

Soils & Structures

THE FREYSSINET GROUP MAGAZINE

PANORAMA 9,500 CMC FOR THE NEWPORT SOUTHERN DISTRIBUTOR ROAD

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QSL sugar terminal
The efficiency of an
INTEGRATED SOLUTION



9,500 CMC in Newport

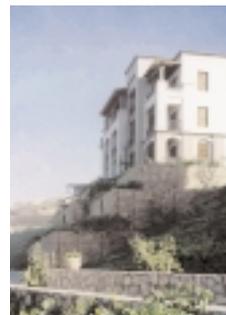
The construction of the Newport Southern Distributor Road by the Morgan-VINCI joint venture in the United Kingdom, is now advancing quickly. The soil treatment work in port areas and in the adjacent tip is being done by Ménard Soltraitement, and will be completed in August 2003. A total of 9,500 controlled modulus columns (about 130,000 m) will be realised.

Prestressed floors for the Cape bank



When Nedcor Bank decided to extend its Regional Headquarters in Cape Town (South Africa), they did so by purchasing the old building next door. As the height of the floors was not the same between both buildings, a four-level car park was constructed with a shopping arcade at ground level and seven levels of office floors. Freyssinet Posten supplied and installed 30 tonnes of unbonded strands and 3,120 anchors for the post-tensioned concrete floors.

4-star TerraPlus



The Pueblo Bonito Sunset Beach hotel in Lower California, Mexico, is a luxury complex built in terraces on a set of 17 platforms that involved the construction of 10,000 m² of retaining walls and the use of new TerraPlus square panels. Tierra Armada

has been working in close co-operation with the main contractor because the region is subject to earthquakes and the nature of the soils has made the design of the structures very complicated. The end result is an aesthetically pleasing project.

Twin bridges in Dubai

A marina is being built in the heart of the southern district of Dubai near Jebel Ali, (United Arab Emirates). It is linked to the Arabian Gulf at each end. Freyssinet Gulf is supplying and implementing prestressing for two identical bridges that cross the Marina. Each 208 m long structure comprises 40 m long end spans and a 128 m long central span. They are prestressed using 37C15 anchors with galvanized steel ducts with around 300 t of post-tensioning strand in each. The project also includes the construction of some 4,000 sqm of Freyssisol Reinforced Earth® retaining walls. The structures should be completed by end of September.

2,700 tonnes of prestressing

Freyssinet will carry out the prestressing work for the Kudankulam nuclear power station in the State of Tamil Nadu, India. This power station is located in the southern part of the country and is being built for the Nuclear Power Corporation of India Limited (NPCIL). Two reactors will be installed and it will be

the largest in the country, with 2,000 MW. The civil engineering works started at the beginning of 2003. Construction will be completed in December 2004, and commissioning by 2007. Freyssinet is working for the Russian Atomstroyexport Company, and will install 514 type 55C15 anchors supplied by the

PPC Company and injected with cement grout before tensioning, and 2,700 t of unbonded strands. The advantages of this solution are that the resulting prestressing is fully measurable, if necessary each strand can be individually retensioned or replaced, and it provides perfect protection against corrosion.

Bridge over the Rio Arade

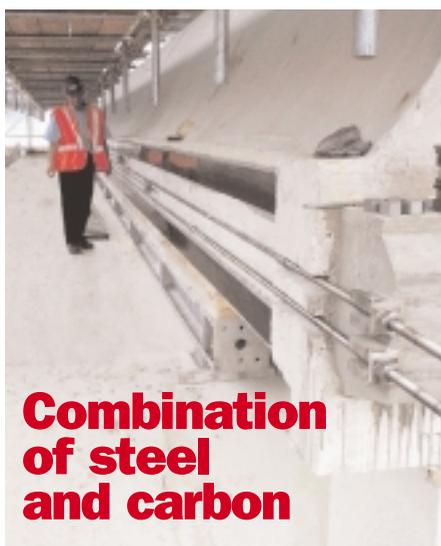


The bridge over the Rio Arade on the A2 motorway between Lisbon and the Algarve, Portugal, is composed of an access viaduct and a bridge. The 400 m long bridge comprises 5 spans that are 56, 90, 110, 90 and 54 m long. It is formed from two prestressed concrete girder decks, and was constructed by successive cantilever construction. The 380 m long viaduct is composed of two prestressed concrete double girder decks. Each deck comprises two main girders and ten 38 m long spans. Freyssinet Terra-Armada Portugal supplied and installed 770 t of prestressing (19C15 and 25C15 units) and temporary balancing cables (130 t). The company installed a total of 2,050 t of prestressing on different bridges along this new motorway in 16 months.

I N B R I E F

EXPRESS SITES

- ▶ **KOREA**
Freyssinet Korea will participate in the construction of 13,600 m² of TerraClass retaining walls for the Mungok-Mureung road in the north of the country.
- ▶ **FRANCE**
STTP, a Freyssinet subsidiary, has built a 6 m high temporary diaphragm wall in Lyons to enable the construction of an underground car park beneath an office building.
- ▶ **MALAYSIA**
Reinforced Earth participated in construction of a 3,360 m², 9 m high platform wall in the Province of Kedah, for the development of a water sports and tourist activities area.
- ▶ **RION-ANTIRION: FIRST STAY CABLES**
The first stay cables for the Rion-Antirion bridge in the Gulf of Corinth in Greece are being installed. The 2,252 m long main structure is built by a French-Greek group led by VINCI Construction Grands Projets, and will use 368 stay cables. Freyssinet is participating in the installation of the 3,800 t of stay cables.



Combination of steel and carbon

The roof of the reading room in Rosemary Murray library in Cambridge University, England, comprises precast concrete arch elements assembled by a system of longitudinal prestressing cables. The cables were severely corroded at one end of the building, and the wires had broken in some places. Freyssinet Ltd implemented a solution combining stainless steel prestressed bars and carbon fibers, at the request of Bluestone Construction. Eight 20 mm prestressing bars were installed in the roof beams. At the same time, 120 mm wide rigid composite carbon fiber boards were applied along the beams over a length of 23 m at eight separate locations. TFC (Carbon Fibre fabrics) was used over curved parts of the arch.

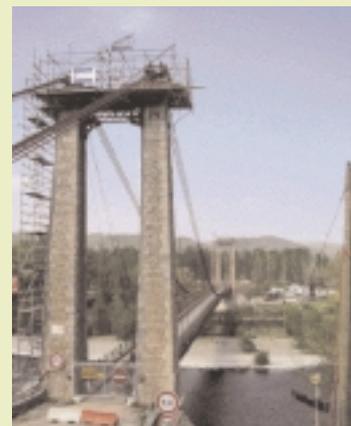
1,200 tonnes of shotcrete

A Freyssinet team composed of up to 25 persons has been performing strengthening work for the Saint-Gobain - Desjonquères factory in Le Tréport, in the Seine-Maritime department in France, over the last seven months, after it was damaged by a fire. Freyssinet used shotcrete to recreate 63 beams in this project to reconstruct and strengthen the structure of this two-storey building. These beams were then prestressed with unbonded single strands. This work was done without interrupting production on the first floor of the plant. This project, started in September 2002, was completed at the end of April, at about the same time that the repair work of 1,800 m² of external surfaces started. It involved the placement of 1,200 t of shotcrete over an area of 2,000 m² and is one of the largest building projects ever undertaken by Freyssinet.



Floirac bridge has been strengthened

Freyssinet was selected to strengthen the Miret suspension bridge in Floirac in the Lot department, France. Built in 1912 its capacity will be increased from 1.5 t to 3.5 t.



MICHAEL N. FARDIS

The prime earthquake protection of a structure should come from its conceptual design



After the symposium of the *fédération internationale du béton (fib)* held in Athens from 6th-9th May, its organiser considers the event and talks about parasismic protection.

Soils and Structures: How important was the Athens fib Symposium?
Michael N. Fardis. - Very important. There were over 520 delegates, 310 of which were international visitors, despite the unfavourable international context. From a technical point of view, the Symposium was a great success, with 207 conferences, led by top class specialists.

What were its greatest achievements?
 The highlighting of 'dry joints' for precast structures was one of the most remarkable success stories presented at the Symposium. Discrete precast concrete elements are in direct contact and connected by means of unbonded internal prestressing tendons. If there is an earthquake, a structure designed in this way deforms and then returns to its original shape when the shock is over. This design creates a building

that is as earthquake-resistant as a monolithic one, despite being flexible. This ingenious system has been tested on a 5-storey building at the University of California in San Diego, U.S.A, and is currently applied in real buildings in North America. The Symposium was also a forum for presenting advanced composite materials that have appeared on the market in recent years as a cost-effective means for strengthening existing buildings to meet present day earthquake protection norms.

