Making it work: the practical use of Tested Assemblies

If you are a designer or a contractor, you may have wondered how to successfully select and apply a wind-tested roof assembly. This case study will help. There is much to know about why Tested Assemblies are important, and the first option for any designer focused on specifying a wind-resistant roof. Check out our other article, ***I have a feeling we're not in Kansas anymore, Toto***: *Designing low-slope roofs for wind uplift resistance* for a more in-depth look at where our standards come from, why they matter and how they can best be incorporated into a project specification.

Photo credit: Tony Delessio

Designing wind-resistant roofs

To some folks, the BCBC and NBCC standards for wind-resistant roofs seem like a jungle of engineering and design requirements. In fact, it really is quite simple and can be summarized in three easy steps:

Step 1: Calculate the <u>Specified Wind Loads</u> for the roof (**Design Authority**)

Step 2: Select the type of roof assembly representative of the project under construction (**Design Authority**)

Step 3: Design the system/assembly securement to meet or exceed the Specified Wind Loads (**Design Authority, Engineer or Roofing Contractor**)

The flowchart at right illustrates the process through all three steps.

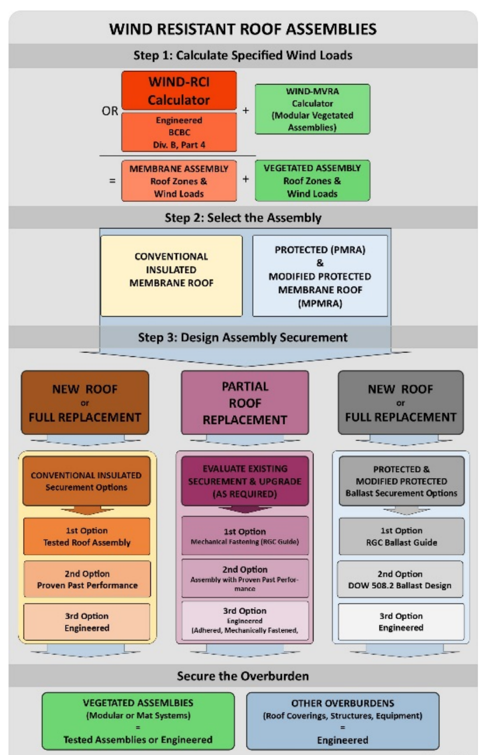


Figure 3.3

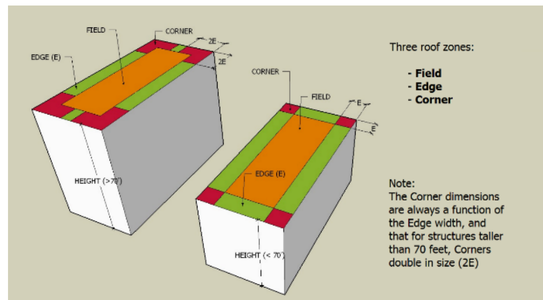
In this Case Study, we'll follow the steps in the flow chart (Figure 3.3, far left side only), and use a fictitious building as our model to work the process to completion.

Step One: calculate Specified Wind Loads

Specified Wind Loads are the negative pressure forces wind exerts on the surface of a roof as the wind passes over it. The term is specific to both the BCBC and the NBCC but adopted by the ***RoofStar Guarantee Standards***, and we will reference it occasionally in this article.

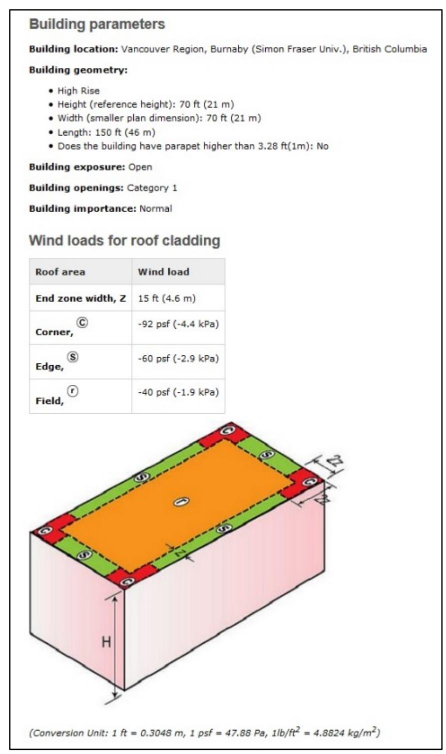
To calculate the specified wind loads for a particular building, the *Design Authority* first must consider the characteristics of the building, in combination with its geographical location. The free Wind-RCI online calculator simplifies this step. The calculator produces a report with a roof diagram similar to the one below, and provides wind load values for the three key roof zones – the Field, the Edges, and the Corners.

