QUALITY AND REPRESENTATIVITY OF WIND MEASUREMENTS

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Abstract

Uncertainty and representativity of meteorological observations depend on the terrain roughness in the vicinity of the observation sites. The measure of representativity also depends on the wind direction. In particular at airports, where local representativity is strong requirement, it is of high importance to have a good view on the windfield at and above the runways, and also in the approach zones. The Royal Netherlands Meteorological Institute uses two methods to transform the measured windspeed to values representative for the surrounding areas, especially to the area above touch down zone. The first method is based on the influence of the roughness on the vertical wind velocity profile. The roughness around the observation site is calculated using a gust analysis as a function of wind direction. For a well qualified statistical analysis providing roughness data, a long term time series of windspeed data is required. The second method is based on a rough visual estimation of the shelter factor using a classification scheme describing the landscape. Every classification correspondends with a value of the shelter factor. These methods give the tools make it possible to present required wind information to the airtraffic. An evaluation of these methods used at several airports will be presented.

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1. *Derivation of potential wind speed from measured wind speed*

The potential wind speed is the average wind speed (averaged out over a period ≥ 1 minute) that would prevail at the site of the wind mast if the immediate surroundings were flat, as per the WMO standard. In practice, completely flat surroundings for all points of the compass are rarely achievable. In order to derive a potential wind from the measured average wind speed, the average wind speed is multiplied by a factor known as the "sheltering factor", which varies for each 20 degree sector of the compass.

The sheltering factor (SF) is calculated for all average wind speed data archived in climate database KIS. This comes down to a SF for every 20-degree sector of wind directions per station**. Two SFs are stored per wind direction sector for stations in a more leafy environment (i.e. where the "roughness" of the terrain varies depending on whether there are leaves on the trees), namely one SF for the summer period (1-May through 1-Oct) and one SF for the winter period (1-Oct through 1-May).

** Comment:

The 18 sectors used are 20, 40, 60… 360. The sector 20.n is the group of directions dd = (20.n - 10) ± 5 and dd = (20.n) ± 5.
Example: sector = 60 actually means the range of wind directions between 45 and 65 degrees.

To allow for possible changes in the "roughness" of the surroundings, the shelter factors are recalculated regularly (i.e. once every three years) and whenever the mast is moved.

The calculation of the shelter factor is based on the relationship between the gustiness of the wind and the roughness of the terrain, z_0. The gustiness is represented by the median value of a set of gust factors: <G>.
In any random period of time τ, e .g. 10 minutes or 1 hour, G = {maximum wind speed during τ} / {average wind speed throughout τ}.

The relationship between <G> and z_0 has been formulated by Wieringa
(Wieringa, Rijkoort, 1983).
A modified version this gust model (Wieringa- Beljaars model) has been described by Verkaik
(Verkaik, 2000):

$$< G >= 1 + \frac{0{,}88}{\ln \frac{z}{z_0}} * \tilde{u}_p$$

- u_p = 2.41 for 10-minute data and 2.99 for hourly data;
- z: (measurement) height (m).

In the case of 10'data, the formula becomes:
$<G> = 1 + \{ 2.12 / \ln (z/z_0)\}$.
This gives: $z_0 (<G>) = z \,.\, \exp\{2.12 / (1-<G>)\}$

In the following calculation of the SF, the assumption is made that the vertical wind profile is logarithmic so that the following applies for the reduction of the average wind speed at height z_1 to height z_2:

$ff_{z1} / ff_{z2} = \{\ln (z_1/z_0)/ \ln (z_2/z_0)\}$

The said assumption is correct up to 60 or 100m altitude and where atmospheric conditions are neutral (applicable where ff > 5 m/s). (Wieringa and Rijkoort, 1983)

The above hypothesis is used when the average wind speed at the measurement site is converted to a "fictivious" average wind speed at z_0 = 0.03 m, as is the assumption that the wind speed at 60 m (meso-altitude) is roughly the same throughout a large surrounding area (radius = 4 km). The reduction to 60 m altitude is actually done first and then the "fictivious" situation. So, we obtain:

