REPORT

Wind Farm Maasvlakte 2 - Crane Hardstands for Wind Turbines along the Soft Sea Barrier

Preliminary Geotechnical Foundation Design

Client: Eneco Wind B.V.

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Eneco

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Enhancing Society Together

Project related

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1 Introduction

Rijkswaterstaat (RWS) has commissioned Eneco to develop the Maasvlakte 2 wind farm with a capacity of more than 100 MW. The wind farm is located near the primary sea barrier, see Figure 1-1. Royal HaskoningDHV is partner of Eneco and provides the design of the wind turbine foundations and the associating civil works, such as the crane hardstands, the cable routing, the construction roads and the transformer station.

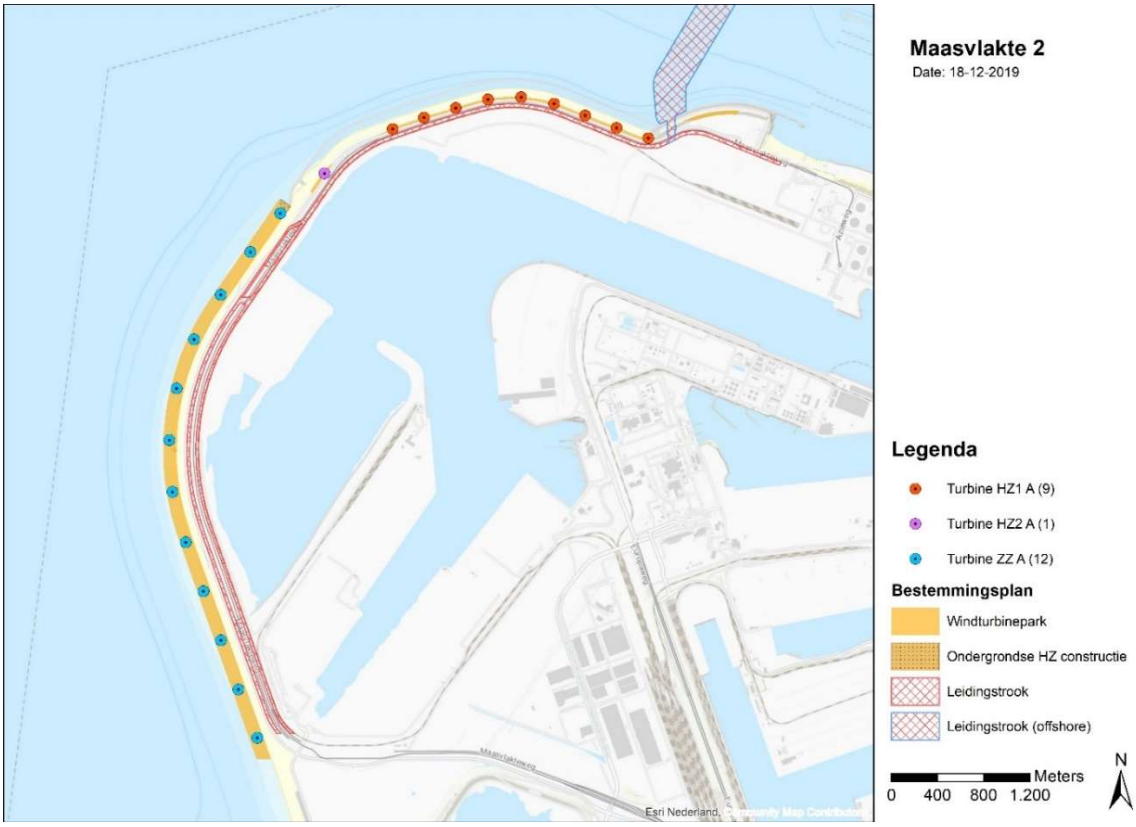


Figure 1-1: Location Wind Farm Maasvlakte 2

This report describes the preliminary geotechnical foundation design for the crane hardstands for the twelve wind turbines near the 'soft sea barrier' (turbine locations 'ZZ' in Figure 1-1). The wind turbines are located on the beach and will be founded on monopiles. Three different design option are considered for the crane hardstand, depending on the existing terrain level:

- Terrain level below mean low sea water level: anchored sheet pile wall with backfill;
- Terrain level in intertidal zone: geotubes with backfill
- Terrain level above mean high sea water level: fill with sand and aggregates.

For each design option the load bearing capacity of the crane platform is verified by shear failure calculations. Settlement calculations are performed to verify the allowable inclination.

At this stage of the project no selection has been made yet of the turbine supplier. Consequently, the crane type is not known yet. The crane hardstands are therefore designed to be suitable for both mobile cranes as well as crawler cranes. In this design, the worst-case (most unfavourable) load conditions are derived based on provided specifications for civil works from the intended wind turbines suppliers.

2 Reference Documents

2.1 Codes and Guidelines

For this project the following codes and guidelines are used:

[REF1] NEN 9997-1+C2:2017, Geotechnical design of structures - Part 1: General rules.
[REF2] NEN-EN 1990/+NB, National Annex to NEN-EN 1990+A1+A1/C2: Eurocode: Basis of structural design.
[REF3] STOWA Publication 2019-02A, Handbook Crane Hardstands for Installation of Wind Turbines., 23 May 2019.

2.2 Specifications for Civil Works

Specifications concerning the loads and dimensions of the crane hardstands are given in:

[REF4] Vestas, Requirements for Site Road Infrastructure, Crane Pads, Hardstands and Installation. Version 10, 2 September 2019.
[REF5] SIEMENS Gamesa, Appendix 1: Site Specific Requirements SG6.0-155-102.5mHH. Rev. Number 00. 16 January 2020.
[REF6] GE Renewable Energy, Technical Documentation Wind Turbine Generator Systems 158 m Rotor Diameter - 50 Hz. Site Roads and Crane Hardstandings Specification. EMEA Version (Europe, Middle East, Africa)

2.3 General Site Data

The following data is used to derive the site and soil conditions:

[REF7] Inpijn Blokpoel, Bodemkundig onderzoek Harde Zeewering. Doc. Nr.: 02P003077-adv-01, 21-06-2013
[REF8] PUMA, Geotechnische beoordeling aanleggebied. Doc. Nr.: puma-q-lb-onb01, 27-02-2008
[REF9] MOS grondmechanica, Sonderingen Windpark 2e Maasvlakte. Doc. Nr.: 4300038842, 4-11-2019
[REF10] Rijkswaterstaat, Memo watervergunning Zachte Zeewering, 23 april 2019
[REF11] PUMA, Harde Zeewering: Geotechnische stabiliteit van Stenig Duin + Blokkendam; Ontwerpnota. Doc. Nr.: puma-mpo-ono02, 15-02-2011
[REF12] Deltares, Bodemdaling in het kustfundament en de getijdenbekkens. Doc. Nr.: 11200538-008-ZKS-0001, 15-02-2018

2.4 Project related documents

[REF13] Kraanopstelplaatsen harde zeewering Situering en dwarsprofielen HZ-02. Doc. Nr.: BG8375-ZZ-XX-DR-0001-HZ-02, d.d. 14-04-2020
[REF14] Business Plan Windpark Tweede Maasvlakte, v02. d.d. 09-01-2020

3 General Principles

3.1 Project prerequisites

Regarding the crane hardstand design there are no project specific prerequisites mentioned in the risk management plan ([REF14], Appendix 2.4).

3.2 Safety and Reliability

3.2.1 Consequence Class and Geotechnical Category

For the crane hardstand foundation, the following parameters are used:

- Reliability class: RC2 (according to NEN-EN 1990/+NB table B2)
- Geotechnical Category 3 (according to NEN 9997-1:2017 section 2.1)

3.2.2 Design Approach

In accordance with the Eurocode 7 the Design Approach 3 (DA3) is applied for the foundation design. For DA3 the design shall be checked against failure in the soil and in the structure, including partial factors on loads (actions) and material properties. The resistance factor is set to 1.0.

3.2.3 Load Factors

The partial load factors are set to:

- 1.5 for bearing capacity analysis in accordance with [REF1][REF1];
- 1.3 for stability analysis.

3.2.4 Material factors

The material factors used for soil material are in accordance with the Eurocode 7 for verification of bearing capacity:

- γ_{ϕ}=1,15 for tanφ;
- $\gamma_{c'}$=1,6;
- γ_{cu}=1,35;
- γ_{γ}=1,1.

For verification of stability the following values are used:

- γ_{ϕ}=1,25 for tanφ;
- $\gamma_{c'}$=1,45;
- γ_{cu}=1,75;
- γ_{γ}=1,0.

3.3 Ultimate Limit State Requirements

In accordance with the Eurocodes the geotechnical foundation design demonstrates that exceeding the following ultimate limit states is sufficiently improbable:

- Bearing capacity of the subsoil;
- Structural strength of the sheet pile wall;
- Overall stability (sheet pile wall and slopes).

3.4 Serviceability Limit State Requirements

Although no criteria are given by the wind turbine suppliers in the specifications, it is set that the maximum total settlement shall not exceed 2cm for the specified maximum loads applied for the period of two weeks on crane hardstands. The criterium is in accordance with the specification of Siemens Gamesa for the crane hardstands along the 'hard sea barrier'

For the serviceability limit state design all partial load and material factors are set to 1.0.

3.5 Crane Hardstand Layout

The crane hard stand is located on the soft sea barrier. Each crane hardstand consists of the following components:

- Crane platform:
- Auxiliary crane platform;

The preliminary layout of the crane hardstand is shown the figure below.

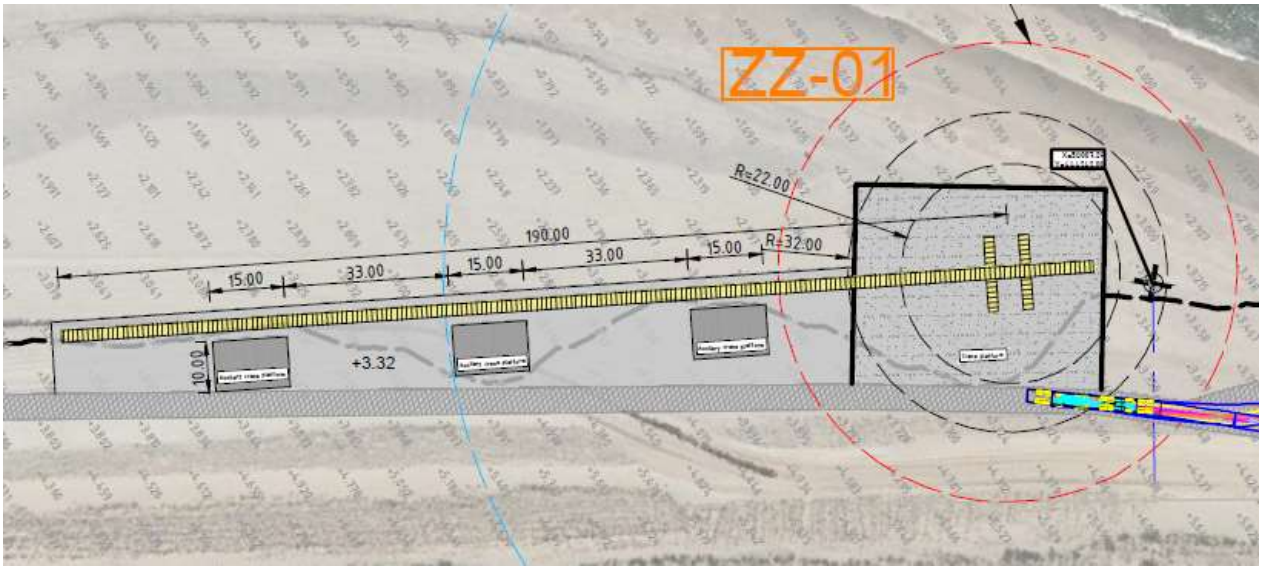


Figure 3-1: *layout crane hardstand location ZZ-01 ([REF13])*

3.6 Foundation levels

The top level of the crane hardstand is set to NAP +3.32 m. This level is based on a water level of NAP +2.32 m, that might occur two times a year and an additional freeboard of 1.0 m to allow for enough dewatering. This high level also allows easy connection with the temporary access road, which is located close to the sand dunes.

3.7 Crane Loads and Requirement for Crane Hardstands

The main crane hardstands (MCHS) shall be suitable for both a mobile crane as a crawler crane. Based on the specification for civil works the most unfavourable loads and most stringent criteria are selected.

3.7.1 General Requirements

General requirements with respect to the crane hardstands are as follows:

- Before or during storms with wind force 7Bf, no vehicles, equipment and materials are allowed on the beach.[REF10];
- During the storm season (October 1 – April 1) it is not allowed to drive piles and excavate [REF10];
- Except for the wind turbine foundations, with the exception of access bridges [REF10].
- The sand that is used for construction of the turbines is obtained from outside the coastal foundation and remains property of the State after application [REF10].

3.7.2 Requirements for the Main Crane Hardstand

The requirements for the MCHS are listed in the following table.

Table 3-1: requirements for the MCHS

Parameter	Requirement	Specification
Typical type of crane	LG1750 or LR11000	[REF4][REF5]
Outrigger spread	16 m x 16 m	Own assumption[1)]
Loaded area (mat dimensions)	Mobile: 4 x (2,4 m x 6,0 m) Mobile: 2 m x 10 m Crawler: 5 m x 10 m	Own assumption[1)]
Length	50 m	[REF4]
Width	20 m	[REF4]
Level to top WTG	+2.0 tot -1.5 m	[REF5][REF6]
Min. Load bearing cap.	260 kPa	[REF4]
Settlement criteria	2cm in 2 weeks	Own assumption[1)]
Longitudinal slope	0%	[REF4]
Lateral slope	0%	[REF4]
Shoulder slope	max. 45˚	Own assumption[1)]
Compaction criteria	$D_{Pr} \geq 100\%$, $E_{V2} \geq 120$ MPa and $E_{V2}/E_{V1} \leq 2.3$	[REF4]

1. Own assumption is based on crane hardstand specifications for wind turbines near the hard sea barrier

3.7.3 Requirements for the Auxiliary Crane Hardstand

The requirements for the ACHS are listed in the following table.

Table 3-2: requirements for the ACHS

Parameter	Requirement	Specification
Typical type of crane	200t crane	[REF5]
Loaded area (mat dimensions)	4 x (2,0 m x 2,0 m)	Own assumption[1)]
Length	15,5 m	[REF5]
Width	11 m	[REF5]
Level to top WTG	Level with road	[REF5]
Min. Load bearing cap.	180 kPa	[REF4]
Settlement criteria	2cm in 2 weeks	Own assumption[1)]

Longitudinal slope	0%	[REF4]
Lateral slope	0%	[REF4]
Shoulder slope	max. 45°	Own assumption[1)]
Compaction criteria	D_{Pr} ≥ 98%	[REF4]

3.7.4 Requirements for the Assembly Area

The requirements for the Assembly Area are listed in the following table.

Table 3-3: requirements for the Assembly Area

Parameter	Requirement	Specification
Typical type of crane	750t crane	[REF5]
Outrigger spread	12 m x 12 m	Own assumption[1)]
Loaded area (mat dimensions)	4 x (2,4 m x 4,0 m) 1 m x 8 m 3 m x 8 m	Own assumption[1)]
Min. Load bearing cap.	200 kPa	Own assumption[1)]
Settlement criteria	2cm in 2 weeks	Own assumption[1)]
Longitudinal slope	0%	[REF4]
Lateral slope	0%	[REF4]
Shoulder slope	max. 45°	Own assumption[1)]
Compaction criteria	D_{Pr} ≥ 98%	[REF4]

3.7.5 Requirements for the Compound Area / Logistics Area

The requirements for the Compound Area and Logistic Area are listed in the following table.

