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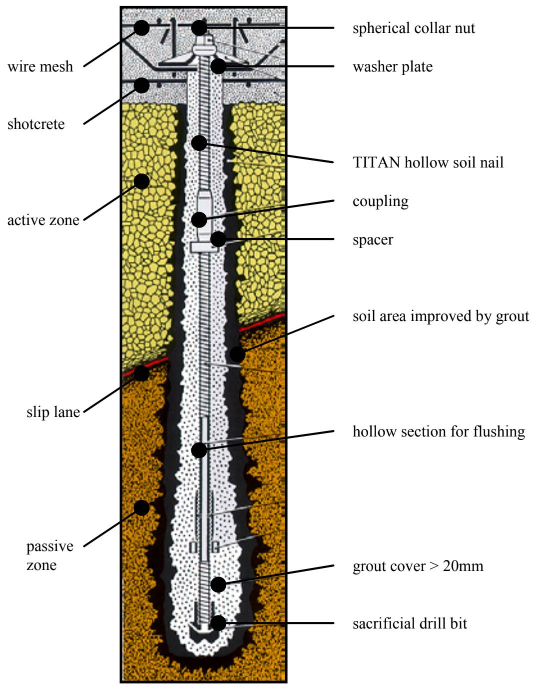
INNOVATIVE SLOPE STABILISATION BY USING ISCHEBECK TITAN SOIL NAILS

New anchor techniques – basics

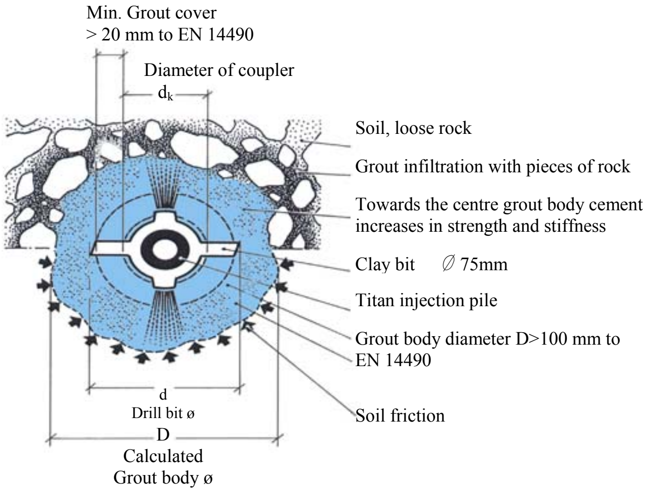
TITAN Drill- and Injection Anchors could be used as soil nails to EN 14490 and are also suitable for use as anchors and rock bolts to DIN 21521, or micropiles to DIN 4128, EAU E 28, DTU-13 micropieux Type IV and EN 14199 Micropiles.

TITAN injection anchors consist of a continuously threaded, hollow reinforcing tendon which acts as the load carrying steel member. This is encapsulated within a grout body of furnace cement with a minimum strength of 25 N/mm² (B25), which allows the transfer of both tensile and compressive forces, by the friction of the threaded tendon, the grout body and the soil.

The schematic structure of a TITAN Soil Nail



GROUT BODY DIAMETERS:
D≥ 2,0 x d for medium + coarse cobbles
1,5 x d for sand and gravely sand
1,4 x d for cohesive soil (clay, marl)
1,0 x d for weathered sandstone, phylitte, slate



The new reinforced tendon consist of a steel tube which is continuously threaded and composed of fine grain structural steel

The threaded tendon acts as the drill rod, the reinforced tendon and the injection tube. The hollow tendon has more favourable values in static conditions compared to a solid bar of the same cross-sectional area, with regard to bending, shear resistance and bond friction.
The continuous thread, (to DIN 488) allows you to cut and couple any length required on site. Various drill bits are available to suit different ground conditions which may be experienced on site.
The grout body interacts with the surrounding ground producing friction at the ground/grout interface, and offers corrosion protection. Centralising spacers are placed before every coupling nut to ensure a regular grout cover of a minimum 20 mm. Tension and compression loads are transferred from the tendon into the grout body and the ground.
TITAN Soil Nails and Micro Piles generate excellent shear bond with the ground and allow the safe working load deformation at the pile head to be calculated to less than 5 mm.

The sketch on the right side shows an excavated grout body. Here the threaded tendon, 20 mm grout cover, the filter cake and the improved ground conditions can be seen.

A longitudinal section of a grout body shows regular, fine cracks within the hardened cement paste, the cracks are directed away from the ribs of the tendon.

A typical TITAN Soil Nail is described as follows:

TITAN 30/11 with 320 kN ultimate load.

TITAN	=	trademark of the company Friedr. Ischebeck GmbH
30	=	outside diameter in mm
11	=	inside diameter in mm

For slope stabilisation mostly TITAN 30/11 to TITAN 40/16 are used depending on the load requirements. Nine different tendon sizes are available, with safe working loads ranging from 100 to 3000 kN:

pile type		30/16	30/14	30/11	40/20	40/16	52/26	73/53	103/78	103/51	130/60
Nominal outside diam.	Mm	30	30	30	40	40	52	73	103	103	130
Nominal Inside diam.	mm	16	14	11	20	16	26	53	78	51	60
Ultimate load	kN	220	260	320	539	660	929	1160	1950	3460	7940
Yield point	kN	180	220	260	430	525	730	970	1570	2750	5250
Yield stress $T_{0,2}$	N/mm²	470	610	580	590	590	550	590	500	500	550
Cross section (A)	mm²	382	395	446	726	879	1337	1631	3146	5501	9540
Weight	kg/m	3,0	3,1	3,5	5,6	6,9	10,5	12,8	24,7	43,4	75,0
thread left hand/ right hand		left	left	left	left	left	right	right	right	right	right
lenghts	m	4	3/4	2/3/4	3	3	3	3	3	3	3

TITAN Injection anchors are installed without casing in one step operation using a rotary percussive drilling hammer and a cementitious grout which cures and stabilises the annulus; No vibration is experienced and noise is kept to within regulations.

