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EUCLID CHEMICAL

High Performance Concrete with Fiber Reinforcement

Bill Lyons FACI
National Business Development Group
Northeast Region
201-401-3391
wlyons@euclidchemical.com

Presentation Outline

- Concrete Cracking
- Concrete Shrinkage
- Fiber Reinforced Concrete
- Design and Specification
- Applications
- ACI 544.4R-18

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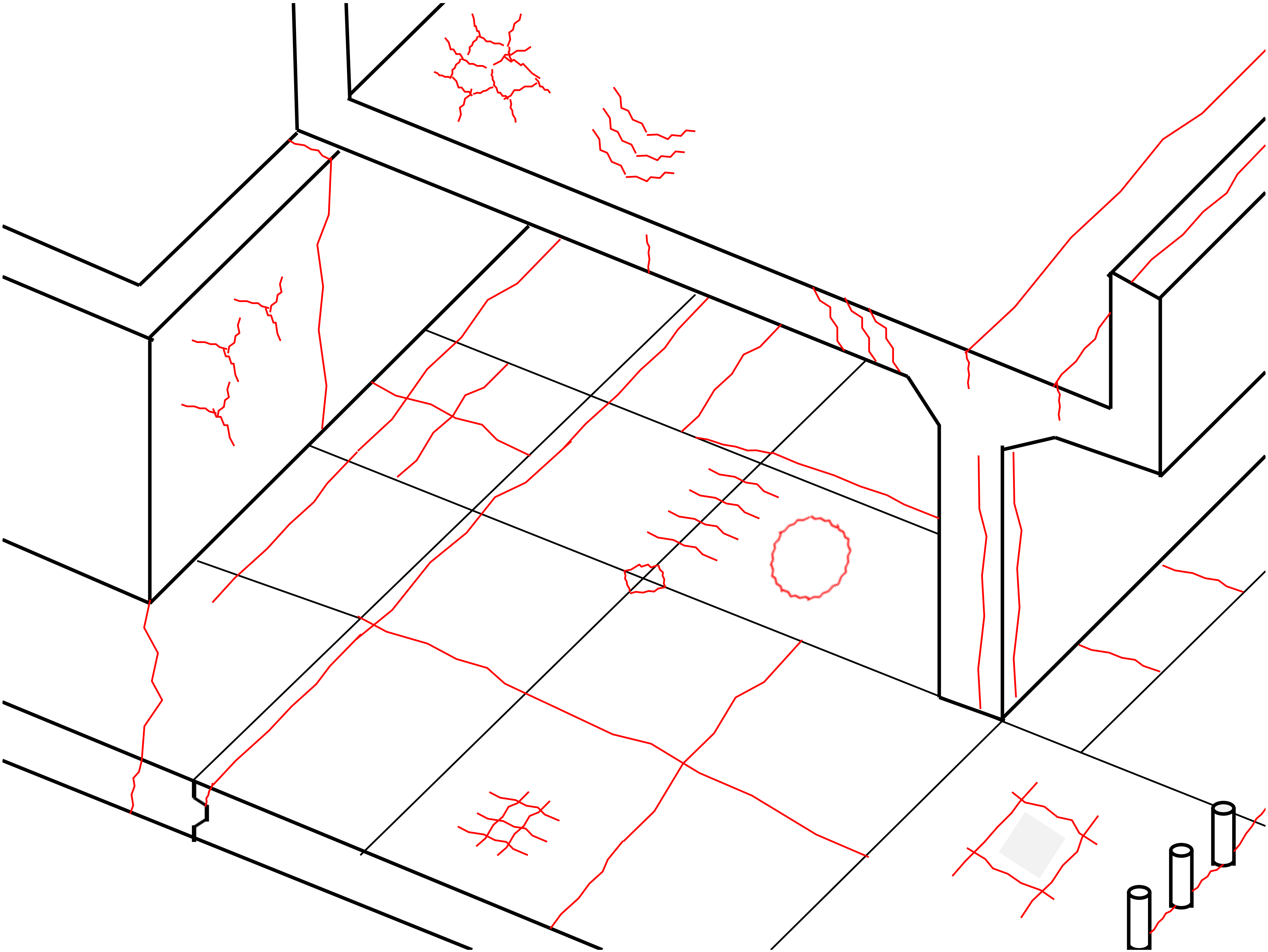
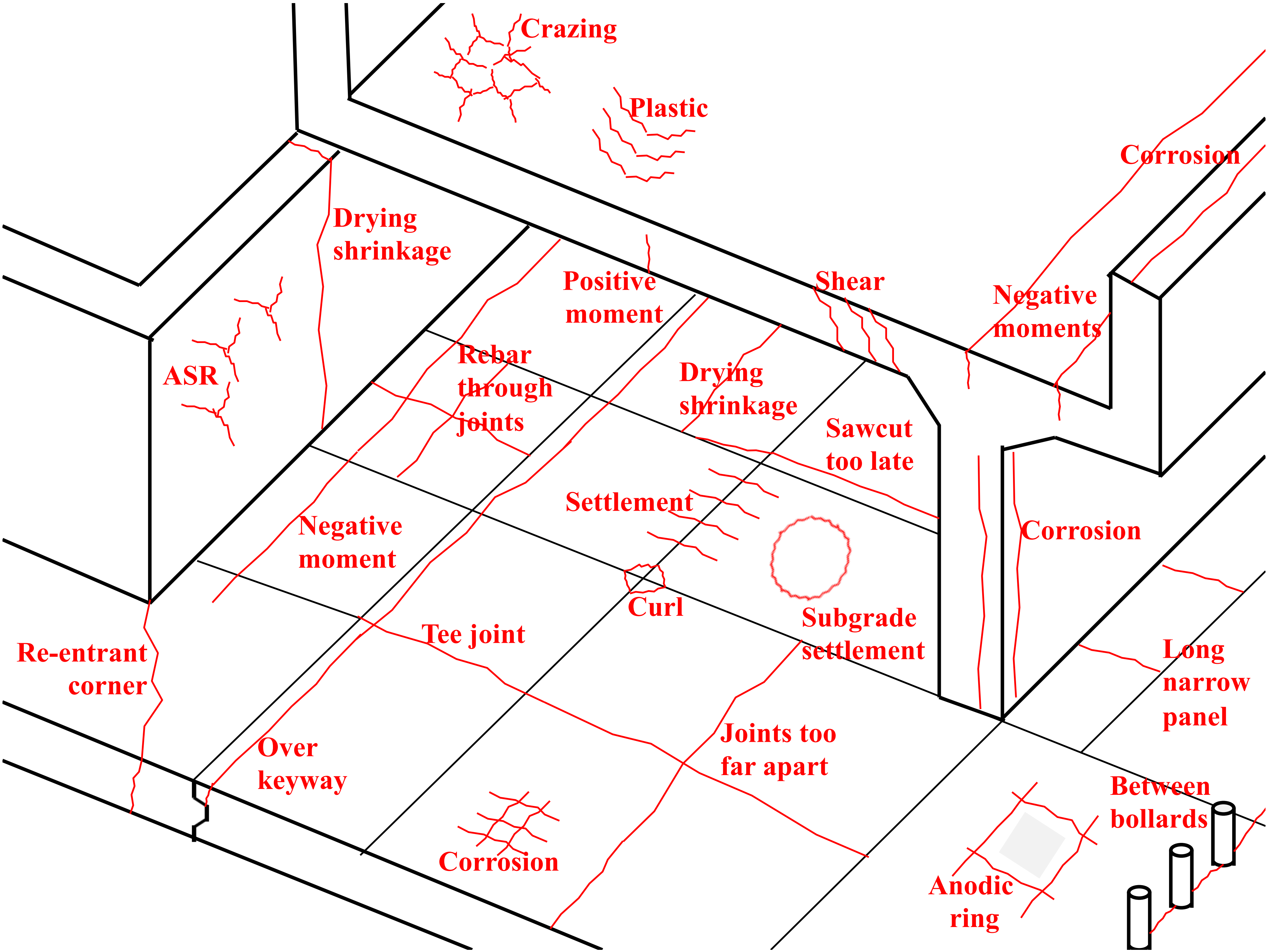
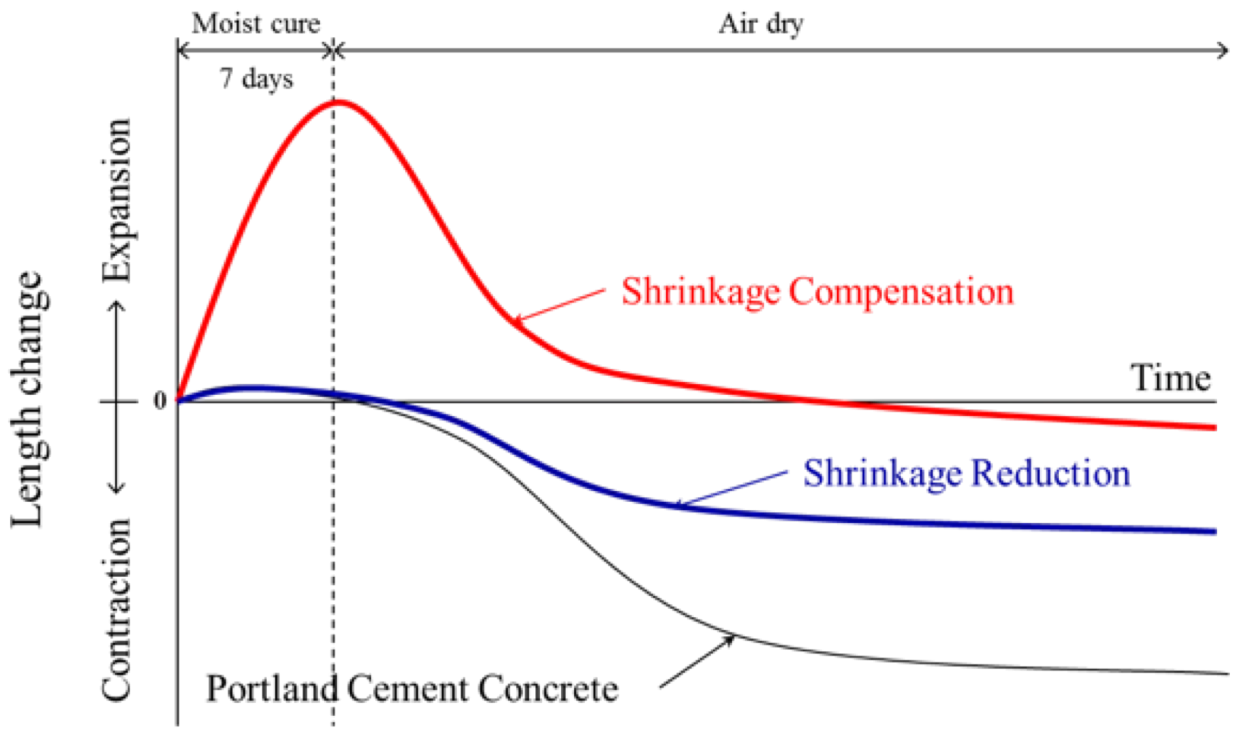



