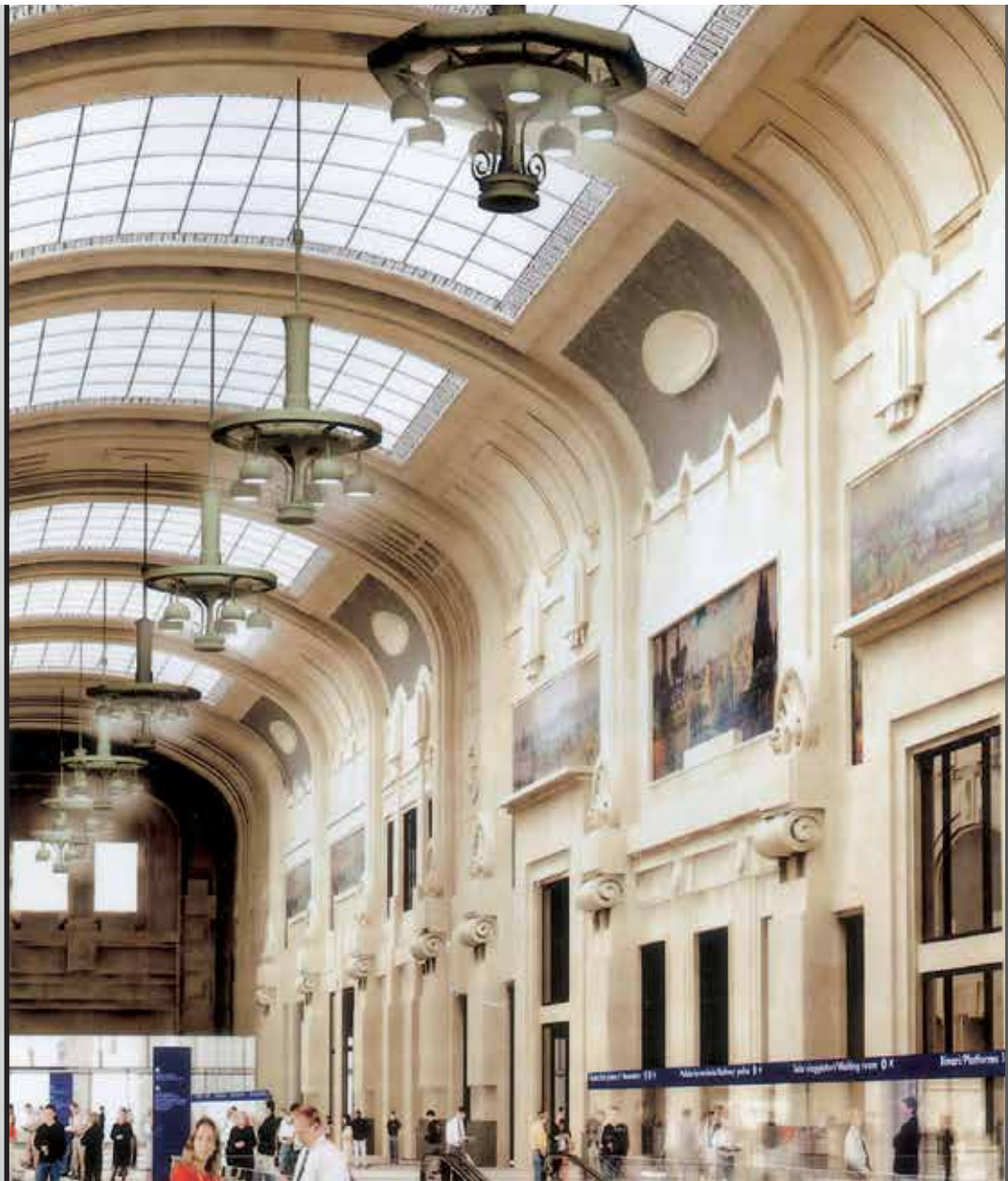


Fiber-Reinforced Polymer (FRP) Composite *Systems*



Central Station
Milan, Italy





www.mapei.com

MAPEI[®]

Global Leader in Concrete Restoration Systems



Self-Leveling Underlayments



Waterproofing



Concrete Repair Mortars



Screed Mortars



Decorative Toppings



Exterior Refinishing



Repair Epoxies



Corrosion Protection



Fiber-Reinforced Polymer

For more information on the complete line of MAPEI products, visit our Website at www.mapei.com.



