Rijkswaterstaat
Ministry of Infrastructure and Water Management

DELTA ACADEMY

Research Report

2018

Fenders Hansweert – Design proposal for improvement of the structure's performance

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Bachelor: Civil Engineering

Company: Rijkswaterstaat See and Delta

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Sullen Lourenco Lehmkuhl
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Rijkswaterstaat
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Preface

The research and design presented in this bachelor thesis was conducted in partnership between HZ University of Applied Sciences and Rijkswaterstaat Sea and Delta, under the supervision of professor ir. Piet Dekker and the in-company mentor Mr. ing. Rien Davidse in cooperation with ing. Anno Dijke. To them I am especially grateful for their faith in me, and for their encouragement and assistance.

This thesis is based on the Dutch design approach of water construction, and has been a challenging assignment due to the lack of information regarding the structure. Nevertheless, the Civil team of the department Waterways A (PPO) were promptly available to help in this journey, and to them I would like to thankfully acknowledge the assistance and support.

In addition to the hosts organizations, I would like to express my gratitude for the help provided by ing. René de Kok and Koch Adviesgroep for their support on the technical matters that were of great importance for the further development of the here presented design. Also, to Volker Infra and in especial Mr. Pascal Legierse, that has provided key information and documents regarding the structure. Furthermore, I would like to thank Mr. Ard Buteijn, the regional waterway traffic manager of Hansweert for the practical information on the local characteristics and practices.

Along my research, I learned that no project is the same, and that solutions must be defined even when not enough information or knowledge is present. I am grateful for the sharing of information, the professional guidance and skilled feedback from all those who became involved in my work.

Finally, I am grateful to my family, that even though far away they are always there to support me, and especially to my boyfriend Maurits, for his love, patience and support throughout the course of this work.

Sullen Lourenco Lehmkuhl

Vlissingen, June 2018

"The engineer is a mediator between the philosopher and the working mechanic and, like an interpreter between two foreigners must understand the language of both, hence the absolute necessity of possessing both practical and theoretical knowledge."

— Henry Palmer

Voorwoord

Het onderzoek en ontwerp gepresenteerd in dit afstudeer rapport werd uitgevoerd in partnerschap tussen HZ University of Applied Sciences en Rijkswaterstaat zee en Delta, onder toezicht van professor ir. Piet Dekker en In-company mentor Mr. ing. Rien Davidse in samenwerking met Anno Dijke. Aan hen ben ik enorm dankbaar voor hun vertrouw in mij, en hun aanmoediging en hulp.

Deze thesis is gebaseerd op de Nederlandse ontwerpbenadering van water constructies, en was een uitdaging wegens het ontbreken van informatie met betrekking tot de structuur. Desalniettemin stond het civiele team van de afdeling waterwegen A (PPO) voor mij klaar om mij te helpen met deze reis, en hen wil ik erkennen en bedanken voor de hulp en ondersteuning.

Naast de gastorganisaties wil ik mijn dank uitspreken voor de hulp die mij geboden is door ing. René de Kok en Koch Adviesgroep; voor hun steun aan de technische zaken die van groot belang waren voor de verdere ontwikkeling van het hier gepresenteerde ontwerp. Ook mijn dank voor Volker Infra, in het speciaal Mr. Pascal Legierse, voor de verstrekking van belangrijke informatie en documenten met betrekking tot de structuur. Voorts wil ik Mr. Ard Buteijn bedanken, de manager van de regionale binnenwateren-verkeer van Hansweert voor praktische informatie over de lokale kenmerken en werkwijzen.

Naast mijn onderzoek leerde ik dat geen enkel project hetzelfde is, en dat oplossingen moeten worden gedefinieerd, zelfs wanneer er niet voldoende informatie of kennis aanwezig is. Ik ben dankbaar voor het delen van informatie, de professionele begeleiding en de bekwame feedback van al diegenen die betrokken raakte in mijn werk.

Als laatste ben ik mijn familie dankbaar die, ook al zijn ze ver weg, altijd daar waren om mij te steunen en vooral aan mijn vriendje Maurits, voor zijn liefde, geduld en steun in de loop van dit werk.

Sullen Lourenco Lehmkuhl

Vlissingen, Juni 2018

"The engineer is a mediator between the philosopher and the working mechanic and, like an interpreter between two foreigners must understand the language of both, hence the absolute necessity of possessing both practical and theoretical knowledge."

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Summary

Some berthing facilities at Hansweert are showing a structural failure where the top element of the dolphin shows an undesired inclination, compromising the functionality and safety of the structure. Rijkswaterstaat Sea and Delta created an assignment in order to define the cause and provide a solution for this problem, which is provided throughout this document. The problem was defined by the use of a root cause analysis, evaluating the past events and possible failures of the structure, which concluded that a design failure is present, where the top element is allowed to rotate, causing increase of the load and therefore failure of elements. An analysis was also developed to determine the capacity of the pile foundation in order to assure the structure's capacity, which has been done with the support of DSheet-Piling and TS/Damwanden, in combination with the Fraanje method calculations. The results led to the need of a deeper penetration depth considering the future vessels that are going to be using the facility, nevertheless the Fraanje method with its less conservative approach supports that the structure is also capable to hold the load as it is. A multi-criteria analysis was performed based on the client's requirements of low implementation time and costs, as for the lifespan and assurance based on technical requirements from the "Eurocode normative". The final solution englobes the elongation of the foundation pile with 2,4 meters and the fixation of the pile cap to the foundation pile with the use of steel plates. In addition, two UPE profiles are used as a lock on the top side of the structure to prevent further rotation. It is recommended a proper investigation on the actual state of the foundation pile and further analysis with the use of "finite-elements" in order to validate and optimize the design hereby proposed.

Overzicht

Een aantal dukdalven faciliteiten in Hansweert tonen een structurele fout waar het bovenste element van de dukdalf een ongewenste inclinatie vertoond, die afbreuk doet aan de werking en de veiligheid van de structuur. Rijkswaterstaat Zee en Delta creëerde een opdracht om de oorzaak en de oplossing te definiëren voor dit probleem, dit wordt verstrekt in dit hele document. Het probleem werd gedefinieerd door middel van een probleemanalyse, een evaluatie van de gebeurtenissen uit het verleden en mogelijke fouten in de structuur, waarin werd geconcludeerd dat een ontwerpfout aanwezig is, waardoor het bovenste element kan roteren, die een toename van de belasting veroorzaakt en dus het falen van de elementen. Een analyse werd ook ontwikkeld om de capaciteit van de stapel fundering vaststellen, om te verzekeren dat de structuur voldoet, die is gedaan met de steun van DSheet-Piling and TS/Damwanden, in combinatie met de Fraanje methode berekeningen. De resultaten hebben geleid tot de noodzaak van een diepere indringingsdiepte met oog op de toekomstige schepen die gebruik moeten gaan maken van deze faciliteit, niettemin de Fraanje methode met zijn minder voorzichtige benadering ondersteunt dat de structuur ook in staat is om de belasting te dragen zoals het nu is. Een multi-criteria analyse werd uitgevoerd op basis van de eisen van de klanten van korte uitvoering tijd en lage kosten, alsook de levensduur en betrouwbaarheid op basis van technische voorschriften uit de "Eurocode normative". De uiteindelijke oplossing is het verlengen van de funderingspaal met 2,4 meter en de fixatie van de deksel van de stapel naar de funderingspaal, door het gebruik van stalen platen. Daarnaast worden twee UPE-profielen gebruikt als een slot op de bovenzijde van de structuur om verdere rotatie te voorkomen. Het is raadzaam een gedegen onderzoek uit te voeren naar de werkelijke stand van de funderingspaal en verdere analyse met het gebruik van "finite-elementen" om het hier voorgestelde ontwerp te valideren en te optimaliseren.

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1 Introduction

The department of Rijkswaterstaat See and Delta is responsible for the transportation infrastructure inland and waterways in the area of Zeeland region and North Sea. As part of it, RWS Sea and Delta is responsible of ensuring the availability and quality of marine and land ways. This area has a high importance due to the connection between the ports of Rotterdam, Amsterdam and Antwerp. The lock of Hansweert is placed in the canal through 'Zuid-Beveland', which connects the Eastern Scheldt to the Western Scheldt, moreover it is also part of the scope of RWS See and Delta.

In this area, the mooring facilities are encountering structural problems and a research is needed in order to define the solution for those problems. In order to do that, a case is opened, and this research was carried on in order to provide a suitable solution.

This document describes the steps to be taken along the research assignment, that had as objective to provide a solution for the client RWS in the case of the Fender in Hansweert. Here the research methods are pointed as the requirements specified by the client.

1.1 Problem Statement

Inspections realized by RWS in the driveways of Hansweert locks have observed several dolphins are compromised by hanging crooked. This curve suspension is a known problem and is already present from the construction. The dolphin consists of a pile and a pile cap. The pile cap hangs over the pile itself with the bottom part attached by a front fender, which are attached to the cap with chains. In the past, however, the chain was the weakest link in the structure and, once the chains break, the fenders tend to fall into the water and damaging the cap of the dolphins making it crooked. It is also possible that the fender shifts so that the cap also hangs obliquely on the inner post.

In 2014, the maintenance contractor applied a change to seven dolphins where a steel cable was used instead of a chain and a lock at the bottom of the fenders in order to prevent the pile caps to become crooked. During a later site visit, however, has been observed that four out of the seven dolphins adapted still have shown the same behavior as the others that have not been adapted.

Figure 1: Dolphin in Hansweert berthing facilities showing inclination. Source: RWS (2017)

1.1.1 Background

Due to the poorly aligned dolphin piles in the Hansweert locks, a dangerous situation arises. The misalignment of the pile caps can possibly cause damage to the ship when docking to these structures. It is possible that a steel beam sticks out instead of the wood that is supposed to be there to protect the ship.

In the past, several maintenance dolphins have been adapted by the maintenance contractor, although they have not showed the desired effect once several of them are already showing the same behavior of crooked caps. Since the chains and the steel cables did not achieve the desired effect on the structure, a different attachment must be worked out in order to solve this problem with the fenders.

1.1.2 Project Location

Lock Hansweert is located in the canal through 'Zuid-Beveland' in the region Zeeland, and it is part of the main route of transportation and waterways in the Netherlands (RWS, 2017). This infrastructure allows the connection between the Eastern Scheldt to the Westerns Scheldt, offering to the water transportation a short connection and therefore a great economic benefit.

Hansweert lock has had a traffic flow of 41,112 Vessels and 6,558 Recreational boats in the year of 2014 (Rijkswaterstaat, 2017), especially considering the route between Rotterdam-Antwerp. The capacity analysis performed by Rijkswaterstaat (2017) shows a scenario of major growth in the waterway traffic in the South-Beveland canal for the period of 2014-2050, that leads to an increased traffic of passage and berthing in the Hansweert lock. This shows the importance of maintaining and improving the capacity of the structures in order to be able to offer its services in the near future.

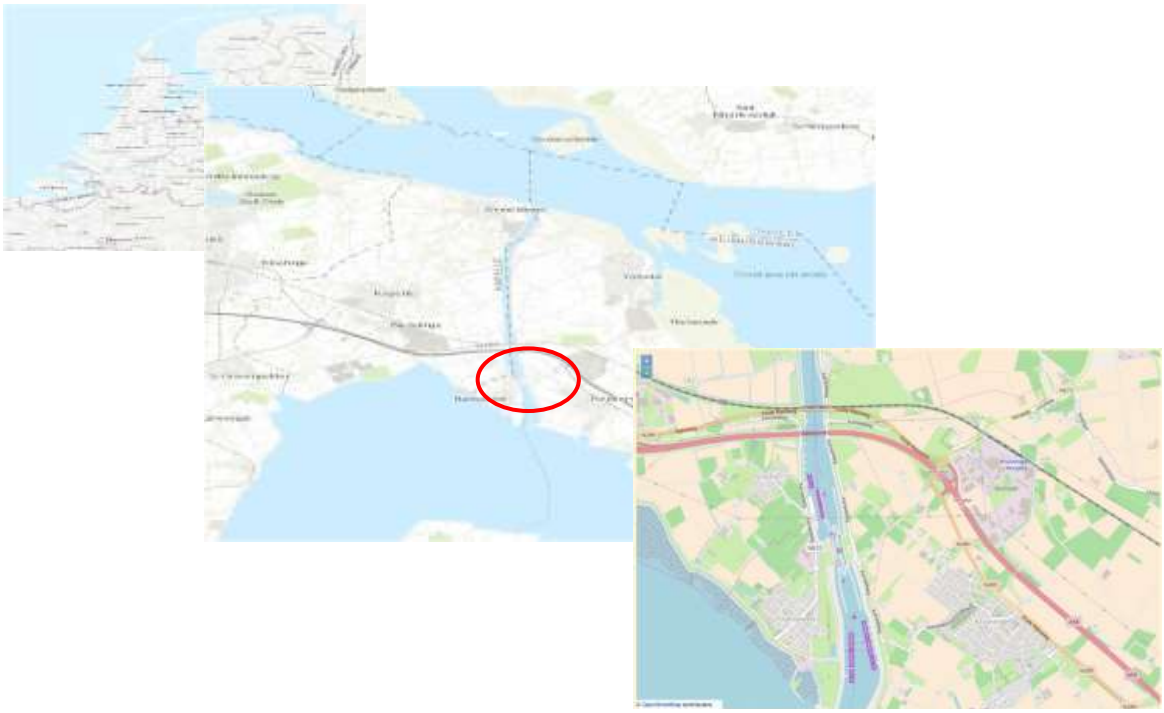


Figure 2 Research assignment location, Hansweert lock - The Netherlands. Source: ArcGIS online and RWS, 2018.

The actual lock has available two chambers with 280 meters length and 24 meters wide and has sliding gates. The tide difference in the Western Scheldt is around 4.5 meters, while in the South-Beveland canal the difference in tide is of around 3 meters (Steenepoorte K. , 2016).

1.1.3 Problem Statement

The dolphins of Hansweert are presenting an inclination in its structure that can compromise its workability as the safety of the users. Therefore a solution for this problem must be encountered.

1.2 Objective

The final objective of this research assignment is to develop a new constructive solution that must be found in order for the fenders to function as a mooring facility in the area of Hansweert lock harbor. This solution must comply with the guidelines and standards of RWS, must be adapted to the environment and meet the shipping traffic of the canal through Zuid-Beveland, for now and in the future.

Delivered products are a design report, with calculations and drawings in which the above solution is described and elaborated. A variance analysis and cost / benefit analysis should be part of the report.

1.3 Research question

What type of mooring structure should be used in order to improve the functionality of the mooring facility in the area of the Hansweert lock harbor?

Sub-questions

1. Why is the steel dolphin fender structure hanging crooked?
2. What are the updated requirements for the water furniture for this waterway?
3. Does the existing structure achieve the capacity needed at the present moment ?
4. What is the load capacity needed in the next 50 years?
5. What are possible solutions in this case?
6. What is the most suitable solution considering time-effectiveness, cost, assurance and safety for the actual situation?
7. What is the design for the encountered solution?

1.4 Research report overview

The research report is based on the sub-questions described above. Chapter 2 is the description of the Theoretical Background with definition of program of requirements as the limits and preconditions defined for the design. Subsequently Chapter 3 describes the methodology used in the approach of capacity analysis and design choices. Chapter 4 describes the design results acquired and the final solution choice. Chapter 5 brings the discussion related to the results and the research process. Chapter 6 gives an overall conclusion of the project. Moreover this document is finalized with the description of the used bibliography along this research.

2 Theoretical Background

This chapter describes the theoretical background to be used for the design process. Here all needed theory for the development of the research is described, in addition also the normative and guidelines that are followed by the design of the dolphin structure.

2.1 General

2.1.1 Definitions and Functions

Breasting Dolphins

These are open berthing structures in the category of pile berths according to Thoresen (2014). The function of this vertical structure is to provide safe mooring for vessels using the waterways.

Hard and Soft impact

An impact is characterized by a hard load, once the energy is completely absorbed by the structure. Nevertheless, an impact can be considered soft in the case of a spring construction that is therefore design to be able to have an allowed displacement in the moment of impact and energy absorption [2] (NEN-EN, 2002).

Serviceability Limit State (SLS)

For the calculation of the capacity of the foundation steel pile structure, the impact given by the mooring forces is considered as the serviceable approach in order to provide a realistic analysis of the current situation [8] (Smits & Meijerink, NIC: Handreiking rekenmethodieken NIC, 2005).

Ultimate Limit State (ULS)

The strength and stability of the structure is calculated based on the ultimate moment and berthing impact load to the structure [8] (Smits & Meijerink, NIC: Handreiking rekenmethodieken NIC, 2005).

2.1.2 Relevant Normative and Guidelines

Below are the normative and guidelines from which this design is based:

[1]	NEN-EN 1990	: Eurocode 1 - Basis of structural design;
[2]	NEN-EN 1991-1-7	: Eurocode 1: Loads on constructions
[3]	NEN-EN 1991-2	: Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges
[4]	NEN-EN 1993-1-1	: Design of steel structures - Part 1: Basis of design
[5]	NEN-EN 1993-1-8	: Design of steel structures - Part 1-8: Connections
[6]	NEN-EN 1993-5	: Design of steel structures - Part 5: Piling;
[7]	NEN-EN 1997-1	: Eurocode 7: Geotechnical design Part 1: General Rules;
[8]	NIC	: Handreiking rekenmethodieken RWS;
[9]	EAU2012	: Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004;
[10]	CUR 166	: Quay wall constructions (Damwandconstructies);
[11]	CUR 288	: Design Guidelines to soil horizontal loads on piles (Ontwerprichtlijnen door grond horizontal belaste palen);

[12] CUR 2001-4 : Design rules for driven piles (Ontwerpregels voor trekpalen)
[13] CUR 2001-8 : Bearing capacity of steel pipe piles;
[14] CUR 2011 : Handbook Quay Walls
[15] PIANC 2002 : Guidelines for the Design of Fender Systems;
[16] RVW2017 : Dutch Directive Waterways 2017 (Richtlijnen Vaarwegen 2017)
[17] ROK 1.4 : Dutch guidelines for infrastructur constructions (Richtlijnen Ontwerp Kunstwerken).
[18] RBK 1.1 : Dutch guidelines assessment of infrastructur constructions (Richtlijnen Beoordeling Kunstwerken).
[19] Waterbouwkunde (1968) : Waterbouwkunde deel 1: Algemene waterbouwkunde

Construction depth and levels

The northern lock complex has a depth of NAP -7.5m and the southern lock complex a depth of NAP -9.0m, as the canal bottom with 100 meters width in order to accommodate the pusher tugs with four dump barges.

Figure 3 Aereal view of Hansweert lock and its facilities.

According to Rijkswaterstaat (2016), the following are the vessels that are present in the local traffic.

Figure 4 List of vessel types that are currently making use of Hansweert Lock. Extracted from Steenepoorte (2016)

2.1.3 Local Characteristics

Tide

The tide pattern in the area shows a difference of 8.2 meters in height between high (+4.80 NAP) and low tide (-3.40 NAP) in an average of 1 time every 50 years (Rijkswaterstaat, 2011). This value is chosen once the design lifespan is considered of 50 years (Rijkswaterstaat, 2017).

Westerschelde
Hansweert

Standen in cm t.o.v. NAP

	Slotgemiddelden			Waarden maansverloop	
Getijtype cq grootheid	**HW-stand**	**LW-stand**	**tijverschil**	**HW**	**LW**
Gem. springtij	277	-226	503	1:55	8:20
Gem. tij	243	-201	444	1:51	8:14
Gem. doodtij	194	-168	362	1:43	8:08
Gem. duur rijzing				6:02	
Gem. duur daling				6:23	
Gem. waterstand		13			

Gemiddelde over- en onderschrijdingsfrequenties		
frequentie	**Overschrijding hoogwaterstanden**	**Onderschrijding laagwaterstanden**
1x per 10.000 jaar	630	
1x per 5.000 jaar	610	
1x per 4.000 jaar	610	
1x per 2.000 jaar	580	
1x per 1.000 jaar	560	
1x per 500 jaar	550	
1x per 200 jaar	520	
1x per 100 jaar	500	
1x per 50 jaar	480	-340
1x per 20 jaar	455	-330
1x per 10 jaar	435	-325
1x per 5 jaar	415	-315
1x per 2 jaar	395	-305
1x per jaar	380	-295
2x per jaar	360	-290
5x per jaar	345	-280
LAT		-283

Hoogst bekende waarde 507 cm 1 feb 1953 Periode 1900-2010
Laagst bekende waarde -350 cm 15 mrt 1964*) Periode 1900-2010

Bijzonderheden:
- 1862 Aanvang waarnemingen
- 1 jul 1880 Peilschrijver geplaatst
- 13 nov 1986 DNM geplaatst

*) Meerdere dagen met minimale waarde.

Figure 5 Western Scheldt - Hansweert location design values for the hydraulic conditions of tide. Extracted from Rijkswaterstaat (2013)

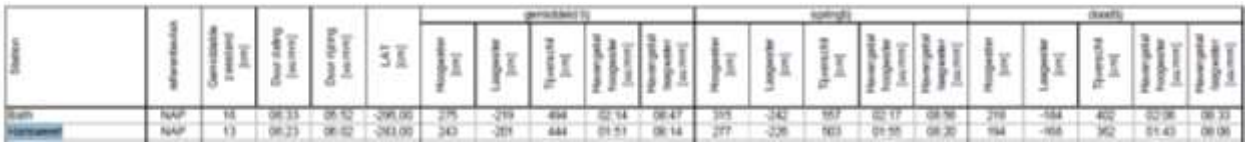


Figure 6 Design values for the tide pattern in the area of Hansweert lock. Source Dillingh (2013)

Geotechnical characteristics

Geotechnical characteristics of the outer and inner canals of the Hansweert lock are similar and are described in a detailed analysis of the geotechnical that is to be found in Appendices V, XII.II and XII.III.

The location is represented by many different soil profiles available in the area, with locations represented by stronger soil and other by weak layers. Both types could be of importance, therefore two different profiles are chosen for the evaluation of the ground conditions. Table1 and Table 2 show a strong profile and a weak profile, consecutively, that are being considered.

Table 1 Soil profile number 70294 representing the strong profile. Source: DinoLOKET (2018)

Layer	Top layer [mNAP]	Layer [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-7,00	2,79	Clay	18	18	27,5	0	18,3	9,5	50
2	-9,79	2,22	Loam	19	19	27,5	0	18,3	9,5	0
3	-12,01	0,40	Sand 1	18	20	25	0	16,7	9,5	50
4	-12,41	2,52	Loam	19	19	27,5	0	18,3	9,5	0
5	-14,93	0,22	Sand 1	18	20	25	0	16,7	9,5	50
6	-15,146	4,18	Loam	19	19	27,5	0	18,3	9,5	0
7	-19,32	4,53	Sand 2	18	20	27	0	18,0	9,5	50
8	-23,85	0,64	Loam	19	19	27,5	0	18,3	9,5	80
9	-24,49	6,11	Sand 2	18	20	27	0	18,0	9,5	50
10	-30,60	1,11	Loam	19	19	27,5	0	18,3	9,5	0
11	-31,72	31,72	Sand 1	18	20	25	0	16,7	9,5	0

Table 2 Soil profile number 70297 representing the weak profile. Source: DinoLOKET (2018)

Layer	Top layer [mNAP]	Layer [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-7,00	2,79	Clay	18	18	27,5	0	18,3	9,5	50
2	-9,79	2,22	Loam	19	19	27,5	0	18,3	9,5	0
3	-12,01	0,40	Sand 1	18	20	25	0	16,7	9,5	50
4	-12,41	2,52	Loam	19	19	27,5	0	18,3	9,5	0
5	-14,93	0,22	Sand 1	18	20	25	0	16,7	9,5	50
6	-15,146	4,18	Loam	19	19	27,5	0	18,3	9,5	0
7	-19,32	4,53	Sand 2	18	20	27	0	18,0	9,5	50
8	-23,85	0,64	Loam	19	19	27,5	0	18,3	9,5	80
9	-24,49	6,11	Sand 2	18	20	27	0	18,0	9,5	50
10	-30,60	1,11	Loam	19	19	27,5	0	18,3	9,5	0
11	-31,72	31,72	Sand 1	18	20	25	0	16,7	9,5	0

2.2 Program of requirements and preconditions

This section describes the limits and boundaries determined for this project based on technical and client requirements. A complete description can be found in Appendix III.

Following the client needs, the design vessel to be calculated for the design is within the class CEMT VIb. Vessels characteristics are described in Table 3.

Table 3 Design vessel characteristics. Source: European conference of ministers of transport (1992)

Class CEMT	Ship Characteristics					
	Length (Lmax) [m]	Beam (Bmax) [m]	Draugh (Dmax) [m]	Tonnage (Tmax) [ton]	Water displacement (ROK) [ton]	Min Height under bridges [m]
VIa	110	22,8	4,5	6000	3000	9,1
VIb	195	22.8	4.5	12000	6000	9.1

The berthing characteristics are described on Table 4 and it shows relevant factors according to common design, practical locally encountered values, and extreme values in case of accidental events.

Table 4 Berthing characteristics based on design examples and local experience. Source: EAU (2012) and Hansweert inspectors (2018).

Berthing characteristics					
Approach velocity			Approach angle		
Design velocity [m/s]	Practical velocity [m/s]	Accidental velocity [m/s]	Design angle [°]	Practical angle [°]	Accidental angle [°]
0,13	0,5-1,0	2,-4,5	15	20	45-90

Technical requirements

This section describes the technical requirements that are to be followed by this research. These conditions are based on the functional requisite for this structure mentioned in Appendix III.

Construction depth and levels

Considering the given design vessel in §2.1.2, and the actual local characteristics, the levels given by Table 5 are to be considered.

Table 5 Design levels according to NAP reference. Source:[18],[19] and [28]

		Western Scheldt Side	Canal side
Water level [mNAP]	Water level	0	0
	Water level HHT	5,07	3,8
	Water level HT	2,26	1,63
	Water level LT	-2,12	-1,37
	Water level LLT	-3,5	-1,7
Construction depth [m]		-9.0	-7.0
Top level dolphin [mNAP]		+6.5	+4.5

Berthing requirements

Concerning the berthing levels according to the water levels, it is defined in the Directive Waterways (RWS, 2017) that the lowest bollard should be around 1,5meters above low water level. The same range should be followed upwards the dolphin up to the top level. In case of a new cap design the bollards should be placed as showed on Table 6. In case of reuse of actual cap, it is assumed that the capacity of the actual bollards are enough.

Table 6 Bollards placement levels and mooring capacity required. Source: Dutch Directive Waterways (RWS, 2017)

Bollards		
Capacity [kN]	Level [mNAP]	
	Western Scheldt Side	Canal side
350	+6,50	+4,50
350	+5,00	+3,00
350	+3,50	+1,50
350	+2,00	0,00
350	+0,50	-
350	-1,00	-
350	-2,50	-

According to Normative Waterways (RWS, 2017), in order to prevent the shock of the bottom of the ship to the pile, the fender panel should be prolonged up to 0,5m below the low water level.

2.2.1 Load cases

Permanent Load: Self-weight

The total weight of the structure is to be considered as 18,8 tones, therefore:

$P_{steel} = 185\ kN$

Variable Load

It consists of maintenance and human charges as vertical load, impact and mooring charges as horizontal load.

An assumption following pedestrian load in bridges according to NEN-EN 1991 (2011), gives a $q_{p,f;k}$ = 2kN/m^2. It is taken as load surface the top of the pile and that gives the area of the pile cap $A_{base,cap}$=2,6m^2, leading to a load $Q_{f,w}$=2kN.

The impact load is calculated according to the berthing energy, that can be calculated according to EAU, PIANC (2002) and ROK (Rijkswaterstaat, 2017):

$$E = 0{,}55 * m_{ship} * (v_{ship} * sin \propto)^2 * C_m * C_e * C_c * C_s$$

$$E_d = 14{,}10[kNm]$$

Considering the ultimate limit state analysis:

$$E_{d,ULS} = 31{,}72[kNm]$$

Where:

E	: Kinetic Energy	[kNm]
m_{ship}	: Weight of ship	[ton]
v_{ship}	: Approach velocity of ship	[m/s]
α	: Approach angle of ship	[°]
C_m	: Hydrodynamic mass factor C_m=1.39	[-]
C_e	: Eccentricity factor C_e=0.08 – calculated in Appendix III	[-]
C_c	: Permeability coefficient C_c=1.0	[-]
C_s	: Material coefficient C_s=1.0	[-]

Also as part of the variable load, the mooring charges are represented by the actions on the bollards which can be found in the Directive Waterways (RWS, 2017), and as shown in Table 6, the required strength for vessels of class CEMT VIb is 350kN.

2.2.2 Strength and Stability

The structure ultimate element is considered to be the foundation pile, therefore these criteria must be calculated. The determination of the vertical and horizontal bearing capacity in relation to pile-soil interaction must be done following NEN-EN 1997 (2016). For the pile resistance calculations must follow

NEN-EN 1993 (2008). The definition of the driven depth for the foundation is to be determined according to the vertical and horizontal bearing capacity at the level that it fulfills the requirements.

2.2.3 Displacement and deflection

The application of permanent and variable loads on the structure can cause effects such as displacements (δ) and deflections (ƒ), but these parameters may not compromise the functionality of the function.

According to NEN-EN 1990 (2002), there is a maximal displacement allowed to the structure which is:

- $\delta_{max,vertical} \leq h/250 = 15,5/250 = 0.06m$
- $\delta_{max,horizontal} \leq h/150 = 15,5/150 = 0.10m$

Note that the structural displacement does not includes the soil displacement.

Following EAU (2012), the maximum deflection allowed for nautical, port operations and structural reasons is of ƒ=1,50 meters, including the soil displacement.

2.2.4 Material Quality

The following material characteristics are required for the design of the structure.

Steel Quality

The quality of steel commonly used in the waterways structures of the region is as follows in Table 7.

Table 7 Steel quality required for design of water constructions in the area of Hansweert lock. Source: PPO RWS See and Delta

EN 10025	Min. Yield Strength [N/mm2]						Tensile Strength [N/mm2]		Thoughness Charpy V (J)	°C
Thickness	<16	>16;<40	>40;<63	>63;<80	>80;<100	>100;<150	<3; <100	>100; <150	<150	
S355JO	355	345	335	325	315	295	490; 630	470; 630	27	0

E_{steel}=210.000 [N/mm^2]

Corrosion of steel

For steel construction elements the corrosion rate to be considered is followed by the normative NEN-EN 1993 (2008) and CUR166 (2014) for a life span of 50 years. In case of steel piles, the corrosion is only considered to happen in the outer side once in the inside no oxygen is present, therefore no corrosion or rust occur. The following rates are to be considered:

Steel pile in the ground :0,026 mm/side *considered to be determinant where great moment occurs.

2.3 Conclusion Chapter 2

Chapter 2 has given the information necessary about the location and structure in order to carry on the research process. Next chapter describes the methodology used for the analysis and design process of the solution design.

3 Methodology

3.1 Current situation

Visual inspections realized in the driveways of Hansweert locks have observed that several dolphins are compromise by hanging crooked, although this curve suspension is a known problem and it is present since the construction. The dolphin consists of a pile cap sitting over a pile, where the pile cap hangs itself with the bottom part attached by a front fender with chains. In the past, the chains were found to be the weakest link in the structure and, once the chains break, the fenders tend to fall into the water and cause damage to the pile cap making it crooked. A shift in the fender can also cause an obliquity in the pile cap on the inner post.

In 2014, the maintenance contractor applied a change to seven dolphins by using a steel cable instead of a chain, and a lock at the bottom of the fenders in order to prevent the pile caps to become crooked. The solution worked for a short period of time, although during later visit to site, four of the seven structures showed the same behavior as before the changes leading to a conclusion that the solution was not effective.

In May 2017, an intern report has shown that the following structures are compromised:

- South front of Hansweert lock: C20/ C21/ C23/ C24/ C26/ C27/ C28/ C29/ C31/ C31/ C32/ C33/ C34/ C35/ C36*
- North front of Hansweert lock (Canal side): F20/ F21/ F23/ D21/ D27/ D31/ D34/ D37 inclusive a berthing structure from the jetty.

Note that the numbers highlighted are also the structures that have been changed. The location of the structures can be seen in the following figure.

On 1st March 2018, in a field visit, the situation seemed to be becoming worst in the visual inspection. Some of the problematic structures had been closed due to the lack of safety for the berth of vessels. In addition to that, according to Hansweert lock supervisors, many vessels do not feel safe to use the structures, and once that is needed, they have been using more mooring facilities in order to guarantee the vessels safety.

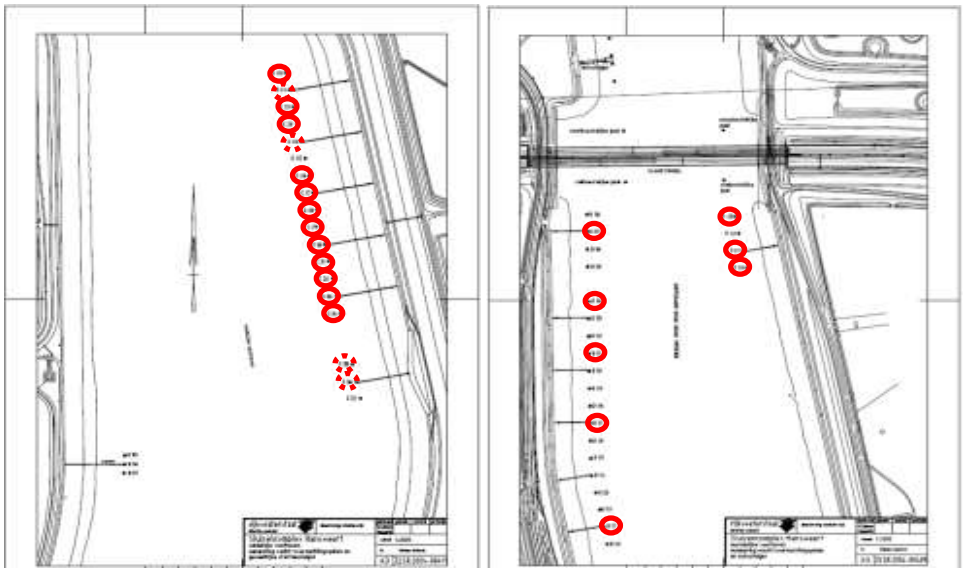


Figure 7 Location of crooked fender in mooring structures. Source: RWS, 2018.

In addition to the misalignment issue with the fenders of the mooring structures, the bollard facility has also shown a design failure. The steel base plate of the bollards are sticking out of the fender panel, generating a high risk of damage to the vessels in a situation of mooring, as can be seen on figure below where the base plate of the bollards is sticking out.

Figure 8 Representation of actual situation of fenders damages. Source: RWS (2018).

In order to analyze the current situation and understand the problem, a Root Cause Analysis (RCA) is developed based mainly on visual aspects and on practical experience of local supervisors and maintenance contractor. Previous problem analysis was not available.

3.2 Analysis of current situation (RCA)

The RCA is fully described as a separate document and can be found in Appendix IV Route Cause Analysis. This method analyses the past events that occurred in order to develop the actual problem, by means of the Fault Tree Method according to NEN-EN-IEC 6270:2015.

As possible root problems, four options were considered as follows:

1. Cap is rotated;
2. Fender rubber is compromised;
3. Fender disappeared or felt;
4. Fender is twisted or misplaced.

Each possibility was analyzed regarding its possible causes and conditions.

It is conclusive in the RCA that, although earlier given the problem was the failure and falling of the fenders, these are being caused by extreme loads applied to the cap that is by design able to freely rotate around the inner pile. These forces, increased by the movement of the cap, lead to the failure of the holding system of the fenders.

The chosen solution for this problem is the fixation of the cap in order to prevent the cap rotation and therefore keeping the structure in the desired position.

3.3 Variance study – Multi-Criteria Analysis

In addition to the misalignment of the cap, for a solution design it is important to assure that the foundation pile still fulfill the required capacity with the vessel requirement of VIb, once the design was previously defined for VIa, according to CEMT (1992).

Regarding the foundation pile, four options of solutions are developed:

1. **Alternative 1 - New dolphin design:**

A new dolphin design is based on a complete new structure, from foundation pile to fender system. In this case, this new dolphin can be considered as an example the design used in the extra mooring places added to the region (Figure 9).

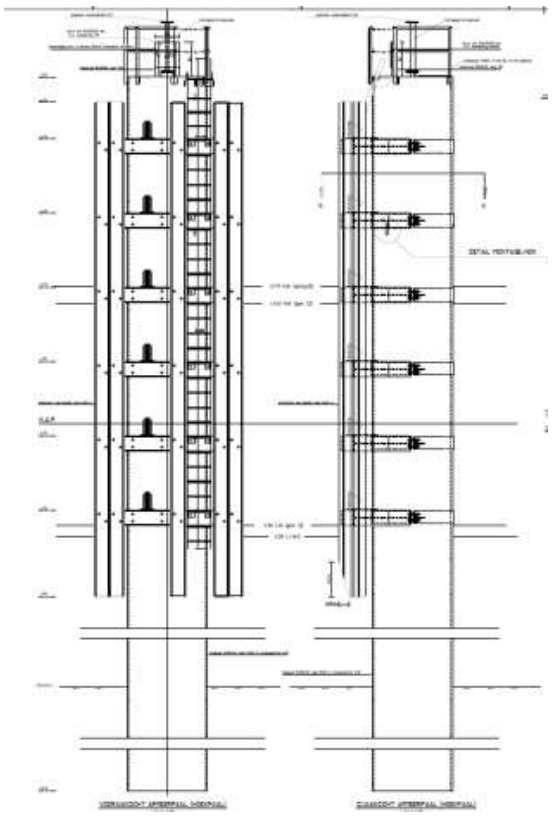


Figure 9 Design of berthing structure placed in the area of Hansweert sluice recently. Source: RWS(2018)

2. **Alternative 2 - Fixation of cap using actual foundation pile:**

For the Alternative 2, the foundation pile is considered sufficient for the requirements and it is reused. In addition to that, a fixation for the cap system is adapted by using the actual structure that is already there as well.

3. **Alternative 3 - Deepening and elongation of actual foundation pile, and fixation of cap:**

Alternative 3 is used when the actual pile is structurally accepted according the requirements and can be reuse, nevertheless the penetration length is found to be insufficient. In this case then the actual pile is driven deeper into the soil and a new piece of pile, with the same characteristics, is welded in order to

provide the required level for mooring purposes. The fixation of the cap follows the same as expected in alternative 2.

4. **Alternative 4 - New foundation pile and fixation of cap:**

Alternative 4 is based on the implementation of a completely new foundation pile, in case the actual pile does not fulfill both structural and geotechnical capacities needed for this construction. Moreover the cap is also fixated as described in the final design.

Each alternative was analyzed based on the following criteria:

- Lifespan – representing 10% of the final result for each alternative, this criteria describes the possible lifespan of the proposed alternative;
- Costs – considered 20% of importance, once the client is willing to invest in order to obtain an effective solution in order to have the structure with full functionality;
- Implementation Time – covers 35% in the final score once it is the requirement of the client that the structure is changed in less time as possible to avoid influence in the local users;
- Assurance and Safety – lastly covering also 35% due to the importance of having a safe berthing structure is a normative and must be fulfilled.

Each criteria is further described as the method used for grading in Appendix VII Multi-Criteria Analysis.

Table 8 shows the final comparison between the four alternatives.

Table 8 Multi-Criteria analysis of all alternatives.

	Alternative 1 New Design			**Alternative 2 Cap Fixation**			**Alternative 3 Pile Elongation**			**Alternative 4 New Pile**		
Criteria	Rate (%)	Fact (%)	Tot	Rate (%)	Fact (%)	Tot	Rate (%)	Fact (%)	Tot	Rate (%)	Fact (%)	Tot
Lifespan	100	10	10	50	10	5	50	10	5	50	10	5
Costs	22	20	4.4	70	20	14	39	20	7.8	50	20	10
Implement Time	50	35	17,5	83	35	29	63	35	22	61	35	21.4
Assurance and Safety	100	35	35	0	35	0	75	35	26.25	100	35	35
	Compatibility (%)		66.9	Compatibility (%)		48	Compatibility (%)		61	Compatibility (%)		71.4

3.4 Definitive design

The definitive design will be defined based on the results of the variance analysis mentioned in §3.2 and §3.3, by selecting the most appropriate solution based on the requirements defined in the Program of Requirements (Appendix III) of the project.

Three options of connection are given to the client and described in the Design Report, in Appendix VIII. The final option is to be chosen based on qualitative analysis of implementation time for the solution. The alternative with simplest implementation is to be chosen.

Following, the definitive design will be checked for the cap connection and draught with the use of the software AutoCAD 2016. The connection drawings are to be found in Appendix IX.III.

3.5 Software's support

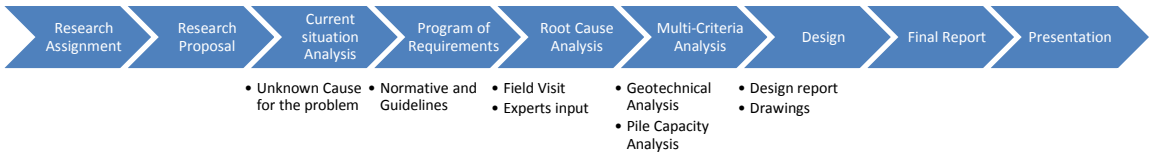
For the calculations and drawings the following programs were used:

- ✓ TS/Damwanden version;
- ✓ DSheet Pile;
- ✓ deKoch Spreadsheet for berthing structure design;
- ✓ AutoCAD 2016 – Student version
- ✓ InfraCAD version 6.0 for AutoCAD 2016 – Student version

3.6 Research method

This research is based on normative and guidelines used in the Dutch industry and followed by the client. This research assignment took place as an office assignment, with field inspections taking place along the assignment in order to verify current situation of structures. Regarding the design for the solution, the guidelines given by the client were be used as basis for the development of the design report in order to be a feasible design to be applied in the future by the client.

The research approach can be schematized by the following chart:



3.7 Conclusion Chapter 3

Based on the chosen research methodology described in chapter 3, the cause for the inclination problem of the structure is the design possibility of freely cap rotation around the pile foundation. This movement can lead to potentially great load causing the failure of the fender chains. Based on previous modifications, the change of the fender systems have not shown positive results once the structure returns to old behavior and it shows new inclination to the cap.

Regarding the foundation pile capacity, the outcome of the chosen methods of DSheet-Piling and TS/Damwanden have shown that the actual steel pile element fulfills the requirements when an elongation is added to the penetration depth up to a depth of NAP – 20 m. Fraanje Method has shown a less conservative analysis and supports the fulfillment of the structures capacity as seen in the field, once the dolphins are already being submitted to extra loads in the practical field. Nevertheless, this research

has chosen to follow the analysis of DSheet-Piling for the final toe level of the structure, once this is a commonly used software for calculation of water structures with similar loads.

Based on the capacity of the pile in both structural and geotechnical requirements, the MCA has led to the use of a new foundation pile. Nevertheless, the elongation of current pile is chosen and the next chapter shows the process used for defining the final solution design based on the choice of the elongation of the foundation pile, as the connection options for the cap fixation and the final design.

4 Design results - Dolphin

The dolphin structure of this project is formed by two main elements the foundation pile and the pile cap with a fender system. This section described the final design chosen by the research outcome in accordance to the clients requirements.

4.1 Foundation Pile

The actual foundation pile has shown a lack of capacity when it comes to the geotechnical analysis generated by DSheet-Piling and TS/Damwanden. Therefore, as shown in the MCA, the alternative 3 of elongating this element is chosen for the final outcome.

4.1.1 Defining penetration depth

The toe level is determined by the iteration check using DSheet-Piling, in combination to the Fraanje Method (1968) for the design of berthing structures.

DSheet-Piling gives an acceptable soil capacity from the depth of -20mNAP as seen in Figure 10.

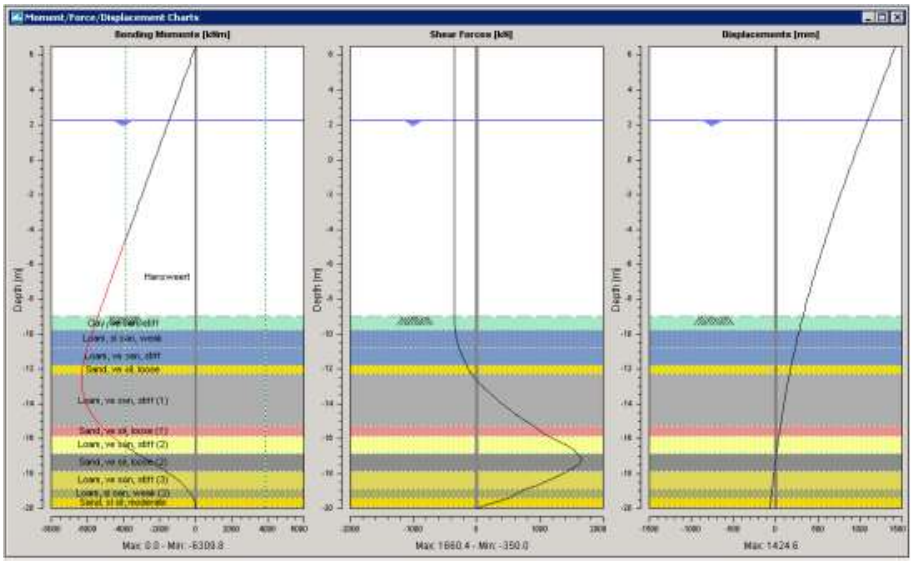


Figure 10 Moment, Force and Displacement charts from DSheet-piling analysis on longer pile and CPT70297, with max displacement of 1,5m and desired load of 350kN.

In addition the analysis following Fraanje (1968), with the soil interaction following Blum's method and structural analysis according to NEN-EN 1990 (2011) as explained in Appendix III, has shown the following results:

Table 9 Input data for Fraanje method for new foundation pile at -20mNAP.

Staalkwaliteit	S	355			
D (buitendiameter)		1016	mm		
t (buispaal dikte)		20	mm		
E (elasticiteitsmodulus)		210000	N/mm2	corrosie ondergrond	
corrosie binnenkant per jaar		0	mm/jaar	omdat grotste	
corrosie buitenkant per jaar		0,026		moment zit in de	
aantal jaar		32	jaar	grond	
γf;q;u (belastingfactor UGT, scheepsstoot)		1,5			
γf;g;u (belastingfactor UGT, troskracht)		1			
γf;ser (belastingfactor BGT)		1			
γdr (soortelijk gewicht van de grond boven water)		18	kN/m3	sand sterk siltig,	
γsat (soortelijk gewicht van de grond onder water)		20	kN/m3	kleiig volgens Dsheet	
γwat (soortelijk gewicht van het water)		10	kN/m3		
φ'rep (hoek van inwendige wrijving)		27,5	°		
hstoot (afstand bodem tot aangrijpingspunt scheepsstoot)		15,5	m	waterverplaatsing	
xm (afstand bodem tot maximaal optredend moment; stoc		2,96	m	omrekenen van ton	
η (waarde to;stoot / xm)		2,56		naar kN:	
m (waterverplaatsing van het schip)		109200	kN	12000	ton
v (aanvaarsnelheid)		0,13	m/s	120000	kN
Ptros;rep (representatieve waarde troskracht)		350	kN	m'	
xm (afstand bodem tot maximaal optredend moment; tros		2,96	m	109200	kN
htros (afstand bodem tot aangrijpingspunt troskracht)		15,5	m		
η (waarde van to / xm)		2,56			
Ltot (totale lengte buispaal)		26,5	m		

Table 10 Output data for Fraanje method for new foundation pile at -20mNAP.

15. Gegevens buispaal:			
D (diameter buispaal)		1016	mm
t (buispaal dikte)		20	mm
Ltot (totale lengte buispaal)		26,5	m
Maatgevende doorbuiging t.p.v. aangrijpingspunt kracht		0,796137	m
Maatgevende doorbuiging t.p.v. top van de buispaal		0,883952	m
Optredend arbeidsvermogen		141,0917	kNm
Toelaatbaar arbeidsvermogen		150,97	kNm
Optredende buigspanning		253,3458	N/mm2
Toelaatbare buigspanning		355	N/mm2
	buispaal	voldoet	

Based on this checks, and the serviceable verification that the piles are capable of handling the required load as shown on the field, the final penetration length is to be considered 11 meter with a pile toe level of -20mNAP.

Table 11 New foundation pile characteristics.

Design Foundation Pile

Diameter	1016	[mm]
Inner diameter	976	[mm]
Thickness	20	[mm]
Actual length	24.1	[m]
Extra length	2.4	[m]
Final length	26.5	[m]

4.2 Cap connection

The cap of the current structure is to be reused and a connection is to be implemented in order to prevent the rotation of the pile cap and therefore the known failure of the structure, as defined by the Root Cause Analysis (Appendix IV).

There were three possibilities considered in cooperation with the client which are described in the next sections.

4.2.1 Connection option 1

For this option the cap pile of diameter 1820mm would be cut in its half and replaced to a distance of 878mm from the center of the foundation pile, reducing the eccentricity of the cap in comparison to the original structure. Six bracing supports would be placed around the inner pile and welded to the half cap structure, which can be regulated by torqueing of the bolts.

This solution requires also a redesign of the top plate, which is reduced to 1280mm. Therefore a new connection to the walking bridge is also needed to be designed, as the replacement of the stairs, cables and traffic plates, as seen in Figure 11.

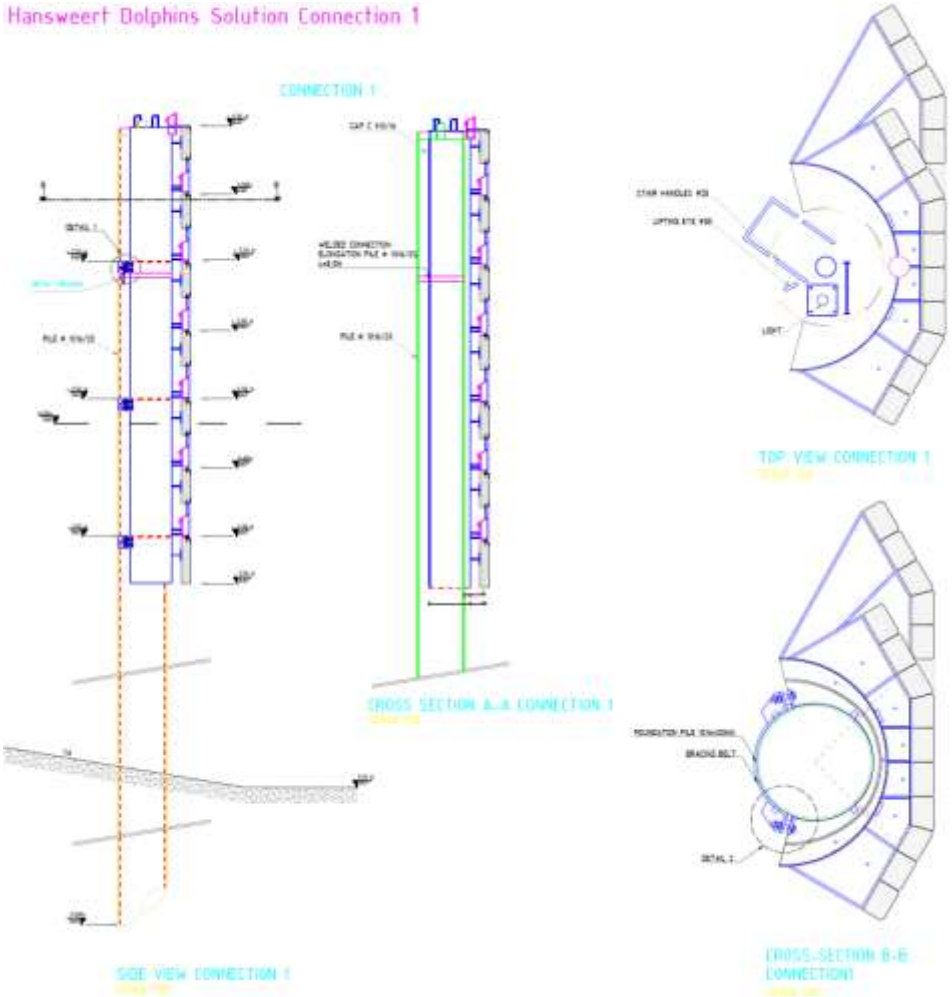


Figure 11 Schema for cap-pile connection 1.

4.2.2 Connection option 2

The second option adapts part of the cap, leaving the top 3 meters of the pile cap intact and removing the half of the remaining length as seen in Figure 12. For this connection the top plate and further elements remain the same.

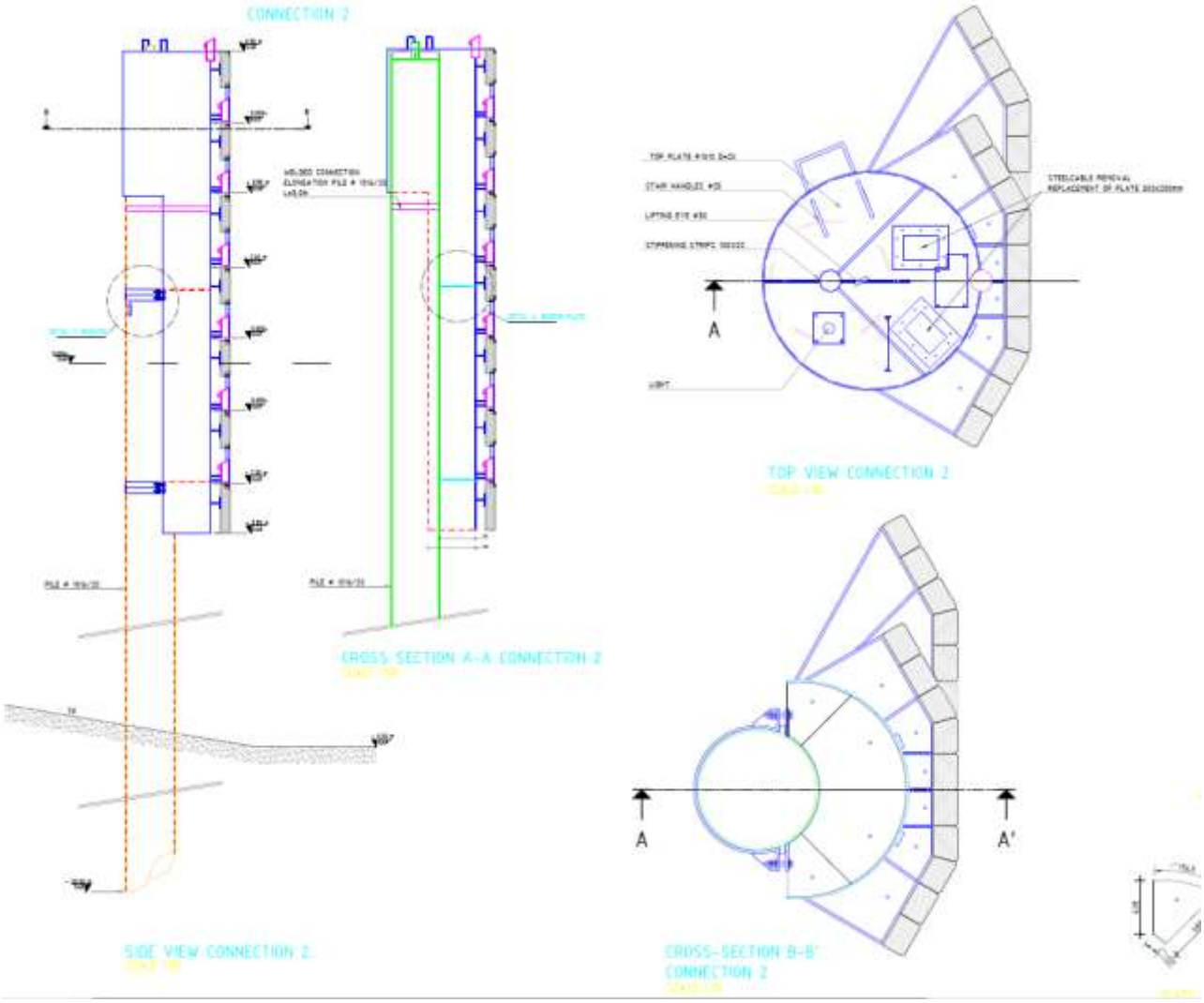


Figure 12 Scheme pile-cap connection option 2.

The same as in connection 1, bracing rings are added to keep the pile cap in position and avoid lateral displacements. Also, a binding plate connection is designed to be placed on the same level of the bracings, to avoid bending of the C cap element (Figure 13).

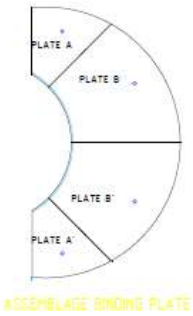


Figure 13 Detail of binding connections of option 2.

4.2.3 Connection 3

Option 3 makes use of the same assemblage existing by adding both connections to the top and bottom sides of the cap.

In the top the cap is held to the foundation pile with the UPE section as seen in Figure 14, preventing the lateral rotation. In addition, to prevent vertical displacement a connection is added in the bottom part of the cap with the implementation of two steel plates. From these, one is welded to the foundation pile and the second to the pile cap. In-situ welding to the bottom part of those plates bring them to one piece and work in prevention to the displacement, as also shown in Figure 14Figure 14. An extra stiffening rib is added to prevent displacement due to compressive forces.

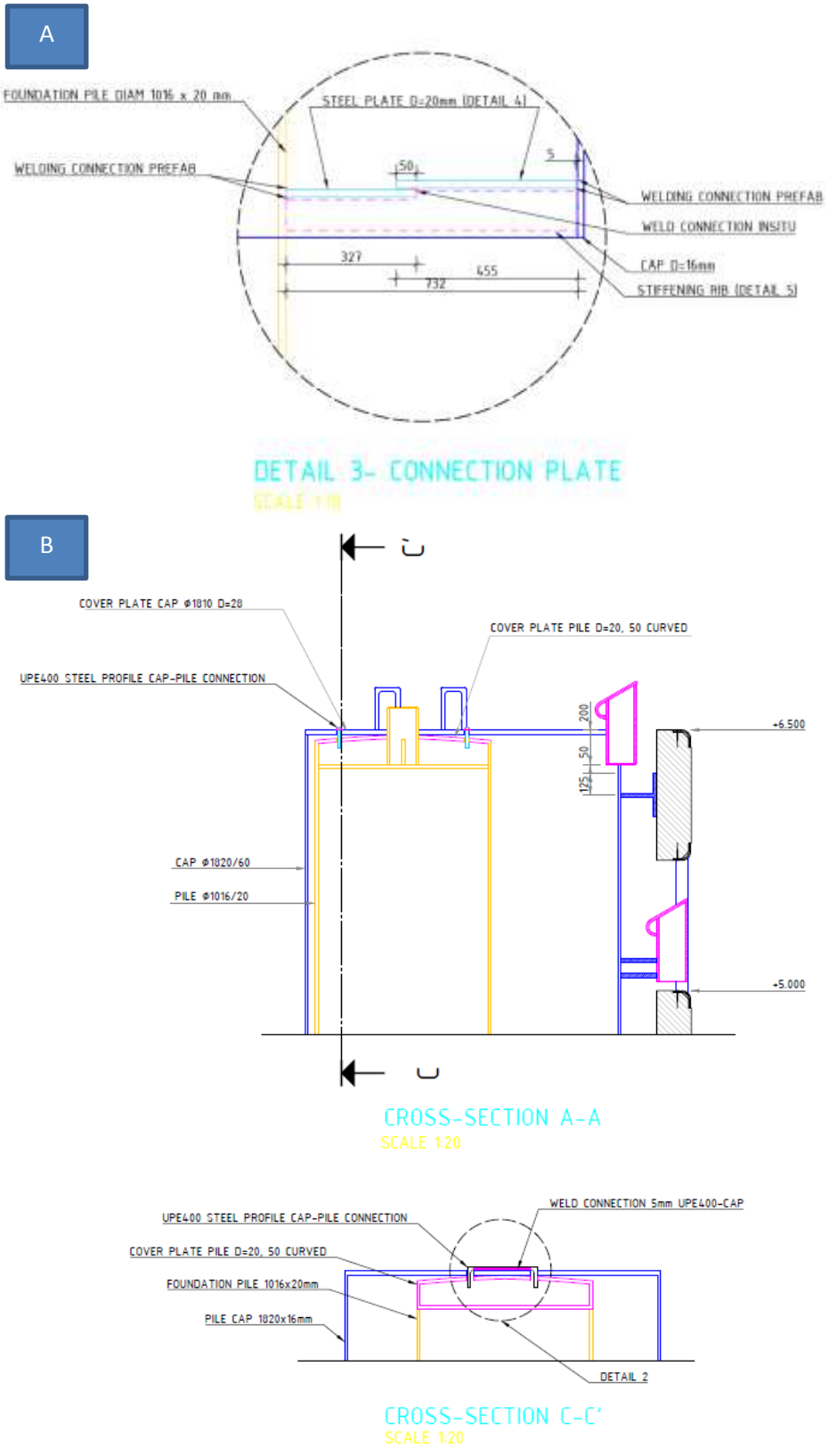


Figure 14 Detail top and bottom connection of option 2.

An overview of this option can be seen in Figure 15.

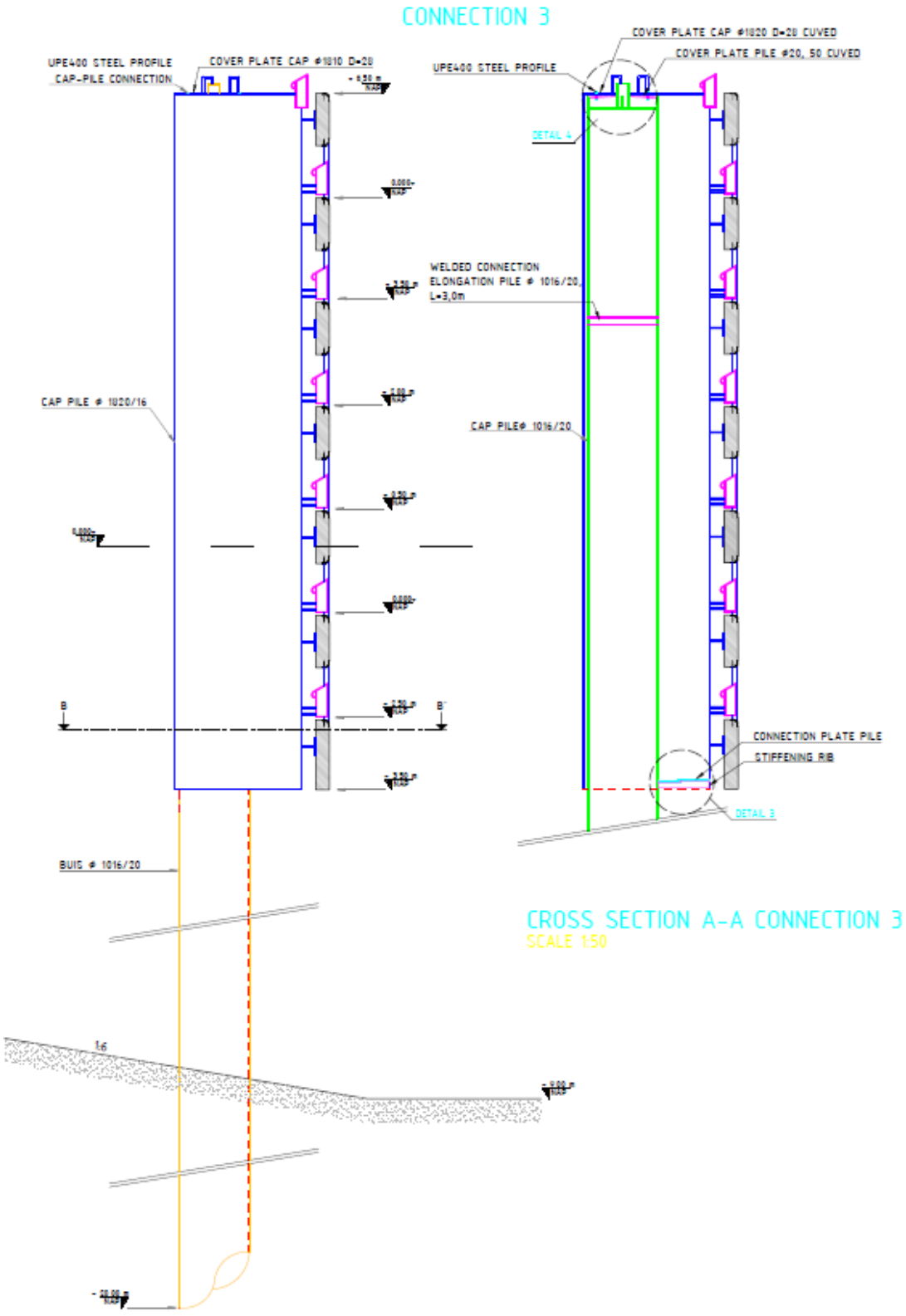


Figure 15 Scheme for pile-cap connection option 3.

4.2.4 Selection & Verification

The cap connection 3 is chosen due to less modifications needed to the pile cap and less extra elements when comparing to the other options. This is considered to lead to a less implementation time and costs.

Connection to foundation pile

In order to verify the UPE section choice as the welding layer, structural calculations are needed to verify if the capacity is enough to support the loads shown in Figure 16.

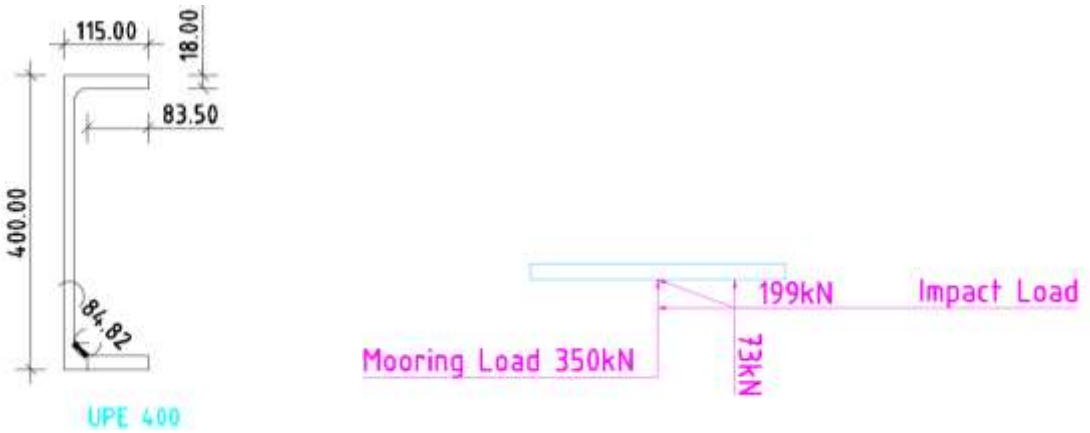


Figure 16 UPE400 section details.

The welding is loaded with the moment caused by the normal mooring load on the main base of the section, in addition horizontal load caused by the impact. These loads are happening in different moment in time, so the check is done for the imperative load.

The impact load is based on the required impact energy of 220kNm in an angle of 20°, giving a $F_{h,1}$=199kN and a $F_{h,2n}$=73kN.

Based on similar designs, the welding layer is chosen to be assumed 5mm, with a critical layer of a_{cor}=4.65. For the normal load caused by the mooring, the l_{eff} =400mm, is assumed to be the length of UPE400. the following check is performed:

$$\tau_{\perp} = \sigma_{\perp} = \frac{F * \sqrt[2]{2}}{4 * a_{cor} * l_{eff}};$$

$$F = F_{morring} + F_{m,d};$$

Where $F_{m,d}$ is the force cased by the moment generated by the mooring load in pulling and pushing the structure in relation to the pile.

$$F_{m,d} = \frac{M_{s,d,A}}{D_{pile}} = \frac{350 * 0.2}{1016} = 68.9kN$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{(350 + 68.9) * 10^3 * \sqrt[2]{2}}{4 * 4.65 * 400}$$

$$\tau_{\perp} = \sigma_{\perp} = 79.6\ N/mm^2$$

$$\sigma_{s,w,d} = \sqrt{\sigma_{\perp}{}^2 + 3 * (\tau_{\perp}{}^2 + \tau_{//}{}^2)}$$

$$\sigma_{s,w,d} = \sqrt{79.6^2 + 3 * (79.6^2 + 0^2)}$$

$$\sigma_{s,w,d} = 159.2 N/mm^2$$

For the check: $\sigma_{s,w,d} \leq \frac{f_y}{0.9*1.5}$

$$\sigma_{s,w,d} = 159.2 \leq \frac{355}{0.9 * 1.5} = 263\ [N/mm^2]$$

The welding and the section are acceptable for the required load.

For the horizontal load of 199kN, it is shared along the top plate of the cap, therefore a check is performed assuming a l_{eff}=1820mm. The welding layer keeps the same as in the previous check, a_{cor}=4.65.

$$\tau_{//} = \frac{F_{h,x,d}}{2 * a_{cor} * l_{eff}} = \frac{199 * 10^3}{2 * 4.65 * 1820} = 11.8\ N/mm^2$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{73 * \sqrt[2]{2}}{4 * 4.65 * 1820} = 3.1\ N/mm^2$$

$$\sigma_{s,w,d} = \sqrt{3.1^2 + 3 * (3.1^2 + 11.8^2)} = 21.4 N/mm^2$$

For the check: $\sigma_{s,w,d} \leq \frac{f_y}{0.9*1.5}$

$$\sigma_{s,w,d} = 21.4 \leq \frac{355}{0.9 * 1.5} = 263\ [N/mm^2]$$

The welding and the section are acceptable for the required load.

4.3 Conclusion Chapter 4 - Final Design

The location of the structures are to remain the same as current positioning. The extra length is to be welded on site in order to reduce implementation time, avoiding removal and transportation of the foundation pile. Figure 17 shows the final design.

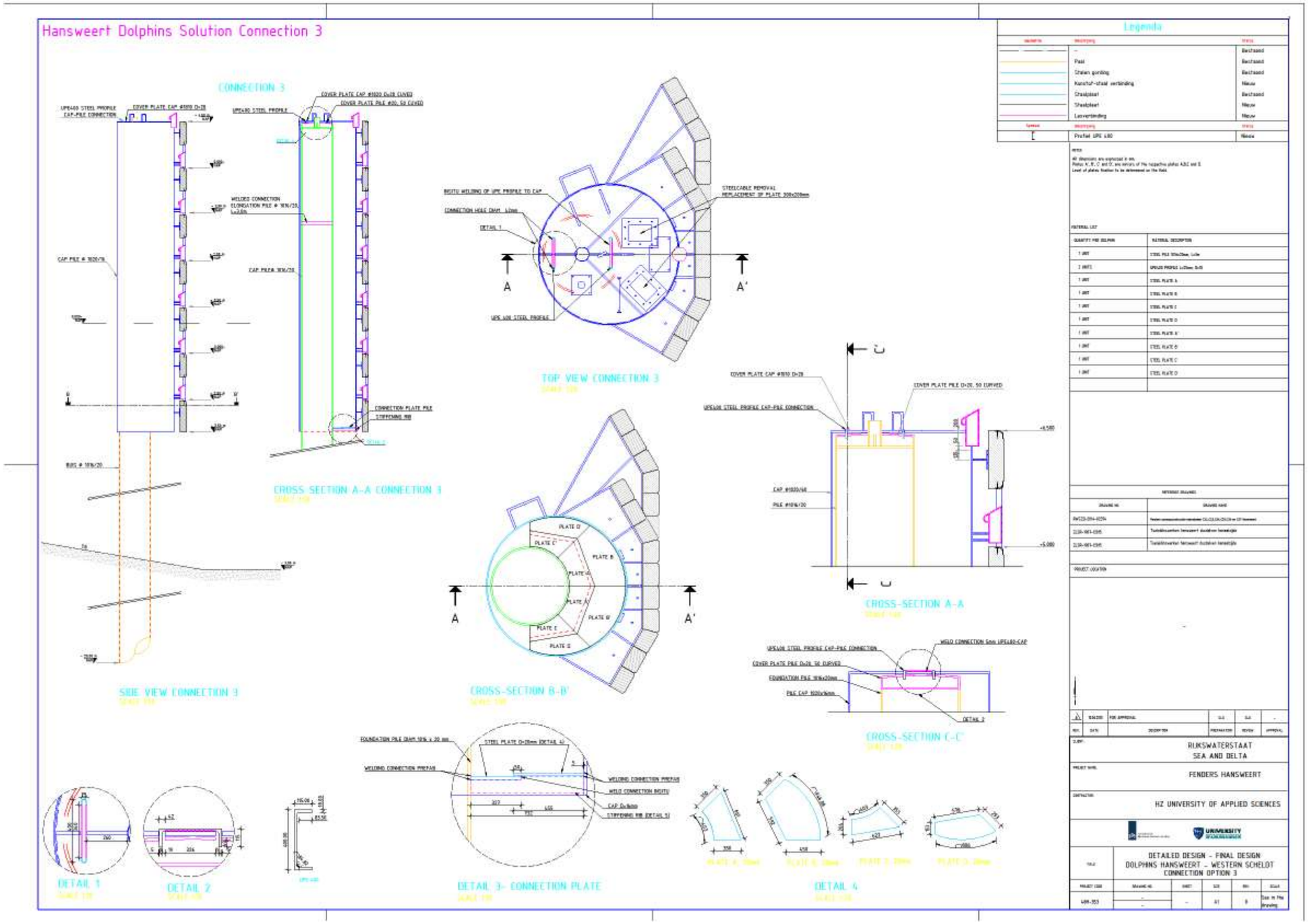


Figure 17 Drawing of Hansweert Dolphin final design

4.4 Costs

The costs for this project are based mainly on the removal of the cap element, deepening of the foundation pile and its extension, the extension piece and welding. The connection elements are also to be considered, although they play a smaller effect in the total price.

Table 12 Cost analysis for implementation of final design based on GWW (2018).

Materials					
Material	Dimensions	Weight [kg/unit]	Price per unit [€]	Units	Total
Extension pile	Ø1016x20mm L=2,4m	$\rho_{steel=}$7800 kg/m^3 w=1179,6	1179.6kg* €5,00/kg steel 5898,00	41	€241.818,00
Steel plate A	V=0,002140m3	16,69	83,45	82	€6.842,90
Steel plate B	V=0,001712m3	13,35	66,75	82	€5.473,50
Steel plate C	V=0,002754	21,48	107,40	82	€8.806,80
Steel plate D	V=0,002203	17,19	85,93	82	€7.046,26
UPE400	0.2m – 72.2kg/m	14,44	72,20	82	€5.920,40
Weld	V=0.0003882m3	3,03	15,14	41	€620,74
				Total:	€276.528,60
	Activities				
Activity			Price Unit[€]	Units	Total
Trilling	3m per dolphin		Per meter 815,00	123	€100.245,00+20% uplifting €120.294,00
Welding	8,25 meters		1003,39	8,25	€8.277,98
				Total:	€128.571,98
	Personal & Equipment				
Personal & Equipment			Price per hour [€]	Hours	Total
Welding pack			42,55	133	€5.659,15
Divers	3 hours per dolphin inclusive inspection and equipment		390,00	123	€47.816,25
Crane pontoon	Hours for trilling, removal and replacement of cap		250,00	827	€206.750,00
				Total:	€260.225,40

Costs are based on GWW 2018 exclusive btw.

Table 13 Total cost estimation overview.

Costs Overview	
Materials	€276.528,60
Activities	€128.571,98
Personal & Equipments	€260.225,40
Total:	€665.325,98

Note that all costs are based on GWW (2018).

4.5 Implementation plan

4.5.1 Preparation work

Ordering of materials, hiring contractors and divers for the process.

4.5.2 Construction phases

- Phase 1 –Mobilization of Equipment

Taking the equipment to the construction location and securing the safety of the area. This is estimated to take a day a work, considering a working day of 8 hours.

- Phase 2 - Removing pile Cap

The first step in the implementation of the solution is to remove the pile cap from the actual structure. This follows with the maintenance of the front panel, removal of fender system and cables, and preparing the steel plates. Removal of the cap is assumed to take 0,75 hour per cap with transportation to shore, giving a total time of 30,75 hours for the removal of 41 elements. For the reformation of the pile cap 4 working hours is estimated per cap with renovation work, giving an estimation time of 164 hours in total. The renovation work can be done onshore, not influencing in the offshore works.

- Phase 3– Pulling pile

While the caps are under maintenance the piling work follows to keep the working flow. The piles are to be elongated in-situ and, in order to be possible for the welding team to do their work above water, the foundation pile is firstly to be pulled from the ground about 3 meters. This will give more time to be used once the tide varies quickly, specially in the Western Scheldt side. This procedure is expected to take around 15 minutes and, while the welding team is busy in the foundation pile connection, the pontoon with the hammer follows to the next pile.

- Phase 4 – Welding pile extension and pile-cap connection steel plates on foundation pile.

With the help of a temporary work, the extension pile is place above the actual pile with the desired levelling above water. Once the extension is in place, the steel plates are welded in position for further connection, as defined per drawing. An estimation of 3 hours work is taken, including replacement of pontoon.

- Phase 5 – Trilling piling 6 meters

With the hammer back to position, the foundation pile with the welded extension is trilled for 6 meters in order to achieve a pile toe level of -20mNAP. The exact penetration needed shall be determined by the site engineer based on the length pulled previously from the ground. It is needed that the top level of the pile maintains at +6.50mNAP as required. For 6 meters trilling a time of around 0,4 hour is estimated per pile, to a total of 16,4 hours work.

- Phase 6 - Replacing pile cap and in-situ welding

The pile top is re-welded to the foundation pile and the connection holes are bored. The caps are placed back in the pontoon from onshore and taken to its final location. There, with the use of a crane pontoon, the cap is replaced to its match structure. Once in place, the diving welders are needed to place the final welding connection on the bottom part, expected to take 0,5 hour per pile(20,5hours in total). Meanwhile, welders are working on placing the UPE section and welding it to the cap. The total replacement of the pile is expected to take 2 hours per piece, with a total of 82 hours.

- Phase 7 – Finishing and cleaning construction area.

All rests of materials and equipment are removed from the project area, leaving the structure clear and safe for usage. One hour per structure should be a wide estimation.

- Phase 8 - Demobilization of equipment and personal

The last phase is to return materials and demobilize personal.

The approximate average duration of the implementation is expected to be one working day per dolphin, or 8 working hours, with a total implementation time of 328 hours for the 41 structures. In order to optimize this time, further analysis must be done with contractor and increasing number of pontoons is one option.

5 Discussion

This report is based on all information available to the case, nevertheless it was noticed that due to the age of the structure great part of the background information is lost or not found. Therefore many estimations were needed and explained along the process.

In addition to that, the current structure has shown problems since its installation, showing a sign of design failure. This report has followed the clients requirements of keeping the implementation time as low as possible in the choice of the final solution, nevertheless, taking into consideration the problematics of the structure, a new structure would be better placed.

Although some elements could still be used in a new design such as the azobe section of the front panel and some furniture, most parts would be disposed with a lifespan left of over 30 years. Environmentally thinking, the client's choice has a better impact on this matter once it reuses the structure in its whole.

Regarding the analytical part of the research, a discrepancy between the software chosen could be seen along this report. A finite-element analysis would have given a better result regarding this construction due to the many variables that are influencing this design. This is also advised by NIC (Smits & Meijerink, NIC: Handreiking rekenmethodieken NIC, 2005), although it was not a feasible application due to time limitation.

6 Conclusion & Recommendations

This research is developed based on client's assignment in order to define a solution to the undesired inclination of dolphins in the berthing area of Hansweert Lock, in the Netherlands. Based on this request, a program of requirements was developed with the client's requirements and technical requirements according to Eurocode normative and national guidelines.

The problem was presented by the client as a failure of the fender system, where rubber fenders were seen to be falling from the structure. Once the actual cause was not previously analyzed in an official report, a Root Cause Analysis (RCA) was decided to be developed along this research in order to define the actual causes and the best approach to avoid it and keep the structure fully functioning. This analysis was qualitatively done with the support of the experts in this structure and local supervisors. Along this analysis a doubt was present due to the low penetration length of the foundation pile shown in the As-built drawings available, and no design report with the actual calculations could be found.

In addition, no information regarding the situation of the foundation pile is to be found. For the causal analysis, to avoid wrong assumptions, the foundation pile is assumed to be in full functionality with an acceptable material quality and inclination. Therefore, the RCA shows that the cause of the structure failure is a design failure of the original structure, the connection between the foundation pile and the pile cap, once it allows full rotation of the cap, possibly increasing significantly the moment and also the force applied on the fenders chain systems. The solution to avoiding further inclination of the structure is then fixing the cap to the foundation pile in order to prevent any kind of rotation, once the load is redirected to the foundation pile.

Although it was assumed that the inner pile fulfilled the requirements for the cause analysis of the problem, in order to assure that the structure is going to handle the load for the next 50 years (as design requirements for dolphins) with the actual pile and with an increasing in class vessel (from VIa to VIb), a Pile Capacity Analysis was performed. The outcome of the chosen analysis are not supporting a common conclusion, and this is expected to happen due to the different methods and the sensitivity to technical parameters. While Fraanje's method supports the capacity fulfillment shown in the field by the structure, DSheet-Piling and TS/Damwanden on the other hand are showing a failure of the system based on the mooring load of 350kN.

Once no detailed analysis was done by dynamic models, due to the great influence of many parameters at the same moment on the structure, and the variability of the ground parameters in the location, this research design proposal is based on a conservative choice, by choosing the alternative of elongating the foundation pile.

Finally, this report has defined that the solution for the assignment Fenders Hansweert is the removal of the rubber fender system and the fixation of its cap element, once the cap rotation is the cause for the failure of the fender system and the inclination of the structure. It is also determined that the foundation pile of the structure is still capable of handling the given load as shown in the calculations based on Fraanje Method and seen on its workability on site. The chosen solution is to elongate the foundation pile in-situ, reducing the implementation time, and fixate the cap to prevent further inclinations problems.

This report recommends the client, Rijkswaterstaat Sea and Delta, to investigate the foundation pile of these structures to assure its protection against corrosion, specially nearby the bottom, where the higher moments are taken and therefore more chances of failure.

In addition, a suggestion is made for improving the background information of the actual structures, in order to reduce research time when it comes to solving problems. The lack of information and inspections on this structure has made the research process longer and more exhausting than necessary.

In relation to the final design, it is advisable to perform an extra FEM analysis with SCIA or similar software for verification and optimizations. Also regarding costs and implementation time, adjustments are to be made in accordance to upcoming offers.

7 Bibliography

Agerschou, H., Dand, I., Ernst, T., Ghoos, H., Jensen, O. J., Korsgaard, J., et al. (2007). *Planning and Design of Ports and Marine Terminals.* London: Thomas Telford Publishing.

Barnes, G. (2010). *Soil Mechanics.* Hamshire: Palgrave Macmillan.

British Standard. (1994). *BD 6349-4 1994 Maritime structures - Part 4: Code of practice for design of fendering and mooring systems.* Standards Board.

Chbab, H., & Waal, H. d. (2017). *Achtergrondrapport Hydraulische Beslastingen - Wettelijk beoordelingsinstrumentarium 2017.* Delft: Deltares.

CUR. (2001). *CUR Rapport 2001-8 Bearing capacity of steel pipe.* Gouda: CUR.

CUR. (2014). *CUR Rapport 166:2012.* BRISwarenhuis.

Dillingh, D. (2013). *Kenmerkende waarden Kustwateren.* Delft: Deltares.

DINOloket. (2018, March 3). *Ondergrondsgegevens*. Retrieved from DINOloket Data en Informatie van de Nederlandse Ondergrond: http://www.dinoloket.nl

EAU. (2012). *Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004.* Arbeitsausschuss.

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT. (1992). *RESOLUTION No. 92/2 ON NEW CLASSIFICATION OF INLAND WATERWAYS (CEMT/CM(92)6/FINAL).* Athens: EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT.

Fraanje, M. J. (1968). Waterbouwkunde Deel 1 Algemene Waterbouwkunde. In M. B. Bolderman, & A. W. Dwars, *Waterbouwkunde* (pp. 443-481). Amsterdam: L.J.Veebs Uitgeversmaatschappij N.V.

GWW. (2018, 05 31). *Cobouw Bouwkosten GWWKOSTEN*. Retrieved from Kosten: http://www.gwwkosten.nl/

NEN-EN. (1997). *NEN-EN 1997-1/A1 Eurocode 7: Geotechnical design - Part 1:.* Brussels: EUROPEAN COMMITTEE FOR STANDARDIZATION.

NEN-EN. (2002). *NEN-EN 1990 Eurocode 1 - Basis of structural design.* NEN-EN.

NEN-EN. (2008). *NEN-EN 1993-5 Eurocode 3: Design of steel structures - Part 5 Piling.* NEN-EN.

NEN-EN. (2011). *NEN-EN 1990+A1+A1/C2 Eurocode 1: Basis of Structural design.* NEN.

NEN-EN. (2011). *NEN-EN 1991-2+C1:Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges.* Rijksoverheid NEN Connect.

NEN-EN. (2013). *NEN-EN 1997-1/A1 Eurocode 7 Geotechnical design Part 1:General Rules.* NEN-EN.

NEN-EN. (2016). *NEN-EN 1997-1+C1+A1/NB National Annex to NEN-EN 1997-1 Eurocode 7: Geotechnical design Part 1: General Rules.* NEN-EN.

Ocean and air technology. (2013, May 11). *Dolphins: mooring, breasting & berthing*. Retrieved May 1, 2018, from Ships aviation & offshore technology - passionate naval architect and tech enthusiast: https://oceanandairtechnology.wordpress.com/2013/05/11/dolphins-mooring-breasting-berthing/

Orr, T. L., & Farrel, E. R. (1999). *Geotechnical design to eurocode 7.* Lodon: Spring-Verlag London Limited.

PIANC. (2002). *Guidelines for the Design of Fender Systems : 2002.* Brussels: PIAN General Secretariat.

Rijkswaterstaat. (2011). *Kenmerkende waarden Getijgebied.* Rijkswaterstaat.

Rijkswaterstaat. (2013). *Kenmerkende waarden Getijgebied 2011.0.* RWS Centrale Informatievoorziening.

Rijkswaterstaat. (2013). *RBK 1.1 Richtlijnen Beoordeling Kunstwerken: Beoordeling van de constructieve veiligheid van een bestaand.* Rijkswaterstaat.

Rijkswaterstaat. (2017). *Deelrapportage Vaarwegen voor de Nationale Markt - en capaciteitsanalyse (NMCA).* Rijkswaterstaat Water Verkeer en Leefomgeving (WVL).

Rijkswaterstaat. (2017). *Richtlijnen Ontwerp Kunstwerken ROK 1.4.* RWS GPO.

RWS. (2017). *Richtlijnen Vaarwegen 2017: Kader verkeerskundig vaarwegontwerp.* Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat.

Smits, G. T., & Meijerink, C. W. (2005). *NIC: Handreiking rekenmethodieken NIC.* Directoraat-Generaal Rijkswaterstaat.

Smits, G. T., & Meijerink, C. W. (2005). *Handreiking rekenmethodieken NIC.* Directoraat-Generaal Rijkswaterstaat.

Steenepoorte, K. (2007). *De sluizen te Hansweert in het Kanaal door Zuid-Beveland.* Rijkswaterstaat Zeeland.

Steenepoorte, K. (2016). *The locks at Hansweert in the South Beveland Canal.* Rijkswaterstaat Zee en Delta.

Thoresen, C. A. (2003). *Port designer's handbook: recommendations and guidelines.* London: Thomas Telford Ltd.

Thoresen, C. A. (2014). *Port Designer's Handbook.* London: Thomas Telford Ltd.

Tomlinson, M. J. (1994). *Pile design and construction practice.* London: E&FN Spon.

Appendices

Appendix I Research Proposal

Rijkswaterstaat
Ministry of Infrastructure and Water Management

DELTA ACADEMY

Fenders Hansweert-Design proposal for improvement of struture performance

Research Proposal

Lourenco Lehmkuhl, Sullen

3/7/18

Graduation Thesis

Research Proposal Final Thesis
Fenders Hansweert –
Design proposal for improvement of structure performance

Research Proposal Final Thesis

Student: Sullen Lourenco Lehmkuhl (71989)

Host University: HZ University of Applied Sciences

Host Company: Rijkswaterstaat Zee en Delta - Middelburg

First Examiner: Mr. P. Dekker

In-Company Supervisor: Mr. R. Davidse

7th March 2018

Version 2.0

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1. Introduction

The department of Rijkswaterstaat See and Delta is responsible for the transportation infrastructure inland and waterways in the area of Zeeland region and North Sea. As part of it, RWS Sea and Delta is responsible of ensuring the availability and quality of marine and land ways. This area has a high importance due to the connection between the ports of Rotterdam, Amsterdam and Antwerp. The lock of Hansweert is placed in the canal through 'Zuid-Beveland', which connects the Eastern Scheldt to the Western Scheldt, moreover it is also part of the scope of RWS See and Delta.

In this area, the mooring facilities are encountering structural problems and a research is needed in order to define the solution for those problems. In order to do that, a case is opened, and this research will be carried on in this document.

This document describes the steps to be taken along the research assignment, that has as objective provide a solution for the client RWS in the case of the Fender in Hansweert. Here the research methods are pointed as the requirements specified by the client.

2. Statement of the research problem

Inspections realized by RWS in the driveways of Hansweert locks have observed several dolphins are compromised by hanging crooked. This curve suspension is a known problem and is already present from the construction. The dolphin consists of a pile and a pile cap. The pile cap hangs over the pile itself with the bottom part attached by a front fender, which are attached to the cap with chains. In the past, however, the chain was the weakest link in the structure and, once the chains break, the fenders tend to fall into the water and damaging the cap of the dolphins making it crooked. It is also possible that the fender shifts so that the cap also hangs obliquely on the inner post.

In 2014, the maintenance contractor applied a change to seven dolphins where a steel cable was used instead of a chain and a lock at the bottom of the fenders in order to prevent the pile caps to become crooked. During a later site visit, however, has been observed that four out of the seven dolphins adapted still have shown the same behaviour as the others that have not been adapted.

2.1. Problem Analysis

Due to the poorly aligned dolphin piles in the Hansweert locks, a dangerous situation arises. The misalignment of the pile caps can possibly cause damage to the ship when docking to these structures. It is possible that a steel beam sticks out instead of the wood that is supposed to be there to protect the ship.

In the past, several maintenance dolphins have been adapted by the maintenance contractor, although they have not showed the desired effect once several of them are already showing the same behaviour of crooked caps. Since the chains and the steel cables did not achieve the desired effect on the structure, a different attachment must be worked out in order to solve this problem with the fenders.

2.2. Research question

What type of mooring structure should be used in order to improve the functionality of the mooring facility in the area of the Hansweert lock harbour?

2.2.1. Sub-questions

a. *Why is the steel dolphin fender structure hanging crooked?*

b. *What are the updated requirements for the water furniture for this waterway?*

c. *Does the existing structure achieve the capacity needed at the present moment ?*

d. *What is the load capacity needed in the next 50 years?*

e. *What are possible solutions in this case?*

f. *What is the most sultible solution considering time-effectivenness, cost, assurance and safety for the actual situation?*

g. *What is the design for the encountered solution?*

2.3. Objective

The final objective of this research assignment is to develop a new constructive solution that must be found in order for the fenders to function as a mooring facility in the area of Hansweert lock harbour. This solution must comply with the guidelines and standards of RWS, must be adapted to the environment and meet the shipping traffic of the canal through Zuid-Beveland, for now and in the future.

Delivered products are a design report, with calculations and drawings in which the above solution is described and elaborated. A variance analysis and cost / benefit analysis should be part of the report.

3. Theoretical Framework

This chapter is going to describe the background information needed for the process of design of a mooring structure, from its foundation to its furniture.

3.1. Berthing/Mooring Facilities

Berth is a facility where one vessel may be safely moored and load/unload cargo or let passengers or vehicles embark or disembark (Agerschou, et al., 2007). A berth facility usually consists of a system of mooring and breasting dolphins, which can be connected or not depending on the requirements.

3.1.1. Fenders

Principles

The function of a fender is to absorb a portion of the kinetic energy of a vessel without damaging it

$$E_f = f * R_m * d_m$$

where:
E_f = the vessel's kinetic energy which is to be absorbed by the fender (in kNm)
f = factor representing the energy absorbing efficiency of the fender system (between 0 and 1)
R_m = maximum fender reaction force (in kN)
d_m = maximum fender deflection (in m)

and the waterfront structure (PIANC, 2002). A rubber fender relation to the energy can be expressed mathematically as follows:

The factor f depends entirely on the characteristics of the fender chosen. The ratio R/E_f, also called the Fender Factor, is used to provide knowledge of a fender system indicating the reaction forces (kN) generated to absorb the energy and transfer it to the mooring structure.

3.2. Lock Hansweert

Lock Hansweert is located in the canal through 'Zuid-Beveland' in the region Zeeland, and it is part of the main route of transportation and waterways in the Netherlands (RWS, 2017). This infrastructure allows the connection between the Eastern Scheldt to the Westerns Scheldt, offering to the water transportation a short connection and therefore a great economic benefit.

Hansweert lock has had a traffic flow of 41,112 Vessels and 6,558 Recreational boats in the year of 2014 (Rijkswaterstaat, 2017), especially considering the route between Rotterdam-Antwerp. The capacity analysis performed by Rijkswaterstaat (2017) shows a scenario of major growth in the waterway traffic in the South-Beveland canal for the period of 2014-2050, that leads to an increased traffic of passage and berthing in the Hansweert lock. This shows the importance of maintaining and

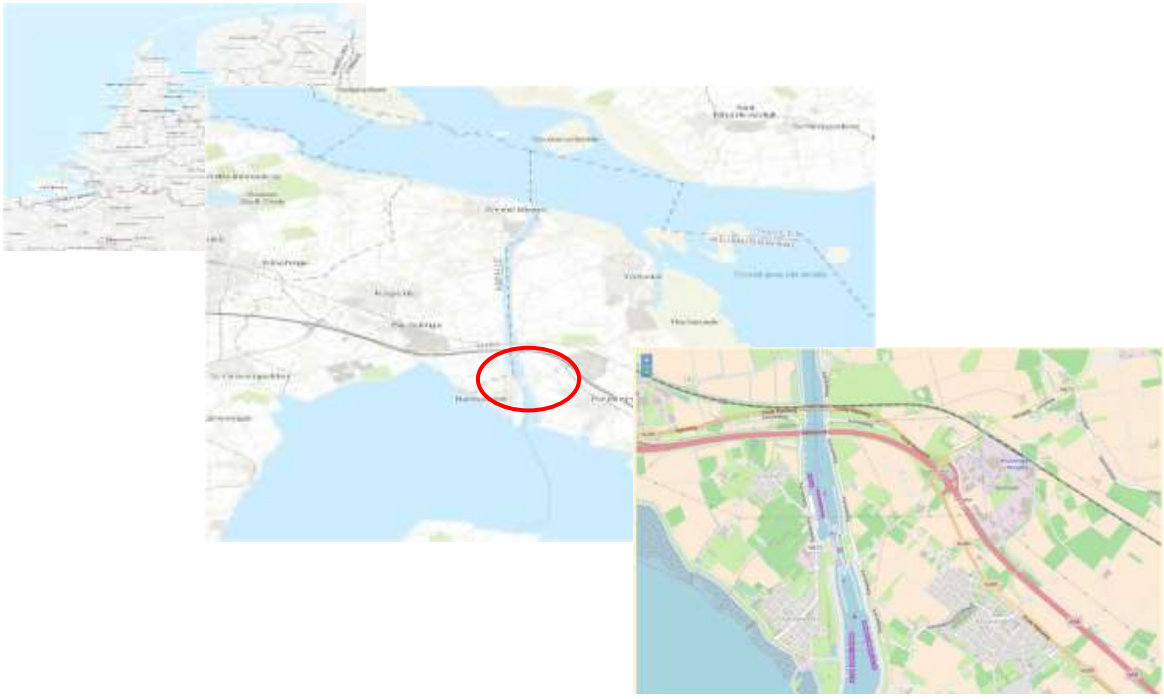


Figure 1 Research assignment location, Hansweert lock - The Netherlands. Source: ArcGIS online and RWS, 2018.

improving the capacity of the structures in order to be able to offer its services in the near future.

The actual lock has available two chambers with 280 meters length and 24 meters wide and has sliding gates. The tide difference in the Western Scheldt is around 4.5 meters, while in the South-Beveland canal the difference in tide is of around 3 meters (Steenepoorte K. , 2016).

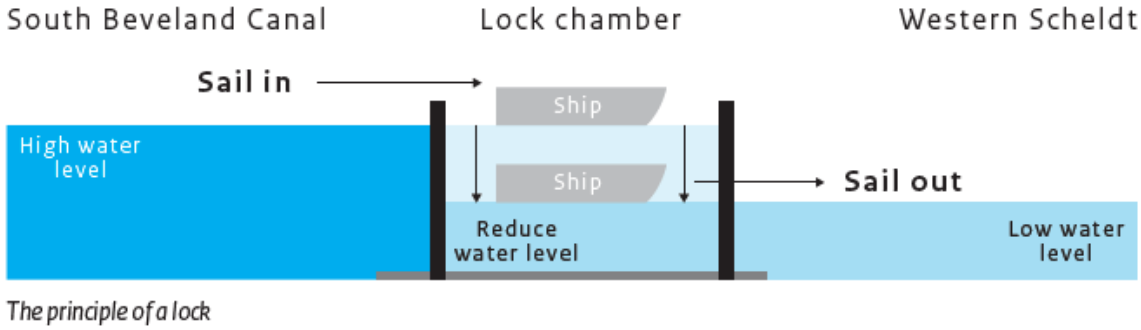


Figure 2 Principle of the lock of Hansweert. Extracted from Steenepoorte (2016).

The northern lock complex has a depth of NAP -7.5m and the southern lock complex a depth of NAP -9.0m, as the canal bottom with 100 meters width in order to accommodate the pusher tugs with four dump barges.

Figure 3 Aereal view of Hansweert lock and its facilities.

According to Rijkswaterstaat (2016), the following figure shows the vessels that are present in the local traffic.

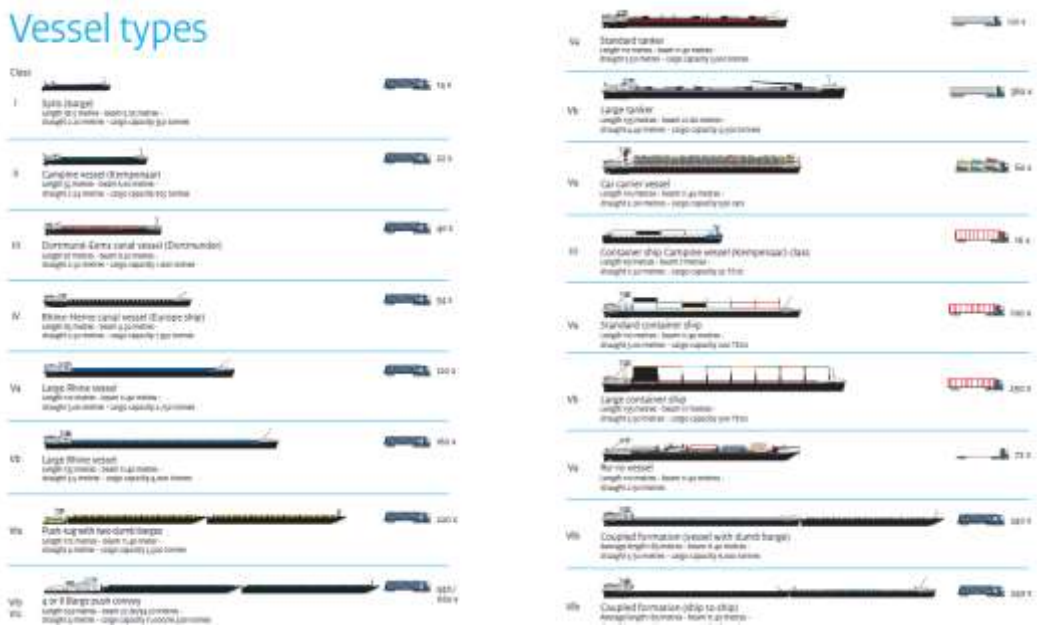


Figure 4 List of vessel types that are currently making use of Hansweert Lock. Extracted from Steenepoorte (2016)

3.2.1. Local Characteristics

Tide

The tide pattern in the area shows a difference of 8.2 meters in height between high (+4.80 NAP) and low tide (-3.40 NAP) in an average of 1 time every 50 years (Rijkswaterstaat, 2011). This value is chosen once the design lifespan is considered of 100 years, once the wet structures should follow

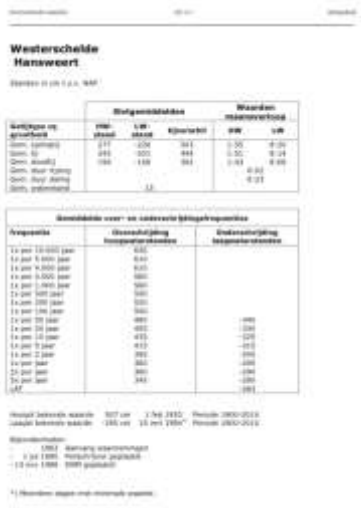


Figure 5 Western Scheldt - Hansweert location design values for the hydraulic conditions of tide. Extracted from Rijkswaterstaat (2013)

the bridges requirements (Rijkswaterstaat, 2017).

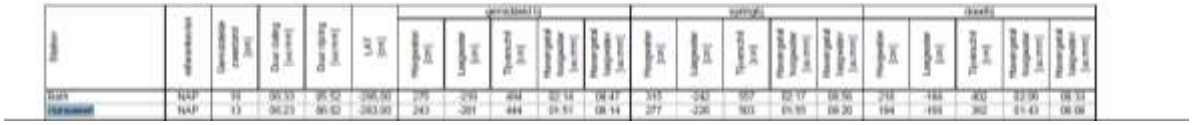


Figure 6 Design values for the tide pattern in the area of Hansweert lock. Source Dillingh (2013)

Geotechnical characteristics

Geotechnical characteristics of the outer and inner canals of the Hansweert lock are similar and will be described in this document by the location represented in the following figures. The location has a layer of fine material in the approximate 3,5 meters, and thin clay layer around NAP -23.3 meters as can be seen on the core sample profile showed below.

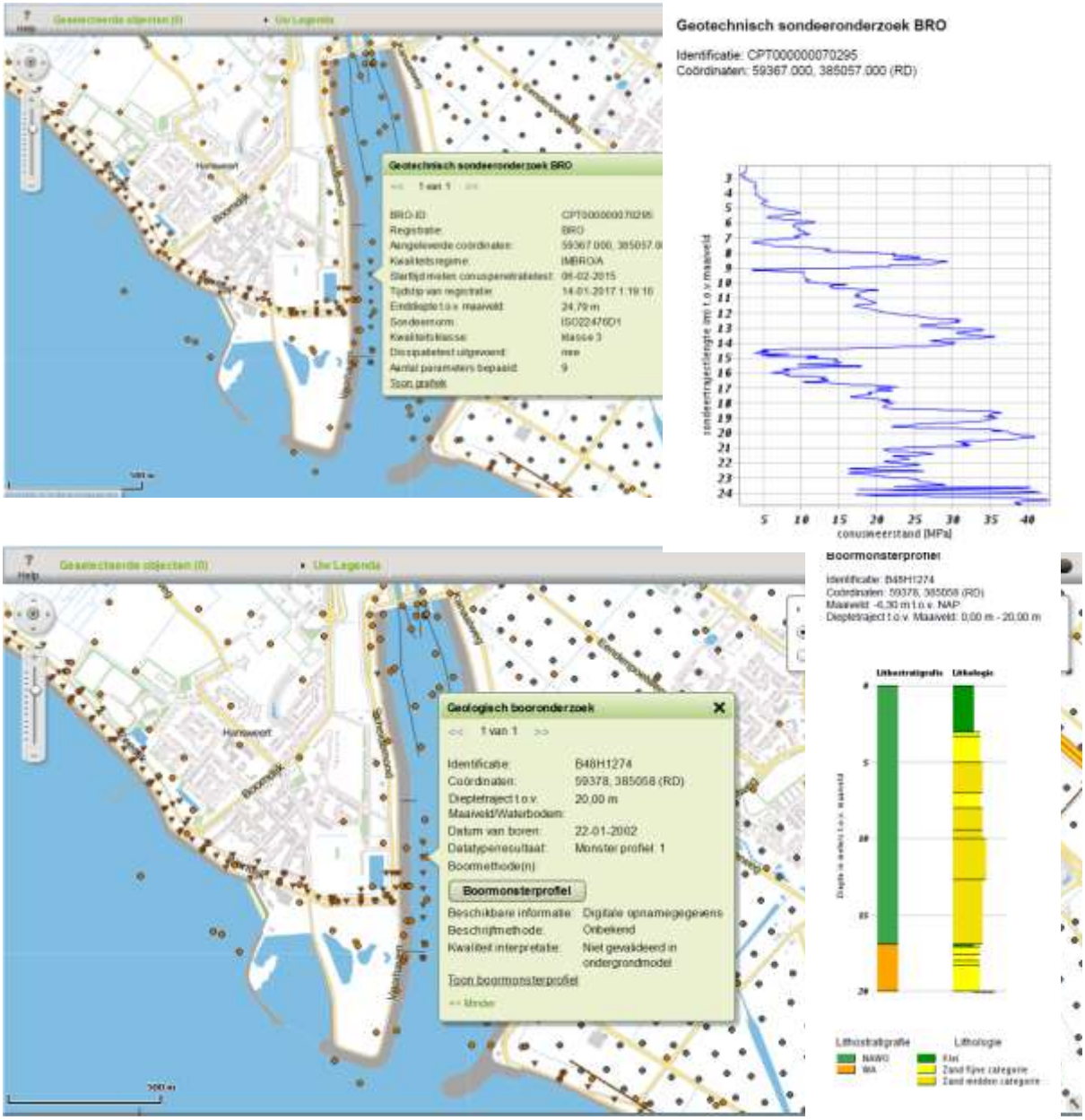


Figure 7 Geotechnical investigation of the Hansweert canal area. Source DINOLoket (2018)

3.2.2. Actual Situation

Inspections realized in the driveways of Hansweert locks have observed that several dolphins are compromise by hanging crooked. This curve suspension is a known problem and it is present since the construction. The dolphin consists of a pile cap sitting over a pile, where the pile cap hangs itself with the bottom part attached by a front fender with chains. In the past, the chains were found to be the weakest link in the structure and, once the chains break, the fenders tend to fall into the water and cause damage to the pile cap making it crooked. A shift in the fender can also cause an obliquity in the pile cap on the inner post.

In 2014, the maintenance contractor applied a change to seven dolphins by using a steel cable instead of a chain, and a lock at the bottom of the fenders in order to prevent the pile caps to become crooked. The solution worked for a short period of time, although during later visit to site, four of the seven structures showed the same behaviour as before the changes leading to a conclusion that the solution was not effective.

In May 2017, an intern report has shown that the following structures are compromised:

South front of Hansweert lock:

C20/ C21/ C23/ C24/ C26/ C27/ C28/ C29/ C31/ C31/ C32/ C33/ C34/ C35/ C36*

North front of Hansweert lock (Canal side):

F20/ F21/ F23/ D21/ D27/ D31/ D34/ D37 inclusive a berthing structure from the jetty.

Note that the numbers highlighted are also the structures that have been changed. The location of the structures can be seen in the following figure.

A visit to site has been taken place on 1st March 2018 and the situation seems to be becoming worst in the visual inspection. Some of the problematic structures have been closed due to the lack of safety for the berth of vessels. In addition to that, according to Hansweert lock supervisors, many vessels do not feel safe to use the structures, and once that is needed, they have been using more mooring facilities in order to guarantee the vessels safety.

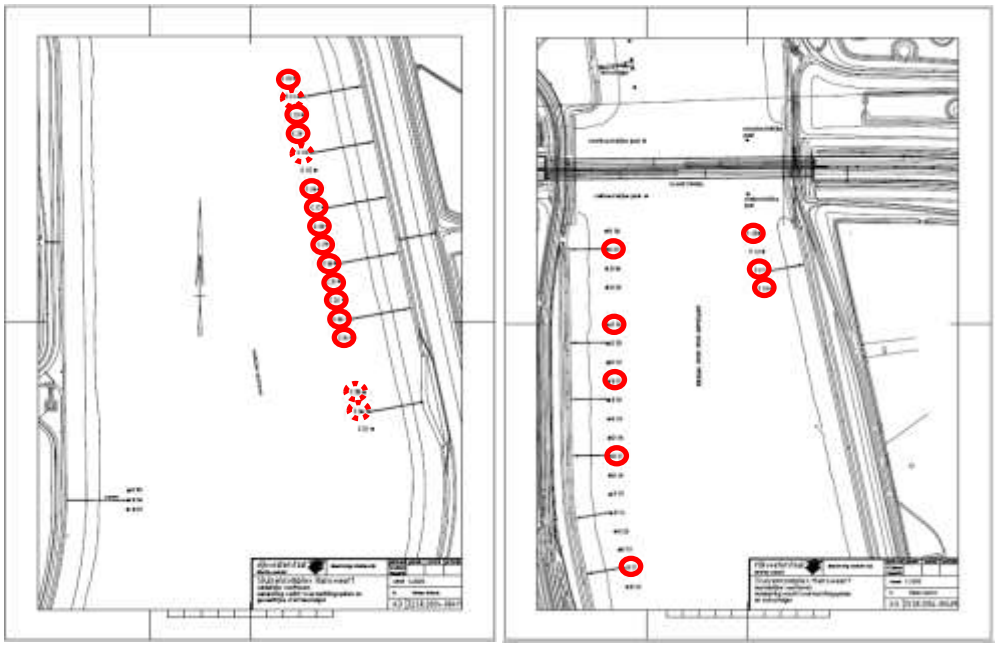


Figure 8 Location of crooked fender in mooring structures. Source: RWS, 2018.

In addition to the misalignment issue with the fenders of the mooring structures, the bollard facility has also shown a design failure. The steel base plate of the bollards are sticking out of the fender panel, generating a high risk of damage to the vessels in a situation of mooring, as can be seen on figure below.

Figure 9 Representation of actual situation of fenders damages. Source: RWS (2018).

3.3.Design background

Design lifespan and Corrosion

The lifespan of the steel structure is to be 50 years (NEN-EN 1990+A1+A1/C2 Eurocode 1: Basis of Structural design, 2011). According to NEN-EN 1993-5 (2008), the corrosion rate for underwater steel structures for a lifespan of 35 years is to be considered 2.63mm/side. Note that the steel structure is to be maintained once they have a lifespan of 15 years, so the lifetime is considered to be 50-15=35 years taking into account the material's corrosion.

3.3.1. Loading Criteria

Loading factors

The berthing facility is classified in the consequence class of CC2 in accordance to NEN-EN 1990, which has the associated load factors:

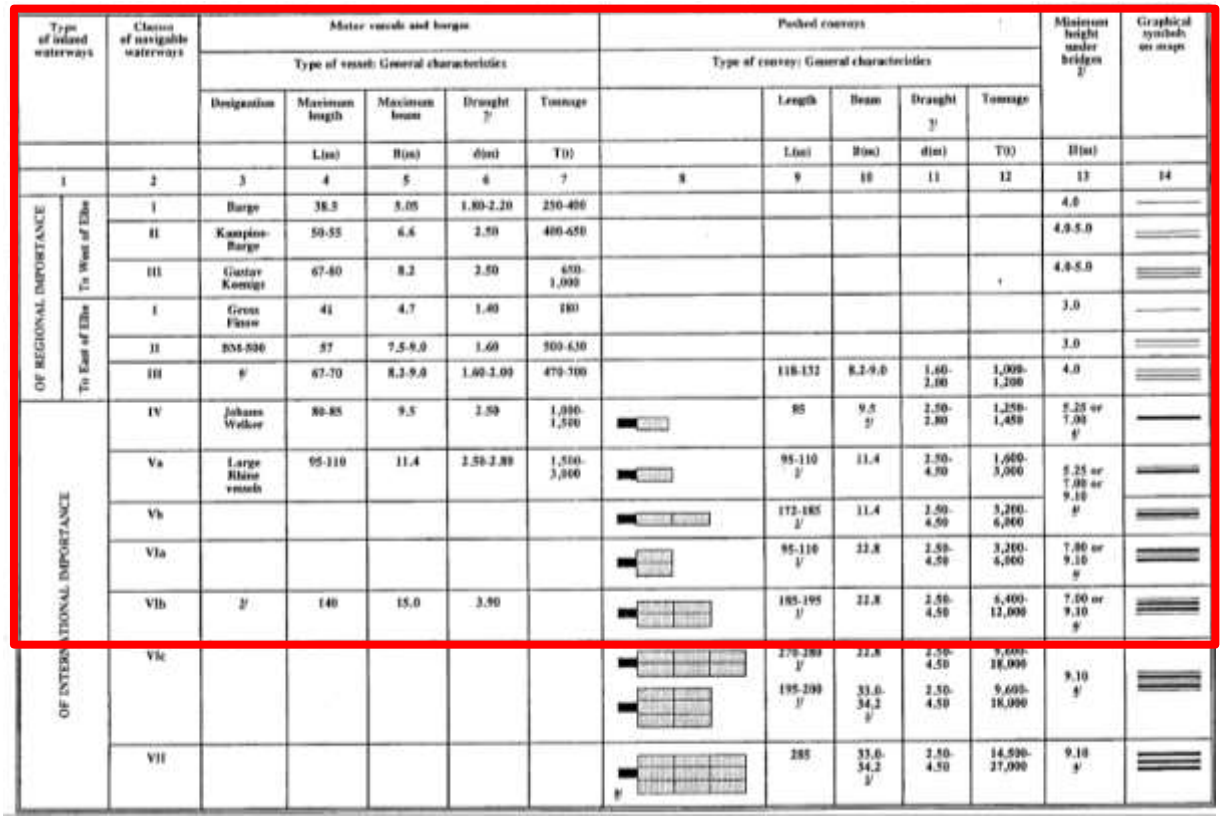
Permanent load: $\gamma_g = 1.20$;
Variable load: $\gamma_Q = 1.50$; $\psi_0 = 0.3$.

