ANSI/SPRI WD-1

Wind Design Standard Practice for Roofing Assemblies

Approved November 17, 2014

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Disclaimer

This standard is for use by architects, engineers, roofing contractors and owners of low slope roofing systems. SPRI, its members and employees do not warrant that this standard is proper and applicable under all conditions.

1.0 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 rooftop design wind uplift pressures that are calculated in accordance with the current version of the International Building Code (IBC). This Standard Practice 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 section of the standard, item 8, for the ballasted roofing system design standard reference).

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 installation specifications and requirements 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).

2.0 Methodology

2.1 Calculate the wind uplift design pressures (loads)

The design wind uplift load shall be calculated for the field, perimeter (or ridge) and corner areas of the roof in accordance with the current ASCE 7 Standard (as referenced in Chapter 15 of the International Building Code).

2.2 Determine the tested wind uplift resistance 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, FM 4450, FM 4470, UL 580, UL 1897 or CSA A123.21-10. Tested Uplift Load Capacity values are available from the roofing system assembly supplier through independent laboratory testing reports, evaluation reports and publications. These values are also available from website listings that are developed and maintained by various independent testing/evaluation entities and laboratories.

2.3 Determine the Factored Tested Load Capacity using an appropriate safety factor

The use of a safety factor shall be considered in order to determine the Factored Tested Load Capacity of a roofing system assembly. Testing reports typically do not include a safety factor as they simply identify the maximum Tested Wind Uplift Load Capacity that a particular roofing assembly is capable of resisting. In order to determine the Factored Tested Load Capacity ($\mathbf{L_t}$), divide the Tested Wind Uplift Load Capacity (from the testing report) by the chosen safety factor. Safety factors, as determined by the designer or specifier, typically range from 1.0 to 2.0.

Factored Tested Load Capacity, psf (L_t) = Tested Wind Uplift Load Capacity, psf/safety factor

Wind uplift resistance values available from evaluation reports, publications and websites often times do 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, no further factoring is necessary. Also, in this instance, in order determine the Tested Uplift Load Capacity, multiply $\mathbf{L_t}$ by the specified safety factor.

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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 ($\mathbf{L_t}$) of that assembly must be greater than or equal to the calculated wind uplift design load for the field area of the roof. If $\mathbf{L_t}$ is less than the calculated design wind uplift load for the field area, the roofing system assembly shall not be used on that particular building.

When $\mathbf{L_t}$ is greater than or equal to the field design pressure, the roofing system assembly, as tested, is suitable for use in the field area of the roof. In order to determine the appropriate assembly layout for the perimeter and corner areas of the roof, compare the $\mathbf{L_t}$ to the calculated wind uplift design loads for the perimeter and corner areas. When $\mathbf{L_t}$ meets or exceeds the calculated design load for either of these areas, the roofing system assembly, as tested, is suitable for use in those areas.

When $\mathbf{L_t}$ is less than the perimeter and/or corner area design loads, 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.

2.5 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. The Tested Wind Uplift Load Capacity of the proposed adhered roofing system assembly was 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; and
4. 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.

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 (**F_n**) needed to meet the calculated design wind uplift load(s) shall be determined using the following equation: **$F_n = (F_t \times L_d)/L_t$**

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

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

L_d is the calculated design load for the perimeter or corner area of a roof, psf.

L_t is the Factored Tested Load Capacity, psf.

Refer to Commentary A for a practical example of rational analysis for an adhered roofing system assembly utilizing mechanically attached insulation/substrate (System 1 Example).

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 (**R_n**) needed to meet the calculated design wind uplift load(s) shall be determined using the following equation: **$R_n = R_t/(L_d/L_t)$**

Where: **R_n** is the ribbon/bead spacing needed to meet the calculated 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 load for the perimeter or corner area of a roof, psf.

L_t is the Factored Tested Load Capacity, psf.

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 (System 2 Example).

Cautionary Note: The **F_n** and **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

2.6.1 Rational Analysis Criteria

This mechanically fastened membrane roofing system assembly rational analysis method shall only be used when the following criteria are met:

Linearly-Attached

The tested wind uplift load capacity of the proposed linearly-attached (rows) mechanically fastened roofing system assembly was determined utilizing a test chamber of sufficient size such that the tested row spacing did not exceed one half of the table length, and that one attachment row was centered along the length of the table. The minimum frame width shall be 8 feet (2.4 m).

Spot-Attached

The tested wind uplift load capacity of the proposed spot-attached mechanically fastened roofing system assembly was 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 shall be 8 feet (2.4 m).

2.6.1.1 Rational Analysis Method—Mechanically Fastened Membrane

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, 2 ft × 3 ft, etc.). This gives the number of square feet 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.

