Attic and Crawlspace Ventilation: Implications for Homes Located in the Urban-Wildland Interface

Stephen L. Quarles and Anton TenWolde

Abstract

Roof (attic and cathedral ceiling) and crawlspace ventilation has commonly been used as a moisture management tool to minimize performance problems associated with excessive moisture accumulation in these spaces. However, for homes located in the urban wildland interface, roof vents in particular provide an entry point into the attic for flame and burning embers. Research conducted at the University of California Fire Research Laboratory have shown that all forms of vents on the underside of the eaves (strip vents, frieze block, etc.), in both boxed and open-eave construction, are almost immediately penetrated under flame impingement exposures, confirming the vulnerability of vents to at least one kind of wildfire exposure. As a result of the observed vulnerability of vents to wildfire, they are sometimes eliminated, or relocated during construction, often without consideration for the potential effect on moisture control. Fortunately, alternative moisture control strategies have been suggested for moisture control and other performance related issues related to roofing. These strategies include alternative venting strategies, and minimizing heat, air, and moisture flow into attic and cathedral ceiling spaces by relying on construction details incorporated on the interior of the building. The objective of this paper is to review the function and vulnerability of vents, and examine alternative options.

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Background

Wildfires in forest, shrub, and grasslands have always been one of the natural events that we, and our ancestors, have had to deal with. In recent years, wildfires have resulted in the destruction of many homes in Florida, many of the western United States, and Australia. The shift of population and housing growth into wildland areas, and the resulting increase in structure losses from wildfire, has increased interest in ways to reduce these losses in urban-wildland interface (UWI) areas.

Structures located in the UWI areas must be designed and built to resist typical wildfire exposures, including burning embers (fire brands), radiant, and flame impingement exposures (2). Fire brands have lead to the ignition and loss of structures some distance from the actual fire front. These losses have resulted from embers either igniting near home vegetation, with subsequent ignition of the structure, or from embers landing on the building, directly igniting building materials. The contribution to structure loss from ignition of non fire-retardant treated wood shake roofs, is well understood, and has resulted in changes to building codes to restrict the use of this roofing material.

Another mechanism for fire brands to lead to the loss of structures is through entry into attic and crawlspace vents, with subsequent ignition of combustible material in those spaces. Research conducted at the University of California Forest Products Laboratory (UCFPL), clearly pointed to the vulnerability of vents and overhangs with regard to ease of entry of flame and burning embers during wildfires, and the importance of material selection in terms of eave construction (4, 8). Since the under-eave portion of the roof is a common location for vents, the combination of vent location with wide overhang can result in a very vulnerable feature from a wildfire exposure perspective. The post-mortem surveys conducted after the October 2003 wildfires in Southern California provided additional evidence that flame and ember entry through vents resulted in the loss of many homes (7). One of the suppression-related problems in wildland fire conflagrations is the inability of firefighters and equipment to protect all of the homes that potentially ignite during these events. As a result, initially small fires in or around structures can grow, and as a result, most homes that ignite are completely destroyed (3). As a result of the common use of vents as a moisture management tool for structures, the vulnerability of vents to flame and ember entry has become a problem area for the design of structures to survive a wildfire. The objective of this paper is to discuss the implications of roof overhang, and vents, on the durability of structures located in UWI areas.

Vents

Venting of crawlspace and attic/cathedral ceiling areas has traditionally been required by local building codes. Ventilation requirements for attic and cathedral ceiling spaces typically range between 1 ft.^{2} of venting per 150 to 300 ft.^{2} of horizontal floor or attic area. Ventilation requirements for crawl spaces are normally 1 ft.^{2} per 150 ft.^{2} of floor area (1:150). Use of vapor retarders (or coatings for interior uses) can reduce the required vent area. For example, use of plastic ground cover (vapor retarder) in crawl spaces can reduce the required amount of vents from 1:150 to 1:1,500, a considerable reduction.

Attic ventilation has become the principal strategy to minimize condensation and ice dams during the winter in colder climates, and to reduce attic temperatures during the summer (14). Common attic vents include those found in the soffit or eave area, gable vents located under the rake, and/or vents located on top of the roof. Vents located on the roof are referred to as 'through-roof' vents, and are called 'eye-brow' or 'dormer' vents. Ridge vents are also commonly used in a 'through-roof' application. Soffit and eave vents are intended to operate as 'intake' vents, whereas through-roof vents can either be inlet or outlet vents, depending on location on the roof. Wind speed and direction, as well as building configuration, will influence the actual flow direction in a given vent. Crawlspace vents have been used to control excess moisture build up, either resulting from moisture evaporation from the soil, or surface or subsurface water enter into the crawl space from the exterior.

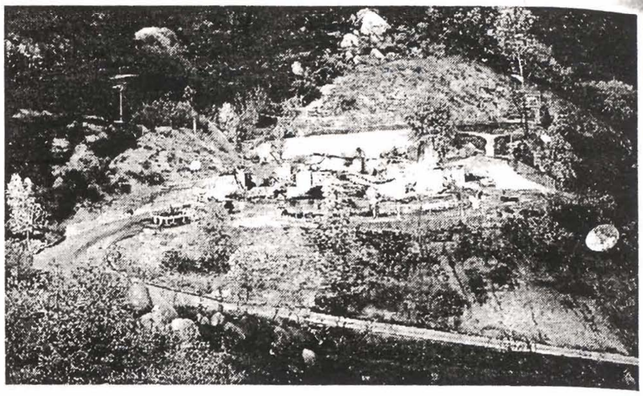

Figure 1. ~ *A noncombustible exterior cladding and roof covering, plus dual pane windows were not enough to save this structure. Ember entry into vents are a probably cause of the initial ignition of this structure.*

Vents can result in structure loss either by allowing direct entry of ember or flame from ignited vegetation, debris, or cladding. Evidence gained from post mortem surveys after the 2003 Southern California fire storms provided evidence of the impact vents can have on structure survivability. **Figure 1** shows a destroyed structure located on top of a hill in rural San Diego County. This structure had stucco cladding, a clay tile roof, and dual pane windows, some of which with tempered glass. All of these materials are recommended for use in fire-safe structures. Vulnerable features included the roof and eave vents, and potentially an insufficient set back from the hill slope and existing vegetation. **Figure 2** shows the open frame eave area of a structure, also in rural San Diego County, that was damaged but not destroyed. Vents were not incorporated into this under-eave area. **Figure 3** provides an example of how ignited vegetation may result in flame entry, in this case into a gable end vent.

Depending on region, building code calls for 1/4-inch or 1/8-inch mesh screen vent coverings, although California building code stipulates a minimum 1/4-inch mesh. Anecdotal evidence from structure loss surveys after recent California wildfires indicates that use of 1/4-inch mesh size screens in vents has not been effective in eliminating entry of burning embers, but because of concern over moisture-related performance problems, building code officials are cautious about allowing 1/8-inch (or less) mesh screens. Smaller mesh sizes are more prone to plugging from airborne debris and paint-over from spray and/or brush when homes

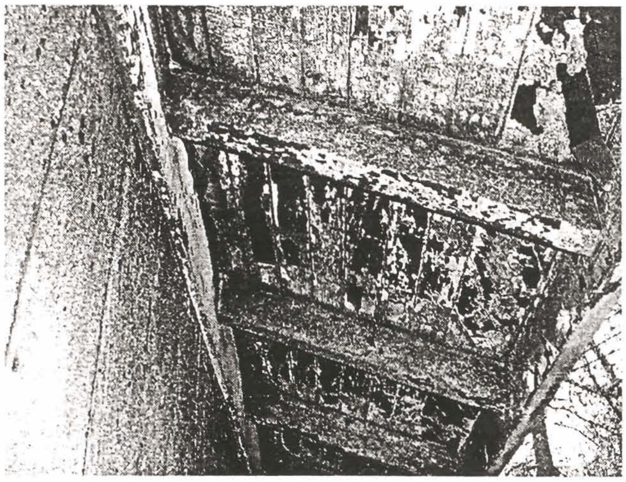

Figure 2. ~ *Vents were not used in the eave area of this fire-damaged home.*

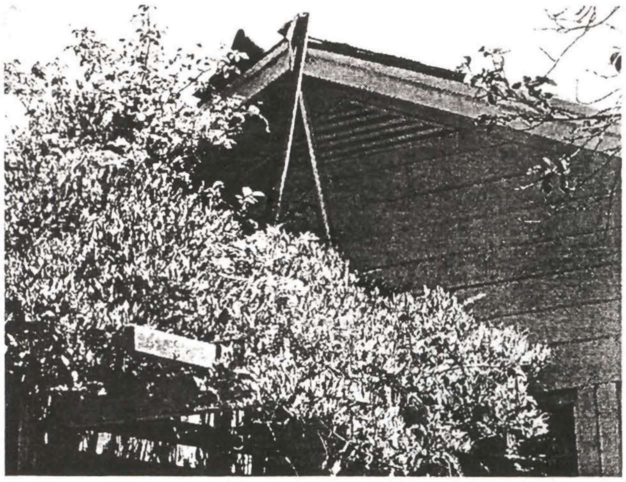

Figure 3. ~ *Climbing vegetation on a horizontal trellis is located immediately below a gable end vent. If ignited from fire brands, flame and/or ember entry into the vent would result in the loss of the structure.*

are painted. Lack of a standard procedure to evaluate vents (and screens) for performance under wildfire exposures (i.e., ability to limit entry of typical size of brands generated during the wildfires), and consequently a way to quantify the potential impact of using smaller mesh screens increases the difficulty in making the argument for homes located in interface areas. Clearly, if use of smaller mesh screens is allowed, it will require an added maintenance burden on the home owner, and potentially add an additional step (protecting vent openings) during home painting projects. Regardless of concerns over moisture performance issues, in bushfire prone areas Australian building code calls for venting mesh sizes less than 1/8-inch (13).

Alternate vent designs are currently being developed that may help resolve the problems regarding use of

Figure 4. ~ *Vents located on an exterior door possibly contributed to loss of this structure by allowing burning embers into the room containing mechanical equipment.*

vents in wildfire prone areas. These designs usually incorporate baffles or louvers that force an indirect path for air and debris movement from the outside into an attic or crawl space, and may also incorporate smaller mesh screens. Code officials have expressed concerns about these designs, particularly regarding maintaining adequate net vent free area, and movement of air into and out of the ventilated spaces. Similar designs have been discussed for use in cold climates to minimize the entry of snow (15), and used in coastal regions subject to hurricanes.

Vents installed in exterior walls to provide for ventilation in rooms containing hot water heaters, and other combustion equipment, have also shown to be vulnerable to brand entry (**Fig. 4**). Similar alternative vent designs may be an option for through-wall vents for these spaces.

In recent years, building scientists have been studying the venting issue, and the environmental conditions (i.e., internal and external relative humidity conditions, and temperature) that would require venting. The argument can be made for both crawlspace and attic/cathedral ceiling vents, but documented wildfire vent issues have been related to ventilation of attic and cathedral ceilings, and therefore the discussion here will exclude crawlspace venting.

Climate zones in North American are shown in **Figure 5**. In the United States, wildfires that have resulted in significant structure loss have been in hot-humid climates (Florida), cold climates (much of the western United States), hot-dry climates (southern California), and marine climates (coastal California). There never has been any technical evidence that in hot, humid climates and hot, dry climates, venting of the roof is

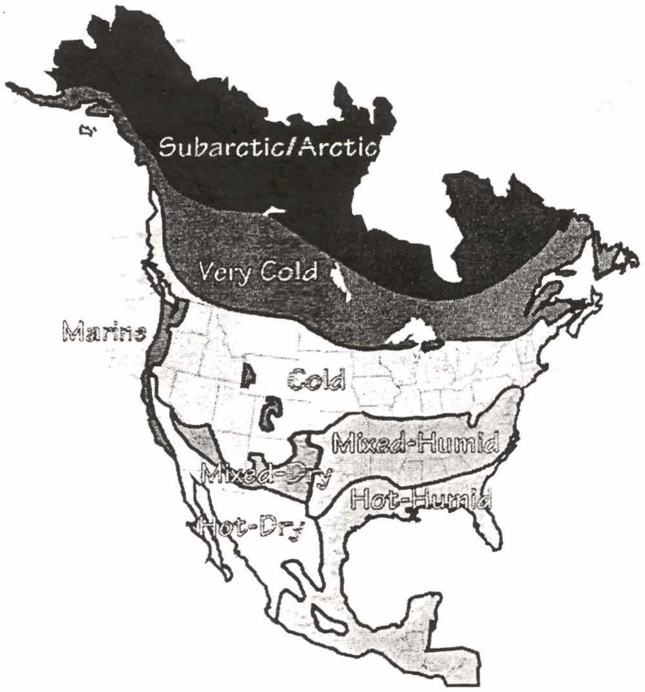

Figure 5. ~ *Climate map of North America (courtesy of Joe Lstiburek, Ph.D., Building Science Corporation, Westford, MA).*

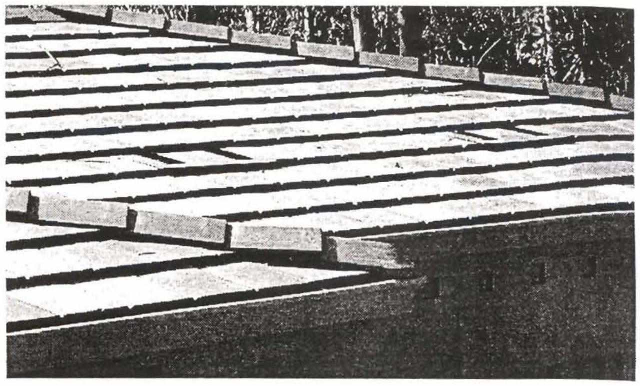

Figure 6. ~ *Additional flat through-roof vents, located on the lower portion of a sloped roof, used instead of the more traditional soffit or eave vent. Two of these vents can be observed in this photograph. With these vents, entry to the attic space is off-set from the openings to the outside, thereby reducing the potential for entry of rain into the attic space.*

needed for moisture control (9). While venting of attics and cathedral ceilings is still recommended in cold and mixed climates, unvented roofs can perform satisfactorily in most of those climates if measures are taken to control indoor humidity, to minimize heat sources in the attic, provide sufficient insulation to avoid ice dams, and to minimize air leakage from the house into the attic (9). Venting is required only in areas with extremely high snow fall (more than 60 lb./ft.^{2} ground snow load), or in areas at high elevations with moderately high snow fall (more than 30 lb./ft.^{2} ground snow load). Tobiasson et al. (16) provide specific recommendations on when venting is required for ice dam prevention, depending on the level of ceiling insulation and elevation. Roof designs for unvented "cathedralized" attic spaces are also available (6, 11). In cathedralized attics, the thermal barrier is moved from the ceiling plane to the roof plane (i.e., just under the exterior roof covering), converting the attic from an unconditioned space to a conditioned space.

Even though the warranty of some roof shingle require attic ventilation, research has consistently shown that ventilation plays a minor role in reducing the temperature of roof shingles, and is therefore likely to have only a minimal impact on the durability of these products (9, 10, 12).

Whereas alternatives approaches to attic and cathedral ceiling ventilation are available for new construction, these may not be as readily implemented in existing structures. Construction and detailing features such as airtight ceilings can be difficult to implement effectively in existing buildings. Those considering unvented attics are cautioned to consider, and plan for the mitigation of moisture-related performance problems that will potentially develop when vents are eliminated without also implementing other alternative control strategies. Fortunately, the most effective measure, indoor humidity control in winter, can often be accomplished effectively by adding a mechanical ventilation system.

In some high wildfire hazard areas, soffit and eave vents are being eliminated, sometimes without consideration to the potential negative impact on the moisture management function of the vent. Where applicable, vents are selectively eliminated, for example only on the side where the wildfire would most likely approach. In some cases, soffit and eave vents are being converted to through roof vents, on the lower slope of the roof (**Fig. 6**). Some existing through roof vents can be vulnerable to both rain (particularly wind-driven rain) and flame and ember entry (**Fig. 7**).

Roof Overhangs

The roof overhang is an integral component of the vent issue, and is therefore including in this discussion. Even without vents, the soffit and eave area is vulnerable during a wildfire. Wind patterns can cause ember accumulation in the eave area, and flame concentration from ignited combustible cladding or near-home vegetation. This would be particularly true for open eave construction, and for this reason, boxed in eaves or soffits are sometimes stipulated for use. More importantly

Figure 7. ~ *An example of a dormer-type through roof vent that would be vulnerable to both wind-driven rain and flames and embers from a wildfire. Debris from nearby pine trees and the untreated shake roof also pose significant problems for this structure.*

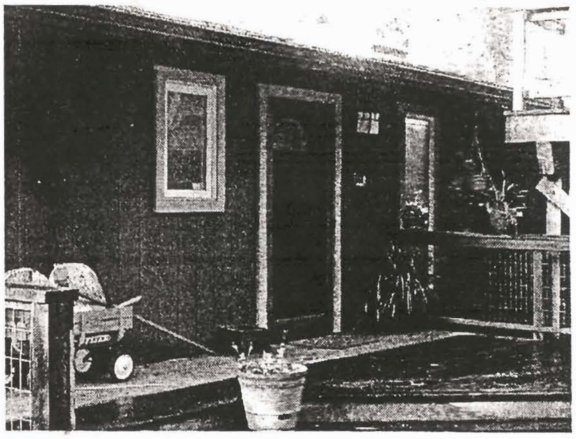

Figure 8. ~ *Wide overhangs on this structure protect the cladding and penetrations (windows and door) from rainfall. Note the dry deck boards near the house, and the wet deck boards away from the house.*

for the purpose of this discussion is the preferred design that incorporates minimal or zero roof overhang as a fire safe feature. Whereas this design feature has definite merit with regard to ember and flame impingement exposures that accompany wildfires, it has a distinct disadvantage with regard to the protection wide overhangs provide from rain exposures (**Fig. 8**). The importance of wide roof overhangs in minimizing exterior related moisture problems has been clearly shown in research (1, 5). Much of the recent construction related litigation has been linked to moisture-related performance problems resulting from moisture entry at penetrations in the exterior wall. Given this information, another alternative would be to use ignition resistant materials in the soffit/eave area, and maintain the use of wide roof overhangs that have a proven track record in reducing moisture problems in structures.

Summary and Conclusions

There is a need to merge moisture and wildfire durability issues. In many cases the building science community agree that attic and crawlspace ventilation can be eliminated in almost all climates. With regard to attic ventilation, the decision process must consider the local climate (especially the annual snow fall amount), indoor relative humidity, and other construction details that minimize movement of vapor into the attic or cathedral ceiling space. With regard to crawlspace ventilation, in addition to the controlling internal moisture sources (typically from the soil), controlling entry of ground water that could result in ponding in crawl spaces, must also be considered. Entry of ground water is usually a grade issue, with the exterior grade being above the interior (crawl space) grade.

Overhangs have been shown to significantly reduce the occurrence of moisture-related durability problems, particularly those related to water entry into the building enclosure at penetrations and intersections. Alternative design and use of ignition-resistant materials that would allow for retention of a wide overhang, yet still provide for a fire-safe structure, would be an overall plus for the durability of a structure.

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