VSL – A WORLDWIDE NETWORK
From concept to site works, the VSL Network of locally operating units adds value throughout all stages of a project by providing fully-customised solutions, developed and implemented by highly-trained and experienced staff working in close partnership with clients. Customers have access to a local partner, while benefiting from global resources, know-how and expertise as well as VSL's continuing development of specialist construction techniques.

VSL – A COMMITMENT TO QUALITY, SAFETY AND SUSTAINABLE DEVELOPMENT
VSL pursues a strong quality, safety and sustainable development policy in keeping with its leading position as a specialist contractor. Proactive management systems have been established to address local needs while ensuring a high common standard throughout the company network.

VSL recognises that its employees are the key to competitiveness, efficiency and safe working practices. The company is committed to “Safety First” and strives for “Zero Accident” by motivating and empowering its employees to act responsibly in order to achieve these goals.

VSL – A SPECIALIST STAY CABLE CONTRACTOR
As leader in stay cable technology, VSL offers the solutions to tackle today’s challenges in cable-stayed construction and develops the next-generation systems in close collaboration with its clients. The recent boom in cable-stayed bridges with considerably increased spans and cable lengths calls for faster erection cycles and increases the dynamic demands on the stay cables. VSL’s lightweight erection equipment, compact strand bundle solutions and its highly-efficient and reliable damping systems lead the way in meeting today’s needs.

Its vast experience led VSL to launch the SSI 2000 system, which has been installed very successfully on more than 100 projects in recent years. VSL’s latest developments extend the SSI 2000 range to provide even greater flexibility for a multitude of applications, while maintaining the system’s proven outstanding performance. VSL’s portfolio is now well over 150 cable-stayed bridges.
New VSL developments in stay cable technology

SSI Saddle, a patented design facilitating simplified pylon layouts resulting in enhanced bridge aesthetics and increased structural efficiency

SSI 2000-C, a compact stay cable system with reduced cable diameter and therefore reduced wind drag

SSI 2000-D, a stay cable protected against corrosion by dehumidification techniques - a patented solution offering the smallest cable diameters available in strand technology and minimising wind drag while fully maintaining the advantages of strand-by-strand replacement

A choice of two damping systems to control cable vibrations efficiently, adapted to the characteristics of the structure

Modern engineering to stringent standards

Designers, owners and authorities are demanding:
- Increased long-term performance of stay cables, tensile members and anchorages; leak-tightness of the anchorage assembly; easy inspection and maintenance; the capability to replace cables with minimal interruption to bridge traffic; and reliable control of cable vibrations
- Minimal wind drag for long spans
- Outstanding static and fatigue behaviour, validated by performance testing
- Incorporation of damping systems at the time of installation or as part of dynamic retrofitting
- Improved aesthetics by using compact anchorages, saddles and coloured cables

Main contractors seek:
- Simple interfaces between deck erection and stay cable installation with a reduced number of activities on the critical path
- Lightweight installation equipment, facilitating a flexible erection schedule that separates deck and pylon construction from the stay cable erection works and minimises the crane time required

Owners benefit from:
- Enhanced durability
- Substantial savings on maintenance

The VSL SSI 2000 Stay Cable System is designed to meet the requirements and applicable specifications issued by fib (International Federation for Structural Concrete), PTI (Post-Tensioning Institute) and CIP (Commission Interministérielle de la Précontrainte).
The SSI 2000 Stay Cable System is based on VSL’s proven strand technologies.

**Compact anchorage**
Fully prefabricated including its corrosion protection in controlled factory conditions.

**Anchorage protection cap with flexible gel filler**
Strands encapsulated by a polymerised and bonded filler, achieving reliable corrosion protection while allowing access for inspection if necessary.

**High fatigue resistance**
Demonstrated in fatigue tests in accordance with *fb* and PTI requirements under combined tensile and bending action.

**Replaceable strand system in a durable stay pipe**
Sheathed, greased or waxed strands with optional galvanization, protected in an HDPE pipe with proven ageing performance. Each strand can be individually monitored, inspected and replaced.

**Individual encapsulation and deviation**
Each strand is individually protected with a multi-layer barrier system inside a leak-tight anchorage assembly and is separately guided to filter bending stresses at the anchorage entrance.