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

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

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

The fastener row spacing or the spot attachment grid spacing of the roofing system assembly being considered shall be reduced so the ft^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.

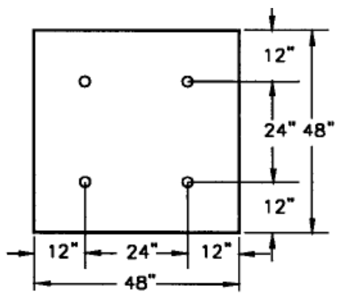
Refer to Commentary A for practical examples of rational analysis for membrane attachment on a mechanically fastened membrane roofing system assemblies (System 3 Example for linearly-attached and System 4 Example for spot-attached). It shall be permissible, as explained in Commentary A, to use the perimeter fastener row spacing in the corner areas provided the perimeter rows are installed in both directions.

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 inches to 6 inches [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 inches to 18 inches [30.5 cm to 46 cm], for example) or increase the spacing between fastener rows (8 feet to 10 feet [2.4 m to 3.0 m], for example).

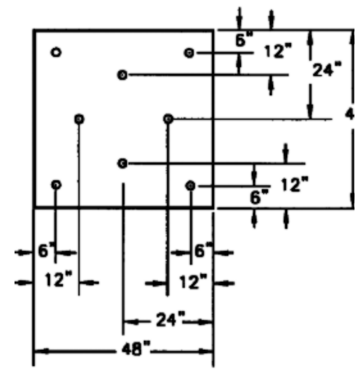
Appendix A

Fastening Patterns

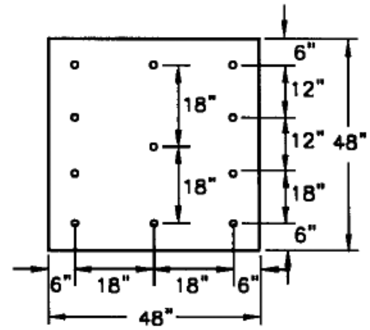
Insulation Board Fastening Patterns
4 feet × 4 feet Boards (1.2 m × 1.2 m)—Adhered Membranes



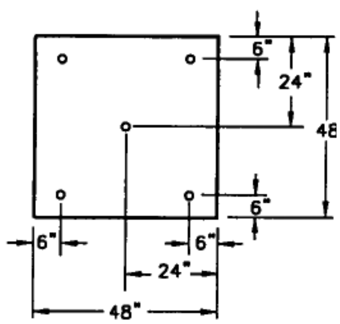
4' x 4' BOARDS
(4 FAST. PER 4' x 4' BOARD)



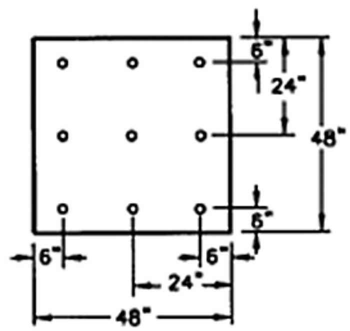
4' x 4' BOARDS
(8 FAST. PER 4' x 4' BOARD)



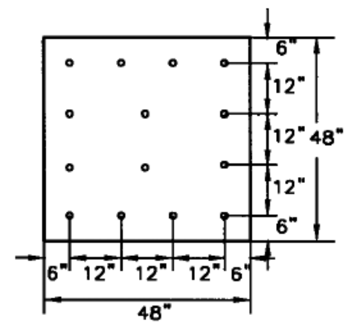
4' x 4' BOARDS
(11 FAST. PER 4' x 4' BOARD)



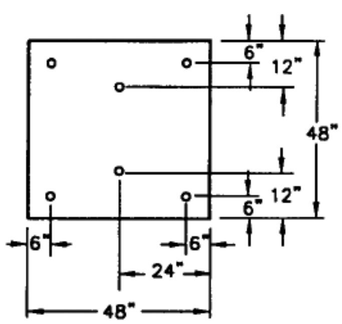
4' x 4' BOARDS
(5 FAST. PER 4' x 4' BOARD)



4' x 4' BOARDS
(9 FAST. PER 4' x 4' BOARD)



4' x 4' BOARDS
(14 FAST. PER 4' x 4' BOARD)



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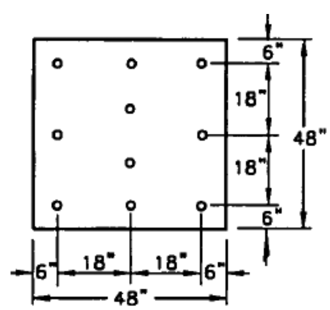
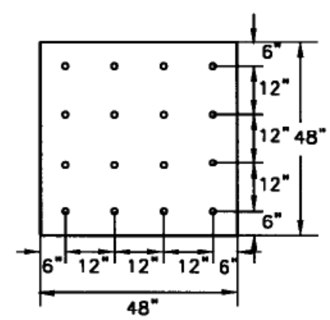
(6 FAST. PER 4' x 4' BOARD)

