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Venting Of Attics & Cathedral Ceilings

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Ice dam on residential roof.

Current building codes typically call for attic ventilation to minimize condensation on the underside of roof sheathing. Summer cooling of attic air, minimizing ice dams, and extending the service life of the roof materials often are cited as additional benefits of attic ventilation. In fact, most asphalt shingle manufacturers warrant their products only for ventilated roofs.

Attic ventilation is firmly established as an important element in residential roof construction, and lack of ventilation is routinely blamed for a variety of problems and failures. For decades the *ASHRAE Handbook—Fundamentals* has included recommendations for attic ventilation to control moisture and tables for the effective thermal resistance of ventilated attics

However, adding attic vents sometimes can be either impractical or undesirable. Architectural details or geometry may be such that effective attic ventilation is improbable in all or part of the roof. Closing vents may be desirable for sound mitigation, especially near airports. Attic vents also may be undesirable for aesthetic or historical reasons.

Roof vents may play a detrimental role in forest fires in residential areas. The vents provide entry for sparks and burning brands into the roof cavity and the fire may spread more rapidly due to the draft in a ventilated space.

Finally, venting rules for attics have been extended to apply to cathedral ceilings, but few studies have been made to confirm the validity of that extension. These issues have led us to reexamine the rationale for the current universal requirement in the United States and Canada for ventilation of all attics and cathedral ceilings in all climatic regions.

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'Venting rules for attics have been extended to apply to cathedral ceilings, but few studies have been made to confirm the validity of that extension. These issues have led us to reexamine the rationale for the current universal requirement.'

Moisture Control in Cold Inland Climates

Rowley et al.[1] provided the first documented evidence that attic ventilation can reduce condensation on roof sheathing during cold weather. Natural attic ventilation and mechanical ventilation were tested in small test houses (57 in. by 57 in. [1.45 m by 1.45 m]) inside a conditioned room, not in full-size buildings exposed to actual weather. The natural ventilation consisted of two gable vents, each with an opening of about 5.6 in^2 (36 cm^2) (total vent opening of 1:288), and the mechanical ventilation consisted of 0.05 cfm/ft^2 (0.25 L/s×m^2). Both types of ventilation were effective in eliminating condensation with an outdoor temperature of –10°F (–23°C) and indoor conditions of 70°F (21°C) and 40% relative humidity (RH). Reducing the vent openings or mechanical ventilation by 50% produced some condensation on the sheathing. This report probably provided the basis for the current requirement that 1 ft^2 (0.09 m^2) of vent opening be provided for every 300 ft^2 (28 m^2) of horizontally projected roof area (1:300 rule).[2] Their conclusions also included a prominent recommendation for indoor humidity control as an effective way to reduce condensation in roof and walls.

Britton[3] of the Housing and Home Finance Agency conducted tests of vented and unvented flat roof assemblies in a steady-state climate chamber. The tests lasted several weeks and measurements were taken intermittently. However, Britton encountered procedural difficulties of sampling during the test, and he noted frost accumulation at anomalous places such as access ports and cable entries. The results of these tests provide some support for attic ventilation. However, this work was interrupted as a result of lack of funds, and the final results for roof systems were never presented. For actual buildings, Britton noted the importance of air pathways between the attic and the foundation area. This understanding is helpful in attic moisture forensics. Britton also recommended attic ventilation, and he appears to be the principal author of the tables on which climate-specific attic ventilation was first based.[4]

Jordan et al.[5] took moisture readings in three attics in Madison, Wis., during winter. Condensation in the attic occurred only in the house with high humidity in the living space. Signs of condensation also appeared in the walls of this home, where the attic gable vent openings totaled about 1:520. The attic with 1:430 vent openings was the driest and had the lowest indoor RH. In all three houses, higher moisture conditions in the attic corresponded with higher humidity conditions in the living space. The importance of indoor humidity also was evident in a recent survey of moisture levels in attics,[6] where "high attic moisture content was not found in the absence of high house humidities."

Early studies on attic moisture generally concluded that ceiling vapor retarders were effective in lowering attic moisture levels. This conclusion led to the provision that the attic vent area could be lowered to 1:600 if a ceiling vapor retarder were present. However, Hinrichs[7] noted that air infiltration through the ceiling into the attic was the major source of condensation. Therefore, he concluded that a vapor retarder was not a dependable means of attic moisture control. Dutt[8] posed the question more directly and, on the basis of his calculations, argued in favor of an airflow retarder in the ceiling in addition to a vapor retarder. Samuelson[9] demonstrated that if no air is moving from the living space to the attic, the higher temperatures in unvented attics makes these attics drier. However, he stated that to guarantee no indoor air movement into the attic, the ceiling has to be airtight and the pressure of the attic air needs to be higher than that of the indoor air (i.e., pressurized attic or depressurized living space).