**Several complementary barriers**
For complete water tightness of the anchorage.

The SSI 2000 wedge anchorages and its tensile members as well as its protective system meet the most stringent requirements for durability, tensile capacity and fatigue performance. Its strand-by-strand technology ensures maximum flexibility and full capability for replacement.

**High fatigue performance**
The anchorage assembly is designed to control the deviation of individual strands and to filter cable vibrations outside the wedge anchorage zone. Its outstanding fatigue performance has been demonstrated in fatigue tests as specified in the latest recommendations by PTI and *fb* with imposed angular deviation of the anchorage from the cable axis. A tension ring or a guide deviator can be used to bundle the strands at the exit of the guide pipe.

**Durability and multi-barrier protection**
All SSI 2000 stay cables are engineered for a design life of 100 years in the most aggressive environments.
The unique feature of individual encapsulation of each strand within the anchorage assembly eliminates the risk of corrosion migration between strands.
The multi-barrier protection system is achieved in the free length by individually sheathed, greased or waxed strands with optional galvanization within the protective outer stay pipe. The protection is maintained in the anchorage assembly by a flexible gel filler injection, which has passed the stringent leak-tightness tests specified by PTI and *fb*.

**Cable installation with lightweight equipment and minimum impact on other erection activities**
The compact nature of the anchorages and the strand-by-strand installation with lightweight equipment frees tower crane time and does not require any heavy deck equipment. Therefore, the stay installation does not impair the key activities in a typical deck and pylon construction cycle.
Cable replacement strand by strand with minimum traffic disruption

Strands can be individually monitored, inspected and replaced: entire cables can be replaced strand by strand. The use of lightweight equipment minimises the impact on vehicular traffic and cable replacement can be achieved under single lane closures.

VSL Dampers

The stay cable can be designed with two types of dampers, the VSL Friction damper or the VSL Gensui damper, or provision can be made for later installation.

Anti-vandalism protection

Designed to protect the stay cable above deck level and to accommodate an optional damping system.

Free tension ring

Located inside the stay pipe. Can be replaced by a guide deviator, depending on the geometry at the exit of the guide pipe.

Anti-vandalism protection

External helical ribs tested in wind tunnel for efficient control of rain-wind induced vibrations. Two options for even lower wind drag – SSI 2000-C and SSI 2000-D with reduced stay pipe diameters.

Three systems are available to meet project-specific aerodynamic requirements.

The standard SSI 2000 system with an optimised stay pipe to control rain-wind induced vibration and minimise wind drag.

SSI 2000-C: the VSL Compact System for long cables

Reduced stay pipe diameters result in lower wind drag on the stay cable and hence a reduction in wind loads on the structure. This can be an important parameter in the design of long-span bridges. The SSI 2000-C compact stay cable range offers significantly reduced stay pipe diameters for the same permissible cable load. While this is the system of choice for exceptionally long cables, special tools are required for its installation.

SSI 2000-D: the VSL Dehumidified System for even lower wind drag

The system maintains all the proven features of the standard anchorage system, while reducing further the cross section of the ducted strand bundle by eliminating the sheathing of the strands and providing equivalent corrosion protection through permanent dehumidification of the cable. The result is the most compact parallel strand stay cable on the market – a system with fully replaceable individual strands and unrivalled low wind drag.

Comparison of equivalent drag diameter of different types of stays

Equivalent Drag Diameter = O.D. Stay Pipe x Drag Coefficient Cd

Cd = 0.6 for SSI 2000 has been determined in wind tunnel testing.

Cd = 0.8 for PWS is based on typical project specification

* PWS = typical parallel wire system

SSS Saddle with fully replaceable strands

For extradosed bridges and cable-stayed bridges with compact pylon arrangements, VSL offers a patented saddle solution compatible with the SSI 2000 system. The compact saddle design allows for strand-by-strand installation and replacement and achieves a safe and reliable anchorage for unbalanced cable loads. Extensive fatigue testing has been carried out in accordance with *fib* requirements to demonstrate that there is equivalent performance between saddle and standard anchorages.
VSL SSI 2000 MAIN DIMENSIONS

