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Handout Material

for

May 27th

CRCA/AGM Conference

Canada

10:15 am - 12:15 pm - 2nd Business Session
Two Decades of SIGDER's Scientific Advancement to North American Roofing Community
Location: Meeting room "Salon AB", Main floor

On Nov. 16, 1994, members of the roofing community met at the National Research Council of Canada and formed a group with a common focus of evaluating roofing systems under dynamic environment. Thus, a Special Interest Group on Dynamic Evaluation of Roofing Systems (SIGDERS) was created. The mandate of SIGDERS joint research program is to carry out generic, pre-competitive research of benefit to all its members. SIGDERS operation is one its kind in the world not only for its legacy of a long-lasting R&D consortia, but also the some of the following industry impacts it created.

Speaker – Dr. Bas Baskaran

- Static vs dynamic evaluations of roofs its pros and cons?
- Diagnoses of a weak link to enable innovation
- Nominal vs Design tensile strength of steel deck – is it important
- Membrane seaming – an investigation of an innovation
- Air leakage vs intrusion – is there any difference
- How much roof edge matters?
- Wind science of Vegetated roofs
- Field measured vs code specification

12:15 pm – 1:30 pm – Lunch for Delegates
Location: "Court Garden", Lower level

Top 10 Q & A

How to Optimize Wind Resistance for Low Slope Membrane-Roofing Systems

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Q1: Weakest Link for Wind Uplift Resistance?

The Canadian model code NBCC 2015 specifies wind load requirements to design low slope membrane roof assemblies. The manufacturer, proponent, or client (MPC) can calculate the design load based on NBCC 2015 or the internet-based tool "*Wind-RCI*". To comply with the NBCC, the CSA A123.21 standard provides test requirements for resistance evaluation. The tested system's wind uplift resistance should be equal to or greater than the design load/wind uplift force.

Wind induces load on the roof. It is resisted by each component by their resistance. This can be illustrated through a force resistance link diagram respectively for Mechanically Attached Membrane Roofing Systems (MARS) in Figure 1 and Partially Attached membrane Roofing System (PARS) and Adhesive Applied Membrane Roofing System (AARS) in Figure 2. All resistance links shall remain connected to ensure the system will be durable and keep the roof in place. Failure occurs when the wind uplift force is greater than the resistance of any one or more of these links. How to choose the appropriate roof components and construction techniques at the early design stage or by replacing/adding components to improve wind uplift resistance during the reroofing? This will be the focus of this paper/presentation.

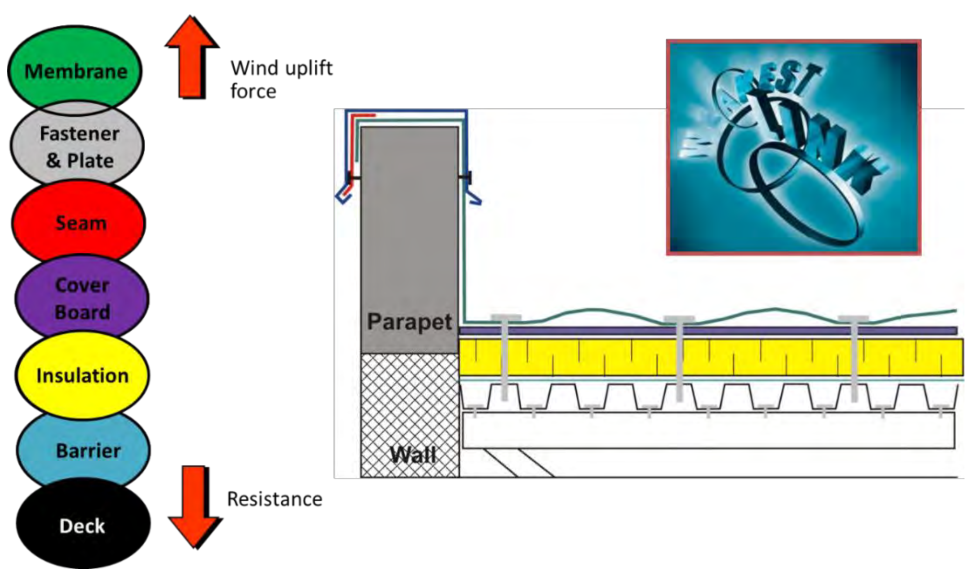


Figure 1: Force resistance link diagram – MARS

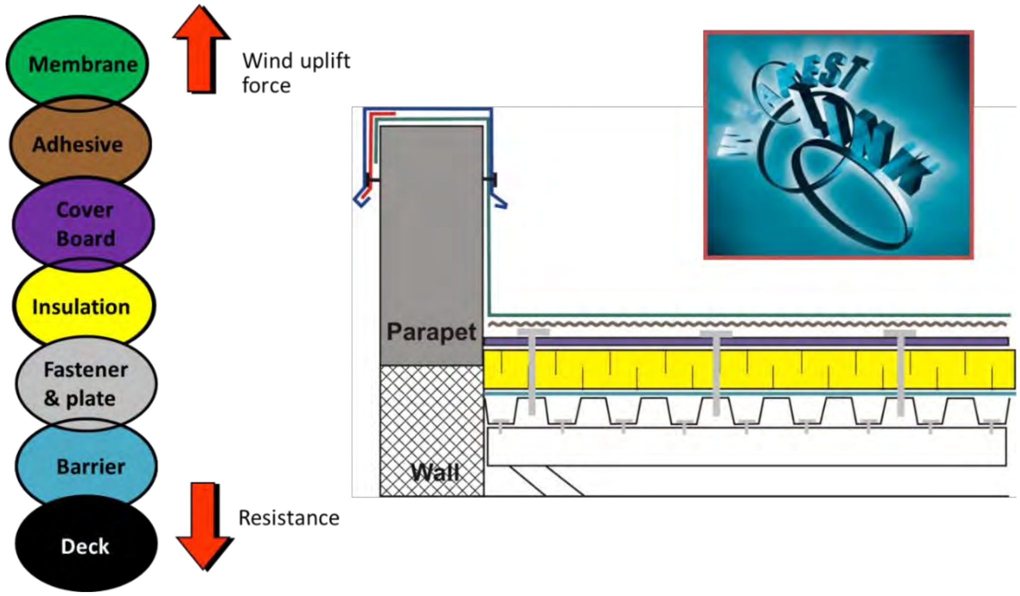


Figure 2: Force resistance link diagram – PARS and AARS

Q2: Role of Structural Deck?

Deck provides structural support and it shall have adequate strength and rigidity to support dead and live loads. These loads either induce compressive or tensile forces or a combination of forces. Steel, concrete, and wood are three common deck materials used on the MARS/AARS/PARS. There is a lot of research related to the use of steel deck on commercial roof systems. Therefore, this paper only focuses on the use of steel deck on commercial roofs. However, SIGDERS has limited research data on concrete deck and wood deck, both deck types are known for having moisture migration issues.

The wind uplift induces tensile forces and these are transmitted to the deck through the structural or pneumatic load path or a combination of both. Therefore, the deck's tensile strength and its attachment to the joists are critical as they can influence the wind uplift resistance of a roof system.

a) Deck attachment methods with Joists
   Welding or fastening to a structural joist are the two common field attachment practices. Two identical sets (Welded vs Fastened) MARS with modified bituminous (Mod. Bit) and thermoplastic membrane were constructed and investigated at the Dynamic Roofing Facility (DRF) of the National Research Council Canada (NRC). Specimens that were installed on decks that are fastened to the joists performed better than the welded specimens. The weld was the weakest link as shown in Figure 3.

