VESTAS V52 – 850 kW, Optispeed^{TM}, Tower top and Foundation loads

This document presents the tower top and the foundation loads extracted from the fatigue and the extreme NVN II_A load analyses.

The wind and climate conditions for the V52 – 850 kW are given in the General Specification.

All reported loads include dynamic effects of the tower, i.e. among other things, that gust reaction factors are included for the extreme load cases performed with deterministic wind action. Further, all loads do not contain any partial safety factors, however the partial safety factor for the load, $_f$, as recommended by NVN is given in the load tables.

In the following tables the co-ordinate system with horizontal X- and Y-axes as shown in Figure 1 has been used.

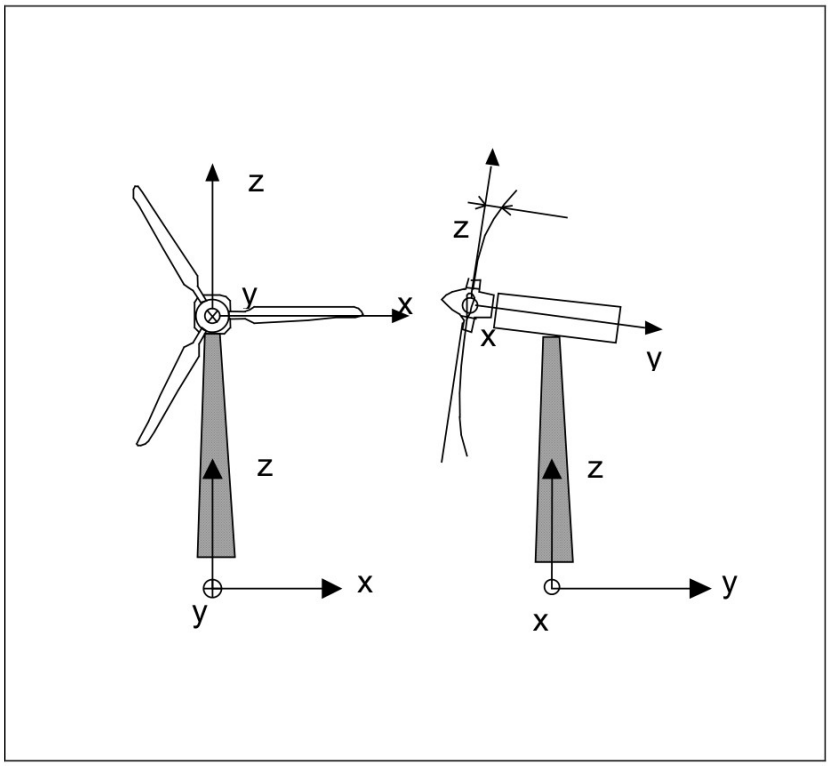


Figure 1 Definition of Co-ordinate System

For all extreme load cases the wind speed, v, and the wind direction, v_{dir}, at the time instant at which the loads occur are reported. The wind direction is measured relative to the Y-axis and is positive in the direction of a compass.

Loads for 40 m Tower

Table 1 and Table 2 list the tower top and foundation loads for a hub height of 40 m. The load components are defined according to the system of co-ordinates with the directions X, Y, Z given in Figure 1. It is assumed that a standard Vestas tubular tower design is used. For the equivalent fatigue loads Wöhler exponents of m = 4 and m = 7 have been used for the load range calculation.

VESTAS V520 – 850 kW, 40 m tower top loads for NVN-II$_A$					
	Extreme load			Fatigue load at n = 10^7	
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4
v (m/s)	27	59.5	59.5	8.5	-
v_{dir} (deg)	-60	-43	-45	0.0	-
F_x (kN)	-16	-183	-182	-	-
F_y (kN)	8	-5	-4	57	112
F_z (kN)	-319	-280	-279	-324	52
M_x (kNm)	778	21	13	87	612
M_y (kNm)	53	-309	-306	-	-
M_z (kNm)	-251	-534	-509	9	615
. f	1.35	1.35	1.35	1.0	1.0

Table 1 Characteristic tower top loads – hub height 40 m. No partial safety factors are applied.

