THERMAL COMFORT IN SUNSPACES

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ABSTRACT Sunspaces as additional living area can be used in different ways. Self intended, it is „habitable" if the air temperature in the sunspace is not less than that of the parent house. Even at a lower temperature it can be „habitable" due to the exposition of the occupant to direct radiation: this effect is analysed in the paper.

1 Introduction

One of the most important and characteristic element of indirect passive solar system is the sunspace. This term can be used only for transitional spaces which

- have transparent exposed building element(s) *and*
- are connected to a room of the parent house *and*
- have no auxiliary heating .

A sunspace can be evaluated from different points of view: among them the following are worth mentioning:

- it can improve the energy balance of the building,
- it represents an additional living area which can be used in different ways for several hours during the year,
- it provides some fabric protection effect (driving rain, wind, air infiltration through cracks),
- it improves the thermal and acoustic comfort and indoor air quality in the parent house (however, the visual conditions in the rooms, attached to it can worsen),
- it adds some aesthetic value, it can fundamentally determine (or in case of refurbishment it can change) the character of an elevation, or the form of the whole building,

All of these features should be evaluated in a complex way. It is of importance to decide in advance, which aspect has the priority, because different priority aspects require different sunspace layouts, forms, details, several times antagonistic ones. As additional living area, for instance, the sunspace should have enough floor area and appropriate layout, thus enough depth in order to facilitate placing some pieces of furniture (table, chairs), optionally some small plants, and to provide access to them, to the windows, doors between the sunspace and parent house, and to the garden. From energy and fabric protection points of view it is advantageous if higher percentage of the elevation is covered by the sunspace, however the cost and the real needs represent a limit of the floor area. As a consequence, "narrower" and deeper sunspace, rather than elongated is requested, thus a smaller part of the elevation is covered.

In this paper some elementary questions of thermal comfort in the sunspace are analysed: how the sunspace can be used as additional living space, how the number of „habitable hours" can be estimated.

2 Thermal comfort conditions

It seems to be unambiguous that the sunspace can be occupied during the summer period. However, prevention of overheating requires efficient shadowing and ventilation. Movable internal shadowing devices are not efficient: due to the absorbed energy their temperature increases resulting in the same heating effect as a built in radiant heating system. External shadowing devices are more efficient, but more expensive. Deciduous trees provide not only shadow but evaporative cooling effect, as well, however, they decrease the solar gain in winter.

Natural ventilation should be based on stack effect. It requires openable windows or ventilators at both bottom and floor level. Big openable elements (like a tip-up door eliminate the border between the sunspace and garden and provide a real transitional space.

In winter three different situations are possible. No doubt, the sunspace can be used as living space when its temperature achieves or exceeds that of the parent house. In this case the door (and vents, if any) between the sunspace and the parent house should be kept open ("*open door* period").

During several hours in a winter season the sunspace temperature is less than that of the parent house. However, it does not mean unambiguously that the sunspace cannot be occupied and the thermal comfort conditions are not acceptable all that time.

Thermal sensation of human beings depends on the air temperature, air movement, relative humidity and radiant heat transfer between the human body and environment. In a "normal" room the question is the temperature of the boundary surfaces and the angle factors between them and the human body. The "radiant temperature", calculated with a simplified equation as

$$t_R = \frac{\sum A_j t_j}{\sum A_j} \tag{1}$$

is one of the most important comfort parameter in a closed space.

This interpretation in a sunspace is not applicable without any further consideration. Due to the high transparent ratio of the boundary construction the occupants of the sunspace are exposed to the solar radiation which provides a direct solar gain for the human body and a positive balance of radiant heat exchange. This solar gain can compensate the convective heat loss of the human body, the result can be acceptable or even optimum thermal comfort sensation. he exposition of occupants to the direct radiation in the sunspace is higher if the roof of it is transparent. On the other hand the transparent roof would increase the risk of overheating in summer.

