

Repair and strengthening of concrete buildings



FREYSSINET

Freyssinet

Founded over 75 years ago, Freyssinet brings together an unrivalled set of skills in the specialist civil engineering sector. With its expertise in the design of elements and structures, the production of materials and equipment and their implementation on site, Freyssinet offers integrated technical solutions in two major fields: construction and structural repair.

Freyssinet's integrated engineering service and involvement in numerous major bespoke projects make it the world leader in its specialist areas of:

Construction - bridges and civil engineering structures, buildings, stadium roofs, wind turbine towers, etc.:

- prestressing;
- construction methods;
- cable-stayed structures;
- structural accessories.

Repair - bridges and civil engineering structures, buildings, industrial infrastructure, marine and waterways structures, water infrastructure, etc.:

- strengthening work using additional prestressing, carbon fibre composites and shotcrete or sprayed UHPFRC;
- protection against the effects of corrosion, earthquakes, fire, chemical attack, etc.;
- maintenance of structural accessories (joints, bearings, prestressing and stay cables).

Freyssinet is a subsidiary of the Soletanche Freyssinet Group, the world leader in soils, structures and nuclear. Freyssinet also offers a range of digital and consulting solutions for the design, construction and operation of infrastructures.

Cover photo: Le Corbusier Building (Cité Radieuse) - France

Repair and strengthening of concrete buildings

Water towers, residential buildings, industrial buildings - Freyssinet has the technology to protect, repair, strengthen and maintain the structures that are essential to our everyday lives.

Freyssinet's repair methods and solutions all come under the Foreva® label. From analysis through design to implementation, it guarantees Freyssinet customers **a service tailored to their requirements**.

Our Foreva® solutions have been tried and tested and are continuously evaluated on the 3,000 projects that we complete each year across our international network of subsidiaries, applying exceptional know-how and technical solutions recognised for their excellent performance for 30 years.



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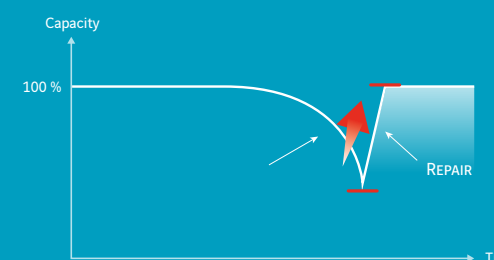
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REPAIR | STRENGTHEN

Repairing or strengthening buildings: two complementary concepts.

REPAIRING a concrete structure

Repairing a structure consists of **making it stronger in order to compensate for an original lack of strength** due to initial defects or to reinstate its initial bearing capacity including when it has been damaged by excessive or accidental stress during use.



ORIGINAL LACK OF STRENGTH

- In design
- In construction

EXCESSIVE STRESS

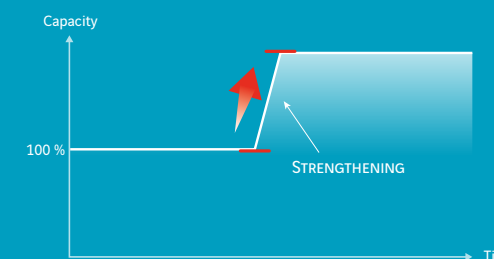
- Static and dynamic loads
- Penetration of moisture
- Penetration of carbon dioxide
- Penetration of chlorides and sulphates
- Chemical attack
- Action of freeze/thaw cycles
- Thermal stresses
- Abrasion

ACCIDENTAL STRESS

- Impacts
- Fires
- Explosions
- Earthquakes

STRENGTHENING a concrete structure

Strengthening consists of **increasing the strength of a structure to withstand live loads that were not originally envisaged**, without the structure having been altered during its service life or once it has been repaired.



INCREASED SERVICE LOADS

COMPLIANCE WITH NEW STANDARDS

- More stringent design regulations
- Effects of snow and wind
- Effects of earthquakes or explosions

CHANGE OF USE

- Change in loading

MODIFICATION OF THE STRUCTURE

- Increased number of storeys
- Lowered foundations
- Addition of columns
- Removal of load-bearing elements
- Creation of openings

Our primary concern: ensuring everyone's safety



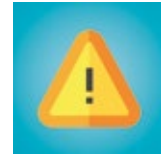
Our "Sustainable Technology" signature expresses our commitment to offering our customers sustainable solutions that respect the environment, providing our employees with an environment where safety, risk management and innovation are constantly in mind.

