Performance of Embedded Gravel Roof Systems in Extreme Wind Loading
August 22, 2007

Technical Working Copy. Mixed units intentionally left in until final content worked out.

Submitted to:

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1 OBJECTIVE OF THIS REPORT

Pursuant to Section 2 of SB 2836 (reprinted in Appendix A),

> Section 2. (1) Before eliminating gravel or stone roofing systems in the Florida Building Code, the Florida Building Commission shall determine and document:
>
> (a) Whether there is a scientific basis or reason for eliminating this option

The Florida Building Commission tasked the investigators to collect basis information from academic and industry reports and papers. This report summarizes windborne debris generation and transport as it pertains to gravel and stone (henceforth referred to only as gravel) roof systems and presents observations from field reconnaissance and wind tunnel studies.

2 POST-HURRICANE OBSERVATIONS

Numerous studies of post-hurricane damage specifically cite roof gravel as a significant source of damaging debris. Both low-rise and high-rise gravel roof systems with and without significant parapets have been documented as a primary source of window breakage and subsequent water penetration and roof system loss from internal pressurization. Minor (1994) presents a synopsis of such observations over many years, including Hurricanes Celia (1970), Frederick (1979), Allen (1980), Alicia (1983), and Andrew (1992). FEMA 490 (2005) refers to roofing aggregate as a major cause of window breakage, including essential facilities. The report recommends the removal of aggregate systems from essential facilities and the development of technically based criteria for aggregate surfacing in other applications. Kareem and Bashor (2006, personal communication July 29, 2007) studied glass and cladding failures in New Orleans after Katrina also noted the presence of roof gravel at the site of many broken windows, as well as gravel blow-off from inspected roofs.

This combined body of observations over many storms, going back to at least 1970, clearly indicates that the issue of gravel blow-off is not just anecdotal or a rare event. This report comprehensively explores the knowledge base of building science and wind engineering research that targets this phenomenon.

[considerably more to add. Meetings still required include Broward County Code Services Division. I'd also be interested in getting GPS coordinates for the examples of BUR systems that performed well in Frances and Jeanne and pulling site wind speeds out of Peter's maps or H*Wind]

3 WINDBORNE GRAVEL: BLOW-OFF, TRANSPORT AND IMPACT EFECTS

It follows that rationale for eliminating gravel roofing in Florida must include reasonable evidence that gravel blow-off occurs at or below design-level event wind speeds. Moreover, it must be shown that the wind carries gravel over a distance and with sufficient velocity to damage the buildings downwind—particularly to fenestration, which is foremost susceptible to small missile impacts. This section presents this basis research in three sections: (1) Gravel Scour and Blow-Off, (2) Gravel Transport and (3) Gravel Damage to Fenestration.

3.1 Gravel Scour and Blow-Off

3.1.1 National Research Council of Canada Wind Tunnel Testing

In the 1970s, Dow Chemical of Canada Limited sponsored a series of wind tunnel tests at the National Research Council of Canada to investigate roof gravel scour and windborne debris generation. In the first project, Kind (1974a) investigated the relationship between gravel size and the surface shear stress required to initiate scouring.

Kind covered the working section floor of the wind tunnel with three different types of gravel:

- ½”– ¾” pea gravel,
- ¾” natural gravel and
- ¾” crushed limestone,

and found that the critical wind speed required at which stone motion began is proportional to the square root of the nominal stone size ($\sqrt{d}$). In a second set of tests, the wind tunnel speed was slowly raised to 85 mph, and the velocities corresponding to the first signs of gravel movement and scour were recorded. Edge and corner (90º vee) upwind obstructions were added in subsequent tests to evaluate the effects of turbulence generated from head-on and cornering winds traveling over buildings parapets. Additionally, two vertical pipes were embedded in the gravel bed in separate rounds of testing to simulate the wake effects of ventilation system attachments.

The lowest wind speed thresholds required to cause gravel scour and blow-off occurred where the winds traveled diagonally over the corner parapet (i.e. where the walls on a full-scale structure are oriented 45º from the mean wind direction, see Figure X). At 70 mph, the vee parapet produced strong vortices that caused the gravel to move sideways and then upward. Scouring was contained to an area that extended 3-4 ft downwind from the parapet.

