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Notitie

Opdrachtgever
LMR

Opgesteld door
B. Hendriksen

Datum
15 oktober 2018

Project
Sea Defence

Kenmerk
AE18043-N01-a

Onderwerp
Toetsing ontwerp aan de NEN3651:2012

Pagina
1 van 8

1. Inleiding

LMR heeft Amsterdam Engineering (AE) gevraagd om de mantelbuis die in project Sea Defence voorzien is voor de elektriciteitskabels van Tennet te beschouwen op basis van de NEN3651:2012. Om dit te kunnen doen heeft AE de D-geo berekening van LMR aangepast voor de lange termijn.

2. Uitgangspunten

Voor de beschouwing zijn de volgende uitgangspunten gehanteerd:

Materiaal	PE100
Diameter	800 mm uitwendig
Wanddikte	72,60 mm (opgave opdrachtgever)
Leverancier	Wavin
Bedrijfsdruk	drukloos
Ontwerptemperatuur	60°C

3. Eisen conform de NEN3651:2012

De NEN3651:2012 stelt eisen aan een HDD die met een primaire waterkering kruist een aantal eisen met betrekking tot:

- Minimale gronddekking in relatie tot de kruin van het waterstaatswerk respectievelijk de waterbodem (paragraaf 9.6.2 van de NEN3651:2012).
- Minimale gronddekking in relatie tot de waterbodem (paragraaf 8.1.6.2 van de NEN3651:2012)
- Minimale gronddekking in relatie tot toelaatbare muddrukken (paragraaf 9.6.2 van de NEN3650:2012).
- Maximale materiaalbelasting tijdens aanleg
- Maximale materiaalbelasting in bedrijf
- Kwel (bijlage D van de NEN3651:2012)

Aangezien de mantelbuis ook nog deels in een gebaggerde sleuf wordt gelegd, dient er ook te worden voldaan aan het verticaal alignement voor een zinker (paragraaf 8.1.6.2 van de NEN3651:2012).

In deze notitie wordt op deze eisen verder ingegaan.

3.1. Minimale gronddekking in relatie tot de kruin van het Waterstaatswerk (HDD)

Op basis van de NEN3651:2012 dient de minimale dekmaat van een leiding ten minste 10 meter te bedragen zowel onder de kruin van het werk als onder de waterbodem.

Ter plaatse van de kruin het waterstaatswerk bedtragt de dekking circa 40 meter, ter plaatse van de waterbodem komt de leiding in de HDD voor het grootste deel op circa 24 meter onder de zeebodem te liggen.

3.2. Minimale gronddekking onder zeebodem

Om van de overgang naar de gebaggerde sleuf mogelijk te maken, wordt er een stuk zeebodem extra uitgebaggerd. Ter plaatse van de overgang van de boring naar een gebaggerde sleuf ligt de HDD lokaal niet geheel op 10 meter. De overgang van diepe ligging, naar ligging in de gebaggerde sleur ligt op circa 270 uit de kustlijn. Gezien de locatie, en het verloop van de leiding wordt vanaf dit punt de leiding benaderd als een leiding onder een vaarweg conform paragraaf 8.1.6.2 van de NEN3651:2012.

Op basis van deze paragraaf dient er ten opzichte van de laagst verwachte bodem 2,0 m aan te worden gehouden voor de ankerzone en 2,0 meter als bufferzone indien er geen bestorting bestand tegen stroming wordt toegepast. Dit geeft een minimale diepte van minimaal 4,0 meter. Hieraan wordt in het ontwerp voldaan.

3.3. Maximale materiaalbelasting tijdens aanleg

De leiding zal middels pipe pushers door de boorgang worden geduwd, en dus niet zoals bij een traditionele HDD worden ingetrokken. Uit de resultaten van de D-geo berekening t.b.v. de aanleg, blijkt dat de maximaal verwachte trekkracht circa 5,0 N/mm^2 bedraagt. Het is de verwachting dat bij het duwen van de leiding de benodigde duwkracht in dezelfde orde grootte zal liggen.

Aangezien bij de trekkracht conform D-geo de materiaalspanning spanning ruimschoots onder de 10,0 N/mm^2 blijft, is het de verwachting dat bij het toepassen van een pipe-pusher de belastingen ook onder de toelaatbare waarde zullen liggen.

Voor de overige belastingcombinaties blijkt dat de leiding op korte termijn ruimschoots voldoet.

	Max allowable stress [N/mm²]	Load combination 1A	Load combination 1B	Load combination 2	Load combination 3	Load combination 4
Sigma_ptest	10.00 (short)	-	-	5.06	-	-
Sigma_py	8.00 (long)	-	-	5.06	-	-
Sigma_axial	10.00 (short)	4.85	4.95	-	-	-
Sigma_axial	8.00 (long)	-	-	-	0.23	7.17
Sigma_tan...	10.00 (short)	-	0.47	-	-	-
Sigma_tan...	8.00 (long)	-	-	-	3.42	7.02

Figuur 1; optredende materiaalbelasting uit D-geo tijdens aanleg

3.4. Maximale materiaalbelasting in bedrijf

Omdat de leiding uiteindelijk alleen als mantelbuis zal worden gebruikt, is ervoor gekozen om de leiding te beschouwen op basis van de resultaten uit de D-Geo berekening. De leiding zal op korte termijn zeker voldoen, echter gezien de degradatie van PE bij verhoogde temperaturen is in samenspraak met de opdrachtgever bepaald met welke eigenschappen er rekening moet worden gehouden op de lange termijn.

Voor het beoordelen van de PE-buis dient er rekening te worden gehouden met:

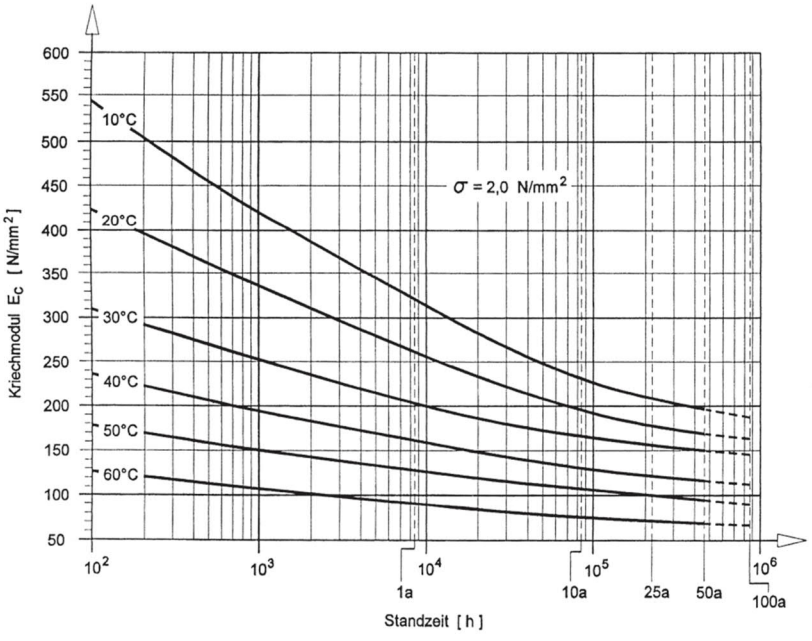
- Axiaalbelasting
- Wandspanning uit bovenbelasting

3.4.1. Te hanteren E-modulus

De axiaal belasting wordt grotendeels bepaald doordat de uitzetting van de PE buis als verhinderd wordt beschouwd. Dit houdt in dat er als gevolg van de temperatuur een axiaalspanning in de buis ontstaat gelijk aan:

$$\sigma_{ax} = \alpha \times \Delta T \times E$$

Voor PE geldt dat de E-modulus sterk afhankelijk is van de temperatuur, en de tijd. Uit het PE handboek van Simona:



Umrechnungsfaktoren für den Spannungsbereich	
σ = 0,5 N/mm²	1,20
σ = 1,0 N/mm²	1,08
σ = 2,0 N/mm²	► 1,00 ◄
σ = 3,0 N/mm²	0,78
σ = 4,0 N/mm²	0,70
σ = 5,0 N/mm²	0,60

E - Modul [N/mm²]		
Spalte	1	2
Temperatur	E_{KZ} 10^{-1} h	E_C 100 min
≤ 10°C	1100	850
20°C	800	630
30°C	550	450
40°C	390	325
50°C	270	230
60°C	190	160

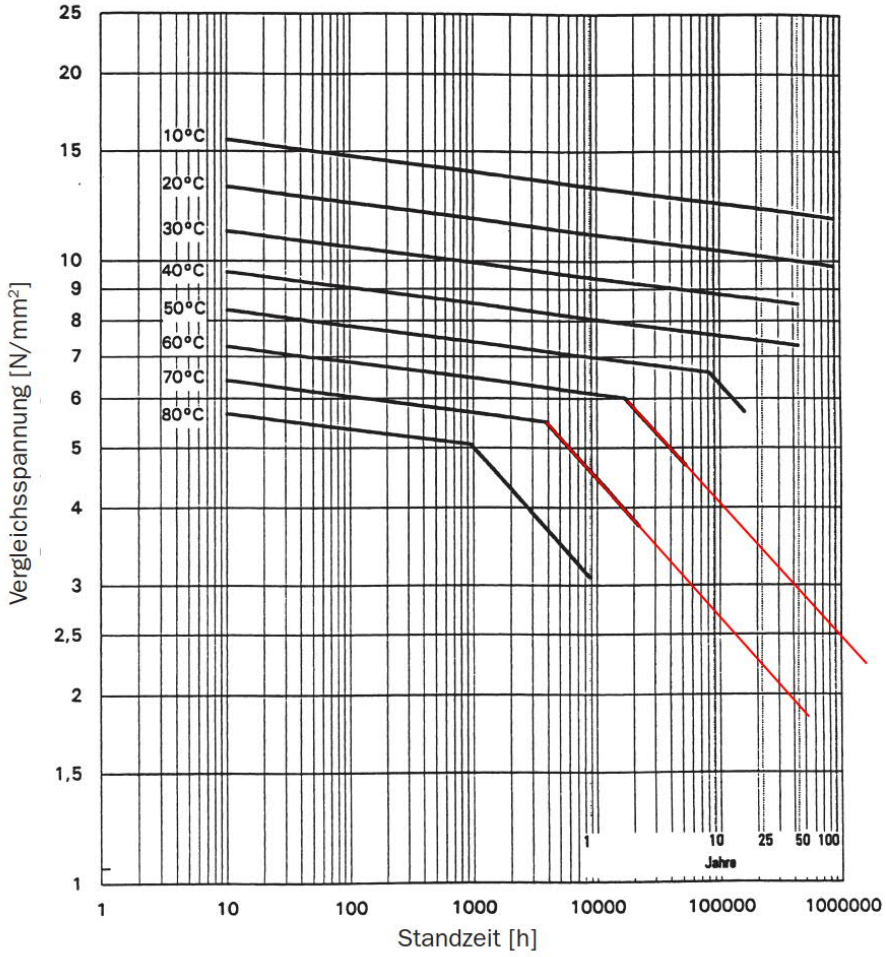
Hinweis :
Werte in Spalte 1 aus DVS 2205-2, Tabelle 6.
Die Angaben in Spalte 2 stellen extrapolierte Werte zwischen E_{KZ} (10^{-1} h) und E_{LZ} (1 Jahr) nach DVS 2205-1 dar.

Figuur 2; E-modulus als functie van tijd en temperatuur, uit PE handboek van Simona

Om rekening met het gedrag van PE te kunnen houden, is er daarom voor gekozen om in D-Geo de bedrijfsdruk terug te brengen naar 0 bar (mantelbuis) en te rekenen met een lange duur E-modulus van circa 70 N/mm^2. Hiermee wordt de axiaalspanning op lange duur correct bepaald, en wordt ook de mogelijke deflectie niet onderschat.

3.4.2. Toelaatbare materiaalspanning op lange termijn

De PE-buis zal als gevolg van de temperatuur van de elektrakabels opwarmten. Uit afstemming met de opdrachtgever blijkt dat het de verwachting is dat de PE buis niet warmer dan 60 graden zal worden. In afstemming met de leverancier is besproken dat de regressielijnen uit het handboek voor Simona ook voor de Wavin leidingen kunnen worden gebruikt.



Figuur 3: MRS waarde van PE functie van tijd en temperatuur, uit PE handboek van Simona

De rode lijnen zijn de extrapolatie voor de toelaatbare spanning bij 60 respectievelijk 70 graden. Bij een levensduur van 40 jaar blijkt dat de leiding nog een vergelijkspanning kan opnemen van circa 3,0 N/mm^2 wanneer de leiding continu op 60 ^{o}C wordt bedreven. Voor de toetsing van de leiding is daarom een MRS waarde van 3,0 aangenomen voor de lange duur. Hierover is een factor 1,25 genomen conform de NEN3650:2012. De te hanteren toetswaarde komt hiermee op 2,4 N/mm^2 te liggen.

3.4.3. Toetsing BC3 en BC4 (bedrijfssituatie)

	Max allowable stress [N/mm²]	Load combination 1A	Load combination 1B	Load combination 2	Load combination 3	Load combination 4
Sigma_ptest	10,00 (short)	-	-	0,00	-	-
Sigma_py	2,40 (long)	-	-	0,00	-	-
Sigma_axial	10,00 (short)	4,85	2,12	-	-	-
Sigma_axial	2,40 (long)	-	-	-	0,05	0,93
Sigma_tan...	10,00 (short)	-	0,52	-	-	-
Sigma_tan...	2,40 (long)	-	-	-	3,33	3,33

Figuur 4; spanningen uit D-geo op basis van lange termijn eigenschappen van PE (geen inwendige druk)

Om BC3 te toetsen, is in D-Geo de inwendige druk in bedrijf op 0 gezet. Hiermee wordt de temperatuurbelasting meegenomen in de uitgevoerde berekeningen. Tevens is in de berekening aangegeven dat de leiding tijdens bedrijf altijd geheel gevuld zal zijn. Uit de resultaten blijkt dat de tangentiële spanning niet voldoet.

Sigma_qn = k·qn·(rg/Ww)·Do	=	4,98	N/mm²

Figuur 5; berekening wandspanning in D-geo, pagina 28

In figuur 5 is:

Sigma_qn	Materiaalspanning als gevolg van buiging van de buiswand
k	momentcoëfficient uit tabel D.1: k= 0,138
qn	bovenbelasting: 109 kN/m² = 0,109 N/mm² (uit de d-geo berekening, pagina 26. Inclusief een factor 1,1 op het gewicht van de grond)
rg	gemiddelde straal van de leiding: 363,7 mm
Ww	Wandweerstandsmoment: $\frac{d_n^2}{6} = \frac{72{,}6^2}{6}$ = 878,46 mm³/mm
d_n	Wanddikte
Do	Uitwendige diameter, 800 mm

3.4.3.1. Controle spanning uit D-geo

Invullen van bovengenoemde waarden geeft een materiaalspanning van 4,98 N/mm². Hierbij dient de indirect overgedragen belasting (volgens D-geo 0,14 N/mm²) nog bij op te worden geteld. Dit geeft totaal 5,12 N/mm². Omdat de gevonden spanning het gevolg is van wandbuiging betreft, dient dit te worden gecorrigeerd met de factor voor buigtrek (0,65). Hiermee komt de tangentiële spanning op 3,3 N/mm².

3.4.3.2. Bepalen wandspanning met neutrale steundruk

In Dgeo wordt echter de neutrale steundruk niet meegenomen.Voor het bepalen van de wandspanning uit bovenbelasting de neutrale steundruk in de boring worden meegenomen conform paragraaf C.4.8.6 van de NEN3650:2012-1. Dit houdt in dat de horizontale steundruk gelijk is aan:

$$Q_{h,r} = \{(1 - \sin\varphi_1) \times Q_{n,r}\} \times \sin 60° \text{ (contacthoek 120°)}$$

Figuur 6 horizontale neutrale steundruk in de boring conform C.4.8.6.

Conform de NEN3650:2012 mag voor bentoniet worden aangehouden dat φ_1 = 25 $graden$. Invullen geeft $q_h = 0{,}5 * q_n$. Voor het meenemen van steundruk kan k_{steun} worden aangenomen als -0,14 (zie tabel D.1 van de NEN3650-1:2003). Analoog aan de formule in figuur 5, geeft invullen:

$$\sigma_{steun} = k_{steun} \times q_h \times {}^{r_g}/_{W_W} \times Do$$

Let op, σ_{steun} is dus negatief (k_{steun}=-0,14). Toevoegen van de steundruk in de formule uit figuur 5 geeft:

$$\sigma_{totaal} = (k_v \times q_n + k_{steun} \times q_h) \times {}^{r_g}/_{W_W} \times Do$$

Dit geeft voor de spanning in het materiaal:

$$\sigma_{totaal} = (0{,}138 \times 0{,}108 - 0{,}14 \times 0{,}5 \times 0{,}108) \times {}^{363{,}7}/_{878{,}46} \times 800 = 2{,}4\ N/mm^2$$

Deze waarde dient nog te worden vermeerderd met de indirect overgedragen bovenbelasting (volgens D-geo 0,14 N/mm^2). Dit geeft 2,54 N/mm^2. Deze spanning komt uit pure buiging, er is dus sprake buigtrek. De gevonden materiaalspanning dient daarom ook nog met 0,65 (zie paragraaf 3.4.3.1) te worden gecorrigeerd. Dit geeft een tangentiele spanning van 1,7 N/mm^2.

tabel 1; berekeningsresultaten, reken houdend met neutrale steundruk

	BC3	BC4	Toelaatbaar	voldoet
σ_{axiaal}	0,05 N/mm^2	0,93 N/mm^2	2,4 N/mm^2	Ja
$\sigma_{tangentieel}$	1,7 N/mm^2	1,7 N/mm^2	2,4 N/mm^2	Ja

Indien er rekening wordt gehouden met de neutrale steundruk dan voldoet de leiding op de lange termijn aan de verwachte belastingen.

3.5. Kwel / erosie

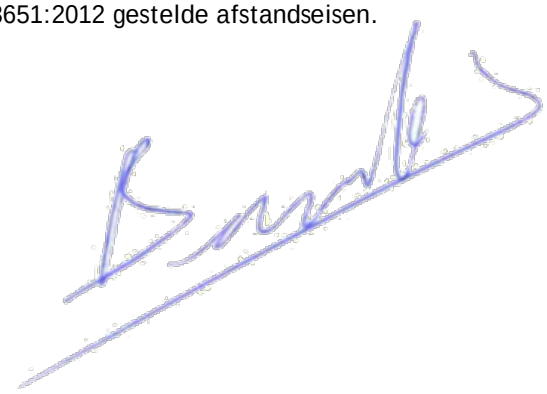
In de voorstudie die uitgevoerd is door Witteveen en Bos is aangegeven dat men een risico ziet op erosie langs de leiding als gevolg van water dat uit de dieper zandlaag naar de oppervlakte stroomt. Echter blijkt uit de nadere beschouwing van Deltares dat de stijghoogte in het zandpakket in de eerste watervoerende laag onder de freatische grondwaterstand ligt, en er geen sprake is van een opwaartse grondwaterstroming. Zie paragraaf 3.4.4 van rapport Beoordeling stabiliteit van de zeewering te Maasvlakte t.g.v. de aanleg van mantelbuizen voor de elektriciteitskabels.

Wel wordt er met de boring een nagenoeg open verbinding gemaakt (diepte van het boorgat zit uiteindelijk op circa 6 meter diep) tussen de twee zijden van de zeewering. Gezien de open verbinding tussen de zee en het Yangtzekanaal zal de freatische grondwaterstand nagenoeg gelijk zijn aan de zeewaterstand.

