Crawlspaces: Considering the Options

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by Brad Turk

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A well-sealed membrane installed in a crawlspace in Spokane, Washington, filled with soil air drawn from the highly permeable soil and by natural house depressurization. Exhausting air beneath the membrane solved this problem.

A surefire way to start an argument in a group of building specialists is to bring up religion, politics—or crawlspaces. Politics and crawlspaces do have a lot in common. You can make up your own jokes. But why crawlspaces? Because many are prone to failure, there is a wide variety of ideas on avoiding or correcting the problems, and there's even disagreement as to whether "crawlspace" is one word or two. Misinformation, myths, and out-of-date codes have contributed to some of the confusion, but many of the approaches do work under certain circumstances. We find that a one-size-fits-all approach can lead to problems. We have only to look at the older HUD housing for Native Americans to see disastrous examples. From Maine to South Dakota to Arizona, most of that housing (including heating systems and wall, roof, and floor assemblies) was identical, with the result that it really only worked well … nowhere.

For crawlspaces, as for the entire house, there are house-specific, local, and regional conditions to consider. Solutions also depend on one's objectives. In the case of an existing house, is it being retrofitted for comfort, energy performance, or pollutant or moisture control? You need to work with what's there when retrofitting an existing building, since certain construction features and conditions will influence your approach and your choice of materials. It is also a question of what makes sense for the climate, and possibly the soil conditions, unless one wants to spend a lot of money on redesign.

In new construction, crawlspaces can be made to work in most climates, and one might want to build a crawlspace for any number of reasons: convenience for routing and maintaining utilities, additional storage, aesthetic or design considerations, or structural reasons such as building a subcrawlspace in an area with expansive soil. (A subcrawlspace is a void below the slab floor of the basement that permits soil/ground movement without it damaging the building.)

Having already stepped into the tar pit by agreeing to this article, I might as well wade in further by offering some general suggestions. When approaching crawlspace work, think like a military planner preparing for a military siege. You must decide where best to establish a defensible perimeter against temperature differences, unconditioned outdoor air, polluted soil air, and water intrusion. In this symbolic battle of the bilge, it may be most beneficial and cost-effective to abandon the crawlspace to the enemy and set up fortifications at the floor between the house and the crawlspace (leave the crawlspace unconditioned).

For other situations, it may be advantageous to hold the line at the crawlspace walls and floor (create a conditioned crawlspace). My personal definition of a conditioned crawlspace is one where the effective thermal and moisture resistances of the crawlspace walls and floor are at least 2 times greater than those of the floor between the house and crawlspace. This simple definition encompasses a variety of real-world options. Note that other people's and code authorities' definitions of a conditioned crawlspace are considerably different.

I believe that, in most situations, it is best to create a conditioned crawlspace. Exceptions would include areas with a very high water table, vulnerability to flooding, and mild climates. For example, in a moderate-climate region like the San Francisco Bay Area—where a lot of older houses do have crawlspaces—an unconditioned crawlspace makes some sense. However, for new construction in this same area, building a conditioned crawlspace may be even more advantageous. The following general recommendations assume that the crawlspace will be conditioned, and are based on our improved understanding of the flow of heat, moisture, pollutants (and the owner's financial resources). Be aware that most of these elements are intended to work together as a system, and that some of the following suggestions may actually contradict requirements of the code and construction authorities.

Insulate the walls. Insulation placed on the outside of the foundation wall (extruded polystyrene or expanded polystyrene—XPS or EPS) has several thermal and moisture advantages, but it can be tricky to install correctly and without damage. It is probably an impractical retrofit in existing buildings, but it works especially well in new construction. Otherwise, use insulation on the inside of the foundation wall. XPS and EPS are also a good choice on the inside if the surfaces are straight and flat, but codes may require that they be covered with a fire-rated barrier.