STANDARD ARRANGEMENT WITH TENSION RING

ALTERNATIVE ARRANGEMENT WITH GUIDE DEVIATOR

<table>
<thead>
<tr>
<th>CABLE UNIT</th>
<th>NUMBER OF STRANDS</th>
<th>BREAKING LOAD AT 100% GUTS kN</th>
<th>AMOVABLE LOAD AT 50% GUTS kN</th>
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<th>STAY PIPE SSI 2000-D</th>
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1. Based on strand specification as per EN 10138 (150mm2, 1860MPa); reduction required for ASTM A416 or BS 5896; GUTS = Guaranteed Ultimate Tensile Strength of strand
2. Recommended max. service stress for stay cables as per fib bulletin No. 30 and CP
3. Recommended max. service stress for extradosed cables as per CP
4. Galvanized and sheathed strand with a minimum sheathing thickness of 1.5mm
**Required clearances**

In case of facing adjustable anchorages, it is recommended to provide two times the minimum clearance. If reduced clearances are required, please contact VSL.

**Optional items**

- **Optional anchorage cap**
  - for adjustable anchorages in severe environments class C5-M and -I as per ISO 12944

- **Optional anti-vandalism pipe**
  - for future provision of damper

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**Adjustable anchorage**

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**Required jack clearances**

In case of facing adjustable anchorages, it is recommended to provide two times the minimum clearance. If reduced clearances are required, please contact VSL.

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**STANDARD ARRANGEMENT**

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**OPTIONAL ITEMS**

- **Adjustable anchorage**
- **Tension ring**
- **Square bearing plate based on concrete strength of 45MPa cube (36MPa cylinder); dimensions can be adjusted for other concrete strength or steel structures**
- **Can be reduced if required; please contact VSL**
- **Larger units available on request**
- **Optional details**
- **Dimensions available on request**
- **SLS Level**
- **Fixed or adjustable anchorages are interchangeable between pylon and deck, see dimensions L1 and L2**

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**Adjustable anchorage**

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<th>ØD2/mm</th>
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DURABLE DESIGN BACKED UP BY THOROUGH DESIGN

Durability and fatigue resistance are of utmost importance for stay cables, together with accessibility of components and monitoring of the structure.

Designed to last
VSL Stay Cables have a design life of 100 years in the most aggressive environments, as defined by the C4 and C5 categories of the ISO 12944 standard. All elements are fully replaceable without requiring modifications to the structure. All the materials used have been carefully selected and all components detailed to meet the highest durability criteria. The SSI 2000 performance even exceeds the stringent durability requirements provided in the relevant recommendations from PTI and CIP. All non-accessible components are supplied with a factory-applied protection system ensuring a 100 year design life without maintenance. The accessible and replaceable elements are designed for a 25 year maintenance interval. The main tensile element of the cable, consisting of VSL-specified strands, is designed with a multi-layer protection system to match the performance of the anchorages. VSL provides a detailed maintenance schedule for each project and can assist clients in the implementation.

Leak-tightness testing for anchorages
The anchorage is the most vulnerable part of a modern stay cable in terms of durability. In order to achieve a continuously protected transition from the free length of the cable into the anchorage zone, it is important to prevent water ingress through the component interfaces, particularly at the lower deck anchorage.
VSL has equipped its anchorages with a redundant multi-layer sealing system, which has passed the leak-tightness tests as defined by PTI and fibré.

Accelerated ageing tests for coloured stay pipes
Correct material selection and manufacturing control is important to avoid variations in the characteristics of the HDPE components used for the outer protection layers of the free length. Ageing effects, UV radiation and/or pollution can deteriorate the condition of the stay pipe over time. The evolution of the mechanical and colorimetric properties is verified by performing accelerated ageing tests.

With a focus on durability throughout all phases, VSL has developed specialist methods and procedures to ensure that the required installation quality is achieved and that any damage that might occur to the components during transportation, handling or installation is detected and rectified prior to project delivery. The modular nature of the system allows for simple replacement of any damaged parts without critical delay to the installation schedule.

Wind tunnel testing

Tensile test on an HDPE stay pipe sample after accelerated ageing

Fatigue test through 2 million cycles

Inspection of a 6-37 anchorage after a leak-tightness test. While being subjected to mechanical and environmental stresses, the anchorage is immersed in a dye solution with a pressure head of 3m.
ROUGH TESTING

Fatigue testing
The fatigue performance of the VSL Stay cable System has been demonstrated in many fatigue tests in accordance with PTI and fib recommendations with stress ranges of 200MPa at 45% GUTS upper stress over two million cycles and a 10mrad deviation at the anchorages.

