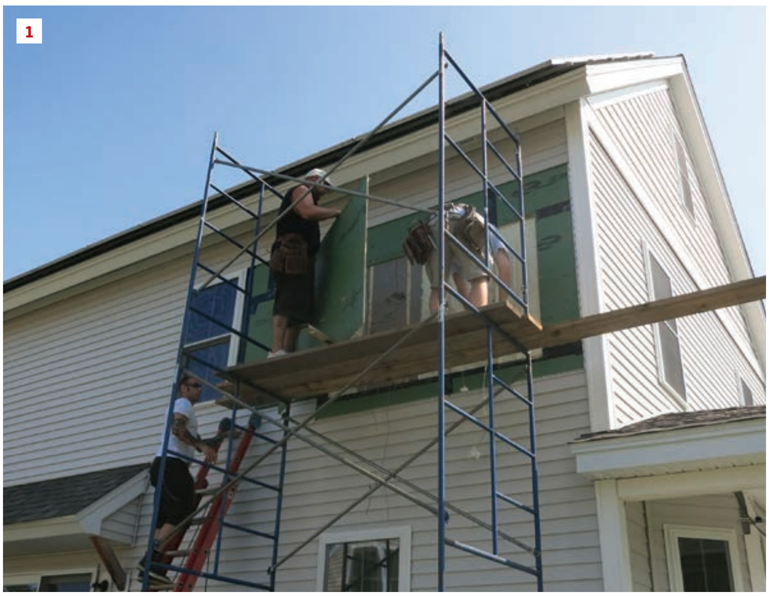
BY TED CUSHMAN

Moisture in Fat Walls—A Closer Look

Last summer, *JLC* reported on research by Kohta Ueno of Building Science Corp. (BSC) into moisture accumulation in double-stud walls (see "Studying Moisture in Fat Walls," Jun/14). Ueno had planted moisture meters on the sheathing of a 12-inch-thick stud wall in a zero-energy house in Devens, Mass., built by Transformations Inc.

Transformations' standard wall system, in place in dozens of homes in a Devens development, is a 12-inch double-stud wall sheathed with Huber Zip sheathing and insulated with medium-density open-cell polyurethane foam, spray-applied in the field. But Carter Scott, Transformations' president, wanted to know if dense-pack cellulose insulation, which might be more economical, would work as well. So the researchers put instruments into walls—on the north and south sides of one of Scott's homes—with three different insulation strategies: 12 inches of dense-blown cellulose; 12 inches of medium-density open-cell spray foam; and 6 inches of the open-cell foam.



1. After three seasons of moisture and temperature monitoring, workers pull sections of Zip sheathing panels from the test wall section of a house in Devens, Mass.

Photos: Building Science Corp.

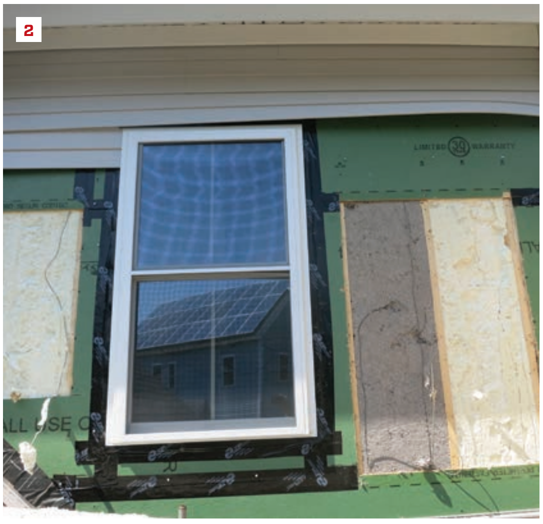
Over three winters of observation, the BSC instruments showed moisture levels in the sheathing rising every winter in all three wall types, as interior humidity penetrated the house walls and condensed against the cold OSB. But when outdoor temperatures rose during springtime, the walls would dry out again, then spend the summer in a dry condition, only to come under moisture attack again the following winter. The cellulose walls got the wettest during the three cold-season cycles, but all three wall types spent a significant amount of time in a risky moist condition during winter and spring.

