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THE BENEFITS OF SHELTER AND SITE PLANNING

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ABSTRACT

The results of a literature review and desk study on the potential for reducing energy demands in building through the appropriate use of shelter and site planning are reported. It is concluded that savings in the region of 5% may be made by sheltering modern housing in the UK. This sheltering can be achieved by appropriate shelter belt design and site planning. In modern, well sealed buildings, the potential for reducing infiltration heat losses by means of shelter are far less than for older buildings. To shelter single glazing can result in significant energy savings, especially if large glazed areas are employed, for example as part of a passive solar building design.

INTRODUCTION

For many centuries it has been recognised by architects and planners that attractive conditions in and around buildings can be created by appropriate site planning and landscaping. Ten or twenty years ago attention was paid specifically to the sheltering of buildings in order to reduce ventilation and infiltration heat losses and in order to create an attractive micro-climate in the gardens and passageways around buildings.

In recent years, the provision of shelter has become less important with regard to its effect on infiltration and ventilation heat losses because the sealing of buildings has been improved and mean air change rates in houses have fallen below 1 ach. Modern, low energy houses are now so well sealed, with air change rates approaching 0.5 ach, that it is no longer so important to reduce infiltration by sheltering because very low levels may cause condensation and odour problems. Shelter, however, can also be used to reduce fabric heat losses and this is still worthy of consideration as a potentially economic option in the design of energy efficient low energy buildings. Such benefits must then be weighed against any reduction in solar gains which might result from shading caused by the shelter.

Effects of Shelter on Fabric Heat Losses

The losses through building fabric are generally limited by three resistances to heat transfer:

(a) Internal surface convection and radiation (R_{si})
(b) Conduction through the building fabric (R)
(c) External surface convection and radiation (R_{so})

The sum of these resistances is often represented in terms of an overall 'U' value for each element of building fabric, where

$$U = \frac{1}{R_{si} + R + R_{so}} \quad (W/m^2K) \quad ....\text{Eqn (1)}$$

Since air movement within a building is usually much less than outside, the boundary layer of air on the inside walls is usually thicker and causes a greater resistance to heat transfer than on the outside. Hence the internal convection coefficient is usually lower than the external coefficient. A typical value is about 0.123 m^2K/W.

The largest resistance to heat flow for most elements of the building fabric is the conduction resistance, since walls and roofs are required by Building Regulations to be well insulated. However, the conduction resistance of windows and doors are usually very much smaller than for the walls by which they are surrounded.

From the point of view of reducing fabric heat losses, shelter may be considered primarily to influence the external convection coefficient and the external radiation heat transfer of building surfaces. The convective heat transfer coefficient varies not only with wind speed, but also with the angle of attack of the wind onto the building surface and the degree of turbulence in the wind itself. The radiative heat losses from the building surfaces vary in accordance with the mean radiative temperature of their field of view, which is strongly influenced by the weather conditions as well as by the proximity and nature of the shelter.

There are several empirical correlations between the surface heat transfer coefficient and the wind speed, and further work on these remains to be done (1). However, in order to derive estimates for the scale of the variations in convective heat transfer coefficient (h) with wind speed (v), the simplified and widely adopted correlation given by the IHVE Guide may be used:

$$h = 5.8 + 4.1\,V$$

where $h = 1/R_{SO}$ (W/m^2K)
and v = wind speed (m/s)

By using this simplified correlation to derive values of R_{SO} for different wind speeds, and assuming constant values for R_{SI} and R, it is possible to determine the variations in typical building fabric U values with wind speed. Examples for some of the most common building elements are shown in Figure 1.

