



In many cases, once the roof's gable ends had buckled, the neighboring trusses collapsed like dominoes. New nailing specs for roof sheathing and better details for truss blocking aim to avert such damage in the future.

AFTER THE STORM: HARD-WON LESSONS

The 24th of this month marks the anniversary of the day Hurricane Andrew chewed its way across South Florida. In the wake of the storm, which took just 90 minutes to turn 65,000 homes into scrap, teams of experts from a host of government and trade groups sifted through the rubble to see what they could learn.

Initially, news reports were filled with charges and counter-charges as to who was to blame. Much of the early criticism fell on builders, who claimed in their defense that Andrew's winds were so far above the 120-mile-per-hour design load in the South Florida Building Code that even well-constructed homes went down.

Early reports by the National Hurricane Center of 140- to 150-mph winds supported this notion, but official estimates of sustained winds were later lowered to 110 to 120 mph by the Wind Engineering Research Council. Recently, the highly respected Atlantic Oceanographic and Meteorological Laboratory concluded that Andrew's highest sustained winds were 136 mph. Since Andrew's winds destroyed or exceeded the range of most gauges, a consensus on wind speed will probably never be achieved.

As the true proportions of the disaster became known — approaching \$20 billion in damages — the finger of blame moved to other quarters. Manufacturers of roofing products, pressed-board sheathing, and trusses were faulted. Dade and Broward Counties' building inspectors came under attack, accused of apathy, incompetence, and corruption. Others charged that the building code itself was seriously flawed.

Consensus emerging. While time has just begun to heal South Florida's physical wounds, it has allowed tempers to cool and given investigators time to sort out and weigh the evidence. Most assessment teams have issued official reports now, including specific recommendations from the American Plywood Association, Truss Plate Institute, Southern Building Code Congress International, and various others.

To a remarkable extent, the experts concur about the human and material failures that made Hurricane Andrew a much more costly disaster than it had to be. Equally important, there is a broad consensus forming on the steps that must be taken to forestall a similar disaster in the future.

As might be expected, these changes in code and practice will affect the Florida building market first, then, more gradually, other coastal areas from Maine to Texas where hurricane-force winds are a threat. In the end, almost everyone in the construction industry — even those hundreds of miles inland — will feel the aftereffects of Andrew.

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EXPERTS AGREE THAT MUCH
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**STRICTER AND CLEARER CODES
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BUILDERS AND INSPECTORS
ARE NEEDED TO AVERT
DISASTER NEXT TIME.**

Workmanship And Materials

It's estimated that 85% of Hurricane Andrew's damage was related to roof failures. Though no one knows the exact number, it's a good guess that 150,000 roofs will have to be rebuilt. Once they failed, the finished interiors of thousands of homes were left open to the elements. When the wind finally subsided, two days of heavy rain completed the destruction.

Shingles, roofing tiles, and felt were the first elements to fail when Andrew came ashore; these were peeled off like banana skins, filling the air with thick clouds of debris.

Those who assessed the storm damage say that all types of roof coverings, including asphalt and fiberglass shingles, concrete and clay roofing tiles, and metal roofing saw substantial failures. In many cases, manufacturers weren't ever required to prove that their products could meet South Florida's wind loading requirements, or their products were simply rubber-stamped without any independent testing.

New shingle standards. Already, trade groups have issued new installation guidelines for roofing shingles. The Asphalt Roofing Manufacturers Association (ARMA) is now recommending six nails per shingle rather than four and says that roofing nails are "preferable" to staples. ARMA also now recommends that roofing