High strength concrete, between 50 MPa and 100 MPa has also been demonstrated as a most suitable material for construction in earthquake zones. The Symposium also focused on the progress made in seismic isolation and energy-dissipation techniques.

Do these developments enable a structure to be suitably protected today?

We are very confident on this new discipline (originating in the 50s), which in recent years has made huge progress in understanding seismic phenomena and structural response to them, and in interpreting and mathematical modelling this response. This expertise allows us to build structures that are capable of sustaining the ground accelerations as well as the horizontal and vertical displacements they induce to it. The prime earthquake protection of a structure should come from its conceptual design. For this reason, the choice of materials and the design of the foundations is of paramount importance. The foundation is the element of a bridge or a building that transmits the earthquake motion to the superstructure. To limit the effects of the motion on the superstructure, a bridge or a building may be 'isolated' from the ground at

the foundation level using special devices. Pile foundations may also prevent failure of the foundation soil in the event of an earthquake. As far as materials are concerned, reinforced or prestressed concrete is a most suitable material for earthquake zones. In addition, structures may be equipped with auxiliary passive or semi-active earthquake protection measures, the cost of which varies according to the structure, the materials used and the region (they may represent a percentage of the overall structural cost that may reach 20-25%).

How far are we from seeing a global set of earthquake protection norms?

Currently each country has its own standards. There is no world-wide harmonisation of design standards. There are, however, three large regions with well-defined norms: Japan, U.S.A. and Europe. The subcommittee of the European Commission for Standardisation which I currently chair, is responsible for drafting 'Eurocode 8' covering the design of structures for earthquake resistance. After 2004, Europe will have its own set of structural design standards which will take into account the specific seismic design requirements of each country. The flexibility of these documents will allow its adoption by non-European countries.

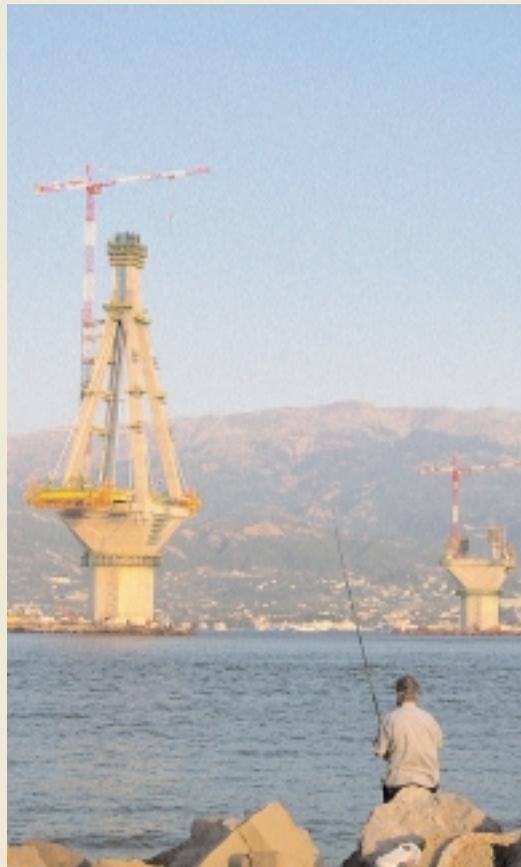
From the University chair to the Rion-Antirion bridge

Professor in Civil Engineering at the Massachusetts Institute of Technologies (MIT) in Boston, U.S.A. for 4 years, Michael N. Fardis joined the University of Patras in Greece in 1982 to take up a similar post and specialised in the design of earthquake-resistant concrete structures.

Since 1999, he has chaired the subcommittee of the European Commission for Standardisation responsible for drafting 'Eurocode 8' regarding the design of earthquake-resistant structures.

Member of the Praesidium of fib (fédération internationale du béton), Michael N. Fardis was the organiser of the symposium on concrete structures in seismic regions held from 6th to 9th May in Athens.

After enjoying a front-line role with the Greek authorities in the call for tenders for the construction of the Rion-Antirion cable-stayed bridge, he is following the project, along with Roger Lacroix and Jan Moksnes, as technical panel for arbitration between the parties of the project.



In the seismically active region of Corinth Gulf, soil displacement between two piles may reach 2 m.

Does taking the earthquake risk into account, call into question the structures' architectural design?

We are faced with a problem of mentality. People living in an earthquake region are more sensitive to the robustness of a building than to its elegance. But robustness and elegance are not mutually exclusive and today we can build earthquake resistant buildings which are very elegant. The engineer and the architect are responsible for balancing robustness with aesthetics.

Have you also seen progress made in ensuring that old structures meet modern norms?

This is our priority in Greece, as a large number of older buildings have to be upgraded. There is an ongoing effort for many years now to rehabilitate buildings and bridges to meet current seismic requirements. This has given rise to new techniques. The development of advanced composite materials is without doubt the best example of this. I think carbon fibre reinforced polymers (like TFC, carbon fiber fabrics) is the most suitable material for this type of work, even better than aramid and fibre-glass reinforced polymers.

Would you say that the Rion-Antirion bridge is the shop-window for

the best practices in parasismic protection?

This bridge is a unique project, characterised by its very long span, its construction in deep water on soft soils, in a region susceptible to earthquakes, with a risk of tectonic movement taken in design to amount to 2 m between two pylons. These features were accompanied by some very demanding construction specifications that required that the superstructure responds essentially elastically to earthquakes with a maximum ground acceleration of almost 0.5 g and a very rich frequency content with a response spectrum almost constant down to frequencies below 1 Hz. The design of such a work called for the most advanced earthquake protection measures, such as hydraulic dampers between the head of the pier and the deck and processes which had not been used before, such as the vertical reinforcement of the foundation soil by up-to-30 m long steel tubes and the use of controlled sliding of the base of the piers as a means of seismic isolation. For the pylons, the designers had to use high-performance and high strength concrete and to ensure that it is ductile through heavy confinement by reinforcement. The stay cables are all equipped with dampers developed jointly by Vinci Construction Grands Projets and Freyssinet.

Successful alliance betw



How can the advantages of high performance processes be improved? The combination of the joint expertise of Ménard Soltraitemet and Austress Freyssinet in soil consolidation and in prestressing to build a sugar terminal in Australia is the answer.

IN THE DESIGN AND CONSTRUCTION of a bulk sugar terminal in Australia, carried out for Queensland Sugar Limited (QSL), Austress Freyssinet and Ménard Soltraitemet working in joint venture, combined Ménard Soltraitemet's know how in soil consolidation with Austress Freyssinet's expertise in prestressing processes and understanding of the local market. This delivered the client a technically and economically viable solution to a challenging project. QSL is the exclusive international

marketer of the raw sugar production of approximately 6,500 cane growers and mill owners in the State of Queensland, Australia. The storage provided by seven terminals across the state ensures a continuous supply throughout the year, although the crushing season only extends from June to December. As part of QSL's continuous upgrading of facilities to ensure its competitiveness, the need for a

new 480,000 t bulk storage facility on the north-eastern coast of Queensland was identified. To maximize the benefits of the proposed storage facility, it was necessary for it to be operational in September 2003 for the latter half of the sugar-crushing season when existing facilities reach capacity.

The site in the port of Townsville had been previously occupied by a coal fired power station, and

included substantial areas of the tidal foreshore, reclaimed by waste from the power station and dredging operations. Consulting Engineers GHD, were appointed by QSL to carry out the geotechnical investigation. Trial pit excavations and piezocone testing were performed, supplemented by core drilling and extensive laboratory testing. The investigations revealed extensive layers of highly compressible

Savings in time, costs and risks

The benefits of the active consolidation techniques, combined with the advantages of the prestressing system, made it possible to guarantee critical programme deadlines. It also provided cost savings by reducing earthworks and material quantities. The guaranteed maximum settlements offered the client peace of mind with regards to the future performance of the structure. Environmental risks associated with more conventional systems were effectively eliminated.

The pressiometer is used to define three

een Soils and Structures



SOIL PREPARATION BY DYNAMIC compaction and dynamic replacement columns conditioned a 42,000 m² platform to withstand a maximum load of 18 t/m².

The ideal solution

'The innovation in design and execution offered jointly by Austress Freyssinet and Ménard Soltraitements, enabled us to overcome technical and programming challenges, both in the geotechnical and structural aspects of our project, explains Ross Broadbent, Enthalpy head of project. We thus benefited from numerous advantages, which were further enhanced by the pro-active management and co-operation displayed during the execution of the works. This literally formed the foundation of the success of our project.'

The joint venture offered a design and construct solution to QSL in March 2002, proposing an entirely new approach for the ground improvement based on Ménard Soltraitements's 'active' soil compaction and reinforcement processes. The recommendation was based on the dynamic replacement and compaction techniques to effectively over-consolidate the soil horizons ensuring that both the bearing capacities and settlement criteria were uniformly achieved on the full footprint of the structure. The proposal further eliminated the time risk, which was of great interest to the client. Enthalpy, Project Managers for QSL, quickly realised the technical and commercial benefits, combined with the significantly reduced construction period. With GHD's support, the soil improvement contract was awarded to Austress Freyssinet working in joint venture with Ménard Soltraitements.