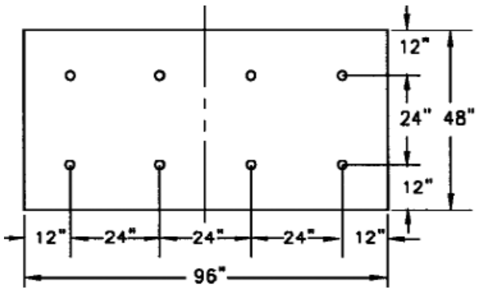


4' x 4' BOARDS
(10 FAST. PER 4' x 4' BOARD)

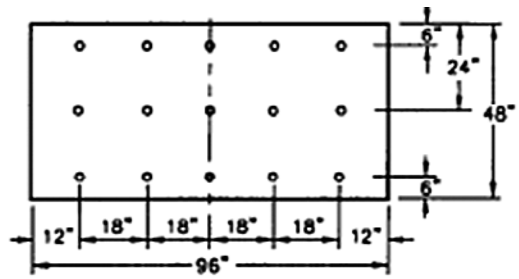


4' x 4' BOARDS
(16 FAST. PER 4' x 4' BOARD)

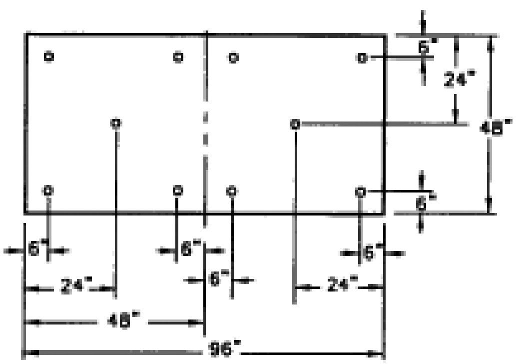
Insulation Board Fastening Patterns
4 feet × 8 feet Boards (1.2 m × 2.4 m)—Adhered Membranes



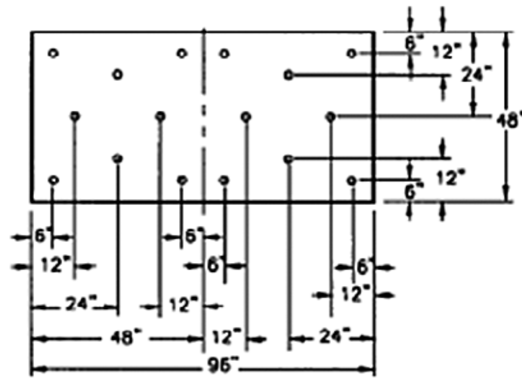
4' x 8' BOARDS
(8 FAST. PER 4' x 8' BOARD)



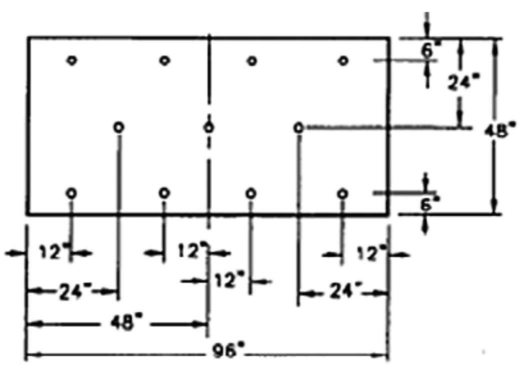
4' x 8' BOARDS
(15 FAST. PER 4' x 8' BOARD)



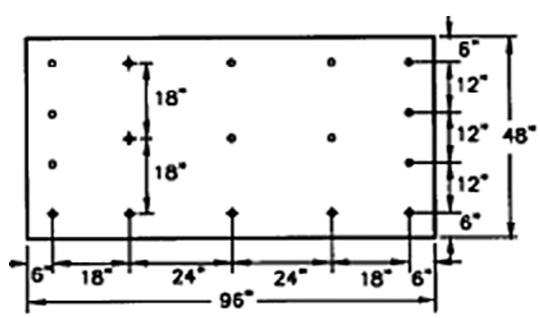
4' x 8' BOARDS
(10 FAST. PER 4' x 8' BOARD)



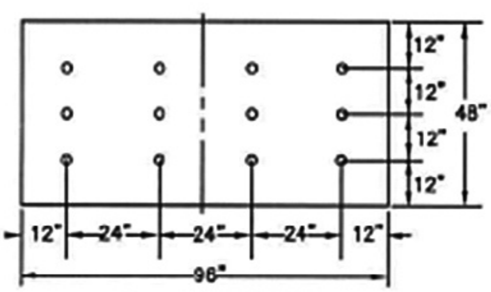
4' x 8' BOARDS
(16 FAST. PER 4' x 8' BOARD)



