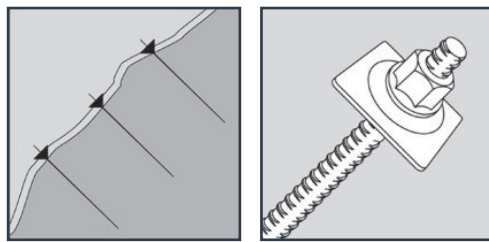


DYWIDAG Geotechnical Systems

DYWIDAG Soil Nails



DYWIDAG Soil Nailing System

Approval Number
Z-20.1-106

Validity
01 May 2012 - 01 May 2017

DEUTSCHES INSTITUT FÜR BAUTECHNIK

(German Institute for Civil Engineering)

Statutory Body

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Ref No.: I 64-1.34.13-15/11

APPROVAL CERTIFICATE

Approval Number:

Z-20.1-106

Applicant:

DYWIDAG-Systems International GmbH
Dywidagstrasse 1
85609 Aschheim
Germany

Object of Approval:

DYWIDAG Soil Nailing System

Valid until:

01 May 2017

This answer changes and extends the period of validity of the general appraisal licensing. This answer encloses two pages. He is valid only in connection with the abovementioned general appraisal licensing and may be used only together with this.

Important Notice

The approval in hand is the translation of a document originally prepared in the German language which has not been verified and officially authorized by the "Deutsches Institut für Bautechnik" (German Institute for Civil Engineering). In case of doubt in respect to wording and/or interpretation of this approval, the original German version of this document shall prevail exclusively. Therefore no liability is assumed for translation errors or inaccuracies.

I. GENERAL PROVISIONS

- 1 This approval certificate is proof of the usability and applicability of the Object of Approval as called for by the state building regulations.
- 2 If in the general building approval requirements for special expertise and experience with the manufacture of construction products and persons in charge according to § 17 section 5 model building code corresponding state regulations are made, please note that this expertise and experience, even with equivalent qualifications from other Member States of the European Union may be assigned. This applies for under the Agreement on the European Economic Area (EEA) or other bilateral agreements submitted by an equivalent proof.
- 3 The general approval does not replace the permits, licences and certificates required by German law for the execution of construction projects.
- 4 The general approval is granted without prejudice to third party rights, in particular private property rights.
- 5 Notwithstanding further regulations in the "Special Provisions" Section, the manufacturer and distributor of the object of approval shall provide the user with copies of the approval certificate; furthermore, they shall inform the user that the approval certificate must be available at the place of use. On request, copies of the approval certificate shall be submitted to all authorities involved.
- 6 The approval certificate may only be copied in its entirety. Any publication of excerpts requires the consent of the German Institute for Civil Engineering. Texts and drawings in advertising material may not contradict the approval certificate. Translations of the approval certificate shall contain the following notice: "Translation from the German original has not been certified by the German Institute for Civil Engineering".
- 7 The approval is not granted irrevocably. The provisions of this approval may be amended or modified subsequently, in particular, if made necessary as a result of new technical findings

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Approval Number:

Z-20.1-106

Applicant:

DYWIDAG-Systems International GmbH
Dywidagstrasse 1
85609 Aschheim
Germany

Object of Approval:

DYWIDAG Soil Nailing System

Valid until:

30 April 2007

The aforementioned object of approval is herewith generally approved by the construction supervision authority in accordance with German building legislation.
This approval certificate comprises ten pages and five appended sheets.

Important Notice

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II. SPECIAL PROVISIONS

1 Object of Approval and Application Range

1.1 General

Object of the following approval is the DYWIDAG Soil Nailing System. The nailing of the soil bodies shall be implemented by use of soil nails and a facing as shown in the appendices taking into account the provisions hereinafter. The measure aims to increase the tensile and shear strength of the soil such that the nailed soil body may be regarded as a monolithic block and verified as such. The facing must not be embedded underneath the bottom of the building excavation. The minimum length of the soil nails results from the evidence of stability in accordance with section 3.

The maximum distance between the nails is 1.5 m in the horizontal and vertical direction and may only be exceeded when the three-dimensional stability has been verified.

1.2 Area of Application

1.2.1 Structural Measures

Soil nails may be used to secure abrupt topographical changes, e.g. excavations and tieback walls, secure existing slopes and stabilize earth bodies subjected to loads during underpinning works at any angle. In this connection temporary (≤ 2 years) and permanent (> 2 years) applications must be distinguished.

1.2.2 Soil Types

Soil nailing may be used in non-cohesive and cohesive soils as specified by the specification of 1054:2005-01, section 5.2.2 and section 5.2.3, and in rock, if the rock behaves like unconsolidated material with regard to soil mechanic analysis. Soil nailing may not be carried out, if soil or groundwater contain substances which attack concrete (cf. DIN 4030-1:1991-06). If the sulphate content of the soil or groundwater is slightly corrosive as specified by DIN 4030-1:1991-06 - Assessment of Waters, Soils and Gases attacking Concrete; Basics and Threshold Values -, Tables 4 and 5, the soil nails may be installed, provided that cement with a high sulphate resistance is used.

1.3 Subsoil investigation

In accordance with DIN 1054 the subsoil investigations required for support structures shall be carried out and evaluated under the direction of an experienced expert in soil mechanics and foundation engineering. It shall also be examined whether the exposed soil is temporarily stable at the intended depth of excavation. The soil may not break up when the facing is formed by shotcreting.

2 Provisions for the Building Product

2.1 Properties and Composition

2.1.1 Steel tendon

Ribbed rebar BSt 500 S-GEWI (IV S GEWI) with thread ribs having diameters of 16 mm, 20 mm, 25 mm, 28 mm, 32 mm, 40 mm, 50 mm or steel rods GEWI bar S 555/700 with thread ribs 63.5 mm dia. generally approved by the construction supervision authority shall be used.

2.1.2 Corrosion Protection and Manufacture of Prefabricated Soil Nails for Installation and Grouting

2.1.2.1 Temporary Installations (Temporary Soil Nail)

For temporary installations of the soil nails the GEWI bars shall be encased with 20 mm thick hardened cement; the minimum cover shall be ≥ 15 mm. For this purpose the GEWI bar shall be provided with spacers whose distance shall be ≤ 2 m pursuant to Appendices 2 and 4.

