VSL NEWS

THE VSL NEWS MAGAZINE • ISSUE TWO 2007

REPAIR WITH CFRP

Active strengthening

Tanks: cryogenic tests

Stonecutters Lifting

highlights

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Cover photo: Stonecutters Bridge, Hong Kong

EDITORIAL

The VSL difference

Our clients expect VSL to provide real technical added value which guarantees a quality and on-time project. This added value is brought about by the commitment and professionalism of our teams, at both the tendering and construction phases. During the preparatory phase, our technical centres in Switzerland and Singapore ensure that effective methods are developed which can be relied on. Our R&D teams continually monitor and improve the products used on site whilst our construction teams ensure that the works are carried out to specification and in an effective and safe manner.

Our proven management procedures and their strict application differentiate VSL. We are committed to manage our operations and expand our business using these strengths and values.

Jean-Philippe Trin, CEO

QUALITY MANAGEMENT

ISO9001:2000 for VSL China

VSL China has successfully applied for the ISO 9001:2000 certification to improve further its competitiveness, competence and profitability.

VSL China's Quality Management System has been certified by the international certification body BSI as meeting ISO9001:2000. The initiative was driven by VSL's management to bring about improvements in performance through the implementation of an ISO9001-certified system. VSL China applied to upgrade its ISO certificate at the request of VSL's senior management and its clients. BSI carried out the assessment in mid-August 2007 and confirmed that VSL China meets all elements within the scope of its registration (manufacture of post-tensioning components and equipment) and the requirements of the management standard ISO9001:2000. VSL China's quality system has been developed with the help of VSL International and CTT (VSL's manufacturing centre located in Spain). Manufacturing Quality Plans have been created for all components. These define the inspection and testing requirements including aspects such as control methods and acceptance criteria. New testing equipment and inspection tools have been introduced to ensure quality and compliance with VSL International's requirements. As a BSI-certified factory and VSL Group-approved Manufacturing Centre, VSL China has more and more products which are approved for export. These include items such as multistrand SC and GC anchorages, slab anchorages and wedges, all produced in line with VSL Group's objectives: quality, standardisation and compatibility. ■

SEWER REHABILITATION

Insituform demonstrates its merits

Hong Kong is beginning one of the world's largest clean water rehabilitation programmes and Insituform Asia Limited (IAL) is well positioned to meet the demands. Its innovative trenchless technologies are ideal for use in one of the most densely populated cities on earth. In September, IAL began work with major local contractor Paul Y Construction Company Limited on a new three and a half year maintenance contract for sewer rehabilitation in the Northern New Territories. IAL, which has been operating in Hong Kong for almost two years, has continued to work for the Water Supplies Department (WSD) under a sub-contract to local contractor U-Tech Engineering Limited. Work has also been undertaken for the Mass Transit Railway Corporation, repairing saltwater mains that provide cooling for the air conditioning systems in some stations. IAL has also recently been asked to provide demonstrations of its PolyFold (see picture) and PolyFlex systems to consultant Maunsell AECOM, acting on behalf of the WSD, prior to use in water contracts. ■

NORMS

Top marks for VSL-CTT structural bearings

CE

CTT Stronghold has received CE mark approval for elastomeric and pot bearings with the CTT and VSL brands. VSL has also obtained a local mark of approval in Portugal for certified structural bearing products. The new standards for structural bearings have been compulsory throughout the European Union since January 2007. All structural bearings must carry the CE mark in compliance with the EU Construction Products Directive 89/106/CEE concerning the standardisation of products. To meet the new regulations prior to applying for the award of the CE mark, CTT Stronghold adapted all of its bearing designs and its manufacturing process as soon as the new standards for elastomeric and pot bearings were published (EN 1337-3:2005 and EN 1337-5:2005). Requirements for individual bearings are critical to their intended use and so the company applied for the attestation of conformity system 1. This involved audits by a certification body and initial type tests at an official laboratory, both approved by the European Committee for Standardisation (CEN). ■

Dampers

VSL and SRI extend agreement

→ **VSL Taiwan and VSL Hong Kong have entered into Exclusive Distributorship Agreements** with Sumitomo Rubber Industries (SRI) for the use of Gensui dampers in building applications. The agreements, which were finalised in January and April 2007 respectively, extend the original Distributorship Agreement with SRI, which applied only to cable-stayed bridge applications. The continued collaboration between SRI and VSL is aimed at extending VSL's coverage in the rapidly-growing market for vibration control in buildings. Frequent earthquakes and seasonal typhoons in Taiwan create a strong demand for vibration control systems such as dampers and base isolation, especially for high-rise commercial and luxury residential buildings. VSL has secured three building contracts since the SRI Gensui Damper was introduced to the Taiwan market in 2007. Installation of the dampers – the first to be used in buildings outside of Japan - will take place in 2008. SRI and VSL's damper business development is proving successful in other parts of the world as well as Hong Kong and Taiwan.

Dr. Matsumoto from SRI gave a presentation introducing the advanced vibration control system to delegates at the XVI National Congress of Seismic Engineering held in Vallarta, Mexico from Oct 31 to Nov 3, 2007, a major seismic engineering conference.

■ *Contact: haining@vsl-tw.com*

Large span roofs

First for Czech Republic

→ **VSL CZ has introduced to the Czech Republic its assembly method** for the large-span roofs widely used on aircraft hangars. The 1,400t roof for a new aircraft maintenance hangar in Mosnov was first assembled on the ground ready for the 35m lift to its final position. Lifting of the 140m by 83.5m roof was carried out with 14 SLU 120/500 hydraulic lifting units, which were located on top of the permanent columns. The lift was controlled with the Bravo system, allowing permanent monitoring of the lifting force and displacement. The successful execution of the project was a result of close cooperation between the designer Excon, client Hutni Montaze, VSL CZ and VSL Heavy Lifting. VSL sees considerable potential for applying the method to other hangars scheduled for construction in the region.

Contact: psevcik@vsl.cz

Slabs

New step in Chilean market

→ **An impressive 100,000m² of slabs have been completed** in just four months at a new shopping mall in Chile. Slab construction for the Mall Alameda in Santiago de Chile was awarded to VSL, which had proposed a very efficient system. The design involves post-tensioned flat slabs, which incorporate shear connectors designed by VSL to resist punching. Use of Nelson stud shear rails controls the punching and allows column heads to be eliminated. A further benefit is that installation is very straightforward, as the Nelson system is simply nailed to the formwork. The absence of column heads and beams allows the use of simple formwork.

Contact: fpino@vslchile.cl

Buildings

Pune market growing in India

→ **The Pune region in India has been an important market** for VSL's PT in buildings activities in India ever since the first contract won in 2000. Since then, VSL has completed more than 170 projects in Pune of which more than 125 projects have been done with the well-known local consultant YS Sane associates. The total area post-tensioned by VSL is 1,600,000m² with over 7,000 tonnes of PT strands consumed. VSL has also worked on projects with other leading consultants such as Sterling Engineering & Hansal Paraik Associates. VSL's major clients include Magarpatta, Infosys, I-flex, Wipro, Kolti Patil developers, DLF-Akruthi, KPIT Cummins & Godrej Developers. At present, VSL is working on 35 jobs with a total post-tensioned area of 350,000m² and consuming up to 175t of PT strand each month. In Pune, many new townships, IT parks and shopping malls are to be built in the near future and VSL is aiming to be an integral part of the building post-tensioning works in many of these developments. ■ *Contact: mphillips@vslindia.com*

Keystone® walls

First for Hong Kong

→ **VSL Hong Kong is carrying out a complete installation package** for Hong Kong's first Keystone wall. The 130m-long and 16m-high wall is already generating interest from other potential clients. It forms part of site formation works for a residential development at Discovery Bay on Lantau Island.

