Insulating Raised Floors in Hot, Humid Climates

Raised floor home in Baton Rouge

Research Findings on Moisture Management

LSU AgCenter Research & Extension

100 Years of Service
Forest Products Laboratory

Raised Floor

Raised floor homes in New Orleans

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Introduction

This document summarizes key information based on a cooperative research project conducted by the U.S. Department of Agriculture's Forest Products Laboratory and the Louisiana State University Agricultural Center. The study was supported by the Forest Products Laboratory, APA–The Engineered Wood Association and the Southern Pine Council. This summary is intended for homeowners, builders, architects, insulation contractors, home inspectors, building officials and consultants. The study itself (Glass and others, 2010) and additional references for further reading are given at the end of this summary.

Why does moisture management matter?

We generally want our homes to be safe, durable and comfortable – all while requiring reasonable amounts of energy for heating or cooling. The last thing homeowners want is to find mold or decay in their homes. The key to preventing growth of mold and decay fungi is proper moisture management. It also is essential for preventing corrosion of nails and screws that hold the structure together and avoiding expansion/contraction damage such as cupping or buckling of wood flooring.

How much moisture is too much?

Wood has a strong affinity for water vapor. At a relative humidity of 50 percent at room temperature, wood holds about 10 percent of its dry weight as absorbed moisture. This percentage commonly is called moisture content. At 80 percent relative humidity, wood moisture content is about 16 percent. When moisture content increases, wood expands. When wood dries, it shrinks. Expansion/contraction damage depends on how much the moisture content changes and how sensitive the particular construction or wood product is to such changes.

The traditional guideline for protecting wood and wood products from rot or decay is to keep the moisture content below 20 percent. Studies have shown, however, that mold growth can occur on wood at moisture content levels above 15 to 18 percent, and corrosion of metal fasteners in treated wood can occur when moisture content exceeds 18 to 20 percent. Reaching these moisture content levels does not mean mold growth or corrosion will necessarily occur. For each of these moisture-related problems, a key factor is the amount of time the wood spends at an elevated moisture level.

How does insulation affect moisture levels?

The rates of wetting and drying of building assemblies, whether they are floors, walls or ceilings, can be affected by thermal insulation. The job of thermal insulation is to slow down heat flow – to help keep the inside of the house warm when it's cold outside and cool when it's hot outside. In addition to its thermal resistance, insulation provides some resistance to moisture migration, and this resistance can vary widely between different types of insulation. Insulation's effect on limiting heat flow will coincidentally make certain parts of the floor assembly warmer (or cooler) than other parts of the assembly. This is important because wood tends to dry when it is warm relative to its surroundings and is prone to moisture accumulation when it is cooler than its surroundings.

Figure 1. Example of an open crawl space.

Figure 2. Example of a wall-vented crawl space.

Three different crawl space types

For the purpose of discussing moisture management, **crawl spaces** can be classified into three different types.

1. We refer to open pier-and-beam foundations as **open crawl spaces.** (See Figure 1, page 3.) Open crawl spaces may have a continuous wall on just the front side and be open on the other sides.
2. We refer to crawl spaces with continuous perimeter walls that include vents to the outside as **wall-vented crawl spaces.** (See Figure 2.)
3. Finally, we refer to crawl spaces with continuous perimeter walls with no vents as **closed crawl spaces.** (See Figure 3.)

A closed crawl space, with regard to air and water vapor movement, is effectively part of the interior space and is intended to be isolated from the ground and the exterior. The ground and perimeter walls typically are covered with a vapor barrier, and the crawl space may be provided with conditioned air. A number of studies in various climates have shown this type of crawl space can remain safely dry, but this method of construction is not typical and is risky in flood hazard areas.

Building codes require that raised floor foundations in flood hazard areas permit floodwaters to move through the space underneath the building. That can be achieved in closed crawl spaces with breakaway panels or vents that normally stay closed but open when floodwaters exert pressure. The long-term ability of these devices to remain sufficiently airtight to provide an essentially closed crawl space has not been demonstrated. Furthermore, in the event of a flood, the crawl space will flood, and the perimeter walls will inhibit drainage and drying after the flood. In addition, potential floodwater contaminants and mold growth, which may occur subsequent to flooding in a closed crawl space, will be coupled with indoor air. Because of these hazards, the closed crawl space is not advisable in flood-prone areas.