KEY FIGURES FOR SOIL IMPROVEMENT

- ▶ **60,000 m²**: total site area.
- ▶ **42,000 m²**: treated ground area.
- ▶ **3,400**: number of treatment columns.
- ▶ **25,000 m³**: volume of imported fill added for ground treatment.
- ▶ **30,000 m³**: volume of earthworks (movement, leveling and compaction).
- ▶ **6 months**: programme duration (including the test phase).

soft alluvial soils in the reclaimed areas, overlain by uncompacted fills of varying origin, with a portion of the sand underlain by very loose sands. The presence of the old structures and the localised improvement of the soils due to their previous surcharge further contributed to the complexity of the founding conditions.

Under full sugar load conditions floor loads of up to 180 kPa will be imposed on the underlying soils, unless correctly designed and treated this would result in bearing capacity failure of the foundations as well as unacceptable differential

settlements with consequential damage to the structure. The 25 m high of the structure, the presence of 4.5 m deep collector tunnels, the settlement sensitive material handling equipment, and the minimum long term maintenance requirement, ruled out any cracking of the floor slabs, adding to the challenges of the project.

High construction costs disqualified initial proposals of piled foundations and suspended floors. Excavate and replace options were ruled out being expensive, having practical limitations as well as potential significant environmental impact.

GHD therefore opted to trial a surcharge treatment by placing a 10.8 m high surcharge, to define the effectiveness and time necessary for soil consolidation under surcharge conditions. The results were positive, both technically and economically, but raised serious concerns with regard to the surcharge period and the possibility of meeting the critical construction deadlines.

Alternative proposal

GHD consulted various parties on possible foundation options, providing Austress Freyssinet the opportunity to submit an alternative for consideration in the early stages of the project. Geoff Holding, Civil Engineering Manager for Austress Freyssinet targeted this as a key project for the recently formed joint venture between Austress Freyssinet and Ménard Soltraitements which had just successfully completed two smaller soil improvement projects in Australia.

Phasing works to save time

Due to time constraints, the project was awarded in phases to allow work to continue while contractual negotiations were finalised. The first phase was awarded in June 2002, and entailed further site investigation work targeted at identifying variations in geological conditions on site. The work was done by Trial Pits, Cone Penetrometer Testing and Boreholes combined with Pressuremeter testing which provided the absolute soil parameters, essential for the design of the soil improvement works.

The first area, comprising the old shoreline above the high water mark, was treated by classic dynamic compaction to den- ▶▶

areas that will be treated to obtain a coherent soil.

►► sify the 5.0 m thick layer of loose beach and aeolian sands overlying a meter of high plasticity soft clay. The second area, in the tidal range, was composed of 4.0 m of highly compressible clay. The thickness of this layer was reduced by 1.5 m prior to reclaiming with sand to form a dry working platform above the tidal range. Stone columns were dynamically driven through the remaining clay layer, followed by a final dynamic compaction treatment of the fills.

The remainder of the site, comprised 2.0 m of variable fills overlying 3.5 m of soft clay. A partial removal of the fill was carried out to facilitate the installation of stone columns to the competent substratum at a depth of 5.5 m, prior to the overall dynamic compaction treatment. Whilst a maximum post-construction settlement criterion was set for the project, the differential settlement criterion of 0.3% was the controlling factor to prevent cracking in the structure and floors and ensure long-term serviceability of the material handling facilities. It is interesting, if little known fact, that after removal of bulk sugar from storage, the remaining stockpile can



GEOTECHNICAL ANALYSES with pressiometers (photo 4) have led to dividing the ground into three different areas that were dynamically compacted (photos 2 and 3) or treated with stone columns to obtain coherent results as per the foundations specifications.

The structure of the building comprises

PARTICIPANTS

- **Owner:** Sugar Terminals Ltd.
- **Operators:** Queensland Sugar Ltd.
- **Project Management:** Enthalpy Ltd.
- **Consulting Engineers:** GHD Ltd.
- Ground Improvement / Earthworks**
- **Main Contractor:** Austress Freyssinet Ltd.
- **Specialised Contractor:** Ménard Soltraitement.
- **Earthworks Sub Contractor:** Mendi Constructions Ltd.
- **Geotechnical Engineers:** Douglas Partners Ltd.
- Construction**
- **Main Contractor:** Walter Construction Ltd.
- **Specialised Contractor:** Austress Freyssinet Ltd.

form and maintain a vertical face. This phenomenon on 20 m high stockpiles, together with the 4.0 m difference between the founding levels of the floor slabs and the underlying conveyor tunnels, provided the biggest challenge in design to Dominique Jullienne, Soil Consolidation Works Manager for the project. Dominique Jullienne engineered the soil improvement by adjusting the compaction effort and replacement ratio of the dynamic treatment, to cater both for the varying site conditions encountered, as well as for the differences in founding levels and loads. Records of the energy input and dis-

placement of all compaction prints were individually recorded, and used to plan and coordinate the phasing of the compaction on a daily basis. Pressure meter testing determined the post-compaction parameters, confirming compliance with both the total and differential settlement criteria.

Optimised prestressing

Austress Freyssinet, working together with the Walter Construction Group, provided the post-tensioned design and installation package for the concrete components of the Sugar Terminal Building. The building superstructure footprint comprises 40,000 m² of post-

tensioned floor slabs and carries floor loads of up to 180 kPa. Three 4.5 m deep concrete reclamation tunnels are located below the floor slabs and extend over a cumulative length of 800 m. A 5.0 m high concrete peripheral wall supports the steel roof trusses and material handling facilities. The total of amount of concrete used was 20,000 m³ with over 500 t of post-tensioning were used to prestress the structure. The 'integrated' solution proposed by the Austress Freyssinet/Ménard Soltraitement joint venture was based on making composite use of the improved soils and prestressing of the structure, which offered both



3 4



FOR THE WHOLE BUILDING, 20,000 m³ of concrete were used, much less than originally planned thanks to the optimisation of the prestressing technique. The foundation supports (photos 5 and 6) and the floor slabs (photos 7, 8 and 9) are prestressed to 90%. The surrounding wall has been vertically prestressed with 5-strand cables laid out every 0.8 m.



7



8



9

three discharge tunnels built under the floor slab.



THE SOLUTIONS PROVIDED by the joint venture have allowed lead times as well as total and differential settlement requirements to be met.

cost and time savings to the client. The tunnel structures were fully disconnected from the floor structures thus allowing the floors to be effectively stressed and shorten without any localised constraints or effects from the much stiffer tunnel structures. Vertical post-tensioning was introduced into the wall elements. Post-tensioning allowed significant reductions in the dimensions of the floor slab and eliminated the need to pour longitudinal expansion joints in the concrete, thereby limiting the jointing of the slabs to 3 transverse joints, eliminating the need for costly maintenance associated with such joints. The construction sequence was

simplified, shrinkage was limited, and the 50 m x 50 m floor modules were poured at night to eliminate concrete related cracking problems. Building work was staged to overlap with the soil improvement phase by the progressive handing over of portions of the site after completion of soil improvement and subsequent verification testing. In conclusion, the Global Freyssinet Warranty that will be provided to the Client on completion, offers an integrated extended performance coverage for the both the ground improvement and the building works redesigned by Austress Freyssinet. ■

STRUCTURES/CAPE GIRARDEAU BRIDGE

A new crossing over the Mississippi

Freyssinet is supplying the prestressing for the towers and stay cables of the largest bridge ever built in the State of Missouri, USA.



THE STATE LINE between Missouri and Illinois to the east of the town of Cape Girardeau runs along the Mississippi river. It is crossed by a steel bridge that was put into service at the end of the 1920s, terminating the ferry service across the river. For many years, it was the only crossing point within the 500 km distance between Saint Louis and Memphis, and even today it is the only crossing from the region to the neighboring state, the closest neighboring bridges being 55 km upstream in Chester, and 65 km downstream at Cairo Junction.

