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Part 14: Borehole dynamic probing

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 182, *Geotechnics*.

A list of all parts in the ISO 22476 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Geotechnical investigation and testing — Field testing —

Part 14:
Borehole dynamic probing

1 Scope

This document specifies the equipment requirements, execution of and reporting on borehole dynamic probing.

NOTE This document fulfills the requirements for borehole dynamic probing as part of the geotechnical investigation and testing according to EN 1997-1 and EN 1997-2.

The document specifies technical requirements in respect to equipment and implementation, in order to extensively prevent incorrect appraisals of the subsoil conditions and to limit scatter in the probing results due to equipment and implementation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 10025-2, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

ISO 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

ISO 22475-1, *Geotechnical investigation and testing — Sampling methods and groundwater measurements — Part 1: Technical principles for execution*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
probing
indirect subsoil exploration method in soils normally by driving a cone vertically while measuring the *penetration resistance* (3.4) to derive geotechnical parameters

3.2
borehole dynamic probing
probing (3.1) in the borehole, which is carried out by driving by impact from the borehole base over a defined penetration depth

Note 1 to entry: Here the impact device is directly above the probe in the borehole.

3.3
number of blows N_{30}
blows required for the probe to penetrate by 30 cm, in relation to the depth ranges of 15 cm to 45 cm of the probe depth

3.4
penetration resistance
sum of the tip resistance and negligible skin friction recorded by the *number of blows N30* (3.3)

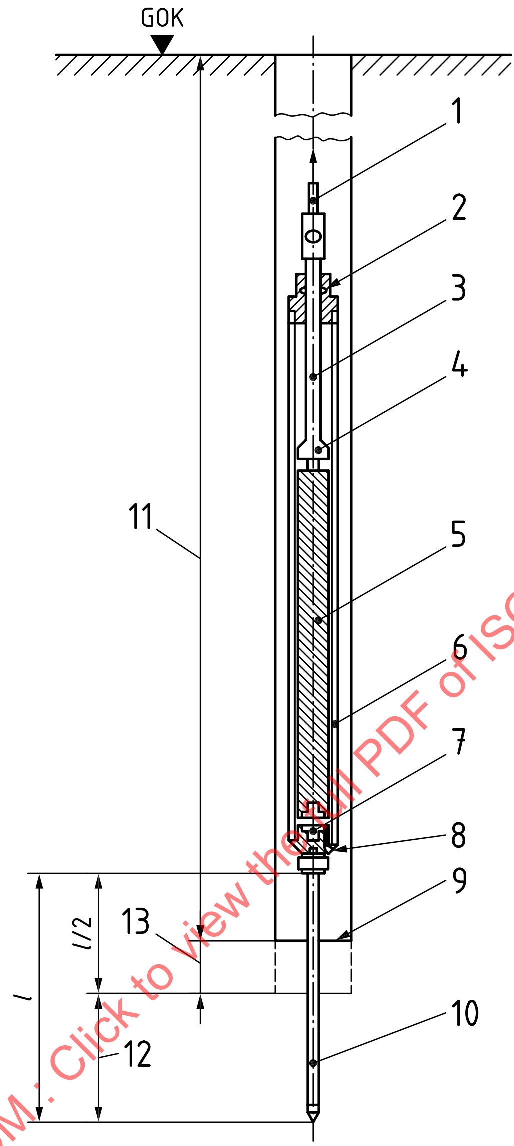
3.5
derived value
value of a geotechnical parameter determined by theory, correlation or empirically

Note 1 to entry: The derived values are used as an initial basis for determining characteristic values according to EN 1997-1:2010, 2.4.3.

4 Equipment

The device for the borehole dynamic probing is shown in Figure 1. The technical data are shown in Table 1.

The device is lowered into the borehole with an encased impact device on the rope and the probe is driven in from there without a rod.



Key

1	rope
2	packing box
3	lifting rod
4	automatic releasing device
5	hammer
6	hollow cylinder, water tight
7	anvil
8	drain plug
9	borehole base
10	cone
11	borehole depth
12	test range
13	penetration under the weight of the device
l	probe length

Figure 1 — Device for borehole dynamic probing

Table 1 — Technical data

Technical data	Symbol	Unit	Value
Tip cross-section area	A_c	cm^2	20

[a] Production tolerances.

