ISCHEBECK TITAN®

PERMANENT
DIBt appr. Z-34.14-209
100+ Years

Anchorages for sheet pile walls

Anchorages for retaining walls

Anchorages for excavation shoring

# Anchorages for retaining structures with TITAN micropiles

## Temporary and permanent

National Technical Approval Z-34.14-209

# Anchorages with TITAN micropiles

In Germany, TITAN micropiles to EN 14199 and DIN SPEC 18539 are covered by National Technical Approval Z-34.14-209 issued by the German Institute of Building Technology (DIBt).

Diverse types of retaining structures and excavation shoring can be tied back cost-effectively with anchors to meet structural requirements. TITAN micropiles used as tension piles according to EN 14199 have proved to be economic alternatives to prestressed ground anchors to EN 1537. Micropiles can be used for new structures and also for tying back existing structures. Gentle, low-vibration installation with compact, lightweight plant is standard, even for situations with difficult access.

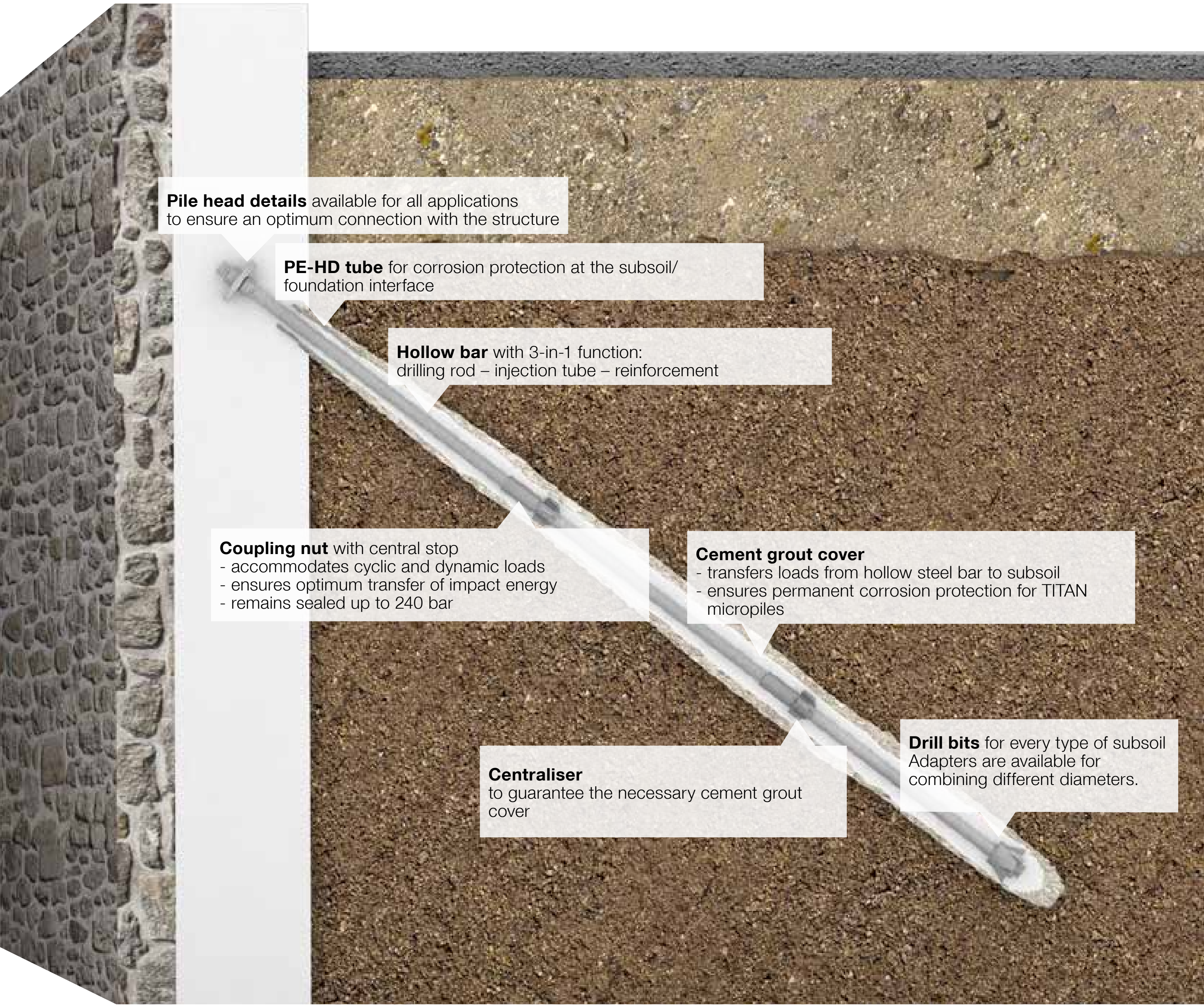
This brochure illustrates very diverse uses in conjunction with multiple head detail options for permanent and temporary applications. There is also a comparison between the loadbearing behaviour of ground anchors and micropiles. The reader will also find information on design as well as behaviour during loading tests and tests on micropiles loaded in tension. A sample text for tenders is included as well.