Managing safety on our sites is therefore our primary duty towards our employees worldwide, whatever the local regulations. We are fully committed to the goal of "Zero Lost Time Injuries"; our rules, our "non-negotiables" and our in-house tools ensure that this commitment will become reality.

"Safety is the only option"

REASONS FOR ACTION

Repair



INITIAL DESIGN OR CONSTRUCTION DEFECTS

Insufficient quality and/or thickness of concrete coating for the environment, incorrectly positioned reinforcing bars



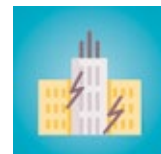
AGEING OF MATERIALS

Natural or accelerated by fatigue stresses



AGGRESSIVE ENVIRONMENTS

Exposure to seawater, sea spray, acid fumes, etc.



EXCESSIVE LIVE SERVICE LOADS

These can result in concrete cracking and/or plastic deformation of metallic reinforcing bars



UNFORESEEN EVENTS

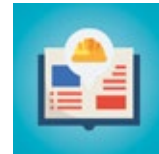
Fires, earthquakes, storms, impacts

Strengthen



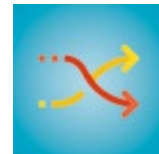
INCREASED SERVICE LOADS

Use of new equipment in a hospital or factory



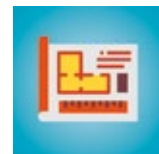
COMPLIANCE WITH NEW STANDARDS

Earthquake protection, for example



CHANGE OF USE

A car park converted into a hypermarket, offices converted into archive storage rooms, for example



MODIFICATION OF THE STRUCTURE

Removal of columns, creation of openings in a wall, etc.

The Freyssinet Advantage

Freyssinet has particular expertise in specific areas:

- Repair after a fire
- Coastal structures
- Balcony repair

FREYSSINET EXPERTISE

With 75 years of experience in strengthened and prestressed concrete structural repair, Freyssinet's Foreva® solutions bring you the guarantee of a turnkey service to add value to your buildings.

Whatever the type of structure, Freyssinet has developed specific solutions for repairing and/or strengthening concrete buildings:

• Work after accidents for insurers

- Making safe and repairing balconies suffering from construction defects and/or corroded reinforcing bars due to water tightness defects
- Making safe and repairing deficient structures after a fire (car parks, residential buildings)
- Seismic strengthening of houses and buildings
- Stabilisation of houses by consolidation of clay soil

• Expert, tailored action

- Renovation and protection of façades exposed to sea spray
- Strengthening of roofs before installation of solar panels
- Strengthening of house foundations
- Load transfer to new columns or foundations by heavy jacking

Freyssinet supports its customers throughout the development and execution of their projects:

- Assistance with structural diagnosis
- Assistance with choosing a repair and/or strengthening solution
- Suitability tests
- Sizing calculation
- Construction methods
- Implementation of specialized techniques
- Monitoring

The main building repair and strengthening techniques highlighted in this brochure are as follows:

- Dry process shotcrete
- Additional prestressing
- Carbon fibre composites
- Improvement and stabilisation of existing foundations

The Freyssinet Advantage

- High-added-value techniques
- Tested and proven solutions under the Foreva® label
- Approved by our Structures and Corrosion Protection technical department
- Implemented by qualified personnel

Special techniques

In the field of buildings, Freyssinet also has expertise in:

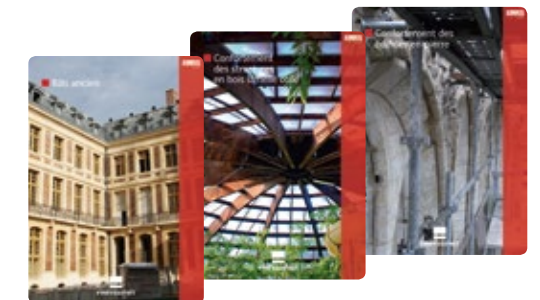
- corrosion protection of reinforcing bars, particularly in strengthened and prestressed concrete.



Special applications

In the field of buildings, Freyssinet also has expertise in:

- renovating heritage buildings;
- strengthening timber structures;
- strengthening stone buildings.



ABDALI MEDICAL CENTRE (CLÉMENTCEAU NETWORK) AMMAN, JORDAN

Structural strengthening of a 125-m tower,
ancillary buildings and four basement levels.
Change of use from residential building to hospital.
2,000 tonnes of dry process shotcrete.