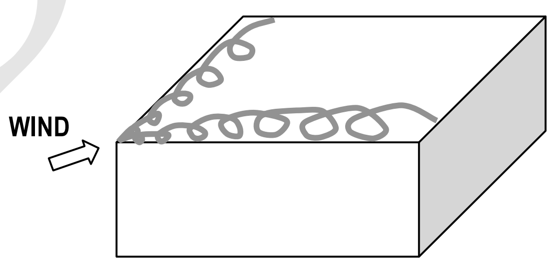

Figure X. Winds traveling over the corner parapet

The first series of the Kind (1974a) tests did not consider the effects of the building shape—that is, to say, only the roof itself was tested. Kind (1974b) followed with a second series of experiments using three 1:10 scale warehouse/factory building models with four interchangeable parapets of varying height. Tests were performed in the National Aeronautical Establishment 30 ft x 30 ft wind tunnel, which was calibrated to produce a open exposure terrain conditions (z_0 = 0.075 m). During testing, wind speeds were gradually increased, and research personnel recorded four critical gust speeds listed below:

Table X. Critical Gust Speeds at Roof Height

Threshold	Gravel Behavior
V_{c1}	first stone motion observed
V_{c2}	scouring occurs more or less indefinitely
V_{c3}	gravel propelled over *windward* parapet
V_{c4}	gravel propelled over *leeward* parapet

Kind concluded that for the most critical building orientation (45º), the building length (l) to width (w) ratio was found to have no importance as long as the parapet height H was much smaller than the building dimensions l and w. It was also found that as is the case for V_{c1} and V_{c2}, V_{c3} is proportional to $\sqrt{d}$. No such clear relationship was found for V_{c4}, especially for tall parapets, although this appears to be insignificant. Kind and Wardlaw (1976) later observed:

> "It appears that from the tests however that V_{c4} is normally equal to or greater than V_{c3} and that for speeds equal to or greater than V_{c3} large quantities of stones are blown off the rooftops and many of these stones fly considerable distances downstream of the building where they are apt to cause damage."

The results of these experiments were condensed into a rational procedure to estimate four critical gust speeds for design. For a low-rise buildings dimensioned in accordance with

$$2.5\left(h+3H\right)\leq l+w,$$

gravel will become windborne and pass over the windward parapet at the rooftop gust speed,

$$V_{c3}=86\text{ mph}\cdot\sqrt{\frac{d}{0.75\text{ in}}}\cdot F_{p3}$$

where d = nominal gravel size (in) and F_{p3} = parapet height factor that increases with ratio of the parapet height H to the building height h.

Values of V_{c3} and V_{c4} are provided in Table X for ¾ in nominal size gravel and multiple low-rise building shape combinations. V_{c4} was determined by multiplying V_{c3} by a H/h dependent factor determined from an empirical curve provided for a low-rise building with dimensions of $w = l$ = 75 ft and h = 15 ft. For taller buildings of similar footprint, this approach will result in an overestimation of the wind speed required to propel gravel off of the leeward parapet.

Table X. Critical Rooftop Wind Speed Thresholds (mph) for ¾" Gravel
(do not compare to ASCE 7 Basic Wind Speeds)

	H / h				V_{c3} : Wind Speed Threshold for Gravel Exiting Windward Parapet				V_{c4} : Wind Speed Threshold for Gravel Exiting Leeward Parapet			
Parapet Height *H* (ft)	0.5	1.0	2.0	3.0	0.5	1.0	2.0	3.0	0.5	1.0	2.0	3.0
Building Height *h* (ft)												
20	0.025	0.050	0.100	0.150	67	73	86	99	87	90	96	104
30	0.017	0.033	0.067	0.100	65	69	77	86	84	85	87	90
40	0.013	0.025	0.050	0.075	63	67	73	80	82	82	82	84
50	0.010	0.020	0.040	0.060	63	65	71	76	82	80	79	79
60	0.008	0.017	0.033	0.050	62	65	69	73	81	79	77	77

The wind speeds in Table X correspond to the gust velocity at *roof height* in open terrain and must be adjusted for comparison to the design (basic) wind speeds found in ASCE 7 (2006), which correspond to a 3 s gust measured at 10 m in open exposure. To convert them, the square roots of the velocity pressure coefficients K_z from Table 6-3 in ASCE 7 were multiplied with the V_{c3} and V_{c4} values in Table X to produce the basic wind speed equivalents found in Table X:

Table X. Critical 10 m Wind Speed Thresholds (mph) for ¾" Gravel

	H / h				V_{c3} ASCE 7 Basic Wind Speed Equivalent				V_{c4} ASCE 7 Basic Wind Speed Equivalent			
Parapet Height *H* (ft)	0.5	1.0	2.0	3.0	0.5	1.0	2.0	3.0	0.5	1.0	2.0	3.0
Building Height *h* (ft)												
20	0.025	0.050	0.100	0.150	72	79	93	107	94	98	104	113
30	0.017	0.033	0.067	0.100	65	69	78	87	85	85	88	91
40	0.013	0.025	0.050	0.075	62	65	72	78	81	80	80	82
50	0.010	0.020	0.040	0.060	60	63	68	72	78	77	76	76
60	0.008	0.017	0.033	0.050	59	61	65	69	76	75	72	72

With few exceptions, the combined windward and leeward wind speed thresholds are generally found to be less than 44.7 m/s (100 mph), which corresponds to the lowest ASCE 7 (2006) design wind speed for the State of Florida.