## Range of applications

**Anchorages for sheet pile walls**
- Quayside structures
- Flood defence walls
- Bridge wing walls
- Locks and hydraulic engineering structures
- Alongside waterways

**Anchorages for retaining walls**
- Edge beams
- Bored cast in-situ pile walls
- Diaphragm walls
- Gabion walls
- Refurbishment of historic retaining walls
- Verge stabilisation

**Anchorages for excavation shoring**
- Bearing pile walls
- Sheet pile walls
- Bored cast in-situ pile walls
- Diaphragm walls




**Advantages for designers**

- System has a National Technical Approval in Germany
- Flexible application options for difficult boundary conditions
- Suitable for all soils
- Low structural deformations without prestressing

**Advantages for contractors**

- One installation method for all types of applications
- Suitable for use in confined sites
- Fast progress on site
- Unaffected by changing soil conditions

**Advantages for clients**

- Permanent corrosion protection
- Highly reliable installation method
- Avoids major interference with existing works
- Economic system

## Benefits of the system

The TITAN micropile is a composite pile with a continuous thread which requires a technical approval when used in Germany. The tension and/or compression loads applied to the pile are transferred from the hollow steel tendon to the ground via the grout body. In order to achieve an optimum shear bond, the tendon has a profile that complies with all the main requirements for steel reinforcing bars to EN 10080/DIN 488. The tendon functions as drilling rod, injection tube and reinforcement (3-in-1 principle). The hollow bars are steel tendons, which are usually 3 m long and are joined together with coupling nuts.

**Permanent corrosion protection**
Dynamic pressure grouting of the TITAN micropile produces a grout body that interlocks with the surrounding subsoil. TITAN hollow steel tendons satisfy the main requirements for steel reinforcing bars, which means that an excellent shear bond is achieved between the tendon and grout body. With crack widths < 0.1 mm in the grout, the cement grout cover required by the National Technical Approval therefore guarantees permanent corrosion protection for the system. TITAN micropiles can therefore be used for permanent applications without the need for additional corrosion protection measures. According to EN 1990, Table 2.1, category 5, permanent means 100+ years without any restrictions.

**Coupling nut**
The coupling nut has a central stop (steel ring and seal) and is designed for...
- cyclic tension/compression loads
- dynamic loads
- optimum transfer of impact energy
- a grouting pressure of up to 240 bar

**Steel grade**
- Hollow steel bar made from S460 NH fine-grain structural steel
- Yield stress $f_{y,k}$ = 400–600 N/mm²
- Elongation at maximum load $\varepsilon_{uk}$ or $A_{gt} \geq 5.0\%$
- Notched impact energy of raw material W ≥ 40 J/cm³ (at -20°C). That minimises the risk of damage caused during installation by rotary percussion drilling.

## Advantages for installation

Installation is normally carried out with hydraulically operated drifters with an appropriate flushing head.
Many different base machines and drilling rigs are available on the market to suit the most varied applications.