[b] These are the parts (hollow cylinder, anvil and probe) without the moving parts for lifting and releasing the hammer.

[c] There is no need to indicate production tolerances here.

Table 1 *(continued)*

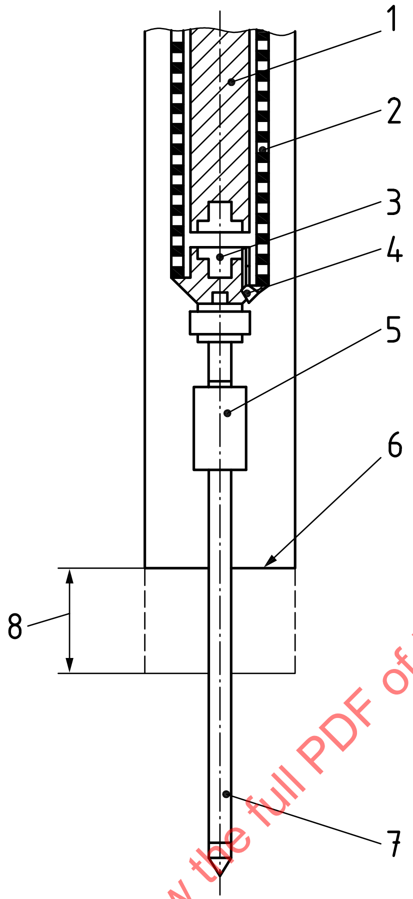
Technical data	Symbol	Unit	Value
Tip diameter	d	mm	50,5 ± 0,5[a]
Wear limit	d_{min}	mm	49
Mass of hammer	m	kg	63,5 ± 0,5[a]
Height of fall	h	m	0,76 ± 0,01[a]
Diameter of the lifting rod	D_h	mm	45[c]
External diameter of the cone	d	mm	120[c]
Mass of the drive-in device[b] without additional weight	m_1	kg	91 ± 2[c]
Cone length	l	m	0,9[c]
Test depth from borehole base	t	m	0,45

[a] Production tolerances.

[b] These are the parts (hollow cylinder, anvil and probe) without the moving parts for lifting and releasing the hammer.

[c] There is no need to indicate production tolerances here.

The hammer shall be located in a watertight hollow cylinder. In case of application depths of more than 20 m under water, additional weights shall be used between the cone and hollow cylinder (see Figure 2).

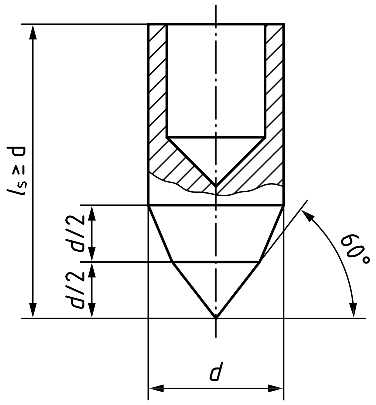


Key

1 hammer
2 hollow cylinder
3 anvil
4 drain plug
5 additional weight
6 borehole base
7 cone
8 penetration under the weight of the device

Figure 2 — Location of the additional weight

The dimensions of the cone tip are given in Table 1 and Figure 3. The material shall correspond to a steel quality S 235 JR minimum according to EN 10025-2.



Key

d tip diameter

l_s tip length

Figure 3 — Cone dimensions

5 Test procedure

5.1 General

The initial depths for the borehole dynamic probing in a borehole shall be specified.

The probing device defined in this document may be used to explore the subsoil — depending on its state and the boring device used — down to depths of ≈60 m.

Deviations from this document and their effects on the result shall be substantiated and reported. The symbols are shown in Table 2.