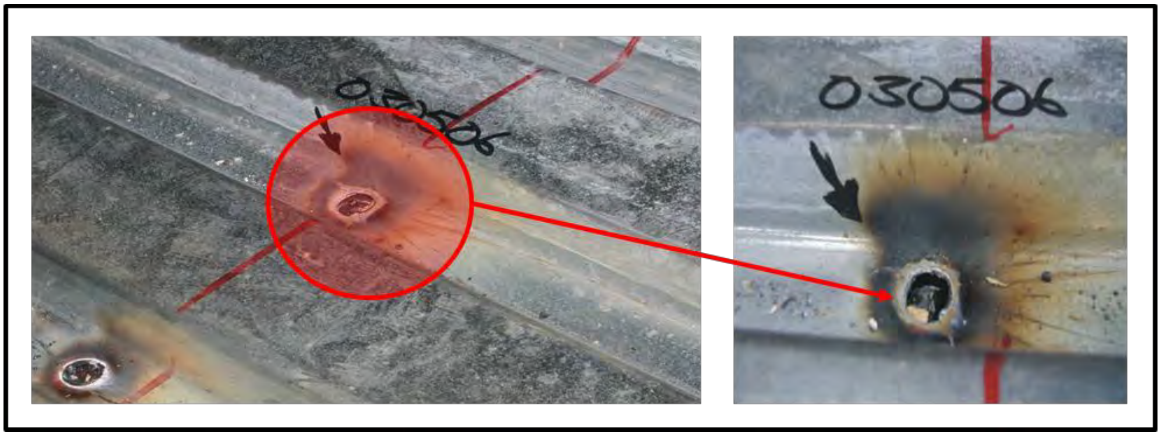


Figure 3: Deck weld failure mode

b) Deck strengths
Steel deck strengths are determined by the combination of the thickness and yield strength. The most common decks used in North America are 22 Ga and 20 Ga with 230 MPa (33 ksi) and 550 MPa (80 ksi). Two identical MARS systems with thermoplastic membranes were constructed and tested at the DRF of the NRC. The first specimen that was installed on 22 gauge, 550 MPa (80 ksi) had a lower sustained pressure of 7.90 kPa (165 psf) than the second system and the failure mode was determined to be due to the membrane fastener pulled out from deck as shown in Figure 4. The second specimen was installed on 20 gauge, 550 MPa (80 ksi) steel deck, passed a sustained pressure of 8.62 kPa (180 psf).

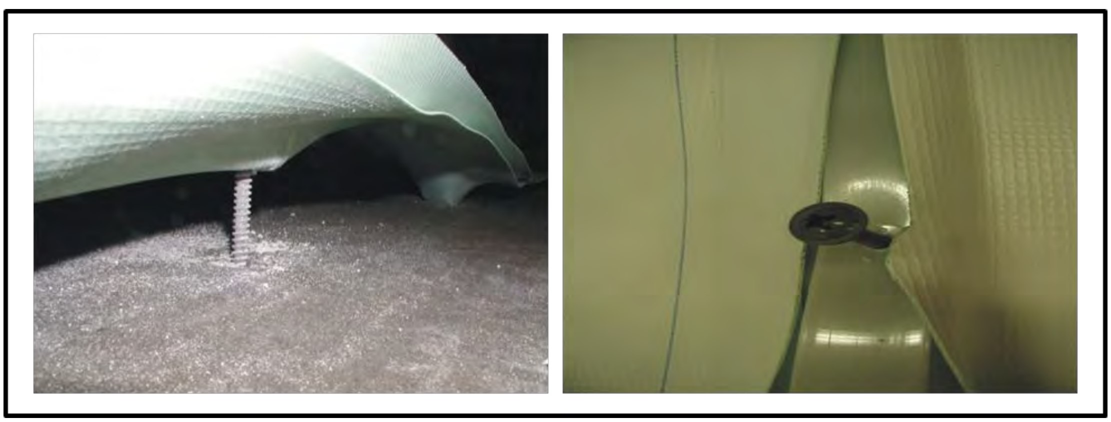


Figure 4: Fastener pullout from the steel deck

Q3: Role of Membrane

Common membranes are thermoset, thermoplastic, and modified bitumen (Mod. Bit.). The membrane must have adequate strength to withstand the stress from wind uplift. The physical/mechanical properties of a membrane such as thickness and tensile strength vary from product to product depending on the chemical composition and the reinforcement materials. As shown in Figure 5, the membrane was stretched around the fastener plates leading it to pull out from the fastener plate, the “cookie cut” failure. In this case, the membrane was the weakest link for that roofing system. Replacing it with a thicker and higher strength membrane will help to increase the wind uplift resistance of the system.

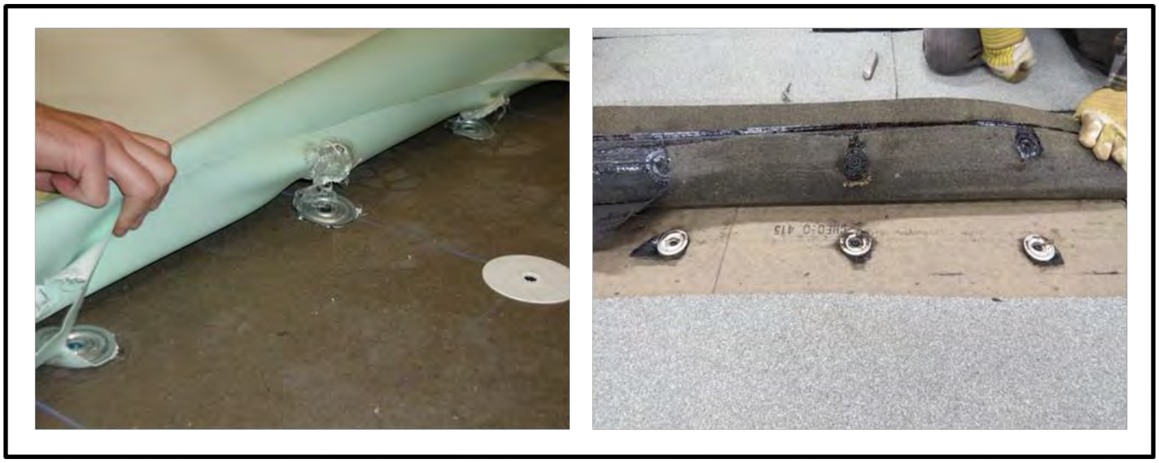


Figure 5: Membrane pull out from the fastener plate

Membrane seam strength is an important parameter that influences wind uplift resistance. The seam must resist fluttering and pulling forces due to wind uplift force. Some manufacturers supply membranes with factory seams, but most of the manufacturers require seaming during construction. There are three different types of seam application methods for MARS. Thermoplastic membrane seams are hot air welded by a robotic machine. Thermoset membrane seams have tape and adhesive. Mod. Bit membrane seams are heat air welded. The SIGDERS research showed that using improper speed and temperature for hot/heat air welding results in a very weak seam as shown in Figure 6. Manufacturers have invented new seam application technologies such as self-adhered seam or torch free seam in recent years, with claims that the new seam application technologies are better than the traditional methods. Further research is needed to investigate the welding window (temperature and speed), the influence of ambient temperature to self-adhered seam and torch free seams on wind uplift resistance.

For the MARS with thermoplastic membrane, there are two seaming techniques, one side weld (OSW) and double side weld (DSW) as shown in Figure 7. The SIGDERS research showed the roofing system with DSW performed better than OSW. DSW system sustained a minimum of 15% higher wind uplift resistance than OSW system. The OSW system develops an asymmetrical force by pulling the bottom membrane. The fasteners are experiencing a single direction wind load, which will rock the fasteners sideways and cause fatigue deformation at the steel deck/fastener engagement locations. This fatigue ultimately results in the fastener pullout from the steel deck. The DSW system develops symmetrical forces along the horizontal direction, this minimizes the rocking action on fastener.

The membrane width ranges from 1.83 m to 3.66 m (6’ to 12’). The spacing between two fasteners on the seam is called fastener spacing (Fs) and the row spacing between two rows of fasteners on the seam is called fastener row spacing (Fr). The recommended practice is fastener row oriented perpendicular to steel deck flange as shown in Figure 8.