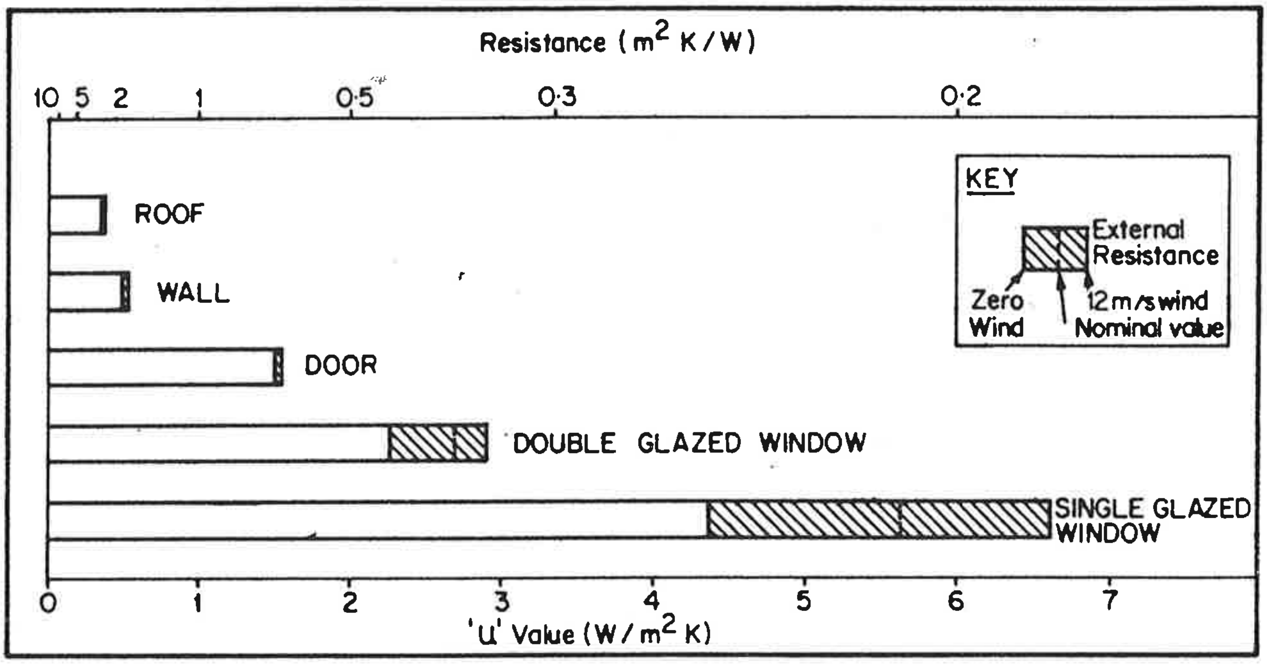

Figure 1 The Effect of Wind Speed on Typical 'U' Values for Building Elements

It can be seen from Figure 1 that the most important effects of wind speed are on areas of single glazing. This of course, is important for passive solar buildings where the areas of glazing are larger than usual, particularly on south facing facades.

The effects of having such sizeable heat losses from windows can be mitigated at night by the use of insulating shutters or heavy curtains, so it is mainly during daylight hours that the sheltering of windows will be of benefit.

Effects of Shelter on Ventilation Heat Losses

Modern low energy houses are usually very well sealed, but their infiltration and ventilation heat losses still represent up to 25% of the total annual heat losses. Air enters and leaves a building either by infiltration through small cracks and gaps in the fabric, or because it is allowed to enter the building through open doors and windows in order to provide fresh ventilation air for the building occupants.

Modern draft sealing techniques allow most houses and conventional buildings to operate with infiltration rates of little more than 1 ach and in some low energy houses with less than 0.5 ach (2). However, because occupants have to enter and leave their buildings, and not all of the internal spaces are used equally, it is common to find rather higher ventilation rates in occupied buildings (1 to 2 achs). In exposed locations, these ventilation rates can vary substantially during the day as wind speeds vary, and can thus cause significant heat loads. By providing shelter around a building it is possible to reduce the variations in local wind speed and hence to reduce the variations in ventilation rates. This has the effect of reducing the ventilation heat loads which would otherwise occur when occupants open doors and windows.

It is only feasible to use shelter for reducing ventilation heat loads in buildings which are naturally ventilated and shallow in plan. Deep plan buildings with forced ventilation or air conditioning do not benefit from shelter in this way.

For industrial buildings, a notoriously difficult problem is that of minimising the heating loads in areas around loading bays, and around doorways used by fork lift trucks. It is possible to reduce such problems by taking account of the prevailing wind directions when positioning such entrances, and by the use of appropriate shelter.