Table 2 — Symbols

Symbol	Name	Unit
N_{30}	number of blows between 15 cm to 45 cm	—
$N_{0\text{-}15}$	number of blows between 0 cm to 15 cm	—
$N_{15\text{-}30}$	number of blows between 15 cm to 30 cm	—
$N_{30\text{-}45}$	number of blows between 30 cm to 45 cm	—
$N_{30,a}$	number of blows between 15 cm to 45 cm above ground water level	—
$N_{30,u}$	number of blows between 15 cm to 45 cm underground water level	—
σ'_{vz}	effective vertical stress in the depth *z* below the foundation base	MPa

5.2 Test preparation

The borehole dynamic probing is performed from the borehole base. ISO 22475-1 applies to the boring procedure. The borehole diameter shall not be more than 250 mm. If casing is used, this shall not extend below the borehole base. The test area shall be undisturbed.

The borehole base shall be cleaned to the lower edge of the casing in order to prevent the effects of boring sludge or caving in. When cleaning the borehole base negative pressure effects shall be avoided by slow withdrawal of the drilling equipment.

The water level in the borehole shall be kept above the ground water level. If confined ground water is expected, the borehole base shall be stabilised by excess water pressure.

5.3 Equipment checks and calibration

Besides the probe diameter and tip opening angle, the verticality of the probe and lifting rod shall also be checked before carrying out the borehole dynamic probing. The required height of fall shall be checked after every test. The automatic release device shall be checked in operation.

Water shall not penetrate into the hollow cylinder. The tightness shall be monitored via the water drain plug after every test.

The functionality of the device shall be checked after any damage, overloading and repair, but at least every 6 months, unless shorter periods are set by the manufacturer. The test report shall be kept with the probing device.

5.4 Probing procedure

Before lowering the probe, the actual height situation of the borehole base shall initially be measured, which then corresponds to the initial point of the probe tip. After this, the probe shall be lowered to this depth.

The degree of penetration under permanent weight in comparison to the borehole depth shall be measured to determine a disturbance zone at the borehole base. If the penetration depth is greater than 15 cm, the bore shall be sunk deeper and the borehole dynamic probing re-initiated.

After lowering the probe, the blows shall be counted three times each for 15 cm of penetration. The critical number of blows N_{30} is the number of blows between 15 cm to 45 cm. In soils of particularly low strength with a penetration by one blow above 15 cm, the penetration shall be indicated for one blow respectively. In soils of high strength with more than 50 blows per 15 cm of penetration, the penetration shall be indicated for 50 blows and then the probing shall be interrupted.

When using the borehole dynamic probing in water depths of more than 20 m, the buoyancy force of the lifting rod from the hollow cylinder is greater than the weight of the device under lifting force, owing to the water pressure onto the cross-section of the lifting rod. The lifting rod with the ram can then no longer be lifted out of the hollow cylinder, as the complete device is raised. Therefore, additional weights shall be attached between the hollow cylinder and the probe tip. Table 3 contains the masses of the additional weights for the probing device in relation to the water depth.

Table 3 — Masses of the additional weights for the probing device

Water depth in m	0 to 20	>20 to 30	>30 to 40	>40 to 50	>50 to 60	>60 to 70	>70 to 80
Additional weight in kg	0	15	33	52	70	89	≥107

5.5 Field records

The header sheet with measuring record according to Annex A shall be filled out for every borehole dynamic probing.

The borehole base, degree of penetration and upper edge of the test area shall be noted for every borehole dynamic probing carried out in the borehole. The number of impacts per 15 cm penetration shall also be entered in the layer directory according to ISO 14688-1 and ISO 22475-1.

The following shall also be recorded:

a) weather conditions;

b) probing interruptions with an indication of their duration;

c) unwanted processes during the test procedure (e.g. in the blow sequence and penetration, temporary obstructions, strained ground water level, cause of a premature termination etc.);

d) observations at the drawn probe tip.

6 Test evaluation and result mapping

The number of blows N_{30} shall be applied as a bar diagram next to the bore profile at the relevant depth. The bar length next to the bore profile and the associated number indicates what number of blows is required per 30 cm penetration. The bar thickness shall be selected true to scale.

The borehole dynamic probing shall be reported in such way that the results can be checked and evaluated by a third person.

For the purpose of identification and quality assurance, all test reports and representations shall also contain the following information:

a) name of the implementing company;

b) designation of the test report (object name, project name);

c) number of the test program or the order;

d) position and number of the bore and the borehole dynamic probing.

