QuakeWrap™

THE FRP RETROFIT EXPERTS

Services

Turn-key Service

- From feasibility consultation through design, delivery, and installation

As Needed Services – choose for your team's needs

- On-site feasibility study
- Cost estimates
- Project consultation
- Engineering design – assistance or complete design
- Materials selection
- Application test data
- Guidelines, usage tips, and installation instructions
- Materials and equipment delivery
- Supervisor and support for contractors
- Complete installation – we are licensed contractors
- Training in use, design, and installation
- Software for design with FRPs
- Certification for contractors

Products

- QuakeWrap™ Fabrics:
  - Carbon
  - Glass and carbon
  - Glass
- PipeWrap™ Fabrics:
  - Carbon
- Carbon Plate
- QuakeBond™ - non-toxic, durable, and odorless:
  - Primer
  - Tack coat
  - Saturating resin

Equipment

- Impregnator Machine – provided for the duration of the application process

Research

Dr. Ehsani and his researchers at the University of Arizona conduct ongoing research and have authored or co-authored more than 50 technical papers on FRP applications in reinforced concrete beams and columns, slabs, tilt-up walls, unreinforced masonry walls, parapets, steel girders, wood beams, and pipes and utility tunnels. Please visit the QuakeWrap website (www.QuakeWrap.com) for links to these papers and other resources and findings to help you plan for your project.

Fiber Reinforced Polymers

Fiber Reinforced Polymer (FRP) is an exceptionally strong and versatile material, with special characteristics that make it the solution of choice in a growing range of applications, from underground pipe repair to historic preservation. FRPs are constructed of fibers such as glass and carbon and embedded in a resin matrix that protects them and distributes their loads evenly. Their anisotropic properties, different when measured along different axes, allow for exactly the required strength in each direction. This makes FRPs particularly effective for seismic conditions.

Because FRPs are very flexible prior to curing, they can be easily applied to surfaces of varying shapes. They are light enough to be handled without lifting equipment on the job site, and then enough to be applied to low-access spaces without interrupting operations—adding as little as ⅛-inch thickness to surfaces. This minimal change to mass of structure also eliminates the need to make foundation adjustments or other costly construction, reducing overall project costs. Once cured, these materials become **two-to-three times as strong as steel**.

Advantages

- Non-intrusive
- Quick and easy to apply in tight spaces
- Versatile, adapting to any structural shape
- Low-weight, with high tensile strength and excellent fatigue behavior
- Non-toxic
- Odorless
- Leak-proof
- Two-to-three times stronger than steel
- Corrosion-resistant
- Thermally compatible with common construction materials

Uses

- Increase shear strength
- Increase flexural strength for both positive and negative moments
- Increase stiffness at service loads
- Reduce cracked widths for enhanced durability and corrosion resistance
- Provide containment
- Prevent leaks
- Enhance ductility

U.S. Patent No. 5,640,825

"Method of Strengthening Masonry and Concrete Walls with Composite Strap and High Strength Random Fibers" – **June 1997**

www.QuakeWrap.com

PIPES AND TUNNELS

The Problem:
Underground pipes and tunnels are often weakened due to corrosion of reinforcement. Replacement is not only expensive and requires excavation, but it also recalls in long interruption in service.

The Solution:
Specially designed PipeWrap™ fabrics wrapped in one or more layers on the interior surface restore the original strength of these structures. Strengthening of pipes increases operating pressure of the system and reduces friction losses, resulting in larger flows. If the pipe is exposed, the fabric can be wrapped on the exterior surface of the pipe.

Test Results:
Tests conducted by the Palo Verde Nuclear Generating Station have demonstrated the effectiveness of this technique. The steel cables in a new section of a 9-ft. diameter pre-stressed concrete pipe were intentionally cut to simulate damage caused by corrosion of reinforcement. The pipes were wrapped with carbon fabric and were pressurized. Testing was stopped once the pressure in the repaired pipes exceeded the original “pre-corrosion” strength of the pipe.

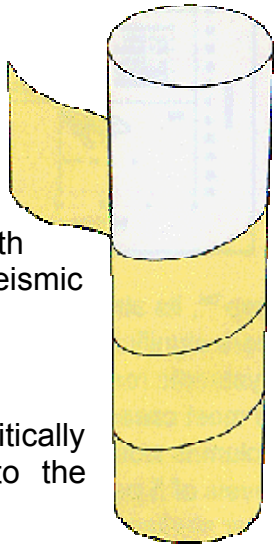
QuakeWrap™ Advantages

- Leak proofing and strengthening achieved simultaneously
- No excavation required (access through manhole)
- Corrosion-resistant system can withstand various chemicals
- Non-toxic, odorless resins allow installation with little ventilation
- No reduction in inside diameter of pipe
- Smooth finish reduces friction losses in pipe
- Compatible for use with potable water

COLUMNS

The Problem:

Insufficient and/or poorly defined reinforcement in concrete columns has resulted in catastrophic collapse of many bridges and buildings in recent earthquakes.



