The Fallacies of Venting Crawl Spaces

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Almost 70% of the houses in South Carolina have crawl space foundations. We build more crawl space foundations than any other state in the country. Yet we continue to have problems with our crawl spaces. These problems include mold and decay, elevated radon levels, and termite and other pest concerns. We see condensation on ductwork, mold on joists, termite and wood boring beetle damage and cupped hardwood floors. Our current solution is to increase ventilation of the crawl space.

At an Affordable Comfort meeting that I recently attended, a speaker from Canada said that venting crawl spaces in the southeastern US was lunacy. I have to agree. In this paper, I will discuss some of the fallacies I see with our current practice of venting crawl space foundations, and provide guidelines for a higher performance crawl space.

Fallacy #1 - A research basis for current crawl space ventilation guidelines exists. Supposedly we vent crawl spaces to help control moisture. Looking back through historical documents we find several documents that discuss venting crawl spaces. In 1939, the Forest Products Lab published "Use and Abuse of Wood in House Construction" which contains "Screened vents totaling 3 percent of the house are best, with a thoroughly insulated floor… One small ventilator in each wall is hardly enough in the damp South."

In 1942, the Federal Housing Administration's "Property Standards and Minimum Construction Guidelines" contained the first requirement for ventilation of crawl spaces in regulatory literature. It pre-dates any known research on crawl space performance. These requirements state in part "Provide a sufficient number of foundation wall vents to assure a total ventilating area equivalent to 1/2 percent of the enclosed area plus 1/2 square foot for each linear feet of wall enclosing that area."

In 1948, the Housing and Home Finance Agency (HHFA) published "Crawl Spaces: their effect on dwellings." This document contains a discussion of some investigative work done by Britton on several housing complexes. Britton said "when ventilation to the extent of 1/1500 of the building area was cut into the crawl space walls, in conjunction with ventilation of approximately 1/500 of the building area in the loft space walls and the covering of the crawl space ground with 55# mineral surfaced roofing, all trouble was apparently eliminated." An interesting note with this discussion was that Britton was investigating attic moisture problems.

Britton included the note "Where crawl space floors are covered with 55# mineral surfaced roll roofing in an effective manner, the specified wall ventilation may well be reduced as much as 90% for controlled construction." The HHFA followed with another document that stated "Where a good cover is applied over the entire surface of the ground in the crawl space, very little ventilation [10% of formula] is needed."

The next thing we see is updated code requirements. The Minimum Property Standards of 1958 state "At least 4 foundation wall ventilators shall be provided, one located close to each corner of the space, having an aggregate net free ventilating area not less than 1/150 of the area of the basementless spaces, or ground surface treatment in the form of a vapor barrier material…plus at least 2 foundation wall ventilators having an aggregate net free ventilating area not less than 1/1500 of the area of the basementless space." The only difference I see between this 1958 code and the 2000 IRC code is that today we require a minimum of four vents at the 1/1500 ventilation level.

From my investigations and those of Bill Rose of the Building Research Council at the University of Illinois, research to support these recommendations and the code does not exist. What I can find in the literature appears to be limited to a field investigation with several moisture control steps happening at once. I do not see an evaluation of the effectiveness of each step. That is: When attic ventilation AND foundation ventilation AND a soil cover were added, the ATTIC moisture problem was fixed. These papers certainly contain good information, but I do not think it contains enough information to support our existing building codes and ventilation requirements.

In addition, nothing in the literature was found that scientifically supports partially covering the soil in a crawl space.

Fallacy #2 - We build houses the same today as when current crawl space ventilation guidelines were established. Many things have changed in the houses we build today versus what we built back in the 1930's-1950's. We often build on wetter sites (because many of the high-and-dry ones are gone.) We also build houses deeper into the ground. (I cannot count the times I have crawled DOWN into a crawl space.) We build smaller overhangs without gutters and downspouts, and sometimes do not slope the land away from the foundation.

The most significant change we have made in the last 50 years, in my opinion, is air conditioning. In many parts of the country, we make a standard practice of creating artificially cooler temperatures in our homes. Now we easily create temperatures that are near or even below the dew point temperature of the surrounding air. Condensation occurs on surfaces that never before experienced condensation. Air conditioning has upset the balance we used to experience, and the balance we were using when the ventilation codes were created.

