

**Foundations**



**Underpinning**



**Resisting uplift**



**Foundations and underpinning  
using TITAN micropiles**  
temporary and permanent

National Technical Approval Z-34.14-209

# Foundations and underpinning with TITAN micropiles

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

Micropiles transfer tension or compression forces as well as cyclic loads into the ground via skin friction according to DIN EN 14199. The German Institute of Building Technology (DIBt) has issued National Technical Approval Z-34.14-209 for TITAN micropiles. They are therefore the only tubular grouted micropiles that can be used for permanent applications with a design life exceeding 100 years.

The hollow bar simultaneously acts, as the drilling rod, injection tube and reinforcement for the micropile. The TITAN system can be used in any type of soil, including unstable soils.

Injecting a cement grout through the hollow steel tendon ensures that the borehole is filled from the bottom to the top. Additional operations such as inserting and extracting casings and complex multi-stage grouting are unnecessary.

The system is fast, simple and flexible. There are many potential applications for TITAN micropiles, e.g. foundations, underpinning, resisting uplift, geothermal installations and dynamic/cyclic load applications. Irrespective of the type of application, the installation method is always the same.

TITAN micropiles...

- represent an approved system for temporary and permanent applications,
- can be used in restricted sites where access is difficult
- are installed with low vibration whether using lightweight equipment or standard drilling rigs

## Mast foundation for a new overhead line

Arlon – Steprenich, Belgium

The precast concrete foundations for the overhead line masts were placed into position. The precast elements had an opening through which the TITAN 40/16 micropiles were installed. Two types of foundations were used, one with four micropiles and the other with seven. The installation was carried out directly from the railway carriage, where all the equipment was contained. Due to the light weight mast used, the second track remained fully operational during the installation.

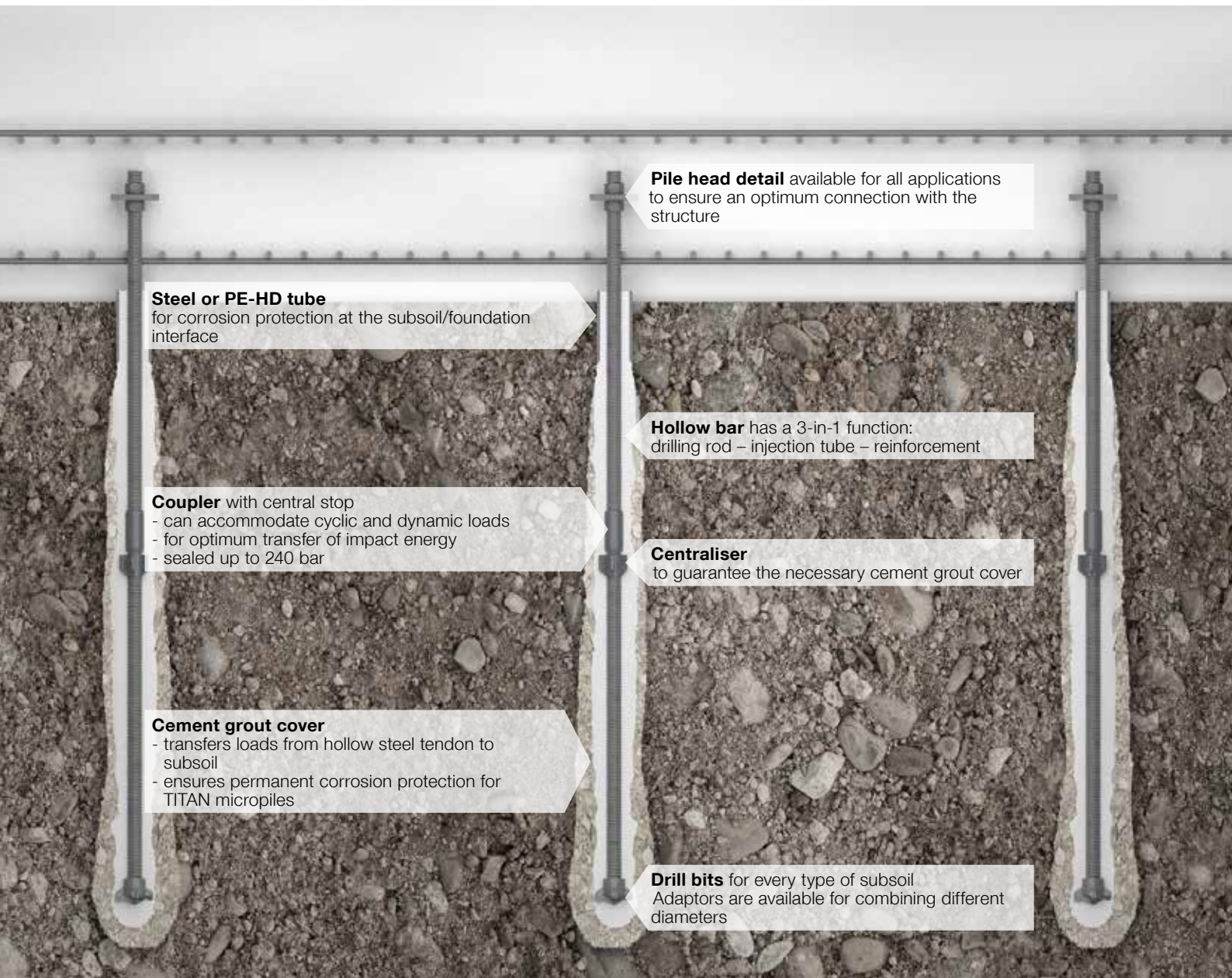
## Foundations for a noise barrier

Railway line, Leipzig Central – Leipzig-Leutzsch

The noise barrier foundations included TITAN 40/16 and TITAN 73/53 micropiles, which were designed to carry dynamic loads. The TITAN micropiles were used because of the proximity of the apartment blocks to the railway line, which didn't allow for the use of conventional foundations. In addition an embankment ran along the line of the apartment blocks directly behind the noise barrier.







#### Advantages for designers

- System has a National Technical Approval
- Suitable in restricted access and limited boundary (party wall) conditions
- Low-settlement system
- Suitable for all soil types

#### Advantages for contractors

- One installation method for all types of applications
- Suitable for use in confined sites
- Increased production rates
- 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 tensile and/or compressive 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 DIN EN 10080/DIN 488. The tendon functions as drilling rod, injection tube and reinforcement (3-in-1 principle). The hollow bars are generally steel tendons, which are usually 3 m long and are joined together with a coupling nut.