2.1.2.2 Permanent Installations (Permanent Soil Nail)

The corrosion protection for permanent soil nails shall be applied at the factory. The GEWI bar shall be sheathed with a corrugated duct over nearly its entire length (cf. Appendices 3 and 4); the corrugated sheathing used shall either be made of PVC-U as specified by DIN EN ISO 1163-1:1999-10, polyethylene with a moulding compound as specified by DIN EN ISO –1872-1:1999-10 – PE, E, 45 T 022 - or polypropylene with a moulding compound as specified by DIN EN ISO 1873-1:1995-12 – PP – B, EAGC, 10-16-003 or DIN EN ISO 1873-1:1995-12 - PP - H, E, 06-35-012/022. Care must be taken to ensure that only straight tubes are used and that they are also delivered in this condition. The sheathing must have a uniform wall thickness of ≥ 1 mm; only tubes may be used which do not have any trapped bubbles and whose pigmentation is uniform. The dimensions for the sheathings are given in Appendix 4.

If required, the individual segments of the PVC-U sheathings shall be screwed into each other and conglutinated with PVC adhesive. PE or PP sheathings shall be used as unspliced tubes. The sheathing shall be closed with a plastic end cap on the earth-side. For inclined nails the annulus between the GEWI bar and sheathing shall be grouted from bottom to top with cement grout in accordance with DIN EN 447:1996-07. In addition, DIN EN 445:1996-07 and DIN EN 446:1996-07 shall be observed. It must be ensured that a distance of ≥ 5 mm between the GEWI bar and the sheathing is kept by spacers centered every 1.0 m. Instead of spacers, a round steel helix 5 mm dia. or a plastic spacer cord 6 mm dia. made of PE or PVC with a pitch of 0.5 m may be used. The cement grout injected sheathing shall encase the GEWI bar such that it extends into the area of the facing.

The sheathings shall be centered in the drillhole by use of spacers and covered by at least 10 mm of cement grout (see Appendix 4).

2.1.3 Air-Side Anchorage

The GEWI bars shall be anchored with GEWI anchorages as required by the approval certificates for threaded coupler splices and anchorages for GEWI bars (approval Nos. Z-1.5-76 and Z-1.5-149). In case of deviations from the stipulations set in the approval certificates, e.g. with regard to the additional reinforcement, the load capacity of the anchor plates must be demonstrated. This also applies for the transfer of the forces into the facing. The transfer of the forces into the facing (e.g. splitting forces) must be verified on a case-to-case basis (see also section 3.4).

The GEWI bars may also be anchored with domed nuts and domed plates as shown in Appendix 5. The transfer of the forces in the facing (e.g. splitting forces) must be verified on a case-to-case basis (see also section 3.4).

2.1.4 Coupler Splices

The GEWI bars may be spliced with couplers in accordance with the approval certificates for threaded coupler splices and anchorages for GEWI bars having diameters of 16 mm, 20 mm, 25 mm, 28 mm and 32 mm (approval certificate No. Z-1.5-76) as well as for GEWI bars having the diameters of 40 mm and 50 mm (approval certificate No. Z-1.5-149) and for GEWI bars 63.5 mm dia. (approval certificate Nr. Z-1.5-2) (see also Appendices 2, 3 and 4 as well as section 4.6).

The couplers shall be torqued with lock-nuts.

In case of predominantly dead load applications, lock nuts may be abandoned, if a heat shrink sleeve is shrunk in accordance with Appendix 4.

2.2 Manufacture, Storage, Transport and Labelling

2.2.1 Storage and Transport

The permanent soil nails may only be lifted off the assembly platform after hardening of the cement grout. Special care must be taken during transport and storage of the corrosion protected soil nails that the corrugated sheathings may not be damaged (e.g. parallel storage in sheet pile profiles or similar).

2.2.2 Labelling

The delivery note for the soil nail prefabricated for installation and grouting shall be marked by the manufacturer with the conformity symbol pursuant to the conformity symbol regulations issued by the German States. Labelling may only be carried out, when the requirements pursuant to section 2.3 have been met.

Among others the delivery note shall include the information for which soil nails the components are determined and in which factory they have been produced. Only components for one specified soil nail type may be delivered on one delivery note.

2.3 Conformity Evidence

2.3.1 General

Based on an in-house production inspection and a regular external supervision including a first testing, every fabricating plant must observe the following provisions to confirm conformity of the anchor components and the prefabricated anchors for installation and grouting in accordance with the provisions of this approval certificate.

The manufacturer of the anchor components and the prefabricated anchors shall commission a recognized certification institution to issue the conformity certificate as well as a recognized inspection agency for the external surveillance including product inspections.

The certification institution shall submit a copy of the conformity certificate issued to the German Institute for Civil Engineering for information.

In addition, the German Institute for Civil Engineering shall be provided with a copy of the report on the first testing for information.

2.3.2 Industrial Production Control

An industrial production control shall be established and implemented in every fabricating plant. By "industrial production control" the continuous monitoring of the production by the manufacturer is understood which ensures that the manufactured building products comply with the provisions of this general approval.

The results of the industrial production control shall be recorded and evaluated. The recordings shall at least include the following information:

- Description of the building product or the basic material respectively and its components
- Nature of the control or inspection
- Dates of manufacture and inspection of the building product or the basic material respectively or its components
- Result of the controls and inspections and, if applicable, comparison with the requirements
- Signature of the person in charge of the industrial production controls

The records shall be kept for at least five years and shall be submitted to the inspection agency employed for external surveillance. On request, they shall be presented to the German Institute for Civil Engineering and the responsible supreme construction supervision authority.

In case of insufficient test results, the manufacturer shall immediately take the necessary actions to remedy the defect. Building products not meeting the requirements shall be handled in such a way that excludes any confusion with complying products. After the defect has been remedied, the corresponding test shall be repeated immediately – as far as technically feasible and to prove the removal of defects.

The in-house production control shall at least include the following measures:

2.3.2.1 GEWI Bars, Anchoring Components and Parts for Coupler Splices

Only GEWI bars, anchoring components and parts for coupler splices (see details shown in section 2.1.4) shall be used for which an evidence of conformity has been produced pursuant to the provisions of the corresponding approval certificates.

The stipulations for the receiving inspection set in the approval certificates shall be observed.

2.3.2.2 Heat Shrink Sleeves

The material properties of the heat shrink sleeves and the bonding agent shall be attested by certificate of conformity "2.1" in accordance with DIN EN 10 204. The wall thickness shall be measured at 3 locations on the basic material and the bonding job determined per batch (100 pieces). The decision whether a batch is accepted or rejected shall be made in accordance with section 2.3.2.4.

