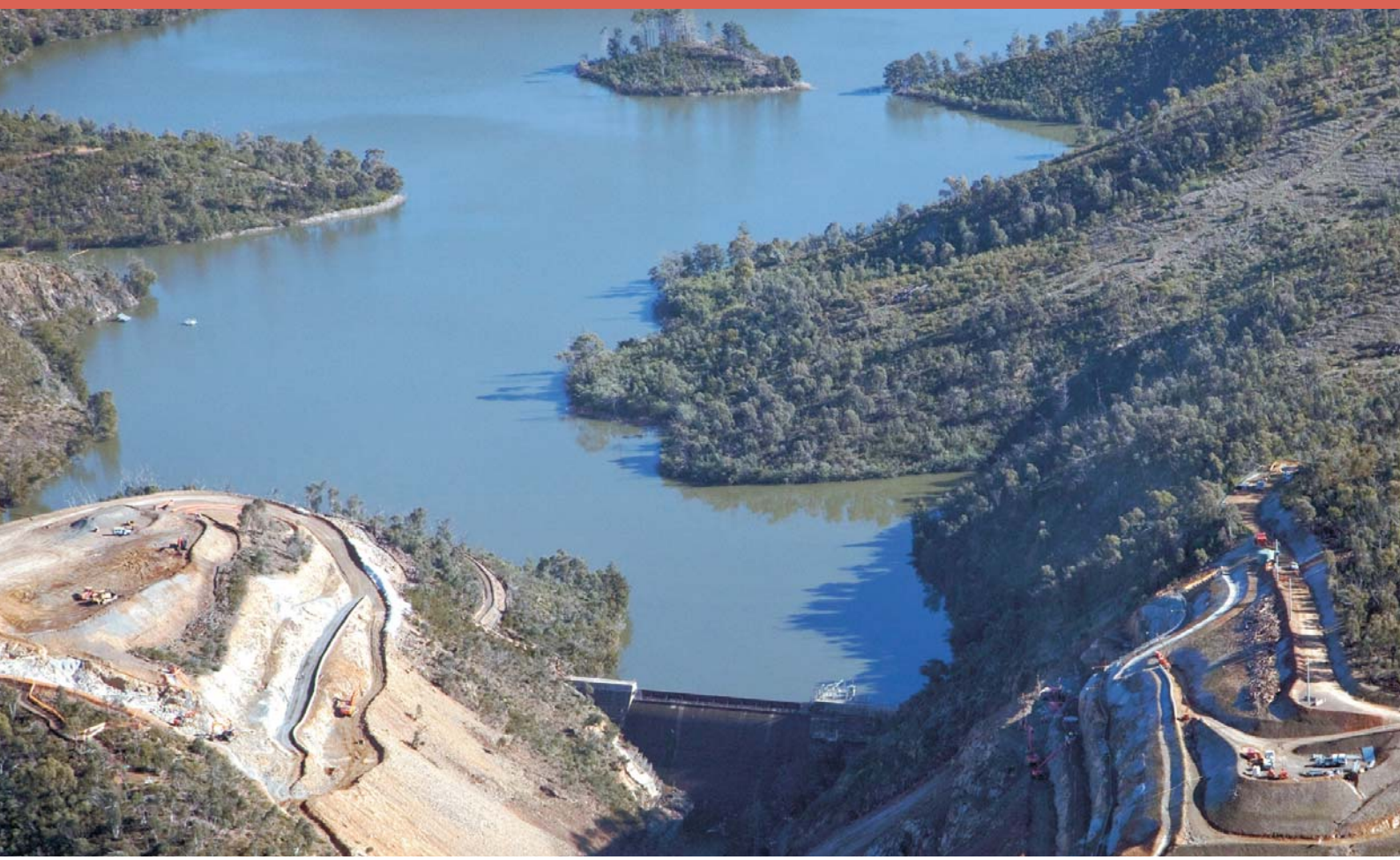
Dam Maintenance and Enhancement



IMPROVE, PRESERVE, SECURE

SOLETANCHE FREYSSINET

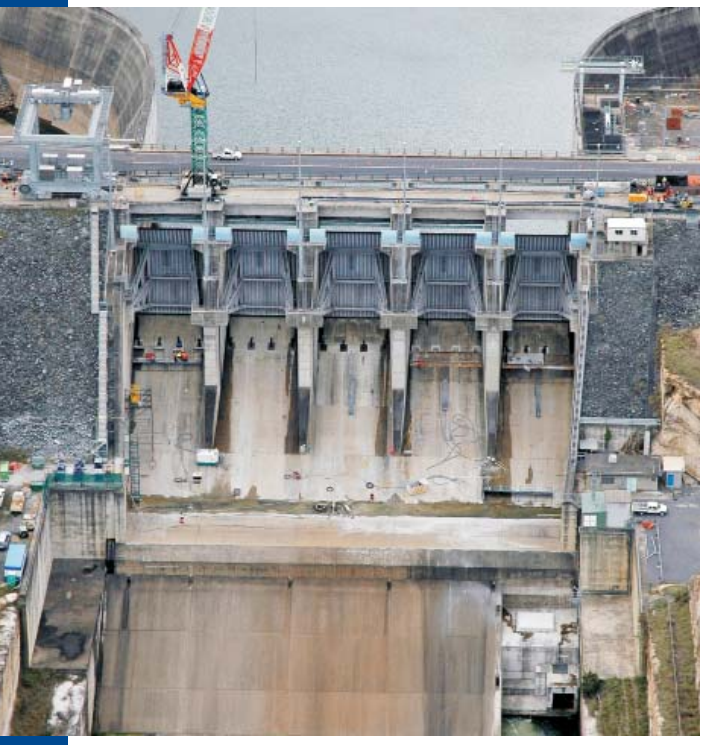
SUSTAINABLE TECHNOLOGY

R13

INTRODUCTION

Dams are often seen as the ultimate civil engineering structure. The enormous energy of the water they hold can either be a vital source of electric power or have devastating effects on the populations and assets downstream. Hence, dams remain under constant scrutiny and their owners regularly perform maintenance or upgrade operations, to address the following problems:

- Aging and deterioration of concrete structures or mechanical components
- Seepage within the dam or its foundations
- Insufficient safety factor against instability of dam in case of flood
- Insufficient storage capacity



▲ *Wivenhoe Dam, Australia: Spillway stabilisation with large capacity rock anchors*

Global Expertise

