

# TOP 10 QUESTIONS AND ANSWERS

on

## STATIC VS. DYNAMIC WIND TESTING

for Commercial Roofs

By Bas A. Baskaran, PhD, PEng

# 1

### WHAT ARE THE ATTRIBUTES OF WIND ON A ROOF?

Wind is a random process. When it separates from the roof edges, it creates zones of suction (negative) pressure. This suction effect has two characteristics: (a) it varies from one zone of the roof to the other – spatial variations; (b) it varies from one period of time to another – fluctuations with respect to time. One can distinguish the spatial variations from zones of higher to lower suction as “corner,” “edge,” and “field,” while the time fluctuations are simplified through statistical approach by calculating the mean, peak, and standard deviation.

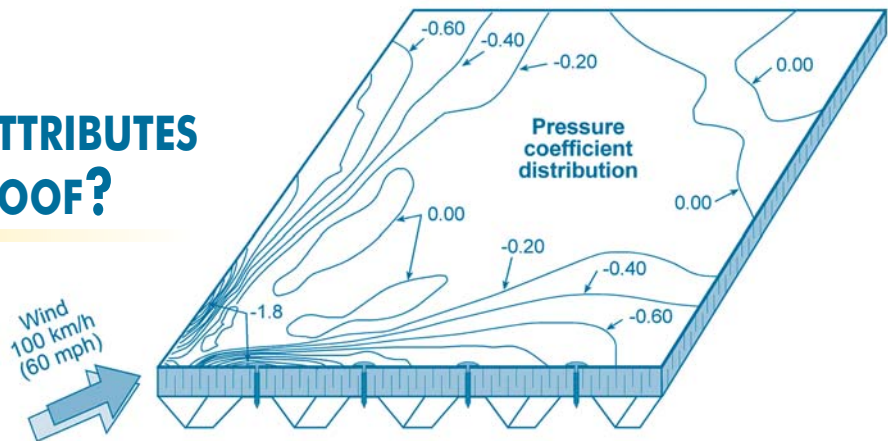


Figure 1: Spatial wind pressure variation over a roof.

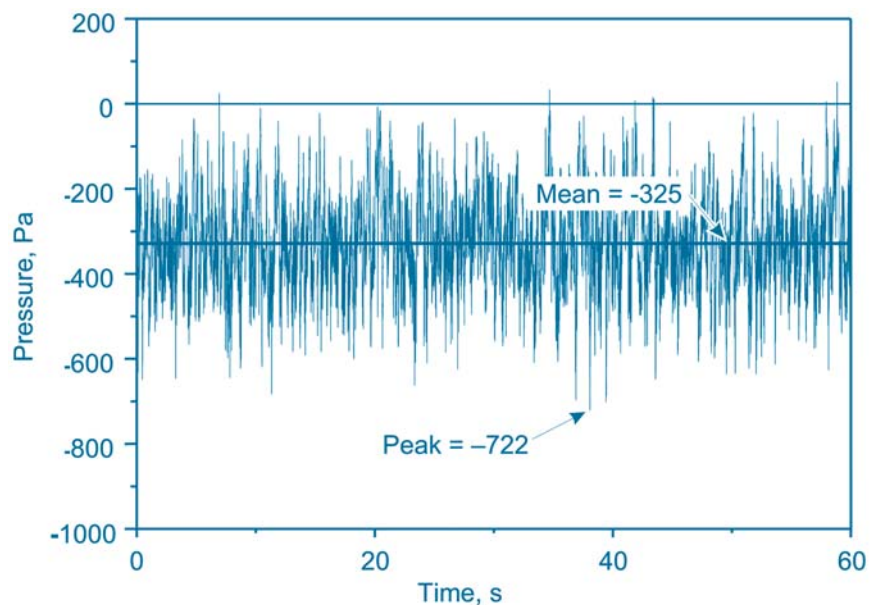


Figure 2: Pressure fluctuations at a location on a roof.

