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BREFAN - A DIAGNOSTIC TOOL TO ASSESS THE ENVELOPE AIR LEAKINESS OF LARGE BUILDINGS

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ABSTRACT

A major factor in the ventilation of buildings, and their energy performance is the leakiness of the building envelope. In some circumstances, this adventitious leakage through the building fabric is a source of excessive ventilation which can lead to energy waste and, in some cases, to discomfort.

The air leakiness of the building envelope can be determined by carrying out whole-building leakage tests. BREFAN is a fan 'pressurisation' rig designed for such tests in most non-domestic buildings. The measurements so obtained can be used to quantify the variation of air leakage through the fabric as a function of the applied pressure differential across the envelope. A 'leakage' index can also be evaluated and used as a diagnostic measure of the constructional quality of the external fabric.

This paper gives results from field measurements in five large buildings in the UK. Measurements in two office buildings show that the external envelope of one specifically designed and constructed as a low-energy office (LEO), is twice as tight as the other built in a more conventional manner. Comparison with buildings tested in North America shows that the LEO is as tight as those.

Measurements in two old, industrial 'hangar' buildings are compared with one built within the last decade under current UK Building Regulations. Although the leakage index shows the new building to be only half as leaky as the old, comparison with tight Swedish industrial buildings shows that a further fivefold reduction is possible.

Finally, tests in a large Law Court building are briefly described to show how BREFAN can be used as a diagnostic tool in a more qualitative manner. By depressurising the building, a possible cause for complaints of insufficient internal heating during cold weather was traced to excessive air leakage through the roof.

INTRODUCTION

Adequate ventilation is essential for the health, safety and comfort of the occupants of buildings, but excessive ventilation leads to energy waste and, in some cases, to discomfort. In naturally ventilated buildings, air enters either through purpose-built openings, like windows or by uncontrolled leakage (infiltration) through cracks and gaps in the building envelope. It is necessary to have the means to quantify this overall leakage, either to assess the effectiveness of any remedial measure (like draughtstripping) in a problem building or to assure the quality of a new one.

The Building Research Establishment (BRE) has developed BREFAN (1), a multi-fan pressurisation system designed to quantify the envelope leakage of most large non-domestic buildings like offices and single-celled industrial buildings. The leakiness of the envelope is quantified by sealing an appropriate number of these fan units into an outside doorway and measuring the air flow required to maintain a set of pressure differences across the building envelope.

This paper presents results from field measurements in five large UK buildings. Of these, measurements in two office buildings are given to highlight the difference in envelope leakage between a conventional building and one built specifically as a low-energy office. The leakiness of both is then compared with North American office buildings.

Measurements from two conventional and older hangar-type industrial buildings are compared with newer buildings built under current UK building regulations. They are also compared with tight Swedish buildings of similar type to indicate the limits to which buildings can be tightened using available construction techniques.

BREFAN can also be used as a tool to qualitatively diagnose and identify individual portions of the building's fabric which are leakier than others. Qualitative as well as quantitative tests in a newly-built law court complex are described.

BREFAN SYSTEM

The system consists of a number of identical fan pressurisation units. Each unit is fully portable and the 762 mm diameter fans are powered from conventional 13 A sockets. Single-phase to three-phase speed controllers are used which stabilise the fan speeds when more than one fan unit is being used. Each fan is capable of providing a flow rate of 5.5 m^3/s against a building envelope pressure difference of 50 Pa. Airflow through each fan is measured using a conical inlet designed to British Standard BS 848 (2). The number of fans used at any time in a building is determined by both the leakiness of the building and the maximum pressure difference required between the inside and the outside.

METHOD OF TESTING AND ANALYSIS

Flexible ducting is used to connect the fan units to 'false' plywood door panels temporarily sealed (Fig 1) into external doorways. It is necessary to keep all outside doors and windows shut and all internal doors open. Tests must be carried out when the outside wind speed is very low. The fans can be arranged to either pressurise or depressurise the building. Flow rates Q m^3/s through the fans are measured (2) by the conical inlet over a suitable range of building pressure differentials, ΔP Pa.

