Conflicting Design Issues in Wood Frame Construction

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ABSTRACT

In order for structures to provide adequate long-term performance, they must be designed and built to resist the imposed loads. These loads can be both structural and environmental in nature. This paper addresses performance issues related to design and materials selection as they relate to exposure from environmental elements. Of the environmental elements (e.g., moisture, fire, uv exposure), it is the contribution of the imposed moisture loads that usually result in the performance issues affecting durability. Buildings located in the urban-wildland interface (UWI) can also be exposed to the environmental load of wildfire. Testing has recently been conducted at the University of California Fire Research Laboratory whereby exterior building components and assemblies were exposed to simulated wildfire conditions. One of the results of these tests showed that construction details commonly used to protect a structure from moisture were often in conflict with those which would more effectively protect the same structure against the flame impingement and burning brand exposures typical for homes located in the UWI and subjected to wildfire. Examples of conflicting moisture-wildfire design issues include attic and crawlspace ventilation and roof overhangs. Traditional vents are vulnerable to flame and ember entry, but depending on the climate, are considered important from a moisture management perspective. Similarly, wide roof overhangs are considered a good design feature to protect cladding from rainfall, and can be good from a solar gain (energy conservation) perspective depending on location, but are a poor design feature from a flame impingement perspective. The objective of this paper is to present information on these conflicting design issues, and to explore how best to design structures located in the UWI.

KEYWORDS

Design features, structures, urban-wildland interface (UWI), wildfire, rain

BACKGROUND

Structures are designed and built to withstand certain imposed loads, as mandated by local and regional building codes. Traditionally we have been concerned about typical structural loadings (e.g., wind, earthquake and snow) that a structure could be exposed to. Depending on the likelihood of certain events that can have significant structural impact on the structure, regions can modify the basic building requirements to make the structure more resistant to a given imposed load.

For a number of reasons, improving the durability of structures has attracted more attention in recent years, and much of the attention has focused on protecting the materials on and within the building envelope against external exposures, the most common being moisture from both internal and external sources. Although construction details and design features related to moisture control are not always implemented, they are generally understood and have been well documented. Design features regarding energy performance of structures are also readily available, as well as those intended to make structures more “fire-safe”. As is the case with moisture, fire-safe construction can address fires that start inside the structure, and those that result from exterior sources (wildfires).

Testing was recently conducted at the University of California Forest Products Laboratory (UCFPL) fire laboratory whereby exterior building components and assemblies were exposed to simulated wildfire conditions. One of the results of these tests showed that construction detailing and design features that were effective in protecting a structure from the infiltration of external moisture (usually in the form of rain) directly counter to those that would be used to protect the same structure against flame and burning brand exposures typical for homes located in the urban-wildland interface (UWI).

Since there are many factors that could be considered when designing a structure, tradeoffs inevitably occur. One of the critical issues regarding the long-term performance of a structure is appropriate planning for the anticipated exposures, but in order for design professionals to make informed decisions, all of the exposure issues must be available. The objective of this paper is to present information on the conflicting design issues that exist between rain, wildfire, and, to some extent, energy conservation features, and to begin discussions on how best to design structures located in the UWI where wildfire (bushfire) poses a threat.

PERFORMANCE ISSUES: DESIGN OF COMPONENTS AND ASSEMBLIES

Similarities and differences were noted between design features that would be used to protect the exterior envelope from moisture/rain and those that would be used for wildfire. The similar design features for both moisture and wildfire design are the importance of proper detailing at the joints and penetrations. Obtaining adequate moisture and wildfire protection in the field of a given material or assembly (i.e., away from the edges) is the easiest to accomplish. Penetration of moisture and fire typically occurs at joints. This is why flashing details are so important when considering moisture management issues, and the same is true for fire penetration. The conflicting design issues deal with the “gross” design features and in the selection of materials. Examples of these gross design features include the width of the roof overhang, use of attic and crawlspace ventilation, and the spacing of deck boards in attached, spaced-board decks. These conflicting design issues will be addressed in the following sections.

