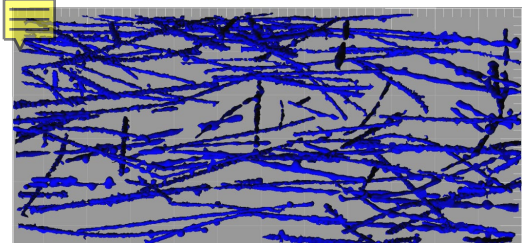


Fiber Reinforced Concrete for Pavement Overlays

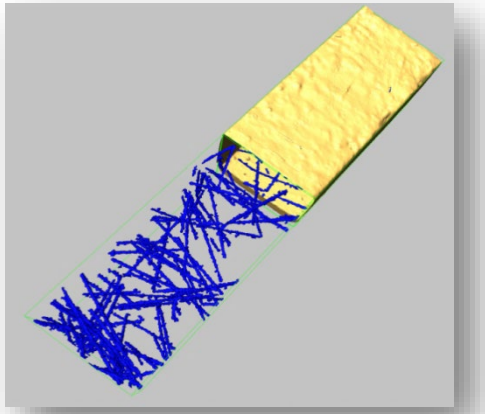
Jeffery Roesler, Ph.D., P.E., University of Illinois Urbana-Champaign

April 3, 2019

TTCC/Fiber Reinforced Concrete Project

National Concrete Consortium

Denver, CO



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  - TTCC/Fiber-Reinforced Concrete Project
    - “Fiber Reinforced Concrete for Pavement Overlays” Technical Advisory Committee
  - National Concrete Consortium
  - National Concrete Pavement Technology Center (Iowa State)
    - Peter Taylor, Steve Tritsch, etc.
  - Snyder and Associates, Inc.
    - Jerod Gross, Dale Harrington

NATIONAL CONCRETE CONSORTIUM

FRC Overlay Project - Main Tasks

1) Develop ***software tool*** for calculating fiber performance for concrete overlays (Residual Strength Estimator)

- Functional class, traffic, existing asphalt condition, bond condition, concrete/asphalt thickness; New concrete strength and proposed slab size
- Recommend residual strength for FRC (ASTM C 1609)

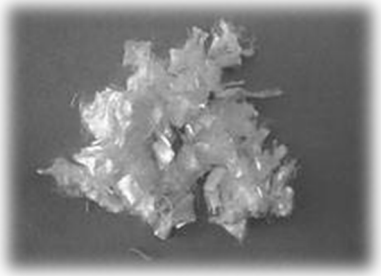
2) Develop ***Tech Briefs***

- FRC for concrete overlays (8 pp)
- Overview of FRC Bridge Decks (4pp)

3) Detailed ***Reports*** on FRC overlays and decks

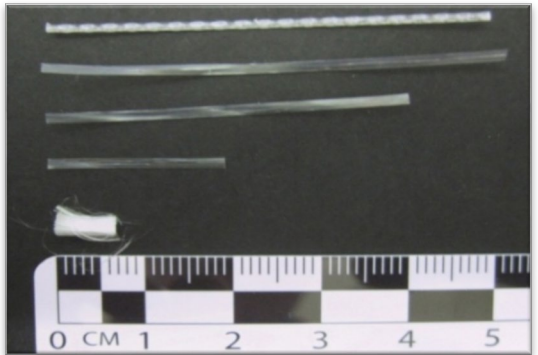
4) Deliver ***three 60-minute webinar*** on FRC & pavement overlays.

