



## Composite Strengthening Systems™



FIBER-REINFORCED POLYMER (FRP) REPAIR AND REINFORCEMENT SOLUTIONS

# Composite Strengthening Systems™

## Reinforcement Solutions Using Composite Strengthening Systems™

Simpson Strong-Tie® Composite Strengthening Systems™ (CSS) provide efficient solutions for the structural reinforcement and strengthening of concrete, masonry and timber structures in need of repair or upgrade.

CSS solutions are engineered, specified and installed to solve a host of structural deficiencies or demands in existing structures:

- Durability problems due to poor or inappropriate construction materials
- Inadequate design or construction
- Increased loading requirements due to code or use changes
- Increased life-span requirements made on aging infrastructure
- Exceptional or accidental loading
- Seismic retrofit
- Blast mitigation

Fiber-reinforced polymer (FRP) systems are simply defined as high-strength and lightweight reinforcements created by combining carbon or E-glass fibers with a polymer material. Traditionally, FRP has been used in the civil, aerospace, and automotive industries for applications requiring high strength-to-weight ratios and rigidity. More recently, the performance characteristics of FRP strengthening have become increasingly popular in construction and retrofit applications, specifically in aging, damaged or overloaded concrete structures.

### CSS Advantages

- In-house engineering providing sealed drawings for all 50 states and Canada
- Local field support and training
- Economically increase capacity without significant weight or mass
- Extremely high tensile strength
- Very lightweight and user-friendly installation
- Non-corrosive
- Low aesthetic impact
- Compatible with many finishes and protective coatings

#### Applications

##### Seismic Retrofit

- Shear strengthening
- Displacement/ductility
- Life safety

##### Load Rating Upgrade

- Increased live loads
- New equipment
- Change of use

##### Damage Repair

- Deterioration/corrosion
- Blast/vehicle impact

##### Defect Remediation

- Size/layout errors
- Low concrete strengths

##### Blast Mitigation

- Hardening
- Progressive collapse

#### Elements

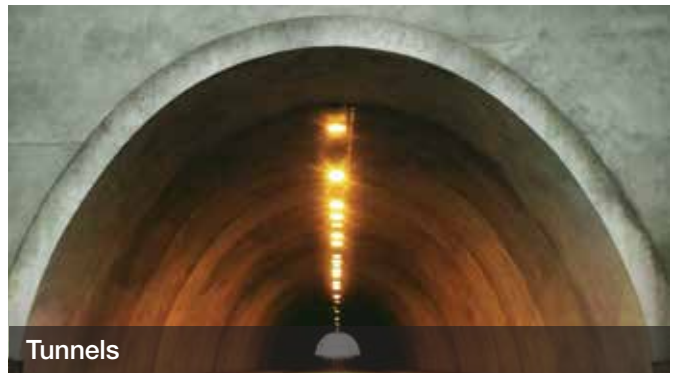
- Columns
- Beams
- Slabs
- Walls
- Piles
- Pier caps

#### Substrates

- Concrete
- Masonry
- Timber

## Structures

Increases to load capacity, seismic strengthening and repair of damaged structures are the most common scenarios where FRP has proven to be more economical than traditional strengthening methods.





# Composite Strengthening Systems™

## System Solutions for Reinforcement

The primary benefit of FRP systems versus traditional retrofit methods is that significant flexural, axial or shear strength gains can be realized with an easy-to-apply composite that does not add significant weight or mass to the structure. Steel plate bonding, concrete section enlargement and steel jacketing have been the renovation methods of choice for decades, yet corrosion, bond degradation and installation difficulty are consistent challenges to overcome, and the resultant retrofit generally adds weight, reduces usable space, clearance, or both.

