DYWIDAG

GEOTECHNICAL SYSTEMS

DYWIDAG Soil Nailing System

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Applicant:
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Subject of approval:
"DYWIDAG" Soil Nailing System

The above mentioned subject is hereby granted general construction supervisory authority accreditation/approval.
This Approval consists of 19 pages and five Annexes.
The subject was first approved on 20 February 1989 by the construction authorities.

Important Notice
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II SPECIAL PROVISIONS

1 Subject of the regulation and scope of use or application

1.1 Subject of approval and scope of use

(1) The subject of the Approval is the “DYWIDAG” soil nailing system from DYWIDAG Systems International GmbH, consisting of:

- load-carrying elements of reinforcing steel bars with B500B thread ribs and nominal diameters of 16 mm, 20 mm, 25 mm, 28 mm, 32 mm, 40 mm or 50 mm,
- load-carrying elements of steel bars with GEWI steel S 555/700 thread ribs and nominal diameter of 63.5 mm,
- couplers and anchoring elements made of steel
- other components.

(2) The “DYWIDAG” soil nailing system may be used for temporary (≤2 years) and permanent (>2 years) applications.

(3) In case of soil nails for permanent use (>2 years), the steel load-bearing element is provided with a corrosion protection system consisting of corrugated plastic sheathing grouted with inner cement grout.

(4) The “DYWIDAG” Soil Nailing System may be used for soil nailing to secure terrain changes (e.g. excavation pit walls or slope cuts), to secure existing embankments and to stabilize loaded soil during underpinning work with any wall inclination.

1.2 Subject of approval and scope of use

(1) The subject of approval is the planning, design and installation of the “DYWIDAG” soil nailing system, consisting of “DYWIDAG” soil nail system, cement grout and facing of sprayed concrete or precast concrete elements.

(2) The “DYWIDAG” Soil Nailing System is a measure to increase the tensile and shear strength of soil to the extent that the nailed soil body can be seen and verified as a monolithic block.

(3) The “DYWIDAG” Soil Nailing System must be manufactured as shown in Annexes 1 to 4, taking into account the following provisions. Additionally, a distinction must be made between temporary (≤2 years) and permanent (>2 years) applications.

2 Provisions for the construction product

2.1 Properties and composition

2.1.1 Steel tendon

(1) Only reinforcing steel bars/steel bars with thread ribs may be used according to Table 1.

Table 1: Nominal diameter and steel grade

Nominal diameter [mm]	Reinforcing steel bars/Steel bars with thread ribs as per Approval[1] no.				
	Reinforcing steel bars with B500B thread ribs			Steel bars with thread ribs S 555/700	
	Z-1.1-58	Z-1.1-59	Z-1.1-167	Z-1.1-1	Z-1.1-198.1
16	X		X		
20	X		X		
25	X		X		
28	X		X		
32	X		X		
40	X	X			
50	X	X			
63.5				X	X

(2) Reinforcing steel bars with B500B thread ribs and steel bars with S 555/700 thread ribs may be joined trough couplers as per Table 2 (see Annexes 1, 2 and 3).

Table 2: Connecting and anchoring devices

Nominal diameter [mm]	Coupler connections and anchoring as per Approval[1] no.			
	Reinforcing steel bars with B500B thread ribs			Steel bars with thread ribs S 555/700
	Z-1.5-76*	Z-1.5-149*	Z-1.5-174*	Z-1.5-2
16	X		X	
20	X		X	
25	X		X	
28	X		X	
32	X		X	
40		X	X	
50		X	X	
63.5				X

* Combining couplers or anchoring elements between the mentioned Approvals is not permitted. To avoid confusion, only anchoring and connecting devices from one and the same Approval may be used at each construction site;
for Ø16 mm to 32 mm – no. Z-1.5-76 or no. Z-1.5-174,
for Ø40 mm or 50 mm – no. Z-1.5-149 or no. Z-1.5-174
.

1 general construction supervisory authority approval, general construction supervisory authority approval / general design-type approval or general design-type approval

(3) Reinforcing steel bars with B500B thread ribs and steel bars with S 555/700 thread ribs must be anchored in the facing using anchoring elements as per Table 2. For the respective diameters, anchor plates are used with the geometrical dimensions specified in Annex 3 and material specification S235JR as per DIN EN 10025-2. In case of non-dynamic impacts, the reinforcing steel bars with B500B thread ribs from Ø16 mm to Ø32 mm can also be anchored with spherical collar nuts and domed plates as per Annex 4.

2.1.2 Permanent soil nails corrosion protection components

(1) Corrugated plastic sheathing designed for corrosion protection must be made either of PVC-U as per DIN EN ISO 21306-1, polyethylene with molding compound as per ISO 17855-PE-HD, E, 44-T022 as per DIN EN ISO 17855-1 or of polypropylene with molding compounds ISO 19069-PP-B, EAGC, 10-16-003 or ISO 19069-PP-H, E, 06-35-012/022 as per DIN EN ISO 19069-1. It is important to ensure that only straight pipe sections are used. Empty pipes must have a uniform wall thickness of ≥1 mm; only pipes without any bubbles and with even pigment distribution may be used. The dimensions of empty pipes are specified in Annex 3.

(2) A distance of ≥5 mm between the load-carrying element and the empty pipe must be ensured by spacers that should be arranged at every 1.0 m. Instead of spacers, a round steel helix Ø5 mm, pitch 0.5 m, or a plastic helix Ø6 mm of PE or PVC, pitch 0.5 m may be used as per Annex 2.

(3) For filling the ring space between the load-carrying element and the corrugated plastic sheathing, inner cement grout as per DIN EN 447 should be used. Additionally, DIN EN 445 and DIN EN 446 must be observed.

(4) To complete the corrosion protection and overlap of the coupling elements at joint sites, use corrosion protection heat shrink sleeves (e.g. CPSM) as per DIN EN 12068 with the classification “Coating EN 12068-C30” made of radiation-crosslinked polyethylene, which is lined on the inside with a butyl rubber based adhesive with corrosion inhibitors; the amount of adhesive must be at least 700 g/m^2. The heat shrink sleeves are to be shrunk with hot air, infrared radiation or a soft flame of a gas burner; the wall thickness in the shrunken state must be ≥1.5 mm.

2.2 Production, packaging, transport, storage and marking

2.2.1 Production and corrosion protection of the “DYWIDAG” soil nailing system prefabricated for installation and grouting

(1) The following works should be carried out at the plant.

(2) Components for short-term soil nails (≤2 years) and permanent soil nails (>2 years) of the “DYWIDAG” soil nail system are assembled depending on the planned use duration. Short-term soil nails are packaged at the plant, whereas in the case of permanent soil nails, the plant must additionally arrange a corrosion protection system consisting of corrugated plastic sheathing injected with inner cement grout.