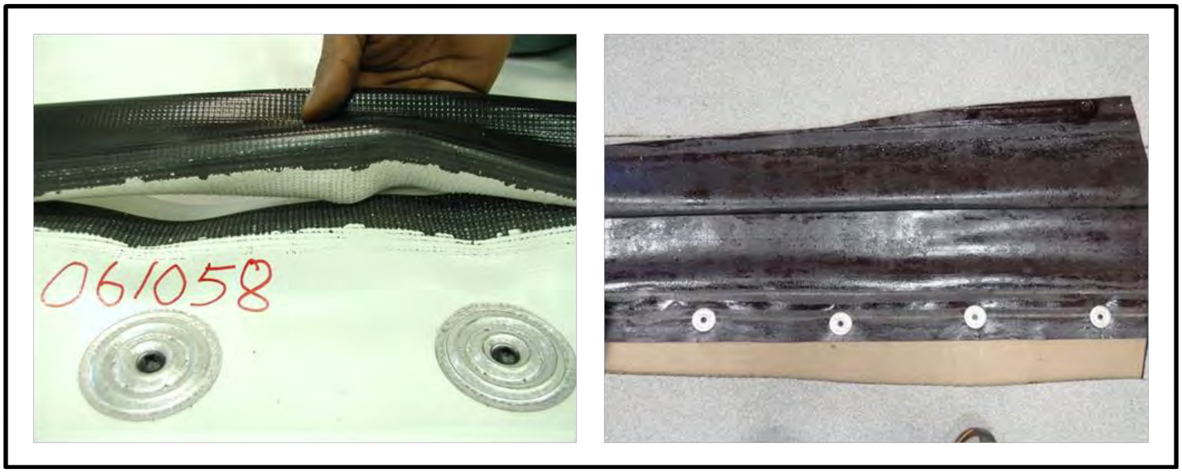


Figure 6: Membrane seam failure

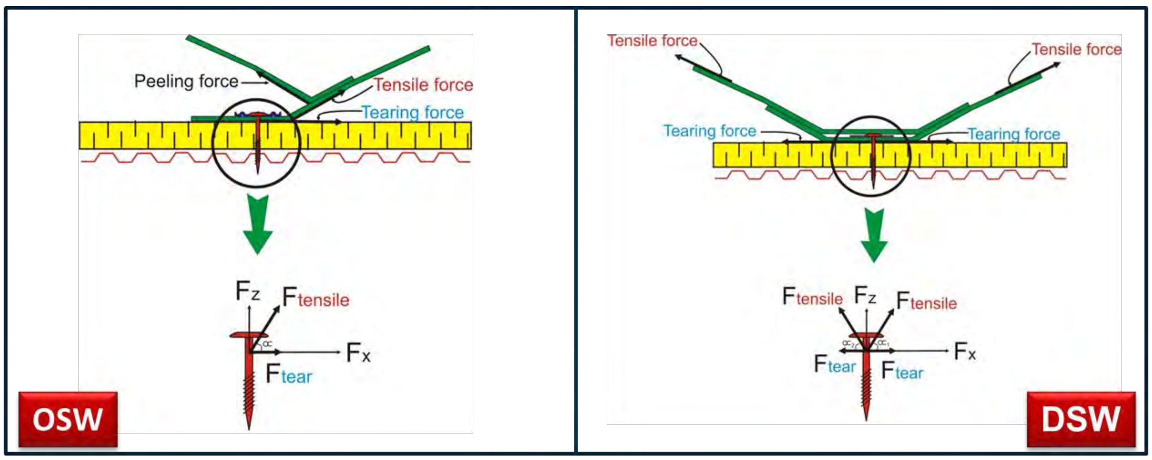


Figure 7: OSW vs DSW for MARS

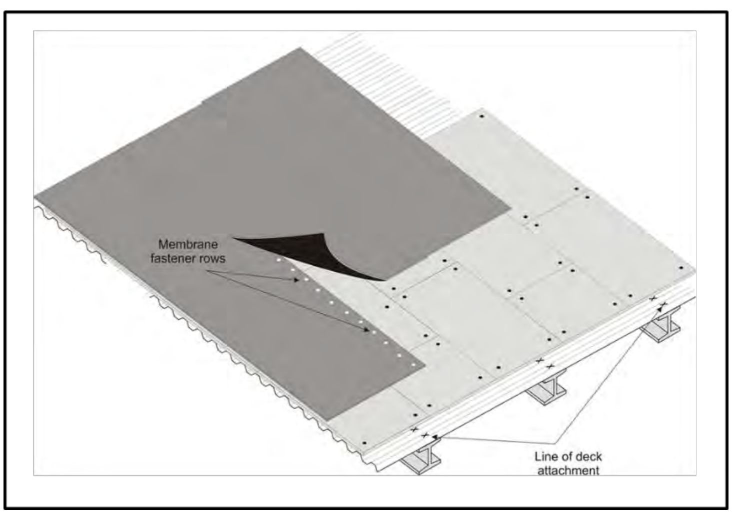


Figure 8: Membrane fastener rows are perpendicular to the deck flanges

Q4: Role of Insulation/Cover board

In addition to the deck and membrane, Insulation is the third most important substrate/roofing component in a roofing system. The preliminary function of insulation is a thermal barrier for the roofing system. The cover board enhances the resiliency and durability of the system. It is installed below the membrane and above the insulation to minimize the deterioration of other components during the service life of the roof. As substrate, both should have sufficient compressive strength and pull-through strength. A weaker pull-through strength can cause a "Cone cut" on the substrate board as shown in Figure 9. In the AARS and PARS, the membrane is adhered to the top facer of the insulation/cover board. The interface peel strength between the membrane and the substrate should be able to resist the shear forces created from the wind uplift force to avoid failures shown in Figure 10.

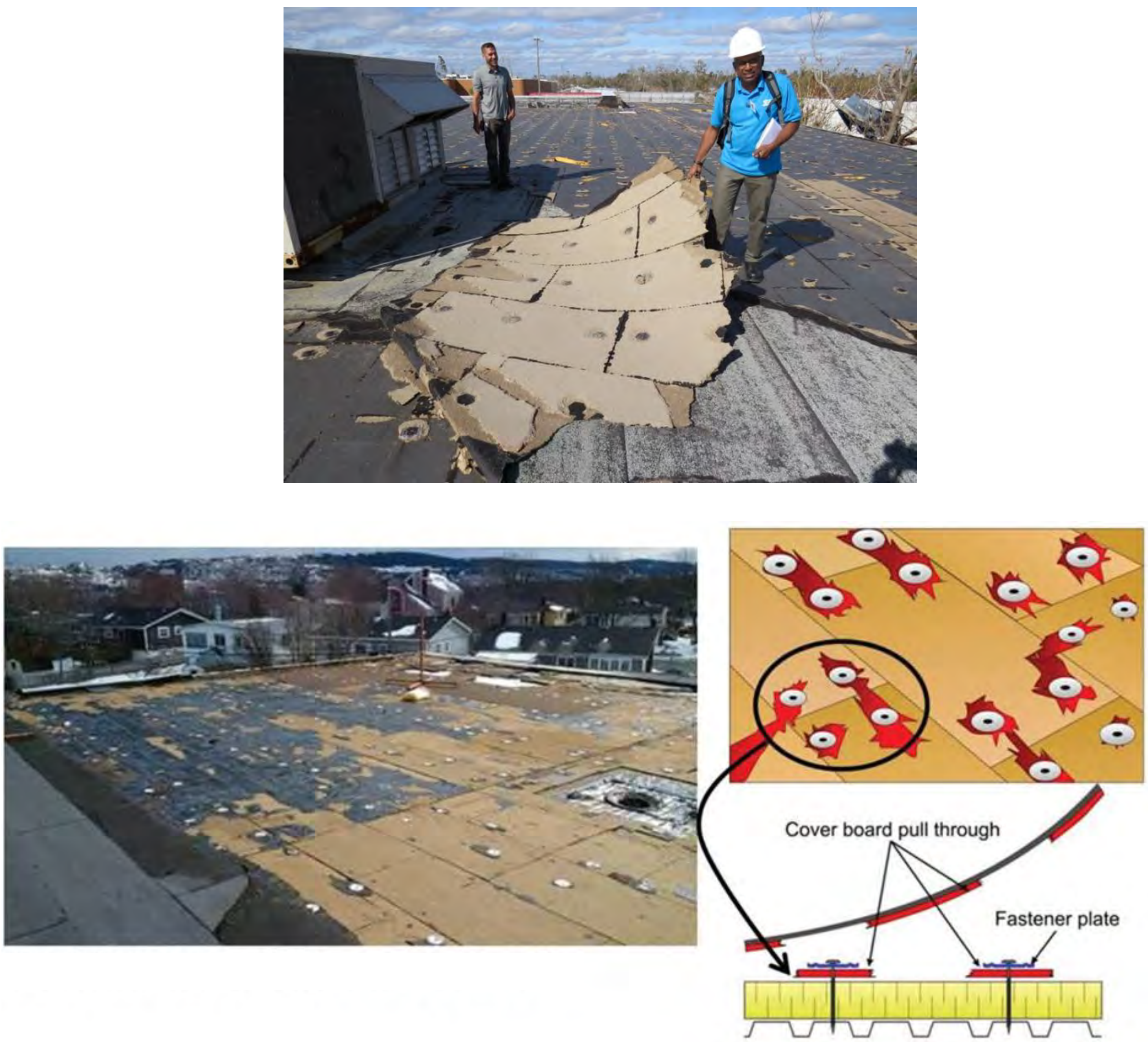


Figure 9: Substrate pull out from the fastener and plate

Figure 10: Facer delamination failure

Q5: Role of Vapour Barrier (VB)

VB offers a certain resistance to airflow in addition to its preliminary function of limiting vapour diffusion into the roofing system from indoor. Based on SIGDERS research, systems with VB increased the wind uplift resistance 25% to 50% than the systems without VB as shown in Figure 11. The wind uplift resistance was varied depending on the air permeability of the VB and type of roofing assembly.

