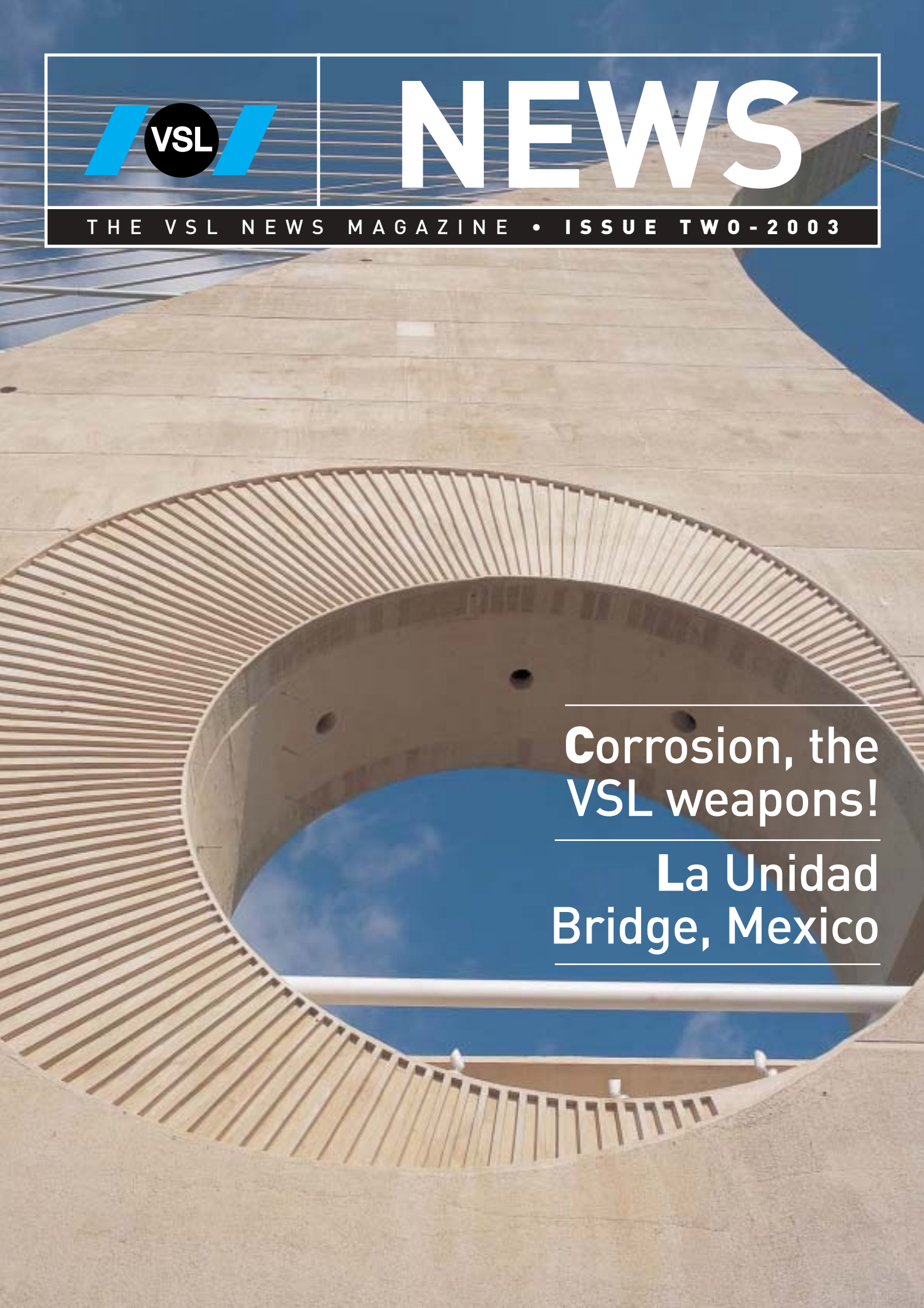


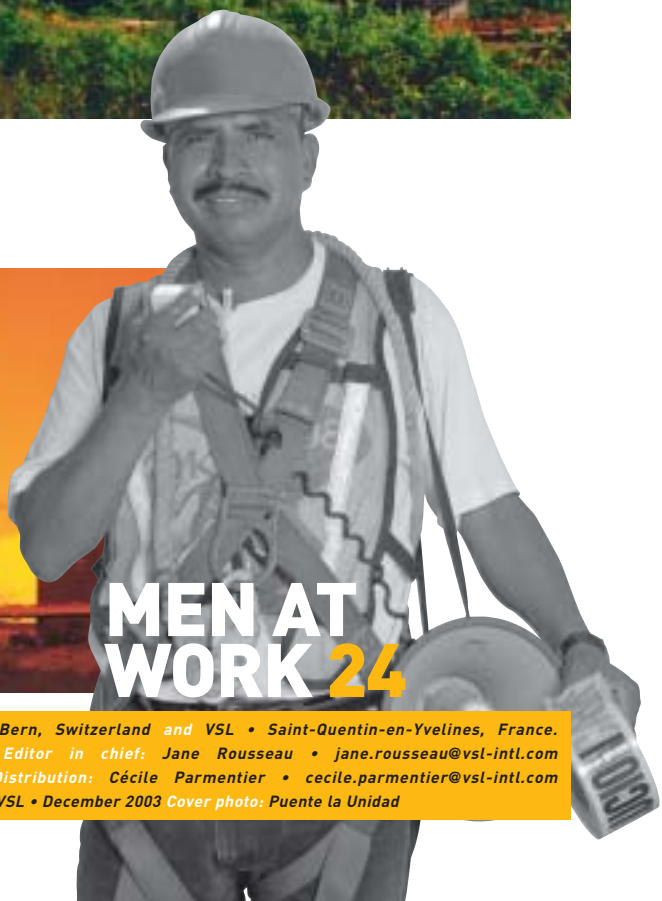
NEWS

THE VSL NEWS MAGAZINE • ISSUE TWO-2003

Corrosion, the VSL weapons!

La Unidad Bridge, Mexico

highlights



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EDITORIAL

Combating corrosion: a job for specialists

Ground anchor tendons, stay cables, internal and external post-tensioning systems, bearings, joints... our products are the constituent elements of structures. They are part of the structural solution of a project, so corrosion prevention must be an essential concern in their design and application. Some new weapons in the fight against corrosion have been provided recently by our R&D team. These include electrically isolated tendons (EIT) particularly for ground anchors; VSL-HPI® grout optimised for the characteristics of the cement and additives; and the new CS 2000 post-tensioning system, combined with plastic ducts and specially designed isolating plates to allow total encapsulation of the cable. We are also offering technologies with our systems that enable clients to continually monitor some structural parameters and track their evolution over time. The aim of all these systems and processes is to bring our clients greater confidence in the durability of structures.

Besides our product R&D policy, we are constantly seeking to strengthen the competencies of our teams at the worksites and to improve the quality of the components they use, particularly in the areas of grouting and stressing of stay cables. Our network subsidiaries implement an active quality policy, as exemplified by VSL in Hong Kong, where recently we simultaneously obtained ISO9001:2000 (Quality), OHSAS18001:1999 (Health and Safety) and ISO14001:1996 (Environment) certification for all our activities.

We are fighting the battle against corrosion as a team, within the VSL group, and with our clients and their engineering offices. Optimising details that will make a difference, and doing so during the design stage of a project, is an effective way to make structures more durable.

Jean-Philippe Trin

Stressbars

Nails for Buddha protection

→ **In March 2001, Afghanistan's Taliban rulers** partially destroyed the famous Buddhas of Bamiyan. Unesco has declared the monuments a world heritage site and as a priority to prevent further erosive damage. Geotechnical specialists Ing. G. Rodio SpA have been instructed to secure the silty sandstone and agglomerate cliffs from potentially-dangerous rockfalls using nailing and netting techniques. VSL supplied free of charge pre-grouted permanent Y1050 stressbar nails (3.5 to 4 tonnes) in order to secure the area around the smaller, though equally as impressive, 35-m high Buddha. ■

Contact: deccleston@vsl-schweiz.ch

USA

Three PTI awards for VSL

→ **The awards presented at the Post-Tensioning Institute (PTI) Annual Meeting,** held in California, recognize the year's outstanding post-tensioning projects within the construction industry. VSL was honored for the following: the Interstate 895 Connector in Richmond, Virginia (Best in Class Bridges); Frank Lloyd Wright's Fallingwater Restoration in Mill Run, Pennsylvania (Honorable Mention, Industrial and Special Applications); and University Hall Strengthening in Charlottesville, Virginia (Honorable Mention, Strengthening/Rehabilitation). ■

Contact: bgallagher@structural.net

Mivan

Working by hand

→ **VSL Philippines has successfully secured a contract for the design,** supply and operation of nearly 3,000 m² of a "Mivan" hand-laid aluminium formwork system for a 41-storey condominium project. All of the project's concrete elements are being formed using the "Mivan" system. Since no suspended ceiling has been included in the design, the client saw a distinct advantage in the high-quality and high-precision surface finish the system is able to produce, coupled with a reduced floor-to-floor cycle plus the fact that no tower crane time is required as the system is being moved by hand. The capability of pouring difficult areas such as ledges, pipe chases and stairs as monolithic concrete pours also incited the client to opt for this solution. VSL will form over 103,000 m² in all on the project, which is scheduled to peak by July 2004. ■ *Contact: m.phillips@ph.vsl-intl.com*

France

Back on A29

→ **In June 2003, VSL France was awarded the post-tensioning contract** for the incrementally-launched, prestressed concrete La Bresle Viaduct viaduct (756 m long) on the A29 motorway between Amiens and Neufchatel-en-Bray (Normandy). In 2002, VSL had already provided post-tensioning for 60 bridges along with more than 300 tons of prestressing steel. Part of this post-tensioning work was completed with CS 2000 6-12 units. This was the first use on such a broad scale in France. ■

Contact: michel.guichard@vsl-france.com

Certification

Management systems

→ **In November VSL and Intrafor in Hong Kong completed certification** to ISO9001: 2000 (Quality), OHSAS18001: 1999 (Health & Safety) and ISO14001:1996 (Environment) for all business units and the full scope of activity, making them the first companies in the group to achieve this.

The management systems are integrated which greatly improves efficiency. This also allowed certification to be conducted, using an integrated management system approach, which significantly reduced the duration of the audit. ■ *Contact: mark.divers@hk.vsl-intrafor.com*

Strengthening

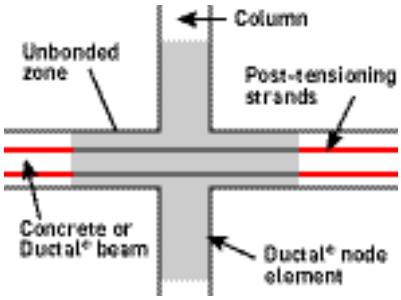
VSL launches a new line

→ **As a leading supplier of specialty reinforcement systems,** VSL has launched in the US a line of strengthening products for use in the construction, repair and upgrade of buildings, bridges, parking garages, and special structures. VSL's product offering includes carbon fiber- and glass-reinforced systems, steel-reinforced systems, and post-tensioning systems, a full range of alternatives for structural upgrades, together with feasibility studies, load testing, design support, value-engineered proposals, detailing, and contractor consulting. ■ *Contact: bgallagher@structural.net*

Earthquake protection

A frame for buildings?