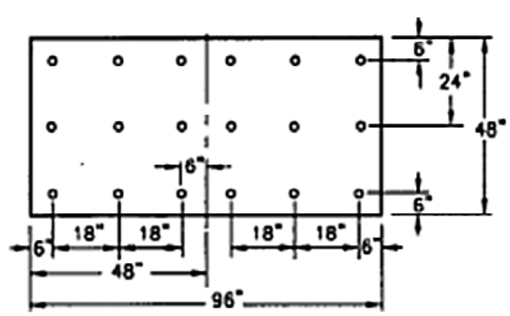
4' x 8' BOARDS
(11 FAST. PER 4' x 8' BOARD)



4' x 8' BOARDS
(17 FAST. PER 4' x 8' BOARD)

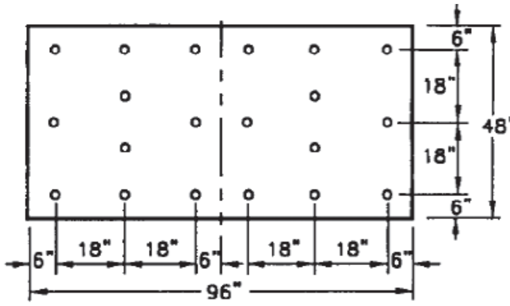


4' x 8' BOARDS
(12 FAST. PER 4' x 8' BOARD)

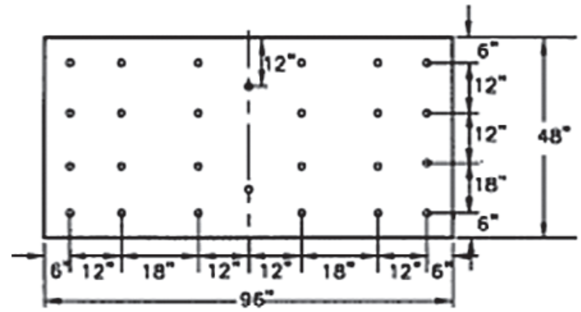


4' x 8' BOARDS
(18 FAST. PER 4' x 8' BOARD)

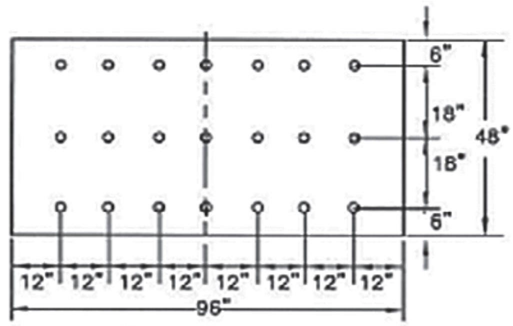
Insulation Board Fastening Patterns
4 feet × 8 feet Boards (1.2 m × 2.4 m)—Adhered Membranes (continued)



4' x 8' BOARDS
(20 FAST. PER 4' x 8' BOARD)



4' x 8' BOARDS
(26 FAST. PER 4' x 8' BOARD)



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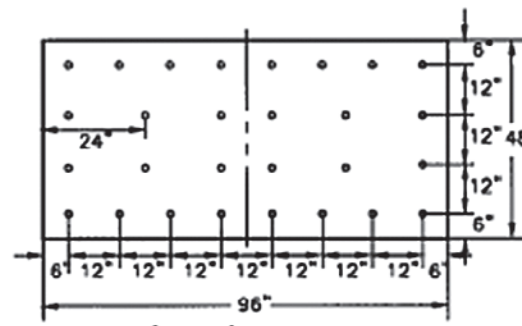
(21 FAST. PER 4' x 8' BOARD)



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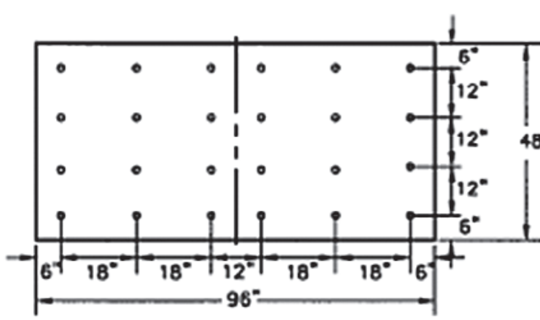
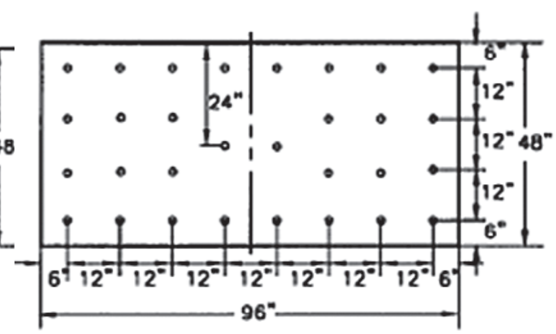
(28 FAST. PER 4' x 8' BOARD)



