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WINDOWS

By Rudi Diamant

The function of windows in a building from the energy balance point of view is quite interesting. On the one hand, even multiple glazed windows have a far lower thermal resistance than badly insulated walls and therefore contribute largely to winter heat losses. On the other hand, solar radiation through windows is of very considerable importance even during the winter months as it contributes a lot of heat during daylight hours. In summer, of course, and in hot countries the heat received during the day through windows can be excessive and cause acute discomfort. With most buildings in Britain this is not much of a problem as the remedy is simply to draw curtains, leave the windows open or both. This, of course, would not do in hot countries, or countries which have more extreme weather conditions than ourselves, such as the United States. In those places one has to fit air chillers.

Let us now look at the function of windows in Britain during the winter months from the energy point of view.

As the thermal conductivity of glass is quite high (0.85 W/m K), and window glass is very thin, the only thermal resistance in the case of a single glazed window are the two layers of air close to the outside and the inside surface of the pane. If there is a high wind blowing, the thermal resistance of the outside layer can virtually be disregarded, leaving just the inside layer, to keep out the cold. This is not very effective. Fitting of even the flimsiest of net curtains makes a big difference, and at night it is essential that heavy curtains should be drawn. In a cold country like the UK, double glazing should really be standard. The thermal resistance of a window pane is doubled under wind-still conditions and trebled under high wind conditions.

Unfortunately, the calculation of all this when done by hand, is exceedingly complicated. The maths involved can only be tackled satisfactorily by a computer. Computer programs are available that deal specifically with windows. WINDOW evaluates the U-value and SOLAR the solar heat gain through windows during daylight hours.

Program WINDOW

The most important factor to consider when calculating the U-value of windows is undoubtedly the wind speed, because this affects the thickness of the external air laminar layer, as well as air infiltration through gaps and cracks of the window frame. The type of window frame used is also important, as is the percentage of the window area which it occupies. Then we come to the question of multiple glazing. In the UK double glazing is just about the limit, but in many other Northern European countries triple glazing is already coming to the fore. The gap between the two panes is most important. If it is too narrow, the width of the two vital laminar air layers is naturally restricted. However, there is an optimum upper limit of around 12 mm, beyond which internal convection between the panes destroys most of the effect of thicker insulating air layers.

The position of the windows concerned in the building is also of importance. Corner windows are affected more by the wind than windows in the centre and therefore more heat is lost by convection currents. The equations dealing with ventilation heat losses through windows, which are used in the program, have all been derived from the West German DIN 4701 specifications. These constitute, to my mind, the best general mathematical guides to insulation problems. ▶

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Print-out No. 1    No net curtains fitted

               Program  WINDOW

YOU HAVE FED IN THE FOLLOWING DATA:

Windspeed =  1.5  m/s
The window is a vertical type
The frame is of hardwood opening construction
The window is in the middle of the building
The length of air cracks round window =  2.77  metres/sqmetre window area
The window is double glazed
Net curtains are not fitted
Curtains are drawn at night
The window frame constitutes  5  % of window area

RESULTS

THE DAYTIME  U-VALUE OF THE WINDOW =   2.5568  W/sqm K

THE NIGHT-TIME U-VALUE OF THE WINDOW =   1.1479  W/sqm K

THE ADDITIONAL U-VALUE DUE TO AIR INFILTRATION =  .1123  W/sqm K
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Print-out No. 2    Net curtains fitted

               Program  WINDOW

YOU HAVE FED IN THE FOLLOWING DATA:

Windspeed =  1.5  m/s
The window is a vertical type
The frame is of hardwood opening construction
The window is in the middle of the building
The length of air cracks round window =  2.77  metres/sqmetre window area
The window is double glazed
Net curtains are fitted
Curtains are drawn at night
The window frame constitutes  5  % of window area

RESULTS

THE DAYTIME  U-VALUE OF THE WINDOW =   1.4469  W/sqm K

THE NIGHT-TIME U-VALUE OF THE WINDOW =   .8538  W/sqm K

THE ADDITIONAL U-VALUE DUE TO AIR INFILTRATION =  .1123  W/sqm K
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Skylights have to be dealt with in a separate way, both in program WINDOW and program SOLAR, as different equations come into play.

Finally, of course, we must take into consideration curtains. These are absolutely vital in cutting down heat losses, especially at night. During the day, net curtains are most effective in reducing heat losses, while still allowing solar radiation to enter. And they are far cheaper than double glazing.

The calculation of heat penetration through windows is extremely complicated. In the first place it depends on latitude, and on the month of the year, as this governs the height of the sun and its intensity, as well as the number of hours per day during which solar heat is being received. Figures differ appreciably as to compass direction if the window is in a vertical wall, or if the window is in fact a skylight.

South facing windows and skylights receive direct, diffused and reflected radiation through most of the day. East facing windows receive most of it during the morning, while west facing windows receive the bulk in the afternoon. Windows facing into any other compass direction only receive diffused solar radiation, which is far less. The data used in Program SOLAR for these calculations were established by research work carried out in Sweden and Canada by Hoglund and Stephenson and were published in the book: Fonsterteknik (Window Technology) by I. Hoglund and B. Ahlgren (Byggforlaget, Stockholm 1973).

