ISCHEBECK TITAN

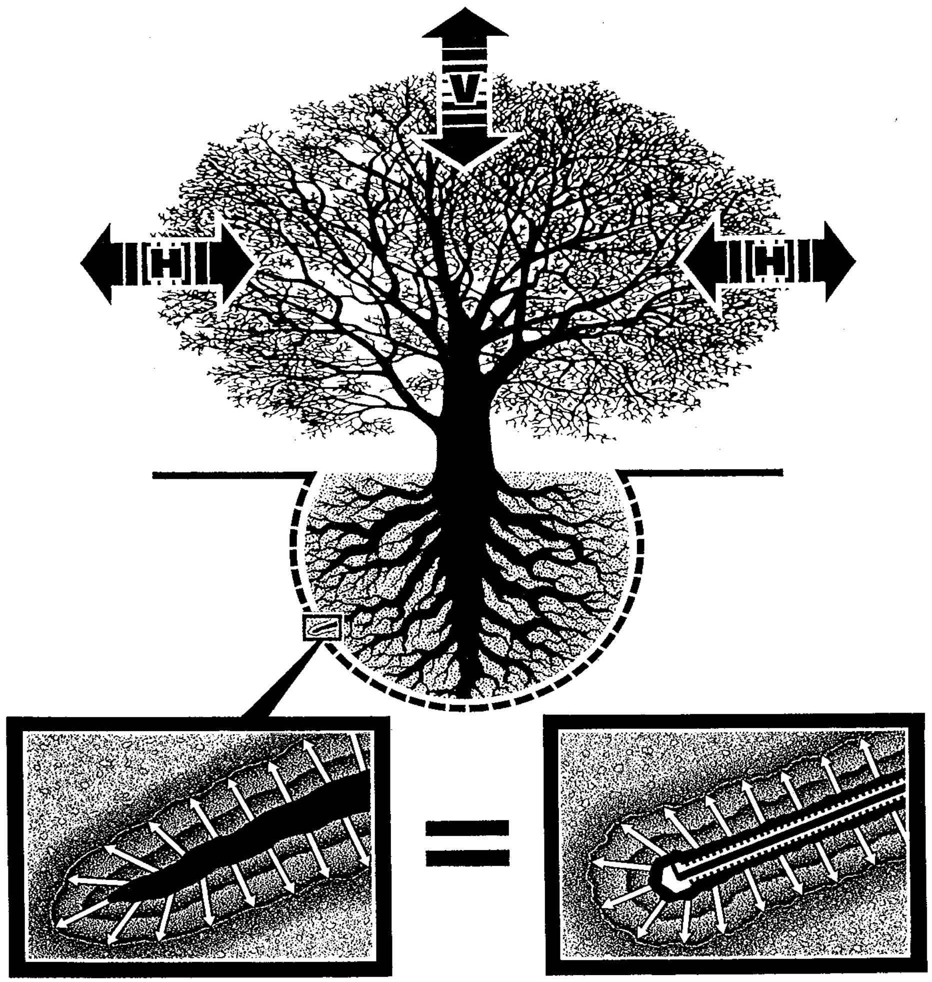
FRIEDR. ISCHEBECK GmbH, Ennepetal, Germany, founded in 1881, *actual view 2010*

International Society for Micropiles
10th International Workshop on Micropiles
September 22-25, 2010, Washington, DC, USA

THE DESIGN AND EXECUTION OF DRILLED AND FLUSH-GROUTED TITAN MICROPILES IS GOVERNED IN EUROPEAN UNION (EU) BY NATIONAL TECHNICAL APPROVAL Z-34.14-209 (DIBT)

Dipl.-Ing. E.F. Ischebeck <ischebeck@ischebeck.de>

From Lizzi's pioneering vision of "Pali Radice" to - type 1 and type 2 Micropiles according to EN 14199 "Micropiles" and national technical approval for Titan drilled Micropiles.



ROOT

GROUTED MICROPILE

ISCHEBECK TITAN

To learn from Nature

Bionik – From Roots to Micropiles Type 1 and 2
Dr. F. Lizzì's Vision of Pali Radice" in 1952

4 fundamental Experiences:

- **Both Roots and Micropiles can transfer tension or compression loads to the ground.**
- **Roots and Micropiles increase the cohesion of the ground and form a monolithic, composite foundation material.**
- **The increased volume of roots through growth or the pressure grouting of micropiles both create confinement of the soil.**
  As a result there is an improvement in shear bond values and smaller displacements of the roots and micropiles.
- **A network of roots forms splayed Micropiles, which work like rebar in reinforced concrete or glasfibre – used in reinforced plastic (GRP).**

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Allgemeine bauaufsichtliche Zulassung

Zulassungsnummer: Z-34.14-209

Antragsteller: Friedr. Ischebeck GmbH
Loher Str. 31-79
58256 Ennepetal

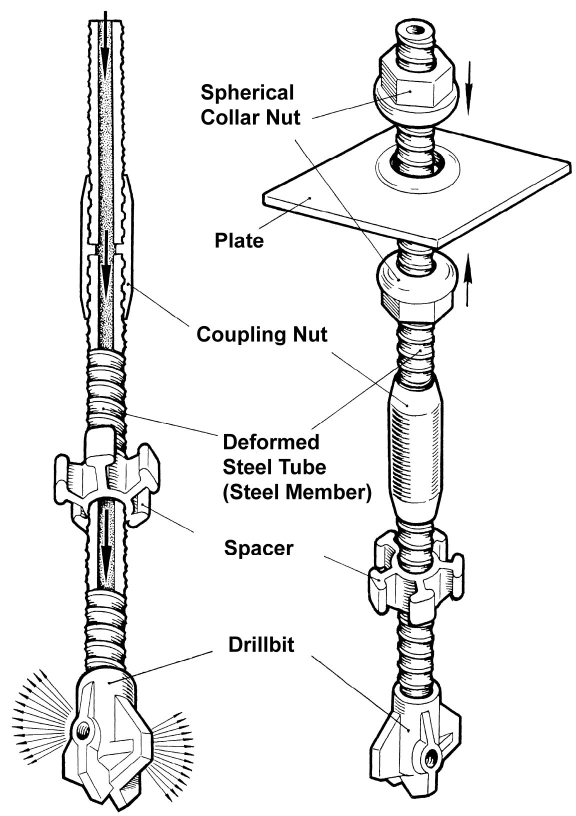
Zulassungsgegenstand: Verpresspfähle TITAN

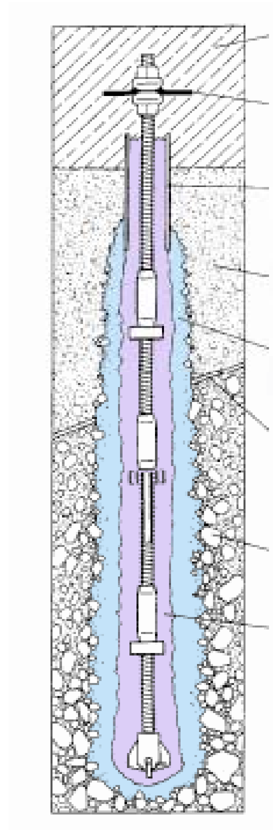
Geltungsdauer bis: 30. April 2013

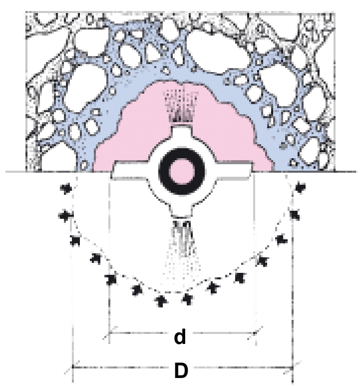
Der oben genannte Zulassungsgegenstand wird hiermit allgemein bauaufsichtlich zugelassen.
Diese allgemeine bauaufsichtliche Zulassung umfasst 14 Seiten und acht Blatt Anlagen.

Deutsches Institut für Bautechnik
33

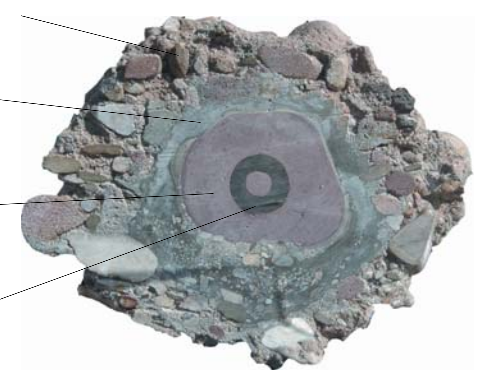
Micropile TITAN – Main Components







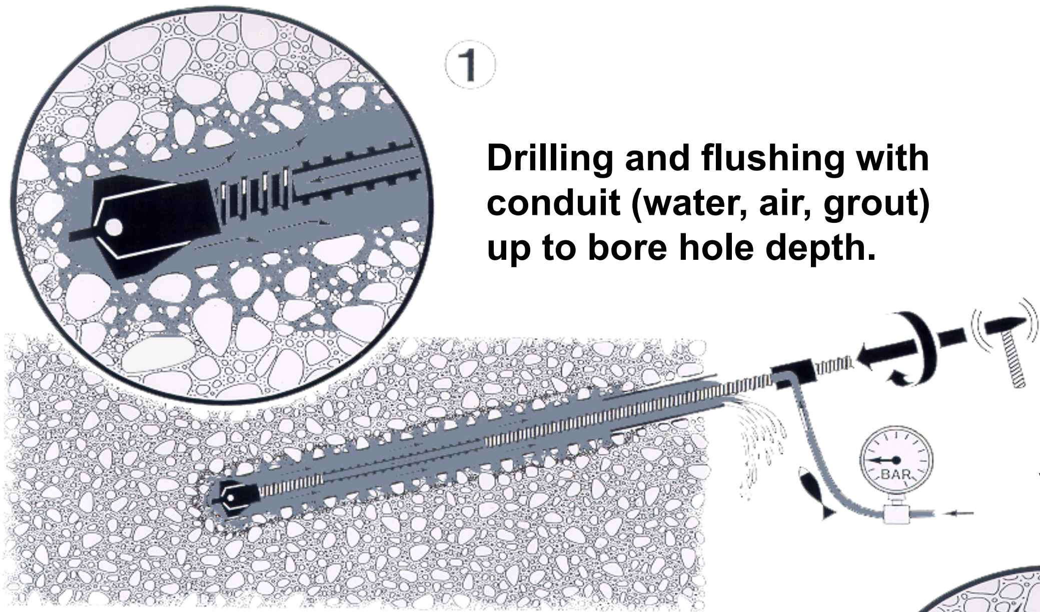
D ≥ d + 75 mm for gravel
d + 50 mm for sand
d + 25 mm for sand-silt
d + 10 mm for wheathered rock, clay



Installation of TITAN Drilled Micropiles
The same procedure for all ground conditions

1

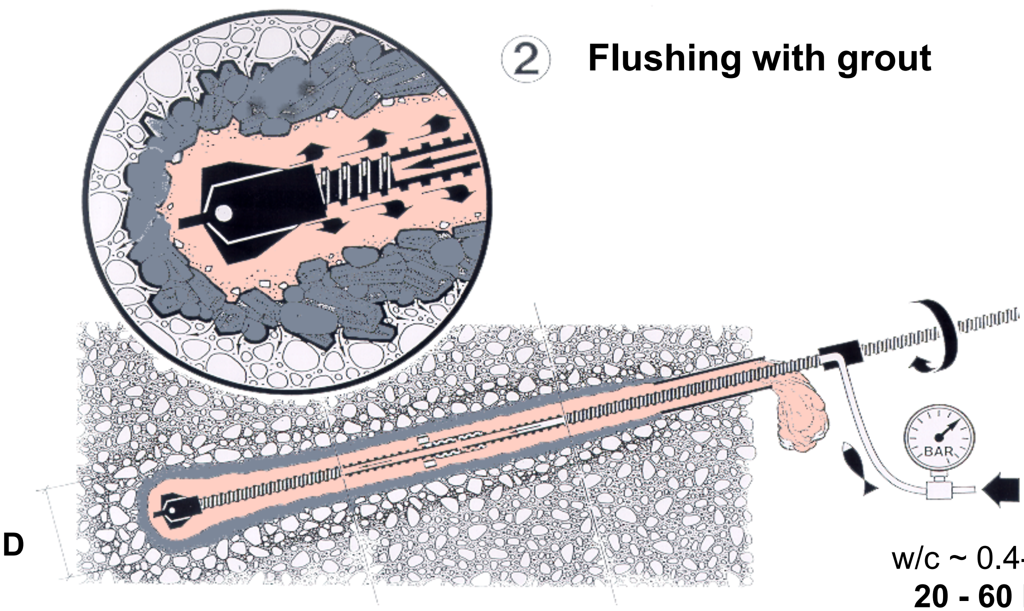
Drilling and flushing with conduit (water, air, grout) up to bore hole depth.



