BRANZ FACTS
ROOF VENTILATION #2

Testing the airtightness of residential roof spaces in three dwellings

New Zealand houses and their roof spaces are becoming more airtight. Without proper management of indoor moisture, this can lead to a build-up of moisture and problems with mould. BRANZ has developed a measurement procedure to estimate the airtightness of residential roof spaces and has tested it on three buildings. This could be a useful tool to help determine roof ventilation requirements to avoid mould and moisture problems.

NEW ZEALAND houses are becoming more airtight. This makes them easier to heat because air does not escape through gaps, but it also means that the natural replacement of moist indoor air with fresh outdoor air is a slower process. Ventilation needs to be more carefully considered by house designers and occupants. Without sufficient ventilation, moisture and pollutants can build up and lead to mould growth.

The same pattern applies to roof spaces. BRANZ has inspected a number of relatively new buildings where mould has grown on structural timber and roofing underlay. Because the thermal insulation in houses typically sits on the ceiling lining, the roofing above is exposed to extremes of temperature. It can fall to temperatures below the surrounding air temperature as heat is radiated into the clear night sky. If the temperature drops below the dew point temperature, condensation starts to form. In an airtight roof space, the moisture may accumulate over time. (For more about this, see Fact sheet 1 *Roof space ventilation in New Zealand houses*.)

The dual fan method used to assess airtightness in roof cavities. The top fan in the door blows air into the living space while the bottom fan and ducting move outside air into the roof space.

The new test procedure

Airtightness in buildings is typically measured by a blower door measurement. The equipment is a modified door that fits in a door opening, with a fan that can be operated at various speeds to achieve specific airflow rates. With all the doors and windows shut, the whole living space is pressurised, typically up to 50 Pascals. While holding the pressure constant, the airflow out of the building through gaps in the envelope is recorded. The process is described in AS/NZS ISO 9972:2015 *Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method*.

The leakage results together with the internal volume measurement of the building provide a measure of air changes per hour (ach). Old villas and bungalows in original condition typically have an airtightness of around 20 ach, while the living spaces of newly built homes are typically around 3–5 ach.

These are comparative figures only. The ach tests are carried out with a pressure of 50 Pascals – well above typical pressures that drive natural air infiltration in a house. A house with an airtightness of 3 ach at

50 Pascals will not have anywhere near three complete changes of air each hour. A very rough rule of thumb to find the actual long-term infiltration rate (valid for buildings that are more air-leaky) is to divide the 50 Pascals result by 20.

The standard blower door approach cannot be used to test roof space airtightness because results could be compromised by airflow passing between living areas and roof space through the ceiling. BRANZ tackled this problem by developing a procedure using two fans. The first fan pressurises the living space while the second channels outside air through ducting into the roof space. If both living area and roof space are pressurised to the same value, there will be no airflow across the ceiling lining. Using two fans therefore allows researchers to calculate an effective leakage area just for the roof envelope alone.

Because pressure at 50 Pa is not always achievable in roof spaces due to their leaky nature, the analysis was performed at 40 Pascals.

The BRANZ test house

The test method using dual fans was trialled on the ventilation test building at the BRANZ campus at Judgeford, Porirua. The building has a gable roof with corrugated profiled metal cladding on roofing underlay on mesh. The insulated ceiling is standard plasterboard with square stopping.

No passive roof ventilation elements are installed. The dwelling does not show any signs of mould in the roof space. While it is not inhabited and consequently does not have normal moisture sources, the building is frequently adjusted to high internal moisture levels for scientific purposes. A number of artificial, controllable ventilation openings can provide an air exchange path from the living space to the roof space. For this experiment, these were shut.

The results for the test are shown in Table 1. An air exchange rate at 50 Pascals was estimated at 137 ach. As explained earlier, this is a comparative figure – the actual average air exchange rate for the roof space over a 9-day testing period was approximately 2.7 ach.

How do the results relate to practical or regulatory terms? There are no specific roof ventilation requirements in the New Zealand Building Code or in the referenced standards. There are in some other countries, however. The size of the ventilation is often described as a ratio between the net free opening area of the vents to the area of insulated ceiling. While ratios ranging from 1:150 to 1:600 can be found, 1:300 seems to be a frequently specified ratio. Calculations indicate that the BRANZ test house only meets 67% of the 1:300 requirement. In other words, it is relatively airtight and would not comply with the roof space ventilation requirements in some overseas regimes.

