CLIMATE AND ENERGY USE IN ATRIA

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Glazed spaces have become a common feature in new buildings. Both small glazed spaces such as verandas and balconies, and larger ones covering whole courtyards, streets and squares, have been built. Existing buildings have also converted; balconies have been provided with glazing and the spaces between buildings have been covered with a glazed roof in order to provide climatic protection. Glazed spaces occur in both commercial and residential buildings.

However, merely providing a glazed roof for a space does not mean that the climate will automatically become just right. It is an inherent property of a glazed space that it is greatly affected by the outside climate. A lot of solar radiation enters through large glazed areas, and this can give rise to high temperatures in the summer. Since the insulation capacity of glass is inferior to that of a well insulated wall or roof, the glazed space is also greatly affected by the outside temperature. This implies, in turn, that low indoor temperatures can occur, especially during the cold and dark winter months in Northern Europe. A well thought-out building design can make use of the outside climate to create the best possible climate inside the glazed space. It is only when this is not enough that heating or cooling may be provided - or the space must be redesigned.

It is important to elucidate the general relationships between building design and climate in a glazed space, and between building design and energy needs in the glazed space in combination with adjoining buildings. Parameters such as the geometry of the building, type of glazing, orientation, thermal inertia, airtightness, ventilation system and sunshades affect climate and thermal comfort in the glazed space and energy requirements for heating and cooling. Some of these parameters are determined early in the design stage which means that the climate in the glazed space and energy requirements will also be indirectly determined at an early stage, maybe without any proper analysis.

In this article some important parameters are discussed. More results from case studies and theoretical studies are presented in [1].

Solar utilisation

Solar radiation has a major influence on the climate in a glazed space, and may of course be utilised in more or less efficient ways. Traditionally, the distribution of solar radiation inside a building has not been of major interest in energy simulation programs since most of the transmitted radiation in a building with ordinary sized windows is absorbed in walls, floors, furniture etc. The transmitted solar radiation is then a good approximation of the solar gain. However, studies of glazed spaces necessitate a detailed calculation of the distribution of solar radiation by the energy simulation program used.

As an example, the calculated distribution of solar radiation is shown for a sunspace with a room behind, see Figure 1. The sunspace consists of single glazed walls and a single glazed roof. The room has two large windows facing the glazed space to the south.

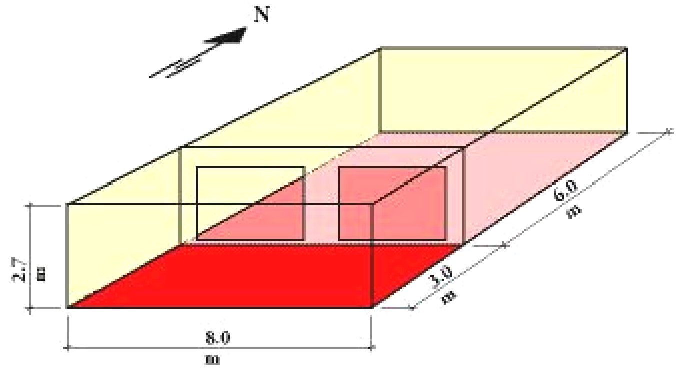

Figure 1 The room with a sunspace.

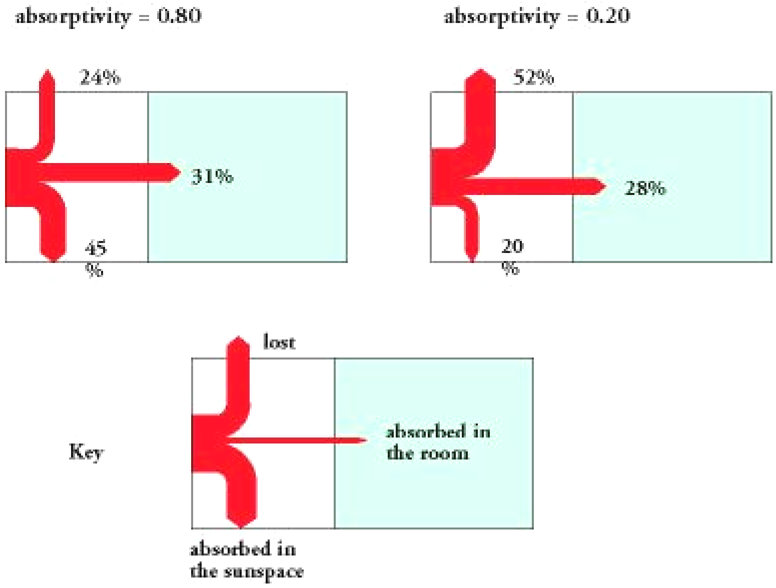

Figure 2 Solar energy balance for a winter day. Solar radiation transmitted into the sunspace is defined as 100%.