w/c ~ 0.7- 1.0
5 -20 bar

2

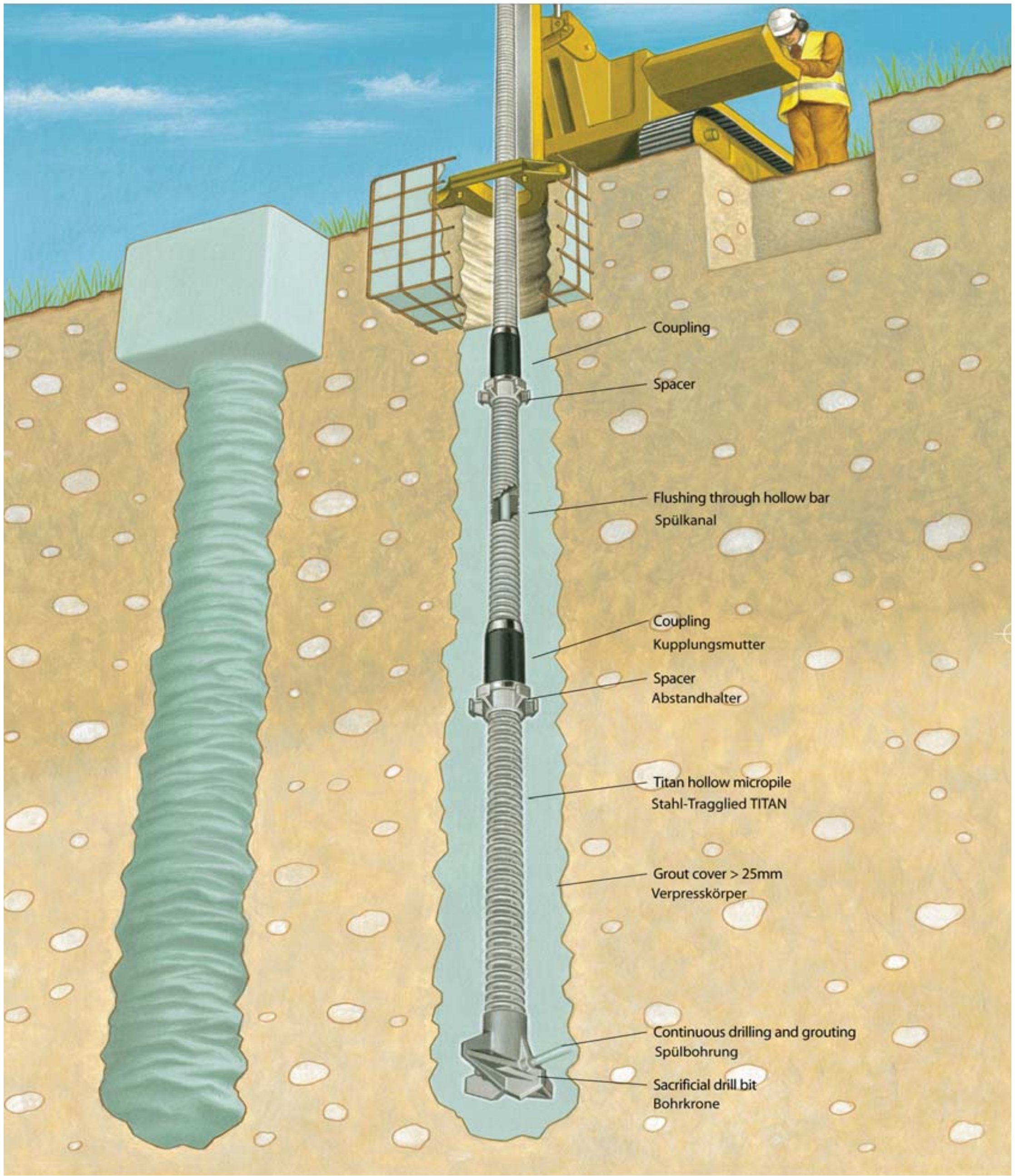
Flushing with grout



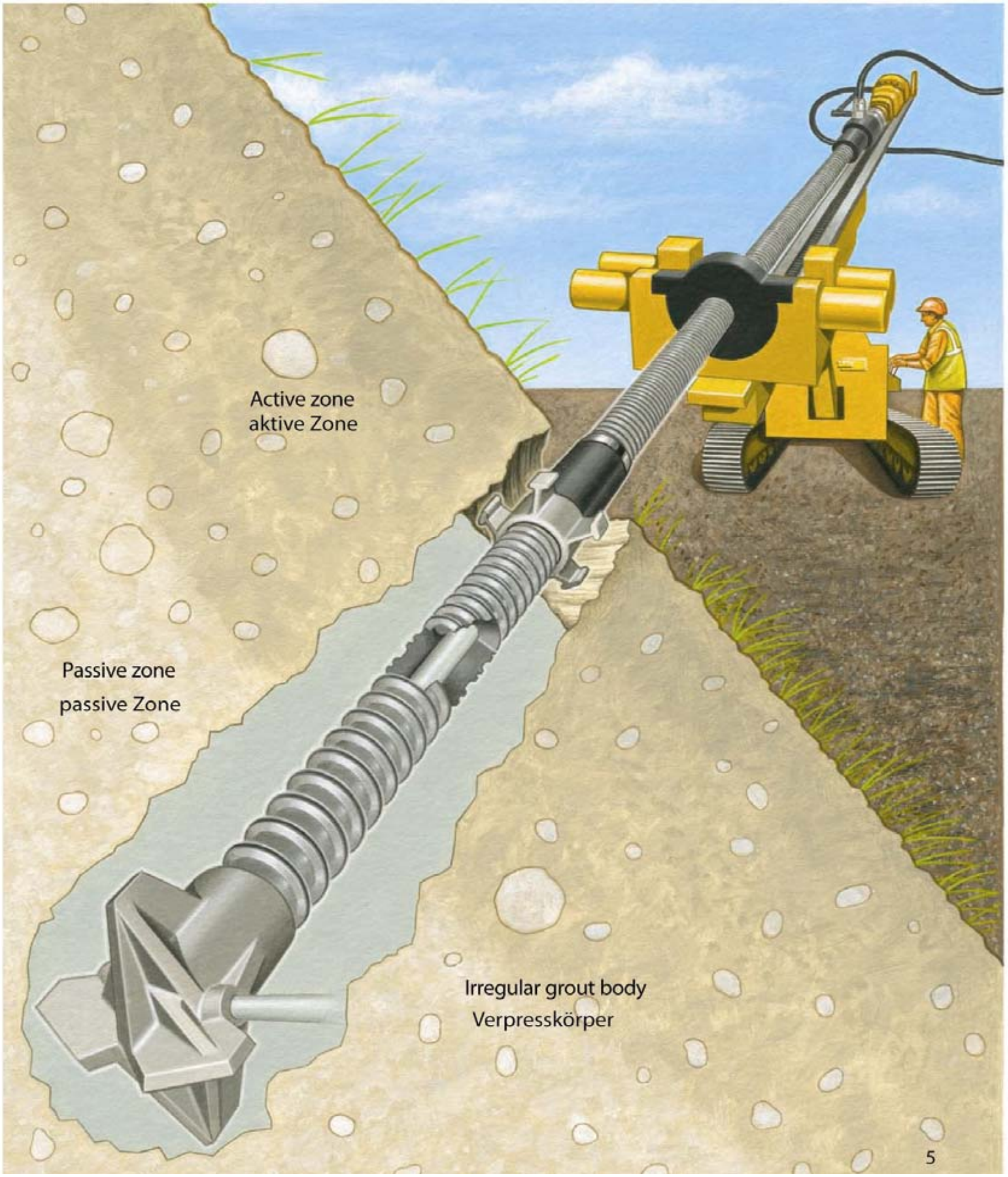
w/c ~ 0.4- 0.55
20 - 60 bar

These are just general rules they can vary depending on pile length, ground and site conditions.

Micropile (DIN EN 14199)

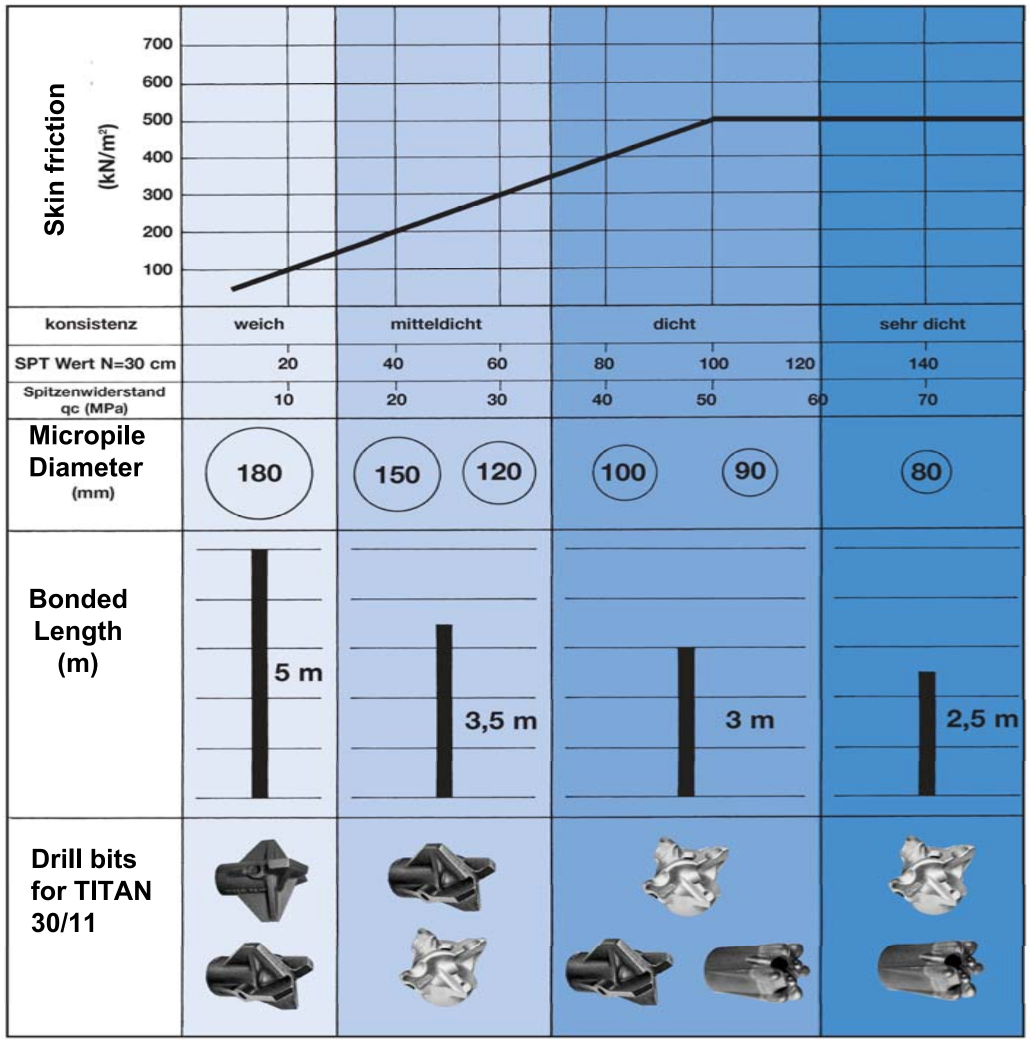


Soil Nailing (DIN EN 14490)