## 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. Controlled crack widths of less than 0.1 mm within the grout, guarantees the permanent corrosion protection for the system according to the National Technical Approval. TITAN micropiles can therefore be used for permanent applications without the need for additional corrosion protection measures.



### Coupling Nut

The coupling nut has a steel ring as a central stop and a seal which is designed for...

- cyclic tensile/compressive loads
- dynamic loads
- optimum transfer of impact energy
- a grouting pressure of up to 240 bar

### Steel grade

- Hollow steel tendon made from S460 NH fine-grain structural steel
- Yield stress  $f_{y,k} = 400\text{--}600 \text{ N/mm}^2$
- Elongation at maximum load  $\epsilon_{uk}$  or  $A_{gt} \geq 5.0 \%$
- Notched impact energy of the raw material  $W = 100 \text{ J/cm}^3$  (at  $-20 \text{ }^\circ\text{C}$ ) minimises the risk of damage caused during installation by rotary percussion drilling.





# Range of applications

The construction and technical advantages of the TITAN micropile system allow the transfer of dynamic cyclic, tensile and compressive forces into the soil making the system extremely versatile. Other possible solutions include the “combi-pile” designed to resist buckling and high pressure injection grouting.



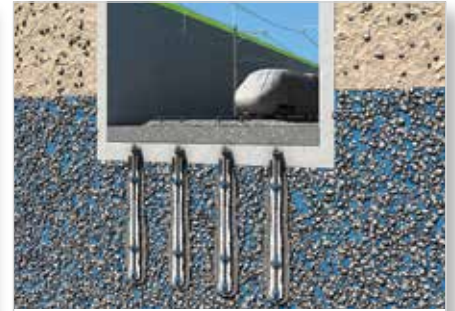
## Foundations

- Transmission pylons, telecommunication masts and wind turbines
- Noise barriers
- Bridge abutments and wing walls
- Buildings
- Tower crane foundations
- Sign gantries and signal masts



## Underpinning

- Building – industrial, residential and commercial
- Masts
- Bridge abutments
- Crane foundations
- Lift shafts



## Resisting uplift

- Water tanks
- Road underpasses
- Deep excavations
- Can be installed through existing structures

# Advantages for installation

Installation is normally carried out with hydraulically operated drifters. In contrast to cased drilling, TITAN micropiles can be installed with much smaller drilling equipment. This means the system can also be used on sites with difficult or complex access issues.

Unlike the GEWI micropile, the TITAN system does not require the use of couplers with an awkward counter nut,

which are used to accommodate cyclic loads. In addition the TITAN micropile system does not require double corrosion protection as needed with the GEWI micropile for permanent applications. Numerous permanent underpinning projects have been completed in existing buildings according to the National Technical approval.





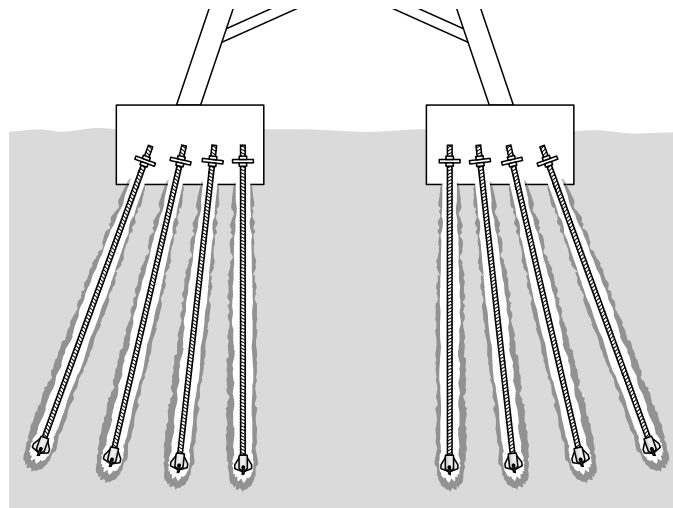
# Foundations

Tower structures are often simultaneously subjected to bending moments, shear, tension and compression loads. Such structures include transmission pylons, telecommunication masts, wind turbines and ski-lift masts. Small groups of TITAN micropiles installed in a radial arrangement can easily accommodate such loads and transfer them to the soil via skin friction.

Mast structures are often erected in remote areas in difficult conditions. The TITAN micropile system enables fast installation with compact, mobile equipment, eliminating complex logistics.

In urban areas where buried utilities are present the TITAN micropile system offers an alternative to bored piles or gravity bases.

Screw-on pile head details enable easy assembly and connection to steel or reinforced concrete superstructures.



## Solar panels founded on TITAN micropiles

The large surface area of the solar panel structure make wind loads the critical design load case. To reduce the structures weight and enable rapid construction, the foundations are replaced with precast concrete elements and TITAN micropiles. The load transfer to the precast concrete elements is generated through the bond. The existing paving (asphalt/concrete) is removed locally and

the lightweight equipment results in minimal damage. The TITAN micropile system generates very little spoil and doesn't require large volumes of concrete as with bored piles and traditional foundations.



Groups of TITAN micropiles are suitable for **bridge foundations** where only minimum settlement is permitted. Pile groups exhibit much less settlement than that of large diameter bored piles.

