The effect of wind speed upon heat requirements and internal temperatures

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Introduction

WHEN CONSIDERING the overall increase in heat loss from an enclosure due to the influence of wind speeds in excess of those specified at a particular design condition, it is necessary to examine the relationship between the ventilation and structural losses in order to assess the additional thermal loads imposed.

The thermal load imposed by the infiltration of cold outside air into the interior of a heated building is a function of the prevailing wind speed and the difference between the internal and external temperatures, which parameters also affect the rate of heat flow through the building fabric. Consequently, the total heat requirement with a strong wind and a moderate external temperature may be equal to, or exceed, that with a light wind and a lower external temperature, and the following note attempts, by means of a simplified analysis, to quantify these factors in terms of their effects upon internal temperatures.

Infiltration loss

The rate of air flow through a given building or enclosure is dependent upon the air tighness of, and the pressure differential across, the containing structure, and the areas and resistances of the openings and interstices to air flow.

The pressure differential is caused either by the wind, in which case air enters through cracks and apertures in the windward side and leaves through similar openings in the leeward side, or due to the buoyancy of the air, commonly termed 'stack effect', caused by the difference in temperature, and hence density, between similar columns of air inside and outside the building. Whilst both effects are applicable at all times, that due to the latter is generally small compared to the former and for the present purposes only that due to the velocity of the wind will be considered.

Wind speed and direction are very dependent upon local topography; for example, the general effects of a built-up area and the particular effects of the presence of neighbouring buildings upon the pressures over the facades of a structure may be so complex as to be virtually unpredictable.

However, it is known from tests that the positive pressure on the windward face of a building ranges from about 0.5 to 0.8 times the velocity pressure of the free wind, and on the leeward face, the negative pressure is about 0.3 or 0.4 times the velocity pressure. Hence the total wind pressure forces acting across a building are approximately equal to the velocity pressure of the wind, and thus the pressure difference acting across an external element could, without introducing excessive inaccuracy, be taken as being equal to one half of this.

The general equation governing the flow of air through window opening joints is:

$$Q = C(\Delta p)^n$$

where Q = the volume flow rate of air per metre of window opening joint, litre/s
C = a window infiltration coefficient, defined as the volume flow rate of air per unit length of window opening joint at a pressure differential of 1N/m², litre/ms
p = the pressure difference across the window, N/m²
and n = an exponent, which for windows, is 0.625

Hence, $Q \propto (\Delta p)^{0.625}$

Now the wind velocity pressure is given by the expression:

$$P_v = \tfrac{1}{2}\rho(v)^2$$

where P_v = the velocity pressure of the wind, N/m²
ρ = the density of the air, kg/m³
and v = the velocity of the wind, m/s

Thus, $P_v \propto (v)^2$, and since $\Delta p \propto P_v$, therefore $\Delta p \propto (v)^2$, therefore $Q \propto (v)^{1.25}$

Hence the thermal load due to air infiltration increases exponentially with the velocity of the wind, and this is demonstrated in Table I for wind speeds of 3, 6 and 9 m/s (7, 13 and 20 mph respectively) relative to a velocity of 2 m/s.

Table I
Increase in heat loss due to air infiltration at various wind speeds

Wind speed, m/s	2	3	6	9
Values of $(v)^{1.25}$	2.38	3.95	9.39	15.59
Increase in ventilation loss	Basis	66%	295%	555%

Structure loss

The average rate of heat flow through an exposed building element is given by the following equation:

$$q = U.A.(t_e - t_o)$$

where q = the rate of heat flow, W
U = the overall coefficient of thermal transmission, W/m²°C
A = the area of the element, m²
t_e = the inside environmental temperature, °C
and t_o = the outside sol-air temperature, which for winter heating applications may be taken as being equivalent to the outside air temperature, °C

Now in the calculation of the thermal transmittance coefficient, the thermal resistances at the inside and outside surfaces are given by the following expressions:

$$(1) \qquad R_{si} = \frac{1}{1{\cdot}2Eh_r + h_c}$$

R_{si} = the thermal resistance at the inside surface, m²°C/W
E = the longwave emissivity factor for the surface, dimensionless,
= 0.9 for normal building materials
h_r = the radiation coefficient, W/m²°C
= 5.7 for a mean surface temperature of 20°C
and h_c = the convection coefficient, W/m²°C
= 3.0 for horizontal flow through walls where air movement does not, for all practical purposes, occur over the surface.

Hence, following substitution, the value of the inside surface resistance is found to be equal to 0.109 m²°C/W

$$(2) \qquad R_{so} = \frac{1}{Eh_r + h_c}$$

where R_{so} = the thermal resistance at the outside surface, m²°C/W

with other symbols as given above and h_r being given a value of 4.6 W/m²°C at a mean surface temperature of 0°C.

