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STRUCTURAL STRENGTHENING WITH FRP COMPOSITES

PRESENTED BY: **ERI VOKSHI, P.E. & SCOTT DISTEFANO**
SIKA CORPORATION, LYNDHURST, NJ

AIA PROGRAM NUMBER: SIK301 & SIK302

BUILDING TRUST

KEY LEARNING OBJECTIVES

- Determine why structures need to be strengthened
- Highlight materials that can be used for structural strengthening along with their advantages and disadvantages
- Design considerations, along with available industry guidelines, for successful use of materials

OUR BUSINESS IS BUILDING SOLUTIONS

MORE THAN 100 YEARS OF EXPERTISE

Our reputation for quality and reliability is illustrated through a comprehensive portfolio of technologies and solutions. Whether we are waterproofing your basement or your roof, sealing your skyscraper or your car, or solving problems with you on your house or your multi-story building, you will see why we are renowned for Building Trust.

SIKA AT A GLANCE

24,000+	EMPLOYEES
100+	COUNTRIES
300+	PLANTS WORLDWIDE
7	NEW PLANTS IN 2019
93	NEW PATENTS IN 2019
5	ACQUISITIONS IN 2019
$8.109 BN	NET SALES IN 2019

A COMPREHENSIVE APPROACH

CONCRETE

WATERPROOFING

ROOFING

BUILDING FINISHING

FLOORING & COATING

SEALING & BONDING

INDUSTRY

REFURBISHMENT

WHEN THOUSANDS OF PEOPLE CAN TRUST RELIABLE MAINTENANCE.

This segment features concrete protection and repair solutions, for example repair mortars, protective coatings, grouts and structural strengthening systems. It includes products for interior finishing, such as leveling compounds. Sika provides technologies for the entire life cycle of commercial buildings, residential properties and infrastructure rehabilitation projects.

SikaGrout®
Sikadur®
Sika AnchorFix®
Sika® CarboDur®
SikaLatex®
Sika Top®
Sikagard®
Sika® FerroGard®
Sikacrete®

- Concrete repair
- Concrete protection
- Hydrophobic impregnation
- Structural bonding
- Structural strengthening
- Tile adhesives and grout
- Facade mortars and protection
- Wall leveling mortars
- Anchoring
- Grouting

QUIZ QUESTION

Have you ever installed the following:

A. Carbon fiber system
B. Glass fiber systems
C. Carbon or glass fiber rods
D. CFRP Plates
E. All of the above

WHAT ARE FRP MATERIALS?

- Composites are a combination of two or more distinct materials

- Fiber reinforced polymers (FRP)
  - Fibers (carbon or glass)
  - Resins (epoxy matrix)

- Reinforced concrete
  - Concrete (matrix)
  - Steel (reinforcement)

COMPARISON OF COMMON FRP FABRICS

CFRP

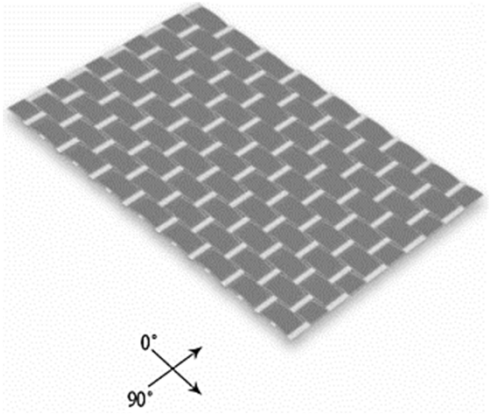
- Active loading
- Damp/wet conditions
- Stiffness driven
- Extreme alkaline conditions

GFRP

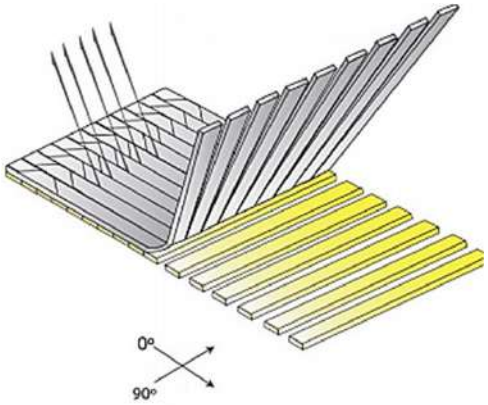
- Passive/seismic loading
- Dry conditions
- Extreme acidic conditions
- Economical

FRP FABRIC TYPES

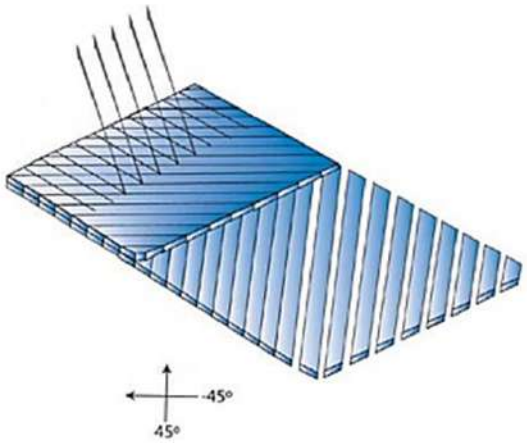
Uniaxial Fabrics



Biaxial Fabrics

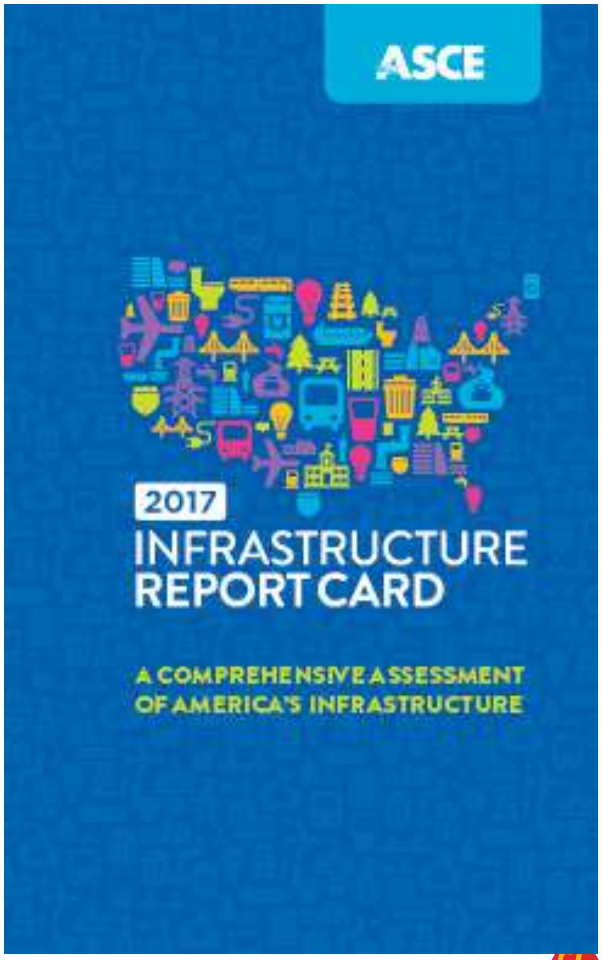


+/-45d Fabrics



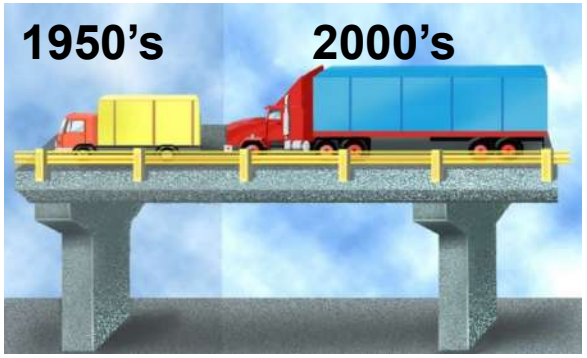
U.S. INFRASTRUCTURE

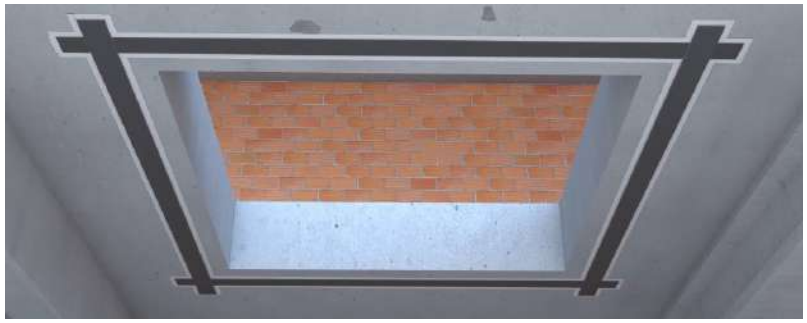
- American Society of Structural Engineers – Report Card
- Overall grade of America's Infrastructure: D+
- Over 600,000 bridges in U.S.
- 1 in 11 rated structurally deficient
- 4 in 10 bridges 50 years or older
- Total infrastructure needs: $4.59 TRILLION over 10 years



WHY DO STRUCTURES NEED STRENGTHENING?

- Insufficient reinforcement
- Corrosion damage
- Change in use
- Structural damage
- Seismic upgrade





ADVANTAGES OF FRP REPAIRS

- Cost/scheduling benefits
- “Get in, Get out, Stay out!”
  - - FHWA Mantra for accelerated construction
- Reduced maintenance costs
- Light weight materials puts less strain on infrastructure
- Non-corrosive, designed for long-term performance
- Less expensive repairs allow for more structures to be repaired with fixed budget

LIMITED ACCESS

STEEL VS. COMPOSITES

- Low material cost
- High installed cost
- Corrosive
- Heavy
- Fabrication required
- High maintenance

- High material cost
- Low installed cost
- Non-corrosive
- Lightweight
- No fabrication required
- Low maintenance

TYPICAL APPLICATIONS

TYPICAL APPLICATIONS

Bridges

- Girder Strengthening
- Column Wrapping
- Pier Upgrades
- Deck Stiffening

TYPICAL APPLICATIONS

Buildings

- Modifications
- Change in use
- Wall strengthening
- Seismic upgrades

TYPICAL APPLICATIONS

Parking Structures

- Shear Strengthening
- Corbel Upgrades
- Corrosion Damage

TYPICAL USAGE OF FRP MATERIALS - SUMMARY

Load Increases

- Increased live loads
- Increased traffic volumes on bridges
- Installation of heavy machinery in industrial buildings
- Vibrating structures
- Changes of building utilization