Berthing loads

The berthing loads will be calculates based on the following starting points:

- *Design vessel in this area will be considered of class CEMT Vib. At this moment the general local traffic in the lock corresponds to class CEMT Via, although bigger vessels are also present according information of the local supervisors. Class CEMT Vib is chosen because the length of the lock chambers is of 280 meters, and that would mean that the higher classes would not fit in the lock, therefore would not make use of the mooring facilities in the area.*

Table 1 Classification of European Inland Waterways. Source: European Conference of Ministers of Transport (1992)



Type of inland waterways		Class of navigable waterways	Motor vessels and barges					Pushed convoys					Minimum height under bridges 2/	Graphical symbols on maps
			Type of vessel: General characteristics					Type of convoy: General characteristics						
			Designation	Maximum length	Maximum beam	Draught 2/	Tonnage		Length	Beam	Draught 2/	Tonnage		
				L(m)	B(m)	d(m)	T(t)		L(m)	B(m)	d(m)	T(t)	H(m)	
1		2	3	4	5	6	7	8	9	10	11	12	13	14
OF REGIONAL IMPORTANCE	To West of Elbe	I	Barge	38.5	5.05	1.80-2.20	250-400						4.0	
		II	Kempen-Barge	50-55	6.6	2.50	400-650						4.0-5.0	
		III	Gustav Koenigs	67-80	8.2	2.50	650-1,000						4.0-5.0	
	To East of Elbe	I	Gross Finow	41	4.7	1.40	180						3.0	
		II	500-550	57	7.5-9.0	1.60	500-630						3.0	
		III	6/	67-70	8.2-9.0	1.60-2.00	470-700		118-132	8.2-9.0	1.60-2.00	1,000-1,200	4.0	
OF INTERNATIONAL IMPORTANCE		IV	Johann Welker	80-85	9.5	2.50	1,000-1,500		85	9.5 5/	2.50-2.80	1,250-1,450	5.25 or 7.00 6/	
		Va	Large Rhine vessels	95-110	11.4	2.50-2.80	1,500-3,000		95-110 5/	11.4	2.50-4.50	1,600-3,000	5.25 or 7.00 or 9.10 6/	
		Vb							172-185 5/	11.4	2.50-4.50	3,200-6,000		
		VIa							95-110 5/	22.8	2.50-4.50	3,200-6,000	7.00 or 9.10 6/	
		VIb	3/	140	15.0	3.90			185-195 5/	22.8	2.50-4.50	6,400-12,000	7.00 or 9.10 6/	
		VIc							270-280 5/ 195-200 5/	22.8 33.0-34.2 5/	2.50-4.50 2.50-4.50	9,600-18,000 9,600-18,000	9.10 6/	
		VII						9/	285	33.0-34.2 5/	2.50-4.50	14,500-27,000	9.10 6/	

Live Loads

The live load on the dolphin deck is only to be used for operational/maintenance purposes, so a uniform load is to be determined.

Wind Loads

- *Wind speeds*
- *Wind loads are calculated following NEN-EN 1991*

Wave and Current loads – to be determined significance in the structure

- Design Waves (Extreme conditions with a return period of 1 in 100 years)
  - Design wave heights
  - Design wave periods
- Local currents

3.3.2. Pile foundation Design

Material Quality

Due to availability and possible reuse of present steel pile foundation, the material of steel will be considered in the analysis. The design values to be used in this report are:

- S355:
  - $f_{y;d}$ = 355 N/mm2;

- f_u = 490 N/mm2.

Structural considerations

In this section the design calculations to establish the form and size of all the principal structural elements. For the design calculations the consequence class to be used in this case is CC2 according to NEN-EN 1990 (2011).

The mooring system consists in the use of the combination of four separate structures, therefore the load applied by the vessel described in the next section will be divided by four in order to calculate the loads of the individual structures.

The lateral force capacity for each pile will be calculated as follows:

Ned/Nb,Rd<=1
Ned<=Nb,Rd

$$Nb,Rd = x*As*fy = [kN]$$

In order to define the maximum moment capacity per pile, the following will be used:

$$MEdmax=Wy,pl*fy$$

Berthing Impact Load or Design Energy – described on section 4.2.1.4.

Geotechnical considerations

The calculation of the bearing capacity of the soil layers and the stability checks is to follow the Eurocode guides (Orr & Farrel, 1999). The structure to be calculated are part of the geotechnical category GC2 (Barnes, 2010).

Design of piles in bending and axial compression will be performed in accordance with EN 1993-1-1. The stability analysis of the structure will be tested following Berezantzev et al.

The limits states needed to be considered in the design of pile foundations are present on the table below.

Table 2 Limit states to be considered in pile design according to Eurocode 7 (NEN-EN, 2013).

Limit state	Considered
Loss of overall stability	
Bearing resistance failure of the pile foundation	
Uplift or insufficient tensile resistance of the pile foundation	
Failure of the ground due to transverse loading of the pile foundation	
Structural failure of the pile in compression, tension, bending, buckling or shear	
Combined failure in the ground and in the pile foundation	
Combined failure in the ground and in the structure	
Excessive settlements	
Excessive heave	
Unacceptable vibrations	

Actions and Design situations

It is recommended from Eurocode 7 that the design values of the actions on piles due to loads on the structure are determined by using partial factors given the table below.

The actions arising from the ground displacement are to be included to the pile design using one of the approaches given in the Eurocode 7. This approach is yet to be chosen based on the ground settlement to be calculated.

Table 3 Partial factors for ultimate limit states in persistent and transient situations. Source: Eurocode 7 (NEN-EN, 2013).

Parameter	Factor	Case A	Case B	Case C	Case C2	Case C3
Partial load factors (γ_F)						
Permanent unfavourable action	γ_G	**1.00**	**1.35**	**1.00**	*1.35*	*1.00*
Variable unfavourable action	γ_Q	**1.50**	**1.50**	**1.30**	*1.50*	*1.20*
Permanent favourable action	γ_G	**0.95** *(0.90)*	**1.00**	**1.00**	*1.00*	*1.00*
Variable favourable action	γ_Q	**0**	**0**	**0**	*0*	*0*
Accidental action	γ_A	**1.00**	**1.00**	**1.00**	*1.00*	*1.00*
Partial material factors (γ_m)						
tanφ'	$\gamma_{\tan\phi'}$	**1.10**	**1.00**	**1.25**	*1.00*	*1.20*
Effective cohesion c'	$\gamma_{c'}$	**1.30**	**1.00**	**1.60** *(1.25)*	*1.00*	*1.20*
Undrained shear strength c_u	γ_{cu}	**1.20**	**1.00**	**1.40**	*1.00*	*1.40*
Compressive strength q_u	γ_{qu}	**1.20**	**1.00**	**1.40**	*1.00*	*1.40*
Pressuremeter limit pressure p_{lim}	γ_{plim}	*1.40*	*1.00*	*1.40*	*1.00*	*1.40*
CPT resistance	γ_{CPT}	*1.40*	*1.00*	*1.40*	*1.00*	*1.40*
Unit weight of ground γ	γ_γ	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
Partial resistance factors (γ_R)						
Bearing resistance	γ_{Rv}	-*	**1.00**	**1.00**	*1.40*	*1.00*
Sliding resistance	γ_{Rs}	-*	**1.00**	**1.00**	*1.10*	*1.00*
Earth resistance	γ_{Re}	-*	**1.00**	**1.00**	*1.40*	*1.00*
Pile base resistance	γ_b	-*	**1.00**	**1.30**	*1.30*	*1.00*
Pile shaft resistance	γ_s	-*	**1.00**	**1.30**	*1.30*	*1.00*
Total pile resistance	γ_t	-*	**1.00**	**1.30**	*1.30*	*1.00*
Pile tensile resistance	γ_{st}	*1.40*	**1.00**	**1.60**	*1.40*	*1.00*
Anchor pull-out resistance	γ_A	*1.30*	**1.00**	**1.50**	*1.20*	*1.00*
Partial action effect and resistance model factors (γ_E, γ_{sd}, γ_{rd})						
Action effects and resistances	γ_{sd}, γ_{rd}	*1.00*	*1.00***	*1.00*	*1.00*	*1.40*

Values in **bold** are partial factors either given or implied in the ENV version of EC7.
Values in *italics* are proposed partial factors not in the ENV that may be in the EN version.
* Partial factors that are not relevant for Case A.
** The use of a model factor greater than unity is discussed in §8.2.

For pile foundations, according to NEN-EN 1997 (2013), soil investigation is important in order to define the ground conditions and that should be to a depth of five times the diameter of the shaft of the pile in order to ensure safety.

Pile Resistance

Bearing capacity of the steel piles are going to follow the guidelines of CUR Rapport 2001-8 Bearing capacity of steel pipe piles (2001) in addition to the Eurocode 3.
In the Netherlands the method described by Van Mierlo and by Koppejan (1952) is commonly used for most pile calculations and it is also described on NEN

D-Pile group software will be used to verify the calculation and for a graphic representation of the application of the forces on the pile structure.

3.3.3. Fender Design

The fender selection and design will be following the flow chart developed by PIANC (2002) as shown below.

1. Program of Requirements

Functional:

- Functional use of the facility (type of cargo, etc.)
- Safe berthing/mooring
- Reduction of ship movement
- Reduction of reaction force

Operational:

- Berthing procedure
- Frequency of berthing
- Units of mooring and operations (adverse weather)
- Range of vessels
- Special aspects of vessels (flare, beltings, list, etc.)
- Only empty vessels
- Stand-off from face of structure (crane reach)
- Fender spacing
- Special requirements
- Type and orientation of waterfront structure

2. Site Conditions

- Wind
- Waves
- Current
- Bathymetry
- Geography
- Tide
- Swell and seiches

3. Design Criteria

- Codes and Standards
- Design vessels to be used in calculations
- Approach velocity normal/extreme
- Approach angle normal/extreme
- Maximum reaction force
- Friction coefficient
- Desired life time
- Safety factors / abnormal berthing
- Maintenance costs
- Environmental considerations (e.g. temperature)
- Chemical pollution

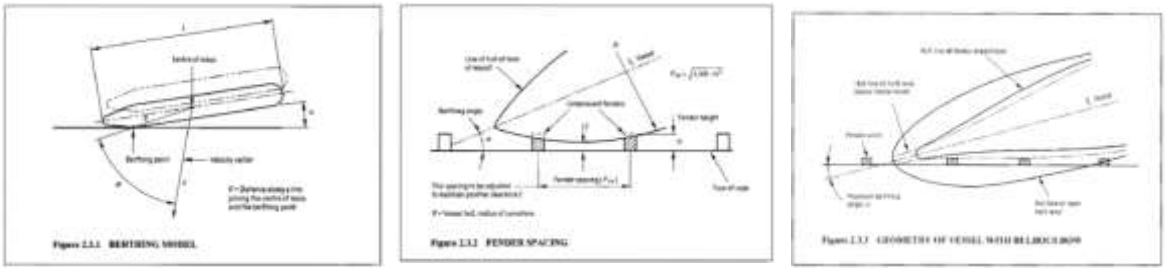
4. Fender Layout – Berthing Vessel

- **Calculation of berthing energy**
  - **Cm – virtual mass factor**
  - **Ce – eccentricity factor**
  - **Cc - berth configuration factor (or cushion factor)**
  - **Cs – softness factor**
- **Calculation of fender energy absorption**
  - **Selection of abnormal berthing factor**
- **Selection of appropriate fenders**
- **Determination of:**
  - **Energy absorption**
  - **Reaction force**
  - **Deflection**
  - **Hysteresis**
  - **Angular compression**
  - **Hull pressure**
- **Check impact on structure/vessel**
  - **Horizontal and vertical loading**
  - **Chance of hitting the structure (bulbous bow, etc.)**
  - **Face of structure to accommodate fender**

5. Final Selection of Fender

- Determine main characteristics of fender
- Check availability of fender

The aspects to be considered in the impact of the forces on the structure and on the vessel are the berthing model, geometry for bulbous bow and fender spacing that can be seen in the schemes below.



Berthing energy – Deterministic Approach

The deterministic approach is chosen once it is the oldest and most commonly used method for the design of fenders (PIANC, 2002).

Kinetic Energy of a moving vessel can be calculated as:

$$E = \frac{1}{2} * M * v^2$$

Where:

E = kinetic energy of the vessel (kNm)
M = mass of the vessel/water displacement (tones) – or Dead Weight Tonnage (DWT)
v = speed of the approaching vessel perpendicular to the berth (m/s)
The design energy that has to be absorbed by the fender is calculated by:

$$Ed = \frac{1}{2} * M * v^2 * Ce * Cm * Cs * Cc$$

Where:

Ed = design energy (normal conditions) to be absorbed by fender system (kNm)
M = mass of design vessel/displacement (tones) – usually 95% confidence level
v = speed of the approaching vessel perpendicular to the berth (m/s) – usually 50% confidence level
Ce = eccentricity factor

$$C_e = \frac{K^2 + K^2 * cos^2\varphi}{K^2 + R^2},$$

K = radius of gyration of the vessel (m) – depending on block coefficient of graph below.

$$K = (0.19 * C_b + 0.11) * L \quad \text{and} \quad C_b = \frac{M}{L * B * D * \rho}$$

C_b = block coefficient (usually between 0.5-0.9 according to PIANC (2002)in case of lack of information)
L = vessel length (m)
B = vessel breadth (m)
D = draft of vessel (m)
ρ = density of water (1.025 ton/m^3 for sea water)
R = distance of point of contact to the center of the mass (m) – measured parallel to the wharf.
φ = angle between velocity vector and the line between the point of contact and the centre of mass.

Cm = virtual mass factor – for longitudinal approach a value of Cm=1.1 is recommended. Otherwise:

$$Cm = 1 + \frac{\pi * D}{2 * Cb * B}$$

Cs = softness factor – for soft fenders and smaller vessels Cs = 1.0; for hard fenders and larger vessels Cs=0.9-1.0.
Cc = berth configuration factor or cushion factor – for open berths as for this project, Cc=1.0.

* the confidence levels and displacements needed for the calculations are displayed in the Appendix C of PIANC (2002).
The fender reaction force can be defined by the manufacturer's performance curve, and then be used for defining the calculated kinetic energy of the vessel. This force is considered a characteristic load and should be considered for the foundation structure design.

Approach velocity according to the British Standard (1994), shall be calculated according the method of Brolsma et al (1977). This method is used because to date no more pertinent or accurate data has been found (PIANC, 2002).

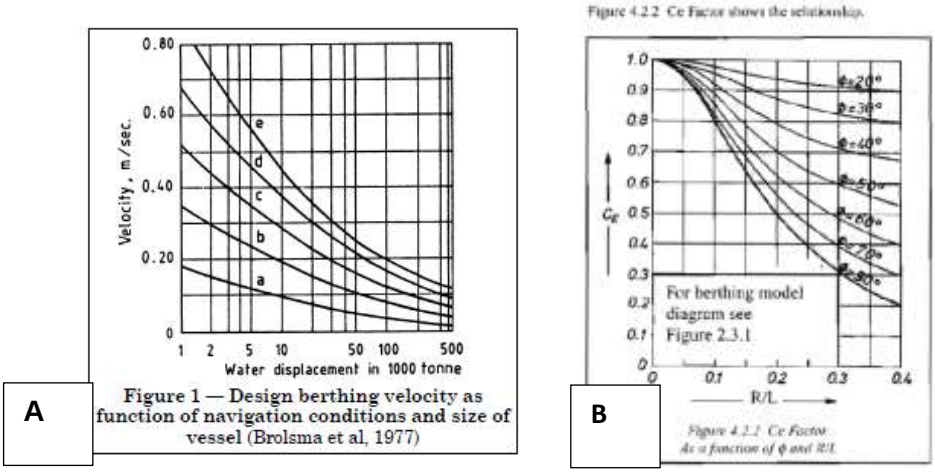


Figure 10 A- graph for design berthing velocity as function of navigation conditions and size of vessel according to Brolsma et al (2017). B – Ce factors as function of degree of approach of vessel to the structure. Source: PIANC (2002)

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Table 4 Standard block coefficient values. Source PIANC (2002)

Table 4.2.2	
For container vessels	0.6 - 0.8
for general cargo vessels and bulk carriers:	0.72 - 0.85
for tankers:	0.85
for ferries:	0.55 - 0-65
for Ro/Ro-vessels	0.7 - 0.8

Factors for abnormal impacts are to be determined, and applied to the design energy, according to the following factors:

- Effect of a fender failure on the berth operation
- Frequency of berthing
- Berths with very low approach velocities
- Vulnerability of structure supporting the fender/fender system
- Range of vessels using the berth
- Hazardous cargoes

Regarding the actual known damage to the structure, the author considers the need of using these extra factors. The following table shows the recommended factors by PIANC (2002).

Table 5 Factors for abnormal impact applied to berthing energy. Source: PIANC (2002).

Table No 4.2.5

Type of Berth Impact	Vessel	Factor for Abnormal Impact Applied to Berthing Energy (Ceb)
Tanker and Bulk Cargo	Largest Smallest	1.25 1.75
Container	Largest Smallest	1.5 2.0
General Cargo		1.75
Ro-Ro and Ferries		2.0 or higher
Tugs, Work Boats, etc.		2.0

Whole life considerations are to be described in the design report.

Fenders in flexible dolphins

For safety reasons, it is recommended to place the fender panel (fender line) with an increased distance from the structure due to the extreme berthing, such as a distance of the double amount of the maximum elastic of the pile enables a possible (plastic) energy absorption of about three times the elastic design energy, provided that the piles has enough yielding capacity.

4. Methodology

This chapter describes the methodological strategy, instruments and analysis to be used along the research assignment, as well as the design methods. The general scope of this research is firstly described in section 4.1. The method will be then separated in sections according to each final product to be delivered from this assignment.

4.1.Scope

This final thesis report has as objective developing a new constructive solution for improving and/or replacing the functionality of the mooring facilities in the area of Hansweert lock harbour. In order to do that, a research on the local characteristics in addition to the actual mooring structure to determine the capacity needed by the structure. An analysis of the old design would then be compared to the obtained information in order to define a cause for the actual situation. Therefore, a list of requirements will be generated and used in the further steps of the process.

Concerning the design proposal, a minimum of three options will be presented, and a comparison method will be used in order to choose the most appropriated options, including a root cause analysis and a multi-criteria analysis. The options will be defined as reparation design or replacement design, and they will be compared mainly regarding the elements of cost and approach time.

Once the optimal proposal is chosen, the design will be developed generating final drawings and a design report for the installation of the structure.

4.1.1. Research Strategy

This research assignment will take place mostly as an office assignment, although field inspections are going to take place along the assignment in order to verify current situation of structures. Regarding the design for the solution, the guidelines given by the client are going to be used as basis for the development of the design report in order to be a feasible design to be applied in the future by the client.

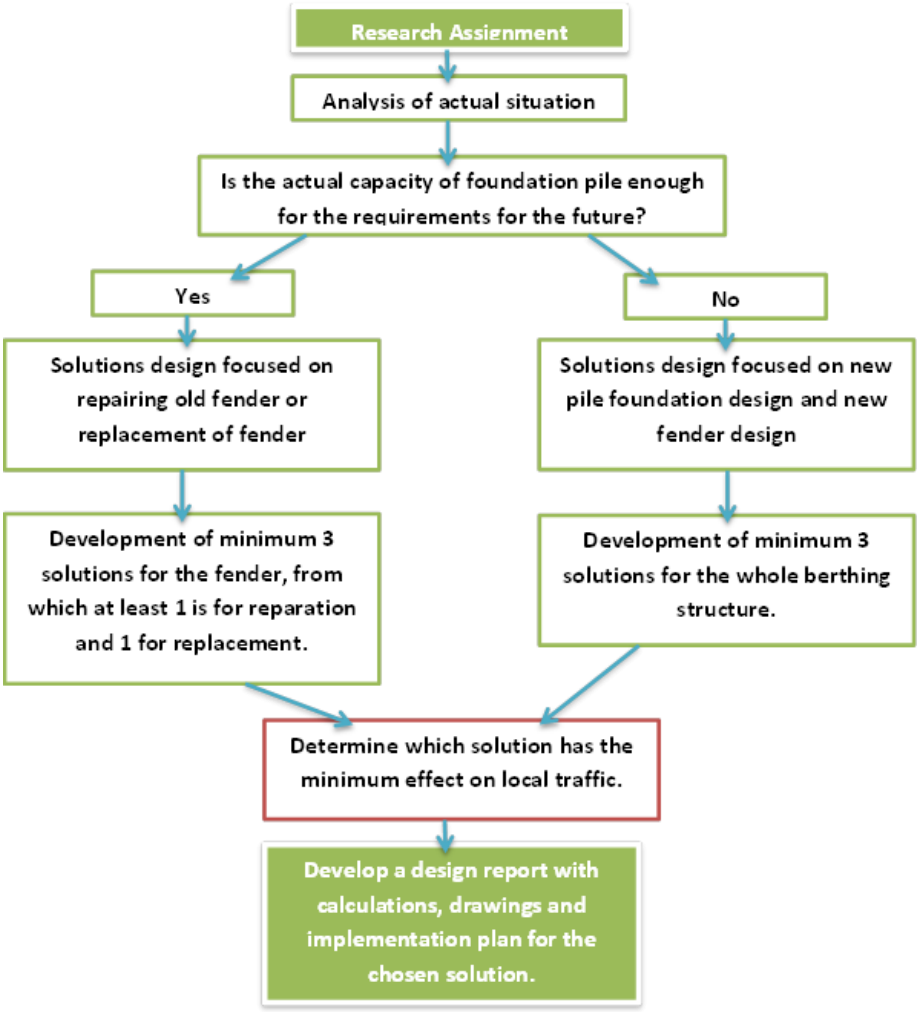


Figure 11 Stream schema describing the steps taken along the research assignment.

4.1.2. Research Tools

Along this research different tools are going to be used in order to optimize this assignment. Among these are meeting with experts, use of media research tools (Google Scholar, DinoLoket, ArcGIS Online, AHN, etc.), documents (such as guidelines from PIANC, CRU, RWS, NEN-EN etc.), literature, software programs (AutoCAD, D-Pile Group, etc.). Every tool used is going to be referred following the guidelines of APA style.

4.1.3. Final Products

This research assignment will provide in its end the following products:

- Evaluation Report of old fender structure damage – performed by the gathering the background information and developing a capacity evaluation for the local soil conditions and actual foundation pile. A root cause analysis is also a part of this product to define the problem to be solved.
- Comparison Analysis of possible solutions – a multi-criteria analysis is to be developed for defining the most suitable solution based on the normative requirements and on client requirements.
- Design Report of the chosen solution (with eventual advice on future requirements for RWS) – based on the clients requirements and choices a design report is given for a possible solution.
- Presentation of final report – the presentation is to be prepared based on the

4.2.Programs

The basis programs to be used in this research will be the following:

- AutoCAD
- MS Office
- MS Project
- D-Pile Group

Note that along the project extra programs may be used when necessary.

4.3.Design codes, Standards and Guidelines

The design of the mooring facility will be based on Dutch national normative, and Eurocode.

The Eurocodes to be adopted for the design are:

- EN 1990 “Basis of Design and actions on structures ”
- EN 1991 “Actions on Structures”
- EN 1993 “Steel Structures”
- EN 1997 “Eurocode 7. Geotechnical Design”
- ROK – Richtlijnen Ontwerp Kunstwerken 1.14 (2017)
- Richtlijnen Vaarwegen 2017 – Kader verkeerskundig vaarwegontwerp (2017)
- RBK 1.1 - Richtlijnen Beoordeling Kunstwerken (2013)
- PIANC Guidelines for the design of fender systems (2002)

Note that along the project extra normative, guidelines and codes may be used when necessary.

4.4.Methodology description

In the following sections the methodology will be described according to its final product.

4.4.1 Evaluation Report Actual Structure

In order to identify the reason why the structure has shown failure, an analysis will be developed according its design. The design of the actual mooring facility has taken place in the year of 1982, when different requirements were present.

A design analysis will be performed with the details used for the design of Hansweert lock, once the design report of the dolphins is not to be found. A comparison table will be generated with the difference in requirements and design capacity of the old structure to be compared to the actual requirements.

In order to do the comparison, the following analysis will be performed:

- Structural analysis – this analysis will follow the instructions placed on NEN-EN 1990 (2011).
- Geotechnical analysis – these analysis will follow the instructions placed on NEN-EN 1997 (2013), NEN-EN 1997 –Dutch Annex (2016) and further parts.

4.4.2 Comparison Analysis Solutions

In this document, a minimum amount of three options will be described and analyzed according to the criteria's of costs, time, future capacity and effect of implementation. The most important criteria required by the client are the effect on the traffic during the construction/repair of the structure for the implementation of the solution.

4.4.3 Design Report

Once the mooring structures are considered by RWS 'wet structures' (Natte Kunstwerken), according to the ROK 1.4, these structures must meet the requirements of the normative NEN-EN 1990, NEN-EN 1990/A1 and NEN-EN 1990/NB (plus associated ROK parts) and CUR (2001).

5. Expected Results

According to background information provided by the client and the local interview with supervisors, it is expected the following outcomes:

- The actual fender structure does not meet the capacity required for withstanding the vessels that are in need of the structure at this moment, and that would be the cause for the structure to be standing crooked;
- The actual fender design has failures that can cause damage to the boats, once pieces of steel are standing out of the fender alignment.
- The foundation pile does still offer enough capacity to the berthing structure, so it can be reuse and the need for changing the pile does not appear.
- The pile cap and fenders are to be changed for a new structure.

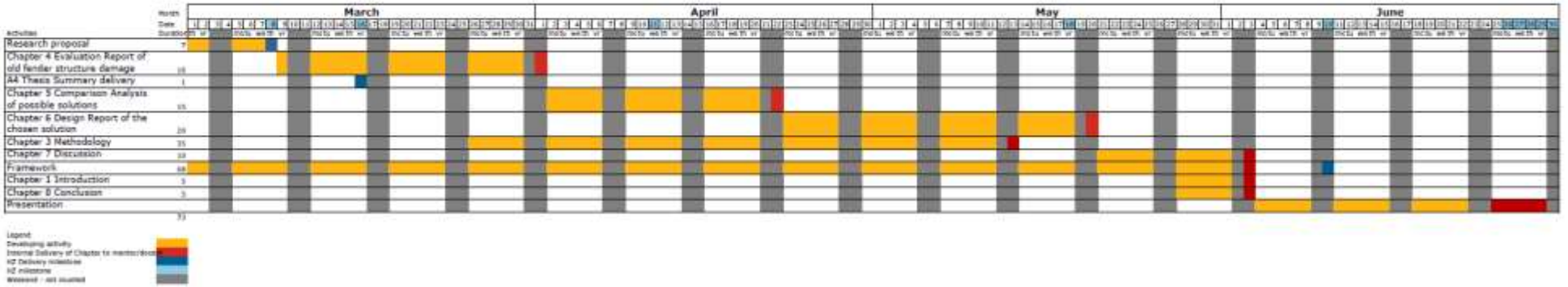
This research assignment will generate as final document an Advisory Report which consists of an evaluation of the current situation, the proposal and choice of solution and a design report with all the calculations, drawings and implementation plan for the encountered solution.

The Advisory Report can be defined as:

- Cover Sheet
- Preface
- Contents
- Chapter 1 Introduction
- Chapter 2 Theoretical Framework
- Chapter 3 Methodology
- Chapter 4 Evaluation Report of old fender structure damage
- Chapter 5 Comparison Analysis of possible solutions
- Chapter 6 Design Report of the chosen solution (with eventual advice on future requirements for RWS)
- Chapter 7 Discussion
- Chapter 8 Conclusion
- References
- Appendices

In order to present this research product, a presentation will take place at the host university where it will be submitted to evaluation.

6. Timetable


March
April
May
June
Research proposal
Chapter 4 Evaluation Report of old fender structure damage
A4 Thesis Summary delivery
Chapter 5 Comparison Analysis of possible solutions
Chapter 6 Design Report of the chosen solution
Chapter 3 Methodology
Chapter 7 Discussion
Framework
Chapter 1 Introduction
Chapter 8 Conclusion
Presentation

7. References

Agerschou, H., Dand, I., Ernst, T., Ghoos, H., Jensen, O. J., Korsgaard, J., et al. (2007). *Planning and Design of Ports and Marine Terminals.* London: Thomas Telford Publishing.

Barnes, G. (2010). *Soil Mechanics.* Hamshire: Palgrave Macmillan.

British Standard. (1994). *BD 6349-4 1994 Maritime structures - Part 4: Code of practice for design of fendering and mooring systems.* Standards Board.

Chbab, H., & Waal, H. d. (2017). *Achtergrondrapport Hydraulische Beslastingen - Wettelijk beoordelingsinstrumentarium 2017.* Delft: Deltares.

CUR. (2001). *CUR Rapport 2001-8 Bearing capacity of steel pipe.* Gouda: CUR.

CUR. (2014). *CUR Rapport 166:2012.* BRISwarenhuis.

Dillingh, D. (2013). *Kenmerkende waarden Kustwateren.* Delft: Deltares.

DINOloket. (2018, March 3). *Ondergrondsgegevens*. Retrieved from DINOloket Data en Informatie van de Nederlandse Ondergrond: http://www.dinoloket.nl

EAU. (2012). *Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004.* Arbeitsausschuss.

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT. (1992). *RESOLUTION No. 92/2 ON NEW CLASSIFICATION OF INLAND WATERWAYS (CEMT/CM(92)6/FINAL).* Athens: EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT.

Fraanje, M. J. (1968). Waterbouwkunde Deel 1 Algemene Waterbouwkunde. In M. B. Bolderman, & A. W. Dwars, *Waterbouwkunde* (pp. 443-481). Amsterdam: L.J.Veebs Uitgeversmaatschappij N.V.

GWW. (2018, 05 31). *Cobouw Bouwkosten GWWKOSTEN*. Retrieved from Kosten: http://www.gwwkosten.nl/

NEN-EN. (1997). *NEN-EN 1997-1/A1 Eurocode 7: Geotechnical design - Part 1:.* Brussels: EUROPEAN COMMITTEE FOR STANDARDIZATION.

NEN-EN. (2002). *NEN-EN 1990 Eurocode 1 - Basis of structural design.* NEN-EN.

NEN-EN. (2008). *NEN-EN 1993-5 Eurocode 3: Design of steel structures - Part 5 Piling.* NEN-EN.

NEN-EN. (2011). *NEN-EN 1990+A1+A1/C2 Eurocode 1: Basis of Structural design.* NEN.

NEN-EN. (2011). *NEN-EN 1991-2+C1:Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges.* Rijksoverheid NEN Connect.

NEN-EN. (2013). *NEN-EN 1997-1/A1 Eurocode 7 Geotechnical design Part 1:General Rules.* NEN-EN.

NEN-EN. (2016). *NEN-EN 1997-1+C1+A1/NB National Annex to NEN-EN 1997-1 Eurocode 7: Geotechnical design Part 1: General Rules.* NEN-EN.

Ocean and air technology. (2013, May 11). *Dolphins: mooring, breasting & berthing*. Retrieved May 1, 2018, from Ships aviation & offshore technology - passionate naval architect and tech enthusiast: https://oceanandairtechnology.wordpress.com/2013/05/11/dolphins-mooring-breasting-berthing/

Orr, T. L., & Farrel, E. R. (1999). *Geotechnical design to eurocode 7.* Lodon: Spring-Verlag London Limited.

PIANC. (2002). *Guidelines for the Design of Fender Systems : 2002.* Brussels: PIAN General Secretariat.

Rijkswaterstaat. (2011). *Kenmerkende waarden Getijgebied.* Rijkswaterstaat.

Rijkswaterstaat. (2013). *Kenmerkende waarden Getijgebied 2011.0.* RWS Centrale Informatievoorziening.

Rijkswaterstaat. (2013). *RBK 1.1 Richtlijnen Beoordeling Kunstwerken: Beoordeling van de constructieve veiligheid van een bestaand.* Rijkswaterstaat.

Rijkswaterstaat. (2017). *Deelrapportage Vaarwegen voor de Nationale Markt - en capaciteitsanalyse (NMCA).* Rijkswaterstaat Water Verkeer en Leefomgeving (WVL).

Rijkswaterstaat. (2017). *Richtlijnen Ontwerp Kunstwerken ROK 1.4.* RWS GPO.

RWS. (2017). *Richtlijnen Vaarwegen 2017: Kader verkeerskundig vaarwegontwerp.* Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat.

Smits, G. T., & Meijerink, C. W. (2005). *NIC: Handreiking rekenmethodieken NIC.* Directoraat-Generaal Rijkswaterstaat.

Smits, G. T., & Meijerink, C. W. (2005). *Handreiking rekenmethodieken NIC.* Directoraat-Generaal Rijkswaterstaat.

Steenepoorte, K. (2007). *De sluizen te Hansweert in het Kanaal door Zuid-Beveland.* Rijkswaterstaat Zeeland.

Steenepoorte, K. (2016). *The locks at Hansweert in the South Beveland Canal.* Rijkswaterstaat Zee en Delta.

Thoresen, C. A. (2003). *Port designer's handbook: recommendations and guidelines.* London: Thomas Telford Ltd.

Thoresen, C. A. (2014). *Port Designer's Handbook.* London: Thomas Telford Ltd.

Tomlinson, M. J. (1994). *Pile design and construction practice.* London: E&FN Spon.

Appendix II Current Situation Analysis

Rijkswaterstaat
Ministry of Infrastructure and Water Management

DELTA ACADEMY

2018

Current Situation Analysis

Lourenco Lehmkuhl, Sullen (PPO)
Rijkswaterstaat Zee en Delta
12-6-2018
Version 1.0

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1 Introduction

This document assembles the found information regarding the structure in analysis. The next sections will describe design parameter that were to be considered in the implementation process, following Rijkswaterstaat requirements and regulations.

2 Design parameters 1986

Limits and preconditions for the design of Hansweert dolphins are assumed to be the same as for the whole lock complex and for general berthing facilities, once the design report for this structure specifically is not to be found.

2.1 Relevant documents

[18] ZLSR-1987-12014 : Drawing Toeleidinswerken hansweert ducdalven westerscheldezijde;
[19] ZLSR-1987-12015 : Drawing Toeleidinswerken hansweert ducdalven kanaalzijde;
[20] ZLSR-1987-12251 : Drawing Toeleidingswerken Hansweert Matentekening Azobe beslag dukdalven westernschelde en kanaalzijde;
[21] ZLSR-1990-02084 : Drawing Toeleidingswerken hansweert bevesting rubber fender en apheffen speling en zekering mantel tbv ducdalven;
[22] ZLSR-2004-00408 : Drawing Sluizencomplex Hansweert Situ Voorhaven KZB;
[23] ZLSR-2004-00409 : Drawing Sluizencomplex Hansweert Situ Voorhaven KZB;
[24] ZLSR-2004-00411 : Drawing Sluizencomplex Hansweert Situ Voorhaven WST;
[25] RWSZL-2011-04940 : Drawing Fender opvangconstructie meerstoelen hansweert;
[26] RWSZD-2014-02374 :Drawing Fender opvangconstructies C21,C22,C24,C35,C36 en C37 HWS met zijdelings gefixeerd;
[27] RWSZD-2014-02504 :Afleverdossier spec nr 20-21 aanbrengen 19st opvangconstructie en 4 fenders aan de meerstoelen D20 t/m D37 sluizencomplex Hansweert;
[28] ZLSR-1991-00032 : Uitgangspunten en randvoorwaarden geleidewerken Hansweert
[29] ZLSR-1987-00001 : Overeenkomst tot uitvoering en wijziging van Bestek SS1239a
[30] ZLSR-1987-00003 : Conservering op de constructie en kunststof blokken
[31] ZLSR-1987-00004 : Aandachtspunten ten aanzien van onderhoud
[32] ZLSR-1987-00005 : Toeleidingswerken Hansweert
[33] 48H-353-BC-03-2009 : Hansweert Steigers en meerpalen

2.2 Load requirements

2.2.1 Energy

The required energy absorption for a pile is of 120kN, also valid for the dolphins.

2.2.2 Berthing levels

According to [28], the berthing levels are to be placed one meter above the water level. Following the given values of 2.3.1, the current levels can be seen:

Table 1 Mooring levels required for Hansweert dolphins.

	Type	Mooring Level	
Canal side	HWL	+4,80	mNAP
	LWL	-0,70	mNAP
Western Scheldt side	HWL	+6,00	mNAP
	LWL	-2,50	mNAP

2.3 Hydraulic conditions

2.3.1 Water level

Canal through South Beveland side

Table 2 Water level parameters from the side of the Canal through South Beveland.

Type	Water Level	
Highest water level (HHWL)	+3,80	mNAP
Average high water level (HWL)	+1,63	mNAP
Average low water level (LWL)	-1,37	mNAP
Lowest water level (LLWL)	-1,70	mNAP

Western Scheldt side

Table 3 Water level parameters from the side of the Western Scheldt.

Type	Water Level	
Highest water level (HHWL)	+5,07	mNAP
Average high water level (HWL)	+2,26	mNAP
Average low water level (LWL)	-2,12	mNAP
Lowest water level (LLWL)	-3,50	mNAP

2.3.2 Soil characteristics

The local soil has different characteristics depending on the lock side.

Canal through South Beveland side

The canal side is described as a clayey sand, with a bottom level between -7,50mNAP and -9,00mNAP.

Western Scheldt side

The western Scheldt side is represented by sandy soil with a bottom level of -9,00mNAP.

2.4 Structure design

All information regarding the design of the element in study was taken from the drawings [18], [19] as original as-built drawings, once there are still structures that were not modified and to analyze the actual cause for the failure in question.

The dolphin is formed by the combination of two major elements, a foundation pile and a pile cap. The pile cap is a 1820mm pile with a thickness of 16mm, which has attached the fender system with the presence of a azobé panel, two fenders of 600x300x1000, fender chains, and connection to the walking bridge. The pile cap has a length of 10 meter in the Western Scheldt side, and one of 7,50 meters in the canal side. The foundation pile is a 1016mm diameter with 20 mm, and a total length of 24,1meters in the Western Scheldt side, and one of 20,65 meters in the canal side.

All these features can be seen in drawings [18], [19], [20], [21].

It is noted that both reports and drawings do not give the same information regarding the structure. The drawings as as-built documents are taken into consideration for further design purposes.

2.4.1 Structure elements

Steel pile

Steel quality: FeE490kr, according to [32], although it is not been found practical values for this code, leading to an assumption of steel use of the quality S355JO which is commonly used by RWS See and Delta in similar constructions.

Protection layer: the protection layer required in this structure, and expected to have been used, is a combination of b1-2xd21 in the factory. For installation purposes, where welding is needed an extra layer is applied in situ with b6-C12-2xd22. Where:

- b1- steel following Swedish norm SIS-05-5900/1967, grade SA $2^1/2$;
- b6- brush with steel-brush;
- C12- zinc rich two component paint based on ethyl-silicate, with a dry layer of 25µu;
- d22- two component paint based on epoxy resin with dry layer of 75µu;
- d21-two component paint based on epoxy resin with dry layer of 200µu.

Azobe panel

Balks of 300x200mm are used for assembling the panel, and are treated with drying products Mobil-CER o.d.

Rubber fenders

Two rubber fenders of 600x300x1000 are used per pile, with a basis of styrene-butadiene. They are located in the lower part of the pile cap and it is placed between the cap and foundation pile with the support of chains connected to the inside of the cap. In addition a small plate is placed also in the inside of the cap, right under the fenders assumed to provide vertical support.

The absorption energy required by the requirement is of 68kN by a bending of 350mm.

3 Modifications

Two main modifications were applied to the structure, from which one in 1990 with considering the rotational issue, and the second later on in 2014 with a cable and holding system for the rubber fenders.

Chronologic detail of events is vague due to the lack of reports. It is known that the dolphins and its fenders were installed in between 1987 and 1988, as shown in the drawings in Appendix I-I – Original structure drawings.

Speculations are that the pile cap had a certain inclination since the moment of installation back in 1987, nevertheless this is not documented in any report or drawing available.

In the year of 1990 the first modification was done. The Appendix IX– 1st Modification drawings, shows the details of the new elements added to the original structure where it is possible to see that a chain system was clamped in the bottom of the cap to prevent the fenders to fall, and the top has been adjusted to reduce possibility of rotation of the cap. It is although not clear how many structures were modified at this time.

In 2014, the maintenance contractor applied a second change to seven dolphins where a steel cable attached to the top of the pile cap was used instead of a chain attached to its walls. Later on in the same year, a third modification was added when lock at the bottom of the fenders was designed in order to prevent the pile caps to become crooked. This elements can be seen in drawing

During a later site visit, however, has been observed that four out of the seven dolphins adapted still have shown the same behavior as the others that have not been adapted.

Table 4: Chronologic description of events.

Date	Description of event or action
01-01-1987	Installation of Dolphins. Actual date is not known.
01-01-1990	1st modification – addition of clamp chains to bottom of cap and plates on top to reduce rotation.
01-01-2011	2nd Modification – installation of support cables.
28-05-2013	Order of service generated from RWS.
30-08-2013	Quotation from maintenance company received for the improvement of 19 foundation plates and 4 fenders, from dolphins D20 to D37.
30-08-2014	3rd modification. Report of work from maintenance company for the 3rd modification.
25-05-2017	Inspection reports that 4 out of the 7 dolphins that were fixed are hanging crooked again.
01-03-2018	Begin analysis of the situation by the internship research. All structures are still hanging crooked.

4 Practical information

The following information is based on the experiences of the lock supervising team.

- Largest inland barges - about 10000 tons (variation 1000-3000ton)
- Coasters / small seagoing vessels also moor
  - Length 60-100m
  - Tonnage 800-3000ton
  - Max 5 meters high
- I do not know the height of the cranes / "deck load". But this can be pretty big.
- This "deck load" on pontoons can for instance be parts for cranes, windmills, bridges or cylinders/tanks for a factory to be built somewhere.
- Passing large ships
  - Wave
  - Suction
- Occasionally it happens that clusters break some time after passing large (drifting) shipping. This can happen especially at low water levels.
- Wind gusts can occur up to wind force 10 to 11 bft. (11 bft-very heavy storm, 103-117 km / h; 28.5-32.6 m / s; enormous damage to forests)
- Flow rates for the port can be as much as 5 miles (flood flow). * "In the port I have never seen that parameter could affect the mooring."
- Mooring angle depends on "free space".
- If the ships have to moor in front of and behind them between other ships, the angle will (have to) be larger.
  - Consider 10 to 20 degrees if there is sufficient space to up to 45 degrees if there is little space.
  - With a lot of wind, I have sometimes seen a ship almost angled towards poles to be able to put a mooring wire here, or to see it almost at right angles to the post.
- For example, 1 to 2 (max 1 m / s) knots to 4 to 5 knots (max 2.5 m / s), with the proviso that at the moment of hitting / mooring against the pile the speed is almost zero (or should be). "However, most skippers are proficient and expert in handling frequently and very well with their ships."

5 Actual condition of Pile Structure

The actual condition of the pile is based on visual analysis and on the latest inspection in the structure.

5.1 *Visual Analysis*

Figure 1 Visual inspection of 2017.

5.2 *Inspections*

No inspection was ever done in the foundation pile structure in the high water level. However, an inspection report from 2009 shows the situation encountered in the outer pile cap, that can be used as an estimation for the condition of the inner pile. The inspection has also carried an analysis of the width of the pile wall from the foundation pile.

Above high water level

According to this report the piles have shown a reduction in the epoxy layer as seen in table below.

Western Scheldt side: Right: C20-37; Left: G35-37

Canal side: Right:F20-23; Left: D20-38

3.1.1 Conserveringsdikte (koolteer epoxy systeem)

De dikte van de conservering is gemeten op het deel boven de hoogwater lijn, de resultaten zijn vastgelegd in tabel A.

Conserveringsdikte

Locatie	N	Gem.	Min./max.	Afw.
Paal C21	25	470	170 / 888	485
Loopbrug bij paal C21	50	438	193 / 757	153
Paal C27	25	640	249 / 1130	223
Loopbrug bij paal C27	50	409	158 / 846	175
Paal C29	25	349	204 / 519	85.9
Paal C36	25	451	247 / 668	97.7
Paal D21	35	371	131 / 605	150
Paal D23	15	316	193 / 497	92.1
Paal D25	15	239	172 / 397	53
Loopbrug bij paal D24	50	454	215 / 807	112
Paal D27	20	309	143 / 547	83.7
Paal D29	15	405	255 / 727	126
Loopbrug bij paal D30	50	417	216 / 846	118
Paal D31	15	322	234 / 472	74.8
Paal D33	20	302	173 / 545	107
Paal 5	25	327	105 / 667	165
Paal D36	20	291	207 / 430	53.4
Loopbrug bij paal D36	50	443	167 / 767	142
Paal F21	35	383	174 / 1270	230
Paal F22	15	316	210 / 446	86.1
Paal F23	20	372	179 / 561	130

Tabel A

N = aantal metingen
Gem. = gemiddelde dikte in mu.
Min./ max. = laagste en hoogst gemeten dikte in mu.
Afw. = standaard afwijking

Figure 2 Inspection values of conservative paint layer above water level.

We assume that these values indicate the reduction in 22 years, once no other inspection or maintenance report is found.

Locale roestvorming (koolteer epoxy systeem)

Locatie	Totale roest opp.	Totale herstel opp.	Opp. Paalbrug	Perc.
Paal C20 t/m C37 Gemiddeld	1,3 m2	5,3 m2	69	7,7 %
Paal C20 t/m C37 Hoogste	2,2 m2	8,8 m2	69	12,8 %
Paal C20 t/m C37 Laagste	0,8 m2	3,2 m2	69	4,6 %
Paal D20 t/m D37 Gemiddeld	1,5 m2	5,9 m2	47	12,6 %
Paal D20 t/m D37 Hoogste	2,8 m2	11,2 m2	47	23,8 %
Paal D20 t/m D37 Laagste	0,6 m2	2,4 m2	47	5,1 %
Paal F20 t/m F23 Gemiddeld	1,1 m2	4,4 m2	47	9,4 %
Paal F20 t/m F23 Hoogste	2,4 m2	9,6 m2	47	20,4 %
Paal F20 t/m F23 Laagste	0,6 m2	2,4 m2	47	5,1 %
Loopbruggen C21, C24, C27, C30, C33 en C36, Gemiddeld	2,3 m2	9,3 m2	235	4,0 %
Loopbr. D21, D24, D27, D30, D33, D36 en F21,Gemiddeld	1,9 m2	7,8 m2	130	6,0 %

Tabel E

Figure 3 Average rust formation for pile cap.

Under lowest water level

This measurements were done 2 meters below the lowest water level and generated the following table.

Staaldikte meting								
Locatie	Hoogwaterlijn, paalmuts				Ca. 2m onder laagwaterlijn, draagpaal			
	Noord	West	Zuid	Oost	Noord	West	Zuid	Oost
Paal C21	15.8	16.0	16.0	16.0	20.7	20.6	20.5	20.6
Paal C26	15.9	15.9	15.9	16.0	20.5	20.2	20.4	20.4
Paal C27	15.9	15.8	15.9	15.8	20.8	20.7	20.5	20.6
Paal C29	15.7	15.9	15.8	15.8	20.4	20.5	20.5	20.5
Paal C30	15.9	15.8	15.9	15.9	24.5	24.4	24.6	24.5
Paal D21	15.8	15.8	15.9	15.8	20.4	20.4	20.3	20.3
Paal D24	15.9	15.8	16.0	15.9	20.4	20.4	20.4	20.3
Paal D30	15.8	15.9	15.9	15.9	20.5	20.5	20.6	20.5
Paal D36	15.7	15.7	15.9	15.9	20.9	20.7	20.6	20.3
Paal F22	15.9	15.6	15.9	15.8	20.4	20.3	20.3	20.4

Tabel H (maten in mm)

Figure 4 Measurements of steel thickness. Not specified situation in case of thickness increase.

5.3 Conclusion

The cap shows an erosion of the pile, where the cap thickness is as design 16mm. The maximum erosion is shown in pile F22, with a loss of 0.4mm in the western side.

On the other hand, the foundation pile shows overgrowth in all cases, coming to a maximum of 4.5mm. Nevertheless, is also known that overgrowth can be a cause for weakening of material.

The epoxy layer has shown to be within the lifespan, even though rust is still present. The area of rust formation is covering up to 20% of the pile cap.

Therefore this report advises RWS to perform a material inspection in the foundation piles for the area below low water level and an thickness inspection of the foundation pile above high water level. Relative to the epoxy coat, it is advisable to evaluate the type being used once rust areas are still present, then the epoxy coat does not have the desired effect.

Appendix III Program of Requirements

Rijkswaterstaat
Ministry of Infrastructure and Water Management

DELTA ACADEMY

2018

Program of Requirements

Lourenco Lehmkuhl, Sullen (PPO)
Rijkswaterstaat Zee en Delta

12-6-2018

Version 2.0

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1 Introduction

In order to develop a dolphin design for improving its functionality in the area of Hansweert lock, the Netherlands, a program of requirements is assembled. This report is based on normative and guidelines for the technical design of dolphins in the country, local characteristics and client preferences.

Content

This report represents the program of requirements to be used in this project. The following division can be seen in the following pages: Chapter 2 –Hydraulic requirements; Chapter 3 – Functional and Technical requirements; Chapter 4 – General Assumptions.

2 General Requirements

This chapter describes the general hydraulic requirements that are applied to this research assignment.

2.1 Project Location

The location of this project is situated in the front and back harbors of the Hansweert Lock, in the Netherlands. Figure 1 represents the location in the map.

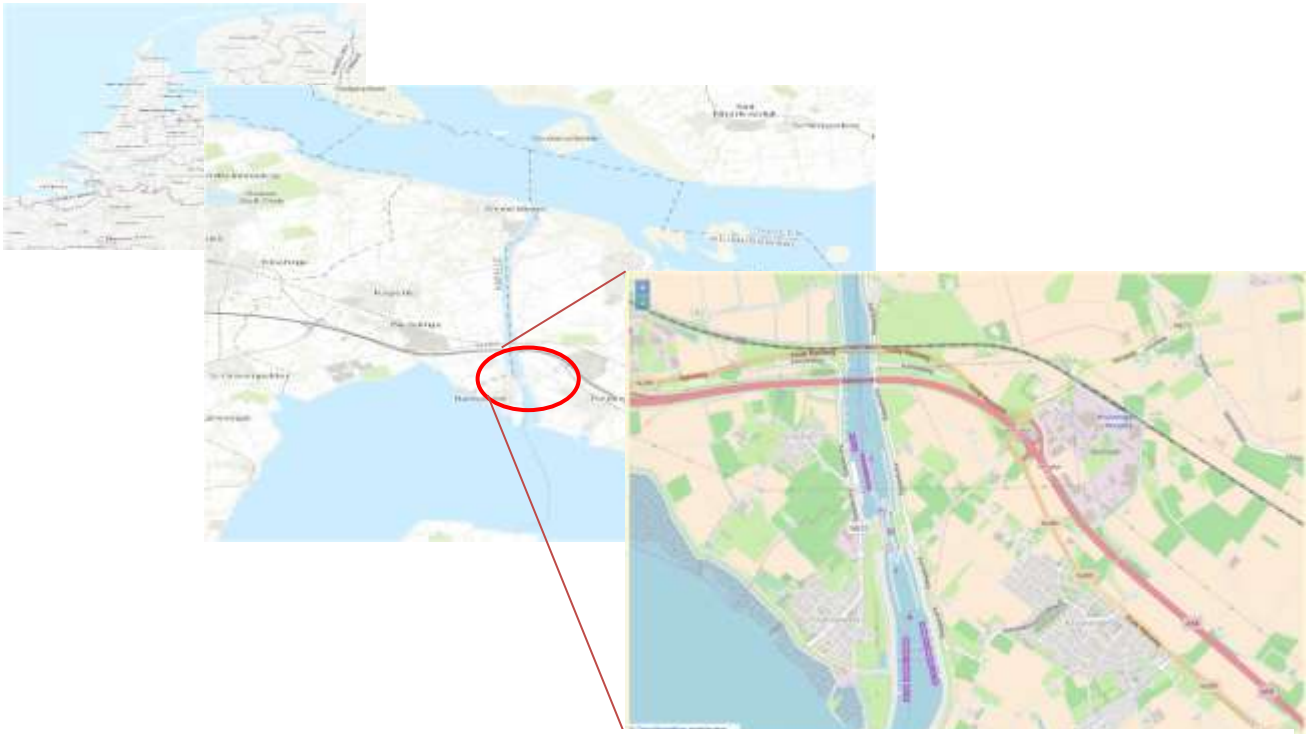

Figure 1 Project location: Hansweert lock in relation to the Netherlands. Source: ArcGIS Online

The location shows a tidal variation in both sides of the lock. The maximum ide variance is of 4.38m in the Western Scheldt (WS) side, where it gives a high tide is NAP + 2.26 m and low tide NAP - 2.12 m.

once the influence of the tide is higher in the south side of the lock, this side is considered to have a critical influence of the tide and therefore is chosen for the design.

Regarding the canal depth, the situation shows a water depth in the south side of NAP – 9 m (WS); and NAP - 7,5 m in the north side (CS).

2.3 Geotechnical characteristics

The location is represented by many different soil profiles available in the area, with locations represented by stronger soil and other by weak layers. Both types could be of importance, therefore two different profiles are chosen for the evaluation of the ground conditions. Table 1 and Table 2 show a strong profile and a weak profile, consecutively, that are being considered.

Table 1 Soil profile number 70294 representing the strong profile. Source: DinoLOKET (2018)

Layer	Top Layer [mNAP]	Layer [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-8,00	3,67	Loam	19	19	27,5	0	18,3	9,5	50
2	-11,67	1,02	Sand 1	18	20	25	0	16,7	9,5	0
3	-12,69	0,92	Loam	19	19	27,5	0	18,3	9,5	50
4	-13,61	8,15	Sand 2	18	20	27	0	18,0	9,5	0
5	-21,76	0,20	Loam	19	19	27,5	0	18,3	9,5	50
6	-21,959	0,10	Sand 1	18	20	25	0	16,7	9,5	0
7	-22,06	0,22	Loam	19	19	27,5	0	18,3	9,5	50
8	-22,28	0,20	Clay	18	18	22,5	0	15,0	9,5	80
9	-22,48	1,64	Loam	19	19	27,5	0	18,3	9,5	50
10	-24,12	2,20	Sand 1	18	20	25	0	16,7	9,5	0
11	-26,31	2,11	Sand 3	19	21	35	0	23,3	9,5	0
12	-28,43	2,35	Sand 2	18	20	27	0	18,0	9,5	0
13	-30,78	0,34	Loam	19	19	27,5	0	18,3	9,5	50
14	-31,12	31,12	Sand 2	18	20	27	0	18,0	9,5	0

Table 2 Soil profile number 70297 representing the weak profile. Source: DinoLOKET (2018)

Layer	Top Layer [mNAP]	Layer [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-7,00	2,79	Clay	18	18	27,5	0	18,3	9,5	50
2	-9,79	2,22	Loam	19	19	27,5	0	18,3	9,5	0
3	-12,01	0,40	Sand 1	18	20	25	0	16,7	9,5	50
4	-12,41	2,52	Loam	19	19	27,5	0	18,3	9,5	0
5	-14,93	0,22	Sand 1	18	20	25	0	16,7	9,5	50
6	-15,146	4,18	Loam	19	19	27,5	0	18,3	9,5	0
7	-19,32	4,53	Sand 2	18	20	27	0	18,0	9,5	50
8	-23,85	0,64	Loam	19	19	27,5	0	18,3	9,5	80
9	-24,49	6,11	Sand 2	18	20	27	0	18,0	9,5	50
10	-30,60	1,11	Loam	19	19	27,5	0	18,3	9,5	0

Appendix V (found attached to final report) describes the CPT samples for defining the chosen profiles layers.

2.4 Project Boundaries

Spring Fender System

A deeper analysis of the structure with the calculation of the spring system that belongs to the fender structure will not be assessed in this research.

Dolphins

The berthing system as a whole is to be considered, although finding a solution for the inclination of the pile cap is the main goal of this research. The structure has the function of berthing ships and, in this case is defined as breasting dolphin due to its functions of assisting in the berthing of vessels by taking up some berthing loads; and serving as mooring point to restrict the longitudinal movement of the berthing vessel (Ocean and air technology, 2013).

Berthing Energy

The berthing energy is calculated based on the decisive ship characteristics. Once the berthing energy is mainly influenced by the mass of the vessel and its approach velocity, the critical class is also the highest one in the location defined as CEMT VIb.

Thermic load

The thermic load is not taken into consideration in this design.

Wind Load

The wind load on the dolphin is not considered crucial to this design, therefore it is not used in the calculations. Nevertheless, its influence on the berthing vessels is added by the factor application in the vessel mass displacement.

Walking bridges

The walking bridges and its connection to the dolphins are not being considered in this research, once the pile cap is to remain the same, therefore no changes are to occur in this part of the structure.

2.5 Life-span

The life-span of the structure follows the guidelines of NEN-EN 1990 (2011), with a design life of 50 years. Nevertheless, a practical design life of 82 years (50 years from this moment) is also given taking into consideration that the reusability of the actual structures is a client requirement and it has had already a service time of 32 years.

The recommended reliability index β (ultimate limit states) is for RC3 with an index of β=4,3, in a reference period of 50 years.

2.6 Consequence class and load combinations

This construction belongs to the consequence class CC2, according to NEN-EN 1990 (2011), Table B1, for structures that has medium impact for loss of human life, economic, social or environmental which is relevant but not critical in case of structural failure.

For the load combinations, the loading factors for general structures and bridges are relevant for this design. Table 3 shows the loading factors for both types of structures represented.

Table 3 Loading factors for general structures and bridges according to Eurocode 1. Source: NEN-EN 1990 (2011)

Permanent and Temporary structural design	Permanent Load		Dominant variable load	Variable loads simultaneously with the predominant		Type Structure
	Unfavorable	Favorable		Decisive	Others	
6.10a	$1.35*G_{k,jsup}$	$0.9*G_{k,j,inf}$		$1.5*\psi_{0.1}*Q_{k,1}$	$1.5*\psi_{0.i}*Q_{k,1}$	General
6.10b	$1.20*G_{k,jsup}$	$0.9*G_{k,j,inf}$	$1.5*Q_{k,1}$	$1.5*\psi_{0.1}*Q_{k,1}$	$1.5*\psi_{0.i}*Q_{k,1}$	General
6.10a	$1.30*G_{k,jsup}$	$0.9*G_{k,j,inf}$	1.35 (ψ=1.0)	1.5 (with ψ=1.0)		Bridge
6.10b	$1.20*G_{k,jsup}$	$0.9*G_{k,j,inf}$	1.35 (ψ=1.0)	1.5 (with ψ=1.0)		Bridge

Once in the case of stand-alone dolphins large horizontal force occurs, it is assumed that the function of general buildings is more suitable for this design. Therefore the related combination load will be used.

The factor ψ to be used in this design is as NEN-EN 1990 (2011), following the wind load due to the similar horizontal influence on the structure and it is shown in Table 4.

Table 4 Representative berthing load factors. Source: NEN-EN 1990 (2011)

Load	Ψ_0	Ψ_1	Ψ_2
Berthing load	1.0	0	0

2.7 Partial Factors

The partial factors γ for ultimate limit states and correlation factors ξ for pile foundations in all design situations are given according to Annex A from NEN-EN 1997 (2016).

The partial factors for the verification of equilibrium limit state (EQU) for the soil parameters when including minor shearing resistances are shown in Table 5. The design approach 3 is chosen for this design with the verification that the limit state of rupture or excessive deformation will not occur by using the combination sets of partial factors according to: A1(STRU) or A2(GEO)+M2+R3 (NEN-EN, 2016).

Table 5 Partial factors for resistance calculations according to design approach 3. Source: (NEN-EN, 2016).

Resistance	Symbol	Set R3
Base	γ_b	1.0
Shaft (compression)	γ_s	1.0
Total/combined (compression)	γ_t	1.0
Shaft in tension	$\gamma_{s,t}$	1.1

Partial resistance factors for pile foundations verification of structural (STR) and geotechnical (GEO) limit states must also be applied conform Table 6-Table A.6 from NEN-EN 1997 (2016), for driven piles in this case.

Table 6 Table A.6-Partial resistance factors for driven piles for the use of soil parameters. Source: NEN-EN 1997 (2016)

Soil Parameter	Symbol	Value
Angle of shearing resistance	$\gamma_{\varphi'}$ *	1.25
Effective cohesion	$\gamma_{c'}$	1.25
Undrained shear strength	γ_{cu}	1.4
Unconfined strength	γ_{qu}	1.4
Weight density	γ_{γ}	1.0
*This factor apply to tan φ		

The correlation factors to be applied to derive the characteristic resistance of axially loaded piles for the verifications of structural (STR) and geotechnical (GEO) limit states are described on Table A.10 from NEN-EN 1997 (2016), and described in Table 7.

Table 7 Table A.10-Correlation factors for calculation of axially loaded piles by using ground tests. Source: NEN-EN 1997 (2016)

ξ for n= number of profiles of tests	1	2	3	4	5	7	10
ξ_3	1,4	1,35	1,33	1,31	1,29	1,27	1,25
ξ_4	1,4	1,27	1,23	1,20	1,15	1,12	1,08

3 Requirements

For this design the following requirements must be followed.

3.1 Client Requirements

According to Rijkswaterstaat assignment, the following conditions should be followed if in accordance to the technical and functional requirements of a berthing structure.

- Design Vessel: CEMT Class VIb;
- Lowest impact on local traffic - implementation time;
- Lowest budget possible;
- Realistic design approach following Dutch normative;
- Reuse of actual structure as much as possible;
    - Pile characteristics:
        - D=1016mm;
        - t= 20mm;
        - L_{pile} =24,10m;
        - Steel quality: S355JO;
    - Pile cap characteristics:

- D=1820mm;
- T=16mm;
- $L_{pile,cap,WS}$=10,00m; $L_{pile,cap,WS}$=7,50m;
- Steel quality: S355JO;

- Fender characteristics:
  - 2 x Rubber Cylinder (D=600, d=300, L=1000);
  - Rubber quality original unknown – DIN53504 –Mpa selected for modifications;
- Actual pile overhang:
  - 15,5m – Western Scheldt;
  - 12m – Canal South-Beveland;
- Actual pile foundation penetration in the soil:
  - 8,6m – elevation of -17,6mNAP(WS);
  - 8,6m – elevation of -16,15mNAP (CS).

Following these needs, the design vessel to be calculated for the design is within the class CEMT VIb. In addition to that, the class VIa is also considered for the analysis of the actual situation. Vessels characteristics are described in Table 8.

Table 8 Design vessel characteristics. Source: European conference of ministers of transport (1992)

Class CEMT	Ship Characteristics					
	Length (Lmax) [m]	Beam (Bmax) [m]	Draugh (Dmax) [m]	Tonnage (Tmax) [ton]	Water displacement (ROK) [ton]	Min Height under bridges [m]
VIa	110	22,8	4,5	6000	3000	9,1
VIb	195	22.8	4.5	12000	6000	9.1

The berthing characteristics are described on Table 9 and it shows relevant factors according to common design, practical locally encountered values, and extreme values in case of accidental events.

Table 9 Berthing characteristics based on design examples and local experience. Source: EAU (2012) and Hansweert inspectors (2018).

Berthing characteristics					
Approach velocity			Approach angle		
Design velocity [m/s]	Practical velocity [m/s]	Accidental velocity [m/s]	Design angle [°]	Practical angle [°]	Accidental angle [°]
0,13	0,5-1,0	2,-4,5	15	20	45-90

3.2 Functional requirements

The dolphin consists of different parts, which are mainly foundation pile, pile cap, rubber fenders, chains, fender azobé panel, connection plates. In order to the structure to function as a berthing facility, all parts must be in accordance to design values. Nevertheless, this report is focusing on the functioning of the pile foundation and the pile cap, the elements considered crucial for the functionality at this moment according to Root Cause Analysis and Pile Capacity Analysis. Therefore an assumption is taken that besides the elements considered in this design, all other parts are still in full functionality for the next 50 years.9.1

Berthing function

The main function of a breasting structure is to provide a secure mooring for vessels (Tomlinson, 1994), which is provided by the transformation of the impact force into a reaction force that both the ship and the berthing structure are safely able to withstand (Thoresen, Port designer's handbook: recommendations and guidelines, 2003).

3.3 Technical requirements

This section describes the technical requirements that are to be followed by this research. These conditions are based on the functional requisite for this structure mentioned in §3.2.

3.3.1 Dimensions

In order to allow a safe berthing and mooring for the ships, the following criteria shall be fulfilled along the design process.

Construction depth and levels

Considering the given design vessel (§3.1), and the actual local characteristics, the levels given by Table 10 are to be considered.

Table 10 Design levels according to NAP reference. Source:[18],[19] and [28]

		Western Scheldt Side	Canal side
Water level [mNAP]	Water level	0	0
	Water level HHT	5,07	3,8
	Water level HT	2,26	1,63
	Water level LT	-2,12	-1,37
	Water level LLT	-3,5	-1,7
Construction depth [m]		-9.0	-7.0
Top level dolphin [mNAP]		+6.5	+4.5

Berthing requirements

Concerning the berthing levels according to the water levels, it is defined in the Directive Waterways (RWS, 2017) that the lowest bollard should be around 1,5 meters above low water level. The same range should be followed upwards the dolphin up to the top level. In case of a new cap design the bollards should be placed as showed on Table 6. In case of reuse of actual cap, it is assumed that the capacity of the actual bollards are enough.

Table 11 Bollards placement levels and mooring capacity required. Source: Dutch Directive Waterways (RWS, 2017)

Bollards		
Capacity [kN]	Level [mNAP]	
	Western Scheldt Side	Canal side
350	+6,50	+4,50
350	+5,00	+3,00
350	+3,50	+1,50
350	+2,00	0,00
350	+0,50	-
350	-1,00	-
350	-2,50	-

According to Normative Waterways (RWS, 2017), in order to prevent the shock of the bottom of the ship to the pile, the fender panel should be prolonged up to 0,5m below the low water level.

3.3.2 Load cases

Permanent Load: Self-weight

The self-weight of the structure is defined by the sum of the weights from the foundation pile and cap which are the most significant influence in the total. For the calculation, the density of steel is considered 7800 kg/m^3.

The total weight of the structure is to be considered as 18,8 tones, therefore:

$P_{steel} = 185\ kN$

Variable Load

It consists of maintenance and human charges as vertical load, impact and mooring charges as horizontal load.

The maintenance and human load is defined by the use of the structure in case of needed maintenance and for the use of the ladders by passengers to reach the walking bridge. An assumption following pedestrian load in bridges according to NEN-EN 1991 (2011), gives a $q_{p,f;k}$ = 2kN/m^2. It is taken as load surface the top of the pile and that gives the area of the pile cap $A_{base,cap}$=2,6m^2, leading to a load $Q_{f,w}$=2kN.

The impact load is calculated according to the berthing energy, that can be calculated according to EAU, PIANC (2002) and ROK (Rijkswaterstaat, 2017):

$$E = 0{,}50 * m_{ship} * (v_{ship} * sin \propto)^2 * C_m * C_e * C_c * C_s$$

Where:

E	: Kinetic Energy	[kNm]
m_{ship}	: Weight of ship	[ton]
v_{ship}	: Approach velocity of ship	[m/s]
α	: Approach angle of ship	[°]
C_m	: Hydrodynamic mass factor	[-]
C_e	: Eccentricity factor	[-]
C_c	: Permeability coefficient	[-]
C_s	: Material coefficient	[-]

The hydrodynamic mass factor can be calculated according to Vasco Costa formula and it is the same for both CEMT classes VIa and VIb:

$$C_m = 1 + \frac{2 * D}{B}$$

Where:

D	: Draught of ship	[m]
B	: Width of ship	[m]

Therefore:

$$C_m = 1 + \frac{2 * 4{,}5}{22{,}8}$$
$$C_m = 1{,}39$$

The eccentricity factor is calculated based on the different angles of approach for the design vessel VIb. In the situation of 15° approach, it has a value of approximately C_e=0,1.

Following EAU (2012), an open construction as a dolphin has a permeability coefficient of C_c=1,0. Also, due to the spring effect of a single-pile berthing structure, it can be classified as soft structure and therefore has a material coefficient of Cs=1,0.

Once all the coefficients and factors are determined, the characteristic design berthing energy can be calculated for a perpendicular approach, and therefore the highest possible energy:

$$E_d = 0{,}5 * 12000 * 0{,}13^2 * 1{,}39 * 0{,}1 * 1{,}0 * 1{,}0$$
$$E_d = 14{,}10[kNm]$$

Considering the ultimate limit state analysis, the energy can be than calculated with an increase factor for the variable load acting on the approach velocity of the ship. This leads to the calculation of the ultimate berthing energy:

$$E_{d,ULS} = 0{,}5 * 12000 * (0{,}13 * 1{,}5)^2 * 1{,}39 * 0{,}1 * 1{,}0 * 1{,}0$$
$$E_{d,ULS} = 31{,}72[kNm]$$

Also as part of the variable load, the mooring charges are represented by the actions on the bollards which can be found in the Directive Waterways (RWS, 2017), and as mentioned in §3.3.1, the required strength for vessels of class CEMT VIb is 350kN. This can be calculated as:

If $L * B * T < 1000m^3 \rightarrow F_{bollards} = 60 + \frac{L*B*T}{10}$

If $L * B * T > 1000m^3 \rightarrow F_{bollards} = 150 + \frac{L*B*T}{100}$

In the case of CEMT class VI, all ships have a L*B*T>1000m^3. Therefore:

$$F_{bollards,VIb} = 150 + \frac{195 * 22{,}8 * 4{,}5}{100}$$
$$F_{bollards,VIb} = 350\ [kN]$$

3.3.3 Strength and Stability

The construction elements of a berthing structure must comply with enough strength and stability capacities according to the technical requirements in §3.3.2 in order to be able to provide the functionality required in §3.2.

In this report the structure ultimate element is considered to be the foundation pile, therefore these criteria must be calculated. The determination of the vertical and horizontal bearing capacity in relation to pile-soil interaction must be done following NEN-EN 1997 (2016). For the pile resistance calculations must follow NEN-EN 1993 (2008). The definition of the driven depth for the foundation is to be determined according to the vertical and horizontal bearing capacity at the level that it fulfills the requirements.

3.3.4 Displacement and deflection

The application of permanent and variable loads on the structure can cause effects such as displacements (δ) and deflections(ƒ), but these parameters may not compromise the functionality of the function.

According to NEN-EN 1990 (2002), there is a maximal displacement allowed to the structure which is:

- ✓ $\delta_{max,vertical} \leq h/250 = 15{,}5/250 = 0.06$ m
- ✓ $\delta_{max,horizontal} \leq h/150 = 15{,}5/150 = 0.10$ m

Note that the structural displacement does not includes the soil displacement.

Following EAU (2012), the maximum deflection allowed for nautical, port operations and structural reasons is of ƒ=1,50 meters, including the soil displacement, once it is more realistic than the 0,10 m proposed by Eurocode 1 (NEN-EN, 2011).

3.3.5 Material Quality

The following material characteristics are required for the design of the structure.

Steel Quality

The quality of steel commonly used in the waterways structures of the region is as follows in Table 12.

Table 12 Steel quality required for design of water constructions in the area of Hansweert lock. Source: PPO RWS See and Delta

EN 10025	Min. Yield Strength [N/mm2]						Tensile Strength [N/mm2]		Thoughness Charpy V (J)	°C
Thickness	<16	>16;<40	>40;<63	>63;<80	>80;<100	>100;<150	<3; <100	>100; <150	<150	
S355JO	355	345	335	325	315	295	490; 630	470; 630	27	0

E_{steel}=210.000 [N/mm^2]

3.3.6 Corrosion of steel

For steel construction elements the corrosion rate to be considered is followed by the normative NEN-EN 1993 (2008) and CUR166 (2014) for a life span of 50 years. In case of steel piles, the corrosion is only considered to happen in the outer side once in the inside no oxygen or water is present, therefore no corrosion or rust occur. The following rates are to be considered:

Steel pile in the ground	: 0,026 mm/side * considered to be determinant due to location of maximum load.
Steel pile permanently underwater	: 0,120 mm/side
Steel pile in atmospheric zone	: 0,050 mm/year/side ** not considered in the calculations because of pile coating that prevents this type of corrosion.

4 Requirements and Preconditions

This section defines the required guidelines and normative to be used along this research and design report.

4.1 Normative and guidelines

For the design process the following norms are to be followed:

[1]	NEN-EN 1990	: *Eurocode 1 - Basis of structural design;*
[2]	NEN-EN 1991-1-7	: Loads on constructions;
[3]	NEN-EN 1991-2	: Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges;
[4]	NEN-EN 1993-1-1	: Design of steel structures - Part 1: Basis of design;
[5]	NEN-EN 1993-1-8	: Design of steel structures - Part 1-8: Connections;
[6]	NEN-EN 1993-5	: Design of steel structures - Part 5: Piling;
[7]	NEN-EN 1997-1	: Eurocode 7: Geotechnical design Part 1: General Rules;
[8]	NIC	: Handreiking rekenmethodieken RWS;
[9]	EAU2012	: Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004;
[10]	CUR 166	: Quay wall constructions (Damwandconstructies);
[11]	CUR 288	: Design Guidelines to soil horizontal loads on piles (Ontwerprichtlijnen door grond horizontal belaste palen);
[12]	CUR 2001-4	: Design rules for driven piles (Ontwerpregels voor trekpalen);
[13]	CUR 2001-8	: Bearing capacity of steel pipe piles;
[14]	CUR 2011	: Handbook Quay Walls;

[15] PIANC 2002 : Guidelines for the Design of Fender Systems;
[16] RVW2017 : Dutch Directive Waterways 2017 (Richtlijnen Vaarwegen 2017);
[17] ROK 1.4 : Dutch guidelines for infrastructur constructions (Richtlijnen Ontwerp Kunstwerken);
[18] RBK 1.1 : Dutch guidelines assessment of infrastructur constructions (Richtlijnen Beoordeling Kunstwerken);
[19] Waterbouwkunde (1968) : Waterbouwkunde deel 1: Algemene waterbouwkunde.

4.2 Correspondent Documents and Drawings

[18] ZLSR-1987-12014 : Drawing Toeleidinswerken hansweert ducdalven westerscheldezijde;
[19] ZLSR-1987-12015 : Drawing Toeleidinswerken hansweert ducdalven kanaalzijde;
[20] ZLSR-1987-12251 : Drawing Toeleidingswerken Hansweert Matentekening Azobe beslag dukdalven westernschelde en kanaalzijde;
[21] ZLSR-1990-02084 : Drawing Toeleidingswerken hansweert bevesting rubber fender en apheffen speling en zekering mantel tbv ducdalven;
[22] ZLSR-2004-00408 : Drawing Sluizencomplex Hansweert Situ Voorhaven KZB;
[23] ZLSR-2004-00409 : Drawing Sluizencomplex Hansweert Situ Voorhaven KZB;
[24] ZLSR-2004-00411 : Drawing Sluizencomplex Hansweert Situ Voorhaven WST;
[25] RWSZL-2011-04940 : Drawing Fender opvangconstructie meerstoelen hansweert;
[26] RWSZD-2014-02374 : Drawing Fender opvangconstructies C21,C22,C24,C35,C36 en C37 HWS met zijdelings gefixeerd;
[27] RWSZD-2014-02504 : Afleverdossier spec nr 20-21 aanbrengen 19st opvangconstructie en 4 fenders aan de meerstoelen D20 t/m D37 sluizencomplex Hansweert;
[28] ZLSR-1991-00032 : Uitgangspunten en randvoorwaarden geleidewerken Hansweert;
[29] ZLSR-1987-00001 : Overeenkomst tot uitvoering en wijziging van Bestek SS1239a;
[30] ZLSR-1987-00003 : Conservering op de constructie en kunststof blokken;
[31] ZLSR-1987-00004 : Aandachtspunten ten aanzien van onderhoud;
[32] ZLSR-1987-00005 : Toeleidingswerken Hansweert;
[33] 48H-353-BC-03-2009 : Hansweert Steigers en meerpalen.

5 Bibliography

Agerschou, H., Dand, I., Ernst, T., Ghoos, H., Jensen, O. J., Korsgaard, J., et al. (2007). *Planning and Design of Ports and Marine Terminals.* London: Thomas Telford Publishing.

Barnes, G. (2010). *Soil Mechanics.* Hamshire: Palgrave Macmillan.

British Standard. (1994). *BD 6349-4 1994 Maritime structures - Part 4: Code of practice for design of fendering and mooring systems.* Standards Board.

Chbab, H., & Waal, H. d. (2017). *Achtergrondrapport Hydraulische Beslastingen - Wettelijk beoordelingsinstrumentarium 2017.* Delft: Deltares.

CUR. (2001). *CUR Rapport 2001-8 Bearing capacity of steel pipe.* Gouda: CUR.

CUR. (2014). *CUR Rapport 166:2012.* BRISwarenhuis.

Dillingh, D. (2013). *Kenmerkende waarden Kustwateren.* Delft: Deltares.

DINOloket. (2018, March 3). *Ondergrondsgegevens*. Retrieved from DINOloket Data en Informatie van de Nederlandse Ondergrond: http://www.dinoloket.nl

EAU. (2012). *Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004.* Arbeitsausschuss.

EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT. (1992). *RESOLUTION No. 92/2 ON NEW CLASSIFICATION OF INLAND WATERWAYS (CEMT/CM(92)6/FINAL).* Athens: EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT.

Fraanje, M. J. (1968). Waterbouwkunde Deel 1 Algemene Waterbouwkunde. In M. B. Bolderman, & A. W. Dwars, *Waterbouwkunde* (pp. 443-481). Amsterdam: L.J.Veebs Uitgeversmaatschappij N.V.

GWW. (2018, 05 31). *Cobouw Bouwkosten GWWKOSTEN*. Retrieved from Kosten: http://www.gwwkosten.nl/

NEN-EN. (1997). *NEN-EN 1997-1/A1 Eurocode 7: Geotechnical design - Part 1:.* Brussels: EUROPEAN COMMITTEE FOR STANDARDIZATION.

NEN-EN. (2002). *NEN-EN 1990 Eurocode 1 - Basis of structural design.* NEN-EN.

NEN-EN. (2008). *NEN-EN 1993-5 Eurocode 3: Design of steel structures - Part 5 Piling.* NEN-EN.

NEN-EN. (2011). *NEN-EN 1990+A1+A1/C2 Eurocode 1: Basis of Structural design.* NEN.

NEN-EN. (2011). *NEN-EN 1991-2+C1:Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges.* Rijksoverheid NEN Connect.

NEN-EN. (2013). *NEN-EN 1997-1/A1 Eurocode 7 Geotechnical design Part 1:General Rules.* NEN-EN.

NEN-EN. (2016). *NEN-EN 1997-1+C1+A1/NB National Annex to NEN-EN 1997-1 Eurocode 7: Geotechnical design Part 1: General Rules.* NEN-EN.

Ocean and air technology. (2013, May 11). *Dolphins: mooring, breasting & berthing*. Retrieved May 1, 2018, from Ships aviation & offshore technology - passionate naval architect and tech enthusiast: https://oceanandairtechnology.wordpress.com/2013/05/11/dolphins-mooring-breasting-berthing/

Orr, T. L., & Farrel, E. R. (1999). *Geotechnical design to eurocode 7.* Lodon: Spring-Verlag London Limited.

PIANC. (2002). *Guidelines for the Design of Fender Systems : 2002.* Brussels: PIAN General Secretariat.

Rijkswaterstaat. (2011). *Kenmerkende waarden Getijgebied.* Rijkswaterstaat.

Rijkswaterstaat. (2013). *Kenmerkende waarden Getijgebied 2011.0.* RWS Centrale Informatievoorziening.

Rijkswaterstaat. (2013). *RBK 1.1 Richtlijnen Beoordeling Kunstwerken: Beoordeling van de constructieve veiligheid van een bestaand.* Rijkswaterstaat.

Rijkswaterstaat. (2017). *Deelrapportage Vaarwegen voor de Nationale Markt - en capaciteitsanalyse (NMCA).* Rijkswaterstaat Water Verkeer en Leefomgeving (WVL).

Rijkswaterstaat. (2017). *Richtlijnen Ontwerp Kunstwerken ROK 1.4.* RWS GPO.

RWS. (2017). *Richtlijnen Vaarwegen 2017: Kader verkeerskundig vaarwegontwerp.* Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat.

Smits, G. T., & Meijerink, C. W. (2005). *NIC: Handreiking rekenmethodieken NIC.* Directoraat-Generaal Rijkswaterstaat.

Smits, G. T., & Meijerink, C. W. (2005). *Handreiking rekenmethodieken NIC.* Directoraat-Generaal Rijkswaterstaat.

Steenepoorte, K. (2007). *De sluizen te Hansweert in het Kanaal door Zuid-Beveland.* Rijkswaterstaat Zeeland.

Steenepoorte, K. (2016). *The locks at Hansweert in the South Beveland Canal.* Rijkswaterstaat Zee en Delta.

Thoresen, C. A. (2003). *Port designer's handbook: recommendations and guidelines.* London: Thomas Telford Ltd.

Thoresen, C. A. (2014). *Port Designer's Handbook.* London: Thomas Telford Ltd.

Tomlinson, M. J. (1994). *Pile design and construction practice.* London: E&FN Spon.

Appendix IV Route Cause Analysis

Rijkswaterstaat
Ministry of Infrastructure and Water Management

2018

Root Cause Analysis

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Rijkswaterstaat Zee en Delta
3/8/2018

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1 Introduction

The department of Rijkswaterstaat See and Delta is responsible for the transportation infrastructure inland and waterways in the area of Zeeland region and North Sea. As part of it, RWS Sea and Delta is responsible of ensuring the availability and quality of marine and land ways. This area has a high importance due to the connection between the ports of Rotterdam, Amsterdam and Antwerp. The lock of Hansweert is placed in the canal through South-Beveland, which connects the Eastern Scheldt to the Western Scheldt, moreover it is also part of the scope of RWS See and Delta.

In this area, the mooring facilities are encountering structural problems and a research is needed in order to define the solution for those problems. Due to the poorly aligned dolphin piles in the Hansweert locks, a dangerous situation arises. The misalignment of the pile caps can possibly cause damage to the ship when docking to these structures. It is possible that a steel beam sticks out instead of the wood that is supposed to be there to protect the ship.

A root cause analysis (RCA) is part of this research and has the objective to define the causes for this problem in order to evaluate the current situation and the possible solutions. This document describes the problem as a system, in order to define all the possible causes. All information used in this report is taken from RWS background and guidelines.

2 Event Description

This section provides a description of the event that is being analyzed. It provides a clear and concise description of the problem that triggered this Root Cause Analysis. It states the date, time, detailed description of the event/problem, who detected the problem, who it affected, and how it affected them with the most possible accuracy.

Inspections realized by RWS in the driveways of Hansweert locks have observed several dolphins are compromised by hanging crooked. This curve suspension is a known problem and is already present from the construction. The dolphin consists of a pile and a pile cap. The pile cap hangs over the pile itself with the bottom part attached by a front fender, which are attached to the cap with chains. In the past, however, the chain was the weakest link in the structure and, once the chains break, the fenders tend to fall into the water and damaging the cap of the dolphins making it crooked. It is also possible that the fender shifts so that the cap also hangs obliquely on the inner post.

Figure 1: Actual situation of berthing in Hansweert area. Source RWS (2017)

Date and time that this problem has begun is not clear, a description of the gathered information is expressed in Chapter 3. Figure 1 shows that the users, due to the insecurity of the berthing structure, are using extra ropes around the pile cap instead of the boulders in order to berth in this location.

3 Chronology of Events / Timeline

Chronologic detail of events is vague due to the lack of reports. It is known that the dolphins and its fenders were installed in between 1987 and 1988, as shown in the drawings in Appendix I-I – Original structure drawings.

Speculations are that the pile cap had a certain inclination since the moment of installation back in 1987, nevertheless this is not documented in any report or drawing available.

In the year of 1990 the first modification was done. The Appendix I-II – 1st Modification drawings, shows the details of the new elements added to the original structure where it is possible to see that a chain system was clamped in the bottom of the cap to prevent the fenders to fall, and the top has been adjusted to reduce possibility of rotation of the cap. It is although not clear how many structures were modified at this time.

In 2014, the maintenance contractor applied a second change to seven dolphins where a steel cable attached to the top of the pile cap was used instead of a chain attached to its walls. Later on in the same year, a third modification was added when lock at the bottom of the fenders was designed in order to prevent the pile caps to become crooked. This elements can be seen in drawing

During a later site visit, however, has been observed that four out of the seven dolphins adapted still have shown the same behavior as the others that have not been adapted.

Table 1: Chronologic description of events.

Date	Description of event or action
01-01-1987	Installation of Dolphins. Actual date is not known.
01-01-1990	1st modification – addition of clamp chains to bottom of cap and plates on top to reduce rotation.
01-01-2011	2nd Modification – installation of support cables.
28-05-2013	Order of service generated from RWS.
30-08-2013	Quotation from maintenance company received for the improvement of 19 foundation plates and 4 fenders, from dolphins D20 to D37.
30-08-2014	3rd modification. Report of work from maintenance company for the 3rd modification.
25-05-2017	Inspection reports that 4 out of the 7 dolphins that were fixed are hanging crooked again.
01-03-2018	Begin analysis of the situation by the internship research. All structures are still hanging crooked.

4 Investigative Team and Method

This section describes how the investigative team is assembled, who it consists of, and how it gathers the data to be used in the analysis. This is an important part of the RCA because a majority of time spent in RCA is gathering data about the event/problem.

4.1 Team

The investigation team consists of one researcher with the support of the team of the department PPO Waterways A from Rijkswaterstaat Sea and Delta, in addition is also the maintenance company Volker Infra which was consulted for gathering the information of the actual situation.

4.2 Method

In order to perform a success Root Cause Analysis the normative NEN-EN-IEC 6270:2015 is followed. All data gathered for this report is part of the database of Rijkswaterstaat or personal knowledge about the situation once physical data is not available.

The method chosen to be conducted is the Fault Tree or Success Tree Method. The criteria used for this choice can be seen in Appendix II- Method selection.

4.2.1 The Fault Tree or Success Tree Method

According to NEN-EN-IEC 6270:2015, the process for developing a fault/success tree is as follows:

1. Define the focus event to be analyzed and record it as the starting point for the tree.
2. Establish the immediate necessary causal factors of the focus event and display them in a box linked by an arrow to the focus event. The tree may be drawn horizontally or vertically. These are the first level causal factors of the focus event.
3. Establish the logic relationships between the immediate causal factors using AND and OR Gates. The events at inputs of an AND gate have to be both necessary and sufficient to cause the event above. OR gates may be used during the analysis to describe potential causal factors that require investigation.
4. Examine each causal factor to decide whether it is a root cause or the result of underlying causal factors.
5. Validate potential causal factors and update the tree accordingly.
6. Continue down the tree until the stopping rule is reached.

When the tree is developed, the possibility of causal factors relating to people, equipment and the environment is considered for each causal factor at each level. These should not be separated out at the top of the tree."

5 Findings and Root Cause

This section describes the findings of the investigation and explain the root cause(s) based on these findings. Also, it is possible that results in findings are not directly related to the root cause of the problem. These are also captured as product/process improvement steps in an effort to improve the product.

5.1 Approach

Following the Fault tree method, the outcome is delivered in Appendix III – Fault Tree Event Map. This section will describe the path followed in order to create this map, and in addition describe and analyze the root causes for this problem.

This problem analysis begin with the cause of Inefficiency of the Berthing Facility in Hansweert. This problem can be visually seen on site, as in the image below, and it looks like the pile cap (where the fender system is placed) is crooked.

Figure 2: Dolphin in Hansweert berthing facilities showing inclination. Source: RWS (2017)

Nevertheless, once the structure is composed of a cap over a foundation pile, the situation of the latest is not to be seen. Therefore there is the possibility that the foundation pile is also showing inclination and may be the reason why the cap looks crooked.

In order to approach all possible scenarios and causes for this problem, even though there is no current information regarding the situation of the inner pile, the event map takes into consideration also the possibility that the foundation pile can be crooked. The head relation of the problem can be seen in the Figure 3.

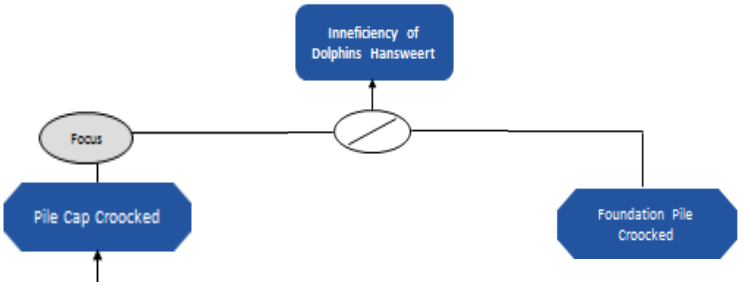


Figure 3: Fault Tree Head relation of the Event Mapping.

5.2 Events

This section will describe in detail the path of the cause root analysis per main event. The two main events in this situations are the Pile Cap is crooked and the Foundation Pile is crooked.

5.2.1 Pile Cap Crooked

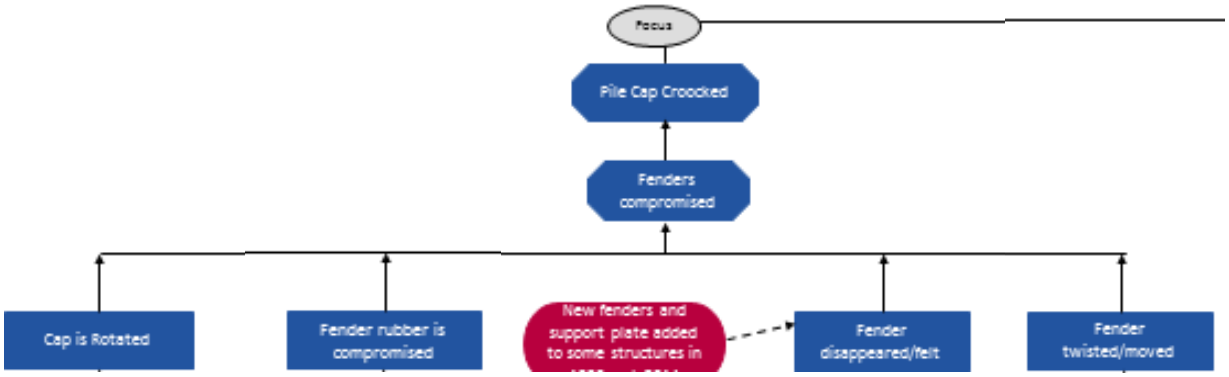


Figure 4: Fault tree Pile Cap Crooked event described.

The main reason to this event is the dysfunction of the fender system present in the inner area of the pile cap, once it should allow the structure to keep in place once its function is fulfilled. This cause is described in the scheme as 'Fenders compromised', as shown in Figure 4.

There are few reasons why this would happen and that could be:

5. Cap is rotated;
6. Fender rubber is compromised;
7. Fender disappeared or felt;
8. Fender is twisted or misplaced.

1. Cap is rotated

The possible rotation of the cap can add extra forces to the chains and supports of the fenders, leading to failure of these elements. Analyzing the original structure, it is concluded that the top, and only connection between the foundation pile and the cap, allows full rotation of the cap around the center point of the foundation pile. This shows a design failure and the detail of this connection can be seen in Figure 5.

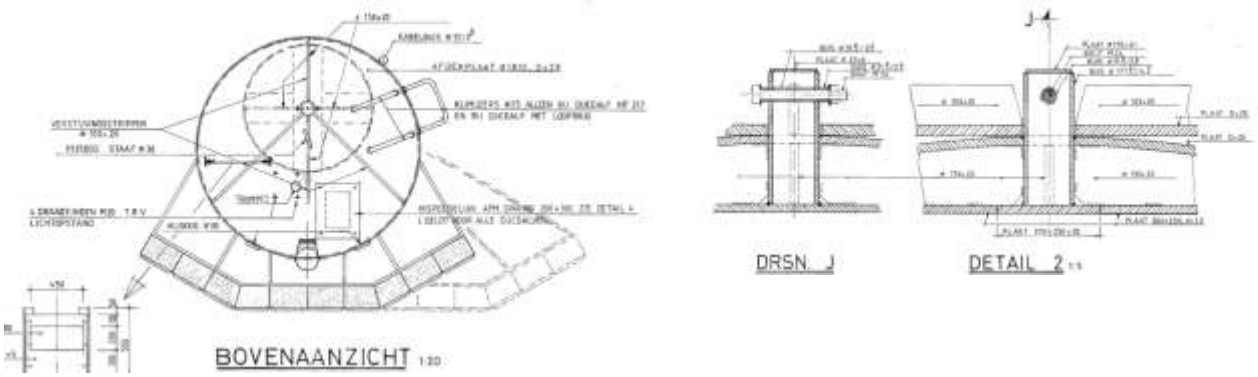


Figure 5: Detail of cap and foundation pile connection on the top. Extracted from drawing ZLSR-1987-12014, RWS (2017).

The only element that could prevent this rotation could be the clamp bolt in the backside of the cap, with the function of reducing the space between the cap and the fenders by applied a certain pressure. If the pressure was correctly applied, that would reduce the chance of rotation once the cap would have no free space to move.

This cause has already been considered in 1990, when the first modifications were made (Figure 6). Detailed explanation of this improvement is not found, nevertheless the Appendix I-II – 1st Modification drawings, RWS (2017), shows the changes applied then. Unfortunately it is not clear how many either which structures had this modification to evaluate its efficiency.

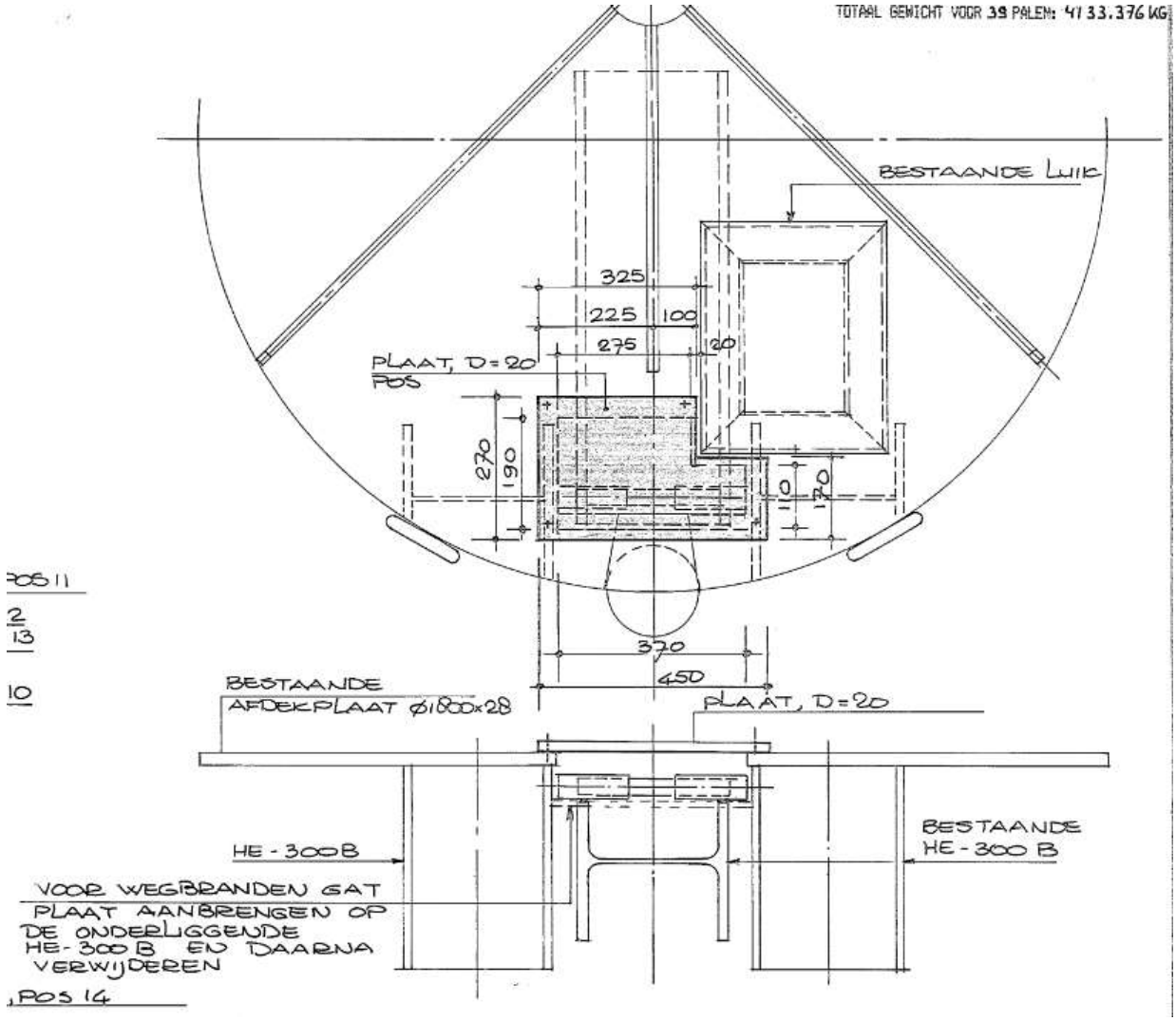


Figure 6: Detail of first modifications in 1990 in the pile cap. Extracted from drawing ZLSR-1990-02084, RWS (2017).

Further modifications have not taken into account the rotation of the cap.

2. Fender rubber is compromised

There are two possibilities considered for this occurrence, either the fender type chosen does not have enough capacity (and bends completely having no function) or the rubber fender is broken. The event map shows this situation as a scheme in Figure 7.

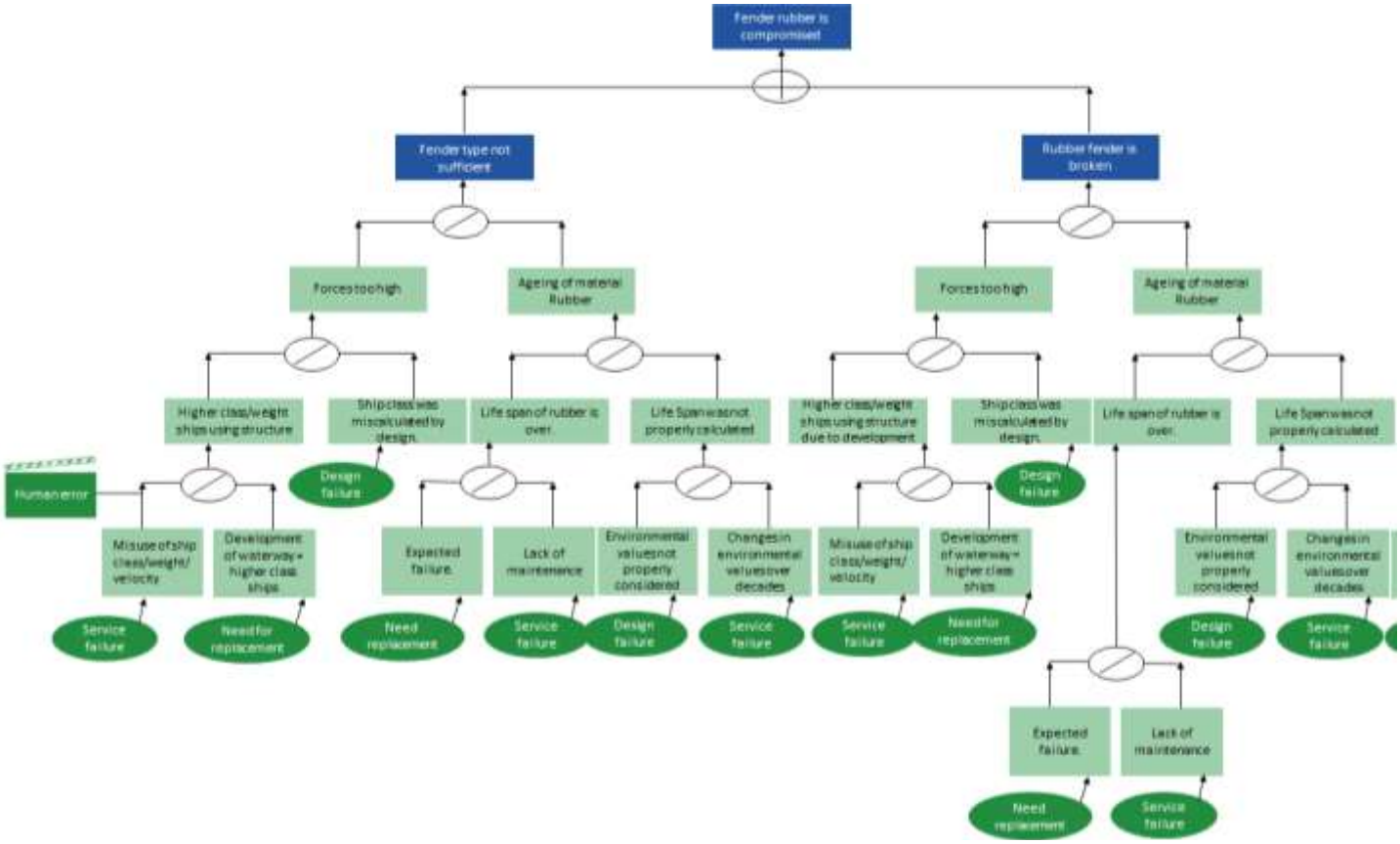


Figure 7: Fault Tree schema for the cause of a fender to be compromised.

The lack of capacity is directly related to the forces that are acting on the structure and the quality of the material. Related to the forces acting on the structure two events can have happened, the ships using the structure have an impact (higher class/weight/velocity) then designed; the environmental and hydraulic conditions were miscalculated by the design or changed with time; or the design has miscalculated this forces since the beginning.

The breakability of the rubber is also related to the design capacity of the material, but in addition to that, the ageing of the material has a great influence in the breakability. The material has been exposed to the environment for the last 32 years, so that could mean that the life span of the rubber material is done and it would need replacement. In this case this should be considered by the original design, nevertheless no design or maintenance report was found for this structure so no information can be found if this failure was predicted or not.

Nevertheless there is also the possibility that the design rubber is not selected correctly, by a poor choice during the design phase the system can also be compromised and a failure can occur. Once again, due to the lack of information about original design, this is once more speculation.

3. Fender disappeared or felt

For this situation to occur the support elements of the fender should be compromised. In this case, the fenders are attached to the inner side of the cap through chains and supported below by a support plate as seen in Figure 8.

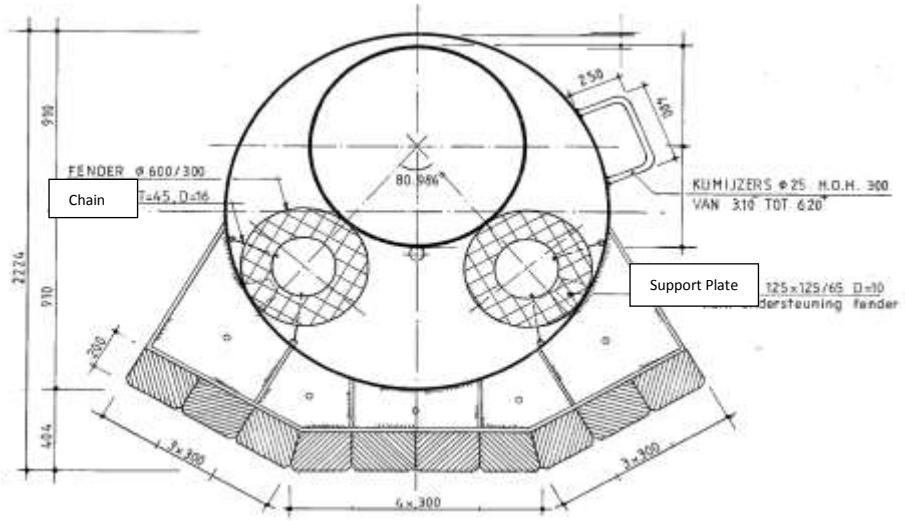


Figure 8: Dolphin Hansweert drawing - details of the inner fenders. Extracted from drawing ZLSR-1987-12014, RWS (2017).

It is shown that the support plate would not cause the fall of the fenders directly, in case the chains are still working. In that case, for the original design, this failure occur only if the chains are broken. The breakability of the chains could happen in case of high load or deterioration of material. Once again, the high load can be related to the development of the waterways and therefore the presence of bigger vessels, also could be caused by the misuse of the structure (high berthing velocity, high impact against structure), the environmental/hydraulic conditions or a design phase miscalculation (load, direction, material). The detailed relations can be seen in Figure 9.

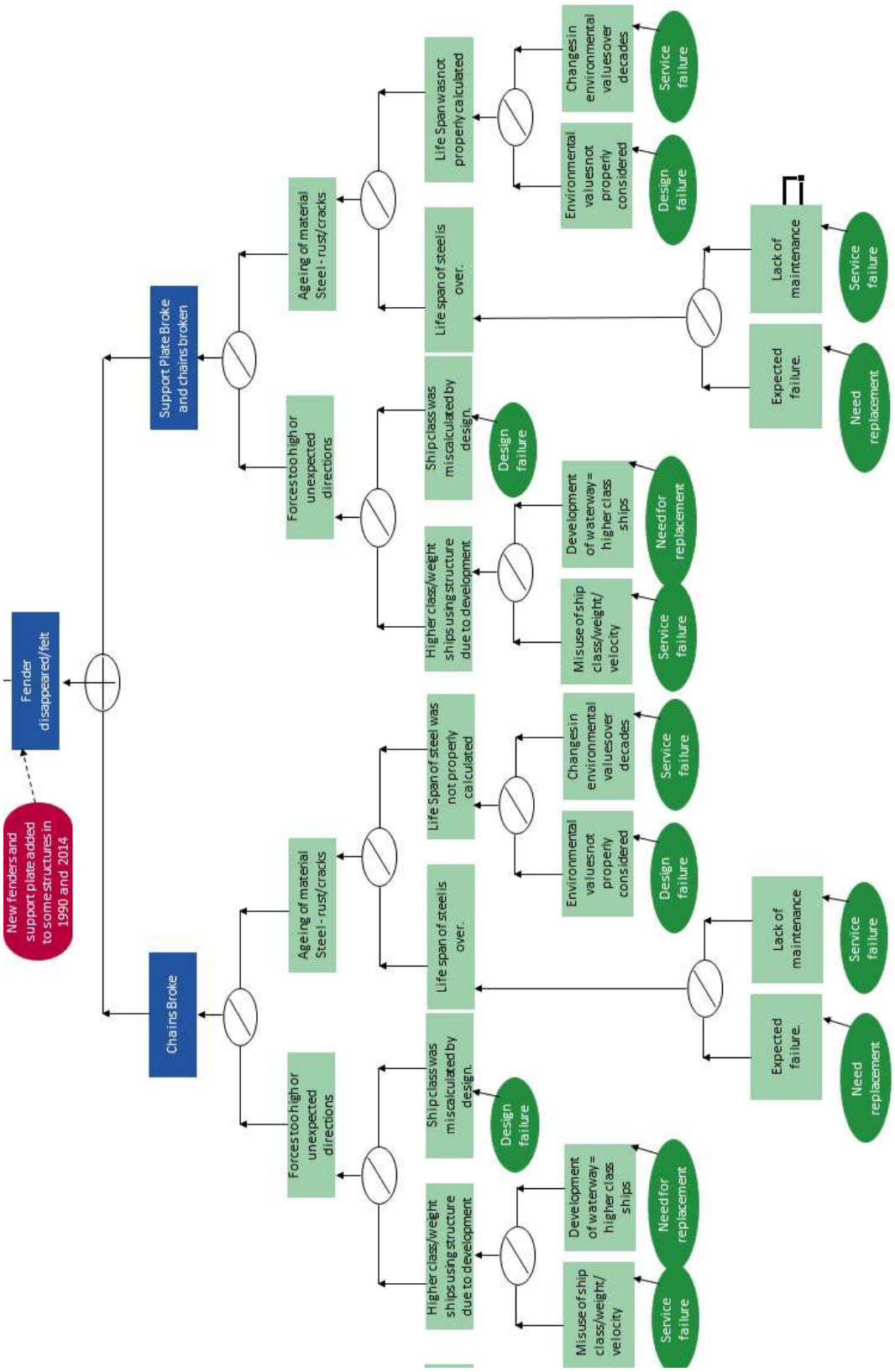


Figure 9: Fault Tree scheme for the cause of the disappearance of fenders.

4. Fender is twisted or moved

As shown in Figure 10, the twist of the fender or its movement inside the cap can also be a cause of its displacement. The original cap structure has a clamp bolt (Figure 11) in its backside with the function of reducing the space between the cap and the fenders by applied a certain pressure.

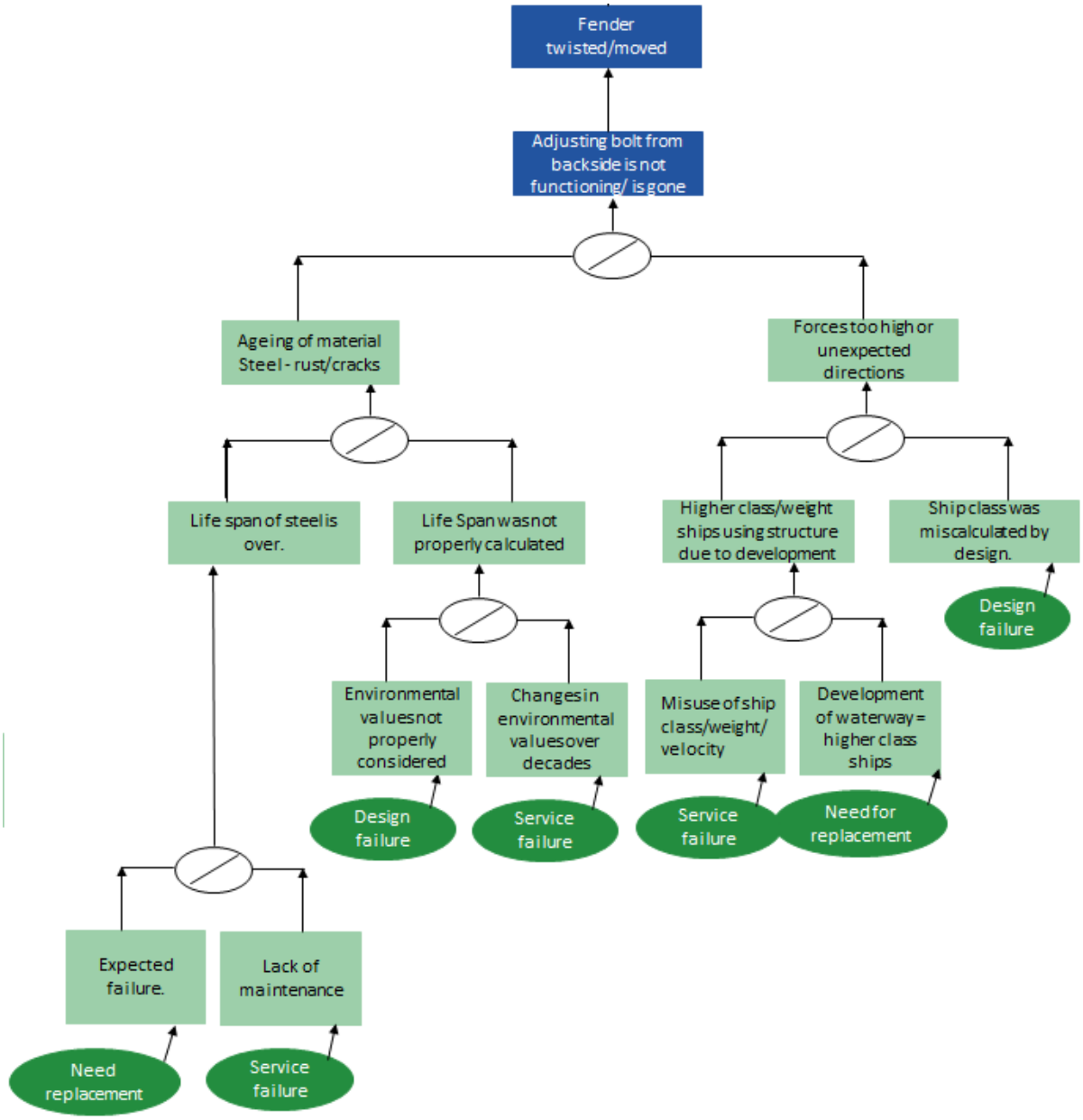


Figure 10: Fault Tree scheme for the cause of the twisting of the fenders.