In instances where air movement occurs over the surface the value of the convection coefficient may be derived from the expression:

$$h = 5.8 + 4.1v$$

where v = the wind speed, m/s

The outside surface resistance used in

Table II

Variation in outside surface resistance with wind speed

Wind speed, m/s	2	3	6	9
h_c	14.0	18.1	30.4	42.7
R_{so}	0.055	0.045	0.029	0.021

Table III

Variations in heat flow per unit area for various building elements

Element		Wind Speed, m/s 2	3	6	9
Single	U value	6.10	6.49	7.25	7.69
glazing	% increase	Basis	6.4	18.9	26.1
Solid	U value	2.18	2.23	2.31	2.36
wall	% increase	Basis	2.3	6.0	8.3
Cavity	U value	1.57	1.59	1.63	1.66
wall	% increase	Basis	1.3	3.8	5.7
Insulated	U value	0.993	1.003	1.019	1.028
wall	% increase	Basis	1.0	2.6	3.5

Table IV

Percentage increase in structure loss for various proportions of single glazing

Area of glass / Total area	Wind speed, m/s 3			6			9		
	Solid	Cavity	Insulated	Solid	Cavity	Insulated	Solid	Cavity	Insulated
0.1	3.3	2.8	3.2	9.0	8.4	9.2	12.5	11.9	12.6
0.2	4.0	3.8	4.3	11.3	11.2	12.5	15.6	15.8	17.2
0.3	4.5	4.5	4.9	13.0	13.2	14.4	18.0	18.4	19.9
0.4	5.0	5.0	5.3	14.4	14.7	15.7	19.9	20.4	21.6
0.5	5.3	5.3	5.6	15.5	15.8	16.6	21.4	21.9	22.9

Table V

Summary of increases in structure losses due to variation in wind speed

Area of glass / Total area	Wind speed, m/s 3	6	9
0.1	3%	9%	12%
0.2	4%	11%	16%
0.3	5%	13%	19%
0.4	5%	15%	21%
0.5	5%	16%	22%

Table VI

Overall increase in heat requirement due to increases in both ventilation and structure losses

Area of glass / Total area	Wind speed m/s	Infiltration loss as a fraction of total heat requirement 0.05	0.10	0.20	0.30	0.40
0.1	3	6%	9%	16%	22%	28%
	6	23%	38%	66%	95%	123%
	9	40%	67%	121%	176%	230%
0.2	3	7%	10%	16%	23%	29%
	6	25%	39%	68%	96%	124%
	9	43%	70%	124%	178%	232%
0.3	3	8%	11%	17%	23%	29%
	6	27%	41%	69%	98%	126%
	9	46%	73%	126%	180%	233%
0.4	3	8%	11%	17%	23%	29%
	6	29%	43%	71%	99%	127%
	9	48%	74%	128%	181%	235%
0.5	3	8%	11%	17%	23%	29%
	6	31%	45%	73%	100%	128%
	9	49%	75%	129%	182%	235%

Table VII

Summary of the overall increase in heat requirement due to increases in both ventilation and structure losses

Wind speed, m/s	Infiltration loss as a fraction of total heat requirement 0.05	0.10	0.20	0.30	0.40
3	8%	11%	17%	23%	29%
6	28%	42%	70%	98%	126%
9	44%	71%	125%	179%	233%

the computation of the 'Standard' U values published in the IHVE Guide conform to the currently accepted concept of 'Normal' exposure, which assumes that a wind speed of 2 m/s is applicable at the surface, this being equal to two-thirds of that at roof level.

However, the speed of the prevailing wind will affect the thermal resistance of the boundary layer at the outside surface, which in turn will affect the overall value of the transmittance coefficient, thereby increasing the rate of heat loss from the structure for higher wind speeds. The variation in the values of the outside surface resistance, again for wind speeds of 3, 6 and 9 m/s, are shown in Table II, with the variation in the overall U value for single glazing and walls of the three following constructions being given in Table III.

(a) 9 inch thick (uninsulated) solid brick wall, plastered internally.

(b) 11 inch thick (unventilated) cavity brick wall, plastered internally.

(c) 10½ inch thick (unventilated) cavity wall having insulating block inner leaf, plastered internally.

We may now calculate the combined increase in heat flow through these alternative constructions incorporating various fractions of glass, and a summary of these results is given in Table IV from which it will be observed that since the U values of the walls have a comparatively slight effect relative to the proportion of glazing, this data may be condensed to that shown in Table V.

Increase in total loss

The data in Tables I and V enable us to estimate the overall increase in thermal load relative to the total heat loss at the original design condition and wind speed of 2 m/s.

For example, if 10% of the original total heat loss was attributable to infiltration, then for an external wall area incorporating 20% single glazing, the overall increase in thermal load with a prevailing wind speed of 6 m/s would be equal to (295% of 0.1) + (11% of 0.9) = 39.4%.

The figures in Table VI have been compiled on this basis, from which it may be observed that since the variation in the overall increase in heat requirement due to the area of glass is small relative both to the original proportion of heat loss due to infiltration and the effect of the wind speed, these data may be summarized as shown in Table VII.

Decrease in internal temperatures

The data in Table VII facilitate determination of:

(a) The reduction in internal temperature due to the influence of wind speeds in excess of 2 m/s at the original external design temperature.