(3) The steel load-bearing elements of the permanent soil nails are embedded in a corrugated plastic sheathing injected with inner cement grout over almost its entire length (see Annex 2) up to any joints. Requirements to be observed during manufacturing of the corrosion protection system include, but are not limited to the following:

- To maintain a distance of ≥5 mm between the steel load-bearing element and the corrugated plastic sheathing, spacers as per Section 2.1.2 (2) should be used. On the earth side of the permanent soil nails, an injection or end cap should be used, made of the same material as the corrugated plastic sheathing (plastic and molding compound as per Section 2.1.2 (1)). The end cap should be connected with the corrugated plastic sheathing through cams and glued. The open-air end should be closed with a ventilation cap made of PE, sealed with suitable adhesive tape. If the steel load-bearing element is spliced, PE injection or ventilation caps must be arranged at the end of the corrugated plastic sheathing, taking into consideration the free bar ends required for the coupling, and sealed with a suitable adhesive tape. In case of corrugated plastic sheathing made of PE, the injection or ventilation cap made of PE may be glued to the corrugated plastic sheathing so that the sealing with a suitable adhesive tape can be omitted. The individual sections of the corrugated plastic sheathing made of PVC-U that may be required must be screwed together and carefully sealed with an adhesive suitable for PVC or by wrapping with adhesive tape suitable for PVC. Continuous pipe sections should be used as PE or PP sheathing.
- The ring space between the steel load-bearing element and the corrugated plastic sheathing, if the load-bearing element is positioned diagonally, should be grouted from bottom to top with inner cement grout as per Section 2.1.2 (3). For this purpose, the prepared steel load-bearing element must be positioned on an inclined plane, so that grouting from the lowest point (injection or end cap) and venting at the highest point (ventilation cap) can be ensured. To ensure complete filling, the ventilation cap must be connected to a 0.5 m long filling hose or a settling funnel.

2.2.2 Packaging, transport and storage

(1) The effectiveness of the corrosion protection of permanent soil nails depends on the integrity of the corrosion protection components. Therefore during the transport, storage and installation of the “DYWIDAG” soil nailing system, care must be taken to ensure that the corrosion protection components, including, but not limited to the corrugated plastic sheathing, are not damaged through improper handling. Items must be stored above ground, contamination of steel load-bearing elements or corrugated plastic sheathing is unacceptable.

(2) Depending on the temperature, the “DYWIDAG” soil nailing system prefabricated for permanent use may be removed from the assembly bench at the earliest one day after grouting with inner cement grout at the plant. Further transport and installation is allowed not earlier than 2 days (48 h) after grouting with inner cement grout at the plant.

2.2.3 Marking

(1) The prefabricated or prepackaged “DYWIDAG” soil nailing system and the delivery note of the system must be marked by the manufacturer with the mark of conformity in accordance with the national conformity mark regulations. Such marking is allowed only if the requirements as per Section 2.3 are met.

(2) The delivery note must especially state the use that the “DYWIDAG” soil nailing system is intended for and the plant where it was manufactured. One delivery note should only regard parts of one type of soil nails.

2.3 Conformity confirmation

2.3.1 General

The confirmation of conformity of the soil nail components and the “DYWIDAG” soil nailing system prefabricated for installation and grouting with the provisions of the general technical approval covered by the Approval must be provided for each manufacturing plant in the form of a declaration of conformity from the manufacturer based on plant production control and a certificate of conformity from a recognized certification body and regular external monitoring performed by a recognized monitoring body in accordance with the following provisions:

Issuing a certificate of conformity and the external monitoring, including the product tests to be carried out, require from the manufacturer of the soil nail components and the prefabricated "DYWIDAG" soil nailing system to engage a recognized certification body and a recognized monitoring body.

The manufacturer submits the declaration of conformity by marking the construction products with a conformity mark with reference to the intended use.

The certification body must provide the German Institute for Building Technology with a copy of the certificate of conformity they have issued.

Additionally, a copy of the initial test report must be submitted to the German Institute for Building Technology.

2.3.2 Plant production control

(1) A plant production control must be set up and carried out at every manufacturing plant. The plant production control is understood as a continuous monitoring of production carried out by the manufacturer, by means of which the manufacturer ensures that the construction products they manufacture meet the provisions of the general construction supervisory authority approval granted under this Approval.

(2) The plant production control shall include at least the measures listed in Annex 5 regarding incoming goods control and control during manufacturing.

(3) Results of the plant production control must be recorded and evaluated. Such records must contain at least the following information:

- designation of the construction product or the initial material and its components;
- nature of the control or inspection;
- date of manufacturing and inspection of the construction product or the initial material or its components;
- results of the controls and inspections and, if applicable, a comparison with the relevant requirements
- signature of the person responsible for the plant production control.

(4) Such records must be retained for at least five years and presented to the monitoring body responsible for external monitoring. They must be presented to the German Institute for Building Technology and to the competent highest construction supervisory authority on request.

(5) If the inspection result is unsatisfactory, the manufacturer must immediately take the necessary measures to remove the defect. Construction products that do not met the requirements must be handled in such a way so as to exclude confusion with the conforming ones. When the defect is removed, the respective inspection must be repeated immediately – insofar as it is technically possible and necessary to prove that the defect has been removed.

2.3.3 External monitoring

(1) At every manufacturing plant, the plant itself and the plant production control must be controlled through external monitoring on a regular basis, in any case at least twice a year.

(2) An initial inspection must be carried out as part of external monitoring. Samples are to be taken for spot checks and also the testing tools are to be controlled. The sampling and inspections are the responsibility of the recognized monitoring body.

(3) The results of the certification and external monitoring must be retained for at least five years. They must be presented by the certification body or the monitoring body to the German Institute for Building Technology and to the competent highest construction supervisory authority on request.

3 Provisions for planning, design and installation

3.1 General

The “DYWIDAG” soil nailing system must be planned, designed and executed in accordance with technical building specifications, including, but not limited to DIN EN 1997-1, DIN EN 1997-1/NA and DIN 1054, unless otherwise specified below.

3.2 Planning

3.2.1 General

(1) The “DYWIDAG” soil nailing system may be used in cohesive or non-cohesive soils (see DIN EN 1997-1 in conjunction with DIN EN 1997-1/NA and DIN 1054, Section 3.1). Soil nailing must not be carried out if the soil or underground water contains substances that react with concrete (see DIN 4030-1). If sulfate contents in the soil or ground water in accordance with DIN 4030-1, Table 4 is weakly aggressive (XA1), the soil nails can be installed if a cement with high sulfate-resisting (SR cement) as per EN 197–1 is used for manufacturing.

(2) According to DIN EN 1997-1 in conjunction with DIN EN 1997-1/NA and DIN 1054, the geotechnical surveys required for retaining structures must be carried out and evaluated under the direction of a geotechnical expert. It must also be inspected whether the existing soil is temporarily stable at the planned excavation depth. The soil must not break out if the facing is made of sprayed concrete.

(3) The maximum nail distance is 1.5 m in the horizontal and vertical direction; this value may only be exceeded if proof of spatial stability is provided.

(4) The soil nails are to be produced with a minimum angle of 10° to the horizontal plane.

(5) The execution planning documentation must include information resulting from the details implementation planning. This includes, but is not limited to the following information:

- grid of nail distances and the soil nail inclination;
- integration of the nail heads in the facing;
- creation of any required coupling points using couplers (coupler splices);
- cement grout composition, minimum cement stone overlap and spacers;
- design load and design resistance of the nails in accordance with Section 3.3.3 for inspections in accordance with Section 3.4.6.

3.2.2 Facing and integration of the nail heads

(1) The facing can be made of sprayed concrete or precast concrete elements. Sprayed concrete must correspond at least to the strength class of C 25/30 concrete. For production and inspection, DIN EN 14487-1 and DIN 18551 apply. The sprayed concrete skin does not transfer any forces into the subsoil – the earth pressure must act in the direction of the soil nails in order for the equilibrium of forces to be achieved. However, they do not necessarily need to be perpendicular to the facing.

(2) In case of heavily relaxing soils and/or construction measures where deformations must be kept small, wall protections (e.g. piles, pre-injections) may have to be arranged before the excavation.

