BUILDING CODE ISSUES of Residential Underfloor Moisture in Warm, Humid Climates

PART 1 OF 2

By Larry Elkin, PE

Introduction

The link between crawl space moisture and attic moisture has been documented since the late 1940s. In fact, some of the current practices for crawl space venting were developed to help resolve moisture trouble in the roofs of apartment buildings. Given that crawl space and attic moisture problems are sometimes coupled, it is important for a prudent roofing professional to have an understanding of crawl space moisture dynamics.

On still other projects, delamination of plywood roof sheathing and condensation on nails through any kind of roof sheathing was directly traced to wet crawl space conditions where humid air was raised through thermal differences to cold, inadequately ventilated roof surfaces. (Ralph Britton, Housing and Home Financing Agency, 1948).

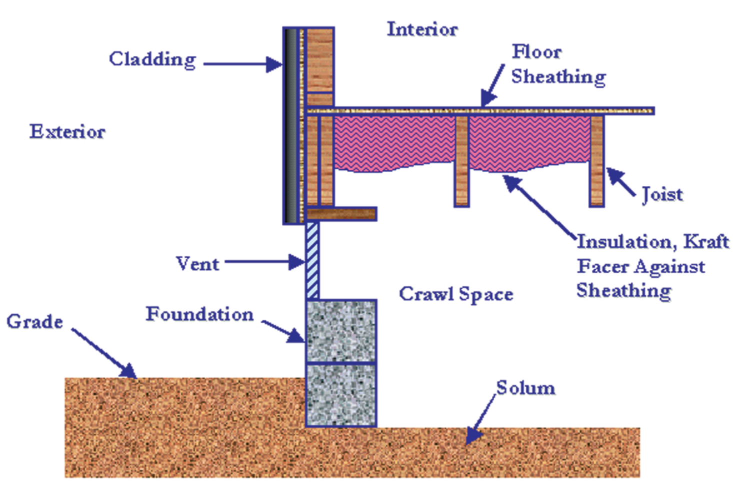

Figure 1: Components of typical crawl space construction.

This article will explore the history of crawl space moisture research. A second article, to be published in November, will provide a case study of a home with underfloor problems in a flood-prone area.

History

Crawl space moisture problems have existed in many areas of the United States for more than 50 years. A common and long-held belief is that ventilation is critical with respect to controlling crawl space moisture. However, ventilation as a moisture control strategy has become suspect in recent years. In fact, ventilation of crawl spaces in warm, humid climate areas is likely to increase the moisture within crawl spaces. Much of the current research is focusing on the sealed crawl space technique (SCST) as an improvement over ventilated crawl spaces. In the SCST, the vents are closed and the crawl space is essentially converted into a small basement. However, there are some circumstances that preclude the use of the SCST.

Several researchers and building code commentaries have touched on the idea of sealing the floor assembly above a crawl space using a sealed floor technique (SFT). The SFT places the hygrothermal envelope at the bottom of the floor assembly with an air and vapor retarder oriented toward the exterior. The crawl space is treated with a complete vapor retarding layer across the solum, but the vents remain operable. The floor assembly above the hygrothermal envelope communicates via a series of floor vents to the interior of the home. The purpose of this paper is to explore available literature that supports the SFT and show how the SFT can be employed within the framework of the existing building codes.

In 1994, William B. Rose presented a paper entitled, *A Review of the Regulatory and Technical Literature Related to Crawl Space Moisture Control.* This paper traces the origins of ventilation as a crawl space moisture control strategy to the 1940s in work performed by Ralph Britton at the National

Housing Agency (NHA). About a decade later, in 1958, the Federal Housing Administration (FHA) issued the Minimum Property Standards in which the ratios for ventilation area (still used in current codes) were introduced.

