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Överglasning av stora byggnadsvolymer

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En tvärvetenskaplig utvärdering av ett köpcentrum

BYGGFORSKNINGSRÅDET

INNEHÅLL

Summary

Large glass–covered spaces related to shopping centres, hotels, office buildings etc are quite common nowadays, at the same time as systematized experiences of the function of these spaces are still relatively limited. The aim of this thesis is to provide additional knowledge and experience of large glass–covered spaces (atrium buildings) by means of studies of a large number of problem areas. The glazed pedestrian precincts of the rebuilt Skärholmen Centre in south–west Stockholm are the main object of these interdisciplinary studies. Emphasis is placed on technical and physical conditions, though these are supplemented by sociological investigations. The method employed includes various field measurements and theoretical calculations, together with interviews and questionnaires.

From the point of view of construction and installation techniques Skärholmen Centre is relatively simple and conventional, that is to say, the results presented here have been obtained without the need to consider any kind of advanced experimental construction. The glazed pedestrian precincts have floor–heating coils and a mechanical supply and exhaust ventilation system.

The thermal climate of the glass–covered pedestrian precincts of Skärholmen Centre, with as well as without active heating with floor–heating coils, is good on the whole, which is evident from comprehensive determinations of both thermal comfort and temperature conditions, as well as from supplementary sociological investigations. Various items of clothing, mainly outdoor clothes, lead to compensation for various climates (seasons) which are shown to be of great importance. The indoor temperature varies greatly during the day, and this has proved to correspond to a considerable saving in energy compared with what would happen if the temperature were to be kept more constant.

In spite of having no cold downdraught protections (special heaters), the experience of Skärholmen Centre shows that cold downdraught in practice does not have to cause any major problems in a glass–covered space. In winter, however, it is difficult to avoid much lower temperatures in the vicinity of outer entrances than those obtaining in the central areas of the glass–covered space. Here, the temperatures noted at floor level are clearly linked to the distance inside the entrances that consist of revolving doors.

Field measurements carried out at Skärholmen Centre indicate that even in summer this large glass–covered space provides a thermal climate that is generally favourable. An unpleasantly warm climate and problems with solar radiation in summer have largely been avoided. It is shown that an outdoor temperature of 25 °C corresponds to an approximate break point in this case; above this outdoor temperature the average temperature during the afternoon is lower indoors than outdoors. Important reasons for this favourable result are the protection provided from solar radiation by surrounding buildings and the varying geometry of the glazing and the relatively limited glazed surfaces, but also passive cooling from the air–conditioned surrounding buildings would also seem to have a bearing on the moderate indoor temperatures. In this case solar radiation has remarkably little effect on the mean indoor temperature. The conclusion drawn from these results is that in the Scandinavian climate large glass–covered spaces can well be undertaken in a way that avoids problems of excessive temperatures, even without air conditioning or even such things as curtains.

A supplementary study has been made of the thermal comfort in glazed pedestrian precincts in a Tokyo shopping mall. Even at these more southerly latitudes with a much warmer climate than that of Scandinavia it emerges that in summertime a very simple glass–covered space can in fact provide a cooler and consequently better thermal climate indoors compared with the outdoor one.

The relationship between the indoor and outdoor temperature provides a good deal of interesting information about temperature conditions where glass–covered spaces are concerned, and the relationship shows in principle the "extent" to which the space is heated. In order to quantify the degree of heating the following is introduced:

$$DH = 100 \cdot (1 - k) \ (\%)$$

where DH = the degree of heating (%) and k = the slope of the straight line that constitutes the best approximation of the indoor temperature as a function of the outdoor temperature. This degree of heating enables a simple comparison of the temperature conditions (the degree of heating in relation to the outdoor climate) between different glass–covered spaces and/or buildings in general.

In this case the degree of heating for the glazed pedestrian precincts with floor heating in operation during the heating season is about 85 % both day and night (with indoor temperatures of about 19 °C and 15 °C respectively at an outdoor temperature of 0 °C). Without floor heating the degree of heating during the day is still over 80 %, though it falls to below 60 % during the night (with indoor temperatures of about 17 °C and 13 °C respectively at an outdoor temperature of 0 °C).