2.3.2.3 Corrosion Protection of the Permanent Soil Nails

2.3.2.3.1 Sheathings

The composition of the moulding compound shall be attested by certificate of conformity "2.1" in accordance with DIN EN 10 204:2005-01. One sheathing shall be taken per batch (100 tubes) to measure the wall thickness at one internal and one external corrugation and on the flank of the tubes. The decision whether a batch is accepted or rejected shall be made in accordance with section 2.3.2.4.

2.3.2.3.2 Cement Grout within the Sheathings

Cement grout inspections shall be carried out pursuant to DIN EN 447:1996-07. In addition, DIN EN 445:1996-07 and DIN EN 446:1996-07 shall be observed.

2.3.2.3.3 Production of the Corrosion Protection

The corrosion protection measures to be carried out in the factory pursuant to section 2.1.2 shall be verified by visual inspection on each soil nail (statistical evaluation not necessary).

2.3.2.4 Check Plan

In case each single measured value equals or exceeds the minimum value stipulated, the batch shall be accepted. If not, further samples may be taken. The same measurements as on the first sample shall be carried out on those samples. The measuring results shall be summed up with the previous measurements. The mean average value \bar{x} and the standard deviation s are calculated from all values. In case the resulting test value (numerical value)

$z = \bar{x} - 1.64 s$ equals or exceeds the minimum value stipulated, the batch shall be accepted, otherwise rejected.

2.3.3 External Surveillance

The industrial production control in each fabricating plant shall be regularly checked by an external surveillance, but at least twice per year.

As part of the external surveillance a first testing shall be carried out. Samples for sampling inspections shall be taken and the inspection tools controlled. Sampling and inspections are incumbent on the respective recognized inspection agency.

The results of the certification and external surveillance shall be kept for at least five years. On request, they shall be presented to the German Institute for Civil Engineering and the responsible supreme construction supervision authority by the certification institution or inspection agency.

3 Provisions for Planning and Design

3.1 General

For the planning and design of structures by use of soil nails the following provisions shall apply:

3.2 Internal and External Stability of the Nailed Soil Body

The following stability tests shall be carried out:

- Slide stability inside and underneath the nailed soil body as specified by DIN 1054:1976-11 (see Figure 1, Appendix 1).
- Evidence that the force resulting from constant loads cuts the sole area in the core (stability against tilting; see Figure 1, Appendix 1),
- Ground failure safety (see Figure 1, Appendix 1): evidence shall be produced in accordance with DIN 4017:1979-08,
- Investigation of the sliding body (see Figure 2, Appendix 1).

The least favourable position of the sliding line shall be determined, contrary to DIN 4048:1981-07, by variation of the angle ϑ . Active loads from soil pressure, weight of the nailed soil body and external loads shall be taken into account in the sliding bodies to be varied.

These loads are counteracted by resistive forces from friction and cohesion in the sliding line as well as restraining forces of the nail sections located outside the sliding body (cf. section 3.3).

The counteraction of resistive and active loads must result in a safety factor of

$$\eta \geq 2.0 \text{ (load case 1)}$$

$$\eta \geq 1.5 \text{ (load case 2)}$$

If the evidence is produced in accordance with the Fellenius rule

$$\eta_r = \frac{\tan(\text{cal}\varphi)}{\tan(\text{required}\varphi)}$$

the safety factor is

$$\eta_r \geq 1.4 \text{ (load case 1)}$$

$$\eta_r \geq 1.3 \text{ (load case 2).}$$

These investigations shall be carried out for

- the conditions during construction significant for the stability with the safety requirements of load case 2

- the final condition of the structure with regard to the sole joint (or for sliding bodies starting from the sole joint) and with regard to the intermediate joints significant for stability (or sliding bodies starting from them) with the safety requirements of load case 1.

In addition, evidence of the

- stability against gliding as specified by DIN 1054:1976-11 and
- safety against failure of the ground as specified by DIN 4084:1981-07

Shall be produced for the deeper joints, if the ground under the nailed soil has lower shear strengths. If necessary, these evidences shall also be produced for conditions during construction.

3.3 Verification of the Nails

The evidence which results in the greatest nail loads shall be decisive for the dimensioning of the nails.

For this purpose the following investigations shall be carried out:

- Load components in the nails based on the testings of the sliding body for final conditions or conditions during construction (see section 3.2)
- Load components in the nails from the active soil pressure on the facing (see section 3.4)

Evidence shall be produced that the tension in the GEWI bar does not exceed $R_s/1.75$ and that the loads can be transferred from the nail into the ground with a safety factor of 2.0 (see section 4.7).

In case of not predominantly dead loads it shall be shown pursuant to DIN 1055-3 that the permissible fatigue stress range of the steel tendon or the coupler splices and the anchorages respectively is not exceeded. The permissible fatigue stress ranges can be taken from the corresponding general approvals for GEWI bars or threaded coupler splices and anchorages for GEWI bars.

3.4 Facing

The soil pressure acting on the facing from the nailed soil body may be assumed to be 0.85 times the value of the active soil pressure in accordance with Coulomb's theory, but without taking into account the cohesion. The active soil pressure may be calculated as a rectangular distribution. Even if the soil is stratified, the overall soil pressure may be considered uniformly. Active soil pressures from local loads and loads from ground anchors may not be reduced. The wall friction angle shall be specified with $\delta = 0$.

The dimensions of the facing shall comply with DIN 1045:2001-07. Regarding the nail heads, the evidence against punching and partial pressure shall be produced in accordance with DIN 1045:2001-07.

3.5 Deformations

Horizontal movements of 2 ‰ to 4 ‰ of the wall height have been measured for this type of construction in tests under dead loads, in which the lengths of the nails were 0.5 to 0.7 times of the wall height. If the deformations must be restricted, the safety factors defined in section 3.2 shall be increased.

4 Provisions for the Installation

4.1 General

The applicant shall maintain a list of the structures secured with permanent soil nails indicating the structure, the type and the number of soil nails installed.

4.2 Drilling activities

The boreholes shall be cased, unless it is demonstrated on site that the uncased boreholes are stable and that no earth can break off into the borehole when the soil nail is inserted. The minimum borehole diameter is specified in sections 2.1.2.1 and 2.1.2.2 and in Appendix 4; the boreholes shall be drilled with a minimum inclination of 10° to the horizontal.