Crazing
Plastic
Corrosion
Drying shrinkage
Positive moment
Shear
Negative moments
ASR
Rebar through joints
Drying shrinkage
Sawcut too late
Settlement
Corrosion
Negative moment
Curl
Subgrade settlement
Tee joint
Re-entrant corner
Long narrow panel
Joints too far apart
Over keyway
Between bollards
Corrosion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


Dry heat and windy conditions caused widespread cracking

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**

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

Fiber reinforcement

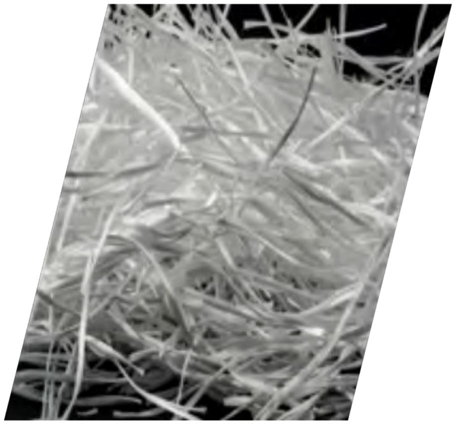
- Fibers are used in concrete for the same reason that straws were used in mud bricks thousands of years ago: **post-crack strength.**

- Structural fibers provide additional tensile and flexural capacity. (not compressive)

How to Differentiate the Fiber Types –

micros & macros

- In general, the "industry" has accepted that steel macro-fibers and "older" micro-synthetic fibers (fibrillated, monofils, etc) are not used under the same conditions.
- Micro-synthetics – "secondary" reinforcement; plastic shrinkage only
- Steel fibers – industrial floor design; replacement of heavier reinforcing configurations
- Synthetic macro-fibers can be thought of like steel fibers, but simply not made of steel. The physical characteristics of these fibers (length, tensile strength, diameter, etc.) are all different, when compared to traditional micro-synthetics.
- Dosages of macro-fibers should be calculated by engineering requirements.



Typical Fiber Types & Dosage Rates

Micro-Synthetic Fibers

- monofilament polypropylene and other synthetic materials

0.5 to 1.5 pcy for control of plastic shrinkage cracking only

Micro-Synthetic Fibers

- fibrillated polypropylene

1.0 to 1.5 pcy for control of plastic shrinkage and some temperature and shrinkage cracking as a replacement for very light WWM

Macro-Synthetic Fibers

- monofilament polypropylene and other synthetic materials

3.0 to 10 pcy for temperature and shrinkage cracking control and limited structural reinforcement – highly engineered calculations

Steel Fibers

deformed geometry drawn steel wires

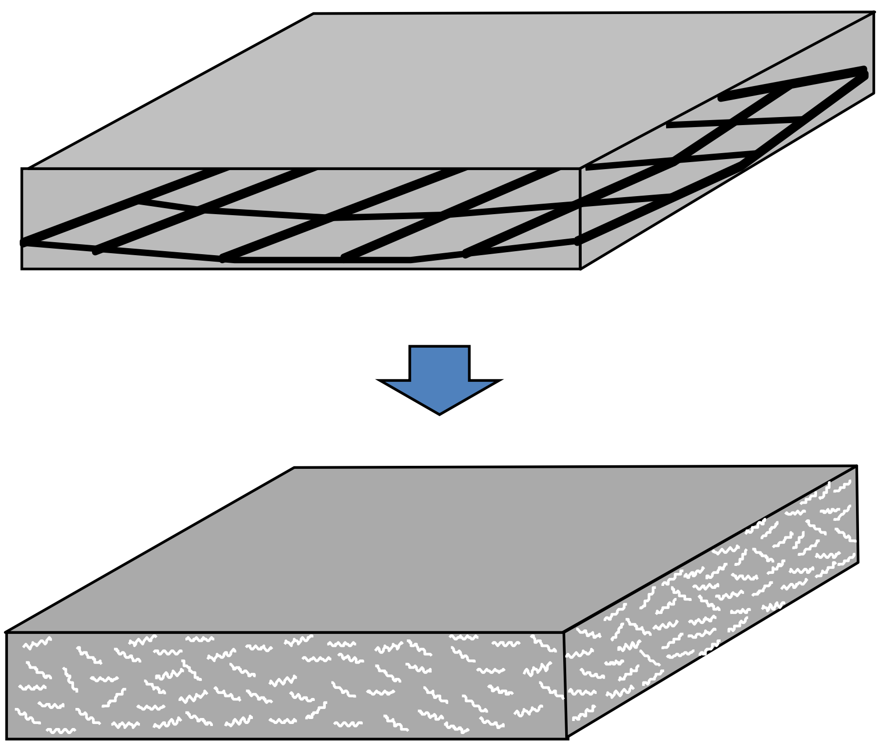
15 to 100 pcy for temperature and shrinkage cracking control and limited structural reinforcement – highly engineered calculations

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 (if any)
- Less spalling and chipping
- Increase in long-term durability



Performance and Specifications

- Not all fibers are created equal!

Calculated fiber dosages are becoming more prevalent in the specification community and will ‘force’ manufacturers to provide test data and documentation that a specific fiber type is suited for the application.

- fiber alternate shall be macro-fiber (steel or synthetic) complying with ASTM C1116 and provide equivalent tensile and/or bending resistance to # 4 rebar (Grade 60) placed 2” from top of a 6” slab or mid-depth in a 8” wall……….

and / or

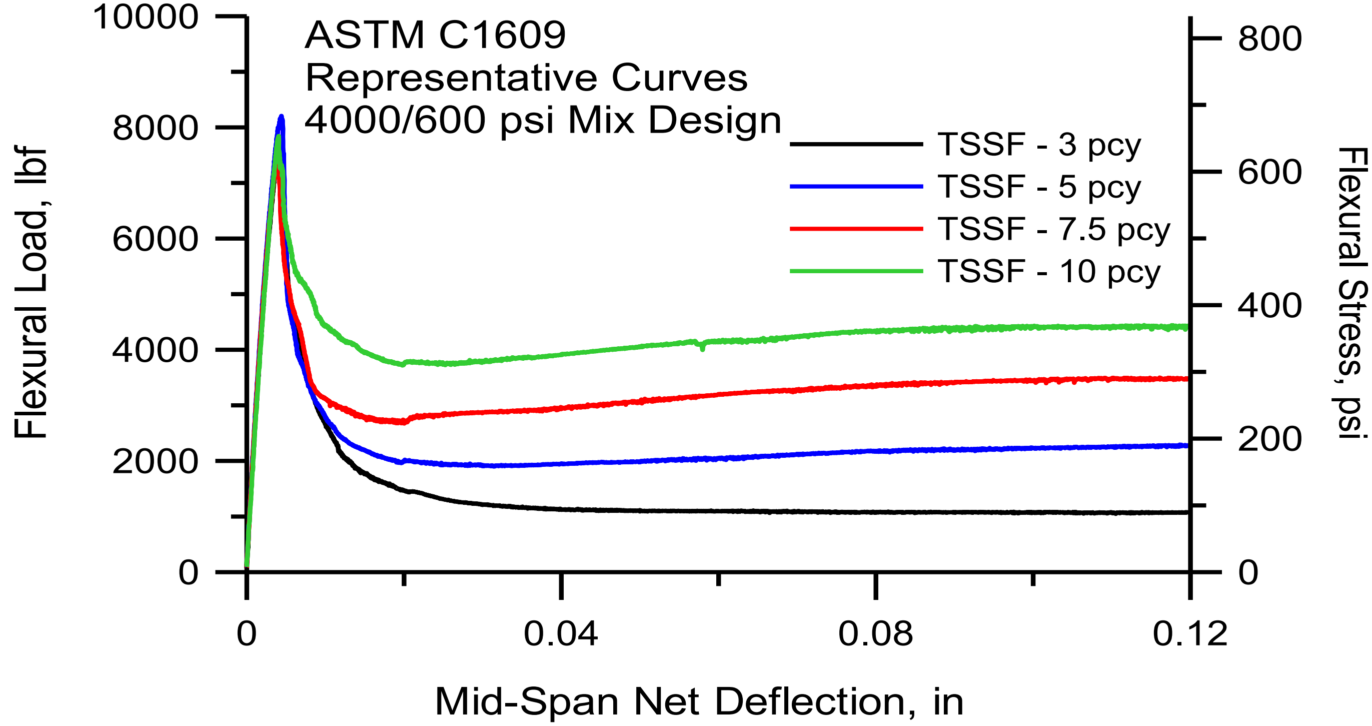
- “A minimum fe3 of 200 psi
- Approved dosage rate shall satisfy the performance requirements".

- **Not all fibers are the same**, that is why it is important to specify fibers based on their "performance" in "fiber-reinforced concrete (FRC)".

- Parameters related to the residual strength of FRC ($\mathbf{R}_{e,3}$ and $\mathbf{f}_{e,3}$) can be used for specifications. The values depend on the design and specifics of the project.

ASTM C 1609 ????

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

The majority of floors in FedEx Ground distribution centers have fiber-reinforcement.

