RETROFITTING CFRP FOR STRUCTURAL STRENGTHENING AND RESTORATION

Commercial Projects and Applications

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RHINO™
CARBON FIBER
REINFORCEMENT PRODUCTS

EXPERIENCE AND SUPPORT THAT DELIVERS

Established in Heath, Ohio, the **Rhino Carbon Fiber** company is an industry leader in producing concrete crack repair and structural strengthening products and has been for over 20 years. Supported by a dedicated testing and research center, as well as facilities in the US and Canada, we not only produce some of the highest quality products available in the industry, but we continually work to improve our products. Our engineering and R&D departments put all of their energy and expertise into ensuring that we offer products that are reliable, easy-to-install and long-lasting. We work hard every day to make this a reality for our customers. We work closely with our customers to meet and exceed their expectations for their projects through our word-class, value-added service.

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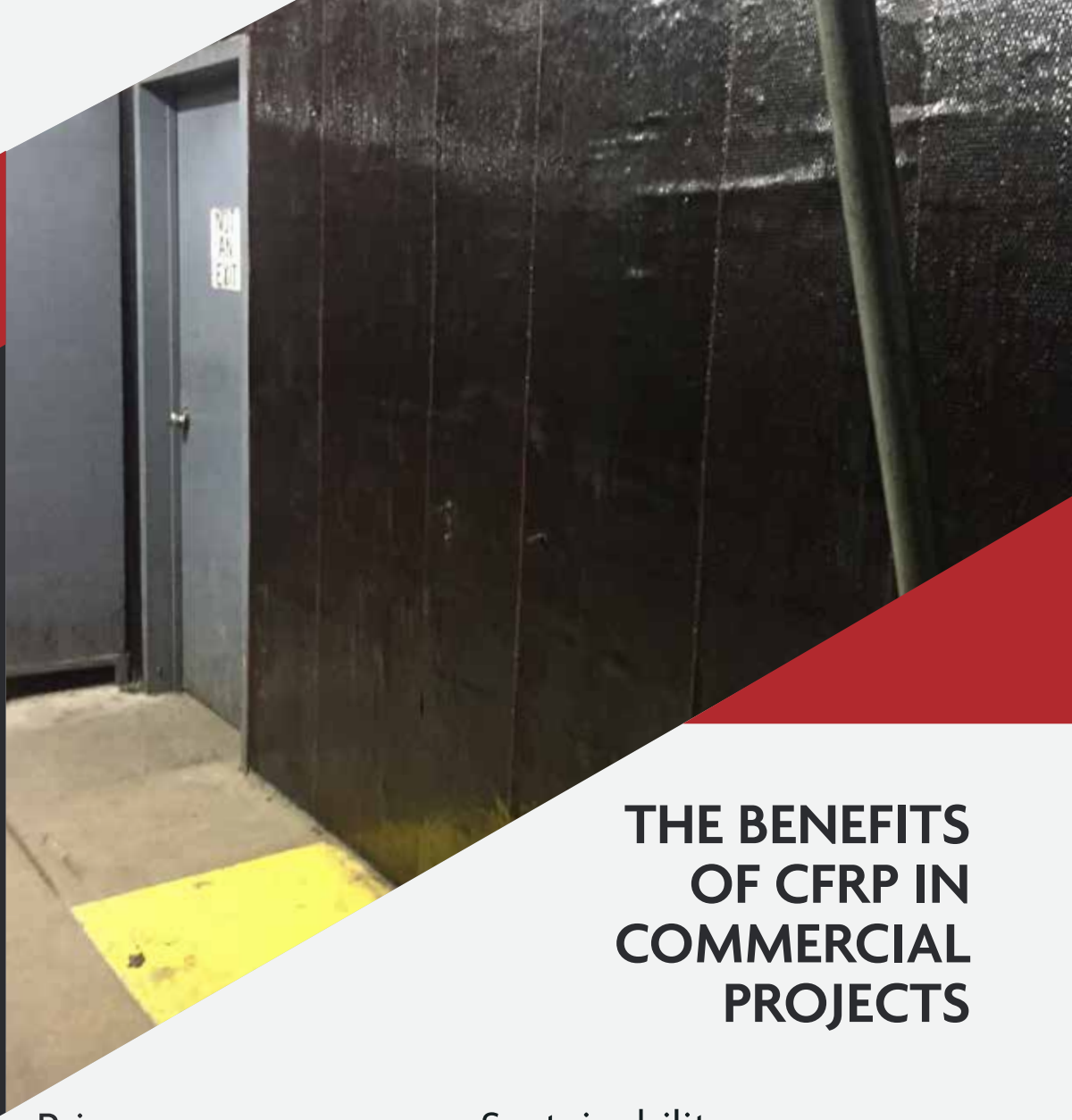