Best-fit power-law profiles of the form,

$$Q = K \, \Delta P^n$$

where the coefficient K and the exponent n ($0.5 < n < 1.0$) are constants, are fitted to the data by transforming the above equation to the form,

$$\log_e(Q) = \log_e(K) + n \log_e(\Delta P)$$

and fitting a linear regression line on the transformed variables.

It is sometimes necessary to compare the envelope leakage characteristics between buildings of different shapes and sizes. The air flow rate $Q_{\Delta P}$ (at a specified pressure differential ΔP) per unit permeable external surface area S of the building has been shown (1) to be a measure of the constructional quality of the building fabric with respect to air leakage. Although this index is usually evaluated at a 50 Pa pressure differential (3) for dwellings, a lower target pressure of 25 Pa is used for larger non-domestic buildings (1).

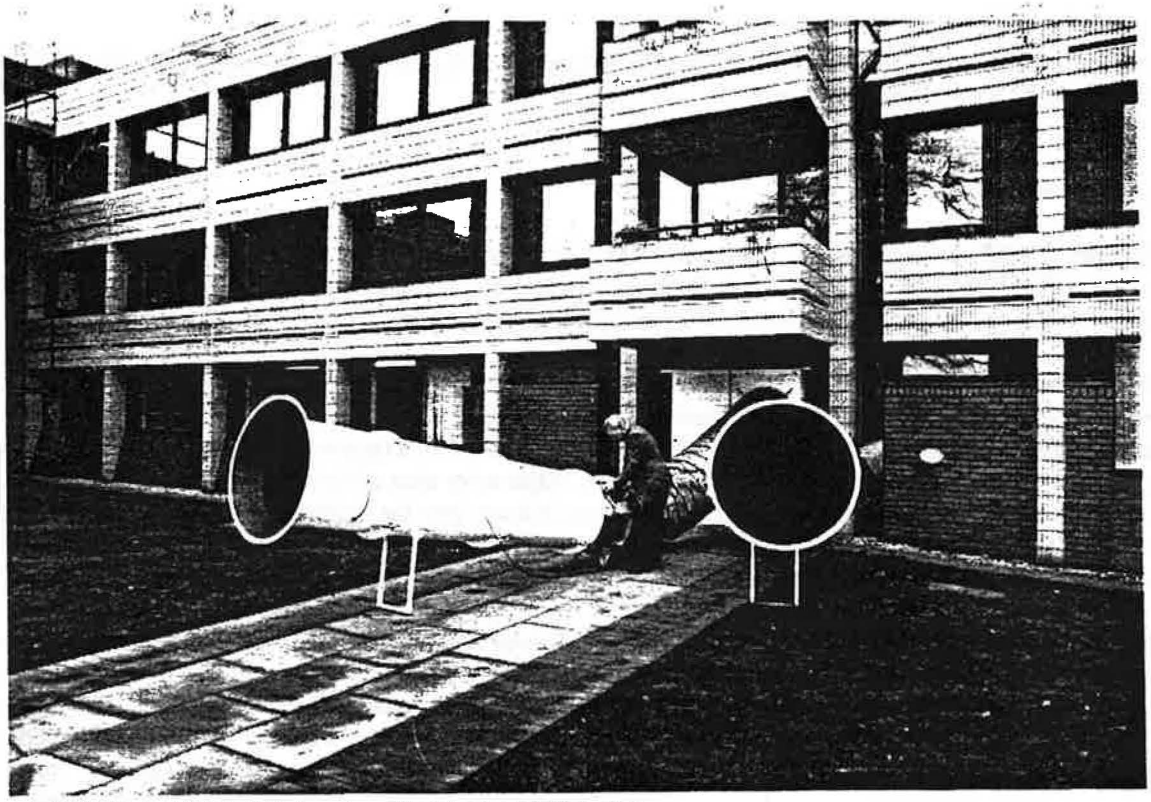

FIGURE 1. BREFAN fans installed in the LEO building

FIELD MEASUREMENTS

Office buildings

BREFAN pressure tests were carried out in two medium-sized office buildings at the BRE site in Garston. One of these is a well-insulated three-storey 'low-energy' office (LEO) incorporating a number of energy saving features. It was mechanically ventilated but the ventilation system is currently disabled to enable assessment of a particular heating system (4). The building volume is estimated as 5315 m^3 and the external surface area at 1750 m^2. The second is a more conventional, naturally ventilated office with estimated volume 6254 m^3 and surface area 2195 m^2. Full details of both buildings are given elsewhere (5).

The resulting airflow rates were plotted against the applied pressure differential across the outside wall envelopes for the two buildings together with best-fit power law profiles. Values of 0.412 and 1.388 m^3/s per Pa^n for the coefficient K together with 0.58 and 0.51 for the exponent n were obtained for the LEO and conventional building respectively (1,5). With these values, calculations show that at 25 Pa, the LEO building is more than twice as tight as the conventional office building.

Single-celled industrial buildings

BREFAN was used for whole-building pressure tests on a 25-year-old 'hangar' building (known in the UK as a 'Marston' shed) at the BRE site in Garston. The roof and walls of the 4690 m^3 building are externally clad with corrugated asbestos cement sheeting and lined internally with plasterboard. The permeable area of the building was estimated as 1400 m^2. Best-fit power law profiles on the measured data (1) gave a coefficient of 2.041 m^3/s per Pa^n and an exponent of 0.64.