In addition, the following data shall be provided in the reports for field and laboratory tests:

e) date of the test;

f) depth of the drilling and upper edge of the test area of the borehole dynamic probing;

g) designation of the test with reference to corresponding standards;

h) implementation of the device inspection;

i) data on the use of additional weights;

j) deviations from the essential requirements of critical standards or recommendations;

k) monitoring of the impact device in respect to water penetration;

l) all interruptions and obstructions;

m) signature of the device owner and responsible expert at the company.

7 Qualitative evaluation and derivation of geotechnical parameters

7.1 General

Geotechnical effects shall be considered in the qualitative evaluation of the results of borehole dynamic probing and the derivation of geotechnical parameters (quantitative evaluation).

In order to avoid misinterpretations, it shall be noted that the probing results in layers close to the surface (1 m to 2 m) are less meaningful. Interruptions to the probing process shall be noted.

The following shall be considered as geotechnical effects on the penetration resistance:

— the distinct effect of ground water especially in the case of low penetration resistances;

— in the case of coarse-grained soils outside the compactness, also the grain structure, grain size distributions, grain form and grain roughness, mineral type, cementation and tension state in the soil;

— in the case of fine-grained soils, the phase state, plasticity and structure;

— in the case of mixed-grain soils, the mass fraction of the coarse grain as well as the plasticity and phase state of the fine grain;

— in the case of organic soils, the structure, age, formation, preloading and admixtures of other soil types.

7.2 Qualitative evaluation

Qualitative evaluations may be conducted:

— for comparison of the results attained in a key drilling with the borehole dynamic probing with the results from other probing performed in parallel — e.g. dynamic probing according to ISO 22476-2, cone penetration tests according to ISO 22476-1 — for determining and tracking layer horizons in the subsoil;

— for evaluating the homogeneity and inhomogeneity of the subsoil encountered in the corresponding drilling.

7.3 Derived values

Quantitative relations between

— the probing result and a geotechnical parameter, and

— the results of probing with different probes

shall be determined for the relevant soil type within definite validity limits in a verifiable form (e.g. observing the limits of the random test, above and below ground water). At the same time, it shall be noted that the output variable (independent variable) and target variable (dependent variable) shall not be inverted when reproducing stochastic relations by approximation functions (e.g. B.1 to B.4).

In coarse-grained soils, relations can be derived between geotechnical parameters and the results of the borehole dynamic probing.

In case of fine-grained soils or mixed-grain soils with highly cohesive fractions, the quantitative evaluation of the results should only be conducted under very familiar local conditions as well as with consideration of specific correlations or if any reference to fine grained soils is cleared.

Geotechnical parameters can be derived from the results of the borehole dynamic probing as calculation parameters for civil engineering purposes (e.g. foundation measurement).

Various correlations between the results obtained with different probing devices as well as between the results of the borehole dynamic probing and certain geotechnical parameters have been established. Nevertheless, they cannot be regarded as universally valid.

The correlations indicated as examples in B.1 to B.4 between the results of the different probing devices as well as correlations between the results of the borehole dynamic probing and certain geotechnical parameters shall be regarded as conservative estimate correlations and can only be used for the framework conditions described there (including the probing devices described in ISO 22476-1 and ISO 22476-2).

NOTE The angle of friction ϕ' can be derived from the obtained relative density I_D according to EN 1997-2 or from the tip pressure according to ISO 22476-1.

Annex A
(normative)

Header sheet with measuring record for borehole dynamic probing

The content of the header sheet is normative. The user is free to arrange the layout.

Borehole no.:

Location of borehole (exact or approximate):

Height of borehole above MSL					
Client /Job no.					
Site/Project					
Contractor					
Operator					
BDP No.					
Date and time of BDP					
Depth of borehole base, in m					
Degree of penetration, in cm					
Upper edge of test area, in m					
$N_{0\text{-}15}$					
$N_{15\text{-}30}$					
$N_{30\text{-}45}$					
N_{30}=$N_{15\text{-}30}$+N_{30+45}					
Remarks					
Was the impact device checked for water penetration before and after probing? yes/no*					
Was the equipment checked in accordance with ISO 22476-14:2020, Clause 4 and 5? yes/no*					
* Delete as appropriate.					