The Keystone modular block-facing provides an attractive finish to the reinforced fill block whilst permitting the easy inclusion of curves, foundation steps and planter walls into the structure. Automated production blocks enabled the coloured facing blocks for the entire project to be cast within three days. VSL Hong Kong - working for main contractor China Overseas Civil Engineering - proposed Keystone, an alternative to a tiered grey panel faced wall. The solution was selected by client Hong Kong Resort Company Ltd. as it offered improved aesthetics whilst allowing to withstand higher building loads. This enabled additional apartments to be built above the wall. ■ *Contact: alice.lin@vsl-intrafor.com*

Tatarstan

Repeat success

→ **Exactly two years after the completion of its first stay cable bridge in Kazan,** VSL Switzerland has carried out the installation, stressing and tuning of 16 stays for the Kazan 2 Bridge. The first bridge was handed over at the City of Kazan's millennium celebrations. This new bridge, which is parallel to the first one, was designed by Moscow's Guiprostransmost design institute and constructed by NUR-1, one of the leading contractors in Tatarstan. The parties involved – the client, engineer, main contractor and subcontractors including VSL - were the same as those on the first bridge. Close co-operation has enabled a very successful project, to the full satisfaction of the Government of Tatarstan. The completion of the latest bridge project in this Russian Federation republic has further strengthened VSL's position there.

■ *Contact: christophe.petrel@vsl.com*

REPAIR AND STRENGTHENING WITH CFRP

Advanced active stre

ngthening

VSL has added an advanced active strengthening system to its wide range of construction and engineering products and services. This eco-friendly tool is CarboStress®, a post-tensioning system which takes full advantage of the outstanding properties of carbon fibre reinforced polymer (CFRP) materials.

As structures continue to age, there will be increased demand for proven means of evaluating and repairing reinforced and/or prestressed concrete. Years of service and exposure may have left these structures in need of substantial repair, restoration and strengthening. Similarly, bridge strengthening may be required in order to accommodate increased live loads, changing design requirements or upgraded codes. Strengthening is also useful in situations such as where structures have suffered damage or deterioration, where defects have come to light, where the static load system has changed, where a structure is subject to excessive deformation or cracking, or if its design life needs to be extended.

Active versus passive

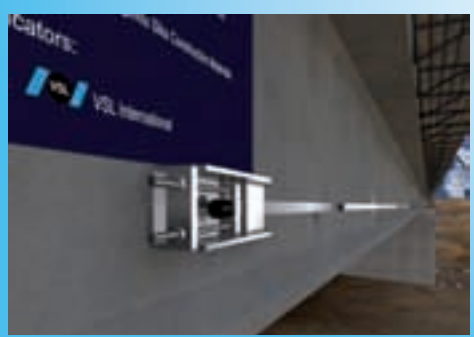
Strengthening techniques are categorized as passive or active, depending on how the loads interact with the retrofitted materials that are applied to the structure. *Passive* systems are

VSL's repair & strengthening services

- Concrete forensics
- Advanced concrete repair
- Passive strengthening
  - Bonded CFRP (design & application)
  - Bonded SRP – Hardwire® (design & application)
- Active strengthening
  - External post-tensioning
  - CarboStress® post-tensioned CFRP
- Protection
  - Ductal® - Blast mitigation
  - Dampers - Vibration mitigation
  - Cathodic protection - Corrosion mitigation

applied when no participation in stress-sharing is required and the retrofitting material is only engaged when additional loads are applied and/or additional deformation occurs. Traditional methods of passive strengthening include section enlargements, steel plate bonding and the external bonding of fibre-reinforced polymer materials to the structure. Stress in the existing steel reinforcement is often the limiting factor for a passive strengthening system. Unloading the structure prior to the

The VSL CarboStress® system is a carbon fibre post-tensioning system. The load from the CFRP plate is transferred via a steel anchorage into the structure. The actual connecting element of the element to the structure is either a steel shear pin or a steel plate. The tensioning operation of the CFRP tendon is done on the stressing anchorage. Several types of anchorages can be used.



Rapid strengthening without disruption at Xiaofeng Railway Bridge, Changsha, China

Mounting of CFRP tendon into anchorage

The Xiaofeng Railway Bridge in Hunan Province was selected as a pilot project to demonstrate the effectiveness and simplicity of the VSL CarboStress® System. The bridge is a simply-supported structure with three 20m-long spans. Engineers had observed numerous vertical crack lines extending from the bottom to the top throughout each beam. After extensive laboratory tests by the owner, Beijing Guangdong Rail Line, the structure was strengthened using 18m of CarboStress® tendons on each side of the beams. The installation process caused no disruption to the rail service.

application of a passive system is not always possible or may increase the overall project costs.

An *active* system will be required in situations where the strengthening technique is required to reduce the stress immediately by sharing the existing loads. Traditional methods of active systems include external post-tensioning (PT) using stress bars or PT strands grouted in HDPE (high-density polyethylene) pipes. While these active systems have proved to be effective, the construction detailing, wet works, duration and heavy equipment involved are often major considerations in terms of the inconvenience to users and resulting costs.

The CarboStress® Post-Tensioned CFRP System developed jointly by VSL and Sika requires only minor demolition work in the form of concrete coring for the load-transfer dowels. The CFRP plates are then mounted onto the structural member via the anchorages and then stressed.

Not only does the system save time and reduce inconvenience to users, but it is also more eco-friendly as demolition is minimal and there is no requirement for traditional construction materials such as concrete, reinforcing bars and aggregates.

PT maximising CFRP's benefits

Fiber Reinforced Composite materials have different mechanical properties -E modulus, and tensile strength- and combined with different resins such as epoxy or polyester, they form a wide range of FRP composites: Carbon (CFRP), Glass (GFRP) or Aramid fibre (AFRP). Aramid fibre has high strength resistance, and is mainly used to produce bullet resistant and other body armor products. Glass fibre is mainly used in construction against earthquake, and to provide ductility.

Carbon fibre reinforced polymers were developed in the late 1960s and have been applied extensively for structural strengthening around the world. The last decade has seen further developments in their use as post-tensioned

Longitudinal strengthening of Sung San Bridge deck, Seoul, Korea

Large transverse cracks were detected at several locations in the deck slab of this multi-span bridge. Analysis determined that they were the result of an increase in traffic loading beyond that for which the longitudinal reinforcement had originally been designed.

The VSL CarboStress® System was chosen for the longitudinal strengthening. Steel saddles were installed to deflect the CFRP plates in order to prevent debonding at the haunches.

Structural strengthening of Clinton & Hopkins Bridge, Ohio, USA

The structure is a multi-span bridge consisting of 16 prestressed precast boxes which had then been connected on site. A leaking and defective drainage system had resulted in premature corrosion propagating on the prestressing strands.
The CarboStress® System was applied successfully to supplement the damaged bending reinforcement and to restore the structural strength of the bridge. CFRP fabric was also used to strengthen the anchorage zones for the CarboStress® System because of the slender design of the box girders. This project received the 2004 Award of Excellence for the Transportation Category by the ICRI (International Concrete Repair Institute).

strengthening tendons for application on bridges and other structures.

The CarboStress® Post-Tensioned CFRP System was developed to provide owners with a highly-advanced system for strengthening various types of structures.
It can be used on bridges, civil structures, commercial and private properties, industrial and manufacturing facilities as well as petrochemical, oil and gas plants, tanks, culverts. It may be used for restoring or enhancing earthquake resistance or for strengthening any additional openings required in existing structures under conversion.

This advanced system is based on the principle of non-bonded external prestressing and consists of CFRP tendons with concentrated force transfer at the plate ends.

The basic elements of the system are made up of the CFRP plate, two CFRP stress heads, a steel dead-end anchorage and a steel live-end anchorage, where the stressing will be carried out.
The load from the CFRP plate is transferred via the steel anchorages into the structure. The actual connection between the anchorage and the structure is made by either shear pins or steel plates. The CFRP tendon is then

installed onto the anchorages and the stressing is carried out at the live anchorage. Whilst the anchorage has several standard options, it can also be easily adapted to suit project specifics.

