ANSI/SPRI WD-1

Wind Design Standard Practice for Roofing Assemblies

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1 Introduction

This Wind Design Standard Practice provides general building design considerations as well as a methodology for selecting an appropriate roofing system assembly to meet the building's calculated rooftop design wind uplift pressures. This document is appropriate for non-ballasted Built-Up, Modified Bitumen, and Single-Ply roofing system assemblies installed over any type of roof deck. (Refer to the Related Reference Documents on page 16, item 2, for the single-ply ballasted roofing system design standard reference).

This Standard Practice has been written specifically for use in North America, but it is also suitable for use by other countries utilizing the project prescribed jurisdictional wind design and wind uplift testing standards.

A Commentary section is provided at the end of this document to offer explanatory and supplementary information designed to assist users in complying with this Standard Practice. The commentary is intended to create an understanding of the requirements through brief explanations of the reasoning employed in arriving at these requirements, or to provide other clarification.

This Wind Design Standard Practice shall be used in conjunction with the published installation instructions of the manufacturer or supplier of the specified roofing system assembly. This Standard Practice is applicable to new roofing projects, reroofing projects (removing the existing materials and replacing with new materials) and recovering projects (covering over the existing roofing materials with new materials).

This document does not address the wind uplift design of the structural deck.

2 Methodology

2.1 Rooftop wind uplift design pressures (design loads)

The design wind uplift pressures shall be calculated by the designer of record for the field, perimeter and corner areas of the roof in accordance with the ASCE 7 Standard as referenced in the local building code. There are three or four design areas depending on the ASCE 7 issuance year referenced. The areas are; 1′ (interior field), 1 (field), 2 (perimeter) and 3 (corner). Calculated design loads that are Ultimate Load values shall be converted to Allowable Loads when using this Standard Practice. The following equation shall be used to make this conversion:

$$\mathbf{L_d = \text{Ultimate Load (psf or kPa)} \times 0.6}$$

2.2 Determine the Tested Wind Uplift Load Capacity of the roofing system

The Tested Wind Uplift Load Capacity of a roofing system assembly shall be determined by testing in accordance with ANSI/FM 4474, UL 580, UL 1897 or CAN/ULC A123. Tested Uplift Load Capacity values are available from the roofing system assembly supplier through independent laboratory testing reports or evaluation reports, and from website listings that are developed and maintained by various independent testing/evaluation entities and laboratories.

2.3 Determine the Factored Tested Load Capacity

The Factored Tested Load Capacity **(L_t)** is determined by dividing the Tested Wind Uplift Load Capacity by a safety factor as specified by the designer of record. Refer to Commentary C to read a discussion on choosing a safety factor.

$$\mathbf{L_t = \text{Tested Wind Uplift Load Capacity} / \text{safety factor}}$$

2.4 Verify suitability of a roofing system assembly for a particular building

In order for a roofing system assembly to be considered for use, the Factored Tested Load Capacity (**L_t**) of that assembly must be greater than or equal to the calculated Wind Uplift Design Load (**L_d**) for the field area of the roof. This load comparison is to be made with zone 1 and not the zone 1′ area that has been included for the first time in ASCE 7-16. If **L_t** is less than **L_d** for the zone 1 area, the roofing system assembly shall not be used on that particular building.

When **L_t** is greater than or equal to **L_d** for the zone 1 area, the roofing system assembly, as tested, is suitable for use in the field zone 1 area of the roof. (The zone 1′ area is addressed in Section 2.4.1). In order to determine the appropriate assembly layout for the perimeter and corner areas of the roof, compare **L_t** to **L_d** for the perimeter and corner areas. When **L_t** meets or exceeds **L_d** for either of these areas, the roofing system assembly, as tested, is suitable for use in those respective areas.

When **L_t** is less than **L_d** for the perimeter and/or corner areas, one of the rational analysis methods described in Sections 2.5 and 2.6 of this document shall be used for enhancing the roofing system assembly in those areas.

2.4.1 Field Zone 1' Area

When the ASCE 7-16 Standard is used to determine design wind uplift pressures, a zone 1' will be identified for certain building configurations. When the 1' zone exists there are two options, one of which must be chosen, for selecting a roofing system assembly for that area. $\mathbf{L_d}$ for zone 1' will always be less than $\mathbf{L_d}$ for zone 1. Therefore, one option is to use the roofing system assembly chosen for zone 1 in the zone 1' area. The second option is to choose a different roofing system assembly in which $\mathbf{L_t}$ for that assembly meets or exceeds $\mathbf{L_d}$ for the zone 1' area.

