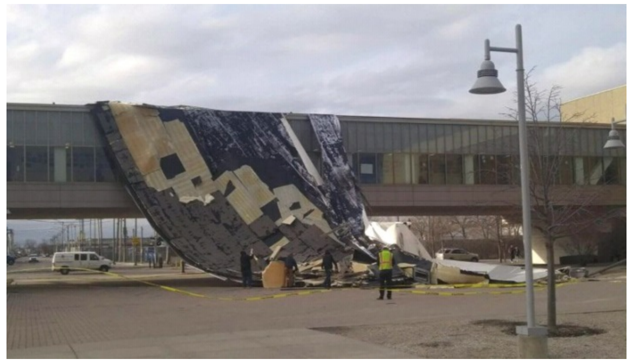
I have a feeling we're not in Kansas anymore, Toto (Part 2)

Designing low-slope roofs for wind uplift resistance



In Part 1 of this article, we took a look at the subject of wind and negative wind pressure, examined the change in building codes for Canada and British Columbia, and compared roof assembly test methods between Canadian and American standards. In this second of three parts, we'll put it all together and describe how a roof can be properly designed for wind resistance, almost as easily as tapping those ruby slippers together three times.

There's no place like home: designing wind-resistant roofs

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

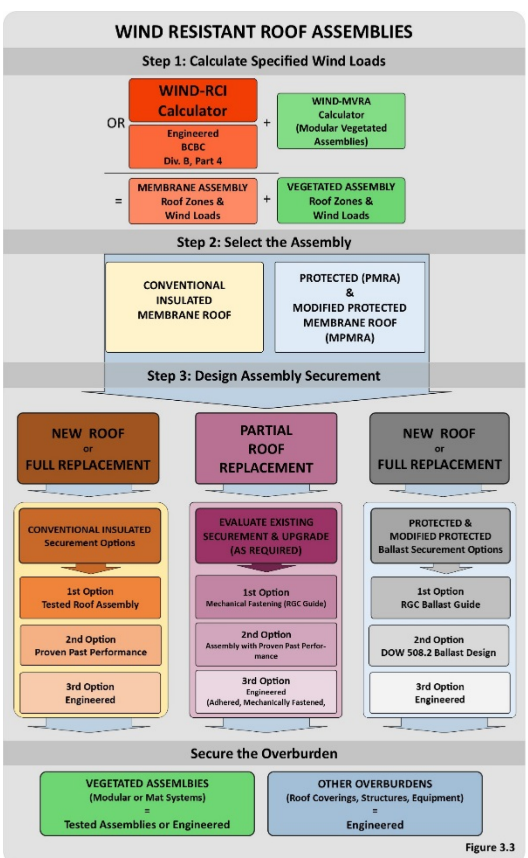


Figure 3.3

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**)

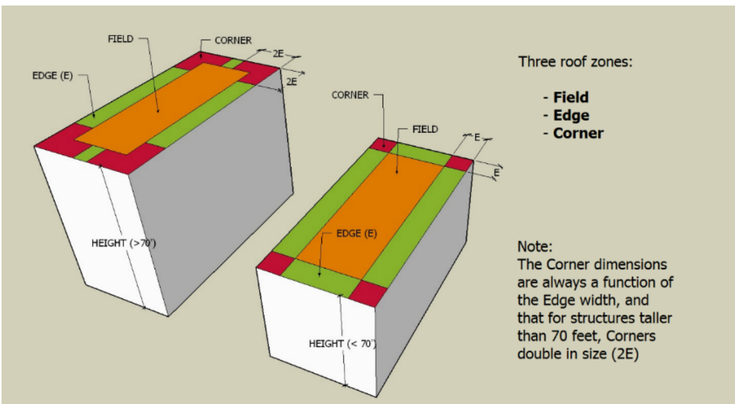
The flowchart at left illustrates the process through all three steps.