C. Macro Synthetic Fiber: As shown on drawings, macro synthetic fiber reinforcement shall be used for the purpose of controlling temperature and drying shrinkage cracking. Macro-synthetic fibers are not intended, nor shall be permitted, to replace structural reinforcing steel required by design without FXG review and approval. Micro-synthetic fibers and cellulose fibers shall not be permitted. Macro Synthetic Fiber shall meet the following criteria:

1. Type: Fiber shall meet the requirements of ASTM C1116 for Type III Synthetic Fibers
2. Length: Fiber length shall measure 1½" - 2".
3. Post Crack Residual Strength: Fiber shall provide a minimum post-crack residual strength value (fe3) of 200 PSI when measured in accordance with ASTM C1609. Fiber manufacturer shall provide data in accordance with this requirement.
4. Tensile Strength: Fiber shall provide a minimum tensile strength of 70 KSI when tested in accordance with ASTM D2256
5. Modulus of Elasticity: Fiber shall provide a minimum modulus of elasticity of 1200 KSI when tested in accordance with EN 14889
6. Aspect Ratio: Fiber shall provide an aspect ratio of 70 – 90

DOT Fiber Specification

Oregon
DEPARTMENT OF TRANSPORTATION
Construction Section
800 Airport Road SE
Salem, OR 97301-4798
503/986-3059

Standard Guidelines for Product Review
Synthetic Blended Fiber Reinforcing; Section 02045.30
April, 2014

02045.30 – Synthetic Blended Fiber Reinforcing

General – Synthetic Blended Fiber Reinforcing submitted under this category will be used in HPC Bridge Decks and SFC Overlays as shown on the plans or specifications.

Test a currently approved ODOT HPC 4000- ¾" and SFC(MC) 3000- ½" mix design in accordance with the latest version of ASTM C1579. Test sample materials shall be obtained from Knife River in Central Point, Oregon. Test samples shall use the constituents currently used at the plant, i.e. cement, fly ash, silica, agg., admixtures, etc.

Test a currently approved ODOT HPC 4000- ¾"and SFC(MC) 3000- ½" mix design in accordance with the latest version of ASTM C1399. HPC and SFC test samples shall be obtained from Knife River in Central Point, Oregon. HPC and SFC test samples shall use the constituents currently used at the plant, i.e. cement, fly ash, silica, agg., water, admixtures, etc.

Fiber dosage rates developed for QPL inclusion will be noted in the QPL listing remarks section and used for production on ODOT projects which specify fiber reinforcing.

Specifications:

1. ASTM C1116, Section 4.1.3, Type III Synthetic, Polyolefin Fibers.
2. ASTM C1579 Plastic Shrinkage Cracking of Restrained Fiber Reinforced Concrete: Report results for manufacturers recommended dosage rates. Minimum reduction > or = 85%.
3. ASTM C1399 Average Residual Strength of Fiber Reinforced Concrete: Report results for manufacturers recommended dosage rates. Minimum residual strength > or = 195 psi.

To apply for inclusion on the QPL, submit the following:

Colorado DOT

February 18, 2016

REVISION OF SECTION 601
FIBER-REINFORCED CONCRETE

Section 601of the Standard Specifications is hereby revised for this project as follows:

Subsection 601.03 shall include the following:

Where Fiber-Reinforced Concrete is specified or designated in the plans, the concrete mix shall include approved polyolefin fibers. Unless otherwise specified, a minimum of 3.5 pounds per cubic yard of polyolefin fiber reinforcement shall be evenly distributed into the mix. Mixing shall be as recommended by the manufacturer such that the fibers do not ball up. Polyolefin fibers shall meet the requirements of ASTM C1116 and ASTM D7508.

Where Macro Fiber-Reinforced Concrete is specified or designated in the plans, the concrete mix shall include approved macro polyolefin fibers. A minimum of 4.0 pounds per cubic yard of macro polyolefin fiber reinforcement shall be evenly distributed into the mix. If less than 4.0 pounds per cubic yard of macro polyolefin fiber reinforcement is used in the mix, the Contractor shall provide test results showing the mix design has a residual strength of 170 psi as determined by ASTM C1609. Mixing shall be as recommended by the manufacturer such that the fibers do not ball up. Macro polyolefin fibers shall meet the requirements of ASTM C1116 and ASTM D7508 with the following exceptions:

(1) Tensile strength shall be a minimum of 65 ksi
(2) Modulus of Elasticity shall be a minimum of 1,000 ksi
(3) Cut length shall be 1.5 to 2.2 inches
(4) Aspect Ratio shall be 50 to 100

Subsection 601.05 shall include the following:


Concrete Pavements
NORTH
9

Performance Whitetoppings

DOT initiatives, specification

- DOT’s are increasingly looking at fiber concrete to use in whitetoppings and pavement construction to extend service life
- IL, IN, UT (decks); coming to OH, KY

- QPL driven, minimum performance requirements – ie: Re_3> 20%
- Large order projects, highly competitive
- Fibers ideally suited for finishing

INDOT SR 9 FIBER REINFORCED CONCRETE PAVEMENT

- 6 miles (10 km) of pavement was completed in 2017
- Requiring 14,000 yd^3 (10,700 m^3) of concrete
- Dosage 4 lbs/yd^3 (2.4 kg/m^3)
- Performance based specification
- Concrete was jointed at 6 ft. (1.8 m)

CR44 Bridge Deck Overlay Hinckley Ohio

CR44 BRIDGE DECK OVERLAY

- High Performance Modified Concrete Mixture
- Research project through ODOT & University of Akron
- 130 yd^3 of concrete
- Increase durability and service life through reduction of cracking

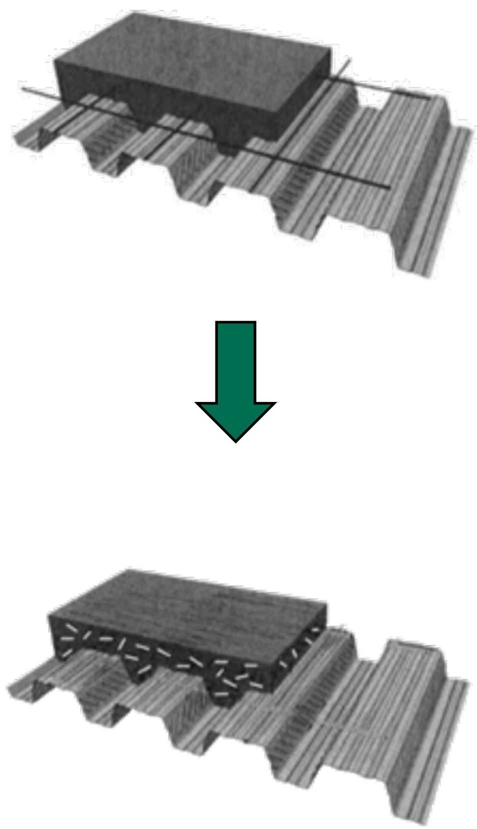
BLACK OAK CASINO RV PARK (CA)

- 6 inch concrete pavement for RV parking
- Total area – 206,400 ft2 (19,174 m2)

Fibers for Composite Metal Decks (CMD)

CODE Approved

Steel Deck Institute (SDI C-1.0.) allows for using macro fibers in composite metal deck to replace wire mesh. This language is included in the IBC 2015.

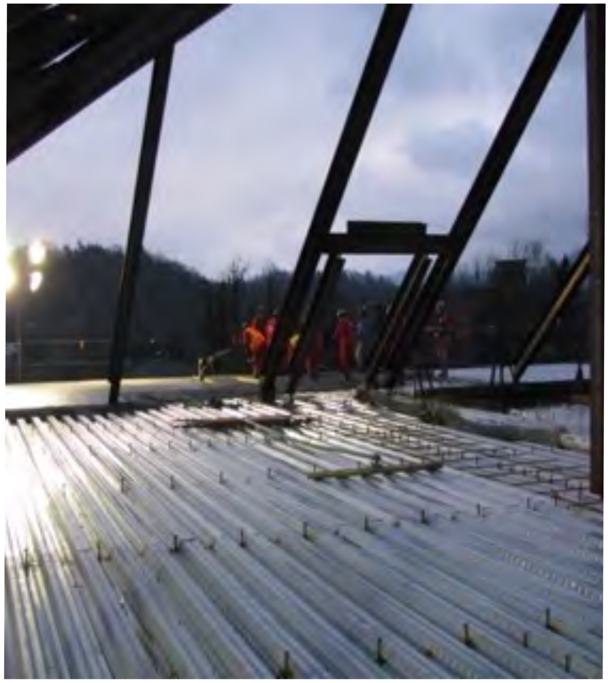


6. Reinforcement:
   a. Temperature and shrinkage reinforcement, consisting of welded wire fabric or reinforcing bars, shall have a minimum area of 0.00075 times the area of the concrete above the deck (per foot or meter of width), but shall not be less that the area provided by 6 x 6 – W1.4 x W1.4 welded wire fabric.

      Fibers shall be permitted as a suitable alternative to the welded wire fabric specified for temperature and shrinkage reinforcement. Cold-drawn steel fibers meeting the criteria of ASTM A820, at a minimum addition rate of 25 lb/cu yd (14.8 kg/cu meter), or macro synthetic fibers "Coarse fibers" (per ASTM Subcommittee C09.42), made from virgin polyolefin, shall have an equivalent diameter between 0.4 mm (0.016 in.) and 1.25 mm (0.05 in.), having a minimum aspect ratio (length/equivalent diameter) of 50, at a minimum addition rate of 4 lb./cu yd (2.4 kg/m^3 are suitable to be used as minimum temperature and shrinkage reinforcement.

Fibers for deck construction

- Steel decking acts as stay-in-place formwork, carries and distributes loads to joists and columns
- Concrete placement provides a level wearing surface and rigid mass to structure
- Reinforcement in concrete can be in different forms depending on design and function



IBC 2015 permits fiber for temp / shrinkage steel replacement on c-m-d projects

- Some projects require UL/ULC report on fire resistance (2 hour fire rating).
- Light-medium gauge mesh can be replaced with macro-fibers (synthetic or steel).
- Heavier mesh or rebar conversion may lead to a higher dosage for


Precast
Products
Finfrock Precast, FL

Precast Products

Crack control, engineered design

Burial Vaults and Septic Tanks

Steel fibers used in tunnel lining segmental units.

