

TITLE : 3D FEM analysis to determine the effects of a ship collision against a wind turbine monopile foundation.

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1. Introduction.

In the south part of the Dutch North Sea quite a number of windfarms will be built according to the roadmap 2023-2030. This has significant consequences for the ships sailing in this area. Recently Rijkswaterstaat has investigated the cumulative effects of wind farms for the ship safety. This investigation has been carried out by the research institute MARIN, see lit. [1]. From this study it follows that with the increasing number of wind farms, the increase in probability for a ship to ship collision is limited. What does increase however is the probability for a collision between a sailing or a drifting ship and a wind turbine foundation with possible economic damage (for ship and/or turbine), damage to maritime life and personnel damage.

For this reason, mitigating measures will be taken to assure that the ship safety will remain at the present level. These measures are aimed at the existing smaller wind farms (OWEZ, Luchterduinen, Princess Amalia and Gemini) and the wind farms belonging to the roadmap 2020, e.g. Borssele, Hollandse Kust (zuid), Hollandse kust (noord), Hollandse Kust (west), North of the Waddeneilanden en IJmuiden Ver, see Table 1.1.

Wind farm	Country	Owner	Capacity (MW)	Turbines (nrs)	Status	Year operational
Prinses Amaliawindpark	Nederland	Eneco	120	60	Realized	2008
Luchterduinen	Nederland	Eneco	129	43	Realized	2015
Windpark Borssele (Borssele III t/m IV)	Nederland	Blauwwind (Eneco, Shell, DGE en Van Oord)	731.5	77	Realized	2021
Gemini	Nederland	Gemini	600	150	Realized	2017
Windpark Borssele (Borssele I t/m II)	Nederland	Ørsted	752	94	Realized	2020
Windpark Borssele (Borssele V Leegwater)	Nederland	Two Towers (van Oord, e.a.)	19	2	Realized	2021
NoordzeeWind (OWEZ)	Nederland	Vattenfall	108	36	Realized	2008
Windpark Hollandse Kust Zuid (1 t/m 2)	Nederland	Vattenfall	770	70	Being built	2023
Windpark Hollandse Kust Zuid (3 t/m 4)	Nederland	Vattenfall	770	70	Being built	2023
Hollandse Kust (noord) I, II	Nederland	CrossWind (Shell en Eneco)	700		Being built	2023
Hollandse Kust (west) VI	Nederland	Ecowende (Shell en Eneco)	756		Planned	2026
Hollandse Kust (west) VII	Nederland	Oranje Wind Power II (RWE)	700		Planned	2026
Waddeneiland Noord	Nederland		700		Planned	2026
IJmuiden Ver	Nederland		4000		Planned	2027

Table 1.1: Windfarms in the Dutch part of the North Sea.

Despite all the investigations and the assistance of experts of all kinds of organisations (governments and market parties) uncertainties still exist with respect to the actual risks (the chance of a collision times the consequences for man, milieu, and economy). Also, there are uncertainties concerning the effectivity of mitigating measures such as the application of Vessel Traffic Management (VTM) and the Emergency Towing Vessel (ETV).

To determine which kind of other mitigating measures can be taken to improve ship safety, a monitoring and research program ‘Monitoring & Onderzoeksprogramma Scheepvaartveiligheid Wind op Zee’ (MOSWOZ) has been started by Rijkswaterstaat. This program is aimed at the following objectives:

1. Decreasing the uncertainties with respect to knowledge gaps and assumptions for increased safety risks (defined as the product of “chance x effect”) at sea with respect to offshore wind farms.

2. Decreasing gaps and uncertainties in assumptions with respect to the effectivity of mitigating measures for safety at sea.
3. Monitoring whether mitigating measures are sufficient to decrease the risk or whether additional measures must be taken.
4. Giving the opportunity to timely implement innovations in the area of wind energy at sea.

In the context of MOSWOZ Rijkswaterstaat has initiated a study in 2019 and 2022 to the possible effects of a collision between a drifting or a sailing ship and a wind turbine foundation in the Dutch part of the North Sea. The study in 2019 has been carried for 2 conceptual foundations for the North Sea area and the study in 2022 has been carried out for 4 foundations inside 2 wind farms that have been built and are presently operational. The purpose of these studies was to give more insight in the actual behaviour and possible failure modes of the foundations when being impacted by a drifting or sailing ship.

Recent events have shown that such scenarios are realistic. On 31 January 2022 the drifting bulk carrier *Julietta D* collided with the Hollandse Kust Zuid Beta transformer station jacket and also with one of the foundations for the wind turbines yet to be constructed, see Figure 1.2. Even more recently on 24 April 2023 the sailing general cargo ship *PETRA L* collided with a wind turbine foundation of Orsted's Godewind wind farm, NW of Norderney, Germany, North Sea, while en-route from Poland to Merksem Belgium, with 1,500 tons of grain on board. The German water police reported that it sustained massive damage in the form of a 3-by-5-meter hole on its starboard side, see Figure 1.3. The ship reported water ingress but was able to make it to port at Emden, Germany, on April 25. No one was injured.

The results of the studies carried out in 2019 and 2022 have been reported in lit. [2] to [4]. These studies investigate the dynamic behaviour of an offshore wind turbine monopile foundation in the Dutch part of the North Sea. For these studies use is made of a beam element model of the monopile, transition piece and tower, with the turbine nacelle and rotor and the ship modelled by a mass point. The material model used for the foundation is an elastic-ideal plastic model, with the plastic limit equal to for yield limit or the shell buckling limit. The soil resistance is represented by non-linear springs that model the soil resistance using p_y/p_z -curves. The soil in the Dutch part of the North Sea consists mainly of non-cohesive soils that are generally accepted to be non-gapping. Hence the kinematic hysteresis soil model has been used to model the soil behaviour, meaning that the applied load with positive displacement first follows the compression curve during loading and then, during unloading, the load decreases with the same slope as the slope at zero displacement. Then, when the load has returned to zero again and the displacement reduces further it follows the shifted tensile curve. When the loading again reverses, it first increases with the same slope as the slope at zero displacement and then follows the shifted compression curve, and so forth, see Figure 1.1. So, in this case hysteresis occurs. The stiffness of the impacting ship hull is modelled by a non-linear spring according to the DNV standard DNVGL-RP-C204, see Figure 1.4, that models the elasto-plastic resistance of the ship as function of the deformation of the hull. The results of these are the displacements, velocities, and accelerations of the foundation and the wind turbine as function of time and the failure modes of the foundation due to the impact. This beam model is suitable to get a general impression of the behaviour of the foundation such as whether plastic deformation or collapse of the foundation will occur and if so at which location, e.g. at the impact point, above the impact point in the transition piece or the tower, below the impact point but above seabed or inside the soil. Also, it is determined whether the foundation is able to stop the ship or that the foundation is overrun by the ship. Finally, it is established whether the turbine in case of foundation collapse is likely to move towards the ship or away from the ship.

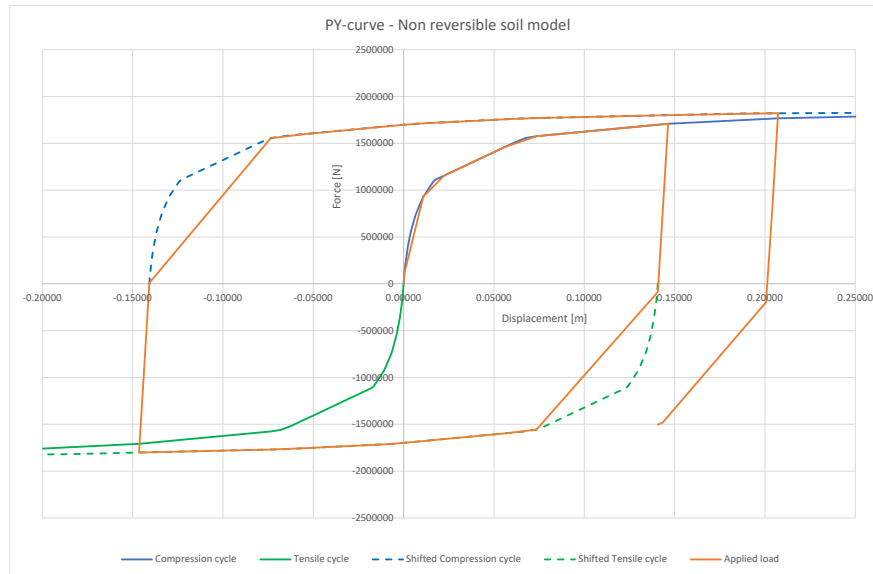


Figure 1.1: The kinematic hysteresis soil model, loading and unloading curve.

Although the beam model gives a good insight in the general behaviour of a wind turbine foundation when being impacted by a drifting or a sailing ship, the beam model still has some severe limitations. Some of these limitations are:

1. The plastic deformation and rupture of the ship hull cannot be determined, meaning that it cannot be determined whether there is a danger for a spill of its cargo or fuel oil or even whether there is a danger for the sinking of the ship.



Figure 1.2: Foundation after collision with the Julietta D.



Figure 1.3: Damage to the general cargo ship PETRA L after collision with a wind turbine foundation of the Godewind wind farm.

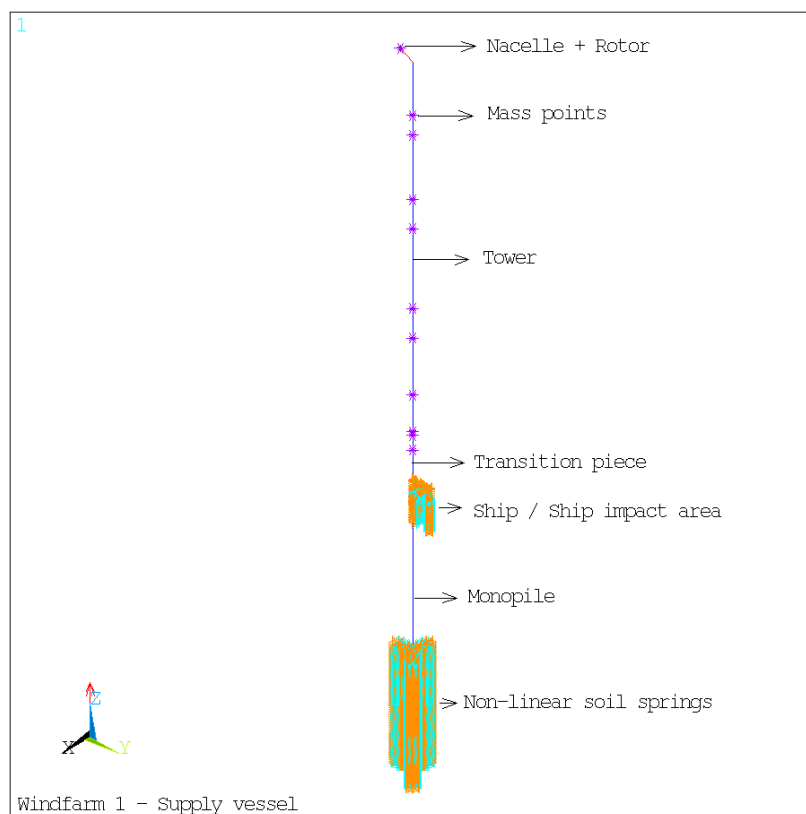


Figure 1.4: FE beam model for ship impact against an offshore wind turbine foundation.

2. Local denting of the foundation at the point of impact, especially during a sailing impact, cannot be simulated with the beam model. This local denting will affect the stability of the foundation during the impact and also after the impact.
3. The plastic or shell buckling behaviour of the foundation cannot be modelled accurately with the beam model. This can lead to either an overestimation or underestimation of the foundation support capacity, depending on the acceleration loads acting on the turbine. Also, this might affect the actual motion of the turbine during impact at the moment of collapse of the foundation, e.g., moving towards the ship or moving away from the ship.

To get more insight in these aspects it is required to generate a detailed FE model that models the ship's hull and the foundation in a 3D shell model that is capable of simulating large deformations, full plastic deformation using true stress-strain curves including hardening effects, shell buckling and shell rupture, following the guidelines in DNV-RP-C208, see lit. [6]. An example of such models for offshore supply vessels with a draught of 6 [m] is shown in lit. [7].

In this document the specifications for such a more detailed analysis based on the results presented in lit. [2] to [4] is presented.

2. Summary of the main impact results using a 3D beam model.

In lit. [3] and [4] the collision between various drifting and sailing ships has been investigated for 2 existing wind farms in the Dutch part of the North Sea. The main characteristics of the investigated ships are presented in Table 2.1 and the main characteristics of investigated foundations are presented in Table 2.2.

The main failure modes identified in lit. [3] and [4] during the collision between the drifting or sailing ships and the foundations are as follows:

1. No pile or tower failure, just elastic foundation deformation, the foundation remains standing and oscillates in its 1st eigenmode after the impact, see Table 2.3, mode 1.
2. Tower failure (defined as the onset of plastic deformation) but no tower collapse, see Table 2.3, mode 2.
3. Tower failure (defined as the onset of plastic deformation) and finally collapse (development of a plastic hinge) of the tower with the turbine moving towards the ship, see Table 2.3, mode 3.
4. Tower failure (defined as the onset of plastic deformation) and finally collapse (development of a plastic hinge) of the tower with the turbine moving away from the ship, see Table 2.3, mode 4.
5. Soil collapse, without tower or pile failure (defined as the onset of plastic deformation), see Table 2.3, mode 6.
6. Soil collapse combined with tower failure (defined as the onset of plastic deformation) and finally collapse (development of a plastic hinge) of the tower, with the turbine moving towards the ship, see Table 2.3, mode 5, or with the turbine moving away from the ship, see Table 2.3, mode 6.

Due to the collapse of the soil, the foundation moves away from the ship, while due to the failure and collapse of the tower the nacelle tends to move towards the ship. Which of the 2 counteracting motions becomes dominant cannot be simulated with the present beam model and depends on the velocity with which each failure develops. It is thus not possible to predict whether the tower collapse will result in the turbine dropping down on the ship or the soil failure leading to the turbine moving away from the ship.

7. Pile failure (defined as the onset of plastic deformation) inside the soil combined with soil collapse, tower collapse (development of a plastic hinge) due to the inertia of the nacelle with the turbine moving towards the ship, see Table 2.3, mode 7.
8. Pile failure (defined as the onset of plastic deformation) inside the soil combined with soil collapse, tower collapse (development of a plastic hinge) due to the inertia of the nacelle with the turbine moving away from the ship, see Table 2.3, mode 8.

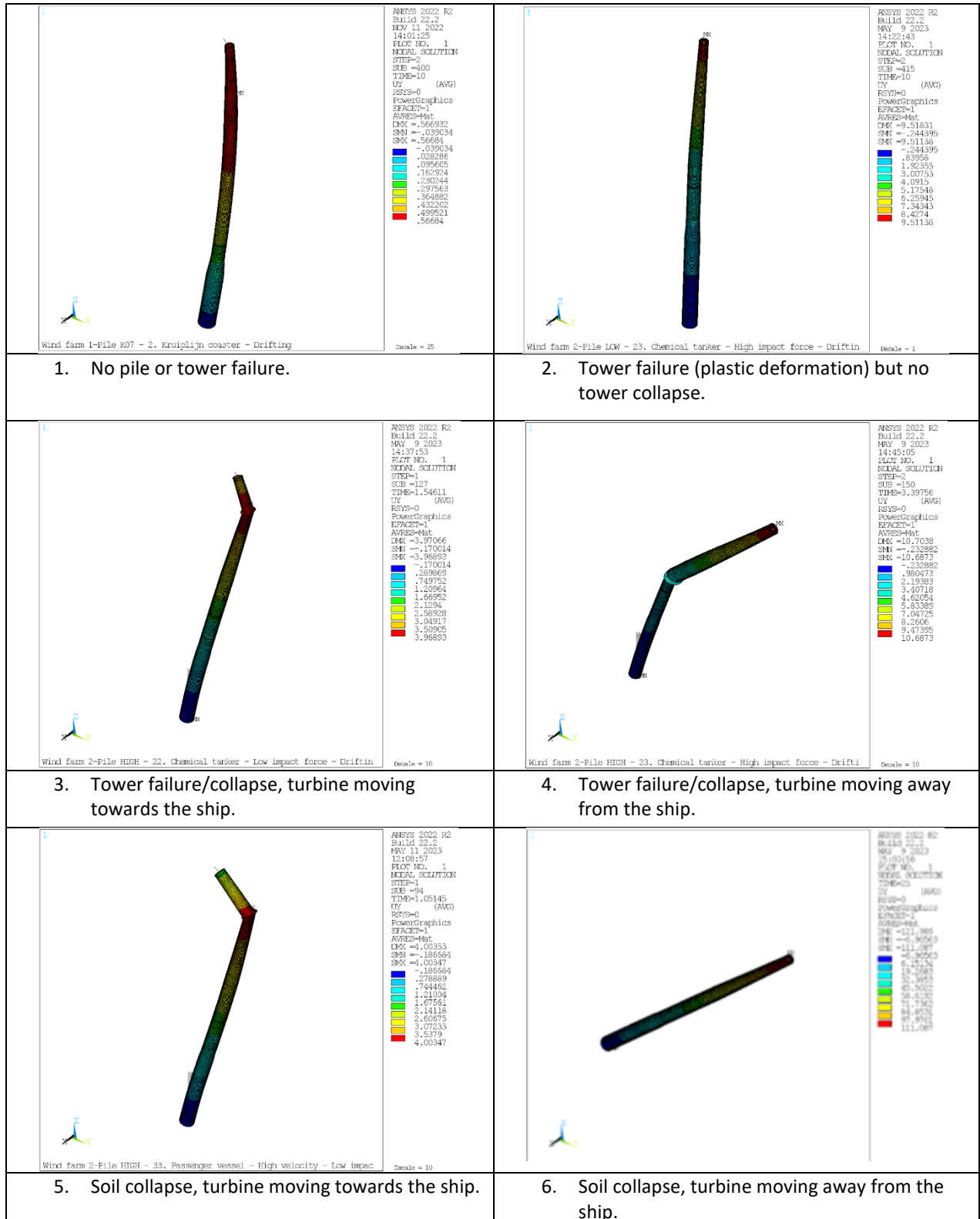
The occurrence of these failure modes for the various combinations of ships and foundations are presented in Table 2.4.

Typical dimensions.		Kruiplijn Coaster	Supply vessel	Chemical & Product tankers	Passenger vessels	Container ship
Gross Tonnage	GT	1554 GT	3200 GT	10000 GT	100000 GT	192784 GT
Length Lpp	m	77.40	76.20	135.00	242.00	379.40
Width B	m	11.30	19.70	23.00	36.00	59.00
Design Draught D	m	5.33	7.45	12.00		31.35
Maximum depth T	m	3.73	6.10	8.30	8.30	16.00
Lightweight	ton	807.00	2,555.00	4,800.00		
Deadweight	ton	2,046.00	4,300.00	16,200.00		199,272.00
Displacement	ton	2,853.00	6,855.00	21,000.00	42,700.00	223,000.00
Displacement plus added water mass frontal	ton	3,138.30	7,540.50	23,100.00	46,970.00	245,300.00
Displacement plus added water mass broadside	ton	3,994	9,597	29,400	59,780	312,200
Bulb below water	m	n.v.t.	2.70	1.50	1.80	
Stem above water	m	3.65	8.44	9.00	16.20	
Drifting						
Combined Wind drift and eq. Current velocity	knots	2.78	2.78	2.62	3.40	2.20
	m/s	1.39	1.39	1.31	1.70	1.10
Typical drifting kinetic energy	MJ	3.87	9.29	25.15	86.29	192.01
Normal sailing						
Normal sailing velocity (1 knot ~ 0,5 m/s)	knots	10.80	15.00	14.00	29.00	7.60
	m/s	5.40	7.50	7.00	14.50	3.80
Normal sailing kinetic energy	MJ	45.76	212.08	565.95	4,938	1,771

Table 2.1: Review of ship properties for the ships used in the investigation.

Identification			Wind farm 1	Wind farm 2
Turbine	Rated power	[MW]	8	9.5
	Nacelle plus rotor mass	[tonnes]	450.4	478.4
	Hub height	[m LAT]	118.025	108.85
	Rotor diameter [m]	[m]	167	164
	Lower position of blade tip	[m LAT]	34.525	26.85
Tower	Top elevation	[m LAT]	115.735	105.81
	Bottom elevation	[m LAT]	25.415	19.15
	Top diameter	[mm]	4145	4530
	Bottom diameter	[mm]	6000	6500
	Maximum wall thickness	[mm]	47	37
	Minimum wall thickness	[mm]	20.9	16
	Steel quality		S355	S355
Transition piece	Top elevation	[m LAT]	25.415	--
	Bottom elevation	[m LAT]	6.314	--
	Top diameter	[mm]	6000	--
	Bottom diameter	[mm]	6000	--
	Maximum wall thickness	[mm]	87	--
	Minimum wall thickness	[mm]	47	--
	Main platform	[m LAT]	17.848	18.5
Pile	Steel quality		S355	--
	Top elevation	[m LAT]	6.314	19.15
	Bottom elevation	[m LAT]	-41.262 to -69.852	-50.35 to -63.35
	Top diameter	[mm]	6000	6500
	Mudline diameter	[mm]	7800 / 8500	6900 / 7400
	Maximum wall thickness	[mm]	90 / 108	88
	Minimum wall thickness	[mm]	56 / 66	58 / 62
	Water depth	[m]	17.7 to 38.1	21.1 to 34.6
	Pile penetration	[m]	23.562 to 31.752	28.75 to 29.25
	Steel quality		S275 / S355	S275 / S355
Water level	MSL	[m LAT]	1.72	1.72

Table 2.2: Main characteristics of the wind farms.



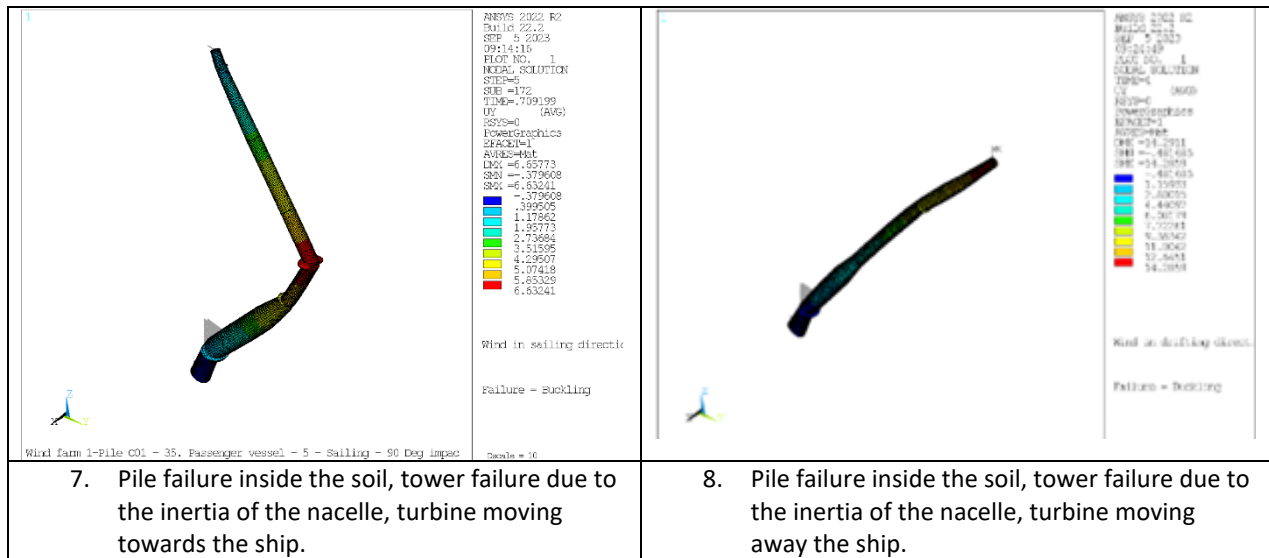


Table 2.3: Graphical presentation of detected failure modes.

Drifting / Sailing										
Ship	Simulation run	Ship motion	Impact direction	Wind load	Soil model	Load / Speed	Failure mode			
							Wind farm 1		Wind farm 2	
Foundation							WD 17.7m / PD 23.56m	WD 38.1m / PD 31.75m	WD 21.1m / PD 29.25m	WD 34.6m / PD 28.75m
Kruiplijn coaster	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	1	1	1	1
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	6	1	1	4
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	1	1	1	1
Supply vessel	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	2	1	1	1
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	3	3	3
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	5	3	3	3
Chemical & Product tankers	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	6	1	4	4
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	5	5	5
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	5	5	5	5
Passenger vessels	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	2	4	4
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	5	5	5
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	5	5	5	5
Container ship	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	6	6	6	6
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	5	5	5
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	5	5	5	5

With wind, yield failure criterion.

Drifting / Sailing										
Ship	Simulation run	Ship motion	Impact direction	Wind load	Soil model	Load / Speed	Failure mode			
							Wind farm 1		Wind farm 2	
Foundation							WD 17.7m / PD 23.56m	WD 38.1m / PD 31.75m	WD 21.1m / PD 29.25m	WD 34.6m / PD 28.75m
Kruiplijn coaster	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	1	1	1	1
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	2	4	4	4
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	1	1	4	3
Supply vessel	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	2	2	3	4
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	3	3	3
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	5	3	3	3
Chemical & Product tankers	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	2	3	4
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	5	5	5
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	5	5	5	5
Passenger vessels	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	3	3	3
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	7	5	5
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	5	5	5	5
Container ship	1	Drifting	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	8	6	6
	2	Sailing	90 Deg; Below rotor	With wind	Non reversible	High load / Nominal speed	5	5	5	5
	3	Sailing	270 Deg; Below nacelle	Against wind	Non reversible	High load / Nominal speed	5	5	5	5

With wind, shell buckling failure criterion.

