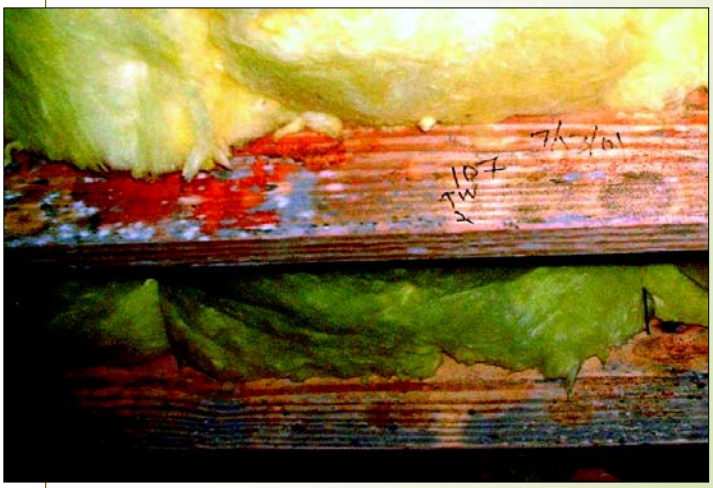
Crawl Space Mold

Liability or Business Opportunity?

Are you at a loss for what to do when you encounter mold in a crawl space? Here's a review of ground-breaking research that's been conducted in North Carolina.

By Bruce Davis and Bill Warren

In the past several years, mold has emerged as a major issue for the entire building industry, as well as the pest management industry. The issue stems from thousands of insurance claims and lawsuits, including successful, multi-million dollar settlements, that identify building mold as a health problem for tenants and homeowners. Most building professionals agree that the area in the home most prone to growing mold is the typical crawl space fitted with foundation vents (wall vents). Pest management companies are vulnerable to mold liability because of the simple fact that they spend so much time in crawl spaces. Consequently, every pest management business needs to know more about mold, both from managing liability, as well as developing a new business opportunity: crawl space mold and moisture management.



This colorful mold bloom developed during a three-day period of rainy weather in a wall-vented crawl space.

Almost anyone who goes into crawl spaces has seen mold growing on the wood joists, sills, support beams and subflooring. Generally these are surface molds that range from light spotting and coverage to thick mold blooms that cover large surface areas. During rainy and humid weather, wall vented crawl spaces often become damp with moisture levels exceeding 70 percent relative humidity for long periods of time. When this happens, the excess moisture encourages mold to grow on the wood and on any other organic material that is in the crawl space.

Crawl spaces in humid climates — like the Southeast, the Gulf Coast states and Northwest regions — are most prone to surface mold problems. Crawl space mold is most readily noticed when it grows on the floor joists and joist beams, but molds can grow everywhere in the crawl space, including on the exposed ground surface and settled dust, as well as on plumbing lines and HVAC ductwork. As soon as the floor frame is covered with subflooring, a crawl space can trap moisture and become an ideal environment to grow mold. Now that most homes are air conditioned, the crawl space mold problem has worsened. Crawl space moisture readily condenses on cold floor framing and ductwork in air-conditioned homes.

In the past, the sight of crawl space mold has not been an issue. However, because of the news media's recent heightened attention to mold, lawsuits, insurance claims, and air quality concerns of homeowners and tenants, crawl space mold has the potential to become a major management and liability issue — particularly for the pest management industry. An increasing number of home inspectors are noting the presence and amount of crawl space mold in their inspection reports. Treating and removing crawl space mold is turning out to be expensive. This is difficult and labor-intensive work that needs to be performed with worker and occupant safety controls. Consequently, mold removal or remediation con-

In wall-vented crawl spaces during the summer, moist crawl space air readily condenses on air conditioning ductwork. Wood framing that absorbs condensed moisture invites surface mold growth.

tractors typically charge $3,000 and higher for crawl space mold cleanup.

Since damp crawl spaces themselves do not generally result in wood decay or insect problems, in some cases, more often than not, pest management professionals have simply "looked past the mold" when performing crawl space inspections, moisture management and insect control work. Given the mold liability issue, the industry needs to question whether this "looking past the mold" approach is an acceptable business practice. Indeed, ongoing research indicates that some of the industry's established moisture control strategies may foster or exacerbate crawl space mold blooms.

