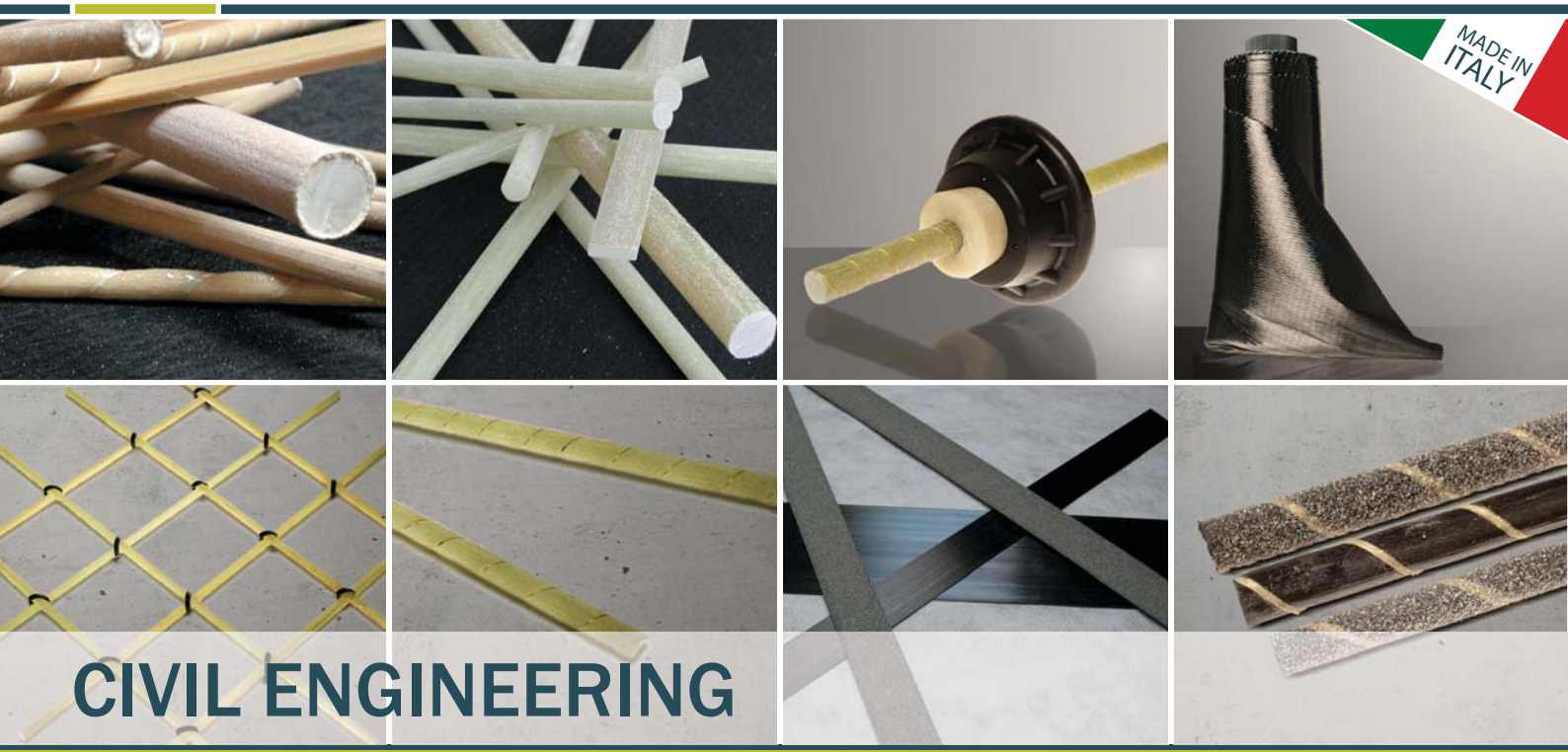
sireg



CIVIL ENGINEERING

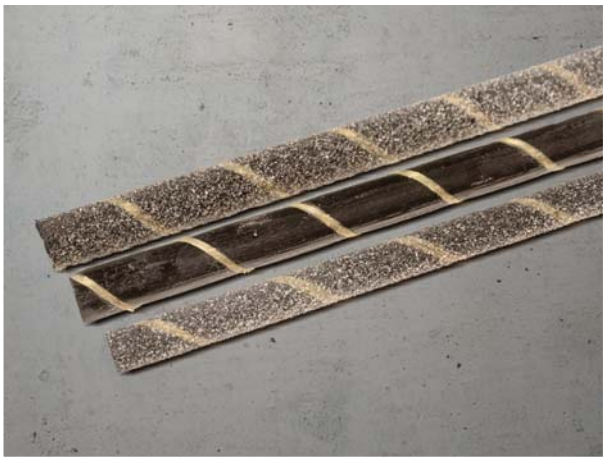
COMPOSITE MATERIALS FOR STRUCTURAL REINFORCEMENT

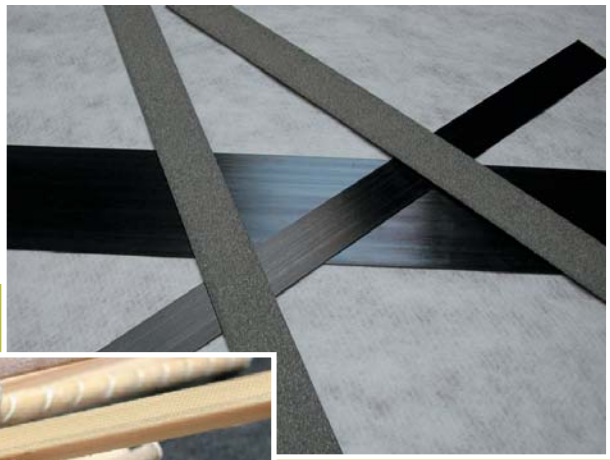
SIREG FRP PRODUCT LINE FOR STRUCTURAL REINFORCEMENT CARBOPREE® - GLASSPREE® - ARAPREE®

The use of composite materials (commonly called FRP or Fiber Reinforced Polymers) to strengthening and repair existing structures dates back to more than 20 years ago.
