ARTICLE

CLIMATIC DESIGN OF A NEW HOUSING AREA

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In 1984 the municipality of Frederikshavn in northern Jutland, Denmark initiated a project for the climatic design of a new housing area. The site is particularly exposed to strong winds all the year round and one of the major tasks was to design the overall building site and the buildings so that major improvements in the exterior wind environment were achieved.

Furthermore the design brief from the municipality called for an overall climatic design, where low-energy solutions were combined with consideration of the exterior environment near the buildings.

THE WIND ENVIRONMENT

One of the prime objectives of the project was to improve the possibilities of resting or strolling comfortably out of doors in summer conditions.

Initial monitoring of the local wind climate, the wind velocity and direction, were performed by the RISO test station. One remarkable results was that, contrary to the usual situation in Denmark, the wind from the west and south-west is not predominant in this area. Wind from the north-west was found to be most frequent. The reason for this phenomenon is the particular topographical conditions. West and south of the housing area, the altitude rises from 40 m above sea level to 80 m above sea level. Thus, there is a sheltering effect that explains the change in predominant wind direction.

This finding had a strong impact of the layout of the 27 buildings and the shelter belts (natural windshields) around the buildings, as shown below.

OUTDOOR COMFORT

Based on historical climatic data and a detailed local monitoring programme, the possibilities for comfortable rest and strolling during summertime were analysed. This was done using the comfort criteria set up by Professor Fanger, who suggested that human comfort is dependent upon:

- clothing level;
- level of activity;
- air temperature;
- wind velocity.

The relationship between these parameters are presented as shown in Figure 1, here shown for persons sitting in sunlight.[1] A similar, but slightly different, relationship between the comfort parameters has been given by Penwarden and Wise.[2]

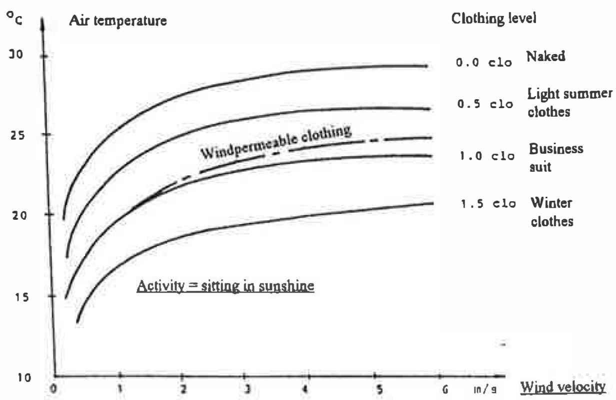

Figure I. Comfort diagram after reference 1. Combinations of wind velocity, temperature and clothing level, for which it is comfortable to sit outside in the sun

From the analysis of the climatic data, the frequency of given combinations of temperature and wind speed are known, corresponding to the combinations of wind velocity and temperature in Figure 1.

The effect of shelter belts on the wind velocity behind the belts is taken from Geiger,[3] who showed that a shelter belt of mean density will reduce the wind velocity behind the belt to 40–60% of the undisturbed wind velocity. This is valid up to a distance of 10 times the height of the shelter belt (Figure 2).

The main results from the analysis of improvement of the comfort for people outdoors are:

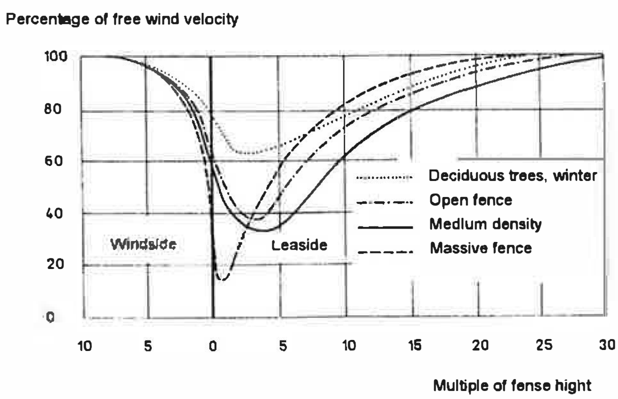

Figure 2. Wind velocity behind a wind shield of varying density (after Geiger[3])