4.3 Cement Grout for Filling of the Boreholes

4.3.1 Composition

Source material for the grout are cements with special properties in accordance with DIN 1164-10¹ and the cements from table 1 in accordance with DIN EN 197-1² – under observance of the actual exposition class in accordance with DIN EN 206-1³ in connection with DIN 1045-2⁴ (tables 1, F.3.1 to F.3.2) –, water in accordance with DIN EN 1008⁵, and (if necessary) additives in accordance with DIN EN 934-2⁶ in connection with DIN V 18998⁷ under observance of DIN V 20000-100⁸ respectively with general German approval and aggregates with max.4 mm grain diameter in accordance with DIN EN 12620⁹ in connection with DIN V 20000-103¹⁰. The water/cement ratio must be between 0.35 and 0.50; in particular in cohesive soils the lowest possible ratio shall be chosen. The cement grout must be mixed mechanically, and must not segregate and lump before it is injected.

| Basic cement type | cement type labelling | |
|-------------------------|---------------------------|------------|
| CEM I | Portland cement | CEM I |
| CEM II | Portland slag cement | CEM II/A-S |
| | | CEM II/B-S |
| | Portland pozzolana cement | CEM II/A-P |
| | | CEM II/B-P |
| Portland fly ash cement | CEM II/A-V | |

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- 1 DIN 1164-10:2004-08 Special cement - Part 10: Composition, requirements and conformity evaluation for special common cement
DIN 1164-10 Ber1:2005-01 Corrigenda to DIN 1164-10:2004-08
- 2 DIN EN 197-1:2004-08 Cement - Part 1: Composition, specifications and conformity criteria for common cements; German version EN 197-1:2000 + A1:2004
- 3 DIN EN 206-1:2001-07 Concrete - Part 1: Specification, performance, production and conformity; German version EN 206-1:2000
- 4 DIN 1045-2:2001-07 Concrete, reinforced and prestressed concrete structures - Part 2: Concrete; Specification, properties, production and conformity; Application rules for DINEN 206-1
DIN 1045-2/A1:2005-01 Amendment A1 to DIN 1045-2:2001-07
- 5 DIN EN 1008:2002-10 Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete; German version EN 1008:2002
- 6 DIN EN 934-2:2002-02 Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures; Definitions, requirements, conformity, marking and labeling
DIN EN 934-2/A1:2005-06 Admixtures for concrete, mortar and grout - Concrete admixtures - Part 2: Definitions, requirements, conformity, marking and labeling; German version EN 934-2:2001/A1:2004
DIN EN 934-2/A2:2006-03 Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures Definitions, requirements, conformity, marking and labeling; German version EN 934-2:2001/A2:2005
- 7 DIN V 18998:2002-11 Assessment corrosion behavior of admixtures according the series DIN EN 934
DIN V 18998/A1:2003-05 Assessment corrosion behavior of admixtures the series DIN EN 934; Amendment A1
- 8 DIN V 20000-100:2002-11 Application of building products in structures - Part 100: Concrete admixtures according DIN EN 934-2:2002-02
- 9 DIN EN 12620:2003-04 Aggregates for concrete; German version EN 12620:2002
- 10 DIN V 20000-103:2004-04 Use of building products in construction works - Part 103: Aggregates according to DIN EN 12620:2003-04

| | | |
|---------|---------------------------|------------------|
| CEM II | Portland shale cement | CEM II/A-T |
| | | CEM II/B-T |
| | Portland-limestone cement | CEM II/A-LL |
| | Portland composite cement | CEM II/B-M (S-V) |
| CEM III | blast furnace cement | CEM III/A |
| | | CEM III/B |

4.3.2 Grouting of the Boreholes

The boreholes shall be filled with cement grout from the ground end via the drill casings or grout tubes. Post-grouting is permissible. Once the initial grouting has set or fully hardened, further injections of cement grout can be made. For this purpose, the soil nail shall be equipped with a post-grouting tube provided with grout valves before the installation (see Appendices 2 and 3). The set cement grout can be loosened up with the aid of water; post-grouting shall, however, be carried out with cement grout as described in section 4.3.1.

4.4 Facing

Excavated areas shall be protected by the facing without delay. For strongly expanding soils and/or construction projects for which deformations have to be kept to a minimum, wall reinforcements shall be put in place in advance prior to the excavation (e.g. piles, pregrouting), if necessary.

The facing may consist of shotcrete or precast concrete elements. Shotcrete must at least correspond to the strength class of B 25. DIN 18 551 shall apply to the manufacture and testing.

Provision shall be made for adequate drainage so that no water pressure builds up behind the facing.

4.5 Anchoring of the Soil Nails on the Facing

For anchoring of the soil nails on the facing anchor plates (see section 2.1.3) shall be placed vertical to the tendon in fresh shotcrete or in a mortar bed. If domed plates or domed nuts are used, an angle compensation of $\pm 15^\circ$ to the tendon axis is possible. The borehole shall be grouted up to the front edge of the wall; the remaining hollow space caused by the inclined position of the nail shall be filled with shotcrete. After hardening of the shotcrete shell the nuts shall be fastened by hand. For permanent soil nailing systems a shotcrete layer of at least 5 cm shall be placed over the nail heads and reinforced with N 94 welded wire fabric. If the facing consists of prefabricated elements, the nail heads shall be protected equally well.

4.6 Coupler Splices

The distance between the locations of the joints must be ≥ 1 m. The couplers must always be secured against unscrewing in accordance with Appendices 2 and 3. With permanent soil nails the free bar ends as well as the internal thread of the couplers shall be provided with a Denso-Jet or Vaseline Cox GX coating such that the interior space of the coupler is completely filled after the assembly. Subsequently, the coupler shall be protected by a heat shrink sleeve in accordance with DIN 30672:2000-12 and corresponding to Appendix 3. The heat shrink sleeves must have a minimum wall thickness of 1.5 mm in the shrunk condition. The heat shrink sleeves shall be shrunk on through hot air, infrared radiation or by the soft flame of a gas burner.

4.7 Tests

4.7.1 Test loadings

The mathematical working load F_w of the soil nail assumed in the soil mechanic analysis shall be verified by test loadings. The test loadings shall be performed on at least 3% of all nails or on 3 nails per soil type. For construction projects with less than 100 nails at least 5% of the nails, but at least 3 nails, are to be subjected to a test loading.

