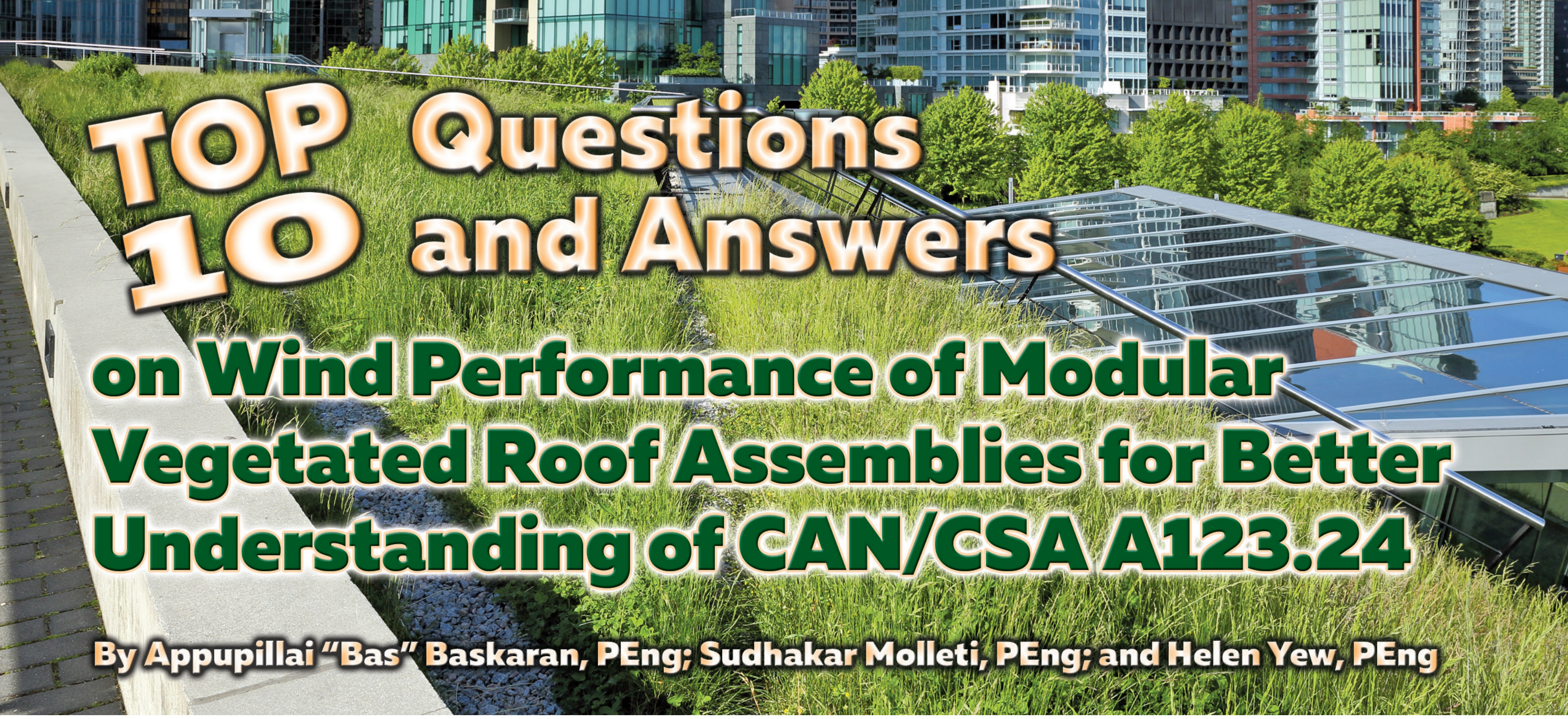


TOP 10 Questions and Answers on Wind Performance of Modular Vegetated Roof Assemblies for Better Understanding of CAN/CSA A123.24