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Multiple applications

Individual requirements

- Significant decrease in production cycle time
- Reduced labor costs
- Reduction in breakage and repair costs
- Elimination of the potential for corrosion

- Crack - prevention
- Increased ductility
- Impact resistance
- Less spalling







Tools and Resources

- Engineered Design Guides
- Fiber Software Program
- Phone Calculator App

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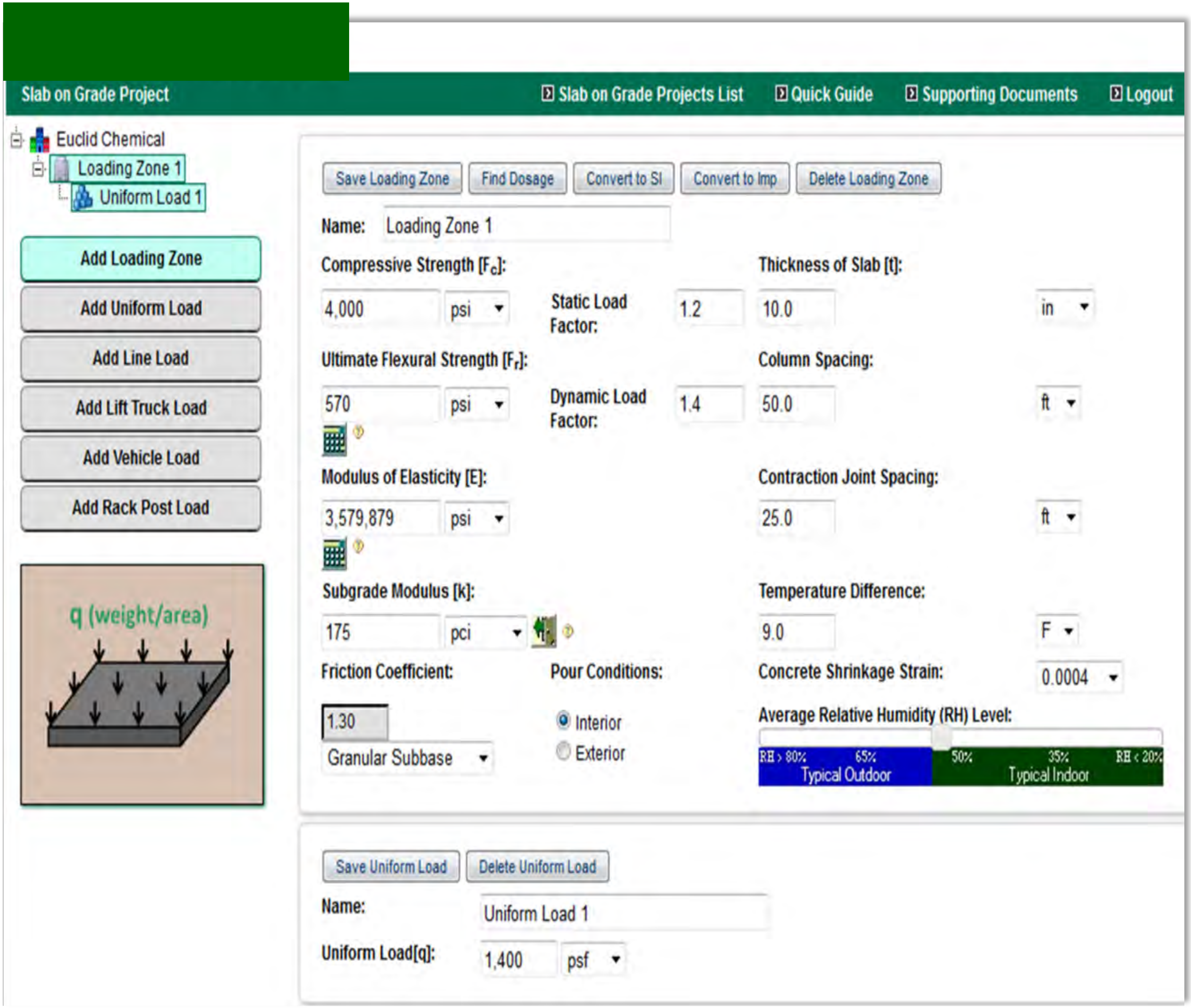
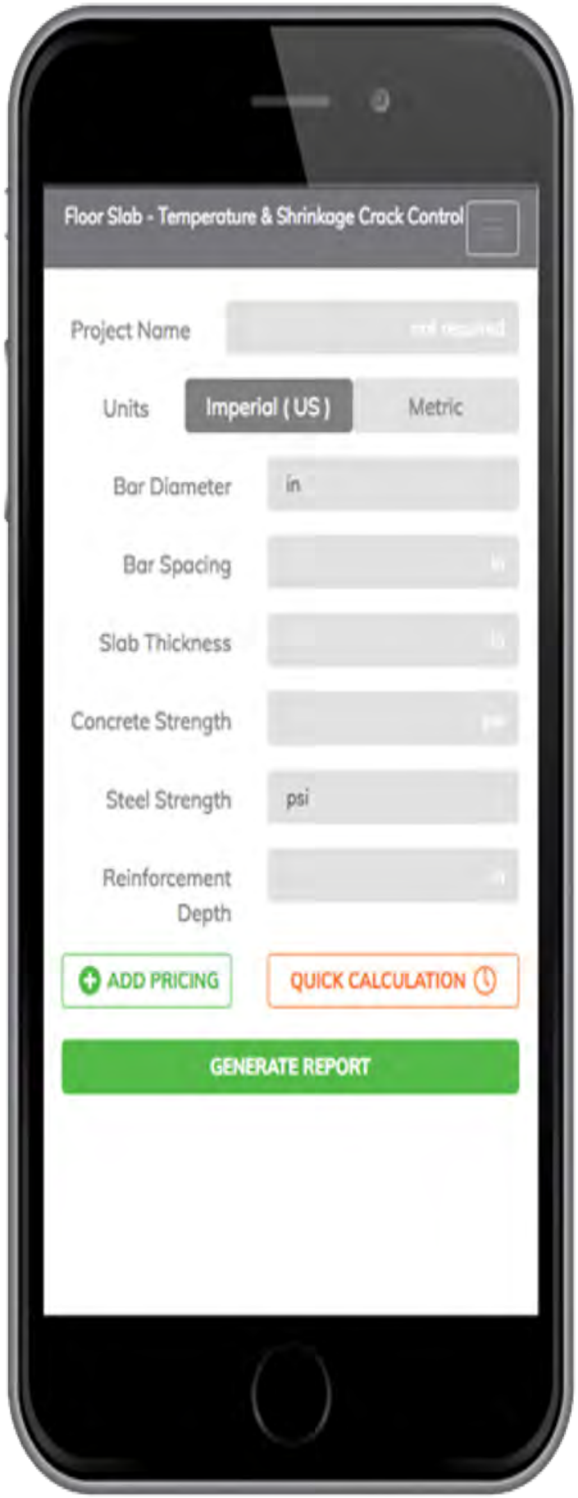


Slab on Grade Project
Slab on Grade Projects List
Quick Guide
Supporting Documents
Logout
Euclid Chemical
Loading Zone 1
Uniform Load 1
Add Loading Zone
Add Uniform Load
Add Line Load
Add Lift Truck Load
Add Vehicle Load
Add Rack Post Load
q (weight/area)
Save Loading Zone
Find Dosage
Convert to SI
Convert to Imp
Delete Loading Zone
Name: Loading Zone 1
Compressive Strength [Fc]: 4,000 psi
Static Load Factor: 1.2
Thickness of Slab [t]: 10.0 in
Ultimate Flexural Strength [Fr]: 570 psi
Dynamic Load Factor: 1.4
Column Spacing: 50.0 ft
Modulus of Elasticity [E]: 3,579,879 psi
Contraction Joint Spacing: 25.0 ft
Subgrade Modulus [k]: 175 pci
Temperature Difference: 9.0 F
Friction Coefficient: 1.30
Granular Subbase
Pour Conditions:
Interior
Exterior
Concrete Shrinkage Strain: 0.0004
Average Relative Humidity (RH) Level:
RH > 80% 65% 50% 35% RH < 20%
Typical Outdoor
Typical Indoor
Save Uniform Load
Delete Uniform Load
Name: Uniform Load 1
Uniform Load[q]: 1,400 psf



Bar diameter has a “drop down” menu with common options for size

Bar spacing should contain the lowest numerical value;

example: 6” x 12” – enter 6

Steel strength “drop down” menu has three options; wire is typically 70 ksi, rebar is 60 ksi

For a quick calculation of fiber dosage, without a report, select the button

ASTM and ACI Approvals

ACI and ASTM do not endorse, certify or prohibit the use of materials – there is no “approved by ACI” type of language in any specification.

Design of Slabs on Grade

ACI 360 CHAPTER 11

11.2.2 Design Principles

Macro synthetic fibers provide increased post-cracking residual strength to concrete slabs-on-ground. The same principles for steel in section 11.3.3 can be used for macro synthetic fibers.

ACI 360 (Slab on Grade) is undergoing a revision that will include macro-fibers and extended joint possibilities

ASTM Standards for Fiber

C1116	Standard Specification for Fiber-Reinforced Concrete and Shotcrete
D7508	Polyolefin Chopped Strands for use in Concrete
C1609	Flexural Toughness (Beams)
C1399	Average Residual Strength
C1550	Flexural Toughness (Round Panels)
C1579	Plastic Shrinkage

+ additional testing on abrasion, fatigue, creep, durability, stength, etc.

D7508/D7508M – 10

TABLE 1 Conformance Requirements for Chopped Strands for Use in Concrete

Chopped Strands Attributes	Micro Chopped Strands	Macro Chopped Strands	Hybrids Chopped Strands
Compliance with Specification C1116/C1116M, Type III	Required	Required	Required
Denier	580 or less	581 or greater	As Designated – Must be stated
Finish Content	1.5 % max	1 % max	1.5 % max on Micro Portion 1 % max on Macro Portion
Tensile Strength	N/A	Greater than 344.4 MPa [50 000 psi]	Micro Portion (N/A) Macro Portion – Greater than 344.4 MPa [50 000 psi]
Cut Length	3 – 50 mm	12 – 65 mm	As Designated – Must be stated

A wealth of information on fibers…

544.1R	Fiber-Reinforced Concrete
544.2R	Measurement of Properties of Fiber-Reinforced Concrete
544.3R	Guide for specifying, proportioning, mixing, placing, and finishing FRC
544.4R	Guide to Design with Fiber-Reinforced Concrete
544.5R	Report on the Physical Properties and Durability of Fiber-Reinforced Concrete
544.7R	Report on Design and Construction of Fiber-Reinforced Precast Concrete Tunnel Segments
544.8R	Report on Indirect Method to Obtain Stress-Strain Response of Fiber-Reinforced Concrete
544.9R	Report on Measuring Mechanical Properties of Hardened Fiber-Reinforced Concrete
506R	Guide to Shotcrete
506.1R	State-of-the-art report on Fiber-Reinforced Shotcrete
506.2	Specification for Shotcrete
440R	State-of-the-art report on Fiber-Reinforced Plastic (FRP)
302.1R	Guide for concrete floor and slab construction
325.10R	State-of-the-art report on roller compacted concrete pavement
207.5R	Roller compacted mass concrete
330R	Guide for design and construction of concrete parking lots
330.1	Standard specification for plain concrete parking lot
332.1R	Guide to Residential Concrete Construction
360R	Design of slabs-on-grade
116R	Cement and concrete terminology


An overview of ACI 544.4R-18
Design Guide for
Fiber Reinforced Concrete
October, 2018

ACI 544 – Fiber Reinforced Concrete

Committee Mission: Develop and report information on concrete reinforced with short, discontinuous, randomly-dispersed fibers.