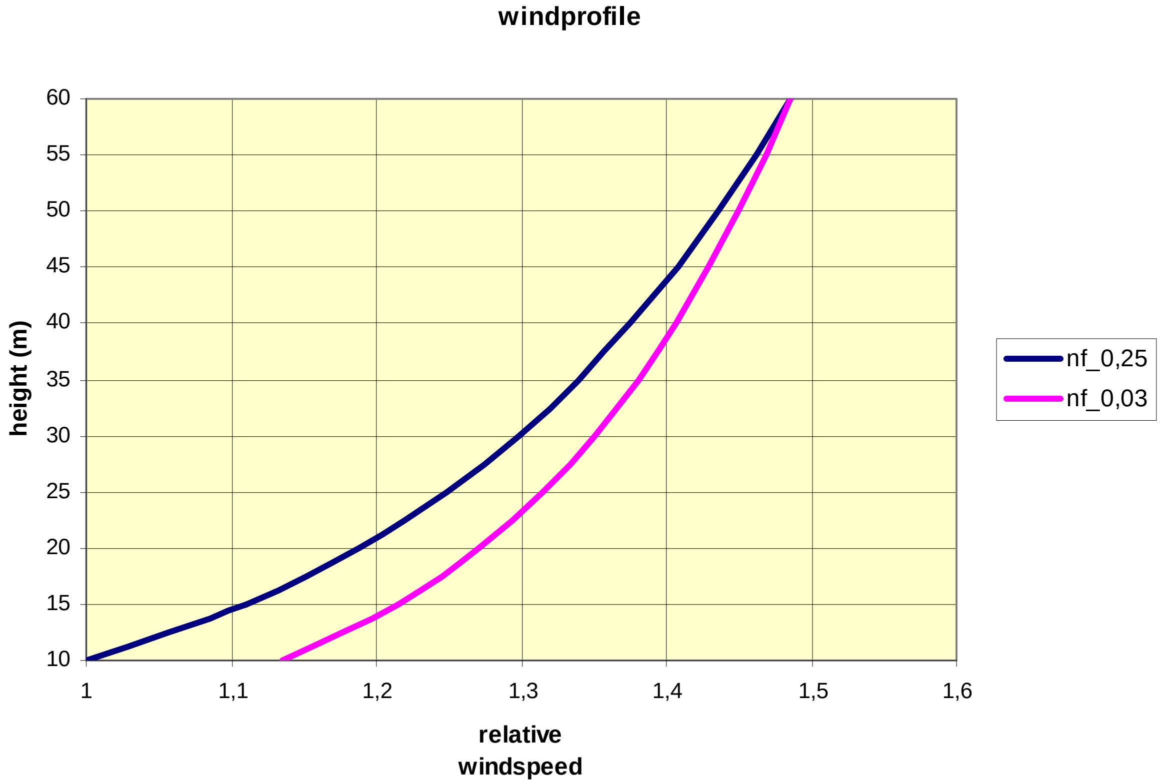

Fig.1. Profile windspeed

$SF = ff_{pot} / ff_{met} = \{ \ln (10/z_{0p}) / \ln (60/z_{0p}) \} / \{ \ln (z/z_{0s}) / \ln (60/z_{0s}) \}$

z_{0p} = roughness for flat surroundings;
z_{0s} = actual roughness at the location of the wind mast; this is calculated for every wind direction sector of 20 degrees;
z = sensor height.

Filling in z_{0p} = 0.o3 m and z = 10 m gives:

$$BF = \frac{1 + \left(\frac{1{,}79}{2{,}3 - \ln z_{0s}} \right)}{1{,}308}$$

Recently the shelterfactors of the 8 windstations at Amsterdam Airport Schiphol (figure 2) have been calculated per 10 directiondegrees. The results are presented herewith (table 1, figure 3).

