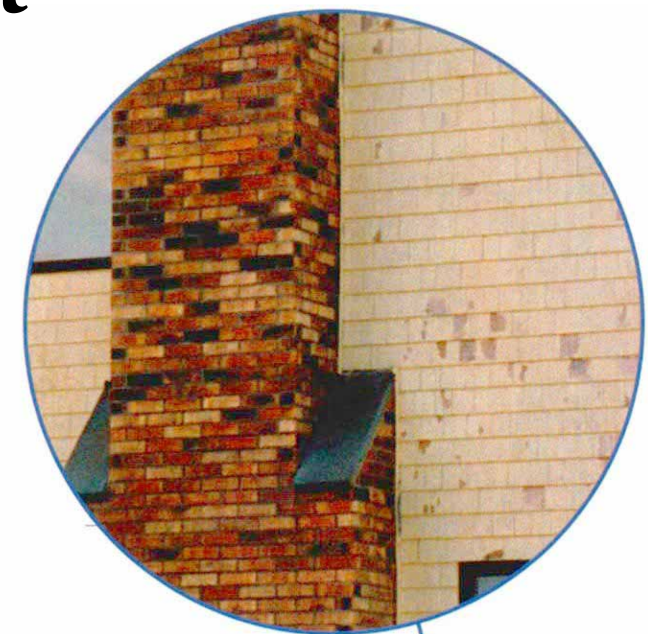
Ensuring the Durability of Energy-Efficient Houses



Why are so many of todays homes plagued by rot, mildew and stale air, and what can we do about it?

BY STEPHEN SMULSKI

Paint problems. To prevent premature paint failure, exterior wood products should be back-primed, end-primed and top-coated within two weeks with two coats of a high-permeability paint or solid-color stain.

The energy-efficient wood-frame houses of the 1980s and '90s are the most comfortable, the most expensive and very likely the least durable houses ever built in the United States. Over the past 20 years, the frequency of moisture-related problems in new houses has skyrocketed. Frustrated homeowners complain increasingly of window condensation, mold and mildew indoors; of extractive staining and peeling paint outdoors (top photo); and of rotting windows, doors, trim (bottom photo, facing page), siding, sheathing and framing. All these problems are occurring within a few years of construction.