CAN MOLD MAKE PEOPLE SICK? Medical research clearly shows that molds cause health problems for people with allergies or asthma. Molds produce allergens (substances that can cause allergic reactions), irritants, and in some cases, potentially toxic substances (mycotoxins). Allergic reactions to mold are common. Inhaling or touching mold or mold spores may trigger hay fever-type symptoms, such as sneezing, runny nose, red eyes and skin rash (dermatitis). Reactions can be immediate or delayed. Increasingly, mold exposure is identified as a trigger for asthma attacks. In addition, mold exposure can irritate the eyes, skin, nose, throat and lungs of non-allergic people.

"Toxic mold" is the new term being used by the media and in lawsuits and insurance claims. The major toxic mold concern is *Stachybotrys chartarum* (referred to in this article as *Stachybotrys,* a black mold that typically blooms after major or sustained water damage caused by flooding, or roof, pipe or water heater leaks).

Breathing the mycotoxins that *Stachybotrys* produces has been linked to serious health problems, including sustained memory loss and pulmonary hemorrhaging (bleeding lung) disease in babies. Despite the success of mold lawsuits, there is limited medical research that supports the toxic mold medical claims.

CRAWL SPACE RESEARCH. Building professionals have long recognized that crawl spaces are prone to moisture problems. In 1994, a national symposium on crawl space moisture problems concluded that crawl spaces are dangerously wet (Issues in Crawl Space Design and Construction, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., Winter meeting, January 1994).

In the spring of 2001, a research project began to study how crawl space moisture levels can be controlled and reduced. Funded by the U.S. Department of Energy, the project is directed by Bruce Davis of Advanced Energy in Raleigh, N.C., and managed by Bill Warren. The project team includes Dr. Achilles Karagiozis of Oak Ridge National Laboratory; Dr. Wayne Thomann, Duke University; Dr. John Straube, University of Waterloo, Canada; Architect Bill Rose, University of Illinois at Champaign-Urbana; Dr. Joe Lstiburek, Building Science Corporation; Physicist Anton TenWolde, U.S. Forest Products Laboratory; and Environmental Scientist Terry Brennan, Camroden Associates.

The experiment monitors 12 identical new crawl space homes located in eastern North Carolina. The crawl space homes are divided into groups to compare traditional crawl spaces with wall vents to closed crawl spaces without wall vents. The experiment compares temperatures, moisture levels, wood moisture content, mold levels, radon, air leakage and energy use in the crawl spaces and in the homes. Information and reports about this project can be viewed and downloaded at the project Web site, www.crawlspaces.org.

The crawl space experiment has been monitored for nearly two years. Ongoing results clearly indicate that the closed crawl spaces consistently outperform the wall vented crawl spaces in terms of moisture, mold, comfort and energy performance.

Focusing on moisture results, battery operated data loggers record the temperature and relative humidity (RH) in the crawl spaces, inside the homes and outdoors every 15 minutes. Graph 1 on page 76 shows that closed crawl spaces (red line) stayed dry during the humid summer months. In sharp contrast, the wall vented crawl spaces (blue line) stayed damp most of the time.

Notice how closely the wall-vented crawl spaces follow the outdoor humidity levels (green line) and stay above 70 percent RH for about 80 percent of the time. This means that in the summer, the wall vents keep the crawl spaces wet as opposed to drying them out.