→ **Designing a connection node with a BFUP material** is an old idea, yet one to be applied. Using post-tensioning combined with Ductal® nodes constitutes an ongoing research effort between VSL and Japanese partners in the quest for cost-effective seismic protection. The use of post-tensioning necessitates unbonded strands at the level of the beam-column connection: unbonded strands allow the connection to loosen, inducing the mild rebar to plasticize and hence allowing for energy to dissipate. The nodes therefore are heavily stressed, making them difficult to design with conventional concrete. The use of Ductal® would considerably improve the overall system: the enhanced ductility would smooth deformations. ■ *Contact: mouloud.behloul@vsl-intl.com*



PRESS REVIEW

Post-tensioning: the invention of the century

For its 100th anniversary, the French magazine "Le Moniteur", no 1 for the construction industry, asked its readers to name the last century's most significant innovation. The building process using prestressing was awarded the distinction and the specific project used to highlight this process was the Viaduct over the Rhone River in Avignon (southern France) for the TGV Méditerranée high-speed train line: two independent concrete decks for which VSL performed the prestressing work.

Go to Demon. *A new Web site dedicated to VSL monitoring activities (contact: jbdomage@vsl-schweiz.ch) has been created to provide the assigned project engineer, main contractor and owner with remote access to project data in real time: sensors, technical reports, calibration reports, videos, photos, etc.*

VSL load cell. *VSL (UK) was contracted to return to Kingston Bridge in Glasgow (Scotland) to load-check a selection of external PT tendons. During this inspection visit, VSL installed an Hc160 mono-strand load cell onto one of the existing external post-tensioned tendons to ensure the long-term monitoring of these tendons.*

PRESTRESSING STEEL

Corrosion: the


EIT at Raron Bridge, Switzerland

Corrosion protection of post-tensioning tendons has become a significant concern for many owners. The corrosion of prestressing steel may cause much more serious problems than that of normal reinforcement as prestressing tendons normally have a small cross-sectional area under very high stress. Environmental loads such as chloride attack due to deicing salts or seawater have increased in the last decades. Increased awareness of the aspect of durability has lead to demands for improved performance of the post-tensioning systems in corrosion protection and the possibility to monitor the tendons.

VSL has invested since long into the improvement of the protection of tendons and was the first company to introduce robust plastic duct system, PT-PLUS, for encapsulation of post-tensioning tendons. This is now becoming a standard solution in many countries. More recently, VSL has developed the CS 2000 anchorage system, which allows full encapsulation of the tendon anchorage in plastic and which is fully compatible with the PT-PLUS system. The CS 2000 also allows to electrically isolate the tendon from the structure and therefore monitor the protection of the tendon throughout the design life of the structure. Any defect in the encapsulation during the design life, e.g.ingress of water into the tendon, will be detected immediately. Appropriate measures may then occur early before the repair cost become excessive or before there is any safety risk for the structure.

As for stay cable systems, a new approach of durability in terms of corrosion protection of exposed metallic surfaces has lead VSL to design durability of a stay cable on a rational basis, allowing to specify adequate protection according to the expected environment and the design life of the stay.

Here are some of VSL's weapons – independant or combined – to fight the civil engineer's and bridge owner's shared nightmare: corrosion...

VSL weapons!

Tendons

EIT concept for improved protection and monitoring

The benefits of electrically-isolated prestressing tendons are beeing promoted by VSL. It is now possible to check the condition of the encapsulation by a simple measurement of electrical resistance and impedance between the tendon and the structure...

Today technology allows producing steels with very high strength, but these materials are more susceptible to brittle fracture caused by corrosion and hydrogen embrittlement[1]. Research on structures have shown that corrosion of the prestressing steel occurs at points where water and chloride ions can penetrate. The metallic ducts can not be considered as a barrier. Demands for improved performance of the PT systems in corrosion protection and the possibility to monitor the tendons.

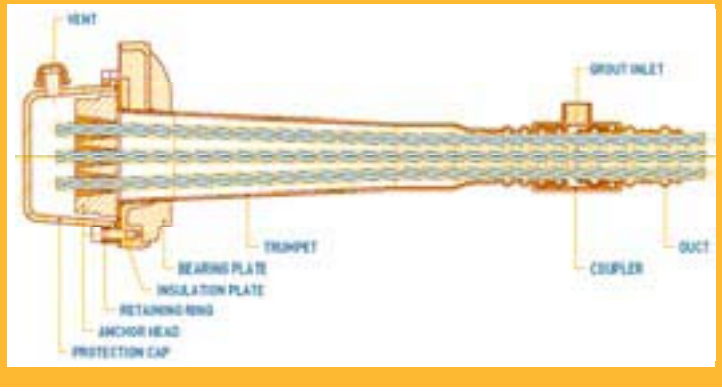
EIT on rails

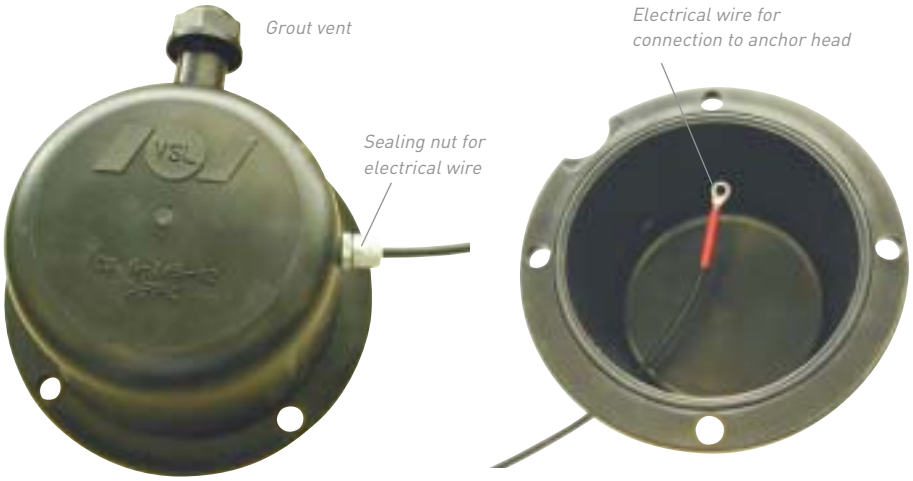
Corrugated plastic PT tendon sheathing was introduced in the 1960s and disappeared during the petrol crisis (1970). When investigating fretting fatigue and fretting corrosion of tendons with metallic ducts, polymeric materials were introduced again for tendon ducts, this was the starting point of a fully isolated tendon. The increasing concern about corrosion and stray currents of the high strength steel lead to the requirement for electrical isolation of all 945 permanent ground anchors at the railway station Stadelhofen, Zürich, in 1985; this was the break through for Electrically Isolated Tendons (EIT) applied to ground anchors, and to post-tensioning tendons. ▶

CS 2000 anchorage and PT-PLUS duct

The combination of the anchorage of the VSL Composite System 2000 (CS 2000) and the VSL PT-PLUS duct integrates a complete and practical solution for electrically isolated PT tendons (EIT).

- *The anchorage is made of steel, high performance mortar and plastic taking advantage of progress in material technology, manufacturing and design. The CS 2000 anchorage accommodates up to 37 prestressing strands diameter 0.6", grade 1860 MPa.*
- *The PT-PLUS plastic duct fully encapsulates and isolates the strand bundle by nature and continuity along tendon. Detailing is most important at anchorage level in order to guarantee full encapsulation and electrical isolation. The elements that complete the encapsulation at the anchorage are a standard PT-PLUS coupler with inlet, the plastic trumpet, the insulation plate and the plastic protection cap.* ■





CS Protection cap with wire for electrical resistance measurement.

Reference to standards

The most complete document giving guidance for EIT is the "Measures to ensure the durability of post-tensioning tendons in RC concrete structures" document[2], published by the Swiss Federal Highway Agency and the Swiss Railways in 2001. The guideline proposed three categories for Post-Tensioning tendons in terms of corrosion protection. Tendons of category C require complete electrical isolation to protect against stray currents and to allow to monitor the integrity of the tendon encapsulation.The Guideline indicates criterias for the choice of the categories and gives information for the measuring procedure and the interpretation of the results.

AC impedance mesurements

The use of electrically isolated tendons allows to control the electrical isolation and the integrity of the duct after construction and to monitor the corrosion protection of the steel strands during service life with simple AC impedance measurements (called 'electrical resistance measurements'). The measurements require a sound electrical connection to each individual tendon and another connection to the rebars. Monitoring of the electrically isolated tendons is performed with AC impedance measurements at frequency of 1 kHz (LCR meter ESCORT 131). From laboratory studies the limiting values for a sound encapsulation was found to be 500 kW*m (59 mm PT Plus duct).

Increase of resistance with time

The flyover "P.S. du Milieu" near Avrenches is about 100 m long and consists of six sections with five columns. The anchorage zone is constructed with robust plastic ducts and plastic sleeve and electrically isolated anchorages. Six electrically isolated tendons (length 100 m, PT PLUS duct diameter 59 mm) were measured in order to control the integrity of the duct after construction. Five of the six tendons showed ohmic resistance between 7 kW and 28 kW, thus fulfilling the criteria of 500 kW*m. Tendon nr. 6 had a short circuit because of a metallic contact between tendon and structure.

On another flyover, "Près du Mariage" (length 49.3 m, PT PLUS duct, diameter 76 mm), the ohmic resistance was monitored from the time of grouting up to three years. The six individual tendons showed some scatter, but the overall trend is an increase of the resistance with

PT-PLUS: The VSL leak tight coupling device

Plastic ducts offer significant advantages for corrosion protection as an independent barrier to seal the tendon (in addition to concrete and grout) even across active cracks, also providing the possibility to electrically isolate the tendon. ■

Several reports such as the FIP recommendation and the EOTA guidelines are giving guidance for Electrically Isolated Tendons. The most complete is the Guideline published jointly by the Swiss Federal Highway Agency and the Swiss Railways in 2001. It is beeing applied by VSL on Raron Railway Bridge, Valais.

time. This can be explained by the hydration of the grout and the surrounding concrete and the subsequent drying out; this trend is expected to continue in the future service life of the structure. This allows to detect the ingress of water in a very early stage: if (chloride containing) water reaches a defect in the duct, the concrete and the grout get wet and the electrical resistance of this tendon will not increase any more but drop significantly. Thus the measurement of the electrical impedance at the normal inspection intevals represents a simple but very effective early warning system to detect a corrosion risk situation. New mesuring methods now allow to accurately locate any damage in the encapsulation. The owner can then take specific action at the tendon location, as may be found required.

