Roof Gravel – Control by Design

By Michael D. Fischer, Director of Codes and Regulatory Compliance – Asphalt Roofing Manufacturers Association

Gravel aggregate has been used as a surface material on asphalt roofs for more than a century with tremendous success and widespread acceptance from building designers and building owners. Despite the long record of performance, recent concern about gravel blow-off during wind storms has kindled a debate about the use of gravel on roof projects in hurricane-prone regions. The debate has spilled over to the building code arena, as stakeholders continue to seek ways to improve building performance during tropical storms and hurricanes. High winds can cause roof gravel to become airborne, and under certain circumstances the impact of the gravel can then damage other materials. Windows, curtain-walls, and storefronts with large glazing areas are particularly susceptible to damage from wind-borne debris of all types.

Storm Stories

When Hurricane Alicia struck Houston in 1983, roof gravel was cited as a contributing cause of glass breakage in the central business district. The Committee on Natural Disasters[1] under the auspices of the National Research Council (NRC) reported that windborne debris was one of four mechanisms resulting in breakage of glass and cladding failure. The report also cited pressures that exceeded the wind design values, improper installation and *racking* of the fenestration as causing glass failures. Missile impact from windborne debris including roof gravel was considered a major contributor to glass breakage during Alicia. This determination, however, deserves closer scrutiny; the conclusion regarding windborne debris came from a survey conducted by glass distributors on behalf of the Houston Code Review Committee.

It is important to note that downtown Houston is not located in a windborne debris region; glazing is not required to be tested for missile impact. The NRC report noted that while Alicia was not an above-design event, the construction sequence of the city buildings may have resulted in channelization and interference effects that contributed to building failures. In summary: given the wind-related building design issues and glazing installation problems, it is a small wonder that there was significant glass breakage. How much of the breakage was due primarily to windborne debris (and roof gravel) and how much was caused by overstressed and overloaded glazing will be part of the ongoing debate.

After Hurricane Katrina destroyed much of Gulfport, MS, I had the opportunity to participate in an IBHS post-disaster study team. Katrina was atypical of most major hurricanes; the storm-surge caused most of the destruction. Wind damage on or near the gulf-front was almost irrelevant. Despite the damage pattern, there were a few examples of glazing failures and successes that point us towards a solution to damage from windborne debris and roof gravel.

The Hancock Bank Building (fig.1) shows a classic pattern. Broken glass along much of the lower portions of the building is a clear indication of windborne debris damage. Since wind pressures acting on the building were likely greater at the higher floors, we would expect wind load failures to occur farther from grade. The higher floors do show some glass damage; this might have been caused by wind vortices that lifted debris and sent it over the side of the building façade, where it was then in a position to impact the glazing elements. The Hancock Bank Building was built before windborne debris requirements were part of the Mississippi building code.

A different result can be seen by looking at a newly constructed building located directly on the coast. The Island View Casino

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Tougher Windows Too

When Hurricane Andrew wreaked havoc in Florida in 1992 it sparked a revolution in building code development. The building failures associated with penetration of the exterior envelope due to wind pressure or impact from windborne debris during Andrew set the stage for a new generation of buildings, products and systems. When Broward and Dade counties updated their building codes in 1994, it not only affected the roofing industry but also the regulations pertaining to glass manufacturing.

"In the test lab, excessive window deflection with regular laminated glass limits the number of applications that glass can satisfy," says Tom Kopec, North American Architectural Manager for DuPont.

Florida's building code now requires minimum embedment of gravel into the asphalt flood coat to minimize gravel blow-off during high-wind events. Proper roof design along with the use of impact resistant components and cladding provide a balanced approach to ensuring building performance during tropical storm and hurricane events.

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Resort (Fig. 2) includes laminated glazing that meets missile impact test requirements. Despite the presence of nearby, older structures that provided a source of windborne debris – including roof gravel – there was comparatively little glazing damage to the Island View.

The contrast between the performances of these two buildings is significant. Changes in structural design, opening protection, and installation methods, as well as code enforcement and inspection, account for the minimal damage to the Island View while less than one mile away, the Hancock Building suffered devastating damage.