Research into the benefits of vapor retarding ground covers (VRGCs) progressed concurrently with ventilation recommendations. Early concerns about the durability of VRGCs were subsiding by the late 1950s. By 1994, Rose and Tenwolde reported, "There is general agreement among the authors, as well as in previous literature, that ground covers are effective in reducing humidity in the crawl space and the rest of the building." The authors referred to are researchers who contributed to ASHRAE's Technical Data Bulletin, *Recommended Practices for Controlling Moisture in Crawl Spaces.*

Perhaps the most significant research into crawl space moisture control is the ongoing project entitled, "A Field Study Comparison of the Energy and Moisture Performance of Ventilated Versus Sealed Crawl Spaces in the South." This joint project, led by Advanced Energy of Raleigh, North Carolina, includes four preliminary project reports.

The *Characterization Study Pilot* validated the need for improved crawl space construction. The *Field Study Pilot* included side-by-side comparisons of homes with traditional, ventilated crawl spaces, and homes utilizing the SCST. The results of the *Field Pilot Study* show that the SCST can provide drier and more durable crawl space construction. The *Hygrothermal Performance Study Pilot*, being performed by Oak Ridge National Laboratory, used data acquired from crawl spaces to develop and validate advanced hygrothermal modeling of crawl space performance. The *Technology Assessment Report* expands the work begun by Rose by exploring building code provisions and current construction practices. While this project represents a leap forward in the understanding of crawl space moisture control, it focuses on the SCST as the control strategy.

Since the 1970s, several researchers have suggested that placing a vapor retarder on the bottom of the floor joists could provide an effective means of protecting the floor from crawl space moisture. In 1978, Duff reported that the moisture content of the floor joists of a test hut in Athens, Georgia, remained between 10 and 12 percent during a two-year testing period when a vapor retarder was installed on the bottom of the floor joists. Oddly, Duff stated that although use of an underfloor vapor barrier keeps the floor dry, this method is not recommended where possible plumbing leaks would result in trapped moisture.

It is unclear why the fear of plumbing leaks would cause Duff to discard the continual benefits of the underfloor vapor retarder. Plumbing leaks should not be a frequent occurrence. This author's experience is that severe, plumbing leak-related damage is possible regardless of the vapor retarder location. Furthermore, water damage from spraying leaks, such as those associated with pin holes or small cracks in pipes suspended below the floor structure (common in warm climates) could be avoided by placing the vapor retarder on the bottom of the floor joists.

In 1991, Joe Lstiburek and John Carmody published the *Moisture Control Handbook: New, Low-rise, Residential Construction*, which included seven foundation designs for warm and humid climates. Two of the these designs – Crawl Space 1 and Crawl Space 2 – show insulated floors with vapor retarders oriented downward. In 1994, Rose indicated that, "The undersides of joists must not be allowed to remain exposed to the crawl space, but should be covered with a vapor retarder."

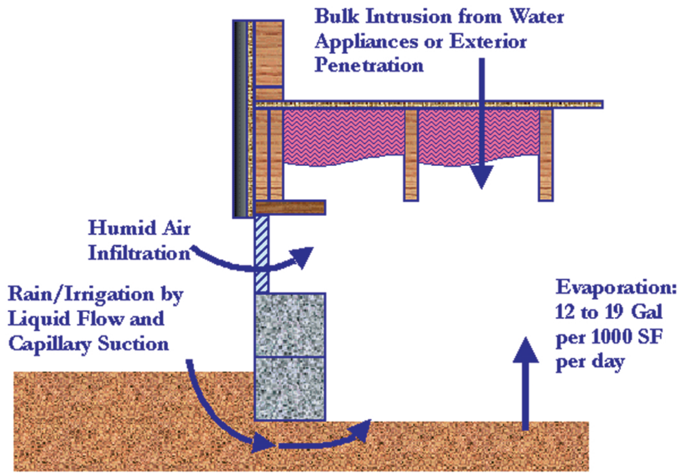

Figure 2: Moisture sources that impact crawl spaces.