During the test loading a tensile force shall be applied at the nail head in steps of 20 kN up to the maximum test load of 2 times the working load F_w . If the tensions in the GEWI bars intended for the nailed soil body exceed a value of $0.9 \beta_s$, nails with a higher load-bearing capacity, but with the same soil-bond characteristics shall be used for the test loadings. The displacements shall be read after 1, 2, 5, 10 and 15 minutes during the test loading which shall be kept constant. The observation period shall be prolonged, if the displacement Δs exceed 0.5 mm between 5 and 15 minutes. In these cases the observation shall be continued until Δs is ≤ 1.0 mm over a time interval of t_1 to $t_2 = 10 t_1$. Provided that one of the conditions is fulfilled for all nails tested, the evidence of the adequate load-bearing capacity in the soil is produced. Care shall be taken during the test loading to ensure that the nail is not supported by the facing.

4.7.2 Group Effect

If the distance between the nails is less than about 0.8 m, the mutual impact due to the group loading shall be investigated by subjecting at least 4 directly adjacent nails to a load.

5 Provisions for Usage, Support and Maintenance

5.1 Re-Checks

If the structure is subjected to special requirements regarding deformations, re-checks – deformation measurements – shall be performed after the soil nailing has been carried out. The necessity for this can be gauged from the type of structure and/or the in-situ soil, taking into account public safety and order. The decision about the necessity for, the scope and duration of and the intervals between the deformation measurements shall be made based on the design data in agreement with an experienced expert in soil mechanics and foundation engineering.

Certified by

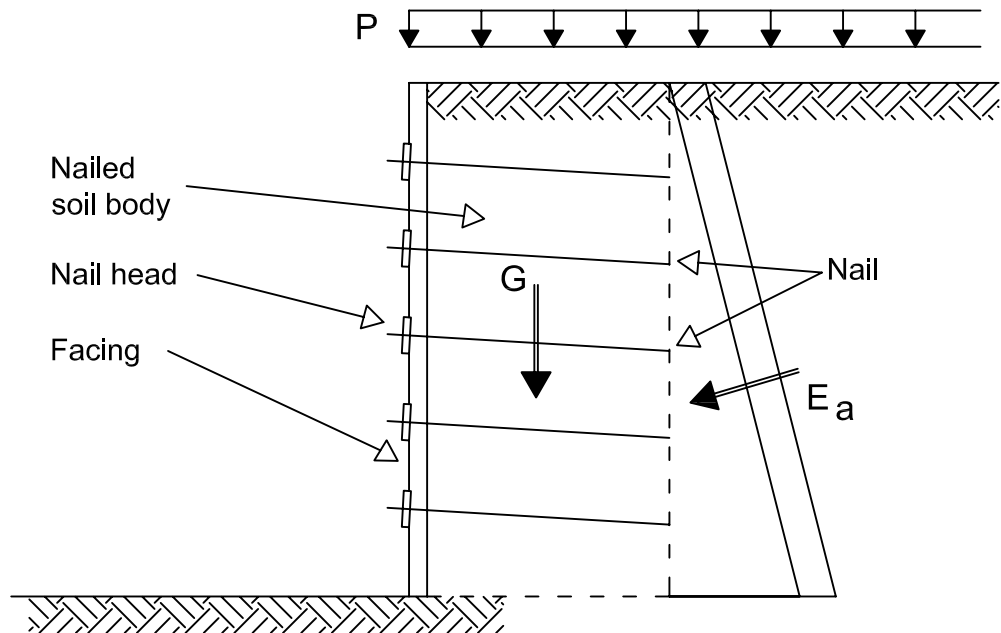


Fig. 1: Stability investigation on the total system

Estimate of the loads for verification of the resistance to slip, tilt and ground failure (shown for foundation joint).

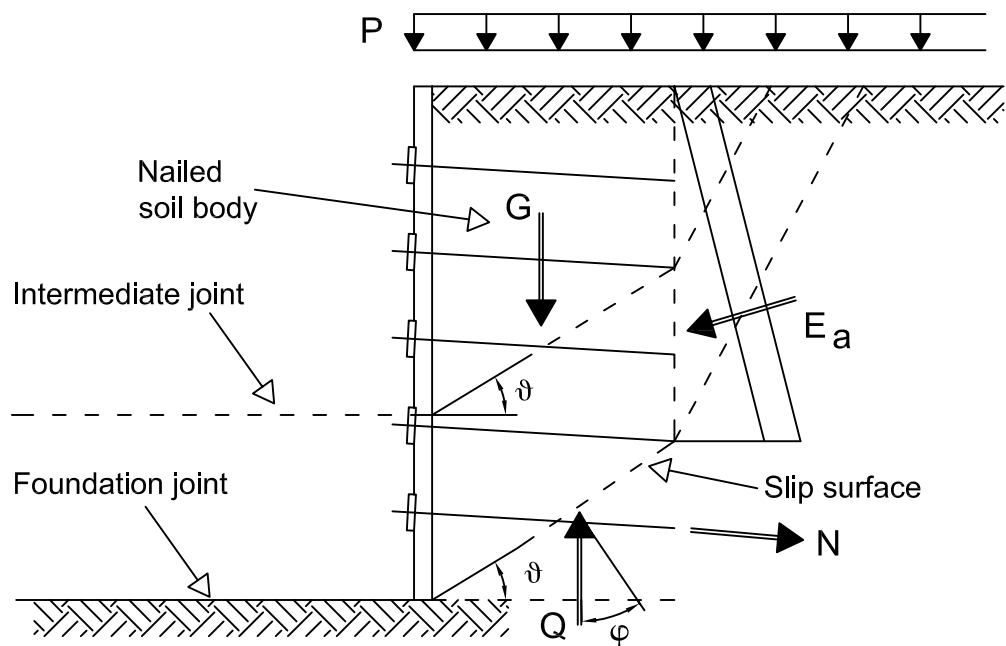
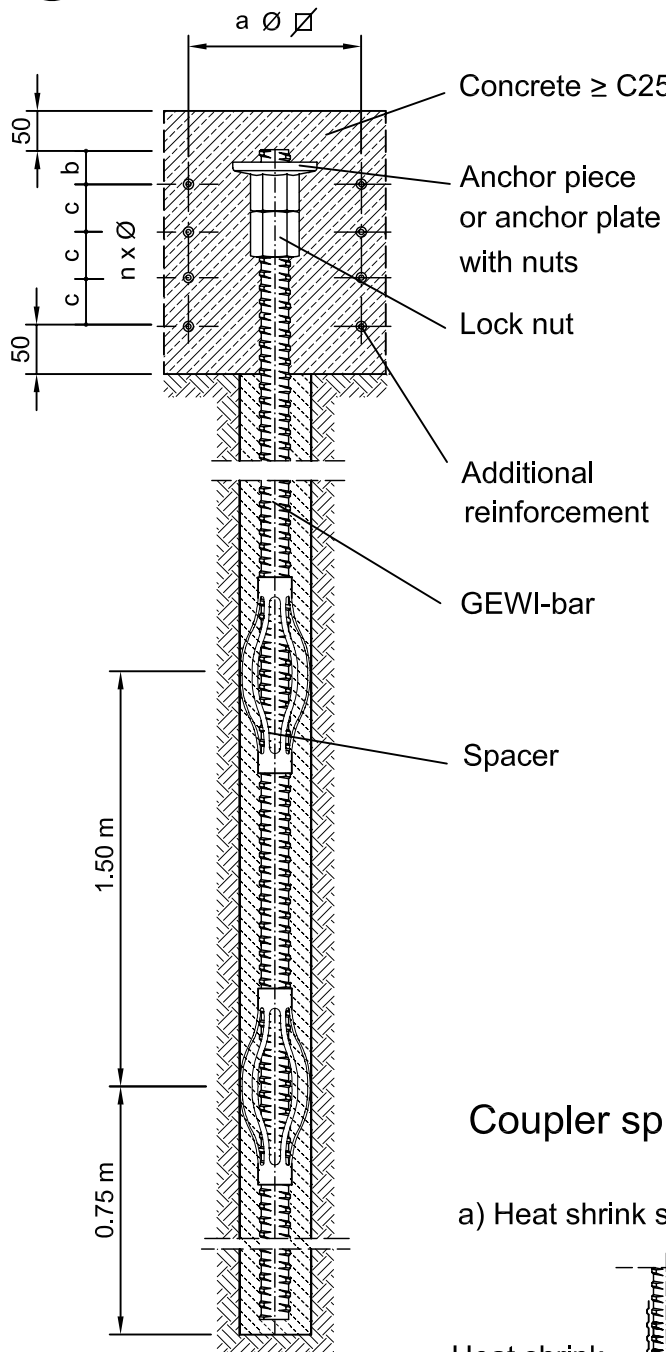