In Figure 2, the solar energy balance is shown for a clear winter day in Copenhagen, Denmark (latitude 56°N). Solar radiation transmitted into the sunspace is defined as 100%. The calculations are made with the computer program DEROB-LTH which uses a geometrical description of the building in order to calculate the distribution of solar radiation. In this example the absorptivity of opaque surfaces was set to either 0.20 (light) or 0.80 (dark). As can be seen, a large amount of solar radiation is retransmitted to the outside, especially when the surfaces are light, i.e. when the absorptivity is low.

The proportion of transmitted solar radiation which is retained varies for different geometries of the glazed space and adjacent buildings. While the proportion of transmitted radiation which is retained in a building with ordinary sized windows is about 95 - 100%, for a glazed space this proportion may vary between 30 and 85%. See Figure 3 which shows the proportion of transmitted solar radiation retained in four types of glazed space. The glazed spaces in this example are double glazed (clear glass) and 20% of the walls between the glazed space and adjacent buildings consists of double glazed windows.

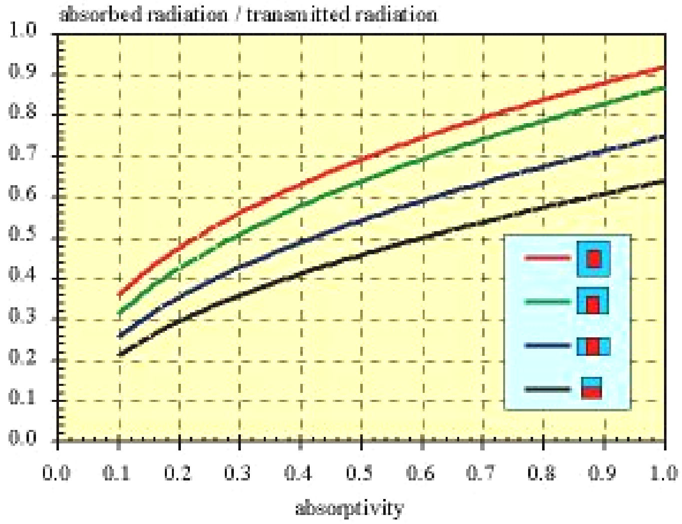

Figure 3 The proportion of transmitted solar radiation which is absorbed in four types of glazed spaces with double glazing, as a function of the absorptivity of interior opaque surfaces.

The example in Figure 3 is taken from a study which concludes that the type of glazed space, the transmission properties of the glazing and the absorptivity of the surfaces inside the glazed space have great significance for the proportion of the transmitted solar radiation which is retained inside the glazed space. On the other hand, the geographical position, orientation and time of year are of less importance. Correct assessment of what proportion of the solar radiation will be retained inside the glazed space is particularly important when solar radiation is powerful, i.e. in the spring, summer and autumn. Faulty assessment can have a considerable influence on estimation of temperature in the glazed space, on thermal comfort and on the energy required for heating or cooling.

Further studies show that simulations of atrium buildings or other types of glazed spaces must be based on a geometrical description of the buildings, with transmission through windows, reflection and absorption taken into account [2]. Consequently, energy simulation programs which assume that all transmitted solar radiation is utilised should only be used for buildings with ordinary window sizes.

Passive climatic control

The term passive climatic control refers to climatic control of the glazed space by means of methods and building design such that the desired climate can be achieved without major recourse to mechanical equipment. Use may be made of solar radiation, heat storage capacity, solar protection, vents, and a purposeful geometrical design of the building.

The geometry of the building is of great importance for the climate in the glazed space as well as for heating and cooling requirements. It is the geometric relation between the glazed space and adjacent buildings that determines how well solar radiation and heat losses from adjacent buildings can be utilised. For example, a glazed veranda will hold a lower temperature level with passive climatic control than a glazed courtyard with buildings on two, three or four sides.

What mainly determines the temperature level in a glazed space with passive climatic control is the relationship between the specific losses and the specific gains. This relationship is denoted *G* and can be written

$$G = \frac{\textit{specific losses from the glazed space to the outside}\ (\mathrm{W/^oC})}{\textit{specific gains from the buildings to the glazed space}\ (\mathrm{W/^oC})} \qquad (1)$$

The specific losses / gains are the sum of transmission and ventilation losses / gains with the temperature difference of one degree Celsius. For each glazed space, the value of *G* can be calculated and in this way a direct assessment of the temperature level can be given. Solar radiation is then excluded. The smaller the value of *G*, the higher the temperature level is in the glazed space. This guaranteed temperature level, or minimum temperature, in the glazed space can be easily calculated as

$$T_g = T_o + \frac{1}{1+G} \cdot (T_i - T_o) \qquad (2)$$

where

T_g = temperature in the glazed space (°C)
T_o = outside temperature (°C)
T_i = temperature in adjacent buildings (°C)

A greenhouse without any adjacent warmer buildings has a *G* which is infinitely large. An atrium with *G* equal to 1 has a guaranteed temperature which is the mean value of the outside temperature and the temperature in adjacent buildings.

