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Research Report from Czechoslovakia

The Influence of Infiltration on the Heating of a Building

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Introduction

When designing a heating system it is necessary to estimate the probability of the design heat losses of the heated space being exceeded. Design outdoor weather statistics are collected and published for this purpose. Such statistics are usually in the form of dry bulb and wet bulb temperatures. In the case of sensible transmission and infiltration heat losses, however, it might be argued that outdoor temperature and wind speed are the most relevant climatic parameters. The extreme value of the heat losses can, theoretically, be reached at various combinations of outdoor temperature and wind speed, but for an accurate evaluation of the climate conditions, it is necessary to know the correlation between the outdoor temperature and the wind speed.

Besides the climatic parameters, the heating load calculation also influenced by the thermo-technical properties of the building (insulation and air-leakage of the building envelope, thermal mass of the building etc), the situation of the building, what part of the day it will be used, its internal load, and the nature of its occupancy. On the basis of these factors and of course in accordance with economical relations, the probability level of the heat loss exceedance is estimated. This is decisive for the selection of the design outdoor weather conditions.

The task of this study is not the analysis of these influences when calculating the heat losses. Instead the influence of wind and temperature on the total heat losses at 1% probability exceedance of the heat losses is being investigated. The calculation is based on the correlation of the outdoor temperature, the wind speed and its direction, the transmission coefficient correlation and the air-leakage of the curtain wall.

The necessity of the design outdoor temperature and the wind speed correlation has been proved.[1] The author has stated that the independent selection of the design outdoor temperature and the wind speed aims at considerable over-estimate of the heat loss. He has also proved that the peak value of the heat losses can be mostly reached at mild temperatures with higher wind speed. Therefore the common application of the low temperature in combination with the high wind speeds is not correct or economical.

Design weather conditions for the given locality are mostly unchangeable. It is possible that the heat losses in permeable walls will be greater on windy days with mild temperatures than on calm days with low outdoor temperatures. Therefore when selecting the design weather conditions, the mutual dependence of the transmission coefficient (U - value) and airtightness (F - value) must be considered.

Inside this issue:

Meteorological Data

For the selection of the outdoor design values, meteorological data covering a ten year period from 16 October until 15 April for a single site (Bratislava Airport)[2] was used. The information was based on the average hourly measurements during a whole day in open country at a height of 10m. On the basis of this data the joint cumulative distribution function of outdoor temperature (t_o) and the wind speed (v) for eight directions was produced.[3] From this function, using the least square method, the functional dependence between the outdoor temperature and the wind speed (which were exceeded for only 1% of the time) was found for all height directions. The best fit was expressed by the exponential function:

$$v_\alpha = a^{t_o} . b + c \qquad (1)$$

where a, b, c are equation coefficients and α is the wind direction.

Figure 1 presents the graphic expression of Equation 1 and the temperature $t_o = -13.0°C$, for which the probability to be reached or exceeded, independent of the wind speed, equals 1%.

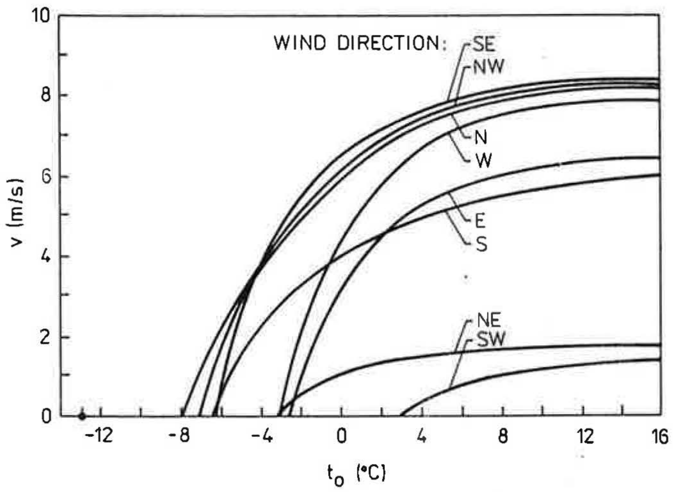

Figure 1: Wind temperature dependence at 1% time exceedance for various wind directions

Example Calculation

The heat loss of the room in a hypothetical residential building was calculated using the described procedure. The transmission heat loss was calculated assuming steady state conditions. The well known crack method was employed for the calculation of the infiltration heat loss, while the wind speed was expressed by Equation 1.