Fig. 2: Sliding body investigation

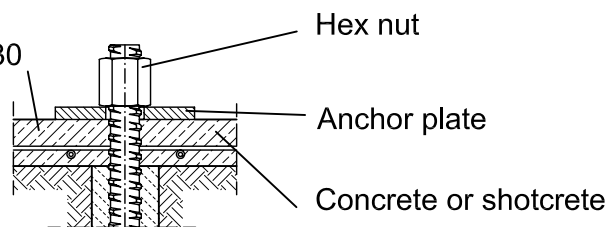
Determination of the least favourable slip surface by variation of the angle ϑ in the foundation joint and in the intermediate joints.

| | | |
|--|--|--|
| DYWIDAG SYSTEMS International | DYWIDAG Soil Nailing System | Appendix 1 to the general German approval Z-20.1-106 of 2007-April-05 |
| | Stability investigation on the total system and sliding body investigation | |

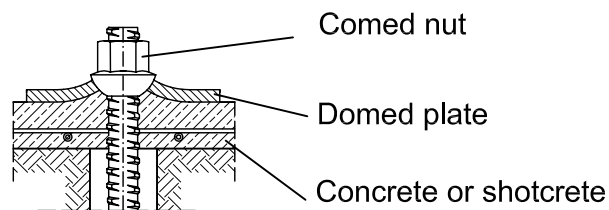
① GEWI End anchorage



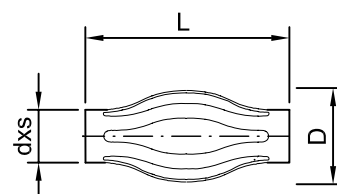
② Plate anchorage



③ Domed plate anchorage



Spring basket spacer



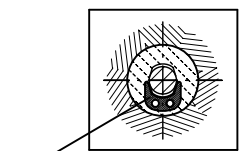
Coupler splice (with optional locking methods)

