Photo: Jim Bradley

Major Surgery for a Failing Fat Wall

Modern materials and proper details restored the double stud wall to a high-performance system

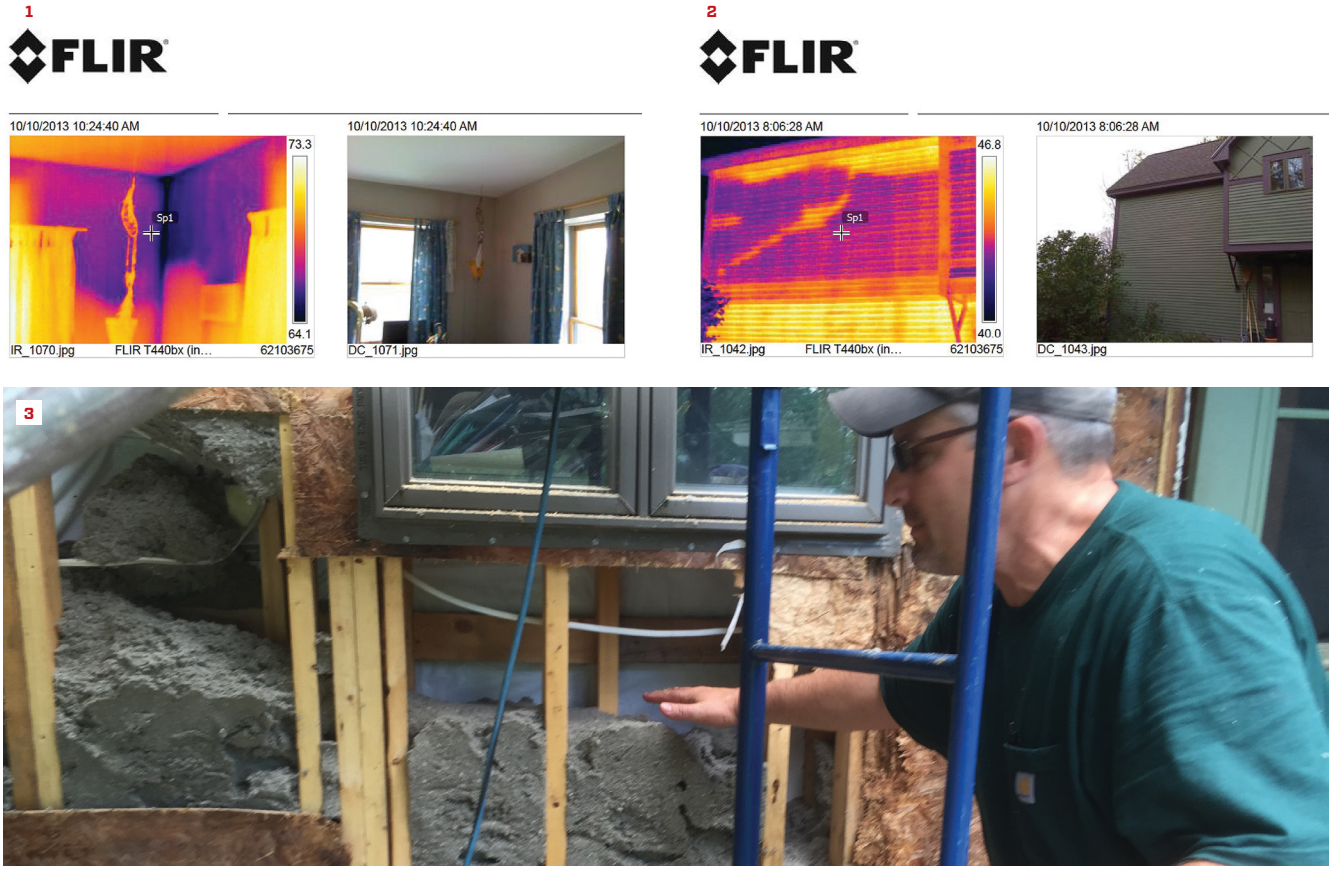
BY JIM BRADLEY

I'm a builder and remodeler in northern Vermont, specializing in home performance. My company, Caleb Contracting, does a lot of energy-efficiency retrofit work on existing homes, with many of those jobs referred to us from the state's energy-efficiency utility, Efficiency Vermont.