Fiber Type (Size)



Micro-Fibers

- Material:
  - Synthetic, natural or glass fibers
- Dosage:
  - 0.05 to 0.2% by volume
  - 0.75 to 3 lb/cy
- Fiber dimensions:
  - Diameter < 0.012 inch
  - Length < 0.5 inch

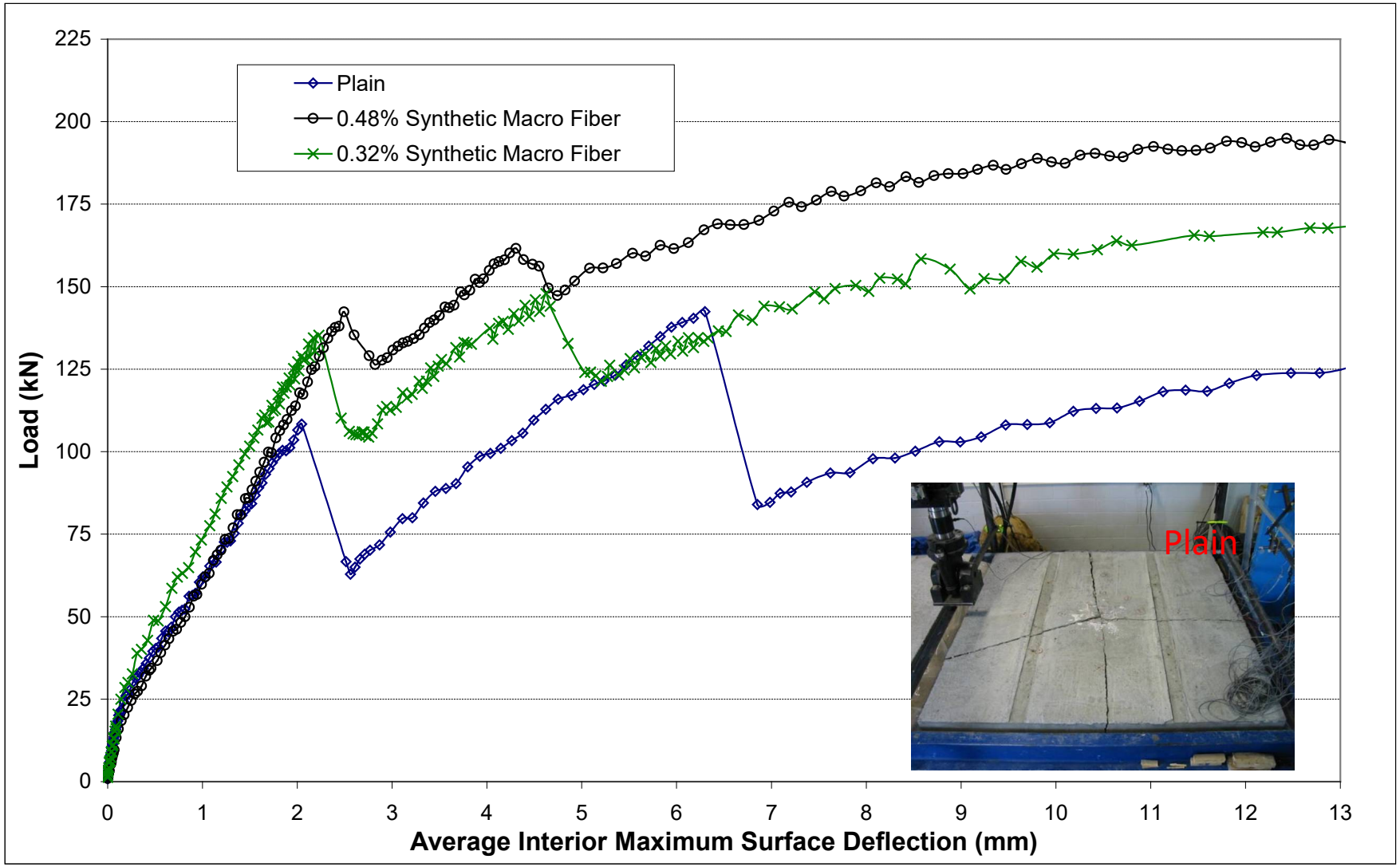


Macro-Fibers

- Material:
  - Synthetic or steel
- Dosage:
  - 0.2 to 0.5% by volume
  - 3 to 8 lb/cy (synthetic) or 25 to 75 lb/cy (steel)
- Fiber dimensions:
  - Diameter > 0.012 inch
  - Length 0.5 to 2.5 inches