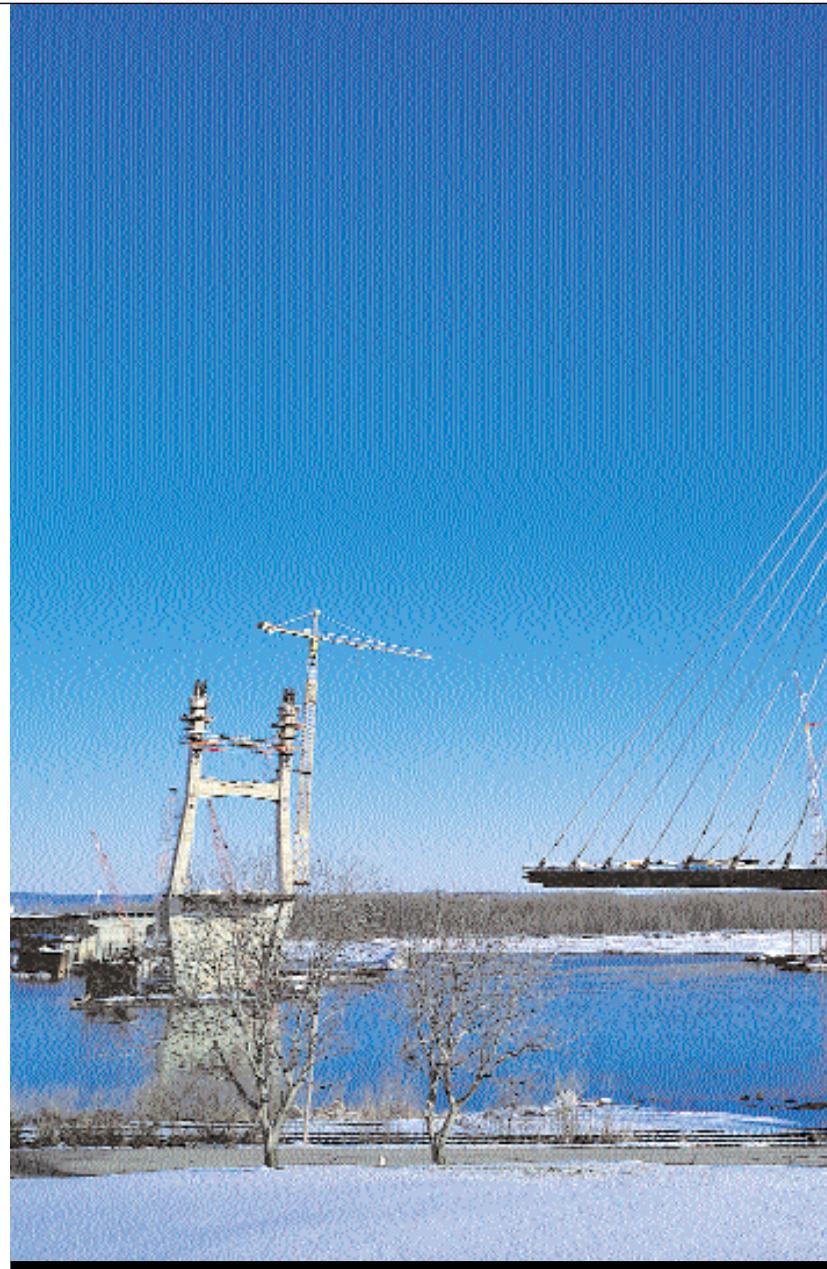
This structure is crucial for local exchanges, and it has been condemned to be closed shortly: its width (twice 3.35 m) is increasingly unsuitable for the continuously increasing traffic needs (average 17,000 vehicles per day) and in particular increases the risks of accidents between heavy goods vehicles. This situation has led the Missouri Department of Transportation (Modot) to initiate construction work of a bridge that can carry a daily traffic of 26,000 vehicles, the estimated traffic volume for 2015. Construction work was interrupted for four years as a result of foundation problems, and the site then started again in 2000 after completion of soil consolidation under the

control of a new main contractor, TBI (Taylor Brother Inc.). The authorities have already decided to name the future bridge after Bill Emerson, in memory of the Senator for Missouri in the American Congress who died in 1996, and had adopted a firm position in favor of this project.

Composite steel-concrete deck

The Bill Emerson bridge is a conventional design symmetrical about its center, consisting of a cable stayed structure with two 100 m tall double H towers and a total length of 636 m, two 143 m side spans and a 350 m central span. It is 31.5 m wide, and carries twice two 3.65 m traffic lanes and two 3 m wide emergency stop shoulders. On the east side, in Illinois, the bridge is accessed from a viaduct with eleven 52 m long spans.

The bridge deck is a steel and concrete composite structure. Its lower part comprises 27 pre-assembled steel elements, its total weight is 1815 t, and the top slab is composed of 116 precast concrete slabs each weighing 45 t. The deck is prestressed using 35 mm diameter bars, and is supported by type 19, 31, 37 and 54C15 stay cables distributed in two layers, the longest of which is 180 m.



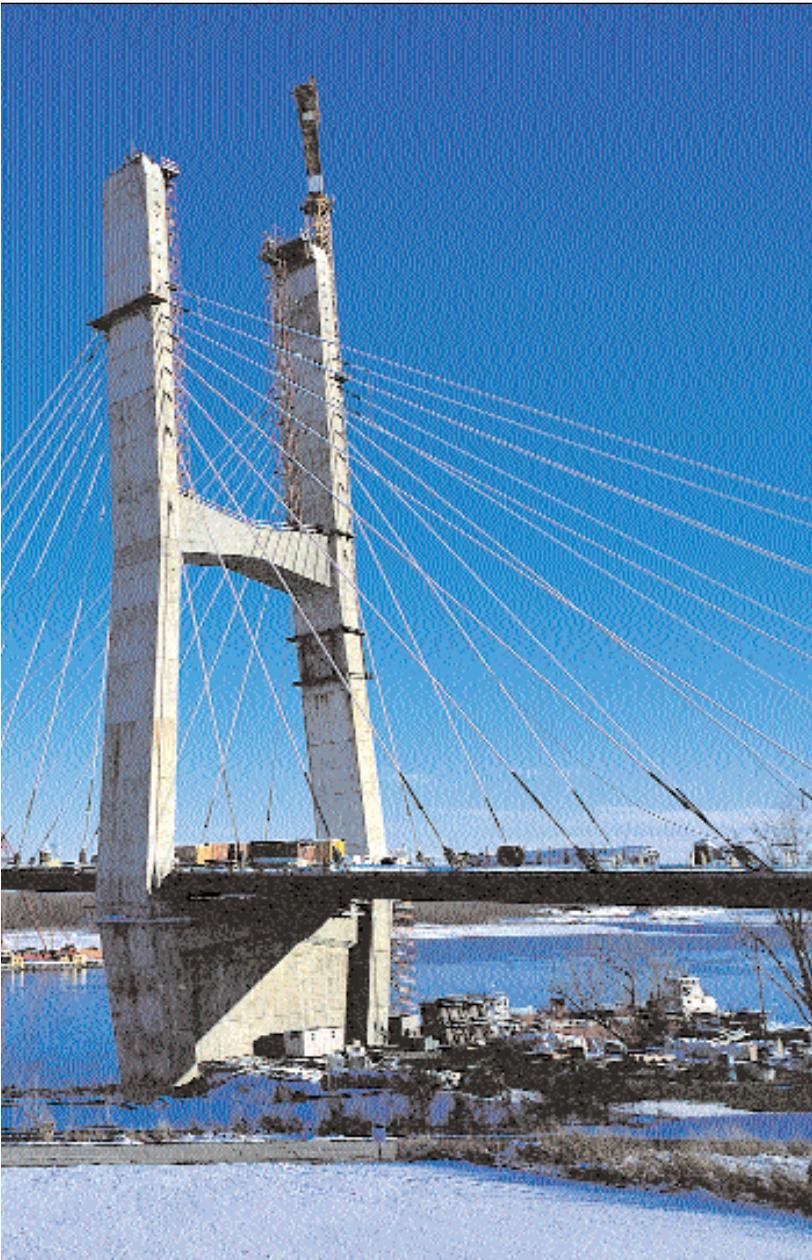
Freyssinet will need to supply almost 750 t of sheathed and greased strands to build this structure. All stay cables are injected with cement grout.

Apart from the supply of materials and equipment for the stay cables and technical assistance, Freyssinet is also involved in the supply of prestressing for the towers, to be installed adjacent to the diaphragms using fourteen 19C15 cables (20.5 t), and in the stay anchor area using 256 cables varying from 4C15 to 13C15 (35.4 t).