As an example, measurements from the glazed courtyard at the block Tärnan in Landskrona are shown, see Figure 4. Landskrona is situated in the south of Sweden (latitude 56°N). The glazed courtyard is surrounded by residential development. It was built in 1983. The courtyard is approx. 200 m² and is covered with single glazing.

Figure 4   The glazed courtyard at Tärnan.

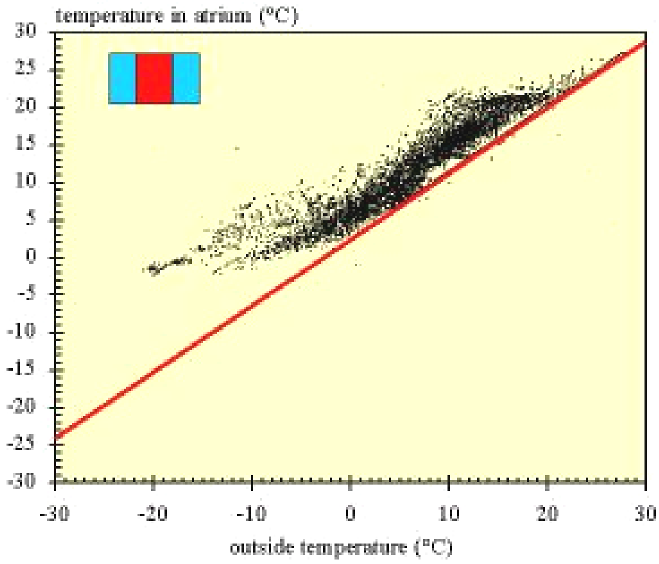

Figure 5   Temperature in the courtyard at Tärnan as a function of outside temperature. The plots represent measured hourly values during 1987. The line represents the calculated lowest temperature in the courtyard under passive climatic control conditions, without solar radiation.

In Figure 5, the temperature in the courtyard is plotted as a function of outside temperature. The plots represent hourly values measured at Tärnan during 1987. The line represents the theoretically lowest temperature in the courtyard at different outside temperatures calculated according to Equation 2. The factor G is 7.8 which means that the specific losses of the glazed space are 7.8 times higher than the specific gains from adjacent buildings, under steady-state conditions.

In Figure 5, it can be seen that the actual temperature in the courtyard can vary considerably, but the lowest temperature at a certain outside temperature is very near the steady-state line. When the outside temperature is below freezing, the measurements deviate from the line. The reason for this is that the glazed space was temporarily heated in order to maintain the temperature above freezing so that the plants could survive. This particular year was considerably colder than a normal year.

Different ventilation systems can be used in order to achieve a higher temperature in a glazed space and/or lower energy requirements. Reduced energy requirements can be accomplished by using the glazed space as a preheater for the supply air to the adjacent buildings. The exhaust air from the buildings can also be used as supply air to the glazed space in order to obtain a higher temperature level.

A good ventilation system design is to use the exhaust air from the buildings as supply air to the courtyard and at the same time to use a heat exchanger to transfer heat from the exhaust air from the courtyard to the supply air to the buildings. In this way a high temperature level in the glazed courtyard is obtained in combination with low fabric and ventilation losses in adjacent buildings. However, heat exchangers should not be used in the summer.

Experiences show that a combination of solar curtains and opening vents is an effective means of reducing the temperature in the glazed space during the summer. However, if the outside temperature during the day is close to the temperature in the glazed space, ventilation by opening vents obviously has a limited effect.

The results of case studies also show that the energy contribution from the glazed spaces has been rather small when they are used as buffer zones or to preheat the supply air to the buildings. This reduction in energy for space heating in adjacent buildings has been less than 10%. The main reason for this is that because of the unfavourable design of these glazed spaces heat losses are much higher than heat gains. It can also be seen that solar gain can be significantly reduced if air leakage is high and as a result the temperature in the glazed space will be lower.

Active climatic control

If the climate in the glazed space is not acceptable with passive climatic control, heating or cooling may be provided.

When a glazed space is heated, heating requirements for adjacent buildings will at the same time be reduced. However, the energy needed to heat a glazed space cannot be compensated for by a reduced heating requirement in adjacent buildings, especially not when the glazed space has a high value of *G*. In Figure 6, calculated energy requirements for heating the single glazed courtyard at Tärnan (Figure 4) to a certain minimum temperature are plotted. The reduction in energy requirement in the adjacent buildings due to reduced fabric losses is also plotted. The total heating requirement in the glazed space less the reduced heating demand in adjacent buildings gives the net energy requirement, also shown in Figure 6. The reduction in heating requirement in the adjacent buildings is nowhere near enough to compensate for the requirements in the glazed courtyard.