FRP systems are nowadays used in those structures that need to be reinforced as a consequence of:

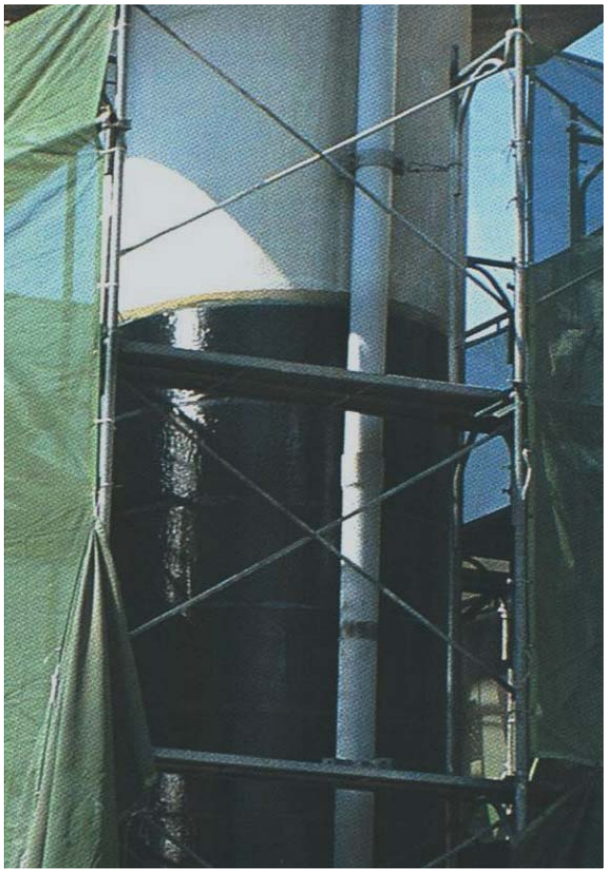
- Deterioration of the existing steel reinforcement
- Errors in design and/or construction
- Change in use
- Change of the design parameters
- Seismic retrofitting
- Increase of service / ultimate load
- Structure upgrading to new seismic codes.