It is important to remember that wind is nearly always strongest at the corners of a roof and along the edge zones, but diminishes in strength as it passes across the field. That is why the report will illustrate these zones and provide a width for the edge zone. The width of the edge is never static, and is always a function of building geometry, but will never be less than 2.0 m (7'). These wind load values are the key to selecting the appropriate Tested Assembly.



Our fictitious building has the following characteristics:

- It is approximately 70' tall, 70' wide and 150' long (21x21x46 m)
- Parapets are equal to or less than 1m (3.28') high
- Exposure is "rough" (suburban, urban or wooded terrain)
- Building is Category 1 ("This category deals with buildings without any large or significant openings, but having small uniformly distributed openings amounting to less than 0.1% of total surface area. Such buildings include high-rise buildings that are normally sealed, have no operable windows and screen doors, and are mechanically ventilated. Some less common low-rise buildings, such as windowless warehouses with door systems not prone to storm damage, also fall into this category" – www.nrc-cnrc.gc.ca)
- Building Importance is "Normal" (all buildings that are *not* Low or High Importance structures)



Building parameters

Building location: Vancouver Region, Burnaby (Simon Fraser Univ.), British Columbia

Building geometry:

- High Rise
- Height (reference height): 70 ft (21 m)
- Width (smaller plan dimension): 70 ft (21 m)
- Length: 150 ft (46 m)
- Does the building have parapet higher than 3.28 ft(1m): No

Building exposure: Open

Building openings: Category 1

Building importance: Normal

Wind loads for roof cladding

Roof area	Wind load
End zone width, Z	15 ft (4.6 m)
Corner, Ⓒ	-92 psf (-4.4 kPa)
Edge, Ⓢ	-60 psf (-2.9 kPa)
Field, ⓡ	-40 psf (-1.9 kPa)

(Conversion Unit: 1 ft = 0.3048 m, 1 psf = 47.88 Pa, 1lb/ft^2 = 4.8824 kg/m^2)

When we enter these data in to the online calculator and finally press "Calculate wind load", the report generates the data and corresponding image at left. Note that the data is provided for the three roof zones. This data will be key in choosing a Tested Assembly.

Step Two: Select the Type of Roof Assembly

The Wind-RCI tool can be used to calculate the Specified Wind Loads for any building, with any roof type, up to 150 feet in height, but the tool is most accurate and useful for roofs designed as conventionally insulated. Buildings taller than that must have their Specified Wind Loads calculated by a qualified engineer.

In our fictitious example, the roof assembly we are designing is conventionally insulated. That means that it must be held in place with fasteners, adhesives or a combination of the two. Roofs that are held down with ballast or pavers, or roofs that also support vegetated assemblies, are the subject of different securement calculations and methods. Again, see ***I have a feeling we're not in Kansas anymore, Toto****: Designing low-slope roofs for wind uplift resistance*.

Step Three: Choose a Tested Assembly

A good Specification will clearly provide Specified Wind Loads and, unless the precise Tested Assembly is included, furnish the contractor with the assembly type and clear securement requirements.