2.5 Rational Analysis Method—Adhered Membrane Roofing System Assemblies

2.5.1 Rational Analysis Criteria

This adhered membrane roofing system assembly rational analysis method shall only be used when *all* of the following criteria are met:

1. The Tested Wind Uplift Load Capacity (without consideration of any safety factor) must be greater than or equal to the calculated corner area wind uplift design load; and
2. The adhered membrane roofing system assembly utilizes either mechanical fasteners or ribbons/beads of an adhesive for insulation/substrate attachment; and
3. When mechanically fastened base or anchor sheets are utilized, the tested attachment pattern must be uniform or repeating such that the number of fasteners utilized per a specified square foot area can be determined.

This rational analysis method shall not be used for adhered roofing system assemblies when the insulation/substrate layer(s) is (are) attached using 100% coverage of any adhesive or hot asphalt. Adhesives applied in ribbons/beads spaced 4 in. or less on center are considered to constitute 100% coverage.

2.5.1.1 Rational Analysis Method—Adhered Membrane with Mechanically Attached Insulation/Substrates

For insulation/substrates attached with mechanical fasteners, the increased number of fasteners ($\mathbf{F_n}$) needed to meet the calculated design wind uplift load(s) shall be determined using the following equation: $\mathbf{F_n = (F_t \times L_d) / L_t}$

Where: $\mathbf{F_n}$ is the number of fasteners needed to meet the calculated design load.

$\mathbf{F_t}$ is the number of fasteners used to achieve the tested load capacity.

$\mathbf{L_d}$ is the calculated design load for the perimeter or corner area of a roof, psf (kPa).

$\mathbf{L_t}$ is the Factored Tested Load Capacity, psf (kPa).

Refer to Commentary A for a practical example of rational analysis for an adhered roofing system assembly utilizing mechanically attached insulation/substrate.

2.5.1.2 Rational Analysis Method—Adhered Membrane with Ribbon/Bead Adhesive Attached Insulation/Substrates

For insulation/substrates attached with ribbons/beads of an adhesive, the reduced ribbon/bead spacing ($\mathbf{R_n}$) needed to meet the calculated design wind uplift load(s) shall be determined using the following equation:
$\mathbf{R_n = R_t / (L_d / L_t)}$

Where: $\mathbf{R_n}$ is the ribbon/bead spacing needed to meet the calculated design load, inches (cm).

$\mathbf{R_t}$ is the ribbon/bead spacing used to achieve the tested load capacity, inches (cm).

$\mathbf{L_d}$ is the calculated design load for the perimeter or corner area of a roof, psf (kPa).

$\mathbf{L_t}$ is the Factored Tested Load Capacity, psf (kPa).

Note: When ribbon/bead-attached insulation/substrate is applied directly to a fluted steel deck, the ribbon/bead spacing will be dictated by the center-to-center spacing of the top (high) flutes of the steel deck. The rationalized ribbon/bead spacing shall be rounded down (when necessary) to coincide with a top (high) flute spacing. If the rationalized ribbon/bead spacing is less than the center-to-center spacing of the top (high) flutes of a steel deck, ribbon/bead attachment of the insulation in that area shall not be acceptable.

Refer to Commentary A for a practical example of rational analysis for an adhered roofing system assembly utilizing ribbon/bead-attached insulation/substrate.

Cautionary Note: The $\mathbf{F_n}$ and $\mathbf{R_n}$ equations shall only be used to increase the number of fasteners or decrease the spacing of ribbons/beads of adhesive needed in the perimeter and corner areas. These equations shall not be used to rationalize backwards and reduce the number of fasteners or increase the spacing of ribbons/beads of adhesive used in the field of the roof.

2.6 Rational Analysis Method—Mechanically Fastened Membrane Roofing System Assemblies

For mechanically fastened membrane roofing system assemblies, the influence area per fastener for the tested assembly ($\mathbf{IA_t}$) shall be determined by multiplying the row spacing by the fastener spacing (along the row). For spot attached systems, multiply the distance between the attachment locations in each direction (2 ft. × 2 ft. [60 cm × 60 cm], 2 ft. × 3 ft. [60 cm × 90 cm], etc.). This gives the number of square feet (square centimeters) of membrane held in place by one fastener. The influence area needed to meet the calculated design wind uplift load(s) shall be determined using the following equation:

$$\mathbf{IA_n = (L_t \times IA_t) / L_d}$$

Where: $\mathbf{IA_n}$ is the area of membrane needed to be held in place by one fastener to meet the design load, ft^2 (cm^2).

$\mathbf{IA_t}$ is the area of membrane held in place by one fastener for the tested assembly, ft^2 (cm^2).

$\mathbf{L_d}$ is the calculated design wind uplift load for the perimeter or corner area of a roof, psf (kPa).