(3) The facing does not need to be integrated below the excavation pit. Adequate drainage must be provided so that no water pressure builds up behind the facing.

(4) For the anchoring of soil nails on the facing, anchoring elements as per Section 2.1.1 (3) should be used. If there is a deviation from the specifications provided therein, e.g. regarding additional reinforcement, the load-bearing capacity of the anchor plates must be verified; this also applies to the introduction of forces into the facing. The transmission of forces into the facing (e.g. splitting forces) must be verified in each individual case (see also Section 3.3.4).

(5) Anchor plates in accordance with Annex 3 are to be laid in fresh sprayed concrete or in a grouting bed perpendicular to the steel load-bearing element. When using calotte plate anchorage in accordance with Annex 4, ±15° angle compensation for the tendon axis is possible.

(6) For permanent soil nailing, a sprayed concrete layer of at least 5 cm must be applied over the nail heads, which must be reinforced with N 94 reinforcing steel mesh or of equivalent or higher quality. If the facing consists of prefabricated parts, the nail heads must be protected to an equivalent or higher standard.

3.2.3 Coupler splices

(1) If steel load-bearing element joints are needed, they are to be implemented using couplers in accordance with Section 2.1.1 (2).

(2) The couplers should be countered with nuts. In case of non-dynamic impacts, lock nuts can be omitted if a fixing heat shrink sleeve or corrosion protection heat shrink sleeve is used as a locking device (see Section 2.1.2 (4)). Fixing heat shrink sleeves (e.g. MWTM) are made of polyethylene; the sealing adhesive mass must be a hot melt adhesive.

(3) For permanent soil nails, a corrosion protection heat shrink sleeve may be used as a heat shrink sleeve in accordance with Section 2.1.2 (4) and as per Annex 3 over the coupling and to complete the corrosion protection system. A cavity between the grout column or the injection/ventilation cap and the coupler splice must be completely filled on both sides of the joint with “Densoplast petrolatum tape” plastic sealing tape as per DIN 30672 before the heat shrink sleeve is applied.

(4) The spacing between the joints in the longitudinal direction of the steel load-bearing element must be ≥ 1 m.

3.2.4 Cement grout for filling boreholes

3.2.4.1 Composition

(1) The starting materials for the cement grout are cements with special properties according to DIN 1164–10 and cements according to EN 197-1 – taking into account the existing exposure classes as per DIN EN 206-1 F in conjunction with DIN 1045-2 (Tables 1, F.3.1 and F.3.2), water as per DIN EN 1008 and, if necessary, additives as per EN 934-2 in conjunction with DIN EN 206-1/ DIN 1045-2 or with general construction supervisory authority approval and natural aggregates for concrete as per EN 12620 – taking into account DIN EN 206-1/DIN 1045-2, Appendix U to be applied.

(2) Unless otherwise specified, the compressive strength of the cement grout after 28 days must be at least that of concrete of strength class C25/30.

3.2.4.2 Short-term soil nails (temporary installation ≤2 years)

For the temporary installation of soil nails, the steel load-bearing elements must be surrounded with 20 mm of cement stone; the minimum overlap is ≥15 mm. For this purpose, the steel load-bearing element must be provided with spacers as per Annex 1 and Annex 3 with a distance of ≤2.0 m.

3.2.4.3 Permanent soil nails (permanent installation >2 years)

Corrugated plastic sheathing of the steel load-bearing elements must be centered with spacers as per Annexes 2 and 3 with a distance of ≤2.0 m. An overlap of at least 10 mm of cement grout must be ensured.

3.2.4.4 Post-grouting

Post-grouting is permitted. For this purpose, the soil nails must be equipped with an injection line with valves (see Annex 1 or Annex 2) already before installation.

3.3 Design

3.3.1 General

(1) Technical building specifications, including, but not limited to DIN EN 1997-1, DIN EN 1997-1/NA and DIN 1054, shall be applicable for the design and dimensioning of nailed supporting structures, unless otherwise specified below.

(2) Nailed supporting structures must be classified at least into geotechnical category GK 2. It must be checked based on DIN 1054, Section A 9.1.3 A (4), whether there are criteria that require classification into the geotechnical category GK 3.

(3) The verifications to be made for the load-bearing capacity limit state and the associated limit states and verification methods are listed in Table 3. Both the final state and the decisive (intermediate) construction states must be verified.

Table 3: Overview of the load-bearing capacity verifications for nailed supporting structures

	Verification	Limit state/ verification method	Section in	
			DIN EN 1997-1	DIN 1054
Nailed supporting structure	Ground rupture	GEO-2	6.5.2	6.5.2
	Sliding	GEO-2	6.5.3	6.5.3
	High eccentric load	GEO-2	6.5.4	6.5.4
	Overall stability	GEO-3	11.5.1	11.5.1
Nails	Material failure	STR		
	Extraction	GEO-3		A 11.5.4.2
Facing	Partial area loading, punching, etc.			A 11.5.4.1
Note: Partial safety factors can be taken from DIN 1054, Tables A 2.1 to A 2.3.				

3.3.2 Verifications for the load-bearing capacity limit state of nailed supporting structures

(1) For the calculation of a nailed supporting structure (weight support wall made of a quasi-monolithic, nailed soil body), a calculated rear wall through the end of the nails is to be assumed as a general case. For the general case, the following must be verified:

(a) ground rupture stability,

(b) slide stability,

(c) protection against loss of balance due to a highly eccentric load,

(d) overall stability.

(2) A separate verification for the limit state EQU according to DIN 1054, Section until 6.5.4 A (3) does not need to be carried out if the conditions regarding the location of the bearing pressure resultant are observed in accordance with DIN 1054, Section A 6.6.5 are complied with. (see also section 3.3.6)

(3) The applicability of the general case must be checked in the particular case when creating the model. In particular in the case of layered soils and different nail lengths, it is possible to verify the overall stability of the relevant rupture mechanisms through varying rupture planes.

3.3.3 Nail verification

Sufficient safety against material failure and a soil nail being pulled out must be verified in accordance with DIN 1054.

3.3.3.1 Design load of nails

The design load of the nails must be determined as per DIN 1054, Section A 11.5.4.1

(a) from the design earth pressure and the surface protection area assigned to the respective element for the limit state GEO-2,

(b) from the deficit of equilibrium of forces and/or moments on sliding bodies, which are limited by rupture mechanisms with straight or bent gliding surfaces, with the gliding surfaces to be varied crossing a portion of the retaining elements. The verification is performed in accordance with DIN 4084 for the GEO-3 limit state.

The greater design load value is decisive.

Regarding (a) – design load $E_{E,d}$ from earth pressure

The design impact on the facing of the supporting structure must be determined, in the GEO-2 limit state, from the characteristic active earth pressure according to DIN 1054 and DIN 4085, taking into consideration the minimum earth pressure, where required, with the earth pressure inclination being assumed to be parallel to the inclination of the soil nails.