Supposing that the quality of the building, to suit the most suitable choice of outdoor weather conditions, is at 1% probability exceedance of the heat losses. The building is 56m high and 33 x 21m in plan, situated in an urban area characterised according to Table 1 in reference 4. The terrain class is IV. The curtain wall of the building consists of the segments 1.5m wide and 2.8m high.

We assumed in the example that the heat loss of the room, which is situated in the middle of the greater wall of the building, occurred only through the curtain wall consisting of two segments described above. The heat loss of the room was calculated in three different height levels of the building; N, SW, W and SW. The values of neutral pressure level (NPL) were used from reference 5, and the inside temperature t_i = 20°C was assumed.

The peak value of heat losses for individual cases were calculated on a programmable pocket calculator. The results can be seen in Figure 2 which includes the percentage proportion of the infiltration and transmission heat losses on the total losses as well.

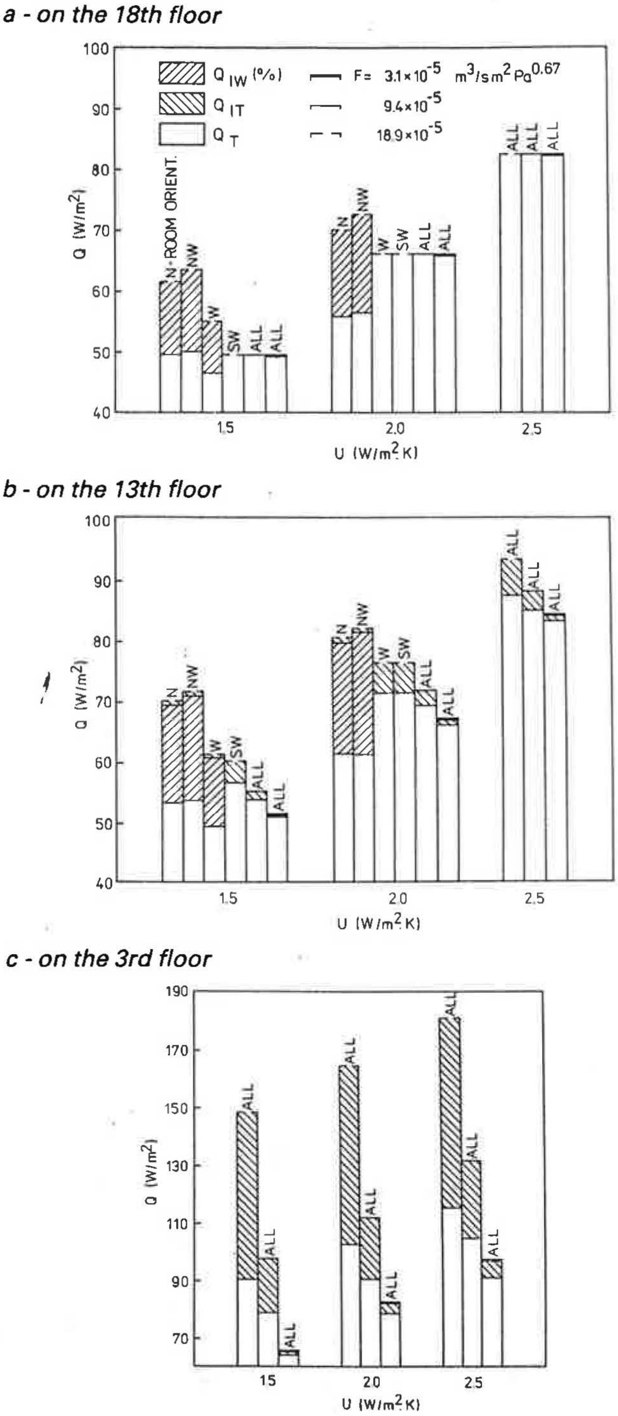

Figure 2: Room heat loss per 1m² of curtain wall and the percentage proportion of wind induced infiltration heat loss (Q_{IW}), stack induced infiltration heat loss (Q_{IT}) and transmission heat loss (Q_T)