Table 3-4: requirements for the Compound Area and Logistics Area

Parameter	Requirement	Specification
Loaded area (mat dimensions)	2 m x 10 m 5 m x 10 m	Own assumption[1)]
Length	40 m	[REF4]
Width	30 m	[REF4]
Min. Load bearing cap.	180 kPa	[REF4][REF5][REF5]
Longitudinal slope	Max. 1%	[REF5]
Lateral slope	Max. 1%	[REF5]
Compaction criteria lower binder course	E_{V2} ≥ 80 MN/m^2 and E_{V2}/E_{V1} ≤ 2.5	[REF5]

4 Site and Soil Conditions

4.1 Geotechnical Soil Investigation

During the tender stage of this project, MOS Grondmechanica performed a geotechnical soil investigation on behalf of Rijkswaterstaat [REF9]. In the project area of the soft sea barrier (ZZ) six CPT's were carried out to a max. depth of NAP – 47 m.

In the table below an overview of the soil investigation is presented. The location of these points and the CPT graphs are shown in Appendix 3.

Table 4-1: Soil investigation CPT locations [REF9]

Name	RD X coordinate [m]	RD Y coordinate [m]	Ground level [m NAP]	End depth [m NAP]
CPT 2	57914.5	444071.7	+4.66	-45.3
CPT 3	57854.9	439658.6	+2.90	-47.0
CPT 4	57395.2	443304.8	+1.63	-40.5
CPT 5	57516.1	440584.7	+3.16	-46.8
CPT 6	57073.0	442326.1	+2.71	-37.6
CPT 11	57176.6	441462.9	+2.52	-47.4

4.2 Ground Level

The existing ground level at the locations of the future wind turbines varies and is subject to morphodynamical processes (sand erosion and deposition due to wind and wave action), see Figure 4-1. The future levels are therefore uncertain and should be considered in more detail during the detailed design stage. For preliminary design purposes the following distinction is made:

	Expected no. of locations
• Terrain level below low water ≤ NAP -0.6 m	5
• Terrain level in intertidal zone, between NAP -0,6 m and NAP +1,32 m	4
• Terrain level above high water NAP +1,32 m	3

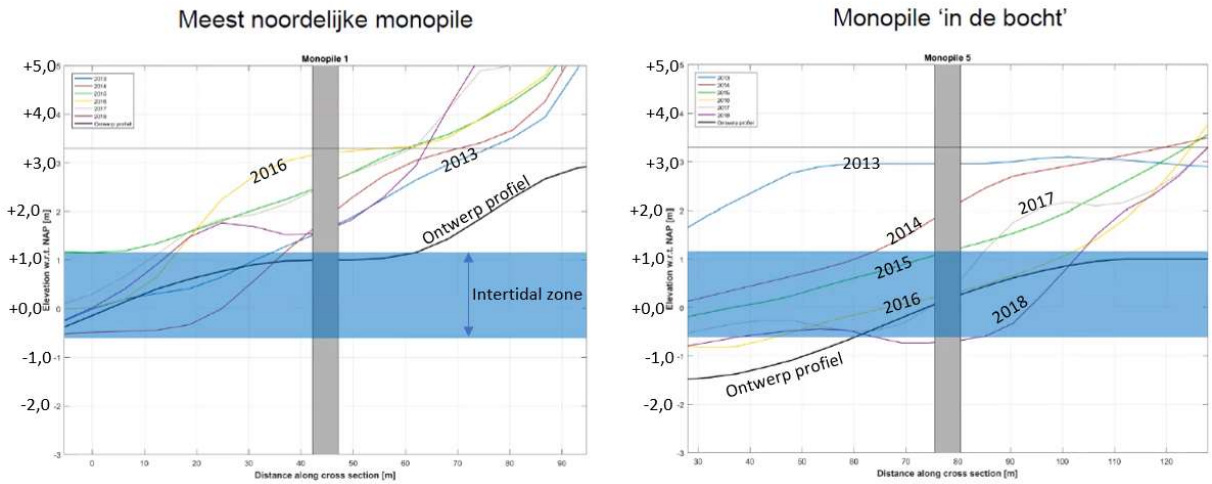


Figure 4-1: Typical variation of the terrain level of the soft sea barrier. Left figure indicates ZZ-01, right figure indicates ZZ-05. Source: Deltares

4.3 Soil Profile

From available sources [REF7][REF9] it is apparent that the subsurface below the soft sea barrier mainly consists of sand. Directly below ground level up to a depth of around NAP -17 to -21 m a thick layer of sand fill is present. The sand texture varies from fine to very course. Its consistency varies from moderately to densely packed (cone resistance of up to 50 MPa).

Below the sand fill the naturally sedimented soil is encountered. At the soft sea barrier between NAP -17 to -21 m and NAP -21 to -34 m -24 this soil profile consists of sandy clay, clayey sand and peat (geological Elbow Formation). Below NAP -21 to -34 m densely packed Pleistocene sand is registered with a cone resistance of up to 70 MPa. In this sand locally and at alternating depths reductions in cone resistance are observed, probably caused by loose packing or course gradation. In the figure below a cross-section along the sea barrier (ZZ and HZ) is shown.

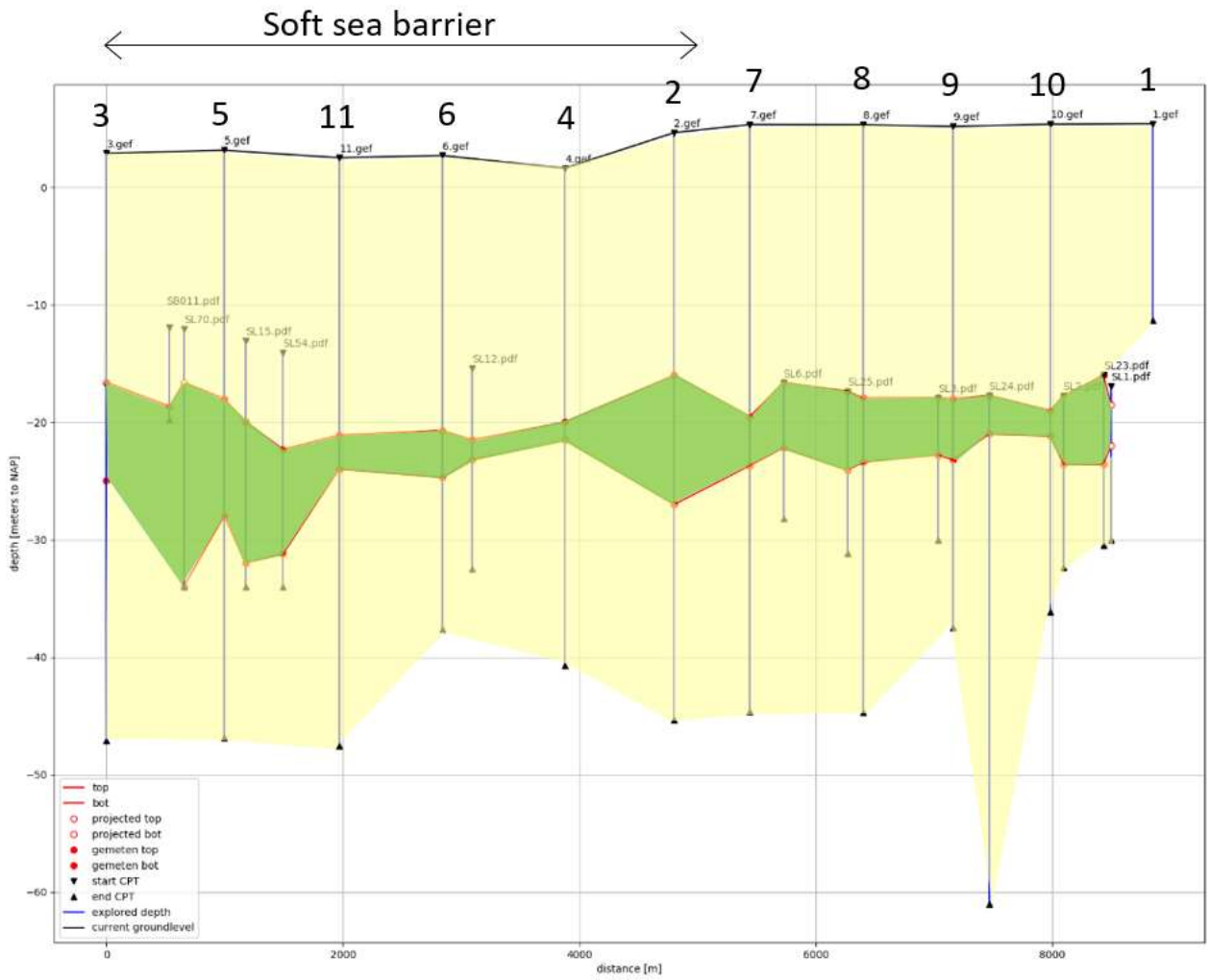


Figure 4-2: geological profile hard sea barrier

4.4 Soil Parameters

Based on the results of the soil investigation, a representative geotechnical soil profile has been schematized for the crane hardstands based on CPT6. At this test location the lowest cone resistances are observed in the upper 10 to 15 m, which is affected depth by crane loading. The characteristic values for the soil parameters are determined based on table 2.b of NEN 9997-1+C2:2017 [REF1] and correlations with CPT using the cone resistance q_c.

Table 4-1: Soil stratigraphy and characteristic values for the soil strength parameters

Top soil layer [m NAP]	Description soil layer	Bulk unit weight γ_{sat} [kN/m^3]	Effective angle of internal friction φ [°]	Effective cohesion c' [kPa]	Undrained shear strength C_u [kPa]
2.7	Clean sand, densely packed	21.0	35.0	0.0	0.0
2.3	Clean sand, densely packed	21.0	35.0	0.0	0.0
-2.5	Clean sand, densely packed	21.0	35.0	0.0	0.0
-4.3	Clean sand, moderately packed	20.0	32.5	0.0	0.0

-9.0	Clean sand, densely packed	21.0	35.0	0.0	0.0
-11.8	Clean sand, moderately packed	20.0	32.5	0.0	0.0
-15,2	Clean sand, moderately packed to densely packed	20,5	33.5	0.0	0.0
-20.0	Clean sand, loosely packed	19.0	30.0	0.0	0.0
-21,5	Peat, moderately packed	12.0	15.0	2.5	20.0
-21.8	Clean sand, loosely to moderately packed	17,5	33.5	0.0	0.0
-23.0	Clean clay, densely packed	20.0	17.5	13.0	13.0
-33.0	Clean sand, moderately packed	20.0	32.5	0.0	0.0

Table 4-2: Soil stratigraphy and characteristic values for the soil compression parameters

Top soil layer [m NAP]	Description soil layer	Bulk unit weight γ_{sat} [kN/m^3]	C_c [-]	C_α [-]	C_{sw} [-]
2.7	Clean sand, densely packed	21.0	0.0031	0.0	0.0011
2.3	Clean sand, densely packed	21.0	0.0031	0.0	0.0011
-2.5	Clean sand, densely packed	21.0	0.0031	0.0	0.0011
-4.3	Clean sand, moderately packed	20.0	0.0031	0.0	0.0011
-9.0	Clean sand, densely packed	21.0	0.0031	0.0	0.0011
-11.8	Clean sand, moderately packed	20.0	0.0031	0.0	0.0011
-15,2	Clean sand, moderately packed to densely packed	20,5	0.0038	0.0	0.0013
-20.0	Clean sand, loosely packed	19.0	0.0115	0.0	0.0038
-21,5	Peat, moderately packed	12.0	0.3060	0.0153	0.1022
-21.8	Clean sand, loosely to moderately packed	17,5	0.0115	0.0	0.0038
-23.0	Clean clay, densely packed	20.0	0.0920	0.0030	0.0300
-33.0	Clean sand, moderately packed	20.0	0.0031	0.0	0.0011

4.5 Ground Water Conditions

The phreatic ground water level is taken equal to the sea water level because the crane hardstands are located near the sea. The following values are applied:

- Mean low ground water level: NAP -0.6 m;
- Mean high water level: NAP +1.3 m;
- Highest ground water level (2 / year): NAP +2.3 m.

As a conservative value the highest ground water level is used in the bearing capacity calculations. For settlements analysis a mean sea level of NAP +0.0 m is assumed.

5 Conceptual Design Principles

5.1 General

The location of the crane hardstands on the beach, in the tidal zone or in the water requires distinct conceptual designs, depending on the hydraulic conditions during construction.

The following three design option are considered for the crane hardstands:

- Terrain level above mean high sea water level (>NAP +1.3 m): fill with sand and aggregates;
- Terrain level in intertidal zone (between NAP -0.6 and +1.3 m): geotubes with backfill;
- Terrain level below mean low sea water level (<NAP -0.6 m): anchored sheet pile wall with backfill.

Even though the sandy subsoil imposes low geotechnical risks, key factors for the foundation design are:

- the constructability in relation the hydraulic conditions;
- the stability of the (soil) structures;
- the bearing capacity;
- the stiffness and deformation.

In the following sections the concept of each design option is described. The stability of the soil and structure (strength) and the degree of deformation are analysed in chapters 6 to 9.

5.2 Crane Hardstands above High Water Level

The sandy subsoil is by nature strong and stiff. For construction of the crane hardstand a fill with strong and well compacted sand and mixed aggregate (soil types separated by a geogrid) up to the level NAP +3.32 m is considered enough to provide resistance to the crane loading. Prior to filling the existing terrain must be levelled and compacted.

The thickness of the unbound mixed aggregate base can be limited by using a geogrid for reinforcement. A benefit of using one or more horizontal layers of a geogrid is that loads are spread more even.

The aggregate is freely draining (capillary rise <0.10 m), so that even during a high tide a dry zone (dewatering depth >0.70m) remains.

The slope of the hardstand (slope max 45˚) should be protected against erosion. This can be done by a geosynthetic layer which is embedded near the toe.

A typical cross section of this design option is shown in Figure 5-1.

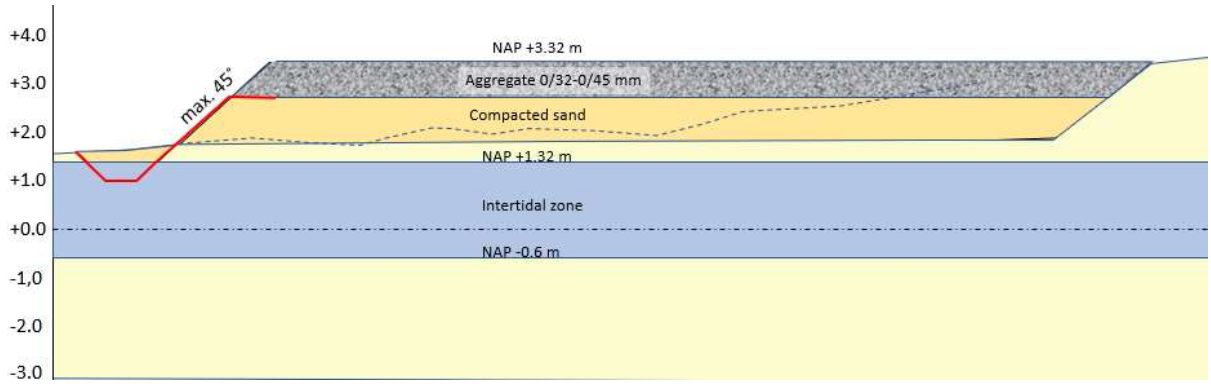


Figure 5-1: Design option for crane hardstand above the high-water level. In order for the aggregate and compacted sand to not mix, an additional geogrid should be added on the boundary between the soil types.