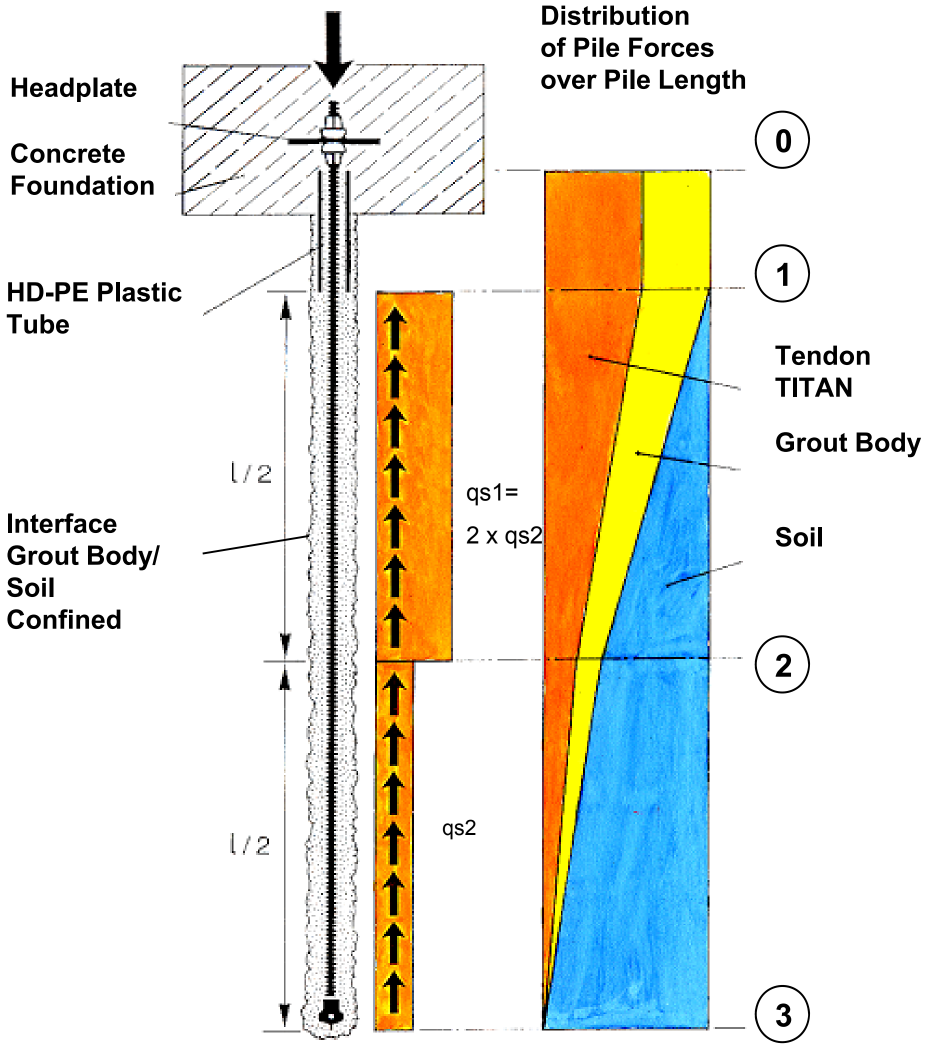


Design Diagramm Micropile TITAN 30/11 in sand and gravel

Pull out resistance depends on type of soil, confinement,
SPT-value, skin friction qs, drill bit diameters, bonded length
Diagram according Bustamente

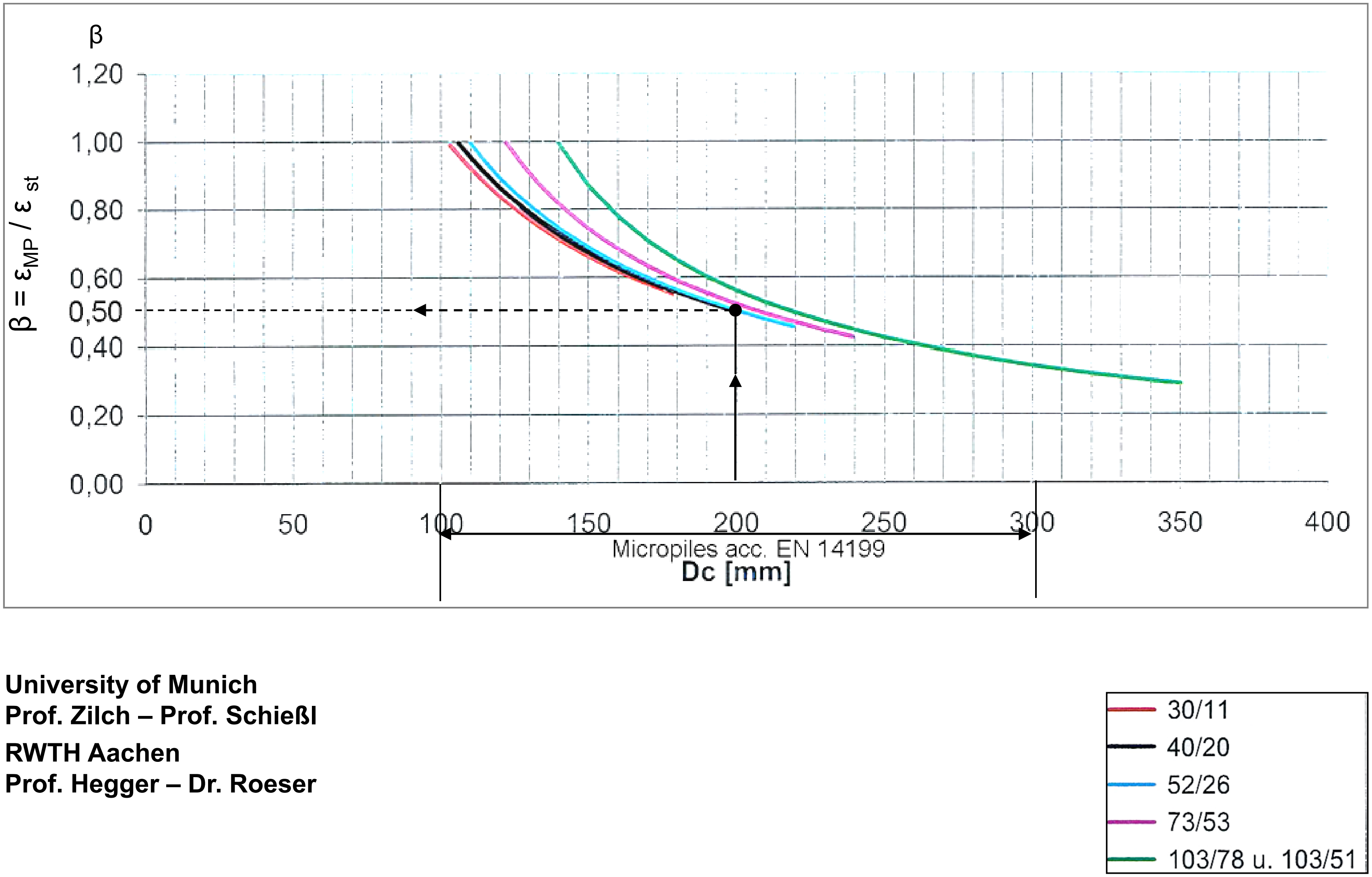


Load Transfer in Composite Micropiles TITAN for one Homogenous Layer of Soil



Monitoring the Distribution of Load Transfer to the Soil by Extensometers, installed inside the hollow Micropile TITAN

Strain Relation $\beta = \varepsilon_{m\ micropile}/\varepsilon_{s\ steel}$ versa Micropile Diameter Dc[mm]



University of Munich
Prof. Zilch – Prof. Schießl
RWTH Aachen
Prof. Hegger – Dr. Roeser

Estimated Displacements of TITAN Drilled Micropiles in Comparison

Example:

Given: **TITAN 52/26, L = 15 m long, SWL = 400 kN (90.000 lbf); D_c = 200 mm,**
E x A = 231 x 10³ kN Axial Stiffness of Steel Member

with Displacement of Steel Member only:

$$\Delta L_{steel} = \frac{F \, x \, L}{E \, x \, A}$$

$$= \frac{400\,kN \, x \, 15\,m}{231 \, x \, 10^3\,kN}$$

$$\boxed{\Delta L_{steel} = 26 \;\; mm}$$

with Displacement of Micropile, free unbonded length;

$$\Delta L_{MP} = \beta \, x \Delta L_{steel} \qquad \beta = \frac{\varepsilon_{MP}}{\varepsilon_{steel}}$$

Read by folie 12: $\beta \approx \; 0{,}5 \;\; for \;\; D_c = 200\,mm$

$$\boxed{\Delta L_{MP} = 13 \;\; mm \; (1/2")}$$

with Measured Displacement of Micropile in the Ground
University of Siegen, Prof. Herrmann, A. Scholl, 2008)

$$\Delta L \qquad = 4{,}57 \; x \; e^{0{,}0013\,x\,F}$$

$$\Delta L \qquad = 4{,}57 \; x \; 2{,}718^{0{,}0013\,x\,400}$$

$$\boxed{\Delta L \qquad = 7{,}7\,mm}$$

with Displacement of Strand Anchor, 3 strands 15,7 mm Ø (0,6"), 6 m free length

without prestressing

$$\Delta L_{strand} = \frac{400 \, x \, 6000}{195 \, x \, 3 \, x \, 150} = 27{,}3\,mm$$

with prestressing to 80 %

$$\Delta L_{strand} = 27{,}3\,mm \, x \, (1 \; - \; 0{,}8) \qquad = 5{,}5\,mm$$

$$\boxed{\Delta L_{strand} \;\; = \;\; 5{,}5\,mm}$$

Conclusion: Displacements of Micropiles - without prestressing (passive Anchors) and
- without designed free length
can be compared with displacement of prestressed strand anchors.

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Folie 14

Verification Tests with Micropiles TITAN 89/67

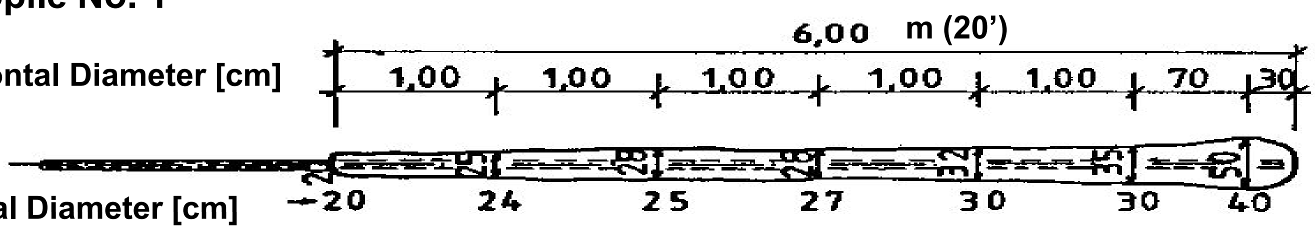
Grundbauingenieure Steinfeld und Partner, Hamburg, 28.10.1985

Nearly horizontal, 15° inclination

Medium Dense Sand, Point Resistance q_c 6MPa

Micropile No. 1

Horizontal Diameter [cm]



Vertical Diameter [cm]

