PINPOINT WEBINAR
March 31, 2021

Thanks for joining us a few minutes early.

We will start promptly at 2 p.m.!

WIND UPLIFT

… a conversation with Rich Boon, P.E., Construction Support Services, Inc

Agenda

2:00 | Start Program and Webinar Housekeeping Items
Debbie Hathorne, CRA Executive Director

2:02 | CRA Announcements & Speaker Intro
Debbie Hathorne, CRA Executive Director

2:05| Wind & Roofing
Rich Boon, P.E., Construction Support Services

3:50 | Q & A

Thank you to our Sponsors:

Industry Leader

Silver Sponsors

Thank you!

Webinar Courtesies:

- Thank you for being on-time.
- All attendees are muted.
- **Use the Q&A at the bottom your screen to send your questions to Debbie.** She will relay them to the speaker(s).
- We will not use the raise hand function, please use Q & A.
- Links and other information will be sent in Chat box if applicable. Otherwise, the chat function is limited and we ask you to use Q&A.
- Due to the number of participants, we may not get to all the questions, but we will try.
- Please participate in our interactive polling through-out the presentation.
- Final note, in order to earn CIU credit, you will be required to answer a final poll question at the end of today's presentation.

Wind Performance and Calculations for Roofing Systems

Agenda Part 1

- *Wind Issues (Recent) History*
- *Methods of attachment*
- *Concerns and areas of concern*
- *Inspection items*

Agenda Part 2

- *Wind Uplift Calculations*
- *FM RoofNav*
- *ASCE7-16*

Last Year

- *We learned about the effects of wind on buildings*
- *We looked at changes in the Building Code based on changes in ASCE7.*
- *We talked briefly about roof securement.*
- ***SIDE NOTE:** Last year we discussed house movement due to drought. The March storm may create a new set of house movement.*

This Year

- *Review of Concepts*
- *More detailed look at securement*
- *Detailed look at calculations*

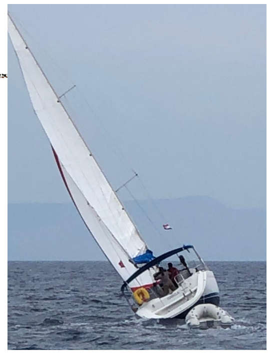
Wind: Moving Air

- *Air is a compressible gas*
- *Air moves from areas where the pressure is higher to areas where the pressure is lower*
- *The changes in pressure can be caused by temperature, Coriolis effect, and the influence of things int he path of moving air.*

Why is it important?

- *Because the differences in air pressure and the wind it creates can produce enormous very localized pressure differences.*

Air has a low density, but it can produce a force



What Drives the Sailboat?

- *The force that drive a sailboat is the difference between the pressure none side and the lower pressure on the other side.*
- *In a roof the difference is between the outside and the inside*

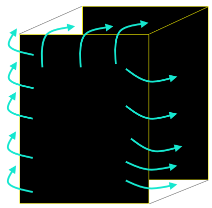
So what about when the wind hits an "Immoveable " object

- *Buildings are relatively immoveable.*
- *The wind has to "go around"*
- *When the wind goes around a building there are forces acting on the components and cladding of the building which includes the roof.*

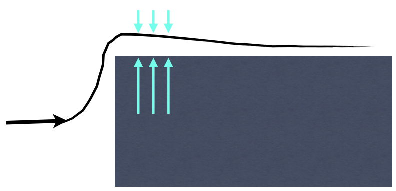
Bernoulli Principle

- *The Bernoulli Principle says the faster the air moves horizontally the less pressure it experts vertically.*
- *Since the air inside is not moving horizontally it exerts pressure vertically, the outside air is going fast horizontally thereby creating a difference in pressure.*

Wind Pressures on Buildings



The increased horizontal velocity reduces the vertical pressure.



C/o Ropa Roofing

Cost in US due to Wind damage?

- *$10,000,000,000*
- *$20,000,000,000*
- *$40,000,000,000*
- *$100,000,000,000*

Cost of Wind and Storm Damage

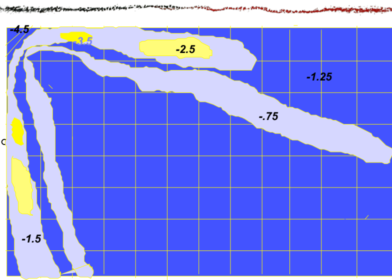
- *$40,000,000,000 in 2019 according to AccuWeather*
- *https://www.accuweather.com/en/business/weather-related-damage-in-2019-amounted-to-a-costly-year-in-the-us/655915*

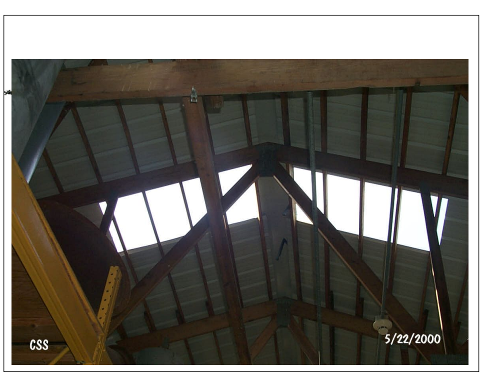
Denver and the Front Range is a "Special' Wind Area

- *The front range sees accelerating winds coming over and out of the mountains.*
- *The front range has gaps that focus winds*
- *The winds warm as they descend so they have more volume that has to move out of the way of the air mass that is behind pushing them.*

Why We Worry

Wind uplift on low rise building

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Roofing Attachment Systems

- *Ballasted*
- *Fully Adhered*
  - *BUR*
  - *Adhesive bonded*
- *Mechanically Attached*
  - *Shingles*
  - *Battens, Bars and Spots*

Ballasted

- *Covered First as they don't fit the numbers*
- *Rely on ballast weight to hold the roof on the building*
- *10 psf of the right stone has worked, but enhancements have been developed.*

1504.4 Ballasted Roofs

1504.4 Refers solely to ANSI/SPRI RP-4 for Ballast

- *Slope <2:12*
- *ANSI/SPRI RP-4 Design Guide*
- ***Table 1504.8 for maximum height for Aggregate surfaced roofs***

Wind Speed (asd)	*85*	*90*	*95*	*100*	*105*	*110*	*115*	*120*	*>120*
B	*170*	*110*	*75*	*55*	*40*	*30*	*20*	*15*	*NP*
C	*60*	*35*	*20*	*15*	*NP*	*NP*	*NP*	*NP*	*NP*
D	*30*	*15*	*NP*	*NP*	*NP*	*NP*	*NP*	*NP*	*NP*

SPRI RP-4 2019

- *Design Standard for Ballasted Single Ply Roofing Systems*

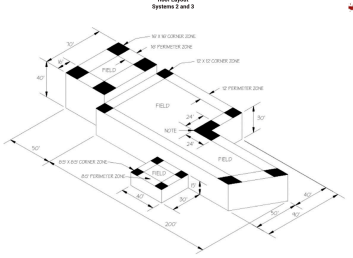
A. From 2.0 inch High Gravel Stop to Less Than 6.0 inch High Parapet
Maximum Allowable Wind Speed (MPH)

Bldg. Ht. Ft.	System 1 Exposure		System 2 Exposure		System 3 Exposure	
	C*	B*	C*	B*	C*	B*
0–15	110	130	140	140	140	140
>15–30	100	105	140	140	140	140
>30–45	95	100	125	140	140	140
>45–60	90	95	120	140	140	140
>60–75	90	95	115	140	140	140
>75–90	No	No	No	No	No	No
>90–105	No	No	No	No	No	No
>105–120	No	No	No	No	No	No
>120–135	No	No	No	No	No	No
>135–150	No	No	No	No	No	No

Ballasted Layouts

Figure 1

Roof Layout
Systems 2 and 3



Note: Reentrant corners are larger than other corners.

Ballasted Systems 1 & 2

System 1
The installed membrane shall be *ballasted* with #4 *ballast*. See Section 3.12.1.

System 2
The installed membrane shall be *ballasted* as follows:

4.1.2.1 **Corner Zone**
The installed membrane in the *corner zone* shall be *ballasted* with #2 *ballast*. See Section 3.12.2 and Figure 1.

4.1.2.2 **Perimeter Zone**
The installed membrane in the *perimeter zone* shall be *ballasted* with #2 *ballast*. See Section 3.12.2 and Figure 1.

4.1.2.3 **Field**
In the *field* of the roof, the installed membrane shall be *ballasted* with #4 *ballast*. See Section 3.12.1. #2 *ballast* shall be the minimum size-weight *ballast* used in wind-borne debris areas. See Section 3.12.2.

Ballasted System #3

System 3
Install the system as follows:

4.1.3.1 **Corner Zone**
In each *corner zone*, an adhered or mechanically attached roof system designed to withstand the uplift force in accordance with ASCE 7 or the local building code, shall be installed in accordance with the provisions for the *corner* location with no loose aggregate placed on the membrane. See Figure 1.

When a protective covering is required, an adhered membrane system shall be used in the *corner zone*. Minimum 22 lb./ft.^{2} (107 kg/m^2) pavers or other material approved by the authority having jurisdiction shall be installed over the adhered membrane. Mechanically fastened membrane systems shall not be used when a protective covering is required.

4.1.3.2 **Perimeter Zone**
In the *perimeter zone*, an adhered or mechanically attached roof system designed to withstand the uplift force in accordance with ASCE 7 or the local building code, shall be installed, in accordance with the provisions for the *perimeter zone* with no loose stone placed on the membrane. See Commentary.

When a protective covering is required, an adhered membrane system shall be used in the *perimeter zone*. Minimum 22 lb./ft.^{2} (107 kg/m^2) pavers or other material approved by the authority having jurisdiction shall be installed over the adhered membrane. Mechanically fastened membrane systems shall not be used when a protective covering is required.

4.1.3.3 **Field**
In the *field* of the roof, install #2 *ballast*. See Section 3.12.2.

Future of Ballasted Systems

- *My Opinion…..*
- *Ballasted systems are going away*
  - *Wind issues*
  - *Hard to find leaks*
  - *Membrane movement*
  - *Rock is no longer as cheap*
  - *Heavier membranes becoming more popular, advantages of HUGE sheets lost.*

Types of Ballasted Systems

- *Poured Concrete*
- *Heavy Weight Pavers*
- *Interlocking Lightweight Pavers*
- *Concrete Topped Extruded Polystyrene*
- *Gravel Ballast*

Latest Update

- *Boulder*
- *Westminster*
- *NO MORE BALLAST*

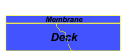
Fully Adhered Systems

- *Relies on "full" adhesion to secure membrane*
- *The insulation is now a portion of the structural system, as are all the component parts of the insulation layer*
- *Flexibility of the insulation matters.*

Formerly Fully Adhered

Wind Performance of Specific Systems

- *Fully Adhered Membrane Systems*
  - *Maximum Wind Speed Determined by Adhesion to Deck*
  - *Adhesion Values Range from 0.5 PSI to 40 PSI*
    - *(2 pounds per square inch to 288 PSF)*
- *Natures forces Captured*
  - *Adhesion*
    - *Mechanical or Chemical*
    - *Deck Movement Must be Accommodated*



Fully Adhered Systems

- *Adhesives are used:*
  - *Hot melt like asphalt*
  - *Solvent based Contact Type*
  - *Water based*
  - *Other polymers and foams*

Fully Adhered Systems

- *What is "full adhesion"?*
  - *100%*
  - *80%*
- *Voids and failed areas can allow air to lift parts of the membrane which leads to progressive failures.*

Mechanically Attached Systems

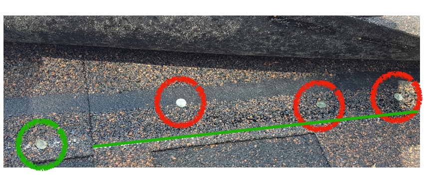
- *Relies of mechanical fasteners to secure the roofing*
- *Shingles most common mechanically fastened system*
- *Bars, battens and spots*

Mechanically Attached Systems

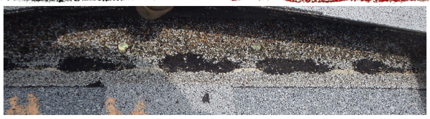
- *The wind uplift calculations provide the uplift:*
  - *Fastener placement/density is engineering*
  - *Driving fasteners is contractor responsibility*
- *Shingles: 6 per strip shingle.*
- *Metal roofing you need a pattern.*

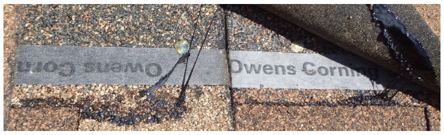
Mechanically Attached: Residential

- *Nail Placement Matters*



Shingle Nails





Watch the meter long shingles:

when the men have 36” arms

Missing nails?

1504.3.2 Metal Panel Roof Systems

- *Metal panel roof systems through fastened or standing seam shall be tested in accordance with UL 580 or ASTM E1592*
- *EXCEPTION: Metal roofs of cold-formed steel, where the roof deck as as the roof covering and provides both weather protection and support, shall be permitted to be designed and tested based on Section 2209.1*

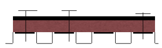
Metal Roofing Securement

- *Before installing a metal roof:*
  - *Demand a fastening pattern that meets the requirements based on ASCE7-16!*
  - *Demand a ridge securement pattern that meets the minimum for the predicted snow load!*
  - *DO NOT BECOME THE “DESIGNER OF RECORD” WITHOUT AN ENGINEERING LICENSE!*

Steam Boat Springs 9-7-20

Wind Performance of Specific Systems

- *Mechanically Attached Systems*
  - *Maximum Wind Speed determined by Fastener-Product Strength*
    - *Fastener Pullout @ 300 lbs, # of fasteners per unit area can be adjusted to uplift load.*
    - *Typically more fasteners in perimeters and corners, and narrower single ply sheets.*
- *Natures Forces Captured*
  - *Strength of Materials*
  - *When an air barrier is used, Pressure equalization may contribute.*



Mechanical Attachment Design

- *The uplifts have to be calculated*
- *The attachment strength of the fasteners needs to be known*
- *The pull-through strength of the materials needs to be known*
- *With the above information a spacing can be developed for fasteners.*

1504.5 Edge Securement for Low-Slope Roofs

- *Low-Slope built-up, modified bitumen and single-ply roof systems metal edge securement, except gutters, shall be designed and installed for wind loads in accordance with Chapter 16 and tested for resistance in accordance with RE-1, RE-2 and RE-3 of ANSI/SPRI ES-1 except V_{ult} wind speed shall be determined from Figure 1609A, 1609B, or 1609C as applicable.*

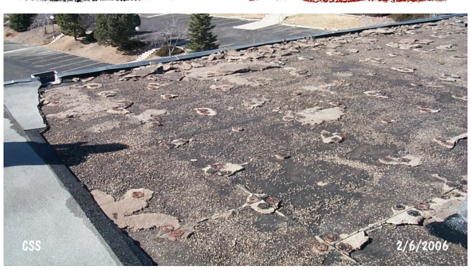
Adhered Systems

- *There are three lines of concern:*
  - *The number and placement of fasteners.*
  - *The pull-through resistance of the insulation board.*
  - *The condition of the facer/adhesive layer between the membrane and the insulation board.*

Same Roof Different Locations

Where's the adhesive?

Pull Through?



1504.3.1 Other roof systems

- *If it falls outside the listed systems, then the code requires testing results from FM 4474, UL 580 or UL 1897*

Contractors:

- *Demand fastening patterns*
  - *The specs need to provide either uplifts or fattening patterns.*
- *Plan to install additional fasteners in the corners and perimeter*
- *Do not assume the specifier knows how to do the wind calculations*

Contractors: (gross approx.)

- *Field- minimum of 1 fastener per 4 square feet covers most of the front range (east of 470) under 30 ft high*
- *Perimeter- 1 every 2 sq.ft. in a band 0.6x height of roof wide*
- *Corners- 1 sq.ft. "L" shaped 0.2x h wide with legs that are 0.6 x h long*

Proof:

Vult = 130 mph
Vasd= 100
H = 30 ft
Exposure C
Enclosed building

$q_z = 0.00256 K_z K_{zt} K_d V^2 K_e$ equation 26.10-1

a. Basic Wind Velocity is **130**$_{ult}$ mph. This is a V_{asd} of **100** mph.
b. The Directionality is $K_d = 0.85$ as defined in Section 26.6.
c. Topographic Factor is: $K_{zt} = 1.0$.
d. Velocity Pressure exposure Coefficient (K_z) is **0.98** Table 30.3.1 exposure height = 3**0** feet.
e. Elevation, $K_e = 0.85$

Determine $q_h = 0.00256 (K_{zt}=1) (K_z=0.98) (K_d = 0.85) (V=100)^2 (K_e=0.85) =$ **18.1 psf**

Zone 1' 18.1 x
Zone 1 18.1 x 1.88 = 34.0 x 4 sq.ft./fastener = 136 pounds per fastener
Zone 2 18.1 x 2.48 = 44.9 x 2 sq.ft./fastener = 89.8
18-ft wide
Zone 3. 18.1 x 3.38 = 61.2 x 1 sq.ft./fastener = 61.2
6-ft wide legs, each leg is 18 ft long.

This is an overkill!

- *Safety Factor of 2*
- *Most fasteners have a maximum load of 250 pounds per fastener*
- *Pull-outs are required for some roof decks*
  - *Tectum, Gypsum, Plywood, OSB etc.*

Calculations

- *FM Global RoofNav*
- *ASCE7-16*

RoofNav

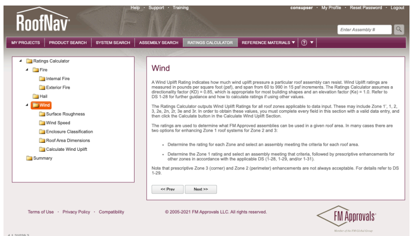
- *Factory Mutual/Global system*
- *It is for their in-house use*
- *Sometimes referenced by owners even if they don't use FM/Global subscribing Insurance Companies.*
- *Designed to reduce losses*
- *They are not Building Code!*

ASCE 7-16: The standard used by the code

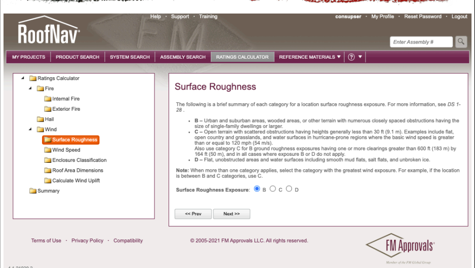
- *Minimum Design Loads for Buildings and Other Structures*
- *Chapters 26, 27, 28, 28, 29, 30, 31 - Wind Loads and how to compute the uplifts for a variety of conditions*
- *Wind Map Basic Velocity now 115 mph vs 90 mph. (115x0.775=89.1 mph)*
- *Methods for calculating uplift on roof surfaces.*
- *Still lots of confusion among engineers and designers (and code officials).*

RoofNav.com

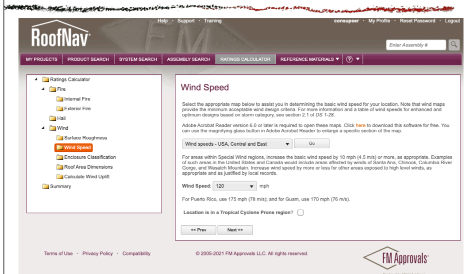
- *Sign up and get account*
- *Click on "Ratings Calculator"*



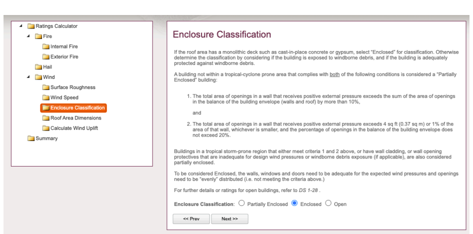
Surface Roughness



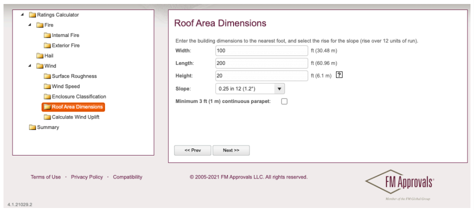
Wind Speed



Enclosure Classification



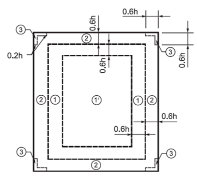
Roof Area Dimensions



RoofNav Layout

Calculate Wind Uplift

Roof Area Properties	Dimensions	100 x 200 ft (30.48 x 60.96 m)
	Height	20 ft (6.1 m)
	Slope	0.25 in 12 (1.2°)
	Min 3 ft (1 m) continuous parapet	N
Site Properties	Surface Roughness	B
	Wind Speed	120 mph
	In a Tropical Cyclone Prone region	N
	Enclosure Classification	Enclosed
Wind Pressures	Zone 1 Prime	24 psf (1.1 kPa)
	Zone 1	42 psf (2.0 kPa)
	Zone 2	55 psf (2.6 kPa)
	Zone 3	75 psf (3.6 kPa)
Wind Uplift Ratings	Zone 1 Prime	60 psf
	Zone 1	90 psf
	Zone 2	120 psf
	Zone 3	165 psf



Calculations

The basic description to calculate wind loading is found in Section 26.10.2:

Determine q_z.

$q_z = 0.00256\ K_z\ K_{zt}\ K_d\ V^2\ K_e$ equation 26.10-1

Definitions:

- ***Basic Wind Speed**, V: Three second gust speed at 33 ft above the ground in Exposure C*
- ***A**llowable **S**tress **D**esign (asd) Wind for non-hurricane areas this is the Basic Wind Velocity times $\sqrt{0.6}$ or 0.775. This is 1609.3.1 in the IBC.*

Roofing is part of Chapter 30- Wind Loads: Components and Cladding

Paramaters:

Basic Wind Speed, V	Section 26.5
Wind Directionality, K_d	Section 26.6
Exposure Category,	Section 26.7
Topographical Factor, K_{zt}	Section 26.8
Ground Elevation Factor, K_e	Section 26.9
Velocity pressure exposure coefficient, K_z or K_h	Section 26.10.1
Velocity Pressure, q_z	Section 26.10.2
Gust-factor	Section 26.11
Enclosure Classification	Section 26.12
Internal Presssure coefficient. GC_{pi}	Section 25.13

Minimum Design Wind Pressure 16 psf acting normal to the surface.

Standard Maps Don't Apply!

Section 26.5 Wind Hazard Map
26.5.1 Basic Wind Speed. The basic wind speed V used in the determination of design wind loads on buildings and other structures shall be determined by…

26.5.2 Special Wind Areas. THE FRONT RANGE

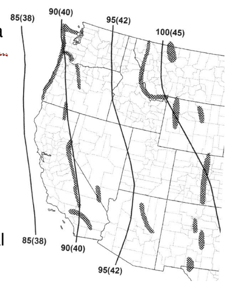
We are a Special Wind area

The velocities are
Basic Wind Velocity

To get "asd"
multiply by 0.775

BUT

We have to check with local municipalities to learn what to use for local wind



Quick Calculation:

- *Approximately what is the Design Velocity for a 100 mph Basic Wind"*

A. *50 mph*
B. *75 mph*
C. *80 mph*
D. *100 mph*

Wind Speed Conversions

Basic Wind Speed V_{mph}	100	110	120	130	140	150	160	170	180	190	200
V_{asd}	78	85	93	101	108	116	124	132	139	147	155

The values:

Basic Wind Speed, V = 120 mph * 0.775 = 93 mph_{asd}
Wind Directionality, K_d = Rectangular = 0.85
Exposure Category, = Exposure B
Topographical Factor, K_{zt} = 1.0
Ground Elevation Factor, K_e = density
Vel. pressure exposure, K_z or K_h = 0.62 = 0.7 (min. Value)
Velocity Pressure, q_z

Directionality

- *This is the factor based on the direction from which the wind strikes the building.*

Table 26.6-1 Wind Directionality Factor, K_d

Structure Type	Directionality Factor K_d
Buildings	
Main Wind Force Resisting System	0.85
Components and Cladding	0.85
Arched Roofs	0.85
Circular Domes	1.0[a]
Chimneys, Tanks, and Similar Structures	
Square	0.90
Hexagonal	0.95
Octagonal	1.0[a]
Round	1.0[a]
Solid Freestanding Walls, Roof Top Equipment, and Solid Freestanding and Attached Signs	0.85
Open Signs and Single-Plane Open Frames	0.85
Trussed Towers	
Triangular, square, or rectangular	0.85
All other cross sections	0.95

[a]Directionality factor $K_d = 0.95$ shall be permitted for round or octagonal structures with nonaxisymmetric structural systems.

Exposure B, C, & D

- *Related to ground roughness and surrounding buildings, trees, etc that can break-up the flow of the wind*
- *Exposure B: Urban and Suburban areas, wooded areas, closely spaced obstructions*
- *Exposure C:Open Terrain with scattered obstruction that have heights generally less than 30 Ft.*
- *Exposure D: Flat, unobstructed areas and open water*

Exposure Effect on Factor, K_h

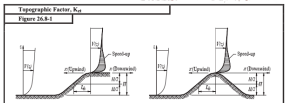
Height Ft	Exposure B	Exposure C	Exposure D
0-15	0.57 (0.7)	0.85	1.03
20	0.62(0.7)	0.90	1.08
25	0.66(0.7)	0.94	1.12
30	0.70	0.98	1.16
40	0.76	1.04	1.22
50	0.81	1.09	1.27
60	0.85	1.13	1.31

Terrain K_{zt}, Usually 1

26.8.1 Wind Speed-Up over Hills, Ridges, and Escarpments

$K_{zt}=(1+K_1K_2K_3)^2$

Topographic Factor, K_{zt}
Figure 26.8-1

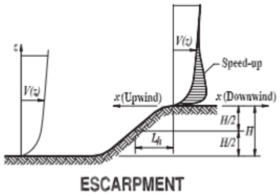


Topographic Multipliers for Exposure C

H/L_h	K_1 Multiplier: 2-D Ridge	K_1 Multiplier: 2-D Escarp.	K_1 Multiplier: 3-D Axisym. Hill	x/L_h	K_2 Multiplier: 2-D Escarp.	K_2 Multiplier: All Other Cases	z/L_h	K_3 Multiplier: 2-D Ridge	K_3 Multiplier: 2-D Escarp.	K_3 Multiplier: 3-D Axisym. Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							1.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

Let's Look at the Details

- *Look at the site*
- *Look at Google Earth*
- *Estimate values if needed*



House on a hill

- *H = ?*
- *L_h = 200 ft*
- *x= 100*

Finding elevations

- *Geo Survey Maps: Topographical maps*
- *Measure it with a barometric altimeter*
- *Google Earth function*

$K_{zt}=(1+K_1K_2K_3)^2$ How much difference does it make?

100 ft high Steep Slope Crest 200 ft back from toe of hill
Building: 100 ft back from crest

H=100
L_h=200
K_1= 0.72

Topographic Multipliers for Exposure C

H/L_h	K_1 Multiplier: 2-D Ridge	K_1 Multiplier: 2-D Escarp.	K_1 Multiplier: 3-D Axisym. Hill	x/L_h	K_2 Multiplier: 2-D Escarp.	K_2 Multiplier: All Other Cases	z/L_h	K_3 Multiplier: 2-D Ridge	K_3 Multiplier: 2-D Escarp.	K_3 Multiplier: 3-D Axisym. Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							1.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

x= distance from crest to building = 100 ft
x/L_h = 100/200 = 0.5.
K_2=0.88

z= height above crest of hill =20 ft z/Lh= 20/200 = 0.1
K_3= 0.74

K_{zt}= (1+(0.72)*(0.88)*(0.74))^2 = (1+ 0.47)^2 =2.2

Elevation Factor
Air Density

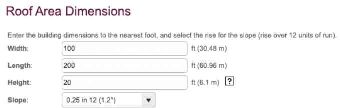
- *The lower the density the lower the airs momentum and the lower the amount of force it can apply.*

Note 2: $K_e=e^{-0.0000362z_g}$ (z_g=ground elev. above sea level in ft.)

Elevation (in feet)	Ground Elevation factor
<0	See note 2
0	1.00
1,000	0.96
2000	0.93
3000	0.90
4000	0.86
5000	0.83
6000	0.80
>6000	See Note 2

Let's insert some values

The sample building that we used for RoofNav are:



Enclosed Building
Exposure B
120 mph basic wind
No Hill

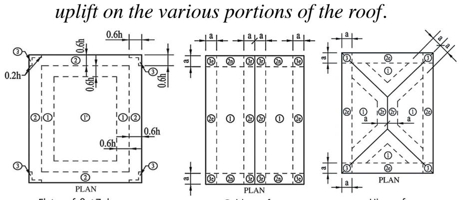
Interior pressure coefficient, GC_{pi}

- *The uplift for a given zone is determined by multiplying qz times a factor based on:*
- *Enclosed, or Semi-enclosed, or Open.*

Enclosure Classification	Interior Pressure Coefficient, GCpi
Open Building	0.0
Partially Open	0.18
Enclosed Building	0.18
Partially Enclosed	0.55

We commonly use 3 Zones

- *Once we have the qz, we can calculate the uplift on the various portions of the roof.*



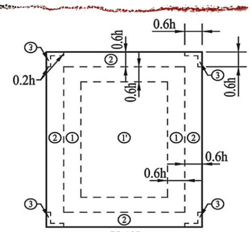
Flat roof, θ ≤ 7 degrees   Gable roof   Hip roof

Where h = Building height

There are more that 3!

For roofs that are sloped up to 1-1/2":12"

- *1', 1, 2 and 3 are interior, field, perimeter and corner respectively*

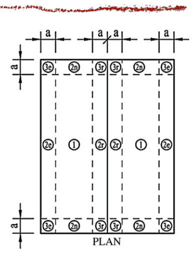


Flat roof, θ ≤ 7 degrees

Gable Roofs: Lots of sections only 3 values

For roofs that are sloped between 1-1/2:12 to 4-1/4:12

- *1& 2e=-2.0*
- *2n, 2r and 3e=-3.0*
- *3r=-3.6*



Gable roof

Location Coefficients (4 zones)

- *Corners*
- *Perimeters*
- *Field*
- *Interior*

Location on roof (roof zone)	External Pressure Coefficients, GC_p, based on ASCE 7 version	
	2005, 2010	2016
Interior	--	-0.9
Field	-1.0	-1.7
Perimeter	-1.8	-2.3
Corner	-2.8	-3.2

Area Uplift Calculations

- *Uplift=* q_z ** [* GC_p*-*GC_{pi}*]*
  - *Interior Conditions:*
  - GC_{pi} *Enclosed. = 0.18*
    Semi-Enclosed/ Semi-Open = 0.55
    Open = 0.0

Solve for q_z

- *Uplift=* q_z** [* GC_p*-*GC_{pi}*]*
- $q_z = 0.00256\ K_z K_{zt} K_d V^2\ K_e$
- $=0.00256\ (K_z = 0.7)\ (K_{zt} = 1.0)(K_d = 0.85)(V=93)^2\ (K_e = 0.8)$
- *=10.5 psf*
- *If V=120 then* q_z *= 17.5 psf*
- *Ignore density and* q_z *=21.9 psf*

Solve for local area uplift

- *Uplift =*q_z** [* GC_p*-*GC_{pi}*]*
- *Interior=10.5*[-.9-0.18]=11.3 psf*
- *(16 psf min per section 30.2.2)*
- *Field=10.5*[-1.7-0.18]=19.7*
- *Perimeter=10.5*[-2.3-0.18]=26.0*
- *Corner=10.5*[-3.2-0.18]=35.5*

FM Values vs Calculated Values

	Calculated Values ASCE7-16	Calculated Values Full 120 mph wind	Calculated Values Full 120 mph wind Sea level Density
		120 mph	120 & ∂
Interior	16	18.9	23.7
Field	19.7	32.9	41.2
Perimeter	26.0	43.4	54.3
Corner	35.5	59.2	74.0

From RoofNav Wind Pressures		
	Zone 1 Prime	24 psf (1.1 kPa)
	Zone 1	42 psf (2.0 kPa)
	Zone 2	55 psf (2.6 kPa)
	Zone 3	75 psf (3.6 kPa)

Why the difference?

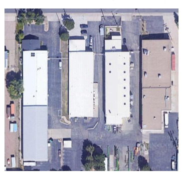
- *FM/Global is protecting their payouts.*
- *The code establishes a minimum design value.*
- *The only reason to specify based on FM is if the building is insured by a member of the FM/Global system.*

Wind Design Requirements

- *You now should be able to perform at least basic wind uplift calculations*
- *You can set up a RoofNav account and let them do the calculations, knowing the values are extremely conservative*

Prove it!

- *25 ft high building*
- *130 mph Basic Wind*
- *Enclosed*
- *200 ft long*
- *50 ft wide*
- *1/2":12" slope to East side*
- *Golden, CO*
- *No hill*

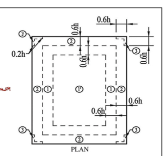


An the answer is:

Basic Wind Speed, V = 130 mph * 0.775 = 100 mph_{asd}
Wind Directionality, K_d = Rectangular = 0.85
Exposure Category, = Exposure B
Topographical Factor, K_{zt} = 1.0
Ground Elevation Factor, K_e = 5,675 ft
Vel. pressure exposure, K_z or K_h = 0.66 = 0.7 (min. Value)

Velocity Pressure, q_z = V^2 x0.85x1.0x0.7x0.8143x 0.00256
= 12.4 psf

Calculate the local loads



- *Uplift =q_z* [GC_p-GC_{pi}]*
- *Interior=12.4*[-.9-0.18]=13.4 psf*
- *(16 psf min per section 30.2.2)*
- *Field=12.4*[-1.7-0.18]=23.3*
- *Perimeter=12.4*[-2.3-0.18]=30.8*
- *Corner=12.4*[-3.2-0.18]=41.9*

Wind Uplift Calculator

Demand uplift values from the specifiers!

- *There are commercial uplift calculators*
- *The CRA just gave you one that is pretty good (within certain limitations)*
- *If you aren't told how to anchor the roof you assume the responsibility for the design.*

Thanks for listening

Questions?

Final comments:

COLORADO ROOFING ASSOCIATION

- Thank you Rich!
- Presentation Handout & Wind Calculation Tools are available at: https://www.coloradoroofing.org/member/education
- A survey will be sent after the seminar, please take the time to respond. Your feedback helps us plan future webinars and seminars.
- Thank you for staying on the webinar the full time. **Please answer this final poll question to earn your CIUs.** Then, you are free to hop off and end your session.

Thank You for attending!