Roof Overhang and Ventilation

The width of the roof overhang on a structure seems to be selected based more on the desired appearance of the structure rather than its ability to perform of a given function, even though there are clear benefits to narrow and wide overhangs, depending on the exposure. Publications dealing with performance and protection of building envelopes recommend wide overhangs to help deflect rain (Lstiburek 2000, Canada Mortgage and Housing Corporation 1999), and narrow overhangs to provide protection against flame impingement and ember exposures common with wildfires (Moore 1981, Webster 1986, NFPA 1991). Germer (2001) reported on a procedure for determining roof overhang based on the need to control solar gain in the building, and is therefore related to energy conservation. In the procedure outlined by Germer, roof overhang is a function of the latitude where the structure is being built, and the vertical distance from the window sill to the roof overhang. In reports issued by the Canada Mortgage and Housing Corporation (Rickens and Lovatt 1996), and Verrall (1966), walls with wider overhangs were associated with fewer water infiltration problems in the walls. Wide overhangs usually provide protection at wall penetrations in the field, but in cases where the base of the sheathing extends below the bottom of the sill plate, or the clearance between ground and sill isn't adequate, it can also minimize splash-back, and the resultant damage to the bottom edge of the sheathing panel.

Roof overhang performance issues related to wildfire exposures are two-fold, one related to ventilation of attics, and the other related to flame impingement on the wall. Attic vents are frequently located on the underside of eaves, and have proven to be vulnerable to both entry of flames (flame impingement exposure) and glowing embers. Our research has 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 (Fig. 1). The advantage of using a noncombustible soffit material is negated when it is used in conjunction with a metal or plastic strip vent. The vulnerability of eave vents to fire has led to their elimination in some areas. The addition of through-roof (eye-brow) vents on the roof surface can compensate for the loss of vent area at the eave, but it is questionable whether the attic area is being as effectively ventilated. Some have questioned the need for attic ventilation at all in hot humid climates (Lstiburek 1999, TenWolde and Rose 1999), and therefore in those climates moisture management and wildfire protection features may not be in conflict. In other climates, eliminating attic ventilation without incorporating other construction details that control the movement of moisture into the attic would not be wise. The use of screens in vents is intended to minimize or restrict the entry of embers into attic spaces, and is clearly more effective than vents without screens in this regard, but they do nothing to restrict penetration from a flame impingement exposure. Another feature that is being used in some regions is baffled vents (with the vents having either a horizontal or vertical orientation). The effectiveness of this design with regard to wildfire exposures has yet to be evaluated, but a similar design has been suggested for minimizing the entry of snow into attics during periods of high winds (Tobiasson 1994). Some local building codes in southern California suggest the use of (but do not require) baffled eave or soffit vents on new construction in the UWI. In these same localities, attic ventilation is not permitted on sides of homes fronting the wildland area (San Diego County 1997).


Flame penetration at a vent

Figure 1. This photograph shows flame penetration through a 2-inch diameter soffit vent located in the center of the wall, as viewed from what would be the interior of a structure. The flame impingement exposure simulates burning vegetation or exterior cladding.

The second performance issue is related to flame impingement on the wall. The flame height on a wall is dependent on the entrainment of air into the flame plume (ASTM 1997). Because the flame is blocked on one side when it is against a wall, it will climb higher than one that is not in contact with a wall. Flames will climb higher yet at a corner. The flame plume will spread onto the surface of the eave (soffit) if an overhang exists due to the reduction of entrained air as the flame turns on the sloped surface (ASTM 1997). Results from research conducted at the UCFPL Fire Research Laboratory showed that flames would enter soffit vents located in an open eave (frieze block vent), and strip vents installed in boxed eaves almost immediately after a flame source was ignited at the base of the wall (Jennings 2000). A 600 kW propane diffusion burner was used, so the flame was able to immediately climb to the top of the wall. The strip vents were installed in 450 mm (18 inch) and 900 mm (36 inch) wide boxed eaves. With the 900 mm overhang the strip vent was located either 150 mm (6 inches) from the wall or 150 mm from the roof edge. If a combustible soffit material is used, wide overhangs can be more vulnerable to a flame impingement exposure even if vents are not used because more material is exposed. In the same study, failure in combustible soffit material occurred at joints in tongue & groove boards (Fig. 2) and at knots and core gaps in plywood soffits.