VSL combination against corrosion

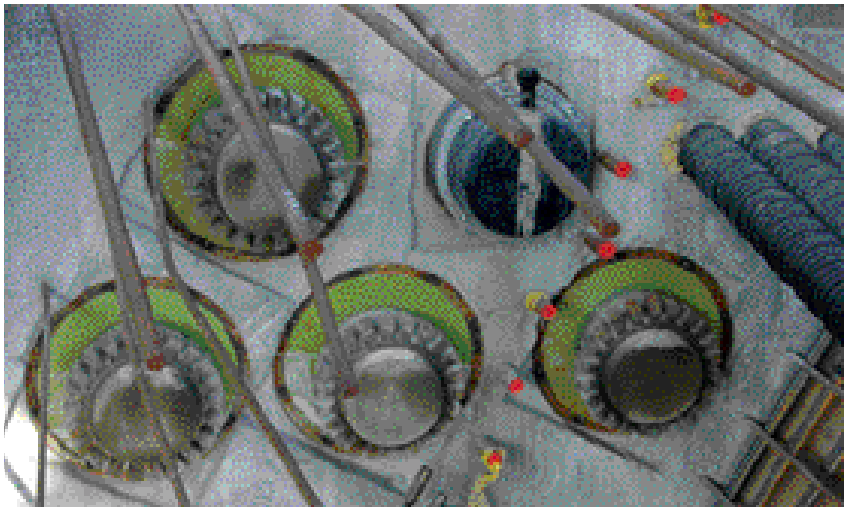
Long and proven experience with electrically isolated ground anchors and tendons has been accu-mulated since 1985 (railway station Stadelhofen, Zürich). The first application in bridges was in 1992 the flyover "PS du Milieu" near Avenches (Vaud). EIT is now used regularly on certain bridge projects in Switzerland. EITs comprising 19 and 22 strands of 15 mm are being installed in the Rhone Bridge at Raron (Valais). The Italian Railway Authorities is using EIT for the new high speed train lines. ■

[1] *FIP Recommendations, "Corrosion protection of prestressing steels" 1996.*
[2] *Guideline "Measures to ensure the durability of post-tensioning tendons in RC concrete structures" Swiss Federal Highway Agency and Swiss Railways, EDMZ (2001)*

Switzerland

Summits of requirements

As part of the Swiss TransAlpine project, at the exit from the new Lötschberg Tunnel, at the Valais end, two viaducts straddle the Rhone River at Raron. As these are railway bridges, for protection against corrosion due to the presence of stray currents, the project manager and the contracting authority demanded that all the prestressing tendons be electrically isolated. Carrying out this work represents a real challenge. These are the first bridges in Switzerland to be electrically isolated with tendons coupled over 14 stages, to meet the very high level requirements of the new Swiss directive on corrosion protection.
Protective shells for the VSL PT-PLUS ducts were specially designed for these bridges.
The coupler trumpets had to be modified to comply with the bridge's geometry. The VSL 6-19 and 6-22 tendons are threaded prior to concreting and coupled with the preceding stage. An extensive check on the tightness of the ducts and anchor head components is performed before closing the formwork.
After concreting, the tendons are tensioned in two stages in accordance with a predefined schedule and vacuum grouting of the tendons is performed immediately afterwards. About 540 tonnes of prestressed concrete, 426 ECS 6-19 and 6-22 anchor bolts and 226 Kp couplers will be installed. The works began in 2001 and will be completed in 2004. ■



End anchorage with the CS grout cap (black PE cap) for EIT tendons and 4 VSL coupling heads. The tendon in the previous concrete section is already stressed, and ready to receive the tendons for the next concrete section. The coupling heads are sitting on the EIT plates (yellow plate beneath the coupling head).

Oil, air, grout, EIT...

Piling up barriers against corrosion

As an absolute must for durability of all tendons, a corrosion protection system should be designed such that the tendon achieves a design life comparable to the structure in which it is installed. This includes protection of materials at all steps. Finally, a multi-layer durability system is the new concept.

Temporary corrosion protection is needed for all post-tensioning components to assure proper functioning (e.g. wedges and wedge cavities, ducts). Suitable packaging/wrapping of prestressing steel must be provided in factory for transportation. Suitable dry and clean storage of prestressing steel must be organised on site to assure proper ventilation.
For extended periods of storage, water soluble oils must be used. Properly selected, these are not harmful to steel and do not need to be removed before grouting of tendon. Such oils are applied in factory but may need to be renewed on site.

Another temporary protection against corrosion is to limit the period between tendon fabrication and grouting, and installation into sheath before pouring concrete (e.g. pr ENV 13670-1: 12/4 weeks). Period between tendon stressing and grouting should also be limited (e.g. AASHTO Standard Specifications: 7/15/20 days). For extended periods, temporary protection of the prestressing steel (e.g. water soluble oils or blowing of dry air) is recommended. Permanent corrosion protection is applied in factory: Individually greased and sheathed monostrand is the most common protection method. Typical application is for small scale tendons in building floors or transverse PT in bridge decks. When applied on site permanent corrosion protection is mostly by injection of cementitious grout (only approved special grouts which have passed the Inclined Tube test should be used). For external PT, injection with wax or grease may also be used but only with approved products in accordance with stringent specifications uch as ETAG.

VSL HPI® grouting.

Grout surrounding

Experience with grouted post-tensioning tendons over about half a century has proven that a cementitious grout can provide an excellent protection to the prestressing steel. Experience has also shown that the quality of the grouting is of prime importance for the durability of post-tensioning tendons for any kind of application (bonded internal tendons, external tendons, slab tendons, stressbars, ground anchors, and stay cables). Incomplete or not grouting has been the origin of a range of problems from corrosion to delayed failures of tendons or parts of it.

The principal objective of grouting is preventing the prestressing steel from corrosion by completely surrounding it in an alkaline environment and filling all cavities with grout. Grouting also achieves an effective bond between prestressing steel and concrete component for bonded applications. Complete filling of all the cavities prevents the penetration of water which can cause corrosion and possible formation of ice (with consequent bursting of concrete) in cold climates. VSL developed the High Performance grout (VSL HPI®) package for post-tensioning works including grouting. When the complete package is provided, including the supply of a grout mix optimised for the intended use, VSL guarantees the complete filling of tendons.

Plastic ducts add significant advantages for protection against corrosion. They create an independent barrier to seal the tendon (in addition to concrete and grout) even across active cracks. Plastic ducts are more reliable friction partner to prestressing steel. They also improve the fatigue resistance of the tendon. Plastic ducts also make it possible to electrically isolate the tendon and protect against stray currents (EIT tendon), to monitor encapsulation and protection of tendon by electrical resistance measurement (EIT), and to confirm the quality of installation of the post-tensioning system (EIT).

Multi-layer protection

However, the corrosion of the reinforcement is usually not the root cause of the durability

VSL HPI® grout mix

problem but rather a consequence of inadequate consideration for durability in the overall design of the structure. A multi-layer protection should therefore be considered:

- the first layer: the overall concept and design of the structure
- the second layer: water-proofing membranes on severely exposed surfaces
- the third layer: dense concrete designed specifically for low permeability
- the fourth layer: a leak tight encapsulation of the tendons with robust, corrosion resistant plastic.
- the last layer of protection: cementitious grout, or by other types of protection systems applied in the factory such as grease and plastic sheathing for monostrands.

Additional layers of protection provided during construction have a relatively insignificant cost compared with repair of durability problems of a structure in operation. It is the owner's and the engineer's obligation to select and specify a suitable combination of independent layers of protection adapted to the particular environment in which the structure is built. As an experienced and well qualified specialist contractor, it is VSL's concern and dedication to assist the decision makers with adequate service when such crucial choices are being made. ■

Stay cables

Corrosion handled for 100 years!

Durability and fatigue strength are the two most important requirements for stay cables. The SSI 2000 stay cable system features for a design life up to 100 years. To achieve this high level of durability, the corrosion protections of each component of the VSL stay cable anchorage have been defined according to the results of a rational analysis of the environment.
The impact of the bridge environment on the protection systems has been defined applying the standard ISO 12944-2 currently used for steel structures. The system has been designed with efficient possibilities of inspection and maintenance.
This analysis has conducted to adapt the geometry of some components, to use new types of assembly with specific material, and to define systems of corrosion protection. For example, there are no bolts for the assembly of the transition pipe to the anchor head of the stressing anchorage. Finally two types of corrosion protection are proposed on the SSI 2000 anchorage:

1) Standard corrosion protection system.

Most aggressive environments (C5)* according to ISO12944-2

Design life of the stay cable system	Accessibility or replaceability of the components	Design life of the corrosion protection system	Period until the first maintenance operations	Period between subsequent maintenance operations
50 years	Replaceable	15 years	15 years	15 years
	Not replaceable Easy access	B 50 years	50 years	15 years
	Not replaceable No access	50 years	No maintenance	

** "**Standard** system" as stringent as in "**Enhanced** corrosion protection"*

2) Enhanced corrosion protection system.

Most aggressive environments (C5) according to ISO12944-2

Design life of the stay cable system	Accessibility or replaceability of the components	Design life of the corrosion protection system	Period until the first maintenance operations	Period between subsequent maintenance operations
100 years**	Replaceable	25 years	25 years	25 years
	Not replaceable Easy access	B 100 years	25 years	15 years
	Not replaceable No access	100 years	No maintenance	

*** **100% more** than CIP (Commission Interministérielle de la Précontrainte, France) recommendations for stay cables.*

***33% more** than PTI (Post-Tensioning Institute, 2000) recommendations for stay cables, design, testing and installation.*

Taiwan

Fast-track beams completed

→ **With VSL in the lead role,** the VSL - Rizzani de Eccher joint venture has constructed approximately 19 km of elevated superstructure for the Obayashi Fu Tsu JV component on Section C215 of Taiwan's massive High-Speed Rail project. Since production got underway in late 2002, casting and erection rates steadily improved through February of this year, reaching a weekly average production of 11 spans (cast and

placed). The launching carriers and support beam system have proven to be particularly effective, with up to 14 spans being placed in a week and up to 3 in a single day. Having completed the 7 free-cantilever bridges in situ along with the erection of 563 full-span segments (740 tonnes each), this innovative and challenging project was finished by early December - over 3 months ahead of the required and already accelerated completion date. ■

Contact: vslrde@ms58.hinet.net

Vietnam

Keen on speed at Kien

→ **The Kien Bridge, located in Hai Phong** is being built by a Japanese-Vietnamese joint venture. With an overall length of 369.8 metres, the bridge consists of two side spans 84.4 metres each and a main span of 200 metres. The bridge deck is constructed using match cast-precast segments 16.7 metres wide. VSL was awarded the stay cable contract in June 2002. The VSL team is a truly international one with a Vietnamese project manager and a site team featuring an Indonesian production manager, a Swedish stay expert and experienced Filipino stay cable supervisors. Due to the tight cycle schedule and the very short time allotted to VSL for stay cable erection, the decision was made to pre-cut the strands into final length on the bridge deck rather than pulling them from the coils. The strands have been installed using the single-strand installation technique; in this manner, the planned execution period could be reduced by a full month. ■

Contact: lpe@vsl-vn.com

Malaysia

No unbalanced moments at Bayan Baru

→ **The Bayan Baru Viaduct is an elevated highway** that runs from Penang International Airport to George Town, the capital of Penang Island, Malaysia. The 1,724-m long pre-cast segmental bridge is divided into 7 modules with 5 or 6 spans each. The viaduct and ramps are match-cast segmental box-girders constructed according to the free cantilevering method (FCM). The main viaduct is being erected using a launching gantry set-up as a two-span system with supports located over the piers on temporary steel towers. The launching gantry does not introduce any unbalanced moments into the structure. VSL's scope of works includes erection

of the segmental box-girder, comprising the design and commissioning of the launching gantry, geometry control and post-tensioning of 2,280 tonnes of strand. Works commenced in January 2002 and are expected to be completed by March 2004. ■

Contact: ckchong@vsl.com.my

Hong Kong

Shaft in the rock at Lok Ma Chau

Following the successful installation of VSoL, Located on the border between Hong Kong and China, the KCRC Spur line extension will alleviate overcrowded conditions at the Lo Wu border crossing during peak days and provide an alternative entry point to Shenzhen. Contract LDB201 covers the construction of tunnels and approach ramps between Sheung Shui station on the East Rail to the Chau Tau viaduct section leading to the new border crossing. The contract calls for the drilling of some 4,000 m of ground investigation, along with the construction of one launching shaft, two emergency access shafts, an enabling shaft for a future station in Kwu Tung and a recovery shaft in Chau Tau, associated with break-in and out, ground treatment, as well as automatic monitoring of movement on the existing tracks. All of this specialist work has been awarded to an integrated joint venture headed by Intrafor. Now nearing completion, the 25,000 m^3 of diaphragm wall have been produced primarily using Intrafor's BC40 cutter, thanks to which Intrafor proposed the excavation of a diaphragm wall shaft through the rock. Ground treatment for construction of the future crossing, to be carried out mainly with jet grouting and "Tube a manchette" grouting, will follow. Underway since January 2002, the foundation work should be completed by June 2004. ■