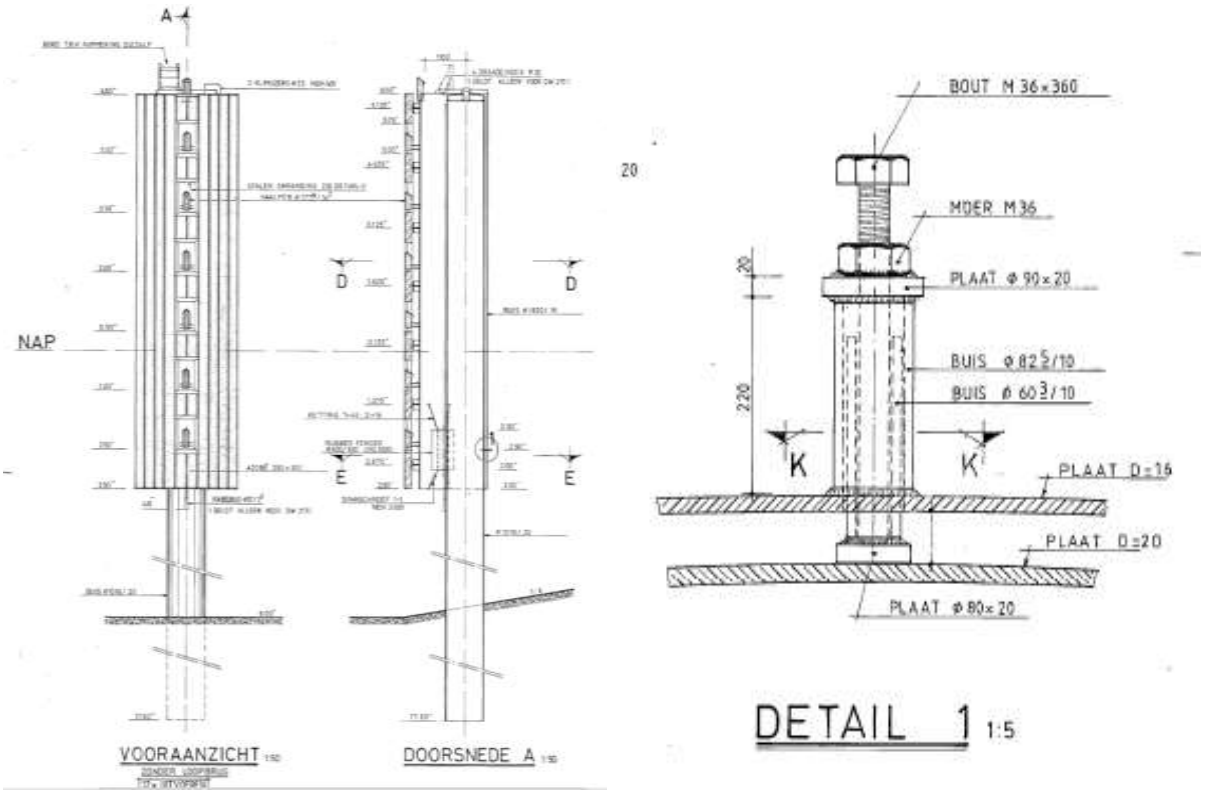


Figure 11: Dolphin Hansweert drawing with clamp bolt detail. Extracted from drawing ZLSR-1987-12014, RWS (2017).

In order for this element to failure, an extra load then the one design has to be applied or the material be compromised. The structural failure can take place in case of to the development of the waterways and therefore the presence of bigger vessels, also could be caused by the misuse of the structure (high berthing velocity, high impact against structure), the environmental/hydraulic conditions or a design phase miscalculation (load, direction, material).

5.2.2 Foundation Pile crooked

The situation of the foundation pile to be crooked is also considered a possibility as seen in the event map in Appendix III –Fault Tree Event Map.

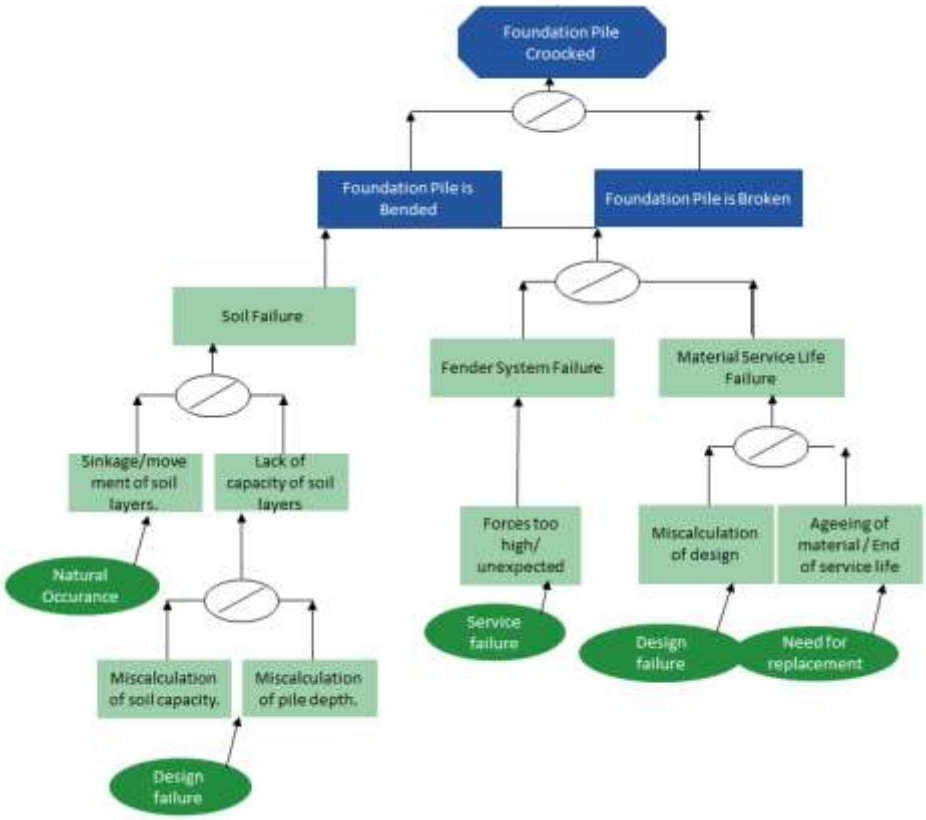


Figure 12: Fault Tree analysis of Foundation Pile Crooked.

No information was found in the database of RWS regarding the condition of the foundation pile, once the cap is covering it totally in the above water part, making the view and inspections difficult in the area. A qualitative approach was then taken by the team by the analysis of images taken on site (Appendix IV – Condition Pile Structure).

5.3 Post Modifications Analysis

Once some modifications were applied and still failures have occurred, a separate Fault Tree Event analysis was performed and can be found in Appendix III-II – Fault Tree Event Map Structure with Modifications and Solutions.

This shows that for both case the ageing of the material is not to be considered, once the issue has been occurring since the installation, or short after that. Therefore that leads to a design failure of the structure. As seen from experience of the years, and previous modifications, the weakest points of this structure is the rubber fender systems, in particularly the chains.

It is concluded by this analysis that the focus problem of the failure of the structure is the failure of the fender and the main causes are the strength of the chains and the rotation of the cap.

6 Conclusion

The team came to the conclusion that the top of most dolphins are aligned within an acceptable displacement, so the foundation pile should be still holding its position. Following this condition, the possible cause that the pile is compromised is set aside for this assignment. Nevertheless there is still no proof that the foundation pile is still in good conditions, so it is recommended that RWS perform a deeper investigation in the foundation pile in order to guarantee its safety and functionality.

Analyzing the Fault Tree, the conclusion of this RCA is that few root causes were found and grouped in four different categories described below.

1. Design Failure – in this case it is clear that the problem is caused due to the failure of the berthing facility design approach. It is understood that the proper boundaries and conditions have not been taken into account in the design phase, resulting in the failure of key elements that leads to the system failure.
2. Service Life Failure – this group represents the failures caused by conditions that have change and could not be expected in the design phase.
3. Use Failure – here are the failures that occur due to the lack of maintenance or misuse of the structures, such as the mooring of a bigger ship, or a ship with a higher mooring speed.
4. Need for replacement - these elements have used of the whole lifespan designed and have fulfilled their functionality for the expected period, therefore they need to be replaced.

The problem was earlier defined as the fenders support elements that are failing . Therefore it is also clear to this research that the main problem for the cap to be hanging crooked is the condition of the fenders, even though it is seen that other design problems are encountered. It is also determined the impact of the rotation of the pile cap on the fender's chains and therefore in the failure of the structure. The focus of the next steps should then be on finding solutions to keep the fender rubbers in place and fixating the cap in order to prevent the inclination of the cap.

6.1 Corrective actions

Corrective actions are results of the RCA that may be taken into account to ensure the same problem is not repeated. These corrective actions will result in changes to a project's scope, schedule, or cost. It is imperative that all of the findings and corrective actions are detailed and formally communicated with the project team so changes can go through the change management process and be implemented in the project plan upon approval.

In this case there are two main corrective actions to be taken:

1. Modification of actual structure – developing a new chain system support for the rubber fenders, and adding a new connection system between the foundation pile and the cap in order to prevent its rotation.

2. Renovation of structure – developing a new dolphin design that is able to function in the next 50 years with less maintenance.

The main corrective action 1 provides a temporary solution for the problem stated as the inclination of the cap in the dolphin structure, once this structure is already on service for more than 32 years and its elements life-span are starting to run-out needing fixing and replacements. Nevertheless this option provides a short-term and cheaper approach to the problem, having less influence on the local traffic. What would reduce the costs in a great deal is that a new pile foundation is not needed, and smaller elements are to be added, also reducing man-power hours.

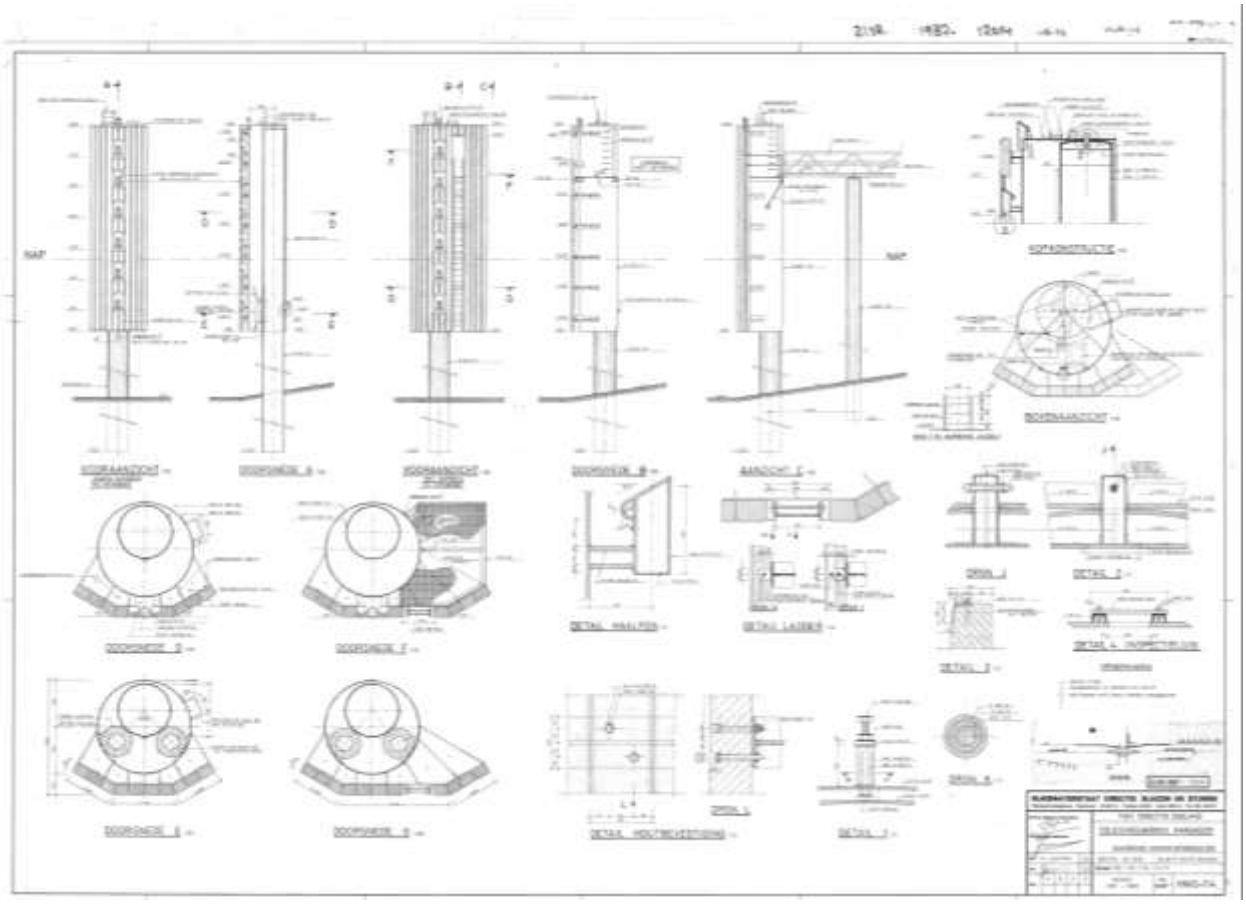
On the other hand, the dolphin structure has shown a design failure since its installation. The trial to approach the problem in a quick and budget way has shown ineffective to this moment. In addition to that, the structure shows also failures in its boulders and ageing of material after 32 years of serving. The investment of a new structure may be a better choice in the long-term, even though the current investment would be greater then a modification in the actual structure.

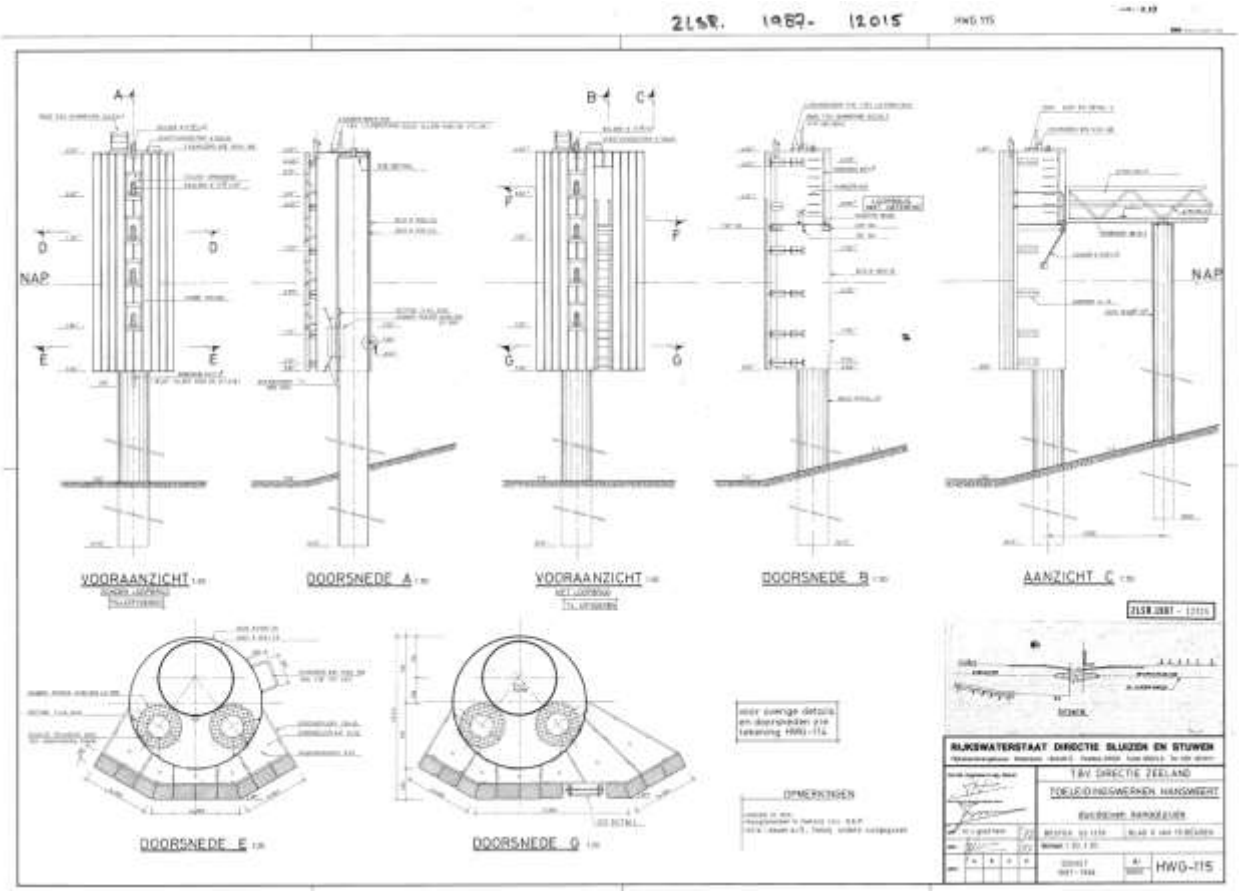
This report advises RWS to do further analysis in order to evaluate the cost-benefit between these two options.

Appendices

Appendix I – Drawings

Appendix I-I – Original structure drawings (1986-1987)

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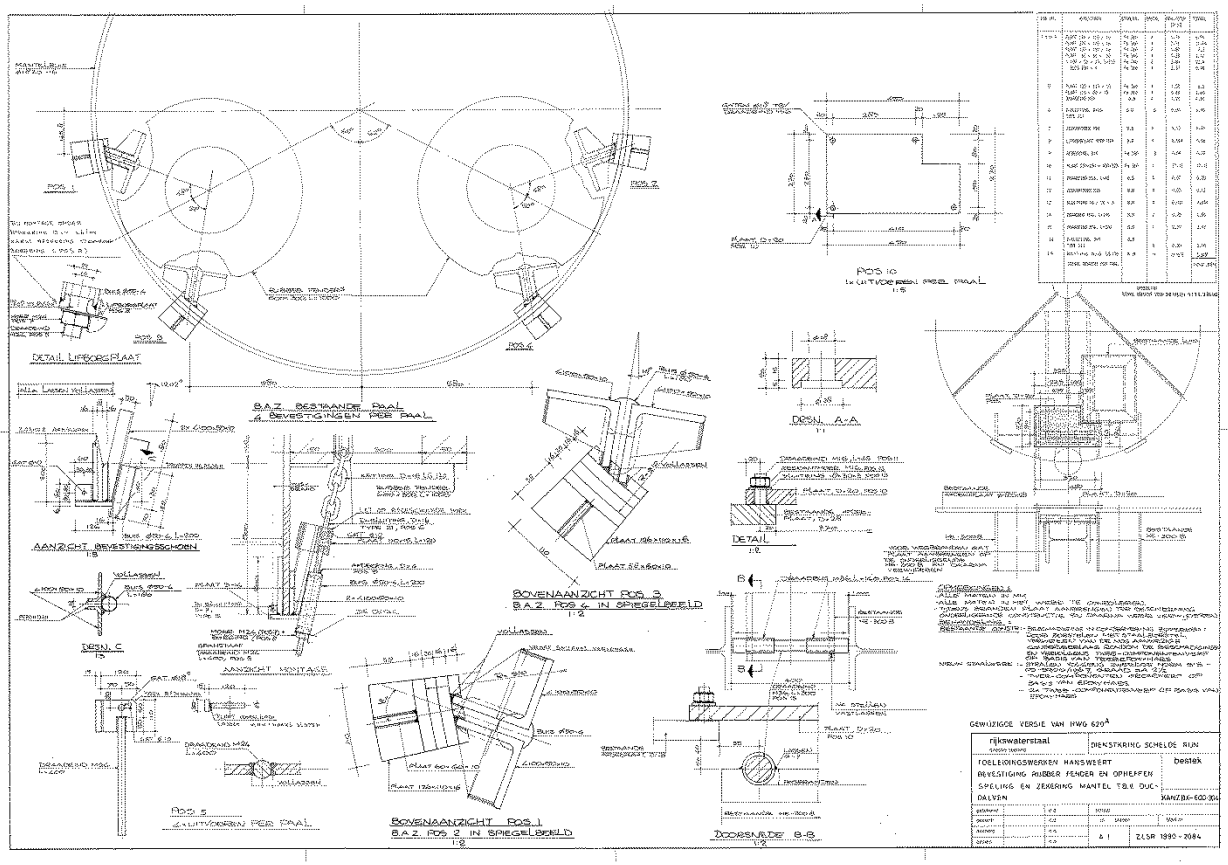
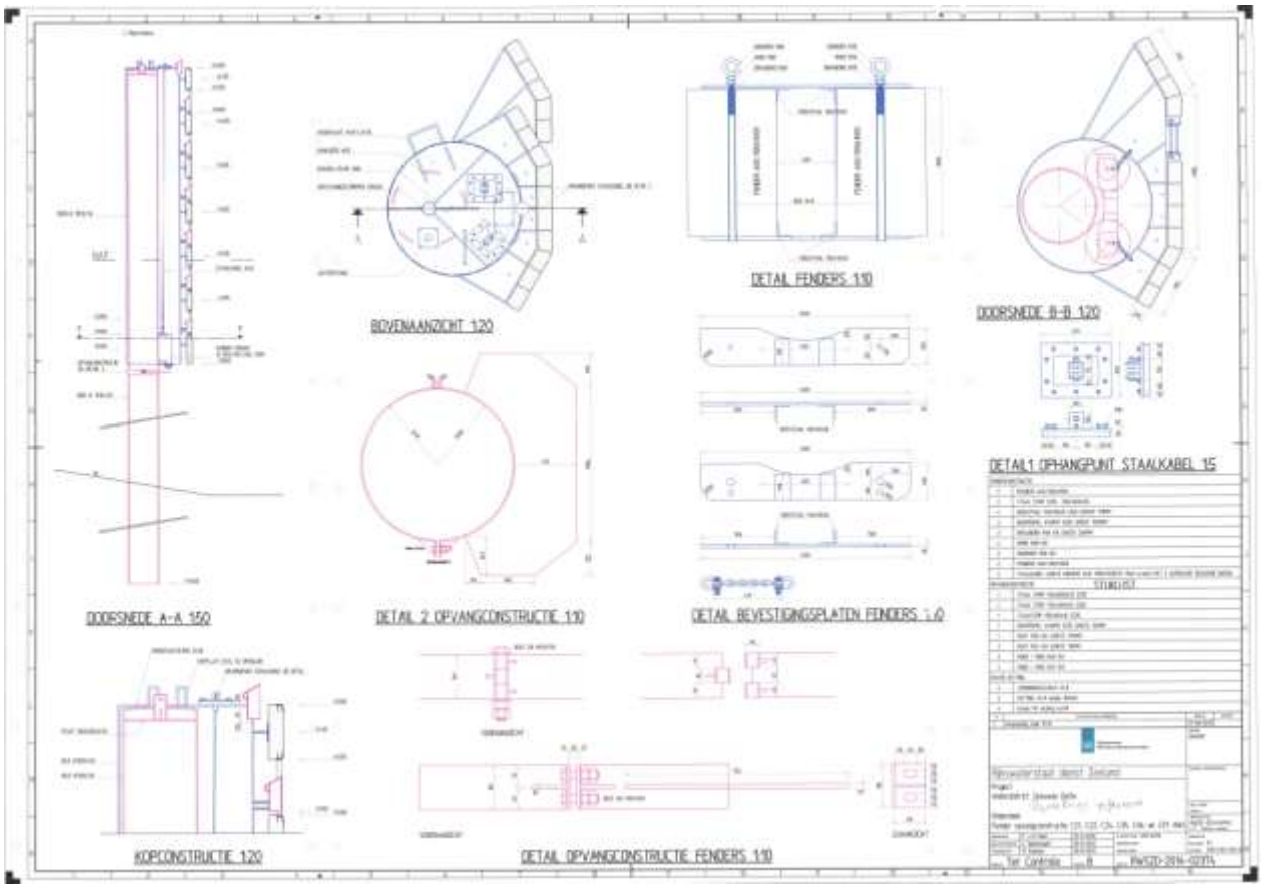
DOORSNEDE D
OPMERKINGEN
RIJKSWATERSTAAT DIRECTIE SLUIZEN EN STUWEN
TBV DIRECTIE ZEELAND
HWO-115

Appendix I-II – 1st Modification drawings (1990)



Appendix I-III – 2nd and 3rd Modification drawings (2014)



Appendix II - Method Selection

According to NEN 62740:2015, different techniques can be used in order to generate a RCA depending on the situation. The selection of a RCA method can be performed by reviewing the technique criteria with the desired outcomes of the analysis.

Table A.2 – Summary of RCA technique criteria

Criteria	Description	Levels
Expertise required	Is the method targeted towards the "sophisticated user" (does it require use of techniques such as theorem proving which requires specific expertise)? Is it suitable for use by domain experts only?	• Intuitive, little training necessary (+) • Limited training required e.g. one day (o) • Considerable training effort necessary, e.g. one week (–)
Tool support	Is tool support necessary?	• Can be well applied without dedicated tool support (+) • Tool support not required but usually needed for effective application (o) • Tool support necessary, can be applied only with dedicated tool support (–)
Scalability	Is the method scalable? Can the method be used cost effectively for simple as well as complex focus events? Can a subset of the method be applied to small, or to less-significant focus events and the full capability applied to large, or to significant focus events? So the question of scalability asks whether the complexity of analysis using the method scales with the complexity of the focus event	• Scales well with complexity (+) • Limited scalability, considerable overhead with every application (o) • Not scalable, the full method has to be applied (–)
Graphical representation	What is the nature of the method's graphical representation? The motivating principle is that a picture is better than a thousand words. It is often more comprehensible to display results of an analysis method as an image, a graph, or other form of illustration, than as purely written text. The desirable properties of a graphical representation are • to display clearly the semantics of causality (including denotation of causal factors, and taxonomy of factors), • to be cognitively (relatively) easily evaluated by a single person, • ideally, a graphical representation could also display the history of the analysis	• Graphical representation with clearly defined semantics and cognitively easy to understand (+) • Graphical representation, but without semantics (o) • No graphical representation defined (–)

Criteria	Description	Levels
Reproducibility	Are the results of the method reproducible? Would different analysts obtain similar results for the same focus event?	• The results can be reproduced, differences are only observed on the representation of the results, wording etc. (+) • A significant amount of the results can be reproduced, but some differences will be observed (o) • The results will depend on the analyst's expertise (–)
Plausibility checks	Are there reasonable, quick plausibility checks on the results obtained which are independent of the tool? What ways are there of checking the "correctness" of the results? One example would be checklists	• There are plausibility checks for almost all aspects (+) • There are plausibility checks, e.g. checklists, but they do not necessarily cover all aspects (o) • There exist only limited means supporting plausibility checks (–)
Intellectual rigour	How rigorous is the method? Rigour has two relevant aspects: • Does the method have a rigorous meaning, formal semantics, for the key notions of causal factor and root cause? Are the semantics easy to apply? • Are the results of the method amenable to formal (mathematical) verification? To what extent is an application of the method so amenable?	• Formally defined and can be formally verified (+) • Semi-formal definition (o) • Informal definition (–)
Time sequence	Does the method contain a representation of time sequence of events?	• Yes (+) • Only indirectly (o) • No (–)
Specificity	The extent to which the method limits analysis to necessary causal factors of the focus event rather than exploring a range of general problems with the system that existed at the time of the focus event and may have contributed	• Method only analyses necessary causal factors of the focus event (+) • Method can be used to analyse contributory factors as well as necessary causal factors of the focus event (o) • Method seeks problems in general whether or not they were necessary causal factors of the focus event (–)

From the given criteria a selection was made from three criteria that were considered essential for this situation. These criteria are described as per importance below:

1. Time Sequence – due to the lack of information regarding the chronology of events in this problem, the method rather not to make use of the time sequence. Therefore the 'No (-)' is chosen.
2. Tool Support Necessary - due to the defined time given for this activity it is important that the technique does not consume much time to be performed. Therefore a method that 'Can be well applied without dedicated tool support (+)' or 'Tool support not required but usually needed for effective application (o)'.

3. Intellectual Rigor - due to the lack of information regarding the original structure, this criteria is chosen to use the 'Semi-formal definition (o)'.
4. Specificity – in order to visualize the system in a whole, it is important that not only the necessary causal factors are analyzed, but also contributory factors. Therefore the 'Method can be used to analyze contributory factors as well as necessary causal factors of the focus event (o)' is chosen.

Table A.3 – Attributes of the generic RCA techniques

	Expertise required	Tool support	Scalability	Graphical representation	Reproducibility	Plausibility checks	Intellectual rigour	Time sequence	Specificity
ECF	o	o	o	+	o	o	o	+	+
MES and STEP	–	o	o	+	+	o	o	+	+
The 'Why' Method	+	+	–	o	–	–	–	–	+
CTM	o	o	+	+	o	o	o	–	+
WBA	o	+	o	+	+	+	+	o	+
Fault tree and success tree method	o	o	o	+	o	o	o	–	o
Fishbone or Ishikawa Diagram	+	+	–	o	–	o	–	–	o
SOL	o	–	+	o	+	+	o	+	o
MORT	+	–	–	o	+	o	o	–	–
AcciMaps	o	o	o	+	–	o	–	–	o
Tripod Beta	–	+	o	+	o	o	o	o	o
CAST	+	+	+	o	o	o	o	+	+
NOTE The criteria for each attribute are described in Table A.2.									

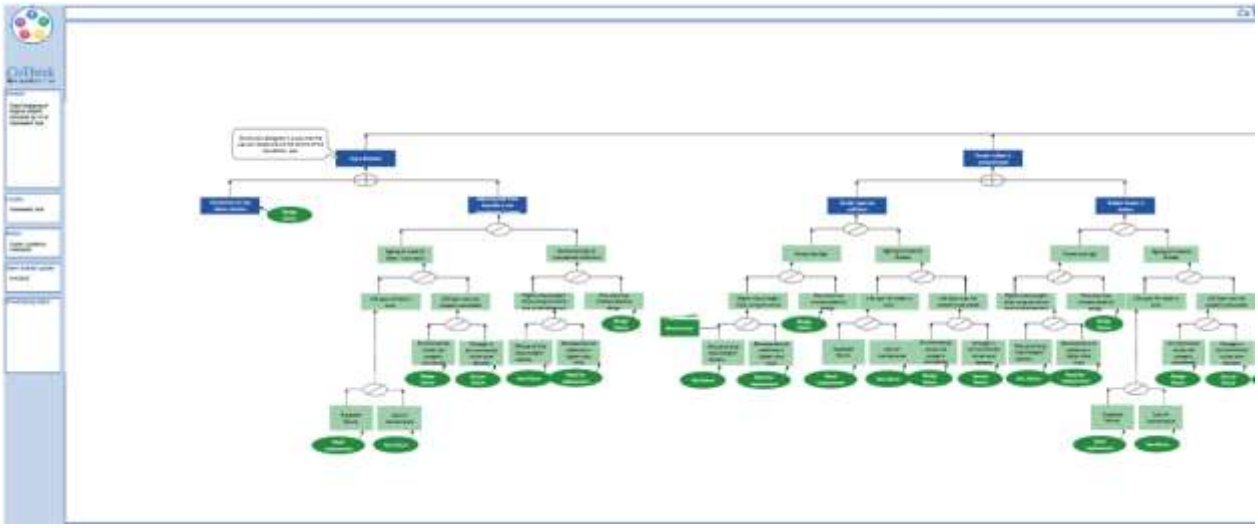
Once the priority criteria have been chosen, analyzing table A.3 of the attributes of the generic RCA techniques, part of NEN 62740:2015, the conclusion is set that the method to be used in this situation is the Fault tree or Success tree method. A description of this method can be seen below:

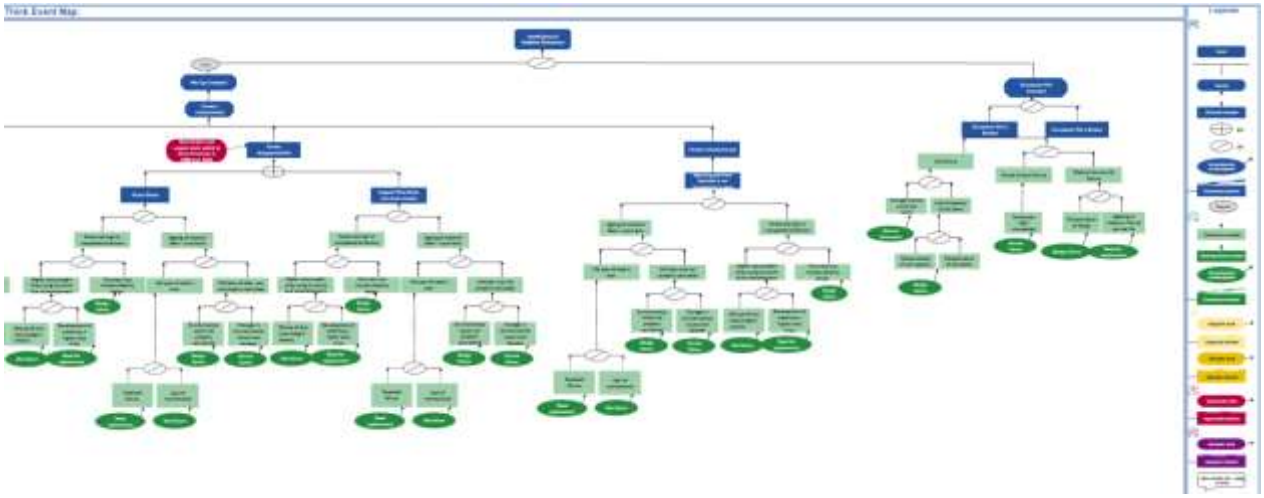
Fault tree and success tree method	Fault or success tree is a graphic display of information to aid the user in conducting a deductive analysis to determine critical paths to success or failure, which are displayed graphically in a logic tree diagram

Subtracted from table A.1 (NEN 62740:2015)

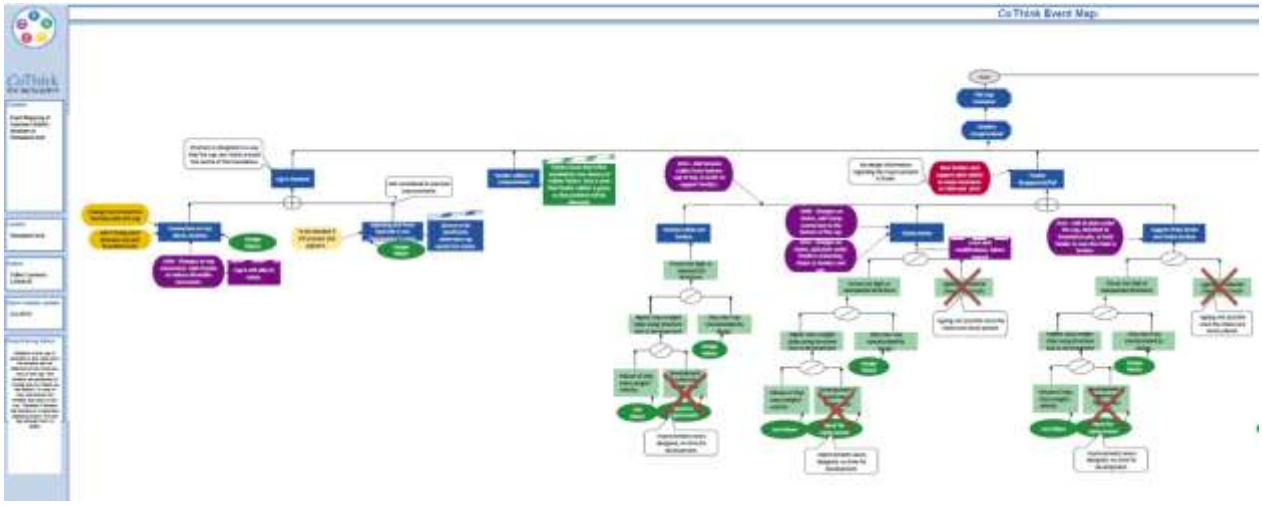
Appendix III – Fault Tree Event Map

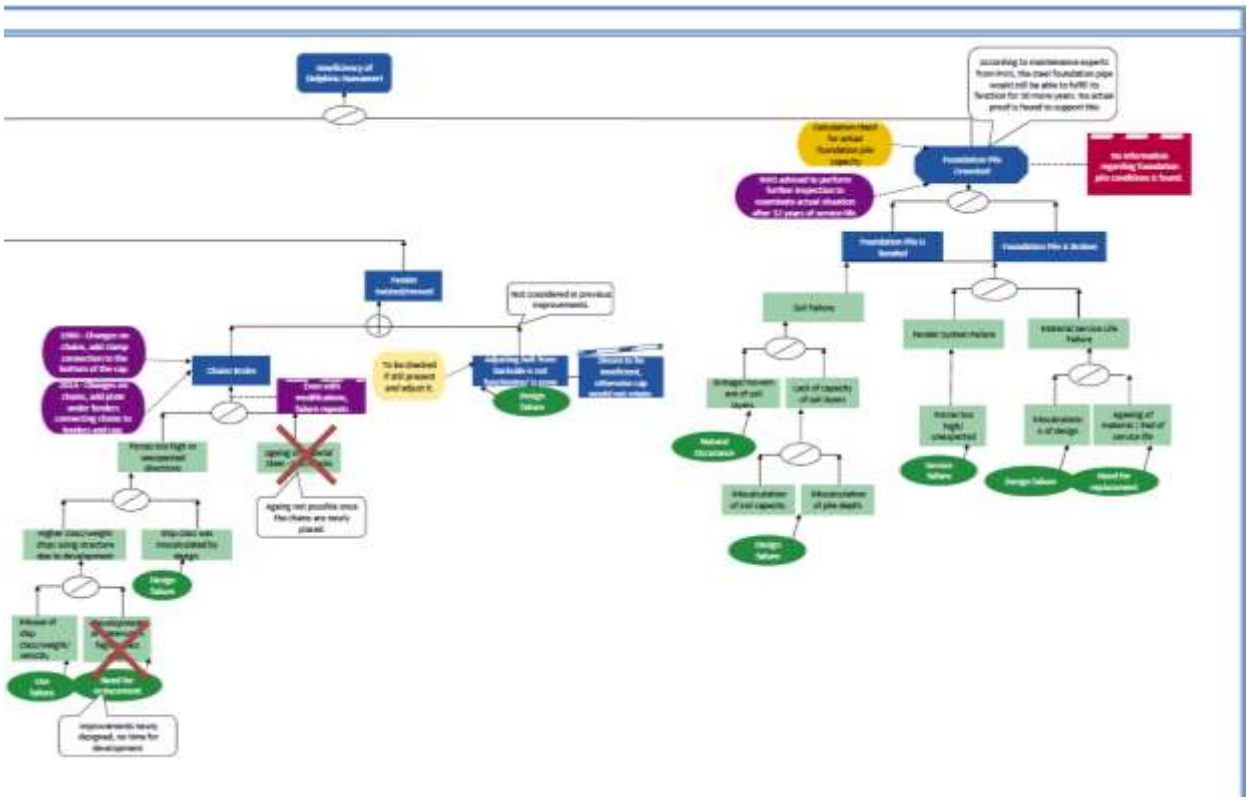
Appendix III-I – Fault Tree Event Map Original Structure





Appendix III-II – Fault Tree Event Map Structure with Modifications and Solutions





Appendix IV – Condition of Pile Structure

Visual Analysis

Inspections

No inspection was ever done in the foundation pile structure in the high water level. However, an inspection report from 2009 shows the situation encountered in the outer pile cap, that can be used as an estimation for the condition of the inner pile. The inspection has also carried an analysis of the width of the pile wall from the foundation pile.

Above high water level

According to this report the piles have shown a reduction in the epoxy layer as seen in table below.

Western Scheldt side: Right: C20-37; Left: G35-37

Canal side: Right:F20-23; Left: D20-38

3.1.1 Conserveringsdikte (koolteer epoxy systeem)

De dikte van de conservering is gemeten op het deel boven de hoogwater lijn, de resultaten zijn vastgelegd in tabel A.

Conserveringsdikte

Locatie	N	Gem.	Min./max.	Afw.
Paal C21	25	470	170 / 888	485
Loopbrug bij paal C21	50	438	193 / 757	153
Paal C27	25	640	249 / 1130	223
Loopbrug bij paal C27	50	409	158 / 846	175
Paal C29	25	349	204 / 519	85.9
Paal C36	25	451	247 / 668	97.7
Paal D21	35	371	131 / 605	150
Paal D23	15	316	193 / 497	92.1
Paal D25	15	239	172 / 397	53
Loopbrug bij paal D24	50	454	215 / 807	112
Paal D27	20	309	143 / 547	83.7
Paal D29	15	405	255 / 727	126
Loopbrug bij paal D30	50	417	216 / 846	118
Paal D31	15	322	234 / 472	74.8
Paal D33	20	302	173 / 545	107
Paal 5	25	327	105 / 667	165
Paal D36	20	291	207 / 430	53.4
Loopbrug bij paal D36	50	443	167 / 767	142
Paal F21	35	383	174 / 1270	230
Paal F22	15	316	210 / 446	86.1
Paal F23	20	372	179 / 561	130

Tabel A

N = aantal metingen.
Gem. = gemiddelde dikte in mu.
Min./ max. = laagste en hoogst gemeten dikte in mu.
Afw. = standaard afwijking.

We assume that these values indicate the reduction in 22 years, once no other inspection or maintenance report is found.

Locale roestvorming (koolteer epoxy systeem)

Locatie	Totale roest opp.	Totale herstel opp.	Opp. Paalbrug	Perc.
Paal C20 t/m C37 Gemiddeld	1,3 m2	5,3 m2	69	7,7 %
Paal C20 t/m C37 Hoogste	2,2 m2	8,8 m2	69	12,8 %
Paal C20 t/m C37 Laagste	0,8 m2	3,2 m2	69	4,6 %
Paal D20 t/m D37 Gemiddeld	1,5 m2	5,9 m2	47	12,6 %
Paal D20 t/m D37 Hoogste	2,8 m2	11,2 m2	47	23,8 %
Paal D20 t/m D37 Laagste	0,6 m2	2,4 m2	47	5,1 %
Paal F20 t/m F23 Gemiddeld	1,1 m2	4,4 m2	47	9,4 %
Paal F20 t/m F23 Hoogste	2,4 m2	9,6 m2	47	20,4 %
Paal F20 t/m F23 Laagste	0,6 m2	2,4 m2	47	5,1 %
Loopbruggen C21, C24, C27, C30, C33 en C36, Gemiddeld	2,3 m2	9,3 m2	235	4,0 %
Looptr. D21, D24, D27, D30, D33, D36 en F21,Gemiddeld	1,9 m2	7,8 m2	130	6,0 %

Tabel E

Under lowest water level

This measurements were done 2 meters below the lowest water level and generated the following table.

Staaldikte meting								
Locatie	Hoogwaterlijn, paalmuts				Ca. 2m onder laagwaterlijn, draagpaal			
	Noord	West	Zuid	Oost	Noord	West	Zuid	Oost
Paal C21	15.8	16.0	16.0	16.0	20.7	20.6	20.5	20.6
Paal C26	15.9	15.9	15.9	16.0	20.5	20.2	20.4	20.4
Paal C27	15.9	15.8	15.9	15.8	20.8	20.7	20.5	20.6
Paal C29	15.7	15.9	15.8	15.8	20.4	20.5	20.5	20.5
Paal C30	15.9	15.8	15.9	15.9	24.5	24.4	24.6	24.5
Paal D21	15.8	15.8	15.9	15.8	20.4	20.4	20.3	20.3
Paal D24	15.9	15.8	16.0	15.9	20.4	20.4	20.4	20.3
Paal D30	15.8	15.9	15.9	15.9	20.5	20.5	20.6	20.5
Paal D36	15.7	15.7	15.9	15.9	20.9	20.7	20.6	20.3
Paal F22	15.9	15.6	15.9	15.8	20.4	20.3	20.3	20.4

Tabel H (maten in mm)

Conclusion

The cap shows an erosion of the pile, where the cap thickness is as design 16mm. The maximum erosion is shown in pile F22, with a loss of 0.4mm in the western side.

On the other hand, the foundation pile shows overgrowth in all cases, coming to a maximum of 4.5mm. Nevertheless, is also known that overgrowth can be a cause for weakening of material.

The epoxy layer has shown to be within the lifespan, even though rust is still present. The area of rust formation is covering up to 20% of the pile cap.

Therefore this report advises RWS to perform a material inspection in the foundation piles for the area below low water level and an thickness inspection of the foundation pile above high water level. Relative to the epoxy coat, it is advisable to evaluate the type being used once rust areas are still present, then the epoxy coat does not have the desired effect.

Appendix V Geotechnical Analysis

Rijkswaterstaat
Ministry of Infrastructure and Water Management

DELTA ACADEMY

2018

Geotechnical Analysis

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Rijkswaterstaat Zee en Delta

12 juni 2018

Version 2.0

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1 Introduction

This report describes the methodology used for the evaluation of the geotechnical characteristics in the region where this project takes place, the canal by Hansweert lock. Along this document also the local parameters are shown and discussed.

2 Calculation Method

2.1 Soil Pressure Coefficient

There are many different methods for calculating the soil pressure. Some of commonly used methods for foundation constructions are Brinch Hansen and Müller-Berslau with shell factor, which both use the calculation of the straight sliding surfaces; and Kötter with shell factor that uses the approach a log-spiral sliding surface.

2.1.1 Brinch Hansen

The maximum passive soil pressure according to Brinch Hansen & Christensen (1961) is:

$$\sigma_p = K_q * \sigma'_v + K_c * c$$

Where:

σ'_p : Maximum passive soil pressure according to Brinch Hansen [];

σ'_v : Effective vertical soil stress [];

c : Cohesion of soil type [];

K_q : Passive soil pressure coefficient according to Brinch Hansen [];

K_c : Cohesion coefficient according to Brinch Hansen [];

The Brinch Hansen cohesion coefficient is to be calculated as:

$$K_c = \frac{K_c^0 + K_c^\infty * \propto_c * \frac{D}{B}}{1 + \propto_c * \frac{D}{B}}$$

Where:

$$K_c^0 = \left[e^{\left(\frac{\pi}{2}+\varphi\right)} * cos\varphi * tan\left(\frac{\pi}{4}+\frac{\varphi}{2}\right) - 1\right] * cot\varphi$$

$$K_c^\infty = N_c * d_c^\infty$$

$$N_c = \left[e^{(\pi * tan\varphi)} * tan^2\left(\frac{\pi}{4} + \frac{\varphi}{2}\right) - 1\right] * cot\varphi$$

$$d_c^{\infty} = 1{,}58 + 4{,}09 * tan^4\varphi$$

$$\propto_c = \left(\frac{K_c^0}{K_c^{\infty} - K_c^0}\right) * 2 * sin\left(\frac{\pi}{4} + \frac{\varphi}{2}\right)$$

The passive pressure coefficient according to Brinch Hansen is:

$$K_q = \frac{K_q^0 + K_q^{\infty} * \propto_q * \frac{D}{B}}{1 + \propto_q * \frac{D}{B}}$$

Where:

$$K_q^0 = e^{\left(\frac{\pi}{2}+\varphi\right)*tan\varphi} * cos\varphi * tan\left(\frac{\pi}{4} + \frac{\pi}{2}\right) - e^{\left(-\frac{\pi}{2}+\varphi\right)*tan\varphi} * cos\varphi * tan\left(\frac{\pi}{4} - \frac{\pi}{2}\right)$$

$$K_q^{\infty} = K_c^{\infty} * K_0 * tan\varphi = N_c * d_c^{\infty} * K_0 * tan\varphi$$

$$K_0 = 1 - sin\varphi$$

$$\propto_c = \left(\frac{K_q^0}{K_q^{\infty} - K_q^0}\right) * \left(\frac{K_0 * sin\varphi}{sin\left(\frac{\pi}{4}+\frac{\varphi}{2}\right)}\right)$$

2.1.2 Methods with shell effect

The theories used for the calculation of sheet pile construction can also be used to determine the ground pressures for a single pile, once it includes also the influence of width and depth of the pile in the active, passive and neutral soil pressures.

Müller-Breslau

The soil pressures factors according to Müller-Breslau can be found by:

$$K_{a,MB} = \frac{cos^2\varphi}{\left(1 + \sqrt[2]{\frac{sin\varphi * \sin(\varphi + \delta)}{cos\delta}}\right)^2}$$

$$K_{p,MB} = \frac{cos^2\varphi}{\left(1 - \sqrt[2]{\frac{sin\varphi * \sin(\varphi + \delta)}{cos\delta}}\right)^2}$$

$$K_n = 1 - sin\varphi$$

Where:

$$\delta = \frac{2}{3} * \varphi \ (in\ peat\ \delta = 0)$$

Kötter

Kötter with shell factor with the approach a log-spiral sliding surface can be calculated by:

$$K_{a,K} = \frac{1 - sin\varphi * \sin(2 * \alpha + \varphi)}{(1 + sin\varphi)} * exp\left\{\left(-\frac{\pi}{2} + \varphi + 2 * \alpha\right) tan\varphi\right\}$$

$$\alpha = \cos(2 * \alpha + \varphi - \delta) = \frac{\sin\delta}{\sin\varphi}$$

$$K_{p,K} = \frac{1 - sin\varphi * \sin(2 * \alpha' + \varphi)}{(1 * sin\varphi)} * exp\left\{\left(-\frac{\pi}{2} + \varphi + 2 * \alpha'\right) tan\varphi\right\}$$

$$\alpha' = \cos(2 * \alpha - \varphi - \delta) = \frac{\sin\delta}{\sin\varphi}$$

In order to consider the influence of the structure in the soil the following shell factors are applied:

$$K^*_{a,K} = \frac{K_{a,K}}{S}$$

$$K^*_{p,K} = K_{p,K} * S$$

$$K^*_{n,K} = K_n$$

Where S = 2.

Moreover, the maximum passive soil stress calculated for sheet-piles and single piles, with the shell factor is:

$$\sigma_p = K^*_{p,K} * \sigma'_v + 2 * c * \sqrt[2]{K^*_{p,K}}\ [\mathrm{kN}/m^2]$$

2.2 Modulus of subsoil reaction – Ménard

In order to calculate the horizontal capacity of the soil its constant modulus of subsoil reaction is needed. This value is determined according to the theory of Ménard is used for the proper application of the program D-Sheet Piling. This factor is dependent on the characteristics of the soil such as cone resistance, water content, stress history, loaded surface, short or long-term loads, and the deformation behavior of the soil type.

The horizontal constant (k_h) can then be found by means of an empirical formula derived by Ménard et al (1971) from field-based experiments:

$$\frac{1}{k_h} = \frac{1}{3 * E_p}\left[1{,}3 * R_0 * \left(2{,}65\frac{R}{R_0}\right)^{\alpha^*} + \alpha^* * R\right]; if\ R \geq R_0$$

$$\frac{1}{k_h} = \frac{2 * R}{E_p}\left[\frac{4 * (2{,}65)^{\alpha^*} + 3 * \alpha^*}{18}\right]; if\ R < R_0$$

Where:

≈ *

α^* : Rheological factor in accordance to Ménard [-];

k_h : Horizontal modulus of subsoil reaction constant [-];

R_0 : Reference radius (0,3) [m];

R : Radius of tubular pile [m];

E_p : Elasticity modulus according to Ménard [MPa];

β : Rheological factor in accordance to Ménard [-];

q_c : Cone resistance [MPa].

The rheological factor is defined according to the soil type and it is described by Ménard as it states in Table 1.

Table 1 Rheological factor for different soil types according to Ménard.

Soil Type	α^* [-]	β [-]
Peat	1,0	3,0
Clay	0,67	2,0
Silt	0,5	1,0
Sand	0,33	0,7
Gravel	0,25	0,5

For a global design consideration, the horizontal modulus of subsoil reaction constant can be defined according to Keijzer (2017) as:

Table 2 Formula for calculation of horizontal modulus of subsoil reaction constant according to Keijzer (2017).

	D_{eq} ≥ 1meter	D_{eq} < 1meter
Sand	$_h = \frac{3 * \ ;}{}$	$_h = 3 * \ ; \quad *$
Clay	$_h = \frac{1,5 * \ ;}{}$	$_h = 1,5 * \ ; \quad *$

Where:

$k_{h;average}$: Average horizontal modulus of subsoil reaction constant [MN/m];

$q_{c;average}$: Cone resistance of soil [MPa];

D_{eq} : Equivalent pile diameter [m].

The global method will be used for the analysis of the current situation, nevertheless the theory of Ménard is applied to the final design.

2.3 Passive resistance per soil layer

The reaction force in each ground level can be calculated by the average passive resistance of the relative soil layer, and it can be calculated as:

$$F_{ea;p;rep} = \sigma'_{p;average} * h * D$$

Where:

$F_{ea;p;rep}$	: Reaction force per soil layer	[kN];
$\sigma'_{p,average}$	: Maximum passive soil pressure with shell factor	[kN/m2]
h	: Thickness of soil layer	[m]
D	: Pile Diameter	[m]

The above formula assumes the maximum passive soil pressure is determined with the influence of the shell factor. When this is not the case, the shell factor must be applied to this formula.

3 Conus Penetration Tests

This section describes the varied sort of soil profiles along both sides of the lock Hansweert where the structures to be calculated are found. In order to use a realistic calculation of the local capacity, an average of five profiles is chosen to be used. Also the softest and the hardest profiles are chosen for the purpose of comparison and check.

3.1 CPT profiles

A total of 12 CPT profiles are present along the South-Beveland canal and the Western Scheldt sides of Hansweert lock, with a depth of 19meters or more according to DINOLoket (2018). The overview can be seen in Figure 1.

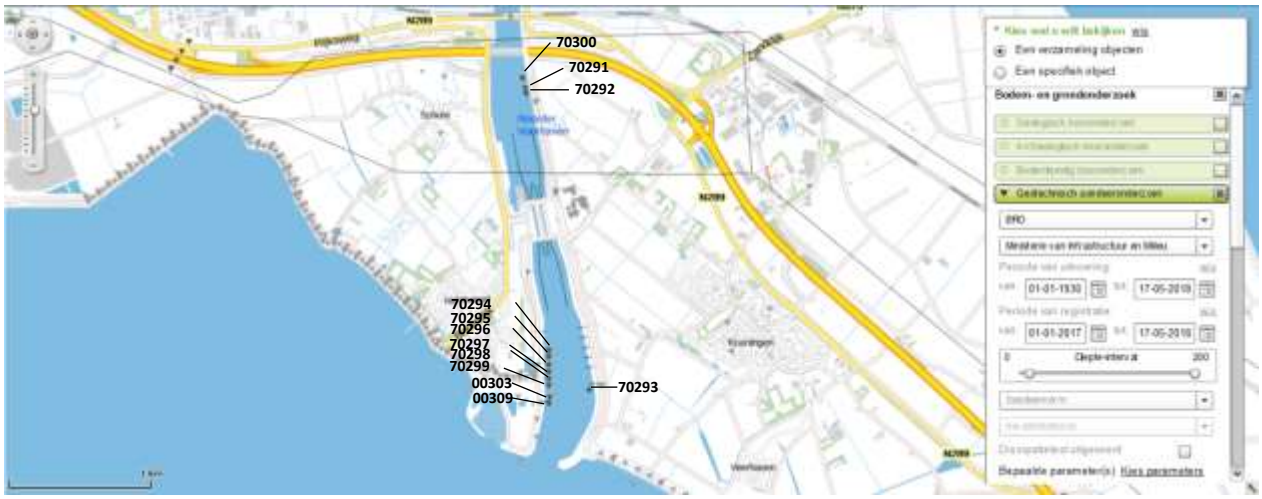

Figure 1 CPT locations according DINOLoket (2018).

3.1.1 Canal South-Beveland Side

The north side of the lock construction is represented by three CPT profiles shown in Figure 2. All of them show a cone resistance higher then 15MPa from a depth of 18 meter under ground level or 25m below NAP, assuming a depth of 7m below NAP. In addition to that, when considering that the shaft resistance is provided from a resistance of 2MPa, profiles A and C show that from a depth of around 14 meters below NAP the soil provides shaft resistance, while B has a deeper begin of around 16,5 meters below NAP.

Note that all samples are taken on the western side of the canal, therefore no representation of the eastern south is present for this project analysis. Therefore it is assumed that the left side of the canal has the same property of the right one.

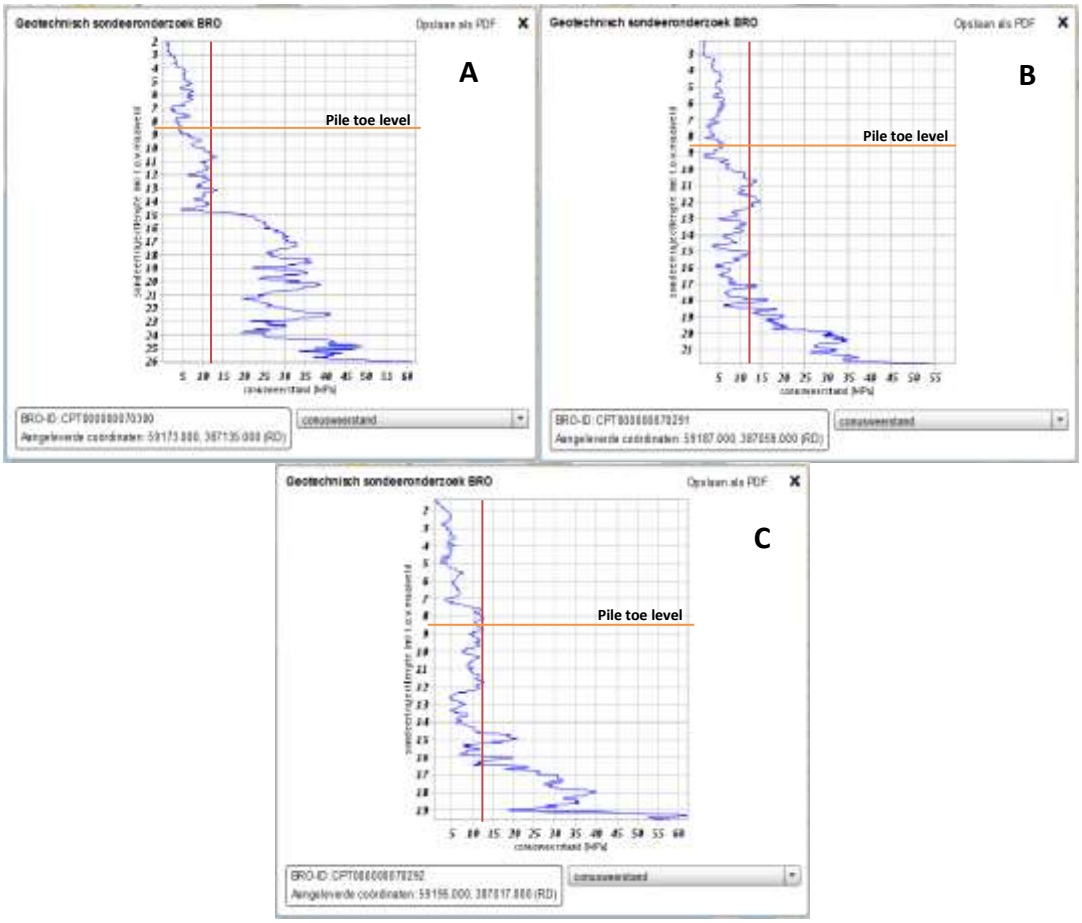

Figure 2 Geotechnical survey cone resistance graph of CPT profiles from the canal side of Hansweert Lock. Source: DINOLoket (2018)

3.1.2 Western Scheldt Side

The south part of Hansweert lock canal is represented by nine profiles from which eight are placed on the eastern side and one in the western side of the canal.

Each profile has an apart distribution, although H and K have a more homogeneous characteristic when comparing to D,E,F G and J. The eastern CPT, "L" in Figure 3, has shown a higher capacity and more homogeneous characteristics when comparing to the western side. Figure 4 shows profiles D,E,F,G,H,I,J,K.

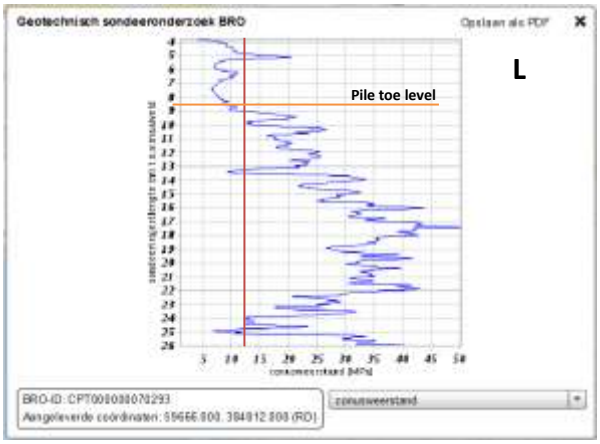

Figure 3 Geotechnical survey cone resistance graph of CPT profiles from the eastern side of the Westernscheldt side of Hansweert Lock. Source: DINOLoket (2018)

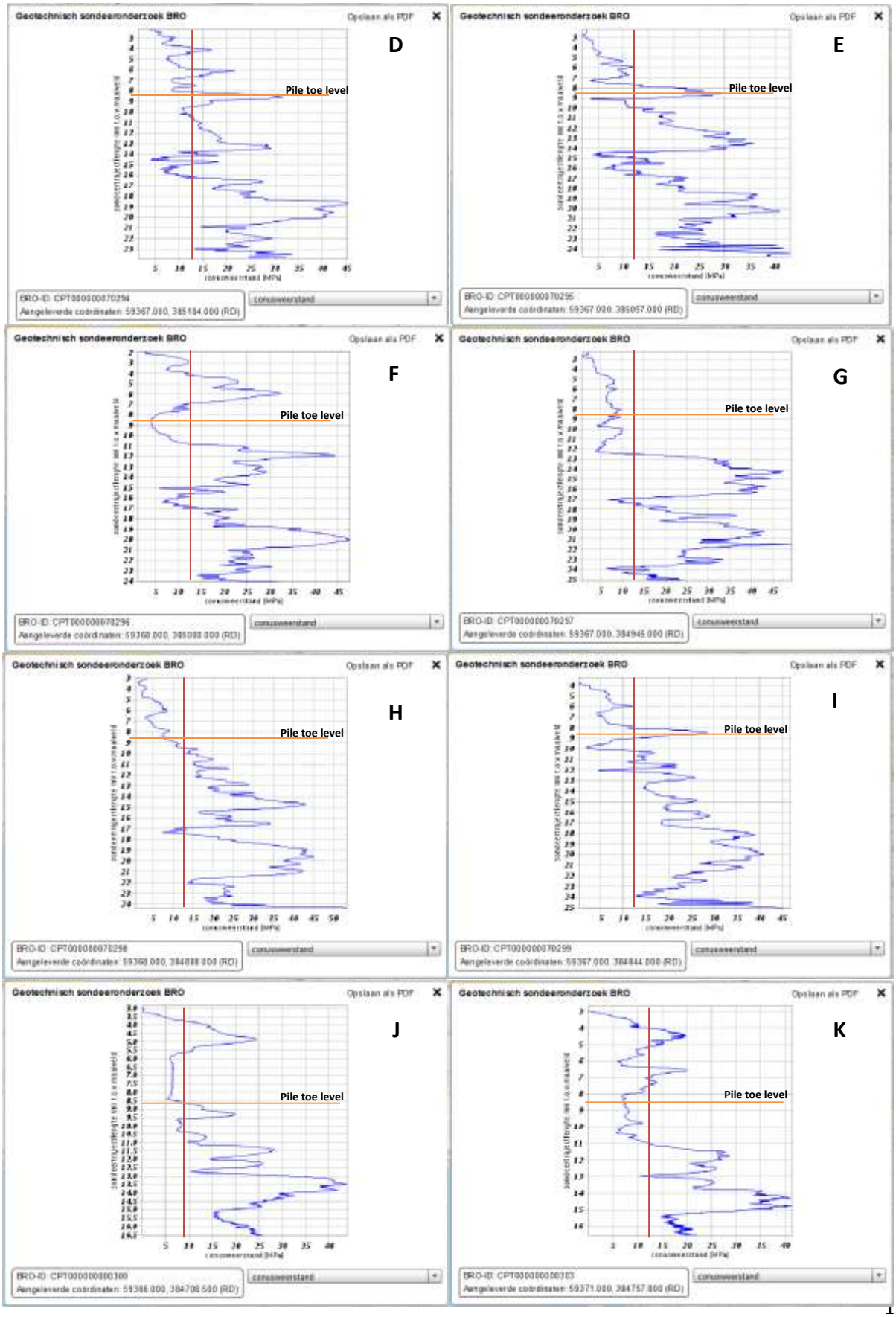

Figure 4 Geotechnical survey cone resistance graph of CPT profiles from the western side of the Western Scheldt side of Hansweert Lock. Source: DINOLoket (2018)

4 Design CPT Profile

4.1 Selection Procedure

In order to analyze the pile capacity the Western Scheldt side is chosen as determinant for the design due to the high influence of tide and waves from the main Western Scheldt canal. Moreover two profiles are then going to be used to define the capacity, one that represents the best case scenario from the data obtained; and a second with the worst scenario.

Analyzing the CPT charts of the cone resistance in §3.1.2, in relation to the current pile toe, it is seen that in profiles D, E, I, J and apparently also in C, the final level of the pile is as expected just above or in a layer with a capacity higher than 12MPa. Profile D shows the pile present in the layer with a thickness of 1,5 meters and therefore is chosen as the positive choice for the design.

Nevertheless for all other profiles this is not the case, leading to the conclusion that they are worst scenarios. The method used to define the profile with less capacity is by selecting the one that has the biggest layer between the pile toe and the below desired layer above 12MPa. As conclusion, the profile G, with a layer of 4 meters in between, is chosen as negative choice for the design.

4.2 Positive Profile

As mentioned in §4.1, the chosen soil diagram for the positive analysis is the CPT70294, represented in Figure 4 by the chart D. Table 3 shows the basic characteristics of each soil layer that are used in further analysis.

Table 3 Soil profile number 70294 representing strong profile. Source DinoLOKET (2018)

Layer	Top layer [mNAP]	Layer thick. [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-8,00	3,67	Loam	19	19	27,5	0	18,3	9,5	50
2	-11,67	1,02	Sand 1	18	20	25	0	16,7	9,5	0
3	-12,69	0,92	Loam	19	19	27,5	0	18,3	9,5	50
4	-13,61	8,15	Sand 2	18	20	27	0	18,0	9,5	0
5	-21,76	0,20	Loam	19	19	27,5	0	18,3	9,5	50
6	-21,959	0,10	Sand 1	18	20	25	0	16,7	9,5	0
7	-22,06	0,22	Loam	19	19	27,5	0	18,3	9,5	50
8	-22,28	0,20	Clay	18	18	22,5	0	15,0	9,5	80
9	-22,48	1,64	Loam	19	19	27,5	0	18,3	9,5	50
10	-24,12	2,20	Sand 1	18	20	25	0	16,7	9,5	0
11	-26,31	2,11	Sand 3	19	21	35	0	23,3	9,5	0
12	-28,43	2,35	Sand 2	18	20	27	0	18,0	9,5	0
13	-30,78	0,34	Loam	19	19	27,5	0	18,3	9,5	50
14	-31,12	31,12	Sand 2	18	20	27	0	18,0	9,5	0

An analysis of this profile layers capacity regarding the actual pile is described in Table 4.

Table 4 Capacity analysis of profile CPT70294.

CPT000000070294				
Summary				
qi [Mpa] [0,7Deq]	qii [Mpa] [4Deq]	qiii [Mpa] [8Deq]	qaverage [Mpa]	qc,z,a [Mpa]
10,79	**10,77**	**8,60**	**10,05**	**10,90**
Capacity Calculation				
αp	1,00		kh	30,64
αs	0,08			
β	1,00			
S	1,00			
Ab	0,80			
D	1,02			
Prmaxpoint	**9,69**	MN/m2		
Rcmaxpoint	**7731,25**	**kN**		
Prmaxshaft	**871,63**	kN/m2		
Shaft length	7,44	m		
Perimeter O	**3,19**	m		
Rmaxshaft	**20698,87**	**kN**		
Rtotal	**28430,12**	**kN**		

CPT000000070294

Summary

qi [Mpa]	[0,7Deq]	qii [Mpa]	[4Deq]	qiii [Mpa] [8Deq]	qaverage [Mpa]	qc,z,a [Mpa]
	10,79		**10,77**	**8,60**	**10,05**	**10,90**

Capacity Calculation

αp	1,00		kh	30,64
αs	0,08			
β	1,00			
S	1,00			
Ab	0,80			
D	1,02			
Prmaxpoint	**9,69**	MN/m2		
Rcmaxpoint	**7731,25**	**kN**		
Prmaxshaft	**871,63**	kN/m2		
Shaft length	7,44	m		
Perimeter O	**3,19**	m		
Rmaxshaft	**20698,87**	**kN**		

Rtotal	**28430,12**	**kN**

Figure 50 shows the graph relation of the CPT 70294 values and its Cone Resistance, Local Friction and Friction number.

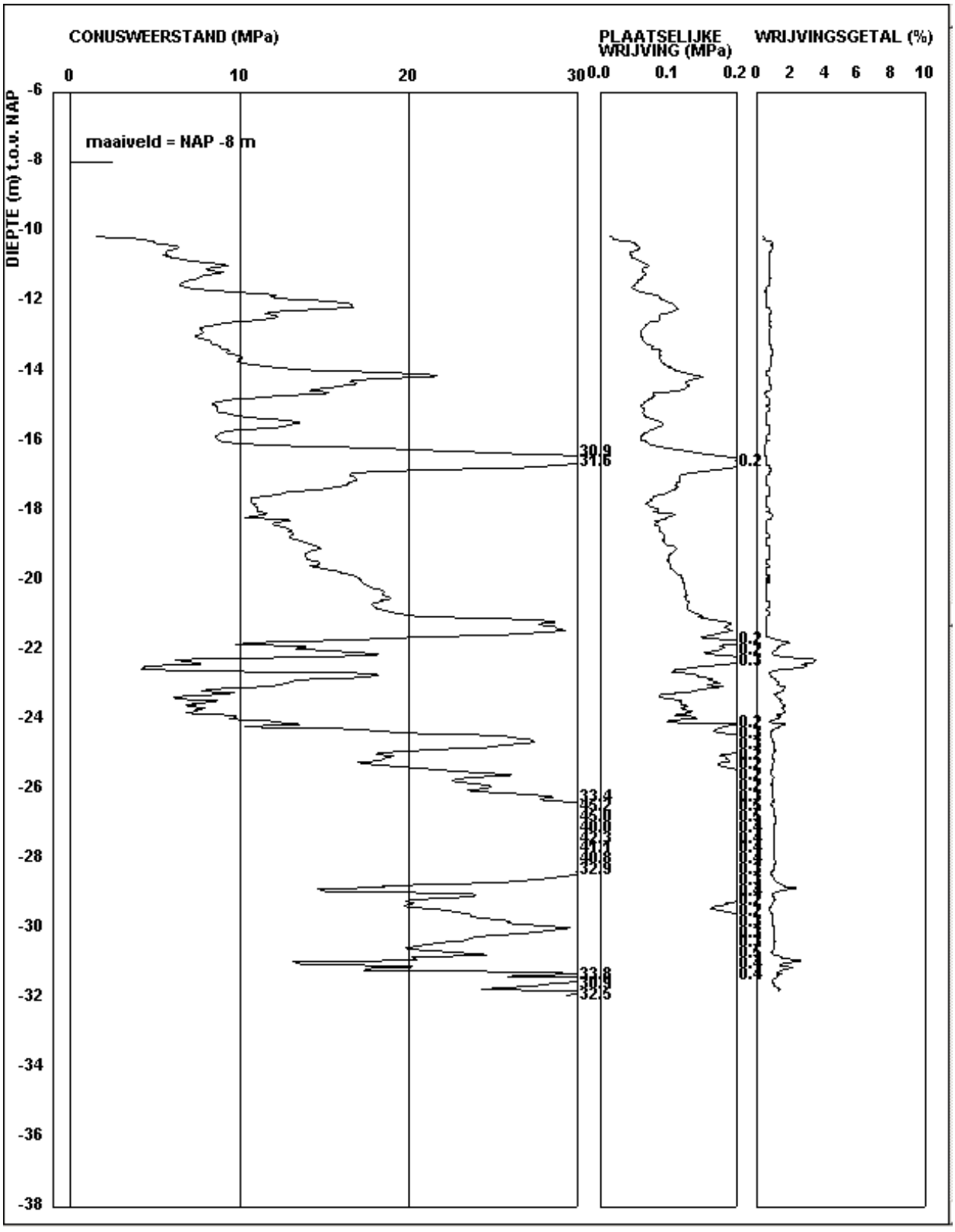

Figure 5 CPT70294 graph with cone resistance, local friction and friction number values. Source: GEFPlot (2018)

4.3 Negative Profile

This data is chosen to be represented by graph G of Figure 49, with the code of CPT 70297. Table 5 shows the basic characteristics of each soil layer that are used in further analysis.

Table 5 Soil characteristics of profile CPT70297.

Layer	Top layer [mNAP]	Layer thick. [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-7,00	2,79	Clay	18	18	27,5	0	18,3	9,5	50
2	-9,79	2,22	Loam	19	19	27,5	0	18,3	9,5	0
3	-12,01	0,40	Sand 1	18	20	25	0	16,7	9,5	50
4	-12,41	2,52	Loam	19	19	27,5	0	18,3	9,5	0
5	-14,93	0,22	Sand 1	18	20	25	0	16,7	9,5	50
6	-15,146	4,18	Loam	19	19	27,5	0	18,3	9,5	0
7	-19,32	4,53	Sand 2	18	20	27	0	18,0	9,5	50
8	-23,85	0,64	Loam	19	19	27,5	0	18,3	9,5	80
9	-24,49	6,11	Sand 2	18	20	27	0	18,0	9,5	50
10	-30,60	1,11	Loam	19	19	27,5	0	18,3	9,5	0
11	-31,72	31,72	Sand 1	18	20	25	0	16,7	9,5	0

An analysis of this profile layers capacity regarding the actual pile is described in Table 6.

Table 6 Capacity analysis of profile CPT70297.

CPT000000070297		(G)		
Summary				
qi [Mpa] [0,7Deq]	qii [Mpa] [4Deq]	qiii [Mpa] [8Deq]	qaverage [Mpa]	qc,z,a [Mpa]
5,37	**5,23**	**4,66**	**5,08**	**6,65**
Capacity Calculation				
αp	1,00		kh	15,50
αs	0,08			
β	1,00			
S	1,00			
Ab	0,80			
D	1,02			
Prmaxpoint	**4,98**	MN/m2		
Rcmaxpoint	**3971,95**	**kN**		
Prmaxshaft	**531,92**	kN/m2		
Shaft length	7,780	m		
Perimeter O	**3,19**	m		
Rmaxshaft	**13208,96**	**kN**		
Rtotal	**17180,91**	**kN**		

Figure 51 shows the graph relation of the CPT 70297 values and its Cone Resistance, Local Friction and Friction number.

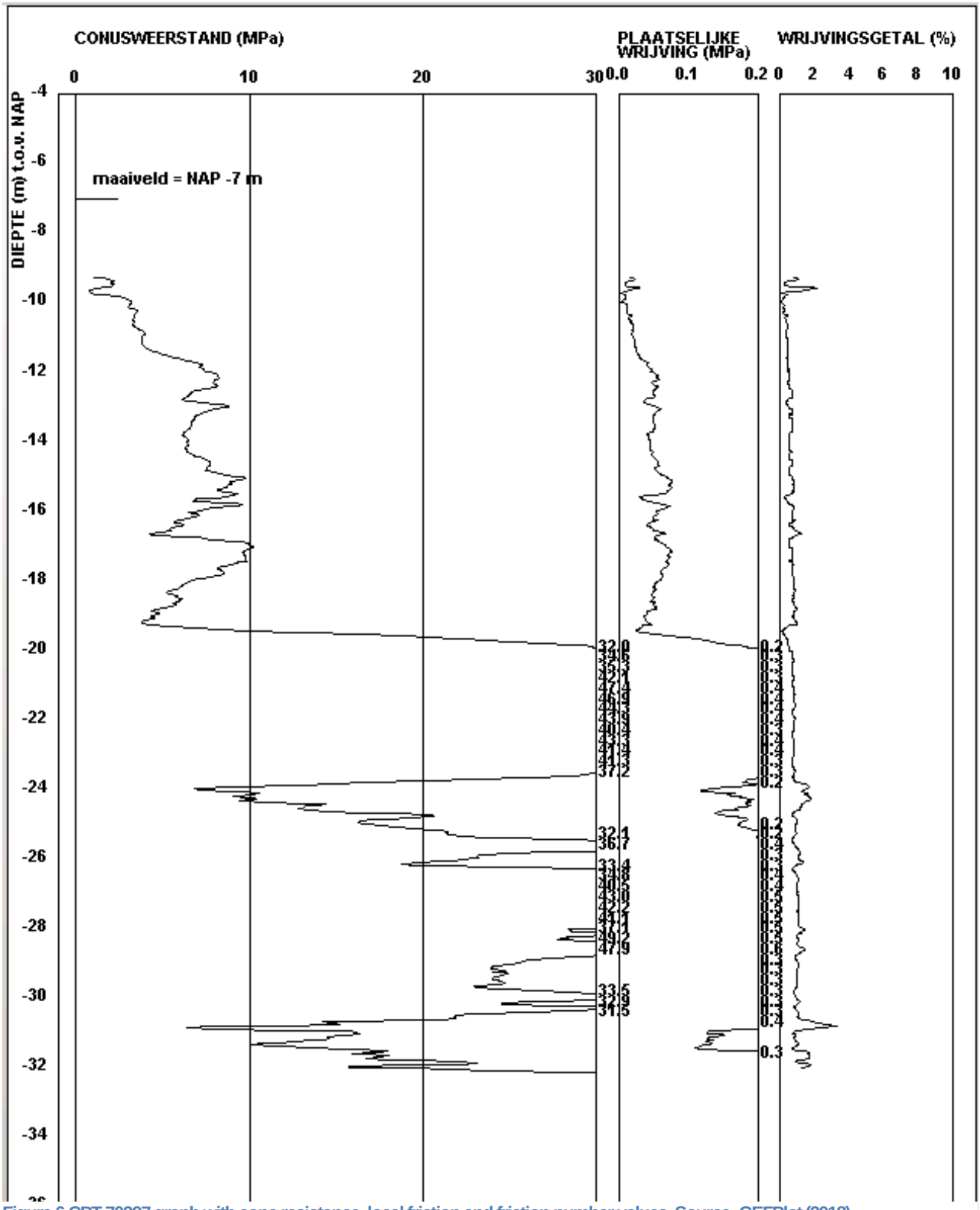

Figure 6 CPT 70297 graph with cone resistance, local friction and friction number values. Source: GEFPlot (2018)

5 D-Sheet Piling

Validation of the capacity of the soil is realized by the use of the program D-Sheet Piling. This section describes the results by running the program in the modulus of Single Pile analysis. The complete report can be found in Appendix X of the final report.

5.1 Positive Profile

This section analysis the positive profile behavior to the application of the required structures and applied loads.

5.1.1 Actual Pile Analysis

The actual pile appears to have the required stability when applying a maximum force of 195kN when the required displacement is set to 1,5m (EAU (2012)), as can be seen in Figure 52. On the other hand, for a maximum displacement of 0,5 as requirement of Eurocode 3 for the structures with the walking bridges, the maximum allowed load is shown to be lower than previously, and set at 160kN in Figure 53.

The actual pile does not supply the required capacity for the required lateral load of 350kN, once when running the program with this value the calculation does not go further due to instability.

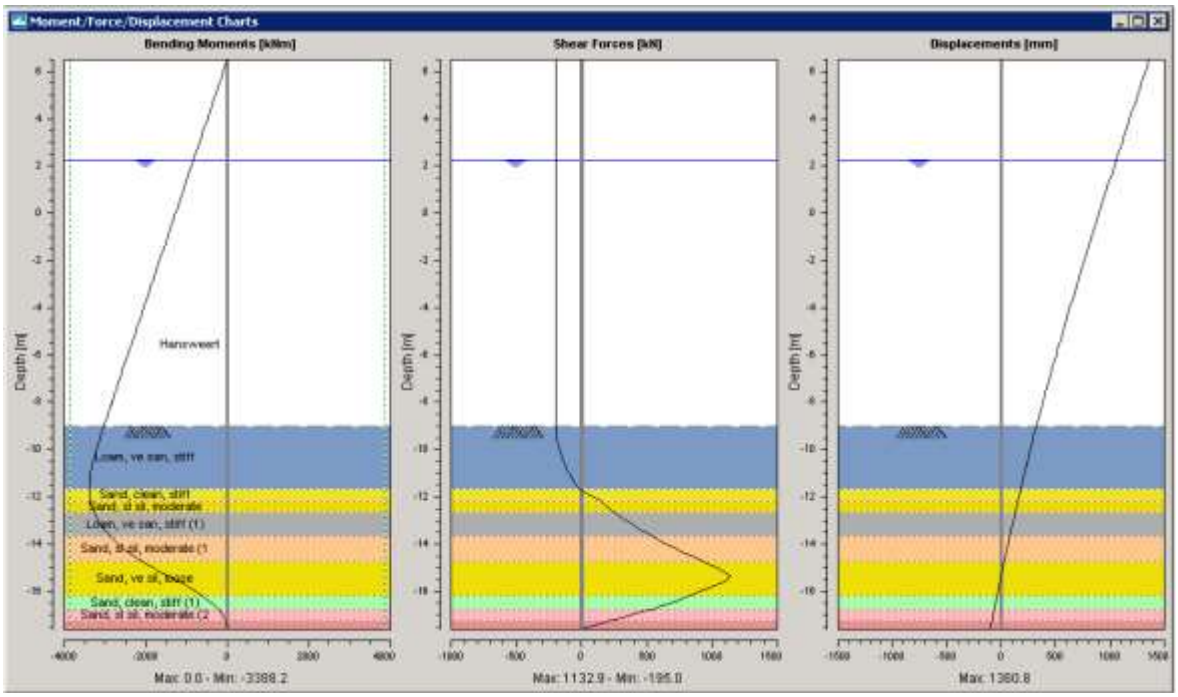

Figure 7 Moment, Force and Displacement charts from DSheet-piling analysis on actual structure and CPT70294, with max displacement of 1,5m.

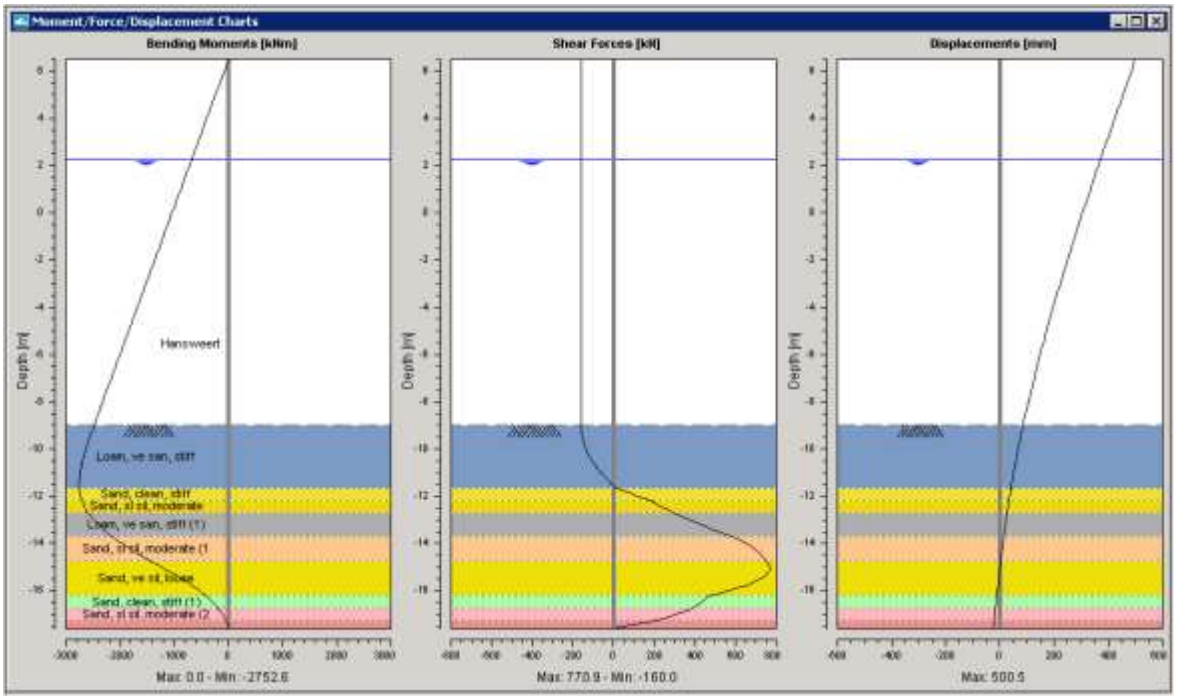

Figure 8 Moment, Force and Displacement charts from DSheet-piling analysis on actual structure and CPT70294, with max displacement of 0,5m.

5.1.2 Analysis for a force of 350kN

At a depth of NAP –20 m the software D Sheet-Piling shows that the soil body is able to support the structure with a displacement lower than the max of 1,5m defined by EAU (2012). Nevertheless the red line in the bending moment graph (Figure 54) shows that the max moment in this case is higher then the one allowed for this pile section. Therefore a structural failure happens according to this program.

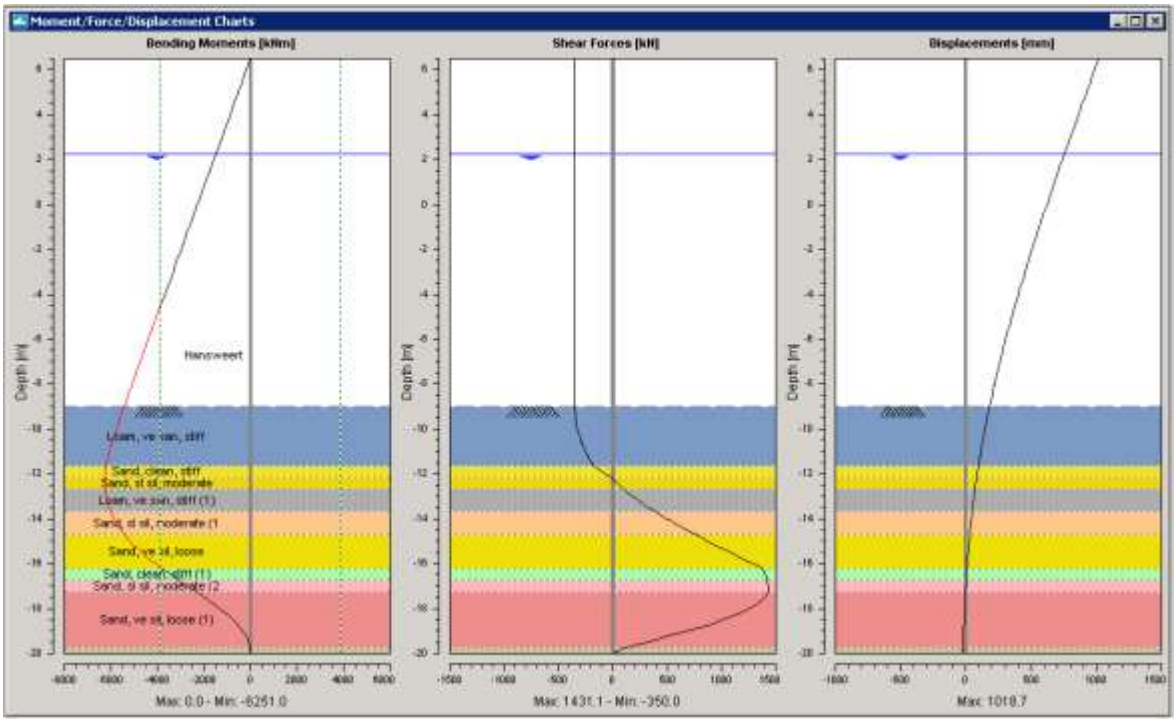

Figure 9 Moment, Force and Displacement charts from DSheet-piling analysis on longer pile and CPT70294, with max displacement of 1,5m and desired load of 350kN.

5.2 Negative Profile

This section analysis the negative profile behavior to the application of the required structures and applied loads.

5.2.1 Actual Pile Analysis

The actual pile appears to have the required stability when applying a maximum force of 175kN when using this diagram and the required displacement is set to 1,5m (EAU, 2012), as can be seen in Figure 55. On the other hand, for a maximum displacement of 0,5 as requirement of Eurocode 3 for the structures with the walking bridges, the maximum allowed load is shown to be lower than previously, and set at 152kN in Figure 56.

CPT000000070297

(G)

Summary

qi [Mpa] [0,7Deq]	qii [Mpa] [4Deq]	qiii [Mpa] [8Deq]	qaverage [Mpa]	qc,z,a [Mpa]
5,37	**5,23**	**4,66**	**5,08**	**6,65**

Capacity Calculation

αp	1,00		kh	15,50
αs	0,08			
β	1,00			
S	1,00			
Ab	0,80			
D	1,02			
Prmaxpoint	**4,98**	MN/m2		
Rcmaxpoint	**3971,95**	**kN**		
Prmaxshaft	**531,92**	kN/m2		
Shaft length	7,780	m		
Perimeter O	**3,19**	m		
Rmaxshaft	**13208,96**	**kN**		
Rtotal	**17180,91**	**kN**		

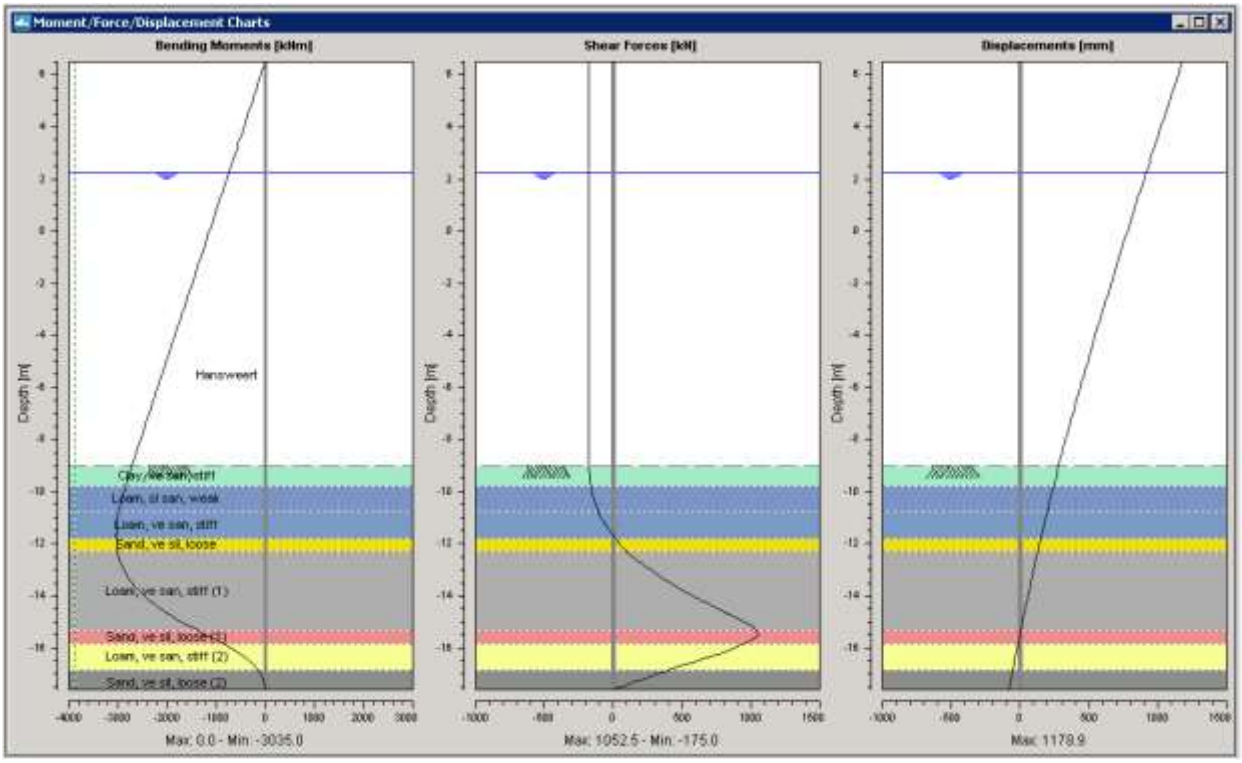

Figure 10 Moment, Force and Displacement charts from DSheet-piling analysis on actual structure and CPT70297, with max displacement of 1,5m.

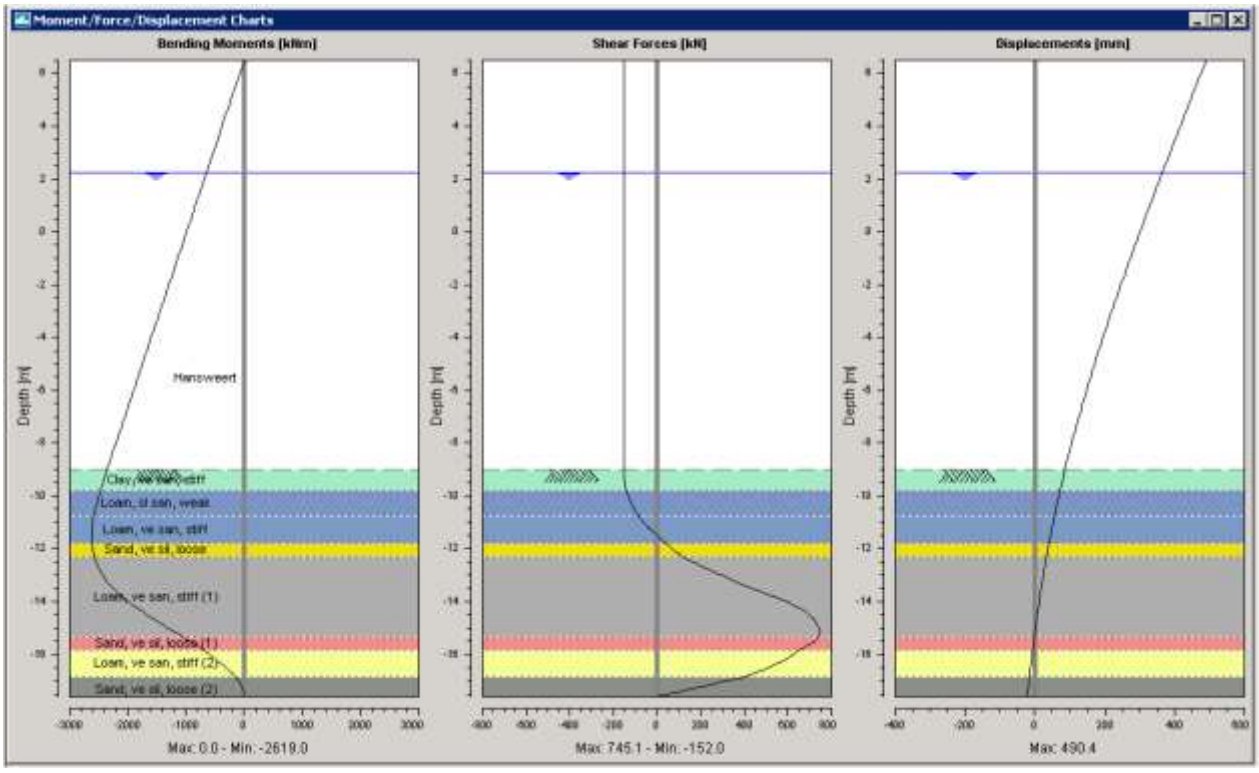

Figure 11 Moment, Force and Displacement charts from DSheet-piling analysis on actual structure and CPT70297, with max displacement of 0,5m.

5.2.2 Analysis for a force of 350kN

At a depth of -20mNAP the software D Sheet-Piling shows that the soil body is able to support the structure with a displacement lower than the max of 1,5m defined by EAU (2012). Nevertheless, the same is observed as for the positive profile with the red line in the bending moment graph (Figure 10) showing that the maximum moment in this case is higher then the one allowed for this pile section. Therefore it is expected a structural failure in this situation, according to this program.

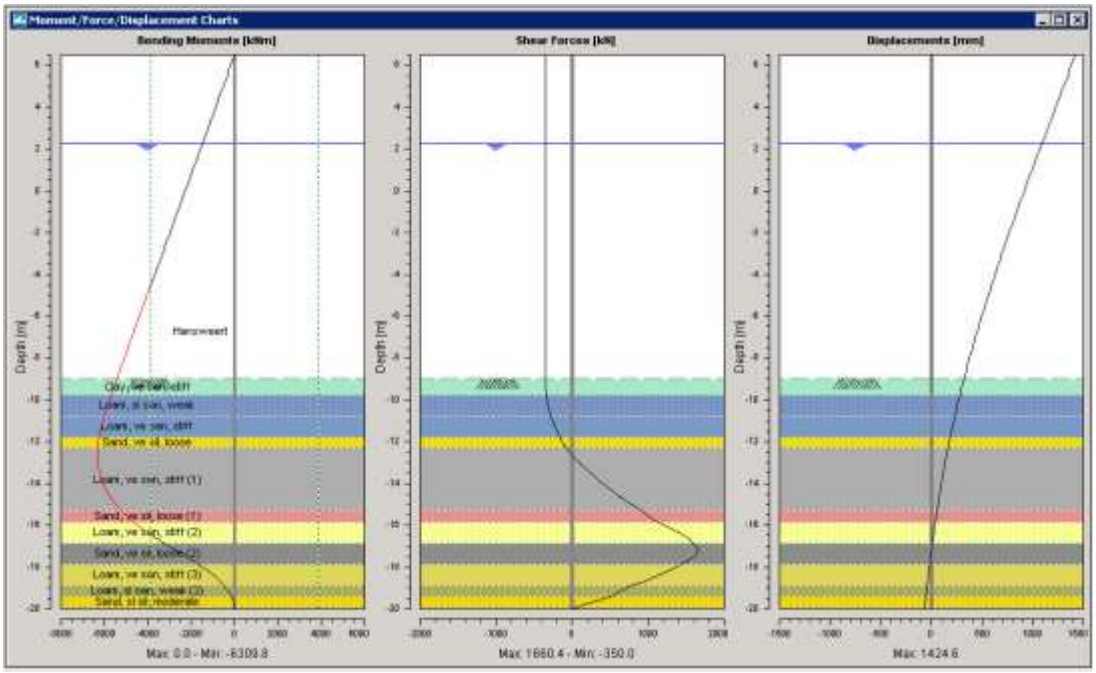

Figure 12 Moment, Force and Displacement charts from DSheet-piling analysis on longer pile and CPT70297, with max displacement of 1,5m and desired load of 350kN.

6 Conclusion

This report describes the geotechnical data of the project location and defines the critical profiles to be used in the design. Therefore this document is an extension of the general project and is to be used as background information for the final design.

In conclusion to this analysis, the pile penetration depth must increase up to a toe level of NAP –20 m, when the soil does fulfill the capacity needed for the applied load. Further analysis of the structural capacity of the pile must be carried on to check if the pile also fulfills this requirement.

7 Bibliography

DINOloket. (2018, March 3). *Ondergrondsgegevens*. Retrieved from DINOloket Data en Informatie van de Nederlandse Ondergrond: http://www.dinoloket.nl

EAU. (2012). *Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004*. Arbeitsausschuss.

Appendix VI Pile Capacity Analysis

Rijkswaterstaat
Ministry of Infrastructure and Water Management

DELTA ACADEMY

2018

Pile Capacity Analysis

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Rijkswaterstaat Zee en Delta

12-6-2018

Version 2.0

Contents

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List of Tables

1 Introduction

This report provides the information needed for the capacity check of the current foundation pile used for Hansweert lock adjacent harbors waiting facilities. Along this document the assumptions used for the calculations is described, as from the methods used and the results obtained.

2 Assumptions

This section describes the assumptions taken for the calculation of the resistance of the structure against the applied load.

2.1 Material

The actual foundation pile is the same used in both sides of the lock and it has the characteristics shown in Table 42.

Table 1: Basic characteristics of cross-section foundation steel pile.

Characteristics of Foundation Pile (W)					
Diameter	D	1016,00	mm	1,016	m
Thickness	t	20,00	mm	0,02	m
Length total	L	24100,00	mm	24,1	m
Length cantilever	Lcantilever	15500,00	mm	15,5	m
Steel resistance	fy	355,00	N/mm2	355000	kN/m2
Steel resistance	fu	490,00	N/mm2	490000	kN/m2
Steel density	ρsteel	0,0000078	kg/mm3	7800,00	kg/m3
Inner Diameter	d	976,00	mm	0,976	m
Area base	Ab	810731,97	mm2	0,810732	m2
Area shaft	As	38461890,54	mm2	38,461891	m2
Area	Aw	20320,00	mm2/m	0,02032	m2
Area net	Anet	62580,53	mm2	0,0625805	m2
Volume	V	1508190668,39	mm3	1,5081907	m3
Inertia constant	I	7763239369	mm4	0,0077632	m4
	E	210000	N/mm2	210000000	kN/m2
	EI	1,63028E+15	Nmm2	1630280,3	kNm2
Elastic Section Modulus	Wel	15281967,26	mm3	0,015282	m3
Plastic Section Modulus	Wpl	19842986,67	mm3	0,019843	m3
Torsional Inertia	It	15526478738	mm4	0,0155265	m4
Torsional Modulus const.	Ct	30563934,52	mm3	0,0305639	m3

Corrosion

The corrosion is determining in the surface in which the highest moment is found in the structure. In this case, the highest moment is placed underground and therefore it can be considered that the corrosion is extremely low or none, once it has low influence of the splash zone, vessel impact and the pile has a cover layer of 400µu thickness of a two-components based paint of tar epoxy resin.

In conclusion, for design purposes the corrosion to be considered is the rate according to CUR (2014) for underground corrosion of 0.026mm/year. In addition to this assumption, once there is lack of information of the current situation of the foundation pile coating, this report advises the client to perform an underwater inspection, nearby the bottom of the canal for a check of the protecting layer. In

the case of damages in this location, further investigation should be done by the client to be able to follow this design, or a corrosion rate is needed to be changed.

2.2 Geotechnical

The local geotechnical information selection is described in Appendix I – Geotechnical Analysis. The design data is shown in Table 43 and Table 44.

Table 2: Geothecnical information positive profile CPT70294. Source: DINOLoket (2018)

Layer	Top Layer [mNAP]	Layer [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-8,00	3,67	Loam	19	19	27,5	0	18,3	9,5	50
2	-11,67	1,02	Sand 1	18	20	25	0	16,7	9,5	0
3	-12,69	0,92	Loam	19	19	27,5	0	18,3	9,5	50
4	-13,61	8,15	Sand 2	18	20	27	0	18,0	9,5	0
5	-21,76	0,20	Loam	19	19	27,5	0	18,3	9,5	50
6	-21,959	0,10	Sand 1	18	20	25	0	16,7	9,5	0
7	-22,06	0,22	Loam	19	19	27,5	0	18,3	9,5	50
8	-22,28	0,20	Clay	18	18	22,5	0	15,0	9,5	80
9	-22,48	1,64	Loam	19	19	27,5	0	18,3	9,5	50
10	-24,12	2,20	Sand 1	18	20	25	0	16,7	9,5	0
11	-26,31	2,11	Sand 3	19	21	35	0	23,3	9,5	0
12	-28,43	2,35	Sand 2	18	20	27	0	18,0	9,5	0
13	-30,78	0,34	Loam	19	19	27,5	0	18,3	9,5	50
14	-31,12	31,12	Sand 2	18	20	27	0	18,0	9,5	0

Table 3: Geothecnical information negative profile CPT70297. Source: DINOLoket (2018)

Layer	Top layer [mNAP]	Layer [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-7,00	2,79	Clay	18	18	27,5	0	18,3	9,5	50
2	-9,79	2,22	Loam	19	19	27,5	0	18,3	9,5	0
3	-12,01	0,40	Sand 1	18	20	25	0	16,7	9,5	50
4	-12,41	2,52	Loam	19	19	27,5	0	18,3	9,5	0
5	-14,93	0,22	Sand 1	18	20	25	0	16,7	9,5	50
6	-15,146	4,18	Loam	19	19	27,5	0	18,3	9,5	0
7	-19,32	4,53	Sand 2	18	20	27	0	18,0	9,5	50
8	-23,85	0,64	Loam	19	19	27,5	0	18,3	9,5	80
9	-24,49	6,11	Sand 2	18	20	27	0	18,0	9,5	50
10	-30,60	1,11	Loam	19	19	27,5	0	18,3	9,5	0
11	-31,72	31,72	Sand 1	18	20	25	0	16,7	9,5	0

2.3 Vessels & Berthing

Following this project's program of requirements, the design vessel is to be considered of CEMT VIb class. The choice for the design values of berthing were taken based on discussion with experts in the subject and the realistic approach of vessels of this category in front harbors of lock. According to the specialists, bigger vessel, although they are heavier they show a better control in the along the berthing process then the smaller vessels.

Taking the practical information into consideration, Table 4 shows the design values for the capacity calculation.

Table 4: Design berthing characteristics

Berthing characteristics	
Approach velocity	**Approach angle**
Design velocity [m/s]	**Design angle [°]**
0,13	**15**

The energy applied on the structure in the process of berthing is determined according to EAU (2012), and further developed in Appendix III- Program of Requirements:

$$= 0{,}50 * \ _h * \left(\ _h * \ \propto \right)^2 * \ * \ * \ *$$

$$= 14{,}10 \left[\ \right]$$

$$, \ = 31{,}72 \left[\ \right]$$

In addition to berthing, the mooring force is also of importance in this situation, once many ships use the facility for overnight. In this case the bollards load are to be expected as 350kN.

Moreover, additionally to the structural displacement allowed, following EAU (2012), the maximum deflection allowed for nautical, port operations and structural reasons is of ƒ=1,50 meters, including the soil displacement.

3 Methodology

The capacity check will be done by following mainly following Fraanje Method (1968), with a validation check with the software's 'DSheet-Piling' (Deltares, 2015) and 'Technosoft Damwanden' (Technosoft, 2017).

3.1 Fraanje Method

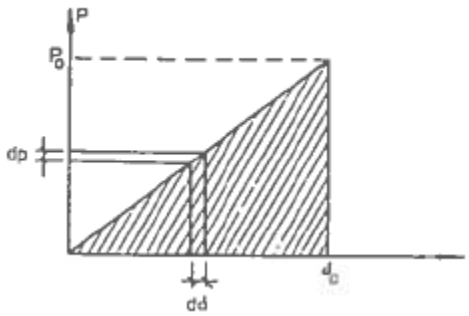
According to Fraanje, dolphins can be considered elastic or rigid constructions, from which the elastic ones reduce the chance of damage both to the ship and to the facilities. A single pile dolphin is defined as an elastic construction once it is composed of slender elements such as the steel pile and fenders.

In this method two types of loads are considered:

1. Static loads, such as mooring forces and the pressure forces, such as wind load on the ship.
2. Dynamic loads, which occur as a result of the transfer of the kinetic energy of the mooring ship and the impact loads due to collisions.

3.1.1 Static Load- Mooring forces

It is assumed that the mooring load increases linearly from zero to the value of P_0, that can be seen in the graph (Figure 1) resulting in an area below the line that is directly related to the energy absorbed by the dolphin. The mathematic solution is found by calculating the integral of the force applied in relation to the displacement occurred with the construction.



$$A = c\int_{o}^{\delta o} PdP = \tfrac{1}{2}cp_o^{\,2} = \tfrac{1}{2}P_o\delta_o$$

Figure 1: Schematic relation between impact and displacement and the influence in the energy applied in the structure for static load. Source: Fraanje (1968)

The potential energy transferred by P to the resilience of the pile and soil then disappears once the load is gone. In case that the resistance of the pile and/or the soil not being sufficient, then a permanent change of the structure occurs.

3.1.2 Dynamic loads – Berthing Collision or Impact

The impact load is given abruptly to the construction, giving a diagram performance of a rectangle once the load is twice as much as the one given by the static load, seen in §3.1.1.

3.1.3 Load combination

Following the law of energy conservation(Figure 2), it is stated that the water displacement caused by the ship has the same value as the displacement of the pile in relation to the force applied.

$$A = \tfrac{1}{2}\, mv^2 = \tfrac{1}{2}\, P.\delta.$$

For dolphins and leading constructions the impact load is more dangerous than de mooring forces, once the latest are usually placed lower. Nevertheless the current structure shows a wide variety of bollards, and the determining point for both impact and mooring forces is at the head of the dolphin, at NAP + 6,50 m. Therefore for this project the limiting load is the highest one found.

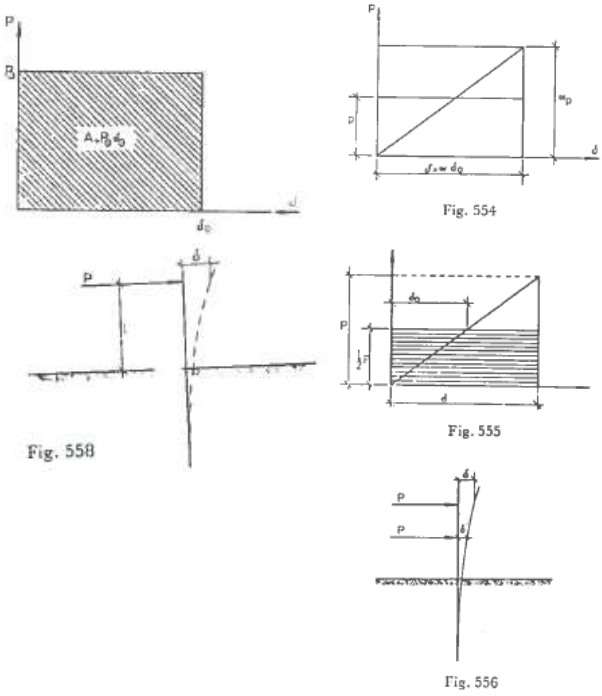


Figure 2: Schematics of relation of load and displacement in the energy applied to the structure. Source: Fraanje (1968)

3.1.4 Deflection – Blum's Method

This approach makes use of the Blum's method in order to define the maximum deflection. This calculation is based on the deflection caused by the elastic bending and the lateral resistance of passive ground pressure for the pile.

The Blum's formula for the classic deflection (Figure 60 3) prevents the use of an inaccurate load on the structure, by considering the point of deflection to be placed where the expected maximum moment is to happen .

The basic deflection considers a rigid connection located in the end of the structure, and it is defined as:

$$\delta = \frac{P * l^3}{3 * E * I}$$

Where:

δ	: Deflection	[mm]
P	: Point load	[N]
l	: Cantilever Length	[mm]
E	: Elasticity Modulus Steel	[N/mm^2]
I	: Inertia constant	[mm^4]

It is proven by Flemhude (1951) and Holtenau (1952) that the displacement of steel piles is dependent on the pile width and Blum's theoretical pile depth (as cited in Fraanje (1968, p. 465)). Blum's theoretical penetration level is to be determined by:

$l = (h + K * t_0)$, where K is a variable factor with an average value of K=0.78 and has a low variability according to Table XXVII from Fraanje (1968).

Therefore the deflection can be determined by using the following formulas(Figure 3):

$$\delta = \frac{P}{3*E*I} * (h + 0.78 * t_0)^3$$, or when = 1,2*t_0; then $\delta = \frac{P}{3*E*I} * (h + 0.65 * t_0)^3$

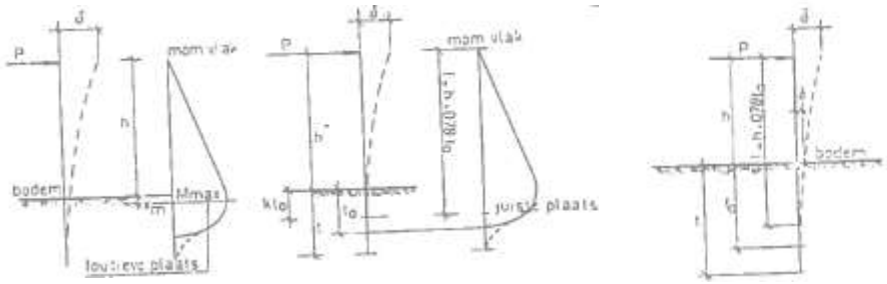


Figure 3: Scheme of Blum's calculation for single piles according to Fraanje. Source Fraanje (1968)

The pile displacement in the ground should give the same value for δ as found in Blum's formula, and it can be found by:

$$= \frac{}{*} * \left\{ \left(\frac{h + 0.78 *}{3} t^0 \right)^3 - \frac{(h + 0.78 * t_0)^2}{2} + \frac{h^3}{6} \right\}$$

Once the constant of inertia has a negative direct influence in the displacement, leading to a smaller displacement as higher as the constant is placed. A relation can also be drawn with the allowable yield value f_y:

$$W = \frac{M}{f_y}; and\ W = \frac{I}{\frac{1}{2} * D}\ [cm^3]\ ; where\ W \cong \frac{0.1}{D} * (D^4 - d^4)\ [cm^3]$$

In conclusion, W has direct positive relation to the wall thickness of the pile (D-d), what leads to a higher resilience also to be directly related to the yield strength and cross-section of the element, in special the wall thickness in the case of piles.

3.1.5 Passive ground pressure

Following Fraanje (1968), the ground pressure coefficient λ_p is to be calculated considering passive ground pressure prism. The active ground pressure is assumed neglectable in this method due low impact of shear stresses.