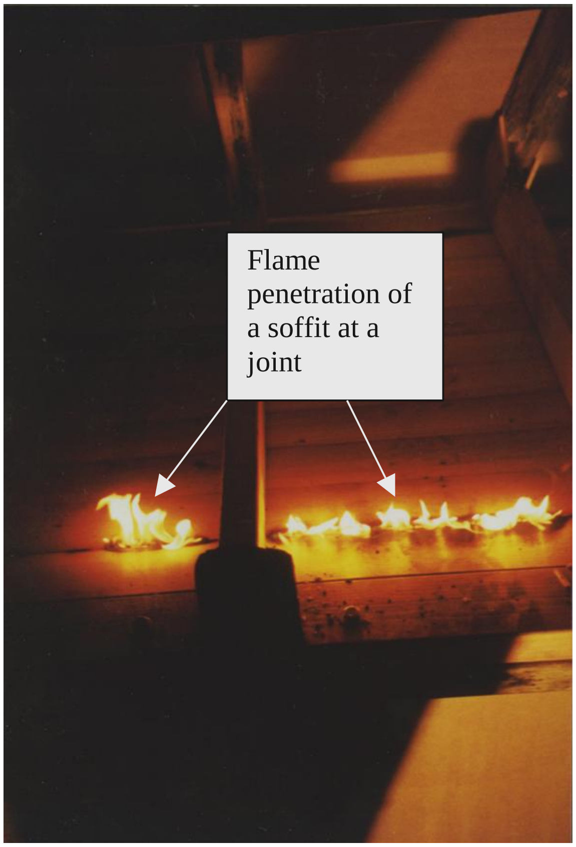


Figure 2. Flame penetration occurred through a T&G joint in a soffit constructed with nominal 1-inch (25 mm) boards. This view is from the interior of the attic/soffit area.

Crawlspace ventilation issues are similar to attic ventilation issues. Some level of crawlspace ventilation is required by code for moisture management, but again the effectiveness of ventilation has been questioned by some building scientists (Rose and TenWolde 1994). Crawlspace vents are often in close proximity to landscaping vegetation, which increase the chances of flame entry into the crawlspace should a wildfire reach the structure. Managing vegetation near a building (developing a ‘defensible space’) is always part of a firewise plan, and using such a plan will reduce the probability of wildfire reaching the structure and of fire penetration into attic and crawlspace vents. Other construction materials and details can be used to compensate for reduced venting that may be required by some codes. The use of a plastic ground cover in a crawlspace can reduce the need for ventilation, but not eliminate it (Quarles 1989), and the appropriate use of an air barrier can reduce the amount of moisture movement into the attic and building envelope. Slab on grade construction can also be used to avoid the crawlspace ventilation issue altogether.

Competing priorities create another conflicting design issue between aesthetics, “energy efficiency” and “firewise” constructions. As indicated by Wilson (2001), vegetation surrounding buildings can provide energy savings for a building, typically by improving the shading of a building. However, homeowners usually prefer vegetation surrounding homes, regardless of the other benefits and dangers.

Roof Overhang and Wall Interactions

The importance of a wide overhang in providing protection for the wall cladding by deflecting water from rain was discussed in the previous section. Our studies have shown that vertical and horizontal joints are the most vulnerable feature with regard to flame penetration into the building envelope. If flame penetration into the building envelope is going to occur in the cladding, it will typically occur at a joint (Fig 3). This implies that, at least for lapped siding, wider patterns would perform better under wildfire exposures because of the reduced number of joints that would be present on the wall. Edge thickness swell can be a problem with some wood-based composite siding materials, and from this perspective, is similar to the fire performance in that wider pattern would reduce the number of affected panels. Moisture related issues in siding are usually associated with biological degradation or dimensional stability (warp). Our experience has shown that warp-related defects are reduced when narrow patterns are used for wood and wood-based materials.