By Appupillai "Bas" Baskaran, PEng; Sudhakar Molleti, PEng; and Helen Yew, PEng

The National Research Council of Canada (NRCC), in collaboration with members of the Canadian roofing industry and vegetated system manufacturers, developed CAN/CSA A123.24, *Standard Test Method for Wind Resistance of Modular Vegetated Roof Assembly*, to evaluate the wind resistance of vegetated roof assemblies (VRAs). The existing literature (NRCA,[1] ANSI/SPRI-RP14,[2] ANSI/GRHC/SPRI VR-1,[3] FEMA P-757,[4] FM 1-35,[5]) and Prevatt et. al 2012,[6] provides only design guidelines and offers little to building officials to determine pass/fail criterial as a consensus standard will do. From the wind resistance perspective, CAN/CSA A123.24 evaluates the coherent wind performance of vegetated roof systems in regard to determining the wind resistance rating of VRAs. This article outlines the top 10 questions on the wind performance of VRAs in order to help users' understanding of the standard.[7]

Q1: What are the attributes of wind on a roof?

Wind is a random process. When it separates from roof edges, it creates zones of suction (negative pressure). This suction has two characteristics: 1) It varies from one zone of the roof to the other, providing spatial variations; 2) It varies from one period of time to another, creating fluctuation with respect to time. One can simplify the spatial variations from zones of higher to lower suctions as corner, edge, and field. A statistical approach is used to simplify the time fluctuations as mean, peak, and standard deviation. See *Figure 1*.

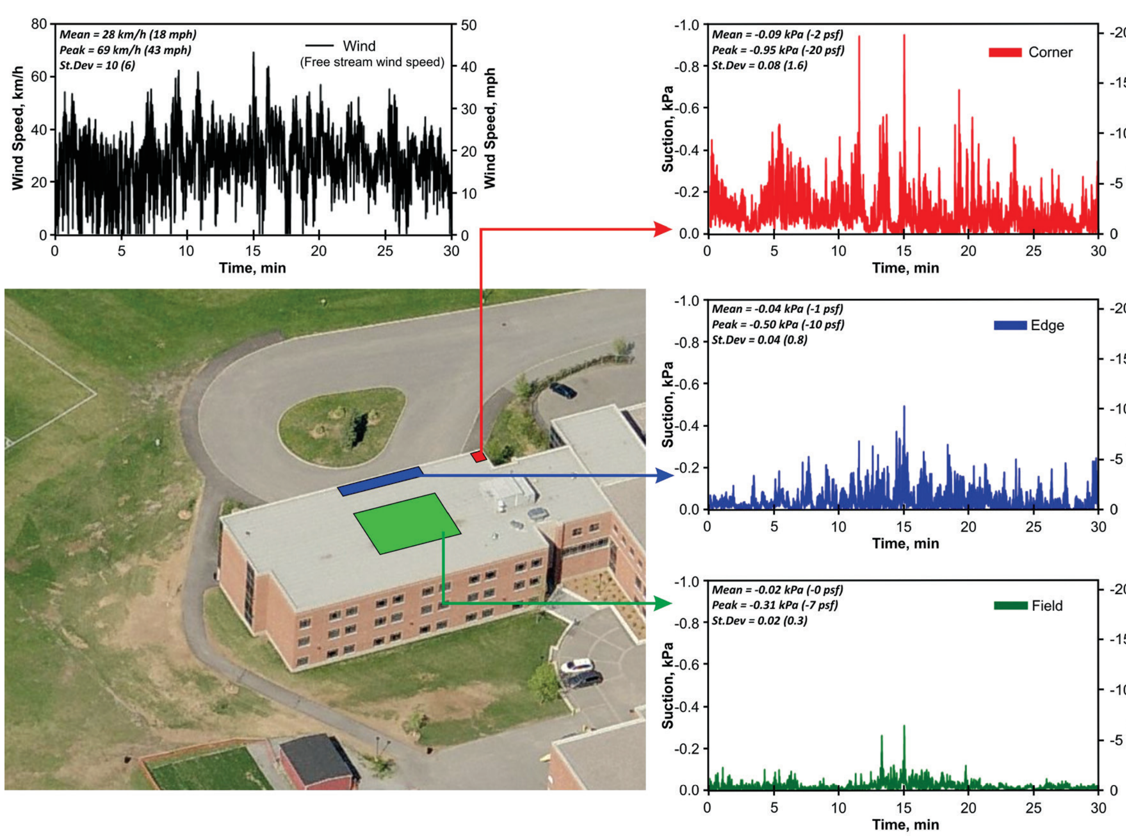
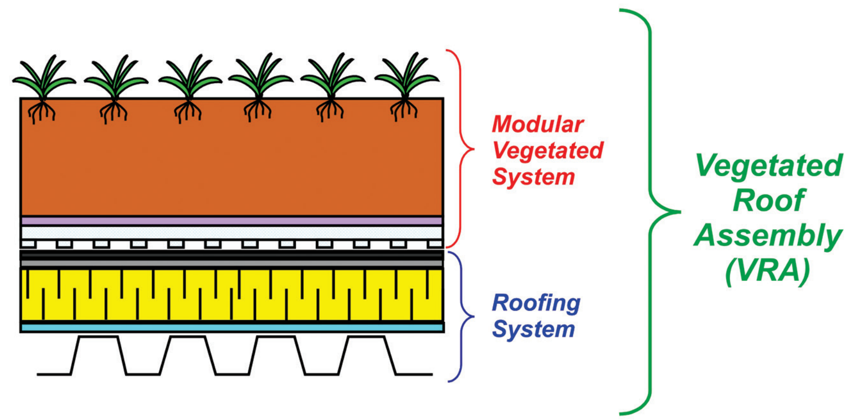


Figure 1 – Wind and its effects on a school building roof measured in Ottawa.

Figure 2 – The roofing system and the vegetated system assembled together form the VRA.



Q2: What is a VRA?

In a vegetated roof assembly (VRA), a roofing system and modular vegetated system are assembled together. A roofing system consists of a deck and roofing or waterproofing membrane. It includes components such as vapor barriers or retarders, insulation, cover board, etc. A modular vegetated system is a system made up of pregrown or precultivated vegetation (modules, blankets, or mats), growth media, root barrier, pavers, and drainage system. In the industry, VRAs are sometimes referred to as "green roofs." However, the term green roof can be misleading because it can be interpreted differently, as follows.

- Green can simply be viewed as the color of the roof (e.g., copper roof).
- The phrase "green roof" is used loosely to denote roofs with environmentally friendly products, such as those made from recycled materials (e.g., bio insulations).
- Roofs with energy-efficient components, such as highly reflective roofing membranes (e.g., white single-plies or modified-bituminous roofs with reflective coatings) can also be referred to as green roofs.

VRAs are, therefore, defined as the intentional placement of an engineered vegetated system over the roof system (*Figure 2*).

Q3: What are the attributes of VRA response to wind?

Wind aerodynamics on VRAs can be viewed as "actions"; the VRA's response is the "reaction." Not all VRAs react to wind in the same way. The responses depend on several factors. Some of them are: membrane attachment method, vegetation type, weight, design, and installation method (i.e., edge restraint conditions). These complex wind dynamics on VRAs can be simplified as effects due to pressure and flow. Flow can cause sliding, overturning, and scouring. Pressure can cause fatigue and uplifting (*Figure 3*).

Q4: How can I calculate design wind loads on a VRA?

Wind loads for building envelope components and claddings are calculated in accordance with Chapter 30 of the American Society of Civil Engineers' ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*, and Part 4 of the National

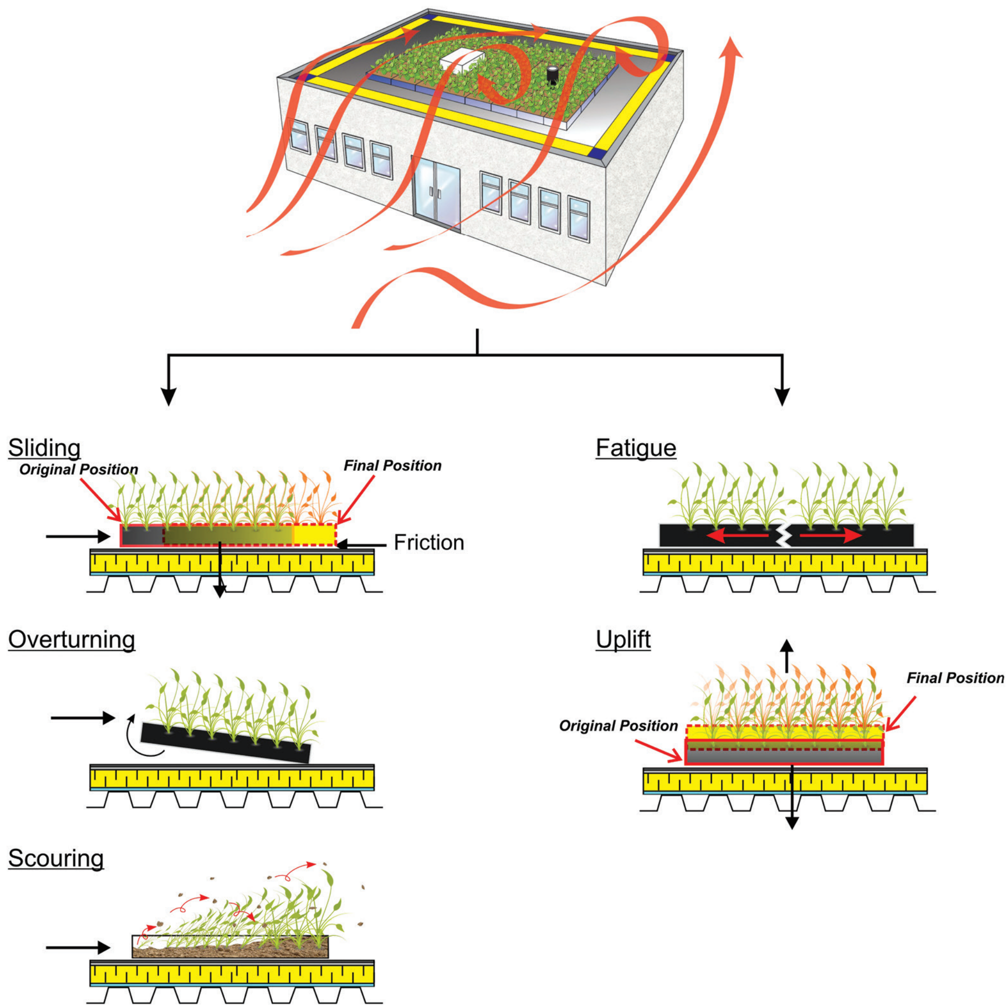


Figure 3 – Wind aerodynamics and failure mechanisms of a VRA.

Building Code of Canada's NBC 2015-NBC. There are no specific wind load calculation procedures for the VRAs in either of these building codes.

Wind-VRA is a simplified Internet-based design tool to calculate the design pressure and wind speed. With conservatism, Wind-VRA duplicates the NBC 2015 procedure. It is available in both English and French and is applicable to Canadian cities coast to coast. Free access to Wind-VRA is available at: http://www.nrc-cnrc.gc.ca/eng/services/windrci/index.html.

Q5: Is there a tool or standard available to validate my VRA design?

The wind resistance of a VRA can be evaluated in accordance with CAN/CSA A123.24, *Standard Test Method for Wind Resistance of Modular Vegetated Roof Assembly*. The test results can be compared to the calculated design parameters in Question 4 above for pass/fail scenarios. The CAN/CSA A123.24 standard is available at: http://shop.csa.ca/en/canada/page/home.

Q6: Why are VRAs subjected to uplift and flow resistance tests?

Uplift tests only evaluate the pressure resistance of VRAs, since the membrane acts as an air barrier in a conventional roofing system. Wind flow aerodynamics can simulate a vegetated system's overturning, scouring, and sliding failure mechanisms. To mimic the wind effects on a VRA (refer to Question 3), both uplift and flow tests are needed.

Q7: Can I use the wind uplift data from a roof system test?

Yes, in a scenario where the VRA has the same roofing system as the one tested under CAN/CSA A123.21, *Standard Test Method for the Dynamic Wind Uplift Resistance of Membrane Roofing Systems*, manufacturers or clients may choose to use the uplift resistance data obtained from CAN/CSA A123.21. Then the manufacturer or client has to perform only the flow test as per Section 7 of the CAN/CSA A123.24 to obtain the flow resistance.

Q8: What steps are involved in the wind design process of VRA?

The complex process can be simplified into three steps. A case study based on NBC 2015 is presented below.

Step 1: Calculate the design wind data

In accordance with NBC 2015, or using Wind-VRA, calculate the design wind load (P_D) for various zones of the roof cladding (for example: Field = 1341 Pa [28 psf], Edge = 1724 Pa [36 psf], and Corner = 2681 Pa [56 psf]) and the wind design speed (V_D) at the roof height of the building (for example: 23 m/s [52 mph]). *Note: Designing the roof assembly according to ultimate limit state (ULS) requires multiplication by 1.4 (principal wind-load-effect factor) to the wind loads for various zones (see NBC Table 4.1.3.2.A – Division B).*

Step 2: Select the VRA

Determine the uplift resistance (P_R) and flow resistance (V_R) of the VRA in accordance with the CAN/CSA A123.24 requirements.

Step 3: Correlation

Select a VRA and related components with uplift resistance (P_R) higher than the design load (P_D), and a flow resistance (V_R) higher than the design wind speed (V_D). (See *Figure 4*.)

Q9: Are there any limitations of the test data?

Test data reflect the system installed as per manufacturers' installation specifications. Details of the tested specimen, including the weight and edge restraints, are documented in the test report. Any variations can affect the test outcome. Furthermore, the design should be validated based on engineering fundamentals such that overturning and sliding can be prevented.

Q10: What other documentation on wind response of VRAs is available?

Research reports were made under the umbrella of a VRA consortium made up of the National Research Council of Canada, Canadian Roofing Contractors Association, Air-Ins Inc., Armtec, Bioroof Systems, City of Ottawa, City of Toronto, LiveRoof, Soprema Canada, Vitaroofs, and Xeroflor towards development of CAN/CSA A123.24.

Some of the existing relevant documentation may be found in the following:

- ANSI/SPRI RP-14, *Wind Design Standard for Vegetative Roofing Systems*
- FLL Guidelines for the Planning, Construction and Maintenance of Green Roofing, 2008
- FM 4477, *Approval Standard for Vegetative Roof Systems*, 2010
- FM Global Property Loss Prevention Data Sheets 1-35, Green Roof Systems
- *NRCA Vegetative Roof System Manual*
- Toronto Green Roof Construction Standards, 2014

