Dry Notes from the Underground

Research shows that homeowners invite mold growth and serious health risks with a finished basement that has moisture problems.

by Don Fugler

Some basements are dry, usable living spaces—whether by design, or simply as a result of the climate or water table. Others—and this may be the majority with older houses—have significant moisture problems. Finishing or adding insulation to a basement with moisture problems may encourage the growth of mold, creating a dangerous situation. Retrofitters and weatherization crews should be careful when undertaking such work to make sure that they are not putting the occupants at risk.

Canada Mortgage and Housing Corporation (CMHC) has undertaken several research projects on damp or wet basements. We have looked at the causes of, and the proposed solutions to, this problem, and we are examining the health implications of living with dampness and mold. CMHC has also been represented on a Canadian committee studying new basements, together with the National Research Council, representatives of the concrete and insulation industries, home builders, and scientists. This committee has been meeting for several years and its final recommendations are expected in 2002. The recommendations listed below are based on the information gathered from all these sources.

Older Basements

What do we know about the condition of basements in older housing?

Different regions will have different construction methods and different degrees of success with water protection. Most of the data in this article come from Canadian research and are applicable to colder regions in the United States. Several studies from both Canada and Europe have focused on the health of people who live in damp houses. These studies have found that children living in damp houses have up to a 50% greater risk of developing respiratory illness. This is similar to the increase in health problems for children living in homes in which both parents smoke. If you care enough for your children's health to smoke outside the house, you should take equal care to prevent moisture problems inside the house.

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In the winter of 1995, CMHC inspected 405 houses in Ottawa, Ontario, that had finished or partially finished basements. These houses were randomly chosen within the city and included the full range of house age, location, soil type, and socioeconomic status of occupants. The research protocol was not exhaustive, but it did include a basement inspection and measurement of relative humidity (RH). Fifty percent of the basements in this sample showed evidence of previous or current water damage (such as stains and efflorescence), and 35% had a noticeable odor that was characterized as "musty," "earthy," or "moldy," with the assumption that such smells are usually due to mold growth within the basement. The houses were tested in midwinter, when RH is usually lowest, and 77% of the basements were in the range of 20%–40% RH. Less than 2% of the basements exceeded 50% RH. There was no correlation between measured RH and evidence of moisture damage or mold.

At a gathering of the home inspection industry in the same year, inspectors from across Canada agreed with these numbers. Depending upon the region, between 20%–50% of the basements they visited had moisture problems. Basements in the prairie regions tended to be dryer; the higher percentages of moisture damage were found in coastal regions or in cities with older houses.

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Don't even think about sleeping in a basement with such extensive moisture damage.

Finished Basements

The next research project looked inside the finished basement walls. If you do have a wet basement and it has finishing (such as framing, insulation, paneling, or drywall), does it really matter if there is wetness behind the wall? CMHC had a consultant look inside 27 walls, many from the 1995 study. The investigation was somewhat biased: 18 of the basements showed evidence of moisture damage; 9 were selected as having no signs of excessive water. The contractor opened up part of each basement wall on all four sides in locations that he felt would be most prone to excessive moisture or that had visible moisture damage. Molds, if found, were sampled by tape and swabs. In the end, samples taken from 16 basements produced detectable mold samples, although not all of them were among the 18 that showed evidence of moisture damage.

The molds were analyzed for species. In each moldy basement, at least one toxigenic or pathogenic mold was present. The contractor also noted that the wall cavities communicated easily with the basement air, particularly at the top of the walls. There was no attempt to air seal or enclose the insulation at the top of each wall. This was also true where a finished wall system met an unfinished foundation wall. In effect, the wall construction did not protect the occupants from what was growing inside the wall. CMHC learned from this project that basements with chronic moisture problems produce molds, and that any mold growth sampled produced at least one variety of mold that could be harmful to human health. The study could not establish whether the quantity of molds was sufficiently high to create a health hazard or whether the house occupants had physical symptoms connected to the mold growth observed. In many of these houses, there was probably too little mold growth, or not enough active growth, to cause a health hazard.

Several CMHC research projects have looked at solutions for damp finished basements. One of the earliest ones looked at using a ventilated-cavity approach; in this approach, the walls and floor of a basement are insulated, but a small fan is used to depressurize the floor and wall cavities. This is a patented method and has not been used for more than several hundred houses. It appears to be successful at keeping moisture and mold growth, if they occur in the cavities, separate from the house air. The depressurization would also draw some drying ventilation air into the cavities. Drawbacks include the need for experienced and trained personnel to set fan flow rates and depressurization levels, and the slightly increased costs over a conventional finished basement. CMHC is not aware of any long-term monitoring of basements treated by this method.