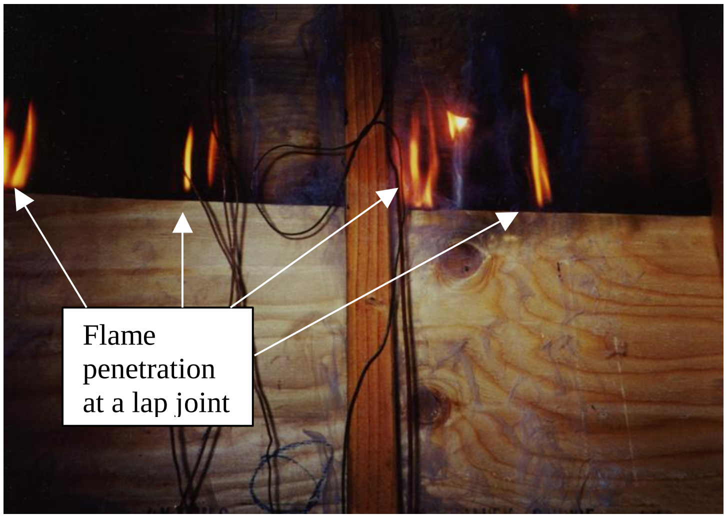
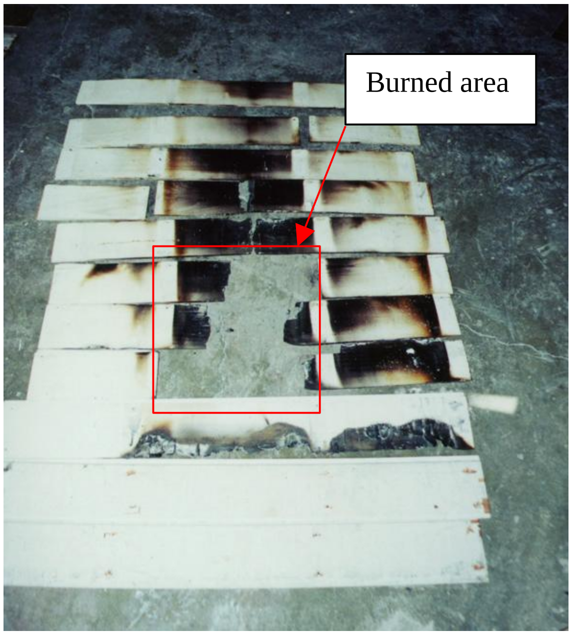


Figure 3. This photograph shows flame penetration on the back side of one of the lap joints in panelized horizontal lapped siding. The flame source was on the front of the siding.

In recent years use of a “rain-screen” design, whereby an air gap is included between the exterior cladding and the underlying sheathing has been discussed as a way of increasing the drying potential of the wall (Lstiburek and Carmody 1993; Quirouette and Rousseau 1998). Straube (1999) refers to this construction as a “screened-drained” wall assembly. This construction technique improves the drying potential of the wall, particularly if the wall is wetted by a leak in the building envelope. Preliminary tests conducted at this lab have shown that with this design damage to combustible siding materials increased, and because of this, the potential for burning through the building envelope also increases. Figures 4 and 5 show the backs of two wood-clad walls after being subjected to a flame impingement exposure for the same time period. The wall shown in Fig. 4 was attached to furring strips and the siding shown in Fig. 5 was attached directly to the building felt. The rain-screen wall suffered more damage as a result of charring and area burned. This result confirms those by Brannigan (1982) who discussed the increased fire susceptibility of a balloon-framed building envelope, whereby fire spreads throughout the cavity from the base of the wall to the roofline (and potentially into the attic). For rain-screen walls, the space between the cladding and sheathing provides a drainage plane, but also provides the confined space and oxygen for the flame to climb the back of the siding once the flame penetrates through the lap joint.