5.3 Crane Hardstands in intertidal Zone

The crane hardstand in the intertidal zone will be under the influence of wave loading and temporary flooding during construction. It is recommended to build to the crane hard stand behind a barrier. The barrier can consist of geotubes filled with sand or precast concrete blocks. For preliminary design the use of geotubes is considered as a flexible solution. The dimensions of the geotubes should be accustomed to the actual site conditions, i.e. the actual height difference. To prevent loss of material a geotextile should be placed behind the geotubes. The backfill with sand and aggregate can be placed and compacted in layers.

A typical cross section of this design option is shown in Figure 5-2.

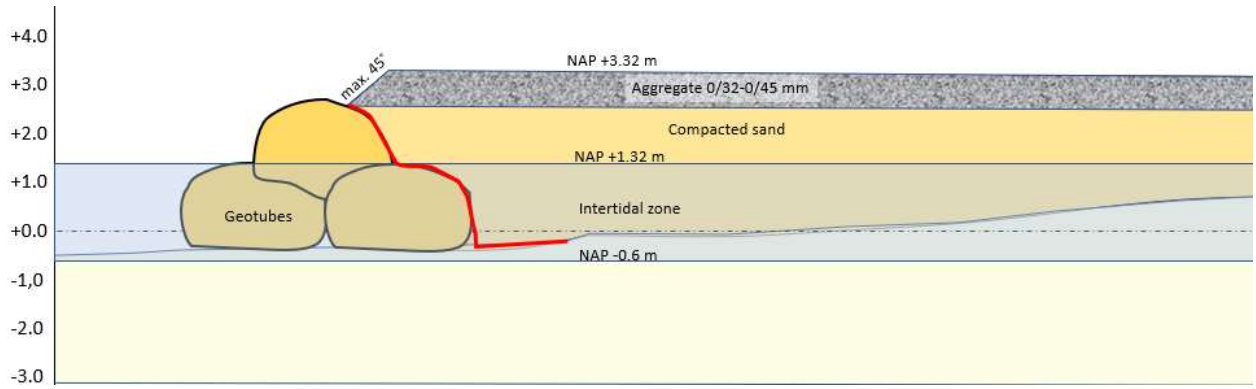


Figure 5-2: Design option for crane hardstand in intertidal zone. In order for the aggregate and compacted sand to not mix, an additional geogrid should be added on the boundary between the soil types.

5.4 Crane Hardstands below Low Water Level

If the terrain level is below the low water level the crane hard stand can be constructed behind an anchored retaining wall. In order to install the steel sheet pile wall a temporary platform is needed with a level above the low water level. After installation of the sheet pile wall the backfill can be placed. The dimensions of the wall can be minimized by using various anchor levels. The anchors can be either steel deadman anchors or geogrid anchors.

A typical cross section of this design option is shown in Figure 5-3.

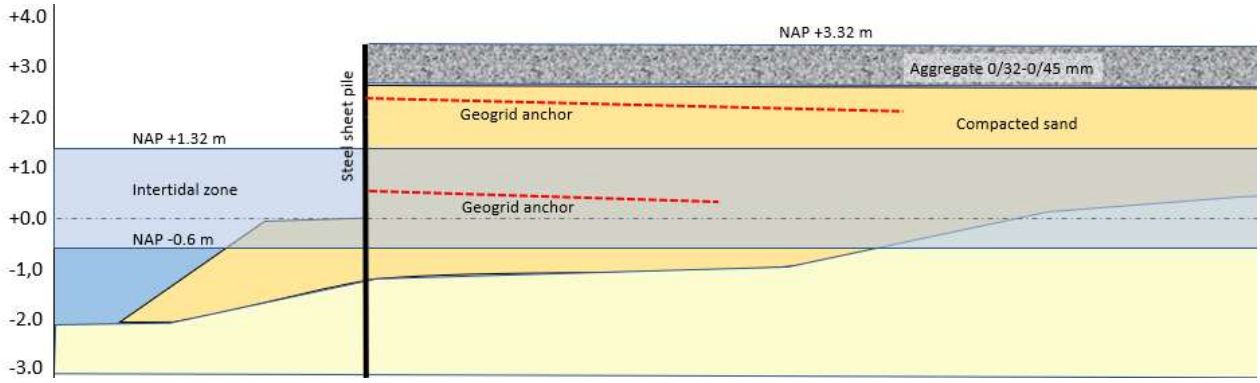


Figure 5-3: Design option for crane hardstand below the low water level. In order for the aggregate and compacted sand to not mix, an additional geogrid should be added on the boundary between the soil types.

6 Bearing Capacity Analysis

6.1 Verification Method

The bearing capacity of the subsoil is checked for the drained situation. The undrained situation is not considered as no cohesive layers are present with the influence depth (upper 5 to 10 m).

The verification is performed for loads as specified in chapter 3. Various dimensions of the loaded area are considered. The mobile crane or crawler crane is assumed to be placed on steel plates or wooden mats on top of an embankment. The embankment consists of compacted mixed granulate material in combination with layers of geogrids (at maximum 0.5 m intermediate distance).

The crane load is assumed to spread at an angle of 45º (1:1) within the embankment with mixed granulate and geogrids. The load spreading capacity of the steel plates or wooden mats is not considered in this stage of the design.

The following formula is used to calculate the bearing capacity (Rd) of the subsoil in the drained state (in accordance with NEN 9997-1: 2017):

$$\sigma'_{max;d} = c'_{gem;d} \times N_c \times s_c \times b_c \times i_c + \sigma'_{v;z;d} \times N_q \times s_q \times b_q \times i_q + 0{,}5 \times \gamma'_{gem;d} \times b' \times N_{\gamma'} \times s_{\gamma'} \times b_\gamma \times i_{\gamma'}$$

$$R_d = \sigma'_{max;d} \times A'$$

The calculations are based on non-eccentric loaded foundations.

6.2 Verification Bearing Capacity

The bearing capacity is verified for the different components of the crane hardstands. The results are presented in the following Table 6-1:

Table 6-1: Results calculations bearing capacity crane hardstands

Hard stand	Foundation carne hard stand	qk [kPa]	Loaded area	Vd [kN]	Rd [kN]	u.c. (Vd ≤ Rd)
MCHS	1.0 m aggregate (0/32-0/45mm) with at least 2 layers of geogrid	250	2.4 m x 6.0 m	6069	6310	0.96
	1.0 m aggregate (0/320/45mm) with at least 2 layers of geogrid	250	2.0 m x 10.0 m	8412	8413	1.0
	1.0 m aggregate (0/32-0/45mm) with at least 2 layers of geogrid	250	5.0 m x 10.0 m	20346	25537	0.8
ACHS	0.8 m aggregate (0/32-0/45mm) with 2 layers of geogrid	250	2.0 m x 2.0 m	1697	1733	0.98
Assembly Area	0.65 m aggregate (0/32-0/45mm) with at least 2 layers of geogrid	200	2.4 m x 4.0 m	3122	3177	0.98
		200	1.0 m x 8.0 m	2664	2786	0.96
		200	3.0 m x 8.0 m	7694	8007	0.96

Compound Area	0.3 m aggregate (0/32-0/45mm) with 1 layer of geogrid	135	2.0 m x 10.0 m	4207	4529	0.93
		135	5.0 m x 10.0 m	10463	16507	0.63

It is recommended to use the same foundation thickness for all three design options.

7 Sheet Pile Wall Design

The design of the Sheet Pile Wall was performed for a 260 kPa Main Crane Hardstand and a 1.0 meter thick aggregate foundation layer.

7.1 Construction Phases

For the installation of the sheet pile wall below the low water level, the various construction phases are considered as shown in Figure 7-1. Considering the intense morphodynamical processes at the soft sea barrier, a conservative estimate of the encountered ground level was made at NAP -2.0 meters (phase 0). The first stage consists of constructing an embankment of sand to NAP +0.0 meters. In stage 2, the sheet pile wall and a first anchor are installed. The soil surface level is then increased to NAP +2.00 meters and a second anchor is installed (stage 3). In the following phase, the soil surface behind the sheet pile wall is increased to NAP +2.32 meters with sand and gravel is added to a height of NAP + 3.32 meters (stage 4). A 12-meter-wide surcharge load of 260 kPa exerted 2 meters away from the Sheet Pile Wall is added in stage 5 on the active side in order to take the load of the cranes into account. In the final stage, the effects of soil scour are considered by reducing the soil surface on the passive side to NAP -1.0 meters.

For the Sheet Pile Wall calculations, the groundwater table was considered at NAP + 2.32 meters on the active side with a low sea level of NAP -0.6 meters (found most critical). The anchors were modelled using rigid supports for translation. The forces exerted on these rigid supports are to be considered in the detailed design phase for the design of the anchors.

The parameters of the added soil were determined based on table 2b of NEN 9997-1+C2:2017 [REF1] and are listed in Table 7-1. The added sand was considered to be loosely packed below NAP -0,30 meters and moderately dense above NAP -0,30 meters. Should the encountered ground level be at a higher elevation than NAP -2.0 meters, then the soil parameters taken for the fill material still represents the most conservative approach for the design of the Sheet Pile Wall. The full calculation can be seen in Appendix 2.

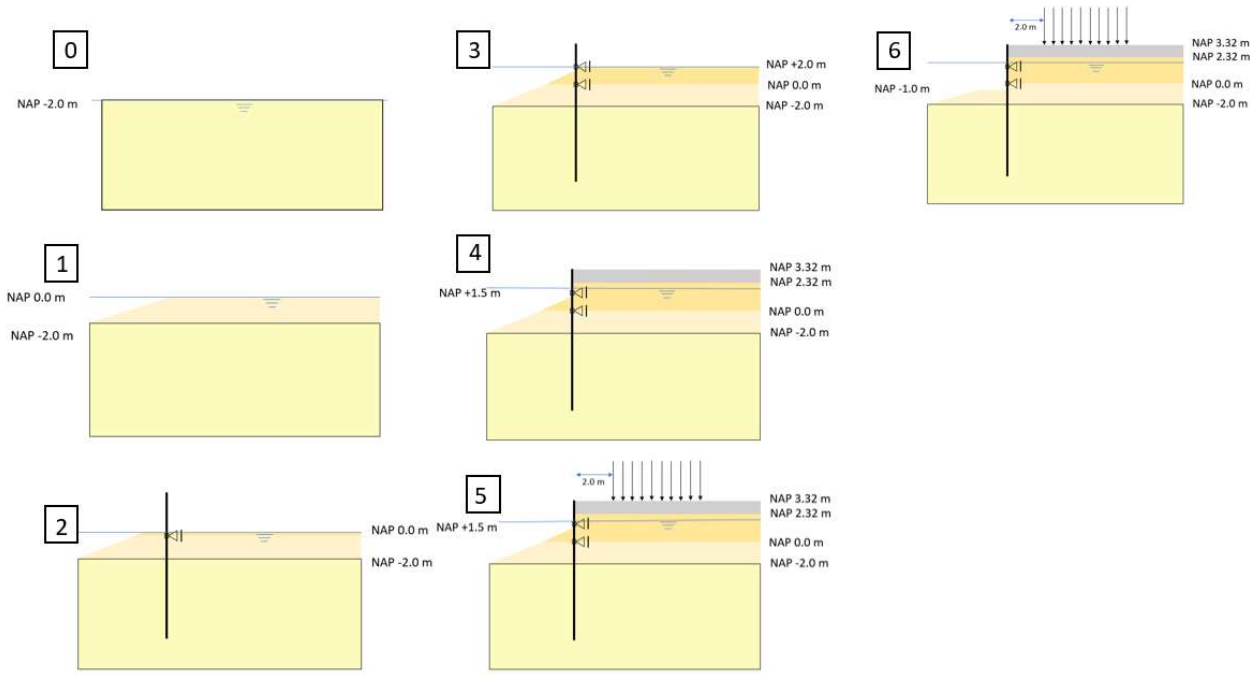


Figure 7-1:phases of the sheet pile wall installation

Table 7-1: Parameters of the added soil

Top soil layer [m NAP]	Description soil layer	Bulk unit weight γ_{sat} [kN/m³]	Effective angle of internal friction φ [°]	Effective cohesion c' [kPa]	Undrained shear strength C_u [kPa]
+3.32	Aggregate	21.0	35.0	0.0	0.0
+2.32	Sand, moderately packed	20.0	32.5	0.0	0.0
-0.30	Sand, loosely packed	19.0	30	0.0	0.0

7.2 Sheet Pile Wall structural Strength and Stability Verification

The structural strength and stability verification were performed using D-Sheetpiling version 18.2.1.20477 (Deltares Software) and conforms with reliability class RC2.
The Sheet Pile Wall consists of an AZ 17-700 (S240) type Sheet Pile where the head of the sheet pile is at NAP +3.32 meters and the toe at NAP -10.0 meters therefore spanning a length of 13.3 meters. Given the short period of serviceability, no effects of corrosion of the Sheet Pile were considered. The results of the structural strength and stability for the six construction stages are given in Table 7-2.

Table 7-2: results of the structural strength and stability for all construction stages

Stage	Maximum calculated bending moment $M_{s;d}$ [kNm/m]	Mobilised passive resistance [%]	Force anchor 1 [kN/m]	Force anchor 2 [kN/m]	Displacements at sheet pile head [mm]	Stability unity factor [-]
1	-	-	-	-	-	-
2	9	14	-	-	0.3	0.01
3	17	18	38	-	0.8	0.20
4	31	22	84	20	1.4	0.30
5	258	55	551	229	5.8	0.73
6	411	64	769	201	8.0	0.80

The maximum allowable bending moment $M_{r;d}$ for an AZ 17-700 (S240) type sheet pile is 415 kNm/m. Given a maximum calculated bending moment of 411 kNm/m, the requirements for the structural strength of the sheet pile wall are fulfilled.

$\frac{M_{r;d}}{M_{s;d}} > 1{,}0$ → Fulfilled

The maximum allowable displacements of the Sheet Pile wall for temporary conditions advised for is 1/100 of the maximum height difference between the passive and active side, with a maximum of 100 mm. A maximum height difference of 4.32 meters occurs at stage 6, which results in a maximum allowable displacement Δx_{max} of 0.04 meters. Given a maximum displacement Δx of 0.008 meters at the pile head, the requirements for the displacements are hereby fulfilled.

$\Delta x \leq \Delta x_{max}$ → Fulfilled

8 Slope Stability Analysis

A slope stability analysis was performed for the crane hard stand above the high-water level, in the intertidal zone and below the low water level. The same soil parameters were used as in Table 4-1 and Table 7-1. A design load of 338 kPa (characteristic load 260 kPa) was applied 2 meters from the top of the slope over a width of 10 meters.

8.1 Slope stability Analysis for the crane hardstand above the high-water level design

The results are given in Table 8-1. The slope is stable for a slope of 45 degrees (with erosion protective geotextile) and two horizontal layers of geogrid. It is recommended to apply a geogrid with a high strength geogrid at the bottom of the aggregate with an effective tensile strength of 600 kN/m (Figure 8-1). The calculation is given in Appendix 3.1.