The post-tensioning of CFRP plates prevent premature debonding of the externally bonded strengthening system and it maximizes their outstanding material properties.

Live traffic scenarios

The selection of an appropriate strengthening system for a bridge requires a detailed condition survey, the definition of future requirements, the determination of alternative approaches, evaluation of the solutions and finally the development of the specifications and methods.
The high flexibility of the CarboStress® anchorage design enables engineers to configure the system to suit specific scenarios.
The thin CFRP plates also enable tendon cross-overs. In addition, the short load transfer of the external PT force through the shear pin strengthens the structure immediately upon stressing.

This system was developed with today's on-site challenges in mind: in most strengthening scenarios, the work has to be executed under full – or, at best, reduced – live traffic levels. The available time frame in such scenarios is usually limited and challenging.
The CarboStress® tendons are

Transverse strengthening of A3 Escher Canal Bridge deck, Glarus, Switzerland

This three-span prestressed box girder bridge on the A3 Sargans-Zurich Motorway was built in 1957. It crosses the Escher Canal near Wesen. During an inspection in 1964, a crack running the whole length of the bridge was observed in the centre of the underside of the deck slab. All that could be done was for engineers to monitor it continuously until a viable solution could be found. It was not until the development of CFRP plates that a plan was made to strengthen the deck slab transversely for both negative and positive moments.

In addition, CarboStress® was applied to the underside of the deck, to act as an external prestressing system. The tensioning force was transferred to the concrete only at the anchorages at the ends of the plates.
The positioning was calculated to achieve the maximum strengthening effect.
A highway authority approval was needed, hence an external witness audited how each tendon was tested to +10% of its working load before it was installed and stressed on site.

Extending the life of a bridge in Grindelwald, Switzerland

The Tschingeley Bridge over the Luetschine is a 50-year-old bridge connecting the well-known winter resort station Grindelwald with its waste disposal plant. The 30m-long structure is post-tensioned with 12 tendons, each made up of seven wires of 7mm diameter. Increasing lorry weights meant that the bridge's carrying capacity was no longer sufficient and had to be improved. Retrofitting measures including external post-tensioning have been carried out with the aim of extending the bridge's life by 10 years.

VSL's CFRP CarboStress® System was chosen because of its inherent advantages including corrosion resistance and light weight. A total of eight CarboStress® tension members - two on each side of the two webs - were installed and stressed in October 2007. Each tendon consists of 60mm x 2.4mm CFRP plates (Sika®CarboDur S624) with a working load of 220kN. The tendons are bonded to the structure, enabling it to carry heavier traffic than before.

lightweight, at just 3.5kg per 10m roll, and can be moved easily by rolling. This is particularly useful in areas where access conditions are tight. In addition, the installation is fast and easy without the need for sophisticated specialist equipment. In temperate climates, the non-bonded system may be applied without the need for any additional curing equipment.

The CarboStress® system has proved to be a success and is catching interest. Engineers and owners are looking for an active strengthening solution with minimal disruption to services and/or when traditional active strengthening systems are not practical or possible. In this respect, VSL is one of the few specialists in the world to have carried out extensive testing of post-tensioned CFRP plate systems and proven them in the field. ■

Seismic upgrade of a nuclear power plant in Switzerland

The Gösgen nuclear power plant was commissioned in 1979 and produces nearly 8 billion kilowatt hours of electricity per year, which represents about 15% of the total Swiss electricity consumption. The emergency feed building had to be strengthened as part of a general seismic upgrade as the four deionized water tanks in which the reactor coolant is stored, did not meet the latest design standards. The tank walls had to be strengthened with a secondary strengthening system using prestressing techniques. To avoid restricting the operation of the plant, the strengthening works on each basin had to be completed in only two days. Surface strengthening which could be applied in just a few hours was therefore necessary.
The ideal solution was CarboStress® with chemically resistant CFRP plates which could be applied in a very short time. They were also able to accommodate the transfer of tensioning forces at the ends of the plates, through concentrated end anchorages into the cross walls.

COMBINING ADVANCED AND TRADITIONAL METHODS

VSL continues its pursuit of creative engineering solutions in the field of Repair and Strengthening, providing ingenious combinations of traditional methods and advanced composites. The following projects illustrate some of the scenarios which VSL had been directly involved to produce long-term, durable and cost effective repair & strengthening solutions for the industry.

Successful bridge pier repairs in Spain with AFRP

A new high speed railway bridge near Girona required additional pier cap reinforcement due to an error made during construction. The reinforcement has to fulfil all engineering requirements – in particular, 6,000kN of horizontal force – as well as aesthetic and durability criteria. The solution combines external post-tensioning using 0.6'' (15mm) strand with a CTT Connector and high-performance protection. A thixotrophic mortar

with corrosion inhibitor is used, together with external AFRP (Aramid Fiber Reinforced Polymer) reinforcement to control mortar cracking. An anti-carbonation coating conceals the 30mm reinforcement that has been added.

Externally bonded CFRP for Spanish railway bridge

A pair of bridges has been successfully repaired by VSL and local contractor IRECA using a technique that combines the use of externally-bonded CFRP and post-tensioning systems. Cracking of the pier cap may have been initiated by poor construction, and made worse by environmentally-induced degradation. Repairing the pier caps has involved restoring durability using epoxy injection, improving structural behaviour through external post-tensioning and controlling surface cracks by bonding CFRP laminates and sheets. The project has maintained the bridge's aesthetics. Benefits of using composites for the strengthening included immunity to corrosion and light weight for easy application at height. This avoided the need for extensive scaffolding and reduced the labour costs. CFRP's availability in virtually any size and length simplifies its use. Although the fibres and resins are relatively expensive compared to traditional strengthening materials, the labour and equipment for installation are greatly reduced. Access requirements are also much simpler. Further work is planned on the bridge: carbon fibre tendons will be installed on some of the piers over the coming months under an experimental programme, supervised by a university and several national concrete institutes.

Saving by sawing on the Fozières Viaduct, France

Located in the South of France on the A75 motorway, the Fozières Viaduct consists of three 40m-long spans and was built in the eighties. Large cracks on the deck supporting beams due to chemical reactions caused by the high temperature of the concrete after pouring during its young age were observed during inspections. The bridge deck load was transferred by computer-controlled hydraulic jacks on temporary supports fixed on the existing pile. The existing cross-beam was sawed into 14 elements of 15 tons each and then lowered to the ground. The new beam (90m^3) was poured after reinforcement and formwork installation. The bridge deck load was then transferred from the temporary supports to the new bearings. Repair works on the second column were carried out in the same way. The motorway reopened to the traffic after six months of works.