Seismic Strengthening

- Column wrapping
- Masonry walls

Damage to Structural Parts

- Aging of construction materials
- Vehicle impact
- Fire
- Blast resistance

Change in Structural System

- Removal of walls or columns
- Removal of slab sections for openings

Design or Construction Defects

- Insufficient reinforcements
- Insufficient structural depth

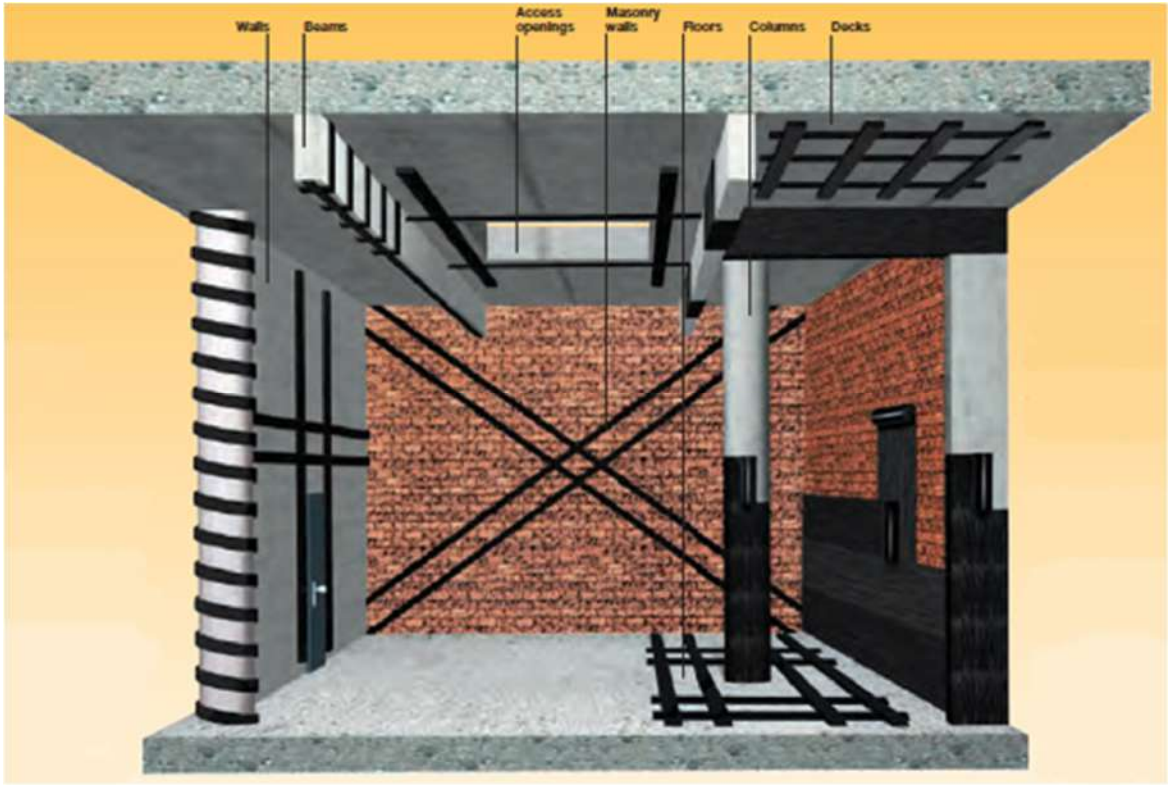
TYPICAL USAGE OF FRP MATERIALS

Flexural

Shear

Confinement

Seismic



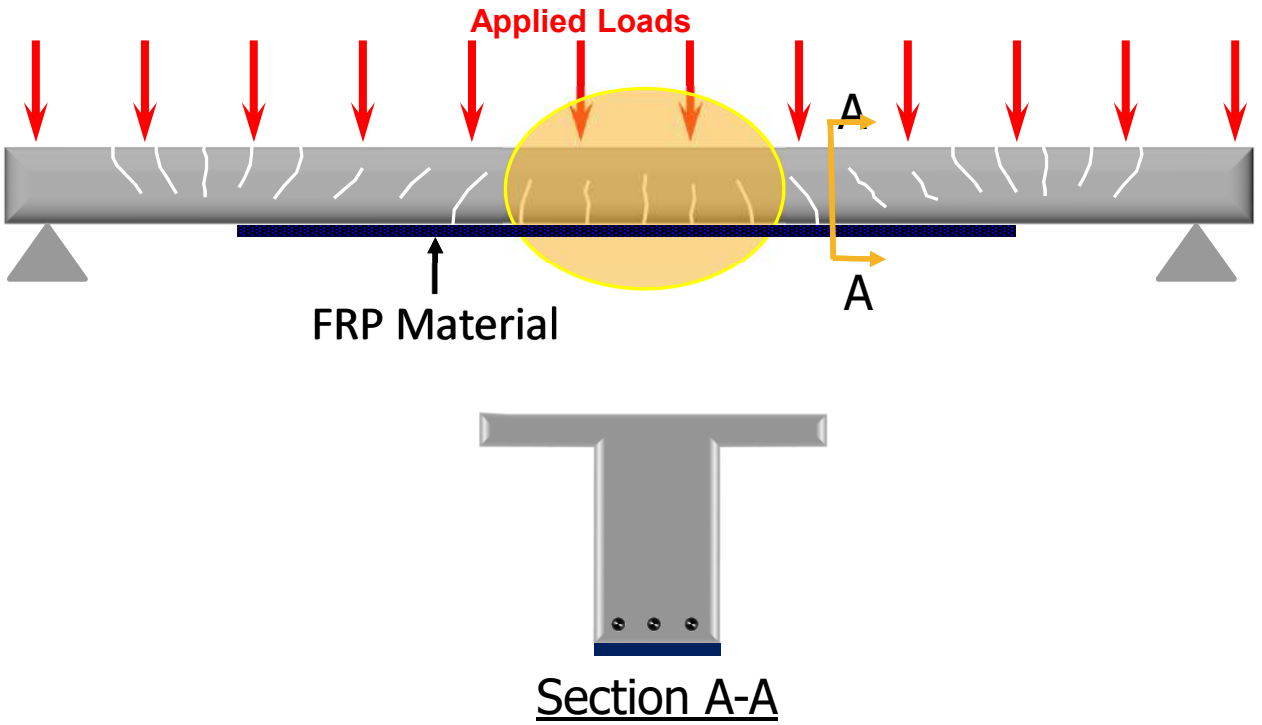
QUIZ QUESTION

What is one of the most preferred FRP systems for flexural strengthening?

A. Wet lay-up systems
B. Pre-cured FRP plates
C. NSM Rods
D. None of the above

FLEXURAL STRENGTHENING

FLEXURAL STRENGTHENING



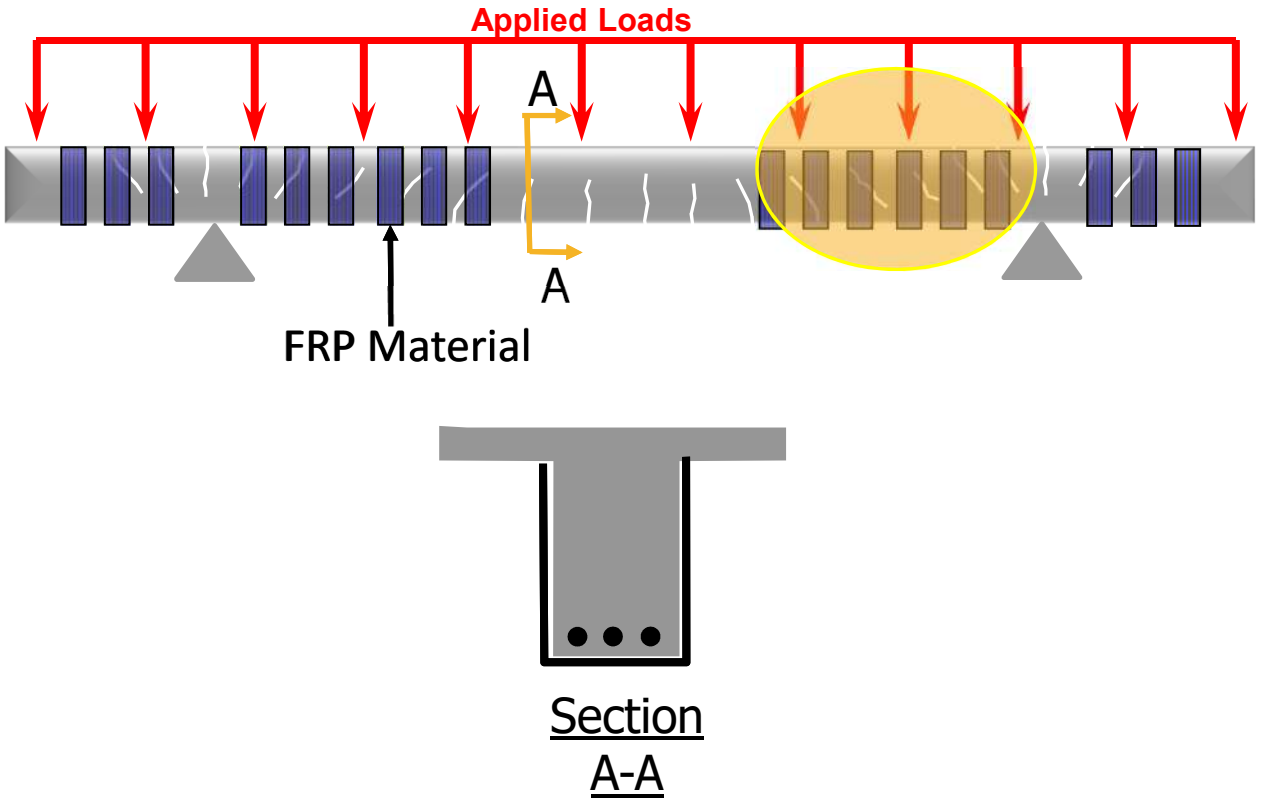
QUIZ QUESTION

What is one of the most preferred FRP systems for shear strengthening?