BY DON BEST

Fastening Roof Tiles

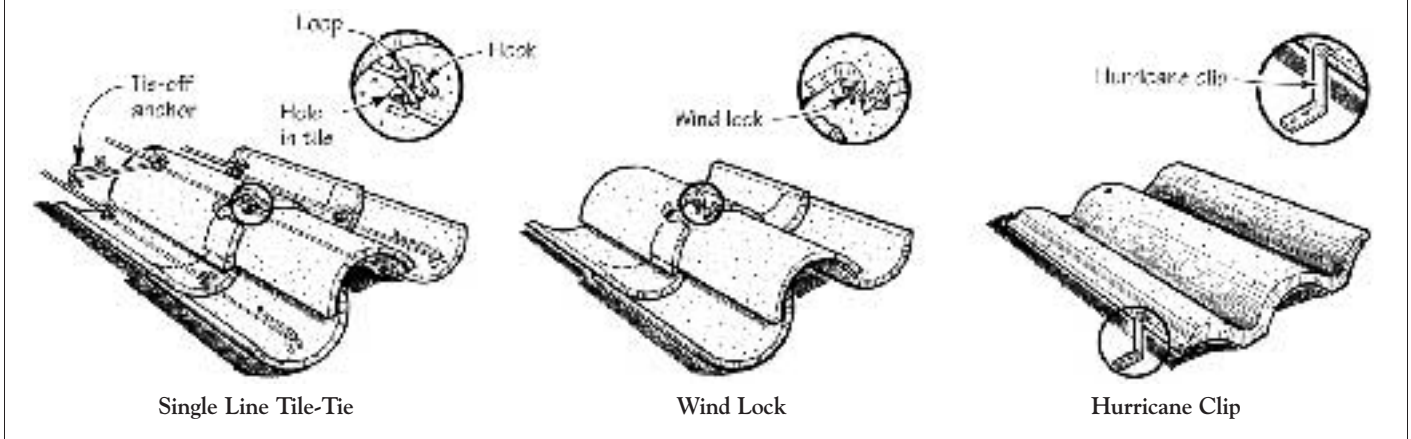


Figure 1. High winds turned clay and concrete roofing tiles into dangerous projectiles that caused extensive damage to surrounding buildings. To prevent this from happening in future storms, South Florida builders are turning to wire tie systems (left) or various types of metal clips (center and right).

cement be used to seal the shingle edges along the eaves and rake. While these recommendations are aimed at coastal areas and other high-wind regions, ARMA's Joe Hobson says that roofers everywhere would be "wise to follow the recommendations."

ARMA is contesting, however, a new Dade County ordinance requiring that shingles sold there be tested to three specific ASTM standards and a 110-mph wind test.

Clay missiles. Concrete and clay roofing tiles also turned out to be a horrendous problem during the storm. Once they broke loose and flew away, they slammed into other houses like incoming missiles — multiplying the storm's destruction.

Rick Olson, with the National Tile Roofing Manufacturers Association, claims that the association's installation guidelines, issued in 1989, would have been sufficient had they been followed in the field. "In virtually all of the failures we saw, the mortar paddies were either too small or missing," Olson noted.

Nonetheless, the Dade County Commissioners are requiring that all manufacturers test their specific tile and mortar bed systems to show that

they can meet code. Furthermore, every house equipped with mortar-set concrete or clay roofing tiles will have to pass a static pressure test in order to receive a certificate of occupancy.

"As a practical matter, this spells the death of mortar-set systems," says Bob Ferrante, eastern regional service manager for Monier Inc., a large manufacturer of roofing tiles. "The test requirements are so rigid and expensive that none of the manufacturers is moving to comply. From here on out, I think roofing tiles in South Florida will be fastened mechanically, using nails, screws, and clips, the way it's done almost everywhere else." (See Figure 1.)

Florida officials are also pushing to have independent tests done on roofing felt to see which materials and installation methods hold up best. As a first step, the Miami Board of Rules and Appeals has mandated the use of 30-pound felt as a minimum.

Sheathing Failures

Even with their roof shingles and underlayment blown away, many thousands of homes might have survived the hurricane had the sheathing held. But sheathing failures were

widespread.

The most common cause of failure was that nails and staples were spaced too far apart, or missed the underlying truss completely. On some badly built roofs, fully half the sheathing nails missed the framing entirely.

"In many cases, a whole house could have been saved had the builder invested another hour of time and an extra bag of nails," says University of Florida engineering professor Ron Cook, who chaired a special workshop on Hurricane Andrew for the Florida Department of Community Affairs.

Roof sheathing usually tore loose first along the gable end or at the eaves. Once the wind had a "bite" on the roof and began ripping off sections of sheathing, the underlying trusses — deprived of their primary lateral support — were left vulnerable.

Staples banned from the roof. In response to the catastrophic failure of sheathing during the storm, the Miami Board of Rules and Appeals has outlawed the use of pneumatic staple guns for roofing work. In theory, everyone agreed, staples can be used effectively to fasten sheathing. But in practice, it turned out, they seldom were. In some cases, staples

were carelessly driven into the sheathing at cockeyed angles. In others, one or both legs of the staple missed the framing. Even experienced builders agree that it's sometimes difficult to tell whether or not you've hit solid wood with a pneumatic stapler.

For similar reasons, there's been pressure on the Board (but no action taken) to outlaw pneumatic nailers. Investigators found that the nail head pull-through capacity of sheathing was sometimes weakened because pneumatic nailers, improperly set, had over-driven the nails and damaged the material.

Pressed-board confusion. The Board also outlawed all pressed-board roof sheathing, stipulating that only 5/8-inch plywood will meet code. However, many expert observers believe that oriented-strandboard (OSB) should not have been banned and will be reinstated for roof sheathing once its performance characteristics are fairly reassessed.

Meanwhile, the American Plywood Association (APA) has proposed that a new nailing schedule be adopted for roof sheathing in all coastal and high-wind regions.

Proper nailing. "A lot of the storm



Figure 2. Countless wood-framed gable ends failed after the wind tore off the sheathing — a truss roof's primary lateral bracing. With the plywood gone, the joint between the wall and gable-end truss opened like a hinge.



Figure 3. Some wood-framed gable ends failed, even with the roof sheathing intact, because of weak splices in the top plate above window openings.

damage wouldn't have occurred if the nailing schedule for sheathing, which calls for a 6d nail every 6 inches along panel edges and every 12 inches on the interior, had been strictly followed," says Thomas Flint, APA's vice-president of standards and regulations. "But because that standard didn't provide enough margin for installation error, we're now recommending that 8d nails be used, to be spaced 6 inches apart along all roof framing and blocking, and 4 inches apart over gable-end walls."

APA's damage assessment team pointed out a common flaw in the way that roof sheathing was nailed off along the rake overhang. They said builders frequently nailed sheathing at 6 inches on-center along the edge of the rake, which is *nonstructural*, while the more critical nailing into the gable end truss — which is structural — was done at 12 inches on-center.

Gable Ends and Trusses

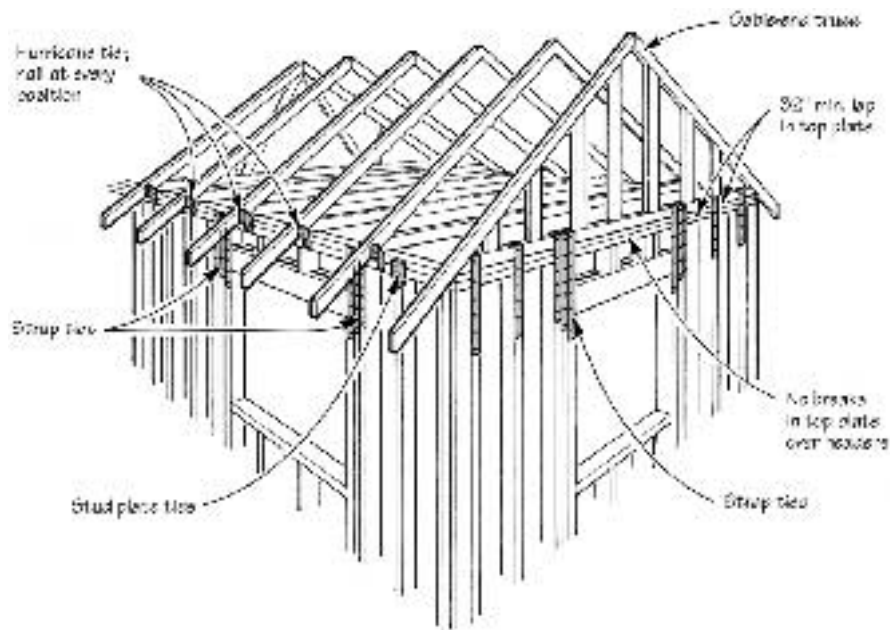
The collapse of wood gable ends was so common during Hurricane Andrew that the Dade County Grand Jury has recommended doing away with them in favor of full-height, reinforced masonry construction. In most gable-end failures, the roof sheathing was first torn away by the wind — removing the trusses' primary lateral support. Without the sheathing, the joint between the gable-end truss and the wood or masonry wall supporting it turned into a hinge (Figure 2).

Weak connections. Another reason that wood-framed gable ends failed so often, engineers concluded, was the weak connection between the gable-end truss and the wall it sat on (Figure 3). To strengthen that connection, engineers are recommending metal framing connectors from gable-end truss to wall, and sufficiently long laps in the double top plate of wood-framed walls (see "Better Roof-to-Wall Connections"). The stiffer top plate will better resist bending at the top of the wall, which tore gaps in numerous houses.

