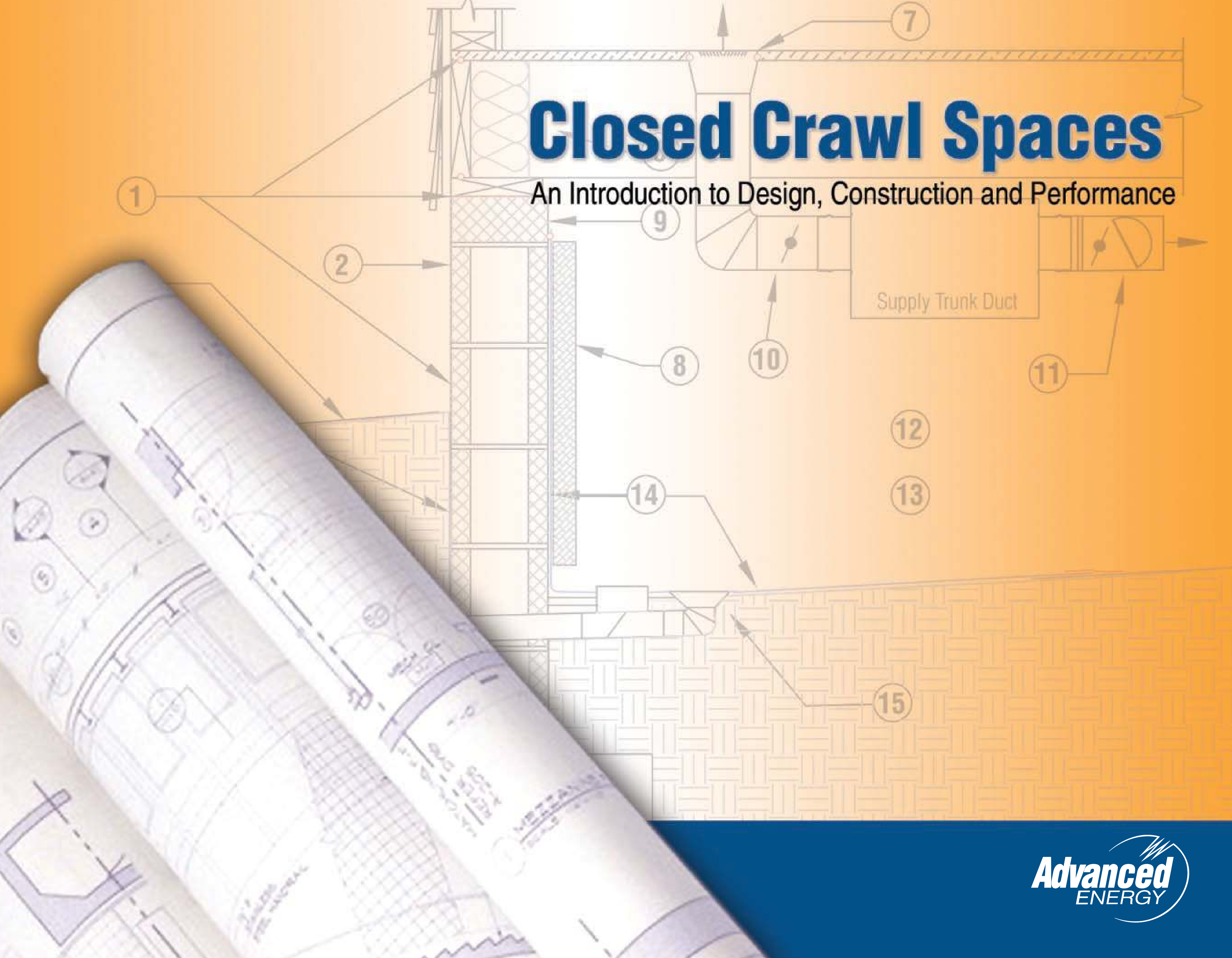
Closed Crawl Spaces

An Introduction to Design, Construction and Performance



Advanced ENERGY

Closed Crawl Spaces

An Introduction to Design, Construction and Performance

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INTRODUCTION

This guide is an introduction to the design components, field implementation, code requirements, and measured performance of crawl space construction in central and eastern North Carolina. While a short section describes steps that builders or property owners can take to improve traditional wall-vented crawl spaces, the majority of this guide focuses on a new design: closed crawl spaces that are not ventilated with outside air.

Many of the guidelines and much of the background information presented in this guide comes from the results of an ongoing Advanced Energy research project, started in the eastern North Carolina town of Princeville in 2001. The Princeville research project compares the performance of wall-vented and closed crawl space foundations in a controlled study. Additional recommendations come from other Advanced Energy research projects, including investigations of crawl space failures, and from collaboration with closed crawl space installers across North Carolina.