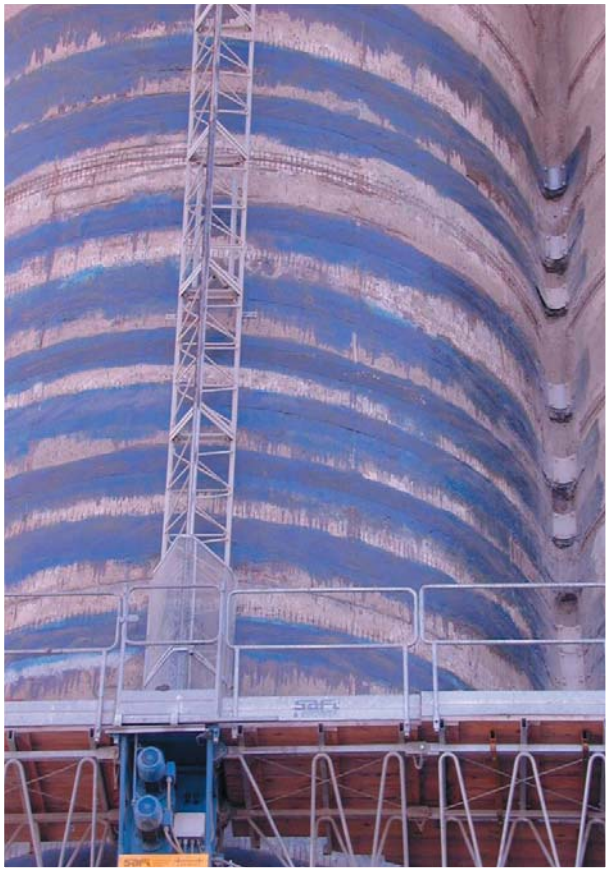
Three types of products are commonly used for this purpose: fabrics, laminates and bars, manufactured with different materials, such as: carbon fibers, glass fibers and aramid fibers.





FRP materials work to strengthen structures when concrete is weak and therefore under tension.
They are placed at the intrados of beams or slabs to increase their flexural strength or on the sides of the same to improve their shear strength.
They can also be used to wrap completely columns or piles in order to provide confinement and to enhance load capacity and ductility, which are the main problems in seismic retrofitting.
FRP materials are therefore a valid solution to improve the seismic performance of concrete or masonry walls, also increasing their capacity to withstand wind loads.





There are reasonable limits to the additional strengthening that FRP materials can provide to the structure (a 50% increase of the performance is considered as a standard limit) and there are applications where FRP systems may not be useful, such as:
• Correction of punching shear
• Increase of the structure compression strength if confinement is not possible.

In general, FRP products can be used in new structures that can not be reinforced with traditional steel materials or in those structures exposed to a high environmental corrosion.

Main benefits of using FRP materials

- Reduction of the deflection (increase in stiffness)
- Reduction and control of structure cracking (increase of its durability)
- Increase of structure load capacity
- Enhancement of structure service and ultimate load
- Enhancement of structure safety

Main advantages offered by FRP materials

- Durability
- Lightweight
- Fast and easy installation
- Possibility of installation in limited access areas
- No alteration of the appearance of the reinforced structure
- Possibility to be applied on surfaces with a complex geometry

In order to obtain the above mentioned benefits, the engineer will have to consider different aspects, such as:

- FRP products type (fabrics, laminates or bars)
- FRP material type (carbon fiber, aramid fiber or glass fiber)
- Length, thickness and orientation of the reinforcement to be realized
- Adhesive type to combine with the FRP product and to comply with the reinforcement aim