In addition to a framed cavity with a porous insulation material such as glass fiber, other constructions deserve attention, such as roof systems with foam thermal insulation (which is relatively vapor impermeable) applied directly to the underside of the roof sheathing. When foam insulation is used in walls and low-slope roof systems, it generally demonstrates good moisture performance. In a sloped roof assembly, equally good moisture performance should be expected. When the foam is directly applied to the sheathing and carefully sealed, there is no moisture performance advantage to venting such roof systems.[10,11] When the foam is located on top of the roof deck, or the roof is made of structural insulated panels, venting is also unnecessary.

This discussion suggests that in cold climates the three most effective measures to lower attic moisture conditions are 1) indoor humidity control; 2) airtight ceilings, preferably combined with positive attic pressures, and 3) attic ventilation. Indoor humidity control is beneficial to the entire building envelope, and should lead the list of recommendations. In cold climates, indoor humidity control is most easily accomplished by ventilating the living space, which also tends to improve indoor air quality. Correcting wet foundations, disabling humidifiers, and correcting backdrafting of combustion appliances help control humidity. Undoubtedly, attic ventilation in a cold climate makes a cavity roof more moisture-tolerant and should be encouraged as an additional safeguard in cold climates. However, alternative strategies should be allowed, especially in the case of older buildings and homes that have shown satisfactory performance or in new buildings where carefully sealed foam insulation is directly applied to the roof sheathing.

In cold climates, cathedral ceiling construction is inherently more prone to moisture damage than is attic construction because isolated conditions are created in each rafter cavity. Therefore, the potential benefits of well-distributed effective venting of cathedral ceilings are also greater than with attics. However, while providing effective ventilation to attics with simple geometries is relatively easy and inexpensive, providing effective soffit and ridge ventilation to each individual cavity in a cathedral ceiling is far more difficult. Goldberg[12] found that vented attics perform better than vented cathedral ceilings. Furthermore, Rose[13] showed that during winter, a cathedral ceiling cavity with ridge vents but without sufficient soffit vents may act as a chimney and admit harmful amounts of humid indoor air into the cavity. Wind washing of the insulation, when cold air penetrates the ceiling insulation, is another common problem with ventilated attics and cathedral ceilings, especially near the soffit vents. In addition, the air space required for venting can be filled with additional insulation in an unvented cathedral ceiling.

In summary, effective venting of attics and cathedral ceilings in cold climates can dilute incidental moisture. This benefit should be weighed against 1) factors that would reduce the effectiveness of ventilation, 2) feasibility of foam-based and other unvented assemblies, and 3) possible detrimental or undesirable effects of ventilation, as described earlier. On balance, we believe venting should be recommended for northern climates, but not as a regulated practice.

Moisture Control in Wet, Cold Coastal Climates

All of the early studies were performed in cold climates or simulated cold climates. More recent data on attic ventilation in cold, wet coastal climates provides a different perspective. In such climates, moisture in the outside air that is carried into the attic by ventilation, is a major source of moisture in the attic. Using computer model simulation, Forest and Walker[14] found that in wet coastal climates in Canada high attic ventilation rates resulted in higher sheathing moisture contents than did lower ventilation rates. The higher ventilation rates produced colder attics without sufficiently lowering attic water vapor pressures, resulting in high attic RH and moisture content in the sheathing. This suggests that unvented attics could have an advantage in wet, cold coastal climates, as long as indoor humidity is controlled by ventilation or dehumidification.

Moisture Control in Hot Climates

No scientific claims have ever been made that attic ventilation is needed for moisture control in hot, humid climates. In these climates, the outside air tends to be much more humid than the inside air, which is cooled and dehumidified by air

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conditioning. In such climates, attic venting tends to increase rather than reduce moisture levels in the attic. Air-conditioning ducts are commonly located in the attic space, and attic ventilation with humid outdoor air may increase the danger of condensation on these ducts. When the ceiling is not airtight, attic ventilation may also increase the latent cooling load in the building. In short, if attic ventilation is required or recommended in hot, humid climates, it must be based on considerations other than moisture control.

Hot, dry climates also do not warrant roof-venting requirements for moisture control. While venting in such climates may result in drier attics, there is no reason to expect serious moisture accumulation in unvented roof cavities. The building designer may wish to vent the roof for reasons other than moisture control.