The Princeville research project has shown that closed crawl spaces do a much better job of controlling crawl space moisture levels than do well-built wall-vented crawl spaces. While relative humidity in the wall-vented crawl spaces exceeds 80% for the majority of the spring and summer months, the Princeville closed crawl space designs control relative humidity below 65% during the same period. The research also shows that the homes built on closed crawl spaces save up to 15% on annual energy usage for heating and cooling when compared to the homes built on wall-vented crawl space foundations.

The Princeville project findings supported a 2004 revision of the North Carolina residential code that governs crawl space construction. The new code language is currently available for use and will be enforced with the next print release of the North Carolina code in 2006. Design guidelines that are based on the requirements of this new code language are highlighted in the guide.

Visit **www.crawlspaces.org** for complete research reports, short videos on key concepts, article links, or to obtain an electronic copy of this document. When online versions of code language related to closed crawl spaces are available, they will also be linked.

Why is the new design called a "closed" crawl space?

This guide uses the term "closed" to describe the alternative to a wall-vented crawl space design, but several other terms are commonly used. The term "closed" is used in the North Carolina building code. Here is a brief background on why "closed" was chosen over other options:

"Unvented"

In fact, several closed crawl space designs are vented, just not with outside air. Two common techniques are ventilation with conditioned air from a duct system and ventilation with conditioned air from the living space.

"Sealed"

The North Carolina residential code does not define a closed crawl space as requiring a sealed vapor retarder, which Advanced Energy recommends. Installers can differentiate this improved design from other closed crawl space designs by calling it "closed with a sealed liner." Furthermore, it is impractical to perfectly air-seal a crawl space. The term "sealed crawl space" suggests an extreme level of air sealing and implies that any small, unsealed air leakage path provides grounds for failing an inspection. In Advanced Energy's experience, it is inappropriate to require code officials to use such a stringent, yet vague, standard for enforcement.

"Conditioned"

Not all closed crawl spaces are conditioned. A closed crawl space that is truly conditioned must have insulation located at the perimeter wall and a thermal barrier covering any foam plastic insulation. Unless specifically designed to do so, closed crawl spaces generally will not maintain the minimum 68° F (20° C) winter temperature required to qualify as a "conditioned area" as defined in the North Carolina (and International) residential code.

The words "closed," "sealed," "unvented" or "conditioned" will likely continue to be used interchangeably to refer to a variety of crawl space designs that do not have ventilation with outside air. Designers, installers, and code officials will need to make sure that the chosen specifications and requirements are clearly understood, whichever name is used.

Background

Crawl space foundations are widely used in building construction throughout the United States, with approximately 250,000 new homes built on crawl spaces every year and an estimated 26 million such homes already in existence. They are especially common in the southeast, where they are found in over 9 million existing homes and around 70,000 new homes per year.

Crawl spaces are inexpensive to build, functional in terms of providing a level foundation for flooring on sloping sites, and convenient spaces in which to locate plumbing, electrical lines, and ductwork for heating and air conditioning systems. Unfortunately, traditional wall-vented crawl spaces can also host a variety of serious moisture and insulation problems.

It is an all too common experience in the building professions to enter a wall-vented crawl space in the spring or summer and find beads of moisture in floor insulation, high wood moisture content, visible mold growing on surfaces, condensation on truss plates, plumbing pipes, air conditioning equipment or ducts, and in some cases, rot in the wood framing. Homeowners complain of high humidity, musty odors, buckled hardwood floors, and mold damage in the home above. Builders, mechanical contractors and insulation contractors routinely bear the brunt of these complaints.

Since the 1940s, residential building codes and conventional wisdom have prescribed passive ventilation with outside air as the means for providing crawl space moisture control. However, in the humid southeastern U.S., this prescription typically contributes to the moisture problems listed above instead of preventing them.

The expense of moisture repairs and the increase in complaints and legal action related to mold growth in homes have made homeowners, property managers, tenants, and the construction industry much more aware of the need to control moisture in homes. This awareness is helping to drive demand from a growing number of consumers and builders to invest the additional effort to incorporate closed crawl space systems in both new and existing homes. The moisture control provided by a properly closed crawl space can dramatically reduce the risk and associated liability of mold and moisture damage in the southeastern climate.

As a performance goal, crawl space foundations should certainly be free of rot. Ideally they should also minimize the conditions that lead to condensation and mold growth. While well built wall-vented crawl spaces may be able to control rot in the southeast, they cannot maintain relative humidity below the 70% threshold that supports mold growth and they routinely experience condensation on a variety of surfaces in the crawl space. Closed crawl spaces can maintain relative humidity below the 70% target and dramatically reduce the potential for condensation on surfaces in the crawl space.

The key components of a closed crawl space system work in tandem to control the variety of water sources that affect crawl spaces:

- Exterior water management prevents intrusion of liquid water
- Air sealed walls minimize the entry of humid outside air
- Vapor retarders minimize the evaporation of water from the ground or perimeter wall
- Mechanical drying systems provide ongoing, active removal of water vapor
- Drains or pumps remove water coming from plumbing leaks or floods

Audience

This guide is intended to provide useful information to a broad range of stakeholders in the residential construction industry.

