WA5.1

CIBSE AM10 EXCERPT ON ENVELOPE FLOW MODELS FOR NATURAL VENTILATION

This appendix presents an excerpt from Section 4.3 of CIBSE AM10 (CIBSE 2005), which was referenced in ASHRAE Standard 62.1's Path B sizing method (ASHRAE 2019), available as an alternate path for prescriptive compliance. The original section, equation, and figure numbering from the reference document has been retained.

4.3 DESIGN PROCEDURES FOR ENVELOPE FLOW MODELS

It is assumed that the basic configuration of the building and the intended flow strategy have been agreed. It is assumed that the required flow rates through openings have been quantified (in magnitude and direction) under specific wind and temperature conditions. The next stage is to size the components of the ventilation system so that the flows will be delivered. Procedures for the initial sizing of openings based on explicit envelope flow models are illustrated below. This is done for a summer condition, but the same procedures can be applied to winter conditions. Before carrying out the calculations there are several preliminary steps:

- ***Step 1: identify isolated rooms and spaces:*** these are rooms that can be isolated from other parts of the building (in terms of their ventilation) and can therefore be treated by very simple explicit envelope flow models. To fall within this category the openings in the internal part of the envelope need to be much smaller than the openings in the external part of the envelope. This can often be the case for the summer design condition, but it is less likely to be valid in winter. Nevertheless, the designer may wish to size the openings on this basis for both design conditions. The two basic cases are single-sided ventilation and crossflow ventilation.
- ***Step 2: determine which parts of the building can be treated as a single space (i.e. a single cell):*** in a single cell all the rooms are connected by openings that are much larger than the openings in the external envelope. With such buildings it is necessary to consider all

openings simultaneously when sizing them. This can be done with explicit single-cell envelope flow models. If the building falls into the category where internal openings are neither very large nor very small in relation to the external openings, it may be desirable to make use of multi-cell implicit envelope flow models. However, in practice it would be simpler to size the openings using an explicit model and then use an implicit model to check the effect of the internal openings. Alternatively, the openings could be sized for the two cases (single-cell and isolated spaces) and the larger values chosen (if the building will operate in both modes).

- ***Step 3: specify the input data required to obtain a solution:*** this will include the positions of the openings, their discharge coefficients and the relevant wind and temperature conditions.
- ***Step 4: size the openings:*** using the relevant procedure.
- ***Step 5: check practicality of the sizes of openings:*** checks should include:
    a. What proportion of each facade does the opening represent? In the winter design case, the Building Regulations recommend certain minimum areas of trickle ventilator. Depending on the design of the building, the proposed area may be greater or less than the recommended value. If the proposed area of trickle ventilation is less, the designer will need to demonstrate that the required air flows can be delivered, possibly by taking account of adventitious openings
    b. What is the velocity of the air through the opening and the implication for draughts?
    c. How sensitive is the design to operational misuse? (For example, if internal doors are shut in a cross-flow design, are transfer grilles necessary?)

If checks such as these identify shortcomings in the design, revised parameters must be substituted in the equations and the viability of the amended design reassessed.

4.3.1 Isolated Rooms and Spaces

A simple example of a building with isolated spaces and rooms is shown in Figure 4.8. On the ground floor, the rooms are isolated and separated by a corridor. The upper two floors are open plan, but isolated from each other.

Four common cases are shown below with the appropriate equations for sizing the areas. Cases 1, 2, and 3 are examples of single-sided ventilation. The ground floor rooms in the building shown in Figure 4.8 rely purely on this form of ventilation. Case 4 is an example of crossflow ventilation. The two upper floors rely on this form of ventilation when wind is dominant but on what is dominant (i.e., case 1 or 2 applied to each wall). Cases 1 and 4 are simple examples of envelope flow models. Cases 2 and 3 rely more on empirical data.

