

VSL soil and rock anchors

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Base: SIA

Recommendation, V 191
1995 edition

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1. Generalities



This is an English translation of the original German and French version dated 5.98, as approved by the GEA Group of Experts. In case of discrepancies, the German and French version prevail.

Reference is also made to EN 1537 "Execution of special geotechnical work - Ground Anchors", where in Annex A the electrical testing of the corrosion protection as specified in SIA V 191 is mentioned.

1. Generalities



- 1.1 Introduction
- 1.2 Basic components
- 1.3 Specifications for post-tensioning steel
- 1.4 Designation of VSL anchors

1.1 Introduction

The aim of the present document on anchors is to inform designers and engineers of the range of possible applications for VSL anchors in soil and rock. It is intentionally limited to the technical elements required for installation works, and excludes calculations and dimensioning methods.

The VSL anchor system was subject to an initial examination by the independent GEA group of experts (Group of Experts specialised in soil and rock anchor systems) and found to comply with the requirements of the SIA V 191 Recommendation (1995) (see appendix chapter 11). The compliance with these requirements is assured by regular checking procedures carried out by ourselves and by external bodies (such as EMPA). In addition, VSL (Switzerland) Ltd. also has an ISO 9002 quality management system.

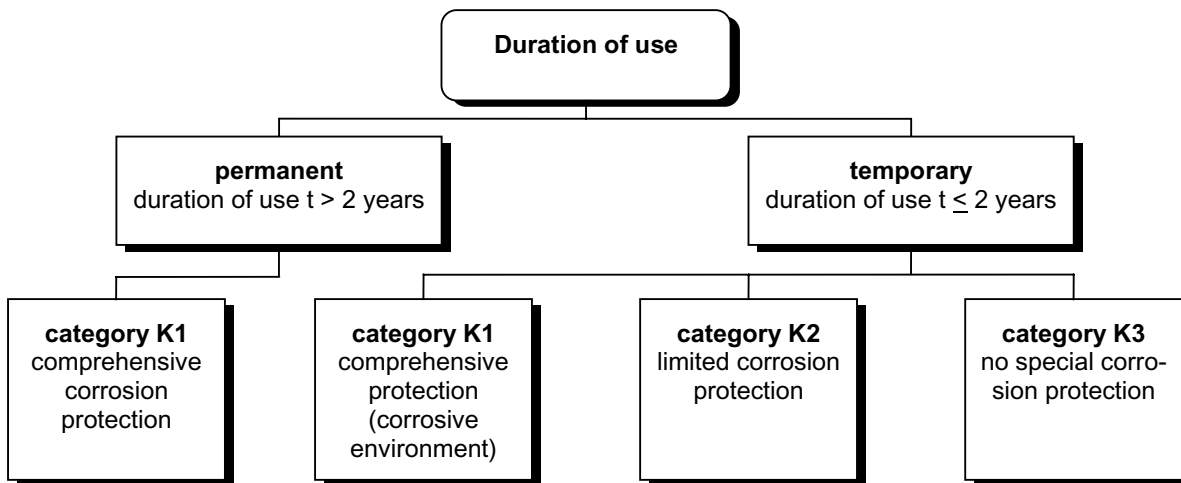
Characteristics of VSL anchors

VSL anchors are strand anchors. As grouted anchors, they can be used in both rock and soil. Their construction principle is always the same and the various types of anchors only differ in certain technical details. It is the sum of these details and the wide range of possible combinations that gives VSL anchor technology its well-known flexibility.

Corrosion protection

The corrosion protection of VSL anchors complies with the SIA V 191 "Post-tensioned soil and rock anchors" Recommendation, 1995 edition.

This defines the following corrosion protection categories:



€ Comprehensive protection (category K1)
applies to all permanent anchors as well as all temporary anchors installed in a corrosive environment or subject to a critical level of stray currents.

€ Limited protection (category K2)
applies to temporary anchors (duration of use in principle being less than two years).

€ No special protection (category K3)
in the case of anchors whose duration of use is less than six months and whose failure would only have minimal consequences and not endanger public safety.

VSL anchors are designed to fulfil their function throughout the working life of the structure.

Anchors with comprehensive protection against corrosion (category K1) allow the integrity of the encapsulation to be checked at any time by measuring the electrical resistance. All components exposed to the elements are protected by the surface application of suitable products. The following table provides indicative values for the duration of use of these components in normal conditions:

Components	Duration of use	Remedial works
Coating of the bearing plate	up to 15 years	Renewal of the coating
Coating of the steel protection cap	up to 15 years	Renewal of the coating or replacement of the cap
Plastic protection cap	up to 25 years	Replacement
Seal in protection cap	up to 20 years	Replacement
Load cell	up to 20 years	Replacement

VSL services

We are able to provide the following services:

- € **Technical support** during the project design phase, preparation of proposals for complicated technical solutions and alternatives, for test systems and for measuring equipment.
- € **Supply** of different types of anchors and various regrouting systems.
- € **Performance** of anchor tests namely investigation, suitability and acceptance tests
- € **Stressing** of anchors, including performance of the stressing test and the subsequent lock-off of the anchor at the P_0 lock-off load.

In Switzerland, VSL generally provide these services as a subcontractor to a drilling contractor. All other works concerning the installation of the anchors are carried out by the drilling contractor or by a local company.

A judicious and economic distribution of work has been established over our long involvement with drilling contractors. This is why, in particular, it is worthwhile allowing the drilling contractor to home and grout the anchors.

The Swiss Association of Post-Tensioning Contractors has drawn up two documents that set the respective scope of responsibilities of anchor installation works for the supplier of the anchors and the drilling contractor. These documents respectively concern temporary anchors (categories K2 and K3) and anchors with comprehensive corrosion protection (category K1).

These conditions are appended to the present document.

- € **Long-term monitoring** of anchors.

1.2. Basic components

A post-tensioned anchor comprises the following main components (figure 1.1):

- € Anchorage element that transmits the anchor load to the anchored load-bearing structure
- € Tendon element that transfers the anchor load from the anchorage to the anchor body
- € The grout body: element that transmits the anchor load to the ground
- € The length of anchor l : distance between the head and the end of the anchor in the soil or in the rock
- € The bond length l_b : length over which the load is transmitted to the anchor body
- € The apparent tendon free length l_{fr} : length between the anchor head and the beginning of the bond length, as provided by the result of static and mechanical soil calculations
- € The effective tendon free length l_f : length of the part of the tendon that effectively lengthens when tensioning takes place.

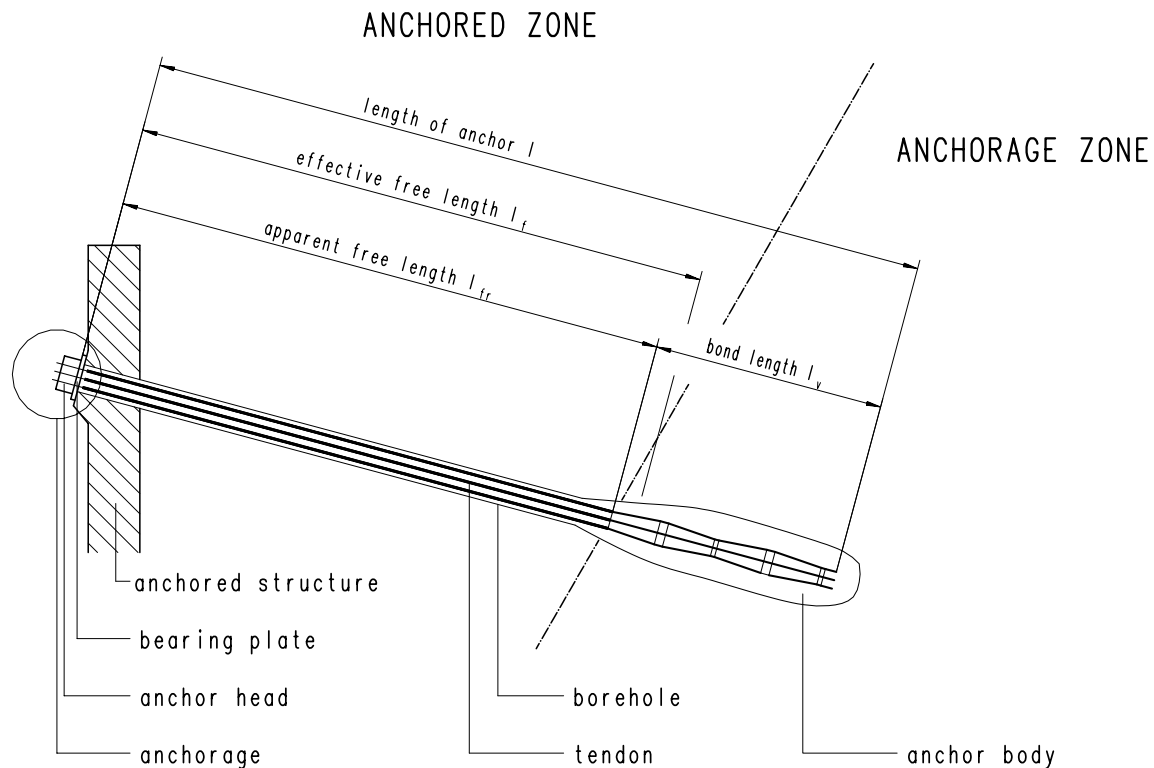


Fig. 1.1

Terms and notations

The present document complies with the SIA V 191 Recommendation for "Post-tensioned Soil and Rock Anchors", 1995 edition. It uses the terms and notations given in this Recommendation, as summarised in table 1.2 below.

Effective anchor load over time $0 < t < \infty$	P
Cross sectional area of the tendon	A_p
Characteristic tensile strength of a tendon	f_{tk}
Characteristic load capacity of tendon	$P_{tk} = A_p \cdot f_{tk}$
Characteristic yield strength of a tendon	f_y
Characteristic yield capacity of tendon	$P_y = A_p \cdot f_y$
Elasticity modulus of the tendon	E_p
Proof load during stressing test	P_p
Proof load during suitability tests	P_{pv}
Anchor lock-off load (at $t = 0$)	P_O
Service load	P_{ser}
Characteristic internal anchor resistance	$R_i = P_{tk}$
Characteristic external anchor resistance	R_a
Determining ultimate resistance of the anchor (the lower of the values of R_i and R_a)	R
Apparent tendon free length	l_{fr}
Effective tendon free length	l_f
Bond length	l_v
Total tendon length	$l = l_{fr} + l_v$
Displacement of the front end of the tensile member	$\div l$
Elastic displacement	$\div l_{el}$
Permanent displacement	$\div l_{bl}$
Theoretical elastic extension of an anchor at P_p	$\div l_r = P_p \cdot l_{fr} / E_p \cdot A_p$
Piston stroke	$\div l_k$
Bearing plate displacement	s
Anchor inclined downwards inclination compared to horizontal ($\eta > 0$: anchor)	η

Tab. 1.2

In accordance with the SIA V 191 Recommendation, the following relationships exist between the anchor loads:

$P_p \leq 0.75 P_{tk}$	$P_{tk} \geq 1.33 P_p$
$P_p \geq 1.25 P_O$	$P_O \leq 0.8 P_p$
$P_O \leq 0.6 P_{tk}$	$P_{tk} \geq 1.67 P_O$
$P_{pv} \leq 0.95 P_y$	
$P_{pv} \geq P_{tk}$ of production anchors	

Tab. 1.3

1.3 Specifications for post-tensioning steel

0.5" strands, $A_p = 100 \text{ mm}^2$

	Unit	0.5"
Characteristic tensile strength of a strand f_{tk}	N/mm ²	1820
Nominal diameter	mm	12.9
Cross sectional area of a strand A_p	mm ²	100
Characteristic load capacity of a strand P_{tk}	kN	182
Characteristic yield strength of a strand f_y	N/mm ²	1640
Specific elongation under maximum load	%	3.5
Contraction ...	%	30
Elasticity modulus (average value) E_p	kN/mm ²	195
Fatigue resistance	cycles	2×10^6
- maximum stress ω_0	% of f_{tk}	70
- stress variation $\pm \omega$	N/mm ²	200
Relaxation after 1000 h, 20° C, 0.70 f_{tk}	%	max. 2.5

Tab. 1.4

Stress-elongation diagram

stress in N/mm²

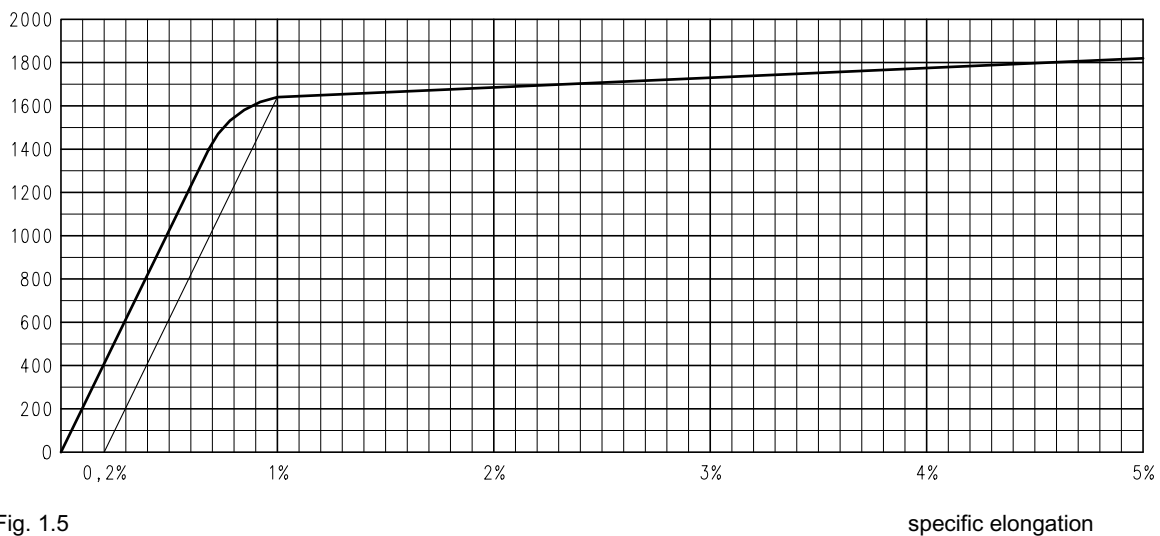


Fig. 1.5

0.6" strands, $A_p = 150 \text{ mm}^2$

	Unit	0.6"
Characteristic tensile strength of a strand f_{tk}	N/mm ²	1770
Nominal diameter	mm	15.7
Cross sectional area of a strand A_p	mm ²	150
Characteristic load capacity of a strand P_{tk}	kN	265.5
Characteristic yield strength of a strand f_y	N/mm ²	1590
Specific elongation under maximum load	%	3.5
Contraction ...	%	30
Elasticity modulus (average value) E_p	kN/mm ²	195
Fatigue resistance	cycles	2×10^6
- maximum stress ω_b	% of f_{tk}	70
- stress variation $\pm\omega$	N/mm ²	200
Relaxation after 1000 h, 20° C, 0.70 f_{tk}	%	max. 2.5

Tab. 1.6

Note:

Type X_F extractable anchors are constructed using 0.6" strands in compliance with the above-mentioned specifications. However, the extraction system reduces the breaking load to 189 kN.

Stress-elongation diagram

stress in N/mm²

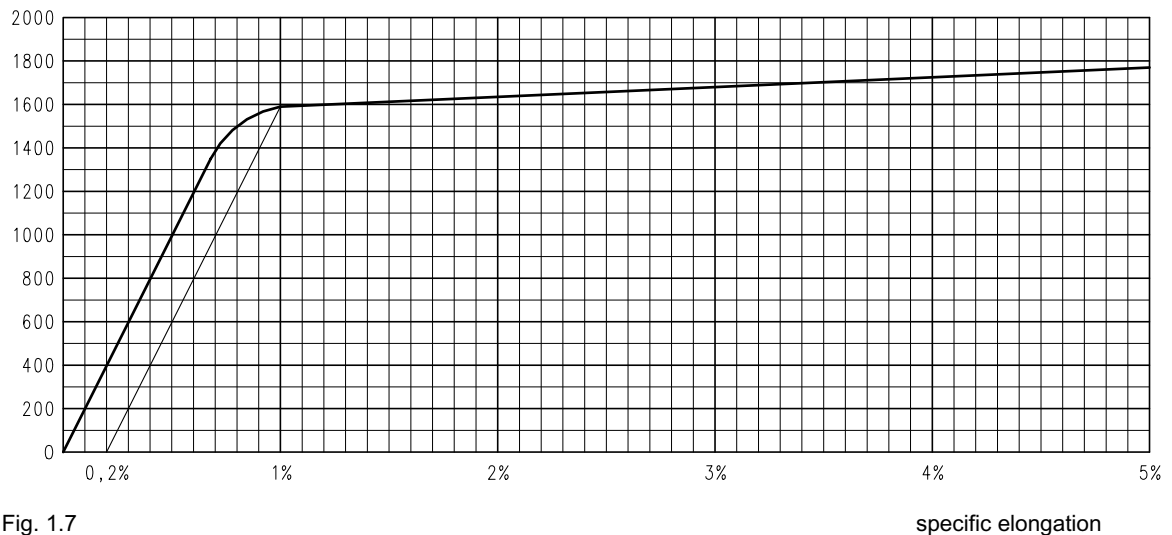


Fig. 1.7

specific elongation

1.4 Designation of VSL anchors

The aim of the following explanations and the diagram (fig. 1.10) is to:

1. serve as a guide in order to have a clear and complete definition of the anchors,
2. act as a check-list to simplify the preparation of bids and order processing.
3. rapidly provide an overall view of the different available VSL anchors through use of the diagram (fig. 1.10).

The elements needed to choose the anchorages are subject to similar diagrams. These can be found in chapter 4 for the temporary anchors and in chapter 5 for the permanent anchors.

The different types of anchors:

Distinction made according to:	Specific characteristics
The period of use	The permanent anchors fulfil their function throughout the working life of the structure. The temporary anchors only fulfil their function for a limited period, generally for a maximum of two years.
The corrosion protection	Category K1, K2 or K3 See chapter 1.1
The nature of the anchoring zone	It is the nature of anchoring zone that gives its name to the anchor: soil anchor in loose soil or rock anchor in rock
The anchor load force	The anchor capacity is at least defined by the proof load (P_p) during acceptance testing, expressed in kN. This value will be used to deduce the breaking load $P_{tk} \geq 1.33 P_p$ and the lock-off load $P_0 \geq 0.8 P_p$.
Type of anchorage (anchor head) (offers possibilities influencing the anchor load during the period of use)	Fixed (EF): the anchor load usually cannot be modified at a later time. Restressable (EF but with a minimum strand projection and shims): the anchor load can be increased, but not reduced. Adjustable (ER): the anchor load can be increased and decreased within certain limits. Destressable/Adjustable (EA): the anchor load can be increased or decreased within certain limits, or totally destressed. Controllable (EG): the anchor load can be checked by means of a jumping load cell GW

Tab. 1.8

The complete description of the anchor must also include the definition of the lengths:
length of an anchor $l = l_{fr} + l_v$.

Specific points	
Inclination of the anchor	<p>Anchors inclined downwards towards the bottom are installed descending from the anchorage; this is the standard case.</p> <p>Anchors inclined upwards towards the top are installed upwards from the anchorage; in practical terms, this is generally only possible for anchors bedded in rock.</p>
Extraction possibility	If necessary, temporary anchors can be manufactured to permit extraction of the free length .
Construction of supports	Depending on the nature of the support either concrete or steel tie beams (waling).
Reinjection or regrouting	<p>On request, all anchors can be equipped with different types of reinjection systems:</p> <ul style="list-style-type: none"> € single reinjection € repeated reinjection with return flushing line € targeted reinjection using a double packer
Other specificities	<ul style="list-style-type: none"> € Anchors against uplift pressure € Anchors with packer <p>See chapter 10 for more details</p>

Tab. 1.9

Examples of accurate designations:

- € Temporary anchor in soil, category K2, downward, with single reinjection, $P_p = 360 \text{ kN}$, $l_{fr} = 12.0 \text{ m}$, $l_v = 6.0 \text{ m}$, with normal anchorage bearing on steel beams.
- € Permanent rock anchor, category K1, upward, without reinjection $P_p = 480 \text{ kN}$, $l_{fr} = 18.0 \text{ m}$, $l_v = 7.0 \text{ m}$, with EG control anchorage.

The corresponding explanations are given in the tables above.

Long-term anchor monitoring

VSL provides a complete long-term monitoring programme. The corresponding details are given in chapters 5 and 9.