SITE INSIGHTS

Spain

Barcelona buzz

→ **Barcelona is famed for its architecture**, and many internationally-renowned architects such as J. Nouvel, A. Isozaki, Toyo Ito, Z. Hadid, D. Chipperfield, D. Perrault, Alonso-Balaguer, Richard Rogers or C. Ferrater are making their mark there with exciting new projects. The boom has enabled VSL to work with major structural consultants to develop solutions to help realise the distinctive designs through key elements as large spans, cantilevers, transfer slabs, etc. A prime example is VSL's cooperation with the structural consultants for the Richard Rogers project, "Las Arenas", where the site of a former bullring, built in 1898, is being transformed into a major leisure and entertainment complex. VSL carried out a key part of the works to retain its distinctive Neo-Mudéjar façade, including stabilisation and load transfer. Additional extensive slab post-tensioning has also been carried out for the civil contractor Dragados. Another current scheme is Arata Isozaki's D38 office development, probably one of the most challenging buildings under construction in the city. Slabs with clear spans of 15x22m and cantilevers up to 15m have been projected with a combination of waffled and ribbed post-tensioning slabs together with edge post-tensioned beams to solve transfers and cantilevers. ■ *Contact: posso@vslsp.com*

Chile

High-level walls in Santiago

→ **VSL Chile is nearing completion** of a 31m-high VSoL® wall in Santiago for the Radial Nor-Oriente road, which is being built by Sacyr. The wall is constructed in two levels and has a total area of 2,600m². Chile's resurgence in road construction is leading to increased demand for retained earth walls, reversing the slow-down of the last two years. VSL Chile is targeting the new projects in order to maintain its market leadership with this product.
■ *Contact: fpino@vslchile.cl*

Mozambique

Limpopo first

→ **A new crossing of the Limpopo River** is the first single box girder bridge ever to be launched in Mozambique, and the only one in southern Africa to have 50m spans. Portuguese contractor Teixeira Duarte is nearing completion of the bridge, which has been eagerly awaited as the original had been destroyed decades ago. The contractor and the designer, Lisconcebe, chose to use incremental launching for the concrete deck. VSL Portugal defined the method, designed temporary works and supervised operations. Its scope also includes the supply of 200t of post-tensioning steel as well as special ILM bearings and expansion joints. It took just five months to complete the launch of the 490m-long deck, using two VSL lift-push jacks with a total horizontal capacity of 640t. Final work is taking place on the PT, bearings and expansion joints. ■

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Spain

VSoL® for Ferrol

→ **High-speed production has been achieved** in the supply of VSoL® retained earth walling to meet challenging targets on a road scheme in Ferrol. Structures on the 15km project include four viaducts and 12 mechanically-stabilised earth walls.

CTT Stronghold was awarded the contract to design and supply 15,000m² of VSoL® at 2,000m² per month. Faster deliveries were later requested to speed up the project and production was increased to achieve a peak of 4,600m² per month. Owner of the scheme is Spain's ministry of civil works and the contractor is FCC Construcción. ■ *Contact: rroussillon@vslsp.com*

NOTE PAD

Long span. *The 900m-long multi-span I-64 Kanawha River Bridge in Charleston is being constructed by the cast-in-situ balanced cantilever method. The bridge's 231m main span will be the longest for a concrete box girder in the USA. VSL was selected by Brayman Construction Company to supply the post-tensioning elements, including some 984t of 0.6" diameter (15mm) post-tensioning steel. Enhanced durability requirements have led to the use of VSL's PT-PLUS™ plastic ducts.*

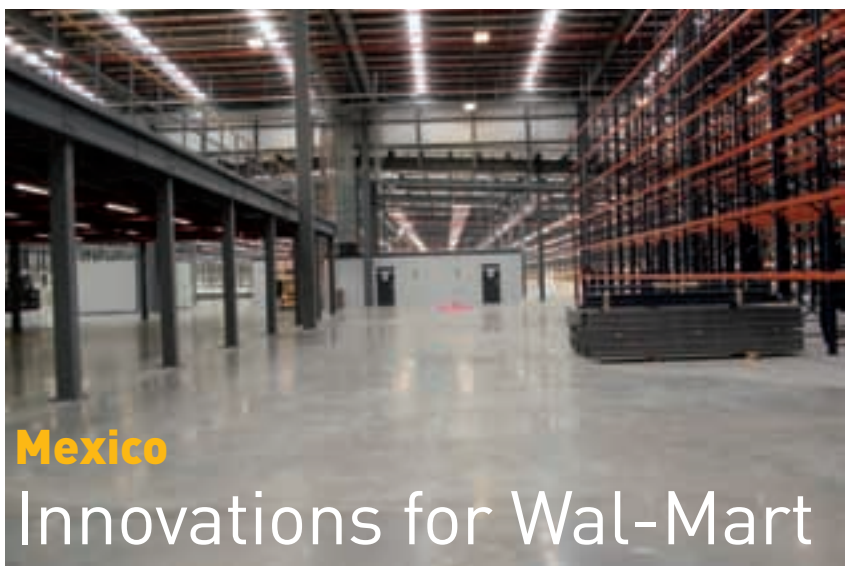
Pier retrofit. *VSL in the USA continues work on the Huey P Long Bridge Widening Project in Louisiana. Its responsibility includes supply and installation of 101t of 0.6" (15mm) strand for the retrofit of the piers used to support the widened bridge. VSL will work on five piers with heights ranging from 32m to 42m.*

Double benefits. *VSL Australia has completed work on two large circular waste water treatment tanks with precast, post-tensioned walls, each consisting of outer and inner walls, located at the Boyer paper mill in Tasmania and at Gippsland Water Factory in Victoria. VSL's scope of works in Tasmania was the wall design, the supply and installation of post-tensioning, while work in Victoria consisted of panel supply, the supply and installation of post-tensioning.*

Mock-up. *On VSL's nuclear containment mock-up under construction in France, VSL will soon begin the first demonstrations to the client for nuclear applications regarding the waterproofing, adjustment and placing of different type of ducts: VSL PT-Plus™, low friction steel sheet duct, steel tubes.*

Canada
Double first

→ **VSL is currently well under way** with work on the signature span stay cable bridge over the north arm of the Fraser River in Vancouver, British Columbia, Canada. When completed, the bridge will become part of the Canada Line Light Rail System. The new structure consists of an extradosed precast segmental box-girder bridge with a continuous deck of 562m and a 180m precast segmental main span. The main span provides clearance for the 150m-wide main navigation channel. Client for the scheme is RSL Joint Venture, made up of Rizzani de Echer and SNC Lavalin. The crossing will become North America's first extradosed cable stay bridge and its first to use the Gensui dampers - this type of damper has already been used on more than 40 bridges in Asia. The main advantages over traditional damping systems are that they are easy to install, require almost no maintenance and have very little temperature and frequency dependency. VSL in Spain and VStructural (VSL's licensee in the USA) have joined forces to supply the VSL Stay Cable system (anchorages for 61 strands 0.6) as well as the Gensui dampers for the bridge. The joint venture's responsibilities include full-time technical assistance on site. The bridge also features a 139m-wide side span, two 45m-high main pylons and two approach piers on each side of the river's north arm. The pylons above deck at the main piers are designed in steel and provide anchorage for the extradosed main-span tendons. The bridge is also designed to carry a pedestrian/cycleway. Construction of the first pylon was completed in August 2007 and the works are scheduled for delivery in spring 2008. ■



Mexico
Innovations for Wal-Mart

→ **Innovative techniques have been incorporated** into the new Wal-Mart Distribution Centre, which was inaugurated in June at Chalco in Mexico. It includes the latest generation of racking systems, designed to achieve the maximum possible storage capacity. VSL Corporation Mexico contributed to the project by constructing a 180mm-thick bonded slab-on-grade, with an area of 7,000m^2, for a key section of the depot. This technology with its inherent advantages is increasingly popular in Mexico. ■

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USA

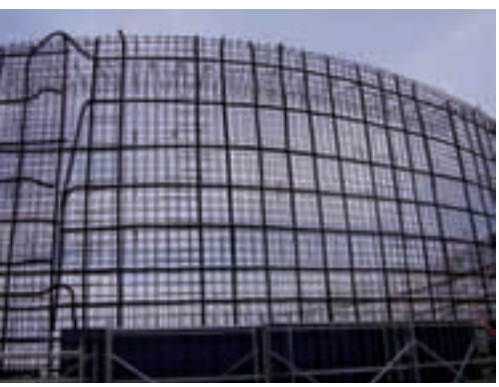
Pushing through 245m

→ **VSL Denver has recently provided and installed a bonded post-tensioning system** for the Legacy Parkway Pedestrian Bridge just outside Salt Lake City, Utah. VSL was hired by Wadsworth Construction to provide the EC16-19 system for the construction of the cast-in-place, single-cell box girder bridge. The strand installation was carried out by the push-through method and the post-tensioning was completed ahead of schedule. The dramatic bridge starts parallel to the parkway before twice turning through 90° to finish parallel on the other side. It has an overall length of 245m, with post-tensioning running continuously over seven piers without intermediate stressing anchorages.