Goals: Develop new documents, revise and update the existing documents to reflect the significant changes in the fiber reinforced concrete development, use, and applications.

Chair: Liberato Ferrara

American Concrete Institute
Always advancing

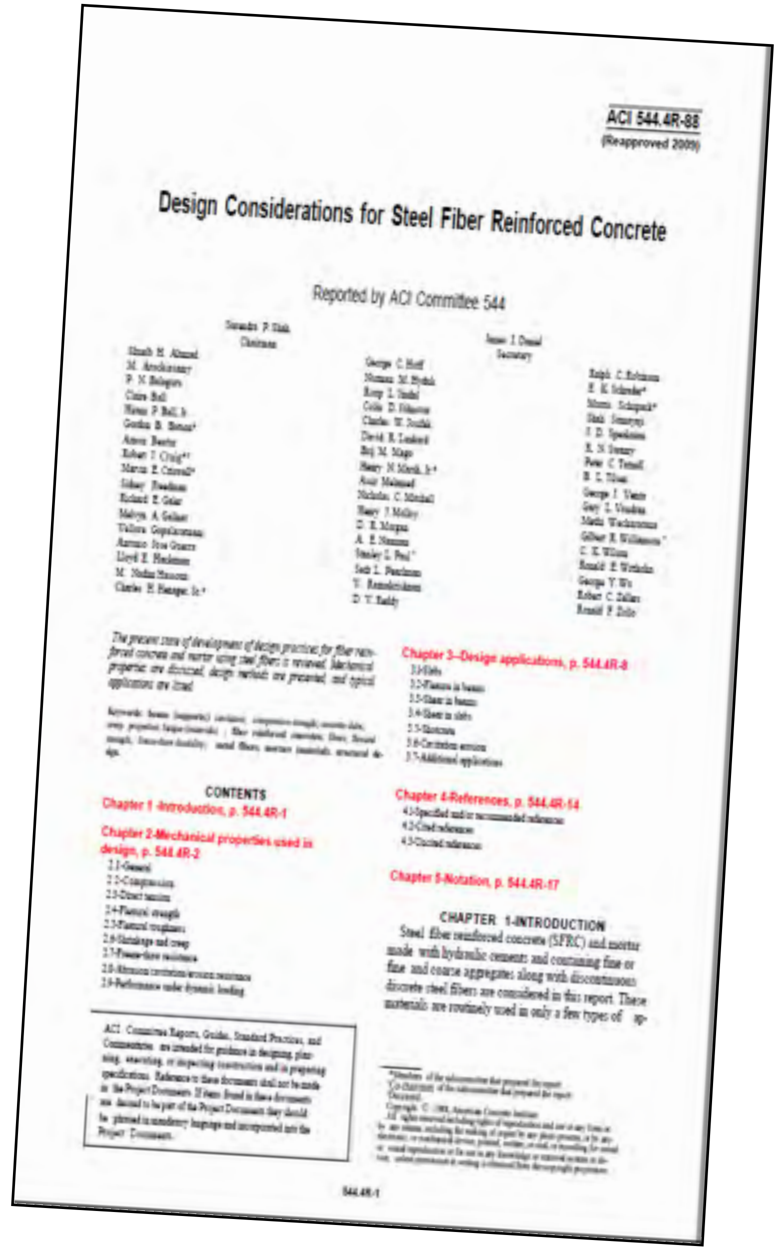
7 active subcommittees

- 544-0A - FRC-Education Production Application
- 544-0C - FRC-Testing
- 544-0D - FRC-Structural Uses
- 544-0E - FRC-Mechanical Properties
- 544-0F - FRC-Durability
- 544-0L - Liaison Subcommittee
- 544-SC - FRC-Steering Committee

ACI 544.4R

In need of a tune-up

- Previous version 30 years old
- Based on steel fiber research and design
- No information on macro-synthetics
- Focused on mechanical properties and design applications



ACI 544.4R-88
(Reapproved 2009)

Design Considerations for Steel Fiber Reinforced Concrete

Reported by ACI Committee 544

CONTENTS

Chapter 1–Introduction, p. 544.4R-1

Chapter 2–Mechanical properties used in design, p. 544.4R-2

Chapter 3–Design applications, p. 544.4R-8

Chapter 4–References, p. 544.4R-14

Chapter 5–Notation, p. 544.4R-17

CHAPTER 1–INTRODUCTION

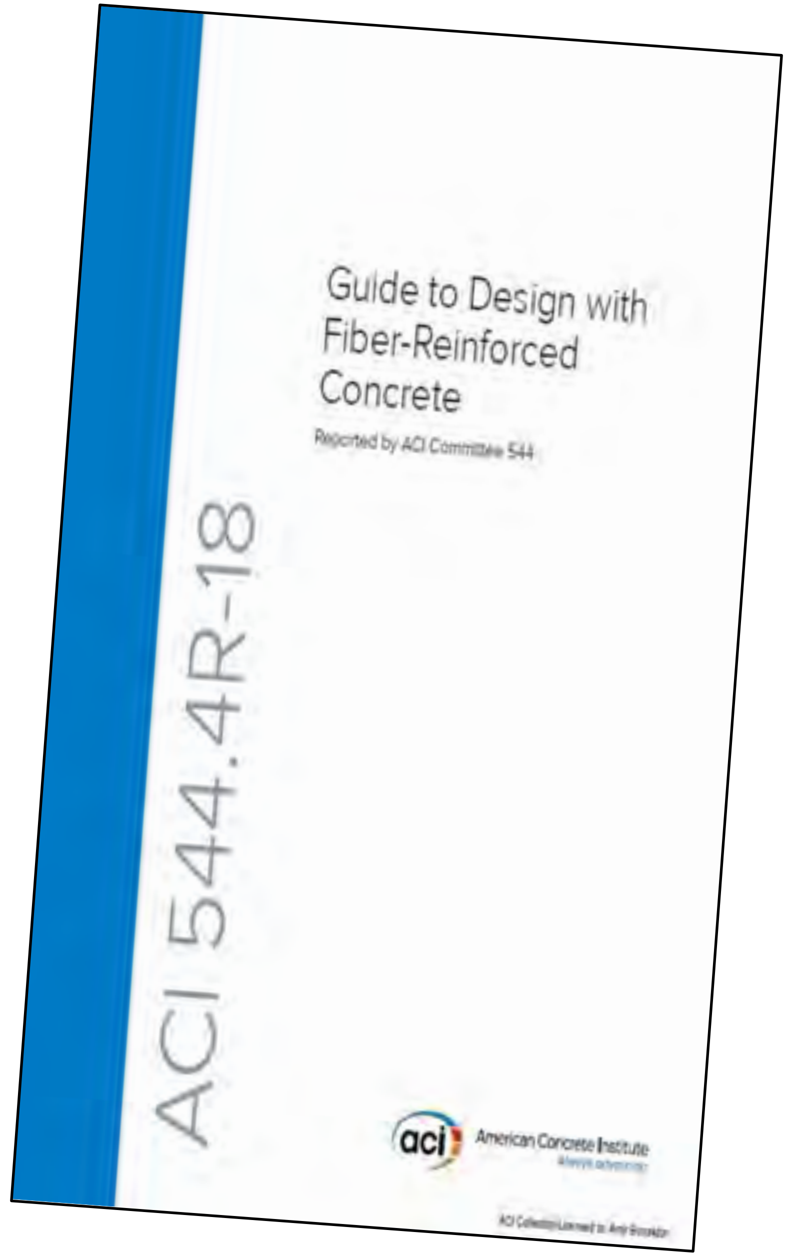
Steel fiber reinforced concrete (SFRC) and mortar made with hydraulic cements and containing fine or fine and coarse aggregates along with discontinuous discrete steel fibers are considered in this report. These materials are routinely used in only a few types of ap-

544.4R-1

Modern FRC Design

4 years of bipartisan efforts

- March 2014: Formation of a task group to rewrite document
- October 2016: sixth (final) draft was balloted
- March 2017: TAC meeting and approval
- October 2017: final changes and back to ACI
- Publication: 2018



Guide to Design with FRC

Scope of Document

This guide is intended for designers who are familiar with structural concrete containing conventional steel reinforcement, but who may need more guidance on the design and specification for FRC.

In this document, fibers are treated as reinforcement in concrete and not as admixture. The design guides in this document have been derived and verified for FRC with steel and synthetic macro fibers only.