Diagram for choosing anchors (tensile member and anchorage)

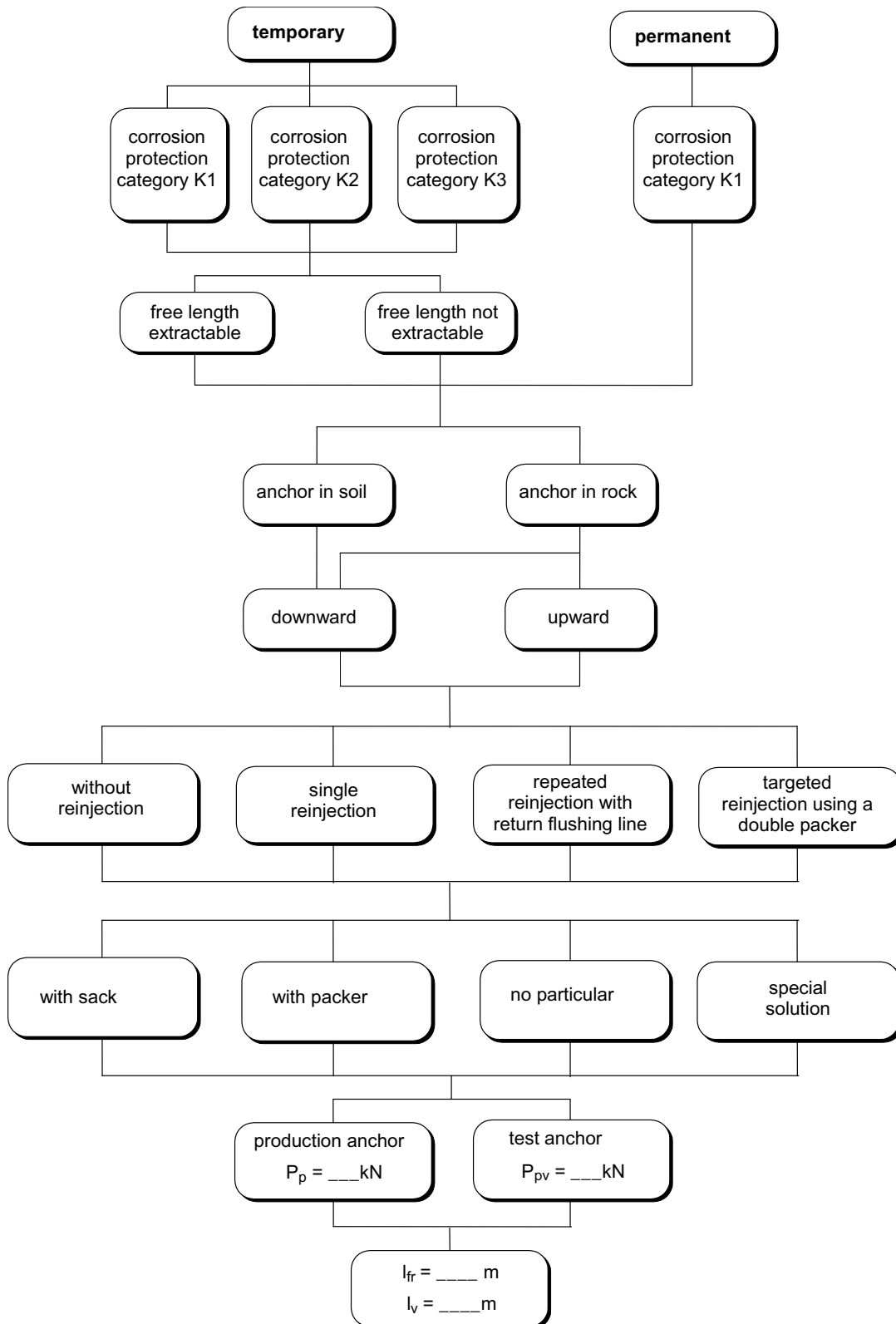


Fig. 1.10

2. VSL temporary anchors Categories K2 and K3



- 2.1 Generalities
- 2.2 Table of sections and anchorage strengths for VSL temporary anchors
- 2.3 Table of sections and anchorage strengths for VSL extractable anchors
- 2.4 VSL temporary anchors in soil, angled downwards
- 2.5 VSL temporary anchors in rock, angled downwards
- 2.6 VSL extractable anchors

2. VSL temporary anchors Categories K2 and K3



2.1 Generalities

Corrosion protection

Temporary anchors have a limited duration of use over time (generally speaking less than two years). They are provided with a limited corrosion protection (category K2). For anchors whose duration of use is less than six months and whose failure would only have minimum consequences without consequence to public safety, no special protection is required (category K3). If the construction phase during which the anchors are in use exceeds two years or if the anchors are placed in a corrosive environment, it is necessary to use anchors with comprehensive corrosion protection (category K1).

Strand sections

VSL temporary anchors in soil or in rock comprise seven wire strands with a standard cross sectional area of 100 mm² or 150 mm².

Bond length l_v

The bond length l_v must be at least 3.00 m and no more than 10.00 m (see chapter 7). The strands are bare. They are alternately held at a distance from one another using spacers and then slowly brought together to obtain an optimal transmission of forces. For anchors with limited corrosion protection, spacers allow the anchor to be centred in the drilled hole and ensure that it is covered by a 20 mm thickness of cement grout.

Apparent tendon free length l_{fr}

Theoretical free lengths of less than 7.00 m should be avoided where possible (see chapter 7). The strands are greased and individually coated using polyethylene (PE), called Monostrands.

Choice of tendon

The choice of tendon is made in accordance with table 2.4 (sections and anchor loads) on the basis of the P_p acceptance test required for stressing tests. Comparable data concerning extractable anchors can be found in table 2.5.

Choice of anchorage

The details and information concerning the choice of the anchorage, as well as information concerning the construction of supports is given in chapter 4.

VSL extractable anchors

The problem of stabilising excavation walls can be economically resolved using temporary anchors. In these types of applications, anchors very often need to extend beyond the site perimeter into the neighbouring plot. For legal reasons and to avoid the anchors interfering with subsequent earthworks on neighbouring sites, it is often necessary to extract the tendons at the end of the works. Because of their simple construction, VSL extractable anchors in soil and in rock provide a reliable and economic solution for the removal of the tendon over the free length of the anchor. Thanks to this extraction, the fees required for use of neighbouring plots can be avoided or at least reduced to a minimum.

2. VSL temporary anchors Categories K2 and K3



Reinjection / Regrouting

Anchors of the same type can present external ultimate loads that vary considerably depending on local geotechnical conditions. In most cases, this external ultimate load resistance can be considerably improved by reinjecting the grout body. It is possible to equip all anchor types with one of the following reinjection systems.

Simple reinjection

A single flexible reinjection pipe equipped with sleeves (manchettes) over the bond length permits a single reinjection. Up to a length of $l_{fr} < 12$ m this system can, following careful rinsing, be reused several times. For lengths greater than $l_{fr} > 12$ m it is recommended that a system with return line be used (see below).

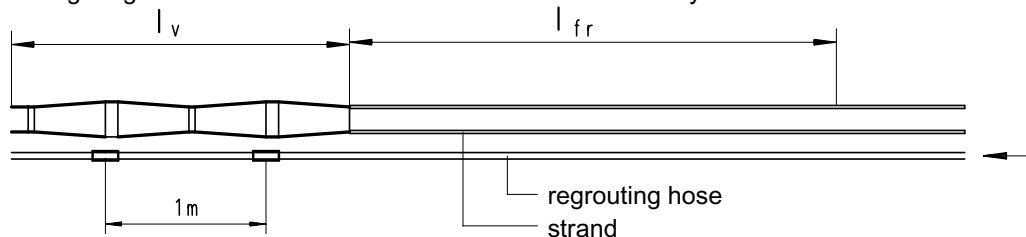


Fig. 2.1

Repeated reinjection with return line

The flexible sleeved injection pipe is extended by a return line that permits a good rinsing after injection, thus avoiding any blocking taking place due to hardened grout. As a result, it is possible to proceed with repeated injections without any difficulties.

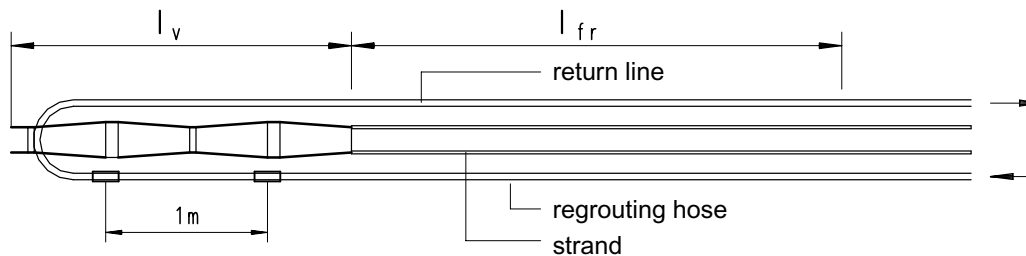


Fig. 2.2

Reinjection by passes with double packer

For the reinjection, the injection pipe is, provided with a packer equipped with two plugs at either end, is introduced into a rigid sleeved pipe. The packer is successively placed in position with each sleeve which is thus individually injected. This system, which by definition provides an optimal performance level and targeted regrouting, nevertheless has the disadvantage of making the anchor more rigid and consequently requires that the diameter of the drilled hole be considerably increased.

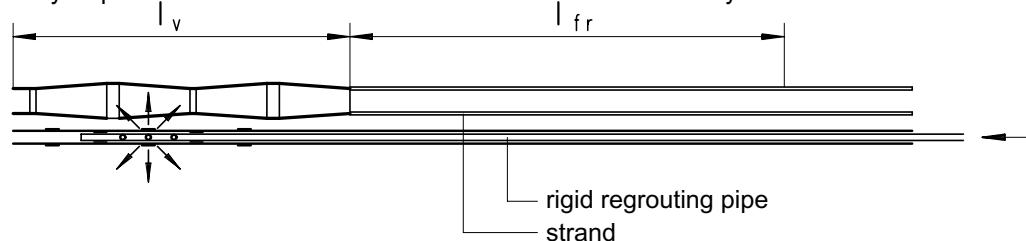


Fig. 2.3

2. VSL temporary anchors Categories K2 and K3



2.2 Table of VSL temporary anchor loads

Breaking load	Load for acceptance tests	Load for suitability tests	Anchor lock-off load	Weight of strands	Steel section	Number and individual sections of strands	Anchorage unit	Maximum diameter of the anchor, with or without RI	
								K2 (mm)	K3 (mm)
R_i $P_{tk} = A_p \cdot f_{tk}$ (kN)	$P_p \leq 0.75 P_{tk}$ (kN)	$P_{pv} \leq A_p \cdot 0.95 f_y$ (kN)	$P_o \leq 0.6 P_{tk}$ (kN)	(kg/m)	A_p (mm ²)				
364	273	311	218	1.6	200	2 x 100	5-3	83	48
546	409	467	327	2.4	300	3 x 100	5-3	83	48
728	546	623	436	3.1	400	4 x 100	5-4	83	48
910	682	779	546	3.9	500	5 x 100	5-7	83	48
1'092	819	934	655	4.7	600	6 x 100	5-7	90	55*
1'274	955	1'090	764	5.5	700	7 x 100	5-7	90	64
1'456	1'092	1'246	873	6.3	800	8 x 100	5-12	99	64
1'638	1'228	1'402	982	7.1	900	9 x 100	5-12	99	74*
1'820	1'365	1'558	1'092	7.9	1000	10 x 100	5-12	99	74
2'002	1'501	1'713	1'201	8.6	1100	11 x 100	5-12	99	74
2'184	1'638	1'869	1'310	9.4	1200	12 x 100	5-12	99	74
2'366	1'774	2'025	1'419	10.2	1300	13 x 100	5-19	119	84*
2'548	1'911	2'181	1'528	11.0	1400	14 x 100	5-19	119	84
2'730	2'047	2'337	1'638	11.8	1500	15 x 100	5-19	119	84
2'912	2'184	2'492	1'747	12.6	1600	16 x 100	5-19	119	84
3'094	2'320	2'648	1'856	13.3	1700	17 x 100	5-19	119	84
3'276	2'457	2'804	1'965	14.1	1800	18 x 100	5-19	119	84
3'458	2'593	2'960	2'074	14.9	1900	19 x 100	5-19	119	-
531	398	453	318	2.4	300	2 x 150	6-2	89	54
796	597	679	477	3.5	450	3 x 150	6-3	89	54
1'062	796	906	637	4.7	600	4 x 150	6-4	99	64*
1'327	995	1'132	796	5.9	750	5 x 150	6-7	99	64
1'593	1'194	1'359	955	7.1	900	6 x 150	6-7	99	64
1'853	1'393	1'586	1'115	8.2	1050	7 x 150	6-7	110	75*

Tab. 2.4

RI: single or repeated reinjection

*) with simple reinjection
diameter reduced by 10 mm

Comments:

- € The problem-free installation of an anchor is dependent on the diameter of the borehole and the formed holes for the passage of the drilling rods. These diameters should be at least 20 mm greater than the maximum diameter of the anchor.
- € The diameter of anchors inclined upwards in rock as well as anchors with multiple reinjection can be provided on request.

2. VSL temporary anchors Categories K2 and K3



2.3 Table of VSL extractable anchor loads

Type XF, extraction of the free length

Breaking load	Load for acceptance tests	Load for suitability tests	Anchor lock-off load	Weight of strands	Steel section	Number and individual sections of strands	Anchorage unit	Maximum diameter of the anchor
$P_{tk} = A_p \cdot f_{tk}$ (kN)	$P_p \leq 0.75 P_{tk}$ (kN)	$P_{pv} \leq A_p \cdot 0.95 f_y$ (= $0.853 \cdot P_{tk}$) (kN)	$P_o \leq 0.6 P_{tk}$ (kN)	(kg/m)	A_p (mm ²)	(mm ²)		(mm)
379	284	323	227	2.4	214	2 x 150	6-2	90
568	426	485	341	3.5	321	3 x 150	6-3	90
758	568	647	455	4.7	428	4 x 150	6-4	90
948	711	808	568	5.9	535	5 x 150	6-7	90
1137	853	970	682	7.1	642	6 x 150	6-7	100
1327	995	1132	796	8.2	750	7 x 150	6-7	100

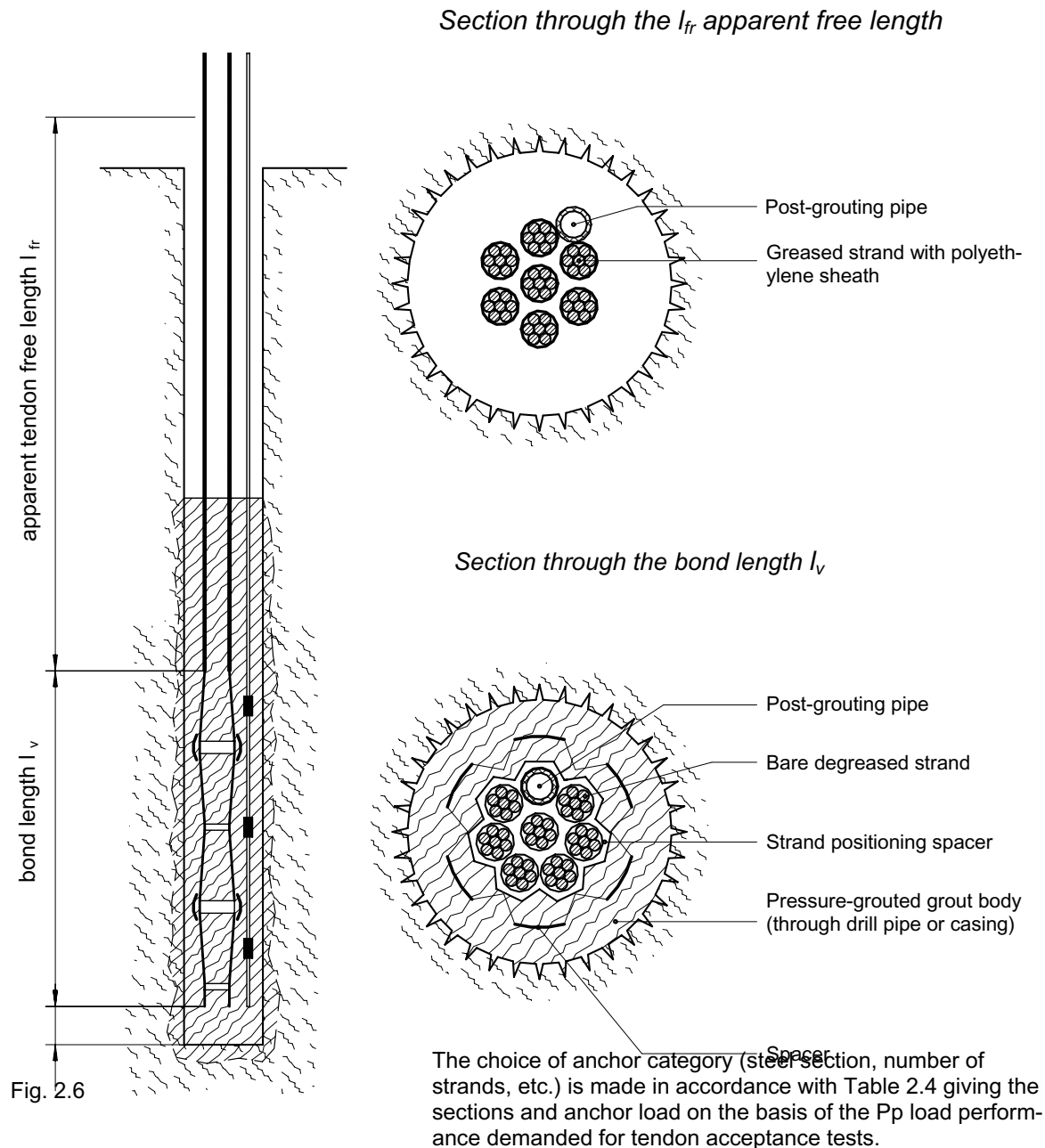
Tab. 2.5

2. VSL temporary anchors Categories K2 and K3



2.4 VSL temporary anchors in soil, inclined downwards

(in practice, anchors in loose soil are typically only inclined downwards)

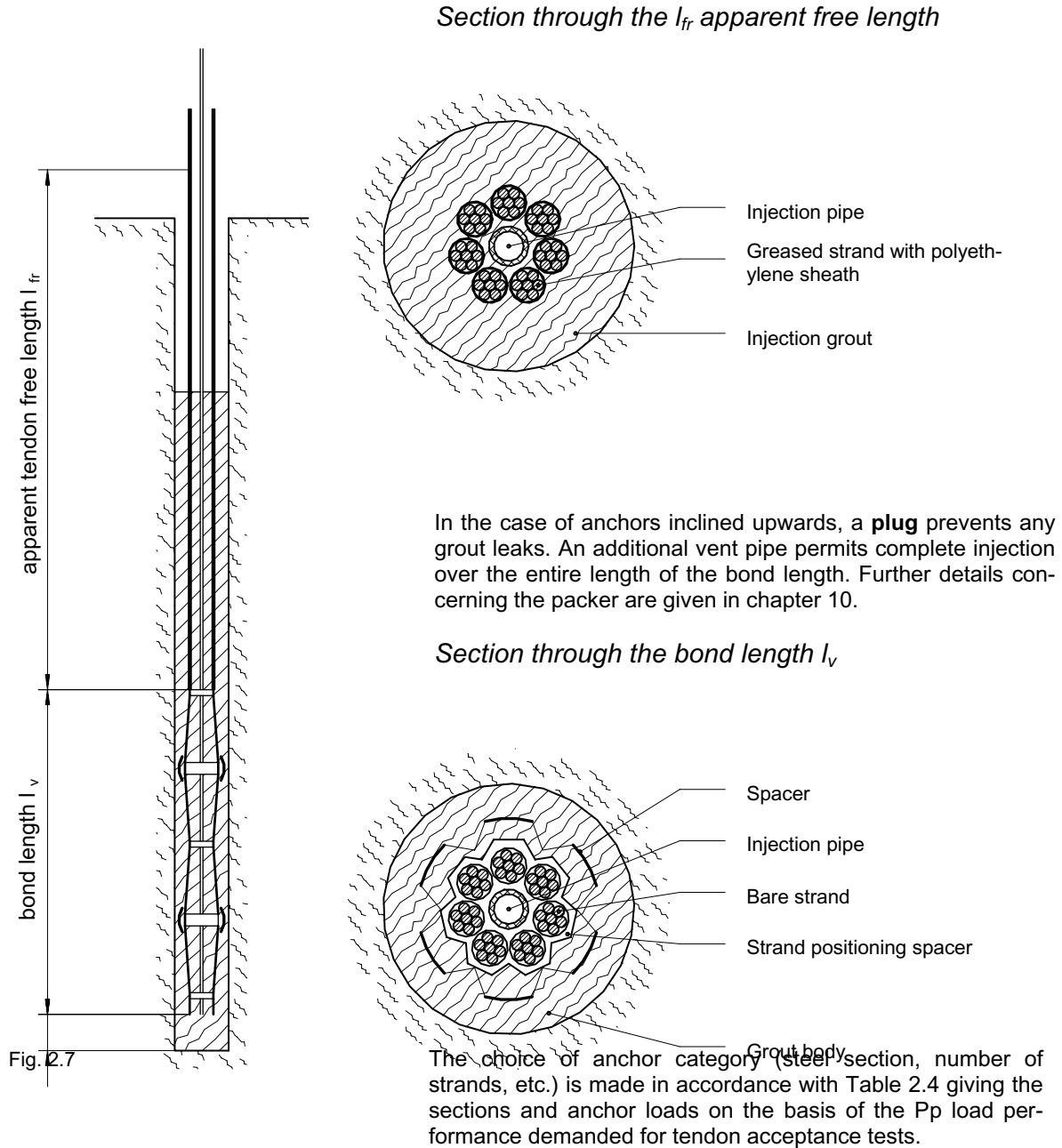


These anchors can be equipped with one of the reinjection systems described in paragraph 2.1. The above diagram represents the normal situation, being simple reinjection.