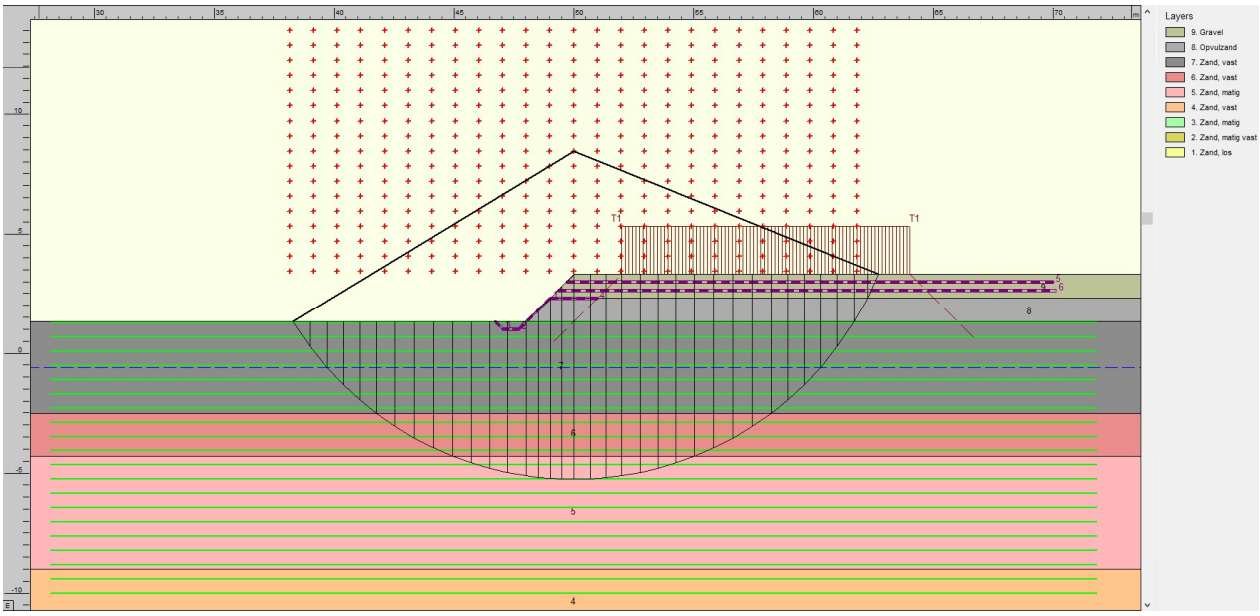


Figure 8-1: representative stability cross-section of the Crane Hardstand above the high-water level and critical slip surface for 10 kN/m geogrids

8.2 Slope Stability Analysis for the crane hardstand in intertidal zone design

The slope stability analysis for the intertidal zone was performed with the added contribution of the geotubes which were modelled as ‘forbidden lines’ (Figure 8-2). The design of the geotube is to be done by the constructor. The results are given in Table 8-1. The slope is stable for a slope of 45 degrees for geogrid tensile strengths of 150 and 600 kN/m for geogrid 1 and 2 respectively. The calculation is given in Appendix 3.2.

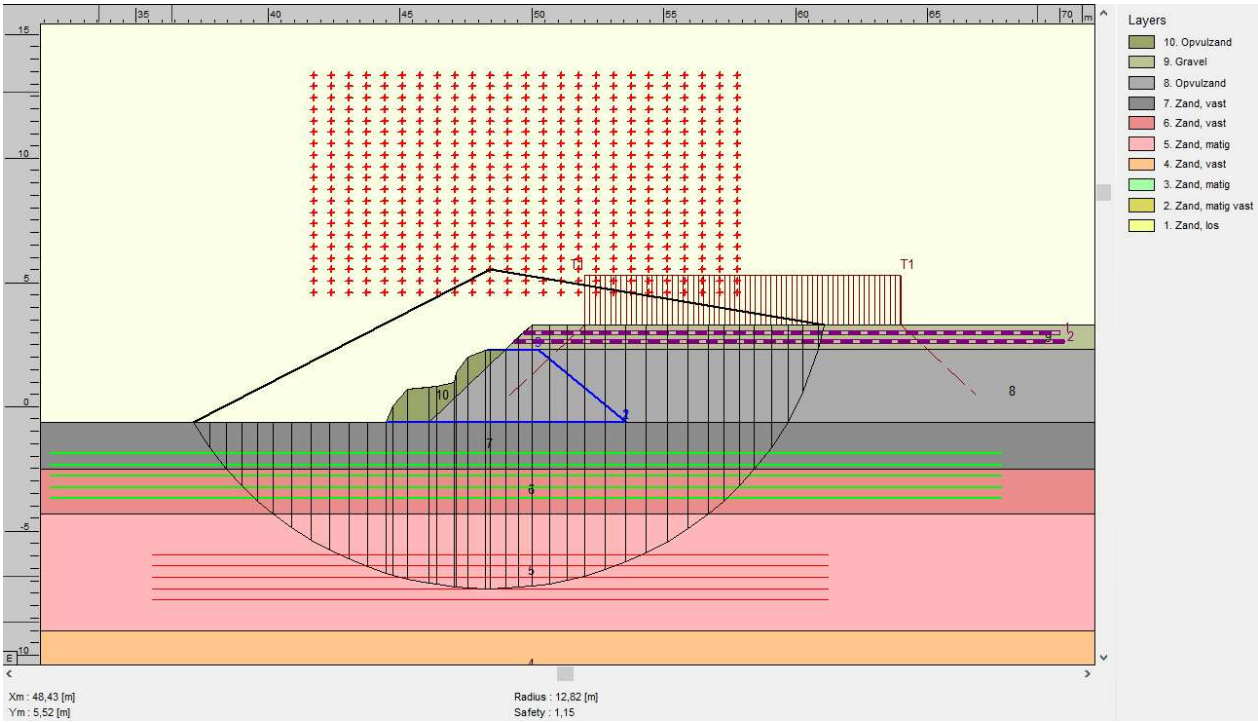


Figure 8-2: representative stability cross-section of the Crane Hardstand for the intertidal zone and critical slip surface

Table 8-1: Stability results for the Crane Hardstand in the intertidal zone

Tensile strength geogrid 1 [kN/m]	Tensile strength geogrid 2 [kN/m]	Unity factor [-]
150	600	0,87

8.3 Slope Stability Analysis design option for the crane hardstand below the low water level design (Sheet Pile Wall)

The results of the slope stability analysis for the Sheet Pile Wall are given in Table 8-2. The slope is stable for an AZ 17-700 (S240) spanning a length of 13.32 meters from NAP +3.32 meters to NAP -10.0 meters with a unity factor of 0.80 for stage 6 (Figure 8-3). The calculation is given Appendix 2.

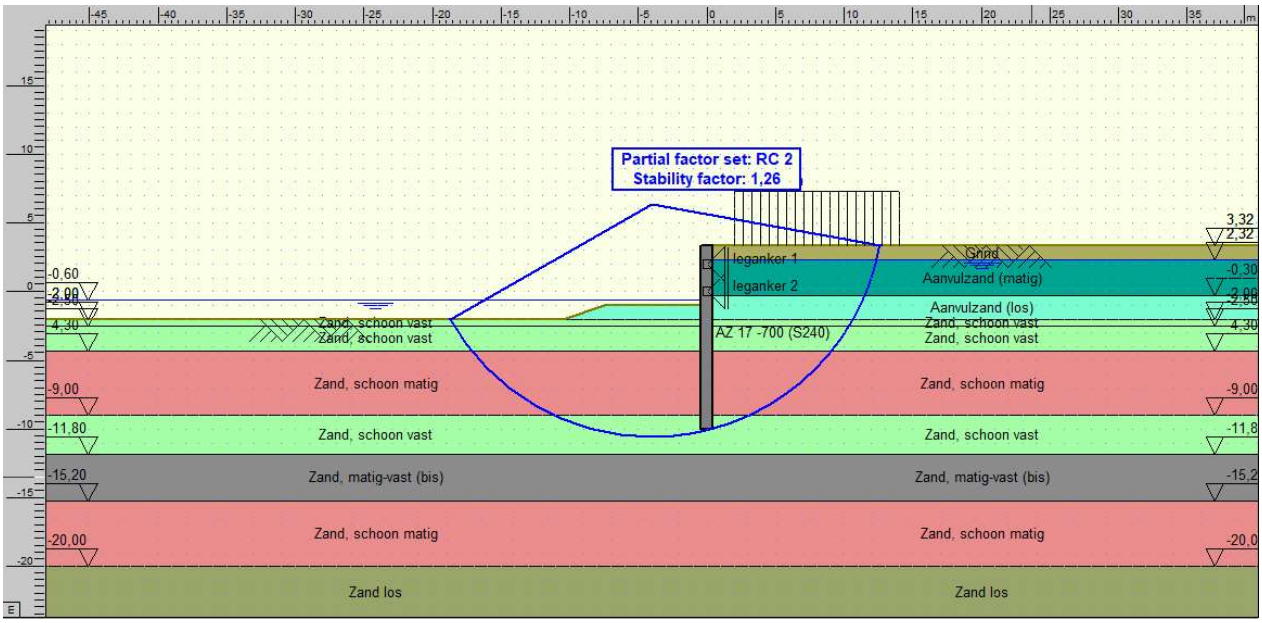


Figure 8-3:representative stability cross-section of the Crane Hardstand below the low water level and critical slip surface at stage 6

Table 8-2: slope stability results Sheet Pile Wall

Stage	Height difference active to passive side [m]	Stability unity factor [-]
1	-	-
2	0.0	0,01
3	0.5	0.20
4	1.80	0.30
5	1.80	0.73
6	4.32	0.80

9 Settlement Analysis

9.1 Verification Method

According to the requirements the total settlement of the crane hardstand shall not exceed a value of 2 cm within 14 days under a loading of a static concentrated load. The verification of this requirement was performed for the operational crane loads without load factors. The loads due to backfill and the compaction of the backfill material will take place immediately during construction and are therefore not considered.
The calculations were performed with D-Settlement 18.1. The load of the main crane was modelled as a 10m x 5m rectangular load (worst case: largest loaded area). The full calculations are available in Appendix 4.1 to 4.3.

9.2 Verification of Settlement

The calculation results are listed in the table below and graphically represented in Figure 9-1, Figure 9-2 and Figure 9-3. For all three cases it can be verified that the expected settlements are less than 2 cm, as required.

Table 3: Settlement results of the Crane Hardstands Design option

Crane	Settlements
Crane Hardstand above the high-water level	0.011 m
Crane Hardstand in intertidal zone	0.010 m
Crane Hardstand below intertidal zone	0.015 m

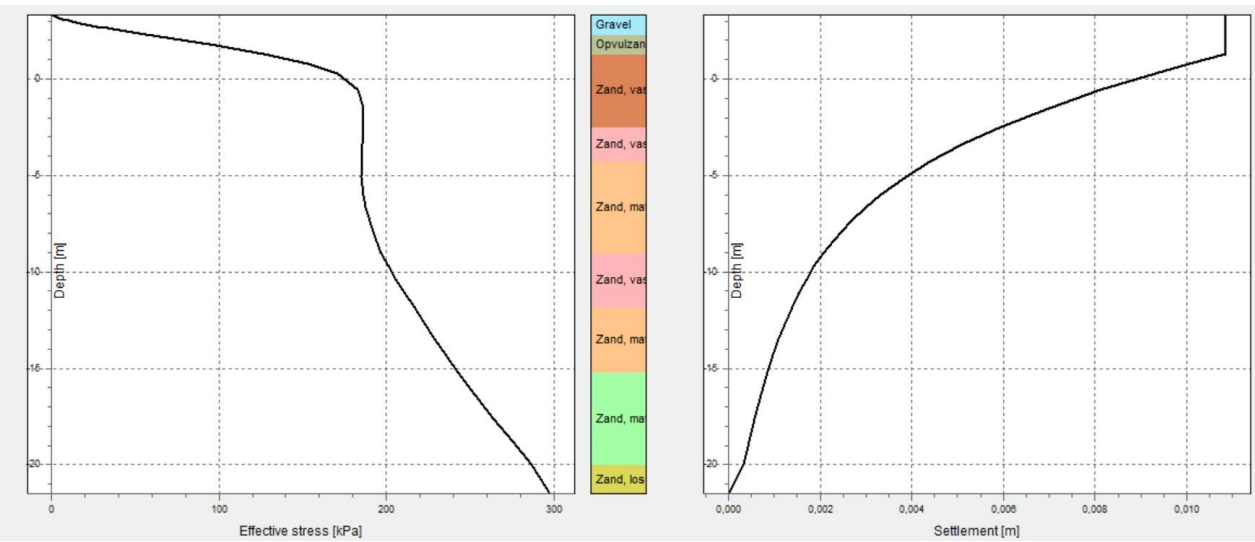


Figure 9-1:settlement results for the Crane Hardstand above high water level

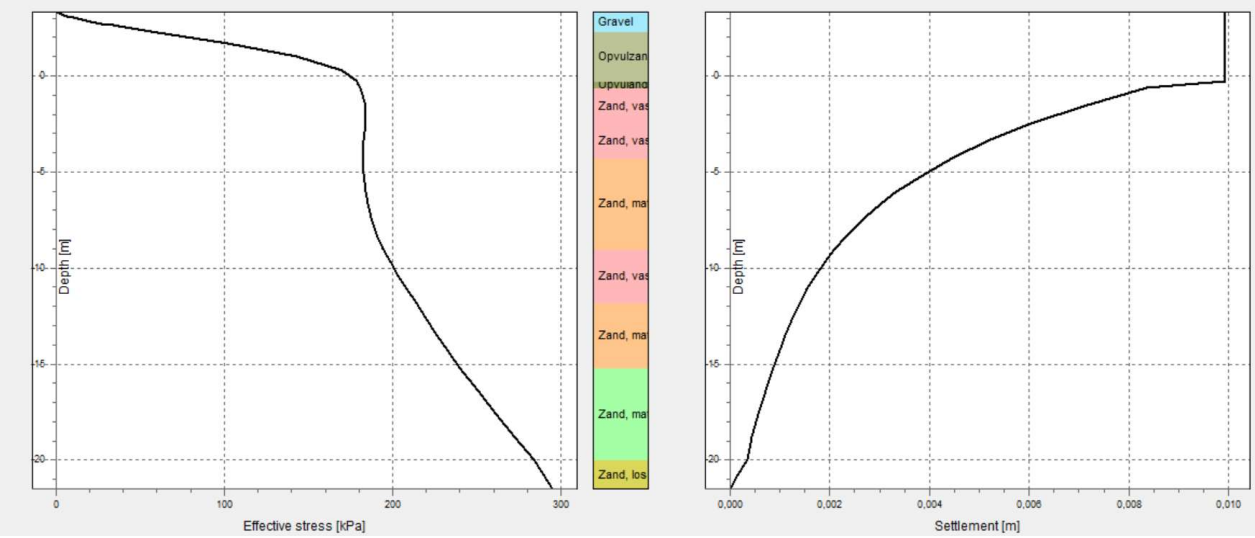


Figure 9-2:settlement results for the Crane Hardstand in intertidal zone

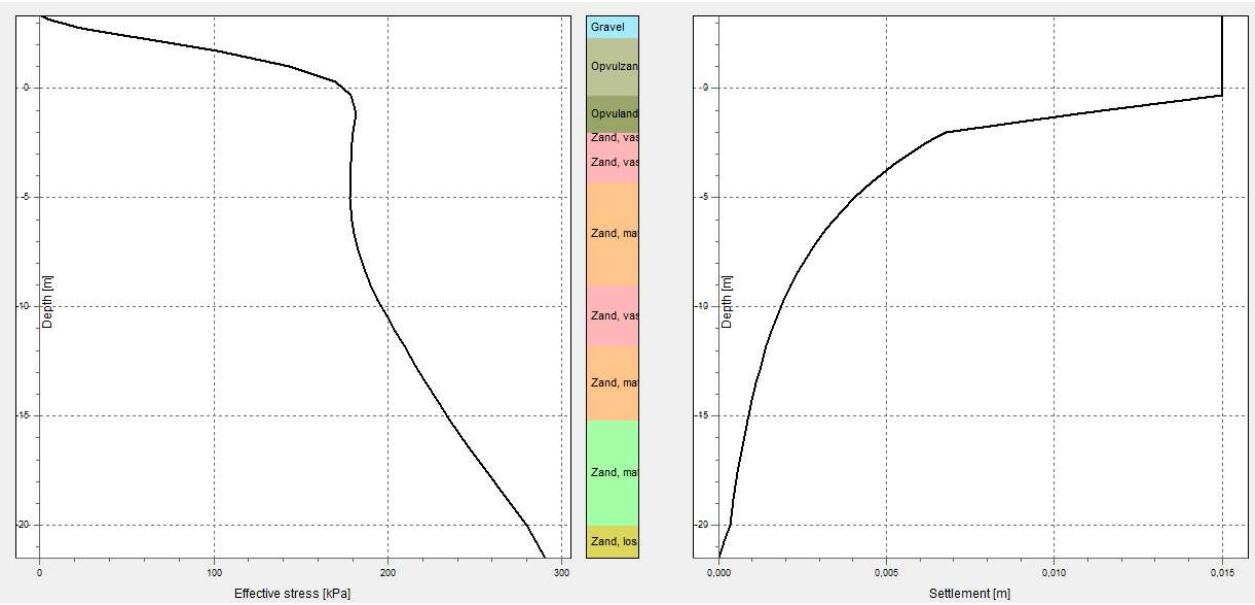


Figure 9-3: settlement results for the Crane Hardstand below low water level

10 Conclusions

The following conclusions can be drawn based on the performed geotechnical calculations:

- The site is characterized by a sandy subsoil with high bearing capacity and low compressibility.
- The top level of the crane hardstands is NAP +3.32 m, one meter above high water with a 2 times a year return period.
- For the various crane hardstands the upper base layer should consist of:
    - MCHS: 1.0 m aggregate (0/32-0/45mm) with at least 2 layers of geogrid;
    - ACHS: 0.8 m aggregate (0/32-0/45mm) with 2 layers of geogrid;
    - Assembly Area: 0.65 m aggregate (0/32-0/45mm) with 2 layers of geogrid;
    - Compound Area: 0.3 m aggregate (0/32-0/45mm) with 1 layer of geogrid;
- The lower base layer can consist of sand. Above sea level the sand should be compacted.
- To prevent erosion and guarantee stability of the crane hardstand the following measures are recommended along the boundaries of the CHS:
    - For CHS above high water level: apply a geotextile on a slope with maximum gradient of 45˚;
    - For CHS in the intertidal zone: apply geotubes which are placed and filled during low tide;
    - For CHS above high water level: apply an anchored sheet pile wall, placed from a temporary platform.