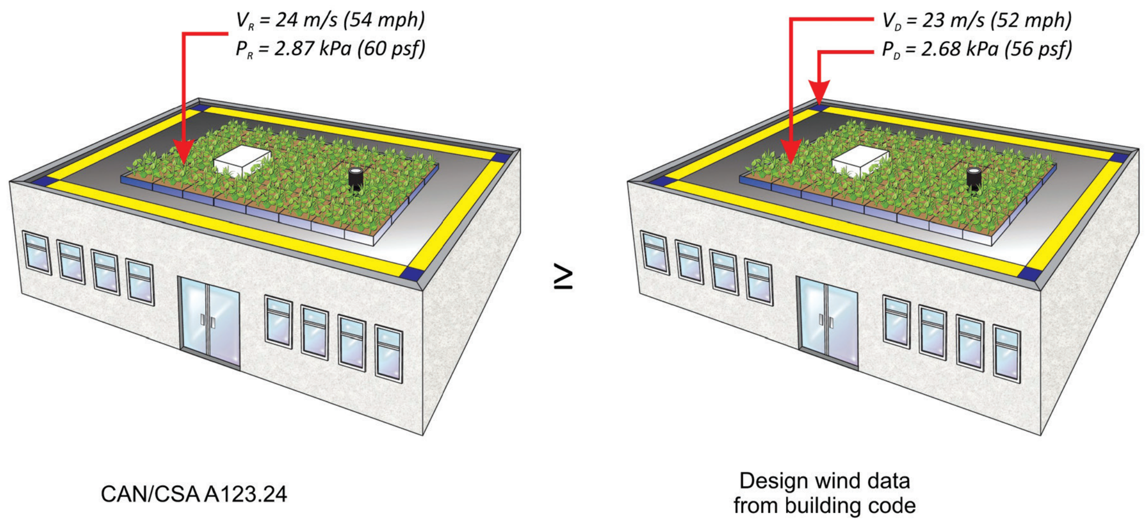


Figure 4 – Both pressure and flow resistances should be higher than the design values.

FOOTNOTES

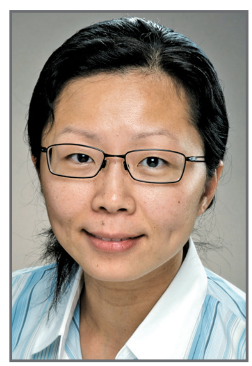
1. NRCA. (2009). *"The NRCA Vegetative Roof Systems Manual, Second Edition."* www.nrca.net.
2. ANSI/SPRI RP-14 (2010), *Wind Design Standard from Vegetative Roofing Systems.* www.spri.org.
3. ANSI/GRHC/SPRI VR-1 (2011), *Procedure for Investigating Resistance to Root Penetration on Vegetative Roof Systems.* www.spri.org.
4. FEMA P-757. (2009). "Mitigation Assessment Team Report: Hurricane Ike in Texas and Louisiana-Building Performance Observations, Recommendations and Technical Guidance."
5. FM 1-35. (2007). "Property Loss Prevention Data Sheets: Green Roof Systems." www.fmglobal.com.
6. D.O. Prevatt, G.A. Acomb, and F.J. Masters. (2012). "Comprehensive Wind Uplift Study of Modular and Built-in-Place Green Roof Systems." Report No. UF01-12 submitted to Florida Building Commission.
7. CAN/CSA A123.24 can be used in conjunction with U.S. wind uplift information. Any country or jurisdiction can adopt a given standard as its own.

Appupillai "Bas" Baskaran, PEng

Dr. Baskaran is a group leader with the NRC and an adjunct professor at the University of Ottawa. He is a member of technical committees with RCI, RICOWI, ASCE, SPRI, ICBEST, and CIB, as well as a research advisor to various task groups of the National Building Codes of Canada. He has authored or coauthored over 200 research articles and has received over 25 industry awards, including the Frank Lander Award from the Canadian Roofing Contractors Association and the Carl Cash Award from ASTM. Dr. Baskaran was recognized by Queen Elizabeth II with a Diamond Jubilee Medal for his contributions to his fellow Canadians.

Sudhakar Molleti, PEng

Dr. Molleti is a research officer in the Performance of Roofing Systems and Insulation (PRSI) Group at NRC, where his work focus is on researching the wind-induced effects on low-slope roofing systems and thermal and hygrothermal performance of roofing systems. Currently, he is working on the wind performance of vegetated roof assemblies, energy and durability performance of PV-integrated roofs, and application of vacuum insulation panels in roofing systems. He is a member of the ASTM D08 and CRCA Technical Committees.



Helen Yew, PEng

Helen Yew is a technical officer with the National Research Council of Canada's Construction Portfolio. She specializes in characterization of roofing materials' mechanical properties using different instruments. She develops web-based tools for wind load calculation on the roof and evaluates wind performance of vegetated roof assemblies. Yew received her master in engineering degree from Carleton University in Ottawa, Canada.