## 2 WHAT ARE THE ATTRIBUTES OF ROOFING RESPONSE TO WIND?

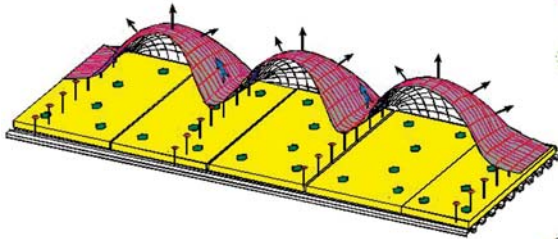
If one views wind-induced pressure on a roof as “action,” then the “reaction” is the response of the roof. Not all roofs respond to wind in a similar manner. The response can be static or dynamic, and it depends on the assembly’s components, attachment methods, and application technologies.

The response of the new generation of mechanically attached systems is different than a conventional, fully bonded system. In mechanically attached systems,<sup>1</sup>

membranes are attached at discrete points or rows. Moderate-to-strong winds will cause the membrane to lift and billow between attachment points or rows. The billow height is primarily a function of the wind load, the fastener row spacing, the load-strain modulus of the membrane, and the presence of an air or vapor barrier (retarder) in the roof system. Wind fluctuations cause the

membrane to flutter, or rapidly flap up and down. The dynamic (or cyclical) loading induced by the fluttering can cause fatigue to the membrane, the membrane fasteners, the substrate onto which the membrane is fastened, or the fastener-to-deck engagement locations.

Mechanically Attached System



Fully Bonded System

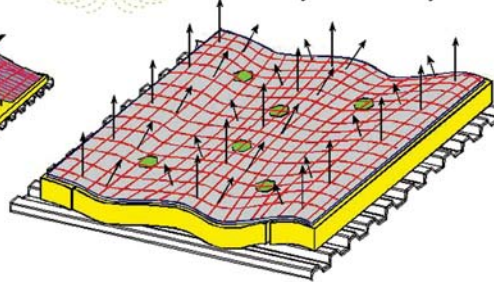


Figure 3: Static (fully bonded system) and dynamic (mechanically attached system) responses.

## 3 WHAT IS A STATIC TEST?

In a static test, roofs are subjected to constant pressure difference across the deck and waterproof membrane. Normally, in the North American roofing community, FM Global (FMG) 4470<sup>2</sup> test method is considered a static test. In that test, all roofs are subjected to static pressure differences as shown in Figure 4.

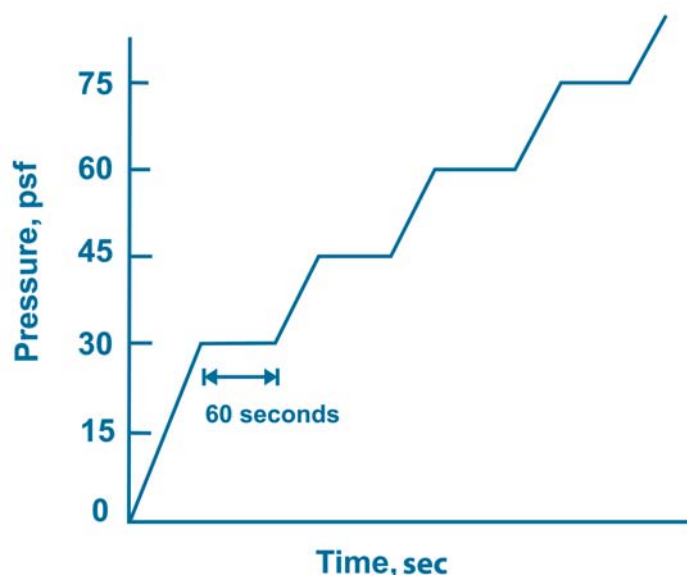


Figure 4: Static load cycle.

# 4 WHAT IS A DYNAMIC TEST?

In a dynamic test, wind pressures vary across the system. The intensities and magnitudes are dependent on the building's aerodynamics and wind exposure. Normally, in the North American roofing community, the CSA A123.21-04<sup>3</sup> test method is considered a dynamic test. In an attempt to mimic Mother Nature, wind dynamics of varying intensities are induced over a roofing system. Each wind gust has a frequency of 0.5 Hz or two seconds.