QuakeWrap™ has anisotropic properties, different when measured along different axes, which makes it particularly effective for seismic conditions. It can restore the capacity of earthquake-damaged columns to the original levels and beyond, and it can be used with undamaged columns to add significant protection during seismic activity.

The Solution:

QuakeWrap™ carbon or glass fabrics wrapped around critically stressed areas provide confinement and add significantly to the strength and durability.

QuakeWrap™ can also restore the capacity of earthquake-damaged columns to the original levels and beyond.

Test Results:

The first comprehensive research study on this subject was carried out by Dr. Ehsani with funding from the National Science Foundation (1991-94). Both active and passive confinement for circular and rectangular columns was investigated. Strength and ductility of the retrofitted or repaired columns was radically enhanced after they were wrapped with QuakeWrap™.

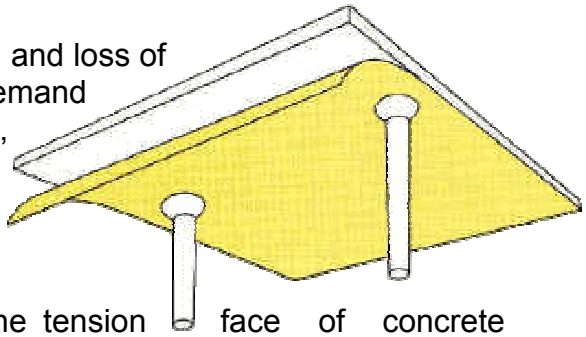
Improperly confined columns fail in shear (shown right). When the column was retrofitted with QuakeWrap™, its strength and ductility were significantly increased (see hysteretic response, shown left); in most cases, the retrofitted columns would not fail up to drift levels of 5%. Numerous later studies by other researchers have reached similar conclusions.

QuakeWrap™ Advantages

- Eliminates or reduces access constraints
- Adapts to sections of circular, rectangular, or any other shape
- Does not increase column dimensions
- Unlike steel jackets, QuakeWrap™ does not corrode
- Can save many damaged columns from demolition

R/C BEAMS AND SLABS

The Problem:
Design/construction errors, excessive deflection, and loss of reinforcement due to corrosion often demand strengthening of floor systems. Additionally, strengthening may be required for increased live load capacity and functional changes.



The Solution:
QuakeWrap™ fabrics and plates bonded to the tension face of concrete beams or slabs increase flexural strength and reduce reflection under service loads. Shear strengthening of beams can be achieved by orienting the fibers in QuakeWrap™ fabrics parallel to the stirrups.

Test Results:
Dr. Ehsani and his associates conducted the first studies on strengthening of beams in the late 1980s and published their first paper in 1990. Since then, hundreds of tests have been carried out worldwide.

The beam tested on the left was retrofitted with QuakeWrap™ glass fabrics for flexure and shear. The flexural capacity of the retrofitted beam (shown in red) was double that of the companion non-retrofitted beam (shown in black).

Proper design leads to ductile behavior of the retrofitted beam by allowing the yielding of the tension steel. The presence of QuakeWrap™ fabric prevents widening of cracks in the beam, resulting in larger stiffness (lower deflection) prior to the yielding of steel.

Lack or improper placement of reinforcing steel often results in the excessive cracking and deflection of concrete slabs. QuakeWrap™ fabrics or plates bonded to the tension face of the slab (top of slab for negative moment and bottom of slab for positive moment) can significantly increase the flexural strength and reduce deflection of slabs. If desired, the deflected slab can be pushed upward prior to the installation of QuakeWrap™ and held in that position until the repair is completed. This will induce pre-tensioning forces in the fabric or plate.

QuakeWrap™ Advantages

- Significant increase in flexural and shear strength
- Does not add to the dimensions of the beam or slab (no loss of overhead clearance)
- Ideal for locations with limited access
- Reduces deflections under service loads

STEEL BEAMS

The Problem:
Steel girders are often weakened as a result of corrosion that reduces the cross-section. Fatigue cracking of the tension flange is also a cause of concern with these elements.