■ *Contact: rredman@structural.net*

Mexico

Refined solution



→ **VSL Corporation Mexico has been involved since February** with the structural design and installation of the PT system for the 16 tanks at the residual water treatment plant for Pemex's Francisco I Madero refinery in Madero, Mexico. The tanks were conceived as post-tensioned structures, including the foundations which consist of piles linked by post-tensioned beams and a slab post-tensioned with VSL's Bondtec System. Both, vertical and horizontal post-tensioning was applied to the walls, using EC5-7 and EC5-6 units respectively. The height of the 18,000m³ tanks is about 11m, with internal diameters of 46m and a wall thickness of 0.4m.

■ *Contact: mmartinez@vslmex.com.mx*

NOTE PAD

VSoL® record. *Record installation speeds are being achieved for the VSol® walls on an access route to the new Tanger Mediterranée port in Tangiers. VSL was awarded the design, supply and erection of more than 24,500m² of VSol® walls with polymeric reinforcement. The walls are being erected in a record time of just six months under the direction of contractor SGTM.*

Special jack. *Post-tensioning work using more than 2,000t of strand is carried out by VSL Middle East for the widening of Al Garhoud Bridge in Dubai. Stressing forces on the larger tendons of up to 8,500kN and the restricted work space required the use of VSL's 12,500kN-capacity special stressing jack. Client for the project is the Road & Transport Authority, Belhasa Six Construct is the contractor and Halcrow Intl. Partnership is the consultant.*

Luxury slabs. *VSL Middle East is undertaking PT work for the Khalidiya Palace Rotana Hotel & Residences project in Abu Dhabi. The scheme consists of four blocks, with up to 24 levels of post-tensioned flat slabs, using more than 700t of strand. Client for the scheme is Sheikh Mohamed Bin Khalid Al Nahyan, the consultant is Khatib & Alami Consolidated Engineering and the contractor is Nurol General Contracting LLC.*

Lucky 13. *VSL Middle East was awarded the post-tensioning work for the precast segments of the 13 Bridge project in Bahrain. The project involved the construction of precast post-tensioned bridge units in steel moulds and used EC 6-19 anchorages and 1,100t of strand. There are 378 segments, each about 16m long and 7m wide. Post-tensioning work was completed three months ahead of schedule.*

Czech Republic

Express cabling

→ **VSL has used its SSI 2000 Stay Cable System** to achieve a dramatic reduction in the installation time for the cables on a new Czech bridge. It took VSL only 28 days instead of the 56 days originally scheduled. This shortening of the original schedule was achieved by advance installation of anchors, prefabrication of HDPE pipes and strands on site in combination with the strand-by-strand method. The bridge crosses the River Odra and Antosovicke Lake on new section of D47 Highway close to the Polish border. Total length of the bridge is 592.7m, with a suspended 201m-long deck supported by a 46.8m-high central pylon. The stay cable system consists of 14 cables on each side, ranging from 23m to 99m. Nearly 140km of strands were installed. The local design office Strasky, Husty and Partners designed the bridge and VSL's client was the main contractor, Skanska. The project is financed by RSD CR, the Road and Motorway Directorate of the Czech Republic. VSL worked closely with the client to achieve the faster cable installation, as the task was on the overall project's critical path. ■ *Contact: jbesta@vsl.cz*

Switzerland

Holding back the shield

→ **A hard rock tunnel boring machine (TBM)** has been put back on track thanks to an innovative solution from VSL Heavy Lifting. The TBM had hit unexpected soft soil during the construction of the highway tunnel de Moutier in the Swiss Jura mountains. Steering of the TBM became impossible because of the resulting reduction in thrust force. VSL Heavy Lifting was asked to provide a means of holding back the top of the shield during TBM operation. The solution that was developed consisted of two SMU-120/550 Strand Moving Units and custom-made controls designed to apply a constant retaining force of up to 1,440kN, regardless of the TBM speed, which varied from zero to 60mm/min. New for this project is fully-automated operation of the SMUs. This allows the TBM to move continuously while the SMUs re-grip every 500mm. Load cells at the anchorages provide continuous readings and an automated emergency stop if necessary. Another first is the record-breaking 435m strand length. A similar operation had been successfully carried out in 2002 on the Dublin Port Tunnel. ■ *Contact: Wolfgang.Schroeppel@vsl.com*

Morocco

Sea-water pipeline

→ **VSL Switzerland has completed the installation of 300t of post-tensioning** on behalf of Somagec at the Jorf Lasfar site, 150km south of Casablanca. This project is the result of a long-term business relationship between VSL and Somagec, one of Morocco's leading construction companies. Work consists of the construction of 2,000m of sea-water pipeline and a balance tower. The 300mm-thick prestressed concrete pipeline has an internal diameter of 2.5m and is post-tensioned transversely and longitudinally. This pipe is used to supply sea water to a phosphoric acid factory. It is made up of 22 independent sections connected to each other by expansion joints. Transverse post-tensioning is provided by sheathed monostrand, making an average of three loops, and VSL 6-1 anchorages. Longitudinally, post-tensioning of each 100m-long section is achieved through the use of VSL EC6-12 anchorages. The balance tower is a hill-top post-tensioned concrete chimney, which is designed along the same principles as the pipe. ■

Contact: k.doghri@bouygues-construction.com

Dubai

VSL at the Ritz

→ **VSL Middle East is nearing completion of post-tensioning works** for client Union Properties at the Ritz Carlton Hotel & Apartments project in Dubai. The project consists of 15 levels of post-tensioned flat slabs, with transfer beams with multi-strand tendons located at the podium level for the hotel block and at two levels of the apartment block. Consultant for the project is Hyder and the main contractor is a joint venture of Bouygues Bâtiment and Target Construction. The total PT floor area is approx. 80,000m^2. More than 550t of 0.6" (15.7mm) diameter strand will be used and the tendons are stressed with SO 6-4 slab anchorages. Floors are typically divided into four pours and built to a 14-day cycle. VSL's scope of work includes slab and beam design, drawing production, supply of all the post-tensioning materials and specialist equipment, together with the provision of specialist supervision.

■ *Contact: johnlizhang@vslme.ae*

Czech Republic

Record library

→ **VSL is installing more than 300t of post-tensioning** for the new Technical Library Project in Prague in the Czech Republic. When completed, it will be the largest post-tensioned building in the region. Construction consists of six post-tensioned levels using the SO 6-4 bonded slab system with a total of 2,200 stressing and passive anchorages. The floor plan is a 75m by 75m "rounded square", with each floor cast in six parts. A typical span is 15m by 15m and the 300mm-thick flat slabs sit on 6m-diameter caps on the supporting columns. Floor heating and wiring are installed together with the rebar and tendons. The six month project is due for completion at the end of 2007, with one floor completed every month. Main contractor for the scheme is a joint venture of Metrostav and OHL ÎS. ■ *Contact: jbesta@vsl.cz*

Hong Kong
Soaring core

→ **VSL's Climbform has now reached the top** of the 300m-high prestigious One Island East building in Hong Kong's Quarry Bay. VSL designed and supplied the Climbform to build the central core in an operation which started in early December 2006. A four-day climbing cycle was achieved in forming the walls for the total climbing operation, whose area totals approximately 141,000m^2. VSL was also awarded the design, supply and installation contract for 66 post-tensioned floors, totalling 112,000m^2. The 285m-thick post-tensioned floor slab in a typical floor spans 13m from the perimeter edge beam to the central core. Again, a four day cycle was achieved. ■ *Contact: brian.lim@vsl.com*