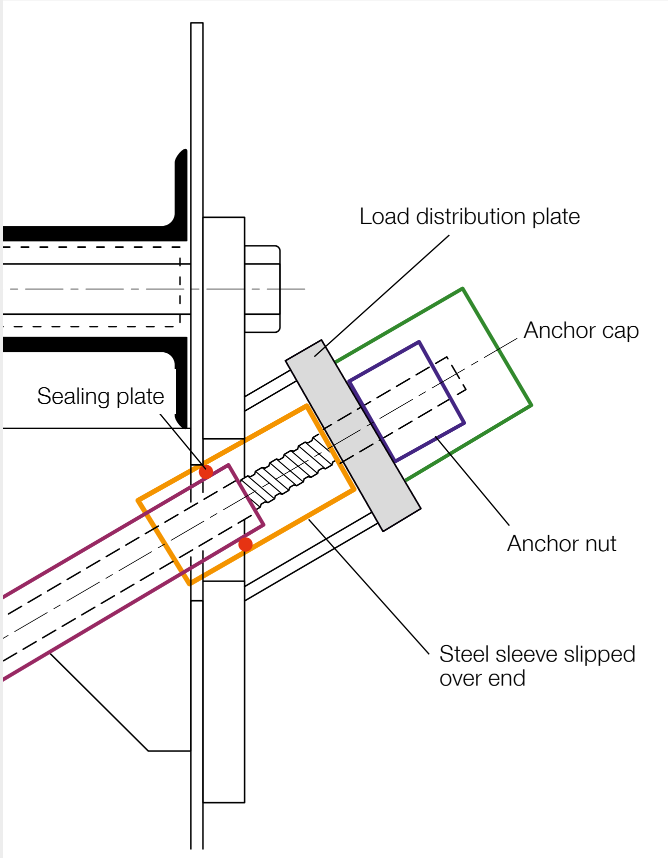
- Being able to mount the drilling rig on many different base machines means that our micropiles can also be installed in situations with difficult, complicated access.
- As a casing is unnecessary the self-drilling method uses much smaller plant compared to other systems.
- Time-consuming counternuts or heat-shrink tubes around coupling nuts are unnecessary.
- The use of 3 m long (max.) hollow steel bars means that there is no need for heavy lifting equipment (cranes), as is the case when installing a pile in a casing, for example.

## Anchorages for sheet pile walls

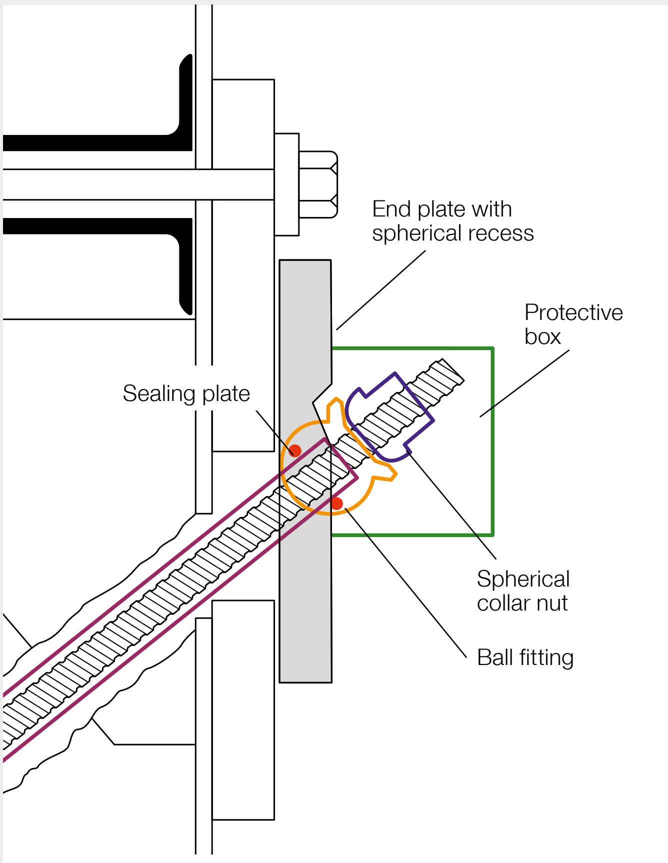

TITAN micropiles can be used to anchor sheet pile walls across a huge range of various specialised civil engineering projects. Depending on the change in ground level and the pile spacings, individual piles can be allocated design loads exceeding 2000 kN. There is a large range of different head details to choose from to suit particular applications. One head detail that has proved worthwhile for all pile types employs an end plate with spherical recess.

This solution combines permanent corrosion protection with the flexibility of being able to accommodate the angle of the pile in the horizontal and vertical directions to suit site conditions. This head detail complies with the requirements for permanent structures defined in EAU (Recommendations of the Committee for Waterfront Structures, Harbours and Waterways).