Whether you manage a concrete dam, a rock or earth filled gravity dam or a water levee, the Soletanche Freyssinet Group provides a wide range of specialist techniques and capabilities in the fields of geotechnical and civil engineering. Drawing on the history of each subsidiary, we collect an impressive portfolio of solutions in dam maintenance and upgrade as well as new dam construction.

▶ *Arapuni Dam, New Zealand: Fissure grouting and jet grouting*

Front Cover: Cotter Dam, Australia: GIN Grouting

Integrated Repair Solutions

We offer integrated solutions combining design, supply and installation, either as a specialist subcontractor or as the main contractor. Guided by the Group motto "Sustainable Technology", we liaise closely with our clients to provide technical excellence in well established solutions or cutting edge techniques developed by our engineers.

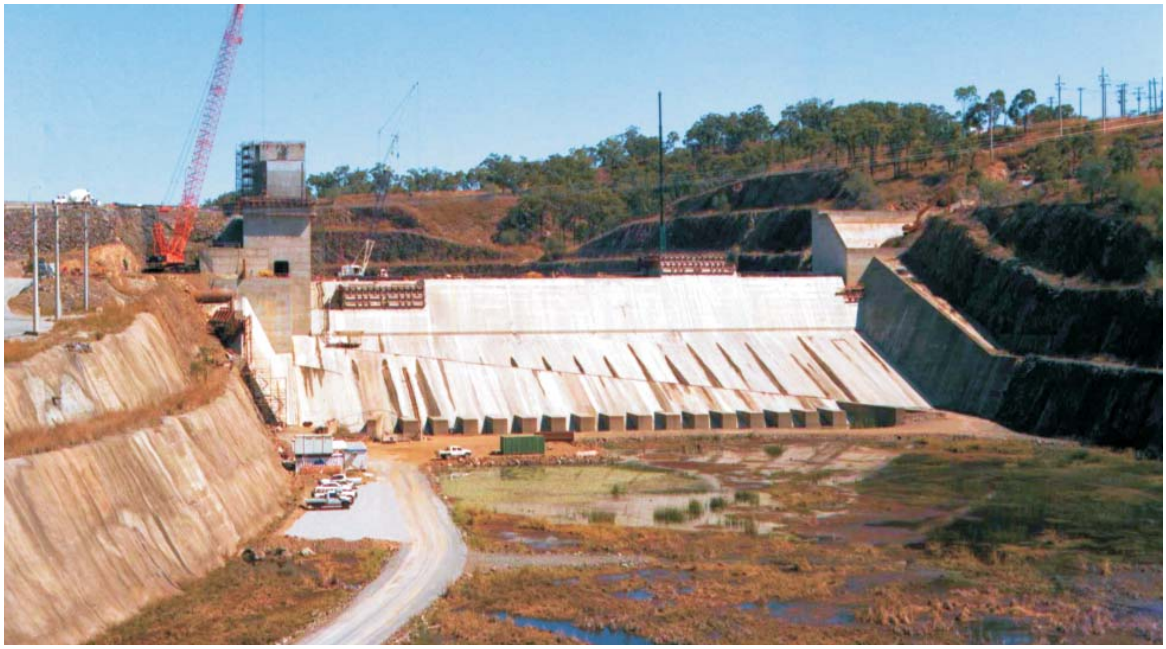
The Group offers a one stop shop for a wide range of techniques:

- Vertical anchoring with ground/rock anchors
- Structural concrete repair and strengthening
- Cut off barriers and drainage of embankment dams
- Seepage control by foundation grouting
- Increasing dam and spillway capacity with fusegates
- Structural and soil continuous monitoring
- Geomembranes

▲ *Clyde Dam, New Zealand: Stabilisation of a rock slope by grouting on left bank of dam using permeation grouting.*

Local Experience

Safety of the workers and of the dam is the first priority for the Soletanche Freyssinet Group. Usually involved in the early stages of projects, the Group entities are working closely with dam owners to analyse and find optimum solutions satisfying all their requirements.



◀ *Awoonga Dam, Australia: Foundation drilling and grouting*

ANCHORING

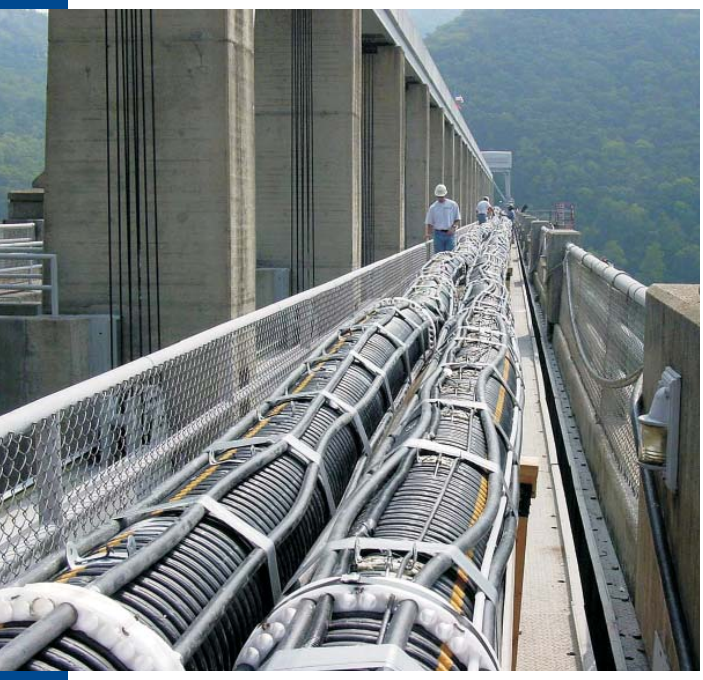
Post-tensioned ground/rock anchors are an efficient way to increase the stability of a concrete dam, or to facilitate an increase in the crest height.

In countries such as Australia or the USA, the local subsidiaries of the Soletanche Freyssinet Group have long track records of dam anchoring, having installed some of the largest capacity anchors in the world. We ideally combine:

- Precise drilling capabilities, using the most recent correctional large diameter drilling techniques of Soletanche Bachy to an angular accuracy of 0.5%
- Fabrication of double anticorrosion protection anchors using the know-how of Freyssinet in post-tensioning
- Specialist plant for safe installation of large anchors, and suitable jacks to stress and proof-load these anchors up to 23,000kN