REPAIR AND STRENGTHENING USING DRY PROCESS SHOTCRETE

Foreva® Shotcrete is mainly used to repair damaged concrete elements or to increase the cross-section and inertia of a concrete element.

Applications

Dry process shotcrete is recommended for:

- **Repairing concrete facing panels** after a fire (cracking, delamination, plastic deformation of passive reinforcing bars and relaxation of the stresses in prestressing reinforcing bars),
- **Replacing concrete coatings contaminated** or damaged by chlorides (dissolved reinforcing bars, spalled coatings, etc.),
- **Stiffening elements that are subject to additional deformation** by increasing cross-section and inertia,
- **Strengthening concrete elements** in tension, shear and compression.

Technologies

Foreva® Shotcrete dry process shotcrete is a robust solution that can be applied to all buildings:

- Sprayed at high speed onto the concrete facing panel on which it bonds and is compacted due to the impact of the aggregate, the shotcrete and the base concrete together form a single element that behaves monolithically.
- The composition of the shotcrete is selected to match the exposure class and strength class of the base concrete.

- Shotcrete generally has a particle size of 0-8 and can be used to produce large volumes quickly. When a smooth finish is required, particularly to allow for painting, 0-4 shotcrete is recommended.

Assistance with diagnosis and feasibility studies

On request, Freyssinet assists with structural diagnosis following a fire or where reinforcing bars have corroded, and then helps customers select the optimum repair or strengthening method for the normal use of the site.

The Freyssinet Advantage

- Shotcrete applied by specialist personnel trained in-house
- Personnel certified in accordance with the national standards in force, where applicable
- All nozzlemen are subject to individual monitoring and training plans

Structural strengthening after a fire

Following a fire, Freyssinet acts swiftly to put in place precautionary measures and make the structure safe. Freyssinet can also assist the building operator when identifying a repair strategy. Repairs using shotcrete can be combined with additional prestressing to return the structure to its original operating condition.



CARREFOUR SUPERMARKET, SAN ISIDRO BUENOS AIRES, ARGENTINA

Structural strengthening of 120 strengthened concrete beams using additional prestressing and 800 secondary beams using TFC® (Carbon Fibre Fabric).

Night work in a supermarket operating during the day.



REPAIR AND STRENGTHENING USING ADDITIONAL PRESTRESSING

Foreva® PT+ is used for repair and strengthening by increasing the prestressing force in a prestressed concrete structure or introducing prestressing force in a strengthened concrete structure.

Applications

Repair and strengthening using additional prestressing are used to:

- **Make safe concrete structures** with defective passive or active reinforcing bars, restoring the initial bearing capacity.
- **Increase bending and shear strength** for beams and sound concrete slabs with a deviated layout.
- **Introduce camber** to compensate for excessive deflection in a sagging element.

Technologies

- Reinforcements using additional prestressing are known as active, as they are placed under load before the live service loads are applied.
- Additional prestressing generally uses prestressing strands protected with grease and placed in an HDPE sheath in the factory, commonly known as monostrands.
- For applications inside buildings, the single strand can be used without additional protection. Outdoors, or when transverse loads might damage their individual sheaths, the single strands are threaded into a protective duct injected with cement grout before tensioning.
- For slabs or medium-span beams, weak additional prestressing force is created using just one or a few strands, the layout of which can be straight or deviated.

- Strengthening using single-strand prestressing makes it possible to use simple metal deviators bolted to the structure to produce the deviated layout of the tendons.
- For longer-span beams, moderate additional prestressing force is generally sufficient.

The Freyssinet Advantage

- Installation by specialist Freyssinet personnel
- Unobtrusive single-strand repair anchors are quick to install and ideal for beam prestressing
- Designed and manufactured by Freyssinet

Freyssinet innovation: 1R15 Anchor

- Prestressing force transferred directly to the support without additional concrete
- Effective and reliable
- Easy and fast to install



Making balconies safe

Balconies are highly exposed to changing weather conditions, and often have pathologies such as cracking or water ingress. Left untreated, these pathologies generate corrosion of the metal reinforcing bars, which can ultimately fail and cause the balcony to fall off the building.

Freyssinet makes defective cantilevered balconies safe by adding prestressing or through carbon fibre composite reinforcement.





SEVESTRE SWIMMING POOL ISSY-LES-MOULINEAUX, FRANCE

Strengthening of 13 prestressed concrete roof shells using carbon fibre fabric composite reinforcements and additional prestressing using greased sheathed monostrands.

