THE SCARY Crawl Space

by David Hales

Depending on where you live, critters from snakes and rodents to spiders, bugs, and armadillos may have taken up residence in your crawl space. Add a little water—or even a lot when flooding occurs—and mold and rot create indoor air quality (IAQ) problems and structural deterioration. Oh, and did I mention that soil gases like radon or methane can find their way into your house through the crawl space? Research has shown that whenever it's warmer inside your house than outside, the buoyancy of the rising warm air in the house sucks air into your home from the crawl space. In heating-dominated climates, 40% or more of the air you breathe in your home originated in your crawl space. Definitely scary—and it's dark down there.

We build crawl spaces because they are cheaper to build than basements, or because ground conditions make building a basement impractical. A crawl space can also provide service access for plumbing, electrical, and heating-and-cooling systems.

NEW TRADITION HOMES

A well-sealed and insulated conditioned crawl space in a new home.

WHICH CRAWL SPACES WORK WHERE?

In recent years, Building America and others have done a lot of research around the country on crawl spaces. By looking at this research, we can learn a lot about which crawl space configuration works where.

Historically, most crawl spaces have been vented to the exterior (see "Definitions" and "Codes"). In some climates—especially with the introduction of central A/C—this can cause problems. In climates with extended periods of hot-humid weather—this includes the Southeast and most of the Northeast and Midwest—closed crawl spaces are the best option. Under hot-humid conditions, warm, moist air enters the vented crawl space from outside and can condense on the cooler surfaces. These cooler surfaces are created within the crawl space by the shade provided by the building and the moderating effect of the contact between the crawl space and the ground. Even when condensation doesn't take place, relative humidity (RH) above 80% for an extended period can support mold growth and eventually rot wooden structural materials. Add A/C to the house, and the floor above the crawl space becomes even cooler—and any ductwork in the crawl space creates an added risk of condensation.

In closed conditioned crawl spaces, insulation is normally placed around the perimeter and not in the floor. With perimeter insulation, the house is coupled to the cooler temperatures of the ground, and this can reduce the overall amount of A/C needed to cool the house. When closed conditioned crawls are used in heating-dominated climates, this same ground coupling can actually increase the heating load of a house, but that may cost very little compared to the cost of damage done by moisture brought in by venting.

In the drier regions of the West, and even—surprisingly—in the marine climates of the Northwest, vented crawl spaces work acceptably most of the time. The hot-dry conditions in summer and the cold-moist conditions in winter do not cause the same problems that hot-humid conditions cause in the rest of the country. In a vented crawl, the insulation should be placed in the floor above the crawl space, properly supported, and in contact with the floor above. There should be no air space between the insulation and the floor.

In colder climates, where basements are traditionally the norm, closed conditioned crawl spaces may be the best option to protect freeze-sensitive plumbing systems.

DUCTS IN CRAWL SPACES

HVAC ductwork can have a significant impact on the crawl space environment. From an energy perspective, well-insulated, well-sealed ducts work best in a vented crawl space. While sealing and insulating ducts in a vented crawl is always beneficial in terms of energy savings, there can be unintended consequences that may increase the risk of condensation in heating-dominated climates. In this climate, heat loss to the crawl may help prevent condensation by maintaining higher and more stable temperatures. In cooling climates, properly sealed and insulated ducts—including a vapor barrier—can reduce the risk of condensation on cold supply ducts.

In closed crawl spaces, where the air and vapor barriers and the thermal boundary are maintained at the crawl perimeter, the energy benefits of sealing and insulating ductwork are minimal.

INSULATION MATERIALS AND PROPER ALIGNMENT OF AIR AND VAPOR BARRIERS

Walls get wet—especially in below-grade crawl spaces. Below-grade walls cannot dry to the exterior, so to avoid problems, they must dry to the interior. Vapor barriers on the interior side of batt insulation can create real problems. Figure 1 shows the RH inside a fiberglass batt on the interior of a crawl space perimeter wall. The batt in the figure has a vapor barrier on the interior surface that traps moisture. In the summer, the assembly is continuously at the dew point, or 100% RH. In the winter, the RH drops, but it is still above 90% almost the entire time. Totally unacceptable!