Contact: jean-luc.godard@hk.vsl-intrafor.com

VSoL® walls to Mickey's house

Following the successful installation of VSoL, retained earth walls on the temporary access road to the new Disney Theme Park site on Lantau Island in 2000, VSL is now introducing VSoL, walls (5,000 m^2)to form the approach ramps leading to bridges on the project's permanent access road. The full package includes design, supply and installation. In order to isolate column movement from the retained earth block under the existing viaducts, a pre-cast concrete shell system was developed to create a permanent void between the 2.0-m diameter bridge support columns and the reinforced fill block. ■

Contact: richard.austin@hk.vsl-intrafor.com

Dubai

Westside Story

Westside Marina in Dubai, one of the most ambitious urban development projects ever undertaken, comprises residential and retail uses along with leisure facilities set around a tremendous manmade marina. VSL Middle East designed and supplied materials and services for the VSoL® reinforced-soil retaining wall (20,000 m^2, 3-km long), which runs parallel to Sheikh Zayed Road, the main highway leading to the Abu Dhabi Emirate. The VSoL® polymeric system was chosen due to the potentially-aggressive nature of the backfill material. ■

Contact: vslburke@emirates.net.ae

Taiwan

Lift on the world's tallest building

The mast on the Taipei 101 Building reaches a height of 508 meters, towering 60 meters above the 101st floor, making this the tallest building in the world. VSL was fully responsible for erection of the mast, which weighs a total of 460 t. The lift was carried out during the typhoon season with design wind speeds of up to 70 m/sec. VSL's temporary works designers also had to ensure that the procedure would remain secure in the event of a severe 100-year earthquake (reaching 7.9 on the Richter scale). ■

Contact: jchang@vsl-tw.com

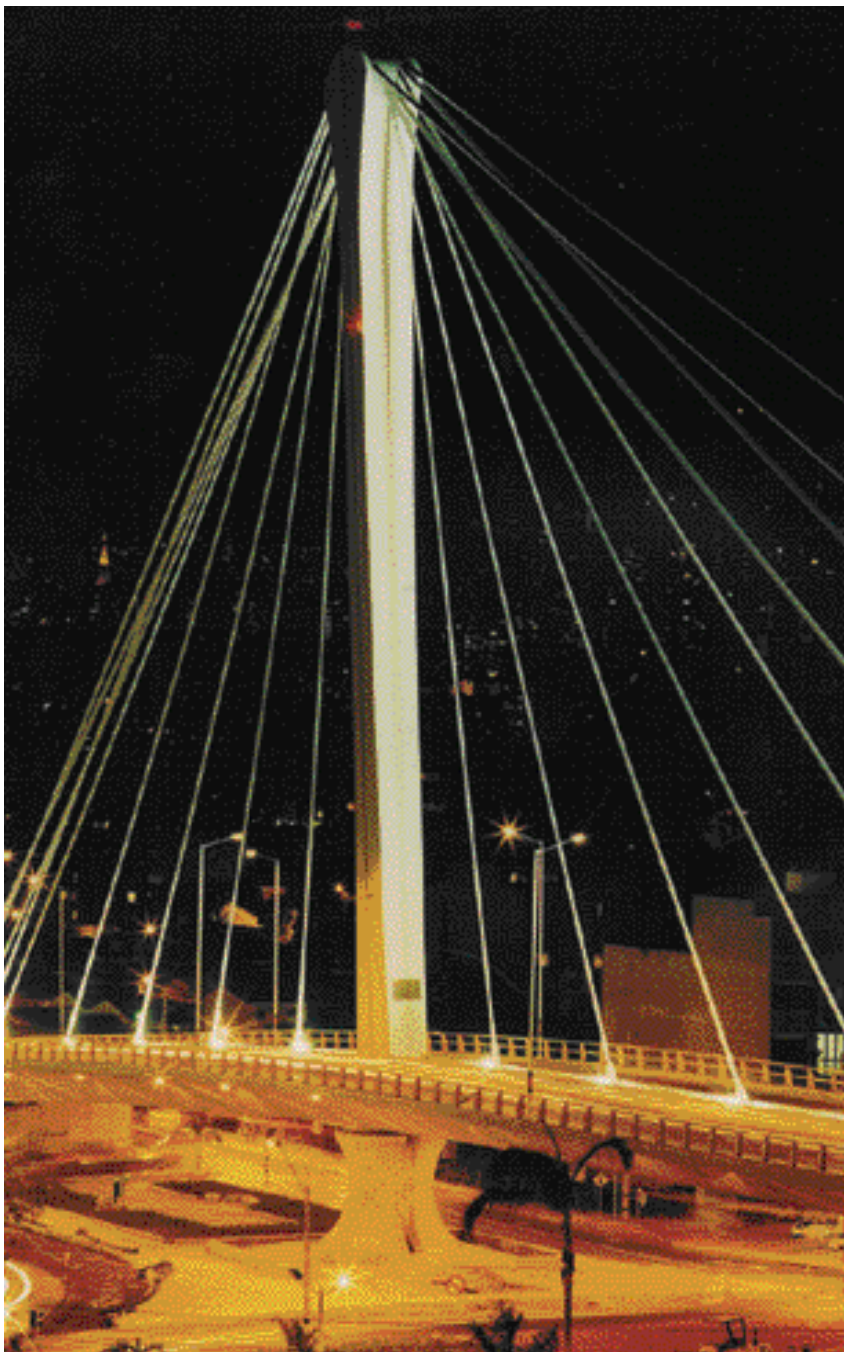
Columbia

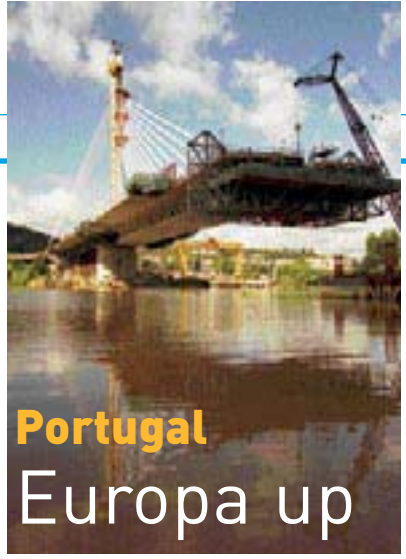
Of stays, saddle and cells

→ **VSL has completed the installation of the stay cables** on the Peldar Cable-Stayed Bridge in Envigado, Colombia. The first contract awarded to VSL in January 2001 encompassed stay cable installation with the new VSL SSI 2000 system: 9 stays with the top saddle, units from 6-37 to 6-91, totaling 110 t of replaceable stays; made up of galvanized, waxed monostrands placed in an external white PE pipe with helical ribs. The spans were 120 m + 60 m in size.

VSL obtained a subsequent contract in 2001 for 1,600 m² of VSoL® walls. A third contract was then signed in the same year for the inclined pylon forms. In 2002, VSL supplied POT-bearings and joints, as well as PT bars and post-tensioning (approx. 120 t). VSL was also awarded the design and supply of the steel saddle on top of the pylon. Monitoring of the bridge has been performed with VSL's new load cells. ■

Contact: epalos@vslsp.com





Portugal

Europa up

→ **On the Europa Bridge,** VSL in Portugal is responsible for providing full installation of approximately 750 t of post-tensioning for the access viaducts and main bridge, as well as 412 t of VSL SSI-2000 stays for the main bridge. Stays are being installed in a 6-day cycle. Completion of the works is scheduled for end of March 2004. ■

Contact: cmoniz@vslsistemas.pt

Chile

2,222 segments

→ **The Metro de Santiago extension program,** to be carried out over several years, calls for up to 33 km of new transit lines. One of the projects launched by the Metro authority was the construction of the Vicuña Mackenna - Puente Alto, a 7,200-m pre-cast segmental viaduct. This contract was awarded in June 2003 to a consortium of Chilean prime contractors: Vial y Vives, Echeverría & Izquierdo and Icafal. VSL was the recipient of a subcontract for viaduct construction, including: pre-casting plant (6 long benches and 6 cells), formworks, launching girders (3 units), supply of PT materials and equipment (1,800 t), bearings (1,800 units), supervision of PT installation, pre-casting plant and erection, along with the engineering work. The total number of segments comes to 2,222, each weighing close to 40 t. The project has been assigned a PPP - priority policy project - status and a September 2004 completion date. ■

Contact: epalos@vslsp.com

USA

Collapsed car park

→ **A parking structure in Colorado collapsed** after an excavation crew deposited gravel on the slab while excavating a pipe trench in an adjacent alley. This excess load was estimated at 2-3 times the design loading. In addition to a slab upgrade performed by VSL, a post-tensioned beam, columns and footings were strengthened as well. VSL provided the structural design, self-performed the post-tensioning, and furnished and installed the reinforcing steel. Moreover, VSL conducted a state condition survey of the entire attached building in order to assess any possible damage as a result of the slab collapse. ■

Contact: bgallagher@structural.net

Uruguay

Slab on grade for river port

→ **The M'Bopicua Logistics and Industrial Terminal,** planned as the region's shipping port for wood production activities, is located on the eastern coast of the Uruguay River. VSL Argentina was awarded the contract for post-tensioning detailing and construction of the 15,500 m^2 post-tensioned external slab pavements. The 250-mm thick pavement was designed to support cranes with a capacity of 100 t and a thermal gradient of 0.9 °C/cm.

The largest single concrete pour without construction joints was 460 m^3 over an area of 1,900 m^2. Total floor area was executed in just 8 weeks, including delays due to poor weather conditions. ■

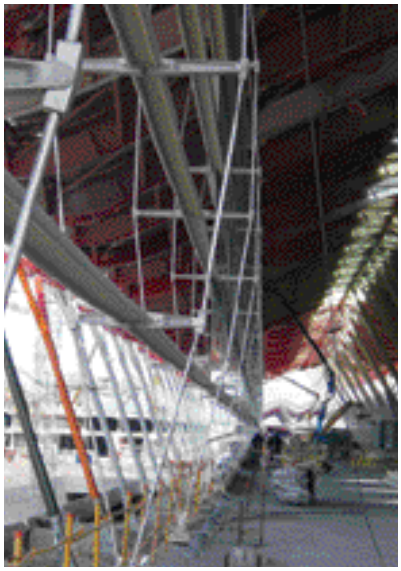
Contact: vslargen@correo.com.ar

Peru

Lifting deep in the forest

→ **In 2002, VSL was awarded the contract to lift 2 deethanizer towers** (49 m high, 175 t) onto the Malvinas plant of the Camisea gas project in the Peruvian forest. The lifting towers needed to be transported by road across the Andes and then by river boat to the remote job site. Following the successful completion of this job, VSL was able to secure 2 more lifts on another plant of the same project, located in Pisco close to the Pacific Ocean, for the Sade-Skanska and Graña y Montero consortium. ■

Contact: epalos@vslsp.com



Spain

Stressed kipper trusses

→ **Extension of the Barajas Airport project,** the largest European construction project during 2002 with a total surface area of 700,000 m^2, was successfully completed in June 2003. This job has further enhanced the experience of CTT Stronghold (VSL in Spain) in the field of stainless steel and architectural applications. The so-called "kipper" trusses of the facade perform a structural function: they are stressed in order to fasten roof beams while at the same time creating the skeleton to support the curtain walls. VSL supplied all of the architectural members in stainless steel (442 complete kits of pieces and bars in various forms - forged, cast, machined or rolled, with an architectural finish), along with components and high-resistance stainless steel bars for the satellite building. ■

Contact : jmartinez@vslsp.com

Russia

Bridge above cargo

→ **As part ot the Saint Petersburg city ring road project,** the Neva cable-stayed Bridge will provide the first and only permanent means of crossing the Neva River in Saint Petersburg with a central span clearance of more than 35 m. All current crossings raise their central spans at night to allow sufficient clearance for cargo vessels to pass beneath. The bridge consists of two identical steel segmental pylons (124 m in height) with a 382-m Neva River crossing span. The construction method adopted differs at each pylon: on one the back-span is complete before the erection of the main span, whereas at the other the balanced cantilever technique is used. As a subcontractor to Mostootryad 19, Russia's second largest civil works contractor, VSL began installing stay cables with the SSI-2000 system in July 2003. VSL's scope of works includes project supervision and the supply and installation of 445,000 m of stay cable strands in 112 stay cables, with strand quantities ranging from 13 to 91. This stay cable installation job is scheduled for completion by April 2004. ■

Contact: cpetrel@vsl-schweiz.ch

India

Link to Nariman Point

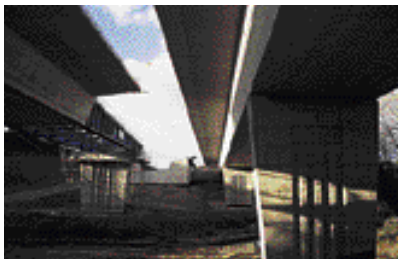
→ **To ease the traffic into the Central Business District** of Mumbai, a new link from Bandra will extend into the sea out to Worli and end at Nariman Point. The 3,500m-long bridge is made up of a 100, 500 and 100 m cable stayed span combination in the middle and typical 50 to 60 m approach spans on either side. Each of the 1,145 segments weighs about 150 t. Production rate is of one segment per day per cell. Typical spans are to be constructed according to the span-by-span method. Total project duration will be 30 months.