VESTAS V520 – 850 kW, 40 m tower, foundation loads for NVN-II$_A$						
	Extreme load			Fatigue load at n = 10^7		
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4	Load range m=7
F_x (kN)	-31	-254	-257	-	-	-
F_y (kN)	17	73	71	60	112	97
F_z (kN)	-672	-633	-632	-677	52	42
M_x (kNm)	391	-1351	-1340	-2149	4231	3688
M_y (kNm)	-944	-8862	-8902	-	-	-
M_z (kNm)	-251	-534	-509	9	615	557

Table 2 Characteristic foundation loads associated with the tower top loads in Table 1. Height of tower from foundation to tower top is 38.1 m. No partial safety factors are applied.

Loads for 44 m Tower

Table 3 and Table 4 list the tower top and foundation loads for a hub height of 44 m. The load components are defined according to the system of co-ordinates with the directions X, Y, Z given in Figure 1. It is assumed that a standard Vestas tubular tower design is used. For the equivalent fatigue loads Wöhler exponents of m = 4 and m = 7 have been used for the load range calculation.

VESTAS V520 – 850 kW, 44 m tower top loads for NVN-II$_A$					
	Extreme load			Fatigue load at n = 10^7	
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4
v (m/s)	27	59.5	59.5	8.5	-
v_{dir} (deg)	-60	-43	-45	0.0	-
F_x (kN)	-24	-189	-189	-	-
F_y (kN)	1	-9	-8	57	95
F_z (kN)	-319	-281	-281	-324	52
M_x (kNm)	781	33	28	93	627
M_y (kNm)	40	-319	-317	-	-
M_z (kNm)	-263	-532	-519	8	614
. f	1.35	1.35	1.35	1.0	1.0

Table 3 Characteristic tower top loads – hub height 44 m. No partial safety factors are applied.

VESTAS V520 – 850 kW, 44 m tower, foundation loads for NVN-II$_A$						
	Extreme load			Fatigue load at n = 10^7		
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4	Load range m=7
F_x (kN)	-43	-284	-286	-	-	-
F_y (kN)	12	90	89	60	94	91
F_z (kN)	-741	-703	-703	-746	52	42
M_x (kNm)	592	-1782	-1790	-2484	3961	3943
M_y (kNm)	-1543	-10868	-10898	-	-	-
M_z (kNm)	-263	-532	-519	8	614	553

Table 4 Characteristic foundation loads associated with the tower top loads in Table 3. Height of tower from foundation to tower top is 42.1 m. No partial safety factors are applied.

Loads for 49 m Tower

Table 5 and Table 6 list the tower top and foundation loads for a hub height of 49 m. The load components are defined according to the system of co-ordinates with the directions X, Y, Z given in Figure 1. It is assumed that a standard Vestas tubular tower design is used. For the equivalent fatigue loads Wöhler exponents of m = 4 and m = 7 have been used for the load range calculation.

VESTAS V520 – 850 kW, 49 m tower top loads for NVN-II$_A$					
	Extreme load			Fatigue load at n = 10^7	
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4
v (m/s)	27	59.5	59.5	8.5	-
v_{dir} (deg)	-60	-44	-45	0.0	-
F_x (kN)	-18	-192	-191	-	-
F_y (kN)	-1	-7	-6	58	90
F_z (kN)	-319	-282	-282	-324	52
M_x (kNm)	787	29	25	97	630
M_y (kNm)	50	-324	-322	-	-
M_z (kNm)	-264	-530	-519	7	616
. f	1.35	1.35	1.35	1.0	1.0

Table 5 Characteristic tower top loads – hub height 49 m. No partial safety factors are applied.

VESTAS V520 – 850 kW, 49 m tower, foundation loads for NVN-II$_A$						
	Extreme load			Fatigue load at n = 10^7		
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4	Load range m=7
F_x (kN)	-37	-288	-289	-	-	-
F_y (kN)	11	92	92	60	90	87
F_z (kN)	-810	-773	-773	-746	52	42
M_x (kNm)	652	-2113	-2108	-2665	4216	4084
M_y (kNm)	-1392	-11952	-11960	-	-	-
M_z (kNm)	-264	-530	-519	7	616	557

Table 6 Characteristic foundation loads associated with the tower top loads in Table 5. Height of tower from foundation to tower top is 47.1 m. No partial safety factors are applied.