Results and Discussion

The main findings of the preliminary analysis are as follows:

- the heat losses of the rooms above the NPL (18th floor) show that the losses are caused at the tight or average curtain walls only through conductive transmission. The infiltration effect is evident only with the loose curtain wall, except for the SW-orientation where higher wind speeds at lower temperatures are very rare.

- the heat losses of the rooms under the NPL (13th floor) show similar properties as above except that a certain small percentage also forms the stack-induced infiltration.

- for rooms situated well below the NPL (3rd floor), the heat losses in the total extent of U-values and F-values are only the function of the outdoor temperature.

It is obvious from the results of this example that for tighter curtain walls the infiltration heat losses are primarily caused by the pressure differences from stack effect. Therefore the heat loss value can be reached at minimum temperature in calm weather conditions when transmission and stack-infiltration heat losses are maximal. The wind effect is only evident at greater air leakage of the wall, or when the influence of the stack effect is negative or very small and only the vertical direction of the wind is important.

The proportion between infiltration and transmission heat losses is variable but it can generally be said that, at given air-leakage of the curtain wall, the proportion of the infiltration heat loss is reduced with the increasing transmission coefficient. The proportion increases with the lower position of the room according to the height of the building, ie together with the increasing importance of the stack effect.

References

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Proposed ASHRAE Standard on the Adequacy of Air Permeability

Report by Martin Liddament, AIVC, UK

A new ASHRAE standard is under consideration which is intended to provide a simple check on the adequacy of air permeability of naturally ventilated, single family dwellings. ASHRAE Standard 136P proposes a hybrid method in which the results of a pressurization test are used in conjunction with a simple air quality model to ensure that concentrations of typical residential contaminants comply with air quality requirements.

In calculating the air change rate, climate, terrain and surrounding shielding are taken into account so that the required level of airtightness can be tailored to suit the individual needs of each dwelling. It is anticipated that this standard will be especially useful in ensuring avoidance of excessive airtightness measures. Excluded from the proposals are dwellings insulated with urea formaldehyde foam insulation and those which are heated by unvented combustion appliances or which are not fitted with extract cooker hoods.

Other Standards

Other associated standards reviewed at the recent ASHRAE Annual Meeting, held in Nashville, USA, were Standard 119P on the air leakage performance of single family dwellings and Standard 62-81 on ventilation for acceptable indoor air quality. Standard 119P is concerned with the setting of airtightness values to eliminate the construction of excessively leaky buildings, while Standard 62-81 aims to define minimum ventilation rates and the necessary indoor air quality parameters to ensure a safe environment for occupants.

Technical Activities

A number of other technical activities related to the field of air infiltration and ventilation were also discussed. Of special interest was Technical Committee TC2.5 on air flow around buildings and Technical Committee TC4.2 on weather data. TC2.5 is sponsoring a project to determine pressure coefficients on typical residential buildings. This database is considered especially important for the calculation of wind-driven air infiltration, passive summertime cooling and the design of smoke and fire control systems. This committee is also sponsoring a seminar on ventilation modelling in wind tunnels, to take place at the Dallas ASHRAE Meeting in January 1988, and a symposium on wind pressure effects on ventilation at the ASHRAE Meeting in Ottawa, Canada, in June 1988.

TC4.2 has released for tender a work statement on the determination of climate variation in metropolitan areas. This activity is aimed at addressing the problem of assessing the climate at a specific location using off-site climatic data. The intention is to develop algorithms relating physical features in and around metropolitan areas to climatic variations. It therefore has important applications in assessing the magnitude of the natural driving forces of infiltration.

For further details on any of these ASHRAE activities, please contact Martin Liddament at the Air Infiltration and Ventilation Centre.