(b) The increase in external temperature necessary due to the influence of wind speed in excess of 2 m/s to maintain the original internal design temperature, and

(c) The internal temperatures able to be maintained with prevailing wind speeds and external temperatures in excess of those at the design condition(s).

For example, if we assume internal and external temperatures of 20°C and 0°C respectively with 10% of the heat load at the design condition being due to infiltration, then for a prevailing wind speed of 6 m/s the increase in heat requirement in order to maintain the original inside/outside temperature difference of 20°C is found, from Table VII, to be 42%.

However, if this additional heat is not available, then the maximum temperature difference able to be maintained without increasing the original heat input will be equal to 20/1.42 = 14°C, which represents a reduction of 6°C in internal temperature from 20°C to 14°C.

Alternatively, the original internal temperature of 20°C could be maintained with a prevailing wind speed of 6 m/s provided that the external air temperature did not fall below 6°C, or again, for a combination of 6 m/s wind speed and an external temperature of 3°C, an internal temperature of 3 + 14 = 17°C could be maintained.

The approximate reductions in internal temperatures due to the influence of prevailing wind speeds in excess of 2 m/s for design inside/outside temperature differences of around 20°C are given in Table VIII.

Table VIII

Reduction in internal temperatures due to increase in wind speed

Wind speed, m/s	Infiltration loss as a fraction of total heat requirement				
	0.05	0.10	0.20	0.30	0.40
3	1°C	2°C	3°C	4°C	5°C
6	4°C	6°C	8°C	10°C	11°C
9	6°C	9°C	11°C	13°C	14°C

Conclusions

Although the foregoing simplified analysis does not take account of many factors associated with this problem, it would nevertheless appear that the incidence of wind speeds in excess of those used for the calculation of heat losses at the design condition can have a significant effect upon internal temperatures.

Consequently, the incidence of prolonged periods of excessive wind speeds during the preheating and cooling periods of intermittently heated buildings may lead to the non-attainment of adequate internal temperatures at the commencement of occupancy and to the necessity for extended preheating periods respectively, whilst the adverse effect experienced during the occupied period may necessitate the occasional use of supplementary heating units in rooms which are normally adequately heated.

South African research on wave power

Exciting research to harness energy from the sea on a large scale is to start at Stellenbosch University early in 1978. The rector said that a research chair in ocean engineering is to be established at the university. The importance of the project is illustrated by the wide support, both local and international, which has been promised. He said the advantages of research into energy from wave motion off South Africa's coast were enormous. The country had almost perfect conditions for the project along its 5780-kilometre of coast. The coastal shelf is suitable for anchoring machinery and the waves are of more constant duration than those off the United Kingdom or Europe.

Mining legislation

The South African Government is considering legislation to rationalise all aspects of coal mining to ensure the country's coal resources are used to the best advantage. The Minister of Mines also said that present inadequate control of coal mining—especially in regard to waste and wasteful mining methods—"should be rectified forthwith."

South Africa had a role to play in defending Western civilisation by making available coal, uranium and technology to a world that is going to be in desperate need of these commodities, said Prof W. J. C. van Rensburg, Director of the Institute for Energy Studies at the Rand Afrikaans University. "However, we should not sacrifice our own self-sufficiency in the process and pick the eyes out of our coal deposits."

As a result of past and present price control policies in South Africa, he said, the percentage extraction was poor, and under present conditions the extractable coal reserves were only around 25 billion tonnes. Control over the industry was fragmented between a number of Government departments and semi-State corporations.

Coal availability

One very real problem that will confront the Electricity Supply Commission sooner or later is coal availability. The Petrick Commission put South Africa's mineable reserves at 80 000-million tons, but only about 25 000-million tons of that is extractable under current economic conditions. But there are other snags. Only 55 blocks of coal exist from which more than 280-million tons can be extracted, even if adjacent areas under different ownership are combined, and there are other consumers—notably Sasol—not to mention export commitments.

Escom feels that either national policy, or the inevitably rising price of coal will restrict its slice of the cake to somewhere around about 5000-million tons. Allowing that some coal-fired plant will be withdrawn between now and the year 2000 and that reserve capacity is a must, that means that only about 50 000MW of coal-fired plant can be supported. This would leave a shortfall on demand which would have to be met by nuclear plant. One estimate put the required nuclear capacity by 2000 at about 11 000MW and stresses that the last pithead coal-fired plant is unlikely to be commissioned much later than just after the turn of the century.

BRIEFS

"**Maintenance research** at BRE" by Dr E. J. Gibson is the subject of No 2 in the Institute of Building's maintenance information leaflets. Enquiries to Englemere, Kings Ride, Ascot, Berks.

BSRIA bibliography on **air curtains** lists 63 references. £1.00 (payable with order) from the Association at Old Bracknell Lane, Bracknell, Berks.

CITB have scheduled three **courses on oil fired heating**, dealing with fault diagnosis, maintenance and repair of domestic modules. Courses are to be held at Long Eaton centre and are free, employers having to pay only for accommodation and wages during training. Enquiries to The Manager, Training Services Agency Skills Centre, Wilsthorpe Road, Long Eaton, Nottingham.