Fallacy #3 - The 1/150 or 1/1500 ventilation area requirements mean something. I used an ASHRAE Standard 51-1985 air flow test device to measure the air flow through foundation vents ranging from 24 square inches of net free area (NFA) to 75 sq. in of NFA. The large NFA vent had a larger flow at a given pressure, but the flow was about 1.75 times that of the small vent rather than 3 times the flow as would be expected from the size difference. A 65 NFA automatic vent has an air flow much closer to the 24 vent than the 75 vent. (This occurs because of the additional screen on the inside of the vent, which is not used in the calculation of NFA for the vent, but provides restriction to air flow.) Therefore, the actual air flow achieved when meeting the 1/150 requirement appears to depend on the NFA of each vent as well as on the total aggregate ventilation area. An equivalent net free area made up of smaller NFA vents will provide more air flow that fewer large NFA vents.

Next, I estimated the air changes per hour in a 3-foot tall crawl space of a 1500 square foot house using these same vents. At 1/150, we would need 60 of the 24 NFA vents. The 60 vents would yield an air change rate of about 6.4 Air Changes per Hour (ACH). In contrast, the larger 75 NFA vent would require only 20 vents and provide only 3.4 ACH. The relatively large 65 NFA thermostatically-controlled vent would only provide 2.6 ACH if the 1/150 ratio was observed.

If we added a complete soil cover as the code allows, we could reduce the ventilation requirement to 1/1500. The number of vents required drops to six for the small 24 sq inch vents, and four for the other vents. This drops the air change rate to 0.64 ACH for the 24 NFA vents, 0.45 ACH for the automatic vent and 0.70 for the large 75 NFA vent.

This investigation has shown that specifying a NFA for crawl space ventilation does not seem to indicate the amount of ventilation that can or will occur in a crawl space. Using smaller NFA vents will provide more ventilation than when using larger NFA vents. Thermostatically controlled vents do not provide flow corresponding to a similar-sized manually-operated vent.

Fallacy #4 - Venting will reduce crawl space moisture levels. In reality, venting will only help reduce crawl space moisture levels when the outside air is dryer than crawl space air, or when enough hot outside air enters and warms the crawl space. Outside air in the summer may actually contain more moisture than crawl space air, and may make the situation worse, not better. In winter, venting will help dry a crawl space, sometimes to a detrimental extreme.

From a psychrometric standpoint, venting a crawl space to remove moisture works when the outside air is dryer than the crawl space air. "Dryer" does not mean a lower relative humidity, but rather a lower absolute humidity. Relative humidity is a ratio of the amount of moisture in the air relative to the amount the air can hold at that temperature. Absolute humidity is the amount of moisture in an amount of air. Air at 85 degrees and 60% RH has the same absolute humidity as air at 70 degrees and 100% RH. So venting a 70F/100% RH crawl space with 85F/60% RH air will not remove moisture.

The dew point temperature is the temperature at which condensation forms as the air is cooled. At the dew point temperature, the air is saturated and any further cooling will result in condensation. In the above example, both the 70F/100% RH crawl space air and the 85F/60% outside air have the same dew point temperature: namely 70F. If we vent a crawl space with air that has a higher dew point temperature than the crawl space air, we will actually be adding moisture to the crawl space rather than removing it.

Here in South Carolina, we often have outside air dew point temperatures around 75F. With air conditioning, cool soils and cold ductwork in our crawl spaces, the dew point temperature in our crawl spaces is often below 75F. When we vent them, we get condensation problems. Floors rot, mold or swell because of excess moisture. Ductwork sweats and becomes saturated with water. Duct energy losses go way up because the insulation isn't insulation when it is wet.

Our mortgage, pest control and home inspection industries flag crawl space wood moisture contents above 20% as a potential problem. At this wood moisture content, mold supposedly can grow. I see problem-free crawl spaces with wood moisture contents of 16%. A wood moisture content of 16% relates to air at about 80% RH. The dew point temperature of a crawl space at 75F/80% RH is about 68F. Why in the world would I want to vent this crawl space with air that has a dew point temperature close to 75F? The result will be condensation on all the cool surfaces in the crawl space.

Hardwood floors over crawl spaces often experience cupping problems in the summer. Wood expands when it gets wet. The typical scenario I see is that air conditioning is keeping the living space moisture lower than the crawl space moisture. This results in uneven moisture levels on the upper and lower surfaces of the wood. The lower, wetter surface expands and causes the boards to cup.

A common solution is to add ventilation to the crawl space, to reduce the moisture levels. Guess what happens in the winter? The boards cup the opposite way. Now our crawl space is vented with relatively dry air such that things in the crawl space really dry out. (As you heat air, its relative humidity drops.) The more ventilation we add to cure summer cupping, the worse the reverse winter cupping. We are slamming the wood moisture levels from one extreme to the other. Other moisture related wood movement such as swelling and shrinking of doors happens in the house as well.

Fallacy #5 - Venting a crawl space is not an energy issue. From an energy standpoint, why would we want to vent a crawl space? In the winter, an unconditioned crawl space is warmer than outside. Bringing in additional cold outside air will only tend to make the crawl space colder, and increase heat loss. In fact, we often install automatic vents that close during the winter just for this reason. The opposite situation occurs in the summer: warm outside air will add heat to a crawl space and increase the cooling load. Since we so often install ducts in crawl spaces, venting increases the energy loss from ducts. Summer-time condensation in duct insulation can easily double the energy losses from ducts.

Fallacy #6 - Increasing ventilation of a crawl space is a viable soil gas mitigation procedure. A potential solution for addressing elevated radon levels in crawl space structures is to increase the ventilation rate of the crawl space. The general rule of thumb is to double the ventilation rate to reduce radon levels by half. My first question is: what's the current ventilation rate? A common mitigation strategy is to add a powered fan to mechanically increase ventilation rates. If we assume a 1/150 ventilated crawl space using 24 sq inch vents and a constant 1 MPH wind, we would need a fan that could provide over 6 air changes per hour. That's 6*4500/60 = 450 CFM, just to reduce the radon levels by 50%. But why increase the ventilation rate of a crawl space to solve a soil gas problem when the increase in ventilation can cause so many other potential problems and expenses?

To Summarize: **Fallacy #1** - a research basis for current crawl space ventilation guidelines exists, when in actuality it does not appear to exist. **Fallacy #2** - We build houses the same today as when today's crawl space ventilation guidelines were established, when in fact our houses today are drastically different. **Fallacy #3** - The total net free area will provide adequate ventilation, when in reality the actual flow measurements of small NFA versus large NFA vents installed to the same NFA ratio are drastically different. **Fallacy #4** - Venting will reduce crawl space moisture levels. Venting will only help reduce crawl space moisture levels when the outside air is dryer than crawl space air, or when enough hot outside air enters and warms the crawl space. Outside air in the summer may actually contain more moisture than crawl space air, and may make the situation worse, not better. In winter, venting will help dry a crawl space, sometimes to a detrimental extreme. **Fallacy #5** - Venting a crawl space is not an energy issue, when in reality it can increase both the heating and cooling load. **Fallacy #6** - Increasing ventilation of a crawl space is a viable soil gas mitigation procedure. Ventilation to reduce soil gas (radon, moisture, etc.) has so many inherent problems as discussed in this paper that, in my opinion, it is not worth the expense or liability.

Un-Venting a Crawl Space: Since moisture is such an issue in crawl spaces, addressing moisture issues is the first priority in closing a crawl space. Exterior water must be directed away from the foundation with proper grading of the lot and proper handling of roof runoff. Crawl space soil should be completely covered with a vapor retarder. Capillary moisture movement should be restricted using either capillary breaks under piers and foundation walls, or by covering foundation walls and piers with a vapor retarder. Foundation walls can be insulated rather than floors over crawl spaces for enhanced thermal performance. In some instances, a dehumidifier will need to be added to the crawl space because of the complexity of home designs and the psychrometrics involved. Specific details for a sealed crawl space can be found on my web site at www.rlcengineering.com.

In a good crawl space, with good moisture control in and around the foundation, moisture problems won't exist. Interior moisture levels will be more stable. Hardwood floors and other interior wood will be more stable and less prone to shrinkage and warping. Energy costs will be lower and duct condensation will be eliminated.

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