Wind At The Edge

Consulting architect **Charles Goldsmith** reviews recent events and recommendations for wind uplift resistant roofing

It doesn't matter how good the roof membrane is — when the edges and flashings fail during a wind storm, the roof covering will usually follow. Hurricane Hugo proved that. Industry experts have repeatedly observed that flashings and edge metal release before the roof covering fails (Figure 1). In some cases, even the wood blocking that held the metal edges pulled away from she building structure (Figure 2).

What lessons were learned as a result of Hugo? If nothing else, experts agree that there has not been enough industry testing of flashing, fastening, and metal edges to simulate the dynamic effect that winds and temperature changes have on roof coverings and, in particular, on metal edges. A limited amount or static testing of edge metal has been conducted but this is primarily by individual manufacturers, and the results have been used only internally for product development. A survey by this writer has found little, if any, thermally-conditioned dynamic testing to simulate the real world environment. The importance of dynamic testing was effectively demonstrated during the Roof Wind Uplift Testing Workshop held in November 1989 at Oak Ridge, Tennessee. The workshop participants reviewed European standards for roof uplift resistance, which included fatigue testing using the latest dynamic test procedures from Europe [the *Proceedings of the Roof Wind Uplift Tilling Workshop* are available from the National Technical Information Service at (703) 487-4650 for $23; the stock number is DE-90008041]. This workshop led to the formation of an industry-wide committee to deal with wind-related roofing issues and task forces dedicated to evaluation and standardization of dynamic test methodologies, and the promulgation of edge metal and air barrier detailing.

Current Guidelines

But hurricanes and high winds won't wait for task force reports, and 21st-Century buildings with aerodynamic spoilers and wind screens on every rooftop are still in the future. The question remains: Can architects prevent future roof failures caused by wind? Where is the design professional to go when looking for the proper basis for design, even adjusted for the calculated wind conditions?

It should be recognized that today's flashing and edge metal detailing was derived by trial and error, and is an art rather than a science. Much of the published information on the subject has yet to be tested in any simulation of the real life conditions of fatigue or climatic changes, yet there is still a lot of information published on this subject.

Professional trade groups, such as the National Roofing Contractors Association (NRCA) and the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) issue manuals of suggested details for flashing and edge metal. Agencies, including Underwriters Laboratories (UL), have issued classification cards covering uplift testing of the roof covering. Factory Mutual (FM) has published loss prevention data sheets covering perimeter flashing and blocking based on wind engineering criteria. To say that this data has not been adequate would ignore the thousands of installations still serving their intended purposes. Yet we spend millions of dollars replacing installations that have Tailed at wind velocities below code design conditions. We need to know how to use the published information properly.

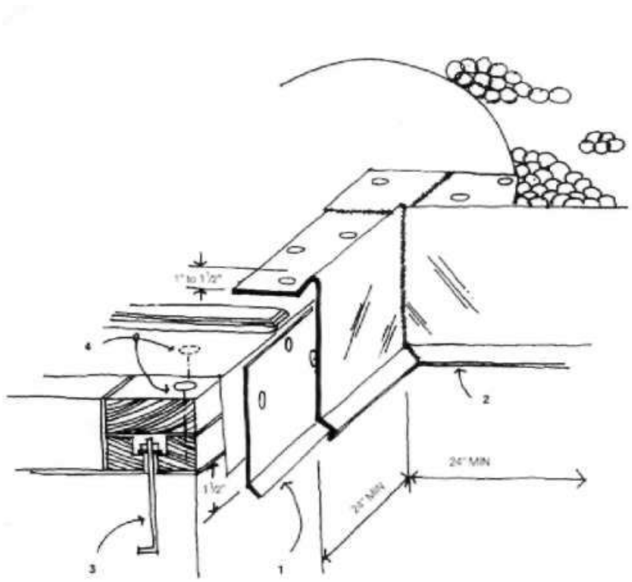
Figure 1.

Figure 2.