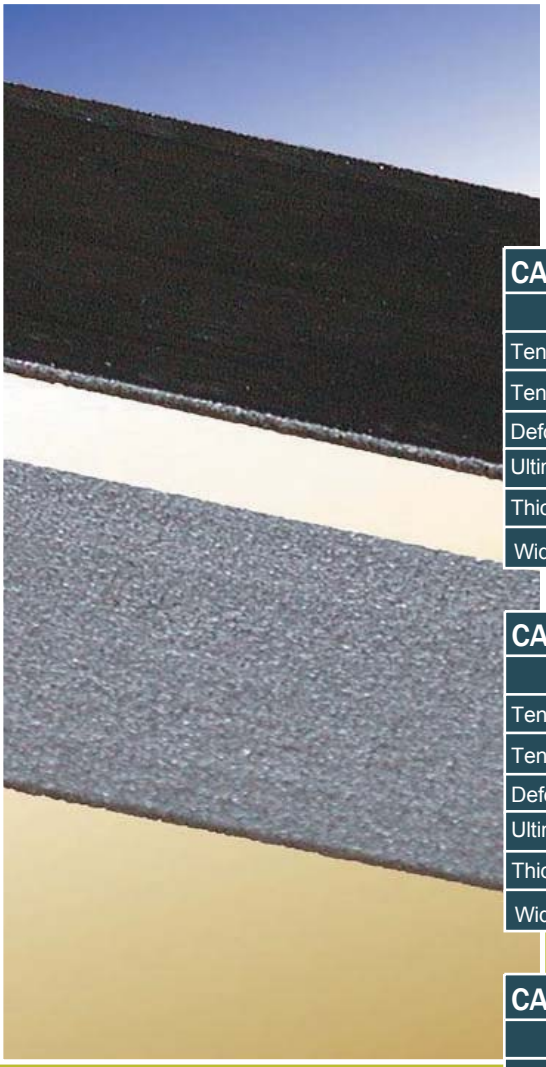
The combination of these parameters is a very important key factor for the project.

For example, the reduction of mid-span deflection under load at service of a beam or slab can be achieved using different types of FRP (fabrics, sheets or bars) or a combination of them or also through a combination of their different lengths or thicknesses.
The evaluation of all these data to match the project requirements is a quite complex operation.
Sireg can offer technical assistance to its customers since the early stage of the project, suggesting the best reinforcing materials to be used according to the most important international codes and guidelines worldwide issued.

TYPES OF REINFORCEMENT - EXTERNAL STRUCTURAL REINFORCEMENT

Beams or slabs flexural strengthening with Carbopree® plates

Carbopree® is a line of carbon fiber reinforcement products.
Sireg Carbopree® plates are commonly used as external reinforcement.
Sireg manufactures both high strength Carbopree® plates (HS) and high modulus Carbopree® plates (HM), in different sizes which can vary between 50 mm and 120 mm width and between 1.2 mm and 1.4 mm thickness.
This allows the engineers to count on a wide range of products and to choose the most appropriate one according to the project requirements.
Carbopree® plates have a smooth side fit to be bonded onto the structure and a rough side coated with quartz sand in order to offer a better adhesion to the finishing materials.
The plates are supplied in rolls of 50m or 100m length to be easily shipped to the jobsite where they can be cut at the desired length.
In comparison with other types of FRP reinforcement products, Carbopree® plates are very easy and quick to be applied.



CARBON FIBER LAMINATE CARBOPREE® HIGH STRENGTH				
	50 x 1.2	80 x 1.2	100 x 1.2	120 x 1.2
Tensile strength ASTM D3039	2800 MPa	2800 MPa	2800 MPa	2800 MPa
Tensile modulus of elasticity ASTM D3039	165 GPa	165 GPa	165 GPa	165 GPa
Deformation ASTM D3039	1.8%	1.8%	1.8%	1.8%
Ultimate load ASTM D3039	168 kN	268 kN	335 kN	403 kN
Thickness	1.2 mm	1.2 mm	1.2 mm	1.2 mm
Width	50 mm	80 mm	100 mm	120 mm

CARBON FIBER LAMINATE CARBOPREE® HIGH STRENGTH					
	50 x 1.4	60 x 1.4	90 x 1.4	100 x 1.4	120 x 1.4
Tensile strength ASTM D3039	2800 MPa	2800 MPa	2800 MPa	2800 MPa	2800 MPa
Tensile modulus of elasticity ASTM D3039	165 GPa	165 GPa	165 GPa	165 GPa	165 GPa
Deformation ASTM D3039	1.8%	1.8%	1.8%	1.8%	1.8%
Ultimate load ASTM D3039	196 kN	235 kN	352 kN	392 kN	470 kN
Thickness	1.4 mm	1.4 mm	1.4 mm	1.4 mm	1.4 mm
Width	50 mm	60 mm	90 mm	100 mm	120 mm