A. *MapeWrap C
Quadri-Ax*
B. *MapeWrap C
Uni-Ax*
C. *Carboplate E 170*

► FRP technology

Fiber-reinforced polymer (FRP) structural composite technology dates back to the mid 1930s, when the first experimental boat hull was manufactured using fiberglass fabric and polyester resin. From this somewhat inauspicious beginning, FRP composites have revolutionized entire industries, including aerospace, marine, automotive, industrial, recreation, home and infrastructure. From military applications in the 1940s to the industrial and manufacturing industries in the 1950s, the use of FRP composites became the preferred alternative to conventional rehabilitation techniques. Primarily, this was due to their high strength-to-weight ratio, and their inherent and superior resistance to weather and the corrosive effects of salt air and sea.

Soon, the benefits of FRP structural composites, especially their corrosion-resistance capabilities, were communicated to the public sector. FRP evolved into architectural applications, starting with the restoration of historic buildings in the late 1950s. The technology entered the infrastructure markets in Europe, Japan and the United States in the 1970s and 1980s, with the rehabilitation of bridge columns, decks and beams, as well as tunnel and marine pier repairs.

The need continues to grow for retrofitting and strengthening of reinforced concrete buildings and bridge structures. Many factors have advanced the use of externally bonded FRP composites as cost-effective and convenient materials for rehabilitation: deterioration caused by environmental effects; damage caused by impact; higher load demand brought on by more severe code requirements, especially in the seismic field; changes in the use of structures; and higher strength and ductility demand to correct design or construction errors.

MAPEI's FRP composite systems

MAPEI's *MapeWrap*[™], *Carboplate*[™] and *Maperod*[™] strengthening systems for concrete and masonry structures are available in several geometries: laminates or carbon fiber plates pre-impregnated in epoxy resin; uni-directional and multi-directional fabrics (bi-axial and quadri-axial) easily adaptable to the shape of the structural member targeted for strengthening; and carbon fiber bars pre-impregnated with epoxy resin. In addition to the advantages of being lightweight and non-invasive, having high tensile strength, and being corrosion-resistant, MAPEI's FRP structural composites are suitable for applications where the aesthetics of the original structure need to be preserved or when strengthening with traditional techniques cannot be effectively employed.

The main parameters that define the features of fiber reinforcement are not only the tensile strength, which usually is much higher than the tensile stress that the FRP reinforcement are subjected to, but also the modulus of elasticity. The higher the modulus of elasticity of the fibers, the higher the stiffening contribution. The most suitable fibers for the restoration of reinforced concrete structures are carbon fibers with medium strength (ultimate tensile strength > 290,075 psi [2 000 MPa]) and medium-high strength ($E = 24.7 \times 10^6$ to 36.2×10^6 psi [170 to 250 GPa]). Fibrous composite materials with a lower modulus of elasticity value should be used to restore masonry buildings or wooden structures. In this case, the use of glass or aramid fiber-based composites with a modulus of elasticity less than 11.6×10^6 psi (80 GPa) is recommended. Polymeric matrixes are preferred because of their capacity to adhere to cementitious substrates better than polyester resins.