Monotonic Load-Deflection of FRC Slab

Plain vs Macro Synthetic Fibers



MACRO-Fiber Reinforcement Benefits for Concrete Pavements & Overlays

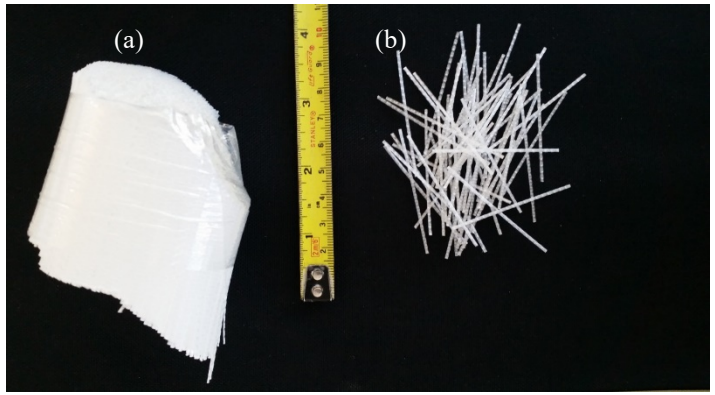
- ***Increase*** *in structural capacity* of slab
  - Can reduce required slab thickness for overlays
- Maintain crack/joint widths
- Non-uniform (variable) support condition
- Tie **longitudinal**/transverse contraction joints
  - *Avoid slab migration*
- Extend overlay serviceability
  - Reduce deterioration rates after initial cracking
  - slab deflect ↑ and displace more easily
  - Thin concrete overlays deteriorate more rapidly under traffic

- Macro-fibers are NOT necessary on every concrete pavement project

Fiber-Reinforced Concrete for Pavement Overlays: Technical Overview *Report*

- General overview of macrofibers in concrete pavements
- Macrofibers types available
- Effect on fresh and hardened properties
- Test methods to specify macrofibers for overlays
- Construction best practices & guidelines
- *Residual Strength Estimator* software overview

https://cptechcenter.org/publications/



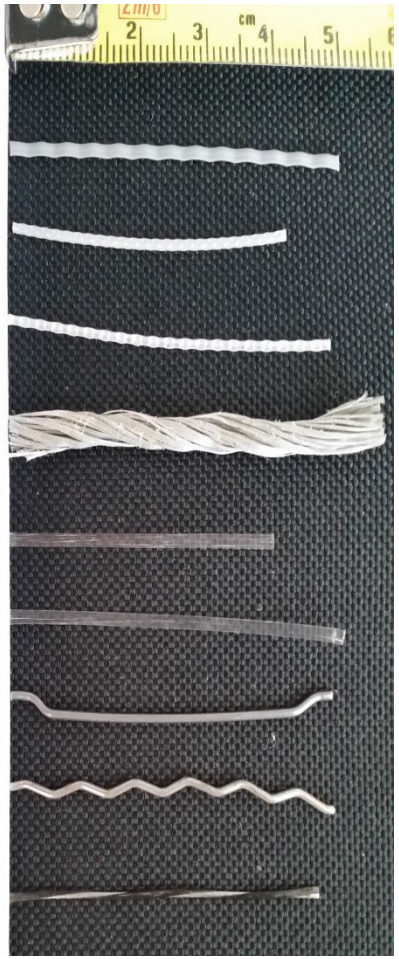
FRC Pavement Overlay Report: T.O.C.

https://cptechcenter.org/publications/

Chapter	Topic
1	Introduction
2	Report Objective
3	FRC Pavement Background
4	Types and Characteristics of Fibers
5	Behavior of FRC Materials for Concrete Pavements
6	Concrete Pavement Design Methodology with FRC Materials
7	Construction Modifications with FRC Pavement Overlays
8	FRC Test Methods
9	Example of FRC Overlay Specifications
10	Miscellaneous Topics on FRC Overlays
11	Summary of FRC Overlays for Pavements