A. Wet lay-up systems
B. Pre-cured FRP plates
C. NSM Rods
D. None of the above

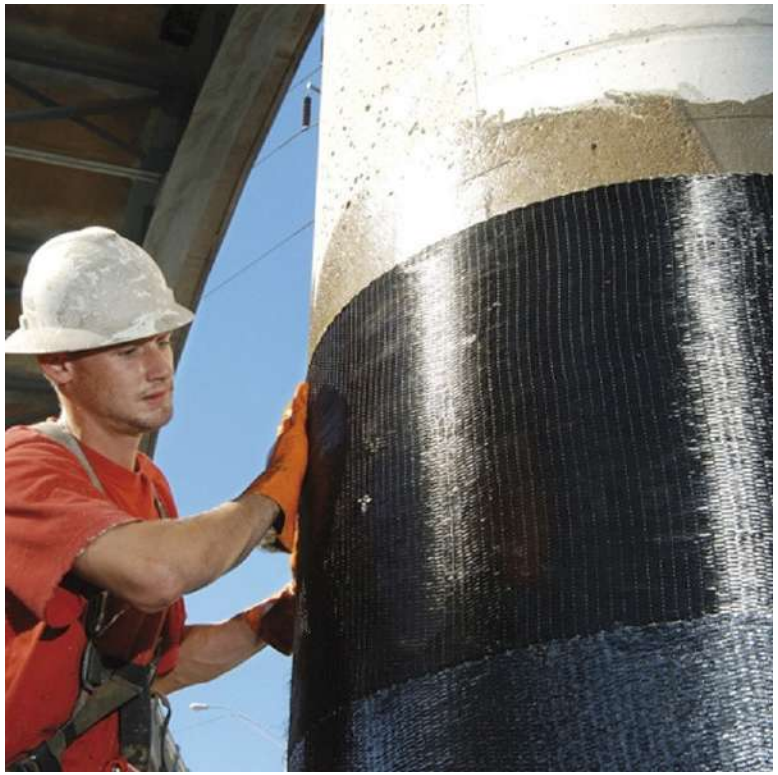
SHEAR STRENGTHENING

SHEAR STRENGTHENING

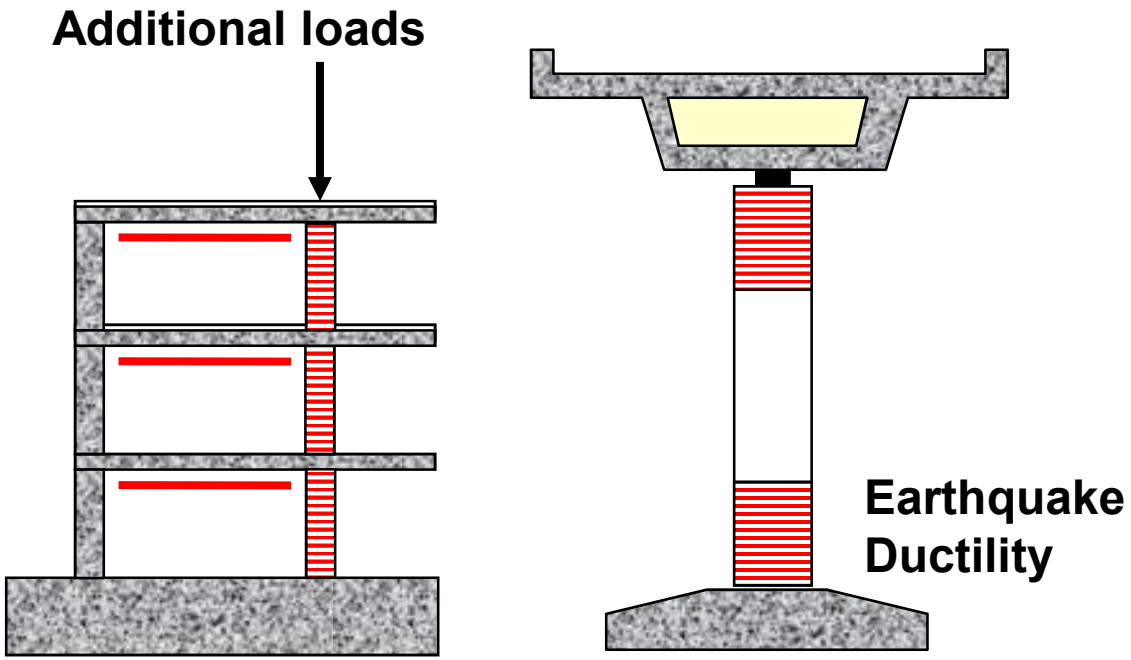


COMBINED STRENGTHENING - ANCHORAGE

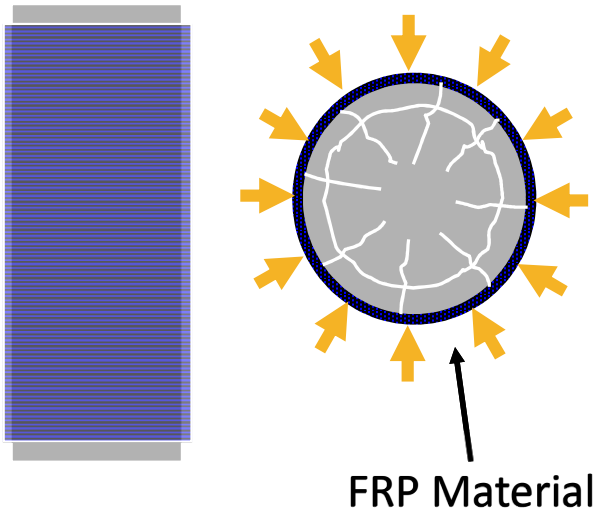
CONFINEMENT



CONFINEMENT / SEISMIC

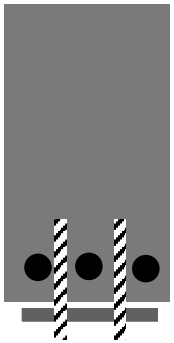


CONFINEMENT



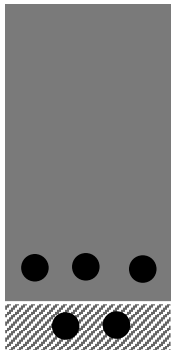
FRP VS. CONVENTIONAL UPGRADE

Simply supported beam; 35% upgrade in live load



Bonded Steel Plate

- 3/16 inch bolted plate
- 245 lb. dead load
- Placed by lift truck



Member Enlargement

- 2 #8 rebar, 4 in. grout
- 2,500 lb. dead load
- Formed and cured

FRP Sheet

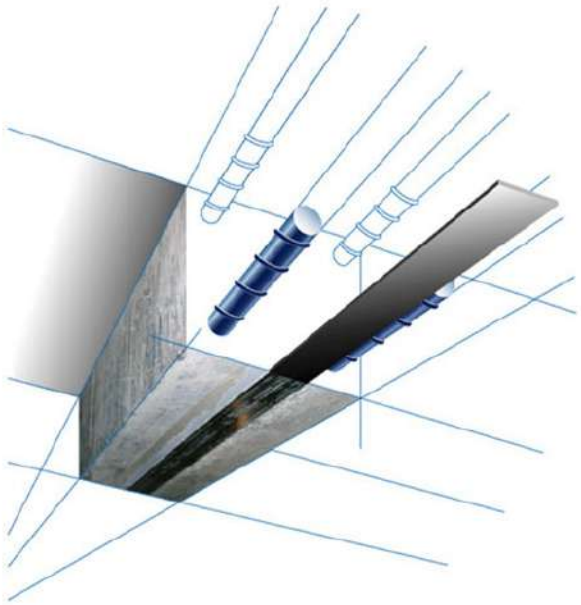
- 1 layer resin bonded
- 6 lb. dead load
- Placed by hand

CODES AND STANDARDS

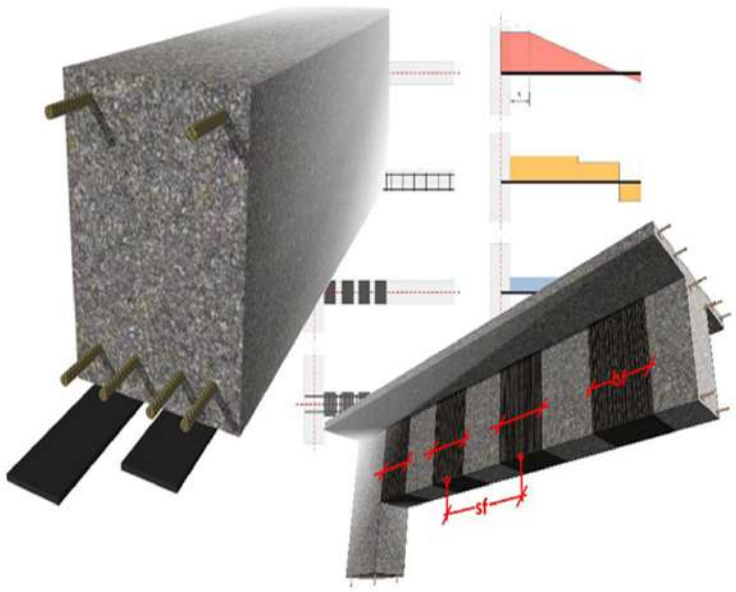
- ACI 440.2R-17
  - Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures
- ACI 562-17
  - Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings
  - Developed for adaptation into International Existing Building Code
  - Use of FRP allowed as long as consistent with ACI 440
- ICC Evaluation Service
  - Technical evaluation of building products for compliance to building codes such as IBC
  - Products independently tested per Acceptance Criteria

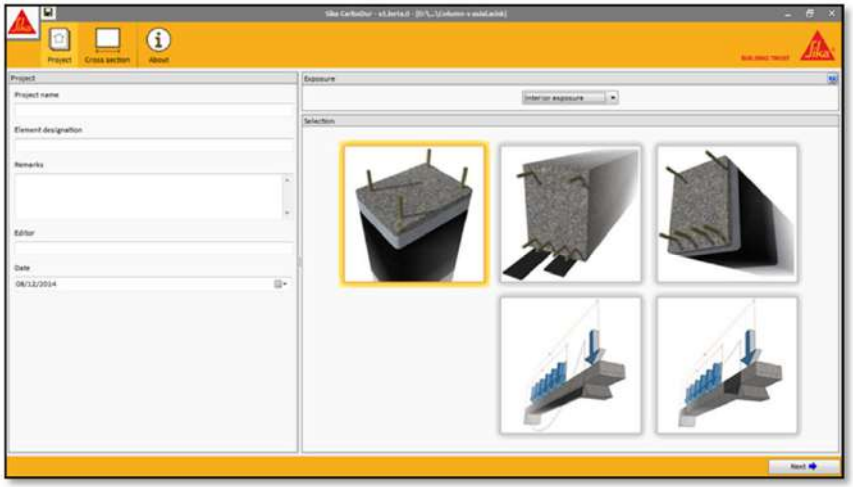
DESIGNING WITH FRP

- Provides secondary reinforcement
- Must comply with local building and fire codes

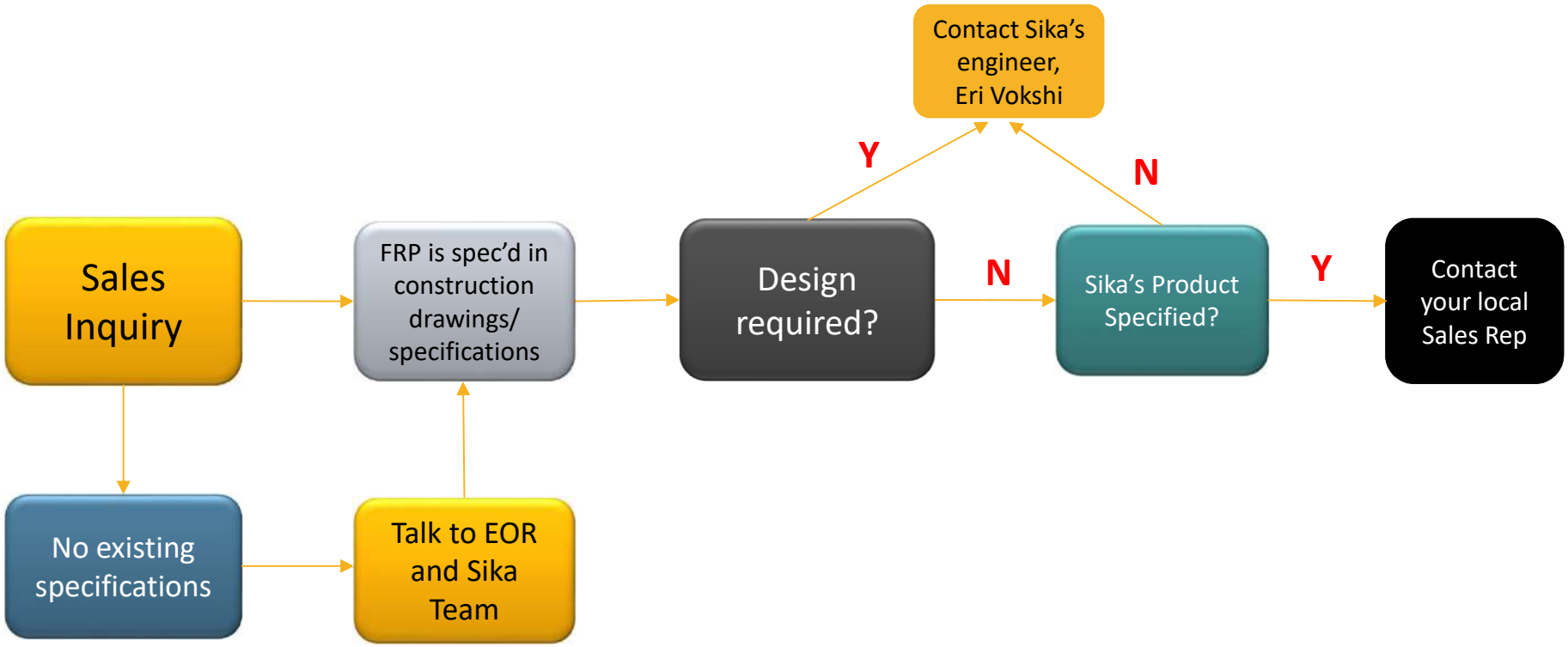


FRP DESIGN SOFTWARE





INQUIRY AND FRP DESIGN PROCESS



BUILDING TRUST

FRP SYSTEMS AT GLANCE

BUILDING TRUST

QUIZ QUESTION

When did Sika FRP systems become commercially available in the U.S. in the construction industry?

A. 1950’s
B. 1970s
C. 1990’s
D. 2000’s

BACKGROUND

- Structural Strengthening was typically done with retrofitted steel
- In the 1980's FRP composites started to be used for strengthening concrete
  - Light weight
  - Easy to apply
  - Material cost offset by ease of application
- Early-mid 1990's, Sika rolls out CFRP & GFRP systems for
  - SikaWrap 103C and SikaWrap 100G
    - Great success
- Transition from steel to composite is near 100%