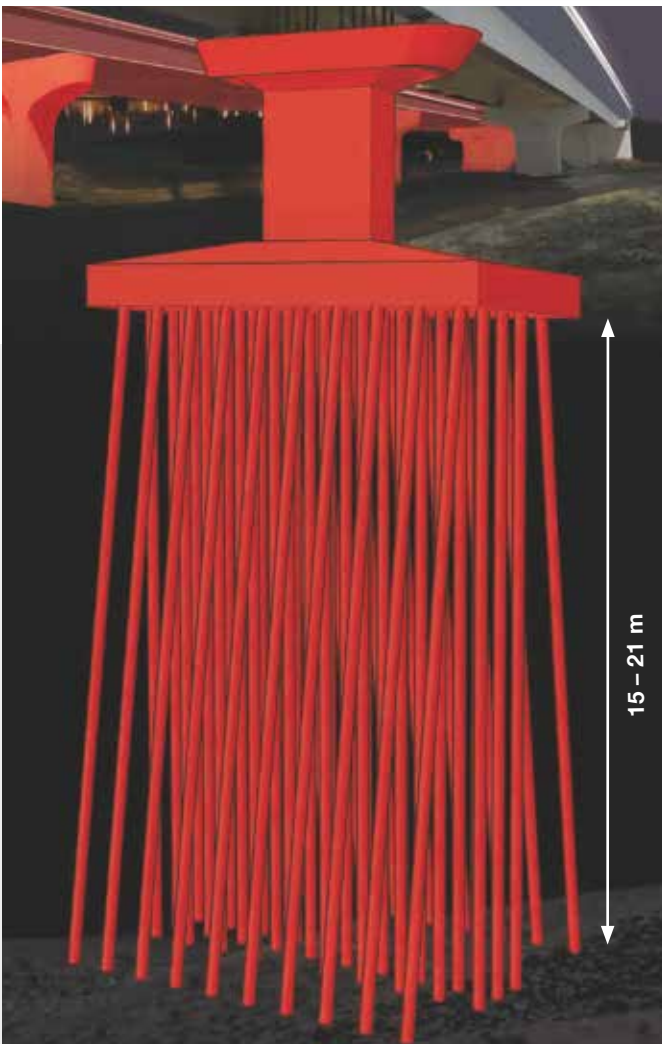


### Foundations for bridge piers

S-3 Expressway, Poland

The S-3 Expressway passes through broad River Paklica valley, with its marshy alluvium soils. TITAN micropiles were used due to the following advantages:

- Better settlement behaviour (pile group) compared to large diameter bored piles
- Lighter/smaller drilling equipment required
- Less complex planning and logistics
- No reinforcement cages required
- Less concrete

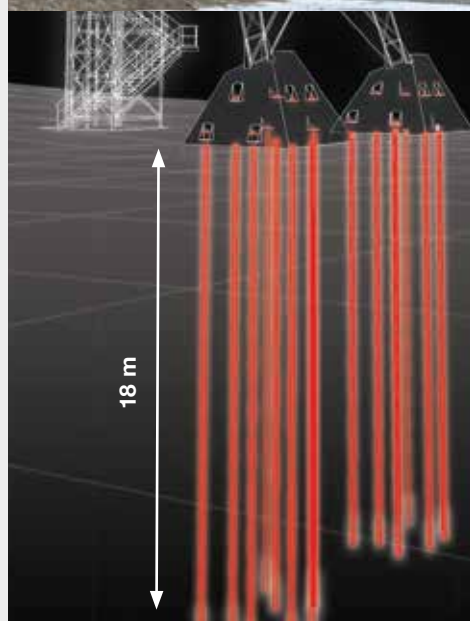


### Less settlement

Detailed calculations based on FLAC 3D were carried out in advance. TITAN 103/51 and 103/78 micropiles 15–21 m long were designed and installed. A settlement of only 13.2–15.7 mm (for 1000 and 1400 kN respectively) for a single pile were measured during the compression suitability tests. Measurements of the settlement behaviour of the bridge foundations showed very low settlements of just 1–4 mm. The settlement figures calculated prior to installation were confirmed by tests.



# Underpinning



## Diverse applications

Silesian Museum, Katowice, Poland  
Almost all TITAN micropile applications were employed in this unusual project.

### 1. Underpinning with TITAN micropiles

The new basement levels were constructed adjacent to and underneath the listed (heritage) buildings. To protect these buildings against damage the existing walls were underpinned using 18 m TITAN 73/53 and 73/56 micropiles.

### 2. Anchorages with TITAN micropiles

A contiguous piled wall was constructed at critical points within the structure. These were tied back with temporary TITAN 40/16 anchors to minimise the displacements of the retaining wall.

### 3. Soil nailing with TITAN micropiles

The main 15 m deep excavation was stabilised with TITAN soil nails.

A lift had to be added to the Warsaw II pit-head frame so that it could be used as a viewing tower. The structure therefore had to be underpinned with 18 m long TITAN 73/53 micropiles.



## Underpinning below power cables

Modifications to a design standard resulted in higher ice load requirements for transmission pylons. This led to the installation of TITAN micropiles in limited headroom, maintaining sufficient clearance from the high-voltage cables above. The TITAN 103/78 micropiles, were installed in short lengths using a lower drilling carriage. Due to the project being located in a sensitive conservation area, the flushing grout was removed from site in a controlled manner.





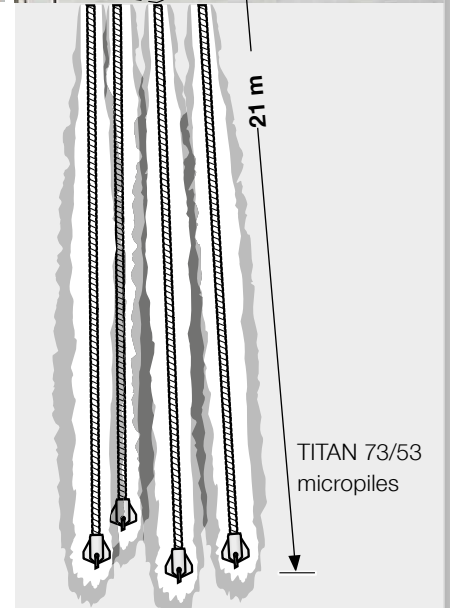
#### **Suitable for use in confined sites**

St. Ignatius Jesuit Church is almost 400 years old and when cracks appeared in the structure it was decided to strengthen the foundations. Traditional strengthening methods involving concrete and small diameter bored piles required excavating to expose the existing foundations. TITAN micropiles can be anchored directly into the masonry foundation, eliminating the need to expose the existing foundations. Approximately 600 TITAN 52/26, 73/53 and 73/45 micropiles were installed over a period of a few months.



#### **Support for a historic facade (custom application)**

Shopping centre, Barcelona  
Converting the former bullring into a shopping centre with underground parking involved retaining the historic facade. The facade is now supported on columns made up of micropiles. In situ concrete beams inside and outside distribute the load of the free-standing facade to the micropiles. The micropiles are attached to the facade with prestressed bars.