Removing the interior vapor barrier from the insulation allows drying to the interior of the crawl space, but this may also allow additional condensation on the cold surfaces of the perimeter wall. The best solution in the Figure 1 example is to use rigid-foam insulation with sealed seams, or to use spray foam. This provides a continuous air and vapor barrier with a material that isn't susceptible to moisture damage. The insulation thickness should be determined by the amount of insulation required for thermal performance.

DO VENTED CRAWL SPACES EVER REALLY WORK?

The results of tests conducted in cold-dry West and Northwest marine climates suggest that vented crawl spaces can work. The Washington State University Extension Energy Program (WSU-EEP), as part of its work for Building America, monitored four test houses in Vancouver and Moses Lake, Washington, for over a year and found that the vented crawls rarely, if ever, reached dew point and that they remained above 80% RH only for brief periods of time. Monitoring of wood moisture content in the crawls showed no moisture buildup, and while the vented crawl spaces in the test houses did maintain higher RH levels on average than found in closed crawl spaces, the RH levels were not a problem. See Figures 2 and 3.

In any crawl space, site water must be properly managed. Vented crawls should be considered only where there is little risk of condensation and no prolonged periods of high RH. Where the average ground temperature is above the average seasonal outdoor dew point, crawl temperatures should be above dew point most of the time, and moisture introduced by venting shouldn't be a major problem (see Figure 5).

Cold Sealed Perimeter Insulation % RH

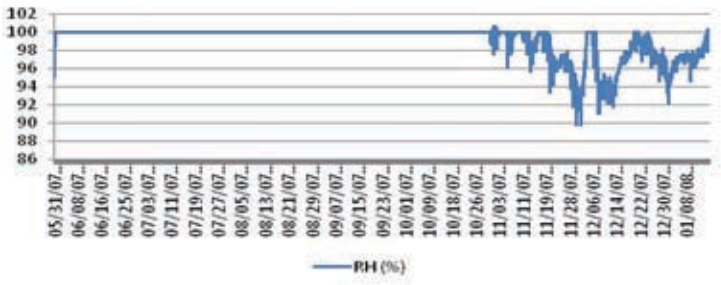
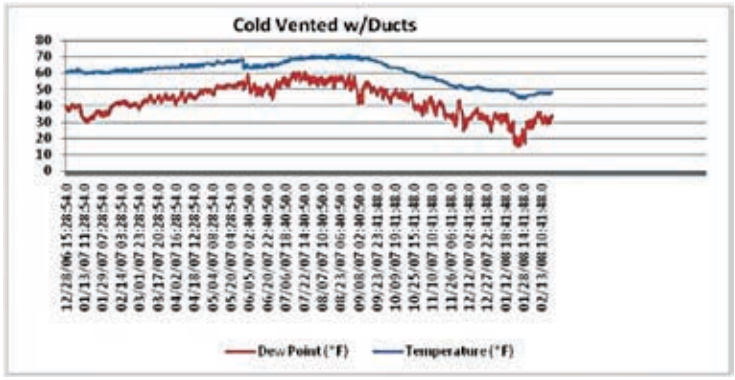


Figure 1. High relative humidity in fiberglass batt with warm side vapor barrier as wall insulation in a closed crawl space. (Author's data.)

Cold Vented with Ducts



Avgerage Temp (°F)	Minimum Temp (°F)	Maximum Temp (°F)	Avg. Temp Above DP Temp (°F)	% Time at DP	% Time Above	Avg. % RH
61	44.7	71.5	17	0	0.09	53

Figure 2. In the Northwest vented crawls rarely, if ever, reached dew point, and they remained above 80% RH only for brief periods of time. (Author's data.)

Definitions

Crawl spaces can be vented or closed. Crawl spaces without venting are usually referred to as unvented, closed, or sealed. In this article I use "closed" to refer to any crawl space without passive vents from the crawl to the exterior.

Vented crawl spaces have the air and vapor barriers and the thermal boundary of the house in the floor assembly above the crawl space and provide passive venting from the crawl to the exterior. Most codes require a minimum of 1 square foot of net free vent area for each 150 square feet of crawl space; they also require that vents be placed to provide cross-ventilation.