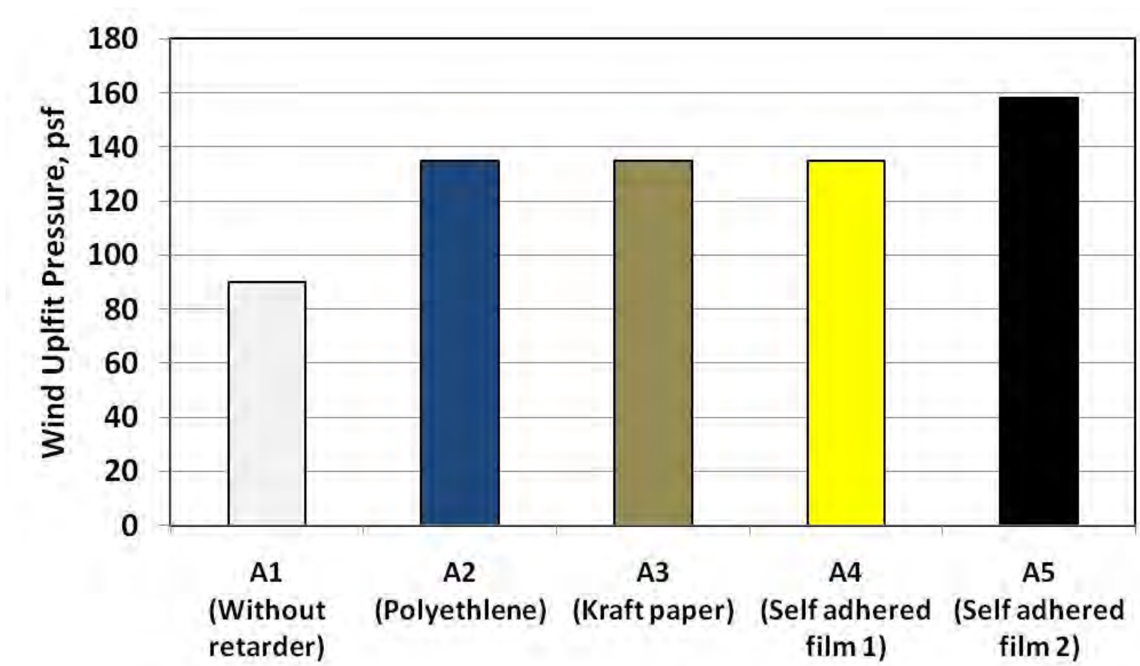


Figure 11: Wind uplift resistance with different types of VB

Q7: Role of Fasteners &, Plates

Accessories, fastener, and plates are used to secure either the membrane or insulation or both to the structural deck.

Fastener/ Deck Engagement: The fastener tip and thread design will determine the fastener pullout resistance (FPR). Figure 12 shows three different fastener sizes along with the physical characteristics of the head, tip, and tread. Figure 13 shows plotted FPR data for 5 fasteners with 4 different types of decks. The data shows that the FPR is higher with a greater shank diameter irrespective of the deck types. The data also shows that the FPR for two different sources with the same fastener type (#15 or #21) measured different values respectively.

Fastener Plate/Membrane Engagement in MARS: This engagement keeps the membrane in place. The barbed plates provide a better clamping force compared to smooth ones. The flat smooth plate allows membrane slippage and tearing along the fastener shank as shown in Figure 14 (left) even at low wind uplift pressures. At high wind uplift pressures, the barbed plate bends due to the membrane billowing and loses its clamping force; the membrane is stretched along the deformed plate portion and results in the membrane being torn as shown in Fig 14 (right). If the membrane tensile strength was lower than the wind uplift load, the membrane would stretch and tear around the fastener plates.

Fastener Plate/Membrane Engagement in PARS: Membrane is adhered to the insulation top. The insulation is secured to deck with fasteners and plates. Based on SIGDERS research, systems with a smooth surface insulation plate increased the wind uplift resistance by 50% than the systems with textured insulation plate. Figure 15 illustrates the failure modes for different insulation plate configurations. Textured hexagonal plate offer the required contact area with the membrane only through the outer and the middle rim of the plate. Smooth circular metal and plastic plates have a larger contact surface area to increase the bonding strength with the membrane.