Some jobs can be accomplished for a few thousand dollars with basic air-sealing and a little added insulation. But sometimes when we investigate a home's envelope and HVAC systems, we find major issues that require extensive work to correct. In this story, I'll walk through one of our more extreme jobs.

The single-family country house shown here dates to the early 1980s and was framed with double stud walls 12 inches thick. The homeowners called us because they had some comfort issues and high energy bills. I'm sure they were hoping that simple measures would improve their situation, but when we took a good look at the house, we found serious flaws—failing insulation, severe moisture damage, mold, rot, and pest infestation.

Fixing those problems required significant reconstruction of



Infrared scans of the home's walls revealed an extreme example of settled cellulose insulation **(1)**, as well as clear evidence that rodents had made tunnels within the walls **(2)**. Removing the moisture-damaged OSB sheathing from the wall exterior confirmed that the insulation had settled badly **(3)**.

the house walls. Before we were done, we needed to tear off the home's siding and sheathing, remove its wall insulation, and rebuild the whole wall assembly from the back side of the drywall out. Not only did we install new Roxul batt and dense-packed cellulose insulation, we installed new smart vapor-control membrane, new vapor-open sheathing, and a new weather-resistive barrier. To top it off, we replaced the home's old, damaged siding and trim with a rainscreen cladding system constructed from more durable materials.

It was much more work than the owners had originally contemplated. But the thorough effort was necessary to keep their home from continuing to deteriorate.

The good news is that with smart design based on sound building science and the appropriate use of modern materials, we were able to turn this house back into the high-performance dwelling that it was originally intended to be—and with reasonable confidence that these systems will perform extremely well for at least another 50 years.