AVAILABLE FRPS SYSTEMS


Epoxy Wet Lay-up Systems


Pre-saturated Wet Lay-up Systems


Dry Lay-up Systems


Pultruded Plates

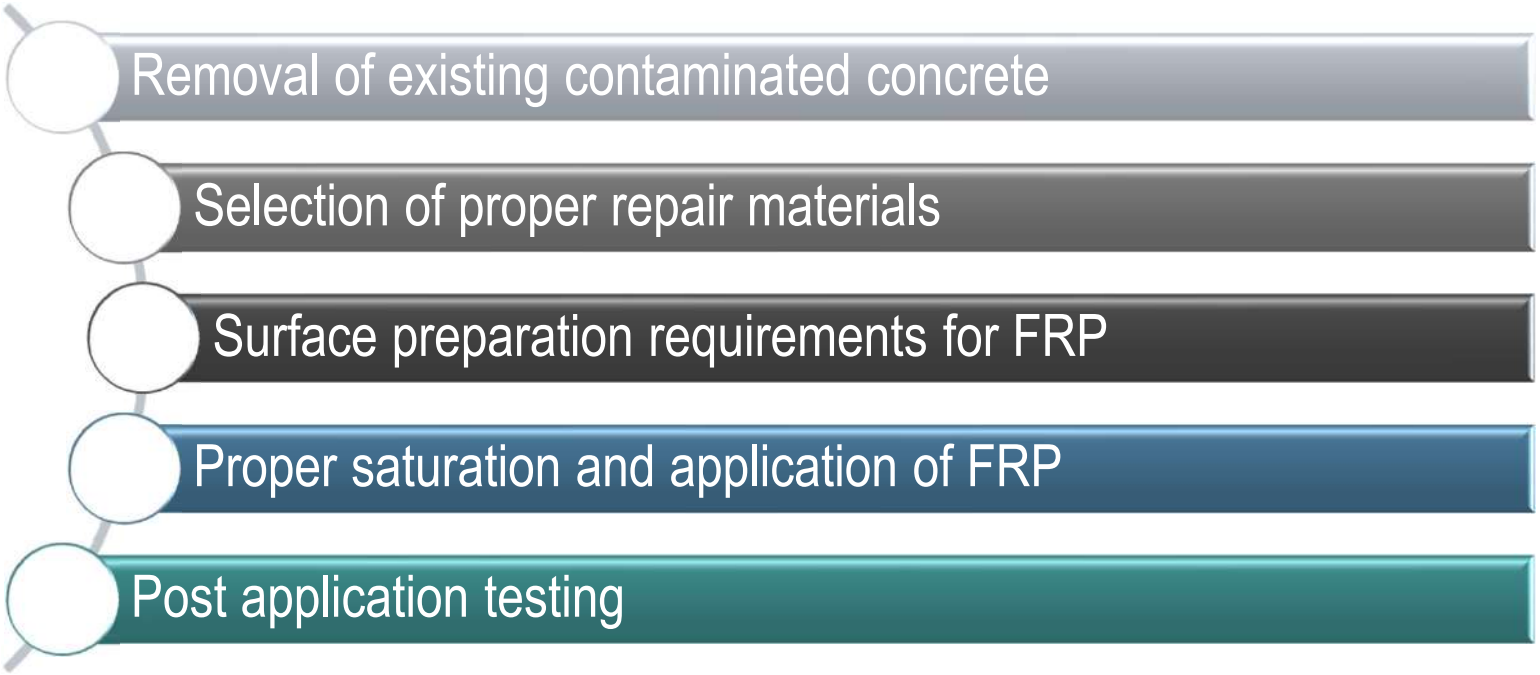

NSM Rods


Post-tensioned FRP Plates


Anchorage FRP System

FRPS SYSTEMS DISCUSSED TODAY

FRP INSTALLATION REQUIREMENTS



SURFACE PREPARATION

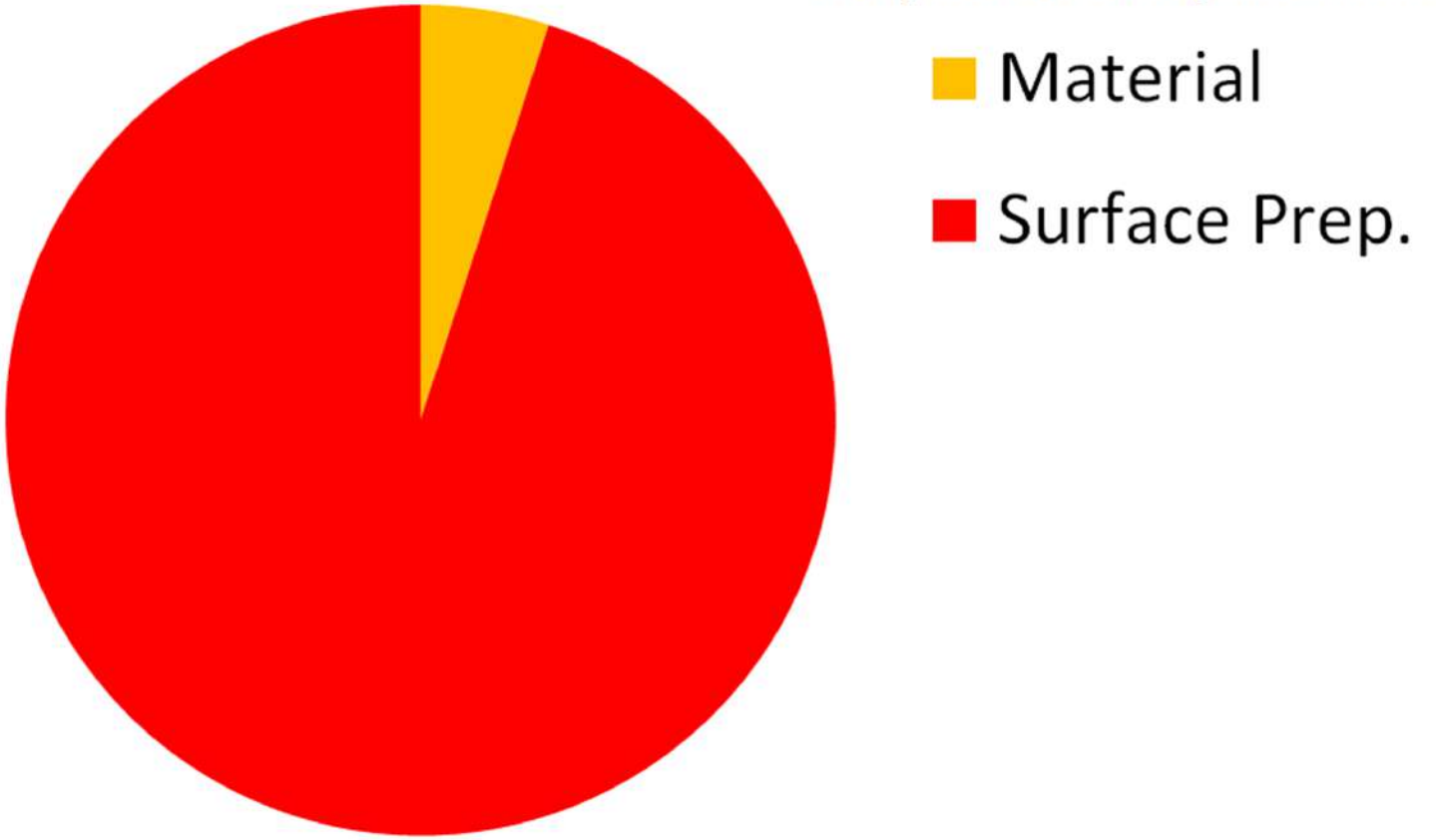
BUILDING TRUST

QUIZ QUESTION

What CSP is required for FRP applicatons?

A. CSP 2
B. CSP 3
C. CSP 4
D. CSP 10

SURFACE PREPARATION



SURFACE PREPARATION STEPS

- Repair
  - Spalls
  - Cracks
  - Voids

- Mechanical Preparation
  - Abrasive/Hydro Blasting
  - Needle Scabbling
  - Grinding

- Cleaning
  - Compressed Air
  - Brush
  - Vaccuum

GUIDELINES

- Industry Focus & Aid
  - Extremely Sensitive Topic
- ICRI => 30+ years Servicing Industry
  - www.icri.org

- Standard concrete repair must come first

- Repair any spalls and delaminations

- Choose repair materials – ICRI 320.2 ->
  - Low shrinkage
  - Compatible modulus
  - Adequate strength
  - Fast Curing (added bonus)

REPAIR - CRACKS

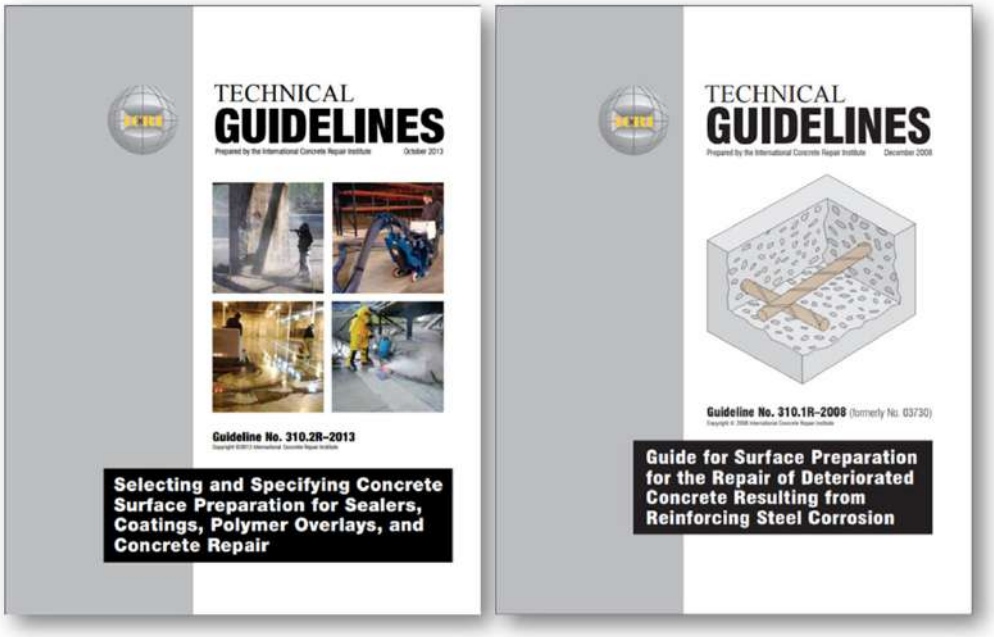
- Must repair structural cracks >10 mils
  - Epoxy Injection/Gravity Feed
    - Sikadur 35 Hi Mod/Sikadur 31 Hi Mod
- Root cause should be determined prior to repair
- Cracks subject to active hydrostatic or osmotic pressure (i.e., running water) should not be treated with epoxy products.
- Cores should be taken to ensure proper penetration and adhesion.

REPAIR - VOIDS

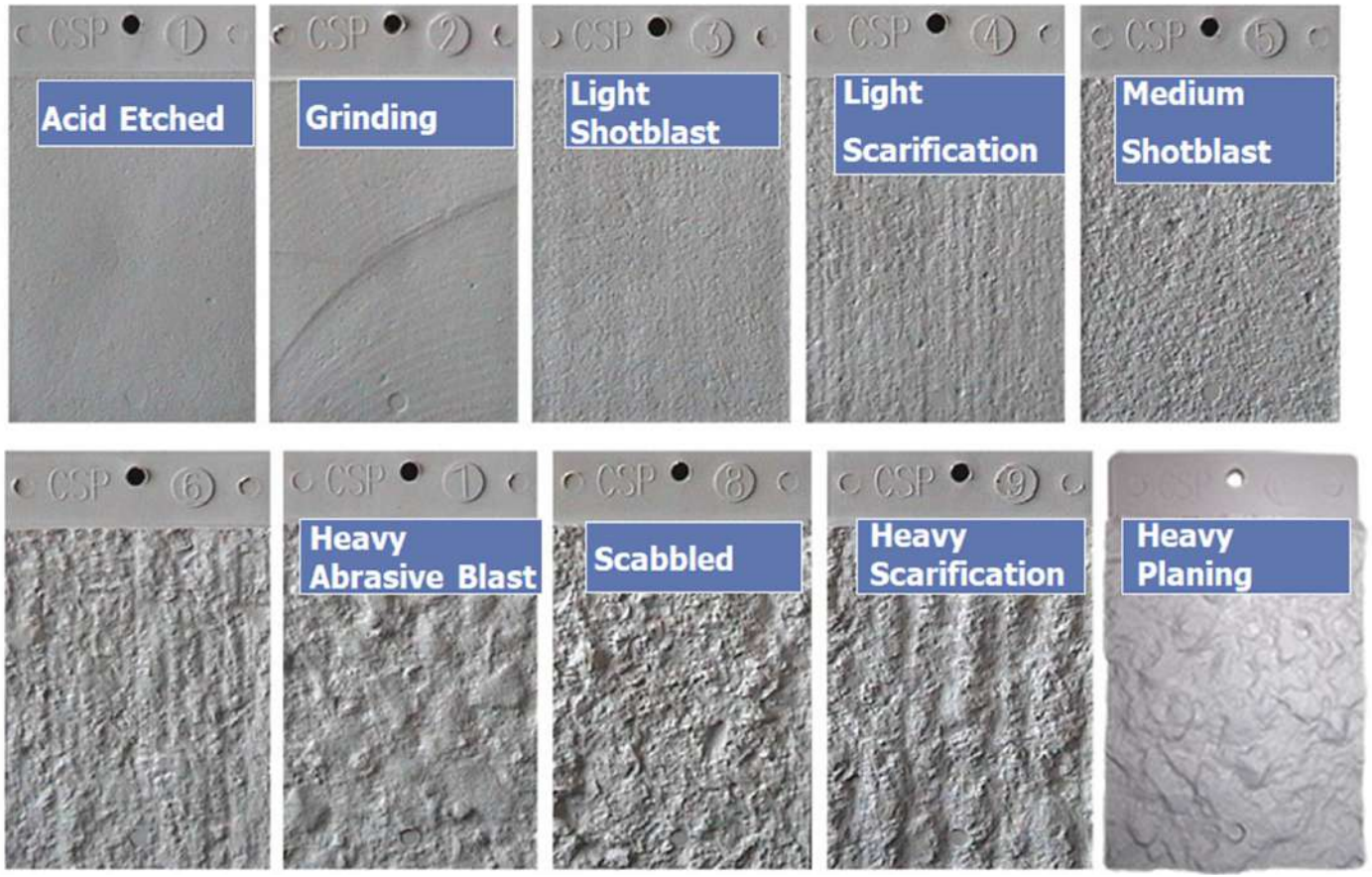
- Must ensure 100% contact of FRP to substrate
- Fill with fast setting epoxy gel
  - Bug Holes
  - Rock Pockets
  - Honeycombs
- Sikadur 30
  - 1" thickness max

