Moisture Control in Crawl Spaces

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Abstract

The need for crawl-space ventilation is examined. Research findings are summarized related to moisture release from the soil, site drainage, the effect of ground covers, ventilation, and the effect of crawl-space conditions on indoor air quality Thorough review leads to the conclusion that crawl-space ventilation may not be necessary, and in some instances, may be counterproductive. Research results provide no convincing basis for the current building code requirements for crawl-space ventilation.

Introduction

Prior to World War II, the basement was the standard type of foundation used in residential construction in the northern United States, and crawl-space construction was limited primarily to foundations for porches, sheds, and outbuildings. In the southern United States, crawl spaces were common, given the widespread use of pier construction and open skirting. During the war, the "basementless house" was introduced as a low-cost solution to the housing crisis. Also during the war, the first description of ventilation requirements for houses without basements appeared in Federal Housing Administration documents (FHA, 1942).

From their very introduction into construction practice in the northern United States during the 1940's, crawl-space homes were viewed as trouble-prone, and over the years many crawl-space moisture problems have been reported. While moisture problems clearly do occur in crawl spaces, such problems do not affect the majority of crawl spaces. In a survey of crawl spaces in Oregon, Washington, and Montana, Tsongas (1994) observed wood decay only in very few cases; where plumbing leaks existed or where wood members were in direct contact with the soil. Generally the crawl spaces that were inspected in this series of surveys were virtually devoid of moisture-related problems.

Moisture problems generally occur when improper drainage or grading around the house lead to wet soil or even standing water in the crawl space. Evaporation of this moisture causes high humidity in the crawl space, and often in the rest of the building. It also sometimes leads to high moisture content in wood framing members in the floor. The traditional responses to these problems have been to install crawl-space vents and to cover the soil with a ground cover (sometimes called a soil cover or vapor retarder). But are these responses adequate or even necessary? Are there better ways to design a crawl space?

In addition to moisture, the soil may release radon into the crawl space. Radon is a radioactive gas that naturally occurs in soil and rock, and has been recognized as a potential cause of lung cancer. Crawl-space design may influence radon entry into the building, an issue not recognized when building code regulations for crawl spaces were formulated.

Moisture Release from Crawl Spaces

Several studies have considered how a crawl space can contribute to the moisture level in a building. Britton (1948) reported an average evaporation rate of 12.1 gal/1000 ft^2/day (490 g/m^2/day or 0.10 lb/ft^2/day). Trethowen (1994) measured a similar average rate of about 10 gal/1000 ft^2/day (400 g/m^2/day or 0.082 lb/ft^2/day), but found a large variation in evaporation rates, both by site and season. Abbott (1983) found that when the soil reaches a "critical" moisture content, its evaporation rate equals that of free water. Britton (1948) also found a maximum rate of 19.1 gal/1000 ft^2/day which corresponds to more than 770 g/m^2/day or 0.16 lb/ft^2/day but such a high moisture-release rate is unlikely to occur in practice.

Site Drainage is Critical

The importance of good site drainage is not controversial. Exterior drainage is critical, and the ground outside the foundation walls must be graded to prevent ingress of water. Level terrain around the building, downspouts that discharge adjacent to the foundation, and irrigation from shrubbery and lawns all can contribute to high soil-moisture contents. Good construction practices also include maintaining an 8-in. (203-mm) clearance between soil and floor framing, providing easy access to the crawl space, and removing debris from the crawl space.

Ground Covers Reduce Humidity

There is general agreement in the literature that ground covers are effective in reducing humidity in the crawl space and in the rest of the building. As early as 1949 the Housing and Home Finance Agency (1949) advocated the use of ground covers, especially in northern climates, and stated that crawl-space ventilation can be reduced by 90% if a ground cover is installed. Moses (1954) confirmed the effectiveness of ground covers. Rose (1994) concluded from his review of regulatory and technical literature that, de-

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spite questions that arose in the 1940's about the durability of ground covers in contact with the soil, these concerns were laid to rest by 1952. Building regulations after 1956 responded by mandating the use of ground covers in crawl spaces. Flynn *et al.* (1994) found that a soil cover lowered moisture conditions sufficiently to prevent further wood decay and mold, even in poorly ventilated crawl spaces with wet soil. Stiles and Custer (1994) also presented data supporting the effectiveness of ground covers.

The view that ground covers effectively reduce moisture entry into the crawl space and the rest of the building is held internationally. Samuelson (1994) reported from Sweden that "plastic sheeting on the ground is essential." Trethowen (1994) reported from New Zealand that "Covering subfloor ground with polyethylene film produced almost immediately a significant drop in the mean moisture content in floor framing timber" and "Polyethylene films applied commercially.. reduced the ground moisture evaporation by at least 70% and possibly as much as 95%." Fugler and Moffatt (1994) described recent changes in the 1995 *National Building Code of Canada* (NRCC), "Every heated crawl space must be provided with a polyethylene ground cover to serve as a moisture barrier; the polyethylene must be weighted down (for example, with concrete), and sealed to the foundation wall." The NRCC also requires a ground cover in unheated crawl spaces, but it permits the use of materials such as asphalt, roll roofing, or 4-mil (0.100-mm) polyethylene. In comparison, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE, 1993) recommends 6-mil (0.15-mm) polyethylene, 45- to 55-lb roll roofing, or 45-mil (1.14-mm) EPDM (ethylene propylene diene monomer) membranes.

In summary, the majority view is that the ground cover is the key element in moisture control in crawl spaces and is undoubtedly effective. Some evidence even suggests that a ground cover is a sufficient means of moisture control in crawl spaces and that no additional measures are needed (Dutt *et al*, 1988, Flynn *et al.*, 1994).

Ventilation may be Unnecessary

Whether or not to ventilate a crawl space is probably the most controversial issue concerning crawl-space design. Many building codes require vents to circulate outside air. However, Rose (1994) provided evidence that the research conducted to support these crawl-space ventilation regulations actually failed to support them. Therefore, he concluded that there is no technical basis in the literature for current or past crawl-space ventilation requirements. Quarles (1989) found that a reduction in ventilation in a crawl space without ground cover led to high moisture conditions and mold, but that ventilation could be eliminated without resultant problems if a ground cover was present. A recent survey in New Zealand (Trethowen, 1994) showed that there usually is not enough crawl-space ventilation to keep up with the high anticipated moisture loads from evaporation in a damp crawl space without a ground cover.

Crawl-space vents can, in fact, be counterproductive. Samuelson (1994) stated that introducing outside air into a cool crawl space during summer, when temperatures are most conducive to mold and decay actually raises crawl-space relative humidity. This practice can easily produce relative humidities of 85-95%, even in a crawl space with dry soil or a soil cover. Stiles and Custer (1994) also found higher relative humidities during summer than during winter. It could be argued that current regulations may produce the worst of all possibilities for summer performance; enough outdoor air enters the crawl space to raise the relative humidity but not enough to raise the temperature, and consequently reduce the relative humidity.

It is important to distinguish between heated and unheated crawl spaces. There is a growing consensus among building scientists that a heated, well-insulated crawl space should not be ventilated with outdoor air (Rose and TenWolde, 1994). Dutt *et al.* (1988) found that unvented crawl spaces with perimeter wall insulation remained dry, while the crawl-space temperature was higher than that in the vented crawl spaces. The *National Building Code of Canada* (NRCC, 1995) defines a heated crawl space as any enclosed crawl space that is either connected to heated spaces elsewhere in the building, or contains unsealed and uninsulated heating ducts. The NRCC does require unheated crawl spaces to be vented to the outdoors.