Indien er wel rekening dient te worden gehouden met een stijghoogte verschil, dan dient er een kwelscherm te worden aangebracht, of een deel van het boorgat te worden gegrout.

4. Conclusie

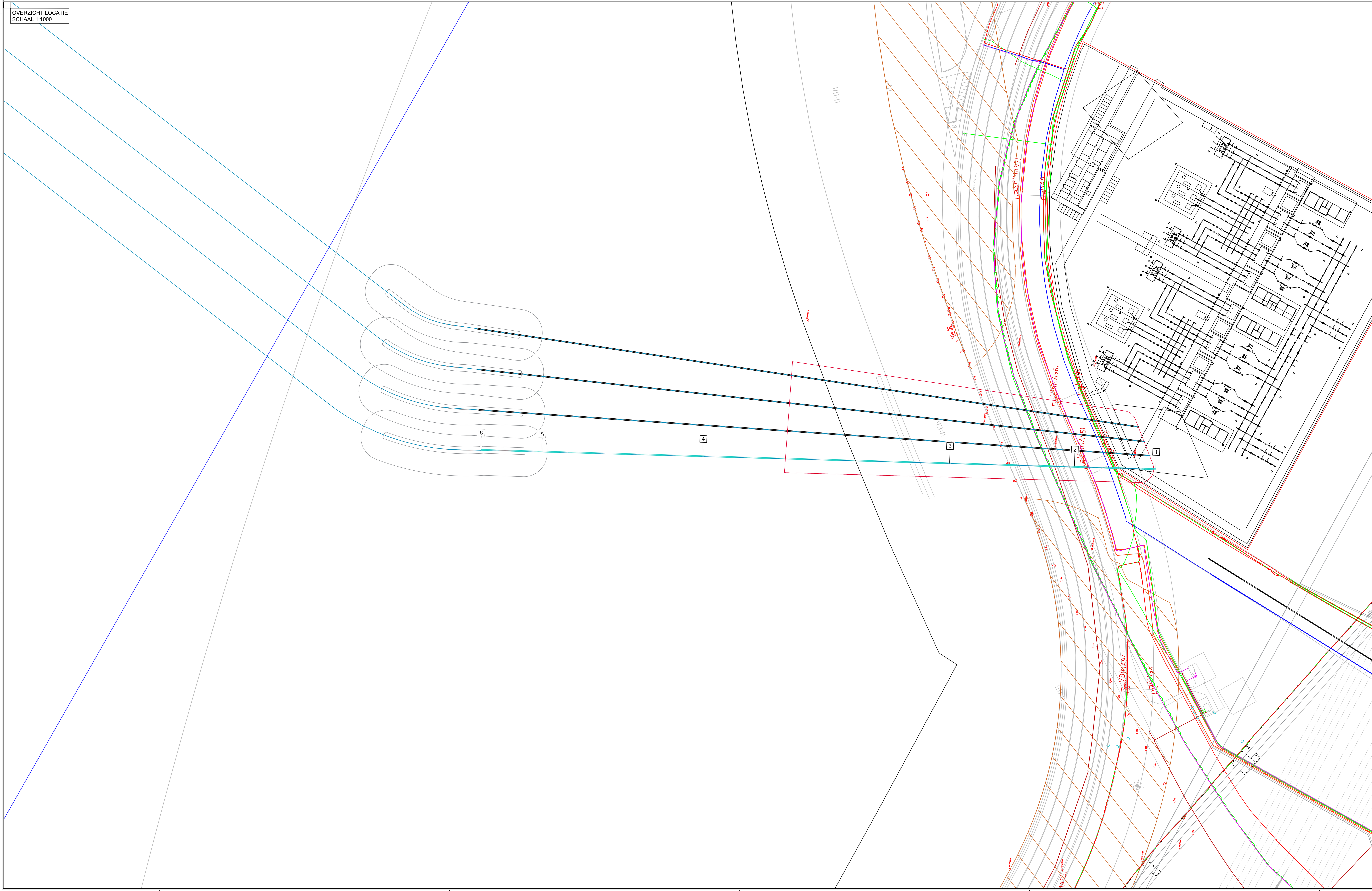
Op basis van de gevonden resultaten wordt geconcludeerd dat de mantelbuis op zowel korte duur als lange duur sterktetechnisch aan de gestelde eisen voldoet. Tevens voldoet het ontwerp aan de in de NEN3651:2012 gestelde afstandseisen.



Bijlage 1, Tekening

DWARSPROFIEL
SCHAAL 1:500

OVERZICHT LOCATIE
SCHAAL 1:1000



	COÖRDINATENLIJST	X	Y	Z(NAP)
1	Intrede	61417.94	444834.65	5.50
2	Begin Verticale Bocht	61412.39	444893.32	-11.40
3	Einde Verticale Bocht	61403.98	444983.37	-26.40
4	Begin Verticale Bocht	61387.28	445161.36	-35.80
5	Einde Verticale Bocht	61376.39	445277.44	-23.90
6	Uittrede	61417.94	444834.65	-12.90

- Lengte boring 496.3 mtr
- Buisdiameter(s) 800 mm
- Verwachte trekkracht N.T.B. KN

KLIC NUMMER: 16O008609
ONTVANGST DATUM: 09-02-2016

JUISTE LIGGING VAN KABELS EN LEIDINGEN DIENT TIJDENS DE UITVOERING BEPAALD TE WORDEN DOOR MIDDEL VAN PROEFSLEUVEN

Sondering
Mechanische boring

SPIEGELLASSEN VOLGENS NEN7200

DOORSNEDE
SCHAAL 1:25

TE BOREN BUIS
1x Ø800mm PE100 SDR11

- Laagspanningskabel(s)
- Middenspanningskabel(s)
- Hoogspanningskabel(s)
- Gasleiding(en) lage druk
- Gasleiding(en) hoge druk
- Datatransport
- Waterleiding(en)
- Vrij verval riolering
- Persriool
- Warmte transport
- Gevaarlijke buisleiding(en)

Wijz	Omschrijving	Getekend	Gecontroleerd	Akkoord	
7	Wijzigingen verwerkt	TM	BV	DV	27-02-2018
6	Dwarsprofiel aangepast	TM	BV	DV	20-02-2018
5	Opmerkingen verwerkt	TM	BV	DV	18-12-2017
4	Boorlijnen aangepast	TM	BV	DV	18-08-2017
3	Boorlijnen aangepast	TM	BV	DV	10-04-2017
2	Wijzigingen verwerkt	TM	BV	DV	03-04-2017
1	Eerste uitgave	TM	BV	DV	29-03-2017

AKKOORD ENGINEERING	AKKOORD UITVOERING	AKKOORD EINDCONTROLE

Energy Solutions B.V.
Ampereweg 27, 2627 BG Delft
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TenneT Taking power further

Project: 220KV SEA CABLES AND HDD – HOLLANDSE KUST ZUID

Titel: HORIZONTAL DIRECTIONAL DRILLING (HDD) SEA DEFENSE
OVERZICHT EN DWARSPROFIEL
ONL–TTB–04086

Onderdeel: HORIZONTAAL GESTUURDE BORING

Opdrachtgever: TenneT TSO B.V.

Status: FOR TENDER

Tekenaar	Gecontroleerd	Goedgekeurd	Datum uitgifte	Tekeningnummer
TM	BV	TK	29–03–2017	1003–0116–01–BT MT

Blad	Aantal	Schaal	Formaat	Documenttype	Bestandsnummer
1	1	Div	A0	TEKENING	1003–0116–01

Bijlage 2, D-geo berekening aanleg

Report for D-Geo Pipeline 18.2

Model : Horizontal Directional Drilling with calculations for settlement
Developed by Deltares

Company:	<Not Registered> <Not Registered>
Date of report:	15-10-2018
Time of report:	09:06:42
Report with version:	18.2.2.20951
Calculated with version:	18.2.2.20951
File name:	G:\..\718535-HKZ-8-20181001-Mud Pressure Calculation
Project identification:	HDD HKZ Mud Pressure Calculation

1 Table of Contents

2 Input Data

2.1 Model Used

Model Used : Horizontal Directional Drilling with calculations for settlement

2.2 Layer Boundaries

Boundary number	Co-ordinates [m]				
24 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
24 - Y -	4,355	4,915	4,796	5,011	5,027
24 - X -	0,000	3,217	6,433	9,650	12,866
24 - Y -	4,967	4,879	4,829	4,815	4,803
24 - X -	16,083	19,299	22,516	25,733	28,949
24 - Y -	4,787	4,706	4,738	4,654	4,657
24 - X -	32,166	35,382	38,599	41,815	45,032
24 - Y -	4,650	4,700	4,706	4,755	4,938
24 - X -	48,248	51,465	54,681	57,898	61,115
24 - Y -	4,916	4,792	4,771	4,816	4,877
24 - X -	64,331	67,548	70,764	73,981	77,197
24 - Y -	4,842	4,883	4,896	4,652	4,805
24 - X -	80,414	83,630	86,847	90,064	93,280
24 - Y -	4,875	4,931	4,977	5,034	5,012
24 - X -	96,497	99,713	102,930	106,146	109,363
24 - Y -	5,006	4,294	4,542	5,874	6,799
24 - X -	112,579	115,796	119,013	122,229	125,446
24 - Y -	7,851	8,870	9,775	10,881	11,793
24 - X -	128,662	131,867	131,879	135,095	138,312
24 - Y -	12,694	13,500	13,503	14,299	14,536
24 - X -	141,529	144,745	145,835	147,962	151,178
24 - Y -	14,451	13,723	13,500	13,065	12,303
24 - X -	154,395	155,497	157,611	160,828	164,044
24 - Y -	11,577	11,271	10,683	9,937	9,280
24 - X -	165,027	167,261	170,478	173,500	176,027
24 - Y -	9,000	8,364	8,022	8,012	8,000
24 - X -	199,073	203,073	207,073	213,795	219,084
24 - Y -	2,000	2,010	2,006	-0,236	-2,000
24 - X -	235,573	243,573	244,021	244,728	260,000
24 - Y -	-7,500	-7,500	-7,799	-8,270	-8,270
24 - X -	269,590	279,180	288,770	298,361	307,951
24 - Y -	-8,241	-8,148	-8,156	-8,212	-8,333
24 - X -	317,541	327,131	336,721	346,311	355,901
24 - Y -	-8,423	-8,641	-8,882	-9,186	-9,477
24 - X -	365,491	375,082	384,672	394,262	403,852
24 - Y -	-9,819	-10,168	-10,499	-10,821	-11,141
24 - X -	413,442	425,000	443,477	456,000	473,000
24 - Y -	-11,488	-12,500	-16,791	-19,700	-19,700
24 - X -	481,000	600,000			
24 - Y -	-17,700	-17,700			
23 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
23 - Y -	4,355	4,915	4,796	5,011	5,027
23 - X -	0,000	3,217	6,433	9,650	12,866
23 - Y -	4,967	4,879	4,829	4,815	4,803
23 - X -	16,083	19,299	22,516	25,733	28,949
23 - Y -	4,787	4,706	4,738	4,654	4,657
23 - X -	32,166	35,382	38,599	41,815	45,032
23 - Y -	4,650	4,700	4,706	4,755	4,938
23 - X -	48,248	51,465	54,681	57,898	61,115
23 - Y -	4,916	4,792	4,771	4,816	4,877
23 - X -	64,331	67,548	70,764	73,981	77,197
23 - Y -	4,842	4,883	4,896	4,652	4,805
23 - X -	80,414	83,630	86,847	90,064	93,280
23 - Y -	4,875	4,931	4,977	5,034	5,012

Boundary number	Co-ordinates [m]				
23 - X -	96,497	96,497	99,713	102,930	103,996
23 - Y -	5,006	4,400	3,700	3,900	4,354
23 - X -	106,146	109,363	112,579	115,796	119,013
23 - Y -	5,270	6,200	7,250	8,270	9,170
23 - X -	122,229	125,446	128,662	131,879	135,095
23 - Y -	10,280	11,200	12,090	12,900	13,700
23 - X -	138,312	141,529	144,745	145,835	147,962
23 - Y -	13,940	13,600	12,900	12,700	12,200
23 - X -	151,178	154,395	155,497	157,611	160,828
23 - Y -	11,500	10,700	10,426	9,900	9,140
23 - X -	164,044	165,027	165,027	165,027	167,261
23 - Y -	8,500	8,200	8,600	9,000	8,364
23 - X -	170,478	173,500	176,027	199,073	203,073
23 - Y -	8,022	8,012	8,000	2,000	2,010
23 - X -	207,073	213,795	219,084	235,573	243,573
23 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
23 - X -	244,021	244,728	260,000	269,590	279,180
23 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
23 - X -	288,770	298,361	307,951	317,541	327,131
23 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
23 - X -	336,721	346,311	355,901	365,491	375,082
23 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
23 - X -	384,672	394,262	403,852	413,442	425,000
23 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
23 - X -	443,477	456,000	473,000	481,000	600,000
23 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
22 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
22 - Y -	4,355	4,915	4,796	5,011	5,027
22 - X -	0,000	3,217	6,433	9,650	12,866
22 - Y -	4,967	4,879	4,829	4,815	4,803
22 - X -	16,083	19,299	22,516	25,733	28,949
22 - Y -	4,787	4,706	4,738	4,654	4,657
22 - X -	32,166	35,382	38,599	41,815	45,032
22 - Y -	4,650	4,700	4,706	4,755	4,938
22 - X -	48,248	51,465	54,681	57,898	61,115
22 - Y -	4,916	4,792	4,771	4,816	4,877
22 - X -	64,331	67,548	70,764	73,981	77,197
22 - Y -	4,842	4,883	4,896	4,652	4,805
22 - X -	80,414	83,630	86,847	90,064	93,280
22 - Y -	4,875	4,931	4,977	5,034	5,012
22 - X -	96,497	96,497	99,713	102,930	103,996
22 - Y -	5,006	4,400	3,700	3,900	4,354
22 - X -	106,146	109,363	112,579	115,796	119,013
22 - Y -	5,270	6,200	7,250	8,270	9,170
22 - X -	122,229	125,446	128,662	131,879	135,095
22 - Y -	10,280	11,200	12,090	12,900	13,700
22 - X -	138,312	141,529	144,745	145,835	147,962
22 - Y -	13,940	13,600	12,900	12,700	12,200
22 - X -	151,178	154,395	155,497	157,611	160,828
22 - Y -	11,500	10,700	10,426	9,900	9,140
22 - X -	164,044	165,027	165,027	167,261	170,478
22 - Y -	8,500	8,200	8,600	8,000	7,600
22 - X -	173,500	173,500	176,027	199,073	203,073
22 - Y -	7,600	8,012	8,000	2,000	2,010
22 - X -	207,073	213,795	219,084	235,573	243,573
22 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
22 - X -	244,021	244,728	260,000	269,590	279,180
22 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
22 - X -	288,770	298,361	307,951	317,541	327,131
22 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
22 - X -	336,721	346,311	355,901	365,491	375,082
22 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
22 - X -	384,672	394,262	403,852	413,442	425,000
22 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
22 - X -	443,477	456,000	473,000	481,000	600,000

Boundary number	Co-ordinates [m]				
22 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
21 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
21 - Y -	4,355	4,915	4,796	5,011	5,027
21 - X -	0,000	3,217	6,433	9,650	12,866
21 - Y -	4,967	4,879	4,829	4,815	4,803
21 - X -	16,083	19,299	22,516	25,733	28,949
21 - Y -	4,787	4,706	4,738	4,654	4,657
21 - X -	32,166	35,382	38,599	41,815	45,032
21 - Y -	4,650	4,700	4,706	4,755	4,938
21 - X -	48,248	51,465	54,681	57,898	61,115
21 - Y -	4,916	4,792	4,771	4,816	4,877
21 - X -	64,331	67,548	70,764	73,981	77,197
21 - Y -	4,842	4,883	4,896	4,652	4,805
21 - X -	80,414	83,630	86,847	90,064	93,280
21 - Y -	4,875	4,931	4,977	5,034	5,012
21 - X -	96,497	96,497	99,713	102,930	103,996
21 - Y -	5,006	4,400	3,700	3,900	4,354
21 - X -	106,146	109,363	112,579	115,796	119,013
21 - Y -	5,270	6,200	7,250	8,270	9,170
21 - X -	122,229	125,446	128,662	131,879	135,095
21 - Y -	10,280	11,200	12,090	12,900	13,700
21 - X -	138,312	141,529	144,745	145,835	147,962
21 - Y -	13,940	13,600	12,900	12,700	12,200
21 - X -	151,178	154,395	155,497	157,611	160,828
21 - Y -	11,500	10,700	10,426	9,900	9,140
21 - X -	164,044	165,027	165,027	167,261	170,478
21 - Y -	8,500	8,200	8,600	8,000	7,600
21 - X -	173,500	175,000	176,027	199,073	203,073
21 - Y -	7,600	7,000	8,000	2,000	2,010
21 - X -	207,073	213,795	219,084	235,573	243,573
21 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
21 - X -	244,021	244,728	260,000	269,590	279,180
21 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
21 - X -	288,770	298,361	307,951	317,541	327,131
21 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
21 - X -	336,721	346,311	355,901	365,491	375,082
21 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
21 - X -	384,672	394,262	403,852	413,442	425,000
21 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
21 - X -	443,477	456,000	473,000	481,000	600,000
21 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
20 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
20 - Y -	4,355	4,915	4,796	5,011	5,027
20 - X -	0,000	3,217	6,433	9,650	12,866
20 - Y -	4,967	4,879	4,829	4,815	4,803
20 - X -	16,083	19,299	22,516	25,733	28,949
20 - Y -	4,787	4,706	4,738	4,654	4,657
20 - X -	32,166	35,382	38,599	41,815	45,032
20 - Y -	4,650	4,700	4,706	4,755	4,938
20 - X -	48,248	51,465	54,681	57,898	61,115
20 - Y -	4,916	4,792	4,771	4,816	4,877
20 - X -	64,331	67,548	70,764	73,981	77,197
20 - Y -	4,842	4,883	4,896	4,652	4,805
20 - X -	80,414	83,630	86,847	90,064	93,280
20 - Y -	4,875	4,931	4,977	5,034	5,012
20 - X -	96,497	96,497	99,713	102,930	103,996
20 - Y -	5,006	4,400	3,700	3,900	4,354
20 - X -	106,146	109,363	112,579	115,796	119,013
20 - Y -	5,270	6,200	7,250	8,270	9,170
20 - X -	122,229	125,446	128,662	131,879	135,095
20 - Y -	10,280	11,200	12,090	12,900	13,700
20 - X -	138,312	141,529	144,745	145,835	147,962
20 - Y -	13,940	13,600	12,900	12,700	12,200
20 - X -	151,178	154,395	155,497	157,611	160,828
20 - Y -	11,500	10,700	10,426	9,900	9,140