MECHANICAL PREPARATION

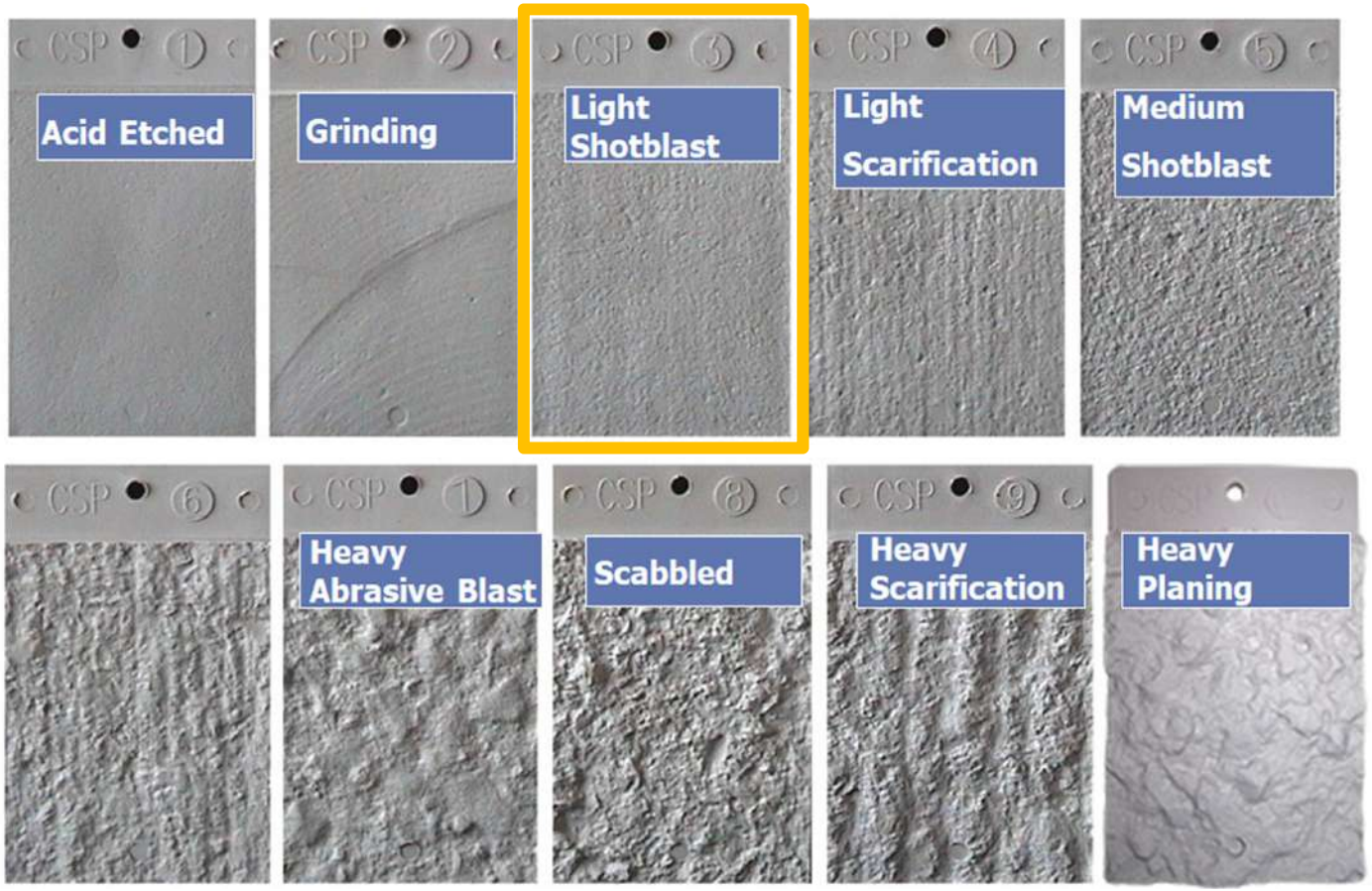
- Useful Guides:
  - Surface Prep for Deteriorated Concrete = #310.1R
  - Surface Prep Methods = #310.2R



MECHANICAL PREPARATION



MECHANICAL PREPARATION



MECHANICAL PREPARATION

- "Methods are not critical, results are!"
- Methods
  - Abrasive blasting (best)
    - Typically avoid silica
  - Grinder
  - Needle Scabbler

- Open pores – allows excellent adhesion

- Remove laitance – eliminate bond breakers

MECHANICAL PREPARATION

- Outside corners rounded to ½" min.
- Inside corners – epoxy filet – ½" radius
- Smooth (but open) & Level

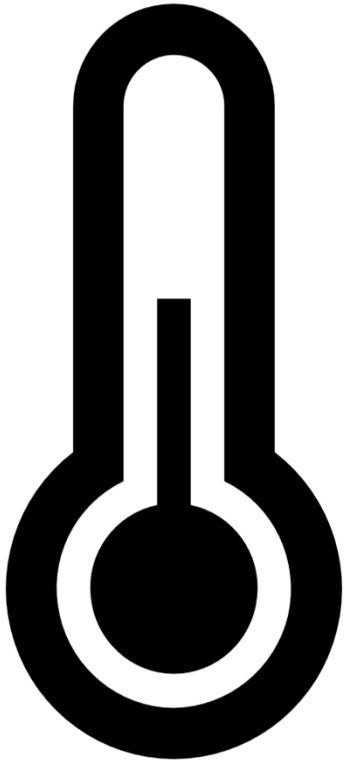
CLEANING

- Prior to application, all substrates must be clean and free of dust

- Substrate shall be:
  - Brushed – stiff bristles to get into the pores
  - Air blasted – oil free
  - Vacuumed – to achieve dust free surfaces

SURFACE PREP – SITE CONDITIONS

- 40 F minimum, and rising!
  - Warm material
- 95 F maximum
  - Need hot weather protocol
    - Avoid direct sunlight
    - Cool material
- Substrate moisture - <4% via Tramex
- Concrete must be 21-28 days old



TESTING SUBSTRATE

Minimum tensile strength = 200 psi

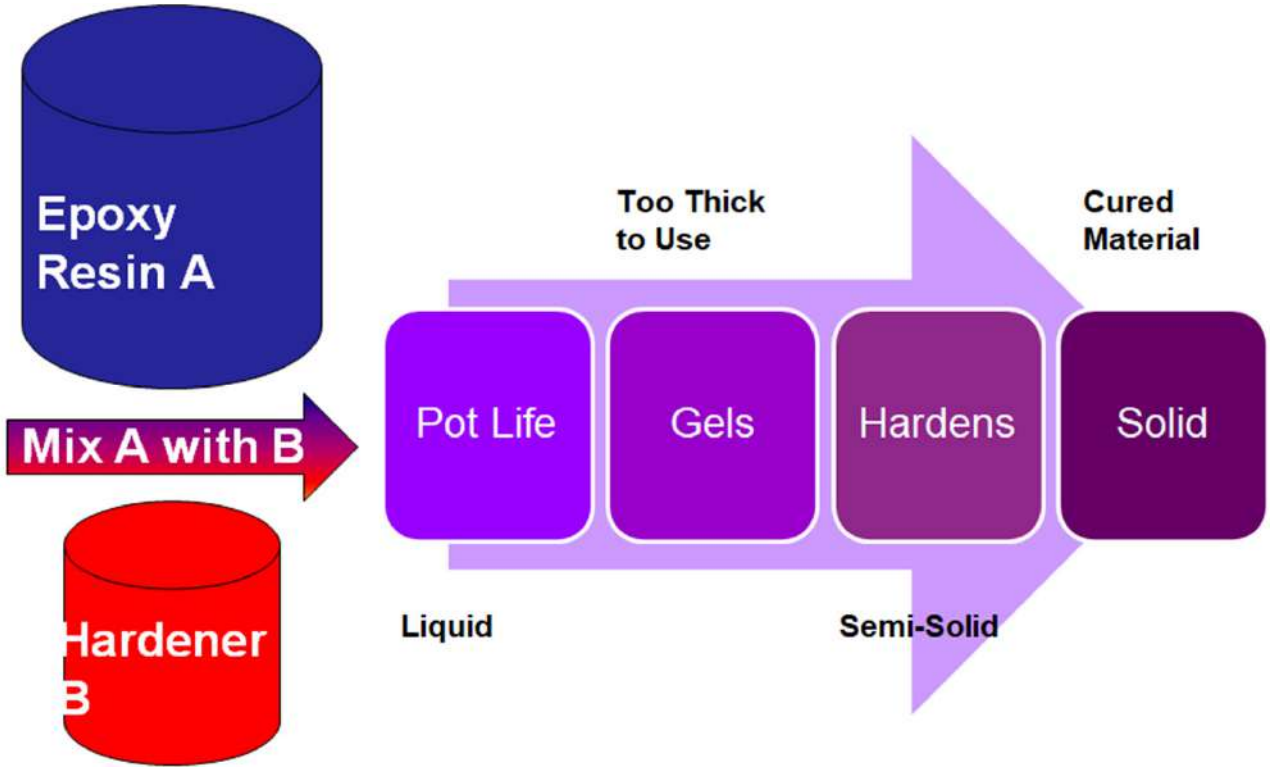
Substrate failure

BUILDING TRUST

EPOXY RESIN BASICS

BUILDING TRUST

HOW EPOXIES WORK



EPOXIES ARE THERMOSETTING RESINS

- Produce Heat during mixing and cure
  - Mixing time is critical – 3 minutes
- In warmer temperature conditions, cure rate is faster.
  - Can cool to slow them down
- Mass dependent
  - Remove from mixing bucket ASAP
- Once cured, thermosetting resins cannot be re-worked by heating.

[To avoid confusion: Thermoplastics
can be re-worked by heating.
Epoxies are not thermoplastics.]

MIXING TOOLS

- 1/2” drive, low speed rotary drill (400 – 600 rpm typical)
- Appropriate epoxy mixing paddle
  - e.g. “Jiffy” or “Exo-mixer”
- Spatula - To scrape side walls of containers

QUIZ QUESTION

Is it allowed to batch down the epoxies used for priming and fabric saturation?

- ❑ Yes
- ❑ No

MIXING – LIKE THIS

Full units only!

MIXING - NOT LIKE THIS!

OR THIS...

OR THIS...

AND DEFINITELY NOT LIKE THIS!

QUESTIONS FROM THE AUDIENCE

FRP INSTALLATION TOOLS

VIDEO

FIELD SATURATED FRP SYSTEMS

BUILDING TRUST

FIELD SATURATED FRP SYSTEM

- The ORIGINAL FRP system
- Longest in the market and most trusted
- Most common resin used is epoxy
- Saturation is done in the field
- Durable in various environments

FIELD SATURATED FRP SYSTEMS

- Repair Imperfections

FIELD SATURATED FRP SYSTEMS

- Prep Work

FIELD SATURATED FRP SYSTEMS

- Mix & Apply Epoxy Primer

FIELD SATURATED FRP SYSTEMS

- Cut fabric to size

FIELD SATURATED FRP SYSTEMS

- Saturate Fabric with Resin – Table or Saturator

QUIZ QUESTION

When should you use a saturation machine for the wet lay-up method?