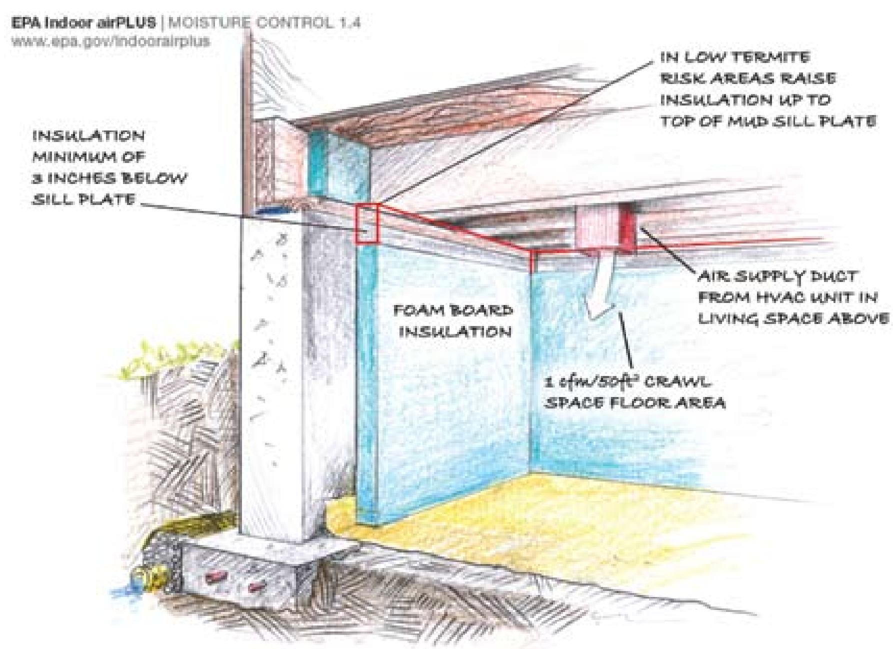

Figure 3. Sketch of a closed crawl space with conditioned air supply. [Illustration: Dennis Livingston, Community Resources. Reprinted with permission of the U.S. Environmental Protection Agency.]

Managing rainwater and soil moisture

Site grading and management of roof runoff can largely determine how wet the soil becomes under a house. In general, the soil around the foundation should be graded so water drains away from the building. Wet soil under a raised house can supply a large amount of humidity to crawl spaces, especially in wall-vented crawl spaces.

An established method of limiting evaporation of moisture from wet soil into wall-vented crawl spaces is to cover the soil with a vapor retarder such as polyethylene, typically 0.15 millimeters (6 mil) or thicker. The use of soil covers in wall-vented crawl spaces is based on a large body of research. If site conditions allow rainwater to wind up on top of the soil cover, however, the soil cover may be counterproductive.

Results from this study showed humidity levels (on an absolute scale) in open crawl spaces were essentially the same as outdoors. This means evaporation from the soil under an open crawl space is overpowered by a high rate of air exchange between the crawl space and the outdoors. This finding suggests if a house is to be built on a site with poor grading and drainage, an open crawl space would be preferable to a wall-vented crawl space.

Water vapor movement

Water vapor generally diffuses from an area of higher concentration to one with lower concentration. This often corresponds with migration from higher temperature to lower temperature. For example, when a building is air-conditioned and the outdoor climate is hot and humid, water vapor migrates through the building shell from outdoors to indoors. This is referred to as inward vapor drive.

Inward vapor drive means water vapor will be absorbed by the subfloor from the outside. This absorbed moisture will migrate through the subfloor and will dry to the inside. When the rate of wetting is higher than the rate of drying, moisture will accumulate in the subfloor. If the moisture content gets too high for too long, problems like mold and rot can occur.

To protect the subfloor from moisture accumulation, the insulation under the subfloor should be selected to provide enough resistance to the inward vapor drive.