CARBON FIBER LAMINATE CARBOPREE® HIGH MODULUS				
	50 x 1.2	80 x 1.2	50 x 1.4	60 x 1.4
Tensile strength ASTM D3039	2300 MPa	2300 MPa	2300 MPa	2300 MPa
Tensile modulus of elasticity ASTM D3039	200 GPa	200 GPa	200 GPa	200 GPa
Deformation ASTM D3039	1.4%	1.4%	1.4%	1.4%
Ultimate load ASTM D3039	138 kN	220 kN	161 kN	193 kN
Thickness	1.2 mm	1.2 mm	1.4 mm	1.4 mm
Width	50 mm	80 mm	50 mm	60 mm

Beams shear and flexural strengthening with Carbopree® fabrics

The most effective method to improve the shear strength of a beam using FRP sheets is to wrap its whole section.
Unfortunately, it is often hardly applicable on jobsite due to the presence of monolithic beams or other supporting elements on the upper part of the beam.
The so called “U wrapping” method, which consists in wrapping the sides and intrados of the beam, is then used.
When the fabric is applied U shaped on the beam, its extremities have to be anchored to it by means of a composite material rod (carbon or glass fiber).

This rod is inserted, together with the fabric, inside a groove previously carried out along the whole length of the beam and the groove is filled with epoxy paste, so to guarantee the anchoring of the fabric.
In this way, the debonding of the fabric extremities can be prevented.
The same result can be obtained using L shaped steel profiles, although this second method is difficult to be carried out and more expensive.

CARBON FIBER SHEET CARBOPREE® HIGH STRENGTH		
	HS 300	HS 600
Tensile strength average ASTM D3039	3900 MPa	3900 MPa
Tensile modulus of elasticity ASTM D3039	230 GPa	230 GPa
Deformation ASTM D3039	1.5%	1.5%
Thickness of dry tissue	0.165 mm	0.330 mm
Weight	300 g/m²	600 g/m²

Columns reinforcement by means of Carbopree,® Arapree® and Glasspree® sheets

The use of FRP Carbopree®, Arapree® and Glasspree® sheets is nowadays the best solution offered by the market to increase the technical characteristics of RC columns, such as:

- axial /compression behavior
- shear moment
- load capacity
- ductility

The application of the fabric is carried out wrapping the column in a continuous way transversely from the base until the section under the slab or beam.
When the columns are subject both to axial and to flexural loads, the use of vertical bars or laminates is recommended.
In case of use of glass fiber sheets for the RC column confinement, any creep problems will occur, thanks to the fact that the column is not under stress.

The low elastic modulus of glass and aramid fiber sheets, if compared to carbon fiber sheets, allows a higher ductility of the column and a better dissipation of the energy released in the event of an earthquake.
Sireg manufactures a great variety of composite materials sheets having different technical features (tensile strength and elastic modulus) and different grammages, in order to offer the engineers the possibility to design the project with really customized material.
Carbopree ® sheets can be manufactured in different grammages: from 300 g/m² up to 600 g/m² in high strength configuration and unidirectional fiber orientation.
Arapree ® sheets can be manufactured in 300 g/m² or 400 g/m².
Glasspree ® sheets can be manufactured in 600 g/m² or 900 g/m².

GLASS FIBER SHEET GLASSPREE ®		
	600	900
Tensile strength average ASTM D3039	1700 MPa	1700 MPa
Tensile modulus of elasticity ASTM D3039	65 GPa	65 GPa
Deformation ASTM D3039	2.6%	2.6%
Thickness of dry tissue	0.23 mm	0.35 mm
Weight	600 g/m²	900 g/m²

INTERNAL STRUCTURAL REINFORCEMENT -

Near Surface Mounted (N.S.M.) technique by means of Carbopree,® Arapree® and Glasspree® rods

In the N.S.M. technique, used to obtain shear and flexural strengthening of concrete structures, Carbopree®, Arapree® and Glasspree® rods, in comparison with traditional steel bars, offer the following advantages:

- excellent resistance to corrosion
- excellent tensile strength
- good fatigue resistance
- very light weight

The application of these bars vary from seismic reinforcement of masonry walls and columns to flexural strengthening of RC slabs and beams.
In the N.S.M. technique, a longitudinal groove is executed along the structure to be reinforced. The groove is than filled with an epoxy paste and afterwards the bar is introduced into it so that the epoxy paste covers it completely.