Appendix 1: Results calculation bearing capacity

Model input

Load and parameter partial factors:

Parameter	Phi	Cohesion	Unit weight	Cu	permanent load	temporary load
Partial factor	1,15	1,6	1,1	1,35	1,5	1,5

Soil profile (the fill sand layers are adapted according to the required gravel thickness):

	Layer	Top [m GL]	Top [m NAP]	g_dry [kN/m3]	g_wet [kN/m3]	cohesion [kPa]	phi [deg]	cu [kPa]
1	Opvulzand	0.00	3.02	18.00	19.00	0.00	32.50	nan
2	Opvulzand (los)	-3.32	-0.30	17.00	19.00	0.00	30.00	nan
3	Zand, vast	-5.02	-2.00	19.00	21.00	0.00	35.00	nan
4	Zand vast	-5.52	-2.50	19.00	21.00	0.00	35.00	nan
5	Zand matig	-7.32	-4.30	18.00	20.00	0.00	32.50	nan
6	Zand vast	-12.02	-9.00	19.00	21.00	0.00	35.00	nan
7	Zand matig	-14.82	-11.80	18.00	20.00	0.00	32.50	nan
8	Zand matig-vast	-18.22	-15.20	18.50	20.50	0.00	33.50	nan
9	zand los	-23.02	-20.00	17.00	19.00	0.00	30.00	nan
10	veen matig	-24.52	-21.50	12.00	12.00	2.50	15.00	20.00
11	zand los-matig	-24.82	-21.80	17.50	19.50	0.00	33.50	nan
12	klei vast	-26.02	-23.00	19.00	19.00	13.00	17.50	13.00
13	zand matig	-36.02	-33.00	18.00	20.00	0.00	32.50	nan
14	nan	nan	nan	nan	nan	nan	nan	nan
15	nan	nan	nan	nan	nan	nan	nan	nan

Ground water level: NAP + 2,32 m

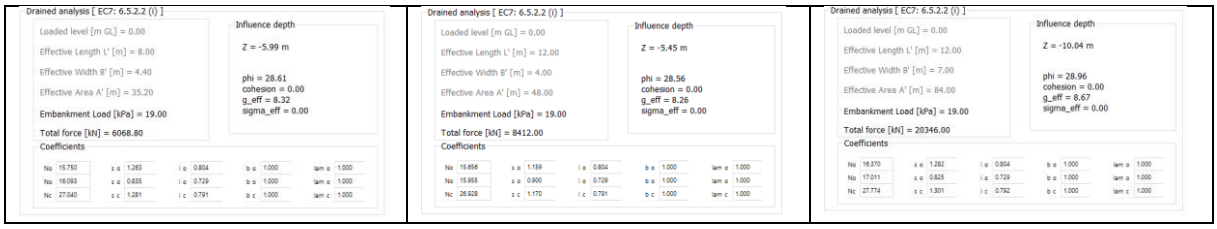
MCHS hard stand

Loads:

Qmin [kN/m2]	Effective length [m]	Effective width [m]	Rep. Vertical Force [kN]	Rep. Horizontal Force [kN]
250	6,0	2,4	5400	540
250	10,0	2,0	7500	750
250	10,0	5,0	18750	1875

Results:

2.4 m x 6.0 m	2.0 m x 10.0 m	5.0 m x 10.0 m



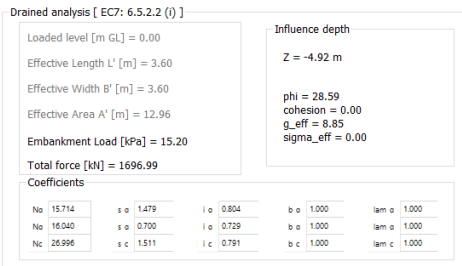
Hard stand	Foundation carne hard stand	qk [kPa]	Loaded area	Vd [kN]	Rd [kN]	u.c. (Vd ≤ Rd)
MCHS	1.0 m aggregate (0/32-0/45mm) with at least 2 layers of geogrid	250	2.4 m x 6.0 m	6069	6310	0.96
	1.0 m aggregate (0/320/45mm) with at least 2 layers of geogrid	250	2.0 m x 10.0 m	8412	8413	1.0
	1.0 m aggregate (0/32-0/45mm) with at least 2 layers of geogrid	250	5.0 m x 10.0 m	20346	25537	0.8

ACHS hard stand

Loads:

Qmin [kN/m2]	Effective length [m]	Effective width [m]	Rep. Vertical Force [kN]	Rep. Horizontal Force [kN]
250	2,0	2,0	1500	150

Results:



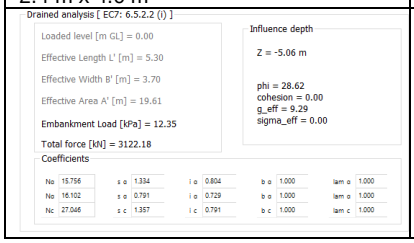
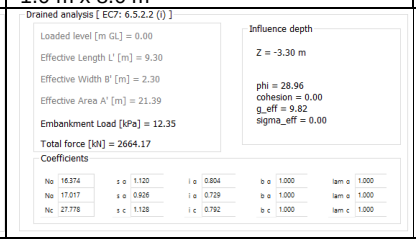
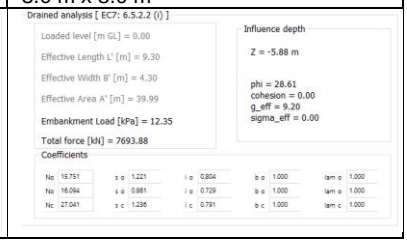
Hard stand	Foundation carne hard stand	qk [kPa]	Loaded area	Vd [kN]	Rd [kN]	u.c. (Vd ≤ Rd)
ACHS	0.8 m aggregate (0/32-0/45mm) with 2 layers of geogrid	250	2.0 m x 2.0 m	1697	1733	0.98

Assembly area

Loads:

Qmin [kN/m2]	Effective length [m]	Effective width [m]	Rep. Vertical Force [kN]	Rep. Horizontal Force [kN]
200	4,0	2,4	2880	288
200	8,0	1,0	2400	240
200	8,0	3,0	7200	720

Results:

2.4 m x 4.0 m	1.0 m x 8.0 m	3.0 m x 8.0 m
		

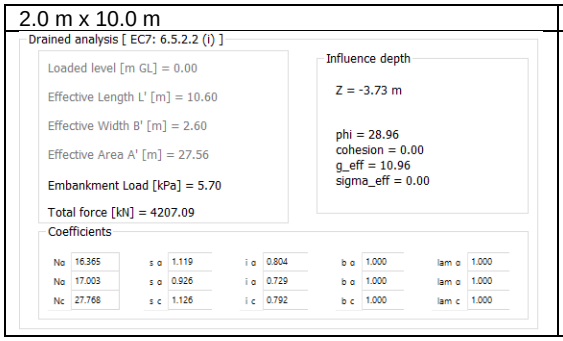
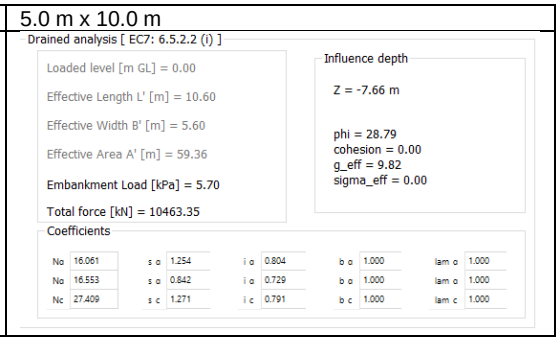
Hard stand	Foundation carne hard stand	qk [kPa]	Loaded area	Vd [kN]	Rd [kN]	u.c. (Vd ≤ Rd)
Assembly Area	0.65 m aggregate (0/32-0/45mm) with at least 2 layers of geogrid	200	2.4 m x 4.0 m	3122	3177	0.98
		200	1.0 m x 8.0 m	2664	2786	0.96
		200	3.0 m x 8.0 m	7694	8007	0.96

Compound area

Loads:

Qmin [kN/m2]	Effective length [m]	Effective width [m]	Rep. Vertical Force [kN]	Rep. Horizontal Force [kN]
135	10,0	2,0	4050	405
135	10,0	5,0	10125	1012,5

Results:

2.0 m x 10.0 m	5.0 m x 10.0 m
	

Hard stand	Foundation carne hard stand	qk [kPa]	Loaded area	Vd [kN]	Rd [kN]	u.c. (Vd ≤ Rd)
Compound Area	0.3 m aggregate (0/32-0/45mm) with 1 layer of geogrid	135	2.0 m x 10.0 m	4207	4529	0.93
		135	5.0 m x 10.0 m	10463	16507	0.63

Appendix 2: D-Sheet Pile results

Report for D-Sheet Piling 18.2

Design of Diaphragm and Sheet Pile Walls
Developed by Deltares

Company:	Royal HaskoningDHV
Date of report:	20-4-2020
Time of report:	15:24:32
Report with version:	18.2.1.20477
Date of calculation:	20-4-2020
Time of calculation:	15:21:02
Calculated with version:	18.2.1.20477
File name:	C:\..\kraanopstelplaatsen_ZZ_2_ankers

Verification according to National Annex of Eurocode 7 in the Netherlands (NEN 9997-1:2016)

1 Summary

1.1 Overview per Stage and Test

Stage nr.	Verification	Displace-ment [mm]	Moment [kNm]	Shear force [kN]	Mob. perc. moment [%]	Mob. perc. resistance [%]	Vertical balance
1	EC7(NL)-Step 6.3		-22,81	-10,01	0,0	11,4	---
1	EC7(NL)-Step 6.4		-22,13	11,11	0,0	11,5	---
1	EC7(NL)-Step 6.5	0,0	0,00	0,00	0,0	7,3	---
1	EC7(NL)-Step 6.5 * 1,20		0,00	0,00			
2	EC7(NL)-Step 6.3		-8,22	-8,14	0,0	13,8	---
2	EC7(NL)-Step 6.4		-9,05	-12,09	0,0	14,0	---
2	EC7(NL)-Step 6.5	-0,3	-3,20	-3,48	0,0	8,6	---
2	EC7(NL)-Step 6.5 * 1,20		-3,84	-4,18			
3	EC7(NL)-Step 6.3		-8,22	-8,14	12,8	13,8	---
3	EC7(NL)-Step 6.4		-9,05	-12,09	12,8	14,0	---
3	EC7(NL)-Step 6.5	-0,3	-3,20	-3,48	8,5	8,6	---
3	EC7(NL)-Step 6.5 * 1,20		-3,84	-4,18			
4	EC7(NL)-Step 6.3		-12,50	9,23	14,5	15,9	---
4	EC7(NL)-Step 6.4		-7,11	-9,69	14,5	16,1	---
4	EC7(NL)-Step 6.5	-0,5	-6,63	-8,07	9,5	9,9	---
4	EC7(NL)-Step 6.5 * 1,20		-7,96	-9,68			
5	EC7(NL)-Step 6.3		16,61	21,45	**16,1**	17,8	---
5	EC7(NL)-Step 6.4		14,96	19,59	**16,1**	18,1	---
5	EC7(NL)-Step 6.5	-0,8	11,38	-16,74	10,6	11,4	---
5	EC7(NL)-Step 6.5 * 1,20		13,66	-20,09			
6	EC7(NL)-Step 6.3		16,61	21,45	0,0	17,8	---
6	EC7(NL)-Step 6.4		14,96	19,59	0,0	18,1	---
6	EC7(NL)-Step 6.5	-0,8	11,38	-16,74	0,0	11,4	---
6	EC7(NL)-Step 6.5 * 1,20		13,66	-20,09			
7	EC7(NL)-Step 6.3		30,93	42,08	0,0	21,9	---
7	EC7(NL)-Step 6.4		24,74	37,95	0,0	22,0	---
7	EC7(NL)-Step 6.5	-1,4	23,60	-36,43	0,0	14,1	---
7	EC7(NL)-Step 6.5 * 1,20		28,32	-43,72			
8	EC7(NL)-Step 6.3		257,62	285,30	0,0	53,1	---
8	EC7(NL)-Step 6.4		173,99	244,43	0,0	55,3	---
8	EC7(NL)-Step 6.5	-5,8	145,30	-211,71	0,0	34,3	---
8	EC7(NL)-Step 6.5 * 1,20		174,36	-254,05			
9	EC7(NL)-Step 6.3		**410,38**	**-395,79**	0,0	61,7	---
9	EC7(NL)-Step 6.4		318,35	-355,26	0,0	**63,7**	---
9	EC7(NL)-Step 6.5	**-8,0**	198,99	-272,56	0,0	42,6	---
9	EC7(NL)-Step 6.5 * 1,20		238,79	-327,08			
Max		**-8,0**	**410,38**	**-395,79**	**16,1**	**63,7**	---

1.2 Supports

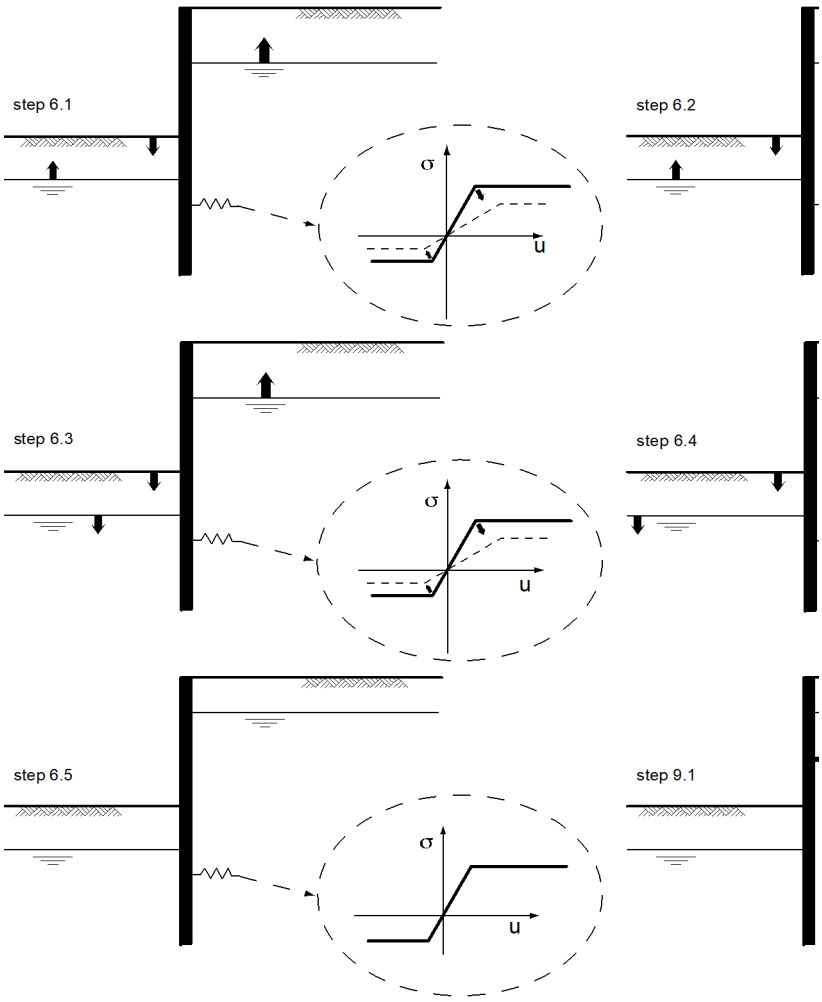
Stage nr.	Verification type	Support leganker 2		Support leganker 1	
		Force [kN]	Moment [kNm]	Force [kN]	Moment [kNm]
1	EC7(NL)-Step 6.3	-	-	-	-
2	EC7(NL)-Step 6.3	-	-	-	-
3	EC7(NL)-Step 6.3	-	-	-	-
4	EC7(NL)-Step 6.3	10,82	-	-	-
5	EC7(NL)-Step 6.3	36,40	-	-	-
6	EC7(NL)-Step 6.3	36,40	-	-	-
7	EC7(NL)-Step 6.3	79,26	-	17,20	-
8	EC7(NL)-Step 6.3	550,60	-	150,57	-
9	EC7(NL)-Step 6.3	768,52	-	76,24	-

Stage nr.	Verification type	Support leganker 2		Support leganker 1	
		Force [kN]	Moment [kNm]	Force [kN]	Moment [kNm]
1	EC7(NL)-Step 6.4	-	-	-	-
2	EC7(NL)-Step 6.4	-	-	-	-
3	EC7(NL)-Step 6.4	-	-	-	-
4	EC7(NL)-Step 6.4	10,83	-	-	-
5	EC7(NL)-Step 6.4	34,43	-	-	-
6	EC7(NL)-Step 6.4	34,43	-	-	-
7	EC7(NL)-Step 6.4	72,68	-	19,35	-
8	EC7(NL)-Step 6.4	465,62	-	190,55	-
9	EC7(NL)-Step 6.4	689,14	-	121,22	-
1	EC7(NL)-Step 6.5 * 1,20	-	-	-	-
2	EC7(NL)-Step 6.5 * 1,20	-	-	-	-
3	EC7(NL)-Step 6.5 * 1,20	-	-	-	-
4	EC7(NL)-Step 6.5 * 1,20	9,61	-	-	-
5	EC7(NL)-Step 6.5 * 1,20	37,56	-	-	-
6	EC7(NL)-Step 6.5 * 1,20	37,56	-	-	-
7	EC7(NL)-Step 6.5 * 1,20	83,31	-	18,93	-
8	EC7(NL)-Step 6.5 * 1,20	502,61	-	229,01	-
9	EC7(NL)-Step 6.5 * 1,20	622,08	-	200,54	-
Max		**768,52**	**-**	**229,01**	**-**

1.3 Overall Stability per Stage

Stage name	Stability factor [-]
Initial	10000,00
ophogen naar NA 0	11,45
Anker plaatsen	11,45
Aanbrengen terp en damwand	6,54
Aanvullen damwand	5,05
Verankering	5,05
Aanvullen tot 3,32	3,41
Aanbrengen belasting	1,38
Scour	1,26

1.4 CUR Verification Steps



End of Report

Appendix 3: D-Geo Stability Results

```
Program     : D-Geo Stability
Version     : 18.1.1.3
Company     : Royal HaskoningDHV
Date        : 16-4-2020
Time        : 14:12:07

Output file : C:\Users\909067\Box\BG8375 WP MV2 Team\BG8375 Technical Data WP
MV2\04_Geotechniek\VO Kraanopstelplaatsen ZZ\D-Stab sommen\ZZ_above high water level.sto
Input file  : C:\Users\909067\Box\BG8375 WP MV2 Team\BG8375 Technical Data WP
MV2\04_Geotechniek\VO Kraanopstelplaatsen ZZ\D-Stab sommen\ZZ_above high water level.sti
==========================    BEGINNING OF DATA     ==========================


               ECHO OF THE INPUT
               =================


 Problem identification :
                        :

 Calculation model      : Bishop
 Default shear strength : C phi

               LAYER BOUNDARIES
               ================

 Boundary no.| Co-ordinates [m]
 ------------|----------------------------------------------------
             |
   9  - X -  |   0.00    48.00    49.00    50.00   100.00
   9  - Y -  |   1.32     1.32     2.32     3.32     3.32
             |
   8  - X -  |   0.00    48.00    49.00   100.00
   8  - Y -  |   1.32     1.32     2.32     2.32
             |
   7  - X -  |   0.00    48.00   100.00
   7  - Y -  |   1.32     1.32     1.32
             |
   6  - X -  |   0.00   100.00
   6  - Y -  |  -2.50    -2.50
             |
   5  - X -  |   0.00   100.00
   5  - Y -  |  -4.30    -4.30
             |
   4  - X -  |   0.00   100.00
   4  - Y -  |  -9.00    -9.00
             |
   3  - X -  |   0.00   100.00
   3  - Y -  | -11.80   -11.80
             |
   2  - X -  |   0.00   100.00
   2  - Y -  | -15.20   -15.20
             |
   1  - X -  |   0.00   100.00
   1  - Y -  | -20.00   -20.00
             |
   0  - X -  |   0.00   100.00
   0  - Y -  | -21.50   -21.50


               PL-LINES
               ========

 Pl-line no. | Co-ordinates [m]
 ------------|----------------------------------------------------
             |
   1  - X -  |   0.00   100.00
   1  - Y -  |  -0.60    -0.60
```

Unit weight of water used for calculation: 9.81 [kN/m3]
The groundwater level is determined by Pl-line number 1

FORBIDDEN LINES

No forbidden lines were input.

SOIL PROPERTIES

Layer no.	Material name
9	Gravel
8	Opvulzand
7	Zand, vast
6	Zand, vast
5	Zand, matig
4	Zand, vast
3	Zand, matig
2	Zand, matig vast
1	Zand, los

Layer number	Gam usat [kN/m3]	Gam sat [kN/m3]	Pl-line top	Pl-line bottom
9	19.00	21.00	1	1
8	19.00	20.00	1	1
7	19.00	21.00	1	1
6	19.00	21.00	1	1
5	18.00	20.00	1	1
4	19.00	21.00	1	1
3	18.00	20.00	1	1
2	18.50	20.50	1	1
1	17.00	19.00	1	-

Layer number	Cohesion [kN/m2]	Phi [degrees]	Dilatancy [degrees]	S [-]	POP [kN/m2]	m [-]
9	0.00	28.00	29.25	-	-	-
8	0.00	27.00	0.00	-	-	-
7	0.00	29.25	0.00	-	-	-
6	0.00	29.25	0.00	-	-	-
5	0.00	27.00	0.00	-	-	-
4	0.00	29.25	0.00	-	-	-
3	0.00	27.00	0.00	-	-	-
2	0.00	27.90	0.00	-	-	-
1	0.00	24.79	0.00	-	-	-

Layer number	Su top [kN/m2]	Su bot. [kN/m2]	Su grad. [kN/m2/m]	POP top [kN/m2]	POP bot. [kN/m2]	Gamma LEM [-]
9	-	-	-	-	-	-
8	-	-	-	-	-	-
7	-	-	-	-	-	-
6	-	-	-	-	-	-
5	-	-	-	-	-	-
4	-	-	-	-	-	-
3	-	-	-	-	-	-
2	-	-	-	-	-	-
1	-	-	-	-	-	-

No degree of consolidation <> 100% input.

CENTER POINT GRID AND TANGENT LINES

```
X co-ordinate grid left                  :   38.15 [m]
X co-ordinate grid right                 :   61.82 [m]
Number of grid points in X - direction   :    25

Y co-ordinate grid bottom                :    3.43 [m]
Y co-ordinate grid top                   :   15.35 [m]
Number of grid points in Y - direction   :    20

Y co-ordinate tangent smallest circle    :    1.26 [m]
Y co-ordinate tangent biggest  circle    :  -10.00 [m]
Number of circles per grid point         :    20
```

No fixed points input.

Total number of center points in the grid: 500
Total number of slip circles in the grid : 10000

MEASURED YIELD STRESS

No measured yield stress input.

LINE LOADS

No line loads were input.

UNIFORM LOAD

Uniform load number	Magnitude [kN/m]	X start [m]	X end [m]	Distrib. degrees	Load Type
1	372.00	52.00	64.00	45.00	Temporary

TREE ON SLOPE

No tree on slope was input.

DEGREE OF CONSOLIDATION : TEMPORARY LOADS

Layer number	Degree of consolidation
9	100
8	100
7	100
6	100
5	100
4	100
3	100
2	100
1	100

GEOTEXTILES

Geotextile number	E.T.S [kN/m]	X start [m]	X end [m]	Y [m]	reduction zone [m]
1	10.00	47.68	49.00	0.99	0.00
2	10.00	47.03	47.69	1.00	0.00
3	10.00	46.72	47.05	1.32	0.00
4	10.00	49.00	50.99	2.31	0.00
5	10.00	49.70	70.00	3.00	3.00
6	10.00	49.33	70.13	2.63	3.00

E.T.S. = Effective tensile strength

NAILS

No nails were input.

EARTHQUAKE

No earth quake factors were input.

********** The input has been tested, and is correct. **********
****

RESULTS OF THE SLOPE STABILITY ANALYSIS
==========

Information on the critical circle : Fmin = 1.126
Calculation method used : Bishop - C phi
==========

X co-ordinate center point : 49.98 [m]
Y co-ordinate center point : 8.45 [m]
Radius of critical circle : 13.71 [m]

The center point of the critical circle is enclosed

Total driving moment : -32123.56 [kNm/m]
Driving moment free water : 0.00 [kNm/m]
Driving moment external loads : -29302.07 [kNm/m]
Iterated resisting moment : 36181.70 [kNm/m]
Non-iterated resisting moment : 35760.21 [kNm/m]

Information of the geotextile results
==========

nr	intersection point X-coord [m]	intersection point Y-coord [m]	embedding length min. [m]	mobilized embedd. tensile strength [%]	mobilized embedd. tensile strength [kN/m]	resisting moment [kNm/m]
1	0.00	0.00	0.00	0	0.00	0.00
2	0.00	0.00	0.00	0	0.00	0.00
3	0.00	0.00	0.00	0	0.00	0.00
4	0.00	0.00	0.00	0	0.00	0.00
5	62.56	3.00	7.44	100	10.00	54.49
6	62.40	2.63	7.73	100	10.00	58.15
Total resisting moment from geotextiles						112.64

END OF D-Geo Stability OUTPUT
==========

```
Program     : D-Geo Stability
Version     : 18.1.1.3
Company     : Royal HaskoningDHV
Date        : 20-4-2020
Time        : 11:43:12

Output file : C:\Users\909067\Box\BG8375 WP MV2 Team\BG8375 Technical Data WP
MV2\04_Geotechniek\VO Kraanopstelplaatsen ZZ\D-Stab sommen\ZZ_in_intertidal_zone.sto
Input file  : C:\Users\909067\Box\BG8375 WP MV2 Team\BG8375 Technical Data WP
MV2\04_Geotechniek\VO Kraanopstelplaatsen ZZ\D-Stab sommen\ZZ_in_intertidal_zone.sti
==========================    BEGINNING OF DATA     ==========================


               ECHO OF THE INPUT
               =================


 Problem identification :
                        :

 Calculation model      : Bishop
 Default shear strength : C phi

               LAYER BOUNDARIES
               ================

 Boundary no.| Co-ordinates [m]
 ------------|-----------------------------------------------------
             |
  10  - X -  |   0.00    44.48    44.72    45.28    46.40    47.04
  10  - Y -  |  -0.60    -0.60     0.07     0.71     0.83     0.98
             |
  10  - X -  |  47.12    47.56    48.23    49.00    50.00   100.00
  10  - Y -  |   1.38     2.02     2.30     2.32     3.32     3.32
             |
   9  - X -  |   0.00    44.48    46.08    49.00    50.00   100.00
   9  - Y -  |  -0.60    -0.60    -0.60     2.32     3.32     3.32
             |
   8  - X -  |   0.00    44.48    46.08    49.00   100.00
   8  - Y -  |  -0.60    -0.60    -0.60     2.32     2.32
             |
   7  - X -  |   0.00    44.48    46.08   100.00
   7  - Y -  |  -0.60    -0.60    -0.60    -0.60
             |
   6  - X -  |   0.00   100.00
   6  - Y -  |  -2.50    -2.50
             |
   5  - X -  |   0.00   100.00
   5  - Y -  |  -4.30    -4.30
             |
   4  - X -  |   0.00   100.00
   4  - Y -  |  -9.00    -9.00
             |
   3  - X -  |   0.00   100.00
   3  - Y -  | -11.80   -11.80
             |
   2  - X -  |   0.00   100.00
   2  - Y -  | -15.20   -15.20
             |
   1  - X -  |   0.00   100.00
   1  - Y -  | -20.00   -20.00
             |
   0  - X -  |   0.00   100.00
   0  - Y -  | -21.50   -21.50


               PL-LINES
               ========

 Pl-line no. | Co-ordinates [m]
```

```
------------|-----------------------------------------------------
            |
  1  - X -  |   0.00   100.00
  1  - Y -  |  -0.60    -0.60
```

Unit weight of water used for calculation: 9.81 [kN/m3]
The groundwater level is determined by Pl-line number 1

FORBIDDEN LINES
==========

Line number	X-start [m]	Y-start [m]	X-end [m]	Y-end [m]
1	44.50	-0.60	53.60	-0.60
2	50.26	2.29	53.60	-0.60
3	48.26	2.29	50.26	2.29

SOIL PROPERTIES
==========

Layer no.	Material name
10	Opvulzand
9	Gravel
8	Opvulzand
7	Zand, vast
6	Zand, vast
5	Zand, matig
4	Zand, vast
3	Zand, matig
2	Zand, matig vast
1	Zand, los

Layer number	Gam usat [kN/m3]	Gam sat [kN/m3]	Pl-line top	Pl-line bottom
10	19.00	20.00	1	1
9	19.00	21.00	1	1
8	19.00	20.00	1	1
7	19.00	21.00	1	1
6	19.00	21.00	1	1
5	18.00	20.00	1	1
4	19.00	21.00	1	1
3	18.00	20.00	1	1
2	18.50	20.50	1	1
1	17.00	19.00	1	-

Layer number	Cohesion [kN/m2]	Phi [degrees]	Dilatancy [degrees]	S [-]	POP [kN/m2]	m [-]
10	0.00	27.00	0.00	-	-	-
9	0.00	29.25	0.00	-	-	-
8	0.00	27.00	0.00	-	-	-
7	0.00	29.25	0.00	-	-	-
6	0.00	29.25	0.00	-	-	-
5	0.00	27.00	0.00	-	-	-
4	0.00	29.25	0.00	-	-	-
3	0.00	27.00	0.00	-	-	-
2	0.00	27.90	0.00	-	-	-
1	0.00	24.79	0.00	-	-	-

Layer number	Su top [kN/m2]	Su bot. [kN/m2]	Su grad. [kN/m2/m]	POP top [kN/m2]	POP bot. [kN/m2]	Gamma LEM [-]

10	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-

No degree of consolidation <> 100% input.

