

WIND UPLIFT RATINGS OF MECHANICALLY-ATTACHED, SINGLE-PLY MODIFIED BITUMINOUS ROOFING SYSTEMS

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INTRODUCTION

Modified bituminous roofing is one of the fastest growing systems for commercial and industrial applications. It occupies the middle ground between the traditional built up roof (BUR) systems and the new generation single ply roof (SPR) systems. Originally developed in Europe, modified bituminous membranes were introduced in the 1970s

defense to the waterproofing characteristics of the system. The cap sheet's upper surface is coated with mineral granules, metal foils, or various liquid coatings. It increases the membrane's weatherability and UV resistance. Installation of the cap sheet can be done in different ways. It can be torched, hot-mopped, cold-applied, or self-adhered to the base sheet.

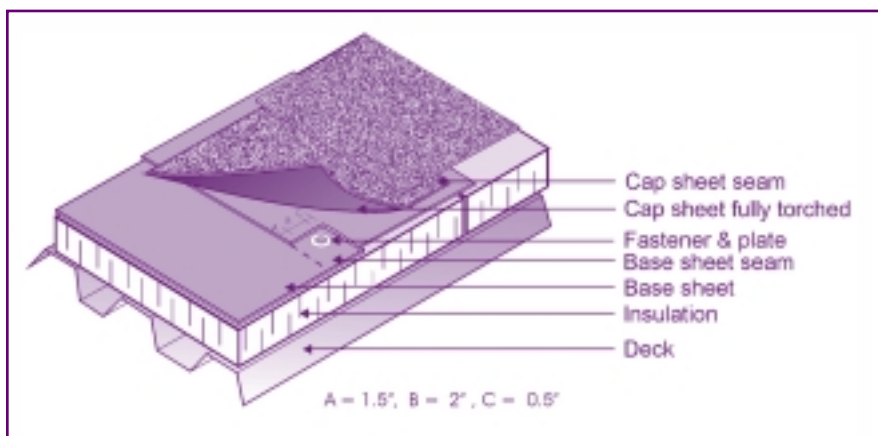


Figure 1: Two-ply system with mechanically-attached base sheet (not to scale).

to the North American market. Membranes are made by modifying bitumen with synthetic polymers – either styrene butadiene styrene (SBS) or atactic polypropylene (APP). They are reinforced with polyester, fiberglass, or a combination of both. This combination enhances the membranes' physical characteristics and adds strength to the overall system.

Conventionally, a mechanically-attached, modified bituminous system consists of two membrane layers – base sheet and cap sheet (Figure 1). The base sheet is installed as the first layer over the insulation with or without a cover board. Mechanical attachment is used to fix the base sheet to the structural deck. It includes fasteners, metal plates of different shapes or sizes, or metal batten strips. At the overlapping, seams are formed either by torching or self-adhering. A "cap sheet," as the name suggests, acts as a top layer to the base sheet and may provide a second line of

NEW DEVELOPMENT

Advancements in material research facilitated development of a new SBS modified bituminous membrane. The manufacturer claims this new generation membrane is heavy duty and that a single membrane layer is expected to perform the function of the traditional base and cap sheets. There is no change in the membrane width — 39-3/8" (1000 mm) — and top surfaces are coated with colored mineral granules or foils. However, the single-layer modified bituminous sheet has a different thickness and density: 0.2" (5 mm) and 468 pcf (7500 kg/m³)