Step 1: Calculate the Specified Wind Loads for the roof (the *Design Authority*)

Specified Wind Loads is the term used by the BCBC and NBCC to denote the calculated upward negative forces wind generates as it blows across a membrane roof assembly. To calculate Specified Wind Loads the easy way, for buildings up to 150 feet tall, use the free Wind-RCI online calculator; for buildings taller than 150 feet, Specified Wind Loads must be determined by an engineer (ref. BCBC Div. B, 4.1.7). These calculations are the responsibility of the Design Authority. The calculator produces a report with graphics similar to those shown here, and provides wind load values for the three key roof zones. Wind load values are the key to choosing a method of securement (see below).

Behind the scenes, the Wind-RCI calculator takes into account the geographical location and characteristics of the building. Division B, Article **4.1.7.1. Specified Wind Load** in the BCBC sets out these requirements; specified wind loads must account for buildings that are *dynamically sensitive* (in simplified terms, 'flexible' rather than rigid), or that are subject to *wake buffeting* (vibrations) or *channelling* effects from nearby buildings (caused by wind tunneling between buildings). These factors play in important role in ensuring the calculation for the building is reasonably correct.

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

One final thought. A Specified Wind Load report, and any roof assembly, whether it be a Tested Assembly or one that is custom-engineered, should be furnished to contractors and roof observers, so that everyone knows what the design requires, and so that the roof is properly constructed.

Step 2: Select the roof assembly type

Before the Design Authority figures out how to secure the roof assembly, he or she must be clear about the type of roof the building will incorporate. This article focuses primarily on conventionally insulated membrane roofs, but of course, there are many ways to approach roof design. Other roofs, such as Protected Membrane roofs (PMRAs), Modified Protected Membrane Roofs (MPMRAs), and vegetated assemblies, require different approaches which are not fully addressed below.

Step 3: Design the assembly securement

Since securement of the roof assembly must meet or exceed the Specified Wind Load calculations, there are three essential ways the design can be achieved – by using a Tested Assembly, using an assembly with proven past performance, or by having a qualified professional engineer design a system specifically for the building. Except for the engineered approach, the choice may be made by the Design Authority or by the roofing contractor (when the Specification is of the *descriptive* sort – see below).

Assembly Design

Three options are immediately available for the design of roof assembly securement, and they are made available through the BCBC. Listed below, they represent a progression from simplicity to complexity, and from low cost (for the user) to high cost. None are 'bad' or wrong, and each has its place, depending upon the requirements of the project.

A. Tested Assembly

Tested Assemblies provide objective performance metrics a designer or contractor can look to for an assembly that will capably resisted Specified Wind Loads. That makes Tested Assemblies the easiest and surest way to match an assembly to a building. Accordingly, the ***RoofStar Guarantee Standards*** strongly recommend that designers first consider using a Tested Assembly for new roofs, or for replacement roofs constructed on a bare deck.

In the absence of an appropriate or available Tested Assembly, the Specification may identify an assembly with 'Proven Past Performance'; this is permissible in the ***RoofStar Guarantee Standards*** provided the assembly's performance under the calculated wind loads can be established in writing, with an engineer-stamped letter of assurance from the membrane manufacturer. Learn more about this below.

Finally, while this paper offers general guidance on the use and application of Tested Assemblies, the reader can learn more by consulting the related guide, *Making it Work: a Case Study* which follows all the steps through a fictitious roof design.

Decks, Securement and Interference

Every new roof system should be installed on a clean, unobstructed surface, but this is essential for Tested Assemblies, since those are the conditions within which they were evaluated in the lab. The *surface* may be the deck itself, or a deck overlay that is sufficiently secured. The ***RoofStar Guarantee Standards*** require unobstructed installation. This requirement is driven by the need for uncompromised roof system securement; anything that interferes with the holding strength of an adhesive or mechanical fastener, or which changes the interplay between exterior and conditioned space air pressures, will adversely affect wind resistance of the roof system and could, as a consequence, result in a roof leak.