Table 2.4: Summary of detected failure modes during drifting/sailing with wind load and using the shell buckling failure stress
(WD = Water Depth; PD = Penetration Depth).

The main conclusions following from Table 2.4 are:

1. The collision between a drifting or sailing 1554 GT kruiplijn coaster with a displacement of ca. 2850 [tonnes] is in most cases survived by the foundation, with a danger of tower failure or maybe collapse under sailing conditions.
2. The same is true for a 3200 GT drifting supply vessel with a displacement of ca. 6850 [tonnes]. The sailing supply vessel will lead to tower failure or collapse.
3. Medium large ships, e.g. 10000 GT tankers with a displacement of 21000 [tonnes] to 100000 GT passenger vessels with a displacement of 47000 [tonnes] lead to tower failure/collapse when drifting and lead to soil failure when sailing.
4. Very large ships such as 200000 GT container ships with a displacement of 223000 [tonnes] simply overrun a foundation when drifting or sailing.
5. The results for the windfarms 1 and 2 are mostly comparable, only foundation K07 behaves somewhat different due to its low water depth of only 17.7 [m] and low penetration depth of only 23.5 [m].

3. Definition of the collision configurations.

3.1. Introduction.

Based on the results presented in lit. [3] and [4] the wind farm, foundation, ships, and impact conditions will be selected for the 3D FEM study to investigate in detail the behaviour of an offshore wind turbine monopile foundation.

3.2. Purpose of the 3D investigation.

The main objectives of the 3D FEM investigation are as follows:

- a. Study the effects of the drifting or sailing impact of a ship against a wind turbine foundation on the ship and especially the damage that can be expected to the ship's hull, the fuel oil tanks, and the cargo area of the ship. This damage can occur in two ways:
 - a. Due to the contact between the ship's hull and the wind turbine foundation.
 - b. Due to a part of the tower with the turbine dropping down onto the deck of the ship.

The possible contact between the blades of the turbine and superstructure of the ship is not part of this investigation, nor is the contact between the ship superstructure and the appurtenances connected to the wind turbine foundation, such as for example the main platform.

- b. Study the actual failure behaviour and failure mode of the wind turbine foundation due to plastic deformation, shell buckling and soil failure to verify the findings of the beam model investigation. Also it must be determined under which conditions it is likely that the turbine due to the foundation collapse will move towards the ship and finally drop down onto the ship resp. that the turbine due to the foundation collapse will move away from the ship.

3.3. Collision configurations.

Based on the information presented lit. [3], [4] and [8] the following configurations are selected for the 3D FEM impact analyses:

3.3.1. Wind farm, foundation and turbine.

It is decided to limit the analysis to the monopile foundation of an existing wind farm of which all relevant data for the analysis are available. This means that the 3D analysis will be carried out for a turbine with an installed power of 9 [MW], a hub height of ca. 110 [m] and a water depth of ca. 30 [m].

The selected wind farm, foundation and turbine are as follows:

- Wind farm : 2.
- Turbine : 9.5 [MW]
- Foundation : WD 34.6m / PD 28.75m
- Water depth : 34.6 [m]

The reason for this choice is that the data set for the foundations and the soil is consistent. Furthermore, the water depth of this wind farm is in line with the water depth to be expected for future wind farms and the water depth is representative for a major part of the wind farm and this water depth is in line with the water depth to be expected for future wind farms.

All the relevant information of the selected turbine and foundation is presented in APPENDIX A.

3.3.2. Impact direction on the wind turbine foundation.

The studies presented in lit. [3] and [4] have shown that the influence of the direction of impact in relation to the rotor position of the turbine is limited. In case of a drifting impact the ship will mostly move in a direction close to the wind direction, although the current direction also has an effect on this. Assuming that the wind turbine rotor is directed towards the wind, it is likely that the impact point is located at the wind side of the foundation, below the rotor. For a sailing ship the impact direction is of course unrelated to the wind direction. For the 3D investigation therefore the following impact directions are prescribed:

- a. Drifting: Impact below the rotor, see Figure 3.1.

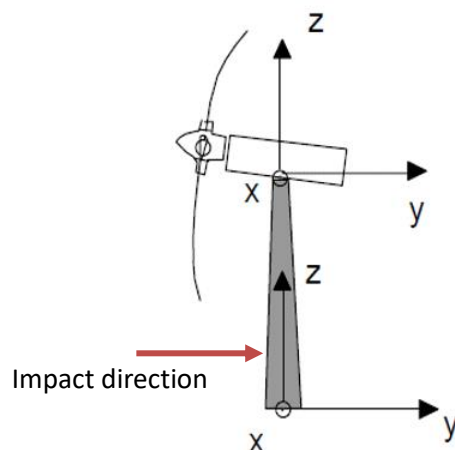


Figure 3.1: Impact below the rotor, drifting with the wind.

- b. Sailing: Side impact, at an angle perpendicular to the rotor axis, see Figure 3.2.

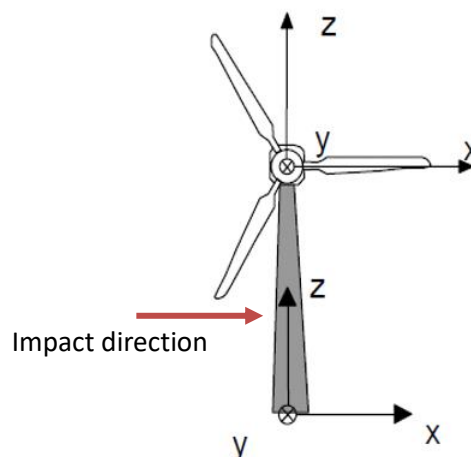


Figure 3.2: Side impact, at an angle perpendicular to the rotor axis.

For both situations it will be assumed that the rotor has been stopped so that gyroscopic effects of the rotating blades are absent, see lit. [4].

Also contact between the rotor blades and the superstructure of the ship, e.g. for a passenger vessel, or between the rotor blades and the ship's cargo, e.g. for a container ship, will not be taken into account. This interaction is out of the scope of this project.

3.3.3. Wind, current, wave and turbine loads acting on the foundation.

The wind, current, wave and turbine load acting on the wind turbine foundation will be taken equal to the load used in lit. [4]. The load characteristics are specified in APPENDIX A. The load will be applied as **a static load acting in a direction parallel to the rotor axis**, see Figure 3.3.

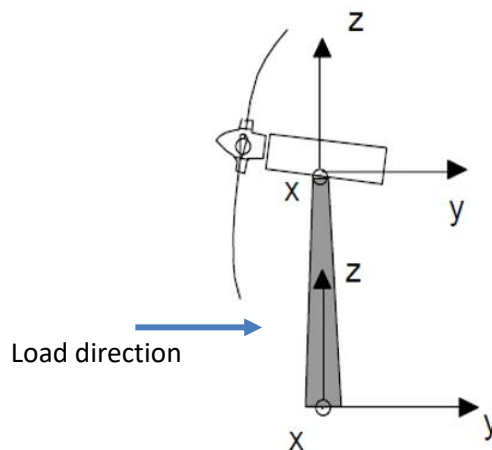


Figure 3.3: Direction of the wind, current, wave and turbine load.

This means that during drifting impact the load will be acting in the same direction as the impact force. This might be advantageous for the direction of motion of the turbine at the moment of impact as due to the operational loads the foundation will bend away from the ship.

During the sailing impact the impact direction will be perpendicular to the operational loads and the operational loads are expected to have a neutral effect.

3.3.4. Water level.

The water level at the moment of impact will be assumed to be equal to Mean Sea Level (MSL). The value of MSL to be used in the analysis is presented in APPENDIX A.

3.3.5. Foundation and turbine modelling in 3D FEM.

Regarding the modelling of the foundation in 3D FEM it is required to model the whole foundation from the lower tip of the pile up to the top flange of the tower with 3D shell elements, taking into account also the flange connections between mono pile, transition piece and tower. This is required to be able to accurately model the failure behaviour of the foundation due to yield and shell buckling. Also, provisions must be taken such that the rupture of the foundation, e.g. at the location of impact, can be modelled. Reference is made to the 3D modelling of the ship structures and appropriate material models as presented in lit. [7], [9], [10] and [11].

The actual bolt connection at the flange interfaces will not be taken into account yet during this part of the study and the 2 flanges parts can be assumed to be rigidly connected or bonded together.

Localized masses in the foundation can be modelled as local mass points connected by contact elements to the shell structure or as added masses to the shell elements.

Provisions must be taken to take into account the added water mass at the inside and outside of the foundation.

Appurtenances connected to the outside of the foundation, e.g. ladders, resting platforms, main platform, will not be taken into account yet during this part of the study.

Detailed information about the turbine and the blades can not be provided. Therefore, it is proposed to model the turbine as a concentrated mass point with the mass and mass moments of inertia equal to the values provided in APPENDIX A.

3.3.6. Added water mass for the foundation.

To account for the effect of the water mass at the inside and at the outside of the foundation at the moment of impact, these water masses have been included in the analyses presented in lit. [2] to [4] as follows:

a. Water at the inside of the foundation.

It has been assumed that the water level at the inside of the foundation is the same as at the outside of the foundation. This water level is assumed to be equal to MSL.

The total mass of the water inside the foundation has been taken into account and has been added to the mass of the pile.

b. Water at the outside of the foundation.

The water level at the outside of the foundation is assumed to be equal to MSL. The added water mass factor used in lit. [2] to [4] is equal to 1.2.

3.3.7. Soil modelling in 3D FEM.

For the design of the wind turbine foundations the lateral and vertical soil properties are described by py-curves as provided in APPENDIX A. These same curves have also been used for the impact investigations in lit. [2] to [4]. For the full 3D impact analysis however a solid soil model must be used, extending over a sufficient distance and depth to capture the deformation of the foundation due to the impact. The available py-curves therefore must be translated to 3D soil model, in such a way that the lateral support as provided by the py-curve soil model is simulated as good as possible. The static failure load of the soil under a horizontal load acting at MSL is presented in APPENDIX A. Also, the dynamic characteristics of the foundation, e.g. the 1st and 2nd order bending modes, should be matched as good as possible, see APPENDIX A.

Reference is made to lit. [12] to [17] for some background information in modelling the soil.

3.3.8. Ships.

The ship types, sizes and drifting resp. sailing velocities proposed for the analysis are presented in Table 3.1.

Nr.	Ship type	Hull	Gross Tonnage	Displacement	Drifting velocity		Sailing velocity		Draught	Impact location	
			[tonne]	[tonne]	[kn]	[kn]	[kn]	[kn]		Drifting	Sailing
1	Coaster	Single	1600	3000	3		10		x	Broadside at COG	Head on
2	Supply vessel	Single	3200	70000	3		15		x	Broadside at COG	Head on
3	Oil/Chemical tanker	Double	10000	20000	2	4	10	20	x	Broadside at COG	Head on
4	Cruise ship	Single	100000	40000	2	4	20	30	x	Broadside at COG	Head on
5	Container ship	Single	200000	220000	2	4	10	20	x	Broadside at COG	Head on
Number of runs					8		8				

Table 3.1: Ship types select for 3D FEM analysis.

The selected combinations give insight in the effects of the ship type and the impact velocity.

a. Drifting impact.

- During drifting the ship will hit the foundation of the wind turbine with its side wall.
- The longitudinal position of this impact point on the side wall of the ship must be at or close to the position of the COG of the ship so that no or hardly any rotation of the ship occurs during impact.
- The impact point on the ship should be in between two main bulkheads, as this will be weakest position for the ship, see Figure 3.4. For the foundation this position is slightly advantageous as at this point the ship stiffness is smaller than when the impact takes place directly at the main bulkhead, resulting in slightly lower acceleration loads on the foundation. However, the emphasis of this 3D study is slightly more aimed towards the worst effects for the ship.

b. Sailing impact.

- For the sailing ship it is assumed that the ship will hit the wind turbine foundation not exactly head-on, but at a small offset from the centre line of the ship and the foundation, so the ship bow will scrape along the pile wall, see Figure 3.5.
As a result, the ship will behave less stiff than during a head-on impact, which is advantageous for the foundation, but the partly grazing impact will probably be more serious for the ship as the hull plates might more easily buckle and rupture during the impact. See for example the collision of the PETRA L against a wind turbine foundation in Figure 1.3.

The required amount of offset depends of course on the ship size and must be agreed upon with RWS before the calculations are started.

Indicative dimensions of the ship size and drifting/sailing velocities that must be used in the analysis are presented in Table 3.2. The actual ships to be used in the analysis must be selected by the tendering companies and these ships must have comparable characteristics as the example ships presented in Table 3.2.

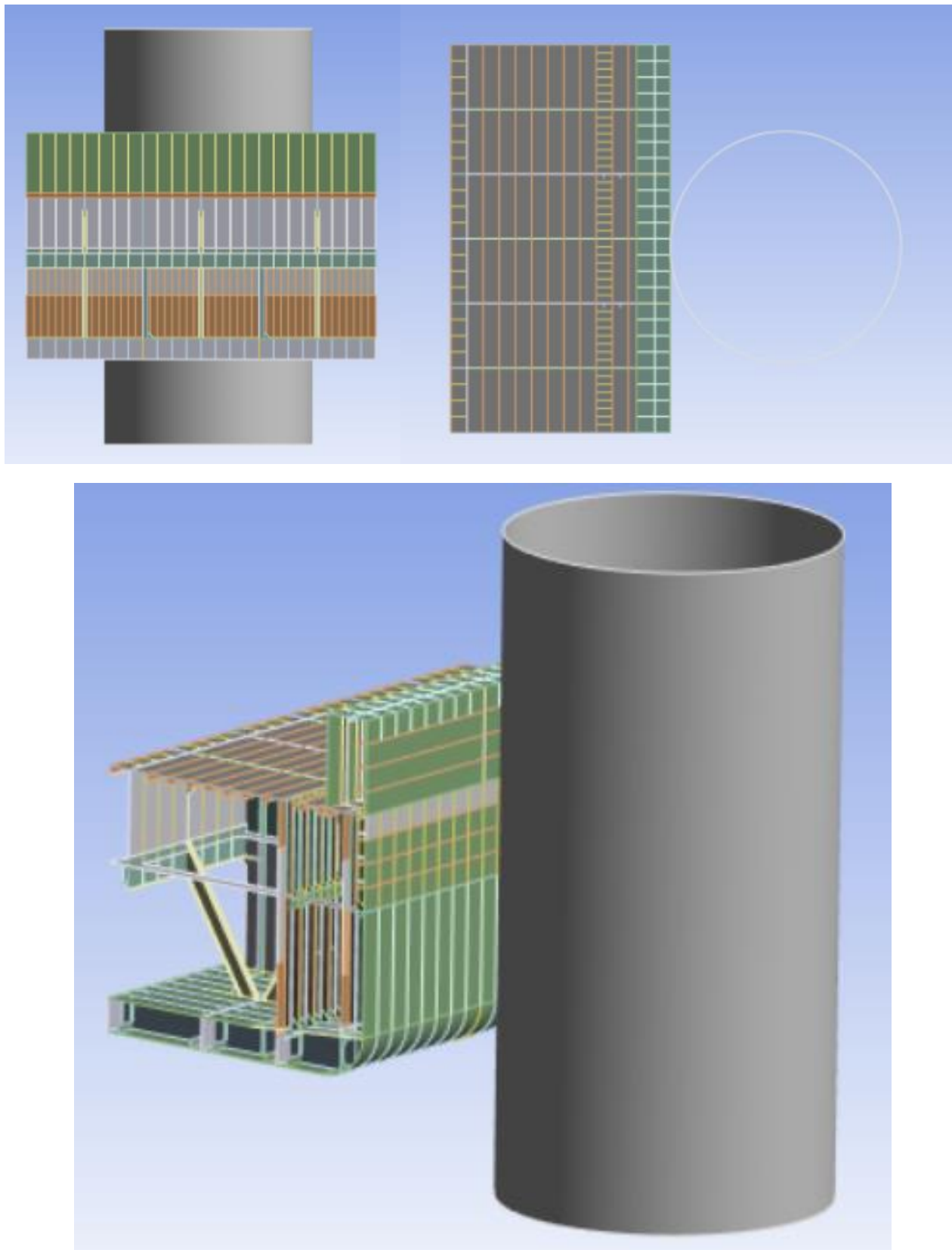


Figure 3.4: Drifting ship impact, pile centre between 2 bulkheads.

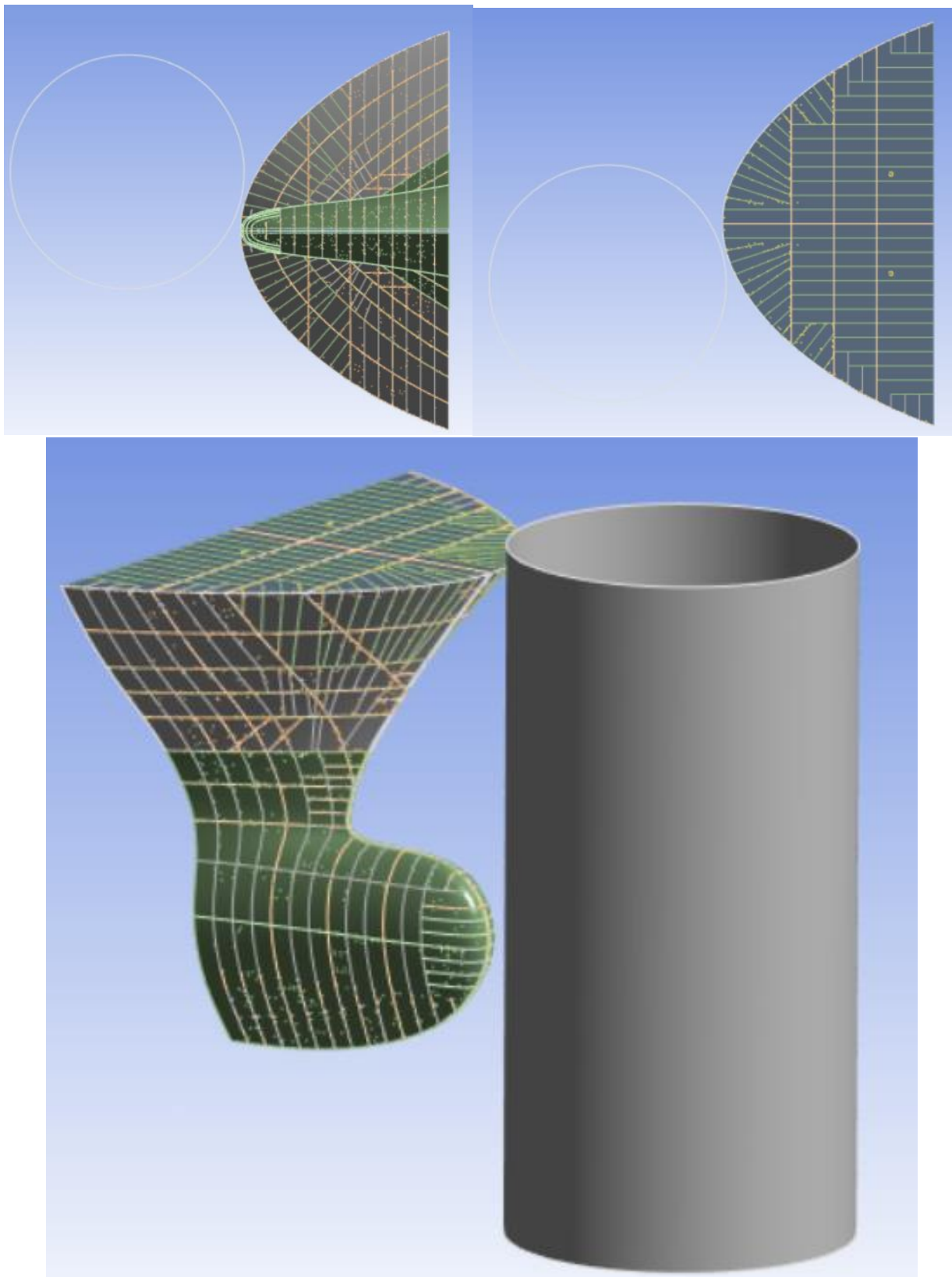


Figure 3.5: Sailing ship impact, just off-centre of the centre line.

Example ships for 3D analysis						
Typical dimensions.				Chemical & Product tankers	Passenger vessels	Container ship
Gross Tonnage	GT	GT	GT	10000 GT	100000 GT	192784 GT
Length Lpp	m			135.00	242.00	379.40
Width B	m			23.00	36.00	59.00
Design Draught D	m			12.00		31.35
Maximum depth T	m			8.30	8.30	12.49
Lightweight	ton			4,800		
Deadweight	ton			16,200		199,272
Displacement	ton			21,000	42,700	223,000
Bulb below water	m			1.50	1.80	
Stem above water	m			9.00	16.20	
Combined Wind drift and eq. Current velocity	knots			2.62	3.40	2.22
	m/s			1.31	1.70	1.11
Normal sailing velocity (1 knot ~ 0,5 m/s)	knots			14.00	29.00	7.60
	m/s			7.00	14.50	3.80

Table 3.2: Example ship dimensions and speeds to be used in the 3D FEM analysis.

3.3.9. Ship modelling in 3D FEM.

Regarding the 3D modelling of the ships and appropriate material models, reference is made to lit. [7], [9], [10] and [11]. To limit the calculation times, it is proposed to model the ship geometry in the direct neighbourhood of the impact location accurately using shell models. This detailed area should extend over such a distance that the whole area directly affected by the impact is covered!

For drifting impact this means that the distance in the length direction of the ship must be sufficient so that it covers the whole length directly affected by the impact, whereas in the width direction of the ship it must cover the whole ship width in order to be able to simulate what happens when the foundation drops down onto the ship.

For the sailing impact also the whole ship width must be included, but also in the length direction of the ship a considerable distance must be taken into account in order to be able to simulate what happens when the foundation and turbine drop down onto the ship.

Outside the detailed modelled section, the ship geometry can be modelled by beam elements and concentrated masses such that the total mass and mass moment of inertia are the same as in the actual ship (including actual mass and added mass in the collision direction). According to lit. [9] Hughes-Liu elements are a good option as they are designed not to fracture and provide out of plane bending not provided by truss elements.

Also, provisions must be taken such that the rupture of the ship hull, e.g. at the location of impact, can be modelled.

An example of such a model is presented in Figure 3.6, although for the purpose of a frontal collision between a ship and a wind turbine foundation at a small offset as indicated in Figure 3.4 and considering the duration of the impact and the fact that the possible dropping down of the tower onto the ship must also be investigated, the part of the ship modelled in detail needs to be extended. A much more detailed model is shown in Figure 3.7.

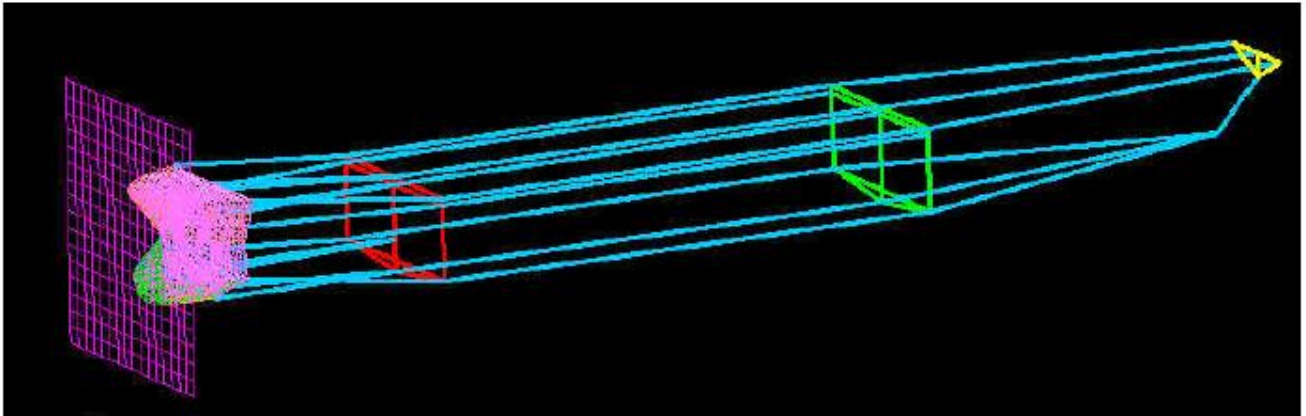


Figure 3.6: Example ship model, taken from lit. [9].

