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Keeping the Roof On: Mechanically Attached Flexible Membrane Roofs Survive High Winds

by A. Baskaran

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This article summarizes the key elements involved in the design of mechanically attached flexible membrane roofs so that they perform well in dynamic wind conditions. It is based on a new wind design guide published in 2005 by NRC-IRC.

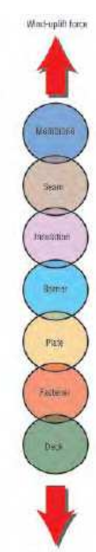
Mechanically attached flexible membrane roofs use flexible sheets as the waterproofing component, and mechanical attachments to resist wind uplift. These types of roofs are used on over 30% of North American commercial buildings due to their economy and relative reliability. They are effective roofing systems, especially for large roof areas. They can achieve strengths similar to those of other types of roofs and up to thirty years of service life with proper design.

A key element in design is to consider and account for dynamic lifting of the membrane due to wind. Recent high-wind storms in British Columbia and elsewhere reinforce this point. Small imperfections in flexible membrane roofs can lead to progressive failures.

Determining design wind loads

Provincial building codes (which use the *National Building Code of Canada 2005* as the model code) provide direction on the design wind load for a given location. Designing roofs with strength over and above (safety factor) the minimum requirements dictated by the design wind loads provides additional security for offsetting construction defects or extraordinary conditions such as extreme winds. The higher the safety factor, the greater the reserve strength there will be for avoiding damage in high winds. Roof designs should be based on a minimum safety factor of 1.5 for systems tested under dynamic conditions.

Designing the roof as a system



A mechanically attached flexible membrane roof is a complex interaction of a number of structural components, such as membrane, seams, fasteners, deck, etc. (Figure 1). For the roof to remain intact, the resistance of each of the structural components must be greater than the design load. Failure occurs when the wind uplift force is greater than the resistance of any one of these links. For example, roof failure can be initiated when a fastener pulls out from the deck, even though the membrane and its seams remain in good condition.

Figure 1. Resistance links of a mechanically attached roof system

Because mechanically attached systems are attached at discrete points or rows, wind can cause the membrane to flutter. This can cause membrane fatigue, or if the fasteners are not secured enough to adequately clamp the membrane, the membrane can fail in the vicinity of the fasteners (Figure 2).

Figure 2. Membrane tear due to a lack of clamping force under the fastener plate

Billowing

Mechanically attached flexible membrane roofs respond to wind loading differently than other roof systems such as ballasted, fully adhered or protected membrane roofs. Wind-induced suction can repeatedly lift the membrane between the attachments and cause elongation and billowing (Figure 3). Billowing can cause fatigue in the membrane, its fasteners, the substrate below the fasteners, or the fastener/deck connection. Therefore, an important design objective is to minimize billowing.

Figure 3. Billowing of a mechanically attached roofing system

Test standard

The NRC Institute for Research in Construction, working with a consortium of industry groups, developed a new North American test standard that mimics real wind effects and achieves failure modes observed under real conditions. It has been adopted as *CSA Standard A123.21-04.* Procuring roofs that meet this new standard will provide the assurance that a membrane has been tested to conditions that reflect the dynamic reality of in-service conditions.

Inspection, maintenance and repair
Because the reliability of a roof depends on the interaction of a number of structural components, a mechanically attached flexible membrane roof can fail progressively, with small failures increasing loads on other components. Regular inspection and repair of the visible links will help ensure that the full designed capability of a roof is available to resist loads during high wind events.

Information on maintenance can be gleaned from maintenance manuals available from the Canadian Roofing Contractors' Association and the National Roofing Contractors Association.

For more information on design issues, readers may consult the author's publication, *A Guide for the Wind Design of Mechanically Attached Flexible Membrane Roofs,* by visiting this site and clicking on publications:
http://irc.nrc-cnrc.gc.ca/bes/prsi/sigders_e.html

The guide is based on ten years of research by NRC with the above-mentioned consortium, representing industry experts in Canada and the United States. It contains sample wind load calculations for Canada and the United States. They include calculations for a hypothetical hospital building in Victoria, BC, designed to provide post-disaster services.

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