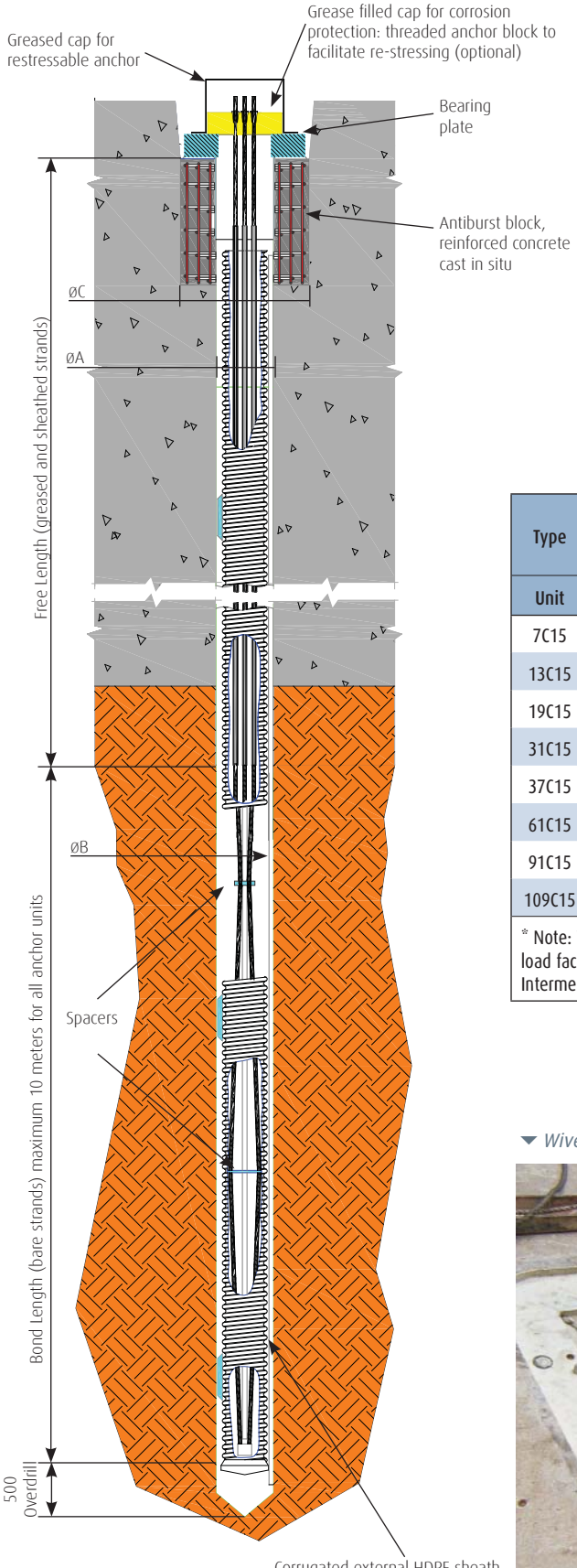
Soletanche Freyssinet anchors are restressable and can be fitted with permanent monitoring sensors, or weighted through periodic inspections.

We also supply and install a high quality stressbar called Freyssibar for stabilising anchors or nails in dam embankments, galleries and spillways.

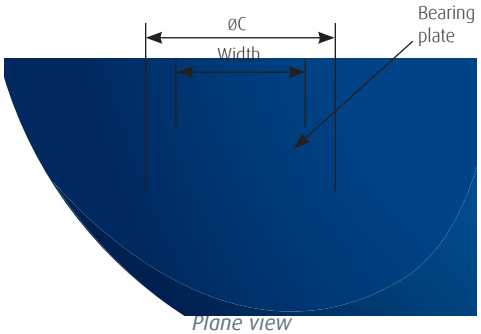


▲ *Bluestone Dam, USA: Large capacity prefabricated 61 strand anchors*

▶ *Ben Chifley Dam, Australia: Temporary access platform for installation and post-tenioning of 31 strand anchors*



Vertical cross section of a typical rock anchor



Plane view

Type	Strands	Ultimate Capacity	Working Load*	Bore*	HDPE Sheath	Bearing Plate			Antiburst Core*
Unit	No.	kN	kN	øA	øB	Width	Thick	Hole	øC
7C15	7	1,950	1,170	150	100	260	40	83	370
13C15	13	3,630	2,175	175	125	340	50	127	500
19C15	19	5,300	3,180	215	152	410	60	143	580
31C15	31	8,650	5,190	255	194	520	80	182	740
37C15	37	10,320	6,195	255	194	550	80	203	780
61C15	61	17,020	10,210	315	258	720	110	332	1,020
91C15	91	25,390	15,235	360	300	870	150	350	1,240
109C15	109	30,410	18,250	360	300	870	150	350	1,240

* Note: Values based on 4 MPa strata shear strength, 40 MPa concrete strength and 60% UTS working load factor
Intermediate units are available on request.

▼ *Wivenhoe Dam, Australia: 61 strand anchor head*

FOUNDATION GROUTING

PERMEATION

Foundation grouting is the injection of a material, usually cement grout, into the foundations of the dam, such that a permanent inclusion is achieved into the pores and fissures reducing the permeability and compressibility of the rock. Two methods are commonly used, Permeation and GIN Grouting.

Permeation grouting relies on impregnating the voids and fissures within the rock and underlying structure and thereby displacing water and air from the voids and replacing it with grout, without hydro-fracturing the existing fissures in the rock from the application of excessive grout pressure.