When the Bill Emerson bridge will be completed at the end of 2003, the thousand lights of its 140 lampposts will be reflected in the water of Old Man River. ■

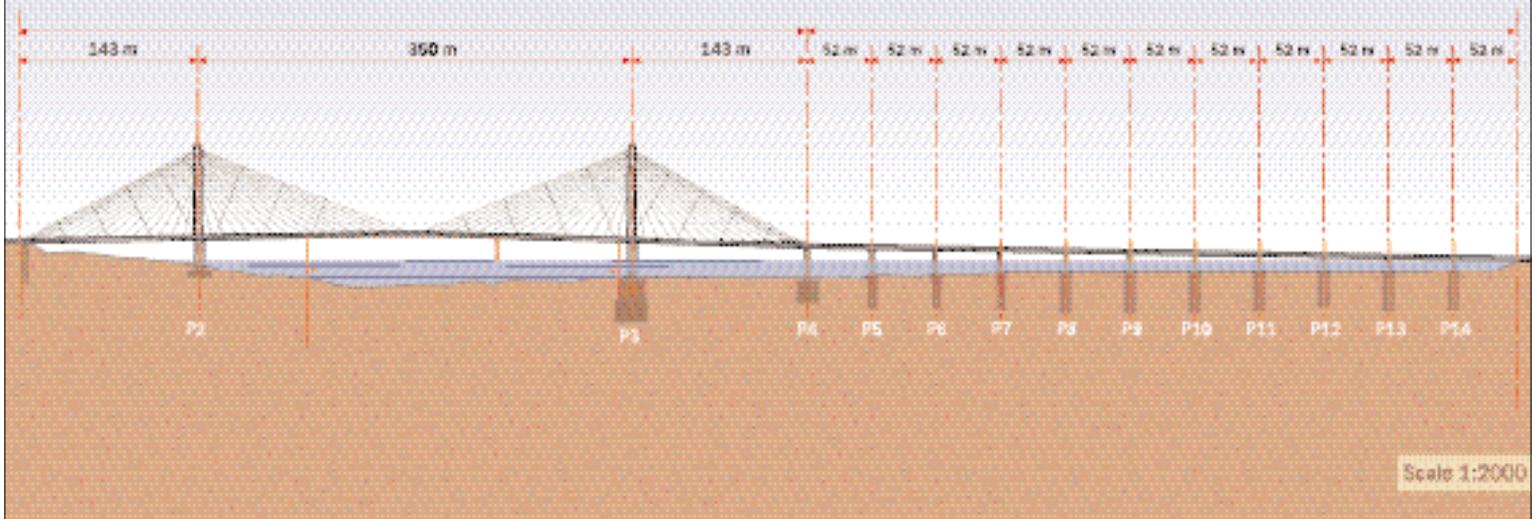
PARTICIPANTS

- ▶ **Client:** Missouri Department of Transportation.
- ▶ **Engineer:** HNTB.
- ▶ **General Contractor:** TBI.
- ▶ **Specialised contractor:** (supply of stay cables and prestressing, technical assistance): Freyssinet.



DESIGNED FOR RESISTING AN 8 FORCE EARTHQUAKE on the Richter scale, parasismic dampers were installed between the pylons and the deck and special devices at each pier to absorb rotating and translation movements. To overcome vibrations of the 128 stay cables, all cables are fitted with needles (eight per layer).

Schematic cross section of Cape Girardeau bridge



SOILS/A89 MOTORWAY

Reinforced Earth improvements in Périgord



The flexibility of use of Reinforced Earth was one of the reasons why this technique was chosen for two work packages on the future Clermont-Ferrand-Bordeaux motorway under construction near Périgueux, France.

FIVE ROAD RETAINING WALLS with heights of up to 18.30 m have to be built on the segment of the A89 motorway between Mussidan and Périgueux in Dordogne, France. The Reinforced Earth technique was the ideal solution for these walls, due to the ease with which it can be blended into the environment, and its capacity for adaptation to the constraints of alternating rock and compressible terrain.

Each cladding panel was made in France in an associated factory of Terre Armée SNC, where special care was taken with quality of the concrete required to resist aggression due to frost and deicing salts. Reinforced Earth was also selected for the Périgueux East - Périgueux West section, but in this case for the 'composite abutments' for two bridges now under construction. In these structures, the load carrying



function was dissociated from the retaining function performed by the Reinforced Earth structure, since the nature of the foundation soil means that large post construction settlements are expected. Therefore each abutment header beam is founded on 0.80 m diameter bored piles protected from foundation movements by 1.10 m diameter concrete shells. The aesthetics of these abutments

are largely due to the ease of placement of the panels and the flexibility that they offer. The entire structures represent 120,000 m² of wall surface area. Terre Armée SNC is responsible for all general stability studies of the reinforced foundations for this project, in addition to its normal services (the supply of cladding and reinforcement, design and technical assistance).

STRUCTURES/ONGA VIADUCT

Strengthening of the deck

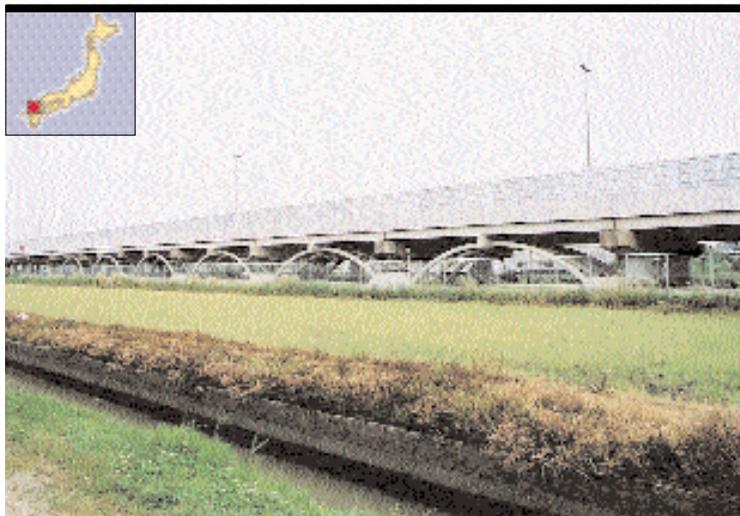
THE 636 M LONG ONGA RAILWAY viaduct in the Fukuoka region (Japan) of western Kyushu Island was opened to traffic in 1974. It comprises 37 spans of strengthened concrete T-girders. After the

major Hanshin earthquake in 1995, the client, the Province of Kitakyushu Roads Department under the authority of the Ministry of Development and Transport, strengthened the bridge piers using

steel plates. This strengthening was found to be insufficient, and a new campaign to strengthen the bridge was initiated. Following the call for bids, a truss strengthening solution proposed by FKK was chosen to make the viaduct satisfy seismic standards. This process was to strengthen the bridge with lightweight trusses forming a simple structure, which would not have been possible using techniques such as steel or carbon fiber lining of the bridge elements. Furthermore, the cost of this solution for strengthening the structure and improving the seismic performances of the viaduct was 40 to 50% lower than the cost of conventional methods. The process is easy to implement and does not require the use of any heavy construction machinery. The system comprises 18 m long trusses made of 40 cm diameter, 1.2 cm thick steel tubes, on which the deck is supported through a

PARTICIPANTS

- ▶ **Client:** Province of Kitakyushu Roads Department, under the authority of the Ministry of Development and Transport.
- ▶ **Consultant:** Chiyoda Engineering Consultants Co., Ltd.
- ▶ **Main Contractor:** Oshima Shipbuilding Co., Ltd.
- ▶ **Specialised contractor** (flat jacks and engineering management): FKK Kyokuto Kogen Concrete Shinko Co., Ltd.



rubber support acting as a sliding bearing. In an earthquake, the sliding bearing isolates the bridge and lateral forces applied to the deck are distributed through the strengthening structures. Loads are applied to the trusses by injecting an epoxy resin in three flat jacks, one located at the high point of each arch and the two others at the arch springings. The arch key then provides a new bearing point for the deck.

SOILS/LOGISTICS PLATFORM IN MARLY-LA-VILLE

'Matchstick' CMCs for express soil treatment



Engineering and contractual constraints obliged Ménard Soltraitement to adapt its controlled modulus columns process and to install small diameter 'matchstick' CMCs on a site in Val-d'Oise, France.

THE SITE on which the future 26,000 m² logistics warehouse for the Cepco-Aventis company is to be built, is a disused open cut Beauchamp sand quarry that had been filled with various materials, originating particularly from demolition work and therefore including many blocks. The fill depth in the building construction zone varies between 6 and 14 m, and the soil investigation showed that the mechanical properties of this ground were poor and very heterogeneous, and therefore unable to resist the design loads of the building slab on grade equal to 50 kPa, plus 10 t point loads due to storage pallets (in some places, loads under the foundation slab will eventually be as high as 120 t).

More than 1,000 m per day

Therefore, treatment was essential to improve the bearing capacity of the soil under the building. This work forms the special foundations package of the global contract and GSE, the main contractor, awarded it as a subcontract to Ménard Soltraitement. The chosen technique consists of making CMCs (controlled modulus columns) with a diameter of 250 mm – which is an unusual value – on a 2.4 m² grid.

'The solution of using small diameter inclusions was chosen because it optimises the design of the slab on grade and the form of its distribution. Since the grid is closer and smaller diameter inclusions are used, bending forces in the slab are lower', explains Loïc Tavernier, the Site Engineer. However, this choice was made not only for technical reasons. 'The larger number of inclusions is compensated by a much lower cost price per metre, due to a smaller consumption of mortar and a very high efficiency (the maximum production was more than 1,000 ml per day per workshop!) which made this solution very economic', adds Philippe Liausu, the Assistant General Manager of Ménard Soltraitement.