### System Solutions for Reinforcement

Type	Slab	Beam	Wall	Column/Pile
Externally Applied Laminates	Flexural/Collector	Flexural/Collector	Tensile/Flexural	Flexural
Near-Surface Mounted Laminates	Flexural/Collector	Flexural/Collector	Tensile/Flexural	Flexural
Fabrics	Flexural/Collector	Shear/Flexural/Collector	Shear/Flexural/Tensile	Shear/Flexural/Confinement



- 1. Slab** — Adds collector reinforcement, negative and positive moment flexural capacity
- 2. Slab opening** — Trim reinforcement
- 3. Beam** — Laminates or fabrics for flexure and/or collector reinforcement, fabrics for shear stirrup reinforcement and potential use of FRP anchors (shown in orange for contrast)
- 4. Wall** — Stiffening, flexural, shear or tensile reinforcement
- 5. New wall opening** — Trim reinforcement
- 6. Column wrapping** — Full column wrap to achieve required strengthening, possibly with additional near-surface mounted laminates or fabric for flexure; effective solution for under-reinforced column ties
- 7. Protective coating** — High-performance protection against exposure, corrosion, chemical attack, abrasion, fire resistance and other environmental factors

## Installation

CSS installation shall be performed only by contractors and personnel who have been properly trained by Simpson Strong-Tie. The following images illustrate general fabric installation. Please visit [strongtie.com/css](http://strongtie.com/css) or call your local RPS Specialist at (800) 999-5099 for information about laminate and underwater fabric installation.



### 1. Prime substrate.

Apply one coat of CSS-ES using a nap roller.



### 2. Apply paste to substrate.

Where minor surface defects are present, apply CSS-EP or CSS-ES thickened with fumed silica in lifts no thicker than 1 in. (25 mm).



### 3. Saturate fabric.

Saturate fabric with CSS-ES mechanically or manually, ensuring that full fiber saturation is achieved.



### 4. Apply fabric.

Apply the saturated fabric before the primer and paste (or thickened epoxy) have cured. Sheets can be cut to required length using heavy-duty scissors.



### 5. Smooth fabric.

Apply the saturated sheet to the primed surface and remove entrapped air using hand pressure, rollers or trowels.



### 6. Apply paste to feather edges.

Feather all seams and edges with CSS-EP or thickened CSS-ES. Allow epoxy to fully cure (approximately 72 hours at 70°F/21°C) and lightly sand epoxy before applying finish coating.

## Components

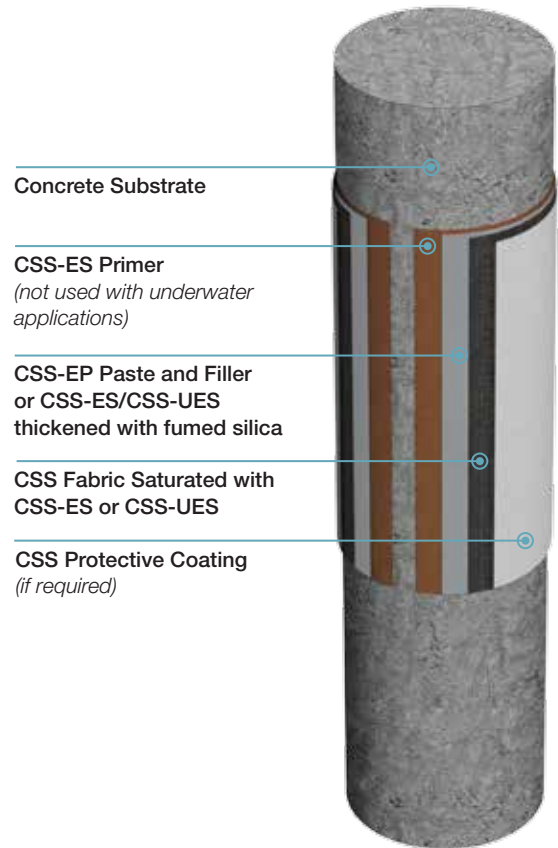
When you are considering FRP for a repair or strengthening solution, the composite material chosen can greatly impact the overall performance and installed cost of the system. We offer a complete line of fabrics, saturants, paste, precured laminates and FRP anchors designed to the specific requirements of each project.

### Fabrics

Several types of code-listed\* and non-code-listed FRP fabrics including carbon fiber and E-glass are available to meet specifier and contractor requirements. Field lamination provides flexibility and short installation time, resulting in lower labor costs and less downtime than are usual with traditional retrofit methods.

