VSL AND GROUND ANCHORS

VSL - geotechnical expertise
VSL has been designing, fabricating and installing post-tensioned ground anchors since 1957, and using bar anchors since the early 1970s. VSL’s experience represents an immense wealth of engineering and practical know-how. Today, increased emphasis on safety, durability, on the environment and sustainability means that engineers are faced with the challenge of complying with more stringent requirements while meeting the growing demands of urban congestion and other site conditions. VSL engineers are trained and experienced in dealing with these issues and can assist clients in achieving their project requirements and goals.

VSL Ground anchor systems are in use around the world, securing famous structures, large dams and retaining walls, holding down underpasses and underground structures, stabilising wind turbine towers and preventing landslides.

CONTRIBUTING TO SUSTAINABLE SOLUTIONS

Saving material
Ground anchors are an efficient way of mobilising dead loads deep in the ground to resist forces that would otherwise require large gravity foundations. Uses include resisting the forces induced by wind, water pressure or tension forces such as those of suspension cables for bridges and buildings, cable cars and the like.

Durability
VSL Ground anchors comply with the most stringent international specifications with regards to corrosion protection.

Removability
Temporary VSL Ground anchors can be made to be removable in order to mitigate the impact on adjacent ground when they are no longer required.

VSL – guided by a strong QSE culture
VSL’s leading position is based on a rigorous and committed quality culture. VSL’s QSE (Quality, Safety, Environment) policy represents a major focus for every service provided. Local teams ensure co-ordination of actions, encourage sharing of experience and promote best practice, with the aim of continuously improving performance. In VSL’s culture, employees are vitally important to the competitiveness and prosperity of the company. VSL is committed to maintaining the highest levels of client satisfaction and personnel safety.

Changing the way we do business
For VSL, sustainable development (SD) means striking a balance in its development model between the economic profitability of its businesses and their social and environmental impact. That commitment is formalised into the VSL SD program which focuses on safety, use of fewer scarce materials and less energy and production of less pollution and waste.
VSL ANCHORS FOR ALL APPLICATIONS

Ground anchors, nails, rock bolts and micropiles
VSL’s Anchoring systems can be divided into two main categories – strand and bar anchors. Their characteristics depend on whether they are tensioned or not, used for rock or soil and whether they are for temporary or permanent use. VSL offers a full range of ground anchor solutions, from basic unstressed temporary bar nails to the most sophisticated post-tensioned electrically isolated strand anchors that can be monitored.

Temporary or permanent
The type of VSL Ground anchor to be used depends on the application, the design, the corrosiveness of the environment, the presence of any stray electrical currents and on the permanent corrosion protection system required. Permanent ground anchors need comprehensive corrosion protection measures, while temporary anchors require limited or no protection.

Compliant with international standards
VSL’s Anchoring systems comply with current national and international standards, including the prevailing European Norm, ASTM, Australian and British Standards and SIA.

<table>
<thead>
<tr>
<th>VSL GROUND ANCHOR SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>low capacity</td>
</tr>
<tr>
<td>&lt; 10 m</td>
</tr>
<tr>
<td>local ground instability</td>
</tr>
<tr>
<td>act more as “reinforcement”</td>
</tr>
<tr>
<td>unstressed rock bolts</td>
</tr>
<tr>
<td>soil nails, micropiles</td>
</tr>
</tbody>
</table>

The general classification of VSL Ground anchors depends on their capacity, length and application.
VSL TEMPORARY STRAND ANCHORS

Economical solution with a two-year service life
VSL Temporary strand anchors have a limited design service life – generally speaking less than two years. Consequently, they have limited corrosion protection. Selection of the tendon and anchorage is made in accordance with VSL data sheets and the engineer’s specifications.

Removable
VSL Temporary anchors can be made to be removable. Removable anchors are required where it is undesirable or unacceptable to leave them in the ground, particularly in urban areas where they often extend into adjacent properties. The methods used by VSL for extracting the free and even the bond lengths are based on specially-designed mechanisms. VSL has a long tradition in these special techniques, with thousands of anchors successfully installed and subsequently removed.

Post-grouting
Ultimate external anchor resistance can be considerably improved by the use of post-grouting around the bond length of the anchor. VSL can provide the following post-grouting systems:
- simple post-grouting;
- repeated post-grouting with a return line;
- repeated and targeted post-grouting using double packers.
For additional details and other features, see VSL’s technical data on pages 15-18. For all anchorages, please consult the VSL data sheets.