Two CMC workshops were set up in predefined areas with different objectives. The first was designed to make inclusions by vibrations to enable the construction of match-

PARTICIPANTS

- ▶ **Client:** Cepco-Aventis.
- ▶ **Engineer and General Contractor:** GSE.
- ▶ **Specialised Contractor:** Ménard Soltraitement.



20 mm maxi

Load tests on a CMC were repeated thirty three times and validated settlements of between 1.5 and 3.8 mm predicted by Ménard Soltraitement, thus respecting the value of 20 mm required by the contract.

stick CMCs in areas with up to 14 m fill thickness. The second was provided with a turntable and a displacement auger, and was used for the treatment of shallower areas to guarantee minimum settlement.

The warehouse access roads cover 7,500 m² and will be used mainly by heavy trucks. Areas under these access roads were consolidated by dynamic compaction with a net-

work of 6 m deep columns on a 2.5 m² grid. A total of seven weeks were necessary to make 42,000 m of matchstick CMCs. ■

STRUCTURES/BELLEVUE BRIDGE

Over the bridge and under the flyover



Innovative construction methods frequently make a conventional site innovative. This is the case for Bellevue bridge in Nantes, where the Freyssinet-Dodin joint venture has successfully continued its road widening work in the presence of road traffic.



65,000 VEHICLES, including 10% of heavy good vehicles, use the single lane between the south and east ring roads in the Nantes area (France), every day. Bellevue bridge over the Loire is an unavoidable and particularly sensitive point along this road and is the site of severe rush hour congestion, which is why the Loire-Atlantique General Council decided to widen the bridge. This work is now under construction and will contribute to

improving traffic fluidity and maintaining continuity of the two dual carriageways on Nantes ring road including the construction of interchanges on each side of the bridge.

15 months work

Bellevue bridge is composed of two parallel and independent decks, one called the downstream deck being 370 m long and 10.5 m wide carrying the inner ring road and the upstream deck being 385 m

long and 12 m wide carrying the outer ring road. The work began on the upstream structure and consisted of widening the 3.20 m deck firstly to widen the road itself (hard shoulder), and secondly to add pedestrian and cyclist tracks that can be used to cross the Loire in complete safety. The work on the upstream deck will last for 10 months and the work on the downstream deck for 5 months. On the upstream deck, eleven 37 m

long, 15.2 m wide and 22 cm thick slabs weighing 300 t each will be cast in situ on the existing deck. Almost 15 thousand 3.6 cm diameter holes were drilled in the top slab for fitting connectors that will fix the new slab to the existing bridge. On the upstream side, a formwork system is used for widening the deck. The group will install prestressing cables in the box beam, to resist loads from the new slab. The work will also include the replace-

ment of bearings and expansion joints. However, an innovative construction method had to be used to reconcile strengthening and concreting work with the heavy traffic. Thus, the group installed a 90 m long, 7 m wide temporary flyover on the deck weighing 160 t, that covers the site as work progresses and over which vehicles pass straddling the work area; a first in France. Obviously, this solution requires that very strict safety rules are respected, and the speed is limited to 30 km/h for cars. The largest operations take place during the week-end to minimize disturbances, and traffic is not interrupted at any time.

A tricky operation

Every Friday evening at 20h00, the bridge on which the work is being done is closed to vehicular traffic, and all the traffic is changed over to the other deck where it is carried by one lane in each direction. The flyover moving operation starts at 10h00 pm, and is a difficult operation due to its size. Saturday morning is spent concreting areas that had been strengthened the previous week-end using a mobile traveler protected by the flyover; at the same time, the next segment is strengthened using a crane. The flyover is then moved above the strengthened area. After one day of curing (Sunday) the concrete has become strong enough to carry traffic again on Monday morning at 7h. ■

PARTICIPANTS

- ▶ **Client:**
Ministry of Development, Transport and Housing.
- ▶ **Engineer:**
Loire-Atlantique Development Authority.
- ▶ **General Contractor:**
Freyssinet-Dodin joint venture.

STRUCTURES/ZERI VIADUCT

530 t suspended

Freyssinet Italy has designed and built an innovative span lifting system on a repair site on the Italian Zeri motorway viaduct between Parma and La Spezia.

ZERI VIADUCT was built in the early 1960s and is composed of two 385 m parallel decks. There are eleven spans in each deck, each span is 35 m long and weighs 530 t, and is composed of four precast beams supported on pier heads and a cast in situ reinforced concrete slab. The maximum height of the piers is about 40 m.

The global contract applies to renovation of the viaduct, and the part subcontracted to Freyssinet Italy by Licis SPA covers lifting of the 22 viaduct spans, which is necessary to replace the neoprene bearings, install the seismic devices and to do the work to strengthen the pier heads. Vincenzo Emprin, Freyssinet Italy's Business Manager, explains: 'The configuration of the piers and

the use of longitudinal strengthening prestressing at the heads obliged us to lift the deck by 2 m to allow room for the tensioning jacks to pass through. This is why Ange Pontier from Freyssinet Italy's Engineering Department specially developed a metallic structure for lifting from above'.

Sixteen 60 t jacks

This system, which is capable of lifting spans individually, is supported directly on pier heads using five steel columns located at the ends of the span. The lifting bars, with continuous threads (36 mm diameter) are inserted through the 100 mm openings drilled in the slab. Retaining bars are fixed to adjacent spans that act as counter-

weights, to avoid the construction of a heavy lifting structure which would therefore be difficult to move.

The actual lifting operation is done by sixteen 60 t jacks with a travel distance of 25 cm controlled by a computer aided control center. When lifting is complete, the metallic structure fitted with special rollers is moved and the openings are reclosed with reoplastic concrete. 'This means of displacement saves the cost of a crane, and also means that the lifting bars and hydraulic systems can be left in place without needing to systematically disassemble and reassemble, which represents a considerable time saving' says Vincenzo Emprin. This is an undoubted advantage since the motorway is to be opened for traffic in the Summer. ■

PARTICIPANTS

- ▶ **Client:** A15 Autocamionale della Cisa.
- ▶ **General contractor:** Licis SPA.
- ▶ **Specialised contractor:**
Freyssinet Italy.
- ▶ **Design office (structure):**
A15 Autocamionale della Cisa.
- ▶ **Design office (lifting):**
Freyssinet Italy.



SOILS/JAMESTOWN BRIDGE



American-Canadian Co-operation

The Canadian team at Reinforced Earth Canada has been working in close co-operation with its sister company in the United States to build the first precast arch structure in the State of New York.

IN DECEMBER 2001, the New York State Department of Transport (NYSDOT) issued a call for bids to replace the old Fairmount Avenue bridge crossing the Chadakoin River at Jamestown. The main characteristics of the new bridge are that it comprises two TechSpan precast concrete arches supported on foundations founded on piles, and concrete spandrel walls. The structure is close to the Canadian border, which is why it was quite natural for Reinforced Earth

USA, to call upon Reinforced Earth Canada's good experience in the construction of large arches. This arrangement, provided the customer with the Group's best expertise.

The largest arches

The Canadian company thus carried out the design and supply of TechSpan arch elements and the general design and supervision of the work, and obtained permits for the design and materials from the Department of Transport. Its Amer-

ican partner will did the design and supply of the TerraTrel spandrel walls. The span of the TechSpan arches for the Jamestown Bridge is 19 m long, making them the largest TechSpan arches ever built in North America. The loose soils at the site required the arches to be founded on piles. A further complexity at the site was due to the foundation level being 3 m below the riverbed. This required the foundations to be built

inside cofferdams. The work for this preliminary step had to be done in phases, which was particularly restrictive because traffic on the bridge could not be interrupted. The first phase of the work consisted of building the foundations by driving vertical piles and delivering materials to site to enable partial construction of the arches. The first four elements of each arch were assembled in less than three days (instead of five days as planned by the main contractor), and the resulting savings on the cost of the crane and labor were 50%. Furthermore, road traffic was not interrupted for more than eight hours, satisfying the authorization given by the NYSDOT Roads Department. The second phase for complete construction of the arches should be completed during the month of August 2003. ■

PARTICIPANTS

- ▶ **Client:** New York State Department of Transport.
- ▶ **Main Contractor:** A & L Inc., Hamburg, New York.
- ▶ **Specialised contractors** (design and supply of materials): Reinforced Earth Canada and Reinforced Earth USA.

STRUCTURES/DUBAI TOWERS

Prestressed concrete floors for two structures

Prestressing concrete floors provide many opportunities for designers. Illustration

THE CAPRICORN AND AL JABER Complex (Shangri-la Hotel) towers have both be built in Sheikh Zayed Road in Dubai, and both building projects are among the most remarkable in the United Arab Emirates due to their architecture and their height.