Hong Kong
Robots keep watch

→ **FT Laboratories, a subsidiary of VSL International, has completed two 18-month projects** using a state-of-the-art robotic system to monitor railway tracks and issue alerts if they were affected by nearby construction work. The Automatic Deformation Monitoring System (ADMS) consists of computer-controlled robotic theodolites, which automatically monitor survey prisms. The system operates 24 hours a day, 7 days a week, and the results are delivered online. It is typically used to monitor critical structures, such as railways and viaducts that are adjacent to construction work or excavations. The latest projects involved monitoring tracks for Kowloon Canton Railway Corporation. Five automatic theodolites were installed, together with 650 survey prisms, and their movements were monitored for 18 months. The results were reported continuously at four hourly intervals, with SMS and e-mail alerts sent out automatically if unusual movements were detected. ■ *Contact: david.clayton@ft.com.hk*

Hong Kong
Tricky truss transfer

→ **VSL HK has been awarded a subcontract** for a complex and challenging operation of lifting and launching four main roof trusses for a bridging link needed as part of the expansion of the HK Convention and Exhibition Centre. The new roof trusses each weigh between 1,200t and 1,500t and span 90m across a harbour channel, at 27m from one another. They are supported on bearings on top of columns at 41m and 57m above ground level. The first two, A and B, are assembled at the position of C and D respectively, then launched sideways by 54m over the existing link bridge. Trusses C and D will then be assembled beneath their final positions. VSL has designed the temporary works to enable the truss installation. The lifting support structure is made of self-balancing lifting brackets mounted on temporary concrete corbels, which in turn are stressed to the top of the permanent columns. The trusses are lifted by SLU330 strand jacks. Next stage is the installation of sliding beam supports, allowing the load transfer. The sliding beams and the trusses will then be launched in alternate stages by strand-jacking to the next column grid before being raised into place. ■ *Contact: henry.chan@hk.vsl-intrafor.com*

India

Compact solution

→ **The 9.5km Bangalore-Hosur Elevated Expressway** is built by the precast segmental construction method, using self-launching overhead gantries. The work is carried out as a public-private partnership on a BOT (Build-Operate-Transfer) basis by Bangalore Elevated Tollway Limited, with three lead companies: Soma, Nagarjuna Construction Company and Maytas. VSL is responsible for all three launching gantries, from their design and fabrication to erection and operation. The scope of work also includes construction engineering and post-tensioning of the deck. As the structure is built in the middle of a busy highway, it was not feasible to erect the gantries using cranes. VSL proposed a solution using VSL SLU-120s mounted on two VSL Heavy Lifting towers erected behind the piers to raise each gantry. The gantry main trusses and upper cross beams were assembled at ground level together with the lifting winch and ancillary equipment and the trusses were lifted simultaneously into position. Pier segments and other components were lifted using the winch. The truss was then locked into position ready for segment erection. ■ *Contact: kailash@vslindia.com*

Thailand

Fast-track lift

→ **Replacement of a 150t generator on the Thatoom Power Station** has been successfully carried out by VSL Thailand in a carefully-planned three day operation using the H450 frame. VSL Thailand was contracted to remove the existing generator and install a new one. The entire fast-track project was completed in just 70 days, from signing the subcontract to demobilising the site - including fabrication, international transport, installation and the lift itself. The operation involved lifting and lowering the equipment by 12m, as well as longitudinal and transverse sliding. The project's short timescale was achieved thanks to the adaptable design of the H450 installation frame. ■ *Contact: jmckenzie@vsl-th.com*

Macau

Cotai climb

→ **Form systems from VSL are proving a great success** in the construction of six towers for four hotels at the Venetian Orient and City of Dreams resort projects on Macau's Cotai Strip. VSL-Intrafor Hong Kong was appointed by Hsin Chong Construction and the Leighton-China State-John Holland JV respectively to design, supply, supervise and commission six sets of formwork for the two projects. Four sets of Climbform and two sets of Jumpform are being used to construct the towers, the tallest of which will reach 159m when completed. Work started on both sites in May 2007 and two sets of Climbform at Venetian Orient had completed their fifth climb by early August. ■ *Contact: Thomas.cheung@vsl-intrafor.com*

Hong Kong

Long holes on course

→ **Intrafor is using the directional coring technique** to drill holes of almost 700m and 1,300m as part of the ground investigation for a huge tunnelling project in Hong Kong. The Harbour Area Treatment Scheme (HATS) is an extension of the earlier Strategic Sewerage Disposal Scheme (SSDS). The aim is to upgrade the water quality of Victoria Harbour. The main works consist of a series of sewage collection tunnels, drop shafts and pumping stations around the northern coastline of Hong Kong Island and a cross-harbour sewerage tunnel leading to a treatment plant at Stonecutters Island. Ground investigation involves drilling

inclined directional core holes along the future tunnel alignments. Gammon Construction Limited was awarded the contract for three directional core holes, two of which were sublet to Intrafor in January 2007. ■ *Contact: mp.chan@vsl-intrafor.com*

RSA

Full speed for Gautrain

→ **Intrafor, in joint venture with local partner Basil Read,** has successfully completed the construction of diaphragm walls for the Park and Sandton underground stations as part of the Gautrain project. The 80km railway will link Johannesburg, Pretoria and OR Tambo International Airport in time for the 2010 soccer World Cup. Intrafor excavated 17,000m^2 of diaphragm wall up to 1.2m-thick, installed 2,845t of steel reinforcement and placed 14,200m^3 of concrete. Shear pin installation and rock fissure grouting were also within the scope of the project, which was completed in August. Challenging geology and the need to complete the project in time led Intrafor to mobilise specialist equipment from Hong Kong, in the form of two 80t rigs using cable-operated clamshells and a new BC40/BG40 trench cutter. ■ *Contact: jeanchristophe.gillard@vsl-intrafor.com*

Malaysia

Heavyweight traveller for light vessel

→ **Form travellers that are among the most massive ever designed** have been used on a new bridge in Banting, Selangor. The bridge over Sungai Langat is intended to provide sufficient clearance for light vessels serving local industries, especially Megasteel, replacing two existing bridges. The cast in-situ bridge - a prestressed double-cell box girder structure – will cross the river with a single 135m-long span. Construction is by the balanced cantilever method using two pairs of form travellers, which carry a maximum concrete weight of approximately 375t. VSL's scope of work includes the design and engineering for the box girder and precast beams; form traveller design and equipment supply; construction engineering for the balanced cantilever work; and supply and installation of prestressing for the main-span box girder and precast beams. In total, the structure uses 384t of prestressing strands. The design was standardised to use 6-19s tendons for both the cantilever and the span tendons, with the longest measuring 120m. VSL is also supplying and installing elastomeric bearings and mechanical pot-bearings. ■ *Contact: ckchong@vsl.com.my*

Malaysia

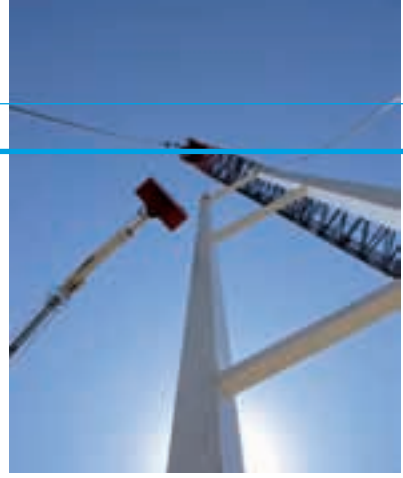
Subang Kelana link

→ **VSL Malaysia and a joint venture partner, Projalma, have been awarded a contract** for the casting and erection of 747 precast segments, the supply and installation of 1,100t of post-tensioning at the Subang Kelana Link, an elevated viaduct consisting of 34 spans of precast segmental twin-cell box girders. The viaduct is built by the free-cantilever method and segments are lifted up in pairs by VSL's strand lifting units. The greatest challenge faced was that the 20m-wide segments had rather thin concrete sections. To protect them from cracking during transportation, most required fitting with supporting props before setting out on the 200km-long journey from the casting yard to the site. The segments adjacent to the pier have also been strengthened by temporary strutting and increases to the bottom slab thickness, so that gantry loads could be transferred to the crosshead. The segment erection works covered the design and supply of the launching girder, the falsework installation and dismantling for the cantilevers and provision of all labour and supervision for both the launching girder operation. VSL was furthermore responsible for all aspects of the construction engineering.
■ *Contact: ckchong@vsl.com.my*

