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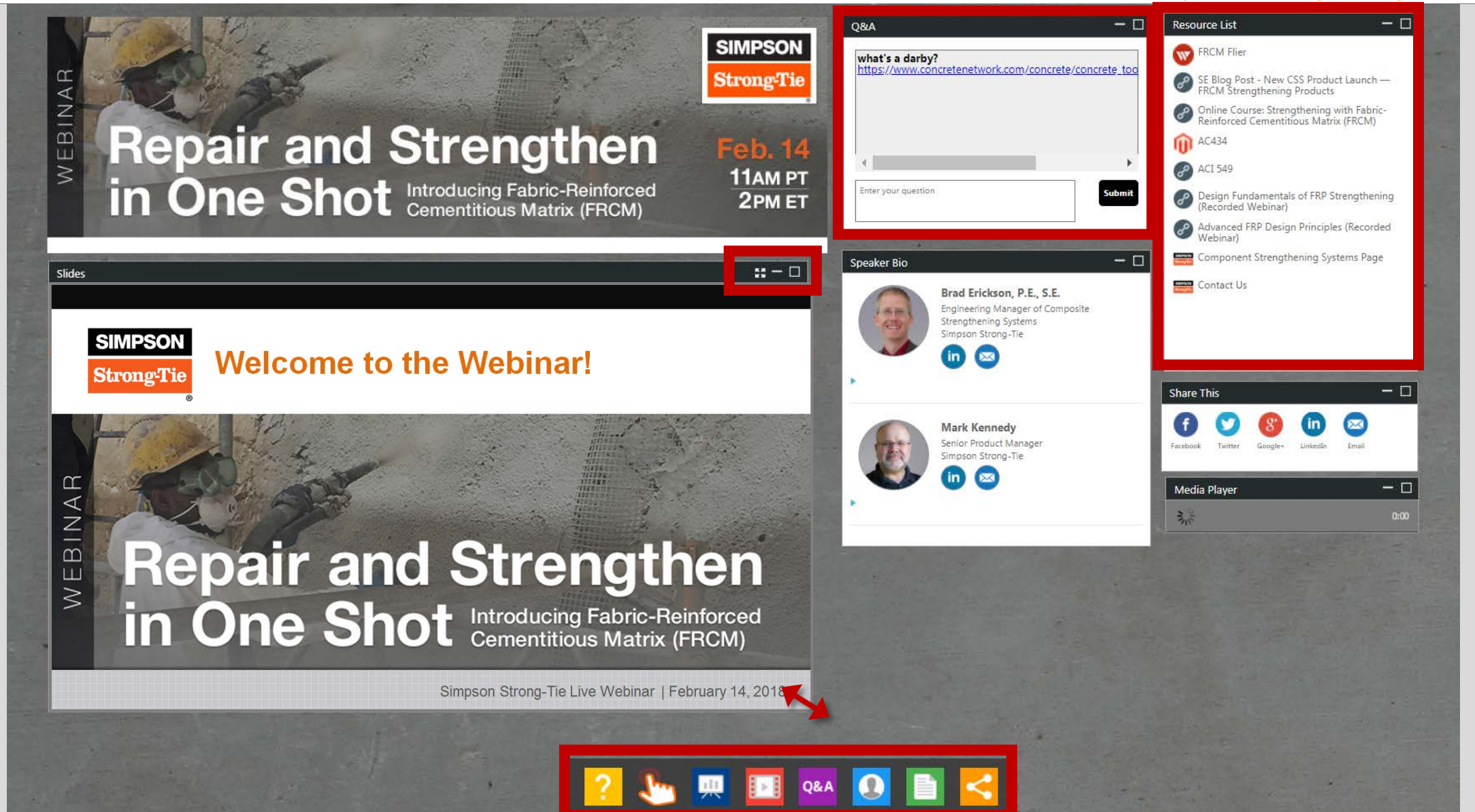

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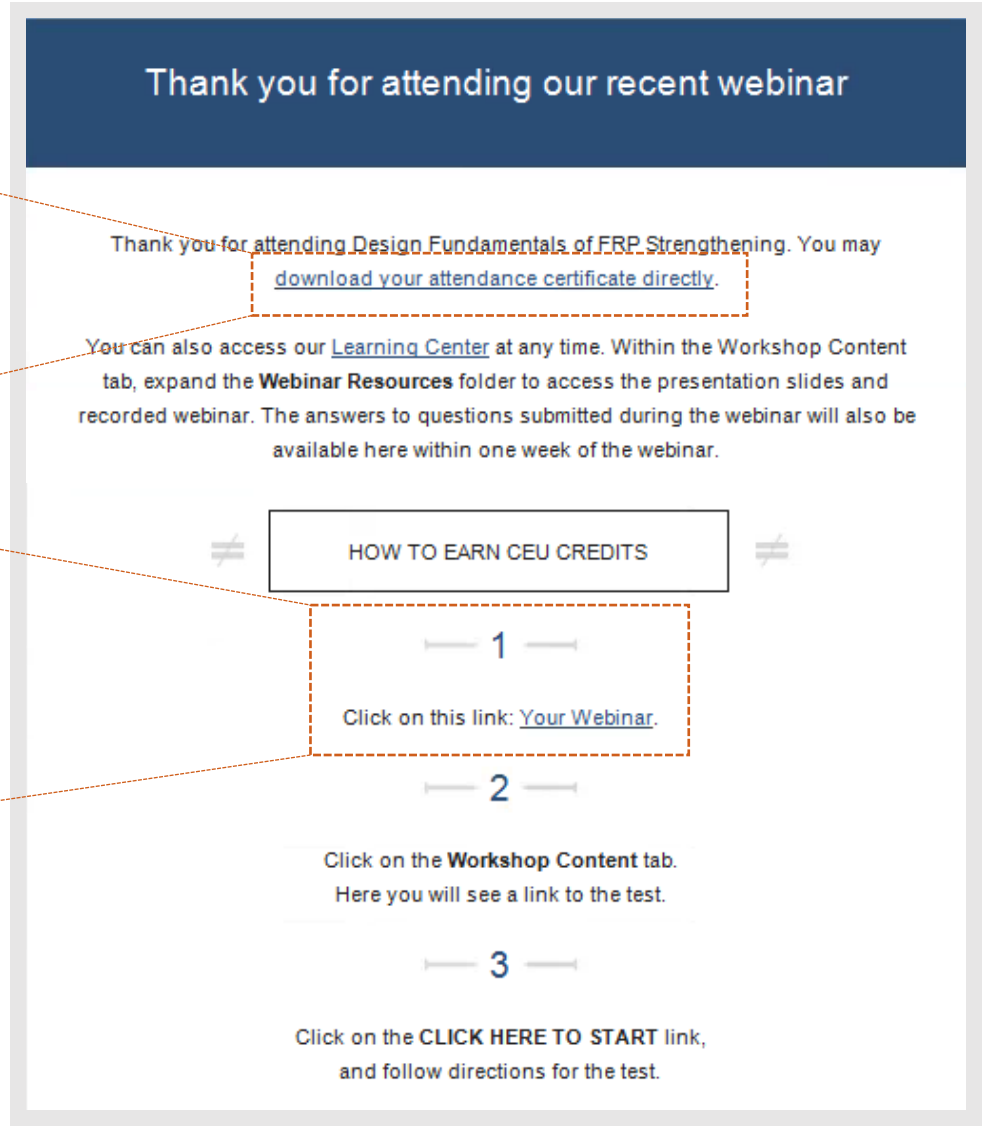