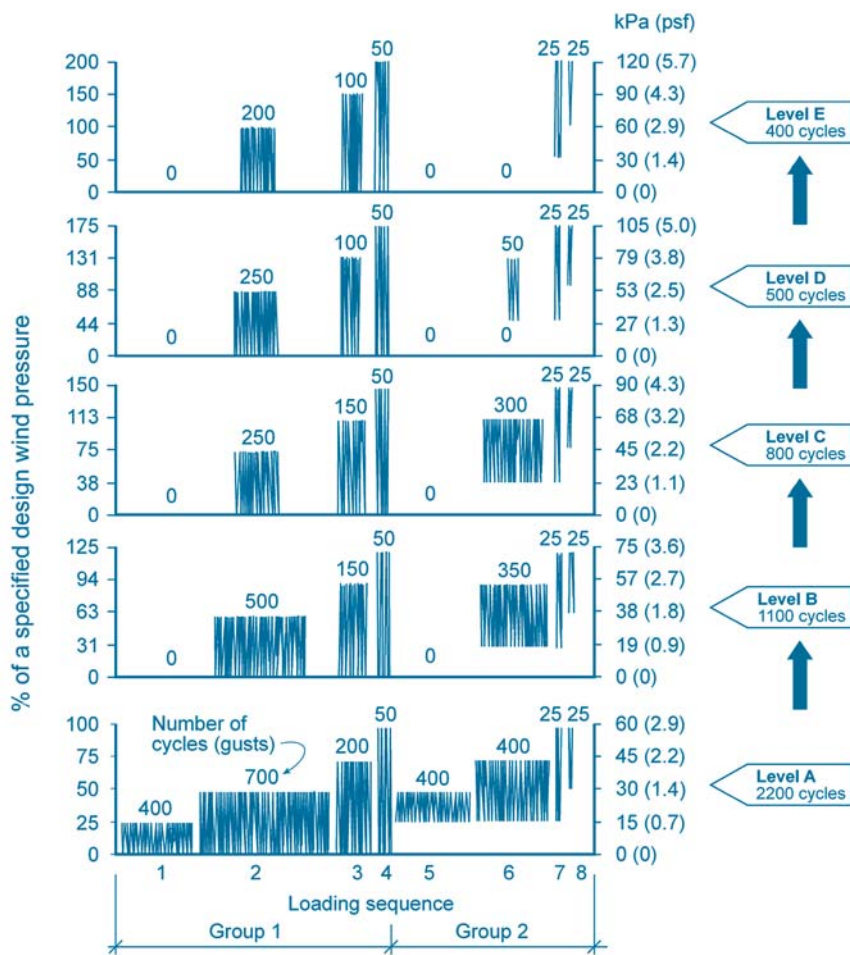


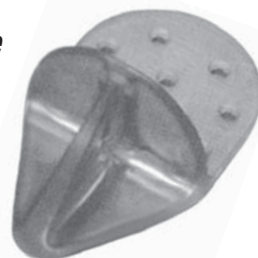
Figure 5: Dynamic load cycle.

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# 5 HOW ARE TEST METHODS DEVELOPED?

The development of a full-scale test procedure requires several levels of generalization on the true wind-induced effect over a roof assembly. Often, these generalizations warrant compromise from a technically sound approach to the practically acceptable procedure. The author is unaware of the level and extent of generalization of the wind-induced effects used in the development of the static test. Nevertheless, the development dynamic of the test involved input from all parties concerned with roofing, including researchers, manufacturers, roofing associations representing contractors, and building owners. (Refer to the acknowledgment section for the SIGDERS consortium participants.)

Six attributes for the development of a dynamic load cycle were selected from the concerns raised by the members and listed, based on priority, as follows:

1. Mimic as much as possible the true wind effects.
2. Simulate failure modes similar to those under field conditions.
3. Account for the variation in roofing components and materials.
4. Be easier to apply in a common laboratory environment.
5. Have a reasonable test-processing time of not more than a day, including setup and testing.
6. Be compatible with local building codes and wind standards.

