Report for D-Foundations 23.1

Design and Verification according to Eurocode 7 of Bearing/Tension Piles and Shallow Foundations
Developed by Deltares

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2 Input Data

2.1 General Input Data

Model	Bearing Piles (EC7-NL)

2.2 General Report Data

Geotechnical consultant :	[redacted]
Design engineer superstructure :	
Principal :	
Title 1 :	KWR opgave waterketen - RWZI Hengelo
Title 2 :	4. Metaalzoutopslag
Title 3 :	D-Foundations 4. metaalzoutopslag bearing piles_NEN2025
Number of project :	141332
Location of project :	

2.3 Application Area Model Bearing Piles

The verifications performed by the model BEARING PILES of D-FOUNDATIONS concern pile foundations on which axial static or quasi-static loads cause pressures in the piles. The calculations of pile forces and pile displacements are based on Cone Penetration Tests. Possible rise of (tension-)piles and horizontal displacements of piles and/or pile groups are not taken into account.

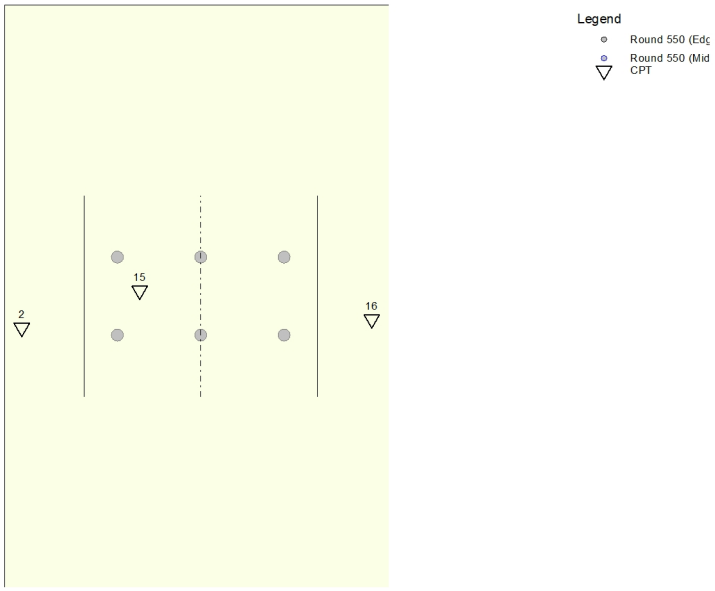
2.4 Superstructure

Rigidity of the superstructure :	Rigid

2.5 General CPT Data

Number of CPT's :	3
Timing of CPT's :	CPT - Excavation - Install

2.5.1 View of CPT's in Foundation Plan



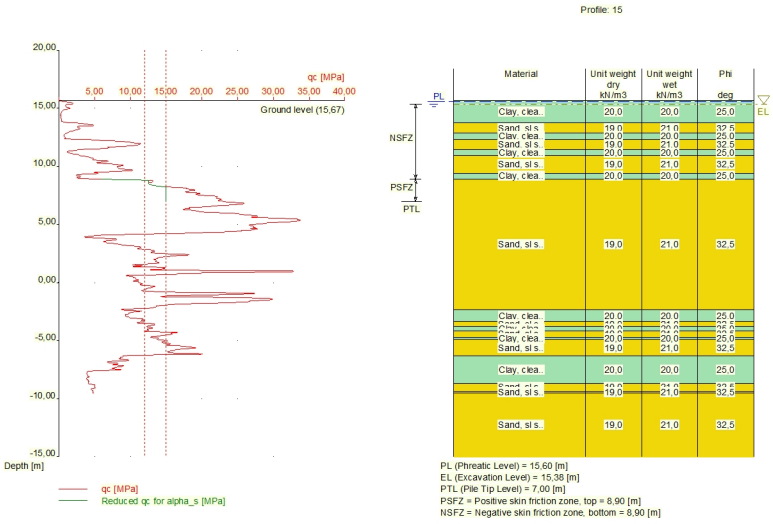
Name CPT	Pile tip level [m R.L.]	Top of pos. friction zone [m R.L.]	Bottom of neg. friction zone [m R.L.]	X-coor-dinate [m]	Y-coor-dinate [m]
15	7,00	8,90	8,90	249316,99	477781,34
16	7,00	8,80	8,80	249327,43	477780,05
2	7,00	8,90	8,90	249311,69	477779,67