Stop outdoor air from entering the crawlspace. This also helps to control moisture and drafts. For example, during warm, humid weather conditions, there is significant moisture in the incoming air, and it can condense on the cool surfaces in the crawlspace (especially on air conditioning equipment). Draft control includes closing or eliminating outdoor vent openings, improving the seal at the sill plate, sealing around utility penetrations, and so on. There are other ways to remove background moisture from the crawlspace than by introducing outdoor air (see the next three recommendations).

Venting a crawlspace with outdoor air is often done to control elevated radon levels in the crawlspace and in the house. The concern is that in a well-sealed crawlspace the radon will accumulate after radon-laden soil air passes around and through the moisture barrier on the crawlspace floor. However, our research experience with controlling radon by natural crawlspace ventilation was mixed. Our Lawrence Berkeley National Laboratory (LBNL) research team investigated various techniques for controlling radon entry into crawlspaces, basements, and slab-on-grade buildings. We found that if radon entry rates were modest, if the openings between the house and the crawlspace were not large (and if there were no leaky ducts), and if the crawlspace vent openings were large enough and were oriented properly, then radon in the occupied spaces was adequately controlled by natural crawlspace ventilation. But if not, other measures should be taken to keep radon out of the building.

We suspected that the crawlspace vents not only provided dilution ventilation but also decoupled the house from the soil by equilibrating crawlspace air pressures to outdoors. In any event, natural venting of crawlspaces in high-radon areas is undependable, unless one has a house on piers, or a house with many crawlspace openings, such as a mobile home with poorly fitted skirting—which is how houses on crawlspaces were originally built.

Mechanical exhaust ventilation of the crawlspace can increase the radon levels in the crawlspace. The resulting radon concentration in the crawlspace will then be a balance between the pressure-driven flow rate of radon into the crawlspace and the ventilation rate. However, the solution to this dilemma is to use active soil depressurization (ASD) radon control, just as one would in a house with a slab over a gravel layer. A 3–4-inch PVC pipe is installed through the slab floor, and routed through the roof. An exhaust fan connected to the pipe depressurizes the subslab zone to keep radon from getting into the building.

In a crawlspace, a polyethylene barrier on the floor serves the same purpose as the slab. The space under the poly sheeting serves the same purpose as the gravel layer—that is, it acts as the radon collection plenum. By mining local radon hot spots, the ASD can, in some instances, increase the radon levels in the gravel layer below the slab. But because the ASD effectively reverses the pressure gradient between radon and the house, the higher radon levels never get into the building. Similarly, an air-tightened crawlspace, or the space below the poly can be effectively depressurized (and ventilated) with respect to the occupied zones by installing an exhaust fan (see "Drying Out a Crawlspace," *HE* Jan/Feb '00, p. 39).

Prevent moisture from entering from the soil surface. Cover the soil surface with poly sheeting that is lapped and sealed and is sealed to the crawlspace walls. I suspect that in many cases the dominant transport mechanism for radon and moisture is the same: pressure-driven flow of soil air into the crawlspace. In other words, if you have elevated radon in a crawlspace, you may also find elevated water vapor levels, since soil air is often saturated. However, there are many potential sources for moisture other than soil air. In cases where diffusion and evaporation are the primary transport mechanisms, lapping and sealing is less important. But the lapping and sealing doesn't hurt; it helps the performance of the crawlspace in other ways; and one never knows how soil conditions may change over time. Some people install a rat slab (see "A Conditioned Crawlspace Checklist," p. 25) to increase the durability and longevity of the poly and its seal. This also makes it easier to work in the crawlspace. Note that the poly sheeting should not be attached to the sill, since moisture can collect on the sill under the poly and cause rot.