Ex Colonia Novarese
Miramare Di Rimini, Italy

**No special equipment
or machinery needed
in this installation of
FRP.**



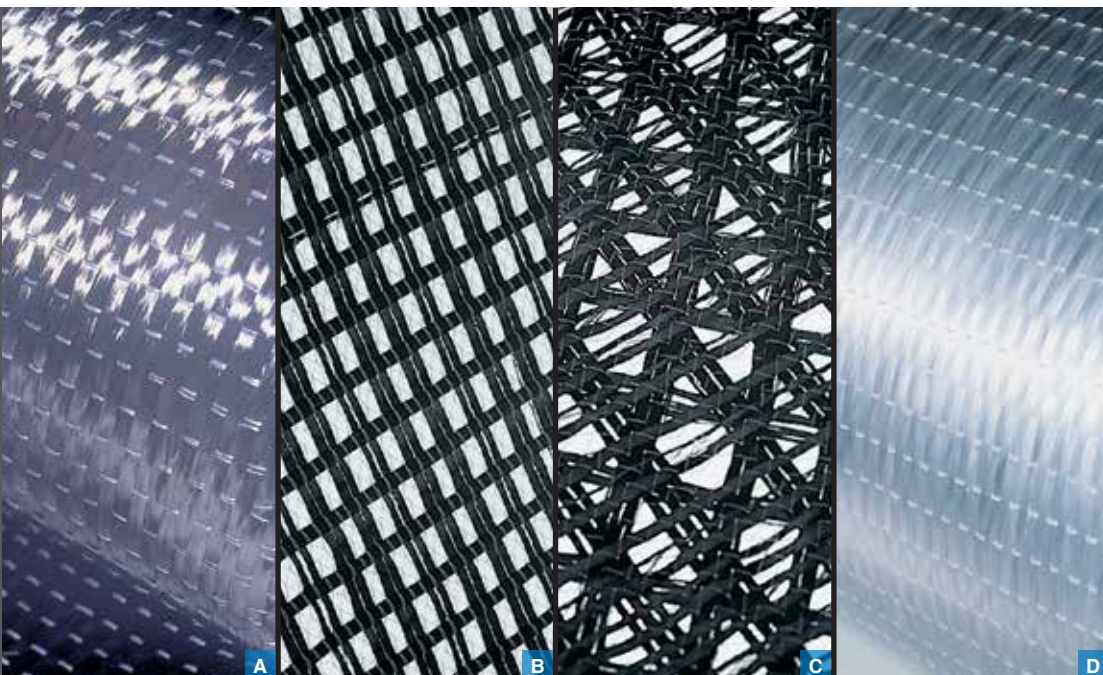
Within the building industry, the use of conventional materials for repair of deteriorated or damaged concrete structures generally is accompanied by operational problems and questions on long-term durability. However, MAPEI's FRP composites are extremely lightweight, are installed without the aid of special equipment or machinery, require less labor, provide shorter installation time, and oftentimes do not necessitate downtime of the structure. When the variables of time, equipment, interruption costs and estimated life-cycle costs are taken into consideration, MAPEI's high-performance composites are more economical than conventional materials.

MAPEI fabrics

A wide range of uni-directional, bi-directional and quadri-directional carbon fiber, glass and aramid fiber fabrics, available in different weights, are in the form of dry, flexible fabrics that should then be impregnated (saturated) with epoxy resins immediately before placement (wet layup) or during placement (dry layup). As the epoxy cures, a rigid composite is formed and shapes itself to the original structure in a monolithic bond. These fabrics are used for confinement of structural elements, such as columns and concrete and masonry walls, for improved ductility and for load-bearing capacity, especially in seismic areas.