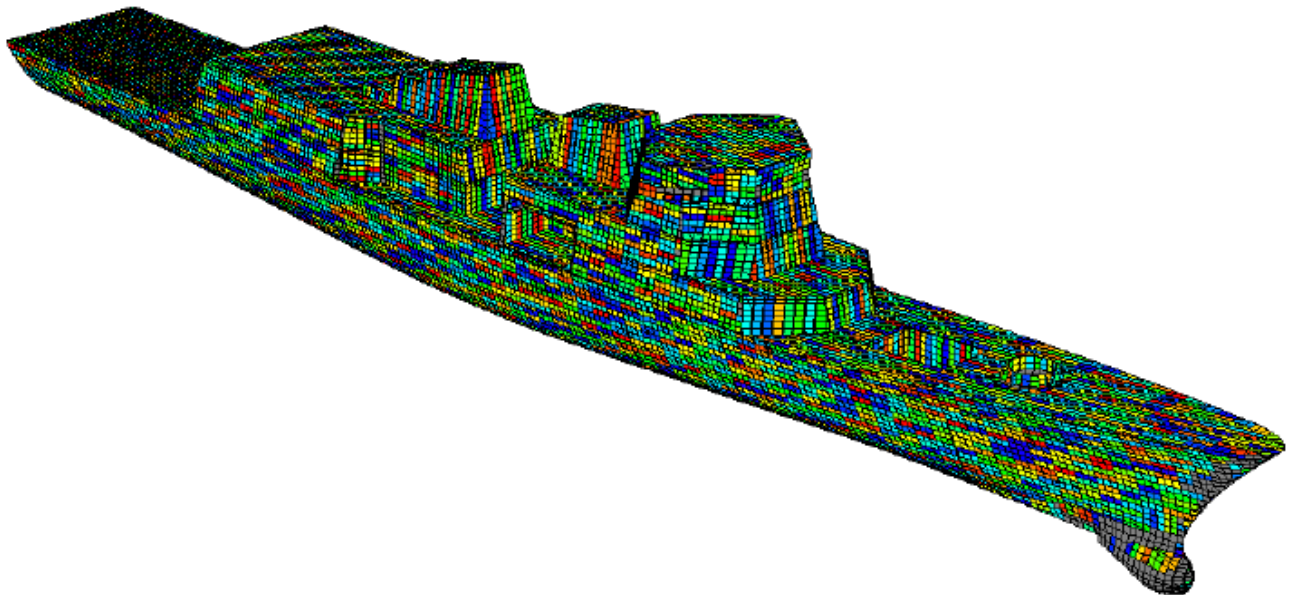


Figure 3.7: Detailed example ship model, taken from lit. [11].

Preferably the calculation is set-up in such a way that both the internal structural response in collision and the external ship dynamics including hydrodynamics are simulated. To save CPU time, an inertia-equivalent method could be used instead of an explicit calculation of the fluid-structure interaction, see lit. [9]. Masses and mass moments of inertia in surge, sway and yaw represent the virtual masses (actual plus added mass) for each ship. To simplify the simulation, the motion of the striking ship can be prevented in the heave, pitch and roll direction, e.g., the translation along the Z-axis, the rotation around the X-axis and the rotation around the Y-axis. These constraints allow the ship model to be fairly simple and provide for a faster solution. The ship motions in heave, pitch, and roll are generally relatively small and less significant in a collision event. This effectively limits ship global motion to the horizontal plane but allows deformed sections a full six degrees of freedom.

3.3.10. Added mass factor.

Determination of the added water mass of a ship is quite complicated. The added mass values depend on hull form and also vary over the duration of the collision, see [9]. For model simplicity, mid-range values are typically used or average added mass coefficients may be used. Coefficients values generally to standardize results when compared to other models, see [9], are:

- Surge : Coefficient = 0.05, so added mass factor = 1.05.
- Sway : Coefficient = 0.85, so added mass factor = 1.85.
- Yaw : Coefficient = 0.21, so added mass factor = 1.21.

These same values must be used in this investigation.

3.3.11. The friction coefficient at the contact location between ship and foundation.

The correct consideration of friction in a ship impact model is important. According to lit. [9] it is found that as friction is increased the penetration of the striking ship into the struck ship is decreased or the absorbed energy per unit penetration is increased.

Several considerations of friction and various static and dynamic friction coefficient values are reported in the literature. The most common value found in the literature for the dynamic friction coefficient is 0.3. Reported dynamic coefficients of friction vary from 0.0 to as high as 0.6 and static coefficients are reported at values between 0.5 and 0.8. Ship collision parametric studies where the dynamic coefficient of friction was varied from 0.0 to 0.6 show that the higher the friction coefficient the faster the loss of kinetic energy of the striking ship. The difference between the friction curves for 0.3 and 0.6 is much smaller than between the curves for 0.0 and 0.3. As a result, it is stated that “the effect of friction will not increase significantly for larger values of the coefficient.”

The studies presented in lit. [6] and [7] have been executed without friction.

As in this study we want to have conservative results regarding the damage done to ship and foundation and because we are investigating frontal impact for a sailing ship and broadside impact of the drifting ship at its COG, so yaw of the ship and scraping of the ship hull against the foundation during the impact is limited, **it is decided to set the friction coefficient in this study equal to 0.**

3.3.12. Wind, wave and current load during drifting or propulsion load during sailing acting on the ship.

The wind, wave and current load acting on a drifting ship or the propulsion load acting on a sailing ship adds a more or less static load to the wind turbine foundation at the moment of impact. The simulations presented in lit. [4] have shown that these loads are much smaller than the maximum impact loads and therefore the effect of the wind, current and propulsion load on the impact results is small. Only when the foundation is just at the verge of collapse due to the impact, the additional wind, current or propulsion load can just push the foundation over the edge.

For this reason, it has been decided **not to include the wind, wave, current or propulsion load acting on the ship in the impact analysis.**

4. Work to be executed.

In this chapter a summary is provided of the work to be executed in the frame of the study towards the effect of a collision between a ship and the wind turbine monopile foundation in the Dutch part of the North Sea.

The purpose of the investigation is presented in Section 3.2

Use must be made of the information and specification provided in Section 3.3 and for the FE modelling of the foundation, the soil and the ship use must be made of the appropriate guidelines as presented in lit. [7], [9], [10] and [11].

1. Model the foundation and the turbine in a 3D FE model and verify and report its properties with the specifications provided in APPENDIX A. Also execute sensitivity analyses to verify model assumptions.
2. Model the soil in a 3D FE model and match the soil behaviour with the behaviour provided by the py-curves presented in APPENDIX A. Also execute sensitivity analyses to verify model assumptions.
3. Verify and report the static and dynamic characteristics of the combined 3D foundation and soil model with the characteristics provided in APPENDIX A.
4. Model the ships and verify and report the model characteristics following the guidelines in lit. [11]. Also execute sensitivity analyses to verify model assumptions.
5. Execute the collision simulations according to the specifications given in Section 3.3.

The simulations must be carried out starting at the moment of initial contact between ship and foundation, where the foundation is already deformed due to the wind, current, wave and turbine loads acting on the foundation. The simulation must can be stopped under one of the following conditions:

- a) The ship has been stopped by the foundation and the foundation is stable and oscillating without further plastic deformation.
 - b) The ship has been stopped by the foundation and the turbine with the failed part has dropped down into the water or onto the ship.
 - c) The ship has fully sailed or drifted over the foundation with the turbine dropped down into the water or onto the ship.
6. Report and discuss the results and present major conclusions and recommendations for decreasing the risk of damage to the ship hull, the fuel oil tanks, and the cargo area of the ship and formulate advises for future work.

5. Literature.

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APPENDIX A : RELEVANT INFORMATION OF THE TURBINE AND FOUNDATION.

Foundation properties

Identification			Wind farm 2
Turbine	Rated power	[MW]	9.5
	Nacelle plus rotor mass	[tonnes]	478.4
	Hub height	[m LAT]	108.85
	Rotor diameter [m]	[m]	164
	Lower position of blade tip	[m LAT]	26.85
Tower	Top elevation	[m LAT]	105.81
	Bottom elevation	[m LAT]	19.15
	Top diameter	[mm]	4530
	Bottom diameter	[mm]	6500
	Maximum wall thickness	[mm]	37
	Minimum wall thickness	[mm]	16
	Steel quality		S355
Transition piece	Top elevation	[m LAT]	--
	Bottom elevation	[m LAT]	--
	Top diameter	[mm]	--
	Bottom diameter	[mm]	--
	Maximum wall thickness	[mm]	--
	Minimum wall thickness	[mm]	--
	Main platform	[m LAT]	18.5
	Steel quality		--
Pile	Top elevation	[m LAT]	19.15
	Bottom elevation	[m LAT]	-63.35
	Top diameter	[mm]	6500
	Mudline diameter	[mm]	7400
	Maximum wall thickness	[mm]	88
	Minimum wall thickness	[mm]	62
	Water depth	[m]	34.6
	Pile penetration	[m]	28.75
	Steel quality		S275 / S355
Water level	MSL	[m LAT]	1.72

Technical information Windfarm 2, Location 'WD 34.6m / PD 28.75m' (anonymized)

1. The Rotor-Nacelle Assembly (RNA)

a) Turbine	9.5 MW
b) Hub height	108.850 [mLAT]
c) Rotor diameter	164 [m]
d) Blade length	-- [m]
e) Rotor mass (hub + 3 blades)	184.502 [tonne]
f) Nacelle mass	293.882 [tonne]
g) Total mass nacelle + rotor	478.384 [tonne]
n) Centre of Gravity (COG) nacelle + rotor	
X _{HVR} (fore-aft) =	0.000 [m]
Y _{HVR} (transverse) =	-0.781 [m]
Z _{HVR} (vertical) =	108.045 [mLAT]
o) Mass moment of inertia nacelle + rotor (wrt. COG)	
I _{xx} =	5.26E+07 [kg m ²]
I _{yy} =	9.62E+07 [kg m ²]
I _{zz} =	5.28E+07 [kg m ²]

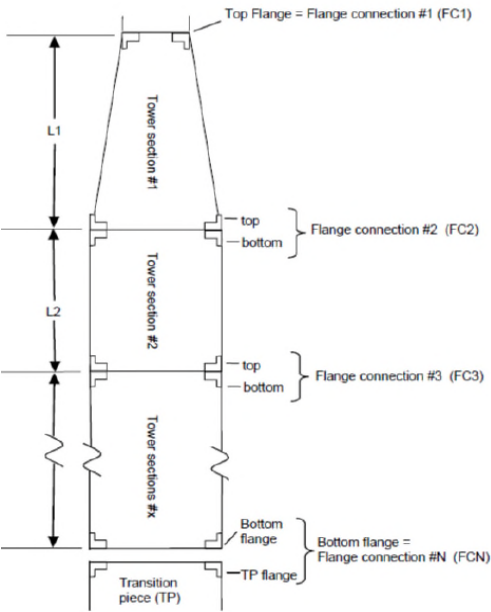
2. Miscellaneous Design properties

a) Design Lifetime	25 [yrs]
b) Distance Tower top - Hub height	3.040 [m]
c) Position top of flange Tower	105.810 [mLAT]
d) Lower position of blade tip	26.85 [mLAT]
e) Position top of flange MP	19.150 [mLAT]
f) Factor on the density to model the Tower internals	1.103 [-]

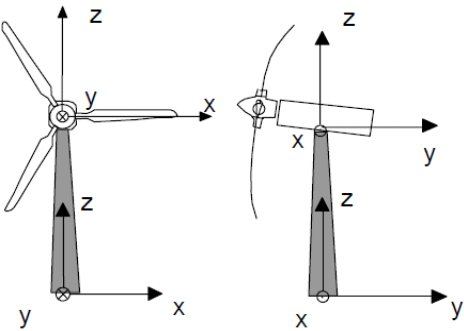
3. Water levels

MSL	1.720 [mLAT]
HAT	3.780 [mLAT]
EHWL _{1yr}	4.430 [mLAT]
ELWL _{1yr}	-0.380 [mLAT]
EHWL _{50yr}	5.200 [mLAT]
ELWL _{50yr}	-0.860 [mLAT]
DWL	5.380 [mLAT]
MWL	1.890 [mLAT]

General set-up and nomenclature tower



Coordinate system



3. Tower added masses

	Distance from LAT [m]	Mass [kg]
Damper	99.63	25000.000
PCM	33.13	55000.000
Tower internals	105.580	3.6
	105.480	27.4
	104.490	61.1
	102.390	65.3
	99.630	66.3
	96.880	67.5
	94.130	70.4
	91.380	72.6
	88.640	75.7
	85.900	80.1
	83.160	84.3
	80.430	88.4
	77.700	93.1
	74.970	97.1
	72.010	97.1
	69.410	104.9
	66.710	108.6
	64.020	112.5
	61.340	116.7
	58.650	120.1
	55.970	123.6
	53.300	128.0
	50.620	114.2
	48.290	115.6
	45.990	116.9
	43.420	107.7
	41.420	157.8
	38.490	149.8
	35.710	139.0
	33.130	143.9
	30.510	148.6
	27.950	115.0
	26.450	166.4
	24.280	165.6
	22.120	166.4
	19.950	47.5
Total mass		83718.85

4. Pile added masses

	Distance from LAT [m]	Mass [kg]
Main Platform	18.500	15000.0
Hang-off platform	17.950	6500.0
Upper ladder	14.000	3000.0
Boatlanding + ladder	4.500	20000.0
Total mass		44500.00

5. Tower layout

Segment	Position	Position	Shell	Shell	Shell	Shell	Material	Mass	
number	top of shell	top of shell	height	OD top	OD bottom	thickness			
[#]	[mmLAT]	[mLAT]	[mm]	[mm]	[mm]	[mm]		[kg]	
1	105810.0	105.810	130.0	4605.0	4530.0	109.3	S355	1562.2	Flange
2	105680.0	105.680	100.0	4530.0	4530.0	25.0	S355	277.8	
3	105580.0	105.580	100.0	4530.0	4530.0	25.0	S355	277.8	
4	105480.0	105.480	760.0	4530.0	4529.0	25.0	S355	2110.7	
5	104720.0	104.720	30.0	4529.0	4529.0	24.0	S355	80.0	Flange
6	104690.0	104.690	80.0	4529.0	4529.0	161.0	S355	1387.5	
7	104610.0	104.610	90.0	4529.0	4529.0	170.3	S355	1647.5	Flange
8	104520.0	104.520	30.0	4529.0	4525.0	24.0	S355	80.0	
9	104490.0	104.490	2100.0	4525.0	4586.0	20.0	S355	4697.8	
10	102390.0	102.390	2760.0	4586.0	4671.0	16.0	S355	5023.3	
11	99630.0	99.630	2750.0	4671.0	4756.0	16.0	S355	5097.3	
12	96880.0	96.880	2750.0	4756.0	4841.0	16.0	S355	5189.5	
13	94130.0	94.130	2750.0	4841.0	4926.0	16.4	S355	5413.4	
14	91380.0	91.380	2740.0	4926.0	5011.0	16.7	S355	5587.9	
15	88640.0	88.640	2740.0	5011.0	5097.0	17.1	S355	5820.1	
16	85900.0	85.900	2740.0	5097.0	5182.0	17.8	S355	6160.3	
17	83160.0	83.160	2730.0	5182.0	5267.0	18.5	S355	6484.2	
18	80430.0	80.430	2730.0	5267.0	5352.0	19.1	S355	6803.1	
19	77700.0	77.700	2730.0	5352.0	5436.0	19.8	S355	7164.1	
20	74970.0	74.970	2720.0	5436.0	5521.0	20.4	S355	7469.0	
21	72250.0	72.250	30.0	5521.0	5521.0	21.0	S355	85.5	Flange
22	72220.0	72.220	90.0	5521.0	5521.0	224.8	S355	2642.5	
23	72130.0	72.130	90.0	5521.0	5521.0	224.8	S355	2642.5	Flange
24	72040.0	72.040	30.0	5521.0	5521.0	21.0	S355	85.5	
25	72010.0	72.010	2600.0	5521.0	5611.0	21.0	S355	7466.4	
26	69410.0	69.410	2700.0	5611.0	5702.0	21.5	S355	8067.1	
27	66710.0	66.710	2690.0	5702.0	5795.0	22.0	S355	8357.6	
28	64020.0	64.020	2680.0	5795.0	5886.0	22.5	S355	8651.9	
29	61340.0	61.340	2690.0	5886.0	5978.0	22.9	S355	8976.9	
30	58650.0	58.650	2680.0	5978.0	6070.0	23.3	S355	9240.9	
31	55970.0	55.970	2670.0	6070.0	6161.0	23.7	S355	9506.6	
32	53300.0	53.300	2680.0	6161.0	6252.0	24.1	S355	9847.6	
33	50620.0	50.620	2330.0	6252.0	6333.0	24.4	S355	8788.2	
34	48290.0	48.290	2300.0	6333.0	6411.0	24.7	S355	8892.7	
35	45990.0	45.990	2270.0	6411.0	6489.0	25.0	S355	8992.0	
36	43720.0	43.720	40.0	6489.0	6489.0	26.0	S355	165.8	Flange
37	43680.0	43.680	110.0	6489.0	6489.0	227.5	S355	3864.3	
38	43570.0	43.570	110.0	6489.0	6489.0	227.5	S355	3864.3	Flange
39	43460.0	43.460	40.0	6489.0	6489.0	26.0	S355	165.8	
40	43420.0	43.420	2000.0	6489.0	6489.0	26.0	S355	8288.1	
41	41420.0	41.420	2930.0	6489.0	6489.0	26.0	S355	12142.1	
42	38490.0	38.490	2780.0	6489.0	6489.0	26.0	S355	11520.5	
43	35710.0	35.710	2580.0	6489.0	6490.0	26.0	S355	10692.5	
44	33130.0	33.130	2620.0	6490.0	6491.0	26.5	S355	11068.0	
45	30510.0	30.510	2560.0	6491.0	6500.0	28.0	S355	11432.8	
46	27950.0	27.950	1500.0	6500.0	6500.0	37.0	S355	8846.0	
47	26450.0	26.450	2170.0	6500.0	6500.0	37.0	S355	12797.2	
48	24280.0	24.280	2160.0	6500.0	6500.0	37.0	S355	12738.2	
49	22120.0	22.120	2170.0	6500.0	6500.0	37.0	S355	12797.2	
50	19950.0	19.950	620.0	6500.0	6500.0	37.0	S355	3656.3	
51	19330.0	19.330	40.0	6500.0	6500.0	37.0	S355	235.9	Flange
52	19290.0	19.290	140.0	6500.0	6500.0	245.0	S355	5291.0	
53	19150.0	19.150							
Total mass								310143.3	

7. Pile layout Pile 'WD 34.6m / PD 28.75m' (Large water depth)

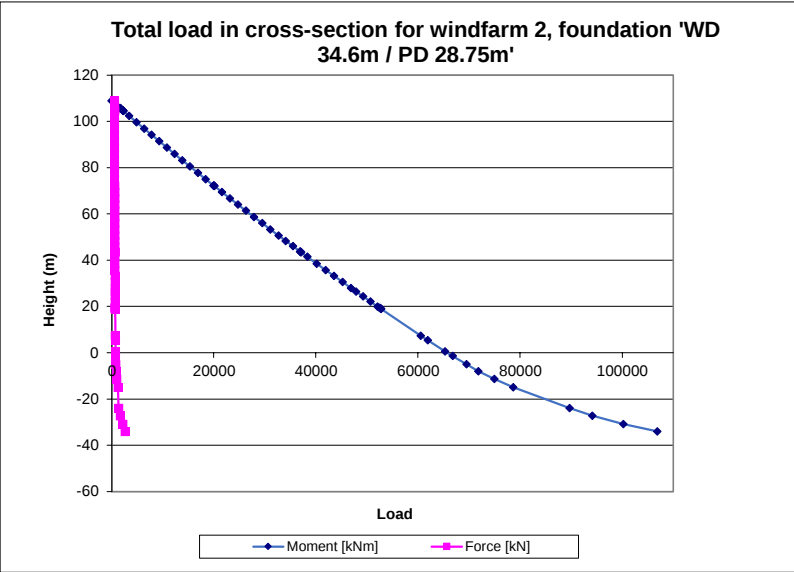
Seabed level: -34.6 [mLAT]
Penetration level: -63.350 [mLAT]
Penetration depth: 28.750 [m]

Pile layout 'WD 34.6m / PD 28.75m' (heaviest/longest pile)								
Segment	Position	Position	Shell	Shell	Shell	Shell	Material	Mass
number	top of shell	top of shell	height	OD top	OD bottom	thickness		
[#]	[mmLAT]	[mLAT]	[mm]	[mm]	[mm]	[mm]		[kg]
1	19150.0	19.150	175.0	6500.0	6500.0	215.0	S355	5831.8
2	18975.0	18.975	50.0	6500.0	6500.0	69.0	S355	547.2
3	18925.0	18.925	11565.0	6500.0	6500.0	69.0	S355	126558.9
4	7360.0	7.360	2000.0	6500.0	6500.0	80.0	S355	25332.3
5	5360.0	5.360	4820.0	6500.0	6500.0	69.0	S355	52746.6
6	540.0	0.540	2000.0	6500.0	6500.0	88.0	S355	27830.8
7	-1460.0	-1.460	3540.0	6500.0	6500.0	74.0	S355	41514.1
8	-5000.0	-5.000	3000.0	6500.0	6920.0	74.0	S355	36331.1
9	-8000.0	-8.000	3345.0	6920.0	7400.0	66.0	S355	38623.4
10	-11345.0	-11.345	3655.0	7400.0	7400.0	66.0	S355	43630.7
11	-15000.0	-15.000	9000.0	7400.0	7400.0	62.0	S275	100979.1
12	-24000.0	-24.000	3300.0	7400.0	7400.0	67.0	S275	39984.3
13	-27300.0	-27.300	3600.0	7400.0	7400.0	82.0	S275	53275.6
14	-30900.0	-30.900	3100.0	7400.0	7400.0	67.0	S355	37561.0
15	-34000.0	-34.000	11600.0	7400.0	7400.0	63.0	S275	132232.0
16	-45600.0	-45.600	15750.0	7400.0	7400.0	62.0	S275	176713.4
17	-61350.0	-61.350	2000.0	7400.0	7400.0	77.0	S275	27811.8
18	-63350.0	-63.350	0.0	7400.0	7400.0	77.0	S275	0.0
Total mass								967504.1

Flange

Technical information Windfarm 2 (anonymized)

Location: 'WD 34.6m / PD 28.75m'					
	Applied load		Total load in cross-section		
Nr	Position	Horizontal	Position	Shear	Bending
	Height	Force	Height	Force	Moment
	[mm]	[N]	[m]	[kN]	[kNm]
Hub height	108900.0	525081.402	108.9	525.081	0.000
1	105810.0	0.000	105.8	525.081	1622.502
2	105680.0	142.892	105.7	525.224	1690.762
3	105580.0	123.867	105.6	525.348	1743.285
4	105480.0	532.594	105.5	525.881	1795.819
5	104720.0	489.202	104.7	526.370	2195.489
6	104690.0	68.112	104.7	526.438	2211.280
7	104610.0	105.264	104.6	526.543	2253.395
8	104520.0	74.298	104.5	526.618	2300.784
9	104490.0	1323.573	104.5	527.941	2316.582
10	102390.0	3052.036	102.4	530.993	3425.259
11	99630.0	3518.720	99.6	534.512	4890.800
12	96880.0	3576.289	96.9	538.088	6360.708
13	94130.0	3640.205	94.1	541.728	7840.451
14	91380.0	3697.348	91.4	545.426	9330.204
15	88640.0	3754.460	88.6	549.180	10824.671
16	85900.0	3818.643	85.9	552.999	12329.425
17	83160.0	3875.328	83.2	556.874	13844.642
18	80430.0	3931.733	80.4	560.806	15364.908
19	77700.0	3995.060	77.7	564.801	16895.909
20	74970.0	4050.543	75.0	568.852	18437.815
21	72250.0	2065.230	72.3	570.917	19985.092
22	72220.0	90.579	72.2	571.007	20002.219
23	72130.0	135.868	72.1	571.143	20053.610
24	72040.0	90.579	72.0	571.234	20105.013
25	72010.0	1995.852	72.0	573.230	20122.150
26	69410.0	4066.316	69.4	577.296	21612.547
27	66710.0	4202.088	66.7	581.498	23171.246
28	64020.0	4254.285	64.0	585.752	24735.476
29	61340.0	4321.546	61.3	590.074	26305.292
30	58650.0	4388.884	58.7	594.463	27892.591
31	55970.0	4439.709	56.0	598.903	29485.751
32	53300.0	4506.476	53.3	603.409	31084.821
33	50620.0	4279.862	50.6	607.689	32701.957
34	48290.0	4008.413	48.3	611.697	34117.872
35	45990.0	4005.516	46.0	615.703	35524.776
36	43720.0	2041.289	43.7	617.744	36922.421
37	43680.0	133.075	43.7	617.877	36947.131
38	43570.0	195.177	43.6	618.072	37015.097
39	43460.0	133.075	43.5	618.205	37083.085
40	43420.0	1809.823	43.4	620.015	37107.814
41	41420.0	4373.738	41.4	624.389	38347.844
42	38490.0	5065.729	38.5	629.455	40177.304
43	35710.0	4755.338	35.7	634.210	41927.188
44	33130.0	4613.986	33.1	638.824	43563.449
45	30510.0	4597.877	30.5	643.422	45237.168
46	27950.0	3606.958	28.0	647.029	46884.328