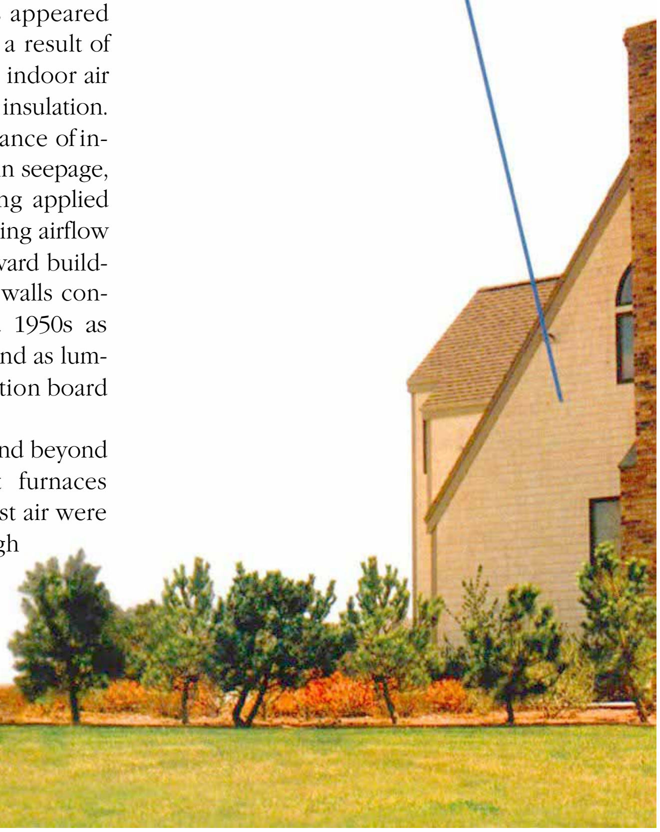
Tighter walls, colder walls

Historically, moisture-related problems were uncommon; the architects, builders and occupants of wood-frame houses relied—perhaps unwittingly—on the natural replacement of air to control indoor humidity and to keep walls dry. Differences in temperature and pressure across a house's envelope provided the driving force for moving air through random leaks in its walls, foundation and attic. As a result, warm, moist indoor air was flushed out and replaced with cooler (and usually drier) outdoor air.

Reliance on the natural replacement of air by way of random leakage worked fine for many centuries until the rapid evolution of technology in the 20th century made it possible to build houses that had tighter and tighter envelopes.

Insulation was first added to walls on a large scale in the 1920s. Functioning as a physical barrier that hindered movement of air and conduction of heat through the wall, the insulation often lowered the temperature of the interior side of the sheathing below the dew point during cold weather. Mildew and mold sometimes appeared on the back of the sheathing as a result of condensation from warm, moist indoor air that escaped through gaps in the insulation. To improve the thermal performance of insulation and to protect it from rain seepage, building papers were soon being applied over the sheathing, further reducing airflow through the walls. The trend toward building tighter, and therefore colder, walls continued through the 1940s and 1950s as plaster was replaced by drywall and as lumber sheathing gave way to insulation board and plywood.

The introduction in the 1960s and beyond of electric heat and low-draft furnaces meant that large volumes of moist air were no longer being expelled through an active chimney. In the 1970s and '80s, widespread adoption

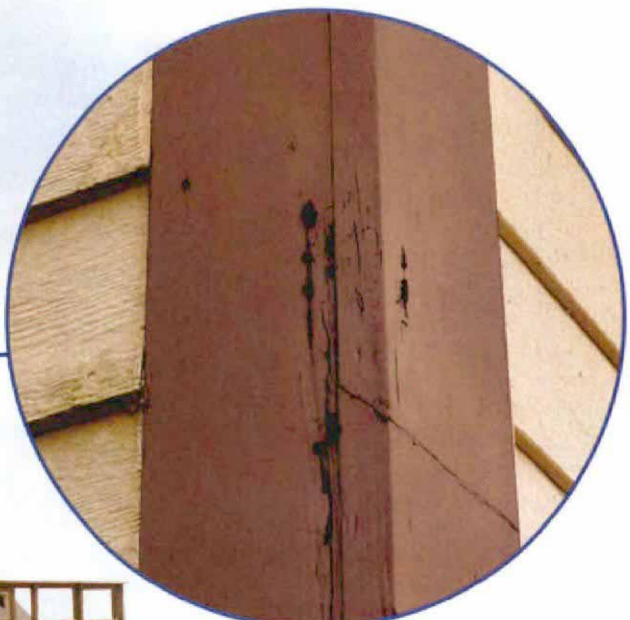


DOUBTFUL DESIGNS AND POOR CONSTRUCTION

New, energy-efficient wood-frame houses experience more moisture-related problems than older houses. Some contemporary house designs, such as this one near the New England coast, lack even basic water-shedding features such as eaves and rain gutters.

No protection for the walls. The lack of gutters and eaves allows runoff from the valley to cascade onto the cedar shingles, causing algae to bloom directly beneath the valley and paint to peel farther down the wall.

Wrapped up tight. Continuous vapor retarders, insulation and air-infiltration barriers make the walls of energy-efficient houses tighter, colder and slower to dry after they get wet.



Vulnerable joints. Water drawn by capillary action into the uncoated end grain inside this joint permitted this trim to rot quickly.