Loads for 55 m Tower

Table 7 and Table 8 list the tower top and foundation loads for a hub height of 55 m. The load components are defined according to the system of co-ordinates with the directions X, Y, Z given in Figure 1. It is assumed that a standard Vestas tubular tower design is used. For the equivalent fatigue loads Wöhler exponents of m = 4 and m = 7 have been used for the load range calculation.

VESTAS V520 – 850 kW, 55 m tower top loads for NVN-II$_A$					
	Extreme load			Fatigue load at n = 10^7	
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4
v (m/s)	27	59.5	59.5	8.5	-
v_{dir} (deg)	-60	-42	-45	0.0	-
F_x (kN)	-30	-197	-196	-	-
F_y (kN)	-4	-6	-5	56	91
F_z (kN)	-320	-282	-283	-324	52
M_x (kNm)	780	32	28	104	629
M_y (kNm)	34	-333	-332	-	-
M_z (kNm)	-236	-545	-527	4	616
. f	1.35	1.35	1.35	1.0	1.0

Table 7 Characteristic tower top loads – hub height 55 m. No partial safety factors are applied.

VESTAS V520 – 850 kW, 55 m tower, foundation loads for NVN-II$_A$						
	Extreme load			Fatigue load at n = 10^7		
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4	Load range m=7
F_x (kN)	-52	-306	-309	-	-	-
F_y (kN)	9	112	109	59	91	89
F_z (kN)	-899	-861	-862	-903	52	42
M_x (kNm)	714	-2943	-2902	-2981	4763	4686
M_y (kNm)	-2368	-14094	-14156	-	-	-
M_z (kNm)	-236	-545	-527	4	616	560

Table 8 Characteristic foundation loads associated with the tower top loads in Table 7. Height of tower from foundation to tower top is 53.0 m. No partial safety factors are applied.

Loads for 60 m Tower

Table 9 and Table 10 list the tower top and foundation loads for a hub height of 60 m. The load components are defined according to the system of co-ordinates with the directions X, Y, Z given in Figure 1. It is assumed that a standard Vestas tubular tower design is used. For the equivalent fatigue loads Wöhler exponents of m = 4 and m = 7 have been used for the load range calculation.

VESTAS V520 – 850 kW, 60 m tower top loads for NVN-II_A					
	Extreme load			Fatigue load at n = 10^7	
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4
v (m/s)	27	59.5	59.5	8.5	-
v_{dir} (deg)	-60	-43	-45	0.0	-
F_x (kN)	-26	-199	-198	-	-
F_y (kN)	1	-7	-6	56	88
F_z (kN)	-320	-283	-284	-324	52
M_x (kNm)	771	36	31	107	640
M_y (kNm)	44	-336	-334	-	-
M_z (kNm)	-230	-543	-527	3	615
. f	1.35	1.35	1.35	1.0	1.0

Table 9 Characteristic tower top loads – hub height60 m. No partial safety factors are applied.

VESTAS V520 – 850 kW, 60 m tower, foundation loads for NVN-II_A						
	Extreme load			Fatigue load at n = 10^7		
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4	Load range m=7
F_x (kN)	-51	-324	-328	-	-	-
F_y (kN)	16	128	125	60	88	86
F_z (kN)	-977	-940	-941	-981	52	42
M_x (kNm)	338	-3604	-3554	-3249	5120	4914
M_y (kNm)	-2412	-15920	-15988	-	-	-
M_z (kNm)	-230	-543	-527	3	615	558

Table 10 Characteristic foundation loads associated with the tower top loads in Table 9. Height of tower from foundation to tower top is 57.8 m. No partial safety factors are applied.

Loads for 65 m Tower

Table 11 and Table 12 list the tower top and foundation loads for a hub height of 65 m. The load components are defined according to the system of co-ordinates with the directions X, Y, Z given in Figure 1. It is assumed that a standard Vestas tubular tower design is used. For the equivalent fatigue loads Wöhler exponents of m = 4 and m = 7 have been used for the load range calculation.

VESTAS V520 – 850 kW, 65 m tower top loads for NVN-II$_A$					
	Extreme load			Fatigue load at n = 10^7	
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4
v (m/s)	27	59.5	59.5	8.5	-
v_{dir} (deg)	-60	-43	-45	0.0	-
F_x (kN)	-24	-205	-204	-	-
F_y (kN)	-7	-13	-11	56	89
F_z (kN)	-320	-284	-284	-324	52
M_x (kNm)	790	47	41	110	644
M_y (kNm)	46	-348	-345	-	-
M_z (kNm)	-241	-543	-529	3	617
. f	1.35	1.35	1.35	1.0	1.0

Table 11 Characteristic tower top loads – hub height 65 m. No partial safety factors are applied.