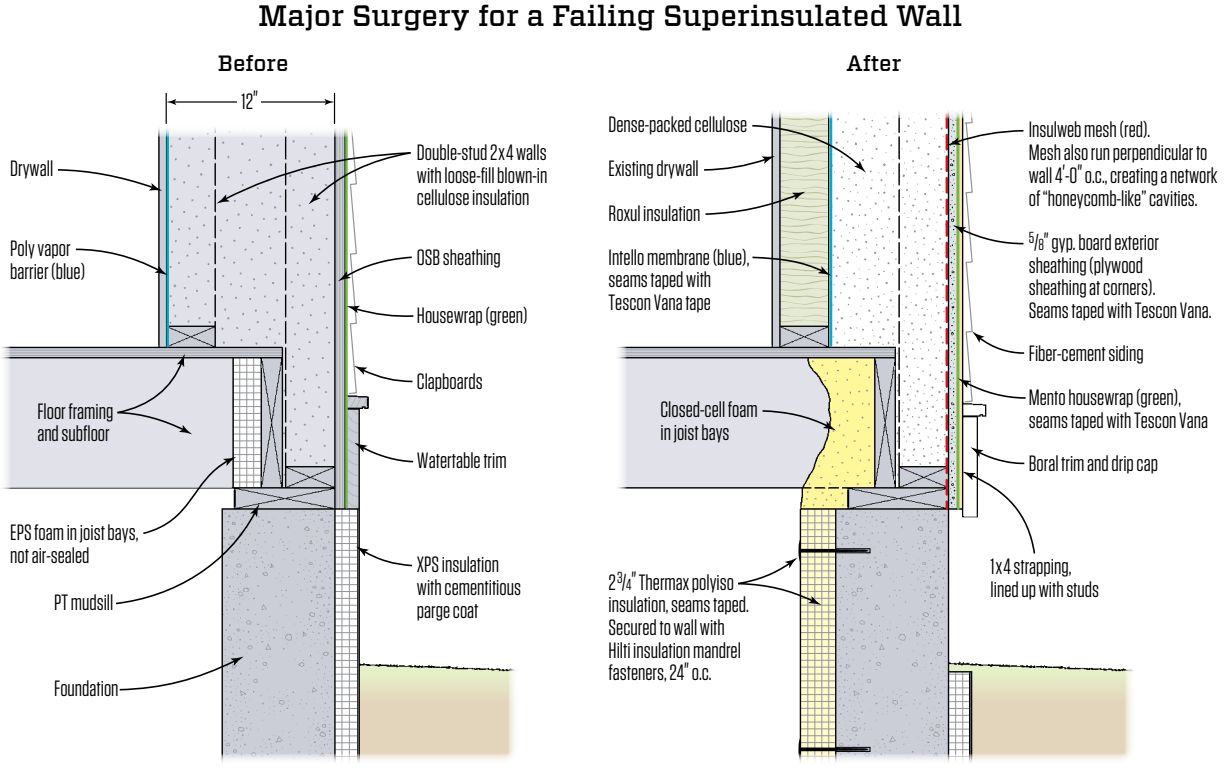
INVESTIGATION

Our routine examination of a house includes a visual inspection, a blower-door test, and an infrared camera scan to identify heat-flow issues. In the case of this house, the visual inspection showed damage to the foam perimeter insulation around the basement foundation, caused by ants who made their home in the insulation, and by woodpeckers who were hunting the ants.

In the attic, we found 20 inches of blown cellulose insulation in good condition, but we noticed some air leakage around the ceiling access hatch (nothing particularly difficult to remedy).

The blower-door test indicated a moderate amount of air leakage—1,366 cubic feet per minute (CFM), which worked out to 3.25 air changes per hour at 50 pascals of pressure (ACH50). This was

Photos: 1&2, Jim Bradley; 3, Tim Healey



Simple in concept, the home's existing double stud wall (left) had failed in practice. Damp cellulose insulation in the open cavity had settled. The author rebuilt the assembly (right) by installing Roxul batts in the inboard stud bays, sealing that inner wall with a smart vapor barrier, and creating a contained honeycomb structure in the outer wall to hold dense-pack cellulose at 3.5 pounds per cubic foot. Vapor-open sheathing with a taped weather barrier and rainscreen siding lets the wall dry outward.

surprisingly good for a house of early 1980s vintage. The blower door helped us pinpoint some typical air leaks, visible as hot or cold spots in our infrared camera images.

In themselves, the air leaks would not have been difficult to address. But the infrared scan of the walls also revealed another kind of serious trouble: major settling of the insulation, which we could see on the infrared images from the outside of the house as red heat blooms in the walls, and from the inside as blue cold areas.

My report to the homeowners read, "All exterior walls were found to have significant settling of the cellulose insulation. We suspect that the cellulose, when installed in the 1980s, was not installed under pressure (dense-pack) as is the current practice. Some walls have seen as much as a 40% reduction in the insulation coverage through settling. There were also areas, notably the front wall of the master bedroom, where rodent pathways were visible on the infrared camera image. Upon direct inspection, the air in the double stud wall cavity in the gable end of the living room was found to have a relative humidity 10% higher than the ambient humidity in the room (64%). This high humidity in the wall cavity near the insulation indicates that the insulation itself is damp, which is a possible invitation to the carpenter ants that have plagued the structure."

The dampness inside the wall was the result of a double vapor-barrier assembly, consisting of a poly liner behind the drywall on the interior wall, plus oriented strand board (OSB) sheathing with a standard housewrap on the exterior. While OSB may be structurally equivalent to plywood in the building code, the two types of structural panel don't have the same moisture transmission characteristics—OSB is less vapor permeable. Depending on the adhesives and the conditions of manufacture, OSB can have a perm rating low enough to be considered a vapor barrier

Illustration by Tim Healey

Built in 1983, the house had typical styling and materials from that era **(4)**. Stripping off the siding revealed the usual OSB sheathing and housewrap, both in a deteriorated condition **(5)**. Ants had tunneled into the foam insulation around the home's foundation **(6)**, pursued by hungry woodpeckers. With the siding removed, the author found that he could flake away the moisture-damaged OSB sheathing with his fingers **(7)**.