Then we have to consider the fact, that there is a general haze in the air, which is a minimum out in the country, and a maximum in industrial areas. This drastically affects the actual amount of heat received. Finally, of course, we unfortunately do not live in a climatic area with constant sunshine. It is cloudy and rainy most of the time, so that even south facing windows only get a fraction of the theoretical solar heat contribution calculated. The fraction of the time when there are clear skies naturally varies with the time of the year. Program SOLAR uses data published by the British Meteorological Office, which are based on the average over a large number of years.

Example:

Let us consider a vertical window in the centre of a building erected at a geographical latitude of 53.5 degrees north (along a line stretching from Grimsby via Manchester and Liverpool to Dublin), in what can be described as a suburban area. The average wind speed, as measured by any commercial anemometer, averages about 1.5 metres/second.

The window measures 1.8 metres by 1.2 metres and is double glazed with a 12 mm cavity between the panes. The glass is mounted in an openable hardwood frame, that accounts for 5% of the total window area. At night heavy fabric curtains are drawn.

Results obtained from programs WINDOW and SOLAR

Print-out No. 1 gives the results of running Program WINDOW, using the data given. No net curtains are fitted.

The marked difference that net curtains make to the U-value of a window is shown by comparing print-outs No. 1 and No. 2.

Print-out No. 3 (Program SOLAR) gives the solar heat penetration through a window which faces south-east during the month of January, while print-out No. 4 gives values involving the same size window during the same month but facing north. Finally, print-out No. 5 gives the values for a skylight of the same dimensions, i.e. 1.8 metres by 1.2 metres, again during the month of January.

Needless to say, any of the numerous parameters which apply to these programs can be altered at will, enabling a designer to obtain comparative figures in a matter of a few minutues, without having to leave the computer keyboard.

All the programs in the series can be used in English (American) units as well as in the SI units shown in this article. All that is necessary is for the user to type in 'E' for English when asked his/her preference. ●

CIRCLE 150

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Print-out No. 3   Program SOLAR   South-east facing windows

The building is situated in a(n) suburban area
The haze factor is 85 %

There are 1 window(s) 1.8 metres high and 1.2 metres wide which are
double glazed and facing SE

The geographic latitude is 53.5 degrees north

THE HEAT WHICH FLOWS INTO THE BUILDING ON CLOUDLESS DAYS BY THE AGENCY OF
SOLAR RADIATION THROUGH THE WINDOWS STATED AMOUNTS TO:
   19.623 MEGAJOULES
OR 5.45 KILOWATT HOURS PER 24 HOUR PERIOD

THE HEAT WHICH FLOWS INTO THE BUILDING ON AVERAGE DAYS BY THE AGENCY OF
SOLAR RADIATION THROUGH THE WINDOWS STATED AMOUNTS TO:
   4.597 MEGAJOULES
OR 1.276 KILOWATT HOURS PER 24 HOUR PERIOD

DURING THE MONTH OF JANUARY
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The building is situated in a(n) suburban area
The haze factor is 85 %

There are 1 window(s) 1.8 metres high and 1.2 metres wide which are
double glazed and facing N

The geographic latitude is 53.5 degrees north

THE HEAT WHICH FLOWS INTO THE BUILDING ON CLOUDLESS DAYS BY THE AGENCY OF
SOLAR RADIATION THROUGH THE WINDOWS STATED AMOUNTS TO:
   1.822 MEGAJOULES
OR .506 KILOWATT HOURS PER 24 HOUR PERIOD

THE HEAT WHICH FLOWS INTO THE BUILDING ON AVERAGE DAYS BY THE AGENCY OF
SOLAR RADIATION THROUGH THE WINDOWS STATED AMOUNTS TO:
   .427 MEGAJOULES
OR .118 KILOWATT HOURS PER 24 HOUR PERIOD

DURING THE MONTH OF JANUARY

Print-out No. 4   Program SOLAR   North facing window
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Print-out No. 5   Program SOLAR   Skylight

The building is situated in a(n) suburban area
The haze factor is 85 %

There are 1 skylight(s) 1.8 metre(s) high and 1.2 metre(s) wide,
which are double glazed

The geographic latitude is 53.5 degrees north

THE HEAT WHICH FLOWS INTO THE BUILDING ON CLOUDLESS DAYS BY THE AGENCY OF
SOLAR RADIATION THROUGH THE WINDOWS STATED AMOUNTS TO:
   5.244 MEGAJOULES
OR 1.443 KILOWATT HOURS PER 24 HOUR PERIOD

THE HEAT WHICH FLOWS INTO THE BUILDING ON AVERAGE DAYS BY THE AGENCY OF
SOLAR RADIATION THROUGH THE WINDOWS STATED AMOUNTS TO:
   1.234 MEGAJOULES
OR .342 KILOWATT HOURS PER 24 HOUR PERIOD

DURING THE MONTH OF JANUARY
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