Since fastener and adhesive patterns are specific and quite restrictive, leaving the installer with little to no 'wiggle room', Design Authorities should consider how specifications for other building systems, such as electrical, impact or even impede the installation of the roof assembly. For example, it is common for electrical circuits to be run across or even directly underneath penetrable roof decks, in an effort to distribute power. This presents the roofing installer with significant challenges, regardless of the roof assembly type. Less obvious, perhaps, are the attendant issues of shock hazards to roof workers, and both immediate and long-term fire hazards to building occupants (the result of fasteners penetrating energized circuits).

As for general building performance, air-leaky penetrations into the roof assembly, like electrical conduit inserted through the roof deck, can compromise the continuity of air and vapour control layers, creating other issues like condensation inside the roof assembly that no one wants on their project. They may also alter the pressure dynamics in a roof assembly, thereby affecting the wind-resistance of the roof.

These issues should give the *Design Authority* pause to consider other options. The RPM offers clear guidance on this subject. For more about this topic, refer to **2.7 Electrical Cables and Boxes** in the ***RoofStar Guarantee Standards***.

For more about how to select a Tested Assembly, see below.

B. Roof Assembly with Proven Past Performance

Roof assemblies with "Proven Past Performance" offer the *Design Authority* options when

- ✓ Material swapping is necessary but the Tested Assembly report doesn't offer a suitable alternate material component
- ✓ A Tested Assembly just isn't available for the roof
- ✓ An assembly that could work simply hasn't been tested in laboratory conditions
- ✓ The Specified Wind Loads exceed the capacity of an available or suitable Tested Assembly

Roof assemblies with a Proven Past Performance record are permitted under Div. B, A-5.1.4.1(5), NBCC 2015) as alternative solutions (refer to Clause 1.2.1.1.(1)(b), Div. A, NBCC). Put simply, the NBCC recognize that not everything must be tested to prove it can withstand wind uplift loads; some assemblies have been around long enough that they are 'proven past performers' and therefore are reliable. Often, these are stock assemblies proposed by a membrane manufacturer. Of course, for roof assemblies with Proven Past Performance to be useful, they must have a long, successful track record (a "body of evidence" – this language has been adopted, word-for-word, by the BCBC from the NBCC 2015). That means that systems with Proven Past Performance must be demonstrably capable of resisting the highest calculated wind loads for the roof under design.

What is a long, successful track record? The BCBC, like the NBCC, suggests such assemblies should have a service life of "a substantial number of years", and recognizes that thirty years is "often used to do life-cycle cost analysis of the viability of investments in building improvements". Obviously, "substantial" is open to interpretation, but the **RoofStar Guarantee Program** accepts a roof assembly as a 'proven past performer' if it has been widely *and* successfully used for at least as long as the expected life of the roof assembly, in conditions that are representative of the project at hand. So, if a roof is advertised to last twenty years, its track record of successfully resisting the Specified Wind Loads of the building should be at least as long as its advertised lifespan.

If the *Design Authority* elects to use an assembly with Proven Past Performance, the *Design Authority* must submit a wind load calculation report to the RCABC, along with written confirmation from the manufacturer's Technical Department that the assembly can withstand the highest calculated wind loads for the project, for the anticipated life of the roof.

While some readers may argue that sufficient securement of a roof assembly can be based on standard securement methods for constituent components (as, for example, fastening patterns for a deck overlay board), it should be understood that the ability of an assembly to resist negative wind loads is a function of the inter-related components in that assembly – they work in concert with each other. One should not assume that individual materials, secured on their own, behave the same way.

Every design specification must provide the contractor with sufficient guidance and information to construct the roof correctly. Therefore, when the *Design Authority* turns to an assembly with Proven Past Performance, the tender package should include detailed securement requirements, together with a comprehensive list of all the roof components. These are required pieces of information for any application for a RoofStar Guarantee.