Applications
• Sheet pile walls, with load transfer by steel beams and wedge plates.
• Pile walls, diaphragm walls and bored pile walls without an encased external trumpet. Placing the anchor requires drilling through the structure.
• Pile walls – the same application as above, but with a previously-encased trumpet.

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How it works

In the bond length, the strands are uncoated steel. Spacers hold them apart one from another in order to obtain an optimal load transfer. External spacers may also be used if required to centre the anchor in the drill hole.

The strands in the free length are normally greased and individually sheathed. Alternatively, strands can be uncoated and assembled in a smooth sleeve, which is sealed at its lower end to prevent grout penetration.
VSL PERMANENT STRAND ANCHORS

Permanent with corrosion protection
Permanent ground anchors fulfil their function throughout the working life of the structure and require comprehensive corrosion protection. They are equipped with watertight, thick-walled polyethylene (PE) encapsulation, which acts as a protective multi-barrier against corrosion. Today’s state-of-the-art permanent anchors are electrically isolated, a technology that has been fully mastered by VSL.

Double corrosion protection (DCP) anchors
Alternatively, VSL Ground anchors can be provided with two protective barriers against corrosion attacks. These DCP anchors, which comply with EN 1537, feature two concentric corrugated ducts in the bond length, where they are pre-grouted prior to installation.

Monitoring
Permanent anchors can be inspected throughout their service life. In addition to visual checks of the anchorage, anchor loads can be measured by lift-off procedures using either a special load cell in combination with a threaded anchor head or by carrying out a pull-out test on the protruding strand bundle. Performing this testing in line with a defined inspection schedule provides a valuable check of the behaviour of the anchors.

Anchorages for all needs
VSL Anchorages are available for use as:
- standard production anchors, where the load is not normally modified after stressing;
- adjustable anchors used for regulating the load;
- control anchors, which allow occasional monitoring with a removable load cell;
- surveillance anchors, used for checking the anchor load with a permanently-installed load cell.

Special lift-off jacks
Where anchors have neither threaded heads nor protruding strands, VSL can provide special jacks with up to 1,670kN capacity that allow the anchor head to be lifted off.
**How it works**

The anchor is built with a corrugated duct in the bond length (two for DCP anchors) and with a smooth sleeve in the free length. Spacers and centralisers ensure that the anchor is centred both in the encapsulation and in the bore hole in order to achieve the required cover. The anchoring capacity can be improved with the same post-grouting system as for temporary anchors. The choice of the tendon is made in accordance with VSL's technical data on pages 15-18 and the engineer’s specification.

For anchorages, refer to the appropriate VSL data sheets.

**Electrically isolated anchors**

Standards such as EN 1537 define different types of corrosion protection systems, including the electrical isolation method. The advantage of this technology is that it allows the integrity of the corrosion protection encapsulation to be checked not only during installation but also throughout the anchor’s service life, by measuring electrical resistance.
VSL BAR ANCHORS

A full range of well proven products
VSL has been marketing bars for the construction industry since the early 1970s and offers an extensive range of hot-rolled and cold-rolled products. VSL's product line complies with international standards including prevailing European standards, ASTM, Australian and British Standards and SIA. Diameters range from 16mm to 75mm, depending on the steel grade, allowing a fine-tuning of the selection to suit the required loads.

Bars for mining and tunnelling
VSL's B450 and S600 bars are used in mining applications while B500 and S670 are used in tunnelling. Different anchoring methods are available and include fully cement and resin grouted bonded anchors, as well as expansion shell anchors. The bar ends can be provided with saw tip, chisel tip or point tip end finishes.

Bars for prestressed anchor applications
VSL Post-tensioned anchors consist of a high-strength Y950/1050 grade steel tendon, which is fitted with a stressing anchorage at one end and a means of permitting force transfer to the grout and rock or soil at the other end. The rock anchor tendon is installed into a prepared hole of suitable length and diameter, then anchored by grouting to the rock and post-tensioned to a specified load. Anchors are usually shop-fabricated and fitted with the required corrosion protection and delivered to sites as either double corrosion protection anchors or single corrosion protection anchors.