Earth pressure distribution for the portion from constant impacts can be assumed to be equal due to the redistributions taking place. The ordinate of the rectangular figure then is:

$$e_{ag,k}(z) = e_{ag,k} = E_{ag,k} \cdot \cos(\alpha) / h = \text{constant} \quad (3.1)$$

with α = inclination angle of the wall (as defined in DIN 4085)
h = wall height

This earth pressure from constant impacts of the sprayed concrete skin may additionally be reduced by 15%.

$$\text{red } e_{ag,k} = 0.85 \cdot e_{ag,k} \quad (3.2)$$

The earth pressure from variable impacts must be specified in accordance with DIN 4085 and may not be reduced. Thus, the resulting design load from earth pressure emerges as:

$$e_{a,d}(z) = \text{red } e_{ag,k} \cdot \gamma_G + e_{ap,k}(z) \cdot \gamma_Q \quad [kN/m^2] \quad (3.3)$$

with γ_G, γ_Q = partial safety factors according to DIN 1054, Table A 2.1 for the limit state GEO-2

For a nail at a depth of z_i the design load thus emerges as:

$$E_{E,d} = e_{a,d} \cdot \Delta F \quad [kN] \quad (3.4)$$

with $\Delta F = s_h \cdot s_v / \cos(\alpha)$
s_h = horizontal nail distance
s_v = vertical nail distance

All aforementioned values relate to the impact area of the analyzed nail i at the depth of z_i. The related area of the facing can differ for nails in peripheral areas (e.g. top or bottom nail layer) from that of the remaining nails.

The decisive design load $E_{E,d}$ for the load-bearing capacity verification according to Section 3.3.3.3 of this Approval is the maximum from all nail forces thus determined.

Regarding (b) – design load $E_{N,d}$ from the equilibrium of forces or moments

For the determination of the design load from the equilibrium of forces and/or moments, protection against terrain rupture must be verified in accordance with DIN 4084, with the sliding surfaces to be varied crossing all of the nails or a part thereof. In this process, the force transmitted via the surface friction per meter of nail length along the force transmission section may be assumed to be constant and equal for all nails. The force of a nail $F_{Ni,d}$ in the anchoring area then emerges as:

$$F_{Ni,d} = T_{m,d} \bullet l_{r,i} \quad [kN] \quad (3.5)$$

with: $T_{m,d}$ = mean axial force per linear meter of nail outside the sliding joint that is required based on mathematical calculations to achieve the limit equilibrium, i.e. in the “passive” or dormant floor area

$l_{r,i}$ = remaining nail length outside the sliding joint at the i^{th} nail

The least safe rupture mechanism is that where $T_{m,d}$ becomes the maximum.

The decisive design load for a nail from the equilibrium of forces or moments emerges for the nail with the greatest remaining length $l_{r,max}$ outside the sliding joint:

$$E_{N,d} = T_{m,d} \bullet l_{r,max} \quad [kN] \quad (3.6)$$

with $l_{r,max}$ = greatest remaining nail length outside the sliding joint

If, according to DIN 1054, Section A 11.5.4.1 A (5), the deficit of the equilibrium of forces or moments is decisive for the design load of a nail, then the area of the facing ΔF allocated to this nail must be loaded with a correspondingly higher design earth pressure. This is derived by dividing the design nail force $E_{N,d}$ required based on mathematical calculations by the area of the facing allocated to the nail. This is often decisive especially at the lowest nail layers.

3.3.3.2 Design resistance of nails

Pull out resistance $R_{A,d}$

The length-related characteristic pull out resistance of a soil nail $T_{Pm,k}$ must be determined by pull out tests performed on-site (nail tests as defined in Section 3.4.6 hereof). The design value of the length-related pull out resistance $T_{Pm,d}$ emerges from the characteristic value as:

$$T_{Pm,d} = T_{Pm,k} / \gamma_a \quad [kN/m] \quad (3.7)$$

with γ_a = partial safety factor as per DIN 1054, Table A 2.3 for the limit state GEO-3

The design value for the greatest pull out resistance of an individual nail then emerges as:

$$R_{A,d} = T_{Pm,d} \cdot l_{r,max} \quad [kN] \quad (3.8)$$

The mean axial force per linear meter of nail $T_{Pm,d}$ must be assumed as constant over the depth t. In the case of t <2.0 m below ground level, $T_{Pm,d}$ is to be reduced by 50%.

Material resistance $R_{B,d}$

The characteristic axial tensile resistance $R_{B,k}$ of the soil nail is determined as:

$$R_{B,k} = A_s \cdot R_e \quad [kN] \quad (3.9)$$

with A_s = nominal cross-sectional area of the steel tendon

R_e = tensile stress at the yield point

The design value of the material resistance then emerges as:

$$R_{B,d} = R_{B,k} / \gamma_M \quad [kN] \quad (3.10)$$

with γ_M = 1,15

In the case of dynamic impacts, fatigue verification must be additionally performed in accordance with the provisions of the relevant general construction supervisory authority approvals for reinforcing steel bars with thread ribs or for anchoring for reinforcing steel bars with thread ribs.

3.3.3.3 Verification of the load-bearing capacity of the nails

The load-bearing capacity of the nails must be verified for the following factors

(1) pull out resistance (ground resistance),

(2) material resistance (component resistance)

The following must be proven:

$$R_{A,d} \text{ or } R_{B,d} \geq \max \begin{cases} E_{E,d} \\ E_{N,d} \end{cases} \quad (3.11)$$

3.3.4 Surface protection verification (facing)

(1) The facing must be designed in accordance with DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA. In the area of the nail heads, verifications of the punching shear forces and of the partial area loading must be performed in accordance with DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA.

(2) The decisive design load emerges, similar as in Section 3.3.3.1 of this Approval, either from earth pressure or from the deficit of the equilibrium of forces and/or moments.

3.3.5 Deformations

(1) If deformations of nailed walls are to be restricted, where there is no building above the wall, it is admissible to proceed in accordance with DIN 4084, Section 11. Where there is a building above a wall, the building design must be classified as geotechnical category GK 3; DIN 1054, section regarding 9.8 and section regarding 11.6 must be observed. Special measures such as the additional use of prestressed anchors may become necessary.

(2) As far as cohesive soils with a tendency to creep are concerned, creep deformations must be taken into account over the long term. Compatibility of possible creep deformations with local boundary conditions must be verified for permanent structures. When testing nailed walls, horizontal movements of up to 4‰ of the wall height have been measured under their own weight. In these tests, the nail lengths were 0.5 to 0.7 times of the wall height.

3.3.6 Verification of serviceability at limit states

To verify serviceability, the requirements as per DIN 1054, Section A 6.6.5, section regarding 9.8 and section regarding 11.6, must be observed. To limit, in particular, a gaping joint and the rotation of the supporting structure, the conditions regarding the location of the resulting bearing pressure must be observed in accordance with DIN 1054 Sections A 6.6.5 A (2) and A (3).

3.4 Installation

3.4.1 General remarks and the contractor

(1) The “DYWIDAG” soil nailing system, prefabricated or ready-made for installation and grouting, must be inspected by the contractor based on the execution planning documentation and delivery note for completeness of all required components. The minimum borehole diameter must be chosen, so that the “DYWIDAG” soil nailing system with the required spacers can be inserted without problems and the minimum overlap with the cement grout can be maintained.

(2) When transported by crane, the “DYWIDAG” soil nailing system is to be held by the upper end directly at the steel or with lifting straps or laid in channels.

(3) The installation of “DYWIDAG” soil nailing system with “DYWIDAG” soil nails and cement grout may only be performed under the responsible technical direction of DYWIDAG Systems International GmbH.

(4) The “DYWIDAG” soil nailing system with “DYWIDAG” soil nails and cement grout may also be installed by companies which can present a current certificate issued by DYWIDAG Systems International GmbH, stating that such company has received comprehensive training in the installation of the “DYWIDAG” soil nailing system with “DYWIDAG” soil nails and cement grout.

(5) During the installation of the “DYWIDAG” soil nailing system, records of proof of proper installation must be retained by the contractor or by the site manager or their representative and a declaration of conformity as per Section 3.4.7 must be submitted.