References

Appendix A – Description of Residual Strength Estimator Software for FRC Concrete Overlay



Common FRC Overlay Questions/Comments

1. When should I consider macro-fibers in a concrete overlay?
2. How do macro-fibers affect contraction joints?
3. How do I quantify the existing pavement condition in the FRC overlay design?
4. What is the difference between bonded and unbonded overlays with FRC?
5. What macro-fiber dosage is required for a concrete overlay?
6. Do I need to update the concrete mixture design for addition of macro-fibers?
7. What specific fiber type should I use and do I need to consider the fiber type when determining the fiber dosage?
8. Will I have corrosion issues if I use steel fibers?

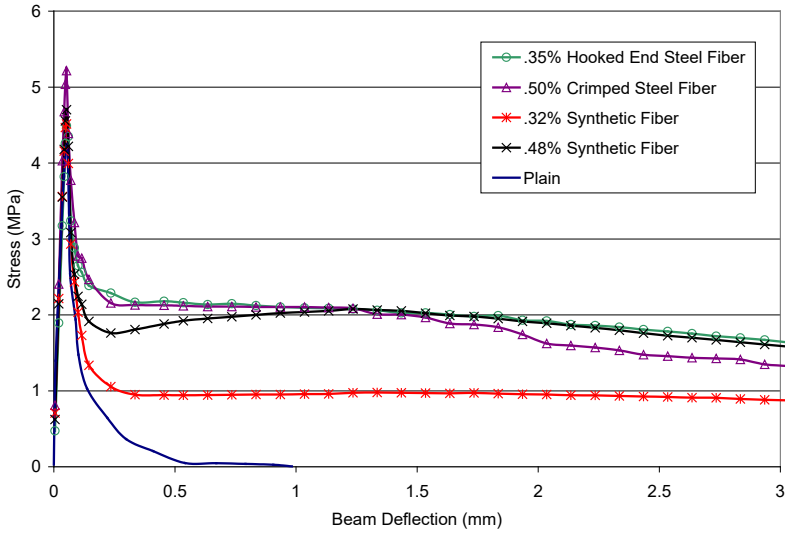
https://cptechcenter.org/publications/

Fiber-Reinforce Concrete Overlay Tech Brief

1. Tech Brief - FRC for Pavement Overlays (*8 pages*)
   - https://intrans.iastate.edu/app/uploads/2019/03/FRC_for_overlays_TB.pdf

-Fiber types, mixture proportions, properties, slab performance, structural design, construction, testing, residual strength

ASTM C1609-12



CP ROAD MAP
shaping the future of concrete pavement

www.cproadmap.org

March 2019

ROAD MAP TRACK 8

PROJECT TITLE
Fiber-Reinforced Concrete for Pavement Overlays

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"Moving Advancements into Practice"

MAP Brief March 2019

Best practices and promising technologies that can be used now to enhance concrete paving

Fiber-Reinforced Concrete for Pavement Overlays

The objectives of this MAP Brief are to provide pavement engineers with necessary information to apply fiber-reinforced concrete (FRC) to concrete overlays and determine the appropriate fiber-reinforcement performance values to be specified in a project and implemented into the structural design calculations for bonded and unbonded concrete overlays.

A spreadsheet tool, the Residual Strength Estimator, has also been developed. The tool provides an estimate of the FRC performance value to specify for a project as well as the effective flexural strength to input into a mechanistic-empirical concrete pavement design software. A comprehensive technical report accompanies this tech brief [1], which provides a more

used as overlays for Navy airfields and commercial airports in the 1970s and 1980s [3]. In the past 15 years, FRC has been successfully implemented for concrete overlays of roadways. Particularly, FRC with bonded concrete overlay on asphalt or composite pavements has seen significant growth in the past 10 years with the overlay thickness ranging from 3 to 6 in.