Underpinning with TITAN micropiles:

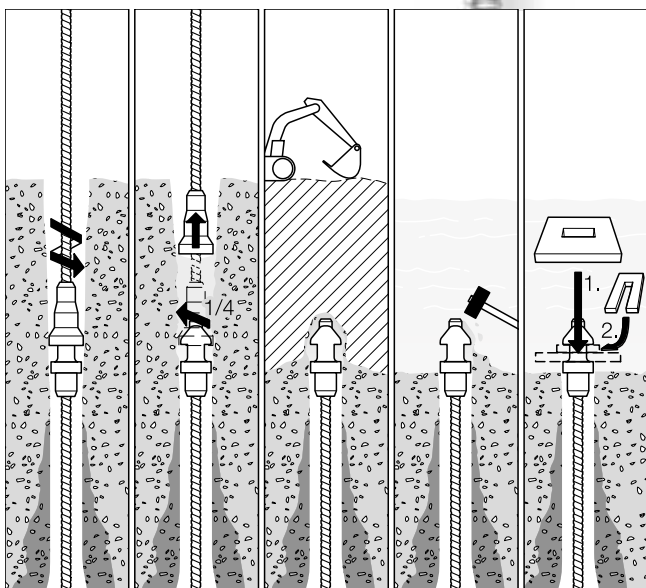
- Can be installed with compact light-weight equipment
- A low noise and low vibration solution

# Protection against uplift

When constructing concrete ground slabs for water tanks, road underpasses, deep excavations, etc. in groundwater, micropiles can be installed to secure them against uplift. Using the new ISCHEBECK bayonet system, it is possible to drill empty holes through water and soil. Once installed, the bayonet systems (bayonet bell + bayonet head for bell or bayonet connector + bayonet coupler with plate) create a structural connection. Piles used to resist uplift can be drilled through soil or water prior to or after excavation. This separates the construction phases and reduces the use of divers to a minimum.

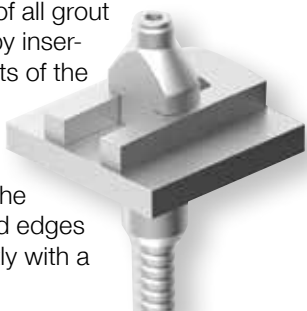
## Drilling through soil

Piles to resist uplift are installed prior to excavation. After reaching the design depth, the "follower" (bayonet bell + hollow bar steel tendon) is uncoupled by turning it a quarter turn in the opposite direction to drilling and extracted. This innovative solution means that it is not necessary to excavate around the piles.



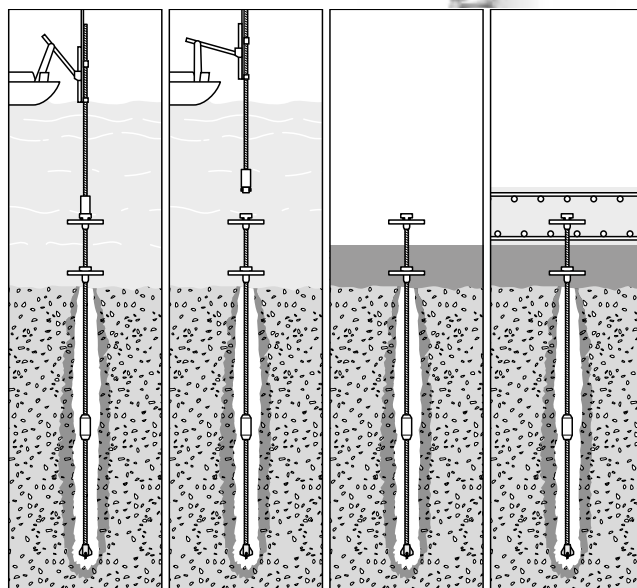
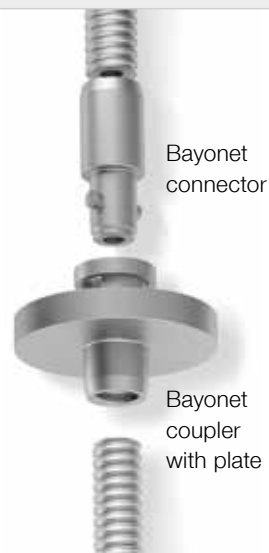
## Attaching an end plate

The bayonet head is cleared of all grout and the end plate fixed tight by inserting a wedge. The components of the system are designed in such a way that it is also possible for divers to use hammers to clear the grout away from the bayonet head with its rounded edges and fix the bayonet plate tightly with a steel wedge.



## Drilling through water

When drilling through water, two end plates are installed at the design depth: one for the underwater concrete and one for the later reinforced concrete foundation. The bayonet head is installed at the design depth from a pontoon and uncoupled by rotating it in the opposite direction. Afterwards, the underwater concrete slab is cast. It is not necessary to employ divers to attach the end plates.