The direct effect of solar radiation could be taken into account even in a "normal" room providing the occupant is exposed to the direct radiation, however, the likelyhood of this position is small due to the geometry of the room.

The compensation effect can be estimated on the base of the classic tool: Olgyay's (modified) bioclimatic chart (Fig.1.). The lowest part of the bioclimatic chart shows the lines of the intensity of solar radiation, the scale on the vertical axis the temperature drop which is compensated.

Fig. 2. shows the interrelation between the air temperature and the intensity of solar radiation. It can be seen that good thermal comfort conditions are possible even if the air temperature is as low as 13 - 14°C. Certainly, in this case the door between the sunspace and parent house should be kept closed (*"closed door* period"), otherwise the convective losses of the parent house would be very high.

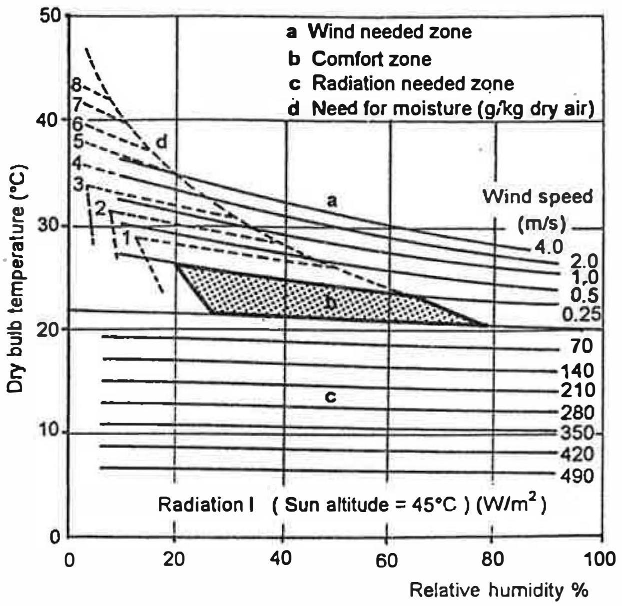

Fig.1 The bioclimatic chart

The distribution of the intensity of solar radiation is shown on Fig. 3., for different months and hours.

From the two data sets above the number of hours when different temperature drops can be compensated by solar radiation can be calculated, the values are shown in Fig. 4.

Self intended, only solar radiation, entering the sunspace can be taken into account. The transmittance of the glazing is supposed to be 0.85 for single and 0.73 for double glazing. The opaque part of the boundary construction is supposed to be 0.15 for metal and 0.25 for wooden frame.

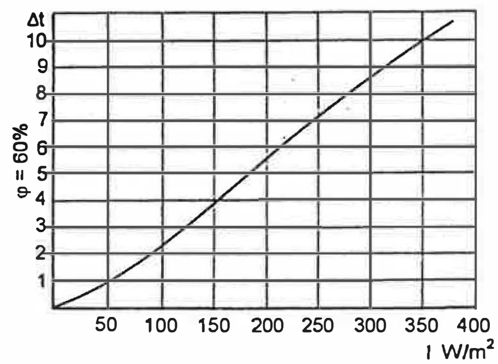

Fig.2 Temperature drop and the compensating intensity

It can be stated, that the number of habitable hours, including the closed door option is much higher than the number of open door option, estimated on the base of indoor temperature.

The altitude of the Sun affects the radiant heat exchange, according to the exposed area of the human body. The angle factor between the Sun and the human body is higher at low altitudes (standing or sitting position is supposed). The correction factor is available in the literature (Fig.5.).