Chapters 1 and 2

Introductions, Scope, Notations and Definitions

- Introduction and background for this document
- Basic information about fibers and FRC
- History of advancements in FRC
- Scope of the document and expectations
- Historical aspects on FRC studies (old 544.4R document)
- Definitions and notations used in the document

Chapter 3

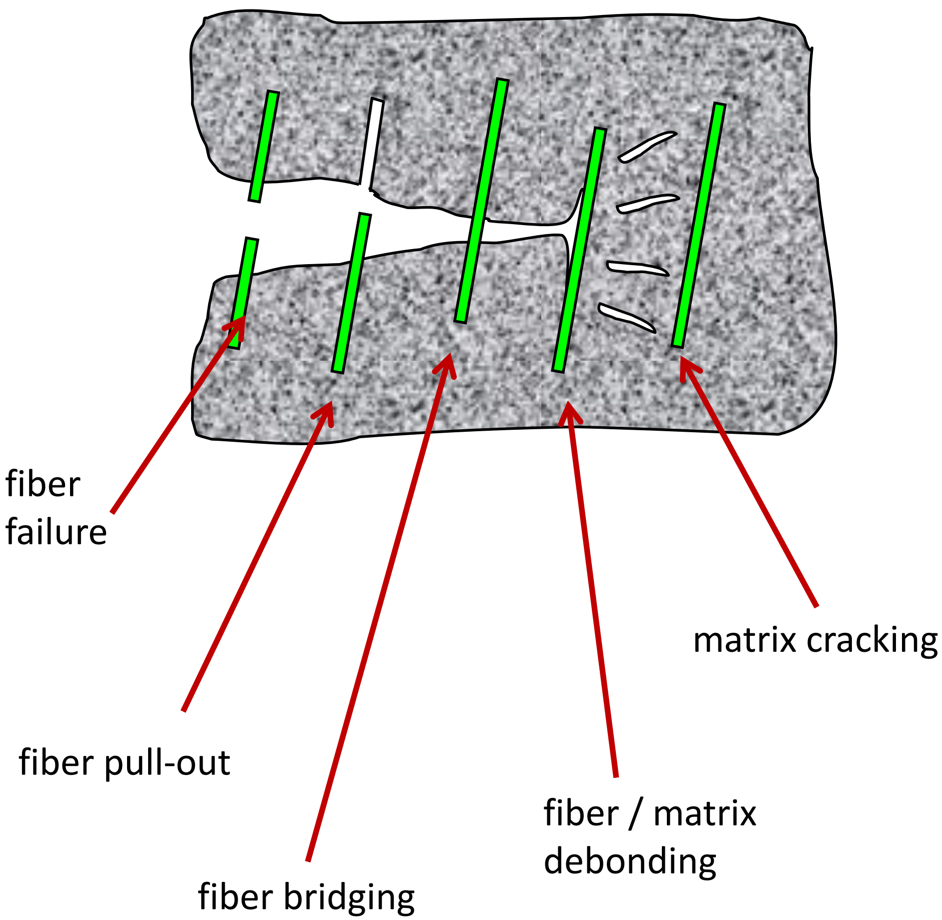
Characteristics of FRC

- Classification of Fibers
- Mechanical Performance of FRC
- Standard Test Methods for FRC
- Strain Softening and Strain Hardening

Classification of fibers based on size (micro vs. macro)
Classification of fibers based on type (steel vs. synthetic)
ASTM requirements for each fiber type
Applications and expectations for each fiber type

Mechanical Properties

How fibers work in concrete

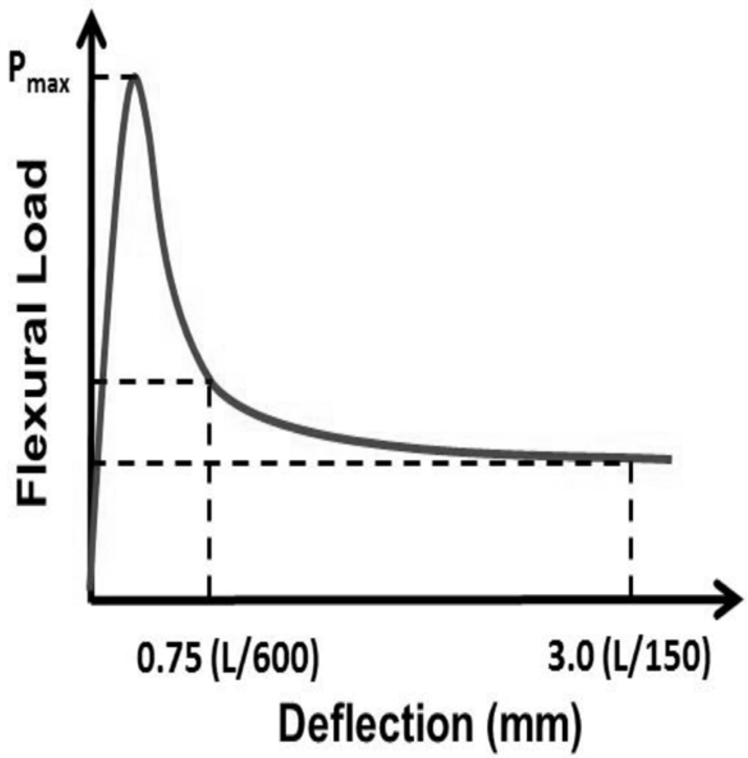


Crack control (bridging) in FRC beam under flexural loading

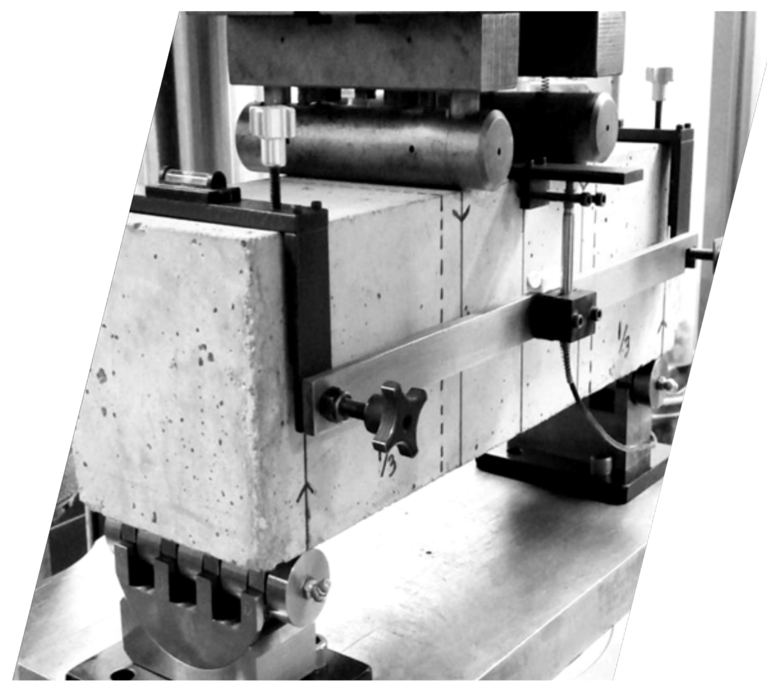
Standardized Testing of FRC

ASTM C1609

$$R_{T,150}^{D} = \frac{150 \times T_{150}^{D}}{f_P \cdot b \cdot h^2}$$

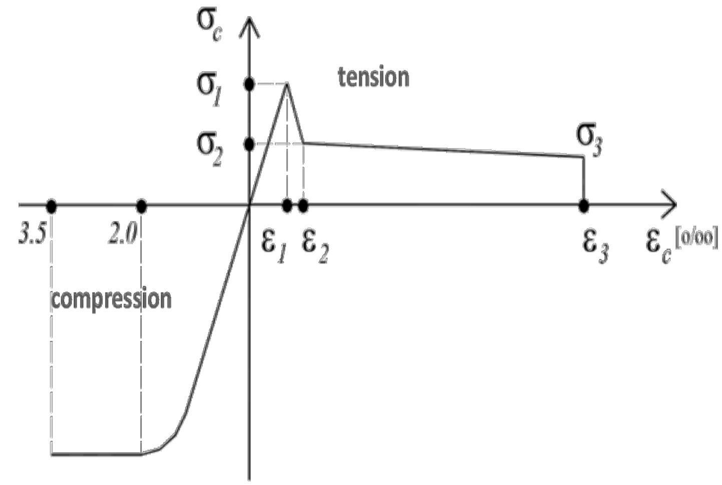


- Four point bending test
- Closed-loop control
- Typically strain-softening behavior



Chapter 4

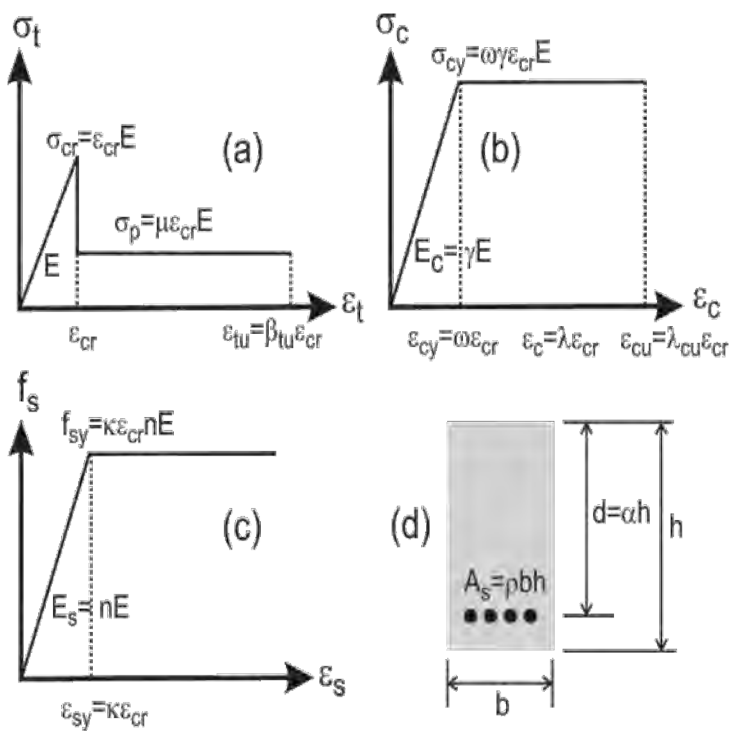
Design Concepts and Guides

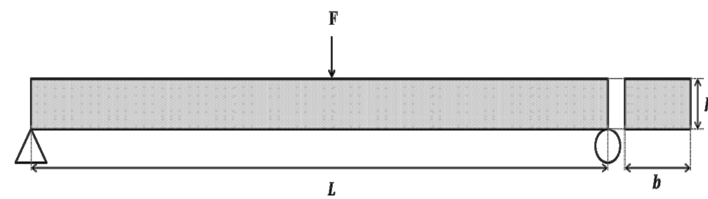


- Design Concepts
- Tensile Stress-Strain Response for FRC
- Correlation of Tensile and Flexural Response for FRC
- Design of RC for Flexure (Stress Block)
- Design of FRC for Flexure – ASTM C1609/C1609M
- Design of FRC for Flexure – Model Code 2010
- Design of FRC for Flexure – Hybrid Reinforcement
- Design of FRC for Shear
- Parametric Based Design for FRC