2. VSL temporary anchors Categories K2 and K3



2.5 VSL temporary anchors in rock, inclined downwards

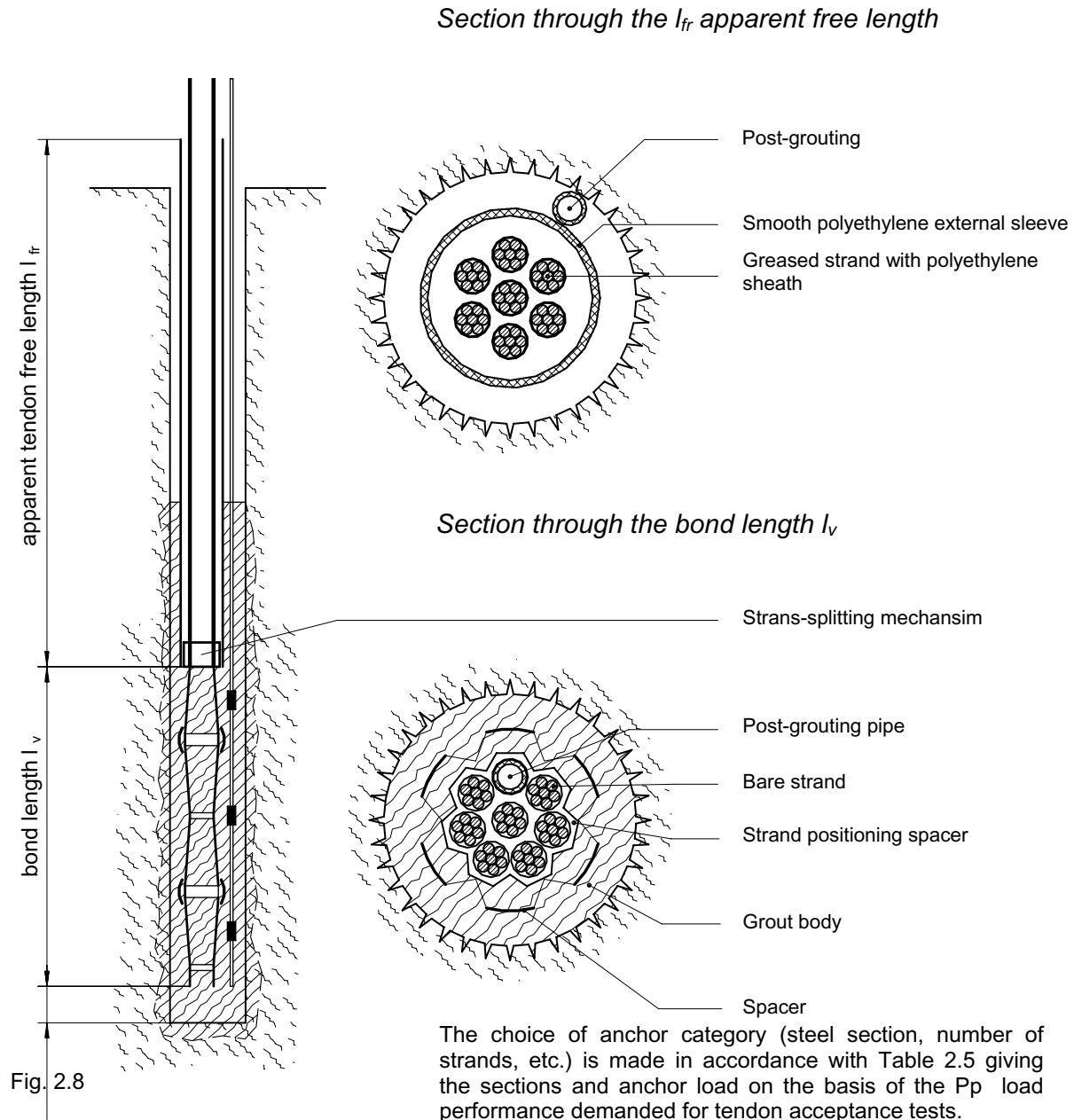


These anchors can be equipped with one of the reinjection systems described in paragraph 2.1. The above diagram represents the situation without reinjection.

2. VSL temporary anchors Categories K2 and K3



2.6 VSL extractable anchors Type XF : extraction of the free length



These anchors can be equipped with one of the reinjection systems described in paragraph 2.1. The above diagram represents the normal situation, being simple reinjection.

3. VSL permanent anchors Category K1



- 3.1 Generalities
- 3.2 Table of VSL permanent anchor sections and anchor loads
- 3.3 VSL permanent soil anchors, inclined downwards
- 3.4 VSL permanent rock anchors, inclined downwards
- 3.5 VSL permanent anchors in rock, inclined upwards

3.1. Generalities

Corrosion protection

Permanent anchors must fulfil their function throughout the working life of the structure. Comprehensive corrosion protection (category K1) is standard for these VSL anchors.

The bare strands are placed in a corrugated polyethylene tube over the bond length. The greased strands are individually sheathed in a PE pipe over the free length and are themselves protected by an external PE pipe with a thick, smooth outer wall. The integrity of the encapsulation is initially checked in the factory by measuring the electrical resistance.

For further information concerning measuring the electrical resistance, consult chapter 8.4.

Strand sections

VSL permanent soil and rock anchors comprise seven wire strands with standard cross section of 100 mm² or 150 mm².

Bond length l_v

Like the temporary anchors, the bond length should be at least 3.00 m and no more than 10.00 m (see chapter 7).

The transfer of loads from the corrugated tube to the enclosing soil takes place through the grout injected into the hole. Spreaders ensure that the anchors are centred in the hole and are provided with a minimum cover. The anchor capacity can be improved by reinjection. The choice of one of the reinjection systems described in chapter 2 is made according to the nature of the soil or the cracking and stratification condition of the rock. The necessary reinjection pipes are fixed to the outside of the anchor encapsulation.

Apparent free length l_{fr}

Here again, theoretical free lengths of less than 7.00 m must be avoided (see chapter 7). The strands are greased and individually coated in polyethylene (PE) over the free length.

Choice of tendon

The choice of tendon is made in accordance with table 3.1 (sections and anchor loads) on the basis of the P_p acceptance test required for stressing tests.

Choice of anchorage

The details and information concerning the choice of suitable anchorage are given in chapter 5.

Reinjection / Regrouting

The reinjection systems described in chapter 2 are also applicable to all permanent anchors.

3. VSL permanent anchors Category K1



3.2 Table of VSL permanent anchor loads

Breaking load	Load for acceptance tests	Load for suitability tests	Anchor lock-off load	Weight of strands	Steel section	Number and individual sections of strands	Anchorage unit	Max. diameter of standard anchor		
								TM without RI	TR without RI TM with RI	TR with RI
$R_i = P_{tk} = A_p \cdot f_{tk}$ (kN)	$P_p \leq 0.75 P_{tk}$ (kN)	$P_{pv} \leq A_p \cdot 0.95 f_y$ (kN)	$P_o \leq 0.6 P_{tk}$ (kN)	(kg/m)	A_p (mm ²)			mm	mm	mm
364	273	311	218	1.6	200	2 x 100	5-3	85	90	95
546	409	467	327	2.4	300	3 x 100	5-3	85	90	95
728	546	623	436	3.1	400	4 x 100	5-4	85	90	95
910	682	779	546	3.9	500	5 x 100	5-7	85	95	95
1'092	819	934	655	4.7	600	6 x 100	5-7	85	95	95
1'274	955	1'090	764	5.5	700	7 x 100	5-7	95	100	105
1'456	1'092	1'246	873	6.3	800	8 x 100	5-12	105	110	115
1'638	1'228	1'402	982	7.1	900	9 x 100	5-12	105	110	115
1'820	1'365	1'558	1'092	7.9	1000	10 x 100	5-12	115	120	125
2'002	1'501	1'713	1'201	8.6	1100	11 x 100	5-12	115	120	125
2'184	1'638	1'869	1'310	9.4	1200	12 x 100	5-12	115	120	125
2'366	1'774	2'025	1'419	10.2	1300	13 x 100	5-19	125	130	135
2'548	1'911	2'181	1'528	11.0	1400	14 x 100	5-19	125	130	135
2'730	2'047	2'337	1'638	11.8	1500	15 x 100	5-19	125	130	135
2'912	2'184	2'492	1'747	12.6	1600	16 x 100	5-19	125	130	135
3'094	2'320	2'648	1'856	13.3	1700	17 x 100	5-19	125	130	135
3'276	2'457	2'804	1'965	14.1	1800	18 x 100	5-19	125	130	135
3'458	2'593	2'960	2'074	14.9	1900	19 x 100	5-19	125	130	135
3'451	2'588	2945	2070	15.6	1950	13 x 150	6-19	150	155	160
3'717	2'787	3'172	2'230	16.8	2100	14 x 150	6-19	150	155	160
3'982	2'986	3'398	2'389	18.0	2250	15 x 150	6-19	150	155	160
4'248	3'186	3'625	2'548	19.2	2400	16 x 150	6-19	150	155	160
4'513	3'385	3'851	2'708	20.4	2550	17 x 150	6-19	150	155	160
4'779	3'584	4'078	2'867	21.6	2700	18 x 150	6-19	150	155	160
5'044	3'783	4'305	3'026	22.8	2850	19 x 150	6-19	150	155	160

Tab. 3.1

RI = single or repeated reinjection / regrouting
 TM = anchor in soil
 TR = anchor in rock

Comments:

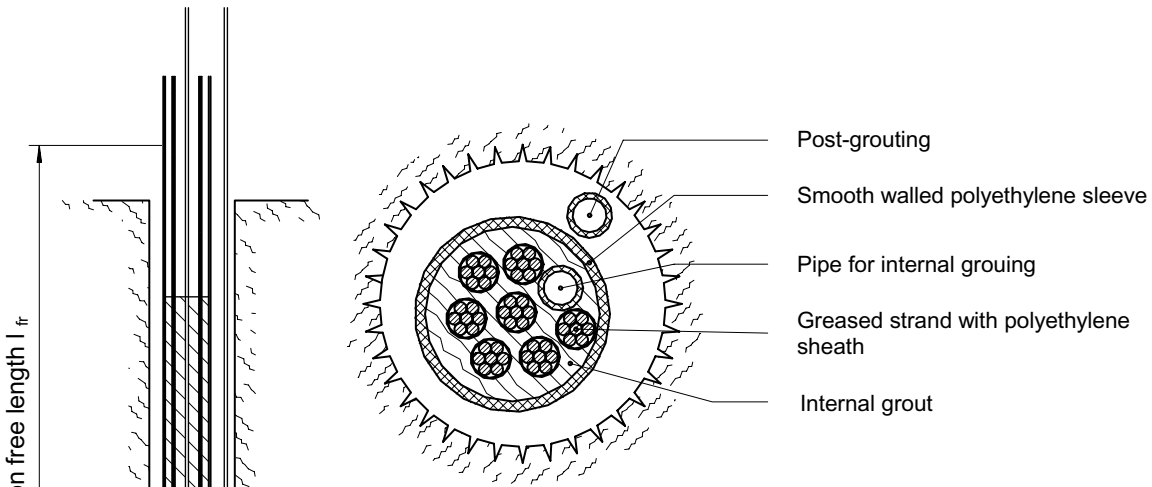
- ∞ The problem-free installation of an anchor is dependent on the diameter of the borehole and the formed hole for the passage of the drilling rods. These diameters should be at least 20 mm greater than the maximum diameter of the anchor.
- ∞ The diameter of anchors inclined upwards in rock as well as anchors with multiple reinjection can be provided on request.
- ∞ **Type 6-19 anchor has not been examined by the GEA group of experts and should only be used as a test anchor.**

3.3 VSL permanent anchors in soil, inclined downwards

3. VSL permanent anchors Category K1



Section through the l_{fr} apparent free length



Section through the l_v bond length

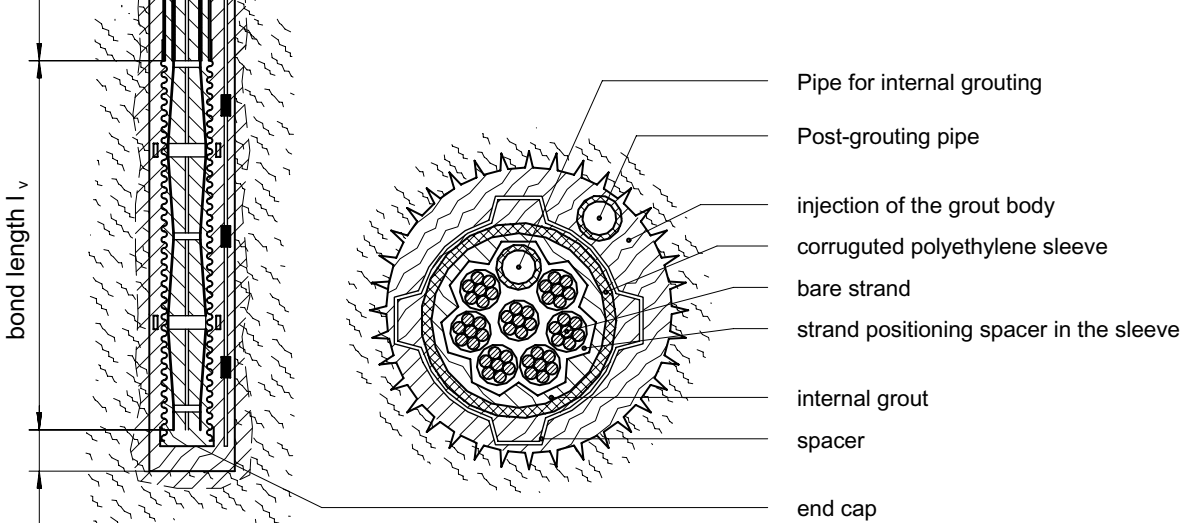


Fig. 3.2

The choice of anchor category (steel section, number of strands, etc.) is made in accordance with Table 3.1 giving the sections and anchor loads on the basis of the P_p load performance demanded for tendon acceptance tests.

These anchors can be equipped with one of the reinjection systems described in paragraph 2.1. The above diagram represents the normal situation, being simple reinjection.

3.4 VSL permanent anchors in rock, inclined downwards

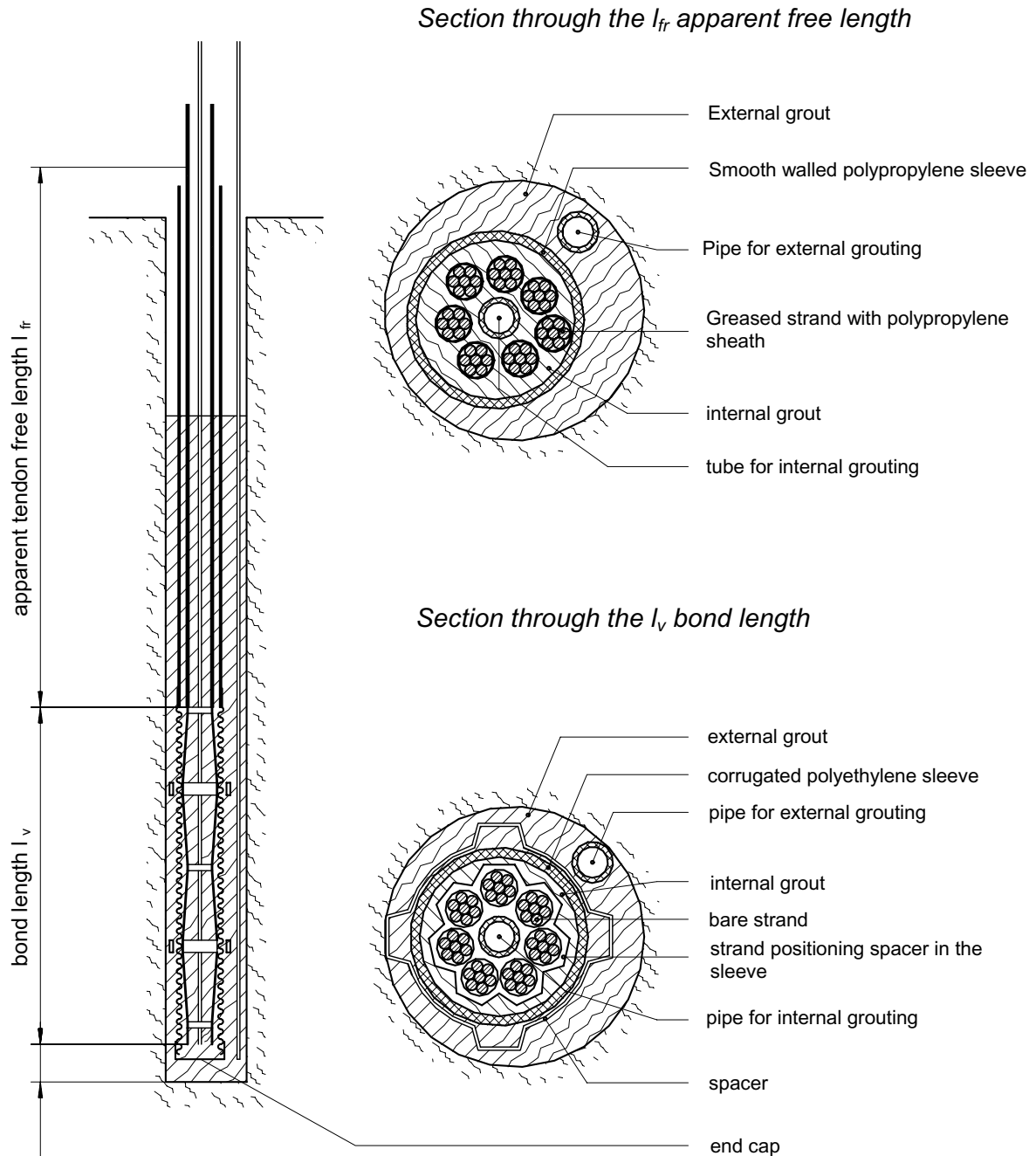


Fig. 3.3

The choice of anchor category (steel section, number of strands, etc.) is made in accordance with Table 3.1 giving the sections and anchor load on the basis of the P_p load performance demanded for tendon acceptance tests.

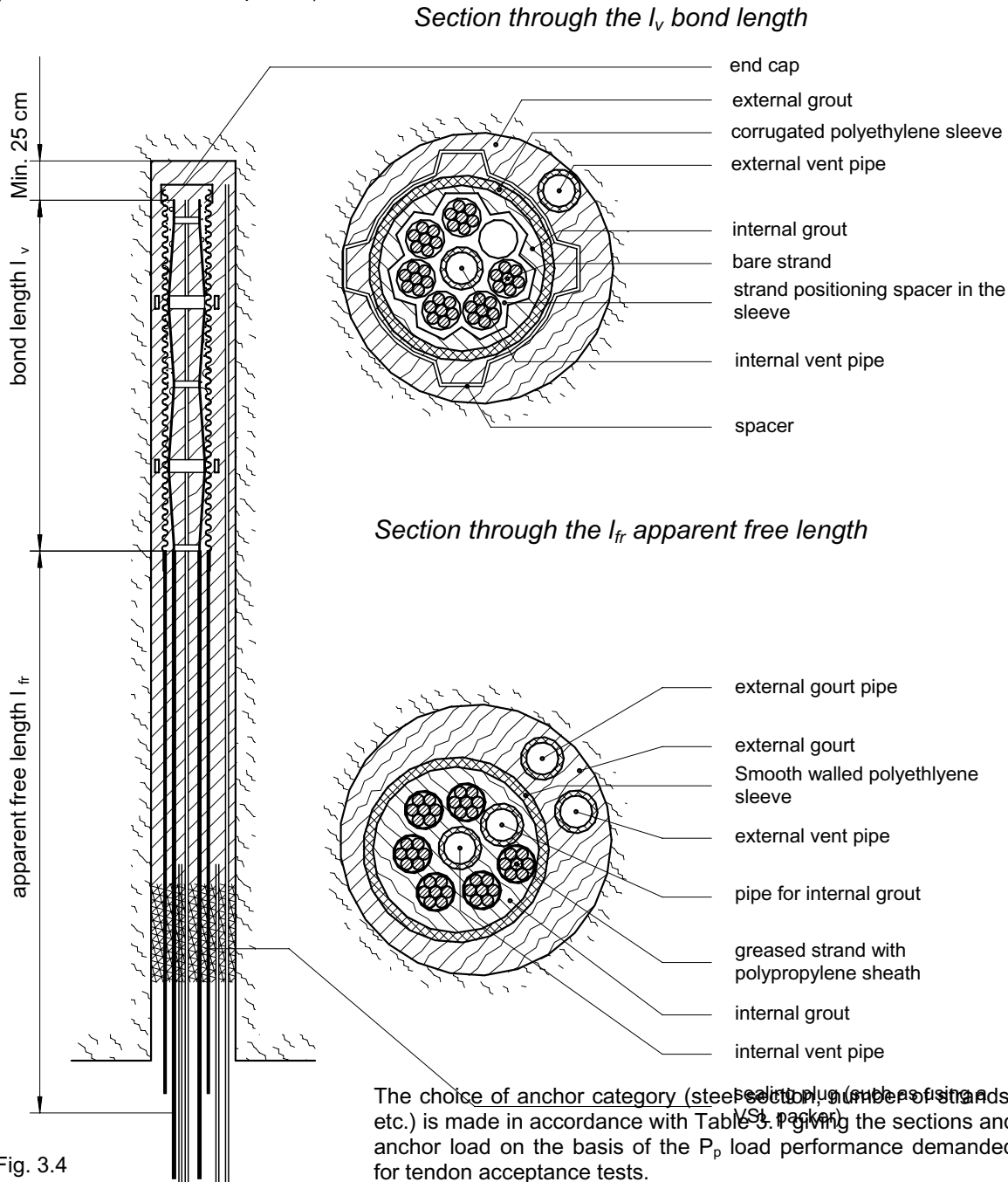
These anchors can be equipped with one of the reinjection systems described in paragraph 2.1. The above represents the normal situation, being simple reinjection.