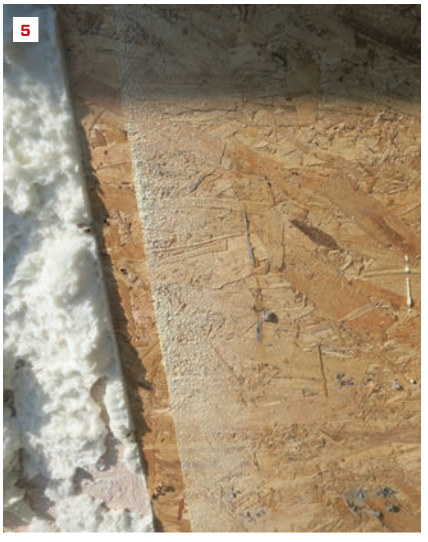
Mold and rot require both heat and moisture to grow. In the winter the walls may be wet, but there's not enough warmth for mold to thrive. In the spring the walls get warmer, but over the course of the season they dry out to the point where there's not enough water to support the mold. So the critical question for wall durability was whether the walls were warm enough and wet enough at the same time—and for long enough—to allow fungus to get a foothold and damage the building. To find out for sure, Ueno and his team decided to cut the test walls open and inspect the sheathing.

In theory, the data from the instruments indicated that the walls had been in danger—particularly during the second of the three winters of observation, when a home ventilation system was inoperative and indoor humidity levels rose above the intended design condition.

In a report posted on the BSC website (buildingscience.com), Ueno writes: "Under high interior humidity loading (nonfunctional ventilation system, 40% to 50% interior relative humidity), all test walls showed moisture contents and sheathing-insulation-interface relative humidities well into the high risk range. The cellulose walls showed particularly high moisture contents (sheathing in excess of 30%), while the open-cell spray-foam walls showed moisture contents in the 18% to 25% range. In addition, the monitoring showed evidence of liquid water condensation (which can result in quick degradation) in all walls, and the condensation was substantial in the cellulose walls. These condensation issues occurred on the north and south sides."

But when Ueno and his colleagues cut the test walls





2. The wall system has good drying potential to both the inside (through the painted drywall) and the outside (through the permeable Zip sheathing), but the cold OSB on the exterior does suffer increased moisture and condensation during the coldest months of the winter.

3. Moisture sensors in the building walls allowed the Building Science Corp. research team to remotely measure and record the moisture content of the framing and sheathing throughout three winters of house operation.

4. Nails rusted slightly after three seasons of moisture accumulation—clear physical evidence of moisture attack, but not as grave as the data had suggested.

5. A close-up of the OSB sheathing removed from contact with the low-density spray foam of the insulated wall cavity shows no sign of fungal attack at all, much less any deterioration that might compromise the sheathing's function.

open to examine the sheathing after three seasons of monitoring, the results were surprising.

Says the BSC report: "Based on the data, calculations, and analysis, all three walls should be at high risk of failure; the analytic tools used indicate that these walls should have failed. However, disassembly showed that the walls were essentially undamaged by the monitored moisture exposure. This suggests that the walls, at least in the configurations tested, were far more robust than current analysis tools would indicate."

"All the instrumentation and monitoring said that these walls got hammered in terms of moisture content, relative humidity, condensation, anything like that," Ueno told *JLC* in a phone interview. "And the current analysis tools in the toolbox say this wall should be toast. But we opened it up and it was like, 'Huh. Well, there's a little bit of grain raise. The fasteners are a little bit rusty. That's about it.'"

MORE ROBUST THAN YOU WOULD THINK

What explains the surprising lack of damage? Ueno says, "Joe [Lstiburek, BSC's founder and principal] has said for years that building assemblies are more robust than we give them credit for. This is a solid demonstration of that fact." But the BSC researchers are not sure themselves exactly why a stud wall that should theoretically be damaged by fungus shows no sign of any fungal attack.

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Protective mechanisms. In a section of the report titled “Protective Mechanisms,” Ueno considers the possibilities.