## Standard head detail employing end plate with spherical recess




**Head detail** to EAU 2012, Fig. R 145-8



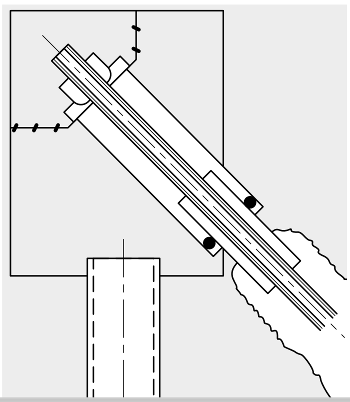

**Head detail** of TITAN system, which complies fully with the EAU 2012 requirements

Front view without protective box

Rear view

Front view with protective box

# Anchorages for sheet pile walls



**Quay wall refurbishment** South Zoll Canal, Hamburg
This quay wall, built in 1887 and protected by a preservation order, required extensive refurbishment to guarantee its stability for future generations. This was achieved by driving a sheet pile wall behind the wall and anchoring the sheet piles with TITAN 103/51 micropiles. Special requirements were placed on the drilling accuracy. Damage to the old structure, founded on timber piles, directly behind the wall had to be avoided at all costs. That made it necessary to employ a steel template to ensure that the direction and angle of the micropiles could be maintained exactly as planned.

In accordance with the details given in Recommendations on Piling (EA Pfähle) for micropiles, the head detail makes use of a capping beam.

**New sheet pile wall** Tourist access to the main port in Peenemünde
In some places one or two existing sheet pile walls had to be drilled through when installing the micro-piles. Corrosion protection in the air/water zone was guaranteed by a steel sleeve filled with cement slurry. The head detail is in the form of the tubular support shown in the photograph.

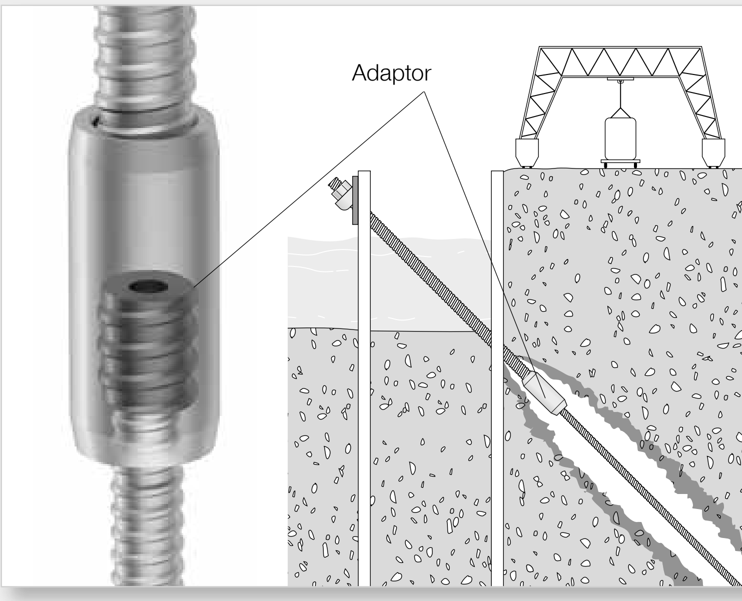
## Corrosion protection for head details

Depending on the different boundary conditions, permanent anchorages call for different corrosion protection solutions for their head details:

- PE-HD tube
- Steel tube
- Oversized steel cross-section

**PE-HD/steel tube**
Plastic or steel tubes can be used as a corrosion protection system to match the requirements of the project specification. The choice between plastic or steel depends on the distance to be bridged in the exposed air/water zone of the structure. Both variations are filled with cement slurry during installation of the pile.
Further information on sizing plastic or steel tubes is available and can be obtained from our engineers.

**Oversized steel cross-section**
Adaptors are available to combine hollow steel bars with different diameters. The steel cross-section can therefore be adapted and hence overdesigned at the parts of the pile where corrosion protection by the cement grout cover cannot be guaranteed. The corrosion rate in the air/water zone can be determined according to EAU to suit the given local circumstances and the design life requirements. The design approach employing the corrosion rate is only valid for the head of the pile and may not be used for the load transfer zone of the micropile.
Detailed information on corrosion rates can be obtained from our engineers.



# Anchorages for retaining walls

Retaining walls are structures for stabilising cuttings and embankments. They are mostly found alongside roads, railways, waterways and rivers, where they represent a cost-effective alternative to sloping embankments. The advantages are the saving of space and the retention of usable areas directly adjacent to the structure, because in contrast to embankments, retaining walls can be built vertically. Generally, retaining walls more than about 2 m high require micropiles to improve their stability.

Micropiles can be used for new retaining walls and also for the refurbishment of existing retaining walls.