(sometimes as low as 0.1 perms). In this case, it appeared that the assembly amounted to a vapor "sandwich"—common practice that is still being replicated today throughout the country.

My recommendation to the homeowners was to remove the home's siding and sheathing and remove and replace all the damp, settled insulation. In rebuilding the wall, I proposed to install vapor-control membranes, airtight but vapor-permeable sheathing, and an effective drainage plane before re-siding the structure.

Windows were a question mark, but as the job progressed, the owner made the decision to replace the windows too.

Our investigation had revealed a particularly bad case of the building-science and construction failures that we commonly encounter in our market. It was an extreme example, but this type of problem is not an outlier. In my area, situations like this are becoming the norm, especially in houses built from the 1980s to the present. This house was a reminder of how important it is for us as building professionals to keep educating ourselves on the most current and field-tested building-science principles, techniques, and materials, so that the structures we build and renovate will continue to offer a healthy and safe environment that is durable as well as energy efficient.

DEMOLITION

In order to protect the existing walls against the weather as we worked, I decided to demo and rebuild the house one wall at a time, sheltering each exposed wall with tarps until we had made the assembly rain-resistant again. As we stripped off the siding and sheathing, we uncovered damp, settled insulation, confirming the evidence of our infrared photos. We were also able to inspect the sheathing and framing directly, and we found that the sheathing was deteriorating from dampness and decay (you could easily pull the OSB apart with your fingers). Most of the wall framing was still

Photos: 4, Jim Bradley; 5, Matt Burstein; 6&7, Tim Healey

The author's crew stripped the compromised OSB sheathing off the stud wall **(8)**, and vacuumed the damp, settled cellulose out from the double stud cavity **(9)**. The team attempted to preserve the existing windows in place, but the failure of the OSB meant that the windows would have to come out in order to repair the sheathing **(10)**. The wall's condition was worst at its base **(11)**, where it rested on the ant-infested perimeter insulation and floor framing.

sound, but the floor framing was not; we discovered that we would need to remove and replace portions of the first-floor band joist where the wood was rotted and infested with ants.

After opening up the walls, we vacuumed out the moisture-damaged and settled cellulose insulation, along with its load of animal droppings, urine, hair, insects, and mildew. That contaminated material and its load of allergens got pumped into disposal bags inside the dumpster.

Interestingly, as we exposed the back side of the drywall on the inner wall frame, we could see how the original builder had carefully air-sealed wiring penetrations and electrical boxes. The home's builders were evidently well-intentioned and had made a serious effort to do a good job—but they were working without a full understanding of the building science involved or of the properties of the materials they employed.

We also removed the poly vapor barrier from the back side of the drywall. The plastic on the inside of the house had caused more problems than it solved, as is commonly the case. Later we would achieve the poly's vapor-control objective using a more advanced material that was more carefully detailed and placed in a more appropriate location within the cross-section of the wall.

RECONSTRUCTION

When we work on any existing house, we keep three objectives in mind. We look at the situation first from the standpoint of health and safety: We want our work to make the house healthier and safer. We don't want to disturb asbestos, for example, or turn the house into a mold factory by introducing moisture issues. Second, we consider the structural soundness of the house: We want to restore the building to a structurally sound condition, and make sure it will stay that way. Energy efficiency is our third priority: We are aiming to cut the home's energy bills—and we

Photos: Tim Healey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The crew installed a smart vapor barrier over batt insulation **(12)**, stapled Insulweb open-weave fabric on the wall **(13)**, and repacked the wall with borate-treated cellulose at 3.5 pounds per cubic foot **(14)**.

will—but not at the price of introducing moisture issues or structural problems.

In this case, the house already had moisture issues that were a health and safety risk and that were damaging the building's wall structure. So we needed to rebuild the home's walls with a structurally sound system that not only provided excellent energy performance, but also preserved the walls against moisture intrusion, while allowing the walls to dry out freely.