SIGDERS consortia and CSA standardization process scrutinized the generalization conducted in the development of the dynamic wind load test procedure. Based on this vision, the CSAA123.21.04 dynamic test was published. Data from extensive wind tunnel studies of full-scale roof assemblies were used, and finite element models were developed to extrapolate the data base.

# 6 THE STATIC TEST TAKES LESS TIME. IS IT BENEFICIAL?

Yes, a static test always takes less time because it is not simulating wind fluctuations. Static wind uplift rating data may be an indicator to compare two systems; however, this test's benefits for engineering design are questionable.

# 7 THE DYNAMIC TEST HAS VARIOUS GUST LEVELS. WHY?

Roofs, during their lifespan, experience winds of varying speeds such as periods of calm winds, moderate winds, and severe winds (hurricane season). As indicated under question #1, the test method should account for these wind speed variations. This is why the dynamic test has varying intensity gusts and uses wind loads specified in the national documents, such as NBCC 2005<sup>4</sup> and ASCE 7-02<sup>5</sup>. Such calculated pressures are used to convert the test pressure ratios in *Figure 5* rather than using an arbitrary selection.

# 8 IS THERE AN EXPERIMENTAL FACTOR TO CONVERT STATIC WIND UPLIFT RATINGS TO DYNAMIC WIND UPLIFT RATINGS?

No. Systems' responses are different under static and dynamic loadings. Even for a particular installation category (say, a mechanically attached system), resistance data from a static test can be different from that of a dynamic one. Significant efforts were made under the SIGDERS consortia to develop an experimental factor to convert the static wind uplift rating into an equivalent dynamic wind uplift rating. It has been concluded (considering the material advancements and application technologies), that use of a single conversion

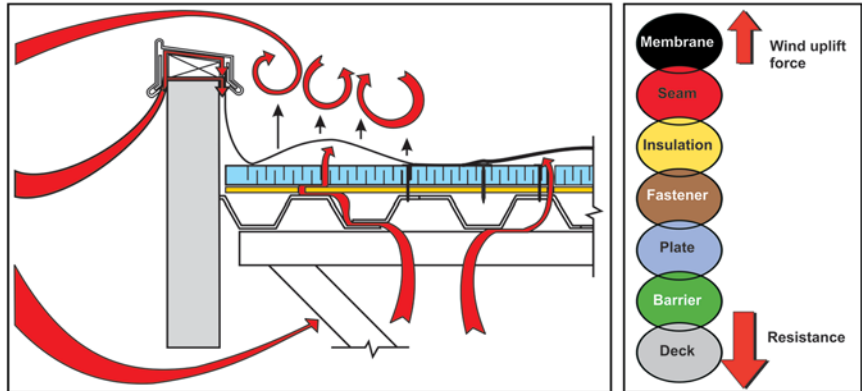


Figure 6: Weakest resistance link chain diagram for mechanically attached system.

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factor is scientifically invalid. This can further be explained by means of a “weakest resistance link” chain (Figure 6).

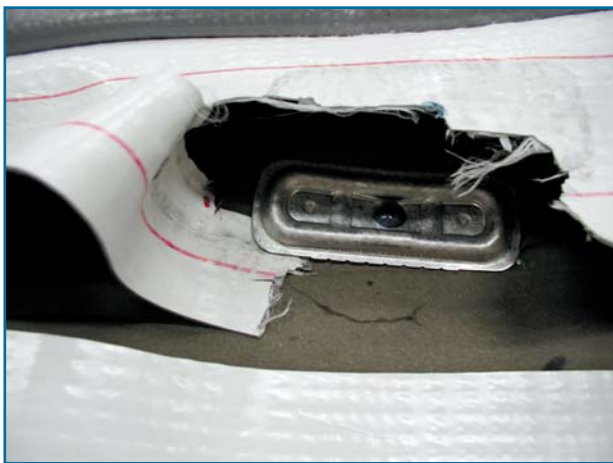
Components of a mechanically attached system are: deck, fasteners, plates, air/vapor barriers (retarders), insulation, and membrane. Each component offers a certain resistance to wind uplift. All resistance links should remain connected for the system to be durable and to keep the roof properly in place.

