Soils&Structures

THE FREYSSINET GROUP MAGAZINE

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N° 218 **September - December 2003**

3,110 m² of TerraClass in Canada

Reinforced Earth Company Ltd. designed and supplied a 12m high, 3,110 m² precast TerraClass facing, which provided long approach retaining walls and bridge supporting abutments over the Puntledge River located near Courtenay, British Columbia on the west coast of Canada.
Since the walls were erected within an old growth rainforest, mature trees and ferns are proximal to the entire wall perimeter. Reinforced Earth building techniques minimized potential damage and impact to the surrounding vegetation during construction. The base of the structure is entirely founded on bedrock, thus eliminating the concern for potential soil erosion and silting within the river floodplain. The Vancouver Island mountain range lies immediately to the east and water levels can vary considerably over short periods of time due to mountainous snowmelt.

Record arch in Poland

Freyssinet Polska is participating in the construction of the new Wolin Bridge in North-Western Poland near the border with Germany. Works started in January 2003 and forms part of a global program to improve infrastructures and stimulate the development of tourism. This 25 m high steel arch bridge is the largest of this type in Poland, with its 180 m long and 12.8 m wide main span suspended above the Dziwna river by 104 stay cables. Freyssinet Polska is doing the prestressing work for the access spans (348 12C15 tendons, 108 12CC15 couplers, giving a total of 180 t of steel), and is supplying the pot bearings and the stay cables.

Strengthening in the United Kingdom

Freyssinet Ltd and its Corrosion Control Services Ltd (CCSL) subsidiary have just completed the strengthening of Blake Bridge in the South West of the United Kingdom, carrying two lanes over the Parrot river close to the town of Bridgewater in the county of Somerset. The work consisted in placing new bearings and expansion joints, and strengthening the bridge structure by the application of carbon fiber boards on the underside of the deck. Cathodic protection was also installed on the piers and abutments.

Kickoff in Lisbon

The European nations football championship that Portugal will host in 2004, was the reason why the government decided to launch an enormous stadium construction program and to renovate its facilities and transport and communication networks. The José Alvalade XXI stadium used by the Lisbon Sporting Club was built for the occasion, and its main feature is a 25,670 m² roof suspended from 4 mast using 16 stay cables. This system, supplied and installed by Freyssinet-Terra Armada SA, uses a new generation Freyssinet anchor device. A show tracing the history of the club and a match between Sporting and Manchester United were the two highlights of the inauguration of the structure on August 6 2003 - a celebration attended by 50,000 spectators, including the Portuguese Prime Minister José Manuel Durao Barroso.

Millau: Stay cables for positioning

Stay cable work on the Millau viaduct project in France started in early summer 2003 when Freyssinet installed cantilever suspension stay cables to support the deck placed by incremental launching. These permanent «launching» stay cables are temporarily fitted with deviation saddles on the tower and the deck, to resist the large catenary variations during incremental launching.

IN BRIEF

▶TURKEY
REAS, Reinforced Earth's Turkish subsidiary, is currently completing the construction of retaining walls on the Gerede-Gümüsova motorway. At the same time, the company is working on six major projects with the Motorways Division and the City of Istanbul, and it has already constructed about 20,000 m² of retaining walls for the city.

▶PANAMA
After lifting the mobile formwork travellers, Freyssinet will supply and install the entire prestressing (750 t) and stay cables (1,320 t) for the new bridge under construction over the Panama Canal.

▶SPAIN
Ménard Soltraitement is currently working on three different sites. The first two sites in Andalusia apply to the construction of the Jerez western ring road and the Los Barrios bypass close to Algesiras, dealing with the construction of 245,000 ml of vertical drains (6 to 16 m deep). The third is located in Martorell, near Barcelona, on the future high-speed line between Madrid and the French frontier, and includes the treatment of 9,000 m² of soil by stone columns.

▶UNITED STATES
Reinforced Earth, the Group's Canadian subsidiary, was awarded two construction contracts for TechSpan arches in Austin, in the state of Texas, in July and September.

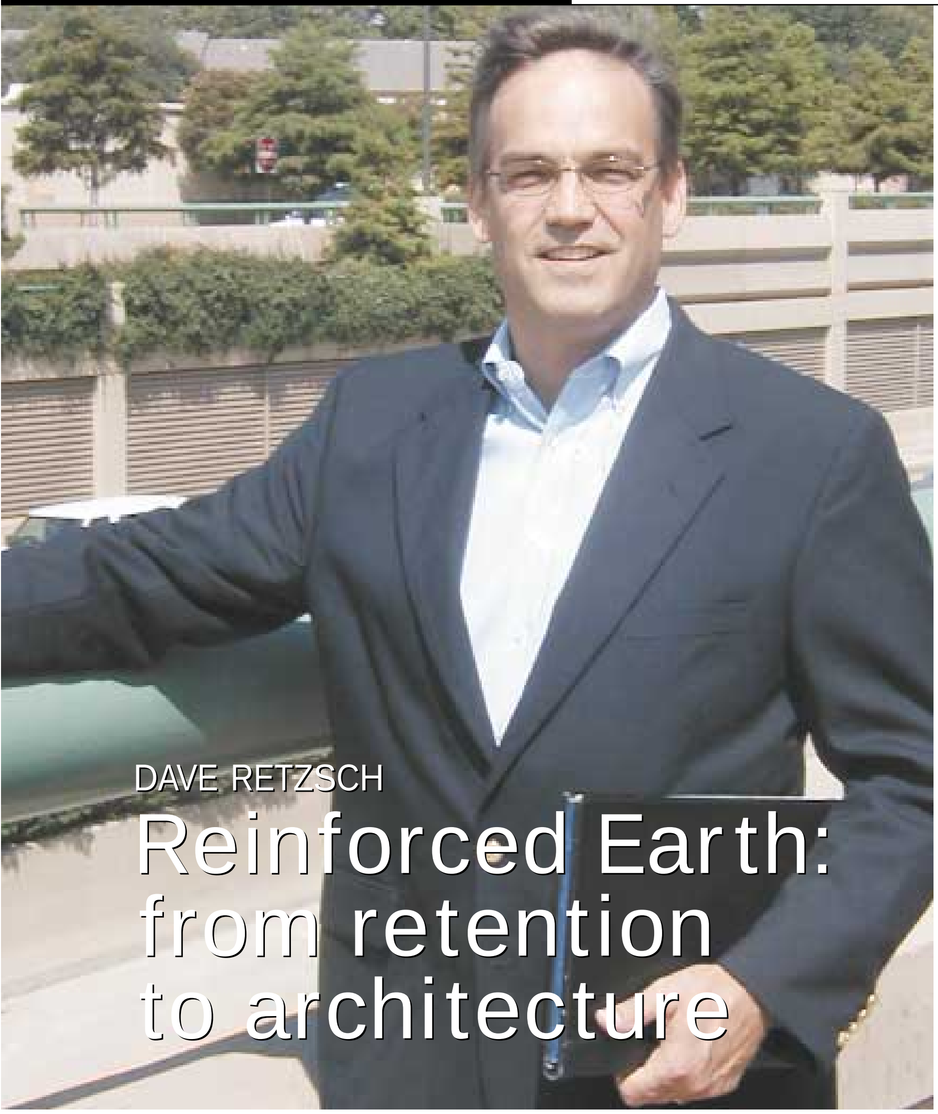
▶UNITED KINGDOM
Ménard Soltraitement is constructing the foundations for the London section of the future Eurostar line (CTRL) (contact 310). 30,000 m of Controlled Modulus Columns (CMC) were already built by mid-September.

33,000 m²
of retaining walls in France

Terre Armée SNC has just been awarded the contract for supply and technical assistance with the construction of Reinforced earth retaining walls (33,000 m²) for the section of the A51 motorway (Grenoble-Sisteron) climbing Coynelle hill as far as Fau Pass. The work will be started in March 2004.