In designing the system, we worked with Floris Buisman of 475 High Performance Building Supply (foursevenfive.com). The experts at 475 are a good resource for design advice in addition to being a U.S. source of some European-made components that aren't widely stocked in this country. With Floris' help, we came up with a wall system in which we have a high level of confidence.

Batts plus dense-pack. The existing house walls were framed as a double 2x4-stud-wall system, and the builders had attempted to fill that entire cavity with loose-fill cellulose insulation.

We had a different plan: We would install Roxul rock wool batt insulation within the inner wall frame and seal up that portion of the wall with a smart vapor-barrier membrane (Pro Clima Intello), applying the membrane to the outboard face of the inner wall studs and taping all the seams. Then we would dense-pack the remaining thickness of the wall with National Fiber cellulose (nationalfiber.com)—this time making sure to pack the insulation in at sufficient density to prevent future settling.

The outside wall was laid out at 16 inches on-center, but the inside wall framing varied—in some places the studs were spaced at 16 inches on-center, and in other places at 24 inches on-center. The irregular framing complicated our planning because we didn't know how much of which size insulation to order until we opened up each portion of the wall and could look at the cavities.

Smart vapor barrier. After insulating the inner wall, we applied Pro Clima Intello smart vapor retarder to the studs to seal the inner cavities and to create a new airtight vapor-control layer for the wall. Intello keeps moisture from entering the wall, but still allows the wall to dry out readily, and with careful taping of the seams, it prevents air infiltration. But to work properly, the membrane needs to be installed with care. In this retrofit situation, the hand labor of attaching the Intello and taping the seams was fussy and complicated—not only did the crew have to work the material into place through the outer stud wall, but they also needed to fit the reinforced sheets around the irregular framing of the inside wall, including various

Photos: Tim Healey

Photos: 15, Tim Healey; 16&17, Matt Burstein

After resheathing the newly insulated walls with vapor-open Gold Bond gypsum board **(15)** and taping the seams with Tescon Vana tape **(16)**, the crew covered the sheathing with Solitex Mento 1000 **(17)**.

scabbed-on pieces that were part of the original window openings.

Open-weave baffles. With the inner wall insulated and the vapor-control membrane installed, the next step was to dense-pack the outer 8 inches of the wall with cellulose. We wanted to be sure to achieve a good dense-pack so the cellulose wouldn't settle the way it had before.

In that regard, there were two issues to consider. First, we didn't want to repeat the mistake of trying to blow cellulose into an entire open wall all at once. Double stud framing is difficult to dense-pack because the center portion of the wall is open along the whole length of the wall. You're essentially trying to fill one whole side of the house with insulation at a time. That's too much volume; you can't achieve high enough air pressure that way to compact the insulation to the required 3.5 pounds per cubic foot. So we had to find a way to divide up the walls into smaller segments.

The second concern was the airtightness of the cavities. We planned to cover the outside of the wall with ProClima Mento, an airtight, vapor-open membrane. In the past when we've dense-packed walls covered in Mento, however, we've learned that the wall cavities can be so airtight that there's no escape path for the air from the insulation blower. This creates so much back-pressure that the insulation doesn't get sufficiently compacted, and settling occurs. In Mento-covered walls, we've actually needed to return with the insulation blower a second time to fill the voids at the top of the wall after the insulation had settled.

For this job, we addressed both of these problems with a single material—Insulweb from Hanes Engineered Materials (insulweb.com). This is the same fabric that is commonly used for dense-packing walls from inside the house.

Insulweb doesn't stretch, and its open weave lets air escape easily—it's designed for achieving high-density insulation packing. We installed the Insulweb as ribs or baffles across the thickness of the walls at 2 feet or 4 feet on-center to keep the insulation contained within smaller bays. Then we stapled more Insulweb across the whole face of the outside wall. This created a honeycomb system of subdivided bays in the wall.