Australia

Mutual support

→ **VSL Australia is assisting Abigroup Contractors** with the construction of Alfords Point Bridge, a 445m-long incrementally-launched double-cell box girder bridge in a southern suburb of Sydney. VSL's scope of work includes the supply, installation and operation of the launching and braking system used for the 21 launches. The system uses ZPE670 launching jacks and SMU330 braking jacks. VSL is also providing post tensioning (169t), 8 rock anchors and elastomeric bearings to the project. To provide better continuity of site labour once each cycle of post-tensioning works are complete, VSL assists Abigroup with formwork and steel fixing operations. Abigroup then assists VSL by providing 'top up' labour on the critical stressing and launching days. ■ *Contact: BHannan@vsl-australia.com*



Australia

From VSoL® to stays

→ **The Albury Bypass project commenced in October 2005.** VSL's initial involvement for the main contractor Abigroup Contractors Pty Ltd was the supply and delivery of 4,133m² VSoL® reinforced soil walls for four railway embankments. This was increased to 9,759m² with the addition of East Albury section. This project was the catalyst for setting up VSL's precast yard in Holbrook 70km North of Albury in NSW. VSL was later awarded the supply and installation of 28 stay bars, ranging from 28 to 74 meters. The bars were manufactured by VSL in Melbourne, transported to the painting contractor then to site at Albury. ■ *Contact: SGrogan@vsl-australia.com*

Malaysia

Big bank

→ **Bank Negara Malaysia – the country's central bank** – has outgrown its current premises and is expanding into new buildings. VSL has carried out prestressing work on one of these, the Financial Services and Resource Centre. The oval-shaped building consists of six floors of offices and five basement levels. The structure is built using a beam and slab system, with a mix of prestressing, reinforced concrete and some steel structural elements. Construction involved close

coordination to accommodate specialist requirements in the building. VSL was responsible for detailing of the prestressing, as well as carrying it out during a 10-month period which was successfully completed in July 2007. ■ *Contact: ckchong@vsl.com.my*

Cryogenic Tests

Think Tanks with VSL's Gc

During the last two years, a total of five cryogenic tests have been successfully conducted using VSL's newly developed Gc anchorages in Switzerland and Korea in accordance with ETA guidelines and FIP recommendations(*) demonstrating that VSL's Gc anchorages are fit for use in cryogenic applications such as LNG & LPG tank projects.

Expected rupture of strand at ultimate load during cryogenic tests

Starting in 2004, countries such as China and Korea have been engaged in a fast track LNG development program with China alone requiring 100 tanks in the coming 15 years. Specifications set by key international Engineer Procure & Construct (EPC) contractors such as CB&I, Whessoe Oil & Gas and IHI require the post-tensioning system for the tank structures to be compliant with the cryogenic criteria of ETAG 013 Guidelines and with FIP recommendations.

In November 2005 VSL conducted its first cryogenic test on the newly developed Gc 6-27 anchorage at empa's laboratory in Switzerland for CBI who is the EPC contractor for the Fujian LNG project in China. The 27 strand anchorage was chosen as it represented the maximum strand number for the most common anchorage sizes used in the design for large LNG tanks from 150,000m^3 to 200,000m^3 which typically range from 12 strands through 27 strands.

European standards, international witness

Subsequent to the success of the Gc anchorage in the Fujian LNG project, which mainly opted for components of European origin, VSL conducted further cryogenic tests at Daewoo's laboratory in Seoul, Korea, using components

** ETAG 013 Guidelines for European Technical Approval of Post Tensioning Kits for Prestressing of Structures, June 2002 and FIP recommendations for the acceptance of post-tensioning systems, 1993*

Cooling of dead end anchorage by injecting liquid nitrogen N2 into cryogenic chamber during 10 cycles loading, Daewoo Laboratory, Seoul

from VSL's manufacturing centre in Hefei, China as well as components from Korea, Australia and Thailand to suit the needs of the projects which may source components from those countries.

In all tests, the post-tensioning anchorages were exposed to cryogenic temperatures by injecting liquid nitrogen (-196°C) into the Gc anchorages. Each test was performed in an official laboratory and has been witnessed by experts from Chicago Bridge and Iron (CB&I) or from the Laboratoire des Ponts et Chaussées (LCPC).

Tests Summary

Date	Anchorage units and strand grades	Laboratory
Nov 05	VSL Gc 6-27, 1860N/mm^2	empa, Switzerland
Jan 07	VSL Gc 6-27, 1770N/mm^2	Daewoo, Seoul Korea
Jan 07	VSL Gc 6-27, 1770N/mm^2	Daewoo, Seoul Korea
Mar 07	VSL Gc 6-27, 1860N/mm^2	Daewoo, Seoul Korea
Jul 07	VSL Gc 6-27, 1860N/mm^2	Daewoo, Seoul Korea

Plastic Trumpet performs well under cryogenic conditions

Immediate benefits

As a result of the successful cryogenic tests, VSL is now supplying and installing the post-tensioning systems for a number of LNG projects in Asia and America: Fujian LNG Project Phase 1, China; Shanghai LNG Project Phase 1, China; Pyeong Teak LNG Project Phase 2, Korea.
VSL has been awarded the post-tensioning of 2 LNG tanks of 160,000m^3 each in Quintero, Chile. This project is promoted jointly by Empresa Nacional del Petróleo, Endesa Chile, Metrogas and BG Group so as to become less dependent on Argentinean gas supply. The main contractor is CBI from the USA whilst the local civil contractor is El Montajes. When completed, these tanks will be the largest ever built in South America with VSL's type Gc anchorages used for both vertical and horizontal tendons. VSL in Chile and Spain will join forces to carry out works scheduled for 2008 and 2009.
VSL India has so far successfully completed 3 LNG tanks in Dabhol, 2 in Dahej and 2 at Hazira for Dabhol Power Corporation, Petronet LNG Ltd and Shell Ltd respectively with the ongoing works on a further 2 LNG tanks in Dahej. All tanks are approximately 80m in diameter and 40m in height with both horizontal and vertical post-tensioning. ■