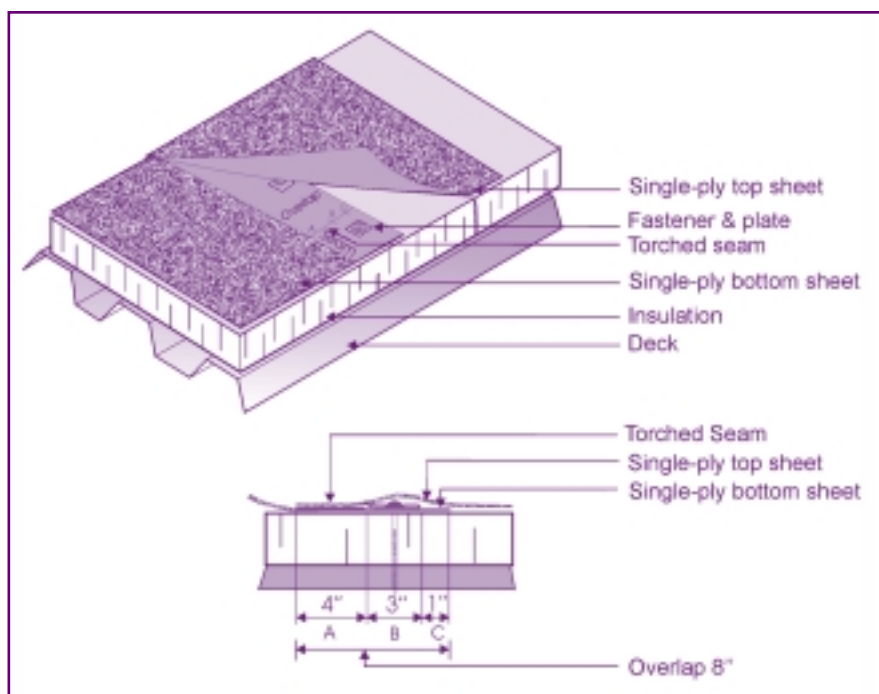


Figure 2: Single-ply, mechanically-attached systems (1" = 25.4mm; not to scale).

respectively. Typical mechanical properties (as determined in accordance with CGSB 37 56M97) are as follows:

- Maximum Load [kN/m (kiloNewton/meter)] MD: 16 [1 klf (kilopound/linear foot)]; XD: 15 (1 klf)
- Ultimate Elongation (%): MD: 74; XD: 68
- Strain Energy (kN/m): MD: 12 (0.8 klf); XD: 9 (0.6 klf)
- Tear Resistance (N): 125 (28 lbf)
- Static Puncture (N): 440 (99 lbf)

According to the manufacturer, the new single-ply, mechanically-attached modified bituminous systems should be used on roofs with slopes greater than three percent. Any roof with slopes of less than three percent must use two-ply systems (refer to Figure 1). The new system is also claiming several advantages such as: reduced application and material costs, application with less torching, and reduction in construction waste.

Nevertheless, there are questions about its wind uplift resistance. To quantify the wind rating of these new systems, experiments were carried out by the National Research Council of Canada (NRCC) and the Special Interest Group for Dynamic Evaluation of Roofing Systems (SIGDERS, a research group co-sponsored by RCI).