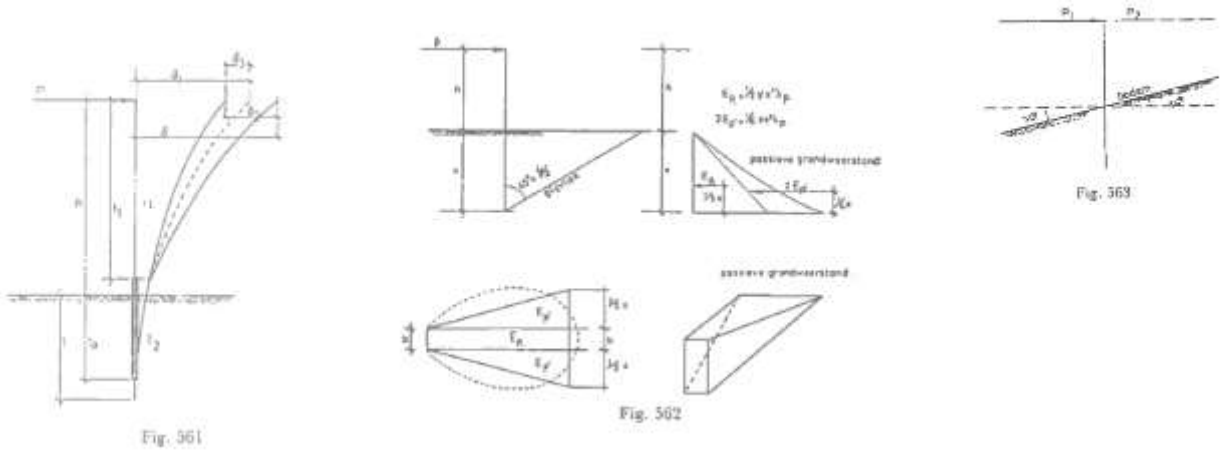


Figure 4: Ground pressure coefficient λp calculation method of Fraanje with prisma. Source Fraanje (1968)

Therefore the passive ground pressure is found as:

$$E_p = E_{p1} + 2 * E_{p2}\ ; and \sum H = 0;$$

$$E_p = P = \gamma * \lambda_p * (b * \frac{x^2}{2} + \frac{x^3}{6})$$

$$\gamma * \lambda_p = f_w; when\ horizontal\ bottom$$

$$P = f_w * \left(b * \frac{x^2}{2} + \frac{x^3}{6}\right)$$

$$\lambda_p = \frac{(\cos\varphi)^2}{\left[1 - \sqrt{\frac{\sin(\varphi+\delta) * \sin(\pm\beta+\varphi)}{\cos\delta * \cos\beta}}\right]^2} = \frac{0.787}{\left[1 - \sqrt{\frac{\sin(18.33)[=0.315] * \sin(36.96)[=0.60]}{0.987 * 0.986}}\right]^2}$$

$$= \frac{0.787}{0.313} = 2.52$$

$$for\ pile\ in\ a\ talud\ bottom$$

$$\delta = -\frac{1}{3} * \varphi = -9.17\ ; for\ single\ pile\ with\ cross - section < 1m^2$$

Where:

γ	:	[kN/m^3]
λ_p	: Passive ground pressure	[-]
f_w	: Soil resistance factor	[]
b	: Width of pile (=D)	[m]

x : Distance from bottom to maximum moment [m]

φ : Friction angle of soil [°]

β : Inclination of bottom= 9.46 [°]

When calculating the friction angle φ, a check must be done to control that the vertical component of the passive earth pressure is not exceeded by the sum of the pile weight and the shell friction.

From graph in Figure 5, the values of λ_p can be read in relation to the friction angle. For this project φ=27.5°, so λ_p=2.52. Considering $\gamma_{soil,\,sat}$=20kN/m^3:

$$f_w = 20 * 2.52 = 50.4\ []$$

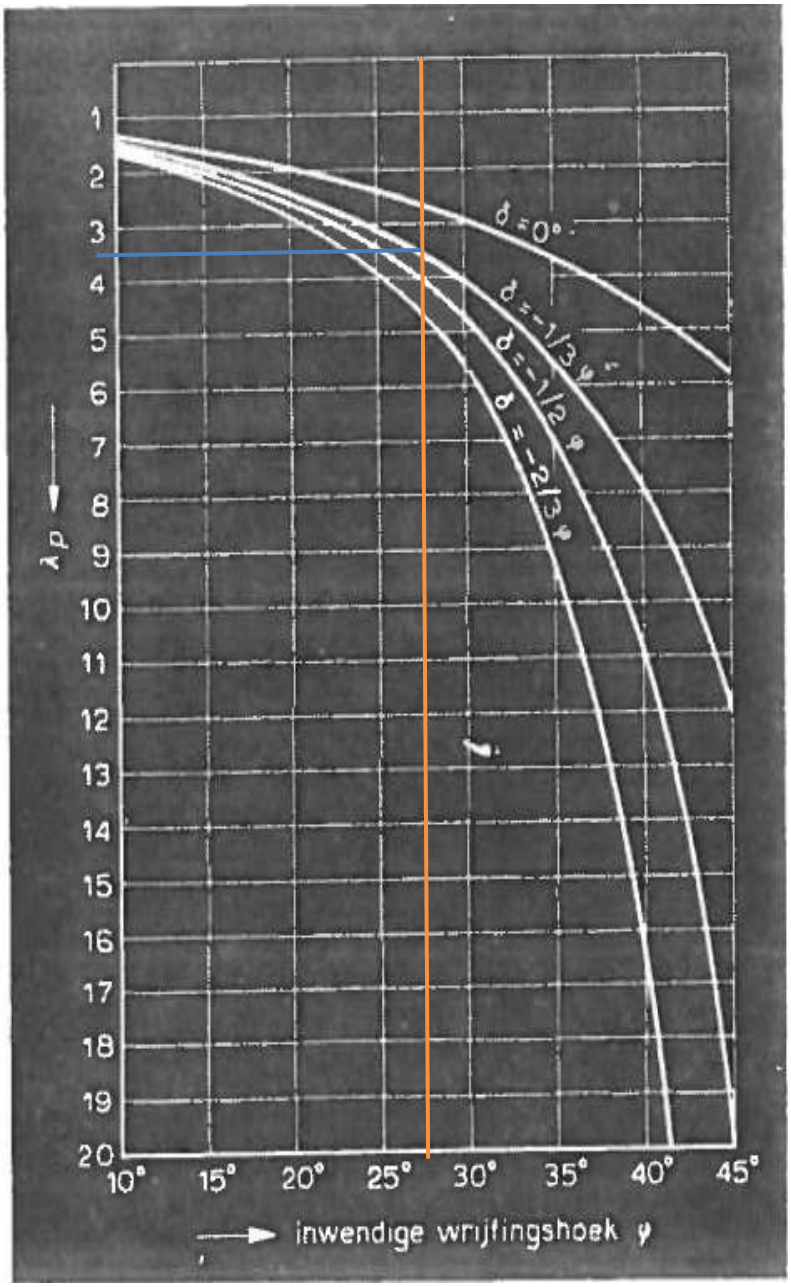


Figure 5: Graphic representation of relation between friction angle and ground pressure. Source: Fraanje (1968)

3.1.6 Calculation according to Blum

As in the calculation of sheet-piles, this approach can also be used for the determination of optimal load calculation of single pile structures. Figure 6 describes the symbols and its elements that are going to be used in the calculation.

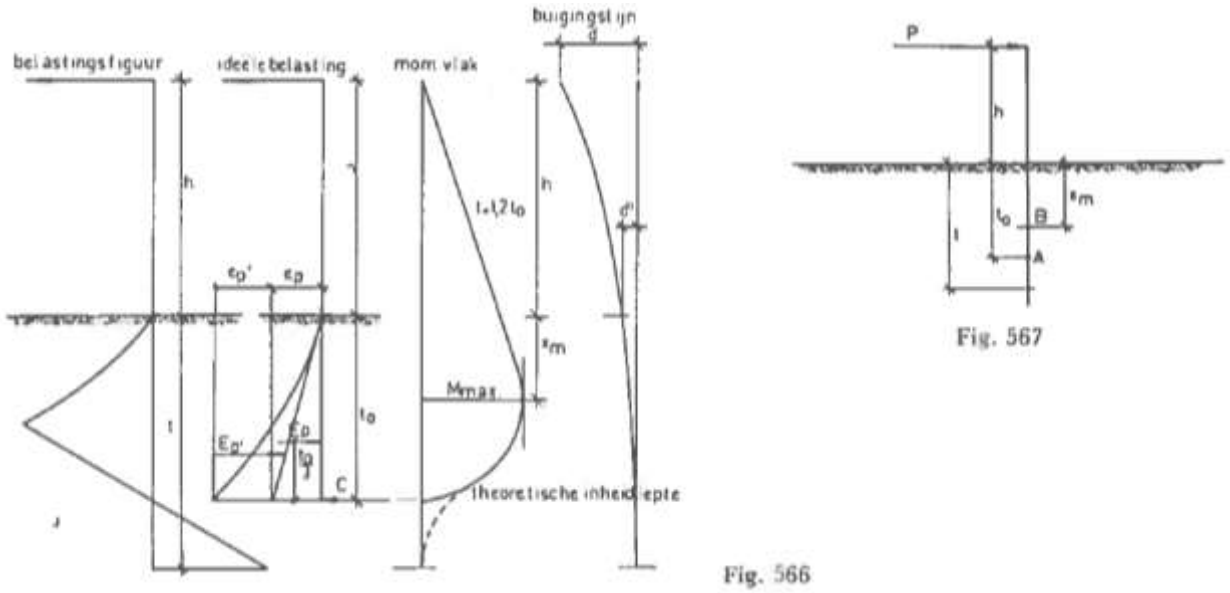


Figure 6: Schematic representing symbols and elements used in the calculation of Sheet-piles according Blum's method. Sourece: Fraanje (1968)

Where:

m	: Water Displacement of ship = G (tf)	[tf*/(m/s^2)]
	Acceleration of Gravity g(m/s^2)	
v	: Vessel velocity	[m/s]
P	: Pressure or Force caused by static load	[tf]
δ	: Displacement due to P	[m]
δ'	: Displacement on the ground level	[m]
f_w	: Soil resistance: $\gamma * \lambda_p$	[tf/m^3]
γ	: Soil volumetric weight of soil above water	[tf/m^3]
γ_0	: Soil volumetric weight of soil under water	[tf/m^3]
h	: Height of impact point of load P from the bottom	[m]
b	: Width of pile where the load is acting	[m]

x_m	: Location of M_{max} underground	[m]
t_0	: Depth of ideal zero moment underground	[m]
t	: Given depth of zero moment underground	[m]
I	: Moment of Inertia in relation to P	[m^4]
W	: Resistance moment in relation to P	[m^3]
E	: Elasticity Modulus = $2{,}1*10^6$	[tf/m^2]
M_{max}	: Maximum moment in ideal load	[tfm]

*Note that for practical conversion, tf is assumed to be tf=10kN

Formulas

The point A, in Figure 6(fig.567), is the theoretical penetration depth given by Blum's method, and B is placed where the maximum moment is encountered.

Considering the force equilibrium, $\sum M_A = 0$, so:

$$P * (h + t_0) - \frac{t_0}{3} * f_w * \frac{b * {t_0}^2}{2} - \frac{t_0}{2} * f_w * \frac{{t_0}^3}{6} = 0;$$

$$where:$$

$$P * (h + t_0) - f_w \left(\frac{b * {t_0}^3}{6} + \frac{{t_0}^4}{24} \right) = 0; \ (1)$$

The moment at a depth x underground is calculated by:

$$M_x = P * (h + x) - f_w \left(\frac{b * x^3}{6} + \frac{x^4}{24} \right) = 0; \ \ (2)$$

And the maximum moment is to be found from the derivate of Mx in relation to x:

$$\frac{dM_x}{d_x} = 0 = P - f_w \left(\frac{b * x^3}{6} + \frac{x^4}{24} \right) = 0;$$

Where:

$$P - f_w \left(\frac{b * x^3}{6} + \frac{x^4}{24} \right) = 0 \ (3)$$

Substituting the value of P in Mx formula, than we find Mmax with $x=x_m$:

$$M_{max} = \frac{f_w}{24} * {x_m}^2 * \{3 * {x_m}^2 + x_m * (4 * h + 8 * b) + 12 * b * h\} = 0; \ (4)$$

By substituting the value of P, found in (3), into formula 1:

$$f_w \left(\frac{b * x^3}{6} + \frac{x^4}{24}\right) * (h + t_0) = f_w \left(\frac{b * {t_0}^3}{6} + \frac{{t_0}^4}{24}\right),$$

$$Therefore:$$

$${t_0}^3 * \frac{t_0 + 4 * b}{h + t_0} = 4 * {x_m}^2 * (x_m + 3 * b) = \frac{24 * P}{f_w} \quad (5)$$

Following formula 5, the relation between the theoretical penetration depth and the serviceable one can be found as:

$$t = 1.2 * t_0 \quad (6)$$

For bigger dolphins, the penetration depth of t_0 is considered sufficient. The experience, according to Fraanje (1968), that an serviceable depth has an extra of 5 to 20% to the higher side. Moreover, in a homogeneous soil profile the theoretical penetration is to be sufficient.

The maximum displacement in relation to P, according to Blum, is found by:

$$\delta = \frac{P * (h + t_0)^3}{3 * E * I} - \frac{f_w * {t_0}^4}{36 * E * I} * \{2.5 * {t_0}^2 + t_0 * (3 * h + 12 * b) + 15 * b * h\} \quad (7)$$

With the bottom displacement of:

$$\delta' = \frac{P * h * {t_0}^2}{2 * E * I} + \frac{P * h * {t_0}^3}{3 * E * I} - \frac{f_w}{E * I} * \left(\frac{{t_0}^6}{144} + \frac{b * {t_0}^5}{30}\right)$$

Analysis of ship impact

Needed values:

1. Ground resistance f_w;
2. Impact height h;
3. Max allowable energy;

The definition of the cross-section is to be done by the process of iteration with trial and error. In this case a known cross-section is to be analyzed, so the max allowable energy can be directly calculated.

$$M_{max} = \frac{W}{\sigma_v} = \frac{1.557 * 10^8}{355} = 438481.24 \ [Nmm \ or \ kNm], \quad where:$$

$$W = \frac{0.1}{D} * (D^4 - d^4) \ [cm^3] = \frac{(1016^4 - (1016 - 40)^4)}{1016} = 155660840.3 \ or \ 1.557 * 10^8 \ [mm^3]$$

By substituting the values of f_w, h and b in formula 4, then x_m can be found. Afterwards, with x_m value, the allowable force P can be defined with formula 3.

Formula 6 gives the needed penetration depth when using the known x_m, while formula 5 gives the theoretical penetration length.

Once the allowable loads are known, the service loads need to be the same or lower than the ones allowed by this calculation. In case they are higher, then the calculation must be redone with the use of a different cross-section.

Analysis of mooring impact

Needed values:

1. Bollard force P;
2. Impact height h;
3. Ground resistance f_w;

With help of formula 3 the value of x_m can be found, with which in formulas 5 and 4 the respective values of t_0 and M_{max} are calculated, while the pile diameter can be defined and checked by:

$$W = \frac{M_{max}}{\sigma_v} = 438481.24\ [Nmm\ or\ kNm]$$

Once the allowable loads are known, the service loads need to be the same or lower than the ones allowed by this calculation. In case they are higher, then the calculation must be redone with the use of a different cross-section.

Needed penetration length

The calculation of the penetration depth can be performed in the same way as for elastic clamped beams according the method of Blum. Once $P=E_p$ it is possible to say that:

$$\frac{P}{f_w} = \frac{{x_m}^2}{6} * (x_m + 3 * b) \quad (8)$$

$$\frac{P_{mooring}}{f_w} = \frac{350}{50.4} = 6.94$$

Dr. Ing. Jenne (as cited in Fraanje (1968)) has developed a monogram (Figure 7) with the interaction between the values of b, P/f_w and x_m, where they can be read and the M_{max} can be found.

The theoretical penetration depth is then calculated based on formula 1.

$$P * (h + t_0) - f_w \left(\frac{b * {t_0}^3}{6} + \frac{{t_0}^4}{24} \right) = 0;\ (1)$$

Substituting the value of P in formulas 5 and 1, following the assumption parameters:

$$\eta = \frac{t_0}{x_m};\ \frac{h}{b}\ and\ \frac{x_m}{b}$$

$$\frac{x_m}{b} = \frac{2.96}{1.016} = 2.91$$

$$\frac{t_0}{x_m} = 2.56;\ \ t_0 = 2.56 * 2.96 = 7.45\ m\ ;$$

$$t = 1.2 * t_0 = 8.94m$$

when it is found that:

$$\frac{h}{b} = \frac{\eta - 3 * \eta + \frac{x_m}{b} * \left(\frac{\eta^4}{4} - \eta\right)}{1 + 3 * \frac{b}{x_m}}$$

$$\eta = 2.56$$

$$\frac{15.5}{1.016} = 15.26 = \frac{\eta - 3 * \eta + \frac{x_m}{b} * \left(\frac{\eta^4}{4} - \eta\right)}{1 + 3 * \frac{b}{x_m}} => x_m = 2.96$$

$$\frac{M_{max}}{f_w} = 160;\ \ M_{max} = 160 * 50.4 = 8064kNm$$

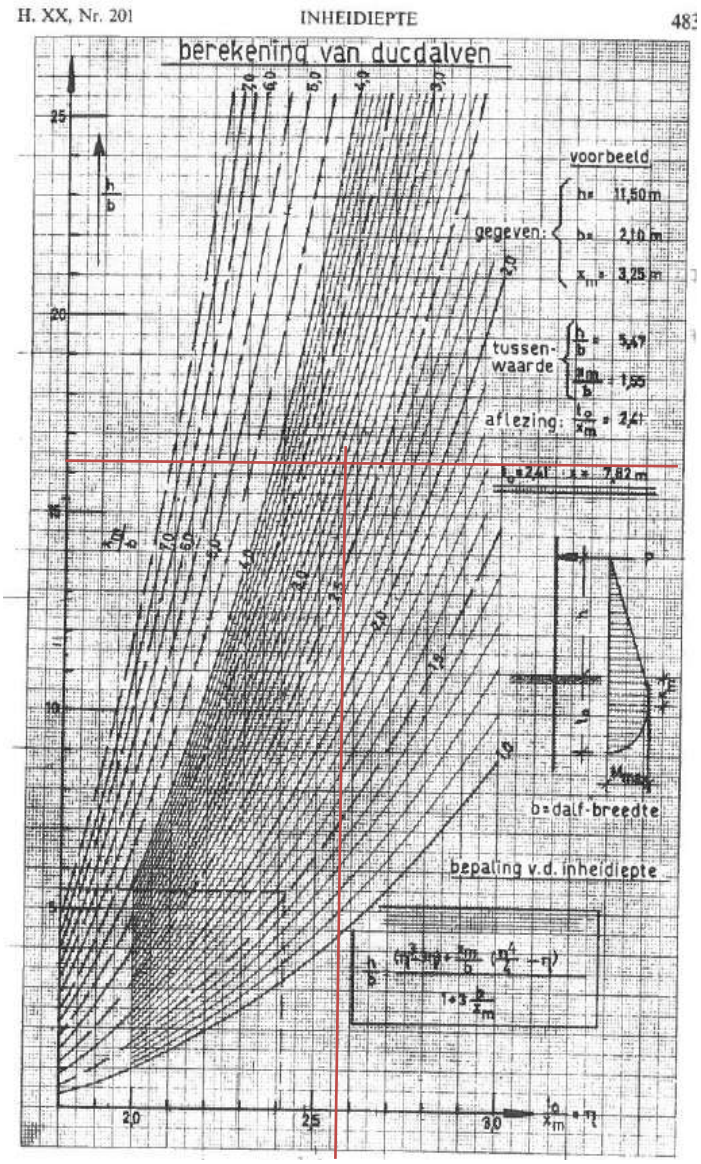


Figure 7: Monogram Dr. Ing. Jenne for calculation of penetration depth. Source: Fraanje (1968)

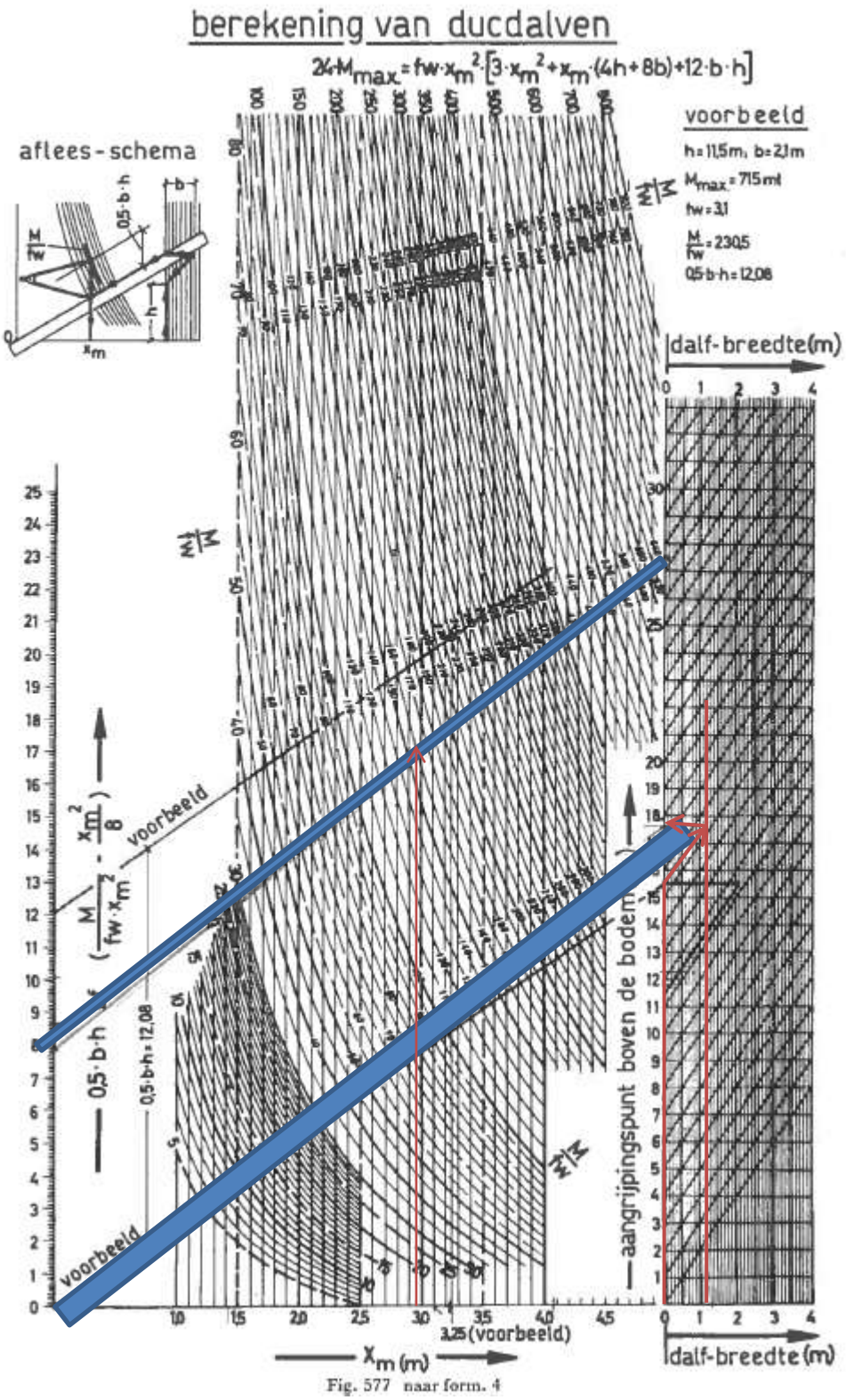


Fig. 577 naar form. 4

Figure 8: Monogram Dr. Ing. Jenne for calculation of maximum moment. Source: Fraanje (1968)

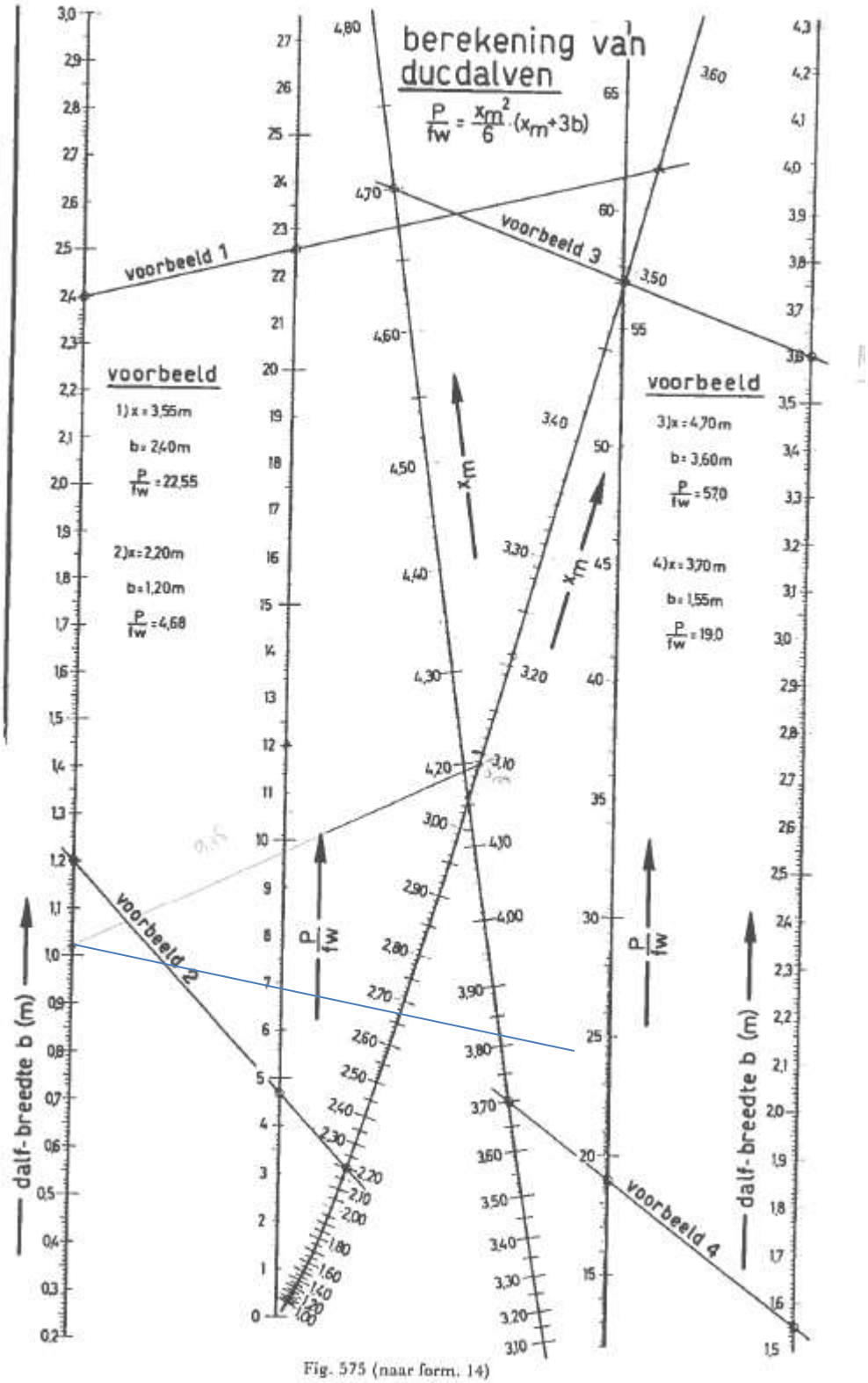


Fig. 575 (naar form. 14)

Figure 9: Monogram for determination of Ps/fw. Source: Fraanje (1968)

4 Current Pile Analysis

This section describes the analysis realized to evaluate the capacity of the current pile, regarding the impact and mooring forces that are applied to the dolphin structure by a CEMT VIb class vessel.

4.1 Fraanje Method

In order to check both impact and mooring forces on the pile section, a combination approach is used following description of Chapter 3.

4.1.1 Current Analysis

The analysis of the current pile is performed by considering a lifetime of 32 years, considering the placement year of 1986. Table 5 shows the input parameters used for this analysis, followed by the summary analysis on Table 6. The complete spreadsheet can be seen in Appendix XII-VI.

Table 5: Input data spreadsheet Fraanje Method for analysis of current pile.

Staalkwaliteit	S	355			
D (buitendiameter)		1016	mm		
t (buispaal dikte)		20	mm		
E (elasticiteitsmodulus)		210000	N/mm2	corrosie ondergrond	
corrosie binnenkant per jaar		0	mm/jaar	omdat grotste	
corrosie buitenkant per jaar		0,026		moment zit in de	
aantal jaar		32	jaar	grond	
γf;q;u (belastingfactor UGT, scheepsstoot)		1,5			
γf;g;u (belastingfactor UGT, troskracht)		1			
γf;ser (belastingfactor BGT)		1			
γdr (soortelijk gewicht van de grond boven water)		18	kN/m3	sand sterk siltig,	
γsat (soortelijk gewicht van de grond onder water)		20	kN/m3	kleiig volgens Dsheet	
γwat (soortelijk gewicht van het water)		10	kN/m3		
φ'rep (hoek van inwendige wrijving)		27,5	°		
hstoot (afstand bodem tot aangrijpingspunt scheepsstoot)		15,5	m	waterverplaatsing	
xm (afstand bodem tot maximaal optredend moment; stoc		2,96	m	omrekenen van ton	
η (waarde to;stoot / xm)		2,56		naar kN:	
m (waterverplaatsing van het schip)		109200	kN	12000	ton
v (aanvaarsnelheid)		0,13	m/s	120000	kN
Ptros;rep (representatieve waarde troskracht)		350	kN	m'	
xm (afstand bodem tot maximaal optredend moment; tros		2,96	m	109200	kN
htros (afstand bodem tot aangrijpingspunt troskracht)		15,5	m		
η (waarde van to / xm)		2,56			
Ltot (totale lengte buispaal)		24,1	m		

Table 6: Output data spreadsheet Fraanje Method for analysis of current pile.

15. Gegevens buispaal:			
D (diameter buispaal)		1016	mm
t (buispaal dikte)		20	mm
Ltot (totale lengte buispaal)		24,1	m
Maatgevende doorbuiging t.p.v. aangrijpingspunt kracht		0,796137	m
Maatgevende doorbuiging t.p.v. top van de buispaal		0,875999	m
Optredend arbeidsvermogen		141,0917	kNm
Toelaatbaar arbeidsvermogen		150,97	kNm
Optredende buigspanning		253,3458	N/mm2
Toelaatbare buigspanning		355	N/mm2
	buis	voldoet	

The actual pile fulfills the required capacity for handling the applied load from the required vessel VIb up to this moment.

4.1.2 Current Analysis with lifespan of 50 years extra

The analysis of the current pile is also performed by considering a lifetime of 82 years, that includes a 50 year lifespan to the pile in case of reuse of the element. Table 7 shows the input parameters used for this analysis, followed by the summary analysis on Table 8. The complete spreadsheet can be seen in Appendix XII-VI.

Table 7: Input data spreadsheet Fraanje Method for analysis of current pile with 50 extra lifespan.

Staalkwaliteit	S	355			
D (buitendiameter)		1016	mm		
t (buispaal dikte)		20	mm		
E (elasticiteitsmodulus)		210000	N/mm2	corrosie	
corrosie binnenkant per jaar		0	mm/jaa	ondergron	
corrosie buitenkant per jaar		0,026		d omdat	
aantal jaar		82	jaar	grotste	
γf;q;u (belastingfactor UGT, scheepsstoot)		1,5			
γf;g;u (belastingfactor UGT, troskracht)		1			
γf;ser (belastingfactor BGT)		1			
γdr (soortelijk gewicht van de grond boven water)		18	kN/m3	sand sterk siltig, kleiig	
γsat (soortelijk gewicht van de grond onder water)		20	kN/m3	volgens Dsheet	
γwat (soortelijk gewicht van het water)		10	kN/m3		
φ'rep (hoek van inwendige wrijving)		27,5	°		
hstoot (afstand bodem tot aangrijpingspunt scheepsstoot)		15,5	m	waterverplaatsing	
xm (afstand bodem tot maximaal optredend moment; stoot)		2,96	m	omrekenen van ton naar	
η (waarde to;stoot / xm)		2,56		kN:	
m (waterverplaatsing van het schip)		109200	kN	12000	ton
v (aanvaarsnelheid)		0,13	m/s	120000	kN
Ptros;rep (representatieve waarde troskracht)		350	kN	m'	
xm (afstand bodem tot maximaal optredend moment; tros)		2,96	m	109200	kN
htros (afstand bodem tot aangrijpingspunt troskracht)		15,5	m		
η (waarde van to / xm)		2,56			
Ltot (totale lengte buispaal)		24,1	m		

Table 8: Output data spreadsheet Fraanje Method for analysis of current pile with 50 extra lifespan.

15. Gegevens buispaal:			
D (diameter buispaal)		1016	mm
t (buispaal dikte)		20	mm
Ltot (totale lengte buispaal)		24,1	m
Maatgevende doorbuiging t.p.v. aangrijpingspunt kracht		0,856343	m
Maatgevende doorbuiging t.p.v. top van de buispaal		0,942244	m
Optredend arbeidsvermogen		141,0917	kNm
Toelaatbaar arbeidsvermogen		162,1757	kNm
Optredende buigspanning		271,8084	N/mm2
Toelaatbare buigspanning		355	N/mm2
	buisp	voldoet	

4.2 DSheet Piling check

In order to validate Fraanje's method, the commonly used DSheet Piling was chosen. The program was run in the mode of single pile, where the calculation makes use of the ground pressure coefficient according Brinch-Hansen and the subgrade reaction following Menard.

4.2.1 Current Analysis

The software shows instability of the system when the current analysis is made with basis of a horizontal load of 350kN, as required by this project.

By iteration method, the maximum horizontal load is found to be 195kN for the positive soil profile CPT 70294, and 175kN for the negative one CPT70297. Both forces give a displacement lower then 1,5m that is accepted by this project as seen in Figure 10 and 11. The complete report can be found in Appendix X.

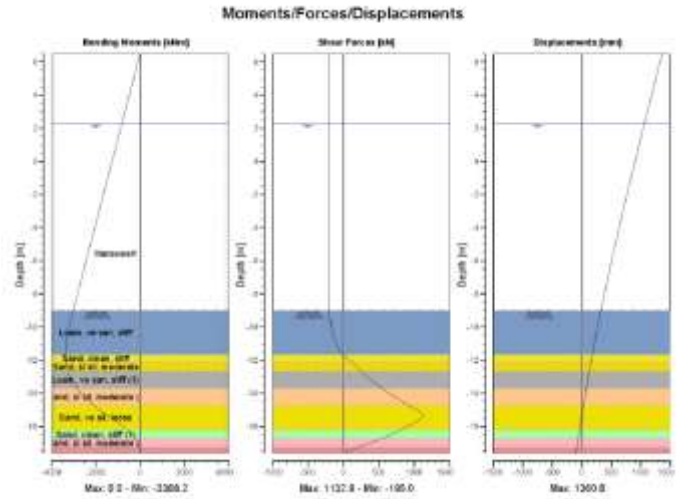


Figure 10: Moment/Forces/Displacement graph of analysis actual pile with profile 70294 according DSheet Piling.

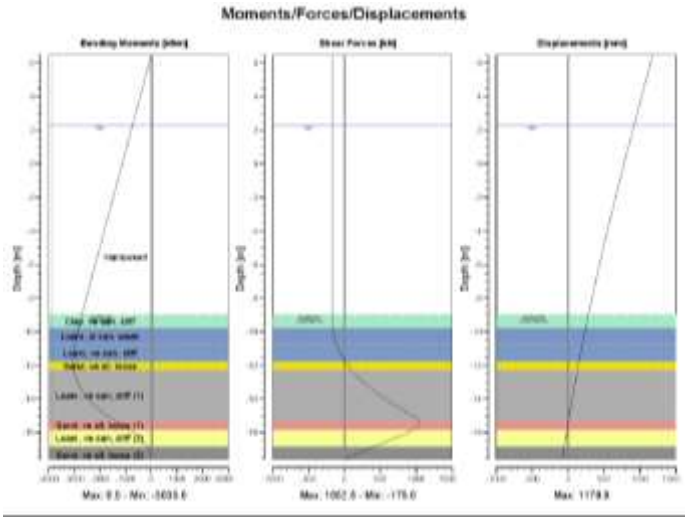


Figure 11: Moment/Forces/Displacement graph of analysis actual pile with profile 70297 according DSheet Piling.

4.2.2 Analysis with 350kN mooring force

Once again, by applying iteration with the program input values, it is found that the pile toe at a depth of NAP – 20,00 meters does show enough capacity from the system to sustain the 350kN force, as seen in Figure 12. The complete report can be found in Appendix X.

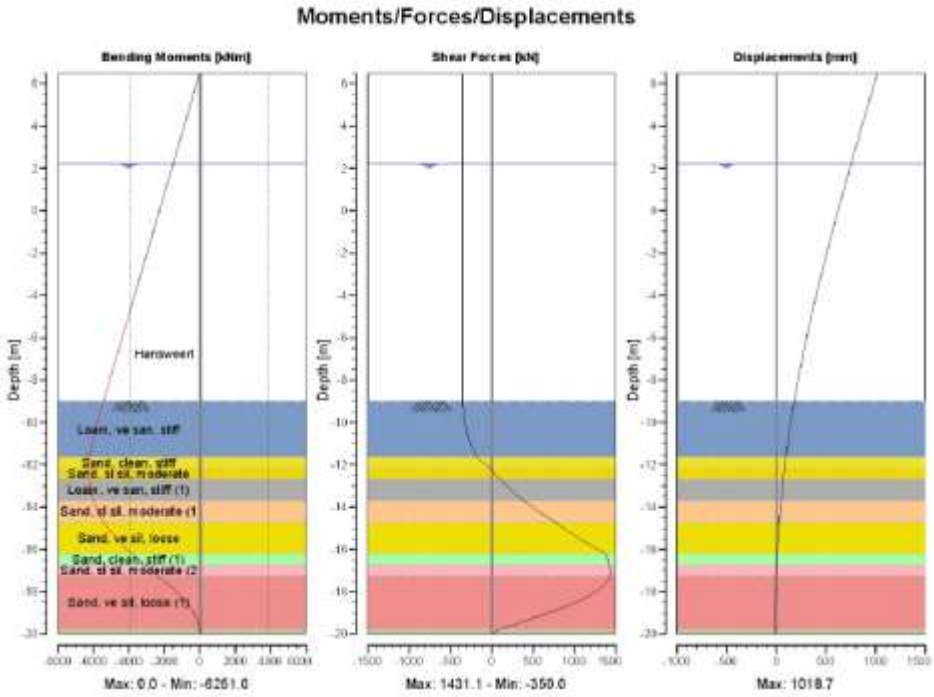


Figure 12: Moment/Forces/Displacement graph of analysis with 350kN at a depth of -20m according DSheet Piling.

4.3 Technosoft Damwanden Check

Technosoft software is used for further verification, once the results between Fraanje Method and DSheet Piling are not similar. This software makes use of user given values for the passive ground pressure that, in this case, were calculated conform Brinch-Hansen and are to be found in the Geotechnical Analysis Spreadsheet file from the Appendix XII-V.

Similar to the results encountered in DSheet Pile, Technosoft has shown that the pile becomes unstable with its actual penetration depth. At a toe level of NAP – 17,60 meters the maximum allowed lateral force is found to be 75kN. Nevertheless, the toe level needed according Technosoft is placed at NAP -25 meters. Table 50 shows the encountered results. Complete reports are to be found in Appendix XI.

Table 9: Calculation of pile capacity at a force of 350kN and penetration depth of NAP -25,00 m, according to Technosoft Damwanden.

Technosoft studentenlicentie blad :21

Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

MAXIMUM VALUES IN THE WALL **CONSTR.PHASE: 1 Bouwfase 1**

		--- Low water level pass. side ----					
		------ SLS ------		---- ULS low ----		---- ULS high ---	
		Value	Level	Value	Level	Value	Level
Displacement	[mm]	1131.51	6.50	2258.08	6.50	1377.08	6.50
Shear force	[kN]	-1094.06	-18.70	-1138.85	-19.91	-1138.52	-19.91
Moment	[kNm]	-7511.80	-12.99	-6423.35	-13.74	-6423.35	-13.74
Axial force	[kN]	-2405.68	-25.00	-2004.73	-25.00	-2004.73	-25.00
Stress	[N/mm²]	44987725.15	-25.00	38469053.27	-13.74	38469053.27	-1

		--- Low water level pass. side ----			
		--- ULS Low ----		--- ULS High ----	
		Value	Level	Value	Level
Displacement	[mm]	2258.08	6.50	1377.08	6.50
Shear force	[kN]	-1138.85	-19.91	-1138.52	-19.91
Moment	[kNm]	-6423.35	-13.74	-6423.35	-13.74
Axial force	[kN]	-2004.73	-25.00	-2004.73	-25.00
stress	[N/mm²]	38469053.27	-13.74	38469053.27	-13.7

		-Low water pass. side-		-High water pass. side-	
	SLS	ULS low	ULS high	ULS low	ULS high
Displacement	[1:mm]	63	18	18	18	42

Nr.	Name profile	Shear force [kN]	Max.Moment [kNm]	Max. norm.force [kN]	Max. Stress [N/mm²]
1	HANSWEERT	-1138.85	-7511.80	-2405.68	44987725.1

HORIZONTAL SOIL FORCES (kN) **CONSTR.PHASE: 1 Bouwfase 1**

	--- Low water level pass. side ---					
	------ SLS -----		---- ULS low ---		---- ULS high --	
	Left	Right	Left	Right	Left	Right
Grain force	1473.20	1823.20	1798.78	2148.78	1798.44	2148.44
Water force	1830.43	1830.43	1830.43	1830.43	1830.43	1830.43
Total	3303.63	3653.63	3629.21	3979.21	3628.87	3978.87
Max. pass. grain resist.	3612.84	4456.39	3049.58	3795.21	3049.58	3795.21
[%] mob. grain resist.	40.78	40.91	58.98	56.62	58.97	56.61

	--- High water level pass. side ---			
	--- ULS Low ----		--- ULS High ---	
	Left	Right	Left	Right
Grain force	1798.78	2148.78	1798.44	2148.44
Water force	1830.43	1830.43	1830.43	1830.43
Total	3629.21	3979.21	3628.87	3978.87
Max. pass. grain resistance	3049.58	3795.21	3049.58	3795.21
[%] Mob. grain resistance	58.98	56.62	58.97	56.61

5 Discussion and Conclusion

The analysis has discrepancies in its results when comparing methods. The checks with the software's DSheet Piling and Technosoft have shown a rather conservative approach. On the other hand, the method of Fraanje is compatible with the practical experience and actual condition of the element, once the dolphin is still in use and does not show any sign structural failure.

The common practice in dolphin design follows the software's mentioned and that leads to a minimum of 11 meters pile penetration in the soil, according to Blum's method, in order to provide the required resistance to the impact force of 350kN. This report advises to follow the conservative approach once the design is already based on low values of expected common practice, although this can give space for human error in the daily use and, consequently, lead to unexpected structure failure.

6 Bibliography

CUR. (2014). *CUR Rapport 166:2012.* BRISwarenhuis.

Deltares. (2015). DSheet Piling [Computer Software]. *Design of Diaphragm and Shee-Pile Walls - Version 15.1*. Delft, The Netherlands: Deltares Systems.

DINOloket. (2018, March 3). *Ondergrondsgegevens*. Retrieved from DINOloket Data en Informatie van de Nederlandse Ondergrond: http://www.dinoloket.nl

EAU. (2012). *Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004.* Arbeitsausschuss.

Fraanje, M. J. (1968). Waterbouwkunde Deel 1 Algemene Waterbouwkunde. In M. B. Bolderman, & A. W. Dwars, *Waterbouwkunde* (pp. 443-481). Amsterdam: L.J.Veebs Uitgeversmaatschappij N.V.

Technosoft. (2017). Technoisoft Damwanden. *Version 6.01 Educational*. Deventer, The Netherlands: Technosoft BV.

Appendix VII Multi-Criteria Analysis

Rijkswaterstaat
Ministry of Infrastructure and Water Management

DELTA ACADEMY

2018

Multi-Criteria Analysis

Lourenco Lehmkuhl, Sullen (PPO)

Rijkswaterstaat Zee en Delta

12-6-2018

Version 2.0

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1 Introduction

The multi-criteria analysis is chosen to be used in order to support the selection of the most appropriate solution for this project.

1.1 Problem recognition

As described in the research proposal (Appendix I), due to the poorly aligned dolphin piles in the Hansweert locks, a dangerous situation arises. The misalignment of the pile caps can possibly cause damage to the ship when docking to these structures. It is possible that a steel beam sticks out instead of the wood that is supposed to be there to protect the ship.

In the past, several maintenance dolphins have been adapted by the maintenance contractor, although they have not showed the desired effect once several of them are already showing the same behavior of crooked caps. Since the chains and the steel cables did not achieve the desired effect on the structure, a different attachment must be worked out in order to solve this problem with the fenders.

In order to define the root problem to this situation, a Root Cause Analysis (RCA – Appendix IV) was performed based on present documentations and local information. The conclusion for this report lead to selecting the rotation of the cap as the ultimate cause for this issue, therefore a fixation of the pile cap is required for every alternative.

In addition to that, an analysis of the current situation with other specialist has brought up the uncertainty of the capacity of the foundation pile, once its placement underground is shown to be less then usually for this kind of structure. Moreover, this possibility is considered in this MCA and advise is given accordingly.

1.2 Goal identification

This variable analysis has the objective of selecting the most suitable solution for the problem mentioned in §1.1, based on the requirements defined in the Program of Requirements (Appendix III).

2 Criteria

In order to choose the most appropriate solution, a multi-criteria analysis is used in order to compare the alternatives with each other in relation to the most important requirements for the client and the structure.
In this case the criteria used for comparison are:

- Lifespan
- Costs
- Implementation Time
- Assurance and Safety

The criteria are described along this section in order to define the factors to be considered by each alternative. Also, an importance factor will be given for each criteria in order to prioritize when it comes to the alternative choice.

2.1 Lifespan

The lifespan of a structure represents the period in which the structure can withstand performing its function without major maintenance. A design life for water constructions vary according to the structure type. Although the suggested lifespan for bridges and major water constructions is set at 100 years, in this project a minimum life time of 50 years is considered as requirement due to the smaller scale of the structure and its costs.

2.2 Costs

The cost of a dolphin structure can be defined by materials (foundation pile, fenders, furniture) and the implementation process and time. In this project the main cost activities are describes in Table 1.

Table 1: Cost definition table used for the MCA selection.

Costs total	Description
Material	This regards the material needed for the solution. Expected components to be required for this structure are: • Foundation Steel; • Rubber fenders; • Chain system; • Coating; • Welding steel connection; • Welding steel extension.
Working hours	Each activity that takes place requires man-hour which has a critical influence in the cost. Expected activities to be required for this structure are: • Removal of pile cap; • Removal of foundation pile; • Renovation of foundation pile (Cleaning/filling); • Coating of foundation pile; • Welding extension to foundation pile; • Driving foundation pile; • Preparing connection cap-foundation pile • Replacing pile cap and furniture;
Equipment & Specialized personal	Mobilization of equipment on water can be a costly activity with high rate rents, therefore it is crucial for a cost analysis. The considered key equipment for this section are: • Pontoons • Cranes • Dive team (inspection and as-built information)

2.3 Implementation time

One of the client's requirement is that the implementation of the solution should cause the minimum disturbance possible to the local traffic, therefore this criteria has an important role in this analysis.

The implementation time is directly influenced by the activities that must take place. An overview of this activities is shown in Table 2.

Table 2: Implementation time definition table used for the MCA selection.

Implementation time	Description
Order and Delivery Material	This regards the material needed for the solution. Expected components to be required for this structure are: • Foundation steel pile; • Extension steel pile • Rubber fenders; • Chain system; • Coating; • Welding steel connection; • Welding steel extension. The availability of material has a direct influence in the implementation time and must be considered.
Working hours	Each activity that takes place requires a minimum duration which has a critical influence in the implementation time. Expected activities to be required for this structure are: • Removal of pile cap; • Removal of foundation pile; • Renovation of foundation pile (Cleaning/filling); • Coating of foundation pile; • Welding extension to foundation pile; • Driving foundation pile; • Preparing connection cap-foundation pile • Replacing pile cap and furniture.
Equipment & Specialized personal	Mobilization of equipment on water can be a time consuming activity, therefore it is crucial for the total implementation time. The considered key equipment for this section are: • Pontoons; • Cranes; • Dive team (inspection and as-built information).

2.4 Assurance and Safety

The assurance and safety of the structure is directly related to its capacity against the loads. In order to evaluate this criteria, a foundation pile capacity analysis is performed in order to determine the assurance and safety of the structure. It is also part of this criteria that it is fulfilled also for the lifespan requires mentioned on §2.1.

2.5 Weighing factors

This section describes the steps used to rate each criteria according to its components and its degree of influence in the final decision.

The rating in this analysis will be carried by comparing the criteria according to its positive (represented as '+1') and negative (represented as '-1') influences. The influence of implementation time is of higher importance to the client than the costs, for example. Taking this into account, the criteria are given also a percentage of priority.

Considering a overall of 100% with the sum of all criteria, each criteria is defined by its importance as in Table 3.

Table 3: Importance rate to be added in the end for the MCA selection.

Criteria	Importance rate (%)
Lifespan	10
Costs	20
Implementation time	35
Assurance and Safety	35

2.5.1 Lifespan

In order to classify the lifespan of the structure in this part, the following assumptions will be made as in Table 4. Table 5 describes the relation to the rating and the percentage grades.

Table 4: Life-span score definition table used for the MCA selection.

Lifespan	Description	Rating
Lifespan>50 y. none or minor maintenance	The design life of the structure is complete, no usability of the components is present, so they are able to handle its function for the design life.	+3
50 y.>Lifespan>30 y. none or minor maintenance	The design life of the structure is partly used so the components need to be inspected and maintenance may be needed. The elements show good conditions and are able to handle its function for the required design life.	+2
50 y.>Lifespan>30 y. major maintenance	The design life of the structure is partly used so the components need to be inspected more often and maintenance is needed. The elements show bad conditions and need major renovation or replacement to be able to handle its function for the required design life.	+1
Lifespan<30 y.	The design life of the structure is partly used so the components need to be inspected and maintenance may be needed. The elements show usable conditions and are not able to handle its function for the complete required design life, although they still can go on for 30 years so they are considered.	-1

The rating of -1 is chosen, instead of the logically using 0, because the impact of the structure having a lifespan below 30 years is great in the choice of the solution, once the requirement is 50 years.

Table 5: Life-span score translation to percentage to be used for the MCA selection.

Lifespan	Analysis
Total	+3=100% +2=75% +1=50% -1=25%

2.5.2 Costs

Each material needed will be considered an extra rating regarding the cost. The increase of the costs are represented by a '-1' sign that represents a negative influence in this criteria(Table 6). Table 7 describes the relation to the rating and the percentage grades.

Table 6:Costs score definition table used for the MCA selection.

Costs total	Description	Needed?	Quantity	Rating
Material	Foundation steel pile;	Yes/no	[-]	-1
	Extension steel pile	Yes/no	[-]	-1
	Rubber fenders;	Yes/no	[-]	-1
	Chain system;	Yes/no	[-]	-1
	Coating;	Yes/no	[-]	-1
	Welding steel connection;	Yes/no	[-]	-1
	Welding steel extension;	Yes/no	[-]	-1
Working hours	Removal of pile cap;	Yes/no	[-]	-1
	Removal of foundation pile;	Yes/no	[-]	-1
	Renovation of foundation pile (Cleaning/filling);	Yes/no	[-]	-1
	Coating of foundation pile;	Yes/no	[-]	-1
	Welding extension to foundation pile	Yes/no	[-]	-1
	Driving foundation pile;	Yes/no	[-]	-1
	Preparing connection cap-foundation pile	Yes/no	[-]	-1
	Replacing pile cap and furniture;	Yes/no	[-]	-1
Equipment & Specialized personal	Pontoons (per pontoon)	Yes/no	1 extra	-1 -1
	Cranes(per crane)	Yes/no	1 extra	-1 -1
	Dive team (inspection and as-built information)	Yes/no	[-]	-1
Total	+18=100%			

Table 7: Costs score translation to percentage to be used for the MCA selection.

Costs	Analysis
Total	+18=100%

2.5.3 Implementation Time

Every activity needed will be considered an extra rating regarding the time needed for implementation, as for the duration of each activity. The increase of time is represented by a '-' sign that represents a negative influence in this criteria as shown in Table 8, from which each negative has a score of -1. Table 9 describes the relation to the rating and the percentage grades.

Table 8: Implementation time score definition table used for the MCA selection.

Implementation Time	Description	Duration long/short/medium	Rating
Material	Foundation steel pile;	long/short/medium	---/--/-
	Extension steel pile	long/short/medium	---/--/-
	Rubber fenders;	long/short/medium	---/--/-
	Chain system;	long/short/medium	---/--/-
	Coating;	long/short/medium	---/--/-
	Welding steel connection;	long/short/medium	---/--/-
	Welding steel extension;	long/short/medium	---/--/-
Working hours	Removal of pile cap;	long/short/medium	---/--/-
	Removal of foundation pile;	long/short/medium	---/--/-
	Renovation of foundation pile (Cleaning/filling);	long/short/medium	---/--/-
	Coating of foundation pile;	long/short/medium	---/--/-
	Welding extension to foundation pile	long/short/medium	---/--/-
	Driving foundation pile;	long/short/medium	---/--/-
	Preparing connection cap-foundation pile	long/short/medium	---/--/-
	Replacing pile cap and furniture;	long/short/medium	---/--/-
Equipment & Specialized personal	Pontoons (per pontoon)	long/short/medium	---/--/-
	Cranes(per crane)	long/short/medium	---/--/-
	Dive team (inspection and as-built information)	long/short/medium	---/--/-

Table 9: Implementation time score translation to percentage to be used for the MCA selection.

Implementation time	Analysis
Total	+54=100%

2.5.4 Assurance and Safety

This criteria is verified according to the capacity and the lifespan possible, as shown in Table10. In case of a 0% found in this criteria, a further discussion must be taken with the client in order to define the risks of pursuing with this solution. Table 11 describes the relation to the rating and the percentage grades.

Table 10: Assurance and safety score definition table used for the MCA selection.

Capacity	Description	Rating
Satisfied with Lifespan>50 y.	Capacity of the steel pile and the ground are in order with the requirements for a lifespan period of 50 years or more.	+3
Satisfied with 50y.>Lifespan>30 y.	Capacity of the steel pile and the ground are in order with the requirements for a lifespan period of between 50 and 30 years.	+2
Satisfied with Lifespan<30 y.	Capacity of the steel pile and the ground are in order with the requirements for a lifespan period of less then 30 years.	+1
Not satisfied	Capacity of the steel pile and or the ground do not fulfill the requirements for a dolphin structure.	-1

Table 11: Assurance and safety score translation to percentage to be used for the MCA selection.

Capacity	Analysis
Total	+3=100% +2=75% +1=50% -1=0%

3 Alternatives

Based on the Root Cause Analysis chapter, it can be concluded that the main problem is the rotation of the cap that is causing the failure of the fender system. Therefore the alternatives are going to follow the approach of fixating the cap instead of changing the rubber fender system. Also, based on the unclear situation of the foundation pile, it is also to be considered to be approached in different ways.
Therefore the alternatives found as solution for the stated problem are:

5. New dolphin design;
6. Fixation of cap using actual foundation pile;
7. Deepening and elongation of actual foundation pile, and fixation of cap;
8. New foundation pile and fixation of cap.

In the next sections the alternatives will be described in detail according the criteria described in the section 4.0 in order to allow further comparison.

3.1 New dolphin design

A new dolphin design is based on a complete new structure, from foundation pile to fender system. In this case, this new dolphin can be considered as an example the design used in the extra mooring places added to the region (Figure 1).

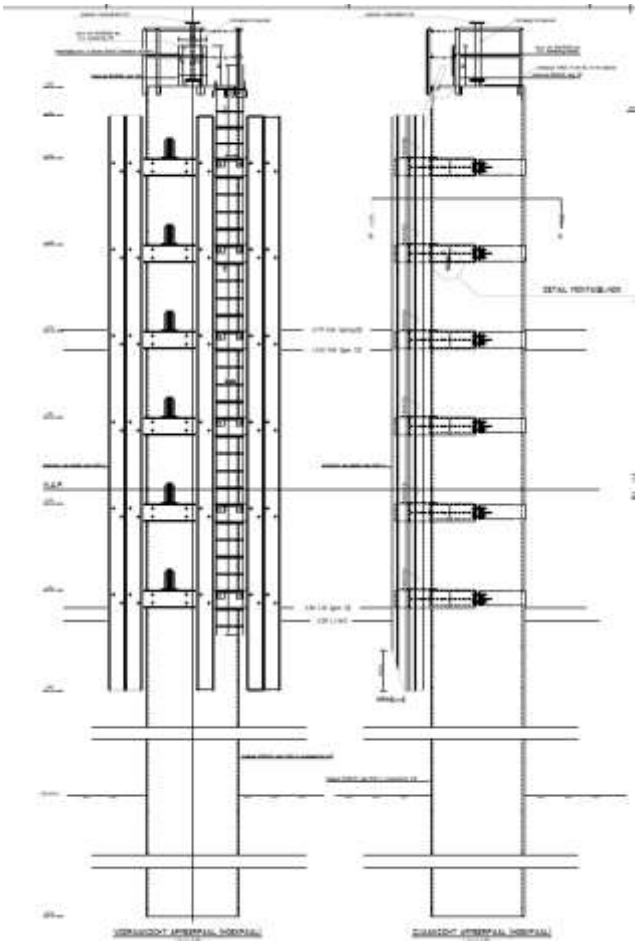

Figure 1: Example possible new design of dolphin for Hansweert area based on recently placed structure. Source: RWS drawing 15027-TEK-1125 (2018)

3.1.1 Lifespan

A new dolphin would have a design lifespan of 50 years old, lasting up to 2068 without or minimum maintenance costs needed in case it is implemented in 2018 (Table 12).

Table 12: Lifespan analysis of alternative 1 - new structure design.

Lifespan	Description	Rating
Lifespan>50 y. none or minor maintenance	The design life of the structure is complete, no usability of the components is present, so they are able to handle its function for the design life.	+3
		=100%

3.1.2 Costs

The costs of a totally new construction is higher when comparing to reuse of old structures. In this case removal costs of old structure, placement of new pile foundation, fender systems, furniture and connection to the walking bridges would have to be made. An extra -4 points are going to be added to the total in order to compensate this analysis, once in reality it is seen that a new construction has a higher cost then when fixing it.

Table 13: Costs Lifespan analysis of alternative 1 - new structure design.

Costs total	Description	Needed?	Quantity	Rating
Material	Foundation steel pile;	Yes	[-]	-1
	Extension steel pile	No	[-]	0
	Rubber fenders;	Yes	[-]	-1
	Chain system;	Yes	[-]	-1
	Coating;	No	[-]	0
	Welding steel connection;	Yes	[-]	-1
	Welding steel extension;	No	[-]	0
Working hours	Removal of pile cap;	Yes	[-]	-1
	Removal of foundation pile;	Yes	[-]	-1
	Renovation of foundation pile (Cleaning/filling);	No	[-]	0
	Coating of foundation pile;	No	[-]	0
	Welding extension to foundation pile	No	[-]	0
	Driving foundation pile;	Yes	[-]	-1
	Preparing connection cap-foundation pile	No	[-]	0
	Replacing pile cap and furniture;	No	[-]	0
Equipment & Specialized personal	Pontoons (per pontoon)	Yes No	1 extra	-1 0
	Cranes(per crane)	Yes No	1 extra	-1 0
	Dive team (inspection and as-built information)	Yes	[-]	-1
	Total=+18			=-10–4=-14 =-78% =+22%

3.1.3 Implementation Time

Table 14: Implementation time Lifespan analysis of alternative 1 - new structure design.

Implementation Time	Description	Duration long/short/medium	Rating
Material	Foundation steel pile;	long	---
	Extension steel pile	Not needed	[-]
	Rubber fenders;	long	---
	Chain system;	long	---
	Coating;	long	---
	Welding steel connection;	medium	--
	Welding steel extension;	Not needed	[-]
Working hours	Removal of pile cap;	short	-
	Removal of foundation pile;	medium	--
	Renovation of foundation pile (Cleaning/filling);	Not needed	[-]
	Coating of foundation pile;	Not needed-new	[-]
	Welding extension to foundation pile	Not needed	[-]
	Driving foundation pile (around 15.5m)	long	---
	Preparing connection cap-foundation pile	Not needed	[-]
	Replacing pile cap and furniture;	short (prefabricated)	-
Equipment & Specialized personal	Pontoons (per pontoon)	medium	--
	Cranes(per crane)	medium	--
	Dive team (inspection and as-built information)	medium	--
	Total=+54		=-27 = 50%

3.1.4 Assurance and Safety

Table 15: Assurance and Safety Lifespan analysis of alternative 1 - new structure design.

Capacity	Description	Rating
Satisfied with Lifespan>50 y.	Capacity of the steel pile and the ground are in order with the requirements for a lifespan period of 50 years or more.	+3
		=100%

3.1.5 Overall Analysis

Table 16: Overall analysis Alternative 1 - New structure design.

	Alternative 1		
Criteria	Rating (%)	Rate with factor (%)	Total
Lifespan	100	10	10
Costs	22	20	4.4
Implementation Time	50	35	17,5
Assurance and Safety	100	35	35
		Compatibility (%)	66.9

3.2 Fixation of cap using actual foundation pile

For the Alternative 2, the foundation pile is considered sufficient for the requirements and it can be reused. In addition to that, a fixation for the cap system is adapted by using the actual structure that is already there as well.

3.2.1 Lifespan

Due to the high maintenance needed for revitalizing the structure, the lifespan score is chosen to be +1 and, consequently, 50% of the total.

Table 17: Lifespan analysis of alternative 2-fixation of cap using actual foundation pile.

Lifespan	Description	Rating
50 y.>Lifespan>30 y. major maintenance	The design life of the structure is partly used so the components need to be inspected more often and maintenance is needed. The elements show bad conditions and need major renovation or replacement to be able to handle its function for the required design life.	+1 =50%

3.2.2 Costs

Table 18: Costs analysis of alternative 2-fixation of cap using actual foundation pile.

Costs total	Description	Needed?	Quantity	Rating
Material	Foundation steel pile;	No	[-]	0
	Extension steel pile	No	[-]	0
	Rubber fenders;	No	[-]	0
	Chain system;	No	[-]	0
	Coating;	No	[-]	0
	Welding steel connection;	Yes	[-]	-1
	Welding steel extension;	No	[-]	0
Working hours	Removal of pile cap;	Yes	[-]	-1
	Removal of foundation pile;	No	[-]	0
	Renovation of foundation pile (Cleaning/filling);	No	[-]	0
	Coating of foundation pile;	No	[-]	0
	Welding extension to foundation pile	No	[-]	0
	Driving foundation pile;	No	[-]	0
	Preparing connection cap-foundation pile	Yes	[-]	-1
	Replacing pile cap and furniture;	Yes	[-]	-1
Equipment & Specialized personal	Pontoons (per pontoon)	Yes	1	-1
	Cranes(per crane)	No	extra	-1
	Dive team (inspection and as-built information)	Yes	1	-1
	Total=+18			=-7=-35% =+65%

3.2.3 Implementation Time

Table 19: Implementation time analysis of alternative 2-fixation of cap using actual foundation pile.

Implementation Time	Description	Duration long/short/medium	Rating
Material	Foundation steel pile;	Not needed	[-]
	Extension steel pile	Not needed	[-]
	Rubber fenders;	Not needed	[-]
	Chain system;	Not needed	[-]
	Coating;	Not needed	[-]
	Welding steel connection;	medium	--
	Welding steel extension;	Not needed	[-]
Working hours	Removal of pile cap;	short	-
	Removal of foundation pile;	Not needed	[-]
	Renovation of foundation pile (Cleaning/filling);	Not needed	[-]
	Coating of foundation pile;	Not needed	[-]
	Welding extension to foundation pile	Not needed	[-]
	Driving foundation pile;	Not needed	[-]
	Preparing connection cap-foundation pile	medium	--
	Replacing pile cap and furniture;	short	-
Equipment & Specialized personal	Pontoons (per pontoon)	short	-
	Cranes(per crane)	short	-
	Dive team (inspection and as-built information)	short	-
	Total=+54		=-9=-17% =+83%

3.2.4 Assurance and Safety

Table 20: Assurance and Safety analysis of alternative 2-fixation of cap using actual foundation pile.

Capacity	Description	Rating
Not satisfied	Capacity of the steel pile and or the ground do not fulfill the requirements for a dolphin structure.	-1 = 0%

Note that the capacity analysis according to Fraanje (1968), in Appendix VI – Pile Capacity Analysis, shows that the pile fulfills the requirements. Nevertheless, following NIC (Smits & Meijerink, 2005), the results must be checked by modelling in software's in order to verify the validity. Once both DSheet Piling and Technosoft have shown a longer penetration depth needed than the actual one, it is chosen to define the capacity as not satisfied for the actual pile.

3.2.5 Overall Analysis

Table 21: Overall Safety analysis of alternative 2-fixation of cap using actual foundation pile.

	Alternative 2		
Criteria	Rating (%)	Rate factor (%)	Total
Lifespan	50	10	5
Costs	65	20	13
Implementation Time	83	35	29.2
Assurance and Safety	0	35	0
		Compatibility (%)	47.2

3.3 Deepening and elongation of actual foundation pile, and fixation of cap

Alternative 3 is used when the actual pile is structurally accepted according the requirements and can be reuse, nevertheless the penetration length is found to be insufficient. In this case then the actual pile is driven deeper into the soil and a new piece of pile, with the same characteristics, is welded in order to provide the required level for mooring purposes.

For this analysis the method of elongating the pile in-situ is considered once it seems to be the best option regarding the implementation time, even though it can be seen as an specific work and may have variability in the cost.

The fixation of the cap follows the same as expected in alternative 2.

3.3.1 Lifespan

Table 22: Life-span analysis of alternative 3 - deepening and elongation of actual foundation pile with cap fixation.

Lifespan	Description	Rating
50 y.>Lifespan>30 y. none or minor maintenance	The design life of the structure is partly used so the components need to be inspected and maintenance may be needed. The elements show good conditions and are able to handle its function for the required design life.	+2 =75%

3.3.2 Costs

Table 23: Costs analysis of alternative 3 - deepening and elongation of actual foundation pile with cap fixation.

Costs total	Description	Needed	Quantity	Rating
Material	Foundation steel pile;	No	[-]	0
	Extension steel pile	Yes	[-]	-1
	Rubber fenders;	No	[-]	0
	Chain system;	No	[-]	0
	Coating;	Yes	[-]	-1
	Welding steel connection;	Yes	[-]	-1
	Welding steel extension;	Yes	[-]	-1
Working hours	Removal of pile cap;	Yes	[-]	-1
	Removal of foundation pile;	No	[-]	0
	Renovation of foundation pile (Cleaning/filling);	No	[-]	0
	Coating of foundation pile;	No	[-]	0
	Welding extension to foundation pile	Yes	[-]	-1
	Driving foundation pile;	Yes	[-]	-1
	Preparing connection cap-foundation pile	Yes	[-]	-1
	Replacing pile cap and furniture;	Yes	[-]	-1
Equipment & Specialized personal	Pontoons (per pontoon)	Yes	1	-1
	Cranes(per crane)	No	extra	-1
	Dive team (inspection and as-built information)	Yes	1	-1
	Total= +20			=-12 =-60% =+40%

3.3.3 Implementation Time

Table 24:Implementation time analysis of alternative 3 -deepening and elongation of actual foundation pile with cap fixation.

Implementation Time	Description	Duration long/short/medium	Rating
Material	Foundation steel pile;	Not needed	[-]
	Extension steel pile	medium	--
	Rubber fenders;	Not needed	[-]
	Chain system;	Not needed	[-]
	Coating;	short	-
	Welding steel connection;	medium	--
	Welding steel extension;	medium	--
Working hours	Removal of pile cap;	short	-
	Removal of foundation pile;	Not needed	[-]
	Renovation of foundation pile (Cleaning/filling);	Not needed	[-]
	Coating of foundation pile;	Not needed	[-]
	Welding extension to foundation pile	medium	--
	Driving foundation pile (around 15.5m)	short (around 3 meters)	-
	Preparing connection cap-foundation pile	medium	--
	Replacing pile cap and furniture;	short	-
Equipment & Specialized personal	Pontoons (per pontoon)	medium	--
	Cranes(per crane)	medium	--
	Dive team (inspection and as-built information)	medium	--
	Total= +54		=-20=-37% =+63%

3.3.4 Assurance and Safety

Table 25:Assurance and Safety analysis of alternative 3 -deepening and elongation of actual foundation pile with cap fixation.

Capacity	Description	Rating
Satisfied with 50y.>Lifespan>30 y.	Capacity of the steel pile and the ground are in order with the requirements for a lifespan period of between 50 and 30 years.	+2 =75%

3.3.5 Overall Analysis

Table 26: Overall analysis of alternative 3 - deepening and elongation of actual foundation pile with cap fixation.

	Alternative 3		
Criteria	Rating (%)	Rate with factor (%)	Total
Lifespan	75	10	7.5
Costs	40	20	8
Implementation Time	63	35	22
Assurance and Safety	75	35	26.25
		Compatibility (%)	63.8%

3.4 New foundation pile and fixation of cap

Alternative 4 is based on the implementation of a completely new foundation pile, in case the actual pile does not fulfill both structural and geotechnical capacities (Appendix V – Geotechnical Analysis) needed for this construction. Moreover the cap is also fixated as described in the final design.

3.4.1 Lifespan

Although the lifespan of the foundation pile is in its full, the cap element with the fender must still go through a major maintenance. Therefore the choice below is made.

Table 27: Lifespan analysis of alternative 4- new foundation pile and fixation cap.

Lifespan	Description	Rating
50 y.>Lifespan>30 y. major maintenance	The design life of the structure is partly used so the components need to be inspected more often and maintenance is needed. The elements show bad conditions and need major renovation or replacement to be able to handle its function for the required design life.	+1 =50%

3.4.2 Costs

Table 28: Costs analysis of alternative 4- new foundation pile and fixation cap.

Costs total	Description	Needed?	Quantity	Rating
Material	Foundation steel pile;	Yes	[-]	-1
	Extension steel pile	No	[-]	0
	Rubber fenders;	No	[-]	0
	Chain system;	No	[-]	0
	Coating;	No	[-]	0
	Welding steel connection;	Yes	[-]	-1
	Welding steel extension;	No	[-]	0
Working hours	Removal of pile cap;	Yes	[-]	-1
	Removal of foundation pile;	Yes	[-]	-1
	Renovation of foundation pile (Cleaning/filling);	No	[-]	0
	Coating of foundation pile;	No	[-]	0
	Welding extension to foundation pile	No	[-]	0
	Driving foundation pile;	Yes	[-]	-1
	Preparing connection cap-foundation pile	Yes	[-]	-1
	Replacing pile cap and furniture;	Yes	[-]	-1
Equipment & Specialized personal	Pontoons (per pontoon)	Yes	1	-1
	Cranes(per crane)	No	1	-1
	Dive team (inspection and as-built information)	Yes	1	-1
	Total= +20			=-10=-50% =+50%

3.4.3 Implementation Time

Table 29: Implementation time analysis of alternative 4- new foundation pile and fixation cap.

Implementation Time	Description	Duration long/short/medium	Rating
Material	Foundation steel pile;	long	---
	Extension steel pile	Not needed	[-]
	Rubber fenders;	Not needed	[-]
	Chain system;	Not needed	[-]
	Coating;	Not needed	[-]
	Welding steel connection;	medium	--
	Welding steel extension;	Not needed	[-]
Working hours	Removal of pile cap;	short	-
	Removal of foundation pile;	long	---
	Renovation of foundation pile (Cleaning/filling);	Not needed	[-]
	Coating of foundation pile;	Not needed-new	[-]
	Welding extension to foundation pile	Not needed	[-]
	Driving foundation pile (around 15.5m)	long	---
	Preparing connection cap-foundation pile	medium	--
	Replacing pile cap and furniture;	short	-
Equipment & Specialized personal	Pontoons (per pontoon)	medium	--
	Cranes(per crane)	medium	--
	Dive team (inspection and as-built information)	medium	--
	Total= +54		=-21=-39% =+61%

3.4.4 Assurance and Safety

Table 30: Assurance and Safety analysis of alternative 4- new foundation pile and fixation cap.

Capacity	Description	Rating
Satisfied with Lifespan>50 y.	Capacity of the steel pile and the ground are in order with the requirements for a lifespan period of 50 years or more.	+3 =100%

3.4.5 Overall Analysis

Table 31: Overall analysis of alternative 4-new foundation pile and fixation cap.

		Alternative 4	
Criteria	Rating (%)	Rate with factor (%)	Total
Lifespan	50	10	5
Costs	50	20	10
Implementation Time	61	35	21.4
Assurance and Safety	100	35	35
		Compatibility (%)	71.4

4 Criteria Analysis

Referring to the criteria analysis overview, as seen in Table 32, Alternative 4 has shown to be the most compatible when using the criteria combination, with a rate of 71.4% of compatibility calculated.

Alternative 1 has a slight longer implementation time and grater costs, taking it to the second position in the ranking. On the other hand, Alternative 2 shows a great combination of implementation time and costs but lacks in the assurance and safety criteria, placing itself in the last position of the list.

Alternative 3 though, shows the a medium implementation time but it has high cost due to the extra work in welding of the pile extension and equipment therefore needed.

Table 32: Multi-Criteria analysis of all alternatives.

	Alternative 1 New Design			**Alternative 2 Cap Fixation**			**Alternative 3 Pile Elongation**			**Alternative 4 New Pile**		
Criteria	Rate (%)	Fact (%)	Tot	Rate (%)	Fact (%)	Tot	Rate (%)	Fact (%)	Tot	Rate (%)	Fact (%)	Tot
Lifespan	100	10	10	50	10	5	75	10	7.5	50	10	5
Costs	22	20	4.4	65	20	13	39	20	8	50	20	10
Implement Time	50	35	17,5	83	35	29	63	35	22	61	35	21.4
Assurance and Safety	100	35	35	0	35	0	75	35	26.3	100	35	35
	Compatibility (%)		66.9	Compatibility (%)		47.2	Compatibility (%)		63.8	Compatibility (%)		71.4

5 Discussion & Conclusion

When analyzing the implementation time and costs Alternative 2 though shows a higher compatibility, but lacks in the capacity analysis used in this report. In case that this option is chosen, then this report advises a deeper evaluation of the capacity with FEM checks in order to prove the safety of the construction. Furthermore, the client takes full responsibility regarding the safety of the construction and its reliability.

Alternative 1, even though it is placed in second place, has the higher cost and implementation time, so that is not the best option for the client.

This report advises the client to use Alternative 4 as the solution approach for the actual problem regarding the foundation piles when it comes to the results of this criteria analysis. Nevertheless, the choice of Alternative 3, although more costly, makes use of the actual pile that still has some lifespan to go in order to dispose it, in addition to a slight lower implementation time when comparing to Alternative 4.

In conclusion, both Alternatives 3 and 4 are interesting choices and are to be chosen by the client.

Appendix VIII Design Report

Rijkswaterstaat
Ministry of Infrastructure and Water Management

DELTA ACADEMY

2018

Design Report

Lourenco Lehmkuhl, Sullen (PPO)

Rijkswaterstaat Zee en Delta

12 juni 2018

Version 2.0

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1 Introduction

This report describes the design steps followed for the dolphin structure of Hansweert based on the choice of the Alternative 3 of the Multi-Criteria Analysis (Appendix VII). This document is divided into the limits and preconditions used as baseline, the calculation used for checking the capacity of the actual foundation pile in the future and the final design characteristics.

2 Limits and Preconditions

This chapter describes the basic data used in the design of the solution for Hansweert berthing structure.

2.1 Normative and Guidelines

For the design process the following norms are to be followed:

Table 1: Normative and guidelines used in the design.

[1]	NEN-EN 1990	: *Eurocode 1 - Basis of structural design;*
[2]	NEN-EN 1991-1-7	: Loads on constructions
[3]	NEN-EN 1991-2	: Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges
[4]	NEN-EN 1993-1-1	: Design of steel structures - Part 1: Basis of design
[5]	NEN-EN 1993-1-8	: Design of steel structures - Part 1-8: Connections
[6]	NEN-EN 1993-5	: Design of steel structures - Part 5: Piling;
[7]	NEN-EN 1997-1	: Eurocode 7: Geotechnical design Part 1: General Rules;
[8]	NIC	: Handreiking rekenmethodieken RWS;
[9]	EAU2012	: Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004;
[10]	CUR 166	: Quay wall constructions (Damwandconstructies);
[11]	CUR 288	: Design Guidelines to soil horizontal loads on piles (Ontwerprichtlijnen door grond horizontal belaste palen);
[12]	CUR 2001-4	: Design rules for driven piles (Ontwerpregels voor trekpalen)
[13]	CUR 2001-8	: Bearing capacity of steel pipe piles;
[14]	CUR 2011	: Handbook Quay Walls
[15]	PIANC 2002	: Guidelines for the Design of Fender Systems;
[16]	RVW2017	: Dutch Directive Waterways 2017 (Richtlijnen Vaarwegen 2017)
[17]	ROK 1.4	: Dutch guidelines for infrastructur constructions (Richtlijnen Ontwerp Kunstwerken).
[18]	RBK 1.1	: Dutch guidelines assessment of infrastructur constructions (Richtlijnen Beoordeling Kunstwerken).
[19]	Waterbouwkunde (1968)	: Waterbouwkunde deel 1: Algemene waterbouwkunde

2.2 Relevant data

Based on client's requirements, the following documents were given in Table 2.

Table 2: Relevant documents for dolphin's design.

Ref.	Doc number RWS	Doc name RWS
[18]	ZLSR-1987-12014	: Drawing Toeleidinswerken hansweert ducdalven westerscheldezijde;
[19]	ZLSR-1987-12015	: Drawing Toeleidinswerken hansweert ducdalven kanaalzijde;

[20] ZLSR-1987-12251 : Drawing Toeleidingswerken Hansweert Matentekening Azobe beslag dukdalven weterschelde en kanaalzijde;
[21] ZLSR-1990-02084 : Drawing Toeleidingswerken hansweert bevesting rubber fender en apheffen speling en zekering mantel tbv ducdalven;
[22] ZLSR-2004-00408 : Drawing Sluizencomplex Hansweert Situ Voorhaven KZB;
[23] ZLSR-2004-00409 : Drawing Sluizencomplex Hansweert Situ Voorhaven KZB;
[24] ZLSR-2004-00411 : Drawing Sluizencomplex Hansweert Situ Voorhaven WST;
[25] RWSZL-2011-04940 : Drawing Fender opvangconstructie meerstoelen hansweert;
[26] RWSZD-2014-02374 : Drawing Fender opvangconstructies C21,C22,C24,C35,C36 en C37 HWS met zijdelings gefixeerd;
[27] RWSZD-2014-02504 : Afleverdossier spec nr 20-21 aanbrengen 19st opvangconstructie en 4 fenders aan de meerstoelen D20 t/m D37 sluizencomplex Hansweert;
[28] ZLSR-1991-00032 : Uitgangspunten en randvoorwaarden geleidewerken Hansweert
[29] ZLSR-1987-00001 : Overeenkomst tot uitvoering en wijziging van Bestek SS1239a
[30] ZLSR-1987-00003 : Conservering op de constructie en kunststof blokken
[31] ZLSR-1987-00004 : Aandachtspunten ten aanzien van onderhoud
[32] ZLSR-1987-00005 : Toeleidingswerken Hansweert

Appendix XI-VIII englobes all the previous data mentioned in a digital version.

2.3 Consequence class and load combinations

Berthing structures are to be considered of consequence class CC2. According to NEN-EN 1990 (2011), the following factors are to be applied:

Table 3: Loading factors for general structures according to Eurocode 1. Source: NEN-EN 1990 (2011)

Permanent and Temporary structural design	Permanent Load		Dominant variable load	Variable loads simultaneously with the predominant		Type Structure
	Unfavorable	Favorable		Decisive	Others	
6.10a	$1.35*G_{k,jsup}$	$0.9*G_{k,j,inf}$		$1.5*\psi_{0.1}*Q_{k,1}$	$1.5*\psi_{0.i}*Q_{k,1}$	General
6.10b	$1.20*G_{k,jsup}$	$0.9*G_{k,j,inf}$	$1.5*Q_{k,1}$	$1.5*\psi_{0.1}*Q_{k,1}$	$1.5*\psi_{0.i}*Q_{k,1}$	General

In addition, for the berthing calculation must use the factor ψ:

Table 4: Representative berthing load factors. Source: NEN-EN 1990 (2011)

Load	Ψ_0	Ψ_1	Ψ_2
Berthing load	1.0	0	0

2.4 Partial factors for geotechnical analysis

The partial factors γ for ultimate limit states and correlation factors ξ for pile foundations in all design situations are given according to Annex A from NEN-EN 1997 (2016).

The partial factors for the verification of equilibrium limit state (EQU) for the soil parameters when including minor shearing resistances are shown in Table 27. The design approach 3 is chosen for this design with the verification that the limit state of rupture or excessive deformation will not occur by using the combination sets of partial factors according to: A1(STRU) or A2(GEO)+M2+R3 (NEN-EN, 2016).

Table 5: Partial factors for resistance calculations according to design approach 3. Source: (NEN-EN, 2016).

Resistance	Symbol	Set R3
Base	γ_b	1.0
Shaft (compression)	γ_s	1.0
Total/combined (compression)	γ_t	1.0
Shaft in tension	$\gamma_{s,t}$	1.1

Partial resistance factors for pile foundations verification of structural (STR) and geotechnical (GEO) limit states must also be applied conform Table 28-Table A.6 from NEN-EN 1997 (2016), for driven piles in this case.

Table 6: Table A.6-Partial resistance factors for driven piles for the use of soil parameters. Source: NEN-EN 1997 (2016)

Soil Parameter	Symbol	Value
Angle of shearing resistance	$\gamma_{\varphi'}$ *	1.25
Effective cohesion	$\gamma_{c'}$	1.25
Undrained shear strength	γ_{cu}	1.4
Unconfined strength	γ_{qu}	1.4
Weight density	γ_y	1.0
*This factor apply to tan φ		

The correlation factors to be applied to derive the characteristic resistance of axially loaded piles for the verifications of structural (STR) and geotechnical (GEO) limit states are described on Table A.10 from NEN-EN 1997 (2016), and described in Table 7Table 29.

Table 7: Table A.10-Correlation factors for calculation of axially loaded piles by using ground tests. Source: NEN-EN 1997 (2016)

ξ for n= number of profiles of tests	1	2	3	4	5	7	10
ξ_3	1,4	1,35	1,33	1,31	1,29	1,27	1,25
ξ_4	1,4	1,27	1,23	1,20	1,15	1,12	1,08

2.5 Lifespan and corrosion

The life-span of the structure follows the guidelines of NEN-EN 1990 (2011), with a design life of 50 years.

For steel construction elements the corrosion rate to be considered is followed by the normative NEN-EN 1993 (2008) and CUR166 (2014) for a life span of 50 years. In case of steel piles, the corrosion is only considered to happen in the outer side once in the inside no oxygen or water is present, therefore no corrosion or rust occur.

Once the highest moment happens underground, the limiting rate corrosion is defined to be:

Steel pile in the ground : 0,026 mm/side * considered to be determinant due to location of maximum load.

2.6 Material quality

The material quality used follows the current usage by the client and the specifications are as in Table 8.

Table 8: Steel quality required for design of water constructions in the area of Hansweert lock. Source: PPO RWS See and Delta

EN 10025	Min. Yield Strength [N/mm2]						Tensile Strength [N/mm2]		Thoughness Charpy V (J)	°C
Thickness	<16	>16;<40	>40;<63	>63;<80	>80;<100	>100;<150	<3; <100	>100; <150	<150	
S355JO	355	345	335	325	315	295	490; 630	470; 630	27	0

2.7 Construction depth and levels

The impact level of NAP + 6,50 m is shown to be determinant for the capacity of the structure, therefore the design level is assumes to be NAP + 6,50 m.

Following the Pile Capacity Analysis(Appendix III), it is found that according DSheet-Piling a minimum penetration level of NAP -20m is required for the withstanding of the mooring load. Therefore the toe level of the pile is considered to be NAP – 20,00 m for the final design.

2.8 Load Cases

2.8.1 Permanent Load

The self-weight of the structure is defined by the sum of the weights from the foundation pile and cap which are the most significant influence in the total. For the calculation, the density of steel is considered 7800 kg/m^3.

The total weight of the structure is to be considered as 18,8 tones, therefore:

$P_{steel} = 185\ kN$

2.8.2 Variable Load

The variable load is considered to be the usage load that is vertically applied in the structure in case of maintenance and installation, and the berthing loads acting horizontally.

Maintenance load

The maintenance and human load is defined by the use of the structure in case of needed maintenance and for the use of the ladders by passengers to reach the walking bridge. An assumption following pedestrian load in bridges according to NEN-EN 1991 (2011), gives a $q_{p,f;k}$ = 2kN/m^2. It is taken as load surface the top of the pile and that gives the area of the pile cap $A_{base,cap}$=2,6m^2, leading to a load $Q_{f,w}$=2kN.

Berthing load

The berthing load can be divided into two different loads, the impact and mooring force.

The impact load is calculated according to the berthing energy, that can be calculated according to EAU, PIANC (2002) and ROK (Rijkswaterstaat, 2017):

$$E_d = 14{,}10[kNm]$$

$$E_{d,ULS} = 31{,}72[kNm]$$

Further description of the impact calculation can be found in Appendix III.

Also as part of the variable load, the mooring charges are represented by the actions on the bollards which can be found in the Directive Waterways (RWS, 2017), the required strength for vessels of class CEMT VIb is 350kN.

2.9 Dimensions

The dolphin structure is to be recycled and therefore reused in this design. The foundation pile to be reused and the pile cap have the following characteristics:

- Pile characteristics
  - D=1016mm;
  - t= 20mm;
  - L_{pile} =24,10m;
  - Steel quality: S355JO
- Pile cap characteristics
  - D=1820mm;
  - T=16mm;
  - $L_{pile,cap,WS}$=10,00m; $L_{pile,cap,WS}$=7,50m;
  - Steel quality: S355JO.

2.10 Geotechnical data

The design is based on the Geotechnical Analysis (Appendix V) and makes use of the CPT70294 as the design soil profile as shown in Table 9.

Table 9: Soil profile number 70294 representing the strong profile. Source: DinoLOKET (2018)

Layer	Top Layer [mNAP]	Layer [m]	Soil Type	γdry [kN/m3]	γsat [kN/m3]	ϕ [°]	α [°]	δ [°]	β [°]	c' [kPa]
1	-8,00	3,67	Loam	19	19	27,5	0	18,3	9,5	50
2	-11,67	1,02	Sand 1	18	20	25	0	16,7	9,5	0
3	-12,69	0,92	Loam	19	19	27,5	0	18,3	9,5	50
4	-13,61	8,15	Sand 2	18	20	27	0	18,0	9,5	0
5	-21,76	0,20	Loam	19	19	27,5	0	18,3	9,5	50
6	-21,959	0,10	Sand 1	18	20	25	0	16,7	9,5	0
7	-22,06	0,22	Loam	19	19	27,5	0	18,3	9,5	50
8	-22,28	0,20	Clay	18	18	22,5	0	15,0	9,5	80
9	-22,48	1,64	Loam	19	19	27,5	0	18,3	9,5	50
10	-24,12	2,20	Sand 1	18	20	25	0	16,7	9,5	0
11	-26,31	2,11	Sand 3	19	21	35	0	23,3	9,5	0
12	-28,43	2,35	Sand 2	18	20	27	0	18,0	9,5	0
13	-30,78	0,34	Loam	19	19	27,5	0	18,3	9,5	50
14	-31,12	31,12	Sand 2	18	20	27	0	18,0	9,5	0

2.11 Relevant Software

For the calculations and drawings the following programs were used:

- ✓ TS/Damwanden version;
- ✓ DSheet Pile;
- ✓ deKoch Spreadsheet for berthing structure design;
- ✓ AutoCAD 2016 – Student version
- ✓ InfraCAD version 6.0 for AutoCAD 2016 – Student version

3 Dolphin design

The dolphin structure of this project is formed by two main elements the foundation pile and the pile cap with a fender system. This section described the final design chosen by the research outcome in accordance to the clients requirements.

3.1 Foundation Pile

The actual foundation pile has shown a lack of capacity when it comes to the geotechnical analysis generated by DSheet Piling and TS/Damwanden. Therefore, as shown in the MCA, the alternative 3 of elongating this element is chosen for the final outcome.

3.1.1 Defining penetration depth

The toe level is determined by the iteration check using DSheet Piling, in combination to the Fraanje Method (1968) for the design of berthing structures.

DSheet Piling gives an acceptable soil capacity from the depth of NAP – 20,00 m as seen in Figure 1.

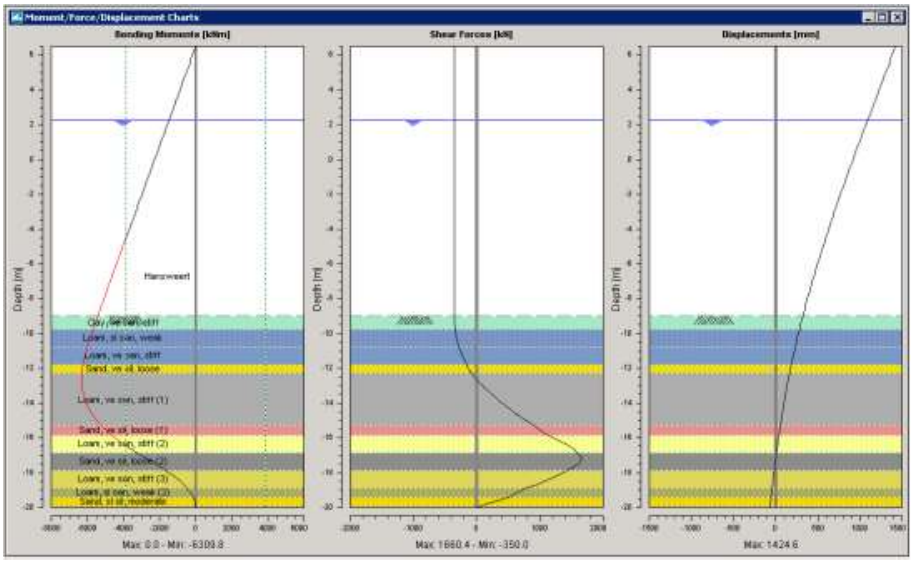


Figure 1: Moment, Force and Displacement charts from DSheet-piling analysis on longer pile and CPT70297, with max displacement of 1,5m and desired load of 350kN.

In addition the analysis following Fraanje (1968), with the soil interaction following Blum's method and structural analysis according to NEN-EN 1990 (2011) as explained in Appendix VI, has shown the following results:

Table 10 Pile capacity analysis according to Fraanje (1968) .

Staalkwaliteit	S	355			
D (buitendiameter)		1016	mm		
t (buispaal dikte)		20	mm		
E (elasticiteitsmodulus)		210000	N/mm2	corrosie ondergrond	
corrosie binnenkant per jaar		0	mm/jaar	omdat grotste	
corrosie buitenkant per jaar		0,026		moment zit in de	
aantal jaar		32	jaar	grond	
γf;q;u (belastingfactor UGT, scheepsstoot)		1,5			
γf;g;u (belastingfactor UGT, troskracht)		1			
γf;ser (belastingfactor BGT)		1			
γdr (soortelijk gewicht van de grond boven water)		18	kN/m3	sand sterk siltig,	
γsat (soortelijk gewicht van de grond onder water)		20	kN/m3	kleiig volgens Dsheet	
γwat (soortelijk gewicht van het water)		10	kN/m3		
φ'rep (hoek van inwendige wrijving)		27,5	°		
hstoot (afstand bodem tot aangrijpingspunt scheepsstoot)		15,5	m	waterverplaatsing	
xm (afstand bodem tot maximaal optredend moment; stoc		2,96	m	omrekenen van ton	
η (waarde to;stoot / xm)		2,56		naar kN:	
m (waterverplaatsing van het schip)		109200	kN	12000	ton
v (aanvaarsnelheid)		0,13	m/s	120000	kN
Ptros;rep (representatieve waarde troskracht)		350	kN	m'	
xm (afstand bodem tot maximaal optredend moment; tros		2,96	m	109200	kN
htros (afstand bodem tot aangrijpingspunt troskracht)		15,5	m		
η (waarde van to / xm)		2,56			
Ltot (totale lengte buispaal)		26,5	m		

Table 11 Continuation from table 10.

15. Gegevens buispaal:			
D (diameter buispaal)		1016	mm
t (buispaal dikte)		20	mm
Ltot (totale lengte buispaal)		26,5	m
Maatgevende doorbuiging t.p.v. aangrijpingspunt kracht		0,796137	m
Maatgevende doorbuiging t.p.v. top van de buispaal		0,883952	m
Optredend arbeidsvermogen		141,0917	kNm
Toelaatbaar arbeidsvermogen		150,97	kNm
Optredende buigspanning		253,3458	N/mm2
Toelaatbare buigspanning		355	N/mm2
	buispaal	voldoet	

Based on this checks, and the serviceable verification that the piles are capable of handling the required load as shown on the field, the final penetration length is to be considered 11 meters with a pile toe level of NAP -20,00 m.

Design Foundation Pile

Diameter	1016	[mm]
Inner diameter	976	[mm]
Thickness	20	[mm]
Actual length	24.1	[m]
Extra length	2.4	[m]
Final length	26.5	[m]

3.2 Cap connection

The cap of the current structure is to be reused and a connection is to be implemented in order to prevent the rotation of the pile cap and therefore the known failure of the structure, as defined by the Root Cause Analysis (Appendix IV).

There were three possibilities considered in cooperation with the client which are described in the next sections.

3.2.1 Connection option 1

For this option the cap pile of diameter 1820mm would be cut in its half and replaced to a distance of 878mm from the center of the foundation pile, reducing the eccentricity of the cap in comparison to the original structure. Six bracing supports would be placed around the inner pile and welded to the half cap structure, which can be regulated by torqueing of the bolts.

This solution requires also a redesign of the top plate, which is reduced to 1280mm. Therefore a new connection to the walking bridge is also needed to be designed, as the replacement of the stairs, cables and traffic plates, as seen in Figure 2.

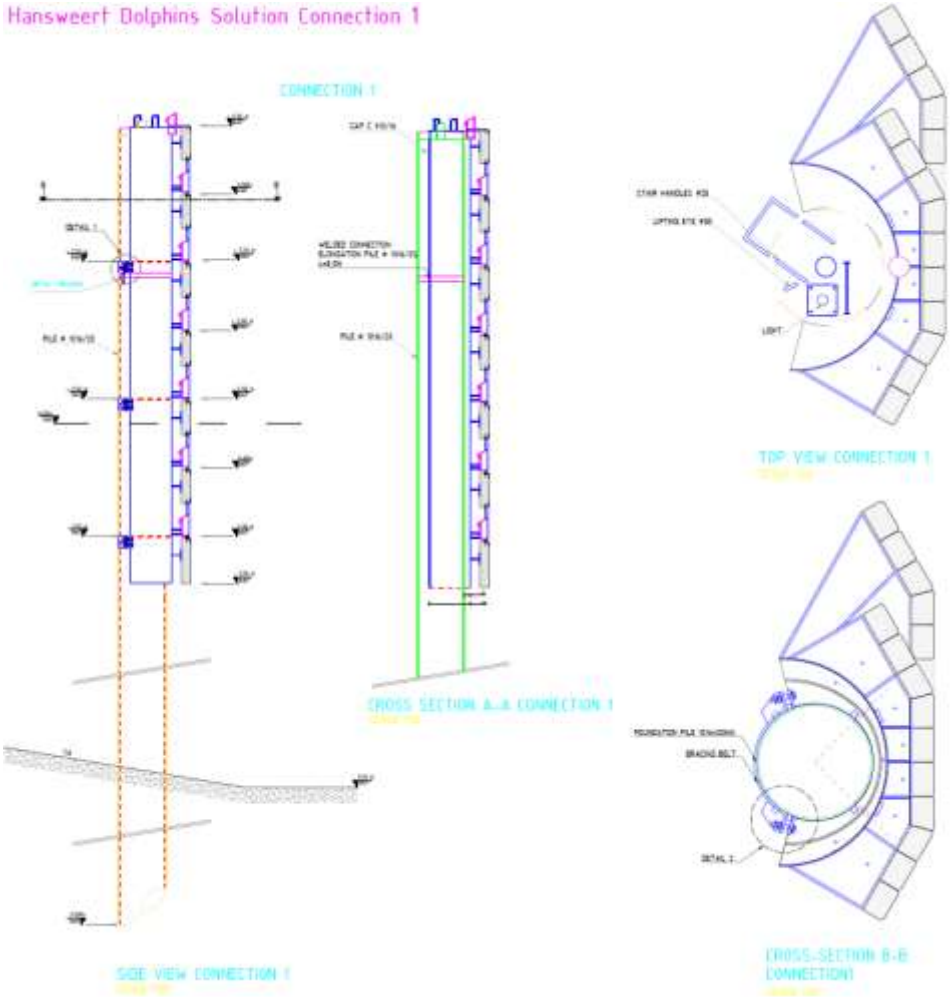


Figure 2 Schema for cap-pile connection 1.

3.2.2 Connection option 2

The second option adapts part of the cap, leaving the top 3 meters of the pile cap intact and removing the half of the remaining length as seen in Figure 3. For this connection the top plate and further elements remain the same.

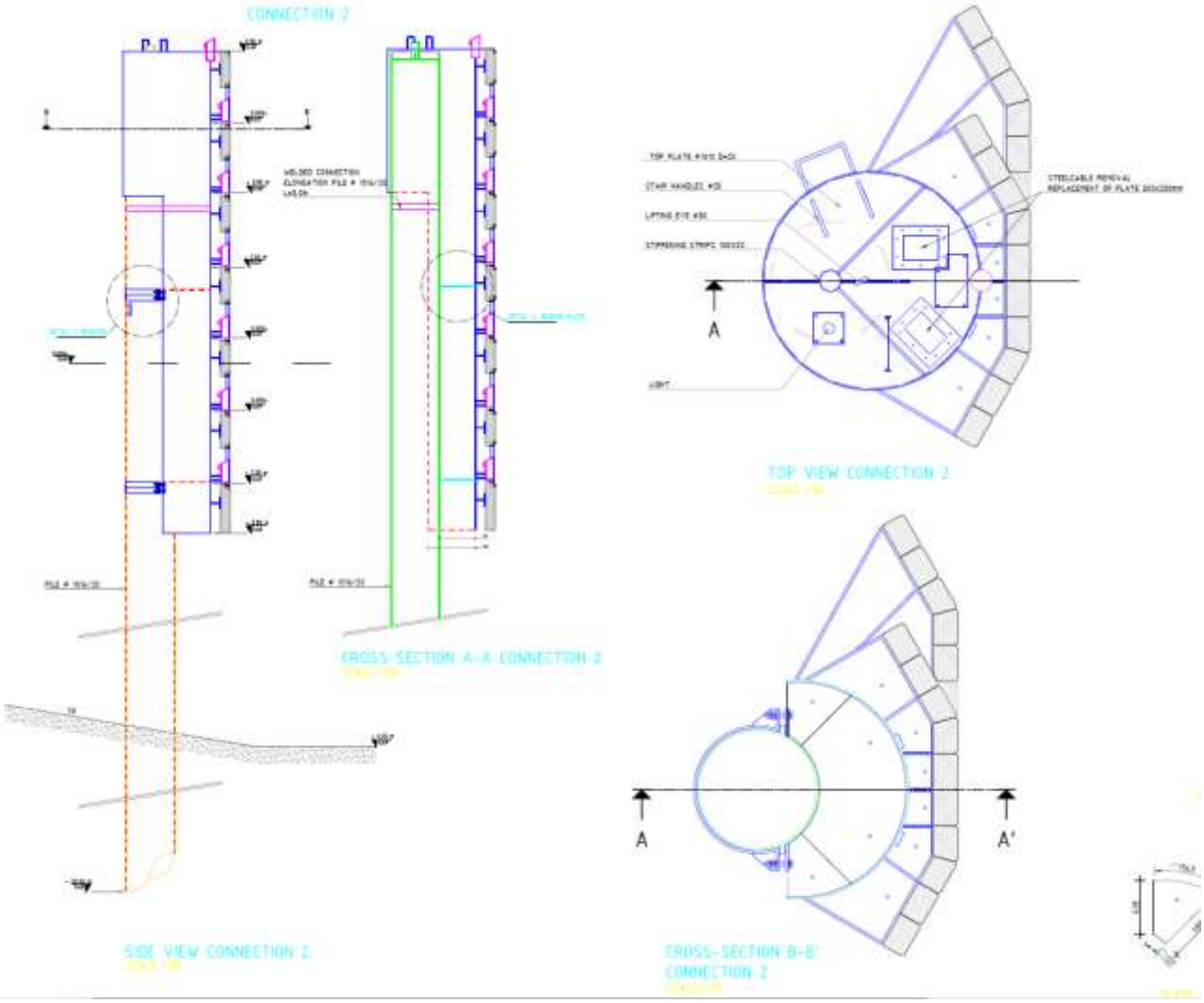


Figure 3 Scheme pile-cap connection option 2.

The same as in connection 1, bracing rings are added to keep the pile cap in position and avoid lateral displacements. Also, a binding plate connection is designed to be placed on the same level of the bracings, to avoid bending of the C cap element (Figure 4).

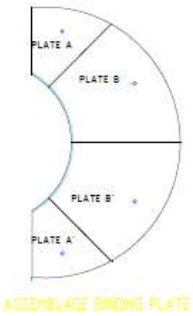


Figure 4 Detail of binding connections of option 2.

3.2.3 Connection 3

Option 3 makes use of the same assemblage existing by adding both connections to the top and bottom sides of the cap.

In the top the cap is held to the foundation pile with the UPE section as seen in Figure 5, preventing the lateral rotation. In addition, to prevent vertical displacement a connection is added in the bottom part of the cap with the implementation of two steel plates. From these, one is welded to the foundation pile and the second to the pile cap. In-situ welding to the bottom part of those plates bring them to one piece and work in prevention to the displacement, as also shown in Figure 5. An extra stiffening rib is added to prevent displacement due to compressive forces.

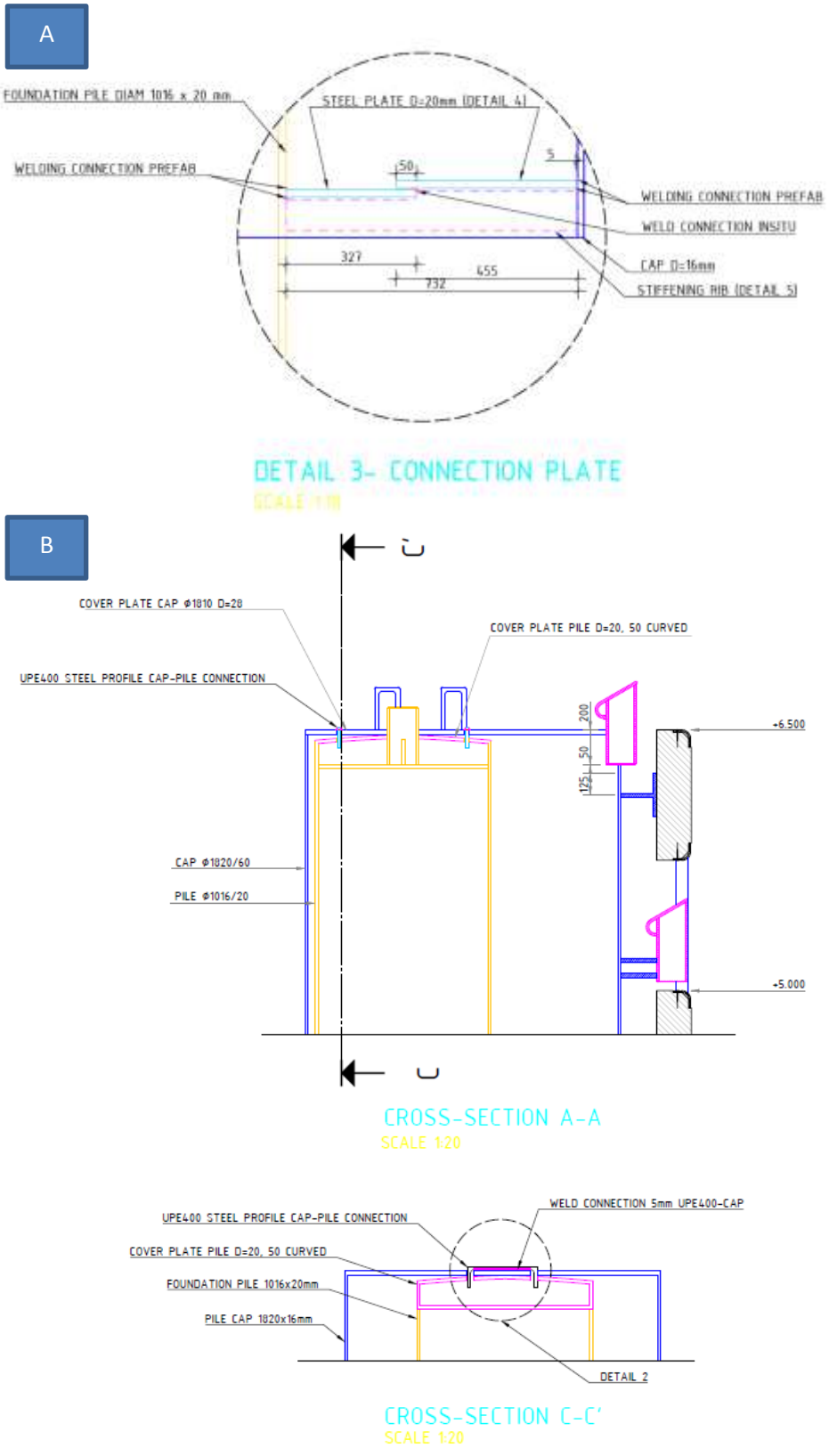


Figure 5 Detail top and bottom connection of option 2.

An overview of this option can be seen in Figure 6.

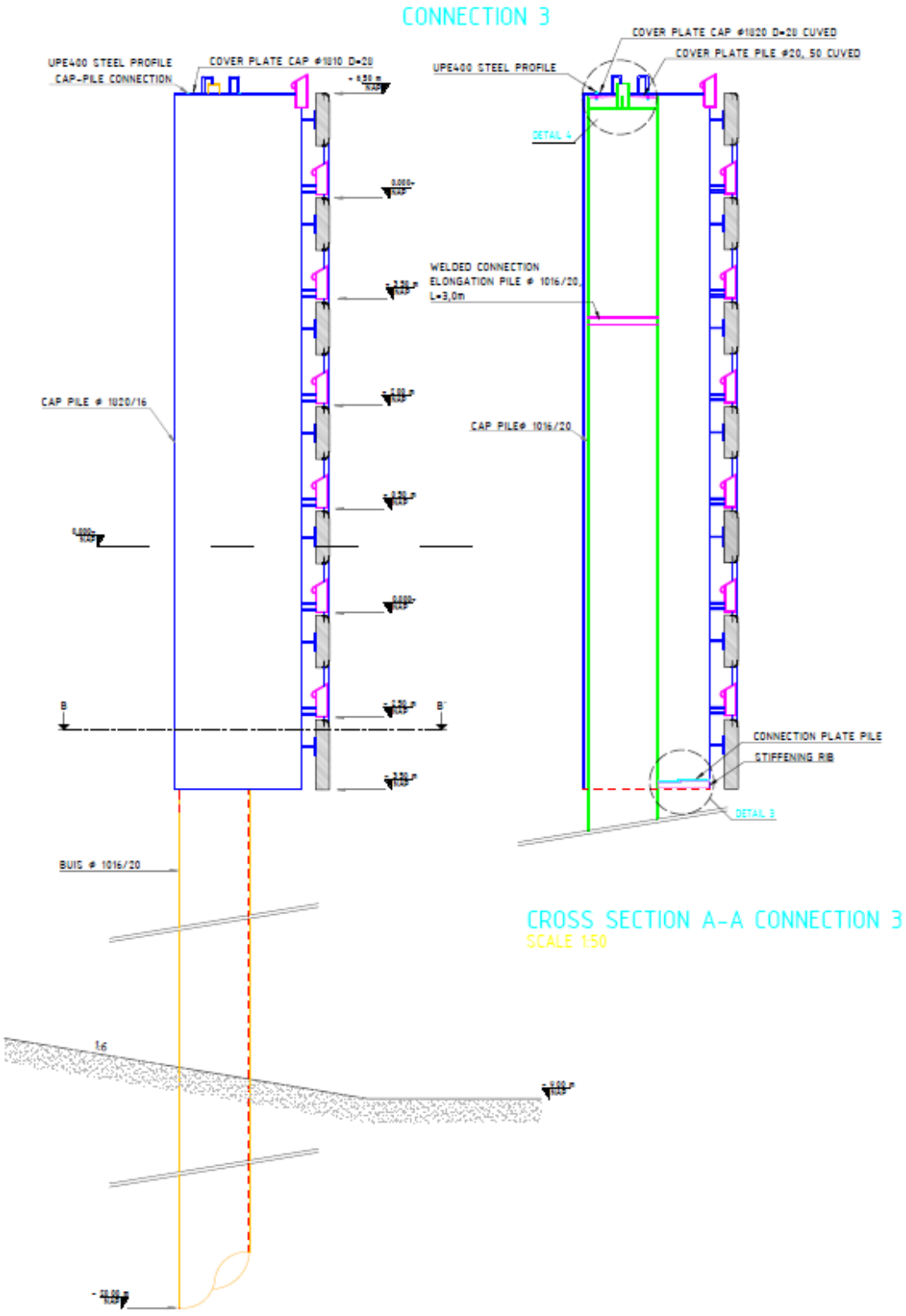


Figure 6 Scheme for pile-cap connection option 3.

3.2.4 Selection & Verification

The cap connection 3 is chosen due to less modifications needed to the pile cap and less extra elements when comparing to the other options. This is considered to lead to a less implementation time and costs.

Connection to foundation pile

In order to verify the UPE section choice as the welding layer, structural calculations are needed to verify if the capacity is enough to support the loads shown in Figure 7.

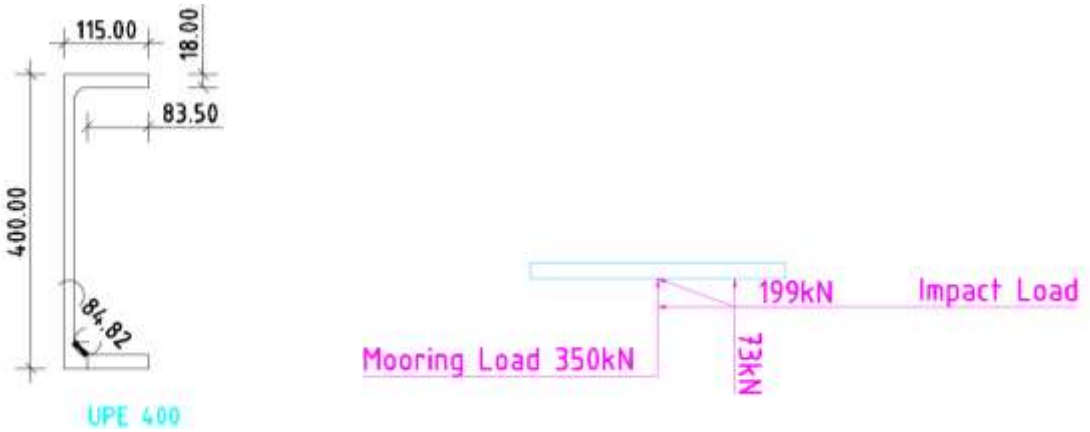


Figure 7 UPE400 section details.

The welding is loaded with the moment caused by the normal mooring load on the main base of the section, in addition horizontal load caused by the impact. These loads are happening in different moment in time, so the check is done for the imperative load.

The impact load is based on the required impact energy of 220kNm in an angle of 20°, giving a $F_{h,1}$=199kN and a $F_{h,2n}$=73kN.

Based on similar designs, the welding layer is chosen to be assumed 5mm, with a critical layer of a_{cor}=4.65. For the normal load caused by the mooring, the l_{eff} =400mm, is assumed to be the length of UPE400. the following check is performed:

$$\tau_{\perp} = \sigma_{\perp} = \frac{F * \sqrt[2]{2}}{4 * a_{cor} * l_{eff}};$$

$$F = F_{morring} + F_{m,d};$$

Where $F_{m,d}$ is the force cased by the moment generated by the mooring load in pulling and pushing the structure in relation to the pile.

$$F_{m,d} = \frac{M_{s,d,A}}{D_{pile}} = \frac{350 * 0.2}{1016} = 68.9kN$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{(350 + 68.9) * 10^3 * \sqrt[2]{2}}{4 * 4.65 * 400}$$

$$\tau_{\perp} = \sigma_{\perp} = 79.6\ N/mm^2$$

$$\sigma_{s,w,d} = \sqrt{\sigma_{\perp}{}^2 + 3 * (\tau_{\perp}{}^2 + \tau_{//}{}^2)}$$

$$\sigma_{s,w,d} = \sqrt{79.6^2 + 3 * (79.6^2 + 0^2)}$$

$$\sigma_{s,w,d} = 159.2 N/mm^2$$

For the check: $\sigma_{s,w,d} \leq \frac{f_y}{0.9*1.5}$

$$\sigma_{s,w,d} = 159.2 \leq \frac{355}{0.9 * 1.5} = 263\ [N/mm^2]$$

The welding and the section are acceptable for the required load.

For the horizontal load of 199kN, it is shared along the top plate of the cap, therefore a check is performed assuming a l_{eff}=1820mm. The welding layer keeps the same as in the previous check, a_{cor}=4.65.

$$\tau_{//} = \frac{F_{h,x,d}}{2 * a_{cor} * l_{eff}} = \frac{199 * 10^3}{2 * 4.65 * 1820} = 11.8\ N/mm^2$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{73 * \sqrt[2]{2}}{4 * 4.65 * 1820} = 3.1\ N/mm^2$$

$$\sigma_{s,w,d} = \sqrt{3.1^2 + 3 * (3.1^2 + 11.8^2)} = 21.4 N/mm^2$$

For the check: $\sigma_{s,w,d} \leq \frac{f_y}{0.9*1.5}$

$$\sigma_{s,w,d} = 21.4 \leq \frac{355}{0.9 * 1.5} = 263\ [N/mm^2]$$

The welding and the section are acceptable for the required load.

3.3 Final Design

The location of the structures are to remain the same as current positioning. The extra length is to be welded on site in order to reduce implementation time, avoiding removal and transportation of the foundation pile.

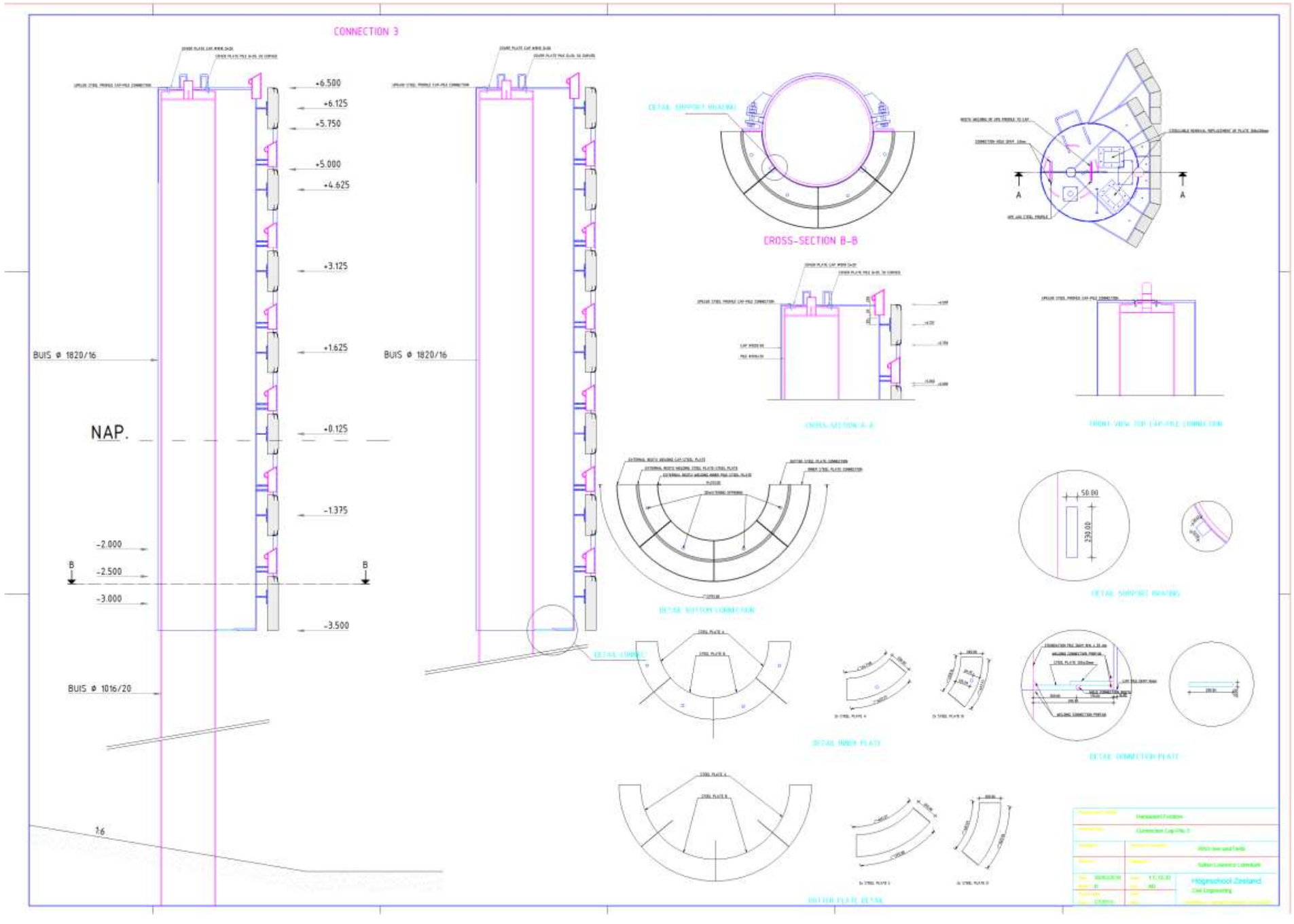


Figure 8 Drawing of Hansweert Dolphin final design.

4 Discussion & Conclusion

This design has been chosen in order to fit in with the clients requirements based on the lowest implementation time possible with a success solution for the problem. With the proposed design this goal is reached.

Further inspection regarding the condition of the foundation pile is advised in order to assure the low corrosion rate used in this method.

In addition, a finite-element analysis is also advised in order to check the structure in its functionality as suggested by the guideline NIC (Smits & Meijerink, Handreiking rekenmethodieken NIC, 2005).

5 Bibliography

CUR. (2014). *CUR Rapport 166:2012.* BRISwarenhuis.

DINOloket. (2018, March 3). *Ondergrondsgegevens*. Retrieved from DINOloket Data en Informatie van de Nederlandse Ondergrond: http://www.dinoloket.nl

EAU. (2012). *Recommendations of the Committee for Waterfront Structures Harbours and Waterways EAU 2004.* Arbeitsausschuss.

Fraanje, M. J. (1968). Waterbouwkunde Deel 1 Algemene Waterbouwkunde. In M. B. Bolderman, & A. W. Dwars, *Waterbouwkunde* (pp. 443-481). Amsterdam: L.J.Veebs Uitgeversmaatschappij N.V.

NEN-EN. (2008). *NEN-EN 1993-5 Eurocode 3: Design of steel structures - Part 5 Piling.* NEN-EN.

NEN-EN. (2011). *NEN-EN 1990+A1+A1/C2 Eurocode 1: Basis of Structural design.* NEN.

NEN-EN. (2011). *NEN-EN 1991-2+C1:Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges.* Rijksoverheid NEN Connect.

NEN-EN. (2016). *NEN-EN 1997-1+C1+A1/NB National Annex to NEN-EN 1997-1 Eurocode 7: Geotechnical design Part 1: General Rules.* NEN-EN.

PIANC. (2002). *Guidelines for the Design of Fender Systems : 2002.* Brussels: PIAN General Secretariat.

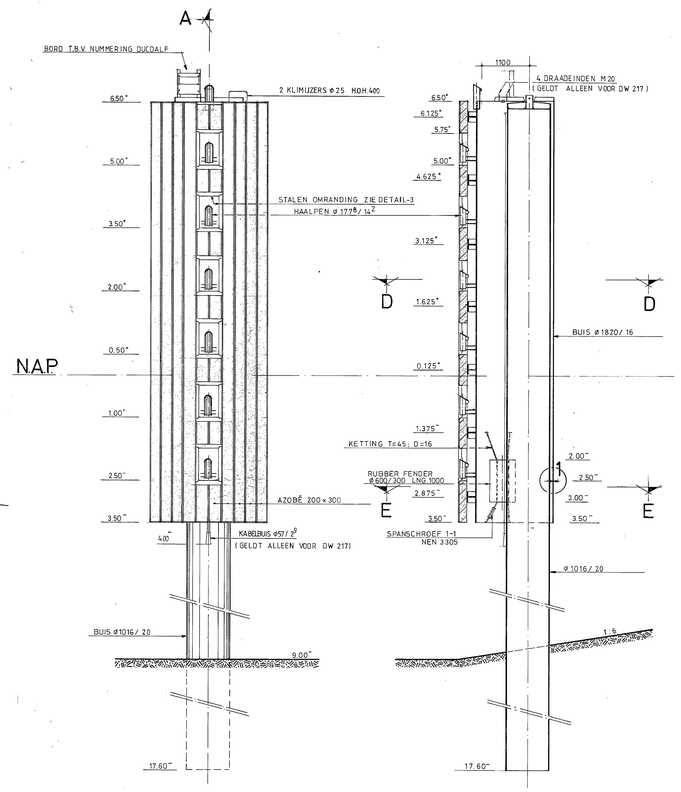
Rijkswaterstaat. (2017). *Richtlijnen Ontwerp Kunstwerken ROK 1.4.* RWS GPO.

RWS. (2017). *Richtlijnen Vaarwegen 2017: Kader verkeerskundig vaarwegontwerp.* Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat.

Smits, G. T., & Meijerink, C. W. (2005). *Handreiking rekenmethodieken NIC.* Directoraat-Generaal Rijkswaterstaat.

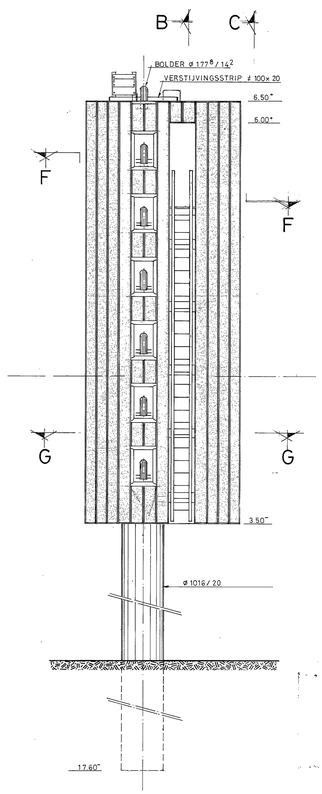
Appendix IX Drawings

Appendix IX.I – Original As-Built Drawings

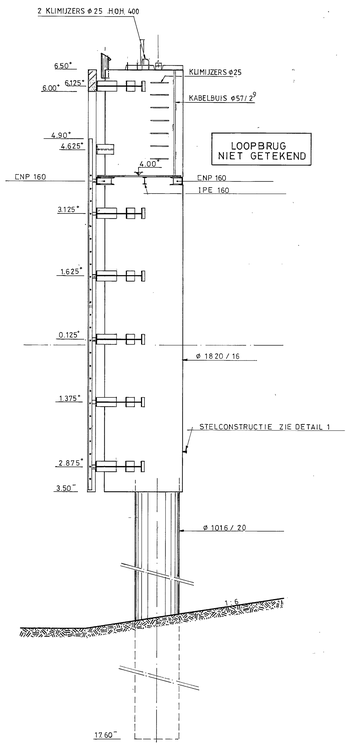


VOORAANZICHT 1:50
ZONDER LOOPBRUG
12 x UITVOEREN

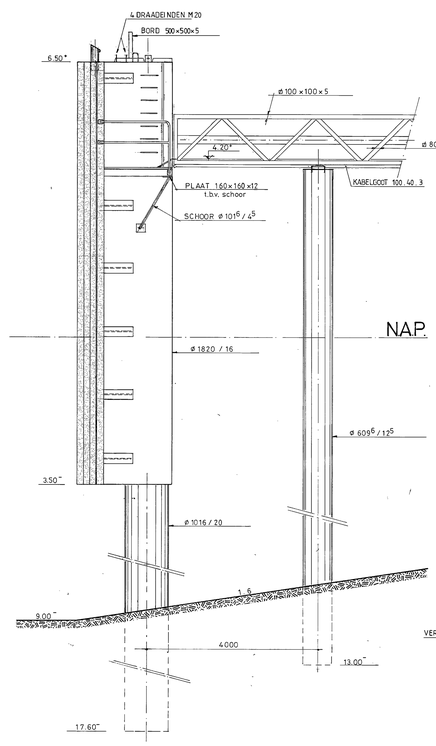
DOORSNEDE A 1:50



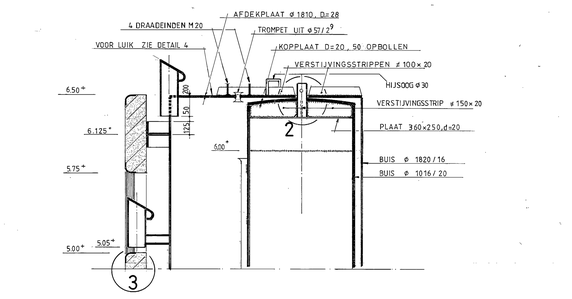
VOORAANZICHT 1:50
MET LOOPBRUG
6 x UITVOEREN



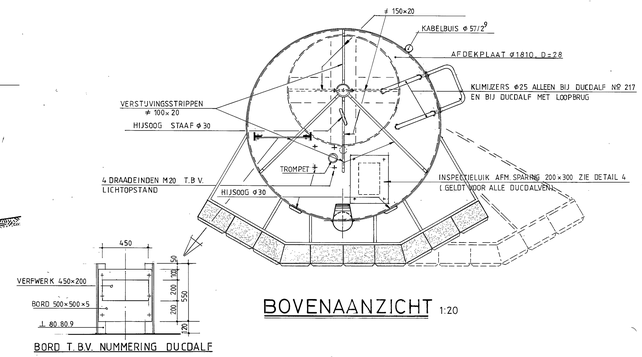
DOORSNEDE B 1:50



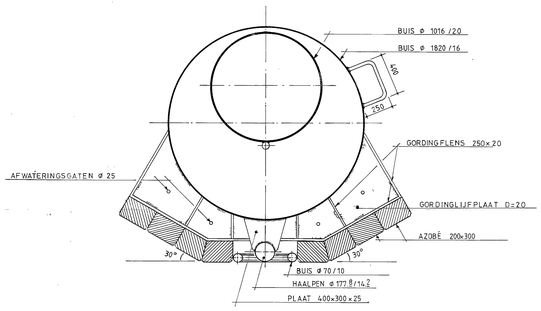
AANZICHT C 1:50



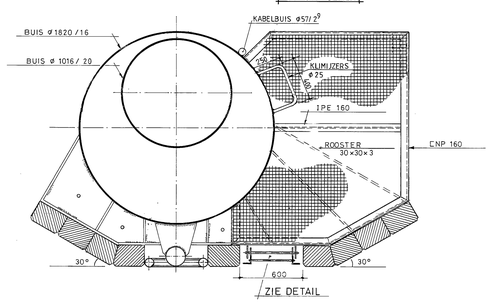
KOPKONSTRUCTIE 1:20



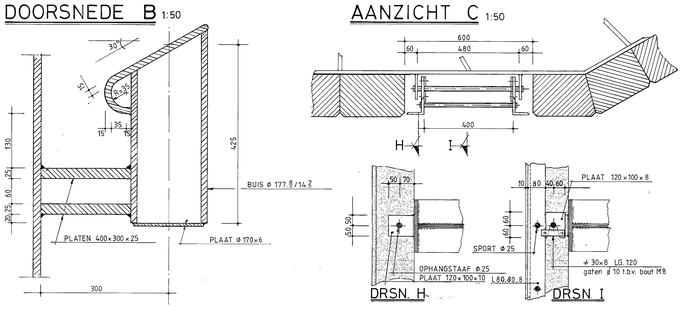
BOVENAANZICHT 1:20



DOORSNEDE D 1:20

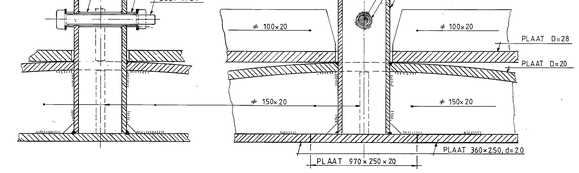


DOORSNEDE F 1:20



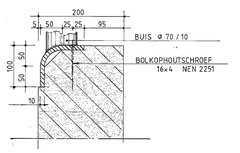
DETAIL HAALPEN 1:5

DETAIL LADDER 1:10

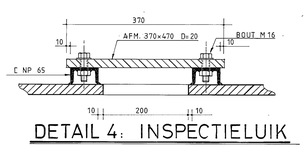


DRSN. J

DETAIL 2 1:5



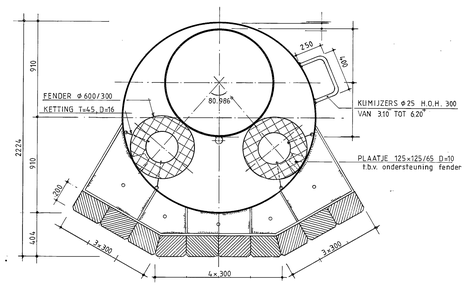
DETAIL 3 1:5



DETAIL 4: INSPECTIELUIK

OPMERKINGEN

- maten in mm.
- hoogtematen in meters t.o.v. N.A.P.
- alle lassen a=5, tenzij anders aangegeven



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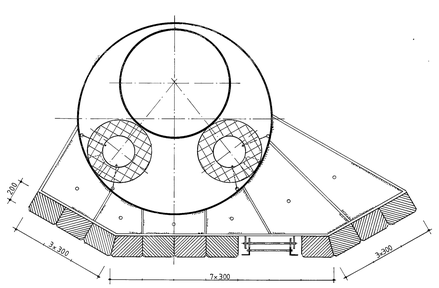
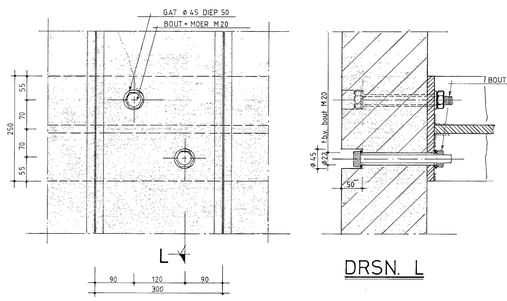
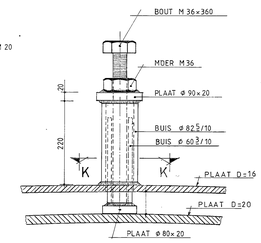


DOORSNEDE G 1:20

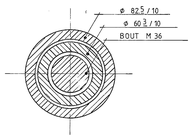


DETAIL HOUTBEVESTIGING 1:5

DRSN. L



DETAIL 1 1:5



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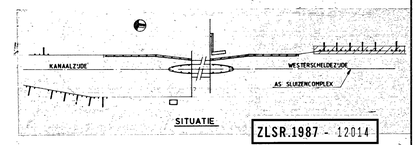


ZLSR.1987 - 12014

RIJKSWATERSTAAT DIRECTIE SLUIZEN EN STUWEN
Rijkskantorengebouw, Westraven Utrecht-Z. Postbus 20000 Code 3502 LA Tel. 030 - 859111

De hfd. ingenieur in alg. dienst:
De technisch inspecteur:

T.B.V. DIRECTIE ZEELAND

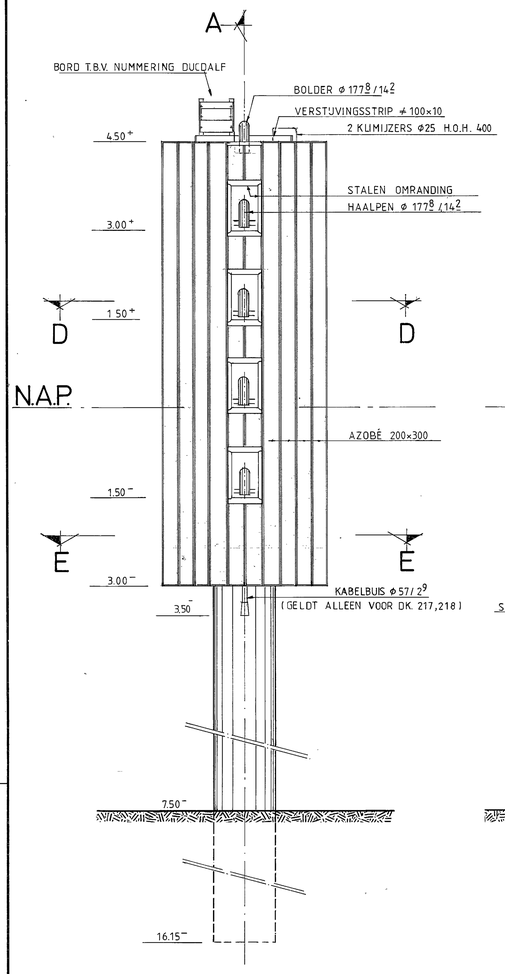
TOELEIDINGSWERKEN HANSWEERT

ducdalven westerscheldezijde

gel.: m.v. goethem					1/87	BESTEK SS 1239 — BLAD 5 VAN 15 BLADEN
gez.:					1/87	Schaal: 1:50 ; 1:20 ; 1:10 ; 1:5 ; 1:2.
gew.:	A	B	C	D		DIENST 1987 - 1988 — Ao SSSE — HWG-114

2LSR. 1987- 12015 HWG. 115

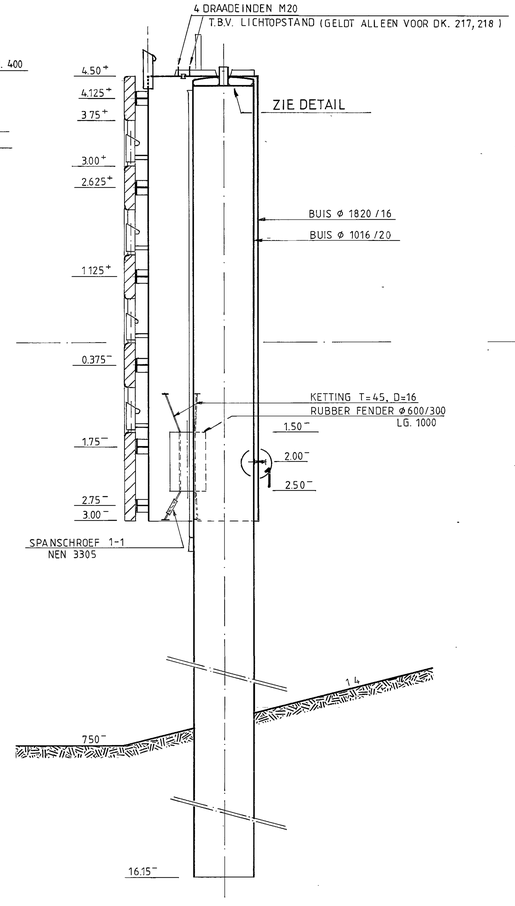
-S-1239



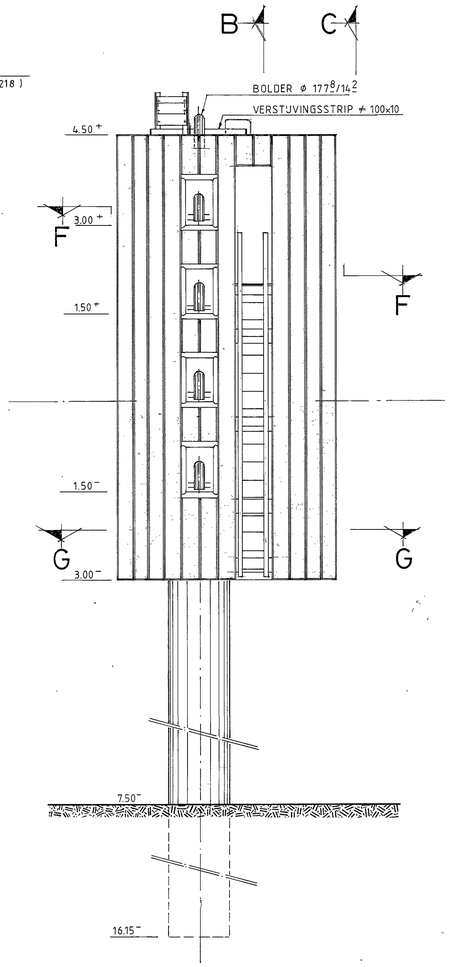
VOORAANZICHT 1:50

ZONDER LOOPBRUG

15 x UITVOEREN



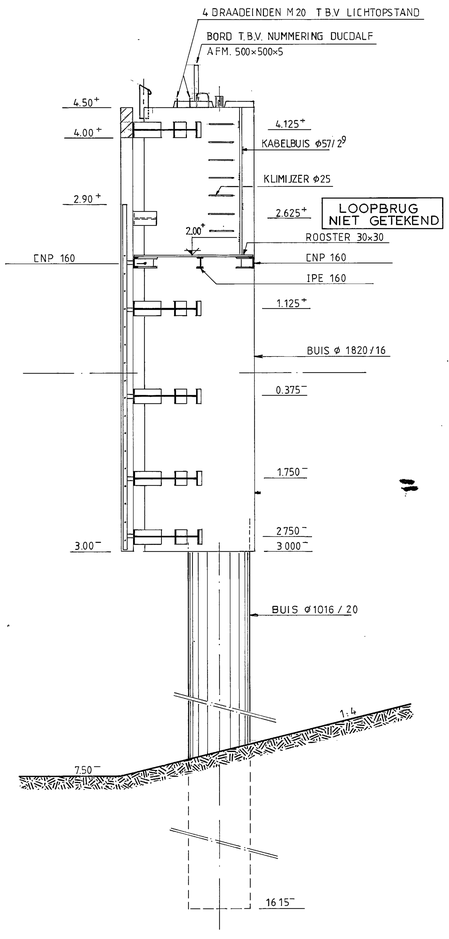
DOORSNEDE A 1:50



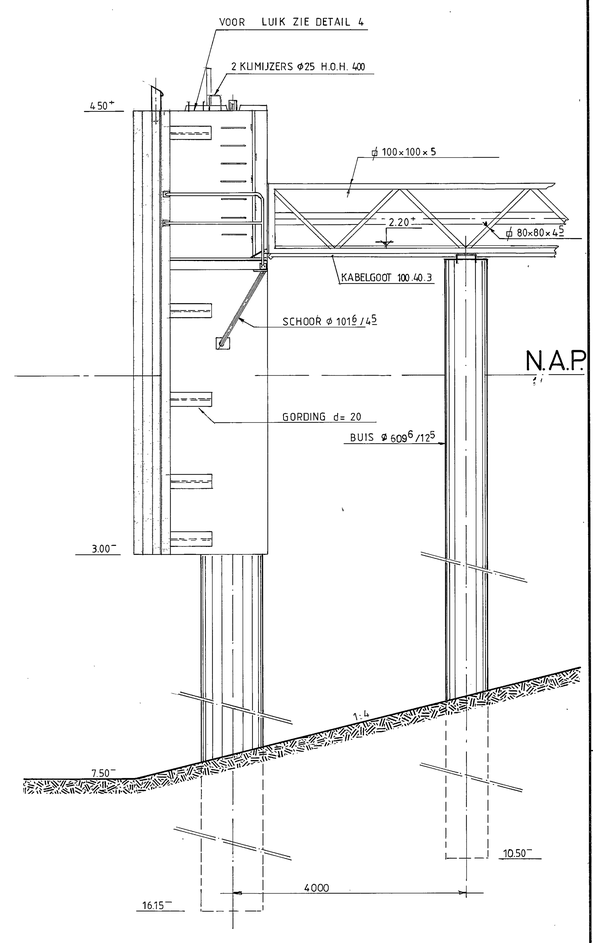
VOORAANZICHT 1:50

MET LOOPBRUG

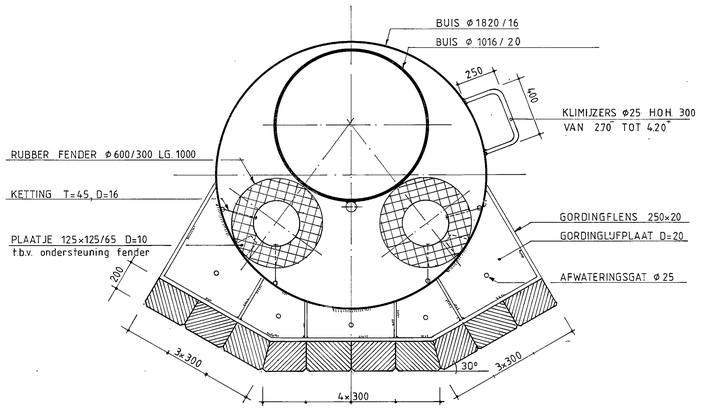
7x UITVOEREN



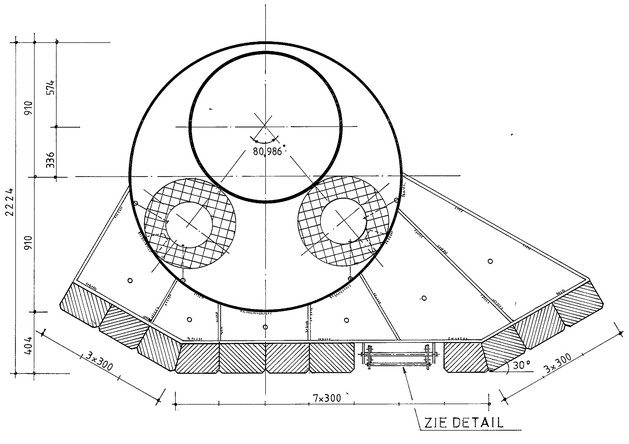
DOORSNEDE B 1:50



AANZICHT C 1:50



DOORSNEDE E 1:20



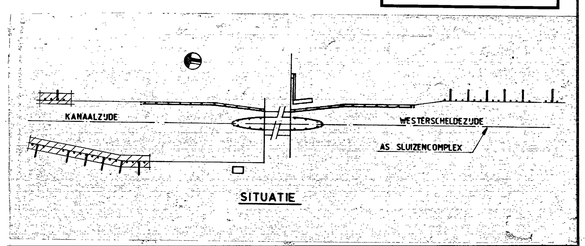
DOORSNEDE G 1:20

voor overige details
en doorsneden zie
tekening HWG-114

OPMERKINGEN

-maten in mm.
-hoogtematen in meters t.o.v. N.A.P.
-alle lassen a=5, tenzij anders aangegeven

ZLSR.1987 - 12015



RIJKSWATERSTAAT DIRECTIE SLUIZEN EN STUWEN

Rijkskantorengebouw Westraven Utrecht-Z. Postbus 20000 Code 3502 LA Tel. 030-859111

De hfd. ingenieur in alg. dienst:

De technisch-inspecteur:

T.B.V. DIRECTIE ZEELAND

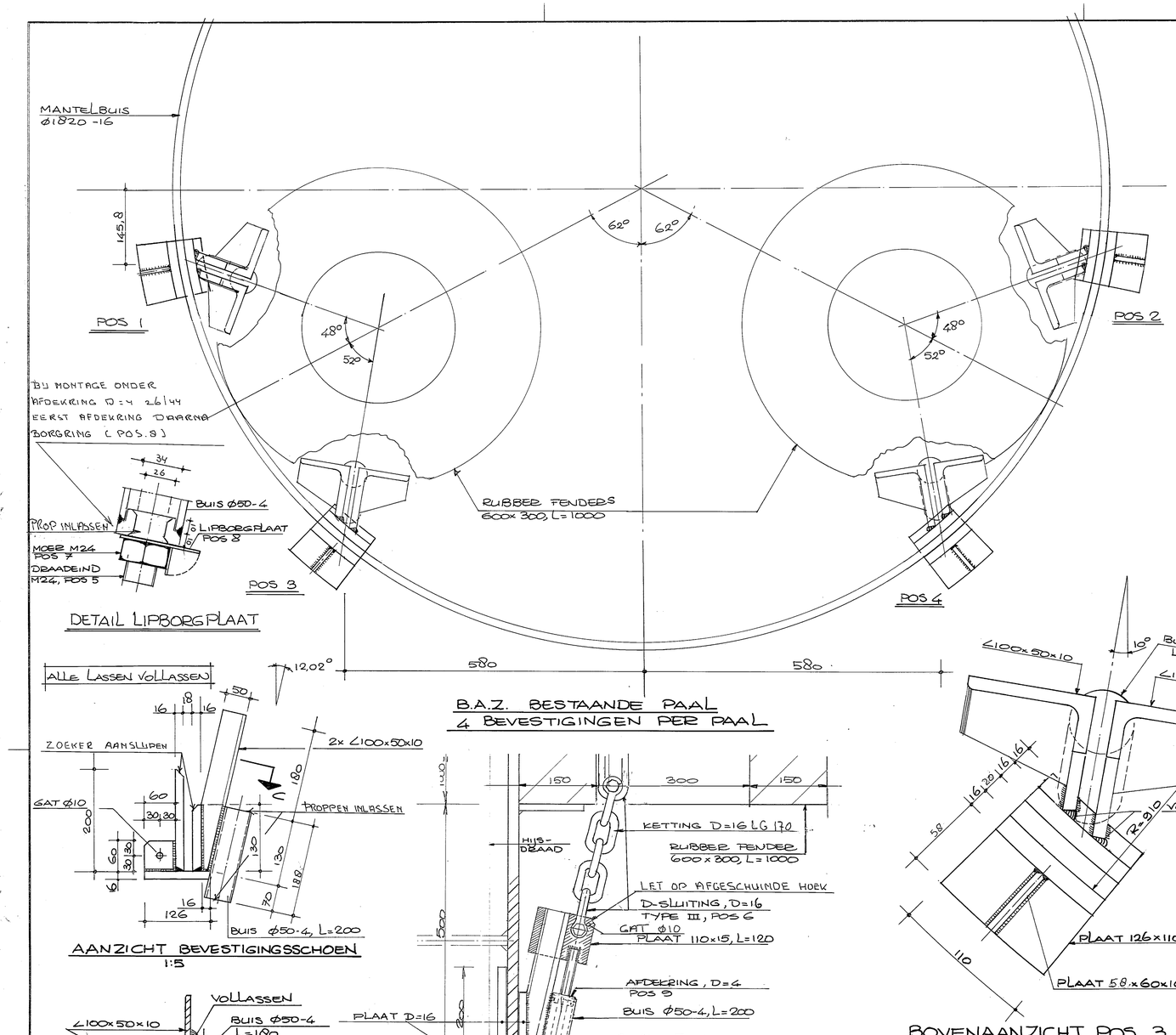
TOELEIDINGSWERKEN HANSWEERT

ducdalven kanaalzijde

get.: m.v. goethem	1/87	BESTEK SS 1239	BLAD 6 VAN 15 BLADEN
gez.:	1/87	Schaal: 1:50 ; 1:20.	
gew.: A B C D		DIENST 1987-1988	A1 SSSE HWG-115

Appendix IX.II – Modifications Drawings

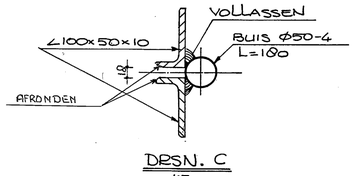
A1 ZLSR 1990 -2084



DETAIL LIPBORGPLAAT

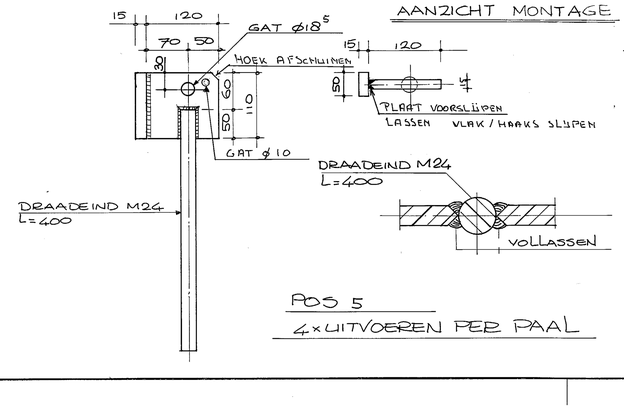
B.A.Z. BESTAANDE PAAL
4 BEVESTIGINGEN PER PAAL

AANZICHT BEVESTIGINGSSCHOEN
1:5



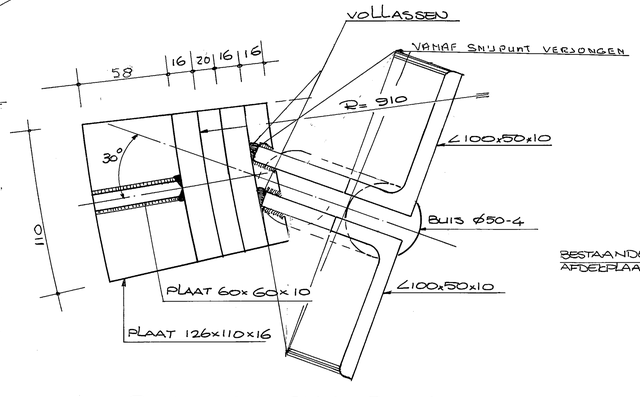
DRSN. C
1:5

AANZICHT MONTAGE

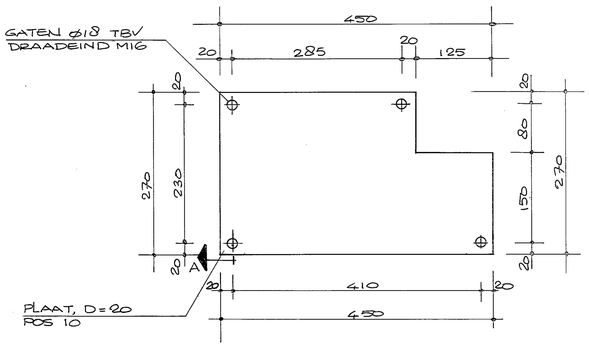


POS 5
4x UITVOEREN PER PAAL

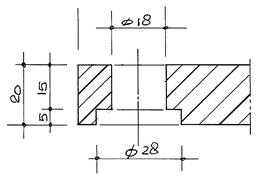
BOVENAANZICHT POS 3
B.A.Z. POS 4 IN SPIEGELBEELD
1:2



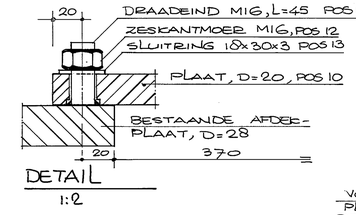
BOVENAANZICHT POS 1
B.A.Z. POS 2 IN SPIEGELBEELD
1:2



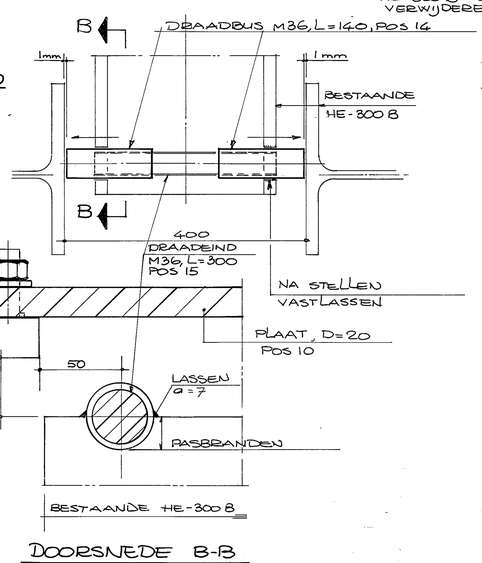
POS 10
1x UITVOEREN PER PAAL
1:5



DRSN. A-A
1:1



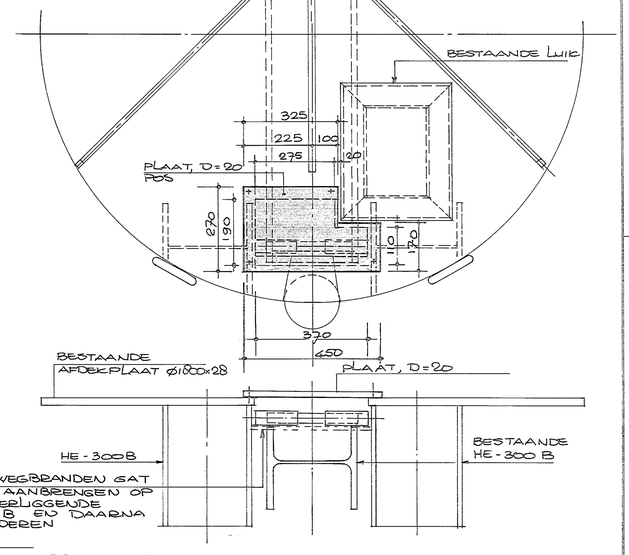
DETAIL
1:2



DOORSNEDE B-B
1:2

POS NR.	AFMETINGEN	STAALKW.	AANTAL	GEW./STUK IN KG	TOTAAL
1 t/m 4	PLAAT 126 x 110 x 16	Fe 360	4	1.74	6.96
	PLAAT 200 x 110 x 16	Fe 360	4	2.76	11.04
	PLAAT 130 x 110 x 16	Fe 360	4	1.80	7.2
	PLAAT 60 x 60 x 10	Fe 360	4	0.28	1.12
	∟ 100 x 50 x 10, l=310	Fe 360	8	2.80	22.4
	BUIS ϕ50 x 4	Fe 360	4	2.37	9.48
5	PLAAT 120 x 110 x 15	Fe 360	4	1.55	6.2
	PLAAT 110 x 50 x 15	Fe 360	4	0.65	2.60
	DRAADEIND M24	8.8	4	1.20	4.80
6	D-SLUITING, D=16 TYPE III	8.8	8	0.80	6.40
7	ZESKANTMOER M24	8.8	4	0.10	0.40
8	LIPBORGPLAAT VOOR M24	8.8	4	0.014	0.06
9	AFDEKRING, D=4	Fe 360	8	0.04	0.32
10	PLAAT 270/150 x 450/325	Fe 360	1	17.11	17.11
11	DRAADEIND M16, L=45	8.8	4	0.07	0.28
12	ZESKANTMOER M16	8.8	4	0.03	0.12
13	SLUITRING 18 x 30 x 3	8.8	4	0.011	0.044
14	DRAADBUS M36, L=140	8.8	2	0.75	1.50
15	DRAADEIND M36, L=300	8.8	1	2.07	2.07
16	D-SLUITING, D=7 TYPE III	8.8	4	0.50	2.00
17	KETTING D=16 LG 170	8.8	4	0.97	3.88
	TOTAAL GEWICHT PER PAAL				105,984

OPMERKING
TOTAAL GEWICHT VOOR 39 PALEN: 4133,376 KG



OPMERKINGEN :
- ALLE MATEN IN MM.
- ALLE MATEN IN HET WERK TE CONTROLEREN.
- TIJDENS BRANDEN PLAAT AANBRENGEN TER BESCHERMING ONDERLIGGENDE CONSTRUCTIE EN DAARNA WEER VERWIJDEREN.

BEHANDELING :

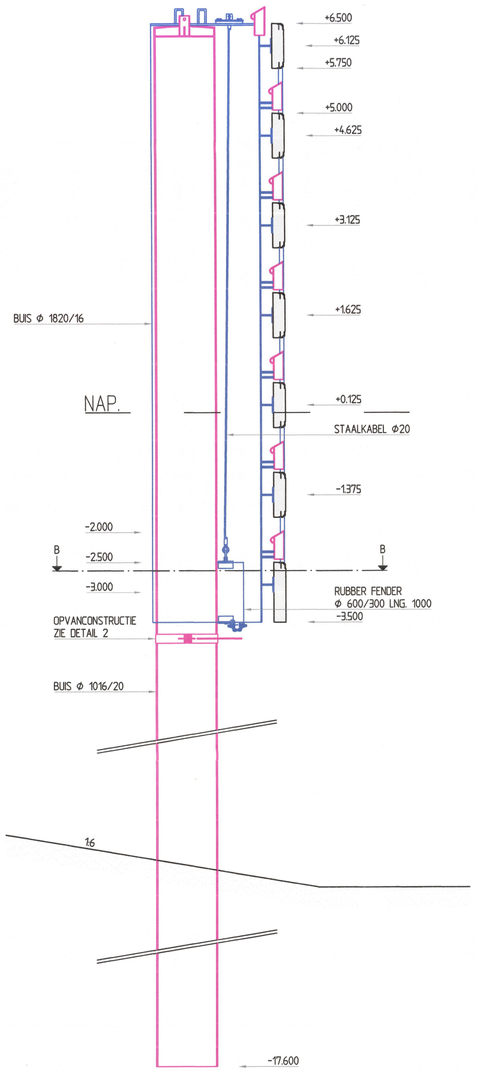
BESTAANDE CONSTR.:
- BESCHADIGING IN CONSERVERING BIJWERKEN : DOOR BORSTELEN MET STAALBORSTEL, VERWIJDEREN VAN DE NOG AANWEZIGE CONSERVEERLAAG RONDOM DE BESCHADIGINGEN EN VERVOLGENS TWEE-COMPONENTENVERF OP BASIS VAN TEEREPOXYHARS

NIEUW STAALWERK :
- STRALEN VOLGENS ZWEEDSE NORM SIS - 05-5900/1967, GRAAD SA 2½
- TWEE-COMPONENTEN GRONDVERF OP BASIS VAN EPOXYHARS
- 2x TWEE-COMPONENTENVERF OP BASIS VAN EPOXYHARS

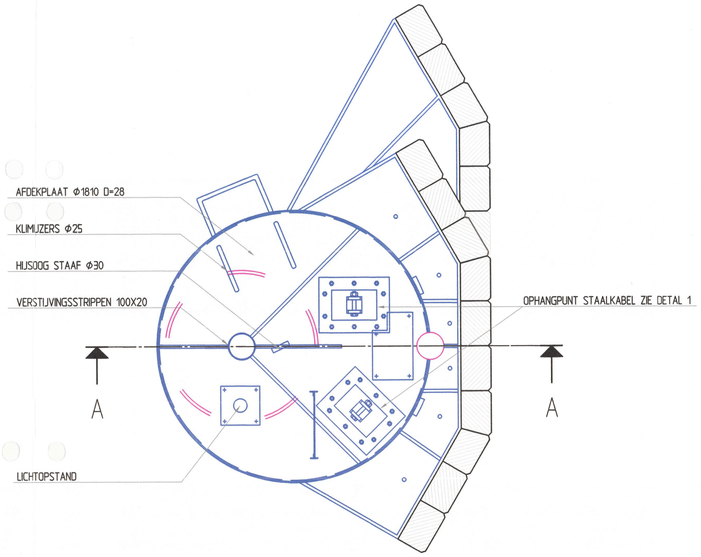
GEWIJZIGDE VERSIE VAN HWG 620A

rijkswaterstaat directie zeeland		DIENSTKRING SCHELDE RIJN	
TOELEIDINGSWERKEN HANSWEERT BEVESTIGING RUBBER FENDER EN OPHEFFEN SPELING EN ZEKERING MANTEL T.B.V. DUC-DALVEN			bestek KANZBX-600-304
getekend	d.d.	schaal	
gecontr.	d.d.	in bladen	blad nr.
accoord	d.d.	A 1	ZLSR 1990 - 2084
gezien	d.d.		

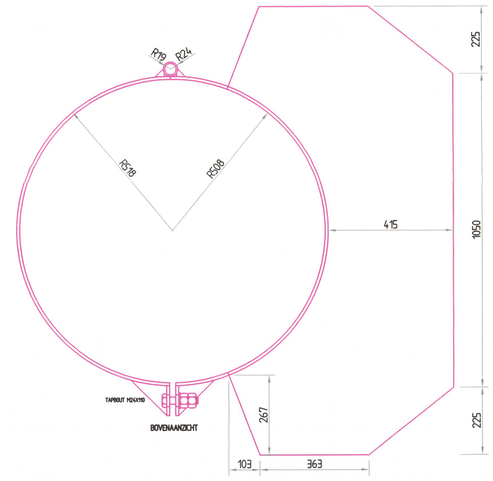
C Meerstoelen



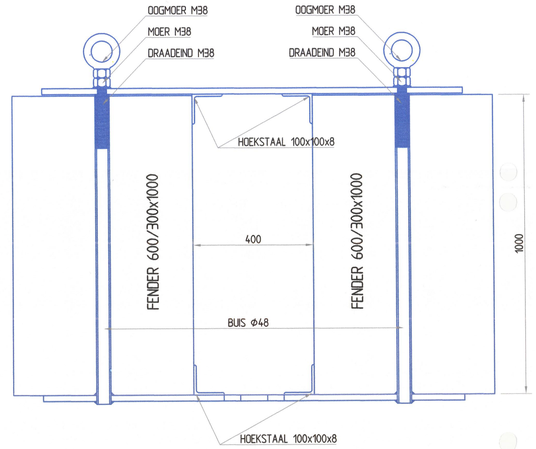
DOORSNEDE A-A 1:50



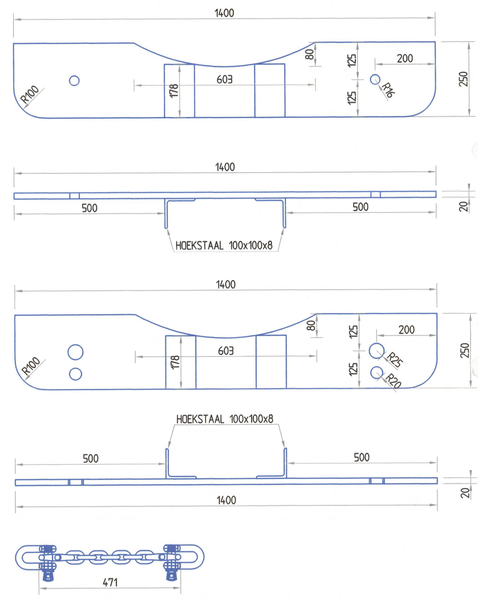
BOVENAANZICHT 1:20



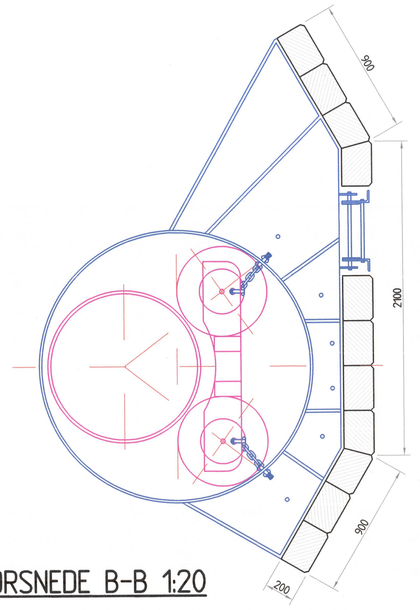
DETAIL 2 OPVANGCONSTRUCTIE 1:10



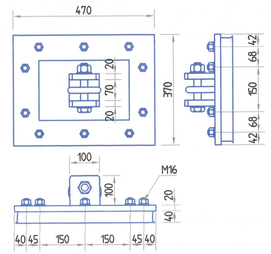
DETAIL FENDERS 1:10



DETAIL BEVESTIGINGSPLATEN FENDERS 1:10



DOORSNEDE B-B 1:20



DETAIL1 OPHANGPUNT STAALKABEL 1:5

FENDERCONSTRUCTIE	
2	FENDERS 600/300x1000
2	STAAL STRIP S235 250x1400x20
4	HOEKSTAAL 100x100x8 S235 LENGTE 178MM
2	BUISPROFIEL Φ48MM S235 LENGTE 1035MM
2	DRAADEIND M38 8.8 LENGTE 265MM
4	MOER M38 8.8
2	OOGMOER M38 8.8
2	FENDERS 600/300X1000
2	STAALKABEL LENGTE 8800MM Φ20 TREKSTERKTE 1960 n/mm2 MET 2 SUPERLOOP GEKLEMDE BUIZEN
OPVANGCONSTRUCTIE	
1	STAAL STRIP 150x3500x20 S235
1	STAAL STRIP 750x1500x15 S235
1	STAALSTRIP 150x100x10 S235
1	BUISPROFIEL Φ48MM S235 LENGTE 150MM
1	BOUT M30 8.8 LENGTE 290MM
2	BOUT M24 8.8 LENGTE 110MM
2	MOER + RING M30 8.8
4	MOER + RING M24 8.8
FIXATIE KETTING	
4	VERBINDINGSCHALM 13-8
2	KETTING 13-8 lengte 300mm
4	Green Pin sluiting 6,5TN

STUKLIJST

nr.	omschrijving wijziging	datum	paraaf
1	Aanpassing naar RTW	27-08-2012	

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

dienst Zeeland

Rijkswaterstaat dienst Zeeland

bureau uitbesteding

Project
Waterdistrict Zeeuwse Delta
Zijdelings gewisseld

akk. RWS
datum

Onderdeel
Fender opvangconstructie C21, C22, C24, C35, C36, en C37 HWS

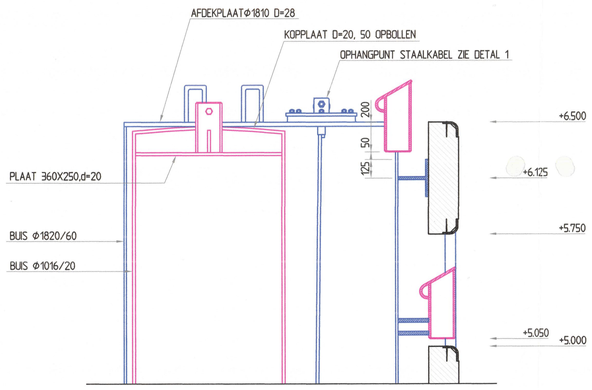
behoort bij RWSZL-2011-04940 in 1 bladen, bladnr.

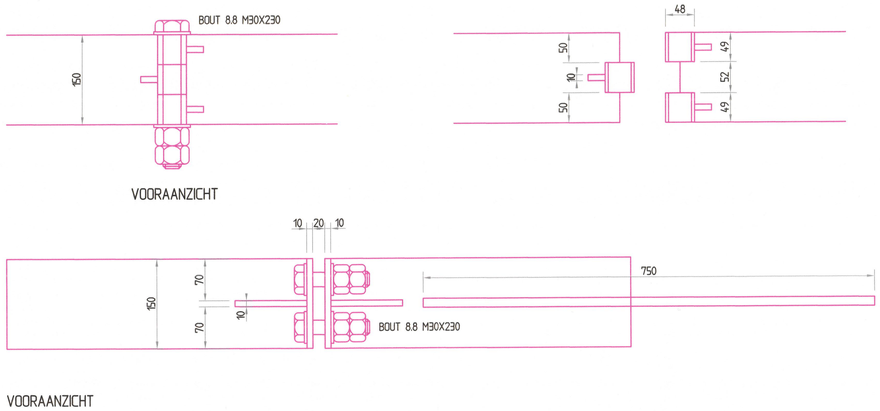
getekend	P. v/d Aker	22-3-2012	projectcode ZLD-6496
gecontroleerd	C. Bosschaart	28-8-2012	dossiercode
uitgegeven	M. Kooman	28-8-2012	dienstcode

tekening
formaat A1
schaal 150/120/110/15

status Ter Controle | versie B | reg.nr. RWSZD-2014-02374

KOPCONSTRUCTIE 1:20





DETAIL OPVANGCONSTRUCTIE FENDERS 1:10

Appendix IX.III – Connection Options Drawings

Hansweert Dolphins Overview PILE-CAP Connection Solutions

Legenda

Geometrie	Omschrijving	Status
	-	Bestaand
	Paal	Bestaand
	Stalen gording	Bestaand
	Kunstof-staal verbinding	Nieuw
	Staalplaat	Bestaand
	Staalplaat	Nieuw
	Lasverbinding	Nieuw

Symbool	Omschrijving	Status
[	Profiel UPE 400	Nieuw

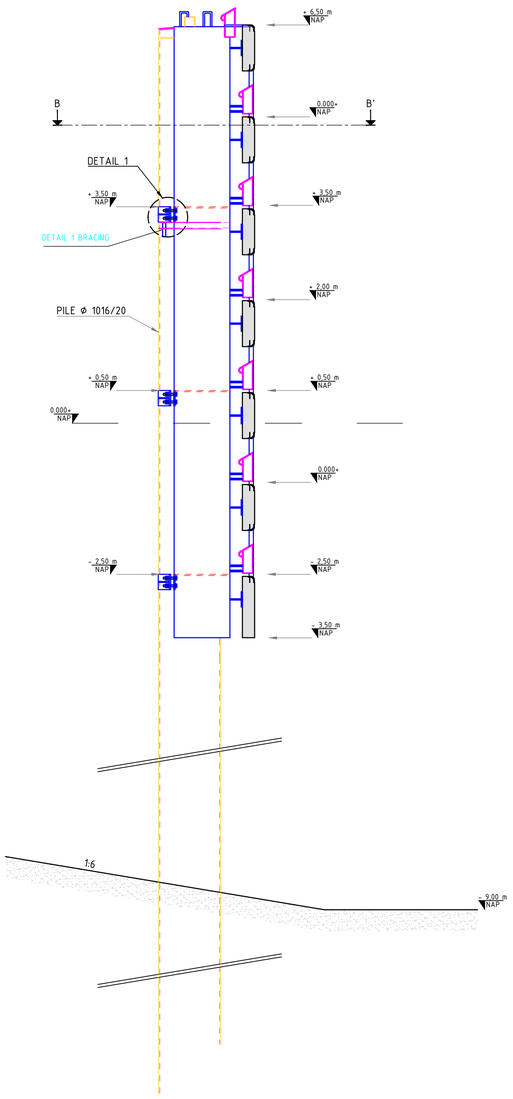
NOTES

All dimensions are expressed in mm.

MATERIAL LIST

QUANTITY PER DOLPHIN	MATERIAL DESCRIPTION

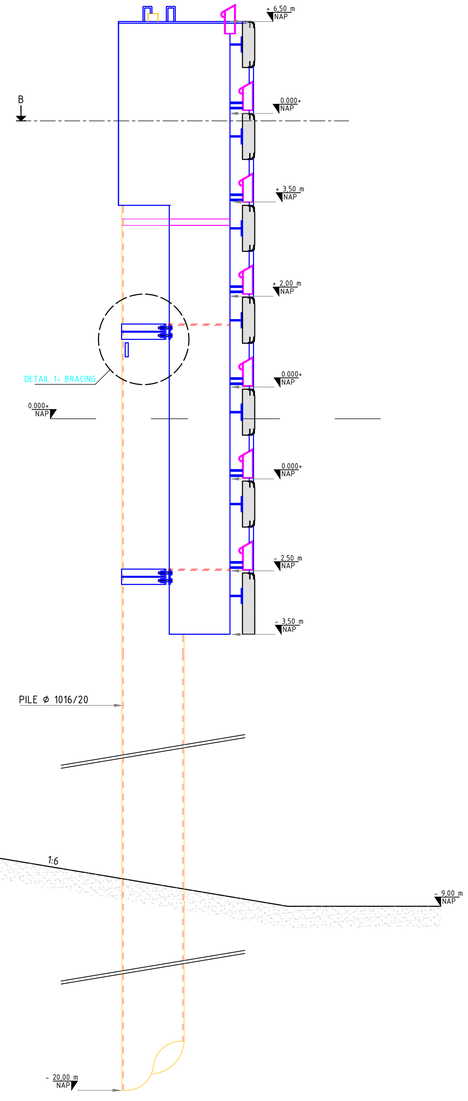
CONNECTION 1



SIDE VIEW CONNECTION 1

SCALE 1:50

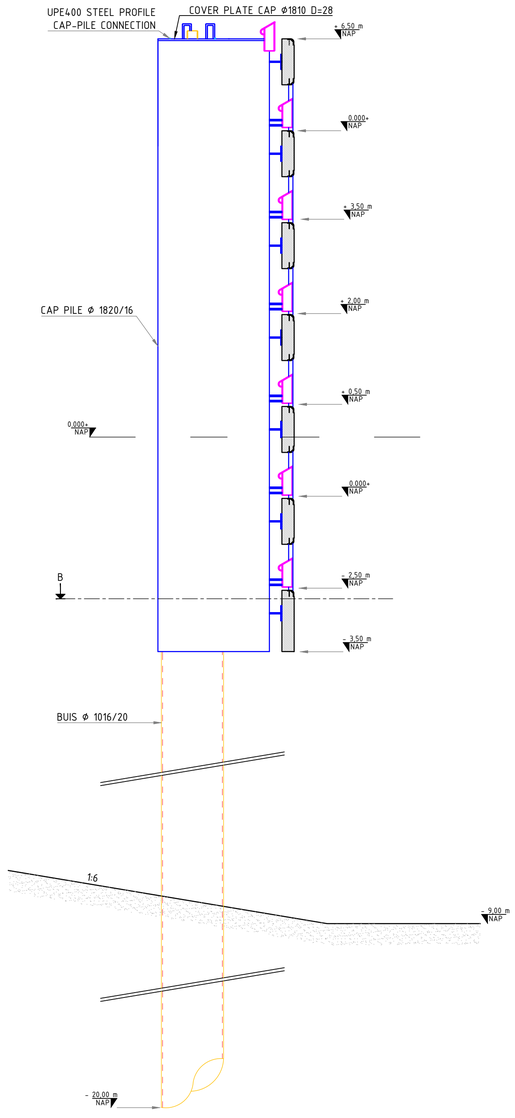
CONNECTION 2



SIDE VIEW CONNECTION 2

SCALE 1:50

CONNECTION 3

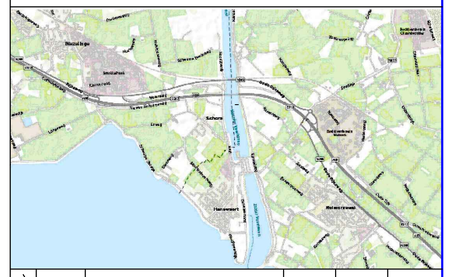


SIDE VIEW CONNECTION 3

SCALE 1:50

REFERENCE DRAWINGS	
DRAWING NO.	DRAWING NAME
RWSZD-2014-02374	Fenders opvangconstructie meerstoelen C21,C22,C24,C35,C36 en C37 Hansweert
ZLSR-1987-12015	Toeleidingswerken hansweert ducdalven kanaalzijde
ZLSR-1987-12015	Toeleidingswerken hansweert ducdalven kanaalzijde

PROJECT LOCATION



REV.	DATE	DESCRIPTION	PREPARATION	REVIEW	APPROVAL
A	10.06.2018	FOR APPROVAL	SLO	SLO	-

CLIENT: RIJKSWATERSTAAT SEA AND DELTA

PROJECT NAME: FENDERS HANSWEERT

CONTRACTOR: HZ UNIVERSITY OF APPLIED SCIENCES

TITLE	DETAILED DESIGN DOLPHINS HANSWEERT - WESTERN SCHELDT OVERVIEW CONNECTION OPTIONS				
PROJECT CODE	DRAWING NO.	SHEET	SIZE	REV.	SCALE
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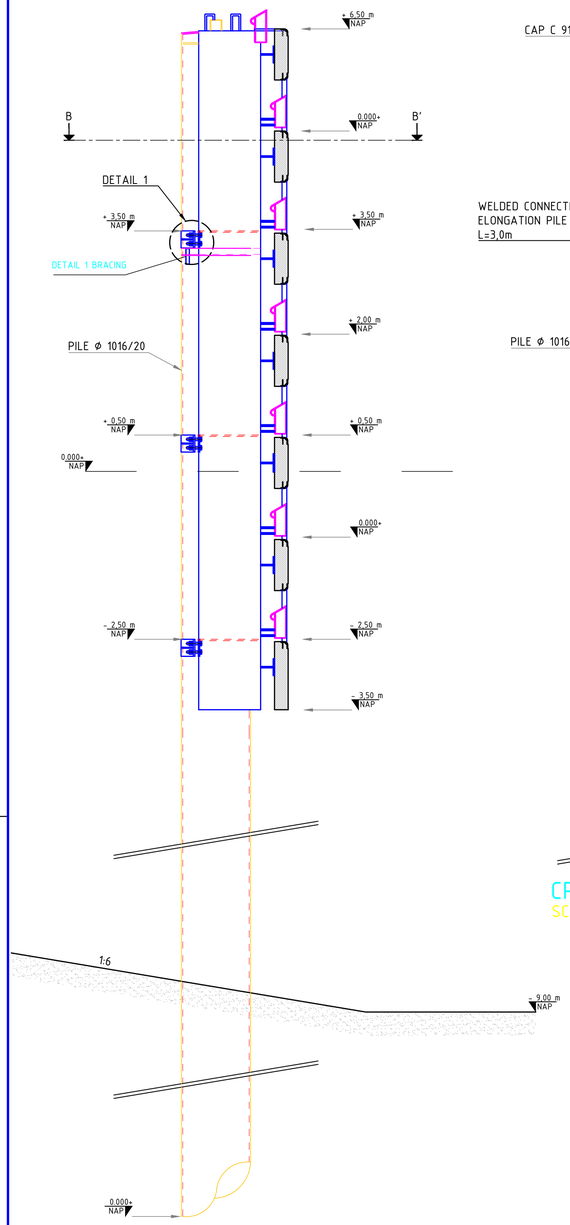
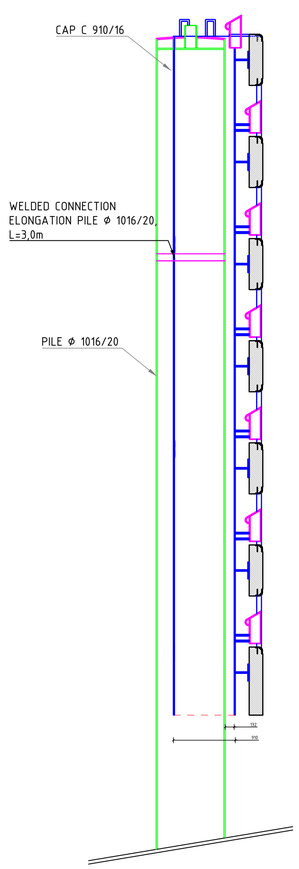
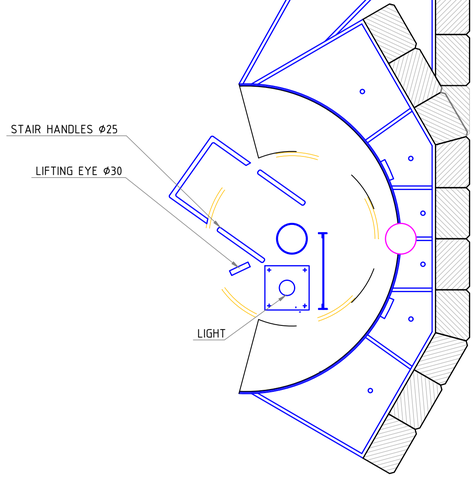


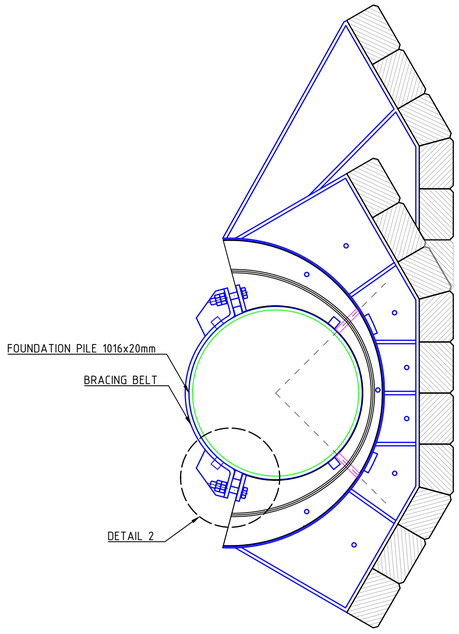


CROSS SECTION A-A CONNECTION 1
SCALE 1:50

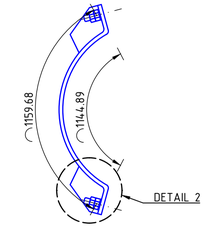
SIDE VIEW CONNECTION 1
SCALE 1:50



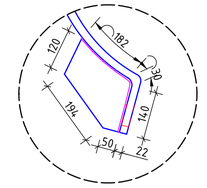
TOP VIEW CONNECTION 1
SCALE 1:20



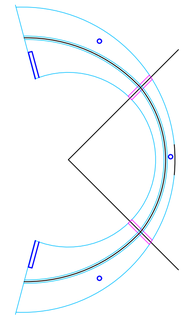
CROSS-SECTION B-B
CONNECTION1
SCALE 1:20



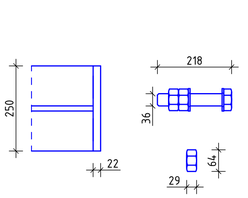
DETAIL - BRACING RING
CONNECTION 1
SCALE 1:20



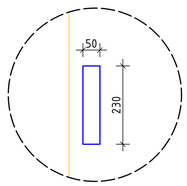
DETAIL 2- CONNECTION BRACING
SCALE 1:10



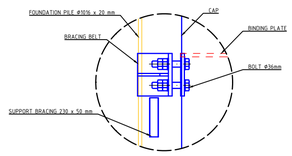
ASSEMBLAGE BINDING PLATE



DETAIL BOLT AND BELT



DETAILS SUPPORT BRACING



DETAIL 1-BRACING
CONNECTION 1
SCALE 1:20

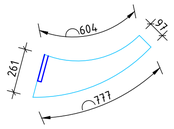


PLATE A

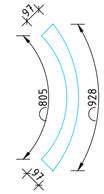


PLATE B

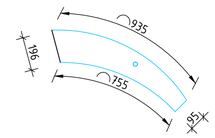


PLATE C

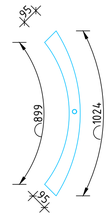


PLATE D

PLATE A'

DETAIL BINDING PLATE
3x with bracing
CONNECTION 1
SCALE 1:20

	Staalplaat
	Staalplaat
	Lasverbinding

NOTES

All dimensions are expressed in mm.
Plates A', B', C' and D', are mirrors of the respective plates
Level of plates fixation to be determined on the field.

MATERIAL LIST

QUANTITY PER DOLPHIN	MATERIAL DES
6 UNITS	BOLT 36mm
18 UNITS	NUT for bolt 4(
1 UNIT	STEEL PLATE A
1 UNIT	STEEL PLATE B
1 UNIT	STEEL PLATE A
1 UNIT	STEEL PLATE B
2 UNITS	BRACING SUPPO
3 UNITS	BRACING C ø 19

REFERENC	
DRAWING NO.	
RWSZD-2014-02374	Fenders opvangcons
ZLSR-1987-12015	Toeleidinswerke
ZLSR-1987-12015	Toeleidinswerke

PROJECT LOCATION

REV.	DATE	DESCRIPTION
1	10.06.2018	FOR APPROVAL

CLIENT:

PROJECT NAME:

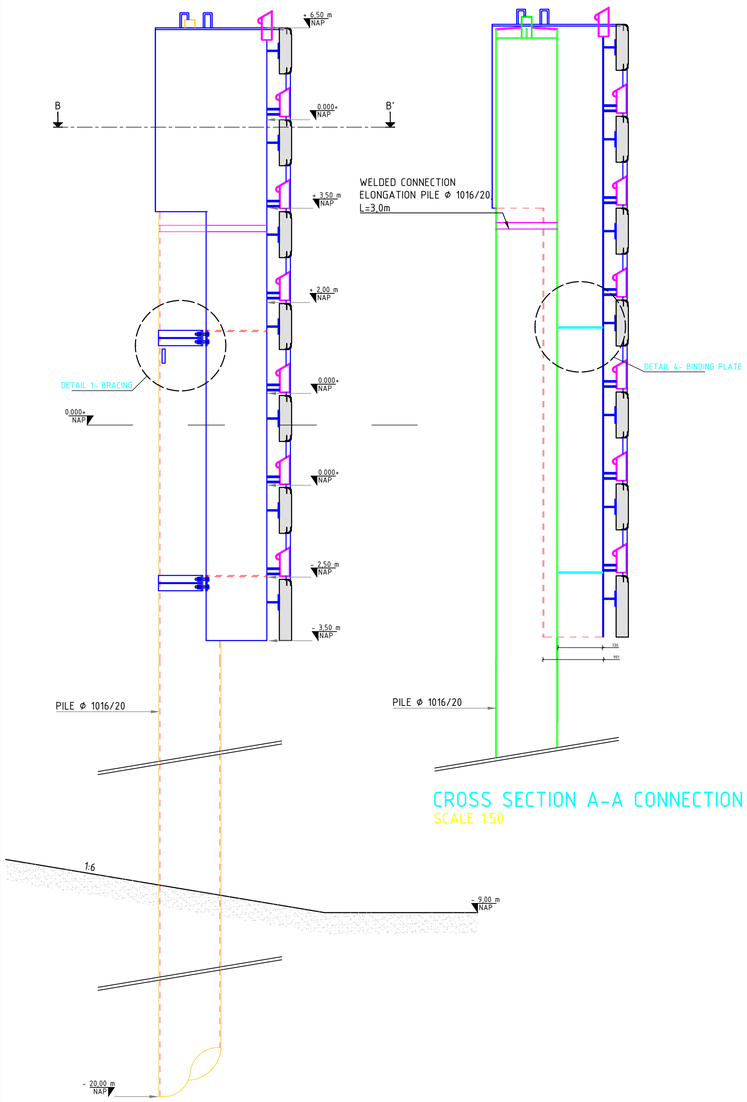
CONTRACTOR:
HZ UNI

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

TITLE	DI DOLPHINS HANS CON
PROJECT CODE	DRAWING NO.
48H-353	- -

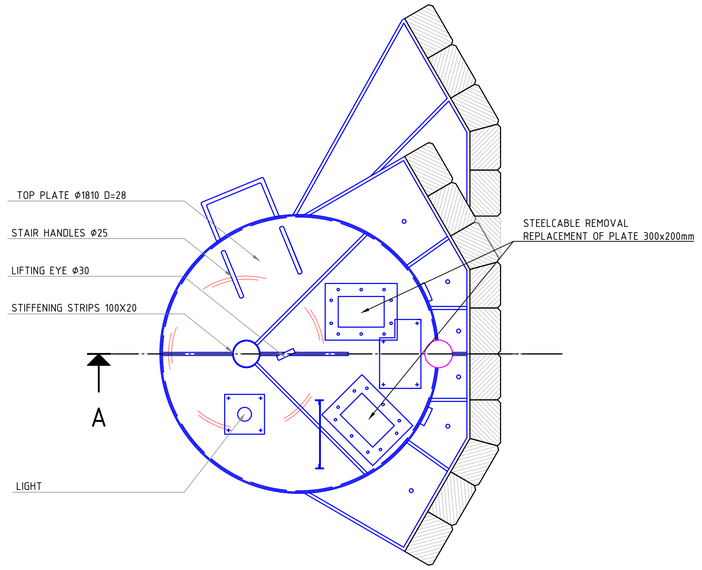
Hansweert Dolphins Solution Connection 2

CONNECTION 2



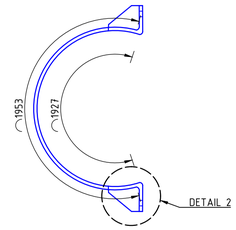
CROSS SECTION A-A CONNECTION 2
SCALE 1:50

SIDE VIEW CONNECTION 2
SCALE 1:50

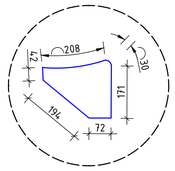


TOP VIEW CONNECTION 2
SCALE 1:20

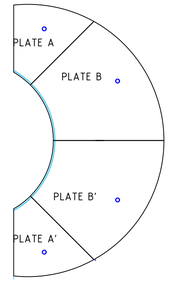
CROSS-SECTION B-B' CONNECTION 2
SCALE 1:20



DETAIL - BRACING RING CONNECTION 2
SCALE 1:20



DETAIL 2- CONNECTION BRACING
SCALE 1:10



ASSEMBLAGE BINDING PLATE

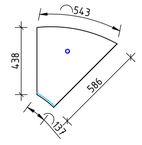


PLATE A, 20mm

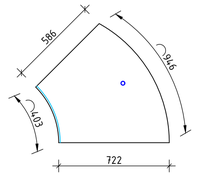


PLATE B, 20mm

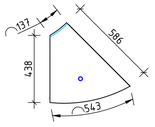


PLATE A', 20mm

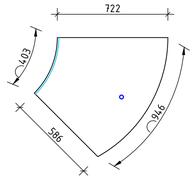
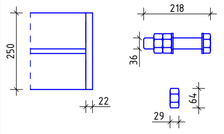
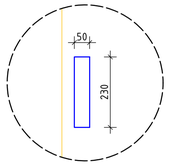


PLATE B', 20mm

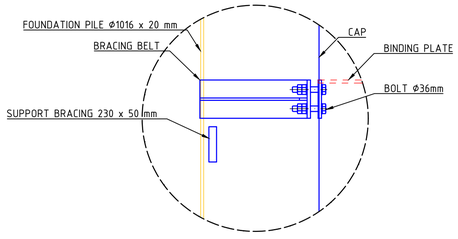
DETAIL 4 - BINDING PLATES CONNECTION 2
SCALE 1:20



DETAIL BOLT AND BELT



DETAILS SUPPORT BRACING



DETAIL 1-BRACING CONNECTION 2
SCALE 1:20

Legenda

Geometrie	Omschrijving	Status
	-	Bestaand
	Paal	Bestaand
	Stalen gording	Bestaand
	Kunstof-staal verbinding	Nieuw
	Staalplaat	Bestaand
	Staalplaat	Nieuw
	Lasverbinding	Nieuw

NOTES

All dimensions are expressed in mm.
Plates A', B', C' and D', are mirrors of the respective plates A,B,C and D.
Level of plates fixation to be determined on the field.

MATERIAL LIST

QUANTITY PER DOLPHIN	MATERIAL DESCRIPTION
4 UNITS	BOLT 36mm
12 UNITS	NUT for bolt 40mm
1 UNIT	STEEL PLATE A
1 UNIT	STEEL PLATE B
1 UNIT	STEEL PLATE A'
1 UNIT	STEEL PLATE B'
2 UNITS	BRACING SUPPORT
2 UNITS	BRACING C ⌀ 1953mm

REFERENCE DRAWINGS

DRAWING NO.	DRAWING NAME
RWSZD-2014-02374	Fenders opvangconstructie meerstoelen C21,C22,C24,C35,C36 en C37 Hansweert
ZLSR-1987-12015	Toeleidingswerken hansweert ducdalven kanaalzijde
ZLSR-1987-12015	Toeleidingswerken hansweert ducdalven kanaalzijde

PROJECT LOCATION

-

REV.	DATE	DESCRIPTION	PREPARATION	REVIEW	APPROVAL
A	10.06.2018	FOR APPROVAL	SLO	SLO	-

CLIENT: RIJKSWATERSTAAT SEA AND DELTA

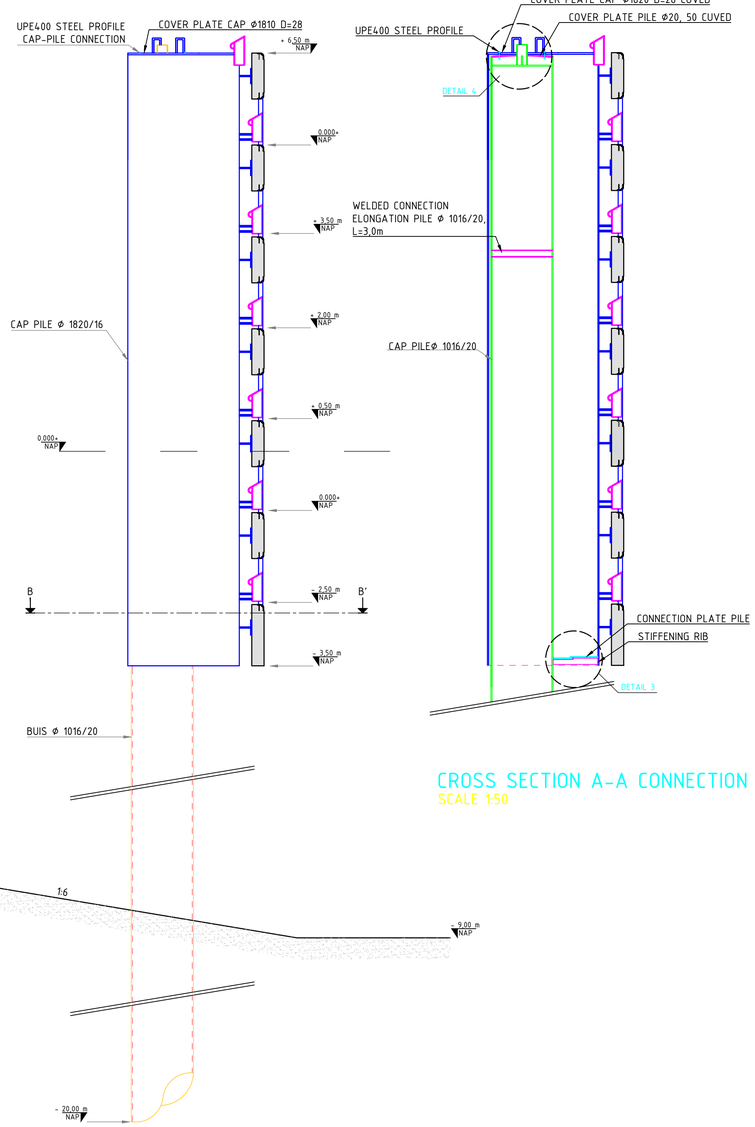
PROJECT NAME: FENDERS HANSWEERT

CONTRACTOR: HZ UNIVERSITY OF APPLIED SCIENCES

TITLE	DETAILED DESIGN DOLPHINS HANSWEERT - WESTERN SCHELDT CONNECTION OPTION 2				
PROJECT CODE	DRAWING NO.	SHEET	SIZE	REV.	SCALE
48H-353	- / -	-	A1	0	See in the drawing

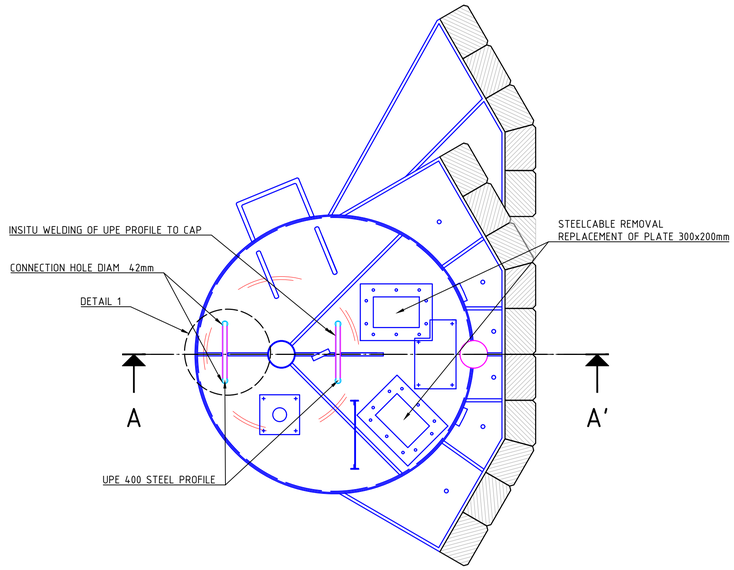
Hansweert Dolphins Solution Connection 3

CONNECTION 3

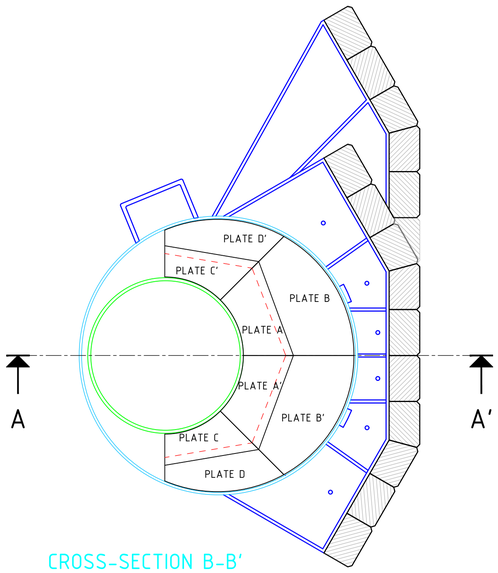


SIDE VIEW CONNECTION 3
SCALE 1:50

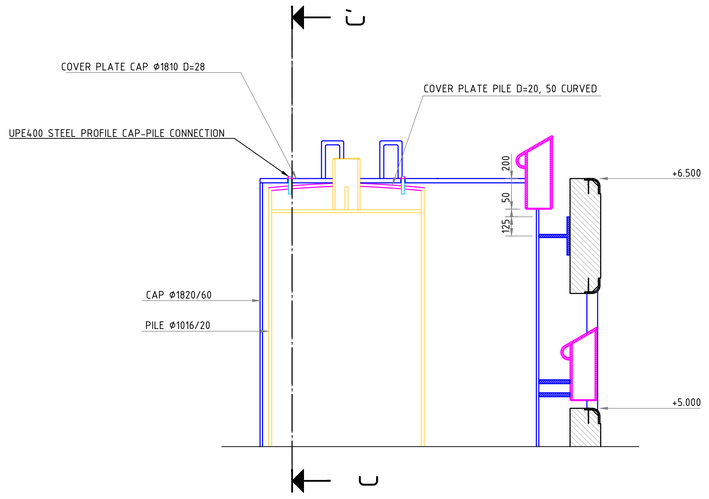
CROSS SECTION A-A CONNECTION 3
SCALE 1:50



TOP VIEW CONNECTION 3
SCALE 1:20



CROSS-SECTION B-B'
SCALE 1:20



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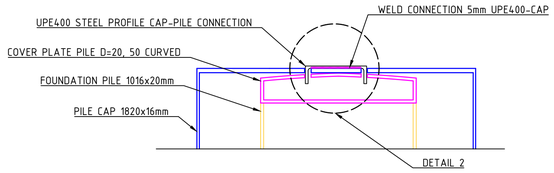
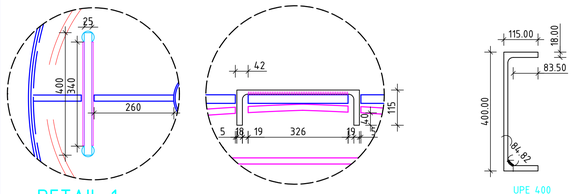
SCALE 1:20



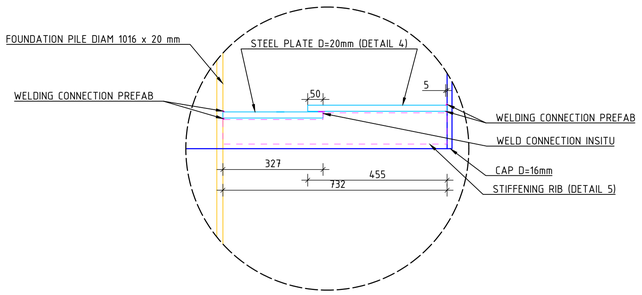
CROSS-SECTION C-C'
SCALE 1:20



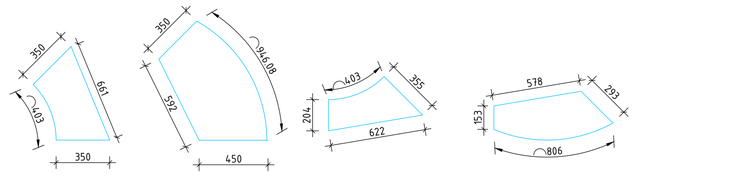
DETAIL 1
SCALE 1:10

DETAIL 2
SCALE 1:10

UPE 400



DETAIL 3- CONNECTION PLATE
SCALE 1:10



DETAIL 4
SCALE 1:20

Legenda

Geometrie	Omschrijving	Status
	-	Bestaand
	Paal	Bestaand
	Stalen gording	Bestaand
	Kunstof-staal verbinding	Nieuw
	Staalplaat	Bestaand
	Staalplaat	Nieuw
	Lasverbinding	Nieuw

Symbool	Omschrijving	Status
[	Profiel UPE 400	Nieuw

NOTES

All dimensions are expressed in mm.
Plates A', B', C' and D', are mirrors of the respective plates A,B,C and D.
Level of plates fixation to be determined on the field.

MATERIAL LIST

QUANTITY PER DOLPHIN	MATERIAL DESCRIPTION
1 UNIT	STEEL PILE 1016x20mm, L=3m
2 UNITS	UPE400 PROFILE L=25mm; D=18
1 UNIT	STEEL PLATE A
1 UNIT	STEEL PLATE B
1 UNIT	STEEL PLATE C
1 UNIT	STEEL PLATE D
1 UNIT	STEEL PLATE A'
1 UNIT	STEEL PLATE B'
1 UNIT	STEEL PLATE C'
1 UNIT	STEEL PLATE D'

REFERENCE DRAWINGS

DRAWING NO.	DRAWING NAME
RWSZD-2014-02374	Fenders opvangconstructie meerstoelen C21,C22,C24,C35,C36 en C37 Hansweert
ZLSR-1987-12015	Toeleidingswerken hansweert ducdalven kanaalzijde
ZLSR-1987-12015	Toeleidingswerken hansweert ducdalven kanaalzijde

PROJECT LOCATION

-

REV.	DATE	DESCRIPTION	PREPARATION	REVIEW	APPROVAL
A	10.06.2018	FOR APPROVAL	SLO	SLO	-

CLIENT: RIJKSWATERSTAAT SEA AND DELTA

PROJECT NAME: FENDERS HANSWEERT

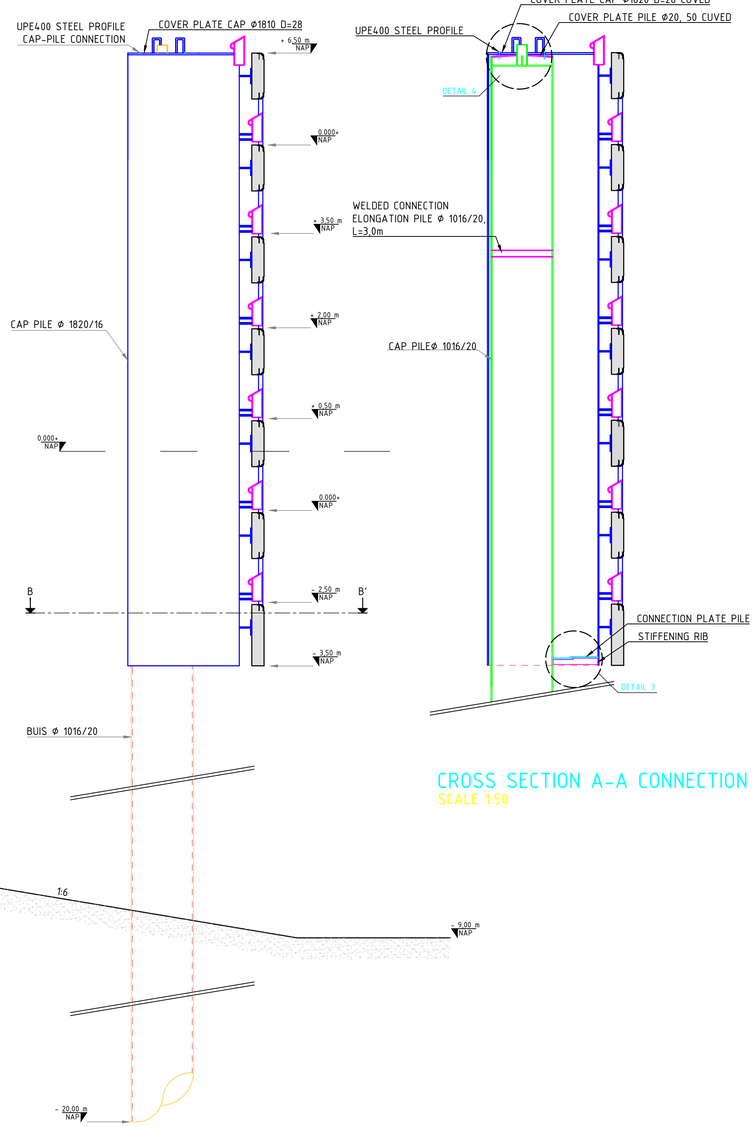
CONTRACTOR: HZ UNIVERSITY OF APPLIED SCIENCES

TITLE	DETAILED DESIGN - FINAL DESIGN DOLPHINS HANSWEERT - WESTERN SCHELDT CONNECTION OPTION 3				
PROJECT CODE	DRAWING NO.	SHEET	SIZE	REV.	SCALE
48H-353	-	-	A1	0	See in the drawing

Appendix IX.IV – Final Design Drawing

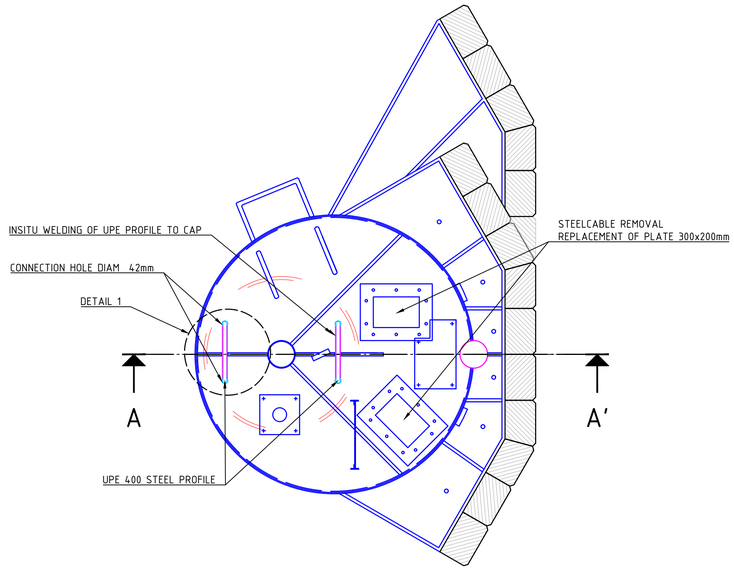
Hansweert Dolphins Solution Connection 3

CONNECTION 3

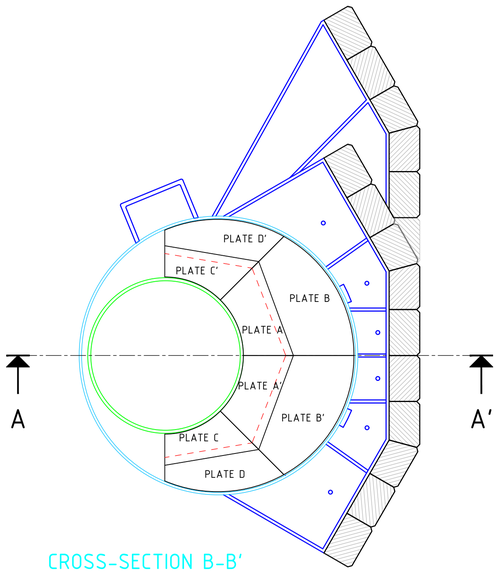


SIDE VIEW CONNECTION 3
SCALE 1:50

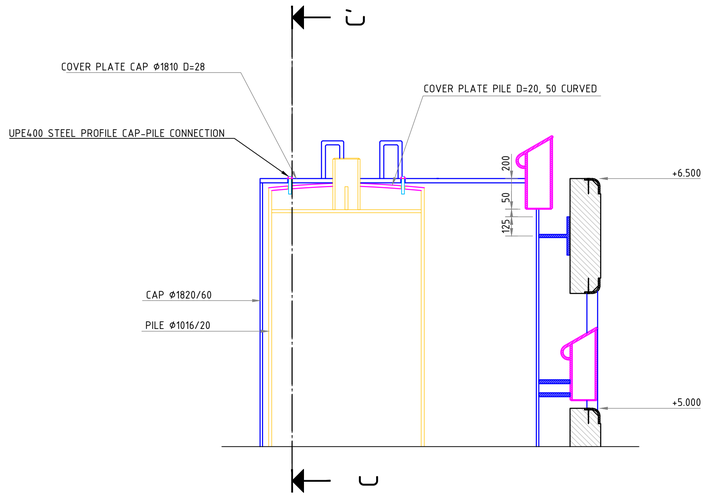
CROSS SECTION A-A CONNECTION 3
SCALE 1:50



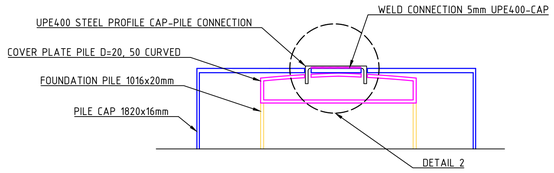
TOP VIEW CONNECTION 3
SCALE 1:20



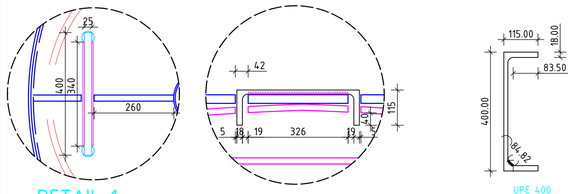
CROSS-SECTION B-B'
SCALE 1:20



CROSS-SECTION A-A
SCALE 1:20



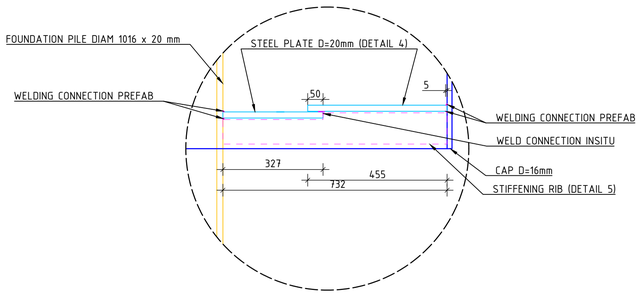
CROSS-SECTION C-C'
SCALE 1:20



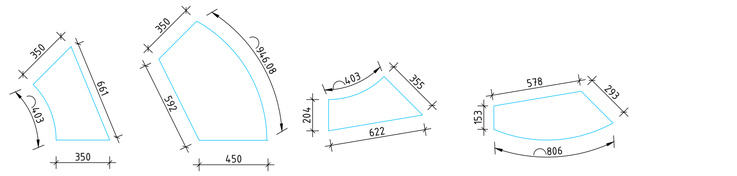
DETAIL 1
SCALE 1:10

DETAIL 2
SCALE 1:10

UPE 400



DETAIL 3- CONNECTION PLATE
SCALE 1:10



DETAIL 4
SCALE 1:20

Legenda

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	Paal	Bestaand
	Stalen gording	Bestaand
	Kunstof-staal verbinding	Nieuw
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	Staalplaat	Nieuw
	Lasverbinding	Nieuw

Symbool	Omschrijving	Status
[	Profiel UPE 400	Nieuw

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1 UNIT	STEEL PLATE D
1 UNIT	STEEL PLATE A'
1 UNIT	STEEL PLATE B'
1 UNIT	STEEL PLATE C'
1 UNIT	STEEL PLATE D'

REFERENCE DRAWINGS

DRAWING NO.	DRAWING NAME
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PROJECT CODE	DRAWING NO.	SHEET	SIZE	REV.	SCALE
48H-353	-	-	A1	0	See in the drawing

Appendix X – Dsheet-Piling Reports

Appendix X.I – Original structure - CPT70294 analysis

Report for D-Sheet Piling 15.1

Design of Diaphragm and Sheet Pile Walls
Developed by Deltares

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Company:	Bouwdienst Rijkswaterstaat
Date of report:	5/21/2018
Time of report:	9:43:19 AM
Date of calculation:	5/21/2018
Time of calculation:	9:41:36 AM
Filename:	U:\Final Thesis Final report\DATA\DSheet Pile\Project1
Project identification:	Hansweert Meerstoelen Paalfundering Analysis

1 Table of Contents

2 Summary

2.1 Overview of Maxima

Displacement [mm]	Moment [kNm]	Shear force [kN]	Mob. perc. moment [%]	Mob. perc. resistance [%]
1360.8	-3388.16	1132.90	0.0	45.5

3 Input Data

3.1 General Input Data

Model	Single pile; Pile loaded by forces
Unit weight of water	9.81 kN/m³

3.2 Pile Properties

Length	24.10 m
Level top side	6.50 m
Number of sections	1

3.2.1 General properties

Section name	From [m]	To [m]	Material type	Diameter [m]
Hansweert	-17.60	6.50	Steel	1.02

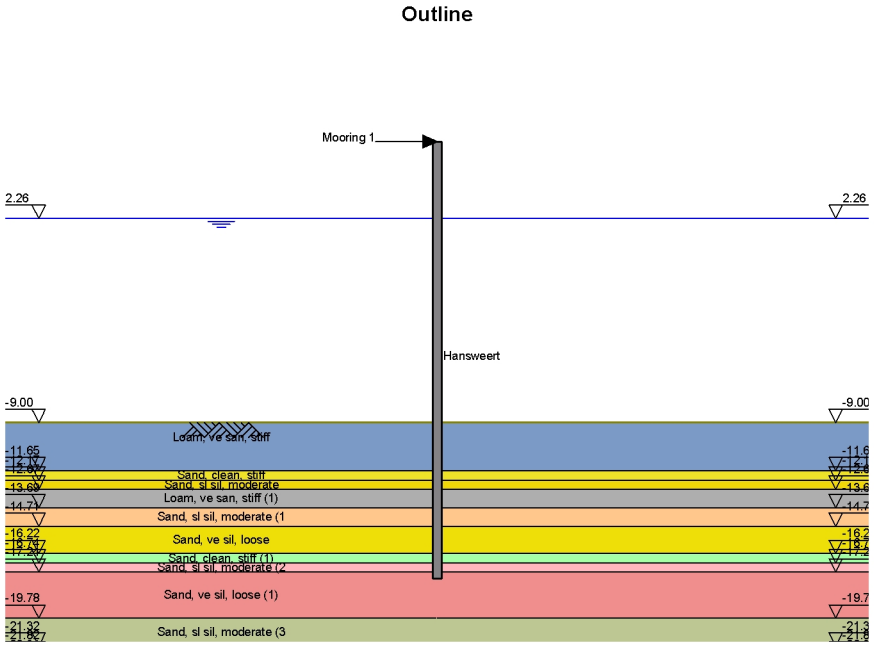
3.2.2 Stiffness EI (elastic behaviour)

Section name	Elastic stiffness EI [kNm²]	Red. factor on EI [-]	Corrected elas. stiffness EI [kNm²]	Note to reduction factor
Hansweert	1.6303E+06	1.00	1.6300E+06	

3.2.3 Maximum allowable moments

Section name	Elas. char. moment [kNm]	Modification factor [-]	Material factor [-]	Red. factor allow. moment [-]	Elas. design moment [kNm]
Hansweert	3875.00	1.00	1.00	1.00	3875.00

3.3 Outline



3.4 Horizontal Forces

Name	Level [m]	Load [kN]
Mooring 1	6.50	195.00

3.5 Water Level

Water level: 2.26 [m]

3.6 Surface

Surface level: -9.00 [m]

3.7 Soil Material Properties

Layer name	Level [m]	Unit weight		Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
		Unsat [kN/m³]	Sat. [kN/m³]			
Loam, ve san, ...	-8.00	19.00	19.00	0.00	27.50	Yes
Sand, clean, stiff	-11.65	19.00	21.00	0.00	35.00	Yes
Sand, sl sil, mo...	-12.17	18.00	20.00	0.00	27.00	Yes
Loam, ve san, ...	-12.67	19.00	19.00	0.00	27.50	Yes
Sand, sl sil, mo...	-13.69	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-14.71	18.00	20.00	0.00	25.00	Yes
Sand, clean, sti...	-16.22	19.00	21.00	0.00	35.00	Yes
Sand, sl sil, mo...	-16.74	18.00	20.00	0.00	27.00	Yes

Layer name	Level [m]	Unit weight Unsat [kN/m³]	Unit weight Sat. [kN/m³]	Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
Sand, ve sil, lo...	-17.24	18.00	20.00	0.00	25.00	Yes
Sand, sl sil, mo...	-19.78	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-21.32	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-21.82	19.00	19.00	0.00	27.50	Yes
Loam, sl san, w...	-22.34	19.00	19.00	0.00	27.50	Yes
Loam, ve san, ...	-22.86	19.00	19.00	0.00	27.50	Yes
Loam, sl san, w...	-23.36	19.00	19.00	0.00	27.50	Yes
Loam, ve san, ...	-23.88	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-24.39	18.00	20.00	0.00	25.00	Yes
Sand, sl sil, mo...	-26.47	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-28.03	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-28.55	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-29.06	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-30.62	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-31.14	18.00	20.00	0.00	25.00	Yes

Layer name	Level [m]	Earth pressure coefficients Active [-]	Earth pressure coefficients Neutral [-]	Earth pressure coefficients Passive [-]	Additional pore pressure Top [kN/m²]	Additional pore pressure Bottom [kN/m²]
Loam, ve san, ...	-8.00	0.00	0.00	5.23	0.00	0.00
Sand, clean, stiff	-11.65	0.00	0.00	11.66	0.00	0.00
Sand, sl sil, mo...	-12.17	0.00	0.00	6.39	0.00	0.00
Loam, ve san, ...	-12.67	0.00	0.00	7.05	0.00	0.00
Sand, sl sil, mo...	-13.69	0.00	0.00	7.20	0.00	0.00
Sand, ve sil, lo...	-14.71	0.00	0.00	6.44	0.00	0.00
Sand, clean, sti...	-16.22	0.00	0.00	16.49	0.00	0.00
Sand, sl sil, mo...	-16.74	0.00	0.00	8.11	0.00	0.00
Sand, ve sil, lo...	-17.24	0.00	0.00	7.07	0.00	0.00
Sand, sl sil, mo...	-19.78	0.00	0.00	8.89	0.00	0.00
Sand, ve sil, lo...	-21.32	0.00	0.00	7.51	0.00	0.00
Loam, ve san, ...	-21.82	0.00	0.00	9.59	0.00	0.00
Loam, sl san, w...	-22.34	0.00	0.00	9.67	0.00	0.00
Loam, ve san, ...	-22.86	0.00	0.00	9.75	0.00	0.00
Loam, sl san, w...	-23.36	0.00	0.00	9.82	0.00	0.00
Loam, ve san, ...	-23.88	0.00	0.00	9.90	0.00	0.00
Sand, ve sil, lo...	-24.39	0.00	0.00	7.90	0.00	0.00
Sand, sl sil, mo...	-26.47	0.00	0.00	9.78	0.00	0.00
Sand, ve sil, lo...	-28.03	0.00	0.00	8.12	0.00	0.00
Loam, ve san, ...	-28.55	0.00	0.00	10.43	0.00	0.00
Sand, ve sil, lo...	-29.06	0.00	0.00	8.22	0.00	0.00
Loam, ve san, ...	-30.62	0.00	0.00	10.61	0.00	0.00
Sand, ve sil, lo...	-31.14	0.00	0.00	11.84	0.00	0.00

3.8 Soil Material Properties calculated using Brinch Hansen

Layer name	Level [m]	Fictive cohesion [kN/m²]
Loam, ve san, ...	-8.00	0.00
Sand, clean, stiff	-11.65	0.00
Sand, sl sil, mo...	-12.17	0.00
Loam, ve san, ...	-12.67	0.00
Sand, sl sil, mo...	-13.69	0.00
Sand, ve sil, lo...	-14.71	0.00
Sand, clean, sti...	-16.22	0.00
Sand, sl sil, mo...	-16.74	0.00
Sand, ve sil, lo...	-17.24	0.00
Sand, sl sil, mo...	-19.78	0.00
Sand, ve sil, lo...	-21.32	0.00

Layer name	Level [m]	Fictive cohesion [kN/m²]
Loam, ve san, ...	-21.82	0.00
Loam, sl san, w...	-22.34	0.00
Loam, ve san, ...	-22.86	0.00
Loam, sl san, w...	-23.36	0.00
Loam, ve san, ...	-23.88	0.00
Sand, ve sil, lo...	-24.39	0.00
Sand, sl sil, mo...	-26.47	0.00
Sand, ve sil, lo...	-28.03	0.00
Loam, ve san, ...	-28.55	0.00
Sand, ve sil, lo...	-29.06	0.00
Loam, ve san, ...	-30.62	0.00
Sand, ve sil, lo...	-31.14	0.00

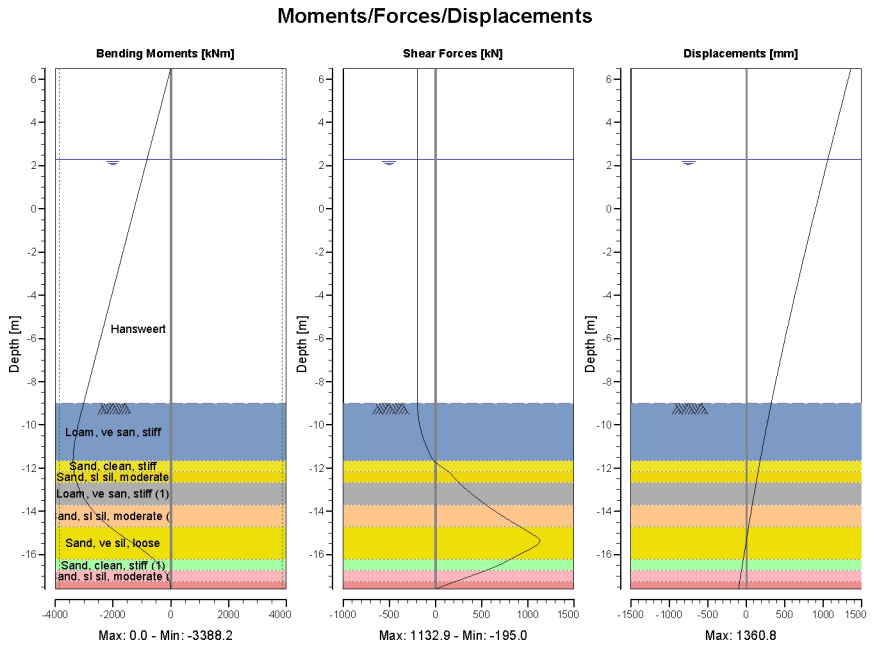
3.9 Modulus of Subgrade Reaction

Layer name	Level [m]	Ménard used	E-Mod Ménard [kN/m²]	Soil type Ménard	Branch 1	
					Top [kN/m³]	Bottom [kN/m³]
Loam, ve san, ...	-8.00	Yes	7800.00	Loam	21611.15	21611.15
Sand, clean, stiff	-11.65	No	n.a.	n.a.	10000.00	10000.00
Sand, sl sil, mo...	-12.17	Yes	5000.00	Sand	18424.93	18424.93
Loam, ve san, ...	-12.67	Yes	7800.00	Loam	21611.15	21611.15
Sand, sl sil, mo...	-13.69	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-14.71	Yes	12000.00	Sand	44219.84	44219.84
Sand, clean, sti...	-16.22	No	n.a.	n.a.	10000.00	10000.00
Sand, sl sil, mo...	-16.74	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-17.24	Yes	12000.00	Sand	44219.84	44219.84
Sand, sl sil, mo...	-19.78	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-21.32	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-21.82	Yes	7800.00	Loam	21611.15	21611.15
Loam, sl san, w...	-22.34	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-22.86	Yes	7800.00	Loam	21611.15	21611.15
Loam, sl san, w...	-23.36	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-23.88	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-24.39	Yes	12000.00	Sand	44219.84	44219.84
Sand, sl sil, mo...	-26.47	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-28.03	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-28.55	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-29.06	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-30.62	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-31.14	Yes	12000.00	Sand	44219.84	44219.84

4 Calculation Results

Number of iterations: 7

4.1 Charts of Moments, Forces and Displacements



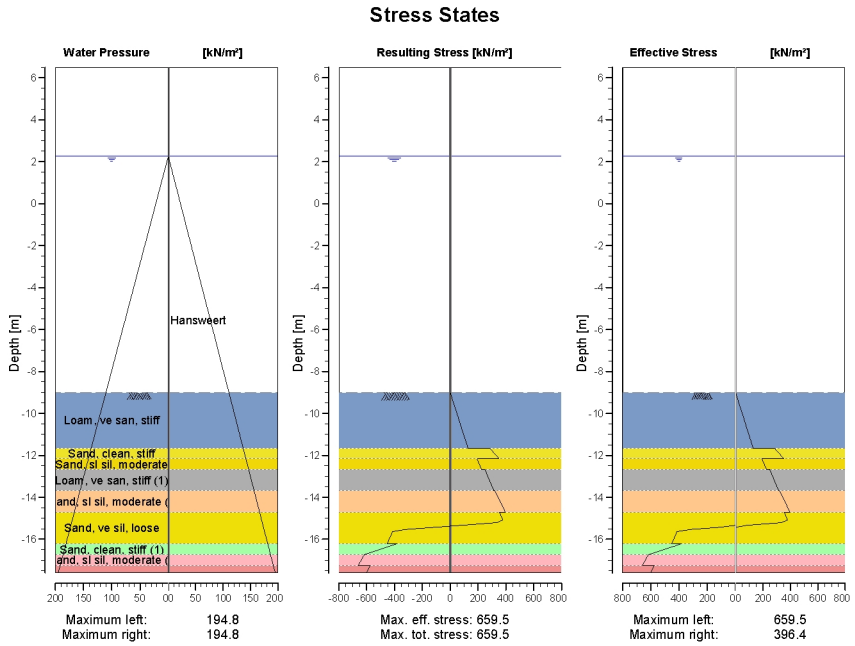
4.2 Moments, Forces and Displacements

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
1	6.50	0.00	-195.00	**1360.8**
1	5.88	-120.90	-195.00	1316.4
2	5.88	-120.90	-195.00	1316.4
2	5.26	-241.80	-195.00	1272.0
3	5.26	-241.80	-195.00	1272.0
3	5.00	-292.50	-195.00	1253.5
4	5.00	-292.50	-195.00	1253.5
4	4.25	-438.75	-195.00	1199.9
5	4.25	-438.75	-195.00	1199.9
5	3.50	-585.00	-195.00	1146.5
6	3.50	-585.00	-195.00	1146.5
6	2.88	-705.90	-195.00	1102.5
7	2.88	-705.90	-195.00	1102.5
7	2.26	-826.80	-195.00	1058.7
8	2.26	-826.80	-195.00	1058.7
8	2.00	-877.50	-195.00	1040.4
9	2.00	-877.50	-195.00	1040.4
9	1.25	-1023.75	-195.00	987.7
10	1.25	-1023.75	-195.00	987.7

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
10	0.50	-1170.00	-195.00	935.5
11	0.50	-1170.00	-195.00	935.5
11	-0.25	-1316.25	-195.00	883.6
12	-0.25	-1316.25	-195.00	883.6
12	-1.00	-1462.50	-195.00	832.1
13	-1.00	-1462.50	-195.00	832.1
13	-1.75	-1608.75	-195.00	781.2
14	-1.75	-1608.75	-195.00	781.2
14	-2.50	-1755.00	-195.00	730.9
15	-2.50	-1755.00	-195.00	730.9
15	-3.33	-1917.50	-195.00	675.6
16	-3.33	-1917.50	-195.00	675.6
16	-4.17	-2080.00	-195.00	621.2
17	-4.17	-2080.00	-195.00	621.2
17	-5.00	-2242.50	-195.00	567.6
18	-5.00	-2242.50	-195.00	567.6
18	-6.00	-2437.50	-195.00	504.6
19	-6.00	-2437.50	-195.00	504.6
19	-7.00	-2632.50	-195.00	443.1
20	-7.00	-2632.50	-195.00	443.1
20	-7.98	-2823.60	-195.00	384.4
21	-7.98	-2823.60	-195.00	384.4
21	-8.00	-2827.50	-195.00	383.2
22	-8.00	-2827.50	-195.00	383.2
22	-8.16	-2858.70	-195.00	373.8
23	-8.16	-2858.70	-195.00	373.8
23	-9.00	-3022.50	-195.00	325.1
24	-9.00	-3022.50	-195.00	325.1
24	-9.77	-3168.92	-180.47	281.6
25	-9.77	-3168.92	-180.47	281.6
25	-10.50	-3287.44	-139.87	241.4
26	-10.50	-3287.44	-139.87	241.4
26	-10.66	-3308.84	-127.48	232.7
27	-10.66	-3308.84	-127.48	232.7
27	-10.77	-3322.36	-118.24	226.8
28	-10.77	-3322.36	-118.24	226.8
28	-11.16	-3361.40	-80.69	206.0
29	-11.16	-3361.40	-80.69	206.0
29	-11.24	-3367.51	-72.06	201.7
30	-11.24	-3367.51	-72.06	201.7
30	-11.52	-3383.20	-39.41	187.0
31	-11.52	-3383.20	-39.41	187.0
31	-11.65	-3387.26	-22.94	180.3
32	-11.65	-3387.26	-22.94	180.3
32	-11.74	**-3388.14**	3.66	175.6
33	-11.74	**-3388.14**	3.66	175.6
33	-11.79	-3387.58	18.91	173.0
34	-11.79	-3387.58	18.91	173.0
34	-12.17	-3356.92	145.64	153.5
35	-12.17	-3356.92	145.64	153.5
35	-12.29	-3338.01	169.72	147.4
36	-12.29	-3338.01	169.72	147.4
36	-12.67	-3258.13	252.29	128.3
37	-12.67	-3258.13	252.29	128.3
37	-13.24	-3071.08	407.61	100.2
38	-13.24	-3071.08	407.61	100.2
38	-13.69	-2857.16	545.40	78.5
39	-13.69	-2857.16	545.40	78.5
39	-14.04	-2645.65	664.76	61.8
40	-14.04	-2645.65	664.76	61.8

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
40	-14.24	-2505.51	737.09	52.3
41	-14.24	-2505.51	737.09	52.3
41	-14.66	-2162.45	898.72	32.7
42	-14.66	-2162.45	898.72	32.7
42	-14.71	-2117.02	918.84	30.4
43	-14.71	-2117.22	919.99	30.4
43	-15.33	-1476.35	1130.47	1.9
44	-15.33	-1475.66	**1132.90**	1.9
44	-15.83	-935.38	985.21	-20.9
45	-15.83	-935.60	983.49	-20.9
45	-16.22	-585.88	808.21	-38.5
46	-16.22	-585.88	808.21	-38.5
46	-16.74	-229.49	541.81	-61.9
47	-16.74	-229.49	541.81	-61.9
47	-16.84	-178.48	478.33	-66.4
48	-16.84	-178.48	478.33	-66.4
48	-17.24	-39.17	216.00	-84.4
49	-17.24	-39.17	216.00	-84.4
49	-17.60	0.00	0.00	-100.6
Max		**-3388.14**	**1132.90**	**1360.8**
Max, minor nodes incl.		-3388.16	1132.90	1360.8

4.3 Charts of Stresses



4.4 Stresses

Node number	Level	Left				Right			
	[m]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
1	6.50	0.00	0.00	-		0.00	0.00	-	
1	5.88	0.00	0.00	-		0.00	0.00	-	
2	5.88	0.00	0.00	-		0.00	0.00	-	
2	5.26	0.00	0.00	-		0.00	0.00	-	
3	5.26	0.00	0.00	-		0.00	0.00	-	
3	5.00	0.00	0.00	-		0.00	0.00	-	
4	5.00	0.00	0.00	-		0.00	0.00	-	
4	4.25	0.00	0.00	-		0.00	0.00	-	
5	4.25	0.00	0.00	-		0.00	0.00	-	
5	3.50	0.00	0.00	-		0.00	0.00	-	
6	3.50	0.00	0.00	-		0.00	0.00	-	
6	2.88	0.00	0.00	-		0.00	0.00	-	
7	2.88	0.00	0.00	-		0.00	0.00	-	
7	2.26	0.00	0.00	-		0.00	0.00	-	
8	2.26	0.00	0.00	-		0.00	0.00	-	
8	2.00	0.00	2.55	-		0.00	2.55	-	
9	2.00	0.00	2.55	-		0.00	2.55	-	
9	1.25	0.00	9.91	-		0.00	9.91	-	
10	1.25	0.00	9.91	-		0.00	9.91	-	
10	0.50	0.00	17.27	-		0.00	17.27	-	
11	0.50	0.00	17.27	-		0.00	17.27	-	
11	-0.25	0.00	24.62	-		0.00	24.62	-	
12	-0.25	0.00	24.62	-		0.00	24.62	-	
12	-1.00	0.00	31.98	-		0.00	31.98	-	
13	-1.00	0.00	31.98	-		0.00	31.98	-	
13	-1.75	0.00	39.34	-		0.00	39.34	-	
14	-1.75	0.00	39.34	-		0.00	39.34	-	
14	-2.50	0.00	46.70	-		0.00	46.70	-	
15	-2.50	0.00	46.70	-		0.00	46.70	-	
15	-3.33	0.00	54.87	-		0.00	54.87	-	
16	-3.33	0.00	54.87	-		0.00	54.87	-	
16	-4.17	0.00	63.05	-		0.00	63.05	-	
17	-4.17	0.00	63.05	-		0.00	63.05	-	
17	-5.00	0.00	71.22	-		0.00	71.22	-	
18	-5.00	0.00	71.22	-		0.00	71.22	-	
18	-6.00	0.00	81.03	-		0.00	81.03	-	
19	-6.00	0.00	81.03	-		0.00	81.03	-	
19	-7.00	0.00	90.84	-		0.00	90.84	-	
20	-7.00	0.00	90.84	-		0.00	90.84	-	
20	-7.98	0.00	100.45	-		0.00	100.45	-	
21	-7.98	0.00	100.45	-		0.00	100.45	-	
21	-8.00	0.00	100.65	-		0.00	100.65	-	
22	-8.00	0.00	100.65	-		0.00	100.65	-	
22	-8.16	0.00	102.22	-		0.00	102.22	-	
23	-8.16	0.00	102.22	-		0.00	102.22	-	
23	-9.00	0.00	110.46	-		0.00	110.46	-	
24	-9.00	0.00	110.46	A		0.00	110.46	P	
24	-9.77	0.00	118.01	A		36.99	118.01	P	
25	-9.77	0.00	118.01	A		36.99	118.01	P	
25	-10.50	0.00	125.18	A		72.06	125.18	P	
26	-10.50	0.00	125.18	A		72.06	125.18	P	
26	-10.66	0.00	126.75	A		79.75	126.75	P	
27	-10.66	0.00	126.75	A		79.75	126.75	P	
27	-10.77	0.00	127.82	A		85.03	127.82	P	
28	-10.77	0.00	127.82	A		85.03	127.82	P	
28	-11.16	0.00	131.65	A		103.77	131.65	P	

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
29	-11.16	0.00	131.65	A		103.77	131.65	P	
29	-11.24	0.00	132.44	A		107.61	132.44	P	
30	-11.24	0.00	132.44	A		107.61	132.44	P	
30	-11.52	0.00	135.18	A		121.06	135.18	P	
31	-11.52	0.00	135.18	A		121.06	135.18	P	
31	-11.65	0.00	136.46	A		127.31	136.46	P	
32	-11.65	0.00	136.46	A		283.93	136.46	P	
32	-11.74	0.00	137.34	A		295.67	137.34	P	
33	-11.74	0.00	137.34	A		295.67	137.34	P	
33	-11.79	0.00	137.83	A		302.19	137.83	P	
34	-11.79	0.00	137.83	A		302.19	137.83	P	
34	-12.17	0.00	141.56	A		351.76	141.56	P	
35	-12.17	0.00	141.56	A		192.82	141.56	P	
35	-12.29	0.00	142.74	A		200.63	142.74	P	
36	-12.29	0.00	142.74	A		200.63	142.74	P	
36	-12.67	0.00	146.46	A		225.38	146.46	P	
37	-12.67	0.00	146.46	A		248.68	146.46	P	
37	-13.24	0.00	152.06	A		285.62	152.06	P	
38	-13.24	0.00	152.06	A		285.62	152.06	P	
38	-13.69	0.00	156.47	A		314.78	156.47	P	
39	-13.69	0.00	156.47	A		321.52	156.47	P	
39	-14.04	0.00	159.90	A		347.20	159.90	P	
40	-14.04	0.00	159.90	A		347.20	159.90	P	
40	-14.24	0.00	161.87	A		361.88	161.87	P	
41	-14.24	0.00	161.87	A		361.88	161.87	P	
41	-14.66	0.00	165.99	A		392.71	165.99	P	
42	-14.66	0.00	165.99	A		392.71	165.99	P	
42	-14.71	0.00	166.48	A		396.38	166.48	P	
43	-14.71	0.00	166.48	A		354.36	166.48	P	
43	-15.33	0.00	172.56	A		82.82	172.56	-	21
44	-15.33	0.00	172.56	A		82.82	172.56	-	21
44	-15.83	427.84	177.46	P		0.00	177.46	A	
45	-15.83	427.84	177.46	P		0.00	177.46	A	
45	-16.22	453.43	181.29	P		0.00	181.29	A	
46	-16.22	385.05	181.29	-	33	0.00	181.29	A	
46	-16.74	619.38	186.39	-	49	0.00	186.39	A	
47	-16.74	618.19	186.39	P		0.00	186.39	A	
47	-16.84	626.45	187.37	P		0.00	187.37	A	
48	-16.84	626.45	187.37	P		0.00	187.37	A	
48	-17.24	659.50	191.29	P		0.00	191.29	A	
49	-17.24	575.25	191.29	P		0.00	191.29	A	
49	-17.60	601.20	194.83	P		0.00	194.83	A	

*

Stat Status (A=active, P=passive, Number is branche, 0 is unloading)
Mob Percentage passive mobilized

End of Report

Report for D-Sheet Piling 15.1

Design of Diaphragm and Sheet Pile Walls
Developed by Deltares

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Company:	Bouwdienst Rijkswaterstaat
Date of report:	5/21/2018
Time of report:	9:46:55 AM
Date of calculation:	5/21/2018
Time of calculation:	9:45:22 AM
Filename:	U:\Final Thesis Final report\DATA\DSheet Pile\Project1
Project identification:	Hansweert Meerstoelen Paalfundering Analysis

1 Table of Contents

2 Summary

2.1 Overview of Maxima

Displacement [mm]	Moment [kNm]	Shear force [kN]	Mob. perc. moment [%]	Mob. perc. resistance [%]
500.5	-2752.58	770.94	0.0	31.9

3 Input Data

3.1 General Input Data

Model	Single pile; Pile loaded by forces
Unit weight of water	9.81 kN/m³

3.2 Pile Properties

Length	24.10 m
Level top side	6.50 m
Number of sections	1

3.2.1 General properties

Section name	From [m]	To [m]	Material type	Diameter [m]
Hansweert	-17.60	6.50	Steel	1.02

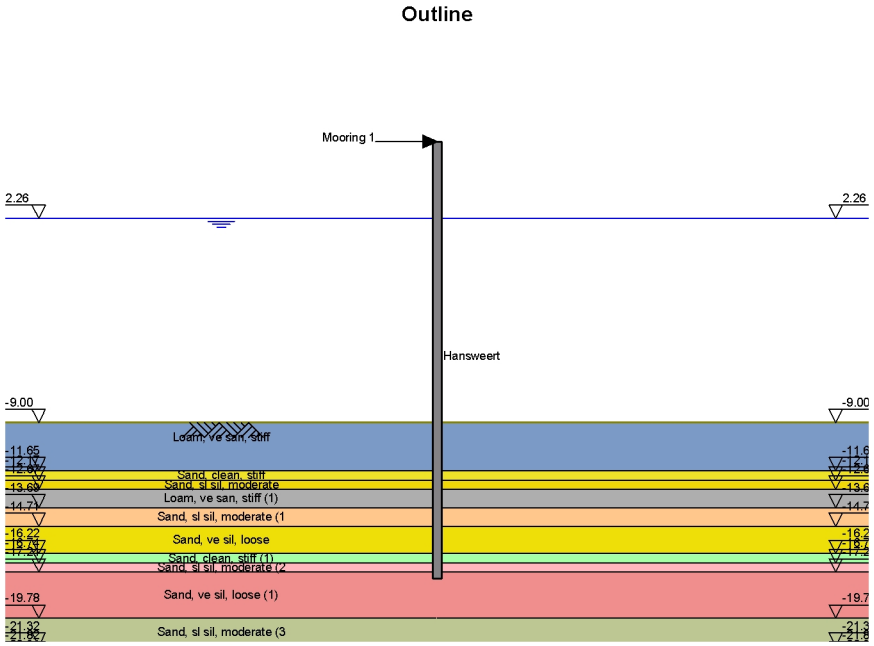
3.2.2 Stiffness EI (elastic behaviour)

Section name	Elastic stiffness EI [kNm²]	Red. factor on EI [-]	Corrected elas. stiffness EI [kNm²]	Note to reduction factor
Hansweert	1.6303E+06	1.00	1.6300E+06	

3.2.3 Maximum allowable moments

Section name	Elas. char. moment [kNm]	Modification factor [-]	Material factor [-]	Red. factor allow. moment [-]	Elas. design moment [kNm]
Hansweert	3875.00	1.00	1.00	1.00	3875.00

3.3 Outline



3.4 Horizontal Forces

Name	Level [m]	Load [kN]
Mooring 1	6.50	160.00

3.5 Water Level

Water level: 2.26 [m]

3.6 Surface

Surface level: -9.00 [m]

3.7 Soil Material Properties

Layer name	Level [m]	Unit weight		Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
		Unsat [kN/m³]	Sat. [kN/m³]			
Loam, ve san, ...	-8.00	19.00	19.00	0.00	27.50	Yes
Sand, clean, stiff	-11.65	19.00	21.00	0.00	35.00	Yes
Sand, sl sil, mo...	-12.17	18.00	20.00	0.00	27.00	Yes
Loam, ve san, ...	-12.67	19.00	19.00	0.00	27.50	Yes
Sand, sl sil, mo...	-13.69	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-14.71	18.00	20.00	0.00	25.00	Yes
Sand, clean, sti...	-16.22	19.00	21.00	0.00	35.00	Yes
Sand, sl sil, mo...	-16.74	18.00	20.00	0.00	27.00	Yes

Layer name	Level [m]	Unit weight Unsat [kN/m³]	Unit weight Sat. [kN/m³]	Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
Sand, ve sil, lo...	-17.24	18.00	20.00	0.00	25.00	Yes
Sand, sl sil, mo...	-19.78	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-21.32	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-21.82	19.00	19.00	0.00	27.50	Yes
Loam, sl san, w...	-22.34	19.00	19.00	0.00	27.50	Yes
Loam, ve san, ...	-22.86	19.00	19.00	0.00	27.50	Yes
Loam, sl san, w...	-23.36	19.00	19.00	0.00	27.50	Yes
Loam, ve san, ...	-23.88	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-24.39	18.00	20.00	0.00	25.00	Yes
Sand, sl sil, mo...	-26.47	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-28.03	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-28.55	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-29.06	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-30.62	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-31.14	18.00	20.00	0.00	25.00	Yes

Layer name	Level [m]	Earth pressure coefficients Active [-]	Earth pressure coefficients Neutral [-]	Earth pressure coefficients Passive [-]	Additional pore pressure Top [kN/m²]	Additional pore pressure Bottom [kN/m²]
Loam, ve san, ...	-8.00	0.00	0.00	5.23	0.00	0.00
Sand, clean, stiff	-11.65	0.00	0.00	11.66	0.00	0.00
Sand, sl sil, mo...	-12.17	0.00	0.00	6.39	0.00	0.00
Loam, ve san, ...	-12.67	0.00	0.00	7.05	0.00	0.00
Sand, sl sil, mo...	-13.69	0.00	0.00	7.20	0.00	0.00
Sand, ve sil, lo...	-14.71	0.00	0.00	6.44	0.00	0.00
Sand, clean, sti...	-16.22	0.00	0.00	16.49	0.00	0.00
Sand, sl sil, mo...	-16.74	0.00	0.00	8.11	0.00	0.00
Sand, ve sil, lo...	-17.24	0.00	0.00	7.07	0.00	0.00
Sand, sl sil, mo...	-19.78	0.00	0.00	8.89	0.00	0.00
Sand, ve sil, lo...	-21.32	0.00	0.00	7.51	0.00	0.00
Loam, ve san, ...	-21.82	0.00	0.00	9.59	0.00	0.00
Loam, sl san, w...	-22.34	0.00	0.00	9.67	0.00	0.00
Loam, ve san, ...	-22.86	0.00	0.00	9.75	0.00	0.00
Loam, sl san, w...	-23.36	0.00	0.00	9.82	0.00	0.00
Loam, ve san, ...	-23.88	0.00	0.00	9.90	0.00	0.00
Sand, ve sil, lo...	-24.39	0.00	0.00	7.90	0.00	0.00
Sand, sl sil, mo...	-26.47	0.00	0.00	9.78	0.00	0.00
Sand, ve sil, lo...	-28.03	0.00	0.00	8.12	0.00	0.00
Loam, ve san, ...	-28.55	0.00	0.00	10.43	0.00	0.00
Sand, ve sil, lo...	-29.06	0.00	0.00	8.22	0.00	0.00
Loam, ve san, ...	-30.62	0.00	0.00	10.61	0.00	0.00
Sand, ve sil, lo...	-31.14	0.00	0.00	11.84	0.00	0.00

3.8 Soil Material Properties calculated using Brinch Hansen

Layer name	Level [m]	Fictive cohesion [kN/m²]
Loam, ve san, ...	-8.00	0.00
Sand, clean, stiff	-11.65	0.00
Sand, sl sil, mo...	-12.17	0.00
Loam, ve san, ...	-12.67	0.00
Sand, sl sil, mo...	-13.69	0.00
Sand, ve sil, lo...	-14.71	0.00
Sand, clean, sti...	-16.22	0.00
Sand, sl sil, mo...	-16.74	0.00
Sand, ve sil, lo...	-17.24	0.00
Sand, sl sil, mo...	-19.78	0.00
Sand, ve sil, lo...	-21.32	0.00

Layer name	Level [m]	Fictive cohesion [kN/m²]
Loam, ve san, ...	-21.82	0.00
Loam, sl san, w...	-22.34	0.00
Loam, ve san, ...	-22.86	0.00
Loam, sl san, w...	-23.36	0.00
Loam, ve san, ...	-23.88	0.00
Sand, ve sil, lo...	-24.39	0.00
Sand, sl sil, mo...	-26.47	0.00
Sand, ve sil, lo...	-28.03	0.00
Loam, ve san, ...	-28.55	0.00
Sand, ve sil, lo...	-29.06	0.00
Loam, ve san, ...	-30.62	0.00
Sand, ve sil, lo...	-31.14	0.00

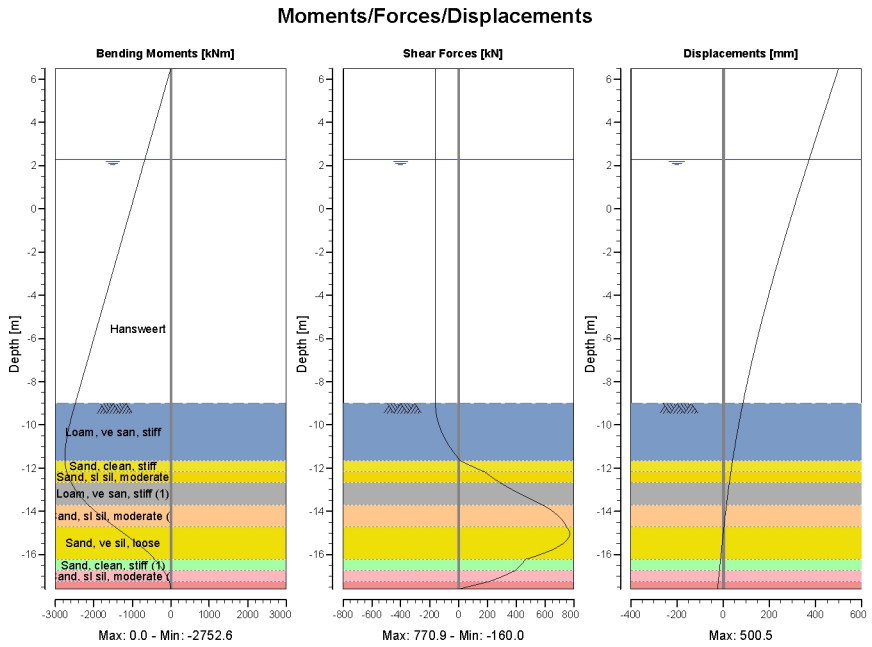
3.9 Modulus of Subgrade Reaction

Layer name	Level [m]	Ménard used	E-Mod Ménard [kN/m²]	Soil type Ménard	Branch 1	
					Top [kN/m³]	Bottom [kN/m³]
Loam, ve san, ...	-8.00	Yes	7800.00	Loam	21611.15	21611.15
Sand, clean, stiff	-11.65	No	n.a.	n.a.	10000.00	10000.00
Sand, sl sil, mo...	-12.17	Yes	5000.00	Sand	18424.93	18424.93
Loam, ve san, ...	-12.67	Yes	7800.00	Loam	21611.15	21611.15
Sand, sl sil, mo...	-13.69	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-14.71	Yes	12000.00	Sand	44219.84	44219.84
Sand, clean, sti...	-16.22	No	n.a.	n.a.	10000.00	10000.00
Sand, sl sil, mo...	-16.74	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-17.24	Yes	12000.00	Sand	44219.84	44219.84
Sand, sl sil, mo...	-19.78	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-21.32	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-21.82	Yes	7800.00	Loam	21611.15	21611.15
Loam, sl san, w...	-22.34	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-22.86	Yes	7800.00	Loam	21611.15	21611.15
Loam, sl san, w...	-23.36	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-23.88	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-24.39	Yes	12000.00	Sand	44219.84	44219.84
Sand, sl sil, mo...	-26.47	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-28.03	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-28.55	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-29.06	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-30.62	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-31.14	Yes	12000.00	Sand	44219.84	44219.84

4 Calculation Results

Number of iterations: 7

4.1 Charts of Moments, Forces and Displacements



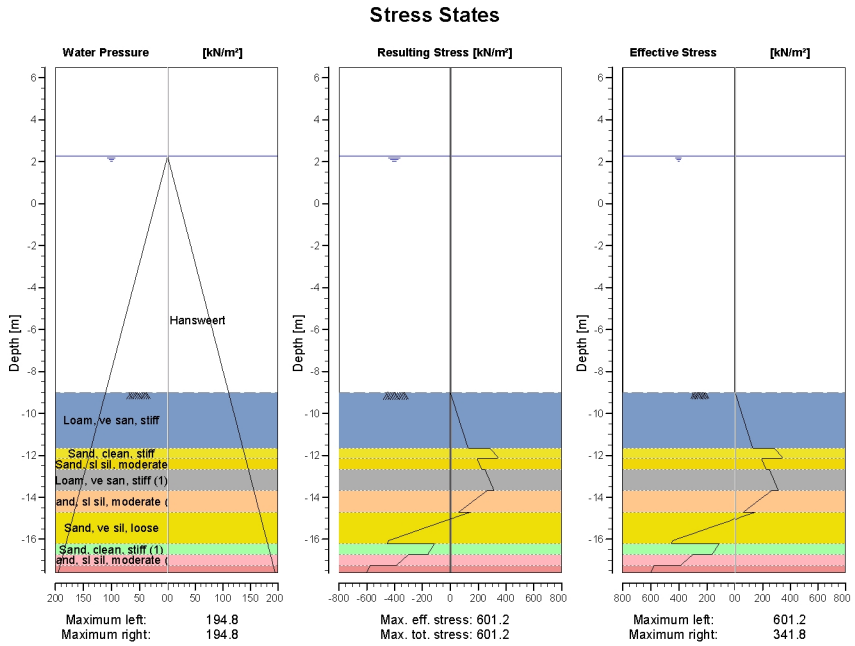
4.2 Moments, Forces and Displacements

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
1	6.50	0.00	-160.00	**500.5**
1	5.88	-99.20	-160.00	481.4
2	5.88	-99.20	-160.00	481.4
2	5.26	-198.40	-160.00	462.4
3	5.26	-198.40	-160.00	462.4
3	5.00	-240.00	-160.00	454.5
4	5.00	-240.00	-160.00	454.5
4	4.25	-360.00	-160.00	431.6
5	4.25	-360.00	-160.00	431.6
5	3.50	-480.00	-160.00	408.8
6	3.50	-480.00	-160.00	408.8
6	2.88	-579.20	-160.00	390.1
7	2.88	-579.20	-160.00	390.1
7	2.26	-678.40	-160.00	371.5
8	2.26	-678.40	-160.00	371.5
8	2.00	-720.00	-160.00	363.8
9	2.00	-720.00	-160.00	363.8
9	1.25	-840.00	-160.00	341.6
10	1.25	-840.00	-160.00	341.6

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
10	0.50	-960.00	-160.00	319.7
11	0.50	-960.00	-160.00	319.7
11	-0.25	-1080.00	-160.00	298.2
12	-0.25	-1080.00	-160.00	298.2
12	-1.00	-1200.00	-160.00	277.0
13	-1.00	-1200.00	-160.00	277.0
13	-1.75	-1320.00	-160.00	256.3
14	-1.75	-1320.00	-160.00	256.3
14	-2.50	-1440.00	-160.00	236.0
15	-2.50	-1440.00	-160.00	236.0
15	-3.33	-1573.33	-160.00	214.0
16	-3.33	-1573.33	-160.00	214.0
16	-4.17	-1706.67	-160.00	192.7
17	-4.17	-1706.67	-160.00	192.7
17	-5.00	-1840.00	-160.00	172.1
18	-5.00	-1840.00	-160.00	172.1
18	-6.00	-2000.00	-160.00	148.5
19	-6.00	-2000.00	-160.00	148.5
19	-7.00	-2160.00	-160.00	126.1
20	-7.00	-2160.00	-160.00	126.1
20	-7.98	-2316.80	-160.00	105.4
21	-7.98	-2316.80	-160.00	105.4
21	-8.00	-2320.00	-160.00	105.0
22	-8.00	-2320.00	-160.00	105.0
22	-8.16	-2345.60	-160.00	101.7
23	-8.16	-2345.60	-160.00	101.7
23	-9.00	-2480.00	-160.00	85.3
24	-9.00	-2480.00	-160.00	85.3
24	-9.77	-2599.47	-145.47	71.2
25	-9.77	-2599.47	-145.47	71.2
25	-10.50	-2692.44	-104.87	58.7
26	-10.50	-2692.44	-104.87	58.7
26	-10.66	-2708.24	-92.48	56.1
27	-10.66	-2708.24	-92.48	56.1
27	-10.77	-2717.91	-83.24	54.3
28	-10.77	-2717.91	-83.24	54.3
28	-11.16	-2743.30	-45.69	48.1
29	-11.16	-2743.30	-45.69	48.1
29	-11.24	-2746.61	-37.06	46.9
30	-11.24	-2746.61	-37.06	46.9
30	-11.52	**-2752.50**	-4.41	42.7
31	-11.52	**-2752.50**	-4.41	42.7
31	-11.65	-2752.01	12.06	40.8
32	-11.65	-2752.01	12.06	40.8
32	-11.74	-2749.74	38.66	39.5
33	-11.74	-2749.74	38.66	39.5
33	-11.79	-2747.43	53.91	38.7
34	-11.79	-2747.43	53.91	38.7
34	-12.17	-2703.49	179.96	33.4
35	-12.17	-2703.48	180.09	33.4
35	-12.29	-2680.44	204.17	31.8
36	-12.29	-2680.44	204.17	31.8
36	-12.67	-2587.47	286.73	26.7
37	-12.67	-2587.47	286.73	26.7
37	-13.24	-2380.78	442.05	19.6
38	-13.24	-2380.79	442.06	19.6
38	-13.69	-2151.36	579.64	14.3
39	-13.69	-2151.35	579.96	14.3
39	-14.04	-1933.37	661.34	10.4
40	-14.04	-1933.37	661.34	10.4

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
40	-14.24	-1797.46	696.41	8.2
41	-14.24	-1797.46	696.41	8.2
41	-14.66	-1493.77	743.92	3.8
42	-14.66	-1493.77	743.92	3.8
42	-14.71	-1456.48	747.27	3.3
43	-14.71	-1456.48	747.25	3.3
43	-15.33	-982.73	**751.96**	-2.9
44	-15.33	-982.73	751.95	-2.9
44	-15.83	-632.40	631.17	-7.8
45	-15.83	-632.39	631.07	-7.8
45	-16.22	-416.96	465.98	-11.5
46	-16.22	-416.98	465.64	-11.5
46	-16.74	-192.93	391.76	-16.4
47	-16.74	-192.93	391.76	-16.4
47	-16.84	-155.32	360.12	-17.3
48	-16.84	-155.32	360.12	-17.3
48	-17.24	-39.17	216.00	-21.0
49	-17.24	-39.17	216.00	-21.0
49	-17.60	0.00	0.00	-24.4
Max		**-2752.50**	**751.96**	**500.5**
Max, minor nodes incl.		-2752.58	770.94	500.5

4.3 Charts of Stresses



4.4 Stresses

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
1	6.50	0.00	0.00	-		0.00	0.00	-	
1	5.88	0.00	0.00	-		0.00	0.00	-	
2	5.88	0.00	0.00	-		0.00	0.00	-	
2	5.26	0.00	0.00	-		0.00	0.00	-	
3	5.26	0.00	0.00	-		0.00	0.00	-	
3	5.00	0.00	0.00	-		0.00	0.00	-	
4	5.00	0.00	0.00	-		0.00	0.00	-	
4	4.25	0.00	0.00	-		0.00	0.00	-	
5	4.25	0.00	0.00	-		0.00	0.00	-	
5	3.50	0.00	0.00	-		0.00	0.00	-	
6	3.50	0.00	0.00	-		0.00	0.00	-	
6	2.88	0.00	0.00	-		0.00	0.00	-	
7	2.88	0.00	0.00	-		0.00	0.00	-	
7	2.26	0.00	0.00	-		0.00	0.00	-	
8	2.26	0.00	0.00	-		0.00	0.00	-	
8	2.00	0.00	2.55	-		0.00	2.55	-	
9	2.00	0.00	2.55	-		0.00	2.55	-	
9	1.25	0.00	9.91	-		0.00	9.91	-	
10	1.25	0.00	9.91	-		0.00	9.91	-	
10	0.50	0.00	17.27	-		0.00	17.27	-	
11	0.50	0.00	17.27	-		0.00	17.27	-	
11	-0.25	0.00	24.62	-		0.00	24.62	-	
12	-0.25	0.00	24.62	-		0.00	24.62	-	
12	-1.00	0.00	31.98	-		0.00	31.98	-	
13	-1.00	0.00	31.98	-		0.00	31.98	-	
13	-1.75	0.00	39.34	-		0.00	39.34	-	
14	-1.75	0.00	39.34	-		0.00	39.34	-	
14	-2.50	0.00	46.70	-		0.00	46.70	-	
15	-2.50	0.00	46.70	-		0.00	46.70	-	
15	-3.33	0.00	54.87	-		0.00	54.87	-	
16	-3.33	0.00	54.87	-		0.00	54.87	-	
16	-4.17	0.00	63.05	-		0.00	63.05	-	
17	-4.17	0.00	63.05	-		0.00	63.05	-	
17	-5.00	0.00	71.22	-		0.00	71.22	-	
18	-5.00	0.00	71.22	-		0.00	71.22	-	
18	-6.00	0.00	81.03	-		0.00	81.03	-	
19	-6.00	0.00	81.03	-		0.00	81.03	-	
19	-7.00	0.00	90.84	-		0.00	90.84	-	
20	-7.00	0.00	90.84	-		0.00	90.84	-	
20	-7.98	0.00	100.45	-		0.00	100.45	-	
21	-7.98	0.00	100.45	-		0.00	100.45	-	
21	-8.00	0.00	100.65	-		0.00	100.65	-	
22	-8.00	0.00	100.65	-		0.00	100.65	-	
22	-8.16	0.00	102.22	-		0.00	102.22	-	
23	-8.16	0.00	102.22	-		0.00	102.22	-	
23	-9.00	0.00	110.46	-		0.00	110.46	-	
24	-9.00	0.00	110.46	A		0.00	110.46	P	
24	-9.77	0.00	118.01	A		36.99	118.01	P	
25	-9.77	0.00	118.01	A		36.99	118.01	P	
25	-10.50	0.00	125.18	A		72.06	125.18	P	
26	-10.50	0.00	125.18	A		72.06	125.18	P	
26	-10.66	0.00	126.75	A		79.75	126.75	P	
27	-10.66	0.00	126.75	A		79.75	126.75	P	
27	-10.77	0.00	127.82	A		85.03	127.82	P	
28	-10.77	0.00	127.82	A		85.03	127.82	P	
28	-11.16	0.00	131.65	A		103.77	131.65	P	

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
29	-11.16	0.00	131.65	A		103.77	131.65	P	
29	-11.24	0.00	132.44	A		107.61	132.44	P	
30	-11.24	0.00	132.44	A		107.61	132.44	P	
30	-11.52	0.00	135.18	A		121.06	135.18	P	
31	-11.52	0.00	135.18	A		121.06	135.18	P	
31	-11.65	0.00	136.46	A		127.31	136.46	P	
32	-11.65	0.00	136.46	A		283.93	136.46	P	
32	-11.74	0.00	137.34	A		295.67	137.34	P	
33	-11.74	0.00	137.34	A		295.67	137.34	P	
33	-11.79	0.00	137.83	A		302.19	137.83	P	
34	-11.79	0.00	137.83	A		302.19	137.83	P	
34	-12.17	0.00	141.56	A		334.06	141.56	-	95
35	-12.17	0.00	141.56	A		192.82	141.56	P	
35	-12.29	0.00	142.74	A		200.63	142.74	P	
36	-12.29	0.00	142.74	A		200.63	142.74	P	
36	-12.67	0.00	146.46	A		225.38	146.46	P	
37	-12.67	0.00	146.46	A		248.68	146.46	P	
37	-13.24	0.00	152.06	A		285.62	152.06	P	
38	-13.24	0.00	152.06	A		285.62	152.06	P	
38	-13.69	0.00	156.47	A		309.99	156.47	-	98
39	-13.69	0.00	156.47	A		264.29	156.47	-	82
39	-14.04	0.00	159.90	A		192.03	159.90	-	55
40	-14.04	0.00	159.90	A		192.03	159.90	-	55
40	-14.24	0.00	161.87	A		151.97	161.87	-	42
41	-14.24	0.00	161.87	A		151.97	161.87	-	42
41	-14.66	0.00	165.99	A		70.39	165.99	-	18
42	-14.66	0.00	165.99	A		70.39	165.99	-	18
42	-14.71	0.00	166.48	A		60.89	166.48	-	15
43	-14.71	0.00	166.48	A		146.14	166.48	-	41
43	-15.33	129.21	172.56	-	33	0.00	172.56	A	
44	-15.33	129.21	172.56	-	33	0.00	172.56	A	
44	-15.83	343.55	177.46	-	80	0.00	177.46	A	
45	-15.83	343.55	177.46	-	80	0.00	177.46	A	
45	-16.22	453.43	181.29	P		0.00	181.29	A	
46	-16.22	114.80	181.29	-	10	0.00	181.29	A	
46	-16.74	163.69	186.39	-	13	0.00	186.39	A	
47	-16.74	301.59	186.39	-	49	0.00	186.39	A	
47	-16.84	318.83	187.37	-	51	0.00	187.37	A	
48	-16.84	318.83	187.37	-	51	0.00	187.37	A	
48	-17.24	387.63	191.29	-	59	0.00	191.29	A	
49	-17.24	575.25	191.29	P		0.00	191.29	A	
49	-17.60	601.20	194.83	P		0.00	194.83	A	

*

Stat Status (A=active, P=passive, Number is branche, 0 is unloading)
Mob Percentage passive mobilized

End of Report

Appendix X.II – Original structure - CPT70297 analysis

Report for D-Sheet Piling 15.1

Design of Diaphragm and Sheet Pile Walls
Developed by Deltares

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Company:	Bouwdienst Rijkswaterstaat
Date of report:	5/21/2018
Time of report:	9:53:52 AM
Date of calculation:	5/21/2018
Time of calculation:	9:52:43 AM
Filename:	U:\Final Thesis Final report\DATA\DSheet Pile\Project1
Project identification:	Hansweert Meerstoelen Paalfundering Analysis

1 Table of Contents

2 Summary

2.1 Overview of Maxima

Displacement [mm]	Moment [kNm]	Shear force [kN]	Mob. perc. moment [%]	Mob. perc. resistance [%]
1178.9	-3035.00	1052.48	0.0	50.2

3 Input Data

3.1 General Input Data

Model	Single pile; Pile loaded by forces
Unit weight of water	9.81 kN/m³

3.2 Pile Properties

Length	24.10 m
Level top side	6.50 m
Number of sections	1

3.2.1 General properties

Section name	From [m]	To [m]	Material type	Diameter [m]
Hansweert	-17.60	6.50	Steel	1.02

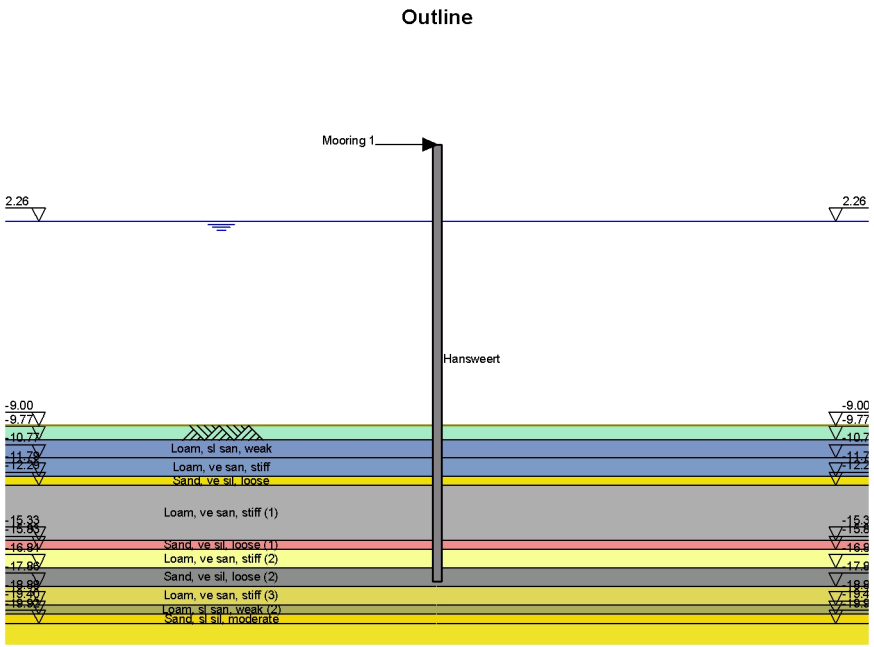
3.2.2 Stiffness EI (elastic behaviour)

Section name	Elastic stiffness EI [kNm²]	Red. factor on EI [-]	Corrected elas. stiffness EI [kNm²]	Note to reduction factor
Hansweert	1.6303E+06	1.00	1.6300E+06	

3.2.3 Maximum allowable moments

Section name	Elas. char. moment [kNm]	Modification factor [-]	Material factor [-]	Red. factor allow. moment [-]	Elas. design moment [kNm]
Hansweert	3875.00	1.00	1.00	1.00	3875.00

3.3 Outline



3.4 Horizontal Forces

Name	Level [m]	Load [kN]
Mooring 1	6.50	175.00

3.5 Water Level

Water level: 2.26 [m]

3.6 Surface

Surface level: -9.00 [m]

3.7 Soil Material Properties

Layer name	Level [m]	Unit weight		Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
		Unsat [kN/m³]	Sat. [kN/m³]			
Clay, ve san, stiff	-7.00	18.00	18.00	0.00	27.50	Yes
Loam, sl san, w...	-9.77	19.00	19.00	0.00	27.50	Yes
Loam, ve san, ...	-10.77	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-11.79	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-12.29	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-15.33	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-15.83	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-16.84	18.00	20.00	0.00	25.00	Yes

Layer name	Level [m]	Unit weight Unsat [kN/m³]	Unit weight Sat. [kN/m³]	Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
Loam, ve san, ...	-17.86	19.00	19.00	0.00	27.50	Yes
Loam, sl san, w...	-18.88	19.00	19.00	0.00	27.50	Yes
Sand, sl sil, mo...	-19.40	18.00	20.00	0.00	27.00	Yes
Sand, clean, stiff	-19.92	19.00	21.00	0.00	35.00	Yes
Loam, ve san, ...	-23.55	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-24.59	18.00	20.00	0.00	25.00	Yes
Sand, sl sil, mo...	-26.66	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-27.70	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-30.28	19.00	19.00	0.00	27.50	Yes

Layer name	Level [m]	Earth pressure coefficients Active [-]	Earth pressure coefficients Neutral [-]	Earth pressure coefficients Passive [-]	Additional pore pressure Top [kN/m²]	Additional pore pressure Bottom [kN/m²]
Clay, ve san, stiff	-7.00	0.00	0.00	4.36	0.00	0.00
Loam, sl san, w...	-9.77	0.00	0.00	5.18	0.00	0.00
Loam, ve san, ...	-10.77	0.00	0.00	5.95	0.00	0.00
Sand, ve sil, lo...	-11.79	0.00	0.00	5.27	0.00	0.00
Loam, ve san, ...	-12.29	0.00	0.00	7.34	0.00	0.00
Sand, ve sil, lo...	-15.33	0.00	0.00	6.47	0.00	0.00
Loam, ve san, ...	-15.83	0.00	0.00	8.28	0.00	0.00
Sand, ve sil, lo...	-16.84	0.00	0.00	6.86	0.00	0.00
Loam, ve san, ...	-17.86	0.00	0.00	8.84	0.00	0.00
Loam, sl san, w...	-18.88	0.00	0.00	9.02	0.00	0.00
Sand, sl sil, mo...	-19.40	0.00	0.00	8.72	0.00	0.00
Sand, clean, stiff	-19.92	0.00	0.00	20.07	0.00	0.00
Loam, ve san, ...	-23.55	0.00	0.00	9.89	0.00	0.00
Sand, ve sil, lo...	-24.59	0.00	0.00	7.92	0.00	0.00
Sand, sl sil, mo...	-26.66	0.00	0.00	9.77	0.00	0.00
Sand, ve sil, lo...	-27.70	0.00	0.00	8.16	0.00	0.00
Loam, ve san, ...	-30.28	0.00	0.00	16.45	0.00	0.00

3.8 Soil Material Properties calculated using Brinch Hansen

Layer name	Level [m]	Fictive cohesion [kN/m²]
Clay, ve san, stiff	-7.00	0.00
Loam, sl san, w...	-9.77	0.00
Loam, ve san, ...	-10.77	0.00
Sand, ve sil, lo...	-11.79	0.00
Loam, ve san, ...	-12.29	0.00
Sand, ve sil, lo...	-15.33	0.00
Loam, ve san, ...	-15.83	0.00
Sand, ve sil, lo...	-16.84	0.00
Loam, ve san, ...	-17.86	0.00
Loam, sl san, w...	-18.88	0.00
Sand, sl sil, mo...	-19.40	0.00
Sand, clean, stiff	-19.92	0.00
Loam, ve san, ...	-23.55	0.00
Sand, ve sil, lo...	-24.59	0.00
Sand, sl sil, mo...	-26.66	0.00
Sand, ve sil, lo...	-27.70	0.00
Loam, ve san, ...	-30.28	0.00

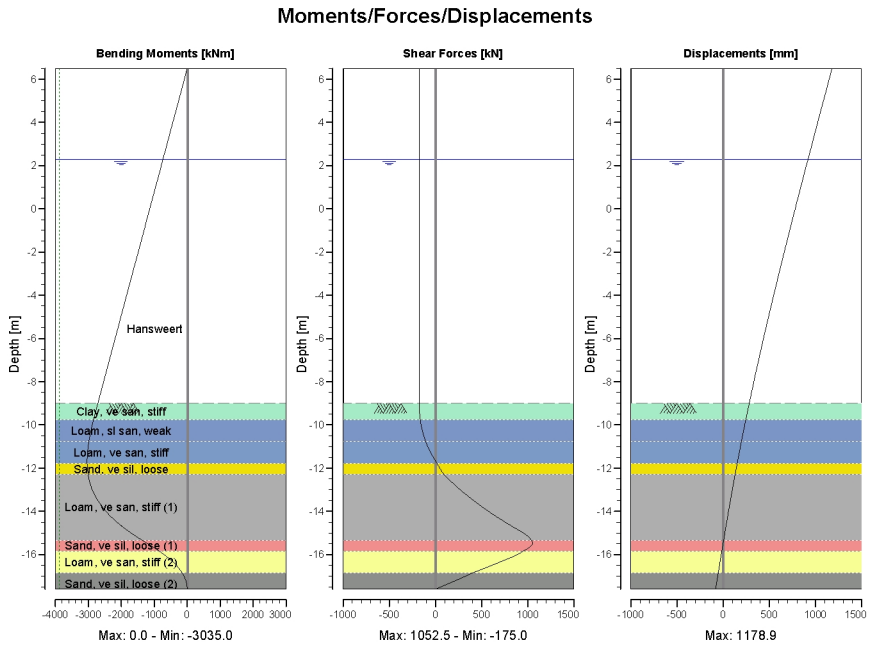
3.9 Modulus of Subgrade Reaction

Layer name	Level [m]	Ménard used	E-Mod Ménard [kN/m²]	Soil type Ménard	Branch 1	
					Top [kN/m³]	Bottom [kN/m³]
Clay, ve san, stiff	-7.00	No	n.a.	n.a.	10000.00	10000.00
Loam, sl san, w...	-9.77	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-10.77	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-11.79	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-12.29	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-15.33	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-15.83	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-16.84	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-17.86	Yes	7800.00	Loam	21611.15	21611.15
Loam, sl san, w...	-18.88	No	n.a.	n.a.	10000.00	10000.00
Sand, sl sil, mo...	-19.40	Yes	5000.00	Sand	18424.93	18424.93
Sand, clean, stiff	-19.92	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-23.55	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-24.59	Yes	12000.00	Sand	44219.84	44219.84
Sand, sl sil, mo...	-26.66	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-27.70	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-30.28	Yes	7800.00	Loam	21611.15	21611.15

4 Calculation Results

Number of iterations: 9

4.1 Charts of Moments, Forces and Displacements



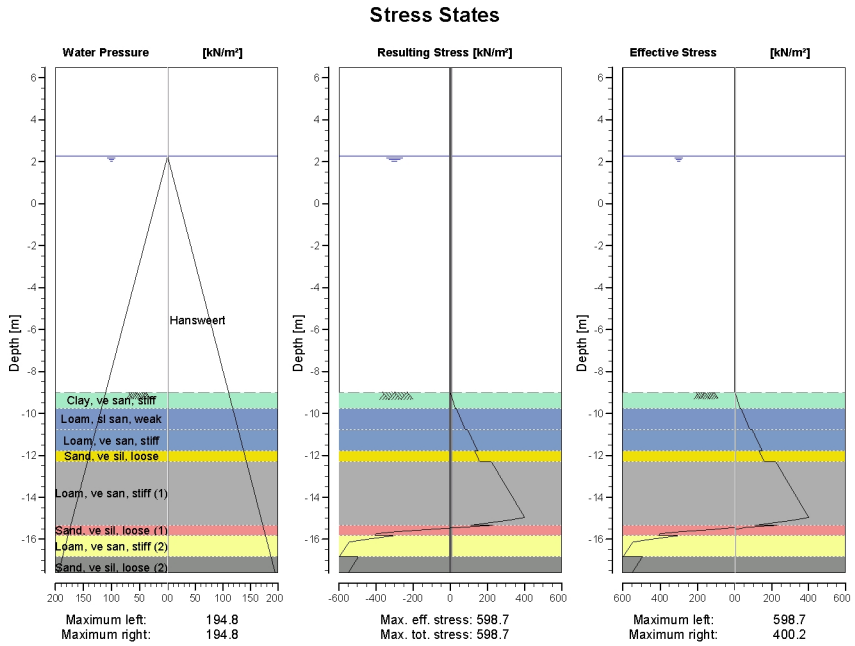
4.2 Moments, Forces and Displacements

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
1	6.50	0.00	-175.00	**1178.9**
1	5.88	-108.50	-175.00	1140.3
2	5.88	-108.50	-175.00	1140.3
2	5.26	-217.00	-175.00	1101.8
3	5.26	-217.00	-175.00	1101.8
3	5.00	-262.50	-175.00	1085.7
4	5.00	-262.50	-175.00	1085.7
4	4.25	-393.75	-175.00	1039.2
5	4.25	-393.75	-175.00	1039.2
5	3.50	-525.00	-175.00	992.8
6	3.50	-525.00	-175.00	992.8
6	2.88	-633.50	-175.00	954.7
7	2.88	-633.50	-175.00	954.7
7	2.26	-742.00	-175.00	916.6
8	2.26	-742.00	-175.00	916.6
8	2.00	-787.50	-175.00	900.7
9	2.00	-787.50	-175.00	900.7
9	1.25	-918.75	-175.00	855.1
10	1.25	-918.75	-175.00	855.1

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
10	0.50	-1050.00	-175.00	809.7
11	0.50	-1050.00	-175.00	809.7
11	-0.25	-1181.25	-175.00	764.7
12	-0.25	-1181.25	-175.00	764.7
12	-1.00	-1312.50	-175.00	720.1
13	-1.00	-1312.50	-175.00	720.1
13	-1.75	-1443.75	-175.00	676.0
14	-1.75	-1443.75	-175.00	676.0
14	-2.50	-1575.00	-175.00	632.4
15	-2.50	-1575.00	-175.00	632.4
15	-3.33	-1720.83	-175.00	584.5
16	-3.33	-1720.83	-175.00	584.5
16	-4.17	-1866.67	-175.00	537.4
17	-4.17	-1866.67	-175.00	537.4
17	-5.00	-2012.50	-175.00	491.1
18	-5.00	-2012.50	-175.00	491.1
18	-6.00	-2187.50	-175.00	436.7
19	-6.00	-2187.50	-175.00	436.7
19	-7.00	-2362.50	-175.00	383.6
20	-7.00	-2362.50	-175.00	383.6
20	-7.98	-2534.00	-175.00	333.0
21	-7.98	-2534.00	-175.00	333.0
21	-8.00	-2537.50	-175.00	331.9
22	-8.00	-2537.50	-175.00	331.9
22	-8.16	-2565.50	-175.00	323.8
23	-8.16	-2565.50	-175.00	323.8
23	-9.00	-2712.50	-175.00	281.9
24	-9.00	-2712.50	-175.00	281.9
24	-9.77	-2844.48	-164.20	244.4
25	-9.77	-2844.48	-164.20	244.4
25	-10.50	-2952.32	-126.93	209.9
26	-10.50	-2952.32	-126.93	209.9
26	-10.66	-2971.71	-115.30	202.4
27	-10.66	-2971.71	-115.30	202.4
27	-10.77	-2983.92	-106.59	197.3
28	-10.77	-2983.92	-106.59	197.3
28	-11.16	-3017.79	-65.68	179.5
29	-11.16	-3017.79	-65.68	179.5
29	-11.24	-3022.67	-56.24	175.8
30	-11.24	-3022.67	-56.24	175.8
30	-11.52	-3033.50	-20.38	163.2
31	-11.52	-3033.50	-20.38	163.2
31	-11.65	**-3034.98**	-2.25	157.4
32	-11.65	**-3034.98**	-2.25	157.4
32	-11.74	-3034.59	10.86	153.4
33	-11.74	-3034.59	10.86	153.4
33	-11.79	-3033.87	18.33	151.2
34	-11.79	-3033.87	18.33	151.2
34	-12.17	-3016.75	73.09	134.5
35	-12.17	-3016.75	73.09	134.5
35	-12.29	-3006.85	92.03	129.3
36	-12.29	-3006.85	92.03	129.3
36	-12.67	-2955.04	182.31	113.0
37	-12.67	-2955.04	182.31	113.0
37	-13.24	-2808.27	336.38	88.9
38	-13.24	-2808.27	336.38	88.9
38	-13.69	-2626.51	473.81	70.4
39	-13.69	-2626.51	473.81	70.4
39	-14.04	-2440.52	590.35	56.1
40	-14.04	-2440.52	590.35	56.1

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
40	-14.24	-2315.46	660.72	48.1
41	-14.24	-2315.46	660.72	48.1
41	-14.66	-2005.46	817.48	31.4
42	-14.66	-2005.46	817.48	31.4
42	-14.71	-1964.10	836.95	29.4
43	-14.71	-1964.28	838.05	29.4
43	-15.33	-1373.51	1037.41	5.2
44	-15.33	-1373.24	**1037.87**	5.2
44	-15.83	-860.57	953.16	-14.1
45	-15.83	-860.76	950.70	-14.1
45	-16.22	-521.86	769.39	-29.1
46	-16.22	-521.90	768.72	-29.1
46	-16.74	-200.05	465.69	-49.0
47	-16.74	-200.05	465.69	-49.0
47	-16.84	-156.51	405.00	-52.8
48	-16.84	-156.51	405.00	-52.8
48	-17.24	-35.73	196.98	-68.1
49	-17.24	-35.73	196.98	-68.1
49	-17.60	0.00	0.00	-81.8
Max		**-3034.98**	**1037.87**	**1178.9**
Max, minor nodes incl.		-3035.00	1052.48	1178.9

4.3 Charts of Stresses



4.4 Stresses

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
1	6.50	0.00	0.00	-		0.00	0.00	-	
1	5.88	0.00	0.00	-		0.00	0.00	-	
2	5.88	0.00	0.00	-		0.00	0.00	-	
2	5.26	0.00	0.00	-		0.00	0.00	-	
3	5.26	0.00	0.00	-		0.00	0.00	-	
3	5.00	0.00	0.00	-		0.00	0.00	-	
4	5.00	0.00	0.00	-		0.00	0.00	-	
4	4.25	0.00	0.00	-		0.00	0.00	-	
5	4.25	0.00	0.00	-		0.00	0.00	-	
5	3.50	0.00	0.00	-		0.00	0.00	-	
6	3.50	0.00	0.00	-		0.00	0.00	-	
6	2.88	0.00	0.00	-		0.00	0.00	-	
7	2.88	0.00	0.00	-		0.00	0.00	-	
7	2.26	0.00	0.00	-		0.00	0.00	-	
8	2.26	0.00	0.00	-		0.00	0.00	-	
8	2.00	0.00	2.55	-		0.00	2.55	-	
9	2.00	0.00	2.55	-		0.00	2.55	-	
9	1.25	0.00	9.91	-		0.00	9.91	-	
10	1.25	0.00	9.91	-		0.00	9.91	-	
10	0.50	0.00	17.27	-		0.00	17.27	-	
11	0.50	0.00	17.27	-		0.00	17.27	-	
11	-0.25	0.00	24.62	-		0.00	24.62	-	
12	-0.25	0.00	24.62	-		0.00	24.62	-	
12	-1.00	0.00	31.98	-		0.00	31.98	-	
13	-1.00	0.00	31.98	-		0.00	31.98	-	
13	-1.75	0.00	39.34	-		0.00	39.34	-	
14	-1.75	0.00	39.34	-		0.00	39.34	-	
14	-2.50	0.00	46.70	-		0.00	46.70	-	
15	-2.50	0.00	46.70	-		0.00	46.70	-	
15	-3.33	0.00	54.87	-		0.00	54.87	-	
16	-3.33	0.00	54.87	-		0.00	54.87	-	
16	-4.17	0.00	63.05	-		0.00	63.05	-	
17	-4.17	0.00	63.05	-		0.00	63.05	-	
17	-5.00	0.00	71.22	-		0.00	71.22	-	
18	-5.00	0.00	71.22	-		0.00	71.22	-	
18	-6.00	0.00	81.03	-		0.00	81.03	-	
19	-6.00	0.00	81.03	-		0.00	81.03	-	
19	-7.00	0.00	90.84	-		0.00	90.84	-	
20	-7.00	0.00	90.84	-		0.00	90.84	-	
20	-7.98	0.00	100.45	-		0.00	100.45	-	
21	-7.98	0.00	100.45	-		0.00	100.45	-	
21	-8.00	0.00	100.65	-		0.00	100.65	-	
22	-8.00	0.00	100.65	-		0.00	100.65	-	
22	-8.16	0.00	102.22	-		0.00	102.22	-	
23	-8.16	0.00	102.22	-		0.00	102.22	-	
23	-9.00	0.00	110.46	-		0.00	110.46	-	
24	-9.00	0.00	110.46	A		0.00	110.46	P	
24	-9.77	0.00	118.01	A		27.49	118.01	P	
25	-9.77	0.00	118.01	A		32.68	118.01	P	
25	-10.50	0.00	125.18	A		67.44	125.18	P	
26	-10.50	0.00	125.18	A		67.44	125.18	P	
26	-10.66	0.00	126.75	A		75.06	126.75	P	
27	-10.66	0.00	126.75	A		75.06	126.75	P	
27	-10.77	0.00	127.82	A		80.29	127.82	P	
28	-10.77	0.00	127.82	A		92.19	127.82	P	
28	-11.16	0.00	131.65	A		113.51	131.65	P	

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
29	-11.16	0.00	131.65	A		113.51	131.65	P	
29	-11.24	0.00	132.44	A		117.88	132.44	P	
30	-11.24	0.00	132.44	A		117.88	132.44	P	
30	-11.52	0.00	135.18	A		133.19	135.18	P	
31	-11.52	0.00	135.18	A		133.19	135.18	P	
31	-11.65	0.00	136.46	A		140.30	136.46	P	
32	-11.65	0.00	136.46	A		140.30	136.46	P	
32	-11.74	0.00	137.34	A		145.22	137.34	P	
33	-11.74	0.00	137.34	A		145.22	137.34	P	
33	-11.79	0.00	137.83	A		147.95	137.83	P	
34	-11.79	0.00	137.83	A		131.07	137.83	P	
34	-12.17	0.00	141.56	A		151.48	141.56	P	
35	-12.17	0.00	141.56	A		151.48	141.56	P	
35	-12.29	0.00	142.74	A		157.93	142.74	P	
36	-12.29	0.00	142.74	A		220.10	142.74	P	
36	-12.67	0.00	146.46	A		245.76	146.46	P	
37	-12.67	0.00	146.46	A		245.76	146.46	P	
37	-13.24	0.00	152.06	A		284.23	152.06	P	
38	-13.24	0.00	152.06	A		284.23	152.06	P	
38	-13.69	0.00	156.47	A		314.61	156.47	P	
39	-13.69	0.00	156.47	A		314.61	156.47	P	
39	-14.04	0.00	159.90	A		338.24	159.90	P	
40	-14.04	0.00	159.90	A		338.24	159.90	P	
40	-14.24	0.00	161.87	A		351.74	161.87	P	
41	-14.24	0.00	161.87	A		351.74	161.87	P	
41	-14.66	0.00	165.99	A		380.09	165.99	P	
42	-14.66	0.00	165.99	A		380.09	165.99	P	
42	-14.71	0.00	166.48	A		383.46	166.48	P	
43	-14.71	0.00	166.48	A		383.46	166.48	P	
43	-15.33	0.00	172.56	A		111.88	172.56	-	26
44	-15.33	0.00	172.56	A		228.92	172.56	-	61
44	-15.83	407.46	177.46	P		0.00	177.46	A	
45	-15.83	305.43	177.46	-	59	0.00	177.46	A	
45	-16.22	551.54	181.29	P		0.00	181.29	A	
46	-16.22	551.54	181.29	P		0.00	181.29	A	
46	-16.74	591.12	186.39	P		0.00	186.39	A	
47	-16.74	591.12	186.39	P		0.00	186.39	A	
47	-16.84	598.73	187.37	P		0.00	187.37	A	
48	-16.84	495.88	187.37	P		0.00	187.37	A	
48	-17.24	523.85	191.29	P		0.00	191.29	A	
49	-17.24	523.85	191.29	P		0.00	191.29	A	
49	-17.60	549.01	194.83	P		0.00	194.83	A	

*

Stat Status (A=active, P=passive, Number is branche, 0 is unloading)
Mob Percentage passive mobilized

End of Report

Report for D-Sheet Piling 15.1

Design of Diaphragm and Sheet Pile Walls
Developed by Deltares

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Company:	Bouwdienst Rijkswaterstaat
Date of report:	5/21/2018
Time of report:	9:54:43 AM
Date of calculation:	5/21/2018
Time of calculation:	9:54:20 AM
Filename:	U:\Final Thesis Final report\DATA\DSheet Pile\Project1
Project identification:	Hansweert Meerstoelen Paalfundering Analysis

1 Table of Contents

2 Summary

2.1 Overview of Maxima

Displacement [mm]	Moment [kNm]	Shear force [kN]	Mob. perc. moment [%]	Mob. perc. resistance [%]
490.4	-2619.04	745.13	0.0	36.6

3 Input Data

3.1 General Input Data

Model	Single pile; Pile loaded by forces
Unit weight of water	9.81 kN/m³

3.2 Pile Properties

Length	24.10 m
Level top side	6.50 m
Number of sections	1

3.2.1 General properties

Section name	From [m]	To [m]	Material type	Diameter [m]
Hansweert	-17.60	6.50	Steel	1.02

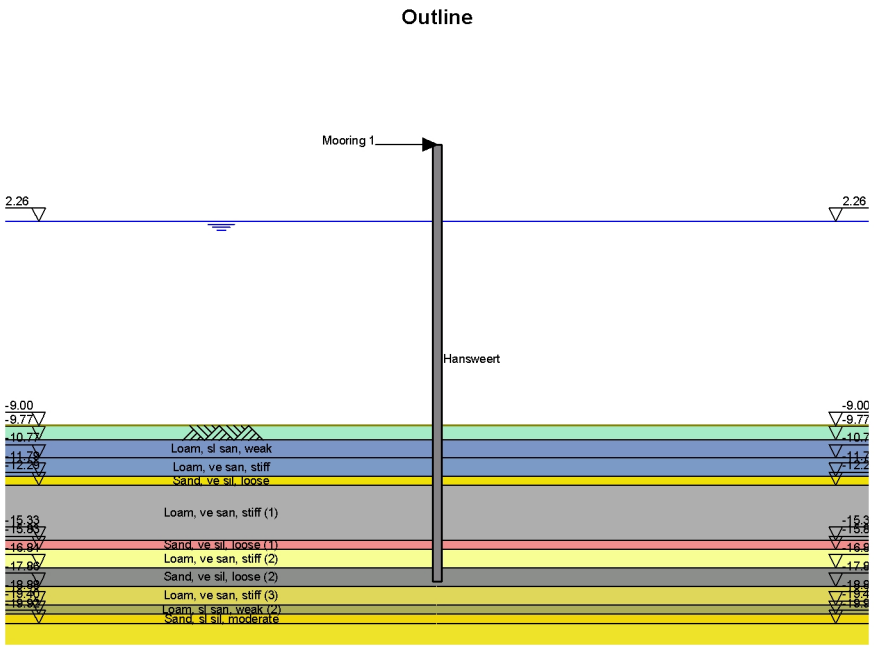
3.2.2 Stiffness EI (elastic behaviour)

Section name	Elastic stiffness EI [kNm²]	Red. factor on EI [-]	Corrected elas. stiffness EI [kNm²]	Note to reduction factor
Hansweert	1.6303E+06	1.00	1.6300E+06	

3.2.3 Maximum allowable moments

Section name	Elas. char. moment [kNm]	Modification factor [-]	Material factor [-]	Red. factor allow. moment [-]	Elas. design moment [kNm]
Hansweert	3875.00	1.00	1.00	1.00	3875.00

3.3 Outline



3.4 Horizontal Forces

Name	Level [m]	Load [kN]
Mooring 1	6.50	152.00

3.5 Water Level

Water level: 2.26 [m]

3.6 Surface

Surface level: -9.00 [m]

3.7 Soil Material Properties

Layer name	Level [m]	Unit weight		Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
		Unsat [kN/m³]	Sat. [kN/m³]			
Clay, ve san, stiff	-7.00	18.00	18.00	0.00	27.50	Yes
Loam, sl san, w...	-9.77	19.00	19.00	0.00	27.50	Yes
Loam, ve san, ...	-10.77	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-11.79	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-12.29	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-15.33	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-15.83	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-16.84	18.00	20.00	0.00	25.00	Yes

Layer name	Level [m]	Unit weight Unsat [kN/m³]	Unit weight Sat. [kN/m³]	Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
Loam, ve san, ...	-17.86	19.00	19.00	0.00	27.50	Yes
Loam, sl san, w...	-18.88	19.00	19.00	0.00	27.50	Yes
Sand, sl sil, mo...	-19.40	18.00	20.00	0.00	27.00	Yes
Sand, clean, stiff	-19.92	19.00	21.00	0.00	35.00	Yes
Loam, ve san, ...	-23.55	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-24.59	18.00	20.00	0.00	25.00	Yes
Sand, sl sil, mo...	-26.66	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-27.70	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-30.28	19.00	19.00	0.00	27.50	Yes

Layer name	Level [m]	Earth pressure coefficients Active [-]	Earth pressure coefficients Neutral [-]	Earth pressure coefficients Passive [-]	Additional pore pressure Top [kN/m²]	Additional pore pressure Bottom [kN/m²]
Clay, ve san, stiff	-7.00	0.00	0.00	4.36	0.00	0.00
Loam, sl san, w...	-9.77	0.00	0.00	5.18	0.00	0.00
Loam, ve san, ...	-10.77	0.00	0.00	5.95	0.00	0.00
Sand, ve sil, lo...	-11.79	0.00	0.00	5.27	0.00	0.00
Loam, ve san, ...	-12.29	0.00	0.00	7.34	0.00	0.00
Sand, ve sil, lo...	-15.33	0.00	0.00	6.47	0.00	0.00
Loam, ve san, ...	-15.83	0.00	0.00	8.28	0.00	0.00
Sand, ve sil, lo...	-16.84	0.00	0.00	6.86	0.00	0.00
Loam, ve san, ...	-17.86	0.00	0.00	8.84	0.00	0.00
Loam, sl san, w...	-18.88	0.00	0.00	9.02	0.00	0.00
Sand, sl sil, mo...	-19.40	0.00	0.00	8.72	0.00	0.00
Sand, clean, stiff	-19.92	0.00	0.00	20.07	0.00	0.00
Loam, ve san, ...	-23.55	0.00	0.00	9.89	0.00	0.00
Sand, ve sil, lo...	-24.59	0.00	0.00	7.92	0.00	0.00
Sand, sl sil, mo...	-26.66	0.00	0.00	9.77	0.00	0.00
Sand, ve sil, lo...	-27.70	0.00	0.00	8.16	0.00	0.00
Loam, ve san, ...	-30.28	0.00	0.00	16.45	0.00	0.00

3.8 Soil Material Properties calculated using Brinch Hansen

Layer name	Level [m]	Fictive cohesion [kN/m²]
Clay, ve san, stiff	-7.00	0.00
Loam, sl san, w...	-9.77	0.00
Loam, ve san, ...	-10.77	0.00
Sand, ve sil, lo...	-11.79	0.00
Loam, ve san, ...	-12.29	0.00
Sand, ve sil, lo...	-15.33	0.00
Loam, ve san, ...	-15.83	0.00
Sand, ve sil, lo...	-16.84	0.00
Loam, ve san, ...	-17.86	0.00
Loam, sl san, w...	-18.88	0.00
Sand, sl sil, mo...	-19.40	0.00
Sand, clean, stiff	-19.92	0.00
Loam, ve san, ...	-23.55	0.00
Sand, ve sil, lo...	-24.59	0.00
Sand, sl sil, mo...	-26.66	0.00
Sand, ve sil, lo...	-27.70	0.00
Loam, ve san, ...	-30.28	0.00

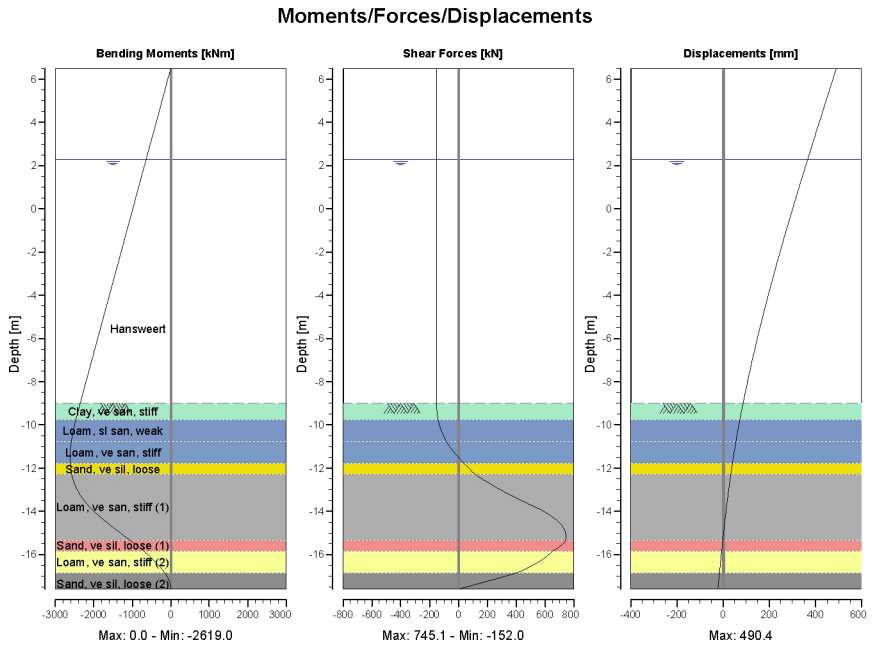
3.9 Modulus of Subgrade Reaction

Layer name	Level [m]	Ménard used	E-Mod Ménard [kN/m²]	Soil type Ménard	Branch 1	
					Top [kN/m³]	Bottom [kN/m³]
Clay, ve san, stiff	-7.00	No	n.a.	n.a.	10000.00	10000.00
Loam, sl san, w...	-9.77	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-10.77	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-11.79	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-12.29	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-15.33	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-15.83	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-16.84	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-17.86	Yes	7800.00	Loam	21611.15	21611.15
Loam, sl san, w...	-18.88	No	n.a.	n.a.	10000.00	10000.00
Sand, sl sil, mo...	-19.40	Yes	5000.00	Sand	18424.93	18424.93
Sand, clean, stiff	-19.92	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-23.55	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-24.59	Yes	12000.00	Sand	44219.84	44219.84
Sand, sl sil, mo...	-26.66	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-27.70	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-30.28	Yes	7800.00	Loam	21611.15	21611.15

4 Calculation Results

Number of iterations: 7

4.1 Charts of Moments, Forces and Displacements



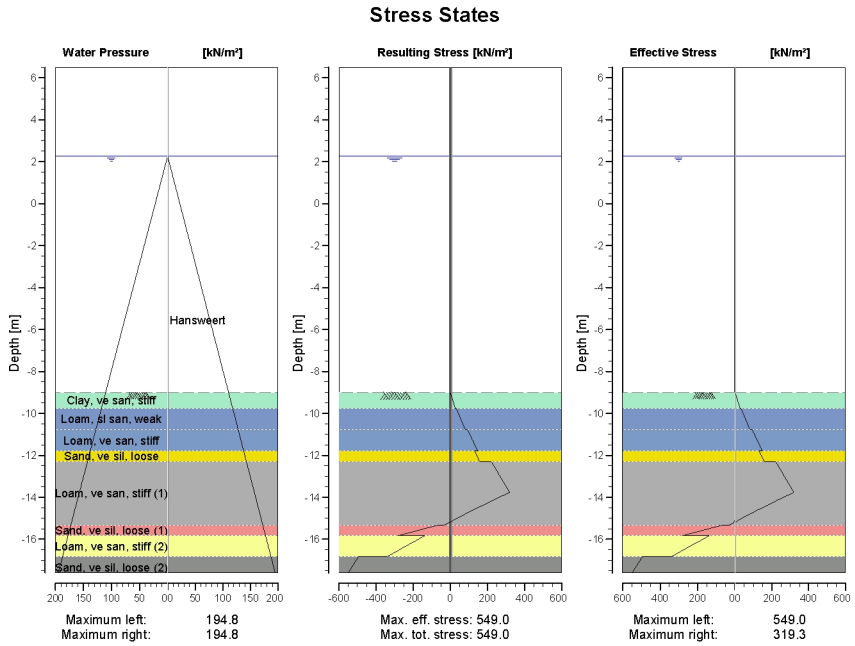
4.2 Moments, Forces and Displacements

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
1	6.50	0.00	-152.00	**490.4**
1	5.88	-94.24	-152.00	471.9
2	5.88	-94.24	-152.00	471.9
2	5.26	-188.48	-152.00	453.4
3	5.26	-188.48	-152.00	453.4
3	5.00	-228.00	-152.00	445.7
4	5.00	-228.00	-152.00	445.7
4	4.25	-342.00	-152.00	423.5
5	4.25	-342.00	-152.00	423.5
5	3.50	-456.00	-152.00	401.4
6	3.50	-456.00	-152.00	401.4
6	2.88	-550.24	-152.00	383.2
7	2.88	-550.24	-152.00	383.2
7	2.26	-644.48	-152.00	365.1
8	2.26	-644.48	-152.00	365.1
8	2.00	-684.00	-152.00	357.6
9	2.00	-684.00	-152.00	357.6
9	1.25	-798.00	-152.00	336.1
10	1.25	-798.00	-152.00	336.1

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
10	0.50	-912.00	-152.00	314.8
11	0.50	-912.00	-152.00	314.8
11	-0.25	-1026.00	-152.00	293.9
12	-0.25	-1026.00	-152.00	293.9
12	-1.00	-1140.00	-152.00	273.3
13	-1.00	-1140.00	-152.00	273.3
13	-1.75	-1254.00	-152.00	253.1
14	-1.75	-1254.00	-152.00	253.1
14	-2.50	-1368.00	-152.00	233.3
15	-2.50	-1368.00	-152.00	233.3
15	-3.33	-1494.67	-152.00	211.9
16	-3.33	-1494.67	-152.00	211.9
16	-4.17	-1621.33	-152.00	191.2
17	-4.17	-1621.33	-152.00	191.2
17	-5.00	-1748.00	-152.00	171.1
18	-5.00	-1748.00	-152.00	171.1
18	-6.00	-1900.00	-152.00	148.0
19	-6.00	-1900.00	-152.00	148.0
19	-7.00	-2052.00	-152.00	126.0
20	-7.00	-2052.00	-152.00	126.0
20	-7.98	-2200.96	-152.00	105.8
21	-7.98	-2200.96	-152.00	105.8
21	-8.00	-2204.00	-152.00	105.4
22	-8.00	-2204.00	-152.00	105.4
22	-8.16	-2228.32	-152.00	102.2
23	-8.16	-2228.32	-152.00	102.2
23	-9.00	-2356.00	-152.00	86.0
24	-9.00	-2356.00	-152.00	86.0
24	-9.77	-2470.27	-141.20	72.1
25	-9.77	-2470.27	-141.20	72.1
25	-10.50	-2561.32	-103.93	59.8
26	-10.50	-2561.32	-103.93	59.8
26	-10.66	-2577.03	-92.30	57.2
27	-10.66	-2577.03	-92.30	57.2
27	-10.77	-2586.71	-83.59	55.4
28	-10.77	-2586.71	-83.59	55.4
28	-11.16	-2611.61	-42.68	49.3
29	-11.16	-2611.61	-42.68	49.3
29	-11.24	-2614.65	-33.24	48.1
30	-11.24	-2614.65	-33.24	48.1
30	-11.52	**-2619.04**	2.62	43.9
31	-11.52	**-2619.04**	2.62	43.9
31	-11.65	-2617.53	20.75	42.0
32	-11.65	-2617.53	20.75	42.0
32	-11.74	-2615.07	33.86	40.7
33	-11.74	-2615.07	33.86	40.7
33	-11.79	-2613.20	41.33	40.0
34	-11.79	-2613.20	41.33	40.0
34	-12.17	-2587.34	96.09	34.7
35	-12.17	-2587.34	96.09	34.7
35	-12.29	-2574.68	115.03	33.1
36	-12.29	-2574.68	115.03	33.1
36	-12.67	-2514.13	205.31	28.0
37	-12.67	-2514.13	205.31	28.0
37	-13.24	-2354.25	359.38	20.9
38	-13.24	-2354.25	359.38	20.9
38	-13.69	-2162.14	496.81	15.7
39	-13.69	-2162.15	496.97	15.7
39	-14.04	-1969.16	601.58	11.7
40	-14.04	-1969.16	601.62	11.7

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
40	-14.24	-1843.98	648.56	9.6
41	-14.24	-1843.98	648.56	9.6
41	-14.66	-1555.88	716.53	5.1
42	-14.66	-1555.88	716.52	5.1
42	-14.71	-1519.92	721.91	4.6
43	-14.71	-1519.91	721.90	4.6
43	-15.33	-1061.57	**742.51**	-1.6
44	-15.33	-1061.57	742.49	-1.6
44	-15.83	-708.27	652.61	-6.4
45	-15.83	-708.27	652.60	-6.4
45	-16.22	-466.52	581.90	-10.1
46	-16.22	-466.52	581.90	-10.1
46	-16.74	-198.72	438.85	-14.9
47	-16.74	-198.72	438.85	-14.9
47	-16.84	-156.51	405.00	-15.8
48	-16.84	-156.51	405.00	-15.8
48	-17.24	-35.73	196.98	-19.5
49	-17.24	-35.73	196.98	-19.5
49	-17.60	0.00	0.00	-22.8
Max		**-2619.04**	**742.51**	**490.4**
Max, minor nodes incl.		-2619.04	745.13	490.4

4.3 Charts of Stresses



4.4 Stresses

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
1	6.50	0.00	0.00	-		0.00	0.00	-	
1	5.88	0.00	0.00	-		0.00	0.00	-	
2	5.88	0.00	0.00	-		0.00	0.00	-	
2	5.26	0.00	0.00	-		0.00	0.00	-	
3	5.26	0.00	0.00	-		0.00	0.00	-	
3	5.00	0.00	0.00	-		0.00	0.00	-	
4	5.00	0.00	0.00	-		0.00	0.00	-	
4	4.25	0.00	0.00	-		0.00	0.00	-	
5	4.25	0.00	0.00	-		0.00	0.00	-	
5	3.50	0.00	0.00	-		0.00	0.00	-	
6	3.50	0.00	0.00	-		0.00	0.00	-	
6	2.88	0.00	0.00	-		0.00	0.00	-	
7	2.88	0.00	0.00	-		0.00	0.00	-	
7	2.26	0.00	0.00	-		0.00	0.00	-	
8	2.26	0.00	0.00	-		0.00	0.00	-	
8	2.00	0.00	2.55	-		0.00	2.55	-	
9	2.00	0.00	2.55	-		0.00	2.55	-	
9	1.25	0.00	9.91	-		0.00	9.91	-	
10	1.25	0.00	9.91	-		0.00	9.91	-	
10	0.50	0.00	17.27	-		0.00	17.27	-	
11	0.50	0.00	17.27	-		0.00	17.27	-	
11	-0.25	0.00	24.62	-		0.00	24.62	-	
12	-0.25	0.00	24.62	-		0.00	24.62	-	
12	-1.00	0.00	31.98	-		0.00	31.98	-	
13	-1.00	0.00	31.98	-		0.00	31.98	-	
13	-1.75	0.00	39.34	-		0.00	39.34	-	
14	-1.75	0.00	39.34	-		0.00	39.34	-	
14	-2.50	0.00	46.70	-		0.00	46.70	-	
15	-2.50	0.00	46.70	-		0.00	46.70	-	
15	-3.33	0.00	54.87	-		0.00	54.87	-	
16	-3.33	0.00	54.87	-		0.00	54.87	-	
16	-4.17	0.00	63.05	-		0.00	63.05	-	
17	-4.17	0.00	63.05	-		0.00	63.05	-	
17	-5.00	0.00	71.22	-		0.00	71.22	-	
18	-5.00	0.00	71.22	-		0.00	71.22	-	
18	-6.00	0.00	81.03	-		0.00	81.03	-	
19	-6.00	0.00	81.03	-		0.00	81.03	-	
19	-7.00	0.00	90.84	-		0.00	90.84	-	
20	-7.00	0.00	90.84	-		0.00	90.84	-	
20	-7.98	0.00	100.45	-		0.00	100.45	-	
21	-7.98	0.00	100.45	-		0.00	100.45	-	
21	-8.00	0.00	100.65	-		0.00	100.65	-	
22	-8.00	0.00	100.65	-		0.00	100.65	-	
22	-8.16	0.00	102.22	-		0.00	102.22	-	
23	-8.16	0.00	102.22	-		0.00	102.22	-	
23	-9.00	0.00	110.46	-		0.00	110.46	-	
24	-9.00	0.00	110.46	A		0.00	110.46	P	
24	-9.77	0.00	118.01	A		27.49	118.01	P	
25	-9.77	0.00	118.01	A		32.68	118.01	P	
25	-10.50	0.00	125.18	A		67.44	125.18	P	
26	-10.50	0.00	125.18	A		67.44	125.18	P	
26	-10.66	0.00	126.75	A		75.06	126.75	P	
27	-10.66	0.00	126.75	A		75.06	126.75	P	
27	-10.77	0.00	127.82	A		80.29	127.82	P	
28	-10.77	0.00	127.82	A		92.19	127.82	P	
28	-11.16	0.00	131.65	A		113.51	131.65	P	

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
29	-11.16	0.00	131.65	A		113.51	131.65	P	
29	-11.24	0.00	132.44	A		117.88	132.44	P	
30	-11.24	0.00	132.44	A		117.88	132.44	P	
30	-11.52	0.00	135.18	A		133.19	135.18	P	
31	-11.52	0.00	135.18	A		133.19	135.18	P	
31	-11.65	0.00	136.46	A		140.30	136.46	P	
32	-11.65	0.00	136.46	A		140.30	136.46	P	
32	-11.74	0.00	137.34	A		145.22	137.34	P	
33	-11.74	0.00	137.34	A		145.22	137.34	P	
33	-11.79	0.00	137.83	A		147.95	137.83	P	
34	-11.79	0.00	137.83	A		131.07	137.83	P	
34	-12.17	0.00	141.56	A		151.48	141.56	P	
35	-12.17	0.00	141.56	A		151.48	141.56	P	
35	-12.29	0.00	142.74	A		157.93	142.74	P	
36	-12.29	0.00	142.74	A		220.10	142.74	P	
36	-12.67	0.00	146.46	A		245.76	146.46	P	
37	-12.67	0.00	146.46	A		245.76	146.46	P	
37	-13.24	0.00	152.06	A		284.23	152.06	P	
38	-13.24	0.00	152.06	A		284.23	152.06	P	
38	-13.69	0.00	156.47	A		314.61	156.47	P	
39	-13.69	0.00	156.47	A		314.61	156.47	P	
39	-14.04	0.00	159.90	A		253.67	159.90	-	75
40	-14.04	0.00	159.90	A		253.67	159.90	-	75
40	-14.24	0.00	161.87	A		206.72	161.87	-	59
41	-14.24	0.00	161.87	A		206.72	161.87	-	59
41	-14.66	0.00	165.99	A		111.22	165.99	-	29
42	-14.66	0.00	165.99	A		111.22	165.99	-	29
42	-14.71	0.00	166.48	A		100.11	166.48	-	26
43	-14.71	0.00	166.48	A		100.11	166.48	-	26
43	-15.33	33.90	172.56	-	8	0.00	172.56	A	
44	-15.33	69.36	172.56	-	19	0.00	172.56	A	
44	-15.83	282.19	177.46	-	69	0.00	177.46	A	
45	-15.83	137.91	177.46	-	26	0.00	177.46	A	
45	-16.22	217.35	181.29	-	39	0.00	181.29	A	
46	-16.22	217.35	181.29	-	39	0.00	181.29	A	
46	-16.74	321.86	186.39	-	54	0.00	186.39	A	
47	-16.74	321.86	186.39	-	54	0.00	186.39	A	
47	-16.84	341.86	187.37	-	57	0.00	187.37	A	
48	-16.84	495.88	187.37	P		0.00	187.37	A	
48	-17.24	523.85	191.29	P		0.00	191.29	A	
49	-17.24	523.85	191.29	P		0.00	191.29	A	
49	-17.60	549.01	194.83	P		0.00	194.83	A	

*

Stat Status (A=active, P=passive, Number is branche, 0 is unloading)
Mob Percentage passive mobilized

End of Report

Appendix X.III – New pile - CPT70294 analysis for 350kN

Report for D-Sheet Piling 15.1

Design of Diaphragm and Sheet Pile Walls
Developed by Deltares

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Company:	Bouwdienst Rijkswaterstaat
Date of report:	5/21/2018
Time of report:	10:06:33 AM
Date of calculation:	5/21/2018
Time of calculation:	10:03:48 AM
Filename:	U:\Final Thesis Final report\DATA\DSheet Pile\Project1
Project identification:	Hansweert Meerstoelen Paalfundering Analysis

1 Table of Contents

2 Summary

2.1 Overview of Maxima

Displacement [mm]	Moment [kNm]	Shear force [kN]	Mob. perc. moment [%]	Mob. perc. resistance [%]
1018.7	-6250.99	1431.13	0.0	38.3

2.2 Calculation Errors

Error
Maximum number of different kinds of bars exceeded! in stage : 1

3 Input Data

3.1 General Input Data

Model	Single pile; Pile loaded by forces
Unit weight of water	9.81 kN/m³

3.2 Pile Properties

Length	26.50 m
Level top side	6.50 m
Number of sections	1

3.2.1 General properties

Section name	From [m]	To [m]	Material type	Diameter [m]
Hansweert	-20.00	6.50	Steel	1.02

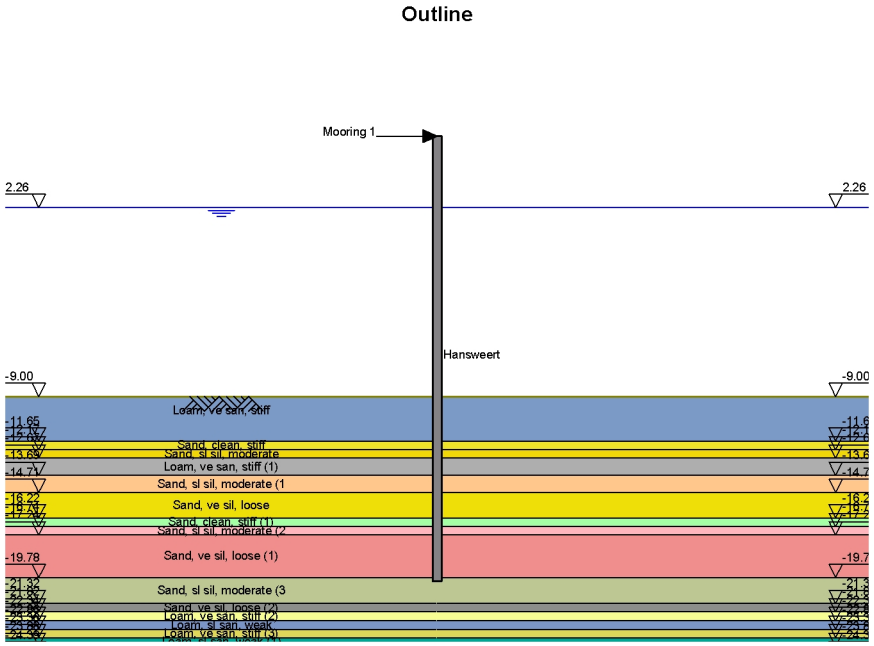
3.2.2 Stiffness EI (elastic behaviour)

Section name	Elastic stiffness EI [kNm²]	Red. factor on EI [-]	Corrected elas. stiffness EI [kNm²]	Note to reduction factor
Hansweert	1.6303E+06	1.00	1.6300E+06	

3.2.3 Maximum allowable moments

Section name	Elas. char. moment [kNm]	Modification factor [-]	Material factor [-]	Red. factor allow. moment [-]	Elas. design moment [kNm]
Hansweert	3875.00	1.00	1.00	1.00	3875.00

3.3 Outline



3.4 Horizontal Forces

Name	Level [m]	Load [kN]
Mooring 1	6.50	350.00

3.5 Water Level

Water level: 2.26 [m]

3.6 Surface

Surface level: -9.00 [m]

3.7 Soil Material Properties

Layer name	Level [m]	Unit weight		Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
		Unsat [kN/m³]	Sat. [kN/m³]			
Loam, ve san, ...	-8.00	19.00	19.00	0.00	27.50	Yes
Sand, clean, stiff	-11.65	19.00	21.00	0.00	35.00	Yes
Sand, sl sil, mo...	-12.17	18.00	20.00	0.00	27.00	Yes
Loam, ve san, ...	-12.67	19.00	19.00	0.00	27.50	Yes
Sand, sl sil, mo...	-13.69	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-14.71	18.00	20.00	0.00	25.00	Yes
Sand, clean, sti...	-16.22	19.00	21.00	0.00	35.00	Yes
Sand, sl sil, mo...	-16.74	18.00	20.00	0.00	27.00	Yes

Layer name	Level [m]	Unit weight Unsat [kN/m³]	Unit weight Sat. [kN/m³]	Cohesion [kN/m²]	Friction angle phi [degree]	Brinch Hansen used
Sand, ve sil, lo...	-17.24	18.00	20.00	0.00	25.00	Yes
Sand, sl sil, mo...	-19.78	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-21.32	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-21.82	19.00	19.00	0.00	27.50	Yes
Loam, sl san, w...	-22.34	19.00	19.00	0.00	27.50	Yes
Loam, ve san, ...	-22.86	19.00	19.00	0.00	27.50	Yes
Loam, sl san, w...	-23.36	19.00	19.00	0.00	27.50	Yes
Loam, ve san, ...	-23.88	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-24.39	18.00	20.00	0.00	25.00	Yes
Sand, sl sil, mo...	-26.47	18.00	20.00	0.00	27.00	Yes
Sand, ve sil, lo...	-28.03	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-28.55	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-29.06	18.00	20.00	0.00	25.00	Yes
Loam, ve san, ...	-30.62	19.00	19.00	0.00	27.50	Yes
Sand, ve sil, lo...	-31.14	18.00	20.00	0.00	25.00	Yes

Layer name	Level [m]	Earth pressure coefficients Active [-]	Earth pressure coefficients Neutral [-]	Earth pressure coefficients Passive [-]	Additional pore pressure Top [kN/m²]	Additional pore pressure Bottom [kN/m²]
Loam, ve san, ...	-8.00	0.00	0.00	5.23	0.00	0.00
Sand, clean, stiff	-11.65	0.00	0.00	11.66	0.00	0.00
Sand, sl sil, mo...	-12.17	0.00	0.00	6.39	0.00	0.00
Loam, ve san, ...	-12.67	0.00	0.00	7.05	0.00	0.00
Sand, sl sil, mo...	-13.69	0.00	0.00	7.20	0.00	0.00
Sand, ve sil, lo...	-14.71	0.00	0.00	6.44	0.00	0.00
Sand, clean, sti...	-16.22	0.00	0.00	16.49	0.00	0.00
Sand, sl sil, mo...	-16.74	0.00	0.00	8.11	0.00	0.00
Sand, ve sil, lo...	-17.24	0.00	0.00	7.07	0.00	0.00
Sand, sl sil, mo...	-19.78	0.00	0.00	8.89	0.00	0.00
Sand, ve sil, lo...	-21.32	0.00	0.00	7.51	0.00	0.00
Loam, ve san, ...	-21.82	0.00	0.00	9.59	0.00	0.00
Loam, sl san, w...	-22.34	0.00	0.00	9.67	0.00	0.00
Loam, ve san, ...	-22.86	0.00	0.00	9.75	0.00	0.00
Loam, sl san, w...	-23.36	0.00	0.00	9.82	0.00	0.00
Loam, ve san, ...	-23.88	0.00	0.00	9.90	0.00	0.00
Sand, ve sil, lo...	-24.39	0.00	0.00	7.90	0.00	0.00
Sand, sl sil, mo...	-26.47	0.00	0.00	9.78	0.00	0.00
Sand, ve sil, lo...	-28.03	0.00	0.00	8.12	0.00	0.00
Loam, ve san, ...	-28.55	0.00	0.00	10.43	0.00	0.00
Sand, ve sil, lo...	-29.06	0.00	0.00	8.22	0.00	0.00
Loam, ve san, ...	-30.62	0.00	0.00	10.61	0.00	0.00
Sand, ve sil, lo...	-31.14	0.00	0.00	11.84	0.00	0.00

3.8 Soil Material Properties calculated using Brinch Hansen

Layer name	Level [m]	Fictive cohesion [kN/m²]
Loam, ve san, ...	-8.00	0.00
Sand, clean, stiff	-11.65	0.00
Sand, sl sil, mo...	-12.17	0.00
Loam, ve san, ...	-12.67	0.00
Sand, sl sil, mo...	-13.69	0.00
Sand, ve sil, lo...	-14.71	0.00
Sand, clean, sti...	-16.22	0.00
Sand, sl sil, mo...	-16.74	0.00
Sand, ve sil, lo...	-17.24	0.00
Sand, sl sil, mo...	-19.78	0.00
Sand, ve sil, lo...	-21.32	0.00

Layer name	Level [m]	Fictive cohesion [kN/m²]
Loam, ve san, ...	-21.82	0.00
Loam, sl san, w...	-22.34	0.00
Loam, ve san, ...	-22.86	0.00
Loam, sl san, w...	-23.36	0.00
Loam, ve san, ...	-23.88	0.00
Sand, ve sil, lo...	-24.39	0.00
Sand, sl sil, mo...	-26.47	0.00
Sand, ve sil, lo...	-28.03	0.00
Loam, ve san, ...	-28.55	0.00
Sand, ve sil, lo...	-29.06	0.00
Loam, ve san, ...	-30.62	0.00
Sand, ve sil, lo...	-31.14	0.00

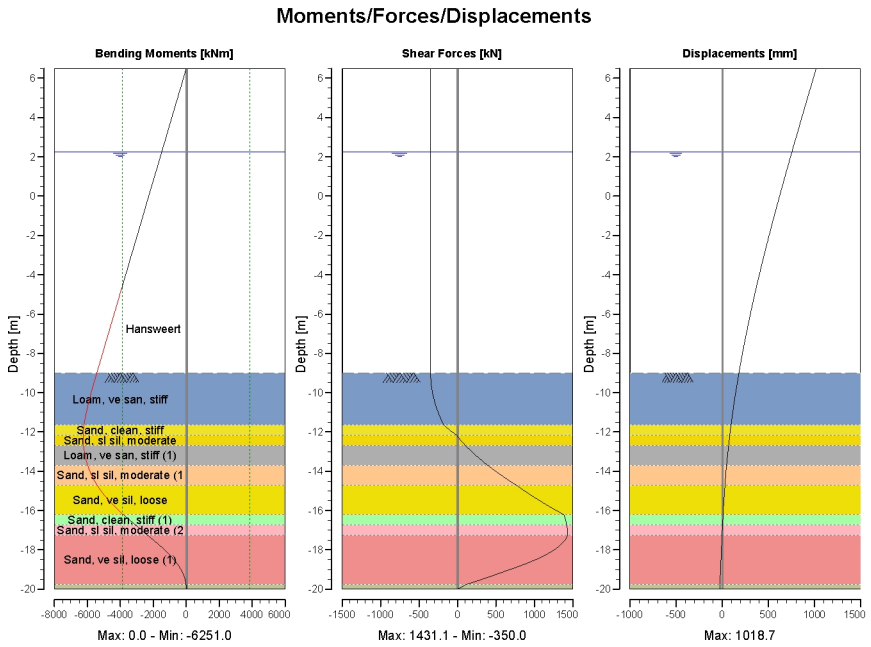
3.9 Modulus of Subgrade Reaction

Layer name	Level [m]	Ménard used	E-Mod Ménard [kN/m²]	Soil type Ménard	Branch 1	
					Top [kN/m³]	Bottom [kN/m³]
Loam, ve san, ...	-8.00	Yes	7800.00	Loam	21611.15	21611.15
Sand, clean, stiff	-11.65	No	n.a.	n.a.	10000.00	10000.00
Sand, sl sil, mo...	-12.17	Yes	5000.00	Sand	18424.93	18424.93
Loam, ve san, ...	-12.67	Yes	7800.00	Loam	21611.15	21611.15
Sand, sl sil, mo...	-13.69	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-14.71	Yes	12000.00	Sand	44219.84	44219.84
Sand, clean, sti...	-16.22	No	n.a.	n.a.	10000.00	10000.00
Sand, sl sil, mo...	-16.74	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-17.24	Yes	12000.00	Sand	44219.84	44219.84
Sand, sl sil, mo...	-19.78	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-21.32	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-21.82	Yes	7800.00	Loam	21611.15	21611.15
Loam, sl san, w...	-22.34	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-22.86	Yes	7800.00	Loam	21611.15	21611.15
Loam, sl san, w...	-23.36	No	n.a.	n.a.	10000.00	10000.00
Loam, ve san, ...	-23.88	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-24.39	Yes	12000.00	Sand	44219.84	44219.84
Sand, sl sil, mo...	-26.47	Yes	5000.00	Sand	18424.93	18424.93
Sand, ve sil, lo...	-28.03	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-28.55	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-29.06	Yes	12000.00	Sand	44219.84	44219.84
Loam, ve san, ...	-30.62	Yes	7800.00	Loam	21611.15	21611.15
Sand, ve sil, lo...	-31.14	Yes	12000.00	Sand	44219.84	44219.84

4 Calculation Results

Number of iterations: 8

4.1 Charts of Moments, Forces and Displacements



4.2 Moments, Forces and Displacements

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
1	6.50	0.00	-350.00	**1018.7**
	6.25	-86.80	-350.00	1003.2
	6.00	-173.60	-350.00	987.6
	5.76	-260.40	-350.00	972.1
	5.51	-347.20	-350.00	956.6
2	5.26	-434.00	-350.00	941.1
2	5.26	-434.00	-350.00	941.1
	5.21	-452.20	-350.00	937.9
	5.16	-470.40	-350.00	934.6
	5.10	-488.60	-350.00	931.4
	5.05	-506.80	-350.00	928.1
3	5.00	-525.00	-350.00	924.9
3	5.00	-525.00	-350.00	924.9
	4.85	-577.50	-350.00	915.5
	4.70	-630.00	-350.00	906.2
	4.55	-682.50	-350.00	896.8
	4.40	-735.00	-350.00	887.5
4	4.25	-787.50	-350.00	878.2
4	4.25	-787.50	-350.00	878.2

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
	4.10	-840.00	-350.00	868.9
	3.95	-892.50	-350.00	859.6
	3.80	-945.00	-350.00	850.3
	3.65	-997.50	-350.00	841.0
5	3.50	-1050.00	-350.00	831.8
5	3.50	-1050.00	-350.00	831.8
	3.25	-1136.80	-350.00	816.5
	3.00	-1223.60	-350.00	801.3
	2.76	-1310.40	-350.00	786.1
	2.51	-1397.20	-350.00	771.0
6	2.26	-1484.00	-350.00	755.9
6	2.26	-1484.00	-350.00	755.9
	2.21	-1502.20	-350.00	752.7
	2.16	-1520.40	-350.00	749.6
	2.10	-1538.60	-350.00	746.4
	2.05	-1556.80	-350.00	743.3
7	2.00	-1575.00	-350.00	740.1
7	2.00	-1575.00	-350.00	740.1
	1.85	-1627.50	-350.00	731.1
	1.70	-1680.00	-350.00	722.1
	1.55	-1732.50	-350.00	713.0
	1.40	-1785.00	-350.00	704.1
8	1.25	-1837.50	-350.00	695.1
8	1.25	-1837.50	-350.00	695.1
	1.10	-1890.00	-350.00	686.2
	0.95	-1942.50	-350.00	677.3
	0.80	-1995.00	-350.00	668.4
	0.65	-2047.50	-350.00	659.5
9	0.50	-2100.00	-350.00	650.7
9	0.50	-2100.00	-350.00	650.7
	0.35	-2152.50	-350.00	641.9
	0.20	-2205.00	-350.00	633.1
	0.05	-2257.50	-350.00	624.4
	-0.10	-2310.00	-350.00	615.7
10	-0.25	-2362.50	-350.00	607.0
10	-0.25	-2362.50	-350.00	607.0
	-0.40	-2415.00	-350.00	598.4
	-0.55	-2467.50	-350.00	589.7
	-0.70	-2520.00	-350.00	581.2
	-0.85	-2572.50	-350.00	572.6
11	-1.00	-2625.00	-350.00	564.1
11	-1.00	-2625.00	-350.00	564.1
	-1.15	-2677.50	-350.00	555.6
	-1.30	-2730.00	-350.00	547.2
	-1.45	-2782.50	-350.00	538.8
	-1.60	-2835.00	-350.00	530.5
12	-1.75	-2887.50	-350.00	522.1
12	-1.75	-2887.50	-350.00	522.1
	-1.90	-2940.00	-350.00	513.9
	-2.05	-2992.50	-350.00	505.6
	-2.20	-3045.00	-350.00	497.4
	-2.35	-3097.50	-350.00	489.3
13	-2.50	-3150.00	-350.00	481.2
13	-2.50	-3150.00	-350.00	481.2
	-2.75	-3237.50	-350.00	467.8
	-3.00	-3325.00	-350.00	454.5
	-3.25	-3412.50	-350.00	441.3
	-3.50	-3500.00	-350.00	428.3
14	-3.75	-3587.50	-350.00	415.3
14	-3.75	-3587.50	-350.00	415.3

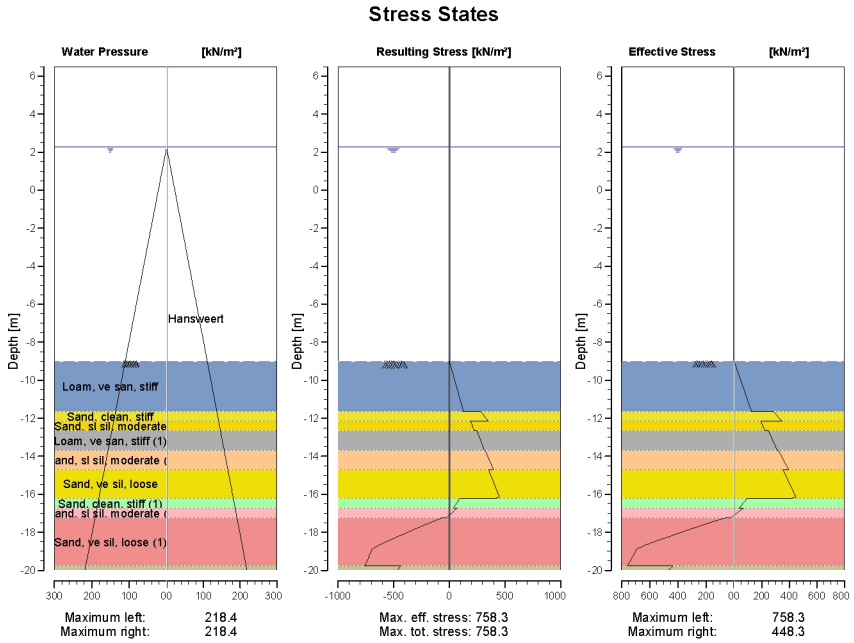
Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
	-4.00	-3675.00	-350.00	402.6
	-4.25	-3762.50	-350.00	390.0
	-4.50	-3850.00	-350.00	377.5
	-4.75	-3937.50	-350.00	365.1
15	-5.00	-4025.00	-350.00	353.0
15	-5.00	-4025.00	-350.00	353.0
	-5.20	-4095.00	-350.00	343.3
	-5.40	-4165.00	-350.00	333.8
	-5.60	-4235.00	-350.00	324.4
	-5.80	-4305.00	-350.00	315.0
16	-6.00	-4375.00	-350.00	305.8
16	-6.00	-4375.00	-350.00	305.8
	-6.20	-4445.00	-350.00	296.7
	-6.40	-4515.00	-350.00	287.7
	-6.60	-4585.00	-350.00	278.8
	-6.80	-4655.00	-350.00	270.0
17	-7.00	-4725.00	-350.00	261.3
17	-7.00	-4725.00	-350.00	261.3
	-7.20	-4793.60	-350.00	252.9
	-7.39	-4862.20	-350.00	244.7
	-7.59	-4930.80	-350.00	236.5
	-7.78	-4999.40	-350.00	228.5
18	-7.98	-5068.00	-350.00	220.6
18	-7.98	-5068.00	-350.00	220.6
	-7.98	-5069.40	-350.00	220.4
	-7.99	-5070.80	-350.00	220.2
	-7.99	-5072.20	-350.00	220.1
	-8.00	-5073.60	-350.00	219.9
19	-8.00	-5075.00	-350.00	219.8
19	-8.00	-5075.00	-350.00	219.8
	-8.03	-5086.20	-350.00	218.5
	-8.06	-5097.40	-350.00	217.2
	-8.10	-5108.60	-350.00	215.9
	-8.13	-5119.80	-350.00	214.7
20	-8.16	-5131.00	-350.00	213.4
20	-8.16	-5131.00	-350.00	213.4
	-8.33	-5189.80	-350.00	206.8
	-8.50	-5248.60	-350.00	200.3
	-8.66	-5307.40	-350.00	193.9
	-8.83	-5366.20	-350.00	187.5
21	-9.00	-5425.00	-350.00	181.3
21	-9.00	-5425.00	-350.00	181.3
	-9.15	-5478.87	-349.42	175.7
	-9.31	-5532.56	-347.68	170.1
	-9.46	-5585.89	-344.77	164.6
	-9.62	-5638.69	-340.70	159.2
22	-9.77	-5690.77	-335.47	153.9
22	-9.77	-5690.77	-335.47	153.9
	-9.92	-5739.32	-329.44	149.0
	-10.06	-5786.92	-322.37	144.1
	-10.21	-5833.40	-314.25	139.3
	-10.35	-5878.63	-305.08	134.6
23	-10.50	-5922.44	-294.87	129.9
23	-10.50	-5922.44	-294.87	129.9
	-10.53	-5931.83	-292.50	128.9
	-10.56	-5941.16	-290.07	127.9
	-10.60	-5950.40	-287.59	126.9
	-10.63	-5959.56	-285.06	125.9
24	-10.66	-5968.64	-282.48	124.9
24	-10.66	-5968.64	-282.48	124.9

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
	-10.68	-5974.84	-280.68	124.2
	-10.70	-5980.99	-278.86	123.5
	-10.73	-5987.11	-277.01	122.9
	-10.75	-5993.18	-275.14	122.2
25	-10.77	-5999.21	-273.24	121.5
25	-10.77	-5999.21	-273.24	121.5
	-10.85	-6020.26	-266.33	119.1
	-10.93	-6040.75	-259.11	116.8
	-11.00	-6060.67	-251.60	114.4
	-11.08	-6079.99	-243.79	112.1
26	-11.16	-6098.70	-235.69	109.8
26	-11.16	-6098.70	-235.69	109.8
	-11.18	-6102.45	-233.99	109.4
	-11.19	-6106.18	-232.28	108.9
	-11.21	-6109.89	-230.55	108.5
	-11.22	-6113.56	-228.81	108.0
27	-11.24	-6117.21	-227.06	107.5
27	-11.24	-6117.21	-227.06	107.5
	-11.30	-6129.75	-220.84	105.9
	-11.35	-6141.94	-214.46	104.3
	-11.41	-6153.77	-207.93	102.7
	-11.46	-6165.22	-201.25	101.2
28	-11.52	-6176.30	-194.41	99.6
28	-11.52	-6176.30	-194.41	99.6
	-11.55	-6181.32	-191.18	98.9
	-11.57	-6186.24	-187.92	98.1
	-11.60	-6191.09	-184.63	97.4
	-11.62	-6195.84	-181.30	96.7
29	-11.65	-6200.51	-177.94	96.0
29	-11.65	-6200.51	-177.94	96.0
	-11.67	-6203.67	-172.71	95.5
	-11.69	-6206.73	-167.43	95.0
	-11.70	-6209.70	-162.11	94.5
	-11.72	-6212.57	-156.74	94.0
30	-11.74	-6215.34	-151.34	93.6
30	-11.74	-6215.34	-151.34	93.6
	-11.75	-6216.84	-148.32	93.3
	-11.76	-6218.31	-145.28	93.0
	-11.77	-6219.74	-142.23	92.8
	-11.78	-6221.15	-139.17	92.5
31	-11.79	-6222.53	-136.09	92.2
31	-11.79	-6222.53	-136.09	92.2
	-11.87	-6231.97	-112.28	90.2
	-11.94	-6239.58	-87.70	88.2
	-12.02	-6245.28	-62.36	86.2
	-12.09	-6249.03	-36.24	84.2
32	-12.17	-6250.77	-9.36	82.3
32	-12.17	-6250.77	-9.36	82.3
	-12.19	-6250.94	-4.62	81.7
	-12.22	**-6250.99**	0.16	81.1
	-12.24	-6250.93	4.98	80.5
	-12.27	-6250.75	9.83	79.9
33	-12.29	-6250.46	14.72	79.3
33	-12.29	-6250.46	14.72	79.3
	-12.37	-6248.74	30.47	77.4
	-12.44	-6245.82	46.60	75.6
	-12.52	-6241.65	63.11	73.7
	-12.59	-6236.22	80.01	71.9
34	-12.67	-6229.48	97.29	70.1
34	-12.67	-6229.48	97.29	70.1

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
	-12.78	-6216.73	126.63	67.5
	-12.90	-6200.58	156.84	64.9
	-13.01	-6180.93	187.90	62.3
	-13.13	-6157.70	219.82	59.8
35	-13.24	-6130.78	252.61	57.4
35	-13.24	-6130.78	252.61	57.4
	-13.33	-6106.86	279.09	55.5
	-13.42	-6080.53	306.12	53.6
	-13.51	-6051.74	333.67	51.8
	-13.60	-6020.45	361.77	50.0
36	-13.69	-5986.61	390.40	48.2
36	-13.69	-5986.61	390.40	48.2
	-13.76	-5958.47	413.54	46.8
	-13.83	-5928.71	437.04	45.5
	-13.90	-5897.28	460.92	44.2
	-13.97	-5864.17	485.16	42.9
37	-14.04	-5829.35	509.76	41.6
37	-14.04	-5829.35	509.76	41.6
	-14.08	-5808.67	523.99	40.8
	-14.12	-5787.43	538.33	40.1
	-14.16	-5765.61	552.80	39.4
	-14.20	-5743.20	567.39	38.7
38	-14.24	-5720.21	582.09	38.0
38	-14.24	-5720.21	582.09	38.0
	-14.32	-5670.01	613.36	36.5
	-14.41	-5617.15	645.16	35.1
	-14.49	-5561.61	677.49	33.7
	-14.58	-5503.32	710.34	32.3
39	-14.66	-5442.25	743.72	30.9
39	-14.66	-5442.25	743.72	30.9
	-14.67	-5434.80	747.73	30.7
	-14.68	-5427.30	751.75	30.6
	-14.69	-5419.76	755.77	30.4
	-14.70	-5412.18	759.81	30.3
40	-14.71	-5404.57	763.84	30.1
40	-14.71	-5404.57	763.84	30.1
	-14.83	-5307.05	809.18	28.1
	-14.96	-5203.85	855.54	26.2
	-15.08	-5094.83	902.93	24.4
	-15.21	-4979.88	951.35	22.6
41	-15.33	-4858.85	1000.80	20.8
41	-15.33	-4858.85	1000.80	20.8
	-15.43	-4756.75	1041.43	19.4
	-15.53	-4650.55	1082.73	18.0
	-15.63	-4540.18	1124.70	16.7
	-15.73	-4425.58	1167.33	15.4
42	-15.83	-4306.69	1210.64	14.1
42	-15.83	-4306.69	1210.65	14.1
	-15.91	-4210.93	1244.89	13.2
	-15.99	-4112.48	1279.54	12.2
	-16.06	-4011.31	1314.60	11.2
	-16.14	-3907.39	1350.06	10.3
43	-16.22	-3800.73	1384.42	9.4
43	-16.22	-3800.71	1384.94	9.4
	-16.32	-3656.18	1394.27	8.2
	-16.43	-3510.75	1402.34	7.0
	-16.53	-3364.54	1409.17	5.9
	-16.64	-3217.68	1414.79	4.7
44	-16.74	-3070.30	1419.23	3.6
44	-16.74	-3070.30	1419.22	3.6

Segment number	Level [m]	Moment [kNm]	Shear force [kN]	Displacement [mm]
	-16.76	-3041.91	1420.55	3.4
	-16.78	-3013.48	1421.79	3.2
	-16.80	-2985.03	1422.95	3.0
	-16.82	-2956.56	1424.04	2.8
45	-16.84	-2928.07	1425.05	2.6
45	-16.84	-2928.07	1425.05	2.6
	-16.92	-2813.93	1428.30	1.8
	-17.00	-2699.58	1430.33	0.9
	-17.08	-2585.11	**1431.13**	0.1
	-17.16	-2470.63	1430.74	-0.7
46	-17.24	-2356.22	1429.16	-1.4
46	-17.24	-2356.22	1429.14	-1.4
	-17.36	-2179.65	1417.73	-2.6
	-17.49	-2004.90	1399.70	-3.8
	-17.61	-1832.79	1375.14	-5.0
	-17.74	-1664.13	1344.16	-6.1
47	-17.86	-1499.70	1306.85	-7.2
47	-17.86	-1499.67	1306.70	-7.2
	-18.06	-1240.46	1231.78	-9.1
	-18.27	-998.23	1140.27	-10.8
	-18.47	-776.34	1032.43	-12.6
	-18.68	-578.10	908.48	-14.3
48	-18.88	-406.65	770.35	-16.1
48	-18.88	-406.87	767.75	-16.1
	-18.98	-330.86	693.79	-16.9
	-19.09	-262.59	619.04	-17.8
	-19.19	-202.13	543.49	-18.7
	-19.30	-149.57	467.14	-19.6
49	-19.40	-104.99	390.00	-20.4
49	-19.40	-104.99	390.00	-20.4
	-19.48	-77.51	333.13	-21.1
	-19.55	-54.37	275.83	-21.7
	-19.63	-35.60	218.11	-22.3
	-19.70	-21.23	159.96	-23.0
50	-19.78	-11.29	101.39	-23.6
50	-19.78	-11.29	101.39	-23.6
	-19.81	-8.63	88.91	-23.8
	-19.84	-6.31	76.30	-24.1
	-19.86	-4.36	63.57	-24.3
	-19.89	-2.76	50.72	-24.5
51	-19.92	-1.52	37.75	-24.8
51	-19.92	-1.52	37.75	-24.8
	-19.94	-0.97	30.28	-24.9
	-19.95	-0.55	22.77	-25.0
	-19.97	-0.24	15.22	-25.2
	-19.98	-0.06	7.63	-25.3
52	-20.00	0.00	0.00	-25.4
Max		**-6250.99**	**1431.13**	**1018.7**

4.3 Charts of Stresses



4.4 Stresses

Node number	Level	Left				Right			
	[m]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
1	6.50	0.00	0.00	-		0.00	0.00	-	
	6.25	0.00	0.00	-		0.00	0.00	-	
	6.00	0.00	0.00	-		0.00	0.00	-	
	5.76	0.00	0.00	-		0.00	0.00	-	
	5.51	0.00	0.00	-		0.00	0.00	-	
2	5.26	0.00	0.00	-		0.00	0.00	-	
2	5.26	0.00	0.00	-		0.00	0.00	-	
	5.21	0.00	0.00	-		0.00	0.00	-	
	5.16	0.00	0.00	-		0.00	0.00	-	
	5.10	0.00	0.00	-		0.00	0.00	-	
	5.05	0.00	0.00	-		0.00	0.00	-	
3	5.00	0.00	0.00	-		0.00	0.00	-	
3	5.00	0.00	0.00	-		0.00	0.00	-	
	4.85	0.00	0.00	-		0.00	0.00	-	
	4.70	0.00	0.00	-		0.00	0.00	-	
	4.55	0.00	0.00	-		0.00	0.00	-	
	4.40	0.00	0.00	-		0.00	0.00	-	
4	4.25	0.00	0.00	-		0.00	0.00	-	
4	4.25	0.00	0.00	-		0.00	0.00	-	
	4.10	0.00	0.00	-		0.00	0.00	-	
	3.95	0.00	0.00	-		0.00	0.00	-	
	3.80	0.00	0.00	-		0.00	0.00	-	

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
	3.65	0.00	0.00	-		0.00	0.00	-	
5	3.50	0.00	0.00	-		0.00	0.00	-	
5	3.50	0.00	0.00	-		0.00	0.00	-	
	3.25	0.00	0.00	-		0.00	0.00	-	
	3.00	0.00	0.00	-		0.00	0.00	-	
	2.76	0.00	0.00	-		0.00	0.00	-	
	2.51	0.00	0.00	-		0.00	0.00	-	
6	2.26	0.00	0.00	-		0.00	0.00	-	
6	2.26	0.00	0.00	-		0.00	0.00	-	
	2.21	0.00	0.51	-		0.00	0.51	-	
	2.16	0.00	1.02	-		0.00	1.02	-	
	2.10	0.00	1.53	-		0.00	1.53	-	
	2.05	0.00	2.04	-		0.00	2.04	-	
7	2.00	0.00	2.55	-		0.00	2.55	-	
7	2.00	0.00	2.55	-		0.00	2.55	-	
	1.85	0.00	4.02	-		0.00	4.02	-	
	1.70	0.00	5.49	-		0.00	5.49	-	
	1.55	0.00	6.97	-		0.00	6.97	-	
	1.40	0.00	8.44	-		0.00	8.44	-	
8	1.25	0.00	9.91	-		0.00	9.91	-	
8	1.25	0.00	9.91	-		0.00	9.91	-	
	1.10	0.00	11.38	-		0.00	11.38	-	
	0.95	0.00	12.85	-		0.00	12.85	-	
	0.80	0.00	14.32	-		0.00	14.32	-	
	0.65	0.00	15.79	-		0.00	15.79	-	
9	0.50	0.00	17.27	-		0.00	17.27	-	
9	0.50	0.00	17.27	-		0.00	17.27	-	
	0.35	0.00	18.74	-		0.00	18.74	-	
	0.20	0.00	20.21	-		0.00	20.21	-	
	0.05	0.00	21.68	-		0.00	21.68	-	
	-0.10	0.00	23.15	-		0.00	23.15	-	
10	-0.25	0.00	24.62	-		0.00	24.62	-	
10	-0.25	0.00	24.62	-		0.00	24.62	-	
	-0.40	0.00	26.09	-		0.00	26.09	-	
	-0.55	0.00	27.57	-		0.00	27.57	-	
	-0.70	0.00	29.04	-		0.00	29.04	-	
	-0.85	0.00	30.51	-		0.00	30.51	-	
11	-1.00	0.00	31.98	-		0.00	31.98	-	
11	-1.00	0.00	31.98	-		0.00	31.98	-	
	-1.15	0.00	33.45	-		0.00	33.45	-	
	-1.30	0.00	34.92	-		0.00	34.92	-	
	-1.45	0.00	36.40	-		0.00	36.40	-	
	-1.60	0.00	37.87	-		0.00	37.87	-	
12	-1.75	0.00	39.34	-		0.00	39.34	-	
12	-1.75	0.00	39.34	-		0.00	39.34	-	
	-1.90	0.00	40.81	-		0.00	40.81	-	
	-2.05	0.00	42.28	-		0.00	42.28	-	
	-2.20	0.00	43.75	-		0.00	43.75	-	
	-2.35	0.00	45.22	-		0.00	45.22	-	
13	-2.50	0.00	46.70	-		0.00	46.70	-	
13	-2.50	0.00	46.70	-		0.00	46.70	-	
	-2.75	0.00	49.15	-		0.00	49.15	-	
	-3.00	0.00	51.60	-		0.00	51.60	-	
	-3.25	0.00	54.05	-		0.00	54.05	-	
	-3.50	0.00	56.51	-		0.00	56.51	-	
14	-3.75	0.00	58.96	-		0.00	58.96	-	
14	-3.75	0.00	58.96	-		0.00	58.96	-	
	-4.00	0.00	61.41	-		0.00	61.41	-	
	-4.25	0.00	63.86	-		0.00	63.86	-	

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
	-4.50	0.00	66.32	-		0.00	66.32	-	
	-4.75	0.00	68.77	-		0.00	68.77	-	
15	-5.00	0.00	71.22	-		0.00	71.22	-	
15	-5.00	0.00	71.22	-		0.00	71.22	-	
	-5.20	0.00	73.18	-		0.00	73.18	-	
	-5.40	0.00	75.14	-		0.00	75.14	-	
	-5.60	0.00	77.11	-		0.00	77.11	-	
	-5.80	0.00	79.07	-		0.00	79.07	-	
16	-6.00	0.00	81.03	-		0.00	81.03	-	
16	-6.00	0.00	81.03	-		0.00	81.03	-	
	-6.20	0.00	82.99	-		0.00	82.99	-	
	-6.40	0.00	84.95	-		0.00	84.95	-	
	-6.60	0.00	86.92	-		0.00	86.92	-	
	-6.80	0.00	88.88	-		0.00	88.88	-	
17	-7.00	0.00	90.84	-		0.00	90.84	-	
17	-7.00	0.00	90.84	-		0.00	90.84	-	
	-7.20	0.00	92.76	-		0.00	92.76	-	
	-7.39	0.00	94.69	-		0.00	94.69	-	
	-7.59	0.00	96.61	-		0.00	96.61	-	
	-7.78	0.00	98.53	-		0.00	98.53	-	
18	-7.98	0.00	100.45	-		0.00	100.45	-	
18	-7.98	0.00	100.45	-		0.00	100.45	-	
	-7.98	0.00	100.49	-		0.00	100.49	-	
	-7.99	0.00	100.53	-		0.00	100.53	-	
	-7.99	0.00	100.57	-		0.00	100.57	-	
	-8.00	0.00	100.61	-		0.00	100.61	-	
19	-8.00	0.00	100.65	-		0.00	100.65	-	
19	-8.00	0.00	100.65	-		0.00	100.65	-	
	-8.03	0.00	100.96	-		0.00	100.96	-	
	-8.06	0.00	101.28	-		0.00	101.28	-	
	-8.10	0.00	101.59	-		0.00	101.59	-	
	-8.13	0.00	101.91	-		0.00	101.91	-	
20	-8.16	0.00	102.22	-		0.00	102.22	-	
20	-8.16	0.00	102.22	-		0.00	102.22	-	
	-8.33	0.00	103.87	-		0.00	103.87	-	
	-8.50	0.00	105.52	-		0.00	105.52	-	
	-8.66	0.00	107.16	-		0.00	107.16	-	
	-8.83	0.00	108.81	-		0.00	108.81	-	
21	-9.00	0.00	110.46	-		0.00	110.46	-	
21	-9.00	0.00	110.46	A		0.00	110.46	P	
	-9.15	0.00	111.97	A		7.40	111.97	P	
	-9.31	0.00	113.48	A		14.80	113.48	P	
	-9.46	0.00	114.99	A		22.20	114.99	P	
	-9.62	0.00	116.50	A		29.59	116.50	P	
22	-9.77	0.00	118.01	A		36.99	118.01	P	
22	-9.77	0.00	118.01	A		36.99	118.01	P	
	-9.92	0.00	119.45	A		44.01	119.45	P	
	-10.06	0.00	120.88	A		51.02	120.88	P	
	-10.21	0.00	122.31	A		58.03	122.31	P	
	-10.35	0.00	123.74	A		65.05	123.74	P	
23	-10.50	0.00	125.18	A		72.06	125.18	P	
23	-10.50	0.00	125.18	A		72.06	125.18	P	
	-10.53	0.00	125.49	A		73.60	125.49	P	
	-10.56	0.00	125.80	A		75.14	125.80	P	
	-10.60	0.00	126.12	A		76.67	126.12	P	
	-10.63	0.00	126.43	A		78.21	126.43	P	
24	-10.66	0.00	126.75	A		79.75	126.75	P	
24	-10.66	0.00	126.75	A		79.75	126.75	P	
	-10.68	0.00	126.96	A		80.81	126.96	P	

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
	-10.70	0.00	127.18	A		81.86	127.18	P	
	-10.73	0.00	127.39	A		82.92	127.39	P	
	-10.75	0.00	127.61	A		83.98	127.61	P	
25	-10.77	0.00	127.82	A		85.03	127.82	P	
25	-10.77	0.00	127.82	A		85.03	127.82	P	
	-10.85	0.00	128.59	A		88.78	128.59	P	
	-10.93	0.00	129.35	A		92.53	129.35	P	
	-11.00	0.00	130.12	A		96.27	130.12	P	
	-11.08	0.00	130.89	A		100.02	130.89	P	
26	-11.16	0.00	131.65	A		103.77	131.65	P	
26	-11.16	0.00	131.65	A		103.77	131.65	P	
	-11.18	0.00	131.81	A		104.54	131.81	P	
	-11.19	0.00	131.96	A		105.31	131.96	P	
	-11.21	0.00	132.12	A		106.08	132.12	P	
	-11.22	0.00	132.28	A		106.84	132.28	P	
27	-11.24	0.00	132.44	A		107.61	132.44	P	
27	-11.24	0.00	132.44	A		107.61	132.44	P	
	-11.30	0.00	132.98	A		110.30	132.98	P	
	-11.35	0.00	133.53	A		112.99	133.53	P	
	-11.41	0.00	134.08	A		115.68	134.08	P	
	-11.46	0.00	134.63	A		118.37	134.63	P	
28	-11.52	0.00	135.18	A		121.06	135.18	P	
28	-11.52	0.00	135.18	A		121.06	135.18	P	
	-11.55	0.00	135.44	A		122.31	135.44	P	
	-11.57	0.00	135.69	A		123.56	135.69	P	
	-11.60	0.00	135.95	A		124.81	135.95	P	
	-11.62	0.00	136.20	A		126.06	136.20	P	
29	-11.65	0.00	136.46	A		127.31	136.46	P	
29	-11.65	0.00	136.46	A		283.93	136.46	P	
	-11.67	0.00	136.63	A		286.27	136.63	P	
	-11.69	0.00	136.81	A		288.62	136.81	P	
	-11.70	0.00	136.99	A		290.97	136.99	P	
	-11.72	0.00	137.16	A		293.32	137.16	P	
30	-11.74	0.00	137.34	A		295.67	137.34	P	
30	-11.74	0.00	137.34	A		295.67	137.34	P	
	-11.75	0.00	137.44	A		296.97	137.44	P	
	-11.76	0.00	137.54	A		298.28	137.54	P	
	-11.77	0.00	137.63	A		299.58	137.63	P	
	-11.78	0.00	137.73	A		300.89	137.73	P	
31	-11.79	0.00	137.83	A		302.19	137.83	P	
31	-11.79	0.00	137.83	A		302.19	137.83	P	
	-11.87	0.00	138.58	A		312.11	138.58	P	
	-11.94	0.00	139.32	A		322.02	139.32	P	
	-12.02	0.00	140.07	A		331.93	140.07	P	
	-12.09	0.00	140.81	A		341.85	140.81	P	
32	-12.17	0.00	141.56	A		351.76	141.56	P	
32	-12.17	0.00	141.56	A		192.82	141.56	P	
	-12.19	0.00	141.79	A		194.38	141.79	P	
	-12.22	0.00	142.03	A		195.95	142.03	P	
	-12.24	0.00	142.26	A		197.51	142.26	P	
	-12.27	0.00	142.50	A		199.07	142.50	P	
33	-12.29	0.00	142.74	A		200.63	142.74	P	
33	-12.29	0.00	142.74	A		200.63	142.74	P	
	-12.37	0.00	143.48	A		205.58	143.48	P	
	-12.44	0.00	144.23	A		210.53	144.23	P	
	-12.52	0.00	144.97	A		215.48	144.97	P	
	-12.59	0.00	145.72	A		220.43	145.72	P	
34	-12.67	0.00	146.46	A		225.38	146.46	P	
34	-12.67	0.00	146.46	A		248.68	146.46	P	

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
	-12.78	0.00	147.58	A		256.07	147.58	P	
	-12.90	0.00	148.70	A		263.46	148.70	P	
	-13.01	0.00	149.82	A		270.84	149.82	P	
	-13.13	0.00	150.94	A		278.23	150.94	P	
35	-13.24	0.00	152.06	A		285.62	152.06	P	
35	-13.24	0.00	152.06	A		285.62	152.06	P	
	-13.33	0.00	152.94	A		291.45	152.94	P	
	-13.42	0.00	153.82	A		297.28	153.82	P	
	-13.51	0.00	154.70	A		303.11	154.70	P	
	-13.60	0.00	155.59	A		308.95	155.59	P	
36	-13.69	0.00	156.47	A		314.78	156.47	P	
36	-13.69	0.00	156.47	A		321.52	156.47	P	
	-13.76	0.00	157.16	A		326.65	157.16	P	
	-13.83	0.00	157.84	A		331.79	157.84	P	
	-13.90	0.00	158.53	A		336.93	158.53	P	
	-13.97	0.00	159.22	A		342.07	159.22	P	
37	-14.04	0.00	159.90	A		347.20	159.90	P	
37	-14.04	0.00	159.90	A		347.20	159.90	P	
	-14.08	0.00	160.30	A		350.14	160.30	P	
	-14.12	0.00	160.69	A		353.08	160.69	P	
	-14.16	0.00	161.08	A		356.01	161.08	P	
	-14.20	0.00	161.47	A		358.95	161.47	P	
38	-14.24	0.00	161.87	A		361.88	161.87	P	
38	-14.24	0.00	161.87	A		361.88	161.87	P	
	-14.32	0.00	162.69	A		368.05	162.69	P	
	-14.41	0.00	163.51	A		374.21	163.51	P	
	-14.49	0.00	164.34	A		380.38	164.34	P	
	-14.58	0.00	165.16	A		386.54	165.16	P	
39	-14.66	0.00	165.99	A		392.71	165.99	P	
39	-14.66	0.00	165.99	A		392.71	165.99	P	
	-14.67	0.00	166.08	A		393.44	166.08	P	
	-14.68	0.00	166.18	A		394.17	166.18	P	
	-14.69	0.00	166.28	A		394.91	166.28	P	
	-14.70	0.00	166.38	A		395.64	166.38	P	
40	-14.71	0.00	166.48	A		396.38	166.48	P	
40	-14.71	0.00	166.48	A		354.36	166.48	P	
	-14.83	0.00	167.69	A		362.49	167.69	P	
	-14.96	0.00	168.91	A		370.63	168.91	P	
	-15.08	0.00	170.13	A		378.76	170.13	P	
	-15.21	0.00	171.34	A		386.90	171.34	P	
41	-15.33	0.00	172.56	A		395.04	172.56	P	
41	-15.33	0.00	172.56	A		395.04	172.56	P	
	-15.43	0.00	173.54	A		401.60	173.54	P	
	-15.53	0.00	174.52	A		408.16	174.52	P	
	-15.63	0.00	175.50	A		414.72	175.50	P	
	-15.73	0.00	176.48	A		421.28	176.48	P	
42	-15.83	0.00	177.46	A		427.84	177.46	P	
42	-15.83	0.00	177.46	A		427.84	177.46	P	
	-15.91	0.00	178.23	A		432.96	178.23	P	
	-15.99	0.00	178.99	A		438.08	178.99	P	
	-16.06	0.00	179.76	A		443.19	179.76	P	
	-16.14	0.00	180.52	A		448.31	180.52	P	
43	-16.22	0.00	181.29	A		415.44	181.29	-	92
43	-16.22	0.00	181.29	A		93.95	181.29	-	8
	-16.32	0.00	182.31	A		81.94	182.31	-	7
	-16.43	0.00	183.33	A		70.18	183.33	-	6
	-16.53	0.00	184.35	A		58.65	184.35	-	5
	-16.64	0.00	185.37	A		47.35	185.37	-	4
44	-16.74	0.00	186.39	A		36.25	186.39	-	3

Node number	Level [m]	Left				Right			
		Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]	Effective stress [kN/m²]	Water stress [kN/m²]	Stat*	Mob* [%]
44	-16.74	0.00	186.39	A		66.80	186.39	-	11
	-16.76	0.00	186.59	A		62.91	186.59	-	10
	-16.78	0.00	186.78	A		59.04	186.78	-	9
	-16.80	0.00	186.98	A		55.18	186.98	-	9
	-16.82	0.00	187.17	A		51.33	187.17	-	8
45	-16.84	0.00	187.37	A		47.50	187.37	-	8
45	-16.84	0.00	187.37	A		47.50	187.37	-	8
	-16.92	0.00	188.16	A		32.30	188.16	-	5
	-17.00	0.00	188.94	A		17.30	188.94	-	3
	-17.08	0.00	189.73	A		2.50	189.73	-	
	-17.16	12.11	190.51	-	2	0.00	190.51	A	
46	-17.24	26.55	191.29	-	4	0.00	191.29	A	
46	-17.24	63.71	191.29	-	11	0.00	191.29	A	
	-17.36	116.61	192.51	-	20	0.00	192.51	A	
	-17.49	168.60	193.73	-	28	0.00	193.73	A	
	-17.61	219.75	194.94	-	36	0.00	194.94	A	
	-17.74	270.14	196.16	-	44	0.00	196.16	A	
47	-17.86	319.83	197.38	-	52	0.00	197.38	A	
47	-17.86	319.83	197.38	-	52	0.00	197.38	A	
	-18.06	400.27	199.38	-	63	0.00	199.38	A	
	-18.27	479.31	201.38	-	74	0.00	201.38	A	
	-18.47	557.20	203.38	-	84	0.00	203.38	A	
	-18.68	634.19	205.38	-	93	0.00	205.38	A	
48	-18.88	693.45	207.38	P		0.00	207.38	A	
48	-18.88	693.45	207.38	P		0.00	207.38	A	
	-18.98	700.94	208.40	P		0.00	208.40	A	
	-19.09	708.44	209.42	P		0.00	209.42	A	
	-19.19	715.93	210.44	P		0.00	210.44	A	
	-19.30	723.43	211.46	P		0.00	211.46	A	
49	-19.40	730.92	212.48	P		0.00	212.48	A	
49	-19.40	730.92	212.48	P		0.00	212.48	A	
	-19.48	736.40	213.23	P		0.00	213.23	A	
	-19.55	741.88	213.98	P		0.00	213.98	A	
	-19.63	747.36	214.72	P		0.00	214.72	A	
	-19.70	752.83	215.47	P		0.00	215.47	A	
50	-19.78	758.31	216.21	P		0.00	216.21	A	
50	-19.78	434.91	216.21	-	46	0.00	216.21	A	
	-19.81	439.22	216.49	-	46	0.00	216.49	A	
	-19.84	443.53	216.76	-	46	0.00	216.76	A	
	-19.86	447.83	217.04	-	47	0.00	217.04	A	
	-19.89	452.14	217.31	-	47	0.00	217.31	A	
51	-19.92	456.44	217.59	-	47	0.00	217.59	A	
51	-19.92	456.44	217.59	-	47	0.00	217.59	A	
	-19.94	458.91	217.74	-	47	0.00	217.74	A	
	-19.95	461.37	217.90	-	48	0.00	217.90	A	
	-19.97	463.83	218.06	-	48	0.00	218.06	A	
	-19.98	466.29	218.21	-	48	0.00	218.21	A	
52	-20.00	468.75	218.37	-	48	0.00	218.37	A	

*

Stat	Status (A=active, P=passive, Number is branche, 0 is unloading)
Mob	Percentage passive mobilized

End of Report

Appendix XI – Technosoft/Damwanden Reports

Appendix X.I – Original pile - CPT70294 analysis – 350kN not stable

Technosoft studentenlicentie blad :1

Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :
Units : [kN][m][degrees] unless otherwise stated
Date : 15-05-2018
Reference level : N.A.P.
File : D:\Gebruikersdata\Desktop\Hansweert.dmw

Toegepaste normen volgens Eurocode met Nederlandse NB

Geotechniek	EN 1997-1:2004	AC:2009	
	NEN-EN 1997-1:2005	C1:2015	NB:2015
	NEN 9997-1:2011	C2:2015	

GENERAL DATA

Reliability class	: RC3	$\gamma_{c'}$	: 1.400
		$\gamma_{\varphi'}$	: 1.200
Calculation method	: Table 9.d	Margin stemming height	: 0.50
Calculation scheme	: All design values	Margin gws low side	: 0.25
		Margin gws high side	: 0.05
		γ sub-grade SLS	: 1.00
		γ sub-grade ULS low	: 1.30
		γ sub-grade ULS high	: 1.00
Loads	:	γ Permanent	: 1.00
		γ Live	: 1.25
Results SLS	:	Factor Tabel 9.d cal. 5	: 1.20
Calculation method	: Elastic	Max. iterations / phase	: 25
		Stop criterion	: 1.00
Level top of wall	: 6.50	Number of constr. phases	: 1
Piling level	: -17.60	Number of wall parts	: 1
Slope of wall	: 0.00	Number of soil types	: 3
Sw. water left	: 2.26	Sw. water right	: 2.26

MATERIALS

Nr.	Mark	E-modulus [N/mm²]	S.W. [kN/m3]
1	S355	210000	78.50

SHEET PILE WALL PARTS

Nr.	Name profile	Inertia	Inert/m	Beta D	Sec.Mod	Sec.Mod/m	Beta B
1	HANSWEERT	.7763E-02	.7640E-02	----	.169E-06	.167E-06	----

Nr.	Profielnaam	Height	Width	Work. Width	Area	Weight	Material
1	HANSWEERT	0.020	1.016	1.016	0.81073	063.64230	S355

SONDERINGSGEGEVENS ALGEMEEN: Sondering 1

Alle niveaus/hoogtes/peilmaten zijn t.o.v.: N.A.P.
Hoogte maaiveld [m] : -9.00

SONDERINGSGEGEVENS TABEL: Sondering 1

Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]	Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]
1	-9.00	0.00	0.000	15	-16.50	8.26	0.103
2	-10.00	0.00	0.000	16	-17.00	8.08	0.086
3	-10.50	5.83	0.033	17	-17.50	13.43	0.122
4	-11.00	14.27	0.085	18	-18.00	11.92	0.101
5	-11.50	18.88	0.099	19	-18.50	25.99	0.180
6	-12.00	18.89	0.143	20	-19.00	22.00	0.152
7	-12.50	9.14	0.093	21	-19.50	13.08	0.141
8	-13.00	6.12	0.055	22	-20.00	36.57	0.252

Technosoft studentenlicentie blad :2

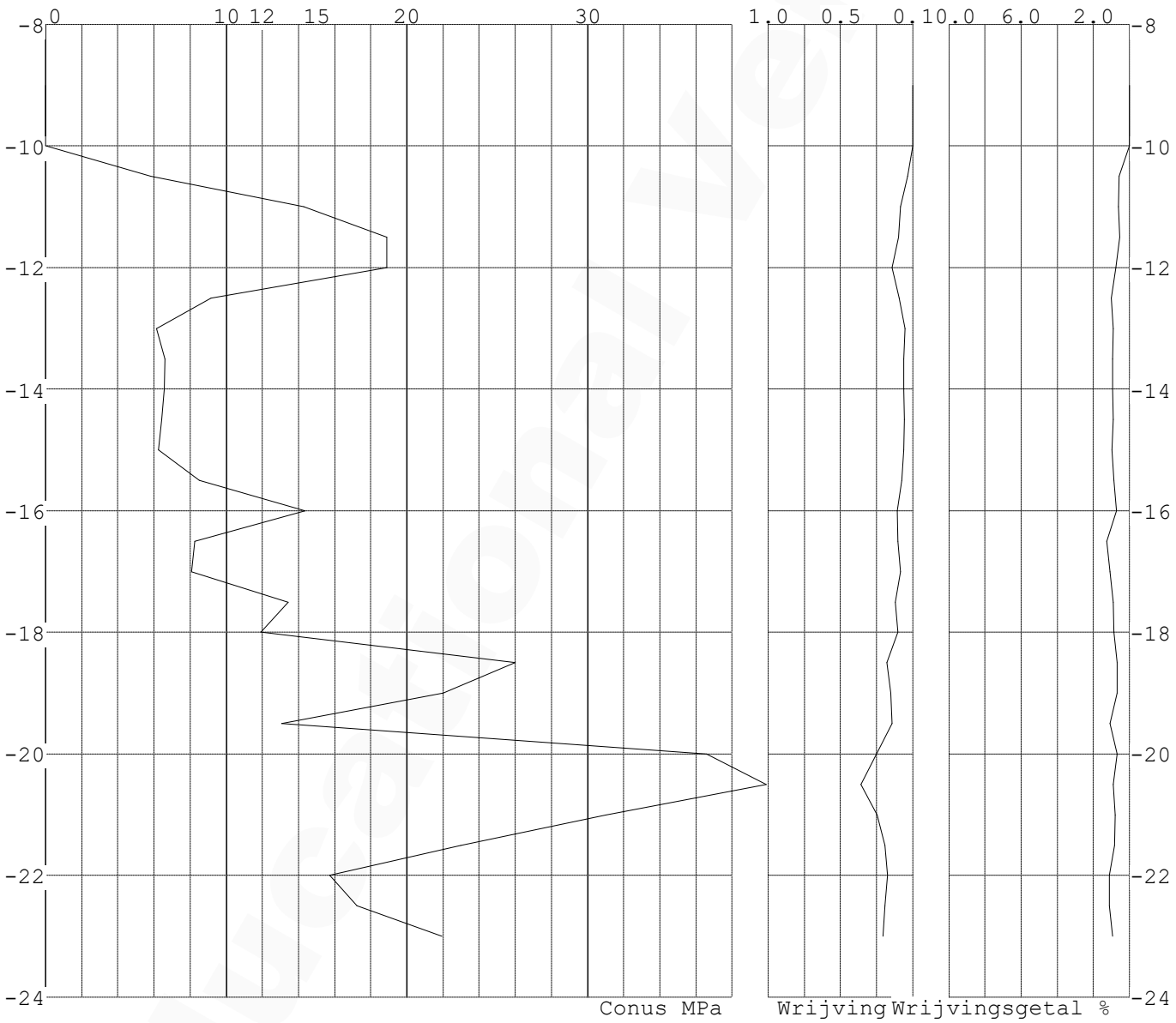
Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :

SONDERINGSGEGEVENS TABEL: Sondering 1

Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]	Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]
9	-13.50	6.59	0.061	23	-20.50	39.91	0.357
10	-14.00	6.56	0.061	24	-21.00	31.01	0.244
11	-14.50	6.41	0.057	25	-21.50	22.98	0.193
12	-15.00	6.23	0.061	26	-22.00	15.72	0.175
13	-15.50	8.50	0.074	27	-22.50	17.24	0.190
14	-16.00	14.35	0.105	28	-23.00	21.94	0.206

SONDERINGSGEGEVENS GRAFIEK: Sondering 1



Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :

SOIL TYPES

Nr.	Description	γ [kN/m^3]	γ_{sat} [kN/m^3]	φ' [°]	$\gamma_{\varphi'}$ [-]	c' [kPa]	$\gamma_{c'}$ [-]	δ [-]	k-value [-]
1	Leem - Zwak zand..	22.00	22.00	35.00	1.200	3.50	1.40	0.000	.0000E+00
2	Zand - Schoon - ..	18.00	20.00	25.00	1.200	0.00	1.40	0.000	.0000E+00
3	Klei - Sterk zan..	20.00	20.00	27.00	1.200	1.00	1.40	0.000	.0000E+00

CONSTR.PHASE : 1 - Bouwfase 1

			Left		Right	
Calc. infl. talus slope		:	As surcharge		As surcharge	
Talus			horz	angle	horz	angle
			0.00	0.00	0.00	9.50
Ground level	SLS	:		-9.00		-9.00
Ground level	ULS	:		-9.00		-9.00
Water level	SLS	:		2.26		2.26
Water level Low	ULS	:		2.26		2.26
Water level High	ULS	:		2.26		2.26

SOIL LAYERS LEFT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	Sw. water	Waterpress. top	Waterpress. bottom	Slide plane	K-act.	K-neu.	K-pas.
1	1	-9.00	10.00	0.00	0.00	Straight	0.271	0.426	3.690
2	2	-11.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
3	3	-11.74	10.00	0.00	0.00	Straight	0.376	0.546	2.663
4	2	-13.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
5	3	-14.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663
6	2	-16.74	10.00	0.00	0.00	Straight	0.406	0.577	2.464
7	3	-17.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663

Nr.	St.	Level	Sub-grade input top	Sub-grade input bottom	Sub-grade calc. top	Sub-grade calc. bottom
1	1	-9.00	30000	30000	30000	30000
2	2	-11.24	50000	50000	50000	50000
3	3	-11.74	10000	10000	10000	10000
4	2	-13.24	50000	50000	50000	50000
5	3	-14.24	10000	10000	10000	10000
6	2	-16.74	50000	50000	50000	50000
7	3	-17.24	10000	10000	10000	10000

Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :

SOIL LAYERS LEFT (ULS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	K-act.	K-neu.	K-pas.
1	1	-9.00	0.345	0.513	2.901
2	2	-11.24	0.475	0.644	2.104
3	3	-11.74	0.446	0.617	2.240
4	2	-13.24	0.475	0.644	2.104
5	3	-14.24	0.446	0.617	2.240
6	2	-16.74	0.475	0.644	2.104
7	3	-17.24	0.446	0.617	2.240

Nr.	St.	Level	Sub-grade low				Sub-grade high			
			Input value		Calc. value		Input value		Calc. value	
			top	bottom	top	bottom	top	bottom	top	bottom
1	1	-9.00	30000	30000	30000	30000	50000	50000	50000	50000
2	2	-11.24	50000	50000	50000	50000	100000	100000	100000	100000
3	3	-11.74	10000	10000	10000	10000	30000	30000	30000	30000
4	2	-13.24	50000	50000	50000	50000	100000	100000	100000	100000
5	3	-14.24	10000	10000	10000	10000	30000	30000	30000	30000
6	2	-16.74	50000	50000	50000	50000	100000	100000	100000	100000
7	3	-17.24	10000	10000	10000	10000	30000	30000	30000	30000

SOIL LAYERS RIGHT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	Sw. water	Waterpress. top	Waterpress. bottom	Slide plane	K-act.	K-neu.	K-pas.
1	1	-9.00	10.00	0.00	0.00	Straight	0.271	0.426	3.690
2	2	-11.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
3	3	-11.74	10.00	0.00	0.00	Straight	0.376	0.546	2.663
4	2	-13.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
5	3	-14.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663
6	2	-16.74	10.00	0.00	0.00	Straight	0.406	0.577	2.464
7	3	-17.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663

Nr.	St.	Level	Sub-grade input		Sub-grade calc.	
			top	bottom	top	bottom
1	1	-9.00	30000	30000	30000	30000
2	2	-11.24	50000	50000	50000	50000
3	3	-11.74	10000	10000	10000	10000
4	2	-13.24	50000	50000	50000	50000
5	3	-14.24	10000	10000	10000	10000
6	2	-16.74	50000	50000	50000	50000
7	3	-17.24	10000	10000	10000	10000

Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :

SOIL LAYERS RIGHT (ULS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	K-act.	K-neu.	K-pas.
1	1	-9.00	0.345	0.513	2.901
2	2	-11.24	0.475	0.644	2.104
3	3	-11.74	0.446	0.617	2.240
4	2	-13.24	0.475	0.644	2.104
5	3	-14.24	0.446	0.617	2.240
6	2	-16.74	0.475	0.644	2.104
7	3	-17.24	0.446	0.617	2.240

Nr.	St.	Level	Sub-grade low				Sub-grade high			
			Input value		Calc. value		Input value		Calc. value	
			top	bottom	top	bottom	top	bottom	top	bottom
1	1	-9.00	30000	30000	30000	30000	50000	50000	50000	50000
2	2	-11.24	50000	50000	50000	50000	100000	100000	100000	100000
3	3	-11.74	10000	10000	10000	10000	30000	30000	30000	30000
4	2	-13.24	50000	50000	50000	50000	100000	100000	100000	100000
5	3	-14.24	10000	10000	10000	10000	30000	30000	30000	30000
6	2	-16.74	50000	50000	50000	50000	100000	100000	100000	100000
7	3	-17.24	10000	10000	10000	10000	30000	30000	30000	30000

NODAL LOADS **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	Level	Type	Angle	Value
1	6.50	Nodal load	0.00	350.00

Fouten en/of waarschuwingen

ERROR 43 : Sheet pile wall is unstable

Appendix X.II – Original pile - CPT70294- 75kN stable

Technosoft studentenlicentie blad :1

Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :
Units : [kN][m][degrees] unless otherwise stated
Date : 15-05-2018
Reference level : N.A.P.
File : D:\Gebruikersdata\Desktop\Hansweert.dmw

Toegepaste normen volgens Eurocode met Nederlandse NB

Geotechniek	EN 1997-1:2004	AC:2009	
	NEN-EN 1997-1:2005	C1:2015	NB:2015
	NEN 9997-1:2011	C2:2015	

GENERAL DATA

Reliability class	: RC3	$\gamma_{c'}$	: 1.400
		$\gamma_{\varphi'}$	: 1.200
Calculation method	: Table 9.d	Margin stemming height	: 0.50
Calculation scheme	: All design values	Margin gws low side	: 0.25
		Margin gws high side	: 0.05
		γ sub-grade SLS	: 1.00
		γ sub-grade ULS low	: 1.30
		γ sub-grade ULS high	: 1.00
Loads	:	γ Permanent	: 1.00
		γ Live	: 1.25
Results SLS	:	Factor Tabel 9.d cal. 5	: 1.20
Calculation method	: Elastic	Max. iterations / phase	: 25
		Stop criterion	: 1.00
Level top of wall	: 6.50	Number of constr. phases	: 1
Piling level	: -17.60	Number of wall parts	: 1
Slope of wall	: 0.00	Number of soil types	: 3
Sw. water left	: 2.26	Sw. water right	: 2.26

MATERIALS

Nr.	Mark	E-modulus [N/mm²]	S.W. [kN/m3]
1	S355	210000	78.50

SHEET PILE WALL PARTS

Nr.	Name profile	Inertia	Inert/m	Beta D	Sec.Mod	Sec.Mod/m	Beta B
1	HANSWEERT	.7763E-02	.7640E-02	----	.169E-06	.167E-06	----

Nr.	Profielnaam	Height	Width	Work. Width	Area	Weight	Material
1	HANSWEERT	0.020	1.016	1.016	0.81073	063.64230	S355

SONDERINGSGEGEVENS ALGEMEEN: Sondering 1

Alle niveaus/hoogtes/peilmaten zijn t.o.v.: N.A.P.
Hoogte maaiveld [m] : -9.00

SONDERINGSGEGEVENS TABEL: Sondering 1

Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]	Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]
1	-9.00	0.00	0.000	15	-16.50	8.26	0.103
2	-10.00	0.00	0.000	16	-17.00	8.08	0.086
3	-10.50	5.83	0.033	17	-17.50	13.43	0.122
4	-11.00	14.27	0.085	18	-18.00	11.92	0.101
5	-11.50	18.88	0.099	19	-18.50	25.99	0.180
6	-12.00	18.89	0.143	20	-19.00	22.00	0.152
7	-12.50	9.14	0.093	21	-19.50	13.08	0.141
8	-13.00	6.12	0.055	22	-20.00	36.57	0.252

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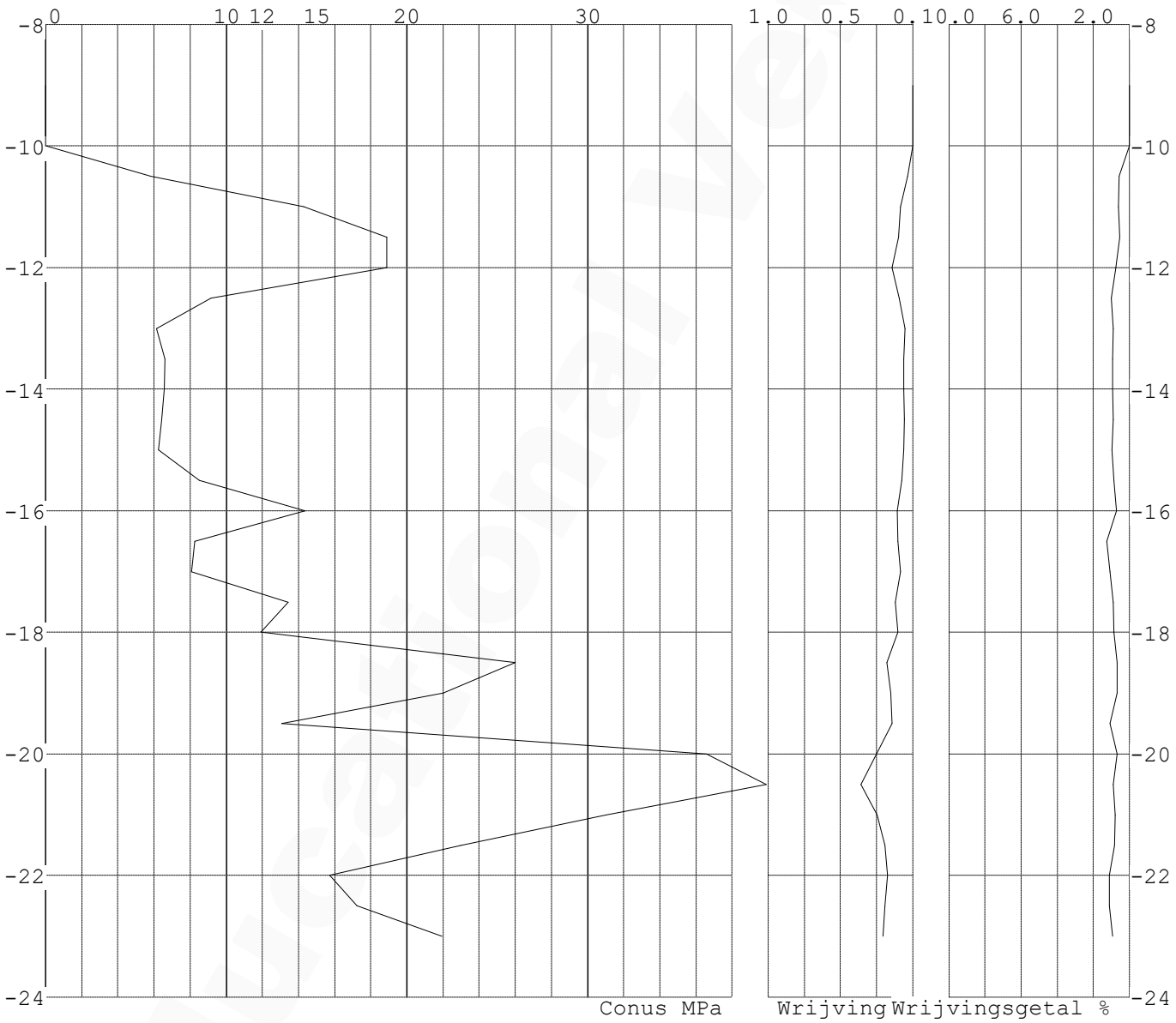
SONDERINGSGEGEVENS TABEL: Sondering 1

Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]	Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]
9	-13.50	6.59	0.061	23	-20.50	39.91	0.357
10	-14.00	6.56	0.061	24	-21.00	31.01	0.244
11	-14.50	6.41	0.057	25	-21.50	22.98	0.193
12	-15.00	6.23	0.061	26	-22.00	15.72	0.175
13	-15.50	8.50	0.074	27	-22.50	17.24	0.190
14	-16.00	14.35	0.105	28	-23.00	21.94	0.206

SONDERINGSGEGEVENS GRAFIEK: Sondering 1



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SOIL TYPES

Nr.	Description	γ [kN/m^3]	γ_{sat} [kN/m^3]	φ' [°]	$\gamma_{\varphi'}$ [-]	c' [kPa]	$\gamma_{c'}$ [-]	δ [-]	k-value [-]
1	Leem - Zwak zand..	22.00	22.00	35.00	1.200	3.50	1.40	0.000	.0000E+00
2	Zand - Schoon - ..	18.00	20.00	25.00	1.200	0.00	1.40	0.000	.0000E+00
3	Klei - Sterk zan..	20.00	20.00	27.00	1.200	1.00	1.40	0.000	.0000E+00

CONSTR.PHASE : 1 - Bouwfase 1

			Left		Right	
Calc. infl. talus slope		:	As surcharge		As surcharge	
Talus			horz	angle	horz	angle
			0.00	0.00	0.00	9.50
Ground level	SLS	:		-9.00		-9.00
Ground level	ULS	:		-9.00		-9.00
Water level	SLS	:		2.26		2.26
Water level Low	ULS	:		2.26		2.26
Water level High	ULS	:		2.26		2.26

SOIL LAYERS LEFT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	Sw. water	Waterpress. top	Waterpress. bottom	Slide plane	K-act.	K-neu.	K-pas.
1	1	-9.00	10.00	0.00	0.00	Straight	0.271	0.426	3.690
2	2	-11.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
3	3	-11.74	10.00	0.00	0.00	Straight	0.376	0.546	2.663
4	2	-13.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
5	3	-14.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663
6	2	-16.74	10.00	0.00	0.00	Straight	0.406	0.577	2.464
7	3	-17.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663

Nr.	St.	Level	Sub-grade input top	Sub-grade input bottom	Sub-grade calc. top	Sub-grade calc. bottom
1	1	-9.00	30000	30000	30000	30000
2	2	-11.24	50000	50000	50000	50000
3	3	-11.74	10000	10000	10000	10000
4	2	-13.24	50000	50000	50000	50000
5	3	-14.24	10000	10000	10000	10000
6	2	-16.74	50000	50000	50000	50000
7	3	-17.24	10000	10000	10000	10000

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SOIL LAYERS LEFT (ULS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	K-act.	K-neu.	K-pas.
1	1	-9.00	0.345	0.513	2.901
2	2	-11.24	0.475	0.644	2.104
3	3	-11.74	0.446	0.617	2.240
4	2	-13.24	0.475	0.644	2.104
5	3	-14.24	0.446	0.617	2.240
6	2	-16.74	0.475	0.644	2.104
7	3	-17.24	0.446	0.617	2.240

Nr.	St.	Level	Sub-grade low				Sub-grade high			
			Input value		Calc. value		Input value		Calc. value	
			top	bottom	top	bottom	top	bottom	top	bottom
1	1	-9.00	30000	30000	23077	23077	50000	50000	50000	50000
2	2	-11.24	50000	50000	38462	38462	100000	100000	100000	100000
3	3	-11.74	10000	10000	7692	7692	30000	30000	30000	30000
4	2	-13.24	50000	50000	38462	38462	100000	100000	100000	100000
5	3	-14.24	10000	10000	7692	7692	30000	30000	30000	30000
6	2	-16.74	50000	50000	38462	38462	100000	100000	100000	100000
7	3	-17.24	10000	10000	7692	7692	30000	30000	30000	30000

SOIL LAYERS RIGHT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	Sw. water	Waterpress. top	Waterpress. bottom	Slide plane	K-act.	K-neu.	K-pas.
1	1	-9.00	10.00	0.00	0.00	Straight	0.271	0.426	3.690
2	2	-11.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
3	3	-11.74	10.00	0.00	0.00	Straight	0.376	0.546	2.663
4	2	-13.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
5	3	-14.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663
6	2	-16.74	10.00	0.00	0.00	Straight	0.406	0.577	2.464
7	3	-17.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663

Nr.	St.	Level	Sub-grade input		Sub-grade calc.	
			top	bottom	top	bottom
1	1	-9.00	30000	30000	30000	30000
2	2	-11.24	50000	50000	50000	50000
3	3	-11.74	10000	10000	10000	10000
4	2	-13.24	50000	50000	50000	50000
5	3	-14.24	10000	10000	10000	10000
6	2	-16.74	50000	50000	50000	50000
7	3	-17.24	10000	10000	10000	10000

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SOIL LAYERS RIGHT (ULS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	K-act.	K-neu.	K-pas.
1	1	-9.00	0.345	0.513	2.901
2	2	-11.24	0.475	0.644	2.104
3	3	-11.74	0.446	0.617	2.240
4	2	-13.24	0.475	0.644	2.104
5	3	-14.24	0.446	0.617	2.240
6	2	-16.74	0.475	0.644	2.104
7	3	-17.24	0.446	0.617	2.240

Nr.	St.	Level	Sub-grade low				Sub-grade high			
			Input value		Calc. value		Input value		Calc. value	
			top	bottom	top	bottom	top	bottom	top	bottom
1	1	-9.00	30000	30000	23077	23077	50000	50000	50000	50000
2	2	-11.24	50000	50000	38462	38462	100000	100000	100000	100000
3	3	-11.74	10000	10000	7692	7692	30000	30000	30000	30000
4	2	-13.24	50000	50000	38462	38462	100000	100000	100000	100000
5	3	-14.24	10000	10000	7692	7692	30000	30000	30000	30000
6	2	-16.74	50000	50000	38462	38462	100000	100000	100000	100000
7	3	-17.24	10000	10000	7692	7692	30000	30000	30000	30000

NODAL LOADS **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	Level	Type	Angle	Value
1	6.50	Nodal load	0.00	75.00

NODE OUTPUT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 5 Deviation : 0.04

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
1	6.50	182.6	75.00	0.00	0.0	0.0	0	0.0	0.0	0
2	6.25	179.5	75.00	-18.71	0.0	0.0	0	0.0	0.0	0
3	6.00	176.5	75.00	-37.41	0.0	0.0	0	0.0	0.0	0
4	5.75	173.5	75.00	-56.12	0.0	0.0	0	0.0	0.0	0
5	5.50	170.5	75.00	-74.82	0.0	0.0	0	0.0	0.0	0
6	5.25	167.4	75.00	-93.53	0.0	0.0	0	0.0	0.0	0
7	5.00	164.4	75.00	-112.24	0.0	0.0	0	0.0	0.0	0
8	4.75	161.4	75.00	-130.94	0.0	0.0	0	0.0	0.0	0
9	4.50	158.4	75.00	-149.65	0.0	0.0	0	0.0	0.0	0
10	4.26	155.4	75.00	-168.35	0.0	0.0	0	0.0	0.0	0
11	4.01	152.4	75.00	-187.06	0.0	0.0	0	0.0	0.0	0
12	3.76	149.4	75.00	-205.76	0.0	0.0	0	0.0	0.0	0
13	3.51	146.4	75.00	-224.47	0.0	0.0	0	0.0	0.0	0
14	3.26	143.5	75.00	-243.18	0.0	0.0	0	0.0	0.0	0
15	3.01	140.5	75.00	-261.88	0.0	0.0	0	0.0	0.0	0
16	2.76	137.6	75.00	-280.59	0.0	0.0	0	0.0	0.0	0
17	2.51	134.6	75.00	-299.29	0.0	0.0	0	0.0	0.0	0

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NODE OUTPUT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 5 Deviation : 0.04

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
18	2.26	131.7	75.00	-318.00	0.0	0.0	0	0.0	0.0	0
19	2.02	128.8	75.00	-336.36	0.6	0.0	0	0.6	0.0	0
20	1.77	126.0	75.00	-354.72	1.1	0.0	0	1.1	0.0	0
21	1.53	123.1	75.00	-373.08	1.7	0.0	0	1.7	0.0	0
22	1.28	120.3	75.00	-391.43	2.2	0.0	0	2.2	0.0	0
23	1.04	117.5	75.00	-409.79	2.8	0.0	0	2.8	0.0	0
24	0.79	114.7	75.00	-428.15	3.3	0.0	0	3.3	0.0	0
25	0.55	111.9	75.00	-446.51	3.9	0.0	0	3.9	0.0	0
26	0.30	109.2	75.00	-464.87	4.4	0.0	0	4.4	0.0	0
27	0.06	106.4	75.00	-483.23	5.0	0.0	0	5.0	0.0	0
28	-0.19	103.7	75.00	-501.59	5.5	0.0	0	5.5	0.0	0
29	-0.43	101.0	75.00	-519.95	6.1	0.0	0	6.1	0.0	0
30	-0.68	98.3	75.00	-538.30	6.6	0.0	0	6.6	0.0	0
31	-0.92	95.7	75.00	-556.66	7.2	0.0	0	7.2	0.0	0
32	-1.17	93.0	75.00	-575.02	7.7	0.0	0	7.7	0.0	0
33	-1.41	90.4	75.00	-593.38	8.3	0.0	0	8.3	0.0	0
34	-1.66	87.8	75.00	-611.74	8.9	0.0	0	8.9	0.0	0
35	-1.90	85.2	75.00	-630.10	9.4	0.0	0	9.4	0.0	0
36	-2.15	82.7	75.00	-648.46	10.0	0.0	0	10.0	0.0	0
37	-2.39	80.1	75.00	-666.82	10.5	0.0	0	10.5	0.0	0
38	-2.64	77.6	75.00	-685.17	11.1	0.0	0	11.1	0.0	0
39	-2.88	75.1	75.00	-703.53	11.6	0.0	0	11.6	0.0	0
40	-3.13	72.7	75.00	-721.89	12.2	0.0	0	12.2	0.0	0
41	-3.37	70.3	75.00	-740.25	12.7	0.0	0	12.7	0.0	0
42	-3.61	67.9	75.00	-758.61	13.3	0.0	0	13.3	0.0	0
43	-3.86	65.5	75.00	-776.97	13.8	0.0	0	13.8	0.0	0
44	-4.10	63.1	75.00	-795.33	14.4	0.0	0	14.4	0.0	0
45	-4.35	60.8	75.00	-813.68	14.9	0.0	0	14.9	0.0	0
46	-4.59	58.5	75.00	-832.04	15.5	0.0	0	15.5	0.0	0
47	-4.84	56.3	75.00	-850.40	16.0	0.0	0	16.0	0.0	0
48	-5.08	54.1	75.00	-868.76	16.6	0.0	0	16.6	0.0	0
49	-5.33	51.9	75.00	-887.12	17.1	0.0	0	17.1	0.0	0
50	-5.57	49.7	75.00	-905.48	17.7	0.0	0	17.7	0.0	0
51	-5.82	47.6	75.00	-923.84	18.3	0.0	0	18.3	0.0	0
52	-6.06	45.5	75.00	-942.20	18.8	0.0	0	18.8	0.0	0
53	-6.31	43.5	75.00	-960.55	19.4	0.0	0	19.4	0.0	0
54	-6.55	41.5	75.00	-978.91	19.9	0.0	0	19.9	0.0	0
55	-6.80	39.5	75.00	-997.27	20.5	0.0	0	20.5	0.0	0
56	-7.04	37.5	75.00	-1015.63	21.0	0.0	0	21.0	0.0	0
57	-7.29	35.6	75.00	-1033.99	21.6	0.0	0	21.6	0.0	0
58	-7.53	33.8	75.00	-1052.35	22.1	0.0	0	22.1	0.0	0
59	-7.78	31.9	75.00	-1070.71	22.7	0.0	0	22.7	0.0	0
60	-8.02	30.2	75.00	-1089.07	23.2	0.0	0	23.2	0.0	0
61	-8.27	28.4	75.00	-1107.42	23.8	0.0	0	23.8	0.0	0

Project : Hansweert
Part :

NODE OUTPUT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 5 Deviation : 0.04

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
62	-8.51	26.7	75.00	-1125.78	24.3	0.0	0	24.3	0.0	0
63	-8.76	25.1	75.00	-1144.14	24.9	0.0	0	24.9	0.0	0
64	-9.00	23.4	72.48	-1162.50	25.4	0.0	0	25.4	10.2	100p
65	-9.25	21.8	64.70	-1180.54	27.9	0.0	0	27.9	31.3	100p
66	-9.50	20.3	54.18	-1196.64	30.4	0.0	0	30.4	42.3	100p
67	-9.75	18.8	40.91	-1210.13	32.9	0.0	0	32.9	53.3	100p
68	-10.00	17.3	24.90	-1220.31	35.4	0.0	0	35.4	64.3	100p
69	-10.24	15.9	5.68	-1226.51	37.9	0.4	1a	37.9	77.6	100p
70	-10.49	14.5	-17.12	-1227.92	40.4	1.2	2a	40.4	92.8	100p
71	-10.74	13.2	-43.50	-1223.66	42.9	2.0	2a	42.9	108.0	100p
72	-10.99	11.9	-73.15	-1212.83	45.4	2.8	3a	45.4	122.0	100p
73	-11.24	10.7	-97.87	-1194.63	47.8	7.3	8a	47.8	106.4	100p
74	-11.49	9.5	-116.39	-1170.16	50.3	11.9	16a	50.3	86.0	100p
75	-11.74	8.4	-137.95	-1141.06	52.8	11.8	14a	52.8	98.1	100p
76	-11.99	7.3	-158.85	-1106.57	55.3	11.7	12a	55.3	95.3	84
77	-12.24	6.2	-177.37	-1066.86	57.8	12.6	12a	57.8	86.7	71
78	-12.49	5.2	-193.62	-1022.52	60.3	13.6	13a	60.3	78.5	59
79	-12.74	4.2	-207.57	-974.11	62.8	14.5	13a	62.8	70.3	50
80	-12.99	3.3	-219.30	-922.22	65.3	15.4	13a	65.3	62.3	43
81	-13.24	2.4	-240.84	-867.39	67.8	17.7	15a	67.8	103.8	71
82	-13.49	1.5	-263.76	-807.18	70.3	20.0	16a	70.3	111.7	76
83	-13.74	0.7	-276.54	-741.24	72.8	21.1	16a	72.8	72.2	46
84	-13.99	-0.1	-276.08	-672.11	75.3	35.9	27	75.3	34.0	21
85	-14.24	-0.9	-268.26	-603.09	77.8	58.0	39	77.8	26.6	15a
86	-14.49	-1.6	-262.58	-536.02	80.3	48.6	30	80.3	25.9	13a
87	-14.74	-2.4	-254.96	-470.38	82.8	57.3	34	82.8	26.9	13a
88	-14.99	-3.1	-245.50	-406.64	85.3	65.8	38	85.3	28.0	13a
89	-15.24	-3.8	-234.29	-345.26	87.8	74.2	41	87.8	29.3	13a
90	-15.49	-4.5	-221.35	-286.69	90.3	82.4	44	90.3	30.6	13a
91	-15.74	-5.1	-206.70	-231.36	92.8	90.5	47	92.8	31.9	13a
92	-15.99	-5.8	-190.30	-179.68	95.3	98.5	49	95.3	32.9	13a
93	-16.24	-6.5	-172.14	-132.11	97.8	106.5	51	97.8	33.9	13a
94	-16.49	-7.1	-152.27	-89.07	100.3	114.4	53	100.3	34.9	13a
95	-16.74	-7.8	-108.98	-51.00	102.8	211.5	100p	102.8	38.3	15a
96	-16.99	-8.4	-67.47	-23.76	105.3	207.9	100p	105.3	41.9	16a
97	-17.24	-9.0	-28.49	-6.89	107.8	222.7	100p	107.8	41.4	15a
98	-17.42	-9.5	-9.80	-1.76	109.6	143.6	60	109.6	39.7	14a
99	-17.60	-10.0	0.00	0.00	111.4	149.2	61	111.4	40.4	14a

NODE OUTPUT (ULS-low, low wlevel) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 8 Deviation : 0.00

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
1	6.50	376.4	75.00	0.00	0.0	0.0	0	0.0	0.0	0

Project : Hansweert
Part :

NODE OUTPUT (ULS-low, low wlevel) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
2	6.25	371.1	75.00	-18.71	0.0	0.0	0	0.0	0.0	0
3	6.00	365.7	75.00	-37.41	0.0	0.0	0	0.0	0.0	0
4	5.75	360.4	75.00	-56.12	0.0	0.0	0	0.0	0.0	0
5	5.50	355.1	75.00	-74.82	0.0	0.0	0	0.0	0.0	0
6	5.25	349.8	75.00	-93.53	0.0	0.0	0	0.0	0.0	0
7	5.00	344.5	75.00	-112.24	0.0	0.0	0	0.0	0.0	0
8	4.75	339.2	75.00	-130.94	0.0	0.0	0	0.0	0.0	0
9	4.50	333.9	75.00	-149.65	0.0	0.0	0	0.0	0.0	0
10	4.26	328.6	75.00	-168.35	0.0	0.0	0	0.0	0.0	0
11	4.01	323.3	75.00	-187.06	0.0	0.0	0	0.0	0.0	0
12	3.76	318.0	75.00	-205.76	0.0	0.0	0	0.0	0.0	0
13	3.51	312.7	75.00	-224.47	0.0	0.0	0	0.0	0.0	0
14	3.26	307.5	75.00	-243.18	0.0	0.0	0	0.0	0.0	0
15	3.01	302.2	75.00	-261.88	0.0	0.0	0	0.0	0.0	0
16	2.76	297.0	75.00	-280.59	0.0	0.0	0	0.0	0.0	0
17	2.51	291.7	75.00	-299.29	0.0	0.0	0	0.0	0.0	0
18	2.26	286.5	75.00	-318.00	0.0	0.0	0	0.0	0.0	0
19	2.02	281.4	75.00	-336.36	0.6	0.0	0	0.6	0.0	0
20	1.77	276.3	75.00	-354.72	1.1	0.0	0	1.1	0.0	0
21	1.53	271.2	75.00	-373.08	1.7	0.0	0	1.7	0.0	0
22	1.28	266.1	75.00	-391.43	2.2	0.0	0	2.2	0.0	0
23	1.04	261.1	75.00	-409.79	2.8	0.0	0	2.8	0.0	0
24	0.79	256.0	75.00	-428.15	3.3	0.0	0	3.3	0.0	0
25	0.55	251.0	75.00	-446.51	3.9	0.0	0	3.9	0.0	0
26	0.30	246.0	75.00	-464.87	4.4	0.0	0	4.4	0.0	0
27	0.06	241.0	75.00	-483.23	5.0	0.0	0	5.0	0.0	0
28	-0.19	236.0	75.00	-501.59	5.5	0.0	0	5.5	0.0	0
29	-0.43	231.0	75.00	-519.95	6.1	0.0	0	6.1	0.0	0
30	-0.68	226.1	75.00	-538.30	6.6	0.0	0	6.6	0.0	0
31	-0.92	221.2	75.00	-556.66	7.2	0.0	0	7.2	0.0	0
32	-1.17	216.3	75.00	-575.02	7.7	0.0	0	7.7	0.0	0
33	-1.41	211.4	75.00	-593.38	8.3	0.0	0	8.3	0.0	0
34	-1.66	206.6	75.00	-611.74	8.9	0.0	0	8.9	0.0	0
35	-1.90	201.7	75.00	-630.10	9.4	0.0	0	9.4	0.0	0
36	-2.15	196.9	75.00	-648.46	10.0	0.0	0	10.0	0.0	0
37	-2.39	192.1	75.00	-666.82	10.5	0.0	0	10.5	0.0	0
38	-2.64	187.4	75.00	-685.17	11.1	0.0	0	11.1	0.0	0
39	-2.88	182.6	75.00	-703.53	11.6	0.0	0	11.6	0.0	0
40	-3.13	177.9	75.00	-721.89	12.2	0.0	0	12.2	0.0	0
41	-3.37	173.3	75.00	-740.25	12.7	0.0	0	12.7	0.0	0
42	-3.61	168.6	75.00	-758.61	13.3	0.0	0	13.3	0.0	0
43	-3.86	164.0	75.00	-776.97	13.8	0.0	0	13.8	0.0	0
44	-4.10	159.4	75.00	-795.33	14.4	0.0	0	14.4	0.0	0
45	-4.35	154.8	75.00	-813.68	14.9	0.0	0	14.9	0.0	0

Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :

NODE OUTPUT (ULS-low, low wlevel) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 8 Deviation : 0.00

					LEFT			RIGHT		
Node nr.	Level m	Displ mm	Shear kN	Moment kNm	Water kN/m²	Grain kN/m²	%	Water kN/m²	Grain kN/m²	%
46	-4.59	150.3	75.00	-832.04	15.5	0.0	0	15.5	0.0	0
47	-4.84	145.8	75.00	-850.40	16.0	0.0	0	16.0	0.0	0
48	-5.08	141.3	75.00	-868.76	16.6	0.0	0	16.6	0.0	0
49	-5.33	136.9	75.00	-887.12	17.1	0.0	0	17.1	0.0	0
50	-5.57	132.5	75.00	-905.48	17.7	0.0	0	17.7	0.0	0
51	-5.82	128.1	75.00	-923.84	18.3	0.0	0	18.3	0.0	0
52	-6.06	123.8	75.00	-942.20	18.8	0.0	0	18.8	0.0	0
53	-6.31	119.5	75.00	-960.55	19.4	0.0	0	19.4	0.0	0
54	-6.55	115.2	75.00	-978.91	19.9	0.0	0	19.9	0.0	0
55	-6.80	111.0	75.00	-997.27	20.5	0.0	0	20.5	0.0	0
56	-7.04	106.8	75.00	-1015.63	21.0	0.0	0	21.0	0.0	0
57	-7.29	102.6	75.00	-1033.99	21.6	0.0	0	21.6	0.0	0
58	-7.53	98.5	75.00	-1052.35	22.1	0.0	0	22.1	0.0	0
59	-7.78	94.4	75.00	-1070.71	22.7	0.0	0	22.7	0.0	0
60	-8.02	90.4	75.00	-1089.07	23.2	0.0	0	23.2	0.0	0
61	-8.27	86.4	75.00	-1107.42	23.8	0.0	0	23.8	0.0	0
62	-8.51	82.4	75.00	-1125.78	24.3	0.0	0	24.3	0.0	0
63	-8.76	78.5	75.00	-1144.14	24.9	0.0	0	24.9	0.0	0
64	-9.00	74.6	73.28	-1162.50	25.4	0.0	0	25.4	7.0	100p
65	-9.25	70.8	67.67	-1180.74	27.9	0.0	0	27.9	22.5	100p
66	-9.50	66.9	59.91	-1197.58	30.4	0.0	0	30.4	31.2	100p
67	-9.75	63.1	50.03	-1212.49	32.9	0.2	0	32.9	39.9	100p
68	-10.00	59.4	38.05	-1224.94	35.4	1.2	3a	35.4	49.3	100p
69	-10.24	55.6	23.31	-1234.41	37.9	2.2	4a	37.9	61.4	100p
70	-10.49	52.0	5.80	-1240.21	40.4	3.2	5a	40.4	73.6	100p
71	-10.74	48.4	-14.34	-1241.66	42.9	4.3	6a	42.9	85.2	100p
72	-10.99	44.8	-36.38	-1238.09	45.4	5.3	7a	45.4	93.9	100p
73	-11.24	41.3	-55.28	-1229.03	47.8	9.6	13a	47.8	85.3	100p
74	-11.49	37.8	-70.40	-1215.21	50.3	14.0	23a	50.3	74.5	100p
75	-11.74	34.4	-88.29	-1197.61	52.8	14.2	20a	52.8	85.7	100p
76	-11.99	31.0	-109.07	-1175.54	55.3	14.4	18a	55.3	97.5	100p
77	-12.24	27.7	-131.53	-1148.27	57.8	15.5	18a	57.8	105.4	100p
78	-12.49	24.4	-155.11	-1115.39	60.3	16.6	18a	60.3	111.0	100p
79	-12.74	21.1	-179.81	-1076.61	62.8	17.7	18a	62.8	116.6	100p
80	-12.99	17.9	-206.02	-1031.66	65.3	18.9	19a	65.3	123.7	100p
81	-13.24	14.7	-232.40	-980.16	67.8	21.1	21a	67.8	126.7	100p
82	-13.49	11.6	-258.83	-922.05	70.3	23.5	23a	70.3	129.2	100p
83	-13.74	8.5	-286.73	-857.35	72.8	24.7	23a	72.8	136.3	100p
84	-13.99	5.4	-315.65	-785.66	75.3	25.8	23a	75.3	141.5	100p
85	-14.24	2.4	-334.03	-706.75	77.8	25.7	21a	77.8	99.3	65
86	-14.49	-0.6	-333.79	-623.24	80.3	41.4	31	80.3	40.4	24
87	-14.74	-3.6	-325.65	-539.80	82.8	65.8	47	82.8	33.3	19a
88	-14.99	-6.6	-311.81	-458.38	85.3	90.2	62	85.3	34.8	19a
89	-15.24	-9.5	-292.30	-380.43	87.8	114.4	75	87.8	36.3	19a

Project : Hansweert
Part :

NODE OUTPUT (ULS-low, low wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
90	-15.49	-12.4	-267.05	-307.36	90.3	138.4	88	90.3	37.4	19a
91	-15.74	-15.3	-236.08	-240.59	92.8	162.4	100	92.8	38.5	19a
92	-15.99	-18.3	-203.92	-181.57	95.3	168.7	100p	95.3	40.1	19a
93	-16.24	-21.2	-170.75	-130.59	97.8	174.3	100p	97.8	41.6	19a
94	-16.49	-24.0	-136.57	-87.91	100.3	179.9	100p	100.3	43.2	19a
95	-16.74	-26.9	-103.49	-53.76	102.8	178.9	100p	102.8	46.6	21a
96	-16.99	-29.8	-71.54	-27.89	105.3	177.5	100p	105.3	49.7	23a
97	-17.24	-32.7	-41.57	-10.01	107.8	188.6	100p	107.8	49.2	21a
98	-17.42	-34.8	-14.03	-2.53	109.6	200.8	100p	109.6	47.8	19a
99	-17.60	-36.9	0.00	0.00	111.4	204.8	100p	111.4	48.9	19a

NODE OUTPUT (ULS-high, low wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
1	6.50	194.8	75.00	-0.00	0.0	0.0	0	0.0	0.0	0
2	6.25	191.7	75.00	-18.71	0.0	0.0	0	0.0	0.0	0
3	6.00	188.5	75.00	-37.41	0.0	0.0	0	0.0	0.0	0
4	5.75	185.4	75.00	-56.12	0.0	0.0	0	0.0	0.0	0
5	5.50	182.2	75.00	-74.82	0.0	0.0	0	0.0	0.0	0
6	5.25	179.1	75.00	-93.53	0.0	0.0	0	0.0	0.0	0
7	5.00	175.9	75.00	-112.24	0.0	0.0	0	0.0	0.0	0
8	4.75	172.8	75.00	-130.94	0.0	0.0	0	0.0	0.0	0
9	4.50	169.6	75.00	-149.65	0.0	0.0	0	0.0	0.0	0
10	4.26	166.5	75.00	-168.35	0.0	0.0	0	0.0	0.0	0
11	4.01	163.4	75.00	-187.06	0.0	0.0	0	0.0	0.0	0
12	3.76	160.3	75.00	-205.76	0.0	0.0	0	0.0	0.0	0
13	3.51	157.1	75.00	-224.47	0.0	0.0	0	0.0	0.0	0
14	3.26	154.0	75.00	-243.18	0.0	0.0	0	0.0	0.0	0
15	3.01	150.9	75.00	-261.88	0.0	0.0	0	0.0	0.0	0
16	2.76	147.9	75.00	-280.59	0.0	0.0	0	0.0	0.0	0
17	2.51	144.8	75.00	-299.29	0.0	0.0	0	0.0	0.0	0
18	2.26	141.7	75.00	-318.00	0.0	0.0	0	0.0	0.0	0
19	2.02	138.7	75.00	-336.36	0.6	0.0	0	0.6	0.0	0
20	1.77	135.8	75.00	-354.72	1.1	0.0	0	1.1	0.0	0
21	1.53	132.8	75.00	-373.08	1.7	0.0	0	1.7	0.0	0
22	1.28	129.8	75.00	-391.43	2.2	0.0	0	2.2	0.0	0
23	1.04	126.9	75.00	-409.79	2.8	0.0	0	2.8	0.0	0
24	0.79	124.0	75.00	-428.15	3.3	0.0	0	3.3	0.0	0
25	0.55	121.1	75.00	-446.51	3.9	0.0	0	3.9	0.0	0
26	0.30	118.2	75.00	-464.87	4.4	0.0	0	4.4	0.0	0
27	0.06	115.3	75.00	-483.23	5.0	0.0	0	5.0	0.0	0

Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :

NODE OUTPUT (ULS-high, low wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
28	-0.19	112.5	75.00	-501.59	5.5	0.0	0	5.5	0.0	0
29	-0.43	109.6	75.00	-519.95	6.1	0.0	0	6.1	0.0	0
30	-0.68	106.8	75.00	-538.30	6.6	0.0	0	6.6	0.0	0
31	-0.92	104.0	75.00	-556.66	7.2	0.0	0	7.2	0.0	0
32	-1.17	101.3	75.00	-575.02	7.7	0.0	0	7.7	0.0	0
33	-1.41	98.5	75.00	-593.38	8.3	0.0	0	8.3	0.0	0
34	-1.66	95.8	75.00	-611.74	8.9	0.0	0	8.9	0.0	0
35	-1.90	93.1	75.00	-630.10	9.4	0.0	0	9.4	0.0	0
36	-2.15	90.4	75.00	-648.46	10.0	0.0	0	10.0	0.0	0
37	-2.39	87.7	75.00	-666.82	10.5	0.0	0	10.5	0.0	0
38	-2.64	85.1	75.00	-685.17	11.1	0.0	0	11.1	0.0	0
39	-2.88	82.5	75.00	-703.53	11.6	0.0	0	11.6	0.0	0
40	-3.13	79.9	75.00	-721.89	12.2	0.0	0	12.2	0.0	0
41	-3.37	77.3	75.00	-740.25	12.7	0.0	0	12.7	0.0	0
42	-3.61	74.8	75.00	-758.61	13.3	0.0	0	13.3	0.0	0
43	-3.86	72.3	75.00	-776.97	13.8	0.0	0	13.8	0.0	0
44	-4.10	69.8	75.00	-795.33	14.4	0.0	0	14.4	0.0	0
45	-4.35	67.4	75.00	-813.68	14.9	0.0	0	14.9	0.0	0
46	-4.59	65.0	75.00	-832.04	15.5	0.0	0	15.5	0.0	0
47	-4.84	62.6	75.00	-850.40	16.0	0.0	0	16.0	0.0	0
48	-5.08	60.3	75.00	-868.76	16.6	0.0	0	16.6	0.0	0
49	-5.33	57.9	75.00	-887.12	17.1	0.0	0	17.1	0.0	0
50	-5.57	55.7	75.00	-905.48	17.7	0.0	0	17.7	0.0	0
51	-5.82	53.4	75.00	-923.84	18.3	0.0	0	18.3	0.0	0
52	-6.06	51.2	75.00	-942.20	18.8	0.0	0	18.8	0.0	0
53	-6.31	49.0	75.00	-960.55	19.4	0.0	0	19.4	0.0	0
54	-6.55	46.9	75.00	-978.91	19.9	0.0	0	19.9	0.0	0
55	-6.80	44.8	75.00	-997.27	20.5	0.0	0	20.5	0.0	0
56	-7.04	42.7	75.00	-1015.63	21.0	0.0	0	21.0	0.0	0
57	-7.29	40.7	75.00	-1033.99	21.6	0.0	0	21.6	0.0	0
58	-7.53	38.7	75.00	-1052.35	22.1	0.0	0	22.1	0.0	0
59	-7.78	36.7	75.00	-1070.71	22.7	0.0	0	22.7	0.0	0
60	-8.02	34.8	75.00	-1089.07	23.2	0.0	0	23.2	0.0	0
61	-8.27	32.9	75.00	-1107.42	23.8	0.0	0	23.8	0.0	0
62	-8.51	31.1	75.00	-1125.78	24.3	0.0	0	24.3	0.0	0
63	-8.76	29.3	75.00	-1144.14	24.9	0.0	0	24.9	0.0	0
64	-9.00	27.6	73.28	-1162.50	25.4	0.0	0	25.4	7.0	100p
65	-9.25	25.8	67.67	-1180.74	27.9	0.0	0	27.9	22.5	100p
66	-9.50	24.1	59.91	-1197.58	30.4	0.0	0	30.4	31.2	100p
67	-9.75	22.5	50.03	-1212.49	32.9	0.2	0	32.9	39.9	100p
68	-10.00	20.9	38.05	-1224.94	35.4	1.2	3a	35.4	49.3	100p
69	-10.24	19.4	23.31	-1234.41	37.9	2.2	4a	37.9	61.4	100p
70	-10.49	17.9	5.80	-1240.21	40.4	3.2	5a	40.4	73.6	100p
71	-10.74	16.4	-14.34	-1241.66	42.9	4.3	6a	42.9	85.2	100p

Project : Hansweert
Part :

NODE OUTPUT (ULS-high, low wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
72	-10.99	15.0	-36.38	-1238.09	45.4	5.3	7a	45.4	93.9	100p
73	-11.24	13.7	-55.28	-1229.03	47.8	9.6	13a	47.8	85.3	100p
74	-11.49	12.3	-70.40	-1215.21	50.3	14.0	23a	50.3	74.5	100p
75	-11.74	11.1	-88.29	-1197.61	52.8	14.2	20a	52.8	85.7	100p
76	-11.99	9.9	-109.07	-1175.54	55.3	14.4	18a	55.3	97.5	100p
77	-12.24	8.7	-131.53	-1148.27	57.8	15.5	18a	57.8	105.4	100p
78	-12.49	7.6	-155.11	-1115.39	60.3	16.6	18a	60.3	111.0	100p
79	-12.74	6.5	-179.81	-1076.61	62.8	17.7	18a	62.8	116.6	100p
80	-12.99	5.4	-206.02	-1031.66	65.3	18.9	19a	65.3	123.7	100p
81	-13.24	4.4	-232.40	-980.16	67.8	21.1	21a	67.8	126.7	100p
82	-13.49	3.5	-258.83	-922.05	70.3	23.5	23a	70.3	129.2	100p
83	-13.74	2.5	-286.73	-857.35	72.8	24.7	23a	72.8	136.3	100p
84	-13.99	1.6	-315.65	-785.66	75.3	25.8	23a	75.3	141.5	100p
85	-14.24	0.8	-332.74	-706.75	77.8	25.7	21a	77.8	94.1	62
86	-14.49	-0.1	-333.84	-623.57	80.3	38.7	29	80.3	43.1	26
87	-14.74	-0.9	-326.00	-540.11	82.8	64.6	46	82.8	33.3	19a
88	-14.99	-1.7	-312.23	-458.61	85.3	89.9	61	85.3	34.8	19a
89	-15.24	-2.4	-292.62	-380.55	87.8	114.7	76	87.8	36.3	19a
90	-15.49	-3.2	-267.21	-307.39	90.3	139.1	88	90.3	37.4	19a
91	-15.74	-4.0	-236.08	-240.59	92.8	163.0	100	92.8	38.5	19a
92	-15.99	-4.7	-203.92	-181.57	95.3	168.7	100p	95.3	40.1	19a
93	-16.24	-5.4	-170.75	-130.59	97.8	174.3	100p	97.8	41.6	19a
94	-16.49	-6.2	-136.57	-87.91	100.3	179.9	100p	100.3	43.2	19a
95	-16.74	-6.9	-103.49	-53.76	102.8	178.9	100p	102.8	46.6	21a
96	-16.99	-7.6	-71.54	-27.89	105.3	177.5	100p	105.3	49.7	23a
97	-17.24	-8.3	-41.57	-10.01	107.8	188.6	100p	107.8	49.2	21a
98	-17.42	-8.8	-14.03	-2.53	109.6	200.8	100p	109.6	47.8	19a
99	-17.60	-9.3	0.00	0.00	111.4	204.8	100p	111.4	48.9	19a

NODAL RESULTS (ULS-low, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
1	6.50	376.4	75.00	0.00	0.0	0.0	0	0.0	0.0	0
2	6.25	371.1	75.00	-18.71	0.0	0.0	0	0.0	0.0	0
3	6.00	365.7	75.00	-37.41	0.0	0.0	0	0.0	0.0	0
4	5.75	360.4	75.00	-56.12	0.0	0.0	0	0.0	0.0	0
5	5.50	355.1	75.00	-74.82	0.0	0.0	0	0.0	0.0	0
6	5.25	349.8	75.00	-93.53	0.0	0.0	0	0.0	0.0	0
7	5.00	344.5	75.00	-112.24	0.0	0.0	0	0.0	0.0	0
8	4.75	339.2	75.00	-130.94	0.0	0.0	0	0.0	0.0	0
9	4.50	333.9	75.00	-149.65	0.0	0.0	0	0.0	0.0	0

Project : Hansweert
Part :

NODAL RESULTS (ULS-low, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
10	4.26	328.6	75.00	-168.35	0.0	0.0	0	0.0	0.0	0
11	4.01	323.3	75.00	-187.06	0.0	0.0	0	0.0	0.0	0
12	3.76	318.0	75.00	-205.76	0.0	0.0	0	0.0	0.0	0
13	3.51	312.7	75.00	-224.47	0.0	0.0	0	0.0	0.0	0
14	3.26	307.5	75.00	-243.18	0.0	0.0	0	0.0	0.0	0
15	3.01	302.2	75.00	-261.88	0.0	0.0	0	0.0	0.0	0
16	2.76	297.0	75.00	-280.59	0.0	0.0	0	0.0	0.0	0
17	2.51	291.7	75.00	-299.29	0.0	0.0	0	0.0	0.0	0
18	2.26	286.5	75.00	-318.00	0.0	0.0	0	0.0	0.0	0
19	2.02	281.4	75.00	-336.36	0.6	0.0	0	0.6	0.0	0
20	1.77	276.3	75.00	-354.72	1.1	0.0	0	1.1	0.0	0
21	1.53	271.2	75.00	-373.08	1.7	0.0	0	1.7	0.0	0
22	1.28	266.1	75.00	-391.43	2.2	0.0	0	2.2	0.0	0
23	1.04	261.1	75.00	-409.79	2.8	0.0	0	2.8	0.0	0
24	0.79	256.0	75.00	-428.15	3.3	0.0	0	3.3	0.0	0
25	0.55	251.0	75.00	-446.51	3.9	0.0	0	3.9	0.0	0
26	0.30	246.0	75.00	-464.87	4.4	0.0	0	4.4	0.0	0
27	0.06	241.0	75.00	-483.23	5.0	0.0	0	5.0	0.0	0
28	-0.19	236.0	75.00	-501.59	5.5	0.0	0	5.5	0.0	0
29	-0.43	231.0	75.00	-519.95	6.1	0.0	0	6.1	0.0	0
30	-0.68	226.1	75.00	-538.30	6.6	0.0	0	6.6	0.0	0
31	-0.92	221.2	75.00	-556.66	7.2	0.0	0	7.2	0.0	0
32	-1.17	216.3	75.00	-575.02	7.7	0.0	0	7.7	0.0	0
33	-1.41	211.4	75.00	-593.38	8.3	0.0	0	8.3	0.0	0
34	-1.66	206.6	75.00	-611.74	8.9	0.0	0	8.9	0.0	0
35	-1.90	201.7	75.00	-630.10	9.4	0.0	0	9.4	0.0	0
36	-2.15	196.9	75.00	-648.46	10.0	0.0	0	10.0	0.0	0
37	-2.39	192.1	75.00	-666.82	10.5	0.0	0	10.5	0.0	0
38	-2.64	187.4	75.00	-685.17	11.1	0.0	0	11.1	0.0	0
39	-2.88	182.6	75.00	-703.53	11.6	0.0	0	11.6	0.0	0
40	-3.13	177.9	75.00	-721.89	12.2	0.0	0	12.2	0.0	0
41	-3.37	173.3	75.00	-740.25	12.7	0.0	0	12.7	0.0	0
42	-3.61	168.6	75.00	-758.61	13.3	0.0	0	13.3	0.0	0
43	-3.86	164.0	75.00	-776.97	13.8	0.0	0	13.8	0.0	0
44	-4.10	159.4	75.00	-795.33	14.4	0.0	0	14.4	0.0	0
45	-4.35	154.8	75.00	-813.68	14.9	0.0	0	14.9	0.0	0
46	-4.59	150.3	75.00	-832.04	15.5	0.0	0	15.5	0.0	0
47	-4.84	145.8	75.00	-850.40	16.0	0.0	0	16.0	0.0	0
48	-5.08	141.3	75.00	-868.76	16.6	0.0	0	16.6	0.0	0
49	-5.33	136.9	75.00	-887.12	17.1	0.0	0	17.1	0.0	0
50	-5.57	132.5	75.00	-905.48	17.7	0.0	0	17.7	0.0	0
51	-5.82	128.1	75.00	-923.84	18.3	0.0	0	18.3	0.0	0
52	-6.06	123.8	75.00	-942.20	18.8	0.0	0	18.8	0.0	0
53	-6.31	119.5	75.00	-960.55	19.4	0.0	0	19.4	0.0	0

Project : Hansweert
Part :

NODAL RESULTS (ULS-low, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

					LEFT			RIGHT		
Node nr.	Level m	Displ mm	Shear kN	Moment kNm	Water kN/m²	Grain kN/m²	%	Water kN/m²	Grain kN/m²	%
54	-6.55	115.2	75.00	-978.91	19.9	0.0	0	19.9	0.0	0
55	-6.80	111.0	75.00	-997.27	20.5	0.0	0	20.5	0.0	0
56	-7.04	106.8	75.00	-1015.63	21.0	0.0	0	21.0	0.0	0
57	-7.29	102.6	75.00	-1033.99	21.6	0.0	0	21.6	0.0	0
58	-7.53	98.5	75.00	-1052.35	22.1	0.0	0	22.1	0.0	0
59	-7.78	94.4	75.00	-1070.71	22.7	0.0	0	22.7	0.0	0
60	-8.02	90.4	75.00	-1089.07	23.2	0.0	0	23.2	0.0	0
61	-8.27	86.4	75.00	-1107.42	23.8	0.0	0	23.8	0.0	0
62	-8.51	82.4	75.00	-1125.78	24.3	0.0	0	24.3	0.0	0
63	-8.76	78.5	75.00	-1144.14	24.9	0.0	0	24.9	0.0	0
64	-9.00	74.6	73.28	-1162.50	25.4	0.0	0	25.4	7.0	100p
65	-9.25	70.8	67.67	-1180.74	27.9	0.0	0	27.9	22.5	100p
66	-9.50	66.9	59.91	-1197.58	30.4	0.0	0	30.4	31.2	100p
67	-9.75	63.1	50.03	-1212.49	32.9	0.2	0	32.9	39.9	100p
68	-10.00	59.4	38.05	-1224.94	35.4	1.2	3a	35.4	49.3	100p
69	-10.24	55.6	23.31	-1234.41	37.9	2.2	4a	37.9	61.4	100p
70	-10.49	52.0	5.80	-1240.21	40.4	3.2	5a	40.4	73.6	100p
71	-10.74	48.4	-14.34	-1241.66	42.9	4.3	6a	42.9	85.2	100p
72	-10.99	44.8	-36.38	-1238.09	45.4	5.3	7a	45.4	93.9	100p
73	-11.24	41.3	-55.28	-1229.03	47.8	9.6	13a	47.8	85.3	100p
74	-11.49	37.8	-70.40	-1215.21	50.3	14.0	23a	50.3	74.5	100p
75	-11.74	34.4	-88.29	-1197.61	52.8	14.2	20a	52.8	85.7	100p
76	-11.99	31.0	-109.07	-1175.54	55.3	14.4	18a	55.3	97.5	100p
77	-12.24	27.7	-131.53	-1148.27	57.8	15.5	18a	57.8	105.4	100p
78	-12.49	24.4	-155.11	-1115.39	60.3	16.6	18a	60.3	111.0	100p
79	-12.74	21.1	-179.81	-1076.61	62.8	17.7	18a	62.8	116.6	100p
80	-12.99	17.9	-206.02	-1031.66	65.3	18.9	19a	65.3	123.7	100p
81	-13.24	14.7	-232.40	-980.16	67.8	21.1	21a	67.8	126.7	100p
82	-13.49	11.6	-258.83	-922.05	70.3	23.5	23a	70.3	129.2	100p
83	-13.74	8.5	-286.73	-857.35	72.8	24.7	23a	72.8	136.3	100p
84	-13.99	5.4	-315.65	-785.66	75.3	25.8	23a	75.3	141.5	100p
85	-14.24	2.4	-334.03	-706.75	77.8	25.7	21a	77.8	99.3	65
86	-14.49	-0.6	-333.79	-623.24	80.3	41.4	31	80.3	40.4	24
87	-14.74	-3.6	-325.65	-539.80	82.8	65.8	47	82.8	33.3	19a
88	-14.99	-6.6	-311.81	-458.38	85.3	90.2	62	85.3	34.8	19a
89	-15.24	-9.5	-292.30	-380.43	87.8	114.4	75	87.8	36.3	19a
90	-15.49	-12.4	-267.05	-307.36	90.3	138.4	88	90.3	37.4	19a
91	-15.74	-15.3	-236.08	-240.59	92.8	162.4	100	92.8	38.5	19a
92	-15.99	-18.3	-203.92	-181.57	95.3	168.7	100p	95.3	40.1	19a
93	-16.24	-21.2	-170.75	-130.59	97.8	174.3	100p	97.8	41.6	19a
94	-16.49	-24.0	-136.57	-87.91	100.3	179.9	100p	100.3	43.2	19a
95	-16.74	-26.9	-103.49	-53.76	102.8	178.9	100p	102.8	46.6	21a
96	-16.99	-29.8	-71.54	-27.89	105.3	177.5	100p	105.3	49.7	23a
97	-17.24	-32.7	-41.57	-10.01	107.8	188.6	100p	107.8	49.2	21a

Project : Hansweert
Part :

NODAL RESULTS (ULS-low, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
98	-17.42	-34.8	-14.03	-2.53	109.6	200.8	100p	109.6	47.8	19a
99	-17.60	-36.9	0.00	0.00	111.4	204.8	100p	111.4	48.9	19a

NODAL RESULTS (ULS-high, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
1	6.50	194.8	75.00	-0.00	0.0	0.0	0	0.0	0.0	0
2	6.25	191.7	75.00	-18.71	0.0	0.0	0	0.0	0.0	0
3	6.00	188.5	75.00	-37.41	0.0	0.0	0	0.0	0.0	0
4	5.75	185.4	75.00	-56.12	0.0	0.0	0	0.0	0.0	0
5	5.50	182.2	75.00	-74.82	0.0	0.0	0	0.0	0.0	0
6	5.25	179.1	75.00	-93.53	0.0	0.0	0	0.0	0.0	0
7	5.00	175.9	75.00	-112.24	0.0	0.0	0	0.0	0.0	0
8	4.75	172.8	75.00	-130.94	0.0	0.0	0	0.0	0.0	0
9	4.50	169.6	75.00	-149.65	0.0	0.0	0	0.0	0.0	0
10	4.26	166.5	75.00	-168.35	0.0	0.0	0	0.0	0.0	0
11	4.01	163.4	75.00	-187.06	0.0	0.0	0	0.0	0.0	0
12	3.76	160.3	75.00	-205.76	0.0	0.0	0	0.0	0.0	0
13	3.51	157.1	75.00	-224.47	0.0	0.0	0	0.0	0.0	0
14	3.26	154.0	75.00	-243.18	0.0	0.0	0	0.0	0.0	0
15	3.01	150.9	75.00	-261.88	0.0	0.0	0	0.0	0.0	0
16	2.76	147.9	75.00	-280.59	0.0	0.0	0	0.0	0.0	0
17	2.51	144.8	75.00	-299.29	0.0	0.0	0	0.0	0.0	0
18	2.26	141.7	75.00	-318.00	0.0	0.0	0	0.0	0.0	0
19	2.02	138.7	75.00	-336.36	0.6	0.0	0	0.6	0.0	0
20	1.77	135.8	75.00	-354.72	1.1	0.0	0	1.1	0.0	0
21	1.53	132.8	75.00	-373.08	1.7	0.0	0	1.7	0.0	0
22	1.28	129.8	75.00	-391.43	2.2	0.0	0	2.2	0.0	0
23	1.04	126.9	75.00	-409.79	2.8	0.0	0	2.8	0.0	0
24	0.79	124.0	75.00	-428.15	3.3	0.0	0	3.3	0.0	0
25	0.55	121.1	75.00	-446.51	3.9	0.0	0	3.9	0.0	0
26	0.30	118.2	75.00	-464.87	4.4	0.0	0	4.4	0.0	0
27	0.06	115.3	75.00	-483.23	5.0	0.0	0	5.0	0.0	0
28	-0.19	112.5	75.00	-501.59	5.5	0.0	0	5.5	0.0	0
29	-0.43	109.6	75.00	-519.95	6.1	0.0	0	6.1	0.0	0
30	-0.68	106.8	75.00	-538.30	6.6	0.0	0	6.6	0.0	0
31	-0.92	104.0	75.00	-556.66	7.2	0.0	0	7.2	0.0	0
32	-1.17	101.3	75.00	-575.02	7.7	0.0	0	7.7	0.0	0
33	-1.41	98.5	75.00	-593.38	8.3	0.0	0	8.3	0.0	0
34	-1.66	95.8	75.00	-611.74	8.9	0.0	0	8.9	0.0	0
35	-1.90	93.1	75.00	-630.10	9.4	0.0	0	9.4	0.0	0

Project : Hansweert
Part :

NODAL RESULTS (ULS-high, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
36	-2.15	90.4	75.00	-648.46	10.0	0.0	0	10.0	0.0	0
37	-2.39	87.7	75.00	-666.82	10.5	0.0	0	10.5	0.0	0
38	-2.64	85.1	75.00	-685.17	11.1	0.0	0	11.1	0.0	0
39	-2.88	82.5	75.00	-703.53	11.6	0.0	0	11.6	0.0	0
40	-3.13	79.9	75.00	-721.89	12.2	0.0	0	12.2	0.0	0
41	-3.37	77.3	75.00	-740.25	12.7	0.0	0	12.7	0.0	0
42	-3.61	74.8	75.00	-758.61	13.3	0.0	0	13.3	0.0	0
43	-3.86	72.3	75.00	-776.97	13.8	0.0	0	13.8	0.0	0
44	-4.10	69.8	75.00	-795.33	14.4	0.0	0	14.4	0.0	0
45	-4.35	67.4	75.00	-813.68	14.9	0.0	0	14.9	0.0	0
46	-4.59	65.0	75.00	-832.04	15.5	0.0	0	15.5	0.0	0
47	-4.84	62.6	75.00	-850.40	16.0	0.0	0	16.0	0.0	0
48	-5.08	60.3	75.00	-868.76	16.6	0.0	0	16.6	0.0	0
49	-5.33	57.9	75.00	-887.12	17.1	0.0	0	17.1	0.0	0
50	-5.57	55.7	75.00	-905.48	17.7	0.0	0	17.7	0.0	0
51	-5.82	53.4	75.00	-923.84	18.3	0.0	0	18.3	0.0	0
52	-6.06	51.2	75.00	-942.20	18.8	0.0	0	18.8	0.0	0
53	-6.31	49.0	75.00	-960.55	19.4	0.0	0	19.4	0.0	0
54	-6.55	46.9	75.00	-978.91	19.9	0.0	0	19.9	0.0	0
55	-6.80	44.8	75.00	-997.27	20.5	0.0	0	20.5	0.0	0
56	-7.04	42.7	75.00	-1015.63	21.0	0.0	0	21.0	0.0	0
57	-7.29	40.7	75.00	-1033.99	21.6	0.0	0	21.6	0.0	0
58	-7.53	38.7	75.00	-1052.35	22.1	0.0	0	22.1	0.0	0
59	-7.78	36.7	75.00	-1070.71	22.7	0.0	0	22.7	0.0	0
60	-8.02	34.8	75.00	-1089.07	23.2	0.0	0	23.2	0.0	0
61	-8.27	32.9	75.00	-1107.42	23.8	0.0	0	23.8	0.0	0
62	-8.51	31.1	75.00	-1125.78	24.3	0.0	0	24.3	0.0	0
63	-8.76	29.3	75.00	-1144.14	24.9	0.0	0	24.9	0.0	0
64	-9.00	27.6	73.28	-1162.50	25.4	0.0	0	25.4	7.0	100p
65	-9.25	25.8	67.67	-1180.74	27.9	0.0	0	27.9	22.5	100p
66	-9.50	24.1	59.91	-1197.58	30.4	0.0	0	30.4	31.2	100p
67	-9.75	22.5	50.03	-1212.49	32.9	0.2	0	32.9	39.9	100p
68	-10.00	20.9	38.05	-1224.94	35.4	1.2	3a	35.4	49.3	100p
69	-10.24	19.4	23.31	-1234.41	37.9	2.2	4a	37.9	61.4	100p
70	-10.49	17.9	5.80	-1240.21	40.4	3.2	5a	40.4	73.6	100p
71	-10.74	16.4	-14.34	-1241.66	42.9	4.3	6a	42.9	85.2	100p
72	-10.99	15.0	-36.38	-1238.09	45.4	5.3	7a	45.4	93.9	100p
73	-11.24	13.7	-55.28	-1229.03	47.8	9.6	13a	47.8	85.3	100p
74	-11.49	12.3	-70.40	-1215.21	50.3	14.0	23a	50.3	74.5	100p
75	-11.74	11.1	-88.29	-1197.61	52.8	14.2	20a	52.8	85.7	100p
76	-11.99	9.9	-109.07	-1175.54	55.3	14.4	18a	55.3	97.5	100p
77	-12.24	8.7	-131.53	-1148.27	57.8	15.5	18a	57.8	105.4	100p
78	-12.49	7.6	-155.11	-1115.39	60.3	16.6	18a	60.3	111.0	100p
79	-12.74	6.5	-179.81	-1076.61	62.8	17.7	18a	62.8	116.6	100p

Technosoft Damwanden release 6.01 (Educational) 21 mei 2018

Project : Hansweert
Part :

NODAL RESULTS (ULS-high, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 8 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
80	-12.99	5.4	-206.02	-1031.66	65.3	18.9	19a	65.3	123.7	100p
81	-13.24	4.4	-232.40	-980.16	67.8	21.1	21a	67.8	126.7	100p
82	-13.49	3.5	-258.83	-922.05	70.3	23.5	23a	70.3	129.2	100p
83	-13.74	2.5	-286.73	-857.35	72.8	24.7	23a	72.8	136.3	100p
84	-13.99	1.6	-315.65	-785.66	75.3	25.8	23a	75.3	141.5	100p
85	-14.24	0.8	-332.74	-706.75	77.8	25.7	21a	77.8	94.1	62
86	-14.49	-0.1	-333.84	-623.57	80.3	38.7	29	80.3	43.1	26
87	-14.74	-0.9	-326.00	-540.11	82.8	64.6	46	82.8	33.3	19a
88	-14.99	-1.7	-312.23	-458.61	85.3	89.9	61	85.3	34.8	19a
89	-15.24	-2.4	-292.62	-380.55	87.8	114.7	76	87.8	36.3	19a
90	-15.49	-3.2	-267.21	-307.39	90.3	139.1	88	90.3	37.4	19a
91	-15.74	-4.0	-236.08	-240.59	92.8	163.0	100	92.8	38.5	19a
92	-15.99	-4.7	-203.92	-181.57	95.3	168.7	100p	95.3	40.1	19a
93	-16.24	-5.4	-170.75	-130.59	97.8	174.3	100p	97.8	41.6	19a
94	-16.49	-6.2	-136.57	-87.91	100.3	179.9	100p	100.3	43.2	19a
95	-16.74	-6.9	-103.49	-53.76	102.8	178.9	100p	102.8	46.6	21a
96	-16.99	-7.6	-71.54	-27.89	105.3	177.5	100p	105.3	49.7	23a
97	-17.24	-8.3	-41.57	-10.01	107.8	188.6	100p	107.8	49.2	21a
98	-17.42	-8.8	-14.03	-2.53	109.6	200.8	100p	109.6	47.8	19a
99	-17.60	-9.3	0.00	0.00	111.4	204.8	100p	111.4	48.9	19a

MAXIMUM VALUES IN THE WALL CONSTR.PHASE: 1 Bouwfase 1

	SLS Value	SLS Level	Low water level pass. side – ULS low Value	ULS low Level	ULS high Value	ULS high Level
Displacement [mm]	182.57	6.50	376.38	6.50	194.83	6.50
Shear force [kN]	-331.85	-13.74	-334.03	-14.24	-333.85	-14.49
Moment [kNm]	-1473.50	-10.49	-1241.66	-10.74	-1241.66	-10.74
Axial force [kN]	-1840.54	-17.60	-1533.78	-17.60	-1533.78	-17.60
Stress [N/mm²]	8824732.07	-17.60	7436210.11	-10.74	7436210.11	-10.74

	Low water level pass. side – ULS Low Value	ULS Low Level	ULS High Value	ULS High Level
Displacement [mm]	376.38	6.50	194.83	6.50
Shear force [kN]	-334.03	-14.24	-333.85	-14.49
Moment [kNm]	-1241.66	-10.74	-1241.66	-10.74
Axial force [kN]	-1533.78	-17.60	-1533.78	-17.60
stress [N/mm²]	7436210.11	-10.74	7436210.11	-10.74

	SLS	Low water pass. side- ULS low	ULS high	High water pass. side- ULS low	ULS high
Displacement [1:mm]	252	77	77	77	229

Nr.	Name profile	Shear force [kN]	Max.Moment [kNm]	Max. norm.force [kN]	Max. Stress [N/mm²]
1	HANSWEERT	-334.03	-1473.50	-1840.54	8824732.1

Project : Hansweert
Part :

HORIZONTAL SOIL FORCES (kN) **CONSTR.PHASE: 1 Bouwfase 1**

	SLS Left	SLS Right	Low water level pass. side – ULS low Left	ULS low Right	ULS high Left	ULS high Right
Grain force	441.06	516.06	532.62	607.62	532.00	607.00
Water force	731.92	731.92	731.92	731.92	731.92	731.92
Total	1172.98	1247.98	1264.54	1339.54	1263.92	1338.92
Max. pass. grain resist.	1076.60	1361.90	920.81	1152.05	920.81	1152.05
[%] mob. grain resist.	40.97	37.89	57.84	52.74	57.78	52.69

	High water level pass. side – ULS Low Left	ULS Low Right	ULS High Left	ULS High Right
Grain force	532.62	607.62	532.00	607.00
Water force	731.92	731.92	731.92	731.92
Total	1264.54	1339.54	1263.92	1338.92
Max. pass. grain resistance	920.81	1152.05	920.81	1152.05
[%] Mob. grain resistance	57.84	52.74	57.78	52.69

VERTICAL FORCES (kN/m) **CONSTR.PHASE: 1 Bouwfase 1**

--- SLS ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-1533.78		
Total		-1533.78		
Nett		-1533.78		(Down)

--- ULS low - Low groundw.lv. pass. side ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-1533.78		
Total		-1533.78		
Nett		-1533.78		(Down)

--- ULS high - Low groundw.lv. pass. side ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-1533.78		
Total		-1533.78		
Nett		-1533.78		(Down)

Project : Hansweert
Part :

VERTICAL FORCES (kN/m) CONSTR.PHASE: 1 Bouwfase 1

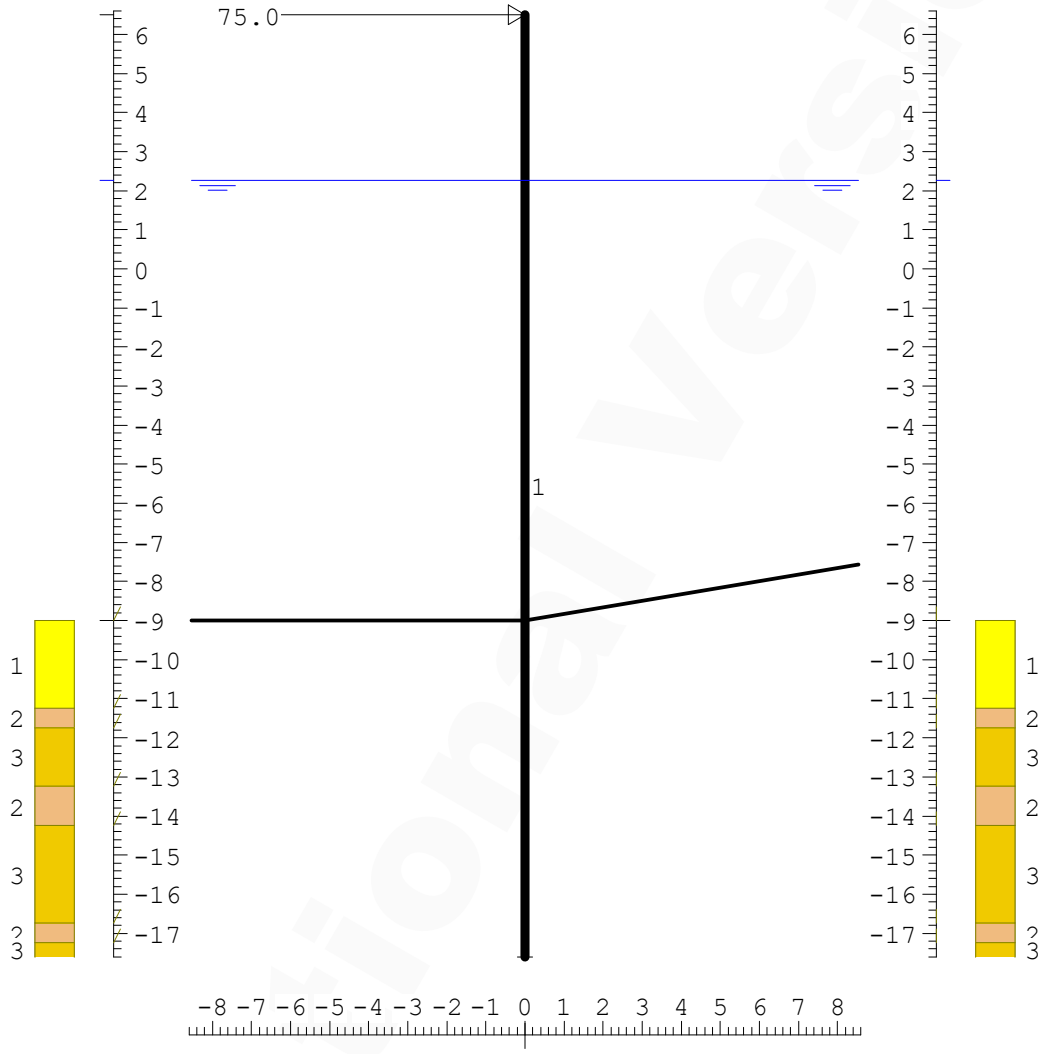
--- ULS low - High groundw.lv. pass. side ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-1533.78		
Total		-1533.78		
Nett		-1533.78		(Down)

--- ULS high - High groundw.lv. pass. side ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-1533.78		
Total		-1533.78		
Nett		-1533.78		(Down)

NOTE: The vertical equilibrium has to be verified by the user, taking into account the capacities i.r.t. wall friction ($F_{a;v;max;d}$, $F_{p;v;max;d}$) and toe resistance ($R_{b;max;d}$). (See CUR 166, 6th print, part 1, page 70, fig. 5.3)

Project : Hansweert
Part :

GRAPHICAL REPRESENTATION INPUT **CONSTR.PHASE: 1 Bouwfase 1**

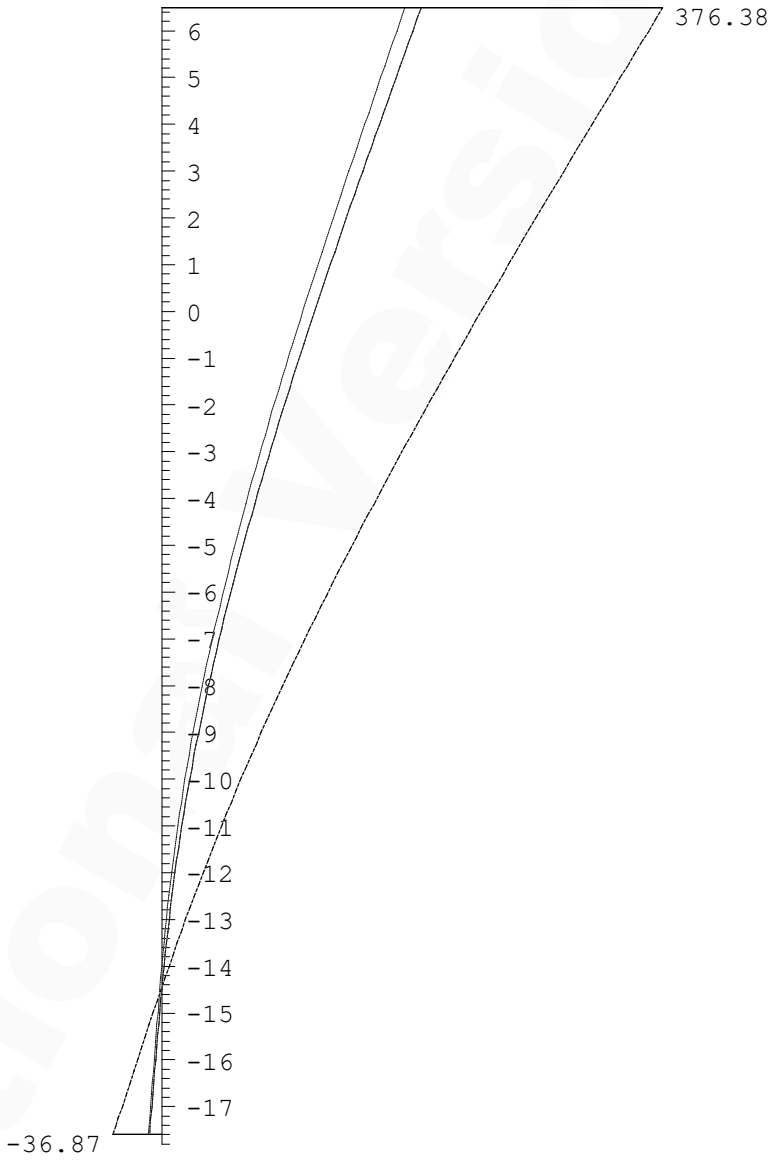


Legend

1 : Leem - Zwak zandig - Vast
2 : Zand - Schoon - Los
3 : Klei - Sterk zandig

Project : Hansweert
Part :

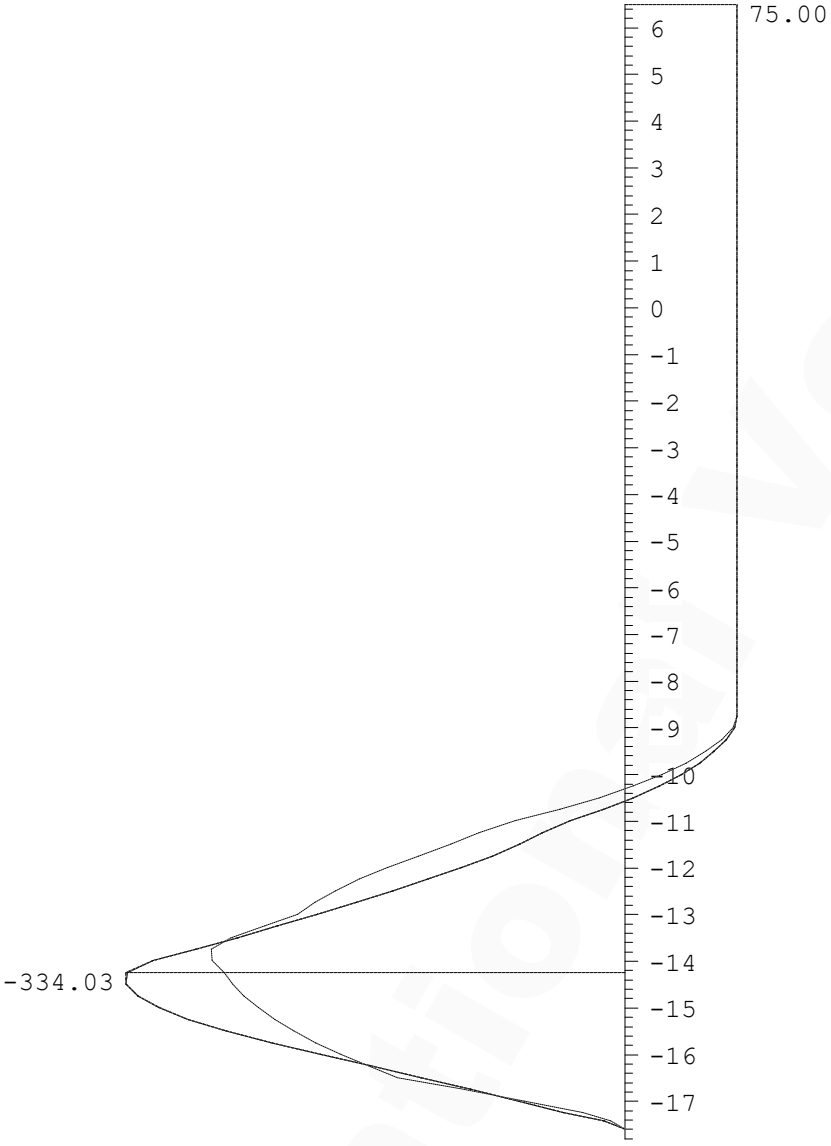
DISPLACEMENTS (mm) **CONSTR.PHASE: 1 Bouwfase 1**



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Project : Hansweert
Part :

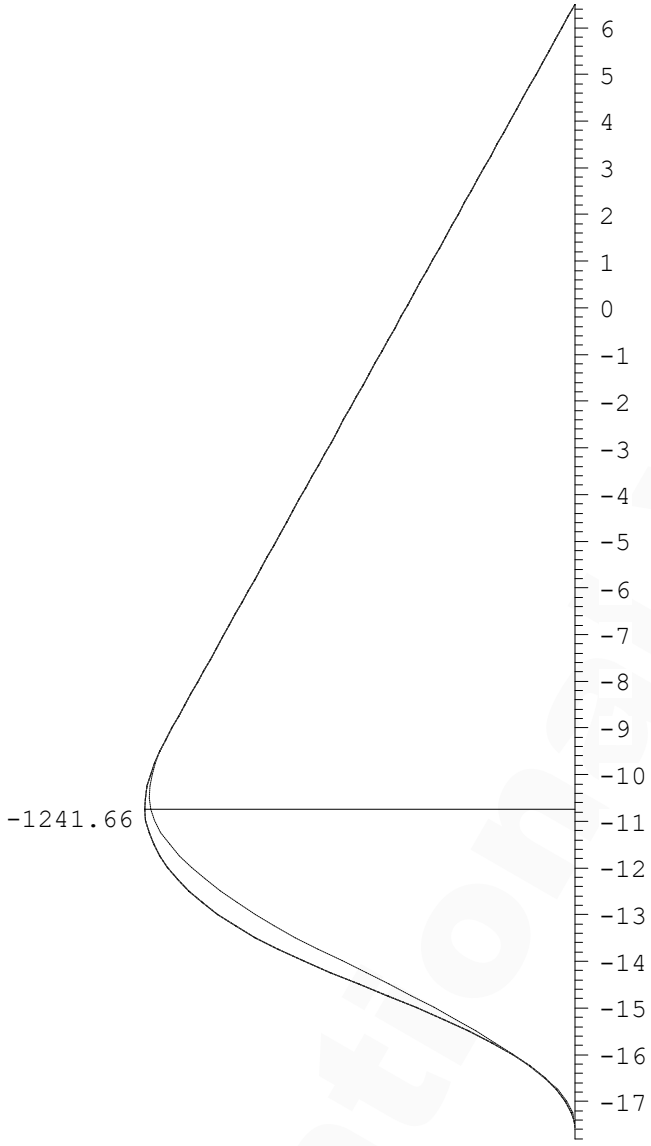
SHEAR FORCES (kN) **CONSTR.PHASE: 1 Bouwfase 1**