3.4.2 Drilling works

(1) The boreholes must be cased, unless it is verified at the construction site that the uncased boreholes are stable and that no earth can fall into the borehole when the soil nails are installed.

(2) Where in as cased borehole the projecting end of the drill set has an edged inner thread or a sharp-edged pipe end, the steel tendons of permanent soil nails may not be inserted into the borehole until an edge-free inserting trumpet or a pipe nipple which fully covers the internal thread of the casing has been put onto the projecting end of the drill set. It must be ensured that the corrosion protection is not damaged when the soil nail is inserted.

3.4.3 Couplings / creating joints

(1) The necessary couplings are to be made with couplers and may be executed in accordance with the execution planning documentation.

(2) The fixing heat shrink sleeves used as anti-rotation elements in short-term soil nails are to be shrunk with hot air, infrared radiation or a soft flame of a gas burner.

(3) In the case of permanent soil nails, petrolatum plastic sealing tape “Densoplast petrolatum tape” is to be melted by heating. The coupling site must then receive corrosion protection heat shrink sleeves shrunk with hot air, infrared radiation or a soft flame of a gas burner.

3.4.4 Filling boreholes

(1) Boreholes must be filled with cement grout from the earth-side end via the drill casings or via grout tubes.

(2) The “DYWIDAG” soil nailing system is to be positioned in the borehole using spacers in accordance with the execution planning documentation (see also Annexes 1, 2 and 3). In the case of cased boreholes, the spacers may be omitted if the casing thickness in the starting pipe or at the nipple passage is ≥2.0 cm and if the shaft is pressed with a pressure higher than the hydrostatic pressure.

(3) The cement grout must be machine-mixed. Before filling, no demixing or formation of lumps may occur. Water content in the cement must be between 0.35 and 0.50 and should be as low as possible especially in cohesive soils.

(4) To verify the compressive strength, tests according to DIN EN 12390-3 must be carried out on at least two series of 3 samples from 7 manufacturing days, in any case at least two series of 3 samples per construction site.

(5) If post-grouting is permissible, in can be made once the initial grouting has set or fully cured after initial grouting or filling with cement grout. Bursting of set cement grout is possible using water; however, post-grouting must be carried out with cement grout.

3.4.5 Anchoring soil nails on the facing

(1) Excavated areas are to be secured immediately with facing.

(2) For the anchoring of soil nails on the facing, anchor plates are to be laid in fresh sprayed concrete or in a grouting bed perpendicular to the steel load-bearing element in accordance with the execution planning documentation. The borehole must be filled up to the front edge of the wall; the cavity left by the inclined position of the nail is to be filled with sprayed concrete or mortar.

(3) In the case of permanent soil nails, the plant-prefabricated corrosion protection of the steel load-bearing element (corrugated plastic sheathing with inner cement grout) must reach up to the area of the facing.

(4) When the sprayed concrete shell hardens, the nuts must be hand-tightened. In the case of permanent soil nailing, the nail heads must be protected using measures in accordance with the execution planning documentation.

3.4.6 Tests

3.4.6.1 Load tests

(1) The pull out resistance of the soil nail stated in the execution planning documentation or assumed for the calculations must be verified by load tests. Load tests must be performed on at least 3% of all nails or at least on 3 nails per soil type.

(2) In the case of load tests, a tensile force is to be applied to the nail head in steps of 20 kN or in a minimum of 5 load stages up to the maximum test load P_P, which is 1.40-fold the design value of the nail load. If, in this process, the force in the reinforcing bars with thread ribs intended for the nailed soil body exceeds the value of 0.8 R_m (determined with the characteristic value of the tensile strength of the test nail) or 0.95 R_e (determined with the characteristic value of the yield strength of the test nail), then nails with a higher load-bearing capacity, but with the same bonding properties with regard to the soil must be used for the load tests. When under constant test loads, the displacements must be read after 1, 2, 5, 10 and 15 minutes. The observation period must be prolonged if the displacement $\Delta s > 0.5$ mm between 5 and 15 minutes. In these cases, the observation must be continued until Δs is ≤ 2.0 mm over a time interval of t_1 to $t_2 = 10\ t_1$. Provided that one of those conditions is fulfilled for all nails tested, a sufficient load-bearing capacity in soil is verified. During the load tests, it must be ensured that the nail is not supported by the facing.

(3) The test may only be carried out on nails from a limit depth of $t_g \geq 2.0$ m below ground level. The length of the bonding section l_V of the test nail must be chosen in such a manner that it corresponds to 70% to 90% of the total length of the longest nail. The length of the bonding section should not vary much in a test series.

(4) Due to the surface friction along the bonding section $l_{V,i}$ (cf. Section 3.3.3), which is assumed to be equally distributed, the mean characteristic axial nail force per lineal meter $T_{Pm,i}$ can be calculated from the maximum test load $P_{max,i}$ achieved in test i.

$$T_{Pm,i} = \frac{P_{max,i}}{l_{V,i}} \quad \text{[kN/m]} \qquad (3.12)$$

From this results the decisive length-related characteristic extraction resistance $T_{Pm,k}$ based on DIN EN 1997-1 7.6.3.2 (5)P as:

$$T_{Pm,k} = MIN\left(\frac{(T_{Pm,i})_{mean}}{\xi_1}; \frac{(T_{Pm,i})_{min}}{\xi_2}\right) \quad \text{[kN/m]} \qquad (3.13)$$

The distribution coefficients ξ_1 and ξ_2 must be applied according to Table 4. In the case of n ≥ 8 tests, the minimum value for the calculation of $(T_{Pm,i})_{min}$ may not be taken into account if it significantly deviates downwards. In the case of doubt, an expert in geotechnical engineering must be consulted for the evaluation of the tests.

Table 4: Distribution coefficients to derive characteristic values from nail load tests

n	3	4	5	6	≥ 7
ξ_1	1.35	1.25	1.15	1.05	1.00
ξ_2	1.35	1.15	1.00	1.00	1.00
n is the number of load tested nails					

3.4.6.2 Group impact

If the distance between the nails is less than 0.8 m, a mutual effect due to group loading must be checked. The arrangement of the test area and the minimum number of nails to be tested can be taken from Figure 1.

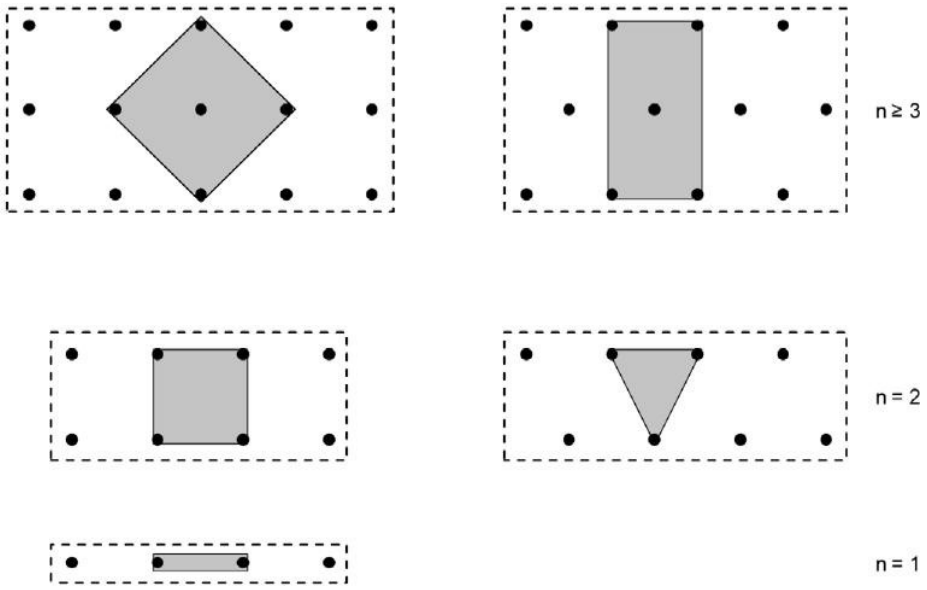


Fig. 1: Arrangement of the test area and minimum number of nails to be tested in the case of group loads dependent on the number of nail rows n

3.4.7 Declaration of conformity of the installation

(1) The contractor must submit a declaration of conformity as per Article 16a section 5 in conjunction with Article 21 section 2 of the MBO[2] to confirm that the design type conforms to the general design-type approval.