MAPEI's FRP fabrics include:

- **MapeWrap C Uni-Ax** – Uni-directional carbon fiber fabrics weighing 9, 16, 18, 27 and 36 U.S. oz. per sq. yd. (300, 530, 600, 900 and 1 200 g per m²)
- **MapeWrap C Bi-Ax** – Bi-directional carbon fiber fabrics weighing 7 and 11 U.S. oz. per sq. yd. (238 and 360 g per m²)
- **MapeWrap C Quadri-Ax*** – Quadri-directional carbon fiber fabrics weighing 11 and 22 U.S. oz. per sq. yd. (380 and 760 g per m²)
- **MapeWrap G Uni-Ax** – Uni-directional glass fiber fabric weighing 27 U.S. oz. per sq. yd. (900 g per m²)



A. MapeWrap C Uni-Ax
B. MapeWrap C Bi-Ax
C. MapeWrap C Quadri-Ax*
D. MapeWrap G Uni-Ax

* Available upon special request. Contact MAPEI's CRS Product Division for delivery schedule.

MAPEI's complete line of resins for the preparation of the substrate, saturation (impregnation) and bonding of the fabrics includes:

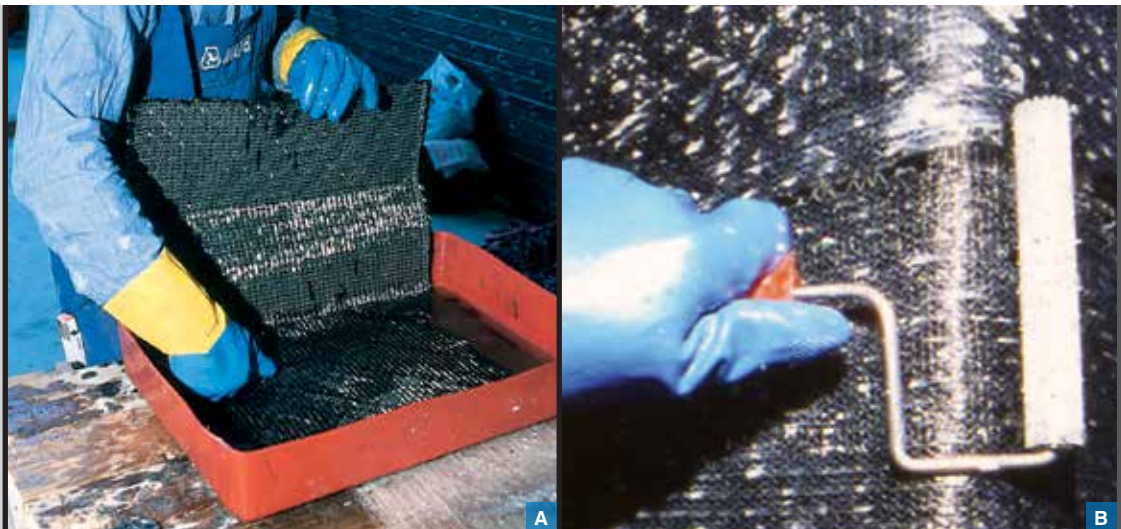
- **MapeWrap Primer 1** – Epoxy primer for improving the substrate quality for the bonding of fabrics
- **MapeWrap 11 and MapeWrap 12** – Smoothing and leveling putty for concrete surfaces

A. *MapeWrap Primer 1*
B. *MapeWrap 11/12*



- **MapeWrap 21** – Superfluid epoxy resin for the saturation (impregnation) of fabrics using the “wet layup” system
- **MapeWrap 31** – Medium-viscosity epoxy adhesive for impregnation of fabrics using the “dry layup” system

A. *MapeWrap 21*
B. *MapeWrap 31*



MAPEI's laminates

These flexible carbon fiber plates are pre-impregnated with epoxy resin by "pultrusion," an industrial process of extrusion under tensile stress. The plates are bonded to the concrete surface elements with thixotropic epoxy adhesives for the repair, flexural strengthening, and upgrade of beams and slabs. With a thickness of 47.2 or 55.2 mils (1,2 or 1,4 mm), laminates 2", 3", 4" and 6" (5, 8, 10 and 15 cm) wide are protected on both sides by a double plastic film that eliminates the need for cleaning and wiping the carbon fiber plate before application.