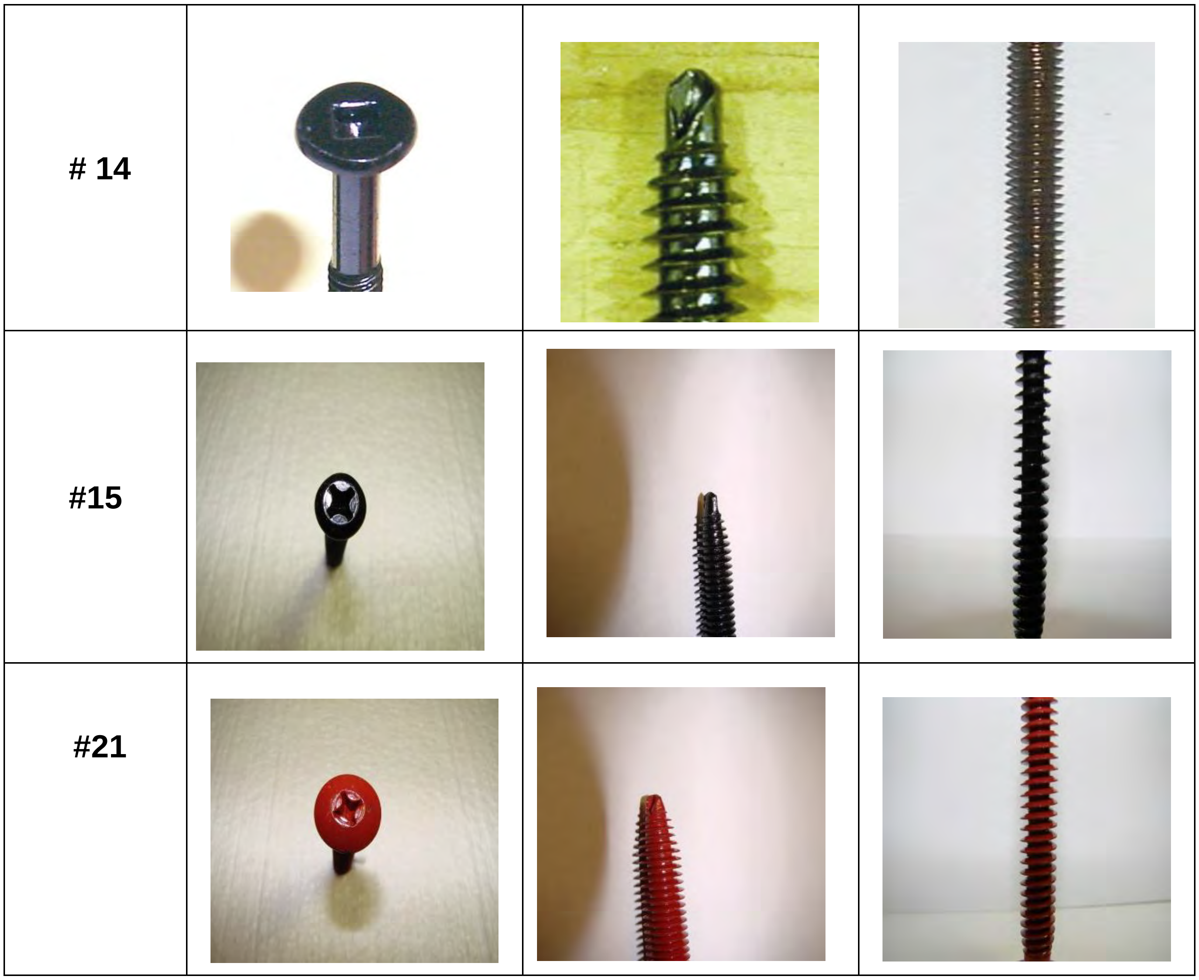


Figure 12: Physical characteristics of the fasteners

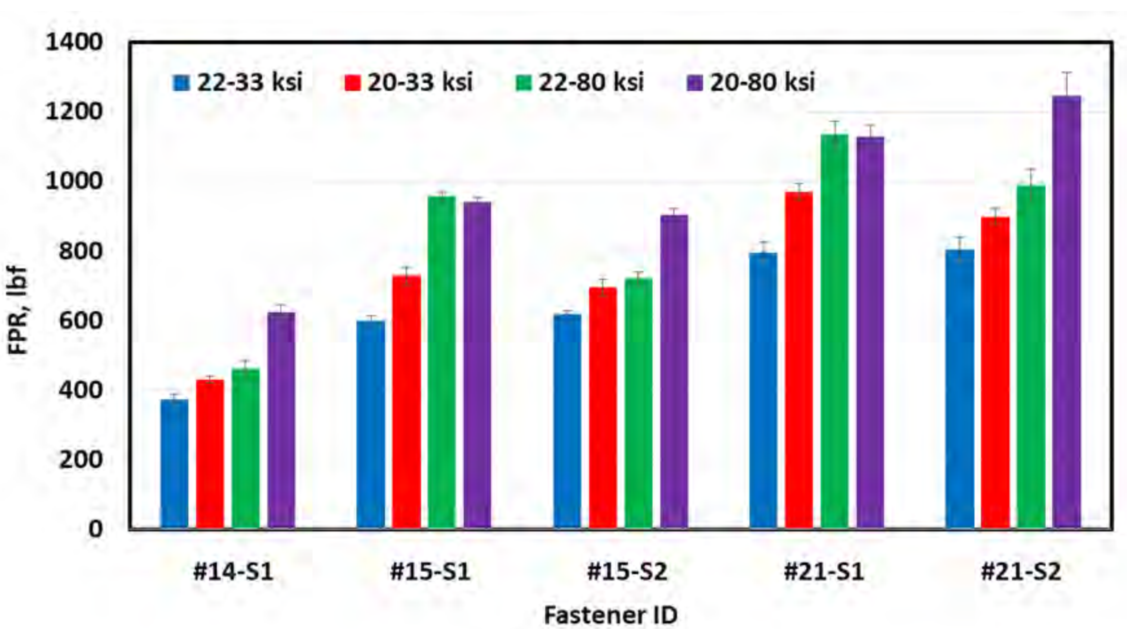


Figure 13: FPR for different deck types

Figure 14: Fastener plate/membrane engagement against wind uplift

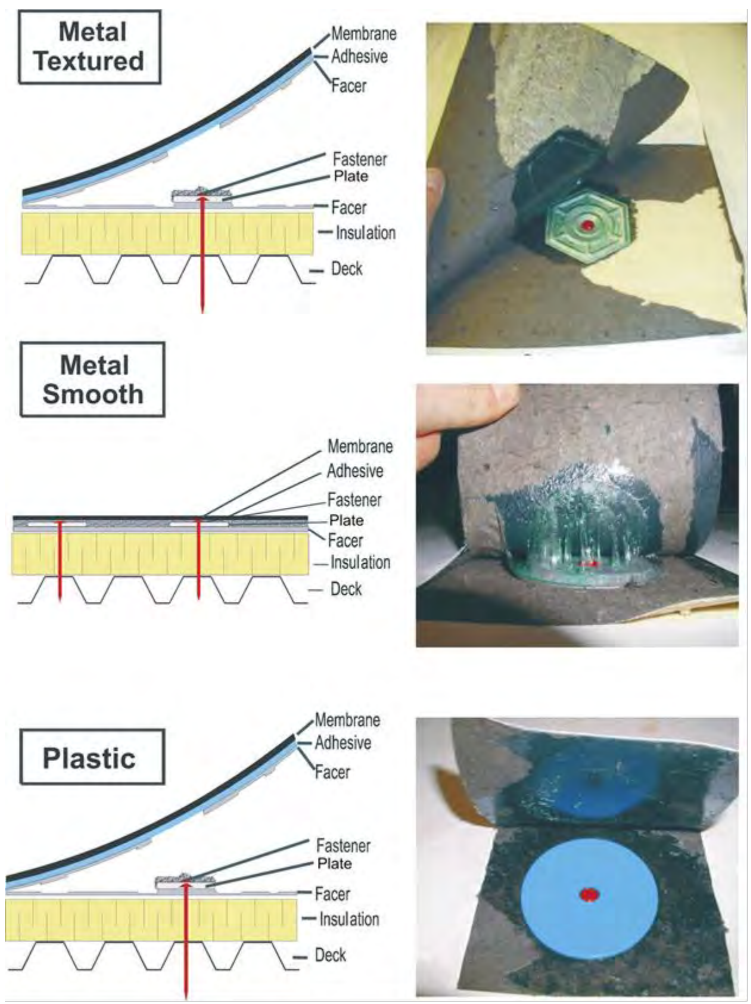


Figure 15: Failure modes observed with different insulation plate configurations

Q8: Role of Adhesive, Adhesive Quantity, and Curing Time?

Adhesive curing time is the key factor to determine the adhesive bond strength. Higher the adhesive bond strength the better the wind uplift resistance. The system failed below 2.87 kPa (60 psf) with 14 days curing time. The system had a wind uplift resistance of 3.59 kPa (75 psf) with 21 days curing time and had wind uplift resistance of 4.31 kPa (90 psf) 28 days curing time. The failure modes for 14, 21, and 28 days are adhesive failure between the cap and base sheet interface, a cohesive failure between cap and base sheets interface, and VB detached from deck interface respectively as shown in Figure 16.

Figure 16: Failure modes varied with curing time for AARS

Q9: Impact of Air Intrusion?

Air intrusion is defined as when the conditioned indoor air enters into the building envelope assembly and cannot escape to the exterior environment with a roof membrane acting as an air barrier. Air intrusion can be a major driving force for movement of moisture in the form of water vapour into MARS. Figure 17 showed the condensation happening below the roof membrane on one of the commercial roofs during field investigation. Limiting air intrusion is critical for good roof design practice, it helps increase wind uplift and thermal resistance, minimize moisture accumulation and condensation issues.

Based on SIGDERS' research, ASTM D7586 *"Standard Test Method for Quantification of Air Intrusion in Low Sloped Mechanically Attached Roofing Assemblies"* was developed in 2011. A series of tests were carried out by the SIGDERS consortium to quantify air intrusion rate for MARS. The result showed the system with VB decreased the air intrusion volume by 50%-80%

depending on the bubble pressure, membrane deflection, and the volume change as shown in Figure 18.