2.6 Soil Data

Number of soil profiles (= number of CPT's) : 3

2.6.1 Soil Profile 15

Belonging to CPT	15
Surface level in [m. reference level] :	15,67
Phreatic level in [m. reference level] :	15,60
Pile tip level in [m. reference level] :	7,00
Top of positive skin friction zone in [m. reference level] :	8,90
Bottom of negative skin friction zone in [m. reference level] :	8,90
OCR-value foundation layer :	1,00
Expected groundlevel settlement in [m] :	0,11
Number of layers in profile :	18

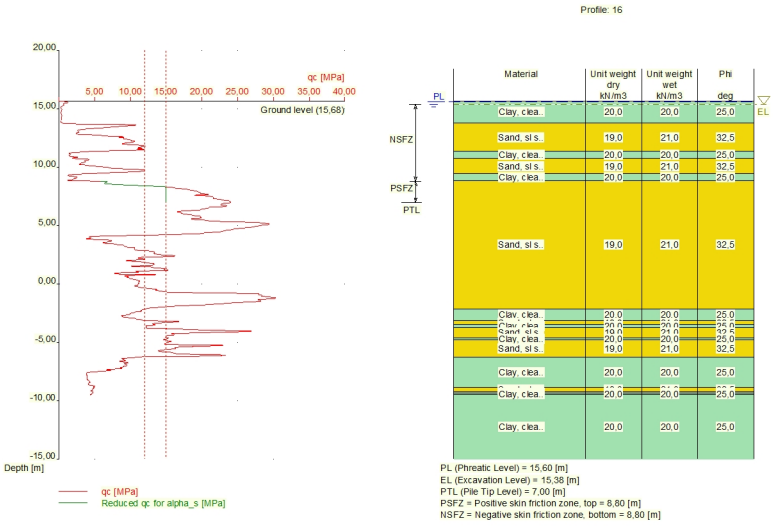


Number layer	Top layer [m R.L.]	Gamma [kN/m3]	Gamma;sat [kN/m3]	Phi [deg]	Soil Type	Median (Sand/Gravel) [mm]
1	15,670	20,00	20,00	25,00	Clay	--
2	13,761	19,00	21,00	32,50	Sand	0,200
3	12,852	20,00	20,00	25,00	Clay	--
4	12,352	19,00	21,00	32,50	Sand	0,200
5	11,443	20,00	20,00	25,00	Clay	--
6	10,943	19,00	21,00	32,50	Sand	0,200
7	9,425	20,00	20,00	25,00	Clay	--
8	8,925	19,00	21,00	32,50	Sand	0,200
9	-2,365	20,00	20,00	25,00	Clay	--
10	-3,374	19,00	21,00	32,50	Sand	0,200

Number layer	Top layer [m R.L.]	Gamma [kN/m3]	Gamma;sat [kN/m3]	Phi [deg]	Soil Type	Median (Sand/Gravel) [mm]
11	-3,783	20,00	20,00	25,00	Clay	--
12	-4,192	19,00	21,00	32,50	Sand	0,200
13	-4,692	20,00	20,00	25,00	Clay	--
14	-4,901	19,00	21,00	32,50	Sand	0,200
15	-6,328	20,00	20,00	25,00	Clay	--
16	-8,673	19,00	21,00	32,50	Sand	0,200
17	-9,382	19,00	21,00	32,50	Sand	0,200
18	-9,491	19,00	21,00	32,50	Sand	0,200

2.6.2 Soil Profile 16

Belonging to CPT	16
Surface level in [m. reference level] :	15,68
Phreatic level in [m. reference level] :	15,60
Pile tip level in [m. reference level] :	7,00
Top of positive skin friction zone in [m. reference level] :	8,80
Bottom of negative skin friction zone in [m. reference level] :	8,80
OCR-value foundation layer :	1,00
Expected groundlevel settlement in [m] :	0,11
Number of layers in profile :	17