The glass–covered pedestrian precincts and surrounding shops in Skärholmen Centre have separate mechanical supply and exhaust ventilation systems, and the planning did not allow for any flow of transferred air via, for example, the entrances. However, it seems clear that the transferred air between surrounding buildings and the glazed space via open shop entrances is very considerable, and this clearly is very important for the energy balance as well as for the thermal climate. The transferred air is obviously the main cause of the variations in the indoor temperature and the main cause of this transferred air is that the mechanical supply and exhaust air flow rates in the shops are different. In summer, when the ventilation is natural, with open entrances and glass hatches, incoming air enters the glazed space in the first place as transferred air via the open entrances to the shops, and not therefore via the open outer entrances.

In most places in the occupied zone of the glazed space the air velocity is low. It is mainly near the outer entrances and the entrances to the shops that the air velocity is considerable, and one small problem in this connection is that the climate in the entrances themselves, in summer as well as in winter, can be experienced as unpleasant and cold because of the high air velocity. Directly under the glass roof (between 5 and 21 m above the floor) there is usually positive pressure, corresponding to air exfiltration. At floor level the pressure varies between slightly positive and negative, and this, inter alia, is important as regards the climate inside outer entrances that consist of sliding doors.

The results as regards the energy balance are based on a large body of material relating to energy consumption recorded as well as to the calculated energy balance. The measurement results show that the average annual consumption of energy corrected to a normal year for heating the whole complex (the glass–covered space and the surrounding buildings) fell by 2 % when the glazed space had floor heating in operation and by 7 % when it had not. According to computer calculations using the BRIS programme corresponding values are 10 % and 14 % respectively. A similar result was also obtained with a much simpler computer calculation and with an ordinary manual calculation with stationary conditions.

The average energy saving of 7 % without floor heating corresponds to almost 500 MWh/year or about 200,000 SEK per year if the price of energy is assumed to be 0.40 SEK/kWh.

The results relating to the measured consumption of energy must in this connection be interpreted with some caution since this result is greatly affected by the control of the heating and ventilation systems. The results obtained from the computer calculations ought also to be interpreted with a certain caution, in view, inter alia, of certain simplifications and rather uncertain input data. Even so, the outcome on the basis of measurements and computer calculations shows a similar result where the energy needed for heating has in fact fallen thanks to the glass–covering. The greater saving of energy obtained according to the computer calculations probably indicates that a certain potential for saving energy has not been utilized.

The measured temperature conditions of the glass–covered space are described relatively well and are given a theoretical explanation by means of the computer calculations. The temperature variations during the winter period are shown to have been due mainly to the transferred air from surrounding buildings, despite the fact that the transferred air flow rate on the basis of measurements has been assumed to correspond to only 17 % of the total air flow rate of surrounding buildings. As a result of this research project, as from the winter of 1988/89 the manager of Skärholmen Centre made a point of replacing virtually all the heating of the pedestrian precincts with transferred air from the shops instead of active heating by means of floor heating coils. The air from the shops is more or less equivalent to free waste heat which was simply lost prior to the glass–covering. According to the computer calculations the saving obtained through the switching off of floor heating corresponds to nearly 300 MWh/year or more than 100,000 SEK a year if the price of energy is assumed to be 0.40 SEK/kWh.

The conclusion of these results is that the planning of large glass–covered spaces affords great opportunities of improving the finances, on the one hand by simplifying or completely eliminating heating installations and, on the other hand, by using mainly free heat for heating purposes. This free waste heat in the form of warmed exhaust air (transferred air) from surrounding buildings is available in all places where the heat content of the air is not utilized in some other way (with, for example, a heat exchanger or an exhaust air heat pump).

Determinations of the humidity conditions of the glass–covered space at Skärholmen Centre during different seasons of the year show that the additional absolute humidity (compared to outdoor air) is low, usually between 0 and 1 g/m^3. Typical values of the relative humidity are from 20 % to 40 % in winter and from 30 % to 60 % in summer. These low values are explained by the increase in air temperature in relation to the outdoor air and also by the fact that the emission of humidity is small in relation to the ventilation.

The dry air means that the risk of condensation is virtually eliminated in this case. Where mycology is concerned it may, to sum up, be noted that glass–covering has not involved any health hazards that can be attributed to the number of microscopic fungus spores in the indoor air, which is logical when the relative humidity is as low as it is in this case.