The flushing and supporting fluid is a cementitious paste consisting of portland cement with a water to cement ratio (W/C) ~ 0,7. By using a typical flushing pressure of approx. 15 bar the water flow evacuates leaving a filter cake which stabilises the drill hole. The filter cake is also known as “primary injection”, this improves the bond friction between the grout body and the soil, as the cement interlocks itself with the soil.
Rotary percussive drilling with cement improves the soil, as it acts like a concrete vibrator. Delft Geotechnics determined that the soils properties where improved by approximately 30%.

By improving both the soil conditions and the pore water pressure by grouting, around the drill hole, the grout body diameter (D) can be calculated as follows:

D ≥	2,0 x drill bit diameter	for medium and coarse cobbles
	1,5 x drill bit diameter	for sand and gravel sand
	1,4 x drill bit diameter	for cohesive soil (clay, marl)
	1,0 x drill bit diameter	for weathered sandstone, phylitte, slate

Grouting with a water cement ratio of W/C = 0,4 without water surplus, the grouting pressure should increase to a minimum 10 bar, according to the ground. The increase in pressure

without a packer is explained by, the rapid curing of particles within the hardened cement and the filter laws of Darcy.
We would like this grouting technique to be known as “dynamic grouting” the opposite to “static grouting” as with a cased drilling technique. Dynamic grouting is not a new development; it is known by drillers as “drill settles”.

Fresh cement paste is repeatedly injected into the hardening cement to integrate and improve the interface between the cohesive soil and the post-grouted cement. If the correct grouting pressure is used, enough bond friction will be developed. The grouting pressure is continually recorded for quality assurance, according to DIN ISO 9001.

Simple corrosion protection and the development of crack-width limitation

Soil nails as well as micropiles generally have developed from smooth tendons to ribbed/threaded tendons; same as reinforced steel.
The pitched thread along the length of TITAN injection anchors complies to DIN 488.

$$f_R = \frac{\text{height of ribs}}{\text{distance of ribs}}$$

for example: $$f_R = \frac{1{,}7 \text{ mm}}{13 \text{ mm}} = 0{,}13 \text{ for TITAN 30/11}$$

The related thread surface 0,13 is very close to the optimised value of 0,15 for reinforced steel. Consequently an optimal friction value is given by such steel. The optimal bond limits the crack-width to less than 0,1 mm.

TITAN soil nails and micropiles, through the ribs create equal crack distribution in the hardened cement paste. Crack width measurements where carried at Technical University Munich.
Excavated grout bodies, reinforced with TITAN 30/11 injection anchors, were tensioned to 1,25 times their working load. The crack widths measured where found to be consistently under the allowable value of 0,1 mm according to DIN 1045/18.6.5 and Eurocode EC 2.

Thus, the grout encapsulating the tendon can be considered as an impermeable form of (simple) corrosion protection, it is important to maintain a grout cover of a minimum of 25 mm for permanent soil nails as required by the EN 14490 (Soil nailing) Annexe A.4.3.5.

TITAN Soil Nails for stabilisation of railway embankments

Soil nailing is used to improve the stability of railway embankments without substantial disturbance to the landscape or the vegetation of the embankment slope being necessary. Self-drilling nails are installed in the embankment in an approx. 2.5 x 2.5 m grid. The nails can be drilled either from the embankment crest or from the embankment toe, using excavator-mounted drilling attachments.

The nails penetrate any possible slip surfaces and tie potential slip bodies to the stable subsurface. They terminate in the slope, without head plates or similar devices, and are not visible once work is complete. The method is used e.g. for the stabilisation of 20 embankment slopes on the route Erfurt - Chemnitz, where approx. 70,000 running metres of TITAN 30/11Soil Nails were installed within just a few months. For the detailed report please do not hesitate to contact Friedr.Ischebeck GmbH.

Fig.1 Installing nails from the embankment crown

TITAN Soil Nails for stabilisation of cuttings of road constructions

As new member of the European Community Slovakia and Poland have launched last year the construction of an express route between Katowice and Zilina. In Zwardon, it is the Polish side of the border between the two countries, TITAN Soil Nails were used to secure the cuttings of the wall.
The height is up to 25 meters and secured by a shotcrete wall with 250mm thickness.

Fig.2 Secured shotcrete wall by TITAN Soil Nails

The total amount of soil nails was about 1600 pieces with more than 20.000 meters of TITAN 30/11, TITAN 40/20 and TITAN 40/16 with safe working loads of 150kN to 300kN. The lengths of the soil nails were from 6-24 meters in a grid of 1,50 x 1,50m.

This infrastructure project included the construction of a bridge for local traffic. The bridge bearing was build the same time as the stabilisation of the high wall. Therefore the foundation of the bridge was build by 10 TITAN Micropiles 73/53 with a safe working load of 554kN.

Fig.3 Micropiles TITAN 73/53 for bridge foundation

Fig.4 Installed bridge