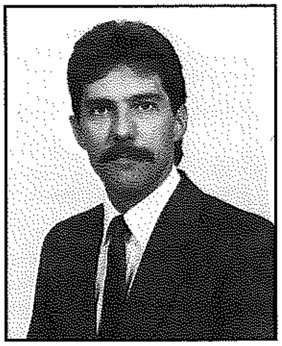
Hurricane Force, Part II

Understanding and Minimizing the Risk of Wind Damage

by Philip D. Dregger, president, Technical Roof Services



(Editor's Note: Philip D. Dregger, president, Technical Roof Services, is a registered engineer and certified roof consultant. He serves as a director for the Roof Consultants Institute and as treasurer for the Roofing Industry Committee on Wind Issues. Dregger has lectured and published extensively, sharing lessons learned from numerous roof investigations. Questions to Dregger and Goveia can be submitted in writing to Technical Roof Services, 395 Civic Drive, Suite C, Pleasant Hill, Calif., 94523).

BUILDINGS are often roofed with loose laid single ply membranes held in place with ten pounds per square foot (psf) of stone ballast. Field experience has shown that many of these ballasted roofs perform well in high wind conditions.

Table 1, taken from the article "Hurricane Force," published by John Goveia and myself in the November/December issue of *Western Roofing* magazine, shows that the design uplift pressures in a 70 mph wind zone for a 30 foot high, low-sloped roof (Case A), are approximately 20 psf in the field and 36 psf along the edge.

This article explores the seemingly perplex question of how single ply roofs withstand uplift pressures in excess of their ballast weights.

Wind Uplift Pressures

	Case A	Case B	Case C
Wind Speed (mph)	70	70	90
Roof Height (feet)	30	300	300
Uplift Pressures*			
Field (psf)	20	34	55
Edge (psf)	36	59	98

Table 1 - **1991 UBS Section 2311: Loads on roof elements and components for conventional enclosed structure with low-sloped roof in flat and generally open terrain.*

Maximum Wind Speed (mph)

Bldg.	System 1		System 2		System 3	
Ht. Ft.	Exposure E	Exposure P	Exposure E	Exposure P	Exposure E	Exposure P
0-15	80	90	100	100	110	120
> 15-30	80	90	100	100	110	120
> 30-45	70	80	90	100	110	120
> 45-60	70	80	90	100	110	120
> 60-75	70	70	90	90	100	100
> 75-90	NO	NO	90	90	100	100
> 90-105	NO	NO	80	80	90	90
> 105-120	NO	NO	80	80	90	90
> 120-135	NO	NO	80	80	90	90
> 135-150	NO	NO	80	80	90	90

Table 2 - Maximum wind speeds (mph) for ballast Systems 1, 2 and 3 with 2-inch to 5.9-inch high parapets. *(Source: ANSI RP-4 Ballasted Design Tables)*

Uplift Resistance

Stone and pavers used to ballast single ply roofs typically weigh between 10 psf and 22 psf. Since these weights are well below most of the uplift pressures listed in Table 1, wind uplift resistance of these roof coverings would seem to fail by definition.

Adding to this concern is a statement in the (Factory Mutual Research Corporation) FMRC Approved Guide, Chapter 18; *"loosely laid roof covers requiring ballast are not approved."* FMRC Loss Prevention Data Technical Advisory Bulletin 1-29, however, outlines recommendations for installation and repair of loose laid ballasted roof coverings. This author was informed that Factory Mutual Regional Offices may review and judge these roof systems "acceptable" as Class 1 constructions on a project to project basis.

Research

In 1976, Kind and Wardlaw conducted wind-tunnel measurements of aggregate scour on scale model buildings and published *Design of Roof Tops Against Gravel Blow-Off*. This and other research conducted in the mid 1970's and early 1980's focused on determining the influence of parapet wall heights on wind uplift pressures and the wind speeds necessary for scour of stone ballast. The research yielded some interesting conclusions:

- Parapet heights as low as one foot greatly decreased maximum uplift pressure coefficients.
- Uplift pressures (pressure differences) above and below stone ballast or pavers stabilize (i.e. equalize) very quickly, making them surprisingly resistant to upward displacement.
- Three-quarter-inch diameter stone is much more likely than 1½ -inch diameter stone to scour and fly off roofs in high wind conditions.

This research helped form the basis for much of the information contained in a document eventually published under the auspices of the American National Standards Institute (ANSI) designated as ANSI/RMA/SPRI RP-4 *Wind Design Guide for Ballasted Single Ply Roofing Systems* (ANSI RP-4).

ANSI RP-4

ANSI RP-4 includes step by step design considerations for selection of three-ballast systems for various combinations of terrain exposures, building height, and parapet wall heights.

Table 2 shows that if the roof described in Table 1, Case A, has a parapet height of four inches, it could be ballasted with System 1: 10 psf of 1½ -inch stone. ANSI RP-4 Design Tables for ballast Systems 1 and 2 are also listed in the International Conference of Building Officials (ICBO) Eval-

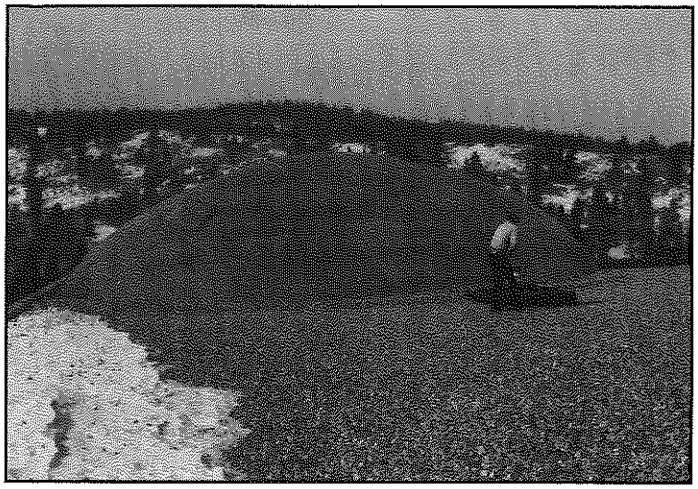


FIGURE 1 - Ballooning of EPDM membrane.
(Photo courtesy of Donnel, Cave and Wilkins.)