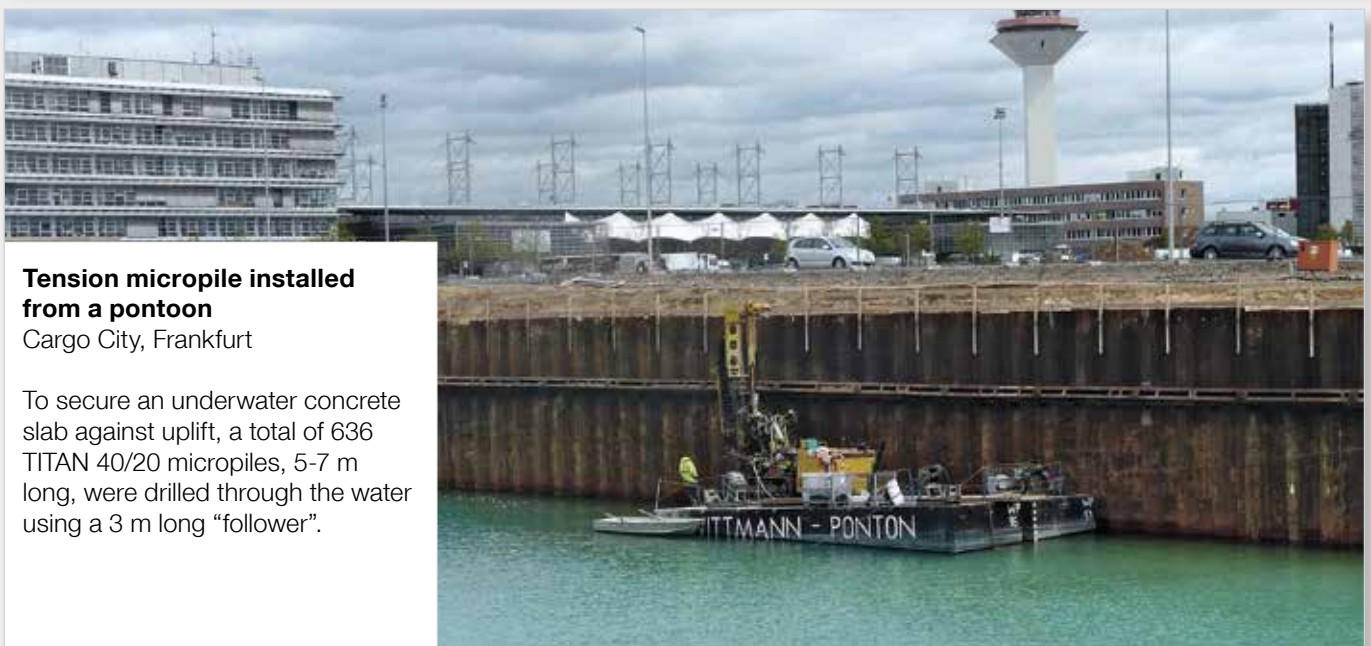


### **Resisting uplift**

S116 underpass, Abu Shagara, Sharjah, UAE

The initial design involved a 4 m thick concrete tunnel floor slab, using the self-weight to resist the uplift. However engineers from Friedr. Ischbeck GmbH proposed an alternative solution using tension micropiles to resist the uplift, reducing the concrete slab thickness to 1.3 m. Besides being a more economical solution, this method benefited the construction programme by

reducing the excavation depth by 3 m. In addition TITAN anchors were installed to tie back the sheet pile walls.



### **Tension micropile installed from a pontoon**

Cargo City, Frankfurt

To secure an underwater concrete slab against uplift, a total of 636 TITAN 40/20 micropiles, 5-7 m long, were drilled through the water using a 3 m long "follower".

# Analyses

TITAN micropiles are designed according to EC7 (DIN EN 1997). The following analyses may need to be carried out depending on the application and the boundary conditions:

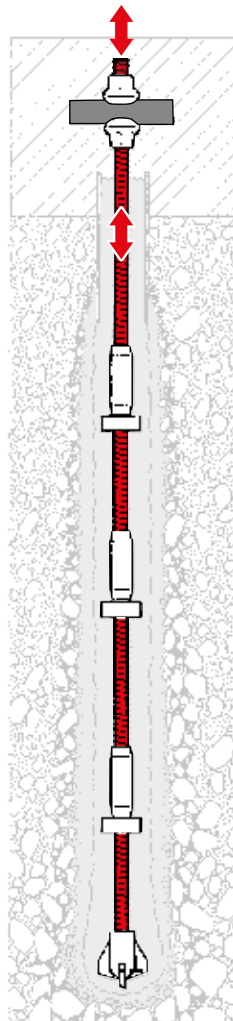
- Load-carrying capacity of pile materials
- Load-carrying capacity of grout/soil friction
- Buckling
- Serviceability
- Durability.

Detailed information on the analyses required can be found in our "TITAN micropile" brochure.



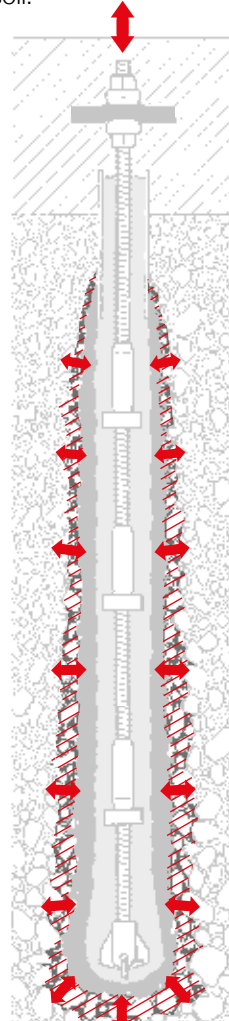
## Verification of load-carrying capacity of pile materials

The analysis requires that the design value of the actions  $E_d$  is less than the design value of the resistance of the hollow steel tendon  $R_{d,t}$ .



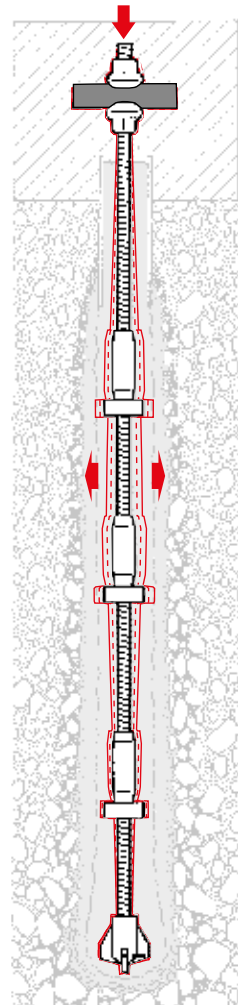
## Verification of load-carrying capacity of grout/soil friction

The load-carrying capacity of the pile in the soil essentially depends on the surface area of the grout body and the skin friction  $q_{sk}$  of the in situ soil.



## Buckling analysis (compression piles)

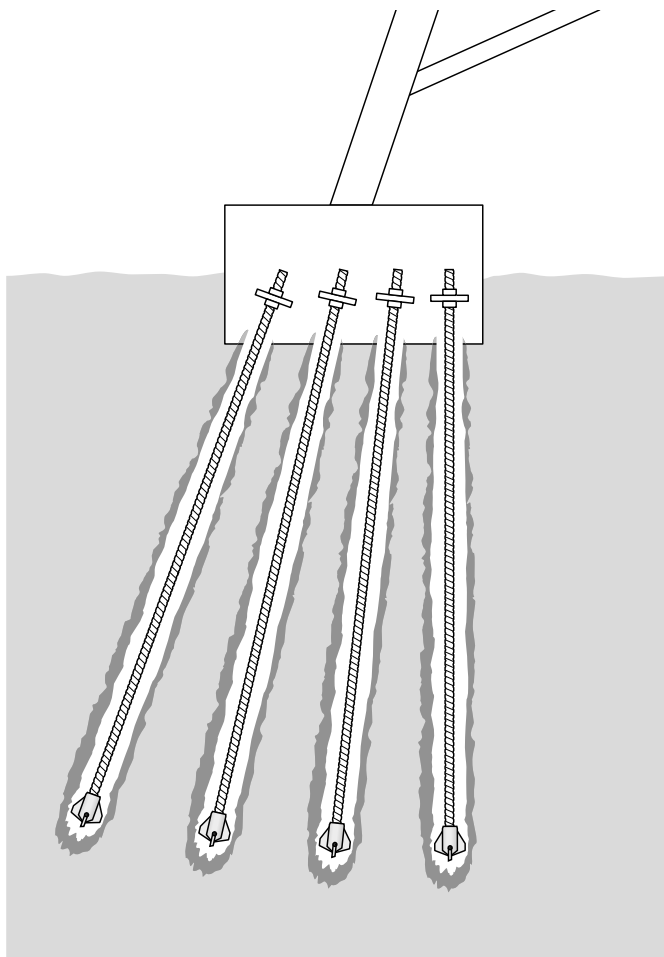
The buckling analysis to EN 1997-1 / EN 14199 only needs to be carried out in very soft soils.