Fig.2. Amsterdam Airport Schiphol, location of windstations

	Shelterfactor							
Direction (10bgr)	*27*	*18C*	*18R*	*22*	*36R*	*36C*	*36L*	*6*
0	0,99	0,98	0,97	1,01	0,96	0,96	0,96	1,01
1	1,04	1,00	1,03	1,05	1,00	0,98	0,99	1,06
2	1,06	1,01	1,04	1,07	1,00	0,98	1,01	1,06
3	1,05	1,01	1,05	1,05	1,00	1,00	1,05	1,02
4	1,06	1,02	1,06	1,04	1,04	1,01	1,05	1,00
5	1,03	1,02	1,05	1,04	1,09	1,02	1,05	0,99
6	1,04	1,02	1,05	1,05	1,11	1,00	1,05	1,00
7	1,04	1,02	1,07	1,08	1,08	1,00	1,04	1,04
8	1,03	1,02	1,08	1,06	1,13	1,01	1,04	1,06
9	1,02	0,98	1,03	1,00	1,15	1,00	0,99	1,01
10	1,02	0,98	1,07	1,03	1,15	1,04	0,98	1,02
11	1,05	1,02	1,05	1,09	1,12	1,05	1,00	1,06
12	1,07	1,02	1,11	1,08	1,07	1,04	1,02	1,05
13	1,05	1,02	1,07	1,11	1,09	1,01	1,01	1,07
14	1,02	0,99	1,04	1,09	1,07	0,99	0,99	1,10
15	1,00	0,99	1,01	1,09	1,06	0,98	0,97	1,09
16	1,00	0,98	0,99	1,11	1,04	0,98	0,98	1,09
17	0,99	0,97	0,97	1,03	1,02	0,97	0,99	1,08
18	0,98	0,94	0,96	0,98	0,99	0,95	0,98	1,05
19	0,99	0,97	0,99	1,04	1,02	0,98	1,00	1,08
20	0,99	0,99	1,00	1,02	1,01	0,98	1,00	1,05
21	1,00	1,01	1,01	0,99	1,01	1,02	1,02	1,03
22	1,01	1,04	1,03	1,00	1,03	1,04	1,04	1,03
23	1,01	1,04	1,02	1,00	1,04	1,04	1,03	1,03
24	1,02	1,03	1,03	0,99	1,04	1,04	1,03	1,01
25	1,03	1,04	1,04	1,01	1,05	1,04	1,03	1,02
26	1,01	1,02	1,03	1,01	1,04	1,03	1,03	1,02
27	0,98	0,99	1,00	0,98	1,02	1,00	1,01	1,01
28	1,00	1,03	1,05	0,99	1,04	1,03	1,03	1,07
29	1,02	1,06	1,06	1,01	1,03	1,04	1,05	1,09
30	1,03	1,07	1,07	1,02	1,07	1,03	1,06	1,09
31	1,02	1,08	1,06	1,01	1,07	1,02	1,08	1,10
32	1,04	1,09	1,05	1,04	1,08	1,02	1,09	1,11
33	1,06	1,06	1,05	1,05	1,05	1,01	1,08	1,09
34	1,06	1,03	1,03	1,05	1,01	0,99	1,05	1,08
35	1,06	1,00	1,01	1,06	0,98	0,99	1,03	1,06
36	1,01	0,98	0,99	1,02	0,96	0,95	0,96	1,02