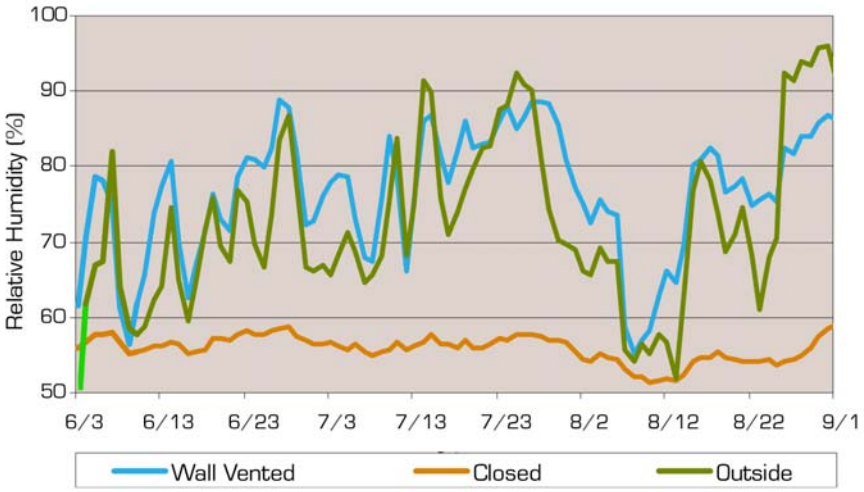
A wall vented crawl space in the study. Note that all exposed ground is fully covered with 6-mil polyethylene.

ENERGY SAVINGS. In addition to moisture and mold benefits, creating a closed crawl space should save on heating and cooling costs. Preliminary data from the experiment site shows that closed crawl spaces have thus far experienced significantly lower space conditioning costs. Additional metering was installed in February 2003 on the heat pumps to record exactly how much electricity the houses use for heating and cooling. The new submetered energy results are expected to pinpoint the amount of savings that result from closing the crawl spaces.

INDUSTRY RESPONSE. These study results strongly bring into question several practices used by the pest management industry to control crawl space moisture. The first regards the use of polyethylene ground vapor barriers. The experiment results show that the poly ground cover alone cannot be depended upon to keep crawl spaces dry enough to prevent mold blooms. At the start of the experiment, all debris and wood scraps were removed from the crawl spaces, and in the wall vented crawl spaces, new layers of 6-mil poly were installed to cover all exposed ground surface. The poly seams were lapped at least 12 inches.

The researchers regularly see large amounts of water droplets collecting on the underside of the clear poly vapor barrier. This means that the ground poly is doing its intended job, which is to prevent ground water from evaporating into the crawl space air. However, despite the carefully installed, 100 percent coverage ground poly, moisture continues to enter and remain in the wall vented crawl

CRAWL SPACE MOISTURE LEVELS (SUMMER 2002)



Graph 1. Notice how closely the wall vented crawl spaces follow the outdoor humidity levels (green line) and stay above 70 percent RH for about 80 percent of the time. This means that in the summer, the wall vents keep the crawl spaces wet as opposed to drying them out.

spaces. This excess moisture creates a damp, mold-friendly climate in the crawl spaces during humid weather conditions, particularly in the summer. Where does excess moisture come from? Two main sources are water vapor in humid outdoor air that enters the crawl space through the wall vents and rain and ground water that wicks through the block walls into the crawl space.

The second issue is the practice of adding new wall vents to increase crawl space ventilation. Since wall-vented crawl spaces closely follow outdoor air water vapor levels, adding new wall vents cannot be expected to keep the crawl space relative humidity below mold-growing levels in humid climates. The drying effect from wall vents comes when the moisture load of outdoor air is lower than the levels in the crawl space. Wall vents need dry weather to dry out a crawl space. This means that most drying occurs in the fall, winter and spring.

It is ironic that many homeowners close the wall vent dampers in the winter to save energy and to keep crawl space pipes from freezing. The irony is that wall vents get closed when they can do the most crawl space drying — during the dry weather of winter. Adding wall vents in the dry Southwest will work but in most other climates in the United States, more vents will not solve mold problems and may just worsen the problem.

The last moisture control strategy to consider is adding crawl space ventilation fans. In a 1,500 square-foot crawl space that is 3 feet high, a 750 cubic feet per minute (cfm) exhaust fan can change the air in the crawl space up to 10 times per hour. This much airflow will accelerate the drying of standing water and puddles. However, crawl space humidity levels will continue to remain high enough to grow mold during humid weather.

CRAWL SPACE MOLD CONTROL. As a bottom line issue, pest management companies need to examine their current moisture management strategies relative to this key question: Can the crawl space moisture control work I do today encourage mold blooms or worsen existing mold problems tomorrow?

Dealing with crawl space mold is often a complicated strategy that divides into two major questions: First, how can moisture levels be controlled to prevent future mold blooms, and second, should existing mold be removed?