Reinforcement on trial

The Reinforced Earth Company South Africa was awarded the contract for the design and supply of spandrel walls for the main crusher in an open cut diamond mine in Elisabeth Bay, in the Namib desert (Namibia). The structures are 16.6 m high and 180 mm thick, and when they are completed, they will comprise 1,136 m² of TerraClass facing. It was decided to use Freyssisol synthetic reinforcement because the presence of highly corrosive iodized chlorides in the local backfill prevented the use of conventional steel reinforcement.



DAVE RETZSCH

Reinforced Earth: from retention to architecture

Reinforced earth constructions are increasingly being used as a form of architectural expression. Dave Retzsch, landscape architect at Carter & Burgess, one of the largest architectural practices in the USA, gives us his view of this new development.

Soils & Structures. - **Over the past few years, retaining walls have started to become real "art walls". Why do you think this is happening?**

Dave Retzsch. - I think that landscape architects are now giving more thought to functional issues like retaining walls and making them an integral part of their designs. This development is the result of changes in the way the profession thinks, especially when it comes to urban projects where people are very sensitive to the improvements we can make to infrastructure and architecture. Reinforced Earth products have proved very popular with the general public and have therefore made a major contribution in this direction.

From the financial point of view, the economies we can now make on a project by using today's construction technologies and methods are also giving us much greater architectural freedom. Here again, Reinforced Earth is a very good example. For project managers like me, it's comforting to know that we can create architectural structures at an affordable cost – which means our approving agencies will accept them – and deliver faultless quality consistently.

"Reinforced Earth's wide range of designs and the opportunity to create customized shapes and patterns gives us the opportunity to put a lot of innovative ideas into practice."

How do you choose the architectural designs and panel layouts for a Reinforced earth structure?

Every project is unique, so when we set out to design a new structure, we do so with no pre-conceptions. On the other hand, we prefer to use flexible construction systems that lend themselves to a wide range of designs.

In most of our projects, we are looking to create environmentally sensitive architectural solutions, which is part of what makes every structure individual.

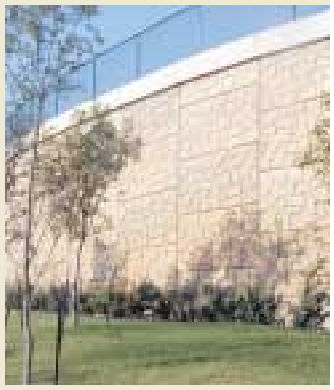
From this point of view, Reinforced Earth's wide range of designs and the opportunity to create customized shapes and patterns gives us the opportunity to put a lot of innovative ideas into practice.

Reinforced earth structures have a variety of applications and they are really integral to many landscape architectural designs.

At Carter & Burgess, we

take the view that structures - whether civil engineering structures or otherwise - and retaining walls are all part of an overall architectural composition. All these elements are interlinked and must work together consistently in the context of individual structures or sites. That's the kind of thinking that led to our design for the North Central Expressway in Dallas. The project involved a long expressway "corridor" – something we know a lot about, having created the concept – in which structures and retaining walls coexist as part of a single design theme.

So in your view a retaining wall can never be treated in isolation?
Well, that obviously depends on the structures concerned. Sometimes the retaining wall is a separate structure with its own design, but still forms part of an overall project. For the Interstate 30 project in Dallas, Texas (which also involved Reinforced Earth USA), we are building a large mural which we are approaching in the same way as a painter might approach a canvas. This retaining wall is distinctive in its artistic concept, but does not stand in isolation because it is integrated into an overall design.



1 – TerraClass (A16, Boulogne-sur-Mer, France).
2 – TerraTrel (interchange Spaak, Montpellier, France).
3 – TerraPlus (Wholesale Club, Texas, USA).
4 – Composition TerraPlus-TerraClass designed by Carter & Burgess for the Central North Expressway in Dallas (Texas, USA) .

At the service of the environment and sustainable development

TerraClass, TerraPlus, TerraTrel... the facings of Reinforced earth walls designed by Reinforced Earth are available in different patterns, colours, textures and materials, which clearly demonstrates the flexibility of the process. Main contractors can create simple or complex, round or straight shapes, and play with size variations and, for certain works, even create vegetal landscaped compositions. Works made in Reinforced earth can be blended in the urban or rural environment and have become genuine works of art, in particular under the impulsion of the USA since the beginning of the 1990's. Reinforced earth is a preferred technique as far as sustainable development is concerned since it makes use of natural backfilling materials and is characterized by specific features such as cleanliness (no pouring of concrete; no heavy equipment required for assembly), rapidity (optimised laying techniques using precast elements) and preservation of the environment (in particular owing to the smaller-scale backfill).

What is your opinion of the panel joints in MSE walls, which, although they interrupt the design, also seem to become part of the pattern?
Since these joints are an integral part of the technology, we are able to work with them. Sometimes, we start with the joint line pattern and it's that which inspires our architectural design and determines the pattern repeats for the entire structure. Other times, we might change the shape of facing panels to achieve a particular look. Reinforced Earth technology is so flexible that we can create one-off designs, while still using the same technology.
Another way of limiting the perception of these joints has resulted from the permanent contact we have with Reinforced Earth USA and that's the idea of creating larger panel sizes, which in turn provides additional design possibilities.

As a landscape architect, do you prefer to use cast-in-place or precast elements for retaining walls?
Actually, I don't really prefer one over the other, but I certainly appreciate the benefits that come with the precast systems in terms of economy, consistency and quality control. Precasting is the preferred mean of obtaining the custom finishes, patterns and architectural motifs we are looking for.
Even though precasting gives better results, every project is intrinsecally complex with different design conditions that require adapted solutions.
So it's good that we have the option to exploit several design alternatives. But the two techniques are compatible and can even complement each other: Reinforced Earth structures are flexible in the way they can adapt and complement other cast-in-place elements as part of the same project.

Do you see the increasing demand for retaining walls as linked to the emergence of sustainable development as a concept?
By allowing us to construct clean durable structures that integrate perfectly into their environment at the same time as preserving natural landscape characteristics, Reinforced Earth seems to complement the sustainable development concept in most cases. Given these considerations and the other advantages they offer – element precasting, speed and flexibility of installation and so on – Reinforced Earth structures undoubtedly have a great future ahead. ■

In the name of innovation

Over the last fifty years, Freyssinet has created an image for itself as a group offering its customers the most sophisticated solutions to soil and structure problems.This passion for invention and perfection was inherited from its founders, and it is also the fruit of an ambitious research policy. Food for thought.

It does not matter if they were awarded by outside organizations (Egis, FNTP) or other initiatives (VINCI innovation award), but the distinctions received since the beginning of the year by Freyssinet for innovation are a good reason for satisfaction and pride, and Bruno Dupety, the Group's Chief Executive Officer makes no secret about it. He is not at all surprised about these awards. "Creativity and innovation form part of our Group's culture and form the heritage from our famous inventors" he says. Eugène Freyssinet, Louis Ménard and Henri Vidal each took steps in their own time to ensure that new construction methods would become universal technologies. And these new technologies now form the foundation for the Group's know how. After the prizes awarded to Régébéton (Siemens prize 2002), and Carbon Fiber Fabric at the end of the 1990s, each of these awards (see p. 19) helps to illustrate the efforts made over many years.
However, some distinctions are unavoidable: "When we talk about innovation, says Bruno Dupety, most of the time we are talking about tools, methods and ways of applied to an original expertise to improve its productivity and efficiencies. But innovation can also mean an entirely different type of invention. Prestressing, stay cables for the Freyssinet system, Reinforced earth, pressure meter and dynamic compaction all suddenly appeared among established construction methods at a given moment, and caused genuine revolutions. Making a distinction between these perspectives is of overriding importance in a Group like ours.