CENTER POINT GRID AND TANGENT LINES

X co-ordinate grid left : 41.74 [m]
X co-ordinate grid right : 57.79 [m]
Number of grid points in X - direction : 25

Y co-ordinate grid bottom : 4.60 [m]
Y co-ordinate grid top : 13.35 [m]
Number of grid points in Y - direction : 20

Y co-ordinate tangent smallest circle : -1.87 [m]
Y co-ordinate tangent biggest circle : -3.68 [m]
Number of circles per grid point : 5

No fixed points input.

Total number of center points in the grid: 500
Total number of slip circles in the grid : 2500

MEASURED YIELD STRESS

No measured yield stress input.

LINE LOADS

No line loads were input.

UNIFORM LOAD

Uniform load number	Magnitude [kN/m]	X start [m]	X end [m]	Distrib. degrees	Load Type
1	286.00	52.00	64.00	45.00	Temporary

TREE ON SLOPE

No tree on slope was input.

DEGREE OF CONSOLIDATION : TEMPORARY LOADS

==========

Layer number	Degree of consolidation
10	100
9	100
8	100
7	100
6	100
5	100
4	100
3	100
2	100
1	100

GEOTEXTILES

Geotextile number	E.T.S [kN/m]	X start [m]	X end [m]	Y [m]	reduction zone [m]
1	150.00	49.70	70.00	3.00	3.00
2	600.00	49.33	70.13	2.63	3.00

E.T.S. = Effective tensile strength

NAILS

No nails were input.

EARTHQUAKE

No earth quake factors were input.

********** The input has been tested, and is correct. **********
****

RESULTS OF THE SLOPE STABILITY ANALYSIS
==========

The center point of the critical circle lies on the edge of the grid.

```
New grid with  : X minimum =   41.74 [m]
                 X maximum =   57.79 [m]
                 Y minimum =    4.60 [m]
                 Y maximum =   13.35 [m]
           tangent minimum =   -5.04 [m]
           tangent maximum =   -3.23 [m]
```

The center point of the critical circle lies on the edge of the grid.

```
New grid with  : X minimum =   41.74 [m]
                 X maximum =   57.79 [m]
                 Y minimum =    4.60 [m]
                 Y maximum =   13.35 [m]
           tangent minimum =   -6.39 [m]
           tangent maximum =   -4.58 [m]
```

The center point of the critical circle lies on the edge of the grid.

```
New grid with  : X minimum =   41.74 [m]
                 X maximum =   57.79 [m]
                 Y minimum =    4.60 [m]
                 Y maximum =   13.35 [m]
           tangent minimum =   -7.75 [m]
           tangent maximum =   -5.94 [m]
```

```
Information on the critical circle  : Fmin =      1.147
Calculation method used             : Bishop - C phi
==============================================================================

X co-ordinate center point      :        48.43 [m]
Y co-ordinate center point      :         5.52 [m]
Radius of critical circle       :        12.82 [m]
```

The center point of the critical circle is enclosed

```
Total driving moment            :    -26205.85 [kNm/m]
Driving moment free water       :         0.00 [kNm/m]
Driving moment external loads   :    -20993.31 [kNm/m]
Iterated resisting moment       :     30045.73 [kNm/m]
Non-iterated resisting moment   :     29594.49 [kNm/m]
```

Information of the geotextile results
==========

nr	intersection point X-coord [m]	intersection point Y-coord [m]	embedding length min. [m]	mobilized embedd. tensile strength [%]	mobilized embedd. tensile strength [kN/m]	resisting moment [kNm/m]
1	61.00	3.00	9.00	100	150.00	378.31
2	60.92	2.63	9.21	100	600.00	1735.23
Total resisting moment from geotextiles						2113.54

END OF D-Geo Stability OUTPUT
==========

Appendix 4: D-Settlement results

Report for D-Settlement 18.2

Settlement Calculations
Developed by Deltares

Company:	Royal HaskoningDHV
Date of report:	16-4-2020
Time of report:	15:35:57
Report with version:	18.2.1.20481
Date of calculation:	16-4-2020
Time of calculation:	14:49:08
Calculated with version:	18.2.1.20481
File name:	C:\..\zettingen\kraanopstelplaatsen_ZZ_zettingen_above_high_water

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2 Echo of the Input

2.1 Layer Boundaries

Boundary number	Co-ordinates [m]				
9 - X -	0,000	100,000			
9 - Y -	3,320	3,320			
8 - X -	0,000	100,000			
8 - Y -	2,320	2,320			
7 - X -	0,000	100,000			
7 - Y -	1,320	1,320			
6 - X -	0,000	100,000			
6 - Y -	-2,500	-2,500			
5 - X -	0,000	100,000			
5 - Y -	-4,300	-4,300			
4 - X -	0,000	100,000			
4 - Y -	-9,000	-9,000			
3 - X -	0,000	100,000			
3 - Y -	-11,800	-11,800			
2 - X -	0,000	100,000			
2 - Y -	-15,200	-15,200			
1 - X -	0,000	100,000			
1 - Y -	-20,000	-20,000			
0 - X -	0,000	100,000			
0 - Y -	-21,500	-21,500			

2.2 General Data

Soil model:	NEN Bjerrum
Consolidation model:	Darcy
Strain model:	Linear
Groundwater level:	Initial determined by Pl-line number 1
Unit weight of water:	9,81 [kN/m³]
Stress distribution	
- Soil:	Buisman
- Loads:	None
End of consolidation:	10000,00 [days]
No maintain profile	
Pc (initial):	Variable parallel to the initial effective stress
Pc (per step):	Automatic increased to the final effective stresses
Creep rate reference time:	1,000 [days]
No imaginary surface	
With submerging	
(only for non uniform loads)	
- Iteration stop criterium :	0,10 [m]
Load column width	
- Non-Uniform Loads :	1,00 [m]
- Trapeziform Loads :	1,00 [m]

2.3 Soil Profiles

Layer number	Material name	Pl-line top	Pl-line bottom
9	Gravel	1	1
8	Opvulzand	1	1
7	Zand, vast + POP	1	1
6	Zand, vast	1	1
5	Zand, matig	1	1
4	Zand, vast	1	1
3	Zand, matig	1	1
2	Zand, matig vast	1	1
1	Zand, los	1	1

2.4 Soil Properties

Layer number	Drained	Unit weight	
		Unsaturated [kN/m³]	Saturated [kN/m³]
9	Yes	19,00	21,00
8	Yes	18,00	20,00
7	Yes	19,00	21,00
6	Yes	19,00	21,00
5	Yes	18,00	20,00
4	Yes	19,00	21,00
3	Yes	18,00	20,00
2	Yes	18,50	20,50
1	Yes	17,00	18,00

Layer number	Storage type	Vert. consolid. coefficient Cv [m²/s]	Vertical permeability [m/s]	Permeability strain mod. [-]	Initial vertical permeability [m/s]
9	Vert. cons.	-	-	-	-
8	Vert. cons.	-	-	-	-
7	Vert. cons.	-	-	-	-
6	Vert. cons.	-	-	-	-
5	Vert. cons.	-	-	-	-
4	Vert. cons.	-	-	-	-
3	Vert. cons.	-	-	-	-
2	Vert. cons.	-	-	-	-
1	Vert. cons.	-	-	-	-

Layer number	POP [kN/m²]	OCR [-]	Equiv. age [days]
9	-	1,00	-
8	-	1,00	-
7	5,00	-	-
6	-	1,00	-
5	-	1,00	-
4	-	1,00	-
3	-	1,00	-
2	-	1,00	-
1	0,00	-	-

Layer number	Secondary swelling type	Secondary swelling factor[-]	Unloading stress ratio[-]
9	Full	-	-
8	Full	-	-
7	Full	-	-
6	Full	-	-
5	Full	-	-
4	Full	-	-
3	Full	-	-
2	Full	-	-
1	Full	-	-

Layer number	Reloading/ swelling ratio RR [-]	Compression ratio CR [-]	Coeff. of sec. compression Ca [-]	Reloading/ swelling index Cr [-]	Compression index Cc [-]	Initial void ratio (e0) [-]
9	0,0000001	0,0000001	0,0000000	-	-	-
8	0,0000001	0,0000001	0,0000000	-	-	-
7	0,0011000	0,0031000	0,0000000	-	-	-
6	0,0011000	0,0031000	0,0000000	-	-	-
5	0,0011000	0,0031000	0,0000000	-	-	-
4	0,0011000	0,0031000	0,0000000	-	-	-
3	0,0011000	0,0031000	0,0000000	-	-	-
2	0,0013000	0,0038000	0,0000000	-	-	-
1	0,0038000	0,0115000	0,0000000	-	-	-

2.5 Rectangular Loads

Load number	Time [days]	Magnitude [kN/m²]	Dimension Width(x) [m]	Dimension Width(z) [m]	Center X [m]	Center Y [m]	Center Z [m]	Shape factor [-]
1	1	250,00	10,00	5,00	50,00	3,32	0,00	0,00

2.6 Verticals

Vertical number	X co-ordinates [m]				
1 - 5	0,000	34,000	35,000	45,000	49,728
6 - 9	55,000	65,000	66,000	100,000	

Discretisation = 20

3 Results per Vertical

3.1 Results for Vertical 5 (X = 49,73 m; Z = 0,00 m)

Depth [m]	Effective Stress [kPa]	Hydraulic head [m]	Loading [kPa]	Settlement [m]
3,320	0,741	3,320	0,740	0,011
3,220	3,089	3,220	1,189	0,011
3,120	6,324	3,120	2,524	0,011
3,020	10,409	3,020	4,709	0,011
2,920	15,286	2,920	7,686	0,011
2,820	20,881	2,820	11,381	0,011
2,720	27,103	2,720	15,703	0,011
2,620	33,852	2,620	20,552	0,011
2,520	41,022	2,520	25,822	0,011
2,420	48,506	2,420	31,406	0,011
2,320	56,201	2,320	37,201	0,011
2,320	56,201	2,320	37,201	0,011
1,820	94,215	1,820	66,215	0,011
1,320	126,957	1,320	89,957	0,011
1,320	126,957	1,320	89,957	0,011
0,800	153,074	0,800	106,194	0,010
0,300	170,731	0,300	114,351	0,009
-0,590	182,949	0,300	116,610	0,008
-1,500	186,455	0,300	109,933	0,007
-2,500	186,306	0,300	98,594	0,006
-2,500	186,306	0,300	98,594	0,006
-3,400	185,501	0,300	87,718	0,005
-4,300	185,292	0,300	77,438	0,004
-4,300	185,292	0,300	77,438	0,004
-5,050	185,158	0,300	69,662	0,004
-6,050	186,220	0,300	60,533	0,003
-6,650	187,516	0,300	55,716	0,003
-7,400	189,776	0,300	50,333	0,003
-8,400	193,772	0,300	44,139	0,002
-9,000	196,643	0,300	40,896	0,002
-9,000	196,643	0,300	40,896	0,002
-9,700	201,081	0,300	37,501	0,002
-10,400	205,890	0,300	34,477	0,002
-11,100	211,023	0,300	31,777	0,002
-11,800	216,441	0,300	29,362	0,001
-11,800	216,441	0,300	29,362	0,001
-12,700	222,867	0,300	26,617	0,001
-13,500	228,874	0,300	24,472	0,001
-14,300	235,118	0,300	22,564	0,001
-15,200	242,386	0,300	20,661	0,001
-15,200	242,386	0,300	20,661	0,001
-16,400	253,018	0,300	18,465	0,001
-17,600	263,970	0,300	16,589	0,001
-18,800	275,187	0,300	14,978	0,000
-20,000	286,622	0,300	13,585	0,000
-20,000	286,622	0,300	13,585	0,000
-20,750	291,989	0,300	12,810	0,000
-21,500	297,419	0,300	12,097	0,000

4 Settlements

4.1 Settlements

Vertical number	X co-ordinate [m]	Z co-ordinate [m]	Surface level [m]	Settlement [m]
1	0,00	0,00	3,32	0,000
2	34,00	0,00	3,32	0,001
3	35,00	0,00	3,32	0,001
4	45,00	0,00	3,32	0,009
5	49,73	0,00	3,32	0,011
6	55,00	0,00	3,32	0,009
7	65,00	0,00	3,32	0,001
8	66,00	0,00	3,32	0,001
9	100,00	0,00	3,32	0,000

End of Report

Report for D-Settlement 18.2

Settlement Calculations
Developed by Deltares

Company:	Royal HaskoningDHV
Date of report:	16-4-2020
Time of report:	15:38:17
Report with version:	18.2.1.20481
Date of calculation:	16-4-2020
Time of calculation:	14:41:22
Calculated with version:	18.2.1.20481
File name:	C:\..\zettingen\kraanopstelplaatsen_ZZ_zettingen_intertidal

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2 Echo of the Input

2.1 Layer Boundaries

Boundary number	Co-ordinates [m]				
10 - X -	0,000	100,000			
10 - Y -	3,320	3,320			
9 - X -	0,000	100,000			
9 - Y -	2,320	2,320			
8 - X -	0,000	100,000			
8 - Y -	-0,300	-0,300			
7 - X -	0,000	100,000			
7 - Y -	-0,600	-0,600			
6 - X -	0,000	100,000			
6 - Y -	-2,500	-2,500			
5 - X -	0,000	100,000			
5 - Y -	-4,300	-4,300			
4 - X -	0,000	100,000			
4 - Y -	-9,000	-9,000			
3 - X -	0,000	100,000			
3 - Y -	-11,800	-11,800			
2 - X -	0,000	100,000			
2 - Y -	-15,200	-15,200			
1 - X -	0,000	100,000			
1 - Y -	-20,000	-20,000			
0 - X -	0,000	100,000			
0 - Y -	-21,500	-21,500			

2.2 Pl-lines

Pl-line number	Co-ordinates [m]				
1 - X -	0,000	100,000			
1 - Y -	0,300	0,300			

2.3 General Data

Soil model:	NEN Bjerrum
Consolidation model:	Darcy
Strain model:	Linear
Groundwater level:	Initial determined by Pl-line number 1
Unit weight of water:	9,81 [kN/m³]
Stress distribution	
- Soil:	Buisman
- Loads:	None
End of consolidation:	10000,00 [days]
No maintain profile	
Pc (initial):	Variable parallel to the initial effective stress
Pc (per step):	Automatic increased to the final effective stresses
Creep rate reference time:	1,000 [days]
No imaginary surface	
With submerging	
(only for non uniform loads)	
- Iteration stop criterium :	0,10 [m]
Load column width	
- Non-Uniform Loads :	1,00 [m]
- Trapeziform Loads :	1,00 [m]

2.4 Soil Profiles

Layer number	Material name	Pl-line top	Pl-line bottom
10	Gravel	1	1
9	Opvulzand	1	1
8	Opvuland (los)	1	1

Layer number	Material name	Pl-line top	Pl-line bottom
7	Zand, vast	1	1
6	Zand, vast	1	1
5	Zand, matig	1	1
4	Zand, vast	1	1
3	Zand, matig	1	1
2	Zand, matig vast	1	1
1	Zand, los	1	1