Failure occurs when the wind uplift force is greater than the resistance of any one or more of these links. For example, the assembly is considered to have failed when a fastener pulls out from the deck even if the membrane and its seams are in good condition. Similarly, a system is con-

sidered failed when a seam tears under gusting wind while other components remain intact. Due to variations in resistance, the failure mode can also vary.

Figures 7.1-7.4 show typical examples of the difference in failure mode and wind uplift rating data between static and dynamic tests for various systems. Note that all these tests were completed at the SIGDERS table setup. As shown, some systems perform similarly, irrespective of the test methods; while for others, there are significant variations. It is worth mentioning that one cannot use similar observations for other systems using the same membrane, as it may have a different application technology.

*COMPARISON OF STATIC VS. DYNAMIC RATING AND FAILURE MODES OF VARIOUS MECHANICALLY ATTACHED SYSTEMS.*



*Static test – Wind uplift rating 150 psf.*



*Dynamic test – Wind uplift rating 60 psf.*

*Figure 7.1: Failure modes of PVC systems.*

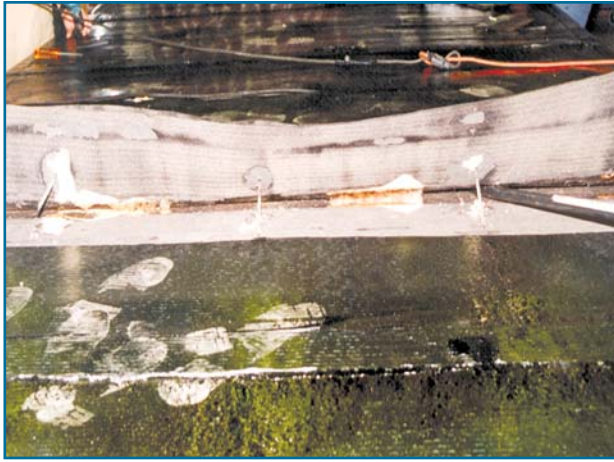


*Static test – Wind uplift rating 90 psf.*



*Dynamic test – Wind uplift rating 45 psf.*

*Figure 7.2: Failure modes of EPDM systems.*



*Static test – Wind uplift rating 60 psf.*

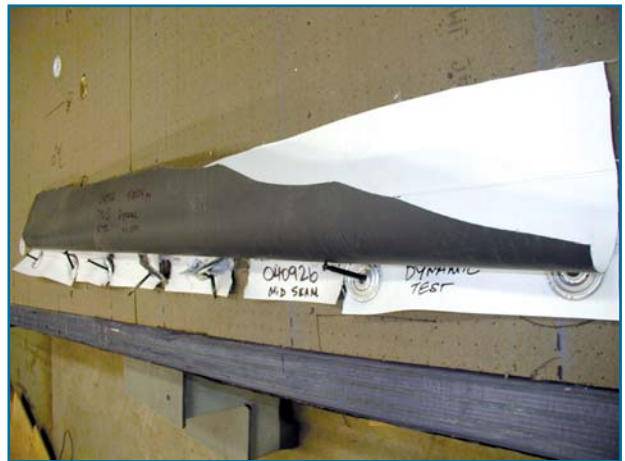


*Dynamic test – Wind uplift rating 75 psf.*

*Figure 7.3 Failure modes of modified bitumen systems.*



*Static test – Wind uplift rating 135 psf.*



*Dynamic test – Wind uplift rating 100 psf.*

*Figure 7.4 Failure modes of TPO systems.*

# 9

## IS THERE A FORMULA TO CONVERT THE WIND UPLIFT RATING TO WIND SPEED?

The wind uplift rating and wind speed are different parameters; therefore, one cannot use a conversion factor. Wind uplift ratings obtained from testing can be used in the design process, as shown below.

# 10 WHAT IS THE USE OF A WIND UPLIFT RATING IN THE DESIGN PROCESS?

## Step 1: Calculate the Design Load

Calculate the wind load for various zones (i.e., field, edge, corner) of the roof assembly in accordance with the local building code.