Will a well-sealed barrier capture the incoming soil gas, causing it to fill like a hot-air balloon? Yes, in some situations; and the problem could be aggravated by exhaust ventilation in the crawlspace (see photo on p. 30). This is one area where not doing it right enough can really screw things up. Nonetheless, I've seen this ballooning effect only once, in a house in Spokane, Washington, and I surmise that it was due, in part, to the very highly permeable soil in that area. We had closed the crawlspace vents and installed an airtight poly barrier over the crawlspace floor as part of our research. We received a concerned call from the homeowner several hours later. He had heard a crackling sound coming from the crawlspace, and upon investigating was horrified to find the barrier bulging at the hatch into the crawlspace. We, on the other hand, were delighted to have such convincing evidence of air moving out of the soil. A slight modification to the exhaust system to draw air from below the barrier addresses most of these concerns. This approach benefits from a tight-fitting barrier, but it is not completely dependent on one. In fact, if the exhaust system can draw air from the crawlspace through leaks in the barrier (which is almost never perfect), it also ventilates and slightly depressurizes the crawlspace proper. This barrier should also help retard entry of pollutants in the soil air (radon, methane, pesticides, VOCs, and other chemicals from old dumps or from industrial, commercial, or agricultural activities).

Eliminate other moisture sources. All of your other efforts are like swimming against the current, if you don't keep water away from and out of the crawlspace. Correct all plumbing leaks, slope surface drainage away from the building, direct downspouts away from the foundation, possibly install footing drains to collect and direct water away from the building, possibly install a sump pump, and keep sprinklers and irrigation equipment from wetting the foundation.

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A poly barrier is being put in place to reduce moisture migrating from the soil surface.

Actively exhaust-ventilate the crawlspace. A small fan is used to ventilate and very slightly depressurize the crawlspace either above or below the poly. This has several benefits. It keeps accumulated moisture and pollutants (including radon) from entering the occupied zones; it pulls conditioned air from upstairs into the crawlspace; and it removes moisture and soil air pollutants to the outside. The exhaust fan should run continuously and should be installed to exhaust air from the crawlspace through the sidewall or rim joist. If there are high radon levels in the crawlspace or below the poly, the exhaust should be routed to avoid exposing people to the contaminated exhaust. To enhance the performance of this system, large gaps and openings between the crawlspace and the occupied spaces should be sealed.

A more efficient approach may be to connect a slightly larger exhaust fan to PVC piping that sucks air from below the poly, as described above. This arrangement not only directly controls moisture and pollutants from the soil, but also ventilates and depressurizes the crawlspace through leaks in the poly.

Most of the details in exhaust ventilation involve doing a good job of sealing, and sizing the fan properly. Interestingly, we had good success in one project by pressurizing a crawlspace with conditioned air from an earth tube. It wasn't as effective in reducing indoor radon levels as depressurization, and the installation was costly, but the depressurization mode caused the water heater to backdraft, since the occupied area of the adobe house was very airtight. (An earth tube may not be suitable in warm/hot-humid climates.) Even more effective in controlling soil gas contaminants in crawlspaces is the subpoly ASD approach. It wasn't used in this house because the crawlspace was inaccessible; it had a maximum of 6 inches of clearance from the soil to the floor joists. (This is illegally tight in most jurisdictions, where 18 inches is a minimum. But the house in question was built in New Mexico about 50 years ago.)

What pressure differential requirement would one want to meet in this situation? Would it be possible to have the air pressure in the occupied space become more negative than the crawlspace? You don't need much of a pressure differential—something on the order of several Pa—and it doesn't have to override every unusual pressure excursion. Exhaust appliances upstairs (such as a range hood, exhaust fan, or dryer) can reverse the house–crawlspace pressure differential, but these appliances are usually used intermittently, and the consequences of contamination from crawlspace air are not acute, as they are when a combustion device backdrafts. When heating/cooling forced air is supplied to and returned from the crawlspace, the pressure effects of the small exhaust fan are usually overwhelmed.