The Titirangi house

BRANZ carried out the same procedure on a 2-storey house close to the sea in Titirangi, Auckland. The house, built in the 1980s and renovated more recently, is shaded for much of the morning by tall vegetation on surrounding hillsides. In the roof space, there was extensive mould growth on roofing underlay and structural timbers.

The northern half of the building has a gable roof with a 75 m² area of insulated ceiling area – this was the area of BRANZ study. A separate skillion roof over the front part of the building, not connected to the gable roof, is not accessible.

The square-stopped plasterboard ceiling would ordinarily provide a good air barrier, but it was penetrated by 22 older-style downlights. The gaps around these provide an easy pathway for moisture-laden air to move from the living areas into the roof space.

The results of the blower test are again shown in Table 1. An effective air leakage area can be calculated. From this, a comparison can be made with the overseas roof ventilation ratio of 1:300. The Titirangi house stands at 59% of this requirement, which means that, in some countries, it would fall far short of compliance.

Other calculations point to the downlights as the main path by which downstairs air gets into the roof space. Additional leakage paths around the roof access hatch or extractor fans are likely to make up the difference.

This movement of moisture-laden air into an airtight space that leads to moisture accumulating are clearly the primary causes of the mould in the roof space. The median value for relative humidity in the roof space

Table 1. Ventilation parameters for the three studied dwellings (from SR401 *Airtightness of roof cavities*).

Building	Leakage flow rate @ 40 Pa [m³/h]	Roof space volume [m³]	Air ex-changes/ hour @ 40 Pa [ach]	Effective leakage area [cm²]	Ceiling insulated area [m²]	Vent area based on 1:300 rule [cm²]	Measured effective leakage area/ suggested area based on 1:300 rule
BRANZ, Wellington	5,930	49.4	120	2,020	90	3,000	67%
Titirangi, Auckland	4,301	58.9	73	1,465	75	2,500	59%
Papakura, Auckland	3,737	46.2	81	1,273	85	2,833	45%

The gap around a downlight in the Titirangi house is clearly visible.

was 75%. However, BRANZ scientists also examined the role that indoor climate played, recording temperature and relative humidity in the kitchen, bathroom and main bedroom over several weeks in September 2017.

There were prolonged periods of time when the relative humidity exceeded 90% in the bathroom. The moisture, probably generated by showers in the morning, was not effectively removed by passive ventilation (the occupants opening windows) or active ventilation (extractor fans venting to the outside). For a quarter of the time, the relative humidity level remained above 80%. The excessive moisture in living spaces, especially the bathrooms, was transported through the air-leaky ceiling to the roof space where a relatively airtight construction meant it couldn't escape.

The Papakura house

The same procedure was carried out on a house in Papakura. Like the Titirangi house, the Papakura house had mould growth in the roof space (although at a lower level). In this case, however, the mould was found shortly after construction was completed in early 2017.

The south-facing gable roof has a standard roof space, which is connected to a smaller space behind a north-facing skillion roof. Although downlights are installed in the plasterboard ceiling throughout the building, they are of recent design with no obvious gaps around the fittings. With an airtight ceiling and acceptable indoor moisture levels, trapped construction moisture was thought to have been a contributor to the roof space moisture problem. However, later during the measurement campaign, it was established that the rangehood had not been ducted to the outside for some months after the building was occupied. Moist air from the kitchen was channelled directly into the roof space for 3–4 months.

The results of the blower test are again shown in Table 1. The Papakura house would meet just 45% of the overseas roof ventilation ratio of 1:300 (net free opening area of vents to the area of insulated ceiling) requirement, indicating a very airtight space. This tight roof space in combination with the moisture influx from the rangehood was bound to create problems.

More information

Fact sheet 1 *Roof space ventilation in New Zealand houses*

Fact sheet 3 *Air permeability of common New Zealand ceilings and ceiling penetrations*

Fact sheet 4 *Moisture and ventilation in skillion roofs*

Rupp, S., Plagmann, M. & Cox-Smith, I. (2018). *Airtightness of roof cavities*. BRANZ Study Report SR401. Judgeford, New Zealand: BRANZ Ltd.

The research reported here was funded by the Building Research Levy under projects DR0803 *Interstitial Moisture in Roof Cavities* and MR0002 *Monitoring Conditions and Air Flows in Roofs*.