REPAIR AND STRENGTHENING USING BONDED CARBON FIBRE COMPOSITE

Carbon fibre composite reinforcements are used in the repair and strengthening of concrete elements to increase strength by adding external reinforcing bars.

Applications

Carbon fibre reinforcements are used to increase **tensile, bending, shear and compressive strength**.

Multiple fabric strips can be overlaid to increase the stress area of the reinforcement. They can also be criss-crossed to provide reinforcement in several directions.

Carbon fibre composites can be used to produce highly durable, fatigue-resistant static or dynamic reinforcements (against seismic effects) without adding further weight.

Technologies

Freyssinet offers the following solutions:

- **Foreva® TFC - fabric**
- **Foreva® LFC - strips**
- **Foreva® RFC - rods**

These types of reinforcements are bonded to the structure with epoxy resin after careful preparation of the substrate.

In the anchor zone between the reinforcement and the structure, carbon fibre braids are often added to improve load transfer and increase the anchor capacity (by up to double).



Reinforcement using a bonded composite is known as passive as they are placed under load by deformation of the structure, i.e. when the strengthened element deforms under a live load.

Reinforcements using carbon fibres in an epoxy matrix are highly durable, not only in terms of mechanical strength and chemical resistance, but also in terms of adhesion.

In the event of direct, extreme exposure to UV, the epoxy resin must be protected with a coating.

The Freyssinet Advantage

- Proprietary systems evaluated and tested by the Freyssinet Technical Department
- Design software made available to design offices (www.e-tfc.com)
- Compliance with the requirements of international regulations
- Technical Assessment Reports and certifications

Strengthening of floors and beams

Due to a change of use during the construction of a school, Freyssinet strengthened the floor and several beams using carbon fibre composite.

Strengthening slabs to increase positive bending strength using carbon fibre composite.



Strengthening beams to increase mid-span bending strength and bearing zone shear strength.



KEITH HARING TOWER, NECKER HOSPITAL PARIS, FRANCE

Strengthening of the tower prior to the demolition of the adjacent building: foundation and structural strengthening, mainly to withstand the wind effects. Ground beams, micro-piles, curved strengthened concrete inner wall. Interior renovation. Project carried out on a working hospital site.

IMPROVEMENT AND STABILISATION OF EXISTING FOUNDATIONS

Underpinning work is used to strengthen building foundations, either as a preventive measure to prepare a structure for a change of use, or as a corrective measure to extend the life of a structure that has been destabilised by ground movement. Underpinning is equally suitable for individual houses, apartment buildings, public buildings and industrial structures.

Applications

Underpinning work is used to **strengthen damaged or inadequate foundations** that are putting the superstructure at risk: the ground might have subsided due to leaking pipes, or have shrunk or expanded following a severe drought.

Whatever the source of the problem, Freyssinet offers a tailored strengthening solution, including deepening foundations, micro-piles and ground beams, active anchors, soil injection and load transfer from old to new foundations (jacking, flat jacks, etc.).

Technologies

Retaining and underpinning work is used to stabilise and strengthen building foundations and can be supplemented if necessary by jacking large structures to straighten them.

We work on both:

- **large buildings:** retention using active anchors, nailing or shotcrete, underpinning by deepening foundations and/or pressure-controlled injection of micro-concrete, cement grout, etc. into the soil, jacking and load transfer to lift and straighten the building using a Computer-Aided Lifting system.
- **individual houses:** mainly underpinning by injecting expanding resin into the soil to improve bearing capacity to stabilise the building and/or a patented underpinning process using pre-loaded micro-piles that strengthen the bed of the foundations.

The Freyssinet Advantage

Range of comprehensive solutions:

- assistance with structural diagnosis and design
- structural repair and strengthening (including retaining, underpinning, jacking, etc.)
- managing related work (such as waterproofing and drainage, façade renovation and finish work)

To find out more



Freyssinet stabilisation and underpinning solutions for individual houses

ForevaSol patented techniques provide a lasting solution to all structural defects caused by geotechnical instability or natural disasters.