Proven technology for protecting the SSI 2000-D
With the SSI 2000-D system, VSL introduces proven dehumidification technology to stay cables, defining a new standard for the industry (see page 10). The D system maintains the highest standards of durability while eliminating the need for individual sheathing of the strands and hence allowing a significant reduction in cable diameters (see page 10).

Equivalent durability using an injected saddle with replaceable strands
The SSI Saddle is the first saddle in the market with injected but replaceable strands. The PE sheathing is removed from the strand at the saddle location. Each strand is individually guided through the saddle and bonded flexible gel filler, effectively preventing any oxygen or corrosive agents from reaching the strand. Full-scale fatigue tests have demonstrated that the saddle fulfils the same fatigue criteria as the standard anchorages and that no fretting corrosion occurs.

Durability requirements for stay cables
- The fib stay cable recommendations specify a design life of 100 years for stay systems installed in bridge structures and emphasise the need for adequate maintenance.
- The CIP stay cable recommendations propose a design life of 50 years for replaceable systems and 100 years for non-replaceable systems and require defined maintenance intervals.

Enhanced durability by systematically controlling vibrations
VSL offers two types of dampers for effective control of the cable vibration: the VSL Friction Damper and the VSL Gensui Damper. Both dampers can either be installed during construction or retrofitted on existing structures. The dampers are designed for maximum durability by minimising the number of moveable parts and selecting the most durable materials.

VSL Structural monitoring solutions
VSL also offers structural monitoring packages. Sensor solutions for permanent or temporary load and deformation measurements on cables can be combined with instrumentation of the structure. This allows collection of all the necessary data to optimise maintenance, validate design assumptions, diagnose mechanisms of deterioration and detect damage at an early stage.
THE VSL SSI 2000-D SYSTEM patent pending

The world’s most compact stay cable strand protected by dry air

Protection cap with inspection window
Not injected hence allowing permanent visual inspection of the anchorage’s condition without the need for dismantling.

Sensors
for permanent monitoring of corrosion-critical parameters
• temperature
• humidity
• air pressure

Standard guide pipe
internally protected by the dry air system

Reduced cost for any cable replacement
Non-sheathed strands

A compact bundle of unsheathed strands protected by dry air
With the SSI 2000-D system, VSL offers the most compact parallel strand stay cable in the market. The resulting wind drag is lower than that of parallel wire cables with equivalent capacity, while the system maintains all the typical SSI 2000 benefits when it comes to installation, inspection and replacement.

The galvanised, unsheathed strands are placed inside an air-tight enclosure, where any optional dampers can also be accommodated. A dehumidifier unit, typically placed inside the pylon, provides a constant supply of dry air at the pylon anchorages, while maintaining a permanent pressure differential between the inside and the outside of the cable. This prevents any ingress of moisture or other corrosive agents from the outside. All structural elements of the stay cable are
protected within this controlled environment where the humidity is maintained below the threshold that would trigger corrosion.

The applied pressure differential ensures that a leak in the system will only result in an increased air demand and will not jeopardise the protective mechanism.

Dry air — a reliable and proven solution
The concept of dehumidification systems to protect steel bridge decks and suspension cables was introduced in the 1970s and is today a well understood and highly reliable solution, applied to some of the most prestigious bridges around the world.

With the SSI 2000-D system, VSL has applied this proven technology to stay cables to offer a state-of-the-art corrosion protection solution.

Use of the latest dehumidification equipment keeps operational and maintenance costs extremely low. Running cost estimates can be provided on request.

Redundancy and equivalent corrosion protection
The principle of multi-barrier protection remains unchanged even though the SSI 2000-D does not make use of individually sheathed strands:
- the stay pipe provides an airtight enclosure, protecting the tensile element against environmental effects
- a protective environment of dry air around the strands prevents moisture and corrosive agents from reaching the strands
- continuous galvanisation of the bare strand provides a final barrier against corrosion in case of scheduled removal or accidental loss of the other two barriers.