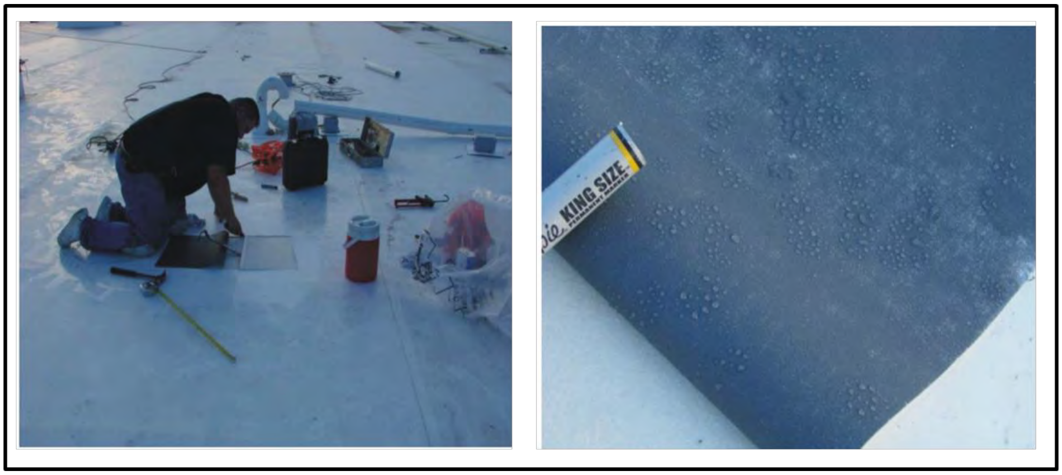


Figure 17: Condensation below the roof membrane

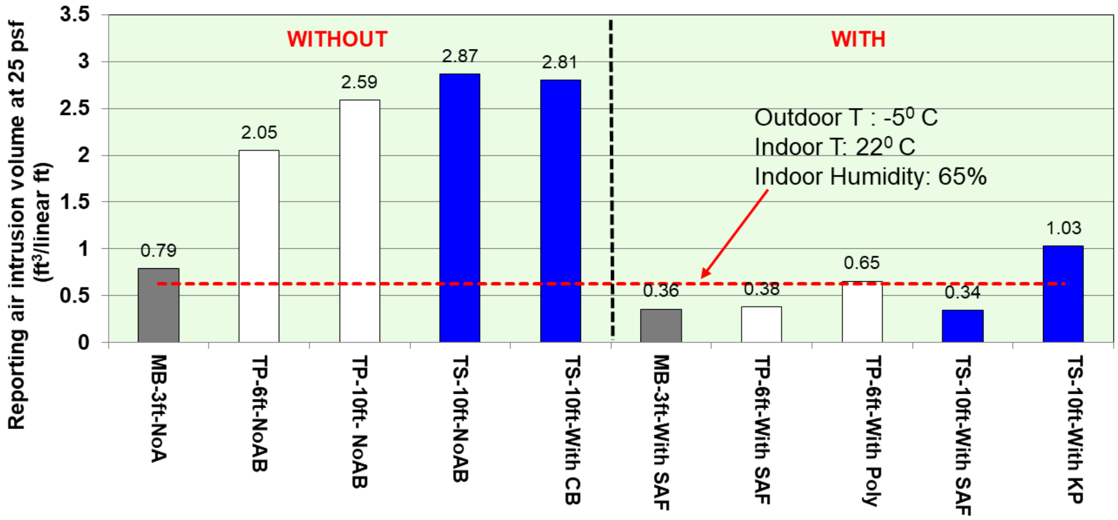


Figure 18: Air intrusion volume with and without the VB

Q10: What is rational analysis?

ANSI/SPRI WD-1 "*Wind Design Standard Practice for Roofing Assemblies*" provides an enhancement method on how to design the perimeter and corner area based on the tested wind uplift resistance with field configurations. SIGDERS is in the process of incorporating this analysis into Wind RCI for the benefit of the roofing community.

Top 10 Questions & Answers on CSA A123.21-2020

Standard Test Method for the Dynamic Wind Uplift Resistance of Membrane-Roofing Systems

Q1: What is the CSA A123.21?

The Canadian model code NBCC specifies wind load requirements to design of roof assemblies. To comply with the NBCC, the CSA A123.21 standard provides test requirements for resistance evaluation. Tested resistance should be equal to or greater than the design load. First published in 2004, CSA A123.21 subsequently revised/edited in 2010, 2014 and latest edition is being published in 2020. The R&D for the standard is being developed by the National Research Council Canada (NRCC) industry-based Consortium, *"Special Interest Group for Dynamic Evaluation of Roofing Systems (**SIGDERS**)".*

Q2: What type of roofing systems are addressed under this standard?

The roofing system is consists of a deck and roofing membrane. It may include components such as vapour barrier or retarders, insulation, cover board, etc. The standard is applicable to low slope membrane roofing systems which fall one of three categories, each of which as describes the way the roof system is secured to the deck/structure as below:

Mechanically Attached Roofing System (MARS): a system in which the roofing membrane is intermittently attached to the deck using fasteners as shown in Figure 1.

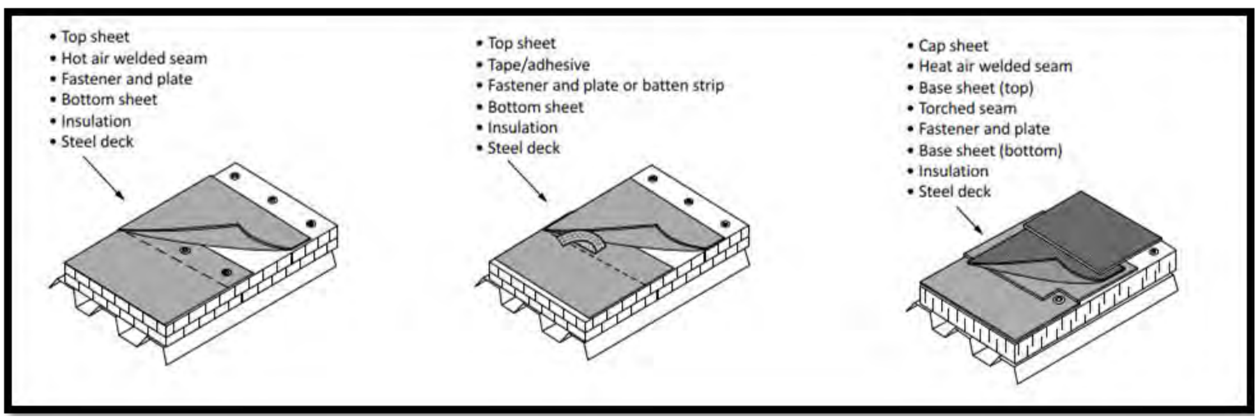


Figure 1: Typical Component Arrangement of MARS

Partially Attached (hybrid) Membrane Roofing System (PARS): a system in which the roof membrane is bonded to the substrate using adhesives and minimum of one component below the membrane is intermittently attached to supporting structure using fasteners as shown in Figure 2.

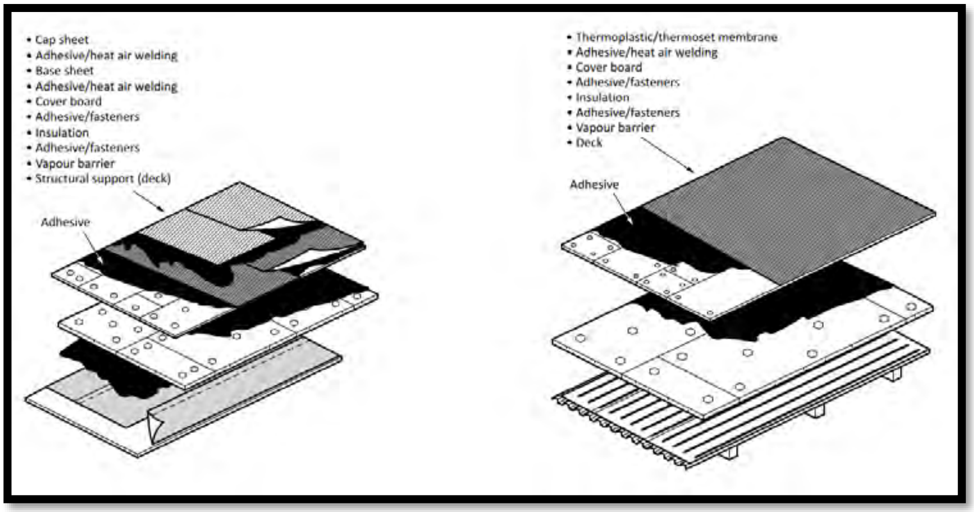


Figure 2: Typical Component Arrangement of PARS

Adhesive Applied Membrane Roofing System (AARS): a system in which the roof membrane is bonded to the substrate using adhesives and all the other components below roofing membrane are adhered using adhesives as shown in Figure 3.