Today’s Presenters

Mark Kennedy

Senior Product Manager,

Composite Strengthening Systems™

Simpson Strong-Tie

Brad Erickson P.E., S.E.

Engineering Manager,

Composite Strengthening Systems™

Simpson Strong-Tie

Agenda

- What is FRCM?
- FRCM Installation Steps
- Where can I use FRCM?
- FRCM Design and Testing
- How Can We Help?
- Q&A

Objectives:

- Describe the process when designing with FRCM
- Discuss the benefits of strengthening with FRCM
- Identify repair and strengthening applications that may benefit from FRCM
- Explain the steps in an FRCM application
- Cite the industry standards used in the design and testing of FRCM
- Find out more about the engineering services offered by Simpson Strong-Tie

What is FRCM?

Fabric-Reinforced Cementitious Matrix

(cement-like) (mortar)

FRCM is in the same family as FRP, but it differs in its design, installation and application benefits.

Typical Internal Steel Reinforcing

Typical External Composite Reinforcing

FRP Components

Fiber Reinforced Polymer (FRP) Systems = Reinforcing Fibers + Polymer Matrix

FRCM Components

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

FRCM Benefits Compared to FRP

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

} *Same as FRP.*

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

} *Unique to FRCM.*

FRCM Installation Steps

WEBINAR: INTRODUCING FABRIC-REINFORCED CEMENTITIOUS MATRIX (FRCM)

FRCM Components

Sprayable cementitious matrix

CSS-CM

Carbon-fiber grid

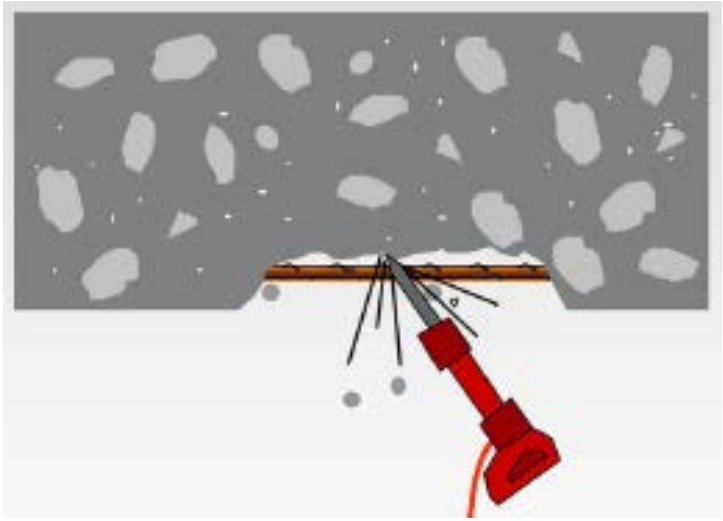
CSS-UCG / CSS-BCG / CSS-HBCG

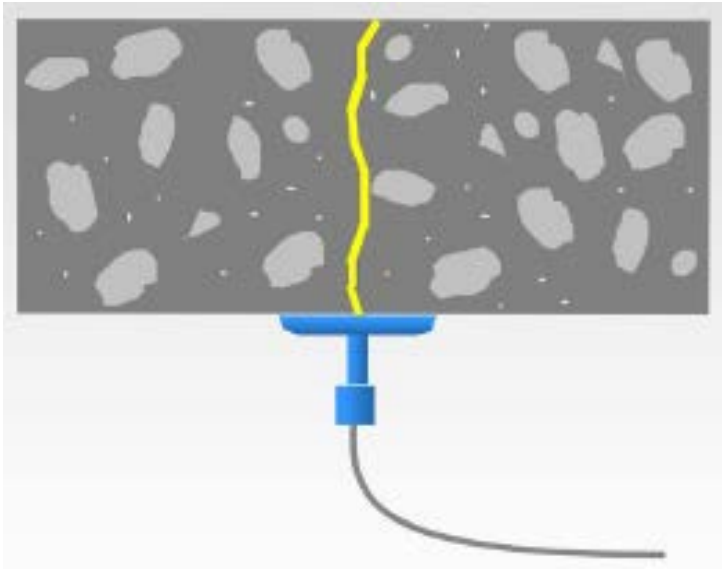
Single-Layer Grid Installation

Prior to application:

Repair deterioration per ICRI Guideline No. 310.1R

- Remove delaminated concrete
- Clean/coat exposed steel
- Inject/seal cracks





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 at ¼″ to ½″ thick

Single-Layer Grid Installation

2. Embed grid into wet matrix using a trowel or wood float

Grid Alignment

Why so important?

