Hurricane Force

Understanding and Minimizing the Risk of Wind Damage

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PROPERTY DAMAGE from hurricanes Andrew and Iniki will likely top $8 billion. National news coverage graphically illustrated the near total destruction experienced where the brunt of these storms made land fall. Preliminary indications from Andrew, however, are that much of the damage to roof coverings and roof decks outside of the hardest hit areas, was experienced at wind speeds well below the 100 mph to 120 mph basic wind speeds required by building codes in the Florida area. Unfortunately, since hurricane conditions were declared and these areas apparently did experience wind speeds higher than 32-38 mph (Beaufort Scale 7), damages may be excluded from most roof manufacturer's warranties.

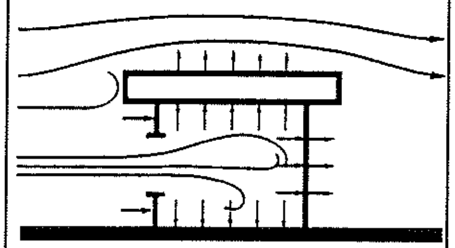

Figure 1

COMBINED PRESSURE differences generated by wind, in a building with windward openings (source: Factory Mutual Corp.).

Hurricanes such as these challenge those of us who specify or install roof systems to ask what we can do to help minimize the risk of wind induced damage.

First, local building codes must be consulted for the minimum design requirements for roof wind uplift pressures. Next, some excellent information from Factory Mutual Research Corporation (FMRC), and other organizations, can be used to select appropriate roof coverings and attachment systems to resist specific wind uplift forces. This article will highlight sections of the Uniform Building Code (UBC) and FMRC Loss Prevention Data Sheets pertinent to construction practices in the West Coast Region.

Wind-Uplift Forces

Winds are diverted as they encounter a building, creating areas of high and low pressure. The difference in air pressure between the outside and the inside of the building *pushes against* the building frame, walls, floors, and other components. Low air pressures that are generated as winds pass over the building tend to lift the roof. As seen in Figure 1, winds can enter building openings on the windward side, pressurize the building interior and increase uplift forces.

Section 2311 of the 1991 Uniform Building Code states... "Every building or structure and every portion thereof shall be designed and constructed to resist the wind effects determined in accordance with the requirements of this section."

UBC Section 2311 "Part II - Wind Design" and FMRC Data Sheet 1-7 "Wind Forces on Building and Other Structures" provide methods to determine uplift pressures. These documents, and other available documents, each yield slightly different uplift pressures. This article will focus on the UBC requirements since they are legally binding on building owners, contractors, designers, and consultants.

UBC, Chapter 23, determines wind uplift pressures depending on the basic wind speed, building height, exposure conditions, location on the structure (e.g. field area or perimeter) and on a building "importance" factor.

Table 1 lists example design uplift pressures calculated using the 1991 UBC criteria for three combinations of wind speed and building height, for a conventional building with a low-sloped roof in an unprotected area.

Design uplift forces, as seen in Table 1, dramatically increase with wind speed and building height. Uplift pressures also increase by 80% from the

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field area of a roof to the perimeter areas. The listed field pressures would need to be increased by 30% if the building was classified as an "open structure."

Special Wind Regions

As indicated in Figure 2, the UBC designates minimum basic wind speeds in the range of 70 mph to 80 mph for much of the West Coast Region. However, coastal areas of Wash. State and Alaska have basic wind speeds of 100 and 110 mph. In addition, the UBC designates certain areas as Special Wind Regions where local records and terrain features indicate 50-year fastest-mile basic wind speeds higher than those shown in the figure. The largest of these regions extends from Lake Tahoe, south along the Sierra Nevada Mountains, to the Mojave Desert in Southern Calif. Another special wind region famous for its easterly Santa Ana winds, extends around the north and east sides of the greater Los Angeles area. A third special wind region is located in the Puget Sound area near Seattle, Wash.

Specifiers and installers must consider these special wind regions and other local terrain features when selecting basic wind speeds. FMRC Data Sheet 1-28S, states that basic wind speeds for use in their calculations should be increased by 10 mph in the special wind regions. Please note that FMRC determines basic wind speeds based on a 100 year mean recurrence interval (1% annual occurrence probability) rather than the 50 year interval (2% annual occurrence probability) specified in the UBC figure. Because of these and other differences, it is important not to interchange uplift pressures calculated by Code and FMRC criteria. If a building requires an FMRC rated assembly, use FMRC calculated pressures but also check these against Code requirements.