3. VSL permanent anchors Category K1



3.5 VSL permanent anchors in rock, inclined upwards

(further information in chapter 10)



These anchors can be equipped with one of the reinjection systems described in paragraph 2.1. The above diagram represents the normal situation, being simple reinjection.

4. VSL anchorages for temporary anchors Categories K2 and K3



- 4.1 Generalities
- 4.2 Overview of the types of VSL anchorages for temporary anchors
- 4.3 Standard VSL anchorage elements for temporary anchors
- 4.4 Options for temporary anchorages
- 4.5 Generally used construction details

4. VSL anchorages for temporary anchors Categories K2 and K3



4.1 Generalities

Figure 4.1 provides an overall view of the main fields of application and the implementation variants of VSL temporary anchors heads.

The dimensioning of the bearing plates (and spirals) is based on the following data:

1. Maximum spacing of the steel support beams or trapezoidal wedges in accordance with Table 4.3
2. Diameter of the trumpet for the passage of VSL anchors in accordance with table 4.5
3. Minimum value of 23 N/mm² for the concrete compression resistance (B 35/25) of the bearing structure at the time the anchors are stressed (P_p acceptance test).

The strands must extend beyond the anchor head to permit the anchors to be tensioned. They must therefore be protected from mechanical deterioration and contamination from mortar, concrete or welding slag. Post-tensioning corrections are possible as long as the strands have not been cut. The strands protruding beyond the head shall only be cut after tensioning if other subsequent operations, such as retensioning, detensioning or anchorage load tests are not to be carried out (information concerning the over-length of strand see chapter 6).

In the case of extractable anchors, the strands extending beyond the anchor head shall not be cut as they are required for the extracting operations.

If the strands have already been cut, the anchor can also be detensioned by cutting the strands at the rear of the bearing plate using a cutting torch. This procedure does not present a problem in the presence of or metal posts. In the case of supports on concrete, this operation is simplified by the use of bearing plates with slots.

The draw-in of the wedges inherent in the tensioning is 6 mm. For further details concerning the tensioning procedure, refer to the following document: "VSL strand post-tensioning system".

Corrosion protection

In the case of temporary anchors with limited corrosion protection (category K2), the anchorage elements exposed to bad weather conditions can be provided with an anti-corrosion coating.

4. VSL anchorages for temporary anchors Categories K2 and K3



4.2 Overview of the types of VSL anchorages for temporary anchors

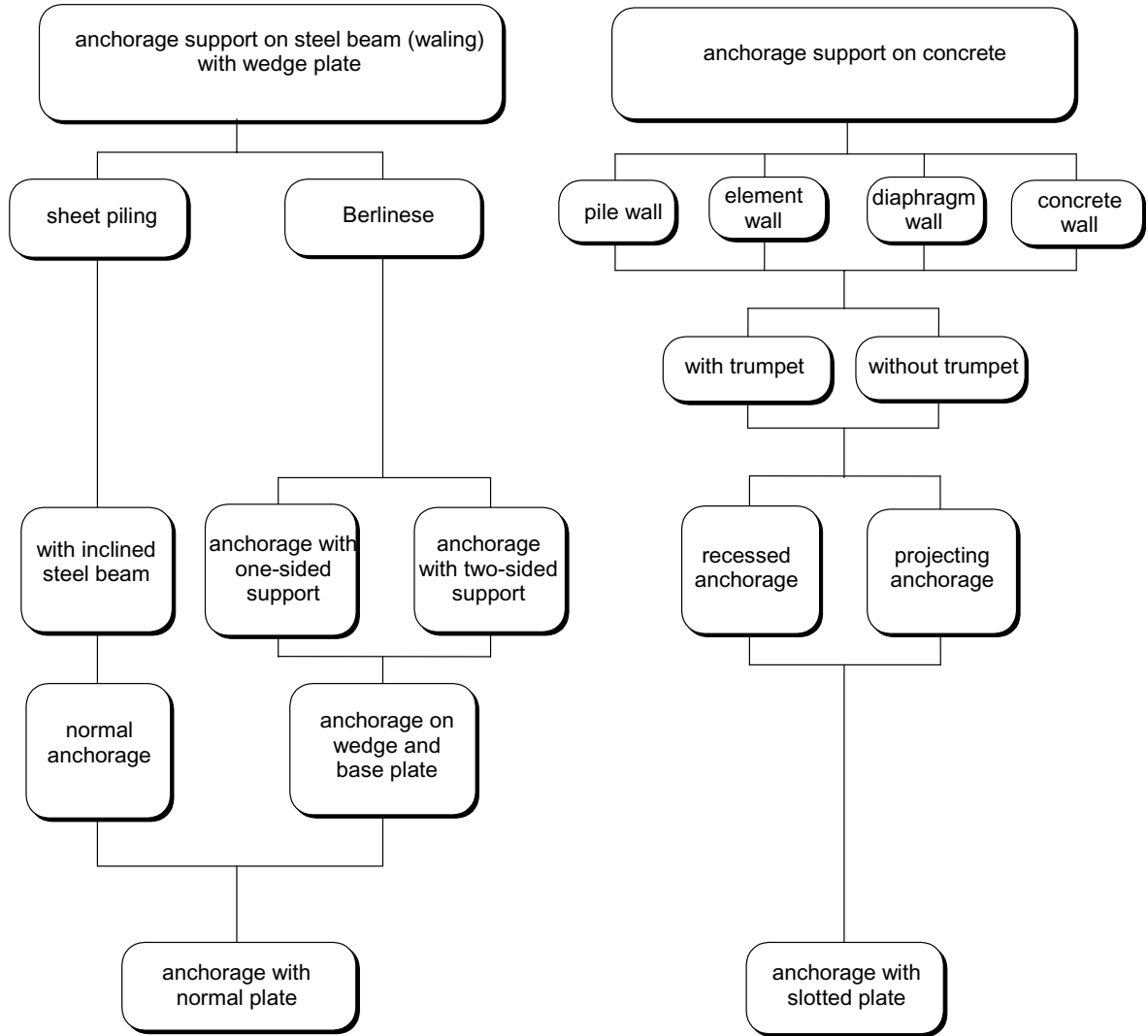


Fig. 4.1

4. VSL anchorages for temporary anchors Categories K2 and K3



4.3 Standard VSL anchorage elements for anchors

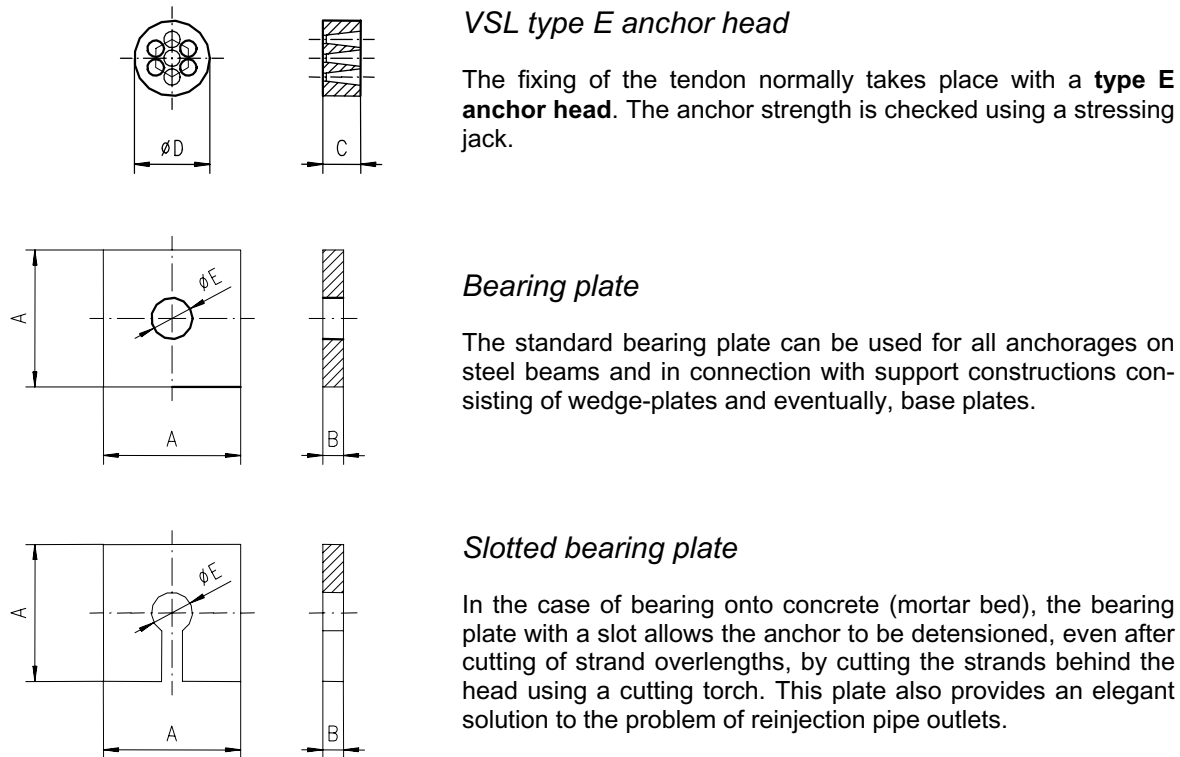


Fig. 4.2

Anchorage type	Bearing plate		Central hole	Width of slot	Anchor head		Spacing of ground beams or frames plate without slot
	A	B	Ø E		Ø D	C	
5-3	190	30	50	30	90	50	80
5-4	220	35	56	30	95	50	80
5-7	250	35	74	35	110	55	95
5-12	300	40	104	40	150	60	125
5-19	380	45	135	40	180	75	150
6-2	190	30	50	30	90	50	80
6-3	220	35	56	30	95	50	80
6-4	230	35	65	30	110	55	95
6-7	290	40	84	35	135	60	110

Tab. 4.3

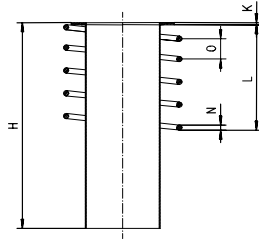
all dimensions in mm

4. VSL anchorages for temporary anchors Categories K2 and K3

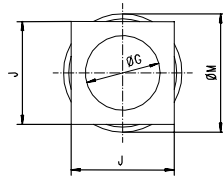


4.4 Options for temporary anchorages

4.4.1 VSL external trumpets for passing through structures



The installation of VSL external trumpets, similar to the trumpets for VSL permanent anchors, in the structure to be anchored means that drilled holes through the concrete and reinforcements can be avoided. The trumpet, with front metal flange and spiral reinforcement, provides a passage for drilling rods and ensures the correct perpendicular positioning of the bearing plate.



When drilling through structures that already exist, such as piles, diaphragm walls, etc., we can, on request, provide trumpets without spirals. The flange serves as a positioning base for the bearing plate as well as an auxiliary element for concreting the anchor end block.

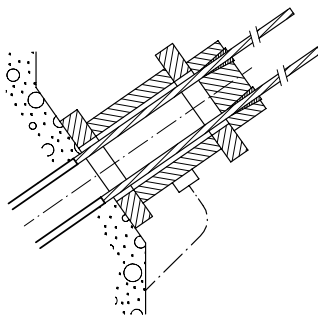
Fig. 4.4

		5-3	5-4	5-7	5-12	5-19	6-2	6-3	6-4	6-7
External trumpet	Ø G	145	145	145	145	177	145	145	145	145
	H	400	400	400	400	550	400	400	400	400
Flange	J	230	260	280	330	420	230	260	280	330
	K	4	4	4	4	4	4	4	4	4
Spiral	L	200	200	250	300	350	200	200	250	300
	M	230	230	255	340	410	230	230	255	340
	Ø N	10	10	12	14	14	10	10	12	14
	O	50	50	50	50	50	50	50	50	50

Tab. 4.5

all dimensions in mm

4.4.2 Control anchors, surveillance anchors



On condition that the strands extend sufficiently from the head, the anchorage load can be checked using a stressing jack (standard control anchor).

The installation of a load cell between the head and the bearing plate (sandwich construction) turns the anchor into a measurement anchor (see figure 4.6).

Abb. 4.6

4.5 Most common construction details

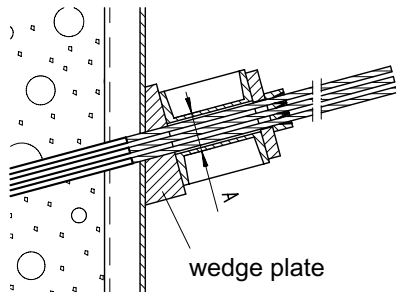
4. VSL anchorages for temporary anchors Categories K2 and K3



Checking the structural safety of the anchor bearing is carried out in accordance with the SIA 161 Metal Constructions standard.

4.5.1 Anchoring of a sheetpile wall (or soldier pile / Berlinese retaining wall) using steel beams (waling)

Inclined steel beam



The steel beams are fixed to wedge plates welded to sheet-piles. They permit the installation of the bearing plates perpendicular to the axis of the anchors.

The transmission of loads behind the anchor head should be checked. It is generally necessary to provide for stiffeners. Spacing A of the steel beams is dictated by the central hole in the bearing plate and the diameter of the drilling tools. The use of standardised VSL bearing plates implies that the spacing of steel beams does not exceed the G values given in Table 4.3.

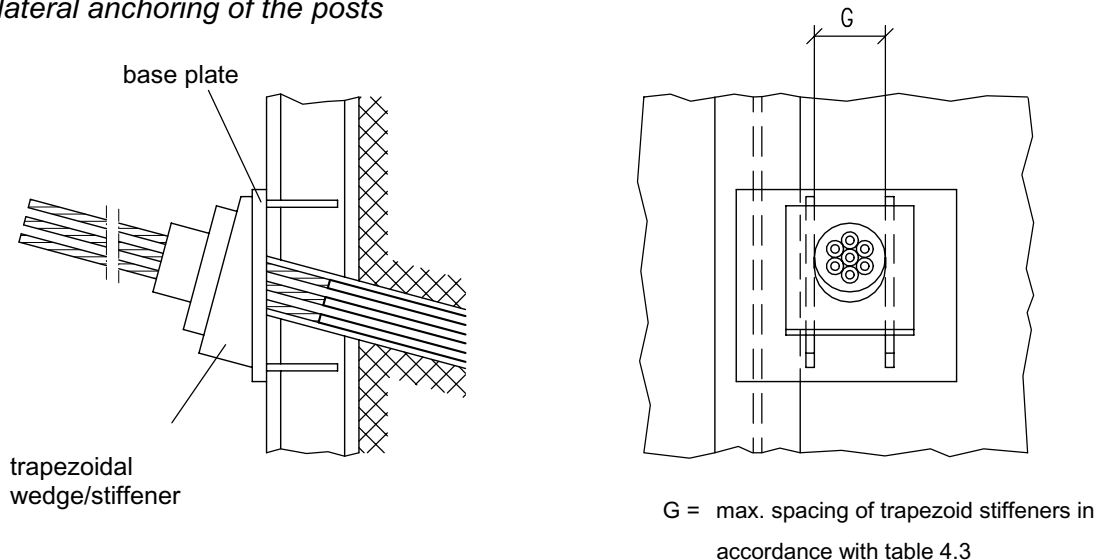
This solution is particularly recommended for sheetpile facings, given that, in any case, each sheetpile needs to be braced on the steel beams.

Fig. 4.7

4.5.2 Anchoring of a soldier pile / Berlinese retaining wall without steel beams

The anchorage force is transmitted to the base plate and the wall by the intermediary of the bearing plate and the trapezoid stiffeners. The latter assure the positioning of the bearing plate perpendicular to the anchor axis. A bilateral anchorage of the posts is also possible.

Unilateral anchoring of the posts



G = max. spacing of trapezoid stiffeners in accordance with table 4.3

Fig. 4.8

4. VSL anchorages for temporary anchors Categories K2 and K3



4.5.3 Anchoring of a pile wall or a diaphragm wall

Unless external trumpets have been first encased in the concrete, the placing of the anchors implies drilling through the structure.

The anchorage can either be recessed or project from the wall alignment. In both cases, the bearing plate should be placed on a mortar bed. In this case, it is worthwhile using a trumpet outside the anchor with a flange.

The compression resistance of the mortar should reach at least 25 N/mm^2 , when the P_p acceptance test is carried out.

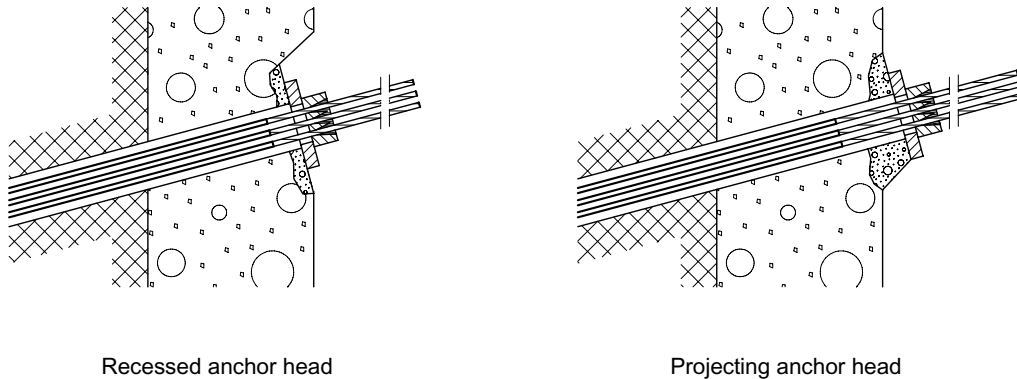


Fig. 4.9

4.5.4 Anchoring using previously encased VSL external trumpets

Drilling through the concrete and the reinforcements of the structures to be anchored, such as distribution beams, miscellaneous supports, underpinning walls, etc. can be avoided by first installing VSL trumpets (Table 4.5).

These trumpets meet two functions. On the one hand, they permit the passage of drilling tools and, on the other, thanks to their spiral, assure the take-up of lateral tensile forces in the area where the load is to be introduced (anti-bursting). The flange acts as a base for the precise perpendicular positioning of the bearing plate.

The compression resistance of the concrete must attain a minimum of 23 N/mm^2 (B35/25) at the moment that the P_p acceptance test is carried out.

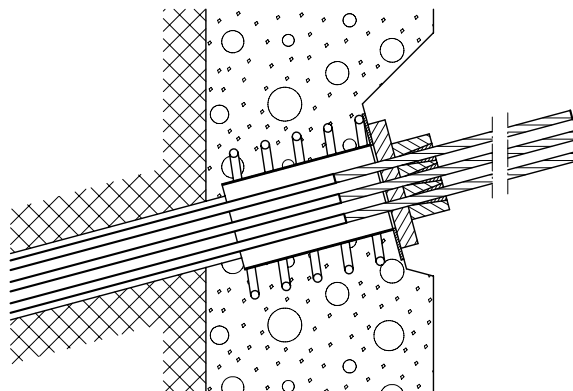


Fig. 4.10

4. VSL anchorages for temporary anchors Categories K2 and K3



5. VSL anchorages for permanent anchors Category K1



5.1 Generalities

5.2 Types of VSL anchorages for permanent anchors

5. VSL anchorages for permanent anchors Category K1



5.1 Generalities

Introduction

The dimensioning of the bearing plate and the spiral is based on a concrete compression resistance of at least 27 N/mm^2 (B 40/30) at the moment of stressing (P_p acceptance test).

The wedge draw-in inherent in the stressing is 6 mm. For further details concerning the tensioning procedure, refer the document: "VSL strand post-tensioning system".

For anchors where the head is to be encased in concrete, it is recommended that a minimum strand protrusion be retained in order to, exceptionally, measure (after demolition of the recess concrete) the existing anchorage load by head lift-off using a stressing jack.

Anchor type 6-19 has not been examined by the GEA group of experts and should only be used as a test anchor.

Corrosion protection

The corrosion protection measures correspond to category K1 protection level (comprehensive corrosion protection).

- ∄ Elements exposed to bad weather are protected by a coating.
- ∄ The annular space between the interior and exterior trumpet is cement grouted and the interior space filled with an anti-corrosion grease.
- ∄ An insulation plate ensures the electrical insulation between the structure and the anchor. It is placed between the anchor head and the bearing plate.

5.2 Types of VSL anchorages for permanent anchors

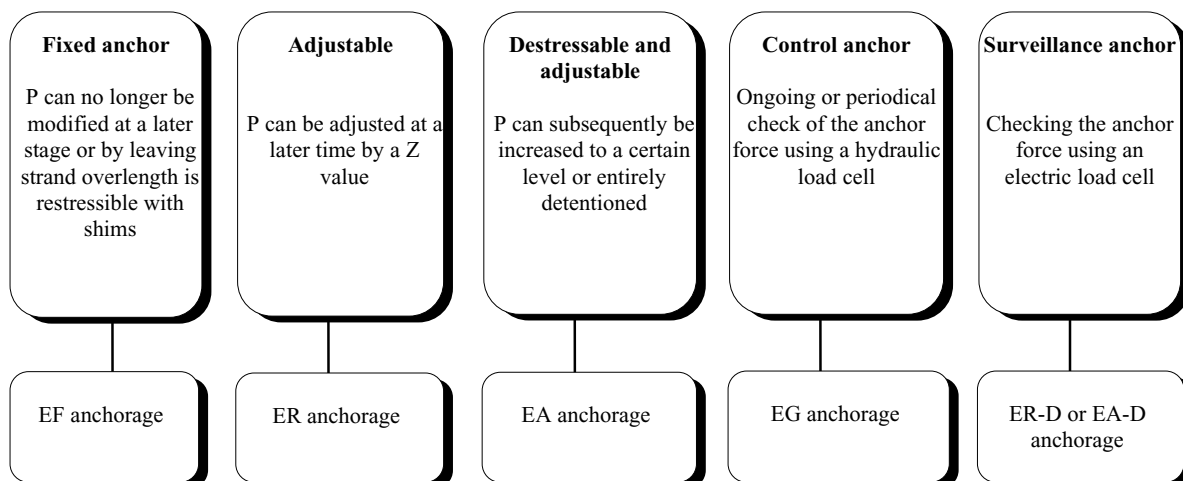


Fig. 5.1

5. VSL anchorages for permanent anchors Category K1



5.2.1 VSL type EF (fixed type, encased in concrete or visible)

The external trumpet with welded flange and spiral is placed in the part of the structure to be anchored. When drilling is carried out after construction of the structure to be anchored, the trumpet provides free passage for the drilling tools. The flange permits the exact positioning of the bearing plate, perpendicular to the anchor axis.