THE BENEFITS OF CFRP IN COMMERCIAL PROJECTS

Price

- The most cost-effective repair and strengthening method
- Reduces Life-Cycle Costs
- Light weight reduces transportation, equipment and labor costs
- Lower traffic disturbance due to quick installation
- Long-term durability, as well as a high resistance to chemicals, results in minimal maintenance

Responsiveness

- Fastest repair and strengthening method
- Resists shear, flexural and torsion forces
- Reduced dead load

Sustainability

- Retrofitting CFRP reduces the negative environmental effects of demolition and rebuild
- Reduces the amount of raw materials used for reconstruction, such as water, concrete, steel, timber etc.
- Decreased energy use in transportation and installation due to its light weight
- Recyclable

Availability

1. **Product** – Carbon fiber is readily available and easily shipped anywhere
2. **Labor –** There are local contractors that install Rhino Carbon Fiber products across North America in commercial projects; we'll put you in touch!

DEMOLITON AND REBUILD VERSUS REPAIRING WITH CFRP

A large portion of old structures all over the world, specifically bridges, require immediate repair or demolition due to aging. The deterioration of bridges occurs due to environmental conditions, climate, location and usage.

According to the Federal Highway Administration (FHWA) & Department of Transportation's National Bridge Inventory Database of 2017, out of 615,000 bridges in the United States, 54,560 are characterized as Structurally Deficient.[1] In Rhode Island State alone, 23% of bridges have been characterized as structurally deficient while the average rate for all states has been 7.9%.[1]

Therefore, many bridges need to be repaired and strengthened or demolished and replaced with new ones. Demolishing existing bridges and building new ones would be so expensive and time consuming that it is not a viable option, not to mention the negative impact on the environment. However, it is possible to use long-lasting methods of repairing and strengthening which result in low maintenance bridges at a reasonable lifecycle cost (LCC).

CFRP strengthening is the more cost and environmentally effective alternative when compared to demolition/rebuild. CFRP-strengthening is also more economical than other retrofitting methods such as welded steel jackets, internal strand splices, external post-tensioning and replacement of damaged girders. These other techniques are heavy in weight, labor-intensive and vulnerable to future corrosion and traffic disruption which increases the LCC in comparison to CFRP.

By using CFRP reinforcement, the agency LCC is reduced by 12% compared to epoxy-coated reinforcement and reduced by 23% compared to black steel.[4]

Using CFRP to repair and strengthen existing structures and/or to build new structures is the most cost-effective, fastest and environmentally friendly technique. It is easier to achieve the desired strengthening of a structure using CFRP.

RHINO CARBON FIBER CRACK REPAIR AND STRUCTURAL STRENGTHENING PRODUCTS

CARBON FIBER FOR STRENGTHENING AND REINFORCEMENT

Rhino Carbon Fiber CFRP

Rhino Carbon Fiber Concrete Crack Lock® Stitches

ADHESIVES FOR SURFACE PREP, WET LAYUP OF CARBON FIBER AND CRACK INJECTION

RCF High Strength Anchoring Epoxy Paste
Multi-purpose adhesive paste for sealing small surface level gaps, pits and cracks, setting injection ports, installing Concrete Crack Lock® stitches and more

RCF Saturant-Adhesive Epoxy
Low-viscosity adhesive for installing CFRP (wet layup)

RCF Polyurethane Injection Expanding Foam
Injection product that expands 15x its volume to fill all voids (use in wet and dry areas)

RCF Structural Epoxy Injection Resin
Injection product that cures stronger than concrete (use in dry areas only)

Commercial Interior CFRP Applications

Commercial Exterior CFRP Applications

Application #1

BRIDGE STRENGTHENING

There are multiple factors that can impact the reliability of RC bridges. Bridges that are deteriorating must be strengthened in order to restore their structural capacity, and CFRP is the best strengthening solution available.