$\mathbf{L_t}$ is the Factored Tested Load Capacity, psf (kPa).

The fastener row spacing or the spot attachment grid spacing of the roofing system assembly being considered shall be reduced so the ft^2 (cm^2) area of membrane held in place by each fastener does not exceed $\mathbf{IA_n}$. For linearly-attached assemblies, the fastener spacing (along the row) shall be the same as was tested.

Refer to Commentary A for practical examples of rational analysis for membrane attachment on mechanically fastened membrane roofing system assemblies.

Cautionary Note: For mechanically fastened membrane roofing system assemblies with linear (row) attachment, only the spacing between fastener rows shall be reduced to meet $\mathbf{IA_n}$. This rational analysis method shall not be used to reduce the spacing between fasteners along the row (12 in. to 6 in. [30.5 cm to 15 cm], for example) in place of reducing the spacing between fastener rows. In addition, this rational analysis method shall not be used to rationalize backwards and increase the spacing between fasteners along the row (12 in. to 18 in. [30.5 cm to 46 cm], for example) or increase the spacing between fastener rows (8 ft. to 10 ft. [2.4 m to 3.0 m], for example).

Commentary Section

This Commentary is not a part of this standard. It consists of explanatory and supplementary material designed to assist users in complying with the requirements. It is intended to create an understanding of the requirements through brief explanations of the reasoning employed in arriving at these requirements or to provide other clarifications. It therefore has not been processed in accordance with ANSI Essential Requirements and may contain material that has not been subjected to public review or a consensus process. Thus, it does not contain requirements necessary for conformance with the standard.

The sections of the Commentary are numbered to correspond to the sections of the standard to which they refer. Since it is not necessary to have supplementary material for every section in the standard itself, there may be gaps in the numbering in the Commentary.

Commentary A

Practical Examples
Roofing System Assembly Selection

Example Building #1—Ultimate Design Uplift Loads

A building with a fluted steel deck has the following calculated ultimate design wind uplift loads determined by using the ASCE 7-16 Standard. The ultimate design loads need to be converted to allowable design loads. A safety factor of 2.0 is being used along with the allowable design loads for this example.

Calculated Ultimate Design Loads

- Interior field area (zone 1’) = -21.1 psf (-1.0 kPa)
- Field area (zone 1) = -36.8 psf (-1.8 kPa)
- Perimeter area (zone 2) = -48.5 psf (-2.3 kPa)
- Corner area (zone 3) = -103.8 psf (-5.0 kPa)

Convert Ultimate Design Loads to Allowable Design Loads using the equation:
$\mathbf{L_d}$ = Ultimate Load (psf or kPa) × 0.6

Converted Allowable Design Loads ($\mathbf{L_d}$)

- Interior field area (zone 1') = -12.7 psf (-0.6 kPa)
- Field area (zone 1) = 22.1 psf (-1.1 kPa)
- Perimeter area (zone 2) = -29.1 psf (-1.4 kPa)
- Corner area (zone 3) = -62.3 psf (-3.0 kPa)

Task
Evaluate the potential use of an adhered roofing system assembly for this building using the methodology outlined in Section 2 of this Standard Practice.

Adhered Membrane Assembly

The recognized listing for the adhered membrane roofing system assembly being considered for this building was tested to a maximum Wind Uplift Load Capacity of -60 psf (-2.9 kPa). The 4 ft. × 8 ft. (1.2 m × 2.4 m) insulation boards were attached using 8 fasteners ($\mathbf{F_t}$) per board.

Determine the Factored Tested Load Capacity ($\mathbf{L_t}$)

Apply the 2.0 safety factor to the -60 psf (-2.9 kPa) Tested Wind Uplift Load Capacity to determine the Factored Tested Load Capacity ($\mathbf{L_t}$):

$\mathbf{L_t}$ = 60 psf / 2.0 = **-30.0 psf**

or

$\mathbf{L_t}$ = -2.9 kPa / 2.0 = **-1.5 kPa**

Verify Roofing System Suitability

In order to determine if this adhered membrane roofing system assembly is suitable for use, compare the Factored Tested Load Capacity (**L_t**) to the calculated field area (zone 1) wind uplift design load. Since **L_t** (-30 psf or -1.5 kPa) exceeds the design load for zone 1 (-22.1 psf or -1.1 kPa), the roofing system assembly, as tested, is suitable for use in the field area of the roof (both zone 1 and zone 1').

Perimeter & Corner Layout Evaluation

L_t (-30 psf, -1.5 kPa) exceeds the calculated wind uplift design load for the perimeter (-29.1 psf, -1.4 kPa) area of the roof, but **L_t** is less than the corner area design load (-39.7 psf, -1.9 kPa). Consequently, the as-tested assembly is suitable for use in the perimeter area but not in the corner area. To determine if rational analysis is acceptable for defining the assembly layout for the corner area, check the requirements of Section 2.5.1 of this document.