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Project : Hansweert
Part :

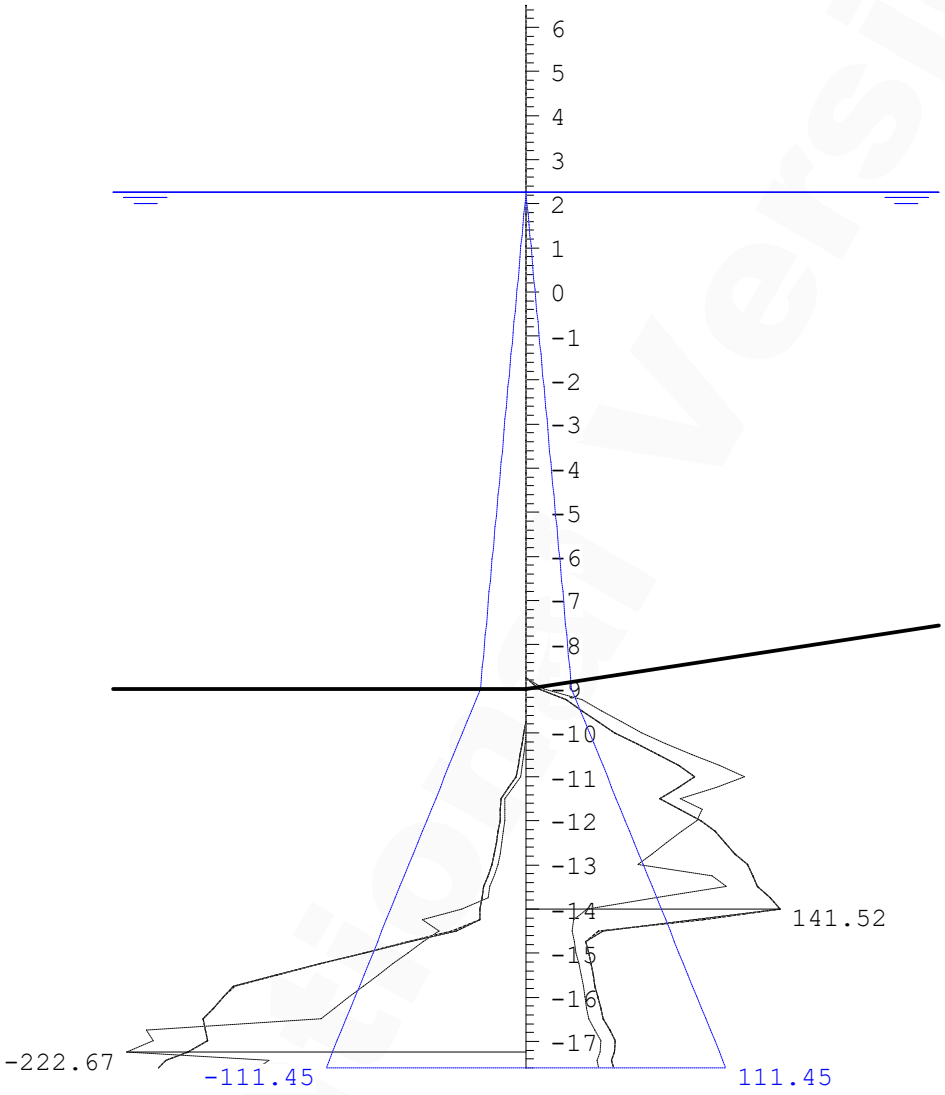
MOMENTS (kNm) **CONSTR.PHASE: 1 Bouwfase 1**



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Project : Hansweert
Part :

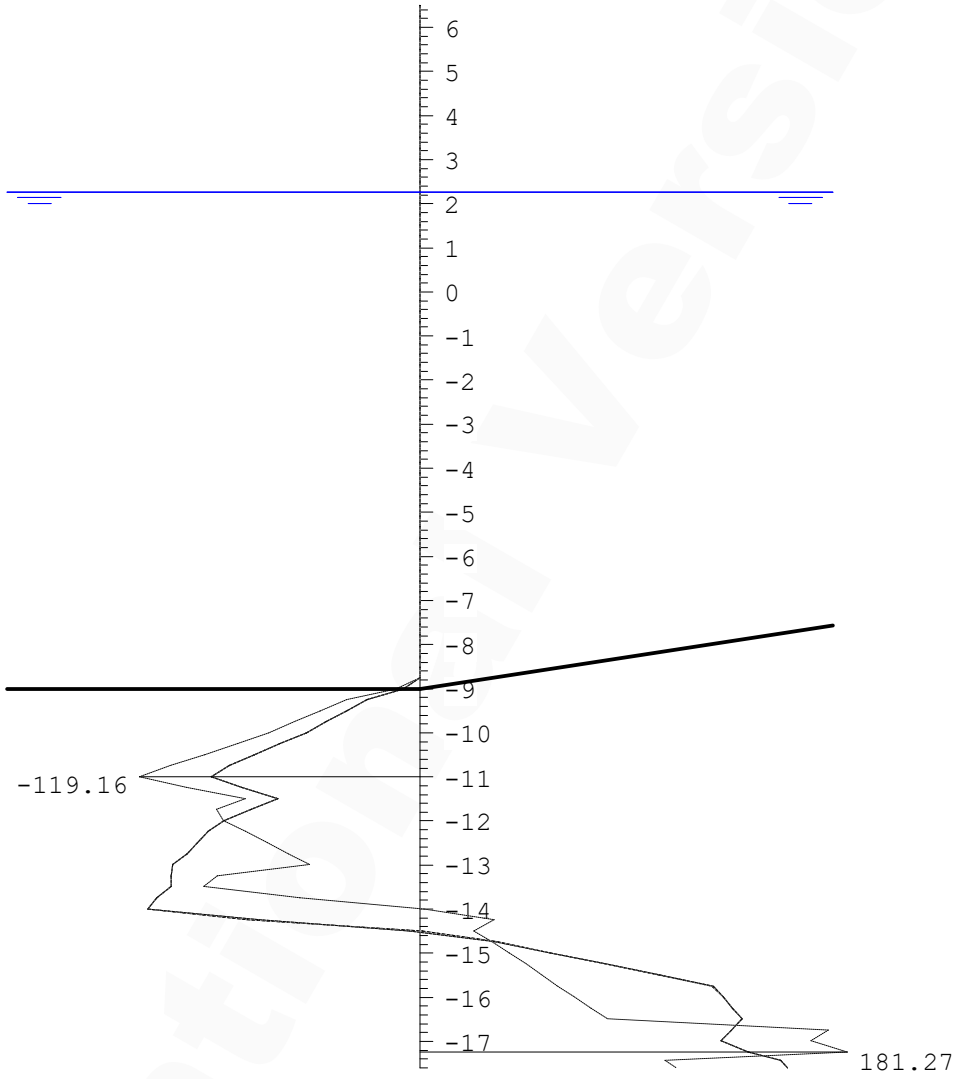
GRAIN- AND WATERPRESSURE (kN/m²) CONSTR.PHASE: 1 Bouwfase 1



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Project : Hansweert
Part :

RESULTING SOIL FORCES (kN/m²) **CONSTR.PHASE: 1 Bouwfase 1**



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Appendix X.III – New pile - CPT70294 & 350kN

Technosoft studentenlicentie blad :1

Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :
Units : [kN][m][degrees] unless otherwise stated
Date : 15-05-2018
Reference level : N.A.P.
File : D:\Gebruikersdata\Desktop\Hansweert 291.dmw

Toegepaste normen volgens Eurocode met Nederlandse NB

Geotechniek	EN 1997-1:2004	AC:2009	
	NEN-EN 1997-1:2005	C1:2015	NB:2015
	NEN 9997-1:2011	C2:2015	

GENERAL DATA

Reliability class	: RC3	$\gamma_{c'}$	: 1.400
		$\gamma_{\varphi'}$	: 1.200
Calculation method	: Table 9.d	Margin stemming height	: 0.50
Calculation scheme	: All design values	Margin gws low side	: 0.25
		Margin gws high side	: 0.05
		γ sub-grade SLS	: 1.00
		γ sub-grade ULS low	: 1.30
		γ sub-grade ULS high	: 1.00
Loads	:	γ Permanent	: 1.00
		γ Live	: 1.25
Results SLS	:	Factor Tabel 9.d cal. 5	: 1.20
Calculation method	: Elastic	Max. iterations / phase	: 25
		Stop criterion	: 1.00
Level top of wall	: 6.50	Number of constr. phases	: 1
Piling level	: -25.00	Number of wall parts	: 1
Slope of wall	: 0.00	Number of soil types	: 3
Sw. water left	: 2.26	Sw. water right	: 2.26

MATERIALS

Nr.	Mark	E-modulus [N/mm²]	S.W. [kN/m3]
1	S355	210000	78.50

SHEET PILE WALL PARTS

Nr.	Name profile	Inertia	Inert/m	Beta D	Sec.Mod	Sec.Mod/m	Beta B
1	HANSWEERT	.7763E-02	.7640E-02	----	.169E-06	.167E-06	----

Nr.	Profielnaam	Height	Width	Work. Width	Area	Weight	Material
1	HANSWEERT	0.020	1.016	1.016	0.81073	063.64230	S355

SONDERINGSGEGEVENS ALGEMEEN: Sondering 1

Alle niveaus/hoogtes/peilmaten zijn t.o.v.: N.A.P.
Hoogte maaiveld [m] : -9.00

SONDERINGSGEGEVENS TABEL: Sondering 1

Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]	Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]
1	-9.00	0.00	0.000	15	-16.50	8.26	0.103
2	-10.00	0.00	0.000	16	-17.00	8.08	0.086
3	-10.50	5.83	0.033	17	-17.50	13.43	0.122
4	-11.00	14.27	0.085	18	-18.00	11.92	0.101
5	-11.50	18.88	0.099	19	-18.50	25.99	0.180
6	-12.00	18.89	0.143	20	-19.00	22.00	0.152
7	-12.50	9.14	0.093	21	-19.50	13.08	0.141
8	-13.00	6.12	0.055	22	-20.00	36.57	0.252

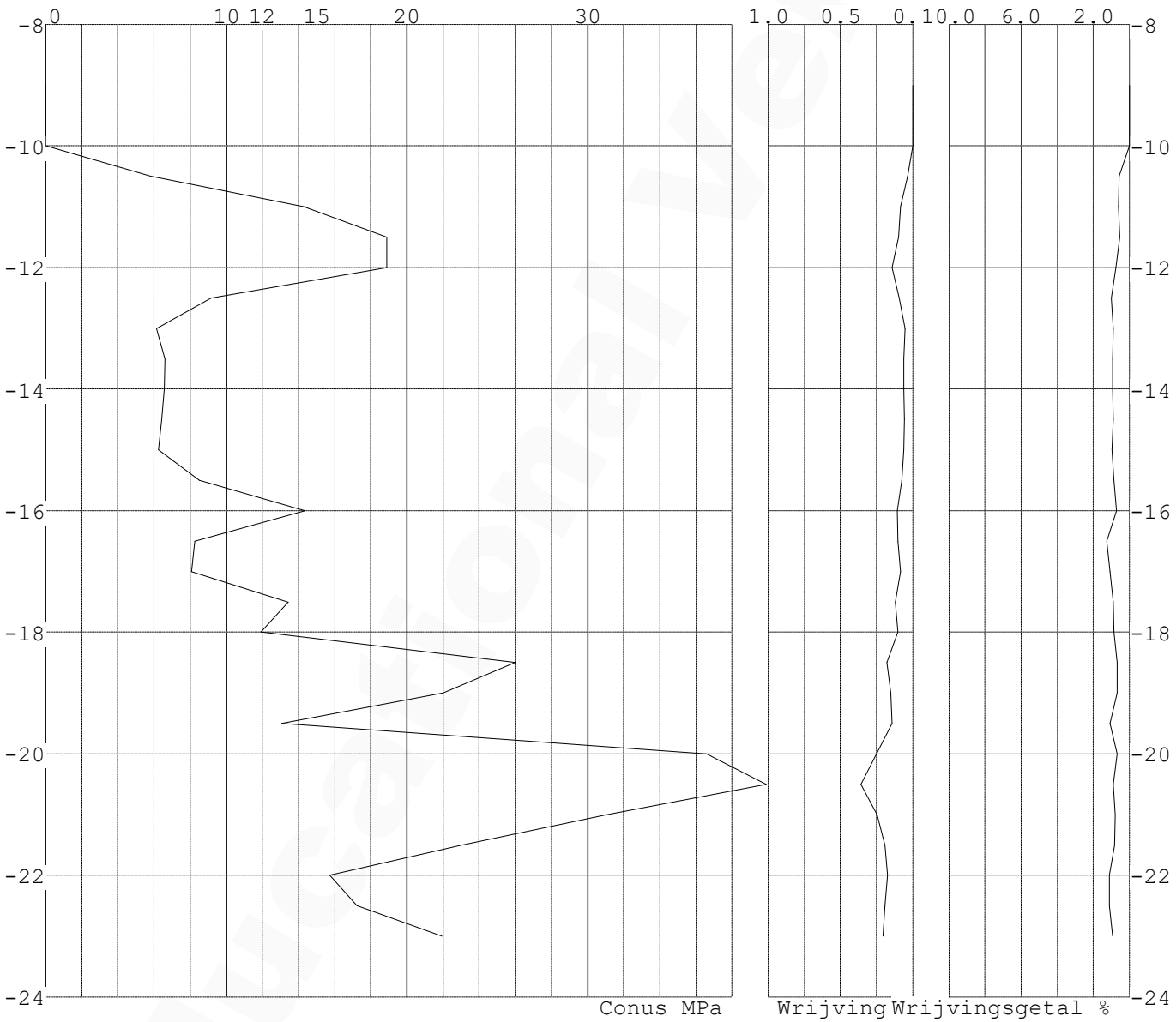
Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

SONDERINGSGEGEVENS TABEL: Sondering 1

Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]	Regel	Niveau [m]	Conus [MPa]	Wrijving [MPa]
9	-13.50	6.59	0.061	23	-20.50	39.91	0.357
10	-14.00	6.56	0.061	24	-21.00	31.01	0.244
11	-14.50	6.41	0.057	25	-21.50	22.98	0.193
12	-15.00	6.23	0.061	26	-22.00	15.72	0.175
13	-15.50	8.50	0.074	27	-22.50	17.24	0.190
14	-16.00	14.35	0.105	28	-23.00	21.94	0.206

SONDERINGSGEGEVENS GRAFIEK: Sondering 1



Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

SOIL TYPES

Nr.	Description	γ [kN/m^3]	γ_{sat} [kN/m^3]	φ' [°]	$\gamma_{\varphi'}$ [-]	c' [kPa]	$\gamma_{c'}$ [-]	δ [-]	k-value [-]
1	Leem - Zwak zand..	22.00	22.00	35.00	1.200	3.50	1.40	0.000	.0000E+00
2	Zand - Schoon - ..	18.00	20.00	25.00	1.200	0.00	1.40	0.000	.0000E+00
3	Klei - Sterk zan..	20.00	20.00	27.00	1.200	1.00	1.40	0.000	.0000E+00

CONSTR.PHASE : 1 - Bouwfase 1

			Left		Right	
Calc. infl. talus slope		:	As surcharge		As surcharge	
Talus			horz	angle	horz	angle
			0.00	0.00	0.00	9.50
Ground level	SLS	:		-9.00		-9.00
Ground level	ULS	:		-9.00		-9.00
Water level	SLS	:		2.26		2.26
Water level Low	ULS	:		2.26		2.26
Water level High	ULS	:		2.26		2.26

SOIL LAYERS LEFT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	Sw. water	Waterpress. top	Waterpress. bottom	Slide plane	K-act.	K-neu.	K-pas.
1	1	-9.00	10.00	0.00	0.00	Straight	0.271	0.426	3.690
2	2	-11.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
3	3	-11.74	10.00	0.00	0.00	Straight	0.376	0.546	2.663
4	2	-13.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
5	3	-14.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663
6	2	-16.74	10.00	0.00	0.00	Straight	0.406	0.577	2.464
7	3	-17.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663

Nr.	St.	Level	Sub-grade input top	Sub-grade input bottom	Sub-grade calc. top	Sub-grade calc. bottom
1	1	-9.00	30000	30000	30000	30000
2	2	-11.24	50000	50000	50000	50000
3	3	-11.74	10000	10000	10000	10000
4	2	-13.24	50000	50000	50000	50000
5	3	-14.24	10000	10000	10000	10000
6	2	-16.74	50000	50000	50000	50000
7	3	-17.24	10000	10000	10000	10000

Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

SOIL LAYERS LEFT (ULS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	K-act.	K-neu.	K-pas.
1	1	-9.00	0.345	0.513	2.901
2	2	-11.24	0.475	0.644	2.104
3	3	-11.74	0.446	0.617	2.240
4	2	-13.24	0.475	0.644	2.104
5	3	-14.24	0.446	0.617	2.240
6	2	-16.74	0.475	0.644	2.104
7	3	-17.24	0.446	0.617	2.240

Nr.	St.	Level	Sub-grade low				Sub-grade high			
			Input value		Calc. value		Input value		Calc. value	
			top	bottom	top	bottom	top	bottom	top	bottom
1	1	-9.00	30000	30000	23077	23077	50000	50000	50000	50000
2	2	-11.24	50000	50000	38462	38462	100000	100000	100000	100000
3	3	-11.74	10000	10000	7692	7692	30000	30000	30000	30000
4	2	-13.24	50000	50000	38462	38462	100000	100000	100000	100000
5	3	-14.24	10000	10000	7692	7692	30000	30000	30000	30000
6	2	-16.74	50000	50000	38462	38462	100000	100000	100000	100000
7	3	-17.24	10000	10000	7692	7692	30000	30000	30000	30000

SOIL LAYERS RIGHT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	Sw. water	Waterpress. top	Waterpress. bottom	Slide plane	K-act.	K-neu.	K-pas.
1	1	-9.00	10.00	0.00	0.00	Straight	0.271	0.426	3.690
2	2	-11.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
3	3	-11.74	10.00	0.00	0.00	Straight	0.376	0.546	2.663
4	2	-13.24	10.00	0.00	0.00	Straight	0.406	0.577	2.464
5	3	-14.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663
6	2	-16.74	10.00	0.00	0.00	Straight	0.406	0.577	2.464
7	3	-17.24	10.00	0.00	0.00	Straight	0.376	0.546	2.663

Nr.	St.	Level	Sub-grade input		Sub-grade calc.	
			top	bottom	top	bottom
1	1	-9.00	30000	30000	30000	30000
2	2	-11.24	50000	50000	50000	50000
3	3	-11.74	10000	10000	10000	10000
4	2	-13.24	50000	50000	50000	50000
5	3	-14.24	10000	10000	10000	10000
6	2	-16.74	50000	50000	50000	50000
7	3	-17.24	10000	10000	10000	10000

Project : Hansweert
Part :

SOIL LAYERS RIGHT (ULS) **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	St.	Level	K-act.	K-neu.	K-pas.
1	1	-9.00	0.345	0.513	2.901
2	2	-11.24	0.475	0.644	2.104
3	3	-11.74	0.446	0.617	2.240
4	2	-13.24	0.475	0.644	2.104
5	3	-14.24	0.446	0.617	2.240
6	2	-16.74	0.475	0.644	2.104
7	3	-17.24	0.446	0.617	2.240

Nr.	St.	Level	Sub-grade low				Sub-grade high			
			Input value		Calc. value		Input value		Calc. value	
			top	bottom	top	bottom	top	bottom	top	bottom
1	1	-9.00	30000	30000	23077	23077	50000	50000	50000	50000
2	2	-11.24	50000	50000	38462	38462	100000	100000	100000	100000
3	3	-11.74	10000	10000	7692	7692	30000	30000	30000	30000
4	2	-13.24	50000	50000	38462	38462	100000	100000	100000	100000
5	3	-14.24	10000	10000	7692	7692	30000	30000	30000	30000
6	2	-16.74	50000	50000	38462	38462	100000	100000	100000	100000
7	3	-17.24	10000	10000	7692	7692	30000	30000	30000	30000

NODAL LOADS **CONSTR.PHASE: 1 Bouwfase 1**

Nr.	Level	Type	Angle	Value
1	6.50	Nodal load	0.00	350.00

NODE OUTPUT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 7 Deviation : 0.14

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
1	6.50	1131.5	350.00	0.00	0.0	0.0	0	0.0	0.0	0
2	6.25	1114.7	350.00	-87.29	0.0	0.0	0	0.0	0.0	0
3	6.00	1098.0	350.00	-174.59	0.0	0.0	0	0.0	0.0	0
4	5.75	1081.2	350.00	-261.88	0.0	0.0	0	0.0	0.0	0
5	5.50	1064.5	350.00	-349.18	0.0	0.0	0	0.0	0.0	0
6	5.25	1047.7	350.00	-436.47	0.0	0.0	0	0.0	0.0	0
7	5.00	1031.0	350.00	-523.76	0.0	0.0	0	0.0	0.0	0
8	4.75	1014.3	350.00	-611.06	0.0	0.0	0	0.0	0.0	0
9	4.50	997.6	350.00	-698.35	0.0	0.0	0	0.0	0.0	0
10	4.26	981.0	350.00	-785.65	0.0	0.0	0	0.0	0.0	0
11	4.01	964.4	350.00	-872.94	0.0	0.0	0	0.0	0.0	0
12	3.76	947.8	350.00	-960.24	0.0	0.0	0	0.0	0.0	0
13	3.51	931.2	350.00	-1047.53	0.0	0.0	0	0.0	0.0	0
14	3.26	914.7	350.00	-1134.82	0.0	0.0	0	0.0	0.0	0
15	3.01	898.3	350.00	-1222.12	0.0	0.0	0	0.0	0.0	0
16	2.76	881.9	350.00	-1309.41	0.0	0.0	0	0.0	0.0	0
17	2.51	865.5	350.00	-1396.71	0.0	0.0	0	0.0	0.0	0

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Project : Hansweert
Part :

NODE OUTPUT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 7 Deviation : 0.14

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
18	2.26	849.2	350.00	-1484.00	0.0	0.0	0	0.0	0.0	0
19	2.02	833.2	350.00	-1569.67	0.6	0.0	0	0.6	0.0	0
20	1.77	817.4	350.00	-1655.35	1.1	0.0	0	1.1	0.0	0
21	1.53	801.5	350.00	-1741.02	1.7	0.0	0	1.7	0.0	0
22	1.28	785.8	350.00	-1826.70	2.2	0.0	0	2.2	0.0	0
23	1.04	770.1	350.00	-1912.37	2.8	0.0	0	2.8	0.0	0
24	0.79	754.4	350.00	-1998.04	3.3	0.0	0	3.3	0.0	0
25	0.55	738.9	350.00	-2083.72	3.9	0.0	0	3.9	0.0	0
26	0.30	723.4	350.00	-2169.39	4.4	0.0	0	4.4	0.0	0
27	0.06	708.0	350.00	-2255.07	5.0	0.0	0	5.0	0.0	0
28	-0.19	692.7	350.00	-2340.74	5.5	0.0	0	5.5	0.0	0
29	-0.43	677.5	350.00	-2426.41	6.1	0.0	0	6.1	0.0	0
30	-0.68	662.4	350.00	-2512.09	6.6	0.0	0	6.6	0.0	0
31	-0.92	647.3	350.00	-2597.76	7.2	0.0	0	7.2	0.0	0
32	-1.17	632.4	350.00	-2683.43	7.7	0.0	0	7.7	0.0	0
33	-1.41	617.5	350.00	-2769.11	8.3	0.0	0	8.3	0.0	0
34	-1.66	602.8	350.00	-2854.78	8.9	0.0	0	8.9	0.0	0
35	-1.90	588.2	350.00	-2940.46	9.4	0.0	0	9.4	0.0	0
36	-2.15	573.7	350.00	-3026.13	10.0	0.0	0	10.0	0.0	0
37	-2.39	559.3	350.00	-3111.80	10.5	0.0	0	10.5	0.0	0
38	-2.64	545.0	350.00	-3197.48	11.1	0.0	0	11.1	0.0	0
39	-2.88	530.8	350.00	-3283.15	11.6	0.0	0	11.6	0.0	0
40	-3.13	516.7	350.00	-3368.83	12.2	0.0	0	12.2	0.0	0
41	-3.37	502.8	350.00	-3454.50	12.7	0.0	0	12.7	0.0	0
42	-3.61	489.0	350.00	-3540.17	13.3	0.0	0	13.3	0.0	0
43	-3.86	475.4	350.00	-3625.85	13.8	0.0	0	13.8	0.0	0
44	-4.10	461.8	350.00	-3711.52	14.4	0.0	0	14.4	0.0	0
45	-4.35	448.5	350.00	-3797.20	14.9	0.0	0	14.9	0.0	0
46	-4.59	435.2	350.00	-3882.87	15.5	0.0	0	15.5	0.0	0
47	-4.84	422.1	350.00	-3968.54	16.0	0.0	0	16.0	0.0	0
48	-5.08	409.2	350.00	-4054.22	16.6	0.0	0	16.6	0.0	0
49	-5.33	396.4	350.00	-4139.89	17.1	0.0	0	17.1	0.0	0
50	-5.57	383.7	350.00	-4225.57	17.7	0.0	0	17.7	0.0	0
51	-5.82	371.2	350.00	-4311.24	18.3	0.0	0	18.3	0.0	0
52	-6.06	358.9	350.00	-4396.91	18.8	0.0	0	18.8	0.0	0
53	-6.31	346.7	350.00	-4482.59	19.4	0.0	0	19.4	0.0	0
54	-6.55	334.7	350.00	-4568.26	19.9	0.0	0	19.9	0.0	0
55	-6.80	322.9	350.00	-4653.93	20.5	0.0	0	20.5	0.0	0
56	-7.04	311.3	350.00	-4739.61	21.0	0.0	0	21.0	0.0	0
57	-7.29	299.8	350.00	-4825.28	21.6	0.0	0	21.6	0.0	0
58	-7.53	288.5	350.00	-4910.96	22.1	0.0	0	22.1	0.0	0
59	-7.78	277.4	350.00	-4996.63	22.7	0.0	0	22.7	0.0	0
60	-8.02	266.5	350.00	-5082.30	23.2	0.0	0	23.2	0.0	0
61	-8.27	255.7	350.00	-5167.98	23.8	0.0	0	23.8	0.0	0

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Project : Hansweert
Part :

NODE OUTPUT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 7 Deviation : 0.14

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
62	-8.51	245.2	350.00	-5253.65	24.3	0.0	0	24.3	0.0	0
63	-8.76	234.8	350.00	-5339.33	24.9	0.0	0	24.9	0.0	0
64	-9.00	224.7	347.48	-5425.00	25.4	0.0	0	25.4	10.2	100p
65	-9.25	214.6	339.70	-5511.48	27.9	0.0	0	27.9	31.3	100p
66	-9.50	204.7	329.18	-5596.03	30.4	0.0	0	30.4	42.3	100p
67	-9.75	195.0	315.91	-5677.96	32.9	0.0	0	32.9	53.3	100p
68	-10.00	185.6	299.90	-5756.59	35.4	0.0	0	35.4	64.3	100p
69	-10.24	176.3	280.68	-5831.23	37.9	0.4	1a	37.9	77.6	100p
70	-10.49	167.3	257.88	-5901.09	40.4	1.2	2a	40.4	92.8	100p
71	-10.74	158.5	231.50	-5965.27	42.9	2.0	2a	42.9	108.0	100p
72	-10.99	150.0	201.85	-6022.89	45.4	2.8	3a	45.4	122.0	100p
73	-11.24	141.6	177.13	-6073.13	47.8	7.3	8a	47.8	106.4	100p
74	-11.49	133.5	158.61	-6117.41	50.3	11.9	16a	50.3	86.0	100p
75	-11.74	125.6	137.05	-6157.06	52.8	11.8	14a	52.8	98.1	100p
76	-11.99	118.0	111.72	-6191.32	55.3	11.7	12a	55.3	113.0	100p
77	-12.24	110.6	84.25	-6219.25	57.8	12.6	12a	57.8	122.5	100p
78	-12.49	103.4	54.63	-6240.32	60.3	13.6	13a	60.3	132.0	100p
79	-12.74	96.5	23.43	-6253.97	62.8	14.5	13a	62.8	139.3	100p
80	-12.99	89.8	-9.19	-6259.83	65.3	15.4	13a	65.3	146.0	100p
81	-13.24	83.4	-41.12	-6257.53	67.8	17.7	15a	67.8	145.4	100p
82	-13.49	77.2	-72.79	-6247.25	70.3	20.0	16a	70.3	146.7	100p
83	-13.74	71.3	-106.40	-6229.05	72.8	21.1	16a	72.8	155.5	100p
84	-13.99	65.6	-141.94	-6202.45	75.3	22.1	16a	75.3	164.2	100p
85	-14.24	60.1	-181.66	-6166.97	77.8	21.6	15a	77.8	180.5	100p
86	-14.49	54.9	-225.31	-6121.56	80.3	21.1	13a	80.3	195.7	100p
87	-14.74	49.9	-270.40	-6065.23	82.8	22.0	13a	82.8	202.4	100p
88	-14.99	45.1	-317.34	-5997.63	85.3	23.0	13a	85.3	210.7	100p
89	-15.24	40.6	-366.36	-5918.29	87.8	23.9	13a	87.8	220.0	100p
90	-15.49	36.3	-417.47	-5826.70	90.3	24.8	13a	90.3	229.2	100p
91	-15.74	32.3	-470.65	-5722.33	92.8	25.8	13a	92.8	238.5	100p
92	-15.99	28.5	-525.34	-5604.67	95.3	26.7	13a	95.3	245.4	100p
93	-16.24	24.8	-581.45	-5473.34	97.8	27.6	13a	97.8	252.1	100p
94	-16.49	21.4	-639.20	-5327.97	100.3	28.6	13a	100.3	259.6	100p
95	-16.74	18.3	-695.66	-5168.17	102.8	31.4	15a	102.8	257.2	100p
96	-16.99	15.3	-750.63	-4994.26	105.3	34.2	16a	105.3	254.2	100p
97	-17.24	12.5	-810.07	-4806.60	107.8	33.4	15a	107.8	274.7	100p
98	-17.48	9.9	-840.80	-4610.16	110.3	32.3	13a	110.3	159.1	54
99	-17.73	7.6	-865.90	-4406.27	112.7	33.2	13a	112.7	136.7	45
100	-17.97	5.4	-885.76	-4196.28	115.1	34.1	13a	115.1	116.0	38
101	-18.21	3.3	-900.83	-3981.49	117.5	35.0	13a	117.5	97.2	31
102	-18.45	1.4	-910.50	-3763.04	120.0	40.1	15	120.0	80.0	25
103	-18.70	-0.4	-911.71	-3542.24	122.4	59.1	22	122.4	64.1	19
104	-18.94	-2.0	-905.11	-3321.15	124.8	76.8	27	124.8	49.5	14
105	-19.18	-3.5	-894.05	-3101.66	127.2	93.3	33	127.2	47.7	14a

Project : Hansweert
Part :

NODE OUTPUT (SLS) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 7 Deviation : 0.14

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
106	-19.42	-4.9	-879.49	-2884.85	129.7	108.6	37	129.7	48.6	14a
107	-19.67	-6.2	-861.70	-2671.58	132.1	122.9	41	132.1	49.5	14a
108	-19.91	-7.4	-840.98	-2462.62	134.5	136.2	45	134.5	50.8	14a
109	-20.15	-8.5	-817.55	-2258.68	136.9	148.6	48	136.9	52.0	14a
110	-20.39	-9.6	-791.62	-2060.42	139.4	160.2	50	139.4	53.3	14a
111	-20.64	-10.5	-763.36	-1868.46	141.8	171.0	53	141.8	54.5	14a
112	-20.88	-11.4	-732.87	-1683.34	144.2	181.2	55	144.2	55.4	14a
113	-21.12	-12.2	-700.29	-1505.62	146.6	190.7	56	146.6	56.3	14a
114	-21.36	-13.0	-665.80	-1335.80	149.1	199.7	58	149.1	57.4	14a
115	-21.61	-13.7	-629.55	-1174.34	151.5	208.1	59	151.5	58.6	14a
116	-21.85	-14.4	-591.64	-1021.68	153.9	216.2	61	153.9	59.9	14a
117	-22.09	-15.0	-552.18	-878.20	156.3	223.9	62	156.3	61.1	14a
118	-22.33	-15.6	-511.22	-744.30	158.8	231.2	62	158.8	62.3	14a
119	-22.58	-16.2	-468.76	-620.33	161.2	238.3	63	161.2	63.2	14a
120	-22.82	-16.7	-424.86	-506.65	163.6	245.1	64	163.6	64.1	14a
121	-23.06	-17.3	-379.62	-403.63	166.0	251.8	65	166.0	65.3	14a
122	-23.30	-17.8	-333.11	-311.57	168.5	258.3	65	168.5	66.5	14a
123	-23.55	-18.3	-285.35	-230.79	170.9	264.7	66	170.9	67.7	14a
124	-23.79	-18.8	-236.35	-161.59	173.3	271.0	66	173.3	69.0	14a
125	-24.03	-19.3	-186.09	-104.28	175.7	277.3	67	175.7	70.0	14a
126	-24.27	-19.8	-134.55	-59.15	178.2	283.5	67	178.2	70.9	14a
127	-24.52	-20.3	-81.73	-26.52	180.6	289.7	68	180.6	71.9	14a
128	-24.76	-20.7	-27.64	-6.70	183.0	295.9	68	183.0	72.8	14a
129	-25.00	-21.2	0.00	0.00	185.4	302.0	68	185.4	74.1	14a

NODE OUTPUT (ULS-low, low wlevel) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 11 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
1	6.50	2258.1	350.00	-0.00	0.0	0.0	0	0.0	0.0	0
2	6.25	2230.7	350.00	-87.29	0.0	0.0	0	0.0	0.0	0
3	6.00	2203.3	350.00	-174.59	0.0	0.0	0	0.0	0.0	0
4	5.75	2176.0	350.00	-261.88	0.0	0.0	0	0.0	0.0	0
5	5.50	2148.6	350.00	-349.18	0.0	0.0	0	0.0	0.0	0
6	5.25	2121.3	350.00	-436.47	0.0	0.0	0	0.0	0.0	0
7	5.00	2094.0	350.00	-523.76	0.0	0.0	0	0.0	0.0	0
8	4.75	2066.7	350.00	-611.06	0.0	0.0	0	0.0	0.0	0
9	4.50	2039.4	350.00	-698.35	0.0	0.0	0	0.0	0.0	0
10	4.26	2012.1	350.00	-785.65	0.0	0.0	0	0.0	0.0	0
11	4.01	1984.9	350.00	-872.94	0.0	0.0	0	0.0	0.0	0
12	3.76	1957.7	350.00	-960.24	0.0	0.0	0	0.0	0.0	0
13	3.51	1930.6	350.00	-1047.53	0.0	0.0	0	0.0	0.0	0

Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

NODE OUTPUT (ULS-low, low wlevel) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 11 Deviation : 0.00

					------ LEFT -------			------ RIGHT ------		
Node nr.	Level m	Displ mm	Shear kN	Moment kNm	Water kN/m²	Grain kN/m²	%	Water kN/m²	Grain kN/m²	%
14	3.26	1903.5	350.00	-1134.82	0.0	0.0	0	0.0	0.0	0
15	3.01	1876.4	350.00	-1222.12	0.0	0.0	0	0.0	0.0	0
16	2.76	1849.4	350.00	-1309.41	0.0	0.0	0	0.0	0.0	0
17	2.51	1822.4	350.00	-1396.71	0.0	0.0	0	0.0	0.0	0
18	2.26	1795.5	350.00	-1484.00	0.0	0.0	0	0.0	0.0	0
19	2.02	1769.2	350.00	-1569.67	0.6	0.0	0	0.6	0.0	0
20	1.77	1742.9	350.00	-1655.35	1.1	0.0	0	1.1	0.0	0
21	1.53	1716.6	350.00	-1741.02	1.7	0.0	0	1.7	0.0	0
22	1.28	1690.5	350.00	-1826.70	2.2	0.0	0	2.2	0.0	0
23	1.04	1664.4	350.00	-1912.37	2.8	0.0	0	2.8	0.0	0
24	0.79	1638.3	350.00	-1998.04	3.3	0.0	0	3.3	0.0	0
25	0.55	1612.4	350.00	-2083.72	3.9	0.0	0	3.9	0.0	0
26	0.30	1586.5	350.00	-2169.39	4.4	0.0	0	4.4	0.0	0
27	0.06	1560.7	350.00	-2255.07	5.0	0.0	0	5.0	0.0	0
28	-0.19	1535.0	350.00	-2340.74	5.5	0.0	0	5.5	0.0	0
29	-0.43	1509.3	350.00	-2426.41	6.1	0.0	0	6.1	0.0	0
30	-0.68	1483.8	350.00	-2512.09	6.6	0.0	0	6.6	0.0	0
31	-0.92	1458.4	350.00	-2597.76	7.2	0.0	0	7.2	0.0	0
32	-1.17	1433.0	350.00	-2683.43	7.7	0.0	0	7.7	0.0	0
33	-1.41	1407.8	350.00	-2769.11	8.3	0.0	0	8.3	0.0	0
34	-1.66	1382.6	350.00	-2854.78	8.9	0.0	0	8.9	0.0	0
35	-1.90	1357.6	350.00	-2940.46	9.4	0.0	0	9.4	0.0	0
36	-2.15	1332.7	350.00	-3026.13	10.0	0.0	0	10.0	0.0	0
37	-2.39	1307.9	350.00	-3111.80	10.5	0.0	0	10.5	0.0	0
38	-2.64	1283.2	350.00	-3197.48	11.1	0.0	0	11.1	0.0	0
39	-2.88	1258.6	350.00	-3283.15	11.6	0.0	0	11.6	0.0	0
40	-3.13	1234.1	350.00	-3368.83	12.2	0.0	0	12.2	0.0	0
41	-3.37	1209.8	350.00	-3454.50	12.7	0.0	0	12.7	0.0	0
42	-3.61	1185.6	350.00	-3540.17	13.3	0.0	0	13.3	0.0	0
43	-3.86	1161.6	350.00	-3625.85	13.8	0.0	0	13.8	0.0	0
44	-4.10	1137.6	350.00	-3711.52	14.4	0.0	0	14.4	0.0	0
45	-4.35	1113.8	350.00	-3797.20	14.9	0.0	0	14.9	0.0	0
46	-4.59	1090.2	350.00	-3882.87	15.5	0.0	0	15.5	0.0	0
47	-4.84	1066.7	350.00	-3968.54	16.0	0.0	0	16.0	0.0	0
48	-5.08	1043.3	350.00	-4054.22	16.6	0.0	0	16.6	0.0	0
49	-5.33	1020.1	350.00	-4139.89	17.1	0.0	0	17.1	0.0	0
50	-5.57	997.1	350.00	-4225.57	17.7	0.0	0	17.7	0.0	0
51	-5.82	974.2	350.00	-4311.24	18.3	0.0	0	18.3	0.0	0
52	-6.06	951.4	350.00	-4396.91	18.8	0.0	0	18.8	0.0	0
53	-6.31	928.9	350.00	-4482.59	19.4	0.0	0	19.4	0.0	0
54	-6.55	906.5	350.00	-4568.26	19.9	0.0	0	19.9	0.0	0
55	-6.80	884.2	350.00	-4653.93	20.5	0.0	0	20.5	0.0	0
56	-7.04	862.2	350.00	-4739.61	21.0	0.0	0	21.0	0.0	0
57	-7.29	840.3	350.00	-4825.28	21.6	0.0	0	21.6	0.0	0

Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

NODE OUTPUT (ULS-low, low wlevel) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 11 Deviation : 0.00

					LEFT			RIGHT		
Node nr.	Level m	Displ mm	Shear kN	Moment kNm	Water kN/m²	Grain kN/m²	%	Water kN/m²	Grain kN/m²	%
58	-7.53	818.6	350.00	-4910.96	22.1	0.0	0	22.1	0.0	0
59	-7.78	797.1	350.00	-4996.63	22.7	0.0	0	22.7	0.0	0
60	-8.02	775.7	350.00	-5082.30	23.2	0.0	0	23.2	0.0	0
61	-8.27	754.6	350.00	-5167.98	23.8	0.0	0	23.8	0.0	0
62	-8.51	733.7	350.00	-5253.65	24.3	0.0	0	24.3	0.0	0
63	-8.76	712.9	350.00	-5339.33	24.9	0.0	0	24.9	0.0	0
64	-9.00	692.4	348.28	-5425.00	25.4	0.0	0	25.4	7.0	100p
65	-9.25	671.7	342.67	-5511.68	27.9	0.0	0	27.9	22.5	100p
66	-9.50	651.2	334.91	-5596.97	30.4	0.0	0	30.4	31.2	100p
67	-9.75	630.9	325.03	-5680.32	32.9	0.2	0	32.9	39.9	100p
68	-10.00	610.9	313.05	-5761.22	35.4	1.2	3a	35.4	49.3	100p
69	-10.24	591.1	298.31	-5839.13	37.9	2.2	4a	37.9	61.4	100p
70	-10.49	571.5	280.80	-5913.38	40.4	3.2	5a	40.4	73.6	100p
71	-10.74	552.1	260.66	-5983.27	42.9	4.3	6a	42.9	85.2	100p
72	-10.99	533.0	238.62	-6048.14	45.4	5.3	7a	45.4	93.9	100p
73	-11.24	514.1	219.72	-6107.53	47.8	9.6	13a	47.8	85.3	100p
74	-11.49	495.3	204.60	-6162.46	50.3	14.0	23a	50.3	74.5	100p
75	-11.74	476.8	186.71	-6213.61	52.8	14.2	20a	52.8	85.7	100p
76	-11.99	458.6	165.93	-6260.29	55.3	14.4	18a	55.3	97.5	100p
77	-12.24	440.5	143.47	-6301.77	57.8	15.5	18a	57.8	105.4	100p
78	-12.49	422.8	119.89	-6337.64	60.3	16.6	18a	60.3	111.0	100p
79	-12.74	405.2	95.19	-6367.61	62.8	17.7	18a	62.8	116.6	100p
80	-12.99	388.0	68.98	-6391.41	65.3	18.9	19a	65.3	123.7	100p
81	-13.24	370.9	42.60	-6408.66	67.8	21.1	21a	67.8	126.7	100p
82	-13.49	354.1	16.17	-6419.30	70.3	23.5	23a	70.3	129.2	100p
83	-13.74	337.6	-11.73	-6423.35	72.8	24.7	23a	72.8	136.3	100p
84	-13.99	321.3	-40.65	-6420.41	75.3	25.8	23a	75.3	141.5	100p
85	-14.24	305.3	-72.36	-6410.25	77.8	25.7	21a	77.8	152.6	100p
86	-14.49	289.5	-107.44	-6392.16	80.3	25.6	19a	80.3	165.9	100p
87	-14.74	274.0	-144.22	-6365.30	82.8	26.7	19a	82.8	173.8	100p
88	-14.99	258.7	-182.70	-6329.25	85.3	27.8	19a	85.3	181.7	100p
89	-15.24	243.7	-222.73	-6283.57	87.8	28.9	19a	87.8	189.0	100p
90	-15.49	228.9	-263.89	-6227.89	90.3	30.0	19a	90.3	194.6	100p
91	-15.74	214.3	-306.17	-6161.92	92.8	31.1	19a	92.8	200.3	100p
92	-15.99	200.0	-350.12	-6085.38	95.3	32.3	19a	95.3	208.1	100p
93	-16.24	185.9	-395.75	-5997.84	97.8	33.4	19a	97.8	215.9	100p
94	-16.49	172.1	-443.05	-5898.91	100.3	34.5	19a	100.3	223.7	100p
95	-16.74	158.5	-489.45	-5788.15	102.8	37.3	21a	102.8	222.9	100p
96	-16.99	145.1	-534.46	-5665.78	105.3	40.1	23a	105.3	220.1	100p
97	-17.24	131.9	-582.31	-5532.17	107.8	39.6	21a	107.8	233.9	100p
98	-17.48	119.4	-633.48	-5390.96	110.3	38.9	19a	110.3	249.9	100p
99	-17.73	107.0	-686.22	-5237.34	112.7	40.0	19a	112.7	257.5	100p
100	-17.97	94.8	-740.51	-5070.93	115.1	41.1	19a	115.1	265.0	100p
101	-18.21	82.8	-796.26	-4891.36	117.5	42.2	19a	117.5	272.1	100p

Project : Hansweert
Part :

NODE OUTPUT (ULS-low, low wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.00

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
102	-18.45	71.0	-853.07	-4698.26	120.0	43.2	19a	120.0	277.5	100p
103	-18.70	59.4	-910.95	-4491.39	122.4	44.3	19a	122.4	283.0	100p
104	-18.94	47.9	-970.39	-4270.49	124.8	45.4	19a	124.8	290.5	100p
105	-19.18	36.6	-1031.38	-4035.17	127.2	46.5	19a	127.2	298.0	100p
106	-19.42	25.4	-1087.51	-3785.06	129.7	47.6	19a	129.7	279.1	91
107	-19.67	14.4	-1123.30	-3521.34	132.1	48.7	19a	132.1	196.2	63
108	-19.91	3.5	-1138.85	-3248.94	134.5	49.7	19a	134.5	113.9	36
109	-20.15	-7.3	-1123.17	-2972.77	136.9	127.8	49	136.9	63.2	20a
110	-20.39	-18.0	-1087.57	-2700.40	139.4	211.4	79	139.4	64.6	20a
111	-20.64	-28.6	-1037.45	-2436.67	141.8	272.8	100p	141.8	66.1	20a
112	-20.88	-39.0	-986.37	-2185.09	144.2	278.2	100p	144.2	67.6	20a
113	-21.12	-49.5	-934.34	-1945.89	146.6	283.6	100p	146.6	69.1	20a
114	-21.36	-59.8	-881.27	-1719.31	149.1	289.1	100p	149.1	70.2	20a
115	-21.61	-70.1	-827.14	-1505.61	151.5	294.5	100p	151.5	71.3	20a
116	-21.85	-80.3	-772.03	-1305.03	153.9	299.9	100p	153.9	72.7	20a
117	-22.09	-90.4	-715.97	-1117.81	156.3	305.4	100p	156.3	74.2	20a
118	-22.33	-100.6	-658.95	-944.18	158.8	310.8	100p	158.8	75.7	20a
119	-22.58	-110.7	-600.97	-784.39	161.2	316.2	100p	161.2	77.1	20a
120	-22.82	-120.7	-541.97	-638.65	163.6	321.7	100p	163.6	78.4	20a
121	-23.06	-130.8	-481.91	-507.22	166.0	327.1	100p	166.0	79.4	20a
122	-23.30	-140.8	-420.87	-390.36	168.5	332.5	100p	168.5	80.8	20a
123	-23.55	-150.8	-358.86	-288.30	170.9	338.0	100p	170.9	82.3	20a
124	-23.79	-160.8	-295.90	-201.27	173.3	343.4	100p	173.3	83.7	20a
125	-24.03	-170.8	-231.98	-129.52	175.7	348.8	100p	175.7	85.2	20a
126	-24.27	-180.8	-167.05	-73.26	178.2	354.3	100p	178.2	86.5	20a
127	-24.52	-190.7	-101.06	-32.76	180.6	359.7	100p	180.6	87.6	20a
128	-24.76	-200.7	-34.02	-8.25	183.0	365.1	100p	183.0	88.7	20a
129	-25.00	-210.7	0.00	0.00	185.4	370.5	100p	185.4	90.0	20a

NODE OUTPUT (ULS-high, low wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.63

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
1	6.50	1377.1	350.00	-0.00	0.0	0.0	0	0.0	0.0	0
2	6.25	1358.0	350.00	-87.29	0.0	0.0	0	0.0	0.0	0
3	6.00	1338.9	350.00	-174.59	0.0	0.0	0	0.0	0.0	0
4	5.75	1319.9	350.00	-261.88	0.0	0.0	0	0.0	0.0	0
5	5.50	1300.8	350.00	-349.18	0.0	0.0	0	0.0	0.0	0
6	5.25	1281.8	350.00	-436.47	0.0	0.0	0	0.0	0.0	0
7	5.00	1262.7	350.00	-523.76	0.0	0.0	0	0.0	0.0	0
8	4.75	1243.7	350.00	-611.06	0.0	0.0	0	0.0	0.0	0
9	4.50	1224.8	350.00	-698.35	0.0	0.0	0	0.0	0.0	0

Project : Hansweert
Part :

NODE OUTPUT (ULS-high, low wlevel) **CONSTR.PHASE: 1 Bouwfase 1**

Number iterations: 11 Deviation : 0.63

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
10	4.26	1205.8	350.00	-785.65	0.0	0.0	0	0.0	0.0	0
11	4.01	1186.9	350.00	-872.94	0.0	0.0	0	0.0	0.0	0
12	3.76	1168.0	350.00	-960.24	0.0	0.0	0	0.0	0.0	0
13	3.51	1149.1	350.00	-1047.53	0.0	0.0	0	0.0	0.0	0
14	3.26	1130.3	350.00	-1134.82	0.0	0.0	0	0.0	0.0	0
15	3.01	1111.6	350.00	-1222.12	0.0	0.0	0	0.0	0.0	0
16	2.76	1092.8	350.00	-1309.41	0.0	0.0	0	0.0	0.0	0
17	2.51	1074.2	350.00	-1396.71	0.0	0.0	0	0.0	0.0	0
18	2.26	1055.5	350.00	-1484.00	0.0	0.0	0	0.0	0.0	0
19	2.02	1037.3	350.00	-1569.67	0.6	0.0	0	0.6	0.0	0
20	1.77	1019.2	350.00	-1655.35	1.1	0.0	0	1.1	0.0	0
21	1.53	1001.1	350.00	-1741.02	1.7	0.0	0	1.7	0.0	0
22	1.28	983.1	350.00	-1826.70	2.2	0.0	0	2.2	0.0	0
23	1.04	965.1	350.00	-1912.37	2.8	0.0	0	2.8	0.0	0
24	0.79	947.2	350.00	-1998.04	3.3	0.0	0	3.3	0.0	0
25	0.55	929.4	350.00	-2083.72	3.9	0.0	0	3.9	0.0	0
26	0.30	911.6	350.00	-2169.39	4.4	0.0	0	4.4	0.0	0
27	0.06	894.0	350.00	-2255.07	5.0	0.0	0	5.0	0.0	0
28	-0.19	876.4	350.00	-2340.74	5.5	0.0	0	5.5	0.0	0
29	-0.43	858.9	350.00	-2426.41	6.1	0.0	0	6.1	0.0	0
30	-0.68	841.5	350.00	-2512.09	6.6	0.0	0	6.6	0.0	0
31	-0.92	824.2	350.00	-2597.76	7.2	0.0	0	7.2	0.0	0
32	-1.17	807.0	350.00	-2683.43	7.7	0.0	0	7.7	0.0	0
33	-1.41	789.9	350.00	-2769.11	8.3	0.0	0	8.3	0.0	0
34	-1.66	772.9	350.00	-2854.78	8.9	0.0	0	8.9	0.0	0
35	-1.90	756.0	350.00	-2940.46	9.4	0.0	0	9.4	0.0	0
36	-2.15	739.3	350.00	-3026.13	10.0	0.0	0	10.0	0.0	0
37	-2.39	722.6	350.00	-3111.80	10.5	0.0	0	10.5	0.0	0
38	-2.64	706.0	350.00	-3197.48	11.1	0.0	0	11.1	0.0	0
39	-2.88	689.6	350.00	-3283.15	11.6	0.0	0	11.6	0.0	0
40	-3.13	673.3	350.00	-3368.83	12.2	0.0	0	12.2	0.0	0
41	-3.37	657.1	350.00	-3454.50	12.7	0.0	0	12.7	0.0	0
42	-3.61	641.0	350.00	-3540.17	13.3	0.0	0	13.3	0.0	0
43	-3.86	625.1	350.00	-3625.85	13.8	0.0	0	13.8	0.0	0
44	-4.10	609.3	350.00	-3711.52	14.4	0.0	0	14.4	0.0	0
45	-4.35	593.7	350.00	-3797.20	14.9	0.0	0	14.9	0.0	0
46	-4.59	578.2	350.00	-3882.87	15.5	0.0	0	15.5	0.0	0
47	-4.84	562.8	350.00	-3968.54	16.0	0.0	0	16.0	0.0	0
48	-5.08	547.6	350.00	-4054.22	16.6	0.0	0	16.6	0.0	0
49	-5.33	532.5	350.00	-4139.89	17.1	0.0	0	17.1	0.0	0
50	-5.57	517.6	350.00	-4225.57	17.7	0.0	0	17.7	0.0	0
51	-5.82	502.9	350.00	-4311.24	18.3	0.0	0	18.3	0.0	0
52	-6.06	488.3	350.00	-4396.91	18.8	0.0	0	18.8	0.0	0
53	-6.31	473.8	350.00	-4482.59	19.4	0.0	0	19.4	0.0	0

Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

NODE OUTPUT (ULS-high, low wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.63

					LEFT			RIGHT		
Node nr.	Level m	Displ mm	Shear kN	Moment kNm	Water kN/m²	Grain kN/m²	%	Water kN/m²	Grain kN/m²	%
54	-6.55	459.6	350.00	-4568.26	19.9	0.0	0	19.9	0.0	0
55	-6.80	445.5	350.00	-4653.93	20.5	0.0	0	20.5	0.0	0
56	-7.04	431.6	350.00	-4739.61	21.0	0.0	0	21.0	0.0	0
57	-7.29	417.8	350.00	-4825.28	21.6	0.0	0	21.6	0.0	0
58	-7.53	404.3	350.00	-4910.96	22.1	0.0	0	22.1	0.0	0
59	-7.78	390.9	350.00	-4996.63	22.7	0.0	0	22.7	0.0	0
60	-8.02	377.7	350.00	-5082.30	23.2	0.0	0	23.2	0.0	0
61	-8.27	364.7	350.00	-5167.98	23.8	0.0	0	23.8	0.0	0
62	-8.51	351.9	350.00	-5253.65	24.3	0.0	0	24.3	0.0	0
63	-8.76	339.3	350.00	-5339.33	24.9	0.0	0	24.9	0.0	0
64	-9.00	326.9	348.28	-5425.00	25.4	0.0	0	25.4	7.0	100p
65	-9.25	314.5	342.67	-5511.68	27.9	0.0	0	27.9	22.5	100p
66	-9.50	302.3	334.91	-5596.97	30.4	0.0	0	30.4	31.2	100p
67	-9.75	290.3	325.03	-5680.32	32.9	0.2	0	32.9	39.9	100p
68	-10.00	278.5	313.05	-5761.22	35.4	1.2	3a	35.4	49.3	100p
69	-10.24	267.0	298.31	-5839.13	37.9	2.2	4a	37.9	61.4	100p
70	-10.49	255.7	280.80	-5913.38	40.4	3.2	5a	40.4	73.6	100p
71	-10.74	244.6	260.66	-5983.27	42.9	4.3	6a	42.9	85.2	100p
72	-10.99	233.8	238.62	-6048.14	45.4	5.3	7a	45.4	93.9	100p
73	-11.24	223.1	219.72	-6107.53	47.8	9.6	13a	47.8	85.3	100p
74	-11.49	212.7	204.60	-6162.46	50.3	14.0	23a	50.3	74.5	100p
75	-11.74	202.5	186.71	-6213.61	52.8	14.2	20a	52.8	85.7	100p
76	-11.99	192.6	165.93	-6260.29	55.3	14.4	18a	55.3	97.5	100p
77	-12.24	182.9	143.47	-6301.77	57.8	15.5	18a	57.8	105.4	100p
78	-12.49	173.4	119.89	-6337.64	60.3	16.6	18a	60.3	111.0	100p
79	-12.74	164.2	95.19	-6367.61	62.8	17.7	18a	62.8	116.6	100p
80	-12.99	155.2	68.98	-6391.41	65.3	18.9	19a	65.3	123.7	100p
81	-13.24	146.5	42.60	-6408.66	67.8	21.1	21a	67.8	126.7	100p
82	-13.49	138.0	16.17	-6419.30	70.3	23.5	23a	70.3	129.2	100p
83	-13.74	129.8	-11.73	-6423.35	72.8	24.7	23a	72.8	136.3	100p
84	-13.99	121.8	-40.65	-6420.41	75.3	25.8	23a	75.3	141.5	100p
85	-14.24	114.1	-72.36	-6410.25	77.8	25.7	21a	77.8	152.6	100p
86	-14.49	106.7	-107.44	-6392.16	80.3	25.6	19a	80.3	165.9	100p
87	-14.74	99.4	-144.22	-6365.30	82.8	26.7	19a	82.8	173.8	100p
88	-14.99	92.5	-182.70	-6329.25	85.3	27.8	19a	85.3	181.7	100p
89	-15.24	85.7	-222.73	-6283.57	87.8	28.9	19a	87.8	189.0	100p
90	-15.49	79.3	-263.89	-6227.89	90.3	30.0	19a	90.3	194.6	100p
91	-15.74	73.0	-306.17	-6161.92	92.8	31.1	19a	92.8	200.3	100p
92	-15.99	67.0	-350.12	-6085.38	95.3	32.3	19a	95.3	208.1	100p
93	-16.24	61.3	-395.75	-5997.84	97.8	33.4	19a	97.8	215.9	100p
94	-16.49	55.7	-443.05	-5898.91	100.3	34.5	19a	100.3	223.7	100p
95	-16.74	50.4	-489.45	-5788.15	102.8	37.3	21a	102.8	222.9	100p
96	-16.99	45.4	-534.46	-5665.78	105.3	40.1	23a	105.3	220.1	100p
97	-17.24	40.5	-582.31	-5532.17	107.8	39.6	21a	107.8	233.9	100p

Project : Hansweert
Part :

NODE OUTPUT (ULS-high, low wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.63

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
98	-17.48	36.0	-633.48	-5390.96	110.3	38.9	19a	110.3	249.9	100p
99	-17.73	31.7	-686.22	-5237.34	112.7	40.0	19a	112.7	257.5	100p
100	-17.97	27.6	-740.51	-5070.93	115.1	41.1	19a	115.1	265.0	100p
101	-18.21	23.7	-796.26	-4891.36	117.5	42.2	19a	117.5	272.1	100p
102	-18.45	19.9	-853.07	-4698.26	120.0	43.2	19a	120.0	277.5	100p
103	-18.70	16.4	-910.95	-4491.39	122.4	44.3	19a	122.4	283.0	100p
104	-18.94	13.0	-970.39	-4270.49	124.8	45.4	19a	124.8	290.5	100p
105	-19.18	9.7	-1031.38	-4035.17	127.2	46.5	19a	127.2	298.0	100p
106	-19.42	6.6	-1088.17	-3785.06	129.7	47.6	19a	129.7	281.8	92
107	-19.67	3.6	-1123.61	-3521.18	132.1	48.7	19a	132.1	194.8	62
108	-19.91	0.8	-1138.52	-3248.71	134.5	49.7	19a	134.5	111.2	35
109	-20.15	-1.9	-1122.53	-2972.62	136.9	129.1	49	136.9	63.2	20a
110	-20.39	-4.5	-1087.57	-2700.40	139.4	208.8	78	139.4	64.6	20a
111	-20.64	-7.0	-1037.45	-2436.67	141.8	272.8	100p	141.8	66.1	20a
112	-20.88	-9.5	-986.37	-2185.09	144.2	278.2	100p	144.2	67.6	20a
113	-21.12	-11.8	-934.34	-1945.89	146.6	283.6	100p	146.6	69.1	20a
114	-21.36	-14.1	-881.27	-1719.31	149.1	289.1	100p	149.1	70.2	20a
115	-21.61	-16.3	-827.14	-1505.61	151.5	294.5	100p	151.5	71.3	20a
116	-21.85	-18.4	-772.03	-1305.03	153.9	299.9	100p	153.9	72.7	20a
117	-22.09	-20.5	-715.97	-1117.81	156.3	305.4	100p	156.3	74.2	20a
118	-22.33	-22.6	-658.95	-944.18	158.8	310.8	100p	158.8	75.7	20a
119	-22.58	-24.6	-600.97	-784.39	161.2	316.2	100p	161.2	77.1	20a
120	-22.82	-26.6	-541.97	-638.65	163.6	321.7	100p	163.6	78.4	20a
121	-23.06	-28.6	-481.91	-507.22	166.0	327.1	100p	166.0	79.4	20a
122	-23.30	-30.5	-420.87	-390.36	168.5	332.5	100p	168.5	80.8	20a
123	-23.55	-32.5	-358.86	-288.30	170.9	338.0	100p	170.9	82.3	20a
124	-23.79	-34.4	-295.90	-201.27	173.3	343.4	100p	173.3	83.7	20a
125	-24.03	-36.3	-231.98	-129.52	175.7	348.8	100p	175.7	85.2	20a
126	-24.27	-38.3	-167.05	-73.26	178.2	354.3	100p	178.2	86.5	20a
127	-24.52	-40.2	-101.06	-32.76	180.6	359.7	100p	180.6	87.6	20a
128	-24.76	-42.1	-34.02	-8.25	183.0	365.1	100p	183.0	88.7	20a
129	-25.00	-44.0	0.00	0.00	185.4	370.5	100p	185.4	90.0	20a

NODAL RESULTS (ULS-low, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.00

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
1	6.50	2258.1	350.00	-0.00	0.0	0.0	0	0.0	0.0	0
2	6.25	2230.7	350.00	-87.29	0.0	0.0	0	0.0	0.0	0
3	6.00	2203.3	350.00	-174.59	0.0	0.0	0	0.0	0.0	0
4	5.75	2176.0	350.00	-261.88	0.0	0.0	0	0.0	0.0	0
5	5.50	2148.6	350.00	-349.18	0.0	0.0	0	0.0	0.0	0

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Project : Hansweert
Part :

NODAL RESULTS (ULS-low, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.00

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
6	5.25	2121.3	350.00	-436.47	0.0	0.0	0	0.0	0.0	0
7	5.00	2094.0	350.00	-523.76	0.0	0.0	0	0.0	0.0	0
8	4.75	2066.7	350.00	-611.06	0.0	0.0	0	0.0	0.0	0
9	4.50	2039.4	350.00	-698.35	0.0	0.0	0	0.0	0.0	0
10	4.26	2012.1	350.00	-785.65	0.0	0.0	0	0.0	0.0	0
11	4.01	1984.9	350.00	-872.94	0.0	0.0	0	0.0	0.0	0
12	3.76	1957.7	350.00	-960.24	0.0	0.0	0	0.0	0.0	0
13	3.51	1930.6	350.00	-1047.53	0.0	0.0	0	0.0	0.0	0
14	3.26	1903.5	350.00	-1134.82	0.0	0.0	0	0.0	0.0	0
15	3.01	1876.4	350.00	-1222.12	0.0	0.0	0	0.0	0.0	0
16	2.76	1849.4	350.00	-1309.41	0.0	0.0	0	0.0	0.0	0
17	2.51	1822.4	350.00	-1396.71	0.0	0.0	0	0.0	0.0	0
18	2.26	1795.5	350.00	-1484.00	0.0	0.0	0	0.0	0.0	0
19	2.02	1769.2	350.00	-1569.67	0.6	0.0	0	0.6	0.0	0
20	1.77	1742.9	350.00	-1655.35	1.1	0.0	0	1.1	0.0	0
21	1.53	1716.6	350.00	-1741.02	1.7	0.0	0	1.7	0.0	0
22	1.28	1690.5	350.00	-1826.70	2.2	0.0	0	2.2	0.0	0
23	1.04	1664.4	350.00	-1912.37	2.8	0.0	0	2.8	0.0	0
24	0.79	1638.3	350.00	-1998.04	3.3	0.0	0	3.3	0.0	0
25	0.55	1612.4	350.00	-2083.72	3.9	0.0	0	3.9	0.0	0
26	0.30	1586.5	350.00	-2169.39	4.4	0.0	0	4.4	0.0	0
27	0.06	1560.7	350.00	-2255.07	5.0	0.0	0	5.0	0.0	0
28	-0.19	1535.0	350.00	-2340.74	5.5	0.0	0	5.5	0.0	0
29	-0.43	1509.3	350.00	-2426.41	6.1	0.0	0	6.1	0.0	0
30	-0.68	1483.8	350.00	-2512.09	6.6	0.0	0	6.6	0.0	0
31	-0.92	1458.4	350.00	-2597.76	7.2	0.0	0	7.2	0.0	0
32	-1.17	1433.0	350.00	-2683.43	7.7	0.0	0	7.7	0.0	0
33	-1.41	1407.8	350.00	-2769.11	8.3	0.0	0	8.3	0.0	0
34	-1.66	1382.6	350.00	-2854.78	8.9	0.0	0	8.9	0.0	0
35	-1.90	1357.6	350.00	-2940.46	9.4	0.0	0	9.4	0.0	0
36	-2.15	1332.7	350.00	-3026.13	10.0	0.0	0	10.0	0.0	0
37	-2.39	1307.9	350.00	-3111.80	10.5	0.0	0	10.5	0.0	0
38	-2.64	1283.2	350.00	-3197.48	11.1	0.0	0	11.1	0.0	0
39	-2.88	1258.6	350.00	-3283.15	11.6	0.0	0	11.6	0.0	0
40	-3.13	1234.1	350.00	-3368.83	12.2	0.0	0	12.2	0.0	0
41	-3.37	1209.8	350.00	-3454.50	12.7	0.0	0	12.7	0.0	0
42	-3.61	1185.6	350.00	-3540.17	13.3	0.0	0	13.3	0.0	0
43	-3.86	1161.6	350.00	-3625.85	13.8	0.0	0	13.8	0.0	0
44	-4.10	1137.6	350.00	-3711.52	14.4	0.0	0	14.4	0.0	0
45	-4.35	1113.8	350.00	-3797.20	14.9	0.0	0	14.9	0.0	0
46	-4.59	1090.2	350.00	-3882.87	15.5	0.0	0	15.5	0.0	0
47	-4.84	1066.7	350.00	-3968.54	16.0	0.0	0	16.0	0.0	0
48	-5.08	1043.3	350.00	-4054.22	16.6	0.0	0	16.6	0.0	0
49	-5.33	1020.1	350.00	-4139.89	17.1	0.0	0	17.1	0.0	0

Project : Hansweert
Part :

NODAL RESULTS (ULS-low, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.00

Node	Level	Displ	Shear	Moment	LEFT Water	LEFT Grain		RIGHT Water	RIGHT Grain	
nr.	m	mm	kN	kNm	kN/m²	kN/m²	%	kN/m²	kN/m²	%
50	-5.57	997.1	350.00	-4225.57	17.7	0.0	0	17.7	0.0	0
51	-5.82	974.2	350.00	-4311.24	18.3	0.0	0	18.3	0.0	0
52	-6.06	951.4	350.00	-4396.91	18.8	0.0	0	18.8	0.0	0
53	-6.31	928.9	350.00	-4482.59	19.4	0.0	0	19.4	0.0	0
54	-6.55	906.5	350.00	-4568.26	19.9	0.0	0	19.9	0.0	0
55	-6.80	884.2	350.00	-4653.93	20.5	0.0	0	20.5	0.0	0
56	-7.04	862.2	350.00	-4739.61	21.0	0.0	0	21.0	0.0	0
57	-7.29	840.3	350.00	-4825.28	21.6	0.0	0	21.6	0.0	0
58	-7.53	818.6	350.00	-4910.96	22.1	0.0	0	22.1	0.0	0
59	-7.78	797.1	350.00	-4996.63	22.7	0.0	0	22.7	0.0	0
60	-8.02	775.7	350.00	-5082.30	23.2	0.0	0	23.2	0.0	0
61	-8.27	754.6	350.00	-5167.98	23.8	0.0	0	23.8	0.0	0
62	-8.51	733.7	350.00	-5253.65	24.3	0.0	0	24.3	0.0	0
63	-8.76	712.9	350.00	-5339.33	24.9	0.0	0	24.9	0.0	0
64	-9.00	692.4	348.28	-5425.00	25.4	0.0	0	25.4	7.0	100p
65	-9.25	671.7	342.67	-5511.68	27.9	0.0	0	27.9	22.5	100p
66	-9.50	651.2	334.91	-5596.97	30.4	0.0	0	30.4	31.2	100p
67	-9.75	630.9	325.03	-5680.32	32.9	0.2	0	32.9	39.9	100p
68	-10.00	610.9	313.05	-5761.22	35.4	1.2	3a	35.4	49.3	100p
69	-10.24	591.1	298.31	-5839.13	37.9	2.2	4a	37.9	61.4	100p
70	-10.49	571.5	280.80	-5913.38	40.4	3.2	5a	40.4	73.6	100p
71	-10.74	552.1	260.66	-5983.27	42.9	4.3	6a	42.9	85.2	100p
72	-10.99	533.0	238.62	-6048.14	45.4	5.3	7a	45.4	93.9	100p
73	-11.24	514.1	219.72	-6107.53	47.8	9.6	13a	47.8	85.3	100p
74	-11.49	495.3	204.60	-6162.46	50.3	14.0	23a	50.3	74.5	100p
75	-11.74	476.8	186.71	-6213.61	52.8	14.2	20a	52.8	85.7	100p
76	-11.99	458.6	165.93	-6260.29	55.3	14.4	18a	55.3	97.5	100p
77	-12.24	440.5	143.47	-6301.77	57.8	15.5	18a	57.8	105.4	100p
78	-12.49	422.8	119.89	-6337.64	60.3	16.6	18a	60.3	111.0	100p
79	-12.74	405.2	95.19	-6367.61	62.8	17.7	18a	62.8	116.6	100p
80	-12.99	388.0	68.98	-6391.41	65.3	18.9	19a	65.3	123.7	100p
81	-13.24	370.9	42.60	-6408.66	67.8	21.1	21a	67.8	126.7	100p
82	-13.49	354.1	16.17	-6419.30	70.3	23.5	23a	70.3	129.2	100p
83	-13.74	337.6	-11.73	-6423.35	72.8	24.7	23a	72.8	136.3	100p
84	-13.99	321.3	-40.65	-6420.41	75.3	25.8	23a	75.3	141.5	100p
85	-14.24	305.3	-72.36	-6410.25	77.8	25.7	21a	77.8	152.6	100p
86	-14.49	289.5	-107.44	-6392.16	80.3	25.6	19a	80.3	165.9	100p
87	-14.74	274.0	-144.22	-6365.30	82.8	26.7	19a	82.8	173.8	100p
88	-14.99	258.7	-182.70	-6329.25	85.3	27.8	19a	85.3	181.7	100p
89	-15.24	243.7	-222.73	-6283.57	87.8	28.9	19a	87.8	189.0	100p
90	-15.49	228.9	-263.89	-6227.89	90.3	30.0	19a	90.3	194.6	100p
91	-15.74	214.3	-306.17	-6161.92	92.8	31.1	19a	92.8	200.3	100p
92	-15.99	200.0	-350.12	-6085.38	95.3	32.3	19a	95.3	208.1	100p
93	-16.24	185.9	-395.75	-5997.84	97.8	33.4	19a	97.8	215.9	100p

Project : Hansweert
Part :

NODAL RESULTS (ULS-low, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.00

					------ LEFT -------			------ RIGHT ------		
Node nr.	Level m	Displ mm	Shear kN	Moment kNm	Water kN/m²	Grain kN/m²	%	Water kN/m²	Grain kN/m²	%
94	-16.49	172.1	-443.05	-5898.91	100.3	34.5	19a	100.3	223.7	100p
95	-16.74	158.5	-489.45	-5788.15	102.8	37.3	21a	102.8	222.9	100p
96	-16.99	145.1	-534.46	-5665.78	105.3	40.1	23a	105.3	220.1	100p
97	-17.24	131.9	-582.31	-5532.17	107.8	39.6	21a	107.8	233.9	100p
98	-17.48	119.4	-633.48	-5390.96	110.3	38.9	19a	110.3	249.9	100p
99	-17.73	107.0	-686.22	-5237.34	112.7	40.0	19a	112.7	257.5	100p
100	-17.97	94.8	-740.51	-5070.93	115.1	41.1	19a	115.1	265.0	100p
101	-18.21	82.8	-796.26	-4891.36	117.5	42.2	19a	117.5	272.1	100p
102	-18.45	71.0	-853.07	-4698.26	120.0	43.2	19a	120.0	277.5	100p
103	-18.70	59.4	-910.95	-4491.39	122.4	44.3	19a	122.4	283.0	100p
104	-18.94	47.9	-970.39	-4270.49	124.8	45.4	19a	124.8	290.5	100p
105	-19.18	36.6	-1031.38	-4035.17	127.2	46.5	19a	127.2	298.0	100p
106	-19.42	25.4	-1087.51	-3785.06	129.7	47.6	19a	129.7	279.1	91
107	-19.67	14.4	-1123.30	-3521.34	132.1	48.7	19a	132.1	196.2	63
108	-19.91	3.5	-1138.85	-3248.94	134.5	49.7	19a	134.5	113.9	36
109	-20.15	-7.3	-1123.17	-2972.77	136.9	127.8	49	136.9	63.2	20a
110	-20.39	-18.0	-1087.57	-2700.40	139.4	211.4	79	139.4	64.6	20a
111	-20.64	-28.6	-1037.45	-2436.67	141.8	272.8	100p	141.8	66.1	20a
112	-20.88	-39.0	-986.37	-2185.09	144.2	278.2	100p	144.2	67.6	20a
113	-21.12	-49.5	-934.34	-1945.89	146.6	283.6	100p	146.6	69.1	20a
114	-21.36	-59.8	-881.27	-1719.31	149.1	289.1	100p	149.1	70.2	20a
115	-21.61	-70.1	-827.14	-1505.61	151.5	294.5	100p	151.5	71.3	20a
116	-21.85	-80.3	-772.03	-1305.03	153.9	299.9	100p	153.9	72.7	20a
117	-22.09	-90.4	-715.97	-1117.81	156.3	305.4	100p	156.3	74.2	20a
118	-22.33	-100.6	-658.95	-944.18	158.8	310.8	100p	158.8	75.7	20a
119	-22.58	-110.7	-600.97	-784.39	161.2	316.2	100p	161.2	77.1	20a
120	-22.82	-120.7	-541.97	-638.65	163.6	321.7	100p	163.6	78.4	20a
121	-23.06	-130.8	-481.91	-507.22	166.0	327.1	100p	166.0	79.4	20a
122	-23.30	-140.8	-420.87	-390.36	168.5	332.5	100p	168.5	80.8	20a
123	-23.55	-150.8	-358.86	-288.30	170.9	338.0	100p	170.9	82.3	20a
124	-23.79	-160.8	-295.90	-201.27	173.3	343.4	100p	173.3	83.7	20a
125	-24.03	-170.8	-231.98	-129.52	175.7	348.8	100p	175.7	85.2	20a
126	-24.27	-180.8	-167.05	-73.26	178.2	354.3	100p	178.2	86.5	20a
127	-24.52	-190.7	-101.06	-32.76	180.6	359.7	100p	180.6	87.6	20a
128	-24.76	-200.7	-34.02	-8.25	183.0	365.1	100p	183.0	88.7	20a
129	-25.00	-210.7	0.00	0.00	185.4	370.5	100p	185.4	90.0	20a

NODAL RESULTS (ULS-high, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.63

					------ LEFT -------			------ RIGHT ------		
Node nr.	Level m	Displ mm	Shear kN	Moment kNm	Water kN/m²	Grain kN/m²	%	Water kN/m²	Grain kN/m²	%
1	6.50	1377.1	350.00	-0.00	0.0	0.0	0	0.0	0.0	0

Project : Hansweert
Part :

NODAL RESULTS (ULS-high, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.63

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
2	6.25	1358.0	350.00	-87.29	0.0	0.0	0	0.0	0.0	0
3	6.00	1338.9	350.00	-174.59	0.0	0.0	0	0.0	0.0	0
4	5.75	1319.9	350.00	-261.88	0.0	0.0	0	0.0	0.0	0
5	5.50	1300.8	350.00	-349.18	0.0	0.0	0	0.0	0.0	0
6	5.25	1281.8	350.00	-436.47	0.0	0.0	0	0.0	0.0	0
7	5.00	1262.7	350.00	-523.76	0.0	0.0	0	0.0	0.0	0
8	4.75	1243.7	350.00	-611.06	0.0	0.0	0	0.0	0.0	0
9	4.50	1224.8	350.00	-698.35	0.0	0.0	0	0.0	0.0	0
10	4.26	1205.8	350.00	-785.65	0.0	0.0	0	0.0	0.0	0
11	4.01	1186.9	350.00	-872.94	0.0	0.0	0	0.0	0.0	0
12	3.76	1168.0	350.00	-960.24	0.0	0.0	0	0.0	0.0	0
13	3.51	1149.1	350.00	-1047.53	0.0	0.0	0	0.0	0.0	0
14	3.26	1130.3	350.00	-1134.82	0.0	0.0	0	0.0	0.0	0
15	3.01	1111.6	350.00	-1222.12	0.0	0.0	0	0.0	0.0	0
16	2.76	1092.8	350.00	-1309.41	0.0	0.0	0	0.0	0.0	0
17	2.51	1074.2	350.00	-1396.71	0.0	0.0	0	0.0	0.0	0
18	2.26	1055.5	350.00	-1484.00	0.0	0.0	0	0.0	0.0	0
19	2.02	1037.3	350.00	-1569.67	0.6	0.0	0	0.6	0.0	0
20	1.77	1019.2	350.00	-1655.35	1.1	0.0	0	1.1	0.0	0
21	1.53	1001.1	350.00	-1741.02	1.7	0.0	0	1.7	0.0	0
22	1.28	983.1	350.00	-1826.70	2.2	0.0	0	2.2	0.0	0
23	1.04	965.1	350.00	-1912.37	2.8	0.0	0	2.8	0.0	0
24	0.79	947.2	350.00	-1998.04	3.3	0.0	0	3.3	0.0	0
25	0.55	929.4	350.00	-2083.72	3.9	0.0	0	3.9	0.0	0
26	0.30	911.6	350.00	-2169.39	4.4	0.0	0	4.4	0.0	0
27	0.06	894.0	350.00	-2255.07	5.0	0.0	0	5.0	0.0	0
28	-0.19	876.4	350.00	-2340.74	5.5	0.0	0	5.5	0.0	0
29	-0.43	858.9	350.00	-2426.41	6.1	0.0	0	6.1	0.0	0
30	-0.68	841.5	350.00	-2512.09	6.6	0.0	0	6.6	0.0	0
31	-0.92	824.2	350.00	-2597.76	7.2	0.0	0	7.2	0.0	0
32	-1.17	807.0	350.00	-2683.43	7.7	0.0	0	7.7	0.0	0
33	-1.41	789.9	350.00	-2769.11	8.3	0.0	0	8.3	0.0	0
34	-1.66	772.9	350.00	-2854.78	8.9	0.0	0	8.9	0.0	0
35	-1.90	756.0	350.00	-2940.46	9.4	0.0	0	9.4	0.0	0
36	-2.15	739.3	350.00	-3026.13	10.0	0.0	0	10.0	0.0	0
37	-2.39	722.6	350.00	-3111.80	10.5	0.0	0	10.5	0.0	0
38	-2.64	706.0	350.00	-3197.48	11.1	0.0	0	11.1	0.0	0
39	-2.88	689.6	350.00	-3283.15	11.6	0.0	0	11.6	0.0	0
40	-3.13	673.3	350.00	-3368.83	12.2	0.0	0	12.2	0.0	0
41	-3.37	657.1	350.00	-3454.50	12.7	0.0	0	12.7	0.0	0
42	-3.61	641.0	350.00	-3540.17	13.3	0.0	0	13.3	0.0	0
43	-3.86	625.1	350.00	-3625.85	13.8	0.0	0	13.8	0.0	0
44	-4.10	609.3	350.00	-3711.52	14.4	0.0	0	14.4	0.0	0
45	-4.35	593.7	350.00	-3797.20	14.9	0.0	0	14.9	0.0	0

Project : Hansweert
Part :

NODAL RESULTS (ULS-high, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.63

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
46	-4.59	578.2	350.00	-3882.87	15.5	0.0	0	15.5	0.0	0
47	-4.84	562.8	350.00	-3968.54	16.0	0.0	0	16.0	0.0	0
48	-5.08	547.6	350.00	-4054.22	16.6	0.0	0	16.6	0.0	0
49	-5.33	532.5	350.00	-4139.89	17.1	0.0	0	17.1	0.0	0
50	-5.57	517.6	350.00	-4225.57	17.7	0.0	0	17.7	0.0	0
51	-5.82	502.9	350.00	-4311.24	18.3	0.0	0	18.3	0.0	0
52	-6.06	488.3	350.00	-4396.91	18.8	0.0	0	18.8	0.0	0
53	-6.31	473.8	350.00	-4482.59	19.4	0.0	0	19.4	0.0	0
54	-6.55	459.6	350.00	-4568.26	19.9	0.0	0	19.9	0.0	0
55	-6.80	445.5	350.00	-4653.93	20.5	0.0	0	20.5	0.0	0
56	-7.04	431.6	350.00	-4739.61	21.0	0.0	0	21.0	0.0	0
57	-7.29	417.8	350.00	-4825.28	21.6	0.0	0	21.6	0.0	0
58	-7.53	404.3	350.00	-4910.96	22.1	0.0	0	22.1	0.0	0
59	-7.78	390.9	350.00	-4996.63	22.7	0.0	0	22.7	0.0	0
60	-8.02	377.7	350.00	-5082.30	23.2	0.0	0	23.2	0.0	0
61	-8.27	364.7	350.00	-5167.98	23.8	0.0	0	23.8	0.0	0
62	-8.51	351.9	350.00	-5253.65	24.3	0.0	0	24.3	0.0	0
63	-8.76	339.3	350.00	-5339.33	24.9	0.0	0	24.9	0.0	0
64	-9.00	326.9	348.28	-5425.00	25.4	0.0	0	25.4	7.0	100p
65	-9.25	314.5	342.67	-5511.68	27.9	0.0	0	27.9	22.5	100p
66	-9.50	302.3	334.91	-5596.97	30.4	0.0	0	30.4	31.2	100p
67	-9.75	290.3	325.03	-5680.32	32.9	0.2	0	32.9	39.9	100p
68	-10.00	278.5	313.05	-5761.22	35.4	1.2	3a	35.4	49.3	100p
69	-10.24	267.0	298.31	-5839.13	37.9	2.2	4a	37.9	61.4	100p
70	-10.49	255.7	280.80	-5913.38	40.4	3.2	5a	40.4	73.6	100p
71	-10.74	244.6	260.66	-5983.27	42.9	4.3	6a	42.9	85.2	100p
72	-10.99	233.8	238.62	-6048.14	45.4	5.3	7a	45.4	93.9	100p
73	-11.24	223.1	219.72	-6107.53	47.8	9.6	13a	47.8	85.3	100p
74	-11.49	212.7	204.60	-6162.46	50.3	14.0	23a	50.3	74.5	100p
75	-11.74	202.5	186.71	-6213.61	52.8	14.2	20a	52.8	85.7	100p
76	-11.99	192.6	165.93	-6260.29	55.3	14.4	18a	55.3	97.5	100p
77	-12.24	182.9	143.47	-6301.77	57.8	15.5	18a	57.8	105.4	100p
78	-12.49	173.4	119.89	-6337.64	60.3	16.6	18a	60.3	111.0	100p
79	-12.74	164.2	95.19	-6367.61	62.8	17.7	18a	62.8	116.6	100p
80	-12.99	155.2	68.98	-6391.41	65.3	18.9	19a	65.3	123.7	100p
81	-13.24	146.5	42.60	-6408.66	67.8	21.1	21a	67.8	126.7	100p
82	-13.49	138.0	16.17	-6419.30	70.3	23.5	23a	70.3	129.2	100p
83	-13.74	129.8	-11.73	-6423.35	72.8	24.7	23a	72.8	136.3	100p
84	-13.99	121.8	-40.65	-6420.41	75.3	25.8	23a	75.3	141.5	100p
85	-14.24	114.1	-72.36	-6410.25	77.8	25.7	21a	77.8	152.6	100p
86	-14.49	106.7	-107.44	-6392.16	80.3	25.6	19a	80.3	165.9	100p
87	-14.74	99.4	-144.22	-6365.30	82.8	26.7	19a	82.8	173.8	100p
88	-14.99	92.5	-182.70	-6329.25	85.3	27.8	19a	85.3	181.7	100p
89	-15.24	85.7	-222.73	-6283.57	87.8	28.9	19a	87.8	189.0	100p

Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

NODAL RESULTS (ULS-high, high wlevel) CONSTR.PHASE: 1 Bouwfase 1

Number iterations: 11 Deviation : 0.63

Node nr.	Level m	Displ mm	Shear kN	Moment kNm	LEFT Water kN/m²	LEFT Grain kN/m²	LEFT %	RIGHT Water kN/m²	RIGHT Grain kN/m²	RIGHT %
90	-15.49	79.3	-263.89	-6227.89	90.3	30.0	19a	90.3	194.6	100p
91	-15.74	73.0	-306.17	-6161.92	92.8	31.1	19a	92.8	200.3	100p
92	-15.99	67.0	-350.12	-6085.38	95.3	32.3	19a	95.3	208.1	100p
93	-16.24	61.3	-395.75	-5997.84	97.8	33.4	19a	97.8	215.9	100p
94	-16.49	55.7	-443.05	-5898.91	100.3	34.5	19a	100.3	223.7	100p
95	-16.74	50.4	-489.45	-5788.15	102.8	37.3	21a	102.8	222.9	100p
96	-16.99	45.4	-534.46	-5665.78	105.3	40.1	23a	105.3	220.1	100p
97	-17.24	40.5	-582.31	-5532.17	107.8	39.6	21a	107.8	233.9	100p
98	-17.48	36.0	-633.48	-5390.96	110.3	38.9	19a	110.3	249.9	100p
99	-17.73	31.7	-686.22	-5237.34	112.7	40.0	19a	112.7	257.5	100p
100	-17.97	27.6	-740.51	-5070.93	115.1	41.1	19a	115.1	265.0	100p
101	-18.21	23.7	-796.26	-4891.36	117.5	42.2	19a	117.5	272.1	100p
102	-18.45	19.9	-853.07	-4698.26	120.0	43.2	19a	120.0	277.5	100p
103	-18.70	16.4	-910.95	-4491.39	122.4	44.3	19a	122.4	283.0	100p
104	-18.94	13.0	-970.39	-4270.49	124.8	45.4	19a	124.8	290.5	100p
105	-19.18	9.7	-1031.38	-4035.17	127.2	46.5	19a	127.2	298.0	100p
106	-19.42	6.6	-1088.17	-3785.06	129.7	47.6	19a	129.7	281.8	92
107	-19.67	3.6	-1123.61	-3521.18	132.1	48.7	19a	132.1	194.8	62
108	-19.91	0.8	-1138.52	-3248.71	134.5	49.7	19a	134.5	111.2	35
109	-20.15	-1.9	-1122.53	-2972.62	136.9	129.1	49	136.9	63.2	20a
110	-20.39	-4.5	-1087.57	-2700.40	139.4	208.8	78	139.4	64.6	20a
111	-20.64	-7.0	-1037.45	-2436.67	141.8	272.8	100p	141.8	66.1	20a
112	-20.88	-9.5	-986.37	-2185.09	144.2	278.2	100p	144.2	67.6	20a
113	-21.12	-11.8	-934.34	-1945.89	146.6	283.6	100p	146.6	69.1	20a
114	-21.36	-14.1	-881.27	-1719.31	149.1	289.1	100p	149.1	70.2	20a
115	-21.61	-16.3	-827.14	-1505.61	151.5	294.5	100p	151.5	71.3	20a
116	-21.85	-18.4	-772.03	-1305.03	153.9	299.9	100p	153.9	72.7	20a
117	-22.09	-20.5	-715.97	-1117.81	156.3	305.4	100p	156.3	74.2	20a
118	-22.33	-22.6	-658.95	-944.18	158.8	310.8	100p	158.8	75.7	20a
119	-22.58	-24.6	-600.97	-784.39	161.2	316.2	100p	161.2	77.1	20a
120	-22.82	-26.6	-541.97	-638.65	163.6	321.7	100p	163.6	78.4	20a
121	-23.06	-28.6	-481.91	-507.22	166.0	327.1	100p	166.0	79.4	20a
122	-23.30	-30.5	-420.87	-390.36	168.5	332.5	100p	168.5	80.8	20a
123	-23.55	-32.5	-358.86	-288.30	170.9	338.0	100p	170.9	82.3	20a
124	-23.79	-34.4	-295.90	-201.27	173.3	343.4	100p	173.3	83.7	20a
125	-24.03	-36.3	-231.98	-129.52	175.7	348.8	100p	175.7	85.2	20a
126	-24.27	-38.3	-167.05	-73.26	178.2	354.3	100p	178.2	86.5	20a
127	-24.52	-40.2	-101.06	-32.76	180.6	359.7	100p	180.6	87.6	20a
128	-24.76	-42.1	-34.02	-8.25	183.0	365.1	100p	183.0	88.7	20a
129	-25.00	-44.0	0.00	0.00	185.4	370.5	100p	185.4	90.0	20a

Technosoft Damwanden release 6.01 (Educational) 24 mei 2018

Project : Hansweert
Part :

MAXIMUM VALUES IN THE WALL **CONSTR.PHASE: 1 Bouwfase 1**

	SLS		Low water level pass. side ULS low		ULS high	
	Value	Level	Value	Level	Value	Level
Displacement [mm]	1131.51	6.50	2258.08	6.50	1377.08	6.50
Shear force [kN]	-1094.06	-18.70	-1138.85	-19.91	-1138.52	-19.91
Moment [kNm]	-7511.80	-12.99	-6423.35	-13.74	-6423.35	-13.74
Axial force [kN]	-2405.68	-25.00	-2004.73	-25.00	-2004.73	-25.00
Stress [N/mm²]	44987725.15	-25.00	38469053.27	-13.74	38469053.27	-13.74

	Low water level pass. side ULS Low		ULS High	
	Value	Level	Value	Level
Displacement [mm]	2258.08	6.50	1377.08	6.50
Shear force [kN]	-1138.85	-19.91	-1138.52	-19.91
Moment [kNm]	-6423.35	-13.74	-6423.35	-13.74
Axial force [kN]	-2004.73	-25.00	-2004.73	-25.00
stress [N/mm²]	38469053.27	-13.74	38469053.27	-13.74

	SLS	-Low water pass. side- ULS low	ULS high	-High water pass. side- ULS low	ULS high
Displacement [1:mm]	63	18	18	18	42

Nr.	Name profile	Shear force [kN]	Max.Moment [kNm]	Max. norm.force [kN]	Max. Stress [N/mm²]
1	HANSWEERT	-1138.85	-7511.80	-2405.68	44987725.1

HORIZONTAL SOIL FORCES (kN) **CONSTR.PHASE: 1 Bouwfase 1**

	SLS		Low water level pass. side ULS low		ULS high	
	Left	Right	Left	Right	Left	Right
Grain force	1473.20	1823.20	1798.78	2148.78	1798.44	2148.44
Water force	1830.43	1830.43	1830.43	1830.43	1830.43	1830.43
Total	3303.63	3653.63	3629.21	3979.21	3628.87	3978.87
Max. pass. grain resist.	3612.84	4456.39	3049.58	3795.21	3049.58	3795.21
[%] mob. grain resist.	40.78	40.91	58.98	56.62	58.97	56.61

	High water level pass. side ULS Low		ULS High	
	Left	Right	Left	Right
Grain force	1798.78	2148.78	1798.44	2148.44
Water force	1830.43	1830.43	1830.43	1830.43
Total	3629.21	3979.21	3628.87	3978.87
Max. pass. grain resistance	3049.58	3795.21	3049.58	3795.21
[%] Mob. grain resistance	58.98	56.62	58.97	56.61

Project : Hansweert
Part :

VERTICAL FORCES (kN/m) CONSTR.PHASE: 1 Bouwfase 1

		Down	Up	
--- SLS ---				
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-2004.73		
Total		-2004.73		
Nett		-2004.73		(Down)
--- ULS low - Low groundw.lv. pass. side ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-2004.73		
Total		-2004.73		
Nett		-2004.73		(Down)
--- ULS high - Low groundw.lv. pass. side ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-2004.73		
Total		-2004.73		
Nett		-2004.73		(Down)
--- ULS low - High groundw.lv. pass. side ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-2004.73		
Total		-2004.73		
Nett		-2004.73		(Down)
--- ULS high - High groundw.lv. pass. side ---		Down	Up	
Design value vertical wall friction active	$F_{a;v;d}$	0.00		
Design value vertical wall friction passive	$F_{p;v;d}$		0.00	
Design value vertical component anchor force	$V_{d;anch.}$			
Sum of vertical point loads	$V_{d;load}$	0.00		
Self weight wall (dry)	$V_{d;s.w.}$	-2004.73		
Total		-2004.73		
Nett		-2004.73		(Down)

NOTE: The vertical equilibrium has to be verified by the user, taking into account the capacities i.r.t. wall friction ($F_{a;v;max;d}$, $F_{p;v;max;d}$) and toe resistance ($R_{b;max;d}$). (See CUR 166, 6th print, part 1, page 70, fig. 5.3)

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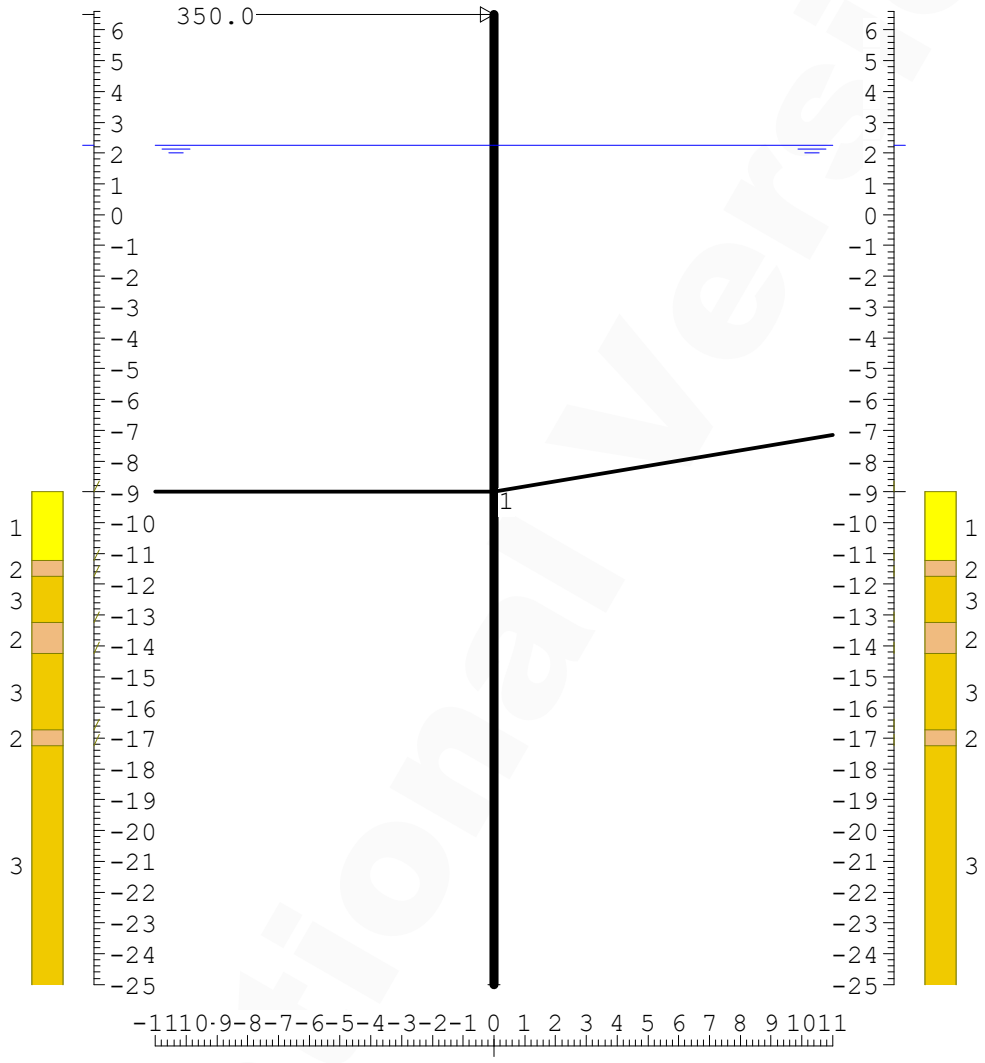
Part :

GRAPHICAL REPRESENTATION INPUT CONSTR.PHASE: 1 Bouwfase 1



Legend

- 1 : Leem - Zwak zandig - Vast
- 2 : Zand - Schoon - Los
- 3 : Klei - Sterk zandig

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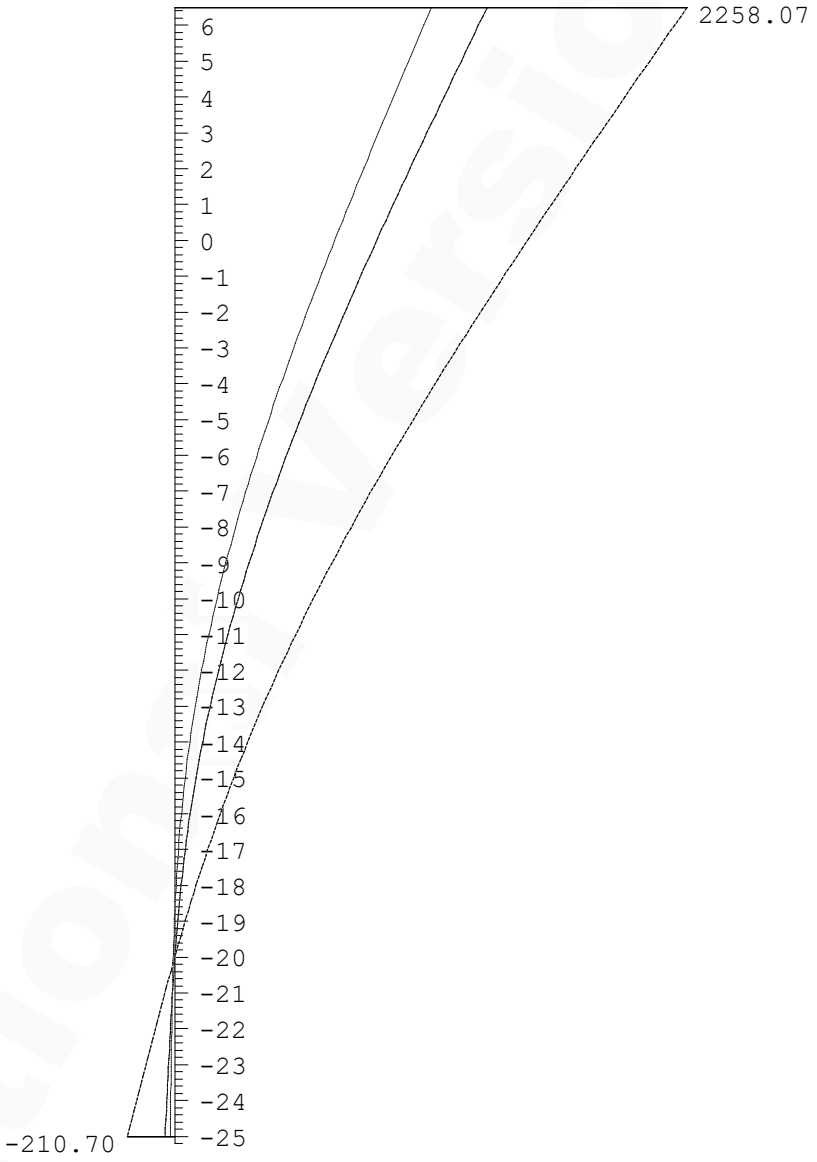
DISPLACEMENTS (mm) **CONSTR.PHASE: 1 Bouwfase 1**



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

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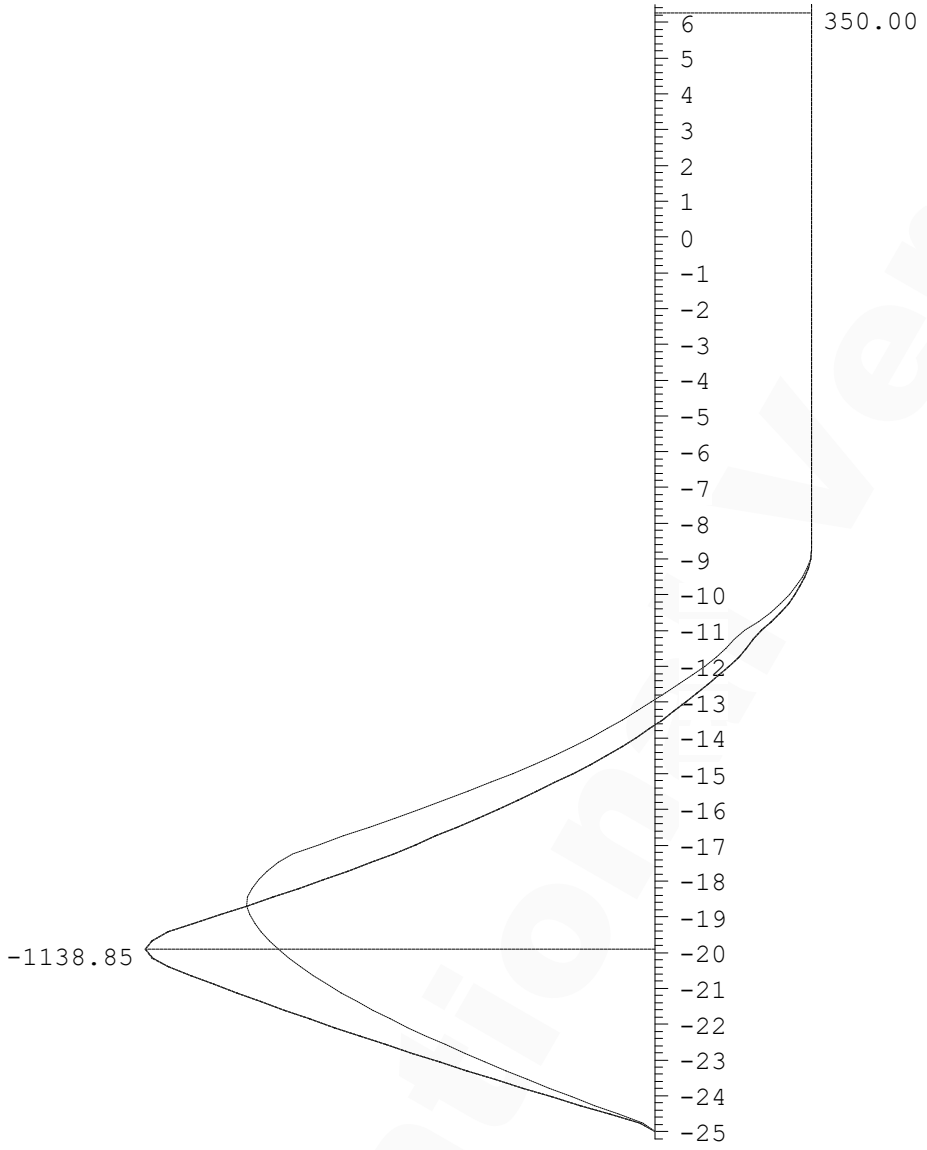
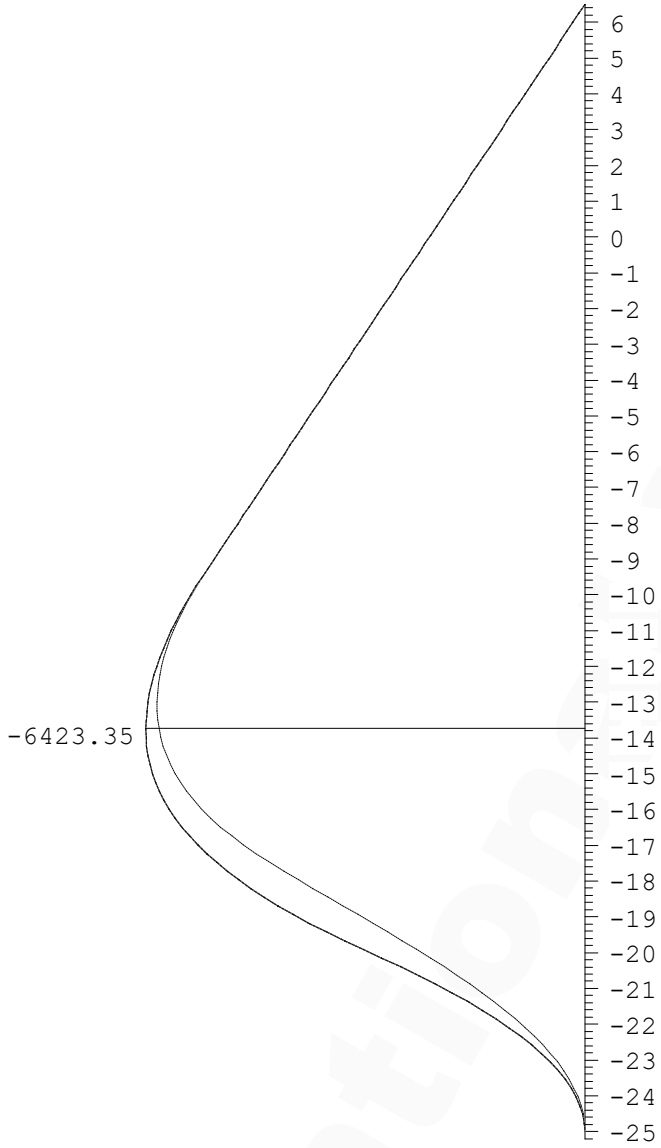
SHEAR FORCES (kN) **CONSTR.PHASE: 1 Bouwfase 1**



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Project : Hansweert
Part :

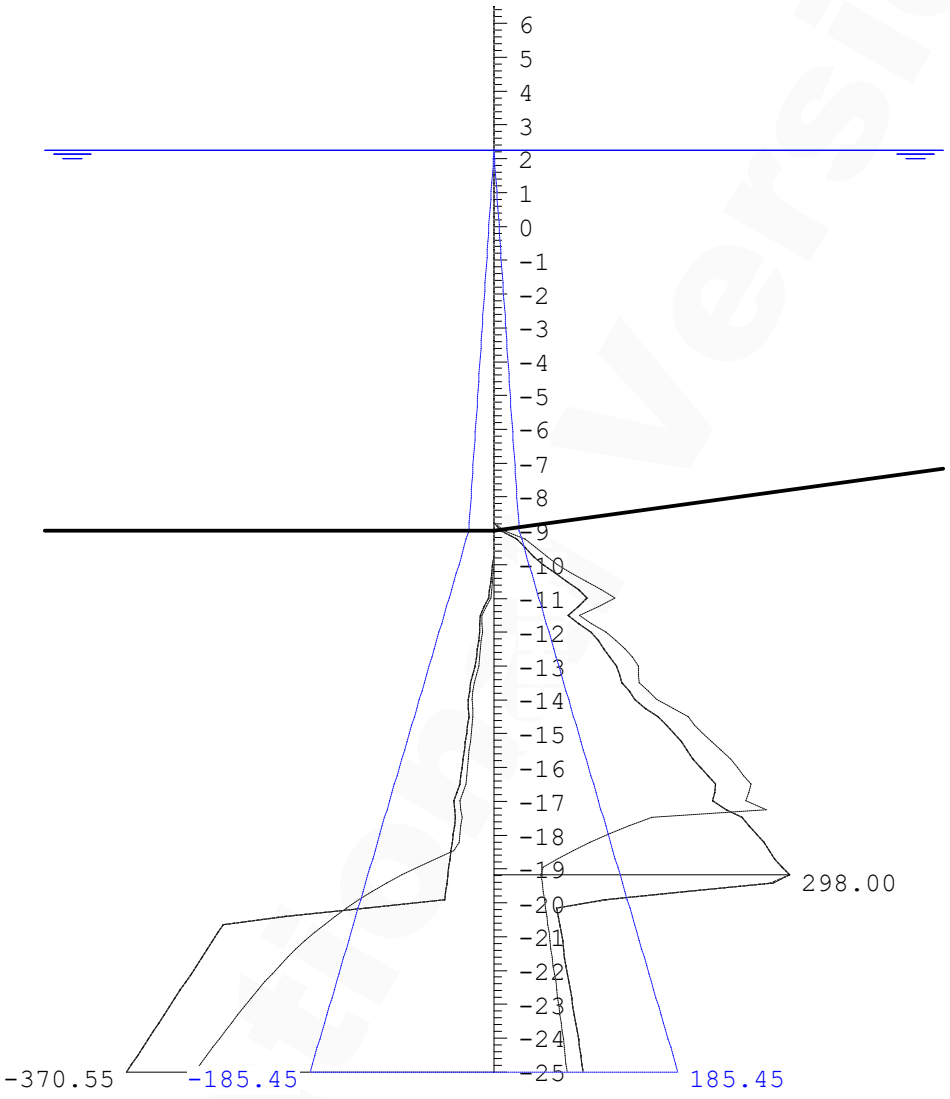
MOMENTS (kNm) **CONSTR.PHASE: 1 Bouwfase 1**



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Project : Hansweert
Part :

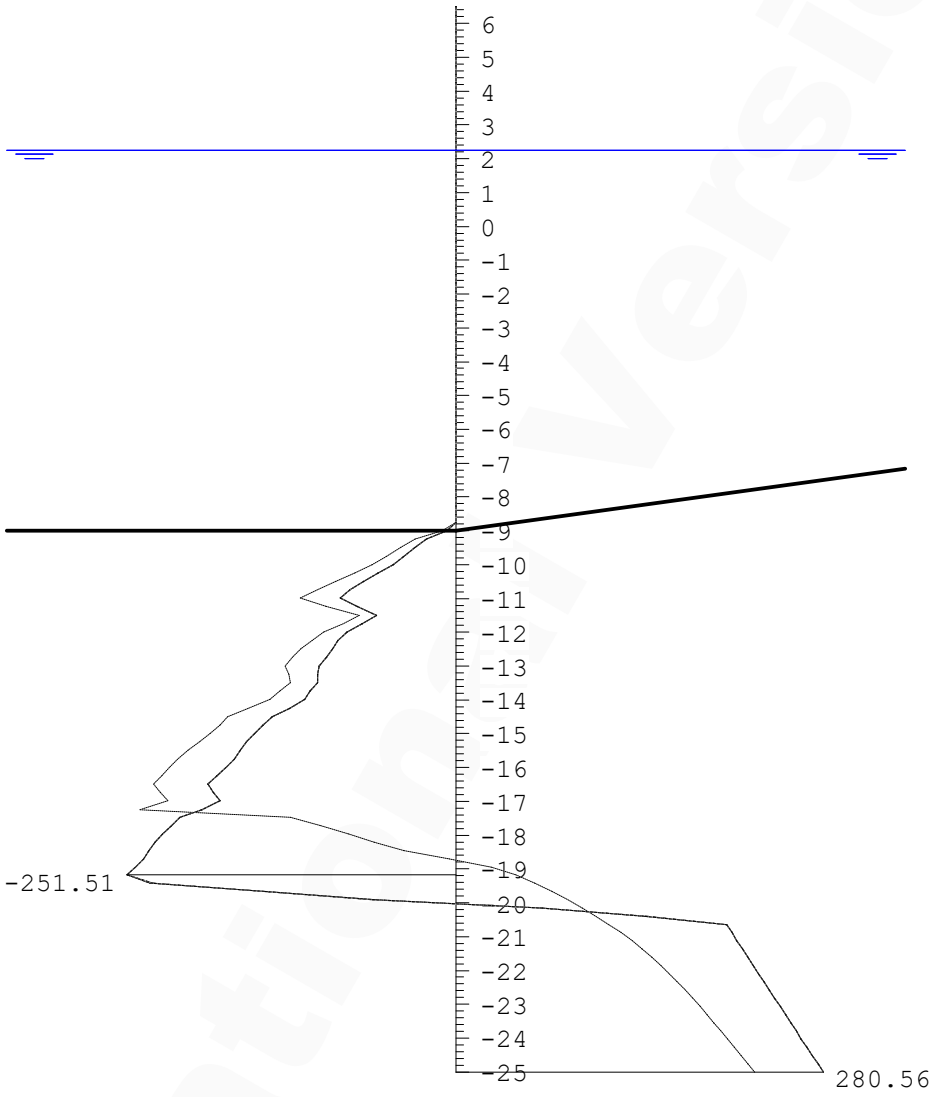
GRAIN- AND WATERPRESSURE (kN/m²) CONSTR.PHASE: 1 Bouwfase 1



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Project : Hansweert
Part :

RESULTING SOIL FORCES (kN/m²) **CONSTR.PHASE: 1 Bouwfase 1**



Legend
SLS
ULS-low, low wlevel
ULS-high, low wlevel
ULS-low, high wlevel
ULS-high, high wlevel

Appendix XII – Digital Appendices

XII.I – RCA Event map Spreadsheet

XII.II – CPT Analysis Spreadsheet

XII.III – D-Foundations Report

XII.IV – MCA Analysis Spreadsheet

XII.V - Geotechnical Analysis Spreadsheet

XII.VI – Pile Capacity Analysis Spreadsheet