VSL's scope of works includes construction engineering services for the bridge, casting yard set-up, segmental cell formwork design, design of launching gantry, loading installation design, pier tie-down, technical audits, and the supply and execution of all post-tensioning work (4,600 Mt). VSL has conducted anchorage efficiency and load transfer tests (both static and dynamic), in compliance with FIP standards. On this project, VSL has also completed endoscopic testing on the grouted tendons and friction testing on the ducts. ■

Contact: ganesh@vslindia.com

Ireland

Twin decks



→ **Based on a VSL detailed design, VSL Systems (UK) was awarded full construction** of the incrementally-launched twin decks of Brides Glen Bridge, a project serving to complete the Dublin western bypass. The VSL scope of works comprised the detailed design in prestressed concrete, all construction methods and temporary works design, full construction of bridge superstructures above the pier head level, including all temporary works and installation of POT bearings as well as expansion joints. Each of the 158-m long bridge structural elements would be too short on its own to fully benefit from the economic advantages of the Incremental Launching Method (ILM). This was overcome by the reuse of the formwork, launching nose and launching equipment for the subsequent construction of the second deck. Completion of the works is scheduled for December 2003. ■

Contact: aschwarz@vsl-schweiz.ch

Greece

Olympic re-tensioning

→ **VSL is taking part in the refurbishment of the Peace and Friendship Stadium roof.** VSL's scope of works includes corrosion inspection, survey of the cable net structure and anchors, and calculation of re-tensioning forces. Since the 1999 Athens earthquake, both a permanent and relative displacement (60 to 80 mm) of the torus has occurred. Measurements have indicated a force deficit of 15 to 27% for the main cables, 17 to 24% for the stabilizing cables and a 54-mm decrease in central knot height due to the relaxation of cable steel and concrete shrinkage and creep. VSL is also providing a package of post-tensioning works on a major interchange with 10 bridges at the Faliron Estuary in Athens. ■

Contact:gkarmoutis@vsl.gr

France

External and internal PT

→ **The works carried out by VSL in France on the Anguienne Viaduct** from May 2003 through November 2003 included external and internal post-tensioning: 190 tons of strands, 72 anchors Ec 6-19, 12 Ec 6-31 anchors (internal) and 16 Ed 6-31 anchors (external). ■

Contact: michel.guichard@vsl-france.com

NOTE PAD

Pilsner ring - *On the D5 Highway connecting Prague with Nuremberg, a ring road is currently under construction around the old brewery town of Pilsner. On the Ejpovice-Cernice section, to be opened to traffic by the end of 2003, VSL has already supplied 200 t of internal post-tensioning on 6 different bridges.*

Shatin Heights - *VSL Hong Kong has recently completed its largest VSoL, temporary wall project to date: a 240-m long, 4,500-m² mesh-faced wall on the Shatin Heights project. For a length of 60 m, the wall is freestanding with a mesh facing on either side of the 14-m wide retained earth block.*

Overlifts - *VSL Singapore and VSL Switzerland teamed up to lift the heat exchangers of the two boilers, each consisting of 12 modules with a final weight of over 1400 t. To assist the delivery of the modules in the very limited space available, VSL performed several additional lifting and lowering operation, before the final level was reached.*

All in one - *VSL has been awarded the largest single-development contract for an industrial facility, which is to be named Capital One and located near the International Business Park in Jurong East, Singapore. VSL is responsible for the the design and installation of post-tensioning works for the entire development: 250,000 m².*

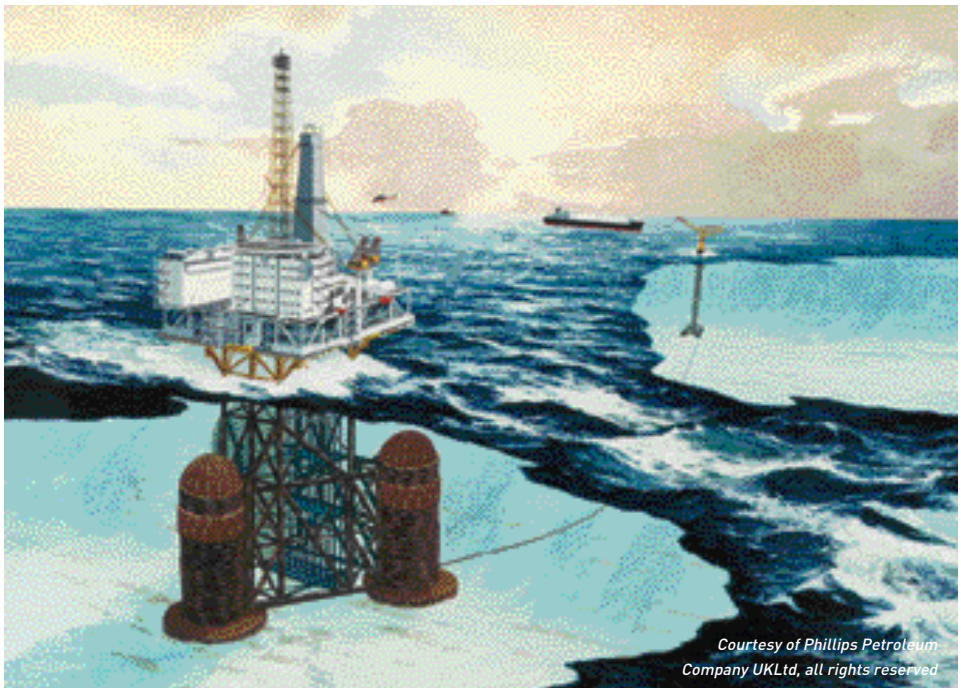
Norway

Strands and bubble for tank demolition

→ **After 25 years of operations, the Maureen oil field platform,** which weighs some 105,000 t, was moved from the North Sea to an inshore position just off Stord Island. The heavy base will form part of a new quay wall, whereas most of the steel has been cut and recycled. The massive 12,000-t deck was placed on a barge and brought close to the quayside. There it was skidded over a 90-meter distance onto the wharf for dismantling. A launching speed of 12 m/hr was achieved for this task. The upper part of the substructure was then brought directly into the scrapyard while the lower 40 m, weighing some 66,000 tons, were left in place. In order to separate the 3 storage tanks from the lattice frame under stable conditions, the self-weight had to be balanced against buoyancy. Barges were located against the three sides of the lattice frame; on each barge, 8 VSL jacking units were attached and lifting 5 m allowed absorbing the calculated load. The first tank was then cut off, pulled away with tugs and positioned into one half of a floating concrete ring, which was then closed with the second half. Moving the tanks close enough to their final position required another 22 m of lifting. From 16 VSL jacks located on the concrete ring, the lifting cables were attached to the skirt of the tank. In order to assist with this lifting operation, air was blown underneath the tank. Once the tank had reached the highest level, 5,000 t were hanging on the strands and a 6,000-t air bubble was supporting the massive structure.

To hold the air in place, the tank had to be maintained in an absolutely horizontal position. Using two tugs controlled by a GPS system, the tanks were then moved cm by cm over a prepared base near the existing quay wall. At the final location, the tanks were lowered by 8 m onto the seabed. After all three tanks had successfully been placed, the lattice still had to make its final journey. Using the 24 SLU 330, it was lifted an additional 8 m out of the water. During this time, the barges had to remain within 1 degree of the horizontal. Most of this massive structure will eventually be hidden within a new quay and appear in recycled steel components. ■

Contact: djunker@vsl-schweiz.ch



France

Repair works at Plaisir

→ **At the Plaisir Shopping Center outside of Paris on a 2,100-m² pedestrian walkway** composed of beams prestressed using 17-m span bonded wires, with the spans being connected to one another by means of a compression slab, structural disorders have become apparent. Security could be jeopardized due to: concrete carbonation, corrosion of steel rebar, concrete spalling, as well as major cracking of the joists. The repair work led by VSL France in the capacity of general contractor should be performed without causing any disturbance to shopping center traffic nor interruption in commercial activity, i.e.: removal of existing thermal insulation, reinforcement of the lower slab face by means of shotcrete treatment, treatment of the corroded steel rods, repair and injection of cracks using epoxy resin, preventive treatment of the structurally-intact concrete elements, reinforcement of the joist by carbon fibers (180 m²) to compensate for the lack of shearing force steel, and reinstallation of a thermal insulation layer by flocking. This project, which started up in May 2003, has mobilized 10 of VSL's specialists and will be completed at the end of the year. ■

Contact: vbuchin@vsl-europe.com

France

Slipping viaduct

→ **The Fréjus Tunnel connects the French Alps (Modane) with Italy (Bardonecchia).** Supported by shallow foundations, the Charmaix viaduct on this road was located in an unstable slide zone. Just after its completion (1978), an analysis of structural disorders, focusing at the deck level, revealed distortions in the supports, with beam heels of successive bays coming into contact with the concrete and causing spalling, despite an initial 5-cm construction clearance. Moreover, ground instrumentation confirmed movements in both of the mountain slopes framing the Charmaix ravine. These movements, observed over thicknesses of several tens of meters, slip at a rate of 1 to 2 cm a year at nearly constant speed, except for acceleration at the time of snowmelt.