(2) The contractor's declaration of conformity must at least contain the following information:

- approval number
- designation of the building project
- the date of installation
- contractor's name and registered office
- confirmation that the installation is in compliance with the design documents
- documentation of the basic materials and delivery notes

2 Model Building Code (Musterbauordnung, MBO) version of November 2002, last amended by means of the decision of the Conference of the Minister of Construction of 25 September 2020

- the nature of the controls or inspections
- the date of the control or inspection
- the results of the controls and inspections and, if applicable, a comparison with the relevant requirements
- special notes
- name, company and signature of the person in charge of the controls and inspections.

(3) If the inspection result is unsatisfactory, the necessary measures must be taken immediately to remove the defect. When the defect is removed, the respective inspection must be repeated immediately – insofar as it is technically possible and necessary to prove that the defect has been removed.

(4) Records must be available at the construction site during the construction period. Following completion of the works, records must be retained by the company for a minimum of five years.

(5) Copies of the records must be handed over to the client for incorporation into the construction file and presented to the German Institute for Building Technology and to the competent highest construction supervisory authority on request.

4 Provisions for use, maintenance, and service

If special requirements are to be imposed on the structure with regard to deformations, after soil nailing inspections must be repeated and include deformation measurements. Whether this is necessary can be established based on the type of structure and/or the soil conditions on-site, taking into account public safety and order. The decision regarding the necessity and the scope, time intervals and duration of the deformation measurements is to be made based on the design data in consultation with the commissioned geotechnical engineering expert.

List of standards

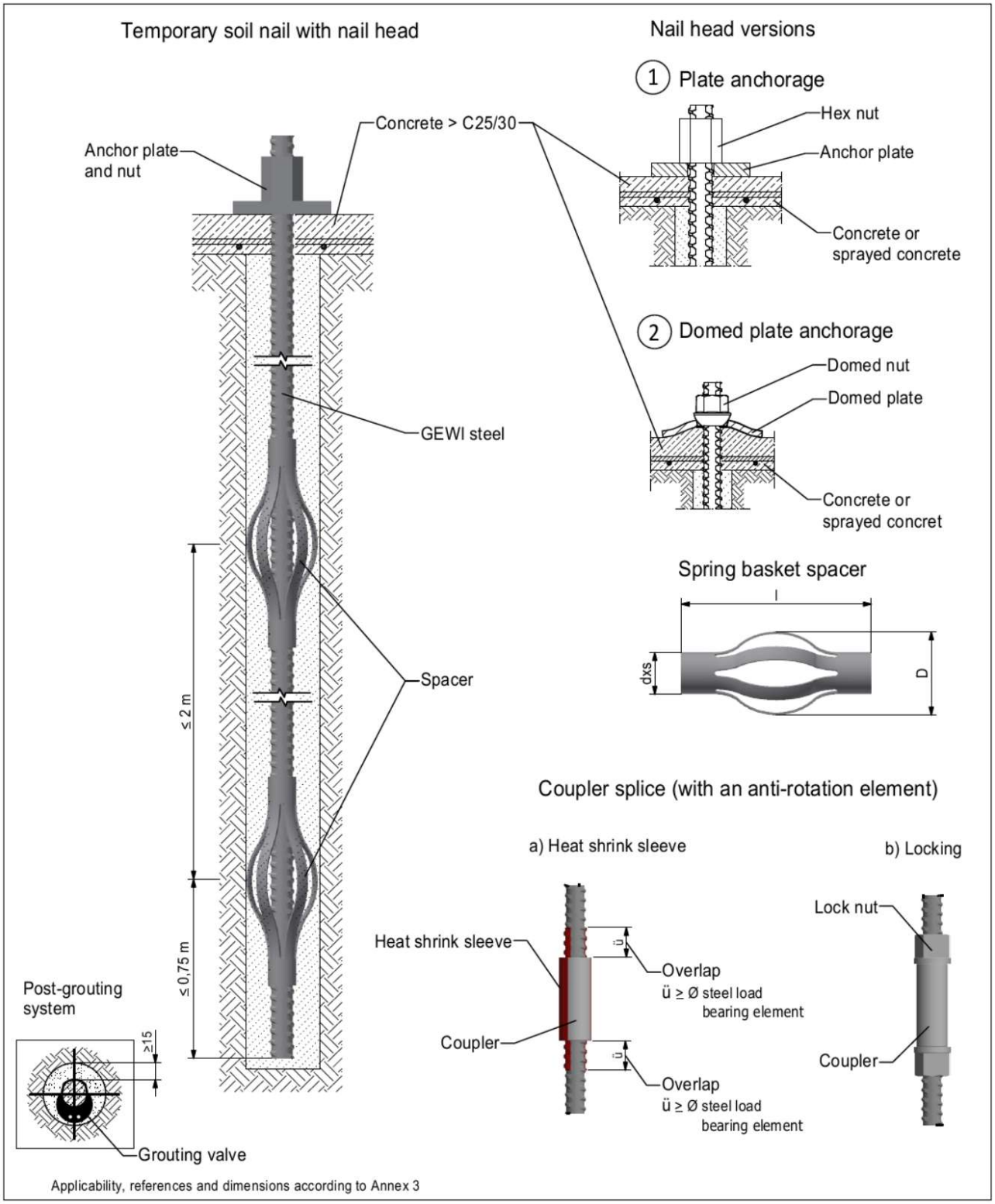
EN 197-1:2011	Cement – Part 1: Composition, specifications and conformity criteria for common cements; (in Germany replaced with DIN EN 197-1:2011-11)
DIN EN 206-1:2001-07	Concrete – Part 1: Specification, performance, production and conformity; German edition EN 206-1:2000
DIN EN 206-1/A1:2004-10	Concrete – Part 1: Specification, performance, production and conformity; German edition EN 206-1:2000/A1:2004
DIN EN 206-1/A2:2005-09	Concrete – Part 1: Specification, performance, production and conformity; German edition EN 206-1:2000/A2:2005
DIN EN 445:1996-07	Grout for prestressing tendons – Test methods – German edition EN 445:1996
DIN EN 446:1996-07	Grout for prestressing tendons – Grouting procedures – German edition EN 446:1996
DIN EN 447:1996-07	Grout for prestressing tendons – Grouting procedures – Requirements for common grouts – German edition EN 447:1996
EN 934-2:2009+A1:2012	Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – Definitions, requirements, conformity, marking and labelling; (in Germany replaced with DIN EN 934-2:2012-08)
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 edition EN 1008:2002