- Grid is designed to resist load in tension
- 5 degree tolerance (1 inch per foot slope max)
- Avoid kinks, folds, waves

Single-Layer Grid Installation

3. Apply second layer of cementitious matrix at ¼″ to ½″ thick

Single-Layer Grid Installation

4. Screed and trowel to desired finish
5. Allow for full cure by keeping wet for 3-5 days after installation
6. Finish coat as desired

Multiple-Layer Grid Installation

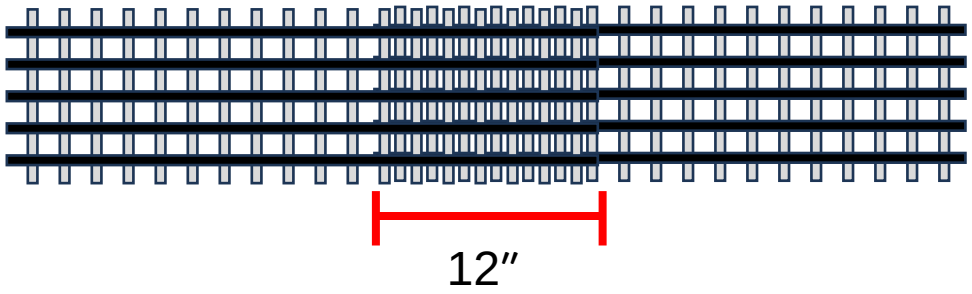
Repeat steps 2 and 3 as specified

2. Place grid into wet matrix and embed using a trowel or float

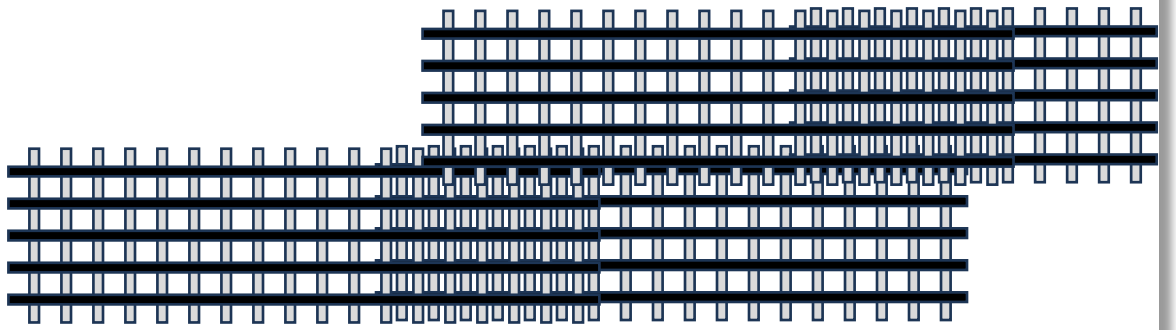
3. Apply additional layer(s) of cementitious matrix at ¼″ to ½″ thick

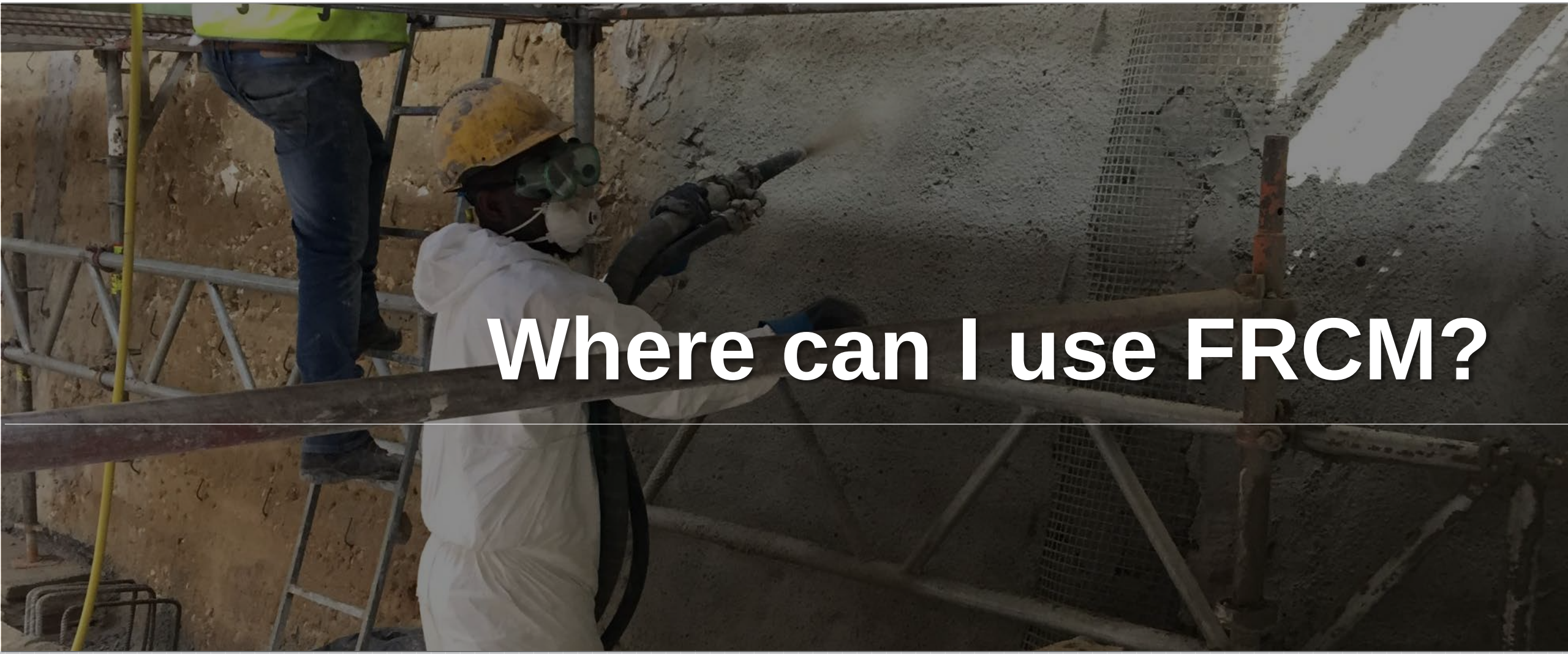
Overlapping and Staggering

Overlapping is determined by drawings and specifications, minimum 12″ overlap



Stagger laps





Where can I use FRCM?