It was decided to free the structure from its moving support by creating a maneuvering interface at ground level to enable, at all possible degrees of freedom, repositioning the structure from time to time into its initial location. The project, awarded to VSL France, consisted for each pile of expanding the foundation soleplate, introducing prestressed reinforcement at the pile base, incorporating the pile underneath the reinforcement, separating the pile from the soleplate by sawing, installing sliding supports and screw-jacks with a capacity to maneuver 4 x 1,000 tons, and then moving the pile onto the soleplate to an extent equal and opposite to the ground movement. An initial recalibration was performed in 1990, followed by a second in 1997. VSL is currently executing the third such adjustment. No traffic flow restriction has had to be imposed during these recalibration phases.Though based on a simple notion, these works have still required a highly-detailed design study, project preparation and execution. ■ *Contact: jean-claude.peslier@vsl-france.com*

NOTE PAD

Spanish abutments - *VSL in Spain completed three VSoL® projects in October 2003: the Levante Highway between Escandón and Teruel for two 12.45-m high abutments (2,250 m²); the construction of 3 abutments totaling 2,850 m² for upgrading the N1 motorway in Condado de Treviño; and on-site supervision for the construction of a new lane on the B30 highway close to Barcelona.*

Greek travelers - *As part of the Egnatia Highway Crossing in Northern Greece, VSL was awarded a contract for 3 cantilever bridges; the scope of work includes supply and installation of 730 t of strands along with operations of two pairs of 200-t form travelers. Work began in April 2002. Completion in February 2005.*

Overpasses - *VSL France has been awarded the post-tensioning (530 t) of 76 prestressed concrete bridges as part of the 125-km A28 Rouen-Alençon motorway project (west of Paris), a concession held by the Alis JV. Works started up in September 2003 and will last for 12 months.*

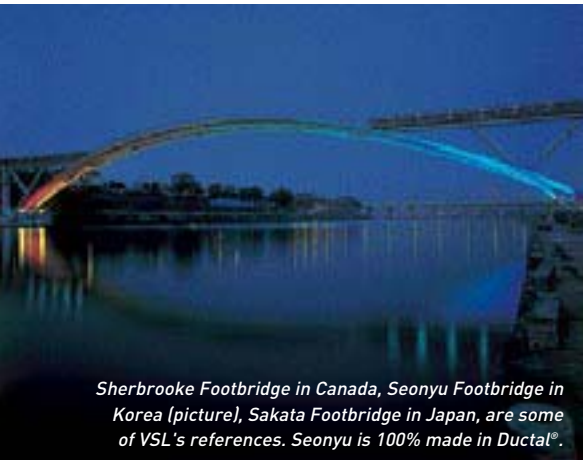
Royal protection - *On the pre-cast segmental Royal Park Bridge in Florida, VSL saved the contractor both time and money by recommending reusable deviator voids, or "diablos", that served to eliminate the need for steel pipe and neoprene duct couplers. The external duct was essentially joint-free from anchor to anchor, thus improving the grouting process.*

Ductal® structures

Footbridges: why not thin and blue?

Footbridges featuring original forms, with thin profiles and very slender structures, a multiplicity of textures and as durable as granite: Ductal® makes all these bold advances possible...

Bridges were initially built for pedestrians... made of wood, then came stone and designs nowadays call for concrete or steel. Footbridges are first intended to fulfil a functional purpose, namely that of ensuring a safe crossing of roads, rivers or railways. Today, the architectural consideration for integrating these structures into the urban environment has become more critical in the final design choice. Steel footbridges allow satisfying such requirements yet entail sizable maintenance costs. Wood, in the form of glue-laminated timber, results in soaring construction costs and moreover lends an inconsistent level of structural durability. The option of using concrete is often rejected: concrete is considered as unrefined and unable to provide thin and slender structures. The advent of Ductal®, following a 10-year research effort aimed at innovating material design, has led to reconsidering such preconceptions. This material allows introducing revolutionary forms with thin profiles, very slender footbridges with a multiplicity of textures and as durable as granite.



Sherbrooke Footbridge in Canada, Seonyu Footbridge in Korea (picture), Sakata Footbridge in Japan, are some of VSL's references. Seonyu is 100% made in Ductal®.

A slab four times as thin

In the case of conventional concrete structures, the choice of thickness is dictated by code rules pertaining to rebar coating - an unavoidable design element - to prevent against corrosion. In using Ductal®, the material's high bending strength enables designing structural components without any passive reinforcement, thereby permitting the thickness to be very small. For a footbridge deck, a 3-cm thick slab in Ductal® could therefore be substituted for a reinforced concrete slab measuring at least 12 cm. In order to balance the primary structural stresses, the VSL technique calls for relying upon post-tensioning. The performance of Ductal® is such that the post-tensioned cables and strands are coated to just the right extent, yielding a structural element geometry that has been specially tailored for the job.

A 1:30 slenderness ratio

While aesthetics remains a subjective notion, it cannot be denied that an attractive degree of slenderness generally lends elegance to a structure. Civil engineering structures are designed first to withstand their dead weight, which amounts to 65% of the load-bearing capacity; in other words, only 35% of this capacity actually gets allocated to the applied loading! The major reduction in dead weight inherent in Ductal® structures, reaching on average a factor of 3, makes it possible to enhance their slenderness to a point of creating new forms. A slenderness ratio of 1:30 can thus be achieved instead of the 1:22 conventionally used. The predominant condition therefore guiding structural design becomes deformation, like for steel structures, as opposed to strength as is the case with concrete. Any geometrical shape proves feasible for structures built with Ductal®: arches, cable-stayed structures, isostatic spans, lattice structures, and the list goes on... The door - or rather the span - is wide open to the delight of the architect's imagination.

Colorful concrete

No aggregates are to be found in Ductal®. Outside of the fibres, the coarsest element does not exceed

0.6 mm. This level of fineness in the material's constituents enables faithfully reproducing the shape drawn by the formwork skin. All types of moulding can now be envisaged by the designer eager to make an imprint: decorative moulding, bas-relief, hieroglyphic inscriptions, monumental motifs, grain effect, smooth finish...
Moreover, away with the drab grey concrete: the colour of Ductal® (between "traffic grey A - RAL 7042" and "window grey - RAL 7040") can be adapted to satisfy the designer's mood: white, or shaded for the solid elements in red, green or blue, etc. For the time being however, architects are sticking with grey out of tradition that calls for concrete to be grey, just like grass is green and sky blue. The age of coloured concrete still lies on the horizon...

In good state, with no need for maintenance

The Ductal® material is composed of a very dense and closed matrix that prevents the intrusion of any aggressive elements, thus providing a source of outstanding durability; neither paint nor finishing are required. The cost of maintaining footbridges typically corresponds to painting both the structure and superstructure (railings, cornices), plus applying another coat of waterproofing.
Should the superstructure be integrated within the structure, as is the case for the bracket design footbridges, all these costs simply vanish.
For the construction of high-visibility footbridges, integration into the surrounding urban environment constitutes a major concern on the part of municipal authorities seeking to improve the image reflected by their cities. The small quantities of material that go into building Ductal® footbridges result in limiting material cost overruns to 10%. In reality, the cost of the completed structure depends above all on the architect's approach: for an ambitious project, construction costs using Ductal® stay in line with those of a steel-based project, yet with the added bonus (in whatever colour) of maintenance costs being slashed.

Coloured concrete

No aggregates are to be found in Ductal®. Outside of the fibres, the coarsest element does not exceed 0.6 mm. This level of fineness in the material's constituents enables faithfully reproducing the shape drawn by the formwork skin. All types of moulding can now be envisaged by the designer eager to make an imprint: decorative moulding, bas-relief, hieroglyphic inscriptions, monumental motifs, grain effect, smooth finish...
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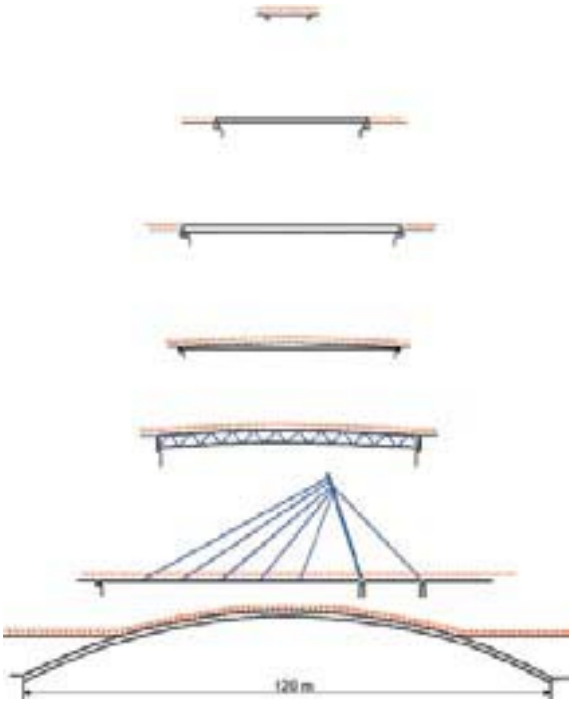
Super slim to fit all spans



Slab
Span: 5-15 m

"U"-shaped section
Straight beam
Span: 15-35 m

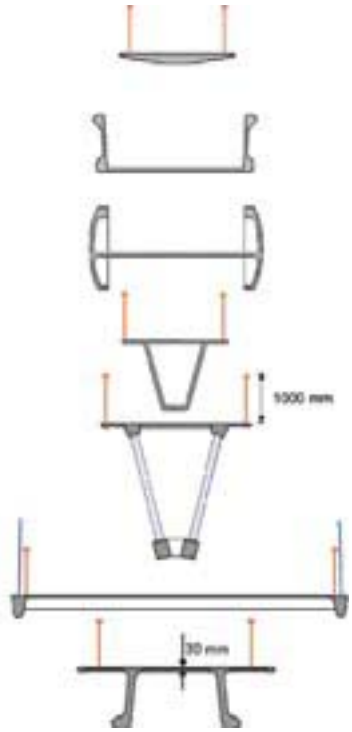
Bracket design section
Straight beam
Span: 35-50 m

Caisson
Variable-height
Straight beam
Span: 50-80 m

Lattice
Straight beam
Span: 60-100 m

Double-ribbed slab
Cable-stayed structure
Span: 60-100 m

n-arc section
Span: 100-150 m



There is someting wonderfully prosaic about naming a bridge 'Puente la Unidad' (Bridge of Unity). After all, bridges are symbolic of nothing more and nothing less than unity.