4' x 8' BOARDS
(24 FAST. PER 4' x 8' BOARD)



4' x 8' BOARDS
(30 FAST. PER 4' x 8' BOARD)

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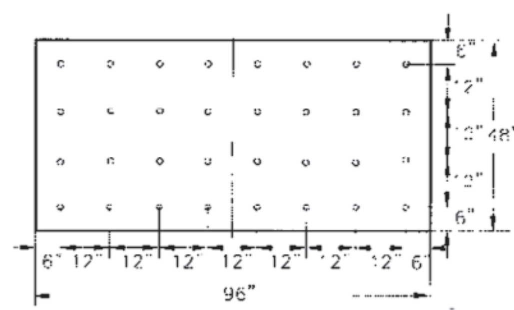
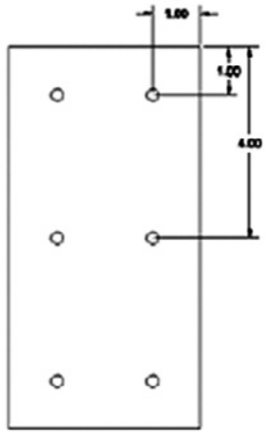


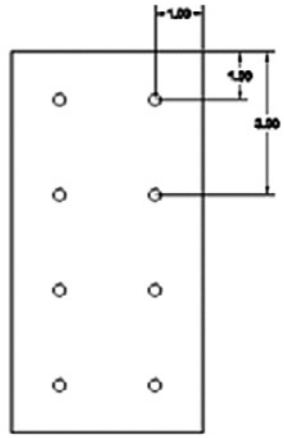
4' x 8' BOARDS
(32 FAST. PER 4' x 8' BOARD)

Spot-Attached (Grid) Membrane Fastening Patterns
4 feet × 8 feet (1.2 m × 2.4 m) Boards

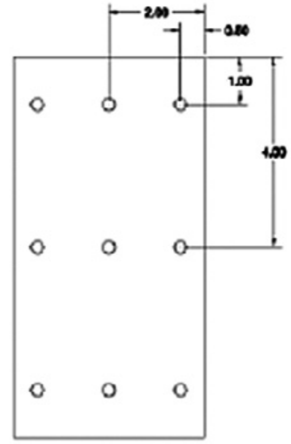
6 fasteners per board



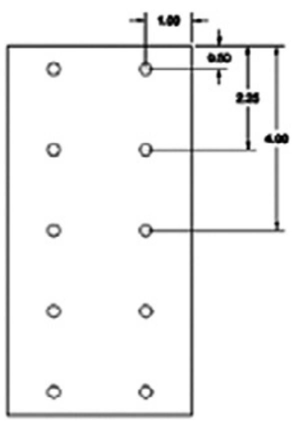
8 fasteners per board



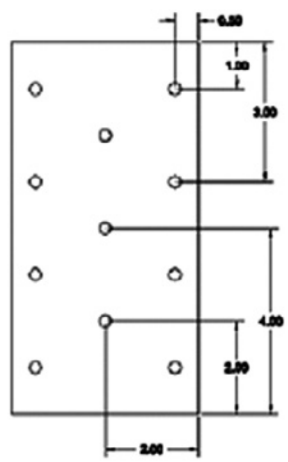
9 fasteners per board



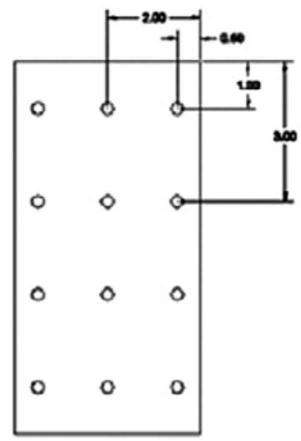
10 fasteners per board



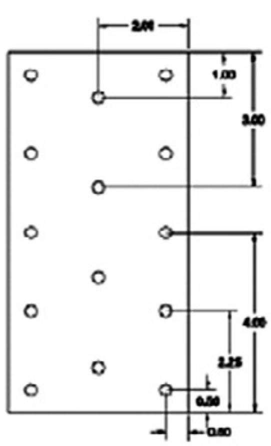
11 fasteners per board



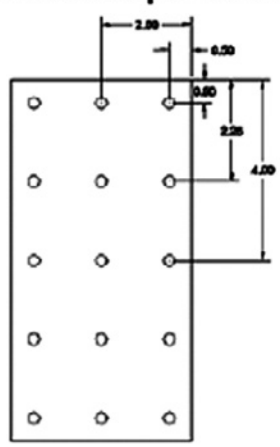
12 fasteners per board



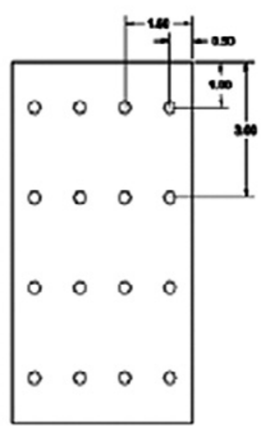
14 fasteners per board



15 fasteners per board



16 fasteners per board



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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.