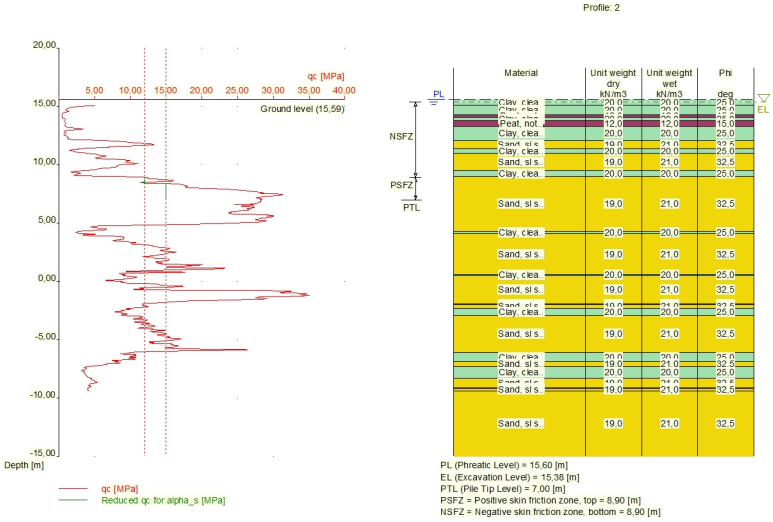


Number layer	Top layer [m R.L.]	Gamma [kN/m3]	Gamma;sat [kN/m3]	Phi [deg]	Soil Type	Median (Sand/Gravel) [mm]
1	15,680	20,00	20,00	25,00	Clay	--
2	13,771	19,00	21,00	32,50	Sand	0,200
3	11,353	20,00	20,00	25,00	Clay	--
4	10,753	19,00	21,00	32,50	Sand	0,200
5	9,435	20,00	20,00	25,00	Clay	--
6	8,835	19,00	21,00	32,50	Sand	0,200
7	-2,145	20,00	20,00	25,00	Clay	--
8	-3,172	19,00	21,00	32,50	Sand	0,200
9	-3,481	20,00	20,00	25,00	Clay	--
10	-3,781	19,00	21,00	32,50	Sand	0,200

Number layer	Top layer [m R.L.]	Gamma [kN/m3]	Gamma;sat [kN/m3]	Phi [deg]	Soil Type	Median (Sand/Gravel) [mm]
11	-4,608	20,00	20,00	25,00	Clay	--
12	-4,808	19,00	21,00	32,50	Sand	0,200
13	-6,262	20,00	20,00	25,00	Clay	--
14	-8,852	19,00	21,00	32,50	Sand	0,200
15	-9,270	20,00	20,00	25,00	Clay	--
16	-9,379	20,00	20,00	25,00	Clay	--
17	-9,479	20,00	20,00	25,00	Clay	--

2.6.3 Soil Profile 2

Belonging to CPT	2
Surface level in [m. reference level] :	15,59
Phreatic level in [m. reference level] :	15,60
Pile tip level in [m. reference level] :	7,00
Top of positive skin friction zone in [m. reference level] :	8,90
Bottom of negative skin friction zone in [m. reference level] :	8,90
OCR-value foundation layer :	1,00
Expected groundlevel settlement in [m] :	0,11
Number of layers in profile :	26



Number layer	Top layer [m R.L.]	Gamma [kN/m3]	Gamma;sat [kN/m3]	Phi [deg]	Soil Type	Median (Sand/Gravel) [mm]
1	15,590	20,00	20,00	25,00	Clay	--
2	15,090	20,00	20,00	25,00	Clay	--
3	14,290	12,00	12,00	15,00	Peat	--
4	14,090	20,00	20,00	25,00	Clay	--
5	13,790	12,00	12,00	15,00	Peat	--
6	13,290	20,00	20,00	25,00	Clay	--
7	12,090	19,00	21,00	32,50	Sand	0,200
8	11,390	20,00	20,00	25,00	Clay	--
9	10,990	19,00	21,00	32,50	Sand	0,200
10	9,490	20,00	20,00	25,00	Clay	--
11	8,990	19,00	21,00	32,50	Sand	0,200

Number layer	Top layer [m R.L.]	Gamma [kN/m3]	Gamma;sat [kN/m3]	Phi [deg]	Soil Type	Median (Sand/Gravel) [mm]
12	4,290	20,00	20,00	25,00	Clay	--
13	4,090	19,00	21,00	32,50	Sand	0,200
14	0,590	20,00	20,00	25,00	Clay	--
15	0,490	19,00	21,00	32,50	Sand	0,200
16	-1,910	20,00	20,00	25,00	Clay	--
17	-2,010	19,00	21,00	32,50	Sand	0,200
18	-2,310	20,00	20,00	25,00	Clay	--
19	-2,910	19,00	21,00	32,50	Sand	0,200
20	-6,110	20,00	20,00	25,00	Clay	--
21	-6,910	19,00	21,00	32,50	Sand	0,200
22	-7,310	20,00	20,00	25,00	Clay	--
23	-8,310	19,00	21,00	32,50	Sand	0,200
24	-9,110	20,00	20,00	25,00	Clay	--
25	-9,210	19,00	21,00	32,50	Sand	0,200
26	-9,410	19,00	21,00	32,50	Sand	0,200