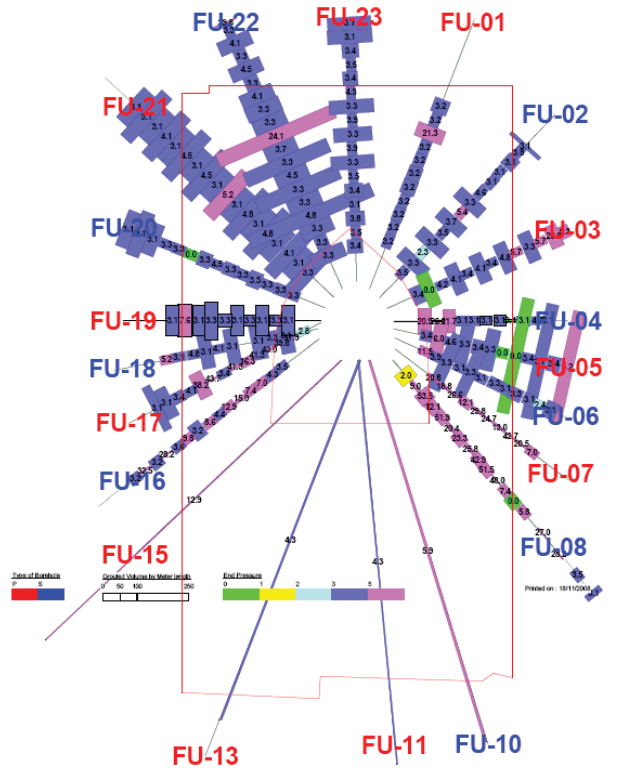
Although grouts are most commonly cement based, they can be combined with clay or fly ash. Other grouts include resins, bitument based emulsions and chemical grouts.

Grouts are required to have high levels of fluidity and stability and in the case of high penetration, particulate grouts contain extremely fine particles.

▲ *Teesta Dam, India: Jet grouting and grout injection*

▶ *Salanfe Dam, Switzerland: Grouting works on a deep cut-off curtain in rock*

Grout Intensity Number



GIN graph of grout infusion generated by Soletanche Bachy software

Grout Intensity Number (GIN) grouting is a method of permeation grouting developed by Dr Giovanni Lombardi for the sealing of rock fissures beneath a dam. It offers a different approach to permeation methods and other concepts of rock grouting. Indeed the grouting parameters are defined prior to the introduction of grout from a preliminary campaign of water testing and trial grouting.

GIN grouting methodology relies heavily on preliminary trials, to facilitate the adoption of an "Intensity Number", maximum pressure and maximum consumption from which a GIN curve is derived. The trials are used to determine an appropriate grout consistency. Then the adopted GIN parameters and mix design are used throughout the subsequent contract works, eliminating the need for water testing and manipulation of grout consistency.

Soletanche Bachy has developed computer controlled grouting equipment to ensure the optimal implementation of the GIN method and has many references for its application throughout the world.

Cotter Dam, Australia: GIN grouting

CUT OFF BARRIERS AND DRAINAGE

▲ *Wolf Creek, Kentucky USA: Hydrofraise ready to start cut-off wall excavation*

▲ *Leigh Reservoir, United Kingdom: Cement bentonite cut off barrier installed from the dam crest*

The most important component of an earth dam is the core, the function of which is to create an impermeable barrier within the dam, in order to prevent the flow of water through the dam embankment. However the material properties of the core will change in the long term.

When a dam core ceases to perform its function satisfactorily, remedial measures may be needed to address the deterioration of the core cut-off barrier.

Similarly during the service life of a dam, foundation rock may degrade as evidenced by increasing seepage below the dam. In this case a similar range of measures can be invoked.

Jet Grouted Columns

An arrangement of overlapping jet grouted columns to form a continuous impermeable barrier provides an economical solution of dam core rehabilitation for depths of up to 30 metres. Soletanche Bachy teams have perfected the technique of jet grouting over many years, and are well qualified to treat the most critical dams.

DRAINS

Slurry trench technology, employing a ground supporting slurry to stabilise the trench excavation, forms the basis of cut off wall installation. The slurry in the trench may be self hardening, as with bentonite cement or may be replaced with impermeable backfill material, as with the soil bentonite and diaphragm wall method.

Where deficiencies are identified in the foundation rock as well as the dam core, the diaphragm wall method offers the means of installing a cut off barrier by using excavation equipment purpose made for cutting through the rock.

Cut Off Walls

Permeable barrier collector drain excavated under biopolymer. First used in Australasia at Hays Creek Dam in New Zealand

A drainage cut off barrier offers an alternative to the more common impermeable barrier techniques. Any upstream seepage is collected in the barrier and removed by pumping, thus avoiding the destabilising effect of elevated pore water pressures in the downstream embankment.