In the case of the cellulose-insulated walls, the borate treatment in the cellulose may deserve partial credit (borates in cellulose function as a preservative as well as a fire retardant). Writes Ueno, “In the product installed at this site, the cellulose insulation contains 15% or less (by weight) boric acid and sodium tetraborate pentahydrate; other cellulose insulation manufacturers use ammonium sulfate in this role in conjunction with borates. Previous field observations have provided evidence that these preservatives can migrate into adjacent materials (e.g., sheathing or gypsum board), thus providing them with some protection.”

“What the cellulose guys say, and what I’ve seen too, is that cellulose does a nice job of protecting whatever it’s in contact with,” Ueno told *JLC*. “I know that the cellulose guys sometimes over-sell it, but the bottom line is, there is a lot of truth to that.”

But what about the foam-insulated walls? Ueno considered several possibilities. One suggestion was that the foam might be depriving mold organisms of oxygen to grow. But Ueno doesn’t think that hypothesis rings true. “If you look at the foam under a microscope,” he says, “it’s basically an open web. If you were a tiny person, you could walk between these cells. So there is no way that oxygen is being held out. And if you read the food-science literature, you learn that mold needs only a minuscule amount of oxygen to grow. So it’s probably not the oxygen thing.”

What about temperature? “Another thing we were kicking around was, is it the flash heating [the chemical reaction that generates heat when spray foam is applied]?” says Ueno.

“Does it sterilize that surface, and then it’s encapsulated?” asked Ueno. “But again, look at the food-science stuff, and the temperatures you need to kill mold seem to be really hot for half an hour. Spray foam is not staying hot for half an hour in a wall.”

Another possibility is that the spray foam is creating a thin, dense layer of plastic film over the OSB when the spray first contacts the board, forming a barrier between mold spores and the OSB food source. Or, perhaps the foam insulation creates a capillary pathway that stores moisture and draws it away from the OSB. Ueno says there's nothing in the available literature about those possibilities—leaving the question, for the time being, unanswered.

But whatever is going on with the Transformations walls, Ueno says, nobody should assume that the same good luck would protect some other wall that gets exposed to similar moisture conditions. "One of the things I pointed out in the report is, it could be the combination of this specific sheathing with this specific cellulose or this specific spray foam," he explains. "I'm not positive."

Letting walls dry. In the final analysis, Ueno and his colleagues are holding to the recommendations they formulated before their destructive investigation revealed the undamaged walls. "The cellulose walls clearly showed the highest moisture accumulation: the use of interior vapor control more restrictive than Class III (latex paint) is recommended," Ueno writes. A Class II vapor retarder (1 to 0.1 perm; for example, a variable-permeability membrane or vapor retarder paint) will reduce moisture risks to more reasonable levels. However, Ueno continues, "It is entirely likely that many double-stud walls insulated with cellulose with only Class III vapor control provide fine service. A Class I vapor retarder (polyethylene) is not recommended because it completely eliminates inward drying."

As for the spray-foam walls, where moisture accumulation was less extreme, Ueno writes, "It is a marginal judgment call whether a Class II vapor retarder is needed or warranted.

"The ocSPF [open-cell spray foam] material, at the thickness applied, provides reasonable vapor control (2.0 to 2.5 perms in 12-in.). The use of a Class II vapor retarder would definitely be conservative, but the double-stud walls insulated with ocSPF have a history of providing excellent performance in this builder's houses." (These recommendations, Ueno cautions, are specific to the conditions in a Zone 5a climate like Massachusetts; in colder climates, other methods might be advisable.)

BOTH WALLS WORK

Carter Scott, the builder whose concerns prompted the BSC study, told *JLC* in an interview in February that he's comfortable now with either type of 12-inch double-stud wall. In a planned development near Northampton, Mass., in fact, Scott now plans to build both ways. Thirty-two of the units are part of a co-housing community where the planners prefer cellulose for its "green" attributes. The remainder of the development is slated for spec houses, which will most likely get spray foam. Depending on the amount of rooftop solar on each house, most of the houses will exceed net-zero performance, producing more energy each year than they consume.

Contributing editor Ted Cushman is based in Peaks Island, Maine.