DIN 1045-2:2008-08	Concrete, reinforced and prestressed concrete structures – Part 2: Concrete – Specification, properties, production and conformity – Application rules for DIN EN 206-1.
DIN 1054:2021-04	Subsoil – Verification of the safety of earthworks and foundations – Supplementary rules to DIN EN 1997-1.
DIN 1164-10:2013-03	Special cement – Part 10: Composition, requirements and conformity evaluation for cement with low effective alkali content
DIN EN 1992-1-1:2011-01	Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings; German edition EN 1992-1-1:2004 + AC:2010
DIN EN 1992-1-1/NA:2013-04	National Annex – Nationally determined parameters – Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings
DIN EN 1997-1:2009-09	Eurocode 7: Geotechnical design – Part 1: General rules German edition EN 1997-1:2004 + AC:2009
DIN EN 1997-1/NA:2010-12	National Annex – Nationally determined parameters – Eurocode 7: Geotechnical design – Part 1: General rules
DIN 4030-1:2008-06	Assessment of water, soil and gases for their aggressiveness to concrete – Part 1: Principles and limiting values
DIN 4084:2009-01	Calculation of embankment failure and overall stability of retaining structures
DIN 4085:2017-08	Subsoil – Calculation of earth pressure
DIN EN 10025-2:2019-10	Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels; German edition EN 10025-2:2019
DIN EN 10204:2005-01	Metallic products – Types of inspection documents; - German edition EN 10204:2004
DIN EN 12068:1999-03	Cathodic protection – External organic coatings for the corrosion protection of buried or immersed steel pipelines used in conjunction with cathodic protection – Tapes and shrinkable materials; German edition EN 12068: 1998
DIN EN 12390-3:2019-10	Testing Hardened Concrete – Part 3: Compressive Strength of Test Specimens; German edition EN 12390-3:2009
EN 12620:2002+A1:2008	Aggregates for concrete; (in Germany replaced with DIN EN 12620:2008-07)
DIN EN 14487-1:2006-03	Sprayed concrete – Part 1: Definitions, specifications and conformity; German edition EN 14487-1:2005
DIN EN ISO 17855-1:2015-02	Plastics – Polyethylene (PE) molding and extrusion materials – Part 1: Designation system and basis for specifications (ISO 17855-1:2014); German edition EN ISO 17855-1:2014
DIN 18551:2014-08	Sprayed concrete – National application rules for series DIN EN 14487 and rules for design of sprayed concrete constructions

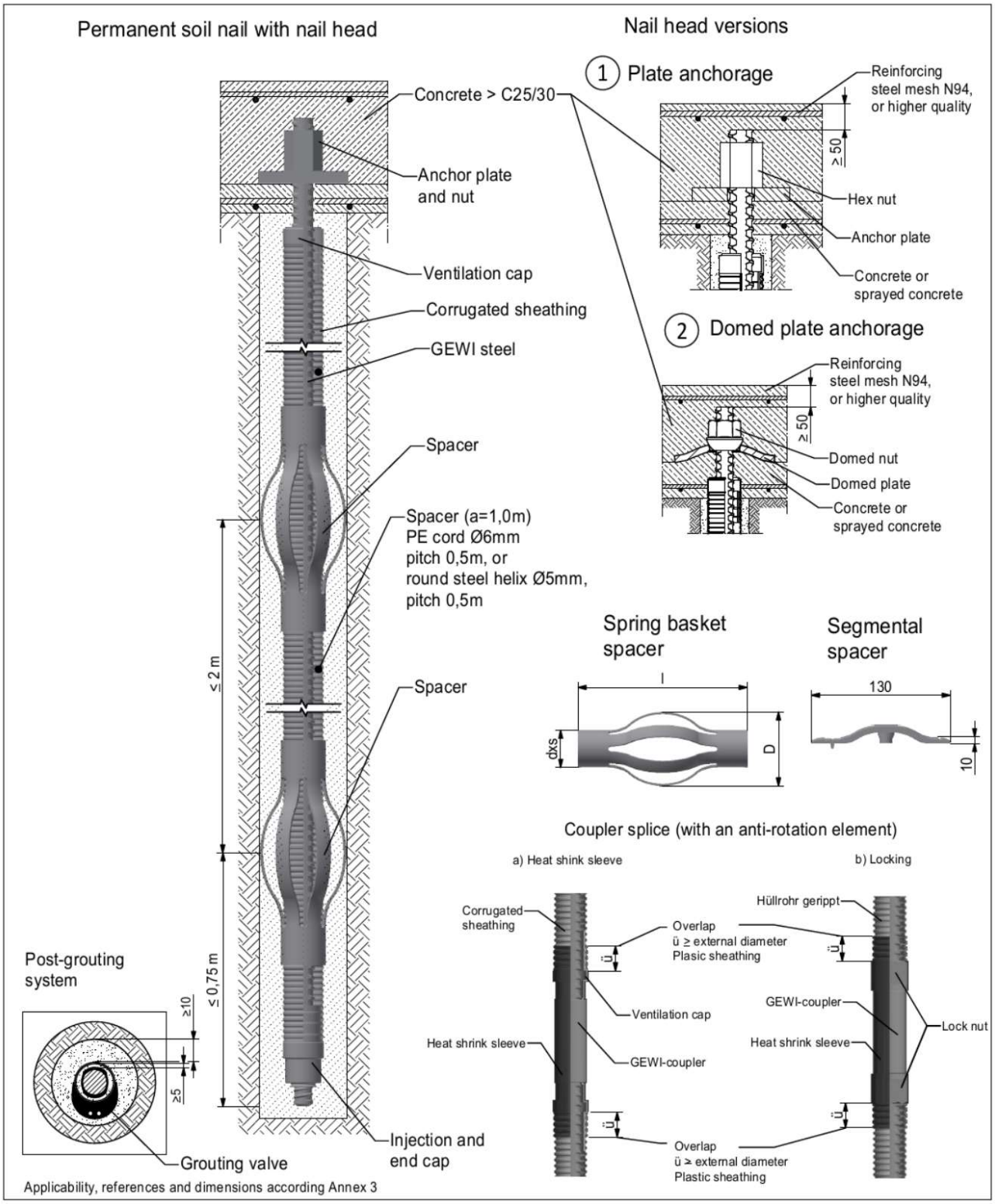
DIN EN ISO 19069-1:2015-06	Plastics – Polypropylene (PP) molding and extrusion materials – Part 1: Designation system and basis for specifications (ISO 19069-1:2015); German edition EN ISO 19069-1:2015
DIN EN ISO 21306-1:2019-07	Plastics – Unplasticized poly(vinyl chloride) (PVC-U) molding and extrusion materials – Part 1: Designation system and basis for specifications (ISO 21306-1:2019); German edition EN ISO 21306-1:2019
DIN 30672:2000-12	External organic coatings for the corrosion protection of buried and immersed pipelines for continuous operating temperatures up to 50°C – Tapes and shrinkable materials

Bettina Hemme
Office Supervisor

Certified
Banzer



"DYWIDAG" Soil Nailing System	Annex 1
Short-term soil nail system plan	



"DYWIDAG" Soil Nailing System	Annex 2
Permanent soil nail system plan	

Temporary an permanent soil nails

GEWI steel	Ø	16	20	25	28	32	40	50	63,5
Steel grade		B500B Z-1.1-58, Z-1.1-59, Z-1.1-167							S 555/700 Z-1.1-1, Z-1.1-198.1
Anchoring									
1 Plate anchorage		based on the accessory approvals Z-1.5-76 or Z-1.5-174*					Z-1.5-149 orr Z-1.5-174*		Z-1.5-2
-Anchor nut									
-Anchor plate	a x a	80 x 80	90 x 90	110 x 110	120 x 120	120 x 120	150 x 150	190 x 190	245 x 245
	s	10	12	15	20	30	40	45	50
2 Domed plate anchorage		see Annex 4					—		—

