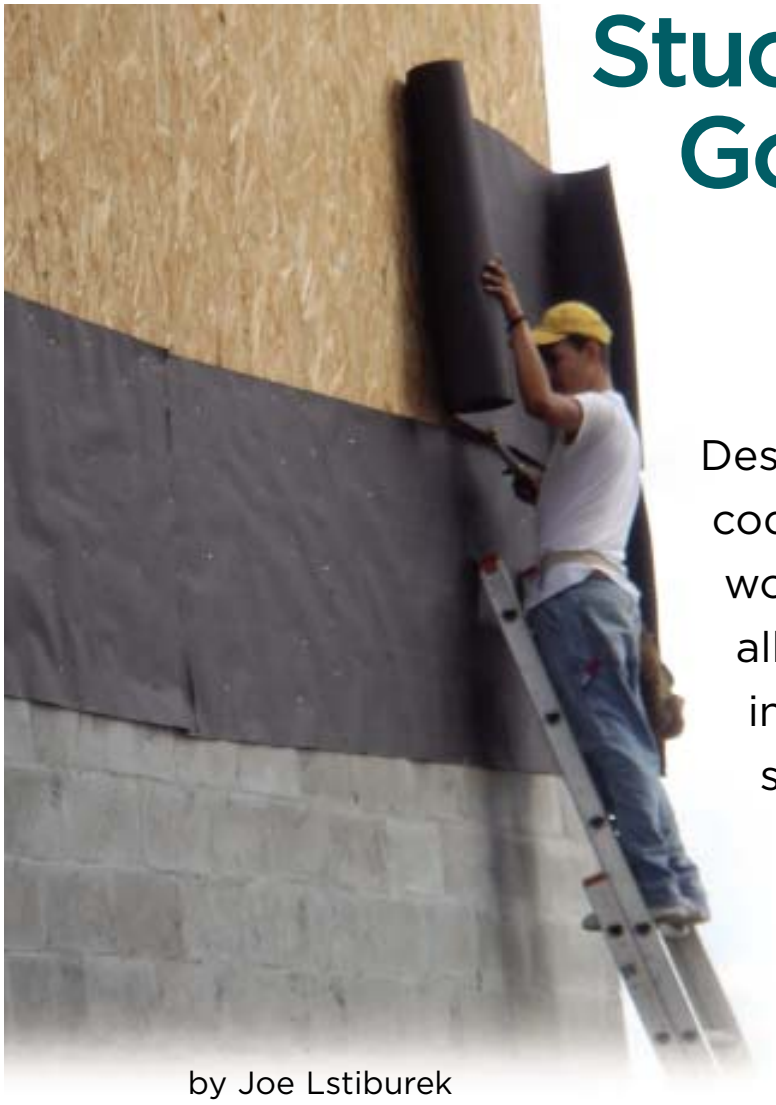
Lessons From Florida's Hurricanes

Why Stucco Walls Got Wet



Designs, methods, codes, and workmanship all played a role in Florida's soggy storm experience

by Joe Lstiburek

The four hurricanes that struck Florida last summer proved the effectiveness of the tough building codes passed by the state after Hurricane Andrew's strike in 1992. Hurricanes Charley, Frances, Ivan, and Jeanne killed dozens of people, but not one of those deaths was caused by failure of any structure built to the new codes.

Unfortunately, though, many stucco-clad homes in the state experienced a problem we would not be discussing if they had simply fallen down or blown away: They got wet.

After 20-plus inches of windblown rain soaked the whole region, there were hundreds of reports of water intrusion through stucco walls of otherwise undamaged homes. The Florida Home Builders Association hired my company, Building Science Corporation, to investigate the situation, identify causes, and propose solutions.

We applied a wide range of investigative techniques (see Figure 1, next page): We inspected homes soaked by the storms as well as new

homes built after the storms; we tested and experimented with new buildings and mocked-up assemblies; and we did bench-top testing of materials and components, including felt paper, plastic housewraps, and windows. We also reviewed relevant codes and standards, and interviewed builders, contractors, materials suppliers, manufacturers, and code officials.

In this article, I will explain what we learned. Anyone who wants to keep rain out of a building might benefit from the lessons of Florida's wet walls. After all, whether you build in Florida or somewhere else, water is water, wind is wind, and the laws of physics are the same.

Why Stucco Leaks

We were asked to focus on stucco-clad homes. Actually, there are two kinds of stucco used in central Florida: traditional "hard coat" or "three-coat" stucco, and the modern "cementitious decorative finishes," popularly called "thin-coat stucco." Both types of cladding let water into homes during the storms.

