GE RENEWABLE ENERGY
WIND OFFSHORE

Constructieve uitgangspunten

Haliade-X Prototype

Foundation Works for the WTG and the metmast

Rev	Section Modified and Revision Description	Date	Author
00	First Issue	26/07/2018	ADF
01	Update after comments from the municipality of Rotterdam	01/08/2018	ADF
02	Update after comments from the municipality of Rotterdam	03/08/2018	ADF
03	Update after comments from the municipality of Rotterdam	08/08/2018	ADF

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1 Preamble

GE Renewable Holding BV ("GE"), headquartered in Breda (The Netherlands) with its engineering offices based in Nantes (France) and Barcelona (Spain), is currently developing a testing site in Rotterdam.
The purpose of the project is to build a prototype of a new Wind Turbine Generator in the area of SIF Group at the Tweede Maasvlakte, the Netherlands.
GE will be responsible for the design, certification, procurement, delivery, installation, commissioning, testing and completion of the WTG including works at the site of SIF Group.

The WTG prototype will be associated to a met-tower also located at the site of SIF Group.

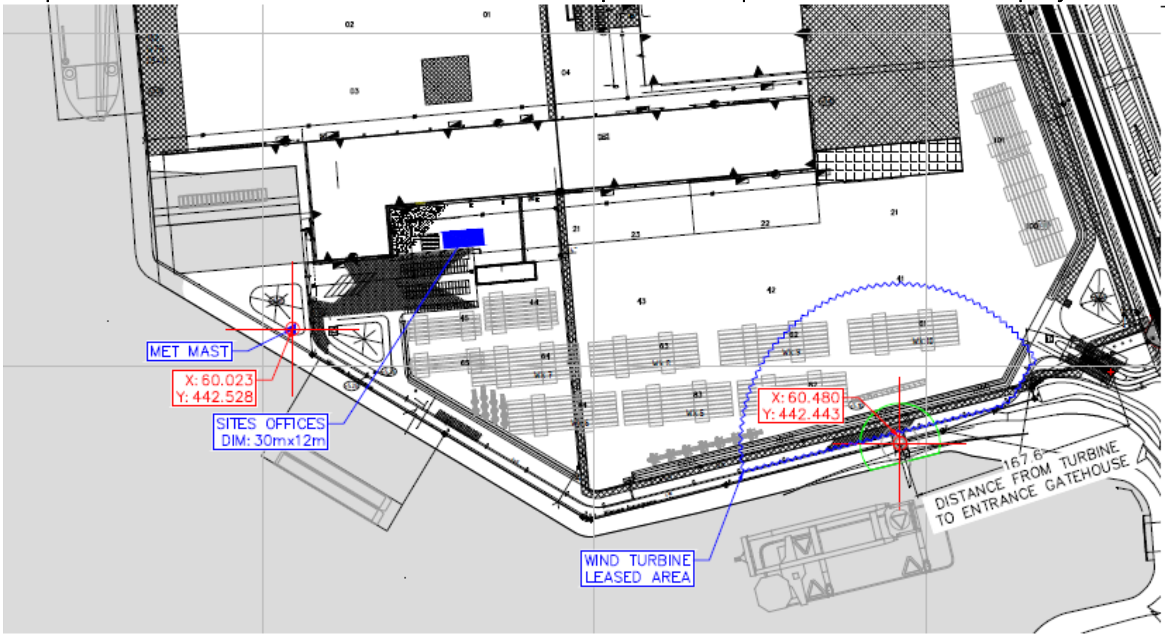
Those equipment and the associated foundations must be dimensioned in accordance with site specific data (weather and soil conditions notably) and comply with Dutch's norms, standards and regulation.

2 Location of the Site

The site is located in Rotterdam Maasvlakte, The Netherlands. The WTG will be positioned at 31U569524 /5757340 according to UTM coordinates in a land leased by the company Sif Offshore from the Port of Rotterdam. The Site is onshore.

3 Description of the site

The Site is located on an area which was reclaimed on the sea in 2013 with dredged material. Purpose of this work was to extend the available space of the port area for industrial projects.



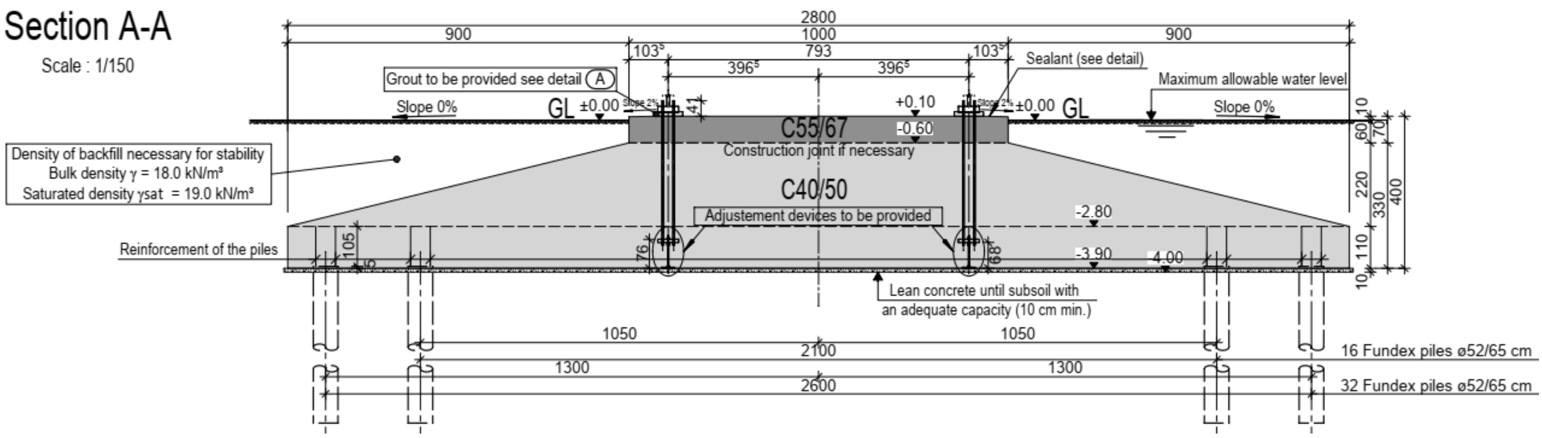
4 Purpose of this report

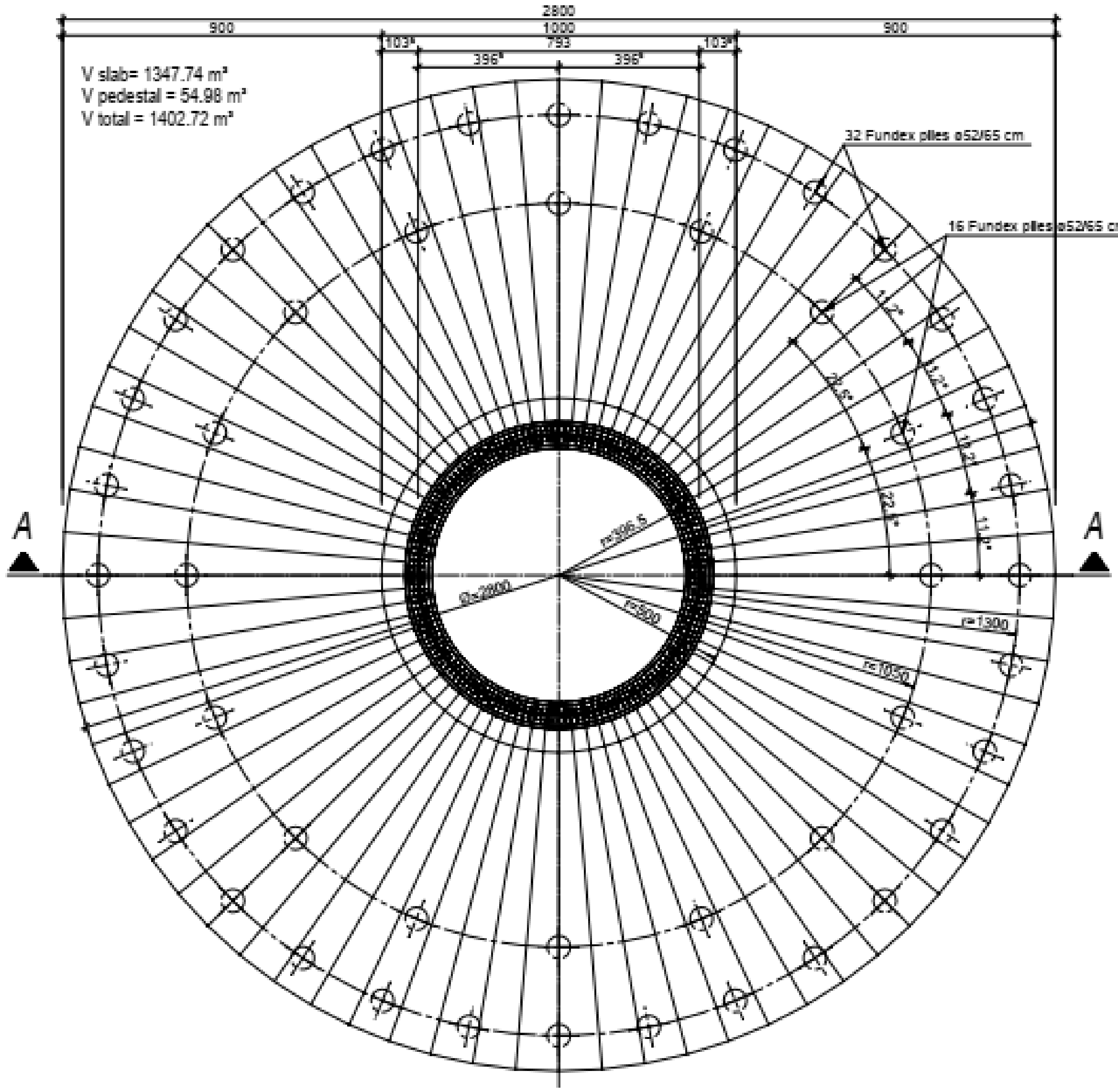
The purpose of this report is to determine the constructive starting points. Based on these principles, the final calculations of the foundation of the WTG and the metmast will be set up in execution phase.

5 Foundation of the WTG

5.1 Principle of the design

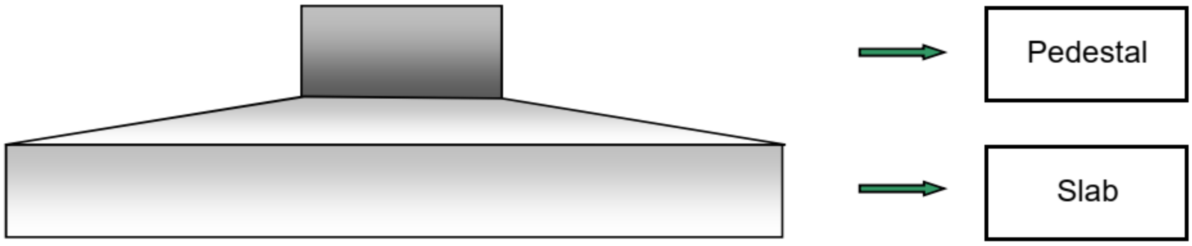
GE has contracted CTE Wind to perform a design of the foundation. The concept is based on a concrete slab of 28 meters diameter supported by 48 piles.





5.2 Dimensions

Wind turbine foundations are designed in two steps:
Foundation dimensions and reinforcement design



The dimensions of the foundations are based on several key criteria :
the stability, the differential settlement, the dynamic stiffness, the no-tensile and piles at lift-off and the distance of piles

The differential settlement :
The maximum rotation of the tower must be limited according to the requirements of the manufacturer. In general, a maximum rotation of 3mm/m is employed.
The maximum rotation also defines the differential settlement.

The dynamic conditions are ensured by:
$K\varphi$,dyn > $K\varphi$,dyn allowable
$K\varphi$,dyn > $K\varphi$,dyn min
Kxy,dyn > Kxy,dyn min
Where the allowable dynamic stiffness is supplied by GE Renewable energy.

5.2.1 Concrete and Reinforcement

The foundation reinforcement is determined based on two criteria:
Calculation of reinforcement according to Eurocode 2 and verification of the fatigue of reinforcement according to Eurocode 2 / Model Code 1990.

The reinforcement is calculated using a finite element method, with the software ANSYS according to Eurocode 2.

The concrete grade is chosen following verifications of the compressive strength according to Eurocode 2, and of the fatigue according to Eurocode 2 / Model Code 1990.

The verification for fatigue is then performed for both the pedestal and the slab, based on Eurocode 2 / Model Code 1990 for the selected reinforcement.

5.2.2 Design hypotheses (in correspondence with IEC-61400)

Terrain category: 0 (Sea or coastal area exposed to the open sea)
Design life time of 20 years

Reinforced concrete density: 2,50 T/m^3
Density of backfill: 1,80 T/m^3 (without buoyancy)
Density of backfill: 1,90 T/m^3 (with buoyancy)
Pedestal concrete: C55/67
f_{ck} = 55MPa
γ_c = 1.50
f_{cd} = 36.7 MPa
Slab concrete: C40/50
f_{ck} = 40 MPa
α_{cc} = 1.00
f_{cd}=26.7 MPa
Grout: C100/115
f_{ck} = 100 MPa
α_{cc} = 1.00
f_{cd}=66.7 MPa
Yield strength of reinforcement: 500 MPa
γ_s = 1.15
$\gamma_{s,fat}$ = 1.15
f_{yd} = 455 MPa

NOTE: This design was made with the initial prototype loads. The last version of the prototype loads has been sent to certification. Once the certified loads are available a report will state if there is any difference with the initial loads used for the foundation design and the civil work company in charge of the foundation works will be required to use those certified loads for the execution design.