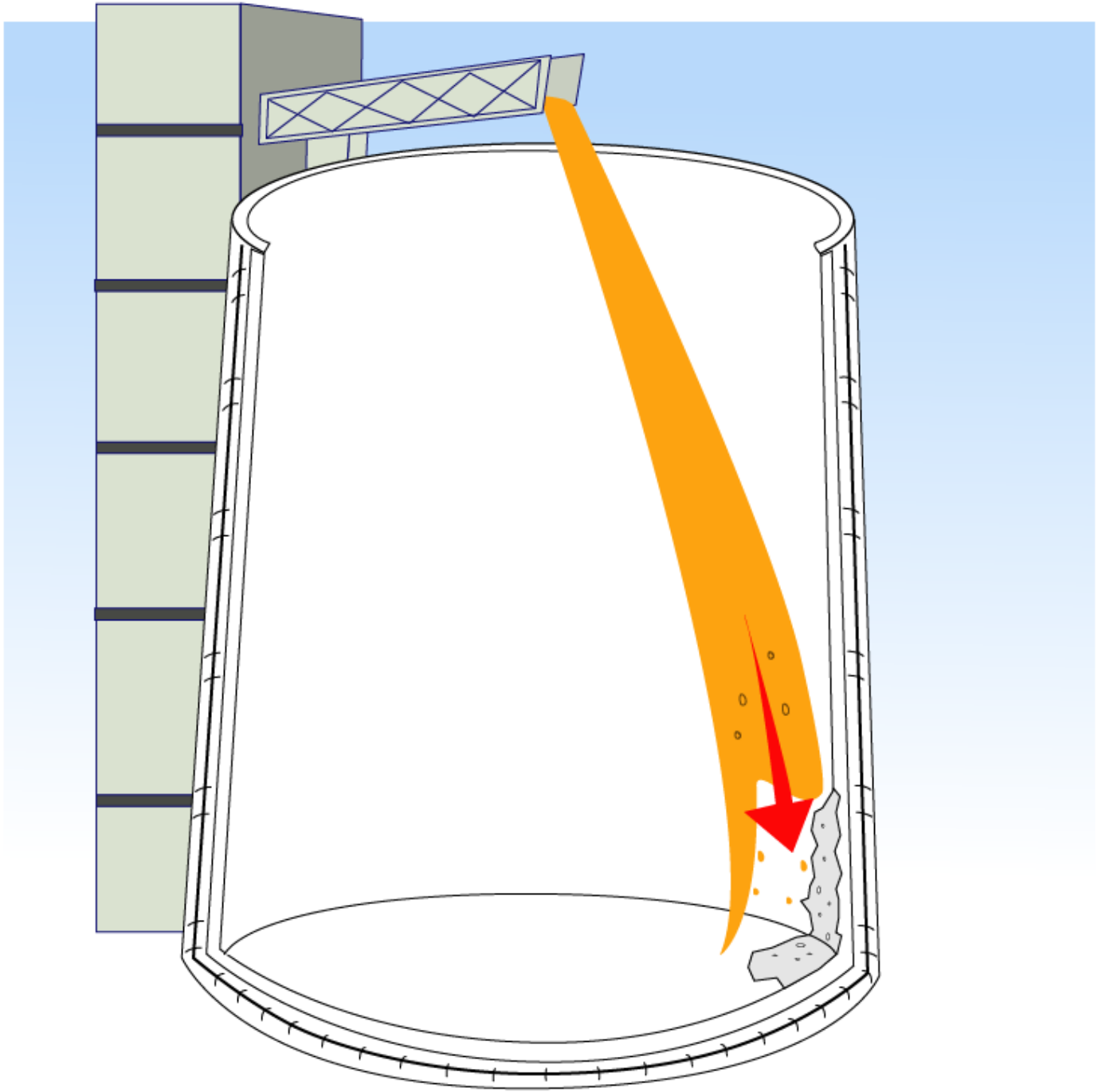
Traditional Shotcrete vs. FRCM

Traditional Shotcrete Repair

FRCM Repair

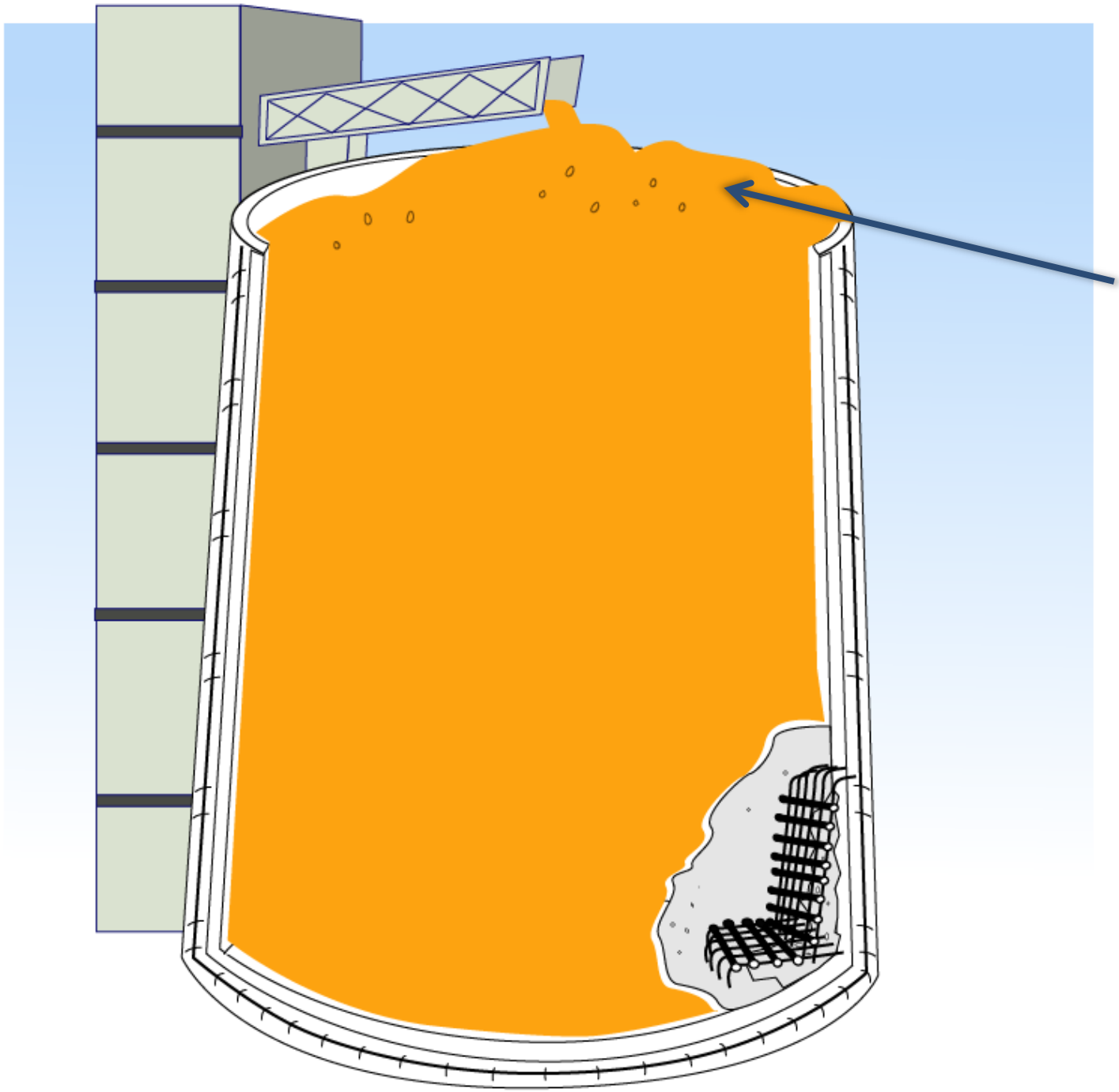
Traditional Shotcrete vs. FRCM

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 negligible weight to structure
❑ Shotcrete typical psi at 4,000	✓ Cementitious matrix is a high-performance mortar with psi at 7,500