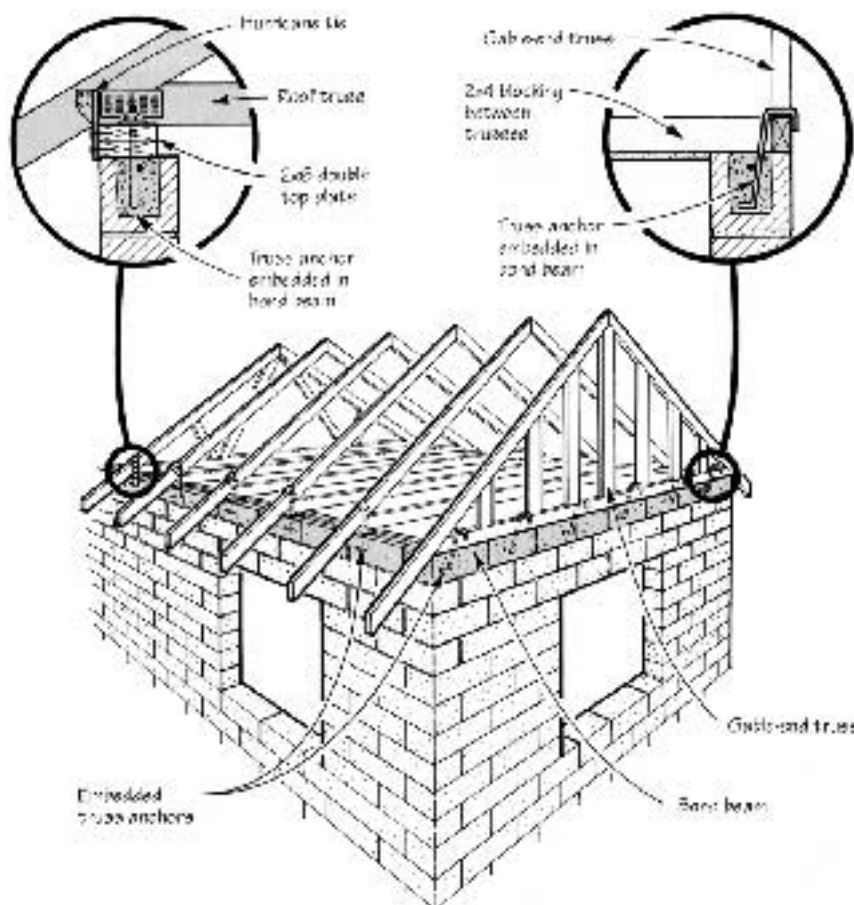
In many cases, once the gable end of the house had buckled, the whole truss system folded in on itself like an accordion (see photo, page 27). Structural experts agree that much of this additional damage would have been averted had there been sufficient blocking between the trusses, especially in the first two spaces nearest the gable end. Installed and nailed properly, such blocking would increase the diaphragm action of the two roof planes and ceiling plane, thereby strengthening the trussed roof structure (Figure 4, next page).

Who specifies bracing? Bracing is critical since trusses are engineered to work together as a system and have little individual strength. At issue is not only what bracing is needed, but also who should specify it. Builders are generally not equipped to do the

Better Roof-to-Wall Connections



Wood-to-Wood



Wood-to-Masonry

Gable ends were a common source of truss roof failure in Hurricane Andrew, because of weak connections between gable-end trusses and the walls below. Engineers are recommending the use of metal framing connectors, properly spaced and nailed, to prevent the problem from recurring.