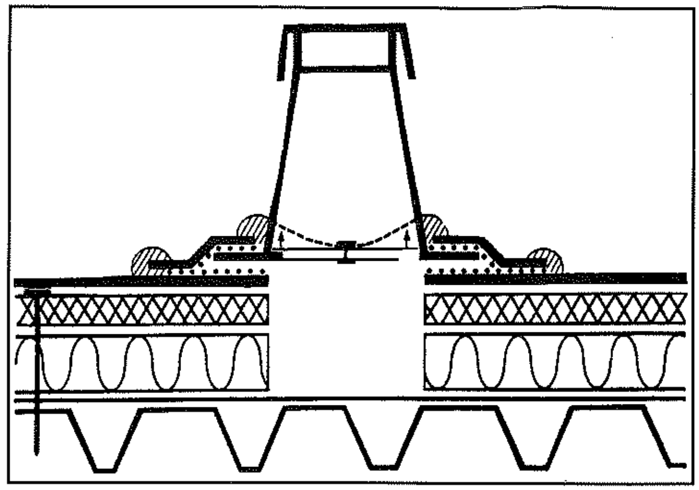


Figure 2 - One-way valve for equalization of air pressure beneath roof membranes.
(Source: Kelly Energy Systems, Inc.)

uation Service acceptance criteria for wind uplift of membrane roofing on buildings less than 90 feet above grade with basic wind speeds of no more than 100 mph.

A recent paper by Tom Smith, NRCA, et al, entitled *Hurricane Hugo: Evaluation of Wind Performance and Wind Design Guidelines for Aggregate Ballasted Single-ply Membrane Systems,* provided evidence that ANSI RP-4 is maybe somewhat nonconservative and that the wind speeds allowed by the document are substantially higher than those allowed by the 1976 Kind and Wardlaw paper. In addition, ANSI RP-4 does not address ballooning of a loose-laid membrane, which results from air infiltration and the development of high air pressures below the membrane.

Ballooning

To resist uplift pressures, loose-laid and ballasted roof systems rely at least partially on air retarders or on deck constructions that resist rapid air flow, to keep wind uplift pressures acting on or "felt" by the membrane below ballast weights. This critical role, however, is not always understood and air retarders or provisions for sealing decks are sometimes inadequately incorporated into the roof design.

Steel decks, especially acoustical steel decks, are considered air permeable while cast-in-place concrete decks are considered air impermeable. Installers should pay special attention to perimeter edge conditions and penetration openings since these items can greatly influence the anticipated air flow characteristics of a deck construction.

Assuming the building described in Case A of Table 1 is roofed with a ballasted single ply and has an air permeable deck construction, wind speeds as low as 35 mph could quickly produce uplift pressures in excess of ten pounds per square foot below the membrane near a windward corner. If wind speeds then increase or are sustained at this level, the membrane will begin to lift and displace the stone ballast well before wind speeds typically associated with the onset of scour are obtained.

The role of ballast in high wind speed conditions is, therefore, primarily to hold the membrane down against much smaller uplift pressures on the membrane associated with relatively small amounts of air infiltration into the space between the membrane and roof deck. It is desirable, therefore, to air retard or otherwise seal air permeable deck constructions roofed with ballasted single ply membranes to help guard against wind uplift.

Figure 1 shows that if a non-reinforced single ply membrane is laid loose and ballasted over an air permeable deck construction, it may balloon in strong winds to a height of several feet.

Pressure Equalization

Figure 2 shows a proprietary system that uses pressure equalization to combat wind uplift pressures on roof membranes. These systems equalize air pressure differences above and below the membrane rather than attempt to hold the membrane down against wind forces. "One way" valves are mounted on the roof surface to vent or equalize excess air pressures as they are created during wind conditions. The roof deck is sealed to minimize infiltration of interior air and the counterproductive repressurization of the space between the deck and the membrane. If properly installed, including sealing the deck, these systems can be quite effective.

Air equalization systems can be used in recover situations. Care must be exercised, however, to check that the old roof is properly secured or attached. If not, the old roof system may balloon and blow off despite effective pressure equalization in the recover system. Sealing at the roof perimeter and at any new penetrations is also important. Finally, potentially catastrophic consequences could result if the one-way valves are improperly installed or if they are sealed at a later date as attic vents are sometimes sealed in a misguided attempt to "save energy."

Summary

Field experience and research supports the successful use of stone and pavers to ballast single ply roofs. However, care should be exercised when utilizing recommendations contained in ANSI RP-4 since recent articles purport that they may be somewhat non-conservative. The use of air retarders should be strongly considered in all ballasted single ply roof systems that incorporate air permeable deck constructions. Proprietary systems utilizing pressure equalization techniques offer a novel and, if properly installed, effective method for roof systems to resist wind uplift.