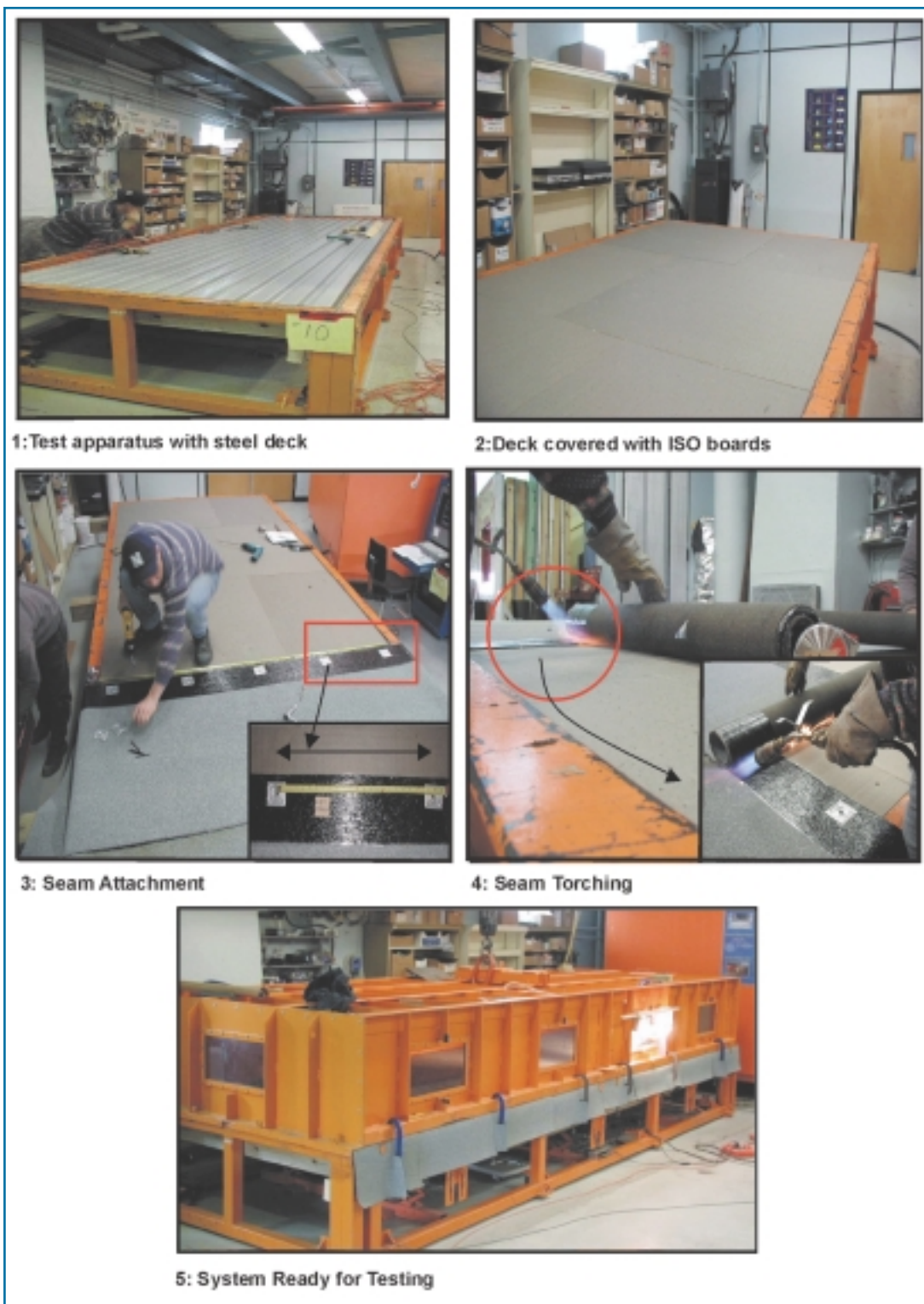


Figure 3: Installation of a single-ply, mechanically-attached system at the Dynamic Roofing Facility laboratory.

EXPERIMENTAL APPROACH

Tested System

Following the manufacturer's installation procedures, the roof applicator installed the system on the SIGDERS table. 1.5"-thick (81 mm) ISO insulation boards were loose-laid over nominal 22 ga. steel deck (Figure 2). The single-ply, modified bituminous membrane sheet was unrolled over the insulation. To maintain continuity, sheets were

overlapped by about 8" (203 mm). Mechanical fasteners were used at the bottom sheet to secure it to the steel deck. Fasteners were 2-7/8" (73 mm) long with a 3"-square (76 mm) metal plate. Of the 8" (203 mm) overlaps, only 4" (101 mm) were torched to form seams. Fasteners were placed along the seam from 12-inch (305 mm) to 24-inch (610 mm) intervals, depending on the system, and experiments were conducted on four systems.