Advantages of Strengthening with CFRP:

- Quickly restore structural capacity
- CFRP reduces beam deflection by as much as 20%[5]
- The corrosion of CFRP strips within a period of 100 years has been approximately 4%[6]
- Static deflection and frequency are relatively stable, showing only a 5% reduction in the period of 100 years[6]
- Prevents the concrete cover from cracking

Easy and fast installation

Excellent corrosion and fatigue properties

High strength to weight ratio

Application #2

COLUMN, BEAM AND LIGHT POLE PEDESTAL STRENGTHENING

Repairing and strengthening existing RC structures has become increasingly popular within the industry. The most common techniques of strengthening them are jacketing, steel jacketing and CFRP jacketing. CFRP has a greater demand than the other options due to its superior specifications.

Advantages of Strengthening with CFRP:

- Increases stiffness as well as strength of the section
- Prevents buckling
- Improves load-carrying capacity
- Enhances flexural stiffness and tolerates more deformation (enhances strength by up to 160%)[7]
- Can be applied for shear (enhances strength by up to 109-122%)[8] or torsion strengthening (enhances strength by up to 92%)[9]
- Strengthening I-beams by externally bonding CFRP to the bottom flanges has demonstrated significant potential as an alternative to steel
- Lightweight for ease of installation in tight spaces
- Reduces costs of transportation and installation

Easy and fast installation

Excellent corrosion and fatigue properties

High strength to weight ratio

Application #3

SLAB AND SWIMMING POOL STRENGTHENING

Concrete can crack for a variety of reasons depending on its usage and the way the structure has been constructed. Repairing pools using carbon fiber is the best long-term solution; it not only strengthens the crack itself, but also the affected area around the crack.

Rhino Carbon Fiber Concrete Crack Lock® stitch advantages:

- 10x stronger than grade 30 steel rebar
- Repair and reinforce concrete cracks, increasing structural integrity and seismic strength
- Less concrete is removed than other applications
- Less epoxy is needed to complete the repair
- Less time and labor required to complete the repair (cost savings)
- Takes full advantage of the carbon fiber's tensile strength (other systems rely on the epoxy strength)
- Minimal aesthetic impact; can easily be painted over or covered with a finishing product
- Easy-to-install

Easy and fast installation

Excellent corrosion and fatigue properties

High strength to weight ratio

Application #4

SEISMIC STRENGTHENING AND DAMAGE REPAIR (WALLS, DECKS, ACCESS OPENINGS AND SLABS)

There are a variety of structures that are seismically vulnerable, and many are in danger of failure. Several seismic strengthening methods are available, however, CFRP is the preferred strengthening solution due to its remarkable gains which prevent premature failure during seismic activity or blasts.

Advantages of Strengthening with CFRP:

- CFRP-strengthened walls increase in ultimate strength by 14-60% in one-way RC walls and 3-41% in two-way RC walls, depending on the CFRP layout[16]
- CFRP applied at 45-degree angles to the corners of wall openings is highly effective in reducing principal stress[17]
- Increased lateral resistance of masonry walls strengthened with diagonal CFRP strips is 115%, while this amount for masonry walls strengthened with steel strips is 58% (displacement ductility is 1.97 times higher than unreinforced walls)[18]
- It is possible to increase the average load-bearing capacity of RC slabs by about 40%[19]
- The flexural capacity of CFRP-strengthened two-way slabs increases by about 35.5%[19]
- The ultimate load-bearing capacity of CFRP-strengthened one-way slabs with an opening increases by about 24-92%[20]
- Deflection in one-way slabs is reduced 40-49% at service load and 47-62% at ultimate load[20]
- Crack widths in one-way slabs are reduced 44-76% at service load and 86-95% at ultimate load[20]
- Strengthening RC slabs with CFRP increases their punching shear capacity by up to 29%[21]

Easy and fast installation

Excellent corrosion and fatigue properties

High strength to weight ratio

Application #5

SILO AND WATER TOWER STRENGTHENING

Silos and water towers are structures in which their validity, as well as durability during design, construction and utilization, are of high importance. If cracks start to form, they reduce the reliability of the structure's performance as the material inside can leak out or be exposed to air, affecting chemical properties and expiration date. A globally accepted method of strengthening is the usage of externally bonded CFRP.

