Fabric-Reinforced Cementitious Matrix

(cement-like) (mortar)

FRCM is in the same family as FRP, but it differs in how it's installed and how it benefits certain applications.

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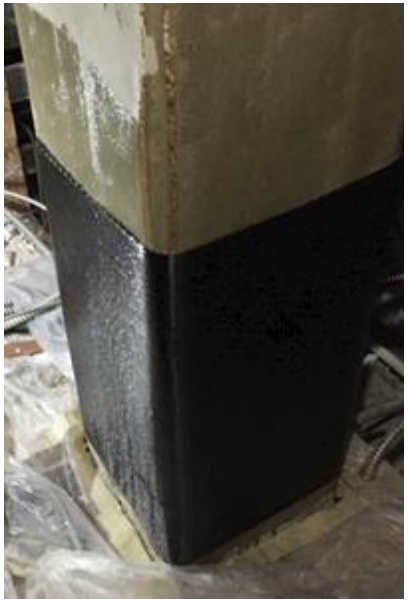
Outline of Topics

1. What is FRCM?
2. FRCM Application Steps
3. Where can I use FRCM?
4. FRCM Design and Testing
5. How can manufacturer(s) help?

What is FRCM?

A New Method of Composites

FRP Fabric



FRP Laminate

FRCM

FRCM Components

Fabric-Reinforced Cementitious Matrix (FRCM) Systems = Carbon-Fiber Grid + Cementitious Matrix

FRCM Benefits Compared to FRP

- High tensile strength
- Low impact
- Conforms to existing shapes
- Fast installation
- Cost-effective solution

Note that these benefits are the same as FRP.

- Matches substrate
- Applies on wet surfaces
- Heat resistance of matrix
- Provides protective barrier
- Repairs as it adds strength (minimal surface prep needed)

Note that these benefits are unique to FRCM.

FRCM Application Steps

Single-Layer Grid Installation

Prior to application:

Concrete surface profile should be between CSP 6-9 (ICRI)
This means you can repair surface inconsistencies as you add strength.

Fig. 6.6: CSP 6 (medium scarification)

Fig. 6.7: CSP 7 (heavy abrasive blast)

Fig. 6.8: CSP 8 (scabbled)

Fig. 6.9: CSP 9 (heavy scarification—rotomilled)

Single-Layer Grid Installation

Prior to application:

Be sure the surface has been wet to ensure a saturated surface-dry (SSD) condition per ICRI guidelines.

Single-Layer Grid Installation

1. Apply first layer of cementitious matrix (CSS-CM), being sure to completely coat area ½″ thick
2. Embed grid into wet matrix using a trowel or wood float
3. Apply second layer of cementitious matrix at ¼″ to ½″ thick
4. Screed and trowel to desired finish
5. Allow for full cure by keeping wet for 3-5 days after installation

Where can we use FRCM?

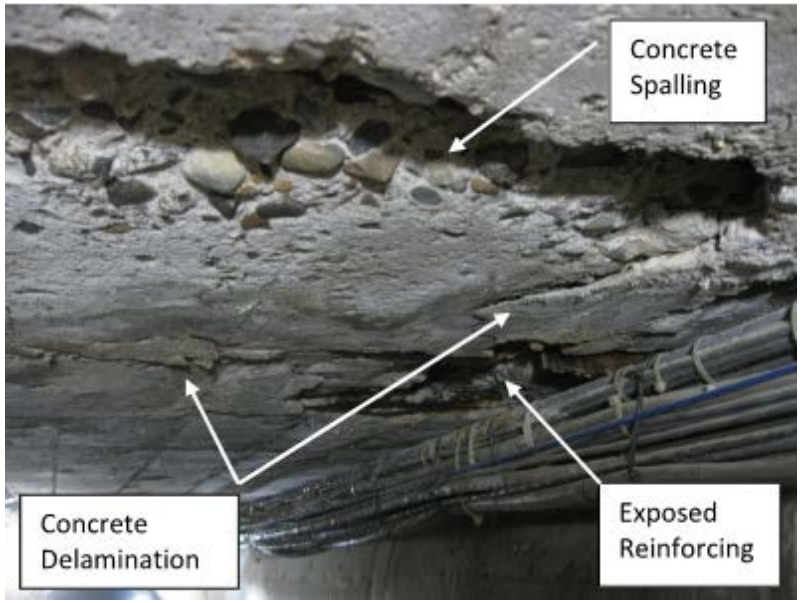
Traditional Shotcrete Repair

FRCM Repair

Traditional Shotcrete Repair	FRCM Repair
❑ Specialty contractor to tie rebar cage ❑ Specialty contractor to spray shotcrete	✓ Same contractor installs FRCM system
❑ Rebar installation time-intensive	✓ Carbon-fiber grid installs in minutes, saving time and money
❑ Additional 1.5″–3″ shotcrete cover over rebar	✓ No steel = no cover requirements. Only ≈1″ volume change in total repair
❑ Additional weight needs to be calculated into total building loads	✓ Adds significantly less weight to structure
❑ Shotcrete typical psi at 4,000 psi	✓ Cementitious matrix is a high-performance mortar with psi at 7,500 psi