1. Tested Wind Uplift Load Capacity is greater than the calculated corner area design load X
2. Roofing system assembly utilizes mechanical fasteners for insulation attachment √

Since **L_t** is less than the corner area design load, rational analysis is not permissible for the corner area. An alternate roofing system assembly with an **L_t** greater than the corner area design load will need to be selected for use in the corner area. However, as an option, this alternate roofing system assembly could be used over the entire roof.

Ultimate Wind Uplift Design Load Notes

The use of ultimate wind uplift design loads (without conversion to allowable design loads) is possible with this document if required by the designer of record. The methodology outlined in Section 2 of this document will still be applicable.

When calculating wind uplift design loads utilizing either ultimate wind speed maps (as contained in ASCE 7-16) or using a safety factor of 1.0 with allowable loads, rational analysis for the perimeter and corner areas for adhered membrane roofing system assemblies will not be possible. The reason is that the 1.0 safety factor is contained in the Rational Analysis rule: *"The Tested Wind Uplift Load Capacity (without consideration of any safety factor) must be greater than or equal to the calculated corner area wind uplift design load".* In this instance multiple assemblies can be used in the field, perimeter and corner areas (to meet the specific zone uplift pressures) or one assembly (that meets the corner design load) can used across the entire roof. This "lesson learned" applies only to adhered membrane roofing system assemblies. The Rational Analysis rules are different for mechanically fastened membrane roofing system assemblies.

Example Building #2 – Allowable Design Uplift Loads
(Used for the following 4 examples)

A building with a fluted steel deck has the following calculated allowable design wind uplift loads determined by using the ASCE Standard (pre 7-16 edition, therefore no 1' zone). A safety factor of 2.0 is being used along with the allowable design loads for this example.

Calculated design wind uplift loads:

- Field area = -25.6 psf (-1.2 kPa)
- Perimeter area = -42.9 psf (-2.1 kPa)
- Corner area = -64.6 psf (-3.1 kPa)

Note: The ASCE 7-10 and earlier Standards do not include a zone 1' area.

Task

Evaluate the potential use of four roofing system assemblies for this building using the methodology outlined in Section 2 of this Standard Practice. The roofing system assemblies to be evaluated are as follows:

Assembly 1—Adhered membrane over insulation attached with mechanical fasteners.

Assembly 2—Adhered membrane over insulation attached with ribbons/beads of a cold adhesive.

Assembly 3—Linearly-attached mechanically fastened membrane.

Assembly 4—Induction-Welded (grid-attached) mechanically fastened membrane.

Example Building # 2—Assembly 1
Adhered Membrane over Insulation Attached with Mechanical Fasteners

The recognized listing for the second adhered membrane roofing system assembly being considered for this building was tested to a maximum Wind Uplift Load Capacity of -90 psf (-4.3 kPa). The 4 ft. × 8 ft. (1.2 m × 2.4 m) insulation boards were attached using 16 fasteners (**F_t**) per board.

Determine the Factored Tested Load Capacity (L_t)

Apply the 2.0 safety factor to the -90 psf (-4.3 kPa) Tested Wind Uplift Load Capacity to determine the Factored Tested Load Capacity (**L_t**):

L_t = -90 psf / 2.0 = **-45.0 psf**

or

L_t = -4.3 kPa / 2.0 = **-2.2 kPa**

Verify Roofing System Suitability

In order to determine if this adhered membrane roofing system assembly is suitable for use, compare the Factored Tested Load Capacity (**L_t**) to the calculated field area wind uplift design load. Since **L_t** (-45 psf or -2.2 kPa) exceeds the design load for the field of the roof (-25.6 psf or -1.2 kPa), the roofing system assembly, as tested, is suitable for use in the field area of the roof.

Perimeter & Corner Layout Evaluation

L_t (-45 psf, -2.2 kPa) exceeds the calculated wind uplift design load for the perimeter (-42.9 psf, -2.1 kPa) area of the roof, but **L_t** is less than the corner area design load (-64.6 psf, -3.1 kPa). Consequently, the as-tested assembly is suitable for use in the perimeter area but not in the corner area. To determine if rational analysis is acceptable for defining the assembly layout for the corner area, check the requirements of Section 2.5.1 of this document.

1. Tested Wind Uplift Load Capacity is greater than the calculated corner area design load √
2. Roofing system assembly utilizes mechanical fasteners for insulation attachment √

Since the requirements of Section 2.5.1 are met, rational analysis is permissible. Note: If the Tested Wind Uplift Load Capacity was less than the corner design load, rational analysis would not be permissible. A higher rated roofing system assembly would need to be selected for use in the corner area, or for the entire roof.