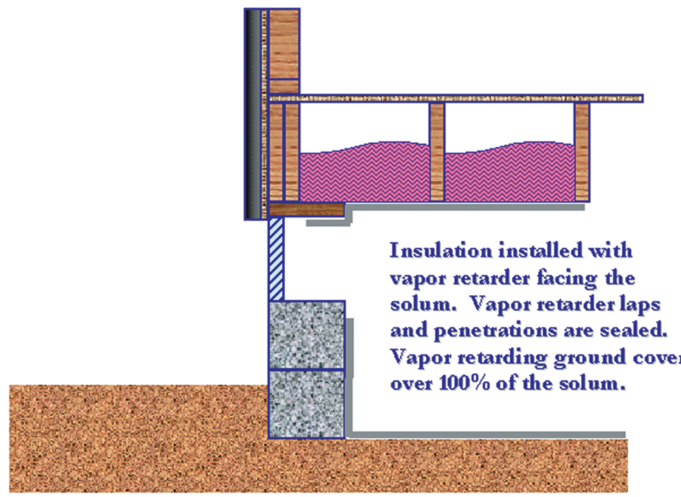

Figure 3: Example of a crawl space treated with the Sealed Floor Technique.

Building Code Review

The focus of this paper is residential crawl spaces. As such, the building code review is limited to the Council of American Building Officials' (CABO) One and Two Family Dwelling Code and the International Residential Code (IRC). These codes are often applied to residential construction. The 1998 International One and Two Family Dwelling Code, which was not widely adopted, is not considered in this paper.

Beginning in 1986, there have been five editions of the residential code language (1986 CABO, 1989 CABO, 1992 CABO, 1995 CABO, and 2000 IRC). The requirements for crawl space ventilation have not changed significantly between the first and last of these codes. Excerpts of the requirements include:

- The space between the bottom of the floor joists and the earth under any building (except spaces occupied by a basement or cellar) shall be provided with ventilation openings through foundation or exterior walls.

- The minimum net area of ventilation openings shall not be less than 1 square foot for each 150 square feet of crawl space area.
- One such opening shall be within 3 feet of each corner of said building.

A list of exceptions has accompanied the crawl space ventilation requirements in each edition of the code. One significant exception is as follows:

- Ventilation openings may be vented to the interior of the buildings where warranted by climatic conditions.

Concurrent with the publication of each code edition, CABO produces a document entitled *Application and Commentary* to provide clarification for many sections of the code. The 1992 and 1995 editions included the following note regarding crawl space ventilation:

> A number of exceptions are provided to address a variety of conditions wherein openings through the walls or exterior are either reduced or eliminated. Alternatives include the ventilation of the space into the interior of the building where climatic conditions warrant such an option, such as areas where the climate is moderate and dry.

Figure 4: Left unchecked, crawl spaces can suffer high severity moisture-related damages. The floor framing in this Georgia home partially collapsed during a holiday dinner party. Wood-destroying fungi compromised the strength of the wood members to such an extent that they could not support design level loads.

Advanced Energy probed this point in an exchange of letters with Building Officials and Code Administrators, Inc (BOCA). BOCA indicated the following:

> Simply stated, the exception gives the authority having jurisdiction the latitude to establish whether moisture condensation is likely in underfloor (crawl) spaces based on geographic location, climatic conditions unique to specific areas within a jurisdiction, or other localized experience derived from valid experimental evidence or observation.
>
> Through reasonable interpretation of the code, the phraseology, "openings to the interior" means any opening in the building thermal envelope that communicates with or connects the underfloor (crawl) space to the conditioned space.

It was not until the 1992 edition that CABO introduced language addressing moisture vapor retarders. The 1992 and 1995 editions of the CABO have the verbiage below.

> In all frame walls and floors and ceilings not ventilated to allow moisture to escape, an approved vapor retarder having a maximum perm rating of 1.0, when tested in accordance with Procedure for Desiccant Method ASTM E 96, shall be used on the warm-in-winter side of the thermal insulation.

Exceptions:

1. In construction where moisture or its freezing will not damage the materials.
2. In hot and humid climate areas where either of the following conditions occur: 67˚F or higher wet-bulb temperature for 3,000 or more hours during the warmest six consecutive months of the year, or 73˚F wet-bulb temperature for 1,500 or more hours during the warmest six consecutive months of the year.