Table 1, Calculated shelterfactors at Amsterdam Airport Schiphol

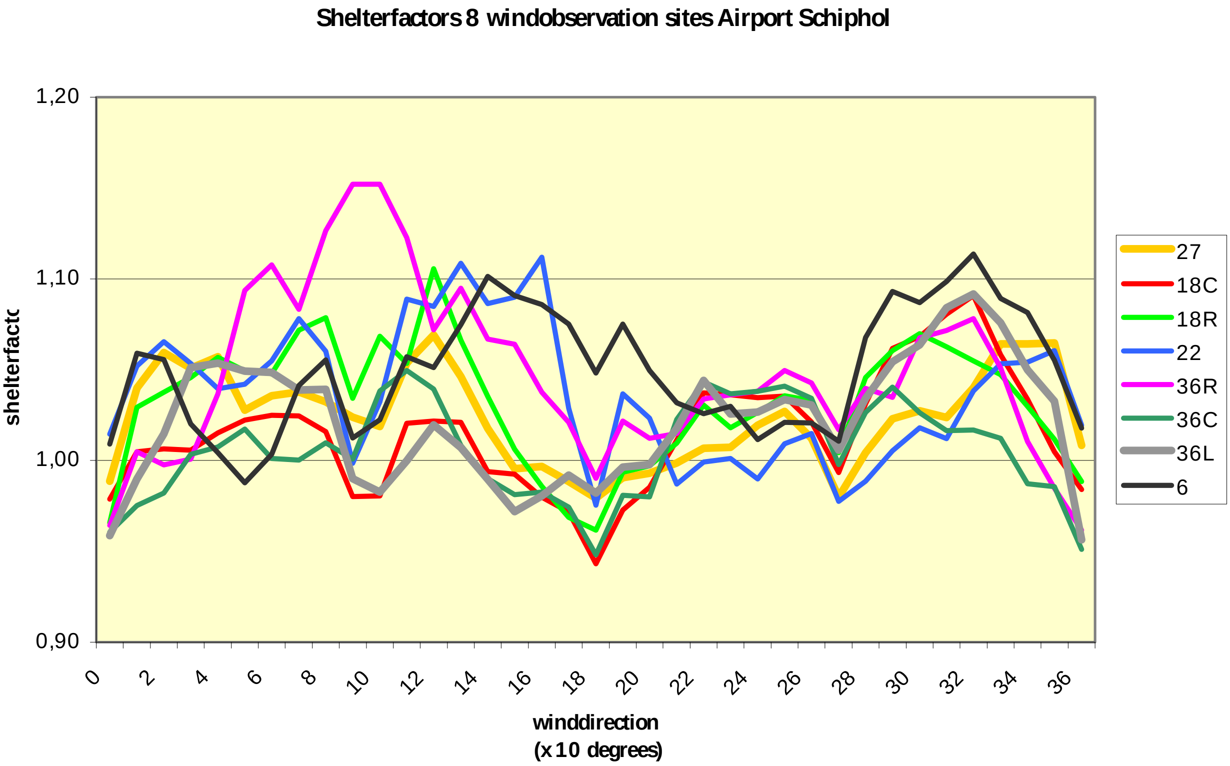

Fig.3. Calculated shelterfactors at Amsterdam Airport Schiphol

2. Discussion of the shelterfactor in relation to the relative obstacleheights and the roughness of the surroundings

The roughness Z_0 and the shelterfactor SF can be classified using the scheme of Davenport. (Davenport 1960)

Class.	*Type*	Z_0	*SF*	*Landscape*
1	Sea	0,0002	0,89	Open sea or lake
2	Flat	0,005	0,94	Landsurface without any obstacles or vegetation, or ice surface
3	Open	0,03	1,00	Flat country with lgrass
4	Rough, open	0,1	1,06	Flat country with low vegetation and some incidental obstacles (distance between 20 x obstacle height)
5	Rough	0,25	1,14	Country with vegetation, row of trees, bigger obstacles (distance between 15 x obstacle height)
6	Very rough	0,5	1,22	Clusters of obstacles (farmhouses, trees) with open areas (distance between 10 x obstacle height)
7	Closed	1	1,36	Surface completely covered by high obstacles without any significant open area
8	City	2	1,62	Centre of city or woods

Table 2, Classification shelterfactors

A description have been made of the surroundings of windmast 22 Airport Maastricht-Aachen(table 3, figure 4)

direction (degr)	*Object*	*distance (m)*	*height (m)*	*rel.obst. height (%)*	*estimated shelter-factor*
0-24	Hangars	600-1480	6-20	1,35	1,01
28-37	Row of trees	1590	12	0,75	
36-43	Buildings	700	8	1,14	
44-46	Edge of building	545	16	2,94	1,03
47-52	Schreiner building	347	16	4,61	1,05
53-69	KLM-building	213	16	7,51	1,16
108	tower	3600		0,00	
118	Farm house	790	8	1,01	
118-128	Row of trees	1120	16	1,43	1,01
130	House	831	5	0,60	
133-182	Buildings	835		0,00	
153	tower	490	20	4,08	1,04
182-192	High trees	1720	20	1,16	
187	Low buildings, sheds	447		0,00	
202-212	Row of trees	540	14	2,59	1,02
213	House	1660		0,06	
232	Radar	1445		0,00	
232-245	Trees beside highway	1040		0,00	
245-272	Hangars	895		0,00	
263-271	Row of trees	770	17	2,21	1,02
272	Tower	590	27	4,58	1,05
272-285	Buildings	542	12	2,21	1,02
285-302	Law buildings	473	3	0,00	
280-303	Trees beside highway	680-570	28-15	4,12	1,05
304-305	Board commercials (vodafone)	484	18	3,72	1,04
328-330	Trees	580-611	12-18	2,95	1,03
334	Farm house	550	5-6	1,09	
334-346	Row of high trees	550	20	3,64	1,04
346-360	Hangars, sheds	600-1480	6-20	1,35	1,01