Samuelson (1994) presented an innovative approach in which the indoor air is mechanically exhausted to the crawl space, and crawl-space air is exhausted to the outdoors, with heat exchange for energy efficiency. By ensuring a slight negative pressure, air in the crawl space should not enter the living space. This integrated approach to crawl-space and whole-house ventilation not only promises a very attractive and energy-efficient solution to crawl-space moisture problems, it also should alleviate any concerns about radon entering the living space.

Several authors have recently advocated eliminating venting requirements for heated as well as unheated crawl spaces. Tsongas (1994) found no evidence in his survey that crawl spaces with a ground cover need to be ventilated, and strongly recommended that ventilation requirements be eliminated from the building codes. Stiles and Custer (1994) also proposed that crawl spaces should have an effective moisture barrier and should be totally sealed, with no operable vents, while some conditioning should be included to ensure that the crawl space is dried.

In summary to the knowledge of the authors, no research findings have demonstrated a need for crawl-space ventilation with outdoor air for moisture control, as long as a ground cover has been installed. However, it maybe desirable to ventilate certain crawl spaces for air quality reasons (e.g., radon). Two different crawl-space designs seem to be emerging, with differing ventilation requirments:

- If the crawl space is heated, then it may be ventilated with indoor or heated air, provided this is done in an energy-efficient manner.
- If the crawl space is unheated, and the envelope provides effective thermal and moisture separation between the crawl space and the living space, then the crawl space may be vented with outdoor air.

of course, crawl spaces generally do not have effective moisture separation from the living space, but it does not appear that moisture-related problems can be effectively resolved by ventilation.

In short, ventilation often is not an effective means of moisture control in crawl spaces. Emphasis on ventilation distracts attention from more effective techniques of moisture control, such as providing proper drainage and installing ground covers.

Indoor Air Quality Affected by Crawl Space

There is legitimate concern about radon entering from the soil into the living space via the crawl space. Soil covers and effective separation between living space and crawl space each contribute to the solution in unheated crawl spaces. Unvented crawl spaces may pose more of a challenge. The requirement in the *National Building Code of Canada* for a carefully installed, heavy, 6-mil (0.15-mm) polyethylene ground cover for heated crawl spaces was originally intended for radon control (Fugler and Moffatt, 1994). The integrated approach presented by Samuelson (1994) effectively addresses this concern by exhausting air directly to the outside and providing a slight negative air pressure in the crawl space.

One possible drawback of using ground covers is that they may provide a favorable environment for mold growth below the cover. If spores from these molds find their way into the indoor air, they may cause allergic and respiratory problems for occupants. It is not clear if this actually happens or if the spores are contained under the ground cover. If this problem indeed occurs, removing the ground cover and installing crawl-space vents should be considered. However, the homeowner or contractor must make certain that removing the ground cover does not lead to moisture and mold problems in the crawl space or elsewhere in the building.

Conclusions and Recommendations

The following conclusions can be derived from published research findings:

- There should be proper drainage away from the foundation, sufficient clearance between the soil and the floor framing, and access to the crawl space.
- Crawl spaces should have ground covers for moisture control. These should be installed carefully to limit evaporation from the soil as well as entry of radon into the crawl space.
- There is no convincing technical basis for current code requirements for ventilation.
- Heated crawl spaces should not be vented with outdoor air.
- Unheated crawl spaces may be vented, but there is no overriding need to do so for moisture control if an effective ground cover is present.

It is increasingly clear that crawl-space ventilation may not be necessary. In crawl spaces with high loads, ventilation cannot adequately dilute the moisture. Crawl spaces with ground covers generally have low moisture loads. These loads are low enough so that ventilation is not necessary; indeed ventilation may be counterproductive because it reduces energy efficiency, increases the likelihood of pipe freezing, and introduces moisture from the outside air. However, research can provide only technical information on the ineffectiveness of ventilation. The responsibility of refining the building codes so that they better reflect the research findings is the task not only of researchers, but of the larger professional design and construction community. The active participation of researchers in such refinement can be very constructive.

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