- **Carboplate E 170** – Carbon fiber plates available in thicknesses of 47.2 and 55.2 mils (1,2 and 1,4 mm), available in widths of 2", 3", 4" and 6" (5, 8, 10 and 15 cm); and offered with a modulus of elasticity of 24.6×10^6 psi (170 GPa). Additional specific thicknesses, widths and elastic moduli are available upon request.



A. Carboplate E 170
B. Double "peel ply"
protects carbon
fiber plates.

A complete line of resins exists for the preparation, smoothing and leveling of the concrete substrate and for the adhesion of the plate systems:

- **MapeWrap Primer 1** – Epoxy primer for improving the substrate quality for the bonding of plates
- **MapeWrap 11** – Smoothing and leveling epoxy putty for concrete surfaces and plate adhesive, suitable for applications at temperatures between 41°F and 73°F (5°C and 23°C)
- **MapeWrap 12** – Smoothing and leveling epoxy putty for concrete surfaces and plate adhesive, suitable for applications at temperatures greater than 73°F (23°C)



**St. Francis of
Assisi Basilica**
Assisi, Italy

MAPEI 'near-surface-mounted' products

- **Maperod C** – Carbon fiber bars pre-impregnated with epoxy resin by “pultrusion,” available in widths of 5/16" and 3/8" (8 and 10 mm), with high tensile strength and a modulus of elasticity of 22.5×10^6 psi (155 000 MPa). The product is protected by a plastic film that eliminates the need for wiping and cleaning the bars.

Maperod C



A complete line of resins exists for the preparation, smoothing and leveling of the concrete substrate and the adhesion of the bar systems:

- **MapeWrap Primer 1** – Epoxy primer for improving the substrate quality for the bonding of bars
- **MapeWrap 11** – Smoothing and leveling epoxy putty for concrete surfaces and bar adhesive, suitable for applications at temperatures between 41°F and 73°F (5°C and 23°C)
- **MapeWrap 12** – Smoothing and leveling epoxy putty for concrete surfaces and bar adhesive, suitable for applications at temperatures greater than 73°F (23°C)

Central Station
Milan, Italy



MAPEI's cords

- **MapeWrap C Fiocco** – High-strength cords made from uni-directional carbon fiber threads, to be impregnated with *MapeWrap 21* to provide structural and functional restoration of concrete and masonry elements. *MapeWrap C Fiocco* is particularly suited for restoration of historical structures, including vaulted ceilings and masonry facing walls of brick and stone. The cords are available in diameters of 1/4", 5/16", 3/8" and 7/16" (6, 8, 10 and 11 mm), and in 32.8-foot (10-m) rolls.

FRP products available upon request include:

- High-strength, steel, and fiberglass cords, steel fabrics, fiberglass pultruded bars, and pre-primed, alkali-resistant fiberglass mesh for strengthening of masonry, stone and volcanic ash substrates.

Where to use

MAPEI's FRP composite systems products can be used as an alternative to conventional methods for the repair and static upgrade of all types of reinforced, prestressed concrete elements and steel structures, particularly in areas where conventional methods are not suitable or could cause additional problems. Furthermore, an FRP system from MAPEI is an excellent alternative to additional strengthening techniques based on the application of steel plates.

Here are some repairs that can be carried out with MAPEI's FRP composite systems products:

- Wrapping of axial-loaded concrete elements such as columns, pillars, bridge and piers, in order to improve the capacity to carry compressive loads or improve the ductility of the concrete elements
- Wrapping of cylindrical hollowed structures subjected to internal hydrostatic pressure such as pipes, silos and tanks
- Seismic upgrade of column-beam connections in order to improve the ductility of the structure



Fabrics easily adaptable to the shape of structural members

Wrapping of axial-loaded concrete elements



Advantages

MAPEI's FRP products have a number of advantages with respect to conventional technologies:

- **Simplicity and speed:** Because they are lightweight, these products can be applied with no particular equipment, with less manpower, in extremely short time and without downtime of the structure.
- **High durability:** The carbon fabrics and plates do not corrode, a problem usually dealt with when using steel plates.
- **No increase of seismic loads:** Repairs are carried out on the structural elements of the concrete structure. This is a very important aspect, especially in the seismic field where loads are proportional to the in-situ weight of the structure.
- **Complete reversibility:** Because the reinforcements and the layers of adhesive can be removed, work performed with MAPEI's FRP composite systems products is completely reversible. This especially matters when temporary safety measures are taken, as on temporary structures.

Application procedure of the *MapeWrap* fabric systems

Substrate preparation:

As a first step, it is necessary to evaluate whether the substrate that needs reinforcement is sound or deteriorated. If the concrete is sound, the substrate must be cleaned of any oils, grease and surface deposits by sandblasting or high-pressure water. If the concrete surface is deteriorated, remove the deteriorated sections of the concrete structure, remove any rust from steel reinforcement and repair the section with products from MAPEI's Concrete Restoration Systems line. This process is vital because good-quality repairs dictate the quality of the substrate onto which the reinforcement will be bonded. Proceed with smoothing out all the sharp edges where the fabric will be applied. It is recommended to prepare a round level having a bending radius not less than 3/4" (19 mm) long.



Seeding *MapeWrap C Uni-Ax 300* with sand aggregate in preparation for the protective coating

Applying *MapeWrap* fabrics via the “wet layup system”:

Spread an even coat of *MapeWrap Primer 1* with a brush or roller over the clean and dry concrete surface. Wait about 1 hour and then smooth it to a thickness of 1/32" to 5/64" (1 to 2 mm) with *MapeWrap 11* or *MapeWrap 12*, depending on the temperature (*MapeWrap 12* has longer workability). Before application, impregnate the fabric with *MapeWrap 21* by plunging it directly into a trough. Remove the fabric from the trough, let it drip and then wring it by hand (protected with rubber waterproof gloves) until the excess resin is removed completely.

A. Smoothing and leveling of concrete surface

B. “Wet layup system”



As an alternative, the fabric impregnation can be carried out with a special machine fitted with a bucket and a series of rollers that automatically saturates, drips and wrings the fabric. Apply the *MapeWrap* fabric, making sure it is spread without wrinkles. First pass over the fabric with a stiff rubber roller and then an aluminium roller with a worm screw, in order to completely eliminate any air bubbles formed during the application.

Applying *MapeWrap* fabrics via the “dry layup system”:

Spread an even coat of *MapeWrap Primer 1* with a brush or roller over the clean and dry concrete surface. Wait about 1 hour and then smooth for a thickness of about 1/32" to 5/64" (1 to 2 mm) with *MapeWrap 11* or *MapeWrap 12*, depending on the temperature.



“Dry layup system”

Apply a first coat, by brush or roller, of *MapeWrap 31*. Immediately afterward, apply the *MapeWrap* fabric, accurately flattening it by hand (protected by rubber waterproof gloves). Apply a second coat of *MapeWrap 31*. First pass over the fabric with a stiff roller, and then use an aluminium roller with a worm screw.

Application procedure with *Carboplate* systems

Prime the surface that needs to be reinforced with *MapeWrap Primer 1* (particularly porous surfaces or in environments with high relative humidity). Apply a uniform layer of 40 to 60 mils of *MapeWrap 11* or *MapeWrap 12* (depending on temperature) with a flat trowel over *Carboplate* on the side where the protective film has been removed. Apply a 40-mil layer of *MapeWrap 11* or *MapeWrap 12* also on the clean and dry substrate that will receive the plate. Ensure that the adhesive layer is applied when *MapeWrap Primer 1* is still fresh. Install the *Carboplate*, applying constant pressure over the whole surface. Use a stiff rubber roller and remove any excess resin adhesive with a trowel, making sure that the plate is not moved.

Pirelli Skyscraper
Milan, Italy



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FRP Composite Systems

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