Strengthening the Roof Diaphragm

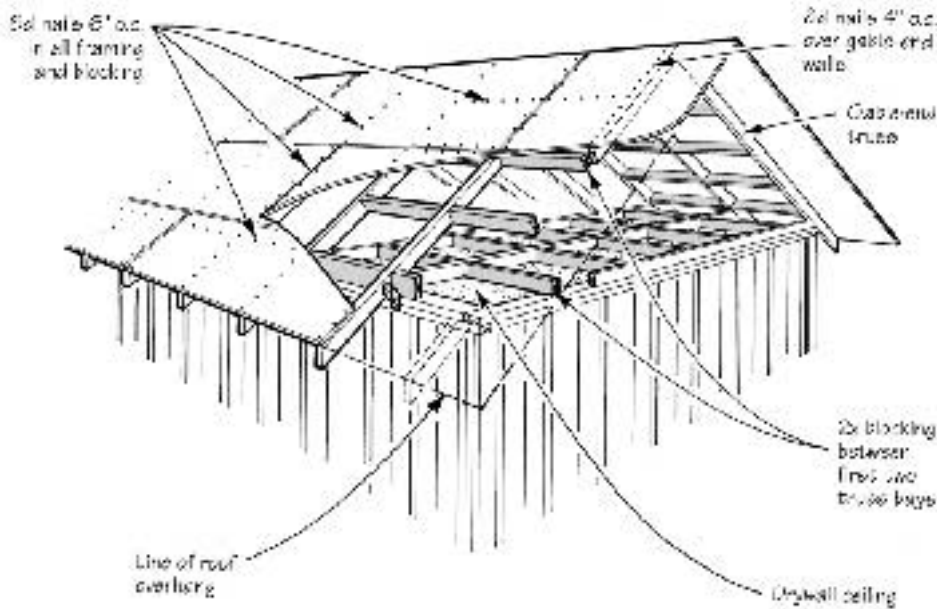
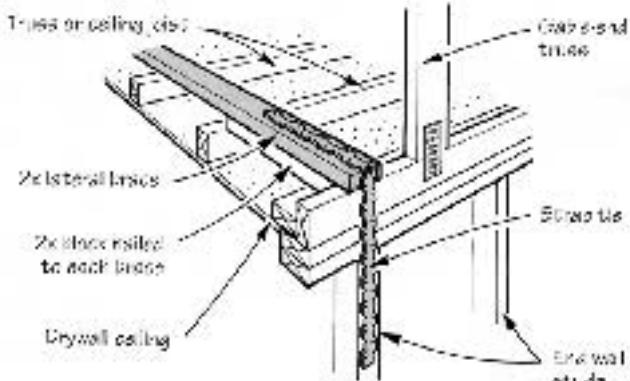


Figure 4. To strengthen the diaphragm action of the roof sheathing and ceiling, future codes may require blocking along the top and bottom chords of trusses (above). An alternate detail, from the National Forest Products Association, transfers loads to the ceiling diaphragm through 2x4 lateral braces (left).



necessary engineering, and manufacturers claim that they don't know how a set of trusses will ultimately be used. Codes offered little guidance here as well. To eliminate any confusion, Florida legislators and code officials want truss manufacturers — as well as project architects and engineers — to take more responsibility for specifying proper blocking and bracing.

A contributing factor in the loss of some roofs was that the hurricane straps required by the South Florida Building Code (also called hurricane ties or clips) were sometimes either missing or installed incorrectly, with too much free play at the joint (Figure 5). Without these one-inch-wide straps securing the roof to the wall, hurricane winds can take a whole roof off, especially if the house's windows and doors have been broken, which allows the wind to pressurize

the interior and push up on the roof. A growing number of construction experts say that metal strapping is a smart and cost-effective design feature even for houses that aren't in coastal areas.

Despite the new recommendations, many home builders along the Florida coast say that they won't go back to building wood-framed gable ends on top of masonry walls — even if the revised building code allows it. This is due both to their poor performance and to the high price of lumber.

Hip roofs. Another legacy of the hurricane in South Florida is the growing bias toward hip roof designs. Hip roofs generally fared better in the storm than gable-style roofs because the framing at the end of the building is held together better and because hip roofs don't present a flat, vertical gable end for the wind to attack.

Walls, Windows, and Doors

"CBS" walls — short for concrete block and stucco — generally held up well during Hurricane Andrew. The exceptions, as noted above, were CBS homes that didn't have full-height masonry gable ends. Otherwise, failures were limited to houses in which the tie columns that are required to reinforce the walls were either improperly installed or missing (Figure 6). Masons sometimes inserted the steel reinforcing rod down through the hollow block but neglected to pack the cavity with grout, which rendered the steel worthless. Examiners also found collapsed walls in which some or all of the tie columns had never been installed.

In wood-framed houses that had wall cladding rather than stucco, the most conspicuous failures were with hardboard siding, which tore loose in the wind (Figure 7). Observers say

that this type of cladding had a poor reputation among builders even before the storm hit and that its use was declining.