PORTFOLIO



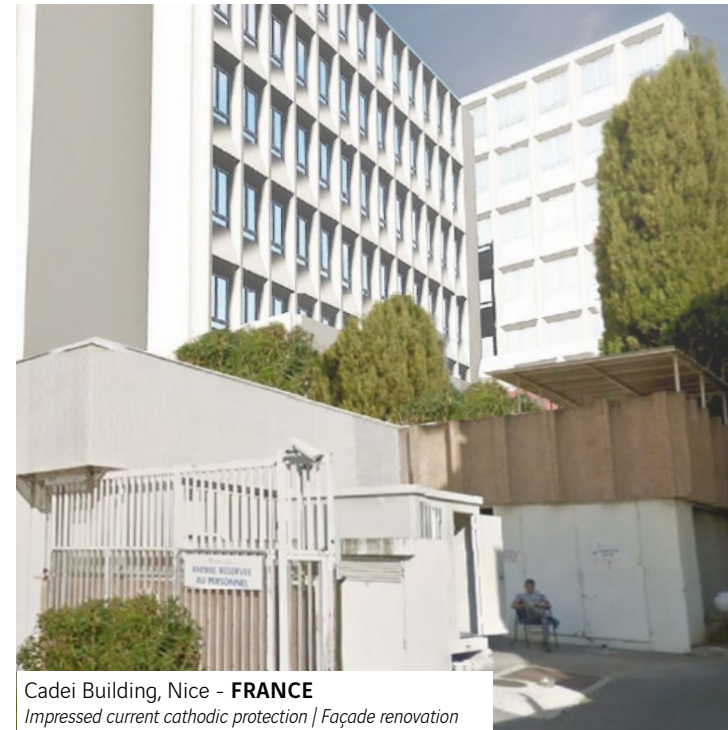
Abdali Medical Centre (Clémenceau Network), Amman - **JORDAN**
Shotcrete | TFC®



The Dubai Mall - **UNITED ARAB EMIRATES**
TFC® strengthening



Shopping centre in Valencia - **SPAIN**
TFC® strengthening following the creation of openings in the concrete structure



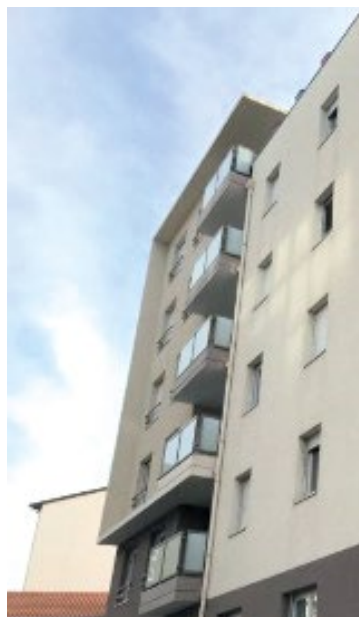
Cadei Building, Nice - **FRANCE**
Impressed current cathodic protection | Façade renovation



Iron Mountain Offices, Morangis - **FRANCE**
Micropiles



MLC Centre, Sydney, NSW - **AUSTRALIA**
Façade repair and restoration | Cathodic protection



The Seven Apartment Building, Lyon - **FRANCE**
Balcony repair and strengthening: Carbon fibre braid | Jacking | Crack grouting



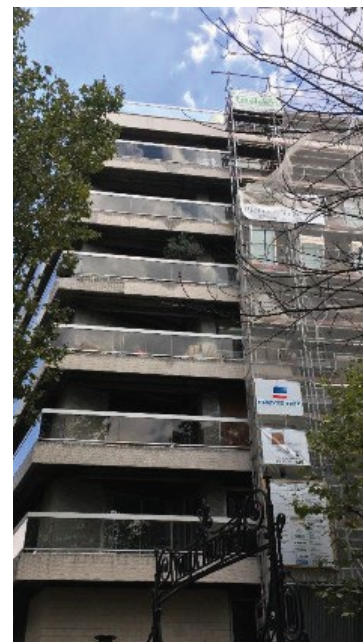
Simmon Apartment Building, North Carolina - **UNITED STATES**
Corrosion protection



Office building, Noisy le Grand - **FRANCE**
Underpinning of foundations | Shotcrete | TFC®



Customhouse Quay, Wellington - **NEW ZEALAND**
Additional prestressing



Balconies on Rue Molitor, Paris - **FRANCE**
Balcony strengthening: additional prestressing | TFC®



Arched roof warehouse, Chasse-sur-Rhône - **FRANCE**
Repair by: Crack injection | TFC® strengthening



Guilloteau Cheese Factory, Belley - **FRANCE**
Seismic strengthening using additional prestressing | TFC®



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