A. Always
B. Depending on the project size
C. Only if I have one
D. Only if the owner requests it

FIELD SATURATED FRP SYSTEMS

FIELD SATURATED FRP SYSTEMS

- Remove air bubbles

APPLICATION VIDEO – WET LAY-UP SYSTEM

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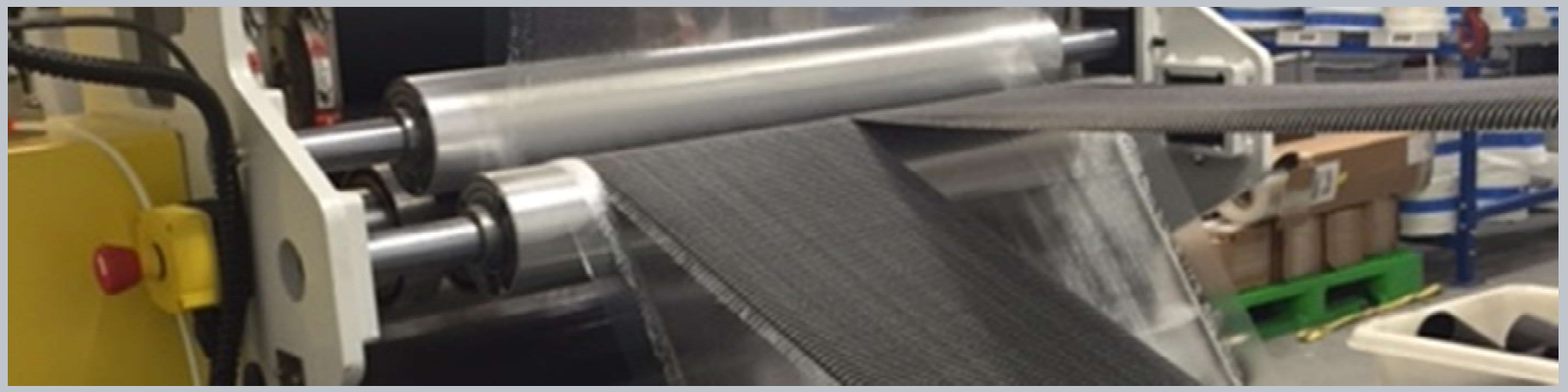


PRESATURATED SYSTEMS

BUILDING TRUST

PRE-SATURATED FRP SYSTEM

- What is a pre-saturated system?
- Pre-saturated systems have been used in aerospace industry
- Consistent resin to fabric ratio
- Reduction in Labor
- Application efficiency
- Non hazardous
- Saturating resin is an aliphatic PU, which are inherently durable and UV resistant

PRESATURATED SYSTEM

Prep Concrete

PRESATURATED SYSTEM

Mix epoxy primer and apply on the substrate

PRESATURATED SYSTEM

- Prime Concrete

PRESATURATED SYSTEM

- Open foil pouches when ready to apply

TRUST

PRESATURATED SYSTEM

- Cut “wet” fabric if necessary

PRESATURATED SYSTEM

- Lay Wrap

STRENGTHENING EVOLUTIONS

COMPOSITES

- High material cost
- Low installed cost
- Needs resin
- Light weight
- Low maintenance
- No fabrication

PRESAT. COMPOSITES

- Higher material cost
- Lower installed cost
- Resin included
- Light weight
- Low maintenance
- No fabrication

ADVANTAGES

- Quality in the field
  - Known Resin to Fabric Ratio
    - Within 5%
  - Material Certs for engineers
    - Strengths
    - Modulus
    - R:F Ratio
  - ISO 9001 Plant
    - Full Traceability
- Drop in replacement for current products
- Reduction in Labor
  - Reduce 5-6 man crew by 2-3 men
- Application efficiency
  - Increase work rate by 20-30%
  - 4 day project down to 3
    - No need to move saturated fabric around
- Ease of delivery
  - Single source
  - Non hazardous
    - Can be easily transported or air freighted

FIELD SATURATED SYSTEM – INSTALLATION STEPS

- Order & Ship Resin
- Order & Ship Fabric
- Prepare concrete
- Bring Saturator on site
- Mix Epoxy Primer
- Prime Concrete
- Fabric is cut on site (if necessary)
- Set up saturator
- Fabric is then saturated (saturator or table/rollers)
- Piece by piece, saturated fabric transported and given to installers
- Applied to primed surface
- Left to cure
- Clean up saturator and site
- Dispose of Resin pails

PRE-SATURATED SYSTEM – INSTALLATION STEPS

- ~~Order & Ship Resin~~
- Order & Ship Fabric
- Prepare concrete
- ~~Bring Saturator on site~~
- Mix Epoxy Primer
- Prime Concrete
- Fabric is cut on site (if necessary)
- ~~Set up saturator~~
- ~~Fabric is then saturated (saturator or table/rollers)~~
- ~~Piece by piece, saturated fabric transported and given to installers~~
- Applied to primed surface
- Left to cure
- ~~Clean up saturator and site~~
- ~~Dispose of Resin pails~~

APPLICATION VIDEO – PRESATURATED SYSTEM

BUILDING TRUST

DRY LAY-UP

BUILDING TRUST

QUIZ QUESTION

Dry lay-up installation technique can be used for any of the CFRP or GFRP fabrics, as long the installer does a good job rolling the fabric into the primer layer.

- ❑ True
- ❑ False

DRY LAY-UP INSTALLATION METHOD

- A simplified wet lay-up application method
- Applicable for very thin carbon or glass fabric systems
- Reduction in labor
- Application efficiency

DRY LAY-UP INSTALLATION

- Prep Concrete

DRY LAY-UP INSTALLATION

- Apply epoxy primer

DRY LAY-UP INSTALLATION

- Apply dry fabric on the primer and roll it to to ensure epoxy comes through the fabric.

DRY LAY-UP INSTALLATION

- Apply epoxy on top of the installed system to ensure full saturation

DRY LAY-UP INSTALLATION

- Sand broadcasting (if required)

APPLICATION VIDEO – DRY LAY-UP SYSTEM

BUILDING TRUST

FRP PLATES

BUILDING TRUST

FRP PLATES

- Sika® CarboDur® Plates are pultruded CFRP
- Designed for strengthening concrete, timber and masonry structures
- Higher stiffness than the wet lay-up systems
- Lightweight
- Non-corrosive

QUIZ QUESTION

How do the CFRP plates come in the field?

A. 1 ft long pieces, ready to be glued in the field together
B. Pre-cut to the size required
C. Coiled and ready to be cut in the field to the required length
D. None of the above

CLEANING CFRP STRIPS

BUILDING TRUST

CUTTING STRIPS ON-SITE

MIXING EPOXY RESIN

- Pre-mix components
- Low speed drill
- Uniformly blended

APPLYING EPOXY TO SUBSTRATE

APPLYING EPOXY ONTO CFRP

STRIP INSTALLATION

- Set strip by hand
- Work from one end to the other
- Moderate pressure

ROLLING CFRP ONTO CONCRETE

- Moderate pressure
- Ensures intimate contact

APPLICATION VIDEO – FRP PLATES

BUILDING TRUST

PROJECT COMPLETION

BUILDING TRUST

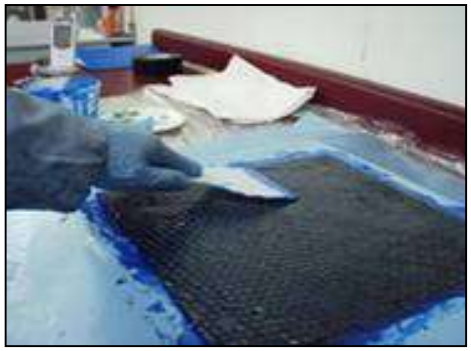
PROTECTIVE COATINGS

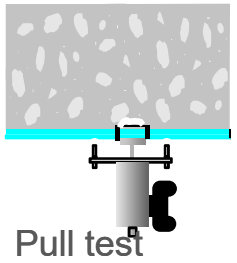
Before

After

QC ACCEPTANCE CRITERIA

- Delamination
  - Limits of delaminated FRP area to ensure adequ
- Material Testing





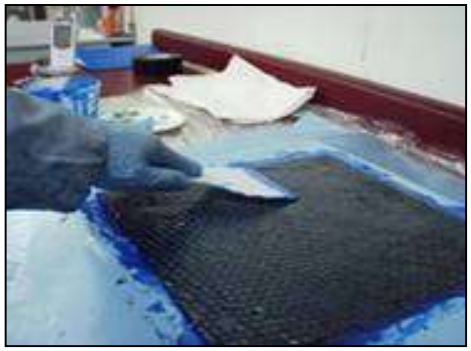
QUIZ QUESTION

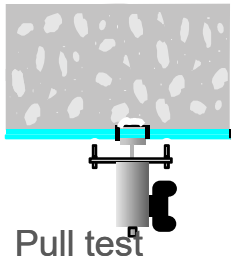
What are the most common tests for quality assurance in the field?

A. Panel tests
B. Bond strength tests
C. Epoxy glass transition temperature
D. A & B

QC ACCEPTANCE CRITERIA

- Delamination
  - Limits of delaminated FRP area to ensure adequ
- Material Testing
  - Tensile tests of laminate from field
- Bond
  - Pull off tests to determine bond strength to concrete
  - Minimum 200 psi (1.4 MPa)





FIRE PROTECTION OF FRP

BUILDING TRUST

ASTM E84

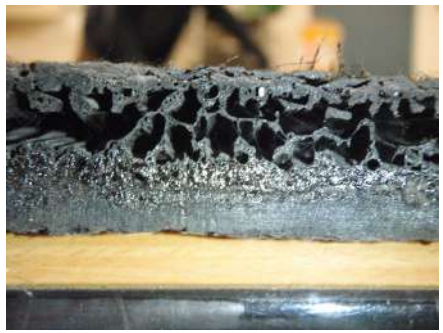
STANDARD TEST METHOD FOR SURFACE BURNING CHARACTERISTICS OF BUILDING MATERIALS

- Quantifies flame spread rate
- Quantifies amount of smoke generated

ASTM E-84 TEST

- Intumescent coating is sacrificial element in test
- Class A rating achievable for interior or exterior use
- System tested up to **18 layers** of FRP/epoxy system – Class A rating





BUILDING TRUST

STRUCTURAL FIRE ENDURANCE TEST

- NRC Canada – Test facility, Ottawa, CA
- Testing administered by Queens Univ.
  - Prof. Mark Green
- UL witnessed test
  - T beams
  - Columns
- Systems tested
  - CFRP fabrics
  - GFRP fabrics
  - CFRP plates
- Sikacrete-213F
  - Fire-resistive mortar

BUILDING TRUST

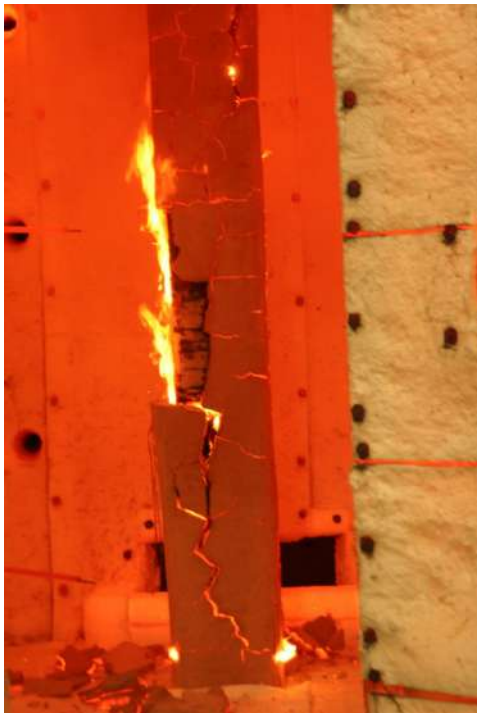
FIREPROOFING - SHOTCRETE

- Structural Fire Endurance test
- UL witnessed test
- Systems tested
  - CFRP fabrics
  - GFRP fabrics
  - CFRP plates
- Fireproof Shotcrete
  - Hydraulic bound, vermiculite-based, fire-resistive mortar
  - Contains aggregates and admixtures which are highly effective in resisting heat from fires
  - Applied by wet spray process

COLUMN TEST

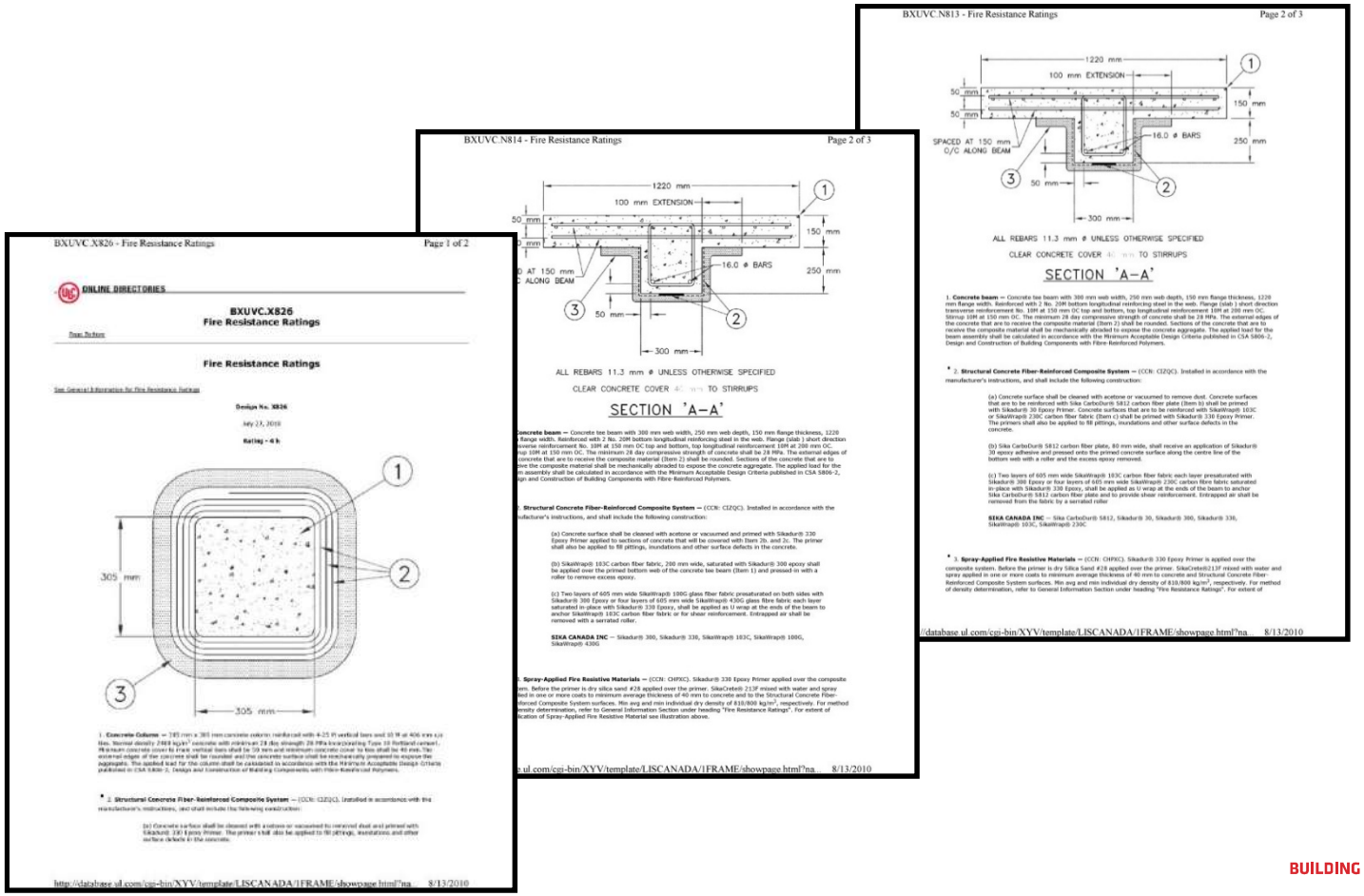
- **Square** columns
- Columns provided with **fire insulation** to protect FRP wrap
- Columns tested **under sustained concentric axial service load** in the column furnace at NRC
- Tested to 2,000F

