Designing and Building Hurricane-Resistant Homes

Mercedes Homes and its partners set out to create and construct a truly hurricane-resistant house.

by William Zoeller

A production builder's efforts to identify better wall systems to use in homes led to the development of a disaster-resistant housing solution for the southeastern United States—a solution that proved its worth last October when Hurricane Wilma slammed into that region of Florida. Florida-based home builder Mercedes Homes started working with DOE's Building America research teams in 2000 to develop an advanced wall system to replace the concrete masonry unit (CMU) block construction typically used in Florida. After researching and prototyping a variety of systems, including precast concrete, Mercedes Homes selected a cast-in-place concrete wall system.

Beginning in 2001, the concrete wall system, dubbed the Solid-Wall-System (SWS) by the builder, was rigorously examined and engineered by researchers from the University of Florida's Program for Resource Efficient Communities and Steven Winter Associates, Incorporated (SWA), using funding provided by the Federal Emergency Management Agency (FEMA). The results of those studies were impressive, showing a marked potential performance improvement during windstorm events, as compared to the regionally standard CMU walls. In 2001 Mercedes Homes started implementing the SWS as a standard offering. By the spring of 2004, Mercedes had built cast-in-place concrete walls on more than 2,000 Florida homes; by October 2005, that number had grown to nearly 4,000.

The 2004 hurricane season provided an extensive real-world test for the concrete houses when a record number of tropical storms pounded Florida and the Southeast. In evaluating the aftermath, SWA and University of Florida researchers found that the concrete homes performed exceptionally well in resisting hurricane force winds, including hurricane-induced uplift and lateral loads; these walls even helped protect the homes from wind-blown debris. What became evident, however, was that most of the damage to buildings throughout the region resulted not from catastrophic structural failures, but from wind-driven rain intrusion.

Combining the original structurally based engineering research with the lessons learned from the 2004 hurricane season, Mercedes Homes and its partners set out to design and build a truly hurricane-resistant house. The prototype was completed in early 2005 at Huntington Lakes, a Mercedes Homes Community in Rockledge, Florida. This house combines a number of advanced building technologies to offer homeowners three levels of hurricane protection: superior structural strength; greater resistance to wind-driven rain; and improved poststorm recovery. In addition to hurricane "hardness," the prototype has several features that increase energy efficiency. These include insulated low-e windows; an air handler located in conditioned space (now a standard Mercedes practice with its new plans); a 13-

WILLIAM ZOELLER

Mercedes Homes' concrete wall system starts with a steel-reinforcing cage consisting of a 6 x 6 steel mesh and vertical #5 steel bars placed at 48 inches on-center.

WILLIAM ZOELLER

More than 4,000 concrete SWS homes have been built, including this community in Rockledge, Florida.

WILLIAM ZOELLER

The structural superiority of the new Mercedes models comes primarily from the cast-in-place concrete wall system —the SWS.

SEER heat pump; and Energy Star appliances. This combination of features proves that builders can construct cost-effective, energy-efficient, hurricane-resistant homes—providing true value and security to their customers.

Structural Protection

The structural superiority of the new Mercedes models comes primarily from the cast-in-place concrete wall system—the SWS. Typical residential construction in much of Florida consists of CMU walls for single-story homes. Although CMU construction is stronger and more durable than standard frame construction, CMU-constructed homes, when subjected to a tropical storm, are still susceptible to water intrusion, lateral and uplift wind load failure, and penetration damage caused by wind-driven debris ("missiles").

The SWS homes are constructed using 3,500 psi concrete placed in modular aluminum forms to create the 6-inch walls. The concrete encloses a steel reinforcing cage of 6 inch x 6 inch road-mesh combined with vertical reinforcing bars placed at 4-ft intervals. The cage is specifically designed to evenly distribute direct wind, lateral, and point loading from missile impact across the wall surfaces to minimize point stresses, which can lead to failure. The cage connects to steel in the concrete slab, and the roof trusses are held by wet-set tie-downs (or hurricane straps) embedded every two feet in the concrete as the walls are poured. The steel-reinforced concrete wall assembly acts as a monolithic composite system with superior resistance to hurricane-induced forces. Typical wind speeds for a Category Five tropical storm range up to 155 mph, with wind-borne debris traveling well upward of 100 mph. Engineering analysis and destructive testing show that the cast-in-place system can withstand missiles fired at up to 200 mph.

Structural strength is not the only advantage of the cast-in-place system. Concrete walls have high thermal mass, reducing energy transfer between interior and exterior surfaces. This in turn reduces the homeowner's energy bills. The continuously poured system minimizes interior temperature fluctuations and drafts and reduces noise transmission. Rigid foam insulation is laminated directly to the interior surface of the concrete before the roof trusses and interior partitions are installed. This substantially simplifies the construction process and ensures a continuous insulation layer with no breaks or gaps.