The National Concrete Overlay Explorer (overlays.acpa.org) lists 89 FRC overlay projects from 2000 to 2018. An Illinois study of FRC overlays reported better performance compared to similar plain concrete overlays [4]. Multiple laboratory-scale slab tests with macrofiber reinforcement have shown that the flexural and ultimate load capacity of FRC slabs and the load transfer efficiency (LTE)

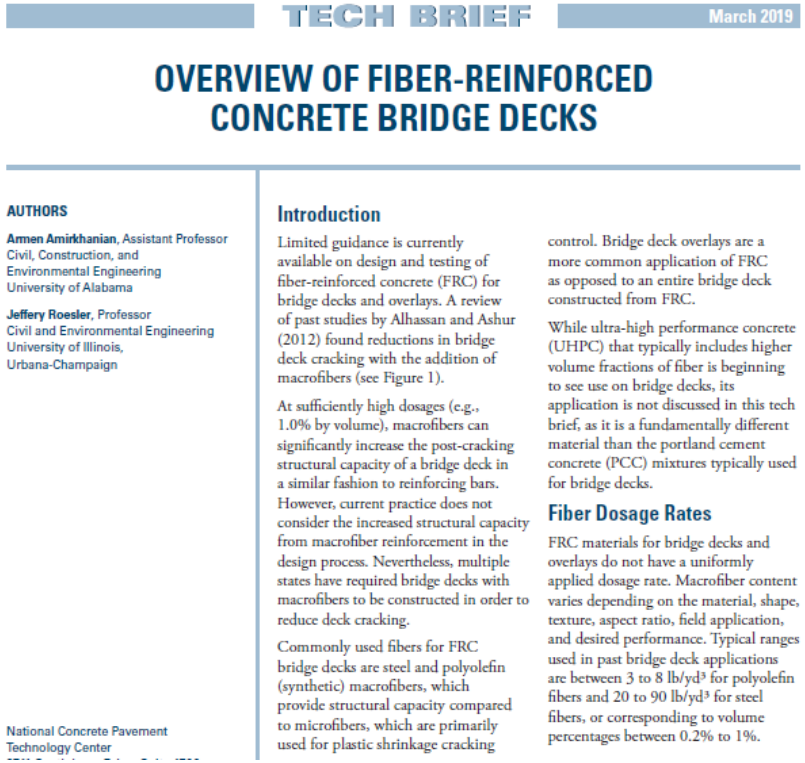
Concrete Mixture changes for FRC Overlay

- Batching/mixing
  - Trial concrete mixture should be made first
  - At < 0.5% volume fraction of fibers, typically no need to change batching/mixing
    - Slump loss may occur.
  - Fiber Balling may occur if:
    - Fibers added too quickly
    - Fiber volume too high
    - Fibers already clumped (in delivery bags)
    - Mixer inefficient or worn blades
    - Mixture too stiff
    - Concrete mixed too long after fibers added
    - Mix sequencing - fibers added to mixer before other ingredients

  - If Mix adjustment required: Add water reducer or ↑ Paste content.

Fiber-Reinforce Concrete Bridge Deck Tech Brief

2. Tech Brief - Overview of Fiber-Reinforced Concrete Bridge Decks (4 pgs)
   - https://intrans.iastate.edu/app/uploads/2019/03/FRC_bridge_decks_ovw_TB.pdf



TECH BRIEF March 2019

OVERVIEW OF FIBER-REINFORCED CONCRETE BRIDGE DECKS

AUTHORS

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Introduction

Limited guidance is currently available on design and testing of fiber-reinforced concrete (FRC) for bridge decks and overlays. A review of past studies by Alhassan and Ashur (2012) found reductions in bridge deck cracking with the addition of macrofibers (see Figure 1).

At sufficiently high dosages (e.g., 1.0% by volume), macrofibers can significantly increase the post-cracking structural capacity of a bridge deck in a similar fashion to reinforcing bars. However, current practice does not consider the increased structural capacity from macrofiber reinforcement in the design process. Nevertheless, multiple states have required bridge decks with macrofibers to be constructed in order to reduce deck cracking.

