Evaluating Ballasted Single-ply Roof Systems

RP-4 stone ballast stays put during Florida hurricanes

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Stone-ballasted membranes constitute about 10 percent of all newly constructed built-up and single-ply roofing systems, and many older systems continue to perform well in the low-slope roofing market.

Unfortunately, in their zeal some structural engineers have confused the smaller and lighter pea gravel used on built-up roofs (BURs) for fire and weather protection with the large size stones used as ballast on some single-ply roofing membranes.

Because these engineers can cite window damage from pea gravel, they have developed restrictive requirements — based on no science — for all stones used in roofing applications. These mandates are found in Section 1504.8 of the 2006 International Building Code (IBC).

For code officials evaluating ballasted single-ply roof systems, the most detailed guidance referenced in the IBC is ANSI/SPRI Standard RP-4 19972002, "Wind Design Standard for Ballasted Single-Ply Roofing Systems." The standard can be downloaded free of charge at the Single Ply Roofing Industry's (SPRI's) Web site, www.spri.org.

RP-4 defines a ballasted roof as a membrane roofing system that is usually loose laid on the roof deck and held in place by the weight of stone aggregate or precast concrete pavers. The weight of the stone or pavers employs the force of gravity to hold the roof membrane in place and counter the uplift forces of wind.

Minimum requirements in the RP-4 standard call for stone not smaller than ASTM D448 #4, and/or 18 psf pavers or interlocking pavers.

The new (2006) International Building Code requirements limit the use of stone ballast to buildings less than 110 feet high in cities and 35 feet high in open country. Ironically, as the code stands, a pea-graveled BUR could be installed on a 110-foot-tall building with no gravel stop or parapet wall. A ballasted single ply using larger stone would be limited to a 45-foot-tall structure under the same conditions.

In open country, both pea-graveled and stone ballasted roofs are limited to 35-foot-tall buildings. RP-4 allows a bit more leeway, with ballasted roofs allowed on buildings up to 45 feet in height, with no gravel stop required. However, with a 36-inch parapet in place, RP-4 accepts a gravel-ballasted roof on buildings up to 105 feet.

This large retail building in Punta Gorda, Fla., with a ballasted, loose-laid, unreinforced EPDM membrane, experienced wind speeds in excess of 140 mph during Hurricane Charley. Even without a gravel stop, ballast remained in place in some locations along the south perimeter. (Photos courtesy of RICOWI Inc.)

Parapets over 24 inches are effective in reducing uplift in all roof types but are particularly effective on roofs with stone or gravel ballast. It's a rather simple concept: the stone has to jump over the parapet to create a downstream effect. In several cases examined in the RICOWI Wind Investigation Program (WIP), where high parapets existed, no pea gravel left the roof; it was piled against the parapet.

"The code disallows large stones on roofs with no parapet over 45 feet in height but approves small stones on 100-foot-tall buildings with no parapet," summarizes one roofing industry expert. "RP-4 is based on wind science, but the code is based on a structural engineer's lack of understanding of wind science."An additional lack of understanding held by some engineers and code officials is that the small stones, (called fines) find a way to jump out of the average sized stone matrix that are part of the ASTM D448 gradation. This was proven *not* to be true in research completed by the National Research Council of Canada and other sources.

In fact, the design criteria for RP-4 are based on actual wind tunnel testing and confirmed by wind studies and is specific to building height and wind speed and stone size. Actual field performance data was used — and confirmed by independent organizations — using small- and large-scale wind tests. This was augmented by extensive collaboration from the country's leading wind experts, followed by industry and peer review. As an ANSI standard, RP-4 has been processed through the rigorous consensus system developed by that organization.

"RP-4 was originally developed in 1985 based on wind tunnel tests that generated more data than new airplane testing at that time," says David Roodvoets, president and owner of DLR Consultants, Montague, Mich., and technical director of SPRI. "The code limitations developed in 2004 and included in the 2006 code do not consider any factors that wind engineers would consider important."

Real-world roofing experience

The Roofing Industry Committee on Weather Issues (RICOWI) has begun to released data from their Wind Investigation Program (WIP) on inspections of 93 low-slope and 91 steep-sloped roofs in Florida in the immediate aftermath of Hurricane Charley in August 2004 and Hurricane Ivan in September 2004. The study is available for free download at www.RICOWI.com. More than 50 experts examined roof shape, materials, edge conditions, installation details and degree of deterioration, if any. They found a wide range of roof performance, from no damage to complete displacement, or blow-off.

"From the ballasted roofs observed in the Charley and Ivan investigations, I would conclude that stone ballasted roofs did not contribute to the debris stream from these hurricanes," said Roodvoets, RICOWI's wind event coordinator. "Worst case, after Katrina, we saw a few stones lying around near a building with a ballasted roof. In Ivan and Charley, there was some movement of stone on the roof, but the stone did not blow off, even when the building height and wind zone requirements did not comply with RP-4."

This ballasted retail building roof experienced ballast and membrane displacement, but the parapet wall kept the stones on the roof.

Code officials concerned about stone ballast size can have stone screened according to ASTM D 448. However, a relatively quick measure of stone size can be accomplished by laying a ruler on the stone and determining average size by eye.

Gravel scour in right hand corner of ballasted roof after Hurricane Ivan. See the photo above for a close-up of the stone size used for this application.

According to RICOWI investigators, scouring of ballast was evident on some roofs affected by hurricanes Charley, Ivan and Katrina. However, the roofs that experienced significant scouring did not comply with RP-4 requirements. Some hurricane winds exceeded 140 mph; however, RP-4 limits ballasted systems to 140 mph basic wind speed zones. Systems installed in 140 mph wind zones were designed for maximum 110 mph wind zones. Systems were also installed on roofs greater than 75 feet tall with no parapet. (Note: some of these roofs were likely installed before RP-4 existed.)

RP-4 recommends that if gravel scour of 50 square feet or more occurs, the ballast needs to be upgraded with larger stones or pavers in the scour area. "A system designed and installed according to RP-4 should not show scour," says Roodvoets. "If the winds were significantly over design speed, then the stone should only move a short distance and not blow off the roof." Movement of stone ballast was a minor issue in the Gulf Coast hurricanes of 2004, according to the RICOWI investigators

At this writing, SPRI and the National Roofing Contractors Association are working to clarify the stone ballast issue in the 2007-2009 edition of the IBC. "We may not have this corrected in this year's hearings, but we are working to separate out the requirements for adhered pea gravel and the larger stones required by RP-4," reports Roodvoets. **RSI**

Report details real-world roof performance

Poor workmanship and improper materials and specifications were the primary causes of hurricane-related roof failures in Florida and on the Gulf Coast.

"Failure of roofing systems was because of system failure at the perimeter, and punctures and tears from debris," said SPRI Technical Director David Roodvoets. "The membrane attachment to the deck cannot resist the loads created when the perimeter securement fails, and this leads to progressive loss of membrane coverage (peeling of the membrane from the deck)."

What's more, "the issue of fastener corrosion was seen over and over again," said Andre Desjarlais of the Oak Ridge National Laboratory in Tennessee and a member of the RICOWI team. He noted that coastal specifications should specify fasteners with coatings that are unaffected by the salt air environment.

Another factor affecting roof performance, was intensely high hurricane winds speed winds entering buildings through openings, such as shattered windows and open doors. However tightly sealed a building can remain during the hurricanes often determined the fate of the roof and in some cases the entire structure. Some roofing membranes failed after walls or windows were damaged, providing uplift to the roof in excess of what the building was designed to endure.

Before Hurricane Charley, the last recorded storm to make landfall in Punta Gorda, Fla., was in 1943, and many of the older buildings there had been through the previous storm. Furthermore, one of the on-site indications was that many of the roofs seen there by the inspection teams had been poorly maintained.

"What we saw was a lot of deferred maintenance that compromised the roofing system," Desjarlais said.

Other findings were that the cleat gauge was less than currently recommended by FM Global LPDS 1-49 and ANSI/SPRI ES-1. In addition, corrosion of roof edge fasteners contributed to expansion of edge damage into the field of the roof.

Other key findings include:

- Energy efficient buildings tend to be better designed
- Failures occurred primarily at perimeters and due to flying debris. Wind-blown missile damage to roofs was significant
- Missiles included lightning rods and pieces of HVAC equipment
- Fastener corrosion was a major contributor to system loss
- Open or broken windows and doors caused structural failures
- Buildings constructed after Hurricane Andrew (1992) performed 100 times better than older structures
- Poorly maintained roofs were more failure prone
- Lack of enhanced perimeter base sheet fastening caused edge damage that affected the field of the roof
- Nearly 95 percent of roof failures were caused by poor workmanship and substituted materials
- Uncoated nails and improper nail spacing caused problems on perimeter nailers
- Poorly constructed roofs would have failed in less-than-hurricane force winds