Another advantage of concrete is that it inherently resists mold, termites, and rot, because it contains no organic matter. Concrete may also be inherently waterproof, depending on its ultimate strength; 5,000 psi is virtually waterproof, while 3,500 psi is water resistant. For these homes, the exterior finish coatings in combination with the 3,500 psi concrete provide complete waterproofing. The moisture that can enter CMU walls at joints, especially when the joints are deformed by structural load, is eliminated in the monolithic system, as is the potential for water storage within the hollow CMU cavities. And the houses are safer from fire as well as water; with their 6-inch solid concrete walls, they have up to a three-hour Class A fire rating.

Wind-Driven Rain Protection

Wind-driven rain can enter the home at vulnerable points from foundation to roof. Water intrusion at ground level can be mitigated by creating shallow indentations or recessed seats in the foundation slab to prevent rain from being driven or sucked into the home under the exterior doors and walls. The recessed seats work well in

conjunction with out-swing entry doors—a somewhat unconventional but practical solution to a common source of damage. In the aftermath of the 2004 storm season, researchers found that high wind forces on in-swing entry doors allowed considerable water to enter the home, because the weather-stripping gaskets rely on pressure in the opposite direction. Complete blow-in failure of an in-swing door during hurricane-force winds can result in significant water damage, and even to changes in internal pressure that contribute to roof uplift and significant structural damage. Following Hurricane Wilma in October 2005, Mercedes found that owners who had opted for in-swing doors, rather than the now-standard out-swing configuration, suffered more instances of damage. As a final protection for openings, the builder offers removable hurricane shutters as an option to all home buyers.

Exterior wall surfaces are protected with elastomeric sealant at form joints and at the concrete form snap-tie locations. Although concrete is poured continuously across multiple forms, the change in texture at vertical form joints and tie connections creates a vulnerability to water infiltration. Applying sealant to these form joints is a simple and effective way to prevent damage. A continuous drainage plane covers roof trusses on gable ends to prevent sheeting water from entering the building assembly at the truss-to-wall transition. In addition to the house wrap that is typically installed over the vertical wall sheathing, a separate building-paper-backed wire mesh is installed over the house wrap before the stucco finish is applied. This creates a foolproof drainage plane and makes for proper stucco adhesion. Wall surfaces are finished with a high-performance acrylic coating, which is capable of flexure and which bridges small gaps, to prevent the exterior walls from absorbing water during sustained heavy rainstorms.

At the roof level, researchers recommended several strategies to protect against water intrusion. A peel-and-stick underlayment was adhered directly to the roof decking beneath the shingles to create a secondary roof drainage plane. This provides backup protection in case of lost or damaged shingles—a common casualty of tropical storms. And the envelope often fails when water sheeting off the roof spills down the fascia board and is driven by wind or surface tension into the soffit vent openings. To prevent this from happening, a redesigned fascia extends 1 inch below the soffit to form a drip edge, directing water down and away. A new perforated soffit board product with recessed rather than surface openings limits water intrusion while encouraging greater air circulation—and faster drying—within the eave assembly. A simple change to baffled ridge and roof vents was also used to prevent water form entering the structure. Typical roof vents are not configured to prevent the entry of horizontal rain, while the baffled designs do just that (see Figures 1 and 2).

WILLIAM ZOELLER

SWA and Mercedes continue to collaborate on hurricane-resistant homes, including this two-story concrete prototype currently under construction.

WILLIAM ZOELLER

The recessed seat at the edge of the floor slab makes it more difficult for storm-driven water to penetrate the joint between the concrete walls and the floor slab.

Poststorm Recovery

Most of the losses from the 2004 hurricane season resulted from water intrusion. When rain or moisture wets parts of the wall or floor assembly, mold can grow indoors undetected for many months, compromising indoor air quality and causing significant long-term damage to the home. Water damage and mold growth become more severe when power outages prevent the homeowner from drying out the home quickly following a storm.

To aid in poststorm recovery, a natural gas-fueled generator is offered as an option to home buyers throughout the Florida market. (The natural gas grid tends to be far more robust than the electrical grid, as virtually all the natural gas infrastructure is below grade. Even if electrical power lines are below grade, transfer stations and transformers often are not.) The unit allows homeowners to use shopvacs, fans, and dryers during poststorm recovery when power outages are common, greatly reducing the risk of mold growth and long-term damage. Mercedes Homes also offers a generator-ready electrical service panel that can be easily connected to a portable generator. Even if the homeowner cannot initially afford to buy a natural gas generator, each home is now prewired and equipped for a generator to be installed at a later date, as needed.