For projects with large, overhead and vertical surface areas

For projects that require a surface repair



For projects that require a higher level of heat resistance

For projects that can’t afford a significant volume change

For projects that require the ability to transmit water

Ideal Application: Tunnels and Mines

Substrate damage needs repair

No room for significant enlargement

With FRCM, we repair and add strength in one step

FRCM Design

Design Standards

ACI 549.4R-13

Guide for the Design and Construction of Externally Bonded FRCM Systems for Strengthening Concrete an Masonry Structures

- Covers both concrete and masonry
- Contains design equations, examples, limitations, QC/QA recommendations, etc.

Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings

ACI 562

- Mentions strengthening with externally bonding composites (FRP & FRCM) but also covers general retrofit requirements

Design Considerations

APPENDIX B—DESIGN LIMITATIONS

Parameter	Concrete			Masonry	
	Flexure	Shear	Axial	Out-of-plane	In-plane
ε_{fe} or ε_{fd}	Less than 0.012	Less than 0.004	Less than 0.012 and ε_{ccu} less than 0.01	Less than 0.012	Less than 0.004
ϕ	0.9 to 0.65 based on ε_t	0.75	0.9 to 0.65 based on ε_t	0.6 for flexure 0.8 for shear	0.75
f_{fe}/f_{fd}	0.2 to 0.55 based on fiber	NA	NA	NA	NA
Allowable maximum enhancement*	50 percent	50 percent	20 percent	URM: 6000 lbf./ft (87.6 kN/m); Reinforced masonry: 50 percent	50 percent

*Allowable maximum enhancement is above existing capacity. ACI 562-13 supersedes when limits are lower than as listed in this table.

Design Considerations

Existing Capacity Demands

Exposure Coefficients

Serviceability

ACI 562-16 Equations 5.52a&b:

$$(\varphi R_n)_{existing} \geq (1.1D + 0.5L + 0.2S)$$

or

$$(\varphi R_n)_{existing} \geq (1.1D + 0.75L)$$

whichever is greater

This is so a building will still be able to support itself in case the FRP / FRCM system is compromised.

Design Considerations

Existing Capacity Demands

Exposure Coefficients

Serviceability

- ✓ Ambient and surface temperatures between 41°F and 86°F
- ✓ Wet-cure completed FRCM application

Design Considerations

Existing Capacity Demands

Exposure Coefficients

Serviceability

The service stresses in the steel must be checked for the desired performance.

Structural Testing: Column Testing Results

Control
285,000 lb

1 Layer UCG
485,000 lb

2 Layer UCG
650,000 lb

Napa County Courthouse – Seismic Upgrade

(Napa, California)

- Building damaged in 2014 Napa earthquake (6.0 magnitude)
- Unreinforced masonry & brick building
- EOR – ZFA Structural Engineers
- General Contractor – Alten Construction, Inc.
- FRCM Subcontractor – Pullman SST.
- WHY FRCM?
- Shear strengthening required on most walls
- Nominal strengthening on remaining walls
- Cracking on multiple interior and exterior walls
- Mock-up required with actual building materials

Before FRCM

After FRCM

Structural FRCM Repairs

(ZFA Structural Drawings)

REPAIR SCHEDULE	
REPOINT	REPOINT CRACKED MORTAR JOINTS EXCEPT WHERE GROUT INJECTION OR FIBER REINFORCED CEMENTIOUS MATERIAL IS SPECIFIED
GROUT INJECT	GROUT INJECT ALL CRACKS 1/16" IN WIDTH OR GREATER UNO ON ELEVATIONS
BRICK RECONSTRUCTION	IF SPALL AREA IS LESS THAN 16" SQUARE AND DOES NOT EXTEND FULL DEPTH FILL W/ MORTAR, OTHERWISE RECONSTRUCT AREA WITH BRICK. NOTIFY ENGINEER OF RECORD IF AREA EXCEEDS 24" SQUARE
FIBER REINFORCED CEMENTIOUS MATERIAL (FRCM) OVERLAY	AS INDICATED PER PLAN, ELEVATIONS, AND SPECIFICATIONS. GROUT INJECT ALL CRACKS 1/16" OR GREATER BELOW FIBER REINFORCED CEMENTIOUS MATERIAL. REPOINT/GROUT ON FARSIDE OF EXISTING BRICK WALLS WHEN OVERLAY IS INSTALLED ON ONE FACE ONLY
CMU REPLACEMENT	AS INDICATED PER PLANS, ELEVATIONS, AND SPECIFICATIONS