IRC/NRC Column Furnace and Column after Fire Testing



Purpose: Obtain ASTM E119 fire endurance ratings / verify models and UL Rated System

UL LISTINGS – 4 HR. RATING



BXUVC.X826 - Fire Resistance Ratings Page 1 of 2

ONLINE DIRECTORIES

BXUVC.X826
Fire Resistance Ratings

Fire Resistance Ratings

Design No. X826

July 23, 2010

Rating - 4 h

1. **Concrete Column** — 305 mm x 305 mm concrete column reinforced with 4-25 M vertical bars and 10 M at 406 mm o/c ties. Normal density 2400 kg/m³ concrete with minimum 28 day strength 28 MPa (exposing Type 10 Portland cement). Minimum concrete cover to main vertical bars shall be 70 mm and minimum concrete cover to ties shall be 40 mm. The external edges of the concrete shall be rounded and the concrete surface shall be mechanically prepared to expose the aggregate. The applied load for the column shall be calculated in accordance with the Minimum Acceptable Design Criteria published in CSA S806-2, Design and Construction of Building Components with Fibre-Reinforced Polymers.

* 2. **Structural Concrete Fiber-Reinforced Composite System** — (CCN: CIZQC). Installed in accordance with the manufacturer's instructions, and shall include the following construction:

(a) Concrete surface shall be cleaned with acetone or vacuumed and primed with

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BXUVC.N814 - Fire Resistance Ratings Page 2 of 3

ALL REBARS 11.3 mm ø UNLESS OTHERWISE SPECIFIED

CLEAR CONCRETE COVER 40 mm TO STIRRUPS

SECTION 'A–A'

Concrete beam — Concrete tee beam with 300 mm web width, 250 mm web depth, 150 mm flange thickness, 1220 mm flange width. Reinforced with 2 No. 20M bottom longitudinal reinforcing steel in the web. Flange (slab) short direction transverse reinforcement No. 10M at 150 mm OC top and bottom, top longitudinal reinforcement 10M at 200 mm OC. Stirrup 10M at 150 mm OC. The minimum 28 day compressive strength of concrete shall be 28 MPa. The external edges of the concrete that are to receive the composite material (Item 2) shall be rounded. Sections of the concrete that are to receive the composite material shall be mechanically abraded to expose the concrete aggregate. The applied load for the beam assembly shall be calculated in accordance with the Minimum Acceptable Design Criteria published in CSA S806-2, Design and Construction of Building Components with Fibre-Reinforced Polymers.

* 2. **Structural Concrete Fiber-Reinforced Composite System** — (CCN: CIZQC). Installed in accordance with the manufacturer's instructions, and shall include the following construction:

(a) Concrete surface shall be cleaned with acetone or vacuumed and primed with Sikadur® 330 Epoxy Primer applied to sections of concrete that will be covered with Item 2b. and 2c. The primer shall also be applied to fill pittings, inundations and other surface defects in the concrete.

(b) SikaWrap® 103C carbon fiber fabric, 200 mm wide, saturated with Sikadur® 300 epoxy shall be applied over the primed bottom web of the concrete tee beam (Item 1) and pressed-in with a roller to remove excess epoxy.

(c) Two layers of 605 mm wide SikaWrap® 100G glass fiber fabric presaturated on both sides with Sikadur® 300 Epoxy or four layers of 605 mm wide SikaWrap® 430G glass fibre fabric each layer saturated in place with Sikadur® 330 Epoxy, shall be applied as U wrap at the ends of the beam to anchor SikaWrap® 103C carbon fiber fabric or for shear reinforcement. Entrapped air shall be removed with a serrated roller.

SIKA CANADA INC — Sikadur® 300, Sikadur® 330, SikaWrap® 103C, SikaWrap® 100G, SikaWrap® 430G

* 3. **Spray-Applied Fire Resistive Materials** — (CCN: CHPXC). Sikadur® 330 Epoxy Primer applied over the composite system. Before the primer is dry Silica Sand #28 applied over the primer. SikaCrete® 213F mixed with water and spray applied in one or more coats to minimum average thickness of 40 mm to concrete and to the Structural Concrete Fiber-Reinforced Composite System surfaces. Min avg and min individual dry density of 810/800 kg/m³, respectively. For method of density determination, refer to General Information Section under heading "Fire Resistance Ratings". For extent of application of Spray-Applied Fire Resistive Material see illustration above.

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BXUVC.N813 - Fire Resistance Ratings Page 2 of 3

ALL REBARS 11.3 mm ø UNLESS OTHERWISE SPECIFIED

CLEAR CONCRETE COVER 40 mm TO STIRRUPS

SECTION 'A–A'

1. **Concrete beam** — Concrete tee beam with 300 mm web width, 250 mm web depth, 150 mm flange thickness, 1220 mm flange width. Reinforced with 2 No. 20M bottom longitudinal reinforcing steel in the web. Flange (slab) short direction transverse reinforcement No. 10M at 150 mm OC top and bottom, top longitudinal reinforcement 10M at 200 mm OC. Stirrup 10M at 150 mm OC. The minimum 28 day compressive strength of concrete shall be 28 MPa. The external edges of the concrete that are to receive the composite material (Item 2) shall be rounded. Sections of the concrete that are to receive the composite material shall be mechanically abraded to expose the concrete aggregate. The applied load for the beam assembly shall be calculated in accordance with the Minimum Acceptable Design Criteria published in CSA S806-2, Design and Construction of Building Components with Fibre-Reinforced Polymers.

* 2. **Structural Concrete Fiber-Reinforced Composite System** — (CCN: CIZQC). Installed in accordance with the manufacturer's instructions, and shall include the following construction:

(a) Concrete surface shall be cleaned with acetone or vacuumed to remove dust. Concrete surfaces that are to be reinforced with Sika CarboDur® S812 carbon fiber plate (Item b) shall be primed with Sikadur® 30 Epoxy Primer. Concrete surfaces that are to be reinforced with SikaWrap® 103C or SikaWrap® 230C carbon fiber fabric (Item c) shall be primed with Sikadur® 330 Epoxy Primer. The primers shall also be applied to fill pittings, inundations and other surface defects in the concrete.

(b) Sika CarboDur® S812 carbon fiber plate, 80 mm wide, shall receive an application of Sikadur® 30 epoxy adhesive and pressed onto the primed concrete surface along the centre line of the bottom web with a roller and the excess epoxy removed.

(c) Two layers of 605 mm wide SikaWrap® 103C carbon fiber fabric each layer presaturated with Sikadur® 300 Epoxy or four layers of 605 mm wide SikaWrap® 230C carbon fibre fabric saturated in-place with Sikadur® 330 Epoxy, shall be applied as U wrap at the ends of the beam to anchor Sika CarboDur® S812 carbon fiber plate and to provide shear reinforcement. Entrapped air shall be removed from the fabric by a serrated roller

SIKA CANADA INC — Sika CarboDur® S812, Sikadur® 30, Sikadur® 300, Sikadur® 330, SikaWrap® 103C, SikaWrap® 230C

* 3. **Spray-Applied Fire Resistive Materials** — (CCN: CHPXC). Sikadur® 330 Epoxy Primer is applied over the composite system. Before the primer is dry Silica Sand #28 applied over the primer. SikaCrete® 213F mixed with water and spray applied in one or more coats to minimum average thickness of 40 mm to concrete and Structural Concrete Fiber-Reinforced Composite System surfaces. Min avg and min individual dry density of 810/800 kg/m³, respectively. For method of density determination, refer to General Information Section under heading "Fire Resistance Ratings". For extent of

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CASE STUDIES

BUILDING TRUST

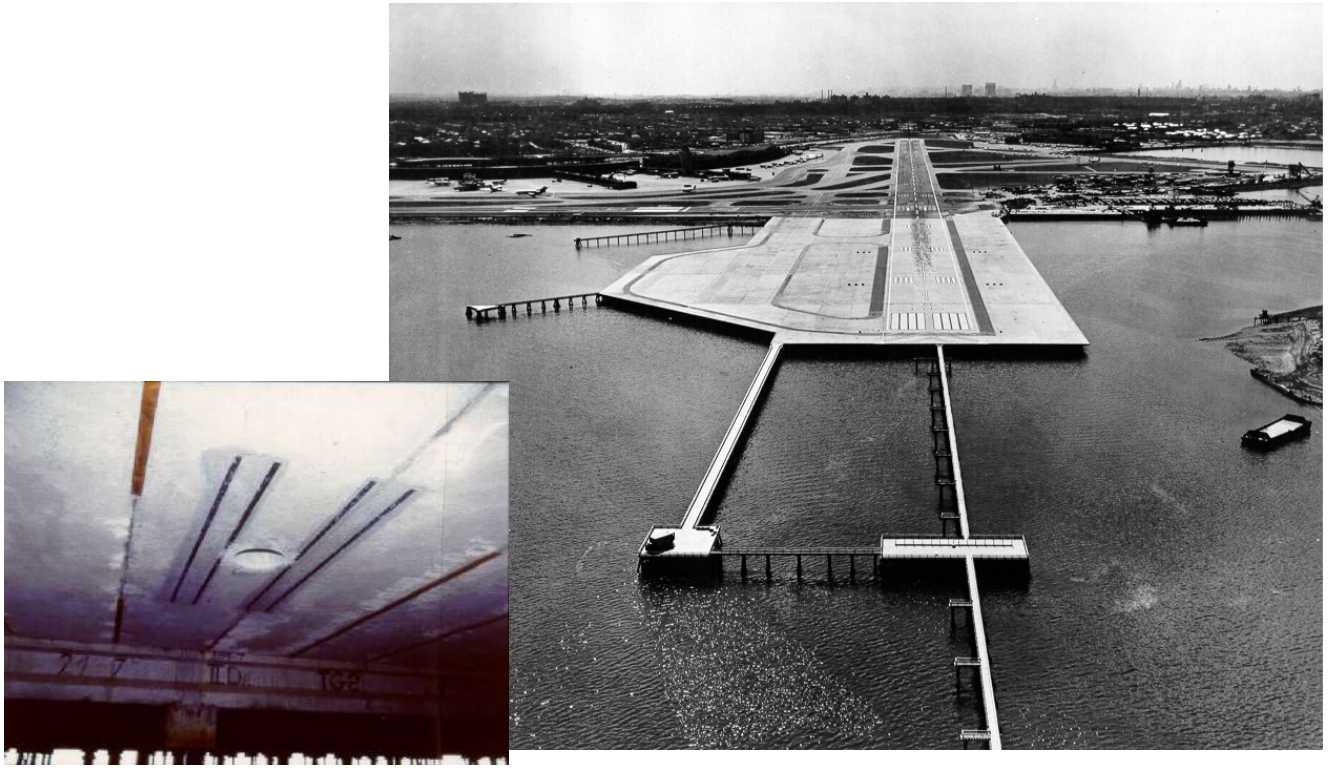
CENTRAL PARK WEST CONDO

- New octagon shaped staircase cut into reinforced concrete slab
- Carbon fiber plates inserted into grooves cut into concrete on top and bottom of slab