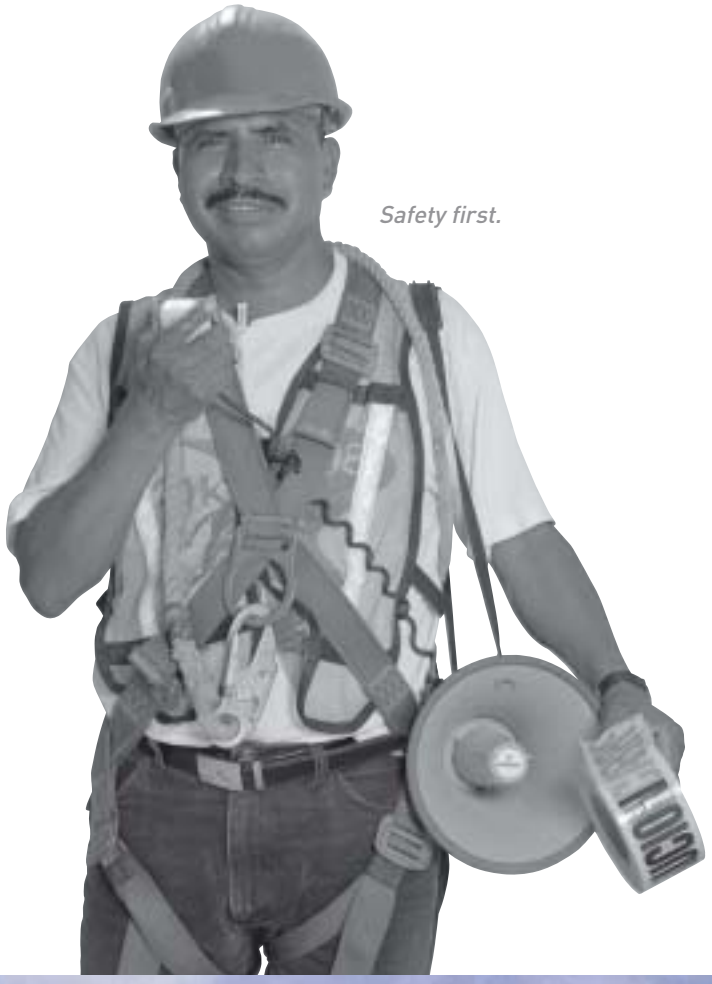
Puente la Unidad, Mexico

Working toward unity

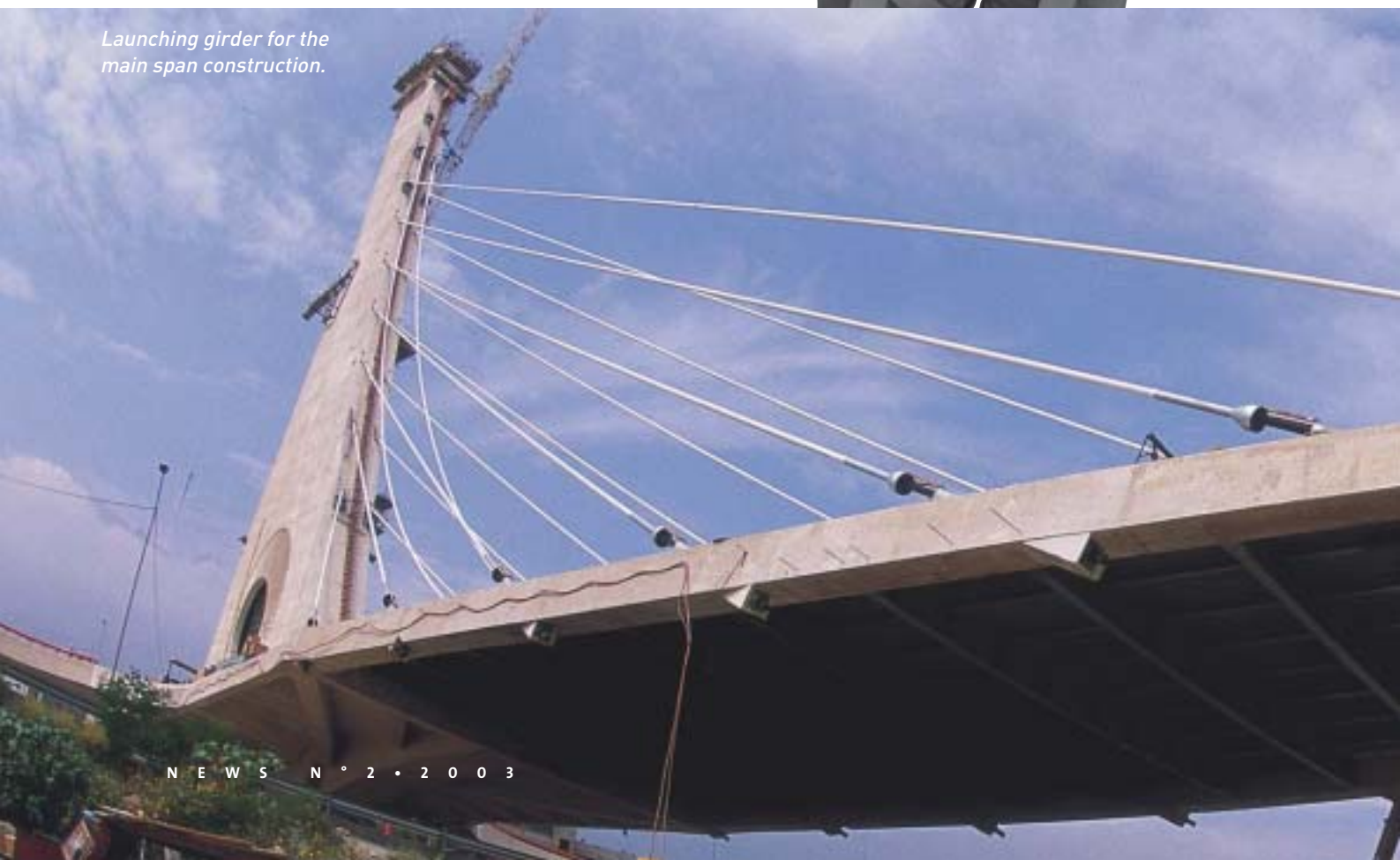
Three hundred workers, twenty full-time engineers, one million two hundred thousand two hundred blueprints, fifteen foremen, eighty thousand hours of engineering. Fifty professionals designing and supervising the projects within and outside the country. Superintendants, resident engineers, general foremen, foremen, gangers, journeymen, labourers. All working toward unity.

TECH SHOW

The building of each bridge is, in the minds of its architects and engineers, a supreme act of faith in creating that sense of unity. Modern cable-stayed bridges like the Puente La Unidad seem to revel all the more in their defiance of the most basic law of physics: gravity.



Safety first.

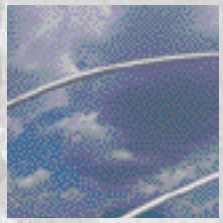


Launching girder for the main span construction.

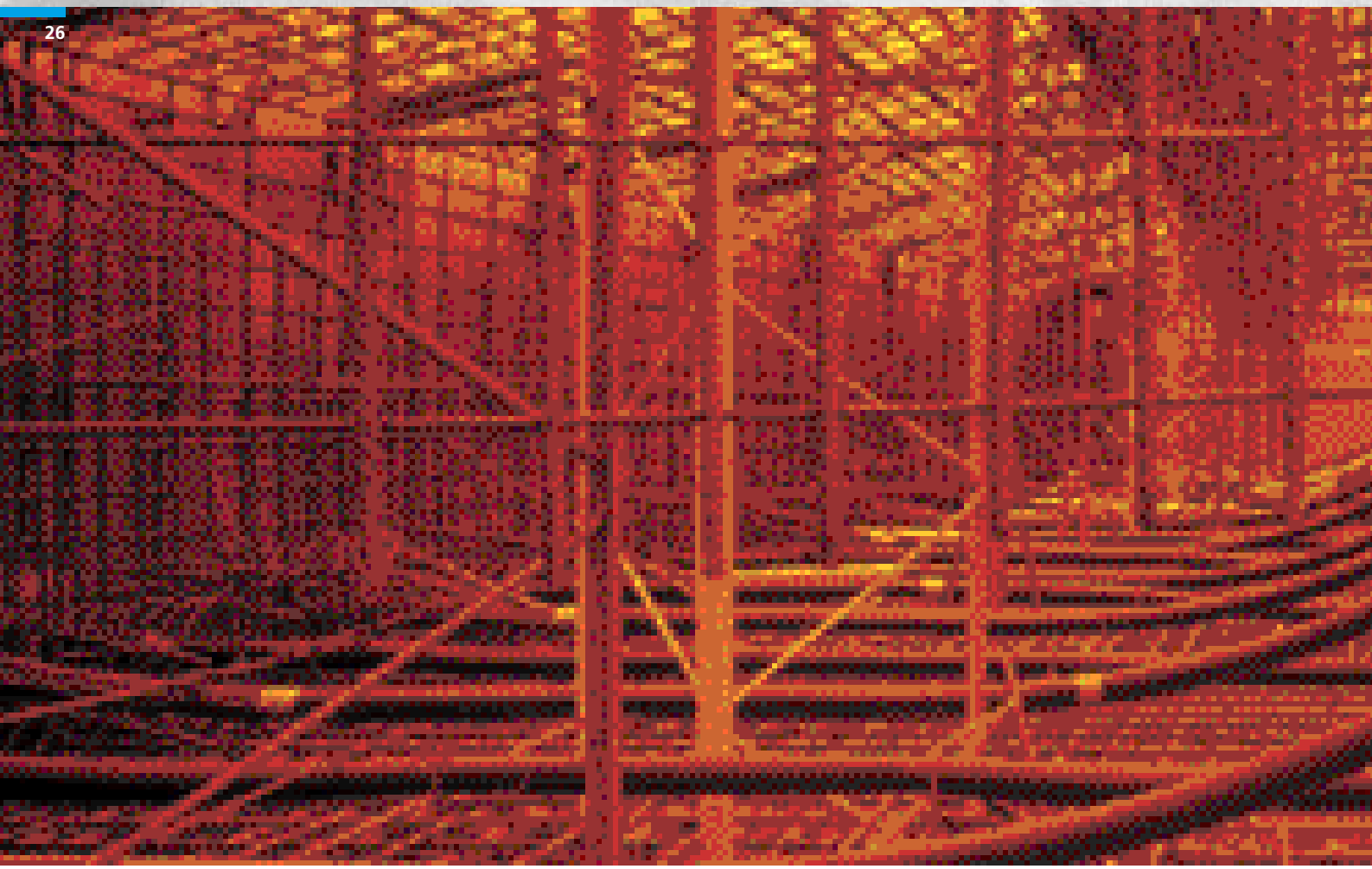
300 km of strand installed.

VSL's experience in the field of post-tensioning and related engineering goes back almost half a century. VSL handles all post-tensioning works with its own personnel and equipment, and provides appropriate technical support, both during planning and on site.

TECH SHOW

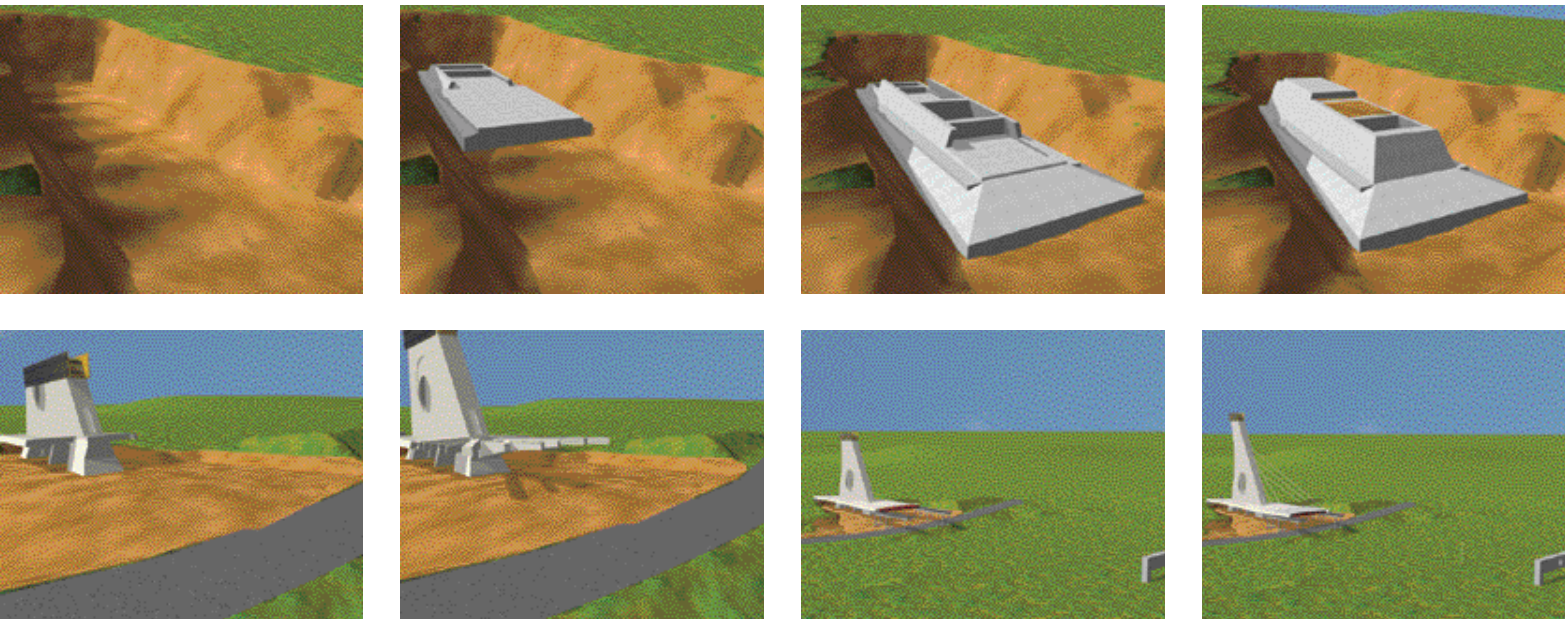


The deliverance of the mind is wisdom
The deliverance of the heart is love
The deliverance of the senses is beauty
The deliverance of the hancs is work.
A saying among Indian carpenters.