For builders and closed crawl space installers, we hope this reference provides effective guidance towards good design and implementation of closed crawl spaces, with tips about pitfalls to avoid and available alternatives. The background information on code development and field research is offered to help you gain acceptance of your closed crawl space designs by code officials and sub-contractors.

For code officials, we hope that the discussion on the development and components of the North Carolina residential code provides a resource for understanding the newly available code language. Outside of North Carolina, we offer this information as a resource for the development and adoption of similar code language to meet the needs of other regions.

For property owners and private home inspectors, we hope that this guide provides knowledge for assessing existing wall-vented or closed crawl spaces as well as tools for specifying and purchasing new closed crawl spaces.

Using this Guide

The closed crawl space designs and processes presented in this guide are not the only ones that are acceptable. They are simply examples that have performed successfully in Advanced Energy field testing or in projects by professional installers in North Carolina. There are many other closed crawl space designs that can perform acceptably and that meet the requirements of the North Carolina residential building code. As we verify the performance of additional designs and techniques we hope to add them to this reference, along with updated information gained from long-term monitoring.

It is important to keep in mind that the designs and techniques presented in this guide are not definitive specifications. If you are a builder, property owner, or other contractor planning to install closed crawl spaces, we invite you to adjust these designs and processes to your local site conditions, code requirements, home design, construction processes and occupant needs to ensure success. Remember that closed crawl spaces share the same vulnerability of other foundation types or residential water control components: Just like basements, slabs, window and roof flashings, foundation waterproofing or plumbing, a closed crawl space that is installed improperly can do more harm than good.

Please note that the sample designs and processes discussed here have been tested primarily in low-volume construction of closed crawl spaces in small homes with simple foundation plans. Builders of the more complex homes typically found in mainstream residential construction will likely need to adjust the sample construction process, especially if they build in high volume. Future Advanced Energy research will focus specifically on the delivery of closed crawl spaces in the production builder environment.

We anticipate that the performance improvements seen in closed crawl spaces in the Princeville project will translate very well to similar homes throughout the southeastern U.S. Future Advanced Energy research will also

A view of the homes in the Princeville research project. Six homes are located on each side of the same street.

confirm whether closed crawl spaces deliver similar improvements for moisture control and energy use in homes of different geometry in different climates.

The Ventilation Myth

Why doesn't ventilation with outside summer air dry out a southeastern crawl space? The traditional method of controlling moisture in crawl spaces is to provide passive ventilation with outside air. However, wall-vented crawl spaces routinely experience moisture problems like condensation, surface mold growth, high wood moisture content, or wood rot. The typical "cure" for such problems has been to add more ventilation, either in the form of additional ventilation openings to the outside or by installing a fan or multiple fans to intentionally move more outside air through the crawl space. Advanced Energy research has confirmed over the long term what we and other building scientists have measured repeatedly in previous short-term investigations of crawl space failure: *the outside air contains more water vapor than the air in the crawl space during the warm seasons, and has no potential to dry the crawl space.* Instead, the outside air ends up contributing water vapor to the crawl space.

To understand why, first we need to define three properties of air: temperature, relative humidity, and dew point temperature. Temperature is the most familiar property, and is simply a measure of the heat in the air. But what exactly is relative humidity?

At any moment, the air around you contains a certain amount of water vapor. At the current temperature, there is also a limit to how much water vapor that air can contain before the water vapor condenses into liquid water… better known to us as "condensation" or "rain". Relative humidity is the ratio of actual water vapor in the air to the maximum amount of water vapor that the air can possibly hold at the current temperature. So, the relative humidity changes if either the amount of water vapor in the air changes or the temperature of the air changes. If the relative humidity in one location is 90% and the relative humidity in another location is 40%, you can't tell which location has more water vapor unless you also know the air temperatures. Cold air can hold less water vapor than warm air, so if air gets cooler without losing water vapor, its relative humidity increases.

Dew point temperature, often just called "dew point," is a more direct indication of how much water vapor is in the air. If you change the temperature of air without adding or removing water vapor, the dew point stays the same. If you remove water vapor, the dew point goes down whether or not the air temperature changes. If you add water vapor, the dew point goes up whether or not the air temperature changes. As you might guess, the dew point measurement tells you the temperature at which the water vapor in the air will condense into liquid water, either because the air cools down to the dew point temperature, or because the air comes into contact with a surface that is cooler than its dew point temperature.