Experimental study

Conditions were monitored in a dozen Louisiana homes – eight in New Orleans and four in Baton Rouge. Eleven of the 12 homes were located in flood hazard areas and were constructed with open pier foundations. The sole home in the sample with a wall-vented crawl space incorporated a vapor-retarding soil cover, in accordance with conventional recommendations. The 11 other homes (with open crawl spaces) did not incorporate soil covers.

Air temperature and humidity were measured with data loggers placed indoors, outdoors and in crawl spaces. Moisture content and temperature of the wood or plywood subfloor was measured, typically twice each month. Monitoring started in October 2008 and concluded in October 2009.

Figure 4a. Example of rigid, foil-faced polyisocyanurate foam.

Figure 4b. Example of closed cell spray foam.

The sample of 12 houses included six different insulation systems:

A. 2-inch-thick, rigid, foil-faced polyisocyanurate foam insulation installed below the floor joists. All seams were sealed with foil tape, penetrations were sealed with spray foam and rim joist areas were insulated with spray foam type D below (Figure 4a, page 5).

B. 2 inch average thickness of approximately 2 pounds per cubic foot closed cell sprayed polyurethane foam below the subfloor (Figure 4b).

C. 2.6 inch average thickness of medium-density (1 pound per cubic foot) open cell sprayed polyurethane foam below the subfloor.

D. 3.4 inch average thickness of low-density (0.5 pounds per cubic foot) open cell sprayed polyurethane foam below the subfloor (Figure 4c).

E. Same as D, except with the addition of one coat of a spray-applied vapor retardant paint coating (nominal perm rating less than 0.5).

F. 6.25-inch, kraft-faced fiberglass batts installed between floor joists with the kraft facing up against the subfloor, supported by metal rods (Figure 4d, page 7).

All insulation systems were nominally R-13, except the batt insulation, which was nominally R-19.

Houses in New Orleans originally were insulated with fiberglass batt insulation. Contractors removed batt insulation from half of the floor and replaced it with rigid foam or spray foam insulation. Floors in the Baton Rouge houses were insulated entirely with rigid foam and/or spray foam.

Results

The main results are summarized here, followed by a discussion of the main factors affecting subfloor moisture levels and the implications.

- For all 12 houses the predominant vapor drive was inward from May through October (when air conditioning was running). During the other months, the difference between indoor and outdoor water vapor pressure (a way of expressing humidity on an absolute scale) was small.

Figure 4c. Example of open cell spray foam.

Figure 4d. Example of typical fiberglass batt insulation.

- Air temperature in open crawl spaces was very close to outdoor air temperature. These crawl spaces were slightly warmer than outdoors in cold weather and slightly cooler than outdoors in warm weather.
- In contrast, the wall-vented crawl space was considerably warmer than outdoors in cold weather and considerably cooler than outdoors in warm weather.
- In all crawl spaces, water vapor pressure essentially was the same as outdoor vapor pressure.
- Moisture conditions within plywood or solid wood subfloors were found to depend on several variables:
  - Season of the year.
  - Indoor temperature during summer.
  - Type of interior floor finish.
  - Type of under-floor insulation.

Seasonal effect

In most cases, a seasonal trend was observed of higher subfloor moisture content during summer and lower subfloor moisture content during winter. This is a result of the subfloor being cooler than the crawl space during the months when air conditioning is running and warmer than the crawl space during the winter. The seasonally varying temperature differences between the subfloor and the crawl space are amplified by the thermal insulation, which is located between the subfloor and the crawl space.

Air conditioning and indoor temperature

For a given type of insulation and interior floor finish, subfloor moisture content generally increased with decreasing indoor temperature during summer. That is, the cooler the air conditioning was keeping the temperature indoors, the wetter the subfloor. The potential for low air conditioning set-point temperatures to cause problematic moisture accumulation in floors over crawl spaces in the southeastern United States has been recognized for decades (Verrall 1962).

