WindBASE

Dutch innovation since 1983

Safe, innovative and cost-effective wind turbine foundations

Stufib

9 september 2023

WindBASE

Axel Jacobs

Director Windbase
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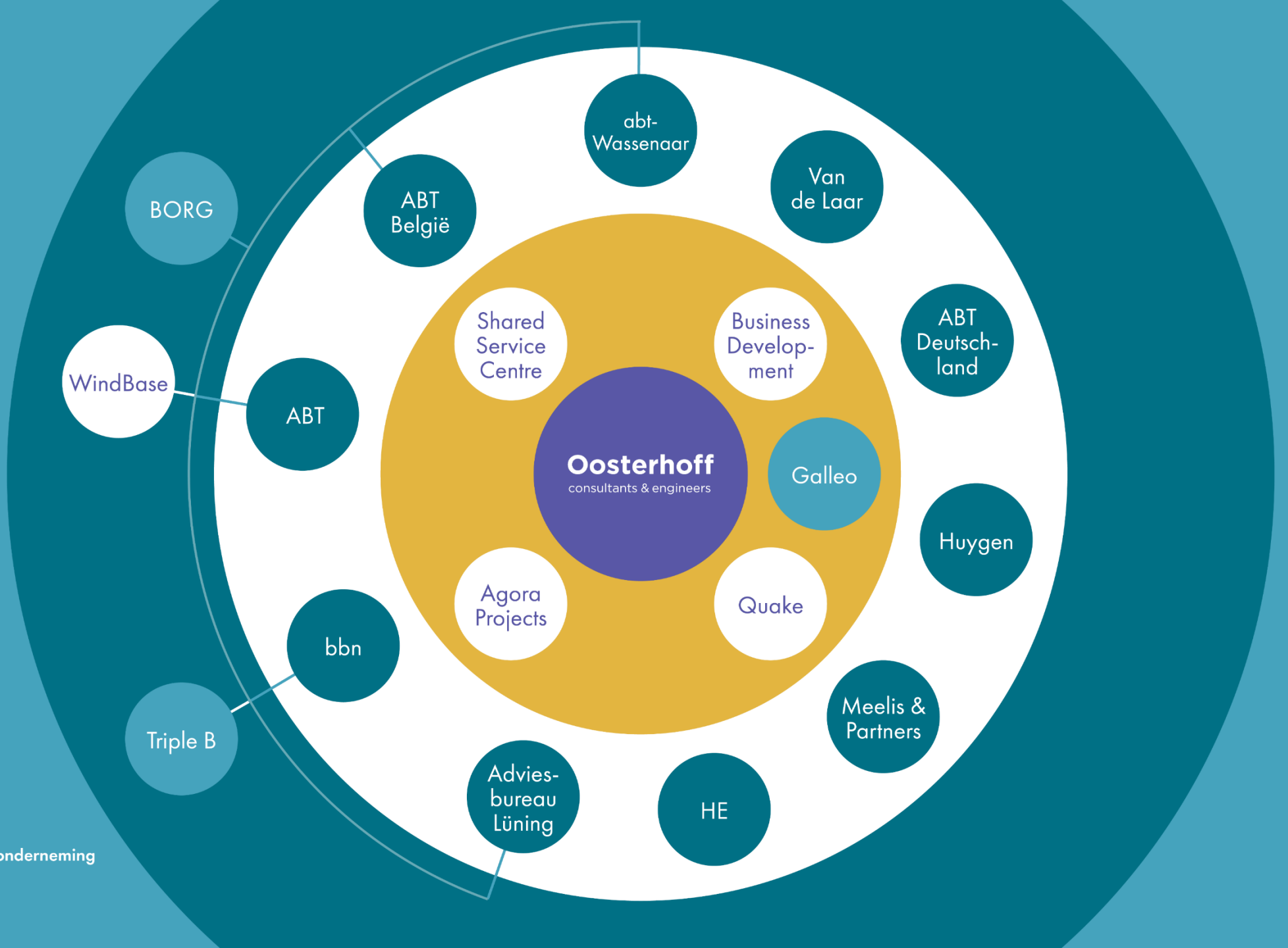
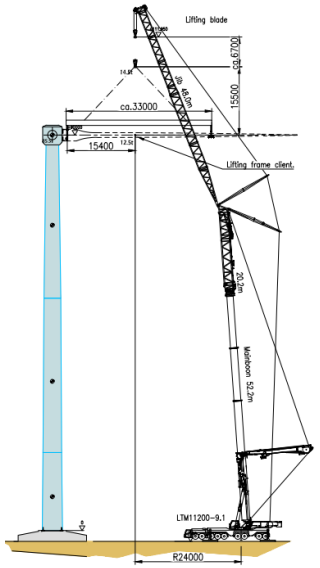
+31 (0) 26 36 835 46
a.jacobs@windbase.eu
www.windbase.eu/axeljacobs



50% Oosterhoff dochteronderneming

- ○ Borg
- ○ Galleo
- ○ Triple B

Windturbines


Lifting blade
ca.6700
15500
ca.33000
15400
Lifting frame client.
Mobilkran 52.2m
LTM11200-9.1
R24000

1983-1993

30 m hub height
300 kW

1993-2003

50 m hub height
750 kW

2003-2013

80 m hub height
1800 kW

2013-2023

125 m hub height
4000 kW

2023-2033

175 m hub height
8000 kW

abt

WindBASE

Analytical models | 2D plate models | 3D FEM odels

Projecten

WindBASE

Hopefield, South Africa

- 36 x V100 wind turbines, Gravity foundations

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Windplan Blauw, the Netherlands

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Wind park Slufterdam, the Netherlands

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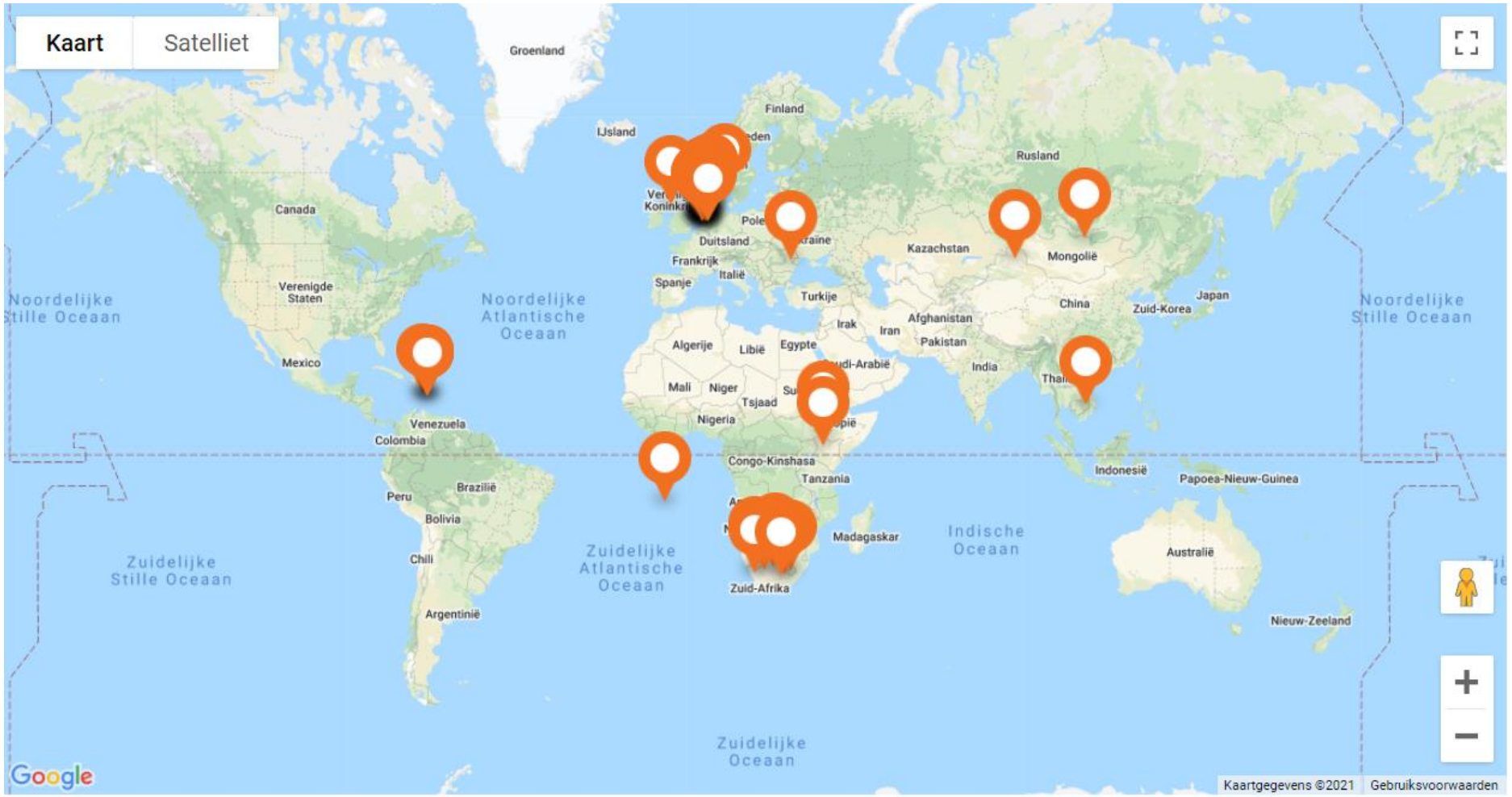
Playa Kanoa, Curaçao

- 5 x V90 at 80 m hub height, rock anchor foundation

WindBASE



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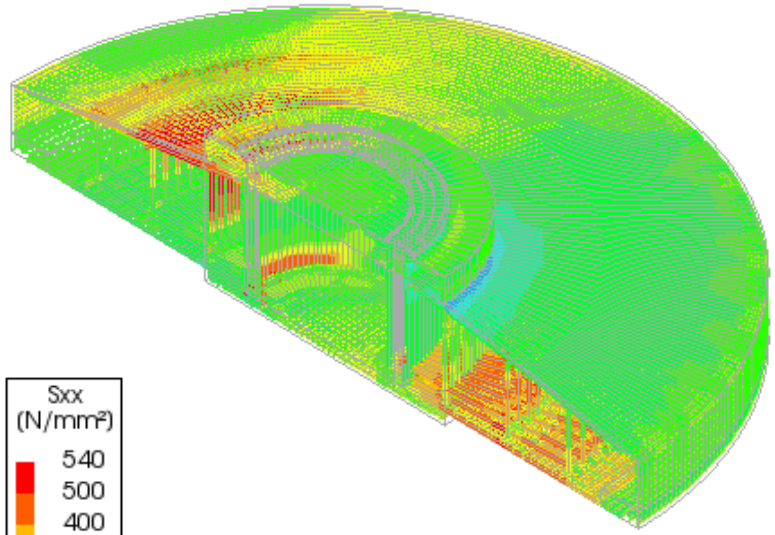
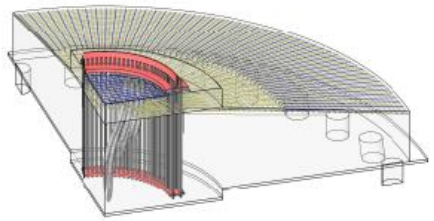
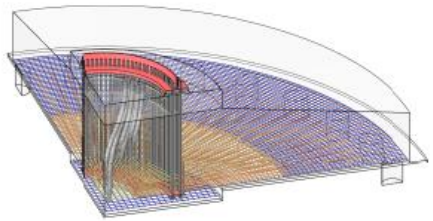
Scope

WindBASE

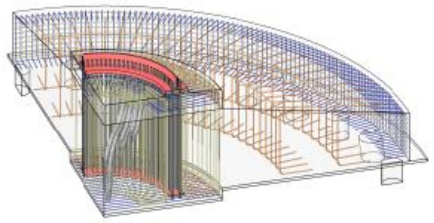




bovenwapening 3D



onderwapening 3D

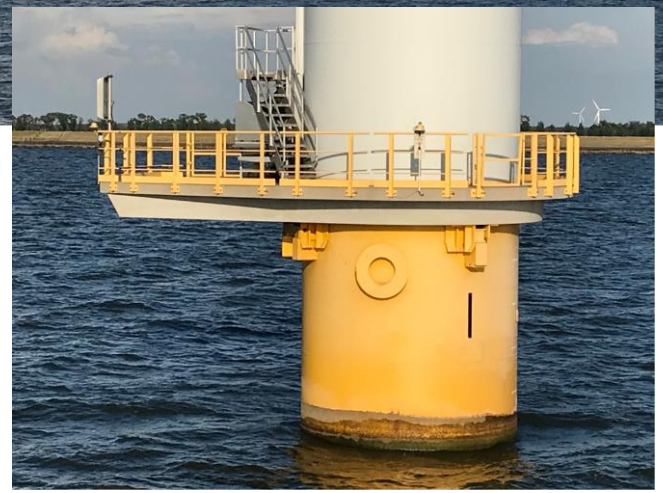


haarspelden, beugels 3D

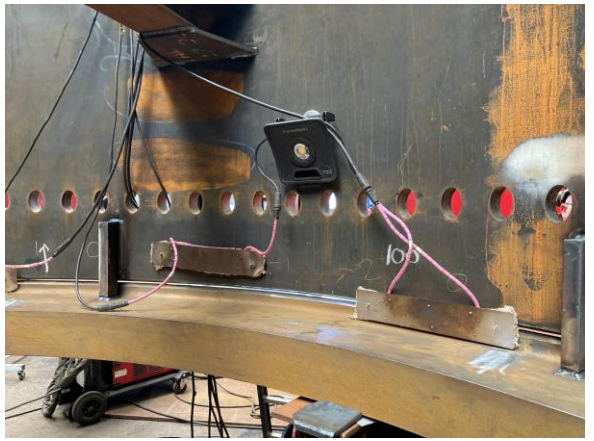
2de hands turbines en fundaties / levensduurverlenging