To help homeowners to remove moisture if water entry occurs, the houses are built with nonorganic finish materials. Mold grows particularly quickly on paper, adhesives, and other organic matter. The storm-resistant prototype utilizes a new paperless drywall product offered by Georgia Pacific. This product uses a glass-reinforcing mat facing over gypsum; it resists mold growth better than traditional paper-faced products. Removing damaged drywall, and the mold it supports, was one of the most common storm-related repairs faced by homeowners following the '04 hurricanes.

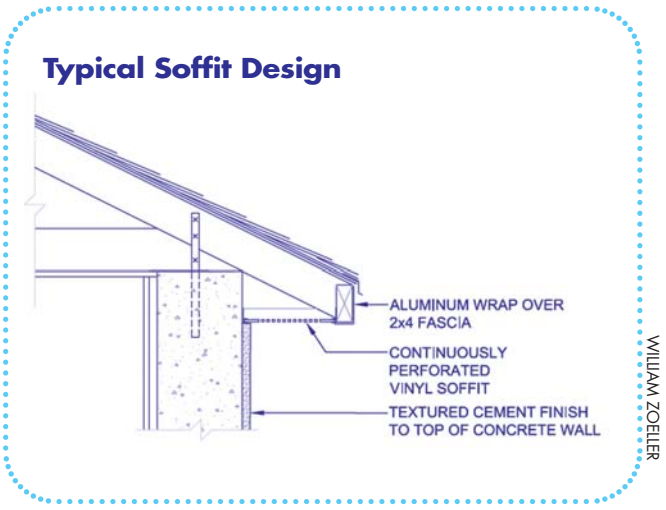

Figure 1. The typical soffit design for new home construction in Florida is susceptible to water intrusion from direct wind pressure, suction on the lee-ward side of the house, and from surface tension as the water sheets off the roof and clings to the fascia and soffit.

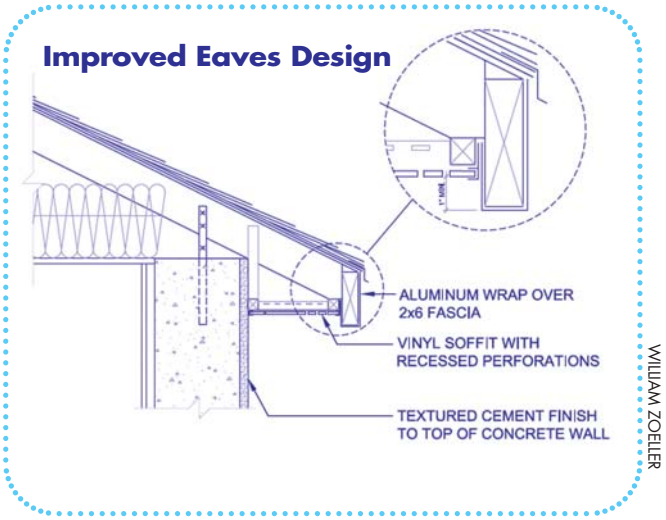

Figure 2. The improved eaves design features an extended fascia forming a drip-edge to defeat the rain water's surface tension, and a reconfigured vented soffit with recessed perforations arranged along the top of perpendicular ridges. Additional blocking is also installed to prevent soffit blow-out.

Major Improvements, Minor Damage

The concrete SWS homes are now standard in several Mercedes Homes divisions in central Florida. Although SWS is incrementally more expensive than the CMU construction it replaces, the benefits to the homeowners and to the builder—production time for the walls is reduced from five days to two—easily outweigh the costs. The now-standard water intrusion and storm recovery measures add about $2,200 to the cost of the homes, and the upgrade options (generator and shutters) add another $8,000.

By the time Hurricane Wilma scored a near-direct hit on the Melbourne area in October, Mercedes had completed and sold 343 new homes built using the improved specifications. In only 16 of these homes did the owners report any damage—and all of the damage was minor. Problems included water intrusion from two in-swing front doors, which were installed at the owner's request, a ridge vent leak where the old design was inadvertently used, and shingle damage where no leak was reported. SWA and Mercedes continue to research and develop advanced hurricane-resistant housing solutions including two-story cast-in-place wall systems, as well as performance testing of more conventional building assemblies. With ongoing improvements, Mercedes expects to see even less damage, and more happy homeowners, in the future.

William Zoeller is an architect and senior associate with Steven Winter Associates, Incorporated, of Norwalk, Connecticut.

For more information:

For more information on SWA and Mercedes Homes, go to www.swinter.com/ and www.mercedeshomes.com/.