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MACDATA
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Airtightness of windows: Energy conservation versus natural ventilation

Abstract
The air infiltration performance of windows is important when determining a building's natural ventilation requirements. Investigations at Paisley College suggest the drive for energy conservation and low infiltration rates has adversely affected natural ventilation bringing a consequent risk of dampness and condensation.

A simplified design procedure is recommended to assist designers to achieve a better balance between energy conservation and ventilation.

■ INTRODUCTION

Weathertightness of windows has been investigated by the MACDATA unit of Paisley College of Technology for the past 20 years. In this time over 1200 windows have been tested and classified using the appropriate British Standard publications[1 2 3 4]. The window classifications are based on the overall performance with respect to air infiltration, water penetration and wind resistance. Windows which failed the performance classifications for weathertightness failed generally in the watertightness test and rarely in the air infiltration test[5 6]. This has resulted in windows achieving a higher classification for air infiltration than necessary with a consequent reduction in natural ventilation and a greater risk of condensation and dampness[12].

The results of the weathertightness investigations have been analysed[7] with reference to existing standards for natural ventilation[8 9 10] and the balance between energy conservation needs and ventilation requirements investigated.

■ BACKGROUND

Weathertightness testing of windows has been carried out in the United Kingdom since 1968. The methods of testing and classifying windows were initially governed by BS 4315[2] and BS DD4, 1971[1] and were later superseded by BS 5368[4] and

Pressure classification		Derived correlation	Notes
Ref	Pressure (Pa)	$\frac{Q}{L} = a\,(\Delta p)^n$	
I	150	a = 0.5668, n = 2/3	Maximum infiltration of 16 m³/h/m at given pressure classification
II	200	a = 0.4678, n = 2/3	
III	300	a = 0.3570, n = 2/3	
IV	600	a = 0.0928, n = 2/3	Applicable only when stringent performance levels required.

Table 1: BS 6375 Air infiltration classifications[3]

BS 6375[3]. Compliance with BS 6375 requires a combined satisfactory performance for air infiltration, water penetration and wind resistance[5 6].

The air infiltration performance of the window is an important consideration in determining natural ventilation requirements for a building. Published standards[8 9 10] for determining natural ventilation performance have shown considerable variations. The published analysis[7] provides up-to-date criteria for determining natural ventilation based on weathertightness testing for air infiltration. The analysis is related to the BS 6375 performance levels for air infiltration given in Table 1 (see page 65).

The windows are generally supplied for test in "as new" condition. Although the test method takes some account of the quality control in the manufacturing process, it takes no account of random factors such as bad handling and poor installation on site. Nevertheless, provided reasonable supervision is exercised in the factory and on site, the test results give an excellent indication of the performance to be expected in practice.

■ RECOMMENDATIONS FOR DESIGN

The published analysis highlighted the different and opposing aims of standards for weathertightness and natural ventilation with respect to air infiltration through the opening joints of windows.

Energy conservation may be achieved by restricting the air infiltration which may also lead to condensation and dampness problems. These problems may be avoided by supplying heating and ventilation at the expense of energy conservation. A balance is therefore required between energy conservation needs and ventilation requirements for the complete building. A balance is also essential for component parts of the building such as windows.

The problem of striking the correct balance is hampered by natural ventilation being dependent on atmospheric conditions and other factors such as stack effect, orientation, shape and internal layout of the building.

BS 6375 relates design criteria to the "exposure" of the window. The exposure is expressed as a design wind pressure. This pressure, the wind pressure for structural design purposes, is determined from meteorological wind speed records, geographical location, ground topography and building dimensions.

A statistical analysis of wind speed records gives a basic wind speed which is defined as the maximum speed averaged over a three second period on a once in 50 year's probability and adjusted to give a value corresponding to 10 m above ground in an open situation.

Values of basic wind speeds and correction factors for topography, ground roughness and building shape are given in BS 6375 in conjunction with BS CP3[11]. The BS 6375 relationships between design wind pressure and pressure classification for air infiltration are given in Table 2.

Design wind pressure (Pa)	BS 6375[3] Pressure classification for air infiltration
Up to 1200	I : 150 Pa Performance expected from opening light that is close fitting and without air seals
	II : 200 Pa Suitable for most dwellings and many other buildings
1200 to 2000	II : 200 Pa or III : 300 Pa Depends on design of building. Guidance on selection given in BS 6375
Over 2000	III : 300 Pa
—	IV : 600 Pa Applicable for any design wind pressure when stringent performance levels are required.