Engineered Solutions

Parametric Based Design for FRC and Solved Example





$$M_u = \frac{6\times 2.41\,\text{MPa}\times\sqrt{41.36}}{1.32\left(2.41\,\text{MPa}+2.54\times 41.36\right)}\times 4.2\text{ kN-m} = 2.78\text{kN-m}$$

$$\phi M_n = M_u = 0.203+\frac{F(1.21\,m)}{4}\text{kN-m}=2.78\text{kN-m}$$

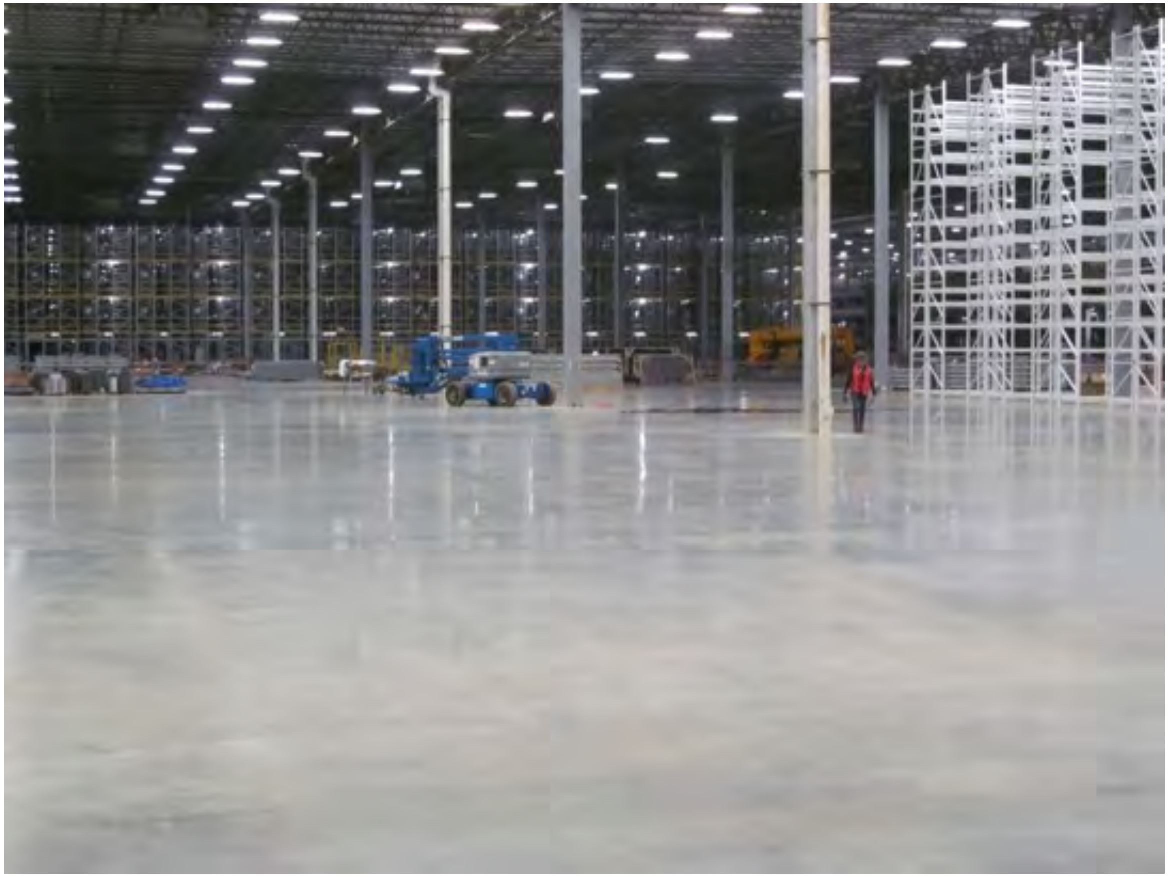
$$F=8.52\text{ kN}$$

Material model for singly reinforced concrete design

Chapter 5

Design for Specific Applications

- Slabs-on-Ground
- Extended Joint Spacing
- Elevated Floors/Slabs on Pile
- Composite Steel Decks
- Precast Units
- Shotcrete
- Crack Control and Durability



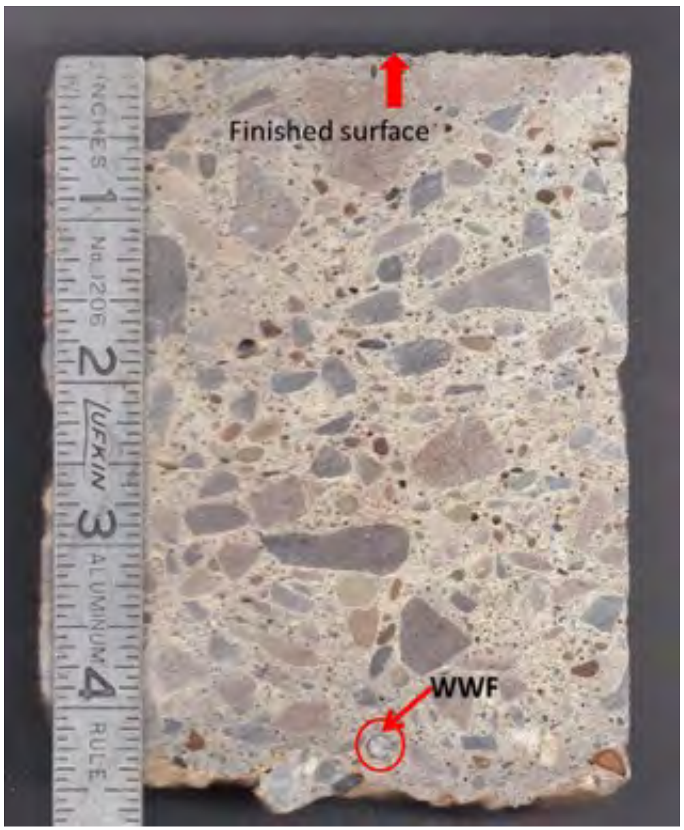
Slabs on Ground

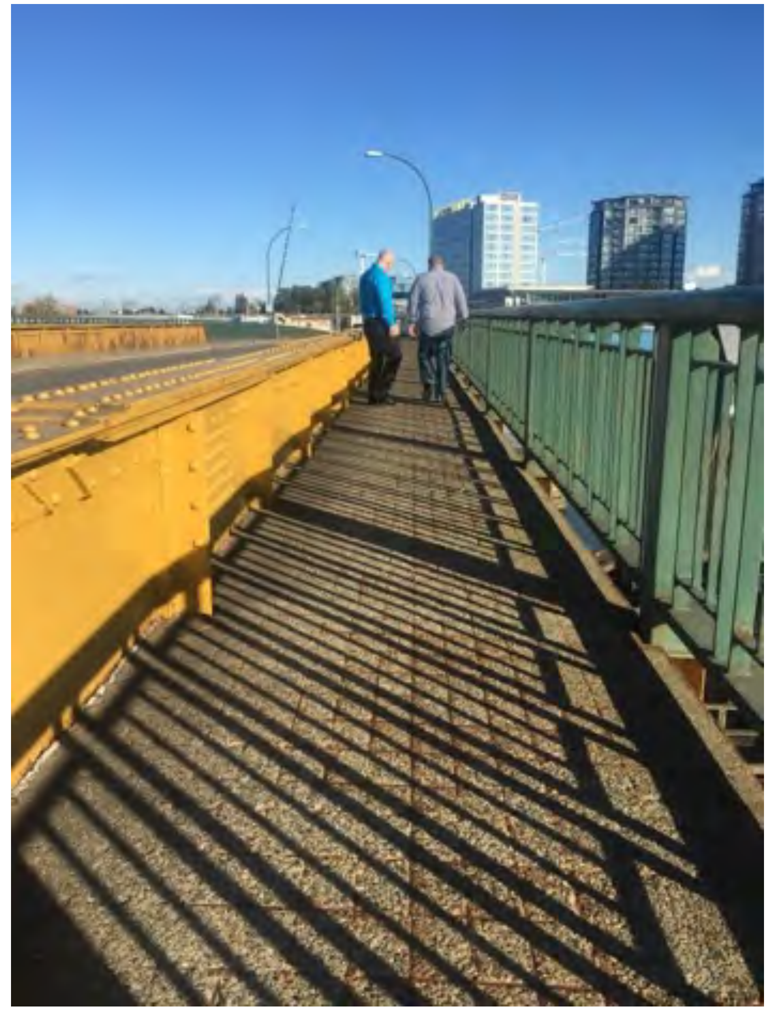
Interior and exterior construction

FRC slabs using low shrinkage concrete
and extended joint spacing

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)!





Shotcrete

Moment design and crack control

- Repair work
- Slope stabilization
- Swimming pool construction
- Underground support

NESMEA
North Eastern States' Materials Engineers Association

Chapter 6

Construction Practices

- Mix Design Recommendations for FRC
- Workability of FRC
- Adding and Mixing Fibers
- Placing, Consolidation and Finishing FRC
- Quality Control for FRC
- Contraction (Control) Joints
- Specifying FRC

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Adding and Mixing Fibers

Different methods, different costs

Considerations – speed, costs, safety, fiber type, job site, specifications

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Placing, Consolidating and Finishing FRC

Same as conventional concrete

FRC can be finished with similar tools as used for unreinforced concrete.

Davis Monthan AFB Tucson

Fresno/Broom

Port of Long Beach

Specifying FRC

Summary of Fiber Reinforcement Tests & Parameters

	Reinforcement Purpose	
	Shrinkage/Temperature Crack Control	Post-Crack Tensile/Flexural Capacity
Fiber Type	Synthetic microfiber Steel and synthetic macrofiber	Steel and synthetic macrofiber
Test Method	ASTM C1579 or ASTM C1581*	ASTM C1609 or ASTM C1550 **
Test / Spec Parameter	% in crack width reduction	Flexural residual strength or toughness

* Prescriptive (dosage based) language may be used instead.
** Equivalent BS tests are EN 14651 and EN 14488

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

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

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

XS
AADD
OSD
IH

^^

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).