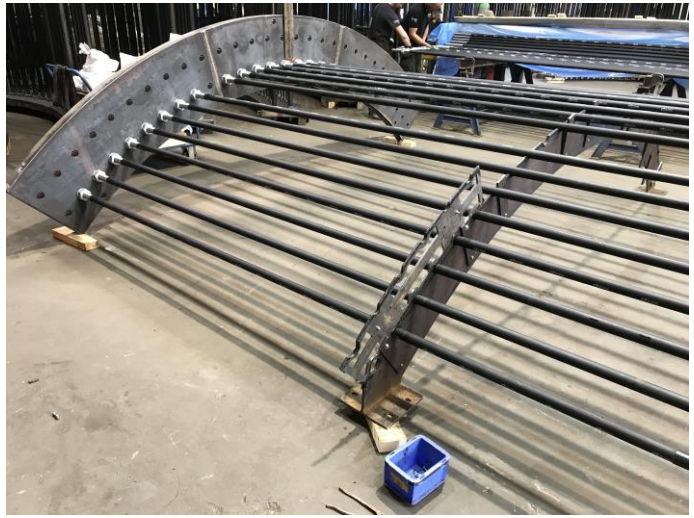
IVER
EXPERTS IN WIND

schadeonderzoek



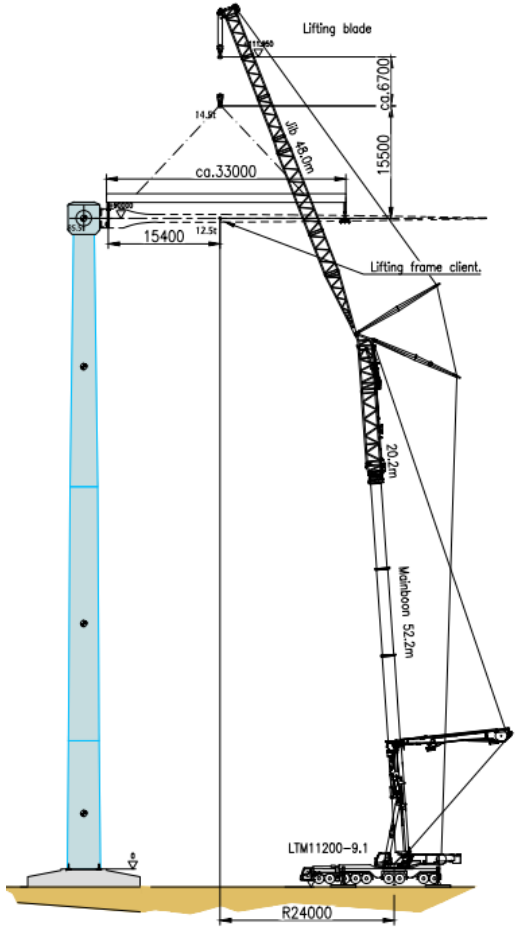
WESTERMEERWIND



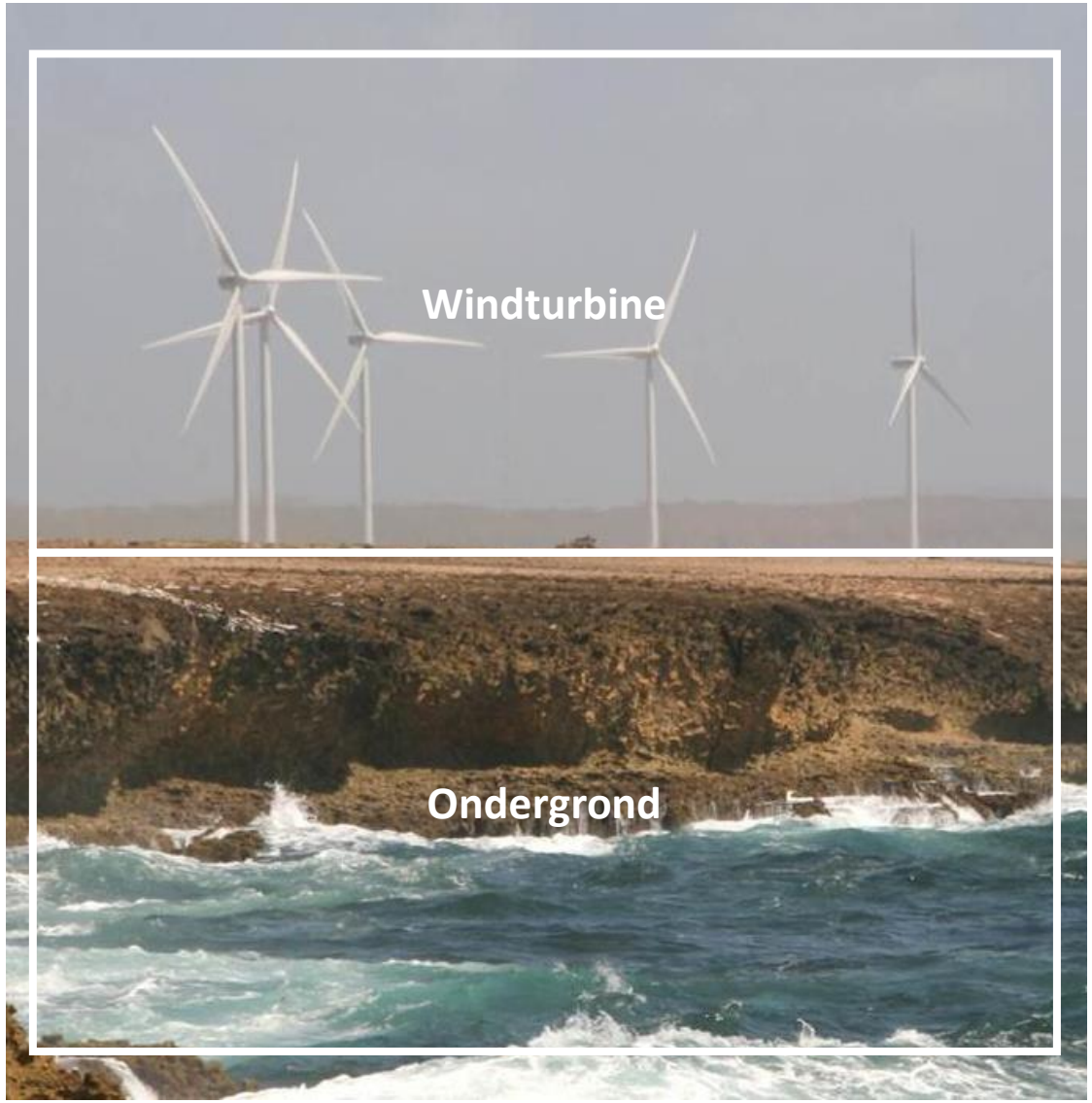


Constructief staalwerk en coating

Civiele infra en Kraanopstellingen



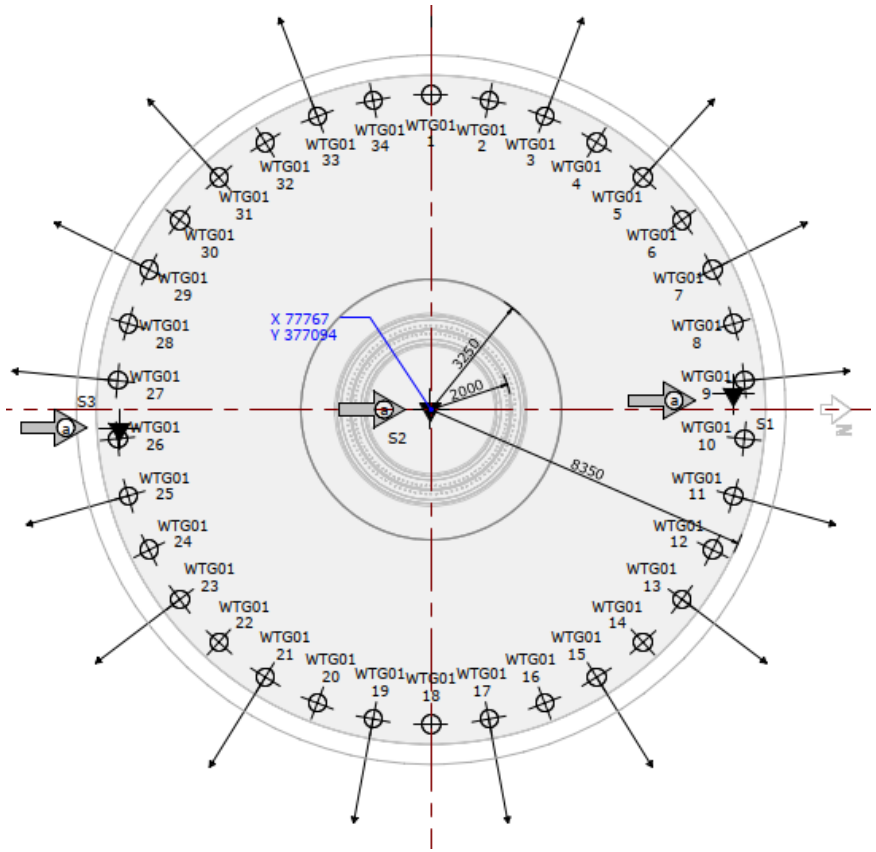
Fundering

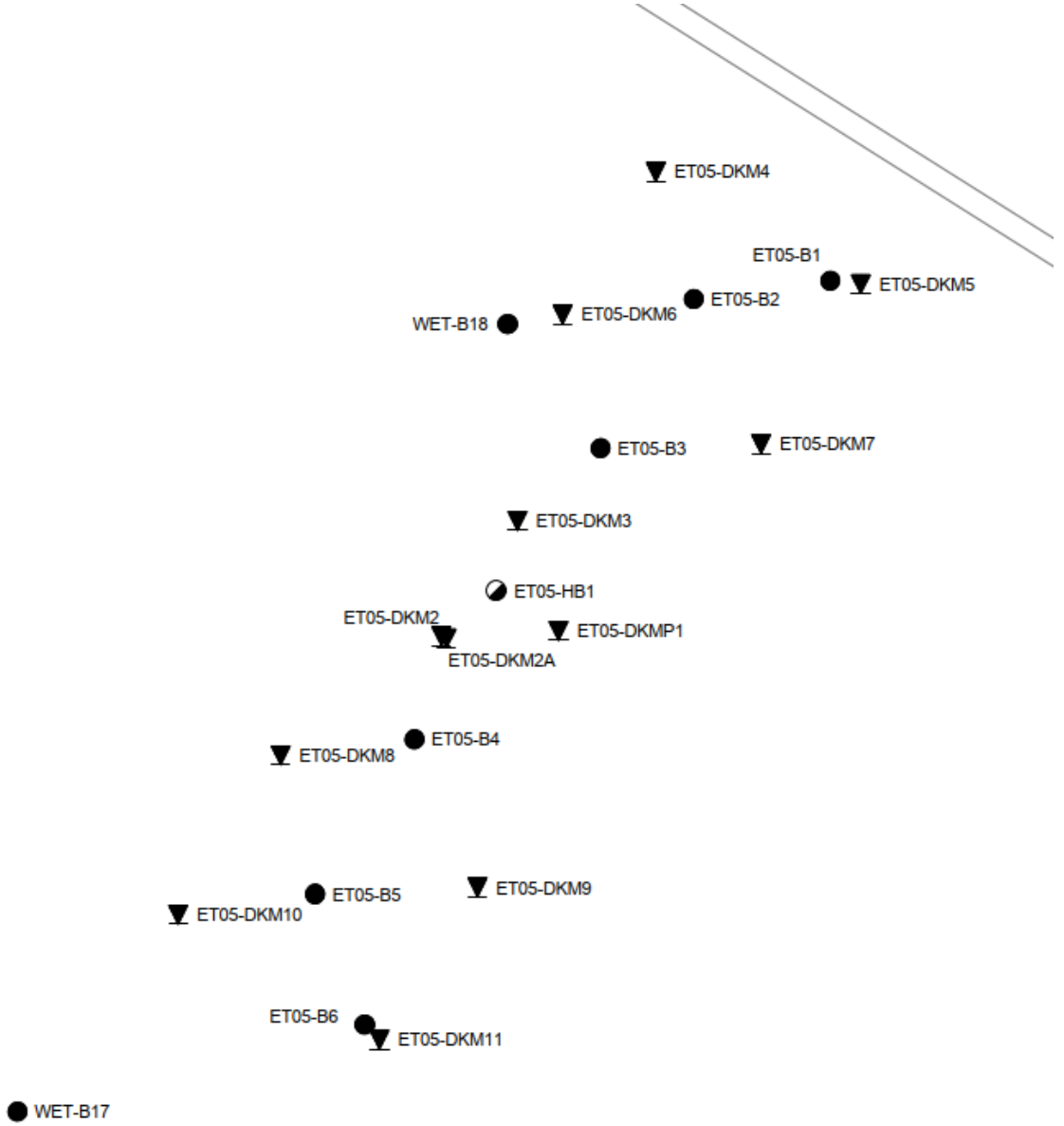


Fundering

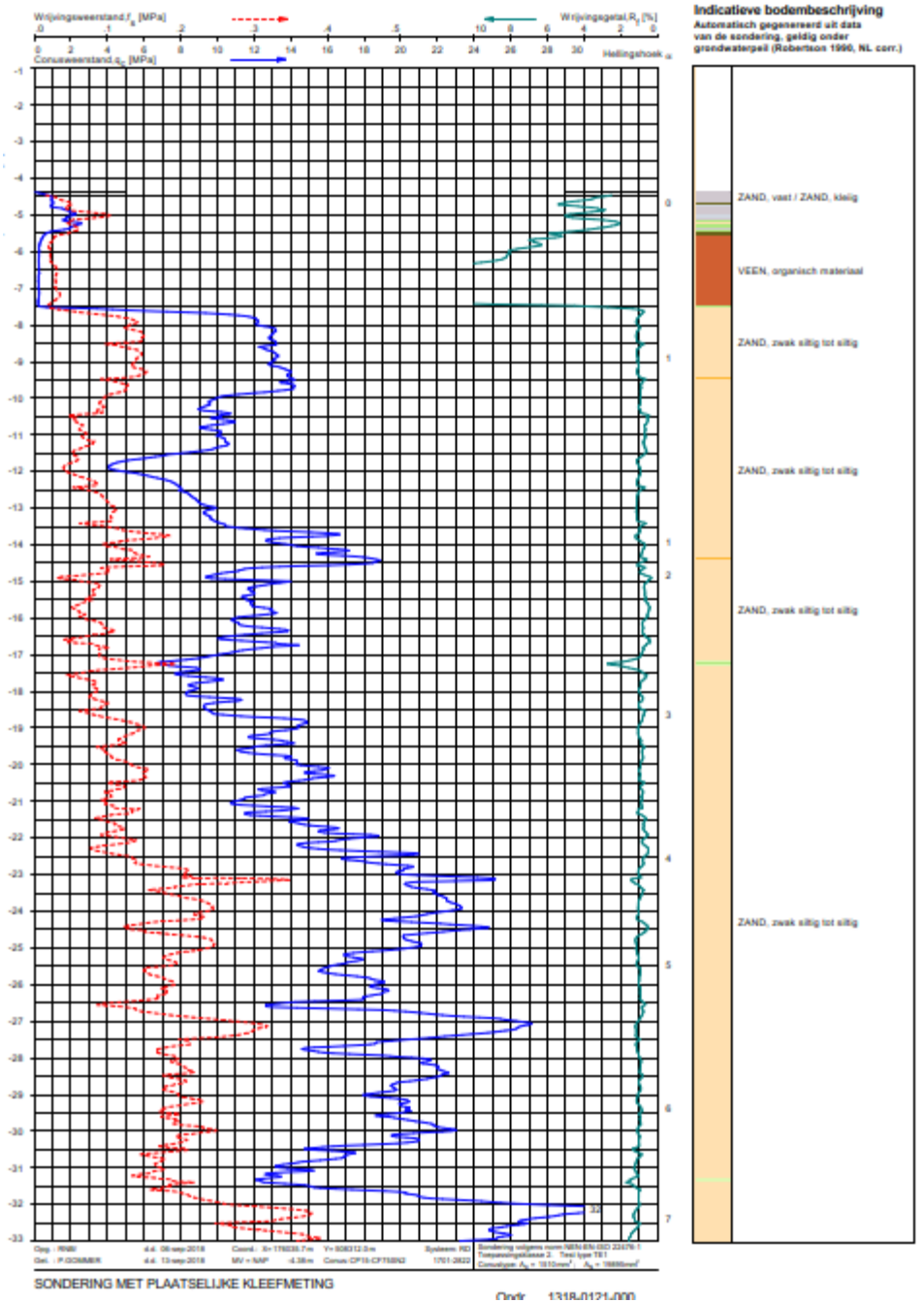
Ondergrond

Grondonderzoek in Nederland



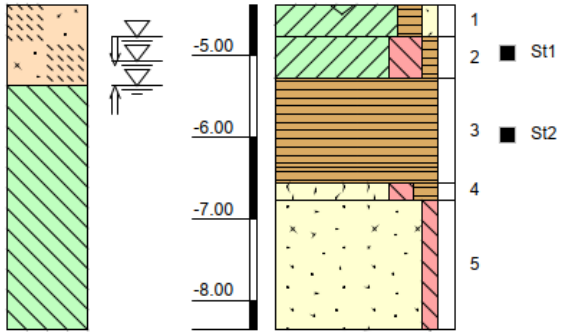


Sonderingen = cpt’s



Boringen

Boring: WRT-B21 **Veldclassificatie** Pagina 1 van 1



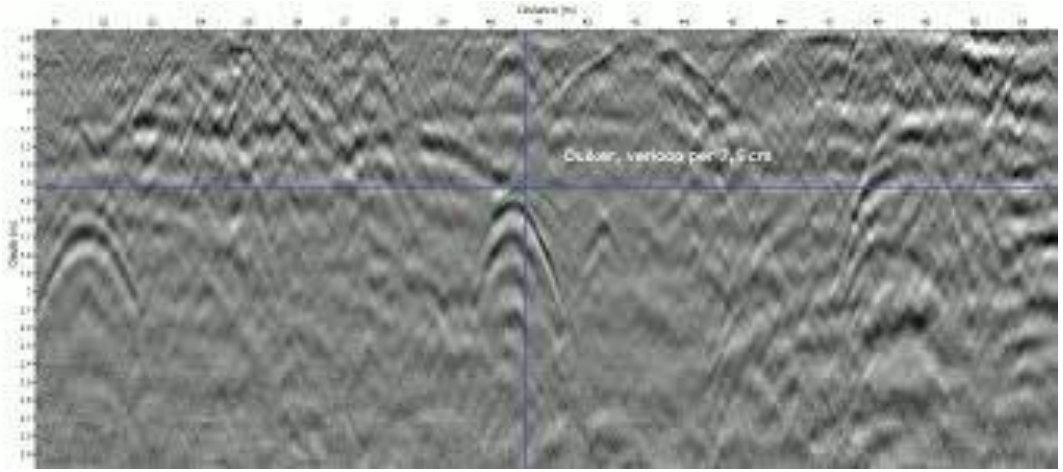
Bodembeschrijving volgens NEN 5104

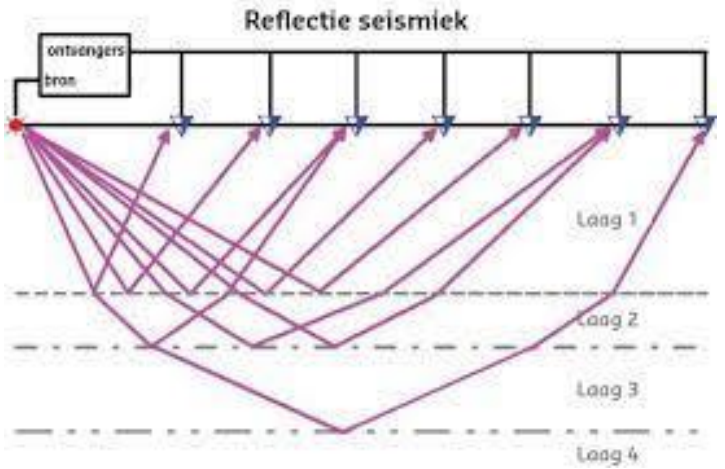
-4.37 tot -4.77 Klei, zwak zandig, matig humeus, stevig, resten wortels, sporen schelpen bruin-grijs
-4.77 tot -5.27 Klei, sterk siltig, zwak humeus, matig stevig, sporen roest, lenzen zand, licht grijs-bruin
-5.27 tot -6.37 Veen, mineraalarm, matig stevig, donker bruin

-6.37 tot -6.57 Veen, mineraalarm, matig stevig, donker bruin
-6.57 tot -6.77 Zand, zeer fijn, matig siltig, matig humeus, donker bruin
-6.77 tot -8.37 Zand, matig fijn, zwak siltig, licht wit

Lab onderzoek

Geofysisch grondonderzoek





Site verkenning ten behoeve van windpark op Aruba

Ondergrond rotsachtig. Grote boulders met fijn material daartussen.

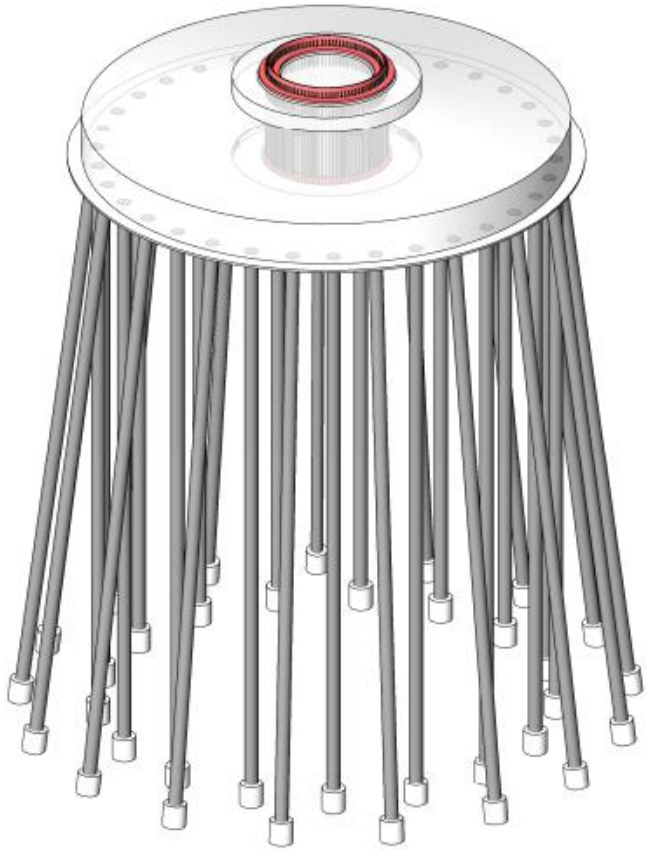
Voorlichting over niet gesprongen munitie uit WW2 in Ardennen ten behoeve van bouw fundaties windturbines

Ontwerp en begeleiding bouw. Ondergrond rotsachtig met toplaag van gebroken material.

Grondonderzoek en site verkenning in Kenya ten behoeve van een gepland windpark.

Moerasachtig gebied

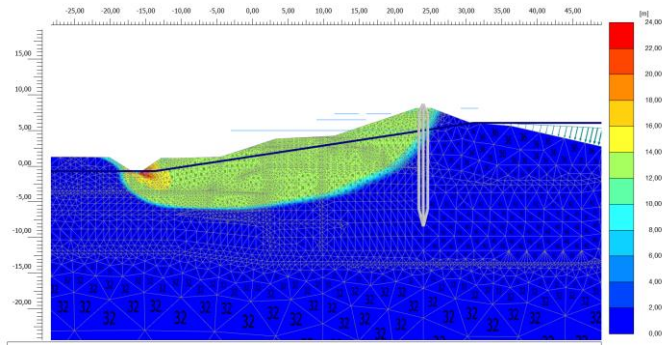
Funderingsprincipes




bam
grondtechniek


G24

WP Oostpolderdijk



WP Hartel

Normen & Belastingen

INTERNATIONAL STANDARD

IEC 61400-1

Third edition
2005-08

Wind turbines –

Part 1:
Design requirements

IEC

Reference number
IEC 61400-1:2005(E)

Nederlandse norm

NEN-EN-IEC 61400-6
(en)

Wind energy generation systems - Part 6: Tower and foundation design requirements (IEC 61400-6:2020,IDT)

DNV·GL

STANDARD

DNVGL-ST-0126 Edition July 2018

Support structures for wind turbines

Mitteilung des DIBt
Technische Regel

Referat I 8
Bautechnisches Prüfamt
Grundlagen der Standsicherheit

Richtlinie für Windenergieanlagen

Einwirkungen und Standsicherheitsnachweise für Turm und Gründung

Stand: Oktober 2012 – Korrigierte Fassung März 2015

NEN-EN 1992-1-1:2005+A1:2015+NB:2016+A1:2020 Beton - Algemeen

Table 2 – Design load cases

Design situation	DLC	Wind condition	Other conditions	Type of analysis	Partial safety factors
1) Power production	1.1	NTM $V_{in} < V_{hub} < V_{out}$	For extrapolation of extreme events	U	N
	1.2	NTM $V_{in} < V_{hub} < V_{out}$		F	*
	1.3	ETM $V_{in} < V_{hub} < V_{out}$		U	N
	1.4	ECD $V_{hub} = V_r - 2$ m/s, V_r, $V_r + 2$ m/s		U	N
	1.5	EWS $V_{in} < V_{hub} < V_{out}$		U	N
2) Power production plus occurrence of fault	2.1	NTM $V_{in} < V_{hub} < V_{out}$	Control system fault or loss of electrical network	U	N
	2.2	NTM $V_{in} < V_{hub} < V_{out}$	Protection system or preceding internal electrical fault	U	A
	2.3	EOG $V_{hub} = V_r \pm 2$ m/s and V_{out}	External or internal electrical fault including loss of electrical network	U	A
	2.4	NTM $V_{in} < V_{hub} < V_{out}$	Control, protection, or electrical system faults including loss of electrical network	F	*
3) Start up	3.1	NWP $V_{in} < V_{hub} < V_{out}$		F	*
	3.2	EOG $V_{hub} = V_{in}$, $V_r \pm 2$ m/s and V_{out}		U	N
	3.3	EDC $V_{hub} = V_{in}$, $V_r \pm 2$ m/s and V_{out}		U	N
4) Normal shut down	4.1	NWP $V_{in} < V_{hub} < V_{out}$		F	*
	4.2	EOG $V_{hub} = V_r \pm 2$ m/s and V_{out}		U	N
5) Emergency shut down	5.1	NTM $V_{hub} = V_r \pm 2$ m/s and V_{out}		U	N
6) Parked (standing still or idling)	6.1	EWM 50-year recurrence period		U	N
	6.2	EWM 50-year recurrence period	Loss of electrical network connection	U	A
	6.3	EWM 1-year recurrence period	Extreme yaw misalignment	U	N
	6.4	NTM $V_{hub} < 0,7\ V_{ref}$		F	*
7) Parked and fault conditions	7.1	EWM 1-year recurrence period		U	A
8) Transport, assembly, maintenance and repair	8.1	NTM V_{maint} to be stated by the manufacturer		U	T
	8.2	EWM 1-year recurrence period		U	A

Table 1 – Basic parameters for wind turbine classes[1]

Wind turbine class		I	II	III	S
V_{ref}	(m/s)	50	42,5	37,5	Values specified by the designer
A	I_{ref} (-)	0,16			
B	I_{ref} (-)	0,14			
C	I_{ref} (-)	0,12			

In Table 1, the parameter values apply at hub height and

V_{ref} is the reference wind speed average over 10 min,

A designates the category for higher turbulence characteristics,

B designates the category for medium turbulence characteristics,

C designates the category for lower turbulence characteristics and

I_{ref} is the expected value of the turbulence intensity[2] at 15 m/s.

Table 3 – Partial safety factors for loads γ_f

Unfavourable loads			Favourable[9] loads
Type of design situation (see Table 2)			All design situations
Normal (N)	Abnormal (A)	Transport and erection (T)	
1,35*	1,1	1,5	0,9

* For design load case DLC 1.1, given that loads are determined using statistical load extrapolation at prescribed wind speeds between V_{in} and V_{out}, the partial load factor for normal design situations shall be $\gamma_f = 1,25$.

If for normal design situations the characteristic value of the load response $F_{gravity}$ due to gravity can be calculated for the design situation in question, and gravity is an unfavourable load, the partial load factor for combined loading from gravity and other sources may have the value

$$\gamma_f = 1,1 + \varphi\varsigma^2$$

$$\varphi = \begin{cases} 0,15 & \text{for DLC1.1} \\ 0,25 & \text{otherwise} \end{cases}$$

$$\varsigma = \begin{cases} 1 - \left| \frac{F_{gravity}}{F_s} \right|; & |F_{gravity}| \le |F_s| \\ 1; & |F_{gravity}| > |F_s| \end{cases}$$

Characteristic Extreme							
Lead	LC/Family	PLF	Type	Mbt1	Mzt1	FndFr	Fzt1
Sensor	[-]	[-]	[-]	[kNm]	[kNm]	[kN]	[kN]
Mbt1	14EcdNTVrpa(fam99)	1.35	Abs	**191400**	1385	1176	-8821
Mzt1	23NTMSCVo00(fam237)	1.35	Abs	35960	**-10760**	205.7	-8645
FndFr	14EcdVrpa00(fam93)	1.35	Abs	185700	2325	**1241**	-8820
Fzt1	12IceUvra00(fam68)	1.35	Abs	147600	1981	803.2	**-8977**

Table 2-1 Characteristic Extreme (excl. PLF). Load cases sorted with PLF.

Characteristic Extreme							
Lead	LC/Family	PLF	Type	Mbt1	Mzt1	FndFr	Fzt1
Sensor	[-]	[-]	[-]	[kNm]	[kNm]	[kN]	[kN]
Mbt1	62E50b07000(fam380)	1.10	Abs	**197000**	1413	1363	-8777
Mzt1	23NTMSCVo00(fam237)	1.35	Abs	35960	**-10760**	205.7	-8645
FndFr	62E50b08000(fam381)	1.10	Abs	196300	1492	**1383**	-8783
Fzt1	62E50b18000(fam391)	1.10	Abs	62840	-1315	538.2	**-8988**

Table 2-2 Characteristic Extreme (excl. PLF). Load cases sorted without PLF.

Production loads				
		Char. load	Prob.:1e-2	Prob.:1e-4
M_{res}	[kNm]	191400	151293.54	158079.41
M_z	[kNm]	-10756.20	-2923.42	-4986.00
F_{res}	[kN]	1240.69	872.98	1002.51
F_z	[kN]	-8976.63	-8886.47	-8911.02

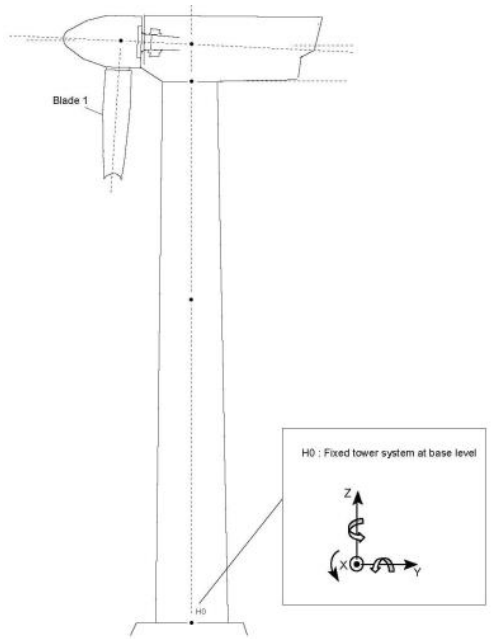
Table 3-1 Production Loads.

Concurrent values for rotational- and lateral stiffness										
Rotational stiffness	[GNm/rad]	100	120	152	193	245	311	394	450	500
Lateral stiffness	[MN/m]	14.0	10.5	7.6	6.4	6.0	6.0	6.0	6.0	6.0

Table 5-1 Minimum lateral stiffness.

The natural frequency of the tower must be within the frequency interval [0.141 Hz; 0.155 Hz]

Design Life : 25 years



Equivalent and Mean Fatigue Foundation Loads				
		Mean load	Range m = 4	Range m = 7
Fy_OmniDir	[kN]	632.95	781.34	740.99
Mx_OmniDir	[kNm]	-114147.20	55976.29	74611.26
Mz	[kNm]	-170.88	8698.29	8553.23
Fx_OmniDir	[kN]	6.56	405.91	391.55
My_latScaled_OmniDir	[kNm]	6468.68	28364.63	29411.42

Table 4-1 Fatigue loads for N=1E7 cycles.

Appendix B. Markov matrices

This appendix contains the Markov Matrices for the shear force, the bending moment and the torsional moment in the bottom of the tower.

Orig

Markov Matrices															
F_y_OmniDir [kN]			Mx_OmniDir [kNm]			Mz [kNm]			Fx_OmniDir [kN]			My_latScaled_OmniDir [kNm]			
Level	Range	Cycles	Level	Range	Cycles	Level	Range	Cycles	Level	Range	Cycles	Level	Range	Cycles	
1.4370E+03	0.0000E+00	7.5399E+01	1.2878E+05	6.8319E+03	1.3917E+01	9.1696E+03	4.5355E+02	1.0022E-01	5.2890E+02	0.0000E+00	1.7988E-03	8.0500E+04	0.0000E+00	1.2971E-04	
1.3807E+03	0.0000E+00	2.1624E+02	1.2878E+05	0.0000E+00	2.0834E+01	8.6563E+03	4.5355E+02	1.0022E-01	5.0355E+02	0.0000E+00	2.3719E+00	7.7249E+04	0.0000E+00	1.3057E-04	
1.3245E+03	1.3387E+02	2.6776E+00	1.2113E+05	1.3664E+04	3.5000E+00	8.1429E+03	1.8142E+03	5.8406E-01	4.7820E+02	0.0000E+00	4.3765E+00	7.3999E+04	2.9107E+03	1.3993E-04	

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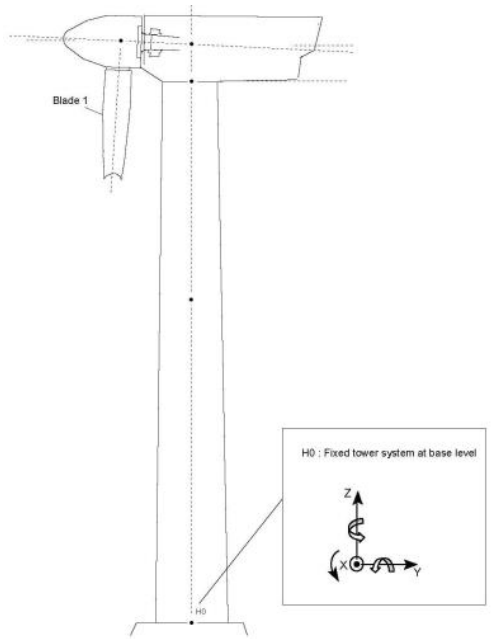

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Orig

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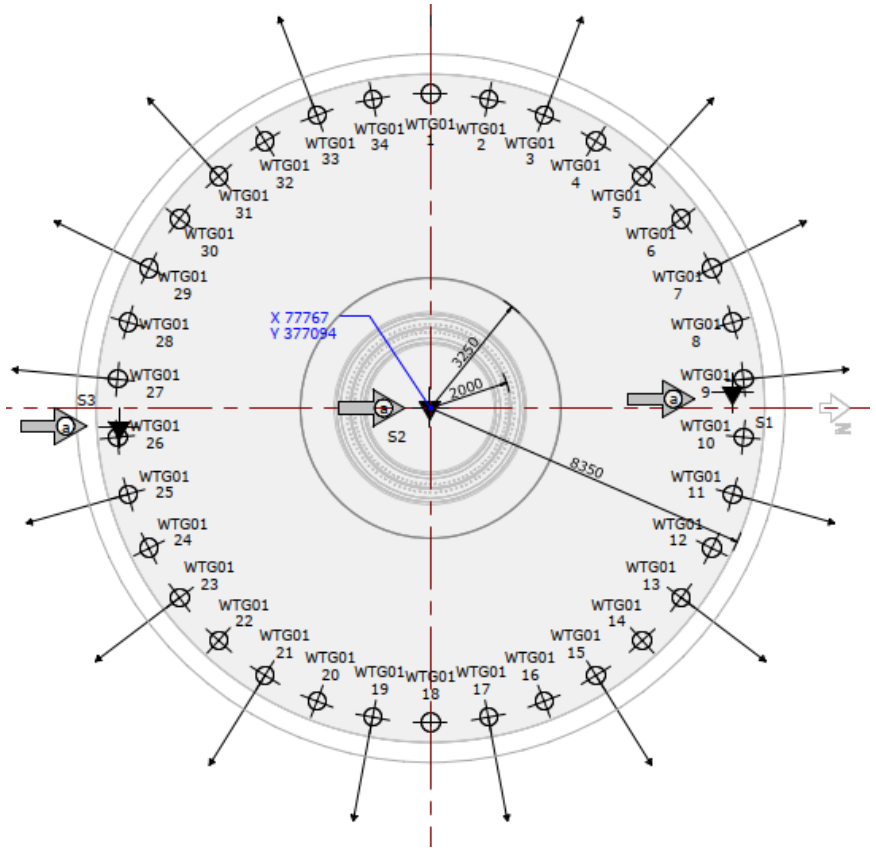
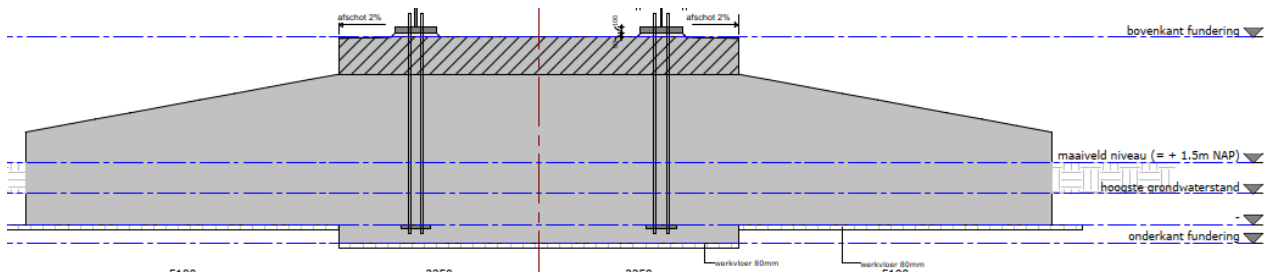
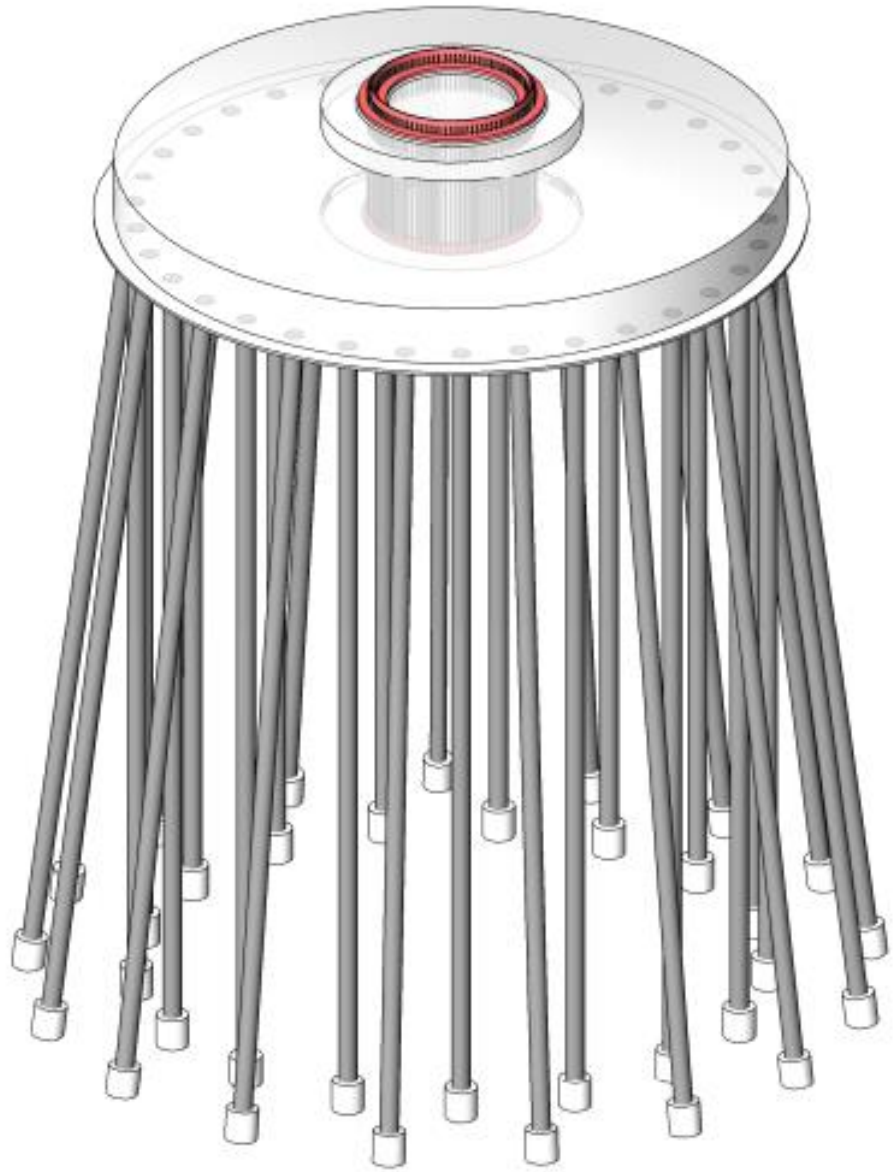
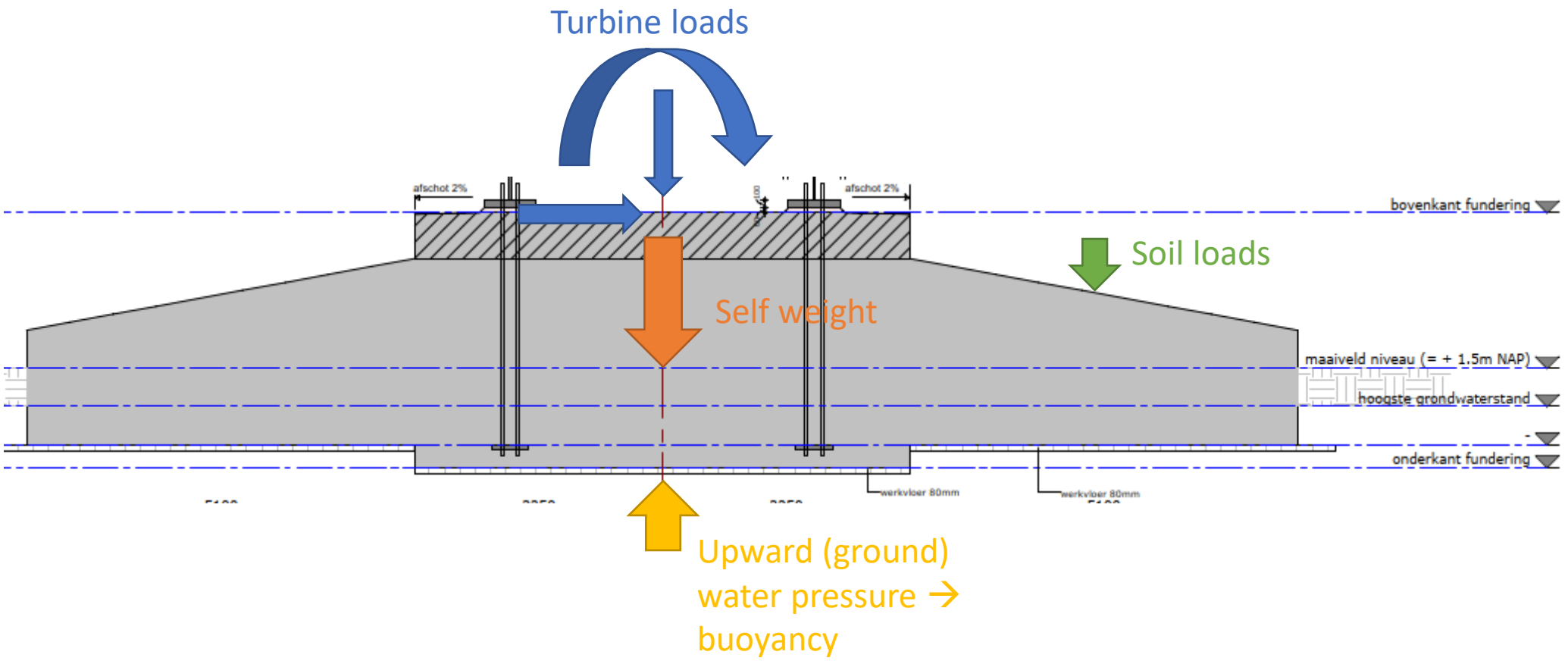
Level	Range	Cycles	Level	Range	Cycles	Level	Range	Cycles	Level	Range	Cycles	Level	Range	Cycles	
1.4370E+03	0.0000E+00	7.5399E+01	1.2878E+05	6.8319E+03	1.3917E+01	9.1696E+03	4.5355E+02	1.0022E-01	5.2890E+02	0.0000E+00	1.7988E-03	8.0500E+04	0.0000E+00	1.2971E-04	
1.3807E+03	0.0000E+00	2.1624E+02	1.2878E+05	0.0000E+00	2.0834E+01	8.6563E+03	4.5355E+02	1.0022E-01	5.0355E+02	0.0000E+00	2.3719E+00	7.7249E+04	0.0000E+00	1.3057E-04	
1.3245E+03	1.3387E+02	2.6776E+00	1.2113E+05	1.3664E+04	3.5000E+00	8.1429E+03	1.8142E+03	5.8406E-01	4.7820E+02	0.0000E+00	4.3765E+00	7.3999E+04	2.9107E+03	1.3993E-04	

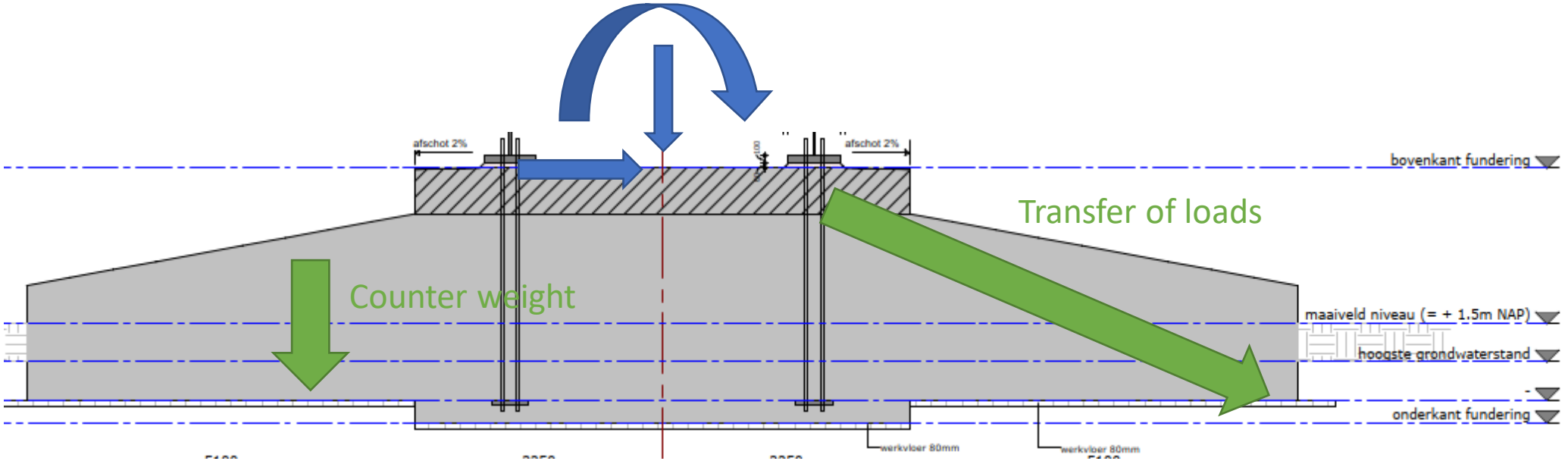
Ontwerpprincipes

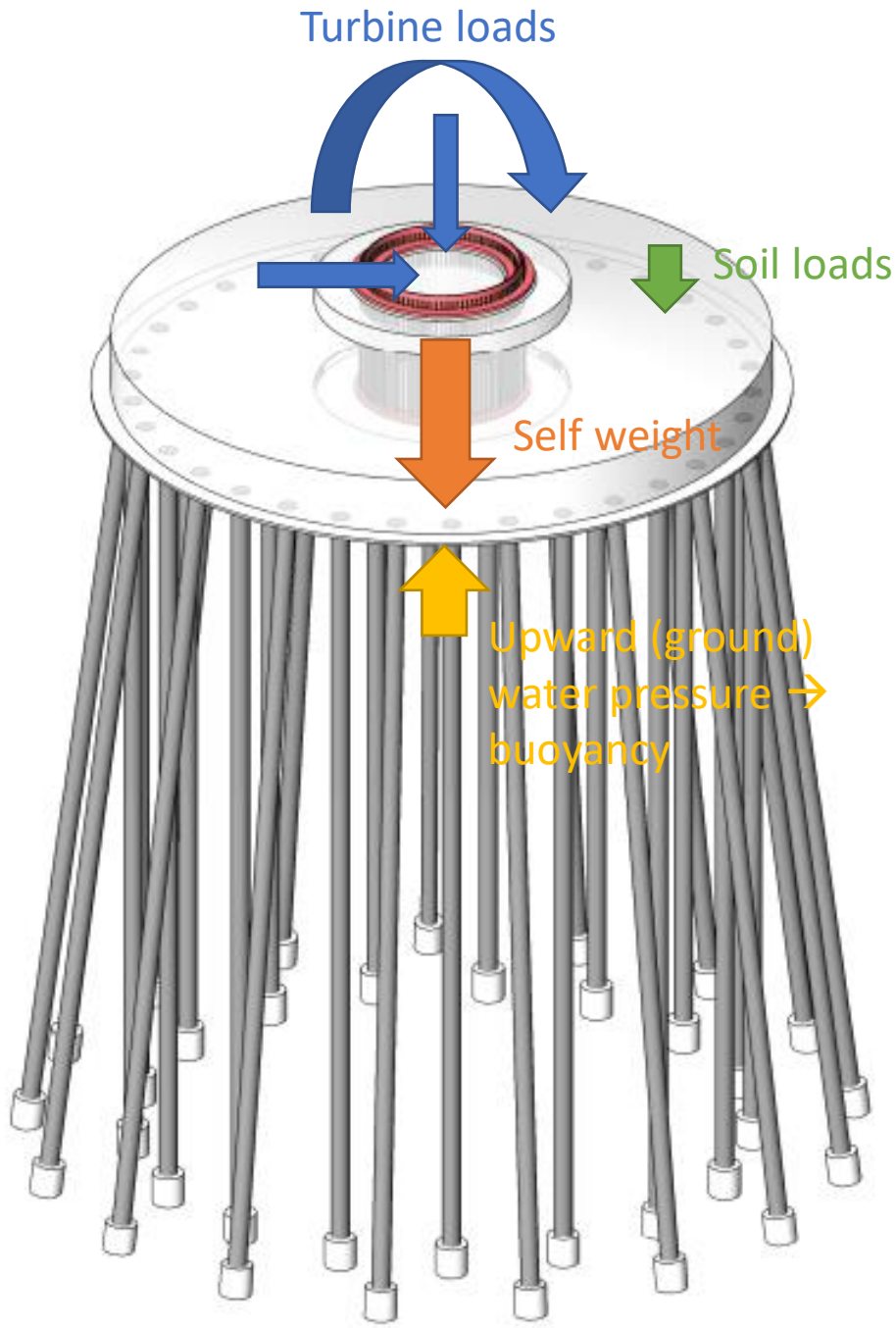

WTG01 1
WTG01 2
WTG01 3
WTG01 4
WTG01 5
WTG01 6
WTG01 7
WTG01 8
WTG01 9
WTG01 10
WTG01 11
WTG01 12
WTG01 13
WTG01 14
WTG01 15
WTG01 16
WTG01 17
WTG01 18
WTG01 19
WTG01 20
WTG01 21
WTG01 22
WTG01 23
WTG01 24
WTG01 25
WTG01 26
WTG01 27
WTG01 28
WTG01 29
WTG01 30
WTG01 31
WTG01 32
WTG01 33
WTG01 34
X 77767
Y 377094
3250
2000
8350
S1
S2
S3
N

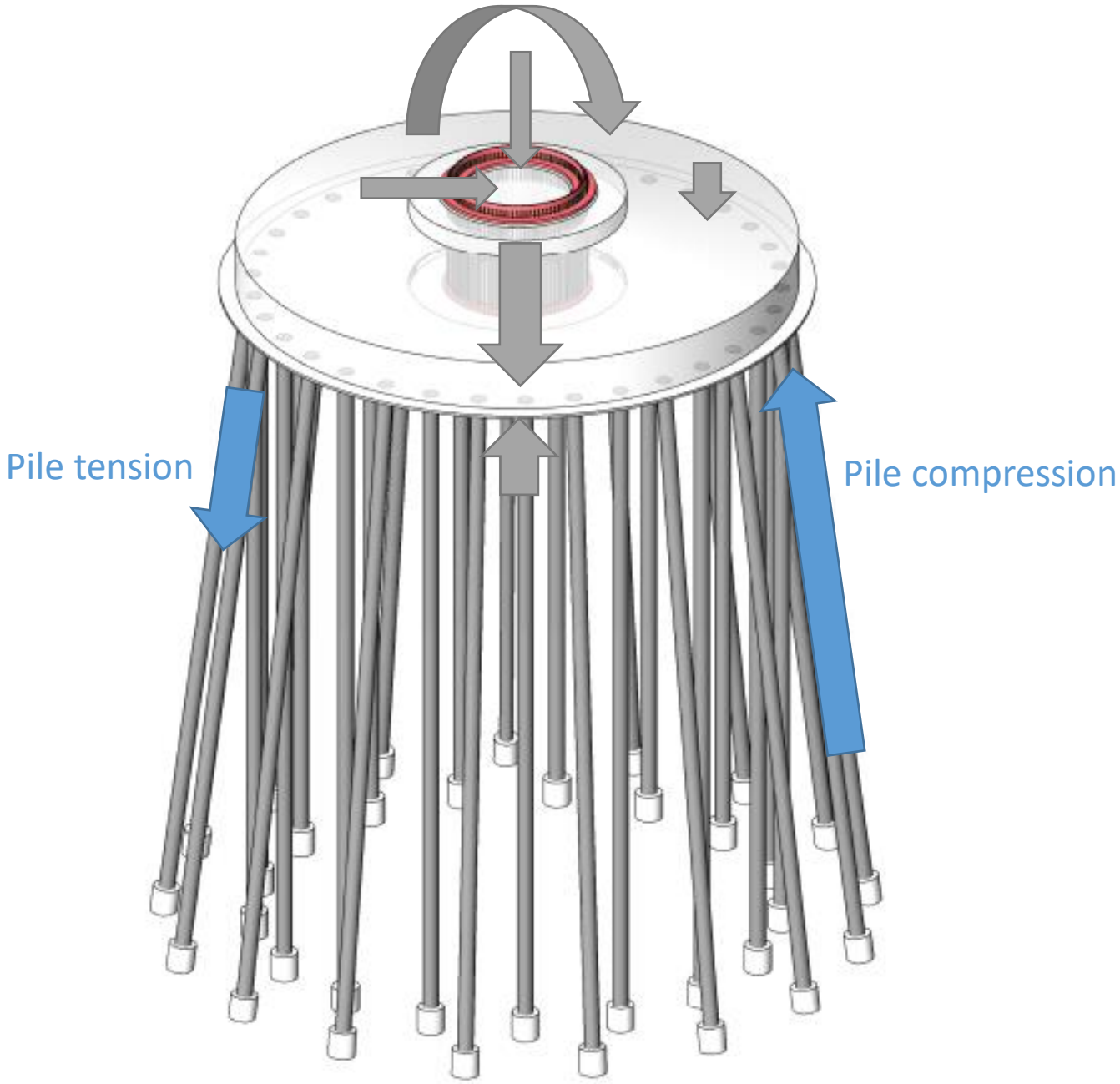

afschot 2%
afschot 2%
bovenkant fundering
maaiveld niveau (= + 1.5m NAP)
hoogste grondwaterstand
onderkant fundering
werkvloer 80mm
werkvloer 80mm

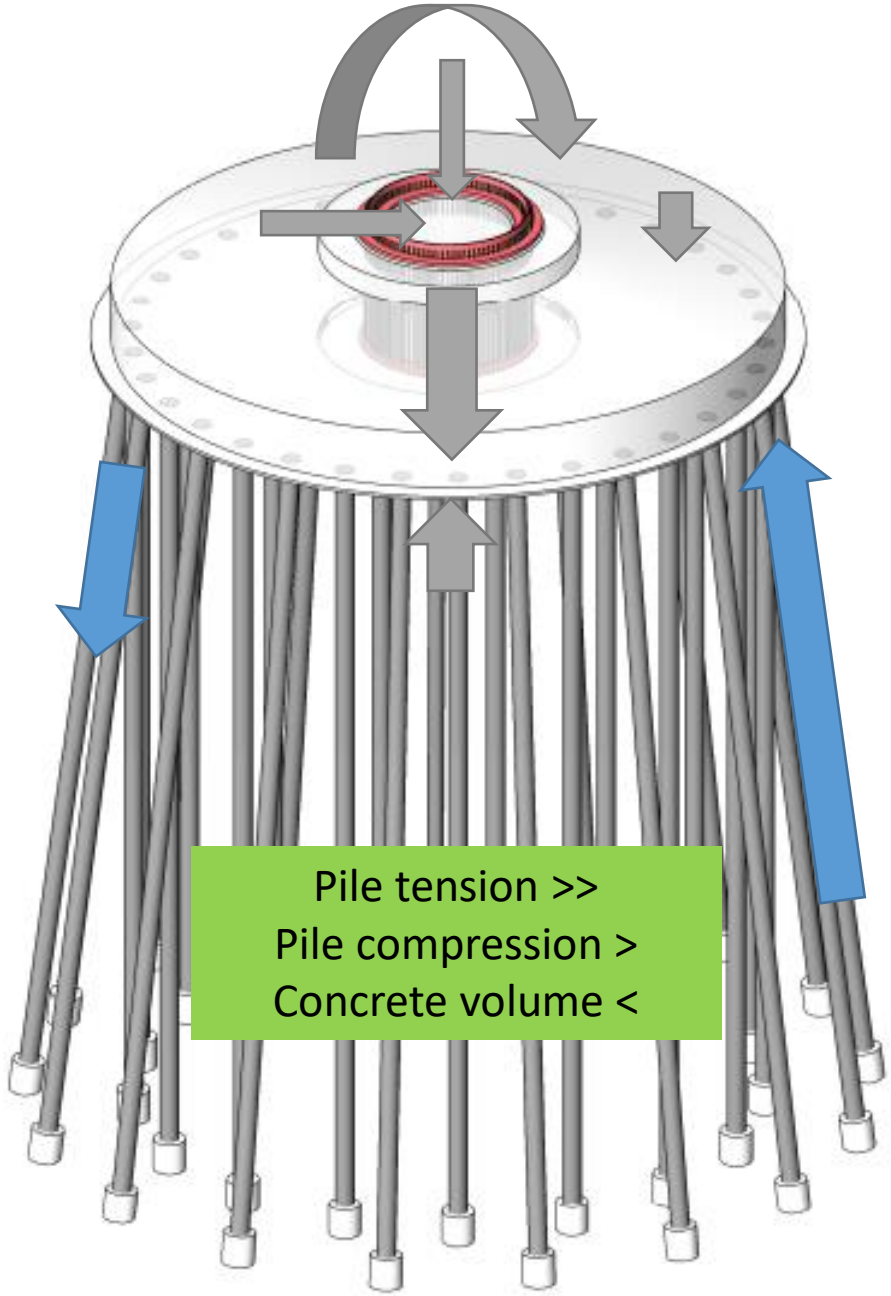


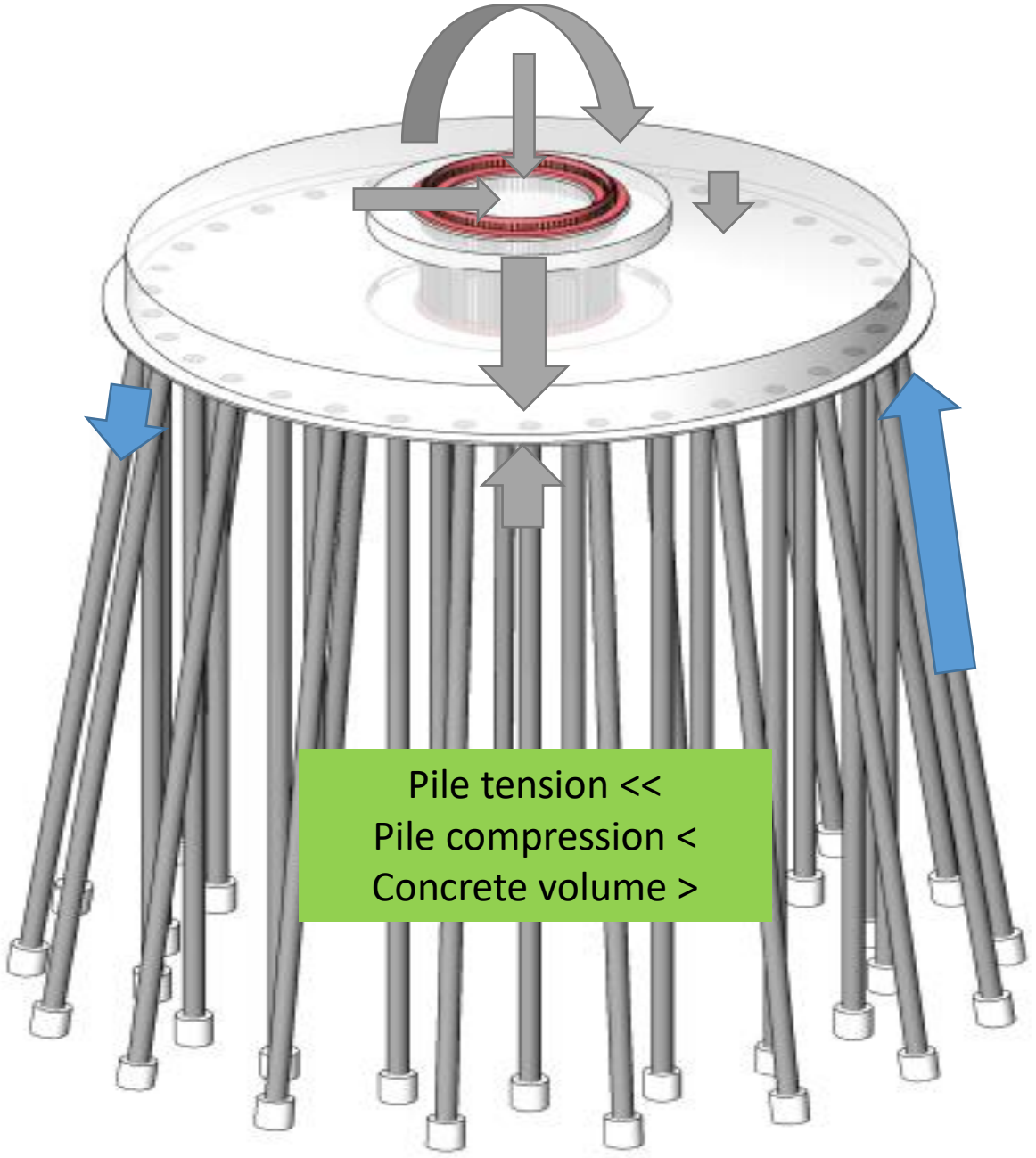

Turbine loads
afschot 2%
afschot 2%
bovenkant fundering
Soil loads
Self weight
maaiveld niveau (= + 1.5m NAP)
hoogste grondwaterstand
onderkant fundering
werkvloer 80mm
werkvloer 80mm
Upward (ground) water pressure → buoyancy


afschot 2%
afschot 2%
bovenkant fundering
Transfer of loads
Counter weight
maaiveld niveau (= + 1.5m NAP)
hoogste grondwaterstand
onderkant fundering
werkvloer 80mm
werkvloer 80mm


Turbine loads
Soil loads
Self weight
Upward (ground) water pressure → buoyancy


Pile tension
Pile compression


Pile tension >>
Pile compression >
Concrete volume <


Pile tension <<
Pile compression <
Concrete volume >

Hoe inefficient een normale windturbinefundering eigenlijk is.

Ontwerprandvoorwaarden

Geometry

Strength

Durability

Stiffness

dependency

Requirements that affect the shape of the foundation:

- By the customer (e.g. accessibility of the wind turbine)
- Permit (e.g. level of the top of foundation; max. foundation diameter)
- Make-ability of the base (e.g. slope of top of base)
- Incorporation of tower anchorage.
- Conduit tubes.
- Also see “design information”

To be able to resist and transfer forces:

- Extreme wind turbine loads
- Fatigue loads
- No tensile forces on piles during production loads (no-gapping criterion)

To be able to resist long term impacts:

- Crack width
- Concrete cover
- Concrete mixture

To be assure the correct eigen frequency of the total wind turbine system:

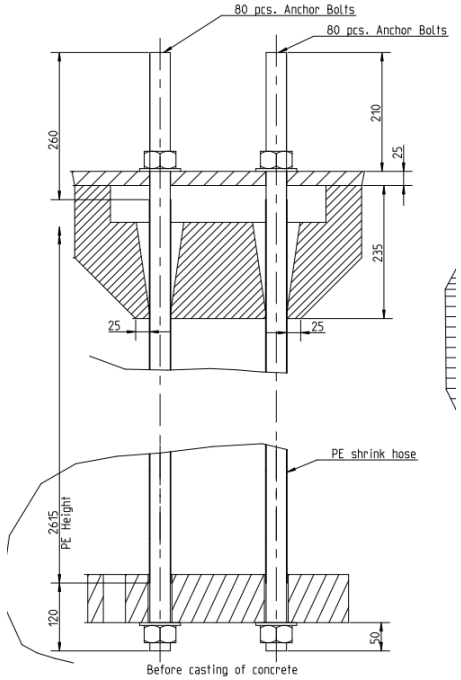
- Rotational stiffness
- Translation stiffness
- Verticality of the tower.

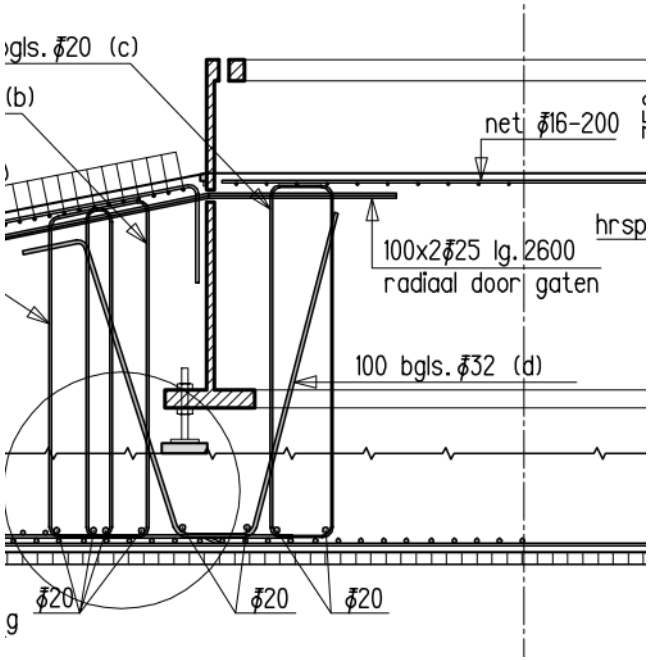
Eurocode + NA

Project specific

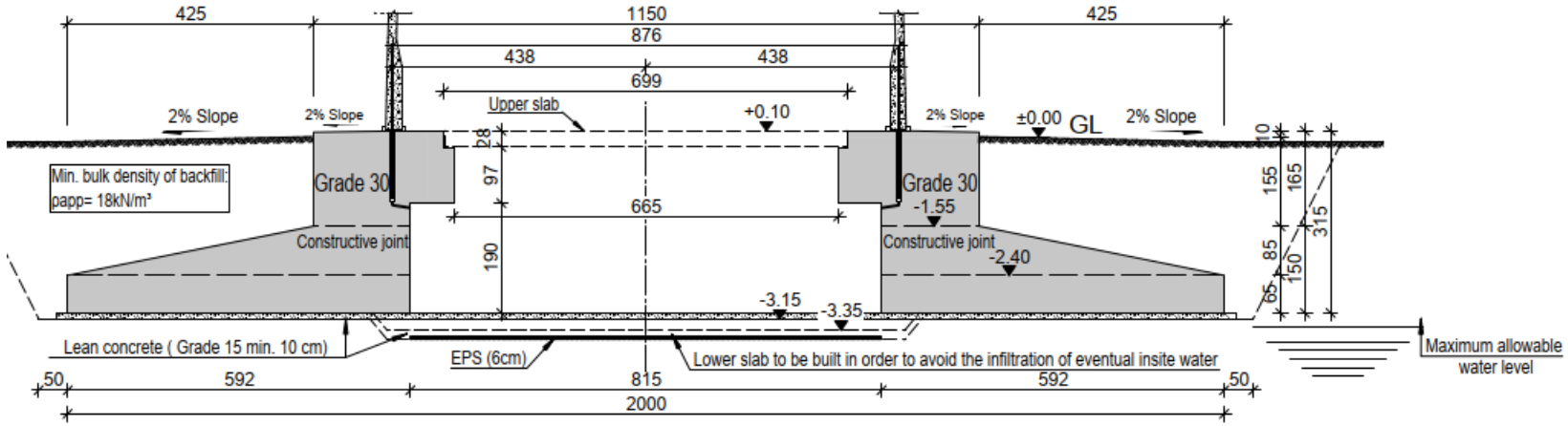
Wind turbine guidelines (e.g. DNV)

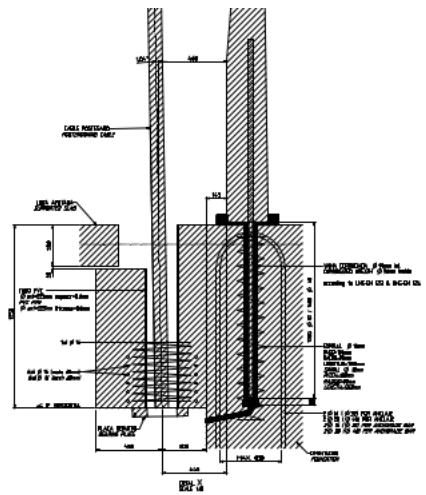
Torenverankering

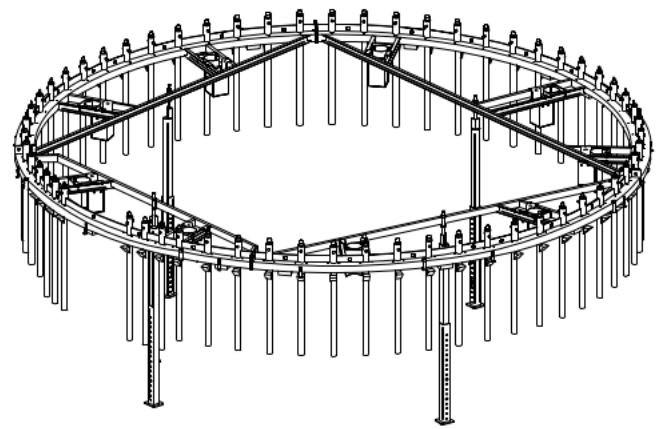

80 pcs. Anchor Bolts
80 pcs. Anchor Bolts
260
210
25
235
25
25
PE shrink hose
2615
PE Height
120
50
Before casting of concrete


bgls. ϕ20 (c)
(b)
net ϕ16-200
hrsp
100x2ϕ25 lg.2600
radiaal door gaten
100 bgls. ϕ32 (d)
ϕ20
ϕ20
ϕ20
g

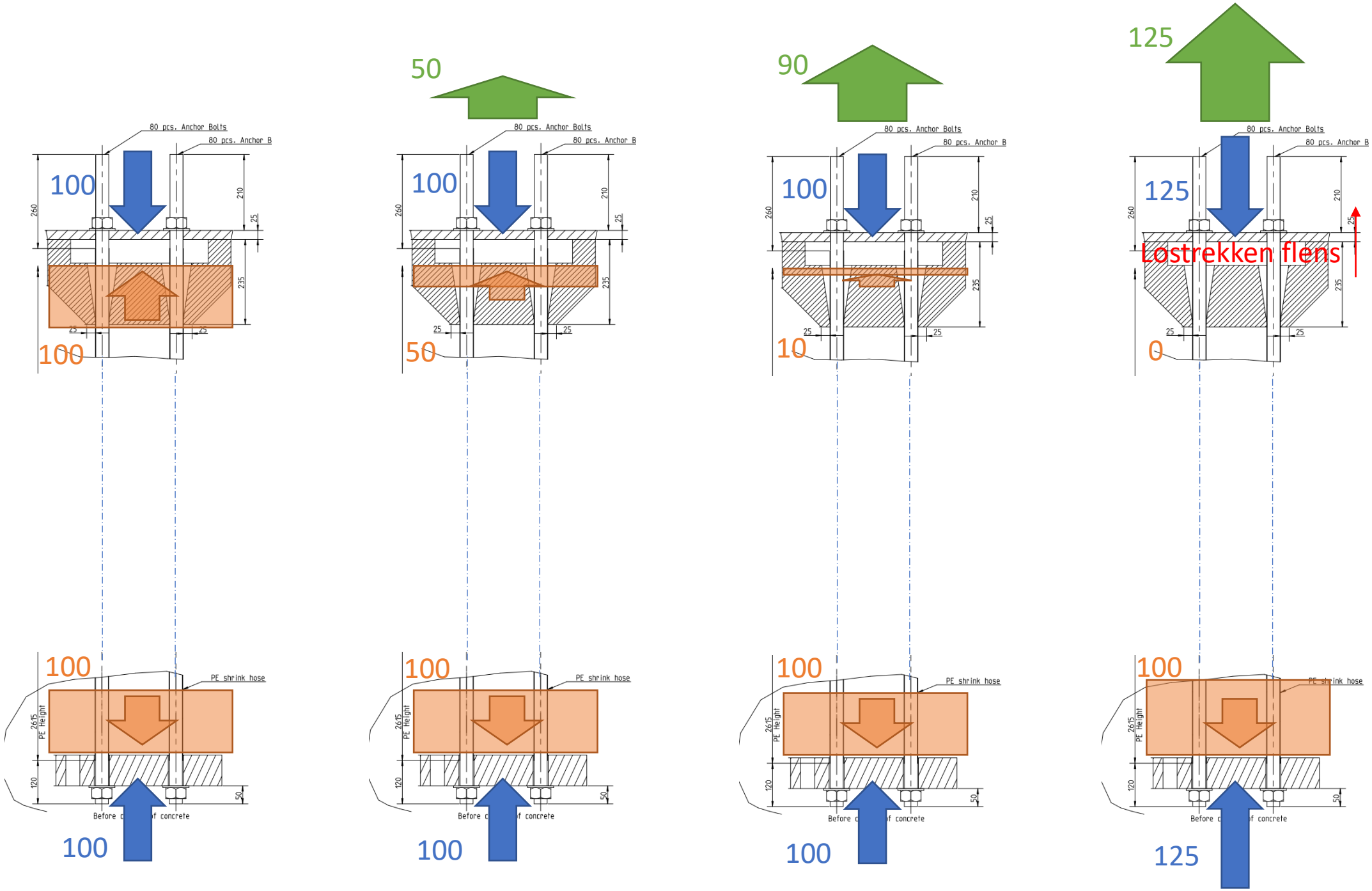
1/125

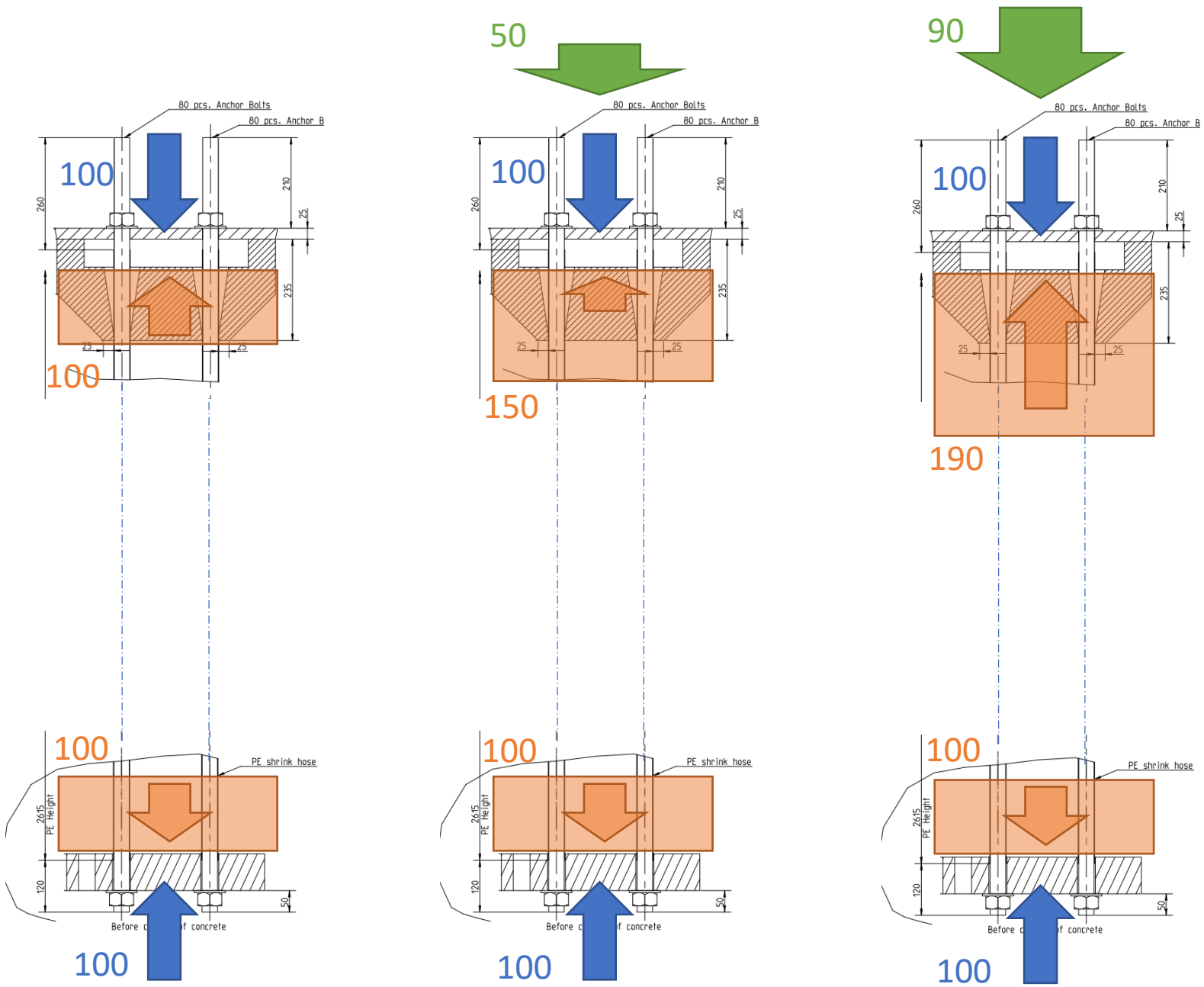




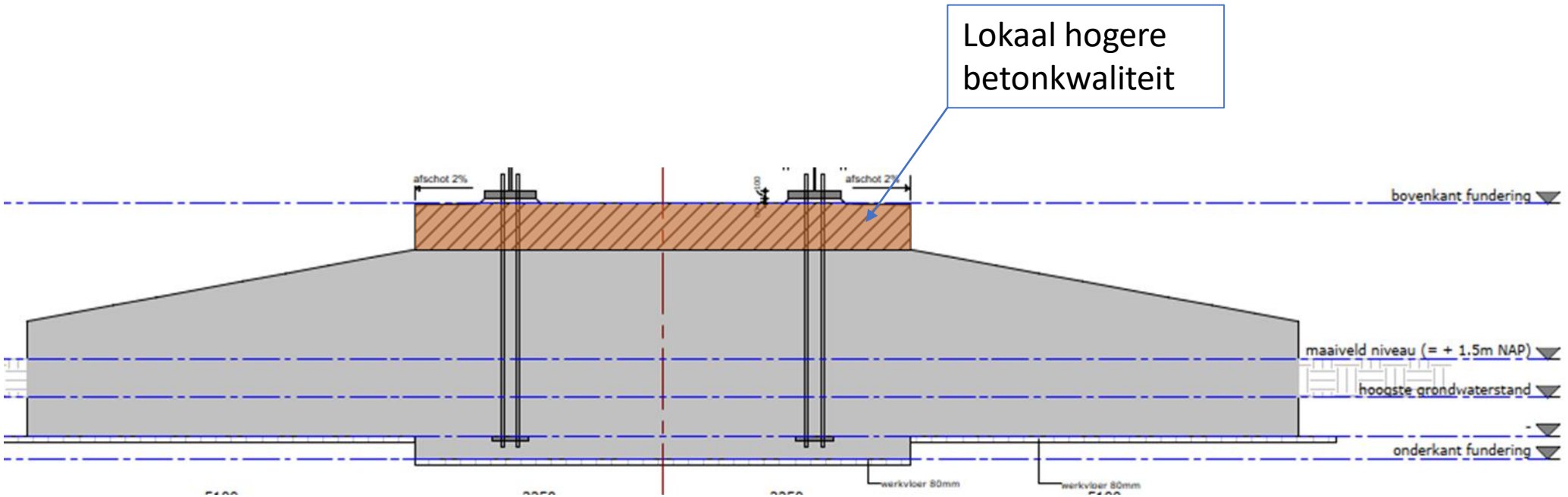


FOUNDATION CAGE TEMPLATE DETAIL
(SEE NOTES)

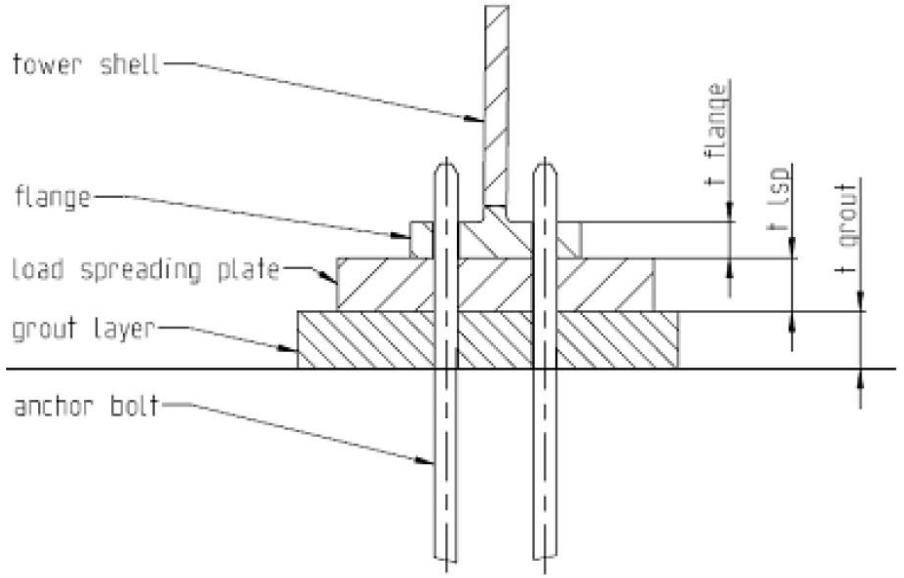

80 pcs. Anchor Bolts
80 pcs. Anchor B
100
100
260
210
25
235
25
25
PE shrink hose
2615
PE Height
120
50
100
50
100
10
0
125
Lostrekken flens
125

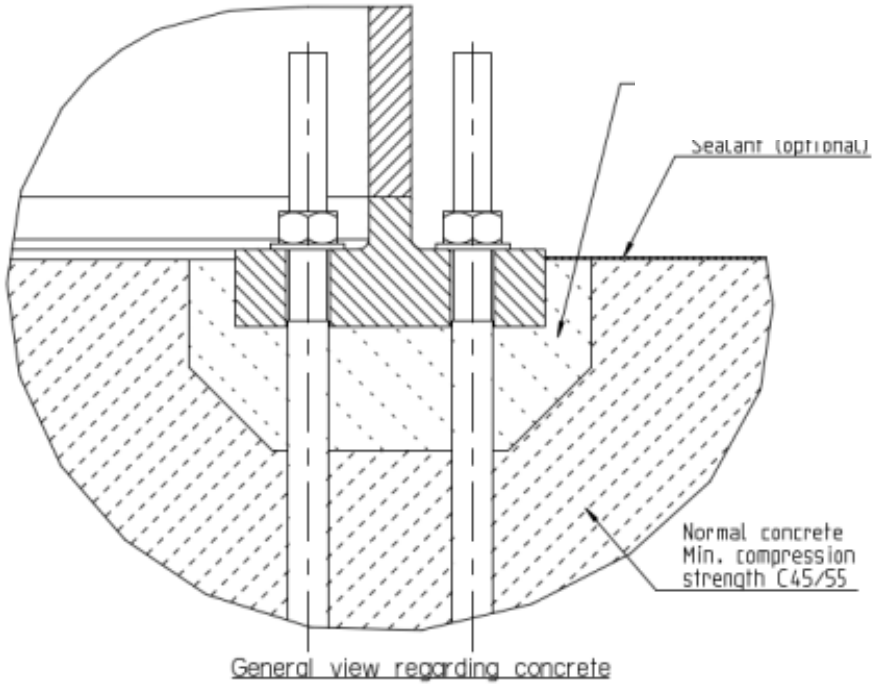

50
90
80 pcs. Anchor Bolts
80 pcs. Anchor B
100
260
210
25
235
25
25
100
150
190
PE shrink hose
2615
PE Height
120
50
Before c f concrete
100

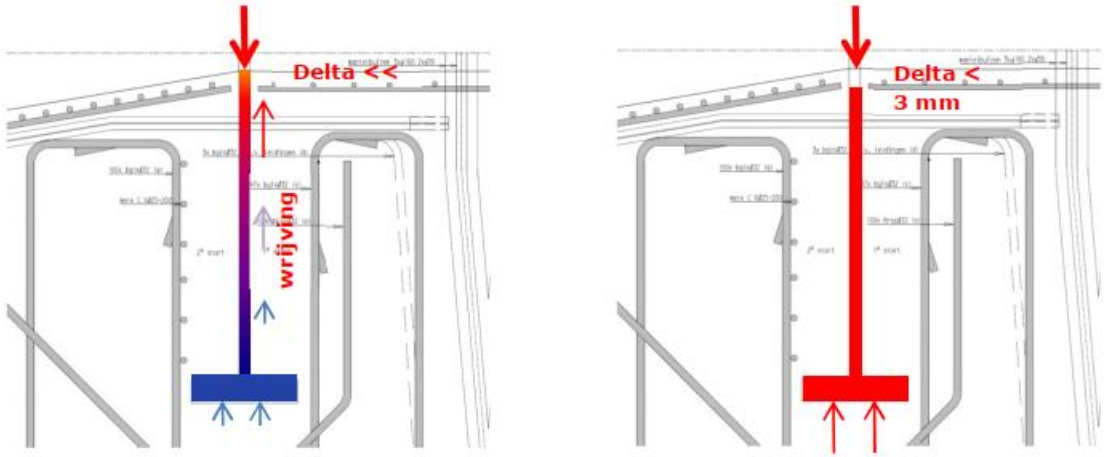
Groutvoeg, een belangrijke verbinder


Lokaal hogere betonkwaliteit
afschot 2%
afschot 2%
bovenkant fundering
maaiveld niveau (= + 1.5m NAP)
hoogste grondwaterstand
onderkant fundering
werkvloer 80mm
werkvloer 80mm

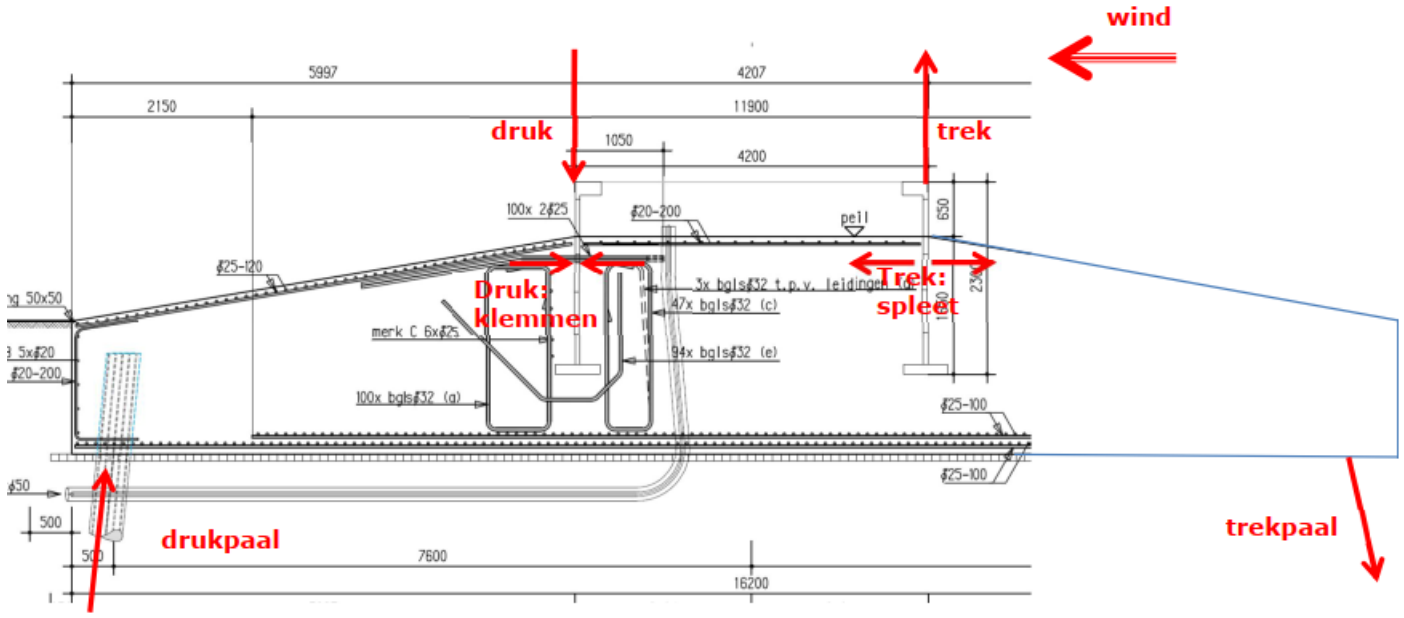
grout details



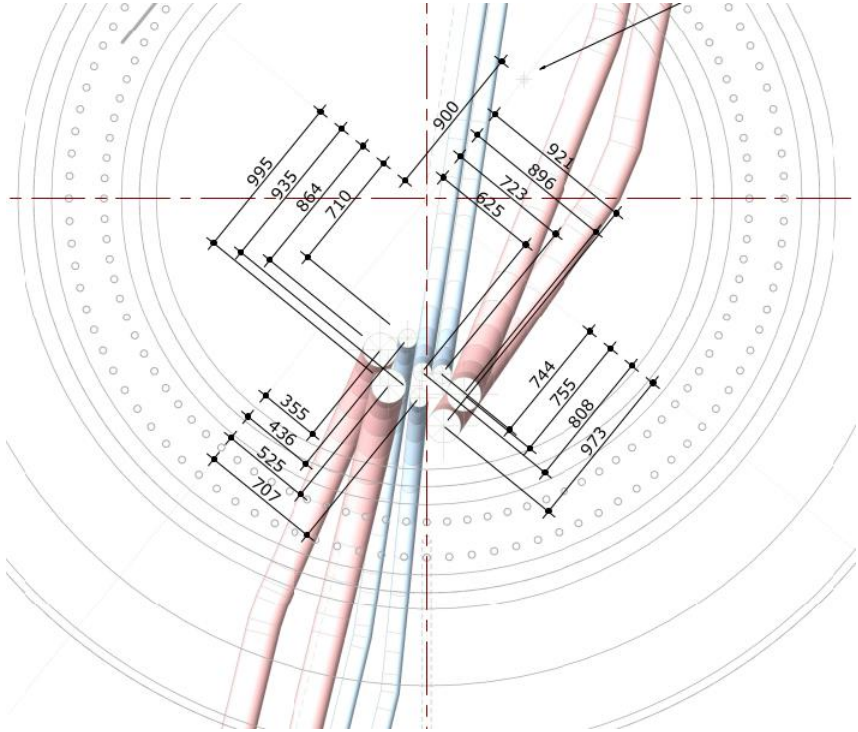


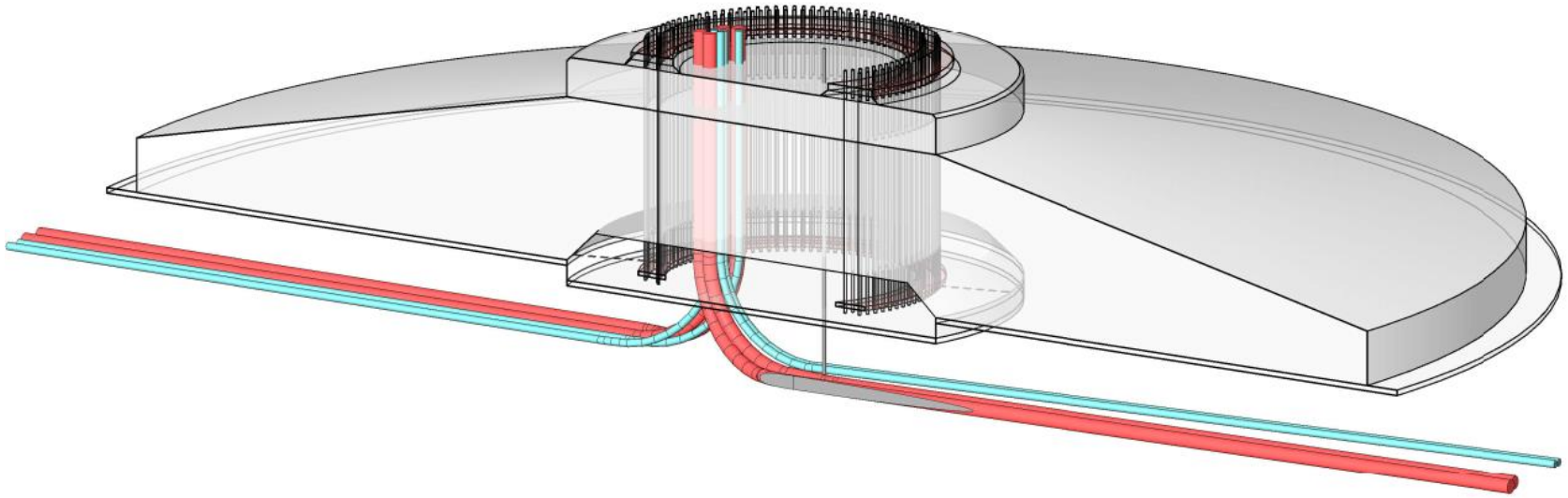


Figuur 4: verschil in afdracht bij wrijving / geen wrijving (rood is hoge staalspanning)

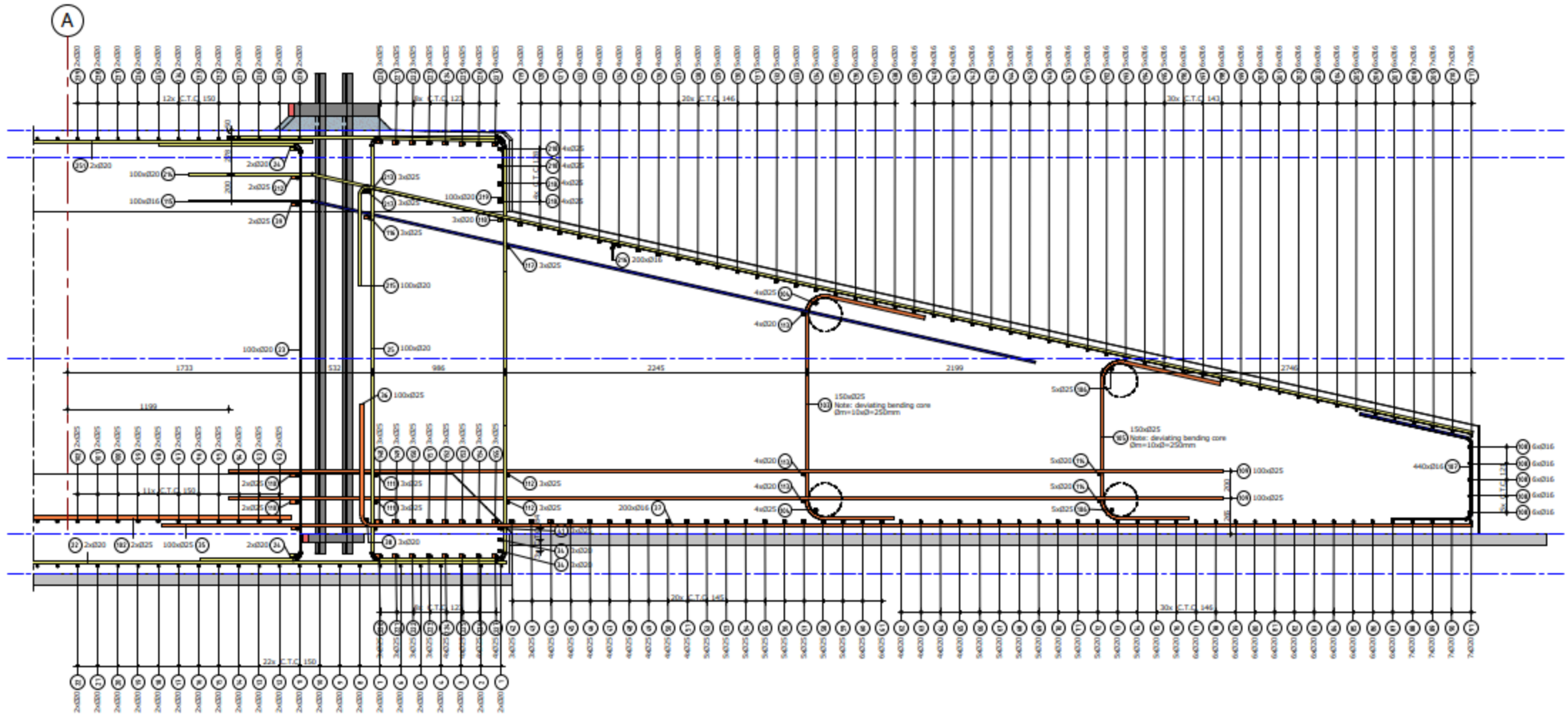


Mantelbuizen


995
935
864
710
900
924
896
723
625
355
436
525
707
744
755
808
973



Wapening



doorsnede wapening

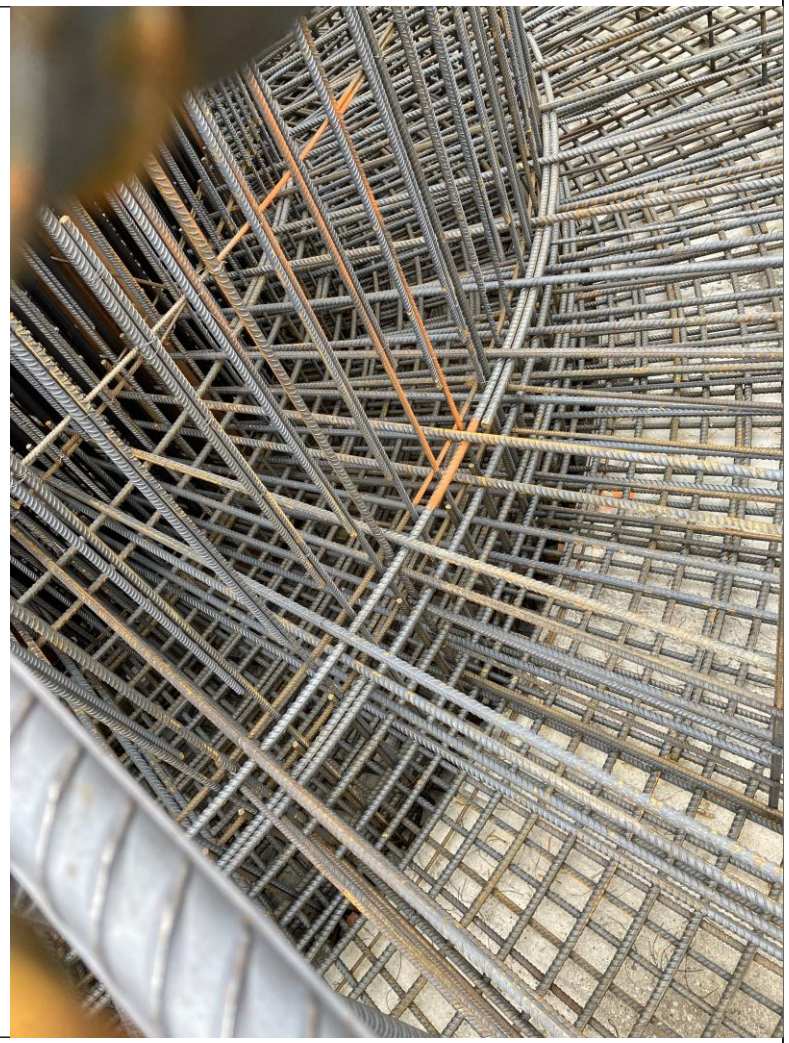
schaal 1 : 20

WindBASE

Stufib

5 september 2023

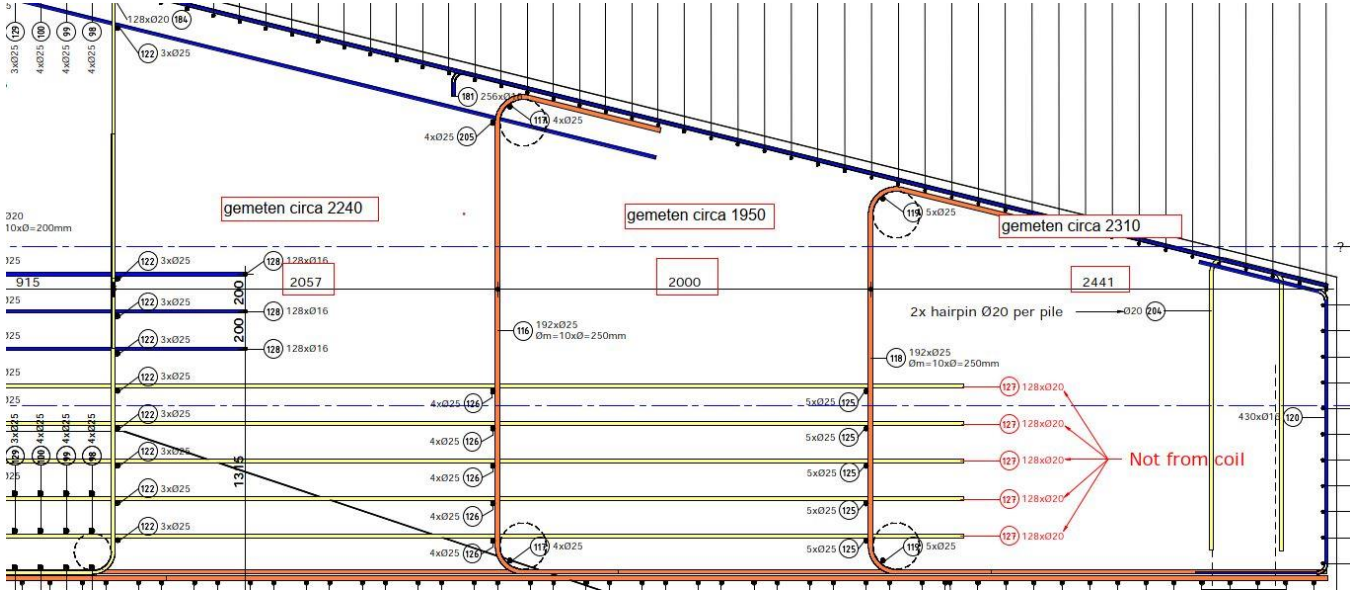
WindBASE



Stufib

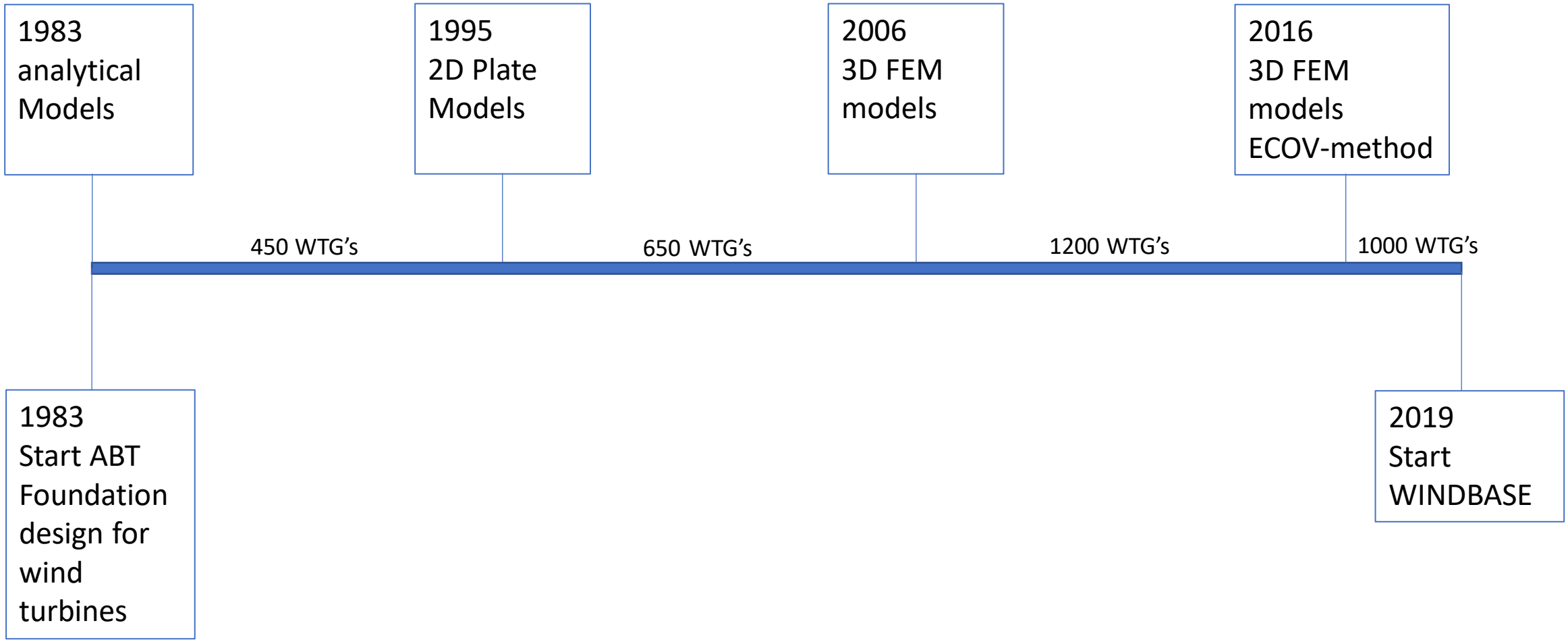
5 september 2023

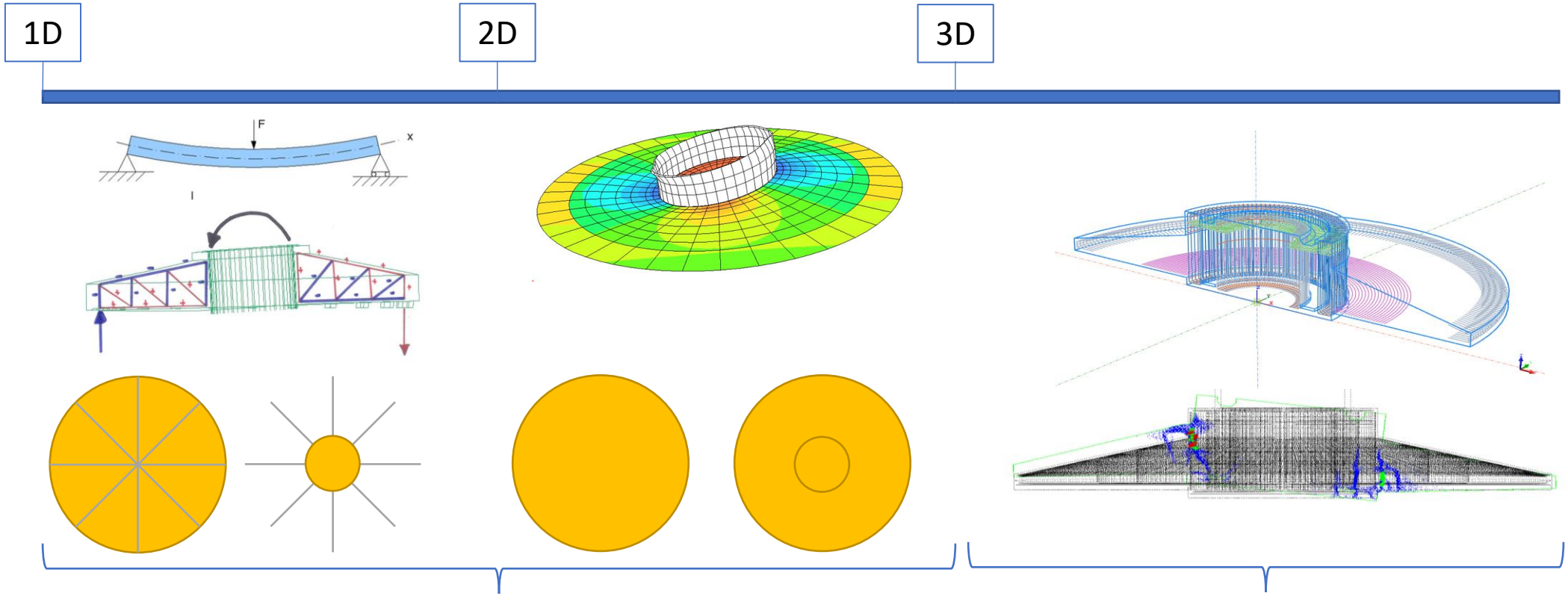
Afwijkende buigradius vanuit oogpunt van vermoeiing worden bepaalde staven met een ruimere buigdoorn ontworpen.


gemeten circa 2240
gemeten circa 1950
gemeten circa 2310
915
2057
2000
2441
2x hairpin Ø20 per pile
Not from coil
128xØ20
3xØ25
4xØ25
5xØ25
128xØ16
192xØ25
Øm=10xØ=250mm
200
1305

Ontwerpmodellen

WindBASE

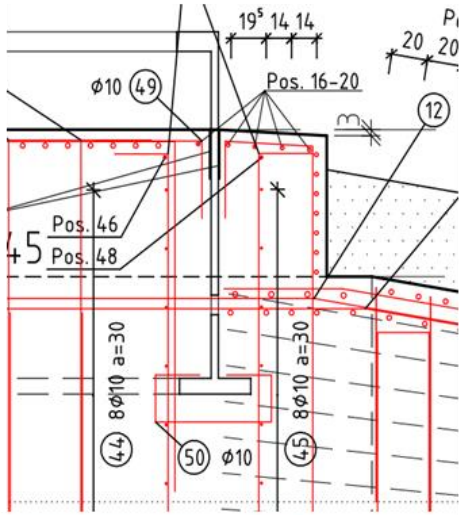

1983
analytical
Models
1995
2D Plate
Models
2006
3D FEM
models
2016
3D FEM
models
ECOV-method
450 WTG's
650 WTG's
1200 WTG's
1000 WTG's
1983
Start ABT
Foundation
design for
wind
turbines
2019
Start
WINDBASE