A cautious designer should select floor insulation that can accommodate lower-than-average temperatures during the air conditioning season without resulting in moisture accumulation in the subfloor. On the other hand, homeowners in hot, humid climates can reduce the risk of seasonal moisture accumulation if they set the thermostats controlling their air conditioners as high as they feel is practical. Houses in the study with summertime indoor temperatures of 78 degrees F or higher did not show elevated subfloor moisture levels, regardless of the type of floor insulation. Higher air conditioner thermostat settings will, along with reducing the risk of moisture problems in subfloors, result in less energy consumption. Use of ceiling fans and stand-alone dehumidifiers can improve summertime comfort levels in homes with higher air conditioning set-point temperatures.

Interior floor finish

For a given indoor temperature and type of insulation, summertime subfloor moisture content generally was higher under an impermeable floor finish such as vinyl than under carpet. Vinyl is very impermeable and prevents inward drying of the subfloor. Carpet, on the other hand, is much more permeable to water vapor. Hardwood flooring with polyurethane finish and ceramic tile are less permeable than carpet but considerably more permeable than vinyl. Impermeable floor finishes, by inhibiting inward drying of the subfloor, raise summertime subfloor moisture content.

Types of insulation and resistance to water vapor flow

For a given indoor temperature and type of interior floor finish, higher subfloor moisture content during summer was found with more permeable insulation. Greater permeability allows for water vapor to migrate through insulation and into subfloor materials.

Foam board faced with aluminum foil is essentially impermeable to water vapor. Closed cell spray foam insulation is somewhat impermeable. These types of insulation showed good performance, preventing summertime moisture accumulation in subfloors.

In contrast, open cell spray foam and batt insulation are much more permeable. Open cell foam gave subfloor moisture contents above 20 percent in some cases when vinyl flooring was present and the air-conditioned indoor temperature was relatively low during the summer. This type of insulation was not reliable for preventing summertime moisture accumulation in subfloors.

Batt insulation, although giving lower subfloor moisture contents on average than open cell foam, also gave some elevated moisture levels (above 20 percent moisture content). The glass fibers do not provide much resistance to water vapor diffusion, but the kraft paper facing, right below the subfloor, does provide some resistance. The kraft facing becomes more permeable as relative humidity increases, however, and in the southeastern United States, the outdoor relative humidity commonly is above 80 percent.

In a few instances, open cell foam was finished with a coat of vapor retardant paint. One reason for choosing this combination is that open cell foam plus paint is less expensive than closed cell foam. If the floor finish was carpet, the application of vapor retardant paint over open cell foam had no discernable effect on subfloor moisture content. It should be noted, however, that subfloor moisture contents under carpeted floors never became elevated, due to the moderately high vapor permeability of the carpet.

In contrast, if the floor finish was vinyl, the vapor retardant paint applied over open cell foam appeared to result in lower subfloor moisture contents on average (relative to an otherwise identical floor system with the vapor retardant paint omitted), but some individual moisture readings still exceeded 16 percent moisture content. The data regarding the effect of vapor retardant paint were not conclusive, and further research is needed to determine whether the combination of open cell foam and vapor retardant paint can be a reliable strategy for preventing summertime moisture accumulation in subfloors in this climate.

Raised floor home in Baton Rouge

Summary

Twelve houses in New Orleans and Baton Rouge, La., were monitored over a one-year period. In all 12 houses the predominant vapor drive was inward from May through October (when air conditioning was running). During the other months, the difference between indoor and outdoor water vapor pressure was small.

The air temperature in open crawl spaces was very close to outdoor air temperature. These crawl spaces were slightly warmer than outdoors in cold weather and slightly cooler than outdoors in warm weather. In contrast, the wall-vented crawl space was considerably warmer than outdoors in cold weather and considerably cooler than outdoors in warm weather. In all crawl spaces, water vapor pressure was essentially the same as outdoor vapor pressure.

Moisture conditions within plywood or solid wood subfloors generally showed a seasonal trend of higher moisture content during the summer and lower moisture content during the winter. Subfloor moisture content during summer generally increased with decreasing indoor temperature (the lower the air conditioning kept the temperature, the wetter the subfloor), increased with decreasing permeability of the interior floor finish (wetter subfloor under vinyl than under carpet) and increased with increasing permeability of the under-floor insulation (wetter subfloor with open cell sprayed polyurethane foam than with closed cell sprayed polyurethane foam). **Foil-faced rigid foam and closed cell sprayed polyurethane foam exhibited good performance, keeping subfloor moisture content within acceptable levels.** In contrast, open cell sprayed polyurethane foam and fiberglass batt insulation were not reliable for preventing summertime moisture accumulation in subfloors.