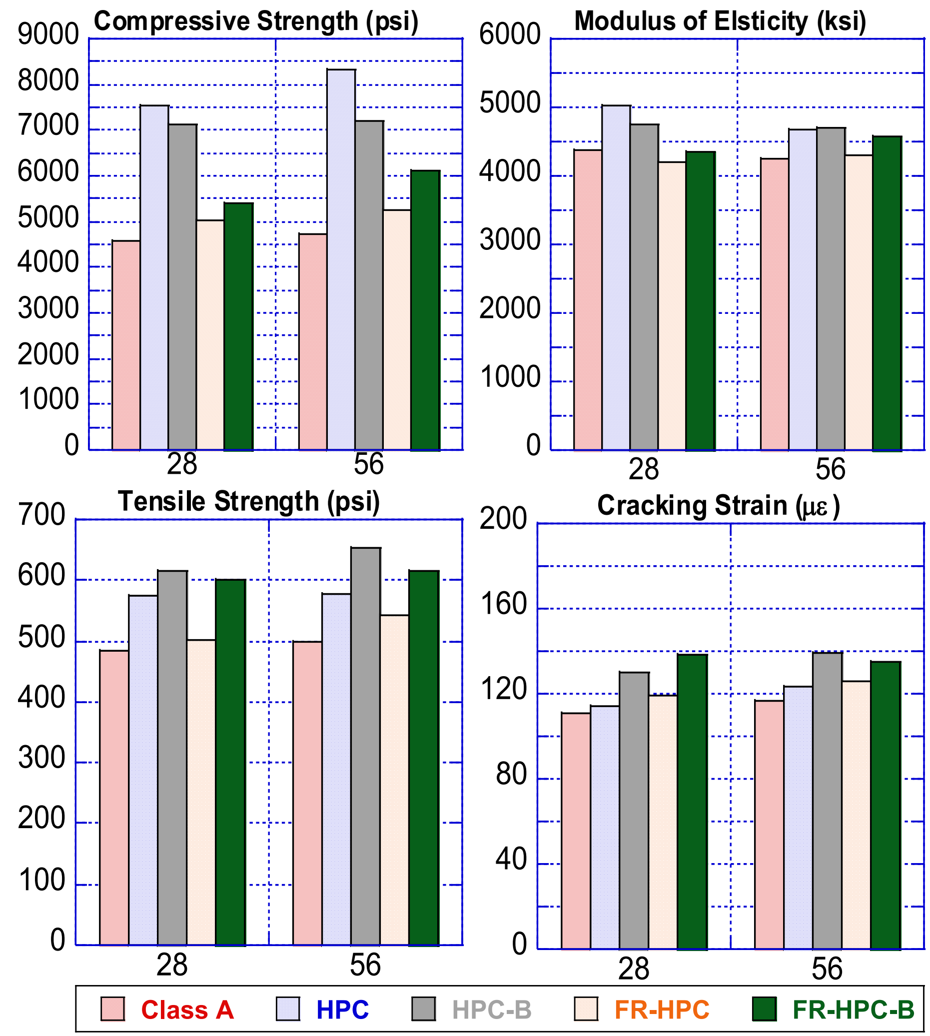
CALTRANS spec:
1 lb/yd^3 micro and 3 lb/yd^3 macro fibers
¾ gal SRA (0.032% shrinkage)

Task 1 – Laboratory Material Testing

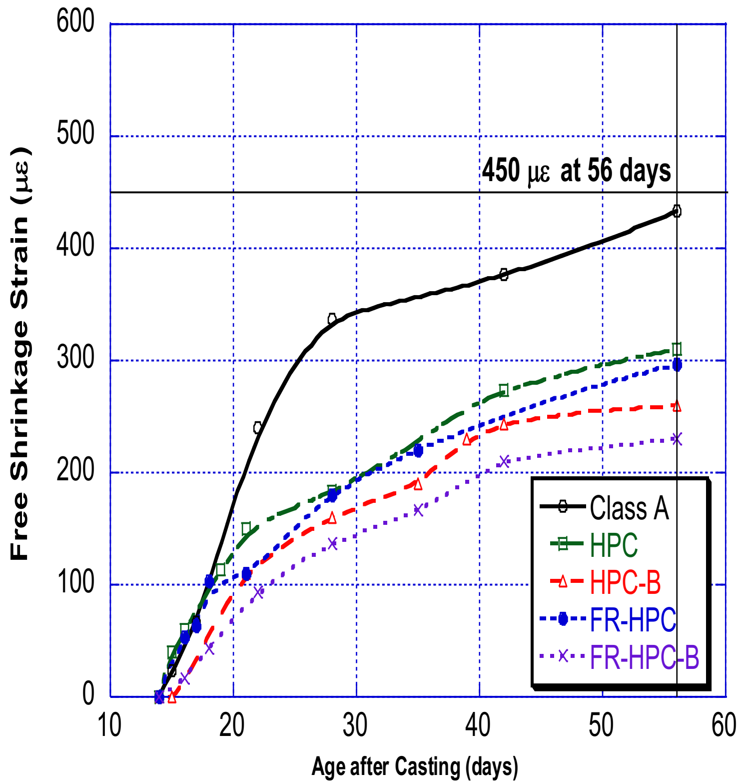
B – stands for Blended Aggregate
FR – stands for Fibers

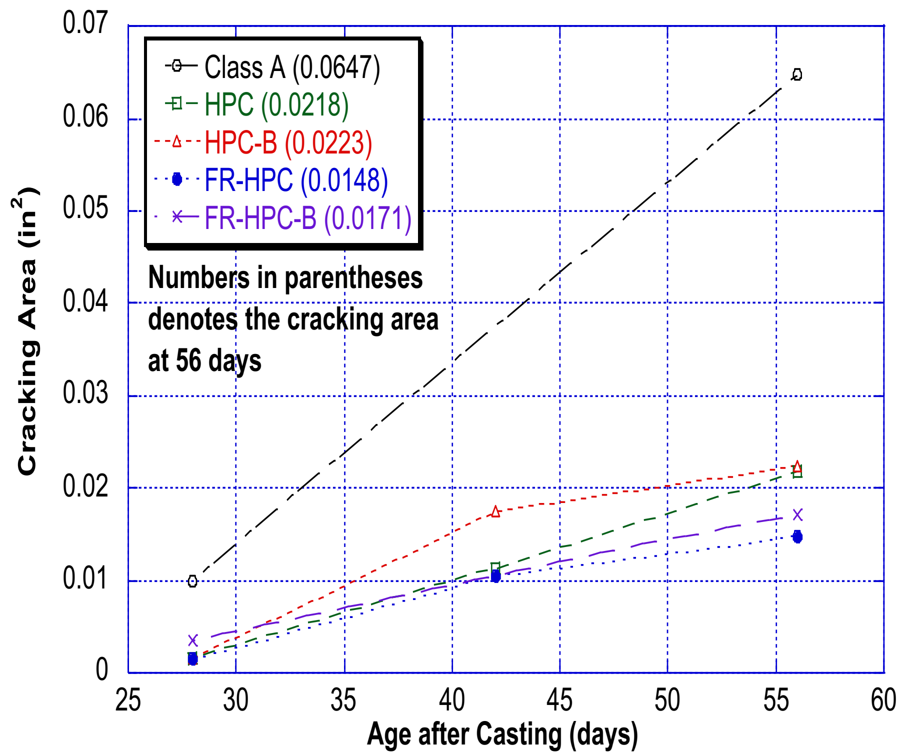
Mix Designs with Macro Fibers

Mix ID (lb/cy)	Class A	HPC	HPC-B	FR-HPC	FR-HPC-B
Cement, Type I	658	520	520	520	520
Fly Ash, Class C	-	130	130	130	130
Silica Fume	-	25	25	25	25
Total Cement	658	675	675	675	675
w/b ratio	0.410	0.382	0.382	0.382	0.382
#57	1,800	1,800	1,500	1,800	1,500
#8	-	-	300	-	300
Sand	1,205	1,113	1,113	1,113	1,113
HRWR (oz/cwt)	2.0	2.5	2.0	2.5	3.5
AEA (oz/cwt)	1.0	1.0	1.0	1.0	1.0
Macro Fibs (lb/cy)	-	-	-	PPF 5lb	PPF 5lb
Slump (in.)	7	8	4	6	6.5
Air (%)	5.5	-	-	8.5	7



Shrinkage and Cracking Performance





Macro Polypropylene Fibers (added to HPC) reduced:

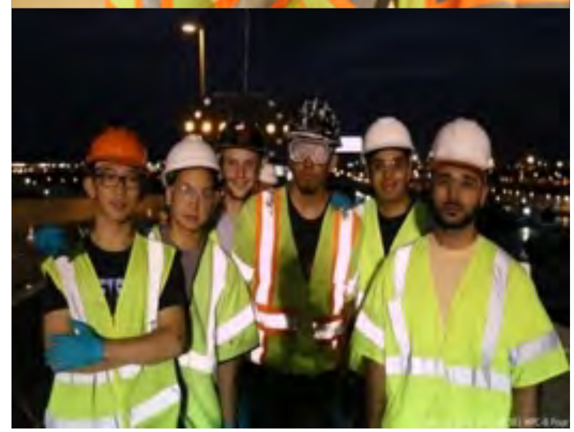
- Free Shrinkage: 27% (w/HPC) & 46% (Class A)
- Cracking Area: up to 22% (HPC) & 73% (Class A)
- Max. Crack Width: up to 12% (HPC) & 35% (Class A)

Task 3 – Mock-up Slab

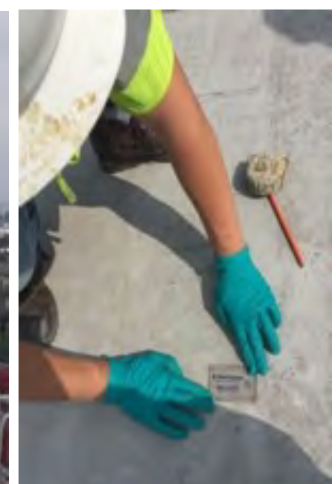
Field Validation

- A mock-up slab was cast to validate the applicability of the proposed FR-HPC mixture prior to casting the actual bridge decks
- The concrete passed the slump and air test.
- No issues were found during mixing, pumping, casting and finishing the concrete.

Field Implementation and Testing



- FR-HPC was successfully implemented on the major highway bridge deck replacement in NJ.
- Field Crack Mapping (3 field trips in 300 days) show that FR-HPC reduces number of cracks by 5.3%, narrower mean crack width by 28.6%, and lower cracking area by 33.3%, compared to HPC.
- Another crack map will be performed one year after opening to traffic.
- A technical specification is prepared.



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Hani Nassif, PE, PhD, FACI, Professor and Director

Adi Abu-Obeidah, PhD, Research Associate

Chaekuk Na, PhD, Research Associate

Rutgers Infrastructure Monitoring and Evaluation (RIME) Group

Questions, Comments, Discussion?

Bill Lyons FACI

National Business Development Group – Northeast Region

201-401-3391

wlyons@euclidchemical.com

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