2.7 Pile Types

2.7.1 Pile type : Round 550

Pile type : User defined (low vibrating)
Note: This user defined pile type is considered to be of a in place formed type.
Hence the characteristic value of the friction angle at the pile shaft (delta) will be taken as 1.0 * phi.

Pile type for determination of execution factor alpha_s in sand/gravel:
Continuous flight auger pile

Pile type for determination of exectution factor alpha_s in clay/loam/peat:
alpha_s clay/loam/peat according to table 7.d, art. 7.6.2.3 (i)
NEN 9997-1+C2:2017
Note : alpha_s depends on the soiltype and relative depth.

Pile type for determination of pile class factor alpha_p :
User defined
alpha_p : 0,3000
Evidence to support chosen alpha_p should be provided.

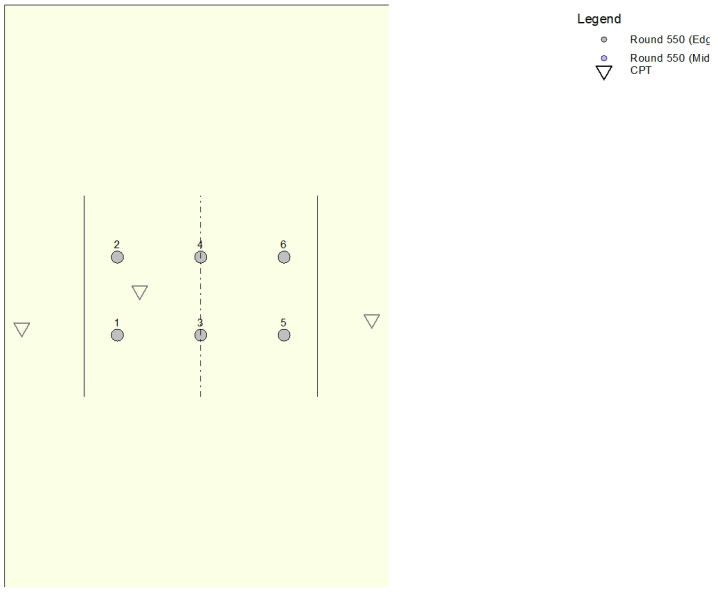
Pile type for use in load/settlement curves : 2
Materialtype for pile : Concrete
Slip layer : None
Pile shape : Round pile
beta (Shape factor) according to figure 7.i, NEN 9997-1+C2:2017.
s (factor for influence of the shape of the crosssection of the pile base) according to NEN 9997-1+C2:2017.

Pile dimensions :
Diameter [m] : 0,550

2.8 Foundation Plan

Number of piles : 6
Number of collaborating piles* : 6
* : 0 = not defined, 1 = non rigid superstructure, >1 = rigid superstructure