Figures 4. The back of wood siding installed using a rain-screen technique after exposure to a flame impingement source. The damage to the siding was more severe than damage to similarly exposed siding attached flush against the building felt (see Fig. 5).

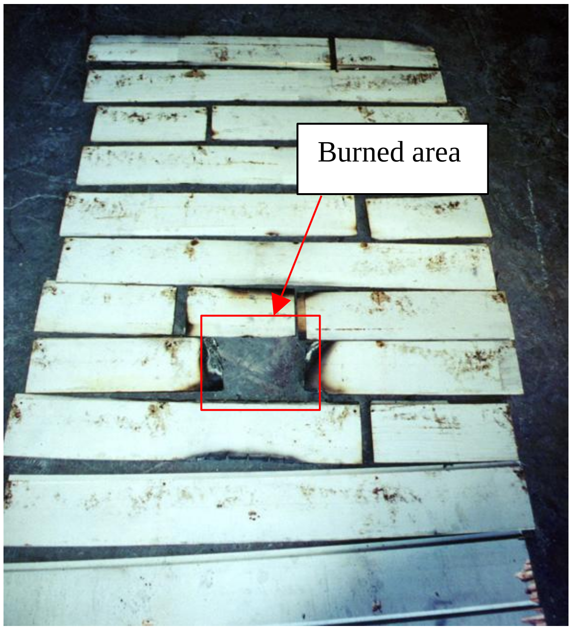


Figure 5. The back of wood siding installed flush against building felt after exposure to a flame impingement source.

Spaced-board Decks

Spaced-board decks obtain their best service life if the deck boards are spaced, and the between-boards gaps are maintained by clearing out the debris that can accumulate in the gaps. The air circulation that is facilitated by the gaps improves the drying potential of the deck boards, and the underlying support framing. However, these same gaps that allow for drainage and drying also provide radiant surfaces that enhance the burning, thereby increasing the rate at which the deck is degraded. These effects are shown in Figs. 6 and 7. These photographs show the increased fire hazard related to gapping the deck boards.

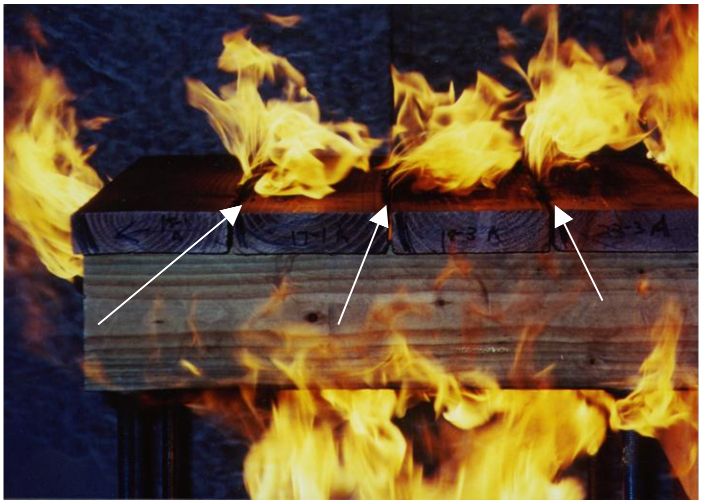


Figure 6. Flame impingement extending upward through gaps between the deck boards in a deck subjected to a flame impingement exposure.

Figure 7. When deck boards are butted, flames cannot easily penetrate between board spaces. The rate of thermal degradation of the deck is minimized.

Vertical screening and lattice systems are sometimes constructed around the perimeter of spaced-board decks in order to limit the entry of embers, and perhaps to discourage under-deck storage of materials. For large decks, the screen and lattice construction could limit ventilation, and therefore the drying potential, of wetted framing members, particularly in locations away from the perimeter where air circulation would be reduced.