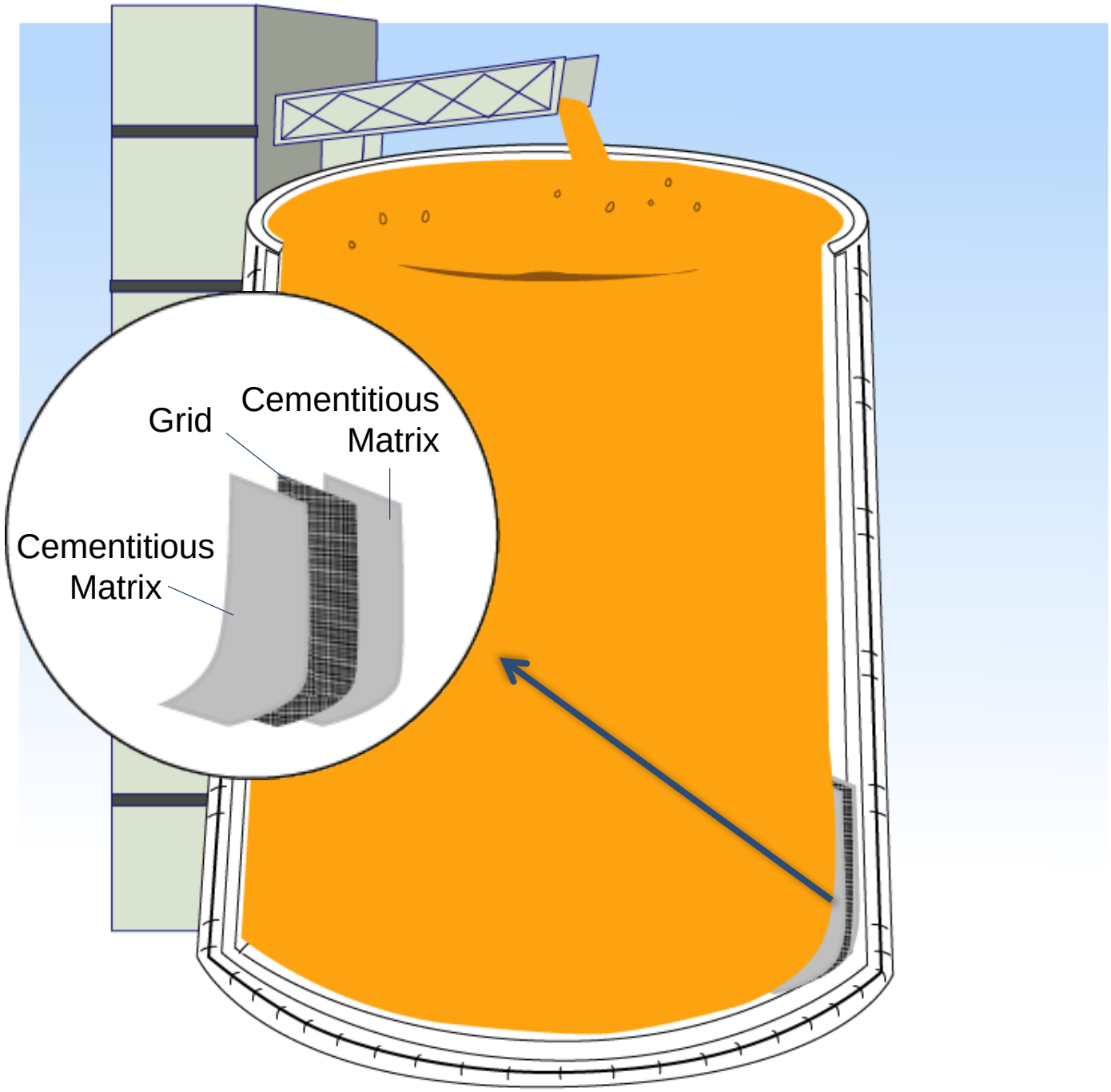
Grain Concrete Silo Needs Repair

- ✓ Concrete on the side of the grain silo has deteriorated
- ✓ Damage was caused by grain abrasion
- ✓ Repair and additional strengthening is needed



Shotcrete Repair Method

- ✓ Considerable volume change results in grain displacement
- ✓ More subcontractors needed
- ✓ Repair takes longer to installer (28 days until fully cured)