Now we could work our way along the wall with the blower hose, packing each bay at full density. And when we were done, we could inspect the whole wall for voids or soft areas, so we wouldn't need to come back—not next week, and not 10 years from now.

Vapor-open sheathing. Now that the wall was fully insulated, we needed to replace the failed OSB sheathing we had removed during demolition. We don't usually use OSB for sheathing—we prefer plywood because it's less

Over the vapor-open Solitex Mento 1000 weather-resistive barrier, the crew applied 1x4 strapping to create an air channel behind the new fiber-cement lap siding **(18)**.

prone to deterioration from moisture, and it's more vapor-open, so it allows walls to dry out more readily. But for this wall, we chose an even more vapor-open material: ⅝-inch Gold Bond eXP gypsum board sheathing from National Gypsum (nationalgypsum.com).

Gold Bond is moisture-resistant and has a fiberglass coating that boosts its structural capacity as wall bracing. It's designed for attaching to the outside of wall framing, and can be left exposed to the weather during construction if necessary. Best of all for our purposes, it has a perm rating of 20 perms—more permeable than plywood, and much more permeable than OSB. This optimized our wall system for drying to the exterior.

Gold Bond is approved for wall bracing in the IRC, but plywood has a higher shear capacity for helping a wall resist the lateral load of wind pressure. So at the corners of the house, we used 4 feet of ⅝-inch plywood instead of the gypsum board, for increased racking resistance.

Strictly speaking, we didn't need to tape the seams between Gold Bond panels, because we were planning to cover the gypsum board with a drainage-plane membrane that would have taped seams. But the weather while we were completing this work was unpredictable, with a frequent threat of thunderstorms. So we went ahead and taped the seams of the Gold Bond sheathing with Pro Clima Tescon VANA tape, a vapor-open but waterproof construction tape, to eliminate the risk that wind-driven rain would get through the cracks in the half-completed walls and wet the freshly installed cellulose insulation.

Drainage-plane membrane. Over the top of the taped Gold Bond and plywood sheathing, we installed a drainage plane of Pro Clima Solitex Mento 1000. Mento is highly vapor-permeable (rated at 38 perms), but it's watertight, so it can perform as the wall's weather-resistive barrier. We taped the seams of the Mento using Pro Clima Tescon VANA tape, a vapor-open, waterproof, airtight,

Photo: Matt Burstein

The crew installed insect-screening vent baffles at the base of wall between strapping pieces **(19)**, then applied rot-proof, bug-proof Boral synthetic trim board to the wall **(20, 21)**. Later, they would side the wall with HardiePlank fiber-cement lap siding.

and extremely tenacious tape. With the Mento installed, we were ready for our rainscreen cladding system.

SIDING AND TRIM

Our rebuilt wall system's sheathing and weather-resistive barrier are vapor-open, allowing moisture to escape toward the outside. The siding and trim have to allow that moisture to escape all the way to the outdoor air. So we installed a rainscreen siding system, with HardiePlank lap siding (jameshardie.com) nailed over 1x4 strapping. We used Boral TruExterior composite trim (boralamerica.com) for the frieze board and water table, the corner boards, and the cornice and rake trim. HardiePlank is a fiber-reinforced cement composite, and Boral TruExterior is a composite of fly ash recovered from coal-burning power plants and combined with polyurethane. Neither material is vulnerable to rot or insect damage.

HardiePlank carries a 15-year warranty that covers the color coat on the material, as long as the siding is installed according to the manufacturer's instructions. That warranty applies even when the material is applied directly to the housewrap, with no air space behind it. By installing the boards as we have over a ½-inch air space, we think we may be able to expect even longer service.

To preserve the warranty on the HardiePlank, we were careful to install it according to the manufacturer's instructions. For example, you must leave all the field joints uncaulked, but put flashing behind each of those joints. Some builders use housewrap behind the field joints, but we like to use a metal coil stock with a black finish. That way if the gaps widen at all, they won't be obviously visible to somebody driving by on the street.

Jim Bradley is a BPI-certified home-performance contractor, builder, and remodeler based in Vermont.

Photos: Tim Healey