Commonly used fibers for FRC bridge decks are steel and polyolefin (synthetic) macrofibers, which provide structural capacity compared to microfibers, which are primarily used for plastic shrinkage cracking control. Bridge deck overlays are a more common application of FRC as opposed to an entire bridge deck constructed from FRC.

While ultra-high performance concrete (UHPC) that typically includes higher volume fractions of fiber is beginning to see use on bridge decks, its application is not discussed in this tech brief, as it is a fundamentally different material than the portland cement concrete (PCC) mixtures typically used for bridge decks.

Fiber Dosage Rates

FRC materials for bridge decks and overlays do not have a uniformly applied dosage rate. Macrofiber content varies depending on the material, shape, texture, aspect ratio, field application, and desired performance. Typical ranges used in past bridge deck applications are between 3 to 8 lb/yd³ for polyolefin fibers and 20 to 90 lb/yd³ for steel fibers, or corresponding to volume percentages between 0.2% to 1%.

National Concrete Pavement Technology Center

FRC Overlay Project – Webinars (60 min.)

https://cptechcenter.org/recorded-webinars/

1. Fiber Reinforced Concrete Overview for Concrete Pavement and Overlays

General overview of fibers used for concrete pavements with an emphasis on macro-fibers and their effect on concrete properties and pavement construction.

- https://vimeo.com/297350236

2. Effect of Macrofibers on Behavior and Performance of Concrete Slabs and Overlays

Review the significant findings of macro-fiber addition to concrete slabs on grade, which include the increase in plain concrete slab capacity, reduction in crack widths, and increase in pavement performance.

- https://vimeo.com/299518241

3. Overview of Macrofiber Software and Guidelines for Concrete Overlay Design

Provide an overview of the macro-fiber software for determining the recommended fiber reinforced concrete residual strength values for application to concrete overlay design.

- https://vimeo.com/304860866

Residual Strength Estimator Software: FRC Overlays

Residual Strength Estimator for Fiber-Reinforced Concrete Overlays

Instructions: Run an overlay design software to determine the design inputs. Select design choices from the drop-down menus below to narrow down the recommended performance requirement of FRC for the proposed overlay pavement. Determine the effective flexural strength to input into overlay design software instead of design concrete flexural strength. Prepare specifications to achieve design residual strength of FRC material.

Design Input Choices

Type of Overlay Road	Arterial	
Millions of ESALS in Design Life	0.01 to 5.0 million ESALs	
Asphalt Pre-Condition*	Fair	*refer to Tech Report to example estimates of asphalt pre-condition
Desired New Concrete Thickness	4.5 to 6 inch PCC thickness	
Remaining HMA Thickness after Milling	4.5 to 6 inches HMA remaining	
Overlay Slab Size	6ft joint spacing	
Desired Performance Enhancements *(this will generate a higher residual strength, but not included in effective flexural strength)*	basic FRC overlay	
Plain Unreinforced Concrete Flexural Strength (*MOR*) *based on 28 day Four Point Bending (ASTM C78 or ASTM C1609)*	550	psi

Design Suggestions/Warnings:

https://intrans.iastate.edu/app/uploads/2019/03/Residual-Strength-Estimator-for-FRC-Overlays-Jan-11-2019_public.xlsx

Effective Flexural Strength Equation

- $MOR' = MOR + f_{150}$
  - *MOR* = plain concrete flexural strength
  - f_{150} = residual strength
  - *MOR'* = effective (modified) flexural strength of FRC

Note:

$f_{150} = f_{150}^{150}$

- f_{150}= 125 psi (FRC mix for example)
- *MOR* = 625 psi (ASTM C78 at 28 days)
- $MOR' = 625\ psi + 125\ psi = 750\ psi$

- $Stress\ Ratio\ (SR) = \frac{Total\ Stress(?)}{MOR'} = \frac{(\sigma)}{MOR + f_{150}}$
- Fatigue Life: $Log\ N_f = 17.61 - 17.61\frac{\sigma}{MOR'}$

Altoubat et al. (2007)
Bordelon and Roesler(2012)

Questions & Further Information

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  - CPTech Center https://cptechcenter.org