This sheet is free from copyright and can be used and copied in public.

Any other information:

____

____

____

Name and signature of operator:

____

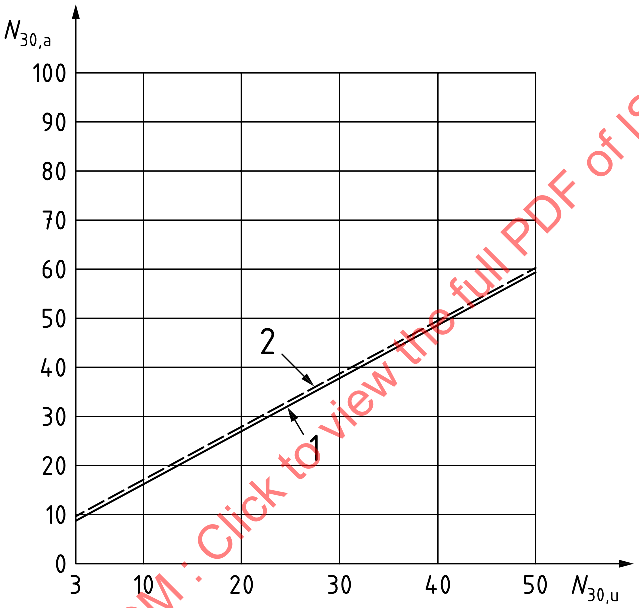
Name and signature of responsible expert at implementing company:

____

Annex B
(informative)

Examples of relations for considering the effect of ground water and relations between the results from probing with different probes as well as the derivation of geotechnical parameters

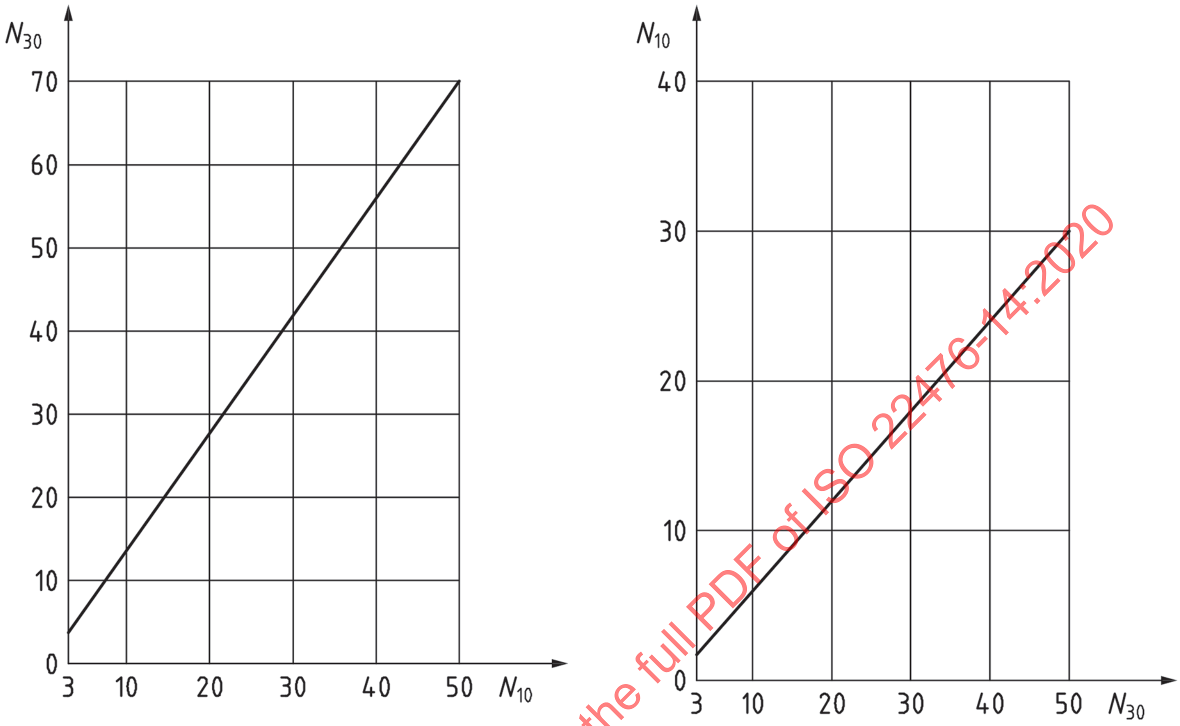
B.1 Examples of relations for considering the effect of ground water in coarse-grained soils



Group symbol:	poorly-graded sand (1)	well-graded gravel sand mixture (2)
Coefficient of uniformity:	$U \leq 3$	$U > 3$
Consistency:	—	—
Ground water:	in and above ground water	in and above ground water
Output variable:	$N_{30,u}$	$N_{30,u}$
Target variable:	$N_{30,a}$	$N_{30,a}$
	Equation:	Equation:
	$N_{30,a} = 1,1 \cdot N_{30,u} + 5$	$N_{30,a} = 1,1 \cdot N_{30,u} + 5,9$
	Equation is valid where:	Equation is valid where:
	$3 \leq N_{30,u} \leq 50$	$3 \leq N_{30,u} \leq 50$

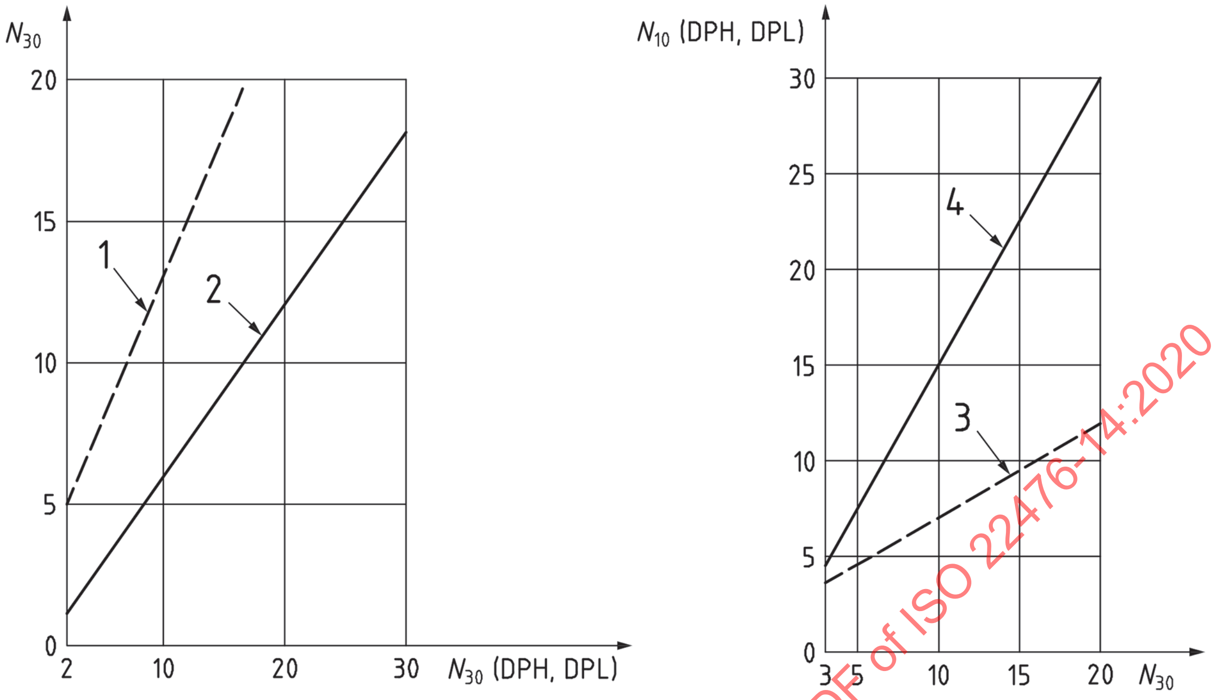
Figure B.1 — Comparison between the number of blows N_{30} of the borehole dynamic probing above and in the ground water in case of poorly-graded sand and well-graded gravel-sand mixture

B.2 Example of relations between the results of the borehole dynamic probing and those of different probes