While there is a lot of disagreement about mold and health, scientists, mold specialists and government agencies like the U.S. EPA agree that the key to controlling mold is to reduce excess moisture. The results from the crawl space research project described previously show that in humid climates, three things need to be done to keep crawl spaces dry: fixing water entry problems, closing off the wall vents, and installing a full-ground moisture barrier that can effectively reduce crawl space moisture levels.

In the real world it can be difficult to meet these three requirements on a given home. Strategies and costs differ for new construction and existing homes. Focusing on existing homes, a typical crawl space mold control plan involves the following elements:

- Train job supervisors in crawl space moisture management work. Because this will be a new line of work, training, work specifications and information resources are limited at this time. The crawl space research project plans to develop training materials in 2003.
- Conduct a detailed crawl space inspection to identify water entry problems, current moisture levels, extent of visible mold, pest control requirements, etc. Crawl spaces should not be closed off if either of the following conditions is present: unresolved major water entry problems or the presence of gas or oil furnaces or water heaters that are supplied with combustion make-up air from the crawl space. Combustion safety strategies can be employed that will allow these crawl spaces to also be closed. One item not to overlook is the hot water heater temperature and pressure relief line, as well as the drain pan. These overflow pipes should not terminate in the crawl space. Add piping to run these lines to outdoors to prevent a water heater overflow from flooding the crawl space.
- Protect workers' health with respirators, safety glasses and protective clothing. Mold air testing by the crawl space research project shows that mold levels in the air increase dramatically when people enter and move around in crawl spaces.
- Seal off rising ground moisture from evaporating into the crawl space air. Remove all debris and materials from the crawl space so that all exposed ground can be fully covered with a layer of at least 6-mil polyethylene. Lap seams 12 inches. Greater details and better materials are being developed.
- Install a crawl space drain. This will prevent plumbing leaks and house water spills from creating standing wa-

Above is a closed crawlspace in the study. The 6-mil polyethylene is brought up the wall leaving a 3-inch termite inspection strip at the top.

CRAWL SPACE RH SUMMARY

(JUNE-AUGUST 2002)

PERCENTAGE OF TIME	VENTED	CLOSED
Above 80% RH	39%	0%
Above 70% RH	79%	0%
Above 60% RH	94%	0%
Above 50% RH	100%	100%

Table 1. While the closed crawl spaces ran between 50 percent and 60 percent relative humidity all the time, the wall vented crawl spaces stayed above 70 percent RH for 79 percent of the time, and above 80 percent RH for 39 percent of the time. Since surface molds tend to grow above 70 percent RH, wall vented crawl spaces support mold growth.

ter on top of the ground poly. Install one or more drains to daylight or to a sump pump. A drain line to daylight should include a backflow water damper and rodent mesh screening at the discharge end.

• Prevent moldy crawl space air from entering the house by sealing floor holes and duct leakage. Mold spores and gases (mycotoxins) readily become airborne. Sealing the floor and ducts creates a barrier that keeps moldy crawl space air out of the house.

• Close the crawl space from outdoors. Seal wall vent openings with rigid

Too much water has wicked through this wall. This problem needs to be fixed before the crawl space can be closed.

foams blocks cut to fit and seal with caulk, mastic or expanding foam. Also, seal all plumbing, electric and other wall penetrations. Adjust the crawl space access panel/door so that it tightly closes. Sealing a crawl space can reduce moisture levels to the point that hardwood flooring shows gaps and sheetrock joints crack. On the other hand, some buckled hardwood floors have laid down.

• After wall vents are closed, use a dehumidifier to force dry the excess moisture in the crawl space. It is highly recommended that a permanent dehumidifier be installed in the crawl space to ensure that low moisture levels (45 percent to 55 percent RH) are maintained. Other moisture control strategies are under investigation.

• Monitor the crawl space performance. Provide the homeowner with a remote bulb relative humidity meter located in the home that displays the crawl space relative humidity level. Inspect the crawl space periodically to ensure that water entry does not lead to standing water collecting on top of the ground poly. Install a radon canister in radon areas to ensure that crawl space radon levels remain at safe levels.