### Benefits

- Conforms to irregular shapes
- Can be cut/field-adjusted to address odd shapes/orientations
- May be placed in multiple layers for increased capacity gain
- Variety of tow composition and orientation allows for design flexibility



### Cured Composite Properties – Fabrics

Product	Type	Direction/ Orientation	Available Weight(s)	Tensile Strength	Tensile Modulus	Elongation at Break	Thickness	Code-Listing
CSS-CUGF	E-Glass Fabric	Unidirectional	27 oz./yd. <sup>2</sup>	56,000 psi (390 MPa)	3,300 ksi (23,000 MPa)	1.7%	0.05 in. (1.3 mm)	ICC-ES ESR-3403
CSS-CUCF	Carbon Fabric	Unidirectional	11 oz./yd. <sup>2</sup>	128,000 psi (880 MPa)	14,200 ksi (98,000 MPa)	0.9%	0.02 in. (0.5 mm)	ICC-ES ESR-3403
			22 oz./yd. <sup>2</sup>				0.04 in. (1.0 mm)	
			44 oz./yd. <sup>2</sup>				0.08 in. (2.0 mm)	
CSS-CBGF	E-Glass Fabric	Bidirectional +/- 45	24 oz./yd. <sup>2</sup>	40,000 psi (280 MPa)	2,900 ksi (20,000 MPa)	1.4%	0.034 in. (0.86 mm)	ICC-ES ESR-3403
CSS-UCF	Carbon Fabric	Unidirectional	10 oz./yd. <sup>2</sup>	110,000 psi (760 MPa)	11,000 ksi (76,000 MPa)	1.0%	0.02 in. (0.5 mm)	—
			20 oz./yd. <sup>2</sup>				0.04 in. (1.0 mm)	
CSS-BCF	Carbon Fabric	Bidirectional +/- 45	18 oz./yd. <sup>2</sup>	84,000 psi (580 MPa)	6,000 ksi (41,000 MPa)	1.4%	0.034 in. (0.86 mm)	—
		Bidirectional 0/90	18 oz./yd. <sup>2</sup>	82,000 psi (570 MPa)	6,300 ksi (43,000 MPa)	1.3%	0.04 in. (1.0 mm)	
			6 oz./yd. <sup>2</sup>	60,000 psi (414 MPa)	6,000 ksi (41,000 MPa)	1.0%	0.01 in. (0.25 mm)	
CSS-BGF	E-Glass Fabric	Bidirectional 0/90	12 oz./yd. <sup>2</sup>	45,000 psi (310 MPa)	2,500 ksi (17,000 MPa)	1.8%	0.017 in. (0.43 mm)	—
			18 oz./yd. <sup>2</sup>				0.026 in. (0.66 mm)	

\* When laminated with CSS-ES or CSS-UES saturating resin, post-cured for 48 hours at 140°F/60°C and tested per ASTM D3039. Tensile properties based on five percent fracture approach per ACI.

## Components

### Precured Carbon Fiber Laminate

Simpson Strong-Tie now offers an epoxy-based, pultruded, unidirectional, high-strength, non-corrosive carbon-fiber-reinforced polymer (CFRP) precured laminate code listed\* for structural reinforcement applications. Available in a variety of widths (10–150 mm) and thicknesses (1.2–2.8 mm) and may be cut to length.

#### Benefits

- Code listed per ICC-ES
- No field saturation required
- Highest tensile capacity available
- Lower overall installed cost/labor savings



Precured Carbon Fiber Laminates

### Near-Surface-Mounted (NSM) Laminates

NSM laminates are used to increase the load-carrying capacity of concrete and masonry structures by embedding laminate strips in precut grooves on the concrete cover of the elements to be strengthened. This practice requires less surface preparation work and, after cutting the groove, requires minimal installation time compared to the externally bonded reinforcing technique.