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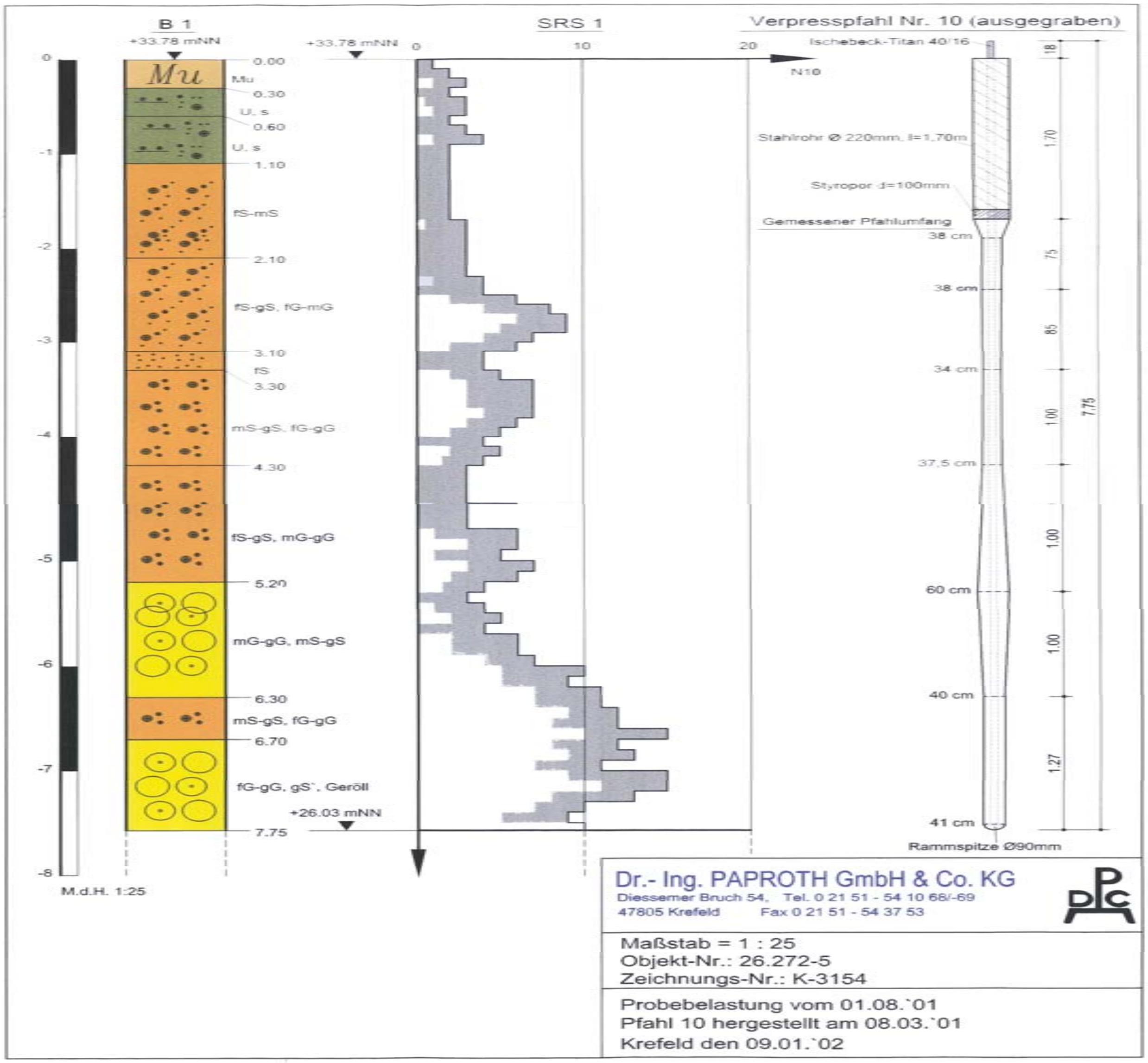
Folie 15

Exhumed Micropile TITAN 40/16 - Grout Body Diameter depends on S.P.T. or C.P.T. Test



Tests on TITAN Micropiles 40/16 were included in FRENCH NATIONAL RESEARCH PROJECT (FOREVER). This was to improve design of single and splayed micropiles.

Several tests were carried out in St-REMY-LES-CHEVREUSE in 1998. The micropiles were installed within the loose, fine and dry sand of Fontainebleau.

TITAN Micropiles 40/16, length 5 m, drill bit 70 mm, flushing grout w/c=0,9, grout pressure 8 – 20 bar.

Results:

1. **Skin friction qs = 74 kN/m²**
   Micropiles TITAN fulfil the requirements of the French DTU 13.2 micropieux
   Typ IV (IRS or postgrouted)

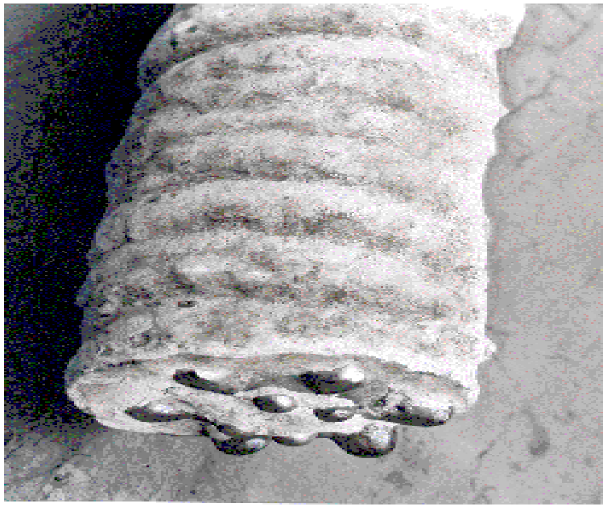
2. **Loadtransfer in compression was 7% by end bearing, 93% by friction**

3. **Micropile Diameter D=113 mm**
   Drill bit d = 70 mm,
   D = (1,5 ÷ 1,8) x d

4. **No visible cracks observed within the grout body**

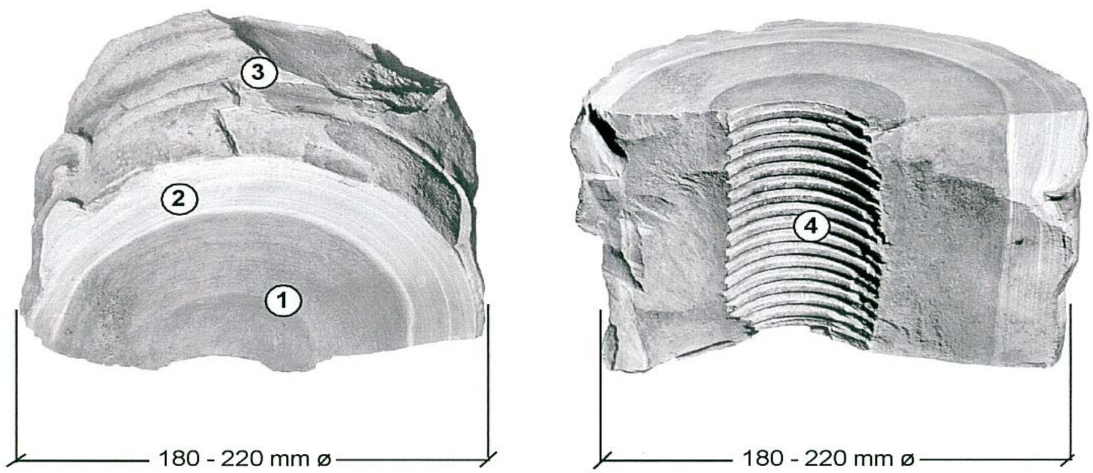
5. **Steel tendon centred within the grout body**

6. **Succesful Dynamic integrity testing using the French method SIMBAT which was confirmed by CEBTP**



An exhumed grout body of a TITAN 103/78

installed in very fine, loose sand, 40 m below water table, S.P.T. approx. 3, q_c = 15 MPa



① Neat (full strength) grout = Ordinary Portland cement, qualtity B25, unconfined compressive strength > 25 N/mm²

② Filter cake (Membrane) = concentration of cement, stabilised the annulus, brighter and darker rings show different W/C- mixture

③ Very good shear bond

④ TITAN 103/78 centered in the micropile, almost constant grout cover   (C > 50 mm) > 2”

Verification Test with TITAN 103/78 Micropiles - Lochau (Halle) April 2005, Prof. Dr. Wichter

12 m

15 m

18 m

21 m

24 m

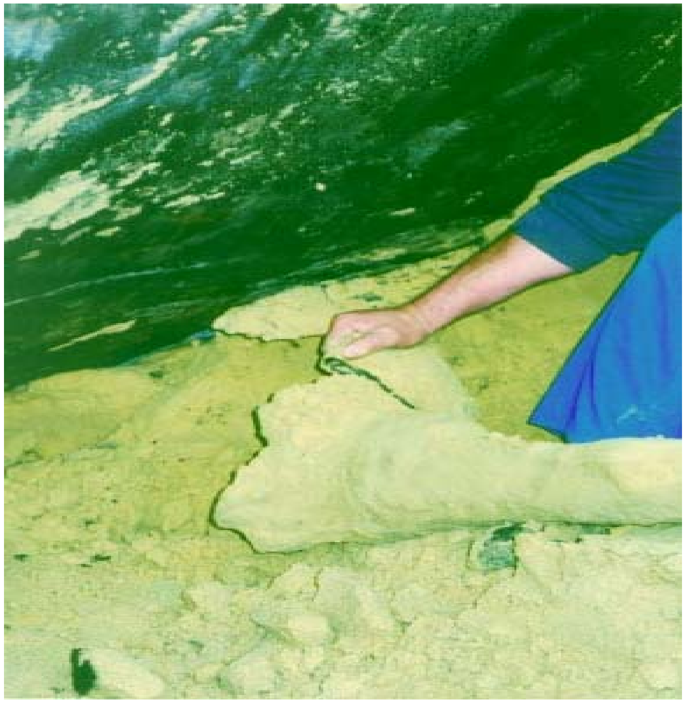
27 m
Deviation 0,66 m

Light plastic clay (cohesive soil)

Near horizontal, 20 ° inclination

Deviation $\frac{0{,}66\,m}{27\,m}$ = 2,5 % < 4 %

Required by EN 14199 “Micropiles”, Annexe B
max. length limited to 33 m (110’)

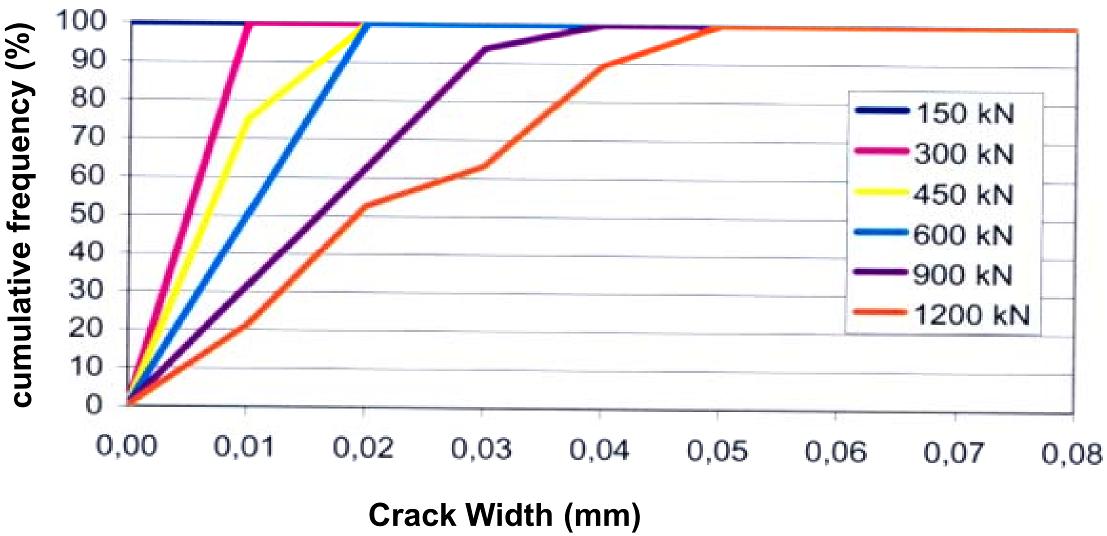


Exhumed Micropile TITAN 30/11

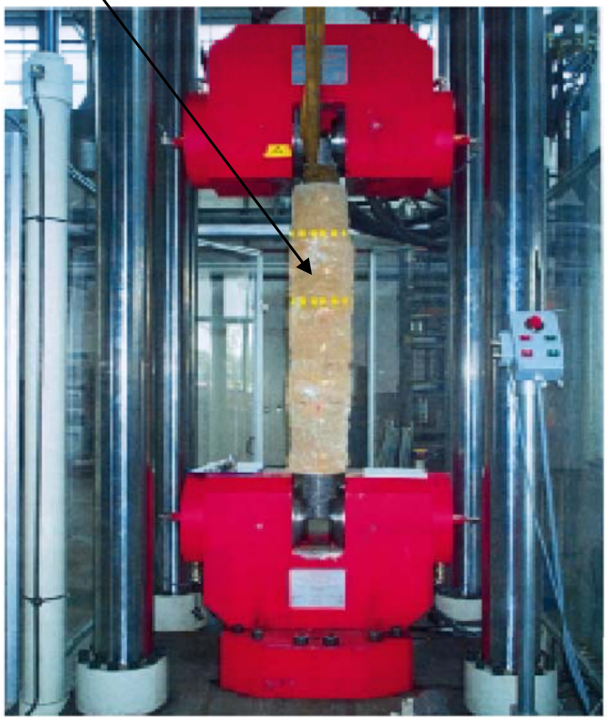
Claquage

Global Postgrouting through the drill-bit within 2 to 3 hours after initial pressure grouting increases the Pull-Out-Resistance in non-compacted sand e.g. by Stretching the Grout Body to form a Trumpet.