Closed (unvented) crawl spaces come in a variety of configurations. Some are actively conditioned; some have an intentional passive connection to the conditioned part of the house; and in extreme cases, some have an active dehumidification system (see "Dehumidifier Metering Study," p. 44). Insulation is normally at the perimeter of the crawl with a continuous air and vapor barrier on the ground and running up the perimeter wall to the sill plate or to a termite inspection strip, where required.

Closed power-vented crawl spaces generally look like closed unconditioned crawl spaces but include an exhaust fan to draw air from the crawl space to the exterior. The primary advantage of this system is its ability to reverse the stack effect and decouple the air in the house from the crawl—especially during the heating season. Codes generally require 1 CFM of power venting for every 50 square feet of crawl space area.

RISKS IN CLOSED CRAWL SPACES

WSU-EEP conducted tracer gas testing in vented and closed power-vented crawl spaces in a marine climate (Vancouver, Washington) in December 2006. The results showed that vented crawls provide a significantly higher air change rate with the exterior than closed crawls. Vented crawls averaged about 3.5 ACH, while the closed power-vented crawls averaged about 1 ACH. Additional radon testing showed that radon levels in the closed crawls—with a relatively low dilution rate—were roughly 10 times the levels measured in the vented crawls. The tracer gas testing also showed that roughly 40% of the air in the homes with vented crawl spaces that we tested originated in the crawl space. In the closed power-vented crawls that we tested, the stack effect was substantially offset by the venting—less than 5% of the house air originated in the crawl spaces. Because the power venting had substantially decoupled the house from the crawl, radon levels within the living area of the homes were still below EPA action levels.

Reversing the stack effect with power venting should improve indoor air quality (IAQ) by decoupling the house from the crawl space. The price of decoupling is the added cost of running and maintaining the crawl space exhaust fan. In closed crawls without power venting, or if the exhaust fan fails, the lower dilution rate creates the risk of a higher concentration of pollutants entering the house from the crawl.

Wood Moisture Content

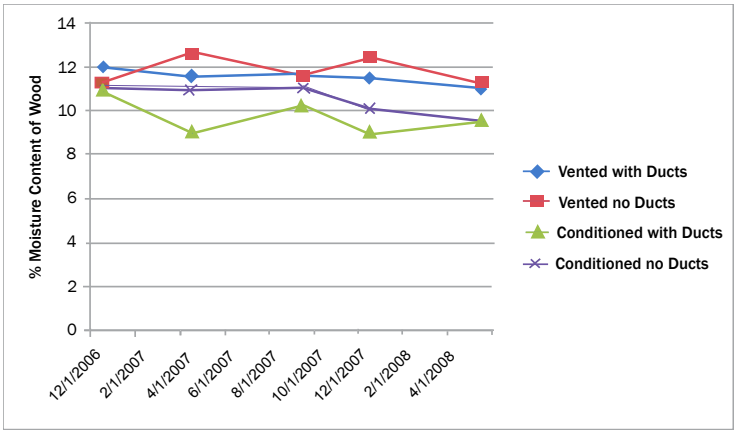


Figure 3. Wood moisture content as measured in vented and closed crawl spaces with and without HVAC ductwork in a marine climate. (Author's data.)

Codes

From the **2009 International Residential Code (IRC)**, the applicable sections on vented and closed crawl spaces are Section R408.2 Openings for under floor ventilation, and Section R408.3 Unvented crawl space.

The **2009 International Energy Conservation Code (IECC)** includes requirements for insulation levels on crawl space walls based on climate zone. See Section 402.2.9 Crawl space walls.

The IRC does not require crawl space ventilation if all of the following conditions are met:

1. A ground cover is provided. This ground cover must include a class 1 vapor retarder with lapped sealed seams, extending at least 6 inches up the stem wall and attached to the wall.
2. The crawl space is conditioned. Conditioning is direct if the crawl space is supplied with conditioned air at the rate of 1 CFM per 50 ft^2 of crawl area. Conditioning is induced if the crawl space air is power vented to the exterior at 1 CFM per 50 ft^2 of crawl area and draws conditioned air from the house to the crawl through a transfer grill or duct.
3. The perimeter walls are insulated (according to section N1102.2.9 of the IRC).