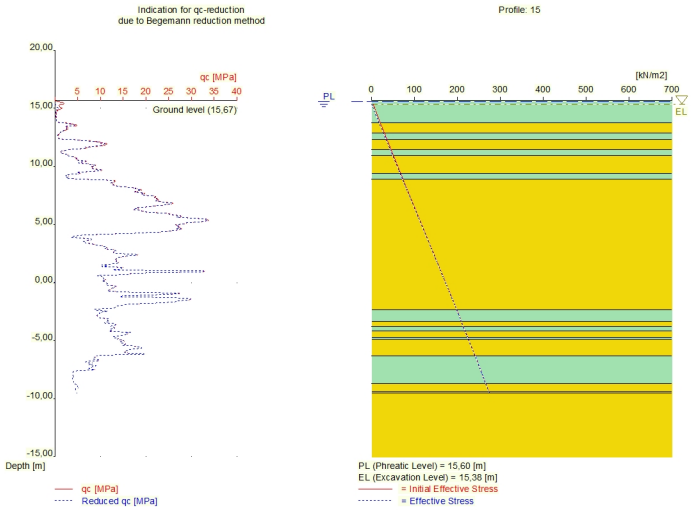
2.8.1 View of Foundation Plan



Pile nr/name	X-coordinate [m]	Y-coordinate [m]	Fc;d (EQU/STR/GEO) [kN]	Fc;d (SLS) [kN]	P0 [kN/m2]	Pile head level [m R.L.]
1: 1	249315,99	477779,34	581,32	415,91	0,00	15,60
2: 2	249315,99	477782,84	581,78	416,34	0,00	15,60
3: 3	249319,74	477779,34	579,35	407,33	0,00	15,60
4: 4	249319,74	477782,84	597,81	421,29	0,00	15,60
5: 5	249323,49	477779,34	529,79	377,10	0,00	15,60
6: 6	249323,49	477782,84	572,64	407,50	0,00	15,60

2.9 Excavation Data

Excavation level in [m. reference level] :	15,38
Reduction model :	Begemann
Distance edge pile to excavation boundary [m] :	1,50



2.10 Totalized Loads (design values)

Total load on all piles
For limit state EQU/STR/GEO in [kN] : 3442,69
For Serviceability limit state in [kN] : 2445,47

2.11 Requirements

Limit state STR/GEO
Maximum allowed settlement in [m] : 0,100
Serviceability Limit State
Maximum allowed settlement in [m] : 0,050

2.12 Overruled Parameters

All parameters according to standard.

2.13 Model Options

Use pilegroup for negative skin friction (standard)
Do not create intermediate results file
Use reduction for continuous flight auger piles (standard)
Use the influence of excavations (standard).

2.14 Model Options

Selected pile types :
- -Round 550

Selected profiles :
- -15
- -16
- -2

3 Bearing Piles (EC7-NL): Results Complete Verification

3.1 Remarks

When checking the survey and testing of soil according to NEN 9997-1+C2:2017 art. 3.2.3 section (e), the program uses the provided CPT test level. It does NOT take into account possible different pile tip levels. When different pile tip levels are used in this calculation, the user itself must check for possibly required additional survey and testing of soil.

Performing the check on NEN 9997-1+C2:2017 art. 3.2.3, the average distance between the different CPT's used for this check is 25 m.
The requirements set by NEN 9997-1+C2:2017 art. 3.2.3 are met.

The requirements set by NEN 9997-1+C2:2017 art. A.3.3.3 are met. The variation (6,41%) is ok (<= 12%).

3.2 Calculation Parameters

3.2.1 Pile Factors

gamma;b (NEN 9997-1+C2:2017, table A.6 A.7 A.8, Limit State EQU/STR/GEO) :	1,20
gamma;b (NEN 9997-1+C2:2017, table A.6 A.7 A.8, the Serviceability Limit State) :	1,00
gamma;s (NEN 9997-1+C2:2017, table A.6 A.7 A.8, Limit State EQU/STR/GEO) :	1,20
gamma;s (NEN 9997-1+C2:2017, table A.6 A.7 A.8, the Serviceability Limit State) :	1,00
xi3 (NEN 9997-1+C2:2017, table A.10b, for N = 3) :	1,18
xi4 (NEN 9997-1+C2:2017, table A.10b, for N = 3) :	0,94

Xi 3 has been used.

3.2.2 Pile type : Round 550

Pile type : User defined (low vibrating)
Note: This user defined pile type is considered to be of a in place formed type.
Hence the characteristic value of the friction angle at the pile shaft (delta) will be taken as 1.0 * phi.

Pile type for determination of execution factor alpha_s in sand/gravel:
Continuous flight auger pile

Pile type for determination of exectution factor alpha_s in clay/loam/peat:
alpha_s clay/loam/peat according to table 7.d, art. 7.6.2.3 (i)
NEN 9997-1+C2:2017
Note : alpha_s depends on the soiltype and relative depth.

Pile type for determination of pile class factor alpha_p :
User defined
alpha_p : 0,3000
Evidence to support chosen alpha_p should be provided.