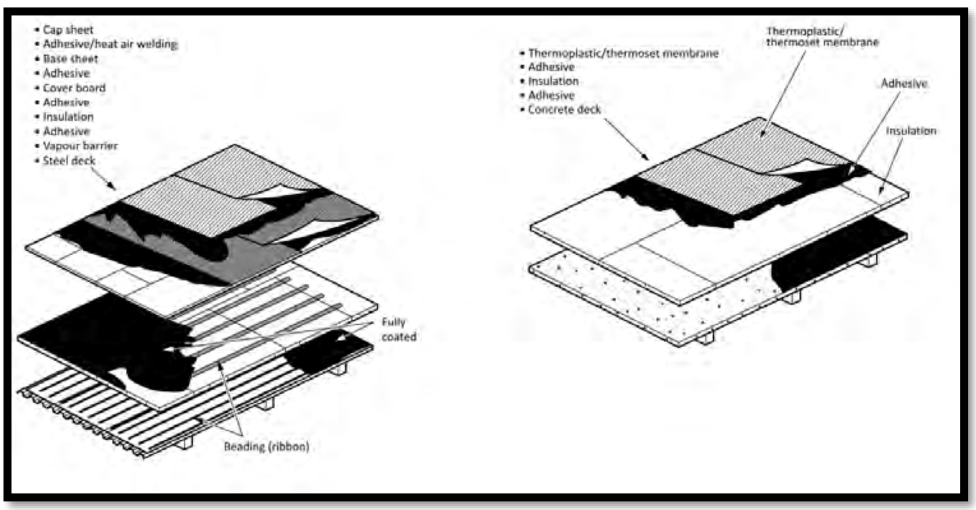


Figure 3: Typical Component Arrangement of AARS

Q3: How the CSA A123.21 is codified?

NBCC 2015 (Section 5.2.2.2) specifies the wind uplift resistance of the membrane roofing assemblies shall be determined in accordance with the requirement of CSA A123.21 as shown in Figure 4.

> **5.2.2.2. Determination of Wind Load**
> (See Note A-5.2.2.2.)
>
> **1)** This Article applies to the determination of wind load to be used in the design of materials, components and assemblies, including their connections, that separate dissimilar environments or are exposed to the exterior, where these are
> a) subject to wind load, and
> b) required to be designed to resist wind load.
>
> **2)** Except as provided in Sentence (3), the wind load referred to in Sentence (1) shall be 100% of the specified wind load determined in accordance with Article 4.1.7.1.
>
> **3)** Where it can be shown by test or analysis that a material, component, assembly or connection referred to in Sentence (1) will be subject to less than 100% of the specified wind load, the wind load referred to in Sentence (1) shall be not less than the load determined by test or analysis.
>
> **4)** Except as provided in Sentence (5), the wind uplift resistance of membrane roofing assemblies shall be determined in accordance with the requirements of CAN/CSA-A123.21, "Dynamic Wind Uplift Resistance of Membrane-Roofing Systems." (See Note A-5.2.2.2.(4).)
>
> **5)** Membrane roofing assemblies with proven past performance for the anticipated wind loads need not comply with Sentence (4). (See Note A-5.1.4.1.(5).)

Figure 4: CSA A123.21 provision in the NBCC 2015

Q4: What are major revisions in the CSA A123.21-2020 edition?

In addition to some editorials and inclusion of the updated referenced standards, there are four major revisions in the CSA A123.21-2020 as follows:

1: To align with, the Load Resistance Factor Design (LRFD) is introduced.

2: To minimize uncertainty in the PARS and AARS test termination, quantifiable failure criteria is presented.

3: To expand test data, component swap flow diagrams are developed.

4: To ensure uniformity and consistency among test labs when performing the CSA A123.21 test, guidelines are presented.

Q5: What is the LRFD and resistance factor?

In the LRFD, the design load is multiplied by a load factor which is greater than 1.0 to account for the uncertainties in the load determination. To obtain wind uplift resistance, the system capacity is multiplied with resistance factor. The resistance factor is less than one. NBCC provides the following guidance for the determination of the resistance factor, *"NBCC 2015, section 4.1.3.2 specifies the definition of resistance factor, ϕ, is a factor applied to a specified material property or to the resistance of a member, connection or structure, and that, for the limit state under consideration, takes into account the variability of dimensions and material properties, workmanship, type of failure and uncertainty in the prediction of resistance".*

SIGDERS performed extensive data analysis using the existing experimental data base which had over 8000 tested system. To calibrate the uncertainness involved in the test data, probabilistic approaches with varying reliability index were used. In consultation with SIGDERS's membership, a 95% reliability was selected for the determination of the resistance factor. Additional details are reported by Baskaran et al (2018), *"Climate Change Adaptation Technologies for Roofing"* Proceedings of the IIBEC international Conference, Houston, TX.

Q6: What is the resistance factor for roofing system to comply with the NBCC?

To determine the resistance factor, the CSA A123.21-20 provides two options:

1. When the tested sustained pressure is higher than 11.5 kPa (240 psf), a minimum of 3 test data points is needed to determine the resistance factor (*refer the CSA A123.24,"Standard test method for wind resistance of modular vegetated roof assembly"*).
2. When the tested sustained pressure is less than or equal to 11.5 kPa (240 psf), a maximum resistance factor of 0.65 can be applied or Option 1 can be used.

These options are explained via the following numerical examples.

Example 1: The manufacturer/ proponent/ client (MPC) has a tested system with sustained pressure 8.62 Kpa (180 psf).

In this scenario**,** the MPC decides to use resistance factor of 0.65

$$\text{Wind uplift resistance, } R = P_s \times \phi$$
$$\text{R} = 8.62\ kPa \times 0.65$$
$$\text{R} = 5.60\ kPa\ (117\ psf)$$

If the MPC decides to test 3 specimens, then

$$R = 8.38\ kPa \times 0.80 = 6.70\ kPa\ (140\ psf)$$

Refer Annex 1 for the determination of 0.80.

Example 2: The MPC has a tested system with sustained pressure 13.4 Kpa (280 psf). Since the sustained pressure is above 11.5 kPa (240 psf), the resistance factor determination required 3 test data points and the procedure shown in the Annex 1 should be followed.

Q7: Why can't an MPC use 0.65 as resistance factors for systems above 240 psf?

As discussed in Q5, the resistance factor 0.65 was calibrated with the existing experimental data base of the previously tested systems. The data base had limited number of data points to apply probabilistic methods to statically calibrate a resistance factor for system above 240 psf. Moreover, the SIGDERS professional judgment proposed a minimum 3 specimens test approach to reduce the uncertainty risk. This proposal is in consistent with the other roofing industry practices *(refer the American Iron and Steel Institute, "A design guide for standing seam roof panels CF00-1").*

Q8: What are the new refined failure criteria to terminate a test?

Variations existed among the testing labs in terminating the AARS and PARS tests. To address this industry concern, the CSA A123.21-2020 provides quantifiable parameters as follows:

- When the delamination area of a single blister exceeds 10 ft^2 or 10% of the test specimen area or the delamination area of multiple blisters exceeds 20% of the test specimen area.
- When the total length of cracks and creases in the insulation or cover board exceed the minimum dimension of the board

Q9: How is system equivalence achieved?

CSA A123.21-20 provides three component swap flow diagrams respectively for MARS, PARS, and AARS. Each component swap flow diagram specifies small scale test that needs to be done before alternate component can be swapped to grant the same sustained pressure as the tested system. An example is shown in the Annex 2.

Q10: How are test labs calibrated, to ensure uniformity and consistency among laboratories when various performing CSA A123.21 test?

Several North American Labs are claiming that CSA A123.21 tests can be performed. In order to create uniformity and consistency for the interpolation of the standard, SIGDERS created guidelines for the calibration requirements. This process can be done in accordance to the," *ISO/IEC 17025; General Requirements for the Competence of Testing and Calibration Laboratories*". To ascertain the test accuracy and to maintain the level of confidence via statistical variation, mainly two requirements, namely, accuracy of the simulated pressure and ability to maintain the gust durations requirements should be compared and validated.

ANNEX 1

If the MPC decides to determine the resistance factor based on CSA A123.24, then 3 or more identical specimens need to be tested.