Ventilated Membrane Decks

Wood-framed membrane decks (waterproof decks) have a solid surface and therefore would not have the conflict related to deck board spacing. Wood-frame membrane decks that are enclosed on the underside are usually vented, and therefore they would experience the same issues related to ventilation regarding ease of flame penetration. The vented membrane-deck shown in Fig. 8 is particularly vulnerable because of the growth of vegetation under the deck, and also because the building is located at the top of a ridge (not visible from the photograph). Flame entry into the joist cavities of these decks provides and easy access to the wall cavity, and therefore the structure.

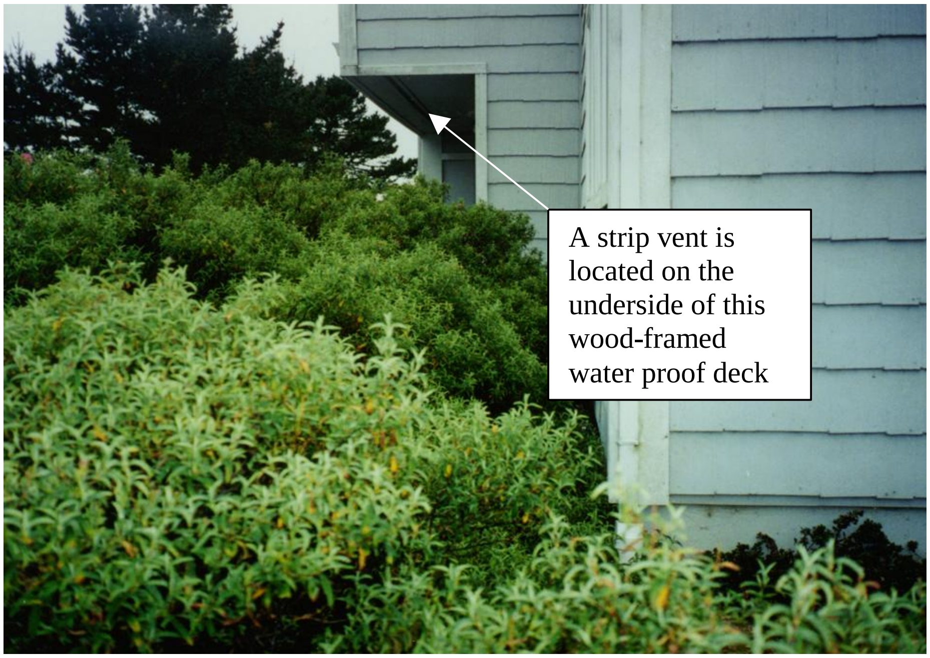


Figure 8. The strip vents commonly used in woof-framed waterproof decks are subject to the same flame and ember entry problems as crawlspace and attic vents. In this case, vegetation growing under the deck increases the potential danger to the structure.

SUMMARY

Basic design features that provide protection against rain and wildfire are often in conflict. For example, regarding exposure to rain, the performance of building components and assemblies can be enhanced if wide roof overhangs are used, if adequate ventilation of attics and crawlspaces is incorporated, and if the deck boards in spaced-board decks are gapped. If the structure design focused on maximizing performance assuming wildfire exposures, the opposite applies, and the roof overhang would be narrow, soffit and crawlspace venting would be eliminated, and deck boards in spaced-board decks would not be gapped at all. For homes built in the UWI it may be necessary to utilize the design features that are most effective against wildfire exposures, but this should not occur at the expense of the overall durability of the building. Other construction techniques and details must compensate for the anticipated change in performance. These techniques could include incorporation of air barriers to minimize the movement of moisture into the building envelope and use of vents that are designed to resist wildfire exposures but still allow sufficient movement of air to remove excess moisture. Elimination of the roof overhang would require greater attention to installation detailing at penetrations and may require a change to materials that are more dimensionally stable. Since many buildings are currently built with narrow overhangs, the need for more careful installation is understood. These changes may also mean that the time interval between normal maintenance tasks, such as painting and caulking, may have to be reduced.

Homes built in the UWI should be designed to perform well for all the anticipated exposures, and it is important to acknowledge and design for them. Trade-offs may have to be made, but this should not be at the expense of making the structure overly vulnerable to any given exposure.

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