		Partial factor				**Comments**
	Load case*	For wind	For weight of tower	For RC + backfill	For water	
1	GAA14-Vrp-pdc-0-a180 -1	1.35	1.35	1.35	1	50 years wind gust
2	GAA14-Vrp-pdc-0-a180 -2	1.3	1	1	1	50 years wind gust
3	GAA14-Vrp-pdc-0-a180 -3	1.35	1.35	1.35	1	50 years wind gust
4	GAA14-Vrp-pdc-0-a180 -4	1.35	0.9	0.9	1	50 years wind gust
5	GAA62a-Ve50t-120n-s6	1.1	1.1	1.1	1	Accidental load case
6	GAA62a-Ve50t-120n-s6	1.1	0.9	0.9	1	Accidental load case
8	GAA12-10-n-s3	1	1	1	1	Lift-off
9	GAA14-Vrp-pdc-0-a180	1	1	1	1	Characteristic load case
10	Mi+50%	1	1	1	1	Average fatigue +50%
11	Mi-50%	1	1	1	1	Average fatigue -50%
12	GAA62a-Ve50t-120n-s6	1.35	0.9	0.9	1	50 years wind gust

*The combinations of CTE Wind are done according to the NEN IEC 61400-1

Method of calculation

Ultimate Limit States verifications (load cases 1, 2, 3, 4)
Maximum compression load capacity of the pile: according to geotechnical report
Maximum load capacity of the piles: according to geotechnical report
Distance between axis of piles > 3 times of pile diameter
Verification of punching of the piles
Calculation of reinforcement according to Eurocode 2

Accidental Limit state verifications (load cases 5, 6, 10, 12)
Maximum compression load capacity of the pile: according to geotechnical report
Maximum tension load capacity of the piles: according to geotechnical report
Verification of punching of the piles
Calculation of reinforcement according to Eurocode 2

Serviceability Limit State for characteristic load verifications (load case 9)
Maximum compression load capacity of the pile: according to geotechnical report
Maximum tension load capacity of the piles: according to geotechnical report
Differential settlements and dynamical rotational stiffness

Serviceability Limit States verifications (load case 8)
Maximum compression load capacity of the pile: according to soil report
No tensile in the piles is allowed under load case

Limit State of Fatigue verification (load cases 10, 11)
Fatigue of the material – concrete and steel – on the foundation slab and the piles
The Limit State of Fatigue is verified according to Eurocode 2 and Model Code 1990
The verification is performed separately for the concrete and the reinforcement

Standards

NEN IEC61400-1 Edition 4
NEN-EN 1992-1-1+C2: 2011/NB:2016 nl
NEN-EN 1990 and NEN-EN 1992-1-1+C2:2011/NB: 2016 nl fatigue check
NEN 9997-1+C2: November 2017
GL 2010
IEC61400-6 (Draft)

Geotechnical report supplied by: FUGRO n°1018-0166-000 Version 2.0, date 12/06/2018

Static values:	Dynamic value:
Kv pile = 220 kN/m	Kv pile = 485000 kN/m
Kh pile = 21000 kN/m	Kh pile = 42000 kN/m
Kr pile = 3000 kN/m°	Kr pile = 3000 kN/m°

Load cases defined by GE Renewable Energy: OFF-ENG-EXT-FRM-001 / WF*: 157670745
Type of machine: Prototype tower
$K\varphi$,dyn = 529000 MN.m/rad
$K\varphi$,stat = 176333 MN.m/rad
Kh,dyn = 1790.0 MN/m

6 Piles for the WTG foundation

GE has contracted Fugro NL Land B.V to perform geotechnical site investigation and engineering of the pile for the foundation of the WTG. The report of this site investigation is attached in Annex 1.
This is the final report from Fugro as they were only able to make CPT at the edge of the riprap in an early design phase of the project. The civil works contractor will make additional CPT in the foundation area once a sheet piles wall has been erected and some earthworks has been made. The results from those additional CPTs will be needed to confirm the final design of piles and foundation.