Our testing of Florida homes confirmed what we already knew about stucco: It always cracks, and the cracks always leak. In homes we tested, stucco that was cracked leaked at the cracks; and where the stucco was not cracked, it did not leak (Figure 2, next page). But there's a little more to the story than that.

Traditional stucco and thin-coat stucco aren't fundamentally different. Both are surface treatments applied to a substrate, and they behave in a generally similar fashion. Most important, neither can be considered waterproof or leakproof. On the contrary, when you use either, you can be sure it'll leak. But with both decorative thin stucco and traditional three-coat stucco, there are ways to decrease the frequency of cracking.

Traditional stucco. This centuries-old coating is supposed to go on in three coats. The first is the scratch coat. It's applied about 3/8 to 1/2 inch thick and allowed to cure. Because it's cement, it shrinks as it

Figure 1. Members of the author's investigative team examined stucco walls with infrared cameras (A) and camera probes (B). To measure water leakage, they applied hydrostatic head tests (C) as well as simple water sprays and simulated wind-driven rain (D).

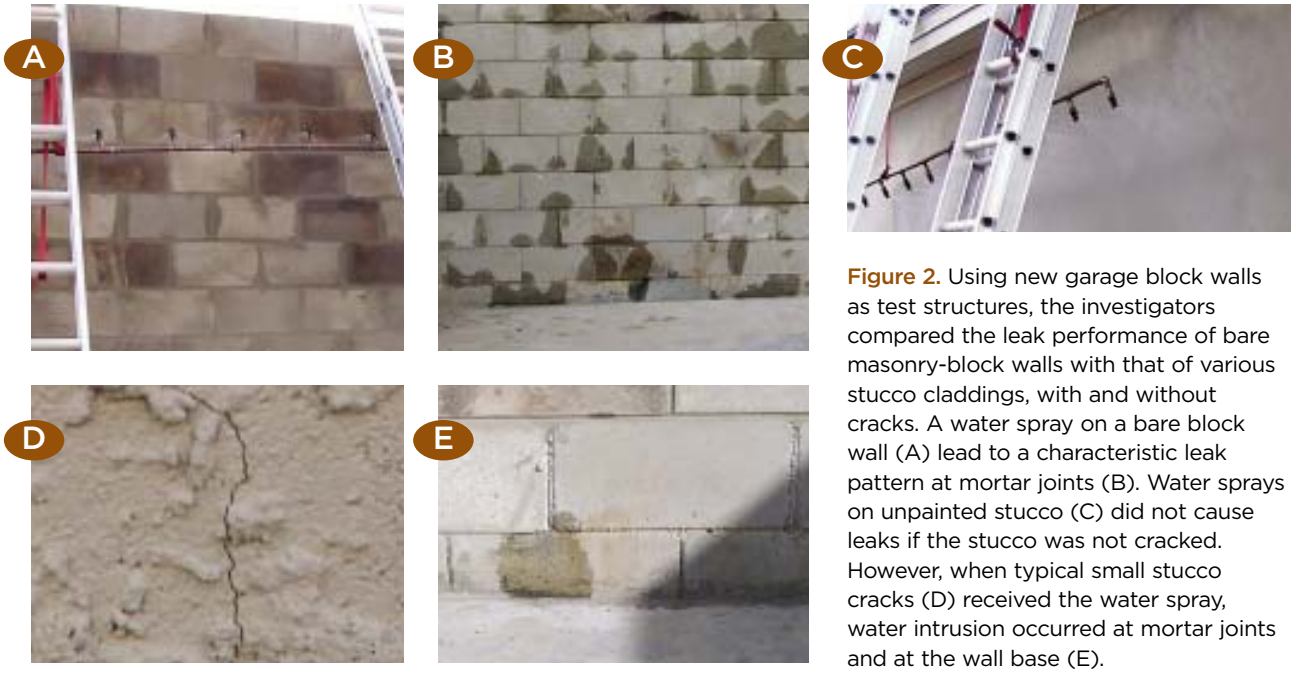


Figure 2. Using new garage block walls as test structures, the investigators compared the leak performance of bare masonry-block walls with that of various stucco claddings, with and without cracks. A water spray on a bare block wall (A) lead to a characteristic leak pattern at mortar joints (B). Water sprays on unpainted stucco (C) did not cause leaks if the stucco was not cracked. However, when typical small stucco cracks (D) received the water spray, water intrusion occurred at mortar joints and at the wall base (E).

cures, and as it shrinks, it cracks. Then, two or three weeks later, when it is done shrinking, you go back and apply the brown coat, which serves to fill in the shrinkage cracks in the scratch coat. After that cures, you go back yet again and apply the finish coat (the color coat), and you're done.