A testmachine with grout body 180 - 220 mm ø, 1200 mm long reinforced with TITAN 103/51, SWL 1000 kN



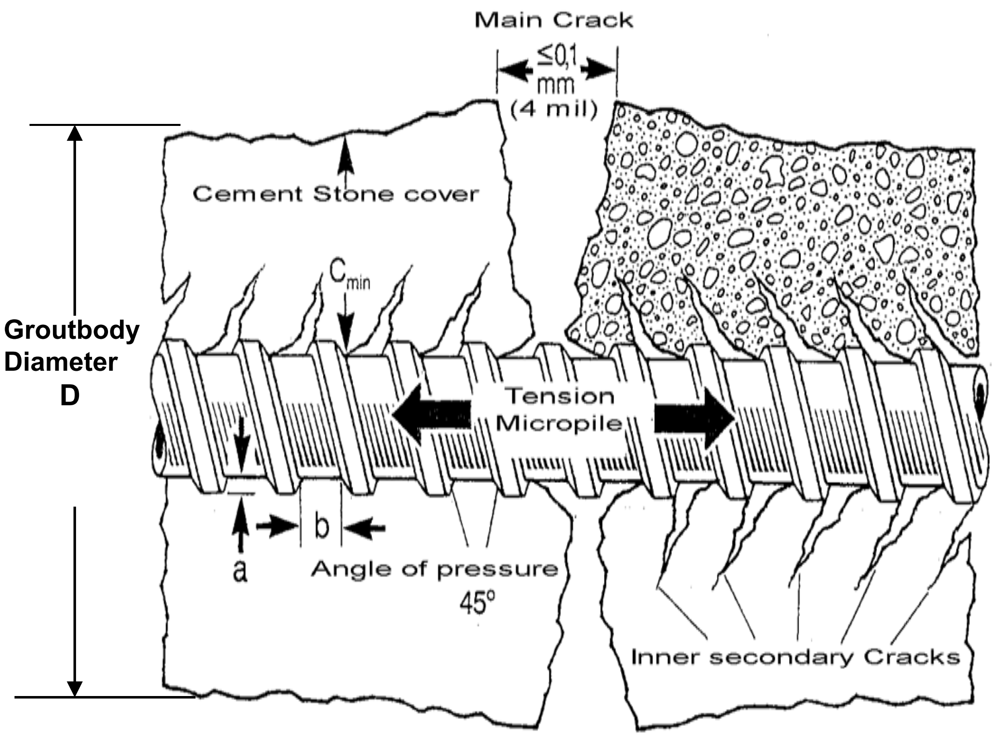
Position of Coupler



University of Munich
Institute for Building material and Construction
Prof. Zilch – Prof. Schießl

Model of micropile under axial loading acc. to Goto

Showing both:
the tension stiffening effect and crack width limitation.



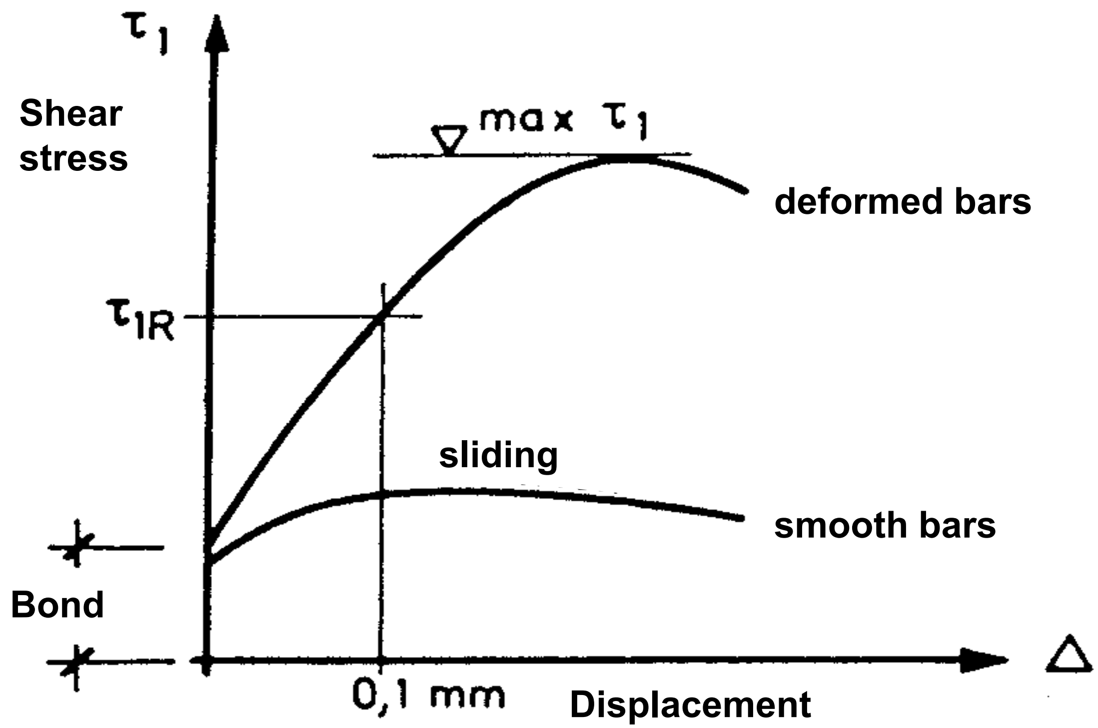
$$\frac{\text{Young's modulus } E_s \text{ of steel}}{\text{Young's modulus } E_c \text{ of concrete}} = \frac{210}{30} \approx 7$$

related rib factor $f_R = \frac{a}{c}$

f_R = 0,21 to 0,33 for micropiles TITAN

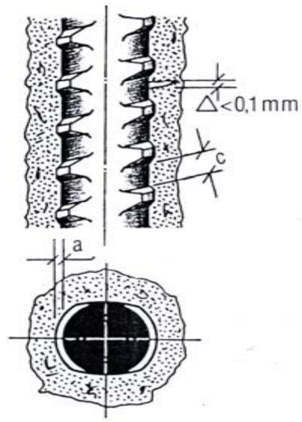
f_R = 0,056 for rebar

Shear Load transfer at interface steel ./. cementstone of micropiles depends on the deformations



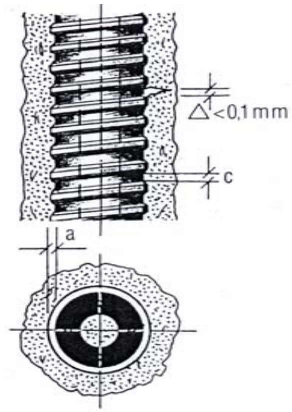
This figure confirms, that shear load transfer is improved by using deformed bars. The development of rebar's over the past 100 years has led to an increase in the use of deformed bars rather than smooth bars in micropiles.

Technical Dvelopment of the Shearbond of Micropiles



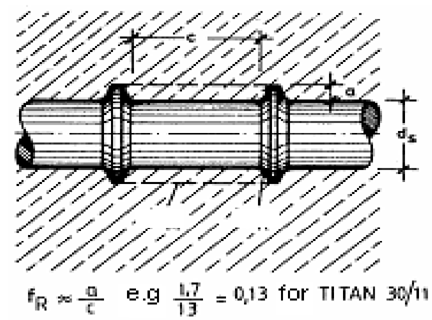
GEWI bar

Projected rib factor
f_R = 0,56 x a/c = 0,074
characteristic load-carrying capacity
230 N/mm²
(to Z-32.1-2)



TITAN hollow bar

Projected rib factor
f_R = a/c = 0,13
characteristic load-carrying capacity
~ 500 N/mm²
(to Z-34.14-209)



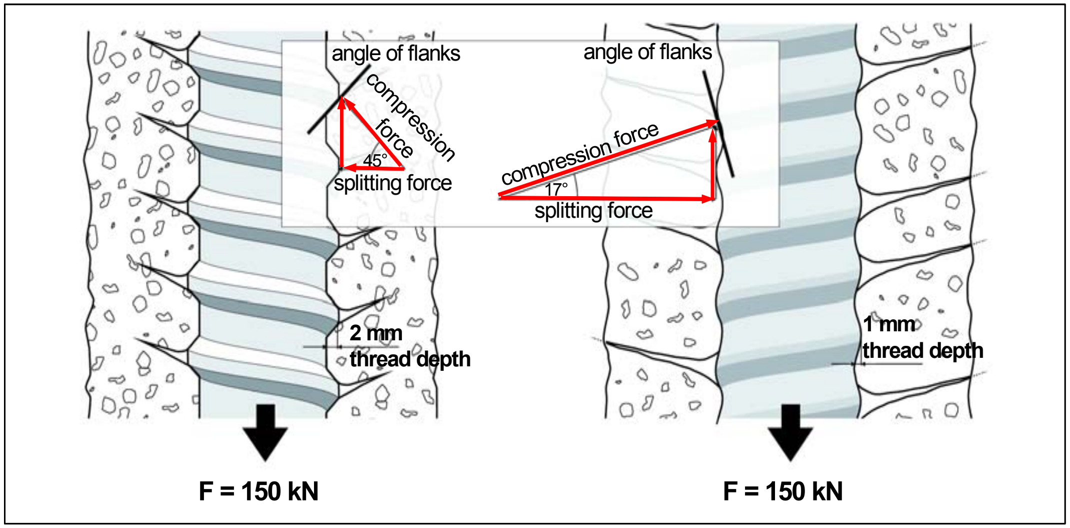
The related rib-factor $f_R = \frac{a}{c}$, which is known for deformed rebars, determines the ranking list in shear load transfer.

e.g. $f_R = 0{,}13$ for a hollow TITAN 30/11 - This figure is better than that of a GEWI rebar with $f_R = 0{,}074$

Significant differences in shear bond

TITAN 30/11
reinfording steel thread
(thread to DIN 488 / ASTM-A 615)

TITAN R 32/15
drilling thread
(R-Thread to ISO 10208)



relation of cross section $\frac{Ac}{A} \geq$ 0,85

Ac = cross section of cement

(without steelbar)

A = total cross section of the micropile

for steel quality fy ≤ 500 N/mm²

all cracks (fissures) are smaller ≤ 0,1 mm

Splitting force in cement is

3 x bigger (3 ~ $\frac{tg\ 45°}{tg\ 17°}$)

thus the cement stone cover must be

3 x bigger for R-threads than for
TITAN threads.

cracks ≤ 0,2 – 0,3 mm [Wichter, Hosp]

Cracks reaching the surface can cause
dangerous axial cracks and damage
corrosions protection!

Conclusion:

R-thread does not comply with the requirements of international reinforcing steel standard. (ASTM A 615, EN 10080, DIN 488)

Additional corrosion protection – e.g. galvanising, sacrificial losses – need to be considered.