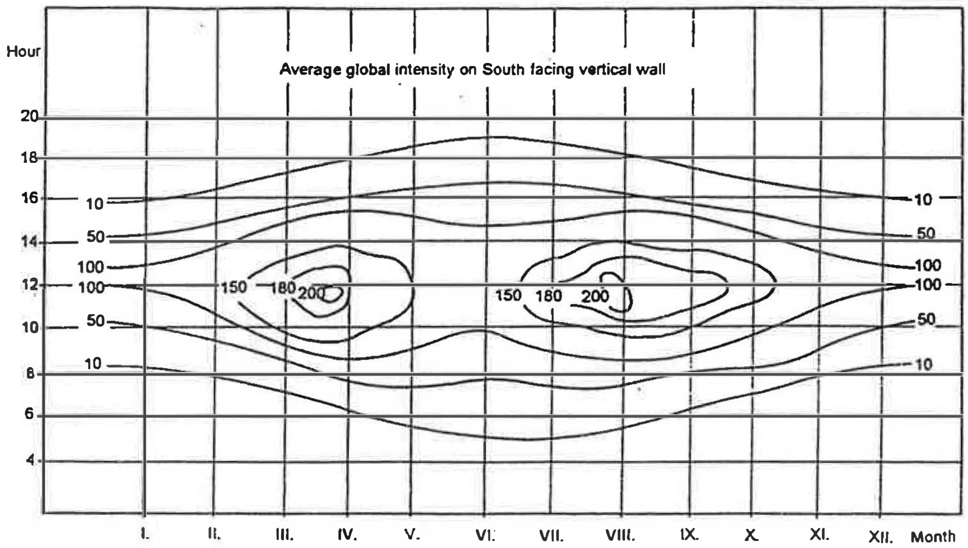

Fig. 3 The intensity of solar radiation on Equator facing vertical wall in Hungary

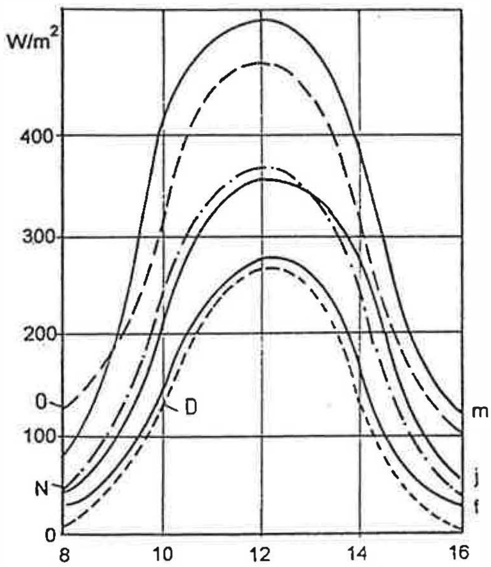

Fig.4 The temperature drop and the compensating corrected intensity in the winter months

3 The algorithm of the calculation

From the bioclimatic chart (for given clothes and activity, and for a given sun altitude) can be determined the intensity of the radiation which compensates a given temperature drop (Fig.1.).

The measured intensity data for the Equator-facing vertical surface are available in form of hourly mean values for the representative days of each month (Fig. 3.).

For the same months and hours the Sun altitude angles are known, the altitude depending correction factors can be read (Fig.5.)

For the representative days the hourly values of the acceptable temperature drop, compensated by the radiation, can be calculated (Fig.4.)

The intensity of the radiation, entering the sunspace, is reduced due to the opaque frame and the transmittance of the glazing. In a double glased sunspace about 60 % of the total intensity can be taken into account.

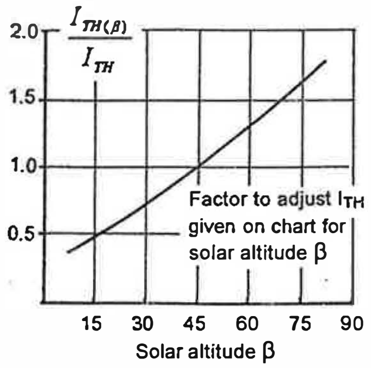

Fig. 5 Correction factor as a function of solar altitude

No hours were considered, when the Sun altitude is less tan 10°: it is likely that at such a low position obstructions (fences, buildings) do not facilitate the solar access. No bigger temperature drop was taken into account than 10 K. It is supposed that the asymmetric radiation (due to the low temperature of the back surface) results in unacceptable discomfort. (The glazing between the sunspace and the parent house is supposed to be the "back surface".) The effect of the asymmetric radiant heat exchange in the practice is less serious. If the occupant moves in the sunspace, the time of the exposition is short, the direction changes. If the occupant is sitting, it is likely that he/she is insulated by the back of the seat. Tricky use also eliminate the effect of the asymmetry.