With each coat you apply, you change the mix of cement, lime, sand, and water slightly, so that each coat is a little weaker, more permeable, and more flexible than the one it covers. Thus the softer, outer coats have relatively more lime and sand — and less cement — than the hard inner coat.

But modern-day stucco applicators, in Florida as well as in other places, typically don't wait several weeks for the first coat to cure; they go back and apply the second coat the same day. That means, of course, that both coats shrink and crack at once — one reason the stucco in Florida leaked as much as it did.

Thin-coat stucco is applied in just one coat, so it's going to crack no matter what. However, with both thin-coat stucco and two- and three-coat applications that are not given time to cure between coats, it's possible to reduce the amount of cracking by using fiber mesh in the mix, and by adding polymers to make the coats more flexible.

So why not change codes to require either a mandatory curing period between coats or the use of additives in the mix? That wouldn't really be a practical solution. Neither technique will prevent shrinkage cracks altogether. Nothing will. More to the point, there's another cause of cracking that we also can't prevent: settlement (Figure 3). Virtually all buildings move and shift enough in the first few years after construction to cause some cracking of the stucco — and no stucco, whether traditional or polymer-modified, is immune to that.

What, then, do we do? The answer is that you have to assume there will be cracks and that water will be able to get through them.

Figure 3. Houses shift after construction as supporting soils consolidate and materials change size with changing temperature and moisture content. This movement of substrates, though typical and expected, inevitably brings about some cracking in brittle surfaces like stucco, creating the need for ongoing maintenance and repair in the early years of a building's service life.

Accordingly, you have to design wall systems that tolerate those leaks, and accept that some maintenance and crack repair by the occupants will be necessary over the years after the home is finished and occupied.

Two Kinds of Walls

The picture in Florida is complicated by the fact that builders there typically use two types of exterior walls on the same house. It's common to lay a concrete-block wall for the first story and then stick-frame second-story walls and gable ends; stucco is applied to both stories. Both types of walls leaked in the Florida storms, for somewhat different reasons.

Building paper and housewrap. Upper-story stick-frame walls, in principle, should function as "drained assemblies." The stucco is applied over a "weather-resistive barrier" (you can use housewrap, asphalt felt, or Grade D asphalt-saturated kraft paper). Any water that penetrates to the weather-resistive barrier is supposed to drain down it until encountering a flashing that directs the moisture out to the exterior.

One reason Florida walls leaked was that the housewraps or papers installed beneath the stucco did not function effectively as a drainage plane (Figure 4). Stucco tends to bond to housewrap and building paper, eliminating the air space in which water is supposed to drain. Also, the housewrap or building paper itself loses water repellency when stucco adheres to it, or when it comes in contact with surfactants (soap-like chemicals that reduce the surface tension of water). In Florida, water that reached the housewrap or building-paper layer in the walls often bled through into the frame assemblies.

Reverse flashing. However, even if the housewrap or building paper had worked as intended, there still would have been problems caused

Figure 4. Upper-story walls in central Florida are typically stick-framed, while lower-story walls are laid up with concrete block (A). Both wall types leaked, but for different reasons. Designed as drained assemblies, frame walls were handicapped by the bonding of building paper or housewrap to the stucco coatings, which prevented free drainage (B). Forced into contact with trapped water, most housewraps allow some water penetration, as shown in table-top testing at the author's shop: Water dripped onto a horizontal housewrap surface (C) soaked into the absorbent test material underneath (D). In the field, saturated stucco coatings over imperfectly performing housewrap allowed water into sheathing and stud bays (E).