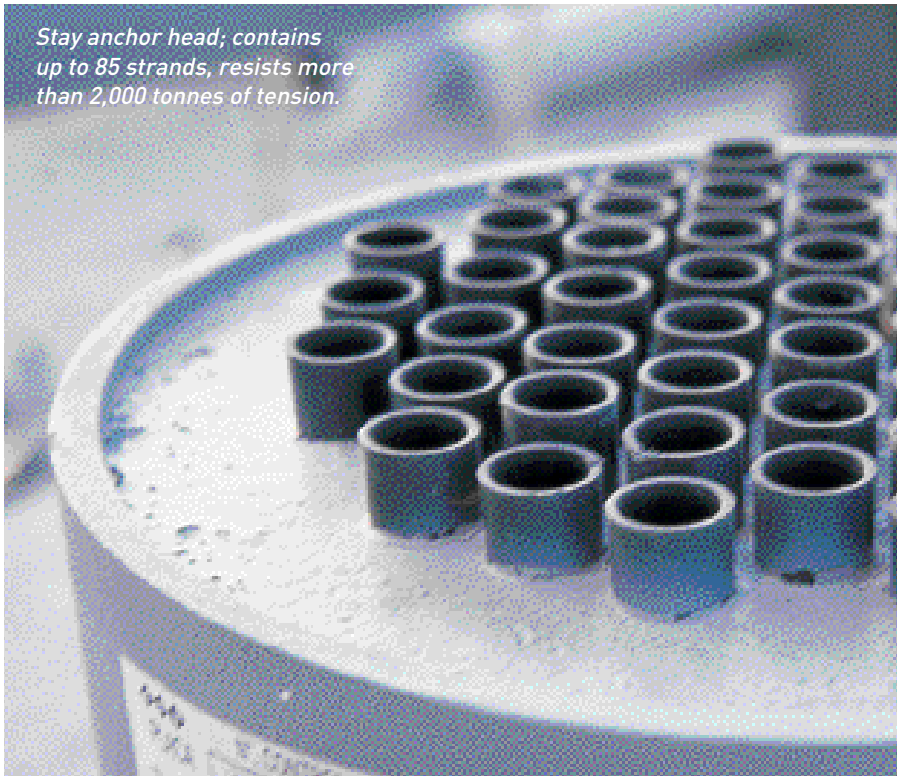


An archway to heaven.

A construction that oscillates and vibrates millimetrically, while the structure remains intact. Magic of mathematics and ingenuity...

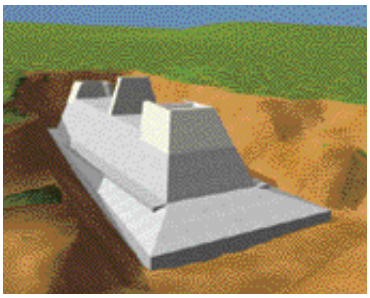
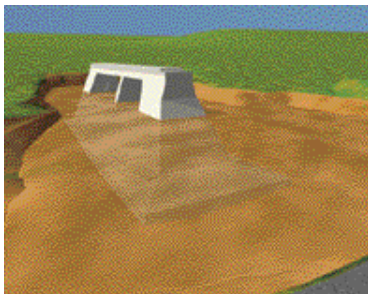
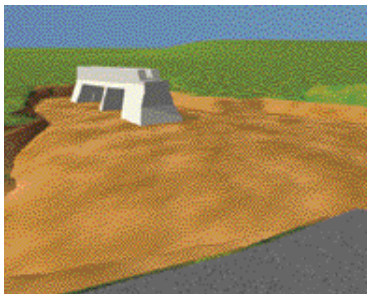
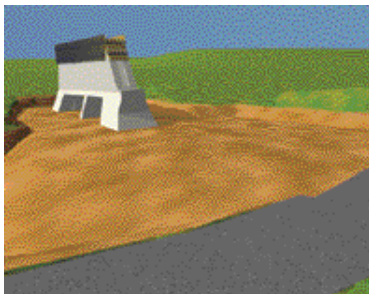
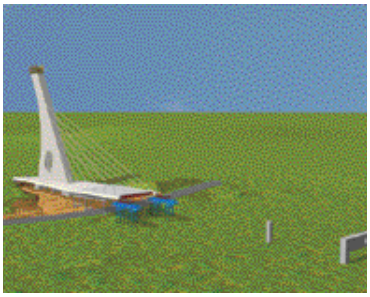
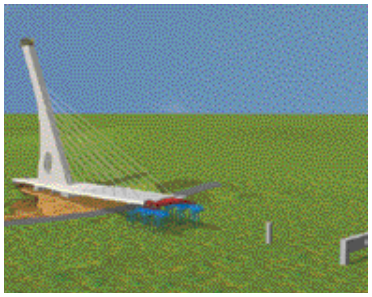
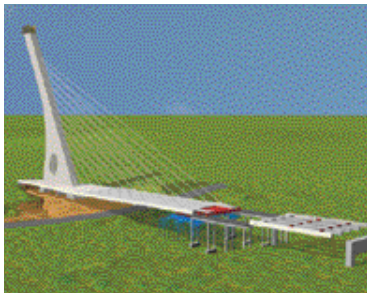
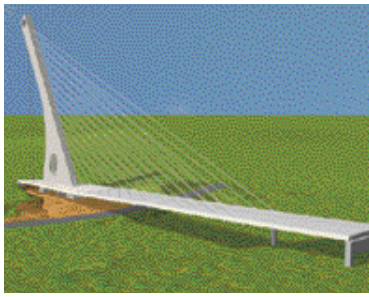


The full construction *of the first stay cable bridge in Monterrey, the Puente La Unidad is the 97th cable-stayed bridge in which VSL has contributed... Proven methods the use of the best available technology and strong team spirit, enabled to meet expectations in both fast track construction and quality. The bridge has a single, 60-degree-inclined, post-stressed pylon on the south side of the crossing. It stands on a massive, 8,000-m³, 5-m-thick concrete slab footing. VSL Mexico's scope in the 50-50 joint venture included project management, complete technical and methods support and part of the production management. VSL Mexico also supplied and installed the 300 tonnes of post-tensioning and the 440 tonnes of stays, using the SSI 2000 system and working round-the-clock shifts on five simultaneous fronts: pylon, stays, in-situ transition span, main span and end span. The bridge was delivered in october 2003.*



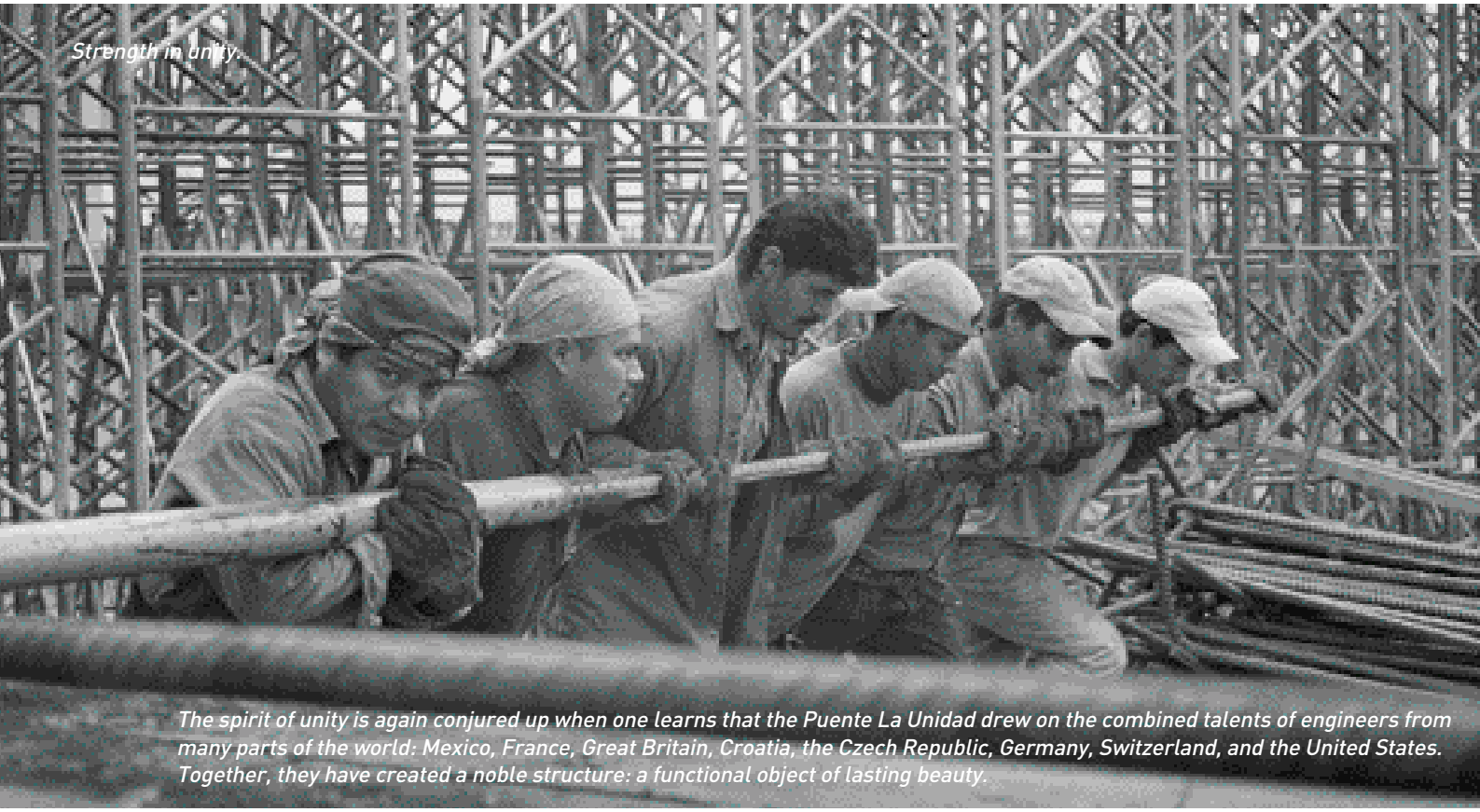
Stay anchor head; contains up to 85 strands, resists more than 2,000 tonnes of tension.

The first strand finding its vital way.

The enormous curved pylon is tensed with sails woven from twenty-eight stays that heroically bear a weight equivalent to that of more than ten Eiffel Towers.

Strength in unity.



The spirit of unity is again conjured up when one learns that the Puente La Unidad drew on the combined talents of engineers from many parts of the world: Mexico, France, Great Britain, Croatia, the Czech Republic, Germany, Switzerland, and the United States. Together, they have created a noble structure: a functional object of lasting beauty.

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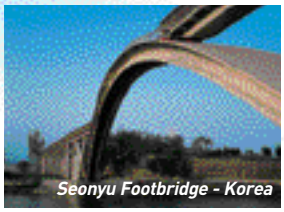
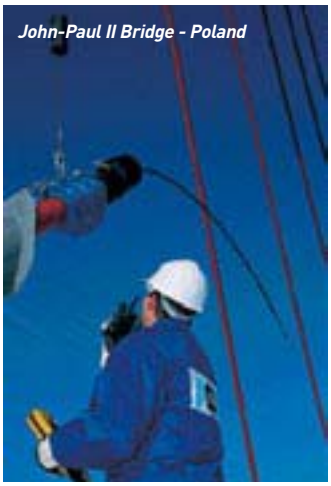

Seonyu Footbridge - Korea


John-Paul II Bridge - Poland


Austrack Project - Australia

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