Table 2: Grade of exposure classifications[3]

BS 6375[3] pressure classsification for air infiltration	Overall correlation for all window types		Correlation for individual windows (with weatherseal)		
	a	n	Type	a	n
IV : 600 Pa	0.0178	0.524	Pivot Hung Tilt & turn Slider	0.0158 0.0300 0.0082 0.0254	0.568 0.330 0.724 0.817
III : 300 Pa	0.0657	0.786	Pivot Hung Tilt & turn Slider	0.0289 0.6153 0.0230 0.1093	0.903 0.337 0.944 0.772
II : 200 Pa	0.0853	0.910	—	—	—
I : 150 Pa	0.6511	0.581	—	—	—

Table 3: Recommended design correlations[7]

When the appropriate weathertightness classification for air infiltration is obtained, the corresponding correlation for natural ventilation by air infiltration can be obtained from BS 5925 in the form of the general equation for air infiltration through the opening joint of a closed window.

$$\frac{Q}{L} = a\,(\Delta p)^n$$

where

a = crack coefficient [m^3/h m Pa^n]
L = length of crack [m]
n = exponent of pressure difference [—]
Δp = applied pressure difference across opening [Pa]
Q = air flow through the opening [m^3/h]

The appropriate pressure difference Δp to be used in determining the natural ventilation rate through a closed window is obtained from BS 5925 by considering meteorological wind speed records, geographical location, ground topography and building dimensions.

In practice, the actual infiltration rates measured during the weathertightness tests may indicate air infiltration rates which are less than the required design values. In these circumstances, additional means of achieving the designed infiltration rate will need to be provided if the balance between energy conservation needs and natural ventilation requirements is to be maintained. It is therefore recommended that all windows should incorporate a controlled ventilator system to maintain this balance.

■ ILLUSTRATIONS OF DESIGN METHOD

The following examples illustrate the proposed method of determining natural ventilation infiltration rates from weathertightness classifications. The weathertightness classification is obtained from BS 6375 and the appropriate correlation from Table 3 used in conjunction with BS 5925 to obtain the natural ventilation rate for design purposes.

In each of the examples, the natural ventilation rate is calculated by assuming that it is achieved for over 50% of the time due to wind effect.

The examples illustrate the correct relationship between weathertightness classification and ventilation requirement. It is necessary to emphasise that the effect of installing a window which has achieved a higher weathertightness classification for air infiltration than is required at a particular location is to reduce the natural ventilation rate and destroy the balance between energy conservation and natural ventilation. It is therefore recommended that all window designs should incorporate a controlled ventilator system to overcome the possibility of a ventilation shortfall.

It should also be emphasised that the 300 Pa classification is the highest classification normally required in the United Kingdom.

The 600 Pa pressure classification is applicable only when stringent levels of performance are required, eg, when there is a special need to limit heat loss, when

Example 1 (right): Building location — City Centre, Oxford Building dimensions — height 10 m, length 10 m, width 3 m

Example 2 (below): Building location — City Centre, Oxford Building dimensions — height 50 m, length 30 m, width 10 m

(a) Weathertightness classification (BS 6375):

Basic wind speed	=	40 m/s
Building height ratio	=	3.33
Building plan ratio	=	1.00
Pressure coefficient	=	1.40
Design wind pressure	=	650 Pa
Classification (Table 2)	=	200 Pa

(b) Natural ventilation correlation (Table 3):

a = 0.0853, n = 0.910

(c) Natural ventilation rate (BS 5925) calculated from $\frac{Q}{L} = a\,(\Delta p)^n$:

Hourly mean wind speed	=	4.50 m/s
Reference wind speed	=	$(4.5)\,(0.21)\,(10)^{0.33}$
	=	2.02 m/s
Pressure coefficient (as above)	=	1.40
Pressure difference Δp	=	$(1.40)\,(0.5)\,(1.2)\,(2.02)^2$
	=	3.43 Pa
Natural ventilation rate	=	$(0.0853)\,(3.43)^{0.91}$
	=	0.26 $m^3/h/m$

ie. The allowance for natural ventilation at a weathertightness classification of 200 Pa is 0.26 m^3/h per metre length of window opening joint.

(a) Weathertightness classification (BS 6375):

Basic wind speed	=	40 m/s
Building height ratio	=	5.00
Building plan ratio	=	3.00
Pressure coefficient	=	1.40
Design wind pressure	=	1428 Pa
Classification (Table 2)	=	300 Pa

(b) Natural ventilation correlation (Table 3):

a = 0.0657, n = 0.786

(c) Natural ventilation rate (BS 5925):

Hourly mean wind speed	=	4.50 m/s
Reference wind speed	=	$(4.5)\,(0.21)\,(50)^{0.33}$
	=	3.44 m/s
Pressure coefficient	=	1.40
Pressure difference	=	$(1.40)\,(0.5)\,(1.2)\,(3.44)^2$
	=	9.92 Pa
Natural ventilation rate	=	$(0.0657)\,(9.92)^{0.786}$
	=	0.40 $m^3/h/m$

ie. The allowance for natural ventilation at a weathertightness classification of 300 Pa is 0.40 m^3/h per metre length of window opening joint.

an abnormal interior environment is intended or when air conditioning is to be employed. For any of these conditions the natural ventilation rate at the 600 Pa pressure classification can be obtained from the appropriate correlation given in Table 3 (a = 0.017, n = 0.524).