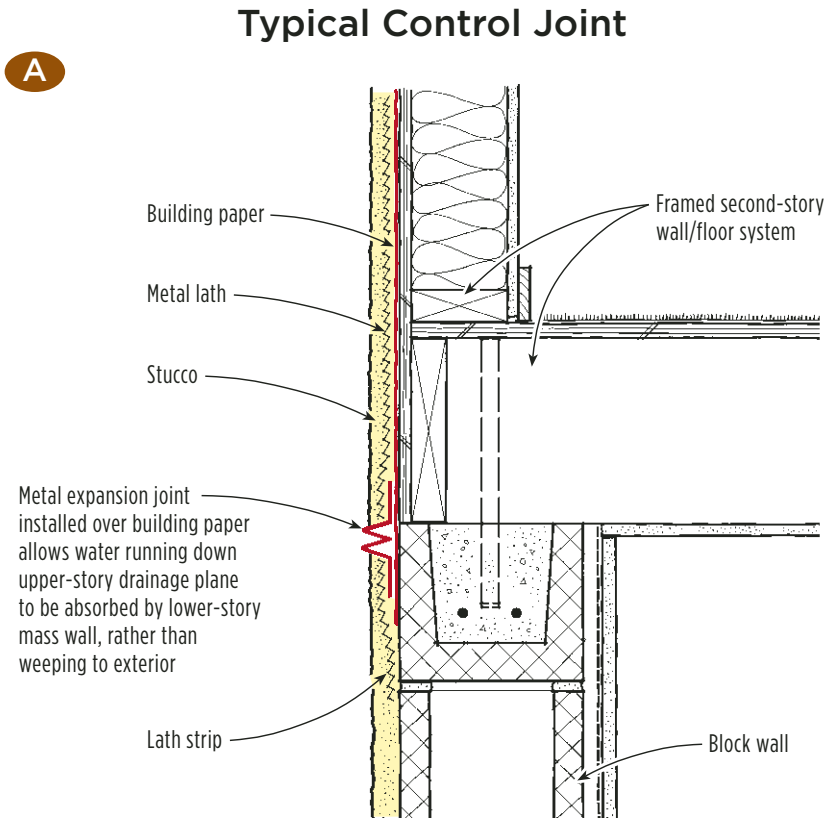


Figure 5. The joint detail typically required in Florida between upper-wall and lower-wall stucco sections (A) does not manage water well. When the control-joint accessory is installed over the top of a continuous sheet of building paper or housewrap (B), water is not kicked to the exterior but is allowed to pass behind the joint into the wall below (C).

by incorrect flashing. At the base of the frame walls, where the upper-story cladding meets the lower-story cladding, builders typically install a metal expansion-joint component over the building paper and run the building paper down into the top edge of the lower-story stucco coat (Figure 5). This detail allows water running down the upper-story drainage plane to flow into the lower-story mass wall, rather than move to the exterior. Builders can't be blamed for using this detail: The method is required by the code, as interpreted by local officials.

Lower-story mass walls. Masonry-block walls with stucco cladding aren't intended to function as drained assemblies. They are "mass assemblies." Water that penetrates the stucco through cracks is supposed to be absorbed by the masonry mass, which it doesn't damage, and then dry slowly to both the exterior and the interior during periods of dry weather (Figure 6, next page). Central Florida's masonry walls, for the most part, were able to manage moderate amounts of rain but were simply overwhelmed by the huge water onslaught from three consecutive hurricanes.

Rather than suggest a modification of the stucco materials or installations, I've suggested a few small design changes that would enhance the ability of these systems to absorb and dissipate water without allowing it to enter living space or damage finishes. But even improved masonry mass walls shouldn't be expected to handle rain-

water that leaks in from windows, service penetrations, or other holes in the wall assembly — and it turns out that leaks at windows and other openings were a major source of water intrusion during Florida's storms.

Windows and Other Penetrations

The industry standards and building-code rules for windows don't require them to be leakproof when facing the kind of wind and rain that central Florida saw in 2004. Windows installed in Florida homes are rated for water holdout at 15 percent of the design wind load, or no lower than 140 pascals of pressure (approximately the pressure of a 35-mph wind). Clearly, these limits were exceeded during August and September of 2004. In a hurricane, the codes expect windows to stay in the wall, but not necessarily to hold out all the rain.

On the other hand, our testing of windows and window assemblies indicates that many of them leaked under conditions well below their listed, rated value. In fact, many tested windows leak under a simple water spray with no wind pressure at all. Factory testing of windows seems to be missing a widespread incidence of leakage at the window-assembly corners. Also, windows are tested as single units, but are often sold as preassembled "mulled" units, with two or more windows combined in a composite arrangement. Every preassembled mulled unit we tested leaked at zero wind pressure (Figure 7).