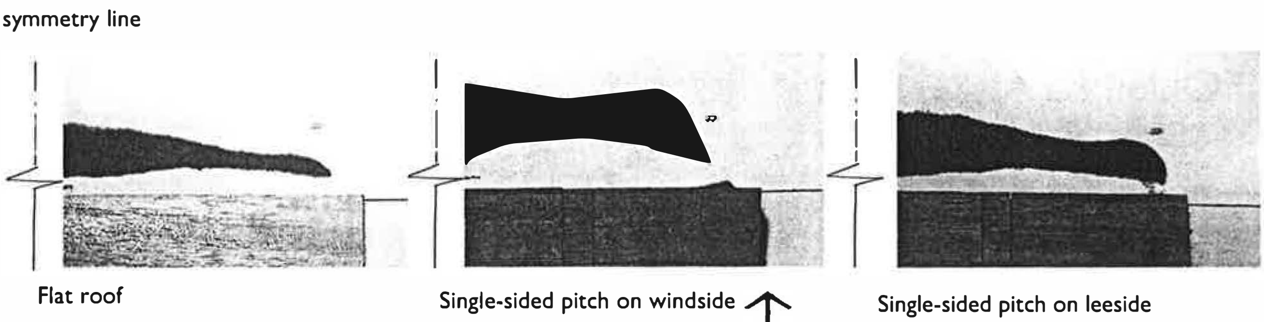

Figure 3. Wind protection from different roof shapes. Wind direction

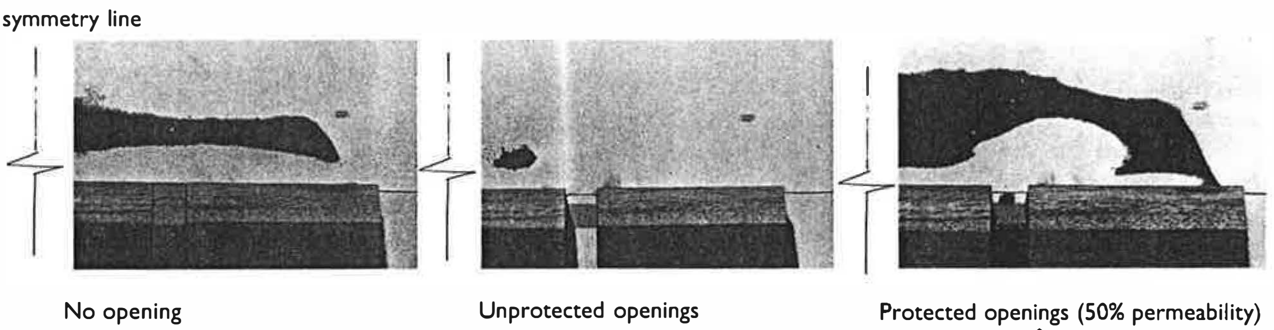

Figure 4. Wind protection with and without openings in a terrace with a pitched roof. Wind direction

- Out of 900 sunshine hours during summertime (15 May to 15 September), it is comfortable to remain outside on terraces and the like for 70 hours if there are no shelter belts and 170 hours if there are shelter belts present.
- Comfortable strolling outside is possible for approximately 370 hours if there are no shelter belts, rising to approximately 520 hours, out of a total of 900 sunshine hours, if there are shelter belts present.

WIND-TUNNEL TESTING

Subsequent to the local climatic monitoring and evaluation, various tests of site layout and building form were made on scale models in the wind tunnel of the Danish Maritime Institute in Lyngby.[4] A pilot project consisting of 27 terrace houses of one or two storeys was chosen for the study. This project was subsequently built and tested at full scale, as described below.

The basis for evaluation was that the overall site should be developed with terrace houses of one or two storeys and that maximum protection against the wind should be provided as soon as the buildings were finished. However, green shelter belts could be added, given further protection of 5 to 10 years, when they were fully grown.

All tests were carried out with two test methods:

- monitoring of velocity with an anemometer;
- visualization with dust, which is gradually removed as the wind velocity is increased.