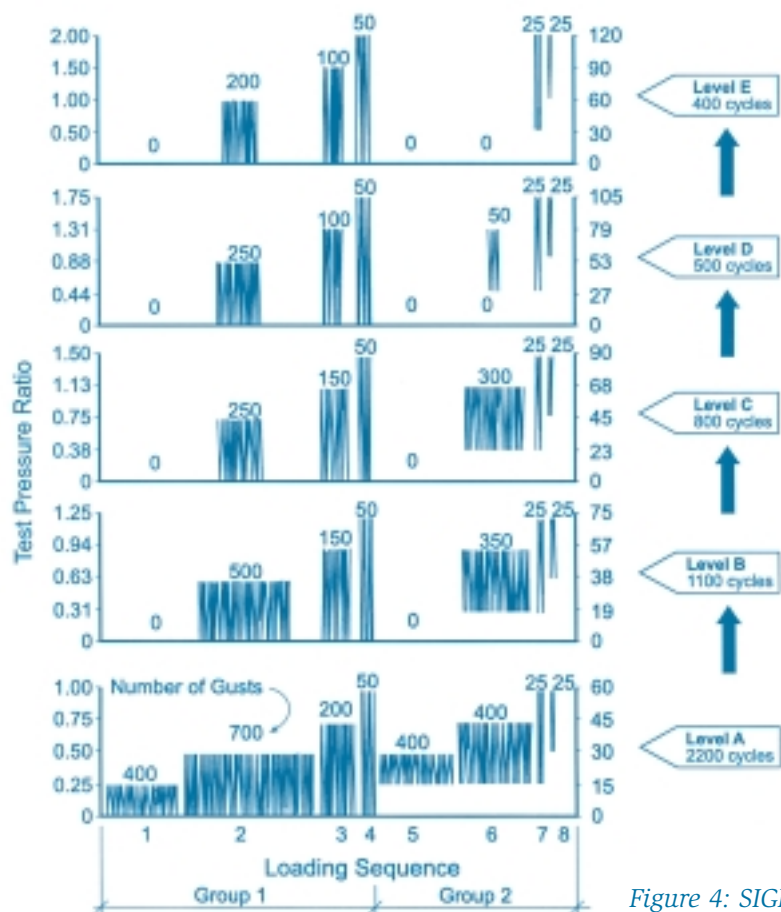


Figure 4: SIGDERS dynamic wind uplift test protocol.

Facility

Wind uplift rating investigations for the above were conducted in the Dynamic Roofing Facility lab (DRF) of the National Research Council of Canada (Figure 3). Using this facility, both static and dynamic test protocols can be simulated. Three systems were subjected to static test, and the fourth was tested under dynamic conditions.

Static Wind Uplift Rating

For the static test, the Factory Mutual (FM) procedure was used at the SIGDERS table¹. In the FM load test, an initial pressure of 30 psf (1436 Pa) was applied and maintained for one minute. The pressure was then increased at a rate of 15 psf (718 Pa) per minute until failure was observed in the test panel. For example, the windstorm classification 1-90 is obtained if the test assembly successfully passes the 90 psf (4309 Pa) pressure.

Dynamic Wind Test Protocol

For dynamic testing, the SIGDERS test protocol² was used. As shown in Figure 4, the SIGDERS dynamic protocol has five rating levels (A to E). To evaluate a roof assembly for a specific wind resistance, all the gusts corresponding to Level A must



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be applied. To evaluate the ultimate strength of the roofing system, testing must be started at Level A and must be continuous when moving from one level to another. To attain a specified rating, all specified numbers of gusts in each level must be completed successfully. For the present investigation, all the tests started from Level A with maximum suction of 60 psf (2872 Pa).

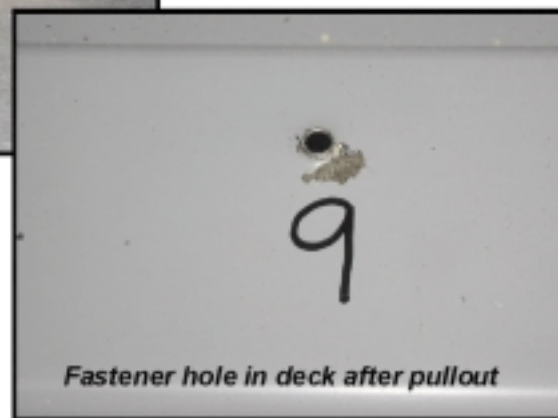
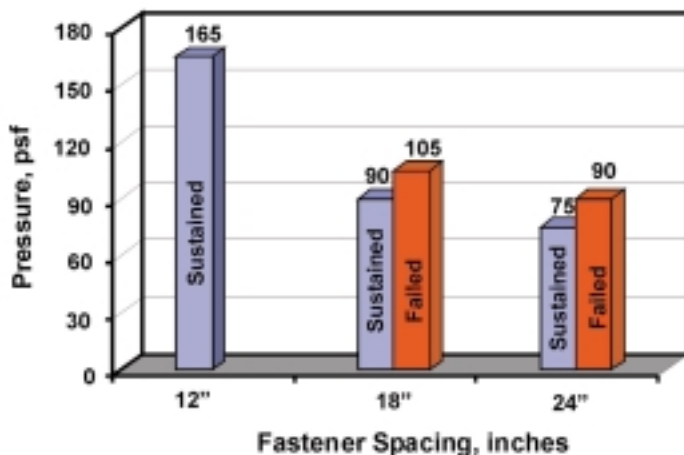
SYSTEM RESPONSE

- System 1 was with 24" (610 mm) fastener spacing. Testing started with an initial pressure of 30 psf (1436 Pa) for one minute, and then the suction was increased by 15 psf (718 Pa) increments each successive minute until failure occurred on the system. System 1 sustained a suction of 75 psf (3591 Pa) and failed at 90 psf (4309 Pa) with fasteners pulling out from the deck.
- System 2, with 18" (458 mm) fastener spacing, sustained a suction of 90 psf (4309 Pa) and failed at 105 psf (5027 Pa).
- System 3, with 12" (305 mm) spacing, sustained a wind suction pressure of 165 psf (7900 Pa) and the test was terminated. Data from the static testing are shown in Figure 5.

