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Crawlspace Myths

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Crawlspace foundations are common in houses built in a band that stretches from the Carolinas across the center of the U.S. to Washington and Oregon. Basements dominate the foundation type in houses north of this line, partly because of deep frost. Slabs dominate in areas below this line. Crawlspace foundations therefore occupy much of the middle of the mixed climate zone, but can be found in all four U.S. climate zones.

Crawlspace foundations make up a higher percentage of foundations in South Carolina than in any other state. Yet South Carolinians are not alone in continuing to have problems with crawlspaces. These problems include mold and decay, elevated radon levels, and termite and other pest concerns. Condensation forms on ductwork. Mold grows on joists. Termites and wood boring beetles cause damage. Hardwood floors cup. The historic and current widely recommended solution to crawlspace moisture problems is to increase or provide ventilation of the

crawlspace.¹⁻¹⁰ However, the National Association of Home Builders (NAHB) appears to be presenting a different recommendation. The NAHB now recommends¹¹ closing vents in the summer as a method of mold prevention.

Is venting a crawlspace necessary for moisture control? If a crawlspace is vented, are there other impacts or ramifications of the venting? Are there better ways to address crawlspace issues, such as moisture, pests, soil gasses, etc.? I believe venting can cause more problems that it solves, and that other, more bene-

ficial ways exist to address crawlspace problems. This article discusses these issues to encourage further discussion and research to ultimately change the way we look at crawlspace foundations.

Myth 1: A research basis for current crawlspace ventilation guidelines exists. Crawlspaces are vented to control moisture. That is how it started; that is why we still do it. Looking back through historical documents, researchers^{12,13} have found several documents that discuss venting crawlspaces. In 1939, the Forest Products Lab published *Use and Abuse of Wood in House Construction*, which states, "Screened vents totaling 3% of the house are best, with a thoroughly insulated floor.... One small ventilator in each wall is hardly enough in the damp South."

The Federal Housing Administration's *Property Standards and Minimum Construction Guidelines* in 1942 contained the first requirement for ventilation of

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6 ... venting can cause more problems that it solves, and other, more beneficial ways exist to address crawlspace problems. 9

crawlspaces in regulatory literature.¹⁴ It predates any known research on crawlspace performance. These requirements state in part: “Provide a sufficient number of foundation wall vents to assure a total ventilating area equivalent to ½ percent of the enclosed area plus ½ ft² (0.05 m²) for each linear feet (0.3 m) of wall enclosing that area.”

The Housing and Home Finance Agency (HHFA) published *Crawlspaces: Their Effect on Dwellings*¹⁵ in 1949. This document contains a discussion of investigative work done by R.R. Britton on several housing complexes. Britton said, “when ventilation to the extent of 1:1,500 of the building area was cut into the crawlspace walls, in conjunction with ventilation of approximately 1:500 of the building area in the loft space walls and the covering of the crawlspace ground with 55 lb (25 kg) mineral surfaced roofing, all trouble was apparently eliminated.” An interesting note with this discussion was that Britton was investigating *attic* moisture problems.

The Minimum Property Standards of 1958 states “At least four 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 two foundation wall ventilators having an aggregate net free ventilating area not less than 1:1,500 of the area of the basementless space.”¹⁶ The only difference between this 1958 code and the 2000 International Residential Code (IRC) is that today we require a minimum of four vents at the 1:1,500 ventilation level.

From my investigations, 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 contain good information, but I do not think they contain enough information to support existing building codes and ventilation requirements.

Following a symposium on crawlspaces,¹⁷ ASHRAE has essentially removed crawlspace ventilation guidelines from the *ASHRAE Handbook—Fundamentals*¹⁸ beginning with the 1997 edition.

Myth 2: We build houses the same today as when current crawlspace ventilation guidelines were established. Many things have changed in the houses built today vs. what was built in the 1930s–1950s when the ventilation guidelines were established. Houses often are built on wetter sites (because many of the high-and-dry sites are gone). Houses are built deeper into the ground. Smaller overhangs are used, often without gutters and downspouts. Proper drainage around the foundation often is neglected, or changed by the occupants.

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

One example of the impact of these changes is on our recommendations for ground covers in crawlspaces. The U.S. Forest Service¹⁹ published a map showing where ground covers are recommended to reduce the potential for “winter” condensation problems in crawlspaces. This map is based on climatic conditions. The map basically leaves out the southeastern U.S., where we may not have “winter” crawlspace condensation problems, but we can have summer condensation problems, especially in an air-conditioned house. Verrall and Amburgey²⁰ mention that “this type of condensation occurs in hot weather and may involve the entire floor area under cooled rooms rather than just peripheries...and it develops much more rapidly than with cold-weather condensation.”

Myth 3: The 1:150 or 1:1,500 ventilation area requirements mean something. I used an ANSI/ASHRAE Standard 51-1985, *Laboratory Methods of Testing Fans for Rating*, airflow test device to measure flow through foundation vents ranging from 24 in.² (0.02 m²) of net free area (NFA) to 75 in.² (0.05 m²) of NFA.²¹ Table 1 shows airflow data from three vents, a 24 in.² (0.02 m²) NFA vent, a 65 in.² (0.04 m²) NFA thermostatically controlled vent, and a 75 in.² (0.05 m²) NFA vent. The 75 NFA vent had a larger flow at a given pressure, but the flow was about 1.75 times that of the 24 vent rather than three times the flow as would be

Vent (NFA)	Pressure	Flow Through Vent	ACH per Pair ^a	ACH at 1:150 ^b	ACH at 1:1,500 ^c
24 in. ²	0.12 Pa	16 cfm	0.21	6.30	0.63
65t in. ²	0.12 Pa	17 cfm	0.23	2.50	0.46
75 in. ²	0.12 Pa	26 cfm	0.35	3.40	0.70
24 in. ²	0.49 Pa	31 cfm	0.41	12.30	1.23
65t in. ²	0.49 Pa	35 cfm	0.45	4.90	0.90
75 in. ²	0.49 Pa	57 cfm	0.76	7.30	1.50
24 in. ²	3.00 Pa	80 cfm	1.07	32.10	3.20
65t in. ²	3.00 Pa	94 cfm	1.25	13.70	2.50
75 in. ²	3.00 Pa	154 cfm	2.05	19.70	4.10
24 in. ²	12.20 Pa	162 cfm	2.16	64.80	6.50
65t in. ²	12.20 Pa	200 cfm	2.67	29.40	5.30
75 in. ²	12.20 Pa	333 cfm	4.44	42.60	8.90

^a Using a crawl space volume = (1,500 ft² × 3 ft tall) assuming one vent as inlet and one vent as outlet. ^b Assuming one-half of total NFA is inlet and one-half is outlet, all at constant and similar pressure difference. ^c At a ratio of 1:1,500, code requires a minimum of four vents. Therefore, four of the 65t and 75 NFA vents would be required, while 6 of the 24 NFA vents would be required.

Table 1: Airflow data from three vents.

expected from the size difference. The 65 NFA automatic vent has an airflow much closer to the 24 NFA vent than the 75 NFA vent. Apparently the additional screen on the inside of the vent, which is not used in the calculation of NFA for the vent, provides additional restriction to airflow. Therefore, the actual airflow achieved when meeting the 1:150 requirement appears to depend on the total aggregate ventilation area more than on the NFA of the vents used. (In addition, the flow through a vent with more than one layer of protective screen, such as the 65t automatic vent, has significantly different airflow characteristics than a similar manually operated vent.)

Air changes per hour also were estimated assuming a 3 ft (0.9 m) tall crawlspace of a 1,500 ft² (139 m²) house using the data for these same vents. At current IRC 2000 required ventilation rates of 1 ft² (0.09 m²) of NFA per 150 ft² (14 m²) of soil area (a vent ratio of 1:150), 60 of the 24 NFA vents would be required. The 60 vents would yield an air change rate of about 6.3 air changes per hour (ACH) at a pressure difference of 0.0005 in. w.g. (0.12 Pa), assuming half would be for infiltration and half for exfiltration. In contrast, only 20 of the larger 75 NFA vents would be required and provide only 3.4 ACH. The relatively large 65 NFA thermostatically controlled vents would only provide 2.6 ACH at the 1:150 ratio.

The IRC 2000 allows a reduction in ventilation to 1:1,500 if the soil in the crawlspace is covered with an approved vapor retarder. The number of vents required drops to six for the small 24 in.² (0.02 m²) vents, and four for the other vents (due

to a minimum four-vent requirement in the code.) The air change rate for the 24 NFA vents at this ratio at 0.0005 in. w.g. (0.12 Pa) pressure is 0.63 ACH, 0.46 ACH for the 65 NFA vent and 0.70 for the 75 NFA vent. In this case, a larger NFA actually provides a higher air-change rate, except when an automatic vent is used. In a larger house where the code 4-vent minimum would not apply for the 75 NFA vent, the small vent would provide more airflow.

This investigation has shown that specifying a NFA for crawlspace ventilation does not logically indicate the amount of ventilation that can or will occur in a crawlspace. Using smaller NFA vents will provide more ventilation than when using larger NFA vents, when installed to the same ventilation requirement ratio. Thermostatically controlled vents do not provide flow corresponding to a similar-sized manually operated vent. In practice, debris, shrubbery, vent wells and other obstructions also will affect the actual amount of airflow through a vent.

Myth 4: Venting will reduce crawlspace moisture levels to non-harmful levels. Excess moisture in a crawlspace can cause three primary problems: 1) High relative humidity can lead to fungal growth and increased insect activity in crawlspaces; 2) High dew-point temperatures can lead to condensation on cool surfaces, which can lead to fungal growth, increased insect activity and increased energy use; and 3) High crawlspace moisture levels can increase latent loads, and contribute to fungal growth and wood expansion problems in the living space. Therefore, crawlspace moisture con-

trol has two objectives: maintaining a low relative humidity in the crawlspace and reducing the potential for condensation on surfaces in the crawlspace.

The moisture content of wood is related to the relative humidity of air in contact with that wood. Wood that is below 20% moisture content is generally considered safe, according to pest control and home inspection industries. Wood will reach 20% wood moisture content when exposed to air at approximately 90% relative humidity.²¹ Therefore, a primary objective is to keep the crawlspace air below about 90% RH.

The other primary objective is to prevent condensation on surfaces in the crawlspace. This can be accomplished by either warming surfaces (typically by adding insulation), or by lowering the dew-point temperature of the air. Adding insulation, such as to a band joist, will sometimes suffice in raising surface temperatures. Insulation that is incorrectly installed under an air-conditioned floor only serves to further cool a surface in contact with high dew point crawlspace air. In other instances, adding enough insulation to an air-conditioner blower cabinet or crawlspace ductwork is not an economical option. Therefore, drying the air, rather than warming a surface is often necessary to prevent condensation.

Can venting keep the crawlspace dry? Venting *can* accomplish this, but only under one condition: When the mixture of ventilation air and crawlspace air results in a crawlspace RH below 90% at virtually every surface in the crawlspace. This entails more than just a psychrometric-mixing situation since surface temperature effects are involved. For example, venting a 65°F (18°C)/95% RH crawlspace in the winter with 50°F (10°C)/90% RH air may result in a RH of only about 70% on the bottom side of the 70°F (21°C) floor sheathing. On the other hand, venting a 70°F (21°C)/95% RH summer crawlspace even with 90°F (32°C)/40% RH air could still result in condensation on the underside of a 68°F (20°C) subfloor.

In fact, at crawlspace conditions of 70°F (21°C)/95% RH, condensation will occur on the 68°F (20°C) subfloor if any crawlspace air contacts the subfloor. In this case, venting with a sufficient quantity of 90°F (32°C)/40% RH air could help. What about at night, when all conditions are the same except that the outside air is now 62°F (17°C)/100% RH (same absolute humidity)? No amount of venting will pull the crawlspace RH below 90%.

Determining how much ventilation air is needed would require knowing moisture entry rates from the soil, foundation walls and outside air, and doing a moisture balance. The “exiting” half of this equation would be constrained by absolute humidity levels equivalent to 90% RH at the coldest surface in the crawlspace. Further complicating this is the coldest surface may often be determined or affected by the inside thermostat setting.

A crawlspace often exhibits all of the symptoms of a room with an oversized air conditioner. The conditioned floor above, cool soil and cold ductwork can address the sensible load. But what is handling the latent load? With a vented crawlspace, the

latent load can be huge. In a sealed crawlspace, a small dehumidifier or other means can be used to address the latent loads.

A System View. So far, I have addressed some of the overall myths about venting crawlspaces, using a mixed, humid climate. The original intent of venting a crawlspace is to prevent conditions for fungal growth and peeling paint. Since a crawlspace is an integral part of the building, venting a crawlspace can affect other aspects of the building.

Much progress has been made recently in reducing the infiltration of outside air into buildings. Infiltration of summer air increases both latent and sensible loads, while infiltration of winter air increases heating loads. Infiltration of summer air increases indoor humidity levels, which increases wood moisture.²² Hardwood flooring can cup, and windows and doors can swell and stick. In winter, infiltration decreases indoor humidity levels, often to the point where additional humidification is needed. Hardwood floors develop gaps, and windows and doors warp. Framing shrinks, resulting in cracks in walls, ceilings and panels. If we put so much effort into reducing infiltration into the living space, why shouldn't we do the same to the crawlspace since it is also an integral part of a building?

From an energy standpoint, venting a crawlspace does not make sense in any climate zone. In the winter, an unconditioned crawlspace is warmer than outside. Bringing in additional cold outside air only tends to make the crawlspace and everything in it colder, and increase heat loss. Many people 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 crawlspace and increase both the latent and sensible cooling load. Where ducts are installed in crawlspaces, venting increases the energy loss from the ducts. These loads are now presented in Tables 7G – 7I of the Air Conditioning Contractors of America's Manual J 8th Edition.²³ Summertime condensation that wets duct insulation will also significantly increase the energy losses from ducts.

Summary

A research basis for current crawlspace ventilation requirements does not exist. The houses we build today are not the same as when current crawlspace ventilation guidelines were established. Using vent net free areas to provide code-required ventilation openings doesn't provide anything close to a consistent ventilation rate. Venting will reduce crawlspace moisture levels only within significant constraints. Venting in the summer can easily add moisture or increase relative humidity in a crawlspace (and the whole house). In winter, venting will help dry a crawlspace (and the house), sometimes to a detrimental extreme. Venting a crawlspace will increase energy loads.

Venting may help address elevated crawlspace moisture conditions in some climate zones. But the potential energy penalties, effects of summer wetting vs. winter drying, the potential for extended period of time in any climate zone where venting may not suffice, and the ease at which closed crawlspaces can func-

tion all weigh against continuing to build vented crawlspaces.

Handling Crawlspaces. A crawlspace should intentionally be made as either part of the inside or part of the outside. If left outside, the floor system over the crawlspace should be addressed just like walls: fully insulated with moisture and air barriers. If made as part of the inside, the building envelope gets pushed outward to include the crawlspace. The soil and foundation walls then become the plane for insulation and moisture and air barriers.

Addressing moisture issues is the first priority in a crawlspace whether it is open or closed. Exterior water must be directed away from the foundation with proper grading of the lot and proper handling of roof runoff. Crawlspace 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. In some instances, a dehumidifier is needed in the crawlspace because of the complexity of home designs and the psychrometrics involved. **Note:** Naturally vented combustion devices cannot be used in sealed crawlspaces.

My proposed building code for crawlspaces would include:

- “Where AC system evaporator coils are installed in an enclosed crawlspace, an auxiliary drain pan and float kill-switch are to be installed under the system.”
- “The space under attached decks and porches with non-watertight decking cannot be open to the crawlspace.
- “Where the crawlspace is enclosed by continuous wall sections, the soil must be covered 100% with a 6-mil poly or better vapor retarder that is continued up the exterior foundation walls to the level of the outside soil.
- “Where the house is to be air conditioned, the crawlspace must be unvented or the underside of the floor system must be airtight with an air retarder system such as spray foam, sealed rigid sheathing, air barrier membrane or similar system. (This would cover houses on open piers as well, and allow vented crawlspaces.)
- “Where air-conditioning ducts are run below the level of the floor joists, the underfloor plenum must be unvented.
- “An alarm system must be provided in the sealed plenum or sealed floor system to alert to elevated moisture levels due to plumbing leaks, etc.
- “Where expected crawlspace moisture cannot be handled by convection or diffusion through the floor over the crawlspace, a mechanical system to control crawlspace humidity levels is required. Other circumstances may warrant a humidity control system as well.

ASHRAE is to be commended for removing crawlspace ventilation guidelines from *ASHRAE Handbook—Fundamentals*. Now we need to push further towards making crawlspaces into controllable environments that allow better protection of the structure and better, more economical control of the indoor environment.

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