A 35-year-old industrial building in Wales was also pressure tested. The 4955 m^3 building, of masonry construction, had a permeable external area of 1694 m^2. Best-fit power law profiles gave a coefficient of

3.936 m^3/s per Pa^n and an exponent of 0.52. The leakage rates $Q_{\Delta P}$ (at a pressure differential ΔP) for these two buildings are approximately equal.

Law-court building

Recently, BREFAN was used as a qualitative tool to identify major air leakage routes in the external envelope of a Law Court building. Staff dissatisfaction had been expressed because some areas were either too hot or too cold, usually depending on the outside air temperature.

This Court is a modern, multicelled, 18000 m^3 building with an envelope area of 4750 m^2 and is mechanically ventilated. With all these ventilation openings to the outside sealed off, BREFAN was used to depressurise the building. With a uniform pressure differential of 12 Pa (approximately equivalent to that set-up by a 5 m/s wind) maintained across the envelope, major entry sites of the cold external air were located simply by using smoke-tubes. It was found that most leakage into the building occurred through specific portions of the roof void with some secondary leakage through cracks along the top edge of most openable windows.

A similar depressurisation test to evaluate the overall leakiness of the building fabric was also carried out. During the test, there was no discernible wind. The outside air temperature was about 6°C while the internal temperature was maintained at about 17°C resulting in a background 'stack' pressure differential ΔP_b between 2 to 3 Pa. In such instances, when the measured pressure differentials have a steady background component induced either by wind or stack, it is necessary to correct the measured data before analysis.

To correct for ΔP_b, a theoretically-correct quadratic form (6),

$$\Delta P_m = \Delta P_b + a.Q + b.Q^2$$

where a and b are constants, was fitted to the measured pressure differential ΔP_m and flow rate, Q, data. Since pressures, unlike flows, are additive (7), ΔP_b can be subtracted from ΔP_m to give the resulting pressures induced by the fans. Figure 2 shows a plot of the corrected pressure versus air flow. A best-fit power law profile was fitted to the data neglecting those below 1 Pa to minimise experimental fluctuations at the low values. A leakage coefficient of 2.35 m^3/s per Pa^n and an exponent of 0.77 were evaluated.