I-57 BRIDGE COLUMN SEISMIC UPGRADE - CAIRO, ILLINOIS

OHIO STATE UNIVERSITY STADIUM

LAGUARDIA AIRPORT RUNWAY NEW YORK CITY



SOUTH SHORE PLAZA MALL

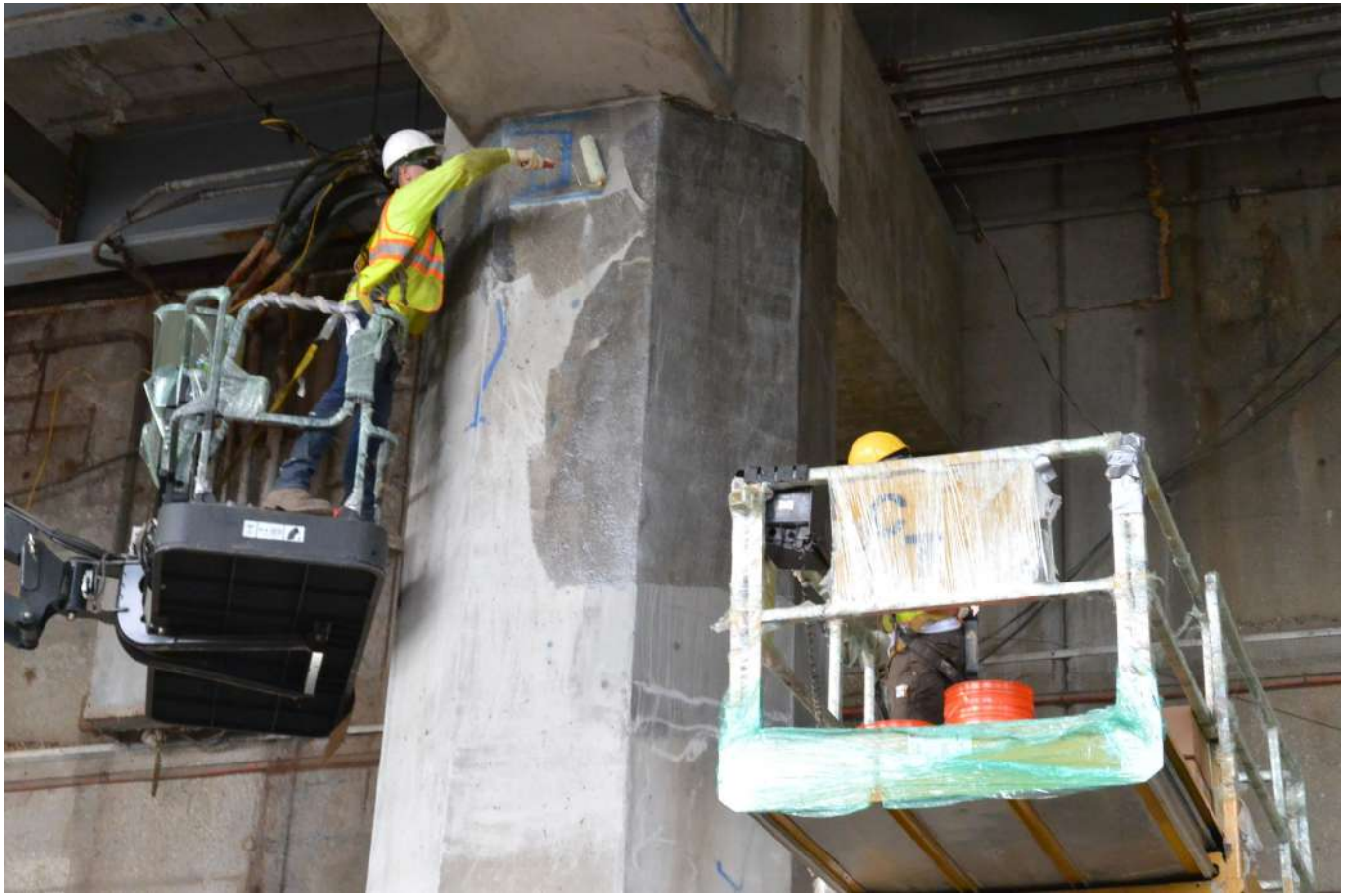
I-80 SALT LAKE CITY

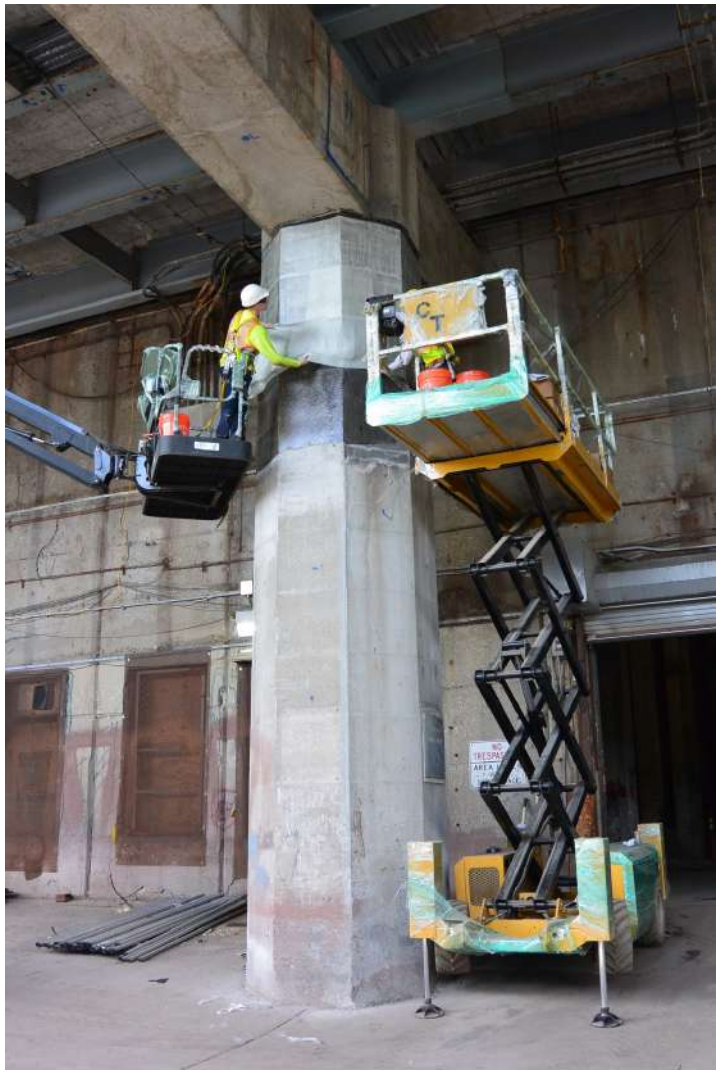
NEWARK AIRPORT

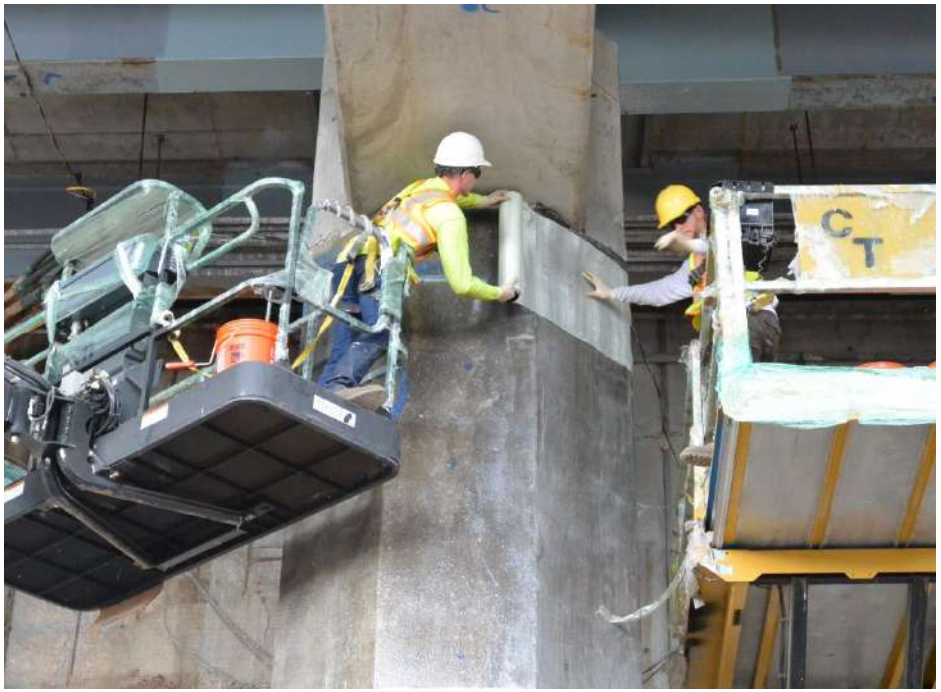
RFK BRIDGE
CONTRACTOR TRAINING

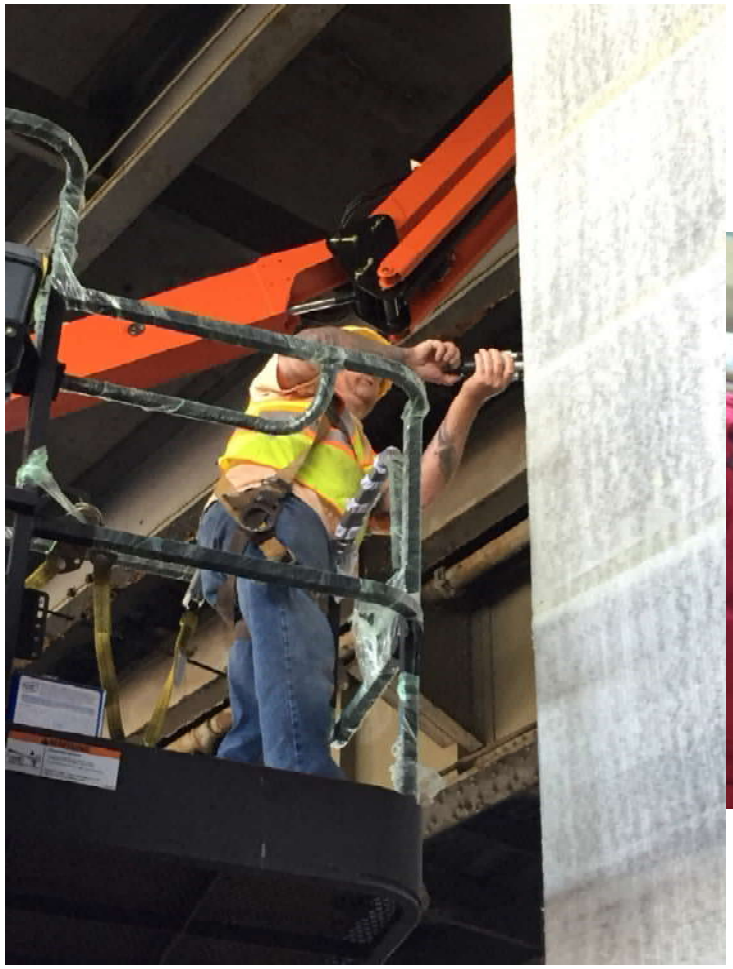
- Contractor came into Sika to receive training on systems and applications
- Applied 28 oz glass fabric as a wet layup
- Introduced to PreSaturated Glass Fabric
  - Immediately switch gears
  - No longer want to saturate
  - Contractor sees major benefits
    - Cleaner
    - Faster
    - Much less labor – plan on only 2 man crew

- Glass PreSaturated Fabric was submitted to Engineer as a substitution.
  - Submitted PDS & SDS
  - Quickly accepted as a substitution









RFK BRIDGE
HOME STRETCH

- Only 2 days after deadline and project is complete.
- Inspector on job constantly to approve work
- 30K sq.ft. were wrapped and coated in Phase 1
  - Bulk of the work was done with 2-3 guys on site at a time
- As of today, over 100K sq.ft. of 100G has been applied on RFK bridge

QUIZ QUESTION

Did this presentation meet your expectations?

A. Yes!
B. Could use some improvements
C. I'd like more information on a specific topic
D. A & C

CONCLUSIONS

As restoration evolves, emerging technologies such as FRP's are cost and time effective solutions for reinforcement of infrastructure

Other advantages include: ease of application, non-corrosive, and conformability

Proper repair and application is critical to ensure successful and long lasting reinforcement

Proper planning, setting-up, tools, conditioning the products are key to a successful install

Sika will provide support from beginning to end of project.

Contact your sales rep Today to learn how to get involved in FRP projects today!

THANK YOU FOR FOR PARTICIPATING!

ANY QUESTIONS?

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