The *Application and Commentary* provides some clarification regarding Exception 2 as follows:

> Moisture migration is more complicated in air-conditioned buildings. A portion of the southern U.S. (along the Gulf of Mexico and the lower Atlantic coasts) is considered a fringe or humid climate. In these and other locations, depending on local experience, moisture migration in air-conditioned buildings is from the outside to the inside. Consequently, in these locations the vapor barrier should be placed in the warm-in-summer (outside) wall face.

While the Application and Commentary provides some insight regarding the applicability of Exception 2, acquisition of the appropriate weather data was required to properly interpret this section of code. Perhaps the most complete source of this information is Engineering Weather Data developed by the Air Force Combat Climatology Center and published by the National Climatic Data Center (NCDC). Unfortunately, the code did not provide a reference for the weather data, the weather data is not in the public domain, and the weather data was not available for local retail purchase in most areas. As a result, typical construction practice was to default to the basic portion of this code section.

The 2000 IRC attempts to simplify this code section with the following language.

> In all frame walls and floors and roof/ceilings comprising elements of the building envelope, a vapor retarder shall be installed on the warm-in-winter side of the insulation.

Exceptions:

1. In construction where moisture or its freezing will not damage the materials.
2. Where the framed cavity or space is ventilated to allow moisture to escape.
3. In counties identified with "footnote a" in Table N1101.2

Table N1101.2 includes a listing of each county in each state of the United States. The benefit of this table is the elimination of weather data research in order to make a code interpretation. The down side is the code presumes that climate conditions follow political boundaries.

In the case of crawl space moisture control, it is particularly difficult to interpret these two sections of code. The reason is that one section of code seems to require that the crawl spaces be ventilated and the second section of code seems to remove the requirement for a vapor retarder when the space is ventilated. In warm and humid climates, ventilation without a protective vapor retarder can result in moisture-related deterioration of wood elements in a crawl space.

A map of the Southeastern United States reveals that many areas of the country located within the warm, humid climate zone are also in hurricane and flood prone areas. In some of these areas, additional code requirements, such as the SBCCI SSTD 10, "Standard for Hurricane Resistant Residential Construction," have been adopted. Section 102 of this document pertains to foundations. Several excerpts follow:

> **102.2.3** Buildings located within a Coastal High Hazard Area (V Zone as defined by the community's Flood Insurance Rate Map) must be elevated so that the bottom of the building's lowest horizontal structural member is at or above the base flood elevation. Buildings located within a Special Flood Hazard Area (A Zone) must be elevated so that the top of the building's lowest floor is at or above the base flood elevation.

Figure 5: The second type of moisture damage starts at the floor sheathing and migrates downward. This type of damage is associated with excessively cool interior floor temperatures and low permeability floor finishes. This photograph shows a section of flooring near a "toe-space" HVAC register where supply air discharges horizontally from below a cabinet.

> **102.2.4** Buildings located within V Zone shall be of pile construction and the foundation shall be structurally designed by a registered professional engineer or architect so that the building and its foundation are

anchored to resist flotation, collapse, or lateral movement due to the effects of wind and water loads acting simultaneously on all building components. The foundation should be either kept free of obstruction or enclosed in a manner that complies with the breakaway wall requirements of the National Flood Insurance Program.

Figure 6: This photograph is interesting, as it shows both types of damage on one floor joist. Damage extends approximately one-third of the width of the board from the top and bottom. The middle third of the joist is bright, yellow, and free of visible damage.

102.25 Buildings located within the A Zone and constructed on foundation walls that have fully enclosed areas below the lowest floor that are subject to flooding shall be designed to automatically equalize hydrostatic forces on exterior walls by allowing for entry and exit of floodwaters. Designs for meeting this requirement shall...meet or exceed the following minimum criteria: a minimum of two openings having a total net free area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above finished grade. Openings may be equipped with screens, louvers, valves, or other devices provided that they permit the automatic entry and exit of floodwaters.