Rational Analysis–Corner Area

To determine the number of fasteners (**F_n**) needed per insulation board for the corner areas of the roof, use the equation **$F_n = (F_t \times L_d) / L_t$**

Where: **F_n** is the number of fasteners per board needed to meet the calculated design load.

F_t is the number of fasteners per board used to achieve the tested load capacity.

L_d is the calculated design wind uplift load for the corner area of the roof, psf (kPa).

L_t is the Factored Tested Load Capacity, psf (kPa).

Corner Area

F_n = (16 fasteners × -64.6 psf) / -45 psf) = **23 fasteners per board**

or

F_n = (16 fasteners × -3.1 kPa) / -2.2 kPa) = **23 fasteners per board**

The final layout for this adhered membrane assembly scenario is to use 16 fasteners per 4 ft. × 8 ft. (1.2 m × 2.4 m) insulation board in the field and perimeter areas and 23 fasteners per board in the corner areas. The extra 7 fasteners added to the corner areas shall be evenly distributed (as best as possible) around the tested fastener layout pattern.

Example Building 2—Assembly 2
Adhered Membrane over Insulation Attached with Ribbons/Beads of a Cold Adhesive

An Evaluation Report listing for an adhered membrane roofing assembly identifies the Factored Tested Load Capacity (**L_t**) as being -37.5 psf (-1.8 kPa). The listing also indicates that testing was conducted using 4 ft. × 4 ft. (1.2 m × 1.2 m) insulation boards attached using ribbons/beads of adhesive spaced 12 in. (30.5 cm) on center (**R_t**). A safety factor of 2.0 was identified in the Evaluation Report as being used for determining **L_t**.

Determine the Tested Wind Uplift Load Capacity

Multiply the -37.5 psf (-1.8 kPa) Factored Tested Load Capacity (**L_t**) by the 2.0 safety factor to obtain the Tested Wind Uplift Load Capacity:

Tested Wind Uplift Load Capacity = 37.5 psf × 2.0 = **-75 psf**

or

Tested Wind Uplift Load Capacity = -1.8 kPa × 2.0= **-3.6 kPa**

Verify Roofing System Suitability

In order to determine if this adhered membrane roofing system assembly is suitable for use, compare the Factored Tested Load Capacity (**L_t**) to the calculated field area wind uplift design load. Since **L_t** (-37.5 psf or -1.8 kPa) exceeds the design load for the field of the roof (-25.6 psf or -1.2 kPa), the roofing system assembly, as tested, is suitable for use in the field area of the roof.

Perimeter & Corner Layout Evaluation

L_t (-37.5 psf or -1.8 kPa) is less than both the perimeter (-42.9 psf or -2.1 kPa) and corner (-64.6 psf or -3.1 kPa) area design loads. Consequently, the as-tested assembly is not suitable for use in the perimeter or corner areas. To determine if rational analysis is acceptable for defining the assembly layout for these areas, check the requirements of Section 2.5.1.2 of this document.

1. Tested Wind Uplift Load Capacity is greater than the calculated corner area design load √
2. Roofing system assembly utilizes mechanical fasteners for insulation attachment √

Since the requirements of Section 2.5.1 are met, rational analysis is permissible.

Note: If the Tested Wind Uplift Load Capacity was less than the corner design load, rational analysis would not be permissible. A higher rated roofing system assembly would need to be selected for use in the corner area, or for the entire roof.

Rational Analysis

To determine the reduced ribbon/bead spacing (**R_n**) for the perimeter and corner areas of the roof, use the equation **$R_n = R_t / (L_d / L_t)$**

Where: **R_n** is the ribbon/bead spacing needed to meet the design load, inches (cm).

R_t is the ribbon/bead spacing used to achieve the tested load capacity, inches (cm).

L_d is the calculated design wind uplift load for the perimeter/corner areas of the roof, psf (kPa).

L_t is the Factored Tested Load Capacity, psf (kPa).