The bar is then finally sealed by means of a finishing epoxy resin or mortar.
One of the most important advantages when using this technology is that there is no need to work on the substrate of the structure since the bar is placed inside it.
Therefore, the application is faster if compared to external reinforcement techniques.

ARAMID FIBER ROD ARAPREE®					
	ø 5.5 mm	ø 7.5 mm	ø 8.5 mm	ø 10 mm	ø 12 mm
Tensile strength ASTM D3039	1400 MPa	1400 MPa	1400 MPa	1400 MPa	1400 MPa
Tensile modulus of elasticity ASTM D3039	70 GPa	70 GPa	70 GPa	70 GPa	70 GPa
Deformation ASTM D3039	2.3%	2.3%	2.3%	2.3%	2.3%
Section	23 mm²	44 mm²	56 mm²	78 mm²	114 mm²
Ultimate load ASTM D3039	32 kN	61 kN	78 kN	110 kN	158 kN

GLASS FIBER ROD GLASSPREE®										
	ø 6 mm	ø 8 mm	ø 10 mm	ø 12 mm	ø 16 mm	ø19 mm	ø22 mm	ø25 mm	ø 28 mm	ø 32 mm
Tensile strength ASTM D3039	1000 Mpa	1000 MPa	1000 MPa	1000 MPa	1000 MPa	900 MPa	900 MPa	900 MPa	900 MPa	850 MPa
Tensile modulus of elasticity ASTM D3039	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa
Deformation ASTM D3039	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%
Section	28 mm²	50 mm²	78 mm²	113 mm²	200 mm²	283 mm²	379 mm²	490 mm²	615 mm²	803 mm²
Ultimate load ASTM D3039	28 kN	50 kN	78 kN	113 kN	200 kN	250 kN	340 kN	440 kN	550 kN	680 kN

The N.S.M. technology is particularly interesting also because it allows flexural strengthening of the negative zones of both slabs and beams.
The application of laminates or sheets (external reinforcement) would instead necessary imply to cover the FRP material, in order to avoid any mechanical or environmental damage and any interference with already existing structures (columns, floors or walls).
Sireg Carbopree ®, Arapree ® and Glasspree ® rods are manufactured in diameters ranging from 3mm up to 40 mm.

CARBON FIBER ROD CARBOPREE ® HIGH STRENGTH					
	ø 3 mm	ø 5.5 mm	ø 7.5 mm	ø 10 mm	ø 12.5 mm
Tensile strength ASTM D3039	2450 MPa	2450 MPa	2450 MPa	2450 MPa	2450 MPa
Tensile modulus of elasticity ASTM D3039	130 GPa	130 GPa	130 GPa	130 GPa	130 GPa
Deformation ASTM D3039	1.8%	1.8%	1.8%	1.8%	1.8%
Section	7 mm²	23 mm²	44 mm²	78 mm²	122 mm²
Ultimate load ASTM D3039	17 kN	56 kN	108 kN	192 kN	300 kN

CARBON FIBER ROD CARBOPREE ® HIGH MODULUS		
	ø 5 mm	ø 7.5 mm
Tensile strength ASTM D3039	2300 MPa	2300 MPa
Tensile modulus of elasticity ASTM D3039	200 GPa	200 GPa
Deformation ASTM D3039	1.2%	1.2%
Section	19 mm²	44 mm²
Ultimate load ASTM D3039	45 kN	101 kN

OTHER FIELDS OF APPLICATIONS OF FRP MATERIALS -

Strengthening of marine structures

One of the most common problems concerning marine structures is the corrosion of the steel used to reinforce them: it deteriorates very quickly, if not properly treated or protected.
Steel protection is very expensive and cannot always guarantee a long durability, whereas composite materials are not affected either by salted water or by marine environment.
Some examples of applications of FRP reinforcing products in marine environment are: retaining walls, piers, floating structures, concrete flooring of docks.