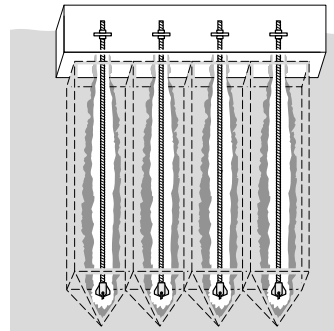
### Design of pile groups

According to DIN EN 14199 micropiles may only carry axial loads. If shear forces and bending moments are present, designers are recommended to employ stiff connections to join several micropiles to form groups. If the micropiles are installed at a slight angle, the lateral and shear forces may be accommodated.



### Pull-out resistance (pile groups)

For a group of tension piles, it is necessary to check the pull-out resistance of the in situ body of soil.



Groups of several micropiles must be checked to establish how they function as a group. According to DIN SPEC 18539, the following rules apply:

Piles that have a minimum spacing of 800 mm in the load transfer area can be considered as individual piles as the piles do not affect each other.

Once the pile spacing is less than 800 mm the groups of compression piles must be analysed for two modes of failure, according to DIN EN 1997-1:

- Failure of the compression resistance of a single pile,
- Failure of the compression resistance of the pile group including the intervening soil as a block.

In doing so, the surface area of the block is included in the calculation of the compression resistance. The lower of the above two values is taken as the design resistance.

# Pile loading tests

- DIN EN 14199
- DIN SPEC 18539
- DIN EN 1997-1, or DIN 1054
- Recommendations on Piling (EA Pfähle)

DIN EN 14199 "Execution of special geotechnical work "Micropiles" assumes that loading tests are performed. The designer must specify whether such tests are carried out on piles installed specially for test purposes or piles that will be incorporated in the final structure. The results of loading tests on preliminary test micropiles are used to assess the load-carrying capacity and for optimising the design.

The test load, number and duration of loading increments and the loading cycles must be planned in such a way that it is possible to draw conclusions about the deformation behaviour, creep behaviour and behaviour upon reloading the piles. Designers can make use of the information given in DIN EN 1997-1, DIN 1054, DIN SPEC 18539 and Recommendations on Piling (EA Pfähle).

Note for testing compression piles:

As TITAN micropiles transfer loads to the soil exclusively via skin friction regardless of whether they are tension or compression piles, the latter may be subjected to a tension test. If a compression test is required, this must be stipulated in the project specification.

Detailed information on pile loading tests can be found in our brochure covering anchorages with TITAN micropiles.



Compression loading test on micropiles in soil with a risk of buckling.



# Text for tender documents

## TITAN micropile in tension and compression (sample extract)

Building measures: "Underpinning the foundations to an electricity pylon"

### Item 1: Permanent micropiles for tension and compression load cases TITAN 52/26

#### Micropile to DIN EN 14199/DIBt Z-34.14-209

Loaded in both compression and tension, design value  $R_d = 565 \text{ kN}$ . The tendon is a hollow bar with 52 mm outside diameter and 26 mm inside diameter. The tendon is a **continuously threaded reinforcing bar to DIN 488** and is **manufactured to DIN EN 10210, grade S460 NH steel**, Ischebeck TITAN 52/26.

A permanent application, with a design life greater than two years. **Corrosion protection is by means of a minimum cement grout cover of 40 mm.** The cement grout must meet the following standards DIN 18301 class BN2 and DIN 18301 class BS1. The average grout body diameter will be 135 mm and centralising spacers will be used at 3 m intervals. The pile head detail will comprise a 580 mm long steel tube, manufactured from grade S235JR, a washer plate 145 x 145 x 28 mm positioned between two spherical collar nuts.

Quantity ..... pieces

Length in m .....

Angle from the vertical in degrees .....

The length of the pile is calculated from the end of the pile in the soil to the underside of the top of the pile.

Installation is by rotary percussive drilling, without temporary casing. The hole is stabilised by drilling and flushing fluid in the form of a cement slurry with a  $w/c = 0.4 - 0.7$ . This is followed by **dynamic pressure grouting** from the bottom of the hole upwards, with a cement grout slurry with a  $w/c = 0.4-0.5$ . Portland cement to DIN 1164-10 and DIN EN 197-1 is to be used, taking into account the exposure class. Pile logs are to be kept for each pile, according to the National Technical Approval. Load tests are to be carried out to DIN EN 1997-1.

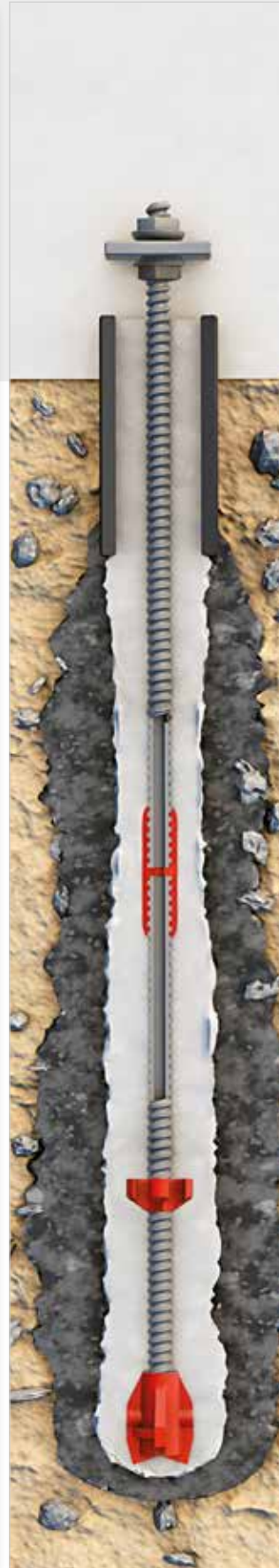
### Item 2: Acceptance test on structural micropiles according to item 1

Tensile test loads to be applied in 2 cycles.

Test load 585 kN ( $F_d < P_p < 0.9 \times R_k$ )

If required, additional information may be provided:

- Volume of grout used
- Cement additives
- Site working conditions
- Pile position
- Contamination of cuttings
- Documentation



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.

