Resistance to air flow through external walls

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INTRODUCTION

The control of energy lost from a building, by air leakage through joints in wall claddings, has been a subject of increasing interest in the UK. Measurements of air leakage characteristics of doors and windows of occupied houses have shown that these components often only account for part of the significant leakage.

In naturally-ventilated buildings a balance must be sought between the need for air exchange and the need for energy control. In particular there may be a need for better control of resistance to air leakage in mechanically-ventilated buildings.

Air flow through or into a wall can have other adverse effects on a building. Air paths through the internal lining allow water vapour into the wall from inside the building. Low air resistance of the outer cladding may allow this unwanted vapour to escape but could expose vulnerable parts of the wall to the outdoor climate and may reduce its thermal efficiency.

DATA AVAILABLE

Some data on the air flow characteristics of walls are available from measurements of actual buildings made in the USA and Norway. Table 1 summarises these results at a standard pressure difference of 200 Pa (20 mm SWG) to enable easy comparison. They are converted from reported results at various pressures using the relation

$$V \propto p^n$$

where V = the flow rate

p = the pressure differential across the wall

and n = 0.65. This exponent can vary between 0.6 and 0.7 depending on the characteristics of the air leakage path.

Two hundred Pa is a convenient test pressure. The actual pressure difference obviously varies – for the majority of situations and most of the time it would be considerably lower than this.

As Table 1 shows, the air flow covers a wide range from 3 to 27 $m^3 h^{-1} m^{-2}$ of wall. The few laboratory measurements available from other sources[4,5] are similarly varied but lower in magnitude. For similar units these range from 0.1 for a plastered and painted, 212 mm thick brick wall, to 11 for a plain brick wall of similar thickness.

EXISTING STANDARDS

The above data have little resemblence to various standards or regulations that exist in other countries. The values in Table 2, which shows the variation of air leakage allowed by different standards, have been converted to equivalent values of 200 Pa pressure differential. These represent considerably tighter standards than achieved in existing buildings and it is not clear as to whether they are being achieved in new construction. Before a standard can be developed in the UK it is necessary to establish further

Table 1 Measured data from buildings

Description	Air leakage ($m^3 h^{-1} m^{-2}$) at 200 Pa	Number of buildings
Multi-storey curtain wall[1]	17–27	3
Multi-storey concrete or metal panel[2]	4–16	8
Timber frame and rendered brick[3]	3– 4	2
Timber frame and brick only[3]	18–27	2

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data on the air tightness being provided with common forms of construction and also to decide whether it is feasible to increase this resistance by modifying details.

LABORATORY MEASUREMENTS

A difficulty with laboratory measurement is in ensuring the wall sample includes the miscellaneous edge or junction details that would exist in practice and that it is representative of reasonable site workmanship. At PRL a rig capable of including a large wall area (16 m^2), as well as various wall junctions, has been built so that air leakage characteristics of current wall types can be examined (see Figures 1 and 2). The aim when constructing the test walls has been to provide the constraints that would exist on site to give an appreciation of erection difficulties, in order that their effect on air tightness might be assessed. It has also been attempted to provide a standard of workmanship that might reasonably be expected on a building site.

Four test walls have been examined:

1 A concrete panel cladding similar to that used with some school buildings.

2 A timber frame wall of single storey panels typical of that used in housing.

3 A composite profiled aluminium cladding with rigid plastic foam lining produced mainly for industrial buildings.

4 A profiled steel cladding with separate insulation and plasterboard lining also used mainly on industrial buildings.

Table 2 Known standards and codes for the air leakage of walls

Source	Air leakage ($m^3 h^{-1} m^{-2}$) at 200 Pa
Nordic regs 1965[6]	2.1
US Dept of Housing 1970[7]	2.3
Canadian Industrial Spec[8]	2
Danish Standard	2.6

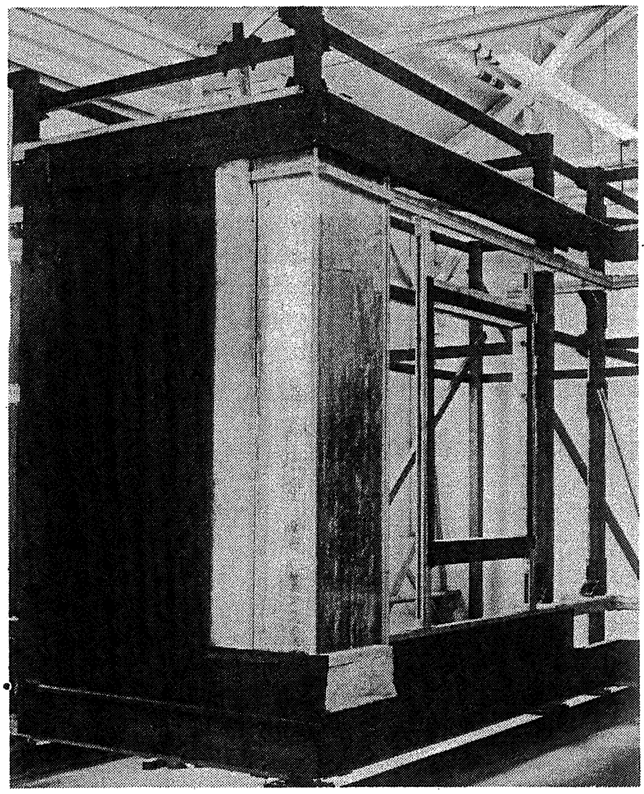

Figure 2 Partly constructed test wall of a metal profiled cladding

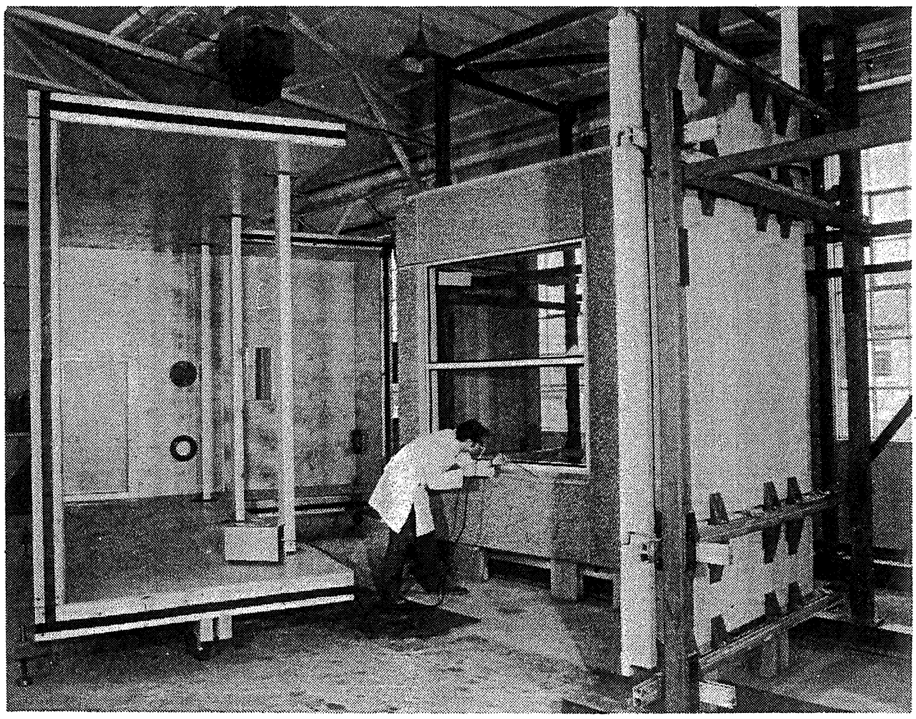

Figure 1 Rig for determining air permeability of walls. The pressure box on the left can be clamped to the wall perimeter which has corner-wall junctions. A fibre optics probe is being used to examine wall details

RESULTS

Table 3 gives the average air leakage for the test facade which was approximately 6.8 m long by 2.5 m high. It includes, where appropriate, the air leakage at floor and roof junctions and at window-wall junctions. An average value for any building will therefore depend on the leakage of particular details and the frequency of their occurrence in relation to the dimensions of the wall. For example, a high leakage through a floor to wall joint will have less influence on the average value through a tall wall than a low one.

The details contributing to the major leakage were identified by making successive measurements with different details sealed.

The joints between panels provide most of the air leakage paths in test wall No 1 (concrete panels). For test wall No 2 (timber panels) the perimeter joints make the major contribution and for the two metal claddings both are considerable. The window to wall joint is a detail in 'dry' construction that is difficult to make air-tight unless considerable reliance is placed on sealants; a better window sill and flashing system is needed. (Studies of moisture in timber frame walls[9] also revealed this detail to be commonly deficient.)

Modifications could be devised which would reduce the leakage paths. With some, the simple addition of an appropriate flexible foam strip would suffice. For the linings to the metal claddings the cover strips would require altering to stiffen them and/or to provide a tighter clamp around the edges of the linings.

Leakage of the outer cladding is often purposely provided and reliance is then placed on the internal lining to provide the barrier against air flow. However the dry lining of the concrete panel test wall, which was better sealed than walls observed in some buildings, had a leakage rate double that of the outer cladding.

As mentioned previously the size of the wall will influence the average leakage rates. These have been estimated from the results in Table 3 and are given in Table 4. The average leakage rates are generally lower especially with the factory type claddings. The relative importance of different junctions has also changed.

IMPLICATIONS

The results are indicative of the resistance to air flow that might be achieved with reasonable standards of workmanship. With modifications to the detailing the larger leakage rates could be substantially reduced. For example, it should be possible to reduce the timber frame house rate to 5 $m^3h^{-1}m^{-2}$ at 200 Pa and the industrial building claddings to between 10 and 20 $m^3h^{-1}m^{-2}$ at 200 Pa. To put these values in context, tests[10] on closed windows with draught stripping showed that the average leakage per metre length of openable light ranged between the equivalent of 6 and 20 m^3h^{-1} at 200 Pa. This could represent 30 to 90 $m^3h^{-1}m^{-2}$ of a typical household window. Because the wall usually covers a larger area than the windows and doors, a wall leakage rate of 5 $m^3h^{-1}m^{-2}$ at 200 Pa could provide 30 per cent or more of the total leakage rate.

The question remains however, is a better air resistance than that currently being achieved worth aiming for? Before it can be answered there must be further studies relating air exchange rates to resistance of the various building elements and also studies of the needs for air exchange, the methods by which it should be provided and the energy loss caused by air exchange.

Table 3 Recordings of air leakage for various test facades

Test Wall	Average air leakage at 200 Pa ($m^3h^{-1}m^{-2}$)	Details contributing to major leakage	Percentage contribution
1 Precast concrete panels, gasket joints, plasterboard lining	5	Horizontal joints between panels	50
		Cross over joints between panels or panels to window	50
2 Timber-frame panels, fibreboard sheathing, rain screen cladding and plasterboard lining	15	Top horizontal joint to floor/ceiling void	80(30)*
	(30)*	Window to wall junctions	20(10)
		Bottom horizontal panel joint	(60)
3 Profiled aluminium cladding with bonded composite insulation and lining	45	Five vertical joints between panels	45
		Top and bottom horizontal joints	35
		Side joints to other walling	20
4 Profiled steel cladding with separate quilt insulation and plasterboard lining	50	Top and bottom horizontal joints	80
		Vertical joints between wall lining panels	20

* Figures in brackets include the bottom horizontal panel joint. The addition of a skirting board, carpeting and decorations would normally seal this junction.

Table 4 Estimated leakage rates for typical buildings with walls described in Table 3

Building	Wall type (Table 3)	Average air leakage at 200 Pa($m^3 h^{-1} m^{-2}$)	Details contributing to major leakage	Percentage contribution
School	1	5	As for Table 3	
2 storey house	2	10*	Horizontal top joint to floor/ceiling void	30
			Window to wall junctions	70
Factory wall (6 m high) with no windows	3	35	Vertical joints	85
			Horizontal top and bottom joints	15
	4	30	Vertical joints	55
			Horizontal top and bottom joints	45
Warehouse wall (15 m high) with no windows	3	35	Vertical joints	90
			Horizontal top and bottom joints	10
	4	20	Vertical joints	65
			Horizontal top and bottom joints	35

* Leakage to roof void and test leakage at bottom of panel not included.

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