Commentary A

Practical Examples
Roofing System Assembly Selection

Example Building (used for all examples to follow)

A building has the following calculated design wind uplift loads as were determined by using ASCE 7:

Field area = -25.6

Perimeter area = -42.9

Corner area = -64.6

The roof deck on this building is fluted steel and the designer/specifier has selected a 2.0 safety factor to be used for this project (except where noted).

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:

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

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

System 3—Linearly-attached mechanically fastened membrane (two assemblies evaluated).

System 4—Spot-attached mechanically fastened membrane.

System 1 Example
Adhered Membrane over Insulation Attached with Mechanical Fasteners

Adhered Membrane Assembly #1

The laboratory testing report for the first adhered membrane roofing system assembly being considered for this building was tested on a 5 feet × 9 feet (1.5 m × 2.7 m) test chamber to a maximum Tested Wind Uplift Load Capacity of -45 psf. The 4 feet × 8 feet (1.2 m × 2.4 m) insulation boards were attached using 6 fasteners (**F_t**) per board.

Determine the Factored Tested Load Capacity (L_t)

Apply the 2.0 safety factor to the -45 psf Tested Wind Uplift Load Capacity to determine the Factored Tested Load Capacity (**L_t**):

L_t = -45 psf/2.0 = **-22.5 psf**
or
L_t = -2.2 kPa/2.0 = **-1.1 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** (-22.5 psf) is less than the design load for the field of the roof (-25.6 psf), the roofing system assembly is not suitable for use on this building.

Note: Even if **L_t** would have been greater than the calculated field design load, this roofing system assembly would still not be suitable since the use of the Rational Analysis methodology would not be permissible for the perimeter and corner areas (testing was conducted on an unsuitably large chamber, refer to Section 2.5.1).

Adhered Membrane Assembly #2

The laboratory testing report for the second adhered membrane roofing system assembly being considered for this building was tested on a 12 feet × 24 feet (3.7 m × 7.3 m) test chamber to a maximum Tested Wind Uplift Load Capacity of -90 psf. The 4 feet × 8 feet (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 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) exceeds the design load for the field of the roof (-25.6 psf), 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) exceeds the calculated wind uplift design load for the perimeter (-42.9 psf) area of the roof, but L_t is less than the corner area design load (-64.6 psf). 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 ✓
3. Tested Wind Uplift Load Capacity determined utilizing a suitably large chamber ✓

Since all Section 2.5.1 requirements 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.

L_t is the Factored Tested Load Capacity, psf.

Corner Area

F_n = (16 fasteners × -64.6 psf)/-45 psf = **23 fasteners per board**
or
F_n = (16 fasteners x -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 feet × 8 feet (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. Fastening pattern examples for insulation boards are included in Appendix A of this document.

System 2 Example
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 ($\mathbf{L_t}$) as being -37.5 psf. The listing also indicates that testing was conducted on a 12 feet × 24 feet (3.7 m × 7.3 m) test chamber using 4 feet × 4 feet (1.2 m × 1.2 m) insulation boards attached using ribbons/beads of adhesive spaced 12 inches (30.5 cm) on center ($\mathbf{R_t}$). A safety factor of 2.0 was identified in the Evaluation Report as being used for determining $\mathbf{L_t}$.

Determine the Tested Wind Uplift Load Capacity
Multiply the -37.5 psf Factored Tested Load Capacity ($\mathbf{L_t}$) by the 2.0 safety factor to obtain the Tested Wind Uplift Load Capacity:

Tested Wind Uplift Load Capacity = -37.5 × 2.0 = **-75 psf**
or
Tested Wind Uplift Load Capacity = -1.8 kPa x 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 ($\mathbf{L_t}$) to the calculated field area wind uplift design load. Since $\mathbf{L_t}$ (-37.5 psf) exceeds the design load for the field of the roof (-25.6 psf), the roofing system assembly, as tested, is suitable for use in the field area of the roof.

Perimeter & Corner Layout Evaluation
$\mathbf{L_t}$ (-37.5 psf) is less than both the perimeter (-42.9 psf) and corner (-64.6 psf) 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 of this document.