# Combi pile

The solution for subsoils with a risk of buckling

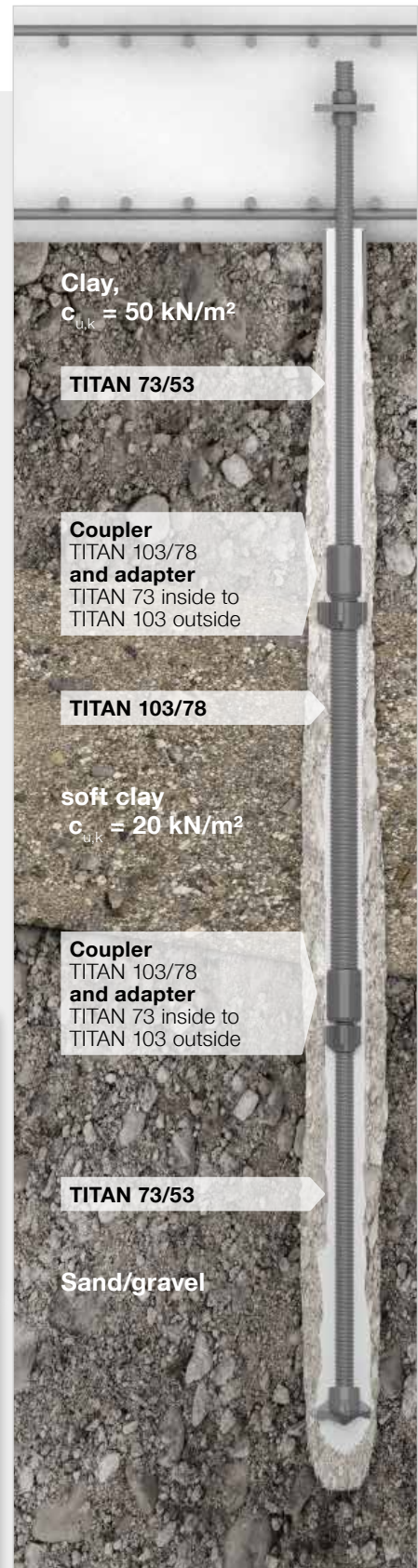
TITAN micropiles can allow the option of combining hollow steel tendons of different diameters to create a combi pile. In many cases using a larger steel cross section over the full length of the pile is unnecessary and uneconomical. "Oversizing" the hollow steel tendon in the soil at risk of buckling, creating the combi pile. Strengthening the hollow steel tendon in the soil at risk of buckling, increases the bending capacity of the micropile and eliminates the need of additional measures, such as installing a steel casing.

Further information on combination piles can be found in our "TITAN micropile" brochure.



## Increasing the diameter of the borehole and thus the grout body

Adapters are used so that drill bits for the next larger steel cross-section can be used, e.g. drill bit for TITAN 103 (Ø 175 mm carbide 3-cutter bit) on TITAN 73/53 hollow steel tendon.

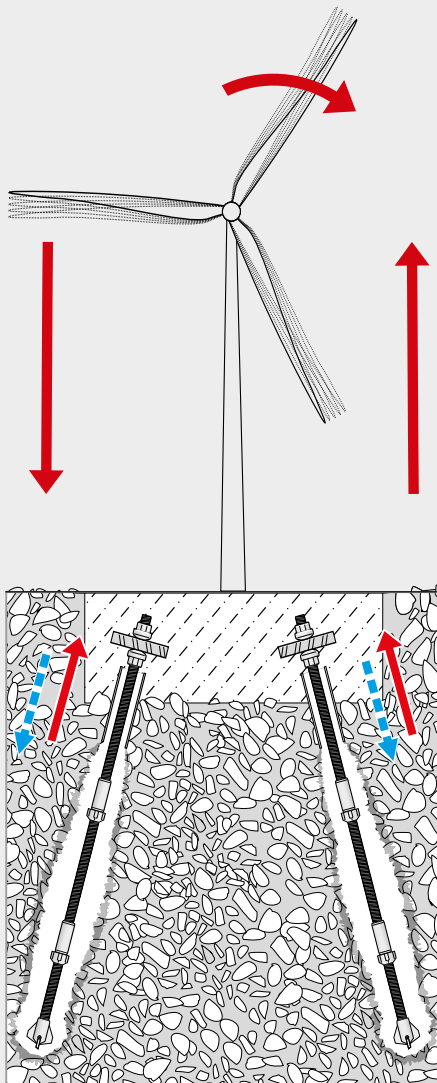




# Coupler

Integrated solution for carrying dynamic loads

Dynamic loads include cyclic and reversed loads and can occur in the foundations of machinery, wind turbines, railway noise barriers and in earthquake zones. It is very important to consider the consequences of such load cases, especially with respect to material fatigue. Particular attention should be taken with coupled tendons as this joint represents a potential weakness.



## Coupler

A coupler with an integral steel ring was developed for the TITAN system. Tightened with a specified torque, it results in a structural, rigid connection between the individual tendons without the need for con-ternuts so that dynamic loads can be transferred to the subsoil.



Within the scope of the approval procedure, the couplers were subjected to fatigue tests with 2 million load cycles at TU München. A permissible stress range of 70 N/mm<sup>2</sup> was determined during the tests. With a lower number of cycles, the stress range can be increased according to the "Wöhler" S-N curve.