CAN/CSA A123.21 establishes three standardized types of conventionally insulated roof assemblies, each expressed with an acronym. These acronyms have been adopted by the ***RoofStar Guarantee Standards***, in order to simplify the language in the RPM. Each assembly type is identified by its method of securement:

> **MARS** (Mechanically Attached Roof Systems) refers to assemblies secured at the membrane layer with screws and plates. There are few of these assemblies that have been tested, and they are listed in the RPM by following the MARS link.
>
> **PARS** (Partially Adhered Roof Systems) refers to assemblies that are both adhered and mechanically fastened. Typically, this means a membrane is adhered to a mechanically secured insulation assembly, inclusive of the insulation overlay. Occasionally, however, only the deck overlay is mechanically fastened; the rest is adhered. Numerous PARS assemblies can be found in the RPM on the PARS page.
>
> **AARS** (Adhesive Applied Roof Systems) are assemblies fully adhered at all levels of the roof assembly. Each Tested Assembly report lists the types of adhesives used in the assembly, and may illustrate adhesive ribbon patterns when low-rise polyurethane adhesives have been used and tested. See the AARS page in the RPM for tested Accepted Materials.

Since we are working with a fictitious building, we'll pretend the Specification calls for a PARS assembly utilizing a 2-ply SBS-modified bituminous membrane. In the absence of specific material requirements beyond the type of membrane, we'll scan the PARS membrane tables in the RPM to find optional systems that exceed the Specified Wind Load values generated by the RCI-Wind calculator report (at right).

We have no parameters concerning the type or thickness of either base or cap membranes, so we'll begin with a review of base membranes. These are displayed in an expandable table on the PARS page. We know that the highest anticipated wind loads, in the corners of our designed roof, will require uplift resistance better than -92 psf (-4.4 kPa); the negative signs merely indicate upward (negative) pressure and should not be used for any subsequent calculations. Therefore, we'll look for base membranes with test values equal to or better than -92 psf.

Scanning the table that lists base membranes, we find several that show a maximum uplift resistance greater than -92 psf. One membrane lists three different securement systems, and we can see that one of the securement systems attained a maximum uplift resistance of -105 psf. Since that value exceeds the corner requirements for the fictitious roof (-92 psf), we will use it for the roof corner zones, and could use it for securement of the entire roof area. However, since there are maximum and minimum uplift resistance values shown in the table, the report itself may offer alternate securement systems we can use for the other roof zones.

1 Tested System	----	-2.90	----	-60.00	Steel	PARS Test Report 2
4 Tested Systems	-1.40	-3.40	-30.00	-70.00	Steel	PARS Test Report 3
3 Tested Systems	-2.10	-5.00	-45.00	-105.00	Steel	PARS Test Report 5

Each report link (blue hyperlink text) opens up a test report in a new window as a viewable PDF. In PARS Test Report 5, we find a table that displays everything we need. In the left column of the table are the various securement systems that were tested (a System, in Tested Assembly reports, refers to the number and pattern of fasteners, or the pattern of adhesive ribbons, required to achieve the listed performance values). The middle column shows the raw data from the laboratory tests. The raw data is unaltered by any safety factor; we won't use that data to select a securement system, but it is good to have, to double-check the adjusted values displayed in the right-hand column. The far right column shows the data adjusted for the safety factor of 1.5 (to check the adjusted values, take the middle column data, leave out the negative sign, and divide the number by 1.5. Example: 67/1.5 = 45). This is the data we want to compare to the roof report generated by the Wind-RCI calculator.

- Dynamic Uplift Resistance (DUR)as per CSA A123.21:

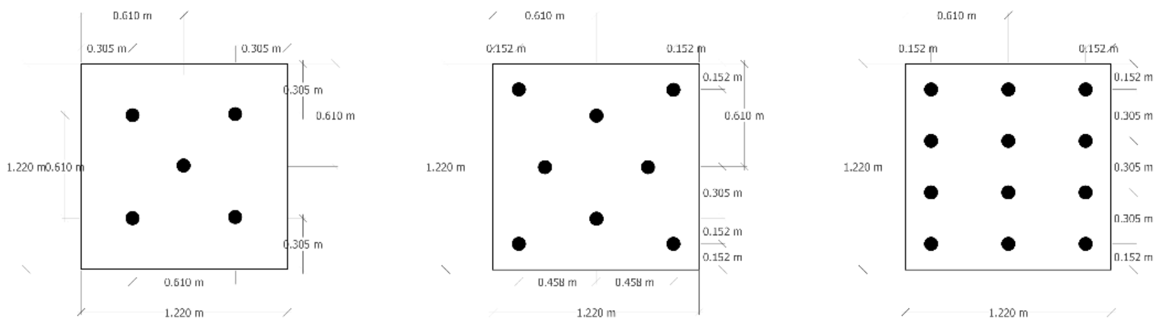
Description	Test observation reading	With SF of 1.5
System A	-3.2 kPa (-67 psf)	**-2.1 kPa(-45 psf)**
System B	-5.4 kPa (-112 psf)	**-3.6 kPa (-75 psf)**
System C	-7.5 kPa (-157 psf)	**-5.0 kPa (-105 psf)**

