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Ventilation

Many houses and small buildings are constructed with a roof or attic space between the upper floor ceiling and the roof deck. Whenever a roof space exists over an occupied interior, measures must be taken to properly ventilate the space. Adequate ventilation can reduce the potential for the occurrence of harmful condensation and the formation of ice dams during the heating season, and excessive heat build-up during the summer months. This bulletin reviews the requirements and means of ventilating roof spaces.

Condensation

In the distant past, most buildings and homes were not built to conserve energy. Few storm doors and windows were installed, and for the most part they leaked air and heat. Under these conditions, the moisture inside also leaked out with the air and through cracks and openings to the outside. Sometimes, an owner of a wood frame house might have experienced the peeling of paint on the cladding, but for the most part, with the exception of the difficulty in keeping the interior warm and free of drafts, few problems were encountered.

The oil crisis of the early 1970's led to the need for the conservation of fuel and improvements in the thermal efficiency of buildings. Two energy saving techniques were to reduce air leakage in the building envelope, and the other was to increase the amount of insulation in walls and roofs. This resulted in higher interior humidity and cooler attic temperatures. Both of these, in turn, increased the potential for condensation in roof spaces in cold weather. To reduce condensation, these spaces must be properly ventilated and ceilings must be made sufficiently airtight.

Condensation, if uncontrolled, can have serious consequences. It can lead to the premature deterioration of the roofing material, decay, or corrosion of the structural elements; a loss in the thermal insulating value of the insulation and damage to interior finishes. Wet attics can provide an environment conducive to the growth of fungi and moulds that may be hazardous to the health of the occupants.

Moisture is transferred from the living areas into the roof space by diffusion due to a difference in water vapour pressure and by air leakage, resulting from an air pressure difference due to wind action, stack action and mechanical ventilation. The latter may be particularly significant in tall buildings where pressurization by substantial excess of supply over exhaust air is required to overcome the pressure differences from chimney action at the lower floors or in houses with supply only ventilation systems. Pressurization magnifies condensation problems that result form the ex-filtration of moist indoor air. When warm air flows into a cold roof space it is cooled and its ability to hold water is reduced. If the temperature of this air falls below the dew point (the temperature at which air has a relative humidity of 100%, the water saturation temperature) condensation will occur. Human activity produces a lot of moisture. The main sources of water vapour include cooking, baths, showers, laundry, houseplants and non-vented combustion appliances. Occupants of houses generate a significant quantity of moisture through breathing and perspiration. Although most new homes are equipped with fans in bathrooms and kitchens, they are not capable of removing all the excess moisture produced. In addition, human comfort depends on a defined range of relative humidity. The American Society of Heating Refrigerating & Air Conditioning Engineers' (ASHRAE) guidelines suggest that 50% RH is the most desirable level of relative humidity in order to maintain airborne infection at a minimum. However, this level of RH may be too high for most houses in Canada under winter conditions and lead to condensation problems. During winter, the type of windows in a house will significantly affect the maximum allowable RH. For example, to avoid damage to sills and to control fungal growth, the indoor relative humidity generally should not exceed 35% if the windows are double glazed. With triple glazed windows the RH may be increased slightly to around 40%. The maximum allowable RH will vary with the geographical location, wind and outside air temperature.

The flow of water vapour through a material by diffusion varies in proportion to difference in vapour pressure across the material and the permeability of the material. If the vapour pressure is higher in the living area than the adjacent roof space, moisture will diffuse through the ceiling into the space. In most occupied buildings we install vapour barriers to slow down the rate of diffusion, however, diffusion cannot be prevented entirely.

Diffusion alone accounts for only a small fraction of the moisture that finds its way into the attic or roof space. Most moisture enters a roof space as a result of air leakage. Air from the living area can leak into adjacent roof spaces through many paths. For example, chimneys, vent pipes, electrical wiring and other services, gaps between wall finishes and the framing, and cracks caused by deflection, shrinkage or settlement. Dryer, bathroom and kitchen fans should never be exhausted into an attic. Exhaust outlets should not be located directly beneath the soffits as warm humid air will be drawn into the attic.

Ice dams

Ice dams form at the eaves of sloping roofs as the result of a combination of snow on roofs, outside temperatures below freezing, heat loss form the building or solar radiation that causes the snow to melt, and an open end of snow where ice can form. As the snow melts form the roof due to heat loss or solar radiation it runs down the slope until it reaches the eaves. As the eaves of most sloped roofs extend past the heated interior space the surface temperature at the eave is generally close to the ambient air temperature. When the ambient air temperature is below freezing the melt water will freeze upon contact. Progressive melting and freezing will cause the ice to build-up at the eaves, preventing the water on a roof from running off. On roofs with roof covers composed of overlapping water-shedding units, water may back up at the ice dams and leak into the roof and wall construction causing considerable damage.