Basement Rehabilitation

Another research project used a case study approach; people in the Quebec City area volunteered their houses as part of a wet-basement rehabilitation survey. Ten houses were selected. The contractor hired by CMHC examined

the basements and ascertained the probable causes of moisture problems. The homeowner then had suggested remedial work performed, and the basement wood moisture levels were measured again after the work was complete. Remedial measures included redoing drainage, fixing cracks, adjusting soil slope, and adding ventilation. Most of the remedial work did result in lowered wood moisture content, signifying that basement moisture sources had been reduced. (A project summary is available from the CMHC Web site.)

Accepting that, despite the risks, many homeowners or renovators will still insulate and finish a damp basement, the last research project looked at wall systems that could drain or dry quickly. Ten types of interior finish were tested. Some were raised off the floor or kept off the concrete wall. Some used materials that were resistant to water damage: steel studs, extruded polystyrene insulation, and paperless gypsum board. Instruments within the walls measured wall cavity RH and wood moisture content in assemblies that used wood studs and plates. The walls were tested in an Alberta research house basement and were challenged with a seven-day foundation leak behind each panel and a 4-inch flood for about five days. In each case, the walls were monitored to see if they dried sufficiently quickly to prevent mold growth. Mold experts state that two days of excessive humidity was enough to start significant mold growth, given a proper substrate for the mold to grow on, such as gypsum board paper, wood, or dust.

Results of this testing show that some of the wall systems did not suffer greatly from the wall leaks. They were able to divert the water away from the insulation and framing or did not absorb a significant amount. While extruded polystyrene did not absorb much water, the RH in the wall space between the polystyrene and the foundation wall stayed high for weeks. Few of the assemblies were able to handle the flood without prolonged wetting. The results show that the wall with blown polyurethane foam stayed relatively dry, and that the proprietary systems were somewhat more successful than the wood frame and fiberglass assemblies. This project is described at greater length in the sidebar (see "Basement Walls That Dry").

What does this research suggest for finishing existing basements? To be somewhat simplistic, almost any wall-finishing system will work in a dry basement; very few will be successful when the basement is leaky, damp, or susceptible to flooding. Here is a list of actions that you can take, in roughly ascending order of risk and expense.

Leave unfinished. In an older house with a rubble masonry foundation, mortar of uncertain quality, no foundation drainage, and the potential for moisture entry, do not finish the interior walls in a cold climate. There is too much risk in

Basement Walls That Dry

If water finds its way into a basement, do any wall systems dry quickly enough to forestall mold growth?

The Canada Mortgage and Housing Corporation performed an 18-month study at the Alberta Home Heating Research facility to test ten basement wall systems for the ability to dry quickly after a wall leak and a flood. The wall systems tested included five variations on conventional wood frame construction, two were of conventional design but used steel studs, and three were proprietary wall systems. One of the three proprietary systems, sprayed polyurethane over wood studs, was tested only against basement flooding.

Moisture and temperature sensors were installed at selected points in each wall cavity. The interior of the test home, including the basement, was kept at a RH of 40%–50%. Basement air temperature was kept at 20° C. In the months following the flood test, relative humidities remained in the 50%–70% range until they dropped in the fall.

The two tests used a controlled leak behind each wall panel to simulate water penetration through cracks, and a flood to a depth of 4 inches. After each wetting, the panels were monitored over a period of months to determine their drying characteristics. Throughout the testing period, each panel was removed and examined for evidence of mold growth.

The wall systems tested were

Standard construction: Wood framing with fiberglass batt insulation, a 0.15 mm (6-mil) polyethylene vapor barrier, and painted gypsum board. Bottom plate rested on the concrete floor (see Figure A).

Improved Standard I: In addition to the standard configuration, a poly-

Variations on a Theme

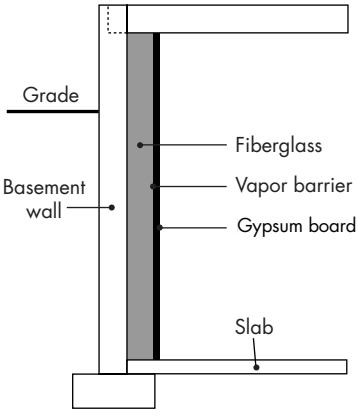

Figure A

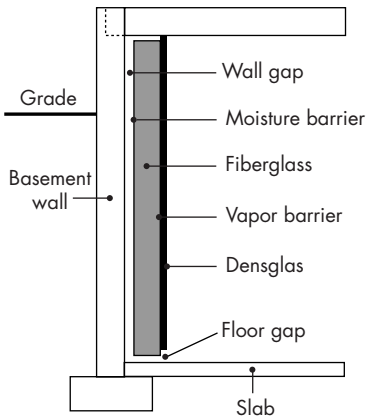

Figure B

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Although this carpet was dry, mold was found inside the basement wall.

disturbing the moisture and temperature environment that has maintained this foundation for decades. My preference is to put money into high efficiency heating equipment and tolerate some heat loss through the walls of these old foundations. If the homeowners are also prepared to add exterior drainage and insulation, interior finishing would pose no problem.