#### Benefits

- Reduced surface prep time for lower labor costs
- Laminate flush with the concrete surface
- May be combined with externally applied fabrics or laminates to achieve biaxial strengthening



Near-Surface-Mounted (NSM) Laminates

### Cured Composite Properties — Laminate

Product	Type	Direction/Orientation	Available Weight(s)	Tensile Strength	Tensile Modulus	Elongation at Break	Thickness	Code-Listing
CSS-CUCL	Carbon Laminate	Unidirectional	N/A	232,000 psi <sup>1</sup> (1,600 MPa)	23,000 ksi <sup>1</sup> (159,000 MPa)	1.0% <sup>1</sup>	0.047 in. (1.2 mm)	ICC-ES ESR-3403
				400,000 psi <sup>2</sup> (2,800 MPa)	24,000 ksi <sup>2</sup> (165,000 MPa)	1.7% <sup>2</sup>	0.055 in. (1.4 mm) 0.110 in. (2.8 mm)	

1. Design value per ICC-ES AC125 durability testing

2. Design value per ISO 527 tensile testing

### Featuring the first code-compliant precured laminate in North America

Our fiber-reinforced polymer (FRP) solutions are now code-listed. With this code report, Simpson Strong-Tie offers the first code-compliant precured laminate in North America. As part of our Composite Strengthening Systems™, our code-listed carbon fabrics also provide some of the highest design values on the market.

Our fabrics include both unidirectional and bidirectional carbon and E-glass, and our precured laminate can be ordered and cut to size.



## Components

### FRP Anchors

High-strength FRP anchors are field laminated and used to carry load into the concrete to effectively improve bond strength, or through the concrete to transfer load for increased capacity. CSS-CA and CSS-GA are carbon and E-glass fiber anchors available in diameters from 1/4" (6.4 mm) to 1 1/2" (38.1 mm) in custom lengths.

### Epoxy Primer and Saturant

CSS-ES is a two-component, high-strength, high-modulus, epoxy resin system used to prime substrates and saturate CSS fabrics. When extended with fumed silica, thickened CSS-ES is used as a high-performance substrate repair material and finish coating.

### Underwater Epoxy Saturant

CSS-UES is a two-component, high-strength, high-modulus epoxy resin which cures underwater to saturate CSS fabrics for submerged substructure applications.

### Epoxy Paste and Filler

CSS-EP is a two-component, high-strength, high-modulus epoxy paste system used to fill and transition irregular substrates and adhere CSS precured laminates.

### Fire Insulation

FX-207 Slurry Seal or spray-applied bonding agent and cementitious fireproofing designed to meet specific commercial and industrial fire protection requirements may be applied over CSS FRP materials for fire insulation. The tested assemblies achieve a four-hour rated system per ASTM E119/UL 263/ULC 263 full-scale fire testing. FX-207 also provides a Class A finish for ASTM E84 flame-spread and smoke-developed classification.

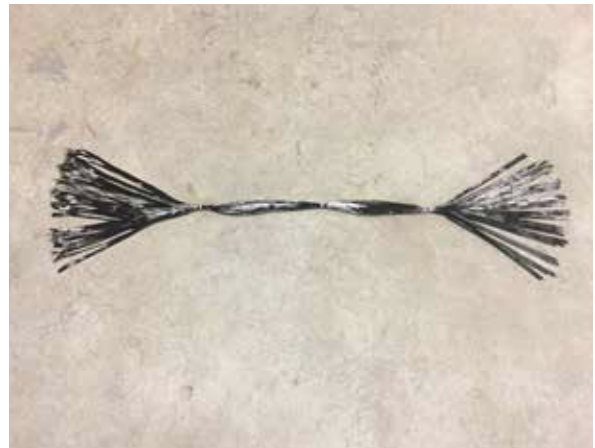
### Protective Coatings

Simpson Strong-Tie has developed an array of formulations designed to offer high-performance protection against exposure, corrosion, chemical attack, abrasion and other environmental factors present in most commercial and industrial facilities.

