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How airtight do houses need to be?

Blower door tests are used to identify air leaks and reduce air infiltration into a house. However, estimating the air infiltration rate – and therefore energy loss – is not as straightforward as many assume. Knowing the physics will help understand why.

BRANZ HAS SEEN considerable confusion recently in the estimations of the amount of air leakage a building experiences in practice compared to its result from a blower door test. While simplifications can be made, doing so without a good grasp of the physics involved can lead to an entirely wrong result.

We've already discussed how out of date the 'divide by 20' rule of thumb is (see *Build* 166 *Airtightness trends*, pages 90–91). Now we'll go into a little more detail on how to get a reasonable answer.

Start with blower door test

A blower door test is a useful quality control measure to gauge the airtightness of a building. It can make sure the building is airtight enough for a mechanical ventilation heat recovery system (MVHR) to potentially deliver optimal payback and good indoor air quality (IAQ). This is all part of good energy-efficient design.

However, using the result to estimate the infiltration a home gets in service is not simple. The pressure exerted across the entire envelope of the building during a blower door test is 50 Pa. This is substantially larger than the pressure differential across the walls of a building in reality.

In the following, we will take you through the steps for estimating how much air infiltrates an urban dwelling in Wellington, given the results of an airtightness test.

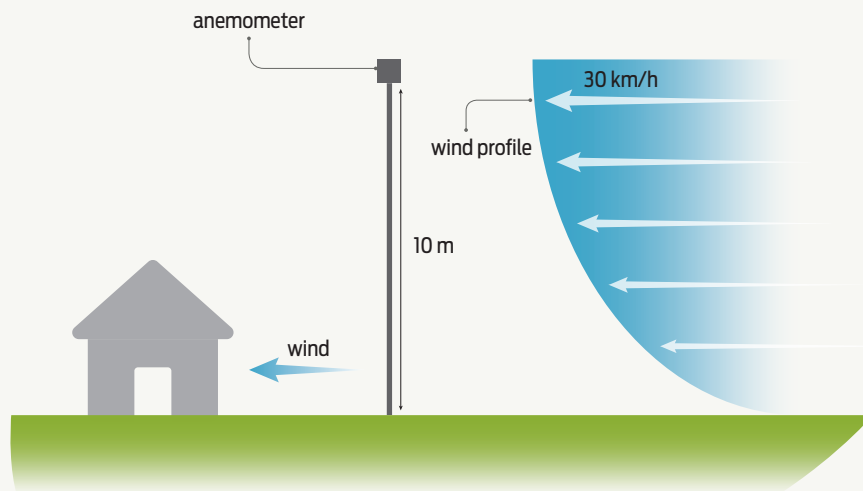


Figure 1 The windspeed at Wellington airport. The so-called reference wind speed is measured usually at the airport at 10m height.

Work out the right windspeed to use

To begin, we need to know our measurements and understand where they come from.

Correct windspeed for height

The windspeed quoted by meteorological services is the wind at an open location such as an airport and at a height of 10 m.

Because windspeed drops as you get closer to the surface of the Earth (due to boundary layer effects) and a single dwelling is much lower than 10 m above grade, the windspeed needs to be corrected.

This is usually done for the height of the middle of the wall of the building – in our example calculation, we'll use 1.2 m, which represents the

median pressure of a 3 m-high dwelling wall (see Figure 1).

Correct for terrain roughness

We also need to correct for the terrain roughness since most dwellings are in an urban setting, not in the middle of an airfield. To perform these corrections, we use a method published by ASHRAE – the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Working through an example

We can now look at our Wellington example and use the average windspeed at Wellington Airport, which is 25.8 km/hr, rounding it up to 30 km/hr to be conservative.

After applying the ASHRAE correction for height and the urban environment, the result yields a windspeed of 3.4 km/hr, remembering that this is at 1.2 m, the height of the centre of the wall of our urban dwelling.

Convert windspeed to pressure

A quadratic is used to convert windspeed to pressure on a façade. In reality, however, as the wind hits the façade the air flows around the building, so not all the wind contributes to the pressure at the wall. To ignore this and transform all the airflow into pressure, the wall would need to be infinitely large.