From our visual inspections of windows in the field, and from a

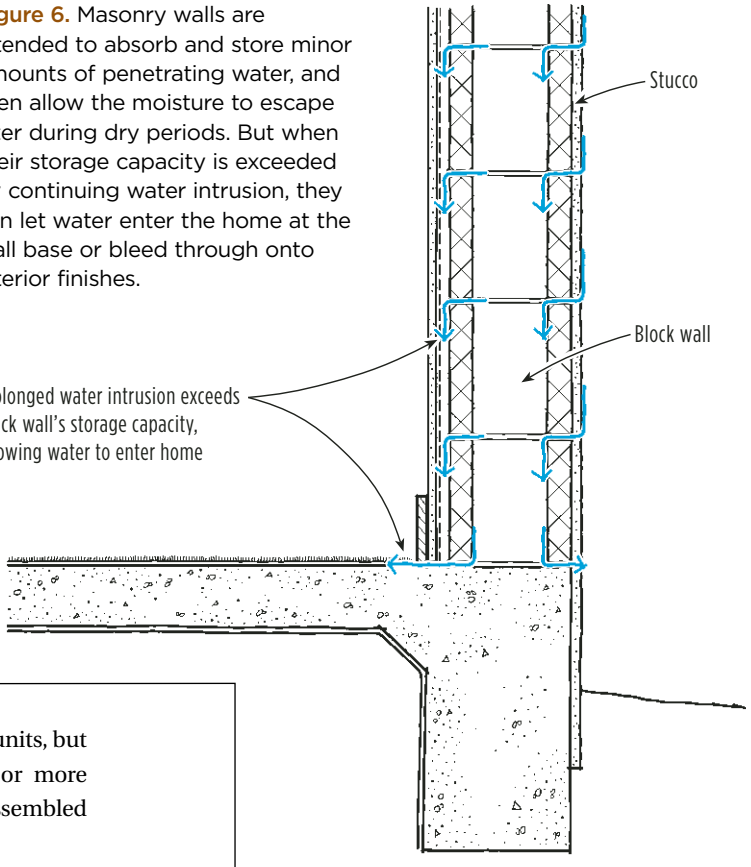


Figure 6. Masonry walls are intended to absorb and store minor amounts of penetrating water, and then allow the moisture to escape later during dry periods. But when their storage capacity is exceeded by continuing water intrusion, they can let water enter the home at the wall base or bleed through onto interior finishes.

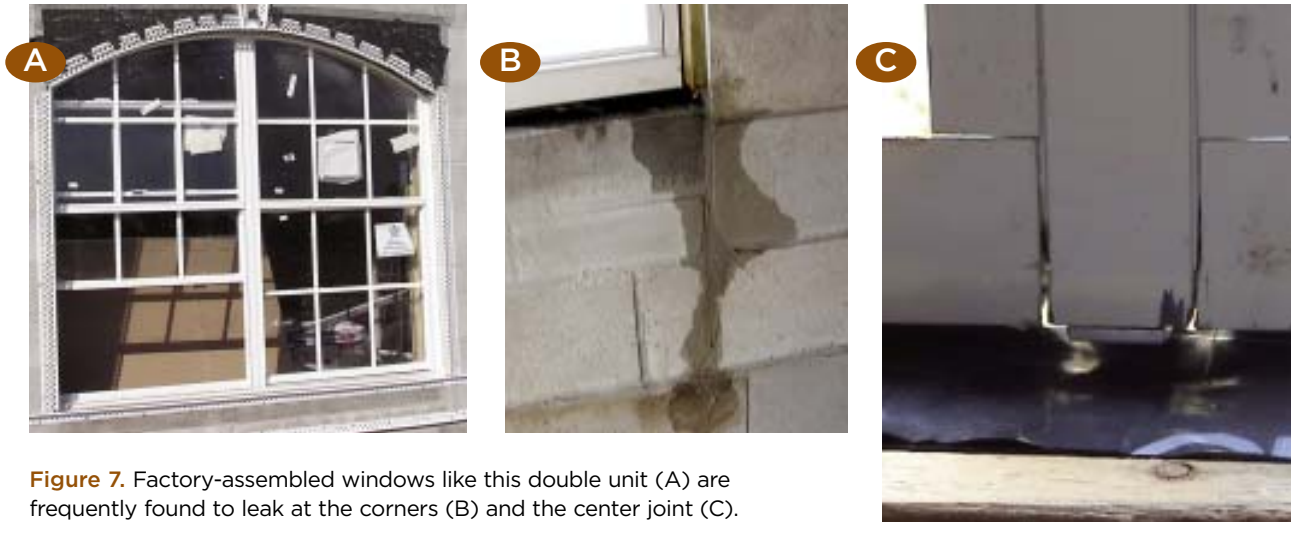


Figure 7. Factory-assembled windows like this double unit (A) are frequently found to leak at the corners (B) and the center joint (C).