Most of the damage inflicted on the lower portions of houses was directly or indirectly related to windows and doors, which were often smashed by incoming roofing tiles and other flying debris. Once windows and doors were broken, giving entry to the wind, the surge of internal pressure inside the house put an additional — often fatal — strain on the roof.

“The single most important thing you can do for a building located anywhere near the ocean is to equip its windows and doors with permanent or removable shutters to protect them against flying debris,” says John Pistorino, a consulting engineer for the Dade County Building Department. He and other investigators point out that all of the wind loading calculations used by engineers and architects assume that the building is enclosed and that the envelope remains intact. Once windows and doors are punctured, all those engineering assumptions are voided.

Storm shutters required. With that in mind, the new South Florida Building Code will make properly installed storm shutters mandatory on all new houses beginning in 1994. Furthermore, code officials, hoping that many existing homes will be retrofitted with shutters, are pushing county tax authorities and insurance companies to provide homeowners with incentives to retrofit their houses with shutters.

It's worth noting that many Dade and Broward County homes that had storm shutters or that were boarded up with plywood just before the storm still had their windows and doors punched in and ended up suffering serious damage. The reason: Shutters and plywood weren't properly fastened into the frame of the house and blew away in the early minutes of the storm.

In literally thousands of homes, glass sliders, French doors, double-wide garage doors, and other types of doors and windows were blown out, frame and all, because they weren't properly secured to the framing. As a result, building and code officials are pushing for stricter test standards — perhaps through independent labs — to determine the wind loading capacity of windows and doors and to re-examine fastening methods. A parallel effort will be made to increase on-site inspections of window and door installation work.

Lessons For All

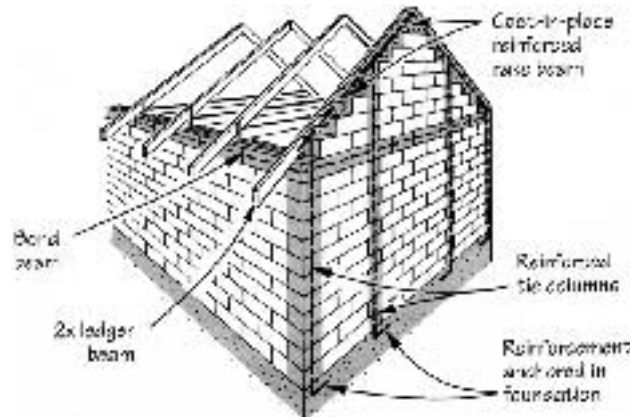
Rather than singling out one villain to blame, the experts agree that serious failures were apparent in every sphere of the construction industry and in many of the agencies responsible for regulating it, including:

- shortcomings in the South Florida



Figure 5. Not enough nails in these hurricane straps allowed the trusses to tear loose from the bearing wall they sat on. The straps must be nailed at every position on all sides of the truss, not just into the top edge.

Masonry Bond Beams and Tie Columns



Bond Beam Corner Detail

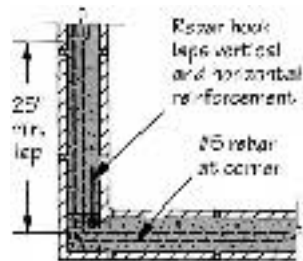


Figure 6. Unreinforced masonry walls did not fare well in the storm — many collapsed. Fully-grouted tie columns should be located at every building corner and at least every 20 feet along walls. Rebar splices in tie columns and bond beams should lap by at least 25 inches.



Figure 7. On wood-frame houses, stucco exteriors stood up much better than cladding such as hardboard and aluminum siding. These dented easily from debris and tore loose in many cases.

Building Code

- a failed inspection and enforcement process
- lack of oversight by qualified engineers and architects
- material failures, including the misapplication of materials
- lack of qualified supervision at the job site
- shoddy work, especially in fast-paced production building
- little knowledge among all players of code requirements, especially items pertaining to wind-resistant construction

New legislation. One of the first legislative responses to Andrew — moving swiftly now through the Florida state legislature — will be a state law mandating continuing education for building professionals. Designers, tradespeople, and inspectors who don't attend courses and can't demonstrate a thorough knowledge of the building codes — particularly hurricane-resistant construction — won't be certified or licensed. The new curriculum is expected to cover serious technical material, as opposed to pep talks and doughnuts from product manufacturers.

Code enforcement is another area that's going to see rapid change in South Florida. Following the release of the Dade County Grand Jury's final report (and others like it), which generally trashed the building inspection and code enforcement process, new inspectors are being hired and trained to provide better preconstruction document review and to carry out more inspections in the field.