Giving moisture a way out. Moisture-caused problems in wood lap siding (mold, mildew, peeling paint) are sidestepped by mounting siding on furring strips at least 5⁄16 in. thick. Wet siding dries into the airspace, which is screened at the bottom to keep out insects and is connected to the ridge vent through the soffit.

of insulating windows and doors, continuous vapor retarders and air-infiltration barriers (center photo, p. 73), coupled with the extensive use of caulks, sealants, gaskets and tapes, dramatically reduced the amount of air and heat that was flowing through a house's envelope.

Moisture: sources and prevention

The upside of all this change is a marked increase in energy-efficiency and occupant comfort. The downside is that tight walls are unforgiving; tight walls that get wet tend to stay wet. When enough moisture accumulates, mold, mildew and decay fungi go to work. Sources of moisture in energy-efficient houses include groundwater, piped water, condensation and precipitation. In some cases, even the water that is naturally contained in green framing members at the time of construction is at fault.

GROUNDWATER. The soil surrounding a house's foundation and floor slab contains water in both liquid and vapor form. Liquid water can seep into basements and crawlspaces through settlement cracks, joints, utility cutouts and other penetrations in foundation walls and floors. Water vapor can diffuse through foundation walls and through floors.

Whatever the source, once it reaches an exposed surface, the water evaporates, increasing the relative-humidity level, which in turn can raise the moisture content of sills, girders, joists and subflooring to mildew and mold-susceptible levels.

KEEPING WATER OUT OF BASEMENTS AND CRAWLSPACES

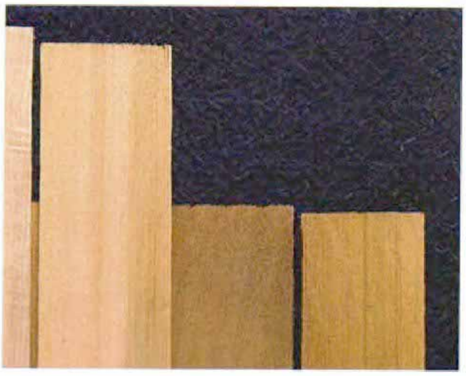
- **Install perimeter drains.**
- **Seal cracks and other points of entry.**
- **Apply waterproofing to the exterior of foundation walls.**
- **Backfill with free-draining soil.**
- **Grade soils so that they slope away from the foundation.**
- **Install gutters and down spouts along eaves.**

The diffusion of water vapor into a basement or crawlspace can be prevented by applying damp-proofing to a foundation's exterior and by installing a vapor retarder—most commonly polyethylene sheeting—under the slab or over the exposed soil in the crawlspace.

PIPED WATER. Pipes sometimes leak. Forceful plumbing leaks are typically discovered and corrected immediately. Although wood may get saturated in these cases, it usually dries out before any fungi can become established. Slow, persistent leaks that are hidden inside walls and floors, on the other hand, can go undetected for long periods and can elevate the moisture content of wood to fungi-attractive levels. Condensation dripping from cold-water supply lines onto wood can also lead to decay, especially in damp basements and crawlspaces; prevention entails wrapping cold-water pipes with insulation.

CONDENSATION. Besides active water leaks, a significant source of indoor moisture is the activities of the occupants themselves: taking showers and baths, cooking, and using humidifiers and unvented clothes dryers. Even seemingly minor sources of mois-

Photo this page: Zachary Gaulkin



Siding and shingle solutions. The three-dimensional mesh beneath these shingles (photo above) mimics traditional skip sheathing by letting shingles dry through the back. Lap siding already in place can be retrofitted with siding wedges that let trapped water escape (photo below).

Capillary culprit. Chronic cracking of paint on the face of this red-cedar siding was symptomatic of a hidden moisture problem caused by a lack of back and end-priming. Removal of the siding revealed water trapped in the overlap between courses.

ture such as respiration, perspiration and houseplants can make a sizable contribution to indoor humidity levels.

Water vapor is carried into walls, floors, ceilings, attics, basements and crawlspaces on convection currents of air flowing through joints and penetrations. During the heating season, warm, moist air entering these spaces is cooled below the dew point, and the excess moisture is deposited as condensation on framing, sheathing and other cold surfaces.