It can be stated, that at average conditions in October, the number of habitable hours with closed doors is at least 8/day. In March 6 hours/day are expected. In February 2-3 hours around noon can be taken into account. In January 2 hours/day is possible providing the air temperature exceeds 13°C in the sunspace. Due to the low altitude even 4 hours/day are possible in November and December, providing the air temperature in the sunspace exceeds 10-11°C and the effect of the asymmetric radiant heat exchange can be reduced either by the position (seat back as added insulation) or by tricky use.

4 Tricky use of sunspace

A „well-trained occupant" has some possibilities to improve the thermal comfort conditions in the sunspace for a short period. The matter of these tricks is, on one hand, the switch-off the heat storage capacity of the sunspace, on the other hand the absorption of radiation which otherwise would pass through the sunspace.

The consequence of the switching off the heat storage capacity is a bigger temperature range in the sunspace (Fig.6.). Although the bigger temperature range reduces the buffer effect during the night, the higher maximum temperature results in a few hours of better thermal conditions. To switch off the heat storage capacity is a relatively simple task: the floor of the sunspace should be covered by a carpet.

Providing the partition between the sunspace and the parent house has a big opaque ratio, the effect can be intensified by covering this opaque wall with curtains. On one hand, the absorbed radiant energy will be converted into convective heat gain, on the other hand, the temperature of the curtain raises more rapidly than would that of the wall. The higher temperature of the back surface reduces the unpleasant effect of the asymmetry of the radiant heat exchange.

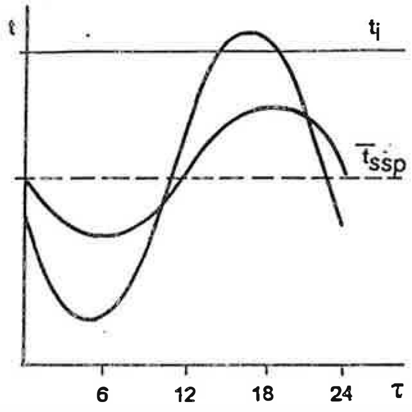

Fig.6 When the heat storage capacity is switched off, temperature swing increases

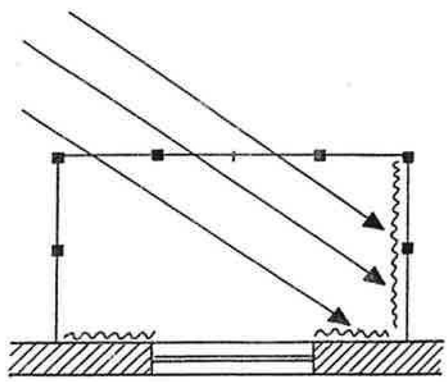

Fig.7 The use of curtains to trap solar energy and/or switch off the heat storage capacity

In added sunspaces at given Sun azimuth intervals a fragment of the direct radiation can pass the sunspace. This fragment can be trapped by a curtain on the inner side of the sunspace (Fig.7.). The by-effect is again the higher temperature of the curtain - a surface, opposite to the Sun position - which reduces the effect of the asymmetric radiant heat exchange.

5 Conclusions

Acceptable comfort conditions may exist in a sunspace even at 12- 13 ^oC air temperature providing the occupant is exposed to direct solar radiation of 200 - 250 W/m^2 intensity. Certainly it would be a misuse of the sunspace to open the door between the sunspace and the parent house at such condition, however, the sunspace is „habitable" with closed door. Tricky use of sunspace - temporary application of carpets, curtains increases the number of „habitable hours". These options increases the value of the sunspace as added living area.

6 Acknowledgement

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