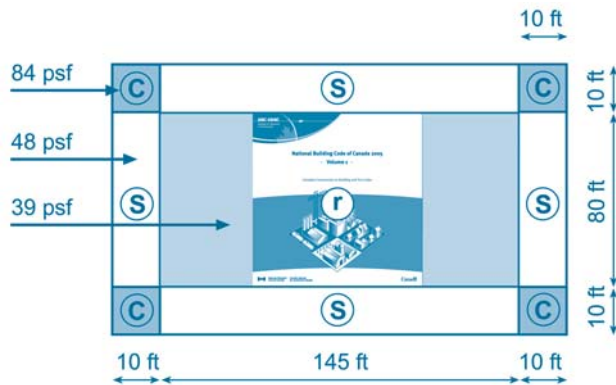


Figure 8 - Wind load diagram.

First, the rating data should be converted to resistance. Using a safety factor, divide the rating to obtain the resistance. The designer then correlates the resistance with the required design load to validate that the resistance is always higher than the load requirement. A simplified case study is presented below.

## Step 2: Select the Roof Assembly

Use a minimum safety factor of 1.5 if the wind uplift rating of the roof assembly and components is obtained from dynamic testing. Use a safety factor of 2.0 if the uplift rating is obtained from static testing. This provides the resistance data.

	<u>Required System Rating from Dynamic Testing</u>	<u>Required System Rating from Static Testing</u>
<b>Corner</b>	$84 \times 1.5 = 126$ psf or higher	$84 \times 2 = 168$ psf or higher
<b>Edge</b>	$48 \times 1.5 = 72$ psf or higher	$48 \times 2 = 96$ psf or higher
<b>Field</b>	$39 \times 1.5 = 59$ psf or higher	$39 \times 2 = 78$ psf or higher

## Step 3: Correlation

Select roof assemblies and related components with resistance data higher than the load data.

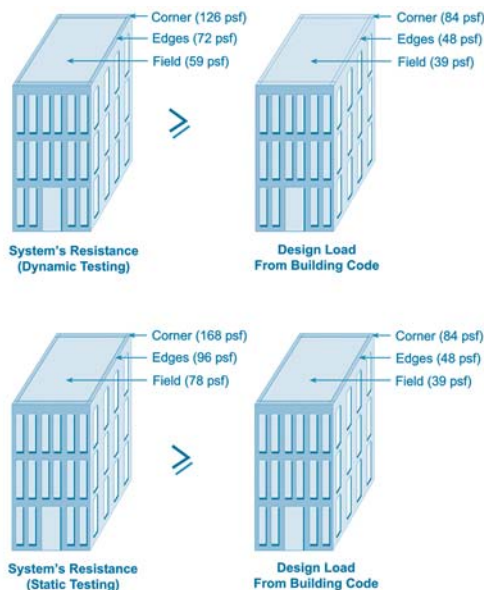


Figure 9 - Correlation of resistance with load.

## Step 4: Generalization

In some cases, it may be economical to use a single set of components for both the edge and corner zones. In such cases, the corner zone resistance data should be applied to the edge zone (not vice versa).

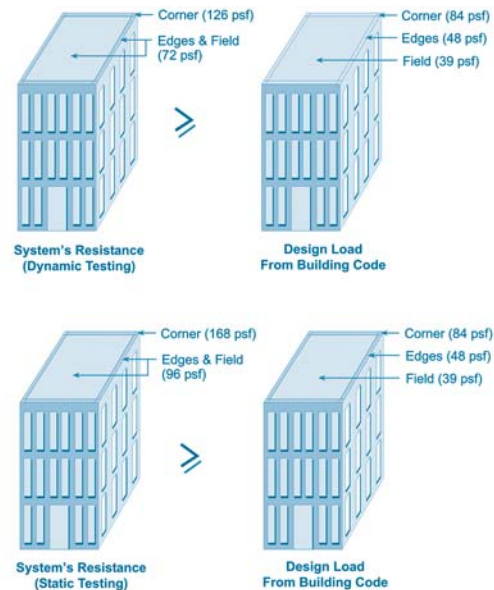



Figure 10 - Correlation of resistance with load - generalization.