However galvanising of sacrificial losses are not allowed in Germany (DIBt) and some other countries.

Therefore R-thread finds acceptance only for temporary tunnelling applications or less than 7 – 50 years life time, depending on ground conditions. [ETA-08/0277 MAI]

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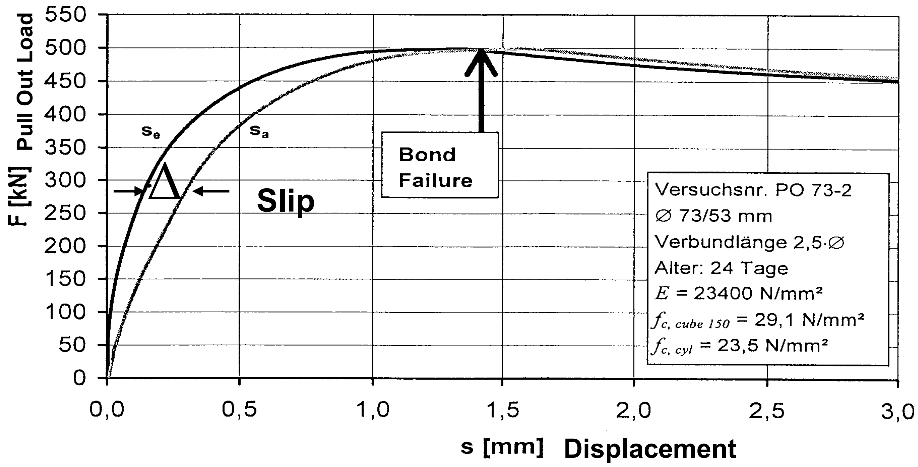
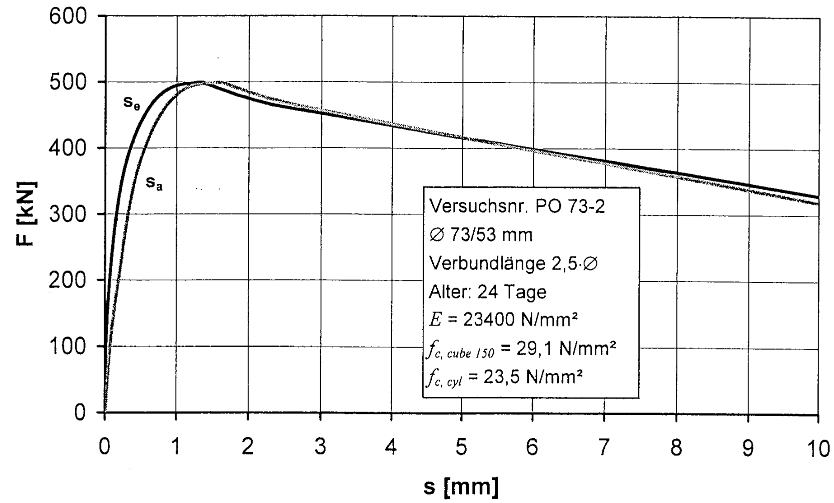
Bond Test (Pull Out Test)

Pull out tests were carried out according to RILEM/CEB/FIP Recommendation RC 6
For the tests two types of grout were used C25/25 and C35/45.

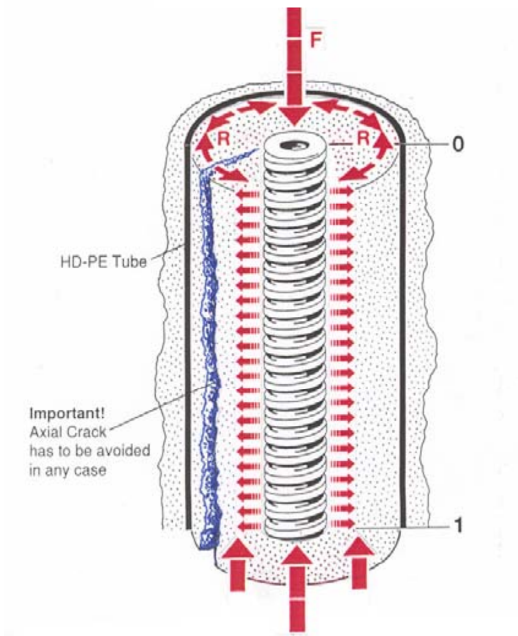


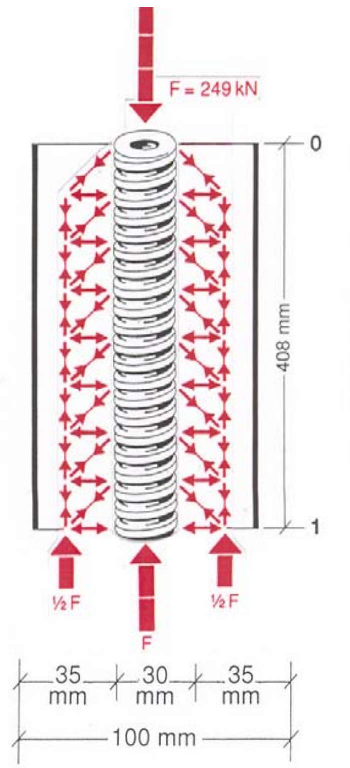


TITAN drilled micropiles can be designed same as rebars. No limitation in bonded length due to the stiff shearbond.
No limitation in bonded length, as known with strand anchors. Deformations of TITAN bars fullfill requirements of ASTM A 615.

Load transfer by the grout cover

Calculation Model for Circular Forces R caused by Shear Bond and Squeezing





Necessary Length 0 – 1 for Load Transfer F from Tendon to Grout Body

Circular Force R in Grout Body, caused by
- Squeezing (Difference in Poisson figure)
- Shear Bond

Circular Force R has to be balanced:
By the cross section of cementstone cover C and the tension stress of cementstone e.g. ft = 3 N/mm²

TITAN DRILLED MICROPILES in Tension

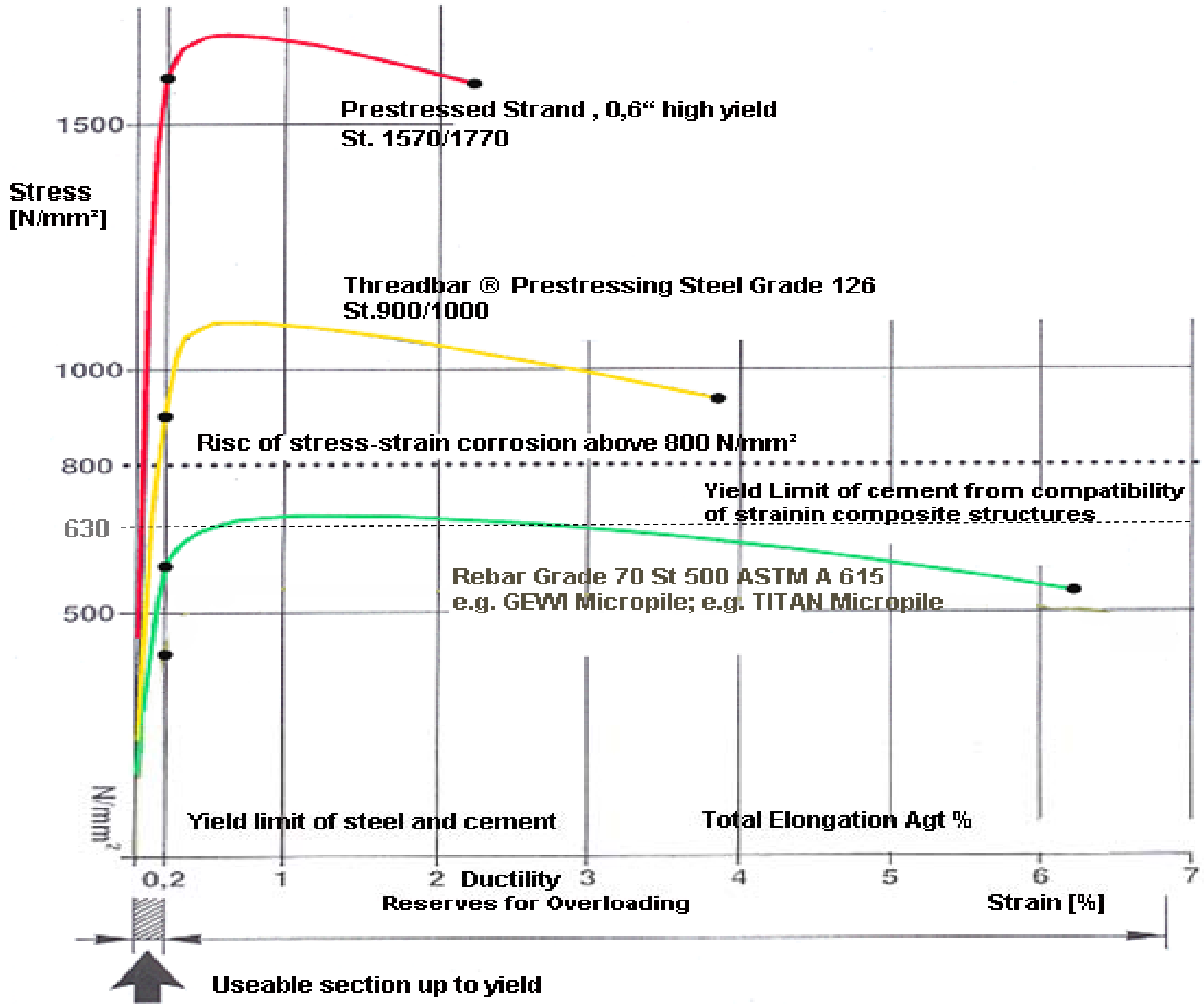
Cementstone Cover C [mm]	Type					
	40/20	40/16	52/26	73/53	103/78	103/51
	35	35	35	35	35	35

TITAN DRILLED MICROPILES in Compression

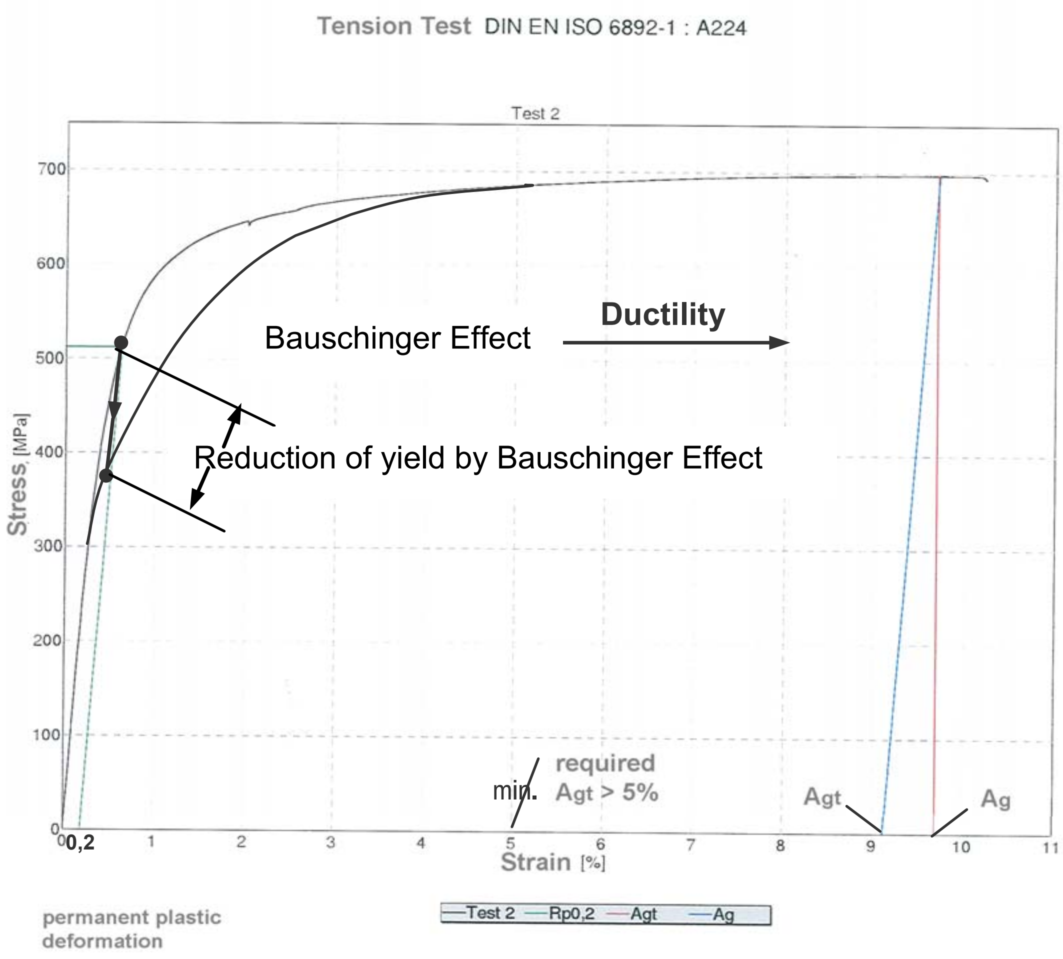
Cementstone Cover C [mm]	Type					
	40/20	40/16	52/26	73/53	103/78	103/51
	30	30	40	55	80	80