Shelter Belt Design

It has been recognised for many centuries that local wind speeds can be reduced by planting shelter belts, and such belts have been studied both in the field and through the use of wind tunnels. Shelter belts, however, have usually been used to reduce the wind speeds in high wind conditions when there is a risk of wind damage, rather than to reduce the mean annual wind speed for energy conservation purposes.

The literature on shelter belts is dominated by studies which have considered strong winds in open conditions, and the potential for reducing high wind speeds by the use of trees and hedges. This literature is relevant to the problem of energy conservation in buildings but does not provide all the necessary information on it. When considering energy conservation in buildings it is important to consider the variations in belt porosity between winter and summer, and the low wind speed performance of the shelter belt.

The aim of planting a shelter belt is to reduce the velocities of the wind over the full height of the buildings which are being sheltered, because a significant source of ex-filtration in buildings is through the roof. The shelter is mainly needed in the winter months in the UK, and therefore there are advantages in selecting evergreens for use in shelter belts.

If a shelter belt is solid, such as a brick wall, then the wind will be deflected by the belt causing local accelerations of the wind, and eddies will form on the lee side of the wall. Eddies and vortices formed between the wall and the building can result in infiltration or ex-filtration with a magnitude similar to that which would have occurred had the wall not been present.

It is particularly important to ensure that there are no vertical 'gaps' in a shelter belt, because these can produce regions of locally increased velocity. Such gaps may occur naturally if trees are used as the main shelter and their branches do not grow near to the ground (see Fig 2).

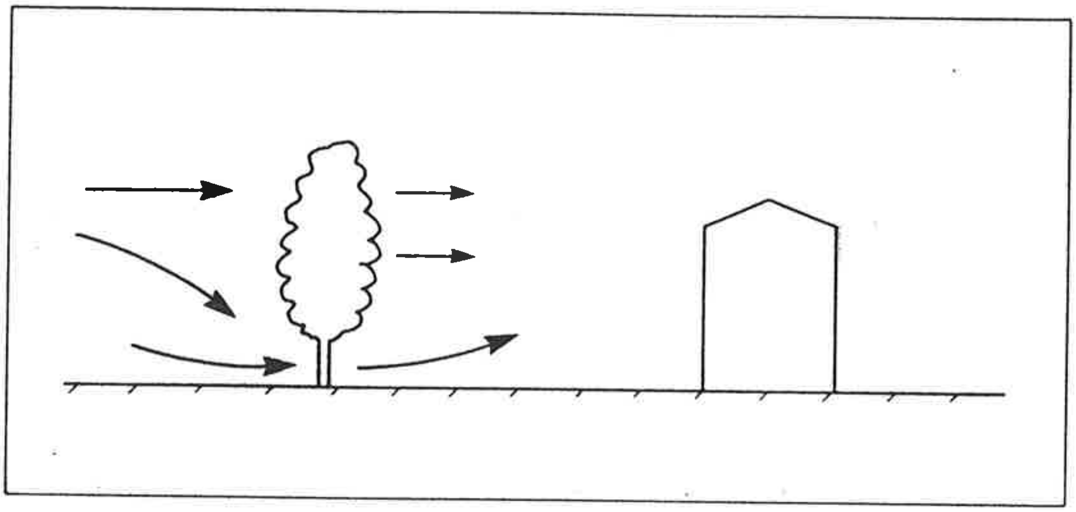

Figure 2 Wind Velocities Increased at Low Level by Trees without Low Branches

The problem illustrated in Figure 2 can be minimised by using a combination of trees and hedges or of trees and porous fencing, as shown in Figure 4. Similarly, gaps in a shelter belt for roads or gates should be protected such that local areas of increased velocity do not result. A suitable layout, based on the work of Harrje (3) is illustrated in Figure 3. This shows a shelter belt extending slightly beyond the length of the house to afford protection to the side walls, and additional trees placed to 'plug' the gap' in the belt in order to permit the passage of a roadway.

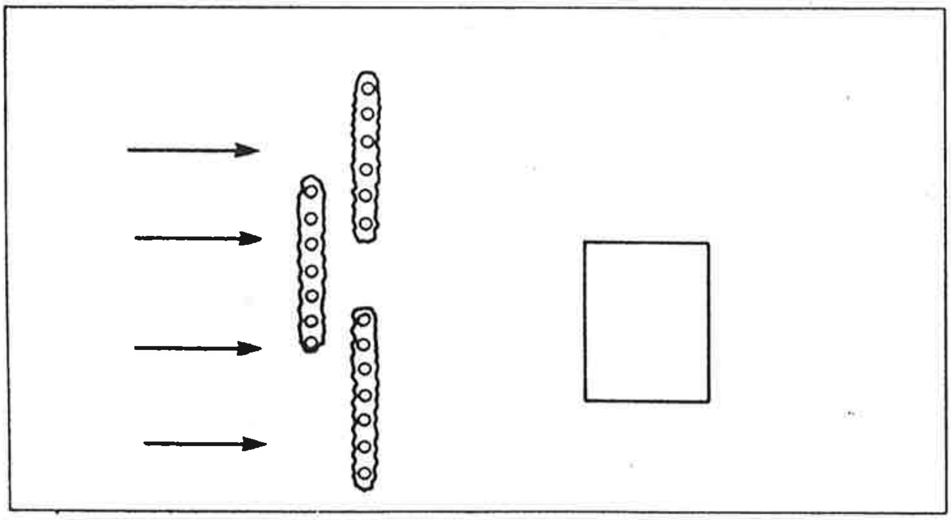

Figure 3 Layout of Shelter Belts to Allow Passage of a Roadway

In an estate of houses, the buildings themselves may be used to shelter each other from the prevailing wind. This is most obviously done by means of terraced housing, but detached housing may also be sited in such a way that shelter is maximised.

Shelter Belt Positioning

The wind speeds downstream of a shelter belt vary as the distance from the belt, and with the belt porosity. The greatest speed reductions occur immediately downstream of a very dense (low porosity) shelter belt, but such reductions are usually accompanied by eddies and vortices which raise the mean velocity rapidly within a few shelter belt heights.

For the commonly recommended shelter belt (Refs 3, 4, 5) with an average porosity of about 50%, the minimum wind speed occurs at a distance of a few shelter belt heights from the belt (say 2-6 H). A good rule of thumb for designers would appear to be about 3 H (see Figure 4). Few planners would wish to plant at less than 2 H for reasons of safety, tree root growth and shading. To plant at a distance of more than about 6 H allows significant re-establishment of the free wind regime.