Location: 'WD 34.6m / PD 28.75m'					
Nr	Applied load		Total load in cross-section		
	Position	Horizontal	Position	Shear	Bending
	Height [mm]	Force [N]	Height [m]	Force [kN]	Moment [kNm]
47	26450.0	3261.426	26.5	650.290	47854.872
48	24280.0	3847.949	24.3	654.138	49266.001
49	22120.0	3847.949	22.1	657.986	50678.940
50	19950.0	2479.395	20.0	660.466	52106.770
51	19330.0	586.523	19.3	661.052	52516.259
52	19290.0	199.000	19.3	661.251	52542.701
53	19150.0	295.000	19.2	661.546	52635.276
54	18975.0	199.951	19.0	661.746	52751.046
55	18925.0	8985.028	18.9	670.731	52784.134
56	7360.0	19090.525	7.4	689.822	60541.138
57	5360.0	12696.016	5.4	702.518	61920.782
58	540.0	43853.994	0.5	746.372	65306.916
59	-1460.0	15894.000	-1.5	762.266	66799.660
60	-5000.0	16000.000	-5.0	778.266	69498.080
61	-8000.0	164979.571	-8.0	943.245	71832.877
62	-11345.0	70353.762	-11.3	1013.599	74988.032
63	-15000.0	209333.333	-15.0	1222.932	78692.736
64	-24000.0	136788.676	-24.0	1359.721	89699.126
65	-27300.0	321220.096	-27.3	1680.941	94186.205
66	-30900.0	472690.173	-30.9	2153.631	100237.593
67	-34000.0	472690.173	-34.0	2626.321	106913.850

Flange

Flange

120

Total load in cross-section for windfarm 2, foundation 'WD 34.6m / PD 28.75m'

Tower-Pile

Location: 'WD 34.6m / PD 28.75m'									
Nr	Elevation		Height [mm LAT]	Thickness [mm]	OD Top [mm]	OD Bottom [mm]	Mass [kg]	Material	Yield Stress [MPa]
	Top	Bottom							
	[mm]	[mm]							
1	105810.0	105680.0	130.0	109.3	4605	4530	1562.22	S355	320
2	105680.0	105580.0	100.0	25.0	4530	4530	277.75	S355	345
3	105580.0	105480.0	100.0	25.0	4530	4530	277.75	S355	345
4	105480.0	104720.0	760.0	25.0	4530	4529	2110.67	S355	345
5	104720.0	104690.0	30.0	24.0	4529	4529	79.992	S355	345
6	104690.0	104610.0	80.0	161.0	4529	4529	1387.45	S355	320
7	104610.0	104520.0	90.0	170.3	4529	4529	1647.53	S355	320
8	104520.0	104490.0	30.0	24.0	4529	4525	79.9565	S355	345
9	104490.0	102390.0	2100.0	20.0	4525	4586	4697.79	S355	345
10	102390.0	99630.0	2760.0	16.0	4586	4671	5023.25	S355	355
11	99630.0	96880.0	2750.0	16.0	4671	4756	5097.29	S355	355
12	96880.0	94130.0	2750.0	16.0	4756	4841	5189.52	S355	355
13	94130.0	91380.0	2750.0	16.4	4841	4926	5413.35	S355	345
14	91380.0	88640.0	2740.0	16.7	4926	5011	5587.91	S355	345
15	88640.0	85900.0	2740.0	17.1	5011	5097	5820.09	S355	345
16	85900.0	83160.0	2740.0	17.8	5097	5182	6160.33	S355	345
17	83160.0	80430.0	2730.0	18.5	5182	5267	6484.22	S355	345
18	80430.0	77700.0	2730.0	19.1	5267	5352	6803.06	S355	345
19	77700.0	74970.0	2730.0	19.8	5352	5436	7164.09	S355	345
20	74970.0	72250.0	2720.0	20.4	5436	5521	7468.96	S355	345
21	72250.0	72220.0	30.0	21.0	5521	5521	85.4521	S355	345
22	72220.0	72130.0	90.0	224.8	5521	5521	2642.55	S355	320
23	72130.0	72040.0	90.0	224.8	5521	5521	2642.55	S355	320
24	72040.0	72010.0	30.0	21.0	5521	5521	85.4521	S355	345
25	72010.0	69410.0	2600.0	21.0	5521	5611	7466.44	S355	345
26	69410.0	66710.0	2700.0	21.5	5611	5702	8067.07	S355	345
27	66710.0	64020.0	2690.0	22.0	5702	5795	8357.64	S355	345
28	64020.0	61340.0	2680.0	22.5	5795	5886	8651.88	S355	345
29	61340.0	58650.0	2690.0	22.9	5886	5978	8976.95	S355	345
30	58650.0	55970.0	2680.0	23.3	5978	6070	9240.86	S355	345
31	55970.0	53300.0	2670.0	23.7	6070	6161	9506.59	S355	345
32	53300.0	50620.0	2680.0	24.1	6161	6252	9847.56	S355	345
33	50620.0	48290.0	2330.0	24.4	6252	6333	8788.23	S355	345
34	48290.0	45990.0	2300.0	24.7	6333	6411	8892.69	S355	345
35	45990.0	43720.0	2270.0	25.0	6411	6489	8992.05	S355	345
36	43720.0	43680.0	40.0	26.0	6489	6489	165.763	S355	345
37	43680.0	43570.0	110.0	227.5	6489	6489	3864.31	S355	320
38	43570.0	43460.0	110.0	227.5	6489	6489	3864.31	S355	320
39	43460.0	43420.0	40.0	26.0	6489	6489	165.763	S355	345
40	43420.0	41420.0	2000.0	26.0	6489	6489	8288.14	S355	345
41	41420.0	38490.0	2930.0	26.0	6489	6489	12142.1	S355	345
42	38490.0	35710.0	2780.0	26.0	6489	6489	11520.5	S355	345
43	35710.0	33130.0	2580.0	26.0	6489	6490	10692.5	S355	345
44	33130.0	30510.0	2620.0	26.5	6490	6491	11068	S355	345
45	30510.0	27950.0	2560.0	28.0	6491	6500	11432.8	S355	345
46	27950.0	26450.0	1500.0	37.0	6500	6500	8845.99	S355	345
47	26450.0	24280.0	2170.0	37.0	6500	6500	12797.2	S355	345
48	24280.0	22120.0	2160.0	37.0	6500	6500	12738.2	S355	345
49	22120.0	19950.0	2170.0	37.0	6500	6500	12797.2	S355	345
50	19950.0	19330.0	620.0	37.0	6500	6500	3656.34	S355	345
51	19330.0	19290.0	40.0	37.0	6500	6500	235.893	S355	345
52	19290.0	19150.0	140.0	245.0	6500	6500	5291.04	S355	320
53	19150.0	18975.0	175.0	215.0	6500	6500	5831.78	S355	320
54	18975.0	18925.0	50.0	69.0	6500	6500	547.164	S355	325
55	18925.0	7360.0	11565.0	69.0	6500	6500	126559	S355	325
56	7360.0	5360.0	2000.0	80.0	6500	6500	25332.3	S355	325
57	5360.0	540.0	4820.0	69.0	6500	6500	52746.6	S355	325
58	540.0	-1460.0	2000.0	88.0	6500	6500	27830.8	S355	325
59	-1460.0	-5000.0	3540.0	74.0	6500	6500	41514.1	S355	325

Location: 'WD 34.6m / PD 28.75m'									
Nr	Elevation		Height	Thickness	OD Top	OD Bottom	Mass	Material	Yield
	Top	Bottom							
	[mm]	[mm]							
60	-5000.0	-8000.0	3000.0	74.0	6500	6920	36331.1	S355	325
61	-8000.0	-11345.0	3345.0	66.0	6920	7400	38623.4	S355	325
62	-11345.0	-15000.0	3655.0	66.0	7400	7400	43630.7	S355	325
63	-15000.0	-24000.0	9000.0	62.0	7400	7400	100979	S355	335
64	-24000.0	-27300.0	3300.0	67.0	7400	7400	39984.3	S355	325
65	-27300.0	-30900.0	3600.0	82.0	7400	7400	53275.6	S355	325
66	-30900.0	-34000.0	3100.0	67.0	7400	7400	37561	S355	325
67	-34000.0	-45600.0	11600.0	63.0	7400	7400	132232	S355	335
68	-45600.0	-61350.0	15750.0	62.0	7400	7400	176713	S355	335
69	-61350.0	-63350.0	2000.0	77.0	7400	7400	27811.8	S355	325
70	-63350.0	-63350.0	0.0	77.0	7400	7400	0	S355	325

Masses

Z-axis reference = LAT
Positive direction Z-axis = Upward

Location: 'WD 34.6m / PD 28.75m'								
Nr.	Item	COG			Mass [kg]	Mass moment of inertia		
		X [mm]	Y [mm]	Z [mm LAT]		Ixx [kgm^2]	Iyy [kgm^2]	Izz [kgm^2]
1	RNA & tower-top adapter mass	0.000	-781.124	108045.238	478384	52610684.8	96182584.7	52808100
2	Tower internals	0.000	0.000	105580.000	4	0	0	0
3	Tower internals	0.000	0.000	105480.000	27	0	0	0
4	Tower internals	0.000	0.000	104490.000	61	0	0	0
5	Tower internals	0.000	0.000	102390.000	65	0	0	0
6	Damper	0.000	0.000	99630.000	25066	0	0	0
7	Tower internals	0.000	0.000	96880.000	67	0	0	0
8	Tower internals	0.000	0.000	94130.000	70	0	0	0
9	Tower internals	0.000	0.000	91380.000	73	0	0	0
10	Tower internals	0.000	0.000	88640.000	76	0	0	0
11	Tower internals	0.000	0.000	85900.000	80	0	0	0
12	Tower internals	0.000	0.000	83160.000	84	0	0	0
13	Tower internals	0.000	0.000	80430.000	88	0	0	0
14	Tower internals	0.000	0.000	77700.000	93	0	0	0
15	Tower internals	0.000	0.000	74970.000	97	0	0	0
16	Tower internals	0.000	0.000	72010.000	97	0	0	0
17	Tower internals	0.000	0.000	69410.000	105	0	0	0
18	Tower internals	0.000	0.000	66710.000	109	0	0	0
19	Tower internals	0.000	0.000	64020.000	112	0	0	0
20	Tower internals	0.000	0.000	61340.000	117	0	0	0
21	Tower internals	0.000	0.000	58650.000	120	0	0	0
22	Tower internals	0.000	0.000	55970.000	124	0	0	0
23	Tower internals	0.000	0.000	53300.000	128	0	0	0
24	Tower internals	0.000	0.000	50620.000	114	0	0	0
25	Tower internals	0.000	0.000	48290.000	116	0	0	0
26	Tower internals	0.000	0.000	45990.000	117	0	0	0
27	Tower internals	0.000	0.000	43420.000	108	0	0	0
28	Tower internals	0.000	0.000	41420.000	158	0	0	0
29	Tower internals	0.000	0.000	38490.000	150	0	0	0
30	Tower internals	0.000	0.000	35710.000	139	0	0	0
31	PCM	0.000	0.000	33130.000	55144	0	0	0
32	Tower internals	0.000	0.000	30510.000	149	0	0	0
33	Tower internals	0.000	0.000	27950.000	115	0	0	0
34	Tower internals	0.000	0.000	26450.000	166	0	0	0
35	Tower internals	0.000	0.000	24280.000	166	0	0	0
36	Tower internals	0.000	0.000	22120.000	166	0	0	0
37	Tower internals	0.000	0.000	19950.000	48	0	0	0
38	Main Platform	0.000	0.000	18500.000	15000	0	0	0
39	Hang-off platform	0.000	0.000	17950.000	6500	0	0	0
40	Upper ladder	0.000	0.000	14000.000	3000	0	0	0
41	Boatlanding + ladder	0.000	0.000	4500.000	20000	0	0	0

Tower
Mono pile

Loads

Location: 'WD 34.6m / PD 28.75m'		
Section nr	Distance top of Section to LAT	Horizontal Force F
[-]	[mm LAT]	[N]
Hub height	108900.000	525081.402
1	105810.000	0.000
2	105680.000	142.892
3	105580.000	123.867
4	105480.000	532.594
5	104720.000	489.202
6	104690.000	68.112
7	104610.000	105.264
8	104520.000	74.298
9	104490.000	1323.573
10	102390.000	3052.036
11	99630.000	3518.720
12	96880.000	3576.289
13	94130.000	3640.205
14	91380.000	3697.348
15	88640.000	3754.460
16	85900.000	3818.643
17	83160.000	3875.328
18	80430.000	3931.733
19	77700.000	3995.060
20	74970.000	4050.543
21	72250.000	2065.230
22	72220.000	90.579
23	72130.000	135.868
24	72040.000	90.579
25	72010.000	1995.852
26	69410.000	4066.316
27	66710.000	4202.088
28	64020.000	4254.285
29	61340.000	4321.546
30	58650.000	4388.884
31	55970.000	4439.709
32	53300.000	4506.476
33	50620.000	4279.862
34	48290.000	4008.413
35	45990.000	4005.516
36	43720.000	2041.289
37	43680.000	133.075
38	43570.000	195.177
39	43460.000	133.075

Location: 'WD 34.6m / PD 28.75m'		
Section nr	Distance top of Section to LAT	Horizontal Force F
[-]	[mm LAT]	[N]
40	43420.000	1809.823
41	41420.000	4373.738
42	38490.000	5065.729
43	35710.000	4755.338
44	33130.000	4613.986
45	30510.000	4597.877
46	27950.000	3606.958
47	26450.000	3261.426
48	24280.000	3847.949
49	22120.000	3847.949
50	19950.000	2479.395
51	19330.000	586.523
52	19290.000	199.000
53	19150.000	295.000
54	18975.000	199.951
55	18925.000	8985.028
56	7360.000	19090.525
57	5360.000	12696.016
58	540.000	43853.994
59	-1460.000	15894.000
60	-5000.000	16000.000
61	-8000.000	164979.571
62	-11345.000	70353.762
63	-15000.000	209333.333
64	-24000.000	136788.676
65	-27300.000	321220.096
66	-30900.000	472690.173
67	-34000.000	472690.173
68	-45600.000	0.000
69	-61350.000	0.000
70	-63350.000	0.000

PY-curves

		Level [mLAT]																				
Number	113	Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Y [m]	1	Penetration depth [m]	0	0.0000000	0.0000131	0.0000262	0.0000393	0.0000524	0.0000655	0.0000786	0.0000917	0.0001048	0.0001179	0.0001310	0.0001441	0.0001572	0.0001703	0.0001834	0.0001965	0.0002096	0.0002227	0.0002358
The soil resistance p as a force per unit depth in [N/m].																						
2	-34.6	0.0000000	1452.7935005	2739.5125610	3983.0610576	4991.3317875	5999.6025174	7007.8732473	7920.4490214	8662.6720976	9404.8951739	10147.1182501	10889.3413264	11631.5644026	12373.7874789	13116.0105551	13858.2336314	14600.4567076	15331.7188697	15846.2100934		
3	-35.1	0.0000000	3269.9952023	6075.4387062	8880.8822102	11470.4951577	13657.0489930	15843.6028283	18030.1566637	20216.7104990	22148.2868960	23770.1770279	25392.0671599	27013.9572918	28635.8474238	30257.7375557	31879.6276877	33501.5178197	35123.4079516	36745.2980836		
4	-35.6	0.0000000	3716.4480598	6774.7980312	9833.1480027	12891.4979741	15782.4378960	18182.5126610	20582.5874261	22982.6621912	25382.7369563	27782.8117214	30182.8864864	31989.4414350	33753.2510684	35517.0607019	37280.8703354	39044.6799688	40808.4896023	42572.2992357		
5	-36.1	0.0000000	4141.9522031	7411.8983790	10681.8445549	13951.7907309	17221.7369068	20402.3356474	22956.3986120	25510.4615766	28064.5245412	30618.5875058	33172.6504704	35726.7134349	38280.7763995	40660.9593026	42549.9102181	44338.8611336	46327.8120491	48216.7629466		
6	-36.6	0.0000000	4412.2041354	8012.7974012	11466.4701951	14920.1429890	18373.8157829	21827.4885767	25281.1613706	28032.8210265	30750.0879460	33467.3548655	36184.6217850	38901.8887044	41619.1556239	44336.4225434	47053.6894628	49770.9563823	52059.1660522	54049.2679039		
7	-37.1	0.0000000	4618.3298168	8589.3966586	12206.9345987	15824.4725388	19442.0104789	23059.5484190	26677.0863591	30294.6242993	33331.4678189	36160.2866616	38989.1055043	41817.9243466	44646.7431896	47475.5620323	50304.3808749	53133.1997176	55962.0185602	58790.8374029		
8	-37.6	0.0000000	4807.7247396	9156.8819896	12922.1923466	16687.5027035	20452.8130605	24218.1234174	27983.4337744	31748.7441313	35514.0544883	38987.9057438	41854.9028458	44811.8999478	47768.8970497	50725.8941517	53682.8912537	56639.8883557	59596.8854577	62553.8825597		
9	-38.1	0.0000000	4965.7872173	9673.7321204	13561.4626511	17449.1931818	21336.9237125	25224.6542432	29112.3847739	33000.1153046	36887.8458353	40775.5763661	44558.9160167	47504.7550631	50550.5941096	53596.4331560	56642.2722025	59688.1112489	62733.9502954	65779.7893418		
10	-38.6	0.0000000	5706.3636152	11262.2359326	15731.3336808	20200.4314289	24669.5291771	29138.6269253	33607.7246735	38076.8224217	42545.9201698	47015.0179180	51484.1156662	55440.7521535	58939.3985174	62438.0448813	65936.6912452	69435.3376090	72933.9839729	76432.6303368		
11	-39.1	0.0000000	5752.8269084	11505.6538168	16039.0447550	20543.2349506	25047.4251462	29551.6153418	34055.8055374	38559.9953730	43064.1859286	47568.3761242	52072.5663198	56576.7565154	60457.6461515	63987.0280211	67516.4098907	71045.7917603	74575.1736299	78104.5554995		
12	-39.6	0.0000000	5778.4154501	11556.8309001	16265.2875724	20789.3062301	25313.3248877	29837.3435454	34361.3622030	38885.3808607	43409.3995183	47933.4181760	52457.4368336	56981.4554912	61505.4741489	65165.9921063	68712.7113502	72259.4305940	75806.1498379	79352.8690817		
13	-40.1	0.0000000	5810.6177087	11621.2354175	16534.3139482	21083.9263594	25633.5387706	30183.1511817	34732.7635929	39282.3760040	43831.9884152	48381.6008263	52931.2123275	57480.8256487	62030.4380598	66558.6148966	70130.3561116	73702.0973265	77273.8385414	80845.5797653		
14	-40.6	0.0000000	5849.3566767	11698.7133533	16844.3349036	21424.6359358	26004.9369680	30585.2380003	35165.5390325	39745.8400647	44326.1410969	48906.4421292	53486.7341614	58247.3452259	62727.6462581	67247.3452259	71745.8873500	75332.1823599	78918.4773698	82504.7723797		
15	-41.1	0.0000000	5908.1471182	11816.2942365	17264.9218079	21890.8494777	26516.7771476	31142.7048174	35768.6324872	40394.5601570	45020.4878268	49646.4154967	54272.3431665	58988.2708363	63524.1985061	68150.1261759	72776.0538458	77401.9815156	81169.2268987	84800.2236050		
16	-41.6	0.0000000	5973.8792589	11947.7585179	17742.9717971	22420.2708341	27097.5698711	31774.8689081	36452.1679450	41129.4669820	45806.7660190	50484.0650560	55161.3640930	59838.6631299	64519.2621669	69193.2612039	73870.5602409	78547.8592779	83225.1583149	87378.9784545		
17	-42.1	0.0000000	6036.3574643	12072.7149286	18109.0723929	22954.0668558	27680.6368053	32407.2067548	37133.7767043	41860.3466538	46586.9166032	51313.4865527	56040.0560522	60766.6264517	65493.1964011	70219.7663506	74946.3363001	79699.4761991	84399.2646185	89126.0461485		
18	-42.6	0.0000000	6095.8274061	12191.6548122	18287.4822183	23492.7086071	28266.6558880	33040.6085689	37814.5585498	42588.5085306	47362.4585115	52136.4084924	56910.3584732	61684.3084541	66458.2584350	71232.2084159	76006.1583967	80780.1083716	85554.0583855	90328.0083393		
19	-43.1	0.0000000	6155.1331567	12310.2663134	18465.3994701	24043.7047089	28862.9324680	33682.1602271	38501.3879862	43320.6157453	48139.8435045	52959.0712636	57778.2990227	62597.5276818	67346.7545409	72235.9823000	77055.2100592	81874.4378183	86693.6655774	91512.8933365		
20	-43.6	0.0000000	6210.2951006	12420.5902012	18630.8853019	24596.7513650	29459.8899442	34323.0286235	39186.1672527	44049.3058820	48912.4445112	53775.5831404	58638.7217697	63501.8603989	68304.9990282	73228.1376574	78091.2762867	82954.4191595	87817.5534552	92680.6921744		
21	-44.1	0.0000000	6264.0834419	12528.1668839	18792.5032358	25056.3337678	30064.7441331	34970.2026131	39718.1258289	44781.3258289	49688.5802656	54592.0415495	59497.5010328	64396.5051661	69368.9199081	74213.8794826	79119.3389659	84054.7999397	88930.2579325	93835.7119593		
22	-44.6	0.0000000	6326.5041887	12653.0083774	18979.5125661	25306.0167548	30761.8251997	35715.3985994	40668.9720192	45622.5454390	50576.1188588	55529.6922785	60483.2656983	65436.8391181	70390.4125379	75343.9859576	80297.5939774	85251.3279742	90204.7062170	95158.2796691		
23	-45.1	0.0000000	6386.2097100	12772.4194200	19158.6291301	25544.8388401	31472.3690971	36473.5761665	41477.1973746	46475.9903052	51477.1973746	56475.9903052	61477.1973746	66475.9903052	71477.1973746	76475.9903052	81477.1973746	86475.9903052	91477.1973746	96475.9903052		
24	-45.6	0.0000000	6444.7541326	12889.5082652	19334.2623978	25779.0165303	32195.0735944	37242.1204702	42289.1673459	47336.2142216	52383.2610973	57430.3079730	62477.3544888	67524.4017245	72571.4486002	77618.4954759	82665.5423517	87712.5892274	92759.6361031	97806.6829788		
25	-46.1	0.0000000	6510.0005289	13020.0010578	19530.0015847	26040.0021156	32550.0026445	38108.2382589	43806.1545423	48304.0708256	53401.9871085	58499.9033923	63597.8196756	68695.7359589	73793.6522423	78891.5685259	83989.4840809	89078.4010923	94185.3173756	99283.2335689		
26	-46.6	0.0000000	6578.6119732	13157.2239465	19735.8359197	26314.4478929	32893.0598661	39045.6283654	44596.9271581	49348.2259508	54499.5247345	59650.8235362	64802.1223829	69953.4211216	75104.7199143	80256.0187069	85407.3174996	90558.6162923	95709.9150850	100861.2138777		
27	-47.1	0.0000000	8913.6112542	17827.2225083	26740.8337625	35654.4450166	42639.2094841	49619.1330170	56599.0656498	63578.9800827	70558.9036156	77538.8271484	84528.7506813	91498.6742142	98478.5977470	105458.5212799	112438.4448128	119418.3683456	126398.2918785	133378.2154114		
28	-47.6	0.0000000	8934.2981345	17868.5962690	26802.8940343	35737.1925379	43303.5084162	50299.9278854	57296.4359806	64292.8997629	71388.3635451	78285.8273713	85282.2911095	92278.7548917	99275.7489177	106271.6824561	113268.1462383	120264.6100205	127261.0738028	134257.5375850		
29	-48.1	0.0000000	8954.9986722	17909.9973445	26864.9696017	35737.1925379	43303.5084162	50299.9278854	57													

PY-curves

Number	113	Level [mLAT]																			37	38
	Number	Penetration depth [m]	1	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	
Y [m]	1	0	0.0002489	0.0002620	0.0002751	0.0002882	0.0003013	0.0003144	0.0003275	0.0003406	0.0003537	0.0003669	0.0003800	0.0003931	0.0004703	0.0005475	0.0006247	0.0007020	0.0007792	0.0008564		
2		-34.6	16360.7013171	16875.1925408	17389.6837645	17904.1749882	18418.6662119	18933.1574356	19447.6486594	19962.1398831	20476.6311068	20991.1223305	21505.6135542	22020.1047779	24406.3982535	26502.2564880	28598.1147225	30667.5516393	32071.7624721	33475.9733049		
3		-35.1	38367.1882155	39989.0783475	41610.9684794	43109.3399631	44231.6879832	45354.0360032	46476.3840233	47598.7320433	48721.0800634	49843.4280834	50965.7761035	52088.1241235	58703.4138929	64987.3547886	69555.9251993	74124.4956100	78693.0660208	83261.6364315		
4		-35.6	44336.1088692	46099.9185027	47863.7281361	49627.5377696	51391.3474031	53155.1570365	54918.9667000	56682.7763035	58446.5859369	60210.3955704	61581.2099325	62805.9871497	70025.0101710	77244.0331923	84463.0562136	91480.1350271	96455.2818619	101430.4286966		
5		-36.1	50105.7138801	51994.6647956	53883.6157111	55772.5666266	57661.5175421	59550.4684576	61439.4193731	63328.3702886	65217.3212104	67106.2721196	68995.2230351	70884.1739506	81499.9482808	89208.3641159	96916.7799511	104625.1957862	112333.6116214	120042.0274566		
6		-36.6	56039.3697556	58029.4716073	60019.5734590	62009.6753107	63999.7771624	65989.8790141	67979.9808658	69970.0827176	71960.1845693	73950.2864210	75940.3882727	77930.4901244	89660.4528315	101390.4155387	109658.7021446	117811.2690960	125963.8360474	134116.4029988		
7		-37.1	61619.6562456	63938.1372206	66026.9887466	68115.8402725	70204.6917985	72293.5433244	74382.3948053	76471.2463765	78560.0979022	80648.9494282	82737.8009541	84826.6524800	97138.6607720	109450.6690639	121762.6773559	131283.4076588	139810.4528003	148337.4979418		
8		-37.6	65510.8796617	68467.8767637	71424.8738657	74381.8709677	76718.2748428	78889.0255623	81059.7762817	83230.5270012	85401.2777207	87572.0284401	89742.7791596	91913.5298791	104708.2644622	117502.9990452	130297.7336283	143092.4682114	154088.7368197	162968.3578989		
9		-38.1	68825.6283883	71871.4674347	74917.3064812	77963.1455276	81008.9845741	84054.8236205	87100.6626670	89433.3976160	91677.0466919	93920.6957227	96164.3447536	98407.9937844	111632.4020915	124856.8103987	138081.2187058	151305.6270129	164530.0353200	176872.3965697		
10		-38.6	79931.2767007	83429.9230645	86928.5694284	90427.2157923	93925.8621562	97424.5085200	100923.1548839	104421.8012478	107727.6433340	110307.2461540	112886.8489739	115466.4517939	130671.0227818	145875.5937696	161080.1647575	176284.7357453	191489.3067332	206693.8777211		
11		-39.1	81633.9373691	85163.3192386	88692.7011082	92222.0829778	95751.4648474	99280.8467170	102810.2285866	106339.6104561	109868.9923257	113398.3741953	116789.1220393	119388.0893631	134706.7976790	150025.5059949	165344.2143108	180662.9226267	195981.6309426	211300.3392585		
12		-39.6	82899.5883256	86446.3075694	89993.0268133	93539.7460571	97086.4653010	100633.1845448	104179.9037887	107726.6230325	111273.3422764	114820.0615202	118366.7807641	121913.5000079	137865.0044346	153248.3674852	168631.7305358	184015.0935864	199398.4566371	214781.8196877		
13		-40.1	84417.3209712	87989.0621861	91560.8034010	95132.5446159	98704.2853308	102276.0270457	105847.7682606	109419.5094755	112991.2506904	116562.9919053	120134.7312103	123706.4743532	141626.7185557	157090.2026234	172553.6866910	188017.1707587	203480.5648264	218944.1388941		
14		-40.6	86091.0673896	89677.3623995	93263.6574095	96849.9524194	100436.2474293	104022.5424392	107680.8374491	111195.1324590	114781.4274689	118367.7224788	121954.0174887	125540.3124987	145723.2922111	161305.7181425	176888.2706369	192470.6959853	208053.1849067	223635.6738280		
15		-41.1	88431.2202203	92062.2168356	95693.2134509	99324.2100662	102955.2066815	106586.2032968	110217.1999121	113848.1965274	117479.1931427	121110.1897580	124741.1863733	128372.1829886	149773.8287641	167168.3686809	182892.3736219	198616.3065630	214340.2755041	230064.2444452		
16		-41.6	91040.4117721	94701.8450897	98363.2784073	102024.7117249	105686.1450426	109347.5783602	113009.0116778	116670.4449594	120331.8783130	123993.3116307	127654.7449483	131316.1782659	152897.2225896	173560.8642533	189475.1750137	205389.4857740	221303.7965344	237218.1072948		
17		-42.1	93277.8482280	97434.7801541	101141.7120802	104848.6440062	108555.5793233	112262.5078584	115969.4397845	119676.3717105	123383.3063636	127090.2355627	130797.1674887	134504.0994148	156533.3194501	178202.5394855	196479.7557895	212548.7604069	228617.9422542	244687.1241016		
18		-42.6	95101.9583202	99879.9083011	103944.3253213	107687.7373755	111431.1421497	115174.5506400	118917.9588792	122661.3673925	126404.7758067	130148.1842209	133891.5926352	137635.0010494	159699.2190486	181763.4370477	203546.2131690	219777.3480819	236008.4829949	252239.6179078		
19		-43.1	96332.1210956	101151.3488547	105970.5766139	110579.8278465	114361.9333655	118144.0388845	121926.1440305	125708.2499225	129490.3554414	133272.4609604	137054.5667494	140836.7611994	163128.9766129	185421.2812274	207713.5858418	227253.8633796	243634.5535862	260015.2437369		
20		-43.6	97543.8308307	102406.9694329	107270.1080622	112133.2466914	116996.3853207	121149.6591937	124962.7474613	128775.8357289	132588.9239965	136402.0122641	140215.1005317	144028.1887994	166503.1104420	188978.0320847	211545.9357274	233927.8753701	251313.3472804	267848.9625464		
21		-44.1	98781.1768990	103466.6363823	108552.0958656	113457.5553489	118363.0148321	123268.1383912	128106.1889192	131908.1405807	135754.3972435	139600.6539823	143406.1505653	147293.1672269	169693.5884231	192634.0096194	215424.9381577	237934.8520120	259235.2067228	275914.0749544		
22		-44.6	100111.8530565	105065.4264763	110018.9998961	114972.5733158	119926.1467356	124879.7201554	129833.2935752	134786.8669949	139732.3250113	144327.5687138	147159.8124162	151046.0561187	173952.1670104	196858.2779921	219764.2881797	242670.4996854	265796.6105771	285230.8106277		
23		-45.1	101489.2680684	106490.4751378	111491.6822072	116492.8892766	121494.0963460	126495.3034154	131496.5104847	136497.7175541	141498.9246235	146500.1316929	150977.9246515	154968.5686610	179596.1268115	201095.6849621	224195.3431126	247394.8016631	270394.3594136	293493.9175641		
24		-45.6	102853.7298545	107900.7767303	112947.8236060	117994.8704817	123041.9173574	128088.9642332	133136.011089	138163.9579846	143230.1048603	148277.1517360	153324.1986118	158371.2454875	182134.7250651	205446.9170692	228759.1090734	252071.3010775	275383.4930817	298695.6850858		
25		-46.1	104381.1499423	109479.0662256	114576.9825089	119674.8987923	124772.8150756	129874.9137350	134968.6476423	140066.5639256	145262.6569325	150464.4802090	155681.7663250	160458.2327756	186814.7663250	210393.4041127	233977.0419004	257505.696882	281129.3174759	304779.1133613		
26		-46.6	106012.5126704	111163.8114631	116315.1102557	121466.4090484	126617.7078411	131769.066338	136920.3054265	142071.6042192	147222.9030119	152374.2018046	157525.5005972	162676.7993899	191849.3201382	215641.6228733	239433.9256083	263226.2283434	287018.5310785	310810.8338135		
27		-47.1	140358.1389442	147338.0624771	154317.9860100	161297.9095428	168277.8330757	175257.0663805	181408.0836530	186885.4902835	192362.8969141	197840.305446	203317.7101751	208795.1168056	241079.7837701	273364.4507346	305649.1176990	337933.7846353	366652.7763478	390379.1133613		
28		-47.6	141256.0013672	148250.4651494	155246.9289316	162243.3927138	169239.8564960	176236.3207882	183232.7840604	190229.2478427	196056.2134249	201539.7604948	207022.7075548	212505.6546147	244822.9777122	277140.3008096	309457.6239071	341774.9407045	374092.2701019	400404.6398400		
29		-48.1	142156.6791416	149168.8522770	156181.0254124	163193.1985477	170205.7179538	177121.8081831	184229.7195384	1912412												

PY-curves

Number	Level [mLAT]																											
	113										1	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
	Number	Penetration depth [m]									1	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Y [m]	1	0	0.0009336	0.0010108	0.0010881	0.0011653	0.0012425	0.0013197	0.0013970	0.0014742	0.0015514	0.0016286	0.0017059	0.0017831	0.0018603	0.0019375	0.0020148	0.0020920	0.0021692									
2		-34.6	34880.1841377	36284.3949705	37688.6058033	38792.1173673	39684.7804110	40577.4434548	41470.1064986	42362.7695424	43255.4325862	44148.0956300	45040.7586737	45924.7543498	46201.0925235	46477.4306972	46753.7688709	47030.1070446	47306.4452183									
3	-35.1	87115.2388507	90176.1720986	93237.1053465	96298.0385944	99358.9718423	102419.9050902	105480.8383381	108009.3387988	109955.6992747	111902.0597507	113848.4202266	115794.7807025	117741.1411785	119687.5016544	121633.8621303	123580.2226063	125526.5830822	127572.9446518									
4	-35.6	106405.5755314	111380.7223661	116355.8692009	121331.0160356	124683.0692175	128020.1467842	131357.2243510	134694.3019177	138031.3794844	141368.4570512	144705.5346179	148042.6121846	151379.6897514	153626.6732554	155749.6073442	157872.5414330	159995.4755218	162128.4066106									
5	-36.1	125513.4483348	130843.1125720	136172.7768091	141502.4410463	146832.1052834	152161.7695206	157491.4337577	162108.8468848	165675.0330929	169241.2193011	172807.4055092	176373.5917174	179939.7779255	183505.9641336	187072.1503418	190638.3365499	194204.5227581	197780.6999653									
6	-36.6	142268.9699502	150421.5369017	156736.4863963	162358.1425133	167979.7986304	173601.4547474	179223.1108645	184844.7669815	190466.4230986	196088.0792156	201709.7353327	206808.8236272	209848.3567643	213615.8899015	217383.4230387	221150.9561759	224918.4893131	228691.0265403									
7	-37.1	156864.5430832	165391.5882247	173918.6333662	182445.6785076	189897.6407826	195790.5657614	201683.4907403	207576.4157192	213469.3406980	219362.2656769	225255.1906558	231148.1156346	237041.0406135	242933.9655924	248826.8905712	253157.1342527	257103.0988155	261049.0649487									
8	-37.6	171847.9789781	180727.6000572	189607.2211364	198486.8422156	207366.4632948	216246.0843740	225091.3013452	231220.5882278	237349.8751104	243479.1619930	249608.4488756	255737.7357581	261867.0226407	267996.3095233	274125.5964059	280254.8832885	286384.1701711	292513.4589085									
9	-38.1	186041.8458363	195211.2951028	204380.7443694	213550.1936360	222719.6429025	231889.0921691	241058.5414357	250227.9907022	259397.4399688	266630.3413932	272958.7258290	279287.1102648	285615.4947005	291943.8791363	298272.2635721	304600.6480079	310929.0324437	317247.9171003									
10	-38.6	219587.9211028	230124.2857212	240660.6503397	251197.0149581	261733.3795765	272269.7441949	282806.1088133	293342.4734317	303878.8380501	314415.2026686	323903.1943968	331183.2020015	338463.2096062	345743.2172109	353023.2248157	360303.2324204	367583.2400251	374863.2485403									
11	-39.1	226619.0475744	239137.7513994	249760.5567746	260383.3621498	271006.1675250	281628.9725902	292251.7782754	302874.5836055	313497.3890257	324120.1944009	334742.9997761	345365.8051513	353887.3193525	361219.3092822	368551.2992118	375883.2891415	383215.2790711	390547.2700711									
12	-39.6	230165.1827383	245458.5457889	257006.3798524	267673.0002470	278339.6206416	289006.2410362	299672.8614308	310339.4818253	321006.1022199	331672.7226145	342339.3430091	353005.9634037	363672.5837983	373676.0351271	381045.8505817	388415.6660364	395785.4814910	402997.2485403									
13	-40.1	234407.6229617	249871.1070294	265334.5910971	276243.3250666	286972.4292169	297701.5333673	308430.6375176	319159.7416679	329888.8458183	340617.9499686	351347.0541189	362076.1582693	372805.2624196	383534.3665699	394263.4707202	403101.1891858	410509.3809062	417818.5330205									
14	-40.6	239218.1627494	254800.6516708	270383.1405922	285965.6295135	296810.6785216	307618.2573713	318425.8362210	329233.4150707	340040.9939205	350848.5727702	361656.1516199	372463.7304697	383271.3093194	394078.8881691	404886.4670188	415694.0586866	426501.6247183	437218.1891858									
15	-41.1	245788.2133862	261512.1823273	277236.1512684	292960.1202095	308684.0891506	320654.3523841	331566.4596745	342478.5669486	353390.6742552	364302.7815456	375214.8883660	386126.9961264	397039.1034168	407951.2107072	418863.3179976	429775.4252879	440687.5325783	451598.6449416									
16	-41.6	253132.4180551	269046.7288155	284961.0395758	300875.3503362	316789.6610965	332703.9718569	346576.7646023	357604.9975350	368633.2304768	379661.4634005	390689.6963332	401717.9292659	412746.1621987	423774.3951314	434802.6280641	445830.8609969	456859.0939296	467887.3066600									
17	-42.1	260756.3059490	276825.4877963	292894.6696437	308963.8514911	325033.0333385	341102.2151858	357171.3970332	373196.5887510	389432.4462964	395488.3038419	406634.1613873	417780.1893238	428925.8764782	440071.7340237	451217.5915691	462363.4491146	473509.3606600	484747.5330205									
18	-42.6	268470.7528208	284701.8877337	300933.0226467	317164.1575596	333395.2924726	349626.4273885	365857.5622985	382088.6972114	398319.8321244	414178.2809571	430504.7245042	443431.1680514	455575.6115986	468388.0551457	481009.4986929	493632.9422401	506255.3857872	518887.5330205									
19	-43.1	276395.9339155	292776.6240941	309157.3142727	325538.0044513	341918.6946299	358299.8480085	374680.0749871	391060.7651657	407441.4553443	423822.1455229	439912.9196492	451276.1021928	462639.1242003	474002.2264759	485865.3287514	497628.4310270	509891.5330205	521698.6449416									
20	-43.6	284384.5776324	300920.1928084	317455.8079843	333991.4231603	350527.0383363	367062.6531233	383598.2686882	400133.8838642	416669.4990402	433205.1142161	449740.7293991	466627.3445681	480201.0001985	491671.8391891	503142.6781796	514613.5171701	526084.3561066	537698.6449416									
21	-44.1	292592.8891860	309271.7304176	325950.5716492	342629.4128808	359308.2541123	375987.0953429	392665.9365755	409344.7707801	426023.6190387	442702.4602703	459381.3015019	476602.7433519	492738.9839650	509417.8251966	521657.1966277	532928.4201708	544999.3760749	556998.6449416									
22	-44.6	303270.7936197	318910.7766117	335750.7960373	352590.7425957	369430.7255877	386270.7085797	403110.6915717	419950.6745637	436790.6575557	453630.6405477	470470.6235397	487310.6065317	504150.5895327	520990.5725157	537885.5550577	553977.4818622	566662.3041919	578698.6449416									
23	-45.1	311732.4778896	328740.2880274	345748.1891652	362755.9083030	379763.7184409	396771.5285787	413779.3387165	430787.1488545	447794.9589921	464810.5792677	481819.7691299	498818.3984055	515826.1995433	532834.0096811	549841.8198189	566848.0096811	583857.4400945	599898.6449416									
24	-45.6	321719.4854113	338882.9311443	356046.3768773	373209.8226102	390373.2683432	407536.7140762	424700.1598902	441863.6055421	459027.0512751	476190.4970081	493353.9427411	510517.3884740	527680.8342070	544844.2799400	562007.7256730	579171.1714059	596334.6117389	613487.5330205									
25	-46.1	328286.5930514	350501.6891973	367829.6953962	385157.7015951	402485.7077399	419813.7139928	437141.7201917	454469.7263906	471797.7325894	489125.7387883	506453.9478272	523781.5711860	541109.7573849	558437.7635838	575765.7697826	593093.7379815	610421.7821804	627487.5330205									
26	-46.6	334603.1365486	358395.4392836	380313.8307261	397833.4448763	415353.0509265	432872.6731766	450392.2873268	467911.9014769	485431.5156271	502951.1297772	520470.7439274	537990.3580775	555059.9722277	573029.5863778	590549.2005280	608068.8146781	625588.4288283	643198.6449416									
27	-47.1	414105.4503749	437831.7873885	461558.1244020	485284.4614156	509010.7984292	532737.1354427	556693.4724563	580188.8094699	603916.1464834	627642.4834970	651368.8205106	675095.1572541	698821.4945377	719787.7325778	736247.8966443	752708.0610309	769168.2254175	786276.5330205									
28	-47.6	421497.2654432	447989.8901665	471782.5153297	495575.1409390	519367.7655652	543196.3086194	566953.0159827	590745.6411459	614538.2663902	638330.8914724	662123.5166356	689164.1417989	709708.7666921	733501.3921254	757294.0127886	776856.3362364	793534.0406557	810276.5330205									
29	-48.1	434745.8400323	458591.9274371	482437.1413139	506282.7897548	530128.4381956	553670.0863916	577819.7503770	601665.3831451	625113.0319588	649358.6809797	673202.3288406	697047.977814	720893.6257222	744739.2741630	768584.9210746	792309.5170447	816259.2194855	835076.5330205									
30	-48.6	445240.6141876	469375.2344732	493277.8547588	517180.4750444	541083.0953300	564985.7156156	588888.3599012	612790.9561286	636693.5764724	660596.1967580	684498.8170436	708401.4373292	732304.0561818	756206.6779004	780109.2981860	804011.9184716	827914.5387672	849718.5330205									
31	-49.1	450870.5609294	480629.5897139	504574.7668855	528519.9539991	552465.1393127	576410.3246623	600430.9525366	624255.8805924	648039.6521636	67191.0658808	696136.2517040	720081.4365928	744206.6128127	767971.8017331	791916.9496392	815862.1777625	839678.5330205	863572.5330205									
32	-49.6	456263.3469884	486274.7453412	516062.3685415	540055.8182410	564049.2679406	588042.7176401	612036.1673397	636029.6170392	660023.0667388	684016.5164383	708009.9661379	732003.4158374	756059.8655370	779990.3152365	803983.7693661	827977.2146356	84979										

Number	113 Number	Level [mLAT] Penetration depth [m]	1	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
			0	0.0022464	0.0023237	0.0026387	0.0029537	0.0032687	0.0035837	0.0038987	0.0042137	0.0045287	0.0048437	0.0051587	0.0054737	0.0057887	0.0061037	0.0064187	0.0067337
Y [m]	1																		
2		-34.6	47582.7833920	47859.1215657	48986.3167992	50113.5120328	51240.7072664	52367.9024999	53495.0977335	54622.2929670	55749.4882006	56876.6834342	58003.8786677	59131.0739013	60258.2691348	61385.4643684	62512.6596020	63639.8548355	
3		-35.1	127472.9435581	128741.4612759	131239.2061577	133690.9510395	136154.6959213	138612.4408031	141070.1856489	143527.9305667	145985.6754486	148443.4203304	150901.1652212	153538.9105946	156874.3998576	158274.3998576	160372.1447394	161589.8896212	
4		-35.6	16128.14096106	162421.3436994	172900.8826766	181366.9217359	184587.6646548	187626.5890692	189905.5134387	192624.4378981	195303.3621437	198272.2867271	200661.2111415	203040.1355560	206019.0599705	208697.9843849	210730.9087994	213043.8312318	
5		-36.1	197770.7089662	201154.5409322	210408.9626807	219663.8424928	228917.8061767	238172.2729621	242491.2664810	245855.9278476	248720.5910142	251585.2541808	254449.9137474	257314.5805140	260179.2346806	263043.9068472	265908.5700138	268773.2318014	
6		-36.6	226866.0224502	232453.5558874	247821.4844465	260002.2134328	269781.8084919	279561.4006261	289340.9927903	299120.3509094	308940.3509094	318765.8623993	328541.7221674	338322.9024473	348152.5670628	357985.2738118	367825.6321633	377658.3968008	
7		-37.1	261004.6033782	264945.0279410	281090.7862191	297186.5444973	312993.0613364	323231.0947019	333469.1280674	343707.1614329	353949.1494794	364183.2261639	374421.2615293	377979.4716324	381148.4102514	384317.3488703	387486.2874893	390558.2261088	
8		-37.6	292513.4570537	298642.7439363	318555.4359849	332614.2224794	349373.0089740	366131.7954665	380206.0809177	390632.1052615	401338.1295313	411994.1585143	422650.1780799	433306.2023407	443962.2266105	454547.7536811	465109.2088347	475684.7663506	
9		-38.1	317257.4168793	323585.8017153	349399.5521864	366821.249373	384125.5427913	401429.634544	418734.1298995	436068.4234535	453476.3270999	458473.5033467	469480.6759938	479482.8558405	491495.0320783	502409.2033641	513498.3845810	524506.5608279	
10		-38.6	378454.2672498	382143.2552346	411838.7177737	430790.0763259	451793.4927347	470707.9075193	496962.3237641	516846.7395768	536404.5519475	554900.8849230	561741.2178984	574391.5508739	587004.8838494	599662.2168247	612342.5448003	624992.8877857	
11		-39.1	390547.2690008	398729.2589304	427786.7595499	457694.2601694	480352.1162298	500401.6479472	520451.1787292	540849.7009792	560540.2412292	580599.7747292	586981.3604465	606609.6532229	619357.9109123	632602.1850757	644854.4595921	657602.7348285	
12		-39.6	40355.2969456	410525.1124002	440586.9049545	470468.6975087	499239.5078412	519369.4746178	539498.4413944	559629.4081709	579759.3749474	599889.3417240	620019.3085006	632936.1513022	645274.6539103	658549.1565255	671355.6591266	684	