Initial tests were made to determine how various building shapes would provide protection. For two-storey terrace houses, three different roof constructions were tested; flat roof, single-sided sloping roof and pitched roof. Furthermore, three types of terraces were tested; long closed terraces, terraces with openings and terraces with openings protected by wind shields. The scale was 1:200, and results are shown in Figures 3 and 4.

For each of the six tests shown in the two figures, the results of a dust visualization test is shown. In all cases, the final wind velocity was the same. The area of dark dust that is not removed represents an area with relatively low wind speeds, i.e. the more dust left, the better the wind protection.

There is some difference regarding roof shape, although it is not striking. However, large differences are noted regarding the influence of openings in the terrace. Unprotected terraces give very poor protection on the lee side of the building. The best solution is seen to be openings with a protecting wind shield. Large areas of dust are undis-

Figure 5. Scale model (1:200) used in the wind tunnel. The pilot development of 27 houses is at the front

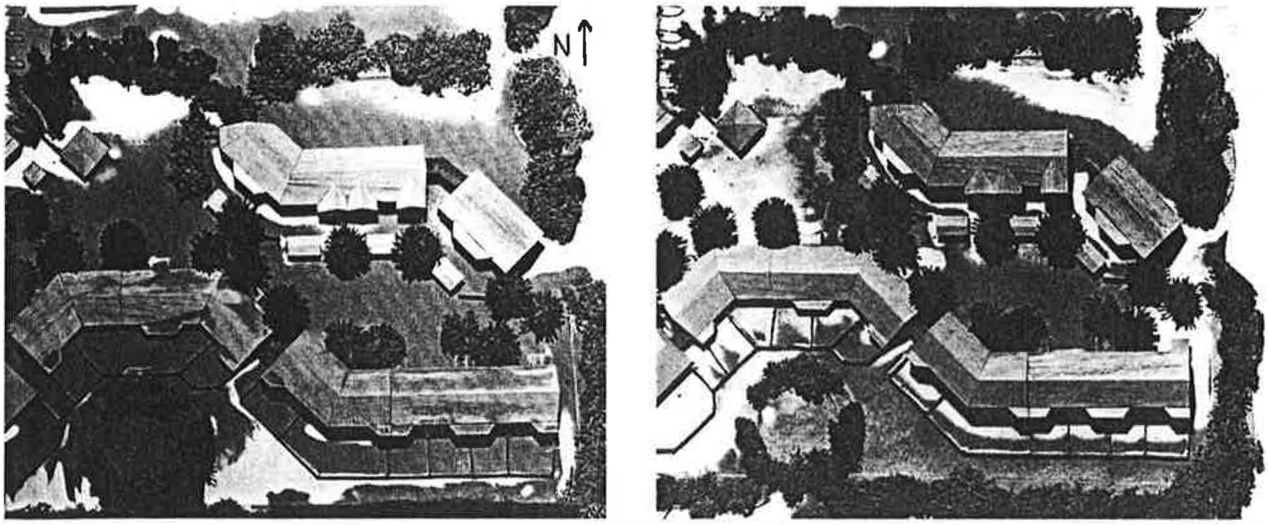

Figure 6. The wind from the south with high (left) and low (right) shelter belts situated south of the southern terrace

turbed, although the area near to the protected opening is not too comfortable.

On the basis of these tests, it was decided that one of the key elements in the layout of the 27 houses should be openings with protection, with the intention of giving shelter behind the houses from year one.

In Figure 5 a 1:200 model of the project is shown. The pilot project of 27 houses is in the foreground, but a planned later development is also shown to the north, while to the north-west the only existing trees in the area are shown. This picture illustrates the final building plan with green shelter belts. The anemometer for measuring wind velocity is seen to the left. A series of tests with various wind directions, with and without green shelter belts, were made.

In Figure 6 the results of two tests with the wind from the south is shown. In the case to the right, the shelter belt south of the southern terrace has a height of approximately 5 meters, compared to the 8 meter roof-pitch height of the buildings. In the case to the left the height of the shelter belt and of the houses is the same. It can be seen that low shelter belts give problems with wind turbulence in front of the houses and poor comfort in the gardens to the south. Shelter belts at the same height as the houses are therefore seen to be important. They carry the wind over the building, a phenomenon that has also been illustrated in a video taken using smoke testing.

For the actual construction, a combination of fast-growing trees and slow-growing permanent trees was chosen, giving full protection 10 years after planting. All the trees are deciduous, so that penetration of the winter sun to the houses is maximum. Figures 5 and 7 also show that straight lines allowing wind directly into the area are avoided; the buildings themselves form a mesh, so as to break up the wind flow.

Construction of the 27 terrace houses started in 1987 and the buildings were occupied in the summer of 1988. In Figure 7 a drawing of the final layout of the project is shown.

In Figures 8 and 9, various features of the realized project are shown. The wind protection in the openings are wooden fences with 50% permeability. And in some cases, gates are added to allow passageway.

The two-storey terraces to the north-east (Figure 7) will be shaded in wintertime by the two-storey terraces to the

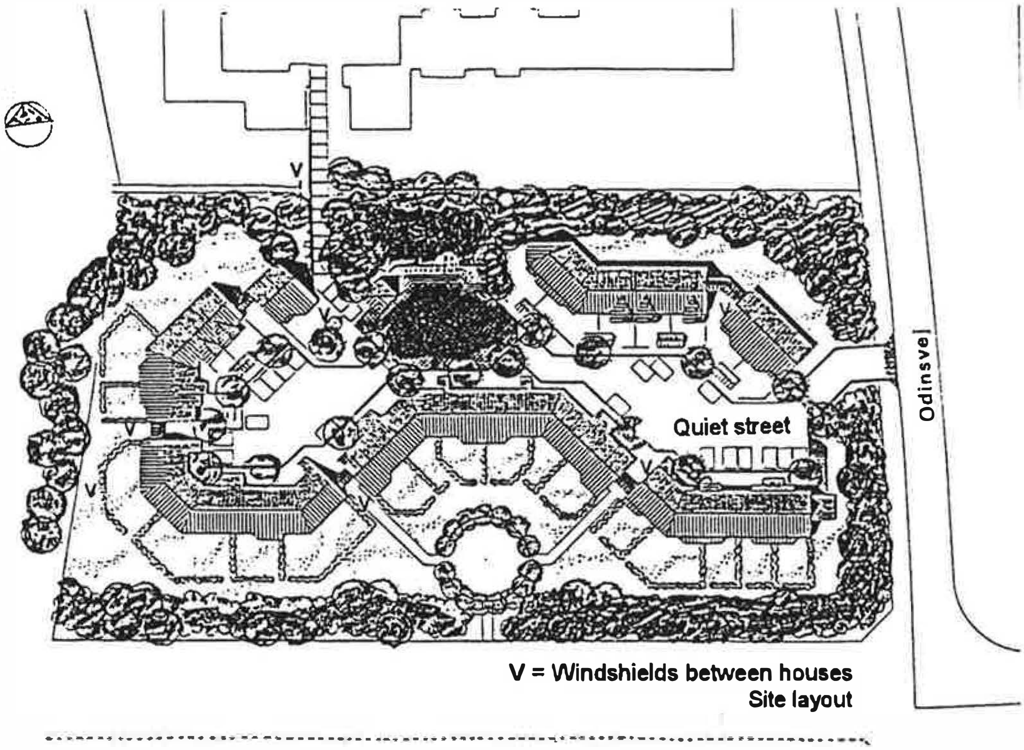

Figure 7. Site layout of the pilot project

south. These particular apartments have therefore been planned so that the solar rooms (living room and kitchen) are on the first floor. The winter sun will therefore reach the main rooms with the largest window area, and the use of passive solar energy is maximized.

FULL-SCALE TESTING OF THE WIND ENVIRONMENT

The wind environment at full scale has been compared with the 1:200 scale testing.[5] In Figure 10 the results of

Figure 8. Two-storey wind shield and the southern facade of a house with the living room on the first floor

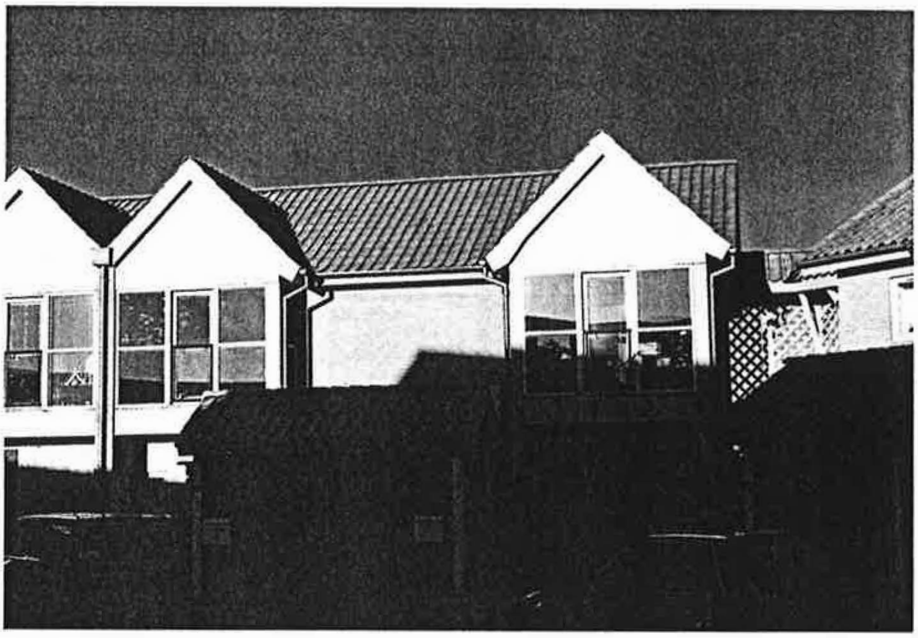

Figure 9. The southern facade of houses with the living room on the first floor. The photograph was taken on 15 November at 11.00 am and shows the shading produced by the houses in front

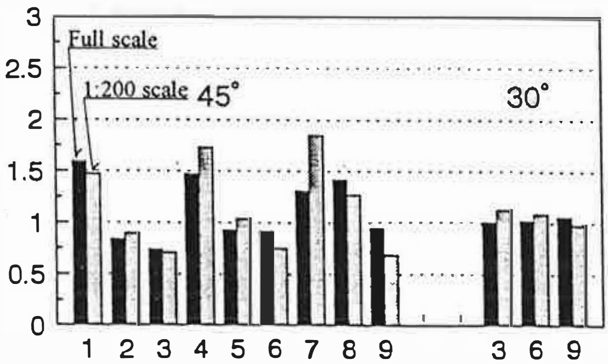

Figure 10. Wind reduction factor on the central square compared to wind without shielding

monitoring of wind in the middle of the area, on the small square, are compared with the 1:200 scale testing, shown as the wind outside the area divided by the wind at various measuring points in the square. The wind directions during full scale test were 45° and 30°, i.e. north-east. Measurements were taken during winter, which means a poorer reduction factor in both cases because there are no leaves on the trees.

It is clear that there is a remarkably good similarity between the results of the on-site monitoring and those of the scale monitoring in the wind tunnel. The figure also illustrates that the wind environment is much better in certain parts of the square. This was also confirmed by dust visualization.

Detailed monitoring of the north-eastern shelter belt was compared with wind tunnel monitoring at a scale of 1:50. In the wind tunnel, wind velocities close to the lee side of the wind shield were higher than those measured ahead of the shield, but by 2–3 m behind the wind shield, a reduction factor of 2.0 was achieved, corresponding to a 50% reduction of the wind speed. The full-scale test showed a reduction factor of 1.54, slightly lower than in the wind tunnel.

In conclusion it can be noted that the model testing in wind tunnel provided a good basis for developing a good building and site layout. Thus, a significant improvement of the local wind environment in the pilot project was achieved. This is confirmed both by wind monitoring in the area, and by the subjective evaluation of the users. Details on the results presented in this paper can be found in references 4, 5 and 6.

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