The Solution:
QuakeWrap™ carbon plates offer an ideal solution for strengthening steel beams.

Test Results:
Several steel/concrete composite girders have been tested at the University of Arizona. The girders were constructed using W14X30 steel sections and spanned 16-feet (4.8 m). To simulate prior damage, 25% of the area of the tension flange was removed. The load-deflection for that beam is shown in black. The tension flange of a similar companion beam was strengthened by applying three strips of QuakeWrap™ DU50C. The behavior of the strengthened beam is shown in red. The strength of the beam was significantly increased; this was also accompanied by a notable increase in stiffness of the girder in the plastic region.

QuakeWrap™ also improves the fatigue behavior of steel beams; retrofitted beams could resist 2.5–3.5 times more cycles of loading compared to non-retrofitted girders.

QuakeWrap™ Advantages

- Increases flexural strength for both positive and negative moment regions
- Restores beam capacity after loss of tension flange area due to corrosion
- Increases stiffness in both elastic and plastic response
- Eliminates stress concentration due to welding
- Improves fatigue behavior

WOOD BEAMS

The Problem:
Increased live load capacity and reduction of allowable stresses in recent codes often require strengthening of wood beams.

The Solution:
QuakeWrap™ carbon plates and fabrics can effectively strengthen structural lumber and glulam beams for both flexure and shear.

Test Results:
Results of some of the research by Dr. Ehsani on glulam beams are shown below. Retrofit of the beam consisted of a carbon plate on the tension face and near-surface mounted carbon plates that were embedded into the compression flange of the beam. The entire beam was also wrapped in a bi-directional carbon fabric.

The retrofitted beam carried 67% more load and exhibited very large deflections at failure. The stiffness of the beam at service loads was also considerably improved.

Other tests of wood beams have shown that the presence of QuakeWrap™ fabrics diminishes the detrimental effects of defects on the strength of these elements.

QuakeWrap™ Advantages

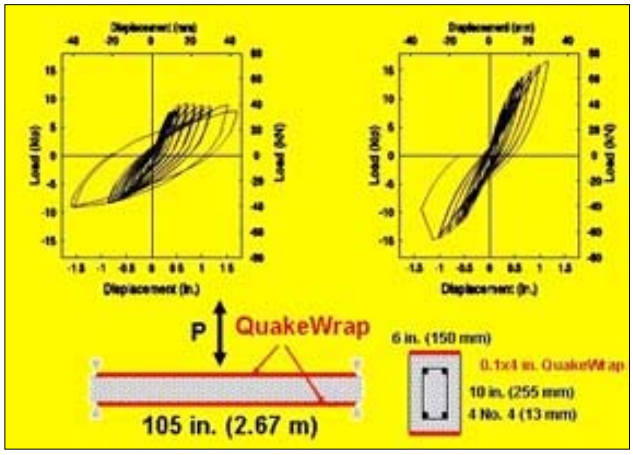
- Little increase in member dimensions
- Improves strength and ductility of wood beams
- Easily installed in tight spaces with limited access

CONCRETE WALLS

The Problem:
Insufficient reinforcing steel often results in cracking of concrete and tilt-up walls. Additionally, introduction of new openings for windows and doors requires strengthening of these regions of the wall.

The Solution:
QuakeWrap™ bonded to one or both faces of the wall acts as a shear and flexural reinforcement. This reinforces the wall and addresses the main causes of the formation of cracks, while it simultaneously seals the cracks, eliminating the need to inject epoxy. If desired, the strengthened wall can be painted or covered with architectural coatings, such as stucco.

Test Results:
QuakeWrap, Inc. tested a wall panel under cyclic out-of-plane loading to simulate earthquake effects. Bonding QuakeWrap™ to both faces of the wall results in significant increase in flexural strength of the panel. QuakeBond™ epoxies perform very well under such loading conditions.

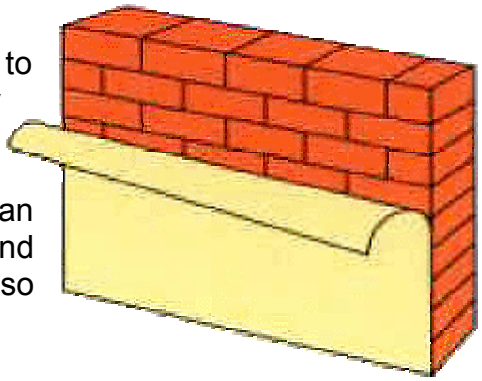


QuakeWrap™ Advantages

- Increases the wall thickness by less than ¼ inch
- Saves costs by coating only a fraction of wall surface
- Much more effective than injection of epoxy into cracks
- Can be used as lintel beam
- Easily applied in tight or low-access spaces

MASONRY WALLS

The Problem:
The inability of Unreinforced Masonry (URM) walls to resist shear and flexure has resulted in many failures in past earthquakes. The lack of monolithic action of the walls results in the scatter of individual elements, which is hazardous and can cause secondary damage. Hollow Clay Tile and unreinforced Concrete Masonry Unit (CMU) walls also share these problems.