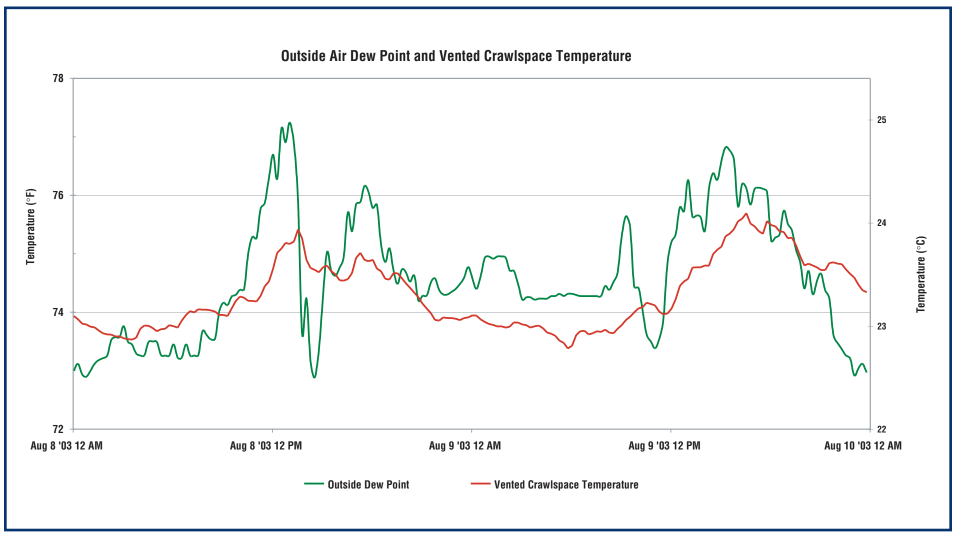
Psychrometric charts and slide rules allow you to calculate the unknown third property of air if you know the other two, for example, calculating dew point when the air temperature and relative humidity are known. They can calculate the change in one property if another property is changed. You can generally obtain a psychrometric chart or slide rule from manufacturers of air conditioning or dehumidification equipment, and there are several on-line psychrometric calculators on the Internet. We have provided a simplified version of the ACCA (Air Conditioning Contractors of America) psychrometric chart in Appendix B.

As an example, let's look at the properties of air on a mild summer day in North Carolina. Let's say it's 85° F (29° C) outside and the relative humidity is 60%. Conventional wisdom tells us that this air is warm and dry, so it should be great for ventilating a crawl space. Using a slide rule or chart, we determine that the dew point of this air is 70° F (21° C), which is relatively dry compared to typical conditions. Now let's assume that air goes into the crawl space. A typical summertime temperature in a wall-vented crawl space is 73° F (23° C), so the outside air cools down. No water vapor has been removed, so the dew point stays at 70° F. The temperature has dropped, so we need to use the psychrometric chart to find the new relative humidity… and now it's a whopping 90%! Furthermore, the temperature of the ductwork, plumbing, and bottom side of the insulation are below 70° F, so the water vapor will condense on those surfaces. It may even condense on the crawl space floor or on the wood framing! It turns out that ventilating with the outside air adds moisture to the crawl space, it does not dry it out.

Summer moisture conditions in central and eastern North Carolina are often much wetter than the example. In the record-setting drought summer of 2002, the outside air dew point exceeded 70° F 44% of the time at Advanced Energy's Princeville research site. In the record-setting rainfall year of 2003, the outside air dew point exceeded 70° F 72% of the summer and was higher than the temperature inside the crawl space almost 20% of the summer.

After noticing light mold growth on floor joists in a wall-vented crawl space, a contractor recommended installation of a powered crawl space ventilation fan to "dry" the crawl space.

After installation of a powered crawl space ventilation fan, so much water condensed on the floor joists that rot set in and destroyed the lower portion of the joists.



This data from the Princeville site shows that for most of a very humid 48-hour period, the outside dew point exceeds 74° F (24° C) and is higher than the temperature inside the crawl space. If this outside air enters the crawl space, the water vapor will condense on surfaces inside. Note that this was not a period of very rainy weather; records indicate only 0.2 inches of rainfall over this entire 48-hour period.

Section 1

Recommended Design Components

Overview

This section presents a variety of design components that meet or exceed the minimum requirements for closed crawl spaces, as specified by the North Carolina residential code discussed in Section 4.

The recommended design components presented here are not the only ones that are acceptable. They are simply examples that performed successfully in the field testing detailed in Section 6, in other Advanced Energy research projects or by professional installers in a variety of locations in North Carolina. There are many other closed crawl space designs that can perform acceptably and that meet the requirements of the North Carolina residential building code.

The design components presented here are not definitive specifications. If you are a builder, property owner, or other contractor planning to install closed crawl spaces, you will need to adjust these design components to your local site conditions, code requirements, home design, construction processes and occupant needs to ensure success.

The dozens of individual components that make up a complete and effective closed crawl space system fall into six general categories of function:

- Moisture management
- Pest control
- Combustion safety
- Thermal insulation
- Fire safety
- Radon safety

This section discusses each category with background information and then specific components. The list of categories follows the order of requirements in the North Carolina residential code. Several specific items, like foundation drainage or foam plastic fire safety, are not in the crawl space code section but are included here in the interest of completeness.

This section uses three symbols to indicate different levels of components:

✔ A red check mark indicates a component that is required by the North Carolina residential code

✚ A green plus sign indicates a component that is recommended by Advanced Energy

★ A gold star indicates an optional component that will provide an extra level of performance or safety

Moisture Management

Moisture management of the finished crawl space is the primary goal of any closed crawl space system, and it involves components both outside and inside the crawl space. Moisture management, for both liquid water and water vapor, uses two basic strategies:

1. Blocking sources
2. Facilitating removal

Note that moisture management during the construction process involves several additional measures which are described in the sample construction sequence in Section 3. We have chosen not to present the components of moisture management in the order used by the North Carolina residential code. Instead, we present them in order of components located outside the crawl space to components located inside the crawl space, since this follows the model of first blocking sources and then facilitating removal.

Moisture Management: Blocking Sources

Roof runoff

✚ Use a system to direct roof runoff away from the house and prevent the runoff from entering the crawl space. This is often a gutter system, but could also be a system of foundation waterproofing, perimeter gravel bed and a drain. Another option is foundation "flashing," for example, a layer of impermeable material like EPDM rubber that extends down and away from the foundation wall below grade for approximately 6 feet.

✔ If sub-surface drain pipes or gutter leaders are used to manage roof runoff, they must not be connected to the crawl space drain. This eliminates the chance that blockages or heavy rains will cause roof runoff to enter the crawl space.

Exterior ground and surface water

✔ Provide site grading around the perimeter of the house with a minimum of 6 inches (152 mm) of fall over 10 feet (3048 mm) of run to direct ground surface water away from the house. Swales or drains may be used if lot lines, slopes, walls, or other barriers prohibit the required grading.

✚ Ensure that landscapers or property owners do not install flower beds, tree mounds, mulch piles or other landscaping features that prevent drainage away from the house. In-ground irrigation systems or yard sprinklers require special attention because they can easily cause a water problem in an adjacent crawl space. Make sure these systems do not put water onto the crawl space walls.

✔ Provide a foundation drain system whenever the exterior grade is 12 inches (305 mm) or more above interior crawl space grade. Keep foundation drain systems separate from crawl space drain systems.

✔ Provide foundation damp-proofing or water-proofing when the exterior grade is above the interior crawl space grade to prevent the flow of water through the wall by capillary action or "wicking."

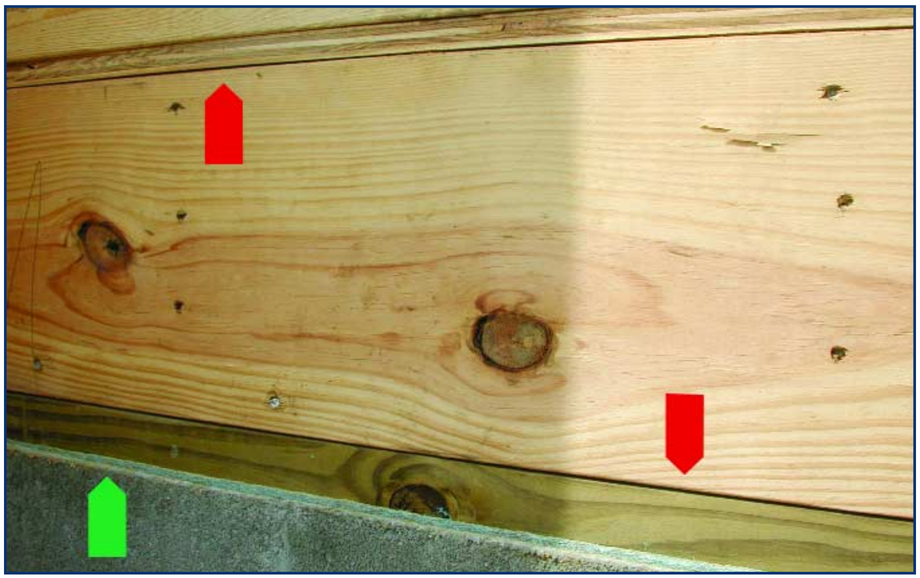
✚ Raise the crawl space grade above the exterior grade to eliminate the need for a foundation drain, damp-proofing or water-proofing.

✚ Protect exterior crawl space access door(s) from roof runoff. For example, if there is no roof runoff system, locate the access door on a gable end wall. Whenever possible, build the bottom of the access at least 4 inches (102 mm) higher than the exterior grade. If raised access is not possible, provide a dam or gravel drain to prevent water entry. Use non-corroding access doors, especially in coastal communities, to prevent deterioration.

The entrance to this closed crawl space is elevated well above exterior grade, reducing the likelihood of water entry in heavy rains or minor flooding. Photo credit: Indoor Environmental Systems.