SEE **K/S-0.1** & SPECIFICATIONS FOR ADDITIONAL INFORMATION

STRUCTURAL FRCM REPAIRS				
GRID LINE	FLOOR	THICKNESS	EXISTING CAPACITY	REPAIRED CAPACITY
1	2ND	16"	-	NOMINAL
1.75	2ND	12"	67.5k	90.5k
2	2ND	12"	92.3k	102.5k
4	2ND	8"	55.9k	69.9k
5	2ND	16"	42.7k	51.2k
A	2ND	16" (2)	-	NOMINAL
D	2ND	12"	125.7k	170k
E	2ND	12"	156.8k	174k
H	2ND	16"	-	NOMINAL
3 NORTH	1ST	12"	117.5k	155.3k
3 SOUTH	1ST	12"	122.2k	131.3k
5	1ST	16"	-	NOMINAL
B	1ST	16"	-	NOMINAL
D	1ST	12"	212k	326.3k
E	1ST	12"	212k	326.3k

NOTE:

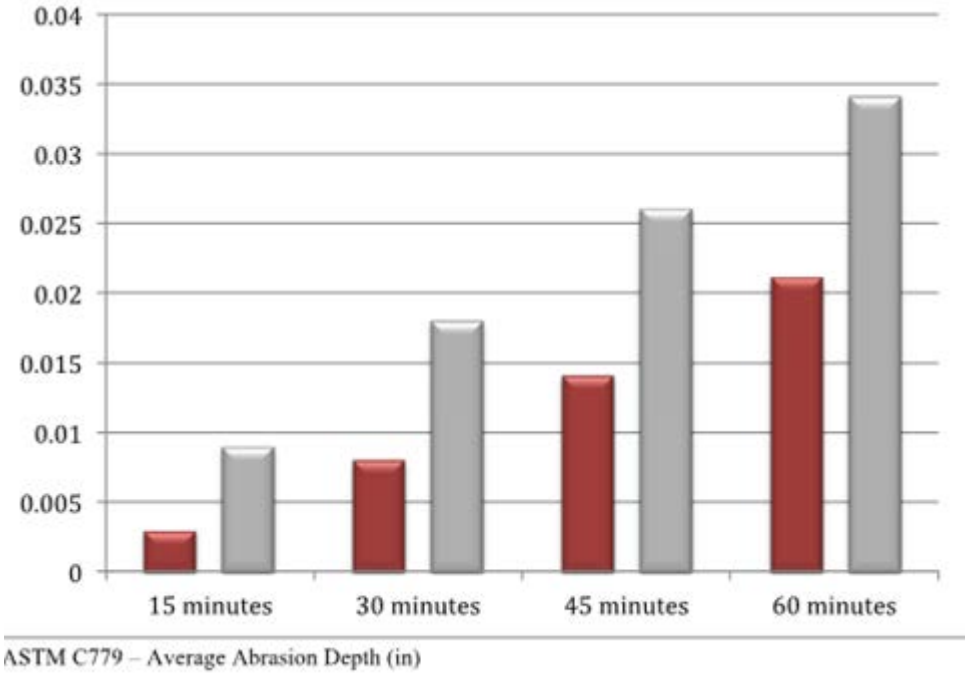
1. OVERLAY SHALL BE PROVIDED AS SHOWN ON PLAN AND ELEVATIONS
2. SEE **L/S-0.1** FOR ADDITIONAL INFORMATION
3. AT WALLS INDICATED AS "NOMINAL" PROVIDE BIDRICTIONAL OVERLAY AS SOHWN IN ELEVATIONS.

FRCM Testing

- Axial Column
- Beam Flexure
- Beam Shear
- Out-of-plane Wall
- In-plane Wall
- Slab
- Tensile Testing for Composite Design Values
- Exterior Exposure
- Durability
- Interlaminar Shear
- Drying Shrinkage
- Void Content
- Freeze/Thaw
- Lap Tensile Strength
- Full Scale Fire
- Bond Strength
- Abrasion Resistance
- Permeability

Abrasion Resistance Test

ASTM C779, "Standard Test Method for Abrasion Resistance of Horizontal Concrete Surfaces"



ASTM C779 – Average Abrasion Depth (in)

The proprietary cementitious matrix improved the abrasion loss over a commercial, prepackaged repair material by the following:

- 15 minutes – 66.7% improvement
- 30 minutes – 55.6% improvement
- 45 minutes – 46.2% improvement
- 60 minutes – 38.2% improvement

How Can Manufacturers Help?

Feasibility Studies	Work with EOR to determine if FRP/FRCM strengthening is possible
Budget Estimates	Engage local trained contractors to provide ROM pricing
Specifications	Fine-tune to meet the project requirements
Drawing Details	Create construction documents
Calculations	Provide for EOR's reference during submittal review

FREE SERVICES!

Thank You

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