FRCM Repair Method

- ✓ Low impact = little to no grain displacement
- ✓ Cementitious matrix matches the base material (benefit when compared to FRP)
- ✓ Quick installation time (still 28 days to fully cure)

Application: Large Vertical and Overhead Surfaces

Higher production rates with sprayable material than with form-and-pour or hand-applied

Application: Low Levels of Strengthening Required

More efficient option than FRP

Application: Surface Repair Plus Strengthening

Repair and add strength at the same time

Application: Heat Resistance or Corrosion Resistance Required

More fire resistant than FRP

More corrosion resistant than shotcrete

Application: Water Transmission

Grid is breathable, and won’t trap moisture beneath the surface

Application: Silos, Bridges, Tunnels, Mines

Ideal for projects that can’t afford a significant volume change

FRCM Design and Testing

WEBINAR: INTRODUCING FABRIC-REINFORCED CEMENTITIOUS MATRIX (FRCM)

Standards We Design To:

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 and 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 lost.

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.

ICC-ES AC434 Testing for Code Report

ACCEPTANCE CRITERIA FOR MASONRY AND CONCRETE STRENGTHENING USING FIBER-REINFORCED CEMENTITIOUS MATRIX (FRCM) COMPOSITE SYSTEMS (AC434)

1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for recognition of fiber-reinforced cementitious matrix (FRCM) composite systems, used for the strengthening of masonry and concrete structures, in ICC Evaluation Service, LLC (ICC-ES), evaluation reports under the 2012 and 2009 *International Building Code*® (IBC). The basis of recognition is IBC Section 104.11.

The reason for the development of this criteria is to provide guidelines for the evaluation of alternative strengthening methods for masonry and concrete structural elements, where the codes do not provide requirements for testing and determination of structural capacity, reliability and serviceability of these products.

1.2 Scope: This criteria applies to passive fiber-reinforced cementitious matrix (FRCM) composite systems used to strengthen existing masonry and concrete structures. Properties evaluated include FRCM material properties; axial, flexural and shear capacities of the FRCM system; performance of the FRCM system under environmental exposures; performance under exposure to fire conditions; and structural design procedures.

1.3 Referenced Codes and Standards:

1.3.1 2012 and 2009 *International Building Code*® (IBC), International Code Council.

1.3.2 ACI 318-11 (2012 IBC), Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute.

1.3.3 ACI 318-08 (2009 IBC), Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute.

1.3.4 ASCE 41-06: Seismic Rehabilitation of Existing Buildings, American Society of Civil Engineers.

1.3.5 TMS 402-11/ACI 530-11/ASCE 5-11 (2012 IBC), Building Code Requirements for Masonry Structures, American Concrete Institute.

1.3.6 TMS 402-08/ACI 530-08/ASCE 5-08 (2009 IBC), Building Code Requirements for Masonry Structures, American Concrete Institute.

1.3.7 ASTM C 138-10b, Standard Test Method for Density (Unit Weight), Yield, and Air (Gravimetric) of Concrete, ASTM International.

1.3.8 ASTM C 157-08, Standard Test Method for Length Change of Hardened Hydraulic Mortar and Concrete.

1.3.9 ASTM C 387/C 387M-11, Standard Specification for Packaged, Dry, Combined Materials for Mortar and Concrete, ASTM International.

1.3.10 ASTM C 947-03 (2009), Standard Test Method for Flexural Properties of Thin-Section Glass-Fiber-Reinforced Concrete (Using Simple Beam with Third-Point Loading), ASTM International.

1.3.11 ASTM C 1583/C 1583M-04^{e1}, Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method), ASTM International.

1.3.12 ASTM D 1141-98 (2008), Standard Practice for Preparation of Substitute Ocean Water, ASTM International.

1.3.13 ASTM D 2247-11, Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity, ASTM International.

1.3.14 ASTM D 2344/D 2344M-00 (2006), Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates, ASTM International.

1.3.15 ASTM D 3165-07, Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading of Single Lap-Joint Laminated Assemblies, ASTM International.

1.3.16 ASTM E 4-10, Standard Practices for Force Verification of Testing Machines, ASTM International.

1.3.17 ASTM E 83-10a, Standard Practice for Verification and Classification of Extensometers, ASTM International.

1.3.18 ASTM E 104-02 (2007), Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions, ASTM International.

1.4 Definitions:

1.4.1 Design Values: The FRCM composite system's load and deformation design capacities that are based on load and resistance factor design (strength design) method.

1.4.2 FRCM Composite Material: A fiber-reinforced cementitious matrix (FRCM) is a composite material consisting of a sequence of one or more layers of cement-based matrix reinforced with fibers in the form of open grid (mesh). When adhered to concrete or masonry structural members, they form an FRCM system. Components are:

1.4.2.1 Structural Reinforcement Grid: Open grid (mesh) of strands made of fibers [i.e., aramid, alkali resistant (AR) glass, carbon, and polyparaphenylene benzobisoxazole (PBO)], consisting of primary direction (PD) and secondary direction (SD) strands connected perpendicularly. The typical strand spacing of PD and SD strands is less than one inch (25.4 mm).

1.4.2.2 Cement-based Matrix: A polymer-modified cement-based binder (mortar) that holds in place the structural reinforcement grids in FRCM composite material.