C. Engineered Design

Occasionally, a Tested Assembly does not work, and an alternative assembly with Proven Past Performance is not available as a substitute. The BCBC and NBCC make further provisions for this – for what it calls *non-tested configurations* (Notes to Part 5, Environmental Separation, **A5.2.2.2.(4) Membrane Roofing Systems**). In this case, the *Design Authority* must still perform calculations for the Specified Wind Loads of the roof, and this can be done using the Wind-RCI calculator or, for taller buildings, with the assistance of an engineer. Securement of the assembly can then be designed by a qualified engineer, by extrapolating test data in conjunction with ANSI/SPRI WD-1 *Wind Design Standard Practice for Roofing Assemblies*.

Choosing a Tested Roof Assembly

Three Assembly Types

CAN/CSA A123.21 establishes three standardized types of conventionally insulated roof assemblies, each expressed as 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.

Choosing an Assembly

To choose a Tested Assembly, first determine your starting point. There are three common ways to find what you're looking for:

a) start with the type of roof assembly (MARS, PARS or AARS)
b) choose an assembly based on wind uplift resistance values
c) choose an assembly based on the membrane or membrane manufacturer you have in mind

Not all roof membranes have been tested in assemblies, but the RPM lists all accepted membranes that have been tested.

One more thing. All Tested Assembly reports will display two different wind uplift resistance values. Only the values reduced by the Safety Factor (1.5) are valid for use in designing or securing the roof assembly. These are commonly shown in a Tested Assembly report using a table like the example below:

Description	Test observation reading	With SF of 1.5
System A	-3.6 kPa(-75 psf)	**-2.4 kPa(-50 psf)**
System B	-5.9 kPa (-125 psf)	**-3.9 kPa (-83 psf)**
System C	-6.9 kPa (-144 psf)	**-4.6 kPa (-96 psf)**

a. Choose by assembly type: choosing a Tested Assembly by type is the most common way of finding a tested assembly. To do this, select the matching link in the RPM and then view all the membranes by type to view all possible options within the ***RoofStar Guarantee Program***.

- **MARS Systems** (mechanically fastened);
- **AARS Systems** (adhered);
- **PARS Systems** (a combination of adhered and mechanically fastened).

The method of attachment may be determined by the type of roof deck

RPM links to material tables based on roof assembly type

b. Choose by Wind Uplift Resistance values: the RPM lists the range of wind uplift values for each membrane that has been tested. This is a quick way to match the roof report to membrane options, particularly when the method of securement hasn't been determined. Simply ensure that the maximum resistance values exceed the corner loads indicated on the Wind-RCI roof report.

Bearing in mind that the corners on the Wind-RCI roof report will always exhibit the highest wind load values, choose a Tested Assembly with maximum resistance capabilities that exceed the corner load values. For the other Field and Edge roof zones,

- use wind resistance values for other attachment system tests shown on the same report (some reports will include up to four different attachment systems), and apply them to the other zones, provided the values in the Tested Assembly report exceed the calculated loads for those zones
- apply a single fastener or adhesive pattern across the roof, regardless of zone differences (do this when alternate attachment securement systems have not been tested)
- calculate fastener or adhesive patterns following the ANSI/SPRI WD-1 methodology, which is referenced in the BCBC and NBCC (ref. BCBC, Div. B, Note A-5.2.2.2(4) **Membrane Roofing Systems**)

c. Choose by membrane: if you are the *Design Authority* and you have a favourite membrane, you can look it up in the Accepted Materials section of the RPM to see if it has been tested. Use the four main search functions in the RPM to find what you're looking for (search by the material type, name, its manufacturer or the system it is specified for). If you search by membrane type using the tables, you will see MARS, PARS or AARS links in a table column to the right of the listed material. Some materials have been tested in more than one type of assembly, which means you'll need to decide at some point how you want the assembly to be secured.

By the way, new test reports often are added to the RPM. Watch for continual updates and additions.

Specifying wind resistance in project specifications

In Part 3, we explore ways the Design Authority can properly and effectively specify wind resistance in project specifications.

About the author:

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