## Acknowledgement

The presented research is being carried out for a consortium – Special Interest Group for Dynamic Evaluation of Roofing Systems (SIGDERS). SIGDERS was formed from a group of partners who were interested in roofing design. These partners include:

**Manufacturers:** Atlas Roofing Corporation, Canadian General Tower Ltd., Carlisle Syntec Incorporated, GAF Materials Corporation, GenFlex Roofing Systems, Firestone Building Products Co., IKO Industries Ltd., ITW Buildex, Johns Manville, Sarnafil, Soprema Canada and Stevens Roofing Systems, Tremco Inc. and Trufast Corporation.

**Building Owners:** Canada Post Corporation, Department of National Defence, Public Works and Government Services Canada.

**Industry Associations:** Canadian Roofing Contractors' Association, Canadian Sheet Steel Building Institute, National Roofing Contractors' Association, and RCI, the Institute of Roofing, Waterproofing, and Building Envelope Professionals. 

## References

- 1 Baskaran, A. and Smith, T.L., "A Guide for the Wind Design of Mechanically Attached Flexible Membrane Roofs," [www.nrc.gc.ca/virtualstore](http://www.nrc.gc.ca/virtualstore), 2005.
- 2 FM Global, "Approval Standard: Class I Roof Covers (FMG 4470)," Norwood, Massachusetts, 2005.
- 3 CSA A123.21-04, "Standard Test Method for the Dynamic Wind Uplift Resistance of Mechanically Attached Membrane Roofing Systems," [www.csashop.ca](http://www.csashop.ca). 2004.
- 4 NBCC. "National Building Code of Canada, National Research Council of Canada, Ottawa, Canada. 2005.
- 5 ASCE. "Minimum design loads for buildings and other structures." ASCE Standard 7 -02, American Society of Civil Engineers, Reston, Va., USA. 2002.

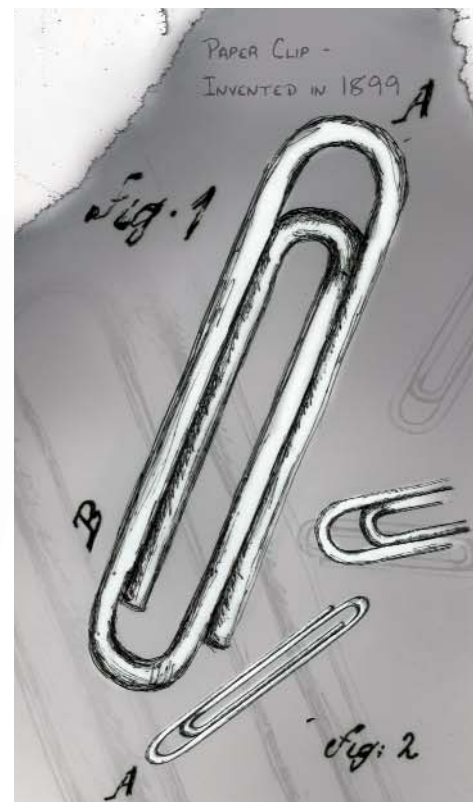
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Dr. Baskaran is a group leader for the Roofing Sub-Program at the National Research Council of Canada, Institute for Research in Construction (NRC/IRC). At the NRC, he is researching the wind effects on building envelopes through experiments and computer modeling. He also acts as adjunct professor at the University of Ottawa. He is the vice-chairperson for the Roofing Industry Committee on Weather Issues (RICOWI) and a member of ASCE, SPRI, and CIB technical committees. He has authored and/or co-authored over 150 research articles in the area of wind effects on buildings. Baskaran received his bachelor's degree in engineering from Annamalai University, Madras, India. His master's degree in engineering and PhD were from Concordia University, Montreal, Canada. Both research topics focused on the wind effects on buildings and earned best dissertation awards from the Canadian Society of Civil Engineers.



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