acc. Z - 34.14-209

Stress/Strain Diagram for typical Anchor Steels



Stress/Strain Diagram with Bauschinger Effect



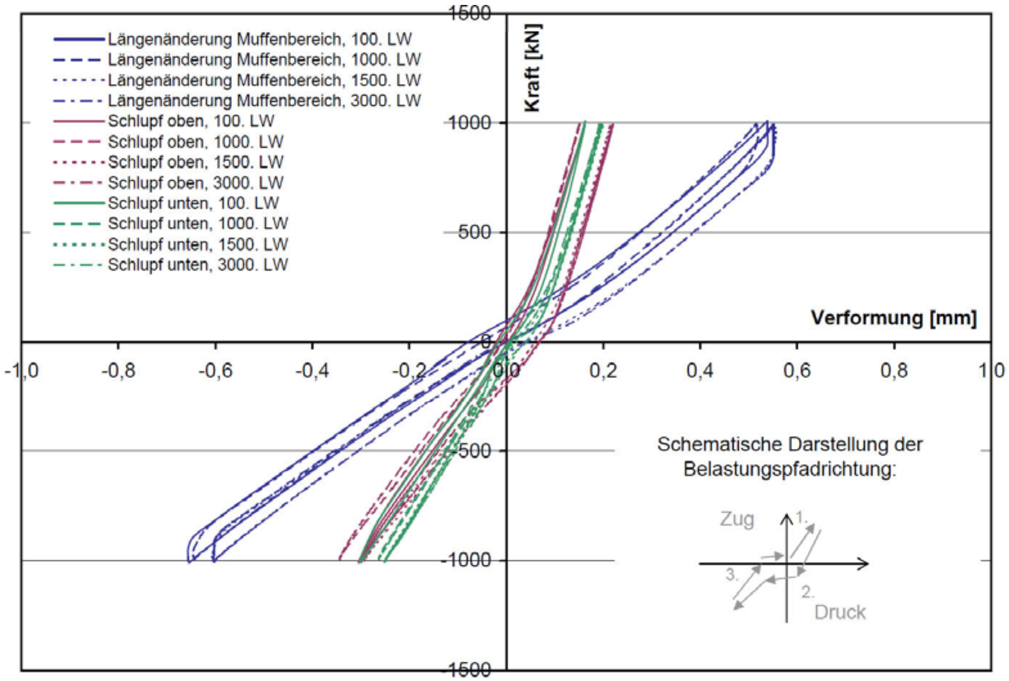
A typical stress-strain diagram of cold formed steel tendons shows the **Bauschinger Effect.** **Bauschinger Effect** means, that the stress–strain graph line is curved, not linear as it should be, according to Hooke and therefore the yield stress is reduced.

Fatigue (Wöhler-Diagram) of coupled steel-tendons under cyclic loading, such as changing from compression to tension.

Fatigue by cyclic loading is reduced using a TITAN micropile with a coupler without counter nuts. The coupler is double locked by a self locking thread (friction angle < tg 6°) and additional Prestressed by the torque of the drill hammer during connection.

Fatigue Test: Coupled TITAN 103/78

Load-Displacement-Curves for a Coupler TITAN 103/78



Loading with ± 1000 kN within 3 seconds of changing from compression to tension.

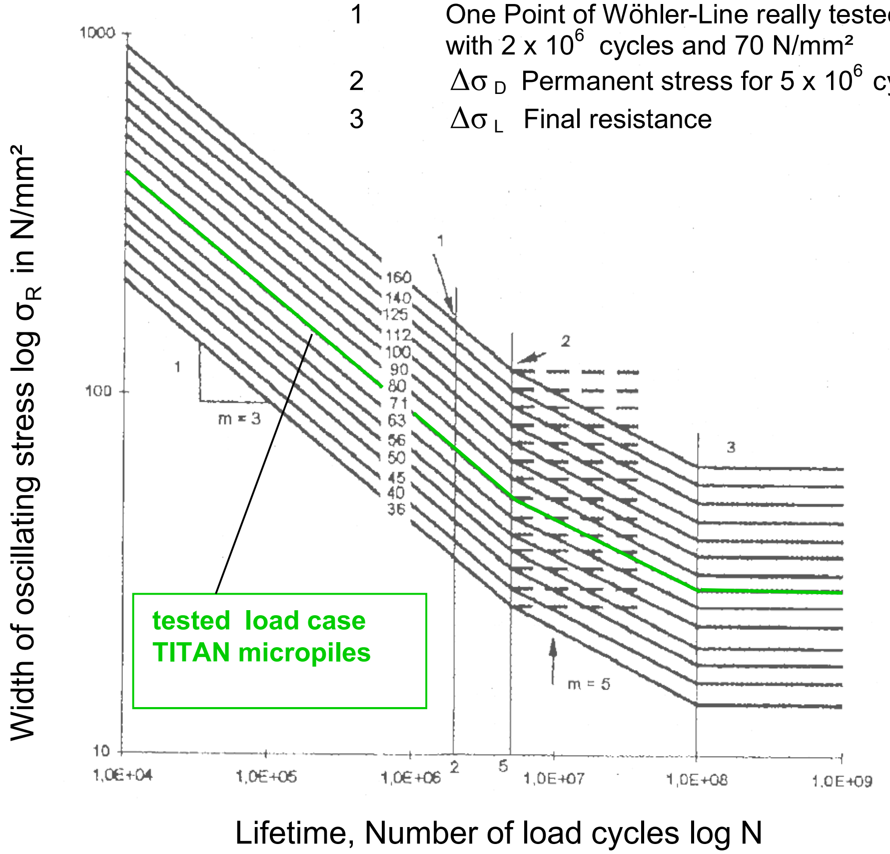
Fatigue (Wöhler)-Diagram for micropiles TITAN 103/78
Oscillating Stress versa Number of Load Cycles

Legend:

1 One Point of Wöhler-Line really tested with 2×10^6 cycles and 70 N/mm²

2 $\Delta\sigma_D$ Permanent stress for 5×10^6 cycles

3 $\Delta\sigma_L$ Final resistance



Example for application of Wöhler-Diagram

Low cycle fatigue in case of seismic events according ISO-DIS 15835-2

Question:

How many cycles are allowed for cyclic loading of ± 1000 kN without damage or reduction in resistance?

$$2 \times \sigma_R = \frac{2 \times 1000\,kN}{3140\,mm^2}$$

$$= 637\ N/mm^2$$

According to Wöhler diagram (green line)

$$N = \frac{70^3}{637^3} \times 2 \times 10^6 \text{ cycles}$$

N_{max} = *2655* cycles < 3000 cycles, which was verified by tests.

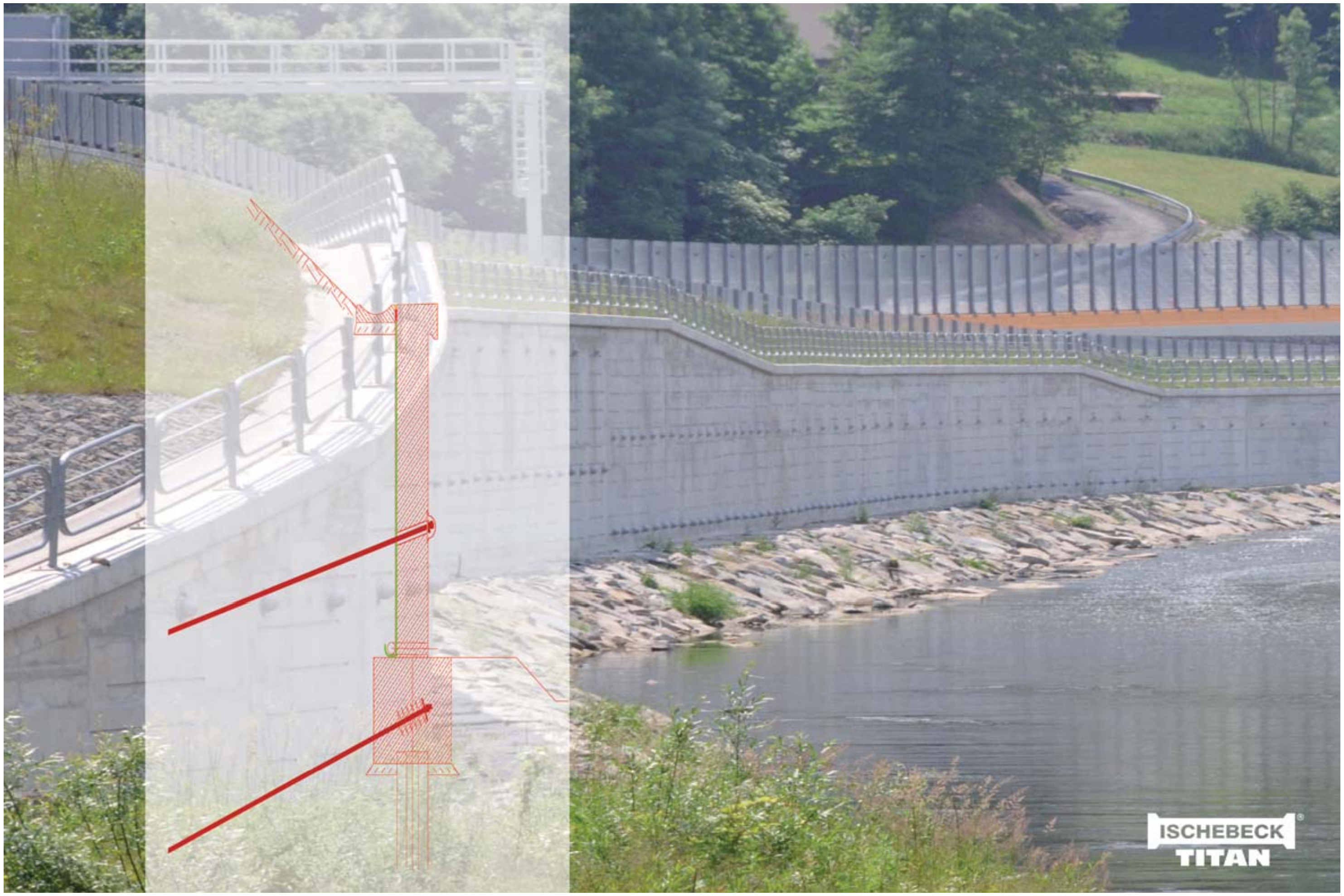
Further Applications:

Foundation of wind-turbines,
Foundation for noise-barriers along high speed rail-lines.