**Anchored bored cast in-situ pile wall with walings**

A new stadium for biathlon and cross-country skiing was built at Krasnaya Polyana for the 2014 Olympic Winter Games in Sochi. Besides numerous anchored retaining walls around the stadium and along the cross-country skiing track, it was also necessary to build a bored cast in-situ pile wall behind the new shooting range which was secured with several kilometres of TITAN micropiles.


**Refurbishment of hillside and mountainside retaining walls**
B11 road, Wolfratshausen
The retaining wall below this trunk road was anchored with micropiles. They were installed with a lightweight drilling rig that was secured on the almost vertical wall by a cable.
The wall above the road was anchored using small plant that required the closing of one carriageway only.

**Anchors for edge beam and retaining wall**
B258 road, Burgring, Monschau
Edge beams and retaining walls over a length of 1340 m alongside this trunk road were rebuilt in five phases on the hillside above the town. The piles required were installed with one carriageway closed off. The vertical piles carry the compression loads and the raking piles carry the tension loads from the structure in this pile trestle arrangement.

**Retaining wall refurbishment**
Neuenheimer Landstrasse, Heidelberg
Old, crumbling retaining wall refurbished with anchored concrete elements. Small plant was used to install the elements between the existing structure at various working levels.


**Rebuilding a retaining wall**
B70, Meppen bypass
An arrangement of vertical large-diameter bored piles and TITAN micropiles installed at an angle of 20° to the horizontal were designed for a new retaining wall. Two approx. 20 m long TITAN micropiles were installed per bored pile to accommodate the tension loads. The head detail consisted of two spherical collar nuts and a washer plate, which was incorporated into the facing of the retaining wall.

**Refurbishment of a gabion wall**
Kaffeebergweg, Schwäbisch Gmünd
An eight-layer gabion wall was designed to straighten a sloping site. The high loads caused severe deformations that exceeded the permissible serviceability requirements. Two rows of TITAN 52/26 micropiles were installed at the base of the wall afterwards to anchor it. The top ends of the 15 m long piles installed at an angle of 20° from the horizontal were secured in a reinforced shotcrete facing.

# Anchorages for excavation shoring

Excavations can be carried out between shoring systems that are permeable or impermeable to water, in the form of flexible or low-deformation assemblies. The walls are anchored as the excavation work proceeds depending on the depth of the intended excavation and the local boundary conditions. Bearing pile, sheet pile and contiguous bored cast in-situ pile walls are regarded as typically flexible excavation shoring solutions. Interlocking and secant bored cast in-situ pile walls, diaphragm walls, jet-grouted walls and soil nailing are regarded as low-deformation options. Temporary anchors to EN 1537 or micropiles to EN 14199 can be used for anchoring such walls.
TITAN hollow steel bars are suitable for both.

**Subsequent anchoring**
Noise enclosure for A1 motorway, Cologne-Lövenich
Owing to the confined installation conditions between the shoring and the noise barrier, the TITAN 30/11, 40/20, 40/16 and 52/26 micropiles were installed with a manually operated drilling rig and midi- and mini-excavators fitted with short drilling rigs. Mobile cranes were used to lower some of the plant into the working area while the motorway was closed.

**Timber wedge clamp wall**
During the construction of the new railway bridge over the road leading from the new B6 trunk road to a military establishment, timber wedge clamps were used in addition to TITAN 40/16 micropiles.

Timber planks are simply fitted in front of the bearing piles with special wedge clamps. Tables are available for the quick preliminary design of this three-part system.

Please refer to our brochure on timber wedge clamps for further information.

**Temporary anchors for sheet pile wall**
New shopping centre, Victoria Square, Belfast
TITAN 103/78 and 103/51 micropiles were used to anchor the sheet pile wall around the excavation. The inside of each pile was flushed clean to measure the positional accuracy.

**Temporary anchors for diaphragm wall**
Road underpass, Moscow
Excavation work was carried out between diaphragm walls secured with temporary anchors. A total of approx. 11 km of TITAN 40/16 und 52/26 micropiles in several rows were installed by core-drilling through the diaphragm walls.

**Temporary anchors for bored cast in-situ pile wall**
New high bay warehouse, Bilstein company, Ennepetal
Two rows of TITAN 52/26 micropiles were used to anchor the contiguous bored cast in-situ pile wall around the excavation.