Wind Behavior

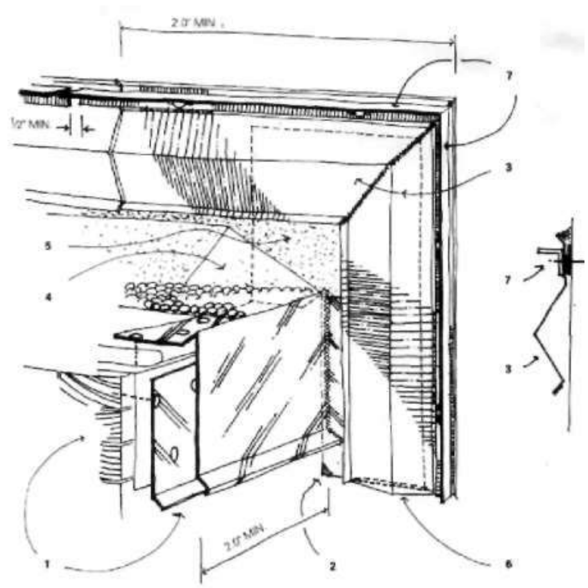
Before general guidelines and details can be useful to the design professional, some basic wind engineering information is in order. Wind affects the roof covering in a number of different ways. As wind flows toward and over a building, it creates a negative (suction) force on the roof, tending to separate the roof components from the body of the structure. This suctional force on the membrane can be added to by the direct positive pressure of the wind as it finds its way through openings and cracks in the windward side of the building and infiltrates the deck to the roof covering. Winds from a corner direction can create tornado-like vortices that cause the highest uplift pressures at roof corners and edges. These varying effects are usually built into the model building code requirements for wind loading, and coefficients are added to provide for the corner and edge effects.

Uplift forces can be formidable, with negative pressures ranging from a low of 10-20 pounds per square foot (psf) for a single story inland building to a high in excess of 200 psf for tall structures on the Florida coast. The design professional needs to learn how to interpret local building code provisions for wind uplift. It is



GRAVEL STOP

1 22 GAUGE CONNTINOUS CLEAT, FASTEN 3" O.C. TURN UNDER 1/2"
2 24 GAUGE GRAVEL STOP FASTEN @ 3" STAGGERED; SHOP FABRICATE ALL CORNERS
3 FASTEN INTO SOLID SUBSTRATE WITH MIN +1/2" @ 24" O.C.
4 RING SHANK NAILS @ 12" O.C. STAGGERED



TYPICAL GRAVEL STOP TERMINAL

1 FOR GRAVEL STOP, CLEAT BLOCKING. ETC . SEE TYPICAL GRAVEL STOP DETAIL 1
2 END PLATE OF 24 GAUGE GALVANIZED METAL. COPE OUT TO MATCH FASCIA PROFILE AND SHOP SOLDER, GALVANIZED PAINT ALL CUTS
3 MITER CUT AND SHOP SOLDER COUNTER FLASHING. McTEH CUT 1 x 1 x 1/8 FASTEN OVER COUNTERFLASHING @ 8"
4 TAPER CANT TO FACE OF GRAVEL STOP
5 CONTINUE BASE FLASHING TO LAP GRAVEL STOP END PLATE AND SECURE UNDER COUNTERFLASHING
6 CL0SE END; SOLDR ALL EDGES
7 PREFAB TERMINATION BAR. FASTENS @ 8" O.C. THROUGH OVAL HOLE

not sufficient to specify "conform to code." Each building requires its own case-by-case calculation.

As the base velocity pressures are calculated for wind speed and height, and the additional code coefficients for terrain, use, gust, and edge influence are added, the basic wind uplift pressures can, in some geographic areas, be increased by a factor of 3.0 or more. This can increase the required wind resistance beyond recognized industry standards. The wind uplift resistance values of roof components, based on Factory Mutual and Underwriters Laboratories testing (in the field of the roof) stop at 90.0 psf without safety factors. Using a minimum safety factor of 2.0 brings the values down to a use factor of 45.0 psf, hardly enough to satisfy some severe wind uplift conditions. Under these severe conditions, standard details may not be adequate. The design professional should review the test data, therefore, from individual manufacturers or design with products to meet uplift conditions specific to the job. It is imperative to match the code uplift requirements with the product wind resistance information. It is not sufficient to merely specify "meet Factory Mutual I-90." An FM or UL designation of 90 does not mean 90 mph. In other words, the architect must match up requirements with the product. Do not assume that published test results of fastener performance will be applicable on your building until you have correlated your conditions with those on which the test data were based. Once this correlation has been verified, then you may be confident that your design will perform under anticipated wind conditions.

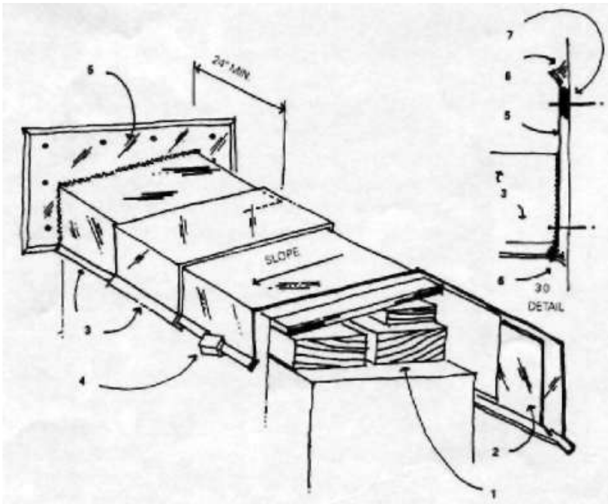
Some product testing of prepared roof coverings stops at an actual wind velocity of 60 mph by UL. It should be remembered that most roof covering materials used today have not been tested to the extreme wind uplift pressures required by codes. Moreover, most roof edge flashing details have never been actually tested at the uplift pressure levels used for testing the field of the roof covering. This may account for much of the high-dollar value of wind loss claims at wind velocities below building code requirement.