Questions and answers

1. The study results indicate that open cell sprayed polyurethane foam and fiberglass batt insulation are not always reliable for raised floor systems in this climate. Is there a suitable retrofit for a raised floor system in which either open cell foam or fiberglass insulation is already installed?

Answer: The study did not address this issue directly. The study did find, however, that properly sealed foil-faced rigid foam insulation installed below the floor joists (without any insulation in the joist spaces) prevented summertime subfloor moisture accumulation. This performance is attributed to the vapor-impermeable aluminum foil facing and the air-sealing details at all edges and penetrations. We therefore expect this type of insulation to be a suitable retrofit for a raised floor system already equipped with fiberglass insulation. As long as the existing insulation and subfloor have not been exposed to elevated moisture levels, it would not be necessary to remove the insulation.

If it is not feasible to add foil-faced rigid foam (due to obstructions, affordability, etc.), the risk of subfloor wetting may be reduced in batt insulated floors by keeping the air conditioning thermostat setting at 78 degrees F or higher and replacing vinyl and other impermeable floorings with more permeable floorings. Although the study did not investigate the effect of drooping batt insulation, we would expect that drooping batts pose an additional risk due to humid air bypassing the kraft vapor retarder, leading to increased moisture accumulation in the cool subfloor of an air-conditioned home. We advise making sure all batts are held in full contact with the subflooring.

Likewise, risk of moisture problems in homes with open cell foam subfloor insulation may be reduced by the same strategies (higher thermostat settings and more permeable flooring). Although the study did not investigate the effect of multiple coats of vapor retardant paint over open cell foam, it is possible this strategy would result in lower summertime subfloor moisture levels.

2. The study results indicate closed cell spray foam is a suitable insulation for raised floor systems in southern Louisiana. Should the floor joists, as well as the subflooring, be covered with closed cell spray foam?

Answer: The study did not address this issue, and we therefore cannot make explicit recommendations. It could be argued from building science principles, however, that covering the joists in wall-vented crawl spaces with closed cell foam is likely to keep them drier *during summer months. As the study indicated, in a wall-vented crawl space, crawl space temperature can be noticeably cooler than outside temperature during summer months while water vapor pressure in the crawl space is very close to that of the outdoor environment. This results in high relative humidity levels in the crawl space. Under these conditions, the joists are likely to reach higher than desirable moisture levels. Therefore, isolating the joists from crawl space conditions by covering them with closed cell foam could reasonably be expected to limit the peak moisture content they reach during summer months. In contrast, in open crawl spaces, both temperature and vapor pressure are very similar to outdoor conditions, and thus seasonal peak moisture content of the floor joists is expected to remain in a safe range. For this reason, covering the joists in open crawl spaces with closed cell foam is not expected to provide substantial benefits.*

3. Will covering floor joists with spray foam increase the risk of termite infestation?

Answer: Covering the joists with spray foam can interfere with performing periodic inspections for termites. The degree of risk concerning termite infestation depends on location of the joists and whether they are preservative treated. Joists that are in contact with piers – or near perimeter walls in the case of wall-vented crawl spaces – have the potential to serve as infestation routes. If joists are not pressure treated, spraying them with borate preservative coating will substantially lower infestation risk. Homeowners who have contracts with pest control operators for termite inspection should follow the contract terms.

4. What is a suitable time of year to install closed cell spray foam insulation?

Answer: In a new home that is not yet occupied, the season for installation would not appear to matter, although it is important to ensure that the floor system is adequately dry before installing the insulation. A floor deck that was constructed with wet lumber or that was exposed to rain before the building was enclosed should be allowed to dry. In an existing occupied home that is air-conditioned during the summer, installation would be best done during late fall, winter or early spring. The floor system moisture content at time of installation will be less important if the interior floor covering is vapor-permeable.

Further reading

Advanced Energy. Various articles on closed crawl spaces. www.crawlspaces.org

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