3.1.2 Colorado State Wind Tunnel Testing

In the late 1990s, Wills et al. (1998, 2002) developed a theoretical model for the UN Internationale Decade for Natural Disaster Reduction Programme. He defined the flight speed threshold for compact objects as:

$$V = \sqrt{2dg\left(\frac{\rho_{gravel}}{\rho_{air}}\right)\left(\frac{I}{C_F}\right)}$$

Where d = gravel diameter, V = wind velocity, C_F = aerodynamic force coefficient (~1), I = fixing strength integrity parameter (= 1 for objects resting on the ground), g = gravitational constant, and ρ_{air} and ρ_{gravel} = the densities of air and gravel.

A series of wind tunnel experiments were carried out at Colorado State University in 1999 to validate the model. Tests were conducted on cubes of different sizes and densities, and the results compared very favorably to the theoretical predictions. For gravel sieved to ASTM D 1863-03, the model predicts the thresholds of flight as:

Table X. Threshold of Flight for ASTM D 1863-03 Gravel Sizes (Wills et al. 1998)

Sieve Size		Wind Speed	
in	mm	m/s	mph
0.093	2.36	10.2	23
0.187	4.75	14.5	32
0.374	9.50	20.5	46
0.492	12.50	23.5	52
0.748	19.00	28.9	65
0.984	25.00	33.2	74

The tabulated values are also in good agreement with Kind and Wardlaw (1976) estimates for low-height parapets. The Wills et al. model predicts a 65 mph critical wind speed for ¾ in gravel, which falls between the 62-67 mph bounds for the 6 in parapet cases (See Table X).

3.2 Gravel Transport

In the previous section, the literature demonstrated that gravel is susceptible to blowing off low-rise building roofs at wind speeds less than basic wind speeds defined in ASCE 7 (2006). This section considers gravel transport from the source roof to the buildings downwind. It is during this time that the drag forces acting on the gravel accelerate it while gravity eventually brings the object to rest on the ground.

3.2.1 Applied Research Associates Model

Based in part on the experimental studies conducted by Kind (1974b), Applied Research Associates, Inc. (ARA) numerically modeled the expected number of aggregate impacts on a building downwind for a range of common low-rise residential and commercial structures located in a suburban exposure. This approach was developed for FEMA's risk assessment software, HAZUS-MH, and has been approved by the Florida Commission on Hurricane Loss Projection Methodology (FEMA 2003).

The model provides enveloped results based on four roof area / height combinations and gravel diameters linearly distributed from 0–2.2 cm, which approximately bounds the gradation requirements found in ASTM D 1863-03. Gravel depth was set to 1.6 in, approximately three times that standard depth for built-up roofs installed in Florida (Johns Manville 2004a, 2004b). This choice, however, only affects the supply of windborne debris but not the propensity for gravel to take flight in extreme winds.

To overcome the computational expense of running the physics-based model in a Monte Carlo simulation, a series of simplified expressions was fit to the physics model outputs. These equations are reprinted below. N represents the expected number of impacts on a 1 m^2 target surface located h meters above the ground during 1 hour:

$$N = n(V,d) \cdot f(x_d, h)$$

$$n(V, x_d) = 53 \frac{1 + \tanh\left(\dfrac{V^{1.11} - 80}{18}\right)}{e^{x_d} + e^{-x_d}} \qquad \text{where} \qquad x = \frac{x_d - 15}{33}$$

$$f(x_d, h) = \begin{cases} \dfrac{60}{h_0} \cos^2\left(\dfrac{\pi}{2}\dfrac{h}{h_0}\right) & if\ h \le h_0 \\ 0 & if\ h > h_0 \end{cases} \qquad \text{where} \qquad h_0 = 30 - \frac{x_d}{10},$$

where $n(V, x_d)$ is the average number of impacts from the ground up to 30 m and is a function of the 10 m 3 second open-exposure wind speed (V) and the center-to-center spacing between the source building and the target building (x_d). $f(x_d,h)$ is an adjustment factor to convert $n(V,d)$ to a target-specific height h. Figures X-X plots the number of expected number of missile impacts over one square meter at 2, 5 and 10 m at a defined height (vertical axis) versus the center-to-center building spacing (horizontal axis). Each figure contains six wind speeds correspond to the design wind speeds in Florida found in ASCE 7 (2006).

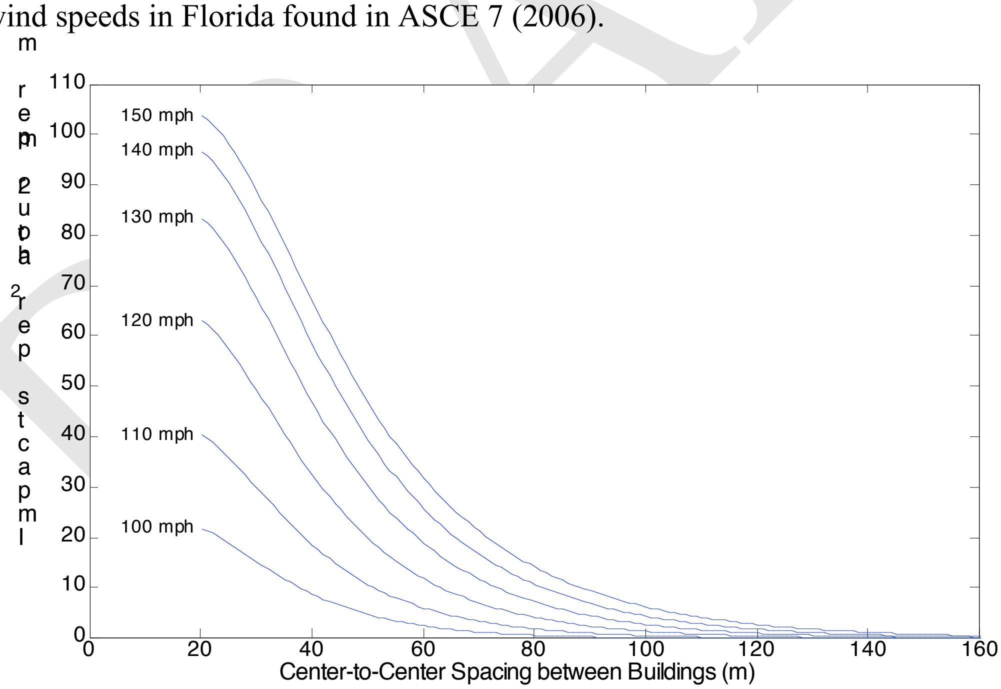

Figure X. No. Impacts / m^2 on Downstream Buildings at a Height of 2 m

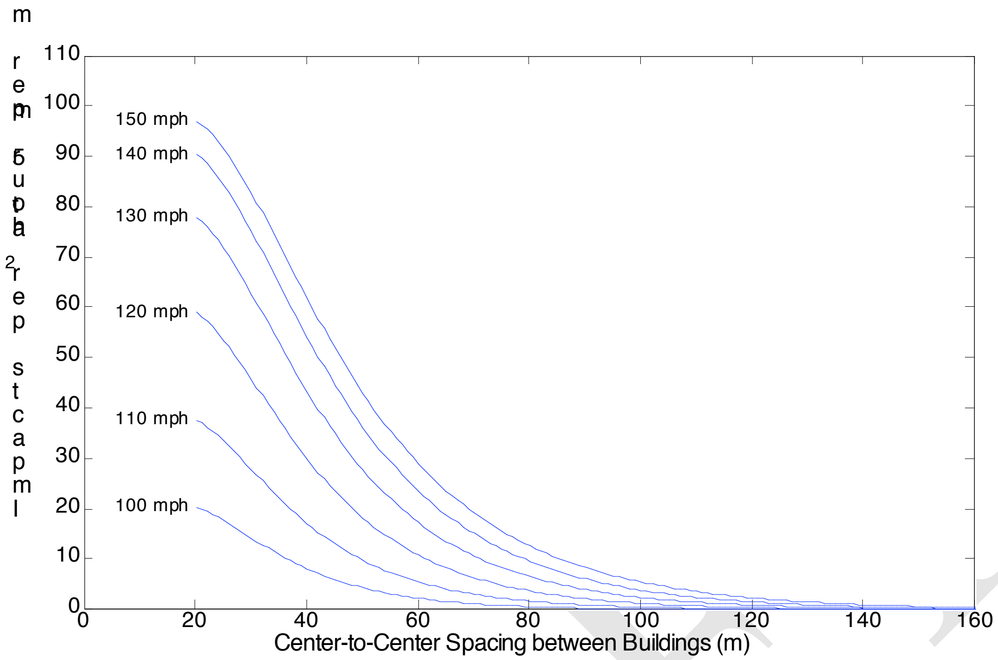

Figure X. No. Impacts / m^2 on Downstream Buildings at a Height of 5 m

As shown in the figures, ARA—and most catastrophe modelers—anticipate that design level wind events will produce gravel blow-off on built-up roof systems. The mitigating factors are that the expected number of missile impacts (1) decreases with center-to-center spacing of the buildings and (2) is inversely proportional to the elevation of interest on the building downwind.

3.2.2 Holmes (2002) Model

Following Wills et al. (1998), Holmes (2002) also developed a theoretical flight model for several idealized debris shapes, including a compact projectile. Holmes (2004) subsequently evolved this model to account for the effects of vertical air resistance, which were found to be significant. [A comparison of the updated model may need to be performed. Or maybe not. We might not be saying much at the expense of making a complicated documented even denser.]

Once the gravel takes flight, drag forces continues to accelerate it to a velocity v_m. Neglecting vertical air resistance, the gravel velocity at time t can be calculated as

$$v_m = \frac{kV^2t}{1+kVt}$$

where

$$k = \frac{1}{2}\left(\frac{\rho_{air}}{\rho_{gravel}}\right)\left(\frac{C_D}{l}\right)$$

and ρ_{air} and ρ_{gravel} = the densities of air and gravel, respectively, C_D = the drag coefficient of the gravel and l = the ratio of the volume to the frontal area (2/3 of the gravel diameter). The time taken for the gravel to accelerate to v_m is

$$t = \frac{1}{k\left(V - v_m\right)}$$

and the distance traveled to reach v_m is

$$x = V\left[t - \left(\frac{1}{kV}\right)\ln\left(1 + kUt\right)\right]$$

The vertical descent can be calculated from the gravitational constant (g = 9.81 m/s^2) as

$$z = -\frac{1}{2}gt^2$$

Figure X displays the results of this method for 0.6 in (5 g) roof gravel dislodged by its minimum rooftop wind speed, calculated as 58 mph by the Wills et al. (1998) method. The uppermost plot is the velocity of the gravel. The middle and bottom plots display the distances traveled horizontally (from drag) and vertically (from gravity). The horizontal axes reference the time elapsed since the gravel took flight.

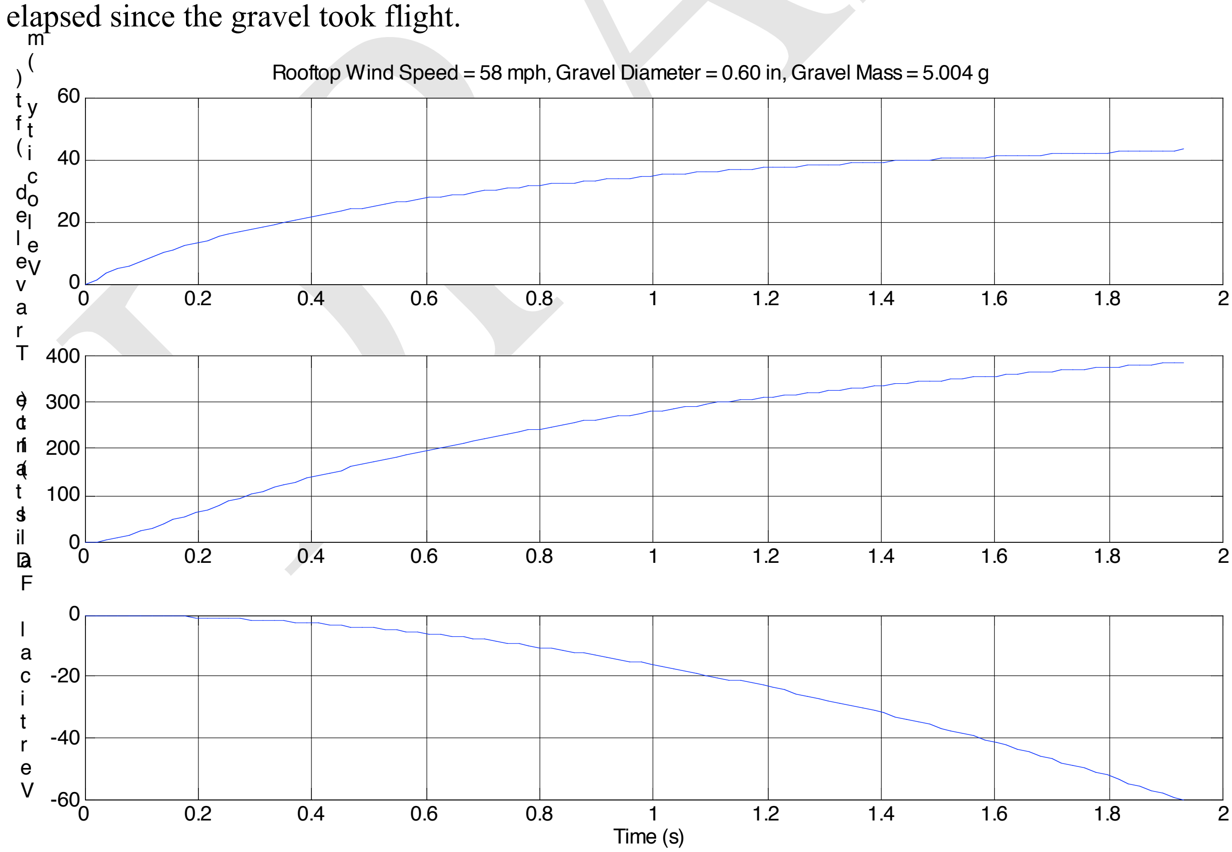

Figure X. Holmes (2002) Gravel Transport Model

3.3 Damage to Fenestration

The previous sections have shown that gravel blow-off occurs at wind speeds less than the design level requirements for the State of Florida and that gravel, once airborne, accelerates over hundreds of feet before reaching the ground or striking a structure downwind. This section evaluates the resistance of fenestration to gravel impact.

Numerous studies have been conducted on annealed (e.g., Harris 1978, more examples), tempered (e.g., example) and laminated (e.g., Ji et al. 1998, Saxe et al. 2002, Pantelides et al. 1993, Dharani et al. 2004) glazing. Variation of the target's surface area has been shown to have little effect on the mean minimum breaking velocity (Minor 1974). Minor et al. (1976) also found that the presence of a uniform pressure affects the character of the breakage but is not responsible for lowering the missile speed required to break glass. The most comprehensive set of results are found from a series of experiments conducted by Harris (1978) and Minor et al. 1978) and are discussed here.

3.3.1 Texas Tech Missile Impact Studies

Minor et al. (1978) conducted tests on 257 annealed and tempered glass of varying thickness to determine the missile impact velocities required to break glass. A 5 gram steel ball, representative of an "average" large size aggregate from a conventional tar and gravel roof was chosen for the projectile. Regression analysis was performed on the results to determine missile impact velocities associated with a 5% probability of failure. These values are tabulated below:

Table X. Mean Minimum Breaking Velocity (Minor et al. 1978): 5% Probability of Failure
Note: Tempered glass has a minimum residual surface stress of 15 ksi

Thickness	Annealed			Intermediate Temper			Highly Tempered		
(in)	m/s	mph	kg · m/s	m/s	mph	kg · m/s	m/s	mph	kg · m/s
3/16	10.2	23	0.051	–	–	–	20.3	45	0.101
1/4	9.5	21	0.048	10.9	24	0.054	–	–	–
5/16	8.6	19	0.043	–	–	–	19.6	44	0.098
3/8	10.9	24	0.055	–	–	–	18.9	42	0.094
1/2	11.8	26	0.059	–	–	–	15.2	34	0.076
3/4	17.3	39	0.087	–	–	–	16.6	37	0.083

The 5% probability of failure gravel speed to break ≤ ½ in thick annealed glass is 19-26 mph. Figure X indicates that this threshold is met within < 0.5 s of the gravel taking flight at rooftop gust speed of 58 mph, which is minimum gust speed to cause blow-off. Assuming a rooftop height on the order of 30 ft, this roughly corresponds to a 70 mph gust if the building was situated in suburban exposure.

During this time, the gravel falls only a few feet (but flies ~ 150 ft downwind). It follows, then, that once gravel is airborne, it can achieve sufficient velocity to damage unprotected annealed glass for low-rise buildings of all height.

3.3.2 Applied Research Associates Numerical Model for Impact Momentum

[need to discuss this with Peter. The assumed gravel size is less than what is used in the other methods presented, and as a result (I think) the wind estimates are higher.]

~~Applied Research Associates (FEMA 2003) developed a generalized method to quantify the 95th percentile impact momentum of windborne gravel based on a 10 m open exposure gust speed:~~

$$M_{95\%} = 2.147\cdot10^{-5}V^2 - 1.379\cdot10^{-3}V + 0.062 \quad \left(kg\cdot ms^{-1}\right)$$

~~Table X compares the mean minimum breaking velocities tabulated in Section 3.3.1 and the corresponding 95% percentile gravel momentum.~~

~~**Table X**. 95% Percentile Impact Momentum of Gravel~~

Glass Thickness	Annealed			Intermediate Temper			Highly Tempered		
	Mom.	10 m Gust Speed		Mom.	10 m Gust Speed		Mom.	10 m Gust Speed	
(in)	kg · m/s	m/s	mph	kg · m/s	m/s	mph	kg · m/s	m/s	mph
3/16	0.051	48.0	107	–	–	–	0.101	78	174
~~1/4~~	~~0.048~~	~~44.9~~	~~100~~	~~0.054~~	~~51.3~~	~~115~~	–	–	–
5/16	0.043	35.8	80	–	–	–	0.098	77	172
3/8	0.055	51.6	115	–	–	–	0.094	75	168
1/2	0.059	54.9	123	–	–	–	0.076	66	148
3/4	0.087	71.5	160	–	–	–	0.083	70	156

~~[big black box: 10 m wind speed (input) → building height → rooftop wind speed → parapet height → windward and leeward critical blow-off speed → trajectory → acceleration → impact momentum (output)]~~

3.3.3 Regarding High Velocity Hurricane Zones

[Add more on the resistance of laminated glass. Is it resilient enough that gravel at or below design wind speed won't hurt it?]. A X m/s (X mph) gust is required to create the equivalent to a 2 gram steel ball traveling at 40 m/s, which is the projectile used in the TAS 201-94 small missile test conducted in accordance with FBC 1626.3.3 and 1626.3.4.

4 SUMMARY

It has been shown experimentally and theoretically that roof gravel used in built-up roofing is susceptible to blow-off in wind speeds lower than the design (basic) wind speeds stipulated for the Florida. At the onset of strong tropical force winds, the results of research presented herein indicate that windborne roof gravel will achieve sufficient momentum to damage unprotected fenestration.

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APPENDIX A. SB 2836

Section regarding gravel roofing systems:

Section 2. (1) Before eliminating gravel or stone roofing systems in the Florida Building Code, the Florida Building Commission shall determine and document:

(a) Whether there is a scientific basis or reason for eliminating this option;

(b) Whether there is an available alternative that is equivalent in cost and durability;

(c) Whether eliminating this option will unnecessarily restrict or eliminate business or consumer choice in roofing systems; and

(d) In consultation with the Fish and Wildlife Conservation Commission, whether eliminating this option will negatively affect the nesting habitat of any species of nesting bird.

(2) Notwithstanding s. 553.73, Florida Statutes, the Florida Building Commission may adopt provisions to preserve the use of gravel roof systems in future editions of the Florida Building Code, if necessary to address the determination of the issues addressed in this section.

Full text of the bill may be found at:

http://www.myfloridahouse.gov/Sections/Bills/billsdetail.aspx?BillId=36579&SessionId=54

APPENDIX B. PROPOSED MODIFICATION #2311

Full text of the modifications and comments may be found at:

http://www.floridabuilding.org/BCISOld/bc/bc_comm_detail.asp?id_mod=2311

ORIGINAL SUBMISSION

Modification #: **Section 553.73, Fla Stat**

Name: Gail Beitelman
Florida Roofing Association
Address: 4111 Metric Drive, Ste 6, Winter Park, FL 32792
E-mail: gail@floridaroof.com
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Code: Building IBC
Section #: 1504.8

Text of Modification [additions underlined; deletions ~~stricken~~]:

1504.8 ~~Gravel and stone.~~ ~~Gravel or stone shall not be used on the roof of a building located in a hurricane prone region as defined in Section 1609.2, or on any other building with a mean roof height exceeding that permitted by Table 1504.8 based on the exposure category and basic wind speed at the building site.~~

~~TABLE 1504,8~~
~~MAXIMUM ALLOWABLE MEAN ROOF HEIGHT PERMITTED FOR BUILDINGS WITH GRAVEL OR STONE ON THE ROOF IN AREAS OUTSIDE A HURRICAN-PRONE REGION~~

~~BASIC WIND SPEED FROM FIGURE 1609 (mph)[b]~~	~~MAXIMUM MEAN ROOF HEIGHT (ft)[a,c]~~ ~~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~~

~~For SI: 1 foot = 304.8 mm; 1 mile per hour = 0.447 m/s.~~
~~a. Mean roof height in accordance with Section 1609.2.~~
~~b. For intermediate values of basic wind speed, the height associated with the next higher value of wind speed shall be used, or direct interpolation is permitted.~~
~~c. NP = gravel and stone not permitted for any roof height.~~

Fiscal Impact Statement:

A. Impact to local entity relative to enforcement of code:
Allows gravel roof systems.

B. Impact to building and property owners relative to cost of compliance with code:
None

C. Impact to industry relative to cost of compliance with code:
None, allows gravel roofs to continue to be installed throughout Florida.

Rationale:

Gravel roofs have been used successfully in Florida for more than 100 years. It is a time-tested system of huge value in Florida.

Please explain how the proposed modification meets the following requirements:

1. **Has a reasonable and substantial connection with the health, safety, and welfare of the general public:**
Allows property owners to continue to purchase an affordable, proven roofing system.

2. **Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction:**
Maintains the use of a proven system**.**

3. **Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities:**
Offers the option of a roofing system that has worked well in Florida.

4. **Does not degrade the effectiveness of the code:**
Does not degrade code.

Comment 1. Mike Ennis, 1100 Rosehill Road, m.ennis@mac.com

Text of Modification [additions underlined; deletions ~~stricken~~]:

The Single Ply Roofing Industry (SPRI) supports proposed code modification #2311. SPRI members have sponsored wind tunnel testing and have extensive field experience with these systems. The Industry Consensus Standard ANSI/SPRI RP-4 (2002) provides ballast design guidelines and is already referenced in the IBC for designing these types of systems.

Ballasted roof systems are cost-effective and have a proven track record of successful performance in Florida.

Comment 2: Jim Carducci-Florida Roofing Association, 4111 Metric Dr Suite 6 Winter Park, FL 32792, Jim@Floridaroof.com

Text of Modification [additions underlined; deletions ~~stricken~~]:

Without approving this modification the FBC would be essentially eliminating gravel surface roofing of all types, an already proven roofing system that has been around for many, many years. There has not been enough research that could support getting rid of gravel roofs entirely and putting a serious financial burden on roofing contractors who specialize in this type of work and to building owners who currently have gravel surfaced roofs, the cost to re-roof with a different type of system would require that the slope be increased to create a minimum drainage as required by manufacturers thus increasing the cost of re-roofing substantially. There is also the impact of migrating nesting birds that have learned to adapt to Florida's population growth and now use gravel roofs for nesting sites. There have already been studies done on these birds and the impact that is already being felt to them by the innovation of roofing materials with added slope replacing gravel surfaced roofs. The was also legislation passed by the Florida Legislature that prohibits the elimination of gravel roofs until these studies are done, below is a copy of the pertinent language dealing with this issue in SB 2836: [SEE APPENDIX A]

Comment 3: Scott Tezak on behalf of FEMA, URS Corporation, 260 Franklin Street, Suite 300, Boston, MA 02110, Scott_Tezak@urscorp.com

Text of Modification [additions underlined; deletions ~~stricken~~]:

The text of IBC 1504.8 should be retained in the FBC. The proposed amendment by the proponent called for the elimination of the section of the IBC that states:

> "Elimination of section 1504.8. This section states that gravel will not be used on the roof of a building located in a hurricane prone region as defined in1609.2 or with a specific mean roof height (table 1504.8)."

We do not support the elimination of the section as proposed.

<u>Fiscal Impact Statement</u>:

A. Impact to local entity relative to enforcement of code:
This proposed code change will have no impact on local code enforcement entities. Enforcement and compliance should be easily obtained as loose-laid systems are easily identified

B. Impact to building and property owners relative to cost of compliance with code:
This proposed code change will have no impact to building and property owners until such a time that they are replacing or installing new roof coverings. At that time, options for roof coverings in hurricane-prone areas will be limited and will not include the loose-laid systems; the market itself will determine if there will be cost implications.

C. Impact to industry relative to cost of compliance with code:
This proposed code change will have no impact to building and property owners until such a time that they are replacing or installing new roof coverings. At that time, options for roof coverings in hurricane-prone areas will be limited and will not include the loose-laid systems; the market itself will determine if there will be cost implications.

<u>Rationale</u>:

The 2006 edition of the IBC incorporated a provision that prohibits aggregate surfaced roofs in hurricane-prone regions. This provision was added in order to reduce glazing damage to buildings and vehicles.

The proponent of the amendment states that aggregate surfaced roofs have been successfully used in Florida and that it is a time-tested system.

Aggregate surfaced roofs can offer good long-term water resistance. However, there is extensive documentation of glazing damage caused by aggregate blown from roofs. One of the early reports on this topic is from Hurricane Alicia (Houston, 1983). Aggregate blow-off caused damage during several hurricane events over the past 20 years including, but not limited to Hurricanes Andrew, Charley, Ivan and Katrina. For documentation and further discussion, refer to FEMA Publications 488, 489 and 549, which document building performance during Charley, Ivan, and Katrina, respectively.

FEMA support the elimination of aggregate surfacings in hurricane-prone regions, or the adoption of technically-based criteria regarding blow-off resistance of aggregate.

<u>Please explain how the proposed modification meets the following requirements</u>:

1. Has a reasonable and substantial connection with the health, safety, and welfare of the general public:

Retaining this section of the IBC will result in the reduction of debris sources in hurricane prone areas, by not allowing roof coverings that have been documented to be extremely vulnerable to displacement during high wind events.

2. **Strengthens or improves the code, and provides equivalent or better products, methods, or systems of construction:**
This proposal strengthens the code by not allowing the use of a building components vulnerable to displacement by high winds in areas that are subject to high winds.

3. **Does not discriminate against materials, products, methods, or systems of construction of demonstrated capabilities:**
The proposed language is performance based. It only discriminates against the use of material, product, method, or systems of construction that have shown to be vulnerable to damage from high winds when proposed for use in areas subject to high winds (i.e., hurricane prone regions as defined by the FBC in 1609).

4. **Does not degrade the effectiveness of the code:**
This proposal strengthens and improves the code by specifically addressing vulnerable roof coverings, which when displaced, often result in damage to the buildings and structures on which they were installed.