PY-curves

Number	113	Level [mLAT]																	87
	Number	Penetration depth [m]	1	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	
Y [m]	1	0	0.0070487	0.0073637	0.0076787	0.0079937	0.0083087	0.0086237	0.0097651	0.0109066	0.0120480	0.0131895	0.0143309	0.0154724	0.0166138	0.0177553	0.0188967	0.0200382	
2		-34.6	64767.0500691	65222.0195488	65446.8175827	65671.6156166	65896.4136506	66121.2116845	66935.8012586	67750.3908327	68564.9804068	69379.5699809	70194.1595550	71008.7491291	71823.3387032	72637.9282773	72889.1026498	73087.2161734	
3		-35.1	165647.6345031	168105.3793849	170563.1242667	173020.8691485	175478.6140303	177936.3589121	182993.8890512	184769.8578436	186545.8266335	188321.7954233	190097.7642132	191873.7330031	193649.7017930	195425.6705829	197201.6393728	198977.6081627	
4		-35.6	216734.7576283	219413.6820428	222092.6064572	224771.5308717	227450.4552861	230129.3797006	239836.8662812	249544.3528618	258189.7149416	260125.8494324	262061.9839232	263998.1184140	265934.2529048	267870.3873955	269806.5218863	271742.6563771	
5		-36.1	271637.8963470	274502.5595135	277367.2226801	280231.8858467	283096.5490133	285961.2121799	296341.7511371	306722.2900942	317102.8290514	327483.3680086	337863.9069657	342781.4509126	344851.5981686	346921.7454246	348991.8926806	351062.0399367	
6		-36.6	330623.8339853	333649.2693698	336674.7047542	339700.1401387	342725.5755232	345751.0109077	356714.1322398	367677.2535719	378640.3749041	389603.4962362	400566.6175683	411529.7389005	422492.8602326	432708.1998758	443894.7628261	447081.3257765	
7		-37.1	393824.1647273	396993.1033463	400162.0419653	403330.9805843	406499.9192033	409668.8578222	421151.9847640	432635.1117057	444118.2386474	455601.3655892	467084.4925309	478567.6194726	490050.7464143	501533.8733561	513017.0002978	524500.1272395	
8		-37.6	461345.2728502	464643.7793443	467942.2858383	471240.7923324	474539.2988264	477837.8053205	489790.4409955	501743.0766706	513695.1723456	525648.3480206	537600.9836957	549553.6193707	561506.2550458	573458.8907208	585411.5263958	597364.1620709	
9		-38.1	528003.0892109	531408.8739239	534814.6586369	538220.4433500	541626.2280630	545032.0127760	557373.3872542	569714.7617325	582056.1362108	594397.5106891	606738.8851673	619080.2596456	631421.6341239	643763.0086022	656104.3830805	668445.7575587	
10		-38.6	637643.2157512	645339.2041413	649254.1125286	653169.0209159	657083.9239032	660998.8376905	675185.0985752	689371.3594599	703557.6203446	717743.8812239	731930.1421140	746116.4029987	760302.6638834	774488.9247681	788675.1856528	802861.4455375	
11		-39.1	670351.0097049	683099.2845813	695847.5594577	7071563.5780430	705509.4467120	709455.3153811	723753.7655153	738052.2156495	752350.6657837	766649.1159179	780947.5660521	795246.0161863	809544.4663206	823842.9164548	838141.3665890	852439.8167232	
12		-39.6	696968.6643429	709775.1669510	722581.6695592	735388.1721673	745565.4330243	749528.6278012	763889.8617000	778251.0955989	792612.3294977	806973.5633965	821334.7972954	835696.0311942	850057.2650930	864418.4989919	878779.7328907	893409.9667895	
13		-40.1	728007.1317917	740884.5771554	753762.0225191	766639.4678829	779516.9132466	792394.3586103	810544.5448940	824987.1010856	839429.6572772	853872.2134688	868314.7696605	882757.3258521	897199.8820437	911642.4382353	926084.9944270	940527.5506186	
14		-40.6	763303.8916657	776267.8549206	789231.8181755	802195.7814304	815159.7446852	828123.7079401	863474.7634544	878014.1844288	892553.6054015	907093.0263751	921632.4473487	936171.8683222	950711.2892958	965250.7102694	979790.1312429	994329.5522165	
15		-41.1	809296.5367965	822390.4344128	835484.3320291	848578.2296453	861672.1272616	874766.0248778	922213.7373670	946711.7703068	961396.3276850	976080.8850632	990765.4424414	1005449.9988196	1020134.5571978	1034819.1145760	1049503.6719541	1064188.2293323	
16		-41.6	861884.9687653	875124.9153472	888364.8619290	901604.8085109	914844.7550927	928084.7016746	976061.6461387	1024036.5875531	1040176.2966395	1055024.0136502	1069871.7306069	1084719.4475636	1099567.1645203	1114414.8817470	1129262.5984338	1144110.3153905	
17		-42.1	901787.7577820	928224.8015474	943249.4729285	956629.8897500	970010.3065715	983390.7233930	1031876.6814276	1082036.2394622	1122248.4950581	1137251.9953199	1152255.4955817	1167258.9958435	1182262.4961053	1197265.9953671	1212269.4966289	1227272.9968907	
18		-42.6	949832.9618659	971078.4717950	992323.9817242	1013569.4916533	1027171.6703884	1040684.3446188	1089469.5573183	1138614.7700178	1185759.9821712	1222757.8468859	1237911.8366062	1253065.8263266	1268219.8160470	1283373.8057674	1298527.7954877	1313681.7852081	
19		-43.1	993824.9262517	1015271.6628752	1036718.3994987	1058165.1361221	1079611.8727456	1099968.8603047	1149431.8229638	1199866.7856228	1249301.7482819	1297736.7109410	1347868.0431665	1342166.2516477	1357464.4601289	1372762.6686101	1388060.8770913	1403539.0855726	
20		-43.6	1039578.4179840	1060813.0140091	1082454.6100342	1104096.2060594	1125737.8020845	1147379.3981097	1211215.4128950	1261099.8263614	1310994.2398278	1360868.6532943	1410753.0667607	1434552.5735741	1449899.7389233	1465426.9042728	1480864.0696216	1496301.2349708	
21		-44.1	1088171.6387766	1107710.6297116	1129541.4920665	1151372.9211615	1173204.3502564	1195305.6032564	1252533.6747905	1325536.4767905	1375666.7883953	1427973.0156040	1476273.0166740	1525686.1922907	1562146.2142224	1594270.7111598	1576942.2058972	1572513.7006446	
22		-44.6	1139572.2863103	1161618.1677242	1183664.0491381	1205709.9305520	1227755.8119659	1249801.6933799	1329868.2696021	1391811.5811226	1449995.0665738	1500808.5520251	1551622.0371674	1602435.5292972	1653249.0083789	1671715.2725345	1687439.5782029	1701363.8811523	
23		-45.1	1195726.9790049	1217980.4583320	1240233.9376591	1262487.4169862	1284740.8961333	1306994.7634004	1362782.0516906	1437568.4206452	1509606.2881585	1576768.4206452	1630364.3415724	1681662.0020642	1732959.8625560	1784257.2006420	1819259.8817585		
24		-45.6	1238703.7761116	1272232.1640325	1298462.0962406	1320919.1176118	1343376.1389829	1365833.1603540	1447209.5636686	1528585.9669831	1608001.4260662	1659771.9911585	1711542.5562580	1763313.1213430	1815083.6864353	1868654.2515276	1918624.8166199	1939383.9740035	
25		-46.1	125498.6615815	1319354.0302392	1353209.3988970	1387006.1244876	1406993.0734500	1432380.0241214	1514589.6030256	1596790.7642562	1709008.7642562	175117.6788339	1803466.9584810	185762.2381223	1908057.5177635	1960352.7974048	2016484.070461	206949.3566873	
26		-46.6	1336632.8700857	1370839.6453868	1405046.4206879	1439253.1959890	1473459.9712901	1505243.6800652	1588315.4069463	1671387.1338275	1754458.8607086	1837530.5875897	1904153.1387607	1956994.9659561	2009836.7931515	2062678.6203469	2115520.4475423	2168362.2743777	
27		-47.1	1529882.4392740	1560943.4800137	1592004.5207533	1623065.5614929	1654126.6023225	1685187.6297248	1796282.4297248	186478.9656009	2007471.2335390	2070471.2335390	2170088.8971980	2241850.5627988	2305502.7130051	2327711.8725189	2349921.0320327	2372130.1915466	
28		-47.6	1594438.2795522	1625571.0270597	1656703.7745762	1687836.2502748	1718969.2695823	1750102.0170898	1862916.2223040	1954803.9003956	2026055.5659964	2098327.2315972	2126098.8719800	2241850.5627988	2305502.7130051	2327711.8725189	2349921.0320327	2372130.1915466	
29		-48.1	1669000.4718951	1692107.3184491	1723314.1650030	1754521.0115570	1785727.8581170	1816934.7046649	1930017.4189472	2043100.1332302	2102769.0535644	2200758.8791252	2263938.6882596	2335868.5056072	2407798.3229547	2471884.2357591	2494142.8955131	2516401.5552672	
30		-48.6	1714374.8130825	1760733.5034678	1792001.7018977	1823269.9003276	1854538.0987574	1885806.2971873	1999111.3292438	2112416.3613003	2216395.7061471	2288474.3990860	2360053.0920248	2432631.7849367	2504710.4779026	2576789.1708415	2642818.8443743	2665126.9968313	
31		-49.1	1761445.5430897	1808218.8620176	1854992.1809455	1893939.9847360	1925273.4320146	1956606.8792933	2070748.3503924	2197233.2925907	2328698.8214915	237777.0768632	2440504.4923272	2504710.4779026	2576789.1708415	2642818.8443743	2665126.9968313	2684834.2984807	
32		-49.6	1																

PY-curves

Number	Level [mLAT]																			
	113										1									
	Number	Penetration depth [m]									88									
Y [m]	1	0									0.0211796									
2		-34.6	73285.3296969	73483.4432204	73681.5567439	73879.6702675	74077.7837910	75115.3522779	75813.9598000	75934.4330497	76054.9062994	76175.3795490	76295.8527987	76416.3260484	76527.1302213	76527.1329787	76527.1357360	76527.1638099		
3	-35.1	200753.5769525	202529.5457424	203658.9672463	204090.9257947	204522.8843432	206785.1558404	209047.4273376	211309.6988348	212198.0059576	212460.6621734	212723.3183892	212985.9746050	213248.6308208	213511.2870365	213773.9432523	214137.7680159	214317.7680159		
4	-35.6	273678.7908679	275514.9253587	277551.0598495	279487.1943403	281423.3288311	289070.3891906	291536.5869692	294002.7847477	296468.9825262	298935.1803047	300522.3259920	300808.6554192	301094.9848464	301381.3142736	301667.6437008	303410.9449643	304130.9449643		
5	-36.1	353132.1871927	355202.3344487	357272.4817047	359342.6289608	361412.7762168	372254.6385882	381954.7039452	384591.6296382	387228.5553321	389865.4810256	392502.4067191	395139.3324126	397668.7254028	397974.8804171	398281.0354314	401398.1314007	401398.1314007		
6	-36.6	439267.8887269	441454.4516773	443641.0146276	445827.5775780	448014.1405284	459465.7000759	470917.2596234	482368.8191709	485939.4971355	488724.6592950	491509.8214545	494294.9836140	497080.1457734	499865.3079329	502650.4700924	506924.2654567	506924.2654567		
7	-37.1	532176.9528525	534466.9536552	536756.9778778	539046.9903904	541337.0029030	553330.3528536	565323.7028042	577317.0527548	589310.4027053	595569.2535396	598486.2090733	601403.1647870	604320.1205007	607237.0762140	610154.0319282	621178.3686541	621178.3686541		
8	-37.6	609316.7977459	621269.4334209	633222.0690960	639063.7150071	641447.3116674	653930.7844564	666414.2572454	678897.7300343	691381.2028233	703864.6756123	713470.9941249	716507.1779253	719543.3617257	722579.5455261	725615.7293265	744171.4779278	744171.4779278		
9	-38.1	680787.1320370	693128.5065153	705469.8809396	717811.2554718	730152.6299501	735312.7192607	766402.8147584	779292.9102561	792183.0057537	805073.1012514	817963.1967491	830714.3374004	838349.4123529	836984.4873054	840119.5622579	866387.6179891	866387.6179891		
10	-38.6	817047.7047222	831233.9683069	845420.2291916	859606.4900763	873792.7509610	891464.7767442	933281.6889001	948098.6010559	962915.5132117	977732.4253675	992549.3375233	1007366.2496791	1019222.8725361	1022826.5591252	1026430.2457143	1061375.3932096	1061375.3932096		
11	-39.1	866738.2668574	881036.7169916	895335.1671258	909633.6172601	923932.0673943	991290.6402418	1006224.6547217	1021158.6692015	1036092.6836814	1051026.6981613	1065960.7126411	1080894.7271120	1095828.7416008	1107020.4837361	1110652.6487212	1147633.2837167	1147633.2837167		
12	-39.6	907502.2006883	921863.4345872	936224.6684860	950585.9023848	964947.1362837	1040160.3951289	1066678.5426518	1081678.4285227	1096678.3070535	1111678.1892544	1126678.0714552	1141677.9536561	1156677.8358570	1171677.7180578	1180574.3628722	1217718.3488356	1217718.3488356		
13	-40.1	954970.1068102	969412.6630018	983855.2191935	998297.7753851	1012740.3315767	1088379.4949578	1136917.1224862	1152001.5879845	1167086.0534828	1182170.5189812	1197254.9844795	1212339.4499778	1227423.9154761	1242508.3809745	1257592.8464728	1299133.9054454	1299133.9054454		
14	-40.6	1008868.9731901	1023408.3941637	1037947.8151372	1052487.2361108	1067026.6570844	1143173.1247799	1216561.1665244	1231747.3221052	1246933.4777600	1262119.6334018	1277305.7890277	1292491.9446535	1307678.1002793	1322864.2559051	1337850.4115309	1391447.4211357	1391447.4211357		
15	-41.1	1078872.7867105	1093557.3440887	1108241.9014669	1122926.4588451	1137611.0162233	1214517.5984080	1291424.1805927	1334924.8160474	1350262.3847828	1365599.9535183	1380937.5222537	1396275.0909981	1411612.6597245	1426950.2284600	1442287.7971954	1510831.4300445	1510831.4300445		
16	-41.6	1188598.0323472	1173805.7493039	1188653.4662060	1203501.1832173	1218348.9001741	1296109.9885731	1373871.0769722	1451632.1653712	1468529.6858825	1484037.5485691	1499545.4112557	1515053.2739424	1530561.1366290	1546068.9993156	1561576.8620023	1647486.1420652	1647486.1420652		
17	-42.1	1242276.4971525	1257279.9974143	1272283.4976176	1287286.9979379	1300290.9979379	1380867.4614832	1459444.4247668	1538021.3800504	1591831.8820933	1607503.1099550	1623174.3370247	1638845.5644904	1654516.7919560	1670188.0194217	1685895.2468874	1760184.8317854	1760184.8317854		
18	-42.6	1328835.7749285	1343989.7646489	1359143.7543693	1374297.7404096	1389451.7338100	1468816.8468223	1548181.9598346	1627547.0728469	1706912.1858593	1736008.4565949	1751836.2257398	1767663.9948846	1783491.7640295	1799319.5331744	1815147.3023192	1938421.4320624	1938421.4320624		
19	-43.1	1418657.2940538	1433995.5025350	1449253.7110162	1464551.9194974	1479850.1279786	1559970.5495574	1640090.9711362	1720211.3927150	1800331.8142938	1889554.6860413	1885533.0890106	1901511.4919799	1917489.8949491	1933468.2979184	1949446.7008877	2092709.1289131	2092709.1289131		
20	-43.6	1511738.4003200	1527175.5656692	1542612.7310184	1558049.8963675	1573487.0617167	1654335.2340551	1735183.4063935	1816031.5787320	1909675.7510704	1977727.9234607	2024268.5021603	2056516.0186459	2072639.7768887	2088763.5531316	2252880.9311742	2252880.9311742	2252880.9311742		
21	-44.1	1608085.9537202	1623656.6901094	1639228.1848468	1654799.6905842	1670371.1743216	1751922.8612178	1833474.5005040	1915026.2379202	1986977.9257885	2061719.3163527	2159681.3051819	2184314.1482634	2200578.0888246	2216862.4293959	2231055.9699417	2389686.1487938	2389686.1487938		
22	-44.6	1718888.1841016	1734612.4870510	1750336.7900004	1766061.0929498	1781785.3958991	1864137.3737670	1946489.3858349	2028841.3403028	2111193.3217707	2193545.3032386	2275897.2847065	2349826.3184592	2366250.2621173	2382674.1037455	2399098.1494337	2566317.3886755	2566317.3886755		
23	-45.1	1835314.3243927	1851009.6670269	1866885.0096612	1882760.3522954	1898635.6949296	1981778.7077945	2084192.7206594	2184064.7335242	2231207.7463891	2314350.7938573	2397495.7221188	2480636.7849837	2540232.8209322	2556814.2071455	2573395.3937508	2742216.6702621	2742216.6702621		
24	-45.6	1955404.5736064	1971425.1732093	1987445.7728123	2003466.3724152	2019486.9720181	2103390.7307954	2187294.4895727	2271198.2483500	2355102.0071273	2439005.7659045	2522909.5246818	2606813.2834591	2690717.0422364	2737116.1071664	2753848.4819025	2924219.1721269	2924219.1721269		
25	-46.1	2091751.0332039	2107933.2540885	2124115.4749730	2140297.6958576	2156479.9167421	2241230.1253004	235980.3338507	2410350.5242170	2485190.7595753	2580230.9593585	2664981.0890918	2749731.7366501	2834481.5852084	2919231.9736651	2958471.8896267	3130559.0963614	3130559.0963614		
26	-46.6	2221204.1019331	2257772.4080912	2274124.1761022	2290475.9441132	2306827.7121243	2392465.8800320	2478104.0479397	2563742.2158475	2649380.3837552	2735018.5516629	2820656.7195707	2906294.8874784	2991933.0553861	3077571.2232939	3163209.3912016	3357091.7767253	3357091.7767253		
27	-47.1	2254499.7600046	2276656.0100003	2298812.2939959	2320968.5779916	2343124.8619872	2459162.6850927	2575200.5888227	2691238.3322404	2807276.1556582	2923313.9790759	3033886.5073964	3057028.5793969	3080170.6513975	3103312.7323980	3126454.7953985	3362074.1907735	3362074.1907735		
28	-47.6	2394339.3510604	2416548.5105742	2438757.6700808	2460966.8296018	2483175.9891156	2599490.7344234	2715805.4797312	2832120.2503900	2948434.9703468	3064749.7156546	3181064.4696324	3268239.0631129	3291435.6150069	3314632.1669030	3337828.7187950	3574002.7974138	3574002.7974138		
29	-48.1	2538660.2150212	2560918.8747753	2583177.5345293	2605436.1942834	2627694.8540374	2744268.8404375	2860841.8341377	2977416.8214878	3093990.8414239	3210564.8042880	3327138.7964381	3448371.2843882	3509506.4226842	3532755.1553565	3556004.6803888	3792714.0674683	3792714.0674683		
30	-48.6	2687434.1492887	2709741.3017459	2732048.4542031	2754355.0666603	2776662.7591175	2893490.7171943	3010318.6752711	3127146.6333479	3243974.5912447	3368082.5495015	3477630.5057983	3594458.4656552	3711286.4237320	3737696.9033122	3780096.1205487	4018215.4792059	4018215.4792059		
31	-49.1	2840697.7086935	2863051.1279063	2885404.5471192	2907757.9663320	2930111.3855488	3047181.6538222	3161425.1020996	3281532.1903770	3398										

PY-curves

Number	Level [mLAT]											
	113	1	104	105	106	107	108	109	110	111	112	113
	Number	Penetration depth [m]										
Y [m]	1	0	0.2072561	0.2681212	0.3289863	0.3898514	0.8903750	1.3908986	1.8914222	2.3919458	2.8924694	15.0000000
2		-34.6	76527.1918838	76527.2199577	76527.2480315	76527.2761054	76527.5069707	76527.7378359	76527.9687012	76528.1995665	76528.4304317	76534.0150000
3	-35.1	214137.8467402	214137.9254644	214138.0041887	214138.0829129	214138.7303011	214139.3776894	214140.0250776	214140.6724658	214141.3198540	214156.9800000	
4	-35.6	303411.0568102	303411.1686561	303411.2805020	303411.3923479	303412.3121115	303413.2318751	303414.1516388	303415.0714024	303415.9911661	303438.2400000	
5	-36.1	401631.2372910	401631.3856719	401631.5340528	401631.6824337	401632.9026425	401634.1228514	401635.3430602	401636.5632691	401637.7834779	401667.3000000	
6	-36.6	508798.4809452	508798.6688516	508798.8567581	508799.0446645	508800.5899112	508802.1351580	508803.6804048	508805.2256516	508806.7708983	508844.1500000	
7	-37.1	624626.6167703	624912.8121686	624913.0435250	624913.2748813	624915.1774381	624917.0799949	624918.9825517	624920.8851085	624922.7876653	624968.8100000	
8	-37.6	747760.6737966	749973.9067030	749974.1850161	749974.4633291	749976.7520338	749979.0407385	749981.3294431	749983.6181478	749985.9068525	750041.2700000	
9	-38.1	870093.7062369	873799.7944846	874301.9812382	874302.3065298	874304.9815621	874307.6565944	874310.3316267	874313.0066590	874315.6816914	874380.3900000	
10	-38.6	1065635.6330575	1069895.8729054	1071758.2236670	1071758.6210108	1071761.8885638	1071765.1561168	1071768.4236699	1071771.6912229	1071774.9587759	1071854.0000000	
11	-39.1	1156121.1554660	1160414.7395746	1163902.0818205	1163902.5175056	1163906.1003580	1163909.6832105	1163913.2660629	1163916.8489154	1163920.4317678	1164007.1000000	
12	-39.6	1231329.8469280	1235642.4063784	1239954.9658288	1240521.4031625	1240525.2194650	1240529.0357674	1240532.8520699	1240536.6683724	1240540.4846748	1240632.8000000	
13	-40.1	1318653.1598717	1322990.2707179	1327327.3815641	1329474.2502755	1329478.3253295	1329482.4003835	1329486.4754375	1329490.5504915	1329494.6255455	1329593.2000000	
14	-40.6	1417634.9691624	1422001.2582813	1426367.5474003	1430297.0534106	1430301.4435365	1430305.8336624	1430310.2237884	1430314.6139143	1430319.0040403	1430425.2000000	
15	-41.1	1545532.9581739	1549942.5511044	1545342.1440349	1558761.7369653	1560557.5931129	1560562.4249041	1560567.2566953	1560572.0884865	1560576.9202776	1560693.8000000	
16	-41.6	1685887.9207402	1696408.6015525	1700867.4082271	1705326.2149018	1709678.6510224	1709683.9277306	1709689.2044388	1709694.4811470	1709699.5758552	1709827.4000000	
17	-42.1	1828820.7041900	1849244.6677429	1853750.1623445	1858255.6594662	1865302.7004299	1865308.5039467	1865314.3074635	1865320.1109803	1865325.9144971	1865466.3000000	
18	-42.6	1977615.1919118	2008452.1592015	2013002.8222228	2017553.4852440	2027432.6444352	2027438.9536679	2027445.2629006	2027451.5721334	2027457.8813661	2027610.5000000	
19	-43.1	2132276.3653121	2171843.6017112	2178625.5183044	2183219.4624408	2196066.5254702	2196073.3816739	2196080.2378776	2196087.0940813	2196093.9502851	2196259.8000000	
20	-43.6	2292807.7549780	2332734.5787819	2350619.1820083	2355254.9041109	2371205.3165871	2371212.7371411	2371220.1576952	2371227.5784922	2371234.9988033	2371414.5000000	
21	-44.1	2459213.0550049	2499486.8761664	2528984.4326279	2533660.5546369	2552849.0448986	2552856.9969973	2552864.9890959	2552872.9811946	2552880.9732933	2553074.3000000	
22	-44.6	2650588.6454262	2691258.5084886	2731928.3715509	2738846.1845159	2761760.5581682	2761769.2365711	2761777.9149740	2761786.5933769	2761795.2717798	2762005.2000000	
23	-45.1	2851622.7945328	2892682.5444706	2933742.2944085	2954463.9566063	2981312.9713063	2981322.3977426	2981331.8241790	2981341.2506154	2981350.6770518	2981578.7000000	
24	-45.6	3059851.3047817	3101287.4161507	3142723.5275197	3177878.4114987	3208826.2136784	3208836.3764691	3208846.5392597	3208856.7020504	3208866.8648410	3209112.7000000	
25	-46.1	3295993.9539914	3337848.0330382	3379702.1120850	3421556.1911318	3466871.2053385	3466882.2322523	3466893.2609661	3466904.2896800	3466915.3183938	3467182.1000000	
26	-46.6	3530983.5849524	3597702.7236182	3639995.4952990	3682288.2669798	3750073.4063402	3750436.8718697	3750448.8480141	3750460.8241586	3750472.8003030	3750762.5000000	
27	-47.1	3439978.2604091	3497283.9408824	3534622.2832308	3541275.7470813	3567324.8672784	3567336.0640059	3567347.2607334	3567358.4574609	3567369.6541884	3567640.5000000	
28	-47.6	3684889.3785664	3742330.6469874	3798278.4919231	3804947.7295787	3836068.2211489	3836080.2886236	3836092.3560984	3836104.4235731	3836116.4910474	3836408.4000000	
29	-48.1	3937721.9944378	3995292.8945161	4052863.7945943	4077177.7091011	4113541.3977877	4113554.3884129	4113567.3790381	4113580.3696632	4113593.3602884	4113907.6000000	
30	-48.6	4198477.6061514	4256172.5151180	4313867.4240845	4357966.1165449	4399745.3654242	4399759.2939190	4399773.2221958	4399787.1504726	4399801.0787493	4400138.0000000	
31	-49.1	4467157.8482476	4524972.3001258	4582786.7520041	4640601.2038823	4694679.1177848	4694694.0339341	4694708.9500833	4694723.8662325	4694738.7823818	4695099.6000000	
32	-49.6	4727782.0394970	4801693.3672219	4859622.6243236	4917551.8814252	4998343.6296866	4998359.5530464	4998375.4762261	4998391.3994059	4998407.3225856	4998792.5000000	
33	-50.1	4974127.4085833	5086337.3543716	5144377.4484198	5202417.5424679	5307102.2517002	5310754.8707563	5310771.8561861	5310788.8416158	5310805.8270456	5311216.7000000	
34	-50.6	5227259.8880878	5378905.6062887	5437052.5678804	5495199.5294721	5622229.0041159	5631879.9587058	5631898.0589701	5631916.1592344	5631934.2594987	5632372.1000000	
35	-51.1	5487182.9717781	5679399.1320923	5737649.965306	5795899.6609689	5945912.5563308	5961735.7683100	5961755.0046796	5961774.2410492	5961793.4774188	5962258.8000000	
36	-51.6	5753900.3109450	5987819.0759166	6046169.1196574	6104519.1633982	6278153.1749449	6300322.2813910	6300342.6721273	6300363.0628636	6300383.4535999	6300876.7000000	
37	-52.1	6027415.4251515	6267725.4709027	6362613.2739929	6421060.0753445	6618950.0060654	6647638.5018956	6647660.1055714	6647681.7092471	6647703.3129229	6648225.9000000	
38	-52.6	6307730.0674789	6548425.7089154	6686982.6921036	6745523.2748786	6968305.1562144	7003684.3998240	7003707.2761152	7003730.1524065	7003753.0286977	7004306.4000000	
39	-53.1	6594846.7464676	6835916.5966795	7019278.3237963	7077909.9602999	7326217.7210065	7368460.9339400	7368485.1053830	7368509.2732260	7368533.4428690	7369118.1000000	
40	-53.6	6888767.7873105	7130201.6082190	7359501.2424599	7418221.1883810	7692688.0454159	7741967.0910479	7741992.6157206	7742018.1403933	7742043.6650660	7742661.1000000	
41	-54.1	7189496.3822968	7431283.5590179	7673070.7357391	7766458.0098772	8067716.9218868	8123864.6173748	8124230.7395564	8124257.6417219	8124284.5438875	8124935.3000000	
42	-54.6	7497034.9696649	7739165.3625094	7981295.7553539	8122621.1593062	8451304.1748978	8507531.5495870	8515198.4910500	8515226.8345632	8515255.1780764	8515940.8000000	
43	-55.1	7811382.2985992	8053847.6558914	8296313.0131836	8486711.4575094	8843450.1841615	8899755.4757505	8914896.8046210	8914926.6138396	8914956.4230583	8915677.5000000	
44	-55.6	8132541.5284089	8375333.3046319	8618125.0808548	8858729.7016036	9244154.9707820	9300535.8947393	9323324.6836568	9323356.0248105	9323387.3659641	9324145.5000000	
45	-56.1	8460514.5908338	8703624.6297490	8946734.6686642	9189844.7075794	9653419.0230405	9709873.9732391	9740483.0723514	9740515.9756176	9740548.8788838	9741344.8000000	
46	-56.6	8795304.9036127	9038724.7231924	9282144.5427722	9525564.3623519	10071242.2058854	10127769.0981043	10166370.9529292	10166405.4720739	10166439.9912187	10167275.0000000	
47	-57.1	9136908.3861837	9380631.5887814	9624354.7913790	9868077.9939766	10497624.8121267	10554222.2953309	10600989.2892746	10601025.4756245	10601061.6619745	10601937.0000000	
48	-57.6	9485329.8894932	9729349.1364809	9973368.3834686	10217387.6304563	1091451.3652860	10989233.1187520	11044337.0459496	11044374.9598213	11044412.8736929	11045330.0000000	
49	-58.1	9840573.1322137	10084881.3120279	10329189.4918421	10573497.6716563	11326396.0600577	11432802.3201161	11489535.9157641	11496454.8519386	11496494.5168366	11497454.0000000	
50	-58.6	10202632.9615015	10447224.2333148	10691815.5051281	10936406.7769415	11746560.3410066	11884929.5709619	11941728.8380587	11957264.1842009	11957305.7015755	11958310.0000000	
51	-59.1	10571510.6629774	10816379.5097487	11061248.3565200	11306117.2032913	12174644.6206568	12345615.2526251	12402478.5863654	12426802.8741436	12426846.3095385	12427897.0000000	
52	-59.6	10854170.7740443	11192353.4151161	11437493.2031521	11682632.9911881	12610649.3814017	12814859.7605847	12871786.0065385	12905071.8609698	12905117.2421249	12906215.0000000	
53	-60.1	11110368.0927920	11575144.3507855	11820549.3158799	12065954.2809743	13054575.4755750	13292663.3143865	13349651.4720665	13392071.1161963	13392118.4721551	13393264.0000000	
54	-60.6	11370981.8119654	11964753.0985296	12210417.9266425	12456082.7547554	13506423.6475983	13779025.6441201	13836074.1989119	13887799.6172017	13887849.0573034	13889045.0000000	
55	-61											

Resonance frequency tower

Tower geometry

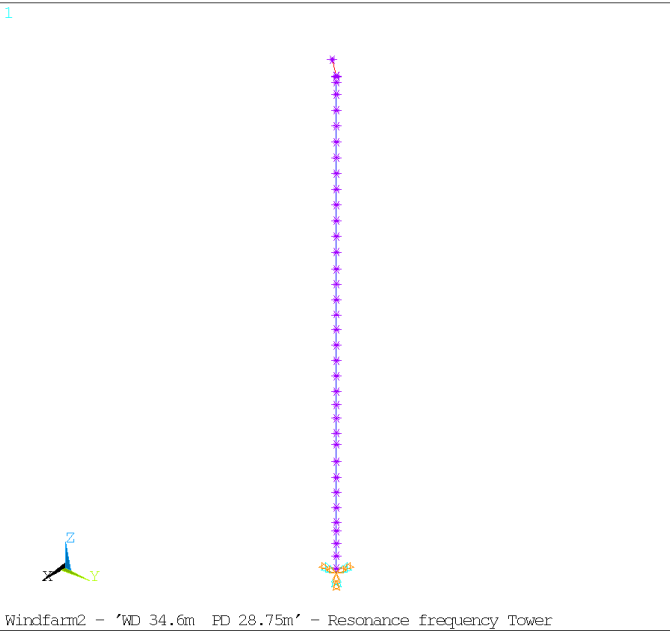
Hub Height at	108.045 [m LAT]
Top tower at	105.81 [mLAT]
Bottom tower at	19.15 [m LAT]

	Excel Input	FEM	Difference	Status
Tower wall height	86660.000	86660.000	0 [mm]	Oke
Tower - Nacelle	2235.238	2235.238	0.000325 [mm]	Oke
Tower shell mass	310143.309	310230.000	86.69134 [kg]	Oke
Tower added mass	562102.849	562103.000	0.150732 [kg]	Oke

Resonance Frequencies

1st resonance mode	0.3084 Hz	1st bending side-side
	0.3136 Hz	1st bending fore-aft
2e resonance mode	1.1123 Hz	1st torsion
3rd resonance mode	1.4882 Hz	2nd bending side-side
	1.8795 Hz	2nd bending fore-aft

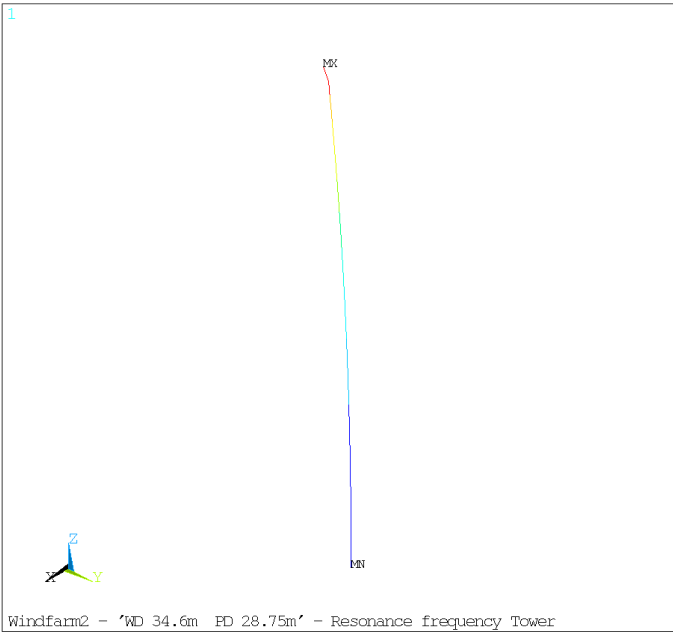
FE-model



ANSYS 2022 R2
Build 22.2
OCT 26 2023
14:04:23
PLOT NO. 1
ELEMENTS
PowerGraphics
EFACET=1
TYPE NUM
ROT

1st resonance mode

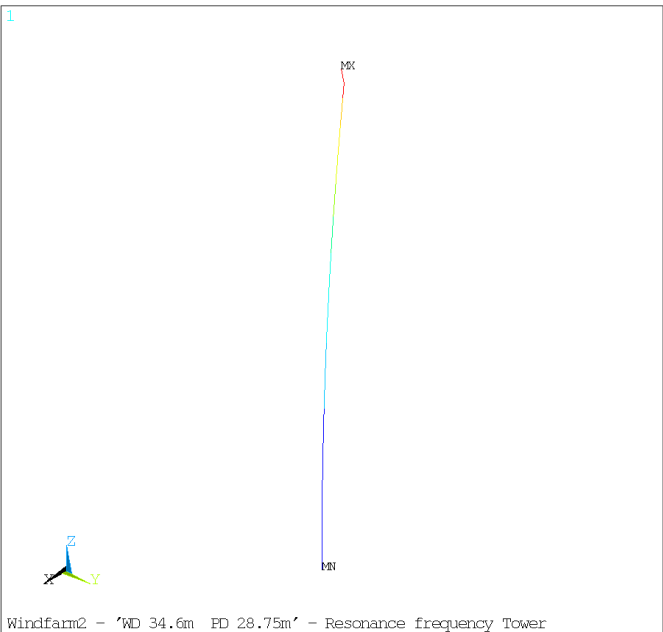
1st bending side-side



ANSYS 2022 R2
Build 22.2
OCT 26 2023
14:05:55
PLOT NO. 1
NODAL SOLUTION
SUB =1
FREQ=.309362
USUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.001316
SMX =.001316

- 0
- .132E-03
- .263E-03
- .395E-03
- .526E-03
- .658E-03
- .790E-03
- .921E-03
- .001053
- .001184
- .001316

1st bending fore-aft

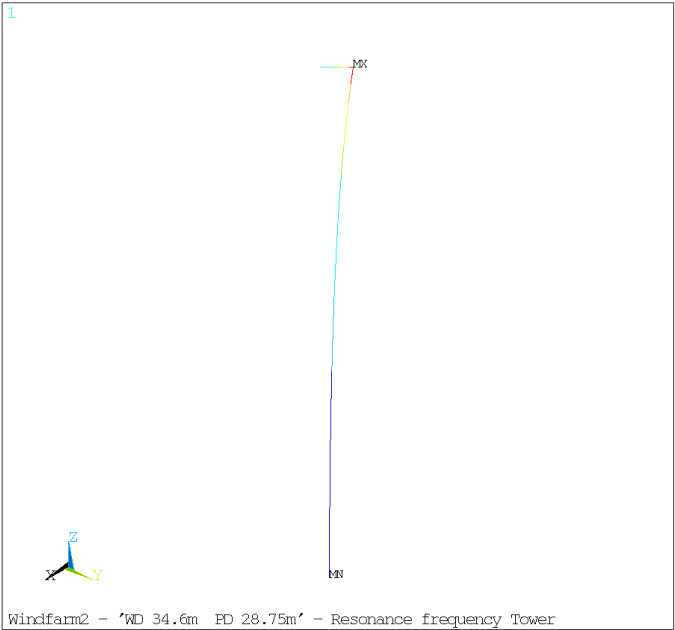


ANSYS 2022 R2
Build 22.2
OCT 26 2023
14:06:17
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =2
FREQ=.313583
USUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.001339
SMX =.001339

- 0
- .134E-03
- .268E-03
- .402E-03
- .536E-03
- .669E-03
- .803E-03
- .937E-03
- .001071
- .001205
- .001339

2e resonance mode

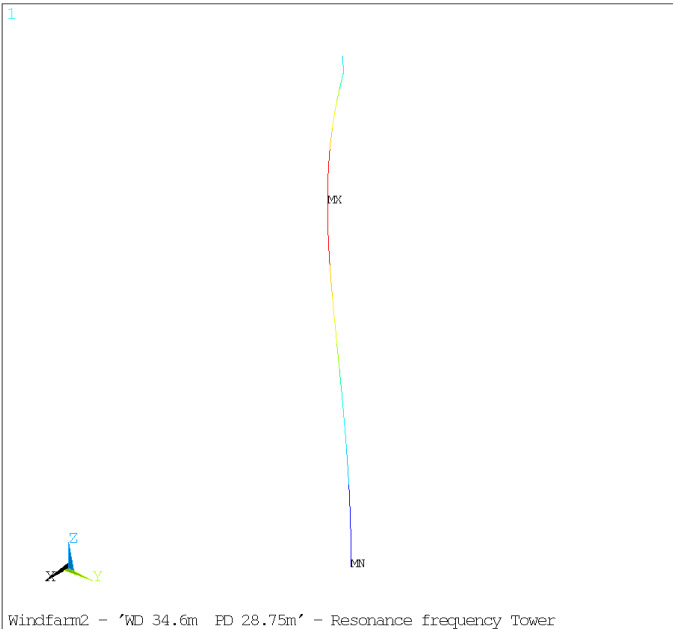
1st torsion



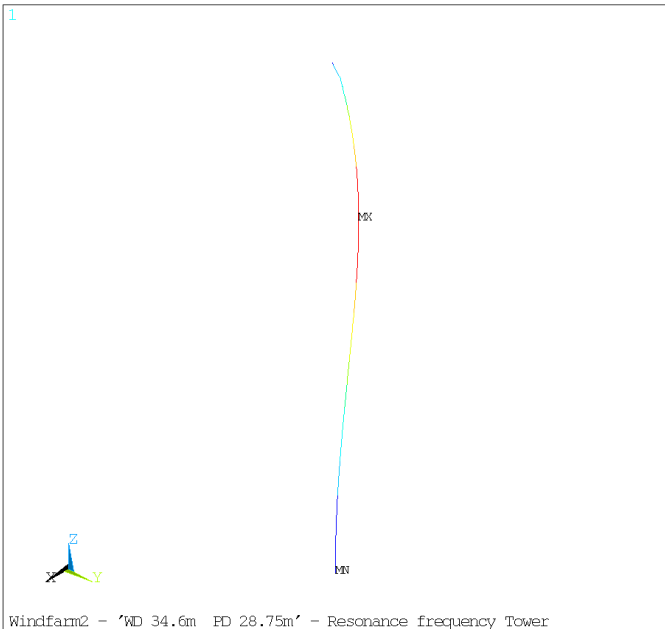
ANSYS 2022 R2
Build 22.2
OCT 26 2023
14:06:24
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NODAL SOLUTION
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SUB =3
FREQ=1.11234
USUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.855E-04
SMX =.855E-04
0
.855E-05
.171E-04
.256E-04
.342E-04
.427E-04
.513E-04
.598E-04
.684E-04
.769E-04
.855E-04

3rd resonance mode

2nd bending side-side



2nd bending fore-aft



Resonance frequency total foundation

Foundation geometry

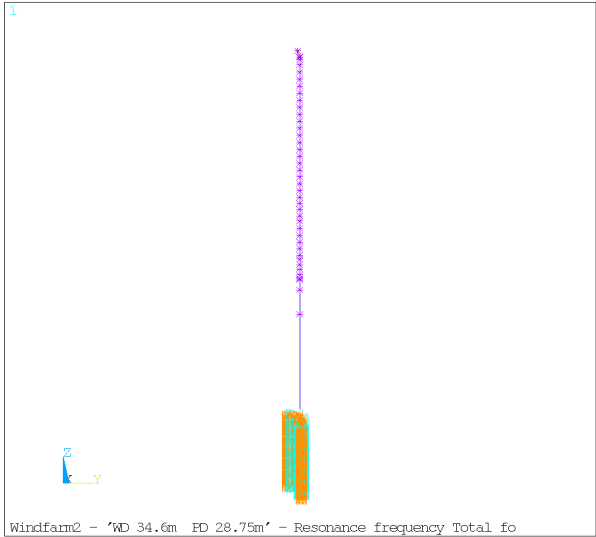
Hub Height at	108.045 [m LAT]
Top tower at	105.81 [mLAT]
Bottom tower at	19.15 [m LAT]
Top pile at	19.15 [m LAT]
Bottom pile at	-63.35 [m LAT]

	Excel Input	FEM	Difference	Status
Tower wall height	86660.000	86660.000	0 [mm]	Oke
Tower - Nacelle	2235.238	2235.238	0.000325 [mm]	Oke
Tower shell mass	310143.309	310230.000	86.69134 [kg]	Oke
Tower added mass	562102.849	562103.000	0.150732 [kg]	Oke
Pile length	82500.000	82500.000	0 [mm]	Oke
Pile shell mass	967504.087	967690.000	185.9126 [kg]	Oke
Pile added mass	44500.000	44500.000	0 [kg]	Oke
Mass internal water in pile		1443820.000	[kg]	
Added external water mass		1801470.000	[kg]	

Resonance Frequencies

1st resonance mode	0.2050 Hz	1st bending side-side
	0.2064 Hz	1st bending fore-aft
2e resonance mode	0.8411 Hz	2nd bending side-side
	0.8845 Hz	2nd bending fore-aft
3rd resonance mode	1.0355 Hz	1st torsion
4th resonance mode	1.5220 Hz	3rd bending side-side
	1.7883 Hz	3rd bending fore-aft

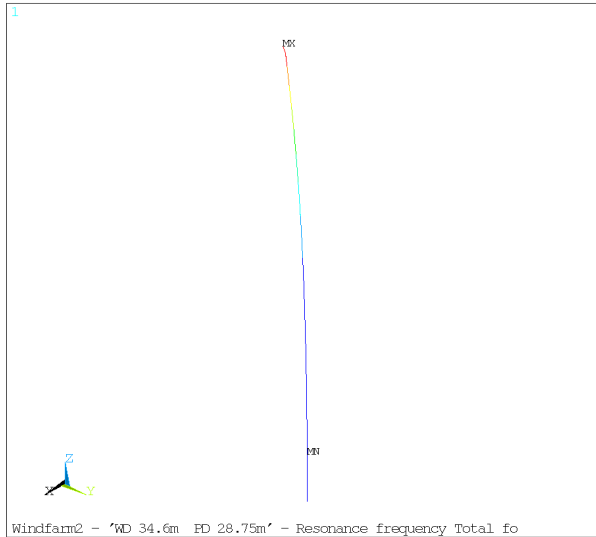
FE-model



ANSYS 2022 R2
Build 22.2
OCT 26 2023
16:47:25
PLOT NO. 1
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PowerGraphics
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TYPE NUM
0
ROT

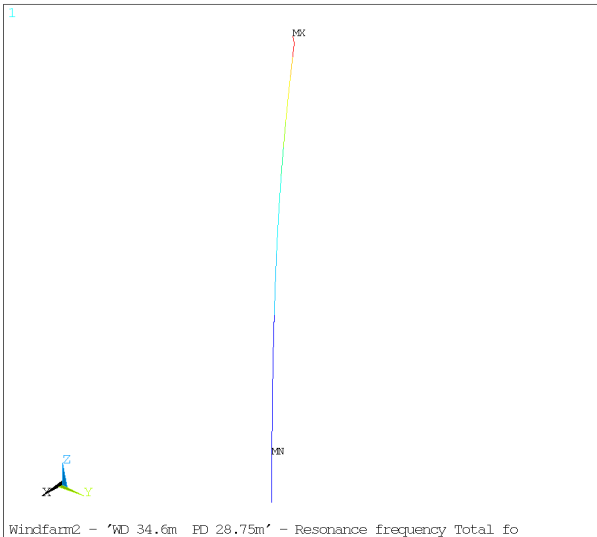
1st resonance mode

1st bending side-side



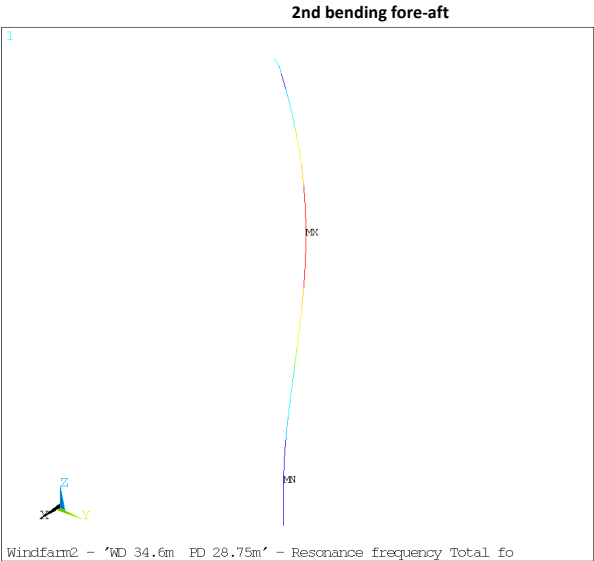
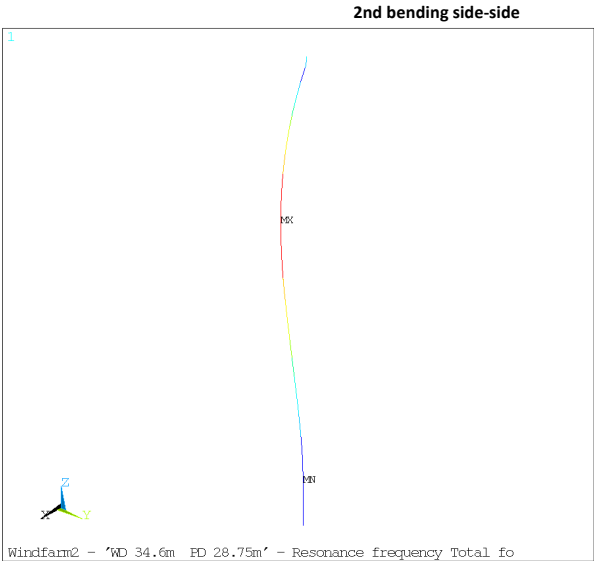
ANSYS 2022 R2
Build 22.2
OCT 26 2023
16:42:57
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USUM (AVG)
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PowerGraphics
EFACET=1
AVRES=Mat
DMX = .001288
SMX = .001288
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.258E-03
.386E-03
.515E-03
.644E-03
.773E-03
.902E-03
.00103
.001159
.001288

1st bending fore-aft

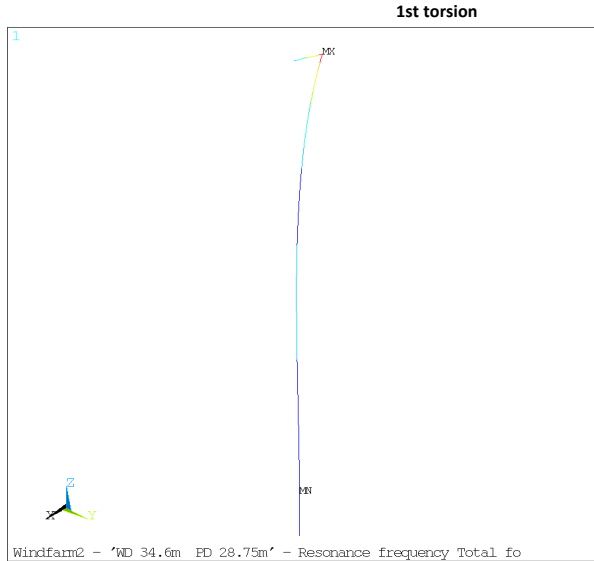


ANSYS 2022 R2
Build 22.2
OCT 26 2023
16:43:08
PLOT NO. 1
MODAL SOLUTION
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SUB =2
FREQ= .206353
USUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX = .001296
SMX = .001296
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.259E-03
.389E-03
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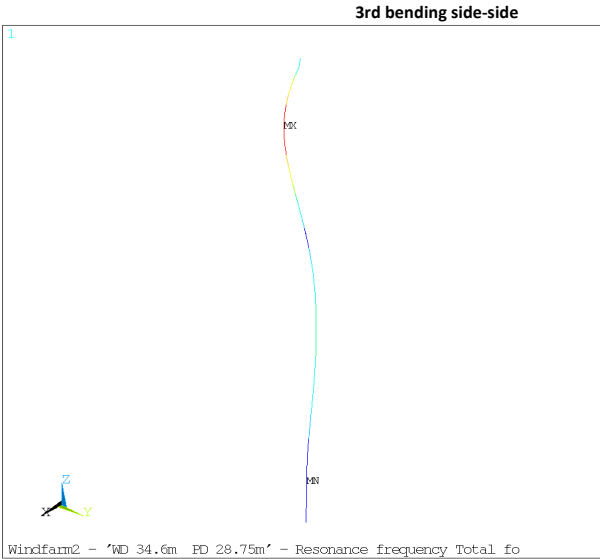
2nd resonance mode



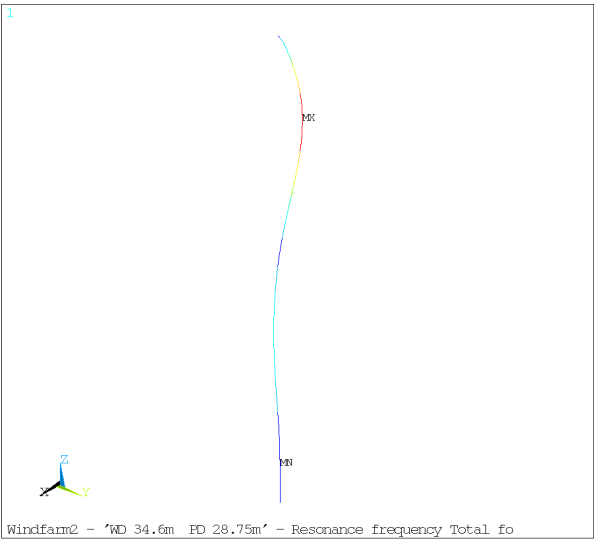
3rd resonance mode



4th resonance mode



3rd bending fore-aft

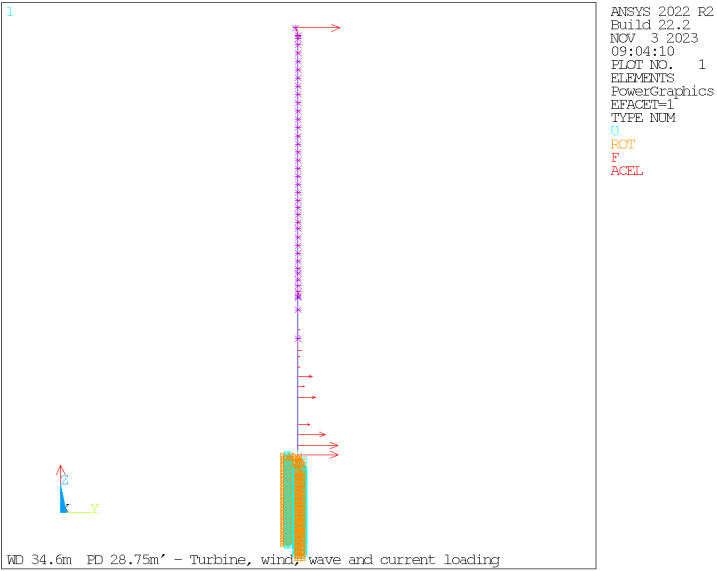
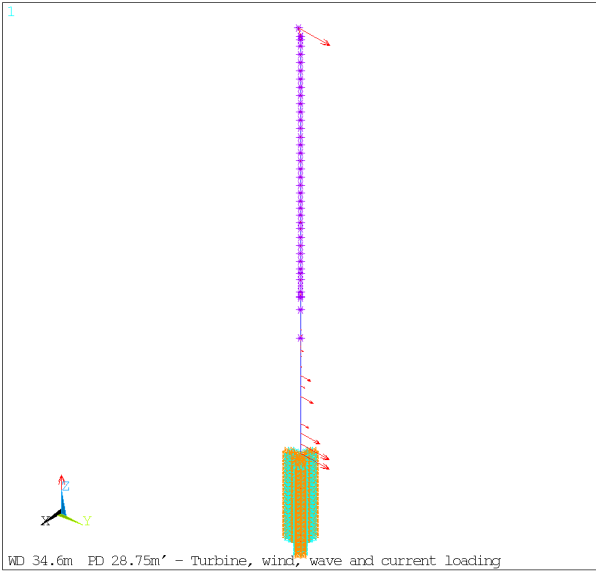


Turbine, wind, wave and current load

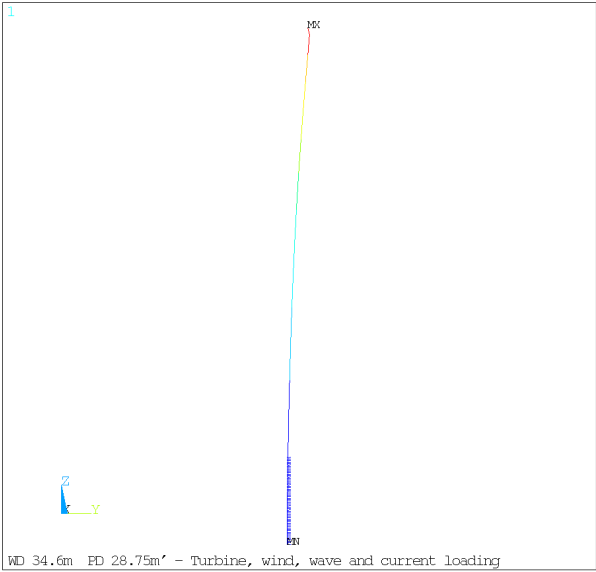
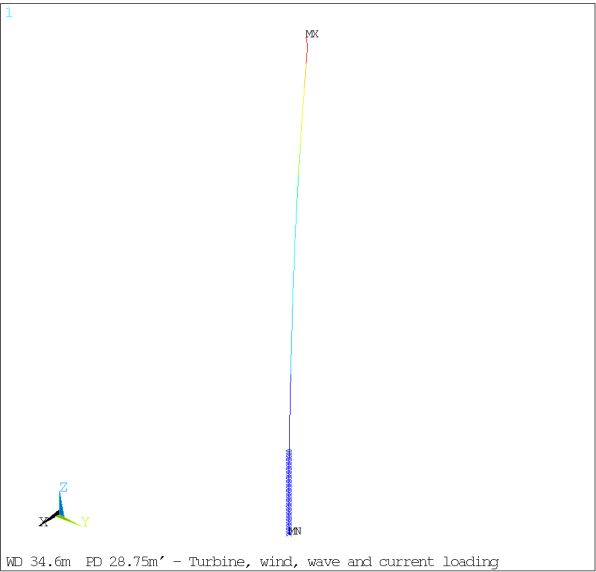
Foundation geometry

Hub Height at	108.045 [m LAT]
Top tower at	105.81 [mLAT]
Bottom tower at	19.15 [m LAT]
Top pile at	19.15 [m LAT]
Bottom pile at	-63.35 [m LAT]

Applied load according to sheet 'Loads input sheet', including gravity load of 9.81 [m/s^2].