Humid Air

- ✔ Seal all gaps between foundation wall and sill plate, sill plate and band joist, and band joist and subfloor. Seal penetrations through the crawl space wall for water service, electrical service, plumbing fixtures, ductwork, etc. Use solid blocking and sealants to seal gaps between the exterior wall opening and ductwork for outdoor packaged-unit heating and cooling equipment, if present.
- ✔ Seal connections from the crawl space to areas under attached porches or decks, which are common sites of liquid water intrusion or entry of humid outside air.
- ✔ Houses in an area prone to flooding or designated as a Special Flood Hazard Area (SFHA) by the Federal Emergency Management Agency (FEMA) or the National Flood Insurance Program (NFIP) must have FEMA/NFIP-compliant flood vents in the crawl space perimeter wall. See the "Flood Vents" sidebar for more information.



This foundation wall has an effective gasket between the sill and the masonry wall, but small gaps between the sill plate and the band joist or between the band joist and the subfloor add up to large leak areas. Close these joints with gaskets or sealants as well.
Photo credit: Building Performance Specialists.

When you see packaged unit equipment on the outside of the crawl space…
Photo credit: Healthy Home Environment.

… there are typically large gaps in the perimeter wall around and between the supply and return ducts. These gaps require solid backing materials and sealants for proper air-sealing. Remove any rubble underneath the opening to reduce the risk of damage to the ground vapor retarder.
Photo credit: Healthy Home Environment.

Seal all penetrations in the perimeter wall.
Photo credit: Indoor Environmental Systems.

- When required, choose flood vents that minimize stand-by air leakage.
- Build hollow-block masonry foundation walls with either a continuous top course of solid masonry or the top course of masonry grouted solid to prevent passage of air from the interior of the wall into the crawl space.

Flood Vents

Flood vents are openings in a foundation wall that automatically allow the free passage of flood water into and out of a foundation in order to equalize hydrostatic forces on the foundation walls. When required in a closed crawl space, choose a flood vent model that reduces standby air leakage as much as possible.

The Federal Emergency Management Agency and the National Flood Insurance Program specify the design requirements for flood vents as well as the guidelines for where they must be implemented. The 2000 (and later) International Codes meet these requirements.

To determine if a property is located in a Special Flood Hazard Area (SFHA) and will be required to have flood vents installed, contact your local building inspections department or governing authority. A property survey and elevation certificate may be required before a final determination can be made.

Non-compliance with flood vent requirements can jeopardize a community's ability to participate in the NFIP or to receive a wide range of federal funds for emergency assistance, construction, property loans, and more. For the individual homeowner, insurance premiums may go up significantly when insurance policies are renewed or when a house is sold if the house does not comply with flood vent requirements.

For additional information, refer to Technical Bulletin 1-93, Openings in Foundation Walls, available from FEMA (www.fema.gov, or 800-480-2520) or contact your state's division of emergency management or floodplain management.

This flood vent has a weather strip to reduce stand-by air infiltration and the central panel is insulated with foam. Photo credit: Hazard Mitigation Contractors, Inc.

Evaporation from the ground and perimeter walls

- ✔ Cover all crawl space ground with a minimum 6-mil polyethylene vapor retarder. Lap seams at least 12 inches (305 mm).

Do not leave any exposed earth in the crawl space! Photo credit: Bill Warren.

- Cover the masonry perimeter walls with minimum 6-mil polyethylene vapor retarder, leaving at least 3 inches (76 mm) of exposed masonry at the top of the wall. Mechanically attach the vapor retarder material and seal it to the wall with duct mastic. Common strategies for mechanical attachment include powder-driven nails, pins or masonry screws that hold the vapor retarder up behind a furring strip or wall insulation.

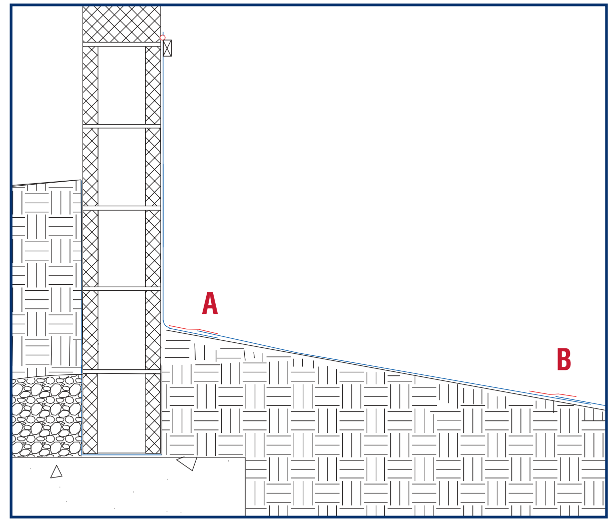
One way to mechanically attach a wall vapor retarder: secure it behind a preservative-treated plywood furring strip attached to the masonry with nails driven through washers. Photo credit: Bill Warren.