Strengthening of concrete structures treated with deicing salts

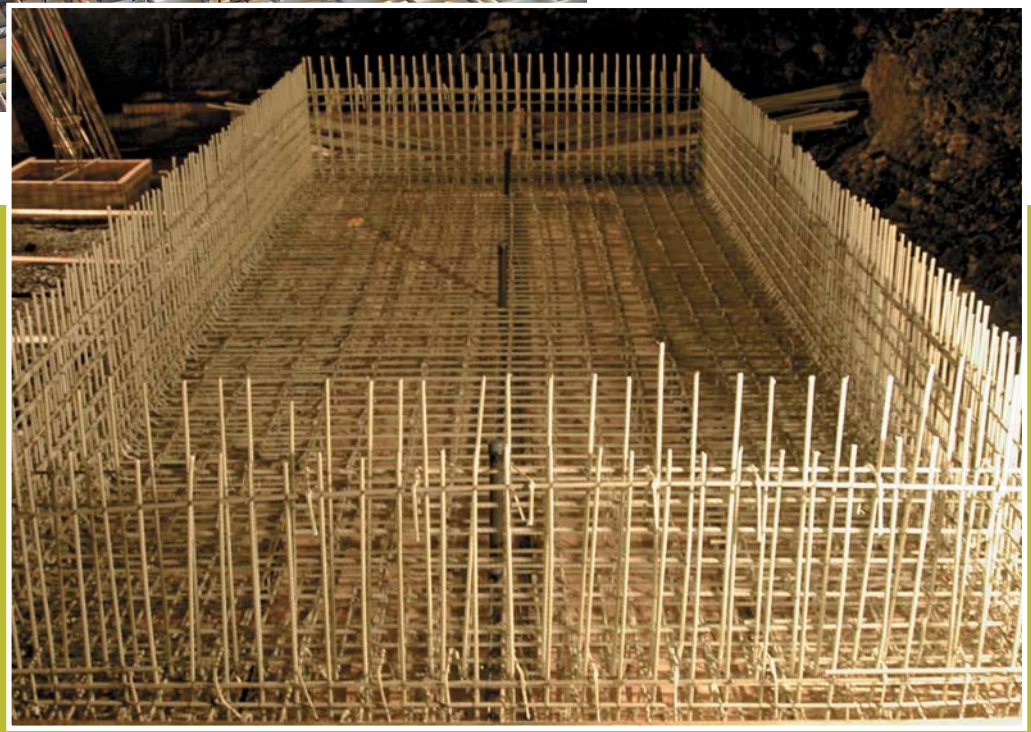
The use of FRP bars represents a solution to the problem of corrosion of structures usually treated with deicing salts such as roads, bridges, concrete floors, concrete safety barriers (Jersey) in cold climate countries.
In case of steel reinforced structures, the substances contained in the deicing salt (usually sodium or magnesium hydrochloride) easily penetrate into the concrete pores, reach the steel reinforcement and quickly corrode it.

For this reason, a lot of countries which are characterized by low temperatures, ice and snow during the winter season, have implemented the use of composite reinforcing materials (rods, mesh) to replace traditional steel reinforcements, since FRP materials are not affected by chloride ions.
This solution allows to reduce the maintenance costs of these structures and extend their durability.

Reinforcement of RC structures subjected to magnetic fields and stray currents

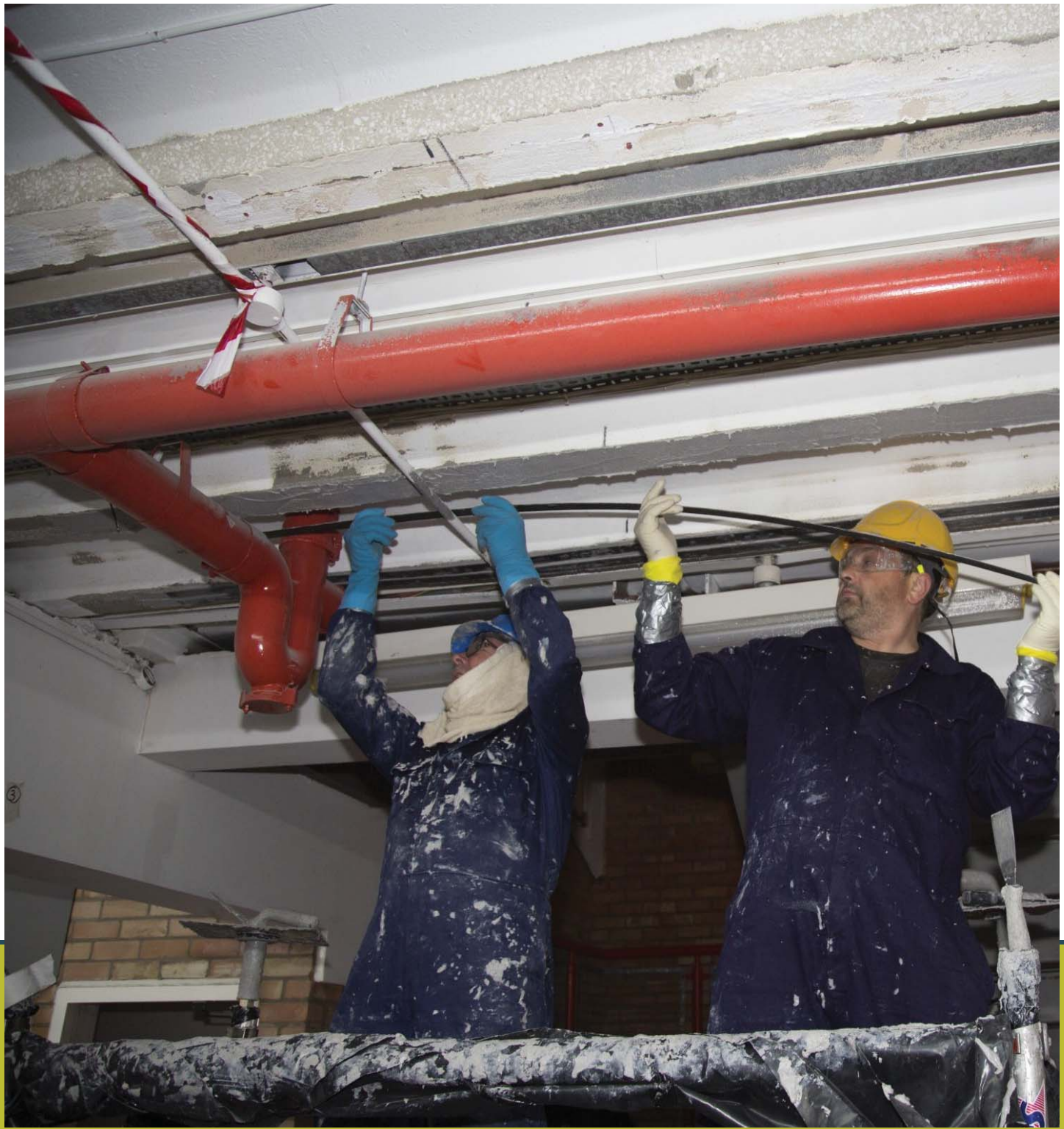
There are special cases where it is necessary to reinforce concrete structures with non-conductive materials or with materials transparent to the magnetic fields, for instance:
airport control towers, MRI rooms, support structures for electrical towers, support structures for radars, basements for turbines in power station facilities.

In the above mentioned cases, the use of standard steel reinforcements is not indicated because steel is very sensitive to magnetic fields and to electricity and therefore it will be quickly eroded by galvanic corrosion.
A cost-effective alternative to steel is represented by composite materials that are not conductive and transparent to electromagnetic fields.



Consulting services:

SIREG can support its customers since the early stage, starting from design to installation on site, providing the necessary technical assistance and design according to the most important international codes and guidelines and thanks to its team of highly qualified experts.



The values in the tables are indicative. Sireg can supply, on demand, detailed technical data sheets of the products with updated values.

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