Product	Type
FX-70-9	Epoxy Coating
FX-442	Aliphatic Urethane Coating
FX-501MS	Elastomeric Metal Coating
FX-501MHB	High-Build Elastomeric Metal Coating
FX-505	Water-Based Acrylic Coating



Carbon FRP Folded Anchor



Carbon FRP Through Anchor



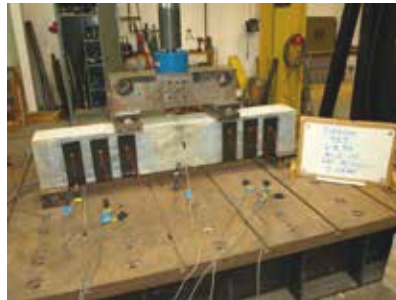
Reinforced Bridge with Protective Surface Coating



## Product Development and Testing

Simpson Strong-Tie Repair, Protection and Strengthening systems offer the industry's most complete and versatile solutions for restoration, rehabilitation and upgrade of commercial and industrial facilities. More than fifty years of demonstrated excellence in engineering and the development, testing and manufacture of the highest-quality structural construction components position Simpson Strong-Tie as the premier choice for performance-critical solutions.

Our in-house, IAS-accredited testing and research facility gives us a distinct advantage in understanding how concrete and masonry structures perform and fail in challenging conditions, and we use this expertise to develop and test solutions in full-scale, real-world environments. Additional testing at independent universities and accredited private laboratories has resulted in reliable Composite Strengthening Systems™ solutions that address structural, durability, corrosion, blast mitigation, fire-resistance and other factors that stress concrete structures.



**Our Repair, Protection and Strengthening Systems for concrete and masonry provide lab-tested, field-proven solutions for reinforcing concrete; we are committed to providing long-term solutions to the most challenging problems.**

## The Tyrell Gilb Research Lab

Opened in July of 2003, the \$12 million Tyrell Gilb Research Laboratory is the hub of Simpson Strong-Tie research and development activities. Named in memory of Tyrell (Tye) Gilb, a former professor of architecture and head of the Simpson Strong-Tie research and development department for 35 years, the 24,000-square-foot research facility is one of the largest privately operated labs in the United States. Constructed of heavy-duty concrete slabs and support walls one-foot thick, the facility can withstand full-scale seismic test scenarios while insulating neighboring buildings from noise and ground vibration. Accredited by IAS for various ICC-ES acceptance criteria (AC) and ASTM test standards, the Tye Gilb lab is equipped with a seismic shake table, two cyclic/static test rigs and a 3D-testing area. The facility also features a three-foot-thick, 10,000,000-pound-capacity, perforated “strong-floor” that has anchor locations every two feet, enabling technicians to attach experiments and loading fixtures directly to the floor.

## No-Cost Engineering and Technical Services



We recognize that specifying Simpson Strong-Tie Composite Strengthening Systems™ is unlike choosing any other product we offer. Leverage our expertise to help with your FRP strengthening designs. Our experienced technical representatives and licensed professional engineers provide complementary design services and support – serving as your partner during the entire project cycle. Since no two structures are alike, each project is optimally designed to the Designer's individual specifications. Our pledge is to address your specific condition with a complete strengthening plan tailored to your needs, minimizing downtime or loss of use, at the lowest possible installed cost.

## Your Partner During the Project Design Phase

During the Designer's initial evaluation or preparation of the construction documents, Simpson Strong-Tie can be contacted to create the most cost-effective customized solution. These plans include detailed design calculations for each strengthening requirement and design drawings with all the necessary details to install the CSS system. Simpson Strong-Tie Engineering Services will work closely with the Design Engineer to provide all the necessary information required to design the system.

## Why Use Our Design Services?

- Assess feasibility studies to ensure suitable solutions to your application
- Receive customized FRP strengthening solutions
- Work with our trained contractor partners to provide rough-order-of-magnitude (ROM) budget estimating
- Collaborate during the project design phase
- Receive a full set of drawings and calculations to add to your submittal
- Maintain the flexibility to provide the most cost-effective solution for your project
- Gain trusted technical expertise in critical FRP design considerations