Step 1: For example, the 3 tested specimens with same components, same roof applicator and same construction details has the following sustained pressures:

Specimen 1 sustained pressure, $P_{s1} = 8.62\ kPa\ (180\ psf)$
Specimen 2 sustained pressure, $P_{s2} = 7.90\ kPa\ (165\ psf)$
Specimen 3 sustained pressure, $P_{s3} = 8.62\ kPa\ (180\ psf)$

Step 2: Calculate coefficient of Variation, COV

$$P_{s,average} = 8.38\ kPa\ (175\ psf)$$

Standard Deviation $= 0.3394$

Coefficient of Variation $= 4.1\%$

Step 3: COV must be less than or equal to 15%. If COV is greater than 15%, data from additional specimens are needed to repeat the Step 2.

Step 4: Calculate resistance factor, ϕ

Resistance factor, $\phi = 1.54e^{-2.5\sqrt{0.06+5.7\ COV^2}}$

$= 1.54e^{-2.5\sqrt{0.06+5.7\ (0.041)^2}} \quad = 0.80$

Step 5: Wind uplift resistance, $R = \ P_{s,average} \times \phi$

$= 8.38\ kPa \times\ 0.80 = 6.70\ kPa\ (140\ psf)$

ANNEX 2

Scenario 1: A MPC tested a MARS system (labelled MARS-A) which sustained 4.31 kPa (90 psf). The MPC plans to install MARS-A as tested, but replace the tested base sheet with one having a different thickness. How will the MPC know if the new system (labelled MARS-B) can achieve the same rating as MARS-A without performing a new full system test?

Via small scale testing, base sheet tensile strength is determined according to ASTM D5147; MARS-A and MARS-B achieve ASTM test values of 14 KN/m (80 lbf/in) and is 15 KN/m (86 lbf/in), respectively. Based on the equivalence flow chart diagram (Figure 5), then, MARS-B is granted a rating of 4.31 kPa (90 psf) since its base sheet tensile strength is higher than MARS-A.

Scenario 2: The MPC plans to install the tested system MARS-A as tested, but replace the vapour barrier with a different source (resulting in a new system, MARC-C). How will the MPC know if the system (MARS-C) can achieve the same rating as MARS-A without performing a new full system test?

Via small scale testing, the air permeability is determined according to ASTM E2178; MARS-A and MARS-C achieve ASTM test values of 0.0005 $L/s/m^2$ (0.0001 cfm/ft^2) and is 0.0015 $L/s/m^2$ (0.0003 cfm/ft^2), respectively. Since the swapped component archieves less resistance to air movement it will adversely affect the wind uplift rating. Based on the equivalence flow chart diagram (Figure 5), MARS-C will have different wind uplift rating and hence a new CSA A123.21 test is needed.

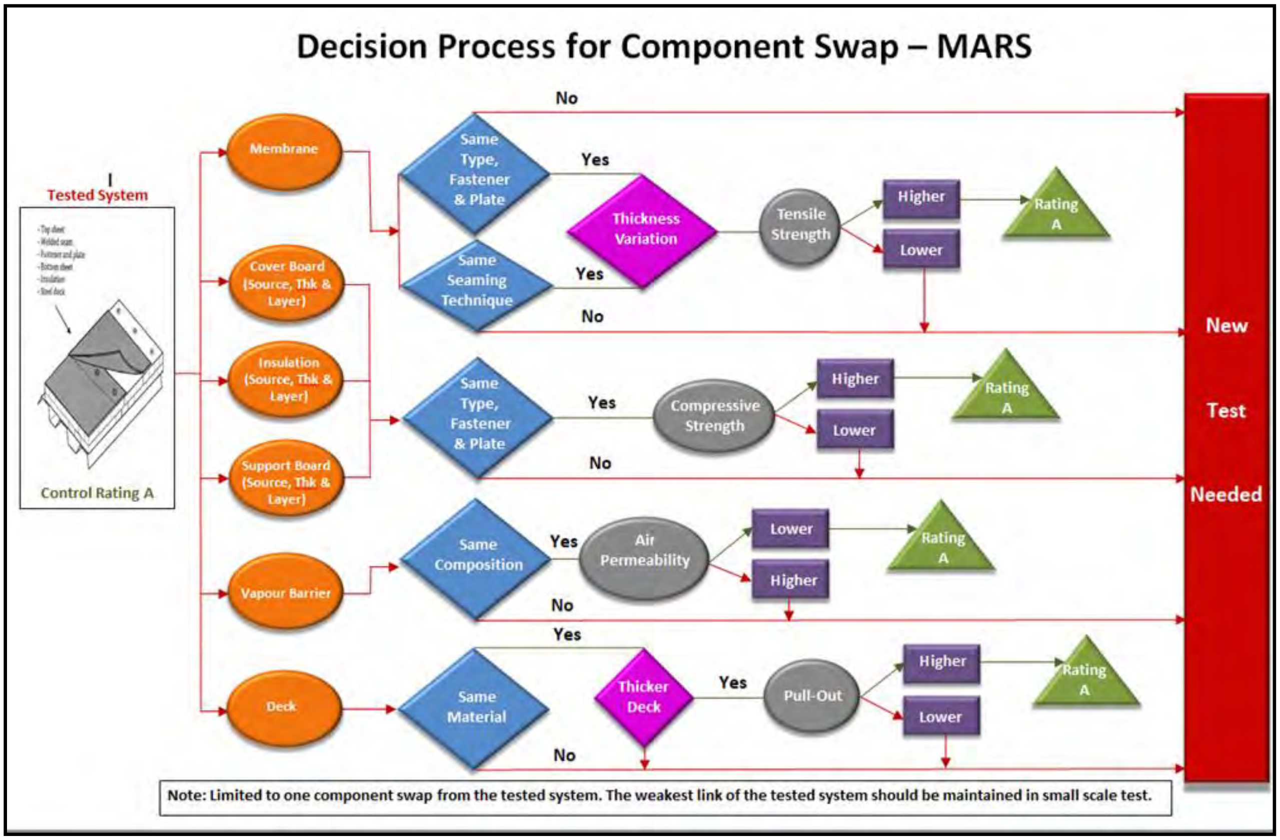


Figure 5: Equivalence Flow Chart for MARS

Guidelines for Alterations to Tested Mechanically Attached Membrane Roofing System (MARS)

Background

The following guidelines for the *Mechanically Attached Membrane Roofing System (MARS)* were developed based on extensive SIGDERS consortia R&D efforts. These were approved by the membership for Tech transfer. This will be presented to the CSA A123 Roofing Committee for possible inclusion into the CSA A123.21.

Definition

Tested System (TS): A system that was constructed, conditioned and tested in accordance to the CSA A123.21.

Altered System (AS): A system that is undergoing alteration (altering or adding or removing a component) from the TS.

Tested Factored Wind Uplift Resistance (TWR): Resistance of the TS derived as per the Annex H of the CSA A123.21-20.

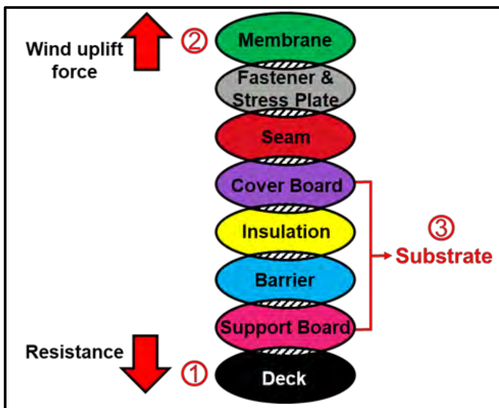
Guidelines

TWR remains equal for alterations to the

- ❑ TS's metal deck with a higher yield strength and thicker gauge deck.
- ❑ TS with a thicker and same family (reinforcement and composition) membrane.
- ❑ TS without/higher permeability Vapor barrier with/lower permeability Vapor barrier.
- ❑ TS by adding a substrate board immediately above the deck.

To obtain equal TWR for the AS, small scale testing shall be carried out as per the following standards. Small scale test data, after statistical validation, shall demonstrate higher or equal properties of:

- ❑ Pullout resistance for alterations to the fasteners
- ❑ Pull through resistance for alterations to membrane stress plate.
- ❑ Pull through resistance of alterations to substrates or insulation stress plate.



Alterations to the

- ❑ **Membrane stress plate**
  (***Pull through - ANSI/SPRI/FM MPO-1***)
- ❑ **Substrates or insulations stress plate**
  (***Pull through - ANSI/SPRI BPT-1***)
- ❑ **Fasteners with Deck**
  (***Pull out - ANSI/SPRI FX-1 2021***)