The Solution:
QuakeWrap™ applied to one or both surfaces of the wall (covering the entire or a fraction of the wall surface) drastically increases the flexural and shear strength of the wall. Retrofitted walls can readily accommodate wall fixtures and openings.

Test Results:
The first comprehensive research study on this subject was initiated by Dr. Ehsani with funding from the National Science Foundation in 1992.

QuakeWrap™ can greatly increase the shear capacity of URM. In the simulated bed joint shear test shown here, no mortar was used. Thus, the nearly 5,000 lbs. Shear capacity achieved is fully attributed to the presence of QuakeWrap™ fabric.

Flexural tests on brick walls have shown that after retrofitting with QuakeWrap™, these elements can sustain over a dozen large displacement cycles. The walls resisted loads more than 12-times their weight and deformed more than 3.5% of the height.

QuakeWrap™ Advantages

- Transforms weak and brittle masonry into a strong and ductile material
- Increases the wall thickness by less than ¼ inch
- Results in monolithic action of masonry units
- Adds very little weight to the building (less than 1 psf)

QuakeWrap Inc.

QuakeWrap is a leading designer, supplier, and installer of Fiber Reinforced Polymer (FRP) products for repair and strengthening of structures. The company is also a pioneer research and development firm committed to providing economical solutions and unparalleled service to engineers, architects, and owners.

Phoenician Resort, Scottsdale, AZ
Retrofitted beams and columns in parking garage

QuakeWrap was founded in 1994 by Dr. Mo Ehsani, an internationally recognized expert and researcher in the use of FRPs and a professor of structural engineering at the University of Arizona. Dr. Ehsani has been featured on CNN, National Public Radio, and in other media, including Engineering News Record (ENR) for his expertise on the strengthening of structures related to earthquakes, terrorist attacks, and other potential structural disasters.

Alcatraz National Park, San Francisco, CA
Retrofitted masonry smoke stack

Since the company's inception, QuakeWrap's revolutionary Fiber Reinforced Polymer products have been used on projects all over the world, from Alcatraz in San Francisco to high-rise towers in the Midwestern United States, to multiple retrofit projects in the country of Turkey. Today, QuakeWrap is a one-stop-shop for engineers, architects, and owners seeking economical solutions for repair and retrofit of concrete, masonry, wood, and steel structures and pipes.

QuakeWrap's Commitment to Service

We are proud that we are trusted for our design, testing, expertise, and problem solving ability. We offer turnkey services from initial price estimates to design, material supply, and installation. And we are committed to rapid response—estimates can often be provided within hours of your call. This is because, when you call QuakeWrap, you will be speaking with a senior structural engineer who is an expert in FRP retrofitting and who has extensive research and field experience. Our engineers are ready to immediately assist you in everything from engineering assessment and product choice to custom product design for your project's unique challenges. We will almost always conduct on-site feasibility studies within days of your call. Just let us know how we can help you.

San Francisco City Hall
Retrofitted hollow clay tile walls in basement

QuakeWrap's Commitment to Discovery

QuakeWrap's founder, Dr. Mo Ehsani, conducted the United State's first research on the feasibility of using FRPs in construction. His pioneering research at the University of Arizona began in 1988 and led to a series of grants from the National Science Foundation (NSF) to conduct the first studies on the uses of FRPs in construction. Those studies tested the feasibility of strengthening concrete columns with FRPs, and seismic strengthening of unreinforced masonry structures. An inventor, author of more than 50 technical papers on FRP technologies and applications, and a professor of structural engineering, Dr. Ehsani is often called upon by media such as Engineering News Report, CNN, and National Public Radio to provide insight and commentary, particularly after earthquakes and other structural calamities. Dr. Ehsani is committed to ongoing research to provide cutting-edge products and technologies that serve practical needs in the construction industry and that improve the strength and safety of the world's structures and infrastructures.

All products and all applications that QuakeWrap offers have been extensively tested at the University of Arizona.

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QuakeWrap™

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