The source of this water is normally melting snow. Since snow is a good insulator, the temperatures in a poorly ventilated (warm) attic are sufficient to melt snow that forms on the roof even in relatively cold weather. Although the primary contributor to snow melting is heat loss from the building interior, solar radiation can also provide sufficient heat to melt snow on a roof. For example, at Ottawa, enough sunlight can be transmitted through 150 mm of snow cover on a clear and sunny day to cause melting at the roof surface when the outside temperature is -10°C with an attic temperature of -5°C.

The total heat loss will depend on the inside temperature conditions, the amount of insulation in the roof system, the amount of air leakage from the inside spaces, and the ventilation between the insulation and the roofing. It is practically impossible to eliminate the formation of ice in sloping roofs entirely. The amount of build-up can be greatly reduced by having sufficient insulation and adequate ventilation. The continuity of the insulation, to eliminate hot spots, is as important as the amount of insulation. The potential for icing can be further reduced by increasing the slope, making the surface slippery so that snow slides off, and by not installing gutters. In a reasonably well-insulated building, the minimum ventilation requirements as prescribed in the building codes are usually adequate to minimize ice damming

Most building codes recognize the potential for ice dam formation and contain requirements for eave protection. Some designers and contractors have gone the extra step to apply waterproof membranes over the entire roof surface prior to the application of the roofing cover to prevent water ingression from ice dams or wind driven rain. However, this may exacerbate the problems associated with harmful condensation. These membranes are often vapour impermeable creating the potential of building a vapour trap within in the roof space. Careful attention to the need for adequate ventilation is necessary when water and vapour impermeable roof covers are applied over attic and roof spaces.

Heat build-up

The Canadian Asphalt Shingle Manufacturers Association has issued a bulletin titled "Proper Ventilation for Asphalt Shingle Covered Roofs". In it they state that both heat and moisture build-up in attics is the primary cause of many roof problems including blistering, distortion and curling of the shingles. It has been theorized that poor ventilation of attics can cause excessive heat build-up and high deck temperatures. Since heat is the major contributor to the aging of materials, this heat build-up is said to contribute to the deterioration of many roof-covering materials. Although a recent study by Simpson, Gumpertz & Heger Inc., demonstrated that geographical location, building orientation, and roof colour have far greater influence on roof surface temperatures than the ventilation below, inadequate ventilation is often cited as the reason for roof performance problems. Material manufacturers may not honour warranties where it can be shown that there is insufficient ventilation of the space below the roof.

Ventilation of roof spaces

Roof spaces can be vented by either natural or mechanical means. In northerly climates natural ventilation is the most common method of venting roof spaces. Wind causes positive pressure on the windward side and negative pressure on the leeward side of a building. As a result, outside air is drawn into the roof space in zones of positive pressure, and expelled in zones of negative pressure. The rate of air change in the roof spaces depends on the velocity and direction of the wind.

Natural ventilation can also result from stack action. As air becomes warmer, its density decreases, and it becomes buoyant and rises. On a sunny day (in winter), the temperature inside the roof space is normally higher than the outside temperature (due to solar radiation and interior heat loss). The heat will tend to rise towards the upper part of the attic. Air exchanged by this means is facilitated by air intake openings at the lower part of the attic, and exhaust openings at the upper part. Unlike ventilation by wind action, ventilation through stack action is more constant depending only on air temperature differences. Natural ventilation can be optimized by making use of both stack and wind action.

Types of roof spaces

If the framing members supporting the roof deck do not also support the ceiling, the roof space or attic is usually fairly large and can be easily ventilated. Air movement is a function of the geometry and volume of the roof space. If the framing members also support the ceiling, as with flat roofs and cathedral ceilings, the resulting roof space is relatively small and more difficult to ventilate, particularly when it is well insulated with thick layers of insulation. These types of roofs, therefore, require more ventilation than common attic type roofs.

Where the roof space is fairly larger, for example cold, uninhabited attic spaces with roof slopes of greater than 1:6, the total net vent area should be at least 1/300th of the area of insulated ceiling. These vents can be located in the soffits, in gable walls, in the roof surface or at several of these locations, but should be distributed so as to provide effective cross ventilation.

For flat roofs, or low sloped roofs (with pitches of less than 1:6) such as cathedral ceilings, the total net vent area should be at least twice as large, or 1:150th of the area of the insulated ceiling. A low slope roof decreases the amount of ventilation that can be achieved through stack action, and the presence of large quantities of insulation often restricts the ventilation space between the insulation and the roof sheathing. In such roofs, moisture will tend to condense on the cold surface of the sheathing and framing members because it cannot dissipate over a large area as it can in attic roofs.