Most wind testing is specific. The designer should become familiar with wind uplift testing procedures used by the manufacturer before specifying the roof covering product, and should verify that the testing methods conform to the building configurations and details of any given project.

In addition to the effects of wind, the designer needs to be aware that severe weather changes can affect edge metal, inducing forces strong enough to eventually loosen the fastener and cause flashing failure and subsequent wind loss. Metal temperatures climb well above 150 F and cool down during rain, sometimes causing a temperature change in excess of 100 F. This force acts at each temperature change.

The thicker the metal, the higher the force against the fastener. A 10' piece of 26-gauge galvanized gravel stop exerts a horizontal force in excess of 3800 pounds while a 22-gauge piece exerts a force of over 6300 pounds. Following industry recommendations, the potential temperature-induced force is over 150 pounds against each fastener in a 22-gauge gravel stop. The metal must be either be restrained from moving or allowed to expand and contract freely. You can't do both. Movement usually can be restrained by using at minimum a 10-gauge fastener placed on 3 inch centers in staggered rows.

Metal expands from and contracts to the middle of



COPING CAP

1 P.T. LUMBER FRONT EDGE TO PROVIDE SLOPE
2 CONTINUOUS CLIP FASTEN AT 3" O.C.
3 COPING CAP WITH 6" JOINT COVER CAP SET INTO TWO ROWS OF-SEALANT, EACH SIDE
4 REVERSE CLIP @ 24" O.C.
5 END PLATE OF 24 GAUGE GALVANIZED METAL COPE OUT TO MATCH PROFILE: SHOP SOLDER. FASTEN TO WALL AND SEAL AT ALL EDGES
6 SEALANT
7 SEALANT TAPE TOP AND TWO SIDES

its length, causing maximum movement at the ends, unless totally restrained. Designers must provide for this condition by ending all flashing with some termination device securely welded, soldered, or attached to its end. It is not advisable to have metal end at 45-degree corners where the forces converge. All metal flashing at corners, "L's" and "T's" should be welded or soldered at joints and should extend 24 inches beyond that joint before meeting another piece of metal. If metal edges are designed to expand and contract freely, the material must be heavy enough to support itself, lie flat, and not allow water underneath. A 1/2 inch expansion gap with a 6 inch joint cover should be provided between any two 10 foot pieces of metal.

Success Is In The Details

Some general recommendations are:

- Test pullout resistance of the specified fastener *in situ:*
- Match fastener materials and metals to prevent corrosion;
- Specify all fasteners securing metal as ring shank, deformed, or threaded to help prevent backout;
- Secure all roof edge metal flanges with fasteners staggered to restrain the metal from movement;

Secure galvanized iron thicker than 24 gauge and extruded metals through oval holes to prevent the dislodgement of fasteners;

- Specify all galvanized sheet steel as minimum ASTM A-527 G90 (zinc coating thickness);
- Provide continuous wind cleats at all roof-edge gravel stops (except at gutters);
- Specify wind cleats to be one gauge heavier than the metal they restrain and fastened in the same way;
- Avoid penetrating the top surface of flashings;
- Specify dry lumber edge blocking (19 percent maximum moisture content) to prevent shrinkage;
- Design blocking wider than the flange it supports;
- When clips, cleats, or folds are designed into a metal roof covering system, verify that all test results for the exact configuration match the code uplift requirements;
- Consult manufacturers of proprietary edge metal for their details and fastening requirements.

Will the standard details work? In tribute to the roofing industry, the fact that there has not been more loss of roof covering because of wind is an indication that roofing products can perform better than present testing methodology indicates. And it indicates that the suggested industry details, although not always tested, do perform satisfactorily under most conditions.

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The author is principal of C. B. Goldsmith and Associates, an architecture, forensic architecture, and roofing consultingfirm in Clearwater, Florida. Goldsmith sits on ASTM Committee D-8 (Roofing, Waterproofing, and Bituminous Materials) and the Wind Engineering Research Council. He is task force chairman of the new Roofing Industry Committee on Wind Issues.

Recommended Reading

In addition to the workshop proceedings discussed in the text, see the roofing library listings on page 125.