COMPARISON OF ENVELOPE LEAKINESS

It is useful to compare the leakiness of the buildings described here not only with one another but with buildings elsewhere. The leakage index evaluated at 25 Pa for all these buildings is shown in Figure 3. It can be seen that while the purpose-built LEO office with a leakage index of 5.5 m^3/s per m^2 is nearly as tight as a representative sample of North American buildings (1), the more conventional UK office is twice as leaky. The Court building, where staff dissatisfaction had been expressed regarding the internal thermal environment, could not be tested at 25 Pa. Extrapolation, however, indicates that this building has an index of 21 m^3/s per m^2, well in excess of values obtained with the other office buildings. It should be noted, however, this is indicative only since extrapolation (to 25 Pa) above the measured region is strictly not valid unless certain conditions (1) are met.

The old industrial buildings give a leakage index in excess of 40 m^3/s per m^2. Comparison with the leakage performance (1) of a newer one, built to current UK Building Regulations Standards shows (Fig 3) that this can be twice as tight. Comparison with the index obtained from measurements (8) in a relatively new Swedish industrial building shows (Fig 3) that there is scope for further tightening of the building envelope, <u>if required</u>.

CONCLUSIONS

BREFAN is a fan pressurisation system designed to measure air leakage rates through the external fabric of most non-domestic buildings. Portability, flexibility and the ability to be powered from conventional mains electricity supplies are some of its design advantages. BREFAN tests in office and industrial buildings show how to do the following:

(a) Characterise the air leakage through the building envelope as a function of the applied pressure differential across the fabric.

(b) Obtain an index which is a measure of the constructional quality of the building fabric and use it to compare the relative leakiness of similar buildings.

(c) Identify major air leakage paths in the building's fabric by depressurising the buildings.

ACKNOWLEDGEMENTS

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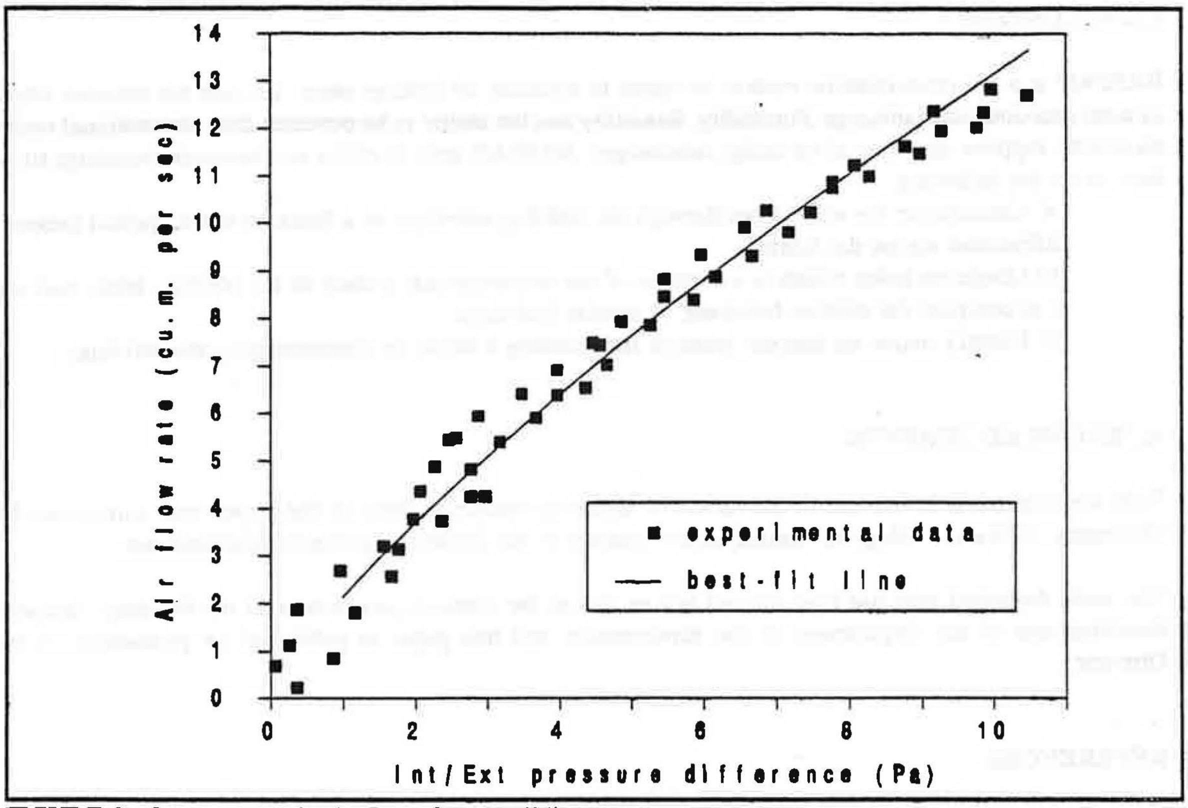