Perimeter Area

R_n = 12 in./(-42.9 psf / -37.5 psf) = **10.5 in.** maximum on center spacing for ribbons/beads

or

R_n = 30.5 cm / (-2.1 kPa / -1.8 kPa) = **27 cm** maximum on center spacing for ribbons/beads

Corner Area

R_n = 12 in. / (-64.6 psf / -37.5 psf) = **7.0 in.** maximum on center spacing for ribbons/beads

or

R_n = 30.5 cm / (-3.1 kPa / -1.8 kPa) = **18 cm** maximum on center spacing for ribbons/beads

Since the steel deck flutes are spaced 6 in. (15 cm) on center, the perimeter and corner ribbons/bead spacing must be rounded down to 6 in. (15 cm) on center. Therefore, the final layout for this assembly scenario is to use ribbons/beads of adhesive spaced 12 in. (30.5 cm) on center for insulation attachment in the field of the roof and ribbons/

beads of adhesive spaced 6 in. (15 cm) on center for insulation attachment in the perimeter and corner areas. Note: If the deck had a smooth (non-fluted) top surface such as concrete, cementitious wood fiber, wood, etc., or if the adhesive was being used to attach multiple layers of insulation, the final layout for this assembly would be to use ribbons/beads of adhesive spaced a maximum of 12 in. (30.5 cm) on center in the field of the roof, 10.5 in. (27 cm) on center in the perimeter area and 7.0 in. (18 cm) on center in the corner areas.

Example Building 2—Assembly 3
Mechanically-Fastened Membrane Linearly-Attached Assembly

The recognized listing for this linearly-attached mechanically fastened roofing assembly being considered for this building was tested to a maximum Wind Uplift Load Capacity of -60 psf (-2.9 kPa). The assembly utilizes an 11.5 ft. (3.5 m) fastener row spacing with fasteners spaced 12 in. (30.5 cm/0.3 m) on center along the row.

Determine the Factored Tested Load Capacity (L_t)

Apply the 2.0 safety factor to the -60 psf (-2.9 kPa) Tested Wind Uplift Load Capacity to determine the Factored Tested Load Capacity (L_t):

L_t = -60 psf / 2.0 = **-30 psf**

or

L_t = -2.9 kPa / 2.0 = **-1.4 kPa**

Verify Roofing System Suitability

In order to determine if this mechanically fastened membrane roofing system assembly is suitable for use, compare the Factored Tested Load Capacity (L_t) to the calculated field area wind uplift design load. Since L_t (-30 psf or -1.4 kPa) exceeds the design load for the field of the roof (-25.6 psf or -1.2 kPa), the roofing system assembly, as tested, is suitable for use in the field area of the roof.

Perimeter & Corner Layout Evaluation

L_t (-30 psf or -1.4 kPa) is less than both the perimeter (-42.9 psf or -2.1 kPa) and corner (-64.6 psf or -3.1 kPa) area design loads. Consequently, the as-tested assembly is not suitable for use in the perimeter or corner areas. Use the rational analysis method referenced in Section 2.6 to determine the assembly layout for these two areas.

Rational Analysis

To determine the appropriate perimeter and corner row spacing, first calculate the influence area per fastener (IA_n) using the equation $IA_n = (L_t \times IA_t) / L_d$

Where: IA_n is the maximum area of membrane to be held in place by one fastener to meet the design load, ft² (m²).

IA_t is the area of membrane held in place by one fastener for the tested assembly, ft² (m²).

L_d is the calculated design load for the perimeter/corner area of the roof, psf (kPa).

L_t is the factored tested load capacity, psf (kPa).

IA_t = fastener row spacing times the fastener spacing along the row

IA_t = 11.5 ft. × 1.0 ft. = **11.5 ft² per fastener**

or

A_t = 3.5 m × 0.3 m = **1.1 m² per fastener**

Perimeter Area

IA_n = (-30 psf × 11.5 ft²) / -42.9 psf = **8.0 ft² maximum per fastener**

or

IA_n = (-1.4 kPa × 1.1 m²) / -2.1 kPa = **0.7 m² maximum per fastener**

Corner Area

IA_n = (-30 psf × 11.5 ft²) / -64.6 psf = **5.3 ft² maximum per fastener**

or

IA_n = (-1.4 kPa × 1.1 m²) / -3.1 kPa = **0.5 m² maximum per fastener**

The row spacing for the perimeter and corner areas shall be determined by dividing **IA_n** by the tested fastener spacing, as follows:

Perimeter Area

8.0 ft.^{2}/1.0 ft. = **8.0 ft. row spacing**

or

0.7 m^2/0.3 m = **2.4 m row spacing**

Corner Area

5.3 ft.^{2}/1.0 ft. = **5.3 ft. row spacing**

or

0.5 m^2/0.3 m = 1.6 m row spacing

There are two possible final layouts for this assembly scenario. The first possible layout is to use a maximum fastener row spacing of 11.5 ft. (3.5 m) in the field of the roof, maximum 8.0 ft. (2.4 m) in the perimeter areas and maximum 5.3 ft. (1.6 m) in the corner areas, all with fasteners spaced 12 in. (30.5 cm) on center along the row. The second possible layout is to use a maximum fastener row spacing of 11.5 ft. (3.5 m) in the field of the roof and a maximum 8.0 ft. (2.4 m) in the perimeter and corner areas. In this second layout however, the perimeter rows must extend into the corners from both directions, creating a cross-hatched fastening pattern.