To compare the static versus dynamic wind uplift performance,



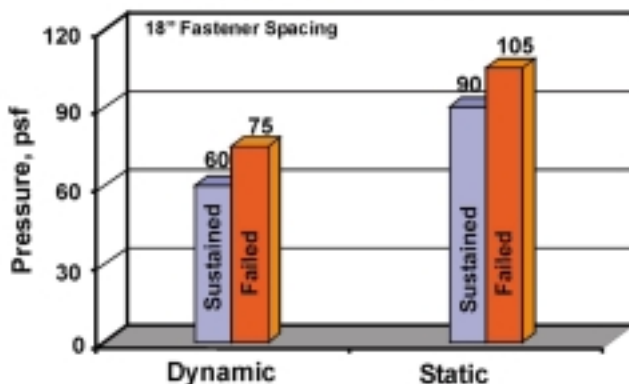
Figure 5: Static wind uplift performance of single-ply, mechanically-attached system.



a new specimen of the System 2 [18" (457 mm) fastener spacing] was constructed at the DRF. Installation procedures were the same as shown in Figure 3. Components such as the membrane, membrane fastener, and plate had similar physical and mechanical properties and were from the same batch. The same roofing applicator installed the specimens for the dynamic test at the DRF. The dynamic wind test was started at Level A. When



Figure 6: Wind uplift performance of single-ply, mechanically attached system.



subjected to dynamic wind loading, the system sustained 60 psf (2872 Pa) suction and failed at 75 psf (3591 Pa). In other words, the system passed all 2200 gusts of Level A and failed at the Sequence 4 at Level B of the SIGDERS load cycle. The observed failure mode was fasteners pulling out from deck. Data from the dynamic testing are shown in Figure 6.

SUMMARY

Wind performance of newly developed single ply mechanically attached modified bituminous roof assemblies was investigated in both static and dynamic environments. Simulated wind dynamics by the SIGDERS protocol reduced the wind uplift rating by 30 psf (1436 Pa), compared to static testing. Fastener pullout was the only observed failure mode irrespective of the static and dynamic test. This indicates that the weakest link was the fastener engagement with the deck. There are two ways to strengthen the link: 1) use a high tensile strength deck;

and 2) adapt a fastener that has differently-engineered thread design.

ACKNOWLEDGEMENT

Data presented in this paper are taken from an ongoing joint research project between NRC and Soprema Canada. The authors thank Martin Cote of Soprema Canada and William Lei of NRC for their help during system installation. ■

1. Baskaran, A., and F. Nabhan, (2000), "Standard Test Method for the Dynamic Wind Uplift Resistance of Mechanically Attached Membrane Roofing Systems," *Internal Report IRC-IR 699*, National Research Council, Canada.
2. Baskaran, A.; Chen, Y., Vilaipornsawai, U. "A New dynamic wind load cycle to evaluate flexible membrane roofs," *ASTM, Journal of Testing and Evaluation* 27(4), 1999, pp. 249-265.

ABOUT THE AUTHORS

Dr. A. 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. Baskaran is the vice-chairperson for the Roofing Committee on Wind 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 Ph.D were from Concordia University, Montreal, Canada. Both research topics focused on the wind effects on buildings and earned the Best Dissertation award from the Canadian Society of Civil Engineers.

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Left to right: Sudhakar Molleti, Michael Sexton, and A. "Bas" Baskaran.

Dynamic Roofing Facility, he is responsible for building and testing roofing systems exposed to environmental conditions such as wind, thermal aging, and moisture.

Sudhakar Molleti is a guest worker at NRC/IRC from Soprema Canada Inc. "Suda" recently finished his masters of engineering and is continuing his Ph.D at the University of Ottawa. He is currently researching the effects of wind on the roofing assembly through computer modeling and benchmarking results with data obtained through experiments.