VESTAS V520 – 850 kW, 65 m tower, foundation loads for NVN-II$_A$						
	Extreme load			Fatigue load at n = 10^7		
	Case 1.3	Case 6.1	Case 6.1	Mean	Load range m=4	Load range m=7
F_x (kN)	-53	-354	-357	-	-	-
F_y (kN)	10	144	142	60	89	88
F_z (kN)	-1056	-1020	-1020	-1060	52	42
M_x (kNm)	786	-4221	-4264	-3602	5576	5575
M_y (kNm)	-2672	-18641	-18697	-	-	-
M_z (kNm)	-241	-543	-529	3	617	559

Table 12 Characteristic foundation loads associated with the tower top loads in Table 11. Height of tower from foundation to tower top is 62.6 m. No partial safety factors are applied.

Fatigue Loads in Tower Section

The mean value of the fatigue load in a given section of the tower is calculated directly from the tower top loads from static equilibrium conditions, while the equivalent load range for the design determining moment M_x is found from the expression.

$$M_x(z) = \sqrt{(M_{Tx})^2 + (F_{Ty} \cdot z)^2 + 2 \cdot \rho \cdot M_{Tx} \cdot F_{Ty} \cdot z}$$

where z is the distance of the considered section measured from the tower top, M_{Tx} and F_{Ty} are the load range values at tower top, and ρ is the correlation coefficient. The latter value is

- ρ = -0.13, for 40 m tower
- ρ = -0.14, for 44 m tower
- ρ = -0.11, for 49 m tower
- ρ = -0.16, for 55 m tower
- ρ = -0.01, for 60 m tower
- ρ = -0.05, for 65 m tower

Natural frequencies

To prevent the tower frequencies to lie close to or within the 3p rotor frequency area a modified Power-Speed curve is used for the low hub heights. This results in two 1p and 3p areas. One for 40, 44 and 49 m hub height and one for 55, 60 and 65 m hub height. The 1p and 3p frequencies for the two hub height groups are indicated in the table below.

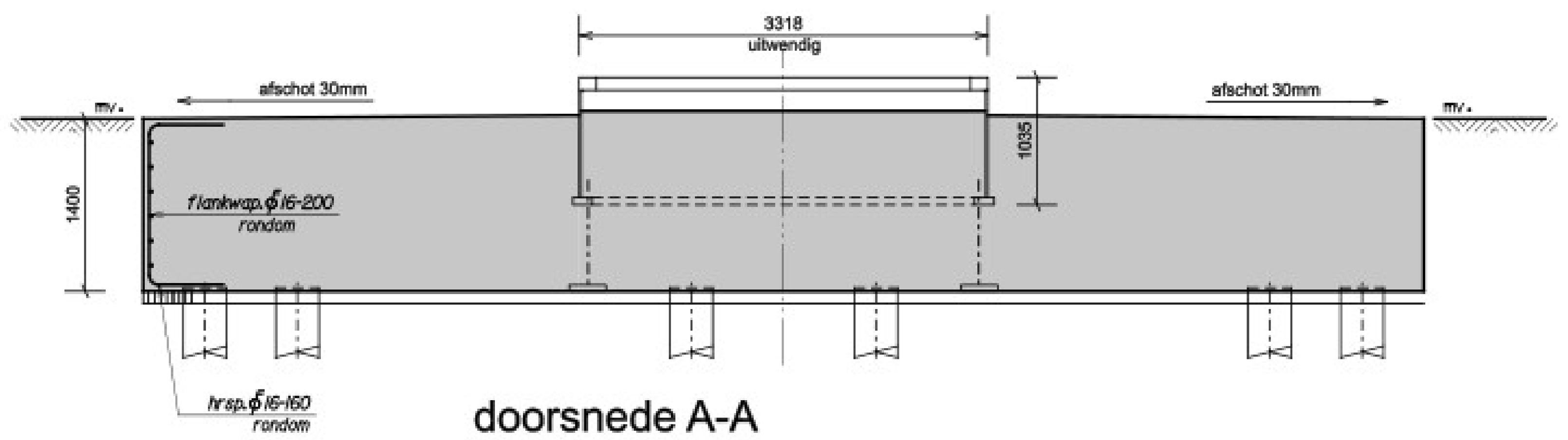
Hub heights	Frequencies	
	1 p, Hz	3 p, Hz
40 m, 44 m and 49 m	0.32 – 0.44	0.96 – 1.32
55 m, 60 m and 65 m	0.24 – 0.44	0.72 – 1.32