Ice Dams

Although attic ventilation is now generally credited for minimizing ice dams, early requirements for attic ventilation were entirely based on minimizing condensation in cold climates. The 1949 publication *Condensation Control in Dwelling Construction*[3] did not mention minimizing ice dams as a potential benefit of attic ventilation, but recommended installation of heavy roll roofing felt or sheet metal under the shingles over the eaves to protect against water leakage from ice dams. By 1967, the "cold roof" concept had been introduced, but it was based on a combination of measures. Baker[15] stated that for a permanent solution to ice dams, "consideration must be given to more adequate roof or ceiling insulation, ventilation of air spaces above the insulation, and moderation of inside temperatures." He observed that on insulated buildings, ice dams form at outdoor temperatures above 15°F (–9°C). Latta[16] recognized the importance of air leaks and recommended attic ventilation, but only after "blocking all passages by which warm air can leak into the space below the roof." Wolfert and Hinrichs[17] only briefly mentioned ice dam minimization in their manual on attic ventilation.

Heat loss into attics from air leaks, ducts or flues can lead to ice dams, even when the attic is vented.

Grange and Hendricks[18] authored the first publication that fully focused on ice dams. They emphasized a combination of attic vents at the eaves and ridge and minimization of all attic heat sources. The importance of attic heat sources strongly emerged in a recent study of 33 houses in Ottawa, ON, Canada.[19] All 16 houses with ice dams had interior chimneys and their attics were about 7°F (4°C) warmer than attics of houses without ice dams. Houses with ice dams also tended to have less insulation in the ceiling and less eave ventilation, either due to fewer soffit vents or fewer insulation baffles at the eaves.

An important study of ice dams was conducted by Tobiasson et al.,[20] who observed that ice dams seldom occurred when outdoor temperatures were above 22°F (–5.5°C). Since ice dams did not occur when the attic air temperature was below freezing, the researchers arrived at a "window" of temperature conditions that lead to ice dams. They concluded that chronic ice dams can be avoided with attic ventilation systems that keep the attic temperature below freezing when the outside temperature is 22°F (–5.5°C), so heat from below does not melt the snow on the roof. In a later paper[21] ventilation of cathedral ceilings was investigated in a large cold room, and equations were developed to determine the inlet and outlet areas and airway heights needed to keep the roof deck in cathedral ceilings below freezing. Guidelines for avoiding icing of both attics and cathedral ceilings are presented in Tobiasson et al.[22] for various roof slopes, airway heights and insulation levels. These calculations do not consider the effect of wind, air leakage up through the ceiling or heat lost up through the snow. They concluded that the need for ventilation is related to the amount of snow to be expected in the area and the amount of insulation in the ceiling. In Philadelphia, Washington, D.C. and Chicago, roofs with at least R-20 (3.5 m^2kW) need not be ventilated. In Madison, Wis., Boston, and Sioux Falls, Idaho, the minimum amount of insulation increases to R-30 (5.3 m^2kW), and in Minneapolis and Portland, Maine, it increases to R-40 (7.0 m^2kW). In Marquette, Mich., and Bangor, Maine, all roofs, no matter how well insulated, need ventilation to avoid ice dam problems.

Durability of Shingles

Many asphalt shingle manufacturers offer warranties containing a clause requiring "code-level" ventilation. Such clauses date from the 1980s, though ventilation requirements were introduced 40 years earlier. One published rationale[23] holds that venting cools shingles, and thereby affects the rate of embrittlement by reducing the rates of oxidation and volatilization of asphalt hydrocarbons.

However, ventilation is a minor factor in the determination of shingle temperature. Rose[24] showed that in Illinois ventilation of a black-shingle, truss-framed roof assembly has a 2% to 3% cooling effect on shingles, but the effect of color is 20% to 30%. Simpson and McPherson[25] found that white roofs were up to 36°F (20°C) cooler than gray roofs, and up to 54°F (30°C) cooler than brown roofs. Cash and Lyon[26] have recently shown through computer modeling that shingle temperature is more strongly a function of geographic location, the direction a roof faces, and surface color than ventilation. Venting cools shingles, but the cooling effect is not strong.

Heating and Cooling Loads

A 1978 workshop at the National Bureau of Standards (now the National Institute for Standards and Technology) brought together several researchers to discuss "Summer Attic and Whole-House Ventilation." The research results were published, and the contributions to that workshop call into question the notion that attic ventilation saves cooling costs.