Note that **System C** has an adjusted uplift resistance value of -105 psf. Since our fictitious roof requires a securement system that matches or exceeds wind uplift resistance of -92 psf, we'll use **System C** for the roof corners.

System B is a good candidate for the perimeter (edges) of the roof, since it achieved uplift resistance of -75 psf, and the report says we need to equal or exceed -50 psf.

As for the roof field, **System A** shows an uplift resistance value of -45 psf, which is a little higher than the report requirement of -40 psf.

The report even shows us how to place fasteners and plates on a 4'x4' (1.2m x 1.2m) panel (see the diagram below).



Fastening patterns from a published Tested Assembly report, illustrating three securement systems

To be fair, not all reports make it this easy. Some reports omit the diagrams but give the descriptive information about fastening or adhesive ribbon spacing. And many reports show only one system of securement. In those cases, the simplest approach is to use the fastener or adhesive pattern for corners and apply that to the entire roof area. If that isn't satisfactory, you can retain the services of a qualified engineer to extrapolate different fastener patterns for the edges and field, using ASNI/SPRI WD-1.

Other Options

Using a Tested Assembly is not the only way to satisfy the requirements of the ***RoofStar Guarantee Standards*** or the BCBC/NBCC, but it is the simplest. Other options include

- choosing a roof assembly with 'Proven Past Performance'
- performing your own calculations (engineered) if the system for which you need fastener or adhesive patterns is not available

For more about these options, and what they mean, see ***I have a feeling we're not in Kansas anymore, Toto***: *Designing low-slope roofs for wind uplift resistance*.

Installing the Roof

Once the design is complete, the roofing contractor must construct the specified roof system and secure it the way it is designed. Project specifications need to provide enough detail for the contractor to work with, including copies of test reports and fastener or adhesive pattern diagrams.

It's tempting to think that any fastener, plate or adhesive type will work, but contractors must strictly adhere to the ***RoofStar Guarantee Standards*** or to the specific requirements published in a Tested Assembly, mandated by the manufacturer of an assembly with Proven Past Performance, or detailed in an engineering specification (whichever is greater). Screw-type fastener pull-out strength increases with fastener size, which is why membranes are secured with #14 fasteners while the other roof components are normally fastened with #12 screws. Mixing these up, and using unspecified or untested adhesives, could make the difference between success and disaster.

Finally, while this article is primarily focused on conventionally insulated roofs, application standards and proper training make all the difference between a roof that stays where it's built, and one that ends up on the ground. The ***RoofStar Guarantee Standards*** provide clear guidelines for Best Practices that make our Guarantee outstanding in its field. See the entire manual at www.rcabc.org.

Signs of the times

Our climate is changing. A 2017 report produced by Metro Vancouver indicates significant climate and local weather pattern change over the next three decades, affecting mean seasonal temperatures, wind and rainfall. Similar changes are anticipated for other regions of British Columbia, and we are witnessing considerable climate shifts across the province.

Designing a roof to meet the demands of the future is what we are about. Our ***RoofStar Guarantee Standards*** are as dynamic as the climate we live with.

We've authored the book on great roofing design and construction standards. Learn more about our ***RoofStar Guarantee Program*** at http://www.rcabc.org/, or visit our Roofing Practices Manual at rpm.rcabc.org/.

About the author:

James Klassen is a RoofStar Technical Advisor and staff writer with the **Roofing Contractors Association of British Columbia**. He is an experienced roofing estimator, a former Occupational Health and Safety professional and independent Insurance Claims Adjuster, and has extensive experience as Facilities Manager for a large private school in British Columbia's Fraser Valley, overseeing building maintenance, grounds management, custodial services, school transportation maintenance and driver education, and capital project planning.