Boundary number	Co-ordinates [m]				
20 - X -	164,044	165,027	165,027	167,261	170,478
20 - Y -	8,500	8,200	8,600	8,000	7,600
20 - X -	173,500	175,000	175,058	196,811	197,348
20 - Y -	7,600	7,000	6,710	0,982	0,850
20 - X -	199,073	203,073	207,073	213,795	219,084
20 - Y -	2,000	2,010	2,006	-0,236	-2,000
20 - X -	235,573	243,573	244,021	244,728	260,000
20 - Y -	-7,500	-7,500	-7,799	-8,270	-8,270
20 - X -	269,590	279,180	288,770	298,361	307,951
20 - Y -	-8,241	-8,148	-8,156	-8,212	-8,333
20 - X -	317,541	327,131	336,721	346,311	355,901
20 - Y -	-8,423	-8,641	-8,882	-9,186	-9,477
20 - X -	365,491	375,082	384,672	394,262	403,852
20 - Y -	-9,819	-10,168	-10,499	-10,821	-11,141
20 - X -	413,442	425,000	443,477	456,000	473,000
20 - Y -	-11,488	-12,500	-16,791	-19,700	-19,700
20 - X -	481,000	600,000			
20 - Y -	-17,700	-17,700			
19 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
19 - Y -	4,355	4,915	4,796	5,011	5,027
19 - X -	0,000	3,217	6,433	9,650	12,866
19 - Y -	4,967	4,879	4,829	4,815	4,803
19 - X -	16,083	19,299	22,516	25,733	28,949
19 - Y -	4,787	4,706	4,738	4,654	4,657
19 - X -	32,166	35,382	38,599	41,815	45,032
19 - Y -	4,650	4,700	4,706	4,755	4,938
19 - X -	48,248	51,465	54,681	57,898	61,115
19 - Y -	4,916	4,792	4,771	4,816	4,877
19 - X -	64,331	67,548	70,764	73,981	77,197
19 - Y -	4,842	4,883	4,896	4,652	4,805
19 - X -	80,414	83,630	86,847	90,064	93,280
19 - Y -	4,875	4,931	4,977	5,034	5,012
19 - X -	96,497	96,497	99,713	102,930	103,996
19 - Y -	5,006	4,400	3,700	3,900	4,354
19 - X -	140,000	193,073	197,348	199,073	203,073
19 - Y -	-2,000	-2,000	0,850	2,000	2,010
19 - X -	207,073	213,795	219,084	235,573	243,573
19 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
19 - X -	244,021	244,728	260,000	269,590	279,180
19 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
19 - X -	288,770	298,361	307,951	317,541	327,131
19 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
19 - X -	336,721	346,311	355,901	365,491	375,082
19 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
19 - X -	384,672	394,262	403,852	413,442	425,000
19 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
19 - X -	443,477	456,000	473,000	481,000	600,000
19 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
18 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
18 - Y -	4,355	4,915	4,796	5,011	5,027
18 - X -	0,000	100,000	140,000	179,073	182,073
18 - Y -	4,967	-4,000	-8,000	-8,000	-6,000
18 - X -	187,073	193,073	197,348	199,073	203,073
18 - Y -	-6,000	-2,000	0,850	2,000	2,010
18 - X -	207,073	213,795	219,084	235,573	243,573
18 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
18 - X -	244,021	244,728	260,000	269,590	279,180
18 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
18 - X -	288,770	298,361	307,951	317,541	327,131
18 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
18 - X -	336,721	346,311	355,901	365,491	375,082
18 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
18 - X -	384,672	394,262	403,852	413,442	425,000
18 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
18 - X -	443,477	456,000	473,000	481,000	600,000

Boundary number	Co-ordinates [m]				
18 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
17 - X -	-32,000	0,000	100,000	140,000	179,073
17 - Y -	-9,000	-9,000	-4,000	-8,000	-8,000
17 - X -	182,073	187,073	193,073	197,348	199,073
17 - Y -	-6,000	-6,000	-2,000	0,850	2,000
17 - X -	203,073	207,073	213,795	219,084	235,573
17 - Y -	2,010	2,006	-0,236	-2,000	-7,500
17 - X -	243,573	244,021	244,728	260,000	269,590
17 - Y -	-7,500	-7,799	-8,270	-8,270	-8,241
17 - X -	279,180	288,770	298,361	307,951	317,541
17 - Y -	-8,148	-8,156	-8,212	-8,333	-8,423
17 - X -	327,131	336,721	346,311	355,901	365,491
17 - Y -	-8,641	-8,882	-9,186	-9,477	-9,819
17 - X -	375,082	384,672	394,262	403,852	413,442
17 - Y -	-10,168	-10,499	-10,821	-11,141	-11,488
17 - X -	425,000	443,477	456,000	473,000	481,000
17 - Y -	-12,500	-16,791	-19,700	-19,700	-17,700
17 - X -	600,000				
17 - Y -	-17,700				
16 - X -	-32,000	0,000	100,000	140,000	179,073
16 - Y -	-14,000	-14,000	-4,000	-8,000	-8,000
16 - X -	182,073	187,073	193,073	197,348	199,073
16 - Y -	-6,000	-6,000	-2,000	0,850	2,000
16 - X -	203,073	207,073	213,795	219,084	235,573
16 - Y -	2,010	2,006	-0,236	-2,000	-7,500
16 - X -	243,573	244,021	244,728	260,000	269,590
16 - Y -	-7,500	-7,799	-8,270	-8,270	-8,241
16 - X -	279,180	288,770	298,361	307,951	317,541
16 - Y -	-8,148	-8,156	-8,212	-8,333	-8,423
16 - X -	327,131	336,721	346,311	355,901	365,491
16 - Y -	-8,641	-8,882	-9,186	-9,477	-9,819
16 - X -	375,082	384,672	394,262	403,852	413,442
16 - Y -	-10,168	-10,499	-10,821	-11,141	-11,488
16 - X -	425,000	443,477	456,000	473,000	481,000
16 - Y -	-12,500	-16,791	-19,700	-19,700	-17,700
16 - X -	600,000				
16 - Y -	-17,700				
15 - X -	-32,000	0,000	100,000	140,000	162,073
15 - Y -	-17,000	-17,000	-10,500	-15,000	-13,000
15 - X -	171,073	176,073	179,073	182,073	187,073
15 - Y -	-10,000	-10,000	-8,000	-6,000	-6,000
15 - X -	193,073	197,348	199,073	203,073	207,073
15 - Y -	-2,000	0,850	2,000	2,010	2,006
15 - X -	213,795	219,084	235,573	243,573	244,021
15 - Y -	-0,236	-2,000	-7,500	-7,500	-7,799
15 - X -	244,728	260,000	269,590	279,180	288,770
15 - Y -	-8,270	-8,270	-8,241	-8,148	-8,156
15 - X -	298,361	307,951	317,541	327,131	336,721
15 - Y -	-8,212	-8,333	-8,423	-8,641	-8,882
15 - X -	346,311	355,901	365,491	375,082	384,672
15 - Y -	-9,186	-9,477	-9,819	-10,168	-10,499
15 - X -	394,262	403,852	413,442	425,000	443,477
15 - Y -	-10,821	-11,141	-11,488	-12,500	-16,791
15 - X -	456,000	473,000	481,000	600,000	
15 - Y -	-19,700	-19,700	-17,700	-17,700	
14 - X -	-32,000	0,000	100,000	140,000	162,073
14 - Y -	-17,000	-17,000	-15,750	-15,000	-13,000
14 - X -	171,073	176,073	179,073	182,073	187,073
14 - Y -	-10,000	-10,000	-8,000	-6,000	-6,000
14 - X -	193,073	197,348	199,073	203,073	207,073
14 - Y -	-2,000	0,850	2,000	2,010	2,006
14 - X -	213,795	219,084	235,573	243,573	244,021
14 - Y -	-0,236	-2,000	-7,500	-7,500	-7,799
14 - X -	244,728	260,000	269,590	279,180	288,770
14 - Y -	-8,270	-8,270	-8,241	-8,148	-8,156

Boundary number	Co-ordinates [m]				
14 - X -	298,361	307,951	317,541	327,131	336,721
14 - Y -	-8,212	-8,333	-8,423	-8,641	-8,882
14 - X -	346,311	355,901	365,491	375,082	384,672
14 - Y -	-9,186	-9,477	-9,819	-10,168	-10,499
14 - X -	394,262	403,852	413,442	425,000	443,477
14 - Y -	-10,821	-11,141	-11,488	-12,500	-16,791
14 - X -	456,000	473,000	481,000	600,000	
14 - Y -	-19,700	-19,700	-17,700	-17,700	
13 - X -	-32,000	0,000	100,000	140,000	162,073
13 - Y -	-19,000	-19,000	-15,750	-15,000	-13,000
13 - X -	171,073	176,073	179,073	182,073	187,073
13 - Y -	-10,000	-10,000	-8,000	-6,000	-6,000
13 - X -	193,073	197,348	199,073	203,073	207,073
13 - Y -	-2,000	0,850	2,000	2,010	2,006
13 - X -	213,795	219,084	235,573	243,573	244,021
13 - Y -	-0,236	-2,000	-7,500	-7,500	-7,799
13 - X -	244,728	260,000	269,590	279,180	288,770
13 - Y -	-8,270	-8,270	-8,241	-8,148	-8,156
13 - X -	298,361	307,951	317,541	327,131	336,721
13 - Y -	-8,212	-8,333	-8,423	-8,641	-8,882
13 - X -	346,311	355,901	365,491	375,082	384,672
13 - Y -	-9,186	-9,477	-9,819	-10,168	-10,499
13 - X -	394,262	403,852	413,442	425,000	443,477
13 - Y -	-10,821	-11,141	-11,488	-12,500	-16,791
13 - X -	456,000	473,000	481,000	600,000	
13 - Y -	-19,700	-19,700	-17,700	-17,700	
12 - X -	-32,000	0,000	100,000	140,000	162,073
12 - Y -	-19,000	-19,000	-15,750	-15,000	-13,000
12 - X -	171,073	176,073	179,073	182,073	187,073
12 - Y -	-10,000	-10,000	-8,000	-6,000	-6,000
12 - X -	193,073	197,348	199,073	203,073	207,073
12 - Y -	-2,000	0,850	2,000	2,010	2,006
12 - X -	213,795	219,084	235,573	243,573	244,021
12 - Y -	-0,236	-2,000	-7,500	-7,500	-7,799
12 - X -	244,728	246,573	250,323	254,323	263,323
12 - Y -	-8,270	-9,500	-12,000	-12,000	-15,000
12 - X -	265,445	443,477	456,000	473,000	481,000
12 - Y -	-15,755	-16,791	-19,700	-19,700	-17,700
12 - X -	600,000				
12 - Y -	-17,700				
11 - X -	-32,000	0,000	100,000	140,000	162,073
11 - Y -	-19,000	-19,000	-15,750	-15,000	-13,000
11 - X -	192,572	235,573	263,323	265,445	443,477
11 - Y -	-13,000	-15,000	-15,000	-15,755	-16,791
11 - X -	456,000	473,000	481,000	600,000	
11 - Y -	-19,700	-19,700	-17,700	-17,700	
10 - X -	-32,000	0,000	100,000	140,000	265,445
10 - Y -	-19,000	-19,000	-15,750	-15,000	-15,755
10 - X -	443,477	456,000	473,000	481,000	600,000
10 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
9 - X -	-32,000	0,000	100,000	140,000	173,849
9 - Y -	-19,000	-19,000	-15,750	-17,500	-17,650
9 - X -	456,000	473,000	481,000	600,000	
9 - Y -	-19,700	-19,700	-17,700	-17,700	
8 - X -	-32,000	0,000	100,000	140,000	173,849
8 - Y -	-19,000	-19,000	-15,750	-18,000	-17,650
8 - X -	456,000	473,000	481,000	600,000	
8 - Y -	-19,700	-19,700	-17,700	-17,700	
7 - X -	-32,000	0,000	100,000	140,000	157,918
7 - Y -	-19,000	-19,000	-15,750	-18,000	-20,493
7 - X -	181,818	202,782	242,595	256,846	295,412
7 - Y -	-19,000	-25,000	-20,000	-25,000	-20,000
7 - X -	325,593	346,128	361,221	386,752	407,745
7 - Y -	-25,162	-20,000	-25,000	-19,815	-25,000
7 - X -	432,843	463,917	481,032	600,000	

Boundary number	Co-ordinates [m]				
7 - Y -	-20,000	-25,000	-20,000	-26,000	
6 - X -	-32,000	0,000	100,000	140,000	157,918
6 - Y -	-19,000	-19,000	-15,750	-23,000	-20,493
6 - X -	181,818	202,782	242,595	256,846	295,412
6 - Y -	-19,000	-25,000	-20,000	-25,000	-20,000
6 - X -	325,593	346,128	361,221	386,752	407,745
6 - Y -	-25,162	-20,000	-25,000	-19,815	-25,000
6 - X -	432,843	463,917	481,032	600,000	
6 - Y -	-20,000	-25,000	-20,000	-26,000	
5 - X -	-32,000	0,000	100,000	140,000	157,918
5 - Y -	-26,000	-24,000	-20,000	-23,000	-20,493
5 - X -	181,818	202,782	242,595	256,846	295,412
5 - Y -	-19,000	-25,000	-20,000	-25,000	-20,000
5 - X -	325,593	346,128	361,221	386,752	407,745
5 - Y -	-25,162	-20,000	-25,000	-19,815	-25,000
5 - X -	432,843	463,917	481,032	600,000	
5 - Y -	-20,000	-25,000	-20,000	-26,000	
4 - X -	-32,000	0,000	100,000	140,000	157,918
4 - Y -	-26,000	-24,000	-22,500	-23,000	-20,493
4 - X -	181,818	202,782	242,595	256,846	295,412
4 - Y -	-19,000	-25,000	-20,000	-25,000	-20,000
4 - X -	325,593	346,128	361,221	386,752	407,745
4 - Y -	-25,162	-20,000	-25,000	-19,815	-25,000
4 - X -	432,843	463,917	481,032	600,000	
4 - Y -	-20,000	-25,000	-20,000	-26,000	
3 - X -	-32,000	0,000	100,000	140,000	158,339
3 - Y -	-28,000	-28,000	-27,000	-29,000	-28,000
3 - X -	184,746	217,863	241,336	266,067	294,570
3 - Y -	-30,000	-28,000	-30,000	-28,000	-30,000
3 - X -	314,692	345,290	366,668	393,495	419,064
3 - Y -	-28,000	-30,000	-28,000	-30,000	-28,000
3 - X -	435,413	454,695	479,300	600,000	
3 - Y -	-30,000	-28,000	-30,000	-28,000	
2 - X -	-32,000	0,000	100,000	140,000	156,243
2 - Y -	-32,000	-32,000	-29,000	-31,500	-34,000
2 - X -	192,711	215,924	248,043	264,390	290,798
2 - Y -	-31,000	-34,000	-31,000	-34,000	-31,000
2 - X -	311,338	337,745	364,991	400,623	416,984
2 - Y -	-34,000	-31,000	-34,000	-31,000	-34,000
2 - X -	445,475	461,819	479,300	600,000	
2 - Y -	-31,000	-34,000	-31,000	-34,000	
1 - X -	-32,000	0,000	24,626	49,776	60,000
1 - Y -	-40,000	-40,000	-47,474	-40,789	-48,000
1 - X -	98,398	109,467	140,000	162,181	200,255
1 - Y -	-40,000	-48,000	-42,000	-48,000	-40,000
1 - X -	210,790	247,204	259,099	294,990	310,396
1 - Y -	-48,000	-40,000	-48,000	-40,000	-48,000
1 - X -	344,872	362,115	397,691	410,264	440,007
1 - Y -	-40,000	-48,000	-40,000	-48,000	-40,000
1 - X -	461,400	479,300	600,000		
1 - Y -	-48,000	-40,000	-40,000		
0 - X -	-32,000	600,000			
0 - Y -	-50,000	-50,000			

2.3 Pl-lines

Pl-line number	Co-ordinates [m]				
1 - X -	-32,000	600,000			
1 - Y -	0,000	0,000			

2.4 Phreatic Line

Piezo-line 1 is used as phreatic line (groundwater).

2.5 Soil Profiles

Layer number	Material name	Piezo-line at top	Piezo-line at bottom
24	klei, bekleding	1	1
23	zandasfalt	1	1
22	breuksteen 10-60 kg	1	1
21	breuksteen 6-10 ton	1	1
20	zand, mf_mv (HL)	1	1
19	zand, mf_mg, l (HL)	1	1
18	zand, mg_v (HL)	1	1
17	zand, mg_mv (HL)	1	1
16	zand, kl_mf_m_t_l (...	1	1
15	zand, mf_mg, l (HL)	1	1
14	zand, mg_v (HL)	1	1
13	zand, mf_mg, l (HL)	1	1
12	div. betonnenblokken	1	1
11	zand, mf_mg, l (HL)	1	1
10	zand, mf_mv diep (...	1	1
9	zand, kl_mf_m_t_v ...	1	1
8	leem, fz_kl (KR)	1	1
7	zand, mg_v (HL)	1	1
6	leem, fz_kl (KR)	1	1
5	klei, m_t_v (KR)	1	1
4	zand, zg_g (KR)	1	1
3	zand, zg_g_s_ki (K...	1	1
2	zand, zg_g (KR)	1	1
1	klei, s (WA)	1	1

2.6 Selected Boundaries

The boundary between (cohesive) undrained top layers and underlaying (non-cohesive) drained layers, is situated at the top of layer number 19: zand, mf_mg, l (HL)
The boundary between compressible top layers and underlaying non-compressible layers, is situated at the top of layer number 19: zand, mf_mg, l (HL)

2.7 Soil Material Data

Name	Gamma unsat [kN/m³]	Gamma sat [kN/m³]	Cohesion [kN/m²]	Phi [deg]	Su top [kN/m²]	Su bottom [kN/m²]
geen sterkte	0,01	0,02	0,00	0,00	0,00	0,00
klei, m_t_s (HL)	17,00	17,00	5,00	17,50	50,00	50,00
zand, mf_mg, l (HL)	18,00	19,00	0,00	30,00	0,00	0,00
zand, mf_mv (HL)	18,00	19,00	0,00	32,50	0,00	0,00
zand, mg_v (HL)	19,00	21,00	0,00	35,00	0,00	0,00
zand, mg_mv (HL)	18,00	20,00	0,00	32,50	0,00	0,00
zand, kl_mf_m_t_l (HL)	16,00	17,00	5,00	30,00	0,00	0,00
zand, kl_mf_m_t_v (HL)	17,00	18,00	5,00	35,00	0,00	0,00
leem, fz_kl (KR)	18,00	18,00	5,00	25,00	80,00	80,00
klei, m_t_v (KR)	16,00	16,00	4,00	19,00	60,00	60,00
zand, zg_g (KR)	19,00	21,00	0,00	32,60	0,00	0,00
zand, zg_g_s_ki (KR_...	19,00	21,00	0,00	30,30	0,00	0,00
klei, s (WA)	20,00	20,00	10,00	27,50	0,00	0,00
zand, mf_mv diep (HL)	18,00	19,00	0,00	28,00	0,00	0,00
klei, bekleding	17,00	17,00	4,00	14,70	50,00	50,00
zandasfalt	16,50	16,50	0,00	31,90	0,00	0,00
breuksteen 10-60 kg	18,00	20,00	0,00	30,30	0,00	0,00
breuksteen 6-10 ton	19,00	21,00	0,00	32,60	0,00	0,00
betonnenblokken	19,00	20,00	0,00	37,50	0,00	0,00
div. betonnenblokken	19,00	21,00	0,00	32,60	0,00	0,00