The method employs typical slurry wall techniques modified with degradable biopolymer slurries to stabilise the trench excavation. Subsequently, these polymers degrade or are degraded to leave a drainage curtain.

A further application of drains is the use of stone columns at the toe of the downstream embankment, which act to relieve elevated pore water pressures and improve soil shear strength characteristics.

▼ *Wolf Creek, Kentucky USA: Cut off diaphragm wall installed from the dam crest 1.4km long*

CONCRETE REPAIR

Freyssinet's well recognised capabilities in concrete repair and structural strengthening have been applied on many dams and hydro-electric structures since 1975. Freyssinet can address the dam itself or inlet wells, pressure pipes, ancillary structures and mechanical components, such as radial valves.

MASONRY OR CONCRETE REPAIR AND PROTECTION

- High pressure water washing or sanding of dam facing to eliminate pollutants
- Breakout of spalled concrete, reinforcement protection and surface preparation
- Crack injection with cement grout, epoxy resin or aqua-reactive resin, where active water seepage must be contained
- Impermeable coatings
- Protection of facings with anti-abrasion systems, eg ultra-high performance concrete

▲ *Pouzin Dam, France: Treatment of the corroded reinforcement steel*

▼ *Pouzin Dam, France: Repair of the concrete with anti carbonation coating*

▼ ▲ *Grangent Dam, France: Dewatering and repair of radial gate lower anchors with new tie rods, including provision of mast climber access*

Structural strengthening

- Shotcrete repair on concrete facings
- Application of bonded carbon fibre reinforced polymers (CFRP) against static and dynamic solicitations (seismic)
- Jacking of dam elements to reinstate compression with flat jacks
- Drilling and anchoring of additional structural or mechanical components
- Underpinning works

Freyssinet usually works as a head contractor and our teams manage all the aspects of the repair project:

- Optimise the repair methodology in accordance with the specifics of the site, often in a remote location
- Design and install safe specialist access systems
- Provide environmental controls and collect any effluent
- Coordinate with the dam operator to meet safety and operational constraints

ADDITIONAL CONCRETE ELEMENTS

Freyssinet's core business in post-tensioning has lead to multiple applications for any civil engineering structure.

The following techniques are particularly relevant to add or replace structural elements on dams:

- On site precasting of large concrete elements, out of match cast modules assembled by post-tensioning
- Lifting and handling of heavy loads using strand lifting jacks

These techniques have been applied to:

- Replacing access bridges or spillway gates
- Installation of precast concrete shafts such as fish lifts or pumping inlets
- Assembling and erection of fusegates to increase storage or discharge capacity

▼ ▲ *Tallowa Dam, Australia: Installation of a fish lift with strand lifting jacks*

▲ *Vallabregues Dam, France: Removal and replacement of a bridge over a spillway*

GEOMEMBRANES

Freyssinet offer waterproofing geomembrane systems as a well proven solution to restore dam impermeability compromised by aging or environmental aggression. These geomembranes have been used on more than 100 dams worldwide since 1970.

In concrete dams watertightness is generally lost by the formation of cracks or by the deterioration of concrete. Similarly in masonry dams the sealing of the joints between the stones can degrade. In both cases, geomembrane systems provide a long-term repair method, which can be installed on the dam facing with minimum surface preparation. Their impermeability is not affected by the environmental conditions at the time of installation.

In embankment dams watertightness can be lost also due to settlements in the dam body or to differential movements that can occur between the dam body and the concrete appurtenances. A geomembrane system will cover cracks in concrete or bituminous facings. Furthermore, with its high ultimate elongation a geomembrane system can sustain settlements and differential movements without leaking.

Geomembrane systems can be installed underwater, at any depth, thus reducing the impact of repair works on the dams operation. Rehabilitation with geomembranes, in the dry and underwater, has been made either to waterproof the entire upstream face of the dam, or only critical areas or cracks.

▲ *Moravka Dam, Czech Republic: Exposed PVC geomembrane to rehabilitate an embankment dam with bituminous concrete facing*

▶ *Kadamparai Dam, India: Exposed PVC geomembrane to rehabilitate a 67m high masonry dam*