Table 3, Surroundings windstation Airport Maastricht - Aachen

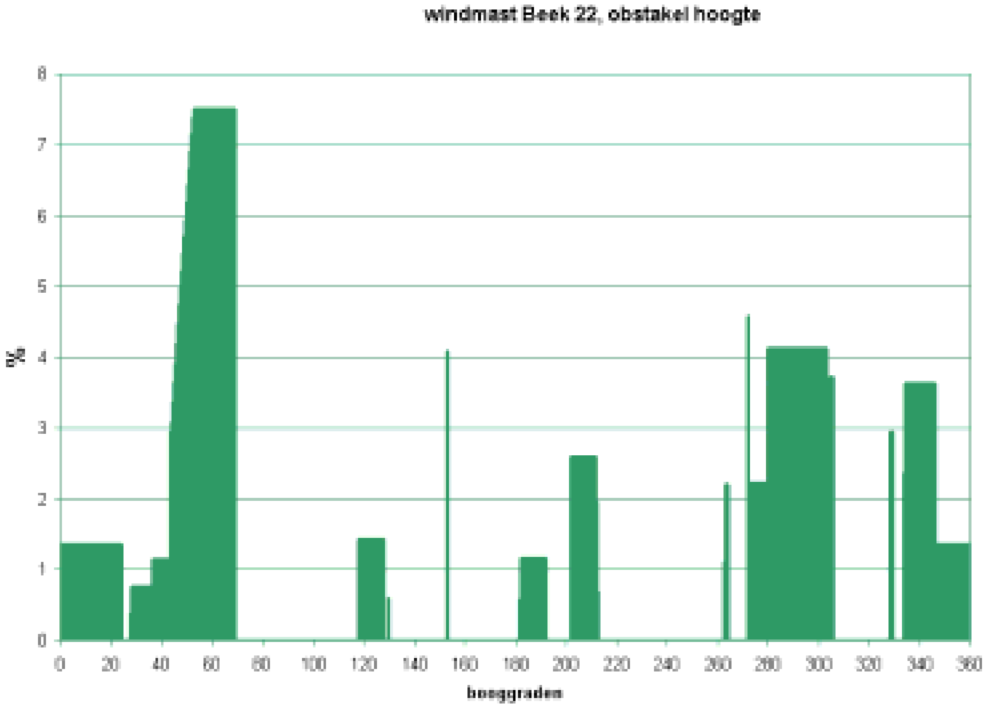

Fig. 4. Relative heights of obstacles around windmast 22 at Airport Maastricht Aachen

The calculated values of the shelterfactors and roughnesslengths per winddirectiondegree of windmast 22 at Airport Maastricht Aachen are presented in table 4 and figure 5.

dd	bf_calc_2004_summer	bf_calc_2004_winter
20	1,052	1,068
40	1,083	1,085
60	1,119	1,125
80	1,059	1,026
100	1,026	0,998
120	1,025	1,006
140	1,153	1,038
160	1,131	1,096
180	1,145	1,1
200	1,122	1,093
220	1,079	1,06
240	1,079	1,052
260	1,127	1,13
280	1,206	1,192
300	1,203	1,185
320	1,176	1,223
340	1,116	1,144
360	1,105	1,054