a) Heat shrink sleeve

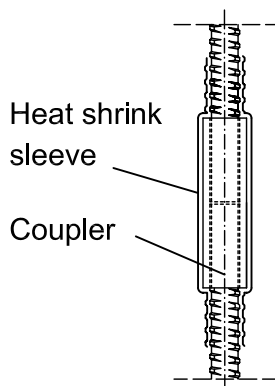
b) Lock nuts

c) Glue

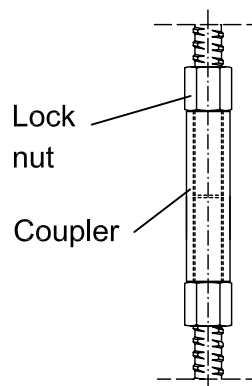
Post-grouting system



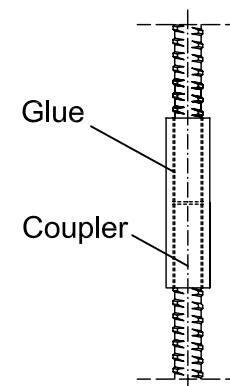
Post-grouting valve



Heat shrink sleeve
Coupler



Lock nut
Coupler

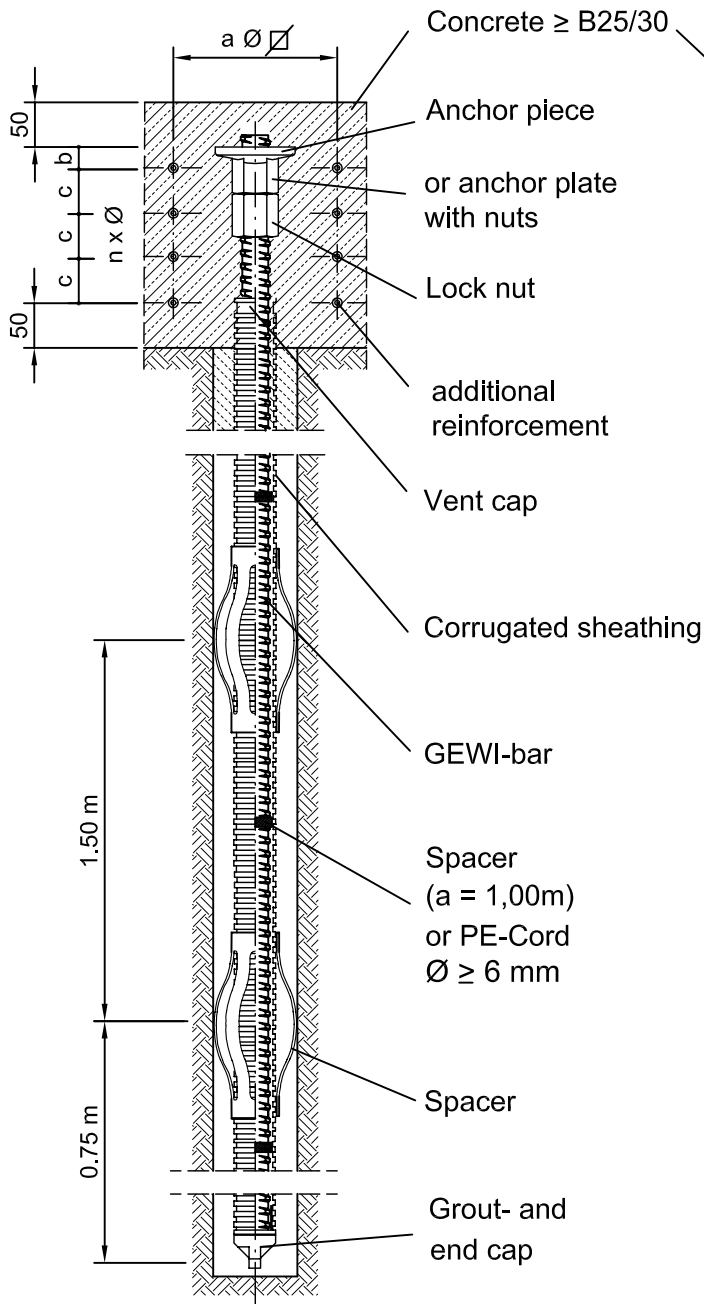


Glue
Coupler

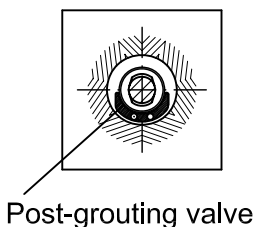
Applicability, references and dimensions acc. to appendix 4

| | | |
|--|--------------------------------------|---|
| DYWIDAG SYSTEMS International | DYWIDAG Soil Nailing System | Appendix 2 |
| | System design Temporary soil nail | to the general German approval Z-20.1-106 of 2007-April-05 |

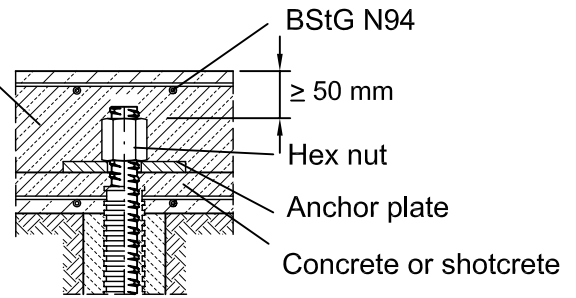
① GEWI-End anchorage



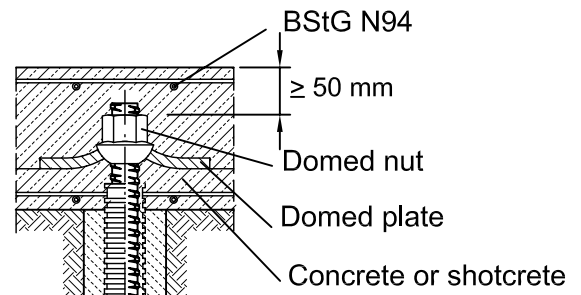
Post-grouting system



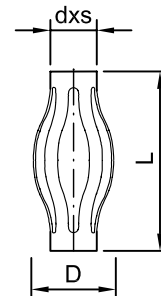
② Plate anchorage



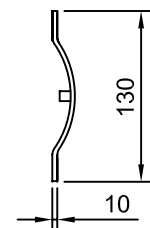
③ Domed plate anchorage



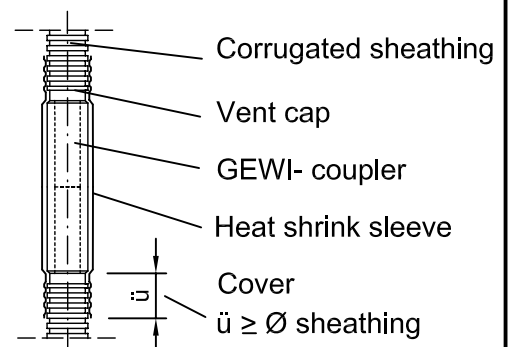
Spring basket spacer



Segment-spacer



Coupler splice



Applicability, references and dimensions acc. to appendix 4

DYWIDAG
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International

DYWIDAG Soil Nailing System

System design
Permanent soil nail

Appendix 3

to the general
German approval
Z-20.1-106 of
2007-April-05

Temporary and permanent soil nails

| | | | | | | | | | | |
|-------------------------|------------|-------------------------------------|---------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|--|
| GEWI steel | Ø | 16 | 20 | 25 | 28 | 32 | 40 | 50 | 63,5 | |
| Steel grade | | BSt 500 S | | | | | | | S 555/700 | |
| Anchorages | | | | | | | | | | |
| 1 End anchorage | | Appr. Z-1.5-76 | | | | | Appr. Z-1.5-149 | | Appr. Z-1.5-2 | |
| 2 Plate anchorage | | With reference to approval Z-1.5-76 | | | | | Appr. Z-1.5-149 | | Appr. Z-1.5-2 | |
| - Anchor nut | | | | | | | | | | |
| - Anchor plate | a x a s | 80 x 80 10 | 90 x 90 12 | 110 x 110 15 | 120 x 120 20 | 120 x 120 30 | 150 x 150 40 | 190 x 190 45 | 245 x 245 50 | |
| 3 Domed plate anchorage | | see appendix 5 | | | | | — | | — | |