Concrete class: XA3
48 piles Fundex D=520/650mm

Concrete C40/50
f_{ck} = 40 MPa
C_{max} = 35 MPa
F^*_{ck} = 25.6 MPa
γ_c =1.5
α_{cc} = 1
k_1 = 1.3
k_2 = 1.05
k_3 = 1.00
f_{cd} = 18.3 MPa
σ_{c_ELS} = 7.7 MPA

<u>Reinforcement</u>
f_{yk} = 500 MPa
γ_s = 1.15
ω_{max} = 0.1 mm
f_{yd} = 400 MPa
Φ_{As} = 25 mm
$\Phi_{As,t}$ = 10 mm

Characteristic of piles
D_{out} = 0.65 m (Pile diameter)
c = 0.07m (cover of concrete, minimal 7cm)

7 Anchor cage for the WTG foundation

References and standards
IEC 61400-1 Edition 3 – 2005
EN 1993-1-1
EN 1993-1-8
EN 1993-1-9
Model code 1990

Material
ISO 4014 for the bolts
ISO 4032 for the nuts
EN 10025-2 for the plates and ring anchor
ISO 7089 for the washers

Load cases
According to the IEC-61400-1 (edition 4) a partial factor of **$\gamma_{q,wind}$ = 1,35** should be used for the Wind Turbine.

GAA62a-Ve50t-120n-s6	γ_F = 1.1
GAA12-10-n-s3	γ_F = 1.0 (Lift-off)
Mi + 50%	γ_F = 1.0
Mi – 50%	γ_F = 1.0
GAA14-Vrp-pdc-0-a180	γ_F = 1.0 (SLS-Characteristic load)
GAA14-Vrp-pdc-0-a180	γ_F = 1.35
GAA62a-Ve50t-120n-s6	γ_F = 1.10

Below an extract of the specific load factors for wind turbines, according to IEC-61400-1 is provided:

7.6.2.1 Partial safety factors for loads

Partial safety factors for loads shall be at least the values specified in Table 3.

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 γ_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

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

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

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

8 Standards and quality for the WTG

The IEC 61400-1 (edition 4) outlines minimum design requirements for wind turbines and specifies essential design requirements to ensure the engineering integrity of wind turbines. Its purpose is to provide an appropriate level of protection against damage from all hazards during the planned lifetime.

The IEC 61400 is concerned with all subsystems of wind turbines such as control, protection mechanisms, internal electrical systems, mechanical systems and support structure. According to IEC 61400 a support structure is defined as the part of the wind turbine comprising the tower and foundation and will be part of the type certification. The foundation is therefore also under IEC 61400.

The IEC 61400 also has its own wind class system, that differs from the NEN 1990. The Haliade wind turbine will be certified according to IEC 61400, wind turbine class I. This means that all control, protection mechanisms, internal electrical systems, mechanical systems and support structures will be designed to withstand the parameters of wind turbine class I. Please find below **Fout! Verwijzingsbron niet gevonden.** the parameters of the wind turbine classes.

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.

In addition to the standards applicable for the foundation, the following standards and codes are applicable to the design of the WTG itself:

Standards	Description
NEN 1010	Safety requirements for low-voltage installations
IEC-61936-1	Safety regulations for high-voltage installations
NEN-HD620-S2	Distribution cables with extruded insulation
EN ISO 12944	Paint and varnishes – Corrosion protection of steel structures by protective paint systems
EN 1461	Hot dip galvanized coatings on fabricated iron and steel articles
EN 10025	Hot rolled products
NEN 10204	Materiel certification
EN 12464	Light and Lightning – Lightning of work places
EN 1838	Lighting applications – Emergency Lighting
EN 547	Safety of machinery – Human body dimensions
EN 795	Personal protective equipment against falls from height. Anchorage devices – Requirements and testing
EN-IEC 62305	Protection against lightning
EN 14121	Safety of machinery – Risk assessment
EN ISO 14122	Safety of machinery
EN 50160	Voltage characteristics of electricity supplied by public distribution systems
EN 50172	Emergency escape lighting systems
EN 50110	Operation of electrical installations – General requirements
NEN 3140	Operation of electrical installations – Additional Netherlands requirements for low-voltage installations
NEN 3840	Operation of electrical installations – additional Dutch requirements for high-voltage installations
IEC 60071	Insulation co-ordination
IEC 60076	Power transformers
IEC 60099	Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems
IEC 60287	Electric cables – Calculation of the current rating
IEC 60793 / 60974	Optical fibres and optical cables
IEC 61000-6-4	Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments
EN55011	Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement
IEC 62271-200	High-voltage switchgear and control gear
IEC 61850	Communication networks and systems in substations