Where the head is to be encased in concrete, the protection cap is filled with anti-corrosion grease prior to the recess being concreted. A minimal strand projection will permit an exceptional verification (after demolition of the recess concrete) of the anchorage load using a tensioning jack.

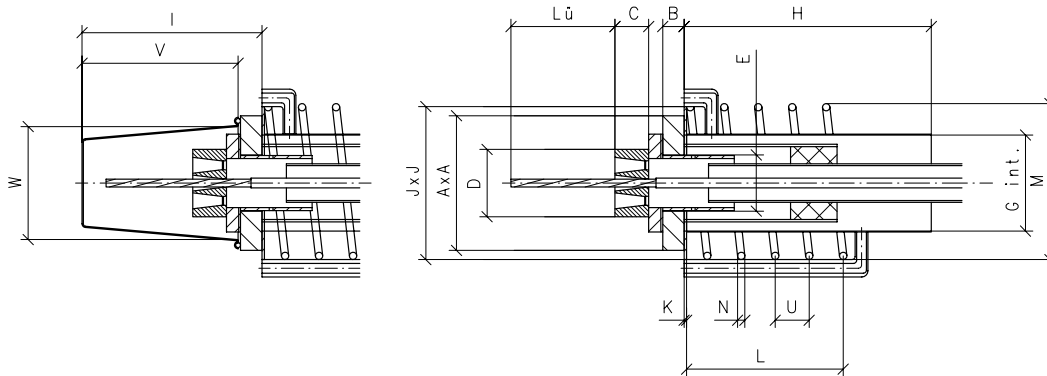


Fig. 5.2

Dimensions of the standard type EF anchorage							
		5-3	5-4	5-7	5-12	5-19	6-19 *
bearing plate	A	200	200	230	300	350	410
	B	30	30	35	45	50	60
	E Ø	77	77	92	112	142	162
anchor head	C	50	50	55	60	75	95
	D Ø	90	95	110	150	180	200
external trumpet	G Ø	145	145	157	197	197	222
	H	400	400	450	550	700	700
	J	230	230	270	350	400	460
	K	4	4	4	4	4	4
spiral	L	200	200	250	300	350	400
	M Ø	230	230	255	340	410	465
	N Ø	10	10	12	14	14	16
	U	50	50	50	50	50	50
protection cap	V	260	260	260	260	300	350
	W Ø	135	135	185	220	260	345
height of the anchor head	I	290	290	295	305	350	410
strand projection	L ü	160	160	160	160	180	200

Table 5.3

Measurements in mm
*) EF 6-19 only as test anchor

5. VSL anchorages for permanent anchors Category K1



5.2.2 VSL type ER (adjustable)

The head of the anchorage type ER is similar to type EF. The only difference is that the outside of the anchor head has a thread on which a nut is assembled. Subsequent tensioning or detensioning of the tensioning force is possible within the limits of a displacement Z. The strand projection must be sufficient to permit checking or adjustment operations using the stressing jack.

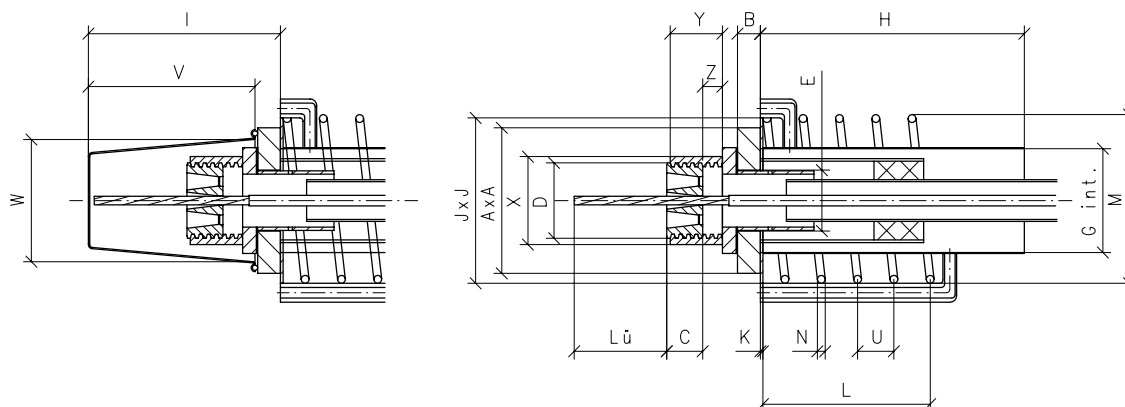


Fig. 5.4

Dimensions of the standard type ER anchorage (adjustable)		5-3	5-4	5-7	5-12	5-19	6-19 *
bearing plate	A	200	200	230	300	350	410
	B	30	30	35	45	50	60
	E Ø	77	77	92	112	142	162
anchor head	C	50	50	55	60	75	95
	D Ø	90	95	114	150	180	210
nut	X Ø	108	114	140	178	219	254
	Y	75	80	90	100	115	130
adjustment	Z	40	40	40	40	40	40
external trumpet	G Ø	145	145	157	197	197	222
	H	400	400	450	550	700	700
	J	230	230	270	350	400	460
	K	4	4	4	4	4	4
spiral	L	200	200	250	300	350	400
	M Ø	230	230	255	340	410	465
	N Ø	10	10	12	14	14	16
	U	50	50	50	50	50	50
protection cap	V	260	260	260	260	300	350
	W Ø	135	135	185	220	260	345
height of the anchor head	I	290	290	295	305	350	410
strand projection	Lü	140	140	130	120	140	170

Table 5.5

Measurements in mm
*) ER 6-19 only as test anchor

5. VSL anchorages for permanent anchors Category K1



5.2.3 VSL type EA (can be detensioned and adjusted)

The head of anchorage type EA permits an adjustment and verification of the anchor load to be carried out at any time using a stressing jack. The external trumpet permits the anchors to be entirely detensioned with an effective free length of up to 30 m.

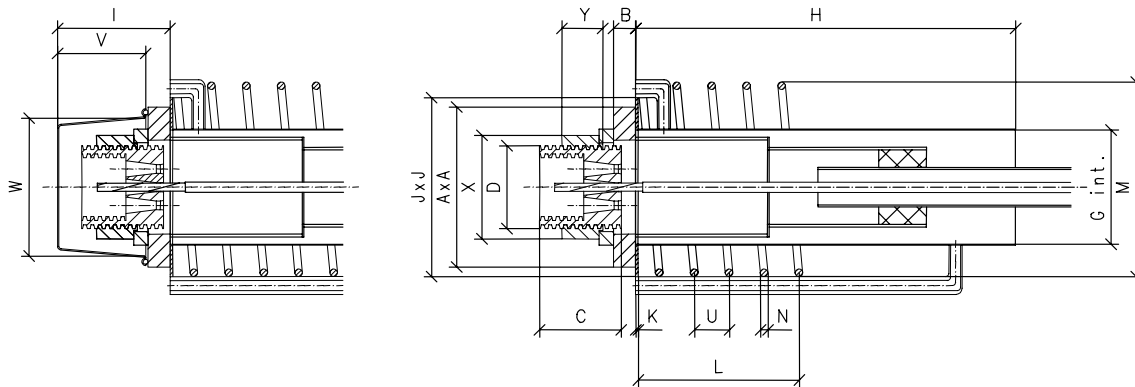


Fig. 5.6

Dimensions of the standard type EA anchorage						
		5-3	5-7	5-12	5-19	6-19 *
bearing plate	A	220	260	320	400	460
	B	30	35	45	50	60
anchor head	C	120	130	130	175	215
	D Ø	97	132	178	226	262
nut	X Ø	125	165	219	273	318
	Y	51	65	65	76	86
external trumpet	G Ø	172	182	247	302	327
	H	600	600	650	800	850
	J	260	300	370	460	520
	K	4	4	4	4	4
spiral	L	250	250	300	400	450
	M Ø	255	310	365	465	520
	N Ø	12	12	16	16	16
	U	50	50	50	50	50
protection cap	V	140	145	145	205	205
	W Ø	185	220	260	345	345
height of the anchor head	I	170	180	190	255	265

Table 5.7

Measurements in mm
*) EA 6-19 only as test anchor

5. VSL anchorages for permanent anchors Category K1



5.2.4 VSL type EG (control anchor)

The EG type anchorage is used where the anchor load must be occasionally monitored. The anchorage corresponds to the type EF head but with external threading on the anchorage head. To carry out the measurements, it is possible to permanently install a VSL type G hydraulic load cell or to screw on a VSL type GW "jumping" load cell. The load cell, connected to a hand operated pump, behaves in the same way as a stressing jack. The reading of the load is made at the moment of lift-off between the anchor head and the bearing plate.

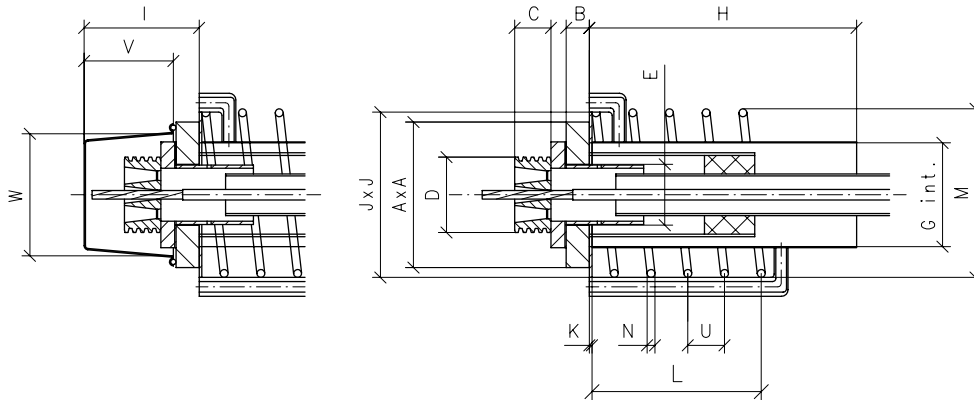


Fig. 5.8

Dimensions of the type EG standard anchorage		5-3	5-4	5-7	5-12	5-19	6-19 *
bearing plate	A	200	200	230	300	350	410
	B	30	30	35	45	50	60
	E Ø	77	77	92	112	142	162
anchor head	C	50	50	55	60	75	95
	D Ø	90	95	114	150	180	210
external trumpet	G Ø	145	145	157	197	197	222
	H	400	400	450	550	700	700
	J	230	230	270	350	400	460
	K	4	4	4	4	4	4
spiral	L	200	200	250	300	350	400
	M Ø	230	230	255	340	410	465
	N Ø	10	10	12	14	14	16
	U	50	50	50	50	50	50
protection cap	V	130	130	140	145	145	205
	W Ø	135	135	185	220	260	345
height of the anchor head	I	160	160	175	190	195	265

Table 5.9

Measurements in mm

*) EG 6-19 only as test anchor

5. VSL anchorages for permanent anchors Category K1



5.2.5 VSL type EG head for control anchors during the checking of the anchor load

EG control anchorage with removable load cell. For anchors placed in recesses, it is necessary to take the necessary free spaces into consideration (see chapter 6).

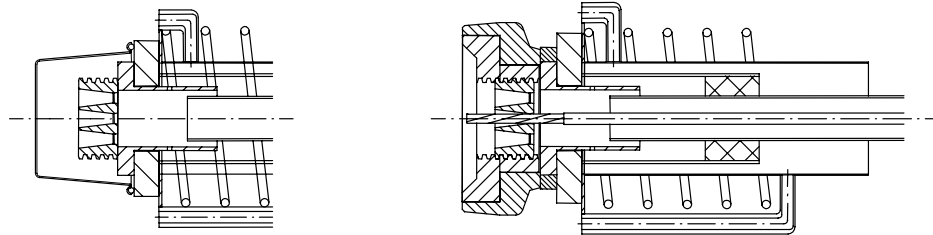


Fig. 5.10

Additional information is provided in chapter 9 Anchor monitoring.

5. VSL anchorages for permanent anchors Category K1



5.2.6 VSL type ER-D and EA-D (surveillance anchors)

The VSL head for surveillance anchors, equipped with an electric load cell, permits periodical or ongoing surveillance of the anchor load. The electric load cell can be dismantled and therefore replaced. Two versions of the surveillance anchor head can be provided.

∅ type ER-D in combination with type ER anchorage permits dismantling and replacement of the load cell without having to detension the anchor.

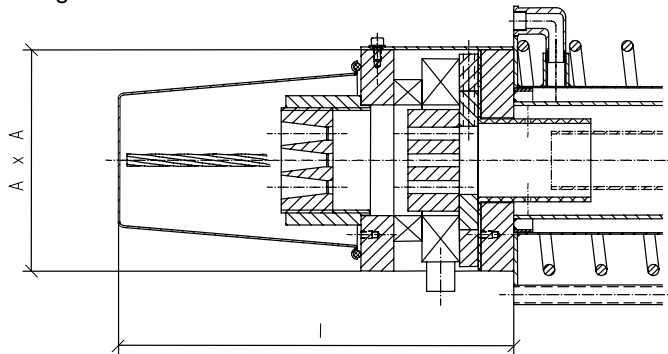


Fig. 5.11

Dimensions of the type ER-D surveillance anchorage							
		5-3	5-4	5-7	5-12	5-19	6-19 *
bearing plate	A	200	200	230	300	350	410
height of the anchor head	l	410	410	420	440	490	560

Table 5.12

Measurements in mm
*) ER-D 6-19 only as test anchor

∅ type EA-D in combination with type EA anchorage requires that the anchor be detensioned to dismantle and replace the load cell.

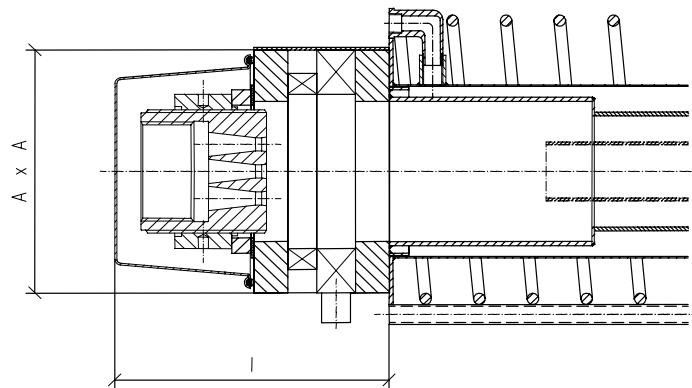


Fig. 5.13

Dimensions of type EA-D surveillance anchorage						
		5-3	5-7	5-12	5-19	6-19 *
bearing plate	A	220	260	320	400	460
height of the anchor head	l	270	285	305	375	395

Table 5.14

Measurements in mm
*) EA-D 6-19 only as test anchor

Additional information is provided in chapter 9.

6. Stressing space requirements and strand over-lengths



6.1 Pockets

6.2 Block-outs and overlengths of strands
for stressing operations

6. Stressing space requirements and strand over-lengths



6.1 Pockets (Blockouts)

The free spaces defined below are necessary for the installation of standard stressing jacks. They are valid for all tensioning operations, simple and comprehensive suitability tests, as well as for subsequent checks of the anchor load using a portable GW type jumping load cell.

The depth of the recess shall ensure a cover of at least 40 mm following subsequent concreting. For heads that remain visible, it is possible to place covers along the alignment of the structure.

The lower face of the recess shall have a slope of at least 5° towards the exterior to allow for water run-off.

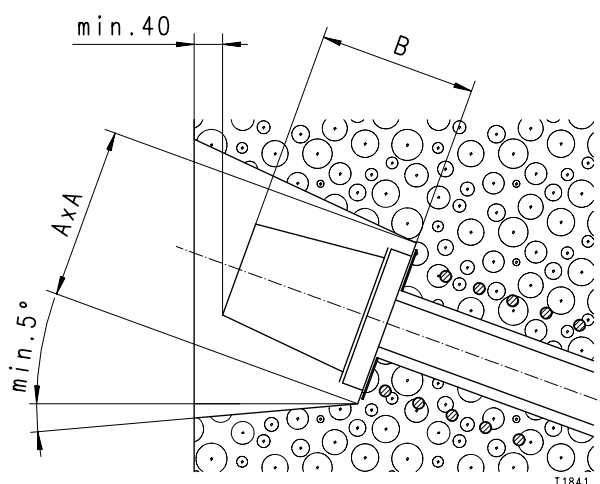


Fig. 6.1

	5-3	5-4	5-7	5-12	5-19	6-19
A (for all types of heads)	300	300	400	440	520	680
B	Height dependent on the type of head see chapter 5.2					

Table 6.2

Measurements in mm

6. Stressing space requirements and strand over-lengths



6.2 Overall dimensions and overlengths of strands for stressing operations

6.2.1 Stressing, including simple acceptance test

During stressing with a simple acceptance test, the measurement of the load is carried out using a pressure gauge. The stressing from zero to P_p can be carried out without the intermediary blocking of the strands up to an elongation of 200 or 300 mm. For specific cases, it is recommended that you contact our specialists.

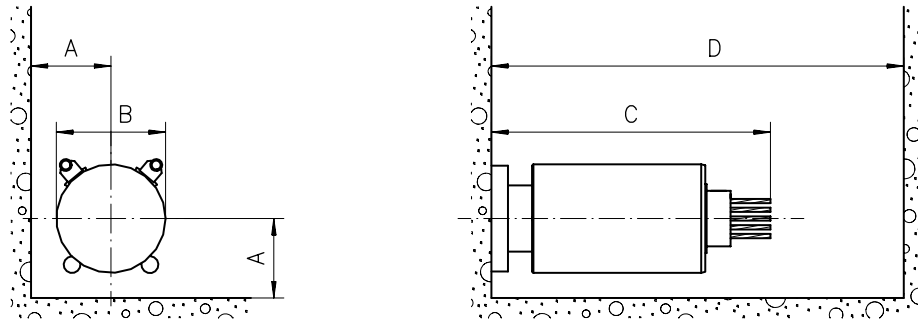


Fig. 6.3

	5-3	5-4	5-7	5-12	5-19	6-19
A	150	150	200	220	260	340
B Ø	200	200	300	350	420	585
C	700	700	850	1100	1150	1150
D	1200	1200	1350	1600	1700	1700

Table 6.4

Measurements in mm

6.2.2 Stressing, including comprehensive suitability test and acceptance tests

During anchor tests and comprehensive tests, it is not possible to carry out intermediate strand blocking. The jacks used must have longer strokes of up to 200 mm or 300 mm. For specific cases, it is recommended that you contact our specialists.

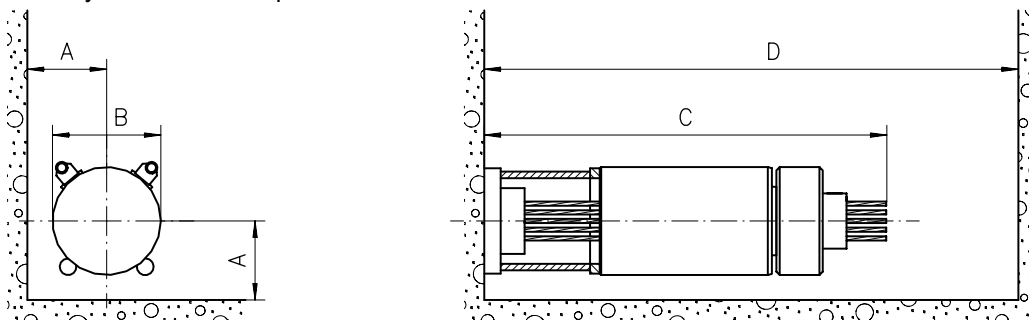


Fig. 6.5

	5 - 3	5 - 4	5 - 7	5 - 12	5 - 19	6 - 19
A	150	150	200	220	260	340
B	200	200	300	350	420	585
C	1000	1000	1250	1700	1800	1800
D	1500	1600	1750	2200	2300	2300

Table 6.6

Measurements in mm

6. Stressing space requirements and strand over-lengths



6.2.3 Extractable anchors

Having tensioned the anchors, it is essential that the strands projecting beyond the head remain in perfect condition. In particular, they must be protected from mechanical damage, welding slag, deformations and buckling. Anchor extraction is not possible if the strands are damaged.