Table 4, Calculated shelterfactors at Airport Maastricht Aachen

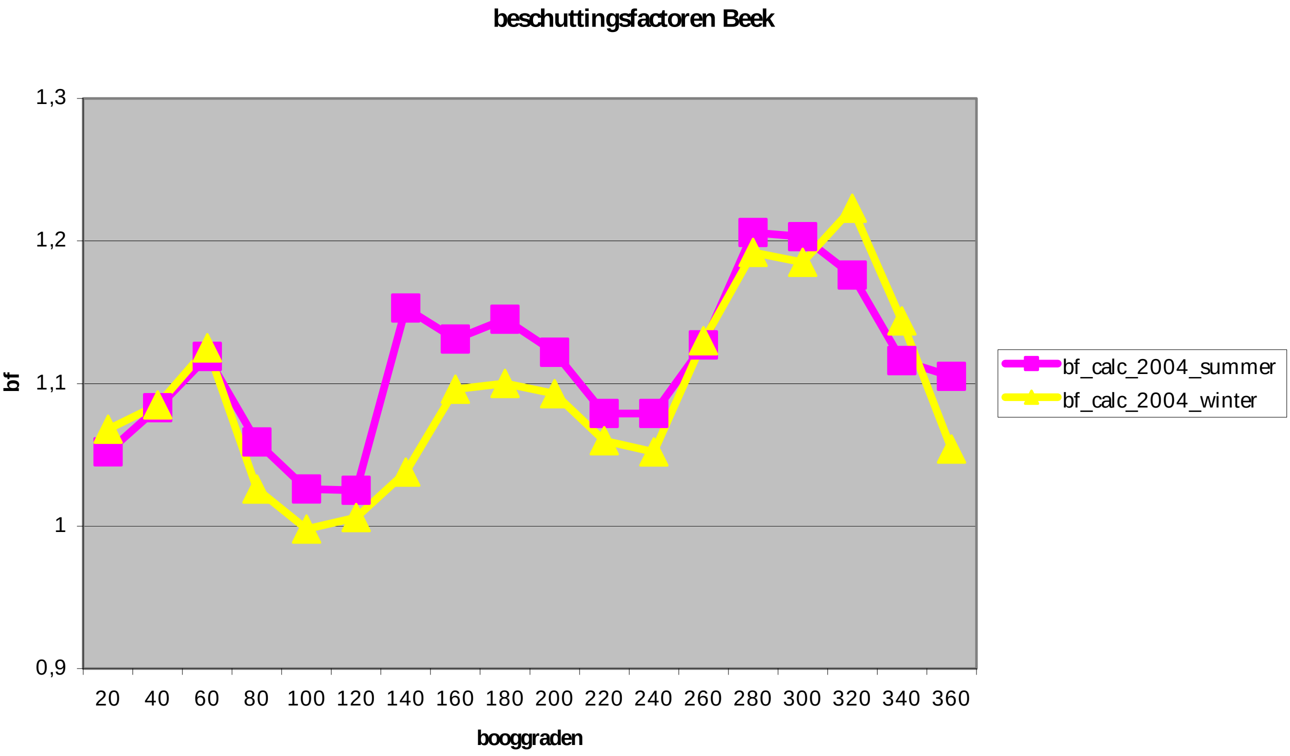

Fig. 5. Calculated shelterfactors at Airport Maastricht Aachen

The calculated values of the shelterfactors and roughnesslengths per winddirection degree of windmast 22 at Airport Maastricht Aachen can be compared with the description of the surroundings, and the interpretation of the Davenport scheme .

One can make the following conclusions with respect to the roughness and shelterfactor:

a) the influence of the buildings in direction 40 – 70 degrees is consistent;

b) the roughnesslength/ shelterfactor in directions 150 – 220 degrees and 260 – 360 degrees is much higher than one may expect because of the big distance of the objects; it means the extreme roughness outside the airport field (hills, trees, buildings) has a a long distance influence on the turbulency of the wind and in this view on the gustfactor and the corresponding shelterfactor at the windstation. It overrules the complete flatness of the airport field in the concerning direction.

3. Setup requirements and conditions for the surroundings

The sensors for measurement of wind speed and direction are mounted on a stable metal or plastic mast. The sensor height is 10 metres above terrain that should in principle be flat.

