

Data for foundation structure analysis

This document provides lines of directions for:

- Extreme and fatigue load data and minimum stiffness on foundation unit
- Dimensions for the bottom of the tower
- Lines of directions for necessary soil investigation
- Foundation design assistance

1. Extreme and fatigue load data and minimum stiffness

Dependent on IEC-Wind class, the foundation loads will be different. It should be noticed that the survival wind speed is normally determining the extreme bending moment on the foundation unit and thus determining the foundation design.

In the following the main design parameters for the major IEC classes are outlined. A class S can be defined if the site wind condition does not match the standard classes.

Since the survival wind speed is determining the extreme bending moment on the foundation unit and since the wind turbine foundation design is normally determined by the extreme bending moment, the relation between the high IEC wind classes and the extreme wind speed in hub height is outlined in the following:

IEC terrain Class	Reference wind speed [m/s]	Extreme steady wind speed in hub height [m/s]	Average wind speed in hub height [m/s]	Turbulence at 15 m/s [%]	Power law exponent	Air density [kg/m ³]
I-A	50	70	10	18	0.2	1.25
I-B	50	70	10	16	0.2	1.25
II-A	42.5	59.5	8.5	18	0.2	1.25
II-B	42.5	59.5	8.5	16	0.2	1.25
III-A	37.5	52.5	7.5	18	0.2	1.25

In the following schemes the applicable load documents for the different IEC classes are mentioned.

65 m tower height:

IEC terrain Class	Applicable load document
I-A	NA
I-B	N47-65-IEC1B-FoundLoads-02.pdf
II-A	N47-65-IEC2A-FoundLoads-01.pdf
II-B	NA
III-A	NA

45 m tower height:

IEC terrain Class	Applicable load document
I-A	NA
I-B	N47-45-IEC1B-FoundLoads-01.pdf
II-A	NA
II-B	NA
III-A	NA

2. Tower bottom dimensions

The tower bottom is available in two options. The following contains a description of the dimensions for these. Further, examples of commonly used foundations fitting these two tower bottom options are shown.

Option 1: A single inside flange.

The foundation is in this case made with an equal single top flange that is part of a welded steel foundation unit that is cast into the steel armored concrete foundation.

For this type of foundation the foundation designed must also provide specification of the surface protection system for the steel unit.

In figure 1 an Example layout for a low wind class foundation with cast in steel unit is shown.

In figure 2 the upper side steel armor for the same foundation is shown.

Figure 3 and 4 shows pictures of the foundation during construction.

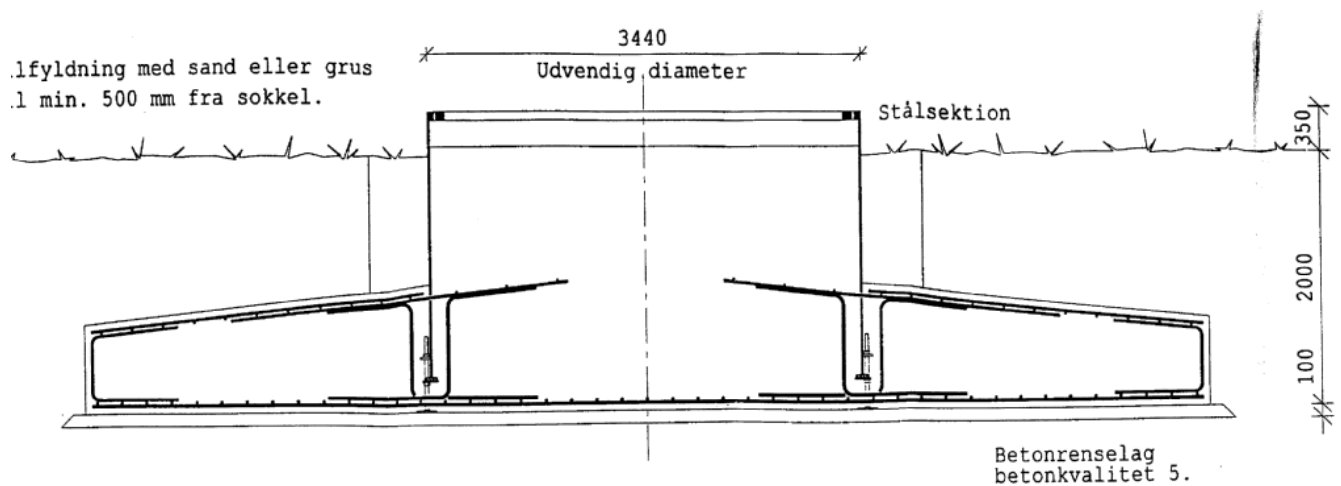


Figure 1. Example layout for a low wind class foundation with cast in steel unit (N47-45m).