Permanent monitoring of the corrosion protection
The integrity of the corrosion protection system can be monitored permanently through continuous measurement of the corrosion-critical parameters of temperature and humidity inside the cable together with the air pressure. In addition, the protective caps at the anchorages can be fitted with transparent windows allowing a simple visual inspection of the anchorage condition. This significantly reduces the time and cost involved in periodic inspections of the anchorage components.

Combining cable and deck protection
Where the SSI 2000-D is used with steel bridge decks or pylons with closed cross section, the dehumidification can protect both the stay cables and the structural steel elements by suitable sizing of the dehumidification units.

Iron Corrosion Rate at different Relative Humidities (%RH)

<table>
<thead>
<tr>
<th>Relative Humidity</th>
<th>Corrosion Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>40</td>
<td>90</td>
</tr>
<tr>
<td>60</td>
<td>120</td>
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</tbody>
</table>

The dry air combined protection
THE VSL SSI SADDLE

VSL has developed a new generation of stay cable saddles combining the advantages of injected saddles with full strand-by-strand installation and strand-by-strand replacement.

Saddles are the solution of choice for many bridges when it comes to compact and slender pylon designs or for extradosed structures. Replacing a pair of pylon anchorages with a single saddle simplifies the detailing and eliminates the need to anchor large splitting forces in the pylon.

The benefits of saddles are widely accepted but their general use had been prevented in the past by the issues of reduced fatigue performance compared to anchorage, the risk of fretting corrosion and the inability to replace single strands.

VSL responded to these challenges with the SSI Saddle. Individual guiding and encapsulation of the strands allows strand-by-strand installation, inspection and replacement while injecting the guide tubes with a special, polymerised and bonded flexible gel filler prevents any ingress of oxygen, hence eliminating the risk of fretting corrosion. The result is a saddle with fully replaceable strands that achieves the same fatigue performance as standard SSI 2000 Anchorages.

The V-effect; maximum friction using wedge action
The SSI Saddle is a steel box filled with Ductal® ultra-high-performance concrete and featuring V-shaped guide voids for each individual strand. This patented geometry provides an efficient wedge action, continuously gripping the strand by friction along the deviated length, while minimising fretting under cyclic loading. The entire saddle is detailed such that the deviation occurs entirely in the strand-to-Ductal® interface with no intermediate layers that could deteriorate over time.

Independently guided and replaceable strands
The saddle allows unrivalled single strand installation, inspection and replacement. Strands can be individually stressed and de-stressed. In the same way that larger anchorage units can have spare strand positions, the saddle can also incorporate additional guide voids to give the option for a future increase in cable capacity.

Seamless integration with the SSI System
The Saddle uses the same strand as the standard SSI 2000 System, with no additional treatment required. The removal of the tightly extruded PE-coating on the deviated length inside the saddle is performed on site.

Continuous multi-barrier corrosion protection
The PE-coating of the strands is removed inside the deviated length of the saddle to achieve strand-to-Ductal® contact. As with the other SSI components, multi-barrier protection has been incorporated:

- An outer casing consisting of a steel box and Ductal® gives protection against ingress of water and corrosive agents
- Injection of the guide voids with a polymerised, bonded, flexible gel filler gives a reliable seal against moisture and oxygen
- Galvanisation of the strand provides protection during the installation period prior to the injection

Transfer of high differential cable forces into the pylon
Unbalanced loading between bridge spans results in a need to transfer differential cable forces to the pylon, which is achieved by high friction in the V-shaped guide voids in the saddle. Consistent friction coefficients in excess of 0.4 are attained in tests.
Proven fatigue performance

VSL has carried out extensive fatigue testing with the SSI 2000 Saddle in accordance with fib recommendations, including a full scale test using a 6-55 unit.

Controlled filtering of angular deviations at the saddle exit

Stay cable anchorages and saddles can be subjected to significant angular deviations at their exits as a result of installation tolerances, vibrations and variations in cable forces. This could cause gradual deterioration of the protective layers of the strand or result in premature fatigue damage. The SSI Saddle avoids this by incorporating a well detailed exit where each strand is individually deviated with the same characteristics as in a standard anchorage, without introducing undesirable stress into the pylon surface.