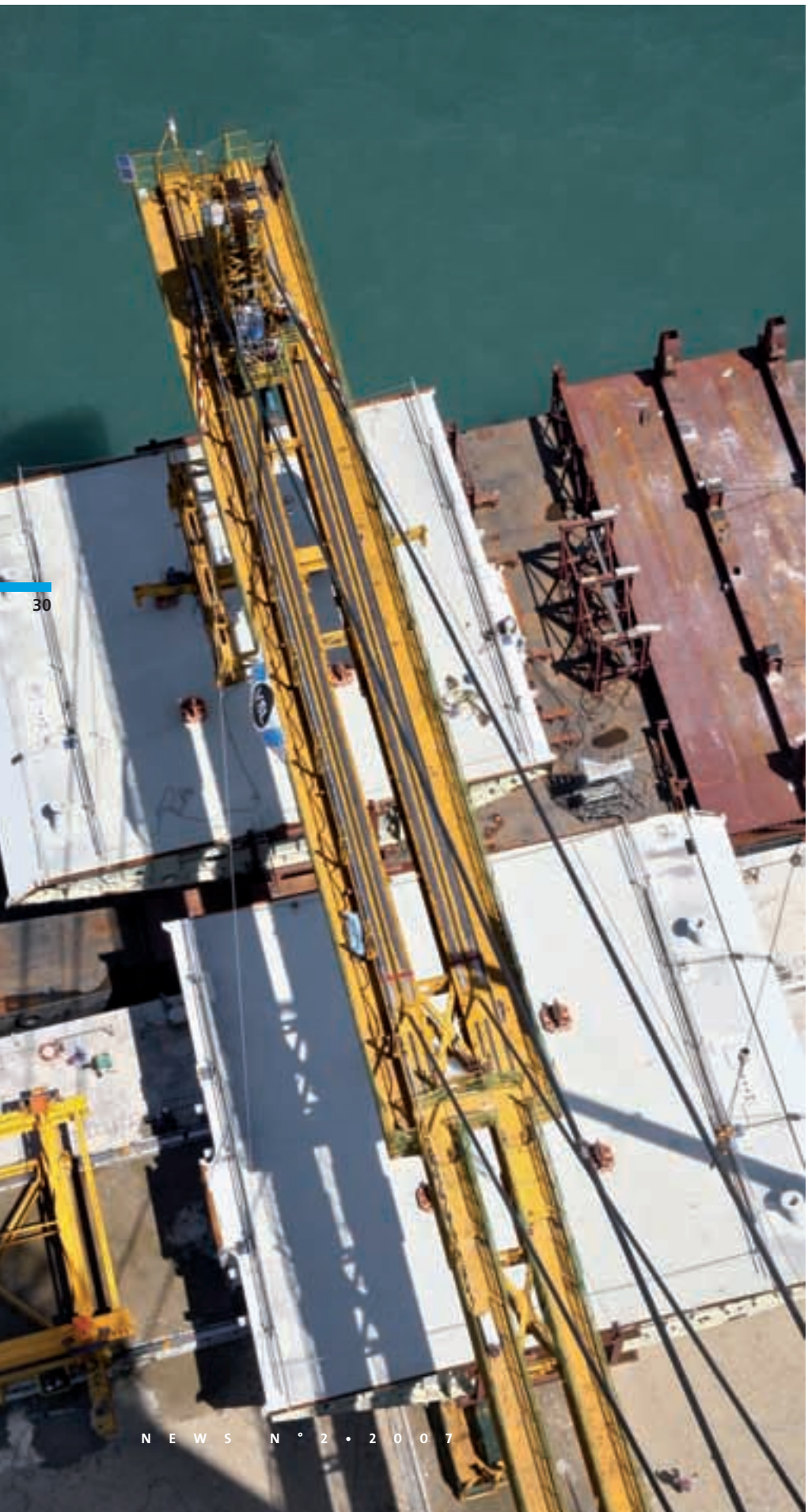
Stonecutters lifting

Hong Kong hoist

VSL Hong Kong has recently completed works on Stonecutters Bridge to erect the steel decks of what will be one of the longest cable stayed bridges in the world. High competencies, innovative heavy lifting solutions and flexibility were necessary.

The Stonecutters Deck Erection contract

The Alliance with the Maeda–Hitachi–Yokogawa–Hsin Chong JV was responsible for the erection of the steel back spans as well as for providing the erection equipment for the main span. The back spans, weighing 4000t each, create the installation platform for the erection of the 1018m long steel deck spanning over Hong Kong's Rambler Channel at the access to the container terminals. The Alliance model applied to this contract due to the necessary flexibility for both VSL and the Joint Venture to tackle the technical challenges of what proved to be a very complex operation at the interface of the three critical project areas – the concrete deck, the concrete towers and the steel deck. The full integration of the project teams allowed the development of an optimized temporary works scheme utilizing the partially completed permanent works wherever possible to support the temporary works in order to minimize the steel quantities.



1 Off-load the back span and slide into assembly position

Segments weighing between 120t and 300t have to be off-loaded at a specially constructed jetty. A 54m long cantilevering unloading frame is connected to the tower shaft with a hinged connection and supported by two pairs of stay cables. A SLU-330 strand jack is mounted on a sledge which slides along the beam driven by a long stroke hydraulic jack. The 14 segments are placed on specially designed carts which slide first perpendicular and then parallel to the bridge axis in order to manoeuvre them around the tower.

2 Define deck lifting sequence

Each deck has to be first lifted by 70m and subsequently slid by 6m towards the tower and 2m towards the concrete back span in order to overcome the geometric constraints due to the sloping tower face and the falsework under the concrete back span. The cross girders connecting the two carriageways can only be erected after completion of the main lift.

3 ***Carry out temporary works for the erection of the steel back spans***

The lifting system comprises of two cable stayed brackets attached to the main bridge tower and a cantilevering lifting frame resting on the completed concrete back span. The tower brackets are formed by 28m long twin steel box girders supported by a corbel at the tower shaft and two planes of stay cables. The stay cables have to be gradually stressed during the load build-up in order to control the deflections. The lifting strand bundles are anchored in horizontal beams pre-stressed to the steel deck which also provide the sliding surface for the longitudinal 2m deck movement. The rear lifting frame consists of a large cross beam sliding along a pair of cantilever beams. All strand jacks are mounted on sledges which can be moved 6m transversally by horizontal SLU-70 jacks.

4 ***Erect the tower brackets***

The tower brackets are erected in free cantilever mode by a 400t crawler crane. A fixed connection is created against the tower shaft to support the partially erected bracket prior to installing the first stay cable. A travelling working platform provides access to the splices and stay cable anchorages. Splices are formed by a combination of shear pins and CT bars allowing rapid splicing at height.

5 ***Erect the deck lifting frame***

The upper cross beam is assembled element by element by 400t crawler crane from the North side and slid across the completed concrete back span by horizontally mounted SLU strand jacks. Once fully assembled it is lifted by a combination of lifting towers and SLU strand jacks and the cantilever beams are threaded underneath by crane.

6 ***Use VSL jacks to lift at 10m/hour for two days***

The main heavy lift utilizes 16 SLU-330 strand jacks and 4 SLU-220 for the vertical movement combined with 6 SLU-70 and 12 high capacity long stroke jacks for the horizontal movements. A lifting speed of more than 10m/h ensures that sufficient time is available for the required horizontal movements and related activities during the two day lifting operation.

7 ***Consider typhoons***

The deck is guided during the lift through a system of guide rollers against the tower and the backspan falsework. To allow tying off the decks over night or in storm wind conditions, three emergency restraint positions are provided where the decks can be rigidly connected to the back span falsework and clamped to the tower shaft. Full typhoon restraint is only provided in final position.

8 ***Monitor with BRAVO***

The simultaneous operation of the 8 lifting points with a total of 20 strand jacks required the use of the BRAVO lift control system to ensure synchronized movement of the two carriageways. The system monitors the level differences between the lifting points as well as the lifting pressures. All lifting operations are controlled from a central command unit. The build-up of the lifting load required a well engineered adjustment sequence between the various load bearing components of the tower bracket and in the back span falsework.

9 ***Lift the cross girders***

The cross girders are lifted one-by-one by a pair of SLU-70 strand jacks supported by a lifting beam. Once in position the cross girders are suspended by PT bars and the strand jacks are transferred to the next location.

10 ***Erect the main span segments***

Four diamond shaped erection gantries fitted with high capacity diesel winches are used to lift the main span segments. They are pre-assembled on the back span steel deck before the heavy lift and lifted together with the decks. The two gantries of each cantilever operate in tandem to lift the deck segments weighing 600t each.

11 ***Load transfer***

The heavy lift system is designed to keep the decks suspended during several months while the cross girders are welded and the permanent stay cables are installed. Critical elements such as the deck connections and the strand anchorages have been detailed for improved fatigue behaviour.
The final load transfer is achieved by stressing the permanent stay cables and subsequent de-tensioning of the lifting strand bundles.

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