# Composite Strengthening Systems™

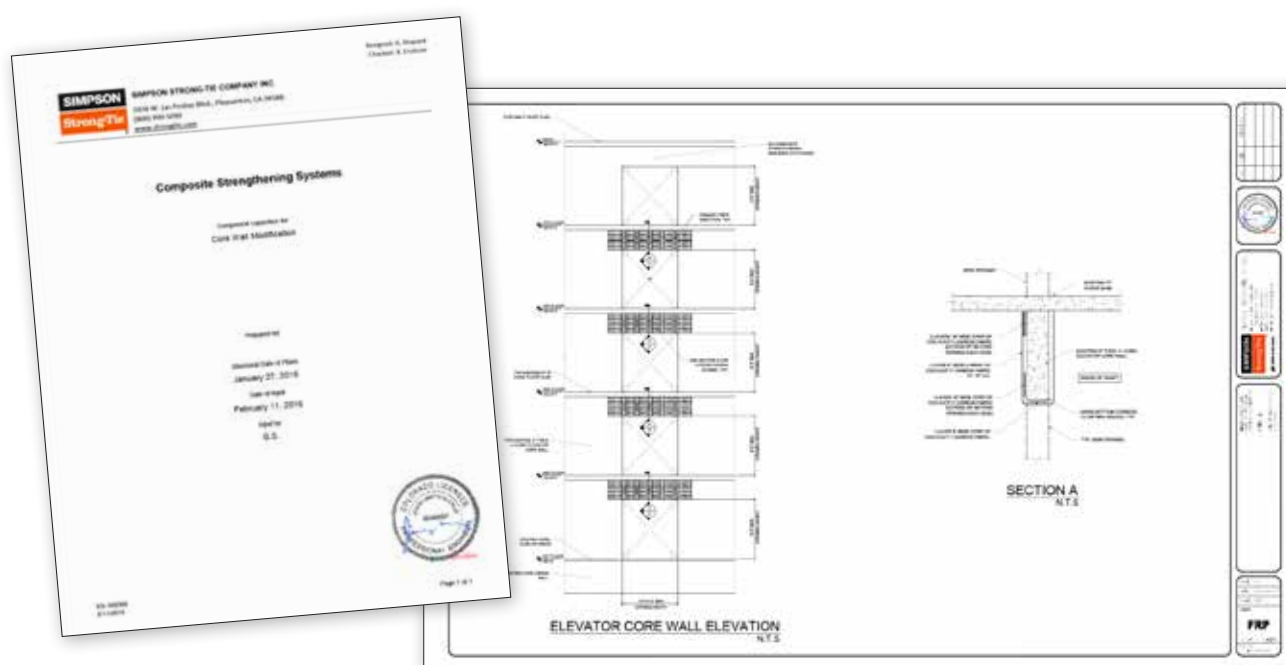
## Method for Specifying

### Typical Engagement Process

Visit [strongtie.com/css](http://strongtie.com/css) to complete the CSS Design Questionnaire. We'll review your submittal and contact you if we have any questions and to assist the Designer in providing all the necessary information. Our team will design a solution to include the most cost-effective CSS products and return installation drawings and calculations to you. The design calculations, drawings, notes and specifications prepared by Simpson Strong-Tie Engineering Services can then be incorporated into the design documents that the Designer will be submitting to the building official.

### The Engineering Package Will Include:

- Specifications prepared for your unique project requirements
- Calculations for each unique element
- Elevation drawings for each element and component
- Typical detail sheet showing installation details
- General notes to include in the plans
- Detailed proposal documentation, including drawings
- Calculations provided for Engineer of Record reference during submittal review
- Sealed drawings for all 50 states and throughout Canada



### Add Simpson Strong-Tie to Your Design Team

For complete information regarding specific products suitable to your unique situation or condition, please visit [strongtie.com/css](http://strongtie.com/css) or call your local RPS specialist at (800) 999-5099.





# Simpson Strong-Tie® Composite Strengthening Systems™ offer high- performance solutions and lasting results.

A trusted manufacturer of the most comprehensive product lines for the infrastructure, commercial, industrial and residential construction markets, we continue to expand our offerings to provide innovative and practical strengthening solutions designed to your individual project specifications. We are continually developing new products and expanding our qualified contractor network to provide best-in-class service, jobsite support and technical expertise. Our team of 60 licensed professional engineers, 14 licensed field engineers and 41 technical representatives is only a phone call away to provide local, onsite support for the entire duration of your repair project.

For complete information regarding specific products suitable to your unique situation or condition, please visit [strongtie.com/css](http://strongtie.com/css) or call your local RPS specialist at (800) 999-5099.