Main dimensions (using VSL SSI 2000)

<table>
<thead>
<tr>
<th>CABLE UNIT</th>
<th>NUMBER OF STRANDS</th>
<th>BREAKING LOAD AT 100% GUTS</th>
<th>MAX. RADIAL BEARING STRESS AT 2.4m RADIUS</th>
<th>STAY PIPE CONNECTION</th>
<th>SADDLE BODY</th>
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<td></td>
<td></td>
<td>kN</td>
<td>MPa</td>
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</tbody>
</table>

Fatigue testing of the VSL Saddle
2,000,000 cycles successfully completed
The mechanisms of dynamic excitation of stay cables are complex and can only be partially addressed in the various general recommendations for cable-stayed structures. VSL applies various stability criteria to estimate the risks of unacceptable cable vibration in order to determine the structural and additional damping requirements. The VSL Stay cable system offers a modular approach for mitigating the risks of cable vibrations.

Helical ribs
The outer stay pipe is fabricated with double helical ribs, which have been optimised in wind tunnel tests for maximum efficiency and minimum drag against vibrations induced by rain and wind.

Two different types of dampers
VSL offers two damping solutions for stay cables: the VSL Friction Damper and the VSL Gensui Damper. Both are highly efficient as well as being extremely durable and require little maintenance. The outstanding long-term performance is based on minimising the number of movable parts, which reduces the wear and tear. This approach makes VSL Dampers significantly more robust than other damping systems.

The VSL Friction Damper is a highly efficient and durable damper for more critical applications, such as long cables or structures with an increased risk of vibration.

VSL Friction Damper – high performance for critical cases
High efficiency: Several comparative tests on full-scale cables fitted with dampers have demonstrated the exceptional efficiency of the VSL Friction Damper. The measured performance has repeatedly exceeded the specified requirements.

Outstanding durability: The friction damper achieves an excellent long-term performance by being designed to work only when needed. It comes into use once the displacement reaches a level that is considered critical for the cable’s performance. Once activated, the damper achieves its maximum damping effect immediately.

Aesthetic solution: The installation of damping systems on stay cables has to be carried out with minimum impact on the visual appearance of the structure. The addition of external damper supports is often undesirable and the compact nature of the friction damper allows it to be fully integrated into the anti-vandalism pipe of the SSI 2000 System.

Other benefits of the VSL Friction Damper:
• Easy access for simplified inspection and maintenance
• Tuning of the damping performance by adjustment of the friction force without the need to dismantle the damper
• Retrofitting on any existing stay cable (strand or parallel wire) on structures where unexpected cable vibrations have been observed
• All components can be replaced on site
• Damping characteristics independent of temperature variations or vibration frequencies

VSL provides expertise to assist owners and designers in analysing the risks of cable vibrations and proposes appropriate mitigation measures.
The VSL Gensui Damper is a simple and robust damper optimised for short to medium length stay cables with moderate damping requirements and for extradosed cables. Both dampers are incorporated into the SSI 2000 system as internal dampers, fully protected inside the anti-vandalism pipe. The dampers can either be installed together with the cable or retrofitted.

**High-damping rubber**
The VSL Gensui Damper is composed of several special rubber pads and the cable’s dynamic energy is dissipated by shear deformation. The damper pads are made of a high-damping rubber developed and manufactured by Sumitomo Rubber Group.

**Great simplicity**
The damper is modular, with the number of pads required depending on the dynamic characteristics of the cable. The simple and versatile system can be easily adapted to any cable size whether as a new installation or as part of a retrofitting solution.

**Excellent durability**
The high-damping rubber pads have a long design life and a high fatigue resistance. They require only minimal maintenance, which allows dampers to be installed even at the pylon where maintenance access is difficult to provide.

**Tailor-made performance**
The damper performance depends purely on the damping characteristics of the rubber pads and can be adjusted by varying the number and type of pads used. The damper performs at its best on short to medium length cables. Its performance can be further enhanced by increasing the distance between the damper and anchorage or by installing a second damper at the pylon. Its performance is independent of the vibration mode and is not particularly sensitive to temperature variations and frequency.

**Compact aesthetics**
The Gensui damper can be fully integrated into the SSI 2000 anti-vandalism pipe with minimum impact on the cable aesthetics. Solutions for retrofitting include simple neoprene boots or compact mounting frames in the case of external dampers.