■ CONCLUSIONS

A method of resolving the different objectives of weathertightness and natural ventilation requirements of windows has been outlined which will assist the designer in achieving a better balance between energy conservation needs and

REFERENCES

1. BS DD4: 1971 *Recommendations for the grading of windows* (superseded).

2. BS 4315: Part 1: 1968 *Methods of test for resistance to air and water penetration* (superseded).

3. BS 6375: Part 1: 1983 (amended 1985) *Performance of windows: classification for weathertightness.*

4. BS 5368: Part 1: 1976 *Methods of testing windows: Air permeability test.*

BS 5368: Part 2: 1980 *Methods of testing windows: Watertightness test under static pressure.*

BS 5368: Part 3: 1978 *Methods of testing windows: wind resistance tests.*

5. T F Provan and J D Younger "Keeping the elements at bay", *Building*, 22 June 1979.

Example 3 (left): Building location — open country, near Glasgow Building dimensions — height 10 m, length 10 m, width 3 m

(a) Weathertightness classification (BS 6375):

Basic wind speed	=	51 m/s
Building height ratio	=	3.33
Building plan ratio	=	1.00
Pressure coefficient	=	1.40
Design wind pressure	=	2700 Pa
Classification (Table 2)	=	300 Pa

(b) Natural ventilation correlation (Table 3):

$a = 0.0657, \ n = 0.786$

(c) Natural ventilation rate (BS 5925):

Hourly mean wind speed	=	5.50 m/s
Reference wind speed	=	$(4.5)\ (0.68)\ (10)^{0.17}$
	=	5.53 m/s
Pressure coefficient	=	1.40
Pressure difference	=	$(1.40)\ (0.5)\ (1.2)\ (5.53)^2$
	=	25.71 Pa
Natural ventilation rate	=	$(0.0657)\ (25.71)^{0.786}$
	=	0.84 $m^3/h/m$

ie. The allowance for natural ventilation at a weathertightness classification of 300 Pa is 0.84 m^3/h per metre length of window opening joint.

Example 4 (below): Building location — open country, near Glasgow Building dimensions — height 50 m, length 30 m, width 10 m

(a) Weathertightness classification (BS 6375):

Basic wind speed	=	51 m/s
Building height ratio	=	5.00
Building plan ratio	=	3.00
Pressure coefficient	=	1.40
Design wind pressure	=	3510 Pa
Classification (Table 2)	=	300 Pa

(b) Natural ventilation correlation (Table 3):

$a = 0.0657, \ n = 0.786$

(c) Natural ventilation rate (BS 5925):

Hourly mean wind speed	=	5.50 m/s
Reference wind speed	=	$(5.5)\ (0.68)\ (50)^{0.17}$
	=	7.72 m/s
Pressure coefficient	=	1.40
Pressure difference	=	$(1.40)\ (0.5)\ (1.2)\ (7.72)^2$
	=	44.43 Pa
Natural ventilation rate	=	$(0.0657)\ (44.43)^{0.786}$
	=	1.30 $m^3/h/m$

ie. The allowance for natural ventilation at a weathertightness classification of 300 Pa is 1.30 m^3/h per metre length of window opening joint.

ventilation requirements with a consequent improvement in economic strategy.

The method forms a useful guideline for regions where natural ventilation is preferred to mechanical ventilation.

Also, the 600 Pa pressure classification for weathertightness performance is applicable to mechanically ventilated buildings and an indication of the air infiltration rate can therefore be obtained from the appropriate correlation.

6. T F Provan and J D Younger "Weathertightness of windows", *Building Technical File,* No 10, July 1985.

7. T F Provan and J D Younger "Air infiltration characteristics of windows", *Energy & Buildings,* 9 (4), 281-292, 1986.

8. BS 5925: 1980 *Design of buildings: ventilation principles and designing for natural ventilation.*

9. CIBSE Guide: Section A4 *Air Infiltration* 1986.

10. ASHRAE: 1981 *Handbook of Fundamentals,* Chapter 22, "Ventilation and Infiltration".

11. BS CP3: Ch 5: Part 2: 1972 *Basic data for the design of buildings,* Chapter 5, "Loading; Part 2, Wind Loads".

12. E Downey and T F Provan "Energy conservation — Side effects of reduced ventilation rates and increased insulation", *Building Technical File,* No 13, April 1986.