If one is successful in sealing the floor membrane, where does the makeup air come from? The upstairs is usually a good source for makeup air, since the air is already conditioned, and will help to condition the crawlspace. Of course, one needs to be careful about routinely causing a large depressurization of the occupied space with the crawlspace exhaust fan, especially in warm or hot-humid climates. This can happen when there are openings between the floor and the crawlspace. In this case, during the cooling season, you could draw moisture-laden outdoor air into the chilled wall and ceiling spaces where it could condense.

One also needs to be careful not to cause combustion appliances that are upstairs to backdraft. However, with a properly sized fan, it's unlikely that the occupied spaces above the crawlspace will be significantly depressurized. The fan capacity may range from 50 to 250 CFM (or larger), depending on the size of the building and the leakage area of the walls and floor. Rather than using a prescribed fan size, I think it's best to size the fan based on measuring the leakage and/or flows required to develop 1-2 Pa of pressure difference.

Avoid installing ductwork in the crawlspace. Leaky ducts can change the desired pressure balance, which is the crawlspace at a lower pressure than the occupied spaces. Even with the crawlspace depressurized, leaky return ducts will draw in and distribute into the occupied spaces any pollutants that have collected in the crawlspace. (Though, if one carefully follows the advice given above, there shouldn't be elevated levels of pollutants in the crawlspace.) Supply ducts that leak into the crawlspace could pressurize the crawlspace, and allow the HVAC equipment to depressurize the occupied space above the crawlspace. Then all bets are off as to what will happen—but it probably won't be what one wants or intends. If ductwork must be installed in the crawlspace, thoroughly seal all joints and fittings to reduce air leakage.

Which is better thermally—putting the ductwork in the attic or in the crawlspace? My take-no-prisoners answer is, don't put your ductwork in either location or in the exterior walls (see "Chasing Interior Ducts," *HE* May/June '02, p. 24). My if-you're-gonna-make-me-answer-this answer is that ductwork in the crawlspace would have better thermal performance. This is because when you're heating, the ductwork is hot and the attic is cold, and when you're cooling, the ductwork is cold and the attic is hot. Therefore, there will be more heat loss in the attic than in the stable-temperature environment of a crawlspace.

Of course, there are other factors to consider—such as, you may not have a choice. For most of us who work in older homes, the ductwork and furnace are already in the crawlspace. And most builders, developers, and home buyers would rather not give up floor space in the house for ducts and HVAC equipment, so it's going to go in the attic or in the crawlspace, despite what I suggest. Consequently, some groups (such as Building Science Corporation) recommend that the HVAC equipment be intentionally and carefully designed, using branches from supply and return ductwork, to supply air to and return air from the crawlspace, with the purpose of conditioning it like the occupied spaces. If this plan is followed, these groups also recommend that the crawlspace be exhaust-ventilated, that a passive stack be installed below a tightly sealed poly barrier on the crawlspace floor, and that the exterior walls be well insulated and well sealed.

Avoid installing combustion equipment in the crawlspace. This is especially important if a fan is exhausting air from and depressurizing the crawlspace; it can cause naturally aspirated combustion equipment to backdraft. In this situation, you should rethink the crawlspace exhaust ventilation system. Boilers, furnaces, and water heaters with power-vented or sealed-combustion equipment are less of a concern, and retrofitting a power vent might be an option. If you are building new, you have the design option of putting the heating and cooling equipment in the conditioned and occupied space and sacrificing floor space. This is the most thermally efficient approach, and in ducted systems it avoids other problems associated with moisture and pollutant movement. If the equipment must go in the crawlspace, install a sealed-combustion system, and condition the crawlspace with carefully balanced supply and return air.

There are a lot more details than I've included here, and there are many caveats that need to be included with any short list like this one—especially with existing buildings. Apply these suggestions cautiously and always with an eye toward the particular situation at hand. Be aware that one size doesn't fit all, and that building and construction is an exercise in unintended consequences, for "when we try to pick out anything by itself, we find it hitched to everything else in the Universe" (John Muir).

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