Pile type for use in load/settlement curves :	2
Materialtype for pile :	Concrete
Slip layer :	None
Pile shape :	Round pile
beta (Shape factor: figure 7.i, NEN 9997-1+C2:2017 art. 7.6.2.3(g) : Pile tip) :	1,00
s (NEN 9997-1+C2:2017 art. 7.6.2.3(h) : factor for the influence of the shape of the crosssection of the pile base) :	1,00

Pile dimensions :
Diameter [m] : 0,550

Number/Name CPT	Alpha_s Sand/ Gravel	Alpha_s Clay/Loam Peat	Alpha_p
1:15	0,0060	--	0,3000
2:16	0,0060	--	0,3000
3:2	0,0060	--	0,3000

3.3 Verification of Limit State EQU

Required by NEN 9997-1+C2:2017 art. 2.4.8: Ed <= Cd.
Rigid superstructure, verify total load on all piles with total bearing capacity

Fc;d = 3442,690 [kN]
Rc;d = 4931,942 [kN]

The requirements of limit state EQU are met, limit state EQU is ok.

Note: Negative skin friction plays NO part in Limit State EQU. Its influence is incorporated in the tests for Limit State STR/GEO and the Serviceability limit state. The intermediate results provide a full overview of all values that are calculated for the negative skin friction.
Purely indicative, the values for the negative skin friction vary from 91 [kN] to 112 [kN] per pile.

3.4 Verification of Limit State STR/GEO

Required by NEN 9997-1+C2:2017 art. 2.4.9: Sd <= Sreq.

Sd = 0,055 [m]
Sreq = 0,100 [m]

Note: The user-defined Sreq differs from the proposed value (0.15 m) as provided by NEN 9997-1+C2:2017. Less strict values should be reviewed carefully.

The settlement requirements of limit state STR/GEO are met, this is ok.

As the superstructure was indicated to be rigid, settlement differences may be neglected, so rotations are not taken into consideration (NEN 9997-1+C2:2017 art. 6.6.2 part c)!

3.5 Verification of Serviceability Limit State

Required by NEN 9997-1+C2:2017 art. 2.4.9: Sd <= Sreq.
For houses, the requirement is : Sreq = 0.05 m. For other types of superstructures a different (well considered) requirement can be specified.

Sd = 0,019 [m]
Sreq = 0,050 [m]

Note: The user-defined Sreq differs from the imposed value (0.05 m) as provided by NEN 9997-1+C2:2017.
The settlement requirements of the Serviceability Limit State are met, this is ok.

As the superstructure was indicated to be rigid, settlement differences may be neglected, so rotations are not taken into consideration (NEN 9997-1+C2:2017 art. 6.6.2 part c)!

3.6 Additional Information

The design values of the maximum shaft tensions (calculated at the transition of positive to negative skin friction) are

At Limit state EQU/STR/GEO: sigma = 2,99 [N/mm2]
At Serviceability Limit State: sigma = 2,25 [N/mm2]

The maximum settlement was found at:
Limit state STR/GEO
Number/Name 16
Pile name: 4

Components of the maximum settlement are :

sneg =	0,000 [m]
sb =	0,061 [m]
sel;d =	0,001 [m]
s2 =	0,008 [m]

Serviceability Limit State

Number/Name	16
Pile name:	4

Components of the maximum settlement are :

sneg =	0,000 [m]
sb =	0,014 [m]
sel;d =	0,001 [m]
s2 =	0,006 [m]

sneg stands for the settlement due to negative skin friction when the expected ground level settlement (egls) is within the next boundaries : 0.02 < egls <= 0.10 meter.

For expected ground level settlement beyond the boundaries, sneg = 0.

3.6.1 The bearing capacity of shaft and point at Limit state STR/GEO

The next table shows the values of the bearing capacities per CPT and these are purely informative.
The presented design values are determined using the maximum value of ksi3 and ksi4.

Number/Name CPT	Bearing Cap. Shaft [kN] Rs;d	Bearing Cap. Point [kN] Rb;d	Bearing Cap. Total [kN]
1:15	195,408	686,493	881,901
2:16	174,811	626,507	801,318
3:2	197,581	585,172	782,753

3.6.2 The bearing capacity of shaft and point at the Serviceability Limit State

The next table shows the values of the bearing capacities per CPT and these are purely informative.
The presented design values are determined using the maximum value of ksi3 and ksi4.

Number/Name CPT	Bearing Cap. Shaft [kN] Rs;d	Bearing Cap. Point [kN] Rb;d	Bearing Cap. Total [kN]
1:15	234,490	823,791	1058,281
2:16	209,773	751,808	961,581
3:2	237,098	702,206	939,304

End of Report