This heavy-duty vapor retarder material is mechanically supported by metal pins with cap washers and sealed to the masonry with fiberglass mesh tape and duct mastic.
Photo credit: Indoor Environmental Systems.

- Seal the ground vapor retarder to interior columns at least 4 inches (102 mm) above the crawl space floor.

- Install the ground and wall vapor retarders as a sealed liner by sealing all seams and connections to masonry with fiberglass mesh tape embedded in duct mastic. If you choose to use a tape product to seal seams, ensure that all surfaces are clean before applying the tape and do not subject tape joints to mechanical stress. Both of these situations have caused tape joints to fail in Advanced Energy research houses.

Vapor retarder material is attached with a furring strip three inches (76 mm) below the top of the masonry wall and sealed to the wall with mastic. The wall vapor retarder material is sealed to the ground vapor retarder to form a continuous liner. Penetrations, like the dryer vent in the photo, are completely air sealed. The top of the masonry wall and the front edge of the sill plate have been painted white with mastic to improve inspectability by pest management professionals.



Overlap seams in the vapor retarder material to reduce the chance that liquid water running downhill from the wall or ground will collect against the underside of the sealed seams. Lap the ground vapor retarder on top of the wall vapor retarder (A) and lap downhill sections of vapor retarder over uphill sections of vapor retarder (B).

- If you use unreinforced 6-mil polyethylene (the material most commonly available at home improvement retail stores), protect it with an additional layer of durable material (for example, artificial turf, vinyl runners, or other carpet material) in storage areas or traffic areas, like a service path to mechanical equipment. Consider using thicker, reinforced vapor retarder materials for improved durability and puncture resistance, and to eliminate the need for additional protective coverings.

✔ The ground vapor retarder must be secured to resist movement or tears.

Why does Advanced Energy recommend installing the vapor retarder as a sealed liner?

Advanced Energy recommends the use of a sealed vapor retarder covering the walls and ground because we have field tested this design as part of a system that provided effective crawl space moisture management. Sealing the seams of the vapor retarder material reduces the risk of damage when people move around in the crawl space, and makes it more likely that a water failure like a plumbing leak will be discovered. The sealed liner is not designed to prevent intrusion of liquid water from the ground, but it will make it less likely. Another unintended benefit may be improved resistance to the movement of soil gases into the crawl space.

Choosing to not use a vapor retarder on the perimeter walls will typically result in more moisture entering the crawl space during warm weather. Choosing not to seal the seams of the ground vapor retarder increases the chance that ground will be exposed. Such a system can still perform acceptably if the installed drying mechanism is capable of removing the resulting additional moisture load.

✚ Secure the ground vapor retarder material as necessary to resist movement due to anticipated traffic. Anchor 6-mil polyethylene with sod staples or galvanized spikes through washers or nailing tins on approximately 12 foot (3658 mm) centers. Use additional staples or spikes to secure the vapor retarder in steeply sloped areas or in heavy traffic areas like the crawl space entrance or service paths. Heavier vapor retarder materials in small crawl spaces or in large crawl spaces with intermediate piers may not need any staples or spikes.

Moisture Management: Facilitating Removal

Please remember that moisture still gets into a properly closed crawl space. Ground moisture can wick up through masonry walls or support columns and evaporate into the crawl space. Rain can wick through the perimeter masonry wall or sill plate and evaporate into the crawl space. Wind, duct leakage or other building pressures will inevitably force some amount of humid air through the perimeter wall, since it's impossible to do a perfect air-sealing job. Plumbing failures or floods put liquid water in the crawl space.

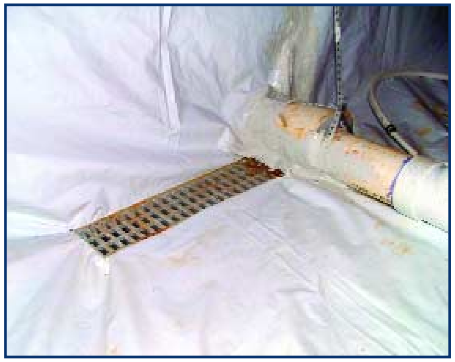
For all these reasons, a closed crawl space needs components that remove both liquid water and water vapor. Duct leakage and diffusion of water vapor to the house above may provide some drying potential for a closed crawl space, but an intentional drying mechanism is required to ensure adequate moisture management.

Some installers and researchers have theorized that the moisture control improvements of closed crawl spaces allow the mechanical contractor to down-size the installed heating and cooling equipment. However, there are few commonly available tools at the time of this writing to calculate the impact of a closed crawl space on the sizing of mechanical equipment for the home.

✔ Grade the floor of the crawl space to one or more low points. Provide a drain or sump pump at each low point to remove liquid water from the crawl space in case of a plumbing leak or other flooding event.