Calculation executed with 'Large displacement on', so the excentricity caused by the bending of the foundation leads to an additional bending moment due to the gravity load.
The maximum lateral displacement is equal to 0.718 [m]



The applied load (theoretical Shear load) and the theoretical calculated Bending load, see sheet 'Wind farm 2 Loads') are compared with the Shear load and Bending moment following from FEM.

The graphs below show:

1. The Theoretical applied shear load corresponds with the shear load following from FEM.

2. The resulting theoretical bending moment corresponds well with the bending load following from FEM.

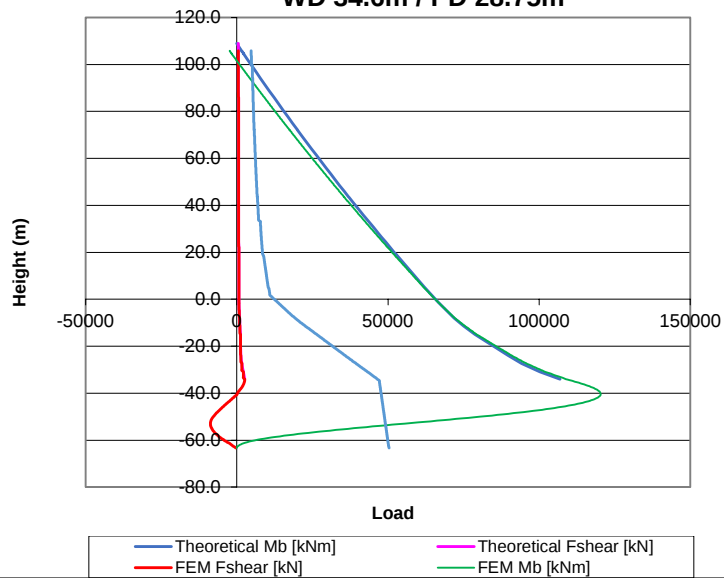
The difference near the top of the foundation is caused by the gravity load acting on the tower and the turbine.

The excentric position of the COG of the turbine relative to the centre line of the foundation leads to a negative moment due to the effect of the gravity

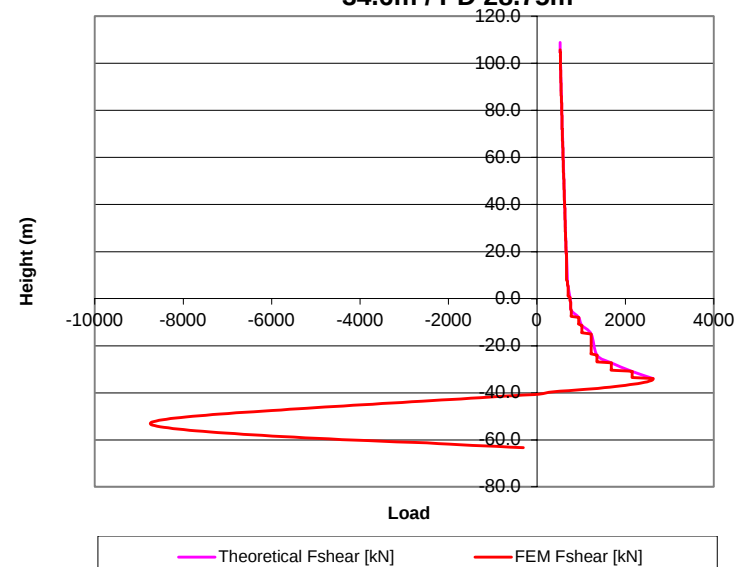
3. The bending moment in the foundation reaches its maximum value inside the soil, at LAT-40m.

Lower down the bending moment reduces to 0 and the shear force becomes negative.

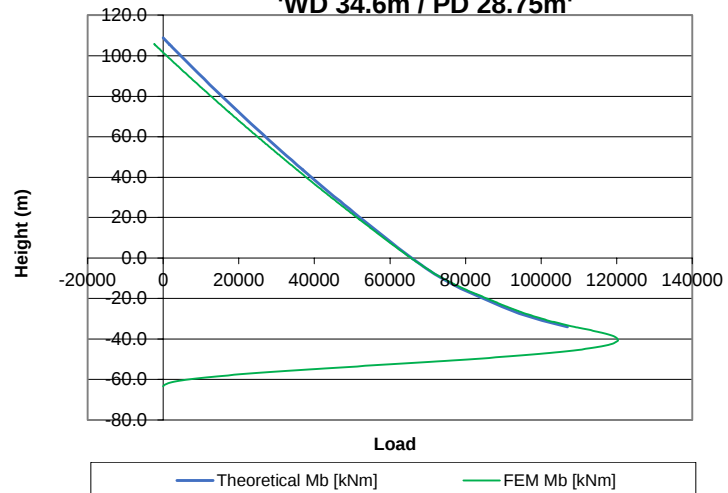
**Total load in cross-section for windfarm 2, foundation
'WD 34.6m / PD 28.75m'**



**Total load in cross-section for windfarm 2, foundation 'WD
34.6m / PD 28.75m'**



**Total load in cross-section for windfarm 2, foundation
'WD 34.6m / PD 28.75m'**



Z	FY	FZ	MX
[m LAT]	[kN]	[kN]	[kNm]
105.810	525.08	4692.90	-2403.30
105.680	525.22	4708.90	-2330.10
105.580	525.35	4711.70	-2273.80
105.480	525.88	4714.70	-2217.40
105.100	525.88	4725.00	-2002.90
104.720	526.37	4735.40	-1788.30
104.690	526.44	4736.10	-1771.40
104.610	526.54	4749.80	-1726.20
104.520	526.62	4765.90	-1675.30
104.490	527.94	4767.30	-1658.30
103.965	527.94	4778.80	-1360.60
103.440	527.94	4790.30	-1062.80
102.915	527.94	4801.80	-764.97
102.390	530.99	4814.00	-467.08
101.930	530.99	4822.20	-204.60
101.470	530.99	4830.40	57.91
101.010	530.99	4838.60	320.45
100.550	530.99	4846.80	583.02
100.090	530.99	4855.00	845.62
99.630	534.51	5109.20	1108.20
99.172	534.51	5117.50	1372.50
98.713	534.51	5125.80	1636.70

98.255	534.51	5134.10	1901.00
97.797	534.51	5142.50	2165.30
97.338	534.51	5150.80	2429.60
96.880	538.09	5159.90	2693.90
96.422	538.09	5168.30	2959.80
95.963	538.09	5176.80	3225.80
95.505	538.09	5185.20	3491.80
95.047	538.09	5193.70	3757.80
94.588	538.09	5202.30	4023.80
94.130	541.73	5211.50	4289.80
93.672	541.73	5220.30	4557.40
93.213	541.73	5229.10	4825.10
92.755	541.73	5237.90	5092.70
92.297	541.73	5246.80	5360.40
91.838	541.73	5255.70	5628.00
91.380	545.43	5265.30	5895.70
90.923	545.43	5274.40	6164.00
90.467	545.43	5283.50	6432.40
90.010	545.43	5292.60	6700.70
89.553	545.43	5301.80	6969.00
89.097	545.43	5310.90	7237.30
88.640	549.18	5320.90	7505.60
88.183	549.18	5330.30	7775.60
87.727	549.18	5339.80	8045.60
87.270	549.18	5349.30	8315.60
86.813	549.18	5358.80	8585.50
86.357	549.18	5368.40	8855.40
85.900	553.00	5378.80	9125.30
85.443	553.00	5388.80	9397.00
84.987	553.00	5398.80	9668.60
84.530	553.00	5408.90	9940.20
84.073	553.00	5419.00	10212.00
83.617	553.00	5429.10	10483.00
83.160	556.87	5440.00	10755.00
82.705	556.87	5450.60	11027.00
82.250	556.87	5461.10	11299.00
81.795	556.87	5471.70	11572.00
81.340	556.87	5482.30	11844.00
80.885	556.87	5493.00	12116.00
80.430	560.81	5504.50	12388.00
79.975	560.81	5515.60	12662.00
79.520	560.81	5526.70	12936.00
79.065	560.81	5537.80	13210.00
78.610	560.81	5548.90	13484.00
78.155	560.81	5560.10	13757.00
77.700	564.80	5572.20	14031.00
77.245	564.80	5583.80	14307.00
76.790	564.80	5595.50	14582.00

76.335	564.80	5607.20	14858.00
75.880	564.80	5618.90	15133.00
75.425	564.80	5630.70	15409.00
74.970	568.85	5643.40	15684.00
74.517	568.85	5655.60	15960.00
74.063	568.85	5667.70	16237.00
73.610	568.85	5679.90	16513.00
73.157	568.85	5692.10	16789.00
72.703	568.85	5704.40	17065.00
72.250	570.92	5716.70	17341.00
72.220	571.01	5717.50	17359.00
72.130	571.14	5743.50	17414.00
72.040	571.23	5769.40	17469.00
72.010	573.23	5771.20	17488.00
71.577	573.23	5783.30	17754.00
71.143	573.23	5795.50	18019.00
70.710	573.23	5807.70	18285.00
70.277	573.23	5819.90	18551.00
69.843	573.23	5832.10	18817.00
69.410	577.30	5845.50	19083.00
68.960	577.30	5858.60	19360.00
68.510	577.30	5871.70	19638.00
68.060	577.30	5884.90	19916.00
67.610	577.30	5898.10	20193.00
67.160	577.30	5911.30	20471.00
66.710	581.50	5925.70	20749.00
66.262	581.50	5939.30	21027.00
65.813	581.50	5952.90	21305.00
65.365	581.50	5966.50	21584.00
64.917	581.50	5980.20	21862.00
64.468	581.50	5993.90	22140.00
64.020	585.75	6008.80	22419.00
63.573	585.75	6022.80	22698.00
63.127	585.75	6036.90	22977.00
62.680	585.75	6051.10	23256.00
62.233	585.75	6065.20	23535.00
61.787	585.75	6079.40	23814.00
61.340	590.07	6094.80	24092.00
60.892	590.07	6109.40	24374.00
60.443	590.07	6124.00	24656.00
59.995	590.07	6138.70	24938.00
59.547	590.07	6153.40	25220.00
59.098	590.07	6168.10	25501.00
58.650	594.46	6184.10	25783.00
58.203	594.46	6199.10	26065.00
57.757	594.46	6214.10	26348.00
57.310	594.46	6229.20	26630.00
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56.417	594.46	6259.50	27195.00
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55.080	598.90	6306.90	28044.00
54.635	598.90	6322.40	28327.00
54.190	598.90	6338.00	28610.00
53.745	598.90	6353.60	28893.00
53.300	603.41	6370.50	29176.00
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49.222	607.69	6519.80	31792.00
48.756	607.69	6537.10	32092.00
48.290	611.70	6555.60	32392.00
47.830	611.70	6572.90	32690.00
47.370	611.70	6590.30	32988.00
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46.450	611.70	6625.30	33583.00
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43.680	617.88	6733.80	35385.00
43.570	618.07	6771.70	35457.00
43.460	618.21	6809.60	35529.00
43.420	620.02	6812.30	35555.00
42.920	620.02	6832.70	35883.00
42.420	620.02	6853.00	36210.00
41.920	620.02	6873.30	36538.00
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20.384	657.99	8441.90	51040.00
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19.330	661.05	8503.40	51767.00
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9.731	670.73	9847.50	58509.00
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8.783	670.73	9949.30	59175.00
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6.360	689.82	10226.00	60897.00
5.860	689.82	10288.00	61258.00
5.360	702.52	10351.00	61619.00
4.930	702.52	10397.00	61935.00
4.500	702.52	10639.00	62251.00
4.060	702.52	10686.00	62575.00
3.620	702.52	10734.00	62898.00
3.145	702.52	10785.00	63247.00
2.670	702.52	10836.00	63596.00
2.195	702.52	10887.00	63945.00
1.720	702.52	10938.00	64294.00
1.620	702.52	11020.00	64368.00
1.080	702.52	11467.00	64765.00
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-5.500	778.27	16994.00	69986.00
-6.000	778.27	17425.00	70398.00
-6.500	778.27	17865.00	70810.00
-7.000	778.27	18313.00	71223.00
-7.500	778.27	18770.00	71636.00

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-9.911	943.25	21080.00	73949.00
-10.389	943.25	21563.00	74425.00
-10.867	943.25	22054.00	74901.00
-11.345	1013.60	22554.00	75377.00
-11.802	1013.60	23036.00	75866.00
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-12.716	1013.60	23998.00	76843.00
-13.173	1013.60	24479.00	77333.00
-13.629	1013.60	24960.00	77823.00
-14.086	1013.60	25441.00	78313.00
-14.543	1013.60	25923.00	78803.00
-15.000	1222.90	26404.00	79294.00
-15.500	1222.90	26927.00	79936.00
-16.000	1222.90	27451.00	80578.00
-16.500	1222.90	27975.00	81221.00
-17.000	1222.90	28498.00	81864.00
-17.500	1222.90	29022.00	82508.00
-18.000	1222.90	29545.00	83151.00
-18.500	1222.90	30069.00	83795.00
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-19.500	1222.90	31116.00	85084.00
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-21.000	1222.90	32687.00	87018.00
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-26.357	1359.70	38314.00	94261.00
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-27.300	1680.90	39309.00	95609.00
-27.814	1680.90	39863.00	96510.00
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-28.843	1680.90	40971.00	98311.00
-29.357	1680.90	41525.00	99212.00
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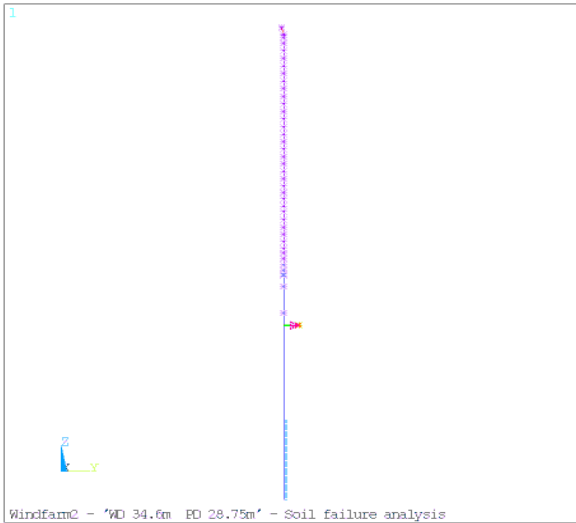
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-34.600	2608.40	47087.00	110430.00
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-45.100	-3938.90	48261.00	110710.00
-45.600	-4376.10	48317.00	108540.00
-46.092	-4796.60	48371.00	106200.00
-46.584	-5199.10	48425.00	103660.00
-47.077	-5589.10	48480.00	100920.00
-47.569	-5991.00	48534.00	97990.00
-48.061	-6404.50	48588.00	94852.00
-48.553	-6799.40	48642.00	91520.00
-49.045	-7161.80	48696.00	88009.00
-49.538	-7490.30	48750.00	84335.00
-50.030	-7786.80	48805.00	80515.00
-50.522	-8053.10	48859.00	76563.00
-51.014	-8280.30	48913.00	72499.00
-51.506	-8465.30	48967.00	68344.00
-51.998	-8608.20	49021.00	64117.00
-52.491	-8699.90	49075.00	59846.00
-52.983	-8741.90	49130.00	55553.00
-53.475	-8724.70	49184.00	51268.00
-53.967	-8647.60	49238.00	47021.00
-54.459	-8516.60	49292.00	42838.00

-54.952	-8336.40	49346.00	38744.00
-55.444	-8111.70	49401.00	34760.00
-55.936	-7848.90	49455.00	30905.00
-56.428	-7548.60	49509.00	27198.00
-56.920	-7211.40	49563.00	23657.00
-57.413	-6837.60	49617.00	20301.00
-57.905	-6427.10	49671.00	17146.00
-58.397	-5979.60	49726.00	14211.00
-58.889	-5494.50	49780.00	11515.00
-59.381	-4971.20	49834.00	9077.30
-59.873	-4408.90	49888.00	6916.10
-60.366	-3807.70	49942.00	5051.00
-60.858	-3164.70	49996.00	3502.60
-61.350	-2486.00	50051.00	2288.50
-61.850	-1989.00	50119.00	1303.90
-62.350	-1459.20	50187.00	584.36
-62.850	-899.79	50255.00	144.71
-63.350	-310.25	50323.00	0.00

Soil failure load

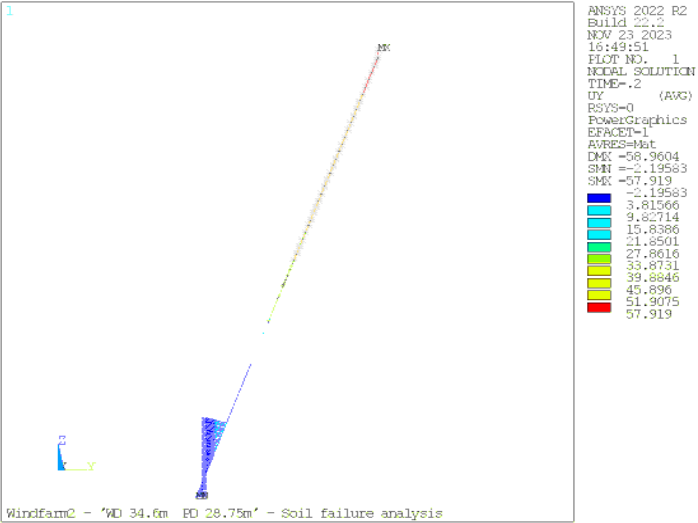
Tower geometry	
Hub Height at	108.045 [m LAT]
Top tower at	105.81 [mLAT]
Bottom tower at	19.15 [m LAT]
Top pile at	19.15 [m LAT]
Bottom pile at	-63.35 [m LAT]
Load application point at	1.72 [m LAT]

Applied load 1.72 [m LAT], no gravity load

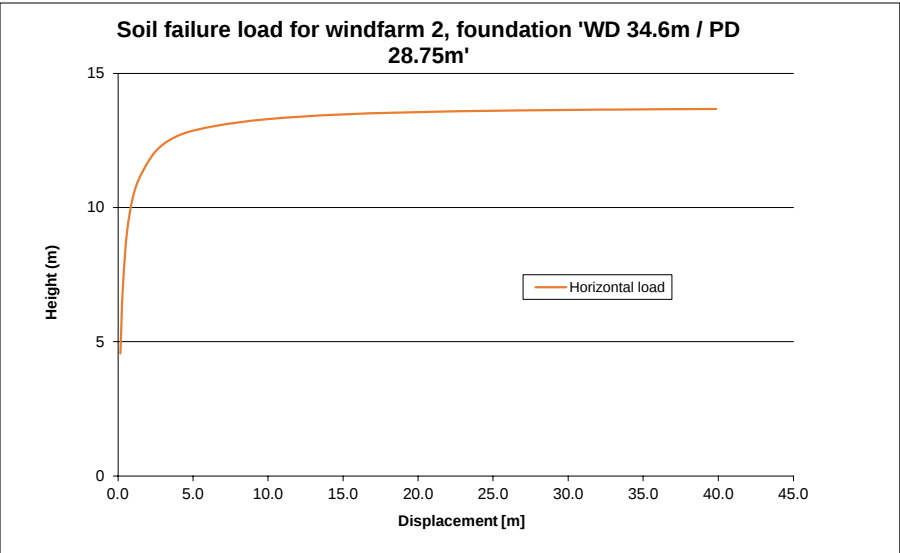
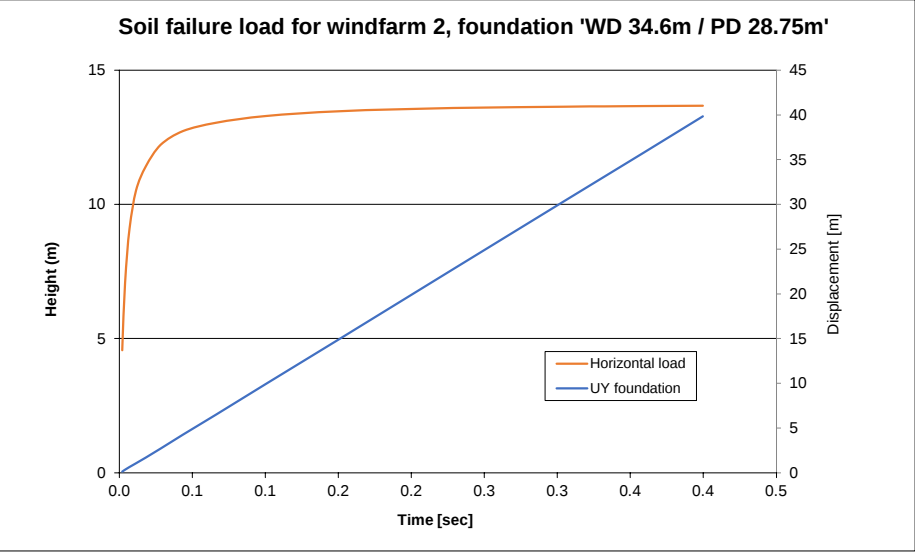


ANSYS 2022 R2
Build 22.2
NOV 23 2023
16:47:20
PLOT NO. 1
ELEMENTS
PowerGraphics
EPACET=1
TYPE NUM
CE

The ship springs are assumed to be linear springs and the ship displacement is gradually increased, pulling the pile in the +Y-direction.
The foundation has been given linear elastic properties so that no plastic deformation of the foundation occurs.
The force gradually increases as function of the soil resistance and reaches a maximum when all PY-curves reach their maximum resistance.



The applied horizontal load and the foundation displacement at the load application point is shown below as function of time.
Also the applied horizontal load at the load application point is shown below as function of the foundation displacement at the load application point.
The soil failure load is equal to :13.7 [MN]



Time	UY foundation	Horizontal load
[sec]	[m]	[MN]
0.002	0.15	4.57
0.004	0.33	7.08
0.007	0.61	9.12
0.012	1.04	10.52
0.018	1.71	11.43
0.028	2.72	12.22
0.044	4.23	12.74
0.066	6.50	13.05
0.101	9.92	13.30
0.152	15.04	13.48
0.229	22.73	13.59
0.306	30.42	13.65
0.332	33.11	13.66
0.359	35.81	13.67
0.400	39.85	13.68