Table 13*: Rotor frequencies.*

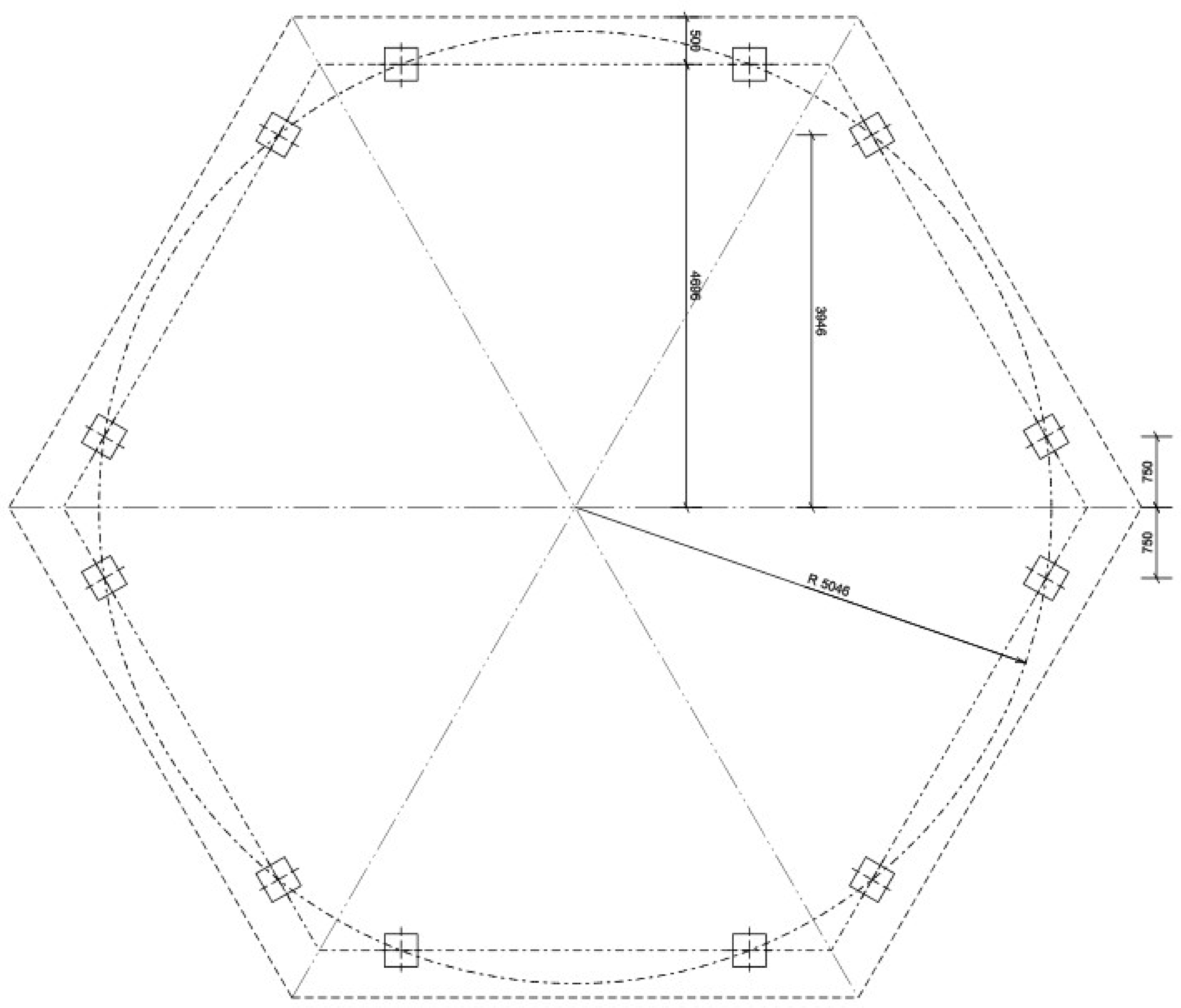
Tolerances on frequencies of the combined turbine, tower and foundation must be within +0% and -5% of the value listed below.