INSTRUMENTATION AND MONITORING

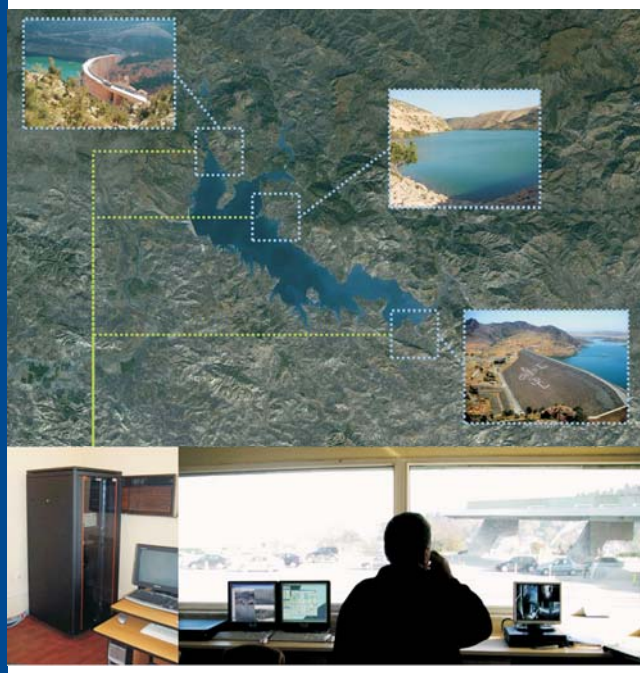
Soletanche Freyssinet has developed high performance instrumentation specific for dam monitoring.

ADVITAM

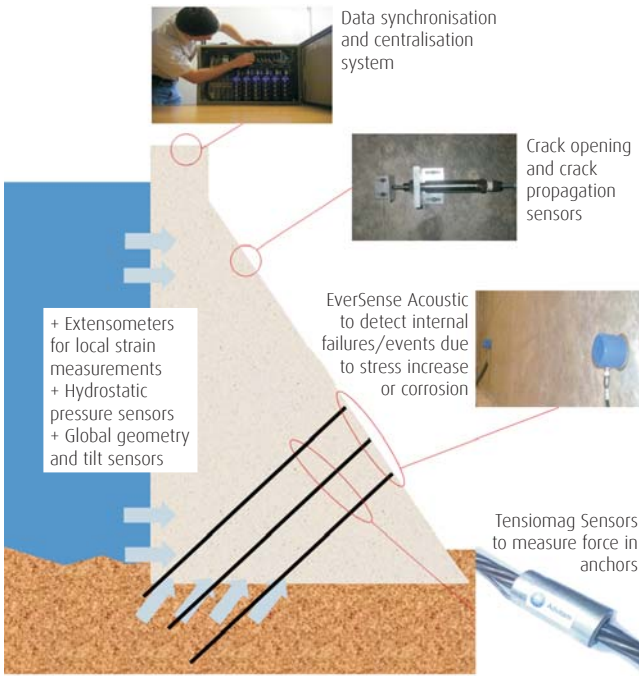
With Advitam Freyssinet offers an integrated solution for long term surveillance, centralising in real time any type of information and providing engineered and directly exploitable data, the EverSence monitoring system.

EverSense analyses the structural behavior from a diversity of sensors located on the dam and its surroundings, detects abnormal events and sends real time alarms.

- Monitoring of tension in rock/ground anchors
- Detection of corrosion in strands for durability assessment
- Monitoring of hydrostatic pressure and leakages
- Monitoring of crack opening and crack propagation
- Surveying of dam geometry and tilt
- Monitoring of global and local strain