Insulate to grade. If a homeowner has sporadic water entry and does not want to spend the money to fix it, do not finish the basement. Leave it empty or use it for storage on raised shelves. If the floor and walls are exposed, they can dry more quickly and be cleaned as necessary. One possible option is to install insulation from the ceiling down to just below grade. This may provide some energy savings without putting the basement at high risk of nurturing mold. Note that insulating to grade on a concrete block wall will not be effective. The hollow cavities in the block wall will simply move the cold air down to the uninsulated blocks.

Install a dehumidifier. If the homeowner does not have a leakage problem but does have a summer condensation

ethylene sheet placed on the wall up to grade as a moisture barrier.

Improved Standard II: Steel stud framing and a drywall alternative, a moisture barrier, Densglas Gold from Owens Corning (a product similar to gypsum board that contains chopped fibers to help maintain structural integrity after wetting). Bottom plate raised ¼ inch off floor.

Improved Standard III: Like Improved Standard II but framing spaced ¼ inch off concrete wall (see Figure B).

Improved Standard IV: Improved Standard I with drywall alternative. Bottom plate ¼ inch off floor.

Improved Standard V: Improved Standard I with drywall alternative and a moisture barrier.

Improved Standard VI: Improved Standard V with bottom plate raised ¼ inch off floor.

Proprietary Wall I: A system from Dow Chemical, called Perimate, made of extruded polystyrene with vertical grooves that may allow water to drain between the insulation and the wall onto which it is applied, a drywall alternative, and a 0.15 mm (6-mil) polyethylene moisture barrier.

Proprietary Wall II: A system from Owens-Corning of vinyl-faced rigid fiberglass panels mounted in a plastic frame.

Proprietary Wall III: Sprayed polyurethane over standard wood framing with drywall alternative.

All the proprietary systems performed better overall than the standard wood and steel stud systems when subjected to both controlled leaks and short-term floods. The proprietary systems either didn't absorb significant amounts of moisture or dried relatively quickly. However, high levels of humidity remained in the cavity behind the extruded polystyrene panel, a condition ripe for mold growth.

The steel stud systems performed better than their wood counterparts when subjected to a short-term flood. However, the stud cavities remained damp, due to water retention by the insulation and polyethylene sheeting.

None of the alternative wood frame systems performed well in both wetting tests. In the case of a controlled leak, the systems that had an external moisture barrier (polyethylene against the concrete wall) caused the water to flow down the wall, under the bottom plate, and onto the floor. These systems with external moisture barriers seemed to offer better performance because the wood was protected from the leak by design. However, no attempt was made to seal the panels perfectly, so results may vary in practice. When subjected to a flood, panels with a moisture barrier retained water longer.

Researchers found no significant mold or mildew in any of the test cavities, although conditions were favorable for mold growth. This may be due simply to a lack of spores to initiate the growth.

This study showed that some wall systems seem to tolerate an occasional wall leak without significant wetting. However, standard or modified stud walls retained too much moisture to be safe during major wall leaks or flooding. Proprietary wall systems had better moisture performance.

problem, this can be solved by the use of a dehumidifier in the basement over the warmer months. Ventilating with outside air in summer will not reduce basement moisture in many regions of North America. Drain the dehumidifier directly to a floor drain or laundry tub.

Install exterior insulation. If the basement has to be excavated to install or repair foundation drainage, recommend that exterior insulation be placed on the concrete during this operation.

Finish and expect a callback. Finally, if you are finishing a basement with dubious moisture performance, consider using either a ventilated-cavity finishing system or one of the proprietary systems that worked best in the Alberta study. Warn the homeowner about the implications of mold growth in basements. Be prepared to be called back some year in the future.

Words of Warning

Despite all these efforts to understand the mechanics of interior basement insulation, there is still significant disagreement about what to do. Some sources, such as the Canadian National Building Code, require a vapor barrier behind the drywall and a moisture barrier (which could be a plastic sheet) against the wall from floor to grade. Some building scientists and insulation manufacturers recommend no plastic or vapor resistance in those walls. One recent attempt has used an exterior house wrap in place of the plastic for the air barrier and the moisture barrier against the wall. So the current advice ranges from full permeability to full impermeability to nothing but drywall and insulation.

One more comment: There is good reason to suggest that the best way to insulate a basement is from the outside. The concrete stays warm, dry, and protected, and the high thermal mass of the foundation walls is now within the thermal envelope. Retrofitting exterior insulation to an existing basement can be tricky, though, because of gardens, porches, driveways, accessibility issues, and high cost. Still, it's a good option to consider if the foundation has to be excavated to deal with drainage problems or concrete repair. Make sure that any exterior insulation is well protected above grade and well drained. Take special precautions in areas with termites.

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Case study on basement renovations:
www.cmh-cschl.gc.ca/publications/en/rh-pr/tech/01-105_e.pdf