Tower height	Natural frequency (NVN II$_A$)
M	Hz
40	0.83
44	0.74
49	0.68
55	0.58
60	0.56
65	0.51

Table 14: Calculated tower frequency for NVN II$_A$.

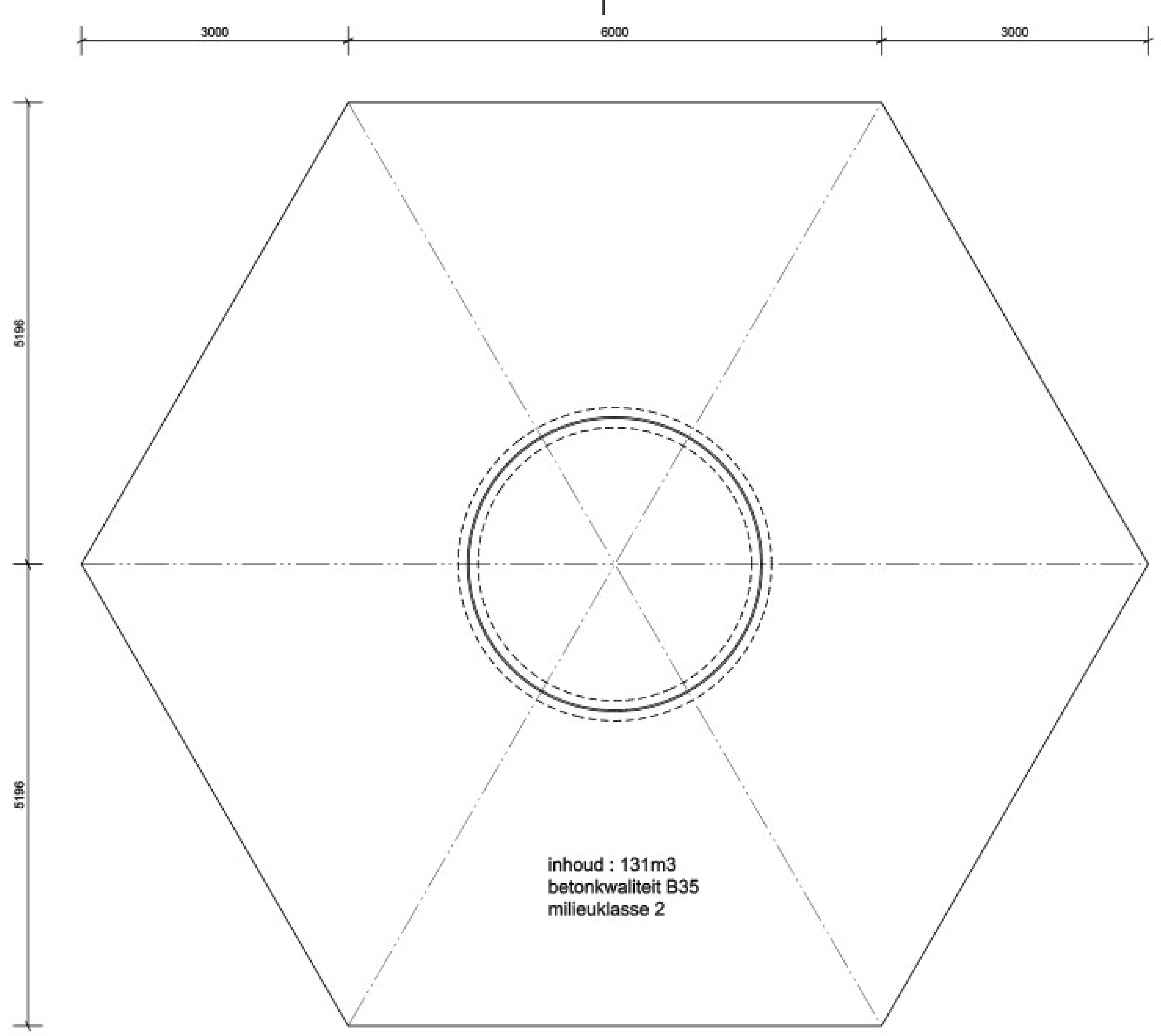


doorsnede A-A

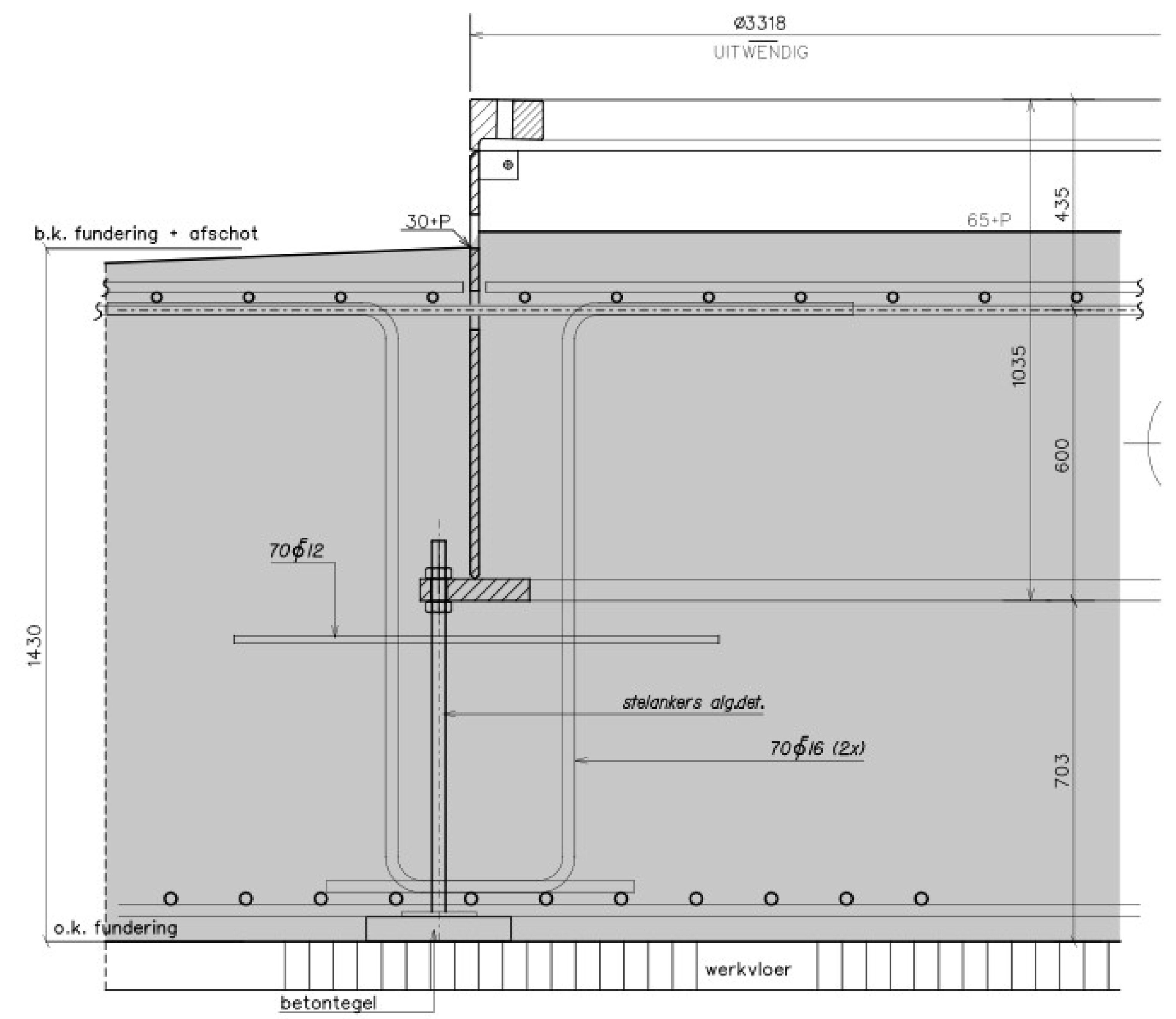


palenplan

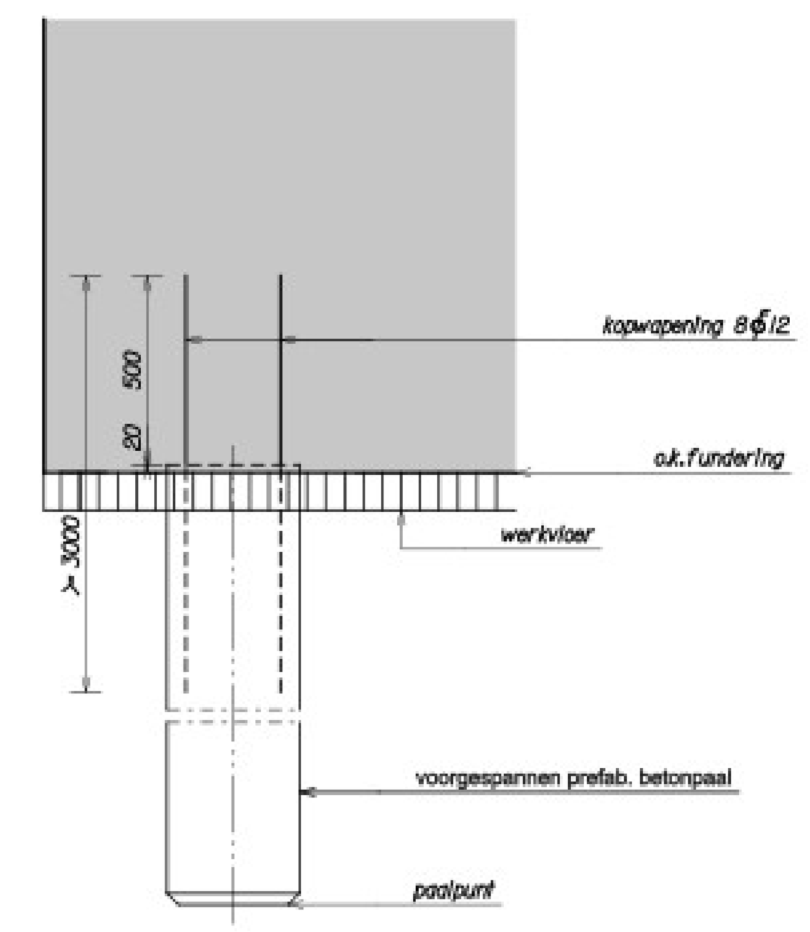
A-A



bovenaanzicht



principe detail ankerbuis
(schaal 1:10)



ALG. PAALDETAIL
(SCHAAL 1:20)

UITGANGSPUNTEN
Belasting conform IEC IIA: DOCUMENT 946538.R1 D.D.19-04-2001 (CASE 6J)
Berekening beton en fundering volgens TGB 1990
Fictieve sonderingen (van -10m tot -15m 10MPa)