▲ *Data centralisation and operation*

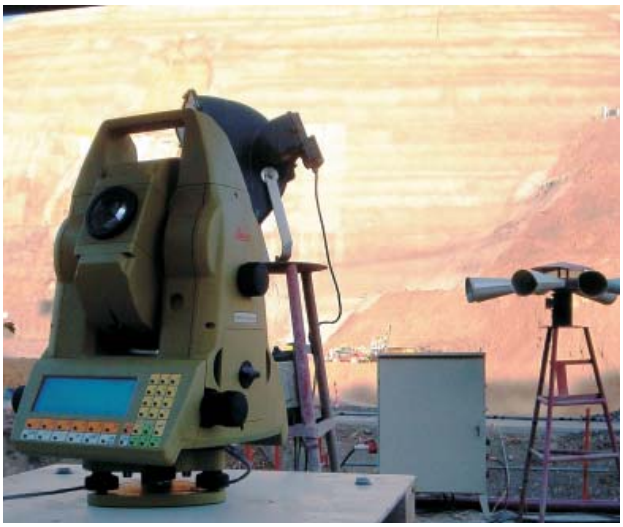


▶ *EverSense dam monitoring systems*

SOLDATA

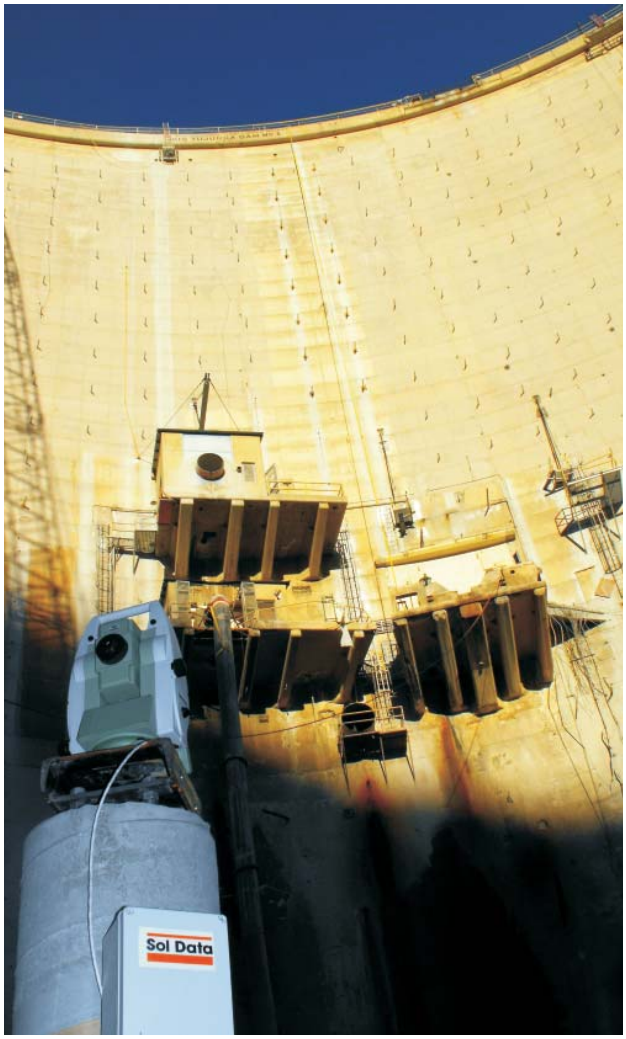
SolData, the Soletanche Bachy subsidiary specialising in instrumentation, focusing on advanced techniques, such as real time and automatic measurement/acquisition systems. They use powerful databases, Geographical Information Systems, inhouse software to provide the client with a global secure access to necessary information at the right time on their assests:

- Survey of dam, embankment or nearby terrain
- Water seepage measurement
- Monitoring of pore water pressure
- Test anchor monitored by the geoscope software which enables the derivation of stress-strain curves

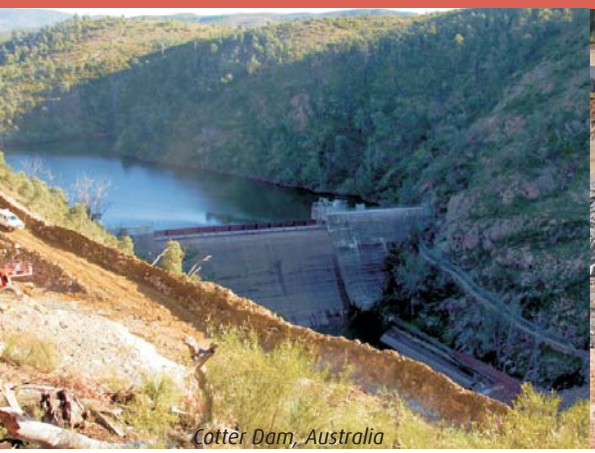


▲ *SolData Koudiat Dam, Morocco*

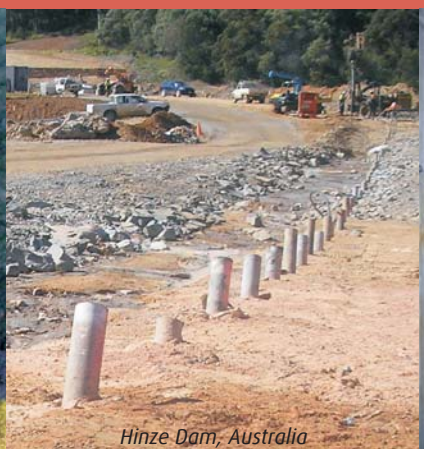
▼ *SolData Big Tujunga Dam, California, USA: Installation of two cyclops, 30 prism targets and Real Time monitoring*



▼ *SolData El Atazar Dam, Spain*



Cotter Dam, Australia



Hinze Dam, Australia

Warragamba Dam, Australia

FREYSSINET

MENARD BACHY

Level 3, 13-15 Lyonpark Road, Macquarie Park NSW 2113
Tel: +61 2 9491 7177 - Fax: +61 2 9491 7199
www.freyssinet.com.au
www.menardbachy.com.au

September 2010