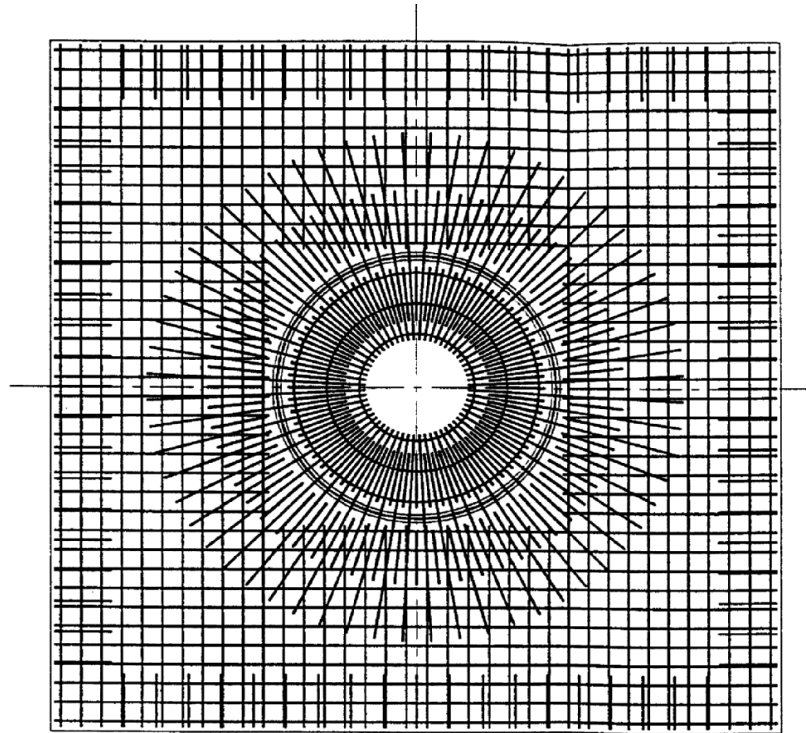


Figure 2. Example of upper side steel armor for a foundation with cast in steel unit.



Figure 3

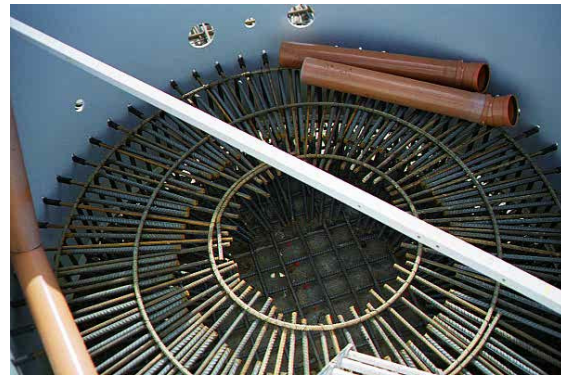


Figure 4

The dimensions for the tower bottom flange for this option are given below. In figure 5, the dimensions for the N47-65 m tower for wind class IB is shown for reference.

Norwin 47 – 65 m tower; single flange bottom dimensions. IEC-Class-IB:	
Inner flange diameter:	3555 mm
Bolt circle diameter:	3814 mm
Outer flange diameter:	3960 mm
Flange thickness:	80 mm
Number of bolts:	168
Bolt hole size:	Ø 33 mm
Flange steel type:	ISO-S275J2G4
Bolt type:	ISO4014-M30-200-10.9-HDG (Hot Dip Galvanized)

Norwin 47 – 45 m tower; single flange bottom dimensions. IEC-Class-IB:	
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Inner flange diameter:	3160 mm
Bolt circle diameter:	3320 mm
Outer flange diameter:	3440 mm
Flange thickness:	65 mm
Number of bolts:	144
Bolt hole size:	Ø 33 mm
Flange steel type:	ISO-S275J2G4
Bolt type:	ISO4014-M30-180-10.9-HDG (Hot Dip Galvanized)