FIGURE 2. Pressure test in the Law-Court building

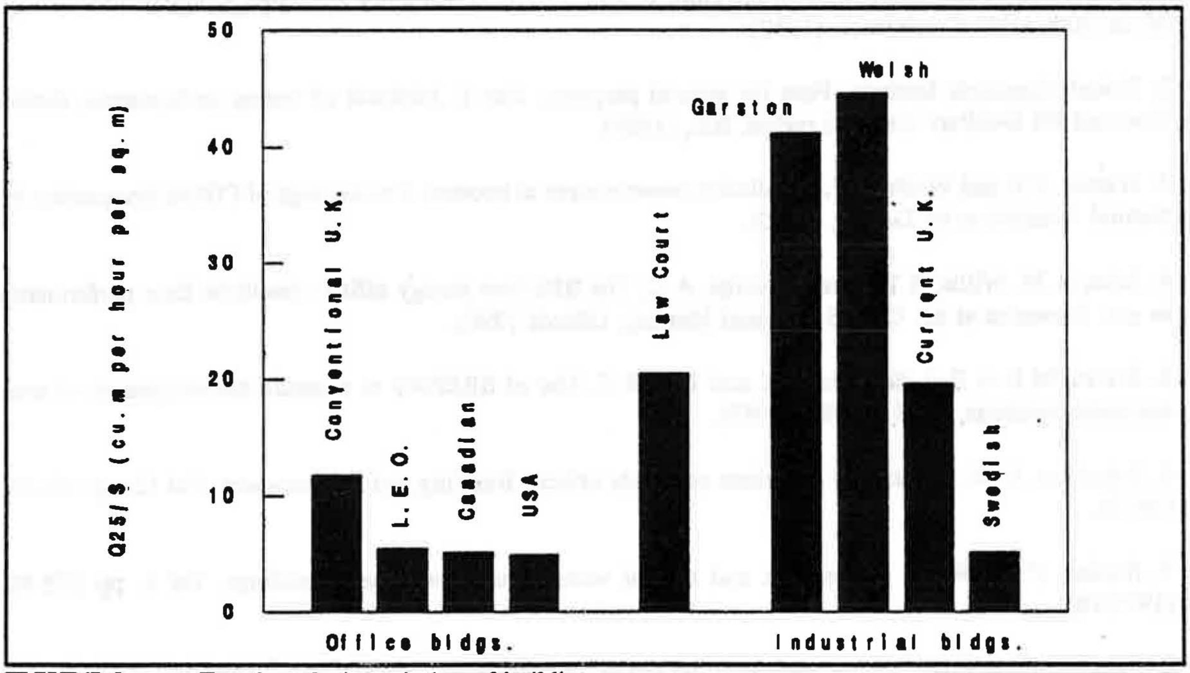

FIGURE 3. Envelope leakage index of buildings