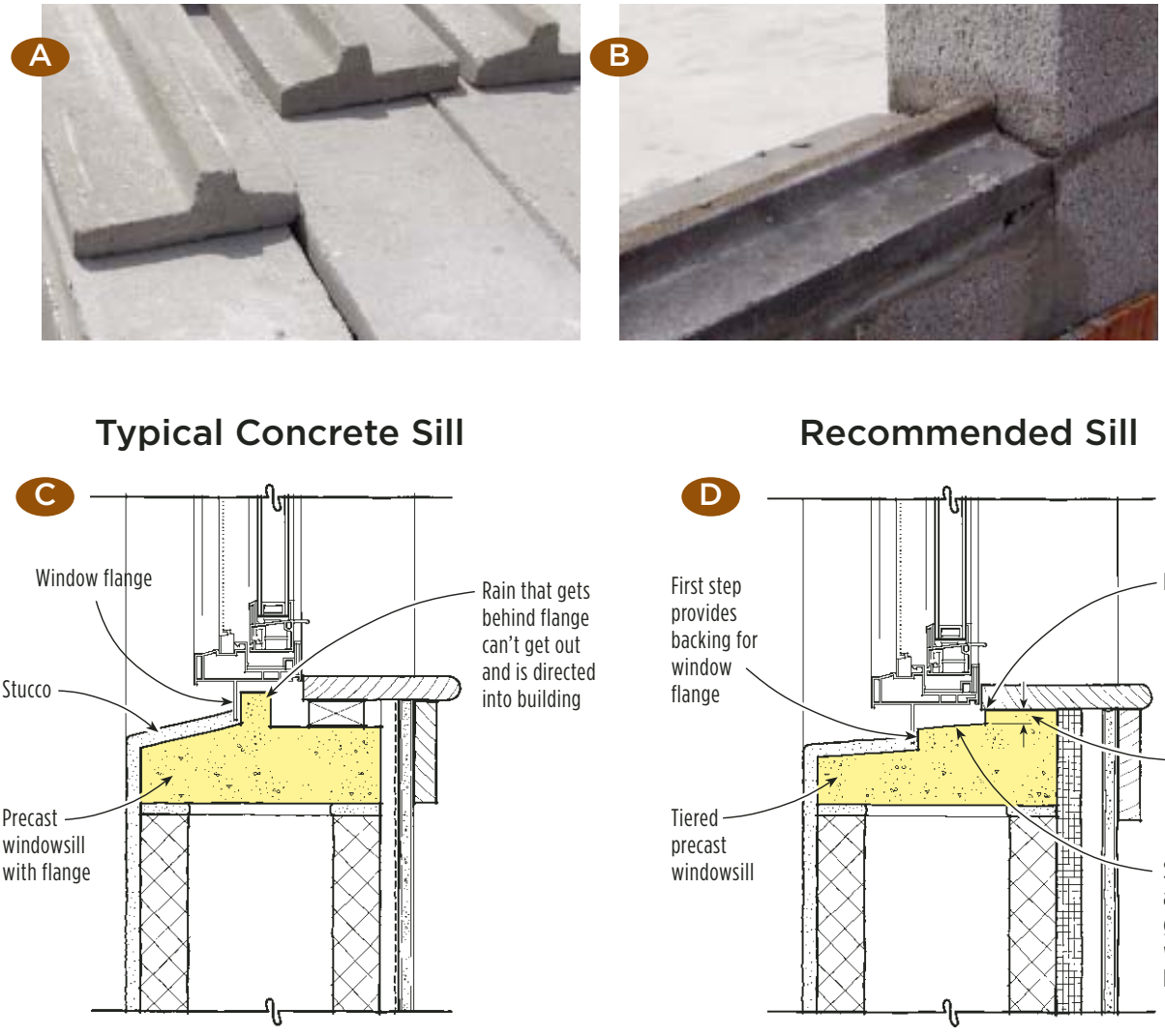


Figure 8. Precast concrete windowsills for block walls (A and B) have a profiled flange attachment rib that directs some leakage toward the interior (C). A better windowsill design would direct water toward the outside (D).

closer look at some randomly selected windows that we took apart, it seems clear that there is a widespread problem with the connections between the windowsill and the window jamb: Windows delivered to the site are likely to be leak-prone before installation.

Window installation is also an ongoing concern. The methods used in Florida, as elsewhere, often don't ensure reliable water management. In particular, precast concrete windowsill components sold into the Florida market are shaped in a way that directs some leakage into — rather than out of — the building (Figure 8).

It would be good if windows delivered to the job could be made to hold water out more effectively. But in the meantime, builders have to be aware of the limited water resistance of window units, and design walls that are tolerant of window leakage.