9 Metmast

Identification:

Localization	Rotterdam
Tower type	Self-supp
Tower height	133,0m
Tower model	H133_W27I20

Calculation parameters:

The calculations have been made in correspondence with Dutch standards NEN-EN 1991-1-4. For the met mast a site specific calculation is made, using the following wind speeds:

terrain category	0	
basic wind speed	**27,0 m/s**	97,2 km/h
wind speed at top	45,1 m/s	162,3 km/h
peak wind speed	58,0 m/s	208,7 km/h
ice thickness	**10,0 mm**	10,0 mm
wind speed at top with ice	28,5 m/s	102,6 km/h
peak wind speed with ice	36,7 m/s	132,0 km/h

The definition of wind class in accordance with the Dutch 'Windgebied – 2'.

Partial factors for ultimate limit state:

The final calculations will be made in correspondence with NEN-EN 1990, table NB.4, using the following parameters

Reliability class	2
Dead load: γ_G	1.20/1.35
Wind load: γ_W	1.50
Ice load: γ_{ICE}	1.50
k factor	0.40
Ice weight	840 kg/m^3

9.1 Design of the mast

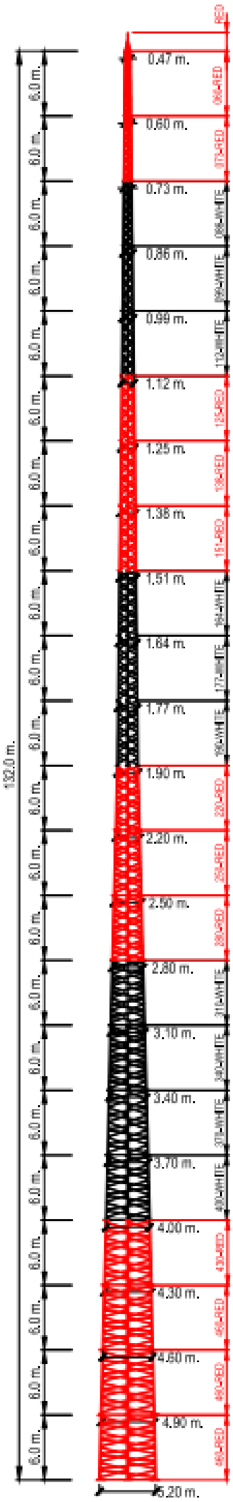
Consequence Class: CC2
Reliability class: RC2
Design lifetime: 20 years

Ancillaries:

	Low level	Top level	weight	Flat wind drag	Round wind drag
At top	132.0m	133.0m	105.0kg	1.0m^2	1.0m^2
Ladder	0.0m	133.0m	2.0kg/m	0.02m^2/m	0.01m^2/m
Linelife	0.0m	133.0m	0.5kg/m	0.01m^2/m	0.01m^2/m

Tower description:

Section		Height (m)	Min width (m)	Max width (m)	Legs section	Brace section
	Top	1.0				
1	EST-060B|S - R	6.0	0.470	0.600	RD 30	RD 14
2	EST-073B|S - R	6.0	0.600	0.730	RD 35	RD 14
3	EST-086B|S – W	6.0	0.730	0.860	RD 40	RD 16
4	EST-099B|S - W	6.0	0.860	0.990	RD 50	RD18
5	EST-112B|S - W	6.0	0.990	1.120	RD 55	RD 20
6	EST-125B|S - R	6.0	1.120	1.250	RD 60	RD 22
7	EST-138B|S - R	6.0	1.250	1.380	RD 60	RD 26
8	EST-151B|S - R	6.0	1.380	1.510	RD 65	RD 30
9	EST-164B|S - W	6.0	1.510	1.640	RD 70	RD 28
10	EST-177B|S – W	6.0	1.640	1.770	RD 75	RD 28
11	EST-190B|S – W	6.0	1.770	1.900	RD 80	RD 30
12	EST-220A|S - R	6.0	1.900	2.200	RD 80	42/4
13	EST-250B|S - R	6.0	2.200	2.500	RD 85	42/4
14	EST-280A|S - R	6.0	2.500	2.800	RD 85	50/4
15	EST-310B|S – W	6.0	2.800	3.100	RD 90	50/4
16	EST-340B|S – W	6.0	3.100	3.400	RD 95	60/4
17	EST-370B|S – W	6.0	3.400	3.700	RD 95	60/4
18	EST-400A|S - R	6.0	3.700	4.000	RD 100	70/4
19	EST-430A|S - R	6.0	4.000	4.300	RD 100	70/4
20	EST-460B|S - R	6.0	4.300	4.600	RD 110	70/4
21	EST-490B|S - R	6.0	4.600	4.900	RD 110	80/4
22	EST-520A|S - R	6.0	4.900	5.200	RD 120	80/4
	Total	133.0				



Tower main frequency without ice	0.368 Hz
Tower main frequency with ice	0.338 Hz
Theorical weight	31143 kg / 305,51 kN

Codes and standards for the met tower

Calculation:

- Eurocode 0: Basis of structural design
- Eurocode 1: Actions on structures
- NEN-EN 1991-1-4 Eurocode 1 : Actions on structures – Part 1.4 General Actions – Wind Actions
- NEN-EN 1991-1-1 +C1:2015/NB:2015 Ontw. nl - National Annex to NEN-EN 1991-1-1+C1: Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings
- NEN-EN 1993-1-9:2006 en - Eurocode 3: Design of steel structures - Part 1-9: Fatigue
- NEN-EN 1993-1-1+C2+A1:2016 nl - Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
- NEN-EN 1993-1-11+C1:2011 nl - Eurocode 3: Design of steel structures - Part 1-11: Design of structures with tension components
- NEN-EN 1993-3-1:2007/NB:2012 en - National Annex to NEN-EN 1993-3-1 Eurocode 3: Design of steel structures - Part 3-1: Towers, masts and chimneys - Towers and masts (includes C1:2009)
- ISO 12494: Atmospheric icing of structures

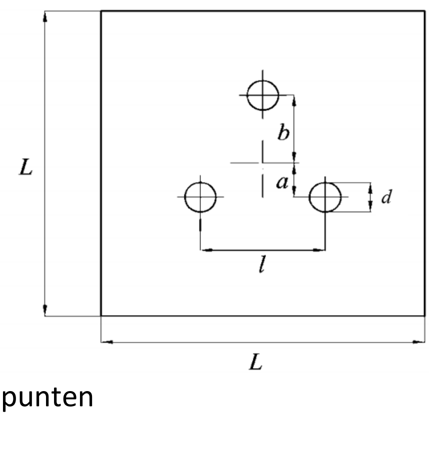
Execution: EN 1090 Execution of steel structures and aluminum structures
Galvanization: EN ISO 1461 Hot dip galvanized coatings on fabricated iron and steel articles
Painting: EN ISO 12944 Corrosion protection of steel structures by protective paint systems

9.2 Design of the foundation

No CPTs have been made at the location of the metmast. The civil work company in charge of the foundation works will have to make additional CPT at the location of the foundation to know the specific soil conditions and to make the final design of the foundation.
Some piles might be required depending on the results of the geotechnical investigations.

	Without ice	**With ice**
Vertical load	272.8 kN	334.4 kN
Horizontal load	144.3 kN	105.5 kN
Bending moment	8152 kNm	6464 kNm
Twisting moment	0.040 kNm	0.020 kNm

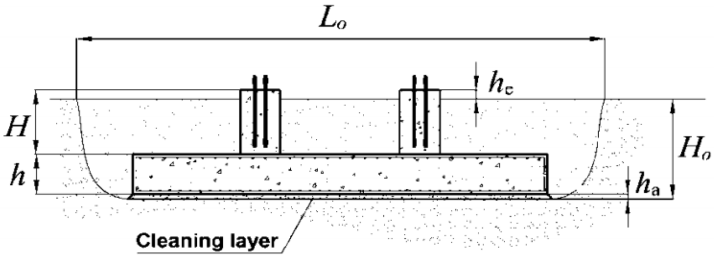
Dimensions:
l = 5200mm
a=1501mm
b=3002mm
d=800mm



Foundation bolts:
Bolts per plate 6
Bolts diameter M36
Bolts length 740mm

Dimensions:

L = 11000mm
h = 700mm
H = 1000mm
d = 800mm
l = 5200mm
a = 1501mm
b = 3002mm
h_a = 100mm
h_e = 100mm
H_O = 1700mm
L_O = 11500mm



Required soil strain:

For permanent actions ≥ 96 KPa
For accidental actions ≥ 147 KPa
The civil work contractor will be required to the specific conditions of soil on site.

Reinforcement steel:

Top grid: Ø20 c/25
Bottom grid: Ø20 c/25
S 500 f_{yk} = 500 MPa   Partial factor: according to NEN-EN 1990 table NB.4

Foundation bolts		
Number	Diameter	Length
6	M36	740mm

Concrete class:

C30/37 fck = 30 MPa Partial factor: γ_c = according to NEN-EN 1990 table NB.4

Quantities:

Digging	**Concrete**	
Total	**C30/37**	**Clear cover**
224.8m³	**98.7m³**	**14.5m³**

Reinforcement Steel				
S-500	**S-500**	**S-500**	**S-500**	**S-500**
Ø10	Ø12	Ø16	Ø20	**Total**
26kg	467kg	0kg	6096kg	**6589kg**

These data are the result of a preliminary calculation. The preliminary calculation is attached in Annex 3. A specific calculation will be made according to the site conditions and NEN-EN 1990 requirements. This calculation will be submitted for approval to the Municipality of Rotterdam, ultimately 6 weeks prior to start of construction.

Codes:
Eurocode 0: Basis of structural design
Eurocode 2: Design of concrete structures
EN 1992-1-1: General rules and rules for buildings
Eurocode 4: Design of composite steel and concrete structures
EN 1994-1-1: General rules and rules for buildings

10 Standards and quality for the metmast

For the met mast several standards apply, but these differ from the wind turbine standards. The met mast will be used for the certification process of the wind turbine. Therefore the basic requirements IEC-61400-12-1 will apply as well.

Design life time of 20 years
Corrosion protection (mind: location at sea shore)
Wind speed measuring range 0 – 75 m/s
Wind direction measuring range 0 – 360° / 0 – 540° / 0 – 720°
Comply with basic requirements according to: IEC 61400-12-1 Ed.1/Ed.2

Standards	Description
NEN-EN 1991-1-1	Action on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings
NEN-EN 1991-1-2	Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire
NEN-EN 1991-1-3	Actions on structures – Part 1-3: General actions – Snow loads
NEN-EN 1991-1-4	Action on structures – Part 1-4: General actions – Wind actions
NEN-EN 1991-1-5	Actions on structures – Part 1-5: General actions – Thermal actions
NEN-EN 1991-1-7	Actions on structures – Part 1-7: General actions – Accidental actions
NEN-EN 1993-3-1	Design of steel structures – Part 3-1: Towers and chimneys – Towers and Towers (includes C1:2009)

Appendix 1 : Data provided to CTE for the design of the anchor cage

DATA		
Anchor Bolts		
Tension to be applied per bolt	P1bolt =	**640KN**
Bolt Metric		**M42**
Bolt nominal diameter	ϕ =	42mm
Bolt sectional area	Ab =	1121mm²
Number of bolts per row (2 rows)	nb =	150
Total number of bolts	nbT =	300
Distance between bolts rows	db =	290mm
Anchor bolt length	L =	3800mm
Bolt tensioning length	btl =	150mm
Bolt length bellow embedded flange	bal =	50mm
Anchor bolt free length	Lf =	3600mm
Tower Bottom Geometry		
Shell Neutral diameter	Dfn =	7930mm
Tower shell Thickness	Tf =	70mm
"T" Flange Geometry		
"T" Flange width	Tfw =	550mm
"T" Flange thickness	Tfe=	150mm
"T" Flange bolt hole diameter	dh =	50mm
Embedded Flange Geometry		
Embedded Flange width	Efw =	550mm
Embedded Flange thickness	Efe=	80mm
Embedded Flange bolt hole diameter	dh =	50mm
General Data		
Concrete equivalent width	beq =	1000mm
Homogeneizeng coefficient	n	5.63

Materials

Foundation Pedestal Concrete			Grout
	Type	**C50**	**C90**
Concrete strength reduction factor	γX	1.50	1.50
Pedestal Concrete strength	fck =	50MPa	90MPa
Concrete design strength	fcd =	33MPa	60MPa
Concrete Young Modulus	Ecm =	37278MPa	43631MPa
Concrete Tangent Modulus	Ec =	39142MPa	45812MPa
Concrete tensile strength	fctm =	4.07MPa	5.04MPa

Anchor Bolts		
	Quality	**10.9**
Anchor bolt steel reduction factor	$\gamma \Sigma$	1.25
Anchor bolt tensile yield strength	fy =	900MPa
Anchor Bolts tensile ultimate strength	fu =	1000MPa
Steel Young Modulus	Es =	210000MPa

Flanges		
	Quality	**S355**
Flanges steel reduction factor	$\gamma \Sigma$	1.15
Flange steel yield strength	fyk =	335MPa
Ultimate tensile strength	fu =	470MPa
Steel Young Modulus	Es =	210000MPa
Flange steel design strength	fyd =	291MPa