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Ventilation dries attic space

BRANZ building physicists recently investigated roof cavity ventilation in a high-altitude holiday home after the owner found condensation problems, including ice forming in the roof cavity.

Ridge cap venting system installed on the holiday house roof.

SKI HUTS and residential buildings at higher altitudes need a bit of extra care during the design and building stages. Buildings that are occupied by a large number of people during the winter months can be particularly vulnerable to moisture-related problems in the roof cavity space.

When cold air meets warm air

Drying out wet skiing gear indoors after a day on the slopes leads to a lot of warm moist air. This moisture-laden air, combined with an air-permeable ceiling, is a recipe for some simple physics to swing into action.

A substantial layer of insulation at the ceiling level, combined with a cold clear night, can further aggravate the problem by making the roof cavity even colder. The warm moist air will migrate through the ceiling and enter the cold roof cavity. Here, it will find the cold surface of the underside of the roof, condense and maybe even freeze.

Passive ventilation solution

Ice in the roof cavity alerted builder Roland Alderton from Hamilton to an issue in his National Park holiday house. With an interest in building science, Roland realised what may be causing the ice formation and decided to install some passive ventilation elements to the roof cavity.

Now, the truss roof cavity is ventilated by several round vents around the perimeter of the soffit and a custom-made ridge cap venting system. The underlay was also cut under the ridge cap.

The footprint of the building is about 60 m^2, and the volume of the roof cavity is approximately 45 m^3. The added net ventilation openings are around 0.2 m^2 at the ridge and 0.25 m^2 around the eaves. A central heating system keeps the house at a comfortable temperature.

Using WAVE to test performance

Discussions between Roland and BRANZ led to an investigation of the roof performance as part of BRANZ's Weathertightness, Air quality and Ventilation Engineering (WAVE) programme.

Airflows measured using tracer gas

To estimate the impact of the installed vents, the airflows were measured throughout the building using a tracer gas system.

Two characteristic tracer gases were emitted continuously at a fixed rate into the roof cavity (zone 1) and the living quarters (zone 2) over several hours. A gas analyser then sampled the concentration over time of these two gases in both zones, giving

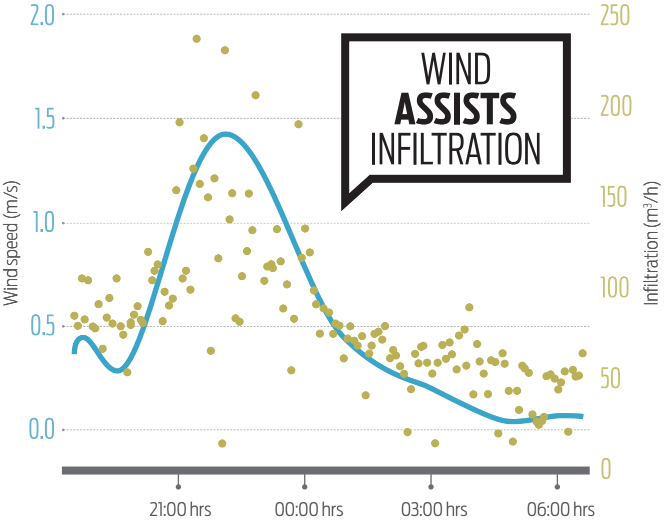

Figure 1: Wind speed (blue) and infiltration into the roof cavity of the National Park building with the vents open.

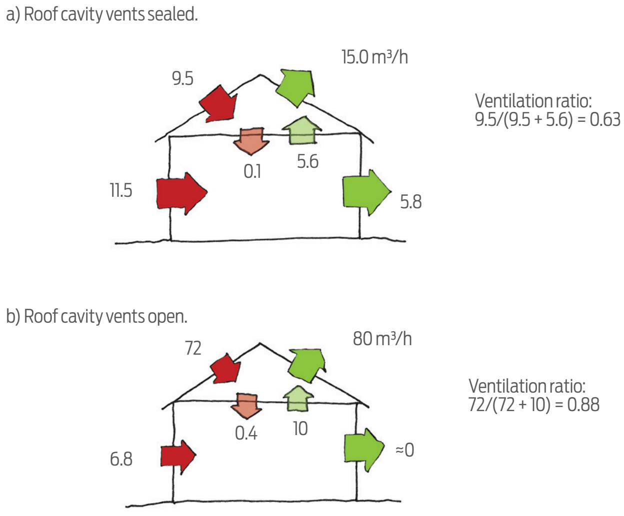

Figure 2: Infiltration and exfiltration in two National Park house experiments. The arrows indicate instantaneous airflows in m^3/h across a boundary.

information about the mixing within the zones and ventilation losses to the outside.

Two mechanisms driving airflow

The airflows in the roof cavity and living quarters are mainly driven by two mechanisms.

First, warm air inside the building creates a stack pressure gradient - the house will act as a chimney drawing air from downstairs into the roof cavity.

Second, a wind flow across the building envelope creates a negative pressure of several pascals in the roof cavity. This again contributes to air flowing from the living quarters into the roof space.

If this moist air hits a surface at or below the dew point temperature, like the roof deck on a cold, clear winter night, it will condense.

Infiltration rates measured

The infiltration rate into the roof cavity of the National Park holiday house was calculated from measured tracer gas concentrations. Figure 1 has an example showing wind speed (blue) and infiltration into the roof cavity.

As expected, there is a good correlation with the wind speed. As the wind picks up around 9 pm, more of the tracer gas molecules are removed from the roof cavity, corresponding to the higher infiltration rate (see Figure 1).

Two tracer gas experiments were conducted for comparison. First, all installed vents were sealed as best as possible, returning the building to the problematic earlier design. Gas concentrations, the temperature and humidity were monitored over a 20-hour period on a reasonably calm day. For the second part of the experiment, the ridge and eaves vents were opened up again.

Figures 2a and 2b show calculated airflows for the two experiments (roof cavity vents sealed and open). Wind conditions were calm with velocities mostly below 1 m/s for both parts of the experiments.

As expected, we see some transport upwards across the ceiling into the roof cavity. The reverse airflow is close to zero within a margin of error. With the vents closed, we see an airflow of about 9.5 m^3/h from the outside into the roof cavity with the same order of magnitude (5.6 m^3/h) coming up from the living room.

This situation changes drastically when the vents are opened. The airflow into the roof cavity increases to more than 70 m^3/h. Airflow from downstairs also increases, however only by a factor of 2.

Moisture removed faster with vents

Consequently, any moisture migrating into the roof cavity from below will be removed much faster with vents in place. A convenient parameter to describe these airflows is the *ventilation fraction* - the ratio between the outdoor-to-roof cavity flow to the total airflow into the cavity, which yields a number between 0 and 1. A number close to 1 means that the air from below - once it has reached the roof space - is effectively removed from the cavity.

For our building experiment at National Park, we derive ventilation fractions of around 0.63 for the sealed case and 0.88 for the vented case (see Figure 2). Previous work where we used experimental data from various commercial roof structures for numerical simulations indicates that ventilation fractions need to be above 0.75 to minimise the risk of condensation.

Experiment proved vents did the job

The issue around how much ventilation of roof cavities is necessary still needs further work. However, these experiments resulted in some firm numbers, underpinning Roland's decision to vent the roof space. So far, he has not encountered any more condensation problems.