11. SEMITRANSPARENT WIND SHIELDS

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Summary

The efficiency of three semitransparent wind shields consisting of vertical boards with different widths and at different spacings has been measured.
A model is given for the mechanism reducing the wind speed, which explains the dependence on width and spacing of the boards, and on the height and the width of the shield.
Shields can be realized which are already effective at a short distance, e.g. 1 meter.

Introduction

Wind shields consisting of vertical parallel boards proved to be a good protection for telescopes which are not stiff enough against wind vibrations for use in the open air (Hammerschlag and Zwaan, 1973). The shield tested so far becomes effective only at distances larger than 3 m. However, a telescope on a small tower platform requires a wind shield that is effective at shorter distances. Therefore we investigated how the properties of the shields vary with the width of the boards and the spaces in between. We carried out measurements on three different shields specified in Table I.

Table I: Dimension of the shields

Shield no.	width of boards	width of gaps	total width of shield	height of shield
1	2 cm	2 cm	4 m	2 m
2	2 cm	6 cm	4 m	2 m
3	9.5 cm	12 cm	5 m	2 m

Measurements

The wind speeds were measured with four integrating cup anemometers and one hot-wire anemometer. One of the cup anemometers was placed 7 m in front of the shield in order to measure the undisturbed wind speed v_o, which ranged from 1.6 m/s to 7.6 m/s during the measurements. The four cup anemometers were read off simultaneously.
The integration times varied from 2 minutes up to 90 minutes. The wind speed reduction factors obtained from the cup anemometers reproduced within a few per cent for all wind speeds between 1.6 and 7.6 m/s.
The response time of the hot-wire anemometer was less than 5 seconds. Consequently the hot-wire anemometer followed the wind gusts and a precise comparison with the integrating cup anemometers was not possible. However, the small and light hot-wire anemometer

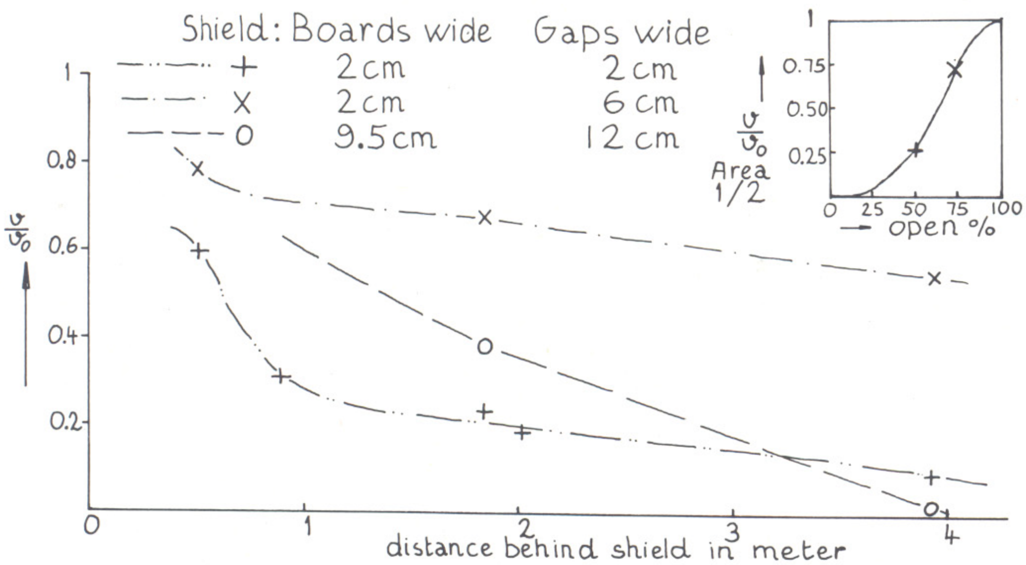

Fig. 1 the wind speed reduction factor v/v_0 for three different windshields. The measuring points obtained from the cup anemometers are indicated by symbols. The small graph in the topcorner shows the relation between v/v_0 and the transparency factor (open %).

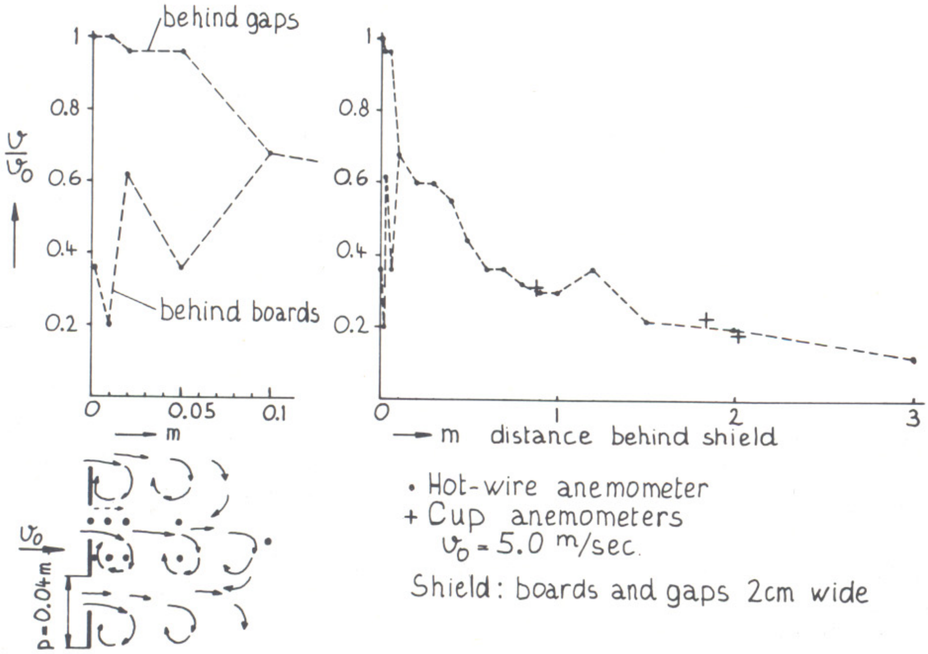

Fig. 2 a typical curve measured by the hot-wire anemometer. The part close to the shield is given in the left-hand graph with an enlarged scale for the distance behind the shield. The positions of the hot-wire anemometer in the area close to the shield are indicated in the left-hand bottom corner.

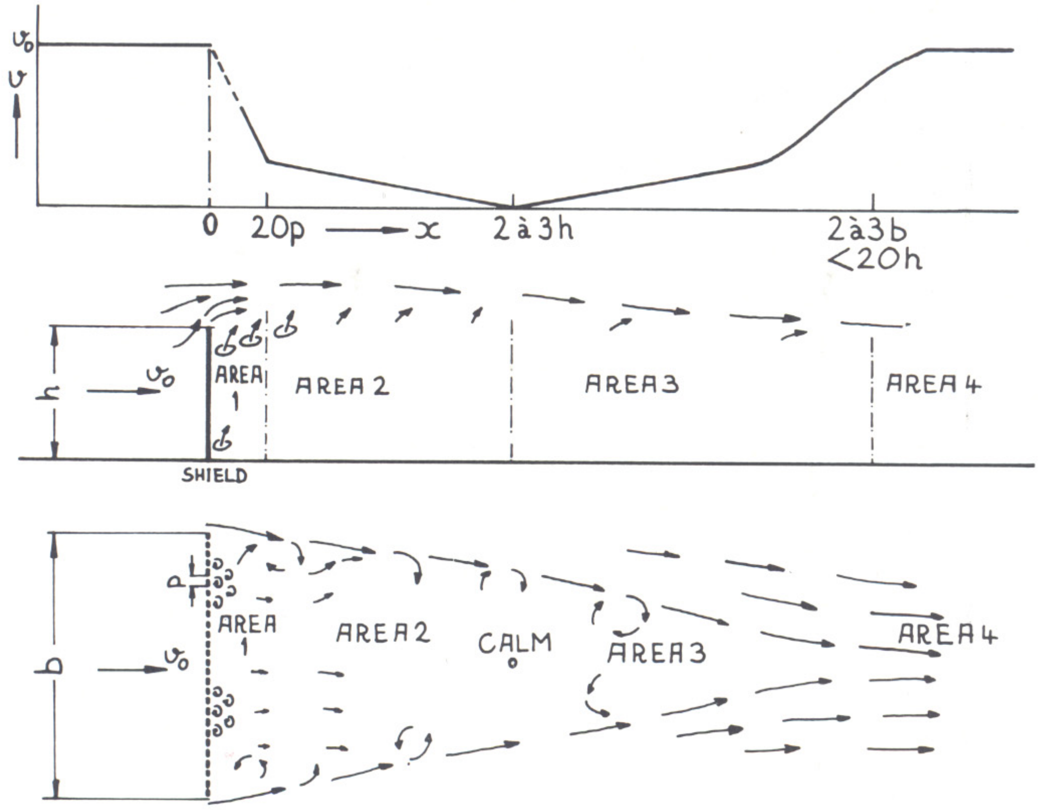

Fig. 3 model for the wind speed reduction behind a shield consisting of vertical boards.

Fig. 5 the wind shields set up on the beach of Ilha da Barreta in South Portugal. The second and third ribbon on the rod show that the turbulent layer between the horizontally stratified air mass behind the shield and the undisturbed wind flow above the shield is very thin.

enabled rough measurement of the wind reduction factor in the area between the discrete measuring points of the cup anemometers.
The results for the three shields are shown in Fig. 1.
A typical curve measured by the hot-wire anemometer is shown in Fig. 2. Apparently a gust occurred during the wind speed measurement at 1.20 m behind the shield.

Discussion of the results

The measurements suggest a model in which the space behind the shield is separated into the four areas as shown in Fig. 3.
In *area 1* there is a rapid decrease of the wind speed through the hierarchy of eddies as described by Hammerschlag and Zwaan (1973). The existence of the eddies was clearly demonstrated by the hot-wire anemometer, see Fig. 2. At a distance of about 20 board periods (p) behind the shield the eddies have lost most of their energy.
The ratio between the width of the gaps to the width of the boards defines the wind speed reduction factor reached at the end of area 1. The measurements with the shields 1 and 2 shown in Fig. 1 illustrate this.
The small graph in the top corner of Fig. 1 shows the relation between the wind reduction factor at the end of area 1 and the transparency, that is the fraction of the shield occupied by gaps (open %).
An estimated curve is drawn through the two measuring points defined by the shields 1 and 2. The curve cannot be extrapolated down to very low transparencies where the open spaces are much smaller than the boards, because eventually a counterflow will develop behind area 1 like in the case of a closed shield. Then the advantages of a partly transparent shield are lost.
In *area 2* there is a further decrease of the wind speed caused by a flow of air upwards into the undisturbed air stream. The upward flow is produced by the suction due to the undisturbed air stream. Yet there is little mixing between the air mass in area 2 and the undisturbed air stream because in area 2 the velocity field is almost horizontally stratified with a minimum of turbulence (see Fig. 5).
The depth of area 2 is two or more times the height h of the shield. The maximum wind speed reduction is reached at the end of area 2.
In *area 3* the wind speed rises again because wind whirls with axes parallel to the vertical boards move inwards from the sides (see Fig. 3, bottom).
In *area 4* the original wind flow is recovered. Area 4 starts at a distance behind the shield equal to 2 to 3 times the width b of the shield. For very large width b the height h will define where area 4 begins.

The areas 1 and 2 largely overlap if the height h of the shield is smaller than 20 times the board period p. This is the case for wind shield 3 with h=9 p. The wind reduction curve for shield 3 does not show the sharp bend between the areas 1 and 2 like the curves for the shields 1 and 2 (see Fig. 1). Moreover, the curves show that the final wind speed reduction at 4 meter behind the shield is larger for shield 3 than for shield 1 although the transparency factor is somewhat larger for shield 3. Apparently a shield with overlapping areas 1 and 2 is more efficient. Probably the reason is that then the eddies survive over longer distances

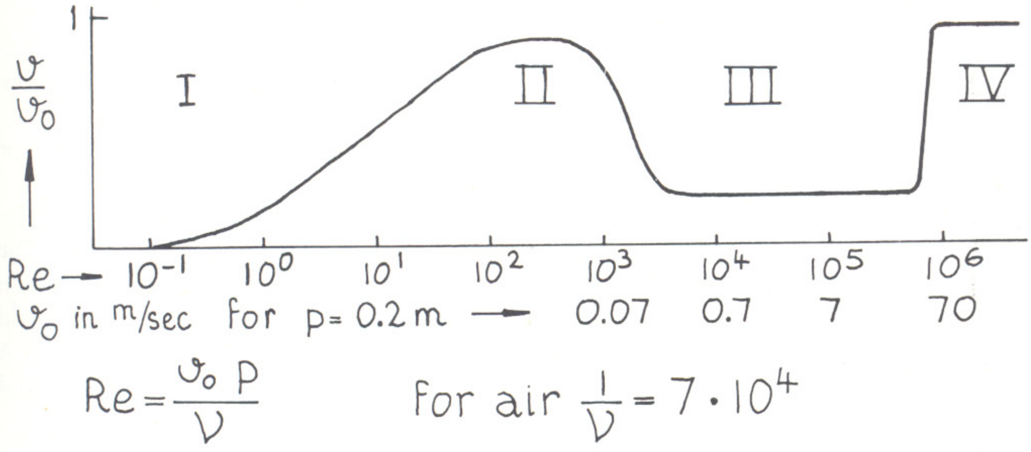

Fig. 4 efficiency of the shield as a function of the Reynolds number; v_0: undisturbed wind velocity; p: period of the boards; ν: viscosity of the air.

behind the shield which reduces the mixing with the undisturbed air stream to a minimum and so increases the upward flow due to the suction effect.

The larger width of shield 3 (see Table I) may be another reason that a higher reduction factor was measured. The wind direction varies continually around an average. We experienced that the measured wind speed reduction factors are no longer completely reliable for distances behind the shield larger than about the width b of the shield. Consequently the widths of the shields were not large enough to measure the final reduction factor at the end of area 2 with confidence.

The ground has little effect on the performance of shields with vertical boards.

If a shield of parallel boards is placed free in an air stream this stream does not bend inward from the sides perpendicular to the direction of the boards. However, from the sides parallel to the boards the stream bends inwards nearly as strongly as in the case of a completely closed shield. Consequently a plane semitransparent shield si still effective at a large distance if it is long in the direction perpendicular to the boards (the width b). Of course in practice a shield for protection will not be plane but it will be arranged in a cylindrical way around the instrument.

The efficiency of the shield is based on the occurrence of eddies. The Reynolds number indicates how well the eddies are developed. In our measurements this number ranged from 4500 to 168000, and within this region well developed eddies were present. Somewhere outside this region the efficiency of the shield may decrease.

The main effects are roughly indicated in Fig. 4. For very high Reynolds numbers the boundary layers become turbulent and no eddies are formed (zone IV in Fig. 4). For low Reynolds numbers the eddies disappear (zone II), but for very low Reynolds numbers the shield will close again because of viscous forces (zone I).

The precise effects in the various zones indicated in Fig. 4 may also depend on the shape and the roughness of the boards, among other things.

Practical conclusions

The experiments showed that shields can be realized that become effective on short distances e.g. 1 m.
For a shield effective at a distance d the period p of the boards should be chosen equal to or smaller than d/20.
This shield is effective for wind speeds v such that the Reynolds number $Re = pv/\nu$ (for air $1/\nu \approx 70.000\ s/m^2$) remains between some thousand and some hundreds of thousands. The height h of the shield is to be chosen only slightly higher than the instrument, but larger than both d/10 and 5 p. So for a desired distance d = 1 m we find $p \leqslant 5$ cm, for p = 5 cm the shield is certainly effective between v = 0.5 and 60 m/s. The shield should be at last 25 cm high. A transparency of 50% is a good compromise between sufficient flow through the shield and yet a high reduction factor of the wind speed.

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References

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