Advantages of Strengthening with CFRP:

- High elastic modulus
- High resistance to harsh environments (ports and marine areas)
- Increases flexural as well as confinement capacity
- Reduces interruption in serviceability
- Reduces costs of repairing and strengthening

Easy and fast installation

Excellent corrosion and fatigue properties

High strength to weight ratio

PROJECT HIGHLIGHTS

Concrete Beam Strengthening

Application

Beam Repair

Location:
Mauritius Island

Client:
PND Contracting

Products Used:
- Rhino Carbon Fiber CFRP (Unidirectional, Vertical): 400 GSM in 6-Inch Widths
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in Various Widths
- RCF Saturant-Adhesive Epoxy

Pool Deck Crack Repair

Application

Slab Repair

Location:
San Francisco, California

Client:
American Restoration

Products Used:
- Rhino Carbon Fiber Concrete Crack Lock® Stitches
- RCF High Strength Anchoring Epoxy Paste

Masonry Wall Reinforcement

Application

Seismic Strengthening and Damage Repair

Location:
Akron, Ohio

Client:
WALLFORCE Foundation Support Systems

Products Used:
- RCF High Strength Anchoring Epoxy Paste
- Rhino Carbon Fiber CFRP (Unidirectional, Vertical): 400 GSM in Various Widths
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in Various Widths
- RCF Saturant-Adhesive Epoxy

PROJECT HIGHLIGHTS

Strengthening Concrete Silos

Application
Crack Repair

Location:
Cupertino, California

Products Used:
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in 24-Inch Widths
- RCF Saturant-Adhesive Epoxy

Historical Water Tower Strengthening

Application
Crack Repair

Location:
Clay City, Kansas

Products Used:
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in 24-Inch Widths
- RCF Saturant-Adhesive Epoxy

Stadium Support Column Repair

Application
Column Repair

Location:
Jasper, Indiana

Client:
LAN Concrete Technology

Products Used:
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in 24-Inch Widths
- RCF Saturant-Adhesive Epoxy

PROJECT HIGHLIGHTS

High Rise Crack Repair

Application

Column Repair

Location:
Nashville, Tennessee

Client:
Ground Up Builders, Inc.

Products Used:
- RCF Structural Epoxy Injection Resin
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in 12-Inch Widths
- RCF Saturant-Adhesive Epoxy

Salt Barn Wall Failure Repair

Application

Seismic Strengthening and Damage Repair

Location:
Cambridge, Ohio

Client:
The City of Cambridge, Ohio

Products Used:
- RCF High Strength Anchoring Epoxy Paste
- Rhino Carbon Fiber Concrete Crack Lock® Stitches
- Rhino Carbon Fiber CFRP (Unidirectional, Vertical): 400 GSM in 24-Inch Widths
- RCF Saturant-Adhesive Epoxy

Crack Repair and Confinement

Application

Crack Repair

Location:
Houston, Texas

Client:
Gadberry Construction Company

Products Used:
- RCF Structural Epoxy Injection Resin
- Rhino Carbon Fiber CFRP (Bidirectional): 560 GSM in 24-Inch Widths
- RCF Saturant-Adhesive Epoxy
- Elastomeric Stucco