# Micropile – ground anchor comparison

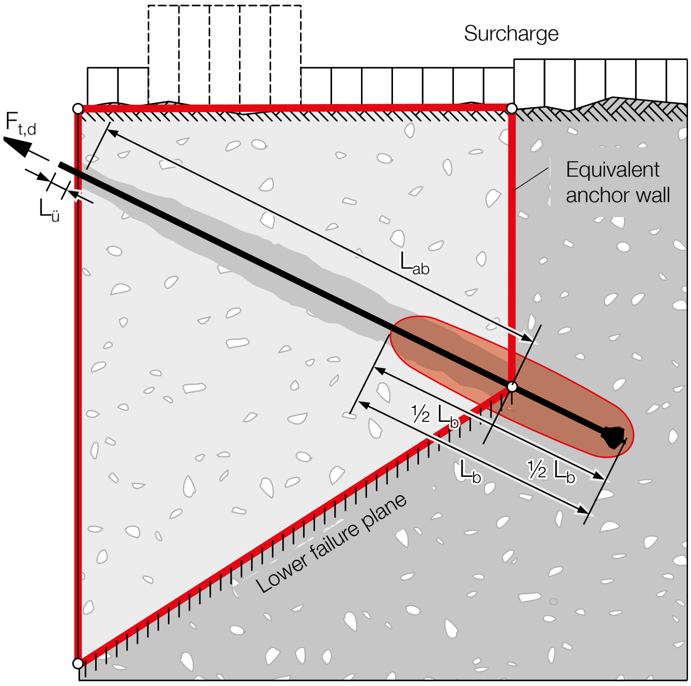
**Micropile** to EN 14199

- Tension and compression
- With or without prestressing
- Scope of testing = 3%
- Head detail **may** be integrated into the structure

**Ground anchor** to EN 1537

- Tension
- Prestressed
- Scope of testing = 100%
- Head detail **must** remain accessible

## Identical design approach for loadbearing behaviour




### Analysis of lower failure plane

Verifying the tension pile/anchor length required to anchor a retaining structure is based on the analysis of the lower failure plane for anchor walls and anchor plates according to Kranz (1940). Based on that and in accordance with EAU 2012*, the analysis of micropiles to EN 14199 and ground anchors to EN 1537 assumes an equivalent anchor wall that intersects the lower failure plane at the centre of the required load transfer length $L_b$. Therefore, the geometry of the soil mass or wedge is defined via the position of $L_b$. The maximum tensile force that can be transfered by the anchor is determined from equilibrium of forces acting on the soil considered as a free body. This force must be greater than the tensile force resulting from the earth pressure calculation, otherwise the position of $L_b$ must be adjusted. (This iterative analysis is generally carried out with appropriate software.)

### Summary

The same design approach shows that the system for calculating tension piles and anchors is identical. In both systems the theoretical minimum anchor length required is bisected by the lower failure plane at the centre of gravity. The common misinterpretation that the lower failure plane in homogeneous subsoil intersects the grout body in the middle of a micropile (grouted over its full length) only applies as long as the micropile is not mobilised. At the serviceability limit state, the position of the load transfer length is identical for both anchors and micropiles.

### Prestressing, corrosion protection

Prestressing is essential for high-strength prestressing steels in order to reduce the elongation of the steel and thus to limit deformations in the structure. However, prestressing is unnecessary for micropiles and so a cost-effective connection between pile head and structure is possible without having to consider additional, costly corrosion protection systems. In addition, it is no longer necessary to check the prestress and corrosion protection during the service life of the structure.

**Modified partial safety factors**

The safety concepts of the two systems are different. The comprehensive testing, starting with suitability tests in advance and ending with an acceptance test for every structural anchor, means that lower partial safety factors can be used for ground anchors to EN 1537 than for micropiles to EN 14199. The much reduced scope of testing, only 3% of the structural piles have to be tested, calls for modified partial safety factors for micropiles to EN 14199. Theoretically, the partial safety factors for ground anchors can be used for micropiles by increasing the scope of testing.

**Note for design**

Part C 3 of the specification for waterfront structures and flood defences published by the Hamburg Port Authority (HPA) no longer permits the use of ground anchors to EN 1537 for permanent structures. The following are just a few of the requirements for the installation of micropiles to EN 14199 in conjunction with DIN SPEC 18539:

- prestressing steels and strands are **not** permitted
- loadbearing tendons may **only** be extended using the couplers prescribed by the manufacturers
- welding of loadbearing tendons is **strictly** prohibited

* Recommendations of the Committee for Waterfront Structures, Harbours and Waterways (EAU 2012)

# Design of a micropile

**(summary)**

### Preliminary design of the load transfer length

$$L_b = \frac{F_{t,d}}{\pi \cdot D \cdot \frac{q_{s,k}}{\gamma_{s,t} \cdot \xi_1 \cdot \eta_M}}$$

where:

$L_b$ = load transfer length (bonded length)
$F_{t,d}$ = design value for axial tension load on one micropile
$\gamma_{s,t}$ = partial safety factor for pull out restistance
$\gamma_{s,t}$ = 1.5 based on empirical values (scatter factor neglected)
$\gamma_{s,t}$ = 1.15 from static pile loading tests
$\eta_M$ = 1.25 (tension pile model factor to DIN 1054/A1)
$D$ = grout body diameter assumed for structural purposes
$q_{s,k}$ = characteristic value of skin friction
$\xi_1$ = scatter factor for static pile loading tests

### Preliminary design of total pile length

$$L_{tot} = L_p + L_{ab} + (L_b / 2)$$

$L_{tot}$ = total pile length
$L_p$ = projection for practical construction purposes
$L_{ab}$ = distance between wall and lower failure plane

### Determination of test load

$$P_p = F_{t,d} \cdot \gamma_{s,t} \cdot \zeta_1 \cdot \eta_M$$

$P_p$ = test load

We would be happy to carry out the preliminary design for you. Please refer to our TITAN micropile brochure for further detailed design information.

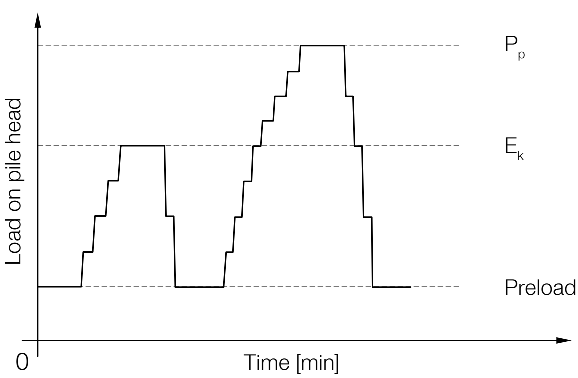
# Load tests

Standards and directives: EN 14199
DIN SPEC 18539
EN 1997-1
EN 1997-1/NA
DIN 1054
Recommendations on Piling (EA-Pfähle)
EN ISO 22477-1 (draft)

In principle, conclusions regarding deformation and creep behaviour, as well as the behaviour upon reloading the micropiles can be obtained within the scope of a loading test. The nature and scope of the tests must be defined in advance of the main works in the project specification or the geotechnical report.

**Tension pile test on test pile**

**Compression pile test**




Pile test with two loading cycles – load introduced over complete length (system A)

**Static load tests** can be carried out on preliminary test micropiles but also on structural piles. Preliminary test micropiles can be structural piles or piles specially installed for test purposes. These piles must be installed and tested prior to the main works. Test piles should be tested to failure as early as possible prior to commencing the main works to obtain information for the pile length design. If structural piles are tested in advance, these must confirm the assumptions made in the preliminary design. The test load results from the preliminary design with a maximum value of 90% of the characteristic load-carrying capacity of the hollow steel tendon.

If acceptance test micropiles (structural piles) are tested after completing the main works, then the serviceability of the piles is checked. If only acceptance test micropiles are tested within the scope of main works, then the results are used to verify the preliminary design on the basis of empirical values. Obviously, the safety factors for the preliminary design are then higher than those for preliminary test micropiles.

**Time of testing**
Information on the time between installing and testing the piles can be found in EN ISO 22477-1 (draft) “Pile load test by static axially loaded compression”. In non-cohesive soil, at least seven days should elapse between the installation and testing of preliminary piles, but at least three weeks in cohesive soil. In non-cohesive soil, acceptance test piles may not be loaded before at least five days have elapsed, but at least 10 days in cohesive soil.

Acceptance tests with observation periods based on EN 1537, with two loading cycles and six loading stages on structural piles for checking the preliminary design against empirical values, have become established in practice. Loading tests to determine pile lengths in advance of the building measures are generally carried out based on Recommendations on Piling (EA Pfähle), with correspondingly longer times between installation and testing.

**Tension pile tests also valid for compression piles**
Generally, tension pile tests can be carried out for compression piles as well. If a compression pile test is required, this must be stipulated in the project specification.