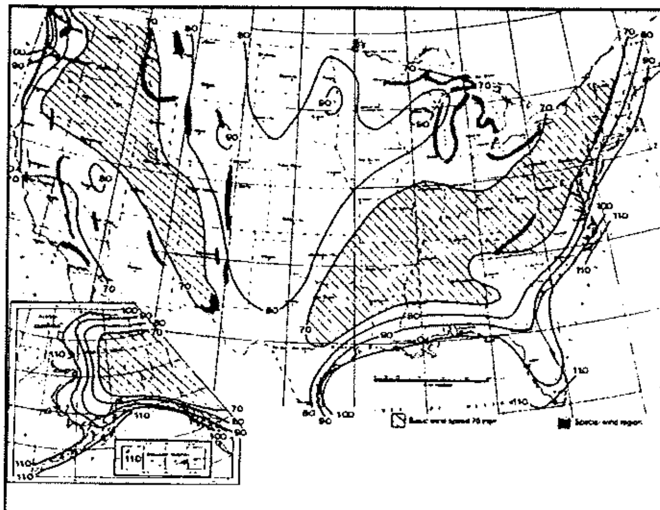

Figure 2: Minimum basic wind speeds, in miles per hour. (Source: 1991 UBC Figure No. 32-1)

Uplift Forces and System Requirements

It can be argued that it may not be appropriate to apply the full Code mandated uplift pressure to roof coverings. Code uplift pressures correspond primarily to pressure differences anticipated between the inside and outside of the building whereas the pressure differences between the roof membrane and the roof deck are likely to be considerably less depending on the air infiltration characteristics of the roof assembly. The relationship between air infiltration and the transfer of pressure differences from the roof deck to the roof covering is a complex issue and will be discussed further in a future article.

Wind Uplift Zone	Parapet Height	Insulation Fastening Needed		
		Field	Perimeter	Corner
Zone 1	<3 ft (0.3 m)	1-60	1-60	1-60 plus 50%
	≥ 3 ft (0.3 m)	1-60	1-60	1-60
Zone 2	< 3 ft (0.3 m)	1-90	1-90 plus 50%	1-90 plus 100%
	≥ 3 ft (0.3 m)	1-90	1-90 plus 50%	1-90 plus 50%

Note: 1-60/1-90 refers to the FMRC-Approved fastener density for the particular fastener/insulation/roof cover combination for Class 1-60/1-90 wind uplift resistance.

Table 2: Insulation Fastening (Source: FMRC Data Sheet 1-28)

Sizing the roof deck and framing members to resist the Code required uplift forces is a fairly straight forward procedure involving proven design methods and standardized tables. Less straight forward, however, is selecting an appropriate roof system to resist these same forces. Conventional, analytical procedures cannot be applied directly to many roof systems. Other more empirical methods must be used to select roof systems that will successfully resist wind uplift. These empirical methods make use of special tests, wind tunnel research and historical data.

Steel Decks

FMRC Data Sheet 1-28, provides guidelines for constructing an insulated steel deck roof, for both new and recover installations. It includes recommendations for Class I and Class II assemblies in relation to fire hazards and recommendations for Class 1-60 and 1-90 roofs in relation to wind resistance. Recommendations are categorized for three "zones" of uplift pressures.

Wind uplift forces for the field area of a roof determine if zone 1, 2, or 3 requirements are applicable. Zone 1 is for roofs with field pressures less than 30 pounds per square foot, zone 2 is for roofs with field pressures between 30-45 pounds per square foot, and zone 3 is for roofs with field pressures greater than 45 pounds per square foot. Zone 1 requires 1-60 securement and zone 2 requires 1-90 securement. Steel decks are not recommended in zone 3. Monolithic cast-in-place decks such as structural concrete should be used. This is discussed later in this article.

Deck Securement

In the field of the roof, Data Sheet 1-28 specifies that securement of the steel deck to joists or other steel supports is by welding 12-inches on center (every other rib) using ½-inch plug welds. Securement of steel panels at side laps is by mechanical fastening at three-foot on center. Welding at side laps is only acceptable on 18-gauge deck.

In zone 1 conditions, securement to

the joists in the corners is spaced six-inches on center (every rib). In zone 2 conditions, deck securement by welding is to be six-inches on center at corners and along roof perimeters. In addition, 5/8-inch diameter plug welds are recommended.

Insulation Fastening

Mechanical fasteners are the only recommended method to secure insulation to steel decks. This recommendation came out of high loss experiences by Factory Mutual Corporation for roofs with insulation adhered with asphalt. One of the main difficulties in using asphalt to adhere insulation is how fast the insulation cools when it contacts a steel deck. Research by the National Institute of Standards and Technology (formerly National Bureau of Standards) indicated asphalt cools from 500° F to 300° F in approximately six seconds after contacting steel decks.