Soil nails, rock bolts, micropiles
The VSL Bar system, which is available in B500 and S670 grades and diameters up to 75mm, is used for soil nails, rock bolts, micropiles and similar applications. The corrosion protection depends on the required service life, the consequences of failure of a group of anchors and on prevailing environmental conditions. VSL offers a full range of protection options to meet the project requirements and that comply with international regulations. Generally, the corrosion protection is defined by the engineer in charge of the project. It can range from no special measures for bars for short-term use to pre-grouted encapsulated bars with a high level of corrosion protection.

The installation and stressing of bar anchors is fast and economical. They are generally used for securing slopes and excavations in rock and soil.
Coarse threaded bars offer important advantages:
- very user-friendly as components remain threadable even under extreme handling conditions;
- easily cut or coupled to adapt to changing site environments;
- good bonding characteristics;
- high ductility.
System components are available for all applications, including domed or flat bearing plates, couplers and nuts for uplift micropiles with alternating loading conditions.
VSL’S SERVICES: TAILORED TO MEET SIT

VSL provides a comprehensive range of services that are tailored to the customer’s requirements.

PREFABRICATION AND DELIVERY

VSL Anchors are typically assembled in a workshop before being transported to site. They can also be fabricated close to the location where they are to be installed. To allow easy installation into the borehole, strand anchors are rolled into a special anchor cradle or moved on wheels.

DRILLING AND INSTALLATION

Installation requires specialist know-how and must follow strict site procedures. Clients can rely on VSL’s expertise to provide these services.

ANCHOR TESTING

Most codes specify tests to confirm the suitability of a particular anchor design in given ground conditions. Such tests are carried out as soon as the grout in the bond length has achieved sufficient strength. VSL has the knowledge, equipment and trained personnel to assist clients with consultancy, and to carry out the testing in accordance with the contract specifications.

- Pre-design and consultancy services to engineers and contractors;
- Drilling;
- Prefabrication and delivery to site;
- Assistance with installation, grouting and supervision;
- Execution of stressing operations including anchor and bar testing;
- Monitoring and maintenance;
- Detensioning and anchor removal;
- Optional rental of equipment such as jacks, pumps, mixers and torque wrenches.
Nails and bolts are normally subjected to testing. Pull-out tests and tension tests are used to determine the external anchor resistance and to demonstrate the bond capacity between the anchor and soil or rock.

Most structures that are secured with permanent anchors are monitored throughout their life. Such monitoring can be done either on a permanent or on a periodic basis. VSL can provide the full range of services including carrying out load monitoring and maintenance together with their reports. Further advice and services are also available to cover the re-stressing of tendons where necessary. Permanent surveillance requires specialised load cells mounted onto the anchor, providing a continuous measurement of the load on the tendons. The device can be connected to an overall online monitoring network.
A WIDE RANGE OF APPLICATIONS

Wind turbine tower, Åland Archipelago, Finland - 2007
Ground anchors have been used to stabilise the tower, avoiding the requirement for a gravity foundation.

Avalanche Tunnel, Switzerland - 2007
Anchors secure the bridge tunnel against the effect of avalanches.

BB Centre, Czech Republic - 2007
Stressing of the pile wall.

Bank of China, Hong Kong - 1987
Ground anchors are installed at the base of the tower to stabilise it against the effects of typhoons.

The Buddhas of Bamiyan, Afghanistan - 2003
The surrounding rock area has been secured with VSL Anchors.
Calheta, Portugal - 2007
Slope stabilisation during excavation

Bridge abutment, Haerkingen, Switzerland - 2005
Temporary and permanent anchors were chosen for the stabilisation of a bridge abutment after the span had been widened.

Tilbury Fort, Great Britain - 1978
An inspection of 340 anchors carried out in 2008 proved that the anchors remained in excellent condition after 30 years in a very aggressive environment.