Dutt and Harrje[27] compared six occupied townhouses in Twin Rivers, N.J., that were equipped with attic fans to similar townhouses without attic fans. The attics with fans were substantially cooler. However, these researchers noted that the heat flux across the ceiling was "a very small part of the house air-conditioning load" and "any difference between the air conditioner use between houses with and without attic fans is not discernible from other factors which lead to house-to-house variation in air conditioner use." Homes with and without powered attic fans used the same amount of energy for cooling, despite the wide difference in attic temperature. With the cost of operating the fan included, mechanical ventilation was a net energy loser.

The authors conclude that some measures, like increased attic or wall insulation, and the judicious location of windows and overhangs are probably effective in conserving energy in both summer and winter. They strongly conclude that means other than ventilation would be more effective in reducing summer cooling costs.

Burch and Treado[28] studied the effect of attic ventilation on heat gain. They compared closed ventilation, soffit vents, ridge vents, two 14-in. (0.36-m) diameter wind-driven turbines, and a 14-in. (0.36-m) diameter roof-mounted attic fan, rated at 1,260 cfm (595 L/s) and controlled by a thermostat. These authors conclude that attic ventilation is not an effective energy conservation procedure for houses with 4- or 6.5-in. (102- or 165-mm) thick loose-fill rockwool ceiling insulation. Performance of soffit vents without ridge vents was much like performance without ventilation, and enhanced ventilation (i.e., ridge vents, turbines, or a power fan) in addition to soffit vents produced less than 3% reduction in daily cooling loads for test houses.

However, Beal and Chandra[29] in a more recent study found that soffit vents were important in providing cooling to the attic. They found that a 1:230 attic vent ratio gave a 25% reduction in heat flow through the ceiling, but did not indicate how much this decreased the total cooling load.

In many houses in the southern Unites States, cooling equipment and/or air distribution or return ducts are located in the attic, despite recommendations against such practice. Ducts usually leak air and thus attic air may be pulled directly into the house. Although venting can lower the dry-bulb temperature of this air, much of the time the wet-bulb temperature is likely to be higher in vented attics, especially in hot, humid climates. Thus, while the additional sensible load resulting from duct leakage may be lower in homes with vented attics, the additional latent load is likely to be higher. Finally, attic ventilation allows outdoor air pressure variations to act directly across the ceiling plane. Homes with attic ventilation may have greater rates of air exchange across the ceiling compared to homes with closed attic air spaces. If so, this would carry a cooling season penalty.

In summary, attic ventilation can cool attic spaces, as insulation installers well know, and it has been tempting to imagine a direct translation of that temperature difference into cooling energy savings. However, heat gain through a well-insulated ceiling represents a small amount of the total sensible gain. Latent load increases due to attic ventilation may offset sensible load decreases, and attic ventilation may slightly increase winter heating loads. As with other desirable performance characteristics, attic ventilation takes a backseat to more direct methods. Savings in cooling energy can be achieved more directly with good insulation levels, efficient and well-maintained cooling equipment, latent load reduction, reduced solar and appliance heat gains, and use of natural strategies such as light-colored surfaces and good interior air flow. It is also advisable not to locate cooling ducts in the attic, or, if they have to be located in the attic to make sure they are well insulated and airtight.

Conclusions

We conclude that while attic ventilation can be beneficial in some circumstances and climates, it should not be viewed as the principal strategy to eliminate moisture and other problems in the attic and roof. Rather, attic ventilation should be part of a broader range of control strategies. Taking all factors into account, we make the following specific recommendations:

1. Indoor humidity control should be the primary means to limit moisture accumulation in attics in cold and mixed climates; we recommend attic ventilation as an additional safeguard. However, we believe it should not be a regulated practice.

2. To minimize the danger of ice dam formation, heat sources in the attic and warm air leakage into the attic from below should be minimized. The need for venting to avoid icing depends on the climate and the amount of insulation in the ceiling. However, ventilation is necessary in climates with a lot of snow to prevent icing at eaves, regardless of insulation level.

3. We recommend venting of attics and cathedral ceilings in cold and mixed climates. However, if there are strong reasons why attic vents are undesirable, unvented roofs can perform well in cold and mixed climates if measures are taken to control indoor humidity, to minimize heat sources in the attic, and to minimize air leakage into the attic from below. However, ventilation is necessary in climates with a lot of snow to prevent icing.

4. Ventilation should be treated as a design option in cold, wet coastal climates and hot climates. Current technical information does not support a universal requirement for ventilation of attics or cathedral ceilings in these climates.

In summary, for each of the most commonly cited claims of benefits offered by attic ventilation (reducing moisture problems, minimizing ice dams, ensuring shingle service life, and reducing cooling load), other strategies have been shown to have a stronger and more direct influence. Consequently, the focus of regulation should be shifted away from attic ventilation. The performance consequences of other design and construction decisions should be given increased consideration.

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