Freyssinet Gulf worked in co-operation with the Clients Representatives to refine the structural aspect of the projects. Many concrete buildings in Dubai are being studied for alternate prestressing solutions which reduced the thickness of the floors and core spaces, reduces the number of load bearing columns (and therefore optimises the layout of the internal space), and finally reduces work construction times.

A suspended mezzanine

There are forty-seven storeys in the Capricorn tower. The solution adopted for floor slabs uses a compact prestressing system composed of flat anchors with four 12.9 mm steel strands grouted after tensioning. Car park floors were also prestressed (a total of 260 t of steel was installed on the structure). The car park was converted by Freyssinet to a post-tensioned structure.

The Al Jaber Complex building comprises two parallel towers and it is now the soon to open Shangri-la Hotel. Its maximum height is 196 m and it comprises 43 floors and 2 basement levels.

Its original design necessitated the construction of post-tensioned load transfer beams on five levels throughout the twin towers.

Six major advantages

- ▶ Lower concrete and rebar quantities.
- ▶ Thin slabs.
- ▶ Easy to install services and networks under the ceiling where flat slabs are used.
- ▶ Reduction in the number of load bearing columns.
- ▶ Increase in the width of openings and traffic spaces (for car parks).
- ▶ Resistance to earthquakes.

Freyssinet Gulf installed 250 t of prestressing steel in total using the 12K15, 19K15 and 27K15 systems. The 4th floor was used to suspend the mezzanine and lower floors with vertical post-tensioning.

A prestressed beam solution to support the floors, proposed by Freyssinet Gulf to the client, was also selected for the adjacent nine-storey car park building. ■

PARTICIPANTS

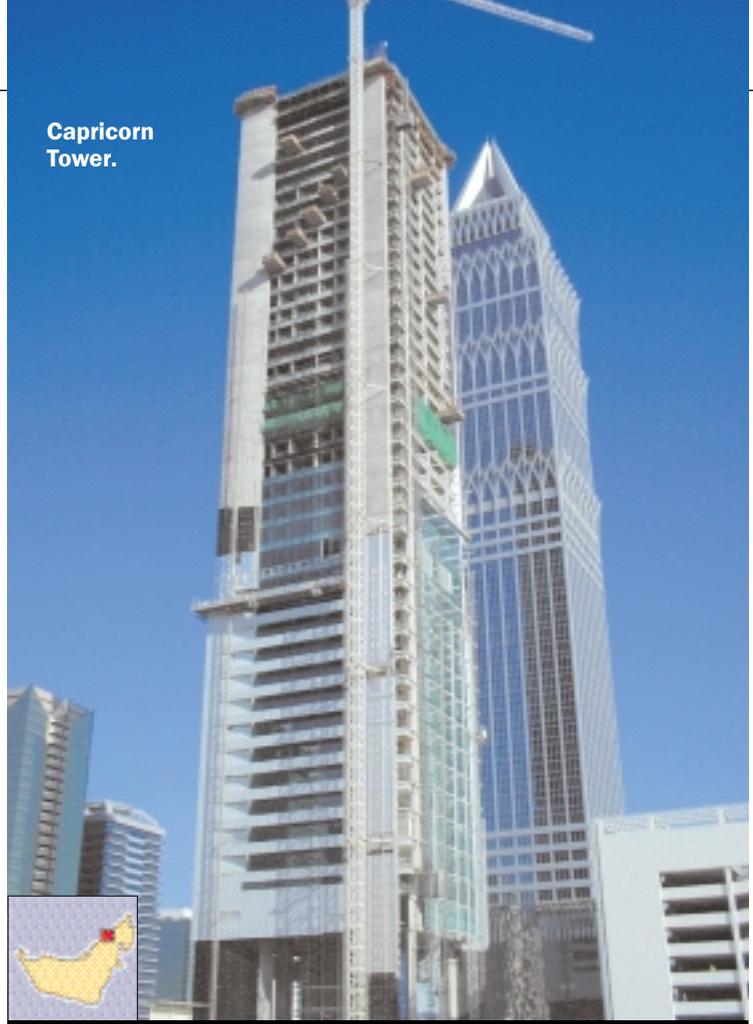
Capricorn Tower

- ▶ **Client:** Ahmed Siddique and Sons.
- ▶ **Engineer:** Schuster Pechtold & Partner.
- ▶ **Design Office:** Dubai Contracting Company.
- ▶ **Specialised Contractor:** Freyssinet Gulf.

Al Jaber Complex Tower

- ▶ **Client:** Obaid Al Jaber.
- ▶ **Engineer:** Al Habtoor Murray and Roberts.
- ▶ **Design Office:** Norr Group.
- ▶ **Specialised Contractor:** Freyssinet Gulf.

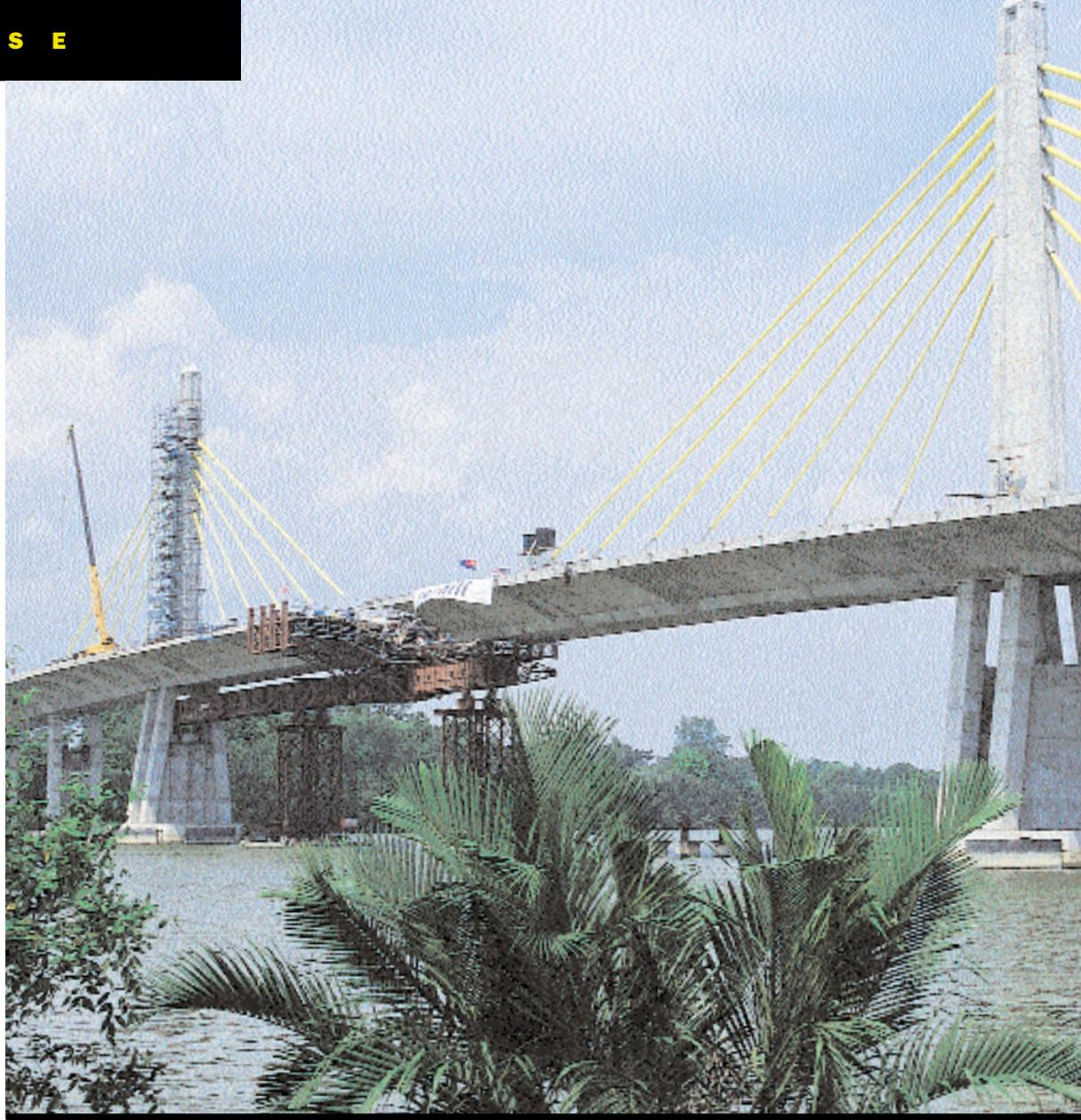
Capricorn Tower.



Al Jaber Complex Tower.