Max.grondwaterstand 0.50 meter onder maaiveld
Insertring: conform tekening vwt11-71a d.d.09-07-02

GEGEVENS FUNDERINGSBLOK
Afmeting en palenplan, zie bovenstaande afbeelding
Wapeningsstaal FeB500
Wapening onder: ∅20-160
Wapening boven: ∅16-150
Radiaal: 60∅20, lengte 1.50 meter
Ophangwapening : zie getekend detail
Paalgegevens: prefab voorgespannen betonpalen
afmeting: 350x350 , lengte ca.14 meter
betonkwaliteit B55
milieuklasse 2

rev.	datum	fase	status	get.	omschrijving
K					
J					
I					
H					
G					
F					
E					
D					
C					
B					
A					
0	18-07-2005	VO	3	hjr	

fase: VO

faseverklaring: VO=Voorlopig Ontwerp, DO=Definitief Ontwerp, B=Bestek, U=Uitvoering
statusverklaring: 1=intern, 2=concept, 3=geldend, 4=goedgekeurd, 5=contract, 6=revisie

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opdrachtgever: VESTAS - Nederland Windtechnologie bv.

project: Basisontwerp
type: V52-850kW-H49m IEC IIA
onderdeel: Funderingsblok en palenplan

raadgevend ingenieur / projectleider / constructeur / tekenaar: [redacted]

project nr.	bouwdeel	schaal	formaat
D7127	400	1:50	A1

code	bouwlaag	bladnummer	type
VV	00	08	V