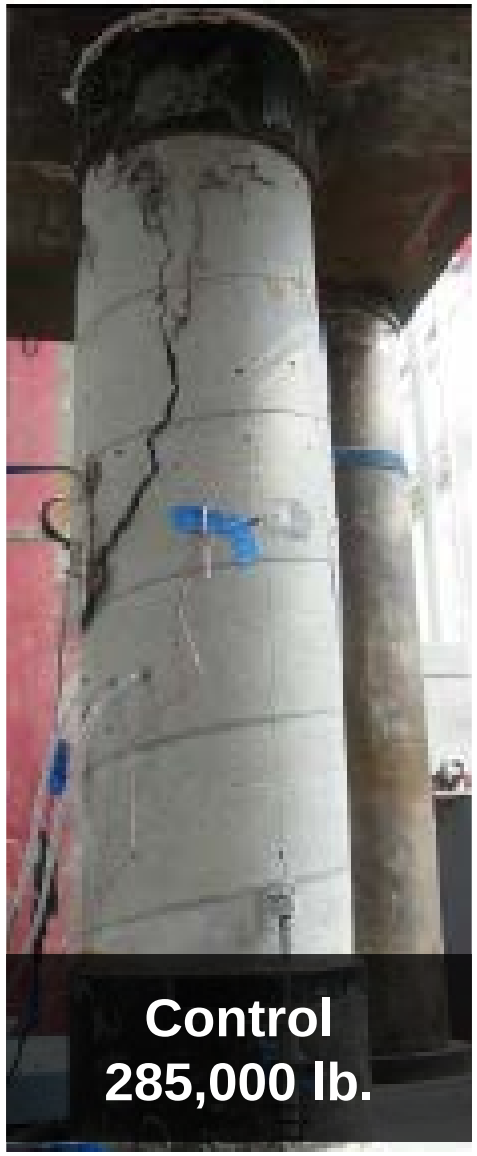
1.4.3 Cracking Load and Displacement: Load and displacement at which the moment-curvature relationship of the masonry or concrete member first changes slope or at which the cracking moment as defined in ACI 318, Section 9.5.2.3, or TMS 402, Section 3.3.5.5, is reached, whichever occurs first.

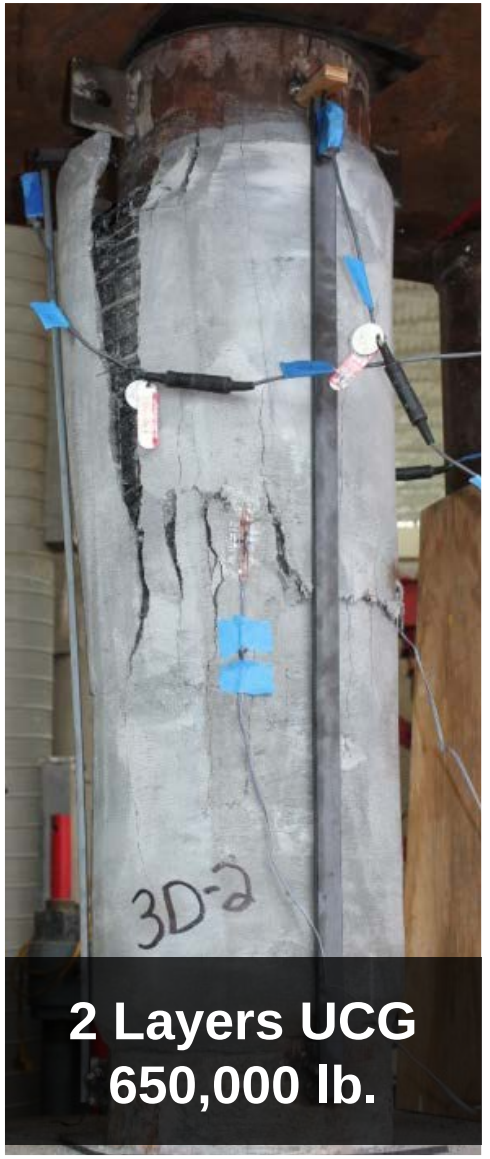
1.4.4 Yielding Load and Displacement: Load and displacement at which longitudinal steel reinforcement of