Summary

It is clear that the flood-related portions of the building code complicate the implementation of the SCST, as the vents cannot be closed. The existing building codes are flexible enough to allow SFT construction. In part two of this paper, an actual repair using the SFT will be described. Data from post-construction monitoring will also be presented. ■

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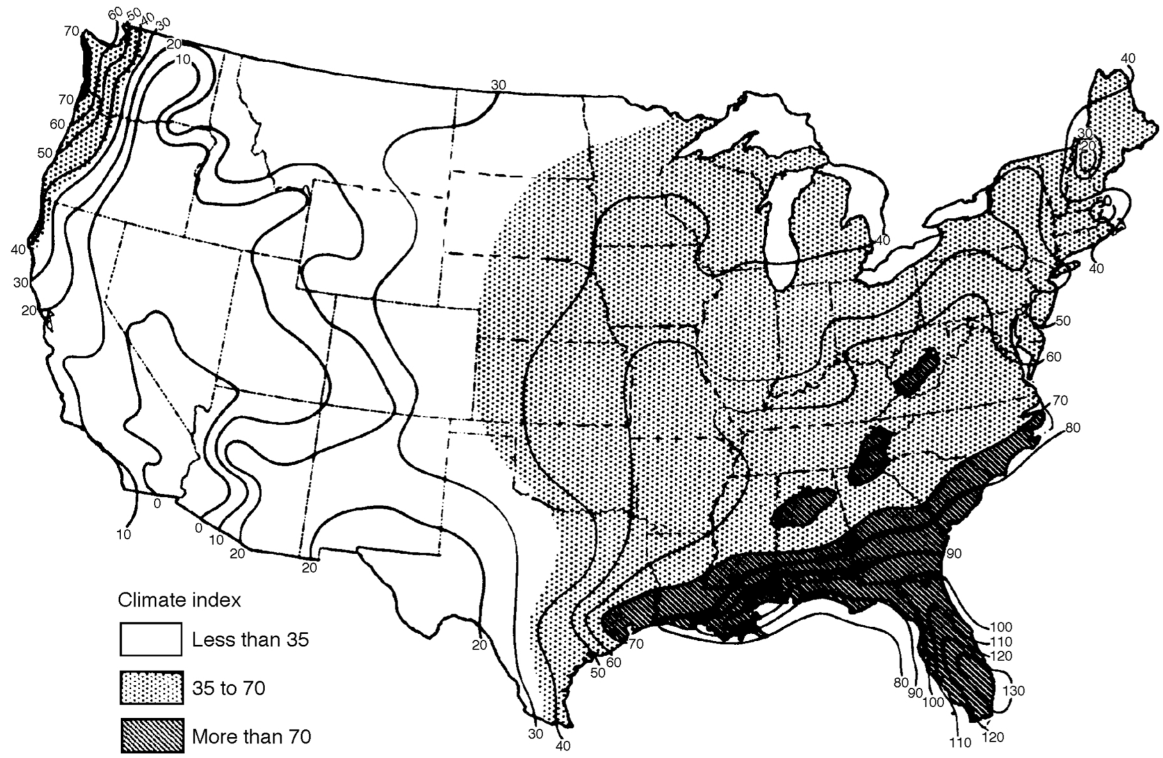

Figure 7: The Decay Hazard Chart from the USDA Forest Product Laboratory's Wood Handbook shows the likelihood of wood decay in various areas of the United States. The dark shaded area also approximates the portion of the country defined as warm and humid in the 2000 International Residential Code.

About the Author

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J. Lawrence Elkin, PE, received his B.S. and M.S. degrees in Mechanical Engineering from Rose-Hulman Institute of Technology. Afterwards, he spent several years designing nuclear magnetic resonance and magnetic resonance imaging equipment. For the last seven years, Elkin has performed forensic evaluations of building failures. Elkin's expertise is primarily in the physics of thermodynamics and fluid dynamics as they apply to building envelope systems. Currently employed at Campbell, Schneider and Associates, LLC, Elkin utilizes the latest techniques to evaluate difficult moisture problems. These techniques include computer-based numeric simulations, electronic data acquisition, and many other advanced field investigation strategies. Elkin's research has resulted in wall, floor, and roof designs specifically developed for use in warm and humid climates. He also provides expert testimony to help resolve construction-related litigation. Elkin is an active member of the Building Environment and Thermal Envelope Council (BETEC) of the National Institute of Building Science (NIBS) and the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE).