WINDOW DESIGN IN HOT DRY CLIMATES

B. Sodagar, B.F. Warren
University of Newcastle upon Tyne
Newcastle upon Tyne, United Kingdom, NE1 7RU

ABSTRACT

The choice of fenestration for a building can significantly affect its thermal performance. In Northern Europe, the main thrust of energy saving measures in houses is directed towards the heating energy consumed during the winter months. In this situation a cooling load rarely exists. In hot dry climates, the situation is different and the climates are often such that both cooling and heating seasons have to be considered. This requires the optimisation of not only the building fabric, but also the choice of heating and cooling systems and fuels. The economic analysis is made more complex where the cost of gas and electricity are widely different. The results of a parametric study of the dependence of energy and environmental performance of a single storey nine zone dwelling on glazed area and shading devices are reported in this paper.

INTRODUCTION

An investigation is currently being carried out in the school of architecture of the University of Newcastle upon Tyne, U.K. into the effects on energy use of varying the thermal performance of houses in hot dry climates using ESP computer program. The program was developed at the University of Strathclyde, U.K. and has undergone extensive third party validation. The dynamic heat flow is calculated by the finite difference method.

HOUSE TYPE

A single storey nine zone dwelling (Fig 1), is being studied using basic weather data from Iran. Since one can have an infinite number of combinations of such aspects as window design, material and fabrications, the scope of the work has been limited to modelling what is considered to be practicable and reasonable. The external walls of the house are 220mm brickwork plastered internally. The floor is concrete on the grade and the roof is a traditional warm roof consisting of concrete slab insulated externally and topped with screed and asphalt. Internal partitions are 110mm brickwork plastered on both sides. The glass chosen is a single pane of 4mm clear float which is the most common and available glass used in the housing industry.

MODELLING CONTROL CONDITIONS

Previous studies had established that for the particular climate under

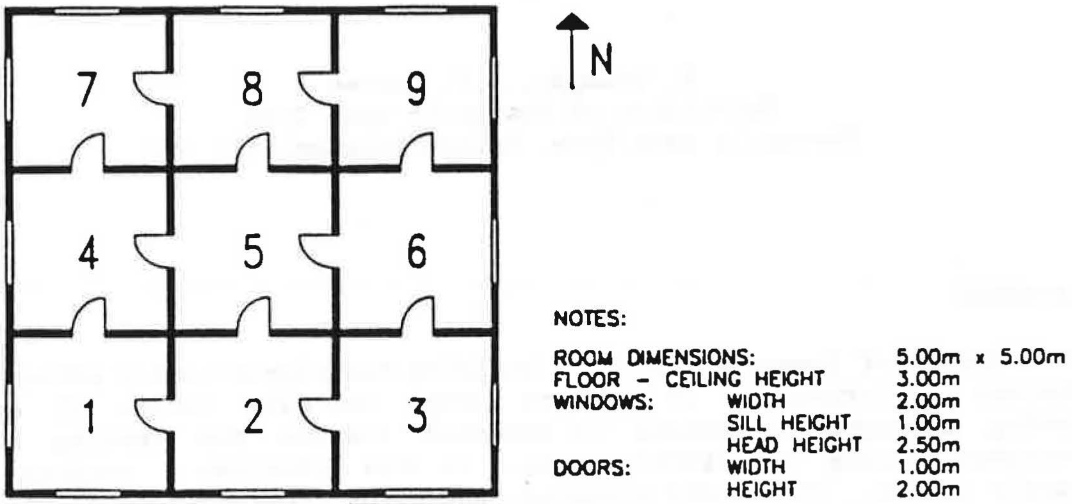

FIGURE 1. Floor plan of the reference house

consideration, the heating season effectively consisted of the months from November to March and the cooling season the months from May to September. During April and October, the weather is such that mechanical heating or cooling would not normally be required.

For both the winter and summer, temperature and ventilation regimes were chosen which were considered to be representative of common practice (Table 1).

RESULTS

In order to examine the effect of window size and its orientation on energy demands of spaces, four rooms of the reference house facing four cardinal orientations were considered, zones 2, 4, 6 and 8. It was assumed that there is no heat flow through internal partitions, i.e. rooms are surrounded by thermally identical rooms. Window design of these rooms was changed. Different areas of glazing were obtained by

TABLE 1. Thermostat set point schedules and ventilation rates

HEATING SEASON			COOLING SEASON		
Time	Controlled Temps.	Ventilation rate ac/h	Time	Controlled Temps.	Ventilation rate ac/h
05 - 09	20°C minimum	1	05 - 23	22°C maximum	1
09 - 15	system off	1	23 - 05	system off	20
15 - 23	20°C minimum	1			
23 - 05	15 (set back)	1			

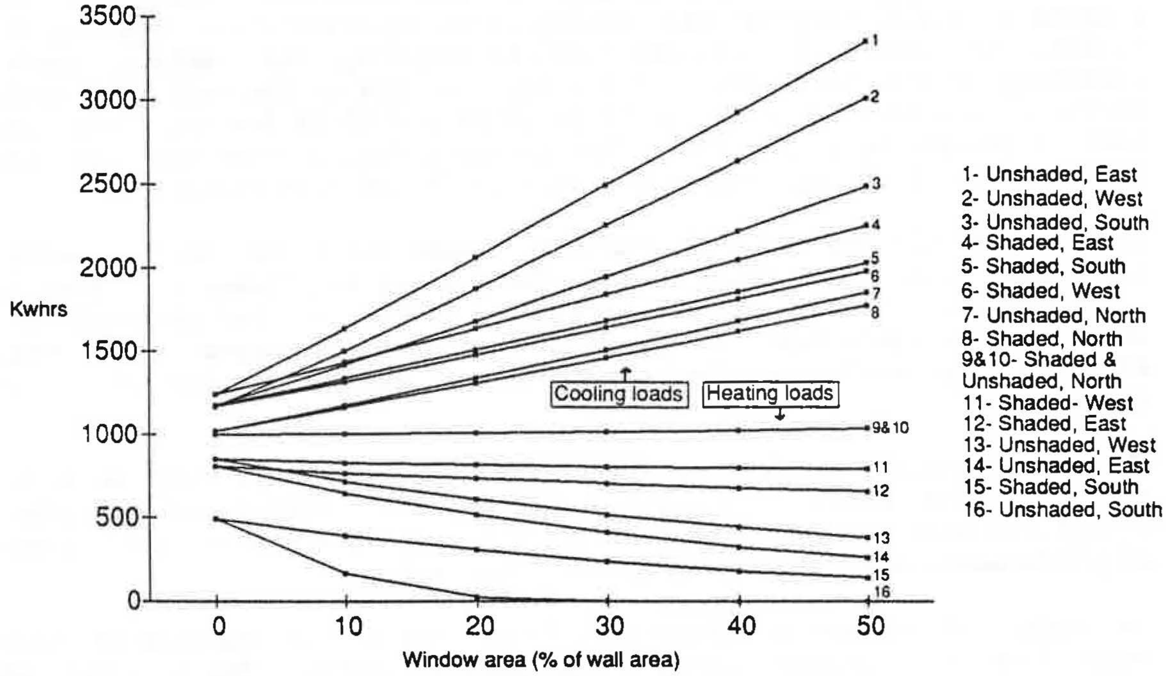

FIGURE 2. The effect of window size and shading on loads

changing the window width whilst keeping the height at a constant 1.5 metres. Changing the width from 1 to 5 metres in increments of 1 metre gives window to wall ratios of 10, 20, 30, 40 and 50 percent respectively. In all cases windows were located centrally on the external walls with a constant window sill height of one metre. Rooms without any windows were also investigated for comparison.

To evaluate the performance of fixed external shading devices, in the first instance the method of Olgyay (1) was used to estimate the size of devices. In our simulation runs it was imposed that the shadow of the device would cast only on the glazing and would not stretch to adjacent fabrics, i.e. fine louvers and/or vertical fins were used. The effect of devices was limited only to intercepting the direct solar radiation, therefore any other heat exchanges which might take place between devices and windows, i.e. by radiation or convection were neglected.

Cooling and heating requirements of rooms with different glazing without shading devices and those with devices designed using the method of Olgyay are shown in Figure 2.

The cooling requirements of north facing rooms are minimal as they do not receive a great quantity of direct solar radiation. Consequently, shading windows does not provide significant reduction in cooling loads. Since in the site in question, latitude 32N, windows facing north do not receive any sun shine during the heating season, i.e. from November to March, one line represents the heating requirements of rooms with and without shading devices (Fig 2).

The effect of window size and shading is quite significant on the thermal performance of rooms facing east and west. Any increase in the glazing area will increase the cooling loads substantially. Shading the windows in summer is very effective in reducing the cooling loads. Providing shading on windows comprising, i.e. 20% of the wall area would decrease the cooling requirements by 20.6% and 20.1% for the east and west orientations respectively. The corresponding percentages for the south and north facing windows are only 10.2% and 2.2% respectively.

Because of the abundance of sunshine, except for rooms facing north, increasing the window areas reduces the heating requirements. Heating loads are increased in presence of shading devices as they obstruct some of the winter sun's rays. Large south facing windows appear to be very efficient in winter as they can harvest a great quantity of solar radiation.

The annual cooling and heating loads represent the energy that has to be extracted and added respectively and are not energy consumptions. Energy consumptions will depend on the refrigeration system coefficient of performance and the heating system efficiency.

In terms of economics, changes in loads need to be considered with respect to their ultimate impact on purchasing energy. The designer of a house and its ultimate occupier will be concerned with running costs and the cost effectiveness of any modification in the design of the building. It is of use, therefore, if the energy consequences of changing the window design can be expressed in terms of cost.

If the annual cooling load is given by Lc Kwhrs, the heating load Lh Kwhrs, then the total annual energy requirements, Qt, is given by:

$$Qt = Lc/cop + Lh/f \quad \text{Kwhrs} \tag{1}$$

Where cop is the coefficient of performance of the cooling system and f the overall efficiency of the heating system. Typically for Iran the cooling system is electricity driven whilst gas is used for heating. If the cost of electricity is Ce per Kwhrs and that of gas Cg per Kwhrs, the total annual cost Ct is given by:

$$Ct = (Lc/cop) * Ce + (Lh/f) * Cg \tag{2}$$

This can be written as:

$$Ct/Cg = (Lc/cop) * N + (Lh/f) \tag{3}$$

Where N is the ratio of electricity cost to gas cost, Ce/Cg.

Values of cop, f and N vary depending on the efficiencies of the refrigeration system, heating system and the local prices of fuels respectively. By assuming that values of cop may vary between 2 and 3, and those of f between 0.6 and 0.8, and N between 3 to 6 different scenarios may be considered. We considered 3 scenarios. In scenario 1 (SC1), we took middle range of variables, i.e. values of 2.5, 0.7 and 4.5 for cop, f and N respectively. By substituting these values in equation 3 we will have:

$$Ct/Cg = 1.8\ Lc + 1.43\ Lh \tag{4}$$

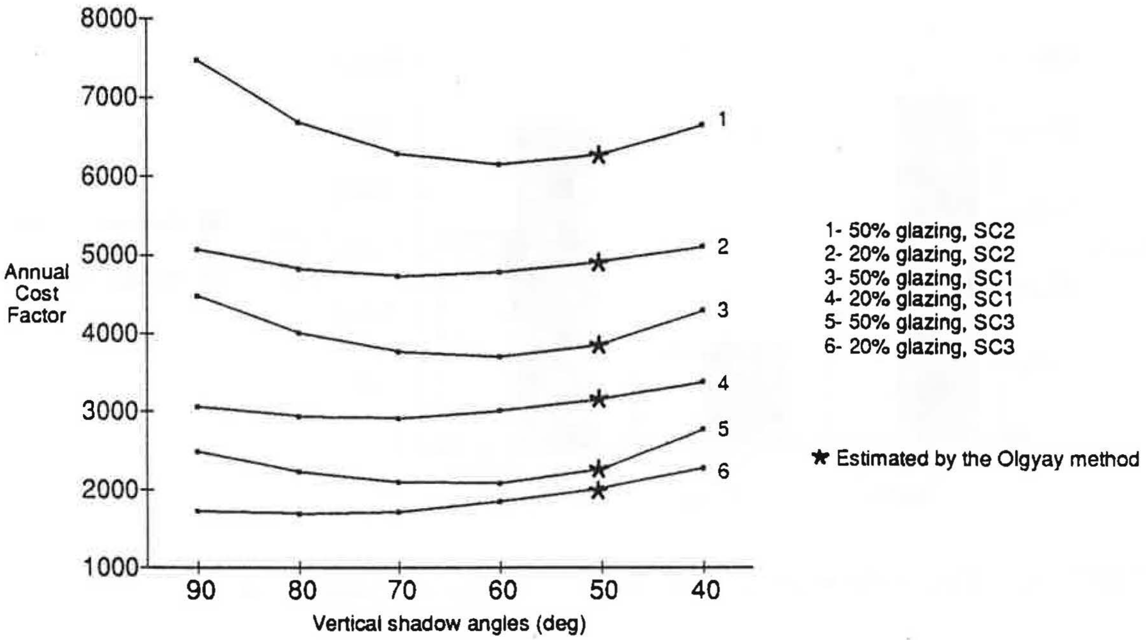

FIGURE 3. Fenestration cost analysis for south facing room

Scenario 2 (SC2) was in the favour of heating loads. i.e. values of 2, 0.8 and 6 were chosen for cop, f and N respectively. And finally in scenario 3 (SC3), values of 3, 0.6 and 3 were assigned for cop, f and N respectively. By substituting these values in equation 3, we should have:

$$Ct/Cg = 3\ Lc + 1.25\ Lh \quad \text{for SC2} \tag{5}$$

and :

$$Ct/Cg = Lc + 1.67\ Lh \quad \text{for SC3.} \tag{6}$$

The cost effectiveness of changes in window design now can be cast into values of Ct/Cg designated as Annual Cost Factor (Ct/Cg = ACF).

In order to investigate the effect of the size of shading devices on energy consumption and consequently the cost of conditioning houses, the design of shading devices of two windows comprising 20 and 50% of the wall area was modified. The results for the south facing windows are plotted in Figure 3. One can see that the size of the shading devices estimated by the Olgyay method is overestimated under any scenario. The results for east and west orientations were more satisfactory.

From results obtained, the fenestration design of the reference house (Fig 1) was changed. Windows comprising 20% of the wall area seem to be appropriate to satisfy visual comfort while being reasonably efficient in energy terms. Windows facing east and west in four corner rooms, zones 1, 3, 7 and 9, were eliminated due to their poor thermal performance. Since shading on windows facing north does not reveal significant savings, no devices were considered for these windows.

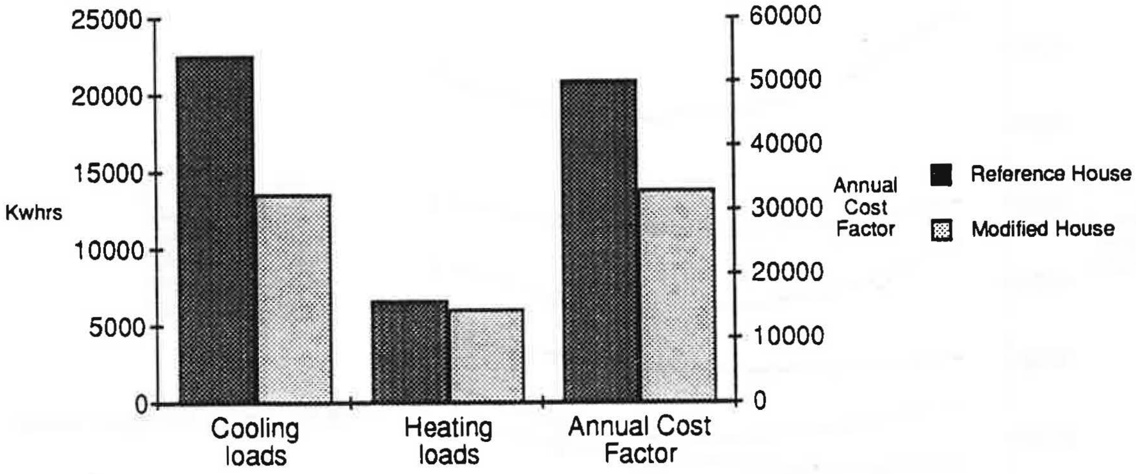

FIGURE 4. The effect of fenestration design on loads and costs

Horizontal shading devices bearing a vertical shadow angle of 70 degrees were placed over south facing windows, and those with an angle of 35 degrees on east and west facing windows.

Annual heating and cooling loads together with the Annual Cost Factors of the house with the new window arrangement were calculated under scenario 1 and are shown together with those of the reference house in Figure 4 . A substantial saving in the annual running cost as much as 34% can be achieved under the new design strategy.

CONCLUSIONS

The results of a parametric study of the dependence of energy performance of a single storey residential prototype on fenestration design was reported in this paper. ESP computer programme was used to analyse the variations in heating and cooling loads due to changes in orientation, size and shading of windows. Substantial savings in the annual running cost of buildings can be achieved under appropriate window arrangements. The simple graphical methods for estimating the size of shading devices, i.e. the Olgyay method may over-estimate the size of the device.

REFERENCES

(1) Olgyay, A. and Olgyay, V., Solar control and shading devices. Princeton University Press, 1957.
(2) Sodagar, B. and Warren, B.F., The effect of mass on comfort and energy requirements in hot dry climates. Proc, XIth International Congress on the Quality for Building Users Throughout the World, User Comfort, Paris 1989, CIB. Theme I, Volume II, pp 255-264.
(3) McKennan, G.T., Building energy needs and window area. BSER&T, Vol 6, 1985.