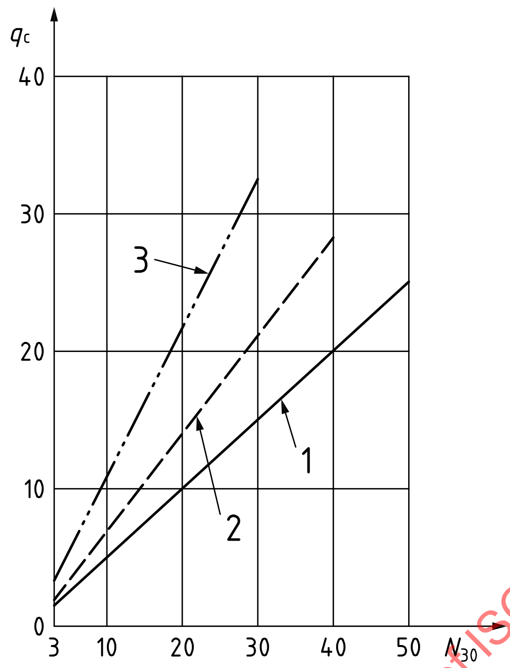
Group symbol:	coarse grained soils	
Coefficient of uniformity:	$U \geq 2$	
Consistency:	—	
Ground water:	above ground water	
Output variable:	N_{10}, N_{30}	
Target variable:	N_{30}, N_{10}	
	Equations:	Equations are valid where:
	$N_{30} = 1{,}4 \cdot N_{10}$	$3 \leq N_{10} \leq 50$
	$N_{10} = 0{,}6 \cdot N_{30}$	$3 \leq N_{30} \leq 50$

Figure B.2 — Comparison between the number of blows N_{30} of the borehole dynamic probing and the number of blows N_{10} of the heavy dynamic probing (DPH acc. to ISO 22476-2) in case of coarse-grained soils above ground water



Group symbol:	low to medium plastic clay	
Coefficient of uniformity:	—	
Consistency:	$0{,}75 \leq I_c \leq 1{,}50$	
Ground water:	above ground water with degree of saturation $0{,}7 \leq S_r \leq 0{,}9$	
Output variable:	N_{10} (DPL, DPH) or N_{30}	
Target variable:	N_{30} or N_{10} (DPL, DPH)	
	Equations:	Equations are valid where:
	DPH: $N_{30} = 1{,}0 \cdot N_{10} + 3$ (1)	$2 \leq N_{10} \leq 13$
	DPL: $N_{30} = 0{,}6 \cdot N_{10}$ (2)	$2 \leq N_{10} \leq 30$
	DPH: $N_{10} = 0{,}5 \cdot N_{30} + 2.0$ (3)	$3 \leq N_{30} \leq 15$
	DPL: $N_{10} = 1{,}5 \cdot N_{30}$ (4)	$3 \leq N_{30} \leq 17$