APPENDIX

1. Haak, A. J. (2018). Life-cycle-cost evaluation of bridges with fiber-reinforced polymers (FRP). University of Rhode Island.
2. Dr Sarah Bell, S. C. (2014). Making Decisions on the Demolition or Refurbishment of Social Housing. UCL policy briefing.
3. Setunge, S. L. (2018). Whole of life cycle cost analysis in bridge rehabilitation. Report 2002-005-C-03.
4. Nabil F. Grace, E. A. (2012). Life-Cycle Cost Analysis of Carbon Fiber-Reinforced Polymer Reinforced Concrete Bridges. ACI structural journal.
5. Klaiber, F. &. (2003). Repair of damaged prestressed concrete bridges using CFRP.
6. Yail J. Kim, J.-Y. K.-S.-T. (2017, July). Condition Assessment of Corrosion-damaged Bridge Girders Strengthened with Post-tensioned Composite Strips. Journal of Physics: Conference Series.
7. S. A. M. C. N. Attari, "Flexural strengthening of concrete beams using CFRP, GFRP and hybrid FRP sheets," Construction and Building Materials, pp. 746-757, 2012.
8. Abdel-Jaber, M. W. (2003). Shear strengthening of reinforced concrete beams using different configurations of externally bonded carbon fibre reinforced plates. Materials and Structures, 291–301.
9. Shokri, M., & Edalati, M. (2017). Comparison of Twisting Angle-Torsional Moment in Unstrengthened Reinforced Concrete Beams with Reinforced Concrete.
10. Beams Strengthened with CFRP Sheets. Journal of History Culture and Art Research, 6(1), 43-58. doi: http://dx.doi.org/10.7596/taksad.v6i1.702.
11. Marinella Fossetti, F. B. (2018). FRP-Confined Concrete Columns: A New Procedure for Evaluating the Performance of Square and Circular Sections. Advances in Civil Engineering.
12. Lei-Ming Wang, Y.-F. W. (2008). Effect of corner radius on the performance of CFRP-confined square. Engineering Structures, 493-505.
13. Wu Y-F, L. T. (2006). Fundamental Principles that Govern Retrofitting of Reinforced Concrete Columns by Steel and FRP Jacketing. Advances in Structural Engineering, 507-533.
14. Siwowski TW, S. P. (2018). Experimental study on CFRP-strengthened steel. Composites Part B.
15. Kambiz Narmashiri, N. R. (2012). Failure analysis and structural behaviour of CFRP strengthened steel I-beams. Construction and Building Materials.
16. Lima, J.-H. D. (2019). Experimental Study on RC Walls with Opening Strengthened by Externally Bonded CFRP. Journal of Composites for Construction, 04019008.
17. Mohammed, B. S. (2013). One way RC wall panels with openings strengthened with CFRP. Construction and Building Materials, 575-583.
18. S. H. Farooq, M. I. (2012). Response of Masonry Walls Strengthened with CFRP and Steel Strips. Arabian Journal for Science and Engineering volume 37, 545–559.
19. Ebead U, M. H. (2004). Fiber-reinforced polymer strengthening of two-way slabs. ACI Structures, 650-659.
20. Wissam D. Salman, A. A. (2018). Behavior of reinforced concrete one-way slabs strengthened by CFRP sheets in flexural zone. International Journal of Civil Engineering and Technology (IJCIET), 1872–1881.
21. Khaled Soudki, A. K.-S. (2011). Strengthening of concrete slab-column connections using CFRP strips. Journal of King Saud University – Engineering. Sciences.
22. ACI313. (2016). Design Specification for Concrete Silos and Stacking Tubes for Storing Granular Materials (ACI 313-16) and Commentary. American Concrete Institute.
23. Maj, M. (2017). Some Causes of Reinforced Concrete Silos Failure. Procedia Engineering, 685-691.
24. Maraveas, C. (2020). Concrete Silos: Failures, Design Issues and Repair/Strengthening Methods. Applied Sciences.
25. Prota, A. (n.d.). Upgrade of RC Silos Using Near Surface Mounted FRP Composites. Retrieved from https://pdfslide.net/documents/upgrade-of-rc-silos-using-near-surface-mounted-frp-composites-upgrade-of-rc.html.
26. Sezen, A. D. (2009). Cause of Damage and Failures in Silo Structures. Journal of Performance of Constructed Facilities, 65-71.

WORLD CLASS PERFORMANCE AND CUSTOMER SERVICE

Rhino Carbon Fiber is an industry leader in concrete crack repair and structural strengthening, providing strong, efficient and easy-to-use products! **Rhino Carbon Fiber** continues to innovate, creating cost and labor effective concrete repair and strengthening solutions for residential and commercial applications.

Why CFRP?

High-Strength – carbon fiber is 10x stronger than steel
Easy-to-Install – light-weight product and quick, straight-forward procedure
Long-Lasting – carbon fiber resists corrosion and does not degrade
Versatile – strengthen walls, wall openings, cracks and more
Less Intrusive – thin yet strong profile doesn't affect square footage

Why Rhino Carbon Fiber™?

Sales Support for Training and Technical Assistance – product and installation information and training
Engineering Support for Complex Projects – assistance with technical project requirements
Marketing Support to Help Grow Your Business – grow your business with sell sheets, case studies and more

We're Here to Help!

Vision

Be the company that relentlessly adds value to everyone we touch

Mission

We exist to make people's lives better by creating better spaces for living, through advanced building materials

Values

- Integrity
- Excellence
- Entrepreneurialism
- Customer Centric
- Winning Attitude

CONTACT US

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1-888-684-3889

www.rhinocarbonfiber.com

info@rhinocarbonfiber.com

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