Ventilation in this type of roof can be improved by installing purlins of at least 38 mm by 38 mm at right angles to the roof joists. This makes it possible for wind coming from any direction to ventilate the roof space, provided that roof vents are installed on all exposed sides.

Purlins may not be necessary if the roof slope is 1:6 or more, provided that the roof framing members run in the same direction as the roof slope, each joist space is separately vented and that a minimum clearance of 63 mm is maintained between the roof sheathing and the top of the insulation. In highly insulated flat and cathedral type roofs, the depth of conventional roof framing may not provide sufficient ventilation space between the insulation and the roof sheathing. Using parallel chord trusses can provide additional depth, and their open webbing facilitates air movement through the roof space.

Because the small roof space in flat and cathedral ceiling type roofs makes it practically impossible to inspect the roof space, it is important to keep the air leakage through the ceiling at a minimum, and to provide adequate ventilation.

Types of vents

Soffit vents, roof vents, ridge vents, gable vents, or any combination thereof may ventilate roof spaces. All vents must be designed to prevent the entry of rain, snow and insects.

Soffit vents along the underside of the roof overhang may be continuous, or consist of individual spaced vents. Soffit vents allow the air to flow easily through the roof space from all wind directions.

Combining soffit vents with vents at the upper part of the roof will further increase ventilation. The passage of air from the soffit should not be restricted by insulation. Deflectors or baffles should be installed to maintain a space between the insulation and the underside of the deck.

Vents should be located at or near the ridge when used in combination with soffit vents. If roof vents alone are used, only a small volume of air within the immediate area of the vents will be displaced. The rule of thumb is that half the venting should be provided at the eaves, and the other half at or near the ridge.

Turbine vents are sometimes installed near the upper part of the roof. They consist of a rotating assembly of wind driven helicoidal blades that draw air from the roof space. However, if suction is created inside the roof space because of insufficient air supply from the outside, moisture may be drawn through the ceiling from the living space aggravating the condensation problem.

In northerly climates using motorized fans to improve ventilation may help cool the living space in hot weather. However, they may lead to problems under winter conditions. By blowing air out of the attic they can lower the air pressure within the attic space relative to the air pressure inside the house. The negative pressure produced increases the amount of humid air leaking through the ceiling. In cold weather, the increased leakage will, in turn, lead to increased condensation. In addition, some of these fans create air currents strong enough to disturb loose fill insulation in the attic.

The most efficient venting system uses continuous ridge vents in combination with soffit vents. This system enables even and continuous ventilation of the attic by combining wind action and stack action. Ridge vents have continuous openings along the ridge. Their location in a zone of negative pressure allows them to act as air exhaust openings for all wind directions. When the wind is at right angles to the ridge, the air enters the attic through the soffit vents on the upwind side and leaves the attic either through the openings at the downwind soffit or at the ridge. When there is little or no wind, stack action will maintain some air movement inside the attic. Rising warm air escaping through the ridge vents will be replaced by cooler air entering through the soffits.

Whichever ventilation devices are chosen, it is imperative that they be properly located. Placing intake and exhaust vents too close together, or not achieving a proper balance, may create areas of stagnant still air within the attic or roof space effectively short circuiting the ventilation. If the system cannot be balanced equally, it is recommended that the intake exceed the exhaust as most problems result from insufficient intake.

Retrofit

The question often arises as to whether additional vents are required when adding insulation to the attic of an existing house. Retrofitting provides a good opportunity to inspect the attic for signs of moisture problems due to condensation. If the existing ventilation of the roof spaces conforms to the applicable building codes, no signs of moisture problems are evident and interior occupancy conditions remain the same, it may be wise to leave the ventilating system unchanged. If, on the other hand, signs of excessive moisture were evident, it would be preferable to correct the problem by improving the air tightness of the ceiling rather than by increasing the total vent area. There is a law of diminishing returns. Adding more vents risks creating negative pressure in the attic and increasing air leakage through the ceiling.

Conclusion

It is not unusual to see a thin layer of condensation or frost on the underside of the deck in very cold weather. This is not indicative of ventilation related problems. During very cold weather, the outside air can hold very little moisture. Most of the moisture that finds its way into the roof space will condense out of the air when it comes in contact with the cold sheathing. Cold air in the attic is not effective in removing condensation because of its low moisture storage capacity. Frost will form, therefore, on the underside of the deck. In most cases, this should not be of concern. When the air gets warmer, as in the late winter, its capacity to absorb moisture increases and more moisture will be removed as drying conditions improve.

Many homeowners misinterpret a dripping or water stained ceiling as signs that the roof cover is defective or has a roof leak. In many instances, the real culprit is not a breech in the roof, but the consequence if ineffective ventilation of the roof space combined with excessive air leakage. Providing adequate attic ventilation can help reduce the potential for condensation, ice dam formation and many other roofing problems.

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