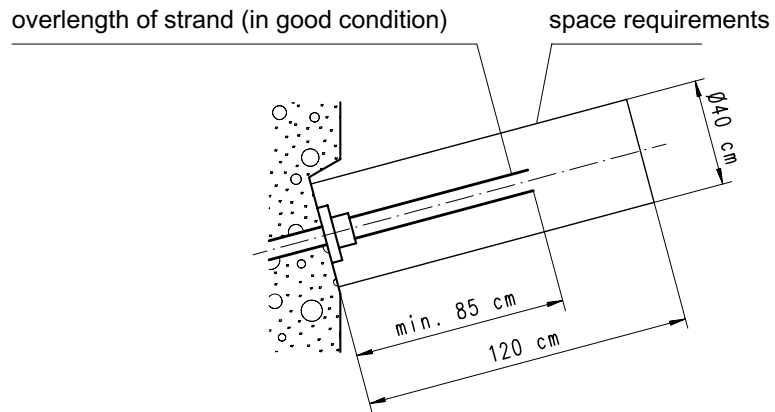


Fig. 6.7

7. Free length and bond length



7.1 Apparent tendon free length l_{fr}

7.2 Effective tendon free length l_f

7.3 Bond length l_v

7.1 Apparent tendon free length l_{fr}

The apparent free length l_{fr} is the length between the anchor head and the beginning of the bond length, as derived from static and soil mechanics calculations.

The necessary apparent free length l_{fr} (and the P_0 transfer force) results from checking the safety and the anchoring suitability of the entire anchored structure.

In order to limit anchor load losses during the period the structure is in use, it might be worthwhile choosing a free length greater than the calculated theoretical length. Generally speaking, the free length should not be less than 7 m.

During stressing, the elongation of the strands in the l_{fr} free length is obstructed by friction inside the sleeve. This frictional force is established during the acceptance test or the comprehensive suitability test. Our experience indicates that the following formula is acceptable:

$$R_{adm} = 15 \text{ kN} + 0.75 \text{ kN/m} \cdot l_{fr}$$

Exceptions are possible for high capacity anchors and for long anchors.

7.2 Effective tendon free length l_f

The effective free length l_f is the length of the part of the tendon that effectively extends in a free manner during stressing. It is established on the basis of stressing suitability tests.

$$l_f (P_p) = \frac{E_p \cdot A_p}{P_p - P_a} \cdot l_{el}$$

The value of the effective free length must be within the following limits:

$$0.9 l_{fr} \leq l_f \leq l_{fr} + 0.3 l_v$$

7.3 Bond length l_v

The bond length is the length over which the load is transmitted to the anchor body. The anchor body transmits the load to the ground.

Having carried out the required test-anchors, the bond lengths valid for the works are set by the project geotechnical engineers in agreement with the contractor. From this moment on, the contractor guarantees the transmission of the anchor load to the anchor body.

The ultimate R_a external resistance must be greater than the ultimate R_i internal resistance of the tendon. In the absence of tensile test results or practical experience within comparable geotechnical conditions, it is possible to use the values given below to estimate the bond length.

A minimum bond length of 3 m is necessary to guarantee the ultimate internal resistance (transmission of strand loads to the injection grout).

Ultimate R_a external resistance and bond length l_v in soil

Type of soil	R_a (kN)	l_v (m)
Normally consolidated clay silt (lacustrine deposits)	150 - 250	4 - 6
Normally consolidated silt (fine sand)	250 - 500	4 - 6
Coarse sand, gravel (alluvial soil)	350 - 600	4 - 7
Super-consolidated silt, fine sand	500 - 900	5 - 8
Coarse sand and compact gravel (slightly agglomerated aggregate)	700 - 1100	5 - 8
Highly compacted mixed soils (ground moraine)	500 - 1200	5 - 8

Ultimate R_a external resistance and bond length l_v in rock

Type of rock	R_a (kN)	l_v (m)
Mollasic marly limestone, slightly weathered	300 - 600	4 - 8
Fine grained mollasic limestone, slightly weathered	400 - 800	4 - 8
Calcareous sandstone, mollasic sandstone, biotite granitic gneiss	800 - 2000	3 - 8
granite, gneiss, hard limestone and hard dolomite	1100 - 5000	3 - 10

The precision of the estimated ultimate external resistance and bedding length values can only be established by tensile tests. The SIA V 191 Recommendation (1995) requires the execution of at least three test anchors per soil area presenting comparable geotechnical characteristics.

8. Anchor tests



- 8.1 Introduction
- 8.2 Anchor test
- 8.3 Stressing performance tests
- 8.4 Measurement of electrical resistance

8.1 Introduction

The following chapters describe the various tests and checks carried out within the framework of anchoring works.

Chapter 8.2: The purpose of the suitability anchor test is to dimension the anchors and define the suitable drilling, grouting and installation methods. The results of these tests provide the basis for evaluating and accepting of the working anchors.

Chapter 8.3: The stressing acceptance test is used to check the capacity and for acceptance of the working anchors. The evaluation bases are provided by the previously carried out suitability anchor tests.

Chapter 8.4 The quality of the corrosion protection is checked by measuring the electrical resistance.

Anchor tests

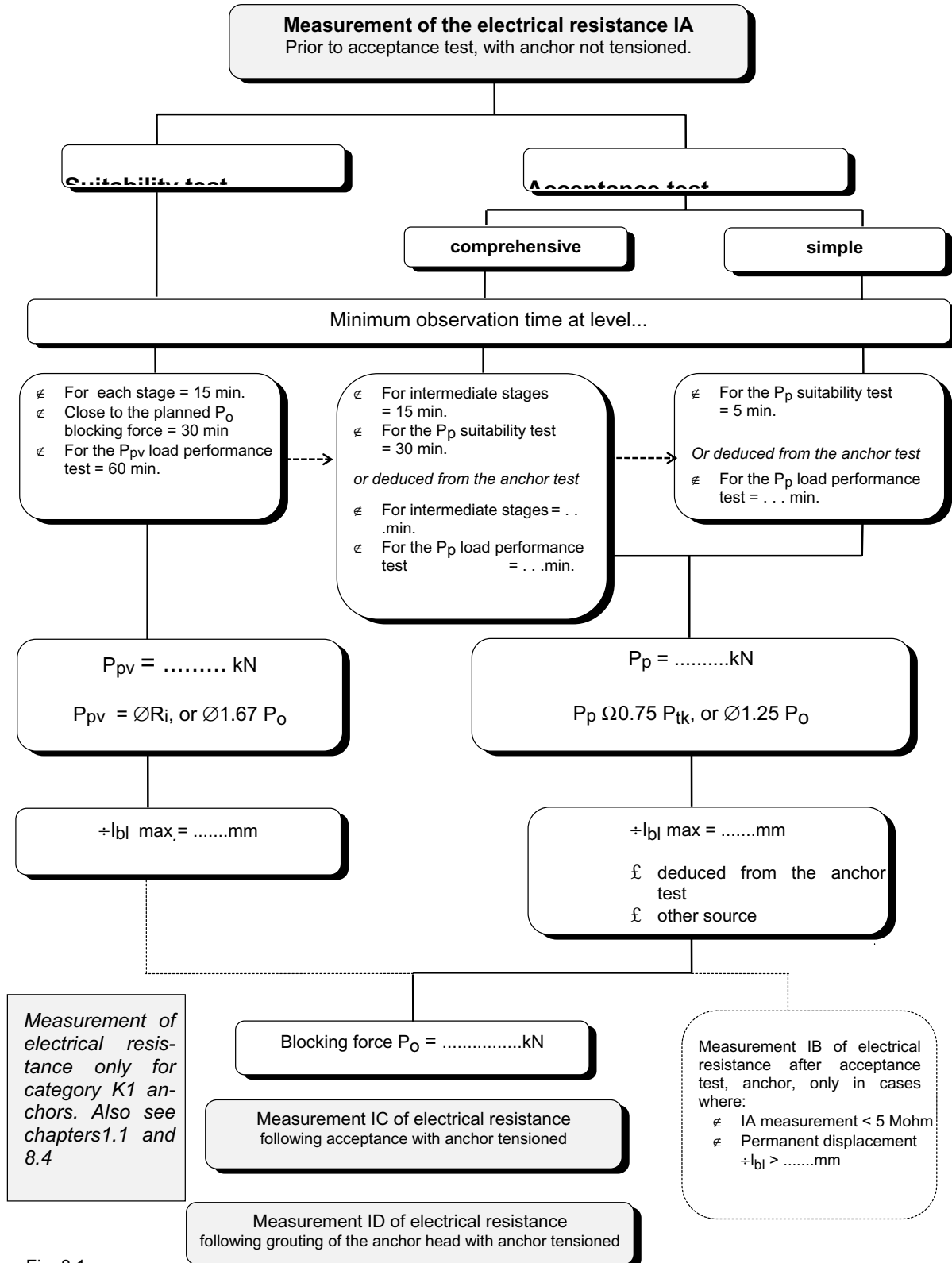


Fig. 8.1

8.2 Anchor suitability test

The aim of the anchor test is to provide the elements necessary to dimension the anchors, particularly the value of the external R_a ultimate resistance that can be attained in a given soil area and the necessary bond length. It also permits the definition of the grouting method, the type of drilling, and the corresponding injection pressures and volumes. The anchor test results provide the basis for evaluation and acceptance of the production working anchors.

The number of test anchors required for the anchoring of a given structure depends on the size of the project, the risks run in the case of anchorage failure and the geotechnical conditions. It is normally necessary to provide for at least three test anchors or 5% per soil type presenting comparable geotechnical characteristics.

8.2.1 The test anchor

Test anchors must have a reinforced tendon in order to be tensioned to $P_{pv} \geq R_i$ of the structure's anchors, respectively $\geq 1.67 \cdot P_0$. For the test, the post-tensioning steel can be stressed up to $0.95 f_y$. Apart from the tendon, the test anchors shall be completely identical to the anchors used in the structure.

In the free length, the annular space between the anchor and the ground, shall have all grout washed away to a minimum of two metres before the bond length in order to avoid transfer of loads from the anchor body into the abutment and to guarantee that the introduction of loads in the ground specifically takes place over the bond length.

8.2.2 Measurements

The values to be measured during the anchor test are the $\pm l$ displacements at the front end of the tendon in parallel with the axis, the $\pm s$ displacements of the bearing plate and the P anchor load. The displacements are normally measured using an indicator mounted on a fixed tripod.

Where it is not possible to use a fixed tripod, such as on scaffolding, the displacement of the anchorage can be measured from the anchor abutment. In this case, it is also necessary to carry out survey measurements in order to monitor the abutment displacements. However, in these conditions, measurements will be less precise.

8.2.3 Level of measurement precision

∅	Establishing the load-deformation curves		
	- displacement	∂	0.20 mm
	- load	∂	2 % of P_{pv}

∅	Establishing the creep behaviour at each stage		
	- displacement	∂	0.05 mm
	- load	∂	0.5 % of P

Readout precision	0.01 mm for the displacement
	1 kN for the load

8.2.4 Performance and evaluation of the anchor suitability test

For the anchor suitability test, an initial force $P_a - (0.1...0.15) P_{pv}$ should be chosen. The range of loads between P_a and P_{pv} shall be divided into a number n of 6 to 10 intervals equal to $\div P$. The displacements reference measurement shall be taken at the level of the initial P_a load. The anchor shall then be successively tensioned to the different load stages:

$$P_1 = P_a + \div P, P_2 = P_a + 2\div P, \text{ etc. up to stage } P_{pv} = P_a + n \cdot \div P$$

At each stage, the load shall be maintained at a constant level to ensure the precision of the measurements, and the position of the anchor head shall be measured at the following times: $t_i = 0/1/2/5/10/15$ min. etc., that is to say at five minute intervals. The bearing plate displacements shall be measured at the same time.

The results shall be incorporated into a creep diagram.

The observation time shall be at least 15 minutes for each stage.

If the anchor meets the creep conditions set for the minimum observation period, it shall be detensioned to level P_a , the permanent displacement measured and the anchor tensioned to the next load stage. During retensioning and without interrupting the process, the $\div l$ displacement value of the preceding stage shall be noted.

At around the level envisaged for P_0 transfer force, the observation time shall be increased to at least 30 minutes. This is in addition to the above-mentioned criteria.

At the P_{pv} test load level, the observation time shall be at least 60 minutes.

The execution of the anchor test is described in detail in appendix 2 of the SIA V 191 Recommendation (1995).

The following pages provide an example of how to establish the test report and evaluate an anchor test.

8. Anchor tests



Project: Tests Nord		Anchor no.: 1B		Stressing Record		FO 3.06 - 03		Page 1 of 2		VSL			
Anchor type: EO 5-76		Category K1 SIA V 101		Jack type: ZPE-7A		Fabr. Nr.: 4013		Load cell type: E 100		Fabr. Nr.: 015			
No. of strands: 6 x 100		mm²		The anchor length: l = 11.0		m		Jack length: l _j = 0.8		m			
Total area A _p : 6000		mm²		The distance between free lengths: l ₀ = 5.0		m		Platen area: = 203.6		cm²			
f _y /f _{yk} : 1840 / 1850		N/mm²		bond length: l _b = 6.0		m		Friction loss: = 5		%			
E-Modulus E _p : 195		kN/mm²		l ₀ + l _b = 11.0		m		Test anchor					
Load stages	Displacement measurements with constant load from a fixed point (mm)												
	kN	0"	1'	2'	3'	4'	5'	6'	7'	8'	9'	10'	11'
P ₀	120	62	0.0	0.00									
P ₁	254	131	6.6	7.70	7.72	7.75	7.76	7.78	7.79				
P ₂	120	62	0.0	0.80									
P ₃	254	131	8.07										
P ₄	388	200	13.3	15.52	15.54	15.56	15.58	15.64					
P ₅	120	62	0.0	1.50									
P ₆	388	200	15.86										
P ₇	522	289	19.9	24.54	24.56	24.60	24.65	24.73	24.78				
P ₈	120	62	0.0	2.64									
P ₉	522	289	25.12										
P ₁₀	656	338	26.6	33.97	34.04	34.10	34.20	34.31	34.40	34.47	34.51	34.53	
P ₁₁	120	62	0.0	3.94									
P ₁₂	656	338	34.92										
P ₁₃	790	407	33.2	44.30	44.38	44.47	44.56	44.66	44.75				
P ₁₄	120	62	0.0	5.38									
P ₁₅	790	407	44.88										
P ₁₆													
P ₁₇													
P ₁₈													

FO300304a.XLS

form. 8.2

8. Anchor tests



Project: Testa Nord		Anchor no.: 18										Test anchor		FO 3.09.03		Page 2 of 2	
Load stages		Displacement measurements with constant load from a fixed point (mm)										Minimum observation time: at $P_1 = 15'$ at $P_2 = 60'$		Creep displacement increase		Conditions	
KN	bar	0'	1'	2'	5'	10'	15'	20'	25'	30'	35'	40'	2-5'	5-15'	15-30'	Condition 1: Control of creep displacement increase (creep value)	
													0.20	0.20		Condition 1 satisfied? <input type="checkbox"/> no <input type="checkbox"/> yes	
P_7																Condition 1 satisfied? <input type="checkbox"/> no <input type="checkbox"/> yes	
P_8																Condition 1 satisfied? <input type="checkbox"/> no <input type="checkbox"/> yes	
P_9																Condition 1 satisfied? <input type="checkbox"/> no <input type="checkbox"/> yes	
P_{10}																Condition 1 satisfied? <input type="checkbox"/> no <input type="checkbox"/> yes	
P_{pv}	924	39.8	55.62	55.74	55.86	56.03	56.15	56.22	56.30	56.35	56.40	56.44	56.49			Condition 1 satisfied? <input type="checkbox"/> no <input type="checkbox"/> yes <input checked="" type="checkbox"/>	
P_4	120	62	8.30	56.53	56.55	56.56	56.58							0.17	0.19	Condition 1 satisfied? <input type="checkbox"/> no <input type="checkbox"/> yes <input checked="" type="checkbox"/>	
P_0	860	340												0.17	0.19	Condition 1 satisfied? <input type="checkbox"/> no <input type="checkbox"/> yes <input checked="" type="checkbox"/>	
Stressed to P_0 on: 17.03.1998		Signed: UOP										Road after: 2' 15'		Condition 2 satisfied? <input type="checkbox"/> no <input checked="" type="checkbox"/> yes <input checked="" type="checkbox"/>			
Condition 2		$f_1 = C \times \Delta u_1 (P_{pv}) = 7.02$ m		Inclination $f_{\text{max}} = 18.75$ kN												Remarks:	
Control of the effective tie length		$f_1 \geq 0.85 l_1 + l_2 = 5.55$ m															
		$f_2 \geq l_1 + 0.5 l_2 + l_3 = 8.80$ m															
Approved on: 04.03.196		Signed: FF1		Tested on: 10.03.1998		Signed: AG		Checked on:		Signed:		Copy to office:		<input checked="" type="checkbox"/>			

form. 8.3



CREEP DIAGRAM

Time / displacement increase graph
for evaluation of creep value
 $k = (l_2 - l_1) / \log(t_2 / t_1)$

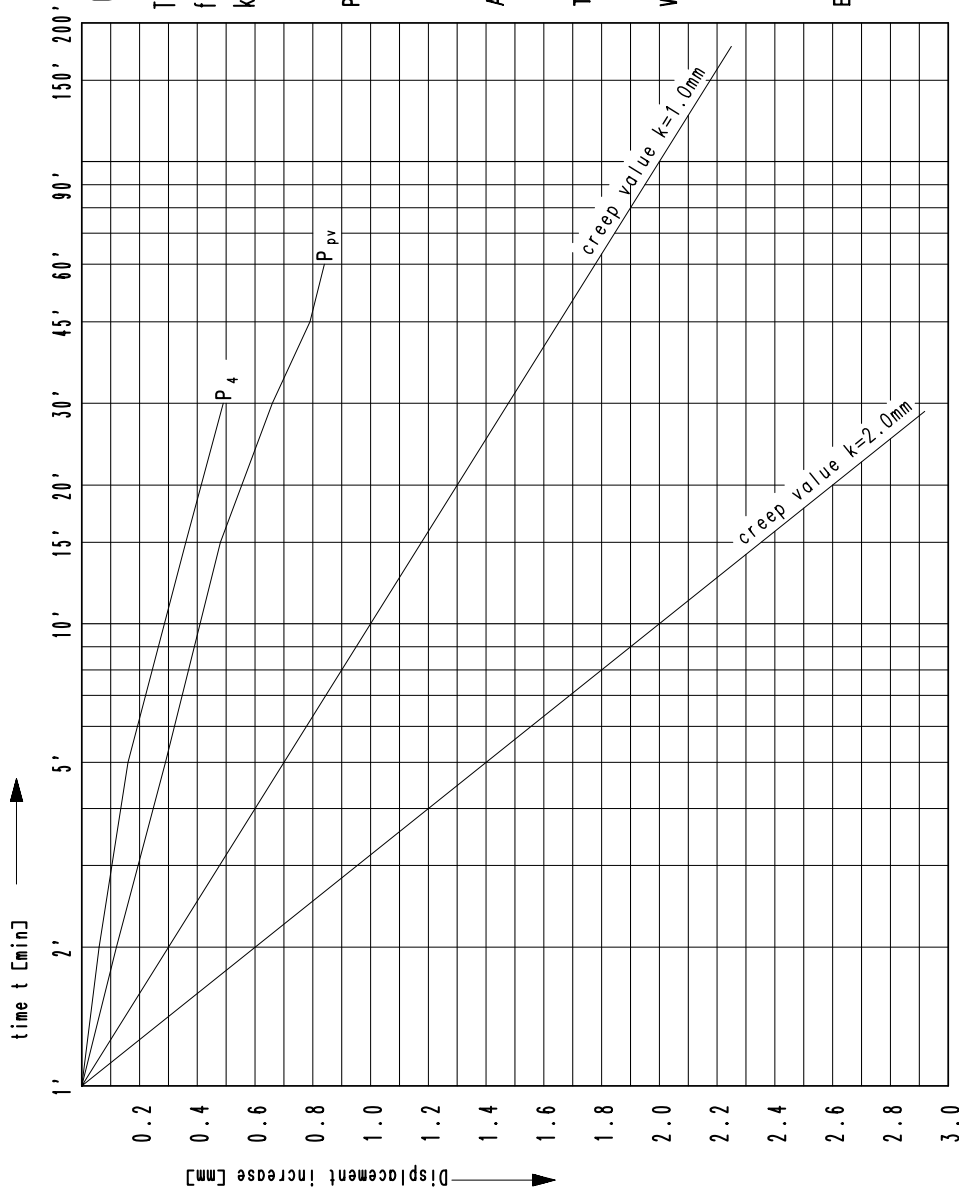
Project: Testa Nord
Anchor Testing

Anchor Nr: 1B

Tested on: 10.03.1998 AC

VSL(Switzerland)AG: *V. J. Long*

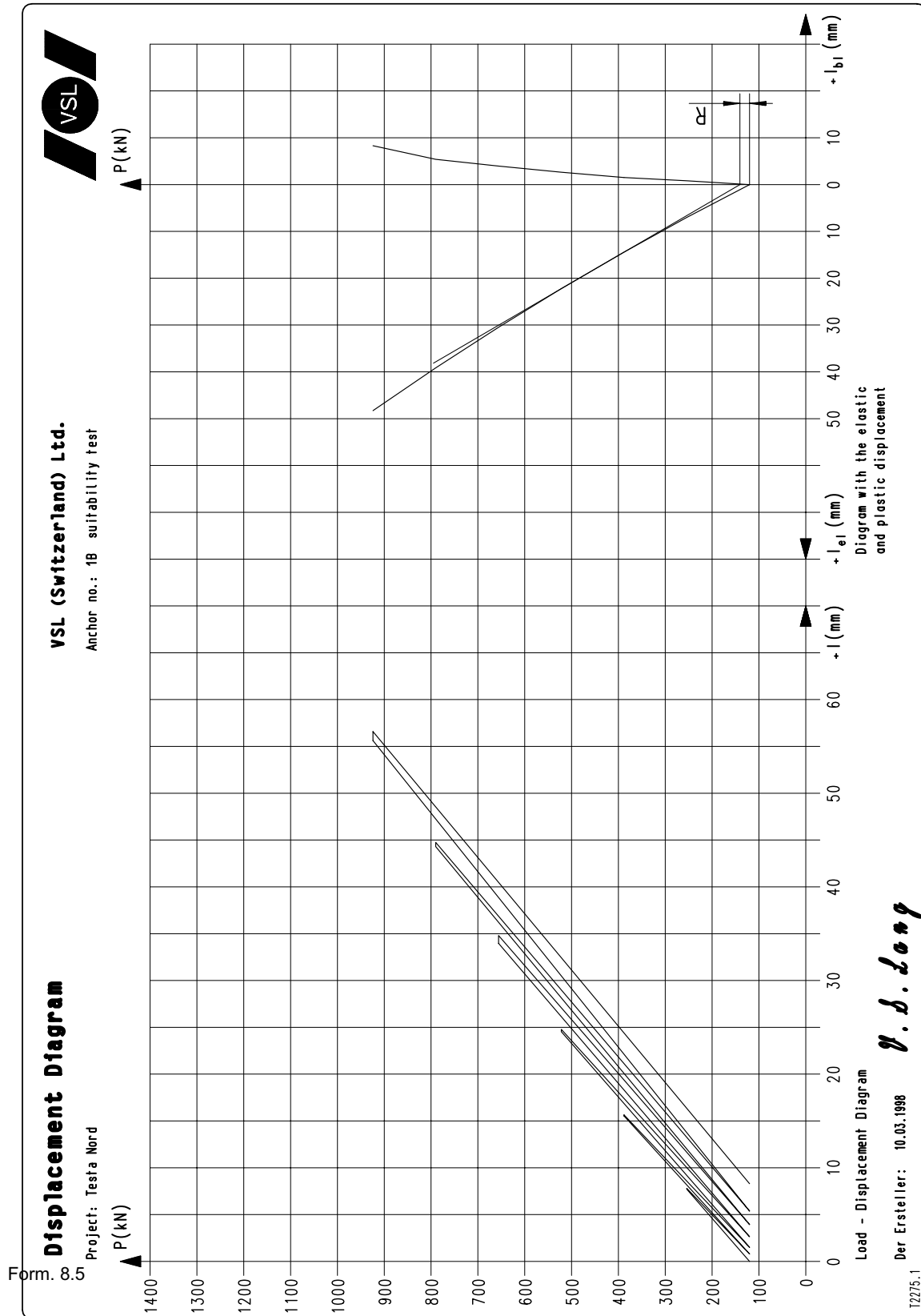
Engineer:



form. 8.4

T1875-2

8. Anchor tests



8.3 Anchor acceptance tests

The aim of the anchor acceptance tests is to control the anchor capacity this being one of the anchor delivery conditions. The necessary basis is provided by first carrying out anchor tests.

All post-tensioned anchors shall be subject to an acceptance test. 10% of all anchors with minimum three shall be subject to a comprehensive acceptance test. As a rule, the remaining anchors shall be subject to a simple acceptance test. For each anchor group, the comprehensive acceptance tests shall take place prior to the simple tests.

The test load is generally $P_p = 0.75 P_{tk}$ and it needs to attain at least $P_p \geq 1.25 P_0$. The levels of precision for acceptance tests are the same as those required by the suitability tests.

8.3.1 Comprehensive acceptance test

The comprehensive acceptance test comprises three loading and unloading stages. The reference displacement measurement shall be carried out at the initial P_a load. The $\pm l$ displacement and the bearing plate displacement shall be measured at each loading stage.

The minimum observation time is normally 15 minutes for the intermediary stages and 30 minutes for the suitability testing force.

If the anchor behaves in accordance with the creep criteria set for the minimum observation period, it shall be detensioned to level P_a , the permanent $\pm l$ displacement shall be measured, and the anchor shall be tensioned to the following stage. During retensioning, the value of the $\pm l$ displacement at the preceding stage shall be noted without interrupting the process. If the anchor also behaves at the level of load P_p in accordance with the set creep criteria and meets all the other conditions, it can be tensioned to load P_0 and blocked at this level.

The carrying out of the extensive tensioning performance test is described in detail in appendix 3 of the SIA V 191 Recommendation (1995).

8. Anchor tests



Project: Testa 800
Anchor type: EG 3-4

FO 3.06 - 02
Stressing Record

Anchor no.: 14
Category K1: SIA V 181

Fabr. No.: 2318
Load cell type: E 103
Fabr. No.: 015

Comprehensive Load Test
 Simple Load Test

No. of strands: 4 x 120 mm ²		Jack type: ZPE 60		Fabr. No.: 2318		Load cell type: E 103		Fabr. No.: 015	
Total area A _c : = 400 mm ²		Total anchor length l = 21.00 m		Jack length l _j = 0.45 m					
l _y / l _z : 1640 / 1020 mm		Applied force per free length l ₀ = 14.00 m		Jack length l _j = 0.45 m					
E-Modulus E _s : = 195 kN/mm ²		Load length l ₀ = 7.00 m		Platten area = 126.4 cm ²					
		l ₀ + l _j = 14.05 m		Friction loss: = 5 %					

Load stages	Displacement measurements with constant load from a fixed point (mm)										Minimum observation time at P ₀ /P ₂ = 15' at P ₀ = 30' when smaller = next stage when in between = wait 10 minutes	Creep displacement increase			Conditions			
	kN	bar	calc.	measured from line t =										2'-5'		6'-16'	15'-30'	Condition 1: control of creep displacement increase (creep value)
P _s	90	75	0.0	0.00	45'	50'	55'	60'	65'	70'	75'	80'	85'	90'	0.15	0.25	0.20	Condition 1 satisfied?
P ₁	240	199	28.2	28.04	28.07	28.09	28.13	28.16	28.18						0.45	0.60	0.40	Condition 1 satisfied?
P _s	90	75	0.0	2.04											0.04	0.05		Condition 1 satisfied?
P ₁	240	19	28.26												creep value k _{adm} = 1.0 mm			no <input type="checkbox"/> yes <input checked="" type="checkbox"/>
P ₂	390	324	56.3	56.86	56.90	56.93	56.96	56.98	56.98						0.03	0.02		Condition 1 satisfied?
P _s	90	75	0.0	3.22											creep value k _{adm} = 1.0 mm			no <input type="checkbox"/> yes <input checked="" type="checkbox"/>
P ₂	390	324	56.79												0.02	0.03	0.03	Condition 1 satisfied?
P _s	90	75	0.0	6.28											creep value k _{adm} = 1.0 mm			no <input type="checkbox"/> yes <input checked="" type="checkbox"/>
P ₀	430	357													0.02	0.02	0.03	Condition 1 satisfied?
Remarks:																		

Installation of load cell type: Fabr. No.: _____

Control of spacing free length: $f_1 \pm 0.3 l_0 + l_j = 13.25$ m; $f_2 \pm l_0 + 0.3 l_0 + l_j = 16.75$ m

Control of spacing free length: $f_1 = C \times A_d / (P_p) = 15.04$ m; $f_2 = \frac{A_p \times E_p}{P_p - P_s} \times 10^{-3} = 0.173$

Condition 3	$f_1 = C \times A_d / (P_p)$	= 15.04 m	Friction factor	= 25.5	kN
Condition 2	Control of the permanent deformation	$\Delta l_{p2} (P_p) = 6.28$ mm	$\Delta l_{p2 adm} \leq 10.00$ mm	- from suitability test <input checked="" type="checkbox"/>	- other <input type="checkbox"/>
Condition 1	Control of creep displacement increase	$\Delta l_{p1} (P_p) = 6.28$ mm	$\Delta l_{p1 adm} \leq 10.00$ mm	- from suitability test <input checked="" type="checkbox"/>	- other <input type="checkbox"/>

Approved on: 14.04.19; Signed: FFI; Tested on: 23.04.1998; Signed: AG; Checked on: _____; Signed: _____

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8.3.2 Simple acceptance test

The simple acceptance test only examines the anchor in terms of the P_p load performance testing. Having observed its creep behaviour, the anchor is detensioned to the level of the initial load and the permanent deformation is measured.

The reference measurement of displacements is also carried out at the level of the initial P_a load. The anchor is then tensioned up to the P_p level. The $\pm l$ displacements at intermediary stages P_1 and P_2 are also measured without interrupting the procedure.

As for the comprehensive acceptance test, the initial P_a load, the P_1 and P_2 intermediary stages as well as the P_p performance testing load are defined.

The observation time at level P_p shall be at least five minutes, on condition that the results of the suitability tests and the comprehensive acceptance tests do not require this period to be longer. The rest of the acceptance test is the same as that used for the comprehensive acceptance test.

The carrying out of the simple acceptance test is described in detail in appendix 3 of the SIA V 191 Recommendation (1995)

8.3.3 Tensioning and blocking of the anchors

On completion of the acceptance test, the anchor can be tensioned and blocked at level P_0 , on condition that it meets the four following conditions:

1. $k \geq k_{adm}$
2. $\pm l_{bl}(P_p) \leq \pm l_{bl adm}$
3. $0.9 I_{fr} \leq I_f(P_p) \leq I_{fr} + 0.3 I_v$
4. The corrosion protection meets the quality criteria.

If one or another of these conditions is not met, it is up to the person responsible for the project to decide what steps should be taken.

8. Anchor tests



Project: Tests Sud
Anchor type: EG 5-4

Anchor no.: 17
Category K1: SIA V 191

FO 3.06 - 02
Stressing Record

Comprehensive Load Test
 Simple Load Test

No. of strands: 4 x 100 mm²
Total area A_p: = 400 mm²
f_y / f_k: 1640 / 1820 N/mm²
E-Modulus E_p: = 195 kN/mm²

Jack type: ZPE 50
Jack length l_j: = 0.65 m
Friction loss: = 5 %

Load cell type: Fabr. Nr.:

Displacement measurements with constant load from a fixed point (mm)

Load stages	measured from time t =										
	0'	1'	2'	5'	10'	15'	20'	25'	30'	35'	40'
P _a 50	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P ₁ 240	28.2	28.65									
P ₂ 390	56.3	59.34									
P _p 540	84.5	93.88	94.00	94.03	94.06	94.09	94.10				
P _a 90	0.0	6.02									
P ₀ 430	357										

Stressed to P₀ + 6 mm

Conditions:

Installation of load cell Type: Fabr. Nr. Load at P_a kN

Condition 3: f₁ = C x Δl_g (P_p) = 15.24 m Friction Rods = 25.5 mm

Control of the expansion free length: f₁ ≥ 0.2 l_j + l_j = 13.25 m
 $C = \frac{A_p \times E_p}{P_p \cdot P_a} \cdot 10^{-3} = 0.173$

f₂ ≤ l_j + 0.3 l_j + l_j = 16.75 m

Minimum observation time

at P₁/P₂ = 0' 2'-3' 9'-15' 15'-30'

at P₃ = 15' 0.15 0.25 0.20

When smaller = next stage

When in between = add

When higher = stabilization

Creep displacement increase

Condition 1 satisfied? no yes

Creep displacement increase

Condition 1 satisfied? no yes

Condition 2 satisfied? no yes

Condition 3 satisfied? no yes

8.4 Electrical resistance measurement

Comprehensive corrosion protection (Category K1)

The quality of the corrosion protection is determined by taking the electrical resistance as the criteria for the tightness of the encapsulation around the anchor and the isolation between the anchor head and the structure.

The electrical insulation between the anchor head and the loadbearing structure on the one hand, and between the anchor and the soil on the other, shall be checked on each anchor once installed and tensioned using the electrical resistance measurement I.

It must be possible to check the electrical insulation qualities of the surveillance anchor and control anchor encapsulation throughout the period that the anchor is used.

8.4.1 Carrying out measurement I

Measurement I consists of measuring the electrical resistance between the tendon and the anchor head on the one hand, and the soil and the anchored structure on the other (figures 8.8 and 8.9).

Measurement voltage	500 V D.C.
Measurement equipment:	electrical insulation measuring equipment, for example: METRISO 500 VW
Measurement range:	Ø10 kohm (0.01 megaohm)

To carry out the measurement, the anchor shall be connected to a positive terminal, and the earth to the negative terminal of the measurement circuit. The earth shall normally be connected to metal parts of a certain size, either existing or assembled on the site. It shall also be possible to use the reinforcements of reinforced concrete constructions on condition that these latter are in contact with the soil, or buried metal water pipelines.

When the measuring takes place, the metal contacts must be clean and the metal surfaces bare.

The R_I electrical resistance measured on the injected and tensioned anchor must present a value of $R_I \geq 0.1$ megaohm.

Comment:

It is recommended that measurements of the anchor's electrical resistance be carried out after it is manufactured, after its installation, after its injection and after the anchor acceptance test.

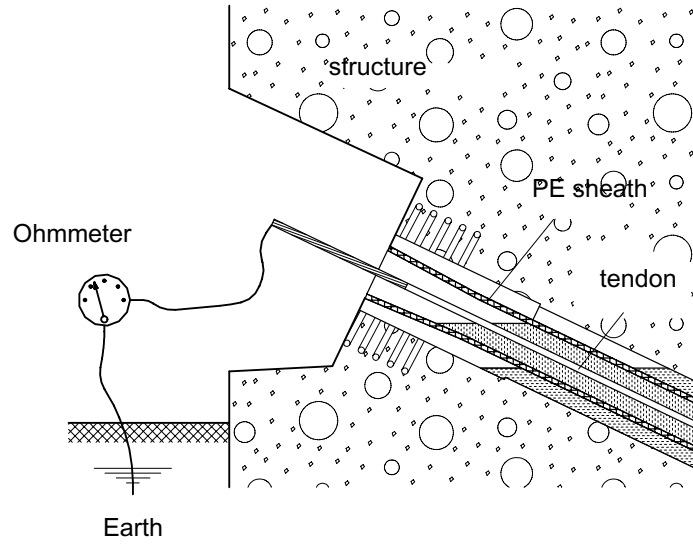


Fig. 8.8

Measurement I of the electrical resistance of a non-stressed anchor

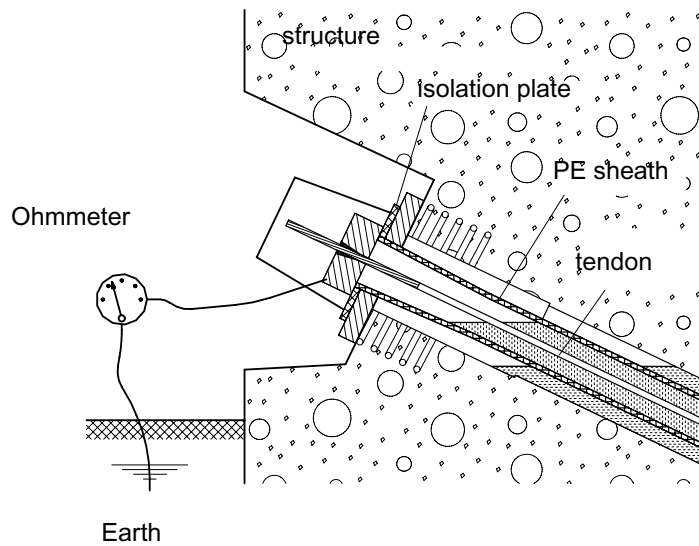


Fig. 8.9

Electrical resistance measurement I of an anchor that has been stressed

8.4.2 Carrying out measurement II

Should anchors be accepted, despite having an insufficient R_I electrical resistance, it is necessary to subject them to measurement II to ensure that the anchor head is not in contact with the loadbearing structure reinforcements.

Measurement II consists of measuring the electrical resistance between the anchor head and the anchored structure reinforcements when a current is passed through the anchor (figure 8.10).

Measurement voltage: approximately 40V AC

Measurement equipment: 4 pole earthing measurement instrument, for example Norma D 3950

Measurement range: 0 to approximately 200 kohm

The measurement is generally carried out between the anchor head and the bearing plate or the flange of the external trumpet. It is also possible to use the bearing structure reinforcements instead of the trumpet.

Care should be taken to ensure that the anchor head area is dry, particularly the insulating plate below the bearing plate. The contact points must be clean and the metal bare. The contacts shall be made using clips or strong magnets. Contact points are not accepted for this measurement.

Measurement II can be rendered inaccurate by atmospheric conditions (humidity of the air), by the presence of humidity in the anchor head area and by any stray currents. If the measurement is repeated several times – and carried out perfectly each time – it is the highest resistance value that shall be taken into consideration.

Resistance R_{II} between the anchor head and the structure reinforcements must have a value of ≥ 100 ohm.

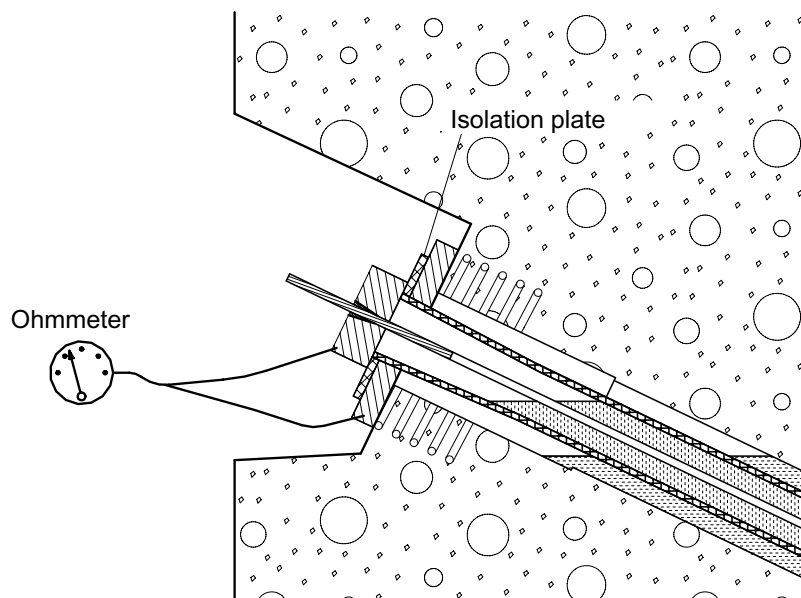


Fig. 8.10

Measurement II of electrical resistance

9.1 Generalities

9.2 Permanent control anchors

9.3 Permanent surveillance anchors

9.1 Generalities

According to the SIA V 191 Recommendation (1995), the anchored works must be monitored throughout the period they in use. To this end, a monitoring programme shall be prepared by the person responsible for the project. It is necessary to draft monitoring instructions, even if the anchors are only used temporarily.

The measurement and control anchors are defined according to their type of use, as follows:

- € Standard control anchor
anchor that, at any time, allows the existing anchor load to be checked by separation of the head using a mobile jack as well as allowing tensioning up to the acceptance test load. This type of anchor can subsequently be post-tensioned to a greater load. However, it cannot be detensioned.
- € Adjustable control anchor
anchor constructed in such a way that it can be tensioned to a greater load as well as permitting partial or total detensioning.
- € Surveillance anchor
control anchor permanently equipped with a load cell permitting the measurement of the post-tensioning load at any time. The load cell can be replaced.

The number of surveillance and control anchors shall be set for each structure, as follows:

	Minimum number in % of all an- chors	Minimum number per part of the structure
Set of measurement and control anchors	5	3

It is possible to decide not to apply the above measures in the case of anchorages whose period of use is less than six months and whose failure would only have minimum consequences and would not endangering the public. However, it is recommended that approximately three control anchors per 100 structural anchors be provided and that there be at least one control anchor per part of the structure.

Extensive corrosion protection (category K1)

The electrical isolation qualities of the surveillance and control anchor encapsulation must be checked throughout the period that the anchor is in use.

9.2 Permanent control anchors

9.2.1 VSL type EG head for control anchor

EG head for a control anchor equipped with a VSL type GW jumping load cell. The measurement of the anchor load is made at the moment of lift-off of the anchor head from the bearing plate.

In the case of heads placed in recesses, the dimensions given for the block-outs must be taken into consideration (see chapter 6).

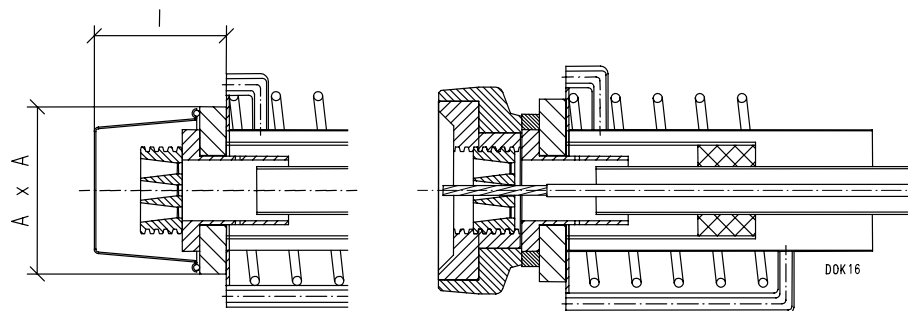


Fig. 9.2

EG anchorage dimensions for the control anchor							
		5-3	5-4	5-7	5-12	5-19	6-19 *
bearing plate	A	200	200	230	300	350	410
height of the anchor head	l	160	160	175	190	195	265

Table 9.3

Measurements in mm
*) EG 6-19 only as test anchor

Jumping load cell for type EG control anchor

	P ₀ max. kN	EG anchorage			Load cell		
		Ø mm	threading mm	H mm	P nom. kN	P max. kN	weight kg
EG 5-3	327	90	Tr 90x6	50	500	600	15
EG 5-4	436	Only with jack					
EG 5-7	764	114	Tr 114x6	55	1000	1200	31
EG 5-12	1310	150	Tr 150x6	60	1500	1800	60
EG 5-19	2074	180	Tr 180x6	75	3000	3600	105
EG 6-19	3026	210	Tr 210x8	95	5500	6100	243

Table 9.4

9.3 Permanent surveillance anchors

9.3.1 VSL type ER-D head for surveillance anchor

The ER-D designation is given to an ER type anchor head equipped with a type D replaceable load cell. The dismantling and replacement of the load cell takes place without having to detension the anchor.

In the case of heads placed in recesses, the dimensions given for the block-outs must be taken into consideration (see chapter 6).

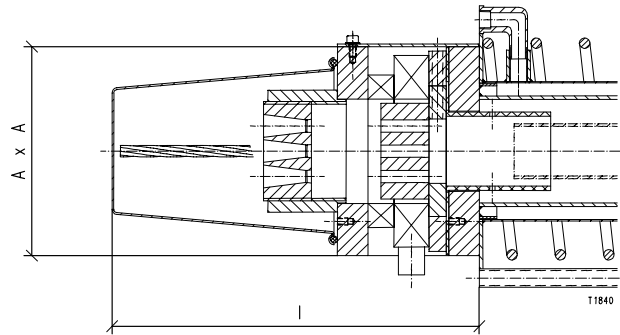


Fig.

9.5

ER-D anchorage dimensions for the surveillance anchor							
		5-3	5-4	5-7	5-12	5-19	6-19 *
bearing plate	A	200	200	230	300	350	410
height of the anchor head	I	410	410	420	440	490	560

Table 9.6

Measurements in mm

*) EG 6-19 only as test anchor

Electric load cell for type ER-D anchorage

anchorage			load cell					
type	P _p max. kN	P _o max. kN	type	Measurement range		Ø A mm	Ø B mm	Ø C mm
				P nom. kN	P max. KN			
ER-D 5-3	409	327	L211 V050	500	750	200	155	110
ER-D 5-4	546	436	L211 V050	500	750	200	155	110
ER-D 5-7	955	764	L212 V100	1000	1500	220	180	120
ER-D 5-12	1638	1310	L216 V 120	1200	1800	260	210	165
ER-D 5-19	2593	2074	L219 V180	1800	2700	300	260	190
ER-D 6-19	3783	3026	L222 V 300	3000	3750	340	290	225

Table 9.7

The load cell is equipped with a measurement cable provided with a plug that can be connected to the readout equipment.

9.3.2 VSL type EA-D head for surveillance anchor

The EA-D designation is given to an type EA anchorage equipped with a type D replaceable load cell. The anchor must be detensioned to dismantle and replace the load cell.

In the case of heads placed in recesses, the dimensions given for the block-outs must be taken into consideration (see chapter 6).

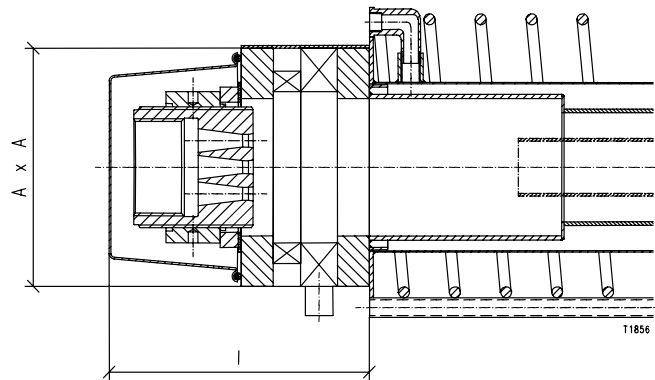


Fig. 9.8

EA-D anchorage dimensions for the surveillance anchor						
		5-3	5-7	5-12	5-19	6-19 *
bearing plate	A	220	260	320	400	460
height of the anchor head	I	270	285	305	375	395

Table 9.9

Measurements in mm

*) EG 6-19 only as a test anchor

Electric load cell for type EA-D measurement anchor

Anchorage			Load cell					
type	P _p max. kN	P _o max. kN	type	Measurement range		Ø A mm	Ø B mm	Ø C mm
				P nom. kN	P max. KN			
EA-D 5-3	409	327	L211 V050	500	750	200	155	110
EA-D 5-7	955	764	L216 V100	1000	1500	260	210	165
EA-D 5-12	1638	1310	L219 V180	1800	2700	300	262	190
EA-D 5-19	2593	2074	On request					
EA-D 6-19	3783	3026	On request					

Table 9.10

The load cell is equipped with a measurement cable provided with a plug that can be connected to the readout equipment.

9.3.3 Type D load cell

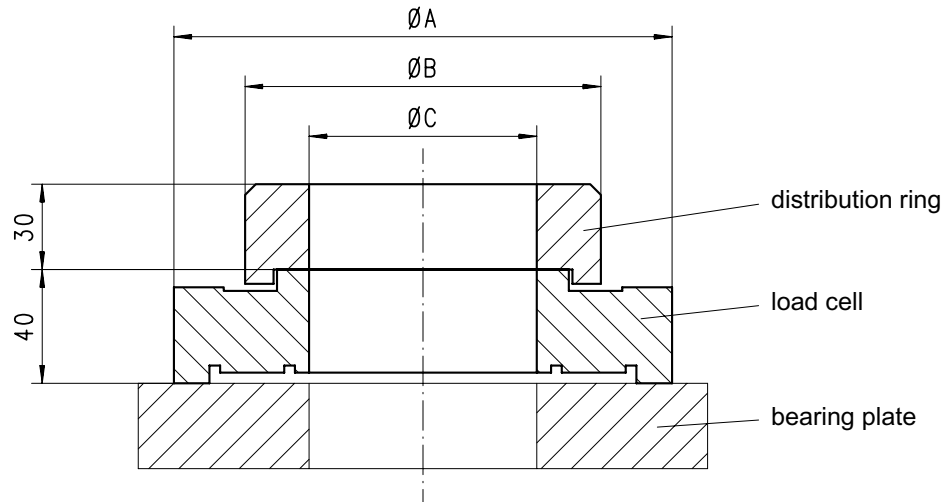


Fig. 9.11

Technical data

Measurement ranges	300 - 3000 kN (see table)
Max. admissible load:	150 % or 125 % of the nominal load
Sensitivity:	0,1 % of the measurement range
Calibration precision:	< 1 % of the measurement range
Resolution:	0.001 mV
Supply:	12 V DC
Output:	1.5 mV/V or 2.0 mV/V
Electrical insulation:	2 KV
Impedance:	1,4000 ohm
Divergence between -20° and + 50° C:	< 0.05 % of the measurement range
Service temperature range:	- 25° to + 60°C
Material:	stainless steel

- 10.1 Generalities
- 10.2 Anchor below water level
- 10.3 VSL packer
- 10.4 VSL sack anchor to control grouting of the bond length
- 10.5 VSL uplift anchor

10.1 Generalities

As indicated in the introduction, we do not intend to use the present chapter to present the large number of possible combinations or technical solutions specific to a given structure. We simply would like to draw attention to a few widely used special cases.

We remain available to assist those responsible for projects to develop technically and economically valid solutions to all presented problems.

10.2 Anchors below water level

Our tensioning jacks can be used underwater. It is therefore possible, with the assistance of divers, to anchor waterway channelling systems and carry out remedial works on river dam piers, dams, bridge piers, docks, wharf walls, piers and mooring buoys.

We remain available to designers for all preliminary studies and detailed designs.

10.3 VSL packer

The VSL plug is used to limit the injection area. It is placed between the exterior face of the encapsulation and the drilled hole.

VSL packers are mainly used for upward sloped anchors in rock. They are also used when an injection over the apparent free length is not advisable or when the bond length injection needs to be pressurised.

The VSL packers is generally assembled in the factory at the transition point between the free length and the bond length. Once the anchor is installed, the plug is grouted (filled with grout), and the water is extruded under the pressure effect. The grouting below the plug can begin immediately after the plug is inflated. However, when the bond length injection needs to be carried out at very high pressure, it is recommended that the injection be carried out 6 to 12 hours after the packer is grouted.

The main advantages of the VSL plug are as follows:

- € All VSL permanent anchors can be equipped with a packer, without any adaptation being required. The packer is assembled on the anchor once it is manufactured (for temporary anchors it is necessary to place a piece of tube and waterproof the space between the sleeve and the strands next to the plug).
- € The corrosion protection remains intact as no fixing through the sleeve is required.
- € The assembly is the same, no matter whether the anchor is angled towards the top or the bottom.

10.4 VSL sack anchor to control grouting of the bond length

The use of the VSL sack anchor is recommended in soils favouring uncontrolled grout losses (cracking, high permeability).

The VSL sack anchor comprises a normal anchor whose bond length l_v is packed in a filtering fabric "sleeve". The diameter of this "sleeve" or "sack" is greater than that of the bore hole. It is folded over the bond length, then knotted next to the l_v / l_{fr} transition and at the end of the anchor. It is connected to an injection tube.

During the injection process, the sack unfolds and opens out to take the form of the drilled hole. The filtration fabric lets through excess water from the grout but retains the cement granules. This prevents an uncontrolled consumption of grout and an undesirable pollution of the groundwater by the cement.

The VSL sack anchor has proved itself on a large number of sites.

The capacity of VSL sack anchors should be verified on each site through the use of tests.

10.5 VSL uplift anchor

In areas where the water table is close to the surface, works are often subject to sub-pressures and it is necessary to compensate for these. Picking up the uplift pressures by anchoring the structure in the adjacent layers using post-tensioned anchors is often more economic than gravity compensation through the use, for instance, of heavy foundations.

Temporary anchors resisting the **uplift pressure** become worthwhile when, for instance, the basement levels of a building need to be stabilised up until the moment that the self-weight of the superstructure attains a sufficient compensatory value.

Permanent stabilisation is essential for isolated underground works, as well as for retention tanks, sewerage treatment plants, swimming pools, stilling basins, etc., whose weight is insufficient when they are drained.

The construction of uplift pressure resistant anchors is dictated by the problems met in crossing through grout curtains and by the hydrostatic pressure that exists at the anchor head level.

VSL uplift anchors are all category K1 (comprehensive corrosion protection), no matter whether they are permanent or temporary.

Variant: flexible insulation

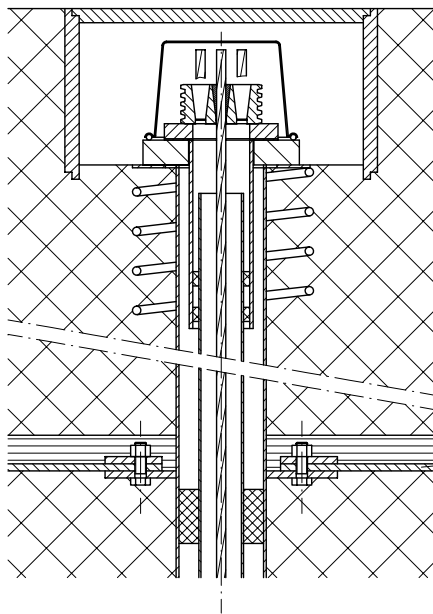


Fig. 10.1

Variant: waterproof concrete

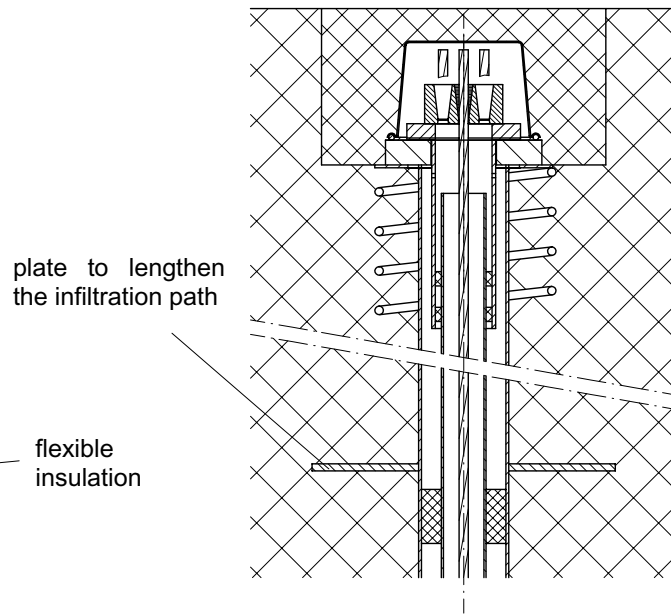


Fig 10.2

11.1 Conditions for the performance of anchors with comprehensive corrosion protection (category K1) in soil and in rock.

The present conditions define the distribution of responsibilities between VSL (Switzerland) Ltd. (referred to as VSL) and the drilling contractor during the installation of VSL anchors with extensive corrosion protection.

The basic reference for this document is the **SIA V191 Recommendation (1995 edition)**.

11.1.1 Delivery

The delivered anchors with comprehensive corrosion protection meet the requirements defined in the SIA V191 Recommendation and have successfully passed the initial examination (by the GEA Group of exports). Continuous internal surveillance and yearly external inspection assure the permanence of the quality.

11.1.2 Unloading

The drilling contractor must take all necessary precautions to ensure that the anchors are not damaged during unloading. In particular, the following is forbidden:

- € to handle the anchors using pointed hooks (risk of buckling)
- € to place the anchors directly onto supports with sharp edges (for example, hydraulic shovel buckets) and in the storage area
- € to drag the anchors on the surface (risk of holes being made and the PE ducts being spoiled).

11.1.3 Intermediate storage

The anchors must be stored on a flat, clean surface. Should a storage platform not be available, use appropriate bracing to ensure that the anchors are not in contact with the ground. No other materials should be placed on the anchors. The storage area must be surrounded stable barriers.

The temperature of the air inside the anchors **must not exceed 40°**. If necessary, the anchors must be sheltered from direct sunlight.

In the case of low temperatures, the anchors must be heated prior to installation (prior to unwinding). The air temperature inside the anchor must be **at least 5°**.

11.1.4 Handover test

The handover test comprises a measurement of the electrical resistance during which the anchor is filled with potable water. If the borehole is dry it is filled with water as well. The required resistance is $R \geq 200$ MOhm with the measurement voltage between the cable and the earthing being 500 V DC (using, for example, METRISO 500 D or equivalent measuring equipment).

a) Bulk delivery of anchors

Anchors that are either bulk delivered or are unwound on a storage area must be tested by the drilling contractor immediately after unloading. The test installation (bath or sealed pipe) is the responsibility of the drilling contractor. Anchors that do not meet the conditions during this test are repaired free of charge by VSL. The anchors must be installed and injected within a four week period dated from the handover test.

b) Delivery of anchors on reels, frames or in cradles

For anchors directly installed from reels, frames or cradles, the handover test is carried out by the drilling contractor in the borehole prior to grouting and prior to the removal of the casing. Defective anchors are repaired free of charge on site by VSL. Their removal from and reinstallation into the borehole following repairs is the responsibility of the drilling contractor.

c) Handover report

The handover test shall be accompanied by a report. If no handover test is carried out, the anchors are considered as accepted without reservation.

11.1.5 Installation

The drilling contractor shall take the necessary measures to ensure that the anchors do not suffer any damage during installation.

- € The casings or the boreholes must be calibrated. The pipes shall have no burrs.
- € The same protection measures required for unloading (see 11.1.2 and 11.1.3) shall be taken during transportation between the storage area and location where anchors are to be installed.
- € Under no circumstances must the anchors rub against sharp edges, such as the entrances of the external trumpet/flange edge.
- € No anchor can be installed if the temperature in the borehole is below **+5°C**.
- € Very long, large capacity anchors require that special measures be taken. These should be agreed sufficiently ahead of the operation between VSL and the drilling contractor.

Anchors, including overlengths, must be centred using an appropriate device in relation to the theoretical borehole axis up to the moment that the anchorage is assembled.

11.1.6 Grouting

When installing an anchor and carrying out the grouting both inside and outside the encapsulation, pressure differences must be limited to the following:

- | | |
|--------------------|---|
| Internal pressure: | max. + 3 bars during the curing process (approx. 24 h.) |
| External pressure: | max. + 1 bar for a brief period (max. 30 minutes). |

The grout between the strand and the plastic sleeve (internal grouting) must meet the requirements of the SIA 162 standard, art. 5 44. Depending on the soil characteristics, it may not be necessary to meet this requirement for the external grouting. No grouting operations can take place if the external temperature is below **+5°C**. Once the anchor is grouted, the area close to the anchorage must be rinsed and grout / cement residues removed in accordance with VSL instructions.

11.1.7 Regrouting

High pressure regrouting can damage the anchor's corrosion protection. In the case of regrouting prior to acceptance tests, the grout pressures must be limited to **25 bars**.

In the case of regrouting for anchors with an insufficient anchor capacity, the max. regrouting pressures must be individually established, with VSL's approval, on the basis of the permanent measured displacement.

11.1.8 Stressing periods

In order for the ground to be reconsolidated following grouting, it is necessary to respect the following minimum periods between grouting and stressing:

- € -anchors in rock and anchors anchored in non-cohesive loose soil : 7 days
- € -anchors anchored in cohesive loose soil : 10 days

11.1.9 Checking the comprehensive corrosion protection

The anchor's comprehensive corrosion protection is checked by using electrical resistance measurement I. This consists in measuring the electrical insulation (the electrical resistance) respectively between the anchor and the soil, the structure respectively, using a 500 V DC measurement voltage. The measuring is carried out before and after each stressing operation.

The comprehensive corrosion protection requirement is met if the anchor, once grouted and stressed, reaches a resistance of **RI Ø0.1 MΩ**. If anchors are accepted with an insufficient R_i resistance (max 10 % of the anchors), it is necessary to provide proof using electrical resistance measurement II that the anchorage head is not in contact with the structure's reinforcements.

The requirement of measurement II is satisfactory if the electrical resistance between the anchorage head and the structure's reinforcement attains **RII Ø100 Ω**, with a 40 V AC voltage measurement (using, for example, Norma D 39 50 or equivalent measuring equipment).

The resistance measurements before and after grouting of the anchor are carried out by the drilling contractor and are established on a protocol. The reports are submitted to VSL. The measurements taken on the anchor after stressing, before and after grouting of the anchorage, are carried out by VSL and established as a protocol. The reports are submitted to the drilling contractor to be transmitted to the client.

11.1.10 Guarantee

Repairs or replacement of anchors that have been damaged after handover and which do not meet the values required by electrical resistance measurement I shall be the at the debit and responsibility of the drilling contractor. In articles 8 32 2 and 8 32 3, the SIA V191 Recommendation defines under what conditions the replacement of deficient anchors can be renounced and where the replacement is the responsibility of the client.

11.2 Conditions for the execution of temporary anchors in soil and in rock (categories K2 and K3)

The present conditions define the distribution of responsibilities between VSL (Switzerland) Ltd. (referred to as VSL) and the drilling contractor during the installation of temporary anchors. The base reference for this document is the **SIA V191 Recommendation (1995 edition)**.

11.2.1 Delivery

The delivered temporary anchors meet the requirements defined in the SIA V191 Recommendation and have successfully passed the initial examination (by the GEA Group of experts). Continuous internal surveillance and yearly external inspection assure continuous quality.

11.2.2 Unloading

The drilling contractor must take all necessary precautions to ensure that the anchors are not damaged during unloading. In particular, the following is forbidden:

- € to handle the anchors using pointed hooks (risk of breaking)
- € to place the anchors directly onto supports with sharp edges (for example, hydraulic shovel buckets)
- € to drag the anchors on the surface.

11.2.3 Intermediate storage

The anchors must be stored on a flat, clean surface. Should a storage platform not be available, use appropriate bracing to ensure that the anchors are not in contact with the ground. No other materials should be placed on the anchors. The storage area must be surrounded by stable barriers.

The anchors must be sheltered from direct sunlight. The ambient temperature in the storage area **must not exceed 40°**.

11.2.4 Installation

The borehole contractor shall take the necessary measures to ensure that the anchors do not suffer any damage during installation.

- € The casings or the boreholes must be calibrated. The pipes shall have no burrs.
- € The same protection measures required for unloading (see 11.2.2 and 11.2.3) shall be taken during transportation between the storage area and location where anchors are to be installed.
- € Under no circumstances must the anchors rub against sharp edges, such as at the edge between flange and external trumpet.
- € No anchor can be installed if the temperature in the borehole is under **+5°C** (for example, in mountainous regions).
- € Very long, large capacity anchors require that special measures be taken. These should be agreed sufficiently ahead of the operation by VSL and the borehole contractor.

11.2.5 Injection

Where the external temperature is below **+ 5°**, it is necessary to supervise the grout between the mixer and the anchor entry point, and take the necessary measures to ensure that the temperature is always at least **+5°**.

Once the anchor is injected, the area close to the anchorage must be rinsed and grout / cement residues removed in accordance with VSL instructions.

11.2.6 Stressing periods

In order for the ground to be reconsolidated following injection, it is necessary to respect the following minimum periods between grouting and stressing:

- € -anchors in rock and anchors anchored in non-cohesive loose soil : 7 days
- € -anchors anchored in cohesive loose soil : 10 days