Temporary soil nails

Spring basket spacer	d x s	20 x 1,5	25 x 1,9	32 x 2,4	40 x 3		50 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
Minimum borehole diameter		56	60	65	68	72	80	90	110
Coupler connections		Z-1.5-76 or Z-1.5-174*					Z-1.5-149 orr Z-1.5-174*		Z-1.5-2
Anti rotation element (optionally): - Secured		Z-1.5-76 or Z-1.5-174*					Approval Z-1.5-149 orr Z-1.5-174*		Z-1.5-2
- Heat shrink sleeve	Type	Fix heat shrink sleeve, e.g. MWTM							
	Ø max/min	35 / 12	50 / 16		75 / 22			95 / 29	140 / 42

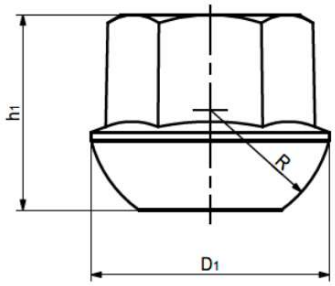
Permanent spoil nails

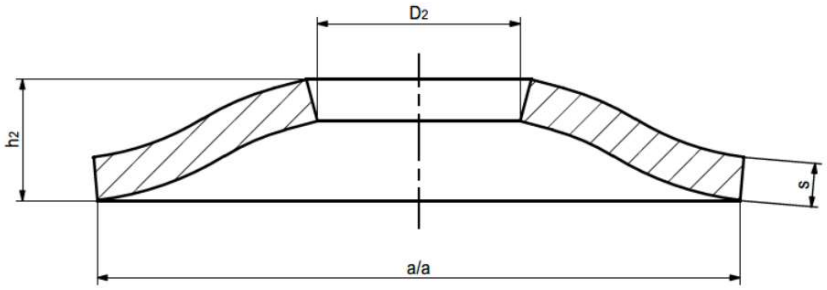
Corrugated sheathing (PVC,PE or PP) s		≥ 1 mm						
	min. Øa / Øi	34,5 / 28	42,5 / 35	50 / 44	56 / 49	65 / 57	80 / 71	100 / 91
Spacer								
- Spring basket spacer	d x s	40 x 3	50 x 3	55 x 3	63 x 3	75 x 3,6	90 x 2,7	110 x 3,2
	L	280	285	275	285	285	285	285
	min. D	100	100	105	125	125	125	175
- Segmental spacer	L	—	—	—	130			
	a	—	—	—	10			
Minimum borehole diameter		55	63	70	76	85	100	120
Coupler connections		Z-1.5-76 or Z-1.5-174*				Z-1.5-149 or Z-1.5-174*		Z-1.5-2
Anti rotation element (optionally): - Secured		Z-1.5-76 or Z-1.5-174*				Z-1.5-149 or Z-1.5-174*		Z-1.5-2
- Heat shrink sleeve	Type	Corrosion protection heat shrink sleeve CPSM						
	Ø max/min	75 / 22					95 / 29	140 / 42

Dimensions in mm

* A combination of couplers or anchoring elements from the mentioned Approvals is not permitted. To avoid confusion, only anchoring and connecting devices from one and the same Approval may be used at each construction site; for Ø 16 mm to 32 mm - no. Z-1.5-76 or no. Z-1.5-174, for Ø40 mm or 50 mm - no. Z-1.5-149 or no. Z-1.5-174.

“DYWIDAG” Soil Nailing System	Annex 3
Short-term 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
Domed	D_1	35	49	55	62	70
Radius	R	19	25	28	32	36
Material (material standard)		G42CrMo4 (DIN EN 10293)				

Domed plate:

Bar diameter	Ø	16	20	25	28	32
External dimension *	a/a	120/120		150/150		200/200
Height	h_2	25	28	31	33	35
Plate thickness	s	5	8	10	10	12
Borehole diameter	D_2	28	38	43	47	52
Material (material standard)		S235JR (DIN EN 10025)				

* Minimum dimensions,
Dimensions in mm

"DYWIDAG" Soil Nailing System	Annex 4
Domed plate anchorage	

	Inspection	Inspection	WPK[1)]	EP/FÜ[2)]	Value
1.	**Incoming goods control:**				
1.1	Reinforcing steel bars with B500B thread ribs	Delivery note	every shipment	X	Conformity mark as per Z-1.1-58, Z-1.1-59 or Z-1.1-167
1.2	Steel bar with thread ribs S 555/700	Delivery note	every shipment	X	Conformity mark as per Z-1.1-1 or Z-1.1-198.1
1.3	Anchoring and connecting devices for reinforcing steel bars with B500B thread ribs	Delivery note	every shipment	X	Conformity mark as per Z-1.5-76, Z-1.5-149 or Z-1.5-174
1.4	Anchoring and connecting devices for Steel bar with thread ribs S 555/700	Delivery note	every shipment	X	Conformity mark as per Z-1.5-2
1.5	Plates (anchor plates, domed plate) for plate anchorage - Material - Dimensions	Delivery note Measurement*	every shipment every shipment	X X	Plant certificate 2.1 Plant drawings, Annexes 3 and 4
1.6	Thickness/diameter of the inner spacers	Measurement*	every shipment	X	≥ 5 mm;
1.7	Corrugated plastic sheathing; end, injection and ventilation caps				
	Molding compound	DIN EN 10204	every shipment	X	Plant certificate 2.1
	Corrugated plastic sheathing wall thickness (at inner and outer rib and at the side)	Measurement*	1 every 100 pcs	X	Plant drawings
	Inner and outer diameter	Measurement*	1 every 100 pcs	X	Plant drawings
1.8	Heat shrink sleeves (fixing heat shrink sleeves [1] and corrosion protection heat shrink sleeves [2])				
	Molding compound ([1] and [2])	DIN EN 10204	every shipment	X	Plant certificate 2.1
	Classification [2]: Amount of adhesive [2]:	EN 12068 Measurement*	1 every 100 pcs 1 every 100 pcs	X X	C30 >700 g/m²
2.	**Control during manufacturing**				
2.1	Corrosion protection heat shrink sleeves – wall thickness at 3 points in shrunk state	Sample and measurement*	1 every 100 pcs	X	≥ 1.5 mm
2.2	Inner cement grout	DIN EN 445	DIN EN 446	X	DIN EN 447
2.3	All of the plant-applied corrosion protection measures	Visual	every load-carrying element	X	Work instructions
2.4	Packaging of the components	Delivery note	every shipment	X	Planning or execution documents

***** Inspection plan:
If each individual measured value is equal to or greater than the required minimum value, L_{os} shall be assumed. In other cases, additional samples may be taken. The same measurements as in the first sample are to be carried out on these samples. The measurement results shall be summarized with the previous measurements. The mean value x and the standard deviation s must be formed from
all measured values. If the test parameter (numerical value)

$$z = x - 1{,}64\ s$$

to be formed therefrom is equal to or greater than the required minimum value, the value L_{os} is to be rejected.

1) Plant production control
2) Initial inspection / external monitoring (2 x annually)

"DYWIDAG" Soil Nailing System	Annex 5
Minimum requirements for plant production control, external monitoring and initial inspection	

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