**Provision of stabilising cross-ties**
While VSL recommends the use of dampers for efficient vibration control, the SSI 2000 System allows also for installation of cross-ties if requested. Cross-ties help to increase the critical wind speed for aeroelastic instability by increasing the natural frequency of the cable. They are however only efficient in the cable plane and their installation and maintenance can constitute a significant additional cost.

**Connection detail**
For subsequent installation of a VSL damping system, the flange welded at the end of the guide pipe and the increased diameter of the anti-vandalism pipe are designed to allow for later installation of a VSL damping system, should cable vibrations need to be rectified. While there is no damper installed, the cable is equipped with a guide deviator or a tension ring.

**Cable equipped with the VSL Friction Damper**
In the event of unexpected cable vibrations, a choice of VSL damping systems - Friction Damper or Gensui Damper - can be installed without modification to the cable assembly.

**Tried and tested**
VSL dampers have demonstrated their outstanding performance in a series of comparative tests on full-scale samples conducted by organisations such as Shanghai’s Tongji University, Hong Kong Highways Department and the Korea Expressway Corporation, as well as on sites. Low maintenance has been confirmed for dampers installed since the mid 1990’s.
STRAND BY STRAND METHOD FOR INSTALLATION OR REPLACEMENT OF CABLES

The strand-by-strand installation methods developed by VSL offer maximum flexibility and can be adapted to specific needs.

All SSI 2000 cables are installed strand by strand using extremely compact equipment and can be inspected and replaced if necessary in the same manner.

An optimised solution to streamline complex bridge erection cycles
The equipment can be handled manually at the anchorage location inside or outside the pylons, whatever their shapes. The strand reels are light and compact compared with prefabricated cables and can be easily lifted, transported and handled. This renders the cable installation largely independent of the logistics of deck and pylon construction. As a significant part of the installation can be carried out off the critical path, tower crane usage is reduced, resulting in cost and programme savings.

The preferred option for cable inspection or replacement under traffic
The compact equipment allows for inspection and replacement of the entire stay cable with minimum impact on the bridge traffic, as a single lane closure is typically sufficient to provide a safe working space. In addition, the strand-by-strand replacement makes the loss of cable force during the works negligible, allowing unrestricted vehicle movements.

Replacement of a 300m cable
In May 2002, VSL replaced a 298m-long cable on the Ching Chau Min Jiang Bridge, which had been damaged when a barge crane collided with the bridge during a typhoon. Site conditions did not allow access for a mobile crane and so all the equipment had to be handled manually. The cable was replaced strand by strand with VSL’s lightweight equipment. This operation demonstrated that even long cables can be replaced with minimum disruption to bridge operations.
The main advantages of the VSL strand-by-strand system installation

- Absolute flexibility to adjust the cable length during construction to address variations in the bridge geometry or late changes to the deck erection methodology
- No requirement for provision of off-site prefabrication facilities
- No significant additional construction loads on the partially-completed structure as light and compact equipment is used.
- Fast erection cycle with partial and staged installation of cables for light composite deck assembly
- No additional requirement on the project's critical path for the use of tower and deck cranes during cable erection, thus reducing the risk of delay
- Lightweight shop prefabricated anchorages can be pre-installed during deck and pylon construction
- Easy second stage stressing with monostrand jacks, providing greater flexibility to designers and contractors by avoiding the relocation of heavy stressing and access equipment
- Improved site safety due to reduced component weights and simplified access arrangements
- Full strand-by-strand replacement
- Fully compatible with the VSL Saddle

Specialist equipment and procedures

The continuous stay pipe is welded on site from elements of standard length. The strands are delivered to site in compact coils and are installed one by one using a small winch system. They are individually stressed by a lightweight monostrand jack from either the deck or the pylon end. The VSL AMS system provides fully automatic control, recording and data management for the stressing operation on site. Specialist procedures are implemented to ensure an equal final force in all strands and safe anchoring of low cable forces at intermediate stressing stages. The system provides absolute freedom to engineers to specify stressing either to a cable force or cable length, depending on the characteristics of the structure. It is even possible to change the cable length during construction if required. Final tuning of the completed cables can be carried out either by monostrand jack or by compact multistrand jacks. A ring nut is provided on the stressing anchorage to allow a reduction in the cable force if necessary without re-gripping the strand.