TAMING THE BEAST

Here are some general tips for taming the beast:

- If the crawl space has a dirt floor, always maintain a continuous vapor barrier on the floor. Use 6-mil black polyethylene sheeting or better.
- If there is a high water table or periodic flooding, make sure that the crawl space is sloped to drain to a sump, which can be drained or pumped to daylight.
- Make sure the outside grade slopes away from the building and that gutter downspouts take water away from the foundation. Don't water your crawl space when you water your landscaping.
- Maintain the perimeter of the crawl space to prevent access by critters; seal holes, penetrations, and access points and screen all vents.
- Clean it up. Remove construction debris—especially wood, cardboard, or other organic material in contact with the ground.
- Don't vent dryers or other appliances into the crawl; make sure that any ductwork is well sealed and well supported and that the ducts terminate outside the crawl space.
- Don't use your crawl space for storage.
- Use radon-resistive building practices in radon-risk areas, as recommended by EPA on their web site.

For closed conditioned crawl spaces:

- Insulate the perimeter walls to the level suggested for above-grade walls in your climate.
- Exterior perimeter wall insulation is a good option to consider, especially in new construction. It eliminates the problems of moisture management associated with interior wall insulation and provides the possible benefits of additional thermal mass within the structure. The downside is you have to protect the insulation from termites and the above-grade portion of the insulation from deterioration caused by weather exposure.
- When insulating a crawl from the interior, you should protect rim joists from condensation with foam insulation.
- Use water-resistant insulating materials, such as rigid-foam board or spray foam properly protected to meet fire ratings. Avoid using air-permeable insulation, such as fiberglass batts or spray-on cellulose.

- Power venting a sealed crawl space to the exterior can reduce the movement of air from the crawl space into the house. This can improve IAQ, but at the added cost of operating and maintaining the exhaust fan.

For vented crawl spaces:

- Insulate the floor above the crawl space to between R-30 and R-38.
- Provide adequate venting (1 square foot net free area venting per 150 square feet of crawl space).
- Arrange vents to provide cross-ventilation.
- Insulate the ductwork for any heating or cooling system to at least R-8.
- Maintain a continuous air and vapor barrier on duct insulation where there is a risk of condensation.
- Protect plumbing pipes from freezing. Insulate the pipes and shelter them from excessive air movement near vents. Well-insulated and sheltered pipes shouldn't require the additional use of heat tapes for freeze protection. Heat tapes can use large amounts of electricity, and improperly installed heat tapes may be a fire hazard.

Conventional wisdom on crawl spaces over the years has ranged from always vent to always seal. As with many things, it's not that simple. It really depends on local conditions. Properly designed and installed closed crawl spaces can be made to work well almost everywhere. On the other hand, vented crawl spaces are not suited for hot-humid regions where there is a risk of condensation. Closed crawls also come with some risks. Without venting there is a smaller dilution factor and the possibility of higher pollutant concentrations. If you power-vent a crawl space the fan must be used and maintained. In heating-dominated climates, there may be an increased heating load in a closed crawl.

When working with a crawl space, always consider local conditions. Evaluate what has worked in your community and remember that the best crawl space design won't make up for poor water management on the site.

>> For more information:

To learn more about conditioned crawl spaces, go to www.energysavers.gov/your_home/insulation_airsealing/index.cfm/mytopic=11480.

and www.energycodes.gov/rc/Vol3_BasementInsulation.pdf.

To learn more about radon, go to www.epa.gov/radon/ and www.epa.gov/radon/pdfs/buildradonout.pdf.

The research discussed in the article will be published in the transactions of the 2010 Building Thermal Envelope Conference: Hales, Lubliner and Gordon; Vented and Conditioned Crawlspace Performance in Marine and Cold Climates of the Pacific Northwest.

David Hales *is an experienced contractor, building scientist, and technical trainer. He is currently a building systems and energy specialist at Washington State University and provides technical support for the Energy Star Homes Northwest Program, Building America, and utility-based programs in the Pacific Northwest.*