low humidity, high wind velocity, and differentials of warm concrete and cool air temperatures, not all those factors are required for plastic shrinkage cracks to occur. Often, they occur with high winds and low relative humidity, regardless of the ambient and concrete temperatures.

Recommendations for the reduction of plastic shrinkage cracking include erection of wind breaks, which are not always practical; use of synthetic microfibers in the concrete mixture; use of fog sprays; the application of surface evapo-

Finishing operations that occur with rainwater on the surface will likely decrease the pavement's surface durability and wear resistance. Following the rain event and prior to continuing any finishing activities, all excess water on the pavement surface should be removed with lengths of large-diameter rubber hose, or squeegees if the concrete has set enough to support personnel. The use of dry cement or sand to dry the pavement surface is not recommended and will generally result in an unacceptable surface. If water cannot be removed for finishing, or if the concrete has set too much for finishing after the rain event, it is best to do nothing at

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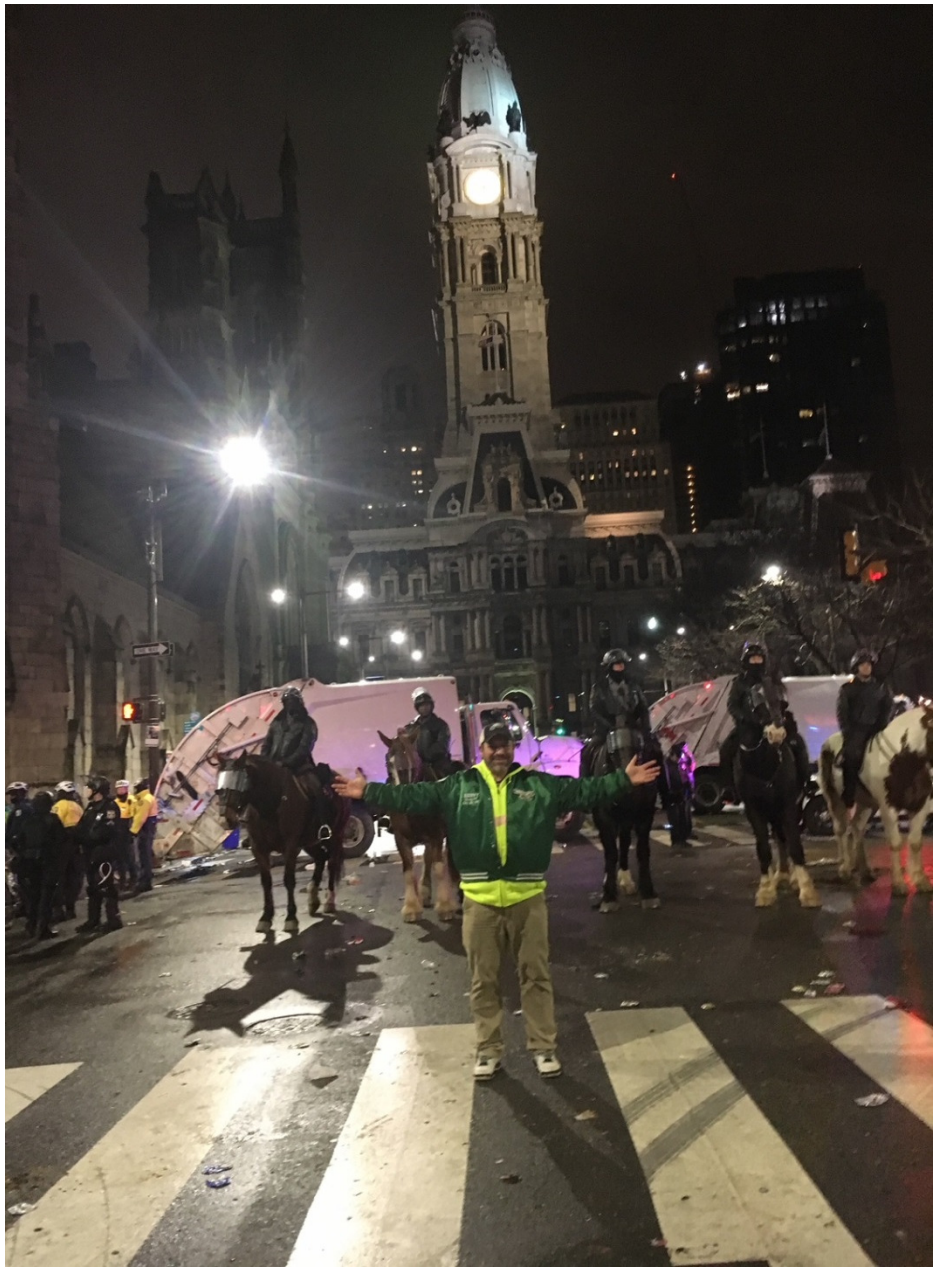
EAGLES
10
13
11




BROAD
CHAMPIONS


YANKEES

Thank you for your time and interest today!

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