Condensation can also be a problem during the cooling season. At this time, the culprit is hot, humid outdoor air that seeps into relatively cooler and drier walls, floors, ceilings, attics, basements and crawlspaces. The framing and subflooring in crawlspaces that lie beneath air-conditioned rooms are especially at peril.

PRECIPITATION. Roofing and siding are major barriers against precipitation; film-forming coatings such as paint and solid-color stains are, too. Exposed surfaces of doors, windows, siding and trim elements are protected by paints or solid-color stains; but water may still be driven by wind, or drawn by capillary suction, into joints and

Voided ventilation. Sheathing and framing in this attic became saturated with condensation during the winter because the soffit vent was blocked with insulation. Otherwise, air flowing from the soffit vent to the ridge vent would have carried this moisture outside as designed.

overlaps to saturate uncoated wood from the ends and back.

Once wet, exterior wood on an energy-efficient house can take a long time to dry. Many exterior paints retard the escape of water vapor into the air, Housewrap and sheathing behind exterior wood slow its movement inward, while the vapor retarder deeper in the wall essentially stops it altogether.

One of the best ways to prevent precipitation-caused problems in new construction is by installing siding over furring strips applied over sheathing and housewrap (photo p. 74). This layout creates a vented airspace behind the siding into which water can evaporate. Existing siding with chronic moisture problems can be retrofitted with thin plastic shims called siding wedges (Shur-line Inc.; 800-828-7848) that are inserted into the overlap between courses (photo bottom left, p. 75). The gap the wedges open reduces the potential for water to be sucked into the overlap by capillary action, and allows air to dry the back of the siding, and the sheathing and framing.

The ends and backs of siding, trim, windows, doors and other exterior-wood products should be finished with a water repellent. The exposed surfaces of these products should be finished with opaque film-forming coatings (i.e., paints and solid-color stains) that combine high water repellency with high permeability to water vapor.

GREEN WOOD. Energy-efficient houses are sometimes framed with green dimensional lumber (GREEN or S-GRN in the grade stamp) or timbers. The amount of water released by a green timber frame as it dries can add up to hundreds of gallons, with the greatest release occurring during the first heating season. As a result, severe window condensation can damage sash, sills and walls. Dehumidifying a house during the first heating season is a good solution.

Because green lumber is wet when it's stacked and banded, it is often infected with live fungi when it arrives at the job site. Once the wood is sandwiched between sheathing and vapor retarder, the fungi have the opportunity to flourish. This problem can be avoided by using kiln-dried lumber (S-DRY or KD19), whose moisture content is too low to support fungal growth.

REDUCE RELATIVE-HUMIDITY LEVELS TO CONTROL CONDENSATION

- Vent clothes dryers, gas-fired appliances and exhaust fans directly outside.
- Place vapor retarders against the warm side of walls, ceilings and floors.
- Seal air-leakage paths.
- Provide adequate roof and attic ventilation.
- Use dehumidifiers.

Energy-efficient homes must be designed and built to shed water

The switch from leaky, warm, forgiving walls to tight, cold, unforgiving walls is not a bad thing. Energy-efficient homes are good for the environment and a good investment for their owners. But building durable energy-efficient homes is complicated, and mistakes can be costly. Declining technology transfer, dubious designs and poor construction practices are the reasons so many bad houses get built.

DECLINING TECHNOLOGY TRANSFER. The principles for designing and constructing durable, energy-efficient wood-frame houses are well established and thoroughly documented, but this information is not reaching many practitioners. Inadequate instruction in vocational schools, colleges and universities; curtailment of outreach services by state cooperative extension agencies and industry trade associations; and the demise of the apprenticeship system have left many architects and builders unaware of the proper use of wood in today's tight houses. (A good source for more information is the two-volume *Builder's Guide to Mixed/Cold Climates* by Joseph Lstiburek; The Taunton Press; 800-888-8286.)