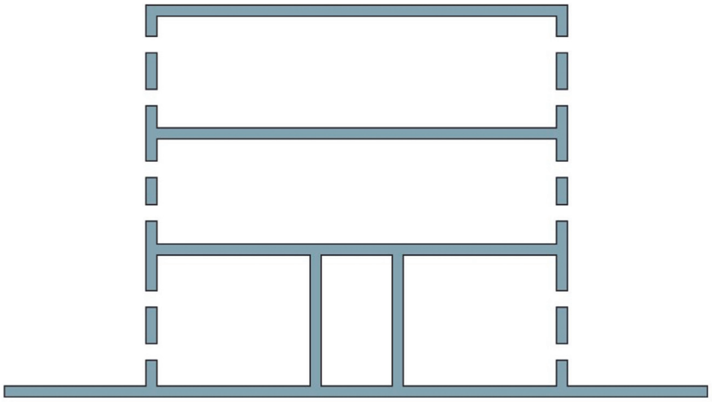

FIGURE 4.8 *Illustration of isolated rooms and spaces.*

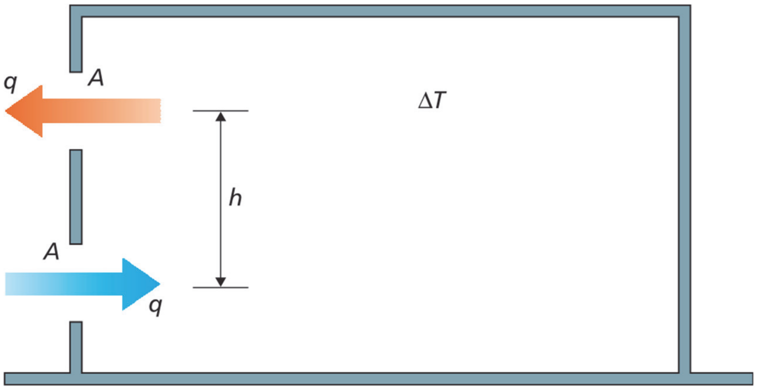

FIGURE 4.9 *Case 1: single-sided ventilation, two identical openings, driven by buoyancy alone.*

Case 1: Single-sided, two vents, buoyancy driven. This case represents single-sided ventilation through two identical vents driven by buoyancy alone, see 4.9.

The area A of each opening required to give a ventilation rate q for a specified value of h is:

$$A = \frac{q}{C_d}\sqrt{\frac{(T_I + 273)}{\Delta T\ g\ h}} \tag{4.12}$$

where A is the area of each opening (m^2), q is the ventilation rate ($m^3 \cdot s^{-1}$), C_d is the discharge coefficient, T_i is the internal temperature (°C), ΔT is the difference between the internal and external air temperatures (K), g is the gravitational force per unit mass ($m \cdot s^{-2}$) and h is the height between the openings (m).

A typical value for C_d is 0.6.

FIGURE A4.11 *Case 3: single-sided ventilation, single opening, driven by wind alone.*

Case 2: Single-sided, single vent, buoyancy driven. partly because only half the area A is available for air entry.

Case 3: Single-sided, single vent, wind driven. Case 3 represents single-sided ventilation through an open window, driven by wind alone see Figure 4.11.

The area required to give a ventilation rate for a specified value of wind speed is:

$$A = q/C\ U \tag{4.13}$$

where U is the wind speed ($\text{m}\cdot\text{s}^{-1}$).

The value of the coefficient C depends on (a) the geometry of the opening, (b) the position at which the reference wind speed is measured and (c) the flow field around the building. Reported values range from about 0.01 to 0.05 when U is measured at the same height as the building. The value is low because the air entry arises as a result of turbulent diffusion.

Case 4: Crossflow ventilation, wind driven. In this case, ventilation is by wind alone see Figure 4.12.

The ventilation area required to give a ventilation rate q for a specified value of ΔC_p is given by:

$$A = q\left(C_d U \sqrt{\frac{\Delta C_p}{2}}\right)^{-1} \tag{4.14}$$

where A is the total ventilation area (each wall) (m^2) and ΔC_p is the difference between the wind pressure coefficients C_{p1} and C_{p2}.

Note: in cases 1 and 4 it is assumed that the openings are identical; different equations will apply if the openings have different areas or discharge coefficients.

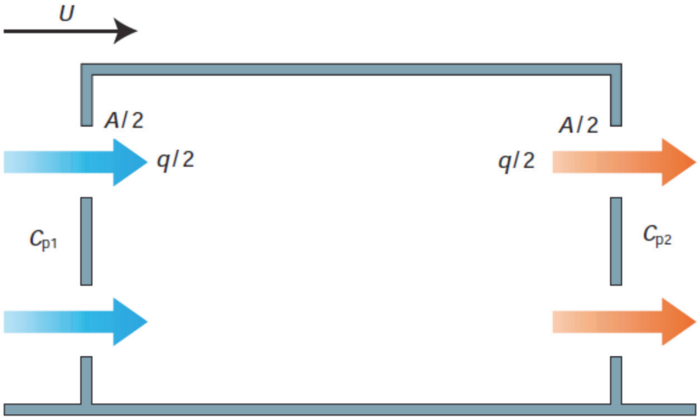

FIGURE 4.12 *Case 4: crossflow ventilation driven by wind alone.*

WA5.1.1 REFERENCES

ASHRAE. 2019. ANSI/ASHRAE Standard 62.1-2019, Ventilation for acceptable indoor air quality. Peachtree Corners, GA: ASHRAE.

CIBSE. 2005. *CIBSE applications manual AM10, Natural ventilation in non domestic buildings*. London: The Chartered Institute of Building Services Engineers.