Paints and Coatings

When we first went to Florida, some people had the idea that we would focus on paints and coatings. Many observers had noticed that homes only a year or two old had shown more leakage than homes that had been around for five or 10 years, and they thought perhaps

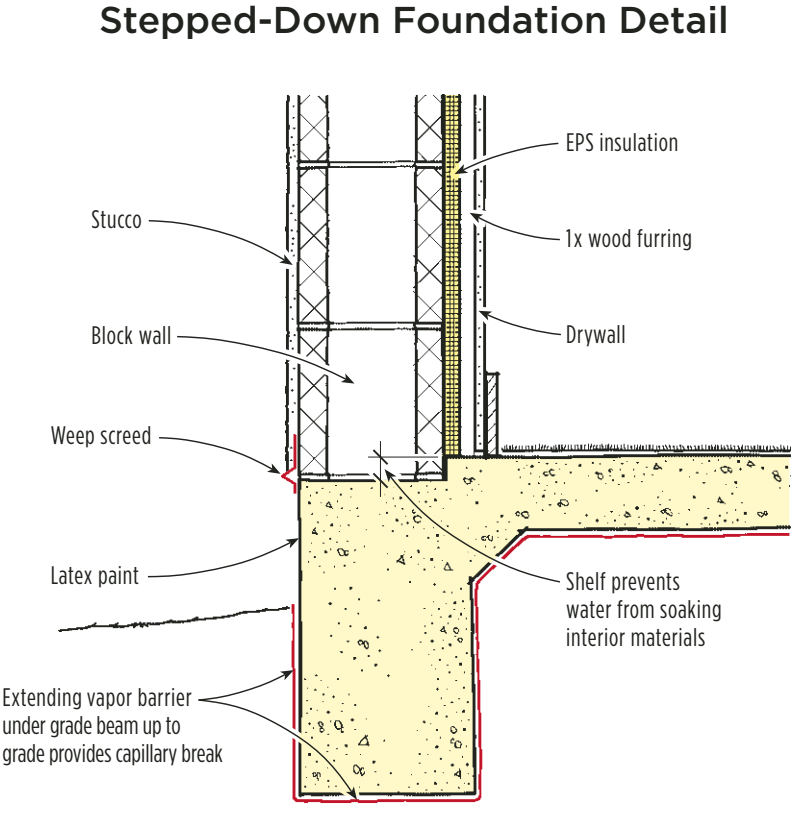
this was because successive repaintings had sealed all the microcracks in the stucco. If we required a high-build elastomeric paint on new homes in the first place, the reasoning went, maybe we could prevent the whole problem.

That idea makes sense, but it doesn't hold up completely. For one thing, all those older buildings were repainted (and the cracks patched using other means as well) only after they had been through the process of shifting and had settled down to some kind of equilibrium. There are very few paints and coatings around that can span the shrinkage cracks in a new building and also stay intact as the building shifts and cracks over its first few years. So while patching and painting a stucco wall is a good idea — in fact, it's necessary maintenance — and it has to be done continuously over the life of a building, it is particularly important during the first two or three years.

Also, high-build paints and elastomeric coatings span microcracks most effectively when the surface is smooth. On rough-surfaced stucco, which is a very common finish in the industry, coatings are much less effective at sealing surfaces (Figure 9).

Figure 9. Paints and coatings are not highly effective at spanning cracks and pinholes in a rough stucco coating. Ordinary paint (A), a 3-mil high-build coating (B), and a 10-mil elastomeric coating (C) all leave pinholes that can be seen under magnification. Thick elastomeric coatings over stucco can also be prone to blistering (D).

Figure 10. To help block walls store greater amounts of incidental water and to direct the moisture back outside rather than allowing it to trickle into the home, foundations should have a stepped-down shelf at the slab edge. A weep screed at the lower termination of the stucco will allow accumulated water to get out.



And to gain flexibility and crack-spanning ability in a coating, you often have to give up vapor permeability, so that the coating may tend to trap moisture within the stucco as well as keep bulk water out. That trapped moisture can cause coatings to blister. Modified stucco mixes may even re-emulsify and turn to goo when you trap moisture in them with a low-permeability coating.

That said, specialty elastomeric coatings hold great promise. The "holy grail" of coatings research has always been to develop a highly elastic coating that also breathes. We're not sure how much it needs to breathe, but generally I think the perm rating should be 10 or higher. And, for the present, specialty coatings should be applied to stucco only by knowledgeable installers. "High build" acrylic paints that get you 5 to 6 mils of thickness at permeabilities of greater than 10 perms are pretty much the optimum performance limit with conventional coating systems.