Name	Soil type	Emod 100 [kN/m²]	Emod top [kN/m²]	Emod bottom [kN/m²]
geen sterkte	-	-	0,01	0,01
klei, m_t_s (HL)	-	-	0,01	0,01
zand, mf_mg, l (HL)	-	-	45000,00	75000,00
zand, mf_mv (HL)	-	-	45000,00	75000,00
zand, mg_v (HL)	-	-	75000,00	110000,00
zand, mg_mv (HL)	-	-	45000,00	75000,00
zand, kl_mf_m_t_l (HL)	-	-	35000,00	50000,00
zand, kl_mf_m_t_v (HL)	-	-	45000,00	75000,00
leem, fz_kl (KR)	-	-	2000,00	3000,00
klei, m_t_v (KR)	-	-	1500,00	3000,00
zand, zg_g (KR)	-	-	45000,00	75000,00
zand, zg_g_s_ki (KR_...	-	-	45000,00	75000,00
klei, s (WA)	-	-	0,01	0,01
zand, mf_mv diep (HL)	-	-	0,01	0,01
klei, bekleding	-	-	0,01	0,01
zandasfalt	-	-	0,01	0,01
breuksteen 10-60 kg	-	-	0,01	0,01
breuksteen 6-10 ton	-	-	0,01	0,01
betonnenblokken	-	-	0,01	0,01
div. betonnenblokken	-	-	0,01	0,01

Name	Adhesion A [kN/m²]	Delta D [deg]	Nu [-]
geen sterkte	-	-	0,00
klei, m_t_s (HL)	-	-	0,30
zand, mf_mg, l (HL)	-	-	0,30
zand, mf_mv (HL)	-	-	0,30
zand, mg_v (HL)	-	-	0,00
zand, mg_mv (HL)	-	-	0,30
zand, kl_mf_m_t_l (HL)	-	-	0,30
zand, kl_mf_m_t_v (HL)	-	-	0,30
leem, fz_kl (KR)	-	-	0,30
klei, m_t_v (KR)	-	-	0,00
zand, zg_g (KR)	-	-	0,30
zand, zg_g_s_ki (KR_...	-	-	0,30
klei, s (WA)	-	-	0,00
zand, mf_mv diep (HL)	-	-	0,00
klei, bekleding	-	-	0,00
zandasfalt	-	-	0,00
breuksteen 10-60 kg	-	-	0,00
breuksteen 6-10 ton	-	-	0,00
betonnenblokken	-	-	0,00
div. betonnenblokken	-	-	0,00

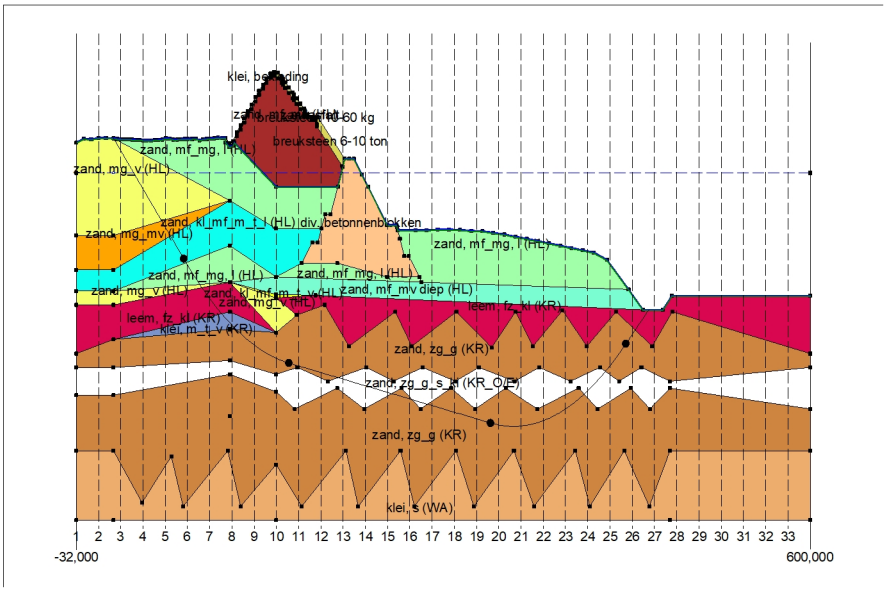
2.8 Soil Material Data for Settlement

Name [-]	OCR [-]	Cp [-]	Cp' [-]	Cs [-]	Cs' [-]
geen sterkte	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
klei, m_t_s (HL)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, mf_mg, l ...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, mf_mv (HL)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, mg_v (HL)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, mg_mv (...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, kl_mf_m_...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, kl_mf_m_...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
leem, fz_kl (KR)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
klei, m_t_v (KR)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, zg_g (KR)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, zg_g_s_ki...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
klei, s (WA)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00

Name [-]	OCR [-]	Cp [-]	Cp' [-]	Cs [-]	Cs' [-]
zand, mf_mv di...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
klei, bekleding	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zandasfalt	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
breuksteen 10-6...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
breuksteen 6-10...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
betonnenblokken	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
div. betonnenbl...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00

2.9 Geometry

2.9.1 Geometry Section, Detailed



2.9.2 Geometry Top View

2.10 Calculation Verticals

Vertical nr.	L-coord [m]	Z-coord [m]	Additional settlement [mm]
1	6,300	3,160	0,00
2	25,450	-2,330	0,00
3	44,610	-7,820	0,00
4	63,760	-13,300	0,00
5	82,910	-18,110	0,00
6	102,060	-21,930	0,00
7	121,210	-24,790	0,00
8	140,360	-26,710	0,00
9	159,510	-27,800	0,00
10	178,670	-28,750	0,00
11	197,820	-29,700	0,00
12	216,970	-30,650	0,00
13	236,120	-31,600	0,00
14	255,270	-32,550	0,00
15	274,420	-33,500	0,00
16	293,580	-34,450	0,00
17	312,730	-35,400	0,00
18	331,880	-36,290	0,00
19	351,030	-36,440	0,00
20	370,180	-35,670	0,00
21	389,330	-33,980	0,00
22	408,490	-31,350	0,00
23	427,640	-27,760	0,00
24	446,790	-23,240	0,00

Locations of the calculation verticals; L represents distance along the pipeline projection in the horizontal plane, incremented with the entry co-ordinate.

2.11 Configuration of the Pipeline

X co-ordinate left point	0,000	[m]
Y co-ordinate left point	0,000	[m]
Z co-ordinate left point	4,967	[m]
X co-ordinate right point	461,000	[m]
Y co-ordinate right point	0,000	[m]
Z co-ordinate right point	-19,700	[m]
Angle left	16,0000	[deg]
Angle right	14,0000	[deg]
Bending radius left, vertical in/out	400,000	[m]
Bending radius right, vertical in/out	400,000	[m]
Bending radius pipe on rollers	60,000	[m]
Lowest level of pipe (centre bore hole)	-36,000	[m]
Angle of pipe (between radii)	-2,8400	[deg]
Number of horizontal bends	0	

The pulling direction of the product pipe is from left to right

2.12 Product Pipe Material Data

Material	Polyethene	
Quality	PE100	
Young's modulus (short)	975,00	[N/mm²]
Young's modulus (long)	350,00	[N/mm²]
Allowable strength (short)	10,00	[N/mm²]
Allowable strength (long)	8,00	[N/mm²]
Tensile factor (alpha)	0,65	[-]
Outer diameter product pipe	800,00	[mm]
Wall thickness (Nominal)	72,60	[mm]
Unit weight pipe material	9,54	[kN/m³]
Design pressure	10,00	[bar]
Test pressure	10,00	[bar]
Temperature variation	70,00	[deg C]

2.13 Pipe Engineering Data

Pipe filled with water on rollers	No	
Part of cross section filled with fluid	100	[%]
Unit weight fluid	10,00	[kN/m³]
Bedding angle	120	[deg]
Load angle	180	[deg]
Relative displacement	10,00	[mm]
Compression index	6,00	[-]
Linear settlement coefficient (alpha_g) for steel	0,0000117	[mm/mmK]
Linear settlement coefficient (alpha_g) for PE	0,0001800	[mm/mmK]
Modulus of subgrade reaction drilling fluid (Kv)	500,00	[kN/m³]
Phi drilling fluid	15,00	[deg]
Cohesion drilling fluid	5,00	[kN/m²]
Factor of friction pipe-roller (f1)	0,10	[-]
Friction pipe-drilling fluid (f2)	0,000050	[N/mm²]
Factor of friction pipe-soil (f3)	0,20	[-]
Special Stress Analysis	not used	
Special Stress Data	not used	

2.14 Drilling Fluid Data

Outer diameter pilot hole	0,330	[m]
Outer diameter pilot pipe	0,168	[m]
Outer diameter preream hole	1,120	[m]
Outer diameter drillpipe	0,168	[m]
Outer diameter bore hole	1,120	[m]
Outer diameter product pipe	0,800	[m]
Annular back flow rate pilot	1500,0	[liter/minute]
Annular back flow rate pre-reaming	2500,0	[liter/minute]
Annular back flow rate ream and pull-back	0,0	[liter/minute]
Circulation loss factor pilot	0,30	[-]
Circulation loss factor pre-reaming	0,20	[-]
Circulation loss factor ream and pull-back	0,20	[-]
Unit weight drilling fluid (gamma)	11,4	[kN/m³]
Yieldpoint drilling fluid (Tau)	0,024	[kN/m²]
Plastic viscosity drilling fluid (Mu)	0,000012	[kN.s/m²]

2.15 Factors

(Polyethene)Safety factor on implosion (Long)	3,0	[-]
(Polyethene)Safety factor on implosion (Short)	1,5	[-]
Contingency factor on total unit weight of material types below and above phreatic level	1,10	[-]
Contingency factor on (drained) cohesion C	1,40	[-]
Contingency factor on undrained shear strength Su	1,40	[-]
Contingency factor on Phi	1,10	[-]
Contingency factor on E-modulus	1,25	[-]
Contingency factor on modulus of subgrade reaction	1,30	[-]
Factor of importance (S)	1,00	[-]
Allowable deflection of steel pipe	15,00	[%]
Allowable piggability of steel pipe	5,00	[%]
Allowable deflection of polyethene pipe	8,00	[%]
Allowable piggability of polyethene pipe	5,00	[%]
Unit weight water	9,81	[kN/m³]
Safety factor on cover (drained layer)	0,50	[-]
Safety factor on cover (undrained layer)	0,50	[-]
Ratio H/Do for boundary between shallow and deep situation	7,50	[-]

3 Drilling Fluid Pressures

3.1 Drilling Fluid Data

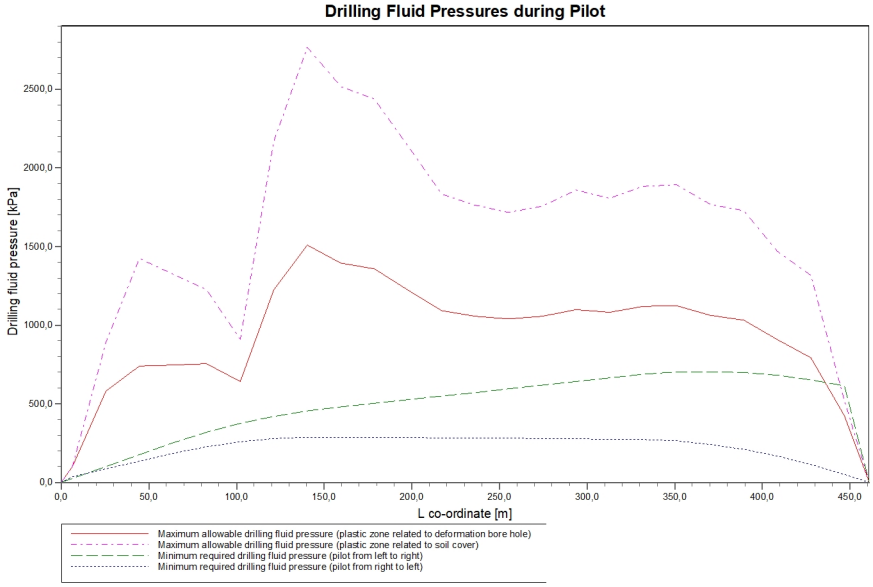
Vertical nr.	Drilling fluid pressures pilot [kN/m²]			
	Max, deformation	Max, soil cover	Min, left	Min, right
1	100	100	25	36
2	581	890	100	85
3	739	1422	176	135
4	745	1324	251	185
5	754	1225	318	227
6	641	909	375	258
7	1223	2168	420	278
8	1508	2766	454	288
9	1394	2517	479	288
10	1357	2437	502	286
11	1221	2137	525	285
12	1091	1833	548	283
13	1056	1762	571	282
14	1040	1716	595	280
15	1056	1757	618	279
16	1097	1858	641	277
17	1081	1807	664	275
18	1118	1882	687	273
19	1124	1893	701	263
20	1062	1769	704	241
21	1031	1727	697	210
22	907	1469	680	167
23	793	1315	651	114
24	423	520	613	50

Vertical nr.	Drilling fluid pressures preream [kN/m²]			
	Max, deformation	Max, soil cover	Min, left	Min, right
1	43	43	21	0
2	440	440	85	0
3	739	950	135	0
4	745	1177	185	0
5	754	1211	227	21
6	641	909	258	62
7	1223	2168	278	93
8	1508	2766	288	113
9	1394	2517	288	123
10	1357	2437	286	132
11	1221	2137	285	141
12	1091	1833	283	150
13	1056	1682	282	159
14	1040	1619	280	168
15	1056	1704	279	177
16	1097	1839	277	185
17	1081	1807	275	194
18	1118	1882	273	202
19	1124	1891	263	202
20	1062	1753	241	191
21	1031	1661	210	170
22	907	1310	167	138
23	793	1022	114	95
24	377	377	50	42

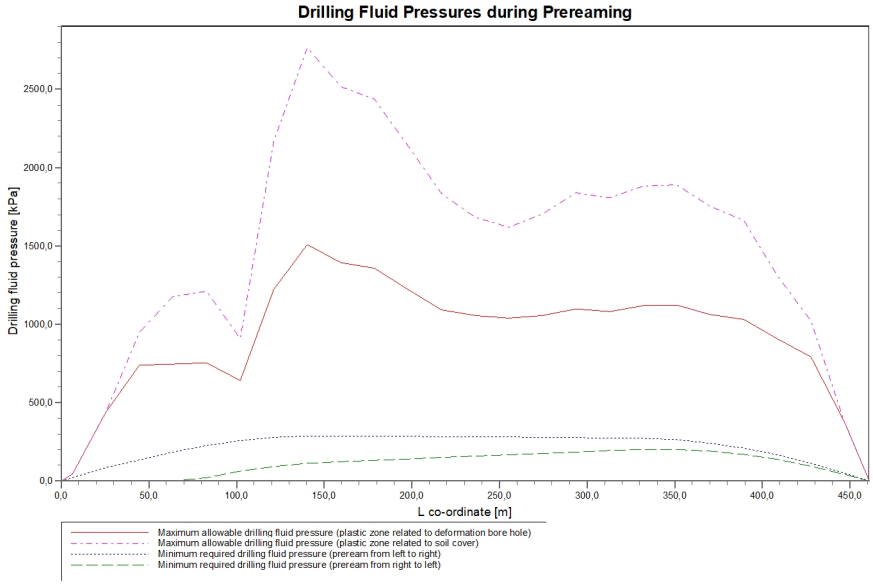
Vertical nr.	Drilling fluid pressures pull back [kN/m²]			
	Max, deformation	Max, soil cover	Min, left	Min, right
1	43	43	0	0
2	440	440	0	0
3	739	950	0	0
4	745	1177	0	0
5	754	1211	21	0
6	641	909	62	25
7	1223	2168	93	58
8	1508	2766	113	80
9	1394	2517	123	92
10	1357	2437	132	103
11	1221	2137	141	114
12	1091	1833	150	125
13	1056	1682	159	136
14	1040	1619	168	147
15	1056	1704	177	157
16	1097	1839	185	168
17	1081	1807	194	179
18	1118	1882	202	189
19	1124	1891	202	191
20	1062	1753	191	182
21	1031	1661	170	163
22	907	1310	138	133
23	793	1022	95	92
24	377	377	42	40

3.2 Drilling Fluid Pressure Plots

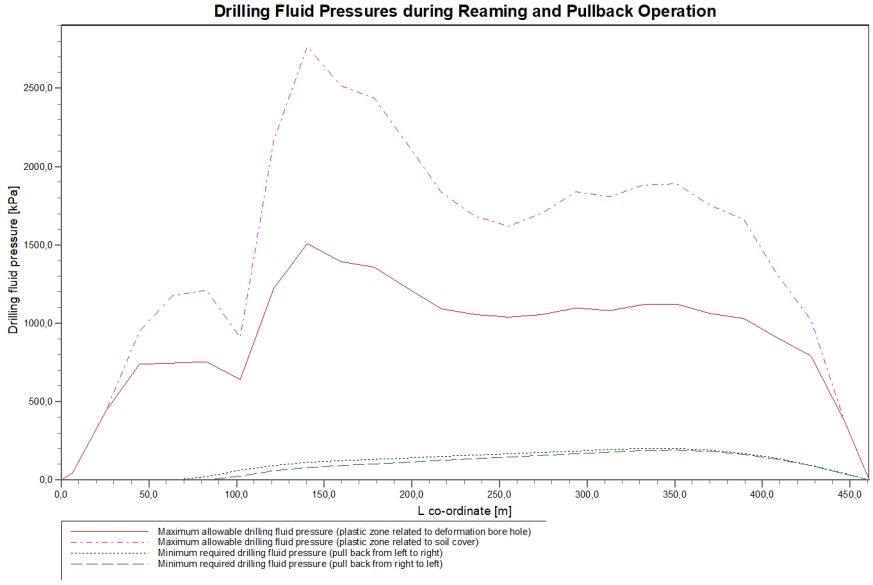
3.2.1 Drilling Fluid Pressures during Pilot



3.2.2 Drilling Fluid Pressures during Prereaming



3.2.3 Drilling Fluid Pressures during Reaming and Pullback Operation



4 Deformations

4.1 Settlements of Soil Layers below the Pipeline

Vertical nr. [-]	Settlement [mm]	Additional settlement [mm]	dv [mm]
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

5 Soil Mechanical Data

5.1 Soil Mechanical Parameters (Pipe: HDPE OD 800 SDR 11)

The list with data and issues is shown hereafter:
Note: safety factors not applied.

q_v;p	Passive soil stress	kN/m²
q_v;n	Neutral soil stress	kN/m²
q_h;n	Neutral horizontal soil stress	kN/m²
q_v,r;n	Reduced neutral soil stress	kN/m²
q_v;e	Vertical bearing capacity	kN/m²
q_h;e	Horizontal bearing capacity	kN/m²
dv	Vertical displacement	mm
k_v;bot	Vertical modulus of subgrade reaction downward	kN/m³
k_v;top	Vertical modulus of subgrade reaction upward	kN/m³
k_h	Horizontal modulus of subgrade reaction	kN/m³
t_max	Maximal friction pipe-lubricant	kN/m²
d_max	Displacement at maximal friction	mm

Vertical nr.	q_v;p [kN/m²]	q_v;n [kN/m²]	q_h;n [kN/m²]	q_v;r;n [kN/m²]	q_v;e [kN/m²]	q_h;e [kN/m²]
1	37	25	19	25	1316	299
2	378	109	81	109	5138	924
3	970	173	29	39	5963	1342
4	1418	208	25	34	5550	1418
5	581	245	25	34	3999	581
6	602	258	24	33	7728	602
7	2537	403	20	27	14370	2537
8	3064	505	20	27	17972	3064
9	2935	437	20	27	12063	2935
10	2844	420	22	29	12297	2844
11	2092	347	23	31	9572	2092
12	1988	302	23	31	8333	1988
13	1845	252	23	31	8850	1845
14	1644	235	21	29	8397	1644
15	1712	246	21	29	8798	1712
16	1901	265	22	29	9447	1901
17	1824	265	21	29	9478	1824
18	1952	270	21	29	9644	1952
19	1954	273	22	29	9729	1954
20	1785	253	22	29	9047	1785
21	1714	237	22	30	8450	1714
22	1472	188	21	29	6062	1472
23	907	143	21	29	4531	1277
24	143	48	36	48	1754	542