Reality much more complex

So how can we account for this? We use what are called C_p values. You can get these from Tokyo University Polytechnic, which has a good public database, or perform wind tunnel experiments to measure how much of the wind is creating the pressure on the wall. At BRANZ, we typically use a computer fluid dynamics model or measurements on a real building.

Figure 2 shows the pressure coefficient or C_p values of a single dwelling. The calculated wind pressure must be multiplied by the average C_p value to obtain the true pressure at a point on the wall.

We see the wind hits the long wall straight on and creates the highest pressure there – shown in red. The C_p value is about 0.6 for this wall. All the other walls, including the ceiling, have a negative C_p value as the wind causes a low-pressure region while flowing around the building.

Reality differs from blower door test

As can be seen, the wind creates a pressure distribution induced by the airflow around the building and is not the same on all sides.

This differs from the pressure distribution in a blower door test, where the pressure of 50 Pa is across all the walls simultaneously – you cannot create the same situation with wind flowing around a building.

Working through the example

With all these corrections applied to the airport wind at 10 m reference height, we calculate that

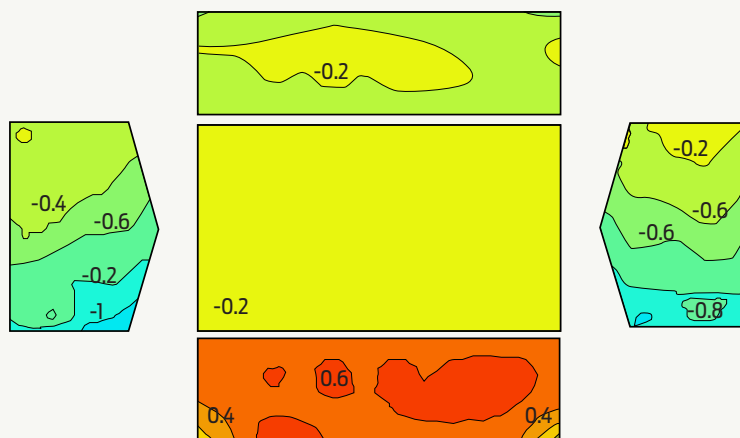


Figure 2

The pressure coefficients C_p of a single-storey building where the wind hits the long wall below (red), which has an average C_p of 0.6.

the pressure at the wall is about 0.6 Pa in the urban and 2.8 Pa in the suburban setting for our case of a 30 km/hr wind at Wellington airport.

Pressure to infiltration? It's a long road

Now that we have a pressure, how do we calculate the infiltration rate? We need to employ a computer model as the infiltration rate is dynamic, changing with both windspeed and direction. This takes a few steps.

The first step is to convert the airtightness result to an equivalent leakage area and then divide this area up spreading it around the building in the model.

Then a series of C_p plots (like Figure 2) must be generated for a range of wind directions (usually every 22.5 degrees), and the resulting C_p values at the location of each leakage opening at each wind direction must then be added to the model.

After applying hourly indoor and outdoor temperatures and hourly corrected wind data, we are then able to run our model.

Results from modelling

Figure 3 from *Build 156 The nitty gritty of airtightness*, pages 86–87, shows the results on four of these models for the ventilation test building at BRANZ. We can vary the airtightness in this building and have calibrated the models with tracer gas experiments.

What can a designer do?

This all seems a little much – and unnecessary – for an architect or designer to do and also most building science consultancies. This is why we talked about simple estimates in *Build 166* and *167*.

For a new build, the leakage we see in practice is substantially less than the old rule of thumb with values of 1/40 (for 3 ach @ 50 Pa) or even 1/100 common. As an example, the BRANZ ventilation building when set up for 1 ach @ 50 Pa, has an infiltration rate of around 0.01 ach.

Gusts have less impact

What about gusts, and the impact they have? The reality is that they are also subject to the same corrections for height and terrain, so their effect is muted substantially, particularly on newer stock. As can be seen in the graphs in the article *Airtightness trends (part 2)* in *Build 167*, pages 74–75, the gusts on the plots lose their puff as the building becomes more airtight. Plus, gusts are just that – short duration events that cannot remove large amounts of energy due to their short duration.

From the structural point of view, gusts are the important factor, but for air infiltration, it's the averages that count. ◀