2.5 Soil Properties

Layer number	Drained	Unit weight	
		Unsaturated [kN/m³]	Saturated [kN/m³]
10	Yes	19,00	21,00
9	Yes	18,00	20,00
8	Yes	17,00	18,00
7	Yes	19,00	21,00
6	Yes	19,00	21,00
5	Yes	18,00	20,00
4	Yes	19,00	21,00
3	Yes	18,00	20,00
2	Yes	18,50	20,50
1	Yes	17,00	18,00

Layer number	Storage type	Vert. consolid. coefficient Cv [m²/s]	Vertical permeability [m/s]	Permeability strain mod. [-]	Initial vertical permeability [m/s]
10	Vert. cons.	-	-	-	-
9	Vert. cons.	-	-	-	-
8	Vert. cons.	-	-	-	-
7	Vert. cons.	-	-	-	-
6	Vert. cons.	-	-	-	-
5	Vert. cons.	-	-	-	-
4	Vert. cons.	-	-	-	-
3	Vert. cons.	-	-	-	-
2	Vert. cons.	-	-	-	-
1	Vert. cons.	-	-	-	-

Layer number	POP [kN/m²]	OCR [-]	Equiv. age [days]
10	-	1,00	-
9	-	1,00	-
8	0,00	-	-
7	-	1,00	-
6	-	1,00	-
5	-	1,00	-
4	-	1,00	-
3	-	1,00	-
2	-	1,00	-
1	0,00	-	-

Layer number	Secondary swelling type	Secondary swelling factor[-]	Unloading stress ratio[-]
10	Full	-	-
9	Full	-	-
8	Full	-	-
7	Full	-	-
6	Full	-	-
5	Full	-	-
4	Full	-	-
3	Full	-	-
2	Full	-	-
1	Full	-	-

Layer number	Reloading/ swelling ratio RR [-]	Compression ratio CR [-]	Coeff. of sec. compression Ca [-]	Reloading/ swelling index Cr [-]	Compression index Cc [-]	Initial void ratio (e0) [-]
10	0,0000001	0,0000001	0,0000000	-	-	-
9	0,0000001	0,0000001	0,0000000	-	-	-
8	0,0038000	0,0115000	0,0000000	-	-	-
7	0,0011000	0,0031000	0,0000000	-	-	-
6	0,0011000	0,0031000	0,0000000	-	-	-
5	0,0011000	0,0031000	0,0000000	-	-	-
4	0,0011000	0,0031000	0,0000000	-	-	-
3	0,0011000	0,0031000	0,0000000	-	-	-
2	0,0013000	0,0038000	0,0000000	-	-	-
1	0,0038000	0,0115000	0,0000000	-	-	-

2.6 Rectangular Loads

Load number	Time	Magnitude	Dimension		Center			Shape factor
	[days]	[kN/m²]	Width(x) [m]	Width(z) [m]	X [m]	Y [m]	Z [m]	[-]
1	1	250,00	10,00	5,00	50,00	3,32	0,00	0,00

2.7 Verticals

Vertical number	X co-ordinates [m]				
1 - 5	0,000	34,000	35,000	45,000	49,728
6 - 9	55,000	65,000	66,000	100,000	

Discretisation = 20

3 Results per Vertical

3.1 Results for Vertical 5 (X = 49,73 m; Z = 0,00 m)

Depth [m]	Effective Stress [kPa]	Hydraulic head [m]	Loading [kPa]	Settlement [m]
3,320	0,741	3,320	0,740	0,010
3,220	3,089	3,220	1,189	0,010
3,120	6,324	3,120	2,524	0,010
3,020	10,409	3,020	4,709	0,010
2,920	15,286	2,920	7,686	0,010
2,820	20,881	2,820	11,381	0,010
2,720	27,103	2,720	15,703	0,010
2,620	33,852	2,620	20,552	0,010
2,520	41,022	2,520	25,822	0,010
2,420	48,506	2,420	31,406	0,010
2,320	56,201	2,320	37,201	0,010
2,320	56,201	2,320	37,201	0,010
1,710	102,044	1,710	72,064	0,010
1,010	143,250	1,010	100,670	0,010
0,300	169,707	0,300	114,347	0,010
-0,300	178,647	0,300	117,173	0,010
-0,300	178,647	0,300	117,173	0,010
-0,450	179,710	0,300	117,008	0,009
-0,600	180,502	0,300	116,571	0,008
-0,600	180,502	0,300	116,571	0,008
-1,550	183,987	0,300	109,426	0,007
-2,500	183,785	0,300	98,593	0,006
-2,500	183,785	0,300	98,593	0,006
-3,400	182,980	0,300	87,717	0,005
-4,300	182,771	0,300	77,437	0,004
-4,300	182,771	0,300	77,437	0,004
-5,050	182,638	0,300	69,661	0,004
-6,050	183,699	0,300	60,533	0,003
-6,650	184,996	0,300	55,716	0,003
-7,400	187,256	0,300	50,333	0,003
-8,400	191,252	0,300	44,139	0,002
-9,000	194,122	0,300	40,895	0,002
-9,000	194,123	0,300	40,895	0,002
-9,700	198,561	0,300	37,501	0,002
-10,400	203,370	0,300	34,477	0,002
-11,100	208,503	0,300	31,777	0,002
-11,800	213,920	0,300	29,361	0,001
-11,800	213,920	0,300	29,361	0,001
-12,700	220,347	0,300	26,617	0,001
-13,500	226,354	0,300	24,472	0,001
-14,300	232,598	0,300	22,564	0,001
-15,200	239,866	0,300	20,661	0,001
-15,200	239,866	0,300	20,661	0,001
-16,400	250,497	0,300	18,464	0,001
-17,600	261,450	0,300	16,589	0,001
-18,800	272,667	0,300	14,978	0,000
-20,000	284,102	0,300	13,585	0,000
-20,000	284,102	0,300	13,585	0,000
-20,750	289,469	0,300	12,810	0,000
-21,500	294,899	0,300	12,097	0,000

4 Settlements

4.1 Settlements

Vertical number	X co-ordinate [m]	Z co-ordinate [m]	Surface level [m]	Settlement [m]
1	0,00	0,00	3,32	0,000
2	34,00	0,00	3,32	0,001
3	35,00	0,00	3,32	0,001
4	45,00	0,00	3,32	0,008
5	49,73	0,00	3,32	0,010
6	55,00	0,00	3,32	0,008
7	65,00	0,00	3,32	0,001
8	66,00	0,00	3,32	0,001
9	100,00	0,00	3,32	0,000

End of Report

Report for D-Settlement 18.2

Settlement Calculations
Developed by Deltares

Company:	Royal HaskoningDHV
Date of report:	16-4-2020
Time of report:	15:37:34
Report with version:	18.2.1.20481
Date of calculation:	16-4-2020
Time of calculation:	15:36:18
Calculated with version:	18.2.1.20481
File name:	C:\..\zettingen\kraanopstelplaatsen_ZZ_zettingen_below_low_water

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4 Settlements 7
4.1 Settlements 7

2 Echo of the Input

2.1 Layer Boundaries

Boundary number	Co-ordinates [m]				
10 - X -	0,000	100,000			
10 - Y -	3,320	3,320			
9 - X -	0,000	100,000			
9 - Y -	2,320	2,320			
8 - X -	0,000	100,000			
8 - Y -	-0,300	-0,300			
7 - X -	0,000	100,000			
7 - Y -	-2,000	-2,000			
6 - X -	0,000	100,000			
6 - Y -	-2,500	-2,500			
5 - X -	0,000	100,000			
5 - Y -	-4,300	-4,300			
4 - X -	0,000	100,000			
4 - Y -	-9,000	-9,000			
3 - X -	0,000	100,000			
3 - Y -	-11,800	-11,800			
2 - X -	0,000	100,000			
2 - Y -	-15,200	-15,200			
1 - X -	0,000	100,000			
1 - Y -	-20,000	-20,000			
0 - X -	0,000	100,000			
0 - Y -	-21,500	-21,500			

2.2 General Data

Soil model:	NEN Bjerrum
Consolidation model:	Darcy
Strain model:	Linear
Groundwater level:	Initial determined by Pl-line number 1
Unit weight of water:	9,81 [kN/m³]
Stress distribution	
- Soil:	Buisman
- Loads:	None
End of consolidation:	10000,00 [days]
No maintain profile	
Pc (initial):	Variable parallel to the initial effective stress
Pc (per step):	Automatic increased to the final effective stresses
Creep rate reference time:	1,000 [days]
No imaginary surface	
With submerging	
(only for non uniform loads)	
- Iteration stop criterium :	0,10 [m]
Load column width	
- Non-Uniform Loads :	1,00 [m]
- Trapeziform Loads :	1,00 [m]

2.3 Soil Profiles

Layer number	Material name	Pl-line top	Pl-line bottom
10	Gravel	1	1
9	Opvulzand	1	1
8	Opvuland (los)	1	1
7	Zand, vast	1	1
6	Zand, vast	1	1
5	Zand, matig	1	1
4	Zand, vast	1	1
3	Zand, matig	1	1
2	Zand, matig vast	1	1

Layer number	Material name	Pl-line top	Pl-line bottom
1	Zand, los	1	1

2.4 Soil Properties

Layer number	Drained	Unit weight	
		Unsaturated [kN/m³]	Saturated [kN/m³]
10	Yes	19,00	21,00
9	Yes	18,00	20,00
8	Yes	17,00	18,00
7	Yes	19,00	21,00
6	Yes	19,00	21,00
5	Yes	18,00	20,00
4	Yes	19,00	21,00
3	Yes	18,00	20,00
2	Yes	18,50	20,50
1	Yes	17,00	18,00

Layer number	Storage type	Vert. consolid. coefficient Cv [m²/s]	Vertical permeability [m/s]	Permeability strain mod. [-]	Initial vertical permeability [m/s]
10	Vert. cons.	-	-	-	-
9	Vert. cons.	-	-	-	-
8	Vert. cons.	-	-	-	-
7	Vert. cons.	-	-	-	-
6	Vert. cons.	-	-	-	-
5	Vert. cons.	-	-	-	-
4	Vert. cons.	-	-	-	-
3	Vert. cons.	-	-	-	-
2	Vert. cons.	-	-	-	-
1	Vert. cons.	-	-	-	-

Layer number	POP [kN/m²]	OCR [-]	Equiv. age [days]
10	-	1,00	-
9	-	1,00	-
8	0,00	-	-
7	-	1,00	-
6	-	1,00	-
5	-	1,00	-
4	-	1,00	-
3	-	1,00	-
2	-	1,00	-
1	0,00	-	-

Layer number	Secondary swelling type	Secondary swelling factor[-]	Unloading stress ratio[-]
10	Full	-	-
9	Full	-	-
8	Full	-	-
7	Full	-	-
6	Full	-	-
5	Full	-	-
4	Full	-	-
3	Full	-	-
2	Full	-	-
1	Full	-	-

Layer number	Reloading/ swelling ratio RR [-]	Compression ratio CR [-]	Coeff. of sec. compression Ca [-]	Reloading/ swelling index Cr [-]	Compression index Cc [-]	Initial void ratio (e0) [-]
10	0,0000001	0,0000001	0,0000000	-	-	-
9	0,0000001	0,0000001	0,0000000	-	-	-
8	0,0038000	0,0115000	0,0000000	-	-	-

Layer number	Reloading/ swelling ratio RR [-]	Compression ratio CR [-]	Coeff. of sec. compression Ca [-]	Reloading/ swelling index Cr [-]	Compression index Cc [-]	Initial void ratio (e0) [-]
7	0,0011000	0,0031000	0,0000000	-	-	-
6	0,0011000	0,0031000	0,0000000	-	-	-
5	0,0011000	0,0031000	0,0000000	-	-	-
4	0,0011000	0,0031000	0,0000000	-	-	-
3	0,0011000	0,0031000	0,0000000	-	-	-
2	0,0013000	0,0038000	0,0000000	-	-	-
1	0,0038000	0,0115000	0,0000000	-	-	-

2.5 Rectangular Loads

Load number	Time [days]	Magnitude [kN/m²]	Dimension		Center			Shape factor [-]
			Width(x) [m]	Width(z) [m]	X [m]	Y [m]	Z [m]	
1	1	250,00	10,00	5,00	50,00	3,32	0,00	0,00

2.6 Verticals

Vertical number	X co-ordinates [m]				
1 - 5	0,000	34,000	35,000	45,000	49,728
6 - 9	55,000	65,000	66,000	100,000	

Discretisation = 20

3 Results per Vertical

3.1 Results for Vertical 5 (X = 49,73 m; Z = 0,00 m)

Depth [m]	Effective Stress [kPa]	Hydraulic head [m]	Loading [kPa]	Settlement [m]
3,320	0,741	3,320	0,740	0,015
3,220	3,089	3,220	1,189	0,015
3,120	6,324	3,120	2,524	0,015
3,020	10,409	3,020	4,709	0,015
2,920	15,286	2,920	7,686	0,015
2,820	20,881	2,820	11,381	0,015
2,720	27,103	2,720	15,703	0,015
2,620	33,852	2,620	20,552	0,015
2,520	41,022	2,520	25,822	0,015
2,420	48,506	2,420	31,406	0,015
2,320	56,201	2,320	37,201	0,015
2,320	56,201	2,320	37,201	0,015
1,710	102,044	1,710	72,064	0,015
1,010	143,250	1,010	100,670	0,015
0,300	169,667	0,300	114,307	0,015
-0,300	178,608	0,300	117,134	0,015
-0,300	178,608	0,300	117,134	0,015
-1,150	181,563	0,300	113,127	0,011
-2,000	179,909	0,300	104,512	0,007
-2,000	179,909	0,300	104,512	0,007
-2,250	179,784	0,300	101,589	0,006
-2,500	179,584	0,300	98,592	0,006
-2,500	179,584	0,300	98,592	0,006
-3,400	178,779	0,300	87,716	0,005
-4,300	178,570	0,300	77,436	0,005
-4,300	178,570	0,300	77,436	0,005
-5,050	178,437	0,300	69,660	0,004
-6,050	179,499	0,300	60,532	0,003
-6,650	180,796	0,300	55,715	0,003
-7,400	183,056	0,300	50,333	0,003
-8,400	187,052	0,300	44,139	0,002
-9,000	189,922	0,300	40,895	0,002
-9,000	189,922	0,300	40,895	0,002
-9,700	194,360	0,300	37,500	0,002
-10,400	199,169	0,300	34,476	0,002
-11,100	204,303	0,300	31,777	0,002
-11,800	209,720	0,300	29,361	0,001
-11,800	209,720	0,300	29,361	0,001
-12,700	216,147	0,300	26,617	0,001
-13,500	222,154	0,300	24,472	0,001
-14,300	228,398	0,300	22,564	0,001
-15,200	235,666	0,300	20,661	0,001
-15,200	235,666	0,300	20,661	0,001
-16,400	246,297	0,300	18,464	0,001
-17,600	257,250	0,300	16,589	0,001
-18,800	268,467	0,300	14,978	0,000
-20,000	279,902	0,300	13,585	0,000
-20,000	279,902	0,300	13,585	0,000
-20,750	285,269	0,300	12,810	0,000
-21,500	290,699	0,300	12,097	0,000

4 Settlements

4.1 Settlements

Vertical number	X co-ordinate [m]	Z co-ordinate [m]	Surface level [m]	Settlement [m]
1	0,00	0,00	3,32	0,000
2	34,00	0,00	3,32	0,001
3	35,00	0,00	3,32	0,001
4	45,00	0,00	3,32	0,012
5	49,73	0,00	3,32	0,015
6	55,00	0,00	3,32	0,012
7	65,00	0,00	3,32	0,001
8	66,00	0,00	3,32	0,001
9	100,00	0,00	3,32	0,000

End of Report