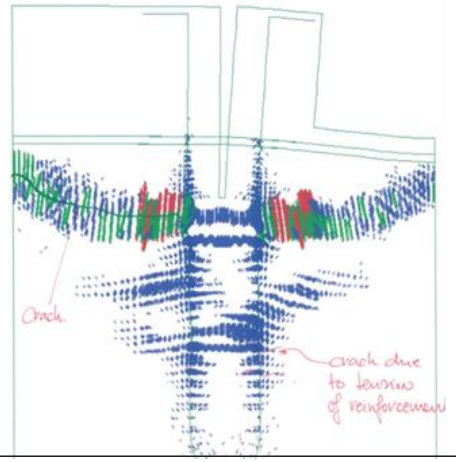


(pre) assumptions regarding load (re)distribution

“real” behaviour

Forgotten mechanisms due to simplified modelling

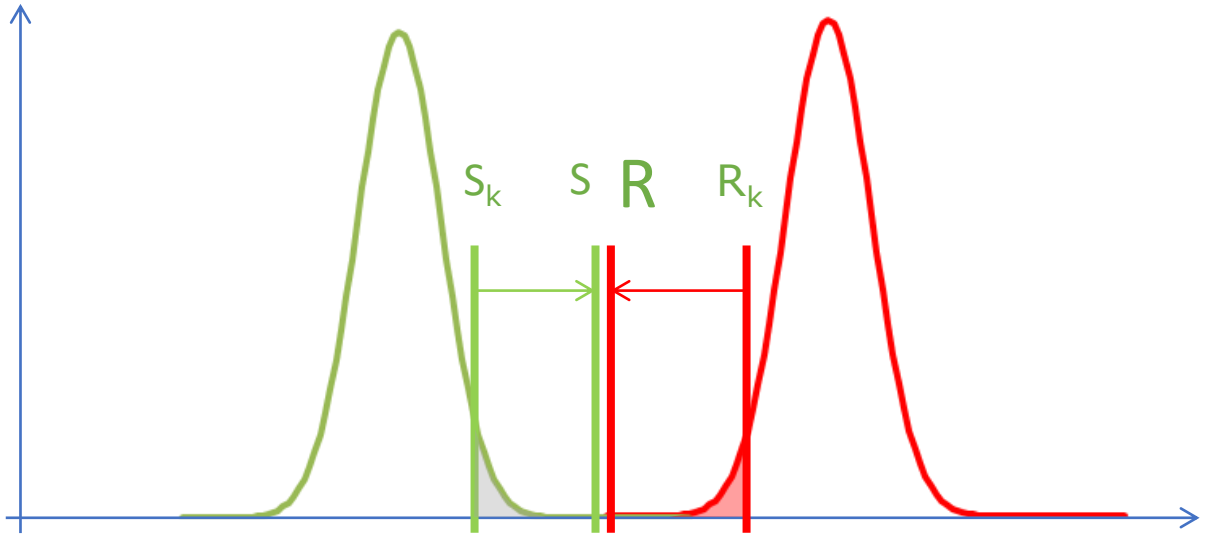




The laws of modelling

Model ≠ Reality

rubbish in = rubbish out

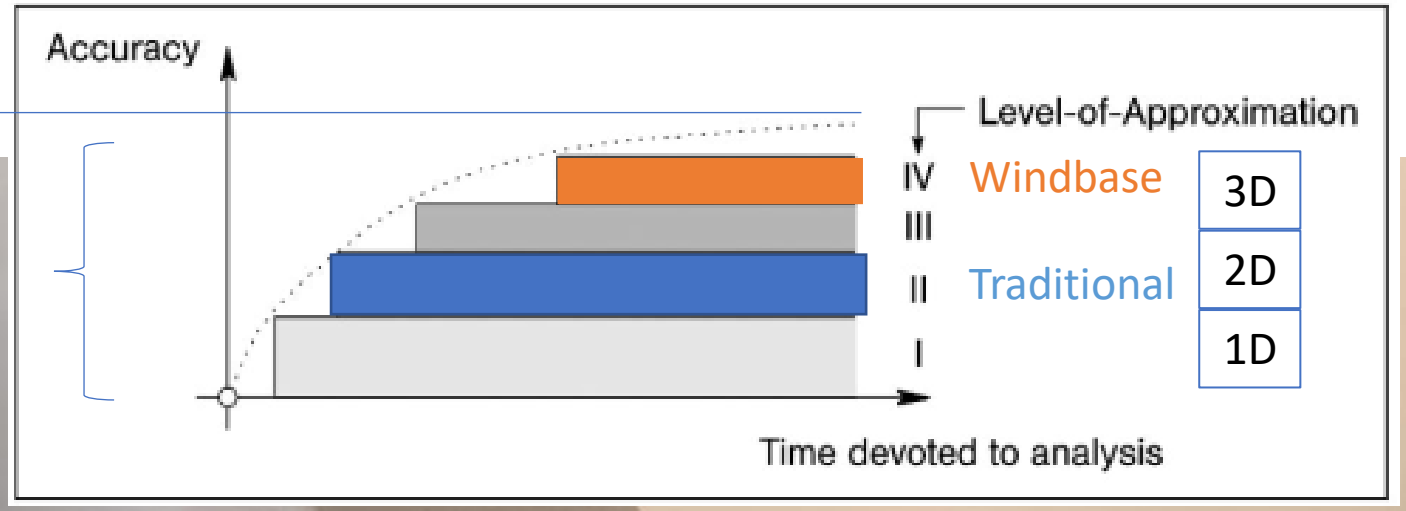


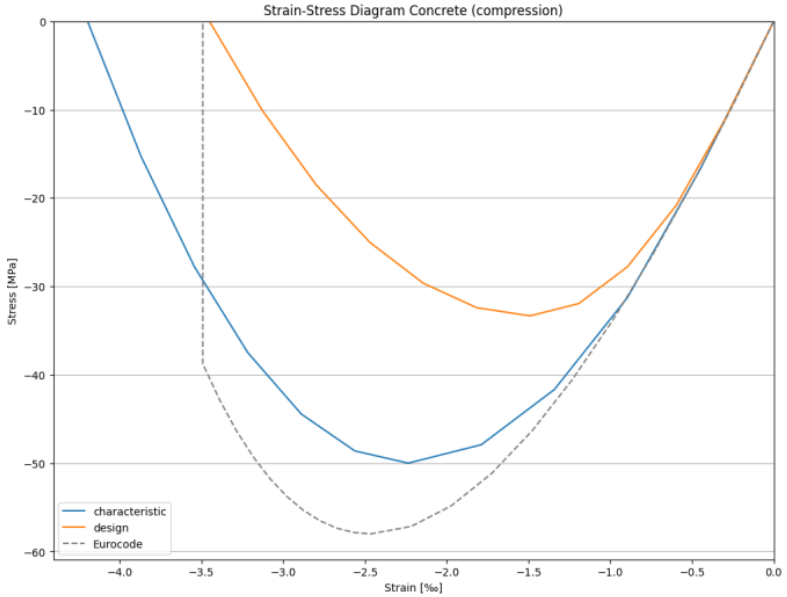
S<R

Living on the edge?

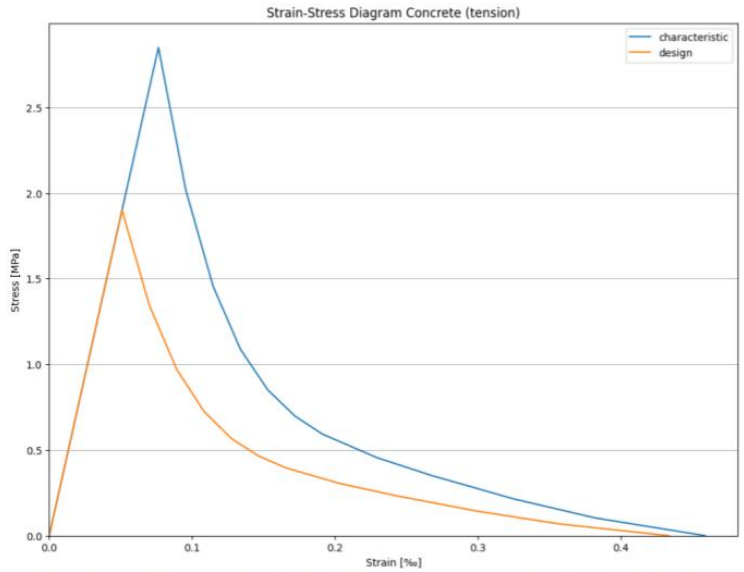
Reality

Models

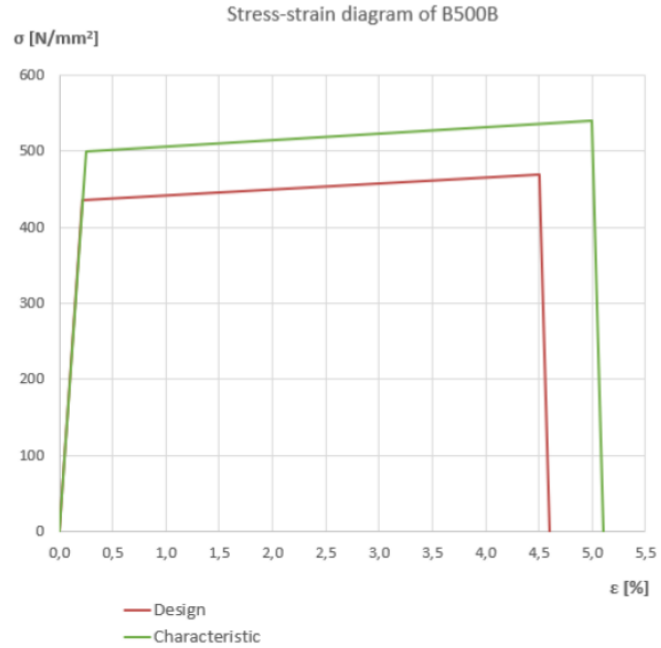




Figuur 18: Spanning-rekdiagram voor het niet-lineaire beton aangebracht aan de bovenzijde van het funderingsblok in druk (geldig voor elementen met een scheurbandbreedte van ca. 250 mm).

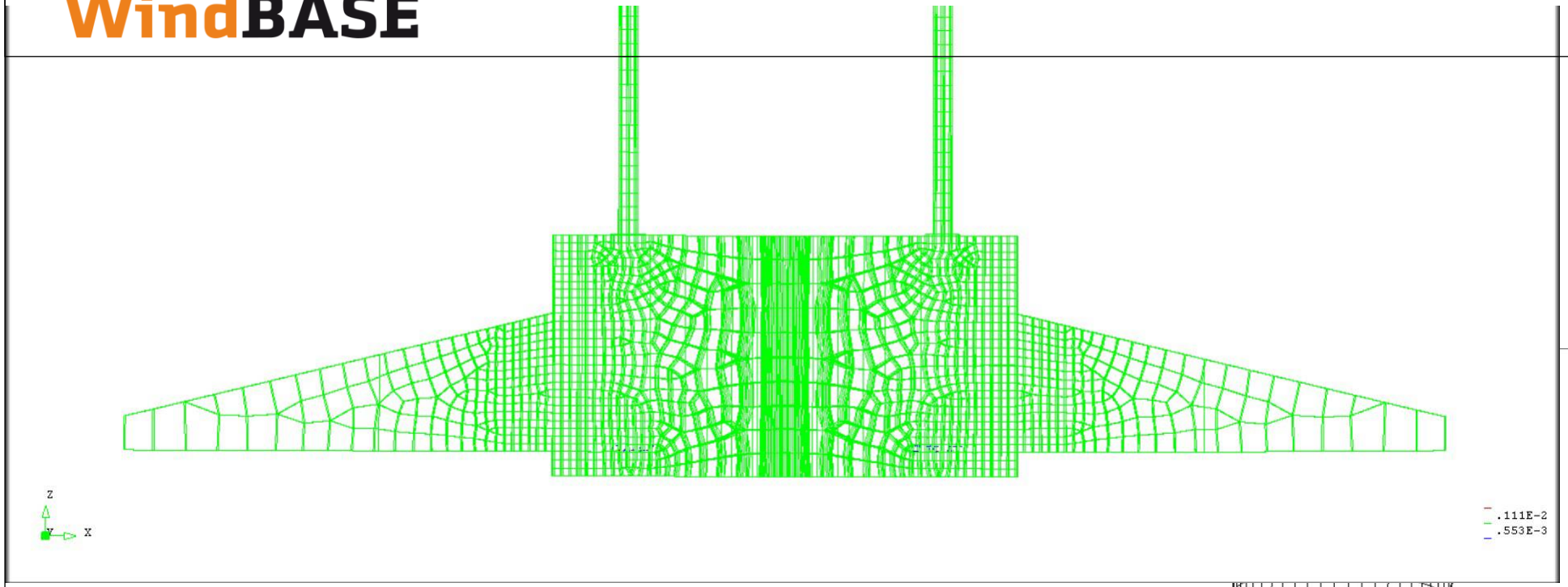


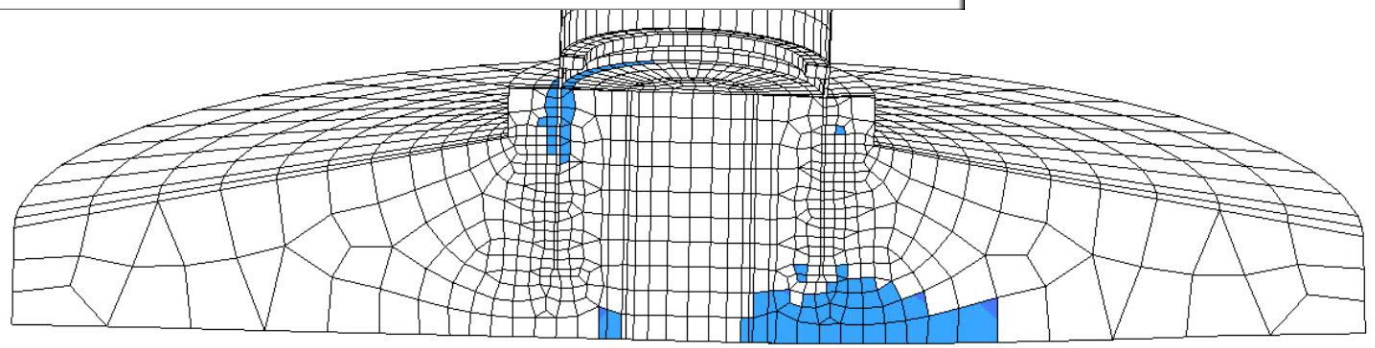
Figuur 19: Spanning-rekdiagram voor het niet-lineaire beton aangebracht aan de bovenzijde van het funderingsblok onder trekspanning (geldig voor elementen met een scheurbandbreedte van ca. 250



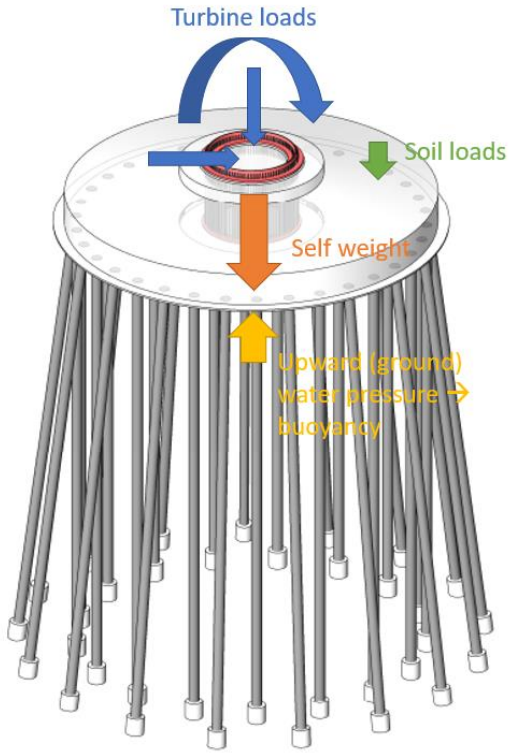
Figuur 20: Spanning-rek diagram voor het toegepaste niet-lineaire wapeningsstaal