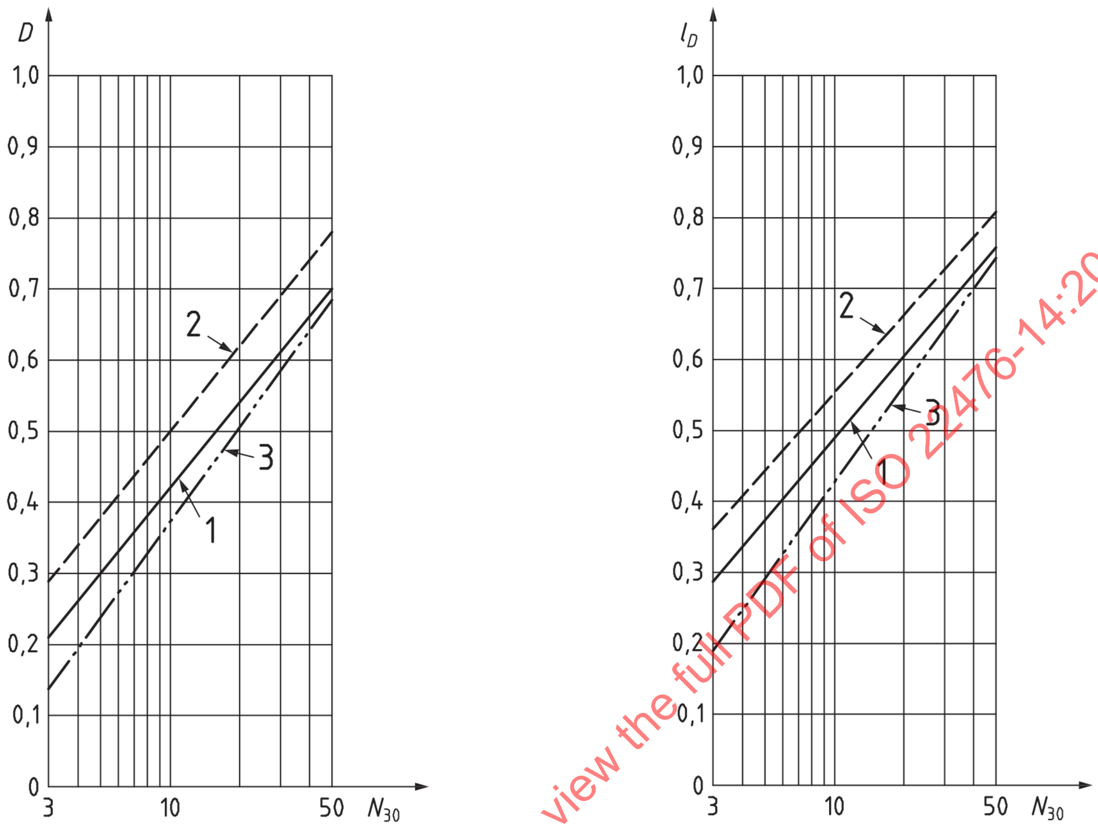
Figure B.3 — Comparison between the number of blows N_{10} of dynamic probing and those of borehole dynamic probing in the case of low- and medium-plastic clay above ground water (DPH and DPL acc. to ISO 22476-2)



Group symbol:	coarse grained soils (1,2,3)	
Coefficient of uniformity:	$U \geq 2$	
Consistency:	—	
Ground water:	above ground water	
Output variable:	N_{30}	
Target variable:	q_c in MN/m^2	
	Equations:	Equations are valid where:
	poorly graded sand: $q_c = 0,5 \cdot N_{30}$ (1)	$3 \leq N_{30} \leq 50$
	well graded sand: $q_c = 0,7 \cdot N_{30}$ (2)	$3 \leq N_{30} \leq 40$
	gravel sand mixture: $q_c = 1,1 \cdot N_{30}$ (3)	$3 \leq N_{30} < 30$

Figure B.4 — Comparison between the number of blows of the borehole dynamic probing and the tip resistance of cone penetration testing (CPT) in coarse-grained soils above ground water

B.3 Examples of relations between the number of blows of the borehole dynamic probing and density



Group symbol:	poorly graded sand (1)	poorly graded sand (2)	well graded sand (3)
Coefficient of uniformity:	$U \leq 3$	$U \leq 3$	$U \geq 6$
Consistency:	—	—	—
Ground water:	above ground water	below ground water	above ground water
Output variable:	N_{30}	N_{30}	N_{30}
Target variable:	D, I_D	D, I_D	D, I_D
	Equations:	Equations:	Equations:
	$D = 0{,}02 + 0{,}400 \lg N_{30}$	$D = 0{,}10 + 0{,}390 \lg N_{30}$	$D = -0{,}08 + 0{,}450 \lg N_{30}$
	$I_D = 0{,}10 + 0{,}385 \lg N_{30}$	$I_D = 0{,}18 + 0{,}370 \lg N_{30}$	$I_D = -0{,}03 + 0{,}455 \lg N_{30}$
	Equations are valid where:	Equations are valid where:	Equations are valid where:
	$3 \leq N_{30} \leq 50$	$3 \leq N_{30} \leq 50$	$3 \leq N_{30} \leq 50$

Figure B.5 — Comparison between the number of blows of the borehole dynamic probing and the density D or density index I_D in case of coarse-grained soils above and in the ground water