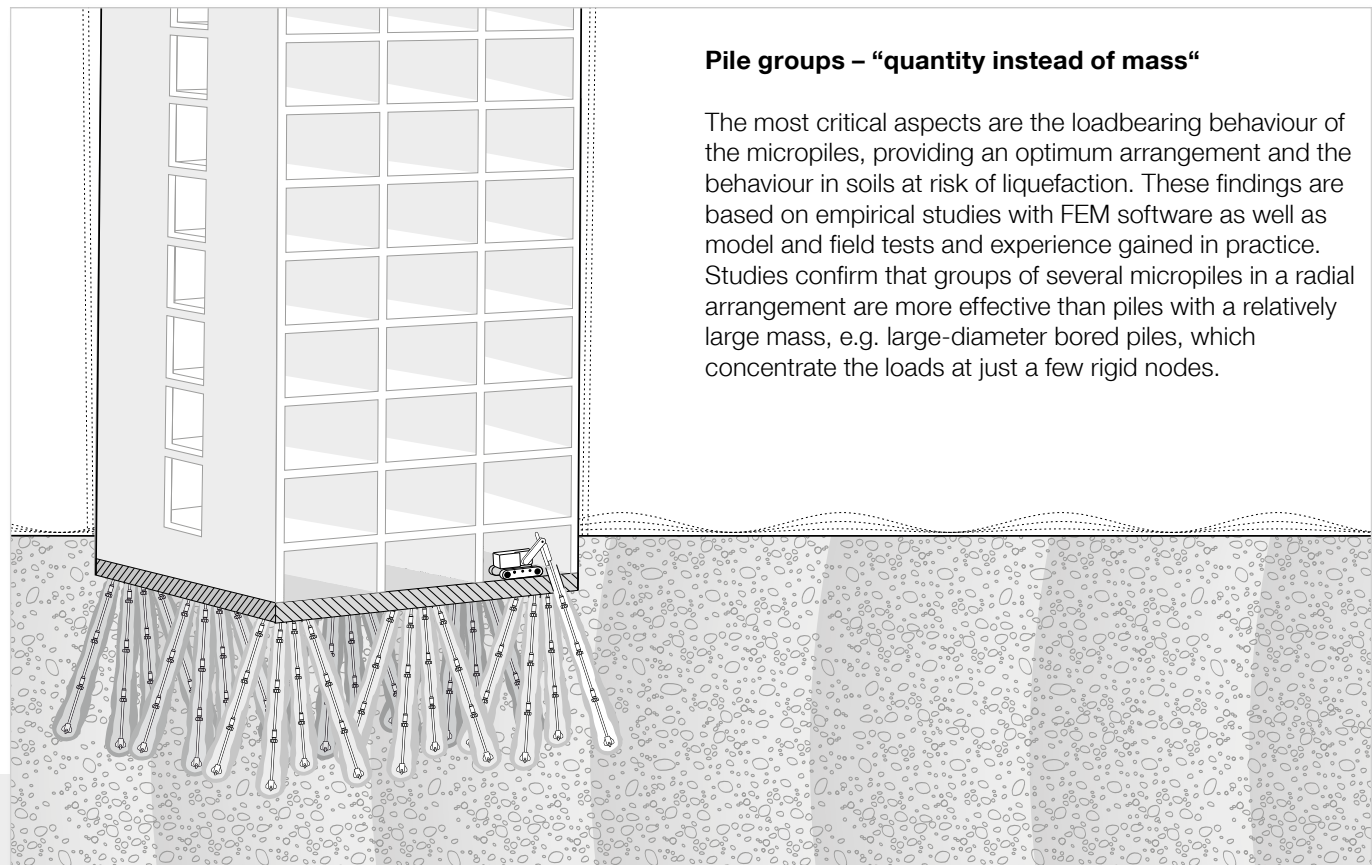


Fatigue test on TITAN 103/78 coupler connection at TU München

# Seismic upgrade

## Groups of micropiles reduce the risk of soil liquefaction

Building to resist earthquakes is one of the most demanding tasks in the construction industry. Earthquakes are uncontrollable natural forces which are very difficult to predict and which can cause enormous damage. In Germany the risk of earthquakes can be regarded as comparatively low. However, many projects carried out in seismic regions indicate that TITAN micropiles are ideal for earthquake-resistant foundations.



### Pile groups – “quantity instead of mass“

The most critical aspects are the loadbearing behaviour of the micropiles, providing an optimum arrangement and the behaviour in soils at risk of liquefaction. These findings are based on empirical studies with FEM software as well as model and field tests and experience gained in practice. Studies confirm that groups of several micropiles in a radial arrangement are more effective than piles with a relatively large mass, e.g. large-diameter bored piles, which concentrate the loads at just a few rigid nodes.

### Experience from practice worldwide

Model tests on TITAN micropiles have established that groups of micropiles considerably reduce the risk of soil liquefaction locally. These findings have been put to use in seismic regions all over the world.

The February 2010 earthquake in Chile, which reached the enormous magnitude of  $M_w$  8.8, was a real “crash test” for the TITAN micropile system. All construction measures carried out for various types of application – foundation piles, anchor piles or micropiles for soil nailing – withstood this extreme test without damage.



Bridge abutment underpinned in 2009 with 40 TITAN 103/78 micropiles in a region in Chile with high seismic activity.



# High-pressure injection

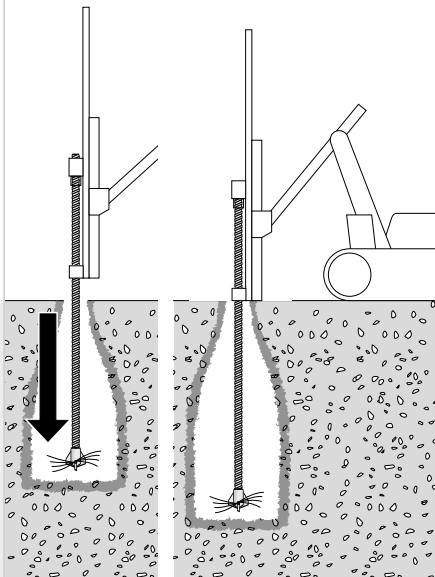
Greater borehole widening compared to conventional methods

Normally, TITAN micropiles are installed with an injection pressure of approximately 5–10 bar. Experience suggests that boreholes can be widened by up to 20–75 mm using this method.

High injection pressures can be used to install TITAN micropiles in very soft soils with very low skin friction. Using pressures of up to 240 bar, larger bodies of grout are created and long bonded lengths reduced. Micropiles can also be installed at an angle, e.g. for anchoring sheet pile walls.



## The principle of high-pressure injection



## Underpinning to a railway viaduct

Installation was carried out using a pressure of approximately 230 bar and drilling at a rate of 0.75 m per minute with a flushing fluid w/c = 0.8. The cement used for pressure grouting is a very fine powder such as DORODUR 135, which is ideal for pressure grouting.

## Pressure tight system

The HPI (high-pressure injection) clay drill bit developed for high pressures has one or two carbide nozzles with an opening diameter of 3.5 mm. The innovative coupling nut, with a central stop, steel ring and seals ensures that the TITAN system is pressure tight.



Grout body injected into soft sand with high pressure (TITAN 40/16 micropile with Ø 110 mm clay bit and carbide nozzle)



HPI (high-pressure injection) clay drill bit



Patented coupler

Whether for soil nailing, anchorages or tunnelling, TITAN micropiles are suitable for a huge variety of applications.



General information and analyses can be found in our "TITAN micropile" brochure. Information on other potential applications can be found in our brochures on soil nailing, anchorages 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.

#### Falsework and Formwork systems



#### Trench lining systems



#### Geotechnical solutions



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



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