Example Building # 2—Assembly 4
Induction-Welded (Grid-Attached) Membrane

The recognized listing for the induction-welded (grid-attached) roofing assembly being considered for this building was tested to a maximum Wind Uplift Load Capacity of -75 psf (-3.6 kPa) using a 2 ft. × 3 ft. (0.6 m × 0.9 m) grid membrane fastener spacing pattern. This grid pattern results in the use of 6 membrane fasteners per 4 ft. × 8 ft. (1.2 m × 2.4 m) insulation board.

Determine the Factored Tested Load Capacity (L_t)

Apply the 2.0 safety factor to the -75 psf (-3.6 kPa) Tested Wind Uplift Load Capacity to determine the Factored Tested Load Capacity (L_t):

L_t = -75 psf / 2.0 = **-37.5 psf**

or

L_t = -3.6 kPa / 2.0 = **-1.8 kPa**

Verify Roofing System Suitability

In order to determine if this mechanically fastened membrane roofing system assembly is suitable for use, compare the Factored Tested Load Capacity (L_t) to the calculated field area wind uplift design load. Since L_t (-37.5 psf or -1.8 kPa) exceeds the design load for the field of the roof (-25.6 psf or -1.2 kPa), the roofing system assembly, as tested, is suitable for use in the field area of the roof.

Perimeter & Corner Layout Evaluation

L_t (-37.5 psf or -1.8 kPa) is less than both the perimeter (-42.9 psf or -2.1 kPa) and corner (-64.6 psf or -3.1 kPa) area design loads. Consequently, the as-tested assembly is not suitable for use in the perimeter or corner areas. Use the rational analysis method referenced in Section 2.6 to determine the assembly layout for these two areas.

Rational Analysis

To determine the number of membrane fasteners (F_n) needed per insulation board for the perimeter and corner areas of the roof, use the equation $F_n = (F_t \times L_d) / L_t$.

Where: F_n is the number of fasteners per board needed to meet the calculated design load.

F_t is the number of fasteners per board used to achieve the tested load capacity.

L_d is the calculated design wind uplift load for the perimeter/corner area of the roof, psf (kPa).

L_t is the Factored Tested Load Capacity, psf (kPa).

Perimeter Area

F_n = (6 fasteners × -42.9 psf)/-37.5 psf = **7 fasteners per board**

or

F_n = (6 fasteners × -2.1 kPa) / -1.8 kPa = **7 fasteners per board**

Corner Area

F_n = (6 fasteners × -64.6 psf)/-37.5 psf = **11 fasteners per board**

or

F_n = (6 fasteners × -3.1 kPa) / -1.8 kPa = **11 fasteners per board**

The final layout for this assembly scenario is to use a minimum of 6 membrane fasteners per 4 ft. × 8 ft. (1.2 m × 2.4 m) insulation board in the field of the roof, 7 fasteners per board in the perimeter area and 11 fasteners per board in the corner areas. However, consideration should be given to using 8 membrane fasteners in the perimeter area and 12 in the corner areas. The extra fasteners will retain a grid-type pattern which will facilitate locating the fasteners after the membrane is installed, particularly if a membrane welding operation is involved. Retaining a grid-type pattern will also improve the finished appearance of the roof.

Commentary B

General Considerations

The following design and installation recommendations should be considered before starting a roofing project:

1. Consult with an engineer to ensure the roof deck is adequately secured to resist the wind uplift forces that will be imposed upon it by the installed roofing system assembly.
2. Conduct fastener pullout tests, where appropriate, to ensure the selected fastener/deck combination will provide adequate wind uplift resistance to the forces that will be imposed upon it by the installed roofing system assembly. This is particularly important for steel roof decks and for recover (covering over an existing roofing system assembly) applications. Pullout testing should be conducted in accordance with the ANSI/SPRI FX-1 Standard.
3. Mechanical fasteners used for insulation or membrane securement shall penetrate through the top flange of a steel deck.
4. Rows of mechanical fasteners, spaced greater than 3 ft. (0.9 m) apart, shall be installed perpendicular to the steel deck ribs to avoid overloading a single rib.
5. Ensure that all mechanical fasteners have the proper penetration into the roof deck. Typical fastener penetrations include: 3/4 in. (19 mm) for steel, 1 in. (25 mm) for wood and 1-1/4 in. (32 mm) for structural concrete. Consult with the roofing system supplier and the product listing for verification.
6. Install an edging or coping detail, where appropriate, that will meet the requirements of the SPRI/FM 4435/ES-1 Standard.
7. The use of the Rational Analysis Methods described in Sections 3.5 and 3.6 of this document may be affected by the test table size used to determine the tested wind uplift load capacity of a particular roofing system assembly. It is general industry practice that the following criteria be followed:
    a. **For adhered membrane roofing system assemblies:** The Tested Wind Uplift Load Capacity of the proposed adhered roofing system assembly should have been determined utilizing a test chamber of sufficient size to allow side-by-side positioning of a minimum of three full-size insulation/coverboard/substrate boards/panels on the test frame.
    b. **For linearly-attached mechanically fastened roofing system assemblies:** The tested wind uplift load capacity of the proposed linearly-attached (rows) mechanically fastened roofing system assembly should have been determined utilizing a test chamber of sufficient size such that the tested row spacing did not exceed one half of the table length. The minimum frame width should have been 8 ft. (2.4 m).
    c. **For spot-attached mechanically fastened roofing system assemblies:** The tested wind uplift load capacity of the proposed spot-attached mechanically fastened roofing system assembly should have been determined utilizing a test chamber of sufficient size to allow positioning of a minimum of nine attachment locations on the test frame. The minimum frame width should have been 8 ft. (2.4 m).