1. Tested Wind Uplift Load Capacity (-75) is greater than the calculated corner area design load ✓
2. Roofing system assembly utilizes mechanical fasteners for insulation attachment ✓
3. Tested Wind Uplift Load Capacity determined utilizing a suitably large chamber ✓

Since all Section 2.5.1 requirements 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 ($\mathbf{R_n}$) for the perimeter and corner areas of the roof, use the equation $\mathbf{R_n = R_t/(L_d/L_t)}$

Where: $\mathbf{R_n}$ is the ribbon/bead spacing needed to meet the 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 wind uplift load for the perimeter/corner areas of the roof, psf.

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

Perimeter Area

$\mathbf{R_n}$ = 12 in./(-42.9 psf/-37.5 psf) = **10.5 inches** maximum on center spacing for ribbons/beads
or
$\mathbf{R_n}$ = 30.5 cm/(-2.1 kPa/-1.8 kPa) = **27 cm** maximum on center spacing for ribbons/beads

Corner Area

$\mathbf{R_n}$ = 12 in./(-64.6 psf/-37.5 psf) = **7.0 inches** maximum on center spacing for ribbons/beads
or
$\mathbf{R_n}$ = 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 inches (15 cm) on center, the perimeter and corner ribbons/bead spacing must be rounded down to 6 inches (15 cm) on center. Therefore, the final layout for this assembly scenario is to use ribbons/beads of adhesive spaced 12 inches (30.5 cm) on center for insulation attachment in the field of the roof and ribbons/beads of adhesive spaced 6 inches (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 inches (30.5 cm) on center in the field of the roof, 10.5 inches (27 cm) on center in the perimeter area and 7.0 inches (18 cm) in the corner areas.

System 3 Example
Linearly-Attached Mechanically Fastened Membrane Assemblies

Mechanically Fastened Membrane Assembly #1

The laboratory testing report for this linearly-attached mechanically fastened roofing assembly being considered for this building was tested on a 12 feet × 24 feet (3.7 m × 7.3 m) test chamber to a maximum Tested Wind Uplift Load Capacity of -60 psf. The assembly utilizes an 11.5 feet (3.5 m) fastener row spacing with fasteners spaced 12 inches (30.5 cm/0.3 m) on center along the row.

Determine the Factored Tested Load Capacity (Lt)

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

$\mathbf{L_t}$ = -60 psf/2.0 = **-30 psf**
or
$\mathbf{L_t}$ = -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 ($\mathbf{L_t}$) to the calculated field area wind uplift design load. Since $\mathbf{L_t}$ (-30 psf) exceeds the design load for the field of the roof (-25.6 psf), the roofing system assembly, as tested, is suitable for use in the field area of the roof.

Perimeter & Corner Layout Evaluation

$\mathbf{L_t}$ (-30 psf) is less than both the perimeter (-42.9 psf) and corner (-64.6 psf) 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 layout for these areas, check the requirements of Section 2.6.1 of this document.

1. Tested Wind Uplift Load Capacity determined utilizing a suitably large chamber ✓

Since the Section 2.6.1 requirement is met, rational analysis is permissible

Rational Analysis

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

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

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

$\mathbf{L_d}$ 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
IA_t = 3.5 m x 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 x 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 x 1.1 m²)/-3.1 kPa = **0.5 m² maximum per fastener**

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

Perimeter Areas

8.0 ft²/1.0 ft = **8.0 ft row spacing**
or
0.7 m²/0.3 m = **2.4 m row spacing**

Corner Areas

5.3 ft²/1.0 ft = **5.3 ft row spacing**
or
0.5 m²/0.3 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 feet (3.5 m) in the field of the roof, maximum 8.0 feet (2.4 m) in the perimeter areas and maximum 5.3 feet (1.6 m) in the corner areas, all with fasteners spaced 12 inches (30.5 cm) on center along the row. The second possible layout is to use a maximum fastener row spacing of 11.5 feet (3.5 m) in the field of the roof and a maximum 8.0 feet (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.

Mechanically Fastened Membrane Assembly #2

An Evaluation Report listing for this linearly-attached mechanically fastened roofing assembly identifies the Factored Tested Load Capacity (**L_t**) as being -50 psf. The listing also indicates that testing was conducted on a 12 feet × 24 feet (3.7 m × 7.3 m) test chamber using a 9.5 feet (2.9 m) fastener row spacing with fasteners spaced 18 inches (46 cm/0.46 m) on center along the row.

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** (-50 psf) exceeds the design load for the field of the roof (-25.6 psf), the roofing system assembly, as tested, is suitable for use in the field area of the roof.