Improving Masonry Mass Walls

Clearly, masonry-block walls — as commonly built in Florida and other places — have a limited capacity to hold and drain water. When cracks and crevices in the wall assembly are full, water trickles onto interior floors at the base of walls. Saturation of walls also leads to humid conditions on interior wall faces, sometimes allowing mold or mildew to grow.

Two proven methods would improve the performance of these walls. First, the foundation slab or footing should be built with a stepped-down seat or shelf where the first course of masonry block is set, as in Figure 10 (previous page). This will direct water that reaches the base of the wall outward to the outdoors, rather than inward, where it can damage floors or cause humidity problems.

The interior-wall face will perform better if covered with a continuous layer of semipermeable rigid insulation, such as commonly available extruded polystyrene (Figure 11). This will reduce vapor migration into the home as well as condensation, preventing moisture from accumulating in the home's drywall.

Allowing Drying to the Interior

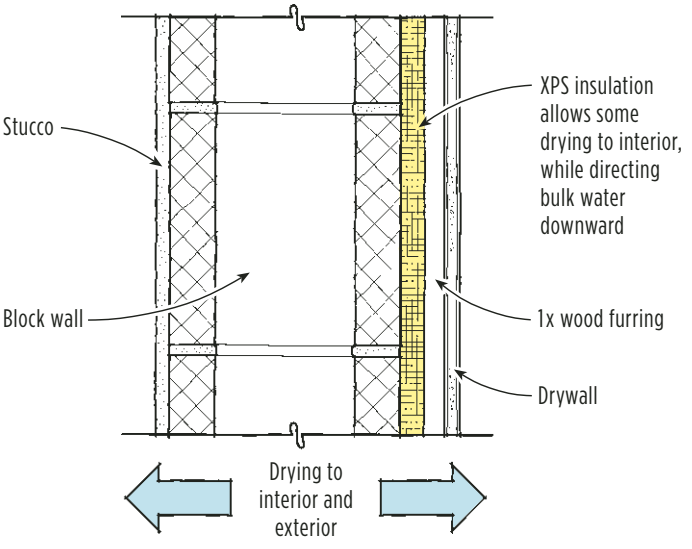


Figure 11. Extruded polystyrene insulation applied to the inside face of the block wall, to the outboard of the interior furring, or to the wall framing will allow some drying by vapor diffusion to the interior, but will direct bulk water downward toward the base of the wall, where it can escape to the outside.

Refining Drained Frame Walls

Wood-frame stucco-clad walls should have a bond break layer installed between the stucco rendering and the drainage plane.

In practice, this means applying two layers of building paper, or one layer of building paper over a layer of plastic housewrap, before applying stucco. At the joint between drained upper-story assemblies and mass-wall lower-story assemblies, a weep-screed flashing should be installed, as in Figure 12.

Window and Flashing Recommendations

There is a problem in Florida and other states where high-wind codes are taking effect that is caused by the contradictions that arise between two imperatives: the obligation to ensure structural integrity and the need to keep out water. In many cases, building officials are enforcing fastening schedules and structural connections at the expense of proper flashing and drainage details.

To fix this problem, all of us — including builders, code officials, and manufacturers — need to think through what we're doing when we attach a window or other component to a wall assembly. Here are a few things to consider:

First of all, whether it's a window, a dryer vent, or a hose bibb, when you install something through a wall, you have to flash the opening. Second, drainage assemblies for windows have to extend all the way to the back of the window, because windows can leak at any point. And, finally, flashings above windows and other penetrations have to catch water from all the way to the back of the cladding system, and have to direct it all the way to the exterior of the building.

Maintenance and Crack Repair

Stucco cracks have to be addressed with ongoing homeowner maintenance. The best practice is to allow stucco walls a reasonable "breaking-in" period, from one to two years. By then, most if not all of the cracks that are going to appear will already be evident. At that point, cracks should be individually sealed with caulking or a brush-in cementitious crack-repair formula, and then the walls can be repainted.

Inspecting walls every few years, and repairing them in this fashion as needed, should be enough to keep a stucco wall performing well for many decades.

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Figure 12. So that horizontal control joints between floors direct water to the outside of the wall, first apply a bridge flashing between the wood frame wall and the block wall below, and then attach a weep-screed flashing that overlaps the lower wall (A). The primary drainage-plane membrane should then be installed overlapping the weep screed (B) before a bond-break paper layer and wire lath (C) are put in place. Finally, stucco can be applied to both walls (D).