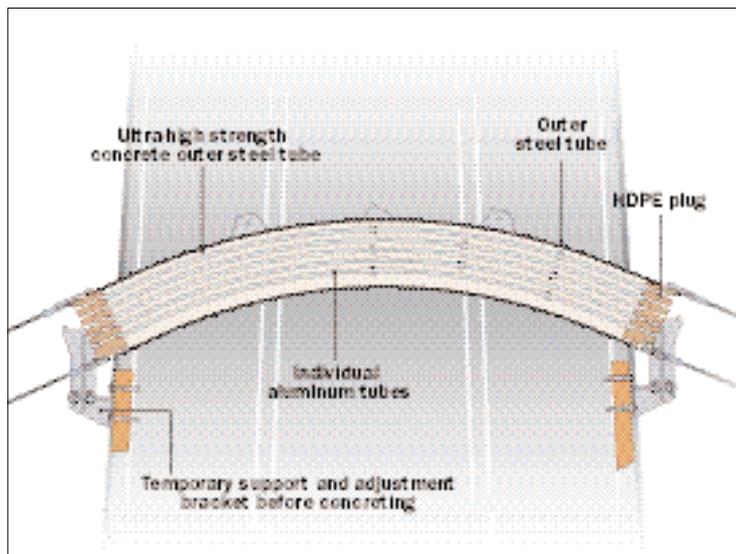
One of the advantages of this process that was awarded the bronze medal in the innovation competition organised by the Egis company, is that it simplifies the design of towers.



Awards for the multitube stay

The direction control saddles technique borrowed from suspension bridges has often been used in the past, particularly with closed cables, to change the direction of a load bearing cable at the crossing over towers. This type of device has also been used for stay cable bridges to make cables continuous at the tower crossing. This was the case for Brotonne and Arade bridges.

The arrangement of the passage using a saddle simplifies the tower design. It is attractive structurally, but it does create a singular point in the cable which in the past made it



difficult to satisfy the requirements of a stay cable.

Forces at the saddle are transferred over a certain length of the 'typical' part of the stay cable that is not designed for this purpose, and the curvature reduces the resistance to fatigue and the ultimate strength of the cable.

A solution adapted to the Cohestand strand

Furthermore, the creation of a fixed point absorbing asymmetric forces is often incompatible with long life of the cable and the possibility of replacing it.

Mutation of a traditional process

COMPOSITION

- A group of individual aluminum tubes bent to a radius of between 2.5 and 4 m.
- An outer steel tube (with a diameter from 300 to 500 mm).
- An HDPE (high density polyethylene) 'plug' at each end.
- Ultra-high performance concrete, injected between the individual tubes and the outer steel tube.

PROPERTIES

- Blocking by friction of asymmetric loads transmitted to the tower equal to 20% Frg (guaranteed ultimate strength) at the failure limit state.
- Resistance to fatigue exactly the same as the stay cable.
- Filtration of cable direction changes at the entry into the saddle.
- Continuity of anti-corrosion barriers.
- Possibility of replacing stay cables strand by strand.

ADVANTAGES

- Aesthetic: additional freedom offered to architects for the tower design.
- Cost savings.
- Ease of replacing strands.
- No maintenance.
- Flexibility of construction (no cement grout to be injected on site).
- Long life due to exceptional fatigue strength and corrosion resistance.

cable saddle

Freyssinet International & Cie proposed a new saddle design to satisfy the specification for the Sungai Muar bridge, Malaysia, written by Jean Muller International. This design is capable of overcoming these disadvantages and guarantees long life.

The 'multitube saddle' based on use of the Cohestrand patented strand, was then developed jointly by Jean Muller International (Guy Frémont) and Freyssinet International & Cie (Jean-Claude Percheron).

With this system, the strands are individually deviated, which elimi-

nates wear problems. The multitube saddle thus offers excellent fatigue performance with stress variations of more than 200 MPa, and provides continuity of anti-corrosion protection of strands and enables individual disassembly. It has been tested and validated by fatigue and friction tests.

Specific installation methods were defined for the site and the strand by strand installation of the stay cables.

The work began in March 2003 and is continuing at a sustained rate. ■

TRADE FAIR Freyssinet booth at TPTEch



Freyssinet booths at the fib (1) conference and TPTEch (2) trade fair

Five months after participating in the fib conference in Osaka, the Freyssinet Group attended the TPTEch trade fair, which was held for the second time at the Cnit, Paris-la-Défense, between March 11 and 13 2003.

This trade fair is a major interface between different technologies and an important meeting place for French public works and civil engineering professionals, and it offered a unique opportunity for Freyssinet to present its activities in the soils and structures activities.

The group also took an active part in the TPTEch conference, particularly through presentations by Benoît Lecinq, Freyssinet Engineering Manager, on reinforcement of the piers for A4 motorway overpasses, and Serge Varaksin, the Ménard Soltraitement Export Manager, on soil consolidation in Hamburg. ■

ARCHITECTURE TerraBlock and the urban environment

The construction of a road junction leading to the palace of the Sheikh of Abu Dhabi provided an opportunity for Freyssinet Middle East to participate in the construction of a bridge access ramp. The upper parts of bridge retaining walls are made of Reinforced Earth® with Freyssisol Soil reinforcement, while 1,700 m² of the lower parts of the walls are constructed using the innovative TerraBlock technique. This system, which is also a Reinforced Earth® retaining process, is composed of prefabricated hydraulically pressed concrete hollow blocks and Freyssisol type reinforcing strip of a specially developed grade. It is a means of making walls with a variable geometry, adapted to the use of all types of granular fill. In particular, the block fabrication process and their ease of placement open up many opportunities for architectural solutions. By the end of this contract, 32,000 m² of TerraBlock walls were on order for similar projects throughout the capital of the Emirate. ■



Palm trees and flowerbeds will be planted on the terraces of this structure.

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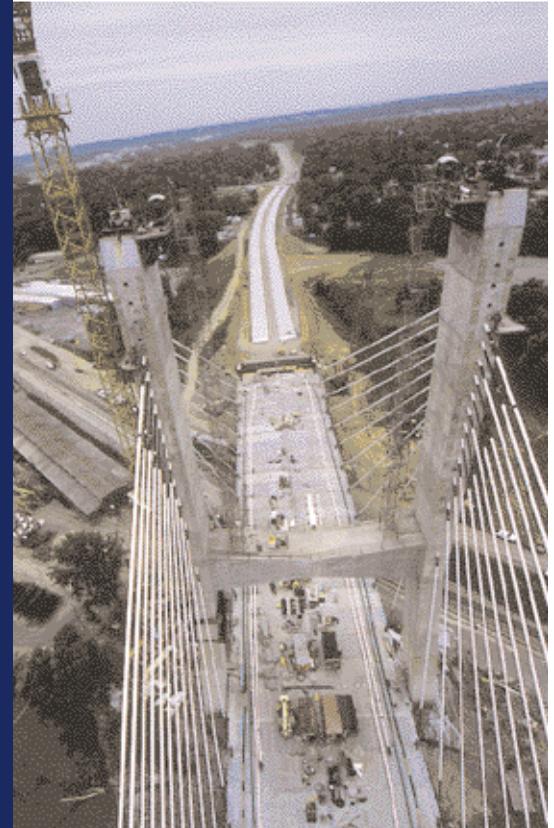
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In the United States, the construction of the Cape Girardeau stay cable bridge is in full swing. This 636 m long structure featuring a 350 m cable stayed span over the Mississippi will replace a 2-lane steel bridge unsuitable for the continuously increasing traffic needs. This project is the biggest ever undertaken in the State of Missouri and it will stand out as the architectural landmark of the town.

FREYSSINET - 1 bis, rue du Petit-Clamart - 78140 Vélizy-Villacoublay - France - Phone: (+33 1) 46 01 84 84 - Fax: (+33 1) 46 01 85 85 - www.freyssinet.com **Publication manager:** Claude Lascols - **Editor:** Stéphane Tourneur (communication@freyssinet.com) - **Contributed to this issue:** Isabelle Angot, François Bignon, Bill Brockbank, Stéphane Cognon, Carlos de Oliveira, Vincenzo Emprin, Guy Frémont, Takao Fujita, Jean-Philippe Fuzier, Ernst Friedlaender, Gary Hall, Geoffrey Holding, Christophe Houix, Anik Jean, Dominique Jullienne, Roger Lacroix, Benoît Lecina, Philippe Liausu, Albert Moizeau, Sylviane Mullenberg, Patrick Nagle, Manuel Peltier, Jean-Claude Percheron, Nicolas Raudin, Pierre Sery, Andrew Smith, Loïc Tavernier, Patrick Valente. **Editorial secretariat:** Jean-Marc Brujaille - **Layout:** Idé - **Photos:** David Houlston, VK Photo Studio, John de Rooy (focus and cover), Francis Vigouroux, Freyssinet and VINCI photographs. Freyssinet is a subsidiary of VINCI.

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