Absent from this list is mold testing or

A too common sight: large puddles collect on top of the ground polyethylene in crawl spaces. Until these puddles evaporate, this crawl space will maintain high relative humidity levels that encourage mold growth.

sampling to determine which types of mold are present. This omission is based on the U.S. EPA's recommendation that, "In most cases, if visible mold growth is present, sampling is unnecessary." Mold testing results are most meaningful when conducted by a trained professional taking multiple samples over time. Consequently, mold testing is expensive.

Until government regulations are established for mold or mold spores in buildings, mold sampling may be best suited for mold lawsuits, specific medical concerns of the occupants and building mold research.

SHOULD MOLD BE REMOVED? Cleaning up existing crawl space mold, or mold remediation, is another business opportunity for pest management companies to consider offering. The first and foremost recommendation is that mold should not be removed from a crawl space unless a mold moisture control plan is included in the job. Otherwise, new mold can grow in the future because of continued levels of excess moisture.

As was pointed out at the beginning of this article, crawl space mold remediation is often difficult and consequently expensive work. Crawl spaces have large surface areas of wood framing to treat or clean. A 2,000 square-foot crawl space with 2- by 10-inch floor joists will have close to 5,000 square feet of wood surface that needs treatment. Crawl space work access is limited and sometimes impossible in low height clearance areas.

To get to all mold contamination, floor insulation batts must be removed and workers have to deal with plumbing pipes, ductwork, wiring and nail obstructions. Supervised worker heath protection consisting of respirators, hand and eye protection and protective clothing should be provided at all times. During removal, the crawl space should be exhausted to the outside through a HEPA filtration system. This prevents crawl space air with elevated mold levels from entering the house.

There are three main strategies to deal with crawl space mold: leave it in place, kill the mold and physically remove the mold.

Leaving the existing mold in place is the least expensive option. This strategy should always include moisture control methods to prevent future mold growth. Home-owners and tenants can best be protected from the remaining mold by preventing crawl space air from entering the house. Stopping this airflow involves sealing floor penetrations and sealing up all air leakage in ductwork and air-handling units that are located in the crawl space.

Second, biocides can be used to kill mold. A common mold biocide is a diluted bleach/water solution containing one part bleach to 20 parts water. The U.S. EPA does not recommend the use of biocides without mold cleanup and removal. The main reason is that dead mold is still allergenic to sensitive people. If biocides are used, the crawl

Pink rigid board insulation and expanding foam is being used to seal off the wall vent and the large opening around the ductwork that goes to the outdoor package heat pump.

This dehumidifier is permanently installed. The green hose drains condensate directly outdoors. Note that a white termite inspection strip has been left at the top of this wall-insulated crawl space.

space must be well ventilated to protect workers.

Removing the mold is the most expensive strategy of the three. Since it is so expensive, mold removal may be best suited for homeowners with severe mold allergy or asthma problems or a home sale that is conditional on mold removal. Two common methods of mold removal are hand cleaning of the wood surfaces with bleach and rinse water wipes or HEPA vacuuming. One new mold removal technique is soda blasting. Using a sand blasting technique, baking soda is used to clean off all crawl space surfaces. After blasting, the baking soda and mold residue is removed from the crawl space and all surfaces are HEPA vacuumed.

NEXT STEPS. Because of the growing mold issue, the pest management industry needs to carefully examine current crawl space pest management and moisture control work practices. Mold moisture control work will require new strategies that have been proven to keep crawl spaces dry enough to prevent mold blooms. Implementing these strategies will require a commitment from the industry to provide training, specifications and guidelines for crawl space mold management services.

Pest management firms that respond to this challenge open up new business opportunities. Those companies that are not up to this challenge expose themselves to potential mold liability issues.

All photos in this story are courtesy of Advanced Energy.

Advanced Energy is a non-profit corporation located in Raleigh, N.C., that serves as a state and national resource to help utility, industrial and residential customers improve the return on their energy investment. Its mission is to create economic and environmental benefits through innovative approaches to energy. Bruce Davis is Research Director and Bill Warren is Crawl Space Project Manager. *This research is funded by the U.S. Department of Energy under Contract No. DE-FC26-00NT40995.*

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