Parking Hinterglemm, Austria - 2007
Temporary stabilisation of an excavation

Nisigaya Factory site preparation, Japan - 2006
Slope stabilisation during excavation
A WIDE RANGE OF APPLICATIONS

Berlin Airport, Germany - 2008
Micropile application

Burriunjuck Dam, Australia - 1994
Anchors installed to prevent overturning due to higher prediction of flood levels

Masied-e-Suleiman HEP Extension, Iran - 2003
Anchors installed in cavern for cable crane

Bullfighting Arena Lisbon, Portugal - 2002
Slope stabilisation during excavation adjacent to a historic building

Daftah-Shis Road and Tunnel Project, UAE - 2008
Slope stabilisation

Pantalla Anclada Viviendas Benahavis, Spain - 2008
Permanent anchors for slope stabilisation

Mendoza Snow Sheds National Road, Argentina - 2004
Traffic disruption has been avoided by building snow sheds where snow would normally accumulate.
VSL GROUND ANCHOR SYSTEM
TECHNICAL DATA

1. STRAND AND ANCHOR PROPERTIES
2. REMOVABLE ANCHORS
3. POST-GROUTING
1 - STRAND AND ANCHOR PROPERTIES

1.1 - STRAND PROPERTIES 13mm (0.5")

<table>
<thead>
<tr>
<th>Strand type</th>
<th>prEN 10138 – 3 (2006) Y1860ST7</th>
<th>ASTM A 416-06 Grade 270</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal diameter d (mm)</td>
<td>12.5</td>
<td>12.9</td>
</tr>
<tr>
<td>Nominal cross section A p (mm²)</td>
<td>93</td>
<td>100</td>
</tr>
<tr>
<td>Nominal mass M (kg/m)</td>
<td>0.726</td>
<td>0.781</td>
</tr>
<tr>
<td>Nominal yield strength f yk (MPa)</td>
<td>1634</td>
<td>1640</td>
</tr>
<tr>
<td>Nominal tensile strength f p (MPa)</td>
<td>1860</td>
<td>1860</td>
</tr>
<tr>
<td>Specif./min. breaking load F pk (kN)</td>
<td>173</td>
<td>186</td>
</tr>
<tr>
<td>Young’s modulus (GPa)</td>
<td>approx 195</td>
<td></td>
</tr>
</tbody>
</table>

1) Characteristic value measured at 0.1% permanent extension
2) Minimum load at 1% extension for low-relaxation strand
3) Valid for relaxation class acc. to prEN 10138-3 or low-relaxation grade acc. to ASTM A 416-06

SA = Soil anchor
RA = Rock anchor
RI = Single or repeated injection

1) Given values can slightly vary from country to country, depending on local availability of PE duct diameters. They are the same for electrically isolated and non-electrically isolated permanent anchors. The values are not valid for anchors inclined upwards and for anchors with a post-grouting arrangement with double packer acc. to 3.3. The diameters of such anchors can be provided on request.
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1.2 - ANCHOR PROPERTIES 13mm (0.5")

<table>
<thead>
<tr>
<th>Anchorage unit</th>
<th>Number of strands</th>
<th>Breaking load Y1860ST7 (prEN)</th>
<th>Grade 270 (ASTM)</th>
<th>Maximum diameter of anchor¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA without RI³</td>
<td>RA without RI³</td>
<td>RA with RI³</td>
<td>SA without RI³</td>
<td>RA without RI³</td>
</tr>
<tr>
<td>d=12.5 mm d=100 mm²</td>
<td>d=12.9 mm d=98.7 mm²</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>[kN]</td>
<td>[kN]</td>
<td>[kN]</td>
<td>[mm]</td>
<td>[mm]</td>
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<tr>
<td>1</td>
<td>2</td>
<td>346</td>
<td>372</td>
<td>377</td>
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<td>3</td>
<td>519</td>
<td>558</td>
<td>561</td>
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<td>3247</td>
<td>3839</td>
<td>3792</td>
</tr>
</tbody>
</table>

SA = Soil anchor
RA = Rock anchor
RI = Single or repeated injection

1) Given values can slightly vary from country to country, depending on local availability of PE duct diameters. They are the same for electrically isolated and non-electrically isolated permanent anchors. The values are not valid for anchors inclined upwards and for anchors with a post-grouting arrangement with double packer acc. to 3.3. The diameters of such anchors can be provided on request.
2) Minimum load at 1% extension for low-relaxation strand
3) Valid for relaxation class acc. to prEN 10138-3 or low-relaxation grade acc. to ASTM A 416-06

Comments:
- To facilitate a problem-free homing of the anchor, the diameter of the borehole and the formed hole of the casing should be at least 20mm greater than the maximum diameter of the anchor.
- Data for anchor units with additional strands are available on request.
- Temporary anchors have a limited corrosion protection with a duration of use in principle of up to two years. Permanent anchors have a comprehensive protection with a duration of use of typically more than two years.
- Values are subject to modification.
1.3 - STRAND PROPERTIES 15mm (0.6”)

<table>
<thead>
<tr>
<th>Strand type</th>
<th>prEN 10138 – 3 (2006)</th>
<th>ASTM A 416-06</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Y1860S7</td>
<td>Grade 270</td>
</tr>
<tr>
<td>Nominal diameter $d$ (mm)</td>
<td>15.3</td>
<td>15.7</td>
</tr>
<tr>
<td>Nominal cross section $A_p$ (mm$^2$)</td>
<td>140</td>
<td>150</td>
</tr>
<tr>
<td>Nominal mass $M$ (kg/m)</td>
<td>1.093</td>
<td>1.172</td>
</tr>
<tr>
<td>Nominal yield strength $f_{p0,1}$ (MPa)</td>
<td>1636$^1$</td>
<td>1640$^1$</td>
</tr>
<tr>
<td>Nominal tensile strength $f_{pk}$ (MPa)</td>
<td>1860</td>
<td>1860</td>
</tr>
<tr>
<td>Specif./min. breaking load $F_{pk}$ (kN)</td>
<td>250</td>
<td>279</td>
</tr>
</tbody>
</table>

| Young's modulus (GPa) | approx. 195 |
| Relaxation$^3$ after 1000 h at 20°C and 0.7 x $F_{pk}$ (%) | max. 2.5 |

1) Characteristic value measured at 0.1% permanent extension
2) Minimum load at 1% extension for low-relaxation strand
3) Valid for relaxation class acc. to prEN 10138-3 or low-relaxation grade acc. to ASTM A 416-06

1.4 - ANCHOR PROPERTIES 15mm (0.6”)

<table>
<thead>
<tr>
<th>Anchorage unit</th>
<th>Number of strands</th>
<th>Breaking load $Y1860S7$ (prEN)</th>
<th>Grade 270 (ASTM)</th>
<th>Maximum diameter of anchor$^1$</th>
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<tr>
<td></td>
<td></td>
<td>$F$ (kN)</td>
<td>$F$ (kN)</td>
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<td>$d=15.3$ mm</td>
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<td>$d=15.24$ mm</td>
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<tr>
<td>SA = Soil anchor</td>
<td>6-2</td>
<td>2</td>
<td>120</td>
<td>108</td>
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<tr>
<td>RA = Rock anchor</td>
<td>6-3</td>
<td>3</td>
<td>780</td>
<td>837</td>
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<tr>
<td>RI = Single or repeated injection</td>
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<td>1080</td>
<td>1116</td>
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<td>4940</td>
<td>5301</td>
</tr>
</tbody>
</table>

1) Nominal values can slightly vary from country to country, depending on local availability of PE duct diameters. For permanent anchors with single duct encapsulation they are the same for electrically isolated and non-electrically isolated permanent anchors. The values are not valid for anchors inclined upwards and for anchors with a post-grouting arrangement with double packer acc. to 3.3. The diameters of such anchors can be provided on request. For information on post-grouting see chapter 3 page 18.
2) The first of the given values are for a simple post-grouting arrangement using a pipe of 16mm external diameter, the second value is for a repeated post-grouting with return line acc. to 3.2. Both values are without external centraliser but including spacers. They can vary depending on local circumstances. For information on post-grouting see chapter 3 page 18. Diameters of anchors without any post-grouting pipe are correspondingly smaller than the first value. Diameters for removable anchors are acc. to chapter 2 page 18.
3) The first of the given values are for the outer corrugated duct in the bond length, the second is the diameter of the anchor including the external spacers. Both values include simple or repeated post-grouting tubes. 6-8 Larger with available upon request.

Comments:
- To facilitate a problem-free homing of the anchor, the diameter of the borehole and the formed hole of the casing should be at least 20mm greater than the maximum diameter of the anchor.
- Data for anchor units with additional strands are available on request.
- Temporary anchors have a limited corrosion protection with a duration of use in principle of up to two years. Permanent anchors have a comprehensive protection with a duration of use of typically more than two years.
- Values are subject to modification.
2 - REMOVABLE ANCHORS

2.1 - Type S, extraction of the total length

<table>
<thead>
<tr>
<th>Anchorage Unit</th>
<th>Number of strands</th>
<th>Breaking load (kN)</th>
<th>Maximum diameter of anchor (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-2</td>
<td>2</td>
<td>346</td>
<td>105</td>
</tr>
<tr>
<td>5-4</td>
<td>4</td>
<td>692</td>
<td>105</td>
</tr>
<tr>
<td>5-6</td>
<td>6</td>
<td>1038</td>
<td>105</td>
</tr>
<tr>
<td>5-8</td>
<td>8</td>
<td>1384</td>
<td>105</td>
</tr>
<tr>
<td>5-10</td>
<td>10</td>
<td>1730</td>
<td>105</td>
</tr>
<tr>
<td>5-12</td>
<td>12</td>
<td>2076</td>
<td>105</td>
</tr>
</tbody>
</table>

Breaking load based on 93 / 100 / 98.7 mm² strand

2.2 - Type XF, extraction of the free length

<table>
<thead>
<tr>
<th>Anchorage Unit</th>
<th>Number of strands</th>
<th>Breaking load* (kN)</th>
<th>Maximum diameter of anchor (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-2</td>
<td>2</td>
<td>371</td>
<td>90</td>
</tr>
<tr>
<td>6-3</td>
<td>3</td>
<td>557</td>
<td>90</td>
</tr>
<tr>
<td>6-4</td>
<td>4</td>
<td>743</td>
<td>90</td>
</tr>
<tr>
<td>6-7</td>
<td>5</td>
<td>929</td>
<td>90</td>
</tr>
<tr>
<td>6-12</td>
<td>7</td>
<td>1857</td>
<td>115</td>
</tr>
<tr>
<td>6-12</td>
<td>12</td>
<td>2229</td>
<td>115</td>
</tr>
</tbody>
</table>

Breaking load based on 140/150 mm² strand

3 - POST-GROUTING

Anchors of the same type can present external ultimate loads that can vary considerably depending on local geotechnical conditions. In most cases, this external ultimate load resistance can be improved by the use of post-grouting around the bond length of the anchor. All anchor types can be equipped with one of the following post-grouting systems:

3.1 Simple post-grouting
Permits single post-grouting of the grout body in the bond length.

3.2 Repeated post-grouting with return line
Permits repeated post-grouting provided the pipe is rinsed after each injection.

3.3 Post-grouting with double packer
Pipe with packer with two plugs each side, introduced into a rigid sleeved pipe, allows individual and targeted grouting.
VSL GROUND ANCHOR SYSTEMS

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SYSTEMS & TECHNOLOGIES

- 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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VSL LOCATIONS

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Americas

ARGENTINA
VSL Sistemas Especiales de Construcción Argentina S.A.
BUENOS AIRES
Phone: +54 11 4326 06 09
Fax: +54 11 4326 26 50

BOLIVIA
VSL Sistemas Especiales de Construcción S.A.
Potosí
Phone: +56 2 119 01 69
Fax: +56 2 119 01 69

CHILE
VSL Sistemas Especiales de Construcción S.A.
SANTIAGO
Phone: +56 2 571 98 20
Fax: +56 2 571 98 20

COLOMBIA
VSL Sistemas Colombia S.A.
Bogotá
Phone: +57 1 226 62 30
Fax: +57 1 226 62 30

MEXICO
VSL Corporation Mexico S.A.de C.V.
MEXICO
Phone: +52 55 55 11 00 36
Fax: +52 55 55 11 40 03

PERU
VSL Sistemas de Construcción Peru S.A.
LIMA
Phone: +51 1 149 38 38
Fax: +51 1 348 28 78

UNITED STATES
VSL America LLC
Baltimore, MD
Phone: +1 410 850 70 03
Fax: +1 410 850 4111

VENEZUELA
VSL Sistemas de Obras y Construcciones C.A.
CARACAS
Phone/Fax: +58 2 212 54 86 75

Africa

EGYPT
Matrix Engineering Company Cairo
Phone: +20 2 344 19 00
Fax: +20 2 344 04 67

SOUTH AFRICA
VSL (South Africa) (Pty) Ltd.
JOHANNESBURG
Phone: +27 11 874 88 20
Fax: +27 11 874 88 21

Europe

AUSTRIA
Grund-Preh- und Sonderbau GmbH
HINSDORF
Phone: +43 2325 87 77 77
Fax: +43 2325 86 56 1

CROATIA
VSL Systems (CZ) Ltd.
SPLIT
Phone: +385 1 349 38 38
Fax: +385 1 349 38 38

CZECH REPUBLIC
VSL Systems (CZ) Ltd.
PRAGUE
Phone: +420 2 571 67 00
Fax: +420 2 571 67 01

GERMANY
VSL Systems GmbH
BERLIN
Phone: +49 30 530 28 06 0
Fax: +49 30 530 28 06 0

SWEDEN
VSL Systems Sweden AB
VÄSTERHANINGE
Phone: +46 8 753 49 73
Fax: +46 8 753 49 72

FRANCE
VSL France S.A.
LABEGE
Phone: +33 1 54 00 96 09
Fax: +33 1 54 00 96 62

FRANCE (South)
VSL France S.A.
LABEGE
Phone: +33 1 54 00 95 33
Fax: +33 1 54 00 96 09

GREAT BRITAIN
VSL Systems UK Ltd.
BEDFORDSHIRE
Phone: +44 1525 45 53 30
Fax: +44 1525 45 53 30

NETHERLANDS
VSL Systems NL
ROESMALEN
Phone: +31 73 543 06 02
Fax: +31 73 543 65 11

SWITZERLAND
VSL (Switzerland) Ltd.
ZURICH
Phone: +41 31 647 60 00
Fax: +41 31 647 60 00

PORTUGAL
VSL (Portugal) Lda.
PORTO
Phone: +351 2 295 84 26
Fax: +351 2 295 84 26

SPAIN
VSL (Spain) Ltd.
BARCELONA
Phone: +34 93 289 23 31
Fax: +34 93 289 23 31

ASIA

BRUNEI
VSL (Brunei) Sdn. Bhd.
KUANTAN
Phone: +60 91 382 39 18
Fax: +60 91 382 39 18

CHINA
VSL Systems (China) Engineering Co., Ltd.
BEIJING
Phone: +86 51 1 382 29 18
Fax: +86 51 1 382 29 18

CHINA PRC
VSL (China) Engineering Co., Ltd.
BEIJING
Phone: +86 551 382 29 18
Fax: +86 551 382 29 18

HONG KONG
VSL China Ltd.
HONG KONG
Phone: +852 2590 22 88
Fax: +852 2590 22 88

HONG KONG
VSL Hong Kong Ltd.
CHAI WAN
Phone: +852 2386 37 32
Fax: +852 2386 37 32

CHINA
VSL China Ltd.
CHINA
Phone: +86 10 515 38 19
Fax: +86 10 515 38 19

KOREA
VSL Korea Co. Ltd.
SEOUL
Phone: +82 2 553 8255
Fax: +82 2 553 8255

JAPAN
VSL Japan Corporation
JAPAN
Phone: +81 3 3345 9153
Fax: +81 3 3345 9153

MALAYSIA
VSL Engineers (M) Sdn. Bhd.
KUALA LUMPUR
Phone: +603 7981 47 42
Fax: +603 7981 84 22

PHILIPPINES
VSL Philippines Inc.
PASIG CITY
Phone/Fax: +83 672 13 95

SINGAPORE
VSL Singapore Pte. Ltd.
SINGAPORE
Phone: +65 3559 12 22
Fax: +65 3559 12 22

THAILAND
VSL (Thailand) Co. Ltd.
BANGKOK
Phone: +66 2 679 75 15 - 19
Fax: +66 2 679 75 04

VIETNAM
VSL Vietnam Ltd.
HANOI
Phone: +84 4 3976 4088
Fax: +84 4 3976 4089

VSL Middle East LLC
UNITED ARAB EMIRATES
Phone: +971 4 885 7225
Fax: +971 4 885 7226

AUSTRALIA
VSL Australia Pty Ltd.
NEW SOUTH WALES
Phone: +61 2 9875 3894
Fax: +61 2 8807 3894

QUEENSLAND
Phone: +61 7 3265 64 00
Fax: +61 7 3265 64 00

VICTORIA
Phone: +61 3 979 503 66
Fax: +61 3 979 503 66

SOUTH AUSTRALIA
Phone: +61 8 810 6817
Fax: +61 8 810 6818

TASMANIA
Phone: +61 3 9875 3894
Fax: +61 3 9875 3894

WA
Phone: +61 9 9294 16 38
Fax: +61 9 9294 16 38

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