**Load test (summary):**

- Preliminary micropile as test pile:
  $R_{c,k}$ or $R_{c,t} = R_{(ks)}$ (ultimate limit state)
- Structural pile as preliminary test pile:
  Tension pile: $P_p = F_{t,d} \cdot \gamma_{s,t} \cdot \xi_1 \cdot \eta_M$
  Compression pile: $P_p = F_{c,d} \cdot \gamma_s \cdot \xi_1$
- Acceptance condition for test micropile:
  Tension or compression pile: $P_p \geq E_d$
- Quality control for structural pile (after testing preliminary test micropile): $P_p = E_k \cdot 1.25$

Note: Test loads applied to structural piles must not have an adverse effect on their serviceability.

**Prerequisites for testing**

When testing micropile anchors (tension piles), it must be proved that the pile load can be transferred in the area of the lower failure plane. To do this, and depending on the subsoil, the hollow steel tendon must be uncoupled from the soil.

The unbonded length can be created as follows:

- Installation of a smooth sleeve (e.g. PE-HD tube)
- Flushing out the cement with a lance or hose while it is still in a fluid state directly after installation.
- Performing a core drilling operation around the pile

**Number of load tests**

Load tests should be carried out on at least 3% of the micropiles, but no fewer than two piles. Load tests can be waived in exceptional circumstances provided the following criteria are satisfied:

- Empirical values for the characteristic skin friction are confirmed by a geotechnical specialist/engineer.
- Soil investigations enable the skin friction to be clearly allocated to the in situ subsoil. Important criteria in this respect are:
  - non-cohesive soils:
    mean tip resistance $q_c$ in cone penetration test
  - cohesive soils:
    undrained shear strength $c_{u,k}$
- The geotechnical specialist/engineer must agree to waving the loading tests.

# Text for tender documents

## Sheet pile wall anchorage (sample extract)

ISCHEBECK specification texts can be very easily and expertly formulated and then downloaded in text, table or GAEB format ready for integrating into your own documents; simply go to http://ischebeck.bauprofessor.de, our publicly available online expert system. Our experts will be happy to advise you.

**Micropile sheet pile wall anchorage, tension, TITAN 73/53, permanent**

**Micropile to EN 14199 / DIBt Z-34.14-209** for anchoring
sheet pile walls, loaded in tension, design value $R_d$ = 783 kN,
hollow steel bar as loadbearing tendon, 73 mm O.D., 53 mm I.D., with continuous reinforcing bar thread to DIN 488,

**made from EN 10210 grade S 460 NH steel**, Ischebeck TITAN 73/53,
hollow steel bar:

……………………………..
(to be entered by tenderer),
permanent application (> 2 years),
**corrosion protection by means of minimum cement grout cover** of 45 mm, subsoil according to report, 195 mm dia. grout body, hollow steel bar centred with centralisers at max. 3 m spacing, pile head detail according to drawing,
**head detail** to drg. No:

……………………………..

Length in m:
……………………………..

Angle with respect to vertical
in degrees:
……………………………..

Installation by rotary percussive drilling without casing, hole stabilised with drilling and flushing fluid in form of cement slurry, **dynamic pressure grouting** from bottom of hole upwards with cement slurry, w/c = 0.4–0.5, Portland cement to DIN 1164-10 and EN 197-1 to be used taking into account exposure class,

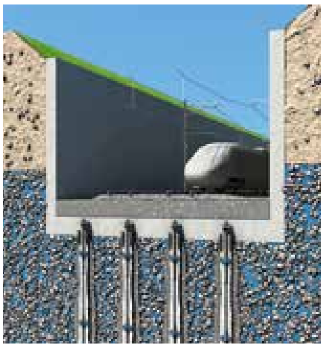
Pile logbook to be kept for each pile according to EN 14199, drilling through obstacles subject to special tariff,

cement consumption in kg/m:

……………………………..

Note:
Further information/items may be necessary regarding:
- quantity of cement used, including additional cement requirements
- confined working conditions (height and width)
- position of starting point for drilling
- whereabouts of cuttings/drilling fluid/cement suspension
- contamination in cuttings
- special services and documentation
- nature and scope of loading tests

Whether for foundations, soil nailing or tunnelling, TITAN micropiles are ideal for a huge range of applications.





Please refer to our TITAN micropile brochure for general information and analyses. Information on other potential applications can be found in our brochures on soil nailing, foundations/underpinning and tunnelling.

The photos reproduced in this brochure represent momentary snapshots of work on building sites. It is therefore possible that certain facts and circumstances do not fully correspond to the technical (safety) requirements.




Certified Management-System to DIN EN ISO 9001 / 2008 ; Registry-No. DE-96-010

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