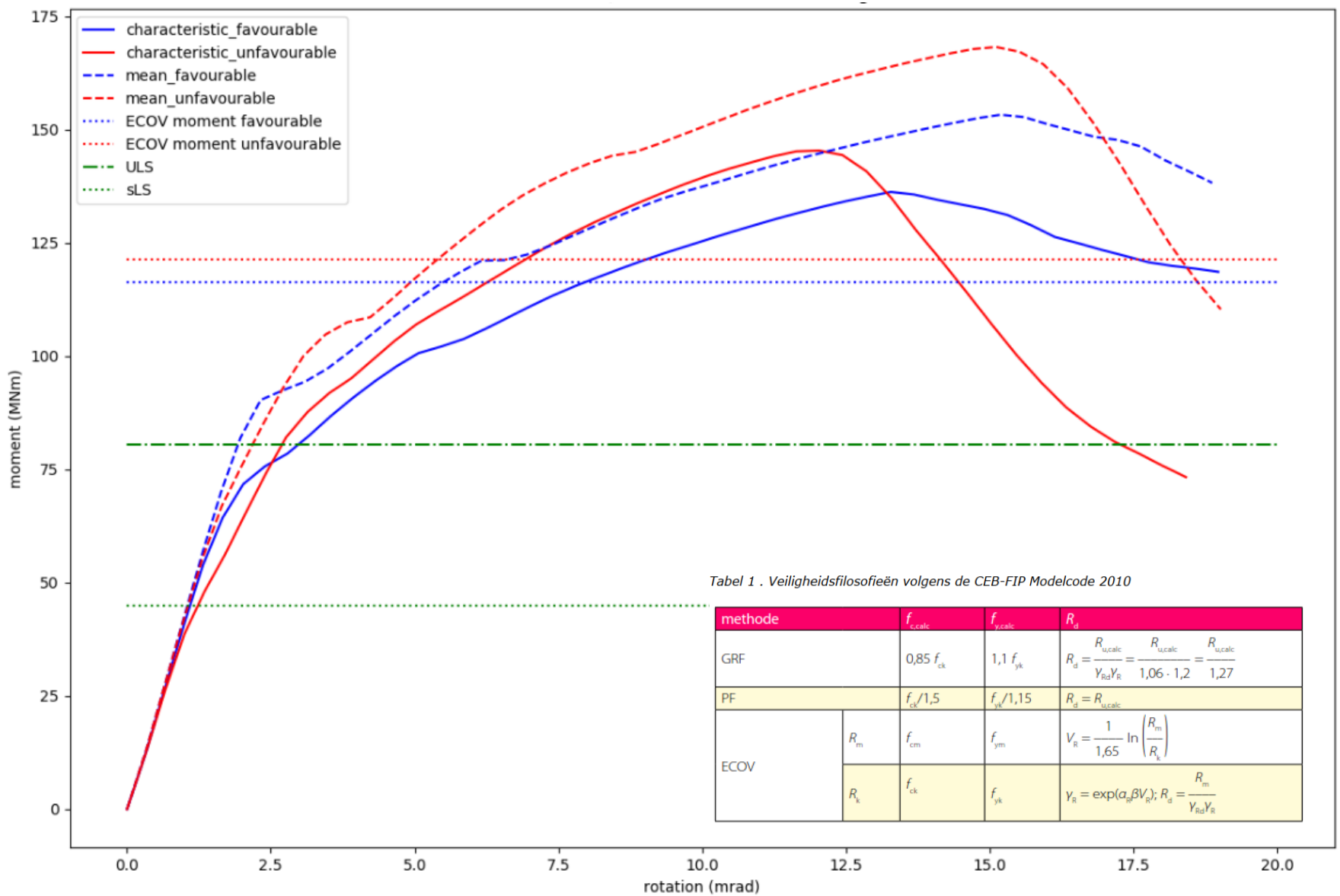
WindBASE





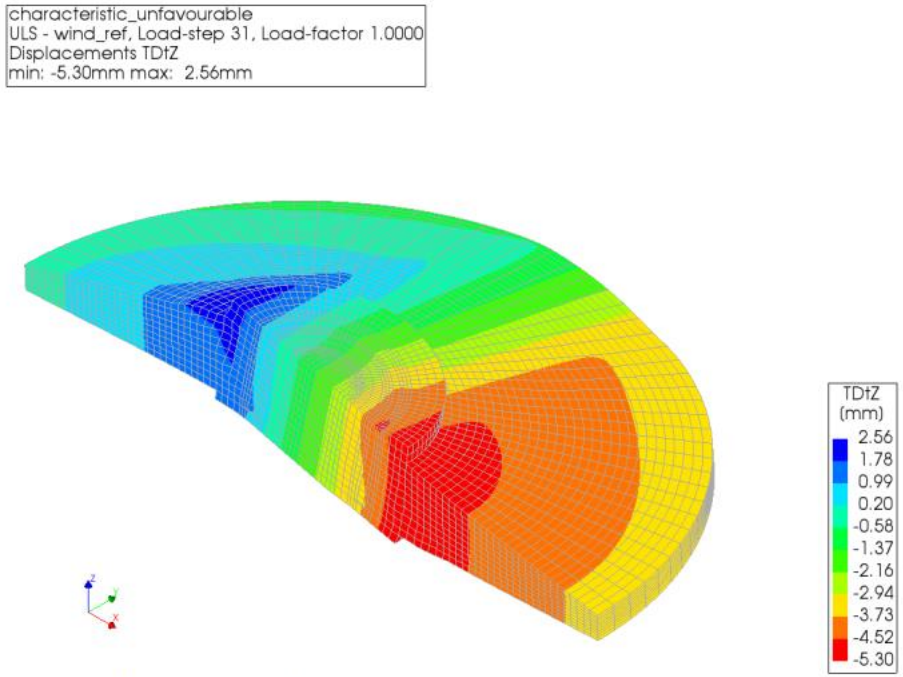
Level IV analysis



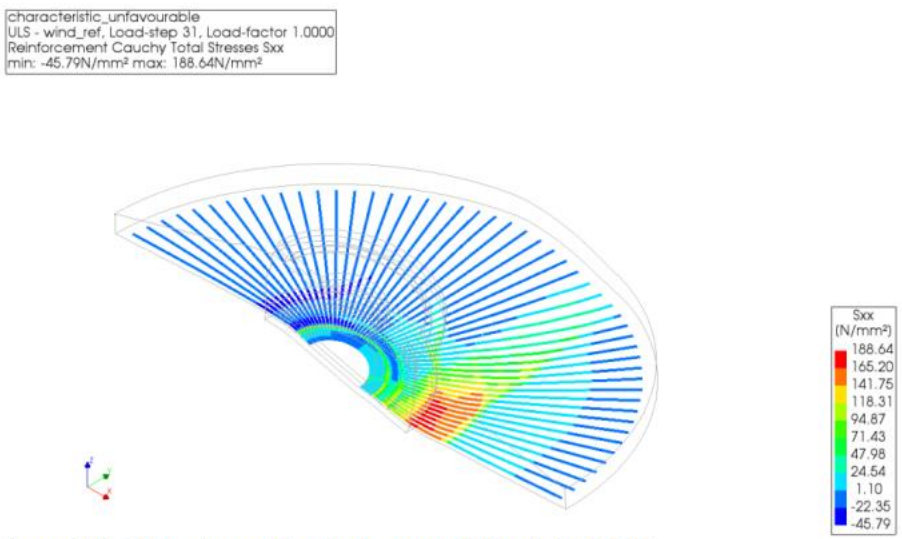


Tabel 1 . Veiligheidsfilosofieën volgens de CEB-FIP Modelcode 2010

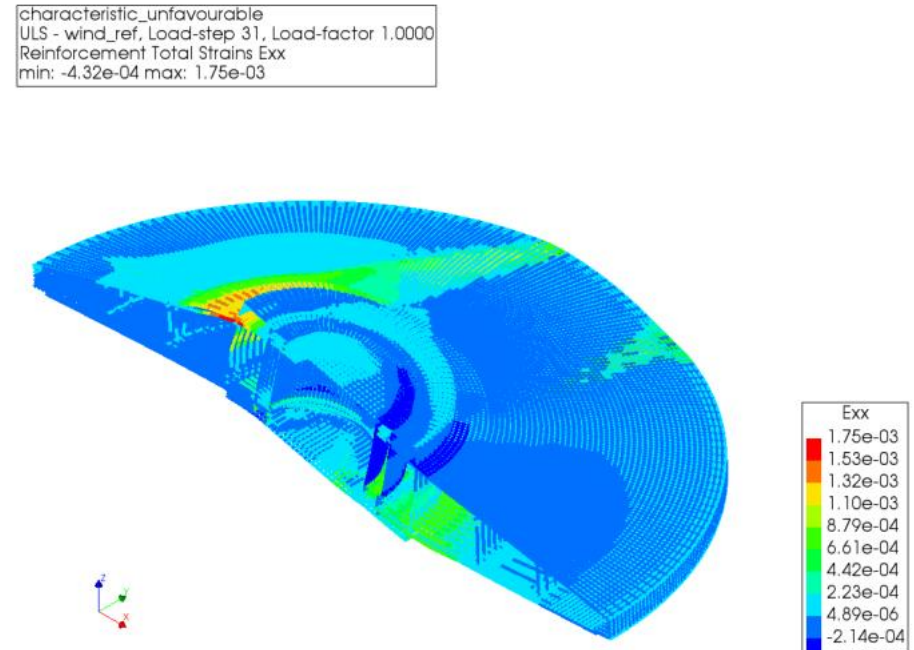
methode		$f_{c,calc}$	$f_{y,calc}$	R_d
GRF		$0{,}85\ f_{ck}$	$1{,}1\ f_{yk}$	$R_d = \frac{R_{u,calc}}{\gamma_{Rd}\gamma_R} = \frac{R_{u,calc}}{1{,}06 \cdot 1{,}2} = \frac{R_{u,calc}}{1{,}27}$
PF		$f_{ck}/1{,}5$	$f_{yk}/1{,}15$	$R_d = R_{u,calc}$
ECOV	R_m	f_{cm}	f_{ym}	$V_R = \frac{1}{1{,}65} \ln\left(\frac{R_m}{R_k}\right)$
	R_k	f_{ck}	f_{yk}	$\gamma_R = \exp(\alpha_R \beta V_R);\ R_d = \frac{R_m}{\gamma_{Rd}\gamma_R}$



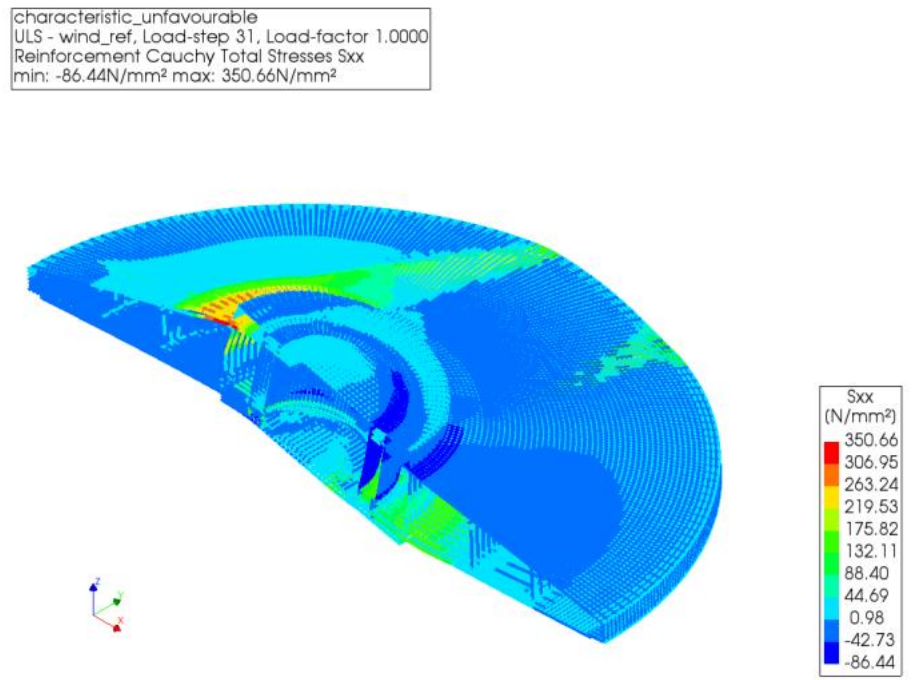
Figuur 83: Vervorming in Z-richting



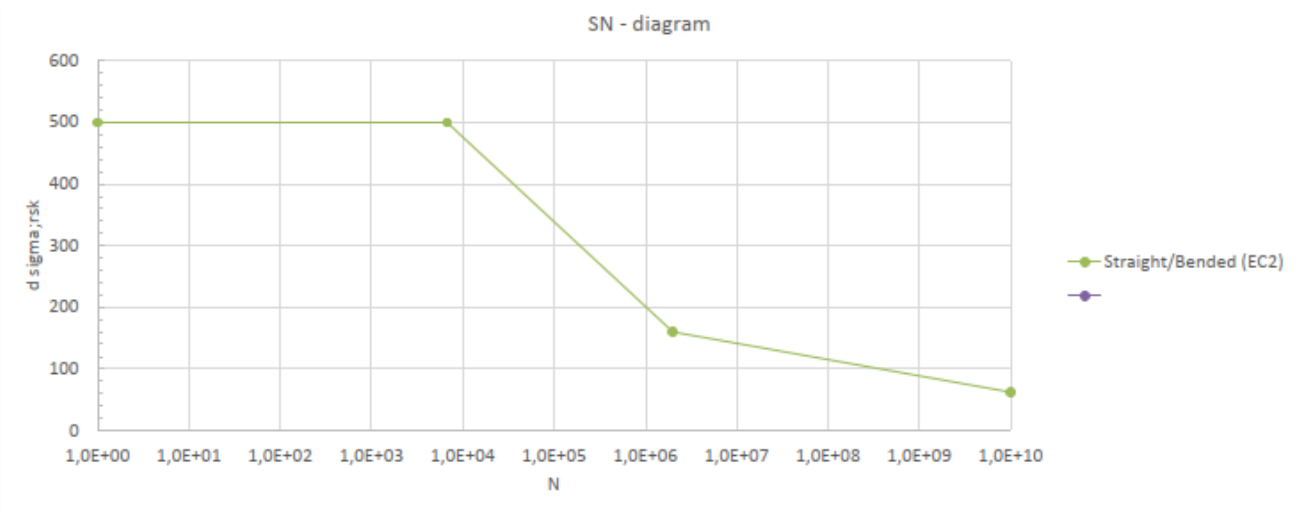
Figuur 106: Wapeningsrekken in de groep RAD-e1_BOT_D25



Figuur 85: Wapeningsrekken, maximale waarden



Figuur 87: Wapeningsspanningen, maximale waarden



Eurocode NEN-EN 1992-1-1 Tabel 6.3N

	straight	welded	
N*	2,0E+06	2,0E+06	[-]
k1	5	3	[-]
k2	9	5	[-]
d sigma;rsk a	160	100	Mpa

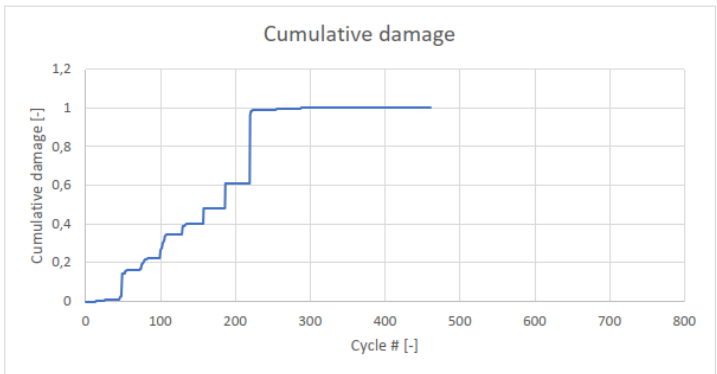
Spectrum:
INPUT R/M
Markov matrices
Mean for Rainflow *kNm*
spectrum fatigue life 20 *years*
fatigue life factor 1,25 -

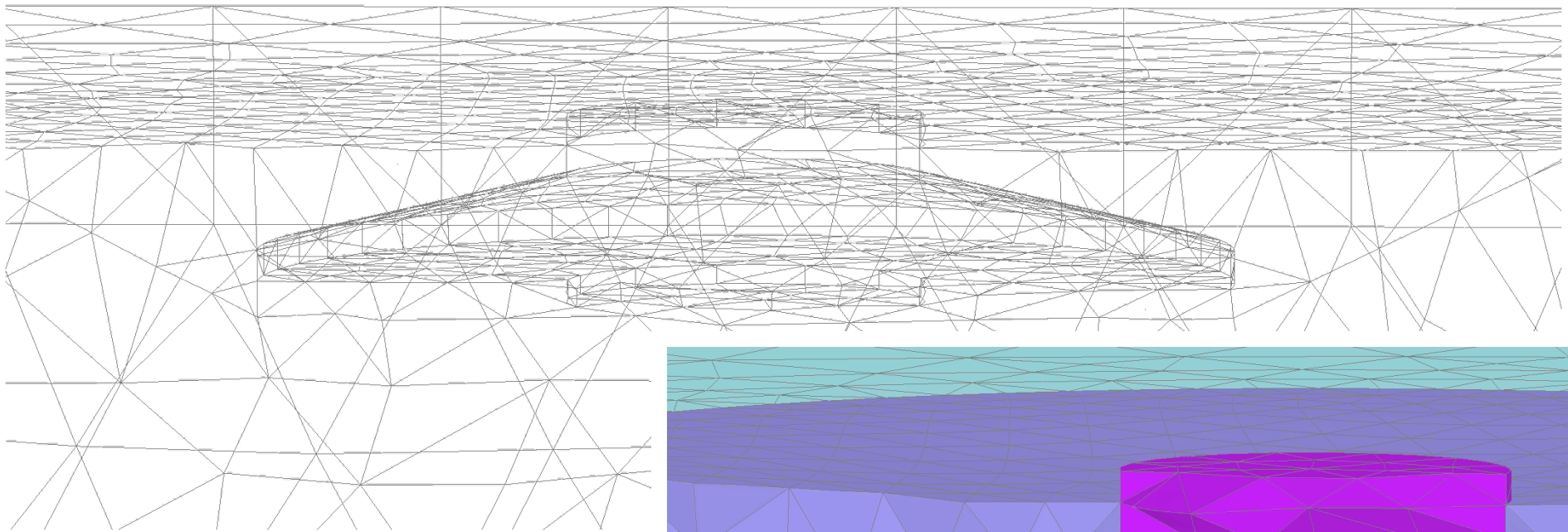
Damage calculation standard rebar:
sigma;ssi = sigma_cor * dM/M tower @REF

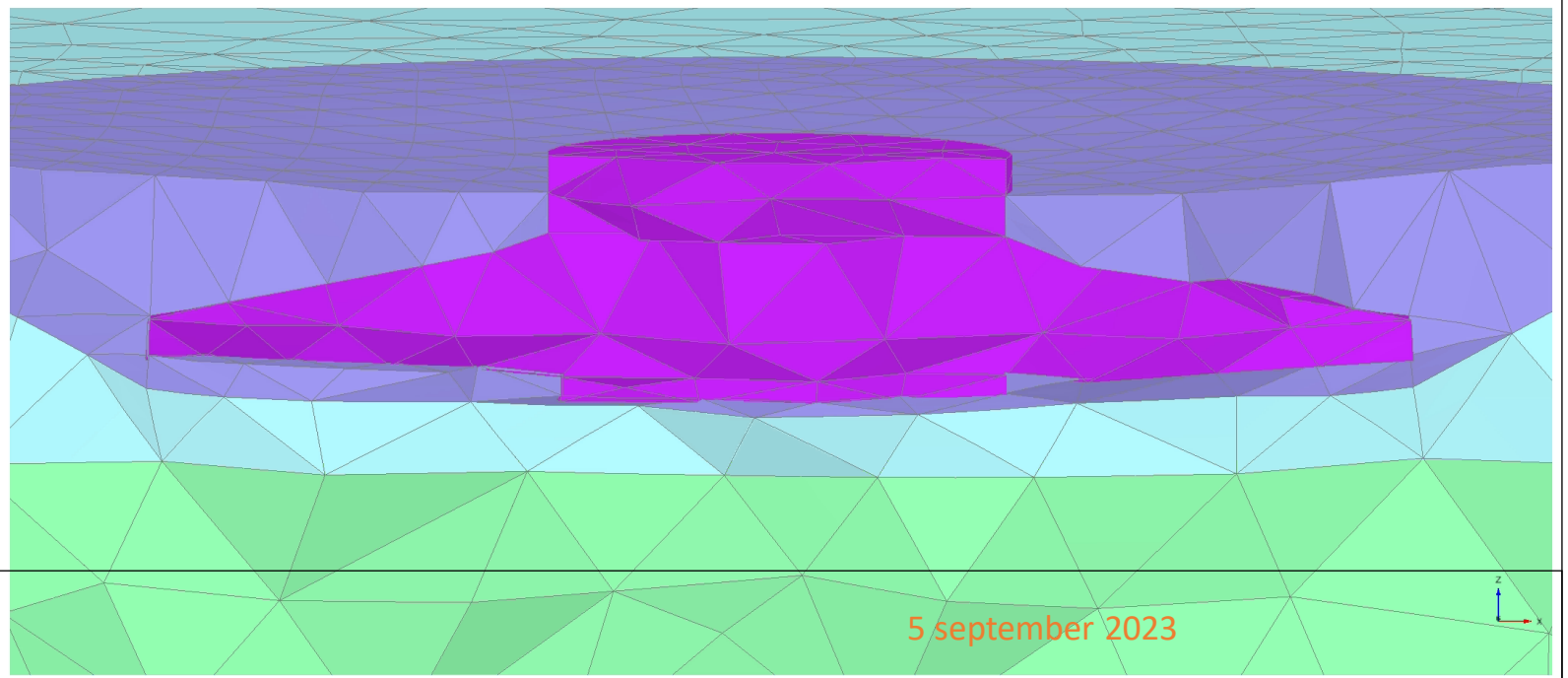
Total damage D tot = 1,00

	Range *kNm*	*Mean Markov* *kNm*	*Frequency* [-]	*Mmax* *kNm*	*Mmin* *kNm*	sigma;ssi Mpa	N [-]	D=n/N [-]	sum(D) [-]
1	2000,0	85000,0	23	86000	84000	8,1	9,16E+17	0,000	0,00000
2	0,0	85000,0	12	85000	85000	0,0	5,64E+158	0,000	0,00000
3	4000,0	80000,0	12	82000	78000	16,2	1,79E+15	0,000	0,00000
4	2000,0	80000,0	230	81000	79000	8,1	9,16E+17	0,000	0,00000
5	0,0	80000,0	12	80000	80000	0,0	5,64E+158	0,000	0,00000
6	4000,0	75000,0	1529	77000	73000	16,2	1,79E+15	0,000	0,00000
7	2000,0	75000,0	5879	76000	74000	8,1	9,16E+17	0,000	0,00000
8	0,0	75000,0	22599	75000	75000	0,0	5,64E+158	0,000	0,00000
9	12000,0	70000,0	1048	76000	64000	48,6	9,09E+10	0,000	0,00000
10	6000,0	70000,0	461	73000	67000	24,3	4,65E+13	0,000	0,00000
11	4000,0	70000,0	14515	72000	68000	16,2	1,79E+15	0,000	0,00000
12	2000,0	70000,0	620730	71000	69000	8,1	9,16E+17	0,000	0,00000
13	0,0	70000,0	1297905	70000	70000	0,0	5,64E+158	0,000	0,00000
14	46000,0	65000,0	12	88000	42000	186,3	9,34E+05	0,000	0,00002

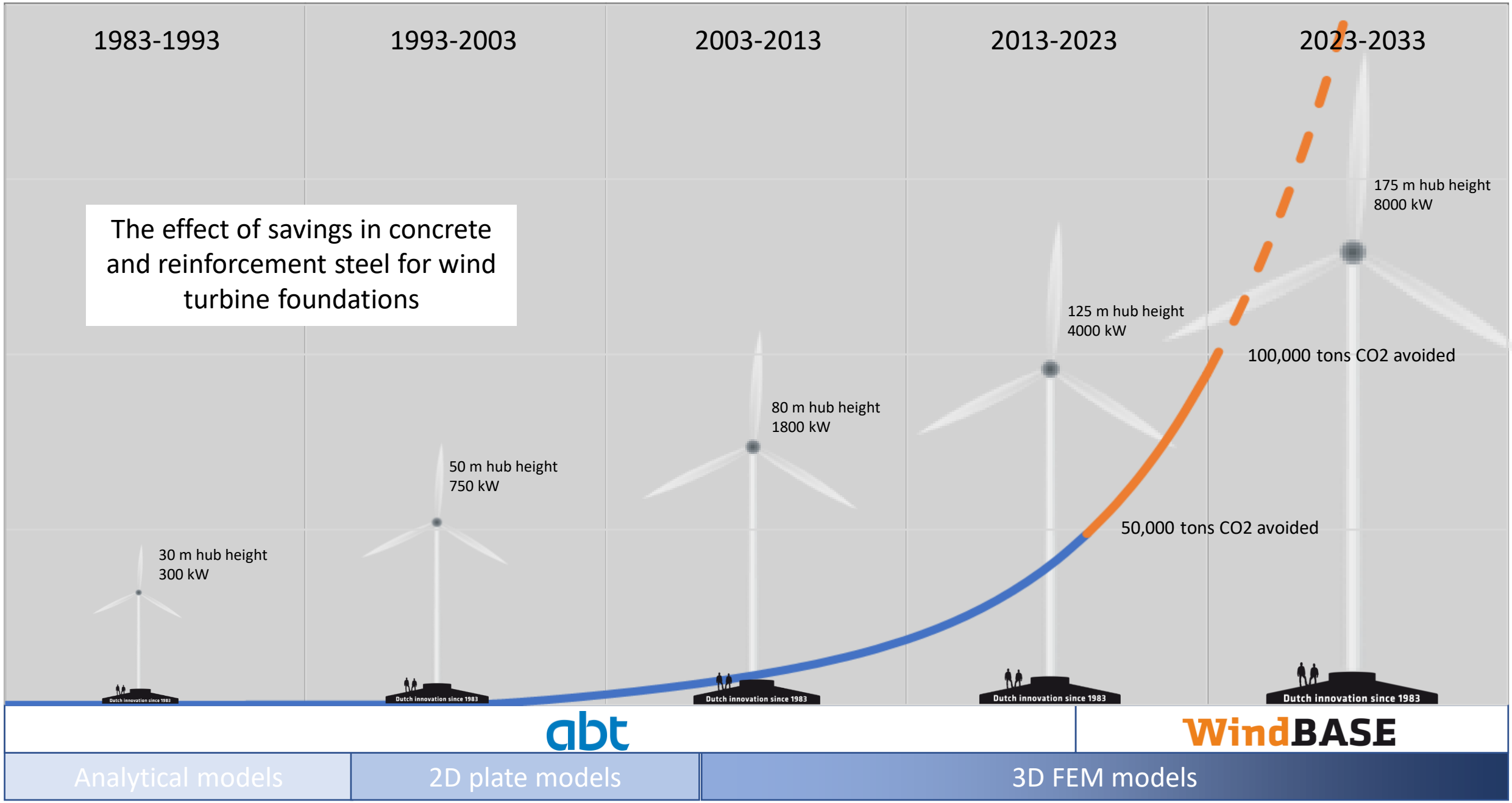
Toetsing wapening en beton op vermoeiing
Scheurwijdtetoets
Minimum wapening







Optimalisatie


1983-1993
1993-2003
2003-2013
2013-2023
2023-2033
The effect of savings in concrete and reinforcement steel for wind turbine foundations
30 m hub height
300 kW
50 m hub height
750 kW
80 m hub height
1800 kW
125 m hub height
4000 kW
175 m hub height
8000 kW
50,000 tons CO2 avoided
100,000 tons CO2 avoided
Dutch innovation since 1983
abt
WindBASE
Analytical models
2D plate models
3D FEM models

WindBASE