The Science

Building science does offer a way to solve the problem of roof aggregate blow-off. Wind tunnel research from decades ago, as well as research projects currently underway, point to the use of roof parapets to provide a simple yet effective solution. Simply put, a correctly designed parapet can reduce the chance that gravel will leave the roof and cause damage to glass or other nearby cladding elements. Just as the edge of a food tray helps you avoid dumping your soft drink on the cafeteria floor, parapets can keep gravel on the rooftop.

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Figure 1 – Hancock Bank Building, Gulfport, MS after Hurricane Katrina

Wind research and resulting roof design recommendations from 1976 by Kind and Wardlaw[2] have demonstrated the control mechanism afforded through a consideration of variables including the roof height, basic wind speed and exposure category to determine what combination of aggregate size and parapet height will reduce the chance of blow-off during a design wind event.

The math is actually simple; the greater the design wind speed and/or the higher the roof, the higher you should build a parapet wall. Is it rocket science? Maybe so.

The Politics

The Florida Building Commission Roofing Technical Advisory Committee (TAC) met last month in Melbourne Beach to consider a number of proposed modifications for the 2011 edition of the Florida Building Code (FBC). The current Florida Code allows the use of aggregate on roofs of buildings in Florida, albeit with some limitations and installation requirements. A proposed modification that would have all but banned the use of gravel on roofs in Florida was not approved by the TAC. Opposition from a number of parties, and a lack of technical substantiation for removing such a widely and successfully used product from the marketplace, resulted in the TAC recommendation. The Commission will consider the proposal during it's deliberations in early December, and advocates from the roofing industry are expected to again show their opposition in testimony during the hearings.

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Figure 2 – Island View Casino and Resort, Gulfport, MS after Hurricane Katrina

The International Building Code (IBC) serves as the base model code for Florida. In recent years, the use of roof gravel in high wind areas has been reviewed during the code development process. The 2006 IBC does not allow roof gravel to be used on buildings in windborne debris regions, and limits its use in the hurricane-prone regions (see Fig. 3).

Ironically, where the use of gravel is allowed under the IBC, there is no minimum parapet requirement[3]. Downtown Houston? The IBC allows aggregate-surfaced roofs on a two-story (30 feet high) building with no parapet. Dallas? A building that is 110 feet tall in downtown Dallas is allowed to have an aggregate-surfaced roof with no parapet.

Conclusion: A Balanced Approach

Roof gravel provides an economical, sustainable and

Table 1504.8

Maximum Allowable Mean Roof Height for Buildings with Gravel or Stone on the Roof in Areas Outside a Hurricane-Prone Region

Basic Wind Speed from Figure 1600 (mph)	Maximum Mean Roof Height (ft)		
	Exposure Category		
	B	C	D
85	170	60	30
90	110	35	15
95	75	20	NP
100	55	15	NP
105	40	NP	NP
110	30	NP	NP
115	20	NP	NP
120	15	NP	NP
Greater than 120	NP	NP	NP

Figure 3 – Table 1504.8 from the 2006 International Building Code
(NP = gravel and stone not permitted for any roof height)

Proceeds of the RCI 25th International Convention energy-efficient surface for built-up, spray polyurethane and single-ply roof coverings. With the recent advances in the study of appropriate parapet design, it makes no sense to ban gravel from use on roofs. It also makes no sense to allow gravel to be used on roofs as high as 170 feet outside of the Gulf and Atlantic coastal regions with no required parapet. The balance?

Incorporate the latest in wind tunnel research to provide designers with guidance on parapet design for gravel-surfaced roof systems.

Promote the proper installation of aggregate materials including sizing selection and embedment into the asphalt where appropriate.

Educate code officials about the need for proper inspection and plan review of roof systems, especially in high wind regions.

1. Hurricane Alicia, Galveston and Houston, Texas, August 17-18, 1983: Prepared By Rudolph P. Savage, National Research Council (U.S.) Committee on Natural Disasters

2. Design of Rooftops Against Gravel Blow-Off, 1976: R.J. Kind and R.L. Wardlaw, National Aeronautical Establishment, National Research Council, Canada

3. Winds of Change: Resolving Roof Aggregate Blow-Off, March 25-30, 2010: Crandell & Fischer, RCI 25th Annual Convention