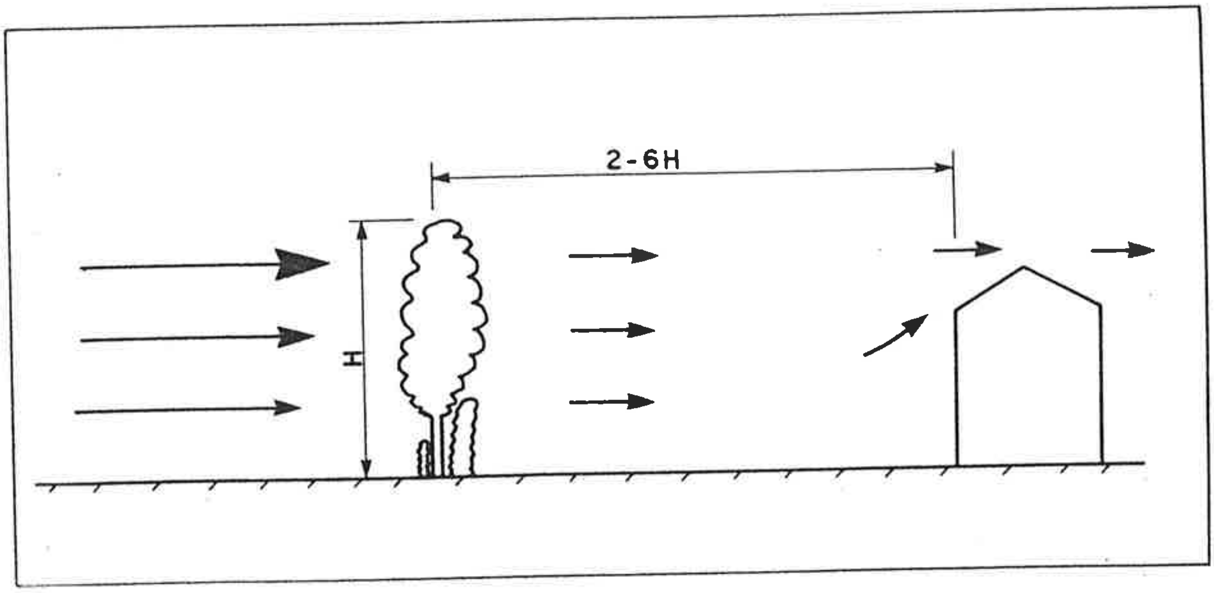

Figure 4 Optimum Spacing between Shelter Belt and Building

At a distance of about 3 H from the shelter belt, average reductions in the free wind speed of 50 to 60% are reported by Dewall (3) for wind speeds in the range from 3 m/s to 7 m/s. This and other evidence in the literature would suggest a rule of thumb reduction of wind speeds of about 50% for average porosity shelter belts spaced at a distance of 3 H from buildings.

Shelter Belt Orientation

Several investigators have considered the problem of sheltering a building from winds which come from different directions. Small deviations from the prevailing wind direction can be accommodated by extending the length of the wind break, but this will not reduce the speeds of winds coming from other directions.

For much of the South of the UK, the prevailing winds come from the south-west, and a shelter belt running from NW to SE would provide the most effective shelter of any linear option. However, because of the constraints of roadways, housing access, and terraced housing layouts, non-linear arrangements of shelter may need to be employed.

Discussion and Conclusions

It has been shown that buildings can be sheltered by an appropriate arrangement of trees and bushes or porous fencing to reduce wind speeds and hence to reduce heat losses. The magnitude of the benefits from shelter depends on the local wind regime and the characteristics of the building itself.

In the south of the UK, where typical mean wind speeds inland are in the region of 3.5 m/s it is reasonable to imagine a reduction in local mean wind speed to between 2 m/s and 2.5 m/s by the appropriate use of shelter, based on the assumption that the shelter will reduce all wind speeds of greater than 2.5 m/s by 50%. This would have the effect of reducing the heat losses from single glazed windows in a typical modern house, with 30% heat loss through its windows, by about 2%.

Similarly, for a typical house with an infiltration rate of about 1 ach, shelter might reduce the infiltration heat losses by up to 20 or 30%. For a typical well insulated house, where infiltration heat losses represent about 20% of the annual heat losses, this would correspond to an annual energy saving of several per cent.

It may thus be concluded that for modern housing in the south in the UK, there is a potential for energy saving through the appropriate use of shelter, and that this saving is likely to lie in the region of about 5% over the year.

For high rise buildings where infiltration is strongly driven by stack effects, and in deep plan commercial and industrial buildings, the benefits of shelter lie mainly in creating a pleasant environment in the garden and around the building entrances. Where entrances are heavily used, for example loading bays and goods entrances, the provision of appropriate shelter may also produce substantial heating energy savings.

REFERENCES

(1) Duffie, J A and Beckman, W A. Solar Engineering of Thermal Processes. Wiley (1980).

(2) Warren, P. Natural Ventilation Rates in Modern Housing. BRE Energy Research, BRE, Garston (1984).

(3) Harrje, D T, Buckley, C E and Heister G M. Building Energy Reductions: Windbreak Optimisation. ASCE Conf. New York (1981).

(4) DeWall, D R and Heisler, G M. Wind break effects on air infiltration in a Mobile Home. Energy and Buildings 5 (1983).

(5) Grist C R. Assessing the Energy Saving Benefits of Windbreaks for Residential Buildings. Dept of Landscape Arch. Univ. of Madison, Wisconsin.

Acknowledgement

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