Prior to Andrew, some building inspectors were writing up to 60 jobs a day (12 to 15 would be a more realistic rate) and some of those, it's been reported, were written in local bowling alleys and bars rather than at the construction site.

Rethinking inspection schedules. In addition to beefing up their staffs, Dade and Broward County officials are also rethinking how they schedule inspections. Many of the failures exposed by Hurricane Andrew were hidden in fastening and bracing details that can't be easily checked unless the inspectors carefully time their visits.

The grand jury also urged county authorities to improve their record keeping so that builders who repeatedly violate the code can be singled out and punished. In the same vein, county authorities are moving to clamp down on unlicensed contractors, who have been operating in droves and without much fear of prosecution.

The Buck Stops With the Builder

While there was much to be faulted in South Florida's code enforcement process, investigators inside and outside the construction industry agree that the responsibility for code

compliance ultimately rests with the builder.

"Building department inspectors can't and shouldn't be the primary quality control in construction," says Gary Nichols, who led the hurricane assessment team for the Southern Building Code Congress International (SBCCI). "Builders have to know the code inside out and take their responsibility for compliance seriously."

Chuck Lennon, executive director of the Builders' Association of South Florida, agrees. "The houses that stood up to Hurricane Andrew were the ones built under close supervision, either by the builder himself or a qualified journeyman, and that had an independent inspector — usually an engineer — check the work," says Lennon. "Houses that were left in the hands of inexperienced carpenters or other unqualified supervisors and that relied on the county building inspectors for quality control went down by the hundreds."

Independent inspections. To reduce the industry's reliance on county inspectors, the Builders' Association of South Florida is pushing for a code change that would make independent inspections mandatory. These would be carried out by a professional engineer or architect, hired by the builder, to complement the work of the county inspectors.

In addition to improving the quality of construction, independent inspections would also help insulate builders against lawsuits. Since code officials and building inspectors can't be sued for damages related to Hurricane Andrew (the government indemnifies itself against such claims), builders found themselves in the bull's-eye when angry homeowners decided to call their lawyers.

It's also likely that the revised codes will require more direct involvement from project architects and engineers, requiring them to take more direct responsibility for their work by visiting the site and signing off on the project.

The code document that contains most of the recommendations endorsed by SBCCI was actually developed in 1990, well before Andrew struck. Developed as a prescriptive document for builders, designers, and inspectors working in high wind regions, the booklet, called *Deemed to Comply Standard for Single and Multifamily Dwelling in High Wind Regions*, is filled with contractor-friendly construction details and work sheets rather than complex engineering standards that even professional designers and inspectors often don't understand.

In the wake of Hurricane Andrew, *Deemed to Comply* will likely be adopted as a technical reference in many code jurisdictions — particularly along the coast — that follow SBCCI's Standard Building Code. For coastal and other high-wind

regions up the eastern seaboard, Building Officials and Code Administrators International (BOCA) is developing a similar prescriptive document of its own.

Different This Time?

"The major failing of all Floridians has been our inability to learn and retain the important lessons that previous hurricanes should have taught us," concluded the members of the Dade County Grand Jury.

Angry jurors. With justifiable anger the jurors pointed to the findings of two earlier Grand Juries, one convened in 1976 and the other in 1990, that reported many of the same shortcomings and failures that their own investigation turned up. Because nothing much was done in response to those earlier warnings, they say, Hurricane Andrew was allowed to become the costliest disaster in U.S. history.

Will things be different this time around? Will there be substantive changes in the way that houses are built?

"Yes," says Lennon. "First of all, you're going to have tremendous, ongoing pressure from the insurance companies and mortgage lenders, who took a real hit in this storm, to make future houses more hurricane-resistant. Second, people along the coast are putting an unbelievable amount of pressure on politicians and code writers to make substantive changes. I think it's fair to say that you can't find anyone in South Florida — every builder included — who didn't lose a house to Hurricane Andrew or knows someone who did." ■

Don Best is a freelance writer in Surry, N.H., specializing in construction topics. All photos courtesy of the American Plywood Association.

For More Information

Coastal Construction Manual, #55
Federal Emergency
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*Deemed to Comply Standard for
Single and Multifamily Dwellings in
High Wind Regions*
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*How to Build Storm-Resistant
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