The acoustics have been studied by field measurements as well as by computer simulations. As was expected, it transpired that the large glass–covering led to no significant increase in noise level, while the reverberation time was considerably longer. The changes are so large that they are assumed to have a negative effect on the way people experience the glass–covered pedestrian precincts. The open entrances of surrounding buildings can more or less serve to absorb noise and the influence of these entrances on the important speech intelligibility is demonstrated. The conclusion is that when planning glass–covered spaces account ought to be taken of the effect of open entrances on the acoustics. This can lead to a saving in that sound absorbents can be partly or wholly replaced by open entrances.

Some results are shown relating to operations, maintenance and durability. After eight years the glass roof and the vertical glazed areas at Skärholmen Centre showed no visible damage and the structure is still proof against water leaks. Experience gained from other structures, however, reveals that leaks have been a usual problem affecting glass roofs, and in many cases these leaks could be explained as ”teething problems” affecting the relatively new glass roofing technology.

Investigations using different methods in the laboratory indicate that six years of using EPDM rubber glazing gaskets have not revealed any significant effect as regards the efficiency of the gaskets. This positive result applies to gaskets facing north as well as south, and it is not expected that any leakage in the glass roof due to the ageing of these gaskets will occur in the foreseeable future.

The glass–covering of the pedestrian precincts at Skärholmen Centre has in practice also led to an often overlooked advantage in that the need for cleaning and window cleaning in surrounding premises is reduced. Since in most cases the costs of cleaning and window cleaning are high, and are for example higher than the costs of heating and electricity, even a relatively small saving will be quite considerable. For this reason, when large glass–covered spaces are planned an attempt should be made to assess the effect on the need for cleaning and window cleaning.

That the glass roof becomes dirty is not a serious problem in this case – cleaning once a year seems sufficient. Nor do snow and ice represent any serious problems. What has been learned confirms that in certain circumstances there is reason to use a reduced snow load for glass roofs.

The sociological enquiries show that the vast majority of people are pleased or very pleased with the glass–covering made at Skärholmen Centre. The glass–covering has led to an increase in the number of new visitors. Many visitors have come more often and have commented on its elegance. Business turnover has increased considerably.

At the same time it is obvious that a glass–covered space such as this can, at least now and then, give rise to certain problems that have to be tackled; one third of those interviewed feel that they sometimes miss the outdoor climate, about one half have felt it has been too warm on occasion, while one third have on at least one occasion felt that the noise level was disturbing. At the same time a number of problems typical of glass–covering have been solved: fewer than one in ten have been blinded or in some other way adversely affected by excessively strong sunlight. Out of seven different adverse reactions it transpired that the feeling of missing the outdoor climate was of greatest importance when assessing public reaction to the glass–covering and this was closely followed by the feeling that the air seemed enclosed. Thus, if a glass–covering is generally viewed as good or bad could to a great extent depend on the air quality.

All things considered, the sociological investigation of, inter alia, Skärholmen Centre shows that large glass–covered spaces in public places are very likely to be appreciated in practice by different groups of users. The few negative remarks that have been made, for example regarding the indoor climate, are connected with problems that are fairly simple to deal with.

The lessons learned from glass–covered spaces in connection with blocks of flats are by no means as positive. The results indicate that large glass–covered spaces in connection with dwellings are less likely to be appreciated by the users than the glass–covered spaces in public places.

Comparisons are made between the results of technical and sociological enquiries. Certain complaints made concerning the thermal indoor climate, the air quality, humidity and the acoustics seem logical enough when compared with the results of measurements etc. It is demonstrated that the colder indoor climate in the glass–covered space in winter can easily be countered by wearing warmer clothing, which explains why virtually none of the visitors felt that the temperature was too low. That the thermal climate in the glass–covered space is in keeping with the outdoor temperature is as it should be since what people wear is determined by the outdoor temperature.

To sum up, there is on the whole good agreement between the results of the two quite separate investigations, that is to say the physical / technical and the sociological / behavioural. Consequently, the results of the two separate investigations support each other, and this means that many of the conclusions from this research project are more certain and general.

To sum up the thesis as a whole, it is clear that in the Scandinavian climate there is every likelihood of large glass–covered spaces in public places functioning well from a technical as well as a social point of view. Through the glass–covering of the pedestrian precincts at Skärholmen Centre it has, for example, been possible to make available 4 000 m^2 of floor space that is appreciated and frequently used in a thermal climate that is good on the whole, at the same time as the energy consumption of heating the whole complex, based on theoretical calculations and measurements, is shown to have been reduced by in the order of 10 %. Finally, it should be noted that large glass–coverings do involve a number of physical / technical problems, but these can be solved by the application of modern technology.