Commentary C

Safety Factor Discussion

A safety factor is not required by either the International Building Code or the ASCE 7 Standard but its use has historically been a common practice within the roofing industry. Determination for the need of a safety factor is the responsibility of the designer of record but typical values range between 1.0 and 2.0. Consideration should be given to using a safety factor of less than 2.0 when Ultimate Design Loads are used without conversion to Allowable Design Loads. Ultimate Design Load calculations have factors of safety inherently included in the wind speed maps making them more conservative than Allowable Design Load values and lessening the need for additional safety factors.

Some wind uplift website listings and most testing reports do not reference a safety factor as they simply identify the maximum Tested Wind Uplift Load Capacity that a particular roofing assembly is capable of resisting. Wind Uplift Load Capacity values available from evaluation reports, publications and some other websites may include a safety factor, which means that the listed wind uplift resistance value is actually the Factored Tested Load Capacity ($\mathbf{L_t}$). In this instance the Tested Uplift Load Capacity is determined by multiplying $\mathbf{L_t}$ by the specified safety factor. When a safety factor of 1.0 is utilized, $\mathbf{L_t}$=Tested Wind Uplift Load Capacity

Various methods exist for applying safety factors and include the following:

a. Allowable Design Load results multiply by safety factor:

Factored Design Load Capacity ($\mathbf{L_d}$) = Wind Uplift Design Pressures × safety factor

b. Tested Load Capacity divided by safety factor:

Factored Tested Load Capacity ($\mathbf{L_t}$) = Tested Wind Uplift Load Capacity / safety factor

Related Reference Documents

Design Standards

1. ASCE 7 Minimum Design Loads for Buildings and Other Structures (available at www.asce.org)
2. ANSI/SPRI RP-4, Wind Design Standard for Ballasted Single-Ply Roofing Systems (available at www.spri.org)
3. ANSI/SPRI RP-14, Wind Design Standard for Vegetative Roofing Systems (available at www.spri.org)
4. ANSI/SPRI/FM 4435/ES-1, Wind Design Standard For Edge Systems Used with Low Slope Roofing Systems (available at www.spri.org)
5. ANSI/SPRI GD-1, Structural Design Standard for Gutter Systems Used with Low-Slope Roofs (available at www.spri.org)

North American Testing Standards

1. ANSI/FM 4474, American National Standard for Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures (available at www.fmglobal.com)
2. ANSI/SPRI FX-1, Standard Field Test Procedure for Determining the Withdrawal Resistance of Roofing Fasteners (available at www.spri.org)
3. ANSI/SPRI IA-1, Standard Field Test Procedure for Determining the Mechanical Uplift Resistance of Insulation Adhesives over Various Substrates (available at www.spri.org)
4. UL 580, Standard for Tests for Uplift Resistance of Roof Assemblies (available at www.ul.com)
5. UL 1897, Standard for Uplift Tests for Roof Covering Systems (available at www.ul.com)
6. CSA Standard A123.21, Standard Test Method for the Dynamic Wind Uplift Resistance of Membrane-Roofing Systems (available at www.ShopCSA.ca)

Informational Data Sheets & Guidelines

1. Application Guidelines for Modified Bitumen, Thermoplastic and Thermoset Roofing Systems (available at www.spri.org)
2. Modified Bitumen, Thermoplastic and Thermoset Details (available at www.spri.org)
3. FM Global Loss Prevention Data Sheets 1-28, 1-29 and 1-49 (available at www.roofnav.com)
4. Wind Design Standard Practice for Roofing Assemblies