Structural Testing: Beams

Structural Testing: Column Testing Video

Structural Testing: Column Testing Video Results

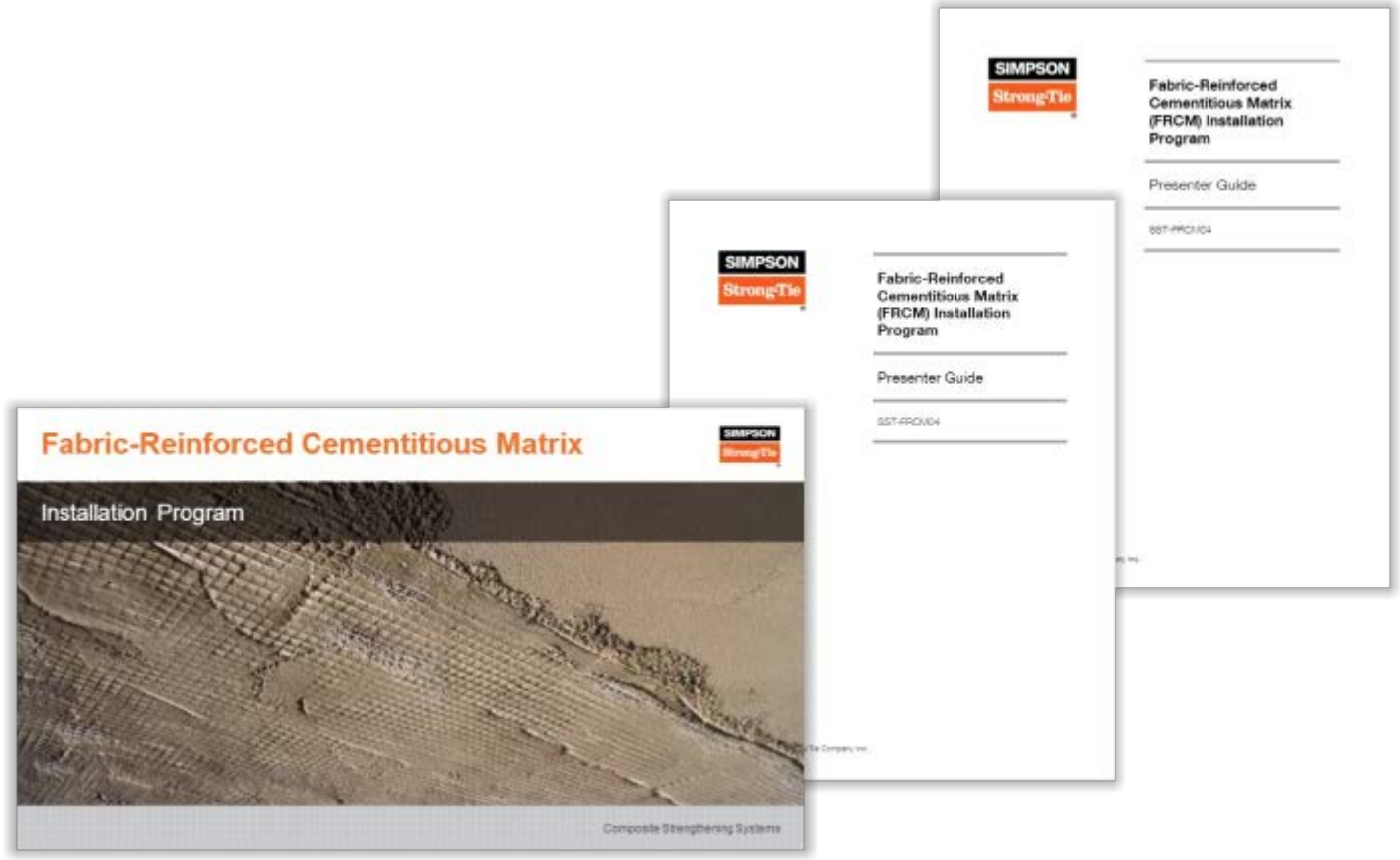




Quality Control and Assurance

Daily Inspection

- Date and time of installation
- Ambient temperature, relative humidity, and weather conditions
- Substrate surface temperature
- Surface preparation method and ICRI concrete surface profile
- Surface cleanliness description
- Grid batch numbers
- Matrix batch numbers, mix ratios, and mixing times
- Etc.



Field Testing

Pull-Off Test

(ASTM C1583)

- Test should exceed 200 psi
- When failure at grid, strength should be at 400 psi

Lab Testing

Mortar Cubes Test

(ASTM C109)

- Brass cubes filled with CM
- Test at 7 and 28 days
- Compressive strength of 7,500 psi at 28 days

Lab Testing

Tension Test with Witness Panels

(AC 434 Annex A)

- *Only required in strengthening applications*
- 2 per day, twice a day
- Panels sent to third-party lab for testing

Specifying FRCM is very similar to specifying FRP

FRCM is another option to specify when:

- Low levels of strengthening required
- Higher heat resistance is required
- Concrete repair is also required in addition to adding strength

Why Simpson Strong-Tie FRCM?

Our product:

- ≠Matrix can be sprayed
- ≠Grid is rigid
- ≠Part of a full CSS line

Our services:

- ≠Free technical and engineering support
- ≠Feasibility studies
- ≠FRCM Installation Training Program
- ≠Budget estimates

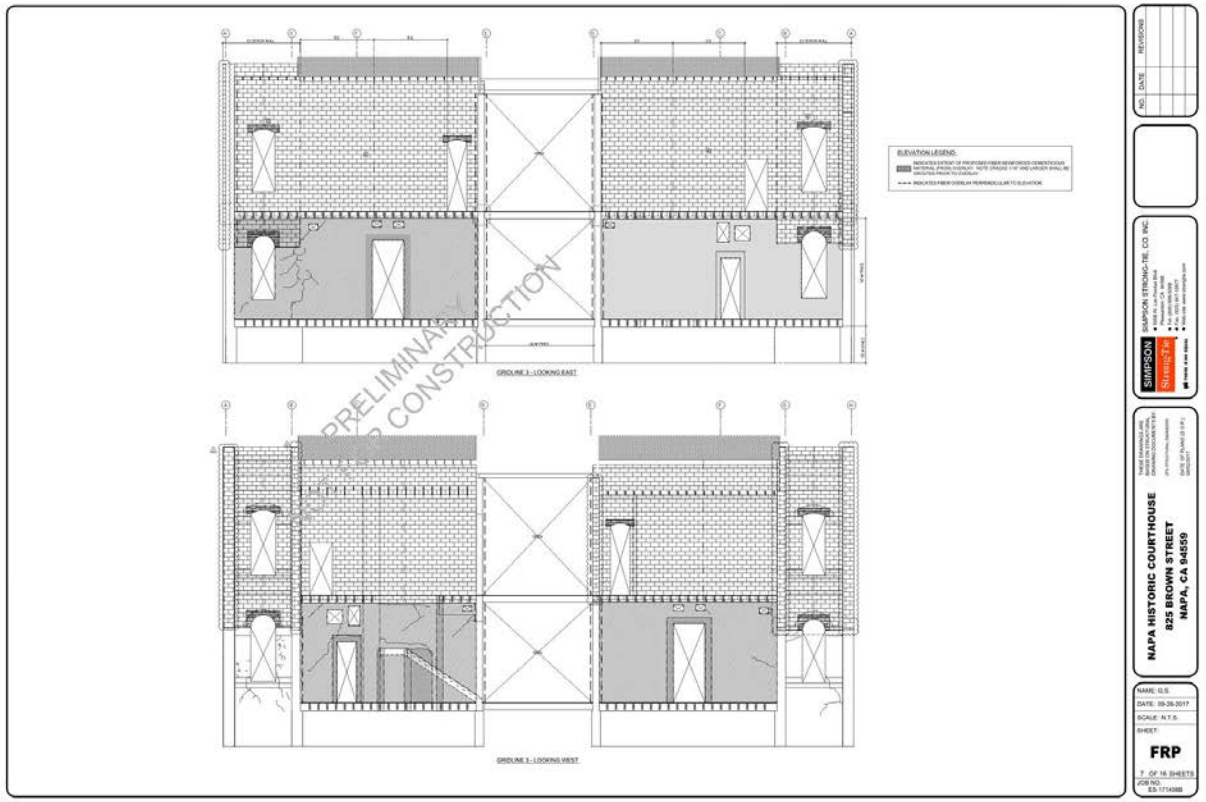
What do we need in order to help?

Existing Design Drawings

- Section dimensions and span lengths
- Steel reinforcing layout
- Material properties

Loads and Capacities

- Existing factored capacity
- New ultimate demand
- Service dead load and live load demands



Sample FRCM design from Simpson Strong-Tie Engineering Services

More Information

1. Download any items from the Resources panel and visit strongtie.com/frcm for more information

2. Fill out your webinar survey evaluation and let us know if we can help you find solutions for your next project.

3. Contact us with any questions: 800-999-5099 or css@strongtie.com