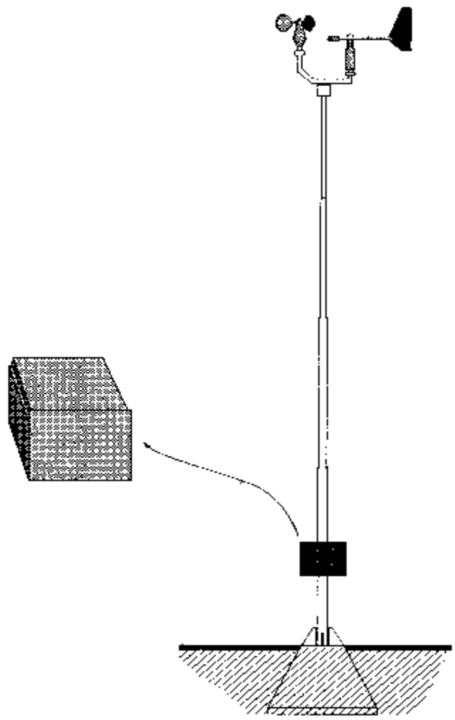

Fig.6. Windmast

a) Conditions relating to the surroundings and the measurement location
The roughness z_0 should be < 0.5 m in all directions. This condition implies a shelter factor SF of < 1.2 (less than 20% reduction of the average wind speed).
The distance from the wind mast to any obstacles in the vicinity must be at least ten times and preferably twenty times the height of the obstacle (applies to all obstacles).
The terrain in the immediate vicinity of the wind mast (radius $\geq$ 100 metres around the measurement site) is flat grassland or a water surface.

b) Conditions relating to the surrounding and the measurement location and representativeness of the observations
The location of the wind mast is such that an observation of the wind can be performed (including any reduction using a shelter factor) that is representative for an area with a radius of 30 km around the measurement site. (NB: for wind measurements on the coast, the degree of representativeness is obviously partly dependent on the wind direction) This condition is based on statistical studies performed by J. Wieringa: *"For a separation of 30km between two observation points in a homogeneous landscape, the difference in wind speed is less than 5% for 90% of the time."* The density of the wind measurement network required then follows from the level of representativeness to be achieved.

c) specific conditions relating to the surroundings and the measurement site on an airfield
The wind observation at an airport must be representative for the wind conditions on the (adjacent) runways for take-off or landing, and in particular for the touchdown zone. In order to realize these objectives as well as possible, the following measure are taken:

- A 10-metre metal wind mast is placed 190 metres away from the centre of the runway. Closer than this to the runway is not possible, since a metal mast may not protrude through what is known as the "obstacle surface". {the obstacle surface is a plane running parallel to the centre of the runway120 metres from it and then rising at a 1 in 7 angle}

- In the case of a so-called “frangible” plastic mast with a sensor at a height of 10 metres, the mast can be placed 115 metres from the centre-line of the runway. Closer than this is not possible, given the wingspan of NLA craft and the disruption of the wind behaviour caused by passing aircraft.

- The measurement height for wind speed and direction should preferably be 10 metres and at least 6 metres, placed above flat ground.

- The wind mast is positioned at least 120 metres from the centre of a runway for taxiing, due to the *ad hoc* effects on wind behaviour due to stationary or moving aircraft.

- The wind mast should be placed at a distance of at least 50 metres and preferably at least 100 metres behind the nearby ILS-GP antenna mast [NB: the ILS mast is an open construction approximately 1 metre in width and 9 metres in height]. When placed behind the ILS mast, disturbance of the wind measurement will only occur for wind directions that are inappropriate for use of the runway. Turbulence effects in the airflow as a result of passing a narrow, porous obstacle such as an ILS mast at a distance of 30 times the width of the obstruction will be virtually damped out anyway, and the wind profile at this distance is once again near enough identical to the profile in front of the obstacle. At a distance of 50 metres from an ILS mast, the wind as measured is in principle no longer perturbed.

- Positioning of the wind mast in front of the ILS mast is only possible if the distance is at least 100 metres, due to the possibility of the wind mast interfering with the ILS signal. Furthermore in this case, maintenance or inspection activities on the wind mast can only be carried out when the runway (and therefore the GP antenna too) is not in use.

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