A matching saddle

The SSI Saddle has been specifically designed to allow application of the same strand-by-strand principles for installation, inspection and replacement of the stay cables. All strands are individually encapsulated and guided within the saddle assembly, which combines the advantages of a saddle solution with the benefits of a strand system.
Puente de la Unidad Bridge, Mexico (2003)
In a 50/50 JV, VSL provided project management, complete technical and method support and part of the production management. VSL Mexico also supplied and installed the post-tensioning, and the SSI 2000 Stay Cable System.

Badajoz Bridge, Spain (1994)
Cables equipped with friction dampers.

Ponte Europa Bridge, Portugal (2002)
185m main span length - 91 strand cables.
Batam Tonton Bridge, Indonesia (1997)
Package: design, supply and installation of stay cables, deck form-travellers and pylon formwork. Construction engineering for the superstructure construction.

Lazarevskyi bridge, Saint Petersburg, Russia (2008)
Stays ranging from 6-55 to 6-73

Taipei Ring road Bridge, Taiwan (2009)
13 pairs of stays on each side of the pylon

Papendorpse Bridge, Netherlands (2002)
120 strand cables

Sungai Johor Bridge, Malaysia (2008)
85 strand cables with length up to 275m
Sucharskiego Bridge, Poland (2001)
Supply and installation of stay cables, with VSL Friction Dampers

Centenario Bridge, Spain (1991)
552m bridge length, with 264m for the main span
Yichong Yiling Bridge, China (2001)
Supply of stay cable system, erection equipment, stay cable engineering, site management and site supervision

Wadi Abdoun Bridge, Jordan (2006)
Curved deck with inclined pylon
Neva 1 Bridge, Russia (2002)
All cables equipped with VSL Friction Dampers

Koshiki Daimyojin Bridge, Japan (1993)
Technical consultation and supply of the prefabricated stay cables

Fred Hartmann Bridge, USA (1995)
Supply of stay cables and supervision at installation
Sunshine Skyway Bridge, USA (1986)  
Supply of post-tensioning and stay cables. Cables anchored to the pylon by saddles and equipped with hydraulic dampers.

Neva 2 Bridge, Russia (2007)  
Supply and installation of stay cables with VSL Friction Dampers.

Merida Arch Bridge, Spain (1991)  
Supply and installation of the stay cables.
Pastaza Bridge, Ecuador (2005)
Supply and installation of the stay cables

Zikova Footbridge, Czech Republic (2007)
Installation of stays and post-tensioning

Rades-la-Goulette Bridge, Tunisia (2007)
Extensive equipment and services

Keppel Bay Bridge, Singapore (2006)
Supply and operation of casting cells, erection of bridge deck, pylon construction, supply and installation of stay cables

Supply and installation of bearings and stay cables

© Jose Cartellone Construct
VSL Stay Cable System

Weonam Bridge, South Korea (2008)
VSL pylon saddles designed to allow cable replacement

Peddar Bridge, Columbia (2002)
VSL Saddle and monitoring services

Liz Bridge, Portugal (2004)
38 stay cables installed in one week

Safi Bridge, Singapore (1995)
An inclined pylon is stabilised by back-stay cables

VSL ASI 2000 25 Stay Cable System
VSL SERVICES FOR STAY CABLE BRIDGES

MONITORING

Relevant information is sent straight back to the user’s desk. The system works with any IT and measurement solution.

DeMon system allows wireless connection from client’s office to any type of sensors on site through internet and wireless devices.

LAUNCHING GANTRIES

HEAVY LIFTING

DAMPERS

Shenzhen Western Corridor - Hong Kong

Stonemcutters Bridge - Hong Kong

VSL dampers
FORM TRAVELLERS & LIFTING FRAMES

REPAIR

SADDLE

BEARINGS

West Tsing Yi - Hong Kong

Figueira Da Foz Bridge repair - Portugal

VSL SSI Saddle for a compact and slender pylon design

Preloaded seismic bearing

Ground anchors

VSoL® walls

D-walls & Piles

Ground improvement

Bridges

Buildings

Slab on grade

Containment structures

Special structures

Heavy lifting

Formwork & Equipment

Structural diagnostics & Monitoring

Repair & Strengthening

Protection & Preservation

Post-tensioning strand systems

Bars & post-tensioning bar systems

Stay cable systems

Damping systems (stays & buildings)

Ductal® UHP concrete

Bearings & Joints

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