Lubrication of bolts before tightening: Molycote

Tightening torque for class 10.9 bolts with above lubrication: 1450 Nm

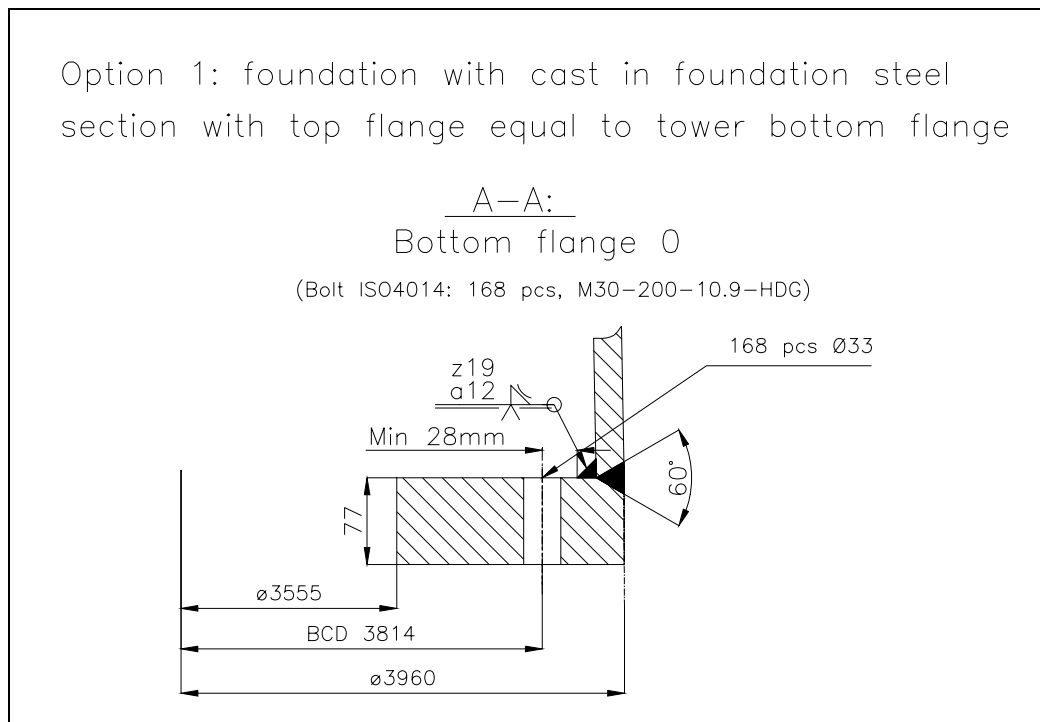


Figure 5. Dimension example for wind class I-B N47-65 m tower bottom

Option 2: A double side flange.

The foundation is in this case made with long cast in bolts (threaded bars) with an anchor ring in the bottom.

For this type of foundation the tower has to be mounted in to stages divided by the curing time of the under cast material. Stage 1: The tower bottom section is placed on nuts screwed onto 3 of the cast in bolts. The tower section is then leveled out and secured with upper nuts and under cast is made except in the 3 places with nuts. After curing the nuts are removed and under cast is made in these 3 places. Stage 2: All the nuts can now be tightened and the upper section(s) of the tower can be mounted.

The dimensions for the tower bottom flange for this option are given below. In figure 6, the dimensions for the N47-65 m tower for wind class IB is shown for reference.

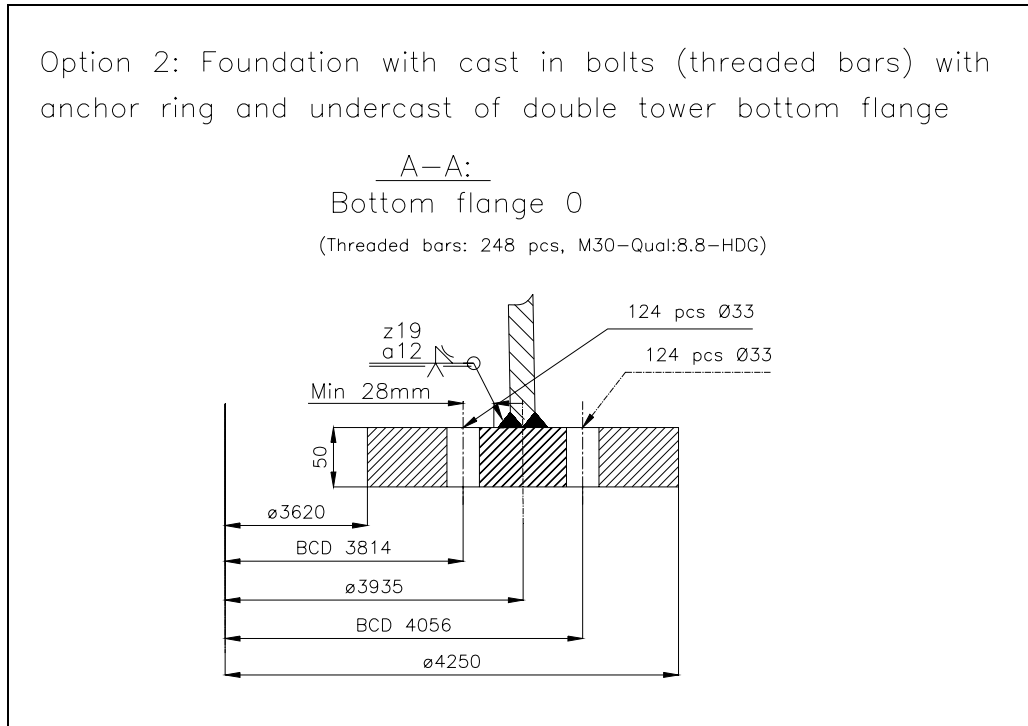


Figure 6. Dimension example for wind class I-B N47-65 m tower bottom

Norwin 47 – 65 m tower; double flange bottom dimensions. IEC-Class-IB:	
Inner flange diameter:	3620 mm
Inner bolt circle diameter:	3814 mm
Center sheet diameter:	3935 mm
Outer bolt circle diameter:	4056 mm
Outer flange diameter:	4250 mm
Flange thickness:	50 mm
Number of bolts:	2 x 124 = 248
Bolt hole size:	Ø 33 mm
Flange steel type:	ISO-S275J2G4
Bolt type:	M30-xxx-8.8-HDG (Hot Dip Galvanized)

Norwin 47 – 45 m tower; double flange bottom dimensions. IEC-Class-IB:	
Inner flange diameter:	3210 mm
Inner bolt circle diameter:	3320 mm
Center sheet diameter:	3426 mm
Outer bolt circle diameter:	3532 mm
Outer flange diameter:	3642 mm
Flange thickness:	40 mm
Number of bolts:	2 x 112 = 224
Bolt hole size:	Ø 33 mm
Flange steel type:	ISO-S275J2G4
Bolt type:	M30-xxx-8.8-HDG (Hot Dip Galvanized)

Lubrication of bolts before tightening: Molycote

Tightening torque for class 8.8 bolts with above lubrication: 1000 Nm

3. Lines of directions for necessary soil investigation

The normal information needed for the foundation design regarding soil conditions is described in the following list. It must however be emphasized that a geotechnical expert with knowledge on the local conditions always must be involved to evaluate if special things should be taken into consideration.

1. Drilling to 6-7 m (20-23 feet) dept to clarify the soil layers.
2. Bearing capacity of the different soil layers:
Sand - Friction angle ϕ_i (deg)
Clay - Cohesion measured by an un-drained shear strength C_u (kN/m^2)
or the bearing capacity directly if other methods are used.
3. Effective weight density of the different soil layers (kN/m^3)
4. Effective weight density of filling soil if excavated soil cannot be used as backfilling
5. Ground water level - assumed maximum is essential
6. Drainable capacity of the ground after installation of the foundation.
7. If the soil is weak and a pile foundation is necessary, the assumed pile length and bearing capacity for pressure and tension is needed

Lightning protection included in foundation design:

The design of the foundation earth electrode shall comply with IEC 61024-1. The earth termination shall have a resistance less than or equal to 10 Ohm. The tower shall be connected to the earth electrode at two points at least. The electrode can be a ring earth electrode, or (better) pole electrodes. (Notice: On the turbines in Denmark a pole electrode on each side of the tower going down to a depth of app. 6 meters have been used to get below the required resistance). A local company with knowledge in this field and in eventual local rules and regulations should be contacted.

4. Foundation design assistance

Norwin can in many cases (not USA) through our specialized consultant assist with dimensioning and design layout of foundation if all necessary information is available, and if it is within the normal range of foundation types.

The estimated price for this work is 8000 EURO per foundation design to be paid in advance.