The FM Approval Guide (FMAG) specifies the number and placement of mechanical fasteners for a specific combination of fasteners, insulation boards, and membranes corresponding to 1-60 or 1-90 securement.

Installers should also comply with other FMRC requirements including providing a minimum of 1 1/2-inch edge bearing for the insulation boards on the top flange of the steel deck to avoid damage from equipment or foot traffic. And, making sure fasteners engage the top flange of the deck rather than the rib to avoid potential problems with fastener stability.

Insulation fasteners must have a minimum pull-out resistance of 300 pounds. If the deck is deteriorated, is of a non-approved configuration or unknown gauge; pull-out tests are required. Typically, a minimum of ten tests or three per 10,000 square feet of roof are recommended.

Additional fasteners or a higher density of fasteners are required in certain roof areas. Table 2 shows that insulation near roof corners in zone 1 may need additional fastening depending on the parapet height. In zone 2, insulation near both roof perimeters and corners need special fastening over that for the Class 1-90 rate specified in the FMAG for the field area.

	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
System Requirement			
FM Class**	1-60	1-90	Zone 3 Construction

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

** Factory Mutual Data Sheet 1-28 "insulated Steed Deck."

Table 1: Wind Uplift Pressures and System Requirements

Wood and Cementitious Decks

FMRC Loss Prevention Data Sheet 1-48, provides guidelines for repair procedures for wind damaged roofs and wind uplift design recommendations for new and recovered constructions utilizing wood and cementitous decks.

Wet-filled, monolithic decks such as cast-in-place concrete or steel with lightweight insulating fill, are the only approved decks for zone 3. In acknowledgment of the reduced uplift pressures on roof coverings over these inherently air impermeable deck constructions, the calculated wind uplift forces can be reduced by 15%. In addition, the FMRC recommended 25% increase in wind uplift forces for buildings with large openings need not be applied.

Wood Decks

One-half or 15/32 inch plywood, is not an FMRC approved sheathing material for Class 1 rated constructions. The minimum approved plywood thickness is 3/4-inch.

Securement of plywood decks to framing members is typically by nails along the edge and along intermediate supports. Nail size and spacing must be determined by a qualified engineer based primarily on the shear required for horizontal plywood diaphragms. Typical maximum nail spacings at panel edges is six-inches and ten-inches on center along intermediate framing members. Spacings as close as 2″ to 2 1/2″ are often observed around the roof perimeter (i.e. diaphragm boundary).

If wider nail spacings are observed

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during roof removal operations, it is prudent to advise the building owner to retain the services of a qualified engineer to judge the suitability of the existing deck prior to installation of a new roof covering.

Uninsulated, built-up roofs over nailable decks are typically secured by mechanical fasteners installed through a base ply. The Factory Mutual Approval Guide (FMAG) lists the required fastener spacing, however, not for plywood decks thinner than ¾-inch.

If the deck is non-approved, pull-out tests are required. A table in FMRC Data Sheet 1-48 can then be used to determine fastener spacing. A minimum pull-out resistance of 40-pounds is recommended.

Insulated Nailable Decks

Insulation over nailable decks must be attached using approved mechanical fasteners. Conventional base ply fasteners are not sufficient to secure insulation boards. The FMAG specifies the type and density of mechanical fasteners for specific insulation boards.

WIND BLOW-OFF of a built-up roof adhered to wood fiber insulation.

FMRC approved wood decks must be minimum ¾-inch plywood or nominal 2-inch lumber. Structural concrete is also acceptable. If thinner wood decks are used, pull-out tests are required to determine fastener resistance and to allow calculation of the required fastener density. In all cases, a minimum pull-out resistance of 300 pounds should be obtained.

Fastener density should be increased in the corners and perimeter per FMRC Data Sheet 1-28.

Conclusion

Wind uplift forces are substantial and must be appropriately anticipated, evaluated and accommodated for to help avoid wind induced damage.

Particular attention should be given to special wind regions and to local terrain features which can result in wind speeds and uplift pressures in excess of basic requirements. For wood deck constructions, pull-out testing is usually prudent to confirm fastener resistance and to determine fastener spacing.

Local building Codes establish wind uplift requirements that are legally binding. Factory Mutual Corporation sets standards for insurance on properties they underwrite. Finally, manufacturers establish installation procedures for warranted roofs. These and other requirements must be researched, clearly understood, and appropriately coordinated when specifying or installing roofs to survive wind uplift.