Bridge foundation

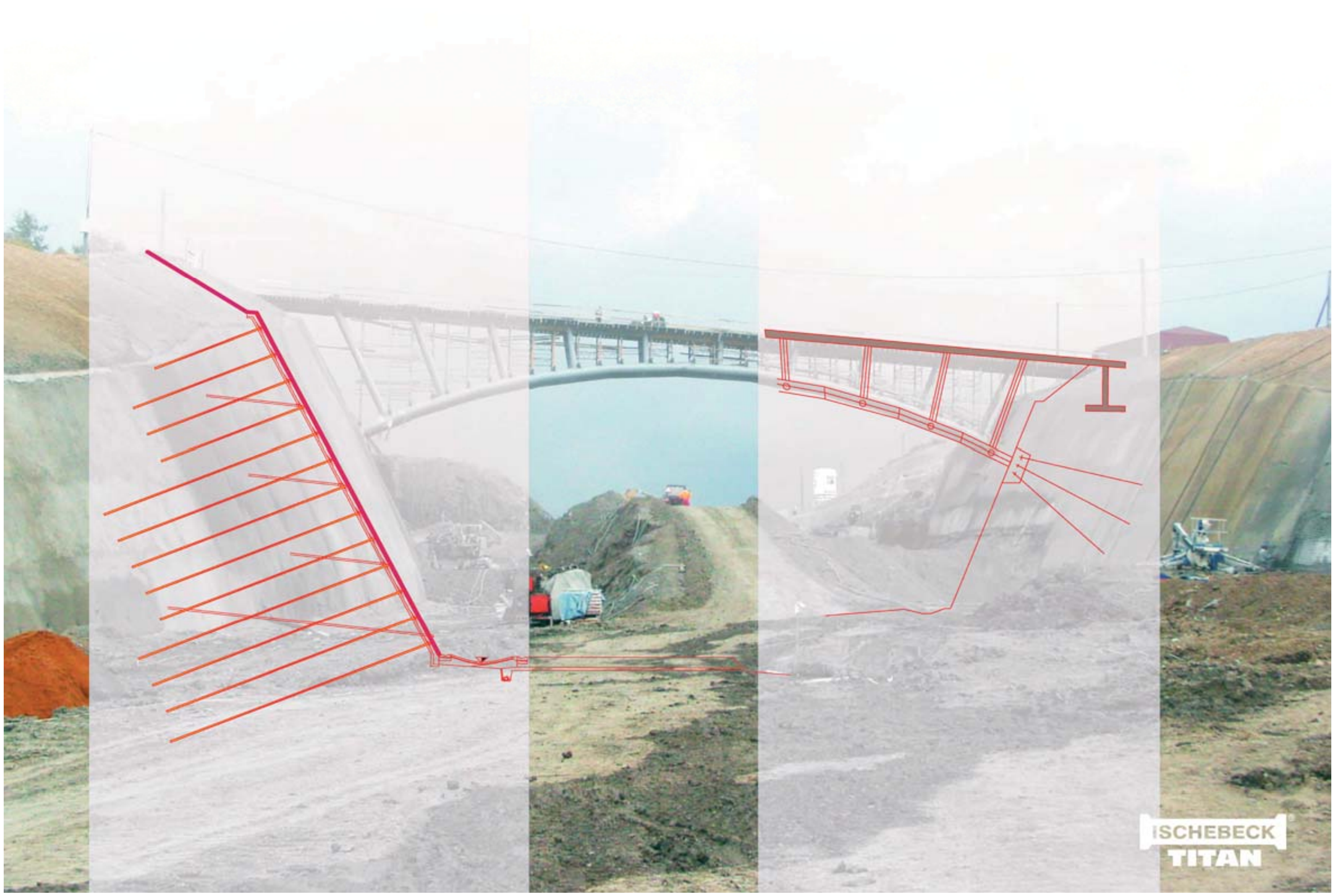
The micro system achieved near uniform resistance and displacements in inhomogenous ground conditions.

Retaining Wall



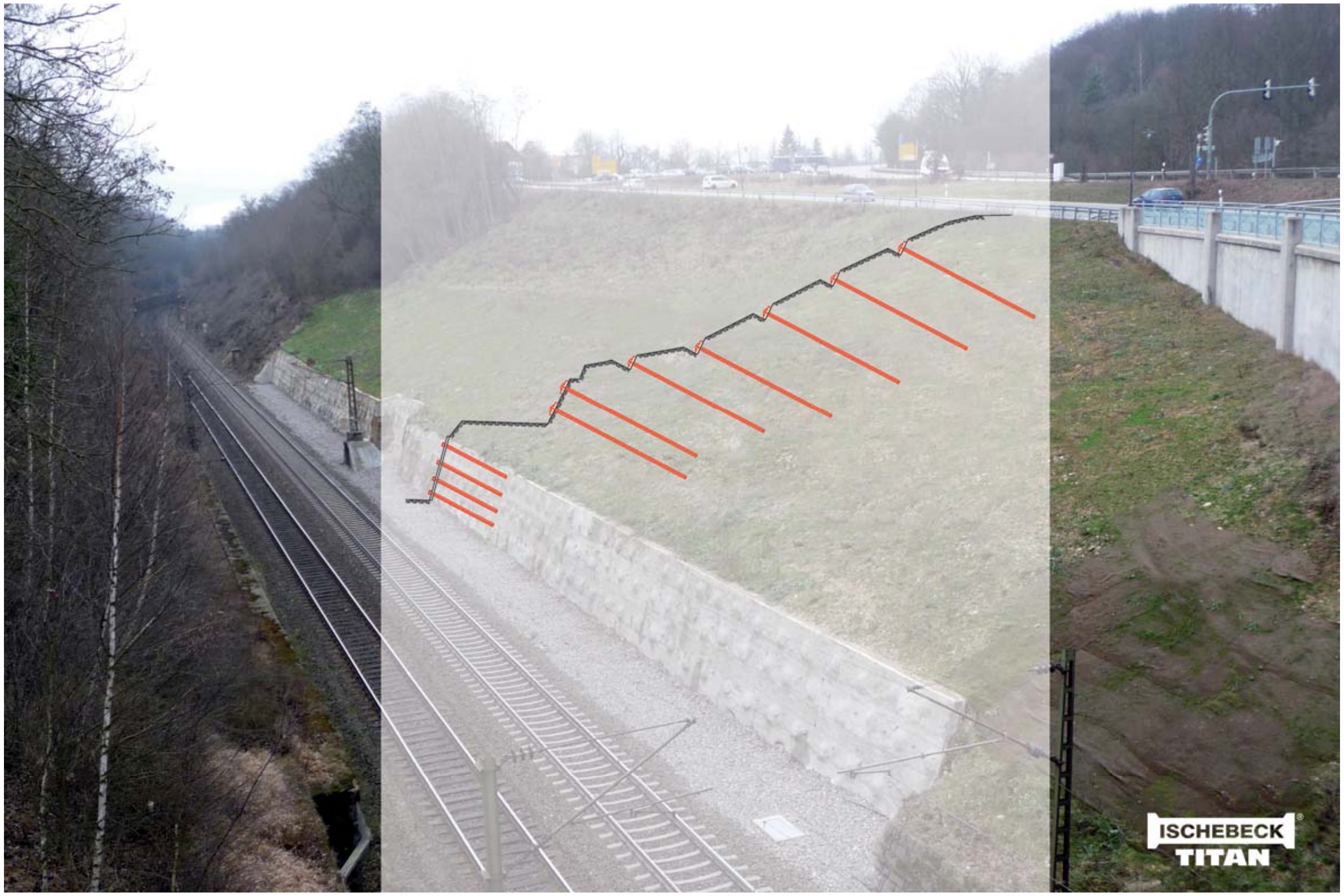
Permanent Tiebacks (passive anchors), without prestressing.

Cutted slopes in road construction



A steep cut slope constructed using soil nails (micropiles), with a soft face, environment friendly

Track widening for high speed railways

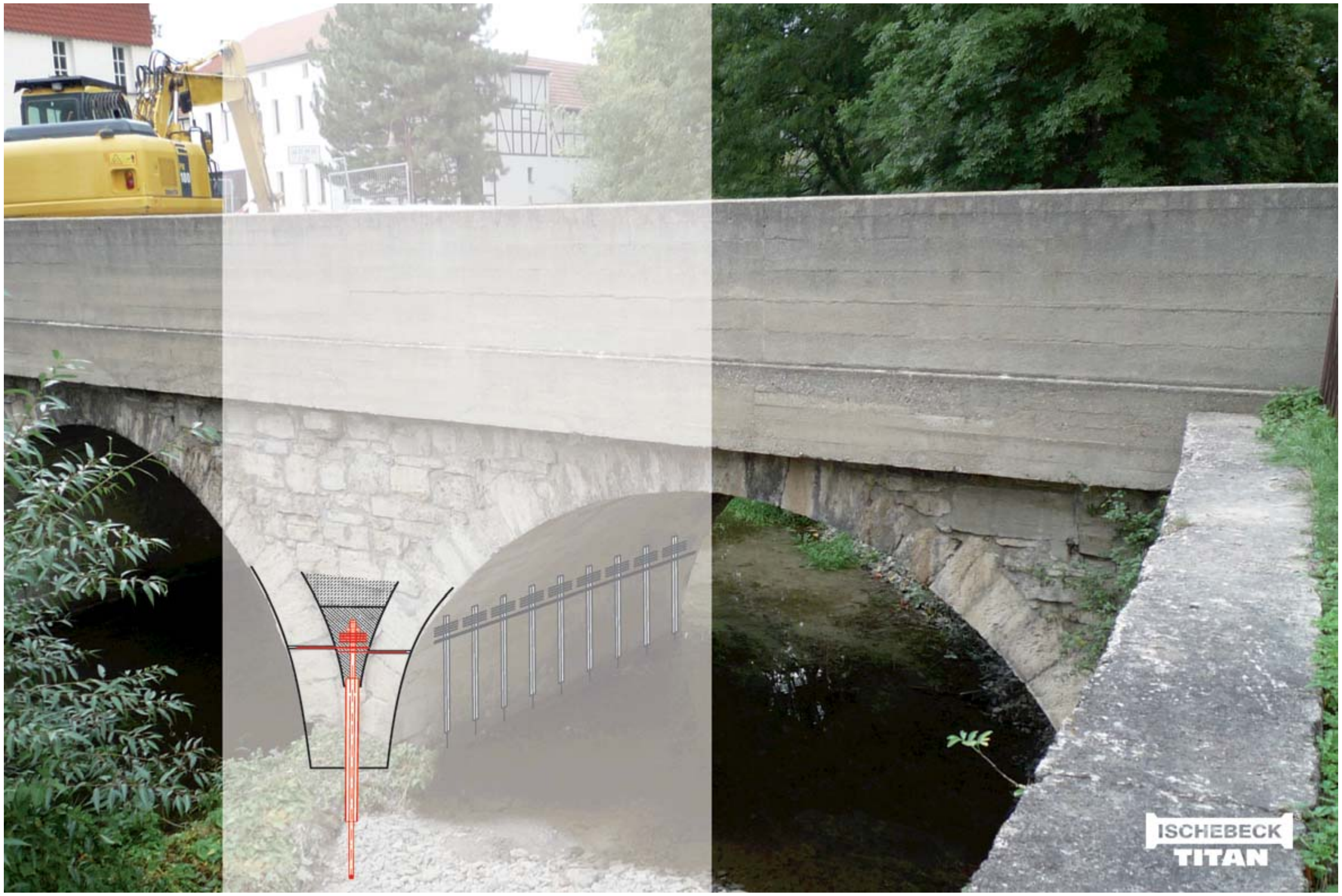


Soil nailed slope with both a soft facing and a hard structural sprayed concrete finish

Foundation for transmission pylons, communication towers and gantries

Drilled TITAN micropiles, are used due to the high axial stiffness and small displacement required without prestressing. The same installation method can be used for schemes with varied ground conditions, which improves the logistics of the project.

Underpinning existing bridge foundations



One of the first applications, because of the extreme stiff axial load transfer of micropiles.

Deep excavation – Anchored sheetpile walls and anti-buoyancy anchors

Back to the roots

New HILTI electric powered drill-hammer - weight ab. 23 kg(50 lbs), 2,2 kw –
– for hand installation of TITAN drilled micropiles in mining and limited space.

Thank you for your kind attention!

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