DUBIOUS DESIGNS. The architect who is unaware of the importance of designing a wood-frame house to shed water cannot knowingly incorporate the proper details into his or her plans—hence, the recent prevalence of questionable architectural trends such as the narrowing of eaves and the elimination of gutters (photo pp. 72-73). Devolution of the roofed porch into the open deck, and the popularity of complicated roofs with multiple intersecting valleys and dormers also promote the wetting of walls by splashing.

Particularly troublesome are designs that sandwich wood between materials of low permeability that trap water. The best examples of this problem are the exterior insulation and finish systems (EIFS) that were introduced to residential construction in the 1990s. With EIFS, rigid-foam panels are glued to plywood or oriented strand board (OSB) sheathing, then skim-coated with synthetic stucco. Touted as being impervious to water when correctly applied, many EIFS installations leaked around doors and windows. The foam prevented wet sheathing and framing from drying to the outside, while the vapor retarder blocked drying to the inside. Sheathing and framing quickly rotted.

All wood-frame walls will eventually get wet during their lifetime; but they must be designed to dry, either to the inside or to the outside.

DESIGN FEATURES THAT PROMOTE WATER-SHEDDING

- **Wide eaves.**
- **Steep roof pitches.**
- **Flashing in roof valleys and at roof/wall intersections.**
- **Chimney crickets.**
- **Door and window flashings with built-in drip edges.**
- **Beveled top edge of horizontal trim.**
- **Sloped windowsills.**
- **Gutters and downspouts that prevent water running off a roof from cascading directly down walls, or splashing back onto walls from a lower surface or the ground.**
- **Exterior wood placed at least 8 in. off the ground to reduce wetting by splash-back.**

POOR CONSTRUCTION PRACTICES. Even good designs can be defeated by poor construction that permits water to intrude from outside or allows excessive moisture to build up inside. Most poor construction practices stem from declining technology transfer: The builder who has not been told of the importance of fully priming all sides of wood siding and trim prior to installation is unlikely to realize intuitively the benefit of doing so (photos right, p. 75). Some builders continue to commit such basic construction errors as venting clothes dryers and exhaust fans into attics and crawlspaces; blocking soffit vents with insulation (photo facing page); and omitting flashing around doors and windows.

Ensuring the durability of energy-efficient houses

The most important consideration in ensuring the durability of energy-efficient wood-frame houses is to use design features and construction practices that keep wood as dry as possible and promote drying if the wood gets wet. As evidenced by Norwegian stave churches, Asian pagodas and the colonial meeting houses and covered bridges of New England, wood-frame buildings can last for centuries.

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How to build durable, energy-efficient houses

- Employ design features and construction practices, such as wide eaves and gutters, that promote water-shedding.
- Install wood siding on furring strips.
- Back- and end-prime exterior-wood products.
- Finish exterior-wood products with opaque, film-forming coatings (i.e., paints and solid-color stains) of high permeability.
- Design wood-frame walls to dry either to the inside or the outside.
- Apply a continuous vapor retarder to the warm side of walls and ceilings.
- Use dry (S-DRY or KD19) framing lumber.
- Use caulks, sealants, gaskets and tapes to seal potential air-leakage paths.
- Employ design features and construction practices, such as grading and perimeter drains, that limit migration of soil moisture into basements and crawlspaces.
- Dehumidify basements and crawlspaces during the cooling season.
- Vent clothes dryers, gas-fired appliances, and bath and kitchen exhaust fans directly outdoors.
- Keep indoor relative humidity below 40% during the heating season.
- Augment low rates of natural air exchange with mechanical ventilation.
- Provide adequate roof and attic ventilation.

Editor's note: A number of builders' conferences address durable energy-efficient building practices. See "Cross Section" (p. 54) for more information.