✚ Use a backflow valve in crawl space drains and a check valve in sump pump out-flow pipes to prevent reverse flow of outside water into the crawl space and to reduce the chance of vermin entry. Floor drains with p-traps that connect to the whole-house plumbing waste drain or to a municipal sewer system may allow entry of sewer gases if (when) the trap dries out and pose a risk of sewage backup.

This crawl space drain and backflow valve assembly is ready for installation.
Photo credit: Indoor Environmental Systems.



The finished ground vapor retarder is sealed directly to the drain opening.
Photo credit: Indoor Environmental Systems.

Use sump pumps if desired or when gravity drains are not feasible. This model includes a cap for the housing and an optional liquid water alarm to detect a failure of the sump pump system.
Photo credit: Indoor Environmental Systems.

- ✚ Terminate crawl space drains or sump pump discharges in ways that reduce the risk of damage or blockage. For example, surround the termination with gravel or shrubbery to reduce the risk of soil blockage or damage from lawn equipment.
- ✔ Provide a mechanical drying system to remove water vapor. Six methods are allowed under the NC residential code discussed in Section 4. See the next item for recommended strategies.
- ✚ Use conditioned air from the supply-side ductwork or stand-alone dehumidifiers to meet the requirement for a mechanical drying system. Advanced Energy has field tested both of these methods. See Section 3, Sample Designs and Construction Process, for a detailed description of these two drying mechanisms and discussion of advantages and disadvantages for each.
- ✔ Terminate appliance water discharge pipes (for example, water heater temperature/pressure relief valves, air conditioner or dehumidifier condensate drains, or water softener discharges) to outside, to an interior pump, or to a crawl space drain.
- ✚ Drain appliance discharge pipes directly to outside or to an interior pump, not to crawl space drains. If the backflow valve in the crawl space drain is installed out of level or if there is water in the drain pipe exerting pressure on the backflow valve, appliance discharges may build up significantly inside the crawl space before they can drain out.
- ✚ Include relative humidity monitors or liquid water detectors in the design to inform occupants of the performance of the system.
- ✶ Install auxiliary condensate drain pans with float kill-switches under air handlers or dehumidifiers in a closed crawl space for added security against overflows due to blockage in the condensate line.
- ✔ Terminate clothes dryer exhaust vents to outside.
- ✚ Terminate all kitchen and bathroom exhaust vents to outside.

Pest Control

Two important goals of a closed crawl space design are to

1. Avoid increasing the risk of damage from subterranean termites or other insect pests

2. Provide the ability for pest management professionals to inspect the structure and provide treatment, when necessary.

Under North Carolina structural pest control regulations, pest management professionals are not liable for infestations or damage already present in hidden or obstructed areas when they perform inspections for real estate transactions if the professional identifies such areas on the inspection report. The definition of "hidden or obstructed" includes areas of the building that would require disassembly with tools or removal of pieces or parts of the building to allow for inspection.

For properties under a service contract or warranty, the pest management contractor may be held responsible for any and all damage that occurs to the property after the date of their treatment. This discourages them from contracting on properties with hidden or obstructed areas. In new construction projects, pest management contractors may be reluctant to provide soil pre-treatment, wood pre-treatment, or an alternative pre-construction treatment unless they have sufficient information about the closed crawl space design to believe that they will have adequate access for the pre-treatment or for future inspections or treatments.

Closed crawl space designs must pay particular attention to materials applied on the perimeter walls, since this is a common path for wood-destroying insects from the ground to the structure. It is not acceptable to drape insulation or vapor retarder materials from the band joist or sill plate to the crawl space floor because this prevents inspection.

✔ Provide a termite inspection gap of at least 3 inches between the top of any wall vapor retarder material and/or perimeter wall insulation and the top of the perimeter masonry wall. Vapor retarder or insulation materials must not contact any wood framing.

This crawl space under construction has careful detailing at all beam pockets to maintain the termite inspection gap at every interface of masonry and wood.
Photo credit: Building Performance Specialists.

✔ Provide a clearance or wicking gap of at least 3 inches between the bottom of any perimeter wall insulation and the crawl space floor surface.

✔ When the perimeter wall of a closed crawl space is insulated, the band joist must also be insulated.

❍ The use of rigid foam on the band joist will seriously impair visual or physical inspection ("probing" or "sounding") of the band by a pest management professional, because the foam may be damaged in the process or impossible to replace in its original condition. Foam insulations with low (< 1 perm) permeability to water vapor will reduce the ability of the band to dry to the crawl space, but would also reduce the potential for condensation on the band when the band is cold.

❍ Insulating the band joist with faced batt insulation, with the vapor retarder facing towards the inside of the crawl space, facilitates inspection or treatment by a pest management professional since it is more easily removed and replaced without damage. This strategy allows some drying of the band joist to the crawl space during the cooling season, but may increase the chance of condensation on the band when the band is cold. The facing material may need to be fire-rated for direct exposure.