Temporary soil nails

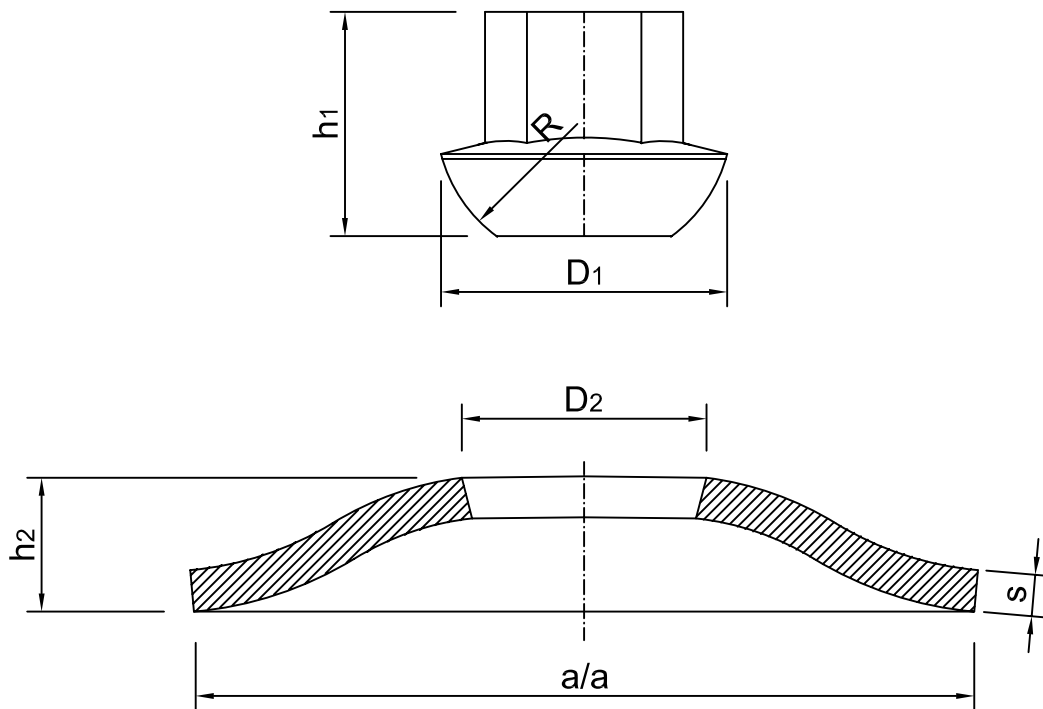
| | | | | | | | | | | |
|---------------------------|-----------|---|----------|----------|---------|----|-----------------|----------|---------------|--|
| Spring basket spacer | d x s | 20 x 1,5 | 25 x 1,9 | 32 x 2,4 | 40 x 3 | | 48 x 3 | 63 x 3 | 75 x 3,6 | |
| | L | 210 | 225 | 235 | 280 | | 285 | 285 | 285 | |
| | min. D | 65 | 70 | 80 | 100 | | 100 | 125 | 125 | |
| Min. borehole diameter | | 56 | 60 | 65 | 68 | 72 | 80 | 90 | 110 | |
| Coupler splice | | Appr. Z-1.5-76 | | | | | Appr. Z-1.5-149 | | Appr. Z-1.5-2 | |
| Locking of coupler splice | | Appr. Z-1.5-76 | | | | | Appr. Z-1.5-149 | | — | |
| - with lock nuts | | | | | | | | | | |
| - with heat shrink sleeve | Type | CPSM | | CPSM | CPSM | | CPSM | CPSM | | |
| | Ø max/min | 37 / 12 | | 50 / 18 | 70 / 26 | | 90 / 36 | 120 / 54 | | |
| - with glue | | Quickly setting adhesive or adhesive tape | | | | | | | | |

Permanent soil nails

| | | | | | | | | | | |
|--------------------------------|------------------------|----------------|-----------|---------|--------|---------|-----------------|----------|---------------|-----------|
| Corrugated sheathing (PVC/ PE) | s | ≥ 1 mm | | | | | | | | |
| | Ø a/i | 34,5 / 28 | 42,5 / 35 | 50 / 44 | | 56 / 49 | 65 / 57 | 80 / 71 | 100 / 91 | |
| Spacer | | | | | | | | | | |
| | - Spring basket spacer | d x s | 40 x 3 | 48 x 3 | 55 x 3 | | 63 x 3 | 75 x 3,6 | 90 x 2,7 | 110 x 3,2 |
| | | L | 280 | 285 | 275 | | 285 | 285 | 285 | 285 |
| | min. D | 100 | 100 | 125 | | 125 | 125 | 140 | 175 | |
| - Segment spacer | L | — | — | — | | 130 | | | | |
| | a | — | — | — | | 10 | | | | |
| Min. borehole diameter | | 55 | 63 | 70 | | 76 | 85 | 100 | 120 | |
| Coupler splice | | Appr. Z-1.5-76 | | | | | Appr. Z-1.5-149 | | Appr. Z-1.5-2 | |
| Locking of coupler splice | | | | | | | | | | |
| - Heat shrink sleeve | Type | CPSM | | | | | CPSM | | CPSM | |
| | Ø max/min | 70 / 26 | | | | | 90 / 36 | | 120 / 54 | |

All measurements in mm

| | | |
|--|---|--|
| DYWIDAG SYSTEMS International | DYWIDAG Soil Nailing System | Appendix 4 to the general German approval Z-20.1-106 of 2007-April-05 |
| | Temporary and permanent soil nails References and dimensions | |



Domed nut:

| | | | | | | |
|---------------------------------|-------|---------------------------|----|------------------------------|----|----|
| Bar diameter | Ø | 16 | 20 | 25 | 28 | 32 |
| Hexagon | a/f | 27 | 32 | 37 | 41 | 46 |
| Height | h_1 | 33 | 35 | 38 | 48 | 57 |
| Spherical collar | D_1 | 35 | 49 | 55 | 62 | 70 |
| Radius | R | 19 | 25 | 28 | 32 | 36 |
| Material (Material standard) | | C45+N (DIN EN 10083-2) | | G 42 CrMo4 (DIN EN 10293) | | |

Domed plate:

| | | | | | | |
|---------------------------------|-------|-------------------------------------|----|---------|----|---------|
| Bar diameter | Ø | 16 | 20 | 25 | 28 | 32 |
| Dimensions * | a/a | 120/120 | | 150/150 | | 200/200 |
| Height | h_2 | 23 | 20 | 23 | 28 | 28 |
| Plate thickness | s | 5 | 8 | 10 | 10 | 12 |
| Hole diameter | D_2 | 28 | 38 | 43 | 47 | 52 |
| Material (Material standard) | | S235JR (St37-2) (DIN EN 10025-2) | | | | |

* Minimum dimensions
All measurements in mm

| | | |
|--|------------------------------------|--|
| DYWIDAG SYSTEMS International | DYWIDAG Soil Nailing System | Appendix 5 to the general German approval Z-20.1-106 of 2007-April-05 |
| | Domed plate anchorage | |

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