Perimeter & Corner Layout Evaluation

L_t (-50 psf) exceeds the calculated wind uplift design load for the perimeter (-42.9 psf) area of the roof, but L_t is less than the corner area design load (-64.6 psf). Consequently, the as-tested assembly is suitable for use in the perimeter area but not the corner area. To determine if rational analysis is acceptable for defining the layout for the corner area, check the requirements of Section 2.6.1 of this document.

1. Tested Wind Uplift Load Capacity determined utilizing a suitably large chamber ✓

Since the Section 2.6.1 requirement is met, rational analysis is permissible.

Rational Analysis
To determine the appropriate 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, ft^2.

IA_t is the area of membrane held in place by one fastener for the tested assembly, ft^2.

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

L_t is the factored tested load capacity, psf.

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

IA_t = 9.5 ft × 1.5 ft = **14.25 ft^2 per fastener**
or
IA_t = 2.9 m x 0.46 m = **1.3 m^2 per fastener**

Corner Area

IA_n = (-50 psf x 14.25 ft^2)/-64.6 psf = **11.0 ft^2 maximum per fastener**
or
IA_n = (-2.4 kPa x 1.3 m^2)/-3.1 kPa = **1.0 m^2 maximum per fastener**

The row spacing for the corner area shall be determined by dividing IA_n by the tested fastener spacing, as follows:

Corner Area

11.0 ft^2/1.5 ft = **7.3 ft row spacing**
or
1.0 m^2/0.46 m = **2.2 m row spacing**

There are two possible final layouts for this assembly scenario. The first possible design is to use a maximum fastener row spacing of 9.5 feet (2.9 m) in the field and perimeter areas of the roof and maximum 5.5 feet fastener row spacing in the corner areas, all with fasteners spaced 18 inches (46 cm) on center along the row. The second possible layout is to use a maximum fastener row spacing of 9.5 feet (2.9 m) across the entire roof area however, the perimeter rows must extend into the corners from both directions, creating a cross-hatched fastening pattern.

System 4 Example
Spot-Attached Mechanically Fastened Membrane

The laboratory testing report for the spot-attached mechanically fastened roofing assembly being considered for this building was tested on a 12 feet × 24 feet (3.7 m × 7.3 m) test chamber to a maximum Tested Wind Uplift Load Capacity of -75 psf using a 2 feet × 3 feet (0.6 m × 0.9 m) grid membrane fastener spacing pattern. This grid pattern results in the use of 6 membrane fasteners per 4 feet × 8 feet (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 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) exceeds the design load for the field of the roof (-25.6 psf), 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) is less than both the perimeter (-42.9 psf) and corner (-64.6 psf) 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 layout for these areas, check the requirements of Section 2.6.1 of this document.

1. Tested Wind Uplift Load Capacity determined utilizing a suitably large chamber ✓

Since the Section 2.6.1 requirement is met, rational analysis is permissible.

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.

L_t is the Factored Tested Load Capacity, psf.

Perimeter Area

F_n = (6 fasteners × -42.9 psf)/-37.5 psf = **7 fasteners per board**
or
F_n = (6 fasteners x -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 x -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 feet × 8 feet (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. Grid pattern fastener examples are included in Appendix A of this document.

Commentary B

General Considerations

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

1. Consult with an architect or 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 should penetrate through the top flange of a steel deck whenever possible.
4. Rows of mechanical fasteners, spaced greater than 3 feet (0.9 m) apart, should 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 inch (19 mm) for steel, 1 inch (25 mm) for wood and 1-1/4 inch (32 mm) for structural concrete. Consult with the roofing system supplier for verification.
6. Install an edging or coping detail, where appropriate, that will meet the requirements of the SPRI/FM 4435/ES-1 Standard.

Related Reference Documents

Design Standards

1. ASCE 7-10 (or older version when specified in a specific building code), Minimum Design Loads for Buildings and Other Structures (available at www.asce.org)
2. ANSI/SPRI GD-1, Structural Design Standard for Gutter Systems Used with Low-Slope Roofs (available at www.spri.org)
3. ANSI/SPRI RP-4, Wind Design Standard for Ballasted Single-Ply Roofing Systems (available at www.spri.org)
4. ANSI/SPRI RP-14, Wind Design Standard for Vegetative Roofing Systems (available at www.spri.org)
5. ANSI/SPRI/FM 4435/ES-1, Wind Design Standard For Edge Systems Used with Low Slope Roofing Systems (available at www.spri.org)

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. FM 4450, Approval Standard for Class 1 Insulated Steel Deck Roofs (available at www.roofnav@fmglobal.com)
5. FM 4470, Approval Standard for Class 1 Roof Covers (available at www.roofnav@fmgloblal.com)
6. UL 580, Standard for Tests for Uplift Resistance of Roof Assemblies (available at www.ul.com)
7. UL 1897, Standard for Uplift Tests for Roof Covering Systems (available at www.ul.com)

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@fmglobal.com)