Heating requirements are much higher for a single than for a triple glazed courtyard. However, cooling requirements in order to obtain 20-22°C in the glazed space are not significantly higher for a single glazed courtyard than for a triple glazed one. This is due to the large influence of solar radiation during the summer.

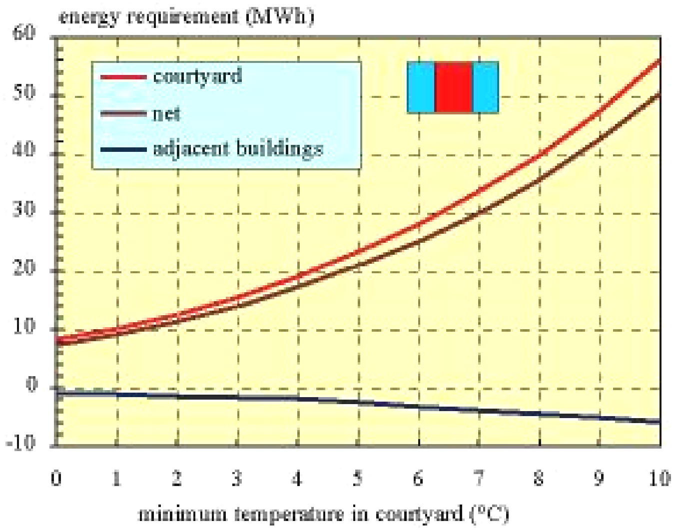

Figure 6 *Energy required in 1987 to maintain a certain minimum temperature in the glazed courtyard at Tärnan, the reduction in energy requirement in the surrounding buildings and the net energy requirement. The energy requirement in the adjacent buildings is defined as equal to zero when there is no heating in the courtyard.*

Airtightness
If a glazed space is to be heated, an airtight climatic envelope is essential. A leaky atrium may easily require twice as much energy for heating as a relatively airtight one. Measurements of airtightness in six atria in Sweden showed that the airtightness at an overpressure of 50 Pa varied between 2 and 64 m^3 per hour and per m^2 of leaking glazed area. This is equivalent to between 0.7 and 14 ach at 50 Pa.

There should be airtightness regulations for glazed spaces which are heated and/or cooled in order to ensure that atrium buildings with active climatic control have a high degree of airtightness. Otherwise, energy requirements may become very high.

Thermal comfort

Thermal comfort in glazed spaces should be studied at the design stage in order to choose the best positions in the space for different activities. These types of studies may also be helpful in deciding the required air temperature in the glazed space. This decision is necessary for the design of the building and the heating and cooling systems.

Studies of three types of glazed courtyards show that it is possible to obtain an acceptable level of comfort with passive climatic control during the winter, if the glazed spaces are mainly used for circulation.

If the glazed space is to be used by a person on a more permanent basis, for example if a reception is placed in the courtyard, heat must be supplied during the winter. However, acceptable thermal comfort is not achieved automatically by heating a glazed space to indoor temperature. Solar radiation, long wave radiation and draught will strongly influence the experience of the thermal environment. Local radiant heating in seating areas may be one way to increase comfort.

During the summer, it is not easy to achieve a high standard of thermal comfort only by reducing the air temperature to 20°C in the glazed space. Nor is ventilation alone sufficient to increase thermal comfort. Solar shadings in combination with natural ventilation are one way to increase thermal comfort.

Development of a design tool for glazed spaces

A very important goal is to produce design guidelines and simple calculation methods for glazed spaces which may be used early in the design stage. These design tools should make it possible to understand how the building design will affect the climate and energy requirements in a glazed space and adjacent buildings.

A computer program easy to use during the design stage will be developed. This design tool will be produced for the assessment of the temperature and energy requirement in glazed spaces. The effect of the glazed space on the energy requirements of the surrounding buildings may also be estimated.

It is intended that the computer program should be used as early as during the preliminary design stage so that the effect which the design of the building will have on climate and energy requirement may be determined. It can be used to get an idea of the difference between alternative configurations and to see which parameters are significant for climate and energy.

The use of such a program right at the preliminary design stage may prevent energy demanding solutions and a poor standard of comfort. The tool will also provide an insight into how glazed spaces behave with regard to climate and energy.

References

[1] Wall, M. (1996). *Climate and Energy Use in Glazed Spaces*. PhD Thesis (Report No TABK-96/1009). Lund, Sweden: University of Lund, Lund Institute of Technology, Department of Building Science.

[2] IEA Task12A3 (1996). *Atrium Models for the Analysis of Thermal Comfort and Energy Use.* Eds: I. Bryn and P.A. Schiefloe. International Energy Agency, Task 12; Building Energy Analysis and Design Tools for Solar Applications, Project A.3; Atrium Model Development.