Vertical nr.	dv [mm]	k_v;bot [kN/m³]	k_v;top [kN/m³]	k_h [kN/m³]	t_max [kN/m²]	d_max [mm]
1	0	69684	783	48779	0,05	7,5
2	0	84964	69906	59475	0,05	7,5
3	0	42660	79251	29862	0,05	7,5
4	0	48976	38399	34283	0,05	7,5
5	0	1541	39807	1078	0,05	7,5
6	0	48023	1520	33616	0,05	7,5
7	0	56403	16551	39482	0,05	7,5
8	0	57052	53873	39937	0,05	7,5
9	0	49931	58121	34952	0,05	7,5
10	0	51598	59344	36119	0,05	7,5
11	0	49191	57737	34434	0,05	7,5
12	0	55155	52725	38609	0,05	7,5
13	0	45103	57836	31572	0,05	7,5
14	0	44830	55249	31381	0,05	7,5
15	0	46553	54424	32587	0,05	7,5

Vertical nr.	dv [mm]	k_v;bot [kN/m³]	k_v;top [kN/m³]	k_h [kN/m³]	t_max [kN/m²]	d_max [mm]
16	0	56941	47192	39859	0,05	7,5
17	0	47468	54915	33228	0,05	7,5
18	0	57161	44696	40012	0,05	7,5
19	0	56994	46337	39896	0,05	7,5
20	0	49401	52980	34581	0,05	7,5
21	0	52015	49029	36411	0,05	7,5
22	0	46317	54047	32422	0,05	7,5
23	0	54386	54816	38070	0,05	7,5
24	0	66347	4464	46443	0,05	7,5

Maximum soil stress : q_v;n;max = 505 kN/m²
Maximum reduced soil stress : q_v;r;n;max = 109 kN/m²
Max. vertical modulus of subgrade reaction (without safety factor) only for verticals in deep situation : k_v;max = 84964 kN/m³
Maximum vertical modulus of subgrade reaction (with safety factor) only for verticals in deep situation : k_v;max = 110453 kN/m³

5.2 Young's Modulus per Layer per Vertical

Layer number	Material name	Type of determination
24	klei, bekleding	User defined
23	zandasfalt	User defined
22	breuksteen 10-60 kg	User defined
21	breuksteen 6-10 ton	User defined
20	zand, mf_mv (HL)	User defined
19	zand, mf_mg, l (HL)	User defined
18	zand, mg_v (HL)	User defined
17	zand, mg_mv (HL)	User defined
16	zand, kl_mf_m_t_l (HL)	User defined
15	zand, mf_mg, l (HL)	User defined
14	zand, mg_v (HL)	User defined
13	zand, mf_mg, l (HL)	User defined
12	div. betonnenblokken	User defined
11	zand, mf_mg, l (HL)	User defined
10	zand, mf_mv diep (HL)	User defined
9	zand, kl_mf_m_t_v (HL)	User defined
8	leem, fz_kl (KR)	User defined
7	zand, mg_v (HL)	User defined
6	leem, fz_kl (KR)	User defined
5	klei, m_t_v (KR)	User defined
4	zand, zg_g (KR)	User defined
3	zand, zg_g_s_ki (KR_...	User defined
2	zand, zg_g (KR)	User defined
1	klei, s (WA)	User defined

Layer number	Vertical 1 (X=-32 m)		Vertical 2 (X=-12,848 m)		Vertical 3 (X=6,303 m)		Vertical 4 (X=25,455 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	45,001	74,999	45,000	75,000	45,000	75,000	45,000	75,000
18	75,000	110,000	75,000	110,000	75,000	110,000	75,000	110,000
17	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
16	35,000	50,000	35,000	50,000	35,000	50,000	35,000	50,000
15	45,001	74,999	45,000	75,000	45,000	75,000	45,000	75,000
14	75,000	110,000	75,000	110,000	75,000	110,000	75,000	110,000
13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Layer number	Vertical 1 (X=-32 m)		Vertical 2 (X=-12,848 m)		Vertical 3 (X=6,303 m)		Vertical 4 (X=25,455 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
5	1,500	3,000	1,500	3,000	1,500	3,000	1,500	3,000
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 5 (X=44,606 m)		Vertical 6 (X=63,758 m)		Vertical 7 (X=82,909 m)		Vertical 8 (X=102,061 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	0,000	0,000	0,000	0,000	0,000	0,000
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	45,000	75,000	45,000	75,000
19	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
18	75,000	110,000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	45,000	75,000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	35,000	50,000	35,000	50,000	35,000	50,000	35,000	50,000
15	45,000	75,000	45,000	75,000	45,000	75,000	n.a.	n.a.
14	75,001	109,999	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	45,009	74,991
10	n.a.	n.a.	0,000	0,000	0,000	0,000	0,000	0,000
9	n.a.	n.a.	45,012	74,988	45,001	74,999	45,001	74,999
8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2,000	3,000
7	n.a.	n.a.	75,001	109,999	75,000	110,000	75,000	110,000
6	2,000	3,000	2,000	3,000	2,000	3,000	n.a.	n.a.
5	1,500	3,000	1,500	3,000	1,500	3,000	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 9 (X=121,212 m)		Vertical 10 (X=140,364 m)		Vertical 11 (X=159,515 m)		Vertical 12 (X=178,667 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	0,000	0,000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	0,000	0,000	0,000	0,000	n.a.	n.a.
20	45,000	75,000	45,000	75,000	n.a.	n.a.	n.a.	n.a.
19	45,000	75,000	45,000	75,000	n.a.	n.a.	n.a.	n.a.
18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	35,000	50,000	35,001	49,999	n.a.	n.a.	n.a.	n.a.
15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	n.a.	n.a.	0,000	0,000	0,000	0,000	0,000	0,000
11	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
10	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
9	45,001	74,999	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000

Layer number	Vertical 9 (X=121,212 m)		Vertical 10 (X=140,364 m)		Vertical 11 (X=159,515 m)		Vertical 12 (X=178,667 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 13 (X=197,818 m)		Vertical 14 (X=216,97 m)		Vertical 15 (X=236,121 m)		Vertical 16 (X=255,273 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	n.a.	n.a.	45,000	75,000	45,000	75,000	45,000	75,000
12	0,000	0,000	0,000	0,000	n.a.	n.a.	n.a.	n.a.
11	45,001	74,999	45,000	75,000	n.a.	n.a.	n.a.	n.a.
10	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 17 (X=274,424 m)		Vertical 18 (X=293,576 m)		Vertical 19 (X=312,727 m)		Vertical 20 (X=331,879 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 21 (X=351,03 m)		Vertical 22 (X=370,182 m)		Vertical 23 (X=389,333 m)		Vertical 24 (X=408,485 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Layer number	Vertical 21 (X=351,03 m)		Vertical 22 (X=370,182 m)		Vertical 23 (X=389,333 m)		Vertical 24 (X=408,485 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	45,000	75,000	45,000	75,000	45,000	75,000	n.a.	n.a.
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

6 Data for Stress Analysis

6.1 General data

Pipeline diameter	:	Do = 800,00 mm
Wall thickness	:	t = 72,60 mm
Unit weight pipeline material	:	gamma_s = 9,54 kN/m³
Unit weight drilling fluid pullback operation	:	gamma_b = 11,40 kN/m³
Combined bending radius	:	Rmin = 400,000 m
Bending radius on rollers	:	Rrol = 60,000 m
Friction coefficient pipe/rollers	:	f1 = 0,10
Friction between pipe and drilling fluid	:	f2 = 0,000050 N/mm²
Friction coefficient pipe / soil	:	f3 = 0,20
Max. vertical modulus of subgrade reaction (without safety factor)	:	k_v;max = 84964 kN/m³

6.2 Buoyancy Control

The friction between soil and pipe is partially caused by buoyancy of the pipeline in the drilling fluid. Uplift forces resulting from buoyancy can be neutralized by filling the pipeline. The optimal volume of fluid placed in the pipe provides the most advantageous distribution of buoyant forces.

Buoyancy of the pipeline when filled with fluid for 100%

Uplift forces	:	573	[kg/m]	
Weight of pipeline (including filling)	:	495	[kg/m]	

Result	:	78	[kg/m]	(Pipeline moves upwards)

6.3 Calculation Pulling Force

During the pullback operation the pipe experiences friction which is based on:

- friction between pipe and pipe-roller (f1 = 0,10)
- friction between pipe and drilling fluid (f2 = 0,000050 [N/mm²])
- friction between pipe and soil (f3 = 0,20)

Due to the friction a pulling force is induced in the pipeline.
The pulling direction of the product pipe is from left to right

This calculation takes into account that the length of the pipe on the rollers decreases while pulling back the pipeline. During the pull back operation the bore hole is supposed to be stable.

Characteristic points	Length pipe in bore hole (m)	Characteristic value pulling force (kN)
T1	0	74
T2	63	82
T3	155	112
T4	329	134
T5	446	172
T6	467	175

The calculated values for the pulling force are characteristic values (without safety factor). According to article E.1.2.1 of NEN 3650-1:2012 it is recommended to use a total factor for stochastic variation and model uncertainty (f) of at least 1.4 for the stress analysis. In the subsequent pipe stress analysis a factor of 1,40 for steel and 1,40 for PE is used and a load factor of 1,00 for steel and 1,00 for PE.

The maximum representative pulling force is 1554 kN, calculation factor excluded. At this pulling force level the stresses in the pipeline are equal to the maximum allowable stress.

7 Stress Analysis of Pipe: HDPE OD 800 SDR 11

7.1 Material Data of Pipe: HDPE OD 800 SDR 11

The list with data and issues is shown hereafter:

Material pipeline	:	Polyethene PE100
Outer diameter	:	Do = 800,00 mm
Wall thickness	:	t = 72,60 mm
Design pressure	:	pd = 10,00 bar
Test pressure	:	pt = 10,00 bar
Temperature variation	:	dt = 70,00 deg Celcius
Length pipeline	:	L = 467 m
Young's modulus (short)	:	E = 975 N/mm²
Young's modulus (long)	:	E = 350 N/mm²
Allowable stress (short)	:	S = 10 N/mm²
Allowable stress (long)	:	S = 8 N/mm²
Factor of importance (S)	:	S = 1,00
Poisson ratio	:	nu = 0,40
Unit weight pipeline material	:	gamma_s = 9,54 kN/m³
Bedding angle	:	beta = 120 degrees
Load angle	:	alpha = 180 degrees
Moment coefficient soil top (indirect)	:	kt' = 0,061
Moment coefficient soil bottom (indirect)	:	kb' = 0,083
Moment coefficient soil top (direct)	:	kt = 0,131
Moment coefficient soil bottom (direct)	:	kb = 0,138
Deflection coefficient (indirect)	:	ky' = 0,048
Deflection coefficient (direct)	:	ky = 0,089
Maximal reduced vertical soil load (without safety factor)	:	q_v;r;n;max = 109 kN/m²
Traffic load (without safety factor)	:	q_v = 0 kN/m²
Max. vertical modulus of subgrade reaction (without safety factor)	:	k_v;max = 84964 kN/m³
Load factor on installation	:	f_install = 1,00
Load factor on reduced neutral soil stress q_n;r	:	f_Qnr = 1,00
Load factor on design pressure	:	f_pd = 1,00
Load factor on design pressure (combination)	:	f_pd;comb = 1,00
Load factor on test pressure	:	f_pt = 1,00
Load factor on temperature	:	f_temp = 1,00
Load factor on traffic load	:	f_v = 1,00
Contingency factor on bending radius	:	f_R = 1,10
Contingency factor on modulus of subgrade reaction	:	f_kv = 1,30
Contingency factor on bending moment	:	f_k = 1,00
Total factor on pulling force for stoch. varia. and model uncertainty	:	f = 1,40
Linear settlement coefficient	:	alpha_g = 0,00018 mm/mmK

7.2 Results Stress Analysis of Pipe: HDPE OD 800 SDR 11

In the calculation 5 load combinations are considered:

- Load combination 1A: start pull-back operation
- Load combination 1B: end of pull-back operation
- Load combination 2: application internal pressure
- Load combination 3: pipeline in operation, no inner pressure
- Load combination 4: pipeline in operation, pressure applied

The wall thickness is 72,6 mm. The calculation hereafter will prove that the pipeline wall thickness is sufficient. The calculations are in accordance with NEN 3650 series.

7.2.1 Load Combination 1A: Start Pullback Operation

Axial stress:

Sigma_b = Mb/Wb = f_k E·Ib /(Rrol·Wb)	=	6,50	[N/mm²]
Sigma_t = f * f_install * T1/A = f * f_install (Lrol * Q * f1)/A	=	0,62	[N/mm²]

Maximum axial stress Sigma_a,max	=	4,85	[N/mm²]

In this load combination the tangential stress is negligible.

7.2.2 Load Combination 1B: End Pullback Operation

Axial stress:

Sigma_b = Mb/Wb = f_k·E·Ib /(Rmin·Wb)	=	0,98	N/mm²
Sigma_t = f * f_install * Tmax/A	=	1,47	N/mm²
Maximum axial stress Sigma_a,max	=	2,11	N/mm²

Tangential stress:

Load qr on pipeline due to reaction of soil in bends (according to NEN 3650-1 annex 5 D3.3):

qr = kv *·y = (0.322·Lambda^2·E·I)/(Do.R/f_R)

Lambda = (f_kv kv·Do/(4·E·I))^0.25	=	1,2E-3	mm-1
qr	=	0,0171	N/mm²
Sigma_qr = k'·qr·(rg/Ww)·Do	=	0,47	N/mm²
Maximum tangential stress Sigma_t,max	=	0,47	N/mm²

7.2.3 Load Combination 2: Application Internal Pressure

Due to internal pressure :

Sigma_py = f_pd . pd·((ru^2 + ri^2)/(ru^2 - ri^2))	=	5,06	N/mm²
Sigma_px = 0.5·Sigma_py	=	2,53	N/mm²
Sigma_ptest = f_pt . pt·((ru^2 + ri^2)/(ru^2 - ri^2))	=	5,06	N/mm²

7.2.4 Load Combination 3: In Operation (Situation without Pressure)

Axial stress:

Sigma_b = Mb/Wb = f_k E·Ib /(Rrol·Wb)	=	0,35	N/mm²
Maximum axial stress Sigma_a,max	=	0,23	N/mm²

Tangential stress:

Sigma_qr = k'·qr·(rg/Ww)·Do	=	0,28	N/mm²
Sigma_qn = k·qn·(rg/Ww)·Do	=	4,98	N/mm²
Maximum tangential stress Sigma_t,max	=	3,42	N/mm²

7.2.5 Load Combination 4: In Operation (with Internal Pressure)

Axial stress:

Sigma_b = Mb/Wb = f_k E·Ib /(Rrol·Wb)	=	0,35	N/mm²

Due to internal pressure :

Sigma_py = f_pd . pd·((ru^2 + ri^2)/(ru^2 - ri^2))	=	5,06	N/mm²
Sigma_px = 0.5·Sigma_py	=	2,53	N/mm²

Sigma_ptest = f_pt . pt·((ru^2 + ri^2)/(ru^2 - ri^2))	=	5,06	N/mm²
Sigma_Temp = dt * gamma_t * alpha_g * E	=	4,41	N/mm²
Maximum axial stress Sigma_a,max	=	7,17	N/mm²

Tangential stress:

Sigma_qr = k'·qr·(rg/Ww)·Do	=	0,28	N/mm²
Sigma_qn = k·qn·(rg/Ww)·Do	=	4,98	N/mm²
Rerounding factor Frr	=	0,566	
Rerounding factor F'rr	=	0,707	

Sigma_t,max = Sigma_py + ((F'rr·. Sigma_qr) + (Frr·. Sigma_qn))

Maximum tangential stress Sigma_t,max	=	7,02	N/mm²

7.3 Check on Calculated Stresses of Pipe: HDPE OD 800 SDR 11

Load combination 1
- Sigma_AxMax < ShortStrength * DamageFactor
- Sigma_TanMax < ShortStrength * DamageFactor

Load combination 2
- Sigma_ptest < ShortStrength * DamageFactor
- Sigma_py < LongStrength * DamageFactor

Load combination 3
- Sigma_AxMax < LongStrength * DamageFactor
- Sigma_TanMax < LongStrength * DamageFactor

Load combination 4
- Sigma_AxMax < LongStrength * DamageFactor
- Sigma_TanMax < LongStrength * DamageFactor

All stresses in all conditions are allowable.

	Max allowable stress [N/mm²]	Load combination 1A	Load combination 1B	Load combination 2	Load combination 3	Load combination 4
Sigma_ptest	10,00 (short)	-	-	5,06	-	-
Sigma_py	8,00 (long)	-	-	5,06	-	-
Sigma_axial	10,00 (short)	4,85	2,11	-	-	-
Sigma_axial	8,00 (long)	-	-	-	0,23	7,17
Sigma_tan...	10,00 (short)	-	0,47	-	-	-
Sigma_tan...	8,00 (long)	-	-	-	3,42	7,02

Stresses in pipeline [N/mm²]

The deflection of the pipeline is 12,0 mm (1,50% x Do). The maximum allowable deflection of the pipeline is 64,0 mm (8,00% x S x Do). The deflection is allowable.
For piggability the maximum allowable deflection of the pipeline is 40,0 mm (5,00% x Do). The deflection is allowable.

7.3.4 Check for Implosion of Pipe: HDPE OD 800 SDR 11

During the pullback operation the drilling fluid gives an external pressure. The highest minimum required drilling fluid pressure during the pullback operation is 202 kN/m², this is less than the maximum allowable external pressure of 1539 kN/m².

As the pipe is completely filled during the pullback operation the external pressure is decreased with the internal pressure of 168 kN/m². The maximum allowable pressure becomes 1707 kN/m².

In operation the water pressure at the lowest point of the drilling gives an external pressure. The maximum water pressure equals 357 kN/m², this is more than the maximum allowable external pressure of 276 kN/m².

If the pipe stays completely filled during operation, the fluid gives an internal pressure of 168 kN/m². This taken in account the total allowable pressure becomes 444 kN/m². This is more than the maximum external pressure.

End of Report

Bijlage 3, D-geo berekening lange termijn

Report for D-Geo Pipeline 18.2

Model : Horizontal Directional Drilling with calculations for settlement
Developed by Deltares

Company:	<Not Registered> <Not Registered>
Date of report:	15-10-2018
Time of report:	09:08:48
Report with version:	18.2.2.20951
Calculated with version:	18.2.2.20951
File name:	G:\..\4–Berekening\berekening HDD Sea Defence sterkte lange termijn
Project identification:	HDD HKZ Mud Pressure Calculation

1 Table of Contents

2 Input Data

2.1 Model Used

Model Used : Horizontal Directional Drilling with calculations for settlement

2.2 Layer Boundaries

Boundary number	Co-ordinates [m]				
24 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
24 - Y -	4,355	4,915	4,796	5,011	5,027
24 - X -	0,000	3,217	6,433	9,650	12,866
24 - Y -	4,967	4,879	4,829	4,815	4,803
24 - X -	16,083	19,299	22,516	25,733	28,949
24 - Y -	4,787	4,706	4,738	4,654	4,657
24 - X -	32,166	35,382	38,599	41,815	45,032
24 - Y -	4,650	4,700	4,706	4,755	4,938
24 - X -	48,248	51,465	54,681	57,898	61,115
24 - Y -	4,916	4,792	4,771	4,816	4,877
24 - X -	64,331	67,548	70,764	73,981	77,197
24 - Y -	4,842	4,883	4,896	4,652	4,805
24 - X -	80,414	83,630	86,847	90,064	93,280
24 - Y -	4,875	4,931	4,977	5,034	5,012
24 - X -	96,497	99,713	102,930	106,146	109,363
24 - Y -	5,006	4,294	4,542	5,874	6,799
24 - X -	112,579	115,796	119,013	122,229	125,446
24 - Y -	7,851	8,870	9,775	10,881	11,793
24 - X -	128,662	131,867	131,879	135,095	138,312
24 - Y -	12,694	13,500	13,503	14,299	14,536
24 - X -	141,529	144,745	145,835	147,962	151,178
24 - Y -	14,451	13,723	13,500	13,065	12,303
24 - X -	154,395	155,497	157,611	160,828	164,044
24 - Y -	11,577	11,271	10,683	9,937	9,280
24 - X -	165,027	167,261	170,478	173,500	176,027
24 - Y -	9,000	8,364	8,022	8,012	8,000
24 - X -	199,073	203,073	207,073	213,795	219,084
24 - Y -	2,000	2,010	2,006	-0,236	-2,000
24 - X -	235,573	243,573	244,021	244,728	260,000
24 - Y -	-7,500	-7,500	-7,799	-8,270	-8,270
24 - X -	269,590	279,180	288,770	298,361	307,951
24 - Y -	-8,241	-8,148	-8,156	-8,212	-8,333
24 - X -	317,541	327,131	336,721	346,311	355,901
24 - Y -	-8,423	-8,641	-8,882	-9,186	-9,477
24 - X -	365,491	375,082	384,672	394,262	403,852
24 - Y -	-9,819	-10,168	-10,499	-10,821	-11,141
24 - X -	413,442	425,000	443,477	456,000	473,000
24 - Y -	-11,488	-12,500	-16,791	-19,700	-19,700
24 - X -	481,000	600,000			
24 - Y -	-17,700	-17,700			
23 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
23 - Y -	4,355	4,915	4,796	5,011	5,027
23 - X -	0,000	3,217	6,433	9,650	12,866
23 - Y -	4,967	4,879	4,829	4,815	4,803
23 - X -	16,083	19,299	22,516	25,733	28,949
23 - Y -	4,787	4,706	4,738	4,654	4,657
23 - X -	32,166	35,382	38,599	41,815	45,032
23 - Y -	4,650	4,700	4,706	4,755	4,938
23 - X -	48,248	51,465	54,681	57,898	61,115
23 - Y -	4,916	4,792	4,771	4,816	4,877
23 - X -	64,331	67,548	70,764	73,981	77,197
23 - Y -	4,842	4,883	4,896	4,652	4,805
23 - X -	80,414	83,630	86,847	90,064	93,280
23 - Y -	4,875	4,931	4,977	5,034	5,012

Boundary number	Co-ordinates [m]				
23 - X -	96,497	96,497	99,713	102,930	103,996
23 - Y -	5,006	4,400	3,700	3,900	4,354
23 - X -	106,146	109,363	112,579	115,796	119,013
23 - Y -	5,270	6,200	7,250	8,270	9,170
23 - X -	122,229	125,446	128,662	131,879	135,095
23 - Y -	10,280	11,200	12,090	12,900	13,700
23 - X -	138,312	141,529	144,745	145,835	147,962
23 - Y -	13,940	13,600	12,900	12,700	12,200
23 - X -	151,178	154,395	155,497	157,611	160,828
23 - Y -	11,500	10,700	10,426	9,900	9,140
23 - X -	164,044	165,027	165,027	165,027	167,261
23 - Y -	8,500	8,200	8,600	9,000	8,364
23 - X -	170,478	173,500	176,027	199,073	203,073
23 - Y -	8,022	8,012	8,000	2,000	2,010
23 - X -	207,073	213,795	219,084	235,573	243,573
23 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
23 - X -	244,021	244,728	260,000	269,590	279,180
23 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
23 - X -	288,770	298,361	307,951	317,541	327,131
23 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
23 - X -	336,721	346,311	355,901	365,491	375,082
23 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
23 - X -	384,672	394,262	403,852	413,442	425,000
23 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
23 - X -	443,477	456,000	473,000	481,000	600,000
23 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
22 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
22 - Y -	4,355	4,915	4,796	5,011	5,027
22 - X -	0,000	3,217	6,433	9,650	12,866
22 - Y -	4,967	4,879	4,829	4,815	4,803
22 - X -	16,083	19,299	22,516	25,733	28,949
22 - Y -	4,787	4,706	4,738	4,654	4,657
22 - X -	32,166	35,382	38,599	41,815	45,032
22 - Y -	4,650	4,700	4,706	4,755	4,938
22 - X -	48,248	51,465	54,681	57,898	61,115
22 - Y -	4,916	4,792	4,771	4,816	4,877
22 - X -	64,331	67,548	70,764	73,981	77,197
22 - Y -	4,842	4,883	4,896	4,652	4,805
22 - X -	80,414	83,630	86,847	90,064	93,280
22 - Y -	4,875	4,931	4,977	5,034	5,012
22 - X -	96,497	96,497	99,713	102,930	103,996
22 - Y -	5,006	4,400	3,700	3,900	4,354
22 - X -	106,146	109,363	112,579	115,796	119,013
22 - Y -	5,270	6,200	7,250	8,270	9,170
22 - X -	122,229	125,446	128,662	131,879	135,095
22 - Y -	10,280	11,200	12,090	12,900	13,700
22 - X -	138,312	141,529	144,745	145,835	147,962
22 - Y -	13,940	13,600	12,900	12,700	12,200
22 - X -	151,178	154,395	155,497	157,611	160,828
22 - Y -	11,500	10,700	10,426	9,900	9,140
22 - X -	164,044	165,027	165,027	167,261	170,478
22 - Y -	8,500	8,200	8,600	8,000	7,600
22 - X -	173,500	173,500	176,027	199,073	203,073
22 - Y -	7,600	8,012	8,000	2,000	2,010
22 - X -	207,073	213,795	219,084	235,573	243,573
22 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
22 - X -	244,021	244,728	260,000	269,590	279,180
22 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
22 - X -	288,770	298,361	307,951	317,541	327,131
22 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
22 - X -	336,721	346,311	355,901	365,491	375,082
22 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
22 - X -	384,672	394,262	403,852	413,442	425,000
22 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
22 - X -	443,477	456,000	473,000	481,000	600,000

Boundary number	Co-ordinates [m]				
22 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
21 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
21 - Y -	4,355	4,915	4,796	5,011	5,027
21 - X -	0,000	3,217	6,433	9,650	12,866
21 - Y -	4,967	4,879	4,829	4,815	4,803
21 - X -	16,083	19,299	22,516	25,733	28,949
21 - Y -	4,787	4,706	4,738	4,654	4,657
21 - X -	32,166	35,382	38,599	41,815	45,032
21 - Y -	4,650	4,700	4,706	4,755	4,938
21 - X -	48,248	51,465	54,681	57,898	61,115
21 - Y -	4,916	4,792	4,771	4,816	4,877
21 - X -	64,331	67,548	70,764	73,981	77,197
21 - Y -	4,842	4,883	4,896	4,652	4,805
21 - X -	80,414	83,630	86,847	90,064	93,280
21 - Y -	4,875	4,931	4,977	5,034	5,012
21 - X -	96,497	96,497	99,713	102,930	103,996
21 - Y -	5,006	4,400	3,700	3,900	4,354
21 - X -	106,146	109,363	112,579	115,796	119,013
21 - Y -	5,270	6,200	7,250	8,270	9,170
21 - X -	122,229	125,446	128,662	131,879	135,095
21 - Y -	10,280	11,200	12,090	12,900	13,700
21 - X -	138,312	141,529	144,745	145,835	147,962
21 - Y -	13,940	13,600	12,900	12,700	12,200
21 - X -	151,178	154,395	155,497	157,611	160,828
21 - Y -	11,500	10,700	10,426	9,900	9,140
21 - X -	164,044	165,027	165,027	167,261	170,478
21 - Y -	8,500	8,200	8,600	8,000	7,600
21 - X -	173,500	175,000	176,027	199,073	203,073
21 - Y -	7,600	7,000	8,000	2,000	2,010
21 - X -	207,073	213,795	219,084	235,573	243,573
21 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
21 - X -	244,021	244,728	260,000	269,590	279,180
21 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
21 - X -	288,770	298,361	307,951	317,541	327,131
21 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
21 - X -	336,721	346,311	355,901	365,491	375,082
21 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
21 - X -	384,672	394,262	403,852	413,442	425,000
21 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
21 - X -	443,477	456,000	473,000	481,000	600,000
21 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
20 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
20 - Y -	4,355	4,915	4,796	5,011	5,027
20 - X -	0,000	3,217	6,433	9,650	12,866
20 - Y -	4,967	4,879	4,829	4,815	4,803
20 - X -	16,083	19,299	22,516	25,733	28,949
20 - Y -	4,787	4,706	4,738	4,654	4,657
20 - X -	32,166	35,382	38,599	41,815	45,032
20 - Y -	4,650	4,700	4,706	4,755	4,938
20 - X -	48,248	51,465	54,681	57,898	61,115
20 - Y -	4,916	4,792	4,771	4,816	4,877
20 - X -	64,331	67,548	70,764	73,981	77,197
20 - Y -	4,842	4,883	4,896	4,652	4,805
20 - X -	80,414	83,630	86,847	90,064	93,280
20 - Y -	4,875	4,931	4,977	5,034	5,012
20 - X -	96,497	96,497	99,713	102,930	103,996
20 - Y -	5,006	4,400	3,700	3,900	4,354
20 - X -	106,146	109,363	112,579	115,796	119,013
20 - Y -	5,270	6,200	7,250	8,270	9,170
20 - X -	122,229	125,446	128,662	131,879	135,095
20 - Y -	10,280	11,200	12,090	12,900	13,700
20 - X -	138,312	141,529	144,745	145,835	147,962
20 - Y -	13,940	13,600	12,900	12,700	12,200
20 - X -	151,178	154,395	155,497	157,611	160,828
20 - Y -	11,500	10,700	10,426	9,900	9,140

Boundary number	Co-ordinates [m]				
20 - X -	164,044	165,027	165,027	167,261	170,478
20 - Y -	8,500	8,200	8,600	8,000	7,600
20 - X -	173,500	175,000	175,058	196,811	197,348
20 - Y -	7,600	7,000	6,710	0,982	0,850
20 - X -	199,073	203,073	207,073	213,795	219,084
20 - Y -	2,000	2,010	2,006	-0,236	-2,000
20 - X -	235,573	243,573	244,021	244,728	260,000
20 - Y -	-7,500	-7,500	-7,799	-8,270	-8,270
20 - X -	269,590	279,180	288,770	298,361	307,951
20 - Y -	-8,241	-8,148	-8,156	-8,212	-8,333
20 - X -	317,541	327,131	336,721	346,311	355,901
20 - Y -	-8,423	-8,641	-8,882	-9,186	-9,477
20 - X -	365,491	375,082	384,672	394,262	403,852
20 - Y -	-9,819	-10,168	-10,499	-10,821	-11,141
20 - X -	413,442	425,000	443,477	456,000	473,000
20 - Y -	-11,488	-12,500	-16,791	-19,700	-19,700
20 - X -	481,000	600,000			
20 - Y -	-17,700	-17,700			
19 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
19 - Y -	4,355	4,915	4,796	5,011	5,027
19 - X -	0,000	3,217	6,433	9,650	12,866
19 - Y -	4,967	4,879	4,829	4,815	4,803
19 - X -	16,083	19,299	22,516	25,733	28,949
19 - Y -	4,787	4,706	4,738	4,654	4,657
19 - X -	32,166	35,382	38,599	41,815	45,032
19 - Y -	4,650	4,700	4,706	4,755	4,938
19 - X -	48,248	51,465	54,681	57,898	61,115
19 - Y -	4,916	4,792	4,771	4,816	4,877
19 - X -	64,331	67,548	70,764	73,981	77,197
19 - Y -	4,842	4,883	4,896	4,652	4,805
19 - X -	80,414	83,630	86,847	90,064	93,280
19 - Y -	4,875	4,931	4,977	5,034	5,012
19 - X -	96,497	96,497	99,713	102,930	103,996
19 - Y -	5,006	4,400	3,700	3,900	4,354
19 - X -	140,000	193,073	197,348	199,073	203,073
19 - Y -	-2,000	-2,000	0,850	2,000	2,010
19 - X -	207,073	213,795	219,084	235,573	243,573
19 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
19 - X -	244,021	244,728	260,000	269,590	279,180
19 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
19 - X -	288,770	298,361	307,951	317,541	327,131
19 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
19 - X -	336,721	346,311	355,901	365,491	375,082
19 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
19 - X -	384,672	394,262	403,852	413,442	425,000
19 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
19 - X -	443,477	456,000	473,000	481,000	600,000
19 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
18 - X -	-32,000	-25,561	-19,171	-12,781	-6,390
18 - Y -	4,355	4,915	4,796	5,011	5,027
18 - X -	0,000	100,000	140,000	179,073	182,073
18 - Y -	4,967	-4,000	-8,000	-8,000	-6,000
18 - X -	187,073	193,073	197,348	199,073	203,073
18 - Y -	-6,000	-2,000	0,850	2,000	2,010
18 - X -	207,073	213,795	219,084	235,573	243,573
18 - Y -	2,006	-0,236	-2,000	-7,500	-7,500
18 - X -	244,021	244,728	260,000	269,590	279,180
18 - Y -	-7,799	-8,270	-8,270	-8,241	-8,148
18 - X -	288,770	298,361	307,951	317,541	327,131
18 - Y -	-8,156	-8,212	-8,333	-8,423	-8,641
18 - X -	336,721	346,311	355,901	365,491	375,082
18 - Y -	-8,882	-9,186	-9,477	-9,819	-10,168
18 - X -	384,672	394,262	403,852	413,442	425,000
18 - Y -	-10,499	-10,821	-11,141	-11,488	-12,500
18 - X -	443,477	456,000	473,000	481,000	600,000

Boundary number	Co-ordinates [m]				
18 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
17 - X -	-32,000	0,000	100,000	140,000	179,073
17 - Y -	-9,000	-9,000	-4,000	-8,000	-8,000
17 - X -	182,073	187,073	193,073	197,348	199,073
17 - Y -	-6,000	-6,000	-2,000	0,850	2,000
17 - X -	203,073	207,073	213,795	219,084	235,573
17 - Y -	2,010	2,006	-0,236	-2,000	-7,500
17 - X -	243,573	244,021	244,728	260,000	269,590
17 - Y -	-7,500	-7,799	-8,270	-8,270	-8,241
17 - X -	279,180	288,770	298,361	307,951	317,541
17 - Y -	-8,148	-8,156	-8,212	-8,333	-8,423
17 - X -	327,131	336,721	346,311	355,901	365,491
17 - Y -	-8,641	-8,882	-9,186	-9,477	-9,819
17 - X -	375,082	384,672	394,262	403,852	413,442
17 - Y -	-10,168	-10,499	-10,821	-11,141	-11,488
17 - X -	425,000	443,477	456,000	473,000	481,000
17 - Y -	-12,500	-16,791	-19,700	-19,700	-17,700
17 - X -	600,000				
17 - Y -	-17,700				
16 - X -	-32,000	0,000	100,000	140,000	179,073
16 - Y -	-14,000	-14,000	-4,000	-8,000	-8,000
16 - X -	182,073	187,073	193,073	197,348	199,073
16 - Y -	-6,000	-6,000	-2,000	0,850	2,000
16 - X -	203,073	207,073	213,795	219,084	235,573
16 - Y -	2,010	2,006	-0,236	-2,000	-7,500
16 - X -	243,573	244,021	244,728	260,000	269,590
16 - Y -	-7,500	-7,799	-8,270	-8,270	-8,241
16 - X -	279,180	288,770	298,361	307,951	317,541
16 - Y -	-8,148	-8,156	-8,212	-8,333	-8,423
16 - X -	327,131	336,721	346,311	355,901	365,491
16 - Y -	-8,641	-8,882	-9,186	-9,477	-9,819
16 - X -	375,082	384,672	394,262	403,852	413,442
16 - Y -	-10,168	-10,499	-10,821	-11,141	-11,488
16 - X -	425,000	443,477	456,000	473,000	481,000
16 - Y -	-12,500	-16,791	-19,700	-19,700	-17,700
16 - X -	600,000				
16 - Y -	-17,700				
15 - X -	-32,000	0,000	100,000	140,000	162,073
15 - Y -	-17,000	-17,000	-10,500	-15,000	-13,000
15 - X -	171,073	176,073	179,073	182,073	187,073
15 - Y -	-10,000	-10,000	-8,000	-6,000	-6,000
15 - X -	193,073	197,348	199,073	203,073	207,073
15 - Y -	-2,000	0,850	2,000	2,010	2,006
15 - X -	213,795	219,084	235,573	243,573	244,021
15 - Y -	-0,236	-2,000	-7,500	-7,500	-7,799
15 - X -	244,728	260,000	269,590	279,180	288,770
15 - Y -	-8,270	-8,270	-8,241	-8,148	-8,156
15 - X -	298,361	307,951	317,541	327,131	336,721
15 - Y -	-8,212	-8,333	-8,423	-8,641	-8,882
15 - X -	346,311	355,901	365,491	375,082	384,672
15 - Y -	-9,186	-9,477	-9,819	-10,168	-10,499
15 - X -	394,262	403,852	413,442	425,000	443,477
15 - Y -	-10,821	-11,141	-11,488	-12,500	-16,791
15 - X -	456,000	473,000	481,000	600,000	
15 - Y -	-19,700	-19,700	-17,700	-17,700	
14 - X -	-32,000	0,000	100,000	140,000	162,073
14 - Y -	-17,000	-17,000	-15,750	-15,000	-13,000
14 - X -	171,073	176,073	179,073	182,073	187,073
14 - Y -	-10,000	-10,000	-8,000	-6,000	-6,000
14 - X -	193,073	197,348	199,073	203,073	207,073
14 - Y -	-2,000	0,850	2,000	2,010	2,006
14 - X -	213,795	219,084	235,573	243,573	244,021
14 - Y -	-0,236	-2,000	-7,500	-7,500	-7,799
14 - X -	244,728	260,000	269,590	279,180	288,770
14 - Y -	-8,270	-8,270	-8,241	-8,148	-8,156

Boundary number	Co-ordinates [m]				
14 - X -	298,361	307,951	317,541	327,131	336,721
14 - Y -	-8,212	-8,333	-8,423	-8,641	-8,882
14 - X -	346,311	355,901	365,491	375,082	384,672
14 - Y -	-9,186	-9,477	-9,819	-10,168	-10,499
14 - X -	394,262	403,852	413,442	425,000	443,477
14 - Y -	-10,821	-11,141	-11,488	-12,500	-16,791
14 - X -	456,000	473,000	481,000	600,000	
14 - Y -	-19,700	-19,700	-17,700	-17,700	
13 - X -	-32,000	0,000	100,000	140,000	162,073
13 - Y -	-19,000	-19,000	-15,750	-15,000	-13,000
13 - X -	171,073	176,073	179,073	182,073	187,073
13 - Y -	-10,000	-10,000	-8,000	-6,000	-6,000
13 - X -	193,073	197,348	199,073	203,073	207,073
13 - Y -	-2,000	0,850	2,000	2,010	2,006
13 - X -	213,795	219,084	235,573	243,573	244,021
13 - Y -	-0,236	-2,000	-7,500	-7,500	-7,799
13 - X -	244,728	260,000	269,590	279,180	288,770
13 - Y -	-8,270	-8,270	-8,241	-8,148	-8,156
13 - X -	298,361	307,951	317,541	327,131	336,721
13 - Y -	-8,212	-8,333	-8,423	-8,641	-8,882
13 - X -	346,311	355,901	365,491	375,082	384,672
13 - Y -	-9,186	-9,477	-9,819	-10,168	-10,499
13 - X -	394,262	403,852	413,442	425,000	443,477
13 - Y -	-10,821	-11,141	-11,488	-12,500	-16,791
13 - X -	456,000	473,000	481,000	600,000	
13 - Y -	-19,700	-19,700	-17,700	-17,700	
12 - X -	-32,000	0,000	100,000	140,000	162,073
12 - Y -	-19,000	-19,000	-15,750	-15,000	-13,000
12 - X -	171,073	176,073	179,073	182,073	187,073
12 - Y -	-10,000	-10,000	-8,000	-6,000	-6,000
12 - X -	193,073	197,348	199,073	203,073	207,073
12 - Y -	-2,000	0,850	2,000	2,010	2,006
12 - X -	213,795	219,084	235,573	243,573	244,021
12 - Y -	-0,236	-2,000	-7,500	-7,500	-7,799
12 - X -	244,728	246,573	250,323	254,323	263,323
12 - Y -	-8,270	-9,500	-12,000	-12,000	-15,000
12 - X -	265,445	443,477	456,000	473,000	481,000
12 - Y -	-15,755	-16,791	-19,700	-19,700	-17,700
12 - X -	600,000				
12 - Y -	-17,700				
11 - X -	-32,000	0,000	100,000	140,000	162,073
11 - Y -	-19,000	-19,000	-15,750	-15,000	-13,000
11 - X -	192,572	235,573	263,323	265,445	443,477
11 - Y -	-13,000	-15,000	-15,000	-15,755	-16,791
11 - X -	456,000	473,000	481,000	600,000	
11 - Y -	-19,700	-19,700	-17,700	-17,700	
10 - X -	-32,000	0,000	100,000	140,000	265,445
10 - Y -	-19,000	-19,000	-15,750	-15,000	-15,755
10 - X -	443,477	456,000	473,000	481,000	600,000
10 - Y -	-16,791	-19,700	-19,700	-17,700	-17,700
9 - X -	-32,000	0,000	100,000	140,000	173,849
9 - Y -	-19,000	-19,000	-15,750	-17,500	-17,650
9 - X -	456,000	473,000	481,000	600,000	
9 - Y -	-19,700	-19,700	-17,700	-17,700	
8 - X -	-32,000	0,000	100,000	140,000	173,849
8 - Y -	-19,000	-19,000	-15,750	-18,000	-17,650
8 - X -	456,000	473,000	481,000	600,000	
8 - Y -	-19,700	-19,700	-17,700	-17,700	
7 - X -	-32,000	0,000	100,000	140,000	157,918
7 - Y -	-19,000	-19,000	-15,750	-18,000	-20,493
7 - X -	181,818	202,782	242,595	256,846	295,412
7 - Y -	-19,000	-25,000	-20,000	-25,000	-20,000
7 - X -	325,593	346,128	361,221	386,752	407,745
7 - Y -	-25,162	-20,000	-25,000	-19,815	-25,000
7 - X -	432,843	463,917	481,032	600,000	

Boundary number	Co-ordinates [m]				
7 - Y -	-20,000	-25,000	-20,000	-26,000	
6 - X -	-32,000	0,000	100,000	140,000	157,918
6 - Y -	-19,000	-19,000	-15,750	-23,000	-20,493
6 - X -	181,818	202,782	242,595	256,846	295,412
6 - Y -	-19,000	-25,000	-20,000	-25,000	-20,000
6 - X -	325,593	346,128	361,221	386,752	407,745
6 - Y -	-25,162	-20,000	-25,000	-19,815	-25,000
6 - X -	432,843	463,917	481,032	600,000	
6 - Y -	-20,000	-25,000	-20,000	-26,000	
5 - X -	-32,000	0,000	100,000	140,000	157,918
5 - Y -	-26,000	-24,000	-20,000	-23,000	-20,493
5 - X -	181,818	202,782	242,595	256,846	295,412
5 - Y -	-19,000	-25,000	-20,000	-25,000	-20,000
5 - X -	325,593	346,128	361,221	386,752	407,745
5 - Y -	-25,162	-20,000	-25,000	-19,815	-25,000
5 - X -	432,843	463,917	481,032	600,000	
5 - Y -	-20,000	-25,000	-20,000	-26,000	
4 - X -	-32,000	0,000	100,000	140,000	157,918
4 - Y -	-26,000	-24,000	-22,500	-23,000	-20,493
4 - X -	181,818	202,782	242,595	256,846	295,412
4 - Y -	-19,000	-25,000	-20,000	-25,000	-20,000
4 - X -	325,593	346,128	361,221	386,752	407,745
4 - Y -	-25,162	-20,000	-25,000	-19,815	-25,000
4 - X -	432,843	463,917	481,032	600,000	
4 - Y -	-20,000	-25,000	-20,000	-26,000	
3 - X -	-32,000	0,000	100,000	140,000	158,339
3 - Y -	-28,000	-28,000	-27,000	-29,000	-28,000
3 - X -	184,746	217,863	241,336	266,067	294,570
3 - Y -	-30,000	-28,000	-30,000	-28,000	-30,000
3 - X -	314,692	345,290	366,668	393,495	419,064
3 - Y -	-28,000	-30,000	-28,000	-30,000	-28,000
3 - X -	435,413	454,695	479,300	600,000	
3 - Y -	-30,000	-28,000	-30,000	-28,000	
2 - X -	-32,000	0,000	100,000	140,000	156,243
2 - Y -	-32,000	-32,000	-29,000	-31,500	-34,000
2 - X -	192,711	215,924	248,043	264,390	290,798
2 - Y -	-31,000	-34,000	-31,000	-34,000	-31,000
2 - X -	311,338	337,745	364,991	400,623	416,984
2 - Y -	-34,000	-31,000	-34,000	-31,000	-34,000
2 - X -	445,475	461,819	479,300	600,000	
2 - Y -	-31,000	-34,000	-31,000	-34,000	
1 - X -	-32,000	0,000	24,626	49,776	60,000
1 - Y -	-40,000	-40,000	-47,474	-40,789	-48,000
1 - X -	98,398	109,467	140,000	162,181	200,255
1 - Y -	-40,000	-48,000	-42,000	-48,000	-40,000
1 - X -	210,790	247,204	259,099	294,990	310,396
1 - Y -	-48,000	-40,000	-48,000	-40,000	-48,000
1 - X -	344,872	362,115	397,691	410,264	440,007
1 - Y -	-40,000	-48,000	-40,000	-48,000	-40,000
1 - X -	461,400	479,300	600,000		
1 - Y -	-48,000	-40,000	-40,000		
0 - X -	-32,000	600,000			
0 - Y -	-50,000	-50,000			

2.3 Pl-lines

Pl-line number	Co-ordinates [m]				
1 - X -	-32,000	600,000			
1 - Y -	0,000	0,000			

2.4 Phreatic Line

Piezo-line 1 is used as phreatic line (groundwater).

2.5 Soil Profiles

Layer number	Material name	Piezo-line at top	Piezo-line at bottom
24	klei, bekleding	1	1
23	zandasfalt	1	1
22	breuksteen 10-60 kg	1	1
21	breuksteen 6-10 ton	1	1
20	zand, mf_mv (HL)	1	1
19	zand, mf_mg, l (HL)	1	1
18	zand, mg_v (HL)	1	1
17	zand, mg_mv (HL)	1	1
16	zand, kl_mf_m_t_l (...	1	1
15	zand, mf_mg, l (HL)	1	1
14	zand, mg_v (HL)	1	1
13	zand, mf_mg, l (HL)	1	1
12	div. betonnenblokken	1	1
11	zand, mf_mg, l (HL)	1	1
10	zand, mf_mv diep (...	1	1
9	zand, kl_mf_m_t_v ...	1	1
8	leem, fz_kl (KR)	1	1
7	zand, mg_v (HL)	1	1
6	leem, fz_kl (KR)	1	1
5	klei, m_t_v (KR)	1	1
4	zand, zg_g (KR)	1	1
3	zand, zg_g_s_ki (K...	1	1
2	zand, zg_g (KR)	1	1
1	klei, s (WA)	1	1

2.6 Selected Boundaries

The boundary between (cohesive) undrained top layers and underlaying (non-cohesive) drained layers, is situated at the top of layer number 19: zand, mf_mg, l (HL)
The boundary between compressible top layers and underlaying non-compressible layers, is situated at the top of layer number 19: zand, mf_mg, l (HL)

2.7 Soil Material Data

Name	Gamma unsat [kN/m³]	Gamma sat [kN/m³]	Cohesion [kN/m²]	Phi [deg]	Su top [kN/m²]	Su bottom [kN/m²]
geen sterkte	0,01	0,02	0,00	0,00	0,00	0,00
klei, m_t_s (HL)	17,00	17,00	5,00	17,50	50,00	50,00
zand, mf_mg, l (HL)	18,00	19,00	0,00	30,00	0,00	0,00
zand, mf_mv (HL)	18,00	19,00	0,00	32,50	0,00	0,00
zand, mg_v (HL)	19,00	21,00	0,00	35,00	0,00	0,00
zand, mg_mv (HL)	18,00	20,00	0,00	32,50	0,00	0,00
zand, kl_mf_m_t_l (HL)	16,00	17,00	5,00	30,00	0,00	0,00
zand, kl_mf_m_t_v (HL)	17,00	18,00	5,00	35,00	0,00	0,00
leem, fz_kl (KR)	18,00	18,00	5,00	25,00	80,00	80,00
klei, m_t_v (KR)	16,00	16,00	4,00	19,00	60,00	60,00
zand, zg_g (KR)	19,00	21,00	0,00	32,60	0,00	0,00
zand, zg_g_s_ki (KR_...	19,00	21,00	0,00	30,30	0,00	0,00
klei, s (WA)	20,00	20,00	10,00	27,50	0,00	0,00
zand, mf_mv diep (HL)	18,00	19,00	0,00	28,00	0,00	0,00
klei, bekleding	17,00	17,00	4,00	14,70	50,00	50,00
zandasfalt	16,50	16,50	0,00	31,90	0,00	0,00
breuksteen 10-60 kg	18,00	20,00	0,00	30,30	0,00	0,00
breuksteen 6-10 ton	19,00	21,00	0,00	32,60	0,00	0,00
betonnenblokken	19,00	20,00	0,00	37,50	0,00	0,00
div. betonnenblokken	19,00	21,00	0,00	32,60	0,00	0,00

Name	Soil type	Emod 100 [kN/m²]	Emod top [kN/m²]	Emod bottom [kN/m²]
geen sterkte	-	-	0,01	0,01
klei, m_t_s (HL)	-	-	0,01	0,01
zand, mf_mg, l (HL)	-	-	45000,00	75000,00
zand, mf_mv (HL)	-	-	45000,00	75000,00
zand, mg_v (HL)	-	-	75000,00	110000,00
zand, mg_mv (HL)	-	-	45000,00	75000,00
zand, kl_mf_m_t_l (HL)	-	-	35000,00	50000,00
zand, kl_mf_m_t_v (HL)	-	-	45000,00	75000,00
leem, fz_kl (KR)	-	-	2000,00	3000,00
klei, m_t_v (KR)	-	-	1500,00	3000,00
zand, zg_g (KR)	-	-	45000,00	75000,00
zand, zg_g_s_ki (KR_...	-	-	45000,00	75000,00
klei, s (WA)	-	-	0,01	0,01
zand, mf_mv diep (HL)	-	-	0,01	0,01
klei, bekleding	-	-	0,01	0,01
zandasfalt	-	-	0,01	0,01
breuksteen 10-60 kg	-	-	0,01	0,01
breuksteen 6-10 ton	-	-	0,01	0,01
betonnenblokken	-	-	0,01	0,01
div. betonnenblokken	-	-	0,01	0,01

Name	Adhesion A [kN/m²]	Delta D [deg]	Nu [-]
geen sterkte	-	-	0,00
klei, m_t_s (HL)	-	-	0,30
zand, mf_mg, l (HL)	-	-	0,30
zand, mf_mv (HL)	-	-	0,30
zand, mg_v (HL)	-	-	0,00
zand, mg_mv (HL)	-	-	0,30
zand, kl_mf_m_t_l (HL)	-	-	0,30
zand, kl_mf_m_t_v (HL)	-	-	0,30
leem, fz_kl (KR)	-	-	0,30
klei, m_t_v (KR)	-	-	0,00
zand, zg_g (KR)	-	-	0,30
zand, zg_g_s_ki (KR_...	-	-	0,30
klei, s (WA)	-	-	0,00
zand, mf_mv diep (HL)	-	-	0,00
klei, bekleding	-	-	0,00
zandasfalt	-	-	0,00
breuksteen 10-60 kg	-	-	0,00
breuksteen 6-10 ton	-	-	0,00
betonnenblokken	-	-	0,00
div. betonnenblokken	-	-	0,00

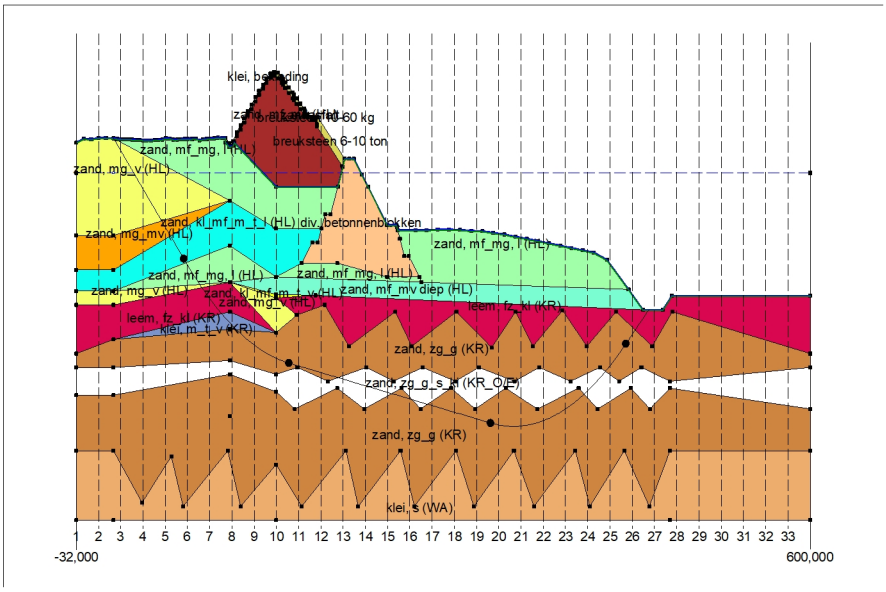
2.8 Soil Material Data for Settlement

Name [-]	OCR [-]	Cp [-]	Cp' [-]	Cs [-]	Cs' [-]
geen sterkte	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
klei, m_t_s (HL)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, mf_mg, l ...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, mf_mv (HL)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, mg_v (HL)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, mg_mv (...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, kl_mf_m_...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, kl_mf_m_...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
leem, fz_kl (KR)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
klei, m_t_v (KR)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, zg_g (KR)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zand, zg_g_s_ki...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
klei, s (WA)	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00

Name [-]	OCR [-]	Cp [-]	Cp' [-]	Cs [-]	Cs' [-]
zand, mf_mv di...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
klei, bekleding	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
zandasfalt	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
breuksteen 10-6...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
breuksteen 6-10...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
betonnenblokken	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00
div. betonnenbl...	1,30	1,00E+00	1,00E+00	1,00E+00	1,00E+00

2.9 Geometry

2.9.1 Geometry Section, Detailed



2.9.2 Geometry Top View

2.10 Calculation Verticals

Vertical nr.	L-coord [m]	Z-coord [m]	Additional settlement [mm]
1	6,300	3,160	0,00
2	25,450	-2,330	0,00
3	44,610	-7,820	0,00
4	63,760	-13,300	0,00
5	82,910	-18,110	0,00
6	102,060	-21,930	0,00
7	121,210	-24,790	0,00
8	140,360	-26,710	0,00
9	159,510	-27,800	0,00
10	178,670	-28,750	0,00
11	197,820	-29,700	0,00
12	216,970	-30,650	0,00
13	236,120	-31,600	0,00
14	255,270	-32,550	0,00
15	274,420	-33,500	0,00
16	293,580	-34,450	0,00
17	312,730	-35,400	0,00
18	331,880	-36,290	0,00
19	351,030	-36,440	0,00
20	370,180	-35,670	0,00
21	389,330	-33,980	0,00
22	408,490	-31,350	0,00
23	427,640	-27,760	0,00
24	446,790	-23,240	0,00

Locations of the calculation verticals; L represents distance along the pipeline projection in the horizontal plane, incremented with the entry co-ordinate.

2.11 Configuration of the Pipeline

X co-ordinate left point	0,000	[m]
Y co-ordinate left point	0,000	[m]
Z co-ordinate left point	4,967	[m]
X co-ordinate right point	461,000	[m]
Y co-ordinate right point	0,000	[m]
Z co-ordinate right point	-19,700	[m]
Angle left	16,0000	[deg]
Angle right	14,0000	[deg]
Bending radius left, vertical in/out	400,000	[m]
Bending radius right, vertical in/out	400,000	[m]
Bending radius pipe on rollers	60,000	[m]
Lowest level of pipe (centre bore hole)	-36,000	[m]
Angle of pipe (between radii)	-2,8400	[deg]
Number of horizontal bends	0	

The pulling direction of the product pipe is from left to right

2.12 Product Pipe Material Data

Material	Polyethene	
Quality	PE100	
Young's modulus (short)	975,00	[N/mm²]
Young's modulus (long)	70,00	[N/mm²]
Allowable strength (short)	10,00	[N/mm²]
Allowable strength (long)	2,40	[N/mm²]
Tensile factor (alpha)	0,65	[-]
Outer diameter product pipe	800,00	[mm]
Wall thickness (Nominal)	72,60	[mm]
Unit weight pipe material	9,54	[kN/m³]
Design pressure	0,00	[bar]
Test pressure	0,00	[bar]
Temperature variation	70,00	[deg C]

2.13 Pipe Engineering Data

Pipe filled with water on rollers	No	
Part of cross section filled with fluid	100	[%]
Unit weight fluid	10,00	[kN/m³]
Bedding angle	120	[deg]
Load angle	180	[deg]
Relative displacement	10,00	[mm]
Compression index	6,00	[-]
Linear settlement coefficient (alpha_g) for steel	0,0000117	[mm/mmK]
Linear settlement coefficient (alpha_g) for PE	0,0001800	[mm/mmK]
Modulus of subgrade reaction drilling fluid (Kv)	500,00	[kN/m³]
Phi drilling fluid	15,00	[deg]
Cohesion drilling fluid	5,00	[kN/m²]
Factor of friction pipe-roller (f1)	0,10	[-]
Friction pipe-drilling fluid (f2)	0,000050	[N/mm²]
Factor of friction pipe-soil (f3)	0,20	[-]
Special Stress Analysis	not used	
Special Stress Data	not used	

2.14 Factors

(Polyethene)Safety factor on implosion (Long)	3,0	[-]
(Polyethene)Safety factor on implosion (Short)	1,5	[-]
Contingency factor on total unit weight of material types below and above phreatic level	1,10	[-]
Contingency factor on (drained) cohesion C	1,40	[-]
Contingency factor on undrained shear strength Su	1,40	[-]

Contingency factor on Phi	1,10	[-]
Contingency factor on E-modulus	1,25	[-]
Contingency factor on modulus of subgrade reaction	1,30	[-]
Factor of importance (S)	1,00	[-]
Allowable deflection of steel pipe	15,00	[%]
Allowable piggability of steel pipe	5,00	[%]
Allowable deflection of polyethene pipe	8,00	[%]
Allowable piggability of polyethene pipe	5,00	[%]
Unit weight water	9,81	[kN/m³]
Safety factor on cover (drained layer)	0,50	[-]
Safety factor on cover (undrained layer)	0,50	[-]
Ratio H/Do for boundary between shallow and deep situation	7,50	[-]

3 Deformations

3.1 Settlements of Soil Layers below the Pipeline

Vertical nr. [-]	Settlement [mm]	Additional settlement [mm]	dv [mm]
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0

4 Soil Mechanical Data

4.1 Soil Mechanical Parameters (Pipe: HDPE OD 800 SDR 11)

The list with data and issues is shown hereafter:
Note: safety factors not applied.

q_v;p	Passive soil stress	kN/m²
q_v;n	Neutral soil stress	kN/m²
q_h;n	Neutral horizontal soil stress	kN/m²
q_v,r;n	Reduced neutral soil stress	kN/m²
q_v;e	Vertical bearing capacity	kN/m²
q_h;e	Horizontal bearing capacity	kN/m²
dv	Vertical displacement	mm
k_v;bot	Vertical modulus of subgrade reaction downward	kN/m³
k_v;top	Vertical modulus of subgrade reaction upward	kN/m³
k_h	Horizontal modulus of subgrade reaction	kN/m³
t_max	Maximal friction pipe-lubricant	kN/m²
d_max	Displacement at maximal friction	mm

Vertical nr.	q_v;p [kN/m²]	q_v;n [kN/m²]	q_h;n [kN/m²]	q_v;r;n [kN/m²]	q_v;e [kN/m²]	q_h;e [kN/m²]
1	37	25	19	25	1316	299
2	378	109	81	109	5138	924
3	970	173	29	39	5963	1342
4	1418	208	25	34	5550	1418
5	581	245	25	34	3999	581
6	602	258	24	33	7728	602
7	2537	403	20	27	14370	2537
8	3064	505	20	27	17972	3064
9	2935	437	20	27	12063	2935
10	2844	420	22	29	12297	2844
11	2092	347	23	31	9572	2092
12	1988	302	23	31	8333	1988
13	1845	252	23	31	8850	1845
14	1644	235	21	29	8397	1644
15	1712	246	21	29	8798	1712
16	1901	265	22	29	9447	1901
17	1824	265	21	29	9478	1824
18	1952	270	21	29	9644	1952
19	1954	273	22	29	9729	1954
20	1785	253	22	29	9047	1785
21	1714	237	22	30	8450	1714
22	1472	188	21	29	6062	1472
23	907	143	21	29	4531	1277
24	143	48	36	48	1754	542

Vertical nr.	dv [mm]	k_v;bot [kN/m³]	k_v;top [kN/m³]	k_h [kN/m³]	t_max [kN/m²]	d_max [mm]
1	0	69684	783	48779	0,05	7,5
2	0	102044	83803	71431	0,05	7,5
3	0	50886	95120	35620	0,05	7,5
4	0	58503	45753	40952	0,05	7,5
5	0	1764	47448	1235	0,05	7,5
6	0	57354	1740	40148	0,05	7,5
7	0	67471	19537	47230	0,05	7,5
8	0	68256	64415	47779	0,05	7,5
9	0	59656	69548	41759	0,05	7,5
10	0	61668	71026	43168	0,05	7,5
11	0	58763	69084	41134	0,05	7,5
12	0	65964	63029	46175	0,05	7,5
13	0	53831	69203	37682	0,05	7,5
14	0	53502	66077	37451	0,05	7,5
15	0	55580	65081	38906	0,05	7,5

Vertical nr.	dv [mm]	k_v;bot [kN/m³]	k_v;top [kN/m³]	k_h [kN/m³]	t_max [kN/m²]	d_max [mm]
16	0	68122	56351	47686	0,05	7,5
17	0	56684	65674	39679	0,05	7,5
18	0	68387	53340	47871	0,05	7,5
19	0	68186	55319	47730	0,05	7,5
20	0	59017	63337	41312	0,05	7,5
21	0	62172	58567	43521	0,05	7,5
22	0	55295	64626	38707	0,05	7,5
23	0	65035	65554	45524	0,05	7,5
24	0	66347	4464	46443	0,05	7,5

Maximum soil stress : q_v;n;max = 505 kN/m²
Maximum reduced soil stress : q_v;r;n;max = 109 kN/m²
Max. vertical modulus of subgrade reaction (without safety factor) only for verticals in deep situation : k_v;max = 102044 kN/m³
Maximum vertical modulus of subgrade reaction (with safety factor) only for verticals in deep situation : k_v;max = 132657 kN/m³

4.2 Young's Modulus per Layer per Vertical

Layer number	Material name	Type of determination
24	klei, bekleding	User defined
23	zandasfalt	User defined
22	breuksteen 10-60 kg	User defined
21	breuksteen 6-10 ton	User defined
20	zand, mf_mv (HL)	User defined
19	zand, mf_mg, l (HL)	User defined
18	zand, mg_v (HL)	User defined
17	zand, mg_mv (HL)	User defined
16	zand, kl_mf_m_t_l (HL)	User defined
15	zand, mf_mg, l (HL)	User defined
14	zand, mg_v (HL)	User defined
13	zand, mf_mg, l (HL)	User defined
12	div. betonnenblokken	User defined
11	zand, mf_mg, l (HL)	User defined
10	zand, mf_mv diep (HL)	User defined
9	zand, kl_mf_m_t_v (HL)	User defined
8	leem, fz_kl (KR)	User defined
7	zand, mg_v (HL)	User defined
6	leem, fz_kl (KR)	User defined
5	klei, m_t_v (KR)	User defined
4	zand, zg_g (KR)	User defined
3	zand, zg_g_s_ki (KR_...	User defined
2	zand, zg_g (KR)	User defined
1	klei, s (WA)	User defined

Layer number	Vertical 1 (X=-32 m)		Vertical 2 (X=-12,848 m)		Vertical 3 (X=6,303 m)		Vertical 4 (X=25,455 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	45,001	74,999	45,000	75,000	45,000	75,000	45,000	75,000
18	75,000	110,000	75,000	110,000	75,000	110,000	75,000	110,000
17	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
16	35,000	50,000	35,000	50,000	35,000	50,000	35,000	50,000
15	45,001	74,999	45,000	75,000	45,000	75,000	45,000	75,000
14	75,000	110,000	75,000	110,000	75,000	110,000	75,000	110,000
13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Layer number	Vertical 1 (X=-32 m)		Vertical 2 (X=-12,848 m)		Vertical 3 (X=6,303 m)		Vertical 4 (X=25,455 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
5	1,500	3,000	1,500	3,000	1,500	3,000	1,500	3,000
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 5 (X=44,606 m)		Vertical 6 (X=63,758 m)		Vertical 7 (X=82,909 m)		Vertical 8 (X=102,061 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	0,000	0,000	0,000	0,000	0,000	0,000
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	45,000	75,000	45,000	75,000
19	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
18	75,000	110,000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	45,000	75,000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	35,000	50,000	35,000	50,000	35,000	50,000	35,000	50,000
15	45,000	75,000	45,000	75,000	45,000	75,000	n.a.	n.a.
14	75,001	109,999	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	45,009	74,991
10	n.a.	n.a.	0,000	0,000	0,000	0,000	0,000	0,000
9	n.a.	n.a.	45,012	74,988	45,001	74,999	45,001	74,999
8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2,000	3,000
7	n.a.	n.a.	75,001	109,999	75,000	110,000	75,000	110,000
6	2,000	3,000	2,000	3,000	2,000	3,000	n.a.	n.a.
5	1,500	3,000	1,500	3,000	1,500	3,000	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 9 (X=121,212 m)		Vertical 10 (X=140,364 m)		Vertical 11 (X=159,515 m)		Vertical 12 (X=178,667 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	0,000	0,000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	0,000	0,000	0,000	0,000	n.a.	n.a.
20	45,000	75,000	45,000	75,000	n.a.	n.a.	n.a.	n.a.
19	45,000	75,000	45,000	75,000	n.a.	n.a.	n.a.	n.a.
18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	35,000	50,000	35,001	49,999	n.a.	n.a.	n.a.	n.a.
15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
12	n.a.	n.a.	0,000	0,000	0,000	0,000	0,000	0,000
11	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
10	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
9	45,001	74,999	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000

Layer number	Vertical 9 (X=121,212 m)		Vertical 10 (X=140,364 m)		Vertical 11 (X=159,515 m)		Vertical 12 (X=178,667 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 13 (X=197,818 m)		Vertical 14 (X=216,97 m)		Vertical 15 (X=236,121 m)		Vertical 16 (X=255,273 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	n.a.	n.a.	45,000	75,000	45,000	75,000	45,000	75,000
12	0,000	0,000	0,000	0,000	n.a.	n.a.	n.a.	n.a.
11	45,001	74,999	45,000	75,000	n.a.	n.a.	n.a.	n.a.
10	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 17 (X=274,424 m)		Vertical 18 (X=293,576 m)		Vertical 19 (X=312,727 m)		Vertical 20 (X=331,879 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Layer number	Vertical 21 (X=351,03 m)		Vertical 22 (X=370,182 m)		Vertical 23 (X=389,333 m)		Vertical 24 (X=408,485 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Layer number	Vertical 21 (X=351,03 m)		Vertical 22 (X=370,182 m)		Vertical 23 (X=389,333 m)		Vertical 24 (X=408,485 m)	
	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]	E-top [MPa]	E-bottom [MPa]
23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
21	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
20	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
19	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
18	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
16	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
13	45,000	75,000	45,000	75,000	45,000	75,000	n.a.	n.a.
12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
8	2,000	3,000	2,000	3,000	2,000	3,000	2,000	3,000
7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
3	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
2	45,000	75,000	45,000	75,000	45,000	75,000	45,000	75,000
1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

5 Data for Stress Analysis

5.1 General data

Pipeline diameter	:	Do = 800,00 mm
Wall thickness	:	t = 72,60 mm
Unit weight pipeline material	:	gamma_s = 9,54 kN/m³
Unit weight drilling fluid pullback operation	:	gamma_b = 11,40 kN/m³
Combined bending radius	:	Rmin = 400,000 m
Bending radius on rollers	:	Rrol = 60,000 m
Friction coefficient pipe/rollers	:	f1 = 0,10
Friction between pipe and drilling fluid	:	f2 = 0,000050 N/mm²
Friction coefficient pipe / soil	:	f3 = 0,20
Max. vertical modulus of subgrade reaction (without safety factor)	:	k_v;max = 102044 kN/m³

5.2 Buoyancy Control

The friction between soil and pipe is partially caused by buoyancy of the pipeline in the drilling fluid. Uplift forces resulting from buoyancy can be neutralized by filling the pipeline. The optimal volume of fluid placed in the pipe provides the most advantageous distribution of buoyant forces.

Buoyancy of the pipeline when filled with fluid for 100%

Uplift forces	:	573	[kg/m]	
Weight of pipeline (including filling)	:	495	[kg/m]	

Result	:	78	[kg/m]	(Pipeline moves upwards)

6 Stress Analysis of Pipe: HDPE OD 800 SDR 11

6.1 Material Data of Pipe: HDPE OD 800 SDR 11

The list with data and issues is shown hereafter:

Material pipeline	:	Polyethene PE100
Outer diameter	:	Do = 800,00 mm
Wall thickness	:	t = 72,60 mm
Design pressure	:	pd = 0,00 bar
Test pressure	:	pt = 0,00 bar
Temperature variation	:	dt = 70,00 deg Celcius
Length pipeline	:	L = 467 m
Young's modulus (short)	:	E = 975 N/mm²
Young's modulus (long)	:	E = 70 N/mm²
Allowable stress (short)	:	S = 10 N/mm²
Allowable stress (long)	:	S = 2 N/mm²
Factor of importance (S)	:	S = 1,00
Poisson ratio	:	nu = 0,40
Unit weight pipeline material	:	gamma_s = 9,54 kN/m³
Bedding angle	:	beta = 120 degrees
Load angle	:	alpha = 180 degrees
Moment coefficient soil top (indirect)	:	kt' = 0,061
Moment coefficient soil bottom (indirect)	:	kb' = 0,083
Moment coefficient soil top (direct)	:	kt = 0,131
Moment coefficient soil bottom (direct)	:	kb = 0,138
Deflection coefficient (indirect)	:	ky' = 0,048
Deflection coefficient (direct)	:	ky = 0,089
Maximal reduced vertical soil load (without safety factor)	:	q_v;r;n;max = 109 kN/m²
Traffic load (without safety factor)	:	q_v = 0 kN/m²
Max. vertical modulus of subgrade reaction (without safety factor)	:	k_v;max = 102044 kN/m³
Load factor on installation	:	f_install = 1,00
Load factor on reduced neutral soil stress q_n;r	:	f_Qnr = 1,00
Load factor on design pressure	:	f_pd = 1,00
Load factor on design pressure (combination)	:	f_pd;comb = 1,00
Load factor on test pressure	:	f_pt = 1,00
Load factor on temperature	:	f_temp = 1,00
Load factor on traffic load	:	f_v = 1,00
Contingency factor on bending radius	:	f_R = 1,10
Contingency factor on modulus of subgrade reaction	:	f_kv = 1,30
Contingency factor on bending moment	:	f_k = 1,00
Total factor on pulling force for stoch. varia. and model uncertainty	:	f = 1,40
Linear settlement coefficient	:	alpha_g = 0,00018 mm/mmK

6.2 Results Stress Analysis of Pipe: HDPE OD 800 SDR 11

In the calculation 5 load combinations are considered:

- Load combination 1A: start pull-back operation
- Load combination 1B: end of pull-back operation
- Load combination 2: application internal pressure
- Load combination 3: pipeline in operation, no inner pressure
- Load combination 4: pipeline in operation, pressure applied

The wall thickness is 72,6 mm. The calculation hereafter will prove that the pipeline wall thickness is not sufficient. The calculations are in accordance with NEN 3650 series.

6.2.1 Load Combination 2: Application Internal Pressure

Due to internal pressure :

Sigma_py = f_pd . pd·((ru^2 + ri^2)/(ru^2 - ri^2))	=	0,00	N/mm²
Sigma_px = 0.5·Sigma_py	=	0,00	N/mm²

Sigma_ptest = f_pt . pt·((ru^2 + ri^2)/(ru^2 - ri^2))	=	0,00	N/mm²

6.2.2 Load Combination 3: In Operation (Situation without Pressure)

Axial stress:

Sigma_b = Mb/Wb = f_k E·Ib /(Rrol·Wb)	=	0,07	N/mm²
Maximum axial stress Sigma_a,max	=	0,05	N/mm²

Tangential stress:

Sigma_qr = k'·qr·(rg/Ww)·Do	=	0,14	N/mm²
Sigma_qn = k·qn·(rg/Ww)·Do	=	4,98	N/mm²
Maximum tangential stress Sigma_t,max	=	3,33	N/mm²

6.2.3 Load Combination 4: In Operation (with Internal Pressure)

Axial stress:

Sigma_b = Mb/Wb = f_k E·Ib /(Rrol·Wb)	=	0,07	N/mm²

Due to internal pressure :

Sigma_py = f_pd . pd·((ru^2 + ri^2)/(ru^2 - ri^2))	=	0,00	N/mm²
Sigma_px = 0.5·Sigma_py	=	0,00	N/mm²
Sigma_ptest = f_pt . pt·((ru^2 + ri^2)/(ru^2 - ri^2))	=	0,00	N/mm²
Sigma_Temp = dt * gamma_t * alpha_g * E	=	0,88	N/mm²
Maximum axial stress Sigma_a,max	=	0,93	N/mm²

Tangential stress:

Sigma_qr = k'·qr·(rg/Ww)·Do	=	0,14	N/mm²
Sigma_qn = k·qn·(rg/Ww)·Do	=	4,98	N/mm²
Rerounding factor Frr	=	1,000	
Rerounding factor F'rr	=	1,000	

Sigma_t,max = Sigma_py + ((F'rr·. Sigma_qr) + (Frr·. Sigma_qn))

Maximum tangential stress Sigma_t,max	=	3,33	N/mm²

6.3 Check on Calculated Stresses of Pipe: HDPE OD 800 SDR 11

Load combination 1
- Sigma_AxMax < ShortStrength * DamageFactor
- Sigma_TanMax < ShortStrength * DamageFactor

Load combination 2
- Sigma_ptest < ShortStrength * DamageFactor
- Sigma_py < LongStrength * DamageFactor

Load combination 3
- Sigma_AxMax < LongStrength * DamageFactor
- Sigma_TanMax < LongStrength * DamageFactor

Load combination 4

- Sigma_AxMax < LongStrength * DamageFactor
- Sigma_TanMax < LongStrength * DamageFactor

In load combination 3/4 stresses are NOT allowable.

	Max allowable stress [N/mm²]	Load combination 1A	Load combination 1B	Load combination 2	Load combination 3	Load combination 4
Sigma_ptest	10,00 (short)	-	-	0,00	-	-
Sigma_py	2,40 (long)	-	-	0,00	-	-
Sigma_axial	10,00 (short)	4,85	2,12	-	-	-
Sigma_axial	2,40 (long)	-	-	-	0,05	0,93
Sigma_tan...	10,00 (short)	-	0,52	-	-	-
Sigma_tan...	2,40 (long)	-	-	-	3,33	3,33

Stresses in pipeline [N/mm²]

The deflection of the pipeline is 55,8 mm (6,98% x Do). The maximum allowable deflection of the pipeline is 64,0 mm (8,00% x S x Do). The deflection is allowable.
For piggability the maximum allowable deflection of the pipeline is 40,0 mm (5,00% x Do). The deflection is not allowable.

6.3.4 Check for Implosion of Pipe: HDPE OD 800 SDR 11

During the pullback operation the drilling fluid gives an external pressure. The highest minimum required drilling fluid pressure during the pullback operation is 202 kN/m², this is less than the maximum allowable external pressure of 1539 kN/m².

As the pipe is completely filled during the pullback operation the external pressure is decreased with the internal pressure of 168 kN/m². The maximum allowable pressure becomes 1707 kN/m².

In operation the water pressure at the lowest point of the drilling gives an external pressure. The maximum water pressure equals 357 kN/m², this is more than the maximum allowable external pressure of 55 kN/m².

If the pipe stays completely filled during operation, the fluid gives an internal pressure of 168 kN/m². This taken in account the total allowable pressure becomes 223 kN/m². This is less still than the maximum external pressure.

End of Report