Anticipate new customer needs

"Innovation, characterized by short cycles, is based on experience and takes its inspiration from real projects. Its purpose is to improve techniques so as to be competitive on our markets and to lower production costs. Everyone is concerned.
Research and Development take place before projects or contracts and they need extensive means. The cycle is three to five years longer. It is a strategic approach, since we must anticipate new needs of our customers, new means of construction, or higher qualitative performances to be achieved, in order to broaden our offer."
Freyssinet's research policy implemented by the Group's two Technical Divisions is to set aside 3% of the 2003 salary cost for research. Projects adopted by General Management prepare for the future and future contracts.
This is the case of the "high performance tensile system", which was awarded the FNTP first prize this year for "research oriented towards the development of deep water offshore, for which we took the entire initiative and a creation that is expected to develop into a long term activity for the Company" says Bruno Dupety. This is also the case for soils, with Controlled Modulus Columns (CMC) that have recently been patented in the United States. "This revolution in foundation design that generated sales of 8 million euro in 2003 and that will probably also be approved by the Véritas inspection agency, passed unnoticed by the juries. But as Bruno Dupety says, although we are delighted to receive awards, the main purposes of our innovation and research policy is to continue to make progress in satisfying our markets, so that we are always at the forefront of our technologies and our businesses.
"Like our prestigious founders, we are not worried about sometimes being ahead of our time. Their exemplary tenacity has resulted in many attractive companies making sustainable long term profits."

Soil: major progress every five years

Soil mechanics is characterized by its complexity and it is still a young science, says Pierre Berger, the Freyssinet Soils Division Manager. Over the last 35 years, Ménard Soltraitement has been working in a specialty activity based on two of Louis Ménard's inventions, namely the pressuremeter and a mathematical equation for modeling soil behavior, and the Company has remained innovative throughout this period, marked by a major advance approximately every ►►

"The main objectives of our innovation policy are to be at the

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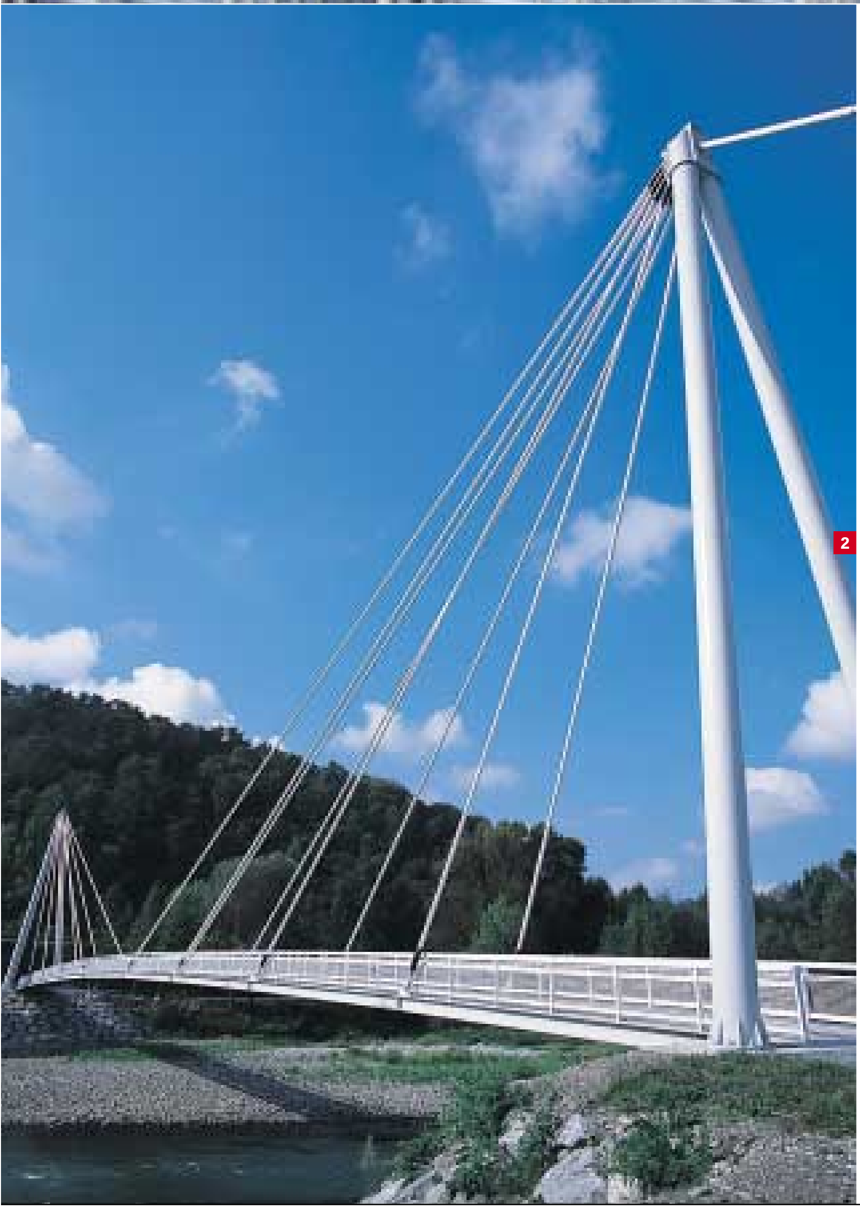

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1. REINFORCED EARTH the construction principle for Reinforced earth structures invented by Henri Vidal in 1963, has now become very popular compared with other existing technologies. Since that time, applied research has continuously improved the technology. The last innovation to date, the HA Ladder reinforcements optimise friction surfaces.

2. COMPOSITE CABLES made of carbon fibre cables and their innovative anchor system, or «high performance tensile system», used in this case on Laroin footbridge (Pyrénées Atlantiques) were developed to solve anchorage needs for offshore platforms that, in the future, will exploit very deep oil bearing deposits.

3. BOTTOM FEED, an innovative feed system for filling stone columns, designed by Ménard Soltraitement, makes vibro-replacement possible for port work and offshore work. This soil stabilization method originally limited to land applications was recently used in the Port of Dunkirk.

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leading edge of our technologies and businesses at all times".

►► five years. This Company's activities have never been separated from research, and every new contract provides an opportunity to think about the optimization of calculation methods or technologies.

Structural research at Ménard Soltraitement is organized around these two main themes; calculation methods are used by engineers who account for one half of the work force, and machines are of overriding importance. We design them ourselves, and they must be powerful, reliable, lightweight, fast and easily handled" said Pierre Berger, reminding us that extraordinary machines were developed in the past, such as dynamic compaction by 250 t masses used in the 1970s on the Nice airport extension site.

1.5 million m² of walls of Reinforced earth made throughout the world every year

After the development of the dynamic compaction technique, the first technique for which a patent was deposited (1969) and that resulted in a saving of 30 to 50% on the construction of conventional foundations using a pile-cap supported on piles in sandy ground, it was quite natural to search for processes adapted to clayey soils, and then to heterogeneous soils and deeper and deeper treatments. Thus, the first step was stone columns (1975), the Menard Vacuum (1988) and then Controlled Modulus Columns (1994).

Vibro-replacement is the most recent in this chain of continuous progress, and illustrates the conquest of new applications by improving machines, and was first used in San Diego, California, in early 2003, and more recently at Flandres wharf in Dunkirk. Due to the special bottom feed system for filling stone columns, the range of application of vibro compaction is now extended to include offshore and particularly harbour works, where its performances give it an advantage over expensive and slow backfill methods.

"With reinforced earth, says Pierre Berger, we have an ingenious invention that in the 1970s became popular very quickly because it halved the cost price for construction of reinforced concrete retaining walls. About 1.5 million square meters of Reinforced earth walls are constructed every year every where throughout the world using this now mature technology, which consists of optimizing design calculations and structures and proposing solutions for all possible cases – such as corrosive media, walls built under water or in the immediate proximity of a vertical rock surface, etc. At the same time, the architectural nature of the technique opened up other research opportunities, aiming at better integration of surface panels in the environment, or the broadening of solutions offered to main contractors (TerraPlus, TerraBlock systems). The most recent of these concepts includes a surface panels system that, like a puzzle, is composed of immense frescos and is extremely successful on the other side of the Atlantic.

Structures: continuous progress with stay cables

"Innovation starts with the structure" says Jérôme Stubler, the Freyssinet Structures Division Manager, convinced through his experience with stay cables - looking at progress on the Normandy bridge site (1995), until development of the HD stay cable, the most recent in the range used on Seohae bridge in Korea, Rion-Antirion bridge in Greece, and Millau viaduct in France – but the same is true for the genesis of the Cohestrand and the collar systems developed for Aquitaine bridge. In every case, the impetus and then progress were based on a study of the specifications. "Normandy Bridge has twice the span of previously constructed cable-stayed bridges, and it marked the first successful use of the patented Isotension process, a new method of placing and tensioning stay cables strand by strand. Similarly, research on the aerodynamics of stay cables and means of damping vibrations created by the wind, have resulted in the development of damper systems and special devices such as helical spoilers welded to ducts. Once problems have been stated, the time necessary for the test and validation period for these key ideas is becoming continuously shorter. In 1999, an ambitious approach centered on a simple question – what information is necessary to make an ideal stay cable? – was backed by the will to sustain and consolidate progress. Three new processes were patented after this study, to protect stay

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The durability and chemistry of materials are becoming increasingly important in civil engineering.

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cables against bending phenomena, to improve the leak tightness of anchors, and to optimize placement systems.

5 to 20 years ahead of the competition, largely due to patents

Continuing research, particularly to improve cable durability, led to the development of Freyssinet anti-UV ducts, internal and external dampers, the Fire Protection Process (FCP - Fire Cable Protection) and the "high performance tensile system".

"Over the last 50 years, says Jérôme Stubler, Freyssinet has been promoting innovation in soils and structures, and has kept a lead of 5 to 20 years over its competitors due to patents and particularly to precisely described know how". Apart from these constraints particularly due to the design of structures, innovation also consists of searching for better cost effectiveness, using mature techniques such as bearings, prestressing and expansion joints, for which it leads to improved production solutions, or design or manufacturing techniques. For example in prestressing, the process for manufacturing of ducts on site starting from (PEHD - Plyduct system) strips provided a means of eliminating transport costs for these elements; Similarly, SmartGel cement grout with programmed thixotropic and setting is made on site.

"Repair work will become increasingly important in the world, but we are only at the beginnings", says Jérôme Stubler. There is enormous scope for investigation and the subject is ripe for innovation. Freyssinet is distinguished by its control over conventional solutions such as shotcrete (concrete restructuring) and additional prestressing (structural strengthening), and also in the last few years by the process for cold gluing of carbon fiber fabrics for strengthening of all types of structures, that is very flexible in use. Although we know how to calculate the forces of a structure with fairly good precision, we still have a lot to discover about steel corrosion phenomena and concrete degradation processes. Durability and chemistry of materials are the next challenge in civil engineering. Freyssinet has recognized worldwide experience with the treatment of concrete reinforcement by cathodic protection. The Régébéton concrete decontamination process illustrates this skill, and has already been used on several sites. We used to be mechanics, but we are now also chemists". ■

1. ORIGINALLY DEVELOPED for use on suspension bridges, Cohestrand can be used in ground anchors and in any application in which tangential forces are combined with the axial force from the cable. It is also used on the most recent generation of cable-stayed structures, such as Sungai Muar bridge in Malaysia (see page 15).

2. THE MOST RECENT Reinforced Earth structural surface panel system broadens the range of TerraPlus, TerraBlock and TerraClass systems, to increase the choice of architectonic expression.

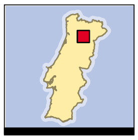
3. SEMI-RIGID AND CEMENTED INCLUSIONS, Controlled Modulus Columns (CMC) reduce the global deformability of a site. The process is particularly suitable for soft or organic ground that will need to resist high loads with severe settlement tolerances.

4. ATMOSPHERIC CONSOLIDATION PROCESS for highly compressible ground, Menard Vacuum consists in of creating a vacuum in an area previously confined by a sealed membrane, using a system of pumps, and with a drains network.

5. RÉGÉBÉTON is a process for regeneration of degraded concrete based on applying an electrolytic paste onto the surface of a structure. It was derived from research started in 1996, and is capable of modifying the basic pH of the material, attacked over time by atmospheric pollutants and chloride ions.

STRUCTURES / **CORGO VIADUCT**

1,080 t of tendons above the vines



Prestressing is conventionally used for continuous bridge deck spans, and is used everywhere on the Corgo viaduct, located in the North of Portugal, including in the construction of the central piers.

THE FUTURE IP3 MOTORWAY link between Viseu and Vila Verde de Rala at the Portugal's northern border will pass through a region with superb countryside consisting of deep valleys covered with vineyards, home of the famous Port wine. The IEP (Instituto das Estradas de Portugal - Portugal's equivalent of the Roads Division) decided to construct viaducts in order to protect this environment. The Corgo viaduct is the most remarkable of these viaducts, both in terms of its geometry and size, and work on it will be completed at the beginning of year 2004. Freyssinet - Terra Armada is supplying and installing its prestressing (1,080 t).

The Corgo viaduct will be operated for 30 years by Norscut, a joint venture composed of the French Eiffage, Egis, CDC Ixis and Contacto Holding companies, inaugurating the virtual toll system in Portugal in which the State pays the concession company an indemnity proportional to the amount of traffic.

Cantilever construction

This elegant viaduct crossing the imposing Corgo river valley between the towns of Peso da Regua and Vila Real was designed by the Portuguese engineer Armando Rito and built by cantilever construction. It comprises two parallel decks with an average length of 625 m (each composed of five spans: three central spans each about 145 m long and two 95 m long end spans, in which the 500 m radius of curvature is compensated by a constant cross slope of 7%. The depth of the reinforced concrete box beams forming the deck varies between 8.5 m for segments adjacent to the pier and 3 m for key segments. The tallest piers are supported on surface foundations and are up to 68 m high, so that the tallest cranes in the Spanish peninsula had to be used to construct them. "These piers are temporarily fitted with four vertical tendons with unbonded strands, to assure lateral stability of the bridge during construction", says Boris Vargas, engineer at Freyssinet-Terra Armada. This arrangement, similar to that used by Freyssinet-Terra Armada for construction of the nearby Regua Bridge in 1996, will compensate for overturning forces caused by the increasing eccentricity of the centre of gravity as cantilever construction progresses.

3 days per segment

Only the segments on the abutments and the end pier P4 are supported on the bearings. The other segments are built into the pier; the assembly is made rigid using eight permanent 15C15 vertical tendons to reduce the quantities of passive steel in the piers and prevent cracking. Temporary prestressing consisting of 19C15 tendons is used for pier P4, and will be removed after the deck has been keyed.

The successive cantilever construction method was chosen due to the very broken relief and the lack of roads to carry materials to site. Thus, each of the eight spans supporting the decks is composed of nineteen 13 m wide and 3.6 to 3.45 m long cast in-situ segments (varying due to the curvature of the bridge) and they are connected to each other by so-called span prestressing. Fifteen 25C15 and four 19C15 tendons will thus be installed on the outer deck, compared with ten 19C15 and nine 25C15 tendons for the inner deck. "The segment construction cycle takes three days, explains Boris Vargas. As soon as the reinforcing cages prefabricated near the site have been placed, Freyssinet's teams can install the prestressing ducts and insert the strands. Tensioning is done between 6 and 12 hours after concreting of the deck".

Continuity prestressing consists of two longitudinal tendons.

The Freyssinet team consists of six persons who will remain on site until April 2004 to complete the prestressing and install WP type expansion joints, and has received operational support from Freyssinet France specialists, particularly for general site organization. ■

A group contribution

The Reinforced Earth technology is also used on the IP3 site. Thus abutments of several viaducts including the Corgo viaduct comprise reinforced earth retaining walls equipped with cross-shaped facing (12,500 m²) and TerraTrel galvanized welded mesh facing (9,000 m²). Two TechSpan prefabricated arches were constructed close to the town of Vila Real to create a passage under the motorway backfill. Finally, beams prefabricated by Freyssinet-Terra Armada were supplied and installed for two small underpasses in the same area.

ILLUSTRATION OF THE TECHNICAL PERFORMANCES OF THE FREYSSINET GROUP

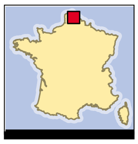
This site also illustrates synergies between its different entities. The Engineering Management of the Spanish-American Division based in Madrid produced the drawings and the design for prestressing of the viaduct, and the Group's Engineering Division in Vélizy, France approved them.

PARTICIPANTS

- **Client:** State of Portugal
- **Engineer:** Norscut
- **Consultant engineer:** Armando Rito
- **Main Contractor:** Norinter
- **Specialized contractor:** Freyssinet - Terra Armada

SOILS / **DUNKIRK**

Innovative work for consolidating a submarine slope



The innovative consolidation solution proposed by Ménard Soltraitement and selected by the Port Authority of Dunkirk, France, has been successfully implemented and work was completed as planned on November 20, 2003.

THE EXTENSION TO QUAI DE FLANDRES (Flanders Wharf) at the Port of Dunkirk required large quantities of dredging work to –16.50 m to enable container ships to dock under all tide conditions. This operation is well controlled technically and did not cause any problems. However, this was not the case for the stability of submarine slopes along the excavations, and special caution was taken due to the memory of a 1987 land slip in Dunkirk that caused more than 200,000 m^3 of materials to collapse into a newly excavated dock site.

Expertises had showed that this collapse was due to the structure of the submarine soil composed of sandy ground in which there was a 2 m thick layer of silt between –13 m and –15 m, and also to differences in the mechanical and permeability characteristics of these materials, the sand being compact and porous and the silt being less permeable and looser. Thus, sliding of the upper sand bed had been caused by liquefaction of silt under the effect of tides.

Complex basic solution...

The specification produced by the Port Authority of Dunkirk planned for the construction of vertical sand drains in silty ground, from a platform above sea level made by placing fill , to guard against the repetition of a similar event.

Precision of a few centimetres

"Construction precision, one of the essential factors for this site, was achieved using computer aided control, explained Loïc Tavernier. The 160 t crane operator placed stone columns with a precision of a few centimetres in a horizontal plane using the DGPS satellite positioning system, while the depth was determined from the inclination of the jib and the length of the unwound cable. The height of the column was determined from the volume of injected material that was measured continuously by sensors. Data specific to each column are recorded on a hard disk to enable perfect traceability of the work done.

The offshore solution as planned and implemented by Ménard Soltraitement avoided long and expensive construction and demolition work of temporary dikes.

"In our opinion, this basic solution was much too expensive and complex for several reasons, said Philippe Liausu, Assistant General Manager of Ménard Soltraitement. Firstly, driving long, large diameter steel tubes in compact sand using conventional techniques introduced a genuine difficulty. And the choice of working on dry land would have required long and expensive operations to construct and then demolish temporary dikes, since these dikes would have had to be removed before dredging operations could start".

...replaced by an innovative alternative to win the contract

After setting up a joint venture with Dredging International and GTM Terrassement, Ménard Soltraitement proposed an alternative with the inclusion of stone columns in sandy ground, passing through the silt layer. The technique consisted firstly of dredging to the – 9 level, and then injecting a draining material between levels – 10 m and – 15 m, working from a pontoon floating in the dock. The 5 m long and 80 cm diameter stone columns composed of siliceous gravel with a size grading of 4/12.5 mm, enable unlimited circulation of water between the sand layers and prevent overpressures and liquefaction of the silt. They also contribute to consolidating the ground. Once the stone columns are in place, final dredging of the dock is possible down to the required depth without any risk of land slip. The client found this solution attractive and adopted it due to its innovative nature and its relatively easy implementation.

Four operators to construct up to 50 columns per day

"The choice of working offshore was not simple, explained Loïc Tavernier, works engineer and site supervisor, since we needed to construct 1,225 stone columns on a 3.50 m square grid over a 15,000 m^2 surface, to achieve the required permeability specifications of more than 10 m/s."
The solution consisted in using a rig designed by the company for a similar site in the Port of San Diego, California, in early 2003. The rig is suspended from the jib of a cable crane carried on a floating pontoon, with a vibrating head, forced into the water and the seabed by a tube string connected to a hopper forming a closed lock pressurized with compressed air. The hopper is supplied with gravel from a second pontoon along a conveyor belt with a telescopic arm, adjustable in direction, length, and height. This material is then propelled into the tube to the vibrating head and injected into the soil under the effect of compressed air. Two operators on each barge did all the work, with an average daily production rate of 30 to 35 columns and a few peaks of 50 columns per day. ■

SOILS / **DARLING ISLAND**

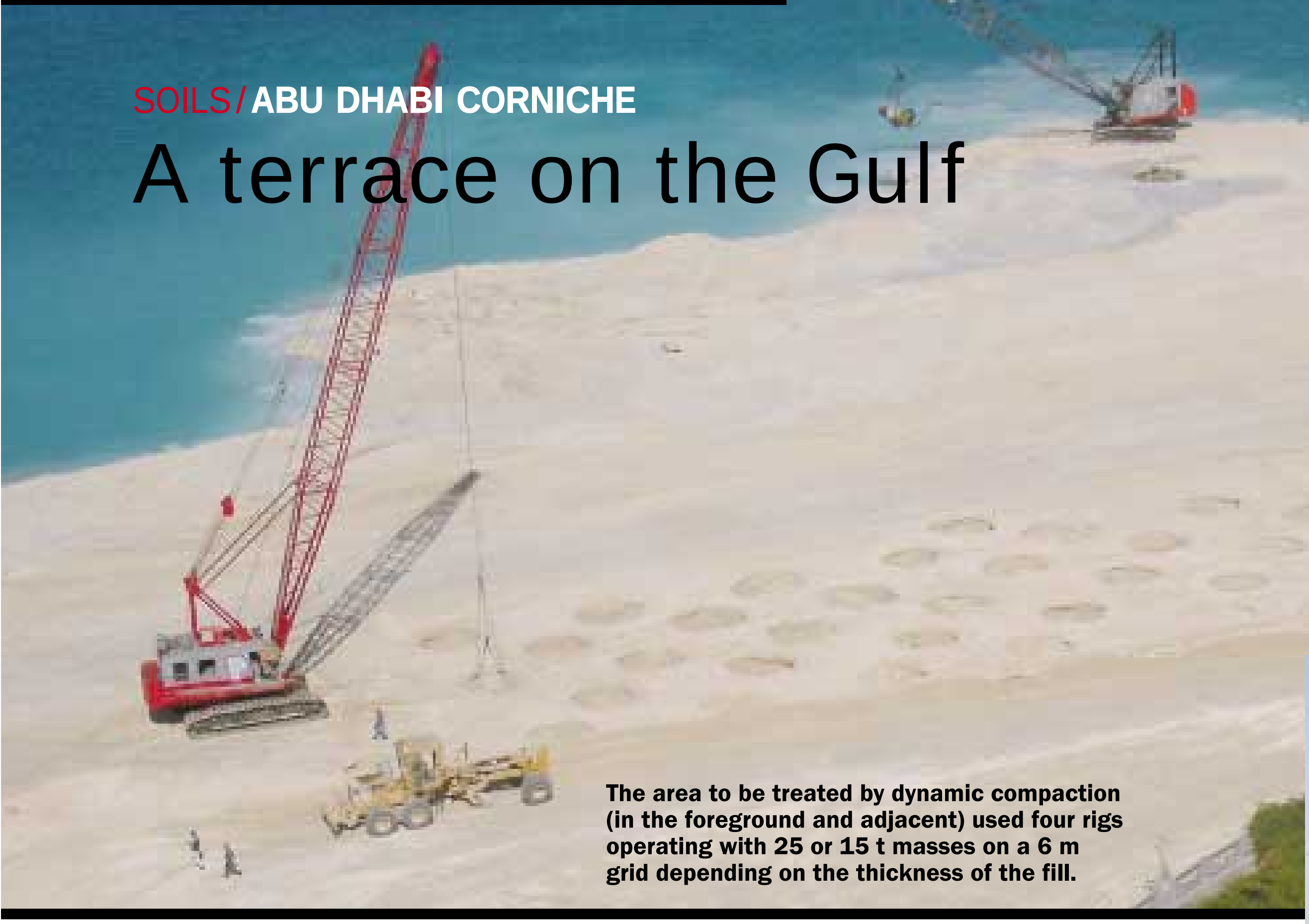
Watertight foundations

A very recent site in Sydney (Australia) demonstrates the advantages of Freyssimix Jet Grouting - flexibility, construction speed and perfect leak tightness.

DARLING ISLAND is the spectacular setting for a new residential development in the heart of Sydney Harbour. The proposed structure required the construction of a water proof retaining wall connecting into bedrock to allow excavation of a combination of single and double storey underground basements for car parking. A Diaphragm Wall or Secant Pile Wall consisting of alternating interlocking un-reinforced ('soft') piles and reinforced ('hard') piles was identified as the likely solution. However, the underlying soil conditions consisting of loose backfilled rubble overlying bed-rock presented difficult conditions for maintaining pile verticality, and an alternative system was required. Recognising that, in order to achieve the degree of water proofing requi-red, the challenge was to ensure that adjacent piles maintained interlock even at their deepest point, Austress Freyssinet's successful proposal was based upon installing Freyssimix Jet Grouted soft piles after the hard piles had been constructed, vice versa to the normal sequence. The primary 600 mm diameter 'hard' piles (at 1.0 m centre's) providing the walls structural support. Austress Freyssinet then 'filled in the gaps' with Jet Grouted "Freyssimix Columns" to ensure groundwater flow was cut-off. The columns were jetted using a highly durable grout mix specifically designed by Austress Freyssinet's in house team for works in marine groundwater environments. The benefits of the Jet Grouting solution included the ability to adjust both size and position of columns, thereby allowing for modifications in the above structure to be incorporated, and the ability to work around obstructions using a range specially adapted coring bits fabricated to suit on-site. The small specialist site based team which completed the 300 linear meters of piled/jetted wall in 6 weeks, some 2 weeks ahead of program. ■

SOILS / **ABU DHABI CORNICHE**

A terrace on the Gulf



The area to be treated by dynamic compaction (in the foreground and adjacent) used four rigs operating with 25 or 15 t masses on a 6 m grid depending on the thickness of the fill.

Ménard Soltraitement teams are taking part in enormous earthworks on the Gulf border in the capital of Abu Dhabi.

ABU DHABI is the largest of the United Arab Emirates and is organizing the next Gulf Countries Council to be held in December 2004. Its ruler, H.H. Sheikh Zayed Bin Sultan Al Nayan, designed the gigantic project to redevelop the corniche facing the Persian Gulf at the northern tip of the town, so as to provide a worthy setting for his guests and to make his capital, which is already one of the most modern cities in the world, even more attractive.

An immense 980,000 m² platform formed of hydraulic fill obtained by dredging the seabed (6.5 million cubic meters of sand) was created, varying from 4 m thick at the point of contact with the old corniche to 12 m deep above the seabed. The risk of erosion by the sea at the point also made it necessary to build a sheet pile fill protection wall.

Avoiding cofferdams

Soil consolidation was necessary because the fill material was not sufficiently dense for building. Pierre Orsat, Ménard Soltraitement Export engineer, told us "Ménard Soltraitement was called in and suggested that the dynamic compaction technique should be used, because it avoids the construction of expensive cofferdams – we needed to work on land at below sea level – and it enables us to work at the final fill level".

Two zones were identified on the site; the largest (95% of the area) in contact with the former corniche, was treated by conventional dynamic compaction. However the second zone located in the area in which sheet piles had to be installed, was a genuine technical challenge for Ménard Soltraitement engineers. "This zone only covered for 5% of the total area to be treated, but it mobilized 80% of our efforts", says Pierre Orsat. The presence of bedrock at the surface made it impossible to embed the sheet piles, and consequently a 3 m deep well-compacted shoe had to be constructed and protected by riprap at its end to keep the sheet pile wall in equilibrium. Consolidation was done by placing fill above sea level in order to densify the soil. Once consolidated and dry, the soil could then be excavated down to the required level. Ménard Soltraitement mobilized four dynamic compaction rigs and 45 persons, in order to complete the site within the allocated seven-month period. The deepest areas were treated by two cranes equipped with a 25 t mass on a 6 m square grid, the other areas were treated using a 15 t mass on a 6 m square grid. The guaranteed minimum settlement was 25 mm.

"Despite temperatures that sometimes rose up to 60°C in the machines, this deep soil compaction and stabilization project was a resounding success", boasted Pierre Orsat.

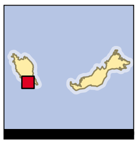
This work were completed in October. In the meantime, in September, Ménard Soltraitement began another 1,100,000 m² soil consolidation project in the Emirate. ■

PARTICIPANTS

- **Client:** Abu Dhabi Town Council
- **Engineer:** DCIL (De Leuw Cather Intl. Ltd).
- **Main Contractor:** Al Muhairy (Abu Dhabi).
- **Specialized contractor:** Ménard Soltraitement.

STRUCTURES/ **MUAR BRIDGE**

Engineering revolution in Malaysia



The Muar Bridge in the South of the Malaysian peninsula, may not break any records in its length or height, but it is one of the world's most innovative cable-stayed structures ever built.

THE PRELIMINARY AND DETAIL DESIGN for the Muar Bridge in Malaysia was done by the Jean Muller International company, and Freyssinet is supplying and installing the prestressing and stay cables for this bridge that, when opened in early 2004, will be one of the most modern cable-stayed bridges in the world.

It is located in the southern part of the peninsula, and is a combined land and river structure. It is 21.4 m wide and 632 m long with a 132 m central span and two 66 m end spans supported on intermediate piers for the river crossing, and is extended on each side of the river by two long approach ramps with six spans each. Its foundations consist of precast prestressed concrete piles (600 mm diameter and 40 m long) on the bank, and driven steel tubes in the river bed (1 m diameter and 50 m long).

Multitube saddles and Cohestrand

Although the deck consisting of a 2.5 m constant depth prestressed concrete box girder with strongly inclined outer webs, is innovative, the most significant technical progress made with this bridge is in its cable-stayed arrangement consisting of 14 stay cables (varying from 37 to 75H15) on each tower, arranged in a central layer. The first innovative feature is that all cables are inserted in yellow HDPE (high density polyethylene) ducts designed and supplied by Freyssinet. The outer layer of the stay cable duct is formulated with anti-oxidant additives and benefits from sacrificial protection against photo-oxidation with a longer life than a standard black HDPE duct.

Another more decisive new feature is that the stay cables are supported by innovative deviation saddles at the towers. This arrangement simplifies the design of towers and improves the general aesthetics of the structure, and was made possible by the use of "multitube saddles" developed by Freyssinet and Jean Muller International (see *Soils & Structures* No. 217), and the Freyssinet's patented Cohestrand. These multitube saddles enable individual guidance of the strands from which the tendon is made and eliminate wear problems caused by friction between strands.

The methods used for construction of the Muar Bridge deck are also innovative, combining cantilever construction and a self-launching truss. Each segment is cast on a mobile traveller fixed to the previous segments and supported on a steel box girder. When one span has been concreted and its tendons have been tensioned, travellers are moved to the position of the next segment. ■

Highlight on Cohestrand

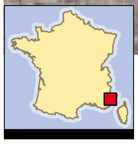
The Cohestrand is composed of seven 15.7 mm diameter high strength steel wires (class 1770 or 1860 MPa) provided with a multi-barrier anti-corrosion protection obtained by galvanising its constituent wires, followed by a water repellent protection complex applied covering all wires in the strand and filling interstitial voids, and finally extrusion of a 1.5 mm thick HDPE duct. The mechanical properties of the protection complex make it capable of resisting compression (clamping or deviation) forces, shear (tangential) forces, and dynamic loads due to traffic. It has a remarkable set of properties – excellent protection against corrosion, bond and mechanical strength of the protection on the steel support of the strand. The Cohestrand is entirely manufactured in the factory and therefore satisfies stringent quality standards, and is easy to install with inexpensive means.

PARTICIPANTS

- **Client:** State of Johor JKR
- **Main Contractor:** Ranhill Civil - Kuala Lumpur.
- **Foundation work:** Antara Koh - Singapore.
- **Design office and technical support:** Jean Muller International.
- **Specialized contractor:** (stay cables, prestressing, bearings) Freyssinet Malaysia, assisted by Freyssinet International.

SOILS/**RN 202 BIS**

Protection from floods and earthquakes



Reinforced Earth was chosen to protect bearings and retaining walls for the new RN 202 bis road viaduct in the Nice hinterland, (France), exposed to flash floods from the Var river and earthquakes.

A VIADUCT CARRIES THE NEW RN 202 bis road between La Manda and Saint-Isidore over the Var river to the North of Nice. The Alpes-Maritimes DDE (Departmental Development Authority) was the client for the bridge and chose Reinforced Earth to support the road on the long approach ramp on the right bank by constructing a 1,126 m long wall with a height of up to 12 m. The choice was made on account of the flexibility of the process, and its architectural advantages. Aesthetics of this structure is an important criterion and was awarded to the architect Charles Lavigne. "No less than three different patterns are used in the complex architectural facing, and manufacture of the facings was awarded to a contractor with a prefabrication plant close to the site", explains Pierre Sery, Manager of Terre Armée SNC.

A torrential river

The project is also unusual because to its complexity, which is due in part to the nature of the river being crossed and the seismic nature of the region. David Brancaz, engineer in the Terre Armée SNC design office, explained "we needed to design a structure capable of resisting an earthquake with an acceleration of 3.5 m/s, one of the highest acceleration anywhere in mainland France."

The level of the torrential Var River can rise by more than 5 m in a few hours during certain times of the year. In order to provide protection against scour, the Reinforced earth wall was founded on a sheet pile wall, which was buried to a depth of 12.50 m and anchored at the top with tie rods. The sudden level variations can cause large pressure differences between the inside and the outside of the structure when the flood level rises and then suddenly drops. For this reason, a free-draining material will be used for the backfill, and the back of the concrete facing will be lined with a continuous geotextile layer up to the 100-year flood level.

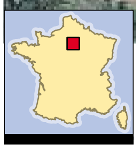
The use of other technical solutions on the left bank illustrates the flexibility of Reinforced earth. Conventional concrete facings were used for the retaining wall of the composite abutment, in which the support function and the earth retaining function are separated. The walls built along the temporary abutment access road were clad with TerraTrel galvanized welded mesh facing panels which can, if necessary, be easily removed. ■

PARTICIPANTS

- **Client:** Ministry of Development, Transport & Housing.
- **Engineer:** Alpes-Maritimes Development & Environment Directorate.
- **Main contractor:** Carillion BTP/TP Spada/Triverio/Bos.
- **Specialized contractor:** Terre Armée SNC (France).

STRUCTURES/**COUPVRAY FOOTBRIDGE**

An all-wood first



Freyssinet, working as the main contractor, only needed slightly more than two months to build the new Coupvray footbridge in the Seine-et-Marne department, France.

ACCORDING TO THIERRY NONNON, Freyssinet's Wood Division Manager, "the 34 m long suspension footbridge leaving a clearance height of 5.30 m for river traffic built by the small town of Coupvray (2,700 inhabitants) to create a new link between its town centre area and its residential area is undoubtedly the first all-wood suspension bridge built in France". At the beginning of summer 2003, work started by the construction of the piers, followed by construction work for the suspension system in July, and then the deck. Two temporary IT15 suspension strands were first tensioned between the piers to enable placement of the permanent suspension cables (composed of 64 galvanized 44 mm diameter steel wires). The team fixed collars, hangers, and other elements necessary to make the deck (and particularly steel bracing on the underside), from a safe position on scaffolding installed on the south pier, at intervals of two meters on these cables. Once the fittings had been put into place over the entire length of the suspension system, the temporary strands were removed and the footbridge was brought into its final configuration. "We installed the joists and deck platform made of red Northern Pine specially treated in a drying oven for outdoors use (conform with biological risks category 4), wood lattice beams designed to stiffen the deck were then put into place before the final adjustments to the bridge geometry were made, and finally the guard rails and access stairs were installed", says Jean-Marc Vilpellet, the supervisor.

The total construction time for this project was only slightly more than two months, and required a team of four persons on average. "The technique used helped us to save time", says Jean-Marc Vilpellet, and we never needed to interrupt river traffic.» ■

SOILS/**SEPON GOLD MINE**

In the Laotian jungle

AUSTRALIAN ENGINEERING and project management company Ausenco asked Reinforced Earth Australia (RECo) to design a structure required for the Sepon Gold Mine, owned by Lang Xang Minerals Ltd and located deep in Laotian jungles. RECo also supplied materials to the site and full time on-site construction assistance.

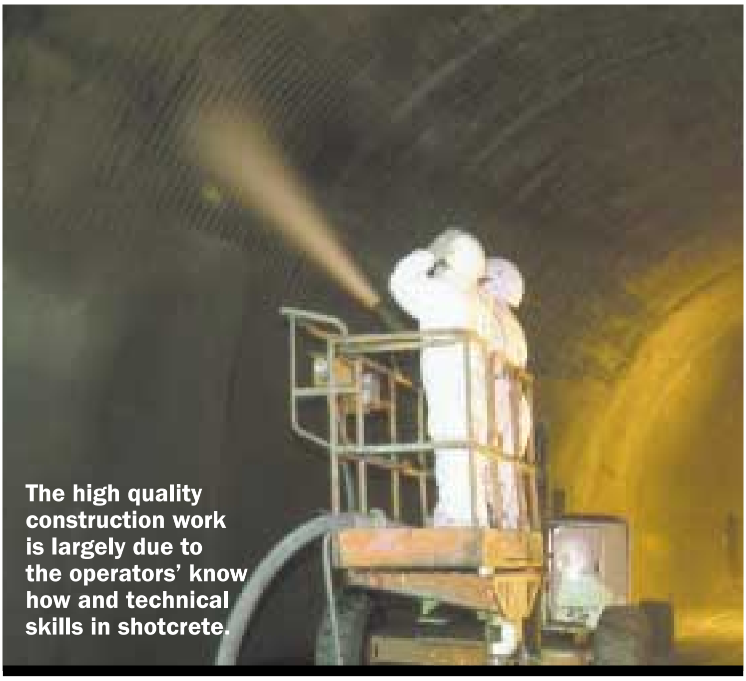
Despite minor difficulties sourcing select fill, the design of the 10 m high TerraMet (galvanized steel faced) dump structure, and manufacture of the materials was undertaken relatively quickly.

When construction began, RECo sent the first of two volunteer supervisors on the grueling journey to the site. Initially, long time RECo foreman Geoff Slavin made the lengthy trip. The journey consisted of various flights to reach the Laotian capital, Vientiane, followed by an extended (10 hour!) very rough four-wheel drive journey on unsealed jungle tracks along the notorious Ho Chi Minh Trail and even a motorboat ride over the famous Mekong River. After three weeks, Geoff Slavin rotated with RECo's James Bye, who stayed until completion.

Working in the hot humid conditions with the enthusiastic Laotian workers was challenging but rewarding. Several times, the roller came perilously close to falling off the edge of the wall. Add to this the threat of unexploded ordinance left over from the Vietnam war and the regular tropical downpours; completing the works was a difficult job! RECo is now negotiating another possible structure for the site, this time at Sepon Copper. ■

QUALIFICATION

A certificate for shotcrete gun operators



The high quality construction work is largely due to the operators' know how and technical skills in shotcrete.

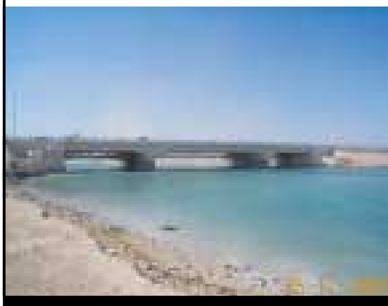
Although the shotcrete technique is more than a century old, it is now developing as never before throughout the world for a wide variety of applications such as wall or embankment facing, construction of tunnels, repair or strengthening of structures. The Asquapro (Association for the quality of shotcrete and sprayed mortar) was created in France in 1989 to improve construction quality and to maintain a high operator qualification level. This organization has many members in public works (clients, main contractors, manufacturers, contractors, etc.) including Freyssinet France.

More recently, the Asquapro has initiated a certificate validating qualification of shotcrete gun operators according to clearly defined criteria, following internal sessions or training provided by contractors. For Philippe Zanker, Freyssinet France's General Manager, this certification "is a guarantee of quality for customers", since it provides the means of having an independent external organization recognize skills present in the company for a long time (with prestigious references such as the Channel repair in 1997, and more recently strengthening of a factory in Le Tréport, in the Seine-Maritime department in France). Moreover, as emphasized by the Association managers, the Asquapro qualification increases the prestige of a physically difficult activity.

At Freyssinet, Alain Maguet and Alain Autissier have organized an annual training session in the shotcrete technique for the last three years. Freyssinet is also the first member company of the association to receive the shotcrete gun operators certificate. It was awarded to 10 persons in the Group in 2003. ■

KNOW HOW

CCSL, corrosion protection solutions



Corrosion Control Services Ltd (CCSL) is a subsidiary of Freyssinet Ltd specialized in the diagnostic, prevention and treatment of corrosion in marine environments, and has recently been awarded several contracts using its processes. Thus Durmon, a system for measuring the penetration of chlorides into concrete based on the use of probes embedded into the material and coupled with an analysis software, will be used in cooperation with Freyssinet Hong Kong on several new structures built in a marine environment in Hong Kong.

In Abu Dhabi (United Arab Emirates), the British subsidiary decided to apply a cathodic protection system on the new Umm Al Nar bridge (photo above) to efficiently prevent corrosion of the reinforcement in a hot and humid marine environment, and to avoid expensive repairs later. A monitoring and control device controlled from the United Kingdom by CCSL engineers was installed on the structure at the same time. ■

the previous standard and is focused on the customer, enabling direct action on the company's processes within a context of continuous improvement.

"It is another step in PPC's development, says Philippe Héry, the company's General Manager; we are now beginning an approach to include safety, risk prevention and environmental aspects in the management system, as well as quality". ■

APPOINTMENT

Jean-Philippe Fuzier was appointed member of the presidium of the *fib* (fédération internationale du béton - international concrete federation) during summer 2003. Jean-Philippe Fuzier was the scientific manager of Freyssinet until December 2002 and is now an adviser to Bruno Dupety, the Group's CEO. He represents the company at international technical conferences and is the author of many scientific publications. He is also the official representative of the *fib* in France, and participates in various working groups in this capacity. He is also Editor-in-Chief of *Structural Concrete*, the Federation's journal.

AWARDS

Meeting with Terre Armée licencees in Japan

Bruno Dupety, Freyssinet Chief Executive Officer, participated in annual meetings of Terre Armée licencees in Japan, which were held in June for the Hirose Group (independent subsidiary of Sumitomo) and in September for the Kawasho Group. He was accompanied by Graham Simkin, special advisor for Reinforced earth activities in Japan. These ceremonies (traditionally called KAI in Japan) have been held regularly for the last fifteen years, and each is attended by 100 to 200 partner companies. They provide an opportunity to report on the Reinforced Earth activity in the country and throughout the world during the previous year, and to analyse development prospects. This year, the ceremonies coincided with the 30th anniversary of the Reinforced earth licence issued in Japan, and as usual the highlight was the award of a certificate of excellence to the ten partner companies with the best performances.

"KAI" Sumitomo-Hirose.

INNOVATION

Three new prizes reward Freyssinet's creativity

Innovation is the fruit of an ambitious research and development policy and is extremely important in the Freyssinet Group. These efforts were rewarded by two prizes awarded to Freyssinet at the VINCI 2003 innovation competition, and more recently the first prize at FNTP 2003. The innovations for which the VINCI prizes were awarded apply to the Viajoint HP expansion joint and the "temporary cables" construction method. The first innovation developed by Freyssinet and Interdesco was the development of a new road expansion joint designed to resist dense traffic and a severe climate due to the use of a dual-component thermosetting binder. Viajoint HP has successfully been tested in the laboratory and is now the subject of full-scale experiments on the Cofiroute network. The second innovation enables economic construction of suspension footbridges. It consists of installing two «temporary cables» along which two lightweight deck handling cranes can travel. With this device, the steel structure of the future footbridge is launched with a different static support system from the final system, making maximum use of the strength and flexibility of the steel. Finally, the latest award was the innovation first prize in a ceremony at the FNTP (Fédération Nationale des Travaux Publics) in July presided over by Daniel Tardy, President of the Professional Public Works Association in France and overseas, for the "high performance tensile system" developed by Freyssinet (for the anchorage of cables) and the Soficar and Bostik Findley companies (for carbon rods). This system is designed for use with cable-supported structures (bridges or offshore platforms) and combines carbon fibre cables with an innovative patented anchor process based on gluing and wedging of composite rods. It was used for the first time on the Laroin footbridge (photo above) near Pau (France).■

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Editorial secretariat: Jean-Marc Brujaille - **Layout:** Idé - **Photos:** Axel Heise, David Houlston, VK Photo Studio, John de Rooy (focus and cover), Francis Vigouroux, Freyssinet and VINCI photographs. Freyssinet is a subsidiary of VINCI.

ZOOM
A collection of seismic equipment

The Rion-Antirion Bridge project between Peloponnese and the continent, managed by Vinci Construction Grands Projets, is now at the peak of its activity. The design of this 2,884 m long multicable-stayed bridge is completely innovative due to its exposure to earthquake, and will be fitted with the latest earthquake-resistant equipment.Thus Freyssinet started its work on site in spring, and is using paraseismic deviators (PSD) to protect stay cables against excessive bending, key blocking devices in anchor blocks, etc. (Details of these techniques will be described in a future issue of *Soils & Structures*).